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Submarine Cables as an Innovation in Engineering, Elene Batlidze, *elenebatlidze10@gmail.com*, ketevan Vezirishvili-Nozadze

Abstract

Submarine cables are a cornerstone of modern engineering, facilitating the transmission of energy and data across vast underwater distances. This research delves into the innovative technologies that have driven the evolution of submarine cables, focusing on advanced insulation materials, robust armoring techniques, and cutting-edge monitoring systems. The study examines their critical applications in renewable energy projects, such as offshore wind farms, and in global connectivity through undersea telecommunication networks. It also highlights the challenges of cable installation and maintenance in deep-sea environments, addressing issues like environmental impacts and fault detection. Submarine cables contribute significantly to sustainable energy infrastructure and the seamless transfer of information, underscoring their role as a transformative innovation in engineering.

Annotation

Submarine cables are pivotal in bridging continents and facilitating renewable energy transmission, representing a remarkable innovation in engineering. This article delves into the transformative advancements in submarine cables within the energy sector, focusing on their essential role in transmitting electricity across underwater expanses. It explores the historical evolution of submarine cables, their construction, and material innovations. The discussion extends to their applications in renewable energy, intercontinental energy exchange, and island electrification. By highlighting recent innovations such as high-capacity cables, dynamic designs, and environmentally friendly materials, this article underscores how submarine cable technology is meeting the challenges of modern energy demands. It also identifies key challenges and future trends,

emphasizing the pivotal role of engineering in shaping a sustainable energy future. Key innovations include the use of advanced insulation materials, such as cross-linked polyethylene (XLPE0, which improves thermal resistance and electrical integrity. Submarine cables are also vital to global telecommunications, forming the backbone of the internet by enabling high-speed data transfer between continents.

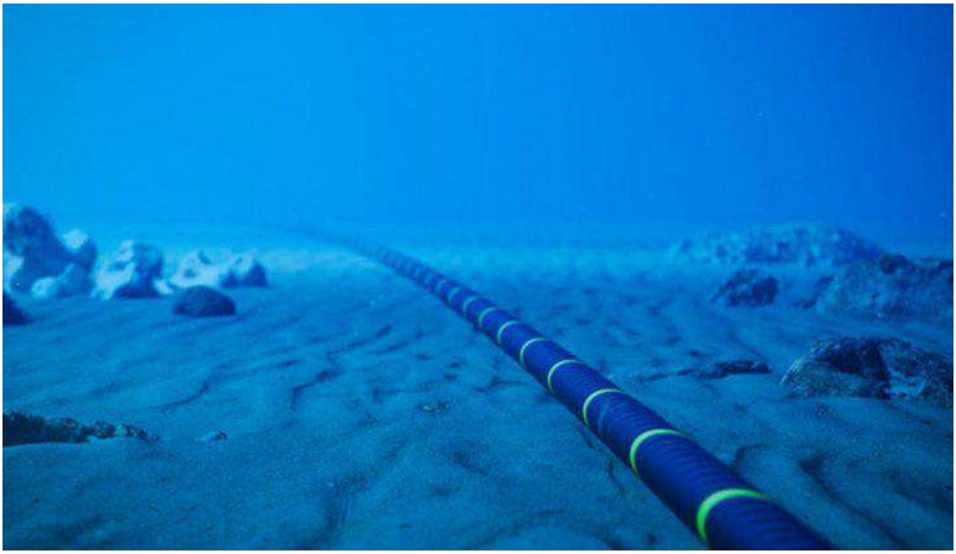
Introduction

Submarine cables are critical components of global energy infrastructure, enabling the transmission of electricity across vast distance underwater. These cables connect countries, power offshore wind farms, and support the transition to renewable energy sources. As global energy demands rise, the engineering of submarine cables has evolved to meet challenges like extreme environmental conditions and high-capacity transmission needs. Submarine cables are specialized cables installed on the seabed to transmit electricity or data. In the context of energy sector, they are primarily used for power transmission across bodies of water. These cables are designed to operate in harsh underwater environments, withstanding high pressures, salinity, and varying temperatures. The history of submarine cables dates back to the mid-19th century with the advent of telecommunication cables. The first transatlantic telegraph cable laid in 1858. While initially used for communication, submarine cable technology expended to include power transmission in the 20th century. Modern submarine cables now play crucial role in meeting the world's energy needs, with advancements in high-voltage technology enabling long-distance power transmission. The primary purposes of submarine cables are: Global communications, energy transmission and connectivity for remote areas.

Environmental impacts of submarine cables

The installation of submarine cables can disrupt marine habitats and ecosystems on the seabed. Trenches dug for cable placement may damage coral reefs, seagrass beds and other sensitive marine environments. Although care is taken to minimize these impacts, some level of habitat disturbance is inevitable. Submarine power cables emit electromagnetic fields during operation, which may affect certain marine species, particularly those sensitive to electromagnetic signals, such as sharks, rays, and some fish species. Research is going to determine the long-term effects of EMFs on marine life. Marine animals may interact with submarine cables in various ways, including physical contact or behavioral changes due to their presence. While most interactions are not harmful, entanglement or collision risks exist, especially in areas of dense cable networks. The use of biodegradable materials and low-impact coatings reduces the environmental footprint of submarine cable installations. The innovations align with global efforts to minimize the ecological impact of energy infrastructure.

Advantages	**Disadvantages**
Minimal long-term footprint once installed	Disturbance to seabed ecosystems during installation
Enable integration of renewable energy sources, reducing reliance on fossil fuels	Electromagnetic fields may affect sensitive marine species like sharks and rays
Use eco-friendly materials reduces long-term environmental impact	Potential leaching of chemicals from older cables into environment
Carefully routed cables avoid significant damage to ecologically sensitive areas	Noise pollution during installation can disturb marine animals and other species
Support for sustainable development in remote areas by providing power and connectivity	Physical presence may alter behavior of marine life or create minor barriers in ecosystems



Picture1.1 Submarine cable at the bottom of the ocean

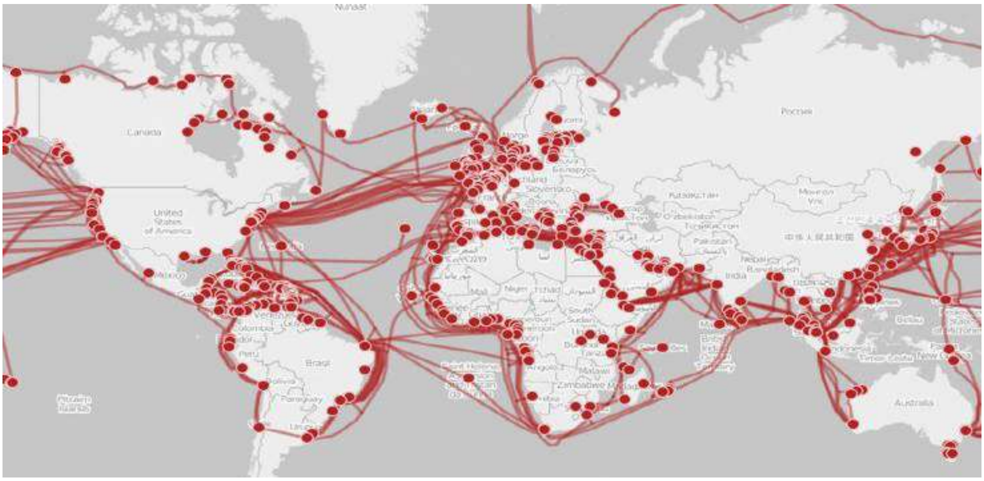
Submarine cables as an innovation in engineering

Pioneering Energy Transmission Technology submarine cabled were among the first technologies to enable the transmission of electricity over long distances across water bodies. Early advancements, such as the first cross-channel telegraph cable in the 19^{th} century, set the stage for modern power cables. High-voltage direct current (HVDC) submarine cables are groundbreaking technology that minimize power losses, making long-distance energy transmission feasible. Enabling Renewable Energy Project Offshore wind farms, tidal energy systems, and floating solar plants rely on submarine power cables to transmit electricity to the mainland. These cables are critical for integrating renewable energy into the power grid. The ability to efficiently connect distant renewable energy sources marks a significant step forward in sustainable energy solutions. The development of advanced insulating materials, corrosion-resistant metals and multi-layered cable structures has significantly improved the durability and efficiency of submarine cables. These innovations ensure cables can operate reliably in extreme underwater conditions, from high pressures to varying temperatures. Submarine power cables reduce reliance on fossil fuels enabling large scale renewable energy deployment, contributing to climate change mitigation. Innovations in cable installation and maintenance techniques, such as using remotely operated vehicles (ROVs) and advanced mapping systems, have minimized costs and environmental impacts. Solving unique engineering challenges, designing and installing cables for underwater environments requires creative solutions to address high pressures, potential damage from marine life and shifting seabeds, Continuous improvements in these technologies showcase the innovative spirit in engineering.

Picture1.2

Successful projects

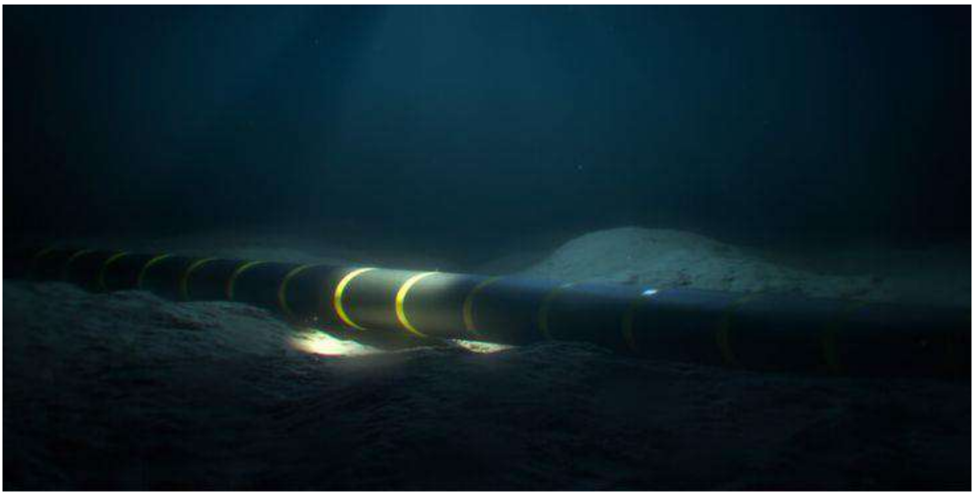
Name	Length	Voltage	Purpose	Operational since
North Sea Link	720 KM	1.4 GW HVDC	Connects power grids of the UK and Norway	2021
Nor Ned	580 KM	700 MW HVDC	Power exchange between Norway and Netherlands	2008
Bass Link	370 KM	500 MW HVDC	Links Tasmania's hydroelectric grid with Australia	2006
Brit Ned	260KM	1 GW HVDC	Facilitates electricity trade between UK and Netherlands	2011



Picture1.3

Georgia and "Black Sea submarine cable project"

Georgia's future with submarine power cables has significant potential, especially given its strategic location, renewable energy resources, and ambitions to become a regional energy hub. Submarine power cables could transform Georgia's energy sector, enabling it to tap into its renewable energy potential, strengthen regionals, international cooperation, and technological advancements could ensure that Georgia becomes a key player in the global energy network. Georgia sits at the crossroads of Europe and Asia, making it a key player in regional energy projects. It connects the energy-rich Caspian region with Europe, providing an opportunity to act as a transit country for electricity. a transit country for electricity. The Black Sea offers a natural corridor for submarine power cables to link Georgia with Europe, Turkey and other neighboring regions.



Picture1.4

Key components of submarine cables

1. **Conductor** – Typically made of cooper or aluminum, the conductor facilitates the efficient flow of electricity
2. **Insulation** – High-quality insulation, such as cross-linked polyethylene, prevents energy loss and protects against electrical faults
3. **Armoring** – Layers of steel wires provide mechanical protection against external damage caused by anchors, fishing activities or marine life
4. **Outer Sheath** – The outermost layer protects against and abrasion, ensuring the cable's longevity.

Picture1.5. Inside of submarine cable

Picture1.6. AI version of inside parts of cable

Conclusion

Submarine cables are integral to the modern energy sector, facilitating the global transition to renewable energy and interconnecting power grids across continents. Through innovative engineering, these cables have become more efficient, reliable and environmentally sustainable. As demand for energy continues to grow, advancements in submarine cable technology will play a cruicial role in shaping resilient and sustainable energy future

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Construction and Architectural Trends after the 1950s, *Maryam Benashvili, Doctoral Program Student, Supervisor: Tamar Chubinidze, Assosiate Professor*

Abstract:

The post-World War II directions and movements in construction and architecture are examined from a historical perspective. Concepts developed in various architectural schools and the views of different renowned architects are shaped by the consideration of regional conditions, technological advancements, and the demographic and social characteristics of the population.

Early post-war architecture focused on meeting basic survival needs and simplifying design due to economic and technological constraints. In the 1950s, residential projects became more active, but they largely remained uniform, shaped by established regional conditions and trends in mass housing.

Global architectural movements emerged, with modernism transforming urban development. Minimalist design became a symbol of contemporary architecture. While neoclassicism existed in the United States, new trends emerged, including brutalism, which emphasized raw concrete and sculptural forms.

Contemporary architecture became increasingly formalist, focusing on aesthetic and psychological effects, placing greater emphasis on artistic expression rather than functionalism. It leaned towards more expressive, sculptural architecture.

In the 20th century, architecture diversified due to technological advancements, the emergence of new materials, and changes in social and economic conditions. Mass production led to standardized design under the influence of commercial demands and economic efficiency. Despite these constraints, architects continued to seek ways to balance creativity with functional and economic viability.

Keywords: modernism, minimalism, , functionalism, , aesthetics.

Architectural and Construction Developments After 1950

Following the cataclysm of World War II, an era of reconstruction began in the countries of Western Europe, which had suffered widespread destruction due to wartime chaos. In this complex yet necessary process, the diversity of architectural and urban development concepts distinctly emerged, shaped by the specific needs, cultural traditions, and contemporary trends of each country. This diversity not only attests to the complexity of the physical recovery process but also reflects the multifaceted nature of Europe's cultural identity.

In the initial stage of post-war reconstruction, due to a deficit of economic and technological resources, architectural design shifted towards utilitarian functionalism. Given the severe consequences of the war, the primary needs of the population were linked to ensuring a minimum standard of living, resulting in the aesthetic aspects temporarily becoming a secondary concern.

From the 1950s onwards, the intensification of residential construction gained new momentum. Architects began designing housing complexes that took into account regional conditions, technological advancements, and demographic-social factors. However, the specifics of mass housing construction led to a structural uniformity of residential blocks, which somewhat indicated a limitation in architectural diversity.

In the early phase of the second half of the twentieth century, during the 1950s, post-war architectural trends spread globally; however, they no longer adhered to a unified structural and stylistic concept. Independent architectural schools emerged in various cultural contexts around the world, where groups of talented architects defined the architectural identity of their regions. In this process, Alvar Aalto played a particularly significant role in Finland, where his work contributed to the formation of an original national style. Meanwhile, in Japan, Kenzo Tange and his contemporaries established a movement that transformed Japanese architecture into a globally recognized avant-garde direction.

During this period, the architecture of Ludwig Mies van der Rohe gained particular popularity. His designed buildings were characterized by the principles of minimalism and laconicism, marking a new phase in architectural practice. His projects, primarily realized in the form of rectangular parallelepipeds, featured flat roofs and transparent glass facades. The predominance of glass and stainless steel in the material palette confirmed a high level of technological aesthetics. Van der Rohe's work is a classic example of modernism, demonstrating the harmonious coexistence of functionalism and minimalism.

An outstanding example of the architectural heritage of the 1950s is the "Lever House" building located in New York, which is considered one of the classic specimens of "International Style." This structure is distinguished by its clear geometric forms, technological excellence, and optimized functionality, which collectively render it a symbol of modern architecture. The design of the "Lever House" represents a consistent embodiment of modernist ideals, where function and form exist in harmonious conjunction.

Post-war architectural development in the United States was particularly dynamic. In the early 1950s and 1960s, neoclassicism maintained significant positions, similar to Europe in the 1930s. However, new architectural trends gradually gained momentum. Neoclassical buildings, with their pomp and grandeur, often lost human scale and emotional connection to the environment, which had a substantial impact on the social and psychological functions of architecture.

In the early phase of the second half of the twentieth century, an intensive construction process was realized on a global scale, in which reinforced concrete structures and lightweight exterior facades played a significant role. The "International Style," established in the 1920s and 1930s, was further refined in the 1950s and became widely disseminated due to technological advancements. The development of construction technologies made it possible to create spaces without load-bearing walls, which became not only a symbol of structural innovation but also of the dynamics of modern life. In the 1960s, mass construction met the socio-cultural and economic realities of Western society.

The mid-twentieth century became a pivotal moment in the evolution of modern architecture. During this period, architectural form was assigned independent aesthetic and ideological significance. Significant resources were expended on the creation of "monuments of the era," which played an important role in terms of public perception; however, their practical use often deviated from everyday needs. Mass construction, on the other hand, maintained a utilitarian and standardized nature, which limited the possibilities for architectural expressiveness.

Le Corbusier underwent significant changes in his creative approach during the post-war period. His "Unité d’Habitation," created in Marseille, served as a pioneering example of a new type of living space, marking a new phase in architectural practice.

The 17-story complex, reinforced by massive columns, featured a unique structural solution. The complex contained 337 different types of residential apartments, commercial spaces, and a daycare center, making it functionally diverse and innovative. However, the attempt to modernize traditional European housing caused certain challenges in the layout of living spaces and economic efficiency within the multi-story complex. Despite these circumstances, the project gained international recognition for its innovative architectural solutions. "Unité d'Habitation" presented concrete not merely as an amorphous material but as a tangible, massive, and solid substance, characterized by rigid and sharp forms with raw surfaces, which later became one of the foundations of brutalism.

In his theoretical writings, Le Corbusier opposed a dogmatic interpretation of simplicity. Although his projects from the 1920s and 1930s were characterized by a laconic aesthetic, their spatial compositions had a high degree of complexity. In the post-war period, his work became even more intricate. As a sensitive researcher of architectural trends, Le Corbusier was one of the first to recognize the cultural and intellectual transformations of the era. The design of the "Chapelle de Ronchamp" offers an unexpected interpretation of architectural forms, heralding a shift from geometric rigor to plasticity and from minimalism to expressiveness.

In Le Corbusier's post-war work, a new concept of architectural formation emerged. Whereas his previous approach was based on functionalism, structural logic, and purposeful rationalism, at this stage, the architectural object transitioned into the category of sculptural creation. Buildings were no longer merely "designed for living"; they became an independent form of architectural expression, approaching the realm of sculptural art. Thus, like Frank Lloyd Wright, Le Corbusier equated the role of the architect with that of the artist, liberating it from stringent mathematical calculations, functional rationalism, and utilitarian demands.

The trend of overcoming the priorities of utilitarian functionalism found extreme expression in the late 1950s and early 1960s through the implementation of the new capital of Brazil, the city of Brasília. The conceptualization of urban planning belongs to Lúcio Costa, while the design of the main architectural complexes was carried out by Oscar Niemeyer. The city's master plan was based on a formal schematic model, sharply distinguishing it from classical urban planning. However, despite its aesthetic uniqueness, the lack of effective integration of spatial connections somewhat limited the city's functionality.

The architectural ensemble of Brazil's governmental center, defined by the formal and stylistic canons of the 20th century, is essentially a successor to the tradition of representative ensembles. Its grandeur and monumentality do not align with the fundamental principles of the theorists of new architecture from the 1920s, who emphasized the anti-democratic nature of classicism.

The plasticity of Brazil's governmental complex is based not on functional and engineering solutions, but on monumental aesthetics, transforming it into a large-scale abstract sculpture that feels spiritually alien to humans. However, the prioritization of artistic aspects in architecture in the early second half of the 20th century, weighted against functional, technical, and economic principles, led to the creation of new architectural compositions. These unique buildings, having withstood the test of time, continue to represent cultural heritage today.

Modern architecture emerged as a humanist response against the prevailing social order. It originates as an independent aesthetic and philosophical movement; however, through historical evolution, it became part of the bourgeois cultural system. In the post-World War II period, modern architecture gained widespread recognition and acceptance, becoming the dominant architectural paradigm in the second half of the 20th century.

In the 1950s, a diverse movement of modern international architecture emerged. In the context of capitalist competition, the growing demand for sensational and visually striking projects led to the neglect of architecture's functional and social values. Architecture from the 1950s, and especially the 1960s, gradually distanced itself from purposeful functionalism, which had been the foundation of modern architecture. Practical requirements receded to the background, while psychological and aesthetic effects became the focal point.

The characteristics of modern cult buildings include the irrationality, diversity, and fantastical, often dramatic expressiveness of compositional and architectural forms. Modern technologies and materials allow for the creation of mystical and emotionally charged spaces.

Diversity has become a key characteristic of contemporary architecture. Unlike past architectural styles, which were defined by rigid forms, defining stylistic unity in the modern era is associated with significant challenges. This diversity is influenced by several factors. First and foremost, the expanded range of building purposes and functional organization has led to a variety of architectural forms, reflected in both spatial arrangements and visual styles. Additionally, the diversity and dynamism of structural and engineering solutions, against the backdrop of technological progress, have contributed to the development of architectural form diversity.

In the 1920s, Le Corbusier, Mies van der Rohe, and Walter Gropius formulated new architectural principles based on reinforced concrete construction. However, the subsequent development of construction technologies led to a diversity of structural and constructive approaches in architecture, fostering an increase in the variety of architectural forms. Consequently, in the formation of modern architectural style, both aesthetic-ideological and functional-technological innovations play a significant role.

The diversity of architectural forms is determined not only by technological progress but also by the increased scale and pace of construction. Historically, the slow pace of construction processes was characterized by the creation of a relatively small number of unique buildings. Mass construction primarily served functional needs and often did not take architectural-aesthetic aspects into account. In the modern era, the sharp increase in the pace of construction has led to the transformation of not only individual complexes but also entire urban environments. For the first time in history, projects created by professional architects took on a mass character. Therefore, the main challenge for contemporary architects has been to develop diverse and innovative solutions that confer a distinctive and optimized character to architectural forms.

A significant influence of economic relations on contemporary architecture is noted. Considering market competition and demand, external aesthetics are often prioritized, equipping architectural compositions with commercial and advertising elements, which undermines their conceptual and functional integrity.

Technical requirements driven by commercial considerations have a significant impact on contemporary architecture, often disregarding the interests of users and the public. However, a designer with a progressive vision, professional ethics, and creative potential can address significant and innovative architectural challenges.

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Forces of water flow on a large stone placed at the bottom of a water channel, Vakhtang Bogveradze, Doctoral Program Student, Supervisor: Eduard Kukhalashvili, Professor

Abstract

In the mountain and foothill regions, a certain part of the territories is located in the zone of destructive influence of mudslides. The mentioned space can (Construction of roads and canals on the slopes, deforestation of forest massifs, destruction of grass cover in the alpine and subalpine zone due to intensive cattle grazing, extraction of mineral resources, etc.) be significantly expanded due to the often unforeseeable actions of man.

In this way, further restoration of damaged areas becomes significantly difficult and often even impossible. Therefore, it is advisable to take all measures in advance in order to minimize such negative processes, including flood events, which to some extent contribute to the disturbance of the existing sustainable state of the surface landscape.

Mudflows of strong destructive power are mainly formed in erosion centers of high mountain regions, which represent a whole system of small beds in the headwaters of mountain watercourses; As a result of the collapse of the mountain rocks and their movement from top to bottom, they are filled with broken masses, then they are subject to exhaustion, brittleness and fragmentation under the influence of various factors. The muddy mass produced as a result of such processes covers the surfaces of the crushed materials together with the slurry and fills the voids between them. The alluvial mixture prepared in this way and accumulated in the erosion center turns out to be the so-called B in a locked position and enough heavy rain, intense snowmelt or other similar reasons for it to move downwards, carrying rock debris, stones, logs, etc. along the way.

In the paper, the minimum average velocity in the cross-section of the water flow, at which the stone starts to slide in the beds with positive and zero slope, is determined.

Using the mentioned method, it is possible to determine the speed of water flow in the case of stone rolling friction. The case of partial immersion of the stone in the water stream will also be taken into account.

Keywords: Mudslide, water flow, Riverbed, stream, The force of friction.

Introduction

Unbound alluvial flow often transports large boulders. In studies related to sedimentary processes, the issue of transport of bottom sediments is often discussed, although a detailed analysis of the movement of large stones is not proposed. The impact of water flow on a large stone located separately at the bottom of the bed is discussed [1,2].

In studies related to sedimentary processes, the issue of transport of bottom sediments is often discussed, although a detailed analysis of the movement of large stones is not proposed. The impact of water flow on a large stone located separately at the bottom of the bed is discussed.

In order to determine the minimum speed for the transport of a large stone by water flow, both for a bed with a positive and negative slope, let's make an equation for the balance of the forces acting on the stone. In this case, special attention should be paid to the friction that occurs between the stone and the water channel bed [3,4].

Main part

When one body moves on the surface of another body, a kinematic “sliding friction'' and “oscillating friction'' are distinguished. Dry friction is also distinguished from dry friction (ie internal friction). The dry friction force according to Amonton's law is equal to

$$F_{sl} = fN$$

(f - is the coefficient of friction; N - is the force of normal pressure of bodies against each other). The dry frictional force of a sphere or circular cylinder with radius r rolling on a flat surface is determined by Coulomb's relation

$$F_{ro} = f_{ro}\frac{N}{r}$$

where f_{ro} - is the coefficient of rolling friction. Generally, the force of rolling friction is less than the force of sliding friction.

Wheel coefficient of friction is essential during the transportation of stones of large diameter and small stones by the flow of water.

In order to determine the minimum speed of stone transportation in a bed with a backflow by the water stream at an angle of inclination Q_1 to the horizontal plane, let's make the balance equation of the forces acting on the stone.

A stone immersed in water and located at the bottom of the bed is acted upon by P_1 - the pressure force of water, directed perpendicularly to the elemental area of the stone; N_1- there is a strong force against this area, due to the flow of water, which surrounds the surface of the stone; G_1 is the weight of the stone; F_1 -- the frictional force of the stone against the bottom, directed against the direction of the water flow.

Then for the pressure force at the speed of the water flow we will have:

$$P_1 = K_{imp}\omega_m V'^2_{fr(t<0)}\frac{\gamma_{wat}}{2g} \quad (1)$$

where – K_{imp} coefficient of hydrodynamic resistance;

ω_m- area of “middel'' stone carving;

Υ_{wat}- specific weight of water;

$V'_{fR}(i<0)$ - The initial velocity of the rock being moved by the water stream (when i<0), which is taken to be equal to the minimum water velocity at which the rock starts to slide (or roll) on the contact surface of the bed.

The friction force against the stone bed due to the forces N_1 and G_1 will be:

$$F_1 = f(N_1 + G_1 cos\theta_1) = f\omega_m V'^2_{fr(t<0)}\frac{\gamma_{wat}}{2g} + fG_1 cos\theta_1 \quad (2)$$

where **f** –is the coefficient of sliding or rolling friction with respect to the stone bed *);

ω_{enc} - It is an area of stone encirclement by the stream.

The weight of the stone is equal

$$G_{st.} = \gamma_{st.}w = \gamma_{st.}K_f\frac{\pi D^3}{6} \quad (3)$$

where $\Upsilon_{st.}$- is the weight of the stone;

w - volume of stone;

K_f- is the stone shape coefficient;

D - is the diameter of the sphere-shaped stone.

Then the weight of the stone in the water will be:

$$G_1 = G_{st} - G_{wat} = (\gamma_{st} - \gamma_{wat})w = K_{fo}(\gamma_{st} - \gamma_{wat})\frac{\pi D^3}{6} \tag{4}$$

The equilibrium equation of the forces acting on the stone placed at the bottom of the bed with a backflow will be:

$$G_1 \sin\theta_1 = P_1 - F_1$$

Considering (1), (2.) and (4.) instead of (5) we will have:

$$K_{fo}(\gamma_{st} - \gamma_{wat})\frac{\pi D^3}{6} sin\theta_1 = K_f \omega_m V'^2_{fr(t<0)} \frac{\gamma_b}{2g} - K\omega_{su} V'^2_{fr(t<0)} \frac{\gamma_{wat}}{2g} - fK_{fo}(\gamma_{st} - \gamma_{wat})\frac{\pi D^3}{6} sin\theta_1$$

***) sliding friction is considered; Similarly, the issue of stone rolling friction can be considered.**

from where

$$V'_{fr(i<0)} = \sqrt{\frac{gK_f(\gamma_{su} - \gamma_{wat.})\pi D^3(\sin\theta_1 + f\cos\theta_1)}{3\gamma_{wat.}(K_{su}\omega_m - f\omega_{su.})}} \tag{6}$$

When , $\theta_1 = 90^\circ$, $\sin\theta_1 = 1$, and $\cos\theta_1 = 0$ i.e. The wall is vertical and (6) will take the form:

$$V'_{fr} = \sqrt{\frac{gK_f(\gamma_{st.} - \gamma_{wat.})\pi D^3}{3\gamma_{wat.}(K_{wat}\omega_m - f\omega_{su.})}} \qquad (7)$$

Dependencies (6) and (7) make it possible to determine the minimum average speed of the year in the cross-section, at which the rock starts to slide in the direction of movement in the bed with reverse.

The following forces will act on a stone at the bottom of a bed θ_2 inclined at an angle to the horizontal plane and with a positive slope (Fig. 1):

P_2 - pressure force:

$$P_2 = K_{wat}\omega_{su}V'^2_{su(i>0)}\frac{\gamma_{wat}}{2g} \qquad (8)$$

N_2 - Shoulder strength

$$N_2 = f\omega_m V''^2_{fr(i>0)}\frac{\gamma_{wat}}{2g} \qquad (9)$$

G_2 - Weight of stone in water

$$G_2 = K_{fo}(\gamma_{st} - \gamma_{wat})\frac{\pi D^3}{6} \qquad (10)$$

F_2 - the frictional force of stone sliding

$$F_2 = \mathrm{f}\left(N_2 + G_2\cos\theta_2\right)$$

$$F_2 = f\left[\omega_m V''^2_{fr(i>0)}\frac{\gamma_{wat}}{2g} + K_{fo}(\gamma_{st} - \gamma_{wat})\frac{\pi D^3}{6}sin\theta_2\right] \qquad (11)$$

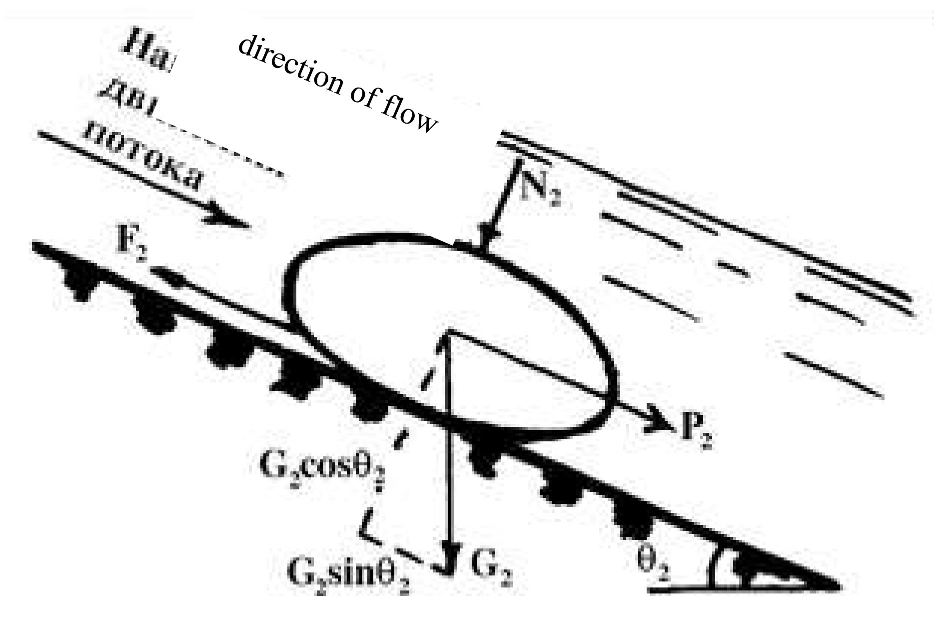
The equilibrium equation will have the following form:

$$P_2 + G_2\sin\theta_2 = F_2$$

(8), (9), (10) and (11) are taken into account

$$K_f \omega_m V'^2_{fr(t<0)} \frac{\gamma_b}{2g} + K_f(\gamma_{st} - \gamma_{wat}) \frac{\pi D^3}{6} sin\theta_2$$
$$= f\left[\omega_m V''^2_{fr(i>0)} \frac{\gamma_{wat}}{2g} + K_f(\gamma_{st} - \gamma_{wat}) \frac{\pi D^3}{6} sin\theta_2\right]$$

from where



draw. 1. Scheme of the forces acting on a large stone placed at the bottom of the bed

$$V''_{fr.} = \sqrt{\frac{gK_f \quad (\gamma_{st.} - \gamma_{в})\pi D^3 (f\, cos\,\theta_2 - sin\,\theta_2)}{3\gamma_{в}(K_c \omega_{м} - f\,\omega_{об})}} \tag{12}$$

When $i = 0$, $\theta_2 = 0$, $\sin\theta_2 = 0$, $\cos\theta_2 = 1$ and instead of (12) we have (that is, for a bed of zero rockiness):

$$V''_{fr.} = \sqrt{\frac{gK_f \quad (\gamma_{st.} - \gamma_{в})\pi D^3}{3\gamma_{wat}(K_{wat}\omega_{м} - f\,\omega_{su})}} \tag{13}$$

Dependencies (12) and (13) make it possible to determine the minimum average speed in the cross section of the water flow at which the stone starts to slide in beds with positive and zero slope.

Comparing (7)-isa and (13), it can be seen that the minimum velocity of water flow, at which it starts to move on a vertical wall, differs from the velocity of water in a bed with zero slope by the magnitude:

$$\frac{Vfr}{Vfr} = \sqrt{f} \tag{14}$$

Conclusion

Using this method, it is also possible to determine the speed of the water flow in the case of rolling friction of a stone. The calculations can also take into account the case of partial immersion of the stone in the water flow.

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Calculation of the n-th derivative of the product of complex functions using Leibniz's method, *Bregvadze Papuna, Bachelor Program Student, Supervisor: Tariel Kvitsiani, Professor*

I. Introduction

In solving technical problems, many solutions involve high-order differential equations and their solutions. In this case, it is necessary to compute the n-th derivative of the solution of the equation, which is often represented as a product of complex functions. For example, if the solution contains a product of two complex functions, then sequentially calculating its n-th derivative is a complex and labor-intensive process.

Let us say, we are given the following 8th-order differential equation [1]:

$$\frac{d^8W_m}{d\varphi^8}+\frac{d^6W}{\partial\varphi^6}+\frac{12R^6}{h^2}\left(\frac{2m-1}{l}\pi\right)^4 W_m=\frac{12R^4}{Eh^3}Q_m(\varphi); \quad m=1,2,\ldots, \qquad (1)$$

Which, for a fixed mmm, can be written as follows:

$$\frac{d^8y}{d\varphi^8}+\frac{d^6y}{d\varphi^6}+a_m^2y=f_m(\varphi), \qquad (2)$$

Where $y=W_m$,

$$a_m^2=\frac{12R^6}{h^2}\left(\frac{2m-1}{l}\pi\right)^4; \quad f_m(\varphi)=\frac{12R^4}{Eh^3}Q_m(\varphi), \qquad (3)$$

The general solution of the differential equation (1) is written as follows:

$$W_m(\varphi)=K_m\sin\varphi+\sum_{i=1,3,5,7} e^{a_{i+1}\varphi}\left(c_i\cos b_{\frac{i+1}{2}}\varphi+c_{i+1}\sin b_{\frac{i+1}{2}}\varphi\right), \qquad (4)$$

$$U(\varphi)=e^{\frac{a_{\frac{i+1}{2}}\varphi}{2}}$$

The second term in (4) represents the product of two and $V(\varphi)=c_i\cos b_{\frac{i+1}{2}}\varphi+c_{i+1}\sin b_{\frac{i+1}{2}}\varphi$

The product of the functions. To simplify the subsequent mathematical operations, let us introduce the following notations:

$$f(\varphi)=U(\varphi)\cdot V(\varphi), \tag{5}$$

$$a_{\frac{i+1}{2}}=a; \quad b_{\frac{i+1}{2}}=b; \quad c_i=c_1; \quad c_{i+1}=c_2, \tag{6}$$

With these notations, the relation (5) will take the following form:

$$f(\varphi)=U(\varphi)\cdot V(\varphi)=e^{a\varphi}(c_1\cos b\varphi+c_2\sin b\varphi), \tag{7}$$

Relation (7) contains the product of two complex functions, and it is necessary to compute its n-th derivative. In [2], a formula is provided that allows the computation of the n-th derivative of a function, which does not involve the notation of the derivatives of previous orders of $Wm\,(\varphi)$, and it has the following form:

$$\frac{d^nW_m}{d\varphi^n}=K_m\sin\left(\varphi+\frac{n\pi}{2}\right)+\sum_{i=1,3,5,7}\sqrt{(c_i^2+c_{i+1}^2)\left(a_{\frac{i+1}{2}}^2+b_{\frac{i+1}{2}}^2\right)^n}\cdot e^{\frac{a_{\frac{i+1}{2}}\varphi}{2}}\times$$
$$\times\cos\left(b_{\frac{i+1}{2}}-\psi_1+n\psi_2\right);, \tag{8}$$

Where

$$\psi_1=\arccos\frac{c_i}{\sqrt{c_i^2+c_{i+1}^2}}=\arcsin\frac{c_{i+1}}{\sqrt{c_i^2+c_{i+1}^2}};$$

$$\psi_2=\arccos\frac{a_{\frac{i+1}{2}}}{\sqrt{a_{\frac{i+1}{2}}^2+b_{\frac{i+1}{2}}^2}}=\arcsin\frac{b_{\frac{i+1}{2}}}{\sqrt{a_{\frac{i+1}{2}}^2+b_{\frac{i+1}{2}}^2}}$$

II. Main Part

To avoid the complications of the arguments $\psi 1$ and $\psi 2$ their relationships, and to simplify the calculations of the expression $\cos(b-\psi_1+n\psi_2)$, we can apply another method to find the n-th derivative of the expression (7). Specifically, as is known, for simple functions, Leibniz's following formula [3] holds true:

$$(U\cdot V)^{(n)}=U^{(n)}\cdot V^{(0)}+n\cdot U^{(n-1)}\cdot V^{(1)}+\frac{n(n-1)}{2!}\cdot U^{(n-2)}\cdot V^{(2)}+\ldots+$$

$$+\frac{n\cdot(n-1)\ldots(n-k+1)}{K!}\cdot U^{(n-K)}\cdot V^{(K)}+\ldots+U^{(0)}\cdot V^{(n)}, \tag{9}$$

Where $U^{(0)}=U \quad \text{და} \quad V^{(0)}=V$

From Leibniz's formula (9) for the product of functions, we can easily derive the general formula for calculating the product of any $U(\varphi)$ and $V(\varphi)$ functions using the method of induction, and, ultimately, $[Wm(\varphi)]$ (n) the general formula for calculating the expression:

$$\frac{d^nW_m}{d\varphi^n}=K_m\sin\left(\varphi+n\cdot\frac{\pi}{2}\right)+$$

$$+\sum_{i=1,3,5,7}\left[C_i\sum_{n=0}^{n}C_n^K\left(e^{\frac{a_{i+1}\varphi}{2}}\right)^{(n-K)}\cdot\left(\cos b_{\frac{i+1}{2}}\varphi\right)^{(K)}+C_{i+1}\sum_{n=0}^{n}C_n^K\left(e^{\frac{a_{i+1}\varphi}{2}}\right)^{(n-K)}\cdot\left(\sin b_{\frac{n+1}{2}}\varphi\right)^{(K)}\right], \tag{10}$$

Where $C_n^K=\dfrac{n!}{K!(n-K)!}\Rightarrow C_n^K=\dfrac{n(n-1)\ldots(n-K+1)}{1\cdot 2\cdot\ldots\cdot K}$

Now, for verification purposes, let's directly calculate using formula (9) $\dfrac{d^2W_m}{d\varphi^7}$, That is, the case when n=7n = 7n=7. Let's first calculate it

$$f^{(7)}(\varphi)=[U(\varphi)\cdot V(\varphi)]^{(7)}$$

Suppose, $K=4m+1$,

Where l=0,1,2,3. Then

$$(\cos b\varphi)^{(K)} = \begin{cases} b^K \cos b\varphi, & \ell = 0, \\ -b^K \sin b\varphi, & \ell = 1, \\ -b^K \cos b\varphi, & \ell = 2, \\ -b^K \sin b\varphi, & \ell = 3, \end{cases} \qquad (\sin b\varphi)^{(K)} = \begin{cases} b^K \sin b\varphi, & \ell = 0, \\ -b^K \cos b\varphi, & \ell = 1, \\ -b^K \sin b\varphi, & \ell = 2, \\ -b^K \cos b\varphi, & \ell = 3. \end{cases} \tag{11}$$

and

will be
$$\begin{cases} (\cos b\varphi)^{(0)} = \cos b\varphi, \\ (\cos b\varphi)^{(1)} = -b \sin b\varphi, \\ (\cos b\varphi)^{(2)} = -b^2 \cos b\varphi, \\ (\cos b\varphi)^{(3)} = b^3 \sin b\varphi, \\ (\cos b\varphi)^{(4)} = b^4 \cos b\varphi, \\ (\cos b\varphi)^{(5)} = -b^5 \sin b\varphi, \\ (\cos b\varphi)^{(6)} = -b^6 \cos b\varphi, \\ (\cos b\varphi)^{(7)} = b^7 \sin b\varphi \end{cases} \qquad \begin{cases} (\sin b\varphi)^{(0)} = \sin b\varphi, \\ (\sin b\varphi)^{(1)} = b \cos b\varphi, \\ (\sin b\varphi)^{(2)} = b^2 \sin b\varphi, \\ (\sin b\varphi)^{(3)} = b^3 \cos b\varphi, \\ (\sin b\varphi)^{(4)} = b^4 \sin b\varphi, \\ (\sin b\varphi)^{(5)} = b^5 \cos b\varphi, \\ (\sin b\varphi)^{(6)} = -b^6 \sin b\varphi, \\ (\sin b\varphi)^{(7)} = -b^7 \cos b\varphi. \end{cases} \tag{12}$$

When n=7n = 7n=7, then the coefficient C_n^K is easy to calculate.

$$C_7^0 = 1; \; C_7^1 = 7; \; C_7^2 = \frac{7 \cdot 6}{1 \cdot 2} = 21; \; C_7^3 = \frac{7 \cdot 6 \cdot 5}{1 \cdot 2 \cdot 3} = 35; \; C_7^4 = C_7^3 = 35$$

$$C_7^5 = C_7^2 = 21; \; C_7^6 = C_7^1 = 7; \; C_7^7 = C_7^6 = 1, \tag{13}$$

(Here, let us use the trivial fact that $C_n^K = C_n^{n-K}$.

Considering (11), (12), and (13), we will obtain:

$$f_1^{(7)}(\varphi) = (e^{a\varphi} \cos b\varphi)^{(7)} = \sum_{K=0}^{7} C_7^K (e^{a\varphi})^{(7-K)} \cos b\varphi = a^7 e^{a\varphi} \cos b\varphi + 7a^6 e^{a\varphi}(-b \sin b\varphi) +$$

$$+21a^5 e^{a\varphi}(-b^2 \cos b\varphi) + 35a^4 e^{a\varphi}(b^3 \sin b\varphi) + 35a^3 e^{a\varphi}(b^4 \cos b\varphi) +$$

$$+21a^2 e^{a\varphi}(-b^5 \sin b\varphi) + 7ae^{a\varphi}(-b^6 \cos b\varphi) + e^{a\varphi}(b^7 \sin b\varphi); \,, \tag{14}$$

$$f_2^{(7)}(\varphi)=(e^{a\varphi}\sin b\varphi)^{(7)}=a^7e^{a\varphi}\sin b\varphi+7a^6e^{a\varphi}(b\cos b\varphi)+21a^5e^{a\varphi}(-b^2\sin b\varphi)+$$
$$+35a^4e^{a\varphi}(-b^3\cos b\varphi)+35a^3e^{a\varphi}(b^4\sin b\varphi)+21a^2e^{a\varphi}(b^5\cos b\varphi)+$$
$$+7ae^{a\varphi}(-b^6\sin b\varphi)+e^{a\varphi}(-b^7\cos b\varphi), \tag{15}$$

Obviously, $f^{(7)}(\varphi)=C_i f_1^{(7)}(\varphi)+C_{i+1}f_2^{(7)}(\varphi)$,

Furthermore, according to the notations in (6) $a=a_{\frac{i+1}{2}}$, $b=b_{\frac{i+1}{2}}$

And finally, we will obtain the formula for calculating the n-th derivative of the functional relation (4):

$$\frac{d^7W_m}{d\varphi^6}=-K_m\cos\varphi+\sum_{i=1,3,5,7}[C_ie^{\frac{a_{i+1}\varphi}{2}}(a_i^7\cos b_{\frac{i+1}{2}}\varphi-7a_{\frac{i+1}{2}}^6b_{\frac{i+1}{2}}\sin b_{\frac{i+1}{2}}\varphi-$$
$$-21a_{\frac{i+1}{2}}^5b_{\frac{i+1}{2}}^2\cos b_{\frac{i+1}{2}}\varphi+35a_{\frac{i+1}{2}}^3b_{\frac{i+1}{2}}^4\cos b_{\frac{i+1}{2}}\varphi-21a_{\frac{i+1}{2}}^2b_{\frac{i+1}{2}}^5\sin b_{\frac{i+1}{2}}\varphi-$$
$$-7a_{\frac{i+1}{2}}b_{\frac{i+1}{2}}^6\cos b_{\frac{i+1}{2}}\varphi+b_{\frac{i+1}{2}}^7\sin b_{\frac{i+1}{2}}\varphi)+C_{i+1}e^{\frac{a_{i+1}\varphi}{2}}\cdot(a_{\frac{i+1}{2}}^7\sin b_{\frac{i+1}{2}}\varphi+$$
$$+7a_{\frac{i+1}{2}}^6b_{\frac{i+1}{2}}\cos b_{\frac{i+1}{2}}\varphi-21a_{\frac{i+1}{2}}^5b_{\frac{i+1}{2}}^2\sin b_{\frac{i+1}{2}}\varphi-35a_{\frac{i+1}{2}}^4b_{\frac{i+1}{2}}^3\cos b_{\frac{i+1}{2}}\varphi+$$
$$-35a_{\frac{i+1}{2}}^3b_{\frac{i+1}{2}}^4\sin b_{\frac{i+1}{2}}\varphi+21a_{\frac{i+1}{2}}^2b_{\frac{i+1}{2}}^5\cos b_{\frac{i+1}{2}}\varphi-7a_{\frac{i+1}{2}}b_{\frac{i+1}{2}}^6\sin b_{\frac{i+1}{2}}\varphi-b_{\frac{i+1}{2}}^7\cos b_{\frac{i+1}{2}}\varphi)]. \tag{16}$$

III. Conclusion

The method we used allows us to avoid the calculations of the arguments $\psi 1$ and ψ 2 their relationships, $\cos(b-\psi_1+n\psi_2)$, which are involved in the computation of the n-th derivative formula (8) derived in [2].

Through verification, we can easily confirm that the result obtained by the direct application of formula (16) exactly matches the expression obtained by sequential differentiation of (7). In a specific test problem, research conducted confirmed that the result obtained from the (16) relation is identical to the result obtained from formula (8) in [2].

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Innovations in Construction,

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Abstract

This article will discuss innovative technologies that are most often used in construction today. Innovations in construction have dramatically changed the industry, increasing efficiency, sustainability and safety. Innovations not only enhance construction capabilities, but also solve pressing challenges such as climate change, urbanization and the need for resilient infrastructure.

Introduction

Innovations in construction are useful for several main reasons:

1. New technologies improve design and construction processes, reduce time and costs. For example, technologies such as Building Information Modeling (BIM) enable better planning and resource management.

2. Innovations such as drones reduce the risk of accidents and enhance worker safety on construction sites.

3. Many innovations focus on environmentally friendly practices such as the use of recycled materials and sustainable construction methods.

4. Scientists have invented materials such as self-healing concrete, which result in structures that are more durable and require less maintenance over time, ultimately saving costs.

5. Rapid urban growth is leading to innovations that enable more flexible and efficient designs that adapt to changing needs and space constraints in urban environments.

6. The integration of IoT and smart technologies enables real-time monitoring and data collection, allowing engineers to make informed decisions about maintenance and upgrades.

7. Innovation can lead to job creation and economic development by fostering new industries and improving infrastructure, which is crucial for the development of society.

8. Innovative approaches contribute to the creation of infrastructure that can withstand extreme weather events and environmental challenges, ensuring long-term viability.

Overall, these innovations lead to safer, more sustainable and more efficient construction practices, which will benefit society.

Main part

When it comes to modern construction, the importance of building materials is undeniable. It is these materials that determine the strength, durability and aesthetic appearance of buildings and structures. The materials used in modern construction are constantly evolving and improving to meet the increasing demands for safety, comfort and energy efficiency. Scientists have invented materials that can respond to environmental changes. For example, self-healing concrete and phase-change materials improve durability and reduce maintenance costs.

Self-healing concrete is an innovative material that automatically repairs itself over time, significantly improving the durability and lifespan of concrete structures. The term became popular in 2015, sparking a lot of interest in the construction industry. This building material continues to be studied to its full potential.

How it works:

1. Concrete contains capsules filled with healing agents (such as epoxy). When cracks form, these capsules break down and release agents to seal the cracks.

2. When water enters the cracks, bacteria become active, consuming nutrients and producing limestone to fill the gaps.fgb

3. It incorporates polymers that react with air to seal the cracks after exposure.

Self-healing concrete extends the life of structures and reduces maintenance needs. It helps maintain structural integrity and prevent the progression of cracks. It is used in the construction of bridges, roads, highways, parking lots, water tanks and dams. All of this is good, but its cost is a hindrance. The price of self-healing concrete can vary significantly based on several factors, including the type of self-healing mechanism used, the scale of the project and regional construction costs. Self-healing concrete can generally cost about 20% to 30% more than traditional concrete, depending on various factors. This means that while standard concrete costs about $100 per cubic yard, self-healing concrete can range from $120 to $130 or more. Scientists are currently working to make its use more affordable.

Overall, self-healing concrete is a promising advancement that enhances the durability, safety, and sustainability of infrastructure, making it a vital area of research and development in construction.

Smart glass is increasingly being integrated into construction and architecture, offering a number of benefits that enhance functionality, sustainability, and sustainability, making it a vital area of research and development in construction.

Smart glass is increasingly being integrated into construction and architecture, offering a number of benefits that enhance the functionality, sustainability and aesthetics of buildings. Smart glass can automatically adjust its transparency based on outdoor lighting conditions, reducing heat gain in buildings. This can lead to reduced energy consumption for heating and cooling systems. By optimizing the amount of natural light entering a space, smart glass reduces the need for artificial lighting, which further reduces energy costs. Many smart glass products filter harmful UV rays, protecting occupants and reducing the deterioration of furniture and interiors. Certain types of smart glass can also provide sound insulation. Smart glass can be used on facades, windows, and interior partitions to create visually appealing designs that incorporate dynamic lighting. Liquid crystal glass can be switched from transparent to opaque, providing instant privacy for conference rooms, bathrooms, or living spaces without the need for curtains or blinds. The initial investment for smart glass can be higher than traditional materials, which can hinder some projects, especially in budget-sensitive developments. The approximate price ranges from $25 to $100 or more. The price depends on the type of glass.

In addition to these building materials, there are a few materials that can respond to environmental changes, making construction easier.

Building Information Modeling (BIM) is very important in construction. BIM is an intelligent, 3D model-based tool that provides users with a digital representation of the physical and functional characteristics of an object. BIM software is used by individuals, businesses, and government agencies to plan, design, construct, operate, and operate buildings and various physical infrastructures, such as electricity, gas, communications, roads, railways, bridges, ports, and tunnels. It can produce accurate and coordinated elements, calculate the quality of building work and energy consumption, and conduct construction safely and efficiently.

Although drones have been widely used in other industries (such as agriculture, public safety, military purposes, science and research, security monitoring, mining, etc.), their use in the construction industry has begun relatively recently. 360-degree panoramas taken from drones reflect a real picture of the situation, which is the best way to manage large-scale facilities. Drones make it easier to create 3D models. Drone technology is one of the most promising developments in the construction industry in recent years. Drones may be used even more widely to transport construction materials. However, their use in this area is still at an experimental level. There are already projects where drones transport various types of small and durable materials to the work site. The use of drones on construction sites allows for the simplification of geodetic work.

Drones perform “photogrammetry” – the collection of spatial data, which is especially important in measuring areas.

Modular construction is a process where building components are manufactured off-site and then assembled on site. This process takes half the time, as several building modules are delivered separately to the construction site and assembled on site. There are two types of modular construction – permanent and temporary buildings. Depending on the size of the building, the size of the modules also varies. The larger the module, the more difficult it is to transport, but overall, the process is still simpler than traditional construction. Such buildings often house clinics, offices and schools. The largest modular construction is in Singapore – Bouygues Batiment International. The high-rise office building is 140 meters high, and its design belongs to the architectural office ADDP Architects. 1899 prefabricated panels were created for the house and 85% of the structure was manufactured off-site. Only the core of the building was built on site from reinforced concrete.

Geotechnical innovations play a significant role in today's world in the construction industry, infrastructure development, and natural disaster management. Geotechnical engineering is a scientific field that focuses on the study of underground structures, soil systems, their properties and behavior, as well as the technologies used to use these systems. As societies have developed, the complexity of geotechnical challenges has increased. The 20th century brought a technological revolution in this field, introducing standardized testing methods and sophisticated equipment for soil investigation, reflecting humanity's continuous quest to understand and use the materials of the earth for the stability and safety of our built environment. Geotechnical engineering determines whether the soil is sufficient to meet the stability of a building or other structure. For this, geotechnical studies are used to reflect the properties of the soil or soil: compactness, strength, water permeability, etc. Geotechnical engineering provides information on how to support a building or infrastructure, such as a foundation, to prevent collapse or soil weakening. Temporary or permanent water flows or acid-soaked soil can significantly damage a building structure if proper waterproofing systems are not planned. Geotechnical engineering is the field that studies water management and soil waterproofing systems to prevent long-term water impacts and structural damage. Geotechnical engineers, who manage the risks associated with the start of construction, actively work to prevent problems and create a safe environment. Geotechnical engineering allows for continuous monitoring at all stages of construction. For example, special sensors are connected to it, which provide constant monitoring of how the ground and underground structures respond to ongoing work and loads.

Smart sensors play a crucial role in construction. Smart sensors allow construction companies to make informed decisions immediately. For example, vibration sensors can detect movement in structures, thereby identifying potential stability issues. Temperature and humidity sensors help monitor environmental conditions that can affect the integrity of building materials. Embedded in concrete, this technology can assess its strength and curing process, which is crucial for the safety of the structure. In addition, air quality measurement sensors are essential to ensure the well-being of construction workers.

Another emerging trend in construction is the use of augmented and virtual reality (AR/VR). **AR** is essentially viewing the world through the lens of an imaginary world. Using AR allows you to plan and arrange spaces even before they are built.

Earthquakes are one of the most destructive forces on Earth - underground seismic waves can destroy buildings, claim lives and cost a huge amount of money to repair. According to the National Earthquake Information Center, an average of 20,000 earthquakes occurs each year - 16 of which end in major disasters. On August 14, 2021, a 7.2 magnitude earthquake struck the southwestern region of Haiti, killing more than 2,000 people. As with other earthquakes, much of the damage was caused by the collapse of buildings, killing people inside. To create a building that is earthquake-resistant, engineers are working to strengthen the structure. One way to resist earthquake forces is base isolation. This technique involves placing an insulating layer or system between a building and its foundation or structure, which ensures that during an earthquake the building will not feel the ground shaking as if it were directly grounded. Base isolation is especially popular in earthquake-prone areas, such as Japan, California, and New Zealand. For example, many hospitals and schools in Japan are equipped with base isolation systems, which provide protection for buildings during giant earthquakes. Dampers are also used during earthquakes to reduce the vibrations of structures. They contain and absorb the energy generated by seismic movements, which makes the building or infrastructure less susceptible to dynamic damage. One of the main challenges during an earthquake is the strong shaking of the building structure, which can lead to breakage, damage, and complete collapse. Dampers provide vibration damping and structural safety. This construction technology allows buildings and other structures to remain stable and resilient during earthquakes. This method involves placing dampers at each level of the building between columns and beams. Each damper consists of piston heads inside a cylinder filled with silicone oil. When an earthquake occurs, the building transmits vibration energy to the pistons, which push the oil. The energy is then converted into heat, dissipating the force of the vibration. Dampers are used as structural protection systems during earthquakes to reduce and contain seismic forces that can cause severe damage. They essentially create a "buffer" between the building and the ground, improving vibration management and reducing risks. The use of modern shock absorbers has become a necessity in the construction of tall buildings, hospitals, and other infrastructure facilities where the risk of earthquakes is high. "Pendulum" constructions or structures help improve stability and at the same time, protect them from vibrations or movements of structures during an earthquake to a small extent or completely.

Conclusion

The future of construction is full of potential, marked by a blend of innovation, sustainability and technology. The future of construction is shaped by cutting-edge technology, sustainability and increased resilience in the face of climate change and urbanization. The future is here, and it is being built by today's builders.

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Changes in the Structure of Fat Granules During Cheese Ripening,

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Abstract

The development of new technologies for milk and dairy products is a topical topic for the world market today.

The work presents a change in the structure of fat granules during the ripening process of cheese, which significantly affects the taste factors of cheese. We conducted observations with a binocular microscope (US1) at different periods of cheese ripening and determined that during aging, fats are localized in the cheese mass.

Keywords: milk, cheese, fat, microscope, localization.

The topic of the doctoral thesis is: "Development of the production technology of Cheese
„Narchvi" therefore the presented article belongs to the field of milk and dairy products.

Cheese is a dairy product, and its diversity is due to differences in production technologies. Cheese has been made since ancient times and is a cultural symbol of many countries.

In Georgia, many traditional cheese-making methods have been adapted, which are characteristic of the regions. For example, Samegrelo is known for its Megrelian Sulguni, Tusheti for its Tusheti Guda cheese, Imereti for its Imeruli cheese, Svaneti for its Narchvi cheese, etc. In Svaneti, the „Narchvi" cheese made by the traditional method is distinguished by both its organoleptic properties and the specificity of its production. Since February 2022, the tradition of making "Narchvi" cheese has been granted the status of a monument of intangible cultural heritage [1]. It has no analogues not only in Georgia, but also in the world.

Its uniqueness, exclusivity of production, and the location of the high-mountainous Svaneti region have led to its appearance and technology, as the low milk yield of cattle during the dry winter and climatic conditions have determined its appearance and technology. It is prepared in late spring and summer and continues as long as the cattle feed on live grass.

Narchvi cheese is packed in wooden boxes (it matures for 3–6 months) and has a long shelf life. It is currently made only in some villages of Upper Svaneti (Latali, Lakhamula, and some villages surrounding Mestia) [2].

In order to popularize “Narchvi” cheese, we have developed a production scheme and technology for making loose cheese.

The classification of cheese, due to its variety (about two thousand types of cheese are known in the world), is divided according to various characteristics: moisture content, fat content, ripening methods, and shelf life.

Depending on the fat content, cheese is divided into categories: non-fat, low-fat, medium-fat, fatty and high-fat cheese. The fat content of cheese is determined in 100 g of dry matter (%). That is, to determine the fat content of cheese, it is necessary to determine the moisture content of the cheese, which is subtracted from the weight of the product. In fatty soft cheese, as a rule, moisture is also higher and, accordingly, fat content is lower, while in fatty hard cheese, due to the low moisture content, the mass fraction of fat increases (however, it is incorrect to talk about the fat content of cheese based on its hardness, since the opposite case may occur - it may not be fatty, but be hard).

When determining the fat content of cheese, it is also important to consider the storage conditions of the product, especially during the ripening of the cheese, since during its dry ripening, the moisture content decreases significantly (it is possible to ripen the cheese wet - in brine).

It should also be noted that, based on scientific research, full-fat cheese does not affect the cholesterol level in the human body, since milk fat is mainly conjugated with linolenic fatty acid and, paradoxically, it prevents the accumulation of fat in the body (the formation of deposits) [3]. So, the high-fat, loose, fermented cheese prepared by us will be recommended for people interested in dieting, despite its high calorie content.

As for the experiment, we investigated and studied the changes in the size and structure of fat globules at different stages of cheese ripening.

To prepare cheese, first of all, we studied the characteristics of the milk, which met the requirements imposed on it (Table 1), pasteurized it at 72 °C for 20 seconds, and since we planned to prepare a fatty cheese (milk fat content 3.98%), we did not perform separation. The remaining procedures for making cheese are similar to those for making cottage cheese (we added solutions of calcium chloride, a leavening enzyme, and pure cultures of lactic acid bacteria to the milk, performed a Delamo incision, and separated the curdled cheese mass from the whey).

Table 1. Raw milk analysis

№	Analysis names	Result
1	Fatty,%	3,98
2	Density, °A	30,3
3	Mineral substances, %	0,72
4	Dry substances, %	8,84
5	Protein, %	3,2
6	Milk temperature during analysis, °C	24,3
7	Lactose, %	4,84
8	Acidity, ^{0} Th	6,7

We subjected the mass separated from the whey to cheddarization on an iron grate, as it was necessary to free the mass from whey as much as possible (Fig. 1). Then we added dry salt (3%), mixed it, shredded the cheese, transferred it to wooden boxes (the box was made of broad-leaved wood, with holes to allow air to circulate in the cheese mass, so that the cheese would not become stuffy during the ripening period and would not allow mold bacteria to multiply. Fig. 2) and pressed it under a pressure of 0.1 MPa for 2 hours. We pulverized (dissolved the stuck parts into granules) and left it in a ripening chamber at 14 °C for 15 days.

Fig.1 Cheddarization of cheese

The cheese we make belongs to the category of fatty cheese, as its fat content is 21.41% after 15 days of aging.

In connection with determining the structural changes of fat granules in cheese, we began periodically (from the very first day) observations of fat granules during cheese ripening.

Fig. 2 Wooden boxes for storing cheese

We observed the cheese on the first, seventh, and fifteenth day of cheesemaking with a binocular/digital microscope US1 (Fig. 3, 4, 5).

Images taken during microscopic observation clearly show that fat globules undergo structural changes during the ripening period - they become more compact/localized, which leads to an improvement in the taste characteristics of the ripened cheese.

On the first day of cheesemaking, during microscopic observation, the structure of fat granules was difficult to see at 40x magnification, as the fat was almost evenly distributed throughout the cheese mass, so we performed the observation at 400x magnification, while on the seventh and fifteenth days, the fat structure is clearly visible at 40x magnification - the fats are more localized/bound.

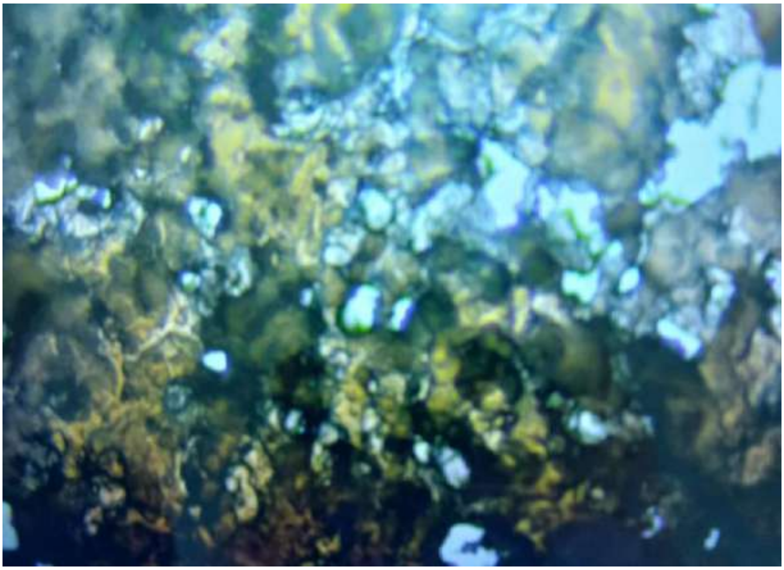

Fig. 3 Structure of fats in cheese at 400x magnification - Day 1.

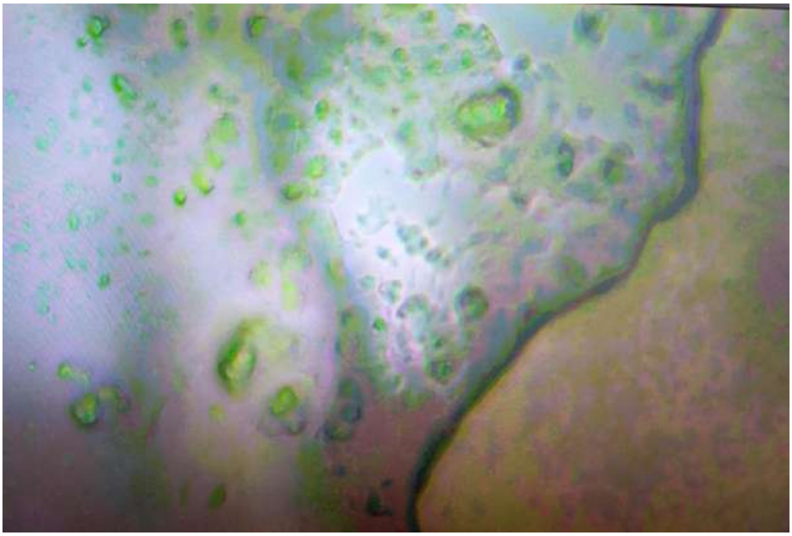

Fig. 4 Structure of fats in cheese at 40x magnification - Seventh day.

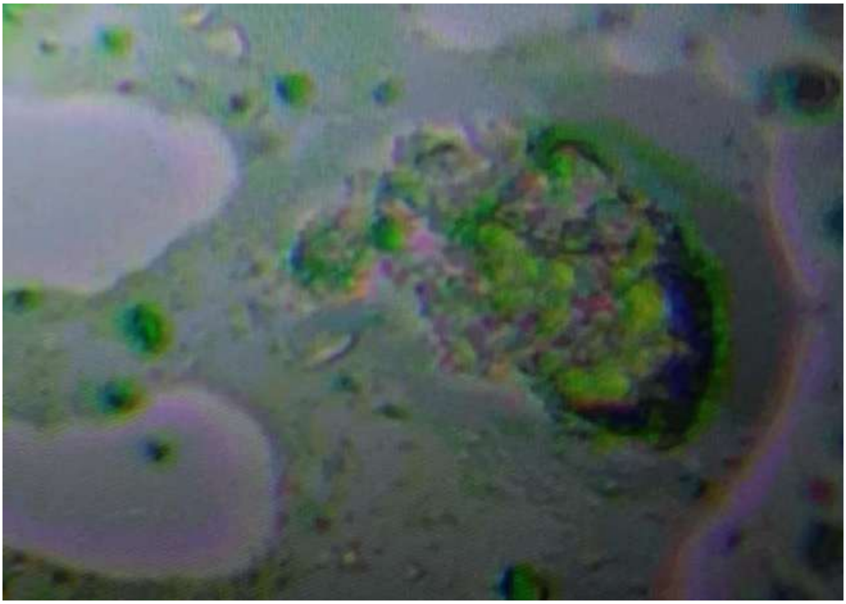

Fig. 5 Structure of fats in cheese at 40x magnification - Fifteenth day.

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Early Medieval Transportation Communications in Western Europe,

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Abstract: The paper discusses the transport communications in Western Europe during the early Middle Ages. It describes the history of the formation and development of the transport systems in cities of that time. Additionally, it highlights the history of the construction of transport networks and roads in the period following the Roman Empire, the general establishment of road networks, and the specific characteristics of water and land transport.

Introduction

Starting from the 5th century AD, the Roman Empire had essentially disintegrated. Monarchies emerged, such as those of the Anglo-Saxons, Franks, Visigoths, Burgundians, and others. Slavery was replaced by feudalism, characterized by large estates owned by the nobility and small farms run by peasants. Feudal lords often waged wars against each other, and a well-developed road network was no longer a necessity for them. Only large states and powerful monarchs, such as Charlemagne (King of the Franks, 742–814), were interested in maintaining roads. Charlemagne not only preserved old roads but also constructed new sections. Ultimately, however, the road network fell into ruin. The cheap labor provided by slaves was no longer available, and local peasants were forcibly employed in road construction, often interrupting their agricultural activities for extended periods. During the era of feudal landownership, most land was controlled by the Church and small-scale feudal lords, who sought to isolate their estates from the common communication network and establish independent transport systems for their own needs. Thus, despite social changes, agriculture remained the main sector of the economy, and the transport networks surrounding it remained largely unchanged, as feudal interests and landownership limited their development.

Main Part

The well-maintained Roman roads deteriorated over the years and transformed into difficult-to-navigate dirt roads. Often, local residents dismantled road surfaces to extract construction stone.

It is worth noting that these processes continued even in the twentieth century. Russian settlers in former East Prussia began systematically dismantling granite pavements and using the stone slabs for building houses from the late 1940s to the early 1950s. In the cities of medieval Europe, many streets were unsuitable for wagons and, in some cases, even for horseback riding. Movement with two-axle carts became particularly challenging. Cargo was primarily transported using pack animals, the population traveled on foot or horseback, while nobles moved in palanquins (see Figures 1. and 2.).

Carts reappeared after the twelfth century when the horse collar was invented. Trade goods were transported in small quantities. In Germany and France, roads often became impassable during rainy seasons until the seventeenth century.

