ავთანდილ კაკაბაძე

ავარიები საქართველოს რკინიგზაზე და მათი გამომწვევი მიზეზები

წარდგენილია დოქტორის აკადემიური ხარისხის
მოსაპოვებლად

საქართველოს ტექნიკური უნივერსიტეტი
თბილისი, 0175, საქართველო
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საქართველოს ტექნიკური უნივერსიტეტი

სამშენებლო ფაკულტეტი

ჩვენ, ქვემორე ხელისმომწერნი ვადასტურებთ, რომ გავეცანით ავთანდილ კაკაბაძის მიერ შესრულებულ სადისერტაციო ნაშრომს დასახელებით: `ავარიები საქართველოს რკინიგზაზე და მთი გამომწვევი მზეზები~ და ვაძლევთ რეკომენდაციას საქარველოს ტექნიკური უნივერსიტეტის სამშენებლო ფაკულტეტის სადისერტაციო საბჭოში მის განხილვას დოქტორის აკადემიური ხარისხის მოსაპოვებლად.

თარიღი

ხელმძღვანელი:
ასოცირებული პროფესორი გ. კვანტალიანი

რეცენზენტები: 1.

2.

ხარისხის უზრუნველყოფის
სამსახურის უფროსი
ასოცირებული პროფესორი /მ. ჯავახიშვილი/

საქართველოს ტექნიკური უნივერსიტეტი

2014 წელი

ავტორი	ავთანდილ კაკაბაძე
დასახელება	ავარიები საქართველოს რკინიგზაზე და მთი გამომწვევი მზეზები
ფაკულტეტი	სამშენებლო
ხარისხი	აკადემიური დოქტორი
სხდომა ჩატარდა	

ინდივიდუალური პიროვნებების ან ინსტიტუტების მიერ ზემოთმოყვანილი დასახელების ნაშრომის გაცნობის მიზნით მოთხოვნის შემთხვევაში მისი არაკომერციული მიზნებით კოპირებისა და გავრცელების უფლება მინიჭებული აქვს საქართველოს ტექნიკურ უნივერსიტეტს.

ავტორის ხელმოწერა

რეზიუმე

naSromSi ganxilulia samTo rkinigzebze matarebelTa usafrTxo moZraobis uzrunvelyofis RonisZiebani. samTo rkinigzebze, gansxvavebiT ioli reliefis rkinigzebisagan moZraobis usafrTxoeba metad problematuria. es ganpirobebulia matarebelTa moZraobis mTeli rigi TaviseburebebiT, rac damaxasiaTebelia samTo rkinigzebisaTvis. garda amisa matareblis usafrTxoebis faqtori gazrdilia agreTve bunebrivi pirobebiTac, rogoricaa mkacri klimati, rTuli geologiuri da hidrogeologiuri maxasiaTeblebi.

rogorc cnobilia, samTo rkinigzebs gaaCnia rTuli gegma da profili. profilis grZivi qanobi bevr SemTxvevaSi aWarbebs 30 ‰. wriuli radiusis mniSvneloba aris 300 m da naklebic.

cicabo grZel daRmarTebze satvirTo matareblebis moZraobisas mosalodnelia samuxruWo xundebis gadaxureba. kompoziciuri masalisagan damzadebuli xundebi mniSvnelovnad zrdis matareblis samuxruWo Zalas, Sesabamisad SesaZlebelia moZraobis siCqareebis gazrda. magram amave dros masalis mcire Tbogamtarobis gamo xdeba Tvlis siTburi gadatvirTva. Tujis xundebis SemTxvevaSi maRali temperaturis gamo mosalodnelia xundis darbileba da Sesabamisad mcirdeba samuxruWo Zala, rac saboloo jamSi zrdis moZraobis usafrTxoebis risks.

xundebis gaxurebis temperatura damokidebulia xundis masalaze, daRmarTis qanobze da moZraobis siCqareze. Teoriulad xundis gaxurebis temperaturis dadgena metad rTulia. am sakiTxis gadawyvetaSi didi wvlili miuZRvis did rus mecniersa da praqtikos profesor v. inozemcevs. mis mier SemoTavazebuli formulis interpretaciis safuZvelze davadgine daRmarTis maqsimaluri sigrZeebi daRmarTis qanobisa da siCqarisagan damokidebulebiT.

grZel daRmarTebze matareblis uwyveti damuxruWebisas mosalodnelia samuxruWe magistralSi da samuxruWe rezervuarsa da cilindrebSi haeris wnevis dacema normaze dabla, rac zrdis avariebis risks. Tanamedrove moZravi Semadgenloba aRWurvilia iseTi haergamanawileblebiT, romlebic Teoriulad uSretia. magram samuxruWo sistemidan haeris gadinebis gamo mosalodnelia sahaero magistralSi wnevis dacema e.w. daSreta. haeris wnevis cvalebadobis dadgena samuxruWo magistralSi Teoriuli gziT SeuZlebelia. amitom uwyveti damuxruWebis drois dasadgenad mivmarTeT eqsperimentebis da uSualod realur pirobebSi Catarebuli cdebis monacemebs. am monacemebis gansjisa da analizis safuZvelze davadgineT, rom uwyveti damuxruWebis dro cicabo daRmarTebze roca $i<30$ ‰ Seadgens 35 wT-s, xolo roca $i\geq 30$ ‰ _ 30 wT-s.

grZel daRmarTebze mosalodnelia agreTve samuxruWe xundebis gaZlierebuli cveTa. gansakuTrebiT Tujis xundebis SemTxvevaSi. naSromSi dadgenilia cicabo daRmarTebis maqsimaluri sigrZeebi xundis sisqisa da qanobisagan damokidebulebiT.

grZel aRmarTebze saangariSo woniani satvirTo matareblebis moZraobisas elmavali moixmars maqsimalur dens. amitomac grZel aRmarTebze mosalodnelia wevis Zravebis gadaxureba. dadgenilia aRmarTebis maqsimaluri sigrZeebi Zravebis gadaxurebis pirobiT.

Seuferxebeli da usafrTxo moZraoba, rogorc zemoT avRniSneT, rTul mTian pirobebSi, damokidebulia agreTve bunebriv pirobebze. samTo rkinigzebze umetes SemTxvevaSi mosalodnelia liandagis Tovlisagan danamqra. msoflio praqtikaSi aris

SemTxvevebi, roca Tovlis namqers liandagidan gadmougdia matarebeli. marabda-axalqalaqis xazze calkeuli ubani xSirad inamqreba. aris iseTi monakveTic, romelic weliwadSi 6 Tvis manZilze danamqrilia da moZraoba Sewyvetilia. maqvs SemuSavebuli rekomendaciebi, romlebic uzrunvelyofen liandagis Tovlisgan dacvas.

imisaTvis, rom ar Seferxdes matareblebis moZraoba, aucilebelia swored SerCeul iqnas matareblis saangariSo wona. gansxvavebiT ioli reliefisagan mTian pirobebSi matareblis wonis dadgenaze gavlenas axdens mravali faqtori. maT Soris SeiZleba davasaxeloT relsis Tavis mdgomareoba, mcire radiusebi, vagonebs Soris gadasabmel mowyobilobaTa simtkice da sxva. rogorc cnobilia, lokomotivis wevis Zala ZiriTadad damokidebulia relssa da lokomotivis Tvals Soris SeWidulobis koeficientis mniSvnelobaze. Cveulebriv pirobebSi am koeficientis sidide elmavlis SemTxvevaSi meryeobs 0.25-is farglebSi.

rogorc gamokvlevebma aCvenes, rogorc CvenTan, ise sazRvargareT am koeficientis mniSvneloba gacilebiT naklebia. gaWuWyianebuli an moyinuli relsis SemTxvevaSi misi sidide SeiZleba Semcirdes 0.15_0.2-mde. SeWidulobis koeficienti mcirdeba agreTve mcireradiusiani mrudebis SemTxvevaSi ($R \leq 500m$).

Cvens mier dadgenilia saangariSo wonis mniSvnelobebi marabda_axalqalaqis xazze.

SemoTavazebuli maqvs saangariSo wonebis e.w. `sezonuri~ normebi, romelic zafxulis periodSi Seadgens 1700 t, xolo zamTris periodSi _ 1300 t.

zemoTdasaxelebuli matareblis moZraobis pirobebis Taviseburebebis gaTvaliswinebiT davsaxeT moZraobis usafrTxoebis RonisZiebani. rogorc gamokvlevebma gviCvenes cicabo qanobiani gadasarbenebis sigrZis malimitirebel pirobebs warmoadgens samuxruWe xundebis gadaxureba da sahaero magistralis daSreta. am ori pirobis erTdrouli gaTvaliswinebiT miiReba saproeqto rkinigzis gadasarbenis optimaluri sigrZe.

Cvens mier Semowmebuli iqna marabda-axalqalaqis rkinigzis xazis yvelaze daZabuli da rTuli gadasarbenebi. yvela gadasarbenisaTvis dasaxulia moZraobis usafrTxoebis RonisZiebebi. kerZod, gadasarbeni TeTriwyaro_nadarbazevi (15 km) ver akmayofilebs verc xundebis gaxurebis da verc magistralis daSretis pirobebs. am gadasarbenze Cveni rekomendaciiT gaixsna damatebiTi asaqcevi punqti ~WivWavi~, ramac sagrZnoblad aamaRla matareblebis moZraobis usafrTxoebis done da gazarda xazis gamtarunarianoba. gadasarbenze winwyaro_TeTriwyaro moewyo e.w. `dasasvenebeli~ moedani, rac saSualebas aZlevs matarebels Seumsubuqos damuxruWebis pirobebi. yvela sadgurebze, romlebic emijneba grZel daRmarTebs, unda moewyos damcveli Cixebi, xolo sadgur `TrialeTze~ _ damWeri Cixi.

Cvens mier Camoyalibebuli rekomendaciebis gaTvaliswineba rogorc arsebul rkinigzaze, aseve axali rkinigzebis daproeqtebisas uzrunvelyofs matareblebis usafrTxo moZraobas.

Abstract

In the work are considered the measures to ensure the safety trains trafic on the mountanuous railways. On the mountainuous railways, in contrast to the having easy relief railways the traffic safety problem is rather problematic. This is stipulated due the number of trains traffic features that are characteristic for mountanuous railways. In addition the train safety factor is increased also by natural conditions such as harsh climate, complex geological and hydrogeological characteristics.

As it is well known, the mountanuous railways has a complicated plan and profile. The longitudinal slope of profile in many cases exceeds 30 ‰. The value of the circular radius is less than 300 m and more.

On the long steeps at freight trains movement is expected the overheating of brake shoes. The manufactured from composite materials brake shoes greatly increases the brake force of train, accordingly is possible to increase in the speed of train. But at the same time due the small thermal conductivity of the material occurs thermal overload of wheels. In the case of cast-iron brake shoes due to high temperature and is expected softening of shoes and accordingly is decreased the braking force that ultimately increases the safety risk.

The shoes heating temperature depends on the shoe's material, the slope of the descent and the train speed. Theoretically the determination of shoe's heating temperature is rather comlex. In solution of this issue great contribution was made by the great Russian scientist and practicing professor V. Inozemtsev. Based on the

interpretation of the proposed by him formula are defined maximum lengths depending on on the slope's descent and speed.

On the long slopes at train continuous braking is expected to drop pressure in brake conduit, in brake reservoir and brake cylinders below normal that increases the risk of accidents. The modern rolling stock are equipped by such air distributors that theorerically are inexhaustible. But because of the air outflow from the brake system is expexted air pressure fall so-called exhaustion. The theoretical definition of air pressure variation in the brake conduit is impossible. Therefore, for determination of continuous braking time consider the data of carrying out experiments and actual conditions. Grounding on the consideration and analysis of these data we define that at continuous braking on steeps when i<30 ‰ the time makes up to 35 minutes - while when i≥30 ‰ - 30 min.

On the long slopes is expected also the enhanced depreciation of brake shoes. Especially in the case of cast-iron brake shoes. In the work is defined maximum lengths of a steep descents depending on shoes thickness and slope value.

On the long rises at movement of design weight freight trains locomotive consumes the maximum power. Therefore, on the long rises is expected traction motor's overheating. Are defined the maximum lengths of rises in conditions of motor's overheating.

In order to not disturb the trains traffic, it is necessary to make right choice of the train design weight. In contrast to the easy relief in the mountainous conditions on the determination of train's weight are influenced many factors. Among them we can list the state of rail head, a small radiuses, strength of hookup between carriages and others. As it is well known, the locomotive traction force is mainly dependent on the value of traction coefficient between rail and locomotive wheel. Usually valaue of this coefficient in the case of the locomotive 's makes nearabout 0.25.

As it is clear from studies, in our country, as well as in foreign countries the value of this considered is much less. Its value may be reduced in the case of pollutants or frozen rail up to 0.15-0.2. The traction coefficient is decreased also in the case of curves with small radiuses (R≤500 m).

By us are determined the values of design weight on Marabda-Akhalkalaki line.

I have proposed a so-called "seasonal" norms of design weights that during the summer makes up to 1700 tons, while in winter up to 1300 tons.

Due consideration of above mentioned train traffic conditions we draw-up the traffic safety measures. As it is clear from investigations on a steep spans the length limiting conditions represents the brake shoes overheating and exhaustion in air brake conduit. Due simultaneously taking into account of these two conditions would be accepted optimal length of the design railway span.

By us was examined the Marabda - Akhalkalaki railway line all most tense and complex spans. For all spans is drawn-up of traffic safety measures. In particular, Tetritskaro - Nadarbazevi (15 km) span did not meet either shoes heating or brake conduit exhaustion conditions. On this span due our recommendation on this point has opened an additional bypass "Chivchavi" point that have significantly improve train line security levels and increased capacity of line. On the span Tsintskaro- Tetritskaro is arranged so-called "Resting" field that gives the possibility to train to improve braking conditions. In all stations that are in adjacent to the long slopes, shall be arrandeg the protective dead-end sidings, while in the station "Thrialeti" - catcher dead-end siding.

The continuous and safe movement, as it is mentioned above, in the complex mountainuous conditions, is depending also on the environmental conditions. On the

mountainuous railways in most cases it is expected to snowdrifr of track. In the world practice there are cases when due snowslide was occurred the derailment of trains. The separate sites on Marabda - Akhalkalaki line often is snowdrifted. Is it such a span that is snowdrifted during 6 months perpendikular year and traffic is stopped. I have developed recommendations that provide protection of track from snowdrift.

The consideration of formulated by us recommendations on the existing railway as well as at design of the new railway line will provide safe movement of trains.

შინაარსი

ცხრილების ნუსხა

naxazebis nusxa

madliereba

minda madloba gadavuxado Cemi sadisertacio naSromis xelmZRvanels, asocirebul profesors gulver kvantalians _ sistematuri konsultaciebisa da saWiro literaturis momaragebaSi gaweuli daxmarebisaTvis.

minda agreTve madloba movaxseno rkinigzebis mSeneblobis mimarTulebis yvela profesor_maswavleblebs Cems mimarT gamoCenili yuradRebisa da daxmarebisaTvis.

Sesavali

ZiriTadi moTxovna, romelic sarkinigzo transportis mimarT waeyenebul ZiriTad moTxovnas warmoadgens matarebelTa usafrTxo da Seuferxebeli moZraobis uzrunvelyofa. rkinigzebze sxva saxis transportTan SedarebiT moZraobis usafrTxoebis xarisxi SedarebiT maRalia, rac SesaZlebeli gaxda moZravi Semadgenlobis teqnikuri aRWurvilobis, signalzaciis, centralizaciis da blokirebis sistemebis gaumjobesebiT, liandagis zeda naSenis mdgradobisa da simtkicis amaRlebiT. naklebad rTul topografiul pirobebSi gamaval rkinigzebTan SedarebiT samTo rkinigzebze moZraobis usafrTxoebis uzrunvelyofa mTel rig problemebTan aris dakavSirebuli.

mTian regionebSi sarkinigzo xazebi ganlagebulia rTul, klimatur, seismur, hidrologiur da sainJinro-geologiur pirobebSi. aseTi teritoriebi xasiaTdeba iseTi movlenebiT, rogoricaa Tovlis zvavebi, TovliT danamqra, kldovani Camoqcevebi, Rvarcofebi, kurumebi, Svavebi da sxv.

maRalmTiani teritoriebis sagzao meurneobisaTvis seriozul problemas warmoadgens Tovlis sqeli saburveli. Aam pirobebSi transportis muSaobas sakmaod aferxebs Tovlis zvavebisa da namqerebis arseboba.

saqarTvelo mTagoriani qveyanaa da rkinigzis xazebis garkveuli nawili gadis sauReltexilo qedebze da ferdobebze. aseTia mTavari magistralis suramis sauReltexilo ubani, marabda_axalqalaqis, quTaisi_tyibulis, borjom_vales ganStoebebi, mSenebare axalqalaqi_karwaxis rkinigzis xazi. suramis uReltexili iTvleboda yvelaze ufro rTul ubnad yofil sakavSiro rkinigzaze. am ubanze qanobis maqsimaluri sidide Seadgens 29.3 ‰, xolo minimaluri radiusis sidide 175 m. marabda_axalqalaqis xazze saxelmZRvanelo qanobi Seadgens 35‰, minimaluri radiusi 300 m. quTaisi_tyibulis monakveTze gvxvdeba 46 ‰ qanobiani monakveTebi.

suramis sauReltexilo ubnis eqspluataciaSi SesvlisTanave avariebis riski am monakveTze gacilebiT meti iyo, vidre sxva ubnebze. ris gamoc miRebuli iqna rigi zomebi moZraobis usafrTxoebis uzrunvelsayofad. magaliTad, sadgurebze wifa, moliTi da da marelisi, SemoRebuli iqna matareblis aucilebeli gaCerebebi 5_10 wT-iT, moewyo damWeri Cixebi sadgurebze wifasa da moliTSi; ramac mkveTrad Seamcires avariebis ricxvi suramis sauReltexilo ubanze.

aqve unda avRniSnoT is garemoeba, rom yofil sabWoTa kavSirSi samTo rkinigzebze moZraobis usafrTxoebis sakiTxebis Seswavlas saTanado yuradReba ar eqceoda, risic erT-erTi mTavari mizezi is gaxldaT, rom aseTi saxis rkinigzebis wili saerTo rkinigzaSi umniSvnelo iyo (daaxlovebiT 1 %). samTo rkinigzebze matarebelTa moZraobis usafrTxoebis sakiTxi mwvaved dadga gasuli saukunis 70-ian wlebSi, roca daiwyo transkavkasiis rkinigzis xazis proeqtis Sedgena. damuSavebuli iqna am xazis sami varianti. sabolood damtkicda e.w. arxotis mimarTuleba saerTo sigrZiT 160 km.

aRniSnul rkinigzis xazze kavkasionis qedis qveS gvirabis sigrZe Seadgenda 23 km-s. Tavidanve rkinigza gaTvaliswinebuli iyo orliandagiani. saxelmZRvanelo qanobi Seadgenda 30 ‰. gadasarbenis maqsimaluri sigrZe aRwevda 22 km-s. swored am sigrZis daZabuli daRmarTis arsebobam eWvqveS daayena matarebelTa moZraobis usafrTxoebis sakiTxebi.

80-ian wlebSi saqarTveloSi aSenda da eqspluataciaSi Sevida marabda_axalqalaqis rkinigzis xazi saerTo sigrZiT 160 km. saxelmZRvanelo qanobi am xazze Seadgens 35 ‰, xolo minimaluri radiusi 300 m. Tavidan rkinigzis xazi gaTvaliswinebuli iyo rogorc adgilobrivi daniSnulebis III kategoriis rkinigza. rkinigzis xazi daproeqtda da aSenda samSeneblo normebidan gadaxriT. saqme is gaxlavT, rom maSindeli normebis Tanaxmad III kategoriis xazze saxelmZRvanelo qanobi ar unda yofiliyo 30 ‰-ze meti sididis.

rogorc cnobilia, marabda-axalqalaqis rkinigzis xazi axalqalaqi-karwaxi-TurqeTis respublikis sazRvaris rkinigzis ubnis mSeneblobis dasrulebis Semdeg gaxdeba saerTaSoriso rkinigzis xazis Semadgeneli nawili. amitomac dRis wesrigSi dadga rkinigzis am xazis reabilitaciisa da masze moZraobis usafrTxoebis uzrunvelyofis sakiTxebi.

rogorc zemoT iyo aRniSnuli, mTian da gansakuTrebiT maRalmTian raionebSi gamaval rkinigzebze moZraobis usafrTxoebis uzrunvelyofa metad problemuria, vidre vake da mTiswina ioli reliefis pirobebSi. es ganpirobebulia rogorc bunebrivi pirobebiT, aseve matareblis moZraobis TaviseburebebiT cicabo qanobian monakveTebze. aseT Taviseburebebs miekuTvneba: grZel cicabo daRmarTebze samuxruWe xundebis gadaxureba, sahaero magistralis daSreta, xundebis cveTa da aRmarTis mimarTulebiT eleqtruli Zravebis gadaxureba.

grZel cicabo daRmarTebze uwyveti damuxruWebisas mosalodnelia samuxruWe xundebis gadaxureba, rac saSiSroebas uqmnis moZraobis usafrTxoebas. kompoziciuri masalisagan damzadebuli xundebis danergvam mniSvnelovnad gazarda samuxruWo Zala da SesaZlebeli moZraobis siCqaris gazrda. amave dros es masala iTvleba cveTamedegad. am dadebiT TvisebebTan erTad kompoziciuri masalis uaryofiT mxares Seadgens misi naklebi Tbogamtaroba (Tujis xundebTan SedarebiT), ris Sedegedac xdeba Tvlis Tburi gadatvirTva. xundebis gaxurebis maqsimalur dasaSveb temperaturad miRebulia 350^0C. xundebis gaxurebis temperatura damokidebulia xundis masalaze, damuxruWebis saxeobaze, moZraobis siCqareze da profilis qanobze. sauReltexilo rkinigzis xazebze xundebis gaxurebis temperaturis Sesamcireblad praqtikaSi miRebulia Semdegi RonisZiebebis gatareba: satvirTo matarebeli Cerdeba gamyof punqtebze ramdenime wuTiT (5_6 wT) xundis gacivebis mizniT. asea magaliTad sadg. wifasa da sadg. moliTze (suramis uReltexili). arsebuli sauReltexilo rkinigzis xazebi aSenebulia Zveli teqnikuri normebiT, amitom gadasarbenebis sigrZe ar aRemateba 7_8 km-s. axali rkinigzebis daproeqtebisas mZlavri lokomotivis Semotanam da moZraobis siCqaris gazrdam gamoiwvia gadasarbenis sigrZeebis dagrZeleba 12_15 km-mde (magaliTad marabda_axalqalaqis ubani). orliandagiani rkinigzis SemTxvevaSi gadasarbenis maqsimaluri sigrZe moqmedi normebis mixedviT Seadgens 30 km-s. yovelive aman samTo rkinigzebze dRis wesrigSi daayena grZeli daRmarTebis sigrZeebis Semowmeba xundebis gadaxurebis pirobiT.

xundis gaxurebis temperatura mraval faqtorzea damokidebuli. amitom misi Teoriuli gziT dadgena erTob rTulia. am sakiTxis SeswavlaSi didi wvlili miuZRvis cnobil rus mecniersa da praqtikoss v. inozemcevs. v. inozemcevis SemoTavazebuli xundebis gaxurebis ganmsazRvreli formulis daxmarebiT Cvens mier dadgenili iqna daRmarTebis maqsimaluri sigrZeebi xundis gaxurebis temperaturisagan damokidebulebiT.

Cvens mier miRebuli Sedegebis sandoobaSi darwmunebis mizniT misi Sedareba moxda uSualod sauReltexilo gzebze Catarebul cdebis SedegebTan. cdebi Catarebuli iqna suramis uReltexilze rkinigzis departamentis da saqarTvelos teqnikuri universitetis TanamSromlebis mier. Sedarebis Sedegad aRmoCnda, rom cdomileba Teoriul da praqtikul Sedegebs Soris aris dasaSvebis farglebSi.

Tanamedrove satvirTo vagonebi aRWurvilia meqanikuri muxruWebiT. grZel cicabo daRmarTebze warmatebiT gamoiyeneba lokomotivis rekuperaciuli damuxruWeba. rekuperaciuli damuxruWeba SesaZleblobas iZleva eleqtroenergiis mniSvnelovani raodenoba ukan davabrunoT sakontaqto qselSi, rasac gamoiyenebs sxva eleqtromavlebi, romlebic am momentSi muSaoben wevis reJimSi. amasTan erTad grZel daRmarTebze umjobesdeba matarebelTa moZraobis pirobebi da saimedoba. rekuperaciuli damuxruWeba amcirebs meqanikuri damuxruWebis wils da Sesabamisad mcirdeba xundebis gaxurebis temperatura. aqve unda aRiniSnos, rom rekuperaciuli damuxruWebisas samuxruWo Zala modis lokomotivze, ramac SeiZleba gamoiwvios liandagis gaZlierebuli moSla. amitom am SemTxvevaSi didi mniSvneloba eniWeba, saerTo samuxruWe Zalis Tu ra nawili modis rekuperaciaze.

Tanamedrove moZravi Semadgenloba aRWurvilia iseTi haergamanawileblebiT, romlebic uzrunvelyofen avtomuxruWebis uSretobas, anu samuxruWo magistralSi haeris wneva normis farglebSia. cicabo qanobebze ($i \geq 18‰$) avtomuxruWebi gadarTuli unda iyos muSaobis samTo reJimze. avtomuxruWebis uSretoba ganpirobebulia muSa kamerebis sahaero magistralidan izolirebiT, xolo samarago rezervuarebi magistralidan mudmivad ivseba SekumSuli haeriT. miuxedavad amisa, grZel daRmarTebze uwyveti damuxruWebisas wnevebi samuxruWo cilindrebSi (sc), samarago rezervuarebSi (sr) da magistralSi (m) SekumSuli haeris gadineba mosalodnelia sahaero magistralis gadabmebSi germetiulobis daucvelobiT, ris gamoc magistralis simkvrivis norma eqspluataciis pirobebSi SesaZlebelia ar iyos daculi (normad miRebulia 1 wuTis manZilze wnevis dacema 0.2 atmosferoTi). samuxruWo magistralSi wnevis normaze dabla daweva amcirebs moZraobis usafrTxoebis pirobebs. sauReltexilo rkinigzebze miRebulia matarebelTa moZraobis Semdegi reJimi: dawesebulia gamyof punqtebze satvirTo matareblebis aucilebeli gaCereba 5_6 wuTiT. am drois manZilze imuxteba sahaero magistrali da civdeba samuxruWe xundebi.

haeris wnevis cvalebadoba sahaero magistralSi Teoriul gaangariSebas ar eqvemdebareba. uwyveti damuxruWebis drois dasadgenad Sesrulda eqsperimentebisa da uSualo realur pirobebSi Catarebuli cdebis monacemebis urTierTSedareba. am monacemebis analizisa da Sejerebis safuZvelze vaskvniT, rom

uwyveti damuxruWebis dro, roca qanobi $i \geq 30‰$, tolia 30 wuTis, xolo roca daZabuli daRmarTis qanobi naklebia 30‰-ze,

_ 35 wuTis.

grZel cicabo daRmarTebze xangrZlivi damuxruWebisas xundi gaxurebis garda ganicis cveTas (gansakuTrebiT Tujis xundebi). kompoziciuri xundebi gacilebiT cveTamedegia, amitom cveTaze mowmdeba mxolod Tujis xundebi. Cvens mier dadgenilia daRmarTis maqsimaluri sigrZe Tujis xundis sisqisa da qanobisagan damokidebulebiT, anu xundis is maqsimaluri sisqe, romliTac matarebels SeuZlia gaiaros dadgenil qanobiani daRmarTi.

cicabo aRmarTze saangariSo woniani satvirTo matareblis moZraobisas elmavali moixmars maqsimalur dens. xangrZlivi moqmedebis Sedegad Ruzis gragnilebi, koleqtori da sakisrebi SeiZleba daziandes, rac gamoiwvevs Zravis simZlavris SezRudvas, izolaciis dazianebas da Zravis mwyobridan gamosvlas. Zravis gaxurebis maqsimaluri temperatura damokidebulia izolaciis klasze da garemos temperaturaze. praqtikaSi Zravis gadaxurebis Tavidan acilebis mizniT mimarTaven lokomotivis muSaobis reJimis Secvlas: elmavali gadayavT muSaobis saaTur reJimze, ris Sedegad erTi saaTis ganmavlobaSi ar aris mosalodneli misi gadaxureba. magram am RonisZiebas uaryofiTi Sedegi mosdevs, kerZod, unda SevamciroT matareblis wonis norma, romelic yovelTvis mizanSewonili ar aris.

zemoTaRniSnulidan gamomdinare, mTian pirobebSi rkinigzebis daproeqtebisas aucilebelia aRmarTis sigrZis Semowmeba Zravebis gadaxurebis pirobiT. naSromSi dadgenilia aRmarTis maqsimaluri sigrZe Tanamedrove elmavlebisaTvis Zravis sawyisi temperaturisagan damokidebulebiT.

rkinigzis transportis usafrTxoebaze garda matareblis moZraobis reJimisa, gavlenas axdens bunebrivi pirobebi. gansakuTrebiT es sagrZnobia samTo rkinigzebisaTvis. vinaidan mTian pirobebSi xSiria Tovlis zvavebi, namqerebi, mewyerebi, qvaTacvena da sxva. adgili aqvs mkacr klimatur, topografiul, geologiur da hidrologiur pirobebs.

saqarTvelos rkinigzis garkveuli nawili gadis sauReltexilo qedebze da ferdobebze (magaliTad, suramis sauReltexilo ubani, marabda_axalqalaqis xazi). marabda_axalqalaqis xazze aris monakveTebi, romelic inamqreba TovliT da mTeli 6 Tvis manZilze moZraoba Sewyvetilia. axla roca es xazi gaxda saerTaSoriso rkinigzis

Semadgeneli ubani, udidesi yuradReba eqceva masze Seuferxebel da usafrTxo moZraobis uzrunvelyofis sakiTxebs.

naSromSi moyvanilia mTeli rigi rekomendaciebi, romelTa gatareba Tavidan agvacilebs liandagis Tovlisagan danamqras.

matarebelTa usafrTxo da Seuferxebeli moZraobis uzrunvelsayofad didi mniSvneloba eniWeba satvirTo matareblis saangariSo wonis dadgenas, vinaidan araswored SerCeuli saangariSo wonis SemTxvevaSi SesaZlebelia matarebeli Seferxdes saangariSo qanobian aRmarTze. es gamoiwvevs moZraobis Seferxebas da gaarTulebs moZraobis organizacias mTel ubanze.

saangariSo wonis dadgenas samTo rkinigzebze gaaCnia mTeli rigi Taviseburebani, vinaidan samTo pirobebSi rkinigzis liandagi ufro metadaa gaWuWyianebuli, sveli da moyinulia, vidre Cveulebriv pirobebSi. es garemoeba mkveTrad amcirebs lokomotivis wevis Zalas (mcirdeba SeWiduloba relssa da Tvals Soris). aseT ubnebze gvxvdeba mcireradiusiani mrudebi ($R \leq 500m$), rac agreTve amcirebs wevis Zalas. gasaTvaliswinebulia agreTve wevis Zravebis gadaxurebis momenti aRmarTis mimarTulebiT.

yovelive zemoTaRniSnulis gaTvaliswinebiT Cvens mier dadgenili iqna matareblis saangariSo wona marabda_axalqalaqis rkinigzis xazisaTvis.