For the most privileged individuals, the elite, there was a form of transportation known as the palanquin. The palanquin was a small, elegant, single-seat cabin with windows, a comfortable seat, and curtains inside. It was carried to the destination by two to four strong men or transported by a horse along with the passenger (see Figure 1.).

The palanquins did not spread easily in all countries. For example, the Duke of Buckingham, who first used this mode of transportation in England in 1581, became the target of criticism not only from ordinary English people but also from the upper class. At that time, the Duke of

Buckingham was accused of using people like animals to carry passengers, as though they were transporting burdens.

Fig. 1. A Noble's Journey in a Palanquin (1556 year)

Fig. 2. Traffic on a Western European Road (1650 year)

By 1643, when the palanquin appeared among the nobility in London as a means of transportation, it sparked great admiration among the upper class, which led to its widespread adoption. More than half a century passed between the rejection and the acceptance of the palanquin in England, during which time the Renaissance era was advancing at full pace (see Figures 3 and 4).

One type of palanquin, the "Portshezi" (meaning chair in French), was used in Tbilisi until the mid-19th century because the city center's cobblestone streets were not paved and became impassable during rain. Information on this can be found at I. Grishashvili House-Museum and in the literary bohemia of Old Tbilisi.

Fig. 3. The movement of a noblewoman

Fig. 4. The movement of a noblewoman

In medieval Europe, a common communication system was created that connected European cities and nearby settlements to transportation networks, enabling peasants and craftsmen to transport and exchange their harvested crops or other products in the cities.

Mass transportation of goods was carried out via river or maritime routes. During this period, city-states engaged in maritime trade developed, such as the Hanseatic League along the Baltic coast (see Fig. 5), Venice (see Fig. 6), and connections between northern and southern maritime port cities via land routes. Most of these routes passed through Germany (see Fig. 7).

Fig. 5. The Hanseatic League of Cities on the Baltic Coast

Fig. 6. Transportation map of Venice (1689 year

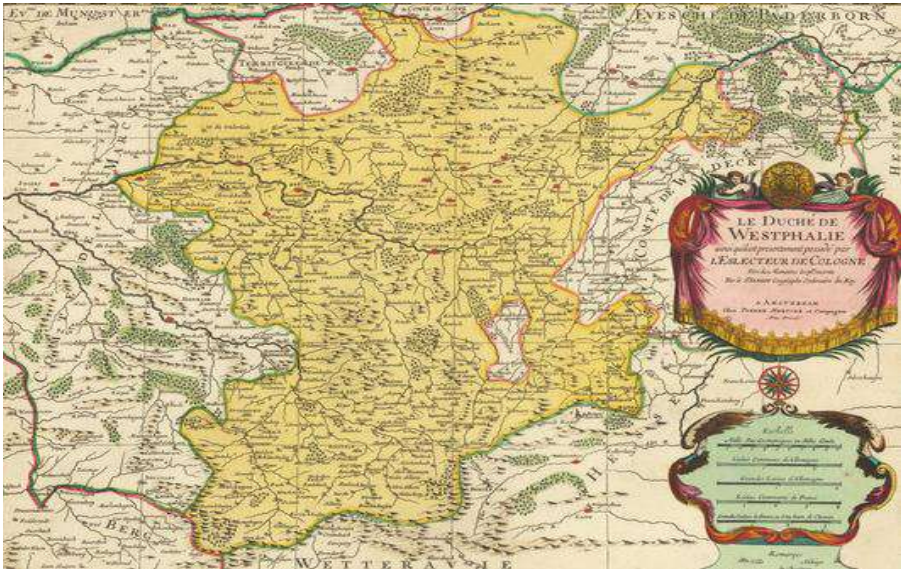

Fig. 7. Germany (Duchy of Westphalia)

If Roman sections were not preserved, other roads were dirt paths. In some places, the surfaces were reinforced with gravel or a mixture of sand and gravel. The width of a wheeled road did not exceed 4.5–5.0 meters. In the mountains, however, roads for palanquin transport were only 1.5–2.7 meters wide.

Also, certain traffic rules were established. A cart without a load would carry the one with a load, a horseback rider would lead the cart, and a pedestrian would follow the horseback rider. On a narrow bridge, priority was given to whoever entered the bridge first. Movement was on the left side, as it made it easier for an oncoming rider to draw a weapon.

In the 13th century, French jurist Philippe de Beaumanoir distinguished five types of roads:

1. Pathway - width 4 feet (≈ 1.40 meters);
2. Single-lane road - 8 feet;
3. Two-way road - 16 feet;

4. Intercity road - 32 feet;
5. "Great road" - 64 feet.

The last three categories (two-way road, intercity road, "great road") were called royal roads. Palanquins were carried by mules, horses, and donkeys. Carts were usually horse-drawn, and rarely drawn by oxen. The speed of travel was slow because it mostly took place during daylight hours. It took two months to transport goods from Nuremberg to Venice. Attacks by bandits were common, so merchant caravans were armed.

In 1285, King Edward I of England issued a law that required the side visibility distance on intercity roads to be no less than 200 feet (≈ 65 meters) on each side, so that merchants could spot attackers in time and prepare to defend themselves. Similar requirements were in place on European roads. According to old laws, goods lost on the roads, like cargo washed up from maritime disasters, became a source of customs revenue for the landowner. They paid little attention to road maintenance, but there were many customs posts. In 1404, there were 24 customs posts near Nuremberg, almost one every 5 kilometers.

Feudal lords often destroyed roads leading to neighboring territories and diverted them to their own land. Despite the difficulties of travel, road movement was intense: merchant caravans, military units, peasants traveling to their lord, postal carriers, pilgrims, and crowds of idle people all tried to reach a place to spend the night by evening. These were usually shelters or barns with horses in the middle and people sleeping along the walls.

In the early Middle Ages and beyond, three types of transportation were common: land, sea, and river transport. The most extensive land network was in Italy and France, while it was smaller in Britain and Spain. By the 12th-13th centuries, commercial purposes began to outweigh military uses for roads. Many customs posts hindered the movement of goods. Travelers moved on horseback, while goods were transported by palanquins. Land routes were widespread where rivers flowed in a single direction, such as in England, Spain, and Italy. The main European continental routes followed the rivers: the Loire, the Rhine, the Danube, and the Rhône (see Fig. 8, 9, 10 and 11).

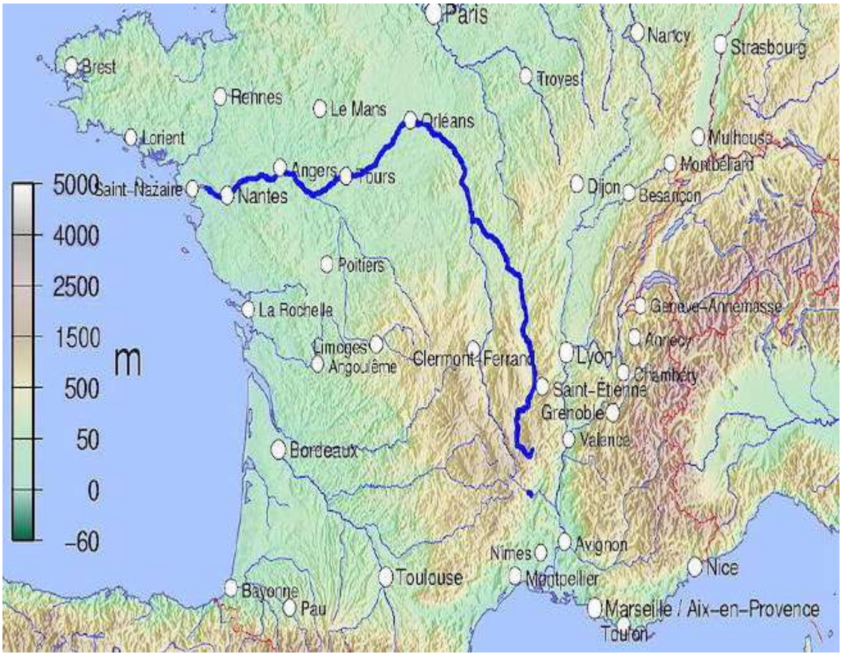

Fig. 8. The Loire River

One of the first road guides was created in France by Dr. Charles Étienne in 1553. He collected information from traders and pilgrims about the time and distance needed to travel on the roads, locations for overnight stops, and the types of services available. It was believed that the distance between overnight stops should be ≤12-15 miles (one French mile ≈ 2.25 km).

Fig. 9. The Rhine River

Fig. 10. The Danube River

Fig. 11. The Rhône River

In Germany, routes connected Western, Southern, and Eastern Europe (see Fig. 12). From Vienna, roads followed the Danube and its tributaries toward the Balkans. From Regensburg (near Munich), they led toward Prague, Krakow, and Russia. From Pomerania, routes extended through Lithuania toward Novgorod.

Fig. 12. 14th-Century Europe

Mountain passes in the Alps played a significant role in the European road network. These passes were categorized into three directions: western, central, and eastern. The western routes were used most frequently, including the Great and Little St. Bernard (see Fig. 13 and Fig. 14), Simplon (see Fig. 15), Mont Cenis, and others. The Simplon routes through the Alps connected the Ligurian Sea coast (see Fig. 16) to Provence and Avignon in France. The St. Bernard pass connected Lombardy and Piedmont to Champagne, Flanders, and the Rhine regions.

From the 13th century onward, the Little St. Bernard and Simplon passes became more commonly used. They facilitated connections between Lombardy and Switzerland (Milan–Basel), and further along the Rhine to Germany, the Netherlands, and Flanders.

Fig. 13. Great St. Bernard Pass

Fig. 14. Little St. Bernard Pass

Fig. 15. Simplon Pass

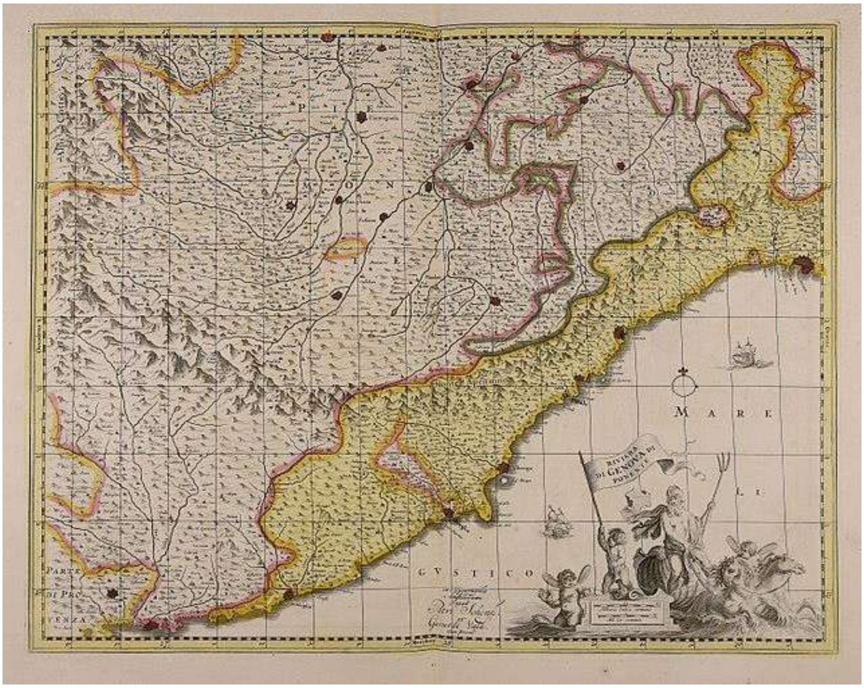

Fig. 16. Ligurian Sea

In the northern part of the European continent, Jutland served as a transportation hub (see Fig. 17), located on the border between the North and Baltic Sea basins. The route connecting these basins passed through Schleswig-Holstein via Bremerhaven, Hamburg, and Lübeck. Later, the Kiel Canal was constructed along this route, built between 1887 and 1895, linking the North Sea and the Baltic Sea.

Conclusion

Thus, the decline in the level of material culture characteristic of early medieval Europe led to the collapse of the transport system, as the level of transportation development achieved at the end of the previous period was no longer in demand. The development of life and cities began in the second half of the Middle Ages – in the 11th-15th centuries.

A 

Fig. 17. Jutland

During this period, trade became more active, which required new means of communication. The prototypes of the current trans-Eurasian transport networks were established around two thousand years ago and generally retained their geographical layout. The development of medieval transport communications and roads had a significant impact on the present communication system. Today, transportation remains one of the driving factors of economic and social development.

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Concept of Spatial Development and Sustainable Tourism of Surami Mountain-Climatic Resort Considering Modern Construction and Engineering Technologies

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Abstract

The study explores the potential development of Surami as a mountain-climatic resort using modern engineering technologies. Emphasis is placed on ecological sustainability and enhancing tourism potential through innovative approaches such as eco-friendly materials, energy-efficient technologies, and smart management systems. Special attention is given to the preservation of natural resources and historical heritage. Modern engineering approaches like 3D scanning and nanoconcrete are utilized. Nanomaterials, EPS, and smart sensors improve thermal insulation and energy efficiency. Renewable energy sources like solar panels and wind generators increase the region's sustainability potential, while sustainable water management systems ensure efficient resource usage.

Keywords: 3D scanning, digital modeling, nanoconcrete, self-healing materials, eco-solutions, sustainable construction, integrated management systems, smart technologies, green cement, natural fiber materials, steel anchors, energy-efficient materials, solar panels, mini wind generators, energy management systems, rainwater harvesting, georadars, mineral wool, natural filtration systems, floating solar panels, gabions.

Introduction

In recent decades, tourism has become one of the most dynamic and rapidly growing sectors of the global economy. Recognized as an economic phenomenon of modernity, its sustainable development is vital for

Georgia's resort-recreational systems, including Surami, a location with exceptional tourist potential. The growing influx of tourists and visitors in Georgia promotes economic activity in tourism and adjacent sectors. For Surami, finding the right niche, creating a targeted plan, and striving for its implementation are crucial. Such an approach will yield long-term national, regional, and local economic benefits, including increased local incomes, job creation, reduced migration, strengthened agriculture, and development of service industries. Surami's natural healing factors include a dry subtropical climate, and a surrounding 120-hectare leafy forest mixed with artificial coniferous plantations. Additionally, the area boasts numerous mineral springs. Sustainable tourism development requires integrated participation from all stakeholders, including government, local communities, visitors, businesses, investors, and NGO's, to:

- Analyze the trends and potential of tourism development.
- Identify priorities for tourism based on the resort's status and location.
- Define challenges to sustainable tourism development.
- Conduct a competitive analysis of the tourism industry.
- Evaluate the economic role of tourism for the resort.
- Establish the roles of public and private sectors, local communities, and NGOs.
- Ensure harmonious coexistence of sectors dependent on recreational resources.
- Analyze the interdependent development of sectors linked to tourism.

Hotel and food industries meeting high standards are essential for the economic development of any tourist region. Surami faces challenges in food service, with existing establishments offering diverse Georgian dishes and local beverages but requiring significant quality improvement. Moreover, Surami lacks a comprehensive spatial planning strategy based on urban development principles, resulting in unplanned growth that restricts effective use of natural resources and limits tourism. Uncontrolled construction and spontaneous settlements negatively affect the resort's ecosystem and biodiversity, necessitating urgent intervention.

Ensuring Ecological Sustainability

Surami is distinguished by its unique ecosystems and climatic conditions, which define its tourism value. Poorly planned construction projects can deplete natural resources, pollute air and water, and damage forests and landscapes, diminishing Surami's natural charm. Construction plans adhering to ecological sustainability principles will:

- Protect Surami's natural environment.
- Improve the quality of life.
- Attract tourists who prefer authentic and clean environments.

Enhancing Tourism Potential

Modern tourists favor locations harmonizing natural beauty with developed infrastructure. A sound construction plan should include:

- Eco-friendly hotels and residential complexes meeting international standards.
- Tourist trails and recreational zones in harmony with nature.
- Development of cycling paths and parks to attract eco-tourism enthusiasts.

Socio-Economic Benefits

Proper development of Surami will boost regional economic activity. Infrastructure improvements will:

- Create jobs, reducing unemployment.
- Increase local income and regional prosperity.

- Strengthening agriculture and service sectors, promoting sustainable growth.
- Stimulate small and medium-sized businesses, diversifying the regional economy.

Reducing Migration and Retaining Population

The presence of environmentally sustainable and tourist-attractive infrastructure in the region will enable local residents to find employment within their community, reducing the need to consider migration. This will contribute to retaining the population and strengthening the social and economic stability of Surami.

Protecting Cultural and Historical Heritage

The town has a rich history that is significant for both the local population and tourists. Preserving cultural and historical heritage is essential during construction processes.

The traces of settlement in Surami are believed to date back to a time long before our era. Archaeological findings in the area indicate that humans have lived here since the Early Bronze Age. Surami was one of the prominent cities of ancient Kartli. In the distant past, a major trade and caravan route from India to Phasis passed through Surami, connecting the East with the West. It can be assumed that the fortress in Surami was built soon after the settlement evolved into a city, as it would have been a necessity. It is worth noting that Surami remained a city until the end of the feudal era, but over the centuries, everything deteriorated to such an extent that now no visible traces of the ancient city remain.

- Modern infrastructure should align with Surami's historical architectural style.
- Restoration and revitalization projects should be implemented around cultural monuments.

- Establishing museums and educational centers will create additional attractions for tourists.

This approach will not only preserve Surami's unique character but also enhance its tourism value. The sites under consideration require individual construction plans tailored to their functional, historical, and tourism significance. Below is a detailed reconstruction vision for each of them:

Surami Fortress – Historical Monument

The tourism potential of Surami Fortress is practically untapped in its current state. A strong pedestrian connection to the boulevard and the forest provides a significant foundation for creating activities around the fortress.

Reconstruction of Surami Fortress

Preservation of Historical Architecture:

- **3D Scanning and Modeling:** Use laser scanning technology to ensure highly accurate restoration of the fortress's exterior and interior spaces.
- **Archaeological Excavations:** Examine the foundation's stability and identify problematic areas.
- **Drone Technology:** Utilize drones to study complex areas of the fortress and assess safety conditions.
- **Restoration of Hidden Structures:** Employ ground-penetrating radar to investigate underground or partially destroyed structures for potential restoration.

  Innovative Materials for Use in the Process:
- Nanoconcrete and Self-Healing Materials: To be used in the restoration of the fortress to enhance the building's resilience against climate change conditions.

- Ecological Solutions: For stone conservation, ensuring the preservation of the historical appearance of the fortress.

  General Ecological and Engineering Recommendations:
- Integrated Management System: Implementation of smart technologies throughout the project to monitor electricity, water, and security processes.
- Partnership with Local Communities: Introduce programs that allow residents to benefit from the new infrastructure.
- Educational Centers: Small educational spaces can be established at each site, enabling visitors to learn more about the project's technologies and environmental innovations.

Construction Processes:

- Use local stone for the restoration of damaged walls to match the original style of the fortress.
- Apply eco-friendly cement and natural fiber materials for structural reinforcement, ensuring no harm to the historic buildings.
- Strengthen the walls with invisible steel anchors to enhance durability without altering the architectural appearance.

Recommended Materials:

- Stone (tested through local chemical analysis).
- Eco-friendly cement.
- Steel anchors.

Surami Children's and Adolescents' Boarding Facility

The boarding facility should become a local tourist center, offering services to both local youth and visitors.

Reconstruction of the Surami Children's Boarding Facility Energy Efficiency and Sustainable Architecture:

- Energy-efficient materials: Modern insulation technologies, such as nanomaterials or expanded polystyrene (EPS), should be used to significantly improve the heating and cooling of the boarding building.

- Solar panels and mini wind turbines: Installation of solar panels on the building's roof to create alternative energy sources.
- Energy management system: A smart sensor system to automatically regulate heating, cooling, and lighting, reducing the electricity costs of the facility by 30%.
- Rainwater harvesting: Green roofs equipped with filtration systems to collect, and reuse filtered rainwater for indoor technical purposes.

Green Environment for Children and Visitors:

- Vertical gardens: Green walls on the exterior façade to improve air quality and enhance the visual appeal of the building.
- Nature-based interior design: For the psychological comfort of children, use eco-friendly and natural materials, such as wood and stone.

Inclusive Design:

- Accessibility for all: The project should include adapted spaces for the visually impaired and individuals with disabilities (elevators, inclined ramps, tactile signs).
- Rehabilitation center: Dedicated spaces to support the physical and psychological development of children (e.g., audiovisual therapy rooms, gym).

Construction Steps:

1. Assessment of the building's current condition:
    - Use ground-penetrating radars and structural tests to evaluate the stability of the foundation and main walls.
2. Reconstruction and modernization:
    - Building facade: Use energy-efficient panels (e.g., mineral wool insulation) to enhance thermal insulation properties.

- Functional spaces: Create multifunctional rooms with user-friendly systems, such as mobile partitions and eco-friendly laminate flooring.

Recommended Materials:

- For insulation: Mineral wool.
- For flooring: Eco-friendly laminate and rubber coating.
- For the facade: Wood or concrete panels with energy-efficient coating.
- For playgrounds: Polymer compounds, metal, rubber.

Suramula River – A Natural Resource

The river's reconstruction aims to create a tourist-friendly and environmentally clean space.

Reconstruction of the Suramula Rive Ecological Protection and Sustainable Engineering:

- Bioengineering for riverbank protection: Plant-based systems along the riverbanks to prevent soil erosion and strengthen the water ecosystem.
- Natural filtration systems: Biological filters within the river that use plants and natural materials to improve water quality.
- Circular water management: A sensor system to monitor water flow and automatically alert authorities in cases of potential pollution.

Energy Innovations:

- Floating solar panels: Placement of floating solar panels on the river to generate energy, enabling the river itself to provide eco-friendly energy for the surrounding area.
- Micro-hydroelectric power stations: Utilizing the river's flow to generate sustainable energy.

Suramula River as a Riverside and Recreational Zone

Construction Steps:

1. Reinforcing the Riverbanks:
   - Use gabions (structures filled with stones and metal mesh) to stabilize the riverbanks.
   - Introduce biological barriers (e.g., planted vegetation along the banks) to control water flow.
2. Park Development:
   - Create pedestrian and cycling paths along the riverbanks. Use natural granite slabs for pedestrian walkways and improved asphalt coating for cycling paths.
   - Build recreational areas with wooden decking and solar-powered lighting.
3. Maintaining Clean Water:
   - Install water filtration systems along the river to protect it from pollution.
   - Place biodegradable waste containers along the banks for proper waste management.
4. Activity Zones:
   - Construct piers for water sports using treated wood that can withstand moisture without causing ecological harm.

Recommended Materials:

Gabions with stone and metal mesh.

- Natural granite and improved asphalt.
- Eco-friendly wood for piers and recreational areas.
- Biodegradable waste containers.
- Install safety cameras and lighting systems along the river, ensuring security and comfort for visitors, even at night.

General Recommendations Essential for All Projects

Ecological Sustainability:

- Use energy-efficient technologies and eco-friendly materials.

- Ensure that all projects comply with environmental standards.

Attracting Investments:

- Secure local and international investments for project funding, including grants for eco-tourism and historical heritage development.

Tourism Attraction Strategy:

- Upon completion of all reconstructions, we actively promote Surami as a regional and international tourist center.

Conclusion:

The proper planning of Surami's construction and development, as well as that of the entire country, can become an example of ecological tourism and sustainable innovation. A well-thought-out plan will ensure:

- Modern and properly executed engineering technologies,
- Prevention of ecological damage,
- Preservation of historical and cultural heritage,
- Growth in the region's tourism potential,
- Improved well-being for residents.
- Additional Information on Modern Materials and Technologies Mentioned:
- 3D Scanning and Modeling: Converting spaces or objects into highly accurate digital models.
- Nanoconcrete and Self-Healing Materials: Innovative concrete that incorporates nanomaterials or repairs its own cracks.
- Ecological Solutions: Environmental innovations for sustainable construction.
- Integrated Management System: Smart technologies ensuring optimal project operations.
- Eco-Friendly Cement: A green cement alternative with minimal environmental impact.

- Natural Fiber Materials: Sustainable fibers based on plant-based raw materials.
- Steel Anchors: Steel reinforcement elements for structures.
- Energy-Efficient Materials: Innovative construction materials designed to save heat and energy.
- Solar Panels and Mini Wind Turbines: Renewable energy sources for small-scale projects.
- Energy Management System: A smart sensor network for optimal energy consumption.
- Rainwater Harvesting: A system for recycling water for technical purposes.
- Ground-Penetrating Radars: Modern technology for soil and subsoil analysis.
- Energy-Efficient Panels: Systems with high thermal insulation, such as mineral wool.
- Mineral Wool for Insulation: An effective and eco-friendly material for thermal insulation.
- Natural Filtration Systems: Ecosystem-based water

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The Importance of Sustainability in Construction, *Ani Gulua,*

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Abstract

The construction industry plays a crucial role in shaping our environment, and this responsibility necessitates prioritizing sustainability. Sustainability refers to the ability to maintain or support a process over time. It is commonly divided into three main concepts: economic, environmental, and social. Numerous sectors and governments have committed to achieving sustainable development goals, such as reducing their environmental impact and conserving resources.

As the global population continues to grow and urbanize, the demand for efficient resources and eco-friendly construction methods has never been higher. Integrating sustainable development principles into construction not only helps reduce environmental impact but also ensures long-term financial benefits, improves public health, and preserves resources for future generations. This article discusses the importance of sustainable construction methods and green solutions in construction projects.

Keywords: constuction industry, 3D-printed concrete, sustainable, cross-laminated timber, nanomaterials, biomaterials.

Introduction

Construction is an ancient human activity. It began with the purely functional need for a controlled environment to moderate the effects of climate.

Human shelters were at first very simple and perhaps lasted only a few days or months. Over time, however, even temporary structures evolved into such highly refined forms as the igloo. Gradually more durable structures began to appear, particularly after the advent of agriculture, when people began to stay in one place for long periods. The first shelters were dwellings, but later other functions, such as food storage and ceremony, were housed in separate buildings. Some structures began to have symbolic as well as functional value, marking the beginning of the distinction between architecture and building. The history of building is marked by a number of trends. Early building materials were perishable, such as leaves, branches, and animal hides. Later, more durable natural materials—such as clay, stone, and timber—and, finally, synthetic materials—such as brick, concrete, metals, and plastics—were used.

Construction today is a significant part of industrial culture, a manifestation of its diversity and complexity and a measure of its mastery of natural forces, which can produce a widely varied built environment to serve the diverse needs of society.

Main part

The history of construction

Primitive building: the Stone Age

The hunter-gatherers of the late Stone Age, who moved about a wide area in search of food, built the earliest temporary shelters that appear in the archaeological record. They may have braced crude huts made of wooden poles or have weighted down the walls of tents made of animal skins, presumably supported by central poles. A tent illustrates the basic elements of environmental control that are the concern of construction. The tent creates a membrane to shed rain and snow. The membrane reduces wind speed as well. It controls heat transfer by keeping out the hot rays of the sun and confining heated air in cold weather.

The agricultural revolution, dated to about 10,000 BCE, gave a major impetus to construction. People no longer traveled in search of game or followed their herds but stayed in one place to tend their fields. Dwellings began to be more permanent. Archaeological records are scanty, but in the Middle East are found the remains of whole villages of round dwellings called tholoi, whose walls are made of packed clay; all traces of roofs have disappeared. Still later the circular form was dropped in favor of the rectangle as dwellings were divided into more rooms and more dwellings were placed together in settlements. The tholoi marked an important step in the search for durability; they were the beginning of masonry construction.

Stone construction in Egypt

Like the other great river valley cultures, Egypt built its cities with mud brick; fired brick did not appear there until Roman times. Timber was used sparingly, for it was never abundant. It was used mainly in roofs, where it was heavily supplemented by reeds. Only a few royal buildings were built with full timber frames. It was against this drab background of endless mud brick houses that a new technology of cut-stone construction emerged in the temples and pyramids of the 4th dynasty. Egypt had excellent deposits of stone exposed above ground; limestone, sandstone, and granite were all available. But the extracting, moving, and working of stone was a costly process, and the quarrying of stone was a state monopoly. Stone emerged as an elite construction material used only for important state buildings. The Egyptians developed cut stone for use in royal mortuary buildings not only for its strength but also for its durability.

Early concrete structures

The possibilities of plastic form suggested by this initially liquid material, which could easily assume curved shapes in plan and section, soon led to the creation of a series of remarkable interior spaces, spanned by domes or vaults and uncluttered by the columns required by trabeated stone construction, that showed the power of the imperial state. Two large fragments of great concrete cross-vault buildings still survive from the late empire. The first of these is a portion of the Baths of Diocletian with a span of 26 meters ; These and other great Roman public spaces spanned by concrete domes and vaults made a major advance in scale over the short spans of the stone frame.

Building support systems

The Romans provided generous water supplies for their cities; all of the supply systems worked by gravity and many of them used aqueducts and syphons. Perhaps the most important use of lead was for pipes to supply fresh water to buildings and to remove wastewater from them. However, the wastewater drainage system was limited, with no treatment of sewage, which was simply discharged into a nearby river, even these fairly modest applications of public sanitation far exceeded those of previous cultures and would not be equaled until the 19th century. Another material that the Romans applied to buildings was glass, which had been developed by the Egyptians who used it only for jewelry and small ornamental vessels. The Romans devised many kinds of colored glass for use in mosaics to decorate interior surfaces. They also made the first clear window glass, produced by blowing glass cylinders that were then cut and laid flat. Glass apparently became fairly common in public buildings and was even used in middle-class apartment houses in the capital.

Stone construction

Beginning in the 9th century, there were the first stirrings of the revival of stone construction in Europe. The Palatine Chapel of Charlemagne at Aachen (consecrated 805) with its octagonal segmented dome spanning 14.5 meters (47 feet), is an early example of this trend.

The first industrial age - Development of iron technology

The last half of the 18th century saw the unfolding of a series of events, primarily in England, that later historians would call the first Industrial Revolution, which would have a profound influence on society as a whole as well as on building technology. Among the first of these events was the large-scale production of iron. The ready availability of iron contributed to the development of machinery. Standard iron building elements soon appeared, pointing the way to the development of metal buildings. Early applications of iron in construction are found several centuries prior to the industrial age. The next type to use the full iron frame was the greenhouse, which provided a controlled luminous and thermal environment for exotic tropical plants in the cold climate of northern Europe.

Manufactured building materials

The production of brick was industrialised in the 19th century. The laborious process of hand-molding, which had been used for 3,000 years, was superseded by “pressed” bricks. These were mass-produced by a mechanical extrusion process in which clay was squeezed through a rectangular die as a continuous column and sliced to size by a wire cutter. The new methods considerably reduced the cost of brick, and it became one of the constituent building materials of the age.

Timber technology underwent rapid development in the 19th century in North America, where there were large forests of softwood fir and pine trees that could be harvested and processed by industrial methods; The production of cheap machine-made nails in the 1830s provided the other necessary ingredient that made possible a major innovation in construction, the balloon frame; the first example is thought to be a warehouse erected in Chicago in 1832. The balloon frame building, made with manufactured materials and requiring only a few hand tools and little skill to build, has remained a popular and inexpensive form of construction to the present day.

Modern technologies of construction

Sustainable building materials play a pivotal role in addressing environmental challenges and promoting a more sustainable future for the construction industry. As the global population grows and urbanization expands, the demand for buildings and infrastructure increases exponentially. However, this surge in construction has come at a significant cost to the environment, including resource depletion, pollution, and greenhouse gas emissions. In this context, sustainable building materials offer a compelling solution by reducing the environmental impact of construction while simultaneously improving the efficiency, durability, and healthiness of buildings.

1. Cross-Laminated Timber (CLT) - is an engineered wood product made by glueing together layers of timber at right angles to each other. CLT is a sustainable, strong, and versatile alternative to traditional building materials such as steel, concrete, and masonry. Advantages of using CLT in construction: Sustainability, Strength and durability, Fire resistance, Speed of construction, Design flexibility, Thermal and acoustic insulation.

2. Insulated Concrete Forms (ICF) - are a type of construction material made from polystyrene foam or polyurethane foam blocks that are stacked and locked together like Legos to create walls. The forms are then filled with concrete to create a solid, insulated wall system. ICF has several advantages over traditional building materials, including: Energy efficiency, Soundproofing, Durability, Faster construction, Eco-friendliness.

3. Smart glass - also known as switchable glass or dynamic glass, is a glass material that can change its properties in response to external stimuli such as light, heat, or electricity. This technology allows the glass to switch between transparent and opaque states, controlling the amount of light and heat that enters a building. Smart glass offers several advantages over traditional glass materials, including: Improved energy efficiency, Increased comfort, Enhanced privacy, Aesthetically pleasing.

4. 3D printing materials - refer to the materials used in the additive manufacturing process, which involves building three-dimensional objects by adding layers of material on top of each other. In

construction, 3D printing materials are used to create building components and structures using large-scale 3D printers. 3D printing materials offer several advantages over traditional building materials, including: Cost savings, Design flexibility, Speed of construction, Sustainability.

5. Carbon Fiber Reinforced Polymer (CFRP) - is a high-strength composite material made up of carbon fibers and a polymer resin matrix. The carbon fibers are strong, lightweight, and stiff, while the polymer resin matrix provides toughness and flexibility. When combined, these materials create a composite that is much stronger and lighter than traditional construction materials such as steel and concrete. The use of CFRP in construction offers several advantages. Firstly, it is much lighter than traditional construction materials, making it easier to transport and install. Secondly, CFRP is strong and durable, making it ideal for use in high-stress applications such as bridges, buildings, and wind turbines. Finally, CFRP is resistant to corrosion and fatigue, which means it has a longer lifespan than traditional construction materials.

6. The permeable concrete, also known as a permeable floor, is a type of concrete developed especially to allow water to pass directly to its lower level. Thus, it is a very interesting coating alternative for application in outdoor areas, facilitating the drainage of rainwater and the surface draining process, preventing the formation of puddles and flooding. For this reason, permeable concrete have become an increasingly popular choice, gaining more and more followers, interested in the wide range of advantages that this material offers with its use. It is made from a mixture of cement, coarse aggregates, and water. However, it contains little or no sand, which results in a porous open-cell structure that water passes through readily.

Conclusion

In conclusion, innovative building materials are revolutionizing the construction industry by providing new solutions to age-old problems. Each of these materials has unique properties and advantages that can help builders and contractors create more sustainable, energy-efficient, and durable structures. By incorporating these materials into construction projects, we can improve the quality of our buildings while reducing our environmental impact. As the construction industry continues to evolve, embracing new materials and techniques is crucial to meeting the demands of the modern world.

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Innovative technologies in construction for a sustainable future,

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Abstract

Civil engineering has always been the cornerstone of human progress — from ancient roads to modern skyscrapers and sustainable infrastructure. However, as globalization and complexity increase worldwide, traditional methods can no longer meet contemporary demands. Today, we stand at the crossroads of innovation, where modern technologies are no longer an option but a necessity. Civil engineering innovations are fundamentally transforming how we design, build, and maintain infrastructure. This process drives us toward new heights of efficiency, sustainability, and safety. In this article, we explore groundbreaking innovations shaping the modern civil engineering field from 3D printing and robotics to smart materials and virtual reality. These technologies represent not merely technical improvements but the beginning of a new era of possibilities. Embracing these innovations is crucial for effectively addressing modern challenges and creating a future that is resilient, adaptable, and visionary.

Keywords: Civil engineering; 3D Printing; Renewable Energy; Robotics

Introduction

Civil engineering is one of the oldest and most essential disciplines, shaping human civilization from its earliest days. In ancient times, civilizations such as Mesopotamia, Egypt, and Rome laid the foundation for infrastructure development. The construction of roads, aqueducts, pyramids, and monumental structures like the Colosseum demonstrated remarkable ingenuity and set the stage for future advancements.

The Middle Ages saw the development of Gothic architecture, with its towering cathedrals and innovative use of pointed arches, ribbed vaults, and flying buttresses. The Renaissance brought further advancements, emphasizing precision, mathematics, and architectural aesthetics, as exemplified by structures like the dome of the Florence Cathedral.

The Industrial Revolution in the 18th and 19th centuries marked a transformative period for civil engineering. The invention of new materials like steel and reinforced concrete, combined with the development of steam engines and machinery, enabled the construction of railways, skyscrapers, and bridges, such as the iconic Eiffel Tower and Brooklyn Bridge.

In the 20th century, rapid urbanization, population growth, and technological progress pushed civil engineering to new limits. Infrastructure projects like highways, dams, and large-scale urban developments required advanced design, planning, and construction techniques.

Today, we stand at the forefront of a new era where modern innovations are essential for addressing contemporary challenges. Technologies such as 3D printing, robotics, artificial intelligence (AI), smart materials, and virtual reality (VR) are revolutionizing the way we design, build, and maintain infrastructure. These innovations not only improve efficiency, safety, and sustainability but also offer solutions for resilient infrastructure in the face of climate change and urban growth.

The evolution of civil engineering reflects a continuous journey of innovation, driven by humanity's need to adapt and progress. Embracing these modern technologies is not just an option but a necessity for building a future that is sustainable, resilient, and forward-thinking.

According to the World Economic Forum's forecast, by 2050, 68% of the world's population will live in cities. To meet this demand, smarter, faster, and more sustainable construction practices are necessary. Modern innovations are the only means to effectively overcome this challenge.

Main part

The Role of 3D Printing in Construction

3D printing is one of the most groundbreaking technologies reshaping the construction industry. It allows engineers to build structures layer by layer, achieving remarkable accuracy, reducing costs, and minimizing waste. This innovative technique enables civil engineers to prefabricate ready-to-use materials, either offsite or directly on-site, streamlining the construction process.

Large-scale 3D printing is already being used to create houses, bridges, and other complex structures that were previously difficult or impossible to build with traditional methods. The environmental benefits of 3D printing are significant, as it reduces resource consumption and waste generation, promoting more sustainable construction practices. This technology also shortens project timelines by simplifying workflows and integrating hybrid methods, combining 3D printing with traditional techniques for increased resilience and efficiency.

Additionally, the combination of drones and 3D printing is enhancing civil engineering practices. Drones equipped with advanced LiDAR sensors and AI-driven data processing provide precise topographical maps and 3D models of construction sites. This helps in better planning, monitoring, and early detection of site issues, mitigating risks effectively. These advancements illustrate how 3D printing and related technologies are shaping the future of construction, making it smarter, faster, and more sustainable.

Artificial Intelligence in Project Management

Artificial intelligence (AI) is transforming project planning and management into civil engineering. By analyzing vast amounts of data, AI tools can help predict risks, optimize resource allocation, and improve project planning quality. AI enhances budget management and time allocation, minimizing delays and improving productivity across construction sites. Additionally, AI algorithms can help track progress, reduce oversights, and ensure projects remain on schedule.

Virtual and Augmented Reality in Civil Engineering Design

Virtual reality (VR) and reality (AR) are transforming civil engineering design and construction processes. These technologies enable engineers to visualize projects in a virtual environment before breaking ground, helping to identify potential issues early in the planning stages and avoiding costly adjustments later. By offering real-time data overlaid on physical structures, AR enhances inspections, improving accuracy and streamlining project assessments. VR and AR also foster better collaboration and precision design. During training, VR provides a safe environment for practicing complex tasks, resulting in better designs, fewer mistakes, and smoother project execution. Incorporating these innovations into construction projects leads to smarter, more sustainable, and resilient infrastructure. Staying ahead of these technologies augmented allows civil engineers to achieve operational excellence and reshape the future of the industry.

Smart Infrastructure and the Integration of IoT and Renewable Energy

Smart infrastructure represents a major advancement in civil engineering, incorporating the Internet of Things (IoT) and renewable energy to create efficient, sustainable, and resilient urban environments.

Smart buildings, bridges, and roads equipped with IoT sensors can communicate and share real-time updates, enabling the monitoring of heating, cooling, lighting, and structural health. This data-driven approach helps predict maintenance needs, optimize infrastructure lifespan, and reduce operational costs. By integrating renewable energy sources such as solar panels, geothermal systems, and wind turbines into building designs, civil engineers are reducing reliance on fossil fuels, promoting energy efficiency, and lowering utility costs. These technologies collectively enhance safety, minimize environmental impact, and align with broader goals of sustainable urban development. Together, IoT and renewable energy integration are paving the way for smarter, more adaptive, and environmentally responsible infrastructure, meeting the needs of growing urban populations while preventing costly breakdowns and promoting energy conservation.

Case Studies in Successful Civil Engineering Innovations

1. NEOM Project in Saudi Arabia: NEOM combines renewable energy, AI, and sustainable infrastructure, offering a blueprint for future urban development.

2. Earthquake-Resistant Structures in Japan: Japan has implemented advanced engineering techniques to make buildings earthquake-

resistant, utilizing materials and construction methods that enhance structural flexibility.

3. Floating Structures in the Netherlands: In response to rising sea levels, the Netherlands has pioneered floating residential structures that adapt to water levels, providing sustainable housing in flood-prone areas.

Building Information Management (BIM)

While CAD vastly transformed the role of designers, Building Information Management (BIM) has proven stunningly versatile, allowing architects, engineers, contractors, and subcontractors to collaborate on the fine details of design and construction by using the same database and computer model.

BIM involves all project stakeholders working collaboratively on a detailed 3D model that includes all the functional systems of a structure--such as pavement or curbs, beams and girders, HVAC and electrical installations, as well as the aesthetics of walls, arches, roofs, and rails. Because BIM is a collaborative process from beginning to end, it allows all preconstruction parties to visualize and analyze design decisions, and pinpoint interferences and other errors, before work begins on site. For contractors, working collaboratively saves innumerable resources, as construction doesn't begin until every party has submitted their designs, ensuring clashes are detected and rectified quickly, easily and ahead of the ground being broken on site.

As transformative as BIM is, it is only the start of what is possible! When Connected Construction principles are added to the equation, the aspiration of BIM becomes attainable. See how it all comes together in The Great Library, a docuseries following a global team as they reimagine a historic landmark using today's most innovative construction technology.

Robotic Total Stations (RTS)

The traditional way of laying out building services on a site involves a team using building drawings and a tape measure, spirit level and theodolite – a precision instrument for measuring angles – to identify attachment points for the likes of cable trays and pipework.

This method, however, doesn't work well with more sophisticated buildings. It is time-consuming and arduous and has a huge margin for error, which can lead to serious consequences, such as clashes with other building services and prefabricated systems that don't fit, leading to time, money and materials being wasted.

Enter Robotic Total Stations (RTS), an electronic theodolite integrated with an electronic distance measurement that can be remotely controlled from distance. Using a tablet equipped with the relevant software, the layout can be completed by a single person, with RTS ensuring greater efficiency, improved accuracy, fewer mistakes and less paperwork, as well as reduced labor costs.

Sustainable Building Materials

As the construction industry looks for ways to reduce carbon emissions, they are turning to more sustainable ways of building. This includes using sustainable building materials, such as Cross-Laminated Timber, reclaimed wood, bamboo, recycled rubber and a long list of innovative materials. Imagine a structure built from straw bales, rammed earth, Hempcrete (concrete-like masterial made from the hemp plant) or ferrock (concrete-like material made from steel dust). Some of these materials actually absorb and trap carbon dioxide, meaning they are carbon-neutral.

Using sustainable building materials is not only good for the planet, it can reduce construction costs, improve structural energy efficiency, and increase property value. With a drop in operational costs, overall construction costs are reduced by 5 to 15 percent, depending on the green material used. There are also regulatory incentives in some areas that make sustainable building more attractive.

Sustainably-made buildings are in high demand. They often have higher occupancy rates and higher rental rates than traditionally-constructed buildings. Green building materials could improve occupant health as well. When it comes to green construction, it's a win-win-win for the industry, the occupants, and the planet.

Robotics

The continued adoption of robotics in construction is another significant development that will shape the industry’s future. However, construction companies face barriers in implementing these technologies including cost of entry and a lack of skills with these specific technologies within teams

On an episode of the Digital Builder podcast, Brooke Gemmell, Emerging Technology Partner at Skanska said, "We're starting to see so many more robotic applications. I think one thing that may be a misconception is just how readily available they are on projects. Most of the tools out there are only being piloted on a select few projects because we're still learning how can we really use these and what's the biggest impact for these tools."

To overcome these hurdles, companies can start with more mature technologies like drones and offsite prefabrication. They also can invest in training programs and partnerships with technology providers to improve their workforce. Brooke believes there is already a strong appetite from the workforce to do so, “I've been on a lot of project sites where we've had robotic solutions deployed, and first off, people are really excited about it. They want to learn more and they want to engage."

Collaboration and communication with technology providers is crucial. By sharing specific needs and challenges, construction companies can shape the development of tailored AI and robotics solutions. It is also beneficial to learn from industry leaders who have effectively incorporated these technologies.

By embracing AI and robotics, construction companies can unlock productivity, efficiency, and safety benefits. These technologies will greatly improve workflow, optimize resource management, and enable faster project delivery.

"Robots are helping people go home earlier, less tired, and with less strain. We're also taking people out of dangerous situations and using robots in those places," added Brooke.

Connecting devices in cities- Internet of Things (IoT)-enabled sensors.

In today's industries (oil and gas, manufacturing, food, dairy, etc), civil engineers are not only responsible for designing and building infrastructure that sustains us but also creating automated systems to help make our lives easier. This is why Industry 4.0 has been coined - it focuses on improving production efficiency by allowing automated machines to communicate with each other without human intervention using sensor networks connected via internet-of-things (IoT).

The internet of things is one step closer to reality. As more smart devices become interconnected, this opens up a whole new level for innovation that will change everything about how we live and work in our city.

Smart factories (aka Factory of the Future) can reduce operating costs while generating quality products at a faster rate than traditional methods used before Industry 4.0 was introduced because they use sensors embedded into machinery that collect real-time data through machine learning algorithms so there are no need for humans working long hours or shifts over

But let's go back to IoTs. It's a fact: civil engineers have been hard at work connecting new technologies to our cities by way of connected smart objects aptly referred to as the IoTs.

With the use of PLCs, HMIs, and SCADA, these IoT-enabled sensors can tell engineers things like how much water a pipe is carrying or what traffic volume looks like on any given day, for example.

Building sensors into these structures allows civil engineers to monitor them easier than ever before from anywhere on earth using modern communication technologies such as cellular phones and satellites.

One application that can really make a difference in natural disaster relief efforts and disaster restoration, such as earthquakes or floods, would be IoT-enabled sensors with predictive analytics features. Using IoT methods can help save billions per year lost due to damages caused by natural disasters because it would allow disaster relief crews faster access.

Conclusions:

With technological advancement continuing at a rapid pace, civil engineering will become increasingly central to building smart, resilient urban infrastructure. As cities expand, civil engineers will need to innovate continuously, using tools like AI, VR, and IoT to create cities that are not only safe and efficient but also environmentally friendly and sustainable.

The renowned engineer Henry Petroski once stated: "As engineers, we have the power to change the world — not merely to study it." Embracing innovations in civil engineering gives us the ability to turn ideas into reality.

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Review on the topic of ozone layer protection and climate change, *Anastasia Dvalishvili, Bachelor Program Student,*

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Abstract

Human-caused climate change is one of the biggest threats our planet faces today. Changes in atmospheric ozone and climate are directly linked because ozone absorbs solar radiation and is also a greenhouse gas. Stratospheric ozone depletion leads to surface cooling, while the observed increases in tropospheric ozone and other greenhouse gases lead to surface warming [28]. 90% of ozone is observed at an altitude of about 25-30 kilometers above the Earth's surface (stratosphere). Stratospheric ozone is formed naturally through the interaction of solar ultraviolet (UV) radiation with molecular oxygen (O_2). Tropospheric or ground-level ozone – what we breathe – is formed primarily from photochemical reactions between two major classes of air pollutants, volatile organic compounds (VOC) and nitrogen oxides (NOx) [26]. The scientific confirmation of the depletion of the ozone layer prompted the international community to establish a mechanism for cooperation to take action to protect the ozone layer. The signing of the the Montreal Protocol , which has been ratified by 197 states, contributed to a significant increase in innovation in the chemical and mechanical engineering industries, which led to the development of more economical and environmentally friendly tecnolologies.

Introduction

Currently, climate change is one of the world's most serious challenges, which in turn leads to global, unpredictable changes in the Earth's hydrometeorological conditions and, as a result, increases the risk of both human diseases and natural disasters (rise in sea level, floods, mudslides, landslides, increased frequency of avalanches, tsunamis, intensification and frequency of storms, forest fires etc.) [24].

Recently, human activities have been the main driver of climate change, s a result of climate change caused by anthropogenic impact, the sizes of continents and oceans, the intensity of solar radiation, the parameters of the Earth's orbit, the transparency of the atmosphere, etc. The scale of climate change in recent years is unprecedented - many changes are irreversible for centuries, especially in relation to the oceans, glaciers and global sea levels. Anthropogenic climate change affects all regions of the world. Between 3.3 billion and 3.6 billion people live in conditions that are highly vulnerable to climate change [7]. The main cause of climate change is the greenhouse effect [23]. The greenhouse effect occurs when greenhouse gases in a planet's atmosphere insulate the planet from losing heat to space, raising its surface temperature [9]. Many of these greenhouse gases occur naturally, but human activities are increasing the concentrations of some of them in the atmosphere, in particular: (water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and others). Some greenhouse gases occur naturally in the atmosphere, while others are produced by human activity [4].

Ozone is a gas that is naturally present in our atmosphere. Each ozone molecule contains three atoms of oxygen and is denoted chemically as O_3. Ozone is found primarily in two regions of the atmosphere (troposphere and stratosphere) [17]. The total mass of ozone in the atmosphere is about 3 billion metric tons. That may seem like a lot, but it is only 0.00006 percent of the atmosphere. The peak concentration (90%) of ozone occurs at an altitude of roughly 25-30 kilometers above the surface of the Earth (stratosphere). At that altitude, ozone concentration can be as high as 15 parts per million (0.0015 percent) [15].

The ozone layer in the stratosphere absorbs a portion of the radiation from the sun, preventing it from reaching the planet's surface. Most importantly, it absorbs the portion of UV light called UVB. UVB has been linked to many harmful effects, including skin cancers, cataracts, and harm to some crops and marine life [3].

Ozone depletion and climate change are linked in a number of ways, but ozone depletion is not a major cause of climate change.

Atmospheric ozone has two effects on the temperature balance of the Earth. It absorbs solar ultraviolet radiation, which heats the stratosphere. It also absorbs infrared radiation emitted by the Earth's surface, effectively trapping heat in the troposphere. Therefore, the climate impact of changes in ozone concentrations varies with the altitude at which these ozone changes occur. The major ozone losses that have been observed in the lower stratosphere due to the human-produced chlorine- and bromine-containing gases have a cooling effect on the Earth's surface. On the other hand, the ozone increases that are estimated to have occurred in the troposphere because of surface-pollution gases have a warming effect on the Earth's surface, thereby contributing to the "greenhouse" effect [17]. Climate is affected by changes in stratospheric ozone, which radiates infrared radiation down to the troposphere [6].

Source and Formation/Degradation of Ozone

Stratospheric ozone is formed naturally through the interaction of solar ultraviolet (UV) radiation with molecular oxygen (O_2). Tropospheric or ground-level ozone – what we breathe – is formed primarily from photochemical reactions between two major classes of air pollutants, volatile organic compounds (VOC) and nitrogen oxides (NOx) [26]. This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight. Ozone is most likely to reach unhealthy levels on hot sunny days in urban environments, but can still reach high levels during colder months. Ozone can also be transported long distances by wind, so even rural areas can experience high ozone levels [10].

While tropospheric ozone poses a significant threat to human and environmental health, stratospheric ozone layer plays a crucial role in protecting life on Earth by filtering out harmful ultraviolet radiation and respectively preventing of climate change [8].

Humans were emitting large amounts of gases that depleted the ozone layer. Ozone layer depleting substances include: chlorofluorocarbons: CFC-10 (CCl_4), CFC-11 (CCl_3F), CFC-12 (CCl_2F_2), CFC-113 (CCl_2FCClF_2), CFC-114 ($CClF_2CClF_2$), CFC-115 ($CClF_2CF_3$); Halon-2011 ($CBrClF_2$), Halon-1301 ($CBrF_3$); Hydrochlorofluorocarbons: HCFC-22 ($CHClF_2$); Acids: HF, HCl, HBr, HNO_3; Microcomponents of the atmosphere: CH_2O, O_3, O(3P), O(1D), H, OH, HO_2, H_2O_2, Cl, Cl_2, ClO, OClO, HOCl, $ClONO_2$, $ClNO_2$, Cl_2O_2, N, NO, NO_2, N_2O_3, N_2O_5, HO_2NO_2, Br, BrO, HOBr, $BrONO_2$, BrCl, as well as Ox (O_3 + O(3P)), HOx (OH + HO_2), NOx (NO + NO_2 + N_2O_3), ClOx (Cl + ClO) and BrOx (Br + BrO) and greenhouse gases that indirectly affect the depletion of stratospheric ozone: N_2O, CH_4 and CO_2 [13]. Sources of ozone-depleting substances are: solvents, refrigerants and foaming agents, cleaning agents, aerosol propellants, fire extinguishers (halons) and agricultural pesticides (methyl bromide) [20]. Sectors that consume ozone-depleting substances: Refrigeration systems; Air conditioning; Aerosols and sterilizers; Fire extinguishers; Foam plastics Fumigation; Smoking [11].

The ozone layer is destroyed/depleted by ultraviolet radiation through reactions with ozone-depleting substances [19]. Ozone-depleting substances, as mentioned, are several classes of synthetic organic compounds that are volatile, persistent, and are carried long distances through the air, reach the upper atmosphere, and react with and destroy ozone molecules present there, resulting in a decrease in the concentration of ozone in the Earth's upper atmosphere. As a result, the ozone layer in the stratosphere becomes thinner, and as a consequence, the amount of solar ultraviolet radiation reaching the Earth's surface increases [21].

The basic process of ozone formation and destruction is described by the Chapman cycle [5]. Formation reactions: $O_2 + h\nu_1 \rightarrow 2O$: (1)

$O_2 + O: \rightarrow O_3$ (2)

Decomposition (destroyed/depleted) reactions: $O_3 + h\nu_2 \rightarrow O_2 + O$: (3)

$O_3 + O: \rightarrow 2O_2$ (4)

Both processes involve the absorption of ultraviolet radiation, but in different spectrums. As a result, the maximum ozone content is formed in the stratosphere - at an altitude of 25-30 km [18]. The decay/destruction of ozone, in addition to the Chapman cycle, occurs in cyclic processes catalyzed by nitrogen oxides, hydrogen peroxide, chlorofluorocarbons (freons) and, to a lesser extent, methane, hydrogen and other substances. Although the Champer cycle does not form a chain process, reaction (4) describes the decay of ozone in chain processes that were discovered later, after the thirties.

The amount of ozone is measured in Dobson units (DU). This is the number of molecules of the gas that would be needed to forming a pure ozone layer 0.01 millimeters thick at 0 degrees Celsius and 1 atmosphere of pressure. The higher the number of ozone molecules, the healthier the ozone layer. Globally, the average total concentration of ozone is usually about 300 DU, which corresponds to 3 millimeters of ozone. However, it is worth noting that the levels of this gas are usually higher near the poles and the equator [21].

Legislative and Technological Advances

The scientific confirmation of the depletion of the ozone layer prompted the international community to establish a mechanism for cooperation to take action to protect the ozone layer. This was formalized in the Vienna Convention for the Protection of the Ozone Layer, which was adopted and signed by 28 countries, on 22 March 1985. In September 1987, this led to the drafting of The Montreal Protocol on Substances that Deplete the Ozone Layer, followed by the preparation of documents on climate change and an international agreement - the UN Framework Convention on Climate Change (1992) and the Framework Convention of the Kyoto Protocol (1997) [25].

The Montreal Protocol controls ozone-depleting substances (ODS) and greenhouse gases that cause climate change [27]. The main objective of the Montreal Protocol is to protect the ozone layer by limiting the global production and consumption of ozone-depleting substances with the aim of their complete elimination based on scientific knowledge and technological information.

To commemorate the signing of the Montreal Protocol on September 16, 1994, the United Nations General Assembly declared September 16 as International Day for the Preservation of the Ozone Layer. The implementation of the Montreal Protocol has proven successful in both developed and developing countries [25]. Subsequently, the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer reached an agreement at a meeting held on 15 October 2016 in Kigali, Rwanda, to phase out the use and production of ozone-depleting substances (reducing the production and consumption of HFCs by at least 80% over the next 30 years), resulting in the Kogala Amendment to the Montreal Protocol, which has been in force in Georgia since October 2023 [12].

Despite the significant reduction in emissions of ozone-depleting substances into the atmosphere achieved in recent years, the "ozone holes" at the poles have not decreased, but on the contrary, have increased. In 2005, the thickness of the ozone layer at the South Pole actually reached record levels (decreased by 50% [2,14]. Changes in climate change factors - temperature, humidity, wind and the presence of various chemicals in the atmosphere - affect the state of the ozone layer, and the state of the ozone layer, in turn, affects the state of the atmosphere and the associated climate changes [29]. The signing of the protocol, which has been ratified by 197 states, contributed to a significant increase in innovation in the chemical and mechanical engineering industries, which led to the development of more economical and environmentally friendly refrigeration systems, among which are such environmentally friendly alternatives to ODS as: ammonia (ODP = 0), carbon dioxide (ODP = 0, GWP = 1), propane (ODP = 0, GWP = 3), isobutane (ODP = 0, GWP = 0.001).

Georgia has been a party to the Montreal Protocol on Substances that Deplete the Ozone Layer since 1997. A package of draft laws related to the ozone layer was developed by the Ministry of Environmental Protection and Agriculture of Georgia and adopted by the Parliament of Georgia in its third reading on June 16, 2023, including the “On Protection of Atmospheric Air” [1,16], which aims to improve the national system for managing refrigerants, including HFCs, increase the quality of services in the refrigeration and air conditioning sector, and implement the commitments undertaken under the Kigali Amendment.

According to the Fourth National Environmental Action Program of Georgia for 2022-2026, in 2020, the consumption of ozone-depleting substances decreased by 56% compared to baseline consumption. ODS is not produced in our country, although requirements are currently being established for their collection, recovery, recycling, and destruction [22].

Conclusions

By phasing out 98% of ozone-depleting substances from household, industrial, and agricultural use, the ozone layer is expected to recover to its 1980 level by 2050 if most countries adhere to international agreements to phase out the production and consumption of ozone-depleting substances and meet their commitments. However, recent studies of atmospheric phenomena have revealed new interactions in the atmosphere that may change the original predictions of the ozone layer recovery timeline. As a result of these new insights, ozone layer recovery is not expected to occur until the 2060s or 2070s [15].

Acting correctly and rationally within the framework of international agreements adopted by each country, raising awareness of each resident and using highly scientific approaches, we have a real chance to reduce the effects of climate change, preserve the ozone layer, reduce the negative impact on the environment in order to live in a safe environment.

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Abstract

This study examines a mid-rise school building and a high-rise multifunctional center, both analyzed using the finite element method with all relevant design loads. The seismic load criteria for the spectral methodology are taken from the current regulatory documents (PN 01.01-09) and (EN 1998–1:2004).

The school building is a four-story structure with one underground floor, located in Tbilisi, near Lisi Lake. The building has a rectangular configuration, measuring 35.45 × 20.05 m with a maximum span of 7.1 m. Structurally, it follows a frame-braced system with reinforced concrete walls and slabs. The first-floor height is 3.9 m, and the typical floor height is 4.2 m.

The multifunctional center is a 44-story high-rise with one underground level, located in Batumi, near the coastline. It also has a rectangular configuration, measuring 39.5 × 32.45 m with a maximum span of 13.1 m. Like the school, it follows a frame-braced system with reinforced concrete walls and slabs. The first-floor height is 5.0 m, while the typical floor height is 3.5 m. Using the seismic criteria from the planning parameters and regulatory methodologies, all required coefficient values for the school building calculations were determined, including the β coefficient.

Introduction

High-rise buildings belong to the first category of structures in terms of reliability and responsibility. Their structural design and construction are closely related to advancements in scientific and engineering technologies. In leading countries, high-rise design standards are well-established, but

Georgia lacks a comprehensive methodological and regulatory framework. As a result, Georgian specialists often struggle to engage in high-rise building design.

However, some Georgian design firms have successfully undertaken high-rise projects in Tbilisi and Batumi. Given the increasing rate of high-rise construction in Georgia, ensuring seismic resistance is a critical issue. Strengthening earthquake-resistant measures is essential in seismically active regions.

Main Analysis

This study presents **two structural models**:

1. The **school building** has a height of **19.5 m**.
2. The **multifunctional center** has a height of **165.1 m**.

Both models were analyzed using **two different seismic standards**:
Georgian Code (PN 01.01-09) – "Seismic-Resistant Construction"

- **Eurocode 8 (EN 1998-1:2004)**

By comparing the results, we can observe the **differences in calculated seismic responses**, particularly regarding the **β coefficient**.

Research Methodology

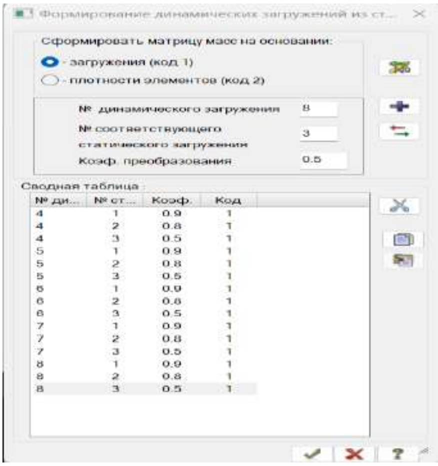
The study analyzes standard tables, dynamic coefficients, primary and secondary load combinations, force distributions, mass matrices, mutually exclusive loads, vertical load coefficients, acceleration spectra, soil types, behavior factors, seismic spectra, and vibration modes.

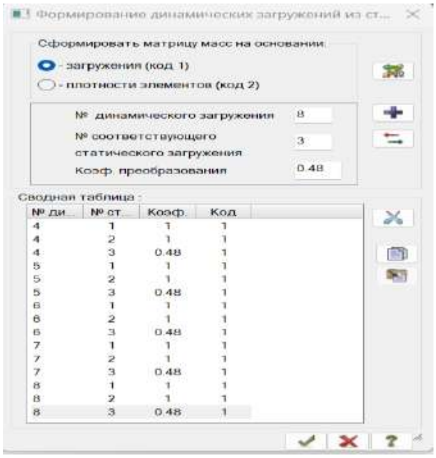
The SRSS (Square Root of Sum of Squares) method is used for summation. The structural calculations were performed in a computer-based numerical model using the LIRA-SAPR 2021 software (license #92095856).

After completing the calculations, we analyzed the displacements, natural vibration modes, and reinforcement requirements to draw final conclusions.

Standard Tables of the Calculation Model

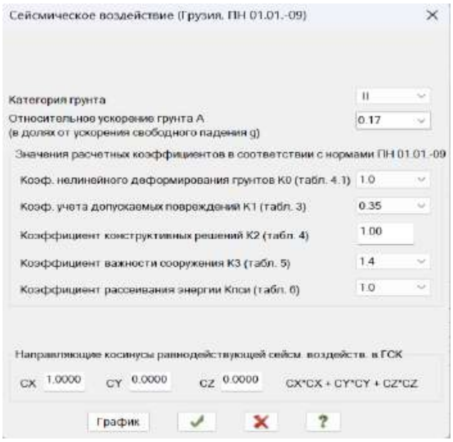
The static loads in the calculation model for seismic analysis are included with the following coefficients:



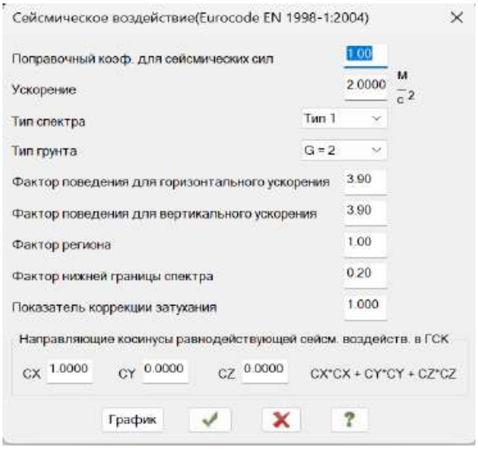


(PN 01.01.-09) (EN 1998 – 1:2004)

Standard Seismic Tables, presenting accelerations and coefficients defined according to the regulatory document:

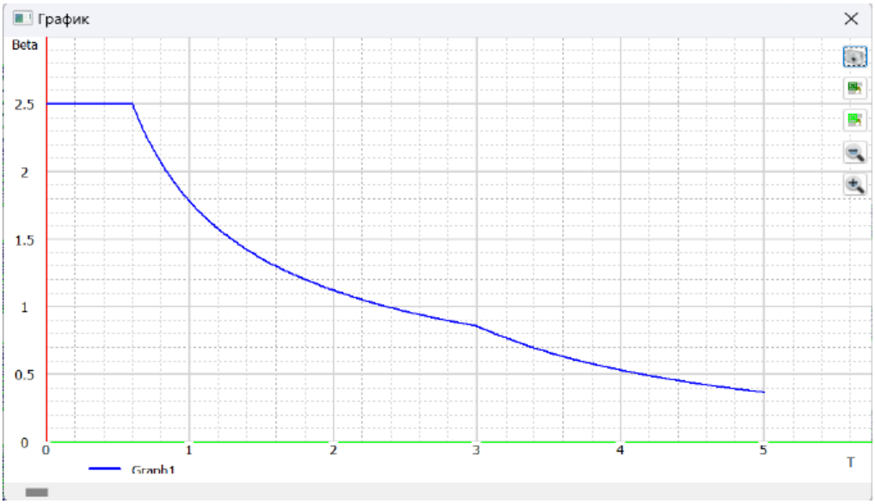


(PN 01.01.-09)

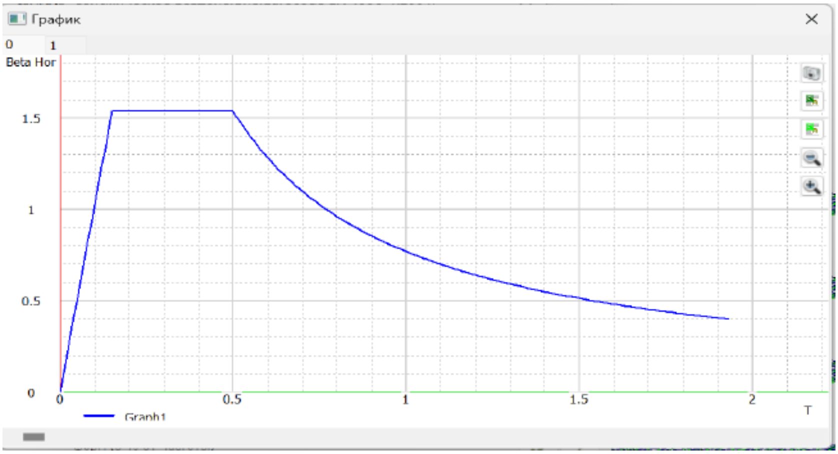


(EN 1998 – 1:2004)

Analysis of the Calculation Model: Acceleration graphs for both regulatory documents:

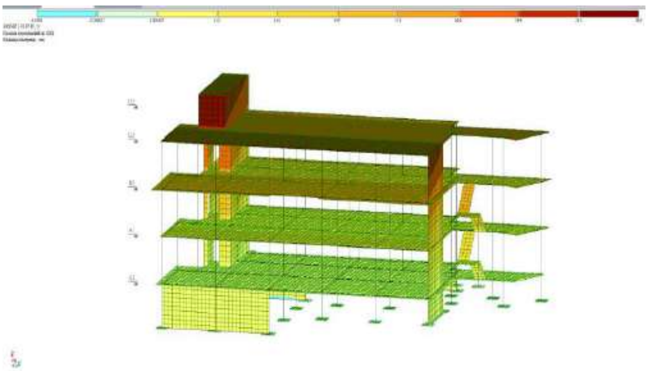


(PN 01.01.-09)

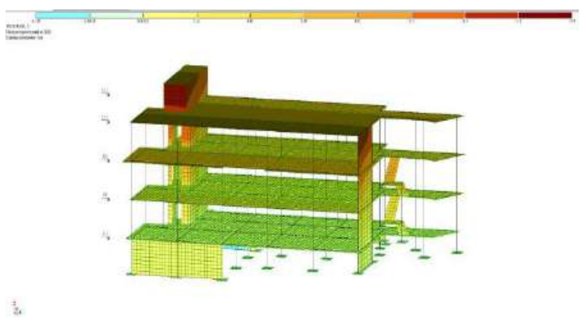


(EN 1998 – 1:2004) Horizontal Displacement of the School Building:

Horizontal displacement in the "X" direction:

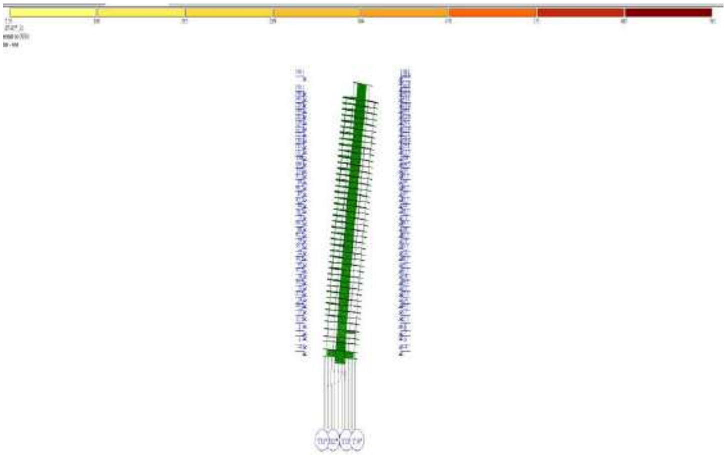


(PN 01.01.-09) Maximum value: 26.6 mm

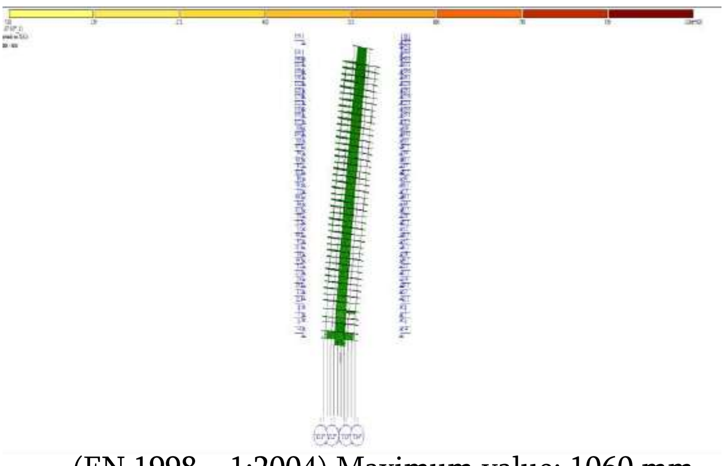


(EN 1998 – 1:2004) Maximum value: 17.9 mm

Horizontal Displacement of the Multifunctional High-Rise Building: Horizontal displacement in the "X" direction:



(PN 01.01.-09) Maximum value: 763 mm



(EN 1998 – 1:2004) Maximum value: 1060 mm

Interpretation of Results

Although Eurocode 8 assigns higher static loads, its seismic displacements (except for Z-axis soil displacements) are 20-30% lower than Georgian norms.

The significant difference is due to the spectral method algorithm embedded in the regulations. The β coefficient (βi), which represents the dynamic coefficient for a given vibration mode, is determined using specific formulas.

Grounds of category I	Grounds of category II	Grounds of category III
$0 \le T_i \le 0{,}4$ β= 2.5	$0 \le T_i \le 0{,}6$ β =2.5	$0 \le T_i \le 0{,}8$ β=2.5
$0{,}4 \le T_i \le 2{,}2$ β = 2.5 (0.4/T$_i$) 2/3	$0{,}6 \le T_i \le 3{,}0$ β= 2.5 (0.6/T)2/3	$0{,}8 \le T_i \le 3{,}0$ β= 2.5 (0.8/T$_i$)2/3
$T_i > 2{,}2$ β=0.8	$T_i > 3{,}0$ β= 7.5 0.62/3/T5/3	$T_i > 3{,}0$ β= 7.5 0.82/3/T5/3

Note: β cannot be less than 0.8 in all cases.

Extracted from the normative document PN 01.01.-09

According to PN 01.01-09, βi cannot be less than 0.8, regardless of building height. This does not account for increased vibration periods in high-rise buildings, leading to higher seismic forces in the Georgian code compared to Eurocode.

Conclusion

The study confirms that Eurocode 8 results in significantly lower seismic displacements than Georgian standards.

To align with modern high-rise building requirements, Georgian norms should be revised, including. Updating national annexes Modifying the spectral method algorithm Adapting regulations to contemporary highrise engineering practices

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Abstract

The construction industry plays a crucial role in shaping our environment, and this responsibility necessitates prioritizing sustainability. Sustainability refers to the ability to maintain or support a process over time. It is commonly divided into three main concepts: economic, environmental, and social. Numerous sectors and governments have committed to achieving sustainable development goals, such as reducing their environmental impact and conserving resources.

As the global population continues to grow and urbanize, the demand for efficient resources and eco-friendly construction methods has never been higher. Integrating sustainable development principles into construction not only helps reduce environmental impact but also ensures long-term financial benefits, improves public health, and preserves resources for future generations. This article discusses the importance of sustainable construction methods and green solutions in construction projects.

Keywords: sustainability, construction, green solutions, sustainable materials

Introduction

Sustainability in construction involves designing, building, and operating structures to minimize negative environmental impacts while maximizing social and economic benefits. This includes using eco-friendly materials, implementing energy-efficient systems, reducing waste generation, and creating healthy indoor environments. The primary goal of sustainable construction is to conserve natural resources, reduce greenhouse gas emissions, and promote the well-being of both residents and the surrounding community. Consequently, sustainable construction plays a vital role in modern building projects and contemporary architecture.

Main part

The construction industry accounts for 36% of global energy consumption and 40% of total CO_2 emissions. Furthermore, recent data reveals that construction activities generate up to 40% of solid waste and consume 30% of the world's raw materials. Beyond environmental impacts, sustainability in construction is critical for the long-term economic and social well-being of communities.

By adopting sustainable construction practices, developers can reduce operational costs, increase the durability of structures, and enhance property value. Sustainable buildings provide residents with healthy living and working environments, improving their well-being and productivity. In turn, this contributes to better quality of life and strengthens the local economy.

As urban populations continue to grow, the demand for sustainable construction will only increase, making it a key strategy for addressing pressing challenges of our time, such as climate change, resource scarcity, and social inequality.

Advantages of Sustainable Construction

The construction industry benefits from sustainability in various ways, covering multiple aspects, including:

- Environmental Benefits

The environmental benefits of sustainability in the construction industry are diverse and far-reaching. By prioritizing eco-friendly construction materials and practices, sustainable construction supports ecosystem preservation, conserves natural resources, and reduces energy consumption. Consequently, this leads to decreased greenhouse gas emissions and a reduced carbon footprint in the built environment. Additionally, green construction methods can enhance water management, minimize waste, and promote biodiversity.

- Social Benefits

The social benefits of sustainability in construction are equally significant as they contribute to the well-being of communities. Sustainable buildings are designed with features that promote healthier indoor environments, such as increased natural light, improved air quality, and green spaces. These elements enhance the physical and mental health of occupants, resulting in increased productivity and overall satisfaction.

Developers can add social value to projects by adopting sustainable construction methods that often emphasize local materials and labor, boosting local economies and creating job opportunities. Through Corporate Social Responsibility (CSR), businesses can take accountability for the environmental, social, and economic impacts of their projects. This enables developers to demonstrate their commitment to sustainable development and establish a positive public image.

- Financial Benefits

By incorporating sustainable practices and materials, developers can significantly reduce long-term expenses, such as energy, water, and maintenance costs. Additionally, sustainable buildings hold higher market value, making them attractive investments for stakeholders. As consumers become more environmentally conscious, the demand for eco-friendly properties increases, offering sustainable construction a competitive advantage.

Challenges

Despite the widespread belief—90% of companies agree that sustainability is vital, only 60% of them actually implement sustainable strategies. Moreover, 34% of firms have reported client demand for green buildings, indicating that this demand is unlikely to fade. Even with the many benefits of sustainable construction, several challenges must be overcome to realize its full potential.

High Initial Costs

The upfront expenses associated with adopting sustainable methods and materials can be higher than traditional construction methods. For instance, in 2018, 40% of firms in the UK identified budget constraints as the primary barrier to implementing sustainable construction practices, while nearly 50% of firms expected green buildings to command higher prices. This financial challenge may deter developers, particularly in regions lacking financial incentives and regulations supporting sustainable construction.

Coordination and Collaboration

Sustainable construction projects often require extensive collaboration and coordination among various stakeholders, which can be complex and time-consuming.

To address these challenges, there is a need for increased awareness, investment, and policy support to shift the construction industry paradigm toward greater sustainability.

Although sustainability in construction offers significant benefits, it is not a quick process. However, this does not mean it is an unattainable goal. With advancements in technology and the adoption of more sustainable alternatives, the cost of these green solutions is becoming increasingly affordable.

Sustainable Materials

The use of sustainable materials is perhaps the most straightforward way to achieve sustainability in construction. By selecting materials such as wood, sustainable concrete, and alternative building blocks made from wool and clay, developers can significantly reduce the environmental impact of their projects.

Sustainable Concrete: One solution in the creation of sustainable concrete is the increased replacement of cement with supplementary binding materials. These materials, already commonly used in modern concrete mixtures, include fly ash, slag cement, and microsilica. Their importance lies in the fact that they are by-products of other industries that might otherwise be disposed of as waste, potentially harming the environment or ending up in landfills.

Innovative Brick Materials: By incorporating wool fibers into clay-based materials and combining them with alginate (a natural polymer derived from seaweed), Spanish and Scottish researchers have developed a building material that is both stronger and more environmentally friendly.

These materials often have low embodied energy, meaning less energy and fewer emissions are involved in their production, transportation, and disposal. Moreover, sustainable materials tend to be more durable and require less maintenance, extending the lifespan of buildings and reducing waste generation. By integrating sustainable materials into construction projects, developers not only contribute to a greener environment but also promote a circular economy, where resources are conserved and reused to their fullest potential.

Plastic Construction Materials

Plastic construction materials can significantly contribute to sustainability in the construction industry. By recycling discarded plastics into strong, durable building materials, the industry can reduce both waste generation and the demand for raw materials. Materials such as recycled plastic lumber are resistant to moisture, pests, and decay, requiring less maintenance and replacement over time.

In addition, the use of plastic materials can lead to weight reduction and improved insulation properties, resulting in energy savings and a reduction in greenhouse gas emissions. By adopting plastic construction materials as alternatives to traditional resources, developers can promote a more sustainable approach to building while minimizing environmental impact.

Benefits of Using Plastic Lumber in Construction

Enhanced Strength: Plastic lumber is much stronger than wood and has a high tensile strength, making it highly resistant to breaking or cracking.

Durability: Unlike organic materials, it does not produce sawdust or degrade in the same way as natural wood.

Low Maintenance: Its resistance to environmental factors makes it a cost-effective and sustainable choice over the long term.

By integrating plastic construction materials into projects, developers can create innovative, sustainable solutions that align with environmental goals and reduce reliance on traditional, resource-intensive methods.

Renewable Energy on Construction Sites

Incorporating renewable energy sources on construction sites is another effective approach to achieving sustainability in construction. By utilizing renewable resources such as solar, wind, and geothermal energy, the industry can significantly reduce dependence on fossil fuels, thereby lowering greenhouse gas emissions and minimizing environmental impact.

Solar Energy:

Solar panels can be deployed on construction sites to harness solar energy, providing power for tools, equipment, and site operations.

Wind Energy:

Wind turbines can be utilized to generate electricity on-site, offering a sustainable solution for energy-intensive construction processes.

Geothermal Energy:

Geothermal systems can provide heating and cooling solutions, reducing energy consumption and reliance on non-renewable sources.

The adoption of renewable energy technologies—such as solar panels, wind turbines, and geothermal systems—can help meet the energy needs of heavy machinery, tools, and site lighting, leading to significant energy savings. Furthermore, integrating renewable energy into the design and operation of completed buildings can further contribute to sustainable development by ensuring long-term energy efficiency and a reduced carbon footprint.

As the global push toward cleaner energy solutions continues, the use of renewable energy in construction projects is becoming increasingly important for achieving sustainability and mitigating the impacts of climate change.

Conclusions

Naturally, adopting sustainable construction methods will reduce your organisation's impact on the environment. If you are the client for a new building, your specification will have a big impact on the specification of the project and the long-term building running costs.

The quality of the design and its sustainability can have long term reputational and corporate social responsibility benefits. If you are a contractor involved in construction, an understanding of new materials and construction techniques may be required in order to be part of the most lucrative and innovative projects.

The truth of the matter is that green buildings do come with lower operating costs. In fact, research suggests that the use of the latest sustainable technologies in construction processes could potentially deliver a remarkable €410bn a year in savings on global energy spending. There are also direct savings available for your organisation; by reducing waste, for instance, you will reduce the fees charged by your waste management company. By adopting more efficient vehicles, you will save on fuel costs.

And there is one more benefit that could have a huge impact on your company; sustainable construction can help your organisation's reputation by demonstrating your sense of corporate social responsibility.

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Abstract

Modular architecture is becoming an innovative approach that accelerates the construction process, reduces costs, and at the same time provides flexible design. This article discusses its history and development, as well as several significant modular projects that are already transforming or will transform modern engineering and architectural approaches. Through specific examples, we evaluate the advantages of modular systems, technical challenges, and their future perspectives. At the end of the article, we discuss how modular architecture can transform urban environments and the construction industry in the coming years.

Main Body

Innovative technologies have always played a significant role in engineering and architecture, and today we see clear examples of this. Nowadays, various technologies serve these fields in different ways. Of particular interest today is the development of mobile construction and modular systems, as well as the potential and possibilities for refining this technology, which will be discussed in detail in this article.

What is Modular Construction?

Modular construction refers to the off-site production of building components (modules) in factory conditions. These modules are then assembled on-site. The combination and configuration of these modules can be done in different ways, adapting to various user needs. Over time, some modules may be developed for new purposes or to improve the execution of certain aspects. These components are, of course, transportable. The modular system is a product and technology of high-level industrialization in construction, distinguished by its exceptional integrity. This underlines its colossal importance in well-known fields for us.

After decades of development, modular construction technology is becoming more mature and plays an increasingly important and irreplaceable role in the construction and engineering sector. Compared to traditional buildings, even concrete ones, modular buildings have clear advantages:

- Construction time can be reduced by more than 50% compared to traditional construction projects.
- On-site labor is reduced by 70%.
- On-site energy consumption is reduced by 70%.
- On-site construction waste is reduced by 85%.
- It can be recycled.

In addition to significantly changing traditional construction approaches and offering major advantages, it plays an important role in architecture as well. Many ideas have been realized, and numerous historical buildings have been constructed with the help of modular systems. Even today, with the development of this technology, many future projects are being planned. As a result of all this, it is essential to understand the history and development of technology that occupies an increasingly larger space in construction, engineering, and architecture every day.

History and Development

The history of modular systems begins quite far back, which might make us doubt the modernity or innovative potential of this technology. However, given its enormous potential, modern projects based on it, and its practicality, we can confidently say that today marks the beginning of the history of modular systems.

Modular construction, which is considered an innovative method today, has been developing for centuries. Even centuries ago, Roman soldiers used pre-made parts to quickly assemble their camps. In the 1600s, a timber panel house shipped from England to Massachusetts is considered the first prefabricated structure. In the 1800s, the British continued sending prefabricated houses to their colonies, including portable cottages to Australia.

In 1908, Sears, Roebuck and Co. began selling prefabricated houses by catalog, allowing customers to buy houses in parts and assemble them on their land. This program was particularly significant for World War I veterans and African Americans who were seeking homeownership during the era of Jim Crow laws.

After World War II, the return of military personnel in America led to a huge demand for housing. Modular construction provided fast and affordable solutions, as seen in projects like Levittown, New York, where prefabricated house parts were used in mass construction.

As we can see in the history of modular construction, its positive attributes were particularly useful in times of crisis. Therefore, we can say that in critical situations, the use of modular technology guarantees fast and high-quality results. This is why modular construction is particularly well-suited for building offices, schools, medical facilities, and other commercial buildings, reducing time and costs compared to traditional construction.

Modern modular construction has developed further due to technological innovations. Computer-aided design (CAD) software and robotic construction allow architects to create high-quality, quickly assembled structures. The history of modular construction shows how innovative approaches can change the construction industry and offer effective, sustainable, and affordable solutions for the modern world.

Modular Systems in Architecture: The "Construction Element"

The role of modular systems in architecture is especially useful and interesting. There are many examples of this. To give just one example, we can look at the unique invention of Georgia's esteemed architect Giorgi

Chakhava (1923-2007), which is an excellent example of effective construction, good engineering, and ideal architectural solutions.

His invention, called the "Construction Element," was patented in 1981. The construction element was meticulously developed by Chakhava, with calculated panel designs, assembly methods, connection details, and the design of the factory conveyor lines needed for their production and improvements.

Panel description: width – 40 cm, length – from 60 cm to 6600 cm, thickness – 10 cm, maximum weight – 0.5 tons. Every 60 cm (in the axes) or multiples of 60 cm has U-shaped indentations, allowing panels to connect easily and securely without additional fasteners.

The practical advantages of prefabricated reinforced concrete panels are low material costs, compact dimensions, light weight, ease of transportation, minimal construction time, simple assembly, no need for welding on-site, no finishing work required, and the use of simple lifting equipment due to the light weight.

The range of applications for prefabricated panels is very broad – from small forms to residential houses and even bridge piers. These elements create a statically stable structure. The structure is self-supporting and does not require additional reinforcement. It is placed on concrete point or strip foundations.

In addition to technical characteristics, these structures are also interesting architecturally, as none of them are the same, and using the same modular elements, entirely different volumes are constructed in each case. Therefore, each building is unique, although it belongs to one system. We can clearly see this in several preserved bus stops built in the 1970-1980s.

Chakhava's invention emphasizes the importance of perfection in modular elements for successful construction using modular systems. Therefore, we can say that one factor in the successful implementation of this technology is the creation of ideal elements, so that by combining them, we can achieve the desired result.

Effective Use of Modular Systems in the Soviet Union

Even in the 1950s and 60s, during Nikita Khrushchev's leadership, typical residential buildings were constructed using modular systems. The main features of these buildings were fast and economical construction, made possible by the use of modular construction systems.

Therefore, we should highlight key facts about the "Khrushchyovkas" that can demonstrate the positive aspects of modular systems: Khrushchyovkas were built using the principles of serial production, with modular blocks. This greatly reduced construction time. Hence, we conclude that modular systems allow for the rapid construction of significant numbers of structures.

These buildings were also inexpensive to build because materials and technologies were optimized. Clearly, modular systems help achieve cost efficiency.

It is also worth noting that all Khrushchyovkas had a standardized layout and elements, which simplified the architectural process. Thus, standardization in modular systems increases the efficiency of production and assembly.

Khrushchyovkas were built on a massive scale throughout the Soviet Union because the system adapted easily to different regions. This provides grounds to say that modular systems scale easily and allow for multifunctional use.

Modern and Minimalist Use of Modular Systems

The principles of modular architecture are widely used in modern fast-built buildings, and its advantages are evident in both residential and commercial spaces. Modular systems are especially popular because they can create structures quickly, economically, and sustainably. We can look at modular containers and projects by renowned architects such as Shigeru

Ban and Adam Kalkin, as well as the construction of hotels in the UK based on modular systems.

For instance, modular containers are adaptations of shipping containers for residential or commercial spaces. Their main advantages are that they are affordable, reusable, and easy to transport and install. Additionally, containers are excellent examples of recycling, which is ecologically beneficial.

These container homes and offices are widely used today for both temporary and permanent housing.

Shigeru Ban's architecture is also of interest. He is known for using innovative and sustainable materials. His projects often involve modular and fast-built systems. One interesting example is his paper houses. After the Kobe earthquake in 1995, Ban created temporary housing from paper tubes, which was quickly assembled and affordable. His structures are easy to assemble and have minimal environmental impact. His approach can be compared to Khrushchyovkas – easily assembled modules, but with more modern and ecological materials.

Another interesting architect is Adam Kalkin, known for using shipping containers to create innovative residential and commercial spaces. His works combine industrial aesthetics and functionality. Kalkin's projects reflect how containers can be quickly transformed into living and working spaces. These projects are fast-built, scalable, and sustainable.

It is also important to mention the use of modular systems in the UK, particularly in hotel construction. These include Premier Inn modular hotels. The rooms of these hotels are made in a factory and then transported and assembled on-site, which reduces construction time by 50%. This approach offers the possibility of creating high-quality spaces that meet standards. By using these modular systems, hotels significantly reduce costs and construction time, making them commercially more successful.

Metabolism

If we delve deeper into the relationship between modular systems and architecture, it's worth noting that a significant breakthrough in architecture was the "Metabolism" movement. Its projects and ideas were realized precisely through modular technology.

Metabolism in architecture refers to a movement that developed in Japan in the 1960s and addressed innovative approaches to urban planning and modular architecture. Architects of the movement, such as Kenzo Tange, Kisho Kurokawa, and Fumihiko Maki, aimed to create flexible urban systems with modular structures capable of adaptation to changing needs.

The main idea behind Metabolism was the possibility of creating urban environments that could evolve over time. The goal was to design structures that could be adapted, expanded, or even disassembled if necessary.

Metabolist buildings are modular in nature, which means they can be easily reconfigured, expanded, or relocated. For example, the famous Nakagin Capsule Tower in Tokyo (designed by Kurokawa) consists of prefabricated capsules that can be replaced or added as needed. This design represents a flexible, modular approach to architecture, where the buildings are adaptable and capable of evolving over time.

Nakagin Capsule Tower

The Nakagin Capsule Tower, designed by architect Kisho Kurokawa in 1972, is a striking example of the Metabolism movement demonstrated through modular construction technology. The building consists of individual capsules that can be easily detached or replaced.

The Nakagin Tower is one of the most renowned examples of using modular systems in architecture. This project combines the architectural ideas of Metabolism with the principles of modular construction, making it unique.

The structure comprised two main concrete towers with 140 individual modules (capsules) attached to them. Its purpose was to create flexible and adaptable living spaces that met the demands of rapidly changing urban life.

Despite the innovative ideas, the Metabolism movement did not achieve widespread practical application. Critics noted that producing and maintaining expensive modular systems was often costly at the time. Additionally, during the 1960s and 1970s, the technology required for implementing such ideas on a large scale was underdeveloped.

This project vividly illustrates the role of modular construction technology in architectural vision. It is also worth noting that modular construction is inherently linked to repetition, which can lead to the risk of what might be termed "boring architecture." However, projects like this demonstrate that, with the right approach, modular technology can become a tool for creating unique architectural solutions.

The Tokyo Bay Project

As mentioned, certain challenges hindered the development of the Metabolism movement. Among those challenges was another masterpiece of this trend that remained a project and was never realized: the Tokyo Bay Development Scheme (Tokyo Bay Project), proposed by Kenzo Tange in 1960. This project aimed to expand Tokyo’s urban space and create a flexible, sustainable, and adaptable city using modular systems.

In the 1950s and 1960s, Japan experienced rapid urbanization due to a sharp population increase, the overload of Tokyo's existing infrastructure, and land shortages in the city center. The Tokyo Bay Development Plan sought to address these challenges by expanding the growing city toward the sea and creating flexible structures. This project was entirely based on modular system principles, a fundamental element of Metabolism.

The main structures, such as bridges and platforms, were permanent, while the living and working spaces attached to them were modular. This system allowed the city to quickly adapt to changes in population size.
New housing and facilities could be added without significant costs, and the prefabricated modules reduced construction time and expenses. The standardization of these modules made the process even more efficient.
The Tokyo Bay Development Scheme is a practical expression of the Metabolism philosophy: the city developed as a living organism with constantly changing parts. The project also sought to coexist with the sea's ecosystem.
Despite its boldness, the Tokyo Bay Plan was never fully realized. The challenges included high costs. Creating artificial islands and modular structures proved economically unfeasible. Moreover, as previously mentioned, the technology required for such a large-scale project was insufficiently developed in the 1960s. Society also viewed such radical changes to living environments with skepticism.
Through this project, the concept of artificial cities became linked to modular construction, marking the first steps toward realizing the cities of the future.

BIG Group’s Floating City

Times have changed, and these ideas have found new realizers. A modern analogy to such a project is the BIG Group's Floating City.
Rising sea levels due to climate change pose one of the most alarming threats to many coastal cities worldwide. By 2050, over 70% of the global population will reside in urban areas, increasing the need for housing and infrastructure. The BIG Group’s “Oceanix City” addresses these challenges by creating a sustainable and eco-friendly city that floats on water.
The city consists of floating platforms connected to each other. Each platform serves a specific function: residential, agricultural, public spaces, etc.

Platforms can be easily added, removed, or replaced as needed. The city uses renewable energy (solar panels, wind turbines). Efficient water resource management and waste recycling ensure environmental sustainability. Most importantly, the BIG project integrates various functions—residential spaces, agricultural zones, and public centers—creating a self-sufficient city model.
The perspective of modular systems and innovative possibilities can also be explored through this city's example. The BIG project starts with space for up to 10,000 residents, with the potential to expand to over 100,000 by adding modules.
As in other modular projects, the modules are prefabricated in factories and assembled on-site, reducing construction time and costs. Each platform can be repurposed; for instance, a residential zone can be converted into a public space or an agricultural area. The modules are made from durable, climate-resistant sustainable materials with minimal environmental impact.
The first concept of Oceanix City was presented in 2019 when the BIG Group and Oceanix publicly showcased the project within the United Nations framework. Between 2020 and 2025, small-scale prototypes are planned for creation and testing. These prototypes will demonstrate the city's stability and functionality under real-world conditions. By 2025, construction of the first pilot city is expected to begin, likely near coastal regions in Asia or Africa most affected by rising sea levels.
If successful, the Oceanix City model could spread worldwide. Floating cities could be adapted to various climatic and geographical conditions. In short, this technology has unlocked numerous innovative possibilities, including the creation of floating cities. Who knows—perhaps in the future, similar ideas could be realized for aerial or space cities. While such concepts might seem unimaginable today, floating cities were equally unthinkable to people of the 20th century.

Conclusion

In conclusion, based on the aforementioned and other projects, it can be summarized that modular systems are less daunted by technical and structural challenges. This technology is also closely tied to standardization. Modular systems are easily scalable and support multifunctional uses.

Regarding their development stages, it is worth noting their direct connection to factory production. Thus, as time progresses, technological advancements enhance the efficiency of modular systems.

Modular construction intersects with numerous technical fields and has significant development potential. Given the mention of factory production, it is also worth highlighting that the use of abandoned industrial spaces, even in countries like Georgia, could be an effective way to develop this technology, offering a convenient option for boosting the domestic economy.

To further develop this technology, which has many advantages over traditional construction, it is essential to refine and standardize the core elements of modular systems. Their proper development could yield interesting and positive outcomes.

Over time, this technology offers many discoveries, including the founding of artificial cities. As time passes, we become increasingly convinced of the utility of modular technology in crisis situations, such as natural disasters, epidemic outbreaks, and others.

Therefore, it is crucial for professionals in architecture, engineering, and construction to possess sufficient knowledge about modular systems to facilitate the realization of many innovative projects worldwide in the future.

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Statistical data on the development of construction business in Georgia,

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Abstract. Statistics, as a science studying mass public events, is committed to ensuring the acquisition, processing and delivery of objective and fair information necessary for socio-economic management of the country. Accordingly, the purpose of statistics, as one of the most important fields of public science, is to provide us with information about the direction in which the field is developing, in which sector growth is taking place, how limited resources are effectively used, What is the rate of employment and standard of living, the rate of price growth, what is the rate of foreign trade, indicators of the construction industry, indicators of the construction industry and their impact on the development of the national economy.

Keywords. Statistics. Construction business. real estate market. turnover capacity. Population density. Number of employees. Average monthly salary.

Introduction

The construction sector is one of the major sectors of the Georgian economy. In terms of attracting direct foreign investments, construction lags behind only the fields of transport and financial activities. On the one hand, the rapid growth rate of the construction industry increases the economy of Georgia and creates additional jobs, but on the other hand, this process is accompanied by certain problems. The basis of the problems is the concentration of approximately 80% of constructions in Tbilisi and Batumi, the current improper legal base and the practice of issuing construction permits. Construction industry in Georgia is regulated by 4 laws, one presidential decree and 6 government resolutions. Unlike some sectors of the Georgian economy, there are many large, medium and small enterprises in the construction sector. In terms of market shares, there is no monopoly or, even more, oligopoly situation. There are 43 large, 281 medium and 6620 small active enterprises in Georgia. However, the wage rate in large enterprises is 2 times higher than in small enterprises, when 43% of employees are employed in small enterprises. In most regions of Georgia, large-scale construction works in the private sector are not actually underway. The opposite picture is in Tbilisi and Adjara. It is mainly the massive constructions taking place in Tbilisi that made the ongoing processes in the construction industry, both the development of the city and the changes in construction regulations, a topical issu

Main part

The construction boom in Georgia started in 2011 and reached its peak in 2013. According to Saxstat data, in 2013 the largest area was built in the last 10 years - 2,278,680 m^2, and the total number of completed objects was 3,163.

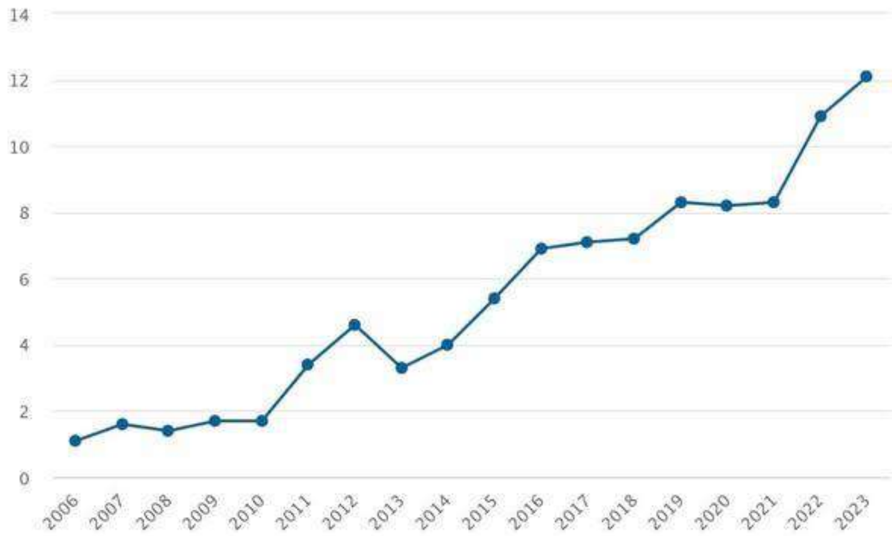
It should be noted that if the construction business is on an upward trend until 2013 and the area of constructions and the number of completed objects are increasing, since 2013 the trend of decreasing construction has been observed. Since 2014, the national currency began to depreciate, which led to an increase in prices. Rising prices have reduced demand.

In 2016, the Georgian real estate market grew significantly (compared to previous years - by 20.2%), at the same time, Tbilisi's real estate market grew by 37.5%, the share of which made up 38.6% of real estate sales nationwide. In 2016, 34,440 sales transactions were recorded in the capital city.

It should be noted that the volume of turnover of the construction sector mostly comes from the share of large enterprises. In 2016, the turnover of other construction enterprises was 4,725.7 million GEL. In

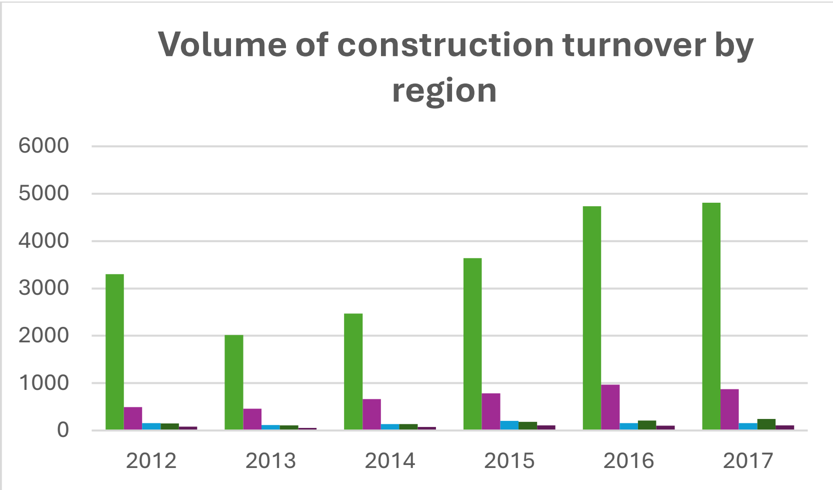
2016, the turnover of the construction sector increased by 354.9 million GEL compared to 2015. In 2017, the turnover of construction enterprises increased compared to 2015 and 2016. which indicates the sustainable development and growth of the construction sector.

Volume of the construction industry, billion GEL



Tbilisi occupies the first place by the volume of construction turnover. It is followed by Adjara, Imereti and Kvemo Kartli.

Tbilisi real estate market is growing more and more. In the first half of 2024, high activity was observed in the market. The number of apartments sold in May amounted to 3,197, which is 7.9% less compared to the same period of the previous year, but the total number of apartments sold in the first 5 months of the year was 15,920, which is an increase of 0.8% compared to the previous year. It should be noted that this growth was fully due to the activity of the primary market (+8.1% y/y), while a 5.1% decrease was observed in the secondary market. This indicates a growing interest in new projects.



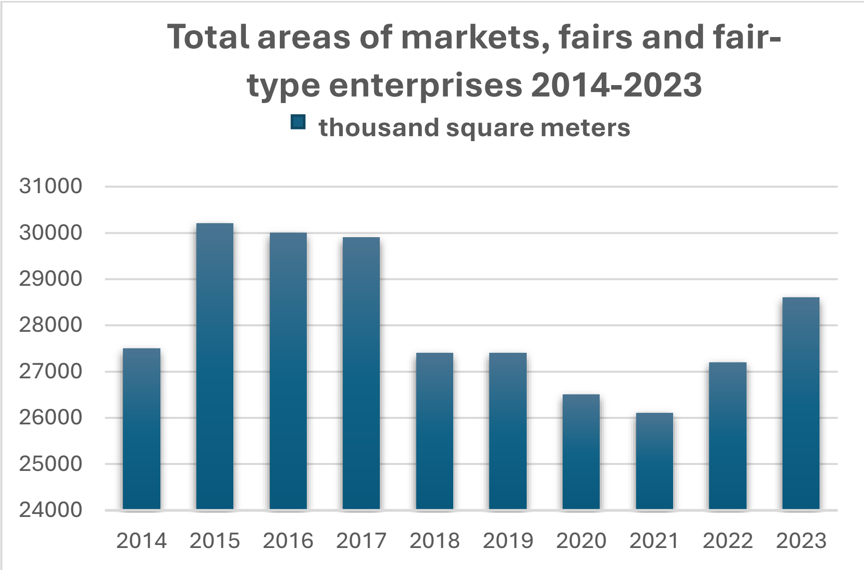
Tbilisi Adjara Kvemo kartli Imereti
Shida qartli

The largest share of the total number of commercial spaces in Tbilisi is occupied by markets and outdoor trade type markets. Modern shopping centers have been operating since 2015. During this period, the first large shopping center "Tbilisi Mall" was opened. It was soon followed by "East Point". In 2016, the third largest shopping center - "Gldani Mall" was opened in Gldani district, which is more than 22 thousand square meters.

In 2017, "Gallery Tbilisi" and Tbilisi Sea Plaza Business Center were opened. "Gallery Tbilisi" shopping center has become one of the most prestigious centers due to its location (on Freedom Square, in the center of the city). Different types of shopping establishments are located on Aghmashenebeli Avenue and in the Old Tbilisi area, which are mostly visited by tourists.

Many shopping centers in Tbilisi are built in such a way that they have more than 3 floors, although not all floors are used by commercial organizations. One of the peculiarities of the shopping centers located in

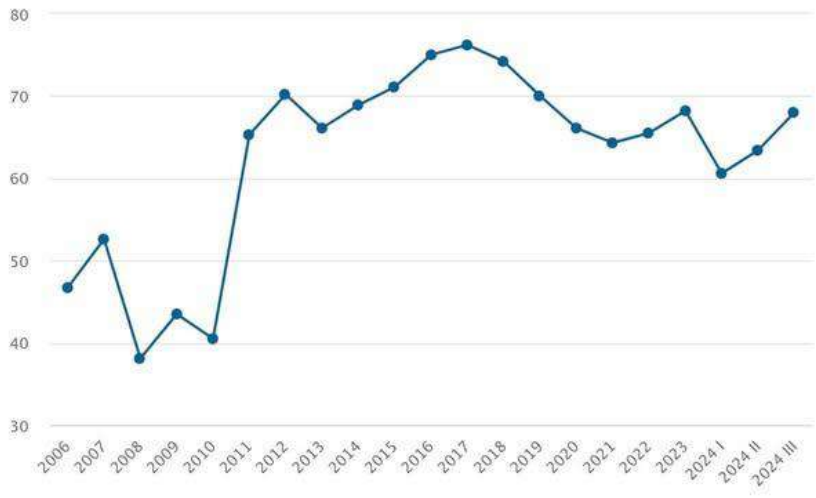
Tbilisi is that the development companies sell the existing commercial spaces instead of renting them, which reduces the investment attractiveness.



The supply of office space in the real estate market in Tbilisi started to increase since 2008. Class A business centers make up only 7% of the rental space, A-, B+, B class 7%, 23% and 1%, and class C and D offices have the largest share - 42%. Compared to Eastern European cities, Tbilisi has a very small amount of office space - 4.6 times less.

The growing trend of the construction business is helping to increase the number of employments in this business sector. In 2016, the number of people employed in construction increased by 4% compared to 2015. A similar trend of growth has been maintained every year to date.

The number of people working in the field of construction, thousand people



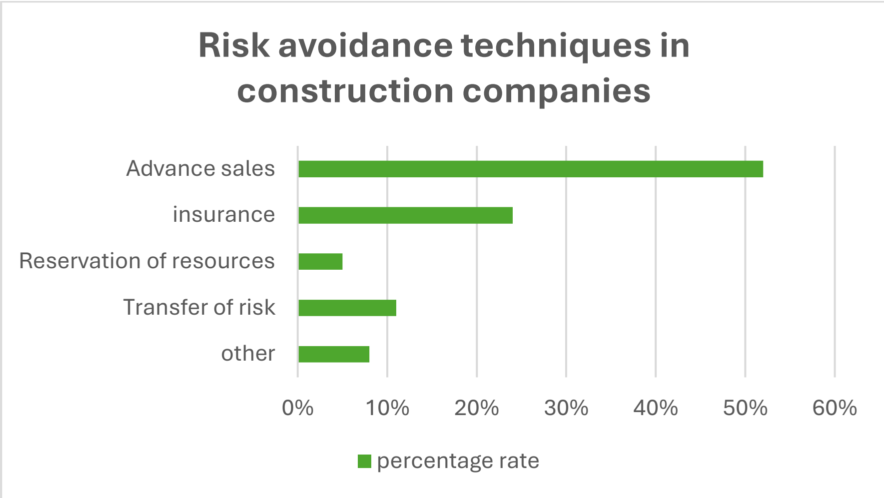
A large share of employees comes from large enterprises. They are followed by medium and small development companies. Most of them are employed in the construction of buildings and structures, mostly in Tbilisi. It is followed by Adjara and Imereti. These data are logical, since the construction business is most active in Tbilisi, Batumi and Kutaisi.

The average monthly salary of construction workers is increasing. For example, in 2015, the average monthly salary of employees in the construction sector increased by 20%. This was caused by currency exchange rate fluctuations and inflation. A 20% increase is quite large. For comparison: in 2014, wages of employees in the construction sector increased by only 9% compared to 2013. In 2016, their salary increased by 8%. The reason for this was that the price of newly built apartments remained the same in some regions, while in others it decreased a little.

According to the preliminary data of the National Statistics Service, the number of employees in the construction industry has slightly decreased by the beginning of 2024. The construction industry is one of the growing sectors of business that is experiencing a shortage of professionals. Due to the insecurity of labor safety norms, construction companies faced fatal consequences. Due to carelessness and low level of awareness, the hired person suffered physical injuries, due to which the hiring company was fined. Companies try to select personnel very carefully. This is especially true for employees who are directly involved in the construction process.

The fate of development companies depends on the release of the volume of products, during which the loss is equal to 0. This happens when the profits from the production are only covering the costs of production and sale of the products. The release of this volume of products is called a self-repurchase program. The financial situation of the development companies is influenced by the amount of expenditure incurred on the release and sale of the products. This cost is divided into two categories: variable and constant costs. The amount of variable costs directly depends on the volume of production, while fixed costs are not related to the volume of production, but to the duration of the enterprise's operation. The financial situation of the company is naturally affected by the price of unit products.

In response to risk, companies most often try to have some kind of guarantee, pre-sale, etc. Some companies reserve resources, insure or transfer risks.



Construction is an industry that is an important sector of the economy in both developed and developing countries. It combines planning, design, construction and other processes. Construction in the public or private sector, by residents or non-residents, is an industry that contributes greatly to the development of the economy. The construction process and construction development companies face various types of risks, the identification of which and the decision to avoid them are vital for the future operation of the company.

Conclusion

In the form of conclusions, we can formulate the main provisions and suggestions. The performance of the construction industry is affected by several important factor. These are:

➢ <u>Taxation, finance and the role of government.</u> very important Fiscal policy of the government. Government is the main client of the construction industry. It always influences directly or indirectly on the construction industry.

- a period of time. In the construction industry, it is quite difficult to determine exactly when this or that project will be completed. The exact time of completion of the project is complicated by the complexity of the construction.
- Response to customer request. In the construction industry, it is impossible to create inventories. Producers produce only the amount of product that is in demand in the market.
- Location. The product produced by the construction industry is related to the place where it is built. Therefore, the location of the construction product directly affects the current or future demand for it.
- Organization. Construction projects require a team of people with different skills.
- technology. In developed countries, the latest technologies are mostly used for construction. The newer the technologies, the higher the quality of the construction project and its value, which in itself leads to an increase in demand for a particular product.

Finally we can say that developed construction Business is an important indicator of the country's economic success.

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Abstract: The role of green construction in sustainable development is actively discussed in the world, although it is often appreciated only in the context of green architecture. In fact, green buildings combine alternative sources of energy, modern technologies for heat, water and air purification, which help reduce environmental pollution and effectively use natural resources. The paper discusses the importance of this approach in improving the greenery of the city and the quality of life. For our country, the development of green buildings will play an important role in urban development and the creation of an ecologically sustainable environment.

Keywords: Green Construction, Sustainable Development, Energy Efficiency, Ecological Sustainability, Green Technologies.

Climate change has a significant impact on the environment and human life. Global warming leads to a decrease in rain and significant changes in temperature, affecting the structure and functioning of natural ecosystems. The intensity of natural disasters is increasing. An increase in temperature and a changing climate affects the quality and quantity of water resources. All this requires a quick and effective response, in response to these challenges, green construction technologies are developed.

Green architecture is a sustainable construction approach that plays an important role in the fight against environmental challenges. It involves efficient management of energy, water and various resources, as well as improving air quality. Technological innovation, integration of natural elements, and political support in this process are critical to create a more sustainable and healthier environment [1,2].

That is why the development of green construction is becoming increasingly popular and necessary, which minimizes the dependence on environmental and resources consumed. This approach focuses on creating the healthiest living spaces, using environmentally friendly materials and pays great attention to energy efficiency.

Green construction improves the urban environment, expands recreational spaces, and promotes sustainable urban planning principles.

Green projects often include community engagement and environmental awareness, facilitating social activism and environmental care [3].

The main principles of green construction include Energy efficiency: The design of the building should be such as to reduce energy consumption using efficient insulation, energy-saving lighting and air conditioning systems.

Sustainable materials: The materials used should have low impact to the environment and, at the same time, preferably local production in order to reduce the ecological impact caused by transportation.

Water management: effective water use and recycling, as well as modern strategies to reduce water costs.

Harmony with the environment: the design of the building should adapt to the natural environment as much as possible and not have a negative effect on the landscape.

Healthy environment: The building must be a qualified and safe living space.

A brilliant example of green construction and architecture, we can consider Shilda Winery, the shape of the building from Georgia is precisely consistent with the environmental conditions of Shilda and the quality of wine. The building is located directly in the vineyard, and it is almost impossible to notice it from above. The heat mass of the soil is used to cool the building, and most of the fade is directed to the north to avoid direct sunlight and reduce energy loss.

Conclusion

Green construction is an important tool in the implementation of sustainable development, which contributes to the protection of the environment and the effective use of natural resources. Its basic principles, such as energy efficiency, sustainable materials use and economical management of water, help reduce environmental impact and create healthy and comfortable living conditions. Green architecture technologies and innovations play an important role in urban development as they help raise public awareness and increase ecological responsibility.

The development of green construction in Georgia significantly leads to the creation of ecologically sustainable and energy-efficient cities, which will also contribute to strengthening the country's position in the international arena. Shilda Winery is a good example that green construction technologies can be successfully used not only for industrial but also for commercial projects to reduce environmental impact and create a sustainable environment [1,2,3].

In conclusion, green construction will not only provide a safe and sustainable environment for future generations, but also have a positive impact on the economy and the improvement of social conditions today, which will ultimately improve the well-being of society for the long term.

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Digital Innovations in Agricultural Science, Anna Kvichidze, Bachelor Program Student, *kvichidze.anna@mail.ru, Supervisor* Ketevan Gordeziani Associate Professor *k.gordeziani@gtu.ge*

Abstract

Digital innovations in agricultural sciences are an important direction based on the development of technologies and the use of data analysis in agriculture. These innovations play an important role in increasing the efficiency of agricultural processes, in the economic use or consumption of resources. They contribute to the development of processes that lead to a reduction in harmful impacts on the environment, which is very important in the context of today's global climate challenges.

Agricultural science is a set of many disciplines that study agriculture, plant and animal production, agronomic technologies and other fundamental principles. This science aims to develop sustainable and productive agriculture in order to increase the efficient extraction, processing, and supply of food. The development of innovative digital technologies is very important, since according to the UN, 8-10% of the world's population does not get enough food or suffers from hunger.

Keywords: Digital innovations, drones, satellite imagery, efficiency gains, greenhouse farming, nursery farming, economic empowerment, agricultural sciences

Main part

n recent years, the use of satellite and drone technologies in agriculture by modern farmers has significantly increased, which is developing innovative and effective approaches in the agricultural sector. Farmers who use modern approaches make 90% more immediate and correct decisions than those who make decisions only based on their own experience and observation of natural conditions.

Drones are used by farmers for monitoring and supervision. With its help, the farmer can inspect agricultural crops (in the case of large farms) without going to the site, see and assess the problem between the rows, detect the health of the soil, the efficiency of the irrigation system or the presence of a disease in the product in the shortest possible time and find a way to solve the problem.

Drones are also used in the agricultural sector for pest control and plant poisoning. During the inspection of rows, it allows you to spray the necessary substance to poison the product with 98% accuracy, so it is possible to treat a specific section of the plant surface, this action reduces the use of chemicals and also harms the environment less.

Imagine how much easier the work is when, when using a drone, you receive information on where more fertilizer is needed or which row the plant needs more water. Timely information is the most important thing in the case of pests. Digital innovations, however, combine all of the above-mentioned details in one space, on one device. The use of drones also significantly reduces labor costs, preventing the waste of human resources, which allows the farmer to increase the efficiency of his business.

Those who are engaged in livestock farming can use a modern drone to inspect suitable pastures in advance, study their area of operation in advance, and even find out what type of grass is in the area, which will allow them to make the right analysis, determine the expected level of productivity of the step taken in advance, and respond immediately in case of a problem. Drones use sensors to take high-quality photos and videos, which helps farmers better understand environmental conditions. The use of drones by farmers in Georgia is still relatively new, although in recent years interest in this digital innovation in agriculture has increased significantly. In order to use a drone, a person must overcome infrastructural and technological barriers, and to collect high-quality information, a professional is needed who will simplify the use of the drone.

In different regions of Georgia, although not uniformly, they still use the above-mentioned innovation.

In the Mtskheta-Mtianeti-Agrarian Land region, drones are used to solve drainage and pest control tasks, in Guria and Adjara, they will be used to care for citrus and tea farms.

A modern innovation is also devices whose sensors are placed on the surface of the field, soil, they constantly monitor soil temperature, humidity, PH level and other environmental factors. A very interesting innovation is called smart greenhouses, in which farmers use Internet-connected systems that receive data on soil moisture, microclimate and other variable parameters and automatically control them according to a memorized standard. A great novelty is farming robots, which are equipped with artificial intelligence and sensors. They perform various tasks in agricultural activities, plant products, collect ready-made fruits, carry out maintenance of their movement area through loaded commands, take care of them, control pests, and eliminate them. These actions save substances and make treatment more accurate. The existence of high-level biotechnology and genetic research plays a major role in the development of the field. Genetic research contributes to the development of new types of seeds and plant varieties that are more durable and resistant to climate change and diseases.

The most important role in the development of the field is played by the continuous exchange of information, from one farmer to another, from one country to another. Contact, cooperation between specialists in the same field is the prerequisite for further success, the introduction and adoption of innovation. That is why it is very important that there are digital (online) platforms (agricultural platforms) that provide farmers with access to updated information and technological opportunities in order to improve and improve their production.

There are several farmers and agricultural companies in Georgia that work with modern standards and use digital technologies - innovations. A good example of the above is the Kakhetian wine producer, a large company. They are already using drones to monitor vineyards.

Despite the fact that there are many innovative examples in Georgia that demonstrate the advantages of adopting modern standards and using innovations, a large part of entrepreneurs are still cautious about introducing new technologies.

Whether farmers create innovative products themselves or implement existing technologies, the result is clear and one: an increase in agricultural productivity, incomes, and the country's economic development. Why do some entrepreneurs, in the same conditions, refrain? While others, on the contrary, are motivated to absorb, disseminate, implement, and develop innovations? In this case, studies have shown that people who have received a better education in the field, who are not afraid of risks, are economically stable, try to introduce innovations into production. Those farmers who refrain from introducing innovations work on the principle of following an example. According to this principle, a farmer who is less familiar with innovations in the agricultural sector sees that another farmer in his neighborhood has received the same product more easily with new technology, becomes interested in the novelty, and next year tries to follow the same practice himself. The use of new innovations reduces human labor, makes products healthier, and brings economic success.

For many years, people working on the land were dependent on environmental factors, and over time, they decided to create a favorable environment for the product they produce, artificially. It was the idea of creating this better environment that led people to the idea of creating a greenhouse. Greenhouse farming is becoming increasingly popular in Georgia, entrepreneurs have the opportunity to produce fruits and vegetables to meet both local and international demand. Greenhouse farming involves growing plants in a special, artificial, closed, technologically equipped environment, where temperature, light intensity, humidity, etc. are constantly controlled. This allows farmers to plan production and receive a stable, maximum income-oriented product. Another important innovation in the agricultural field is smart greenhouses. These are greenhouses equipped with sensors that provide the farmer with constant information about temperature, humidity, and soil pH. The system is designed so that if any plant in the rows needs specific help, this information will be sent to the farmer's device. Greenhouse farming has big advantages:

1. It leads to an increase in yield, since in this environment the entrepreneur is not dependent on climatic conditions; on the contrary, he knows exactly what temperature range to maintain, what time to water the product, etc.
2. It is also important that there is less damage to the environment, as less chemical fertilizers and pesticides are used.

The irrigation system in the greenhouse is very well-organized, using drip irrigation, in which case only the base of the plant is watered. This process saves both annual resources and eliminates excess water from entering the plant. Yields increase under these conditions.

The use of innovation is always accompanied by difficulties, and this is also the case with a smart greenhouse. For small farmers, this is a matter of luxury, sensory equipment requires high-tech work, which can be performed by workers in the field, and their remuneration is unfavorable for small farmers. The cost of electricity is also high, since the use of solar energy is reduced, which provides the plant with light and heat in normal field conditions. A high-tech greenhouse requires the awareness of the workforce, because they need to keep up with the innovation, and small entrepreneurs do not have the funds for all this. If we look at magazines that talk about innovations in agricultural technologies, we will see that high-tech greenhouses have great prospects, since the demand for organic and environmentally friendly products is growing in the world, and the growth of demand encourages farmers to make decisions and take high risks.

In Georgia, interest in smart greenhouses has arisen in the last few years, although this technological innovation is not widespread. The Georgian government is trying to promote modern technologies in agricultural production, for this purpose state programs are being created that help farmers with certain subsidies. However, such high-tech innovations are still less widespread.

There are greenhouses in our country that occupy leading positions, you can view them by production category on the online platform (see the address in the footnote). According to the information provided, "Herbia" produces environmentally friendly products in compliance with modern technologies and quality standards.

Significant innovative changes are underway in the field of nursery farming. The horticultural industry is undergoing a rapid transformation, which is caused by innovative solutions. Using digital tools, the maintenance of nursery products has become simpler, the product has become more sustainable and a prerequisite for economic progress for the entrepreneur. The use of drip irrigation systems and rainwater harvesting has played a significant role in the development of the sector. The use of solar panels, wind energy, has reduced the costs previously required for the existence of the product, which has led to a kind of encouragement for interested parties. 2024 nursery innovations are revolutionizing the horticultural industry. By using smart technologies, sustainable practices and advanced propagation techniques, we are moving towards a sector that can advance and meet the needs of the population, both in our own and in other countries.

Conclusion

Since 2015, Farmer's Day has been celebrated in Georgia every year on November 20. On this day, various events are held by the Ministry of Environmental Protection and Agriculture of Georgia, incentive awards for farmers, fairs are organized, and visitors have the opportunity to get acquainted with the products offered by our entrepreneurs on site. Various types of entertainment events are planned, Georgian traditional sweets, pastries, etc. are prepared on site.

While working on the topic, I learned a lot of interesting information, examples from various developed countries. I believe and believe that in our country, too, after a few years, while writing about the topic that I have proposed to you today, another person will tell you about how most Georgian farmers use drones, how people working in the livestock sector use satellite photos, will tell you about how Georgian entrepreneurs have caught up with trends already existing abroad, which have made their work easier, improved their harvest and economic situation.

A lot of trainings are held to inform farmers, both initiated by the Ministry of Agriculture, and organized with the support of various leading states. Georgians are very purposeful, the main thing is determination, everything is masterable. Information is available to anyone. I would like to wish success to people working in the field.

More high-tech enterprises in Georgia!

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Study of Bending of Rectangular Plates Considering the Action of Forces in the Midplane,

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Abstract

I want to show you how to calculate the forces acting at any point in the mid-plane of the slab and get a real number

The main part

Given a rectangular slab with both normal and shear forces in its midplane, the differential equation for slab bending changes due to the introduction of additional members.

Consider Fig. 1. where the normal and shear forces are denoted by T_(x), T_ (y) and S, and S, respectively, which is in the midplane of the slab.

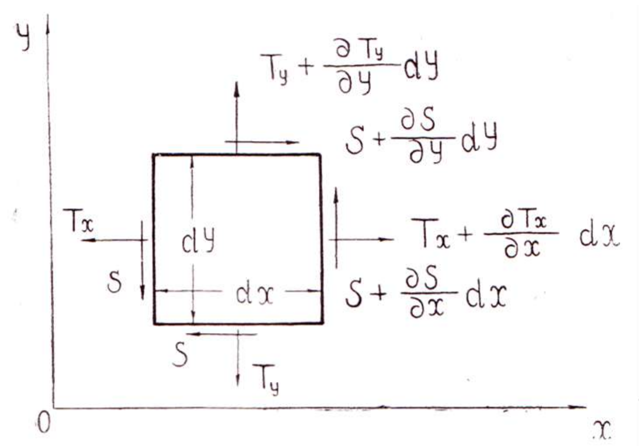

Fig. 1.

Let us consider the equilibrium conditions of an element separated from the slab.

The algebraic sum of the planes of the forces acting on the element along the x and y axes, respectively, looks like this:

$$-T_x dy + \left(T_x + \frac{\partial T_x}{\partial x}dx\right)dy - Sdx + \left(S + \frac{\partial S}{\partial y}\right)dx = \left(\frac{\partial T_x}{\partial x} + \frac{\partial S}{\partial y}\right)dxdy$$

$$-T_y dx + \left(T_y + \frac{\partial T_y}{\partial y}dy\right)dx - Sdy + \left(S + \frac{\partial S}{\partial x}\right)dy = \left(\frac{\partial T_y}{\partial y} + \frac{\partial S}{\partial x}\right)dxdy$$

Element equilibrium requires that:

$$\frac{\partial T_x}{\partial x} + \frac{\partial S}{\partial y} = 0 \ (1)$$
$$\frac{\partial T_x}{\partial y} + \frac{\partial S}{\partial x} = 0 \ (2)$$

To write the third equation, we need to determine what the planes of the forces acting on the element are equal to.

For example, $T_x dy + \left(T_x + \frac{\partial T_x}{\partial x}dx\right)dy$ The sum of the force planes on the z -axis will be: $-T_x dysinx + \left(T_x + \frac{\partial T_x}{\partial x}dx\right)dysin\left(a + \frac{\partial a}{\partial x}dx\right)$, What (2) Due to the smallness of the angle a shown in the fig. 2. $sina \approx tga \approx a \approx \frac{\partial \omega}{\partial x}$

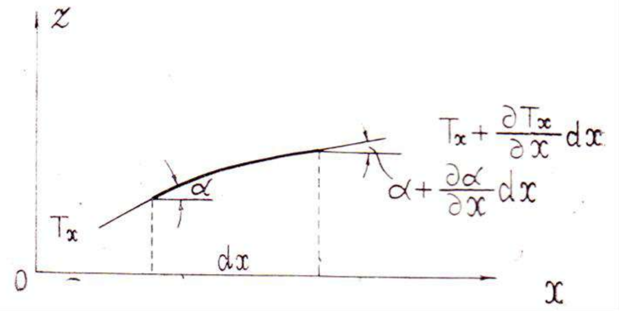

Fig. 2

The sum of the magnitudes of these forces after subtracting the higher-order small quantities will be:

$$-T_x dy\frac{\partial\omega}{\partial x} + \left(T_x + \frac{\partial T_x}{\partial x}dx\right)dy\left(\frac{\partial\omega}{\partial x} + \frac{\partial^2\omega}{\partial x^2}dx\right) = T_x\frac{\partial^2\omega}{\partial x^2}dxdy + \frac{\partial T_x}{\partial x}\cdot \frac{\partial\omega}{\partial x}dxdy$$

Similarly, we will have on the z - axis:

$$T_y\frac{\partial^2\omega}{\partial y^2}dxdy + \frac{\partial T_y}{\partial y}\cdot\frac{\partial\omega}{\partial y}dxdy$$

Let's determine from the Fig. 1. Sdy and $\left(S + \frac{\partial S}{\partial x}dx\right)dy$ plans of forces, Let us first consider the side near the y -axis and the shear force Sdy acting along it. One end is displaced by ω, and the other, and the second one$\left(\omega + \frac{\partial\omega}{\partial y}dy\right)$With , the angle of inclination with respect to the y axis is equal to $\frac{\partial\omega}{\partial y}$. The search for the shear force will be on the z-axis$-S\frac{\partial\omega}{\partial y}$ The opposite side of the element will be tilted at a different angle to the y axis $\left(\frac{\partial\omega}{\partial y} + \frac{\partial^2\omega}{\partial x\partial y}dx\right)$ With. On this page, the thrust force plot will be:

$$\left(S + \frac{\partial S}{\partial x}dx\right)dy\left(\frac{\partial\omega}{\partial y} + \frac{\partial^2\omega}{dxdy}dx\right)$$

The sum of the forces acting on both sides will be:

$$-Sdy\frac{\partial\omega}{\partial y} + \left(S + \frac{\partial S}{\partial y}dx\right)dy\left(\frac{\partial\omega}{\partial y} + \frac{\partial^2\omega}{\partial x\partial y}dx\right) = S\frac{\partial^2\omega}{\partial x\partial y}dxdy + \frac{\partial S}{\partial x}\cdot\frac{\partial\omega}{\partial y}dxdy$$

On the z -axis it will be:

$$S\frac{\partial^2\omega}{\partial x\partial y}dxdy + \frac{\partial S}{\partial y}\frac{\partial\omega}{\partial y}dxdy$$

Finally, if we add up the algebraic sum of all the plans and equalize it to zero, we get the third condition:

$$\frac{\partial N_x}{\partial x}+\frac{\partial N_y}{\partial y}+q+T_x\frac{\partial^2\omega}{\partial x^2}+T_y\frac{\partial^2\omega}{\partial y^2}+2S\frac{\partial^2\omega}{\partial x\partial y}+\left(\frac{\partial T_x}{\partial x}+\frac{\partial S}{\partial y}\right)\frac{\partial\omega}{\partial x}+$$
$$+\left(\frac{\partial T_y}{\partial y}+\frac{\partial S}{\partial x}\right)\frac{\partial\omega}{\partial x}=0 \qquad (3)$$

Where N_x and N_y there are transverse forces.

From the Fig. 1. And Fig. 2. the differential equation for slab bending will have the following form:

$$\frac{\partial^4\omega}{\partial x^4}+2\frac{\partial^4\omega}{\partial x^2\partial y^2}+\frac{\partial^4\omega}{\partial y^4}=2\frac{1}{D}\left(q+T_x\frac{\partial^2\omega}{\partial x^2}+T_y\frac{\partial^2\omega}{\partial y^2}+2S\frac{\partial^2\omega}{\partial x\partial y}\right) \qquad (4)$$

Consider the following example: Suppose we have a finitely supported rectangular slab that experiences a uniformly distributed transverse load and uniformly tensile forces T_x $[q(x,y)=-p,\ T_x=const,\ T_y=S=o]$.

We can represent a uniformly distributed transverse load as the following trigonometric series:

$$-\frac{16p}{\pi^2}\sum_{m=1,3,5,\dots}^{\infty}\sum_{n=1,3,5,\dots}^{\infty}\frac{1}{mn}sin\frac{m\pi x}{a}sin\frac{m\pi y}{b}$$

Then the differential equation of the bend will take the following form:

$$\frac{\partial^4\omega}{\partial x^4}+2\frac{\partial^4\omega}{\partial x^2\partial y^2}+\frac{\partial^4\omega}{\partial y^4}-\frac{T_x}{D}\frac{\partial^2\omega}{\partial x^2}=$$
$$-\frac{16p}{D\pi^2}\sum_{m=1,3,5,\dots}^{\infty}\sum_{n=1,3,5,\dots}^{\infty}\frac{1}{mn}sin\frac{m\pi x}{a}sin\frac{m\pi y}{b}$$

The analytical solution to this equation is:

$$\omega=\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}A_{mn}sin\frac{m\pi x}{a}sin\frac{m\pi y}{b}$$

Where A_{mn} is the unknown coefficient.

Plugging the bending representation into the differential equation for slab bending gives us:

$$A_{mn} = -\frac{16p}{D\pi^6 mn\left[\left(\frac{m^2}{a^2}+\frac{n^2}{b^2}\right)^2+\frac{T_x}{D}\frac{m^2}{\pi^2 a}\right]}, m, n = 1,3,5,\dots$$

Accordingly:

$$\omega = -\frac{16p}{\pi^2 D}\sum_{m=1,3,5\dots}^{\infty}\sum_{n=1,3,5\dots}^{\infty}\frac{1}{mn\left[\left(\frac{m^2}{a^2}+\frac{n^2}{b^2}\right)+\frac{T_x m^2}{\pi^2 D a^2}\right]}\times sin\frac{m\pi x}{a} sin\frac{n\pi y}{b}$$

In other words, tensile forces would cause a certain reduction in the deflection of the slab. Compressive forces would cause the opposite effect.

We have implemented a numerical solution to this problem on a computer. We have written a program in the “Mathematica” language, which has the form of a package.

The novelty is the slab calculation. I studied how the forces are calculated when they are in the middle plane using the computer program "Wolfram" in the form of a "package". The user can provide slab data and use this program to find the solution to the corresponding problem at any point on the slab.

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Innovative technologies of building skyscrapers, *Nikoloz Kobakhidze, Bachelor Program Student, nikolozkobaxidze23@gmail.com, Supervisor: Davit Bostanashvili, Associate Professor*

Abstract: The modern skyscraper is a symbol of technological progress and innovative engineering, humanity has been constantly striving to create stronger, taller and more beautiful buildings, although primitive materials did not allow it. The building principle was also simple and was mainly done by increasing the thickness of the wall, however, in the Gothic style, the masses were distributed with columns and arched structures, which allowed the architects to plan the space better.

Innovative technologies of building skyscrapers

Modern reality was still not enough for this, in sparsely populated areas, there was a need for tall buildings on a small area. Engineers believed that a building with too high a height simply could not withstand its own weight, and a new innovative way was needed to solve this task. This is how the iron frame appeared, it was first used for the construction of bridges and industrial buildings, but soon it became one of the most common means, for the first time it was used by the architect William Le Baron in Chicago, the new technology reduced the weight of the construction and at the same time increased its strength, What made it possible to build a very high skyscraper in a small area, the first skyscraper in Michigan is the Home Insurance Building, which laid the foundation for the construction of new tall buildings: the Eiffel Tower (300m), the Chrysler Building (319), the Empire State Building (381) and others. Man was reaching new heights that he could not even think about in the past. Iron soon replaced brick and became the main material of the industrial revolution.

The iron frame naturally blended with the Gothic style mentioned above and allowed to realize projects that were not completed at that time, for example The construction of the cathedrals of Ulm and Cologne, which took place with centuries-long pauses, was finally completed in this period (19th century). The combination of the iron frame and the Gothic arched structure resulted in miraculous strength and saved the Cologne Cathedral from bombing during World War II, as a result of which it still stands strong today.

Steel-bearing construction also allowed architects to use wider windows, or to completely clad the building in glass instead of brick walls, one of the first people to pioneer this approach was Ludwig Mies van der Rohe, who along with Philip Johnson designed The “Seagram Building”, which had a great influence on subsequent skyscrapers and on 20th century architecture in general, the use of glass and iron as the main materials in this project added many positive features to the building, it was as light as possible, energy efficient and full of light, despite the fact that this skyscraper is already 60 years old, its innovation is still relevant.

Along with maintaining its own weight and height, skyscrapers and engineers faced new obstacles, the structure of the building had to be adapted to the natural conditions and environment as much as possible, not only in terms of ecological cleanliness, but also in terms of safety, The height also created problems with the transportation of construction materials and general human movement, the pace of construction had to be high, and engineers also had to deal with the wind pressure that the skyscraper, Especially its high floors posed a special danger. Specialists gradually overcame these obstacles and conquered new heights.

When a tall building is being designed, of course it is necessary to be easy to move in it, a simple staircase could not meet this requirement, and the solution to this problem is obvious, an elevator, although the first elevators had one fatal flaw, If the rope broke, the person was doomed. Mechanic Elaisha Gsotis created a system that held the elevator, primitive but clever at the same time, a rope hung from a plate that moved on two iron toothed columns, If the rope breaks, the plate twists and grips the teeth, this invention made the elevator safe.

New Heights Needed New Speeds At the time of the World Trade Center, the details were made separately and easily fixed with a puzzle principle, but how can you move a steel structure weighing a ton at such a height, and as fast as possible? At first, the Dereth crane was used in this construction, as was the case with the Empire State Building, but it proved to be too slow a tool. Therefore, builders began to look for innovative technology, and they found it in Australia 4 new cranes were placed in the center of the building, they had a special function, when the 3rd floor was being built, the crane moved from the foundation and was fixed at a new height, because of this function, it was nicknamed "Kangaroo". Builders were building 2 floors a week and in 1970 the World Trade Center became the tallest building.

At the same time in 1970, the builders faced another obstacle, they were tasked with building a 100-story headquarters in Chicago, and this place is known for its winds, the iron frame at high altitudes posed a serious danger, at a height of 500 meters, the wind speed reached 80 km per hour, and the person on the upper floor experienced severe vibrations. To solve this problem, the builders changed the iron frame structure and connected it to the outer walls. To reduce the force of the wind, 9 such towers made Sears Towers as solid as a rock, and even in 90 km/h winds, the top floor of the building only tilts 15 centimeters.

For this obstacle, Norman Foster used a different method, but instead of a cuboidal shape, he created an oval building without each corner, as a result of such a decision, the wind bypasses the building and in this way casts less shadow than if it were rectangular. The project used a mesh shell frame inspired by Russian engineer Vladimir Shukhov, who was known for his designs, the building is also topped with a transparent dome and is as environmentally friendly as possible.

In addition to the above-mentioned obstacles, the skyscraper is always reminded of an earthquake, especially in seismically active areas, for example, the east coast of Asia, which is located in a complex natural cataclysmic belt, and tsunamis, if earthquakes are not a rarity there, Of course, it is necessary to design such a building, which will be calculated as much as possible for such conditions

For example, architects-engineers in Taiwan (China) took on a difficult and challenging task, they were tasked with the tallest building at that time, in an area of high land and hurricanes. The building had to be not too strong to withstand the pressure of the wind, but at the same time strong enough so that it would not be deformed, this puzzling task was mastered by the builders brilliantly. They chose to take their form from bamboo, known for its durability and flexibility. It also has properties that protect against wind pressure, so this decision carried not only an aesthetic and symbolic load, but also a functional one, the building is divided into 8 segments, which work as a separate structural unit and evenly distribute the load, As a result, vibrations are naturally dampened, such a shape also solves the aerodynamic problem and protects the building from the swaying of the winds. Overhangs are installed on the upper and lower edges of each segment, which act as shock absorbers and weaken the mechanical tension.

The building rests on 380 piles, which go 80 meters deep and rest on solid ground rocks, this foundation system has reduced the risk of ground collapse and uneven subsidence, the highest quality steel has been used for the strength of the frame, that allows it to withstand seismically active events up to 9 earthquakes, and the columns on each floor are joined by steel columns, which created maximum strength and stability.

Against the wind and vibrations, the engineers also made the following decision, between the 87th and 92nd units, they installed a massive steel core, the mass of which is 660 tons, during the oscillation of the building, it moves in the opposite direction and maintains stability.

The project had not yet been completed when the 6-point earthquake in Taiwan caused many buildings to collapse and the cranes of Taipei 101 collapsed, but the framework of the yet-to-be-built building was not damaged, which was already an indication of success.

Not all architects strive for height, and try to find and create something else in the skyscraper, for example CCTV headquarters designer Rem Koolhaas took a different approach, instead of building a record-tall building he decided to build a shape similar to a Moebius ribbon and merged the leaning towers into the sky, thus obtaining a unique result. The innovative structure of the building is the result of long-term cooperation between European and Chinese engineers, the facade shows what forces the building relies on: a network of triangular iron tubes, diagrams that create a different image of rhombuses, But at moments it thickens or thins depending on the building load, the self-supporting hybrid facade construction is equipped with high-efficiency glass panels with a solar protection layer and ceramic frit, which creates a soft silvery gray color.

In 2010, Typer 101 lost its status as the tallest building and was replaced by Burj Khalifa. This project was not without obstacles and difficulties, engineers had to build a miracle in the middle of the desert, but the achievements of Taiwanese colleagues made it relatively easy. For example, the properties of the foundation and frame were used in the same way with minor adjustments, but this time the natural conditions created new obstacles. For example, the sun, more specifically the heat caused by it, In the heat, in a place where the temperature reaches 40 degrees even in the shade, cooling systems are necessary for living, however, for a building with such a large area, additional methods were necessary. To avoid the harmful effects of the sun, the builders made a small silver and steel coating on the glass, which did not let ultraviolet rays into the building, in the end, 30 thousand such glass panels were used in Burj Khalifa.