SemoTavazebuli gvaqvs matareblis saangariSo wonis e.w. sezonuri sidideebi, kerZod zafxulis periodSi es sididea 1700 t, xolo zamTris periodSi _ 1300 t.

mTian pirobebSi elwevis upiratesoba TbowevasTan SedarebiT aSkaraa, magram im SemTxvevaSi, roca gadazidvebis zomebi mcirea, advili SesaZlebelia mizanSewonili aRmoCndes Tbowevis gamoyeneba. aseve yuradsaRebia turistul marSrutebze Tbowevis gamoyenebis SesaZlebloba. mTian pirobebSi Tbowevis gamoyenebisas matareblis wonis dadgena dakavSirebulia mTel rig TaviseburebebTan. zRvis donidan simaRlis matebasTan dakavSirebiT mcirdeba dizelis Zravis simZlavre. rac aucileblad unda iqnes gaTvaliswinebuli matareblis saangariSo wonis dadgenisas.

cicabo qanobebze matarebelTa moZraobis Taviseburebebis analizma gviCvena, rom grZeli daRmarTebis sigrZeebi ZiriTadad izRudeba ori pirobiT: xundebis gadaxurebiT da sahaero magistralis daSretiT. am pirobebis erTdrouli gaTvaliswinebiT miiReba daZabuli gadasarbenis optimaluri sigrZe. aqve unda aRiniSnos is

garemoebac, rom erTliandagiani rkinigzis SemTxvevaSi gadasarbenis sigrZis ganmsazRvrelia agreTve xazis gamtarunarianoba. orliandagiani rkinigzis gadasarbenis sigrZe ki izRudeba moqmedi normebiT da igi Seadgens 30 km-s.

Cveni kvlevis obieqts, rogorc zemoT avRniSneT, warmoadgens marabda_axalqalaqis rkinigzis ubani. am ubanze moZraobis usafrTxoebis sakiTxi xazis eqspluataciaSi SesvlisTanave gaxda aqtualuri. ris mizezzac warmoadgenda eqspluataciis sawyis wlebSi am ubanze momxdari rigi avariebi, romlebsac Seewira adamianTa sicocxle da qveyanam ganicada didi ekonomiuri da materialuri zarali. marabda_axalqalaqis rkinigzis xazss Tavisi sirTuliT analogi ar gaaCnia yofil sabWoTa kavSiris sivrceSi. Cvens mier Seswavlili iqna am monakveTis yvela rTuli gadasarbenebi. aseTi ki aris 5 gadasarbeni. yvela maTganis sigrZe Semowmebuli iqna damuxruWebis pirobiT da moZraobis usafrTxoebis uzrunvelyofis mizniT davsaxeT rigi RonisZiebani, rogorebicaa damatebiTi asaqcevis gaxsna, e.w. `dasasvenebeli~ moednebis da Tovldamcavi nagebobebis mowyoba.

Cvens mier Catarebuli kvlevebis Sedegebi da dasaxuli rekomendaciebis danergva mTian regionebSi gamaval rkinigzebze da maT Soris marabda_axalqalaqis xazze SesaZleblobas mogvcems uzrunvelvyoT an gavaumjobesoTY matarebelTa moZraobis usafrTxoeba.

1. literaturis mimoxilva

matarebelTa moZraobis usafrTxoebis sakiTxs didi yuradReba eqceoda rkinigzebis Casaxvis droidan. rkinigzis transportze moZraobis usafrTxoebis xarisxi sxva saxis transportTan SedarebiT ufro maRalia, rac ganapiroba im normebma da wesebma, ris safuZvelzec igeboda da eqspluatacia eweoda rkinigzas.

gamyofi punqtebis ganlagebis sakiTxi erT-erTi sakvanZo sakiTxia rkinigzis daproeqtebisas. rogorc cnobilia, gamyof punqtebs miekuTvneba saubnos Sualeduri sadgurebi, asaqcevebi, orliandagian xazebze-gadaswrebis punqtebi.

gamyofi punqtebis ganlagebis sakiTxs didi yuradReba eqceoda rkinigzis daproeqtebisa da mSeneblobis sawyis stadiidan. am problemisadmi interesi SemTxveviTi ar aris, vinaidan damatebiTi gamyofi punqtebisaTvis moednebis mowyoba eqspluataciis pirobebSi garTulebulia, xolo daZabuli svlis ubnebze dakavSirebulia did danaxarjebTan da rig SemTxvevebSi SeuZlebelia. amitom saWiroa winaswar iyos ganWvretili rkinigzis xazis gamtarunarianobis zrdis dinamika meore liandagis mowyobis gaTvaliswinebiT.

gamyofi punqtebis ganlagebaze bevrad aris damokidebuli rkinigzis xazis samSeneblo da saeqspluatacio xarjebi. rac axlo-axlo aris ganlagebulia gamyofi punqtebi, miT metia gamtarunarianobis sidide, magram SesamCnevad izrdeba kapitaldabandeba. amave dros uaresdeba xazis saeqspluatacio maCveneblebi. izrdeba matareblebis gaCerebaTa ricxvi, metia matareblebis gaqaneba-SeCerebis raodenoba, rac saboloo jamSi iwvevs saSualo siCqaris Semcirebas, eleqtroenergiis da dizelis sawvavis xarjebis zrdas, moZravi Semadgenlobisa da relsebis intensiur cveTas.

Tu gamyof punqtebs ganvalagebT Sori-Sors, maSin mcirdeba samSeneblo Rirebuleba, magram amasTan erTad mcirdeba xazis gamtarunarianobis sidide da dRis wesrigSi dgeba rkinigzis xazis gaZlierebis sakiTxi.

amrigad, gamyofi punqtebis ganlagebis sakiTxis gadawyvetisas unda ganvsazRvroT gadasarbenis iseTi optimaluri sigrZe, romlis drosac adgili eqneba yvelaze xelsayrel Tanafardobas samSeneblo da saeqspluatacio xarjebs Soris.

gamyofi punqtebis ganlagebis sakiTxs araerTi samecniero gamokvlevebi miuZRvnes ucxoeTis da Cveni qveynis mecnierebma. am sakiTxis gadasawyvetad gamokvlevebi aqvs Catarebuli: a. karnalskis, s. orbeliancs, g. Cernomordiks, a.

gibSmans, m. protodianokovs, a. ionesians, a. gasinovs, n. kartaSovas, g. kvantalians da sxva [1] [2] [3].

evropuli qveynebsa da aSS-s rkinigzebze gamyofi punqtebis ganlagebis sakiTxi Teoriul dasabuTebas ar eqvemdebareba da es sakiTxi wydeba yvela konkretul SemTxvevaSi rkinigzis xazis daniSnulebis mixedviT.

bolo xanebSi sazRvargareT aSenebuli rkinigzis xazebi miekuTvneba specializirebul xazebs, romlebic gankuTvnilia: madneulis, naxSiris, tyis masalis da sxva saxis tvirTebis gadazidvebisaTvis. am xazebs gaaCniaT mkveTrad gamoxatuli satvirTo da arasatvirTo mimarTulebebi mcire sididis samgzavro gadazidvebiT. am xazebze satvirTo gadazidvebis aTviseba gaTvaliswinebulia satvirTo matareblebis ricxvis mkveTri SemcirebiT, samagierod izrdeba maTi wonebi, mcirdeba gamyofi punqtebis ricxvi.

magaliTad, avstraliaSi rkinigzis xazze mound-tom preis-post kinZei sigrZiT 288 km ar aris gaTvaliswinebuli arcerTi gamyofi punqti. matareblebis masa Seadgens 14400 tonas.

mavritaniaSi 650 km-ian rkinigzis xazze gaTvaliswinebulia mxolod erTi gamyofi punqti. matareblebis masa Seadgens 14000 t.

ruseTSi gamyofi punqtebis ganlagebis sakiTxi Caisaxa jer kidev maSin, roca ibadeboda rkinigzis daproeqtebis Teoriis elementebi. 1899 wlamde gamyof punqtebs Soris manZili ar unda yofiliyo 16 versze meti.

1899 wels miRebuli teqnikuri pirobebis mixedviT gamyofi punqtebi ise unda yofiliyo ganlagebuli, rom uzrunveleyo 19 wyvili samxedro matareblis gatareba. matareblis masa orTqmavlis weviT toli iyo 575 tonis.

gadasarbenis sigrZeebi sxvadasxva qanobebze iyo sxvadasxva. magaliTad, nulovan qanobze gadasarbenis sigrZe toli iyo 15.8 kilometris. 4 ‰ qanobze _ 12.4 km, xolo 8 ‰ _ 9.1 km.

1925 wels miRebuli teqnikuri pirobebis Tanaxmad gamyofi punqtebi unda ganlagebuliyo iseTi pirobiT, raTa uzrunveleyo 24 wyvili pirobiTi matareblis gatareba. am SemTxvevaSi saxelmZRvanelo qanobian aRmarTze siCqaris sidide Seadgenda 15 km/sT, Tarazul moedanze _ 40 km/sT, daRmarTebze ki 50 km/sT. am pirobiT yvela saxelmZRvanelo qanobze gadasarbenis sigrZe Seadgenda 7 km, xolo nulovan qanobebze _ 14 km.

1931_1934 wlebSi gamocemuli teqnikuri pirobebis mixedviT gamyofi punqtebis ganlagebas unda uzrunveleyo 24 wyvili matareblis gamtaroba. satvirTo matareblis masa Seadgenda 1000 tonas. aseTi pirobebiT gadasarbeni moednis sigrZe Tarazuli moednis SemTxvevaSi Seadgenda 15 km-s, 4 ‰ qanobze _ 10.8 km, xolo 8 ‰ _ 7.2 km-s.

1936_41 wlebSi gamyofi punqtebis ganlageba warmoebda egreTwodebuli `pirobiTi matareblis cxrilebis~ mixedviT. am SemTxvevaSi sagadasarbeno svlis dro miiReboda 36 wT. es principi SenarCunebuli iqna 1946_53 wlebSi gamocemul teqnikur pirobebSi. icvleboda mxolod svlis drois cxrilebi.

zemoTmoyvanili teqnikuri pirobebis mixedviT gadasarbenis sigrZeebi warmodgenilia cxrilSi 1.

cxrili 1

gadasarbenis sigrZeebi teqnikuri pirobebis mixedviT

teqnikuri pirobebi	gadasarbenis sigrZe, km		
	Tarazul moedanze	saxelmZRvanelo qanobi	
		4 ‰	8 ‰
1899	15.8	12.6	9.1
1925	14	7.0	7.0
1931-1934	15	10.8	7.2
1936	18	13.6	10.4
1946	16.3	13.3	10.2
1953	17.1	13.6	10.7

Semdgomi periodis gamokvlevebSi mecnierebis yuradReba mieqca iseT sakiTxebs, rogoricaa gamyofi punqtebis ganlagebis normirebis teqnikur-ekonomikuri dasabuTeba.

SeiZleba gamoiyos gamyofi punqtebis ganlagebis normirebis sami etapi:

I etapi _ 1936-51 w.w. am etapze erTliandagiani rkinigzis xazis gadasarbenis sigrZe ganisazRvra Semdegi ZiriTadi pirobiT:

gadazidvebis minimaluri TviTRirebuleba da erTliandagiani rkinigzis orliandagianad gadakeTeba. am pirobebidan gamomdinare erTliandagiani rkinigzis xazis gadasarbenis xelsayreli sigrZe Seadgenda 8_12 km-s. saxelmZRvanelo qanobi miiReboda 4 ‰_12 ‰-is farglebSi.

II etapi _ 1953-61 w.w. farTod dainerga Tbomavlebi da eleqtruli wevebi, matareblebis gauCerebeli aqceva, mZime woniani matareblebi. yovelive aman ganapiroba teqnikuri normebis gadaxedva. gadasarbenis xelsayreli sigrZis dadgena xdeboda samSeneblo da saeqspluatacio xarjebis minimaluri mniSvnelobis mixedviT. Catarda gamokvlevebi agreTve siCqaris da wonis zrdis damokidebulobisa gadasarbenis sigrZeze.

satvirTo gadazidvebis saangariSo lokomotivebad miRebuli iyo ВЛ23, ВЛ8, ТЭ3, samgzavro gadazidvebisTvis - ТЭ7. wonis normis dadgena xdeboda saxelmZRvanelo qanobebis Semdegi mniSvnelobebisaTvis - 7 ‰, 9 ‰, 11 ‰, samgzavro matareblebis wonad miRebuli iyo 1000 t.

am pirobebidan gamomdinare gadasarbenis optimaluri sigrZe Tbowevisas matarebelTa gauCerebeli aqcevis pirobebSi Seadgenda _ 18_20 km, xolo elwevisas 18_25 km. amasTanave dadginda, rom matareblis masis 1000 toniT gazrdisas gadasarbenis sigrZe izrdeba daaxloebiT 1_1.5 km-iT. aseTive sididis zrdas iwvevs agreTve matareblebis moZraobis siCqaris gazrda satvirTo matareblebis _ 10 km/sT, xolo samgzavroebis 20 km/sT.

III etapi _ 1962-76 w.w. arsebuli normebis Tanaxmad gamyofi punqtebis ganlageba xdeboda saangariSo cxrilebis mixedviT. daisva sakiTxi _ rogor ganvalagoT gamyofi punqtebi, saangariSo cxrilebis Tu realuri matareblebis mixedviT? am sakiTxis Rrma mecnierulma Seswavlam daasabuTa, rom I da II kategoriis rkinigzebze gamyofi punqtebi unda ganlagebuliyo realuri matareblebis raodenobis mixedviT.

1962 wels gamocemul teqnikur normebSi gamyofi punqtebis ganlagebis sakiTxze iyo miTiTebuli Semdegi rekomendaciebi:

satvirTo matareblis masa I kategoriis rkinigzebze gaizardos 6 aTas tonamde, II kategoriis rkinigzebze _ 5 aTas tonamde. matarebelTa gauCerebeli aqceva unda moxdes gamyof punqtebze.

III da IV kategoriis rkinigzebze gamyofi punqtebi unda ganlagdes eqspluataciis me-10 wlisaTvis tvirTdaZabulobis mixedviT. am teqnikuri normebis Tanaxmad gadasarbenis maqsimaluri sigrZe ar aRemateboda 30 km-s.

zemoTmoyvanili teqnikuri normebis moTxovnebi SenarCunebulia Tanamedrove normebSi. 1976 wlis normebSi ufro detalurad aris gaTvaliswinebuli saeqspluatacio muSaobis pirobebi da teqnikuri parametrebis kompleqsuri SerCeva.

rogorc vnaxeT gadasarbenis sigrZe sxvadasxva dros gamoqveynebuli normebis mixedviT ar aRemateba 7_10 km-s. am normebiT iyo aSenebuli saqarTvelos rkinigzac. magaliTad, suramis uReltexilze gadasarbenis sigrZe ar aRemateba 7_9 km-s. aseTive pirobebiTaa aSenebuli `jajuris~ uReltexilis rkinigzac (somxeTis respublika). amitom iyo, rom samTo rkinigzebze moZraobis usafrTxoebis sakiTxis kvleva ar idga wina planze, vinaidan SedarebiT mokle gadasarbenebze uzrunvelyofili iyo moZraobis usafrTxoeba. amas is garemoebac ganapirobebda, rom ar idga dRis wesrigSi samTo pirobebSi rkinigzis mSenebloba.

matareblis moZraobis usafrTxoebis sakiTxi mwvaved dadga gasuli saukunis 70-ian wlebSi, roca daiwyo transkavkasiis rkinigzis xazis proeqtis Sedgena (proeqtis avtori n. svaniSvili). Sedgenili iqna sami varianti da sabolood damtkicda e.w. arxotis mimarTuleba, saerTo sigrZiT 160 km. aRniSnul rkinigzis xazze kavkasiis qedis qveS gvirabis sigrZe Seadgenda 23 km-s. rkinigza Tavidanve daproeqtda rogorc orliandagiani. saxelmZRvanelo qanobi toli iyo 30 ‰, gadasarbenis maqsimaluri sigrZe daZabuli svliT Seadgenda
22 km-s. swored am sigrZis da qanobis daRmaris arsebobam eWvsqveS daayena am monakveTze matareblis moZraobis usafrTxoeba. am sakiTxiT dainteresda inJ. g. kvantaliani (amJamad rkinigzebis mSeneblobis mimarTulebis profesori), romelmac 1977 wels JurnalSi «Транспортное строительство» gamoaqveyna samecniero statia [4].

80-ian wlebSi saqarTveloSi aSenda marabda_axalqalaqis rkinigzis xazi, saerTo sigrZiT 160 km, saxelmZRvanelo qanobiT 35 ‰. rkinigzis es monakveTi Tavidan gaTvaliswinebuli iyo rogorc adgilobrivi daniSnulebis _ III kategoriis xazi. rkinigzis es xazi Tavidanve daproeqtda da aSenda normebidan gadaxriT. saqme is gaxlavT, rom III kategoriis rkinigzaze maqsimaluri qanobi ar unda yofiliyo 30 ‰-ze meti. am monakveTis eqspluataciaSi SesvlisTanave Tavi iCina rogorc saproeqto, ise

samSeneblo xarvezebma. am ubanze adgili hqonda avariebs, rac fataluri SedegiT damTavrda: Seiwira adamianebis sicocxle da qveyanas miadga didi ekonomiuri da materialuri zarali.

rogorc cnobilia, rkinigzis es ubani male gaxdeba saerTaSoriso rkinigzis xazis baqo_Tbilisi_yarsis Semadgeneli nawili. amitom am ubanze gansakuTrebuli yuradReba eqceva moZraobis usafrTxoebis sakiTxs. am xazze daZabuli gadasarbenebis sigrZeebi aRwevs 12_15 km, rac moiTxovs moZraobis sakiTxebis usafrTxoebis gadawyvetas. gadasarbenis sigrZis mTavari SemzRudavi pirobebs ki, rogorc ukve avRniSneT warmoadgens xundebis gadaxureba da sahaero magistralis daSreta.

xundebis gadaxurebis temperaturis dadgena erTob rTuli sakiTxia, radgan is damokidebulia mraval faqtorze. am sakiTxis gadawyvetaze muSaobda da garkveul wilad warmatebuli Sedegi aqvs miRebuli cnobil rus mecniers da praqtikoss prof. v. inozemcevs. [5] [6] [7] [8]. swored mis mier SemoTavazebuli formulis gardaqmnis safuZvelze Cvens mier dadgenilia daRmarTis maqsimaluri sigrZeebi xundebis gadaxurebis gaTvaliswinebiT. Teoriuli kvlevis Sedegebi rom ufro damajerebeli yofiliyo, mivmarTeT im eqsperimentalur monacemebs, romlebic miRebulia realur pirobebSi Catarebuli gamokvlevebiT [9].

rac Seexeba magistralSi haeris daSretis sakiTxs, es sakiTxi saerTod ar eqvemdebareba Teoriul gadawyvetas. am sakiTxis damuSavebis dros visargeble rogorc eqsperimentaluri [10], ise realuri cdebis Sedegad miRebuli monacemebiT.

matarebelTa usafrTxo da Seuferxebeli moZraoba didad aris damokidebuli imaze, Tu ramdenad daculia rkinigza Tovlisa da qarbuqiT gamowveuli liandagis danamqraze.

qarbuqis Seswavla daiwyo me-19 saukunis meore naxevarSi, rac gamowveuli iyo rkinigzis qselis ganviTarebiTa da misi danamqrisagan dacvis aucileblobiT.

pirveli naSromi am sferoSi gamoqveynda 1878 w
e. zlotickis mier, romelmac daasabuTa, rom qarbuqis mier Tovlis umetesi nawilis gadatana xdeba Tovlis safaris zedapirze. e. zlotickim TovlgadamWeri faris muSaobis Taviseburebebis TeoriaSi Semoitana cneba, romelic axlosaa nakadis turbulenturobis TeoriasTan. man praqtikaSi pirvelma gamoiyena or da mravalrigiani Tovldamcavi farebi da tyis zolebi Siga didi wyvetebiT.

e. Subertma germaniaSi da a. Cerniavskim ruseTSi 1888 da 1894 wlebSi pirvelad Camoayalibes mosazreba, rom qaris mier Tovlnatanis moculoba TovlSemkreb zonis farglebSi CamorCeba am zonis zomebs.

e. Cerniavskis mier SemoTavazebuli iqna qvemoT warmodgenili empiriuli damokidebuleba TovldamWeri nagebobis mier gadaWerili Tovlis moculobasa da TovlSemkrebi auzis sigrZes Soris

$$Q_H = \frac{25}{1 + \frac{1750}{L_H}}$$

warmodgenili formulidan Cans, rom rodesac $L_H \to \infty$, $Q_H \to const$, rac srulad Seesabameba qarbuqis bunebas da amave dros iZleva mis fizikur ganmartebas.

me-20 saukunis dasawyisSi qarbuqis Teoriis mniSvnelovani kvlevebi Seasrula e. dolgovma, romelmac ganazogada ekaterinoslavis rkinigzaze gamoyenebul TovldamWer mowyobilobaTa eqsploataciis Sedegebi, aRwera specialurad Seqmnil qarbuqmzomiT Catarebuli kvlevebis Sedegebi da Camoayaliba Tovlis gadatanis Semdegi kanonebi:

1. qarbuqi iwyeba adgilobrivi pirobebisaTvis qaris gansazRvruli siCqaris mixedviT;
2. Tovlisa da niadagis nawilakebi, romlebic monawileoben Tovlis safaris reliefis zedapiris cvlilebaSi, gadaitaneba uSualod mis siaxloves.

am sferoSi seriozuli gamokvlevebi Sesrulebulia n. Jukovskisa da s. Capliginis mier, romlebmac Camoayalibes naxevarcilindris ukan turbulenturi interpretaciisa da mTliani firfitis potencialuri agrigalebis saerTo meTodi.

Semdegi kvlevebi Seasrulebulia a. xrgianis, n. Sveikovskis, a. slezkinisa da v. velcenbaxis mier.

a. xrgianma pirvelad gamoiyena aerodinamikis zogierTi Teoriuli daskvnebi TovliT danamqrasTan brZolis praqtikuli miznebisaTvis.

n. Sveikovskim daamtkica, rom potencialuri nakadebi ar SeiZleba gamoyenebuli iyos winaRobis ukan turbulenturi rkalis aRsawerad.

v. velcendbaxma daadgina TovliT danamqvris mimarT im Wrilebis gansakuTrebuli daqvemdebareba, romelTa RerZebi ganlagebulia qarbuqis mimarTulebis paralelurad.

qarbuqis mimarT interesi gansakuTrebiT gaZlierda wina saukunis 50-iani wlebis Semdeg. t. lilikovis, i. vikersis,

l. dolguminis, m. kotliakovas, v. averianovas, i. kapanevas,

n. rusinas, r. garsias, f. loves mier gamoyenebulia qarbuqis mier Tovlis gadatanis sididis gansazRvris sxvadasxva meTodebi da wamoyenebulia am sidideTa saerTo ricxobrivi Sefasebis sxvadasxva hipotezebi.

1952_1954 wlebSi b. ivanovis, d. melnikis, a. diuninis,

a. komarovis, v. akkuratovis, m. bialobJenkis mier praqtikuli miznebisaTvis SemoTavazebuli iqna TovliT gajerebuli qaris mier gadatanili Tovlis mkvrivi xarjis saangariSo empiriuli formulebi.

nairgvarovani empiriuli formulebis simravle warmoadgens imis dasturs, rom ar arsebobs Teoria, romelic SeZlebda gaeca pasuxi TovliT gajerebuli nakadis meqanikis mTavar kiTxvaze – qarbuqis mier Tovlis transportirebis unaris SesaZleblobis Sesaxeb.

2. Sedegebi da maTi gansja

2.1. daRmarTebis maqsimaluri sigrZeebis dadgena samuxruWe xundebis gadaxurebis pirobiT

meqanikuri damuxruWebisas xaxunis Sedegad xurdeba xaxunSi monawile detalebi da gamoyofili siTbo gamoifrqveva garemoSi. siCqaris zrdasTan erTad izrdeba matareblis kinetikuri energia da Sesabamisad izrdeba samuxruWe sistemis friqciul mowyobilobaTa temperatura.

samuxruWo sistemis saimedoba da moZraobis usafrTxoeba cicabo daRmarTebze bevrad aris damokidebuli samuxruWe xundebis temperaturul reJimze.

gadaxurebis Sedegad irRveva samuxruWe xundebis meqanikuri mdgomareoba da Sesabamisad mcirdeba moZraobis usafrTxoebis garantia. rkinigzis moZravi Semadgenloba ZiriTadad aRWurvilia Tujisa da kompoziciuri masalisagan damzadebuli xundebiT. kompoziciuri masalisagan damzadebuli xundebi xasiaTdeba xaxunis maRali koeficientiT, rac saSualebas gvaZlevs avamaRloT daRmarTebze (da ara marto daRmarTebze) dasaSvebi maqsimaluri siCqareebi. amasTanave kompoziciuri xundebi xasiaTdeba maRali cveTamedegobiT, rac uzrunvelyofs maT normalur muSaobas SedarebiT grZel daRmarTebze.

kompoziciuri xundebis ZiriTadi naklia is, rom maT gaaCniaT dabali Tbogamtaroba, rac mkveTrad zrdis Tvlis siTbur gadatvirTvas. kompoziciuri masalis uaryofiTi mxarea agreTve misi zedapiris sipi zedapiri, rac damuxruWebis sawyiss

momentSi efeqts ar iZleva. amitomac grZel daRmarTebze aucilebelia Tujisa da kompoziciuri xundebi SemadgenlobaSi gamoyenebuli iqnes erTdroulad Tanabari raodenobiT.

xundebis gaxurebis sakiTxis Seswavlas yuradReba mieqca bolo xanebSi. saqme is gaxlavT, rom arsebuli rkinigzis xazebi mTian pirobebSi agebuli iyo Zveli teqnikuri normebiT. am SemTxvevaSi gadasarbenis sigrZeebi da Sesabamisad cicabo daRmarTebi ar iyo didi sididis. magaliTad suramis uReltexilze gadasarbenebis sigrZe ar aRemateba 7_9 km-s. aseTive mdgomareobaa jajuris uReltexilze (somxeTis respublika).

ukanasknel xanebSi lokomotivis simZlavrisa da siCqaris gazrda, moZravi Semadgenlobis teqnikuri aRWurvilobis gaumjobeseba saSualebas iZleva gavzardoT gadasarbenis sigrZeebi, amasTanave gamtarunarianobac sagrZnoblad didia. magaliTad, marabda_axalqalaqis xazze gadasarbenis sigrZeebi aRwevs 10_15 km-s. orliandagiani rkinigzebis daproeqtebisa da mSeneblobis normebis Tanaxmad gamyof punqtebs Soris manZili SeiZleba iyos araumetes 30 km-isa. aseTi grZeli gadasarbenebi da cicabo qanobebis (30_35 ‰) arseboba aucileblad moiTxovs grZeli daRmarTebis sigrZeebis Semowmebas xundebis gadaxurebis pirobiT.

xundebis gaxurebis temperaturis dadgena Teoriuli gziT metad rTulia, vinaidan is damokidebulia mTel rig faqtorebze, rogoricaa: moZraobis siCqare, vagonis wona, grZivi qanobi, xundis da Tvlis masala da sxva.

yvelaze sando da safuZvliani gamokvleva am sakiTxis ekuTvnis sarkinigzo transportis dargSi cnobil rus mecniers v. inozemcevs. mis mier gasuli saukunis 70-ian wlebSi SemoTavazebuli iqna formula, romelsac aqvs Semdegi saxe [5].

$$\frac{(1-\alpha_p)\alpha_R h P \varepsilon S_0}{t S_m d}\left(1-e^{-0.03\sqrt{t}}\right) \le 2 \qquad (2.1)$$

Tu es toloba daculia, maSin xundebis gaxurebis temperatura normis farglebSi iqneba (maqsimaluri gaxurebis

temperaturad miRebulia 350^0C).

zemoTmoyvanil formulaSi Semavali sidideebi Semdegnairad ganimarteba:

α_p - rekuperaciis koeficientia da iTvaliswinebs

rekuperaciul damuxruWebis wils;

α_R - Tburi nakadis gadanawilebis koeficientia; Tujis

xundebisaTvis α_R=0.7, kompoziciuri xundebisaTvis _

α_R=0.95;

h - daRmarTis sawyis da bolo wertilebs Soris simaRleTa sxvaobaa, m;

P - Tvalze mosuli dawolaa, P=10.5 t;

ε - Tvlis muSaobis araTanabrobis koeficientia, ε=1.5;

S_0 da S_m - sxvadasxva tipis vagonebis saangariSo samuxruWo manZilebia, erTgvarovani vagonebisTvis, S_0=S_m;

d - Tvlis diametria, satvirTo vagonebisTvis d=0.87 m;

t - damuxruWebis droa, wm.

prof. kvantalianma am fromulis gardaqmnis Sedegad miiRo gamosaxuleba, romlis saSualebiTac SesaZlebeli gaxda daRmarTis maqsimaluri sigrZeebis dadgena. simaRleTa sxvaoba h Secvlilia namravliT li, sadac i daRmarTis qanobia, l-ki daRmarTis sigrZe.

damuxruWebis xangrZlivoba t Secvlilia gamosaxulebiT $t = \frac{l}{V}$ 3600 wm. Tu formulaSi [2.1] CavsvavT koeficientebis ricxviT mniSvnelobebs, vRebulobT Tujis xundebisaTvis

$$\frac{12.7(1-\alpha_p)li}{t}\left(1-e^{-0.03\sqrt{t}}\right) \le 2 \qquad (2.2)$$

kompoziciuri xundebisaTvis

$$\frac{16.3(1-\alpha_p)li}{t}\left(1-e^{-0.03\sqrt{t}}\right) \le 2 \qquad (2.3)$$

Tu zemoTmoyvanil formulebs amovxsniT l-is mimarT, miviRebT Tujis xundebisaTvis

$$l = \frac{V}{3.24}\ ln^2\left[1-\frac{567}{(1-\alpha_p)Vi}\right] \text{ km} \qquad (2.4)$$

kompoziciuri xundebisaTvis

$$l = \frac{V}{3.24}\ ln^2\left[1-\frac{419}{(1-\alpha_p)Vi}\right] \text{ km} \qquad (2.5)$$

rogorc avRniSneT, formulebSi α_p aris rekuperaciis koeficienti. samTo rkinigzebze warmatebiT gamoiyeneba rekuperaciuli damuxruWeba, romelic iZleva did sargeblianobas. kerZod, mcirdeba meqanikuri damuxruWebis wili da amis gamo iklebs xundebis gaxurebis temperaturac. es RonisZieba iZleva agreTve mdovruli moZraobis SenarCunebis SesaZleblobas. amasTanave mas gaaCnia uaryofiTi Tviseba,

rac imaSi gamoixateba, rom rekuperaciuli damuxruWebisas mTeli samuxruWo Zala modis lokomotivze, rac uwyobs xels liandagis zedanaSenis moSlas. amitom didi mniSvneloba aqvs rekuperaciis koeficientis zomierebis dadgenas. prof. kvantaliani gvTavazobs am koeficientis mniSvnelobad aviRoT 0.3. SevamowmoT, ramdenad misaRebia es sidide. marabda_axalqalaqis rkinigzis am ubanze satvirTo matareblis maqsimaluri saangariSo wona aris 1800 t. maSin meqanikuri damuxruWebisas sruli samuxruWo Zala toli iqneba

$$B_m = (2P + Q)(i_{\text{sax}} - \omega_{ox})\ \text{t}$$

i_{sax} - saxelmZRvanelo qanobia - $i_{\text{sax}} = 35\ \%$;