Wind and sandstorms were also a problem, as we mentioned before, the skyscraper experiences violent oscillations towards the top, because at such a height the wind can develop a speed of 60 to 90 kilometers. to solve this problem, the architects again turned to nature and tried to deceive the wind flow. The building repeats the shape of a flower, it is often compared to a stalactite. This form allows the light to reach the building as much as possible, and also the sudden forms of the facade prevent the formation of storms. Burj Khalifa and the lower 70% with a concrete core, and the rest of the upper part already consists of an iron structure, As concrete cannot withstand excessive vibration and damage would be inevitable, the upper steel frame can withstand up to a meter and a half of oscillations, while also allowing the building to be thinner without losing strength.

Such a height, as well as lifting the concrete was a separate task, in such a hot climate, even using the most powerful equipment, the concrete would harden on the way. For this, a special type of c-50 and c-80 was used while mixing it with ice, the procedure was only at night because of the temperature.

Burj Khalifa still maintains the status of the tallest building, although, of course, many will try and try to surpass this record, there are already projects that aim for new heights, for example Jeddah Tower, whose height should be equal to 1 kilometer, its construction is led by the same people who built the Burj Khalifa, in the same Dubai is also planned to build a new record holder Dubai Greek Tower will compete with Jeddah Tower for the status of the tallest building of the future. Its height is not specified, but it will be between 900 and 1000 meters, this structure can be considered more of a monument than a full-fledged building, although it highlights the thinking and craftsmanship of Dubai engineering.

Construction on the aforementioned projects has begun, but has been halted due to financial reasons, and there are other ideas that are more of a concept at this point, but I believe are still worthy of attention. For example, the sky mile building, which is planned in Japan and represents a city within a city, this futuristic project is planned for 2045, it should be built on water and solve the problem of the population, the main tower of the building consists of a hexagon, which is periodically divided into three axes, which It should lead to structural stability, and the remaining open spaces in the building are left to solve the wind problem, since such a large skyscraper actually plays the role of a sail, these spaces should channel the wind flow and thereby reduce its pressure. At this point, this project is just a concept and only time will tell if it can be implemented.

Skyscrapers have come a long way to get what they are today, and surprisingly, this is not the peak of progress, and as we mentioned in the future project, humanity continues to strive for new heights. which may be accompanied by new obstacles, but there is no unsolvable problem with progress.

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Study of the Possibilities of Capturing and Reusing Exhaust/Flue Gases to Prevent Climate Change on the Example of the Cement Industry,

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Abstract

Generation during the production process and emissions into the atmosphere with exhaust/flue gases (CO2,SOx,NOx) cause the "greenhouse effect" and the problem of global climate change. The cement industry accounts for 6-8% of CO_2 emissions into the atmosphere worldwide.

The paper considers the efficiency of the technological method developed at the Georgian Technical University for capturing and reusing exhaust gases (CO_2, SOx, NOx) from cement industry using local zeolite tuff (clinoptilolite). When exhaust/flue gases pass through a layer of zeolite tuff, a drying-sorption process occurs, during which zeolite tuff captures up to 20% of emissions, namely: in the process of chemisorption of dust particles containing CaO/CaCO3 and in the process of adsorption of CO_2, SOx, NOx. As a result of this process, zeolite tuff acquires new properties - modification. When zeolite tuff modified by cement production emissions is added to the finished product (cement), the compressive strength of concrete increases by about 30%.

Introduction

Global climate change is the greatest challenge facing humanity in the XXI century, and finding ways to prevent it is also a serious challenge and a practical task that must be addressed as a matter of priority.

Accordingly, climate change is one of the most important challenges to sustainable development, with long-term consequences. Global climate change is reflected in the increase in average global temperature. Studies show that the Earth's climate has changed, and most likely, this is due to an increase in the concentration of heat gases in the lower layers of the atmosphere, which is largely due to the intensive consumption of fossil fuels. The in-depth change of the components of the Earth's climatic system is caused by the uninterrupted emissions of heat gases. Analysis of the effects of global climate change shows that rising average temperatures and changes in forecasts in western Georgia since the end of the last century have had some impact on the forest ecosystem. The intensity of forest fires and the spread of pests have increased in eastern Georgia, against the background of heat waves and especially hot days. One of the most negative impacts of climate change is the increase in drought, the depletion of water resources and land degradation. The effects of climate change in Georgia are particularly acute in the agricultural, health, energy and economic sectors. Consequently, climate change is a threat to the sustainable development of the country. The main challenges of climate change policy in Georgia are reducing heat gas emissions, increasing the country's adaptive capacity and developing a transparent reporting system [4].

The cement industry is responsible for 6-8% of global CO_2 emissions into the atmosphere [2,5,7], because at least 0.64 tons of CO_2 are emitted from 1.6-1.8 tons of raw materials used to produce 1 ton of cement. CO_2 is irretrievably emitted into the atmosphere with hot exhauses gases from the clinker kiln (50-400 0C), which is a technological loss, and also worsens the material balance of the enterprise and increases the cost of the cement/clinker. Along with exhaust gases, in addition to CO_2, SOx (1.15–9.18 kg/kg of cement) and NOx (0.285–1.14 kg/kg of cement) are emitted into the atmosphere [6], which contribute to the formation of “acid rain”. Currently, there is no global problem of preventing sulfur and nitrogen emissions, but they are necessary compounds for modifying cement and concrete (sulfitation and nitrification of the contained minerals).

Recently, at least 4 billion tons of cement are producing in the world which have been leading to emissions into the atmosphere: 4 x 0.64 = 2.56 billion tons of CO_2; 0.037 billion tons of SOx; 0.04 billion tons of NOx (1.92 million tons of CO_2, 0.03 million tons of SOx and 0.003 million tons of NOx are emitted from the production of 3 million tons of cement in Georgia). In addition to the fact that these emissions harm the environment, they also cause large and irreversible financial loss to the cement industry.

The aim of our study is to assess the ways to mitigate this problem based on the approaches developed at the Georgian Technical University, which include reducing irreversible emissions of cement production exhaust/flue gases (CO2, SOx, NOx) into the atmosphere and their purposefully utilization in the composition of cement/concrete. To implement the above, the conducted study proposes to use the thermal and sorption properties of zeolite tuff containing the mineral clinoptilolite taking into account its known thermal transformations and sorption properties (its reserves in Georgia exceed 300.0 million tons, and the market value is less than $ 15.0 / ton) [1].

Methodology and Experimental Part

The work uses the method developed at the Georgian Technical University [3], namely, using a laboratory prototype of the drying-adsorption hybrid apparatus LPPA to study the sorption of exhaust gases (CO_2, SOx, NOx) on thermal modified zeolite tuff and the production of cements and concretes based on zeolite tuff modified by CO_2, SOx and NOx formed in exhaust gases.

At the first stage of the research, the briquettes for producing clinker have been prepared in our laboratory by mixing limestone and clay, with added water, briquetting and drying. The content of $CaCO_3$ in the resulting mixture is 80% and humidity - 20%. At the second stage of the research, natural zeolite containing clinoptilolite from the local Dzegvi deposit was processed, namely: the raw material was ground using a laboratory mill to a fraction size of 3-8 mm and dried/dehydrated in a laboratory furnace at a temperature of 300±20°C.

The main component of cement - clinker - was burned at temperatures below 1450 ± 50°C using the furnace (1) of the hybrid drying-adsorption apparatus "LPPA", which is equipped with a briquette loader (2). During the synthesis of clinker from the prepared briquettes at a temperature of about 1400°C, exhaust gases (8) (CO2, SOx, NOx) with a temperature of 150 - 350°C are formed, which enter the LPPA drying absorbtion node (4) through the smoke pipe (3) into a cartridge filled with zeolite tuff (5), the rotation of the cartridge is provided by the engine (6). Through the adsorption unit, the combustion products enter the chimney and then into the atmosphere.

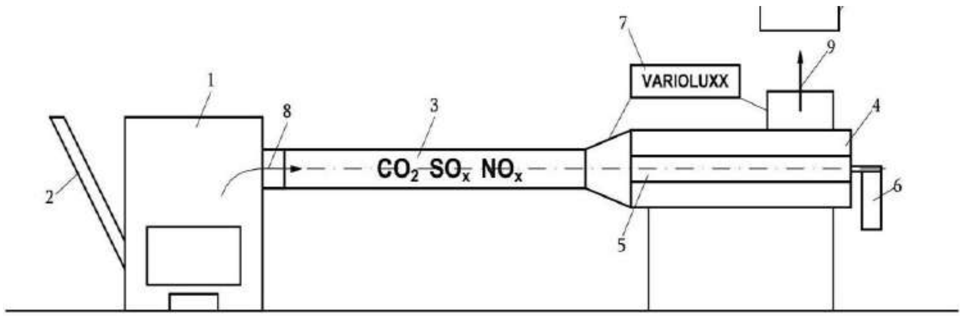

Fig. 1. Laboratory prototype of a production apparatus LPPA
1.Shaft furnace; 2. Briquette loader; 3. Smoke pipe; 4. Drying absorption node; 5. Rotating cartridge; 6. Engine; 7. Gas analyzer “VARIOLUXX”; 8. Exhaust/Flue gases with CO2; 9. Purified flue gas.

Results and Discussion

From the clinker burning side through the pipeline, exhaust/flue gases are fed in a direct-flow mode through a cartridge of 3-8 mm fraction zeolite tuff, and accordingly modify it by sorption (while maintaining a temperature of 50 ± 5°C, moving at a speed of 1-3 m/s). The number of revolutions of the cartridge was 12 rpm, and the duration of contact of the zeolite tuff with gases was 8–10min. The results of exhaust/flue gases emissions during cement production under laboratory conditions using a laboratory prototype of a drying-adsorption hybrid apparatus without a sorbent (zeolite tuff) and with it are presented in the table, from which it follows that up to about 20% of exhaust/flue gases are captured using this method (Table 1).

Table 1: Exhaust/flue gas composition without sorbent and with sorbent during cement/clinker production under laboratory conditions %

Indicators	Without sorbent	With sorbent	Sorption %
CO_2	32.7	13.1	19.6
SOx	0.9	0.7	0.2
NOx	0.3	0.2	0.1
Total	33.9	14.0	19.9

It is noteworthy that when adding heat-treated but unmodified and therefore inactivated zeolite tuff to cement, the surface of concrete products made from it cracks. The technical result of the method we use is the activation of tuff by modification with CO_2, SOx and NOx contained in flue gases, which allows increasing the intensity and strength of cement hardening, as well as preventing cracking of the surface of concrete structures (Figure 2). Figure 2 shows that adding 20% of our modified zeolite to cement increases the compressive strength of concrete by about 30% after 7 days.

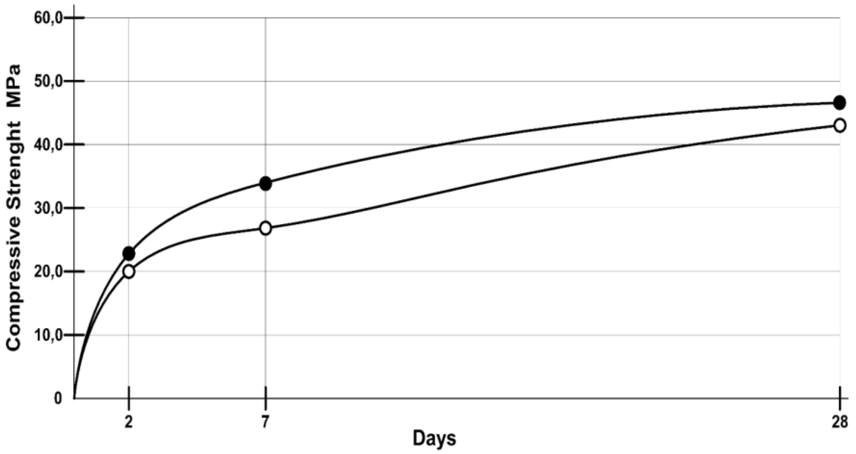

Fig.2: CEM II/A-P 42.5 Change of cement strength

○ 20% Zeolite tuff
● 20% Zeolite tuff + CO_2

Conclusions

The method of capturing exhaust/flue gases emitted during cement production, developed at the Georgian Technical University, is characterized by environmental and economic efficiency. It includes capturing up to 20% of harmful emissions with zeolite tuff and including flue gas-modified zeolite tuff in the composition of finished products (cement). This provides an increase in concrete strength by 30%.

The use of this technological method will reduce the cost of 1 ton of cement by 1.75 USD, and the amount of cement containing modified zeolite tuff in 1 m^3 of concrete is expected to decrease by 0.05 tons, which will reduce the cost of concrete by 2.41 USD.

In addition, the method will contribute to sustainable production with minimal losses and the implementation of state requirements for mitigating the effects of climate change.

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Building Tomorrow: Innovative Materials Shaping the Future of Construction,

Salome Kushashvili, Bachelor Program:Student, salomqush@gmail.com , Supervisor: Elina Kristesiashvili, Professor, e.kristesiashvili@gtu.ge

Abstract: This presentation encompasses some of the most game-changing materials in modern construction. It outlines developments concerning transparent aluminum, aerogel insulation, graphene-enhanced concrete, and other innovative materials that will change the way we build. These materials can improve durability, sustainability, and efficiency and thus pave the way for more intelligent and greener construction.

Keywords: Construction, Innovative Materials, Transparent Aluminum, Aerogel Insulation, Graphene-Enhanced Concrete, Sustainability, Smart Construction, Future of Construction, Revolutionary Materials.

1. Introduction

The construction industry has always been one of the core elements of human progress and has further evolved with every step taken towards technological advancement. As of today, we are at the doorsteps of an era wherein innovative materials, besides redefining how we construct, come forward as a silver lining that will help overcome critical challenges pertaining to sustainability, durability, and efficiency. These materials aren't any concepts of the future; they are here, transforming the industry, and redefining possibilities. This presentation encompasses some of the most exciting materials that are going to shape the future of construction, each with unique features and applications that promise to revolutionize our built environment.

2. Innovative Materials Shaping the Future

Transparent Aluminum Aluminum Oxynitride Amazing material, this is almost like glass, but way stronger. Manufactured with ceramic, the material is strong and translucent (pic.1.).

- What can make it special?
- Strong as steel and lightweight.
- It doesn't scratch and lasts long.

Pic.1. Aluminum Aluminum Oxynitride

Keeps heat out, thus it's great for insulation. Where can it be used?

- High-security windows, like banks or labs.
- Modern-looking buildings with smart designs.

Why it matters: It makes buildings safer, saves energy, and looks futuristic!

AerogelInsulation. Nicknamed "frozen smoke" due to its incredibly light mass, this material is perfectly used for insulation against heating and for keeping heat in (pic.2.).

What's great about it?

- Very little heat passes through it.
- It doesn't burn and it's good for the planet.

- Saves energy consumption in buildings.

Where can it be used?

- Houses that need less heating or cooling.
- Factories and pipes, wherein insulation plays a big role.

Why it matters: Turns buildings into energy-efficient ones and thus saves money and the environment.

pic.2. AerogelInsulation.

Graphene-Enhanced Concrete. This is concrete 2.0. Adding graphene to it makes it stronger and greener (pic.3.).

pic.3. Graphene-Enhanced Concrete

How is it better?

- As a result of less need for cement, there would be less pollution.

- It would last more and can also conduct electricity.

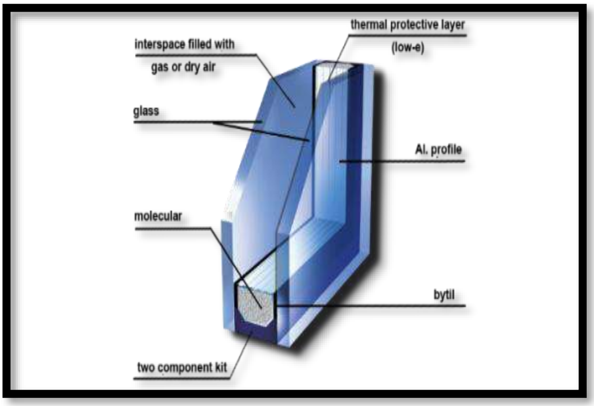
Applications:

- Big projects are those on bridges and skyscrapers.
- Smart infrastructure is required nowadays in cities.

Why it's important: Being green and sustainable, changes the face of construction forever.

Smart Glass:_This glass is super high-tech because it changes transparency with light or heat. (pic.4.).

Pic.4. Smart Glass



What's smart about it?

- Saves energy by cutting down on lighting and cooling.
- Can turn non-transparent for privacy at the push of a button.
- Where is it used?
- Windows in office buildings and smart homes.
- Modern skyscrapers.

Why it matters: Stylish and energy-efficient for a truly futuristic design.

Carbon-Fiber Reinforced Polymers (CFRP): This is a light yet super-strong, weatherproof material. (pic.5.)

Pic.5. Carbon-Fiber Reinforced Polymers (CFRP)

What are its strengths?

- Doesn't rust or get damaged in bad weather.
- Stronger than steel yet much lighter.

Where is it used?

- Supporting bridges and wind turbines.
- Architectural projects that need strength and flexibility.

Why it matters: It lasts longer, and its maintenance is cheaper.

Bioplastics and Bio-Concrete: These are manufactured from renewable feedstocks and, therefore, offer a friendly environmental profile. (pic.6.).

What's great about them?

- They degrade naturally, hence no waste.
- Equally strong as regular construction material

Where can they be used?

- Insulation, tiles, or even temporary structure construction.

Why it matters: It protects the environment with no loss in strength.

Light-Generating Cement: This cement absorbs sunlight during the day and glows at night.

What's special about it?

• It stores energy from the sun and then emits light.

• Its durability is assured, it's eco-friendly.

Where is it applied?

• On the roads, pathways, or even in buildings for decoration purposes.

Why it matters: It reduces electric lighting needs while looking amazing.

Pic.6. Bioplastics and Bio-Concrete

3. Conclusion

Innovative materials lead the future of construction in all ways. The development of revolutionary materials such as transparent aluminum, aerogel insulation, and graphene-enhanced concrete is not only improving construction practices but also tackling global challenges like sustainability and energy efficiency. These innovations are underlining the commitment of the industry to build smarter, greener, and stronger. We are not only redefining the built environment by embracing these innovations but also paving the way for a more sustainable future.

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Wood and Plastic in Future Construction Technologies, Davit Maisuradze, Bachelor Program Student, Supervisor: Giorgi Maisuradze

Abstract

This paper addresses the significance of the combined use of wood and plastic in the modern construction industry. The author discusses the ecological sustainability, energy efficiency, and structural strength of these materials, as well as the advantages and challenges of their combination. The paper highlights innovative technologies that support the integration of wood and plastic, enhancing their efficiency of use. Special attention is given to the role of composite materials that combine the natural properties of wood with the durability of plastic, securing a significant place for them in future construction technologies.

Introduction

The modern construction industry is undergoing remarkable transformations, where new materials and innovative technologies play a pivotal role in the fields of sustainability, energy efficiency, and ecology. Two materials that are gradually assuming key roles in future construction are wood and plastic. Both materials possess unique properties and advantages that, when combined, open new opportunities for architecture and construction processes.

Wood, as a natural resource, is gaining popularity due to its ecological and sustainable nature, while plastic, with its flexibility and durability, creates highly efficient construction materials. Their combination not only enhances the structural and functional properties of each material but also enables fast and cost-effective installation, significantly improving energy efficiency.

This paper aims to explore the combined use of wood and plastic in the future construction industry, their advantages and challenges, as well as the technologies that support the integration of these materials into modern construction.

Sustainability of Wood and Plastic Combinations

The sustainability of wood and plastic combinations depends on several factors, including the type of materials used, their environmental impact assessment, and recyclability. Combined wood and plastic materials, sometimes referred to as composites, can, in certain cases, be highly sustainable. However, the use and production of these materials require the implementation of environmental strategies.

Strength and Durability of Wood and Plastic Combinations

Wood, as a natural material, is biodegradable and recyclable, making it more environmentally friendly. Its use relies on renewable resources, which increases sustainability.

The Role of Plastic: Incorporating plastic with wood enhances the material's mechanical properties, increasing its durability against moisture, temperature fluctuations, and mechanical damage. However, plastic waste is non-biodegradable and may persist in the environment for several decades.

Impact of Plastic and Wood Combinations on Thermal and Mechanical Stability

The inclusion of plastic in wood materials enhances their durability.

Composites remain intact for longer periods, especially under external conditions (e.g., rain, heat, freezing). This makes them more resilient and long-lasting compared to wood alone.

It is also noteworthy that the combined use of wood and plastic creates materials that are relatively lightweight yet very strong. This means that such structures can be manufactured more efficiently and quickly, ensuring cost savings during construction.

Innovative Composite Materials

The combination of wood and plastic often results in the production of composite materials that integrate wood fibers with plastic polymers. Such materials are frequently used as structural components because they are stronger and more durable under various conditions compared to using a single material.

Wood-based composite materials, such as OSB (Oriented Strand Board), MDF, plywood, and others, are often used as parts of lightweight structures. These materials uniquely combine the natural properties of wood (durability, lightness, sustainability) with modern technologies that enhance their mechanical properties. Their use in lightweight structures allows for designs that are both lightweight and strong.

Wood composite materials are often lightweight, reducing the overall weight of lightweight constructions and improving their efficiency. In structures requiring high strength and low weight, composite materials perform ideally. For example, composite lightweight panels that retain the enhanced natural properties of wood provide high density with reduced weight. Wood composite materials used in lightweight structures ensure a high level of structural durability. Such materials are often resistant not only to impact but also to other types of loads, making them particularly effective in lightweight structures.

Electronic Integration

The combination of plastic with modern electronic technologies, such as sensors and artificial intelligence, further enhances the combined use of wood and plastic. These technologies will enable buildings to respond to environmental conditions, optimize control systems, and save energy.

Challenges and Prospects

The combined use of wood and plastic is not a simple process, as both materials have their challenges. Wood can be easily damaged by water and pests, while plastic can harm the environment if not properly recycled. However, modern technologies, such as recycled plastics and new types of wood, minimize these problems.

Despite the challenges, the combined use of wood and plastic remains promising as it ensures sustainability, energy efficiency, and cost-effectiveness—key necessities in the construction industry. Their combination may become a cornerstone of future construction technologies.

Wood and plastic, despite their differing natural and chemical properties, create extraordinary opportunities for future construction technologies through combined use. Their synergy not only increases the structural durability and energy efficiency of constructions but also promotes ecological sustainability, as both materials can have minimal environmental impact if properly processed and recycled.

The future construction industry is clearly heading toward a direction where the combination of natural and synthetic materials will play a leading role. Wood and plastic, with their unique properties, offer the potential for more efficient, faster, and sustainable construction processes. Their use enables not only the creation of economical and optimized constructions but also the reduction of environmental pollution and energy costs in the future.

The potential of wood and plastic as one of the main and innovative directions in future construction technologies is evident. Moreover, the application of these materials will expand further, helping the industry move to a new stage of development where long-term sustainability and ecological care will remain top priorities.

Conclusion on "Wood and Plastic in Future Construction Technologies"

In future construction technologies, wood and plastic can become complementary materials to create sustainable, environmentally friendly, and efficient construction structures. Wood, as a natural and renewable resource, is already widely used in construction; however, its use needs to be more extensive and refined to maximize its durability and ecological advantages. Plastic, which is more associated with thermoplastics and composite materials, can be utilized in various innovative forms, both as structural elements and for small details.

The combination of these two materials ensures both the natural beauty and ecological nature of wood and the durability and versatility of plastic. In their combined forms, such as in composite materials, they can retain high mechanical properties while significantly reducing environmental impact in terms of resource consumption and waste management.

Key future directions include the integration of their use in composite materials, allowing for the creation of more durable and sustainable constructions. Furthermore, it should be noted that reducing the harmful effects associated with plastics through technological innovations, such as the use of bioplastics, will significantly improve their ecological footprint. Thus, wood and plastic in future construction technologies may become among the most important strategic materials, contributing not only to increased energy efficiency but also to the sustainable use of natural resources.

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The main risk factors of hazards in construction, Tengiz Maghlaferidze, Doctoral Program Student, Supervisor: Nana Razmadze, Assosiate Professor

Abstract

This article contains general safety matters. It discusses statistical data of accidents, international labor organization data and available data of Georgia.

Prevention of anticipated risks and accidents at the workplace has become an unsolved problem in the later years. Persons employed for heavy, harmful and hazardous work with increased risk are one of the most unprotected groups in Georgia.

Despite the adoption of the law on labor safety and development of monitoring tools, human life and health is risked almost every day at dangerous workplaces. The number of people who have died or have been injured due to occupational injuries is alarming.

In construction, the risk factors are categorized as follows: physical risk factors (F); accident risk factors (T); ergonomic risk factors (E); chemical risk factors (K); biological risk factors (B); psychological risk factors (H).

Among these, physical risk factors are the most common in construction, leading to severe injuries and fatalities among workers.

This article theoretically discusses and visually presents the sequence of risk and hazard identification, as well as the planning of human work, where safety occupies the most important first step.

The work of construction workers is associated with various types of risks and is characterized by different forms of injuries (see Fig. 1). The high level of injuries is influenced by specific features of the construction industry that distinguish it from other parts of the production sector. These features include the following:

- A large share of small firms and self-employed individuals;
- The wide variety of construction sites and their relatively short lifespan;
- High turnover of the workforce;
- A significant number of seasonal and migrant workers, most of whom are unfamiliar with construction processes;
- Vulnerability to the impact of weather conditions;
- The presence of a wide range of tasks and specialties in construction work.

Moreover, individuals employed in this sector often suffer from various occupational diseases.

It is interesting to review statistical data from developed economies. According to 2021 data, 4,609 fatal accidents were recorded in the United States. Of these, 3% were caused by being struck by objects; 9% by electrical current; 10% by falling objects; 35% by workers falling from heights; and other incidents accounted for 43%.

This statistic indicates that falling from heights is the leading cause of worker fatalities in construction. Even in a developed country like the United States, where construction and installation work safety is regulated at the legislative level (with heavy fines and other forms of liability), the percentage of fatalities due to falls from heights still reaches 35%.

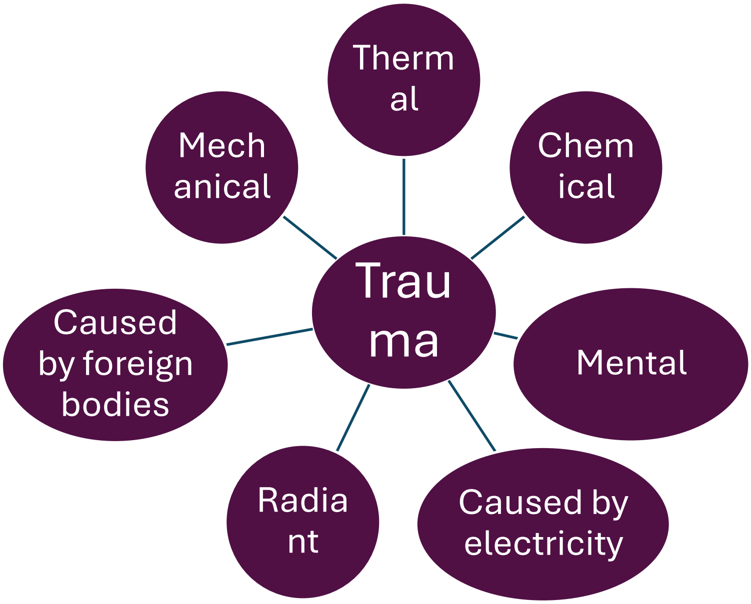

Fig. 1. Types of injuries common in construction

In developing countries with weak democracies, where neither the legislative framework is well-established nor workplace technical safety issues are addressed (such as properly installed scaffolding, safety nets, harnesses, etc.), construction and installation work is associated with high risks, characterized by a high rate of injuries, and often results in fatalities.

Along with injuries, the undesirable sanitary and hygienic conditions should be considered, which are manifested in the presence of dust in the air, soil, and sewage systems, as well as the presence of fuel materials, paints, and their solvents. All of this affects not only the workers directly, leading to occupational diseases, but also impacts on all of us, the entire biosphere, causing significant ecological damage, which could potentially escalate into a global catastrophe.

Types of Risk Factors in Construction.

Risk factors in construction are of the following types:

- Physical risk factors (F);
- Accident risk factors (T);
- Ergonomic risk factors (E);
- Chemical risk factors (K);
- Biological risk factors (B);
- Psychological risk factors (H).

Physical (F) risk factors include:

F 1. Constant noise ; F 2. Impulse noise ; F 3. Air temperature; F 4. Exhaust ventilation; F 5. Crosswind; F 6. Hot and cold objects; F 7. Working in open spaces; F 8. General lighting; F 9. Local lighting; F 10. Emergency lighting; F 11. External lighting; F 12-13. Vibration; F 14. Ionizing radiation; F 15. Ultraviolet radiation; F 16. Laser radiation; F 17. Infrared radiation; F 18. Electromagnetic fields.

Eliminating physical hazards is the most effective and cost-efficient measure for improving the work environment.

Accident risk factors (T) include:

T 1. Risk of slipping; T 2. Risk of tripping; T 3. Falling from heights, inclines, and declines; T 4. Crowded spaces between objects; T 5. Risk of being trapped in a confined space; T 6. Electrical equipment, static electricity; T 7. Transporting loads and other movements; T 8. Oxygen deficiency or lack of oxygen; T 9. Risk of falling into water; T 10-16. Risks from falling objects; T 17. Absence of personal and collective protective equipment; T 18. Hazardous work and risks; T 19. Special situations and defects; T 20. Alcohol and drug consumption; T 21. Deficiencies in signaling and rescue operations; T 22. Deficiencies in first aid systems.

Ergonomic risk factors (E) include:

E 1. Cleanliness and order at the workplace; E 2. Pathways and evacuation route and exits; E 3. Stairs, ladders (folding ladders), and ramps; E 4. Height of the work surface; E 5. Seating arrangements; E 6. Screens and monitors; E 7. Back posture; E 8. Hand posture; E 9. Wrist and finger posture; E 10. Head and neck posture; E 11. Leg posture; E 12. Constantly standing and sitting positions; E 13. Work rhythm and breaks; E 14. Repetitive movements; E 15. Lifting weight, transporting loads; E 16. Tools, machinery, and equipment; E 17. Processed parts; E 18. Auxiliary equipment; E 19. Volume of the workspace; E 20. Ability to change work positions.

Chemical risk factors (K) include:

K 1. Hazardous and harmful chemicals; K 2. Carcinogenic substances; K 3. Allergens; K 4. Flammable and explosive substances; K 5. Dust and fibrous minerals; K 6. Harmful gases; K 7. Vapors, aerosol condensates, and smoke; K 8. Labeling of chemical substances on packaging; K 9. Safety data for chemical substance usage; K 10. Information on the use of chemical substances; K 11. Storage of substances; K 12. Expired chemical substances; K 13. Proper functioning and use of protective equipment; K 14. Proper functioning of first aid equipment; K 15. Proper functioning and use of electrical equipment; K 16. Permits for fire-related work; K 17. Fire extinguishers and related labels; K 18. Evacuation routes and their labeling.

Psychological risk factors (H) include:

H 1. Repetitive monotonous work; H 2. Working alone and night shifts; H 3. Prolonged wakefulness; H 4. Forced work rhythm; H 5. Tension in human relations; H 6. Work speed; H 7. Excessively strict demands or goals; H 8. Lack of professional growth prospects; H 9. Familiarization with work and instructions; H 10. Work stages, descriptions of tasks and responsibilities; H 11. Work hours, overtime, shift work; H 12. Unreliable labor relations; H 13. Deficiencies in work or organizational management; H 14. Unhealthy work atmosphere; H 15. Lack of information; H 16. Risk of violence; H 17. Non-professional forms of communication; H 18. Lack of social support; H 19. Lack of influence opportunities.

As for biological hazards (B), these can include mold, mildew, bites from insects and reptiles, infections, and others.

The determination of work-related hazards and the sequence of risk assessments are shown in Figure 2.

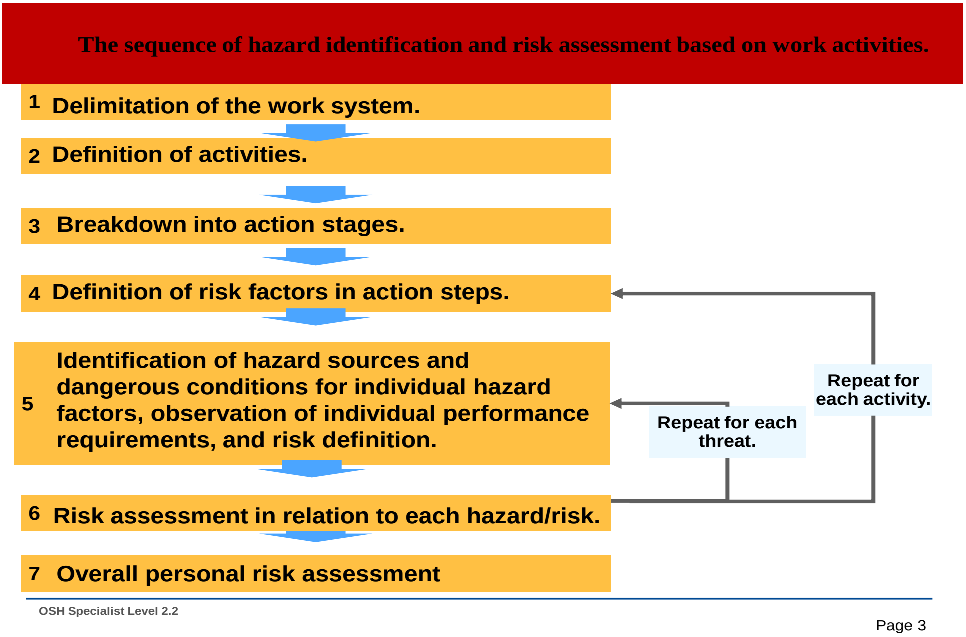

Fig. 2.

Sequence of hazard and risk assessment.

The planning of people's work can be represented in the following schematic "ladder" form (see Fig. 3).

Fig. 3 .

Work planning

As shown in the diagram, the foundational step of the "ladder" is workplace safety, followed by task execution, reasonable workload, employee satisfaction, social compatibility of the job, and worker involvement in the planning process.

Despite the use of new and modern technologies, many heavy tasks are still performed manually. Outdated tools, machinery, and equipment are often used, which lack good design, and their operation is accompanied by poor technical maintenance. Many workers on construction sites lack the necessary experience. It is common for heavy loads to be carried up and down stairs, scaffolding, and platforms. People working on construction sites often suffer from back pain, as well as joint and muscle injuries.

Construction sites often involve tasks where workers experience heavy static loads. When wall and ceiling finishing, painting, and electrical wiring installation are being carried out, workers frequently have their arms raised above shoulder height. In such cases, it is advisable to frequently change work positions.

Being in an uncomfortable working position leads to prolonged working hours and fatigue. For example, performing tasks where the arms are raised above the head quickly leads to shoulder fatigue. If, in addition, bending or twisting is required, the back muscles may become strained. An awkward work posture becomes a cause of the gradual increase in the time required to perform tasks and increases the likelihood of injury, as well as damage to property or equipment.

Each year, there are severe accidents, including fatal ones, due to workers entering confined spaces without prior inspection or proper protective and rescue equipment. Quite often, an attempt to assist and rescue a person ends in tragedy, where both the injured and the inadequately equipped rescuer lose their lives. A clear example of a confined space is a room with a narrow exit. This category can also include open pits and observation wells, sewer collectors, trenches, pipelines, ducts, closed basements, and other places with inadequate ventilation.

A dangerous air environment can be created in the presence of oxygen deficiency and toxic or poisonous gases. Such an environment may result from exhaust gases from equipment and vehicles, the production of carbon dioxide gas in calcareous soil, the decay of sediment in sewer collectors, gas leaks from pipelines, corrosion of metal structures, and the presence of various waste materials and gasoline in industrial and commercial enterprises. Work conducted in confined spaces may render the space hazardous. For example, certain types of painting work, floor tile installation using special adhesives, and the use of detergents and solvents can contribute to this risk.

Many of these accidents could have been prevented if the work supervisors and workers had received proper training and if an effective entry and access control system for the work areas had been in place.

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New Construction Standards: Eurocodes and Their Impact on Georgia's Infrastructure Development,

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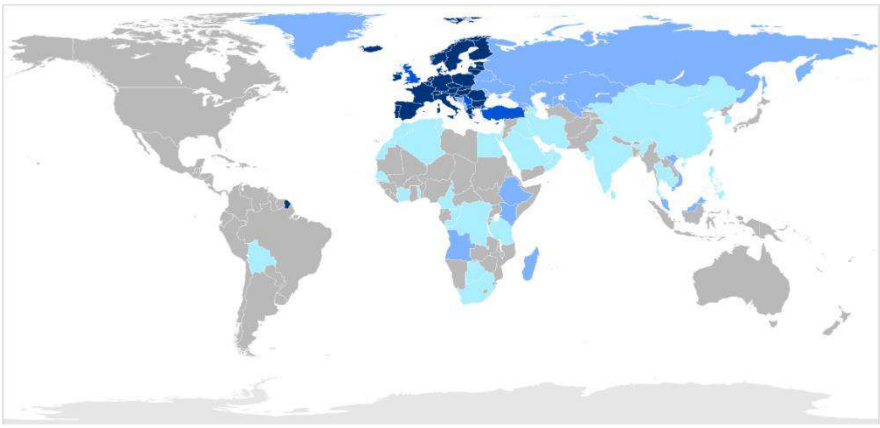
Abstract:

The implementation of Eurocodes in Georgia represents a significant step toward the modernization of the country's construction sector and harmonization with European standards. This process involves both updating technical regulations and retraining professionals, as well as improving the quality of infrastructure projects.

This is a complex process in Georgia, encompassing legislative, technical, and educational components. It will contribute to improving the safety and quality of the country's infrastructure, as well as increasing the international competitiveness of Georgia's construction sector.



Eurocodes used by CEN members (EU and EFTA members)

Eurocodes used by CEN members (EU and EFTA non-members)

Eurocodes used by EU non-members or states in process of adoption

States interested in Eurocodes adoption

Why Were Eurocodes Developed?

The goal of the European Commission is that "Eurocodes should establish unified/common technical norms for the design of buildings and civil engineering works, which will ultimately replace the diverse standards existing in different member states."

What Are Eurocodes?

Eurocodes are a collection of European Standards (EN) for the design of buildings, civil engineering works, and construction products. They were developed by the European Committee for Standardization (CEN). Eurocodes are based on national experience, research results, the expertise of international technical committees, and CEN/TC250 scientific organizations. They provide internationally recognized standards for structural design.

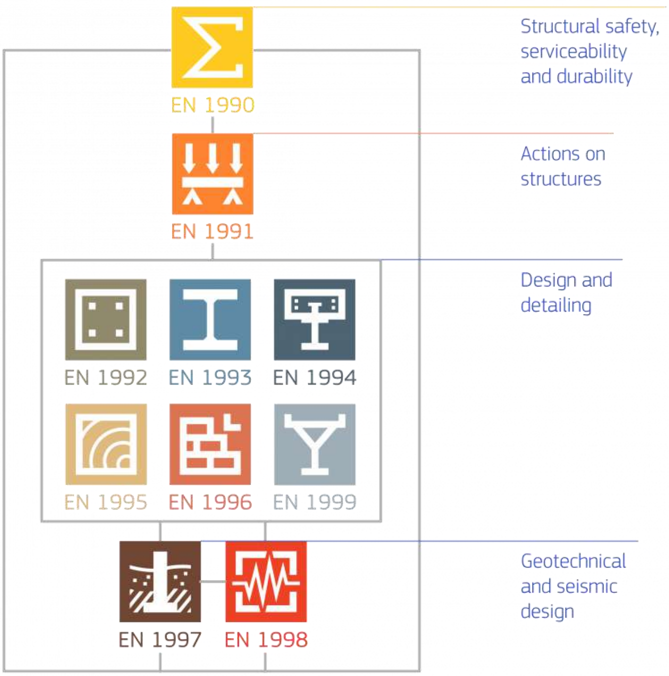
Eurocodes cover all major construction materials (concrete, steel, timber, masonry, and aluminum), all significant areas of structural design (fundamentals, loads, fire, geotechnical design, seismic design, etc.), and a wide range of structures and products (buildings, bridges, towers, silos, etc.).

The Eurocode suite consists of 10 European standards, each containing several sections addressing specific technical aspects, such as fire safety, bridge design, and more. The verification process relies on the concept of limit states, which is used alongside safety factors. Additionally, Eurocodes apply probabilistic methods for design, project testing, and provide guidance on the application of these methods.

The Eurocode Suite

The Eurocode suite consists of 10 European standards for structural design.

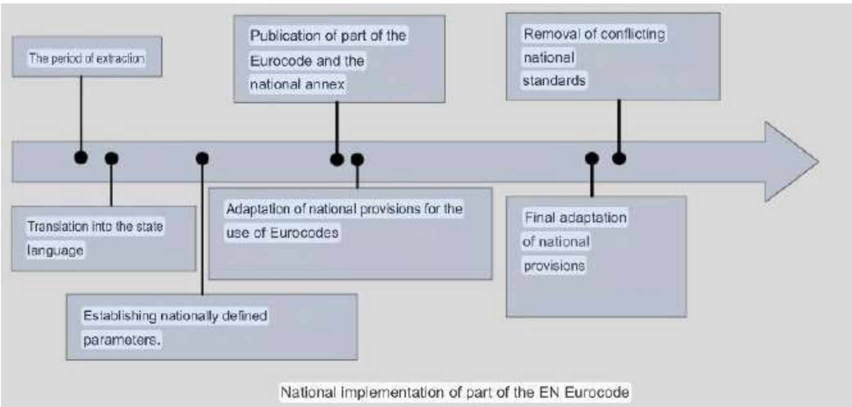
EN 1990	Eurocode: Fundamentals of structural design
N 1991	Eurocode 1: applies to structures
EN 1992	Eurocode 2: Design of concrete structures
EN 1993	Eurocode 3: Design of steel structures
EN 1994	Eurocode 4: Design of multi-layer steel and concrete structures
EN 1995	Eurocode 5: Design of timber structures
EN 1996	Eurocode 6: Design of stone/brick constructions
EN 1997	Eurocode 7: Geotechnical design
EN 1998	Eurocode 8: design of seismic structures
EN 1999	Eurocode 9: Design of aluminum structures



Strategy for Implementing Eurocodes in Georgia

When a part of the Eurocodes becomes available from CEN, national governments and standardization bodies must undertake the following actions:

- Translate the Eurocode part into the national language.
- Establish nationally determined parameters.
- Publish the national standard and annex.
- Adapt national regulations to enable the use of Eurocodes in the country.
- Facilitate the teaching of Eurocodes.



The Georgian government decided to implement Eurocodes, as reflected in a document submitted to Parliament by the Ministry of Economy and Sustainable Development in December 2015. This document outlined a five-year strategy for Eurocode implementation, which includes creating the necessary legislative framework, updating technical regulations, and retraining professionals.

Stages of Implementation:

1. **Translation Phase (up to 1 year):** National standardization bodies must begin translating the Eurocode part into the national language during the implementation period.

2. **National Standardization Phase (up to 2 years):** Member states must establish nationally determined parameters. At the end of this phase, the national version of the Eurocode part must be published along with its annex by national standardization bodies. Member states must also adapt national regulations to enable the use of Eurocodes.

3. **Coexistence Phase:** This phase begins after the end of the national standardization phase. During coexistence, both Eurocodes and existing national systems may be used. The coexistence period lasts up to 3 years, until the final part of the Eurocode package is issued. Member states must adapt their national regulations to ensure clarity in using the Eurocode package. Conflicting national standards must be withdrawn no later than 5 years after the final part of the package comes into effect.

Training

To achieve competent use of Eurocodes, national governments, standardization bodies, and construction professionals must be prepared to apply them. This requires extensive, long-term training.

Three Levels of Training Are Recommended:

1. **First Level:** Focuses on Eurocode implementation policies, national annexes, coexistence with national codes, the Eurocode system, etc., targeted at senior personnel from national governments, standardization bodies, and companies.

2. **Second Level:** Provides an introductory course for each Eurocode.

3. **Third Level:** Offers detailed examples of designing various typical structures using specific Eurocode packages.

Training may involve:

- Long-term training and university education.

- Websites.
- Publishing information related to implementation procedures.
- Design manuals and references.
- Software for design and education.

Professional Retraining

Effective Eurocode implementation requires retraining professionals in the construction sector. To this end, the Infrastructure Construction Companies Association (ICCA) and Element Holding are implementing a project involving international experts to develop a practical Eurocode training module. This module will retrain structural engineers working in the construction sector, ensuring the effective implementation of Eurocode principles.

Impact of Eurocodes on Infrastructure Projects

The adoption of Eurocodes significantly impacts infrastructure projects. For instance, research conducted by the Construction Faculty of the Georgian Technical University shows that calculations performed under Eurocodes require less reinforcement in columns, beams, and floor slabs compared to results obtained under Soviet-era norms (SNiP). Additionally, horizontal displacement of buildings under Eurocodes is lower than under SNiP, indicating that Eurocodes ensure more efficient and safer structures.

Advantages and Opportunities of Eurocodes

- Unified construction safety levels across Europe.
- Common criteria and methods for design to meet requirements for mechanical strength, stability, fire resistance, durability, and economy.
- Improved communication between owners, operators, users, designers, contractors, and manufacturers.
- Facilitated marketing and use of materials and products.

- Development of design aids and software.
- Increased competitiveness of European civil engineering companies, contractors, designers, and manufacturers in global markets.
- A shared foundation for scientific research and experimental design.
- Standardized safety levels in construction across Europe.

Legal and Institutional Framework

Georgia's legislation actively supports the creation of a legal framework for implementing Eurocodes. The 2017 Georgian Law on Construction establishes the foundation for aligning Georgian construction legislation with European norms, including translating Eurocodes into Georgian and developing national annexes.

Conclusion

The implementation of Eurocodes in Georgia signifies a transition toward modern, sustainable, and internationally competitive construction practices. By complying with European standards, the country not only improves the safety and resilience of its structures but also contributes to building a more durable and sustainable future. As infrastructure development continues, the successful implementation of Eurocodes will be critical to ensuring that this growth aligns with sustainable development principles. Achieving this goal requires ongoing investment in education, training, and research, as well as continued support from policymakers, industry professionals, and academia.

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Management of Safety Systems on Construction Site Using Blaze Buster and Rescue Cage,

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Abstract: This document examines the Blaze Buster fire suppression unit and the Crane Rescue Cage, highlighting their critical roles in improving safety on construction sites. We explore their capacities, features, advantages, and practical applications, alongside additional essential equipment used in emergencies, such as stretchers and fire extinguishers.

Key words: Blaze Buster, Crane Rescue Cage, construction safety, fire suppression, emergency equipment, stretchers, fire extinguishers.

Introduction

Construction sites are inherently risky environments where hazards such as fires, equipment mishaps, and structural failures pose significant threats. Safety innovations like the Blaze Buster fire suppression unit and the Crane Rescue Cage have emerged as vital solutions to mitigate these risks, ensuring a safer workplace and enhancing project efficiency. A fire suppression system used for firefighting, is an integral part of any fire protection infrastructure. 'Fire suppression' is a collective term for any engineering group of units that are designed to put out a fire. This can be achieved by applying an extinguishing substance such as water, foam or chemical compounds. This article explores the range of applications within a fire suppression strategy, so site teams and building owners can begin to comply with fire safety regulations and give peace of mind to building occupants and tenants alike.

Research

A fire suppression system is an integral part of any fire protection infrastructure. 'Fire suppression' is a collective term for any engineering group of units that are designed to put out a fire. This can be achieved by applying an extinguishing substance such as water, foam or chemical compounds. This article explores the range of applications within a fire suppression strategy, so site teams and building owners can begin to comply with fire safety regulations and give peace of mind to building occupants and tenants alike.

Broadly speaking, there are five main types of fire suppression systems – all of which have unique properties and benefits based on the respective space in need of protection:

- Gas suppression systems store fire-suppressing liquids, which are pressurized with nitrogen. These liquids contain a chemical agent called FM200, which is quickly released to immediately suppress flames. Since these systems don't use any water, they're particularly beneficial for rooms with large amounts of electrical equipment such as switchboards or server rooms. The gaseous agent is initially condensed in liquid form and stored in compact cylinders, making these systems easy to transport and store.

- Wet chemical foam systems are specifically designed for suppressing fires in kitchens. These kitchen fire suppression systems work by quickly emitting a water-based chemical foam agent directly into a small, localized area. They are usually placed under the canopies of cookers and are activated by either a manual switch or a heat link (a link attached to a wire that breaks when exposed to heat, triggering the foam release valve).

- Water mist systems pose a viable fire suppression solution for spaces that cannot be exposed to large amounts of water. They work by producing droplets that are much smaller than conventional sprinkler systems. This creates a layer of steam that starves fires of oxygen, quickly reducing the temperature of the affected area. Since they use much less water than traditional sprinklers, they can to some extent be considered a more sustainable fire suppression method.

- Foam deluge systems, one of the biggest challenges in fire suppression is effectively safeguarding areas that contain flammable liquids. Foam deluge systems are the most effective means of controlling the spread of these environments. For this reason, they are commonly installed in refineries, aircraft hangers and industrial warehouses. A fire in these types of environments can accelerate tremendously quickly. Therefore, foam deluge systems are designed for the quick widespread application of suppressive materials. Foam deluge systems use a mixture of foam and water to quickly control burning flammable liquids, cooling the surface area. The consistency of the foam causes a thick blanket to starve fires of oxygen and inhibit the release of flammable gases, effectively smothering the blaze. In this sense, they are not unlike conventional fire extinguishers.

- Pneumatic heat detection tubes are designed in a way that makes them very similar to fire extinguishers. Therefore, they can be considered the most compact and mobile fire suppression system. These tubes have two primary components: a pipe and a valve. The pipe is installed around the potential source of fire; when it reaches a certain temperature, it emits a suppressive agent directly onto the flames via the valve. Pneumatic heat detection tubes tackle fires in their beginning stages, located in small areas with little room for maneuver. Therefore, they are ideal for tackling fires in cabinets and cupboards, as well as boats and vehicles. This does mean, however, that they are unsuitable for suppressing large fires and therefore are not recommended for rooms or areas with a high ceiling.

For a given example as a fire suppression system Blaze Burster unit has been used. The Blaze Buster is a compact, yet highly efficient fire suppression system designed for rapid deployment (Fig. 1). Manufactured to handle diverse fire scenarios, it utilizes advanced suppression agents to control and extinguish fires quickly.

The Blaze Buster gives firefighters quick access to firefighting supplies and can be used to carry firefighters to the fire area. Advantages for use that system are following:

- Rapid Response: Quickly extinguishes fires, minimizing damage.
- Portable Design: Easy to transport and deploy in emergencies.
- Environmentally Friendly: Uses non-toxic agents, ensuring minimal environmental impact.
- Cost-Efficiency: Reduces downtime and repair costs after fire incidents.

The Blaze Buster is used in:

- Construction sites for handling machinery and fuel-related fires.
- Industrial zones with high fire hazards.
- Remote project locations where conventional firefighting systems are impractical.

Fig. 1 Blaze Burster System

Firefighters use the Blaze Buster to spray water or fire retardants directly onto the flames. The unit's mobility allows it to maneuver around obstacles and target hard-to-reach areas.

Other hand, the Crane Rescue Cage is a specialized equipment designed to facilitate safe and efficient evacuation of injured or stranded personnel from elevated workspaces (Fig .2).

Fig. 2 Rescue Cage

Given design for the rescue cage allows the unit to be lifted on a high elevated area by the crane using lifting slings attached on each corner of its roof.

Rescue cage equipped with Blaze Buster units and basic safety equipment could be used on construction site as an emergency solution.

A rescue cage is essential for emergency evacuation on high-rise construction sites to perform rescue operations even in confined spaces.

Conclusion

Safety equipment units, such as the Blaze Buster and Crane Rescue Cage, got its decisive role in construction safety management systems. Proper management is crucial to minimize safety risks on construction site. On the other hand, additional tools like stretchers, respirators, and fire extinguishers, form a comprehensive emergency response framework, protecting lives and assets while ensuring operational continuity.

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Net-zero Buildings, Zani Nakashashvili, Bachalor Program Student, *Nakashashvili.zani24@gtu.ge*, Supervisor: Davit Bostanashvili, Associate Professor

Abstract: As the world fights climate change and global warming, sustainability has become very important in building design over the past ten years. From the materials used to build to the energy buildings use, sustainability is now a key factor in deciding if a project will be successful in the long term. Using renewable energy sources and good insulation can help reduce a building's emissions. Buildings use 40% of global energy, so reducing this to nearly zero, or "net zero," is very important in the fight against climate change. Today, architects think about not only the environmental impact of buildings, but also the economic, social, and cultural effects. This way of thinking has led to the idea of "net-zero buildings," which are becoming the next big trend in building design, They are already used in many countries around the world.

Net-zero buildings

Net-zero energy buildings (NZEBs) are a new idea in sustainable architecture. They aim to use as much energy as they produce through renewable sources, like solar or wind power, on-site. This approach changes the way buildings are designed, built, and used. The goal is to reduce harm to the environment and encourage sustainable ways of living.

The concept of NZEBs can be traced back to the 1970s, during the energy crisis when there was a heightened awareness of the need to reduce energy consumption in buildings. Architects and engineers began experimenting with energyefficient design strategies, such as passive solar heating, natural ventilation, and high levels of insulation, to reduce the energy demand of buildings. Improvements in insulation materials, windows, and HVAC systems have made it easier to reduce energy demand in buildings.

Several well-known certification programs are used to certify that a building meets this high standard of sustainability. For example: LEED (Leadership in Energy and Environmental Design), Living Building Challenge (LBC), BREEAM (Building Research Establishment Environmental Assessment Method), Net Zero Energy Building Certification (NZEB), etc.

ZEBs need to produce their own energy on site to meet their electricity and heating or cooling needs. Various microgeneration technologies may be used to provide heat and electricity to the building, including the following:

- Solar (solar hot water, photovoltaics [PV]).
- Wind (wind turbines).
- Biomass (heaters and stoves,boilers, and community heating schemes).
- Combined heat and power (CHP) and micro-CHP for use with natural gas, biomass, sewerage gas, and other biogases.
- Heat pumps (air source [ASHP] and ground source [GSHP] and geothermal heating system
- Other (including fuel cells using hydrogen generated from any of the above renewable sources).

Net zero buildings must use technological advancements and innovative solutions across the construction and energy sectors to be successful. High-efficiency HVAC systems that reduce energy needed for heating and cooling are crucial, along with smart building technologies that allow for real-time energy management adapting to usage patterns to conserve energy are a must. Let's review some in more detail:

Energy Recovery Ventilators (ERVs):

ERVs are critical in managing ventilation in a way that minimizes energy loss. They work by capturing energy from exhaust air and using it to condition incoming fresh air. This is particularly effective in maintaining a comfortable indoor environment without the need for additional heating or cooling energy, which is a significant contributor to a building's energy load.

Phase-Changing Materials (PCMs):

PCMs are substances with a high heat of fusion which, melting and solidifying at certain temperatures, are capable of storing and releasing large amounts of energy. Incorporated into building materials such as wallboards or ceiling tiles, they can absorb excess heat during the day, preventing indoor temperatures from rising too high, and then release that heat when the temperature drops. This passive temperature regulation reduces the need for active heating and cooling systems, conserving energy.

Building Orientation and Natural Resources:

The intelligent design of net zero buildings, including their orientation, is vital for maximizing natural light and reducing the need for artificial lighting. The incorporation of green roofs, living walls, rainwater harvesting and natural ventilation systems leverages natural resources, enhancing energy efficiency and reducing environmental impact. These design principles not only improve the sustainability of buildings but also their aesthetic and health benefits to occupants with the psychological benefits of cleaner air, exposure to more natural sunlight and the well-being that green spaces and house plants can provide.

Smart Grid Integration:

The integration with smart grids enables a dynamic interaction with the energy grid. Through advanced communication capabilities, smart grids facilitate a two-way flow of energy and information, allowing buildings to supply excess energy back to the grid and draw power when necessary. This integration, coupled with energy storage solutions, optimizes energy usage and contributes to a more resilient, efficient, and sustainable energy ecosystem.

By harnessing these technologies, net zero buildings can effectively reduce their energy demand, making it easier to generate the right amount of energy they require themselves, and even contribute surplus energy back to the grid, marking a significant step towards sustainable living and construction practice.

Examples of Zero Energy Buildings:

1. Packard Foundation Headquarters

When designing the Packard Foundation Headquarters, architects and engineers carefully considered all aspects of energy consumption and carbon emissions. They used innovative design ideas and implemented new technologies to improve building energy efficiency. The project demonstrated a high standard of planning, design, and construction, so that with all this the building was a zero-energy consumer. The building was completed in 2012 and is still successfully operating. The office has also received the international "Zero Energy Certificate" from the International Living Future Institute (ILFI).

The office is located on a triangular-shaped block in downtown Los Altos, California. When creating the design, the architect focused on the building's form to prioritize daylight, which led to a two-wing, two-story design. The office consists of narrow office blocks separated by a green courtyard, and all of them are cross-ventilated with opening windows. The facades are mainly oriented to the east and west. Considering the warm climate, the building design takes into account the control of sunlight through the windows, as well as the possibility of ventilation and natural light. The walls use mineral wool insulation, which is better than fiberglass, as it maintains its insulating value and resists the effects of the sun. The windows are made of special heat-reflecting glass. Each system, such as lighting, HVAC, CO2 sensors and solar panels, has its own control system. The Packard Foundation decided to create its own system that would control everything in the building, including room scheduling and security. Therefore, a simple web-based interface was created so that the building staff could easily control the system. To manage comfort and energy consumption, the application simply displays a green or red arrow on their computer, indicating whether windows should be open or closed for natural ventilation. The Packard Foundation Headquarters project demonstrates how good design and energy-efficient systems can create a comfortable, sustainable, zero-energy building. Through careful selection of building controls, efficient HVAC systems, and low-energy equipment, the project reduces energy consumption while maximizing comfort and sustainability.

2. Unisphere

The unisphere is a very large, 19,500 square meter, oval-shaped building. It is the largest zero-energy building in the United States. The following technologies and engineering solutions help generate energy for the unisphere:

• Solar panels: The building has 3,000 solar panels that generate 1,175 megawatt-hours of energy annually. This amount of energy is enough to power approximately 100 homes.

• Labyrinth: There is a long concrete labyrinth below the building. This helps cool the temperature inside the building using natural air.

• Daylighting: The building uses sunlight to reduce the need for artificial lighting. Artificial lighting automatically turns off when enough sunlight enters the building. Incorporating a daylight strategy into the building design helps cut down on energy consumption and enhances the comfort of those inside. The main factors for a successful daylight strategy are the building's orientation, choice of windows, and how the daylight controls and HVAC systems are integrated. A model for both energy use and daylight was created to fine-tune the strategy. Tall ceilings combined with high light-transmitting windows placed near the ceiling and away from the shadow of the building's solar panels will boost the amount of daylight entering the space and improve daylight reach within the building. Photovoltaic sensors positioned throughout the area will automatically adjust the lighting depending on the available natural light.

• Electrochromic glass: Enhanced insulation, triple-glazed windows, and electrochromic glass that adjusts its tint based on the sun's position will aim for a 25% improvement in thermal performance compared to the minimum code requirements. Electrochromic glass changes its tint based on various factors such as the season, sun position, cloud cover, glare from nearby buildings, and even tenant preferences. The tint helps minimize the amount of heat entering the building.

• Natural ventilation: The building is designed to allow natural ventilation during seasons when outdoor air quality is suitable. The ventilation system will operate in three stages: automatic, manual, and mechanical assistance. When conditions allow, windows located below the floor at the perimeter and above the ceiling inside the building will open to create a crossflow of air. The atrium will function as a thermal chimney, using warm air's buoyancy to encourage airflow throughout the building. Additionally, occupants will have the option to manually open windows for personal comfort control within their space.

• Energy exchange with the grid: When a building generates more energy than it needs, it sends the extra energy to the grid. Then, at night or when the sun is out, it can draw the same energy from the grid.

With these smart features, the Unisphere is a zero-energy building that uses renewable energy. It is a great example of how modern building design can be energy efficient.

3. ProCredit Bank Head Office

We also have energy-efficient buildings in Georgia, one of which is the ProCredit Bank Head Office building, which was included in the list of world green buildings. The building is the first in Georgia to be certified for energy and resource efficiency by the international Edge certificate. International auditors assessed the bank's combination of modern architectural design and energy, water and material efficiency, which has been part of the ProCredit Group's eco-friendly strategy for years.

The extensive glazed facade and atrium provide natural daylight to the building, while low-emission glass and thermal insulation minimize heat loss. The entire building is equipped with LED lighting, which has load sensors and lighting control functions. Highly efficient heating, cooling and ventilation equipment provides comfortable ambient air to the building while saving energy. Not only the building itself is important, but also the efficient use of resources, for which ProCredit Bank Georgia installed one of the first rainwater harvesting systems in the country at its head office. In addition, it is the only bank to have its own solar power plant, the system will generate electricity for the bank's own consumption and for charging electric vehicles.

ProCredit Bank Georgia also plans to gradually complete the next stages of EDGE certification for the head office. The company's ultimate goal is to achieve zero carbon emissions, as a result of which the ProCredit Bank Georgia head office will become a 100% carbon-neutral zone.

By meeting the first level of "zero carbon emissions" requirements, ProCredit Bank Georgia hopes to set an example for other companies and encourage them to implement similar environmental initiatives to reduce their negative impact on the environment.

Experts believe that by 2030, zero-energy buildings will become increasingly common, especially in regions with strict environmental regulations. This is partly due to the growing emphasis on reducing carbon emissions and improving energy efficiency. Many countries, especially European countries, have set strict goals in this regard. In 2017, for example, California approved the first net-zero building code in the nation, requiring all new residential construction be zero net energy by 2020, and all new commercial construction by 2030. Mayors from cities such as Portland, San Francisco, and New York have committed to similar policies. the Georgian Parliament has also adopted that goal and is already in force the Law on Energy Efficiency of Buildings, according to Article 6 of which all buildings planned to be built after September 30, 2029 must meet the requirements for nearly zero-energy buildings. Zero-energy buildings are an innovative direction in modern energy-efficient construction, which excludes: the use of fossil fuels in heating and ventilation systems of buildings, minimizing CO2 emissions and establishing maximum thermal comfort in buildings.

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Innovations in Civil Engineering, Davit Nozadze, Bachelor Program Student, *Nozadze.davit24@gtu.ge*, Supervisor: Mikheil Todua, Associate Professor, *Todua.m@gtu.ge*

Abstract:

Civil engineering is one of the most essential fields directly linked to human life. The rapid development of technology and innovations in this field creates new opportunities that significantly improve the efficiency, safety, and sustainability of processes. This article explores the importance of innovations in civil engineering, their practical applications, and notable examples.

Key Points:

- ✓ Innovations in civil engineering introduce new approaches and technologies that allow engineers to better manage projects and resources.
- ✓ New materials, digital technologies, and automation significantly enhance the efficiency of work processes.
- ✓ Practical examples of innovations illustrate how construction can evolve in the coming decades.

Building Information Modeling (BIM)

The integration of Building Information Modeling (BIM) and BIM 360 has revolutionized civil engineering and construction management. With its collaborative platform and enhanced 3D modeling, BIM enhances the accuracy, efficiency, and sustainability of infrastructure projects. This technology bridges the gap between traditional practices and the future of smart construction, improving project deliverables and lifecycle management.

Building Information Modeling (BIM) is a cutting-edge digital process that takes advantage of 3D models integrated with project data to streamline the design, construction, and maintenance of civil engineering projects. BIM 360, Autodesk's cloud-based extension, takes this innovation even further by adding real-time collaboration and data sharing among stakeholders in various locations.

Innovative Features:

- 3D & 4D Modeling: Adds time (scheduling) and cost (budgeting) dimensions to traditional 3D design.
- Clash Detection: Identifies conflicts between elements, e.g., structural and MEP systems.
- Cloud Collaboration: BIM 360 unites remote teams with real-time model updates.
- Lifecycle Management: Tracks project evolution, streamlines maintenance, and improves long-term asset management.
- Basic Principles
- Collaboration: A common platform ensures architects, engineers, contractors, and owners are working from the same up-to-date information.
- Visualization: 3D/4D visual models demystify complex concepts, helping stakeholders make fully informed decisions.
- Efficiency: Automation of BIM reduces errors manually made, and BIM 360 accelerates task and document management.
- Data Integration: It combines geometry, performance data, and scheduling data in one model.
- Sustainability: It improves energy performance and material efficiency to maximize green infrastructure goals.

➢ Examples

➢ Crossrail (UK): The largest infrastructure project in Europe used BIM in the coordination of over 10,000 professionals, allowing better resource planning and avoiding design conflicts.

Image 1. Crossrail (UK

➢ Shanghai Tower (China): BIM aided the structural design and energy modeling of this super-tall skyscraper, increasing efficiency and reducing waste in construction.

➢ Changi Airport Expansion (Singapore): BIM 360 played a key role in managing documentation and real-time communication in the project.

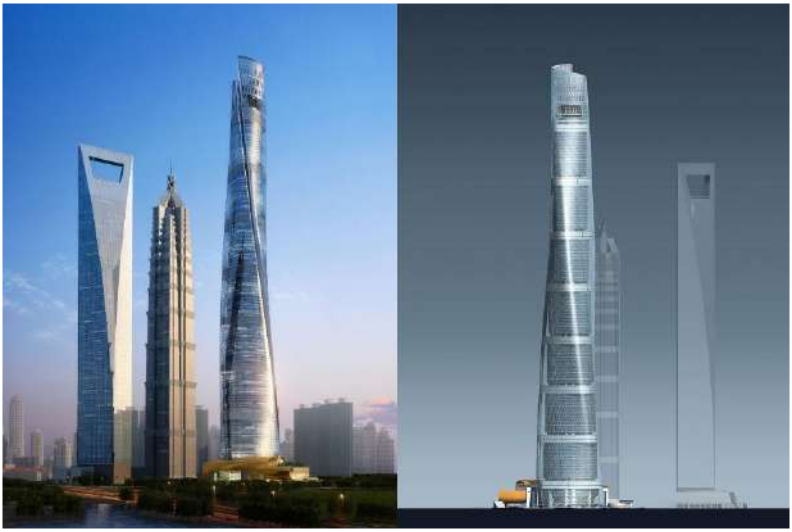

Image 2.

Image 3. Changi Airport

Comparison with the Past

Aspect	Traditional Practices	BIM & BIM 360
Design	2D drawings (CAD), manual revisions	3D/4D models, automated synchronizations
Collaboration	Poor communication, isolated teams	Real-time cloud-based collaboration
Clash Detection	Discovered late in construction	Detected during the design process
Time Efficiency	Time-consuming manual changes	Automated revisions, less rework
Cost Efficiency	Expensive due to mistakes and inefficiencies	Less expensive with improved planning and precision
Sustainability	Little emphasis on energy and material use	Streamlined for green infrastructure objectives

3D Printing in Construction

allows engineers to create complex structures in less time and at a lower cost. 3D printing in civil engineering is one of the most remarkable innovations. Its application

Key Principles:

- Layer-by-layer deposition of material to create a structure.
- Use of specific materials such as concrete, plastic, or metal.
- Automation of processes, reducing the need for manual labor.
- Comparison to the Past:

Traditional construction required heavy machinery and manual labor, increasing time and costs.

3D printing reduces time and costs by up to 60%.

Example: Dubai's "Office of the Future," built using 3D printing technology, significantly reduced construction time and material costs, showcasing the potential of this technology.

Image 4 Office of the Future

Smart Materials

Smart materials, such as self-healing concrete, significantly improve the durability of buildings and infrastructure. Self-healing concrete contains bacteria that react to cracks and fill them, reducing maintenance costs.

Key Principles:

- Use of microcapsules of bacteria in concrete.
- Reaction with water and calcium ions to fill cracks.
- Improved durability of concrete structures over time.
- Comparison to the Past:
- Traditional concrete weakened over time due to cracks.

- Self-healing concrete reduces the need for mechanical repairs.

Example: A pilot project in the Netherlands demonstrated that self-healing concrete reduces maintenance costs by 30%.

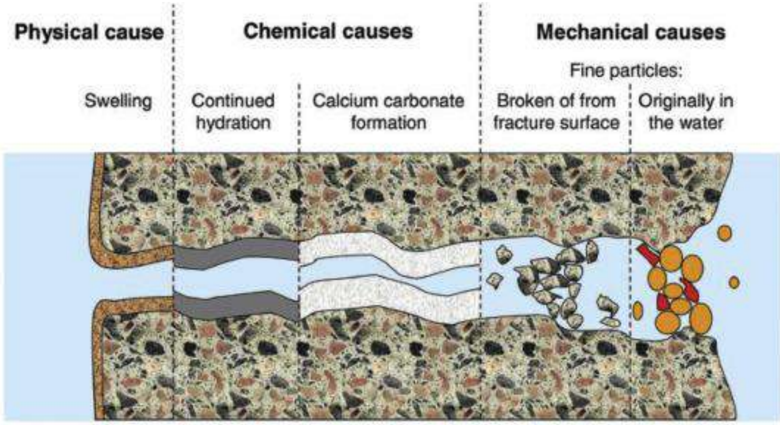

Image 5: The self-healing process in concrete

Construction Automation and Robotics

The use of robots and automation increases the precision of work processes and reduces the need for human labor.

Key Principles:

- Deployment of robotic systems for specific tasks, such as bricklaying.
- Use of automated programming for documentation and resource management.
- Improved safety standards by reducing human involvement in hazardous tasks.
- Comparison to the Past:
- Traditional construction had a higher risk of human errors.

- Robots ensure precise and standardized results.

Example: "SAM" (Semi-Automated Mason) is a semi-automated machine that lays bricks three times faster than a human worker.

Image 6: bricklaying robot SAM

Green Buildings

Green buildings are a key component of modern civil engineering’s environmental approach. They aim to use energy efficiently, reduce waste, and minimize the impact on natural resources.

Key Principles:

- Use of energy-efficient materials, such as advanced insulation systems.
- Maximization of natural lighting in building design.
- Systems for collecting and using rainwater.
- Integration of renewable energy sources, such as solar panels and wind turbines.

Comparison to the Past:

Traditional buildings consumed more energy for heating and cooling.

Green buildings reduce energy consumption by 30% or more.

Example: The "Vauban" green district in Freiburg, Germany, is a prime example of energy efficiency and sustainable infrastructure. The district's houses feature solar panels, energy recycling systems, and prioritize public transportation.

Image 7: Design and eco-technologies of green buildings

Nanomaterials

Nanomaterials are one of the most promising innovations in civil engineering. They enable engineers to create stronger, lighter, and more durable structures, significantly improving construction quality and sustainability.

Key Principles:

- Molecular structure of nanomaterials provides unique properties such as increased strength and flexibility.

- Control of surface properties, such as water and dust resistance.
- Reduced energy consumption during production and use of materials.
- Comparison to the Past:
- Traditional materials are heavier and less durable.
- Nanomaterials ensure lightweight yet resilient structures.

Example: Self-cleaning glass made from nanomaterials, used in modern buildings like "The Shard" in London, reduces maintenance costs and increases energy efficiency.

Image 8: London's The SHARD

Conclusion

Innovations in civil engineering create new opportunities and improve processes, enhancing the efficiency, sustainability, and safety of projects. Practical examples demonstrate that innovations are the foundation for future construction.

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Temporary Roofing System with Deployable Structures,

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Abstract: Temporary roofing systems with deployable structures have emerged as an innovative solution for rapid and efficient sheltering in various applications, including construction, disaster relief, and temporary event spaces. These systems leverage lightweight, modular, and flexible materials combined with deployable structural mechanisms to enable quick assembly and disassembly. This paper explores the design, functionality, and applications of deployable roofing systems, emphasizing their adaptability to different environments and weather conditions. Key considerations include structural stability, material selection, load-bearing capacity, and ease of transportation. The integration of advanced materials and geometric folding mechanisms ensures optimal performance while reducing installation time and resource requirements. The study concludes by highlighting potential improvements in design, sustainability, and resilience to further enhance the practicality of temporary roofing systems with deployable structures.

Key words: Temporary Roofing System, Deployable Structure, Rapid Assembly, Modular Design, Lightweight Materials, Foldable Structures, Structural Stability, Disaster Relief Shelter, Temporary Shelter Solutions, Portable Roofing, Adaptive Architecture, Load-Bearing Capacity, Transportability, Geometric Folding Mechanisms, Sustainable Design.

Introduction

Temporary roofing systems with deployable structures have become a crucial solution in scenarios requiring rapid and efficient sheltering. From construction projects and disaster relief operations to large-scale events and temporary storage facilities, the need for adaptable, durable, and easy-to-install roofing systems is increasing. Deployable structures, characterized by their ability to transition between compact and expanded forms, offer a unique combination of portability, structural efficiency, and versatility. This paper examines the design principles and engineering innovations underpinning deployable roofing systems. These structures leverage advanced materials and geometric configurations to achieve high performance with minimal resources. Key advantages include reduced installation time, enhanced transportability, and the ability to adapt to diverse environmental and operational requirements. The study aims to address critical challenges such as structural stability under varying loads, weather resistance, and sustainability. By integrating cutting-edge technologies and modular components, deployable roofing systems are poised to revolutionize temporary shelter solutions across multiple domains. This introduction sets the stage for a detailed exploration of their design, applications, and future potential.

Method

Implementation for temporary roofing systems have been achieved by using deployable structures. A deployable structure is a type of structure that can change its configuration, typically transitioning from a compact, folded, or collapsed state to a fully expanded, functional form.

Commonly these structures are designed to be lightweight, portable and easily assembled or deployed, making them ideal for temporary applications.

Deployable structures are widely used in fields like architecture, engineering, aerospace, and disaster relief.

Key Characteristics of deployable structures are following:

–Compactness - They can be stored or transported in a small, folded form.

–Ease of Deployment - They are designed for quick and straightforward assembly or transformation.

–Reversibility - Many deployable structures can be folded back into their compact state for reuse.

–Adaptability - They can adjust to different environments and requirements.

–Structural Efficiency - These structures often utilize advanced materials and geometric configurations to ensure stability and strength.

Examples for deployable structures used for a variety of applications follows:

–Tensile Membrane Structures - Using fabric stretched over a lightweight frame.

–Folding Geometries - Origami-inspired designs that unfold into larger forms.

–Scissor Mechanisms - Hinged bars that expand or contract.

–Inflatable Structures - Using pressurized air to create a rigid form.

–Space Applications - Solar panels and antennas on satellites that deploy in space.

Deployable structures have applications in temporary shelters, emergency housing, portable stages, sports facilities, and even space exploration, where compactness and rapid deployment are critical.

Research

To solve the problem, the structure must have the ability to deploy on the X and Y axis independently of each other. The ability to expand independently on the X and Y axis performed by defining the degrees of freedom for each connection of nodes.

Two types of connection nodes are used in the structure:

–A hinge connection allows two members to rotate around their contact point. At the hinge, both members are able to rotate freely with no restraint. Hinge joints only have one degree of freedom, meaning they can only move along one plane. This allows them to flex and extend the joint, moving the limb in or out.

–Slider joint type moves a component along a single axis, with no additional rotation. A slider joint is a one degree of freedom kinematic pair which constrains the motion of two bodies to sliding along a common axis, without rotation; for this reason, it is often called a slider (as in the slider-crank linkage) or a sliding pair.

The system is made up with pantographs. Pantographs are connected horizontally and vertically using different combinations of connecting nodes (Fig 1).

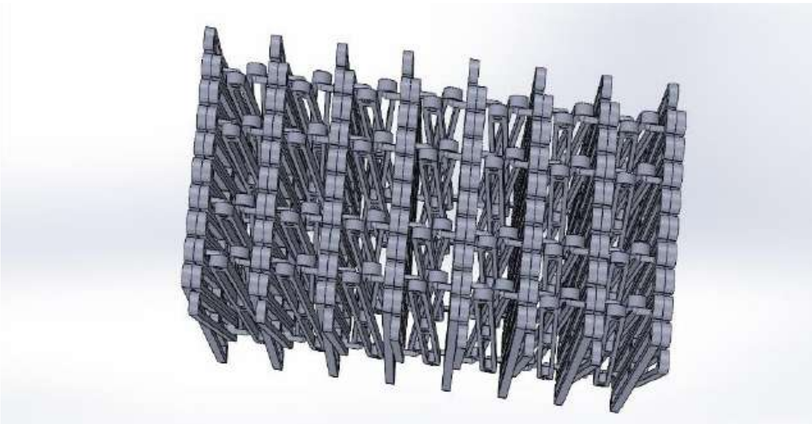

Fig. 1 Pantographs and Connection Nodes

Given configuration allows the system to be deployed independently on the x or y axis (Fig. 2).

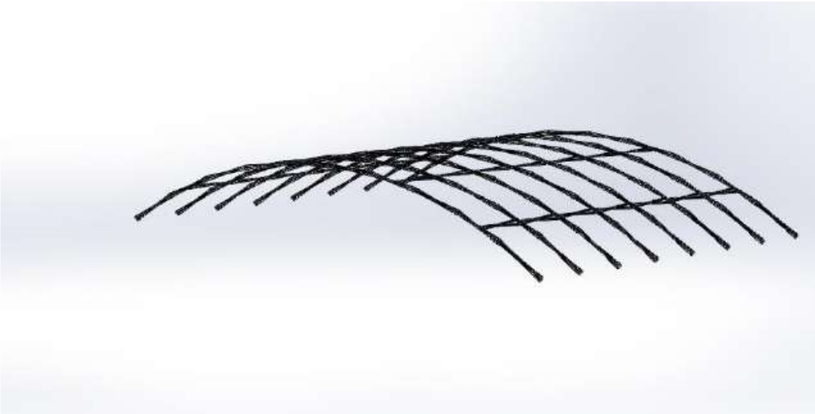

Fig. 2 Structure in Deployed State

For the given example, the height and geometry of the arch is defined by changing the length of the pantograph rods. On the other hand, the extension of the arch, with its length, is achieved by using slide connections.

Discussion

The construction of a roof for a warehouse is associated with a financial cost, especially when the object should not be located on the site constantly.

Availability of a temporary roofing system gives new opportunities to organize events in the open space. Proposed system provides a solution to these problems.

The system has the ability to be transported, which includes a small volumetric dimension when it's folded.

Deployment includes the sequence of unfolding in two directions.

Only one driving device could be used in the opening and folding process and gives the ability to transform each section of the structure.

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The Growing Role of Artificial Intelligence in Architecture,

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Abstract: Artificial intelligence (AI) is a field of computer science that aims to create intelligent machines or programs that can replicate human intelligence. AI relies heavily on data collected by scientists, including history, medicine, and music, to "learn" and respond accordingly. AI has provided significant assistance to architects. Some AI models are trained in interior design, some in conceptual design, and others in rendering or construction documentation. For example, Finch 3D can analyze uploaded building plans and quickly create several interior design sketches, taking into account thermal efficiency. Swapp's AI model learns the style of architects from their previous projects to create designs that match their specific style. Also of interest is the ability of AI to render. Scientists are working on a model that will allow architects to create professional renderings from simple sketches or directly from text requests. However, artificial intelligence models often fail to perceive space and take into account human requirements that only another person can. This often leads to impractical results. Despite its advantages, artificial intelligence will never replace architects. It lacks creativity and the human ability to intuitively take into account emotional and cultural factors in design that only humans can feel. As artificial intelligence develops, regulations will become necessary to stop the process of gradually blurring the boundaries between computers and humans.

The Growing Role of Artificial Intelligence in Architecture

Artificial intelligence is a field of computer science that aims to create an intelligent computer machine/program that will be able to achieve human intelligence. AI is an attempt by scientists to create a computerized intelligence that will do everything faster and better than a human. Artificial intelligence works on the materials provided by scientists, everything is pumped into it: history, science, medicine, music: accordingly, it also “learns” the pumped information and, accordingly, provides us with feedback. For a small historical context, work on artificial intelligence did not begin in the last few years, but rather began in the 20th century.

It is said that the first experiments in the field of artificial intelligence were carried out by the famous British scientist Alan Turing. The historical timing of the development of the field led to a breakthrough in this field starting in 2020 (when artificial intelligence became available to the masses). This breakthrough was facilitated by a gigantic increase in investments in the field of artificial intelligence.

From 2013 to 2021, investments increased by 261.57 billion dollars. There are several types of artificial intelligence: 1) Textual: Artificial intelligence can write essays, poems, assignments and any other textual information in accordance with the supplied request.

Of course, the greatest use is in the textual side of artificial intelligence due to its functions. Many companies have already begun to embed textual artificial intelligence in their products. For example, Microsoft is considering embedding artificial intelligence in office programs, and Apple is also planning a similar change. 2) Visual: Such artificial intelligence can create any type of image or video in accordance with the supplied request.

Fairytale worlds or beautiful paintings generated by artificial intelligence are already popular on social networks. Visual artificial intelligence has already been built into Photoshop, which somewhat simplifies certain routine tasks. 3) Voice imitation: Such artificial intelligence can imitate the voice of any person if you provide it with enough audio recordings and the text that it should say. It can be said that this type is the most dangerous, because it paves the way for the spread of various manipulations, deceptions, and wrongdoing. For example, a married couple in Brooklyn, USA, became victims of financial fraud using a voice generated by artificial intelligence. This voice imitation has also been used for political purposes.

As we have mentioned, artificial intelligence is slowly "learning" and becoming smarter every day. Recently, artificial intelligence has "passed" the US law, business and medical school exams. From this we can say that its "education" is at a serious level. All this is directly related to its profit, which is also growing every year and in just 8 years, by 2032, will reach 1.3 trillion dollars. Nevertheless, it is widely recognized that artificial intelligence has a very difficult time solving elementary mathematical problems. For example, ChatGPT 3.5 incorrectly processed 8 out of 18 data that we put into it as an experiment for this paper.

It should be noted that the centers where the equipment for training artificial intelligence is located, where scientists work on these discoveries, produce a lot of CO^2 and cause irreparable harm to the environment. It has been established that artificial intelligence consumes exactly as much energy to generate one photo as a phone does when fully charged to 100%.

Artificial intelligence in architecture has quite a few models. Some of them work on interior design, some on exterior, some on concepts, some on rendering, etc. This photo of an interior is generated in seconds by artificial intelligence, which had the corresponding request: a house by the sea, etc. (of course, the mentioned model has many problems).

Image 1. AI generated interior with prompt: “a house by the sea”.

There is an artificial intelligence model Finch 3D, which, according to the uploaded plan, taking into account the thermal efficiency of the building, offers several interior projects.

Image 2. Interior plan generated by “Finch 3D”.

The Delve artificial intelligence model works on conceptual development: after specifying a request, it offers possibilities for the conceptual development of the building.

Image 3. Conceptual plans generated by “The Delve”.

There is also an artificial intelligence company called Swap, which specializes in design and related documentation. Swap has created an artificial intelligence model that learns from an architect's previous projects, portfolios, drawings, and paintings, and accordingly designs a building in the style of the studied architect.

Image 4. Company “Swapp”.

Also very important is the capabilities of artificial intelligence in terms of rendering: there are many models that make a good attempt at rendering from sketches or elementary geometric shapes, or directly from text, depending on what is specified. Some examples of buildings generated by artificial intelligence on text requests:

Images 6, 7 and 8 respectively. AI generated photos.

For the purpose of experimenting with artificial intelligence, let's take a basic model of an architectural composition and convert it into simple geometric figures in any graphic editor after that upload it to artificial intelligence at our request. In this case, let's specify eco-friendly high-tech. Accordingly, the result of the experiment:

Image 9. Experiment of rendering with AI.

This artificial intelligence model had difficulty perceiving space and practically did not understand the task. The second artificial intelligence model presented a relatively better version, although it also had problems. The third artificial intelligence model gave us an absolutely dystopian and inhuman picture, which does not meet our requirements at all.

Image 10 and 11 respectively. 2nd and 3rd attempts of rendering with AI.

After discussing all the above-mentioned artificial intelligence models, the question inevitably arises: Will the development of technologies and the refinement of artificial intelligence lead us to the point where architecture as a profession will no longer exist? The answer to this question is negative. Firstly, because artificial intelligence is inhumane. Artificial intelligence cannot take into account the human factors that an architect sees. Artificial intelligence cannot take into account human requirements in the way that another person understands them. Secondly, because artificial intelligence cannot create anything new. Artificial intelligence is a program that is trained on material provided by a human. Originality is actually excluded by its definition. According to a 2024 survey by the Royal Institute of British Architects (RIBA), 41% of architects use artificial intelligence.

The potential for positive development of artificial intelligence is great:

- Artificial intelligence can be used in conceptual research, when we want to find as many and interesting concepts as possible.
- It can be used to generate ideas: how to make a building more eco-friendly, more traditional or more futuristic, etc.
- In the near future, some form of artificial intelligence will definitely be built into graphics programs to simplify routine and boring work.
- Artificial intelligence can be used for approximate budget calculations.
- It can be used to suggest new and modern construction and finishing materials: by uploading a project.
- It can be used for precise analysis of a place, who lives in the neighborhood, whether we are in a historical area, whether construction is planned in the neighborhood. What used to be a tedious and long process to find out can now be easily obtained with a few clicks.
- It can be used to understand massive amounts of information and use it in design

As artificial intelligence gets better every year, regulations will become necessary. Regulations are needed to restore the blurred boundaries between humans and computers. One of the areas that these regulations will affect to some extent will be architecture. We should also note that on the international stage, the United Nations is already actively working on some kinds of regulations with artificial intelligence.

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Negative Temperature (in the Kelvin Scale), *Otari Okroshidze, Bachelor Program Student, Otikookroshidze23@gmail.com, Supervisor: Zaal Tsinadze, Professor z.tsinadze@gtu.ge*

Abstract: In this analysis, the concept of absolute temperature is examined, particularly in relation to negative temperature and its implications. Initially, it is demonstrated that entropy reaches its maximum when particles are equally distributed among cells, with temperature increasing the probability of higher energy states. As temperature increases, the probability and entropy increase until the system reaches an equal distribution of molecules, at which point they attain their maximum. However, as temperature continues to rise beyond this point, entropy and probability begin to decrease, suggesting an impossible scenario unless the temperature is considered negative.

The transition to negative temperature occurs when the distribution of particles in higher energy cells becomes more significant than in lower energy cells. In mathematical terms, if $ln(n_1 / n_2) < 1$, this results in a negative value, leading to the transition to negative temperature. Under such conditions, the system has a higher energy than it would at positive temperatures. This paradox leads to a conceptual explanation: particles can transform into antiparticles with negative energies, clarifying the distribution of particles across cells.

Ultimately, it is shown that negative temperature does not necessarily imply a higher temperature value, but rather represents a state with higher energy compared to positive temperatures.

The concept of absolute temperature is well-known. It represents a quantity proportional to the average kinetic energy: $\frac{\overline{mv^2}}{2} = \frac{1}{2}kT$ (1)

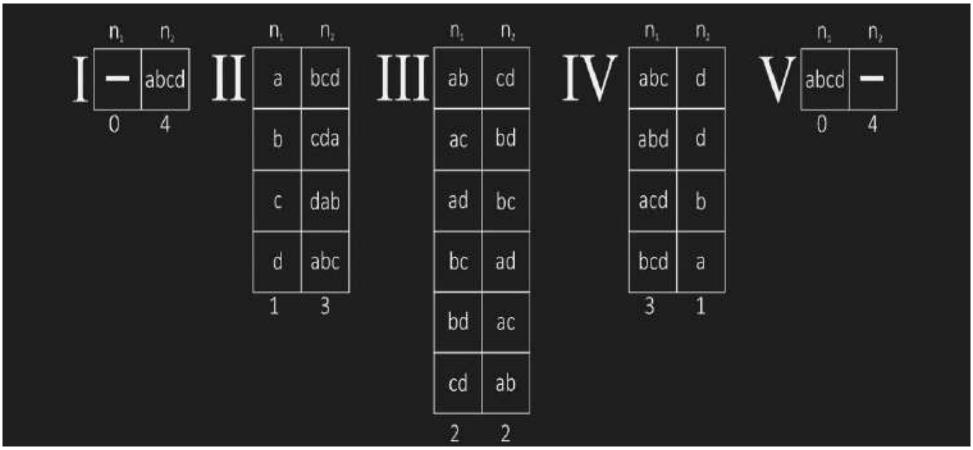
Such a definition inherently excludes the possibility of negative values for temperature in the classical sense. However, if we consider quantum physics perspectives and Einstein's famous equation, E=mc2E = $E = mc^2$, the notion of negative temperature becomes more plausible and less disputable.

A more fundamental definition of absolute temperature also exists: it is a quantity proportional to a parameter 000 in Boltzmann's formula. Under ordinary conditions, this definition aligns perfectly with the classical one, but there are cases where this agreement is disrupted.

In most scenarios, the system under consideration is structured in a way that its particles can possess arbitrarily large energy values ε. Consequently, the parameter 0 becomes infinitely large and strictly positive. (Otherwise, as the energy ε_i increases indefinitely, the number of particles n_i would also grow infinitely, which is impossible since the number of particles in any system is finite.)

Let us recall and clarify Boltzmann's formula for the distribution of particles among cells. Consider a system in statistical equilibrium. According to the second law of thermodynamics, the particle distribution among the cells of such a system is stationary—entropy is at its maximum. This condition allows us to determine the particle distribution among individual cells, $n_1, n_{2,\dots} n_i$. For example, let us consider a system with four particles and two cells.

As we can see, the total number of possible distributions is 16 (i.e., the total number of microstates is 16), while the number of macrostates is only 5. Clearly, the number of microstates is always greater than the number of macrostates. Indeed, transferring a molecule (or particle) from one cell to another changes the microstate, but the macrostate remains unchanged.



The example we presented is a very simple case. In typical macroscopic systems, these numbers are much larger. For instance, if we consider $1ms^3$of gas under normal pressure and at 0^oC, the number of

molecules in the system is on the order of 10^{20}. Under such conditions, direct calculation of microstates and macrostates is practically impossible.

Therefore, it becomes necessary to derive a general formula for determining the number of microstates corresponding to a given macrostate. This formula takes the following form:

$$w = \frac{N!}{\prod_i n_i!} \quad (2)$$

N represents the total number of molecules, i denotes the allowable number of cells, and W is the number of macrostates. If N=4 and i=2

$$w_1 = \frac{4!}{0!4!} = 1 \qquad w_2 = \frac{3!}{1!3!} = 4 \qquad w_3 = \frac{4!}{2!2!} = 6 \qquad w_4 = \frac{4!}{3!4!} = 4$$
$$w_5 = \frac{4!}{4!0!} = 1 \quad (3)$$

It is evident that the maximum number of microstates corresponds to the case where $n_1 = n_2 = 2$, representing an equal distribution of particles between the cells. However, this is only true when the system has no additional constraints other than the conservation of the total number of particles.

Let us impose an additional constraint: all comparable distributions must have the same constant total energy (an isolated system). As we will see, the maximum probability no longer corresponds to an equal distribution.

Entropy can be expressed in terms of the number of particles in each cell:

$s = k\, ln\, w$ (4)

$s = kN\, ln\, N - k \sum_i n_i ln n_i$ (5)

It follows that, in the state of equilibrium, entropy is at its maximum. Therefore:

$dS = 0$ (6)

Indeed, if the only constraint is N=const, then:

$dN = dN_1 + dN_2 + dN_3 = 0$ (7)

$ds = k[\ln n_1\, dn_1 + \ln n_2\, dn_2 + \ln n_3\, dn_3 - d\, n_1 - dn_2 - dn_3] = 0$ (8)

$Let\ us\ define - dN_3 = ?$ Substitute into- ds=0 (9)

$ds = k\{(\ln n_3 - \ln n_1)\, dn_1 + (\ln n_3 - \ln n_2)\, dn_3\} = 0$ (10)

$ln\, n_3 - ln\, n_1 = 0$ და $ln\, n_3 - ln\, n_2 = 0$ (11)

$ln\, n_1 = ln\, n_2 = ln\, n_3 = 0$ (12)

$n_1 = n_2 = n_3$ (13)

We conclude that entropy is maximized when the number of molecules distributed among the cells is equal.

Now, let us consider an isolated system, meaning we impose the condition of constant energy (energy neither flows into nor out of the system).

$dE = \varepsilon_1\, dn_1 + \varepsilon_2\, dn_2 + \varepsilon_3\, dn_3 = 0$ (14)

As in the previous case, calculate the value of dn_3 from the first constraint $dn_3 = -\,dn_1 - dn_2$ and substitute it. We obtain:

$(\varepsilon_3 - \varepsilon_1)\, dn_1 + (\varepsilon_3 - \varepsilon_2)\, dn_2 = 0$ (15)

From this, determine dn_2 and substitute it into the initial equation for calculating dn_3. We obtain:

$\{ln\frac{n_3}{n_1} - ln\frac{n_3}{n_2}\frac{(\varepsilon_3-\varepsilon_1)}{(\varepsilon_3-\varepsilon_2)}\}dn_1 = 0;$ (16)

$ln\frac{n_3}{n_1} - ln\frac{n_3}{n_2}\frac{(\varepsilon_3-\varepsilon_1)}{(\varepsilon_3-\varepsilon_2)};$ (17)

$\frac{\varepsilon_3-\varepsilon_2}{\ln\frac{n_2}{n_3}} = \frac{\varepsilon_3-\varepsilon_1}{\ln\frac{n_1}{n_3}} \equiv \theta;$ (18)

Then: $ln\frac{n_1}{n_3} = \frac{(\varepsilon_3-\varepsilon_1)}{\theta} \Rightarrow \frac{n_1}{n_2} = e^{\frac{\varepsilon_3-\varepsilon}{\theta}l};$ (19)

Let us rewrite this equation as follows:

$\frac{n_3}{e^{-\frac{\varepsilon_3}{\theta}}} = \frac{n_3}{e^{-\frac{\varepsilon_1}{\theta}}} \Rightarrow \frac{n_i}{e^{-\frac{\varepsilon_i}{\theta}}};$ (20)

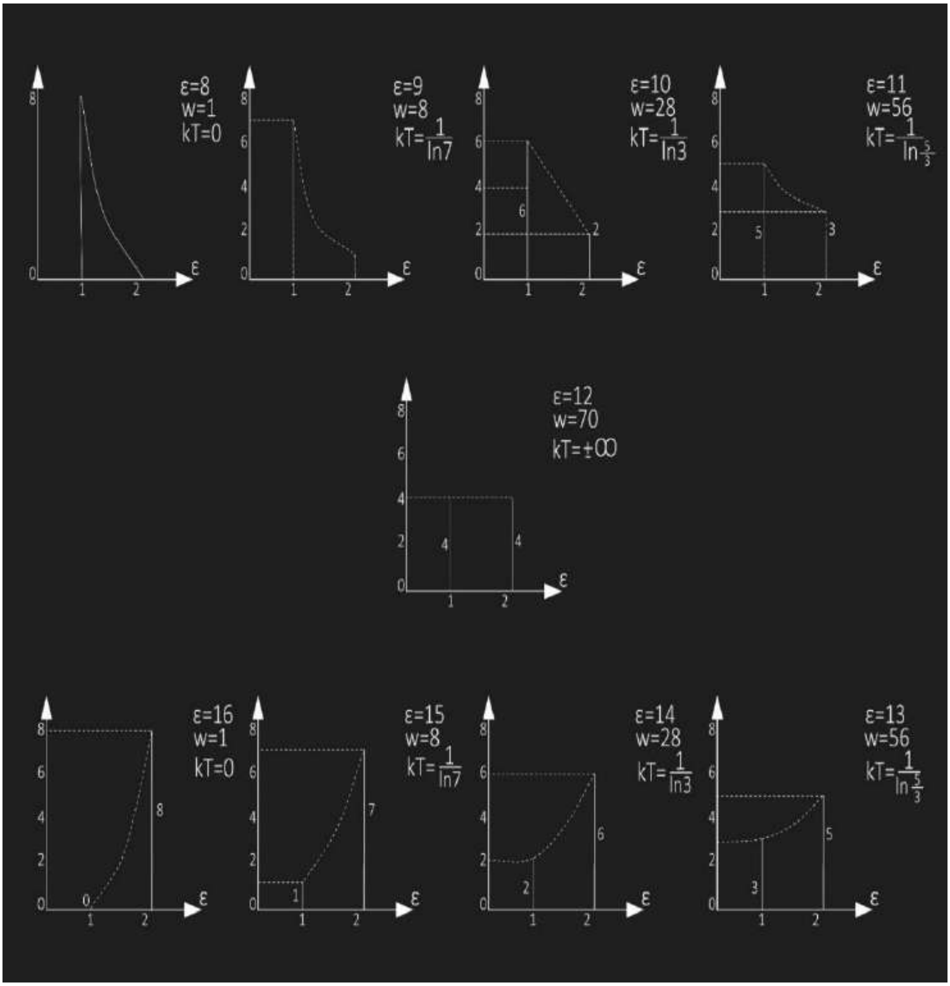
$n_i = n_0 e^{-\frac{\varepsilon_j}{\theta}}$ (21)

$\theta = kT$ And finally:

Finally, the Boltzmann formula

As we mentioned, a completely different picture emerges when the number of particles is finite, and their energies are bounded from above. This situation often occurs (e.g., in systems of atoms or electrons with spin states). As we have seen, in such cases, the Boltzmann distribution is realized with a negative θ.

To illustrate this, let us return to a simple example.



Suppose a particle can exist in only two states (be located in two cells) with corresponding energies of 1 and 2 units. Let the total number of particles remain constant at 8. The minimum energy value will occur when all particles occupy the cell with energy equal to 1.

For the lowest energy state, all particles will be located in the first cell.

For the lowest energy state, all particles are located in the first cell.

$\varepsilon_1 = 8 \cdot 1 + 0 \cdot 2 = 8;$ $w_1 = \frac{8!}{8!0!} = 1;$ $\theta = \frac{\varepsilon_2 - \varepsilon_1}{ln\frac{8}{0}} = \frac{2-1}{\infty} = 0;$ (22)

$\varepsilon_2 = 7 \cdot 1 + 1 \cdot 2 = 9;$ $w_2 = \frac{8!}{7!1!} = 8;$ $\theta = \frac{\varepsilon_2 - \varepsilon_1}{ln\frac{7}{1}} = \frac{1}{\ln 7};$ (23)

$\varepsilon_3 = 6 \cdot 1 + 2 \cdot 2 = 10;$ $w_3 = \frac{8!}{6!2!} = 28;$ $\theta = \frac{\varepsilon_2 - \varepsilon_1}{ln\frac{6}{2}} = \frac{1}{\ln 3};$ (24)

$\varepsilon_4 = 5 \cdot 3 + 3 \cdot 2 = 11;$ $w_4 = \frac{8!}{5!3!} = 56;$ $\theta = \frac{\varepsilon_2 - \varepsilon_1}{ln\frac{5}{3}} = \frac{1}{ln\frac{5}{3}};$ (25)

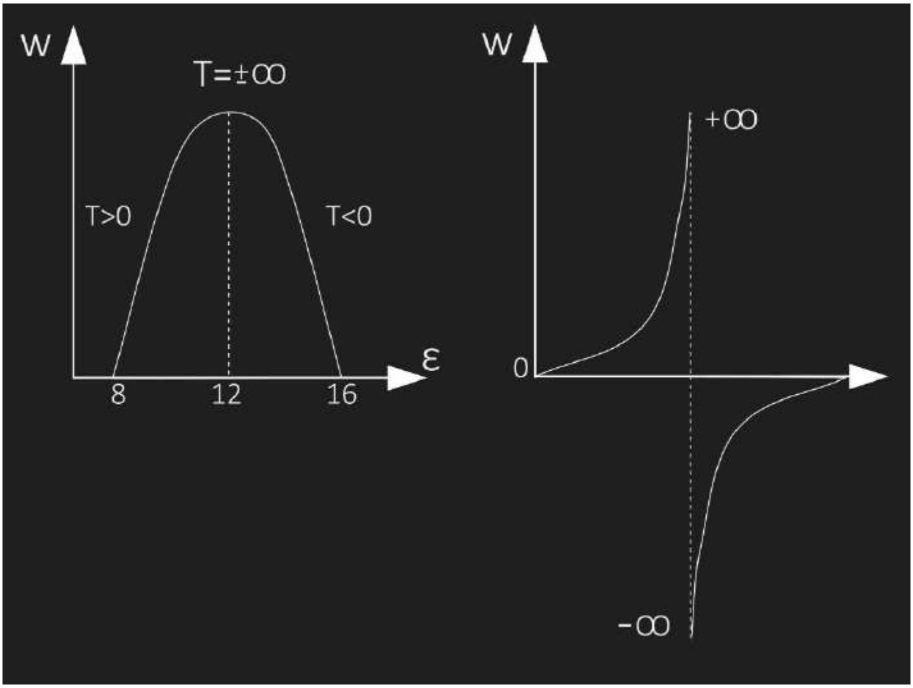
$\varepsilon_5 = 4 \cdot 1 + 4 \cdot 2 = 12;$ $w_5 = \frac{8!}{4!4!} = 56;$ $\theta = \frac{\varepsilon_2 - \varepsilon_1}{ln\frac{4}{4}} = \frac{1}{ln\frac{4}{4}} = \frac{1}{0} = \pm\infty;$ (26)

$\varepsilon_6 = 3 \cdot 1 + 5 \cdot 2 = 13;$ $w_6 = 56;$ $\theta = \frac{1}{ln\frac{5}{3}};$ (27)

$\varepsilon_7 = 3 \cdot 1 + 5 \cdot 2 = 13;$ $w_7 = 28;$ $\theta = \frac{1}{ln\,3};$ (28)

$\varepsilon_8 = 1 \cdot 1 + 7 \cdot 2 = 13;$ $w_8 = 8;$ $\theta = \frac{1}{ln\,7};$ (29)

$\varepsilon_9 = 3 \cdot 1 + 5 \cdot 2 = 13;$ $w_9 = 1;$ $\theta = 0;$ (30)



Now, let us conduct an analysis of the obtained numbers. In state I ($n_1 = 8; n_2 = 0$) the value of θ is zero, which indeed makes sense, because at T=0 conditions, the system has a state where there is no kinetic motion and the energy is minimal. Thus, the probability is minimal and equals one (the thermodynamic probability). Entropy is zero. As temperature increases, higher energy (cell) corresponding particles appear, and their number increases with the rise of T. The probability increases, and entropy also grows. When the distribution of molecules among the cells becomes equal, the probability and entropy reach their maximum. As θ increases indefinitely at higher temperatures, energy continues to increase, and thus entropy and probability start to decrease, which is impossible without considering the sole exception: the system's temperature (θ parameter), if not considered negative. At the beginning of the topic, this discrepancy was presented in classical terms. Finally, at the highest energy, T approaches zero.

The result clearly indicates the possibility of negative absolute temperature (when, in cells with higher energy, $\frac{n_2}{n_1}$ contains more particles than in the lower energy cell). This means that if $ln\frac{n_1}{n_2} < 1$, which is a negative number in mathematics, the transition to negative temperature occurs. As it reaches an infinitely large value, it follows that under negative temperature conditions, the body has higher energy than under positive conditions, i.e., it is higher than positive temperature.

We are left with the conceptual idea of "imaginary" (or antiparticles): particles transform into antiparticles, i.e., particles with negative energy. This makes it clearer how particles are distributed across cells. Indeed, negativity in the beginning involves this concept. If $|T_1| > |T_2|$, it does not necessarily mean that $T_1 > T_2$.

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Using the stochastic optimization method to solve linear and non-linear mathematical programming problems, *Davit Papuashvili, Bachelor Program Student,*

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Abstrac: in the report we will talk about the possibility of using the stochastic optimization method: for solving linear and non-linear problems of mathematical programming. It is known that the mathematical model of many technical and construction objects or structures can be presented as linear and non-linear mathematical programming problems. Therefore, the development of an effective method for solving these types of problems is a very urgent issue. In the report, we will discuss both types of models and try to show the results of their solution.

Introduction

Linear and non-linear mathematical programming methods are used in cases where a special class of problems requires an optimal solution, according to a certain criterion, of course, observing the appropriate restrictions.

The difference between these two optimization methods lies in the fact that the first requires the linearity of the objective function and all constraints, while the second does not require such requirements to be met, i.e. the nonlinear mathematical programming method solves the problem, even when the constraints and the objective function are not linear. To solve linear mathematical programming problems, in most cases, the so-called, the classic method, known as the "simplex" method as mentioned above. An important drawback of this method lies in the complexity and routine of calculations.

There is no single general method for solving non-linear mathematical programming problems, and choosing the appropriate one from the available methods depends on the configuration of the objective function itself, namely its complexity. These difficulties can be: multi-parameter and multi-extremity of the objective function, including the existence of a global extremum, discontinuity of the objective function, the existence of "saddle" and "valley" type points, and many other types of difficulties that created the need for additional measures. Theoretical justification unified general It is logical to create a method that will allow us to solve the above-mentioned problems using one general method, but the unequivocal answer is For cases not yet visited, the following paper is an attempt to overcome the aforementioned difficulties in a relatively simple way and to use the stochastic optimization method to solve both linear and non-linear mathematical programming problems.

1. Formulate a general optimization task.

Let us have an objective function of some object that has the form:

$F(x)=F(x_1, x, \ldots, x_n)$

where $x_1, x_2, \ldots, x_n$ are the parameters of this function and restrictions are placed on them, which can be represented both by equations and in the form of equalities:

$a_{11} x_1 + a_{12} x_2 + \ldots + a_{1n} x_n = b_1$

$a_{21} x_1 + a_{22} x_2 + \ldots + a_{2n} x_n = b_2$

$a_{n1} x_1 + a_{n2} x_2 + \ldots + a_{nn} x_n = b_n$

The task is as follows: to find the extremal value of the objective function and the values of the parameters that ensure the extremal value of the objective function.

To achieve this, the following measures are implemented:

1. At the very beginning, the data for the operation of the method is defined, including all the necessary ones

- objective function f_{max} (x_i, x_2, ..., x_N);

- all available constraints G_j j = 1, 2 ,...M and their number M;

- optimization parameters x_i, i = 1, 2, 3,...,V and their number V;

Stochastic optimization method

Stochastic optimization methods are a class of methods where randomness is used in the process of solving optimization problems, more precisely, optimization variables can be represented as random variables. This particularity allows us to work effectively even in the case of the complex objective function, which was discussed above, and we can add that the objective function may not be differentiable. The positive point of the stochastic optimization method should be noted in detail, which is manifested in the fact that its computer implementation is significantly easier compared to deterministic methods. Let's formulate the essence of the method as follows:

Let us have an objective function of some object that has the form:

$F(x) = F(x_1, x, \ldots, x_n)$,

where x_1, x_2,..., x are the parameters of this function and constraints are imposed on them, which can be represented as equations, or in the form of equalities:

$a_{11} x_1 + a_{12} x_2 + \ldots + a_{1n} x_n = b_1$

$a_{21} x_1 + a_{22} x_2 + \ldots + a_{2n} x_n = b_2$

$a_{n1} x_1 + a_{n2} x_2 + \ldots + a_{nm} x_n = b_n$.

Determine the optimal amount of water cleaned by the water treatment station using the linear mathematical programming method.

Task 1. Suppose we have a water purification station with a certain productivity, from which we need to get two different quality waters for drinking and technical purposes. Water of both quality goes through coagulation and sedimentation processes together. Maximum throughput of appropriate facilities – coagulant farming and sedimentation 3500 m^3/h. Then the water will pass through the filters, the total area of which is 395 m^2. Taking into account the calculated filtration rate, the necessary area of the filter 1 m^3 to filter drinking water is 0.17 m^2 , and to pass technical water 0.07 m^2. After that, drinking water will go through the disinfection process, and technical water will go through the softening process. The conductivity of the chlorinator and the contact pool required for water disinfection is 2000 m^3/h, and the conductivity of the facilities where technical water is softened is 2500 m^3/h.

It Is required to determine the amount of drinking and technical water that provides the maximum income of the aqueduct farm without the reconstruction of the said structures. 1 m^3, the selling price of drinking water is 0.037 lari, and technical water is 0.028 lari.

After everything mentioned above, the mathematical model of the research object can be written as follows:

$x_1 + x_2 \leq 3500$

$0.17\, x_1 + 0.07\, x_2 \leq 395$

$0 \leq x_1 \leq 2000$

$0 \leq x_2 \leq 2500$

Somewhere x_1 and x_2 noted the quantities of purified drinking water and purified technical water respectively, which are not quantities. Must be negative

The objective function, taking into account the revenues of the waterworks farm and whose maximum value we are looking for, is written in the following form:

$f=0.037\, x_1 + 0.028.\ x_2 \to max$

Problem (1), (2) is a problem of linear mathematical programming, in this case, due to its simplicity, the problem can be solved graphically, analytically, as well as using the simplex method, it is also easy to solve it using the applied program Wolfram, we will use the latter. (1) The solution of the first two equations of the system of equations is written as follows:

In[1]:= Solve [{ x_1 + x_2 = 3500, 0.17 x_1+0.07 x_2=395}, {x_1, x_2}]

Out[1]= {{x_1 is 1500 ., x_2 is 2000.}}

If we put numbers from second formula we will get:

in[1]= f=0.037 * 1500+0.028 * 2000

out[1]= **111.5**

The obtained value of f represents the optimal solution of the given task. Fig. Picture shows the block diagram of the implementation of the stochastic optimization method in general.

Plot[{3500-x_1, (395-0.17 x_1) / 0.07 , (111.5-0.037 x_1) / 0.028, 2500), {x_1, 0, 2000}]

The computer program for solving problem using the stochastic optimization method is given below:

```
Private Sub Command1_Click()
‘Wyalsadenis gaangarisheba
Dim AA(2), BB(2), X(2), XM(2), G(4) As Single
AA(1) = 0
BB(1) = 2000
AA(2) = 0
BB(2) = 2500
N = 2
M = 4
S = 1000000
RMAX = 0
 For J-1 To S
 For I = 1 To N
 X(I) = AA(I) + (BB(I) – AA(I)) * Rnd()
 Next I
 G(1) = 2000-X(1)
 G(2) = 2500-X(2)
 G(3) = 3500-(X(1) +X(2))
 G(4) = 395-(0.17 * X(1) + 0.07 * X(2))
 L = 0
 For k = 1 To M
```

```
  If G(k) >= 0 Then
  L = L + 1
  Else
  End If
  Next k
  If L = M Then
  F = 0.037 * X(1) +0.028 * X(2)
  IF F > RMAX Then
  RMAX = F
  For I = 1 To N
  XM(I) = X(1)
  Print "XM(1)="; XM(1), "XM(2)-"; XM(2), "RMAX="; RMAX
  Else
  End If
   Else
   End If
   Next J
   Print "OPTIMUM"
   Print "XM(1)-"; XM(1), "XM(2)="; XM(2), "RMAX="; RMAX
End Sub
```

Determining the optimal parameters of a cylindrical pole with an annular cross-section using the non-linear mathematical programming method.

1. **The goal of optimization** is to determine the values of parameters R and t, which ensure the minimum bone weight G-min. In the presence of restrictions on tension, stability, Vill force of loss of stability, as well as local bulge [1] The geometrical parameters of the cross section are: area of the base

$A = \pi(R+ t)^2 - \pi R^2 = \pi(2Rt +t^2),$

Where **A** is the area of the base, **R**- is the inner diameter of the cylinder, **t**- is the wall thickness of the cylinder.

It is advisable to proceed in such a way that at each stage of each conducted test, the amount of information about the construction should be clear, that is, to exclude unsatisfactory design. Let it grow. At the same time, it is necessary to have options that will be revealed

Thus, it is necessary to agree on the generation of multiple variants of the two trends and to prune the identified unwanted sets. The design procedure proposed below is analogous to a nonlinear mathematical programming problem, where a random search method is used to find the global extremum of a complex objective function.

Numerical values and solution of problem 2:

$\sigma_y = 36.10^3$ lb/in ^{2}, E=3,10 ^{7} lb/in ^{2}, specific gravity factor

$\rho g = 0.283$ lb/in ^{3}, factor k=0.6 for steel, L=144 in., P=25.10 ^{3} lb.

The computer implementation program of the method in the algorithmic language **Visual Basic** is presented below

```
Private Sub Command1_Click()
Dim L As Single, N As Single, M As Single, c As Single,
Gmin As Single, R1 As Single, R2 As Single, t1 As Single,
T2 As Single, scg1 As Single, scg As Single, E As Single,
Q As Single, P As Single, AA(2) As Single, BB(2) As Single,
X(2) As Single, g(6) As Single, scg2 As Single, XM(2) As Single,
k1 As Single, k As Integer, rog As Single, PP As Single
rog = 0.283
L = 144
N = 2
M = 4
c = 32000
Gmin = 30000
E = 30000000

K1 = 0.6
R1 = 4
R2 = 5
t1 = 2
scg1 = 36000
pi = 3.14
```

```
q1 = 25000

Open ”c:\cilindri.txt“ For Output As #2

AA(1) = R1

BB(1) = R2

AA(2) = t1

BB(2) = t2

For J = 1 to c

For i = 1 to N

x(i) = AA(i) + (BB(i) -  AA(i)) * Rnd

Next i

g(1) = x(1) – R1

g(2) = R2 – x(1)

g(3) = x(2) – t1

g(4) = t2 – x(2)

scg = k1 * E * x(2) / x(1) ^ 2

g(5) = scg - scg1

q = 2 * 3.14 * k1 * E * x(2)  ^  2

g(6) = q - q1

ii = 0

For k = 1 To M

If g(k) >= 0 Then ii = ii + 1
```

```
Next k
If ii = M Then
PP=2 * 3.14 * x(1  ) * x(2) + x(2) ^ 2 * L* rog
If PP < Gmin Then
Gmin = PP
For i = 1 To N
XM(i) = x(i)
Next
Print "Gmin="; Gmin "R="; x(1); "t="; x(2)
Gmin = Gmin: R = x(1): t = x(2)
Write #2, Gmin, R, t
Else
End If
End If
Next J
Print "option"
Print "Gmin="; Gmin "R="; R "t="; t

End Sub
```

1. Stochastic methods of optimization are used to solve multi-dimensional (multi-parameter), multi-extremum, including global extremum problems.
   Their use is appropriate also in the case when the optimization function is not differentiable or its analytical form is unknown but calculable.

2. The merit of the mentioned method can be considered such an important feature as stability to ill-defined functions of the "valley type", as well as finding the extreme value of the "saddle type".

3. Computer (software) implementation of stochastic methods of optimization is significantly simpler compared to deterministic methods, and finally

4. Existing methods for solving non-linear problems are strictly individual and require a different approach in a particular case, depending on the characteristics of the objective function. This circumstance was caused by the insufficient power and capabilities of computers, on the one hand, and the lack of perfect mathematical methods on the other hand. To find the global extrema of a complex configuration objective function. The use of a stochastic method of optimization is most likely to become the basis for the creation of a unified method, but at this time it will be necessary to provide the initial data, the calculation of the constraints and their verification, as well as the easy input of the image of the objective function into the computer in the form of standard functions or subroutines, even at the level where it is implemented in practice. A program to match Wolfram's statistical method.

5. An important positive feature of the presented stochastic optimization method is that the Visual Basic program is compatible with such popular programs as Excel and Visual Studio. All this makes it easy to use for students and other users.

The algorithm of the animation model of the pole is presented as follows:

Line (m, n)-(m+t, n-L), vbBlue, B

Line (m+t+2* R, n)-(m + 2* (t+R), n - L), vbBlue, B

Line (m+t, n)-(m+t+2*R, n)

Line (m + t, n – L) –(m+t+2*R, n – L)

The algorithm of the animation model is presented below:

```
Private Sub Command1_Click()

Dim m As Single, n As Single, t As Single, R As Single, L As Single,

G As Single, Gopt As Single

Scale (-144, 30)-(144, -30)

Draw Width = 2

M = 0

N = 25

T = 2.533424

R = 4.705547

G = 336.4208
```

```
L = 20

FillStyle = 4

Line (m, n) – (m + t, n – L) vbBlue, B

Line (m+t+2^ * R,n)-(m+2^ * (t + R) ,n-L), vbBlue, B

Line (m + t, n) –(m+t+2^ * R,n)

Line (m + t, n – L) –(m+t+2^ * R,n-L)

FillStyle = 0

Circle ( (m + t + R, - 2) R

FillStyle = 4

Circle m + t + R, - 2 ), R + t

Print" "

Print" "

Print" "

Print" "

Print" "

Print " G =" ; G ;" R =" ; R ; "t=" ;t

Draw Width = 2

M = 25

N = 25

T = 2.000565

R = 4.886845
```

```
Gmin213.4343

L = 20

FillStyle = 4

Line (m, n) – (m + t, n – L) vbBlue, B

Line (m+t+2^ * R,n)-(m+2^ * (t + R) ,n-L), vbBlue, B

Line (m + t, n) –(m+t+2^ * R,n)

Line (m + t, n – L) –(m+t+2^ * R,n-L)

FillStyle = 0

Circle (m + t + R, -2), R

FillStyle = 4

Circle (m + t + R, -2), R+t

Print " "

Print " "


Print" "

Print " "

Print " "

Print " "

Print " "

Print "Gmin="; Gmin; "Ropt="; R; "topt=";t

End Sub
```

Conclusion

The paper shows the use of the stochastic optimization method for solving linear and non-linear mathematical programming problems. When using this method, it is not necessary to know exactly the nature of the objective function. Computer experiments indicate that the results calculated by the stochastic method of optimization and their comparison with the results calculated by the methods of other well-known authors (Zohtendaik, Frank-Wolf, Kuna-Tucker and others) show that the results obtained by different methods and the results obtained by the stochastic method of optimization coincide with each other, with acceptable accuracy in engineering practice. The above-mentioned approach is implemented in the algorithmic language Visual Basic. The program is quite simple to implement compared to other deterministic methods. Combining them with Excel and Visual Studio is easy and does not involve special difficulties and is convenient for both students and other interested people.

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Abstract: Georgia, as a post-Soviet country with a transitional economy and a pro-Western orientation, still faces numerous challenges in the field of occupational safety. Following the country's independence, socio-economic changes have made the development of occupational safety policies a significant priority, particularly in sectors such as construction. This sector, being one of the most dynamic and growing areas of the economy, places special emphasis on adhering to safety standards.
Key Words: Construction Management, Safety Regulations, Safety Standards, Safety Management Systems.

Introduction

In Georgia, the deregulation policy initiated in 2006 significantly weakened state supervisory mechanisms, leading to legal and institutional gaps. Nevertheless, since 2015, within the framework of the Association Agreement with the European Union and with the support of international donors, occupational safety standards have been gradually strengthened. This progress includes improvements in supervisory systems, refinement of technical regulations, and the establishment of fundamental norms.

However, the practical enforcement of occupational safety standards in the construction sector remains a challenge. Inadequate safety standards pose risks to workers' health and lives, as well as to the sustainable development of the sector. Occupational safety is not merely a technical issue but is closely linked to fundamental human rights, such as the protection of life, health, and dignity.

The process of European integration and the adoption of international best practices provide Georgia with a significant resource. However, it is crucial to adapt these practices to local realities. The introduction of high standards in the construction sector will not only enhance worker safety but also promote economic growth and sustainable development.

The aim of this research is to analyze the current state of occupational safety in Georgia's construction sector, identify key challenges, and propose solutions. The focus will be placed on state policies, the implementation of legislation, and the application of international experience.

Main Part

Based on given research, I would like to highlight some challenges frequently encountered in the construction sector in Georgia regarding occupational safety.

With my opinion, the first and most significant issue is the inadequate assessment of risks. Due to this problem, hazards in workspaces are not properly identified. This issue impacts employees' health and safety while also reducing management's ability to exercise effective control.

On construction sites, there is a problem with infrastructure that does not comply with established standards. Companies do not provide employees with factory-produced work equipment. Non-standardized infrastructure poses a significant risk of physical injuries during the work process.

Employees consider safety equipment to be uncomfortable and physically inconvenient during work. For this reason, they often avoid using personal protective equipment (PPE) during the work process. Neglecting safety equipment by employees has repeatedly led to fatal incidents on construction sites in Georgia. Such incidents not only damage the employer’s reputation but also result in financial penalties for the company.

In Georgia, awareness of safety standards is not sufficiently elevated. Companies do not provide employee training or workshops. Without instructions and training, safety standards are not absorbed, and employees fail to understand why compliance with regulations is essential.

This list represents only a small portion of the issues faced in Georgia today. To better understand these challenges, I visited several construction sites. During these visits, I collected photographic material, which I will share in the article. I am also sharing the results of an interview conducted with a qualified occupational safety inspector. This interview outlines the steps necessary to improve the situation.

· **How would you evaluate compliance with occupational safety standards in the construction sector in Georgia?**

- On a scale of 1 to 10, I would rate it a 4. Companies avoid incurring additional costs. Tender documentation does not account for expenses related to occupational safety, which makes such costs unexpected for companies.

· **What are the most common violations encountered during work processes?**

- Open spaces at heights without protective railings, unprotected openings, partial provision of personal protective equipment (PPE) for employees, indifferent attitudes from supervisors, or their inability to allocate time to rectify safety violations. A shortage of workforce and high turnover rates, along with employers' reluctance to invest in protective equipment. Employers also lack awareness of the importance of these issues.

· **What is the biggest challenge in terms of occupational safety on construction sites, in your experience?**

- Raising employers' awareness and securing the necessary funding. Partially, raising employees' awareness is also needed. They often claim that working with full PPE is uncomfortable.

· Do you think Georgian legislation sufficiently addresses occupational safety standards?

- Georgia has fulfilled its obligations stemming from its association with the European Union. Based on EU directives, Georgia has gradually developed safety standards and regulations since 2014. However, we still have a long way to go to align with international norms. EU directives include sub-standards that are more in-depth and detailed. These are yet to be fully adopted here. It is time to work towards achieving this.

· In what areas do you see the need for improvement from the government?

- More detailed technical regulations are needed. Additionally, there are not enough inspectors to actively monitor all construction sites. When inspections do take place, companies become more mobilized and try their best to follow the instructions provided by inspection services. Otherwise, companies face financial sanctions.

· How often are international standards considered in local practices?

- International standards are rarely or not directly applied. However, our regulations are based on EU directives. International standards are only used if there is no equivalent regulation developed and enforced in Georgia. I personally had to refer to an international standard only once when a local equivalent was unavailable.

· How engaged are inspectors in providing training and consultations for construction companies?

- Minimally. Over the past three years, inspectors visited one of my sites for this purpose only once.

· What steps should the private sector take to ensure occupational safety?

- The private sector should hire professional occupational safety managers or specialists and must strictly follow the instructions they provide.

• How do you see the development of construction safety over the next 5-10 years?

- At the current pace of development, I believe significant progress will be made in 5-10 years, and we will achieve much better results. However, to get closer to international standards, more effort is required from both the government (e.g., detailed regulations, monitoring their implementation) and companies and employees.

Conclusion

Based on given research, it can be said that improper risk assessment, inadequate infrastructure on sites, the non-use of Personal Protective Equipment (PPE), lack of information in the industry, the use of faulty equipment on sites, and other issues are not properly controlled in Georgia, which creates problems for both employees and employers.

In conclusion, it can be said that in order to solve these problems, both the government and the private sector must take joint steps. Let's ask the question: where should we start? It is important to explore European countries that have been operating in this field for a long time, as they have accumulated experience and achieved positive results in the field of labor safety.

We should study the guidelines of European countries and adapt them to our reality to achieve the best results. The government should fund labor safety training courses so that information is more accessible to the public, and awareness in this area is raised.

The government should strengthen regular monitoring and any identified issues should be penalized with financial fines. Joint effort is crucial to solve the problems and further develop this sector.

Through sharing international experiences, and implementing serious and consistent changes, it will be possible to improve labor safety standards in the construction sector and create a safer and more effective working environment.

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How Was Venice Built: An Engineering Marvel, *Kakhi*

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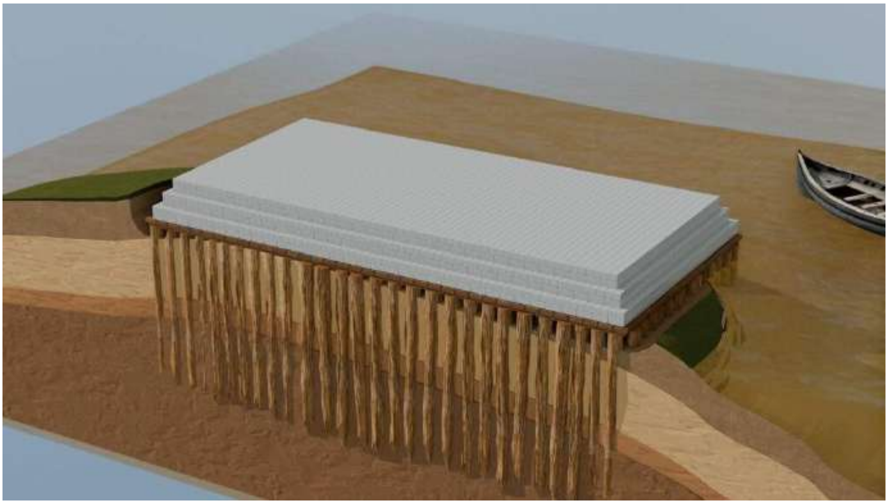
Hisroty

Imagine a city that stands not only on land but also on water—a city that withstands sea waves and natural challenges for centuries. That city is Venice, a fusion of tradition and modern technology. Before we explore the connection between Venice's construction and engineering achievements with future engineering advancements, it’s important to analyze how Venetian engineers and architects achieved sustainability and remarkable stability despite the city's location.

The history of Venice begins in the 5th century when the population moved to the lagoon in search of a protected area to defend themselves from barbarian invasions. Venice is located in northeastern Italy, in the Adriatic Sea lagoon. The city is built on water and is one of the most unique cities in the world, with its entire infrastructure situated on the water’s surface.

An Innovative Foundation: Anchoring the Floating City

In the construction process, wooden piles were first used, driven deep into the mud (about 4-5 meters) until they reached solid clay layers, which provided stability. Despite being made of wood, these underwater piles did not rot due to the lack of oxygen, which prevented decomposition. Over time, the wooden piles naturally hardened in the water as minerals in the water reinforced them. On top of these piles, special stones (Istrian Stone) were placed to create building foundations that stood above the water level. This layer formed a solid base for structures and protected the wooden piles from seawater erosion. This stone was highly durable and provided a stable surface to reduce the weight of the building and prevent sinking or distortion.

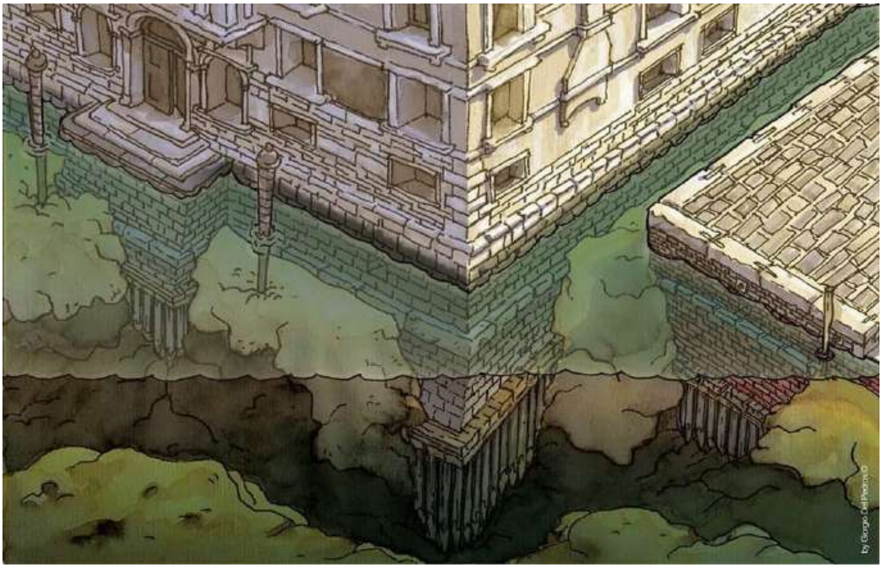


The Rise of Venice's Buildings

After establishing a solid foundation, the buildings were constructed using bricks. Bricks were practical and relatively lightweight, providing good thermal insulation and strength. They were widely used in Venice because they could be locally produced, ensuring a steady supply. Interestingly, during that time, a mixture of lime, sand, and water was used as mortar, which made the buildings lighter. Additionally, external walls were coated with plaster and mineral mixtures to protect them from moisture. For decorative purposes, buildings were often adorned with marble. Marble was a highly valued material in Venice, especially for its aesthetic appeal. However, due to its vulnerability to saltwater damage, it was primarily used in the upper parts of buildings where it had minimal contact with water.

Canals and Bridges

It's worth noting that Venice is a city spread across 118 small islands, making bridges essential to connect them. The city's main canal, shaped like an "S," links Venice's key districts. Several famous bridges span this canal, including the Rialto Bridge. The earliest Venetian bridges were simple wooden structures built to connect the islands. However, wooden bridges were susceptible to damage from saltwater and weather, necessitating regular repairs or replacements.



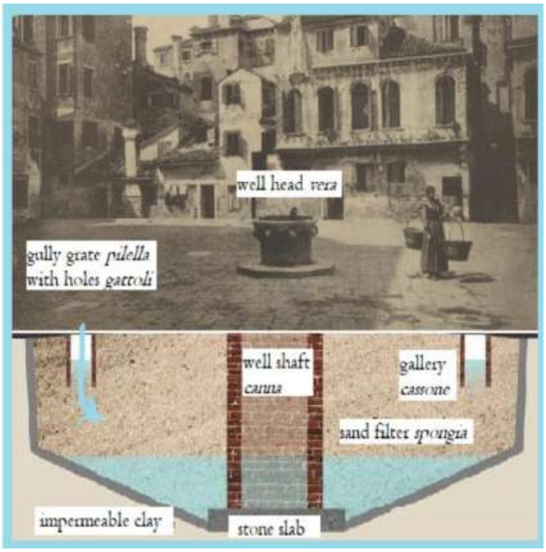
Over time, as engineering and economics advanced, wooden bridges were replaced with stone bridges. Stone bridges were not only more durable but also aesthetically impressive. Their construction required sophisticated engineering and architectural skills. Special attention was given to accommodating boat traffic and ensuring canal stability.

Challenges and Drawbacks

Venice faced many challenges, including a lack of freshwater and waste management. Situated in a saline lagoon without rivers or lakes, and with salty, undrinkable groundwater, Venetians had to develop innovative systems to address these issues. Rainwater became the primary source of drinking water. Systems installed on rooftops and in public spaces collected rainwater. For example, in places like St. Mark's Square, special stone-paved surfaces were designed to collect rainwater, which would flow through filter-like layers of sand and stone and accumulate in underground cisterns.

These cisterns were protected with thick clay linings to ensure they were watertight. Public wells were located across the city, totaling around 600, and served as key points for water access.

Waste management was another significant issue. The city's narrow streets, dense population, and waterways required innovative approaches to manage waste and protect the environment. Initially, Venetians discarded waste directly into the streets, leading to pollution and health problems, including epidemics. To address this, an underground tunnel system was built to collect waste from buildings and discharge it into the canals. These tunnels were constructed approximately one meter below the water level, allowing solid waste to settle in the lower sections while liquids flowed naturally into the canals.



Larger canals, such as the Grand Canal, carried waste to the open sea. However, smaller canals required periodic cleaning to prevent waste buildup and odor.

Nowdays

Although modern engineering has advanced significantly, Venice's approaches to sustainability, water management, and soil stabilization remain relevant for contemporary projects. Venice's experience demonstrates the importance of sustainable and eco-friendly technologies in today's world. Additionally, rising sea levels pose a serious global challenge, making floating cities a potential solution. Countries like the Netherlands are already working on such projects. "The Floating Neighborhood" is one of the most notable projects in the Netherlands, aimed at creating sustainable living environments. This project features floating houses built on special platforms designed to adapt to water dynamics.

To ensure these houses float effectively, materials like concrete, wood, and glass are used. For example, "Frozen Concrete" is water-resistant and often used for floating house platforms. Hydraulic concrete is another type that minimizes water damage and serves as a structural material. Floating houses are typically designed with lightweight structures to ensure stability and durability.

Both Venice and the Netherlands are water-based cities, and their engineering solutions share similarities. While the Netherlands incorporates new technologies like waterproof systems and energy-efficient designs, Venice offers traditional yet sustainable solutions.

Engineering and architecture continue to draw inspiration from Venice's experience in addressing water-related stability and sustainability challenges. Modern innovations prove that these approaches can be adapted and improved for contemporary needs. Venice remains a unique cultural and architectural heritage site, offering valuable lessons for urban design and sustainable engineering in cities worldwide.

About one task related to Friction, *Mea Tkemaladze, Bachelor Program Student, tkemaladze.mea22@gtu.ge, Supervisor: Levan Jikidze, Associate Professor, l.jikidze@gtu.ge*

Annotation

The task investigates the equilibrium of a vertically bent beam with friction taken into account, which serves as an example of a commonly used self-locking mechanism in practice.
The problem is solved using two methods: analytical and geometrical. Two cases are considered: one where the weight of the beam is neglected and another where it is taken into account. In both cases, the critical width of the beam, at which equilibrium is maintained, is determined. It is established that if there is no friction, the equilibrium of the beam is impossible. A correlation is derived that links the critical width of the beam to the coefficient of friction.

About one task related to Friction

Our surrounding world is full of physical phenomena: thunder and lightning, rain and hail, electric current, and more. Among these, friction stands out as one of the most common natural phenomena, playing a crucial role in technology. However, due to the mechanical nature of friction and the complexity of numerous factors influencing it, precise and universal laws governing friction have not yet been established.

In 1883, the renowned Russian engineer and scientist Nikolai Petrov wrote:
"Frictional force is always and everywhere observable. It should be ranked among the most powerful mechanisms through which nature transforms one form of energy into another, gradually replacing them with thermal energy. This force manifests in a wide variety of natural phenomena, sparking interest among scientists in multiple disciplines. Understanding

the laws of friction is essential for astronomers, physicists, engineers, and physiologists."

The experimental study of friction laws was first initiated by Leonardo da Vinci (1452–1519). Through a series of experiments, he established that the frictional resistance of a rope is the same, whether stretched or coiled. He argued that frictional force, arising when one body's surface comes into contact with another, is proportional to the load (normal force), directed opposite to motion, and independent of the contact area.

Approximately 180 years later, Guillaume Amontons (1663–1705) and Charles Coulomb (1736–1806) expanded upon Leonardo's findings. They introduced the concept of the coefficient of friction and defined the principles governing frictional force.

By the end of the 19th century, the study of friction in fluids (viscosity) became increasingly significant. In 1886, Osborne Reynolds (1842–1912) developed the theory of lubrication, laying the groundwork for the advancement of hydrodynamic lubrication.

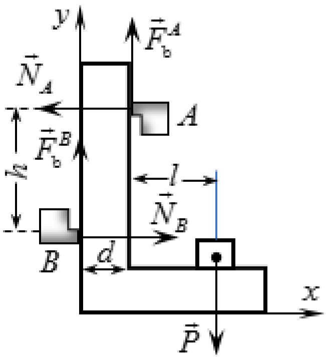
As mentioned, friction is one of the most widespread natural phenomena, playing a vital role in technology. Yet, due to the complexity of the mechanical processes and numerous factors influencing it, universal laws fully describing this phenomenon have not been determined to date.

In practice, when high precision is unnecessary, empirical laws established by Amontons and Coulomb are used to determine frictional force. However, it is important to note that these laws only partially reflect real processes.

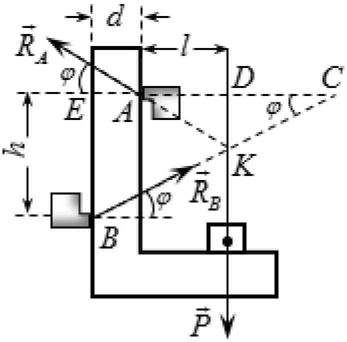
When the determination of frictional force requires exceptional precision, experimental methods are employed. These experiments account for specific pairs of interacting surfaces and the corresponding conditions of friction.

Let us now consider a practical example involving a commonly used self-locking mechanism.

A beam bent at a right angle with its vertical part rests on two supports, A and B, with the distance between them along the vertical direction equal to h . Neglect the weight of the beam and determine the value of the width d for which the beam will maintain equilibrium for any position of the load placed on its horizontal part, assuming the coefficient of friction on the supports is equal to f .



ნახ.1



ნახ. 2

Let the weight of the load be denoted by $\vec{P}$, and the distance from the load to the vertical part of the beam be l . Consider the beam's marginal equilibrium, for which its width is $d = d_{ზღ}$.. In this position, the beam experiences $\vec{P}$, $\vec{N}_A$, $\vec{F}_{ს}^{A}$, $\vec{N}_B$, $\vec{F}_{ს}^{B}$ forces, where $\vec{F}_{ს}^{A}$ and $\vec{F}_{ს}^{B}$ are the limiting magnitudes of the frictional forces generated at points A and **B**, respectively (see Figure 1). If we set up the equilibrium equations, where the moments of the forces are calculated with respect to point **A**, we will obtain:

$$N_A - N_B = 0, \qquad F_{ს}^{A} + F_{ს}^{B} - P = 0, \qquad N_B \cdot h - F_{ს}^{B} \cdot d_{ზღ} - P \cdot l = 0,$$
(1)

Where $F_{ს}^{A} = fN_A$, $F_{ს}^{B} = fN_B$., from the first two equations, we find that:

$$N_A = N_B \equiv N, \quad P = F_{ს}^{A} + F_{ს}^{B} = fN_A + fN_B = 2fN. \qquad (2)$$

If we substitute the values from equation (2) into the third equation of (1) and simplify for **N** , we will get:

$$h - fd_{\text{ზღ}} - 2fl = 0,$$

From which, for the limiting value of the beam's width $d_{\text{ზღ}}$, the following expression is obtained:

$$d_{\text{ზღ}} = \frac{h}{f} - 2l. \tag{3}$$

The equation (3) could also be derived geometrically. For this, instead of the normal reactions and friction forces at points A and B , we introduce the total reactions $\vec{R}_A$ and $\vec{R}_B$ forces, which, in the position of limiting equilibrium, would be tilted by the friction angle φ from the normal (see Figure 2). In the state of equilibrium of the beam, the lines of action of the $\vec{R}_A$, $\vec{R}_B$ and $\vec{P}$ forces intersect at point K. Through simple geometric transformations and mathematical reasoning, we reach the conclusion that:

$$AD = DC = l, \quad EC = EA + 2AD = d_{\text{ზღ}} + 2l,$$

$$\Delta CEB\text{-ში } tg\varphi = \frac{BE}{EC} = \frac{h}{d_{\text{ზღ}} + 2l}.$$

If we take into account that $tg\varphi = f$, , then from the final equation we can easily find that:

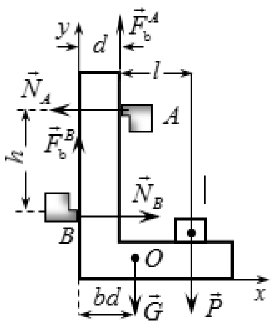
$$d_{\text{ზღ}} = \frac{h}{f} - 2l. \tag{4}$$

Let’s analyze the obtained result. If we reduce the coefficient of friction f to zero in equation (4), then its right-hand side will increase infinitely. Accordingly, equilibrium is possible for any $d > d_{\text{ზღ}}$. In turn, it takes its maximum value when $l = 0.$, meaning the beam will be in equilibrium for any position of the load (when $l \geq 0$), provided that the following inequality holds:

$$d \geq \frac{h}{f}.$$

The smaller the friction, the larger the beam's width d must be. If there is no friction ($f = 0$), it is clear that the equilibrium of the beam is impossible, as it leads to the conclusion that $d = \infty$. must be greater than zero.