ω_{ox} - uqmi svlis winaRobaa; aviRoT $\omega_{ox} = 2.0$ kg/t;

$Q = 1800$ t $2P = 2 \cdot 184 = 368$ t - lokomotivis wonaa (ormagi weva);

e.i $B_m = (368 + 1800) \cdot 33 = 71500$ kg.

rekuperaciuli damuxruWebisas samxruWo Zala erTi lokomotivisaTvis tolia 27000 kg. rekuperaciis koeficienti $\alpha_p = \frac{B_{mp}}{B_m} = \frac{27000}{71500} = 0.33.$ e.i. rekuperaciis koeficientis 0.3-is miReba savsebiT SesaZlebelia (rekuperaciisas viTvaliswinebT mxolod erTi lokomotivis samuxruWo Zalas).

aqve unda avRniSnoT, rom rekuperaciuli damuxruWeba maqsimaluri dasaSvebi siCqaris dadgenisas mxedvelobaSi ar miiReba. is iTvleba rogorc damxmare saSualeba. xundebis gaxurebis temperaturis gamoTvlisas ki rekuperaciis koeficientis sidides mxedvelobaSi viRebT. im SemTxvevaSi, Tu rekuperacia gamoirTveba, maSin saWiro iqneba moZraobis siCqaris Semcireba da am Semcirebuli siCqariT matarebeli Seva uaxloes gamyof punqtze. Tu formulebSi (2.4) da (2.5) SevitanT α_p mniSvnelobebs, $\alpha_p = 0$ da $\alpha_p = 0.3$ miviRebT Tujis xundebisaTvis.

$$l = \frac{V}{3.24} ln^2 \left[1 - \frac{767}{Vi}\right] \text{ km} \qquad (2.6)$$

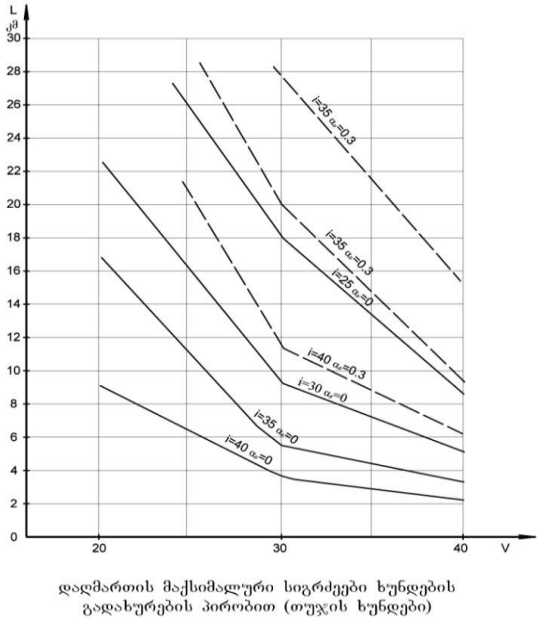
$$l = \frac{l}{3.24} ln^2 \left[1 - \frac{810}{Vi}\right] \text{ km} \qquad (2.7)$$

kompoziciuri xundebisaTvis

$$l = \frac{l}{3.24} ln^2 \left[1 - \frac{419}{Vi}\right] \text{ km} \qquad (2.8)$$

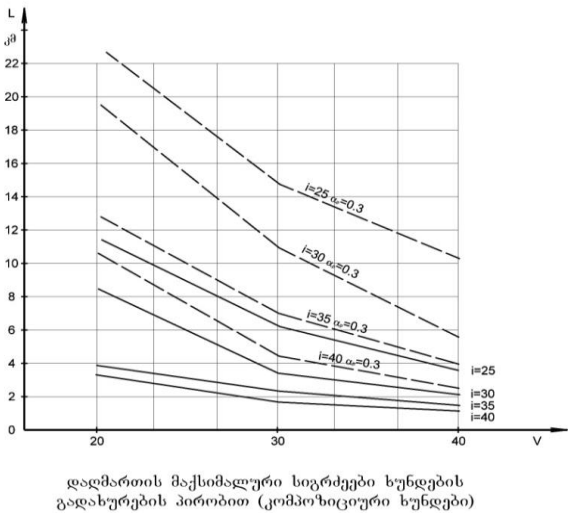
$$l = \frac{V}{3.24} ln^2 \left[1 - \frac{599}{Vi}\right] \text{ km} \qquad (2.9)$$

zemoTmoyvanili formulebis mixedviT dadgenili daRmarTis maqsimaluri sigrZeebi qanobisa da siCqarisagan damokidebulebiT moyvanilia cxrilSi 2, xolo grafikulad warmodgenilia nax. 1 da nax. 2-ze.



დაღმართის მაქსიმალური სიგრძეები ხუნდების გადახურების პირობით (თუჯის ხუნდები)

nax. 1



დაღმართის მაქსიმალური სიგრძეები ხუნდების გადახურების პირობით (კომპოზიციური ხუნდები)

nax. 2

cxrili 2

daRmarTis maqsimaluri sigrZeebi (km) xundebis

gadaxurebis pirobiT

reku-pera-ciuli koef. α_p	xun-dis masa-la	$i = 20$ ‰			$i = 25$ ‰				$i = 30$ ‰			$i = 35$ ‰				$i = 40$ ‰			
		matareblis moZraobis siCqare, km/sT																	
		V=60	V=50	V=40	60	50	40	30	40	30	20	40	30	25	20	40	30	25	20
		daRmarTis sigrZeebi, km																	
α=0	Tuji	7,6	10,8	18,7	4,2	5,6	8,7	18,4	5,1	9,2	52,5	3,3	5,6	11,5	17	2,4	3,8	6,4	9,4
α=0,3	Tuji	23,4	42,5	-	11,2	16,8	34,0	-	15,6	48,9	-	9,2	20	51,8	-	6,2	11,7	21,3	-
α=0	kompoz.	3,4	4,6	6,8	-	2,6	3,7	6,2	2,3	3,6	8,9	1,6	2,4	3,8	5,2	1,1	1,7	2,5	3,4
α=0,3	kompoz.	13,0	23,6	-	-	6,6	10,4	14,8	5,9	11,1	19,9	3,7	6,1	9,8	-	2,7	4,5	8,0	11,8

gasuli saukunis 90-ian wlebSi profesorma v. inozemcevma gamoaqveyna monografia [8], sadac xundebis gaxurebis temperatura damyarebuli siCqariT moZraobis dros gamoiTvleba formuliT:

$$T = \frac{q}{a}(1 - e^{-z})°C \qquad (2.10)$$

sadac: $$Z = \frac{2a\sqrt{t}}{\sqrt{\Pi\lambda\gamma c}}$$

q - Tburi nakadis simkvrivea;

a - Tbogadacemis koeficientia;

λ - Tbogamtarobis koeficientia, Tvlis liTonisaTvis.

λ=10,3 $\cdot 10^{-3}$ kkal/m.wm.

γ - Tvlis liTonis moculobiTi masaa, γ=7850 kg/m^3

c - Tvlis liTonis xvedriTi Tbotevadobaa,

c=0,11 kkal/kg;

t - damuxruWebis xangrZlivobaa, wm.

Tburi nakadis simkvrive q ganisazRvreba moZraobis siCqarisa da damuxruWebis Zalis mixedviT

$$q = \frac{a_R(1 - a_p)b_m PVA\varepsilon}{3{,}6F}$$

sadac: a_R - Tburi nakadis gavrcelebis koeficientia, Tujis xundebisaTvis a_R=0,7, xolo kompoziciuri xundebisaTvis a_R=0,95.

b_m - damuxruWebis xvedriTi Zalaa kv/t, Tanabari moZraobisas; $b_m = i - w_x$

i - daRmarTis dayvanili qanobia, ‰;

w_x - matareblis moZraobis winaRoba uqmi svlisas;

P - Tvalze mosuli dawolaa, P=11 t;

v - moZraobis siCqarea, km/sT;

A - muSaobis Tburi eqvivalentia.

$$A = \frac{1}{427} = 2{,}34 \cdot 10^{-3} \text{ kkal/kgm}$$

a_p - rekuperaciuli damuxruWebis wilia;

F - Tvlis zedapiris farTobia, romelzedac gamoiyofa siTbo, F=0.257 m^2.

Tbogadacemis koeficienti $\alpha = 0.4 \cdot 10^{-2}\left(1 + 0.7\sqrt{v}\right)$ kkal/m^{2}wm. $\sqrt{\Pi\lambda\gamma c}$ gamosaxuleba foladis TvlisaTvis warmoadgens mudmiv sidides da tolia:

$$\sqrt{\Pi\lambda\gamma c} = \sqrt{3.14 \cdot 10.3 \cdot 10^{-3} \cdot 7850 \cdot 0.11} = 5.2846$$

daRmarTebze damyarebuli siCqareebiT matareblis t wamis ganmavlobaSi moZraobisas gavlili gza toli iqneba:

$$L = \frac{vt}{3600} \text{ km}$$

imisaTvis, rom davadginoT daRmarTis maqsimaluri sigrZe xundebis gadaxurebis pirobiT, damuxruWebis dro t SevcvaloT gamosaxulebiT 3600 $\frac{L}{v}$ da formula (2.10) amovxsnaT L-is mimarT, miviRebT

$$L = v\left[\frac{1}{K\alpha}\ln\left(1 - \frac{aT}{q}\right)\right]^2 \text{ km} \qquad (2.11)$$

sadac: K mudmivi sididea da tolia:

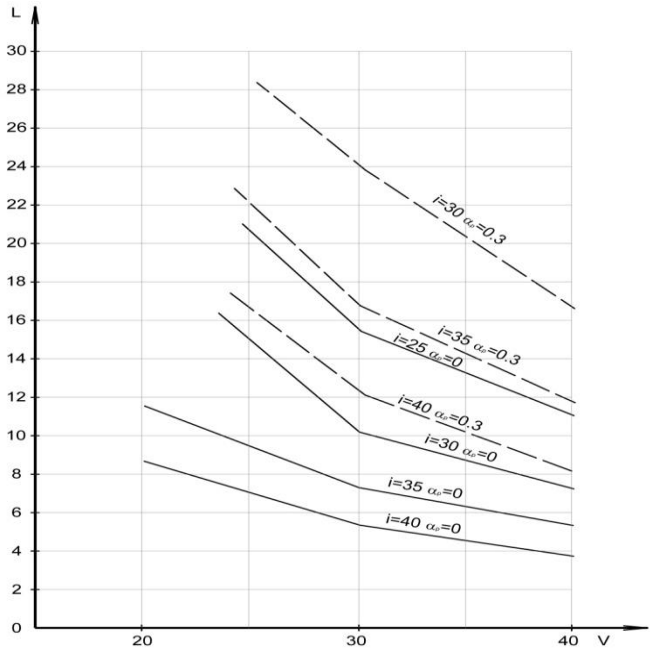
$$K = \frac{2\sqrt{3600}}{\Pi\lambda\gamma c} = 22.707.$$

Tu formula (2.11)-Si SevitanT T-s da q-s mniSvnelobas (T-s maqsimaluri dasaSvebi temperaturaa 350^0), miviRebT

Tujis xundebisaTvis $$L = v\left[\frac{1}{K\alpha}\ln\left(1-\frac{11986\cdot\alpha}{(1-\alpha_p)vi}\right)\right]^2 \qquad (2.12)$$

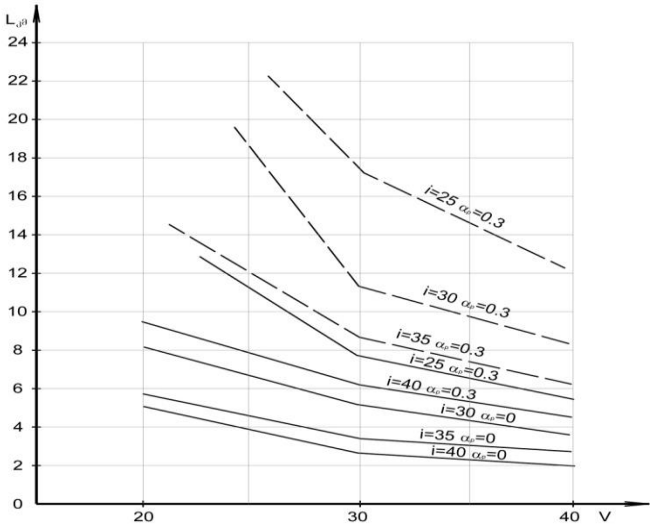
kompoziciuriMxundebisaTvis $$L = v\left[\frac{1}{K\alpha}\ln\left(1-\frac{9542\cdot\alpha}{(1-\alpha_p)vi}\right)\right]^2 \qquad (2.13)$$

qvemoT moyvanil cxrilSi 3 warmodgenilia (2.12) da (2.13) formulebiT dadgenili daRmarTis maqsimaluri sigrZeebi siCqarisa da qanobebisagan damokidebulebiT, xolo am sidideTa grafikuli damokidebuleba mocemulia nax. 3 da nax. 4-ze.



დაღმართის მაქსიმალური სიგრძეები ხუნდების გადახურების პირობით (თუჯის ხუნდები)

nax. 3



დაღმართის მაქსიმალური სიგრძეები ხუნდების გადახურების პირობით (კომპოზიციური ხუნდები)

nax. 4

cxrili 3 **daRmarTis maqsimaluri sigrZeebi (km) dadgenili formula 2.11-is mixedviT**

rekuperaciuli koef. α_p	xun-dis masa-la	$i = 20$ ‰			$i = 25$ ‰				$i = 30$ ‰				$i = 35$ ‰				$i = 40$ ‰			
		matareblis moZraobis siCqare, km/sT																		
		V=60	50	40	60	50	40	30	50	40	30	25	40	30	25	20	40	30	25	20
		daRmarTis sigrZeebi, km																		
α=0	Tuji	11,6	14,4	18,8	7,0	8,7	11,2	15,8	5,8	7,4	10,3	15,0	5,3	7,3	9,5	11,8	3,9	5,4	7,2	8,6
α=0,3	Tuji	26,9	34	45,8	15,8	19,7	26,0	-	-	16,9	24	30	11,7	16,8	20,7	-	8,2	12,1	15,0	-
α=0	kompoz.	5,8	7,5	9,3	3,6	4,4	5.7	7,8	3,0	3,9	5,2	8,3	2,9	3,7	4,6	5,9	2,1	2,8	4,1	5,3
α=0,3	kompoz.	9,6	16,2	21,3	7,9	9,7	12,1	17,8	6,5	8,3	11,7	19,1	5,9	8,2	10,1	13,2	4,4	6,1	7.8	9,7

rogorc 2 da 3 cxrilebis Sedarebidan Cans daRmarTis maqsimaluri sigrZeebi, romlebic dadgenilia (2.1) da (2.11) formulebiT, erTmaneTisagan gansxvavdebian ≈10_15%-is farglebSi (gansakuTrebiT es sxvaoba SeimCneva maRali siCqareebis dros).

Cven miznad davisaxeT dagvedgina am ori formulidan romeli iZleva daRmarTis maqsimaluri sigrZis realur sidides, risTvisac saWiro iyo Teoriuli gaangariSebis Sedegebis Sedareba realur-eqspluataciur pirobebSi Catarebuli cdebis monacemebTan.

eqsperimentebis damuSavebis da misi Sedegebis Sedareba Teoriul monacemebTan warmodgenilia 2.2 punqtSi.

2.2 Teoriuli gaangariSebis Sedegebis Sedareba eqsperimentebis monacemebTan

xundebis gaxurebis temperaturis dasadgenad eqsperimentebi saeqspluatacio pirobebSi Catarda saqarTvelos teqnikuri universitetis TanamSromlebis mier saqarTvelos rkinigzis savagono meurneobis samsaxuris TanamSromlebTan erTad.

cdebi tardeboda suramis uReltexilis xaSuri_zestafonis

monakveTze. eqsperimentebi Catarebuli iqna muxruWebis gamosacdel vagon-laboratoriis daxmarebiT. vagon-laboratoria Cabmuli iyo satvirTo matareblis bolo vagonze.

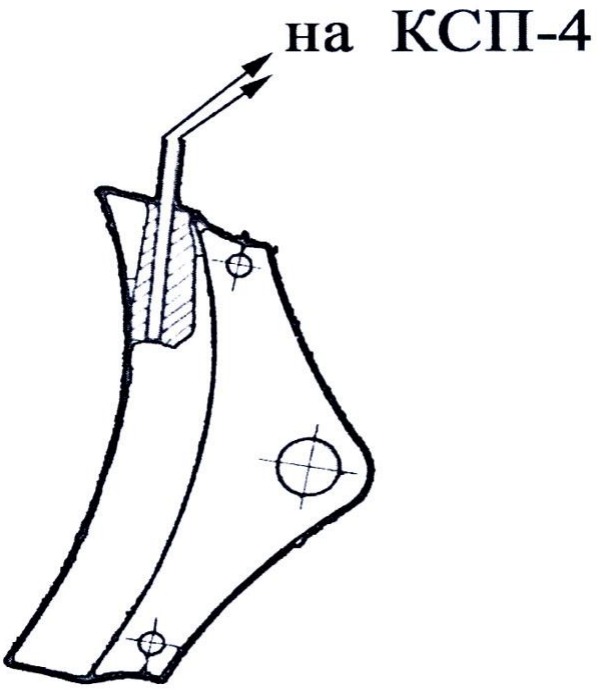
xundebis gaxurebis temperaturis gasagebad xundSi 10 mm siRrmeze magrdeboda Termowyvili (nax. 5). gaxurebis temperaturis Cawera warmoebda potenciometris daxmarebiT [9].

sul Catarebuli iqna 4 cda. cdebi tardeboda rogorc meqanikuri, aseve rekuperaciuli damuxruWebis pirobebSi. qvemoT warmodgenilia 2 cdis Sedegebi.

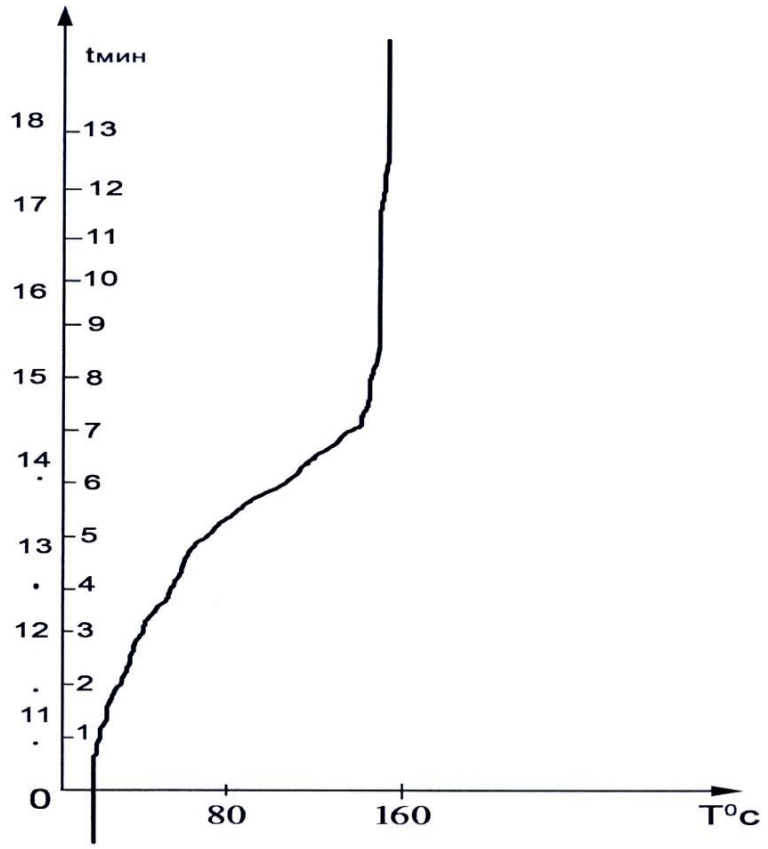
I cda: Tujis xundebi, mxolod meqanikuri damuxruWebiT, sacdeli monakveTi wifis gvirabidan sadgur wifamde. daRmarTis manZili Seadgens 5.2 km-s. dayvanili qanobi _ 20 ‰. moZraobis siCqare 20 km/sT. damuxruWebis xangrZlivoba t=15 wT. potenciometris daxmarebiT xundebis gaxurebis temperaturis Canaweri grafikulad warmodgenilia nax. 6-ze.

mocemuli grafikis mixedviT xundebis gaxurebis sawyisi temperaturaa _ 16^0, xolo saboloo temperatura _ 152^0.

temperaturis nazrdi Seadgens $T = T_{saw} - T_{sab} = 136^0$.



nax. 5 xundSi Termowyvilis damagrebis sqema



nax. 6 xundis temperaturis cvalebadobis grafiki

xundis gaxurebis temperatura gamovTvaloT (2.10) formulis daxmarebiT

$$T = \frac{q}{\alpha}\,(1 - e^{-z})^0 C$$

zemoTmoyvanili monacemebis safuZvelze $\alpha = 0.01654$

$q = 13.24$ t=900 wm

$\sqrt{\Pi\lambda\gamma c} = 5.28 \quad Z = \frac{2\alpha\sqrt{t}}{\sqrt{\Pi\lambda\gamma c}} = 0.18$

Tu CavsvamT am monacemebs zemoTmoyvanil (2.10) formulaSi, miviRebT

$$T = \frac{13.24}{0.01654}\,(1 - e^{-0.18}) = 135^0 C$$

e.i. eqsperimentaluri gziT dadgenili temperatura aris 136^0C, Teoriuli angariSiT ki miviReT 135^0C. am SemTxvevaSi Cveni gaangariSebis sizuste eWvs ar iwvevs.

II cda. kompoziciuri xundebi damuxruWeba_pnevmaturi rekuperaciis gamoyenebiT.

eqsperimentis ubani _ sadgur wifidan - sadgur moliTamde daRmarTis mTliani sigrZe Seadgens 12.3 km-s, dayvanili qanobi _ 21.4 ‰. moZraobis siCqare _ 30 km/sT, matareblis wona P+Q=2897, lokomotivis tipi _ ВЛ 11.

rekuperaciul damuxruWebas awarmoebda erTi lokomotivi. xundis gaxurebis temperatura gaizoma sadgur moliTSi uSualo kontaqtiT da igi Seadgenda 216^0C. xundis gaxurebis sawyisi temperatura iyo 18^0C. temperaturis namati Seadgens:

$$T = 216^0\text{C} - 18^0\text{C} = 198^0\text{C}.$$

wevis gaangariSebis wesebis Tanaxmad erTi ВЛ 11 elmavlis samuxruWo Zala rekuperaciuli damuxruWebis SemTxvevaSi tolia $B_p = 27000$ kg-s, amitom rekuperaciis koeficienti toli iqneba

$$\alpha_p = \frac{B_p}{(2P+Q)(i-W_x)} = \frac{27000}{2897\ (21.4-1.5)} = 0.47$$

amasTanave zemoTmoyvanili monacemebidan gamomdinare:

$\alpha = 0.01936 \quad q = 16.3 \quad t = 1500$ wm $\quad t = 0.29$

gaxurebis temperatura Teoriuli gaangariSebis gziT toli iqneba:

$$T = \frac{16.3}{0.01936}\ (1 - e^{-0.29}) = 197^0 C$$

e.i. am SemTxvevaSic Teoriuli da eqsperimentaluri Sedegebi TanxvedraSia, rac miuTiTebs imaze, rom Cvens mier Catarebuli Teoriuli gaangariSebebi saimedoa da eWvs ar iwvevs.

2.3 cicabo daRmarTebze uwyveti damuxruWebis Ddrois dadgena

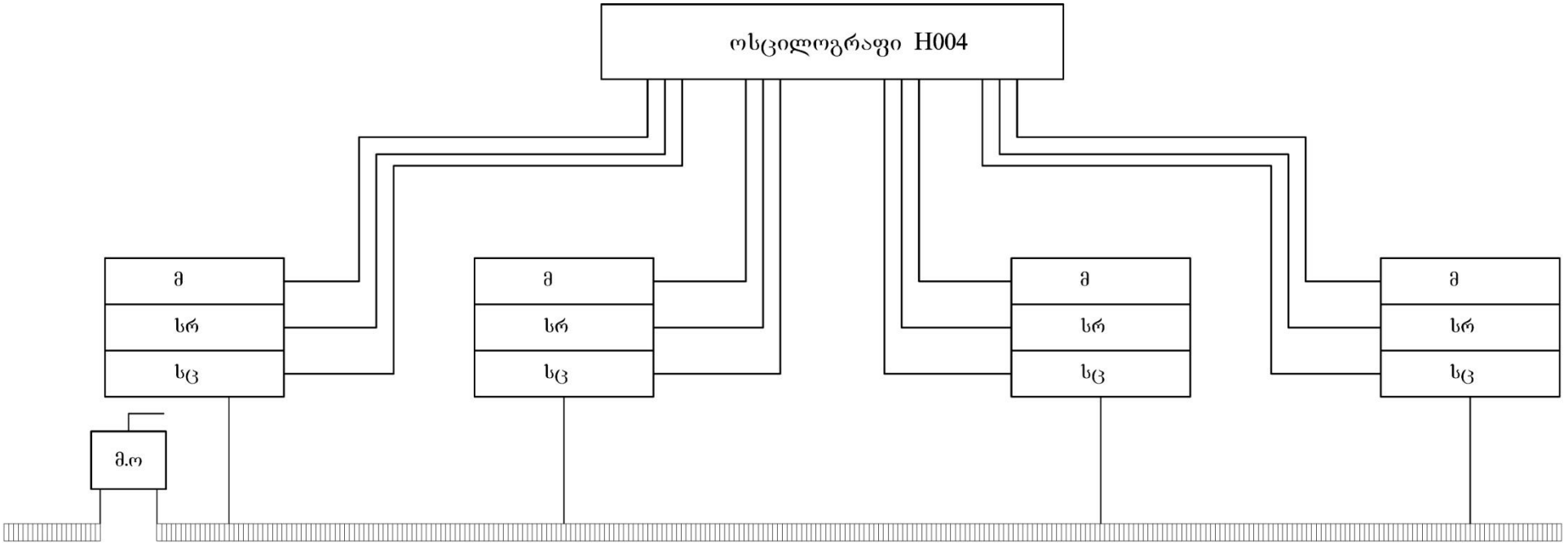
satvirTo moZravi Semadgenloba aRWurvilia haergamanawiebliT #270-005-1, romelic uzrunvelyofs avtomuxruWebis uSretobas. cicabo daRmarTebze avtomuxruWebi gadarTuli unda iqnes muSaobis samTo reJimebze. avtomuxruWebis

uSretoba ganpirobebulia damuxruWebisas samuSao kamerebis sahaero magistralidan izolirebiT, xolo samarago rezervuarebi mudmivad ivseba SekumSuli haeriT magistralidan. miuxedavad zemoT aRniSnulisa, cicabo qanobebze xangrZlivad damuxruWebisas wnevebi samuxruWo cilindrebSi (sm), samarago rezervuarebSi (sr), magistralidan (m) SekumSuli haeris momatebuli gadinebis gamo SeiZleba aRmoCndes normaze dabla. amis gamo magistralis simkvrivis norma eqspluataciis pirobebSi SesaZlebelia daculi ar iyos (normad miRebulia 1 wuTis manZilze wnevis dacema 0.2 atmosferoTi) [14].

imisaTvis, rom uzrunvelyofili iqnes matareblebis moZraobis usafrTxoeba, saqarTvelos sauReltexilo da samTo rkinigzebze miRebulia satvirTo matareblebis aucilebeli gaCereba gamyof punqtebze magistralis haeriT dasamuxtavad (dgomis xangrZlivoba Seadgens 4_6 wuTs) [15].

Cvens amocanas Seadgenda dagvedgina cicabo qanobian daRmarTebze satvirTo matareblebis uwyveti damuxruWebis xangrZlivoba.

es amocana mravali urTierTdamokidebuli faqtorebis gamo Teoriul amoxsnas ar eqvemdebareba. amitom mecnierebi Seecadnen eqsperimentaluri gziT gadaewyvitaT es problema [10]. eqsperimenti Catarebuli iqna yofili sabWoTa kavSiris rkinigzis sakavSiro sakvlevi intitutis avtosamuxruWo laboratoriaSi. qvemoT moyvanilia eqsperimentebis Catarebis mimdevroba da aRweris sqematuri gegma (nax. 7).



nax. 7 jgufuri stendis sqema

jgufuri stendi warmoadgenda satvirTo matareblis pnevmaturi avtomuxruWebis mowyobilobas (matareblis wona 5000 t).

<u>jgufuri stendis ZiriTadi maxasiaTeblebi:</u>

- oTxRerZiani vagonebis ricxvi _ 60;
- samuxruWe RerZebis ricxvi _ 240;
- samuxruWe magistralis sigrZe (ormagi weviT) _ 840 m;
- haeris wneva mTavar rezervuarSi 7-8 atm.;
- wnevis sidide magistralSi _ 6 atm.;
- Wokis gamosavlis sigrZe _ 125 mm;
- saTadarigo rezervuaris moculoba _ 78 l;
- samxruWe cilindris moculoba _ 14.5 l;
- mTavari rezervuaris moculoba _ 7 m^3;
- haergamanawileblis tipi - #270-005 (samTo reJimze);
- memanqanis onkani - #394;
- haeris wnevis cvalebadoba pirvelsa da bolo vagonebs Soris 6/5.7 atm;

magistralis hermetiuloba izomeboda Semdegnairad:

wneva ecemoda 5 atm-mde da izomeboda dro, sanam wneva ar daecemoda 4 atm-mde. am drom Seadgina 55 wami, rac normaze metia.

cdebis mimdinareobisas warmoebda wnevebis Cawera mimRebisa (ЭДД-10) da oscilografis (Н-004) saSualebiT. wnevebi izomeboda samuxruWo cilindrebSi (sc), magistralSi (m) da saTadarigo rezervuarSi (sr) magistralis sigrZis oTx kveTSi: #1, #20, #40 da #60 vagonebze.

pnevmaturi avtomuxruWebis uSretobis xarisxis dasadgenad miRebuli iqna damuxruWebis Semdegi cikli: warmoebda sruli samsaxureobrivi damuxruWeba magistralSi wnevis SemcirebiT 4 atmosferomde da 30 wamis Semdeg haeris gamoSvebidan muxruWebis aSveba magistralSi haeris wnevis 6 atmosferomde momatebiT. gansazRvruli drois Semdeg isev warmoebda sruli samsaxureobrivi damuxruWeba. ciklebi erTmaneTisagan gansxvavdeboda muxruWebis aSvebidan Semdgom srul damuxruWebamde drois intervaliT. e.i. im droiT, ra droSic

mimdinareobda muxruWebis aSveba da damuxtva SekumSuli haeriT saTadarigo rezervuarebidan.

sul Catarebuli iqna 3 cikli. I ciklSi muxruWebis damuxtvis periodi Seadgenda 2.5 wT, II-Si 2.0, III-Si 1.5_1.0 wT. yoveli ciklis bolos warmoebda saeqsterno damuxruWeba da izomeboda wnevebi magistralSi da saTadarigo rezervuarebSi #59 da #60 vagonebze manometris saSualebiT (ix. nax. 7). cxrilSi 4 warmodgenilia haeris wnevebis mniSvnelobebi magistralSi, samuxruWo cilindrebSi da saTadarigo rezervuarebSi bolo ori vagonisaTvis. saeqsterno damuxruWebamde Catarda sul 12 cikli (42 wuTis xangrZlivobiT). damuxruWebis Semdeg wnevam samuxruWe cilindrebSi Seadgina 3.7 da 4.2 atm.

cxrili 4

samuxruWo sistemaSi wnevebis cvalebadoba

(cikli #1)

##	wnevebi damuxruWebis win kg/sm²					wnevebi muxruWebis aSvebamde kg/sm²				
	m	sr		sc		m	sr		sc	
	#60	#59	#60	#59	#60	#60	#59	#60	#59	#60
0.	5.7	6.0	5.5	-	-	-	-	-	-	-
1.	5.3	-	4.6	-	1.6	3.7	4.9	4.5	4.1	4.0
2.	5.2	-	4.6	2.0	1.2	3.7	4.7	4.2	4.0	4.0
3.	5.5	5.7	4.8	-	1.5	3.7	4.7	4.1	4.0	4.0
4.	5.5	-	4.8	3.0	2.0	3.75	4.15	4.1	4.1	4.0
5.	5.5	-	4.7	-	1.7	3.75	4.7	4.1	4.1	4.0
6.	5.5	-	4.7	2.2	1.7	3.7	4.7	4.1	4.1	4.0
7.	5.5	-	4.7	-	1.7	3.7	-	4.05	4.1	4.0
8.	5.2	-	4.8	-	1.6	3.7	4.4	4.05	4.1	4.0
9.	5.3	4.7	4.4	2.8	1.6	3.75	-	4.1	4.0	4.0
10.	5.3	-	4.7	-	1.6	3.7	-	4.0	4.0	40
11.	5.3	-	4.6	-	1.7	3.75	-	4.0	4.0	4.0
12.	5.2	-	4.5	-	1.7	3.75	4.5	4.0	4.1	3.95
13.	saeqsterno damuxruWeba					0	4.4	4.0	4.1	3.9

II ciklis dros (τ_{aSv}=2.0) sul Catarda 8 cda 24 wuTis ganmavlobaSi. am ciklis monacemebi analogiuri iyo I ciklisa. me-3 ciklisas periodiT (τ_{aSv}=1.5 wT) Catarda 5 cda, Semdeg ki Seicvala periodis sidide τ_{aSv}=1.0. am mniSvnelobisaTvis meore sruli samsaxureobrivi damuxruWebis Semdeg miviReT `damyarebuli~ reJimi, romlis drosac wnevebis sididem bolo vagonis samuxruWo cilindrebSi da samarago rezervuarebSi Seadgina Sesabamisad 3.9 da 4.5 atmosfero.

damuxruWebis Semdgomma ganmeorebam gavlena ver moaxdina wnevebis cvalebadobaze. amitom 28 wuTis Semdeg Sesrulda sruli damuxruWeba. saeqsterno damuxruWebis Semdeg wnevebis sidideebi Seadgenda 3.7 da 4.2 atmosferos. Meore ciklis Catarebis Sedegad wnevebis mniSvnelobebi warmodgenilia cxrilSi 5.

cxrili 5

samuxruWo sistemaSi wnevebis cvalebadoba

(cikli #2)

##	wnevebi damuxruWebis win kg/sm²					wnevebi muxruWebis aSvebamde kg/sm²				
	m	sr		sc		m	sr		sc	
	#60	#59	#60	#59	#60	#60	#59	#60	#59	#60
0.	5.7	6.0	5.5	-	-	-	-	-	-	-
1.	5.15	-	4.75	2.5	2.1	3.8	-	4.45	-	4.1
2.	5.05	-	4.65	3.0	2.4	3.75	-	4.25	-	4.05
3.	5.0	-	4.6	3.0	2.4	3.75	-	4.1	-	4.0
4.	5.0	4.7	4.55	3.1	2.4	3.75	-	4.1	-	4.0
5.	4.85	-	4.35	-	3.1	3.75	-	4.05	-	4.0
6.	4.8	4.45	4.35	3.9	3.1	3.75	4.5	4.0	4.0	4.0
7.	4.8	4.55	4.3	3.9	3.1	3.75	-	4.0	-	3.95
8.	4.8	4.5	4.3	3.86	3.1	3.8	-	4.0	-	3.95
9.	4.8	4.6	4.3	3.75	3.0	3.7	-	4.0	-	3.95
10.	4.75	4.6	4.25	3.9	3.1	3.75	-	4.05	-	3.95
11.	4.8	4.6	4.3	3.8	2.9	3.75	-	3.95	-	3.9
12.	4.75	4.55	4.25	3.8	2.9	3.75	-	3.95	-	3.9
13.	saeqsterno damuxruWeba					0	4.3	3.95	4.0	3.9

rogorc cdebis Sedegebidan Cans pnevmaturi avtomuxruWebi samTo reJimze muSaobisas xasiaTdeba maRali xarisxis uSretobiT 30 wuTis ganuwyveteli damuxruWebisas. vinaidan Catarebuli cdebis yvela ciklSi miiRweoda `damyarebuli~ reJimi, ris drosac wnevebi samuxruWo cilindrebSi da samarago rezervuarebSi ar icvleboda, es dro SeiZleba CaiTvalos zemoTmoyvanili cdebis minimalur drod. uwyveti damuxruWebis maqsimaluri drois dasadgenad aucilebelia gaviTvaliswinoT realur pirobebSi samTo rkinigzebze Catarebuli eqsperimentebis Sedegebi. am mizniT saqarTvelos rkinigzis suramis uReltexilze Catarebuli iqna ramodenime eqsperimenti rkinigzis transportis specialistebisa da mecnierebis mier [9].

Cven gavecaniT pnevmaturi avtomuxruWebis gamocdis Sedegebs, romelic Catarebuli iqna suramis uReltexilze gasuli saukunis 70-ian wlebSi. cdebi Catarebuli

iqna navTobmzid satvirTo matarebelze masiT 3340 t, samuxruWo RerZebis ricxvi _ 184. matarebeli eSveboda suramis uReltexilze 2 elmavliT rekuperaciis gareSe. wnevebi samarago rezervuarSi da samuxruWo cilindrebSi izomeboda bolo vagonze yovel naxevar wuTSi manometris saSualebiT. gazomili wnevebis mniSvnelobebi mocemulia cxrilSi 6. am cxrilSi naCvenebia gamyofi punqtebis dasaxelebac, romelzec mimdinareobda magistralis damuxtva.

rogorc cxrilidan Cans, wnevebi samuxruWo cilindrebSi da samarago rezervuarebSi eqspluataciis pirobebSi naklebia, vidre laboratoriul pirobebSi Catarebuli cdebis dros. es garemoeba aixsneba imiT, rom eqspluataciur pirobebSi haeris gadineba samuxruWo sistemidan ufro metia.

cxrili 6

samuxruWo sistemaSi wnevebis cvalebadoba

(suramis uReltexilze Catarebuli cda)

sr	**sc**	**sr**	**sc**	**sr**	**sc**
xaSuri		wifa		moliTi	
6.0	0	5.9	0	3.4	3.3
lixi		6.6	1.4	3.4	3.0
6.2	0	5.4	1.4	5.85	0
5.8	1.5	4.0	2.4	6.0	0
5.7	1.0	4.5	2.6	5.2	1.5
5.7	0.8	4.5	2.0	5.2	1.4
5.2	3.3	5.0	1.4	5.2	1.3

5.0	3.2	5.2	1.0	5.3	1.2
5.0	1.8	4.4	3.5	5.3	1.2
5.2	1.2	4.4	3.0	5.5	1.0
5.8	0.8	4.6	2.5	5.6	0.6
5.9	1.2	4.8	2.2	5.4	0.5
5.4	1.2	4.8	2.0	5.0	1.5
5.2	2.0	4.4	3.4	5.0	1.8
5.0	3.4	4.4	3.0	5.0	1.8
4.9	2.0	4.3	3.3	5.0	1.6
5.6	1.2	4.3	3.3	4.8	1.2
5.7	0.9	4.0	3.4	4.8	2.0
5.4	1.0	3.8	3.4	5.0	2.0
5.6	1.0	3.6	3.3	5.1	1.5
4.8	3.0			5.3	1.1
4.5	3.2			5.3	0.8
4.4	3.2			5.3	1.2
4.3	3.0			5.3	1.0
4.4	2.7			4.6	0.9
4.8	3.0				3.5
4.6	2.7			marelisi	

cdebi tardeboda rogorc rekuperaciiT, ise mis gareSe. ganuwyveteli damuxruWebis drom Seadgina 35 wT. am drois Semdeg wnevebis sididem samuxruWo cilindrebSi da samarago rezervuarebSi Seadgina minimaluri dasaSvebi normebis farglebSi. daRmarTis bolos SeimCneoda gadaxurebuli xundebis Tvlis bandaJze mikvra.

Catarebuli eqsperimentebisa da cdebis monacemebis analizis safuZvelze prof. g. kvantalianma SemogvTavaza uwyveti damuxruWebis dro ganisazRvros 35 wuTiT (ganurCevlad qanobis sididisa).

suramis uReltexilze grZivi qanobis maqsimaluri mniSvneloba Seadgens 29 ‰. ufro rTuli monakveTia marabda_axalqalaqis rkinigzis ubani, sadac profilis qanobi tolia 35 ‰. Sesabamisad satvirTo matareblis moZraobis pirobebi am xazze gacilebiT rTuli iqneba. amitom Cven viZleviT rekomendacias:

1. Tu profilis qanobi aRemateba 30 ‰-s, maSin uwyveti damuxruWebis maqsimaluri dro ganisazRvros 30 wuTiT;
2. Tu profilis qanobi naklebia 30 ‰-ze, maSin uwyveti damuxruWebis dro ar unda aRematebodes 35 wuTs.

viciT ra daRmarTebze uwyveti damuxruWebis xangrZlivoba, Zneli ar aris daRmarTis maqsimaluri sigrZis dadgena

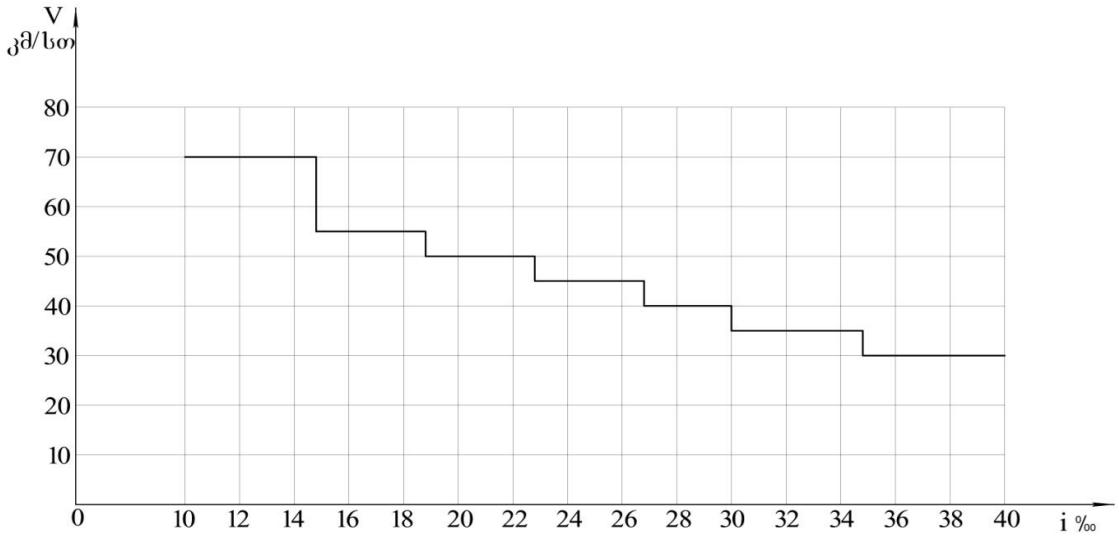
$$l = \frac{V_{saS}\, t_{dam}}{60} \text{ km}$$

V_{saS} daRmarTze matareblis moZraobis saSualo siCqarea.

$$V_{saS} = V_{das} - \Delta V$$

V_{das} daRmarTebze maqsimaluri dasaSvebi siCqarea.

damokidebulia daRmarTis qanobze. dasaSvebi maqsimaluri siCqaris



mniSvnelobebi warmodgenilia nax. 8-ze. [16]

nax. 8. daRmarTebze maqsimaluri dasaSvebi siCqareTa grafiki

ΔV sidide damokidebulia daRmarTis qanobis sidideze da meryeobs 4_7 km/sT-is farglebSi. Cven aviRoT ΔV=5 km/sT.

2.4 daRmarTis maqsimaluri sigrZis dadgena xundebis cveTis pirobiT

eqspluataciis pirobebSi, gansakuTrebiT dayovnebul daRmarTebze did mniSvnelobas aniWeben xundebis cveTamedegobas.

satvirTo matareblebis cicabo daRmarTebze damuxruWebisas friqciuli masalebis gadaxurebis temperaturis zrdasTan erTad izrdeba maTi cveTac.

kompoziciuri masalisagan damzadebuli xundebi gamoirCeva maRali cveTamedegobiT da amitom aseTi xundebi uzrunvelyofen SedarebiT grZel daRmarTebze muxruWebis normalur muSaobas, xolo Tujis xundebis SemTxvevaSi, romlebic ar arian cveTamedegi, daRmarTis win mowmdeba maTi sisqis sakmarisoba. normebis Tanaxmad Tujis xundebis minimaluri sisqe ar unda iyos naklebi 12 mm-sa.

cveTis sidide daRmarTebze matareblis damyarebuli siCqariT moZraobis SemTxvevaSi gamoiTvleba prof. inozemcevis formuliT [8]:

$$\Delta h = \frac{(1-\alpha_p)Vt\sqrt{a}AbP}{F_k(\Delta\tau_{\text{maq}} - \Delta\tau_{\text{saS}})\sqrt{\Pi\lambda\gamma c}} - 2\frac{C_p}{X}$$

sadac: V – moZraobis saSualo siCqarea;

t _ damuxruWebis xangrZlivoba;

α _ temperaturis gamtarunarianobis koeficientia;

A _ muSaobis samuxruWo eqvivalenti;

b _ xvedriTi samuxruWe Zala;

P _ Tvalze mosuli dawola;

F _ xundis geoTermuli farTobi;

$\Delta\tau_{\text{maq}}$ _ temperaturaa, romlis drosac warmoebs Tbur sakontaqto wertilebSi cveTa;

τ_{saS} _ saSualo temperatura xaxunis zedapirze;

λ _ Tbogamtarobis koeficienti;

γ _ Tvlis liTonis moculobiTi masaa;

C _ xvedriTi Tbotevadoba;

X _ faqtiuri sakontaqto farTis koeficienti;

α_p _ rekuperaciis koeficienti.

Tujis xundebis Tbofizikuri maxasiaTeblebis gaTvaliswinebiT zemoTmoyvanili formuliT SesaZlebelia xundis minimaluri sisqis dadgena Semdegi martivi gamosaxulebis saSualebiT:

$$\Delta H = 10 + 0.03\ \Sigma li \ \text{mm}$$

sadac: l _ daRmarTis sigrZe, m;

i _ daRmarTis qanobi.

am gamosaxulebidan SesaZlebelia gamoviTvaloT daRmarTis maqsimaluri

xundis sisqe, ΔH mm	**daRmarTis qanobi, I ‰**	**daRmarTis sigrZe, L km**	**xundis sisqe, ΔH mm**	**daRmarTis qanobi, I ‰**	**daRmarTis sigrZe, L km**

sigrZe xundis sisqesTan damokidebulebiT:

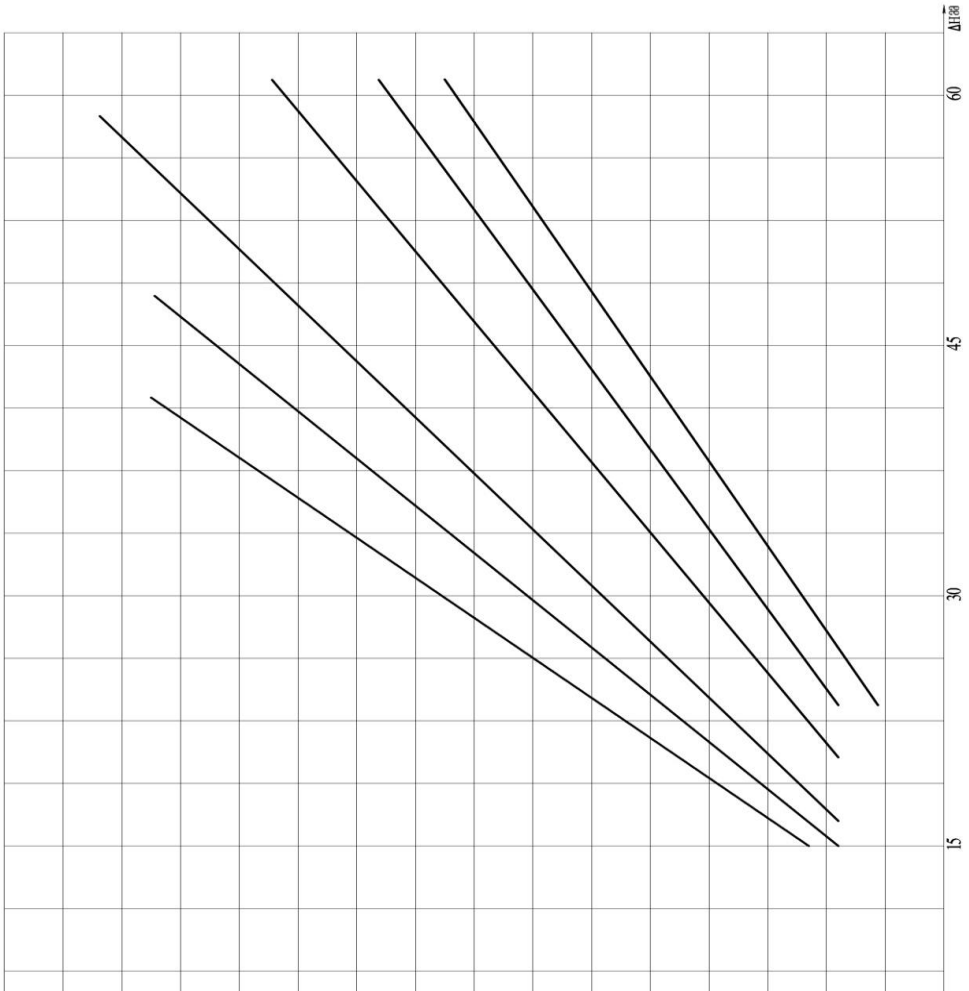
$$l = \frac{33.3\ (\Delta H - 10)}{i} \ \text{km}$$

daRmarTis maqsimaluri sididis mniSvneloba xundis sisqisgan damokidebulebiT warmodgenilia cxrilSi 7, xolo grafikulad nax. 9-ze.

cxrili 7

daRmarTis maqsimaluri sigrZe xundis sisqesTan damokidebulebiT

40 30 20 15	15	66.6 44.4 22.2 11.1	60 40 30 20	30	55.5 33.3 22.2 11.1
40 30 20 15	20	50 33.3 16.3 8.3	60 40 30 20	35	47.6 28.7 19 9.5
60 40 30 20	25	66.6 40 26.7 13.3	60 40 30 20	40	41.7 25 16.7 8.3



Nnaxazi 9. daRmarTis maqsimaluri sigrZis damokidebuleba
xundebis sisqisagan

2.5 SemzRudavi qanobebis zRvruli sigrZis gansazRvra elmavlebis wevis Zravebis gadametxurebis pirobebis mixedviT

elmavlebis wevis Zravebis gadametxureba jer kidev xSir SemTxvevaSi zRudaven elmavlebis wevis xarisxs. mosazreba imis Sesaxeb, rom wevis Zravebis simZlavris gazrdisa da ufro medegi kaJbadorganuli izolaciis SemoRebis Sedegad wevis Zravebis gadaxureba aRar moaxdens arsebiT zegavlenas elmavlebis wevis maxasiaTeblebze, praqtikul muSaobaSi ar dadasturda. saqme imaSia, rom Zravebis simZlavris gazrdas Tan mosdevs datvirTvis gadideba. e.i. izrdeba matareblis masa, moZraobis saangariSo siCqare da denuri datvirTva. marTalia, Tanamedrove elmavlebi aRWurvilia ufro srulyofili wevis ZravebiT, romlebic gadametxurebas ufro xangrZlivad uZleben, magram SezRudva mainc dgeba, radgan ufro meti sigrZis aRmarTebis daZlevis Semdeg, gadametxureba mainc aRwevs Tavis zRvars.

aRniSnulis TvalsaCino magaliTs warmoadgens suramis uReltexilis eqspluatacia. aq didxans muSaobdnen susti simZlavris elmavlebi, romelTa wevis Zravebi swrafad xurdebodnen normamde. 1960 wlamde SemadgenlobaSi erTi elmavali mTlianad muSaobda Zravebis gadametxurebis Sesamcireblad. Semdeg aq danergili iqna ufro mZlavri БЛ 8 tipis elmavlebi. gaizarda Sesabamisad savagono Semadgenlobis masac, gaumjobesda wevis Zravebis gadaxurebis pirobebic, magram mainc saWiro Seiqmna damatebiTi elmavlis gamoyeneba Zravebis gadaxurebis

pirobebis gasaumjobeseblad. amJamad suramis uReltexilze muSaoben ВЛ 10 da ВЛ 11 tipis elmavlebi, romelTa medegoba wevis Zravebis gadametxurebis gaTvaliswinebiT sagrZnoblad aRemateba ВЛ 8 tipis elmavlebs.

elmavlebis wevis Zravebis gadametxureba dResac aqtualur problemas warmoadgens da axali rkinigzebis daproeqtebis dros am garemoebas unda mieqces saTanado yuradReba. am TvalsazrisiT sayuradReboa SemzRudavi aRmarTebis iseTi sigrZis gansazRvra, romelTa daZleva mocemuli tipis elmavals SeuZlia wevis Zravebis normaze metad gadametxurebis gareSe.

rogorc aRniSnuli iyo, mTian pirobebSi rkinigzebisaTvis damaxasiaTebelia grZeli, cicabo aRmarTebi, romelzedac lokomotivis uwyvetma muSaobam didi datvirTviT SesaZlebelia gamoiwvios Zravis gadaxurebis saSiSroeba. Zravis dasaSvebi maqsimaluri temperatura damokidebulia izolaciis klasze, romelTa sidide warmodgenilia cxrilSi 8.[17][18]

cxrili 8

Zravebis gaxurebis maqsimaluri temperatura

izolaciis klasi	**B**	**F**	**H**
Ruzis xvia	145^0	165^0	185^0
polusebis xvia	155^0	180^0	205^0

Eeleqtruli Zravis Semowmebisas gadaxurebaze dgindeba gragnilebis dasaSvebi temperaturis garemos temperaturaze gadaWarbebis sidide

$$\tau_{\text{maq}} = \theta_{\text{das}} - \theta_{\text{gar}}$$

sadac: θ_{das} _ Zravis gaxurebis dasaSvebi temperaturaa (cxr. 8);

θ_{gar} _ garemos temperatura.

garemos saangariSo temperatura ganisazRvreba meteorologiuri sadguris monacemebis safuZvelze Semdegi formuliT:

$$\theta_{\text{das}} = \frac{t_7 + 2t_{13} + t_{19}}{4}\,^0\text{C}$$

sadac, t_7, t_{13} da t_{19} warmoadgens dakvirvebaTa wlebis (ara nakleb 5 wlisa) temperaturis saSualo gazomils 7, 13 da 19 saaTze ivnisis, ivlisis da agvistos TveebSi. Tu es temperatura aRmoCnda 15^0-ze dabali, maSin wevis gaangariSebis normebis Tanaxmad aiReben 15^0-s. Cven gamokvlevebSi garemos temperaturas viRebT 25^0-is tols.

Zravis gaxurebas temperaturis analizurad angariSoben Semdegi formulis daxmarebiT

$$\tau = \tau_\infty \left(1 - e^{-\frac{t}{T}}\right) + \tau_0 e^{-\frac{t}{T}} °C \qquad (2.51)$$

sadac: τ_∞ da T Zravis Tburi maxasiaTeblebia;

t _ Zravis muSaobis xangrZlivoba, wT;

τ_0_ Zravis sawyisi temperaturaa.

(2.51) gantoleba SegviZlia warmovidginoT Semdegi saxiT

$$\tau = \tau_\infty + e^{-\frac{t}{T}} (\tau_0 - \tau_\infty)$$

aqedan:

$$e^{-\frac{t}{T}} = \frac{\tau - \tau_\infty}{\tau_0 - \tau_\infty}$$

ganvsazRvroT Zravis muSaobis maqsimaluri dro

$$t = -Tln\ \frac{\tau - \tau_\infty}{\tau_0 - \tau_\infty}\ \text{wT} \qquad (2.52)$$

aRmarTis maqsimaluri sigrZe saangariSo reJimiT muSaobisas toli iqneba

$$l = \frac{V_{\text{saang.}}}{60}\ \text{km}$$

saaTobrivi reJimiT Zravis muSaobisas

$$l = \frac{V_{\text{saaT.}} t}{60}\ \text{km}$$

sadac: $V_{\text{saang.}}$ da $V_{\text{saaT.}}$ _ Sesabamisad lokomotivis minimaluri saangariSo da saaTuri reJimiT moZraobis siCqareebia. t da l sidideebi Tanamedrove lokomotivebisaTvis sawyisi temperaturisagan damokidebulebiT warmodgenilia cxrilSi 9. (mricxvelSi sruli datvirTviT muSaobisas, mniSvnelSi saaTobrivi reJimiT muSaobisas.

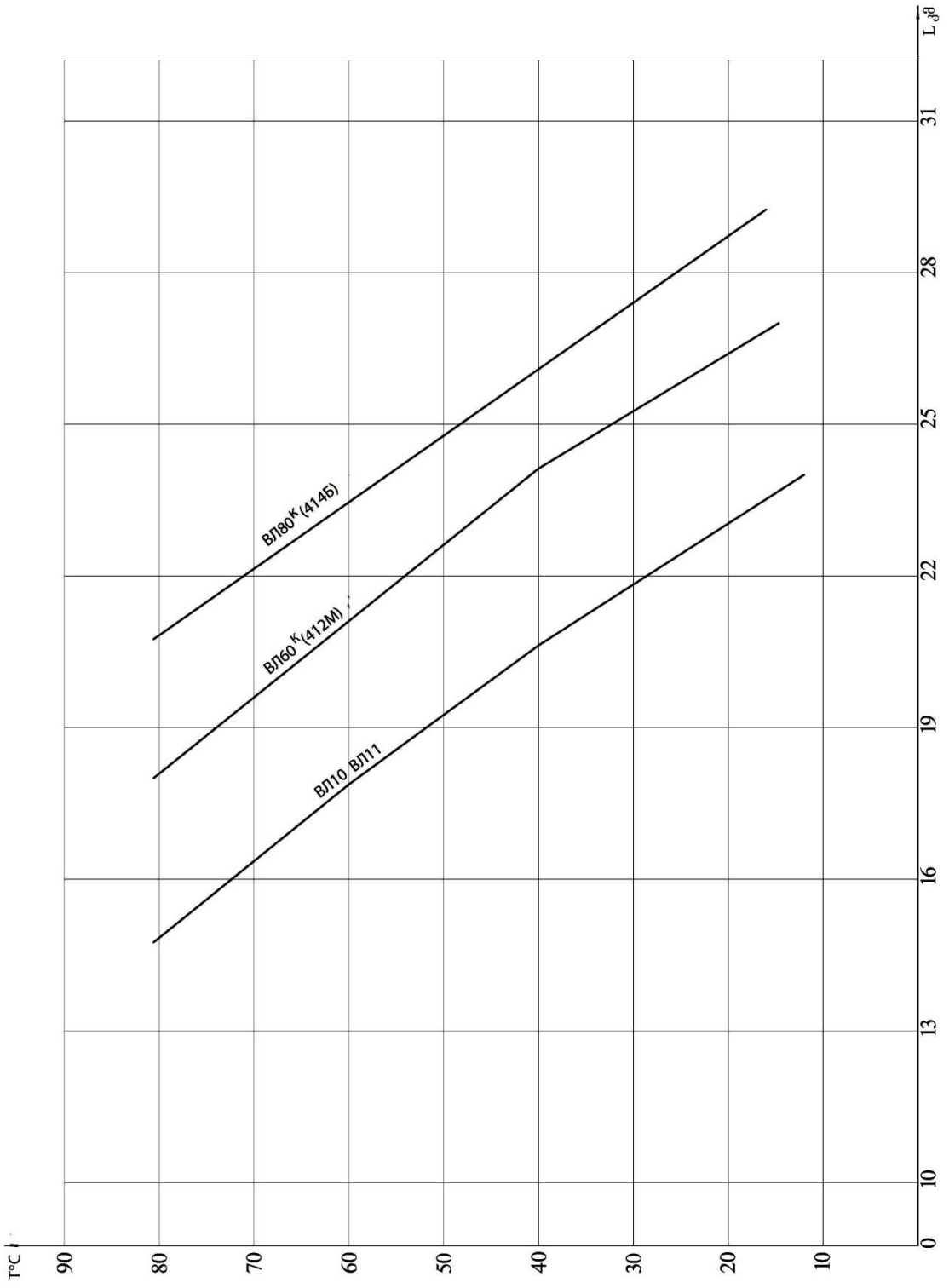
grafikuli damokidebuleba $l = f(\tau_0)$ sruli datvirTvis qveS muSaobisas moyvanilia nax. 10-ze, xolo saaTuri reJimiT muSaobisas nax. 11-ze.