Let's consider the case where the weight of the beam is taken into account, and the weight of the load is proportional to the weight of the beam. Let's say that the weight of the beam is located at the point O, and the weight of the load is at the point $P = kG$.. If we also set up the equilibrium equations in this case, we will obtain:



ნახ. 3

$$N_A - N_B = 0, \quad F_{\text{ხ}}^{A} + F_{\text{ხ}}^{B} - G - P = 0, \qquad (5)$$

$$N_B \cdot h - F_{\text{ხ}}^{B} \cdot d_{\text{ზღ}} - G(b-1)d_{\text{ზღ}} - P \cdot l = 0. \quad (6)$$

From equation (5), considering that $P = kG$, , we will obtain:

$$N_A = N_B \equiv N, \qquad N = \frac{(1+k)G}{2f}.$$

If we substitute the obtained values into equation (6), then, with simple mathematical transformations, the following expression will be obtained for the critical value of the beam's width:

$$d_{ზღ} = \frac{1}{3+k-2b}\left[(1+k)\frac{h}{f} - 2kl\right].$$

As the obtained result shows, in all cases, if friction is not considered, the equilibrium of the beam is impossible. The smaller the friction, the greater the value of $d_{ზღ}$, which, in the case under consideration, will depend on where the center of gravity of the beam is located and the relationship between the weights of the beam and the load.

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Advantages of Vehicle Gasification, *Nikoloz Utmelidze, Bachelor Program Student, Utmelidze.nikoloz24@gtu.ge, Supervisor: Evtikhi Machavariani, Professor*

Introduction

The use of compressed natural gas (CNG) as a vehicle fuel brings economic and environmental benefits to many countries. In the United States, CNG usage contributes to energy independence and emissions reduction. In Italy, where natural gas infrastructure is well-developed, CNG reduces fuel costs and environmental impact. China actively develops its natural gas sector to combat air pollution and improve ecological conditions.

In Georgia, despite the limited adoption of vehicle gasification, there is potential for development in this direction, which could lead to both economic and environmental benefits.

The experiences of these countries demonstrate that the use of natural gas as a vehicle fuel reduces environmental impact, costs, and reliance on petroleum, which is crucial for global sustainable development.

Purpose of the Research

The advantages of using compressed natural gas (CNG) in various countries illustrate that ecological and economic benefits can be achieved through vehicle gasification. This research aims to explore the following issues:

1. Environmental Benefits: How CNG helps reduce air pollution in countries like China and Georgia, where environmental challenges are particularly pressing.
2. Economic Efficiency: Analyzing the experience of countries like the United States and Italy to understand how CNG impacts fuel cost reduction, important for both individual consumers and governments.
3. Infrastructure Challenges: Examining CNG infrastructure in countries like Iran and Pakistan, where natural gas is a primary energy source.
4. Raising Public Awareness: Strategies to attract more users to natural gas, increasing its popularity and reducing dependence on petroleum.
5. Global Sustainable Development: How CNG contributes to global goals like environmental protection, energy security, and combating climate chang

Research

In Pakistan, vehicle gasification is a significant step in environmental protection. The government implements initiatives such as banning diesel fuel for small and medium vehicles in eco-friendly areas, restricting diesel vehicles, and offering favorable loans for transitioning to natural gas. These measures have significantly reduced air pollution and promote green energy use.

Advantages:

- Environmental protection: Improved air quality.
- Economic benefits for users: Natural gas is cheaper.

Disadvantages:

- Financial barriers: Implementing new technologies can be costly.
- Infrastructure issues: Requires development of fueling stations.

In Iran, vehicle gasification plays a vital role in environmental protection and enhancing energy efficiency. The government supports natural gas usage, contributing to cleaner air and more efficient energy consumption.

Advantages:

- Energy efficiency: Natural gas is more efficient and cheaper, enabling users to reduce fuel costs.
- Tax benefits: Exemptions on imported gas equipment encourage green technology adoption and economic diversification.

Disadvantages:

- Technological challenges: Implementing and maintaining the technology for transitioning vehicles to natural gas can be complex and expensive.
- Lack of public awareness: Consumers may not be informed about the benefits of natural gas, hindering widespread adoption.

Additional Advantage:

- Industrial benefits: Industrial facilities using natural gas may receive preferences in municipal contracts, promoting green technology adoption

In Italy, vehicle gasification represents a significant step toward environmental protection and energy efficiency improvement. The government actively promotes natural gas usage, positively impacting air quality and energy resources.

Natural gas emits fewer harmful substances, positively affecting air pollution reduction. Additionally, its use is economically more efficient due to lower costs, reducing fuel expenses. Industrial facilities using natural gas may also receive municipal contract preferences.

However, developing the network of natural gas stations requires investment. Transitioning vehicles to natural gas can be expensive and technologically challenging, posing a serious issue.

Despite these challenges, Italy continues to actively seek the development of its natural gas system, supporting environmental protection, energy security, and economic sustainability.

In China, the use of natural gas vehicles contributes to both environmental protection and energy independence. By 2025, China aims to increase the number of natural gas stations to 13,000 and natural gas vehicles to 10

million. This will be a significant step toward environmental protection and energy efficiency improvement. Natural gas releases fewer harmful substances, significantly reducing air pollution levels in the country.
The Chinese government's initiatives, such as developing gas stations and subsidies for gas-powered vehicles, contribute to environmental improvement, fuel cost reduction, and the country's economic stability. These initiatives reflect China's energy policy, aimed at enhancing green technology and energy efficiency.

In the United States, the use of natural gas vehicles plays a significant role in environmental protection and energy efficiency improvement. Natural gas pollutes the air less, improving air quality and protecting the environment. Additionally, it is more energy-efficient and cheaper, reducing fuel costs.
Allowing natural gas vehicles in protected areas and settlements, without restrictions based on odd and even days or seasonal limitations, helps reduce pollution in cities and ecologically important zones. This policy is considered an additional step toward environmental protection.

As a local resource, natural gas reduces dependence on imports and promotes economic stability. However, building new stations and implementing technologies require significant investments.
Enforcing these regulations and promoting natural gas vehicles support the development of sustainable energy policies and environmental improvement.

In Tbilisi, Georgia's capital, the ongoing development of the public transportation system is gradually transitioning to compressed natural gas (CNG)-powered buses. This initiative aims to improve the city's ecological conditions, as CNG-powered transportation generates significantly less toxic emissions compared to diesel- or gasoline-powered vehicles.
The use of CNG buses in Tbilisi is part of the modernization of municipal transportation, with the main goal of introducing low-emission vehicles. This positively impacts the city's air quality, addressing environmental issues. Additionally, these buses are notable for their quiet operation and economic efficiency.
The Georgian government and various international organizations actively work to introduce more eco-friendly technologies in public transport. Consequently, the city plans to prioritize not only CNG buses

but also electric buses, offering citizens cleaner, safer, and more comfortable travel options.

 

Conclusion

After an extensive and detailed discussion, it can be stated that vehicle gasification is an essential step in both environmental protection and energy efficiency. Initiatives already implemented in countries such as Pakistan, Iran, Italy, China, the United States, and Georgia demonstrate that using natural gas significantly reduces air pollution, promotes energy efficiency, and supports economic sustainability.

The experiences of Western and Eastern countries show that natural gas is cost-effective, environmentally friendly, and energy-efficient. For instance, China's goals and investments in developing gas stations improve air quality, while promoting natural gas vehicles in the United States reduces urban pollution levels.

However, implementing this process requires significant investments, the introduction of new technologies, and infrastructure upgrades, often posing financial challenges. Infrastructure needs, such as setting up gas refueling stations, also significantly affect the pace of gasification in certain countries.

As a result, despite these challenges, vehicle gasification remains a vital step toward environmental protection, economic efficiency, and energy security. The success of these initiatives depends on the effective introduction of technologies, collaboration between public and private sectors, and raising public awareness to achieve broader adoption of natural gas and environmental goals.

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Strengthening Building Structures with External Reinforcement Systems,

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Abstract: This paper discusses the strengthening of construction structures using external reinforcement systems made from basalt and carbon composite strips and laminates. Due to their exceptional mechanical strength, high thermal and chemical resistance, such composite materials are gradually occupying a significant place in the construction industry. Various strengthening methods are described, and the advantages of using composite materials over traditional external reinforcement systems are justified.

Introduction

Currently, more than 10,000 civil, industrial, and cultural buildings in Georgia are in critical condition, requiring reconstruction and strengthening rehabilitation work worth billions of Lari. The reconstruction process involves changing the original design schemes of the load-bearing structures, necessitating their strengthening. This process includes increasing the load-bearing capacity of damaged structures or their elements, achieved through the modification of structures or the strengthening of existing ones using external reinforcement systems, which require reinforcement, concrete, cement, formwork, scaffolding, etc. This area is referred to as "dirty" work, leading to increases in the geometric dimensions of the structures, often causing disruptions in the production process, and ultimately being quite costly. The elements primarily subject to strengthening at construction sites include columns, beams, lower belts of trusses, arches, slabs, and monolithic floor ceilings, whose load-bearing capacity can be restored with the help of composite strips made from carbon, basalt, aramid, and boron fibers. With their assistance, it is possible to significantly extend the operational life of structures in a short time and with minimal labor costs. The proposed strengthening measures have great state significance for the effective design and strengthening of structures. The generalization of the proposed solutions for the reinforcement of construction structures, with the aim of utilizing effective design and reinforcement methods, holds significant state importance.

Basalt and carbon fiber strips and laminates are innovative composite materials with exceptional mechanical, thermal, and chemical characteristics. They exhibit high tensile strength and resistance to temperature and aggressive environments, making them successfully applicable in various industries. The raw materials used for their production are coal and basalt rock (Pic. 1). Natural basalt composites do not emit carbon dioxide into the environment during manufacturing and operation, distinguishing them from other traditional alternative materials. This is due to the fact that basalt fibers are obtained from natural volcanic rocks, which are ecologically clean by nature. It is also noteworthy that Georgia is rich in basalt resources, and a powerful factory, "Basalt Fibers" (located in Rustavi), is already operational, producing a wide range of composite materials (reinforcement, laminates, fibers, basalt wool, etc.).

Pic. 1 Basalt Stone

2 Basalt Rocks

Main Part

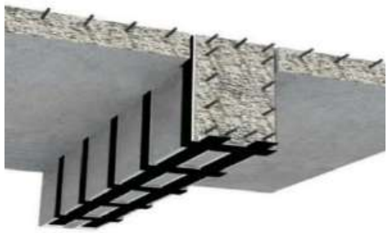
The area of application for external reinforcement includes concrete, reinforced concrete, stone, wooden, and metal structures, as well as structural elements of buildings, door and window openings, stairwells, elevator shafts, etc. Composites allow for the repair of structures at any stage of wear, increase the load-bearing capacity of the structure, eliminate damages that complicate or sometimes render the operation of the object impossible, restore the original physical characteristics of the construction, correct design errors and deficiencies made during the design process, and reduce repair costs (by 30-40%), repair time and labor costs, significantly increasing the operational lifespan of the object at relatively low costs.

The technology for external reinforcement work is as follows: the first stage involves investigating the functional condition of the building, conducting a technical condition expert assessment, and developing an individual strengthening project. Following this, a complex of reconstruction and strengthening works is carried out: removal of the old concrete surface by grinding, exposing the reinforcing steel and covering it with anti-corrosive solution, point restoration of damaged areas, laying carbon (glass, aramid, basalt) fibers on the prepared surface according to the project (if strengthening a column, then wrapping the composite strip around the structure, and finally installing a composite carbon mesh soaked in a special adhesive, resulting in a newly repaired structure with a restored clean surface).

In reinforced concrete structures, the composite strengthening system can be realistically used when the actual compressive strength of the concrete in the structure is at least 15 MPa. Primarily, composites made from carbon and basalt fibers are utilized, characterized by high tensile strength and compressive strength, while the modulus of elasticity is close to that of steel. For instance, currently in Western countries, carbon composite strips have a tensile strength of 3500 MPa and a modulus of elasticity of 230-240 GPA, meaning this material is approximately 8 times stronger and 5 times lighter than A500 class reinforcing steel. Similar properties are observed in composites made from other fibers, but it should be noted that aramid composites exhibit lower compressive strength, while glass composites have a relatively lower modulus of elasticity.

In practice, the strengthening of reinforced concrete structures is commonly carried out using fabric composite strips (Pic. 3; Pic 4.). Composite materials, reinforced with glass, carbon, basalt, or aramid strips, can be used on the outer surface of reinforced concrete columns to restore lost load-bearing capacity.

Pic. 3. Reinforcement of Beams, Columns, and Ceilings with Composite Tape



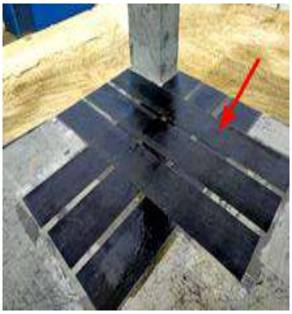
Pic. 4. Reinforcement of a Reinforced Concrete Roof Beam with Composite Tape

The loss of load-bearing capacity is often caused by corrosion of the working reinforcement, external mechanical damage, or increased loads. A circular cross-section column wrapped with a strip limits deformations in the transverse direction and increases compressive strength.

For reliable operation, the strip must be in close contact with the concrete.

Strengthening the roof is a significant stage in restoring and modernizing buildings in critical condition. It is performed from both the upper (Pic. 5) and lower (Pic. 6) sides. Strengthening from the lower side is considered the most effective in areas where tensile stresses act. The primary criterion for such work is determining the actual operational loads, based on which the strengthening project is developed. Strengthening can also be relevant for newly constructed objects if heavy structures or machinery that were not initially considered in the project need to be placed on the roof.

The carbon composite is applied to the lower side of the beams (see Pic. 7). Here, the number of layers of the composite determines the degree of increase in strength.

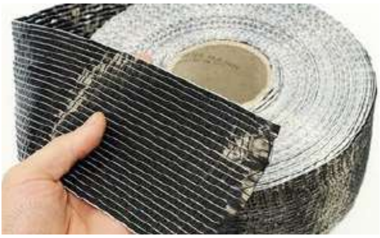


Pic. 5. Reinforcement of a Reinforced Concrete Roof from the Top with Carbon Fiber Tape

Pic. 6. Reinforcement of a Reinforced Concrete Roof from the Bottom with Carbon Fiber Tape

Pic. 7. Reinforcement of a Ribbed Slab with Carbon Composite

Alongside traditional methods for strengthening wooden structures, innovative methods are widely used, specifically strengthening with carbon fiber strips (see Pic. 8; Pic. 9). This method is applicable when increasing the cross-section of the beam is impossible or extremely complicated for various reasons.



Pic. 8 Carbon Fiber Tape

Pic. 9. Reinforcement of Wooden Beams with Carbon Fiber Tape

The advantage of strengthening wooden beams with carbon fiber strips is that it does not require increasing the cross-section with bulky wood and metal components, and it eliminates the need for labor-intensive work. Modern carbon fiber materials (carbon plastics) are characterized by high strength and low weight, effectively handling mechanical loads, and are user-friendly, as they are available in various forms (strips, fabrics, threads, rolls, sheets, etc.).

Strengthening composites is carried out on the structure or its parts through the gradual application of several layers of composite (using epoxy or polyester adhesives). Once the adhesive has cured, the composite layer achieves a strength comparable to that of steel.

A significant advantage of this method is that strengthening does not require occupying workspace around the structure, which is a notably important factor.

In modern conditions, strengthening construction structures with composite materials is often a less labor-intensive and energy-consuming process compared to similar strengthening methods, which is particularly significant for the repair of bridges on automobile and railway highways, as closing a bridge for an extended period incurs considerable financial costs.

Strengthening the load-bearing structures of bridges with carbon or basalt composites allows for an increase in the bridge's load-bearing capacity under standard loads (heavy transportation vehicles).

Bridges may exhibit the following damages: concrete spalling, crack formation, steel corrosion, wood decay, deformation, and failure of elements due to the influence of moving transport, among others, which gradually reduces the bridge's load-bearing capacity and operational safety.

Examples of strengthening reinforced concrete bridges with composite materials are shown in Pictures 10 and 11.

The tensile strength of strips (laminates) made from basalt (carbon) fibers varies between 2000-4840 MPa, and the modulus of elasticity ranges from 80-120 GPA, which exceeds the mechanical characteristics of many traditional materials and enables the structure to maintain structural stability against deformation under both normal and harsh conditions.

Pic. 10. Reinforcement of a Bridge Span Structure with Carbon Composite Tape

Pic. 11 Reinforcement of Longitudinal Load-Bearing Beams with Carbon Fiber Tape

It exhibits high thermal resistance (the melting temperature of basalt is 1400 °C), is less susceptible to thermal surface and depth damage, as heat dissipates quickly throughout the material. It is resistant to alkalis, acids, fresh and saltwater, is impact, abrasion, and corrosion-resistant, lightweight, has good adhesion properties, and is flexible (easily conforms to complex geometric surfaces). Additionally, the production of basalt fibers is a minimally energy-intensive process compared to the production of carbon and glass fibers, among other advantages.

Conclusion

1. The external reinforcement systems made from basalt (carbon) fiber composite strips (laminates) are universal and durable materials that can address many modern engineering problems. With their unique properties (strength, durability, thermal resistance, ecological safety), they can find applications in various branches of industry and contribute to the resilience of manufactured products.

2. Currently, the production of ecologically clean composites and the corresponding demand are steadily increasing, indicating their

significant role in industry, especially in the construction sector, particularly since our country does not face resource extraction issues, costs are gradually decreasing, and the material and its waste can be safely recycled, creating an unconditional opportunity for their use in sustainable engineering solutions.

3. It is noteworthy that the production of basalt fibers and various products based on them involves significant initial investments, but the existence of a powerful factory (Basalt Fibers) in Rustavi provides a good foundation for strengthening this direction, ultimately positively impacting the restoration and strengthening of damaged load-bearing construction structures in the construction sector.

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Construction of Highways Using Modern Innovative Technologies,

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Abstract. The article discusses ways of building innovative technology, in particular grants reinforcement methods. Road construction in fibrobeton use allows us to create a more durable road construction are analysed transport under load road constructive layers of dynamic strain-deformed state of the peculiarities. Also priming traits to improve different types of polymer additives in use, makes it possible to achieve a mixture of the higher hardness of Camas and game, as well as invade and tsamados increase. Studies conducted after analyzing the choice was stopped on the new composition of the polymer additive in the - "NICOFLOK"-the use of. Modernization of technology shall include also the cement used is a mixture of the composition of bitumen is changing polymer danmation more durable and abrasion-resistant cement, which improves road operational characteristics.

Keywords: Geogrid, geotextile, nicoflock, polystyrene foam, polymer additive, stabilizer, fibrobeton

Introduction

In Georgia, as of its mountainous terrain in a country with roads construction and rehabilitation-reconstruction process is widely being introduced innovative technological solutions, in particular - road design and road pavement, arrangement of innovative technologies, which aim which represents the shear deformations and abrasion-resistant construction designed to make vehicles move become available, safer and more comfortable. Increased axial load from and intensivos the road construction, the durability necessary condition occurs, the road network's development. Increased road infrastructure yes Pardoner linked to the country's economic progress with.

Main part

The roads construction and design of innovative approaches to the turn of the highway, the life cycle model is built and the necessary Transport infrastructure, creating the possibility.

As is well known, road pavement, the lower layer of the work of the features is static and especially dynamic loads impact absorption. It should also be noted that the road pavement structural layers of the load over time, increasing the intensity of traffic and vehicle fleet composition in the high carrying capacity of vehicles share the garden needs. Therefore, in order to ensure road construction, reliable resistance to the total load towards his entire service period, it is necessary that the coating layer of the monks in the material and structural bonds energy is also constantly increased, or at least not decrease.

It should be noted that road construction layers between good arrangement,innovative technologies. It gives a problem solving method. Their action of the features of the various physical and mechanical properties of the layers of separation, what voltage for distribution to the basics of sustainability increase.

Geosynthetics materials in the building materials class belongs to, which are polymers on the basis of it is made. These materials are a lot of positive properties, the key is operated for a long term. Groundwater and climatic factors according to individual structural layers of the arrangement of the different working conditions, priming the physical-mechanical properties of improving methods and proper justification when selecting an in-depth analysis requires. Geosynthetics materials for road construction layers between using the problem-solving allows (fig.1). These materials differ in density according to the. The average load on the roads and parking arrangement can be applied to material 250 g/m^2-to and more congested roads and runways of the arrangement 600 G/M^2-up density.

Road repair and restore the innovation form is used for molded asphalt mixture technology, infrared repair, the hydrophobization of Nanoose technologies and chemical presses method. Innovative projects implemented in the field of road construction require the integrated use of the above-mentioned technologies.

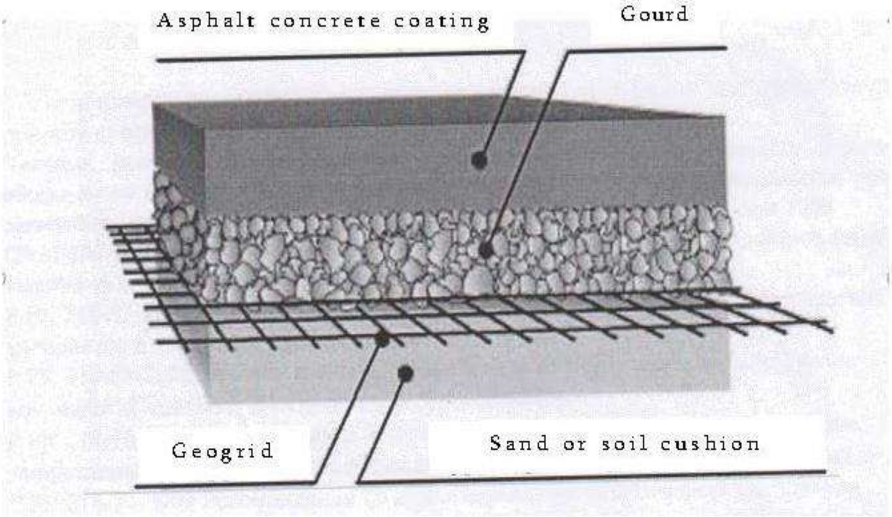

Fig. 1. Use of geosynthetic materials between the ground and the foundation

High transport the load when it is necessary road constructive layers of dynamic strain-deformed state of the peculiarities of the mind, which is controlled by its surface existing characteristics point to the frequency of the category. Fig.2-more presented in the chart, it is obvious that the best effect of the road structure, the elements of the deviation of reduction and the second

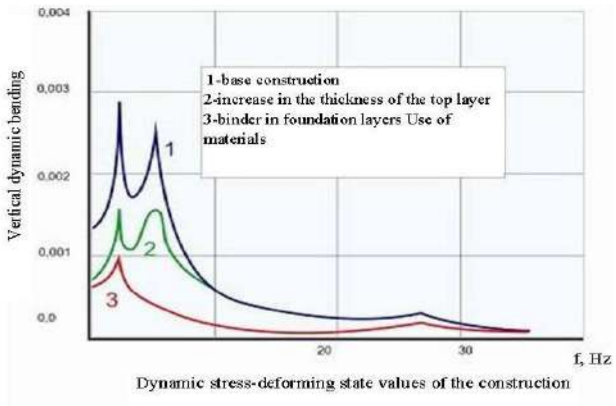

Fig.2. Construction of strain-deformed state

Resonance peak of the correction terms can be achieved by them in the bonding of materials to use when, for example, such as polymer-cement-grouts or hydropolymer-cement-grouts. It is clear that the deflection of the road structure can also be reduced by increasing the base or the top layer of the pavement, but this will lead to increase in the cost of the pavement construction. Which is especially unacceptable in the absence of necessary stone materials in the region.

For the construction of roads world experience, and, above all, in countries such as Germany, Canada, USA, Austria, which are widely use astringent materials fortified grants of roads and airfields construction, it is obvious that priming traits to improve in these countries effectively used in various types of polymer additives makes it possible to achieve a mixture of the higher hardness of Camas and game, as well as invade and tsamados increase (fig.3; fig.4 and fig.5).

Brief information about the use of additives chemical and physical characteristics of the user are as follows: polymer-mineral composition(PMC), which is based on dispersive funnels and mineral heaviness "NICOFLOK"is a composition, which consists of certain minerals with the chemical composition and activation of the brand, as well as polymers that are composed of molecules called "Swartley". Polymer this modification is a macromolecular long side chains. As long chains consisting of several types of molecules, each of which action begins with strictly specified time. This chain will have absorption and moisture-specific indicators (phase formation), which provides a mixture of their action, the necessary duration. Studies conducted after analyzing polymer additives using the choice to stop a new composition of "NICOFLOK". This additive can be used for all type of ground. At the same time, there are no restrictions on the soil mzhavanadze, sulfates, chlorides, plaster of existence. This product is not poisonous, have hygienic certificate, it is possible to transport and storage at low temperature. Its composition, hydrophobic, the only need water, direct contact is avoided. "NICOFLOK"-the consumption of quantitative options range from 0,5%-from 1%-up to a particular type of ground, the weight of the.

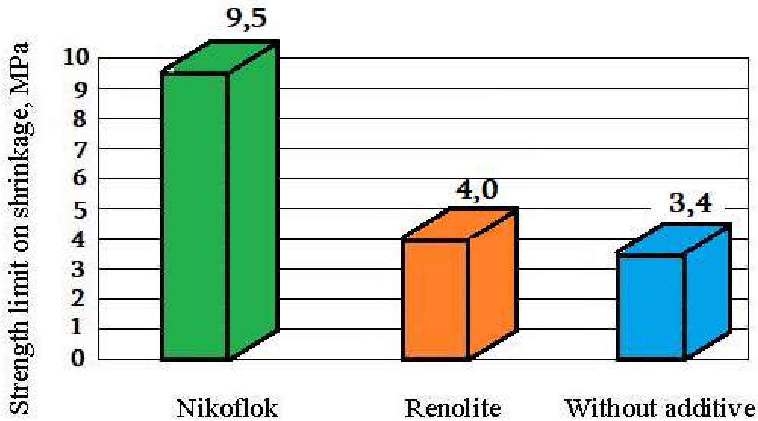

Fig.3. 28 days moisture content of the polymer cement soil sample
Tensile strength in bending

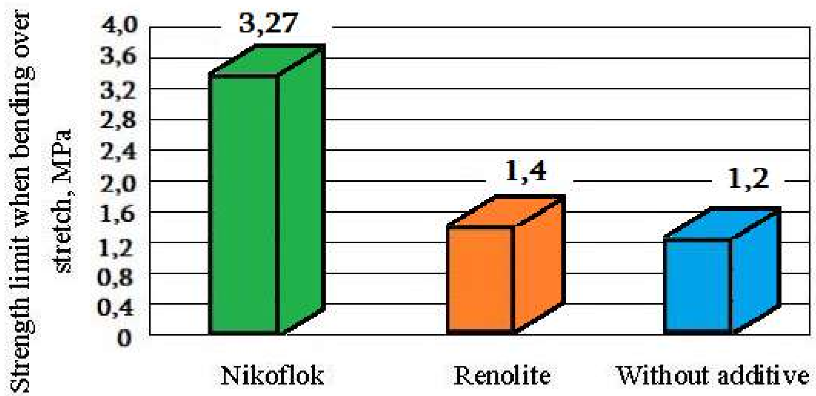

Fig.4. 28 days nouns polymercement sample Hardness of the edge game

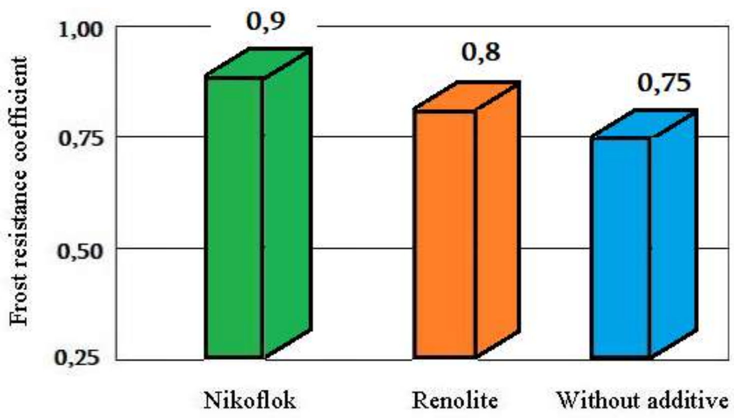

Fig.5. Patterns invaders ratio schedule

The above-mentioned studies, the analysis showed that the other well-known additives compared to ("Renolit", "Geosta", "Perma-Zyme"), "NICOFLOK"'s use provides a more significant increase in the hardness and deformations.

Conclusion

Road construction in the polymer materials used, as new and innovative technology leads to the roadbed and is completely road construction sarees and very meds awareness. Geosynthetics materials used allows us to contact the surface of the protective layer is created at the expense of the improve load-bearing layer of the formation, which prevents additional and load-bearing layer of the material of each other in chaotic and grow reels come in maximum load towards sustainability. This subsequently leads to a remontoire period of increase and significantly reduces the maintenance costs. Good use provides road construction work on the improvement of the dynamic loads under.

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The general formula for the n-th order derivative of the functional dependence of a cylindrical shell, *Mariam Fotskhishvili-Khairutdinova Bachelor Program Student Supervisor: Professor Tariel Kvitsiani, Professor*

I. Introduction

The pressure face of a low-pressure spillway dam is represented by a cylindrical shell with single curvature, which is rigidly (or flexibly) fixed at the base and the apex, while its straightened slopes are immovably hinged (see Fig. 1, a, b). The stress-strain state of the pressure face is described by the semi-moment theory of shells in a cylindrical coordinate system. For this case, the system of equilibrium equations, expressed in terms of radial displacements, is written as follows [1]:

$$\frac{\partial^8 w}{\partial \varphi^8} + \frac{\partial^6 w}{\partial \varphi^6} + \frac{12R^6}{h^2}\frac{\partial^4 w}{\partial \varphi^4} = \frac{12\gamma R^4}{Eh^3} Q(x,\varphi) \qquad (1)$$

Where

$$Q(x,\varphi) = \frac{\partial^3 q_2}{\partial \varphi^3} + \frac{\partial^4 q_3}{\partial \varphi^4} - R\frac{\partial^3 q_1}{\partial x \partial \varphi^2}$$

W is radial movement; q1, q2, q3 _ are the intensities of hydrostatic pressure on the cylindrical coordinate axes; h _ is the thickness of the shell; $R = \frac{R_1 + R_2}{2} -$ is the radius of curvature of the middle surface of the shell, and E - is the Young's modulus (see Fig. 1, a).

(1) To solve the equation Q(x,y) the function is represented in the form of the following convergent series:

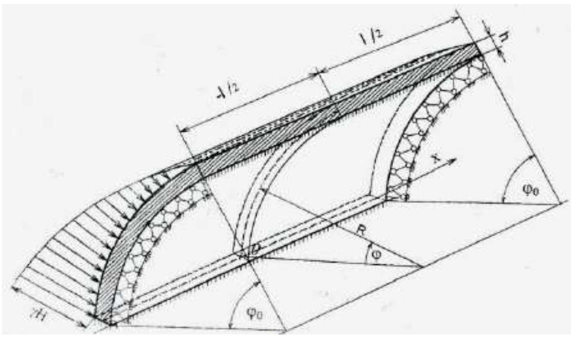
$$Q(x,\varphi)=\sum_{m=1}^{\infty}Q_m(\varphi)\cos\frac{2m-1}{l}\pi x \qquad (2)$$

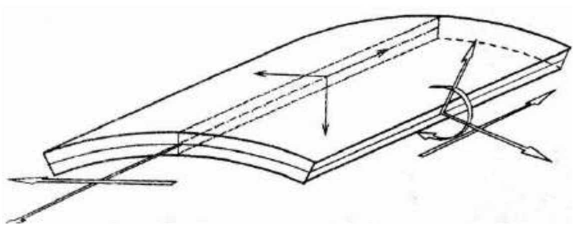
Where Qm (φ) the coefficients are determined by the following formulas

Considering representation (2), the solution of equation (1) $W=W_m(x,\varphi)$ is sought using the form of series (2), i.e.

$$W=\sum_{m=1}^{\infty}W_m(\varphi)\cos\frac{2m-1}{l}\pi x \qquad (3)$$

By virtue of (2)–(3), equation (1) is equivalent to the following system of equations:





See 1. Calculation diagram of the arched roof.

$$\frac{d^8W_m}{d\varphi^8}+\frac{d^6W}{\partial\varphi^6}+\frac{12R^6}{h^2}\left(\frac{2m-1}{l}\pi\right)^4 W_m=\frac{12R^4}{Eh^3}Q_m(\varphi); \quad m=1,2,\ldots \tag{4}$$

For a fixed m, equation (4) can be rewritten in the following form:

$$\frac{d^8y}{d\varphi^8}+\frac{d^6y}{d\varphi^6}+a_m^2y=f_m(\varphi); \tag{5}$$

Where $y=Wm$

$$a_m^2=\frac{12R^6}{h^2}\left(\frac{2m-1}{l}\pi\right)^4; \quad f_m(\varphi)=\frac{12R^4}{Eh^3}Q_m(\varphi) \tag{6}$$

For solving the problem of bending, the differential equation (5) of the 8th order is used, the general solution of which is written in the following form:

$$W_m(\varphi)=K_m\sin\varphi+\sum_{i=1,3,5,7}e^{a_{i+1}\varphi}\left(c_i\cos b_{\frac{i+1}{2}}\varphi+c_{i+1}\sin b_{\frac{i+1}{2}}\varphi\right) \tag{7}$$

Where

$$K_m(-1)^m\cdot\frac{4\gamma l^4}{E\cdot h\cdot R\cdot[(2m-1)\pi]^5}$$

(7) To determine any constants of integration for the differential equation (7), as well as to find the bending moments and other force functions, it is often necessary to compute the derivatives of the function (radial displacements) of various orders, or the derivative of some n-th order. To calculate the n-th order derivative, it is necessary, in turn, to sequentially calculate all the derivatives of the function from the first up to the n-th order. Obviously, solving the problem using this traditional

method is quite labor-intensive and inconvenient. Therefore, we will solve the following problem.

II. Main Part

Problem. We need to derive the general formula for the n-th derivative of the function $Wm(\varphi)$, which will depend only on the n-th derivative of the function $Wm(\varphi)$ and should not include the notation of the derivatives of the previous orders.
Since in equation (7) $Km = const$, $Km\sin\varphi$ the n-th derivative of the term can be easily calculated:

$$(Km\sin\varphi)^{(n)} = Km\sin\left(\varphi + \frac{\pi}{2}n\right) \quad (8)$$

The second term in equation (7) represents $U(\varphi) = e^{\frac{a_{i+1}\varphi}{2}}$ and $V(\varphi) = c_i\cos b_{\frac{i+1}{2}}\varphi + c_{i+1}\sin b_{\frac{i+1}{2}}\varphi$

To the product of the functions, for the purpose of simplifying subsequent mathematical operations, let us introduce the following notations:

$$f(\varphi) = U(\varphi)\cdot V(\varphi)$$

$$a_{\frac{i+1}{2}} = a \quad b_{\frac{i+1}{2}} = b \quad c_i = c_1 \quad c_{i+1} = c_2 \qquad (10)$$

Thus, the following problem needs to be solved:

$$f(\varphi) = U(\varphi)\cdot V(\varphi) = e^{a\varphi}(c_1\cos b\varphi + c_2\sin b\varphi) \qquad (11)$$

The general formula for calculating the n-th derivative of the function, which will directly depend on n and will not depend on the derivatives of the previous orders of n (it is understood that these functions have derivatives of all orders up to n).
To solve this problem, we will use Euler's well-known formula for the

complex representation of an exponential function with a fractional exponent [2]:

$$e^{a+ib} = e^{a}(\cos b + i\sin b)$$

Let us consider examples of the representation of complex numbers using Euler's formula:

$$z = 1+\frac{\pi}{4}i \;\Rightarrow\; e^{1+\frac{\pi}{4}i} = e^{1}\left(\cos\frac{\pi}{4}+i\sin\frac{\pi}{4}\right) = e\left(\frac{\sqrt{2}}{2}+i\frac{\sqrt{2}}{2}\right)$$

$$z = 0+\frac{\pi}{2}i \Rightarrow\; e^{z=0+\frac{\pi}{2}i} = e^{0}\left(\cos\frac{\pi}{2}+i\sin\frac{\pi}{2}\right) = i$$

$$z = 1+i \;\Rightarrow e^{1+i} = e^{1}(\cos 1 + i\sin 1) \approx 0{,}54 + i0{,}83$$

$z = x$ – A real number, i.e

When a=0, we obtain the following Euler's formulas:

$$e^{ib} = \cos b + i\sin b,$$
$$e^{-ib} = \cos b - i\sin b, \qquad (12)$$

From which

$$\cos b = \frac{e^{ib}+e^{-ib}}{2}; \quad \sin b = \frac{e^{ib}-e^{-ib}}{2i} \qquad (13)$$

Obviously, the general formula for *(12)* simplifies significantly by using the formulas f (n) (φ). Considering formula (13), equation (11) will take the following form:

$$f(\varphi) = \frac{1}{2}(c_1 - ic_2)\cdot e^{(a+ib)\varphi} + \frac{1}{2}(c_1 + ic_2)\cdot e^{(a-ib)\varphi} \qquad (14)$$

Because of $(e^{a\varphi})^{(n)} = a^n \cdot e^{a\varphi}$, Therefore, from (14) we will have:

$$f^{(n)}(\varphi)=\frac{1}{2}(c_1-ic_2)\cdot(a+ib)^n\cdot e^{(a+ib)\varphi}+\frac{1}{2}(c_1+ic_2)\cdot(a-ib)^n\cdot e^{(a-ib)\varphi} \tag{15}$$

To simplify the obtained expression, let us introduce auxiliary ψ_1 and ψ_2 angles. Let us assume $c_1^2 + c_2^2 \neq 0$ and $a^2 + b^2 \neq 0$, then the complex number, when written in trigonometric form, will be:

$$\begin{gathered} c_1 \pm i\cdot c_2=\sqrt{c_1^2+c_2^2}\cdot(\cos\psi_1 \pm i\cdot\sin\psi_1), \\ a \pm i\cdot b=\sqrt{a^2+b^2}\cdot(\cos\psi_2 \pm i\cdot\sin\psi_2), \end{gathered} \tag{16}$$

Where

$$\begin{gathered} \cos\psi_1=\frac{c_1}{\sqrt{c_1^2+c_2^2}}, \quad \sin\psi_1=\frac{c_2}{\sqrt{c_1^2+c_2^2}}, \\ \cos\psi_2=\frac{a}{\sqrt{a^2+b^2}}, \quad \sin\psi_2=\frac{b}{\sqrt{a^2+b^2}}. \end{gathered} \tag{17}$$

According to Euler's formulas (12), the formulas (16) are written as follows:

$$\begin{gathered} c_1 \pm i\cdot c_2=\sqrt{c_1^2+c_2^2}\cdot e^{\pm i\psi_1} \\ a + i\cdot b=\sqrt{a^2+b^2}\cdot e^{\pm i\psi_2} \end{gathered} \tag{18}$$

Considering (18), (15) is rewritten as follows:

$$f^{(n)}(\varphi)=\frac{1}{2}\sqrt{(c_1^2+c_2^2)(a^2+b^2)^n}\cdot e^{a\varphi}\left(e^{i(b-\psi_1+n\psi_2)}+e^{-i(b-\psi_1+n\psi_2)}\right) \tag{19}$$

Where

$$e^{i(b-\psi_1+n\psi_2)}+e^{-i(b-\psi_1+n\psi_2)}=\cos(b-\psi_1+n\psi_2)+i\sin(b-\psi_1+n\psi_2)+$$

$$+\cos(b-\psi_1+n\psi_2)-i\sin(b-\psi_1+n\psi_2)=2\cos(b-\psi_1+n\psi_2)$$

Considering the latter, (15) will take the following form:

$$f^{(n)}(\varphi)=\frac{1}{2}\sqrt{(c_1^2+c_2^2)(a^2+b^2)^n}\cdot e^{a\varphi}\cdot\cos(b-\psi_1+n\psi_2), \tag{20}$$

If we consider the expressions (8) and (10), then the n-th derivative of the function $W_m(\varphi)$ will take the following form:

$$\frac{d^nW_m}{d\varphi^n}=K_m\sin\left(\varphi+\frac{n\pi}{2}\right)+\sum_{i=1,3,5,7}\sqrt{(c_i^2+c_{i+1}^2)\left(a_{\frac{i+1}{2}}^2+b_{\frac{i+1}{2}}^2\right)^n}\cdot e^{\frac{a_{\frac{i+1}{2}}\varphi}{2}}\times$$
$$\times\cos\left(b_{\frac{i+1}{2}}-\psi_1+n\psi_2\right) \tag{21}$$

Where

$$\psi_1=\arccos\frac{c_i}{\sqrt{c_i^2+c_{i+1}^2}}=\arcsin\frac{c_{i+1}}{\sqrt{c_i^2+c_{i+1}^2}}$$

$$\psi_2=\arccos\frac{a_{\frac{i+1}{2}}}{\sqrt{a_{\frac{i+1}{2}}^2+b_{\frac{i+1}{2}}^2}}=\arcsin\frac{b_{\frac{i+1}{2}}}{\sqrt{a_{\frac{i+1}{2}}^2+b_{\frac{i+1}{2}}^2}}$$

III. Conclusion

According to the given problem, for calculating the deformations of the cylindrical shell and other force factors, it is necessary to compute the n-th derivatives of the general solution $Wm(\varphi)$ of the differential equation (4), represented by the relation (7). Instead of sequentially calculating the derivatives (which is a labor-intensive process), a functional relation in the form of formula (21) has been used, which allows us to compute the n-th derivative of the function without involving the notation of the derivatives of previous orders. Thus, the problem is solved.

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The Future of Smart Buildings with Architectural Technologies: Challenges and Opportunities, *Mariam Kavtaradze, Bachelor Program Student, mariamkavtaradze11@gmail.com, Ketevan Gordeziani, k.gordeziani@gtu.ge*

Abstract: Each building expresses the creativity of a person and reflects the level of development of his dreams. As we enter the era defined by digital transformation, the definition of what makes building a landmark, changes. Nowadays, buildings are valued by their digitally, that is, how smart they are and how digitally transformed they are. Studies have shown that the number of buildings that will be subject to smart technologies will be increased to 115 million by 2026. A building must meet the norms of creative structure. This means that a building is not just a shelter, but it is an active entity, integrated with both people and the environment. Today we will talk about the stages that have passed to give rise to smart buildings. We will explore the explosion of this type of architectural building that will be built massively in cities in the future.

Keywords: digital innovations, drones, increasing efficiency, agricultural sciences

Main part

The evolution of smart buildings

Smart buildings are not entirely new, as their development begins with early integration with automated systems such as heating, cooling, and lighting. Improvements in architectural technologies have given an impact to the development of smart buildings.

At the heart of smart buildings are interconnected systems that enable us to establish a secure connection between the physical and digital realities. In addition, sensors collect data on various parameters, such as temperature and air quality, energy consumption in buildings, and inform people about constantly changing conditions. Architectural technologies serve to become the creators of smart buildings. Therefore, it provides devices that can be easily integrated into the built building material. Technology playshase to construction, architectural technologies play a crucial role in its existence.

Building Information Modeling

This direction is reshaping the traditional understanding of building landscape and engineering. Pre-defined design can often be and often is based on fragmented parts of drawings and specifications. BIM, on the other hand, offers a unified platform where buildings can be compared with their digital representation. That is, how buildings will be presented and create a unified platform BIM. This technology allows us to go beyond 3D modeling. BIM integrates quite a lot of data and also captures not only the geometry of the physical structure, but also its functionality. This policy approach allows architects and engineers, stakeholders, to develop and refine designs in consultation with each other, with unprecedented accuracy and efficiency. One of the main advantages of BIM lies in its ability to facilitate visualization in a virtual environment to populate digital prototypes. In addition, BIM enables them to learn and interact with buildings before they are built. Such highly developed technology allows any flaws that may exist in the design to be identified and eliminated.

BIM allows us to predict models in advance and form preliminary analysis. The advanced digital technologies of BIM have allowed for increased collaboration. And have given designers the opportunity to create a sustainable innovative environment. As soon as the design phase is completed, implementation begins. In this regard, architects and engineers use the skills and leverage of LOT technologies. Accordingly, sensors which are embedded throughout the entire structure, are constantly collecting data in every second on a multitude of parameters, which include everything from temperature to humidity levels. Architectural technologies serve the viability of smart building ecosystems. In addition, this data empowers the structure to respond in time about the changing needs for people and the environment. For example, sophisticated HVAC systems are equipped with LOT and enable sensors to automatically adjust the heating and cooling system based on outdoor weather conditions and OCUPANSY LEVEL. This system is designed in a way that provides optimal comfort while reducing energy consumption. If any kind of fault occurs, it can be detected and resolved in time with the help of sensors before it becomes a serious problem.

My presentation describes Smart Architectural Technologies (SAT), the main goal of which is to create innovative, intelligent environments that truly respond to people's needs. SAT's work is based on the concept of an empathetic environment, which implies a harmonious combination of architecture, technology and users' needs to create an environment that is not only functional and efficient but also focused on improving the quality of life.

The main ideas of Smart Architectural Technologies (SAT) are:

1. Philosophy and approach:

• The view on the elements of architecture is not traditional: the brick and the sensor are considered to be the elements of equal importance. This means that technology does not change the basic principles of architecture but is combined with them to serve the user as much as possible.

• Architecture and technology are equally important; however, technology is used only when simple and natural solutions are not enough. For example:

• If the building is designed in such a way that all users can see the door, there will be no need to implement complex intercom or video camera systems.

• Maximizing natural light reduces the need for artificial lighting.

2. Areas of application:

The SAT approach is used in areas such as:

• Healthcare – An empathetic environment can help to effectively care for patients and improve processes.

• Social relations – The combination of technology and architecture can give a new dimension to human relationships and communication.

• Residential and public spaces – An innovative approach based on user needs not only reduces costs but also increases comfort and engagement.

3. Goals of an empathetic environment:

• Efficiency and cost reduction: Using technology can simplify daily building processes and avoid unnecessary costs.

• Quality improvement and engagement: The environment is created in a way that helps users feel better and to be more connected to space.

• Sustainable and adaptable solutions: For example, the use of plants in a building is not only visually attractive but also contributes to the environmental friendliness of the environment and allows users to grow plants themselves.

Prof. Dr. Eng. Mazi Mohammadi's vision:

Professor Mohammadi emphasizes the importance of social and technological development in architecture. According to him, an empathetic environment creates energy between technology and sociology, which facilitates new and innovative solutions.

Its main principles are:

• Technology is a tool, not a goal.

• "If the problem can be solved architecturally, we don't use technology – but where it is needed, we choose the most intelligent and modern approaches."

• Architectural solutions directly affect the environment and user behavior.

The Future of Smart Buildings with Architectural Technologies: Challenges and Opportunities

Looking ahead, the potential of smart buildings is boundless. However, to fully realize this potential, several challenges need to be addressed, such as:

• Interoperability issues,

• Data privacy issues

• and the need of professionals who can navigate the complex landscape of architectural technologies.

Within these challenges, there are huge opportunities for innovation and collaboration. By creating an ecosystem of partnerships between architects, engineers, technology providers and policymakers, we can accelerate the adoption of smart building solutions and create more sustainable and user-oriented cities.

Conclusion

Smart buildings are the mix of architecture and technology. They reflect the goals of a connected and sustainable future. Integrating digital systems into the built environment allows us to create spaces that not only impress but also improve the quality of life for future generations.

As we stand on the edge of a new era, it is time to embrace the power and possibilities of architectural technologies.

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Determining the center of impact when no impact impulse reactions are generated in the structural supports,

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Abstract: In the theory of impact, the phenomenon in which the velocity of points of a body changes by a finite amount in a very short period of time is called impact.

If the velocity of the impacting body at the moment of impact is, and the velocity after impact is equal to , then the change in velocity is a finite quantity. Moreover, the entire impact process is carried out in an infinitesimal time interval, which is called the impact time.
The following assumptions are made in the theory of impact:

Introduction

The velocity of a point changes almost instantaneously by a finite quantity;
The momentum of the non-impact force and the displacements of points during impact are neglected as infinitesimal quantities.

An impact is an interaction between bodies, as a result of which, in an infinitely small time interval, the velocity of a point changes by a finite magnitude.

The impact force is the force that arises during the instantaneous interaction of bodies and reaches its maximum value during an infinitely small time interval.

The impact impulse is a finite vector quantity: $\vec{S}_{\text{დ}} = \int\limits_0^{\tau} \vec{F}_{\text{დ}} dt$. (1)

As is known from the theory of impact, the change in the momentum of a material point during an impact is equal to the impulse of the impact on the point: $m\vec{u} - m\vec{v} = \int_0^{\tau} \vec{F} dt \qquad m\vec{u} - m\vec{v} = \vec{S}_{\text{დ}}$ (2)

where S_i is the impulse of the impact force. (2) is called the basic equation of the impact theory.

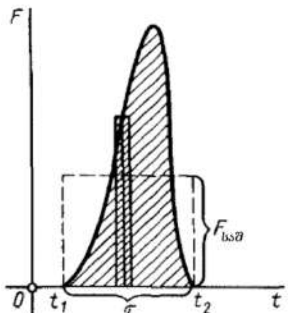
To represent the magnitude of the impact force, we calculate the average value of the impact force. To do this, we use the mean value theorem to integrate (2), we have: $m\vec{u} - m\vec{v} = \vec{F}_{საშ} \cdot \tau$, (3)

Where F_{avg} is its average value over the time of force action. From(3)

$$\vec{F}_{საშ} = \frac{m|\vec{u} - \vec{v}|}{\tau} \quad (4)$$

The numerator of the right-hand side of this equation is a finite quantity, and the denominator is a rather small quantity, so even the average value of the force is very large. Further, the force acting in an infinitely small interval of time, the modulus of which reaches a rather large value, is called the impact force.

To illustrate the change in the modulus of the force, we can construct a graph. Before and after the impact, and in the time interval its modulus reaches a rather large value. Obviously, if there is an impact force, the duration of the impact time, then the graph of the change in the modulus of the impact force from time instant to time instant can have the form shown in Figure 1, the value of is also shown on the same graph. From the moment of the impact, the impact force rapidly increases from zero to its maximum value, then by another law it also rapidly decreases to zero at the end of the impact. In most cases, detailed knowledge of the law of change in the impact force is not required. It is sufficient to know only the total momentum or impact momentum of this



ნახ. 1

rapidly changing force during its impact time, which is determined by formula (1).

To evaluate the modulus of force, let's consider a simple example. Suppose a stone of mass 1 kg falls from a height 10m with an initial velocity, and after the fall it does not bounce. Let's assume that the duration of the impact is t=0,001, and find the value of F_{avg}

Based on the conditions of the problem, the speed of the stone at the moment of impact is $v = \sqrt{2gH} \approx 14{,}1$ (air resistance is neglected), and the speed after impact is . Using formula (4), we get: $F_{\text{საშ}} = \frac{mv}{\tau} \approx \frac{1 \cdot 14{,}1}{0{,}001} \approx 14{,}1$ kn

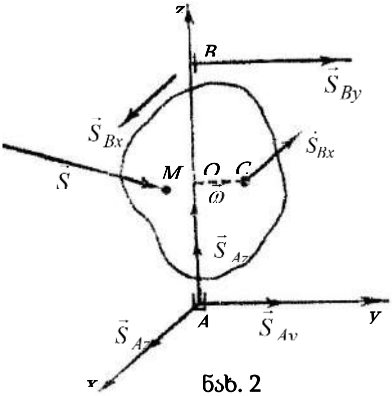
The obtained value of the force is only an average value, if we consider that the maximum value of the force is twice the average value (see Fig. 1), then we get F_{avg} =28.2 Kn. These numbers clearly show why bodies sometimes break as a result of impact.

Main part

Consider the action of impact forces on a rigid body fixed at two points (Fig.2).

The body is fixed at point B by a joint, and at point A by a heel, and the impact impulse acts. As a result of the impact, reactions are induced at points A and B, which have the character of impact forces. As a result of a significant impact, the reactions can reach such a magnitude that they are dangerous for the strength of the bearings and the axis. Let us solve the following problem.

Problem 1. The dynamic characteristics of the body (mass, moments of inertia) and the impact impulse acting on the body are given. Let us determine the reactions of the impact impulse. Suppose the impact impulse acts at point M of the body.



ნახ. 2

Let us choose a coordinate system so that the Ayz plane passes through the center of mass C (Fig. 2). To solve the problem, let us use the theorems of the change in momentum and the change in kinetic momentum in the event of an impact, which in our case will have the following form:

$$M(\vec{v}_{c_2}-\vec{v}_{c_1})=\vec{S}+\vec{S}_A+\vec{S}_B \tag{5}$$

$$\vec{K}_{A_2}-\vec{K}_{A_1}=\vec{r}_M\times\vec{S}+\vec{r}_B\times\vec{S}_V \tag{6}$$

where , $M\vec{v}_{c_1}$ are $M\vec{v}_{c_2}$ the momentum of the body before and after the impact;

$\vec{K}_{A_1}$, $\vec{K}_{A_2}$ –, are the moments of momentum before and after the impact, respectively; and are the radius vectors. By plotting equations (5) and (6) on the axes of the Axyz system, we obtain:

$$\left.\begin{array}{l} S_x+S_{Ax}+S_{Bx}=My_c(\omega_z-\Omega_z),\\ S_y+S_{Ay}+S_{By}=0,\\ S_{Az}+S_z=0. \end{array}\right\} \tag{7}$$

$$\left.\begin{array}{l} -I_{xz}(\Omega_z-\omega_z)=y_M S_x-z_M S_y-z_B S_{By},\\ -I_{yz}(\Omega_z-\omega_z)=z_M S_x-x_M S_z+z_B S_{Bx},\\ I_z(\Omega_z-\omega_z)=x_M S_y-y_M S_x. \end{array}\right\} \tag{8}$$

Where ω_z and Ω_z are the angular velocities of the body before and after the impact; , I is the centrifugal moments of inertia; the moment of inertia of the body about the z axis; the coordinates of the point; the reactions of the shaft A and the bearing B.

From the last equation, the change in the angular velocity of rotation during the impact period is determined:

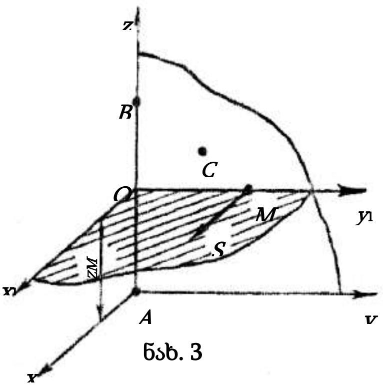
$$\Omega_z - \omega_z = \frac{1}{I_2}(x_M S_y - y_M S_x)\,. \tag{9}$$

If we insert this value of the change in angular velocities into equations (7) and (8), we will find the values of the unknown quantities to be searched for.

Based on the results obtained, we can determine the conditions under which the impulse of the impact force acting on the body is not transmitted to the points of attachment of the axis of rotation, i.e. when the reactions of the impact impulse will be equal to zero. To do this, consider the following problem.

Problem 2. Find a condition that is necessary for the support to not experience any impact impulse reactions in the supports.

Let us assume that the impact impulses at points A and B are zero and find the constraints that apply to the other quantities in equations (7) and (8). In addition, we must assume that, then from equations (7) and (8) we obtain:



ნახ. 3

$$\left.\begin{aligned} &S_x = -My_c(\Omega_z - \omega_z),\\ &S_y = 0,\\ &S_z = 0,\\ &y_M S_z - z_M S_y = -I_{xz}(\Omega_z - \omega_z),\\ &z_M S_x - x_M S_z = -I_{yz}(\Omega_z - \omega_z),\\ &x_M S_y - y_M S_x = I_z(\Omega_z - \omega_z). \end{aligned}\right\} \tag{10}$$

From the second and third equations of (10) it follows that the impact impulse must lie on a line parallel to the axis, i.e. it must be perpendicular to the plane passing through the Az axis of rotation and the center of mass C.

For the convenience of further discussion, let us introduce the axes of the new coordinate system, which will be parallel to the axes of the Axyz system (Fig. 3).

In the new coordinate system . The impulse, according to the above statement, must lie on the Ox1y1 coordinate plane and be parallel to the axis (Fig. 3).

In the new coordinate system (10) the system of equations retains its form. Let us assume that in them $S_y = S_z = 0$, as well as $z_{1M} = 0$, we first use the 4th and 5th equations. Taking into account that $\Omega_z \neq \omega_z$, we obtain:

$$\text{v}\, I_{x_1 z_1} = 0, \quad I_{y_1 z_1} = 0,$$

I.e. For point O, the axis of rotation must be the principal axis of inertia. From the first and last equations of (10), we find:

$$y_M = \frac{I_z}{M y_c}$$

Here we have used the fact that , , . Therefore, the base of action of the impulse must be separated from the axis of rotation by the distance determined by the formula (11) (i.e., by the reduced length of the physical pendulum). Therefore, in order for the impact not to be transmitted to the supports, the following conditions must be met:

The base of action of the impact impulse must be perpendicular to the axis of rotation and the plane passing through the center of mass;

1. The plane containing the momentum of the beam and perpendicular to the axis of rotation must intersect the axis of rotation at a point for which the axis of rotation is the principal axis of inertia;

2. The base of action of the impact impulse must be separated from the axis of rotation by the distance determined by the formula (11).

It is easy to see that the listed necessary conditions also represent sufficient conditions. If they are fulfilled, the system (10) is satisfied for any S_x, and then it follows from equations (7) and (8) that the impact impulse $\vec{S}_A$ and $\vec{S}_B$ reactions are equal to zero.

We can note that the center of impact may not exist, such a situation will occur, for example, when the axis of rotation is not the principal axis of inertia for any point of rotation.

Now let's consider a specific example of determining the center of gravity.

The point M in the Ayz plane (Fig. 3), on which the impact impulse is applied and which satisfies all the above conditions, is called the center of impact.

The center of impact is a point of a rigid body rotating about a fixed axis, at which the impact impulse applied to the axis support does not cause a shock reaction. Therefore, this is a point at which, if we apply the impact force, the axis of rotation of the body should not be affected by the impact.

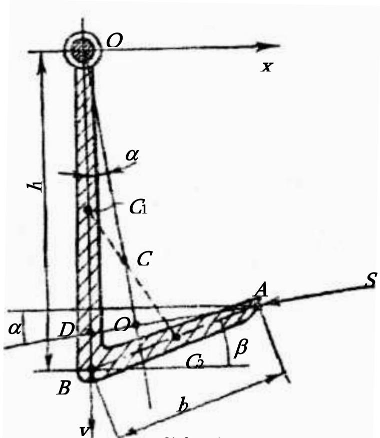
The center of impact coincides with the center of oscillation of a physical pendulum and is separated from the axis of rotation by a distance, which is determined by the following formula

$$h = \frac{I_z}{Md} \tag{12}$$

where is the moment of inertia of the body about the z axis of rotation; M is the mass of the body; d - the distance from the axis of rotation to the center of mass of the body.

Now consider a specific example of determining the center of impact.

Problem 3. The figure shows a structure on which the impact $\vec{S}$ impulse acts at point A. The lever arms $OB = l$ and $BA = l_2$ can be considered as uniform rods, the masses of which are respectively m_1 and m_2. The angle between the lever arms is $OAB = \frac{\pi}{2} - \beta$. It is necessary to determine for what $\frac{l_1}{l_2}$ ratio of the arms and along what line of direction the impact $\vec{S}$ impulse should act so that the impact load is not transferred to the axis of the structure.



ნახ. 4

Solution. Let's draw the Oxy axis system as shown in the figure. Calculate the coordinates of the center of mass of the structure from the condition that the C_1 and C_2 centers of rigidity are the midpoints of the rods:

$$x_c = \frac{x_{c_1} M_1 + x_{c_2} M_2}{M_1 + M_2} = \frac{M_2 l_2 \cos\varphi}{2M}$$

$$y_c = \frac{y_{c_1} M_1 + y_{c_2} M_2}{M_1 + M_2} = \frac{1}{M}\left[\frac{1}{2} M_1 l_1 + M_2\left(l_1 - \frac{l_2}{2}\sin\beta\right)\right]$$

Where $M = M_1 + M_2$ is the total mass of the particle; $x_{c_1} = 0$; $x_{c_2} = \frac{l_2}{2}\cos\beta$; $y_{c_1} = \frac{l_1}{2}$; $y_{c_2} = l_1 - \frac{l_2}{2}\sin\beta$. Let us draw a line OC that makes an angle α with the axis OB. It is clear that.

$$ctg\alpha = \frac{y_c}{x_c} = \frac{l_1(M_1 + 2M_2) - M_2 l_2 \sin\beta}{M_2 l_2 \cos\beta}$$

If we introduce the notation $\frac{l_1}{l_2} = U$, $\frac{M_1 + 2M_2}{M_2} = K$ ($K \geq 0$) Then equality (15) will take the form:

$$ctg\alpha = \frac{KU - \sin\beta}{\cos\beta}. \qquad (16)$$

The magnitude of the angle α is still unknown. We must find it from the basic slope determining the location of the center of impact. First of all, we must note that according to the conditions established above, the base of action of the impulse must be perpendicular to the line OC. Therefore, it makes an angle equal to OB with the $\frac{\pi}{2} - \alpha$ shoulder. Let us draw a perpendicular from point A to the line OC and find the center of impact O1.

$r_c = OC$ and $r_{O_1} = OO_1$ The lengths must meet the following conditions:

$$Mr_c r_{O_1} = I_{Oz}$$

where is the moment of inertia of the structure about the axis of rotation. Let's find these quantities:

$$r_c = \frac{x_c}{\sin\alpha} = \frac{M_2 l_2 \cos\beta}{2M \sin\alpha}, \qquad (18)$$

$$r_{O_1} = OD\cos\alpha = (l_1 - l_2 \sin\beta + l_2 \cos\beta tg\alpha)\cos\alpha, \qquad (19)$$

$$I_{Oz}=\frac{M_1l_1^2}{3}+\frac{M_2l_2^2}{12}+M_2\left[\left(l_1-\frac{1}{2}l_2\sin\beta\right)^2+\frac{l_2^2}{4}\cos^2\beta\right]=$$

$$=\frac{1}{3}\left[(M_1+3M_2)l_1^2+M_2l_2^2-3M_2l_1l_2\sin\beta\right]. \qquad (20)$$

Inserting the values obtained from (18), (19), and (20) into (17), we have:

$$\frac{M_2l_2\cos\beta\cos\alpha}{2\sin\alpha}(l_1-l_2\sin\beta+l_2\cos\beta tg\alpha)=$$

$$=\frac{1}{3}\left[(M_1+3M_2)l_1^2+M_2l_2^2-3M_2l_1l_2\sin\beta\right]. \qquad (21)$$

(21) Dividing both sides of the equality by $M_2l_2^2$ and using the notation obtained above, we have:

$$3[U-\sin\beta)(KU-\sin\beta(+\cos^2\beta]=2[(K+1)U^2-3U\sin\beta+1]. \qquad (22)$$

The problem boils down to solving a quadratic equation:

$$(K-2)U^2-3(K-1)\sin\beta\cdot U+1=0.$$

From where:

$$U_{1,2}=\left(\frac{l_1}{l_2}\right)_{1,2}=\frac{1}{2(K-1)}\left[3(K-1(\sin\beta\pm\sqrt{9(K-1)^2\sin^2\beta-4(K-2)}\right].$$

Both roots will work if the discriminant is nonnegative, i.e.

$$2(K-1)^2\sin^2\beta-4(K-1)\geq 0.$$

It follows from this that:

$$|\sin\beta|\geq\frac{2\sqrt{K-2}}{3(K-1)}. \qquad (11)$$

Note that $K = 2 + \frac{M_1}{M_2}$, therefore the inequalities and are valid $K - 2 > 0$ და $K - 1 > 0$,, i.e. the right-hand side of the inequality is positive. Now let's make sure that this number cannot be greater than one. To do this, we find the extremum of the following function:

$$f(K) = \frac{2\sqrt{K-2}}{3(K-1)}, \quad f'(K) = \frac{2}{3}\left(\frac{K-1}{2\sqrt{K-2}} - \sqrt{K-2}\right) \cdot \frac{1}{(K-1)^2} = 0,$$

From which we get: . We can easily verify that K=3 is a maximum point.

$$f_{\max} = f(3) = \frac{1}{3}.$$

Thus, for any ratio of masses, we can choose such a distance between the sides of the structure $\frac{\pi}{2} - \beta$ that when $\alpha < OBA = \frac{\pi}{2} - \beta$ the axis of the structure will work without the influence of the impact.

When the angle between the sides of the structure is obtuse, then it is impossible to work on the cone without the influence of the impact forces. This is clearly seen from the formulas for U, $\frac{l_1}{l_2}$. The value of the relative magnitude, in this case, turns out to be negative, which is impossible.

The line of action of the impact impulse is determined by the angle . It can be calculated:

$$ctg\alpha = \frac{ku}{\cos\beta} - tg\beta = \quad = \frac{k}{2(K-1)\cos\beta}\left[3(K-1)\sin\beta \pm \sqrt{9(K-1)^2\sin^2\beta - 4(K-2)}\right] - tg\beta.$$

(12)

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Shota Rustaveli National Science Foundation of Georgia PHDF-24-532. Optimization of water supply systems in Gomismta resort,

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Abstract

Gomismta is a summer, high-mountain resort in Guria, Ozurgeti Municipality. Its height in different places varies from 2100 meters to 2755 meters above sea level. The resort is distinguished by its natural and climatic conditions with healing properties, which are determined by the combination of sea and mountain air. Gomismta is known as the kingdom of clouds and fogs, which is caused by the specific climate here. Vacationers and travelers often visit the resort for this very reason. If you climb a high hill, you will see a sun-drenched, endless mountain range covered in fogs. The sun setting in the sea of clouds or the sunrise in the fogs create such a magnificent and unforgettable spectacle that it is impossible to convey either in words or with a camera. You have to see all this with your own eyes. If you visit Gomismta, you can also visit Lake Chinchao, which is located at an altitude of 2,500 meters above sea level. The distance from the resort to the lake is 11 km. There is a road leading to the lake, which is only accessible by off-road vehicles.

Gomismta has the potential to become a world-famous ski resort, which will bring socio-economic benefits to the resort. Local farmers and villagers will be able to provide vacationers with locally produced natural products. In addition, it will become a particularly interesting place for extreme youth.

In 2013, under the supervision of the local authorities, reconstruction works were carried out on a 19-kilometer section of the

access road to the resort. Road retaining gabions, new culverts, road protection dams, and drainage channels were installed.

The Gomismta settlement is supplied with drinking water from springs on the slopes of the mountains, which are collected in improvised iron tanks and then supplied without sanitation to approximately 20% of the settlement. Accordingly, there is no centralized water supply system. The rest of the population has arbitrarily brought water through polyethylene pipes from small-flow springs on the slopes. The springs do not have sanitary protection zones.

Keywords: Resort, source, water supply systems, drinking water

1 Introduction

Gomismta is surrounded by spruce and fir forests, rich in mineral waters and other natural resources. The resort season, like in Bakhmaro, lasts only three months of summer. Winter in Gomismta is snowy and cold, summer is moderately cool. The resort has no infrastructure, no electricity supply and no water supply system. Locals get their water from mountain springs. This is the reason for the lack of bathrooms in Gomismta cottages, in many cases. On Gomismta, like in Bakhmaro, typical wooden cottages are popular, which can be rented. At this stage, the resort does not have a hotel, shops, pharmacy, children's amusement park, cafe or other entertainment. If you decide to relax here, you need to take everything with you and spend time in peace, fresh air, and nature, cut off from civilization.

In the Gomismta resort, the height of the snow cover in winter reaches 4-5 meters (the normative weight of the snow cover is 7.78 kPa = 778 kgf / m2; H = 778 / 200 = 3.89 m). The normative depth of ground freezing is 89-133 cm. The Gomismta settlement does not have a sewage system. The houses are mainly one- or two-story wooden cottages, which are placed on wooden poles at a height of 1.5-2 m from the ground. The population comes down to the forest in winter due to heavy snowfall. The roofs of the houses are gabled, with a strong slope (70° slope) so that the snow does not damage the roofing.

2 Main part

To supply the population of Gomismta with drinking water, sources located approximately 7.1 km away from the settlement were searched as possible water supply sources. We learned about its existence from the local residents through the survey method. It is likely that the sources used for water supply do not dry up and are suitable as a source of water supply at any time of the year. During the study, the estimated water flow rate for both sources was determined and the measurement results gave a total of 2-2.5 liters/seconds.

If we calculate the area of the water intake opening at a flow rate of Q=2L/sec., then the area will be:

$$\boldsymbol{W = \frac{Q}{V_c} = \frac{0.02}{0.4} = 0.005\ m^2 K_1 = \frac{a+c}{a} = \frac{5+1.2}{5} = \frac{6.2}{5} = 1.24}$$

Where V_c=0.4 m/s – the speed of entry of open water into the backflow filter during the movement of the source flow is taken into account. (According to construction norms and rules, V_c=0.2 - 0.6 m/s. If we consider the reduction in area by the total area of the rods, which takes into account the number of rods, the area of their sides, the angle where these rod grooves will be located,

the dimensions of the grooves between the rods, then we can calculate K=(a+c):a The distance between the grooves according to the rods in symmetries is 5 cm, c is the thickness or diameter of the rod, K is a coefficient that takes into account the increase in the area of the opening and is approximately equal to 1.25.

$$\boldsymbol{W_f = 1.25 \times 0.005 \times K_1 =}$$
$$\boldsymbol{= 1.25 \times 1.24 \times 0.005 = 0.077 m^2}$$

If the length of one side is 10 cm and the width is 30 cm, the actual amount of water that will be obtained through one section will be Q=0.070X0.4=2.8 l/s.