cxrili 9

aRmarTis maqsimaluri sigrZe wevis Zravebis

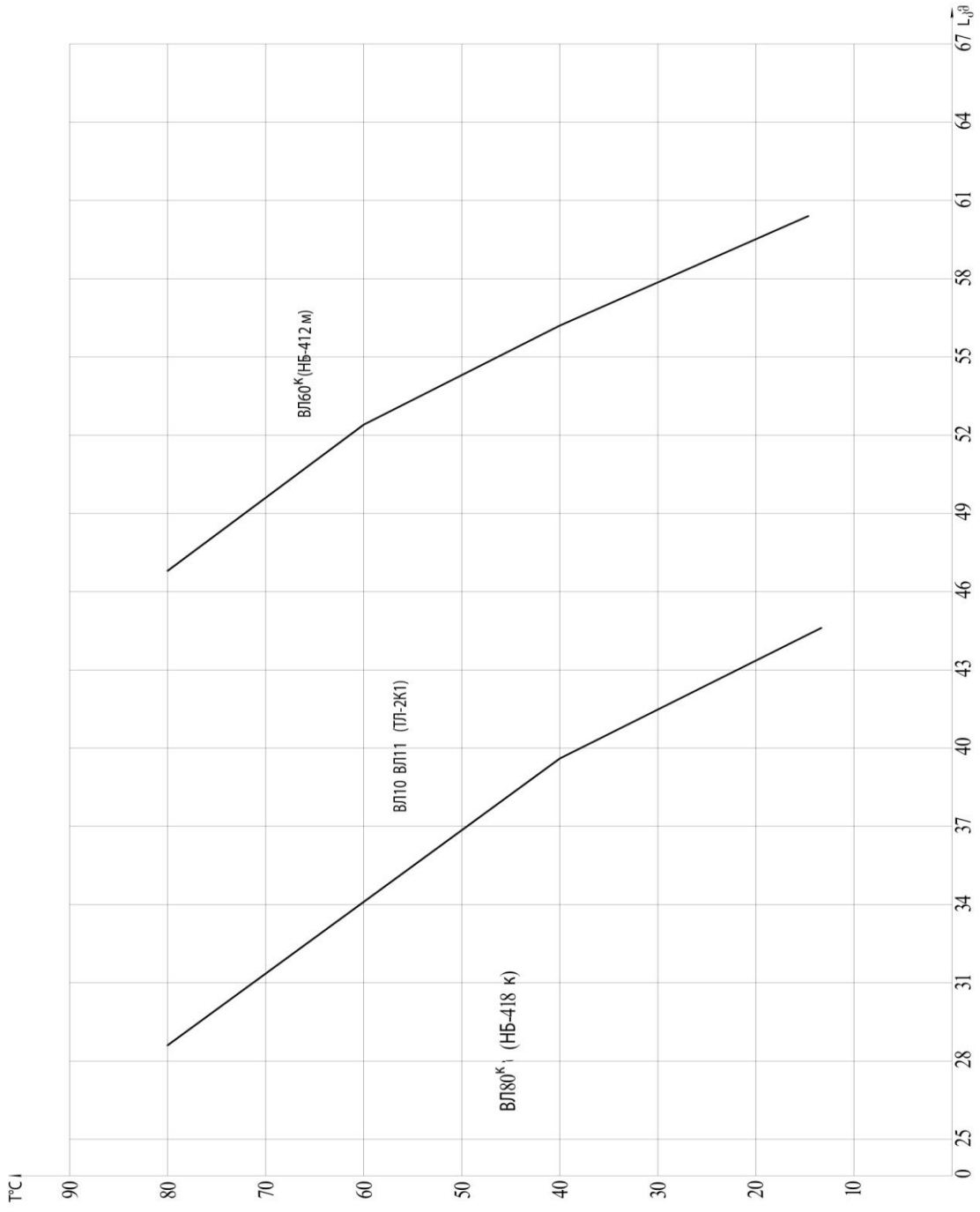
gadaxurebis pirobiT

lokomotivis tipi	**t, wT**				***l*, km**			
	τ_0^0 C				τ_0^0 C			
	15	40	60	80	15	40	60	80
ВЛ10 da ВЛ11 (тл-2л1)	$\frac{37}{59}$	$\frac{32}{52}$	$\frac{26}{45}$	$\frac{19}{35}$	$\frac{28}{47.0}$	$\frac{24.2}{41.6}$	$\frac{19.7}{35.8}$	$\frac{14.5}{27.8}$
ВЛ60К (НБ-412К)	$\frac{33.4}{54}$	$\frac{28.6}{48}$	$\frac{24}{42}$	$\frac{18}{34}$	$\frac{24.4}{47.5}$	$\frac{21}{42}$	$\frac{17.9}{26.7}$	$\frac{13.2}{29.7}$
ВЛ60К (НБ-412М)	$\frac{41.5}{73}$	$\frac{36.8}{67}$	$\frac{33.2}{61.5}$	$\frac{29}{55}$	$\frac{29.6}{64}$	$\frac{26.2}{48.5}$	$\frac{23.6}{54}$	$\frac{20.7}{48}$
ВЛ80К (НБ-418К)	$\frac{33.5}{48}$	$\frac{30}{42.5}$	$\frac{25.5}{37}$	$\frac{19.4}{30}$	$\frac{24.7}{41.5}$	$\frac{22.2}{26.7}$	$\frac{18.7}{32}$	$\frac{14.3}{25.8}$
ВЛ80К (НБ-414Б)	37.5	33	28.2	23	29.2	25.7	22	17.9


T°C
90
80
70
60
50
40
30
20
10
0
10
13
16
19
22
25
28
31
$L_{дБ}$
ВЛ80К (414Б)
ВЛ60К (412М)
ВЛ10, ВЛ11

nax. 10 aRmarTis maqsimaluri sigrZe wevis

Zravebis gadaxurebis pirobiT



nax. 11 aRmarTis maqsimaluri sigrZe wevis Zravebis
gadaxurebis pirobiT (saaTobriv reJimSi)

rogorc grafikebidan Cans, aRmarTis maqsimaluri sigrZe Zravebis gadaxurebis pirobiT saaTuri reJimis dros gacilebiT metia, vidre Zravis sruli datvirTviT muSaobisas.

eqspluataciur pirobebSi Zravis gadaxurebis Tavidan acilebis mizniT xSirad mimarTaven Zravis muSaobis reJimis Secvlas. lokomotivi gadayvanilia saaTobriv reJimze. am SemTxvevaSi aucilebelia matareblis saangariSo masa SevamciroT $\Theta \frac{F_{saaT.}}{F_{saang.}}$ sididemde. rogorc cnobilia cicabo qanobebian daRmarTebze gamoiyeneba rekuperaciuli damuxruWeba. am SemTxvevaSic aucilebelia Semowmdes wevis Zravebi gadaxurebaze, vinaidan rekuperaciuli damuxruWebisas wevis Zala naklebia, vidre wevis reJimSi. amitom daRmarTis sigrZe gadaxurebis pirobiT ar SeizRudeba. rekuperaciuli damuxruWebisas Zravis gaxurebis temperaturis Semowmeba gansakuTrebiT saWiroa im SemTxvevaSi, roca grZel daRmarTis win uZRvis didi aRmarTi.

2.6 daRmarTis zRvruli sigrZis dadgena moZraobis usafrTxoebis pirobiT

Cven ganvixileT yvela is faqtorebi, romlebic zegavlenas axdenen samTo rkinigzebis matareblebis usafrTxo da Seuferxebel moZraobaze. aseT faqtorebs miekuTvneba: xundebis gadaxureba da cveTa gagrZelebul cicabo daRmarTebze, sahaero magistralis daSreta da aRmarTis mimarTulebiT elmavlis wevis Zravebis gadaxureba. yvela zemoTCamoTvlili faqtorebis mixedviT davadgineT cicabo qanobiani monakveTebis zRvruli sigrZeebi, romlebzedac usafrTxo iqneba matareblebis moZraoba.

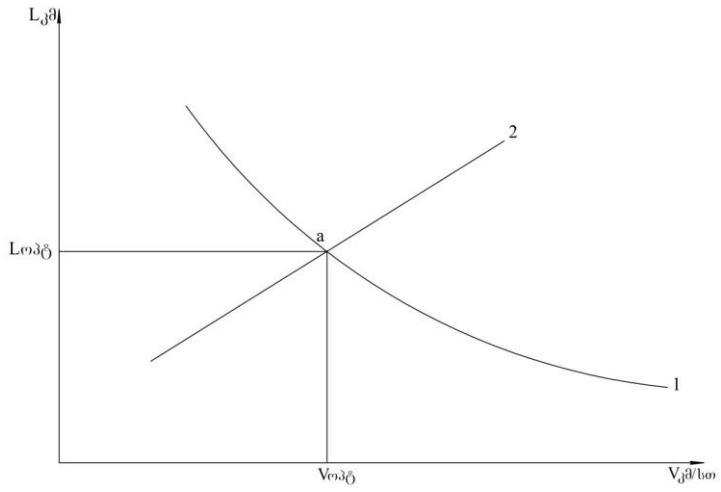
miRebuli Sedegebis gaanalizebis safuZvelze davadgineT, rom daRmarTis zRvruli sigrZe izRudeba ori pirobiT: samuxruWe xundebis gadaxureba da sahaero magistralSi wnevis normaze dabla dacema.

xundebis gadaxurebis temperatura damokidebulia vagonis
wonaze, moZraobis siCqareze, xundis masalaze, daRmarTis qanobze.

rogorc iyo aRniSnuli, kompoziciuri xundebi xasiaTdeba naklebi TbogamtarobiT, vidre Tujis xundebi, amitom daRmarTis zRvruli sigrZe gadaxurebis pirobiT kompoziciuri xundebis SemTxvevaSi naklebia. amitomac Cven daRmarTis maqsimaluri sigrZeebis dadgenisas mxedvelobaSi viRebT mxolod kompoziciur xundebs. xundebis gaxurebis temperatura pirdapirproporciulia daRmarTze moZraobis siCqaris. e.i. maRali siCqarisas ufro male aRwevs xundis temperatura maqsimalur sidides. daRmarTis zRvruli sigrZis gazrda gadaxurebis pirobiT SesaZlebelia moZraobis siCqaris SemcirebiT. magram am dros SeiZleba daRmarTis sigrZe SeizRudos magistralSi haeris wnevis dacemiT.

rogorc eqsperimentalurma gamokvlevebma da uSualod realur pirobebSi Catarebulma cdebma gviCvenes, maqsimaluri dro uwyveti damuxruWebisas ar unda aRematebodes 30-35 wuTs. sahaero magistralis daSretis pirobiT daRmarTis sigrZe SesaZlebelia gavzardoT moZraobis siCqaris gazrdiT.

daRmarTis zRvruli sigrZis dasadgenad erTdroulad unda iyos gaTvaliswinebuli rogorc xundebis gadaxurebis, aseve sahaero magistralis daSretis piroba. am ori urTierTgamomricxavi faqtorebis mxedvelobaSi miReba mogvcems daRmarTis sigrZis iseT sidides, romelzedac uzrunvelyofili iqneba matareblis usarTxo moZraoba. amisaTvis ki saWiroa erTidaigive koordinatTa sistemaSi avagoT rogorc xundebis gadaxurebis, aseve magistralis daSretis mrudebi siCqarisa da qanobisagan damokidebulebiT. am ori mrudis gadakveTis wertili mogvcems daRmarTis optimalur sigrZes (nax. 12).



nax. 12 daRmarTis optimaluri sigrZis dadgena xundebis gadaxurebisa da daSretis pirobebiT

nax. 12-ze warmodgenili

mrudebi 1 da 2 warmoadgens daRmarTis sigrZis damokidebulebas moZraobis siCqaresTan da qanobTan, Sesabamisad xundebis gadaxurebisa da magistralis daSretis pirobebiT.

rogorc grafikidan Cans maRali siCqareebisas xundebis gadaxurebis pirobiT daRmarTis sigrZeebi moklea, vidre daSretis pirobiT, xolo dabali siCqareebis dros ki piriqiT.

imisaTvis, rom gavzardoT daRmarTis zRvruli sigrZe xundebis gadaxurebis pirobiT, saWiroa SevamciroT moZraobis siCqare. am dros mcirdeba daRmarTis sigrZe daSretis pirobiT. daRmarTis optimalur sigrZes orive pirobis gaTvaliswinebiT mogvcems am ori mrudis TankveTis wertili $\grave{\alpha}\tilde{}$. TankveTis wertili gvaZlevs agreTve daRmarTebze dasaSveb optimalur siCqares.

2.7 marabda-axalqalaqis rkinigzis xazis gadasarbenebis Semowmeba damuxruWebis pirobiT

marabda-axalqalaqis rkinigzis xazi erT-erTi urTulesia ara marto saqarTveloSi, aramed mTel yofil sabWoTa kavSiris sivrceSi. igi eqspluataciaSi Sevida gasuli saukunis 80-ian wlebSi. igi Tavidan gaTvaliswinebuli iyo rogorc adgilobrivi daniSnulebis III kategoriis rkinigzis xazi. rkinigzis xazis sigrZe Seadgens 165 km-s. saxelmZRvanelo qanobis sidide 35 ‰. minimaluri radiusi – 300 m. jer kidev xazis daproeqtebisas daSvebuli iqna Secdoma, rac gamoixateboda imaSi, rom saxelmZRvanelo qanobi ar unda yofiliyo 30 ‰-ze meti (amaze miuTiTebs samSeneblo normebi da wesebi). am xazis eqspluataciaSi SesvlisTanave dRis wesrigSi dadga matarebelTa moZraobis usafrTxoebis sakiTxi. saqme is gaxlavT, rom garda profilisa da gegmis sirTulisa es xazi gadis rTul topografiul, geologiur da klimatur pirobebSi. zogierTi misi monakveTi zRvis donidan 2000 metrs da met niSnulze mdebareobs. adgilmdebareoba gamoirCeva mkacri klimaturi pirobebiT (zamTarSi minimaluri temperatura aris -25^0). trasaze gvxvdeba Ria Rrma Wrilebi, romlebic zamTris periodSi TovliT inamqreba da moZraoba iketeba.

am ubanze gvxvdeba cicabo qanobiani grZeli daRmarTebi qanobiT 35 ‰, rac arTulebs mis eqspluatacias da zrdis avariebis saSiSroebas. eqspluataciaSi SesvlisTanave am xazze adgili hqonda matareblis gaqcevas, rac damTavrda fataluri SedegiT (iyo adamianTa msxverpli da didi materialuri zarali).

dReisaTvis, rogorc cnobilia es monakveTi warmoadgens saerTaSoriso rkinigzis xazis (baqo-Tbilisi-yarsi) erT-erT Semadgenel ubans. amitom am xazze matarebelTa moZraobis usafrTxoebas didi mniSvneloba eniWeba.

Cven miznad davisaxeT Cagvetarebina arsebuli sarkinigzo gadasarbenis analizi moZraobis usafrTxoebis pirobebiT da dagvesaxa saWiro rekomendaciebi.

Cveni kvlevis obieqts Seadgens gansakuTrebiT rTuli gadasarbenebi, romlebsac gaaCnia grZeli cicabo daRmarTebi. aseTi gadasarbenebia: 1) winwyaro_TeTriwyaro 2) TeTriwyaro_ nadarbazevi 3) nadarbazevi_bedeni, 4) walka_TrialeTi, 5) Tria-leTi_Tafaravani.

gadasarbeni winwyaro-TeTriwyaro

am gadasarbenis sigrZe Seadgens 10,87 km-s. daZabuli daRmarTis sigrZe Seadgens 9,3 km-s. saSualo qanobis sidide
30,2 ‰.

SevamowmoT grZeli daRmarTis sigrZe kompoziciuri xundebis gadaxurebis pirobiT. 0,3 rekuperaciis koeficientisaTvis gadaxurebis temperaturis mixedviT daRmarTis maqsimalur sigrZes vangariSobT Cvens mier gamoyvanili formulis saSualebiT

$$L = \left[\frac{1}{K\alpha}\ln(1-\frac{\alpha T}{q})\right]^2 \text{ km}$$

daRmarTis sigrZeebi qanobsa da siCqaris sididesTan damokidebulebiT warmodgenilia cxrilSi 10.

cxrili 10

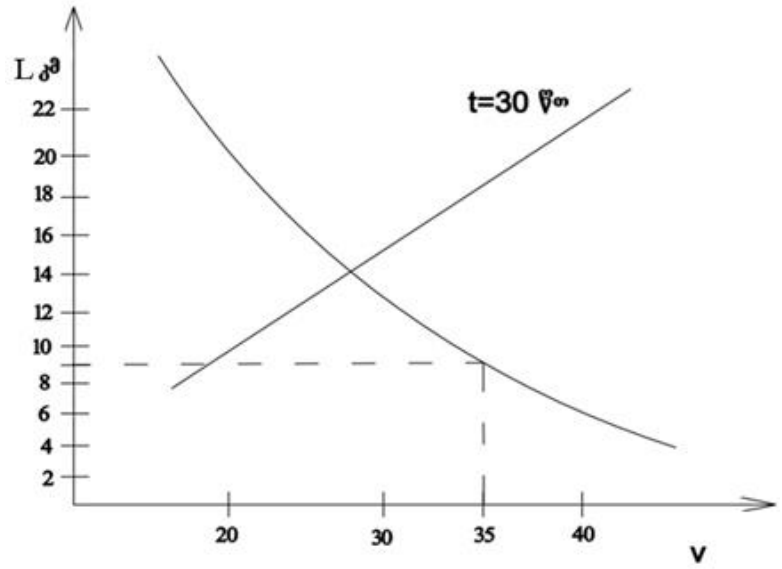
daRmarTis zRvruli sigrZe

(winwyaro-TeTriwyaros gadasarbeni)

V, km/sT	40	30	25
l, km	8,0	11,7	18,8

avagoT grafiki $l = f(i\,V)$ rogorc xundebis gaxurebisaTvis, aseve sahaero magistralis daSretis pirobiT t_{daSr}=30 wT.

rogorc nax. 13-dan Cans am gadasarbenze maqsimaluri dasaSvebi siCqariT moZraobisas daRmarTis maqsimaluri sigrZe xundebis gadaxurebis pirobiT Seadgens 9km-s, realurad ki daRmarTis sigrZea 9,3 km.



nax.13 daRmarTis zRvruli sigrZis dadgena

am gadasarbenze xundebis gaxurebis temperatura zRvruli normebis farglebSia. vinaidan roca maqsimaluri siCqarea
35 km/sT, daRmarTis dasaSvebi sigrZe Seadgens 9,0 km, realurad ki daRmarTis sigrZea 9,3 km. am gadasarbenze saWiroa moZraobis siCqaris Semcireba 32 km/sT-mde an sxva rekonstruqciuli RonisZiebebis gatareba.

gadasarbeni TeTriwyaro-nadarbazevi

es gadasarbeni iTvleba yvelaze Znel monakveTad, radgan misi sigrZe 14,70 km-ia, xolo daZabuli daRmarTis sigrZe Seadgens 13,5 km-s – saSualo qanobis sidide 31,5 ‰.

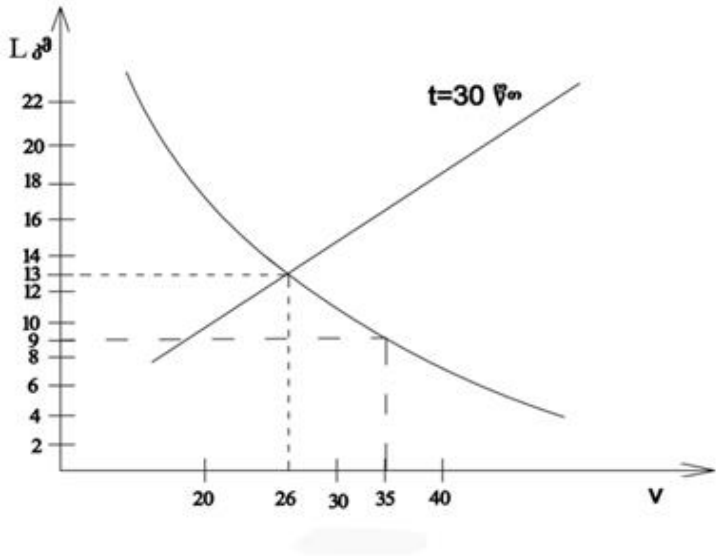
zemoTmoyvanili formuliT vadgenT daRmarTis sigrZes qanobisa da siCqarisgan damokidebulebiT. Sedegebi warmodgenilia cxrilSi 11 da naxazze 14. rekuperaciis koeficientis mniSvneloba Seadgens 0,3-s.

cxrili 11

daRmarTis zRvruli sigrZe

(TeTriwyaro-nadarbazevis gadasarbeni)

V,km/sT	40	30	25
l, km	7,8	11,0	18,0



nax. 14 daRmarTis zRvruli sigrZis dadgena

Aam gadasarbenze 35 km/sT moZraobisas mosalodnelia xundebis gadaxureba. daRmarTis dasaSvebi sigrZe Seadgens 9,0 km, sinamdvileSi ki daRmarTis sigrZe Seadgens 13,5 km. gadaxurebis Tavidan acilebis mizniT unda Semcirdes moZraobis siCqare, magram am dros dgeba daRmarTis sigrZis SezRudva haeris daSretis pirobiT. maqsimaluri daRmarTis sigrZe $V = 26$ km/sT siCqarisas Seadgens 13 km-s, rac ar akmayofilebs pirobas, vinaidan gadasarbenze daRmarTis maqsimaluri sigrZea 13,5 km.

gadasarben TeTriwyaro-nadarbazevze moZraobis usafrTxoebis pirobebis uzrunvelsayofad saWiroa gadasarbenis SuaSi damatebiTi asaqcevis mowyoba.

gadasarbeni nadarbazevi-bedeni

am gadasarbenis sigrZea 14,84 km. daZabuli daRmarTis sigrZe 8,0 km, saSualo qanobi 31 ‰.

daRmarTis maqsimaluri sigrZeebi siCqarisgan damokidebulebiT mocemulia cxrilSi 12

cxrili 12

daRmarTis zRvruli sigrZe

(nadarbazevi-bedenis gadasarbeni)

V	40	30	25
l	8,0	12,0	18,5

rogorc cxrilidan Cans am gadasarbenze maqsimaluri siCqariT moZraobis drosac ki (40 km/sT) xundebis gadaxureba ar iqneba mosalodneli.

gadasarbeni walka-TrialeTi

gadasarbenis sigrZe 8,835 km-ia. daZabuli daRmarTis sigrZe 6,6 km, saSualo qanobi 33,4 ‰.

daRmarTis maqsimaluri sigrZe aRniSnuli qanobisaTvis sxvadasxva siCqaris SemTxvevaSi warmodgenilia cxrilSi 13

cxrili 13

daRmarTis zRvruli sigrZe

(walkai-TrialeTis gadasarbeni)

V,km/sT	40	30	25
l,km	7,0	9,0	13,0

am gadasarbenis xundebis gadaxureba ar aris mosalodneli, vinaidan 40 km/sT moZraobis drosac ki ar miiRweva xundis maqsimaluri temperatura.

gadasarbeni TrialeTi-Tafaravani

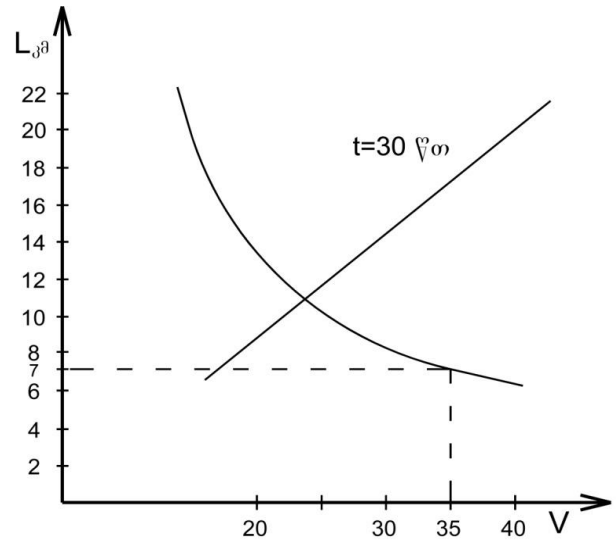
am gadasarbenis sigrZea 10,95 km. daZabuli daRmarTis sigrZe 9,65 km, saSualo qanobi i=33,6 ‰. am monacemebisaTvis daRmarTis maqsimaluri sigrZe siCqarisgan damokidebulebiT mocemulia cxrilSi

cxrili 14

daRmarTis zRvruli sigrZe

(TrialeTi-Tafaravanis gadasarbeni)

***V*,km/sT**	**40**	**30**	**25**	**20**
l,km	6,2	8,5	11,0	14,0



nax.15 daRmarTis zRvruli sigrZis dadgena

rogorc 15 naxazidan Cans am gadasarbenze maqsimaluri dasaSvebi siCqariT moZraobisas (35 km/sT) xundebis gadaxurebis pirobiT matarebeli gaivlis mxolod 7 km-s. gadasarbenze daRmarTis sigrZe ki 9,65 km. am sigrZis daRmarTze rom ar moxdes xundebis gadaxureba, saWiroa moZraobis siCqare Semcirdes 26 km/sT-mde.

3. satvirTo matareblis wonis normis dadgena marabda-axalqalaqis rkinigzis xazze

satvirTo matareblis Semadgenlobis wonis norma erT-erTi mTavari parametria rogorc saproeqto, aseve arsebuli rkinigzisaTvis. masze damokidebulia xazis teqnikur-ekonomikuri maCveneblebi. Tanamedrove pirobebSi sazRvargareTis rigi qveynebis rkinigzis xazze Semadgenlobis wonis norma aRwevs 1000 tonas da mets. samTo rkinigzebze, rogoric marabda-karwaxia matareblis wona garda qanobisa da lokomotivis simZlavrisa izRudeba rigi sxva faqtorebiT, rogorebicaa mcireradiusian mrudebSi Tvalsa da relss Soris SeWidulobis koeficientis Semcireba, cicabo aRmarTebze lokomotivis wevis Zravebis gadaxureba, damuxruWebis piroba da a.S. lokomotivis wevis Zalis sidide mniSvnelovnad aris damokidebuli Tvalsa da relss Soris SeWidulobis koeficientis mniSvnelobaze. am koeficientis mniSvnelobas axasiaTebs cvalebadobis farTo diapazoni da ZiriTadad damokidebulia moZraobis siCqareze,

bandaJebisa da relsebis samuSao zedapiris masalasa da mdgomareobaze, lokomotivis tipze, gzis gegmasa da profilze, adgilmdebareobis klimatur pirobebze da a.S. Aaqedan ZiriTads warmoadgens relsis Tavis mdgomareoba da klimaturi pirobebi.

saproeqto rkinigzisaTvis erT-erT mTavar parametrs Seadgens matareblis saangariSo wonis norma. vinaidan maszea damokidebuli xazis simZlavre da daproeqtebis rigi teqnikuri normebi. savagono Semadgenlobis saangariSo (bruto) wona gamoiTvleba formuliT [17]

$$Q = \frac{F_k - P(\omega_0' + i_{\text{sax}})}{\omega_0'' + i_{\text{sax}}} \text{ t } \ldots (3.1)$$

sadac: F_k – lokomotivis saangariSo wevis Zalaa,

ВЛ II lokomotivisTvis $F_k = 46000$kg;

P – lokomotivis wonaa, P=184 t;

i_{sax} – saxelmZRvanelo qanobia, ‰.

ω_0' da ω_0'' - Sesabamisad lokomotivisa da savagono Semadgenlobis ZiriTadi xvedriTi winaRobebia, kg/t.

gaangariSebisaTvis SeiZleba miaxloebiT miviRoT:

ω_0'=3.0 kg/t; ω_0''=1.5 kg/t.

wevis gaangariSebis wesebis Tanaxmad [17] saproeqto rkinigzebisaTvis matareblis wonis normis dadgenisas lokomotivis wevis Zala mcirdeba elmavlebisaTvis 5%-iT, xolo TbomavlebisaTvis – 7%-iT.

marabda-axalqalaqis rkinigzis xazis saxelmZRvanelo qanobi Seadgens 35 ‰. am monacemebisaTvis satvirTo matareblis wonis norma Seadgens

$$Q = \frac{46000 \cdot 0.95 - 184 \cdot (35 + 3.0)}{1.5 + 35} = 1000 \text{ t}$$

marabda-axalqalaqis rkinigzis xazi gadis rTul topografiul da klimatur pirobebSi. misi calkeuli ubnebi zRvis donidan 2000 metrze met simaRleze mdebareobs. klimati mkveTri kontinentaluria, zamTari mkacri, romelic grZeldeba 6-7 Tve. atmosferuli naleqi 533 mm, Tovlis safarvelis sisqe 111 sm. ubanze gvxvdeba mcireradiusiani mrudebi (R=300 m). yovelive amis gaTvaliswinebiT mosalodnelia relsis Tavsa da wamyvan Tvals Soris SeWidulobis (gadabmis) saangariSo koeficientis Semcireba.

lokomotivis wevis Zalas ZiriTadad gansazRvravs zemoTaRniSnuli ψ_k koeficientis sidide [19] [25].

Semadgenlobis wonis gaangariSebisas wevis Zalis udidesi mniSvneloba gadabmis pirobiT ganisazRvreba formuliT

$$F_k = 10^3 \cdot P \cdot \psi_k \text{ kg} \quad (3.2)$$

sadac, P=∑P da aris lokomotivis gadabmis wona wamyvan RerZze. radgan garkveuli tipis lokomotivisaTvis gadabmis wona mudmivia, wevis Zalis gadabmiT SezRudvis ZiriTad faqtors warmoadgens SeWidulobis koeficienti.

SeWidulobis koeficienti relssa da Tvals Soris ВЛ11

elmavlis SemTxvevaSi gamoiTvleba empiriuli formuliT:

$$\psi_k = 0.28 + \frac{3}{50+20V} - 0.0007V \quad (3.3)$$

ВЛ11 lokomotivis saangariSo siCqare Seadgens 46,7km/sT. am siCqarisaTvis SeWidulobis koeficientis mniSvneloba tolia 0.25.

rogorc Cans, matareblis wonis normis dadgenaSi arsebiTi mniSvneloba aqvs ψ_k koeficients. ψ_k koeficienti metad rTuli bunebisaa, axasiaTebs cvalebadobis sakmaod farTo diapazoni da damokidebulia metad mraval faqtorze, romelTa Soris arsebiTia relsis Tavis mdgomareoba, umTavresad sisvele da gaWuWyianeba. misi bunebis dasadgenad mravali cdebia Catarebuli evropisa da amerikis qveynebSi. Catarebuli cdebis umravlesoba gviCvenebs, rom ψ_k koeficientis udidesi umravlesoba (70%) mSrali relsebisaTvis meryeobs 0.12–0.2 intervalSi, xolo WuWyiani relsebisaTvis 0.05_0.1 farglebSi. e.i. relsis Tavis dasvelebisa da gaWuWyianebis Sedegad (atmosferuli naleqebi, TovliT danamqvra, TrTvili, cvari, mtveri, navTobproduqtebiT gaWuWyianeba da a.S.) es koeficienti mniSvnelovnad mcirdeba. adgilobrivi amocveTebi relsebsa da bandaJebze, adidebs ra savali nawilis rxevas xels uwyobs SeWidulobis koeficientis sididis Semcirebas. matareblis wonis normis dadgenisas zemoTmoyvanili koeficientis mniSvnelobebs Cven ver daveyrdnobiT. saWiroa eqspluataciur pirobebSi cdebis Catarebis safuZvelze dadgindes am regionisaTvis ψ_k-s normatiuli mniSvneloba. SeWidulobis koeficientis mniSvnelobis asamaRleblad mimarTaven kvarcis sufTa silis moyras relsis Tavebze, magram es RonisZieba aRniSnul koeficients mSrali relsebisTvis zrdis mxolod 0.2-mde [21].

wevis Zalis sidide, roca $\psi_k = 0{,}2$, toli iqneba

$$F_k = 10^3 \cdot 184 \cdot 0.2 = 36800\text{kg}$$

Sesabamisad, matareblis wonis norma formula (3.1)-is Tanaxmad tolia $Q = 820$ tonis.

SeWidulobis koeficientis sidide mcirdeba mrudebSi (R<500 m) Tvlebis wacurebis zrdis gamo. SeWidulobis koeficientis Semcireba mrudis radiusis sididesTan damokidebulebiT gaiTvaliswineba koeficientiT $\psi_{kp} = K_\psi \cdot \psi_k$, sadac

$$K_\psi = \frac{250 + 1.55R}{500 + 1.1R} \qquad (3.3)$$

Cveulebrivad, roca saangariSo wevis Zala gansazRvrulia wamyvani Tvalis relsTan SeWidulobis pirobiT, ψ_k koeficientis Semcirebas akompensireben mrudis farglebSi da mis win aRmarTis mxaris qanobis SemsubuqebiT. eqvivalentur qanobs iTvlian Semdegi formulis daxmarebiT:

$$i_\psi = \left(1 - K_\psi\right) \cdot i$$

marabda-axalqalaqis grZivi profilis analizma gviCvena, rom qanobis aseTi Serbileba yvelgan ar aris gaTvaliswinebuli. amitom grZivi profilis gadakeTeba rom ar dagvWirdes, es garemoeba unda gaviTvaliswinoT wonis normis dadgenisas. matareblis wonis norma unda ganisazRvros ara saxelmZRvanelo qanobis, aramed dayvanili qanobis mixedviT.

$$i_{\text{dayv.}} = i_{\text{namd.}} + i_{\text{ekv.}} + i_\psi$$

$i_{\text{namd.}}$ _ namdvili qanobia, ‰;

$i_{\text{ekv.}}$ _ mrudis winaRobis ekvivalenturi qanobia, ‰;

ganvixiloT marabda-axalqalaqis rkinigzis xazis ubani pk477-dan pk488-mde. am ubanze gvaqvs Seqceuli mrudebi radiusiT R=300 m. mrudis winaRoba tolia $i_{\text{ekv.}} = \frac{700}{R} = 2.3$ ‰, xolo formula (3.3)-is Tanaxmad

$$K_\psi = \frac{250 + 1.55 \cdot 300}{500 + 1.1 \cdot 300} = 0.86$$

xolo $i_\psi = (1 - 0.86) \cdot 35 = 4.9$ ‰

profilis namdvili qanobi am ubanze Seadgens 32.7 ‰.

amrigad, dayvanili qanobis sidide toli iqneba

$$i_{\text{day.}} = 32.7 + 2.3 + 4.9 = 39.9\ ‰$$

Semadgenlobis wonis norma formula (3.1)-is Tanaxmad toli iqneba

$$Q = \frac{0.95 \cdot 46000 - 184 \cdot (3 + 39.9)}{1.5 + 39.9} = 865 \text{ t}$$

Tu mxedvelobaSi miviRebT im garemoebas, rom SeWidulobis koeficienti Tvalsa da relss Soris mcirdeba 0.2-mde, maSin wevis saangariSo Zala toli iqneba 36800 kg – am SemTxvevaSi ki wonis norma tolia $Q = 650$t.

rogorc cnobilia, marabda-axalqalaqis rkinigzis xazi xasiaTdeba grZeli cicabo aRmarTebiT, amitom wevis Zravebs muSaoba uxdeba maqsimaluri datvirTviT, ris Sedegac mosalodnelia Zravebis gadaxureba. am movlenis Tavidan acilebis mizniT Zravebi gadayavT saaTobriv reJimze, xolo Tu moZraobis dro daZabul aRmarTze erT saaTs aRemateba, maSin xangrZliv reJimze.

ВЛ II lokomotivisaTvis saaTobrivi reJimis Sesabamisi wevis Zala Seadgens $F_{k(\text{sT})} = 39760$kg, minimaluri saangariSo siCqare $V_{(\text{sT})} = 48.7$ km/sT, xangrZlivi muSaobis reJimisaTvis igive sidideebi Seadgens $F_{k\infty} = 32480$ km da $V_{\infty} = 51.2$ km/sT. marabda-axalqalaqis mimarTulebiT daZabuli, cicabo qanobiani aRmarTis saerTo sigrZe Seadgens daaxlovebiT 46 km. cxadia masze wevis Zravebma unda imuSaos saaTobrivi reJimiT, vinaidan am aRmarTze svlis dro tolia

$$t = \frac{60 \cdot 46}{48.7} = 56.7 \text{ wT}$$

amrigad, satvirTo matareblis wonis norma marabdidan axalqalaqis mimarTulebiT wevis Zravebis gadaxurebis pirobiT (3.1) formulis Tanaxmad Seadgens $Q = 900$ t, rac aRemateba dadgenili wonis normas dayvanili qanobis gaTvaliswinebiT. rac imaze miuTiTebs, rom am ubanze elmavlis saaTobrivi reJimiT muSaobisas wevis Zravebis gadaxureba mosalodneli ar aris.

rogorc zemoT iyo aRniSnuli, marabda-axalqalaqis ubani gamoirCeva mkacri klimaturi pirobebiT da bunebrivia SeWidulobis koeficientis mniSvnelobebi zamTrisa da zafxulis periodSi gansxvavebuli iqneba. SeWidulobis koeficientis faqtiuri mniSvnelobis dasadgenad saWiroa Catardes eqsperimentaluri kvleva am ubanze da dadgindes ψ_k realuri sidideebi. wevis gaangariSebis wesebis Tanaxmad [17] zamTris periodSi uaRresad araxelsayrel pirobebSi (rasac adgili aqvs mocemul regionSi) SesaZlebelia SeWidulobis koeficienti, dadgenili (3.3) formulis mixedviT SevamciroT 15%-iT.

e.i. zafxulis periodSi viRebT ψ_k-s mniSvnelobas 0.25, zamTris periodSi – 0.20. maSin `sezonuri~ wonis normebi toli iqneba: zafxulSi – 1700 t, zamTris periodSi – 1300 t (ormagi wevis SemTxvevaSi).

daskvna

1. matareblis wonis normis marabda-axalqalaqis xazze ormagi wevisaTvis Seadgens 1700 t (zafxuli) da 1300 t (zamTari);
2. zemoTaRniSnuli normebi ar izRudeba wevis Zravebis gadaxurebis pirobiT;
3. SeWidulobis koeficientis faqtobrivi mniSvnelobis dasadgenad saWiroa eqsperimentis Catareba uSualod arsebul xazze;
4. tvirTbrunvis zrdasTan erTad Seiqmneba sammag wevis saWiroba, risTvisac wonis normebi toli iqneba 2500 t (zafxuli) da 2000 t (zamTari).

3.1 matareblebis wonis normis gansazRvris Taviseburebebi mTiani reliefis pirobebSi
Tbowevis gamoyenebisas

Cveni qveynis rkinigza mTlianad eleqtroficirebulia. eleqtroficirebuli rkinigzebis gamtarunarianoba TbowevasTan SedarebiT vake da mTiswina pirobebSi 20_25 %-iT metia, xolo mTian pirobebSi 30_40 %-iT. eleqtrofikaciis Rirebulebis rkinigzebis saerTo RirebulebaSi mniSvnelovan nawils Seadgens (saerTo Rirebulebis daaxlovebiT 20 %).

im SemTxvevaSi, roca gadazidvis zomebi mcirea, advilad SesaZlebelia mizanSewonili aRmoCndes Tbowevis gamoyeneba. Cvens pirobebSi magaliTad turistuli marSrutebis aTviseba, an samrewvelo regionebidan madneulis gamotanis SemTxvevaSi ufro xelsayreli iqneba rkinigzebis daproeqteba TboweviT.

rkinigzebis daproeqtebisas mTian pirobebSi Tbowevis gamoyenebis SemTxvevaSi aucilebelia gaviTvaliswinoT is garemoeba, rom zRvis donidan simaRlis matebasTan erTad mcirdeba dizelis Zravis simZlavre. Tbomavlis wevis Zala [17] am SemTxvevaSi gamoiTvleba formuliT

$$F_k = F \cdot (1 - K_p - K_t) \qquad [3.21]$$

sadac: F - Tbomavlis wevis Zalaa standartul atmosferul pirobebSi (760 mm vercxliswylis svetiT, garemos temperatura 20^0C.)

K_p - koeficientia, romelic iTvaliswinebs dizelis Zravis simZlavris Semcirebas wnevis dacemisas;

K_t - igive, garemos temperaturis matebasTan dakavSirebiT.

zogierTi TbomavlebisaTvis K_p da K_t koeficientebis mniSvnelobebi dadgenilia da mocemulia wevis gaangariSebis wesebSi [17].

cxrilSi 15 mocemulia K_p-is sidideTa mniSvnelobebi, xolo cxrilSi 16 K_t-sidideTa mniSvnelobebi wnevisa da temperaturis cvalebadobasTan dakavSirebiT.

cxrili 15

Ddizelis Zravis simZlavris damokidebuleba simaRlesTan

K_p - koeficientis mniSvnelobebi

Tbomavlis seria	**$h_{bar.}$ kpa (mm vercxliswylis sveti)**					
	101 (760)	99 (740)	96 (720)	93 (700)	91 (680)	88 (660)
TЭ3	0	0.025	0.051	0.078	0.105	0.132
2 TЭ10, 2 TЭ10B,	0	0.028	0.057	0.086	0.115	0.144
2 TЭ10M	0	0.022	0.044	0.066	0.088	0.110
2 TЭ116						

cxrili 16

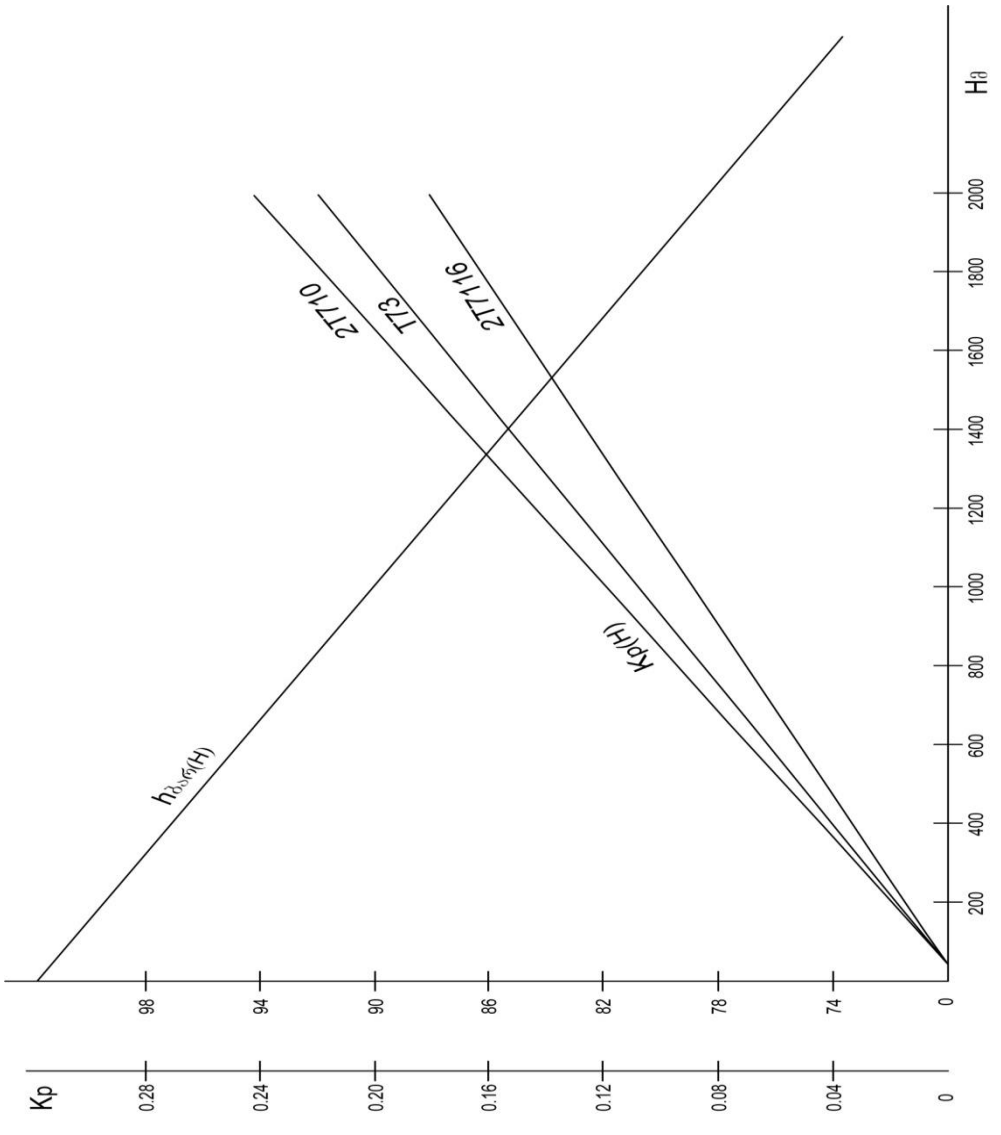
Ddizelis Zravis simZlavris damokidebuleba temperaturisagan

K_t - koeficientis mniSvnelobebi

Tbomavlis seria	**t^0C**			
	< 20	30	40	50

ТЭ3	0	0.045	0.090	0.135
2 ТЭ10Л, 2 ТЭ10,	0	0.050	0.100	0.150
2 ТЭ10М	0	0.040	0.080	0.120

mTian pirobebSi rkinigzebis daproeqtebisas xelsayrelia visargebloT K_p koeficientis damokidebulebiT zRvis donidan simaRlis mniSvnelobasTan damokidebulebiT (nax. 16).



Nnaxazi 16. K_p koeficientis damokidebuleba simaRlesTan

K_p (H) damokidebuleba aproqsimacia swori xaziT kargad gamoixateba gantolebebiT sxvadasxva TbomavlebisaTvis

$$ТЭ3\ K_p = 1.09 \cdot 10^{-4} H \qquad (3.22)$$

$$2\ ТЭ10Л, 2\ ТЭ10В, 2\ ТЭ10М - K_p = 1.09 \cdot 10^{-4} H$$

$$2\ ТЭ116\ K_p = 1.09 \cdot 10^{-5} H \qquad (3.23)$$

zemoT moyvanili monacemebis safuZvelze SeiZleba davaskvnaT, rom dizelis Zravis simZlavre yovel 100 m simaRleze mcirdeba 0.9 ÷ 1.2 %-iT.

analogiuri midgoma aris am sakiTxebze evropis qveynebSi, kerZod germaniis federaciul respublikaSi. atmosferuli wnevis $h_{bar.}$ simaRlesTan damokidebulebas [22] [23] aqvs Semdegi saxe:

$$h_{bar.}=101.325[(288-0.0065H)/288] \qquad (3.24)$$

am formuliT miRebuli sidideebi axlosaa nax. 16-ze naCveneb funqcionalur damokidebulebasTan.

temperaturis cvalebadoba simaRlesTan damokidebulebiT ganisazRvreba formuliT

$$\Delta T=0.0065H$$

zemoT moyvanili temperaturisa da simaRlis damokidebulebis gaTvaliswinebiT germaniaSi dizelis simZlavres gamoiTvlian formuliT

$$N = N_0(1 - \alpha H) \qquad (3.25)$$

N_0 - dizelis simZlavre zRvis donidan $(H = 0)$

α - koeficientia, romlis mniSvneloba icvleba $1 \cdot 10^{-4}$-dan

(gagrilebs gareSe), $3.5 \cdot 10^{-5}$-mde - gagrilebiT.

saTbobis xarji toli iqneba

$$E = E_0(1 + \beta H) \qquad (3.26)$$

E_0 - saTbobis xarjia zRvis doneze;

β - koeficientia, romelic icvleba $1.9 \cdot 10^{-5}$-dan $4 \cdot 10^{-6}$ (gagrilebis gareSe da gagrilebiT).

wevis gaangariSebis wesebis Tanaxmad matareblis masis dadgenisas atmosferuli pirobebis gaTvaliswinebiT Tbomavlis wevis Zala miiReba

$$F = F_k \cdot \left(1 - K_p - K_t\right)$$ - toli.

am SemTxvevaSi saangariSo aRmarTze SenarCunebuli iqneba lokomotivis minimaluri saangariSo siCqare.

im SemTxvevaSi, Tu gza gadis 1000 metramde simaRleze zRvis donidan, masa mcirdeba 10_12 %-iT (lokomotivis seriisagan damokidebulebiT) standartul atmosferul pirobebTan SedarebiT. Tu trasa gadis 1500 metrze zRvis donidan, maSin matareblis masa mcirdeba 15_18 %-iT, xolo Tu trasa gadis 2000 metrze zRvis donidan, maSin masa mcirdeba 22_25 %-iT. amitom mTian pirobebSi aseTi meTodiT matareblis masis gansazRvra yovelTvis ar aris mizanSewonili da ekonomiurad gamarTlebuli. profesor i. kantoris gansazRvris Semdegi meTodi, romlis arsi mdgomareobs SemdegSi: matareblis masis gansazRvrisas lokomotivis saangariSo wevis Zalis mixedviT, romelic miRebulia wevis gaangariSebis wesebSi saxelmZRvanelo qanobze moZraobisas, dabali atmosferuli wnevisa da maRali (20^0-mde) temperaturisas moZraobis siCqare daecema minimalur saangariSo siCqareze dabla.

Cven SevecadeT dagvesabuTebina SemoTavazebuli meTodis teqnikur_ekonomikuri efeqtianoba. amisaTvis CavatareT wevisa da saeqspluatacio ekonomikuri gamoTvlebi pirobiTi mTiani monakveTisaTvis, romlis sigrZe aviReT 300 km. saxelmZRvanelo qanobi 9 ‰, Tbomavlis tipi 3ТЭ10М.

wevis norma lokomotivis wevis Zalis standartuli mniSvnelobisaTvis tolia 7250 t, xolo atmosferuli pirobebis gaTvaliswinebiT H=1300 m da garemos temperatura _ 39^0C; K_p=0.155 da K_t=0.095 wevis Zalas miviRebT $F = F_k \cdot \left(1 - K_p - K_t\right)$ tols da gamoviangariSebT matareblis masas. miviRebT, rom $Q = 6000$t.

pirvel SemTxvevaSi saxelmZRvanelo qanobze aRmarTis mimarTulebiT siCqare gamodis saangariSo siCqareze 17 km/sT-iT naklebi, xolo meore SemTxvevaSi is tolia lokomotivis minimaluri saangariSo siCqaris _ 23.4 km/sT-Si. matareblis masis gazrdis SemTxvevaSi 7250 tonamde moZraobis saSualo siCqare mcirdeba 8 %-iT. matulobs lokomotivis meqanikuri muSaoba da saTbobis xarji, rac aisaxeba matareblis gadaadgilebis xarjebis 15 %-ian zrdaSi (ix. cxrili 17). amasTanave matareblis masis gazrdiT (21%) mcirdeba matarebelTa ricxvi da jamuri saeqspluatacio xarjebi mcirdeba 6 %-iT, xolo salokomotivo jamuri Rirebuleba `l~ - 10 %-iT. moZraobis siCqaris

SemcirebasTan dakavSirebiT izrdeba savagono parkis Rirebuleba `3~. jamuri dayvanili xarjebi l+v+$C \cdot T_{naz.}$ (sadac $T_{naz.}$ - nazRaurobis normatiuli norma - 10 weli) mcirdeba 6 %-iT. marTalia moZraobis saSualo siCqare pirvel variantSi mcirdeba, magram imis gamo, rom matareblis masa didia, amitom xazis gamzidunarianoba izrdeba.

rogorc variantebis Sedarebam gviCvena meore variantSi (roca $Q = 6000$ t) jamuri dayvanili xarjebi 65 %-iT metia, vidre im variantSi, roca $Q = 7250$ t.

cxrili 17

variantebis maCveneblebi

maCveneblebi	**matareblis masa**	
	$Q = 6000$	$Q = 7250$
svlis dro ubanze sT-Si	5.05	5.50
moZraobis saSualo siCqare, km/sT saTbobis xarji, %	57.5	53.0
matareblis gadaadgilebis xarjebi, %	8.43/100	2.62/113
wliuri eqspluataciuri xarjebi, %	100	1.5
salokomotivo parkis Rirebuleba, %	100	94
savagono parkis Rirebuleba	100	90
jamuri dayvanili xarjebi	100	101
	100	94

unda aRiniSnos, rom sakiTxis saboloo gadawyvetisaTvis yovel konkretul SemTxvevaSi saWiroa Catarebuli iqnas variantebis teqnikur-ekonomiuri Sedareba.

sabolood ki SegviZlia davaskvnaT, rom rTul atmosferul pirobebSi matareblis masa unda ganisazRvros lokomotivis standartuli wevis Zalis mixedviT (saangariSo siCqaris SemcirebiT) rac iZleva garkveul ekonomikur efeqts.

4. rkinigzis liandagis Tovlisgan dacva

Cveni qveynis rigi sarkinigzo da saavtomobilo gza ganTavsebulia intensiuri qarbuqis zonebSi, romelic rig SemTxvevaSi drodadro safrTxes uqmnis sarkinigzo da saavtomobilo transports.

Tovlis safariTa da klimaturi zegavleniT gamowveuli cvlilebebi did gavlenas axdenen saxalxo meurneobis praqtikaze, gansakuTrebiT es SeimCneva transportisa da soflis meurneobis sferoebSi.

satransporto obieqtebis TovliT danamqrisagan damcavi Tovldamcavi da TovlSemakavebeli mowyobilobebis daproeqtebisaTvis amJamad ZiriTadad gamoiyeneba empiriuli meTodebi.

mravalwliani gamocdilebebisa da mravalricxovani Secdomebis fasad sarkinigzo da saavtomobilo transportis Sesabamisi specialistebis mier SemuSavebulia Tovldamcav nagebobaTa ase Tu ise warmatebul saSualebaTa kompleqsebi.

Tovlisgan dacvis mTavar, yvelaze ufro rTul da Seuswavlel problemas warmoadgens qarbuqis meqanikis problema. im ZiriTadi fizikur-meqanikuri arsis codna, romlebic iwveven Tovlis deflaciasa da TovliT danamqras, saSualebas mogvcems movaxdinoT am procesebze zegavlena da uaryofiTi temperaturisas qarebis mier Tovlis gadatanis kanonzomierebis dadgena.

qarbuqis meqanikis problemis safuZvels warmoadgens hidrodinamikuri problema, romelic SeiZleba ganvixiloT rogorc polifazuri nakadis hidrodinamikis kerZo SemTxveva. polifazuri da orfaziani nakadebis hidrodinamika ganekuTvneba saerTo hidrodinamikis yvelaze ufro naklebad damuSavebul nawils.

mravalwliani cdebiT SemuSavebulia qarbuqze xelovnuri zemoqmedebis saSualebebi. yvelaze ufro xSirad gamoiyeneba qarbuqis zolSi mowyobili sxvadasxva saxis zRudarebi, romlebic iwveven Tovlis deflaciis Sewyvetas an misi sididis Semcirebas. rig SemTxvevaSi aseT zRudarebs gaaCniaT uku daniSnuleba, qarbuqis nakadis daCqareba da misi akumulaciis ar daSveba.

orive SemTxvevaSi am zRudarebis konfiguracia unda iyos iseTi garsSemomdeni formis, raTa minimaluri danaxarjebiT moxdes maqsimaluri zegavlena

TovliT gajerebul qaris nakadze, Tumca dReisaTvis cudi garsSemomdeni formis mqone nagebobaTa hidrodinamika Tavis ganviTarebis embrionalur stadiaSia.

orfazian nakadSi, romelic qarbuqad iwodeba erTaderT mkvrivi fazis rols umetesad asrulebs Tovli, magram xSiria SemTxvevebi, rodesac qaris mier TovlTan erTad gadaitaneba sxvadasxva saxis gruntis nawilakebi.

qarbuqis gamokvleva SeuZlebelia Tovlis fizikur-meqanikuri Tvisebebis Seswavlis gareSe, romelic safuZvlianad gansxvavdeba qaris nakadis mier gadatanili mineraluri nawilakebisa da organuli Semvsebebis Sesabamisi Tvisebebisagan.

qarbuqis nakadSi ar SeiZleba ugulvelvyoT fazebSorisi gadanacvleba, radgan Tovlis gadatanisas adgili aqvs misi nawilis aorTqlebas. amasTan erTad saWiroa vicodeT Tovlis nawilakebis forma da zomebi, maTi meqanikuri simtkice. sxvadasxva saxis Tovlis granulometriuli Semadgenloba da a.S. yvela zemoT aRniSnuli sakiTxi dReisaTvis arasakmarisadaa Seswavlili.

problemis praqtikuli Sedegebis gamoyenebas didi mniSvneloba gaaCnia rkinigzebisa da saavtomobilo gzebis, samrewvelo sawarmoTa, aerodromebis, qalaqebisa da dasaxlebuli punqtebis, sasoflo-sameurneo melioraciis, gamosazamTrebeli nargavebis da a.S. TovliT danamqrisagan dasacavad.

qarbuqis Teoriis Seswavla mniSvnelovania agreTve Tovlis zvavebTan brZolis, qalaqebis wyliT momaragebis, hidrologiuri prognozirebis, hidroteqnikur nagebobaTa mSeneblobisa da a.S. sferoebSi.

rkinigzisa da saavtomobilo gzis calkeuli ubnebis qarbuqis Sedegad danamqrisagan damcav nagebobaTa daproeqtebisa da mSeneblobisaTvis aucilebelia qarbuqis mier gadatanili Tovlis kanonzomierebis Teoriuli safuZvlebis Seswavla, gaanalizeba da Sesabamisi daskvnebis gamotana.

rkinigzis xazis gamarTul da Seuferxeblad muSaobisaTvis aucilebelia misi dacva Tovlisagan. iseTi mTagoriani qveynisaTvis, rogoricaa saqarTvelo TovlTan brZolas didi mniSvneloba eniWeba. gansakuTrebiT rkinigzis is monakveTebi, romlebic gadis rTul topografiul da klimatur pirobebSi warmoadgenen danamqris did riskebs. marabda-axalqalaqi-karwaxis xazi erT-erTi urTulesia Tavisi klimaturi, topografiuli geologiuri pirobebiT. rogorc cnobilia, rkinigzis es monakveTi erT-erTi Semadgeneli nawilia saerTaSoriso rkinigzis xazis. amitom didi yuradReba unda mieqces masze matareblis Seuferxebel da usafrTxo moZraobis uzrunvelyofas. am xazis zogierTi monakveTi ise

inamqreba Tovlisagan, rom moZraoba izRudeba 5-6 Tvis manZilze. mxedvelobaSia misaRebi is garemoebac, rom aRniSnuli rkinigzis xazi gadis zRvis donidan 2000 m da met simaRleze – alpur da subalpur zonebSi, sadac Tovlis safaris sisqe maRalia, didia agreTve qaris siCqarec. Cvens mier SemoTavazebulia liandagis Tovlisagan dacvis ramodenime RonisZiebani, romelTa praqtikaSi gatareba mniSvnelovnad gazrdis matareblis Seuferxebel da usafrTxo moZraobis pirobebs.

rkinigza unda muSaobdes gamarTulad da Seuferxeblad weliwadisa da dRe-Ramis nebismier monakveTSi. Tovli, romelic liandagze moxvdeba, moZrav Semadgenlobas uqmnis damatebiT winaRobas, amcirebs moZraobis siCqares, izrdeba energetikuli xarjebi da saerTod rTuldeba rkinigzis saeqspluatacio muSaoba. amitom TovlTan brZolas, rogorc msoflios mraval qveyanaSi, CvenTanac didi yuradReba eqceva. TovlTan brZolis xarjebi mniSvnelovan nawils Seadgens saerTo momsaxurebis xarjebSi (aranaklebi 20%). TovlTan brZolis sakiTxi daisva maSin, roca eqspluataciaSi Sevida pirveli rkinigza. gansakuTrebiT aqtiuria es sakiTxi iseT qveynebSi, sadac rkinigza gadis rTul topografiul da klimatur pirobebSi, rogoricaa ruseTi, aSS, Sveicaria, avstria, iaponia, kanada da sxva.

eqspluataciis gansakuTrebulma rTulma pirobebma zamTris periodSi rusi mecnierebis winaSe daayena sakiTxi, gamoemuSavebinaT efeqturi RonisZiebebi liandagis Tovlisagan dasacavad. maT mier SemuSavebuli iqna Tovlisagan damcavi saSualebebi, romlebmac saSualeba misca Seemcirebina xarjebi da moZraobis Seferxebis likvidacia moexdina. 1861 wels pirvelad iqna gamoyenebuli cocxali nargavebi Tovlis danamqris sawinaaRmdegod. 1863 wels inJ. titovma Seqmna droebiTi gadasatani farebi. 1877 wels n. sredinskis mier pirvelad iqna gamoyenebuli 7 zoliani cocxali nargavebi. me-19 saukunis bolos eqspluataciaSi Sevida mudmivi Tovldamcavi Robeebi.

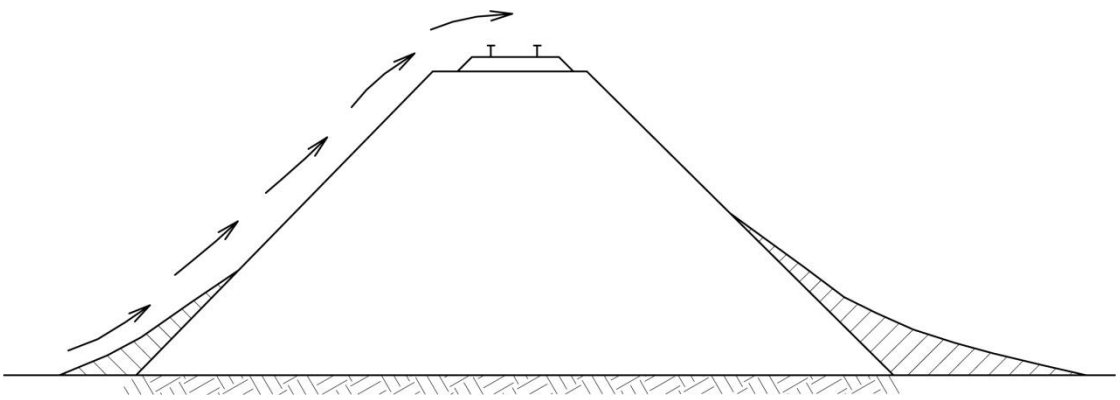
aSS-Si didi yuradReba eqceva Tovlis movlenis Seswavlas, rac ganpirobebulia im garemoebebiT, rom Tovlisagan miyenebuli zarali yovelwliurad ramdenime aseul milions aWarbebs. meore mxriv Tovlis movlenebisadmi interesis gazrda gamowveulia imiTac, rom intensiurad mimdinareobs mTliani regionebis aTviseba (avtomagistralebis mSenebloba, samrewvelo kompleqsi, dasasvenebeli saxlebi da sxva). Tovlis movlenebis SeswavliT aSS-Si dakavebulia aTobiT samecniero, sainJinro, samxedro da samrewvelo dawesebulebebi. bevrma amerikelma mecnierma da

inJinerma SeimuSaves zvavsawinaaRmdego nagebobebis gaangariSebisa da mowyobis meTodebi.

rogorc cnobilia, alpebis qveynebSi didia Tovlisagan miyenebuli zarali. avstriaSi gasuli saukunis 50-ian wlebSi moxda 2 katastrofuli SemTxveva, romelTa msxverpli Seiqmna aseulobiT adamiani, udidesi materialuri zarali miadga qveyanas. jer kidev gasuli saukunis 60-ian wlebSi venaSi daarsda zvavsawinaaRmdego da TqeSsawinaaRmdego instituti satyeo samsaxuris daqvemdebarebaSi. qveynis yvela zvavsaSiS raionebSi instituts aqvs seqciebi. institutis TanamSromlebis mier rekomendaciebi SeiZleba or saxed daiyos: cocxali nargavebis gaSeneba da Tovldamcavi nagebobebis mSenebloba. gansakuTrebiT kargi miRwevebi aqvs avstriul mecnierebs ferdobebis gatyianebis dargSi.