The water intake structure we have developed will actually receive much more water than calculated, but if we take into account the development and construction rates of Gomismta in the future, we will definitely see the need to build a water intake structure that will be able to add one more watercourse to fill the pipes with a cross section of d=100-150 mm, without further reconstruction.

The water intake should be equipped with an overflow pipe in case the water exceeds the design volume. In such a case, the water will flow into the spring bed and act as an overflow pipe for excess water from the building.

Population growth dynamics

Population	Unit	Year	
		2020	2050
Local residents and vacationers	person	12700	15000

Dimension	Unit	Year	
		2020	2050
Local residents and vacationers	person	12700	15000
Specific water requirements	1/person/day	140	140
Small commercial/industrial demand	%	10	10

3 Conclusions

The detailed project should include the following main tasks:

- Detailed boundaries of the project area;
- Criteria used to determine project costs;
- Minimum and maximum pressures in the distribution network;
- Minimum horizontal and vertical distances between sewer and water supply pipes;

- Methodology for placing shut-off and regulating valves in the distribution network;
- Methodology for placing fire hydrants;
- Minimum depth of water supply pipe arrangement;
- Maximum and minimum water flow rates in pipelines;
- Minimum diameter of main pipes of distribution networks;
- Minimum diameter of connections;
- Methodology for placing flushing valves and plungers;
- Methodology for placing pipelines;
- Construction criteria for water production facilities, reservoirs: concrete class, minimum thickness of concrete covering protecting the reinforcement, etc.
- And others.

The following data will be necessary and important for the arrangement of a water supply network for the population, according to which reports will be made for the implementation of a very important and necessary project:

- Current and prospective number of population;
- Planned development;
- Population density taking into account existing and prospective development areas;
- Current and prospective number of tourists;
- Current water consumption of large consumers (industrial, commercial and institutional);
- Approximate location and water consumption of large consumers in the future;
- Detailed description of the current condition of water supply and sewage facilities and pipelines;

The construction and commissioning of the design water intake, which will receive 2.8 l/s of drinking water into the system, will total approximately 10.8 m3/hour, or an average of 241.9 m3/day per day, which will ensure round-the-clock water supply.

The main factors of environmental impact of water supply infrastructure are: emissions into atmospheric air, noise and waste, and the receptors are: local population, flora, fauna, hydrosphere, etc.

These factors mainly have a more or less negative impact on the environment only during construction, while their impact during operation is practically negligible.

Let us briefly consider the negative impacts that the environment may experience during the construction of the infrastructure:

$$Q\frac{residents}{average} = \frac{1500 \times 140}{1000} = 2100m^3/d$$

The main negative impacts during the construction of the source are caused by construction vehicles and mechanisms that will be used to clean the water basin during the expansion, during the construction of water intake and catchment structures, and during the laying of the pipeline.

Given the circumstances that construction should mainly take place away from settlements, outside the sanitary protection zone, it may cause temporary disturbance to sensitive fauna (although it is expected that such receptors will temporarily avoid noisy areas), and as for service personnel, the use of personal protective equipment is recommended during the construction process (GOST 12.4.051-87): noise-canceling earmuffs or earmuffs, noise-canceling helmets or suits.

During the construction of water supply infrastructure, air pollution will increase, which will be caused by the construction of headworks, catchments, etc. At the same time, harmful substances will be emitted from mobile sources (vehicles, construction equipment engines, etc.).

It will be necessary to calculate the costs of water supply according to the technical instructions ("Rambol" table).

$$Q\frac{residents}{average} = \frac{N \times n}{1000} = m^3/d$$

Where N - is the estimated population size for 2050 and N=15,000 people (extrapolated from the “research”); n - is the “net” water consumption rate - and n=140 l/capita per day. Then

Based on the average daily cost, the average hourly cost will be

$$Q\frac{residents}{average} = \frac{Q\frac{residents}{average} \times 1000}{24 \times 3600} = l/sec$$

$$Q\frac{residents}{average} = \frac{2100 \times 1000}{86400} = 24.31\ l/sec$$

The maximum daily consumption of "net" water for drinking and domestic purposes of the population is calculated by the formula

$$Q\frac{residents}{max} = Q\frac{residents}{average} \times K = m^3/d$$

Where K is the maximum coefficient of day-to-day inequality and is determined from the graph based on the population size.

The average daily "net" cost for commercial and budgetary facilities is taken as 10% of the corresponding cost for the population (technical instructions).

$$Q\frac{Commercial}{average} = Q\frac{residents}{average} \times 0.1 = m^3/d$$

$$Q\frac{Commercial}{average} = 24.31 \times 0.1 = 2.43\ m^3/d$$

Given the natural relief of Gomismta and its climatic conditions, operating a unified water supply system will be quite difficult during the winter months, as operating the network and conducting emergency restoration works during heavy rainfall is a major problem.

In order to minimize these shortcomings, electrical control systems should be organized, including all elements, and all possible problems and methods for their effective elimination should be described.

It should also be noted that pressure sensors and flow meters should be installed on internal water supply distribution systems, so that as soon as a certain section is detected with a lower pressure than the standard pressure and the flow rate is significantly higher, the dispatch service should immediately provide the emergency team with information about this.

The area and exact coordinates must be provided electronically so that the emergency team can identify the damaged section in a short time and immediately restore the accident. It is necessary for the emergency team to be provided with the type of damaged section, pipeline diameter and material by the relevant structural units.

Also, the materials required to eliminate the accident must be delivered with the appropriate classification, and the dispatch service must shut off the water supply to the damaged section by manipulating the appropriate electric shut-off and regulating valves.

It should also be noted that during the design phase of the unified water supply system for the settlement we have indicated, great attention should be paid to the selection of the type of head structure. It is recommended to organize underground water intake, since it is less affected by environmental conditions, while in the case of surface water intake, problems will arise in winter conditions and it may freeze completely or, if covered with ice, we will no longer be able to ensure water supply and a deficit will arise in the system, as a result of which the system may partially freeze, the elimination of which requires quite a lot of time and resources.

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Mitigating Lead Contamination in Irrigation Canal Tanks: Sources, Impacts, and Sustainable Bioremediation Strategies,

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Abstract

Irrigation canal tanks are essential for agricultural water management but are increasingly threatened by lead (Pb) contamination, posing severe environmental and public health risks. This study examines global lead pollution in water systems, emphasizing its sources, effects, and mitigation strategies. Findings indicate that lead contamination frequently surpasses permissible limits, particularly in developing regions of Africa and Asia. Lead accumulation in irrigation water adversely affects soil health, crops, and food safety, further endangering human health through bioaccumulation and related health disorders. While traditional lead removal methods are effective, they are often costly and environmentally intrusive. Bioremediation, utilizing microorganisms and plants, offers a sustainable alternative. Organisms like *Pseudomonas putida* and plants such as *Brassica juncea* demonstrate significant potential in detoxifying lead through biosorption, bioaccumulation, and enzymatic transformation. This article explores bioremediation mechanisms, highlighting their feasibility, scalability, and environmental benefits in mitigating lead contamination in irrigation systems.

Keywords: Irrigation Systems, Microorganisms, Bioaccumulation, Biosorption

Introduction

Irrigation canal tanks play a critical role in agricultural water management, providing a reliable water source for crops. However, these tanks are vulnerable to heavy metal contamination, particularly lead (Pb), which poses significant environmental and health hazards. Lead contamination often originates from industrial runoff, agricultural practices, and urban waste. A global study examining lead pollution between 1972 and 2017 across 168 rivers and 71 lakes revealed that permissible standards for heavy metals in water, established by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA), were exceeded more frequently in the 1990s and 2000s compared to the 1970s. Developing regions in Africa and Asia experience higher contamination levels than developed countries in Europe and North America (Zhou, Q., Yang, N., Li, Y., Ren, B., Ding, X., Bian, H., & Yao, X. (2020). *Total concentrations and sources of heavy metal pollution in global river and lake water bodies from 1972 to 2017. Global Ecology and Conservation, e00925.* doi:10.1016/j.gecco.2020.e00925)

In Georgia, rivers such as the Mtkvari, Mashavera, Kazretula, and Lukhuni, located near mining operations, face severe lead pollution exacerbated by insufficient or malfunctioning wastewater treatment systems. Between 2009 and 2015, lead concentrations in industrial wastewater discharged into the Mtkvari River were up to 100 times higher than the Georgian government's permissible limits (Tabagari et al., 2024;(Muradashvili, Nikuradze, & Tsolukidze., 2022).

Lead's toxic properties significantly impact ecosystems and human health. The WHO identifies lead as one of the top 10 chemicals of concern for public health. In 2021, the Institute for Health Metrics and Evaluation (IHME) reported that 1.5 million deaths worldwide were attributed to cardiovascular diseases linked to lead exposure(World Health Organization, 2024). Children are particularly vulnerable due to their heightened sensitivity to lead's toxic effects. Lead can persist in the soil for up to 2,000 years without degrading, and irrigation with lead-contaminated water increases its concentration in the soil. This leads to bioaccumulation in crops, with root vegetables like carrots and potatoes being most affected, followed by leafy greens.

Lead also disrupts soil enzymatic activity and pH balance, negatively impacting soil health and the growth of cultivated plants (Collin et al.,2022). Lead contamination in irrigation systems can directly enter the human food chain through crops and soil, posing significant health risks. Once ingested, lead binds to hemoglobin in red blood cells, potentially causing anemia, liver damage, kidney dysfunction, and disorders in the nervous, cardiovascular, and reproductive systems(Kumar et al., 2020). Preventive measures, such as controlling irrigation water quality, are essential to mitigate lead exposure(). While conventional lead removal methods like chemical precipitation and reverse osmosis are effective, they are costly and environmentally invasive. Bioremediation offers a sustainable and cost-effective alternative by employing microorganisms and plants to detoxify lead-contaminated irrigation water.

This article explores the potential of bioremediation for addressing lead contamination in irrigation canal tanks. It reviews existing methods, highlights microbial strategies, and assesses their feasibility and scalability.

Sources of Lead Contamination in Irrigation Systems

Lead enters irrigation systems through multiple pathways:

1. Industrial discharge, especially from battery manufacturing and metal plating industries.
2. Mining runoff.
3. Urban wastewater and stormwater carrying lead from deteriorating pipelines and paints.

Such contamination not only threatens water quality but also impacts soil health and agricultural productivity. Removing lead from these systems is essential to ensure sustainable agriculture and environmental protection.

Microbial Bioremediation

Key Organisms Used in Lead Bioremediation

A number of studies have been conducted to study the bioremediation capabilities of microorganisms. The following organisms have been mainly used: bacteria, fungi, yeast, algae. Bacteria: Arthrobacter spp., Pseudomonas veroni., Bukholderia spp., Bacillus cereus, Sporosarcina ginsengisol; Fungi: Penicillium canescens, Aspergillus fumigatus; Algae: Cladophora fascicularis, Spyrogyra spp., Spirullina spp; Yeasts: Saccharomyces cerevisiae, Candida utilis. It is noteworthy that these organisms do not destroy metals, but rather convert them into less toxic forms.

Microorganisms used for bioaccumulation should be tolerant to one or more pollutants at increasing levels. Furthermore, they may possess biotransformational abilities, converting the harmful chemical to a less toxic or nontoxic form, allowing the organism to minimize the pollutants toxicity and keeping it contained. Many environmental microbial species exhibit high metal accumulation levels in cell walls or the areas bounded by cytoplasm. This deposit might account for up to 6% of the cell dry mass, and when examined in the context of the water or soil environment, this event can result in a temporary decrease in the concentrations of metal ions(Coelhoet et al.,2015).

Over the past several years, numerous studies have investigated the potential of microorganisms to remediate irrigation water contaminated with heavy metals such as lead (Pb), cadmium (Cd), nickel (Ni), and chromium (Cr). These investigations have primarily focused on reducing the adverse effects of these metals on soils and crops, especially in regions where industrial and municipal wastewater is used for irrigation. A study conducted by Vijay Kumar and his team at Lovely Professional University, India, examined the bioremediation capabilities of two Bacillus strains: *Bacillus thuringiensis* (IS1) and *Bacillus subtilis* (IS14). Both strains exhibited high resistance to heavy metals and were tested for their ability to remove zinc and lead from contaminated water. *Bacillus thuringiensis* proved more effective, achieving a biodegradation efficacy of up to 54% within the first three days. While the efficacy decreased over time, the findings demonstrated the potential of these bacteria for bioaccumulation and bioremediation in polluted environments(Kumar et al., 2015)

Studies conducted in India and other regions highlighted the algae's high bioadsorption capacity, demonstrating its effectiveness in cleaning wastewater and improving the quality of irrigation water. This approach shows promise for large-scale wastewater bioremediation. A study at Lovely Professional University, India, explored the bio-sorption potential of various fungi, including *Pleurotus florida*, *Fusarium oxysporum*, *Penicillium digitatum*, and *Aspergillus awamori*, in removing heavy metals from sewage water. Among these, *Pleurotus florida* exhibited the highest bio-sorption capacity, absorbing significantly more cadmium than the other fungi. (Zolgharnein et al.) demonstrated the uptake of metal ions - copper, zinc, cadmium, and lead by Pseudomonas aeruginosa. They also stated that metal uptake by bacteria is a combination of surface phenomena and diffusion. Pseudomonas putida accumulated cadmium intracellularly and periplasmically, indicating the presence of metal binding and/or efflux systems within the cells that mediate resistance to toxicity of metals. Researchers have investigated the potential of cyanobacteria in removing heavy metals, including lead, from industrial wastewater, demonstrating the applicability of bioremediation in aquatic systems. Also Researchers have investigated the use of Bacillus subtilis bacteria in removing lead from contaminated water, Which showed its high potential for bioremediation applications.

Phytoremediation

Phytoremediation employs plants capable of accumulating or immobilizing lead. Commonly used plants include: **Brassica juncea** (Indian mustard): Known for its hyperaccumulation capacity. **Helianthus annuus** (sunflower): Effective in phytoextraction and fast-growing. **Vetiveria zizanioides** (vetiver grass): Highly tolerant to lead and adaptable to various soils. **Salvinia minima**: A floating aquatic fern that accumulates heavy metals in its fronds.

The Mechanism of Bioremediation

Bioremediation leverages microorganisms, plants, or fungi that can absorb, accumulate, and detoxify lead from water and sediments. The key mechanisms include:

Biosorption involves the binding of lead ions to microbial cell walls through functional groups like carboxyl, hydroxyl, and amino groups. Key mechanisms include ion exchange, where polysaccharides in cell walls interact with metals, and complexation, where functional groups form stable bonds with metal ions. Physical adsorption occurs quickly and reversibly on surfaces, driven by Van der Waals and Coulombic forces, making it suitable for large-scale wastewater treatment. Precipitation involves metal ions forming solid deposits on or within microbial cells, influenced by metabolic changes. These processes highlight the efficiency of biosorption in removing heavy metals from solutions (Karnwal.,2024).

Bioaccumulation: Bioaccumulation is the uptake and accumulation of toxic metals like lead into living cells, surpassing removal rates. This process involves two stages: initial passive binding of metal ions to the cell surface and active transport into the cell when metabolically active. Influenced by exposure routes (diet, solution) and geochemical factors, bioaccumulation serves as an indicator of chemical exposure in polluted environments. Unicellular organisms absorb metals and nutrients through similar pathways. The bioactivity of living cells is crucial for bioaccumulation, as metabolically active cells absorb pollutants, enabling higher biomass growth under optimal conditions, which increases metal ion binding(Nnaji, Onyeaka, Miri, & Ugwa., 2023). Enzymatic Transformation: Certain microbes produce enzymes that can reduce lead ions into less toxic or immobile forms. Phytoremediation: The use of plants to absorb lead through their roots, accumulating it in their biomass for safe disposal or reuse.

The phytoaccumulation of metals involves several steps: Vol.:(0123456789) SN Applied Sciences (2023) 5:125 | https://doi.org/10.1007/s42452-023-05351-6 Review Paper (i) metal mobilization in the rhizosphere, (ii) uptake of metal by plant roots, (iii) translocation of metal ion from roots to the aerial parts of the plant, and (iv) sequestration and compartmentation of metal ion in plant tissues[76]. Phytoaccumulation has been the most popular phytoremediation approach for removing metals and metalloids pollutants from soil in recent years(Nnaji et al., 2023).

Conclusion

Lead contamination in irrigation canal tanks presents a severe threat to agriculture, soil health, and public health. Bioremediation emerges as a promising solution, offering an eco-friendly and cost-effective alternative to traditional methods. By leveraging the capabilities of microorganisms and plants, bioremediation can significantly reduce lead bioavailability and mitigate its environmental impact. Future research should focus on optimizing these methods for large-scale application, considering environmental variability and specific contamination levels. Proactive measures, including improved infrastructure, monitoring, and the adoption of bioremediation techniques, can pave the way for sustainable irrigation practices and safer agricultural systems.

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Reservoirs, distribution network and innovations in water supply and distribution engineering systems, *Ana Shamugia,*

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Abstract

Water distribution is a critically important aspect of civil engineering, ensuring that the population has access to clean water at the required pressure at any time of the day.

Modern water supply and distribution systems are built from modern, sustainable, environmentally friendly materials which minimizes the negative impact on the environment during the construction and operation of these systems and increases the durability of the system.

Just as it is preferable for the population to receive high-quality water, it is also a priority for the environment to return the used water to nature after appropriate treatment. It is important not to miss out and to constantly stay informed about innovative inventions that will make water supply and distribution engineering systems more reliable.

Key words: reservoir; distribution network; innovative technologies

Introduction

In this article, I will focus on the importance of the water supply network and reservoirs, what tasks they must perform to deliver high-quality water to the consumer, on time, with the required pressure. I will also present innovative inventions that will play an important role in increasing the reliability of the system.

I would also like to note that the smooth and reliable operation of all elements of water supply and sewage on the water path to the consumer and after consumption is equally necessary for the water engineering system. Along with the dynamics of population growth, to ensure access to quality water, it is necessary to use innovative technologies in water supply engineering systems, those technologies that have undergone numerous tests and demonstrated a high level of efficiency, which will help modern engineering systems to make quick and competent decisions during operation.

Main part

Tasks of Storage Tanks and Pipe Network to protect the quality of drinking water :

-The transportation time to the consumer should be as short as possible

-Stagnation (wetting) promotes the growth of microorganisms

-Minimize temperature changes during transportation

-It is best to lay the drinking water pipeline network at a depth of at least 1.5 m from the surface: freezing = a technical problem; heating = a quality problem.

An effectively functioning water supply and distribution network, which is highly reliable and delivers high quality water to the consumer, is a water supply network in which the diameters of water pipes are determined taking into account pressure losses (caused by friction of the water flow against the inner walls of the pipes) and water flow velocity; The effective water flow rate in pipes is from 0.8 to 1.0 m/s for standard operation; Pumps and tanks (at the location) to ensure the required water pressure in the water supply system not less than 3 bar and not more than 6 bar at consumer.

The Reservoirs

The pressure water supply tank must have:

-Standard water supply, based on the imbalance between supply and consumption of water over a 24-hour period (peak hours of maximum consumption, such as morning hours, and hours of minimum consumption, such as night hours);

-emergency standard reserve, with provision for an emergency reserve (from 10% to 30%);
-Supply in case of fire, for example, 17 l/s for at least 2 hours.

Efficient abstraction site design based on the maximum daily-average demand (Qmax) , distribution mains design based on peak-hour demand / firefighting (Qmax). The water tank at the highest point determines the highest pressure in the network, and the required pressure in the network is provided by booster pumps.

The pipes in reservoirs: Overflow, Withdrawal, Bottom outlet (discharge).

Reservoirs - Types

Reservoirs situated at the altitude of the distribution network: booster pumps are needed to provide water with adequate pressure;

Elevated storage: Gravity discharge tank (water is held at a height that maintains pressure without additional pumping)

1.Placed at the ground (e.g. slope of a hill)

2.Placed at the top of a tower (expensive)

Pressure tanks (small & very small application).

Reservoirs - Position

Position in relation to the distribution system:

tanks situated between extraction plant and distribution system (better exchange of water within the pipes) and tanks situated at the far side of the distribution system (better safety in case of interruptions; problem with stagnation).

In water supply systems, there are round and rectangular reservoirs single-chamber and multi-chamber, connected by chambers with switching valves. To maintain the quality of water in a reservoir, it is necessary for the water to circulate and move in the internal volume of the reservoir, at the height of the water level in each section of the reservoir, in order to avoid stagnation, which in itself leads to deterioration in water quality and the possibility of algae appearing.

Distribution network

Division of pipes according to their task:

- Transmission mains (operating roughness: 0,1 mm)
- Distribution mains (operating roughness: 0,4 mm)
- Service connections (connections to the houses)

To calculate head losses: slide rule or Formula of Prandtl-Colebrook (see hydraulics).

Distribution network – Mains - Network types

a) Branching pattern with dead ends ; b) Grid pattern with central feeder; c) Grid pattern with looped feeder

Advantage of grid system: higher reliability (supply from more than one side)

Disadvantage: More expensive and lower flow velocity (stagnation, sedimentation).

Innovations in water supply and distribution engineering systems

There is various kind of pipe leaks. Some of them can bring the flood to your home, whereas other do not cause that much damage. Although, finding leakage in pipe system is also a difficult process as they may sometimes small as a pinpoint.

Now, a new system developed by researchers at MIT could provide a fast, inexpensive solution that can find even tiny leaks with pinpoint precision, no matter what the pipes are made of.

The system, which has been under development and testing for nine years by professor of mechanical engineering Kamal Youcef-Toumi, graduate student You Wu, and two others, was described in detail at the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).

The system uses a small, rubbery robotic device that looks something like an oversized badminton birdie. The device can be inserted into the water system through any fire hydrant. It then moves passively with the flow, logging its position as it goes. It detects even small variations in pressure by sensing the pull at the edges of its soft rubber skirt, which fills the diameter of of the pipe.

The device is then retrieved using a net through another hydrant, and its data is uploaded. No digging is required, and there is no need for any interruption of the water service. In addition to the passive device that is pushed by the water flow, the team also produced an active version that can control its motion.

In Saudi Arabia, where most drinking water is provided through expensive desalination plants, some 33 percent is lost through leakage. That's why that desert nation's King Fahd University of Petroleum and Minerals has sponsored and collaborated on much of the MIT team's work.

"We put the robot in from one joint, and took it out from the other. We tried it 14 times over three days, and it completed the inspection every time," Wu says. What's more, it found a leak that was about one gallon per minute, which is one-tenth the minimum size that conventional detection methods can find on average, and a third as large as those systems can find under even the best of conditions.

Pipescan Monitoring System for Drinking Water

A modular sensor system that monitors drinking water quality in pipes under pressure. This device measures up to 10 parameters. The water quality data can be sent to a central database via almost any protocol. Using pipescan throughout your entire network is an ideal solution to monitor drinking water.

Parameters: Chlorine, Color, Conductivity, DOC, ORP, pH, Pressure, Temperature, TOC, Turbidity, UV254.

Conclusions

Properly organized operation of engineering systems and devices involved in all stages of water supply is important for reliable operation of water supply and distribution systems. It is important to maintain the quality of extracted and purified water before its use by the user. To improve existing traditional methods and meet the increased demand for water in the future, it is necessary to implement innovative technologies that will make water supply and distribution systems more efficient and profitable by reducing water losses in the network, by predicting early response to emergency situations and reducing the time to eliminate the problem.

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The Role of Nanotechnologies in Architecture and Engineering,

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Abstract: As known, architecture has a great part in everyday life, and it influences on the whole world. Architectural contrast and integration of a certain building to the area is the main question, but at the same time it`s necessary to be considered what kind of materialsto be used for the building. How to use nanotechnologies and how to implement it in architecture and engineering and its connection to construction is discussed in this article. Using such kinds of innovative technologies will make it possible to control construction materials and their qualities. Nanotechnologies will change construction rule with transforming the basic properties of materials, it will deeply affect on architecture industry on all scales: Interior design, the design of buildings and the city design as well, as it`s possible construction to be implemented using practical and innovated materials, according to nanotechnologies. Architecture will continue to function on a more optimal level.

The Main Part

Nanotechnology is fast developing and has huge potential for many industrial fields and among them, for architecture. Nanotechnology means manipulation of materials and structures at the nanometer level (in particular from 1 to 100 nanometer) where material qualities might differ greatly from their mass analogues. Using these unique qualities, nanotechnology suggests architecture chance for revolutionary changes of building designs in the construction and exploitation process, which gives opportunity to increase efficiency, sustainability and implementation.

“Extraordinary materials” of nanotechnologies can simplify different industrial work. For example, carbon nanotubes, sheets of graphite of an atom thick, which is not only 50 times stronger than steel, but it’s also 10 times light, and transparent and are even electrical conductors for loading. Nanotube is ideal for hydrogen storing, as its nanostructure means that 2 grams has an internal surface area equal to a football field.

Carbon Nanotube has recently discovered unique material, which has amazing electrical, thermal and structural properties. Above mentioned nanotubes potentially might be used as an energy storeroom for fuel cells also as for feeding mobile electronic cells. The meaning of nanotechnologies in architecture is in material control and manipulation on atomic or molecule. This control gives chance to architects and engineers to create such construction materials which has reinforced physical, chemical and mechanical properties, which is less possible with traditional natural materials. There are so many good examples in modern materials by using nanotechnologies, e.g.: adding only 2% of nanoparticulate clay minerals to the polymer coating gives quite different and better result. As polymer coating, without any processing, is damaged easily and heat effects on it greatly, after interactions with nanoparticle, more rigid, durable and scratch-resistant coatings are got. This is useful at certain times, for example, when material fits the certain environment in terms of weight and strength, but it needs protection from the external, potential corrosive environment. In this case, it’s useful to use polymer coating. It gives opportunity urban area to improve both in terms of design and protection and maintenance of buildings.

Nanocomposites that combine new, more traditional nanomaterials, like: steel, concrete, glass and plastic might be much stronger than ordinary materials. Nanocomposite steel is already on the market, which is three times stronger than the ordinary one. In the nearest future nanocomposite reinforcement of steel, concrete, glass and plastic will greatly improve these materials effective, endurance and strength-to-weight ratio. In some nano-studio student projects of Ball-State University, nanotube structural panels create transparent, load-bearing walls, with quantum dots, walls and ceiling light up or change color with the switch turning, but nano-sensors make space, which constantly adapts to the environment and the user.

Nowadays there are two directions in architecture when it comes to the relationship with materials and surface.

a) ''What You See Is What You Get''

The first kind of direction is when architects use natural materials, as authenticity is priority for them and appreciate high quality materials such as natural or solid wood.

b) Artificial Materials

The second direction is when artificial advantage is given to artificial materials. In this case ``fake`` materials are chosen, mainly because of expenses. For example, wood may be replaced with synthetic wood effect plastic, as this method is less expensive, Artificial surfaces are ``perfect``, the color is the same as the pattern and is not changed over time. In the 21st century more and more surface copies are created and high- leveled ones are precisely controlled and easily accessible.

In modern engineering, construction and architecture, in the nearest future the third direction will appear, nano-surfaces, which are created according to main materials (glass, steel etc.). Such ultra-thin surface parameters are not only better, but they might be assigned to new functional properties and become multi-functioned. Nanomaterials can expand the creation of architectural design possibilities and esthetic, functional and emotional properties may be expressed more easily, it`s simply a matter of choice. As an expression `` form follows function`` will be more realized in all kinds of construction task.

One example of nanotechnology usage is Mtatsminda, Lotus effect. It's the most famous which was researched by botanist Wilhelm Bartlot in the 1970s. He studied Mtsatsminda Lotus effect. Surfaces with self-cleaning effect reveal a microscopically water-separated surface, which is covered with tiny particles so, that water can`t contact to the surface for a long time and because of microstructure surfaces, which are already hydrophobic, get less wet. Rough surface effect strengthens more with combination to wax (which is hydrophobic as well). Artificial Lotus Surfaces, which are created by nanotechnologies, don't have the ability of repairing, but after studying and researching this problem might be solved. Lotus effect will be appropriate on surfaces, on which water leaves some spots and prevents cleanliness. In case of using the above-mentioned effect, the advantage is quite evident: Cleaner urban environment and very reduced maintenance requirements. Also, using Lotus self-cleaning effect in wooden surface gives many possibilities: Wood might be given extremely waterproof surface; Lotus plant like nanostructures on a wooden surface, water contact to its surface is reduced and accordingly, instead of penetrating the wood, water breaks down into smaller particles.

Implanting this method in architecture will increase demand for wood use. There is an example of Lotus Effect used in modern architecture: Richard Meier Passis Museum in Rome is an archeologically distinguished place, the complex of three-sided buildings which consists of an entrance gallery, main building exhibits, conference halls and a restaurant, areas for temporary exhibitions, a library and offices. The rest of the building is implemented with large blocks and paved surface, as Meier typical architecture. Self-cleaning cover on the white surface is integrated invisibly to provide color endurance and exterior cleanness.

The second kind of self-cleaning is photocatalytic self-cleaning, which is the most widely used nano-function in building construction. To create photocatalyric cover, materials, consisting of tutan dioxid $TiO2$ particles, are used. As a result, after using this function, existing spots on a building surface and unwanted substances have disappeared with ultraviolet sun rays and then is washed with rain. Present self-cleaning surfaces are produced by using paints of nano-cover tape and have anti-properties of sterilization and pollution. The examples of above-mentioned nanotechnologies usage in architecture are Jubilee Church by Richard Meier; Milani Nature Building by Stephano Boeri Company "Bosco Verticale" Burj Khalipa; Singapore Expo Building; Al Bahr Towers in Abu Dhabi and BNW Welt Building in Munich. The walls of these buildings consist of titan dioxide particles and as a result, the cleanliness of the fade is protected from damage and pollution. Also, effective self-cleaning reacts positively to keep the architecture structure.

One of the potencial direction of nanotechnology in architecture is energy efficiency and sustainability. By developing nanomaterials, energy consumption, reducing carbon dioxide reserves and increasing sustainability will be possible. Using nanotechnology will be possible in order to improve the thermic parameters of buildings. Nanomaterials, such as air grills might be useful as thermal insulations. For example, in accordance with certain requirements it will be possible both to regulate very hot temperatures and to heat cold temperatures, which will reduce demand for heating or cooling. This process will be implemented with phase changing materials (PCM), which are composed with nanoparticles. Such development of construction will greatly improve energy efficiency of buildings.

In spite of a lot of opportunities, some nanoparticles, among them carbon dioxide nanotubes, cause certain risks, e.g. polymers. There is a possibility that to inhale a specific length scale free nanoparticles may be harmful for people `s health, especially at producing time. But if it`s wisely observed and studied, risks will be minimum during the life process of the particles. It`s doubtless, that nanotechnology has big potential to be useful for society, but it must be mentioned, that caring is necessary to provide all these achievements as safely as possible.

Conclusion

In this article all examples are discussed how nanotechnology directions to develop in architecture. Nanotechnology will give the mankind opportunity to move into new areas of added value, to create new architecture and radical changing of the traditional architecture as well. It promotes developing of other technologies and formation of disciplinary works. At the process of architectural planning, knowledge and experience uniting of specialists in different fields is necessary at an early stage. Using of nanotechnology in project and construction will be involved with a lot of applications and in all phase of design, from early sketches to disposal of construction material. In particular, material design will be very important in our imagination about architecture and building planning

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Impact of Pumped storage hydropower plant (PSHP) on the sustainable operation of the energy system,

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Abstract: The operation of a Pumped storage hydropower plant (PSHP) is based on a surprisingly simple principle. It is based on storing water in two or more reservoirs (the number depends on the topography), which are located at different heights. During periods when the load on the unified energy system is minimal (usually at night), the pumped storage power plant operates in the so-called pumping mode and pumps water from the lower reservoir to the upper reservoir. For this, it uses the electrical energy available in the system. During peak operation, the power plant operates in generation mode and consumes the water stored in the upper reservoir. After the peak, the water is pumped back to the upper reservoir and the PSHP is ready for the next cycle.

Introduction

Technological developments have had a major impact on electricity consumption. The demand for electricity is constantly increasing all over the world, and Georgia is no exception. The demand for peak electricity has increased in particular, which is why pumped storage power plants (PSHPs) were created to meet this demand.

Pumped storage power plants have long been operating around the world as the best energy-saving technologies. A pumped storage power plant is a conventional hydropower technology used to store and manage electricity/energy. For this purpose, the PSHP has two reservoirs. When there are low loads in the electrical system, the pumped storage power plant operates in pump mode and accordingly pumps water from the downstream reservoir to the upstream reservoir/reservoir. The water reserve created in the upstream reservoir is often called a “water battery”.

Main part

The operation of a hydroelectric power plant is based on a surprisingly simple principle. It is based on storing water in two or more reservoirs, the number of reservoirs depending on the topography, which are located at different heights. During the period when the load in the unified energy system is minimal (usually at night), the hydroelectric power plant operates in the so-called pumping mode and pumps water from the lower reservoir to the upper reservoir. For this, it uses the electricity available in the system. During peak operation, the power plant operates in generation mode and consumes the water stored in the upper reservoir. After the peak, the water is pumped back to the upper reservoir and the hydroelectric power plant is ready for the next cycle.

Pumped storage power plants are particularly important because they can be brought into operation quickly to generate electricity during peak load periods in the power grid. In most cases, such hydroelectric power plants complete a full cycle every 24 hours.

The first pumped storage power plant was built in the late 19th century. In 1882, two pumped storage power plants with a total capacity of 103 kW were built in the Zurich area of Switzerland. Twelve years later, a similar system began operating in an Italian factory, and the first 1 MW pumped storage power plant was built in Italy in 1908.

By 1940, there were already 40 PSHP in the world, in 1965 - 110, in 2000 - about 300, with a total capacity of 100 GW.

PSHP with a capacity of more than 1000 MW have already been built in the world, a total of 59 stations. The number of stations with a capacity of up to 500-1000 MW has reached 42, while the number of PSHP with a capacity of less than 500 MW in the world is 350.

Forms (types) of electricity consumption in the energy system:

a. Base consumption (the system requires constant consumed capacity);

b. Peak consumption, i.e. day-night (morning peak and evening peak);

c. Seasonal consumption - uneven generation (due to the instability of river flows, reservoir-based PSHP are used);

Accordingly, PSHP are necessary to "smooth out" peak consumption and participate in covering the energy deficit (to neutralize the instability of daily, weekly and seasonal fluctuations).

For the sustainability of the system, the main sources of electricity generation are:

1. Thermal power plants - (TPP) account for (75-80)% of the generated energy.
2. Hydroelectric power plants - (HPS, HPP) their share is (15-17)% (for Georgia (65-75)%)
3. Nuclear power plants - (NPP) their share is (5-6)%
4. Other energy generators (wind, solar, etc.),

Classification of hydro-accumulated power plants:

Three options are considered:

I. According to the accumulation scheme;

II. According to the duration of the accumulation cycle;

III. According to the scheme of the main hydro-power device;

According to the accumulation scheme:

1. Simple type of accumulation PSHP - they are called clean power plants, since there is no water inflow into the upper reservoir.
2. Mixed type PSHP - they have a water inflow into the upper reservoir and provide additional generation.
3. Water flow transmission PSHP - they have different locations of the pumping station and hydroelectric power station.

Accumulation cycle by duration:

1. Daily;
2. Weekly;

3. Seasonal accumulation;

Hydropower According to the device scheme:

1. Four-engine or separate units, consisting of two separate units (engine with pump and turbine with generator);
2. Three-engine (engine - generator, turbine and pump);
3. Two-machine reversible hydraulic device with motor-generator;

Three-machine design HMES are most often used in cases of high-water pressure (more than 300 meters). In this case, bucket (basket) hydraulic turbines are used. HMES units, depending on the height of the water flow, are equipped with rotary-blade, diagonal, radial-axial or bucket (basket) hydraulic turbines, the capacity of which reaches 200 MW.

Hydroaccumulated power plants, built according to the two-machine scheme, have reversible electrical and hydraulic units that can operate in both pump and turbine modes. In the turbine and pump modes, the operation of the two-machine units is carried out in opposite directions of rotation.

PSHP equipped with three-machine units:

a). Pellet turbines;

b). Francis radial-axial turbines;

c). Radial-axial turbines located directly at the engine (economical option);

A new leader has emerged among the pumped-storage power plants. This is the Fenin station, located in China. The capacity of the new HPP is 3600 MW, which is almost 600 MW more than the previous giant station, located in Bass County, USA. A special feature of the Fenin pumped-storage power plant is two underground machine rooms with their equipment. They are equipped with 12 reversible hydraulic units with a capacity of 300 MW, the pump-turbines of which operate at a head of 425 m. Another unusual detail is the station's connection to the power grid via a direct-current line.

Construction of the station began in 2013, and the first hydroelectric units were commissioned in 2019. In general, China is paying great attention to the construction of new pumped-storage power plants, which are crucial for ensuring the reliability of energy supply. Their role is becoming especially important against the background of the rapid growth of solar and wind power generation, which is highly dependent on meteorological conditions.

By 2025, the total capacity of China's pumped-storage power plants should increase to 62 GW, and by 2030 it should reach 120 GW.

At the end of December 2021, the Fenning Hydroelectric Power Plant was commissioned - another important facility, which became the number one HMES in the world, by installed capacity - 3.6 GW.

Georgia's potential:

Hydropower potential resource: 136 billion kWh.
Technically usable hydropower resource: 68 billion kWh.
Economic hydropower resources: 32 billion kWh.
Average multi-year operation of hydroelectric power plants: 8.11 billion kWh.

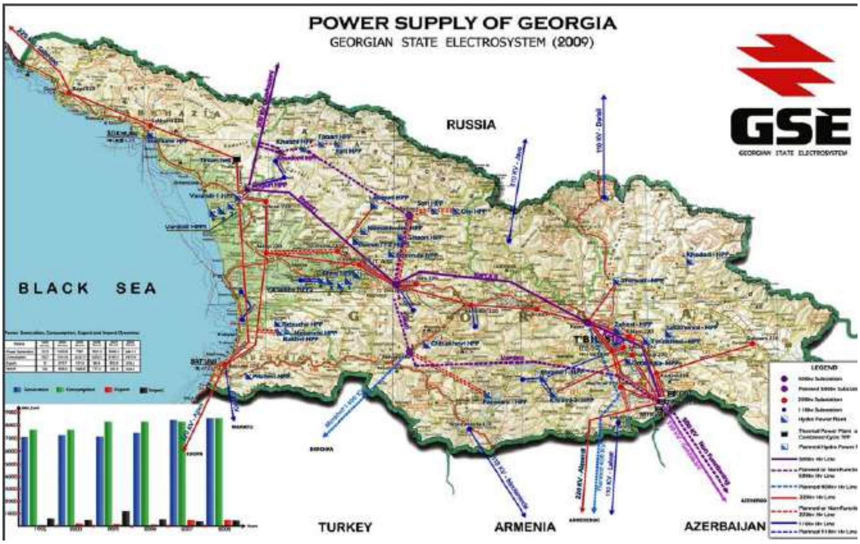
The profitable operation of the hydroelectric power plant is determined by the constant base energy, which can be obtained at the expense of nuclear power plants. Georgia can receive installed base energy after the completion of the ongoing construction of a nuclear power plant in Turkey. During the implementation of the project, Georgia will receive constant base energy, after which it will be obliged to supply the other side of the transaction during peak hours. All this requires the conversion of the Enguri Hydroelectric Power Plant and the Khudoni Hydroelectric Power Plant from HPP to PSHP.

When designing the Enguri Hydroelectric Power Plant, one option was considered to be the construction of a nuclear power plant in Gali, on the basis of which Georgia would receive excess base energy and the Enguri HPP PSHP would operate on the basis of this energy. This project would have brought great progress to Georgia from an economic point of view, however, due to economic and political reasons, the project could not be implemented, and the Enguri Hydroelectric Power Plant project was developed in the form in which it is presented today.

The Khudoni Hydroelectric Power Plant was also designed to operate as a PSHP system, the lower reservoir was to be used as a water storage basin. A 40 MW station was to be located near the lower basin, which would operate on the principle of a turbine-generator, and would also perform the function of a pump, and at a time when excess energy was generated in the country, it would pump water from the lower basin to the upper basin.

The implementation of the above projects would completely eliminate and remove the issue of energy supply in Georgia from the agenda.

Given that Georgia is a water-rich region, it is easy to satisfy not only its own peak hours with peak energy, but also to export energy to the region. The presence of constant base energy in the country will solve the issue of energy supply for the countries of the Caucasus region. In addition to the PSHP, the construction of the Namakhvani hydroelectric power station, which will contribute to the generation of energy during the peak period, will also help with the general energy issue.



Scheme of use of generated energy in Georgia

Technical characteristics of Enguri HPP:

- Arch dam - height 272.5 m. 728 m to the bottom
- Deep water intake
- Pressure diversion tunnel D = 9.5 m and L = 15 km
- Equalization reservoir
- Underground turbine pipelines
- Structure for disc valves
- Underground hydroelectric power station building
- Structure for downstream valves
- Outlet collector and open distribution node 500, 220 and 110 kV
- Volume of the Jvari Reservoir 1100 million m3
- (useful volume 676 million m3)
- Total head 410 m; 226 m - arch dam and 184 m - pressure diversion
- The thickness of the dam at the ridge level - 10 m, and at the top of the dam - 52 m
- There are 7 outlet openings in the dam body for water discharge

• A hydropower plant with a capacity of 1300 MW and an average annual output of 4430 million kWh, depending on the water flow.

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Restorations of Architectural Monuments and Modern Interventions

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Abstract: Georgia possesses its definite architectural heritage, which endured many trials throughout the centuries. Its churches and monasteries are at once spiritual and cultural monuments, carriers of historic events. Nevertheless, time, wars, and natural disasters left their mark on many monuments, and their restoration and preservation became necessary. This paper reviews the restoration practice and modern intervention that has been carried out on Georgian architectural monuments. Specifically, it talks about the restoration of the Bagrati Cathedral, challenges, and criticism concerning the restoration methods used, along with their implication for authenticity and cultural value preservation.

Keywords: Georgia, architectural heritage, restoration, modern intervention, Bagrati Cathedral, cultural preservation, UNESCO, authenticity.

Introduction: The architectural heritage of Georgia is a cornerstone of its cultural identity, with centuries of history, artistry, and religious devotion. Within the many iconic monuments of the country, there is one outstanding symbol of Georgia's rich historical legacy: the Bagrati Cathedral. Constructed in the 11th century, the cathedral is an outstanding example of medieval Georgian architecture with cross-dome structural features and rich design elements.

fig.1. Bagrati Cathedral

Over time, however, Bagrati Cathedral, like many other monuments, has been badly damaged by wars, natural calamities, and the wear and tear of time. Such places do require restoration for their survival but often debates arise on how much one can retain originality and still insert modern interventions. This paper looks into the restoration of Bagrati Cathedral from technical, cultural, and ethical standpoints.

Main part: Historical Importance of Bagrati Cathedral. The Bagrati Cathedral in Kutaisi is one of the masterpieces of 11th-century Georgian architecture, thanks to its cross-dome design and its very advantageous placement on top of a hill. Throughout history, the cathedral has been a place of worship, a ceremonial place for Georgian royalty, and a political unifying symbol for the people of Georgia. Surviving frescoes and pieces of the building are of great value in studying the medieval art and craftsmanship of Georgia. In 1994, Bagrati Cathedral was inscribed on the UNESCO World Heritage List, highlighting its global cultural importance.

The Restoration Process: In 2009, restoration works started at Bagrati Cathedral based on the considerable research and geotechnical studies undertaken in 2008. These studies revealed that the foundation and walls of this cathedral suffered from colossal destruction due to a variety of reasons including the atmospheric conditions, the groundwater impact, and the structural deformations. Therefore, different innovative techniques have been applied during restoration, such as:

Foundation Strengthening: Bore-injected piles for the stabilization of the foundation substantially improved the structural stability and seismic resilience of the cathedral.

Modern Materials Used: Strengthening of walls and arches with the use of reinforced concrete and cement-based solutions was carried out at critical places.

Georadar Surveys: Georadar technology, used for the first time in Georgia, helped in the detection of empty spaces and breaks in walls and arches to assure a correct and accurate restoration process. **Integration of Traditional and Ancient Methods**: For consolidating the foundation, both vertical and inclined anchors have been used; hence, traditional methods are combined with modern engineering solutions.

Challenges and Criticisms: Renovation work on Bagrati Cathedral had also faced many technical and cultural challenges. Among these issues, some of the major ones were:

fig.2. Bagrati Cathedral before restoration

Authenticity versus Functionality: While UNESCO and the public wanted the cathedral to be authentic, the Georgian Orthodox Church was concerned with the functionality of the place as a working place of worship. This led to disputes on the use of modern materials and designs during restoration. International Criticism: UNESCO criticized certain aspects of restoration that were compromising the monument's integrity as a historical site. The use of reinforced concrete and other modern interventions came under particular scrutiny. **Delays and Modifications**: Conflicting viewpoints and UNESCO's directives caused delays and multiple revisions to the restoration plan. Despite these challenges, the restoration achieved significant milestones, including improved seismic stability and the conservation of remaining authentic elements.

Outcomes and Impact: The restored Bagrati Cathedral is now a place of religion and part of Georgia's architectural heritage. Though the questions about certain aspects in the restoration process are still disputed, it has contributed to the elaboration of new methods of restoration and importantly to deeper discussion on protection of the cultural heritage. The project thus points out the need for striking the balance concerning both historical authenticity as well as contemporary needs.

Conclusion: The restoration of the Bagrati Cathedral is one of those crucial moments in the field of cultural heritage protection in Georgia, combining traditional approaches with modern technologies in answering critical structural issues and raising very important debates related to authenticity and functionality. Despite all criticisms, it may be a case study for future protection and preservation work on architectural monuments. The Bagrati Cathedral remains a proud icon of Georgian history, a very sensitive balance between the past and the present in cultural preservation.

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Construction Market: Basic principles and perspectives,

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Abstract

The main principles of the construction market including economic sustainability, investments and modern technologies such as Building Information Modeling (BIM) and 3D printing are discussed. The focus is on the impact of new technologies on the construction process, which reduces costs, improves quality and agility. The prospects include green technologies, energy efficiency and smart buildings that support the long-term development goals of the environment and the market. These trends determine the future of the construction market and increase its competitiveness.

Keywords: Construction Market, Investments, Technology Innovation, Energy Efficiency, Green Technologies Building Information Modeling (BIM).

The construction market is an industry that is one of the most important sectors of the economy and plays an important role in both national and global development. The market is based on several key principles that determine its sustainability and ability to develop new technologies, resources and strategies. This topic discusses the basic principles of the construction market, including investments, technologies and economic sustainability, as well as its prospects for the development of green technologies, energy efficiency and smart buildings [1,2].

The success of the construction market depends on several basic principles that determine its effectiveness and sustainability. First, economic sustainability is important, because construction requires large financial resources, and when improving the market, a balance between demand and supply is necessary.

On the other hand, investments play an important role – it provides not only the launch of new projects, but also additional resources and technological development. Investing, both at the private and state levels, requires a strategic approach and a long-term plan.

Ever-evolving technological innovations play an important role in the growth of the efficiency and quality of the construction market. For example, Building Information Modeling (BIM) and 3D printing technologies that will scale up the construction process, reduce costs and use resources effectively. BIM allows specialists to accurately plan and evaluate the project and all its parts, while 3D printing minimizes manual work,

Which means saving time and finance. The prospects for the development of the construction market do not match only technological advances [3,4]. Its future mainly depends on the modern requirements that increase the competitiveness of the market. One of the important trends is green technologies and energy efficiency.

The world is increasingly attentive to environmental protection and efficient use of energy, which has an inevitable impact on the construction industry. Smart buildings, which are integrated into modern technologies, such as automation and internet cooperation, offer a comfortable and energy-efficient environment, the use of which leads to the development of the market.

In parallel with the development of smart technologies, the demand for green construction standards is growing,

Such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) that determine the energy efficiency and ecological sustainability of buildings. These technologies not only protect the environment, but also contribute to the prolongation of the benefits of structures, which ultimately lead to economic growth and long-term market development. The future of the market depends on the changes in governance management systems that provide efficient management and better performance. In addition, internationalization and support by international standards will become key factors for the future growth of the construction market.

Conclusion

The main principles and perspectives of the construction market show that industry must be well suited and adapted to technological progress, which includes the introduction of modern technologies as well as the implementation of green and energy-efficient approaches. While investments and economic sustainability remain the basis of the market, technological innovations, green buildings and smart technologies contribute to the effective development and growth of the market. In this way, the construction market will be sustainable, creative and technologically sophisticated in the long run.

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Leonardo da Vinci: The Ingenious Engineer of the Renaissance,

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Abstract: When you think of Leonardo da Vinci, your mind likely darts to his remarkable contributions to the world of art – masterpieces like 'The Last Supper' and 'Mona Lisa'. But what if we told you that da Vinci's genius extended beyond his paintbrush, playing a significant role in shaping a critical piece of our modern navigation system – the Canal Lock? In this article, we explore the unique mechanisms that make our waterways navigable and the profound influence of Leonardo da Vinci's designs on their development. We dive deep into the workings of canal locks, including the Leonardo da Vinci Canal Lock.

Key words: Canal, locks, engineering.

Main Part

Decoding the Mechanics of Canal Locks. Before we delve into Leonardo's impact, it's important to grasp the mechanics of the canal lock. But what exactly are canal locks, and how does a canal lock work?

Canal Lock Operation System. Simply put, canal locks are water-filled chambers which serve as elevators for boats. They allow vessels to traverse changes in water levels in our rivers and canals. The process may sound complicated, but it follows a basic yet ingenious step-by-step principle:

1. A boat enters the lock, which is filled to match the level of the waterway from which the boat is coming.
2. The gates close behind the boat, sealing it within the chamber.
3. If the boat is going upstream, water is let into the chamber through valves, causing the boat to rise. If the boat is going downstream, water is let out of the chamber, causing the boat to lower.

4. Once the water level in the lock matches the level of the waterway the boat is moving to, the gates at the other end of the lock open, and the boat continues its journey.

The Birth of Canal Locks. The Maiden Lock and Its Conception

The first lock dates to the 3rd century BC in Ancient Greece at a place called Palaipaphos (modern Kouklia). It was a simple, yet effective design, using a single gate and a sluice system.

Who invented the canal lock? When was the canal lock invented?

- In the year 983 AD in China, an engineer named Chiao Wei-Yo introduced a novel idea.
- His concept involved positioning two barriers a short distance apart.
- This arrangement created a calm water pond or basin between the two barriers.
- The water in this pond could be filled or emptied at will, offering complete control over its level.
- Despite the water's one-way flow, his design allowed boats to travel both downstream and upstream.

Leonardo da Vinci's Revolutionary Canal Lock Design. Leonardo da Vinci, the renowned polymath, was not only an artist but also an innovative inventor. One area where his inventive genius shone was in the design and development of canal locks.

Da Vinci canal lock design was distinctly different from those that came before. It showcased his unique ability to analyze a problem and come up with a more efficient solution. His canal lock was a "miter lock," named for its two gates that met at an angle like a miter joint in carpentry. This design was a departure from the straight-gated locks that were common in his time. This miter lock canal design allowed for a stronger seal as the water pressure itself forced the gates together. This marked a significant step forward in the efficiency and reliability of canal locks.

Application of da Vinci's Canals. His canal lock designs were utilized in several famous canals, such as the Martesana Canal in Italy. This canal, among others, shows Leonardo's engineering prowess and the practical application of his miter lock design. His influence extended far beyond Italy, eventually becoming a standard in canal engineering worldwide. The adoption of his design marked a turning point in the development of effective water navigation systems.

The World's Most Renowned and Colossal Canal Locks. One of the most recognized canal locks worldwide is the Berendrecht Lock. This lock is not only famous for its location in Antwerp, Belgium, a city known for its rich history and spectacular architecture but also for its innovative design.

Fig.1 Berendrecht Lock, Belgium

The Berendrecht Lock was designed to accommodate the largest seagoing vessels, making it the epitome of incredible engineering. Its advanced lock technology makes it a marvel of modern engineering and a significant achievement in water navigation.

Location of the World's Largest Canal Lock . The Three Gorges Dam Ship Lift lock in China represents a marvel of engineering ingenuity. Its vertical design allows ships to ascend and descend an impressive 113 meters in the Yangtze River.

Unlike traditional locks, it uses a 'ship elevator' approach to move vessels vertically in a contained water body. This method significantly reduces the time it takes for a ship to traverse the height difference.

Fig.2 Three Gorges Dam Ship Lift Lock, China

This colossal lock and its innovative design have made the Three Gorges Dam an essential part of global shipping routes. It is a fitting symbol of China's significant contributions to modern canal engineering.

Canal locks are integral to our waterways, yet their importance often goes unappreciated. These innovative contrivances enable ships to traverse the varying elevations along rivers and canals smoothly. Acting as water elevators, they lift and lower vessels by manipulating water levels within enclosed chambers.

Besides aiding in navigation, canal locks have significantly bolstered trade and commerce. Here's how:

- **Streamlined Shipping:** Canal locks make the movement of goods faster and more efficient. Allowing ships to bypass difficult and lengthy routes around geographical obstacles enables a swift and direct path between commercial hotspots.

- **Cost Efficiency**: Canal locks facilitate direct routes, helping reduce fuel consumption and overall shipping costs, which can ultimately lower consumer prices.
- **Global Connectivity:** Canal locks have transformed isolated regions into bustling commercial hubs, fostering economic growth and international connectivity.

Da Vinci's Impact on Today's Miter Locks. Da Vinci's innovative design laid the groundwork for the modern miter locks we see today. He was the first to introduce the miter gate – a pair of gates meeting at an angle, mirroring a 'V' shape close to the water pressure. This design required less force to operate and utilized the water pressure to ensure a tighter seal, a principle that still holds today.

Fig.3 Leonardo da Vinci Canal lock – Milan, Italy

Today, the design of miter locks owes a significant debt to da Vinci's early work. His invention revolutionized how we manage water transport and navigate through waterways with differing levels. Modern-day miter locks, albeit more complex and mechanized, essentially adhere to the same principle established by da Vinci centuries ago.

Da Vinci's Influence on the Panama Canal. The Panama Canal, one of the most critical shipping routes in the world, illustrates the influence of da Vinci's work. This vital waterway, connecting the Atlantic and Pacific Oceans, relies heavily on a locks system.

They are the backbone of the canal's functionality, enabling it to handle massive vessels carrying enormous cargo. Without da Vinci's pioneering work in lock design, a marvel like the Panama Canal may not have been possible.

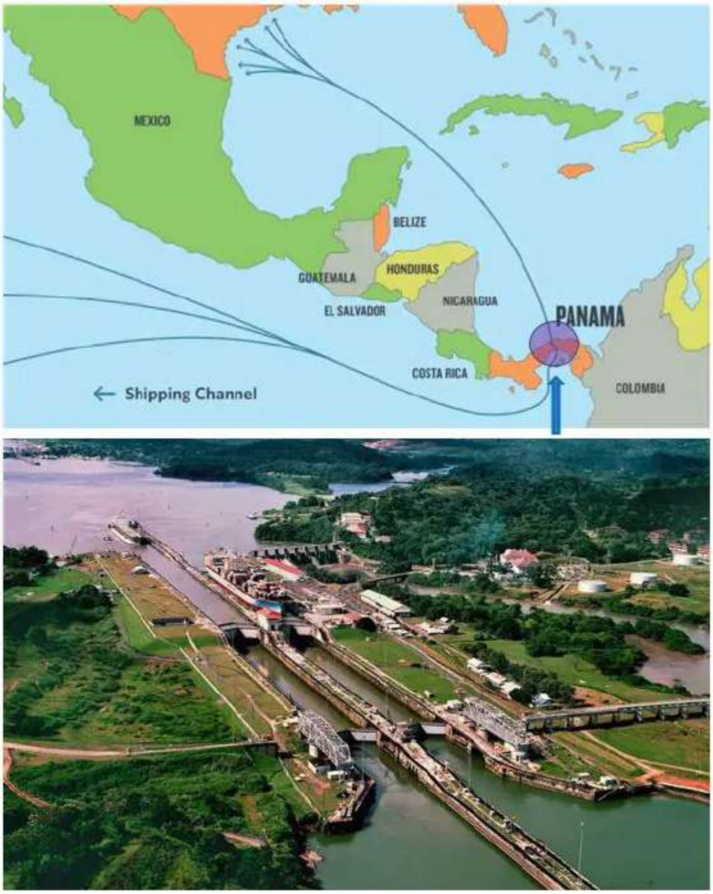

Fig.4 Panama Canal, Panama

Leonardo da Vinci’s influence is a testament to the timeless nature of true innovation. Even centuries after his passing, his ingenious engineering drives our world forward.

Final Thoughts. Da Vinci’s unique miter lock design revolutionized how water levels could be manipulated, providing a more secure and efficient way to move vessels through waterways of varying heights. This pioneering design has been incorporated into countless canal systems worldwide, a testament to da Vinci’s enduring influence.

From enabling more efficient water transportation and facilitating global trade to influencing modern engineering marvels like the Panama Canal and canal locks, Leonardo da Vinci’s contribution to their evolution remains as relevant as ever.

As we sail into the future, the impact of canal locks on our society will continue to resonate, echoing the brilliance of innovators like Leonardo da Vinci.

The canal lock is just one more example of how revolutionary Leonardo was. It is also another example of an invention of his that has survived the test of time long after its inventor, almost making the man himself immortal.

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Sustainable Water Supply Systems for Urban and Rural Areas,

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Abstract

Sustainable water supply systems are essential for meeting the growing demands of both urban and rural populations while maintaining environmental integrity. This paper explores strategies for the development and management of water supply systems that ensure long-term water security and equitable access for diverse communities. In urban areas, challenges include over-extraction, contamination, and rapid population growth, demanding innovative solutions like water reuse, green infrastructure, and efficient resource management. Rural areas, conversely, often face issues of water scarcity and inadequate infrastructure. Implementing rainwater harvesting, community-led initiatives, and decentralized systems can improve resilience and access in these regions. The integration of smart technologies, public policy, and community engagement are pivotal in creating water systems that not only meet present needs but also safeguard resources for future generations. This paper emphasizes the importance of collaboration between governments, local communities, and the private sector in advancing sustainable water supply practices that adapt to diverse geographic, social, and economic contexts.

Keywords: Sustainable water supply, urban water management, rural water access, water security, water reuse, green infrastructure, rainwater harvesting, decentralized water systems, smart water technologies, community engagement, water conservation, climate resilience, resource management

Introduction

Sustainable water supply is a crucial topic for both urban and rural areas. With growing populations, climate change, and the depletion of natural resources, water systems are under immense pressure. Sustainable water supply systems aim to ensure accessibility, quality, and uninterrupted service over the long term, while balancing economic, environmental, and social needs.

Water is not only a necessity but also a driver of economic growth, public health, and environmental stability. A failure in ensuring a sustainable water supply can result in severe social and economic consequences, such as conflicts over resources, health crises, and loss of biodiversity. Therefore, innovative and adaptable solutions must be embraced worldwide.

Main Body

Challenges in Water Supply Systems Limited Water Resources: Decreasing levels in rivers, lakes, and groundwater reserves. Global warming and climate anomalies leading to prolonged droughts and water scarcity. Overdependence on freshwater sources, leaving limited options during lead. Pollution: Industrial and domestic waste contaminating water sources. Agricultural runoff containing chemicals and pesticides, leading to eutrophication. Lack of proper waste management in both urban and rural regions. Infrastructure Deficiencies: Aging pipelines and reservoirs causing inefficiencies and losses of up to 30% in some regions. Inadequate infrastructure in rural areas preventing equitable water distribution. Vulnerability to natural disasters like floods or earthquakes. Economic Constraints: Limited budgets for developing and maintaining modern water systems. High costs associated with implementing advanced technologies such as desalination and treatment plants. Inequitable pricing policies lead to water wastage and accessibility issues. Social and Cultural

Factors: Insufficient awareness among communities about water conservation. Resistance to adopting modern water management practices in culturally traditional areas. Conflicts over water usage among different sectors like agriculture, industry, and domestic use. Principles of Sustainable Water Supply Systems to establish sustainable water supply systems, the following principles must be adhered to: Efficient Management of Water Resources: Implementation of water recycling and recovery technologies to minimize wastage. Monitoring and controlling the use of groundwater to prevent over-extraction and aquifer depletion. Pollution Prevention: Development and operation of advanced water treatment facilities to ensure safe and clean water. Promoting sustainable agricultural practices to reduce chemical runoff. Adoption of Innovative Technologies: Smart systems for real-time monitoring of water usage and early leak detection. Utilization of renewable energy sources, such as solar or wind, to power water systems. Incorporating artificial intelligence for efficient demand forecasting and resource allocation. Community Engagement and Education: Launching awareness campaigns to promote water conservation and hygiene practices. Collaborating with local leaders to integrate sustainable practices within communities. Policy and Governance: Enforcing strict regulations on water usage and pollution control. Encouraging public-private partnerships to fund and maintain sustainable infrastructure. Developing international cooperation to share knowledge and resources. Addressing Urban and Rural Needs Urban Areas: High population density demands rapid and large-scale water distribution systems. Integration of advanced infrastructure, such as automated treatment plants and digital monitoring tools, is essential. Urban wastewater management must address both water reuse and pollution reduction. Rural Areas: Geographic remoteness and limited resources pose unique challenges. Rainwater harvesting systems and solar-powered pumps provide affordable and sustainable solutions.

Strengthening local governance and accountability ensures the longevity of water systems.

Case Study: Georgia: In Georgia, developing sustainable water supply systems remains a pressing challenge. Many regions still rely on outdated infrastructure, while climate change exacerbates the uneven distribution of water resources. However, several initiatives highlight the country's commitment to sustainable development:

Modernization of Treatment Plants: Advanced treatment facilities have been constructed in urban areas to improve water quality and reduce contamination.

Community-Based Rainwater Harvesting Projects: Rural communities in mountainous regions have successfully implemented rainwater collection systems, ensuring water availability during dry periods.

Black Sea Coastal Conservation Efforts: The Adjara region has focused on wastewater treatment and ecological conservation to protect its valuable coastal resources.

Global Examples of Success:

United States: California: Advanced desalination plants and large-scale water recycling programs help combat drought and water scarcity. New York City: The watershed protection program safeguards drinking water quality through natural resource preservation.

Europe: The Netherlands: Renowned for flood control and integrated water management, employing innovative technologies like underground reservoirs. Germany: Promotes decentralized wastewater treatment and urban rainwater harvesting systems to enhance resilience.

Singapore: Singapore's "Four National Taps" strategy ensures water sustainability through desalination, reclaimed water, imported water, and local catchment systems.

Israel: Known for its advanced drip irrigation and efficient desalination plants, Israel maximizes its limited water resources.

Smart Water Systems: The integration of smart technology in water systems has revolutionized the industry: Real-Time Monitoring: IoT sensors enable 24/7 tracking of water quality and usage. Leak Detection Systems: AI algorithms identify and prevent water losses promptly. Predictive Analytics: Big data allows authorities to anticipate water demand and plan accordingly. Smart Meters: Empower consumers to monitor and reduce their water consumption.

Conclusion

Establishing sustainable water supply systems for urban and rural areas is essential for protecting human health, driving economic growth, and preserving the environment. Achieving this goal requires a holistic approach that combines technological innovation, community engagement, policy reforms, and global cooperation. With success stories worldwide, including examples from Georgia, the United States, and Europe, it is evident that sustainable water systems are achievable through innovation, collaboration, and commitment. By adopting these strategies, we can ensure clean and reliable water for generations to come, fostering a future where every drop counts.

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Using the Latest Technologies and Innovations in Construction,

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Abstract: Simplification of technological processes, automation, labor shortage All of this affects the development of construction technologies. Of course, everyone is now looking for ways that will replace humans in the future. People are trying to simplify construction in a way that makes this complex process resemble building with construction Legos. In today's article, we discuss several examples of the latest construction technologies and innovations used in construction. These include ultra-light concrete, modular construction, 3D modelling, drones, AI (artificial intelligence), energy efficiency, and self-healing construction materials.

Technological fields that were developed and used in earlier years have now reached a new stage of development, making it possible to modernize existing systems and increase their efficiency. Prominent examples of modernization include technologies such as modular facades, high-strength concrete, new types of reinforcement, smart home systems, and the digitalization of residential spaces. The development of the sector is also supported by the government's backing of new technologies and innovations. Thanks to this, all processes have been accelerated, and the construction industry is advancing. Human desire to understand every nuance of technology, down to the smallest details, the simplification of technological processes, automation, and labor shortages—these all impact the development of construction technologies. Of course, everyone is now searching for ways that will replace humans in the future.

People are trying to simplify construction in a way that makes this complex process resemble building with construction Legos. Sooner or later, all future technologies – additive technologies, 3D printing, modular constructions, digitization, and modelling technologies–will merge into one automated system, which will minimize human involvement in construction processes. We will encounter only a few of them.

Ultra-light concrete

Ultra-light concrete is expected to be the material of the future. Due to its properties, it should replace the multi-layered facades of modern buildings. Ultra-light energy-efficient concrete with glass-like fillers—foam aggregates—is four times lighter than traditional concrete and has a low density (up to 600 kg/m³). This makes it possible for the building's enclosed structure to be constructed in a single-layer version, while adhering to all existing regulatory and technical documentation. The basis for the production of ultra-light concrete is foam glass aggregate. This closed-cell material is obtained from mineral raw materials such as perlite, opoka, diatomite, and other types of Opoka-perlite species, which ensures its ecological properties and durability. The implementation of this material in modular technology allows for a reduction in construction costs, with a decrease of up to 50% in labor and construction material costs, as well as a reduction in the factory readiness of the building by up to 95%. At the same time, construction is a rather conservative industry, and the adoption of new materials requires a certain level of boldness. Technology must go through several stages before it can be used in industry. Today, the technology involving the use of ultra-light concrete is popular in the construction of individual residences, where there is a quicker and easier response to innovative new products. Additionally, the innovation is already being implemented in the construction of multi-story buildings.

Modular construction

The advantages of modular construction are diverse. The main one is the reduction in construction time, as many processes take place in parallel. While the foundation of the building is being prepared on-site, the modules are already being produced in the factory. Furthermore, the quality of the structures is improved, as the production of modules in controlled factory conditions allows for higher technological standards than traditional on-site construction. Modular buildings, like steel-frame structures, are constructed much faster. They are more durable, environmentally friendly, and seismically resistant.

The construction of such structures is economically advantageous. Hospitals, schools, kindergartens, hotels, and comfortable residential buildings are already being built using this technology.

3D modelling

3D printing technology allows us to produce machinery and components based on pre-ordered designs, and to do so very efficiently, on-site. The production of small architectural forms and everything related to the elements of building services and other similar components is considered the most effective area of construction 3D printing, which is actively developing. In the future, this direction will greatly contribute to the development of facade engineering. Trends in the facade industry also include reducing the costs of building construction and operation, achieving functional and simultaneously original facade designs, and modelling digital information.

Drones

The use of drones for remote monitoring of construction sites saves time and reduces risks. Drones can carry high-precision cameras for information collection and processing. This ensures quality control of construction work.

Artificial Intelligence (AI)

One of the new trends is Artificial Intelligence (AI), which is already being used in many countries. For example, in China, AI designs small, lightweight, standard constructions without human intervention.

AI sensors now manage the construction process. Additionally, these systems analyze data in real-time, optimize building performance for maximum comfort of residents, and simultaneously reduce energy consumption. The development of Artificial Intelligence (AI) in recent years has become one of the main trends across many industries, including construction. AI technologies not only accelerate processes but also offer entirely new approaches to project management. They allow you to automate routine tasks, analyze vast amounts of data, minimize risks, and improve work quality. For example, generative design allows architects and engineers to explore different solutions based on given problems and then choose the best option. Sensor data is increasingly being used. By analyzing real-time data from computer vision, cameras, and sensors, companies automate safety controls on construction sites.

AI-based predictive analytics helps assess potential risks, predict construction delays, and manage risks. Some companies are using AI to address one of the most complex tasks in construction—monitoring and visual documentation. Plan Radar, a platform for construction and real estate projects, has expanded its capabilities for builders with the Site View feature, based on Artificial Intelligence and real-time 360° panoramic imaging. This feature gives builders instant control over the alignment between the construction on-site and the plans, automatically identifying discrepancies or defects. Site View is a real-time 360° panoramic feature that allows builders to automatically capture every stage of construction with high precision. Using AI algorithms, the platform automatically compares the captured images with the existing plan on a 2D map, ensuring complete and accurate information. The team is instantly notified of any discrepancies between the project and the actual state on-site.

This technology offers numerous benefits to builders: remote control of the process from anywhere in the world, real-time visual data, early error detection, identification of stages and discrepancies in the project, and accelerated inspections and audits. Using Site View does not require specialized technical training for the staff. All you need to do is attach a 360° camera to a helmet and walk around the site. This makes technology accessible to a wide range of users, from designers to project managers.

The platform automatically compares the data and records any defects found, significantly speeding up all processes. Discrepancies and problematic areas can be identified early in the project, which also accelerates auditing and inspections. In fact, they can be carried out using visual data. For every issue detected, you can immediately create a task, assign a responsible person, set deadlines, and monitor progress online. Innovative technology ensures complete documentation and allows you to 'rewind time' to view any moment of the construction process. Moreover, such visual information serves as strong evidence in case of disputes or misunderstandings between project participants. Plan Radar's Site View technology is an innovative and powerful tool for improving project quality and accelerating their implementation. With the use of Artificial Intelligence and advanced visual documentation technologies, project participants can minimize risks and improve the efficiency of their teams.