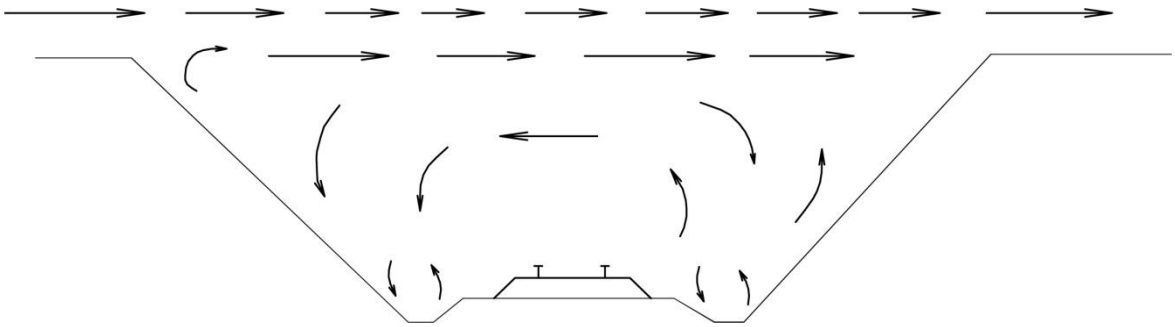
Tovisas rkinigzis liandagi ifareba Tanabari SriT. es garemoeba gansakuTrebul saSiSroebas ar wamoadgens moZraobisaTvis, magram es movlena zrdis moZraobis winaRobas da Tu Tovlis sisqem relsis Tavs 20 sm-iT gadaaWarba, maSin iqmneba saSiSroeba moZravi Semadgenlobis liandagidan gadavardnisa. Tovlis gadatana warmoebs maSin, roca qaris siCqare aRemateba 5 m/wm. qarbuqi seriozul saSiSroebas uqmnis moZraobas, vinaidan Tu liandagi ar aris daculi, warmoiqmneba Tovlis gorebi.

TovliT danamqraze arsebiT gavlenas axdens miwis vakisis ganivi profili. Tu rkinigzis liandagi mdebareobs yrilze, romlis simaRle aRemateba Tovlis safaris sisqes 0.7 metriT, ar inamqreba. es aixsneba im garemoebiT, rom yrili TavisTavad warmoadgens bariers, romelic kumSavs qarbuqs da Sesabamisad zrdis yrilis zemoT qaris siCqares. yrilis orive mxares SeiniSneba Tovlis monatanebi (ix. nax. 17) [24] [25].



nax. 17 yrilis TovliT danamqris sqema

Wrilebi, romelTa siRrme 0.4 metrs aRemateba iTvleba Tovlis danamqris mixedviT saSiS ubnebad. es garemoeba aixsneba im garemoebiT, rom Tovlis namqeri miuaxlovdeba Tu ara Wrils, zustad Wrilis Tavze gaiSleba, kargavs siCqares da Sesabamisad Wrili ivseba TovliT (nax. 18).



nax. 18 Wrilis TovliT danamqris sqema

rkinigzebis daproeqtebisas unda SevecadoT SevamciroT im monakveTebis sigrZeebi, romlebic ganlagebulia WrilSi da dabal yrilze. yrilis minimaluri simaRle dadgindeba Tovlis mosalodneli safaris sisqis mixedviT. moSiSvlebul adgilebSi grZivi profili mizanSewonilia davaproeqtoT yrilis saxiT. yrilis simaRle 0.7 metriT unda aRematebodes Tovlis safaris sisqes (II da III kategoriebze – 0.5 metria). Tovlis mosalodneli ganmeorebadoba I kategoriaze miiReba 1:50 (2%), xolo II da III kategoriaze 1:33 (3%).

Tu yrilis simaRle aRniSnul moTxovnebs ar akmayofilebs, maSin proeqtiT gaTvaliswinebuli unda iqnas TovlsawinaaRmdego saSualebebi (farebi, Robeebi, galerea da sxva).

Cveni qveyana mTagoriania. rkinigza gadis rogorc barSi, aseve mTian regionSic. Sesabamisad zvavsaSiSi adgilebic bevria. magaliTad suramis uReltexili da marabda-axalqalaqis monakveTi. gansakuTrebiT unda aRiniSnos marabda-axalqalaqis rkinigzis xazi. es ubani eqspluataciaSi Sevida gasuli saukunis 80-ian wlebSi. misi saerTo sigrZea 160 km. Tavdapirvelad is iyo adgilobrivi daniSnulebis (III kategoriis). is gadis urTules topografiul da klimatur pirobebSi. misi zogierTi monakveTi zRvis donidan mdebareobs 2000 m da met simaRleze (rac udidesia evropis masStabiT).

raioni uxvTovliania. alpuri da subalpuri zonebis gamo mcenareuli safari umTavresad ar arsebobs. minimaluri saSualo temperatura meryeobs -2_5^0-is farglebSi. Tovlis safaris maqsimaluri simaRle Seadgens 1.2 m. rogorc cnobilia es rkinigzis xazi gaxda saerTaSoriso rkinigzis Semadgeneli nawili. amitom dRis wesrigSi dadga marabda-axalqalaqis rkinigzis xazis reabilitacia-rekonstruqcia da axalqalaqi-karwaxis axali rkinigzis xazis mSeneblobis sakiTxi. mTavrobis dadgenilebiT xazi eqspluataciaSi unda Sevides 2015 wlis bolos.

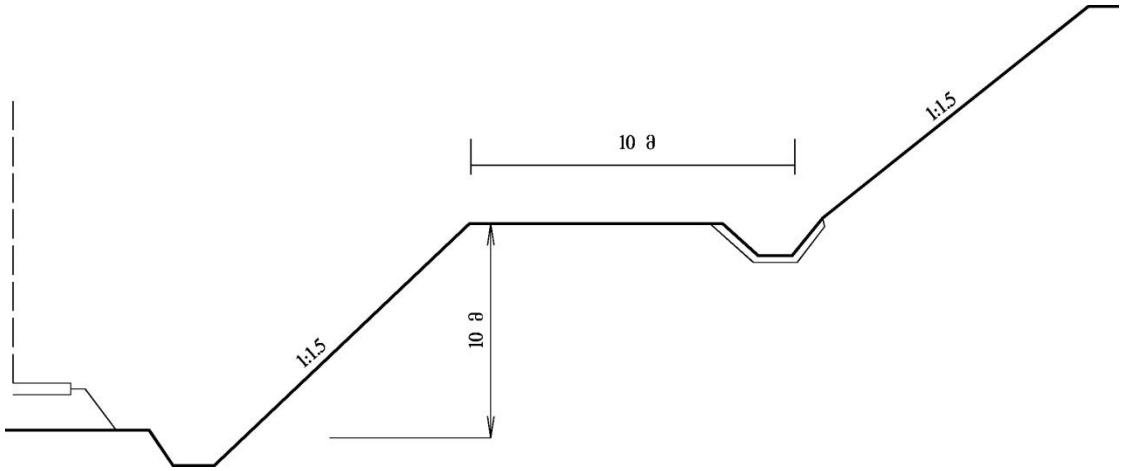
marabda-axalqalaqis rkinigzis monakveTze gvxvdeba Rrma Wrilebi, romlebic yvelaze saSiS monakveTs warmoadgens Tovlisagan danamqris mixedviT. Tovlisagan danamqris gamo weliwadSi 6 Tve xazi umoqmedod aris. danamqvra imdenad intensiuria, rom WrilSi dagrovili Tovli maisis Sua ricxvebamde ar dneba.

rogorc cnobilia saqarTvelo unda gaxdes mowinave turistuli qveyana. amitom momavalSi unda aSendes rogorc rkinigzis xazi, aseve saavtomobilo gzebic. es gzebi ZiriTadad gaivlian mTian pirobebSi, amitom aseTi gzebis Tovlisagan dacvas udidesi yuradReba unda mieqces.

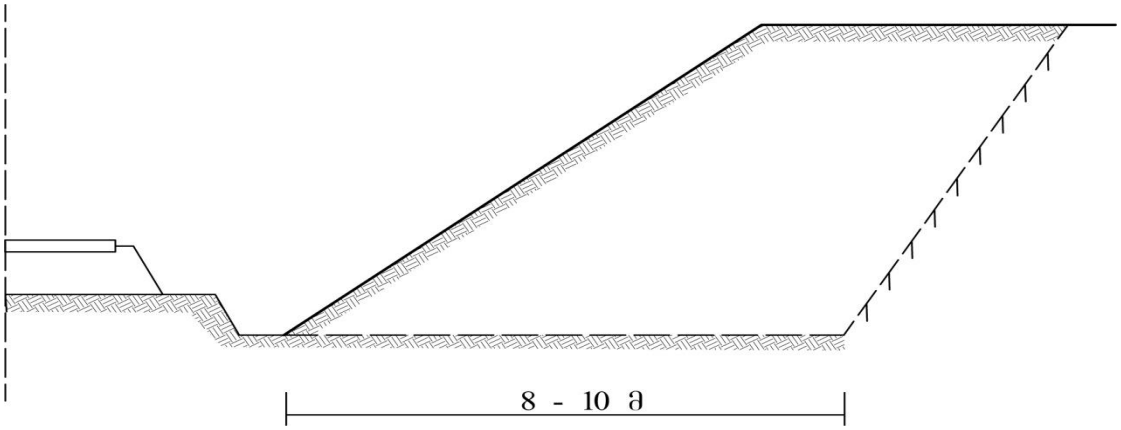
rac Seexeba marabda-axalqalaqis rkinigzis Tovlisagan danamqris yvelaze saSiS ubnebs (Rrma Wrilebs) – proeqtiT gaTvaliswinebulia am ubnebze galereebis mowyoba, xolo rac Seexeba axalqalaqi-karwaxis mSenebare ubans am monakveTze gvaqvs Tovlisagan dacvis ramodenime RonisZiebis SemoTavazeba:

1. Rrma WrilSi (10 m da meti) Taroebis mowyoba (Taros sigane 10 m), nax. 19;
2. Wrilis ferdoebis CamoWra. es RonisZiebebi warmatebiT SeiZleba gamoviyenoT ara Rrma WrilSi (10 metramde). rkinigzis am monakveTze yrilis da Wrilis moculobebs Soris didi disbalansi arsebobs (Wrilis moculoba Seadgens 274292 m^3, yrilis 253037 m^3), amitom mizanSewonili iqneba yrilis ageba ferdobidan CamoWrili gruntiT (aq unda gaviTvaliswinoT gruntis zidvis manZili yrilamde). CamoWris siganem gruntis moculobis mixedviT SeiZleba miaRwios 10÷12 m-s. nax. 20;
3. kombinirebuli meTodi: Tu ferdobis daxra aRemateba 20÷35^0, maSin unda gaviTvaliswinoT Tovldamcavi kedeli, romelic liandagidan minimalur sagabarito manZilze daidgmeba

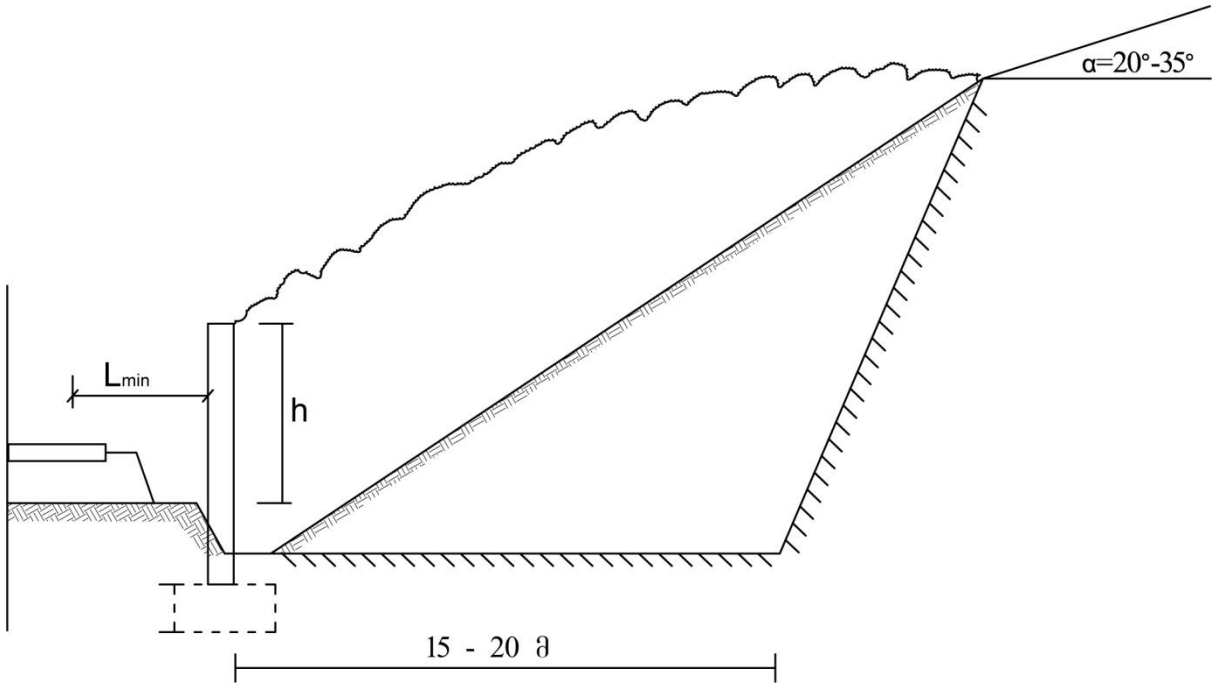
(nax. 21).



nax. 19 Rrma WrilebSi terasebis mowyobis sqema



nax. 20 Wrilis ferdobis CamoWris sqema



N

nax. 21 Tovldamcavi kedlis mowyobis sqema

Wrilis ferdobis daqaneba gruntis saxeobis mixedviT SeiZleba iyos 1:1.05 an 1:1. yvela SemoTavazebul RonisZiebebTan erTad gaTvaliswinebuli unda iyos Tovldamcavi nargavebis gaSeneba.

4.1 rkinigzis trasisa da profilis daproeqteba

im ubnebze, sadac mosalodnelia TovliT danamqra, rkinigzis daunamqravi miwis vakisis mowyobas gaaCnia aqtualuri mniSvneloba, radgan TovliT danamqra xSirad xdeba matarebelTa Semaferxebeli da saxifaTo moZraobis gamomwvevi mizezi, xolo eqspluataciis periodSi TovlTan brZolis procesi saWiroebs did danaxarjebs.

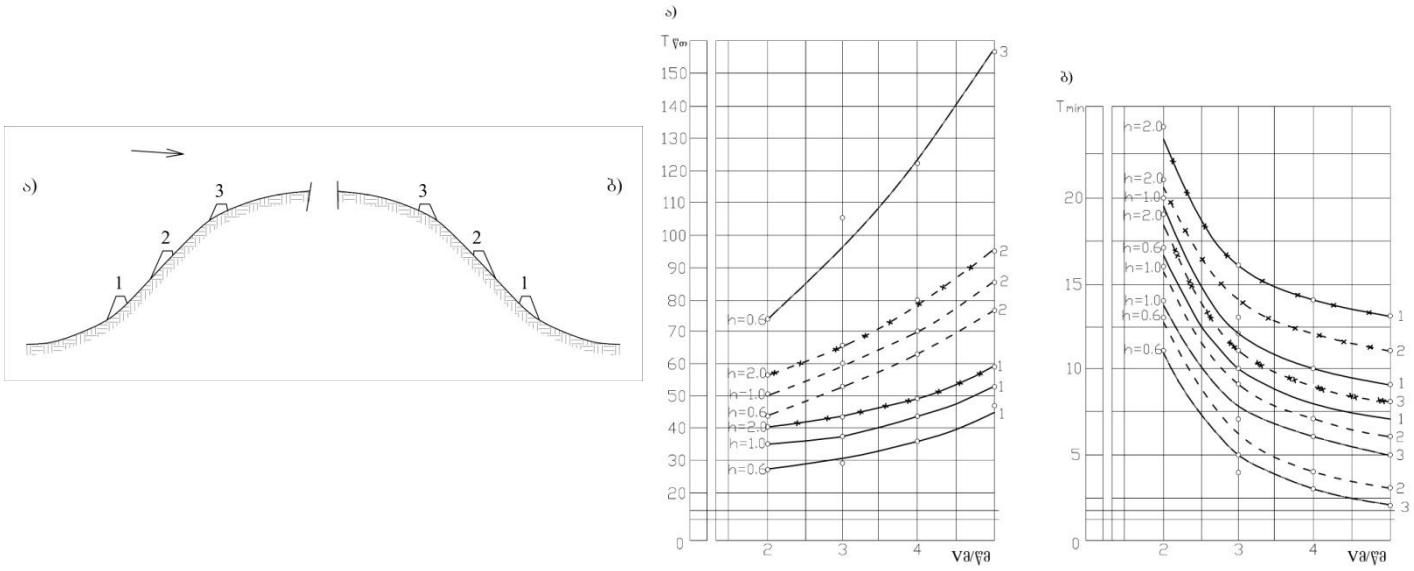
rkinigzebis gegmisa da profilis daproeqteba liandagebis TovliT danamqrisagan acilebis gaTvaliswinebiT arasakmarisadaa asaxuli teqnikur literaturaSi da normatiul dokumentaciebSi.

Tovlis gadatana da danamqra damokidebulia TovldamWeri auzis farTze, liandagis grZiv profilsa da ganiv kveTebze, ubnis geologiur agebulebaze, mosuli Tovlis intensivobasa da raodenobaze, zamTris periodis xangrZlivobaze, qarbuqian dReTa ricxvze, qaris mier Tovlis gadatanis mimarTulebasa da siCqareze.

adgilmdebareobis reliefis yovelgvari cvlileba iwvevs qaris siCqaris cvalebadobas miwis zedapirze. SemaRlebuli adgilebis garsSemovlisas qaris siCqare izrdeba, xolo Cadablebuli adgilebis garsSemovlisas mcirdeba. profilis mkveTrad Secvlis adgilebSi warmoiqmneba qaris siCqaris minelebis an agrigalebis zonebi (aerodinamiuri Crdilebis zona). qaris calkeuli nakadis WavlSi, romelic xvdeba aerodinamikuri Crdilis zonaSi, mcirdeba siCqare, xolo zog SemTxvevaSi adgili aqvs maT ukumoZraobas. amitom qarbuqisa da miwispira qaris dros xdeba aerodinamikuri Crdilovani zonebis intensiuri danamqra.

ferdoze qaris nakadi qvemodan zemoT gadaadgilebisas ganiv kveTSi TandaTan ikumSeba da misi siCqare izrdeba, xolo qaris sawinaaRmdego mxares mdebare ferdoze zemodan qvemoT moZraobisas ganiv kveTSi TandaTan farTovdeba da misi siCqare klebulobs.

naxazze 22 warmodgenilia rkinigzis miwis vakisis SesaZlo ganlagebebi qarpira ferdosa (a) da myudro_qarzurga ferdoze (b) da sxvadasxva simaRlis yrilebis danamqris drois siCqaris sidideebian damokidebulebis grafikebi.



nax. 22 rkinigzis miwis vakisis SesaZlo ganlagebebi qarpira da qarzurga ferdoebze da SesaZlo danamqris grafikebi maTi simaRlisa da qaris siCqaris sidideTa mixedviT

rkinigzebis xazis daproeqtebisas im ubnebze, sadac mosalodnelia TovliT danamqra, garda imisa, rom trasis sigrZe da ZiriTad samuSaoTa moculobebi unda iyos minimaluri, matarebelTa Seuferxebeli da usafrTxo moZraobis uzrunvelsayofad saWiroa daunamqravi liandagis mowyoba.

yvela sxva Tanabari pirobebis SemTxvevaSi rkinigzis xazis daproeqtebisas uzrunvelyofili unda iyos qarbuqisa da miwis zedapirze gadatanili Tovlis miwis vakisidan acileba an misi gadaWera rkinigzis xazamde.

tyiT ganaSenebian ubnebze liandagi ar inamqreba, amitom aseT ubnebze rkinigzis gegmisa da profilis daproeqteba SeiZleba ganxorcieldes yovelgvari SezRudvis gareSe, dadgenili normebis mixedviT, magram Tovlcvenisa da miwis vakisze arsebuli Tovlis dnobis Sedegad wylis datborvisagan dasacavad sasurvelia miwis vakisi daproeqtdes yrilebis saxiT.

gaSlil reliefze, romelic TovliT ar inamqreba, trasa unda ganlagdes yrilebze, romelTa simaRle unda ganisazRvros adgilmdebareobis Taviseburebebis mixedviT.

vake da sustad daseril reliefebze rkinigzis trasirebisas aucilebelia qarbuqis gabatonebuli mimarTulebis dadgena. am mxriv mizanSewonilia trasis mimarTuleba emTxveodes qarbuqis mimarTulebas an misgan gadaxris kuTxis sidide ar aRematebodes 30^0.

qaris liandagis grZivi RerZis mimarT 30^0-dan 90^0-mde kuTxiT mimarTulebis SemTxvevaSi saWiroa yrilis iseTi simaRle, romelic uzrunvelyofs liandagis danamqrisagan dacvas an unda moewyos TovlgadamWeri mowyobilobebi.

yrilis minimaluri simaRle, rodesac trasis grZivi RerZis mimarTulebasa da qaris mimarTulebas Soris kuTxis sidide ar aRemateba 30^0-s SeiZleba viangariSoT formuliT:

$$H \geq h_{\text{T.s.}} + h_0$$

xolo rodesac am kuTxis sidide 30^0-dan 90^0-mdea:

$$H \geq h_{\text{T.s.}} + h_0 + h$$

sadac: $h_{\text{T.s.}}$ - saproeqto ubanze Tovlis safaris sisqea, m;

h_0 - Tovlis safaris saSualo sisqe, romelic grovdeba yrilis gaswvriv zamTris periodSi liandagis gawmendis Semdeg, m;

h_S - miwis vakisis warbas SemaRleba Tovlis yrilis gaswvriv arsebuli zedapiridan, romlis minimaluri sidide Seadgens 0.5 m.

qarbuqis gavrcelebis raionebSi Wrilebi rogorc wesi eqvemdebarebian intensiur danamqras, garda im Wrilebisa, romelTa sigrZe ar aRemateba 400-500 metrs, romlebic ganlagebuli arian sworSi da qarbuqis mimarTulebis paralelurad.

dabali Wrilebi inamqreba ufro swrafad, vidre Rrma Wrilebi, magram matarebelTa usafrTxo moZraobis TvalsazrisiT Rrma Wrilebi ufro saSiSia, radgan maTi gawmenda Tovlisagan gacilebiT rTulia, amitom TovliT danamqrian adgilebze minimumamde unda SevamciroT Wrilebis saerTo sigrZe an gaviTvaliswinoT TovlgadamWeri mudmivi nagebobebis mowyoba.

xeobebSi, romelTa mimarTuleba gabatonebuli qarbuqis mimarTulebas emTxveva, trasa ar inamqreba, magram unda veridoT gverdiT xeobebSi Caweras, sadac mosalodnelia intensiuri danamqra, xolo rodesac qari xeobis ganivad qris, trasa umjobesia gadavitanoT qaris sawinaaRmdego napirze.

gamyofi punqtebis moednebis mimarTuleba unda emTxveodes gabatonebuli qarebis mimarTulebas. maTi ganlageba WrilebSi da mrudeebSi ukiduresad arasasurvelia.

rkinigzis liandagebis TovliT danamqris kanonzomierebebis kvlevisa da naturaluri dakvirvebiT miRebuli gamocdilebebis analizis safuZvelze SesaZlebeli gaxda

gamogvetana daskvnebi TovldamWer saSualebaTa daproeqtebisaTvis saWiro ZiriTadi monacemebis, maTi muSaobis ZiriTadi principebis Sesaxeb da dagvedgina gamoyenebul saSualebaTa dadebiTi da uaryofiTi mxareebi.

arsebul TovldamWer saSualebaTa ZiriTadi naklovnebebi maTi TovliT swrafad Sevseba da dazianebaa, rac iwvevs liandagebis danamqras, xolo eqspluataciis dros maTi namqrisgan gawmenda saWiroebs did SromiT da kapitalur danaxarjebs. amitom maTi muSaobis efeqturobis amaRlebis erT-erT faqtors warmoadgens TovliT gajerebuli qaris moZraobis mimarT iseTi pirobebis Seqmna, rodesac ar moxdeba Tovldamcavebis swrafi danamqra da gaizrdeba maT mier gadaWerili Tovlis moculoba.

gaumWolavi damcavi nagebobis win qaris nakadis moZraoba swrafad icvleba. nagebobis win da ukan warmoiqmneba mdgradi grigaliseburi nakadi, nagebobis ukan miwis zedapirze qaris siCqare iZens ukumimarTulebas, ris gamoc gaumWolavi nageboba swrafad da mcire moculobis TovliT inamqreba.

gisosovani-gamWoli tipis nagebobebi mniSvnelovnad amcireben garveul sididemde gaumWolav nagebobaTa danakliss, magram mTlianad ver xerxdeba am danaklisis aRmofxvra. praqtikuli dakvirvebiT dadgenilia, rom rac ufro metia nagebobis tanSi gamWoli RreCoebis sidide miT ufro grZeli da daxrili forma gaaCnia maT mier gadaWeril Tovlis yrils da Sesabamisad metia misi moculoba.

liandagis TovliT damaqrisagan damcavi RonisZiebebis dasaproeqteblad saWiroa Semdegi monacemebi:

- ubnis gegma horizontalebSi;
- liandagis grZivi profili da ganivi kveTebi;
- TovlSemkrebi auzis farTobi;
- ubnis geologiuri agebuleba;
- mosuli Tovlis intensivoba da raodenoba;
- zamTris periodis xangrZlivoba;
- qarbuqiani dReebis ricxvi;
- Tovlis gadatanis mimarTuleba da siCqare.

ToToeuli ubnisaTvis zemoTaRniSnul monacemebis safuZvelze ganisazRvreba qaris mier Tovlis gadatanis vardula rumbebis mixedviT, romlebic gviCveneben yvelaze

ufro didi raodenobiT gadatanili Tovlis mimarTulebas. am monacemebis mixedviT xdeba ubnebis klasifikacia maTi TovliT danamqris xarisxisa da kategoriis mixedviT.

TovldamWer nagebobaTa Sefasebis xasiaTisa da xarisxis ganxilvisas aucilebelia davadginoT nagebobis tanSi gamavali Tovlis moculoba, raTa maT mier ar moxdes im sididis Tovlis gatareba, romelic gamoiwvevs liandagis danamqras.

nagebobis ukan TovliT gajerebuli qaris nakadidan amogdebuli Tovlis raodenoba tolia kveTebSi Tovlis gadatanis intensiurobisa, romelic gamowveulia qaris siCqaris SemcirebiT da gaiangariSeba formuliT:

$$\Delta q = \propto [(v_1 - v_0)^3 - (v_2 - v_0)^3] \quad (4.12)$$

sadac: $\propto$ - koeficientia, romelic axasiaTebs Tovlis gadatanis sawyis pirobebs;

v_1 - qaris siCqare Semcirebamde (mindvris an velis pirobebSi);

v_2 - qaris siCqare Semcirebis Semdeg (nagebobiT gamowveuli winaRobis Semdeg);

v_0 - qaris is siCqare romelic Seesabameba Tovlis gadatanis dasawyiss.

Tu davuSvebT, rom v_0, v_1 da $\propto$-s sidideebi mudmivia, xolo $v_2 = \int (l)$, sadac l - aris manZili wertilidan rodesac qaris siCqare iwyebs klebas, wertilamde rodesac qaris siCqare iwyebs gazrdas, maSin Tovlis yrilis namatis sidide ganisazRvreba formuliT:

$$\Delta h = \frac{1}{\sigma}\left[\frac{d\Delta q}{dl}\right] = -\frac{3\alpha}{\sigma}(v_2 - v_0)^2 \frac{dv_2}{dl} \qquad (4.13)$$

sadac: σ - aris danaleqi Tovlis simkvrive, t/m^3

Tovlis maqsimaluri sididiT SemaRlebuli adgili anu Tovlis yrilis wveros formirebis wertili nagebobis muSaobis sawyisi momentisaTvis ganisazRvreba Semdegi gantolebiT:

$$\frac{d\,\Delta\, h}{dl} = \frac{3\alpha}{\sigma}(v_2 - v_0)\left[2\left(\frac{dv_2}{dl}\right)^2 + (v_2 - v_0)\frac{d^2 v_2}{dl^2}\right] = 0$$

$$\text{aqedan } \frac{d^2 v_2}{dl^2} = -2\frac{(\frac{dv_2}{dl})^2}{v_2 - v_0} \qquad (4.14)$$

sadac: $v_2 > v_0$, xolo $\frac{d^2v_2}{dl^2}$ - uaryofiTi sididea, amitom Tovlis yrilis wvero, romelic ganisazRvreba (4.13) formuliT gvaZlevs saSualebas davaskvnaT, rom damcavi nageboba swrafad rom ar Seivsos, aucilebelia qaris siCqaris mruds hqondes mdovre moxazuloba siCqaris dacemis sawyisi wertilidan misi minimaluri mniSvnelobis sididis wertilamde. amasTan erTad raTa ar moxdes nagebobis swrafad danamqra aucilebelia qaris siCqaris minimaluri sididis wertili maqsimalurad davaSoroT damcavi nagebobebidan.

amrigad imisaTvis, rom nagebobis ukan qaris siCqaris mruds hqondes mdovre moxazuloba saWiroa gamWoli saxis anu meCxerovani molartyvis mqone nagebobis mowyoba. gamWoli sicarieleebi SeiZleba moewyos rogorc miwis zedapirsa da nagebobis qveda wibos Soris, aseve mis tanSi an orive am kombinaciis saxiT.

damcavi nagebobis qveda nawilsa da mis tanSi gamWoli sicarieleebis datoveba warmoadgens TovldamWeri mowyobilobis efeqturi muSaobis uzrunvelyofis saSualebas, magram am sicarieleebSi gatarebuli Tovlis sididem ar unda Seqmnas liandagebis danamqris safrTxe.

damcavi nagebobis ukan qaris nakadis minimaluri siCqare Tovldasilvis maqsimumis pirobiT ganisazRvreba (4.12) formulis saSualebiT.

Tu davuSvebT, rom v_2 - sidide Seesabameba qaris maqsimaluri sididiT dacemis wertils, maSin:

$$\frac{d\triangle q}{dv_2} = 3\alpha(v_2 - v_0)^2 = 0 \quad \text{aqedan } v_2 = v_{min} = v_0 \qquad (4.15)$$

rogorc warmodgenilidan Cans TovliT dasilvis udidesi sididis misaRwevad aucilebeli ar aris nagebobis ukan qaris siCqaris mTliani CaxSoba. amisTvis sakmarisia, rom velze arsebuli qaris siCqare SevamciroT qaris mier Tovlis gadatanis dasawyisis siCqaremde.