AI technology is expected to continue developing in the near future. Predictions indicate that the average annual growth rate of AI will be 35.14% by 2030. By this time, AI will be able to automate up to 80% of the management processes in construction projects. Neural solutions will monitor budgets, resources, and ongoing work on construction sites, while smart cameras and sensors will assist in identifying errors and preventing accidents in real- time.

AI will become the main tool for analyzing market data, providing accurate price forecasts and logistics, enabling developers to optimize projects. The development of technology will lead to the widespread use of robots on construction sites, drones for site monitoring, and the implementation of automation algorithms for project execution.

Energy efficiency

This is certainly not a new trend, but it will continue to dominate in the near future.

About 40% of global energy consumption is attributed to buildings. Facades, as their envelope, will still play a crucial role in energy savings.

Self-healing construction materials

Self-healing materials are materials that can 'repair' damage using the substances contained within them. These substances can vary widely. Currently, the most popular substances are bacterial and fungal spores. These 'living' materials, which are capable of treating their own 'wounds,' are no longer a fantasy. They are actively being developed, tested, and used. These materials include metals, ceramics, and polymers. Creating self-healing metals is the most challenging. As a result, ceramics and polymers are the most popular. These materials are further categorized based on the type of healing: capsule-based, capillary, and chemical. Capsule-based self-healing materials contain tiny capsules filled with a healing substance. When a crack forms, these 'bubbles' activate and begin 'healing' the wound using their contents. Capillary self-healing materials are those that contain long, thin channels filled with special substances.

Their operation is similar to the capsule-based type: when the container with healing liquids, spores, or bacteria is damaged, they undergo a chemical reaction and begin to self-repair cracks and defects. In the chemical version of self-healing materials, the active substance is directly mixed into the material itself. Depending on the type of damage recovery, there are two kinds of self-healing materials: independent and those requiring external influence. Independent self-healing materials do not need sunlight or high temperatures and can heal their wounds internally.

On the other hand, the second type of self-healing materials require specific external factors for regeneration: sun, water, high or low temperatures, air, etc. It is almost impossible for such materials to self-heal internally without external conditions. Their healing substances only activate upon contact with the necessary external factors, sometimes requiring human intervention. Where can self-healing materials be used? The main field for the use of self-healing materials, of course, is construction. Today, various universities around the world have developed many versions of self-healing materials. Let's look at some of the most popular examples. At North Carolina State University, a self-healing flexible wire was created. Its core consists of liquid metal, and its polymer shell has the ability to heal itself after cracking. This type of wire is most effective for internal wiring in buildings. Using it eliminates the need to replace wallpaper or demolish walls for electrical system disassembly or repair. In the Siberian Branch of the Russian Academy of Sciences' Institute of Physics and Materials

Science, specialists conducted experiments that led to the creation of self-healing ceramics. The key difference between this ceramic and ordinary ceramics is the formation of a glass-like coating at the site of damage.

This regeneration process occurs under high-temperature influence, and its density can be compared to that of diamonds. Scientists plan to use this invention in high-speed aircraft. One of the most talked-about discoveries was self-healing concrete. It has been developed and processed worldwide, with each country developing its own technology using different types of capsules, bacteria, fungal spores, etc. For instance, specialists from the Far Eastern Federal University (FEFU) and the Polytechnic Institute of Russia, in collaboration with scientists from India and Saudi Arabia, developed a concrete that incorporates a water concentrate.

This substance contains the bacterium Bacillus congii, which fills the damage with calcium carbonate ($CaCO3$). Concrete and brick are the most widely used building materials for homes, shopping centers, offices, and so on. The durability and reliability of these materials affect the lives of hundreds of thousands of people who live, work, or rest in these buildings. The creation of self-healing technology makes it possible to extend the lifespan of materials and simplify human life. Currently, these methods are just beginning to be used in practice, but in the future, they will be applied on a broader scale.

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Strengthening and Reconstructing Buildings Using Composite Materials,

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Abstract: In Georgia and capital, currently, more than 10,000 residential or industrial buildings are in a state of severe disrepair and require reconstruction and rehabilitation, which necessitates billions of GEL in capital investment. Expenses can be significantly reduced by improving the technological processes of reconstruction production modes and maximizing the use of existing spaces.

The emergence of high-strength carbon, basalt, aramid, boron, and glass fibers has enabled engineers to develop modern methods and technologies in the construction market, which can be successfully used to restore damaged parts of load-bearing structures and to increase load-bearing capacity. With their assistance, it is possible to extend the operational life of structures in a short time and with minimal labour costs.

Introduction

The execution of reconstruction is mostly accompanied by changes in the loads applied to the structural bearing constructions and the initial accounting schemes, which necessitates an increase in the load-bearing capacity of the structure and, consequently, the need for their reinforcement.

In the context of Georgia, reinforced concrete construction structures are primarily used in industrial and civil buildings; therefore, the generalization and analysis of the proposed initiative holds significant state importance for the purpose of utilizing effective methods for the design and strengthening of such structures.

Main Part

Despite the high cost of composite materials, their use for strengthening construction structures is often economically justified, as it allows for reconstruction to be carried out without interrupting the operation of the building, the use of corrosion-resistant composite reinforcement, minimizing so-called "dirty" work on the site, and significantly reducing the duration of reconstruction, which is, of course, of great importance for the civil sector.

The strengthening of the structure occurs after the development of the corresponding project. The selection of a specific method for strengthening depends on various factors, such as the objectives of strengthening, the condition of the overall building and individual structures; the availability of sufficient space and areas for the storage of strengthening elements; operating conditions, and others.

The classification of methods for strengthening structures is carried out according to various criteria. Based on their purpose, they are divided into two groups: temporary strengthening and permanent strengthening.

The composite systems for strengthening construction structures, which are successfully used in the United States and Western European countries, have provided positive results both under normal conditions and in seismically active regions. A significant advantage of these systems is their simplicity and low labour intensity. The external reinforcement of strengthening structures is based on composite fibs (fibers) and reinforcement made of carbon, glass, aramid, and basalt fibers for the longitudinal and transverse reinforcement of stem elements.

The area of application for external reinforcement includes concrete and reinforced concrete structures; stone and reinforced stone structures; wooden structures; steel structures; structural elements of buildings – window and door openings, roofing slabs, stairwells, elevator shafts, and others.

The technology for external reinforcement works is as follows: in the first stage, an investigation of the functional condition of the building is conducted, a technical condition expert assessment is performed, and an individual project for reinforcement is developed. Subsequently, a complex of reconstruction and reinforcement works of the building (structure) is carried out: removal of the old concrete upper layer by grinding, cleaning, and covering the steel reinforcement with an anti-corrosive solution, localized restoration of damaged areas, and laying of carbon fibers (glass, aramid, basalt) on the prepared surface according to the project. If the reinforcement of a column is taking place, then after wrapping the composite tape around the structure and finally installing the composite carbon mesh soaked with a special adhesive, the material hardens, resulting in a restored clean surface of the newly renovated structure.

pic. 1. Strengthening of reinforced concrete columns and beams with a casing.

pic. 2. Reinforcement of beams, columns, and ceilings with composite tape.

In the reinforced concrete structure for strengthening, before starting external reinforcement with composite materials, it is essential to carry out the following procedures: when the reinforcement is exposed, it is cleaned and treated with an anti-corrosion primer, and then covered with a polymer-cement repair mortar, which ensures the normal adhesion of the old concrete to the new; if the existing reinforcement is not exposed, then the treatment of the concrete surface with a migrating inhibitor is applied, which penetrates the protective layer of the concrete and protects the reinforcement from corrosion.

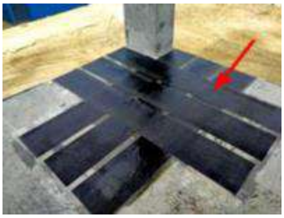
In practice, the combined strengthening of reinforced concrete structures with composites and steel sheathing or textile composite strips is quite common.

Composite materials reinforced with glass fibers, carbon, basalt, or aramid fibers may be used to restore the lost load-bearing capacity of the outer surface of reinforced concrete columns.

Metal Structures of industrial, civil, and transportation buildings are subjected to various factors during the exploitation process – loads, temperature, atmospheric precipitation, aggressive environments, etc., which leads to a reduction in the load-bearing capacity and durability of the building. In contrast, restoration and strengthening are applied.

To strengthen metal structures, modern methods based on the use of fiber-reinforced polymer materials (composites) are employed alongside traditional ones. For this purpose, strip metal, plates, and profiles are used, which are fastened to the structure using bolts and welding connections. The negative aspects of this method include increased weight, enhanced corrosion, metal fatigue, high labour intensity, complexity of execution, and others.

The use of composite materials reinforced with carbon, glass, basalt, and aramid fibers practically eliminates these difficulties in strengthening metal structures. Such materials possess higher strength than steel, lower weight, are corrosion-resistant, are easily processed, and do not require heavy machinery during installation and transportation. For strengthening metal structures, preference is given to composites reinforced with carbon fibers.



pic. 3. Reinforcement of the concrete cover from the top side with carbon fiber tape.

pic. 4. Strengthening of the reinforced concrete cover from the bottom side with carbon fiber tape.

pic. 5. Reinforcement of the composite film with carbon material.

Reinforcement of the Roof is a significant stage in the restoration and modernization of a building in an emergency condition. It is completed from the upper and lower sides. The most effective reinforcement is considered to be from the lower side in the zones of action of tensile stresses.

The reinforced concrete roofs have various configurations: prefabricated hollow cores – used in residential and civil buildings; prefabricated slabs – used in industrial buildings; monolithic – a universal roof that is used in all types of structures.

The universal means of reinforcement for any type of film is the carbon tape FibArm Tape and the carbon grid FibArm Grid.

Strengthening of Wooden Beams. In many cases, the wooden beam is the primary load-bearing element of roofs, intermediate floors, and basements, which is predominantly made from solid wood.

Alongside traditional methods for strengthening wooden structures, innovative strengthening methods are widely used, specifically strengthening with carbon fiber tape.

Pic. 6. Reinforcement of wooden beams with carbon fiber tape.

Modern carbon fiber materials (carbon plastics) are characterized by high strength and low weight, they effectively withstand mechanical loads and are easy to use.

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Innovations in modern civil engineering systems, *Kesaria jabua, BachelorProgram Student,* jabua.kesaria.24@gtu.ge, *Supervisor: Giorgi Chitiashvili, Assosiate Professor,* chitiashviligiorgi01@gtu.ge

Abstract:

Cities are often considered as the abode of prosperity and development. Most of the world's population today lives in urban areas. As the population in cities increases, so does the impact on the environment due to the increased demand for resources. Accordingly, there is a need to implement various engineering innovations in the engineering systems of the city in order to improve the living environment.

Among the many innovative approaches, I would like to highlight the use of green roofs as one of the ways to enrich the environment with oxygen, improve air quality and improve the drainage systems of buildings.

Green roofs, also known as vegetated roofs, involve covering the roofs of buildings with vegetation. This innovative approach brings nature back into the urban environment and provides a number of benefits that I will introduce to you in my article.

Key words: green roofs, air pollution, sustainable environment.

Introduction:

The roof is the upper part of the building that protects it from atmospheric precipitation, sunlight and temperature changes; Also, the roof is an architectural detail that defines the style of the building, the exterior design, and the general look of the building. There are styles of roof: Flat, rocky. Depending on each load and style, the technology of their arrangement also differs.

A green roof, aesthetically and architecturally, is superior to traditional roofs because, as a rule, traditional roofs are not designed for aesthetic purposes. The benefits of green roofs are documented in European numbers or standards. Although, unlike Europe, America, Asia or Africa have different climatic conditions, it does not prevent the microclimate of the green roof from developing under different climatic conditions, if the plants are well selected. The air of big cities (including Tbilisi) is polluted thanks to car exhaust. It is unnecessary to talk about industrial cities, often consumers do not need expensive car filters, and even more so factory smoke pipe filters as a result of this, many toxic substances are mixed in the air, which cause various diseases and also destroy weak insects and animals; Only plants can absorb harmful substances and turn them into oxygen, trees, field flowers, etc.

A solution to this problem was found in Germany in 1960; German architects placed the creative zone on the roof of the building and called this space "green roof" (also known as living roofs, eco roofs in some literature, consumes - plant roof). In this regard, the green roof is a great way to plant parks and gardens on the roofs without wasting extra living space, at the same time, the green roof will add value to the building, providing the user with the closest recreation area They will have beautiful city views. Greening on the roof can be arranged by sowing plants that are bred in special laboratories. Horticulturists and architects create a green roof plan, and plants are planted according to the plan. At the beginning, it is necessary to trace the paths, the edges of which are covered with snow.

Greening is often done by means of lawn rolls, in America or Europe there are organizations that own the fields, which they supply stadiums, parks, courtyards and also green roofs, lawns are rolled on the fields and then transported to the construction site, then they are brought to the roof using a crane and they are laid out in the desired places and in the desired shape. In this way, the arrangement of the roof is quite effective in countries where there is a similar business, because at this time the construction company saves the time needed to grow the plant. gardeners and botanists must decide which time is the most effective for sowing plants.

A green roof uses plant cover to improve the roof's performance under various impacts. Green roofs are divided into two main categories: intensive (Fig. 1) and extensive (Fig. 2). Technically, the difference between them is that intensive green roof refers to an ordinary garden on a roof, they have a layer of deep soil or growing medium on which a wide range of plants can be sown and planted; Similar types of roofs are recommended to be made on buildings of the type where they are often used, where people work or live. Extensive green roofs are simpler, lighter, and thinner in profile.

Fig. 1 Intensive green roof

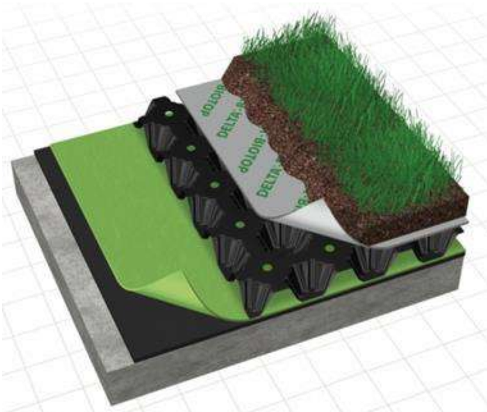
Fig. 2 Extensive green roof

Their profile height ranges from about 15-20 cm (or less) after the bearing layer, on which drought-resistant, small but diverse plants are planted, and the growing medium is saturated with minerals; This type of green roofs are popular for ecological building structures in Europe: in Germany 80% of green roofs are extensive; Because an extensive green roof will more easily have the power to return the investment, which was put into it and will also bring great benefits to the densely populated city, both ecologically and protect it from floods.

Selection of vegetation cover for extensive green roofs is the last but responsible activity of its installation, involving specialists of biologists and botanists who must select Optimal plants for the roof, which can withstand being at a height and adapt to the microclimate of the roof, and the plants should not have strong roots so as not to fall into the drainage layer, the plants should be selected in such a way That they should not attract harmful insects and should not be harmful to each other and to humans. A green roof is important both from an ecological point of view and is the best solution Protect from external influences, namely UV rays, wind, hail, rain and snow.

Main part

Arrangement of the roof is the last but responsible part of the construction. Green roofs, like traditional roofs, require a combination of certain materials to be able to perform effectively during their lifetime. The green roof consists of: vapor insulation, tension, two layers of waterproofing, thermal insulation, drainage, filter, growth layer and vegetation cover.



There are two ways to arrange a green roof: according to the bulk soil and from pre-made blocks.

Bulk soil: in order for the roof to work effectively and not to have problems during operation, it is necessary that the layer of the load-bearing element "base" be prepared and well processed. An extensive green roof can be arranged on different bases. The quality of the base is of great importance for the quality of the Buruli. The base must be dry, clean, cleaned of dust - this ensures a high quality of gluing of foam or mastic layers.

Before the base is cleaned from various types of pollution and water is removed, the roof is traced according to the architectural plan. They demarcate where there should be greenery, and where there should be a walking path. One is separated from the other by metal sheets, which must be attached to a concrete or other type of base.

First, it is sepa-rated from the parapet by the required length, and the sheets are fixed in a vertical position. The height of the sheet is determined by the height of the roof profile. Traces are made so that the roof does not lose its appe-arance over time, and also so that the soil does not spill onto the walkways, etc. Sheets can be made of different materials: plastic, metal, aluminum and wood. Author supervision of the qualification shall be carried out by the architect.

Vapor insulation: the vapor insulation layer protects the material from moisture with water vapor. Determine the vapor insulation to be glued and painted.

Thermal insulation: the method of arranging the thermal insulation layer depends on the material used. The heat insulation layer can be made of loose materials or heat insulation tiles.

During the installation of extensive green roofs, the lightest material is used as a thermal insulation layer, different types of monolithic insulation are avoided, so as not to make the structure heavier.

Waterproofing: it can be arranged from welded roll sheets: for this it is necessary to perform several technical works:

. They will spread the roll on the prepared base, measure the area by providing the edge, if necessary, cut it into specified sizes;

. wrap the wings of the roll towards the middle on a metal or cardboard tube;

. With a single-headed gas lamp, the lower side of the roll to be glued and the mastic of the base, or the surface of the previously glued material, are heated at the same time;

. The wings of the roll are gradually removed with a bent steel rod or foot and glued to the base. After gluing, the entire glued surface is compacted with a soft rolling compactor;

. By exfoliating, they tighten the skin lesions or scar areas;

. The melted mastic coming out of the seams is covered with coarse aggregate.

Pre-made blocks. Blocks can be of different dimensions. The block itself is a kind of plastic drainage on which a protective layer and a means of growth with its plants are pre-arranged, which is arranged on the roof in the following manner; First, the load-bearing layer of the roof should be cleaned of dust and excess water, vapor insulation should be done, preferably with different types of mastics, then it should be stretched to give a slope of 3-7%.

which can be prepared from different types of fermentation, the main properties of the fermentation mixture are: mobility, ease of assembly, water retention capacity, and the hardened fermentation - strength and frost resistance. Roofing with prefabricated blocks is very popular in America and Europe, because the technology of its installation is quite easy and requires much less time. Making a green roof with prefabricated blocks is very effective. On the existing roofs at this time, the following is done: tracing, replacement of waterproofing and subsequent installation of blocks and tracks. At this time, a constructive conclusion is necessary. Green roof arrangement is controlled by building codes and regulations.

greenery. Selection of vegetation cover for extensive green roofs, its installation is the last but responsible activity, as I said, biologists and botanists are involved, who must select the optimal plants for the roof, which can withstand being at a height and get used to the microclimate of the roof.

Also, the plants should not have strong roots, so that they do not fall into the drainage layer. Plants should be selected in such a way that they do not attract harmful insects and they should not be harmful to each other or to humans. Greening of green roofs is also important from an ecological point of view.

A green roof will add value to the building so that users will have the closest recreational area with beautiful city views.

Conclusions:

A green roof has many advantages, including: energy efficiency, improved air quality, drainage system relief, biodiversity support, building longevity and economic benefits. Green roofs are particularly effective in urban areas where the natural functions of the topsoil are limited.

Green roofs also have some disadvantages that are important to consider: high initial costs, maintenance requirements, stress on the structure, poor water management, risk of insects and pests, and moisture problems. Despite these drawbacks, the disadvantages of green roofs can be reduced with appropriate design and maintenance.

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Estimation of residual stresses under plastic torsion using the membrane and sand analogy method, *Mariam Janiashvili, Bachelor*

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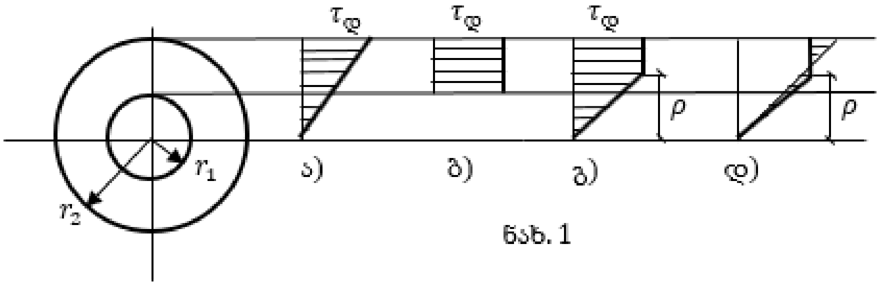
Abstract: Using the classical approach, i.e. when a hollow cylinder is first acted upon by a torque T_1, causing stresses $\tau = \tau_{fl}$, at the points of the external contour of the cross section, then by - T_2, as a result of which the entire cross section of the cylinder is enveloped in plastic deformations, and T, at which the yield stress approaches the area with radius ρ, diagrams of tangential stresses are constructed and by adding them - diagram of residual tangential stresses. Formulas for relative twist angles corresponding to these states are given, and finally, an expression for the residual relative twist angle.

For a shaft with a cross section in the shape of an isosceles triangle, to establish residual shear stresses, the membrane and sand analogy is used. By entering a stress function in the form $\varphi = -G\theta\left(x^2 - \frac{c^2}{4}\right)$, it becomes possible to determine the torque causing the residual relative twist angle θ.

Keywords: Torque, shear stress, shear yield stress, plastic deformation, residual shear stress, membrane and sand analogy, stress function песочная аналогия, функция напряжения.

1. Introduction

To solve the problem posed, we first consider the classical approach, which is as follows. Let us assume that T is the moment as a result of which the first signs of plastic deformation appeared in the cross sections of the hollow cylinder (we denote the internal and external radii, respectively, by r_1 and r_2, and the ratio ${}^{r_1}/_{r_2} = c$), i.e. tangential stress $\tau = \tau_{\wp}$. We get $T_1 = \frac{\pi}{2} r_2^3 \tau_{fl}(1 - c^4)$, where τ_fl is the shear yield strength.



ნახ. 1

Now, we will apply such a torque value T_2, as a result of which the entire cross-section of the cylinder will be enveloped by plastic deformations. If the cylinder material is not strengthening, then $T_2 = \frac{2}{3}\pi r_2^3 \tau_{fl}(1 - c^3)$. Now, let's determine the value T of the torque at which the yield stress approaches a section with radius ρ (Fig. 1)

$$T = \frac{2}{3}\pi r_2^3 \tau_{fl}\left[1 - \left(\frac{\rho}{r_2}\right)^3 + \frac{3}{4}\left(\frac{\rho}{r_2}\right)^3 . \left(1 - \left(\frac{r_1}{\rho}\right)^4\right)\right] \qquad (1)$$

The relative twist angle corresponding to this moment is $\theta = \frac{\tau_\varphi}{\rho \cdot G}$.. The results of the action of torques T_1, T_2 and T are shown in the same Figure 1. Figures a) b) c) show loading, and d) unloading. Since our goal is to identify residual stresses, we will proceed as follows. Let's consider the case of elastic torsion caused by a torque $-T$. It completely compensates for the torque T, i.e. completely relieves the cylindrical shaft, i.e.

$$\frac{-T}{I_\rho} = \frac{q}{r} = G\theta.$$

Thus, the torque $-T$ gave such stress distributions, the summation of which with the stress distribution caused by the torque T, we obtain the distribution of residual stresses in the section (Fig. 1 d).

Now let's consider a special case when, in the cross section of a cylindrical shaft, plastic deformations spread only to a depth $(r_2-\rho)$. By simple algebraic operations we obtain:

When $\rho \le r \le r_2$

$$-\tau = q - \tau_{fl} = \frac{T\cdot r}{I_\rho} - \tau_{fl} = \tau_{fl}\left\{\frac{4r}{3r_2(1-c^4)}\left[1-\frac{1}{4}\left(\frac{\rho}{r_2}\right)^3-\frac{3}{4}c^4\left(\frac{r_1}{\rho}\right)\right]-1\right\}; \quad (2)$$

When $r_1 \le r \le \rho$, equation (2) takes the form:

$$\tau = -\frac{T\cdot r}{I_\rho} + q = \left\{\frac{\tau_{fl}}{\rho} - \frac{4\tau_{fl}}{3r_2(1-c^4)}\tau_{fl}\left[1-\frac{1}{4}\left(\frac{\rho}{r_2}\right)^3-\frac{3}{4}\left(\frac{r_2}{\rho}\right)c^4\right]\right\} = \frac{r\cdot\tau_{fl}}{\rho}\left\{1-\frac{4\rho}{3r_2}\left[1-\frac{1}{4}\left(\frac{\rho}{r_2}\right)^3-\frac{3}{4}\left(\frac{r_2}{\rho}\right)c^4\right]\right\} \quad (3)$$

q - the positive shear stress arising under deformation conditions, which first corresponds to the torque $+T$, and q_1 corresponds to the moment T_{-1}. From (2) and (3) it is clear that the residual stresses are negative on the outer part of the section and positive on the inner part.

Now let's calculate the residual relative twist angle, for which we denote by θ_0,, caused by the acting torque T, the relative twist angle $\theta_0 = \frac{\tau_{fl}}{G\cdot\rho}$. Taking this into account, the residual relative twist angle obtained as a result of unloading is determined from the condition

$$T = \frac{1}{2}\pi G\theta_0' r_2^4(1-c^4);$$

from which

$$\theta_0' = \frac{4\tau_{fl}}{3r_2 G}\left[\frac{1-\frac{1}{4}\left(\frac{\rho}{r_2}\right)^3-\frac{3}{4}\left(\frac{r_2}{\rho}\right)c^4}{(1-c^4)}\right] = \frac{4\theta_0}{3}\cdot\frac{\rho}{r_2}\left[\frac{1-\frac{1}{4}\left(\frac{\rho}{r_2}\right)^3-\frac{3}{4}\left(\frac{r_2}{\rho}\right)c^4}{(1-c^4)}\right]$$

Finally, the residual relative angle

$$\theta_R = \theta_0 - \theta_0' = \theta_0 \left\{ 1 - \frac{\frac{4}{3}\left(\frac{\rho}{r_2}\right)\left[1 - \frac{1}{4}\left(\frac{\rho}{r_2}\right)^3 - \frac{3}{4}\left(\frac{r_2}{\rho}\right)c^4\right]}{(1-c^4)} \right\}$$

2. Main part

Let's complicate the task. Let's consider a shaft with a cross section in the shape of an isosceles triangle, which is subject to torque T_2. Let us assume that plastic deformations cover the entire section. In this case, from the formula

$$T_2 = \frac{2}{3}\pi r_2^3 \tau_{fl}(1 - c^3) \quad (4)$$

we get

$$T_2 = \frac{2}{3}\pi r_2^3 \tau_{fl} \quad (5)$$

Since θ is the relative angle of twist in the case of elastic unloading, then

$$-T_2 = G\theta r_2 \sqrt{\frac{3}{5}} \quad (6)$$

respectively,

$$\theta = \frac{2r_2^3\tau_{fl}}{3} \cdot \frac{5}{r_2^4\sqrt{3G}} = \frac{10\sqrt{3}\tau_{fl}}{9Gr_2}, \quad (7)$$

and the distribution of tangential stresses, after applying the moment $-T_2$, will be expressed as follows

$$\left.\begin{aligned} \tau_{xz} &= \frac{10\sqrt{3}\tau_{fl}}{9r_2^2} \cdot y\left(x\sqrt{3} - r_2\right); \\ \tau_{yz} &= \frac{5\tau_{fl}}{3r_2^2}\left(x^2 + \frac{2r_2}{\sqrt{3}}x - y^2\right). \end{aligned}\right\} \quad (8)$$

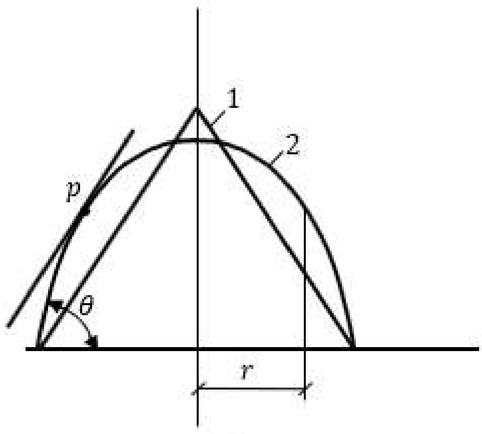
As mentioned above, we consider the case when the entire cross section is subject to plastic deformations. Based on this, the expression of the residual plastic shear stress changes and is displayed as follows

$$
\left.\begin{aligned}
\tau_{xz} &= \frac{10\sqrt{3}\tau_{fl}}{9r_2^2} \cdot y\left(x\sqrt{3} - r_2\right); \\
\tau_{yz} &= \tau_{fl}\left[1 - \frac{5}{3r_2^2}\left(x^2 + \frac{2r_2}{\sqrt{3}}x - y^2\right)\right].
\end{aligned}\right\} \qquad (9)
$$

This distribution is symmetrical with respect to the bisectors of an isosceles triangle.

Now, to establish the distribution pattern of residual shear stress, we will use both the membrane and sand analogies. Let's consider the same problem. The cross section of the shaft is in the plastic stage. The stress function, by analogy with sand, will be a straight circular cylinder. When the unloading is entirely elastic, it can be represented by a membrane analogy. In this case, the volume under the membrane will be equal to the volume of the cone, since, as was said, the loading and unloading torques are equal (Fig. 2) 1 – sand hill. 2 - membrane.

The maximum inclination of the sand hill, at a distance r from the center, will be denoted by m_p, and the inclination of the membrane, which is proportional to stresses during unloading, will be m_e. Based on this, the difference $\left(m_e - m_\rho\right)$ is an estimate of the residual stress on a circle with a radius r. In this case, the difference should not exceed the gradient of the hill $\left|m_e - m_p\right| \leq m_p$. This limitation specifies that the residual stress should not exceed the shear yield strength of the material. From the material reviewed, the following conclusions must be drawn:



ნახ. 2

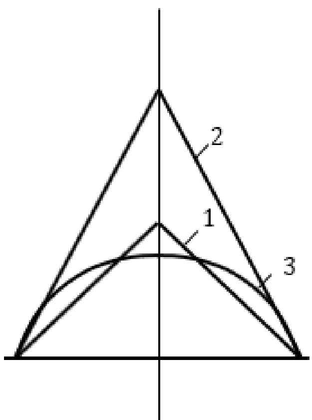
1) Since the membrane is parallel to the axial line (zero elastic stress), then on the cross-sectional axis the residual stresses are positive and equal in magnitude to the yield strength, i.e. equal τ_{φ}.

2) At the point in the drawing where the tangent to the sand hill coincides with the tangent of the membrane, the residual stresses are zero and a subsequent increase r leads to residual stresses of a negative sign, which reach a maximum on the lateral surface.

3) Until the membrane gradient on the surface is $tg\theta < 2m_p$, the unloading will not be completely elastic. Residual stresses in the surface layers of the section are expressed by the above formula (2) or the resulting equation

$$\left.\begin{aligned} \frac{\tau_r}{\tau_{fl}} &= 1 - \frac{4r}{3r_2}; \\ when\ r = r_2;\ \frac{\tau_r}{\tau_{fl}} &= -\frac{1}{3}. \end{aligned}\right\} \qquad (10)$$

This shows that the slope on the outer contour of the membrane is less than twice the gradient of the sand hill. 4) The proposed analogy can be continued further in a more complex case. After unloading, we will apply torque again, only in the opposite direction (with a minus sign). In this case, the angle of twist will increase until the outer surface of the membrane reaches, so-called the second ceiling, which is determined by the second hill of sand, the slope of which will be twice as great as the slope of the first. When this happens, fluidity will be established again, only the tension will be opposite to the tension of the first case. The volume obtained by the new membrane will be expressed by the sum of two volumes: the first volume resulting from the twist angle obtained during unloading and the second -



ნახ. 3

the resulting volume from the subsequent negative twist angle (Fig. 3). This drawing shows the loading of the shaft with torque, subsequent unloading and secondary loading, with the following symbols: 1 - diagram of the first hill of sand; 2 – diagram of the second sand slide (height $2\tau_{\wp}$); 3 - membrane (height $\tau_{\wp}$),), which characterizes shear stress under conditions of plastic deformation.

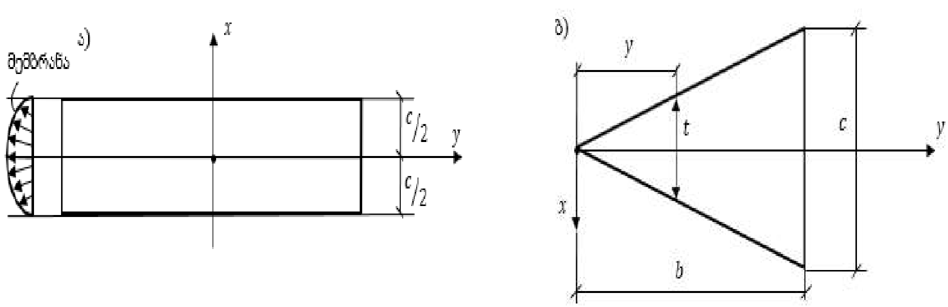
Let's consider a specific numerical example using the proposed method. Let us assume that for elastic torsion of a shaft with a rectangular cross-section, the membrane stress function is given in the following form

$$\varphi = -G\theta\left(x^2 - \frac{c^2}{4}\right), \quad (11)$$

where c – cross-sectional width (Fig. 4) and

$$-\frac{1}{2}c \leq x \leq \frac{1}{2}c \,.$$

Let's use this expression for the stress function and solve the problem for a shaft with a triangular cross section. According to Figure 5.b, i.e. $y/_b = t/_c$, i.e. $t = yc/_b$ arc. Imagine that at



ნახ. 4

point y the membrane has the shape of a parabola perpendicular to the plane Oy in planes. Based on this, the stress function will take the form

$$\varphi = -G\theta\left(x^2 - \frac{c^2y^2}{4b^2}\right), \quad (12)$$

Now, it becomes possible to calculate the torque that causes elastic torsion of a shaft with a triangular cross-section by the value of the angle θ per unit length of the shaft

$$T = 2\int_0^b \int_{-\frac{yc}{2b}}^{\frac{yc}{2b}} -G\theta\left(x^2 - \frac{c^2y^2}{4b^2}\right)dxdy = -4G\theta\int_0^b \left(\frac{x^3}{3}\bigg|_0^{\frac{yc}{2b}} - \frac{c^2y^2}{4b^2}x\bigg|_0^{\frac{yc}{2b}}\right)dy =$$
$$-4G\theta\int_0^b \left(\frac{c^3y^3}{24b^3} - \frac{c^3y^3}{8b^3}\right)dy = \frac{G\theta}{3}\cdot\frac{c^3}{b^3}\int_0^b y^3\,dy = \frac{G\theta c^3 b}{12}; \qquad (13)$$

Regarding torsional rigidity, it is represented by the following relationship

$$\frac{T}{\theta} = \frac{Gc^3b}{12}; \qquad (14)$$

These formulas make it possible, in cases of given shaft dimensions, to solve the problem posed in numbers.

Conclusion:

Expressions are given for residual tangential stresses (8), obtained as a result of the application of an elastically unloading torque $-T_2$, which for the case when the cross section is completely enveloped by plastic deformations are expressed by formulas (9).

To establish the pattern of distribution of residual shear stress, membrane and sand analogies are used simultaneously. The unloaded shaft is loaded again. The angle of twist increases until the outer surface of the membrane reaches a second ceiling, defined by a second hill of sand, the angle of which is twice the first. Accordingly, fluidity is established by the opposite stress. In Fig.4 shows a diagram of loading, subsequent unloading and secondary loading, which characterizes tangential stresses during plastic deformation.

When solving a specific example, a stress function was introduced, which corresponds to the shape of the membrane described by a parabola, and the torque was calculated, which causes a torsion angle by the amount θ of a shaft with a triangular cross section.

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Parametric modelling in architecture and using algorithms for solar stud, *Jlantiashvili Dimitri, Bachelor Program student, jlantiashvili.dimitri@gtu.ge, Supervisor: Mskhiladze Nino, Professor, n.mskhiladze@gtu.ge*

Abstract: Parametric modelling in architecture and integration of algorithmic systems has changed the way the concept, analysis and adaptation of buildings are done. The continuous development of new technologies such as artificial intelligence (AI) and advanced design software has enabled architects to create very efficient and adaptive structures. This innovation allows precise environmental simulation, real -time performance analysis and data-driven decision-making, which promote the limits of durable and responsible design.

One of the most important applications of these advances is in solar studies, where computational algorithms help the architects analyse the strategies for solar radiation, shading and daylight. Through parametric modelling, designer can adjust building form, factor systems and material choices to optimize energy efficiency while maintaining beauty and functional requirements. AI-enhanced simulation further refines this analysis and provides future insights that were impossible to receive with traditional design methods.

This article examines the role of parametric modelling and in architectural solar studies, showing how these units contribute to energy-efficient and empathetic design solutions. By using computational power, architects can design buildings that not only reduce the environmental impact but also increase the user's comfort and spatial experience.

Introduction

Technological progress has always played an important role in the architectural design and construction. From drawings to Computer

AIDED Design (CAD), and now with parametric modelling, the industry has made a significant change. Today, architects benefit from calculation tools to create complex geometry and integrate environmental ideas from early design stages.

One of the most influential regions where parametric modelling and algorithm system excel is solar study. By analysing the solar path, shading and insolation, architects can design buildings that reduce energy consumption and improve quality of life. Algorithms enable real-time simulation, so that date-driven decisions can be made.

This article will take into account how parametric modelling, algorithm processes produce solar studies, which form a new era of intelligent, responsible architecture.

Main Part

Algorithmic Studies for Building Mass and Height Optimization

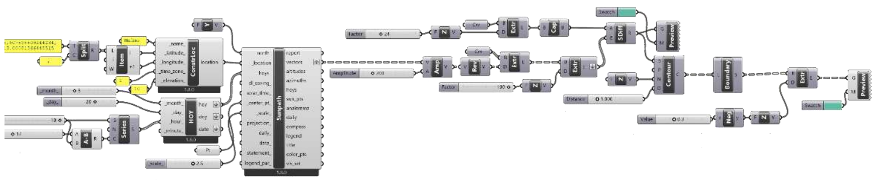
In contemporary architecture, computational design and algorithmic systems are revolutionized how we proceed to designing urban fabric and buildings. One of the most significant challenges in high-density environments is to balance the height and mass of the building with sunlight access to ensure sufficient daylight for all residents. This study uses parametric modelling and algorithmic design to determine the maximum possible height of the building without depriving the inhabitants on the lowest floors from sunlight.

By integrating the solar study into the beginning of the design, architects can create buildings that are not only adapted to spatial efficiency, but which are also responsibly designed in relation to their urban fabric. In this case, the algorithm is based on precise environmental parameters:

- Location: Malmo, Sweden

- Latitude: 55,6076
- Longitude: 13,0008
- Height: 10 m
- Date: March 20 (Spring Equinox)

The equinox date is particularly important as it aligns to the European rules for solar and insulating requirements, ensuring proper daily distribution throughout the year. By using this data, the algorithm analyzes the solar path and calculates the maximum height building can reach without casting excessive shadow to the surroundings.



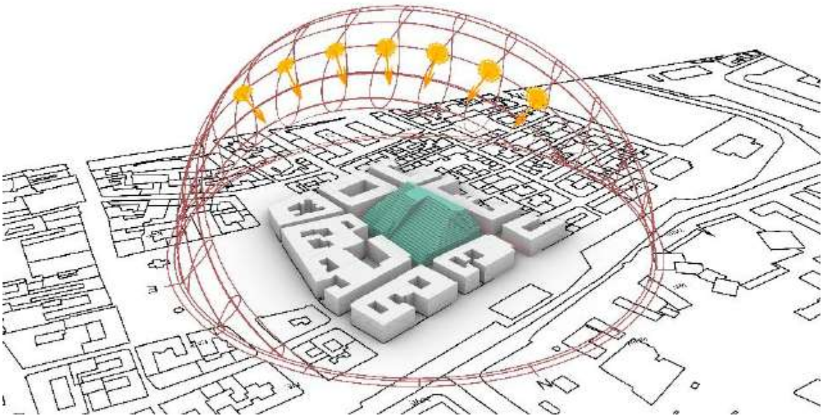
Pic.1. Algorithm for the solar study (proj, by d. Jlantiashvili)

Balancing Constraints and Architectural Freedom

One of the most important results of this study is to create vertical limitations that define the producible volume within the given environmental conditions. Although these obstacles may be limiting to the architects, they actually facilitate a more responsible and informed design process. Instead of relying on arbitrary regulatory laws or generalized boundaries, this computational approach tailors each design to its specific site conditions and ensures that the final building is seamlessly integrated into the environment.

By creating an early building mass, architects can work within well-defined parameters, reducing design iterations and improve efficiency.

This massing model acts as a basis for further processing, where architects can develop interior layouts, optimize facade performance and introduce aesthetic elements without compromising the original environmental responsibilities.



Pic. 2. Solar study with general massing outline (proj. By d.jlantiashvili)

The Role of Algorithmic Massing in Sustainable Design

This method is especially useful in high-density urban areas, where it is important to maintain access to sunlight, energy efficiency and quality of life. The algorithm-driven approach ensures that each building:

- Reduces overshadowing on neighbouring structures
- Provides sufficient daylight for all units
- Optimizes urban density without sacrificing liveability

Finally, while this solar study represents a basic mass instead of a finished architectural design, it establishes a strong foundation for sustainable and context-aware architecture. By taking advantage of computational tools, architects can balance creativity with responsibility and ensure that new development is harmonious and environmentally conscious.

Studio Gang's Use of Solar Studies in Architecture

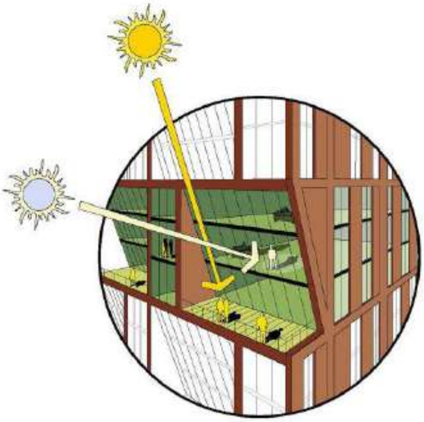
The studio gang led by architect Jean Gang is known for his innovative view of sustainability and contextual design. The main aspect of their methodology is the integration of solar studies into the early stages of architectural development and ensuring that buildings react wisely to the environment. Two of their most notable projects, Solstice on the Park in Chicago and Solar Carve in New York, demonstrate how computational solar analysis can shape form, optimize energy efficiency, and enhance the relationship between built and natural environments.

Solstice on the Park: A Facade Designed by the Sun

Located in Chicago, Solstice on the Park exemplifies how solar studies can drive architectural form and function. The angled facade of this residential tower is based 72° tilt, a calculation derived from the optimal solar angle in Chicago during the summer solstice. By tilting the south-facing glass panels at this specific angle:

- During the summer, overhangs with excessive sunlight, reduce the gains for solar heat and reduce the requirement for air conditioning.
- During the winter, when the sun is low in the sky, the facade allows penetration of the maximum sunlight and naturally heats the interior.

This passive solar strategy significantly improves energy efficiency while creating a visually dynamic facade. The integration of parametric modeling and solar studies in this project aligns with contemporary computational approaches—similar to the study above how algorithm determines optimal building massing based on solar exposure.



Pic. 3. Glazing is calibrated to the optimum sun angles for Chicago's latitude, 72^{O} in summer and 42^{O} in winter. ("Studio Gang" studiogang.com)

Pic.4 . Chicago, IL, "Solstice on the Park" ("Studio Gang" studiogang.com)

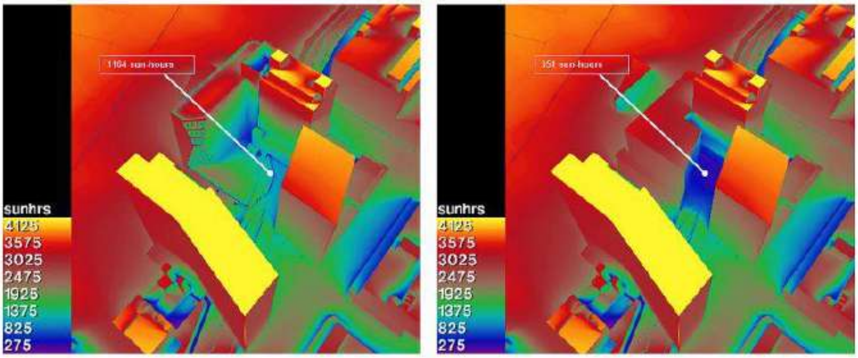
Solar Carve: Sculpting a Building with Sunlight

Solar Carve Tower by the Studio Gang in New York takes a more aggressive approach to the solid design. The project is located along the high line, one of the most visited Urban Parks of NYC, and the project had to be balance maximizeing space while minimizing impact on sunlight access to the park.

Rather than following conventional zoning setbacks, Studio Gang employed solar carving, an algorithmic method that "sculpts" the building's mass by analyzing the sun's path throughout the day and year. This ensures that the tower's form allows sufficient sunlight to reach the High Line. Key strategies include:

- Algorithmic Massing Adjustments: The building's mass was selectively "carved away" based on solar angles, reducing shadow impact on the park and enhancing daylight access.

- Glazed Facade for Light Optimization: The carved portions feature faceted, diamond-shaped glass panels, which not only reduce glare but also reflect and diffuse natural light, softening the building's impact.
- Contextual Responsiveness: massing was determined by environmental constraints rather than arbitrary zoning rules.



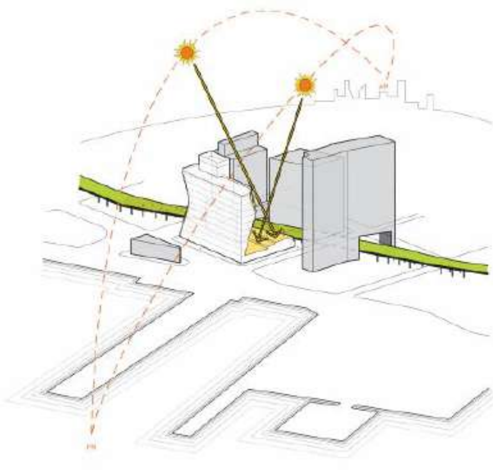
Pic. 5. And Pic. 6. Analysis shows that the solar-carved building form (on the left) allows more sunlight to reach the High Line than the allowable envelope (on the right). Image © Arup

Algorithmic approach to determining building height and mass based on solar accessibility shares several principles with Studio Gang's methodology:

- Both utilize computational solar studies to guide design decisions.
- Both establish vertical constraints that enhance urban livability.
- Both aim for energy efficiency by optimizing building shape in relation to sunlight.

While Solstice on the Park optimizes energy performance for inhabitants, Solar Carve prioritizes preserving urban sunlight for public spaces. Together, they demonstrate how computational solar studies can inform form-finding processes, creating architecture that is both environmentally responsible and aesthetically compelling.

By implementing similar algorithmic methods, architects can design more sustainable, site-responsive buildings that respect their surroundings while maximizing design potential.



Pic. 7. Solar Analysis
("Studio Gang" studiogang.com)

Pic. 8. New York, "Solar Carve"
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Construction Machinery and Mechanisms: A Comprehensive Overview,
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Abstract: This article delves into the crucial role of construction machinery and mechanisms in modern construction, focusing on their applications, examples from Georgia and abroad, and adherence to safety regulations, specifically the 477 regulations on working at height. Highlighting iconic structures like the Burj Khalifa and integrating recent innovations in the industry, this piece offers a comprehensive analysis of tools like cranes, pumps, hoists, scaffolding, and pioneer machines, emphasizing their significance in shaping today's architectural marvels.

Keywords: Construction Machinery, Cranes, Scaffolding, Pumps, Hoists, Innovations, Regulation 477

Cranes: Lifting the Future

Cranes are among the most recognizable symbols of construction. Their ability to lift and transport heavy materials makes them indispensable on construction sites. Tower cranes, for instance, played a pivotal role in constructing the Burj Khalifa, the world’s tallest building. These cranes were custom-built to withstand the extreme heat and high winds of Dubai. Operating at heights exceeding 800 meters, the cranes required precise engineering and coordination, underscoring the complexity of such projects.

In Georgia, cranes are commonly used in urban development projects. For example, the construction of Tbilisi’s Axis Towers relied on advanced mobile and tower cranes to maneuver heavy glass panels and steel frameworks. These machines significantly reduced manual labor while ensuring accuracy and safety.

Recent innovations in crane technology include remote-controlled systems and automation. For instance, smart cranes equipped with IoT (Internet of Things) sensors can monitor weight loads, detect potential hazards, and optimize performance in real time. These advancements not only enhance efficiency but also improve safety standards on construction sites.

Pumps: Managing Concrete and Fluids

Concrete pumps are essential for large-scale construction projects. They transport liquid concrete to hard-to-reach areas, ensuring uniformity and speed. In the construction of the Burj Khalifa, high-pressure pumps delivered concrete to heights of over 600 meters, a record-breaking feat at the time. This technology allowed for continuous pouring, critical for maintaining the structural integrity of such a tall building.

In Georgia, concrete pumps are widely used in infrastructure projects, including bridges and high-rise buildings. The construction of the Kutaisi International Airport's expansion involved advanced concrete pumping techniques to meet tight deadlines and ensure quality.

Innovations in this field include 3D concrete printing, which uses robotic arms equipped with pumps to create complex structures layer by layer. This technology is gaining traction worldwide, offering sustainable and cost-effective solutions for custom designs.

Scaffolding: The Backbone of Construction

Scaffolding systems provide temporary support structures, allowing workers to operate at height safely. The design and assembly of scaffolding must adhere to stringent safety regulations, including the 477 regulation on working at height, which emphasizes risk assessments, protective gear, and proper training for workers.

Pioneer Machinery: Breaking New Ground

Pioneer machinery, including bulldozers, excavators, and trenchers, is vital for site preparation and foundation work. These machines are designed to handle challenging terrains and heavy workloads, making them indispensable in both urban and rural projects.

In Georgia, pioneer machinery was extensively used in the construction of the East-West Highway, a critical infrastructure project that connects major cities. Bulldozers and excavators cleared vast areas, enabling the efficient construction of roads and bridges.

Globally, the construction of the Panama Canal is a historic example of pioneer machinery's impact. Modern equivalents of these machines now include GPS-guided systems that enhance precision and reduce fuel consumption, exemplifying how technology continues to revolutionize the industry.

Innovations in Construction Machinery

The construction industry is rapidly embracing innovations to improve efficiency and sustainability. Autonomous machinery, powered by artificial intelligence (AI), is becoming increasingly popular. For instance, self-driving bulldozers and excavators can perform repetitive tasks with minimal human intervention, reducing labor costs and enhancing safety.

Drones are another groundbreaking innovation. Equipped with high-resolution cameras and sensors, they are used for site inspections, progress monitoring, and even material delivery. In the construction of the Tesla Gigafactory in Nevada, drones were instrumental in tracking progress and identifying potential issues in real time.

3D printing is also making waves, particularly in creating custom components and entire structures. In Dubai, a fully functional 3D-printed office building showcases the potential of this technology to revolutionize construction methods.

Adhering to Safety Regulations: The 477 Regulation

Working at height poses significant risks, making adherence to safety regulations imperative. The 477 regulation emphasizes the importance of risk assessments, the use of personal protective equipment (PPE), and proper training for workers operating at elevated levels.

In Georgia, construction companies must comply with these regulations to ensure worker safety. For example, during the construction of the Bagrati Cathedral's restoration, scaffolding systems were inspected regularly, and workers received specialized training to mitigate risks.

Internationally, projects like the Shard in London have set benchmarks for safety. Comprehensive safety plans, regular audits, and advanced protective gear ensured the well-being of workers during its construction.

Conclusion

Construction machinery and mechanisms are the driving forces behind the modern construction industry. From cranes and pumps to hoists and scaffolding, these tools not only enhance efficiency but also ensure the safety and quality of projects. By integrating innovations such as AI, IoT, and 3D printing, the industry is poised for a future that prioritizes sustainability and precision. Adhering to safety regulations like the 477 standard remains crucial, ensuring that progress does not come at the cost of worker well-being.

As Georgia continues to develop its infrastructure and urban landscapes, the adoption of advanced machinery and strict safety protocols will play a pivotal role in shaping its future. Similarly, international projects serve as benchmarks, showcasing the possibilities when technology and expertise converge.

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Modern Engineering Technologies in Architecture, *Anastasia Tsereteli, Bachelor Program Student, Anastasia.tsereteli2005@gmail.com, Supervisor: Maia Davitaia, Maia_davitaia@hotmail.com*

Abstract

Modern engineering technologies are the basis for studying innovative design and construction methods in architecture. By integrating advanced tools and materials, researchers and practitioners can experiment with new approaches to structural efficiency, environmental sustainability, and aesthetic expression. These technologies allow for the testing of complex geometries, the use of smart materials, and the incorporation of energy-efficient systems, providing valuable insights into how architecture can evolve to meet contemporary challenges. Through such experiments, the potential of modern technologies to transform architectural practice continues to be explored and expanded.

Energy-efficient systems

Engineering energy-efficient systems are designed to reduce energy consumption, minimize environmental impact, and ensure optimal system performance. With the global demand for energy increasing, engineers are challenged to create systems that are not only functional but also sustainable. These systems are essential to addressing pressing issues such as climate change, resource scarcity, and rising energy costs.

The Role of Energy-Efficient Systems in Architecture

Energy efficiency in architecture refers to the design, construction, and operation of buildings in a way that minimizes energy consumption while maintaining comfort and functionality. Buildings are responsible for a significant percentage of global energy consumption and carbon emissions, making energy efficiency a critical area of technological innovation. Modern engineering technologies have enabled architects to rethink traditional practices and adopt solutions that reduce energy demand, enhance performance, and promote sustainability.

To achieve energy efficiency, engineers adhere to several key principles and use advanced methodologies:

Smart Systems Design

Energy efficiency begins with design. Engineers incorporate energy-saving features such as optimized layouts, advanced materials, and efficient components to reduce losses. For example, passive cooling and natural lighting in building design can significantly reduce energy consumption. These systems work together to create buildings that adapt to their environment and occupants, providing a more efficient, sustainable and responsive environment.

Renewable Energy Integration

Incorporating renewable energy sources, such as solar panels, wind turbines or geothermal systems, reduces dependence on non-renewable resources. These systems are often combined with energy storage solutions to ensure consistent performance. Solar energy is one of Photovoltaics, the most widely used renewable resource, used to generate electricity through solar panels or for heating through solar thermal systems. Wind energy is also becoming more integrated into architectural design, with wind turbines providing clean energy for buildings. Sustainable materials such as bamboo, known for their rapid growth and minimal environmental impact, are increasingly being used in construction, replacing more resource-intensive options. Incorporating renewable resources not only reduces a building's reliance on fossil fuels but also contributes to long-term energy savings and environmental protection. As the world moves towards more sustainable practices, renewable resources in architecture are vital to creating buildings that are energy-efficient, environmentally friendly, and support a greener future.

Material Innovation

Materialistic innovations have revolutionized the way buildings are designed, constructed, and experienced. Advances in materials have enabled architects to create structures that are not only more durable and sustainable, but also more efficient and aesthetically dynamic. Innovations such as smart glass, self-healing concrete, and carbon fiber composites are changing the landscape of architecture, providing new possibilities for both form and function. Smart glass, for example, adjusts its transparency in response to light, improving energy efficiency by reducing the need for artificial cooling or heating. Self-healing concrete, embedded with bacteria that produce limescale when cracks appear, extends the lifespan of buildings by automatically repairing damage. In addition, lightweight yet strong materials such as carbon fiber composites allow for more complex and sophisticated designs without sacrificing strength or stability.

These material innovations contribute to sustainable and energy-efficient building practices that offer solutions to the challenges of urbanization and environmental concerns. As material technology continues to evolve, architecture is increasingly able to balance form, function, and environmental responsibility, pushing the boundaries of what is possible in building design.

Green Buildings

Green building engineering focuses on integrating sustainable practices and innovative technologies to enhance environmental performance and efficiency. Engineers play a critical role in the design and implementation of energy-efficient systems, such as energy-efficient HVAC systems, renewable energy sources such as solar panels, and smart water management. They also select sustainable materials and ensure that construction processes minimize waste and reduce carbon emissions. Using environmental engineering principles, green buildings aim to provide healthier, more sustainable living and working environments, while contributing to long-term environmental conservation.

HVAC systems (heating, ventilation, and air conditioning) are essential for controlling the indoor climate of buildings. They regulate temperature, humidity, and air quality to ensure comfort and health. HVAC systems include components such as heaters, air conditioners, fans, ducts, and air filters that work together to provide effective climate control, improve air circulation, and reduce energy consumption. In modern buildings, HVAC systems are often integrated with smart technologies to optimize energy use and respond to environmental changes.

Energy-efficient architecture

Energy-efficient architecture is a design philosophy that prioritizes reducing energy consumption while improving environmental sustainability. Architects such as Pier Luigi Nervi, Frei Otto, Santiago Calatrava, and Rudi Ricciotti have made significant contributions to the field, using innovative techniques and materials that combine efficiency with aesthetics.

1. Material efficiency: All four architects emphasize the use of innovative materials and lightweight structures to reduce embodied energy.

2. Natural systems: They integrate natural ventilation and lighting to reduce operational energy needs.

3. Geometry and form: Their designs harness structural geometry to optimize material use and enhance thermal performance.

4. Innovation: With kinetic facades of tensioned structures, they will push the boundaries of engineering to align aesthetics with sustainability.

These architects have demonstrated that energy efficiency in architecture does not compromise artistic vision, but rather enriches it, paving the way for future sustainable design.

Conclusion

Energy-efficient systems are essential to creating a sustainable future. They provide environmental, economic, and operational benefits while addressing critical global challenges. By utilizing innovative design, advanced technologies, and renewable energy sources, engineers can play a significant role in creating systems that balance performance with sustainability. Despite challenges such as high costs and integration difficulties, the long-term benefits of energy-efficient systems far outweigh the barriers.

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The Golden Gate Bridge, Technical features and construction history,
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Throughout its existence, humanity has gone through many stages. Over time, perspectives on various sciences, such as medicine, astronomy, agriculture, and construction, have broadened significantly.

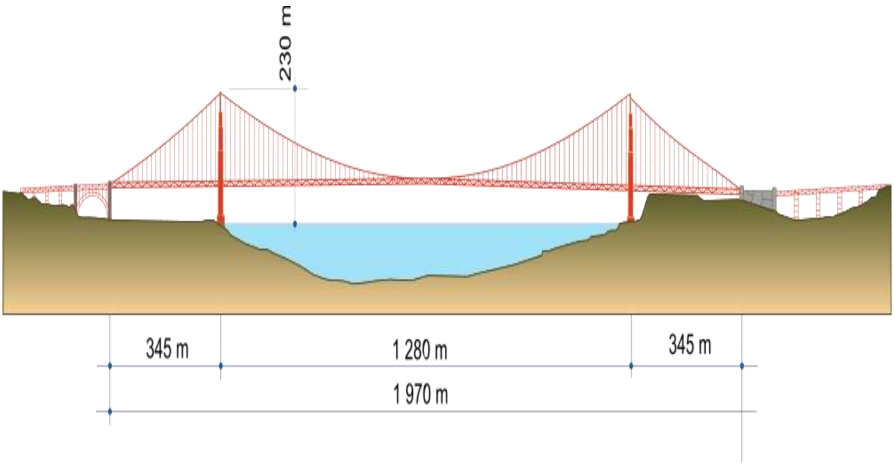
In addition to needing daily living spaces to rest peacefully after a long day, there was a need for structures that would simplify transportation. Roads and bridges fall into this category. The first bridge humans created involved laying a fallen tree trunk across a river. However, over time, the trunk rotted and was carried away by the water, necessitating new solutions. Initially, humans strengthened bridges by adding support, essentially placing the bridge on primitive piles. Over time, materials evolved, and stone began to replace wood (though wood was not completely abandoned).

Bridges underwent significant development, resulting in the variety of bridge types we see today, such as cable-stayed, arch, movable, and others. One of the most notable examples of an arch bridge is the Roman aqueducts, primarily used to supply water to cities. Arch bridges are highly durable because their structure allows the load to distribute evenly towards the supports, enhancing their stability. For example, Roman aqueducts are so robust that trains still travel over them today, highlighting their durability.

Cable-stay bridges are also fascinating. Their cables are connected to counterweights and pylons, balancing the load evenly on both sides. Building cable-stay bridges is particularly practical when constructing intermediate supports is challenging due to terrain, soil conditions, or other reasons.

The most widely used bridges are those constructed with span structures. Classic bridges made from beam spans are widespread. The beams can be made of reinforced concrete or metal. A significant challenge for classic bridges is thermal expansion, which can negatively impact them. To counter this, various compensatory structures are used, placed at the joints between the span sections and their connections to the road.
The connection between the bridge and the road is achieved using transition slabs. One side of the slab rests on the back wall of the bridge abutment, while the other (roadside) rests on the bearing. The beams of the span structure are connected with diaphragms, which are monolithically cast from reinforced concrete. After the monolithic casting of the beams, a reinforced unifying slab is installed on the bridge deck. Following this, waterproofing is applied to prevent water leakage and protect the bridge from damage. After waterproofing, a protective layer of reinforced concrete is added, and finally, the road surface is laid.
Bridge components also include sidewalk blocks with curbs and railings.
Golden Gate
The "Golden Gate" is an engineering masterpiece that many deemed impossible to build. Its construction began on January 5, 1933, in San Francisco and was completed on April 19, 1937. The bridge spans a length of 2.7 km (2,737 meters), with towers reaching a height of 227 meters, and the roadway standing 67 meters above sea level. This clearance allows ships to pass unobstructed beneath the bridge.
According to the initial sketches, the bridge was envisioned with a different design, which did not appeal to the chief engineer, Joseph Strauss. As a result, he hired Charles Ellis, a professor at the University of Illinois, and Leon Moisseiff, a renowned designer of the time, as the bridge's architects. These architects reimagined the bridge's appearance, ultimately giving us the modern-day "Golden Gate."

However, much work had to be done before the bridge's completion. Strauss's primary objective was to ensure the bridge allowed ships to pass beneath it while also enduring the challenging local environmental conditions.



Before Strauss could begin the construction of the bridge, he had to focus on revising its design. This process came with several challenges, one of which was a conflict between Joseph Strauss and Charles Ellis, Strauss's deputy, over the bridge's design. As a result, in 1931, Strauss removed Ellis from the project. The design phase lasted until January 5, 1933, approximately 17 years after initial planning began. During this time, the United States was experiencing the Great Depression, a significant economic crisis. There was a real risk that the project would be canceled. However, despite the economic downturn, the government did not halt the construction of the bridge, as the "Golden Gate" was expected to play a crucial role in boosting the economy.
Once these hurdles were overcome, the most critical phase began: the construction of the bridge.
The first step was preparing the shore supports. Workers excavated over 92,000 cubic meters of soil manually. Following this, they began pouring

concrete with high silicon content to protect it from the corrosive effects of seawater. Constructing the northern support proved much simpler than the southern one, as the northern support reached a solid bedrock foundation just 13 meters underwater.
The southern support, however, presented a far greater challenge. To reach stable bedrock, workers had to descend approximately 30 meters underwater. This required the use of explosives, a task that posed significant risks and difficulties for the divers involved.

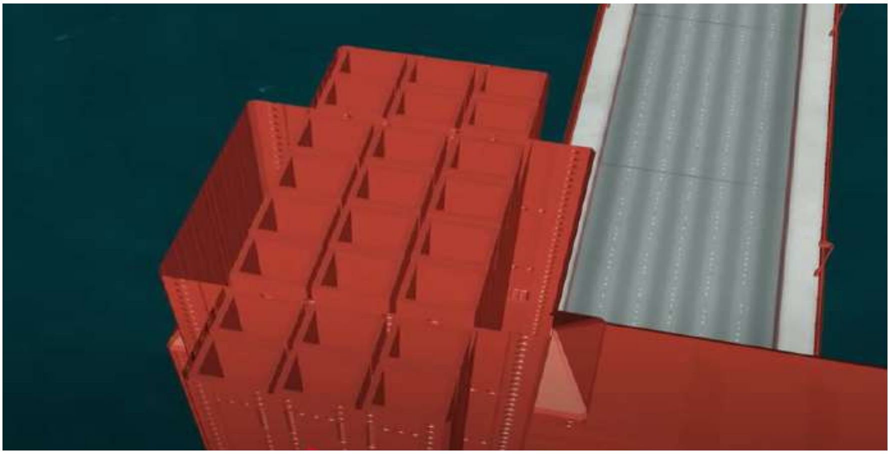
Despite all the challenges, the workers managed to excavate deeply underwater and construct the foundations for the supports. Following this, the process of pumping water out of the inner spaces of these foundations began, preparing them for the installation of steel towers. However, before proceeding with the construction of the tower, an expert assessment was required to confirm that the foundation was indeed resting on solid bedrock. To verify this, specialists descended to a depth of 32.5 meters and confirmed the reliability of the foundation.

Once the supports were constructed, the next step was to place a truss structure on them, which would serve as a transport pathway. A truss spanning over 300 meters was built, but an unforeseen catastrophe soon occurred. A ship, blinded by heavy fog while navigating the bay, accidentally collided with the structure, critically damaging it. Unfortunately, this was not the end of the troubles. A powerful storm struck shortly after, completely destroying the already damaged structure. In response, Strauss ordered the reconstruction of the truss to be raised 1.5 meters higher and reinforced with additional steel cables. This time, the process went according to plan, and the truss was successfully connected to the supports. (This was not the final roadway for vehicles but rather a temporary structure to facilitate access to the foundation.)

Following this, the construction of the tall towers began, enabling the truss structure to be suspended from cables. The "Golden Gate" bridge differed from other bridges due to its need to withstand extreme environmental conditions such as earthquakes and strong winds. While other bridges also face these challenges, the conditions for the Golden Gate were especially severe. It was imperative to make the bridge as flexible as possible to endure strong winds. To achieve this, the towers were constructed with a honeycomb-like structure made of small steel cells, enhancing their flexibility and resilience.

Ultimately, the height of the towers was 227 meters. Compared to other bridges, the height of the **Golden Gate Bridge** stands as follows:

1. **Akashi Kaikyō Bridge** (Japan) – 298 meters (978 feet)
2. **Great Belt Bridge** (Denmark) – 254 meters (833 feet)
3. **Golden Gate Bridge** (USA) – 227 meters (746 feet)
4. **Verrazzano-Narrows Bridge** (USA) – 211 meters (692 feet)
5. **Sihoumen Bridge** (China) – 211 meters (692 feet)
6. **Tsing Ma Bridge** (Hong Kong) – 206 meters (676 feet)
7. **Mackinac Bridge** (USA) – 168 meters (552 feet)
8. **Brooklyn Bridge** (USA) – 84 meters (276 feet)



The next phase was to install the suspension cables, with the main cable length being 2,332 meters (7,650 feet). This main cable was made up of over 25,000 smaller wires, and workers painstakingly connected the wires from one support to the other, which was a highly labor-intensive task. The final diameter of the cables reached approximately 1 meter.

After the cables were completed, the next step was to build the suspended truss structure. It was essential to hang it with perfect symmetry and sequence to ensure the bridge's stability. This phase turned out to be the most dangerous, as most worker fatalities occurred during this process. To reduce these fatal accidents, Strauss ordered protective safety lines across the width of the truss to prevent workers from falling. However, there was still a tragic incident where, despite the safety lines, the crane that was moving along the cable unexpectedly fell and struck a safety line, dragging 13 workers down, of whom only 3 survived. The remaining 10 tragically lost their lives.

Despite the tragic incidents, Strauss was determined to complete the project. He proceeded to suspend the truss on the cables. To prevent the bridge from cracking due to temperature changes, Strauss divided the bridge into sections. Finally, the roadbed was filled with concrete to connect it to the main part of the bridge, and then the road surface was laid.

The bridge was completed on **May 27, 1937**, which means the construction took approximately four years. During the construction, over 600,000 rivets were used, each heated until it was red-hot before being hammered in. Tragically, 11 workers lost their lives during the bridge's construction, and the total cost of building the bridge was $35 million at the time, which is roughly equivalent to $510 million today.

Brief History of the Golden Gate

The Golden Gate Bridge is one of the most iconic structures in the world, located in San Francisco, California. It spans the Golden Gate Strait, the entrance to the San Francisco Bay from the Pacific Ocean, and connects the city of San Francisco with Marin County to the north.

The idea for a bridge over the Golden Gate Strait was first proposed in the early 20th century, but it was not until the 1930s that construction actually began. The Great Depression and the difficult financial situation of the time posed a significant challenge to the project. Despite this, the bridge was financed with a combination of government funds and bonds. The bridge's design was conceived by engineer Joseph Strauss, and the final design was a result of collaboration with architects and engineers, including Charles Alton Ellis and Leon Moisseiff.

Construction of the Golden Gate Bridge began on January 5, 1933, and it was completed in 1937, opening to traffic on May 28, 1937. At the time of its completion, it was the longest suspension bridge in the world, with a main span of 4,200 feet (1,280 meters). Its towers stand 746 feet (227 meters) above the water, and the bridge is painted in its distinctive "International Orange" color, chosen for its visibility in San Francisco's frequent fog.

The Golden Gate Bridge was an engineering marvel of its time, overcoming major challenges such as strong currents, deep waters, and the difficult geology of the area. The construction process was dangerous, and unfortunately, several workers lost their lives during its building. However, the bridge's completion was considered a major achievement and was a symbol of resilience during a time of economic hardship.

Over the years, the bridge has become a global symbol of San Francisco and a major tourist attraction. It is also an important transportation link, carrying millions of vehicles each year across the strait. The Golden Gate Bridge is regularly maintained and undergoes seismic retrofitting to ensure its safety in the event of an earthquake, as the region is seismically active. Today, the Golden Gate Bridge is not only a functional piece of infrastructure but also a cultural landmark. It has been featured in countless movies, photographs, and artworks, cementing its place as one of the most recognizable and admired bridges in the world.

" The Golden Gate is annually inspected and locally rehabilitated to ensure that transportation traveling across or beneath it remains safe.

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