(4.15) formuliT dgindeba TovliT gaJRenTili qaris nakadidan Tovlis mTliani amogdebis piroba qaris siCqaris dawevis dros.

damcavi nagebobis ukan qaris maqsimalurad dasaSvebi siCqare ganisazRvreba imasTan damokidebulebiT, Tu Tovlis ra procentis gatarebaa arasasurveli damcavi zonis ukan. Tu davuSvebT, rom Tovldamcavis muSaobis dasawyisSi Tovlis gatarebis sidide 5%-ia maSin:

$$\frac{Q_{min}}{Q_{max}} \leq 0.05 \text{ an } \frac{(v_{min}-v_0)^3}{(v_{max}-v_0)^3} \leq 0.05 \quad (4.16)$$

anu nagebobis ukan qaris maqsimaluri siCqaris sidide miwis zedapiris Sreze ganisazRvreba utolobiT:

$$v_0 \leq v_{min} \leq 0.45 \quad (4.17)$$

amrigad, 4.15 da 4.17 damokidebulebebiT dgindeba is saerTo pirobebi, romlebic xels uwyobs Tovldamcavis drois didi xnis ganmavlobaSi Sevsebas da uzrunvelyofs maqsimaluri sididis Tovlis gadaWeras.

zemoT ganxiluli moTxovnebi, TovldamWeri mowyobilobebis mier Tovlis minimaluri sididis gatarebisa da mis ukan Tovlis maqsimaluri moculobis gadaWerisa, ganekuTvneba erTrigian Tovldamcav mowyobilobas.

Mmravalrigiani Tovldamcavi mowyobilobebis SemTxvevaSi (4.12) formuliT gaangariSebis Sedegad viRebT qaris siCqaris Semcirebisas TovliT dasilvis sidideTa mniSvnelobebs, romlebic warmodgenilia qvemoT moyvanil cxrilSi 18.

cxrili 18

damokidebuleba mravalrigiani Tovldamcavi mowyobilobebis gamoyenebisas qaris siCqaris Semcirebis sididisa da TovliT danamqras Soris procentebSi

$\Delta\ v\%$	**10**	**20**	**40**	**60**	**80**	**100**
$\Delta\ q\%$	35	60	87	95	100	100

miRebuli monacemebidan SegviZlia davaskvnaT, rom qaris pirvelsawyisi siCqaris SedarebiT mcire sididiT Semcirebac ki xels uwyobs nakadidan mniSvnelovani raodenobis Tovlis gadaWeras.

arsebuli meTodebiT gaangariSebisas mravalrigiani dacvis TiToeul rigs gaaCnia erTidaigive sididis RreCoebi da am pirobebSi Tovlis yrili isileba (inamqreba) pirvelive rigis ukan da mxolod Tovlis umniSvnelo nawili miemarTeba meore rigisaken.

zemoaRniSnuli Taviseburebebidan gamomdinare or da met rigiani TovldamWerebis mowyobisas pirveli rigi SeiZleba moewyos meti sididis RreCoebiT anu meti sididis gamWoli sicarieleebiT. am SemTxvevaSi Tovlis yrils Tovldamcav rigebis ukan eqneba meti sigrZe da damreci qanobi.

4.2 liandagis TovliT danamqrisagan damcavi RonisZiebebi axalmSenebare rkinigzis ubanze axalqalaqi_karwaxi - TurqeTis respublikis sazRvari

axalmSenebare rkinigzis ubanze axalqalaqi-TurqeTis respublikis sazRvarze matarebelTa usafrTxo da Seuferxebeli moZraoba mniSvnelovnadaa damokidebuli liandagis TovliT danamqrisagan damcav da qarbuqian dReebSi Tovlisagan liandagebis drouli gawmendis RonisZiebaTa ganxorcielebaze.

sarkinigzo liandagis sigrZe sadgur axalqalaqidan TurqeTis respublikis sazRvramde Seadgens 22 km-s, aqedan sxvadasxva kategoriisa da xarisxis mqone monakveTebi sigrZiT svlis mimarTulebis marjvena mxares ≈≈12 km, xolo marcxena mxares ≈≈6.6 km eqvemdebareba TovliT danamqrisagan dacvas.

Cvens mier Teoriuli da eqsperimentaluri kvlevebis safuZvelze SemuSavebulia aRniSnul ubanze liandagis TovliT danamqris sawinaaRmdego RonisZiebani, romlebic iTvaliswineben damcavi tyis zolis (cocxali dacva), gadasatani farebisa da gisosis mudmivi Robeebis mowyobas.

TovliT danamqrisaTvis damcav yvela zemoTaRniSnuli saxeebis moqmedebis principi efuZneba TovliT gajerebuli qaris nakadis mimarT winaRobiT gamowveuli nakadis siCqaris Semcirebas, am nakadidan Tovlis amogdebas, mis daleqvasa da nagebobebis win Tovlis safaris warmoqmnas.

Tovldamcavi tyis nargavebi da nagebobebis SerCeva xdeboda Semdegi ZiriTadi moTxovnaTa gaTvaliswinebiT:

- nagebobis mier qarbuqiT gadatanili Tovlis maqsimaluri raodenobis Sekaveba;
- nagebobebi ar unda eqvemdebarebodnen dazianebas Tovlis maqsimaluri sididis Sekavebisas;
- nagebobebis mowyoba ar unda saWiroebdnen did kapitalur da mimdinare saeqspluataciao danaxarjebs;
- sxva yvela Tanabari pirobebisaTvis maT unda hqondeT saukeTeso TovlSekavebis Tvisebebi.

rogorc cnobilia TovliT danamqrisagan rkinigzis dasacavad yvelaze ufro efeqturi da ekonomiuria tyenargavebis zolis mowyoba, romelic saWiroebs minimalur SromiT da materialur danaxarjebs.

teqnikur-ekonomiuri gaangariSebebiT dadgenilia, rom 1 km sigrZis liandagis danamqrisagan tyenargavebiT dacva saWiroebs 6-7-jer nakleb danaxarjebs, vidre amave sigrZis ubnis dacva gadasatani farebis saSualebiT.

tyenargavebi, romlebic ganlagebulia rkinigzis xazis gaswvriv garda imisa, rom icaven liandagebs TovliT danamqrisagan, amcireben qaris siCqares, riTac amcireben matarebelTa moZraobis winaRobas, Tavidan icileben balastis prizmis gaWuWyianebasa da mcire fraqciebis gamoqrevebs.

Tovldamcavi tyenargavebis mowyobisas mniSvnelovan sakiTxs warmoadgens Tovldamcavi tyenargavebis xis jiSisa da buCqnaris asortimentis SerCeva. SerCeva xdeboda saimedo da swrafmzardi kompleqsebis mixedviT, adgilmdebareobis, niadagisa da klimaturi pirobebis gaTvaliswinebiT.

im monakveTebze, sadac adgilmdebareobis, niadagisa da sxva pirobebis gamo tyenargavebiT damcavi zolis mowyoba ver xerxdeboda Tovlisagan dasacavad, gaTvaliswinebuli iqna mudmivi Robeebis, msubuqi an gadasatani farebis mowyoba.

yvela konkretuli ubnisaTvis TovliT danamqrisagan damcavi RonisZiebaTa SerCeva xdeboda SesaZlo sxvadasxva variantis teqnikur-ekonomikuri da ekologiuri maCveneblebis Sedarebis safuZvelze matarebelTa Seuferxebeli moZraobis uzrunvelyofisa da eqsploataciis dros SromiTi pirobebis gaumjobesebis gaTvaliswinebiT.

Tovlisagan damcav saSualebaTa gaangariSeba da daproeqteba ganxorcielda qaris mier Tovlis gadatanisa da winaRobis adgilebSi misi dagrovebis kanonzomierebis, anu TovliTnajeri qaris nakadis im ZiriTadi Tvisebebis dadgenis Semdeg, rogorebicaa: zamTris xangrZlivoba, qarbuqiani dReebis ricxvi, TovlSemkrebi moednis farTobi, mimdebare teritoriis konfiguracia, Tovlis fizikur-meqanikuri maxasiaTeblebi, gabatonebuli qaris mimarTuleba, Tovlis gadatanis intensiuroba da a.S.

liandagis TovliT danamqrili ubnebi xasiaTdebian ori ZiriTadi maCveneblebiT:

danamqris kategoria, romelic damokidebulia liandagis gegmasa da profilze, qaris siCqaresa da mimarTulebaze, adgilmdebareobis reliefze, Tovlcvenis intensiurobasa da raodenobaze, zamTris xangrZlivobasa da wlis ganmavlobaSi qarbuqian dReTa ricxvze.

danamqris xarisxi, romelic ganisazRvra qarbuqis mier wlis ganmavlobaSi liandagis 1 gr. metrze motanili Tovlis moculobiT 15-20 wliani ganmeorebadobisaTvis da romlis mixedviT xdeboda Tovldamcavi SemoRobvis tipisa da mis mier Tovlis dagrovebis SesaZlo raodenobis dadgena.

TovliT danamqris kategoriis mixedviT rkinigzis liandagis Semofargvla xorcieldeboda Semdegi rigiTobiT:

pirvel rigSi – 1-li kategoriis danamqvris iseTi adgilebi, rogorebicaa Wrilebi siRrmiT 0.4 metridan 8 m da meti; nulovani adgilebi, romlebic ganlagebulia damrec

ferdoze; gadasarbenis is liandagebi, romlebic ganlagebulia sxvadasxva doneze; sadgurisa da kvanZebis teritoriebi.

meore rigSi – me-2 kategoriis danamqriani adgilebi, rogorebicaa: Wrilebi siRrmiT 0.4 metramde da nulovani adgilebi.

mesame rigSi – me-3 kategoriis damanqriani adgilebi, rogorebicaa: yrilebi simaRliT 0.7 metramde vake adgilze da 1 m simaRlemde damrec ferdoze.

TovliT danamqrisagan damcavi SemoRobvis tipi da simZlavre SeirCa ise, rom gamoricxuliyo qarbuqis mier Tovlis natanis liandagze dagroveba.

TovliT danamqrisagan liandagis damcavi saSualeba da saxeebi SeirCa cxrilSi 19 warmodgenili monacemebis mixedviTa da adgilmdebareobis pirobebis gaTvaliswinebiT.

cxrili 19

TovliT danamqriT dafarvis ubnebis klasifikacia

danamqris jgufi	danamqriani ubnebis daxasiaTeba, liandagis dacvis saSualebebi da meTodebi	Tovlis raodenoba, m^3/gr.m
1.	***sustad danamqriani ubnebi*** erTi-orzoliani tyis nargavebi; Tanabar RreCoiani farebi; farebi gamWoli qveda nawiliT.	100-mde
2.	***saSualod danamqriani ubnebi*** or-sam zoliani tyis nargavebi; mudmivi Robe simaRliT araumetes 5.5 m; msubuqi gamartivebuli tipis Robe simaRliT 4-5 m.	101-dan 300-mde
3.	***Zlier danamqriani ubnebi*** sam-oTxzoliani tyis nargavebi; erT-orrigiani mudmivi Robeebi simaRliT 5.5 m-mde; msubuqi tipis Robe 5 m simaRliT; damatebiTi Robe 60-70% gamWolobiT.	301-dan 600-mde
4.	***gansakuTrebiT Zlier danamqris ubnebi*** oTx da metzoliani tyis nargavebi; mudmivi Robeebis ori rigi simaRliT 5.5 m-mde, an msubuqi tipis Robeebis simaRliT 5 m-mde; Tovlis gadametbervadi Robeebi; miwis vakisis TovliT daunamqvrian ubnis profilis mowyoba.	600-ze meti

liandagis TovliT danamqrisagan damcav saSualebaTa SerCevisa da ganlagebis dasadgenad TiToeuli konkretuli ubnisaTvis Sedga qaris vardula, romelic mibmuli iqna

rkinigzis xazis mimarTulebasTan. qaris vardula aigo uaxloesi meteosadgurebis, axalqalaqisa da karwaxis meteosadguris monacemebis mixedviT.

qaris vardulis (qaris siCqare da mimarTuleba) agebis Semdeg dadginda zamTris xangrZlivoba, Tovlis safariani farTobebis sidideebi, mimdebare teritoriis maxasiaTeblebi, qarbuqiani dReebis ricxvi, mosuli Tovlis intensivoba, romelTa safuZvelze aigo Tovlis gadatanis vardulebi.

Tovlis is maqsimaluri raodenoba, romelic qaris mier gadaitaneba zamTris periodSi SemoRobvis xazTan gaangariSda formuliT 4.18:

$$S = \frac{1}{10^4 P}\left(\sum_1^n i_1 t_1 \sin_1 + \sum_1^n i_2 t_2 \sin_2 + \sum_1^n i_n t_n \sin_n\right) = \frac{1}{10^4 P}\sum\sum_1^n i\, t \sin\alpha \quad \alpha \ \frac{m^3}{gr.m} \qquad (4.18)$$

sadac: P aris qaris mier gadatanili Tovlis moculobiTi wona, gr/sm^3;

P=0.15 gr/sm^3, Semkvrivebis gaTvaliswinebiT P=0.3 gr/sm^3;

i –Tovlis gadatanis intensivoba, mocemuli siCqarisaTvis, gr/wuT.sm;

t _ Tovlis gadatanis xangrZlivoba, mocemuli mimarTulebiT, wT;

α – kuTxe Tovlis gadatanis mimarTulebasa da Tovlisagan damcav nagebobas Soris;

n – sxvadasxva intensivobiT gadatanili Tovlis SemTxvevaTa ricxvi;

$\frac{1}{10^4}$ _ formulaSi Semaval sxvadasxva ganzomilebaTa gadamyvani koeficienti.

Tovlis gadatanis intensiuroba ganisazRvra formuliT

$$i=CV^3$$

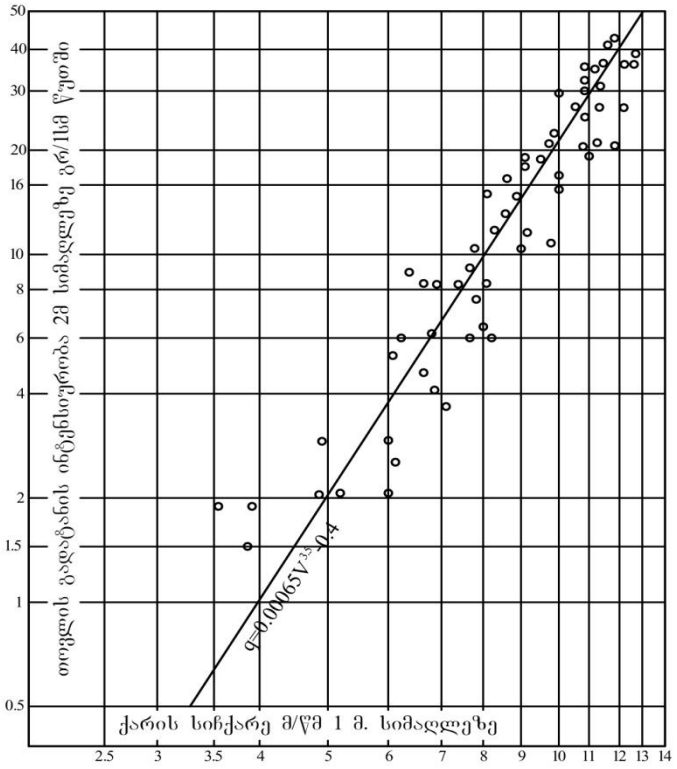
sadac: V aris qaris siCqare fliugeris mixedviT, m/wm;

C – proporciulobis koeficienti, C=0.013.

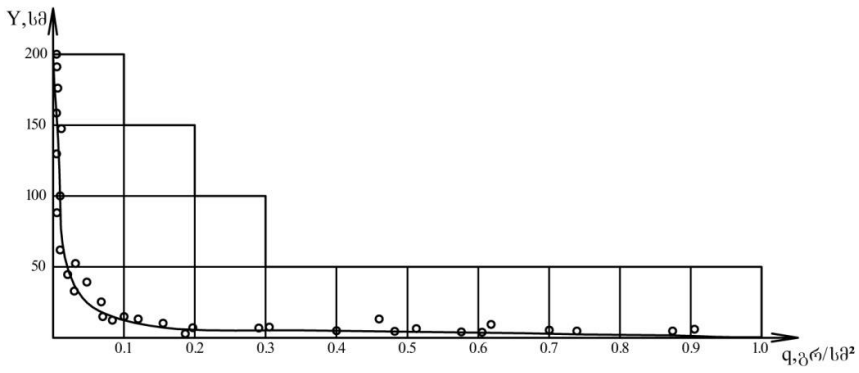
damcav mowyobilobaTa mier TovlSekavebis gaangariSebisas mxedvelobaSi ar iqna miRebuli qari dadebiTi temperaturisas, 6 m/wm-ze naklebi siCqarisas, qari

romelic damcavi SemoRobvis mimarTulebasTan adgenda 30^0-ianze nakleb kuTxes da qari, SemRobavi nagebobis sawinaaRmdego mxridan.

eqsperimentebis saSualebiT dadginda damokidebuleba qvemo qarbuqis SemTxvevaSi qaris siCqaresa da Tovlis gadatanis intensivobas Soris da gadatanili Tovlis xarjis gadanawileba simaRlis mixedviT, romelic warmodgenilia 23-e da 24-e naxazze.

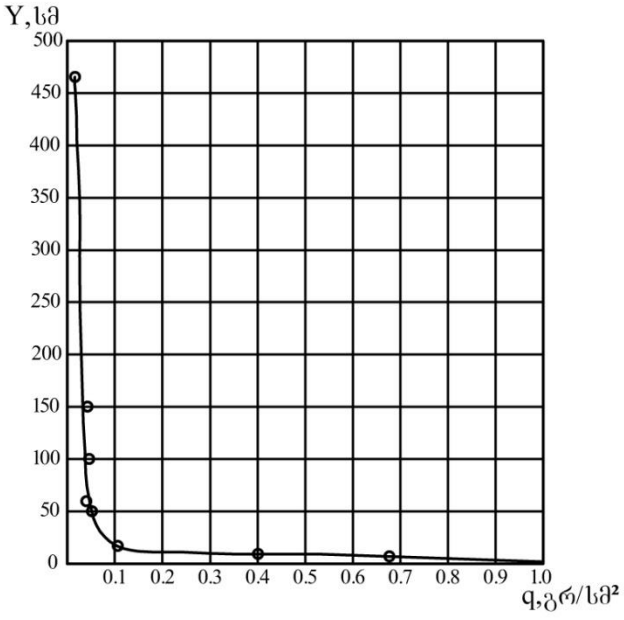


nax. 23 damokidebuleba qaris siCqarisa da Tovlis gadatanis intensiurobas Soris (logariTmul koordinatebSi)



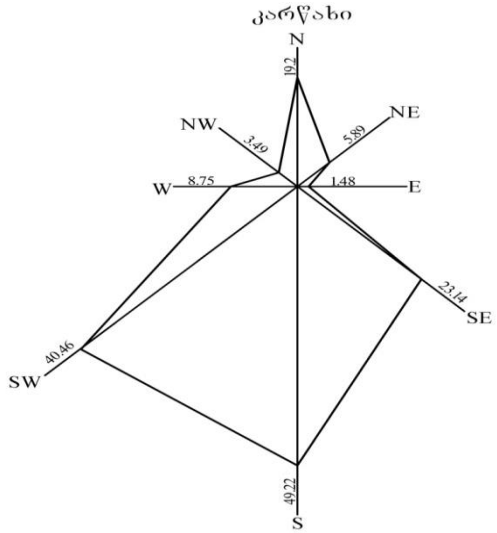
nax. 24 Tovlis xarjis gadanawileba simaRlis mixedviT qvemo qarbuqis SemTxvevaSi

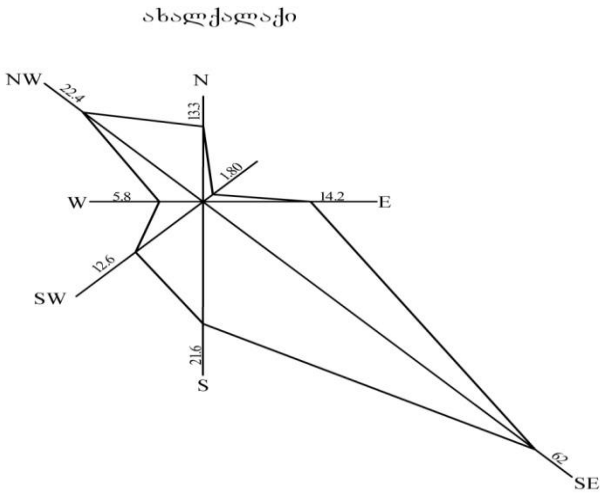
gadanawileba gadatanili Tovlis xarjisa simaRlis mixedviT zemo (saerTo) qarbuqis SemTxvevaSi, rodesac qaris siCqare Seadgens 6 m/wm-s, warmodgenilia me-25 naxazze.



nax. 25 Tovlis xarjis gadanawileba simaRlis mixedviT zemo qarbuqis SemTxvevaSi

qvemoT moyvanil cxrilSi 23 warmodgenilia sakvlev ubnebze qarbuqis dros sxvadasxva mimarTulebiT qaris mier gadatanili Tovlis raodenobis gaangariSebis Sedegebi, xolo
27-e naxazze am cxrilis bolo strofis mixedviT agebuli Tovlis vardulebi.





nax. 26 karwaxisa da axalqalaqis raionebSi Tovlis gadatanis vardulebi (m^3/m)

cxrili 20

karwaxisa da axalqalaqis raionebSi Tovlis gadatanis vardulis gansazRvris sidideebi

№№ r.m.	qaris siCqare, m/wm	Tovlis gadatanis intensiuroba, m^3/m	qaris mimarTuleba															
			C		Ca		a		sa		s		sd		d		Cd	
			qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m	qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m	qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m	qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m	qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m	qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m	qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m	qaris xangrZlivoba, sT	gadatanili Tovlis moculoba, m^3/m
karwaxis raioni																		
1	6-7	0.086	22.4	1.9	6.7	0.6	1.8	0.2	26.6	2.3	57.2	4.9	46.7	4.0	10.5	0.9	4.0	0.3
2	8-9	0.192	12.8	2.5	3.8	0.7	0.9	0.17	15.2	2.92	32.6	6.26	26.6	5.1	5.3	1.02	2.3	0.44
3	10-11	0.362	6.0	2.2	1.8	0.65	0.4	0.14	7.2	2.61	15.4	5.57	12.6	4.56	2.8	1.01	1.1	0.4
4	12-13	0.609	8.5	5.18	2.5	152	0.7	0.43	10.1	6.15	21.7	13.2	17.7	10.78	4.0	2.44	1.5	0.91
5	14-15	0.949	2.2	2.09	0.7	0.66	0.2	0.2	2.7	2.56	5.7	5.41	4.7	4.46	1.0	0.95	0.4	0.38
6	16-17	1.396	1.6	2.23	0.5	0.7	0.1	0.14	1.9	2.65	4.0	5.58	3.3	4.61	0.7	0.98	0.3	0.4
7	18-20	1.967	1.3	2.56	0.4	0.79	0.1	0.2	1.6	3.15	3.4	6.69	2.8	5.51	0.6	1.18	0.2	0.39
8	20-24	2.676	0.2	0.54	0.1	0.27	0	0	0.3	0.8	0.6	1.61	0.5	1.34	0.1	0.27	0.1	0.27
9	25-28	3.50	0	2	0	0	0	0	0.0	0	0.11	0	0.1	0.1	0	0	0	0
zamTris periodSi				19.2		5.89		1.48		23.14		49.22		40.46		8.75		3.49
axalqalaqis raioni																		
1	6-7	0.086	16.0	1.4	2.2	0.2	17.2	1.5	74	6.4	25.2	2.2	15.1	1.3	6.51	0.6	25.2	2.2
2	8-9	0.192	9.1	1.7	1.3	0.2	9.8	1.9	42.2	8.1	14.4	2.8	8.6	1.7	3.7	0.7	14.4	2.8
3	10-11	0.362	4.1	1.5	0.6	0.2	4.4	1.6	19.0	6.9	6.5	2.4	3.9	1.4	1.7	0.6	6.5	2.4
4	12-13	0.609	6.1	3.7	0.84	0.5	6.6	4.0	28.2	17.2	9.6	5.8	5.8	3.5	2.5	1.5	9.6	5.8
5	14-15	0.949	1.5	1.4	0.2	0.2	1.6	1.5	7.0	6.6	2.4	2.3	1.4	1.3	0.6	0.6	2.4	2.3
6	16-17	1.396	1.2	1.7	0.2	0.3	1.3	1.8	5.6	7.8	1.9	2.7	1.2	1.7	0.5	0.7	1.9	2.7
7	18-20	1.967	0.8	1.6	0.1	0.2	0.8	1.6	3.5	6.9	1.2	2.4	0.7	1.4	0.4	0.8	1.2	2.4
8	20-24	2.676	0.1	0.3	0.01	0.04	0.1	0.3	0.5	1.4	0.2	0.6	0.1	0.3	0.1	0.3	0.2	0.6
9	25-28	3.50	0	0	0	0	0	0	0.2	0.7	0.1	0.4	0	0	0	0	0.1	0.4
zamTris periodSi				3.3		1.8		14.2		62		21.6		12.6		5.8		27.9

Tu gaviTvaliswinebT saproeqto teritoriisa da mis Semogarenis Taviseburebebs da saqarTvelos samxreT mTianeTis bunebriv pirobebs, mizanSewonilia arqiteqturul-dekoratiuli nargavebis gamoyeneba.

dekoratiuli gamwvanebisaTvis rekomendirebulia kavkasiuri fiWvi (`kauWa~) da kvrinCxis buCqnari.

tyenargavebTan erTad liandagis Tovldanamqrisagan dasacavad gamoyenebulia mudmivi gisosovani Robeebi.

martivi tipis Robeebis mier Tovlis dagrovebis unaris gazrdis erT-erTi meTodi aris Robis tanSi, mis qveda nawilsa da miwis zedapirs Soris sicarielis – RreCoebis datoveba. es sicariele (RreCo) saSualebas gvaZlevs gadaWerili Tovlis zvinuli gadavwioT dacvis xazidan da amiT gavzardoT saerTo TovlSekavebis unari.

aseTi Robis modelebis eqspertimentaluri kvlevebis Sedegad dadgenilia, rom molartyvis garRvevis sidide ar unda aRematebodes 0.45.

erTrigiani Robis mier TovlSekavebis unari ganisazRvra formuliT

$$Q_1=KH_1^2$$

sadac: Q_1 – erTrigian Robis mier gadaWerili Tovlis moculoba, $m^3/gr.m.$;

H_1^2_ Robis simaRle, m; K _ sacdeli koeficientia, K=7-9.

am formulis mixedviT Cans, rom Robis mier gadaWerili Tovlis moculoba damokidebulia misi simaRlis kvadratis sidideze, magram Robis simaRlis gazrda iwvevs did kapitaldabandebis saWiroebas.

orrigiani Robis mier TovldaWeris sidide ganisazRvra formuliT:

$$Q_2 = \alpha H_2 L + KH_2^2$$

sadac: Q_2 – aris Tovlis saerTo moculoba gadaWerili orrigiani Robis mier, $m^3/gr.m.$;

H_2 – Robis simaRle, m;

L – Robis rigebs Soris manZili, m (miiReba 30 H_2);

K – sacdeli koeficienti, K=7-9.

sacdelma dakvirvebebma gviCvena, rom gadaWerili Tovlis moculoba 6 m simaRlis erTrigian Robesa da 3 metr simaRlis orrigian Robes Soris daaxlovebiT Tanabaria, anu

$$H_2 = \frac{H_1}{2}$$, roca K=9, α=09, Q_2=9 H_2^2

teqnikur-ekonomikuri Sedarebis Sedegad dadginda, rom 6 m simaRlis erTrigad ganlagebuli Robis orrigad ganlagebuli 3 m simaRlis RobiT Secvlis Sedegad masalebis ekomonia Seadgens 25%.

TovldamWeri tyenargavebi da mudmivi Robeebi daproeqtebulia saangariSo maqsimaluri 1:15 (7%) albaTobis moculobis Tovlis gadasaWerad.

zemoT aRniSnuli ganmartebebisa da gaangariSebis, damcavi nagebobebis SesaZlo variantebis teqnikur-ekonomiuri da ekologiuri maCveneblebis Sedarebis safuZvelze, matarebelTa usafrTxo moZraobis uzrunvelyofisa da eqspluataciis periodSi Sromis pirobebis gaumjobesebis gaTvaliswinebiT Cvens mier SemuSavebulia liandagebisa da nagebobebis Tovlis danamqrisagan damcavi RonisZiebebi romelic iTvaliswinebs TovldamWeri tyenargavebis, mudmivi Robeebis da gadasatani farebis mowyobas.

tyenargavebis zolis siganeze 11.5-dan 21.5 metramde, Wadrakiseburad unda ganlagdes xisa da buCqnaris nargavebi.

Tovldamcav nagebobebad gamoyenebulia Semdegi saxis nargavebi: kavkasiuri fiWvi (`kauWa~), kvrinCxis buCqnari.

Tovlisagan dasacavad rekomendirebulia dairgas 3-5 wliani nargavebi, romelTa simaRle unda Seadgendes aranakleb 100 sm-s. nargavebis dargvisas unda SeirCes niadagis ganayofierebisaTvis saWiro tipi da xarisxi. periodulad unda moxdes maTi morwyva da ganxorcieldes movla-patronobis samuSaoebi aranakleb 360 dRis ganmavlobaSi.

qarisa da Tovlis mier xeebisa da buCqnaris dazianebuli nargavebis raodenoba aRwevs mTliani raodenobis 25–30 %-s, ris gamoc mcirdeba tyenargavebis dacvis unarianoba da xdeba Tovlis miwis vakisze gadatana. amis Tavidan asacileblad da axlad darguli nargavebis dacvis mizniT saWiro xdeba gadasatani gisosovani farebis mowyoba.

gadasatani farebi unda dayendes im gaangariSebebiT, rom mis mier gadaWerili Tovlis zvinuli ganTavsdes nargavebidan qaris mimarTulebis mxares.

gisosovan farebs simaRliT 2 m, romlis qveda nawilSi datovebulia 25 sm simaRlis gamWoloba, SeuZliaT 53 m^3 Tovlis gadaWera. farebis win am moculobis Tovlis gadaWeris Semdeg igi wyvets Tavis funqcias da qaris nakadis mier Tovlis

gadatana xdeba farebis zemodan. am SemTxvevaSi saWiro xdeba farebis gadaadgileba. farebis pirveli gadaadgileba xorcieldeba mindvris mxares 20-30 m manZilze, xolo Semdegi gadaadgileba xdeba liandagis mxares Tovlis yrilis zeda nawilSi.

qarbuqiani dReebis damTavrebis Semdeg gadasatani farebi aiReba da xdeba maTi daxarisxeba mdgomareobis mixedviT: farebi romlebic karg mdgomareobaSia, farebi romlebic saWiroeben SekeTebas da farebi romlebic gamousadegaria.

TovldamWeri mudmivi Robeebi ewyoba rkinabetonis anakrebi elementebisagan da Sedgeba sayrdenebisa da frTebisagan. sayrdenebi kveTiT 240×180 mm ewyoba 3 da 4 m simaRleze. sayrdenebs Soris manZili Seadgens 3 m-s. rkinabetonis frTebis sigrZe 3.1 m-ia, xolo kveTis sidide 50×160 mm. sayrdenebis qveda nawili idgmeba A25 klasis monoliTuri betonis fundamentSi.

ganxilul ubnebze liandagis marjvena mxares ewyoba Robe simaRliT 3m, xolo marcxena mxares simaRliT 2 m.

tyenargavebis mTlianma sigrZem Seadgina 13928 m, maT Soris marjvena mxares 9968 m, xolo marcxena mxares 3960 m.

nargavebis zolis sigane ubnis TovliT danamqris sididisa da nargavebis muSa nawilis simaRleze damokidebulebiT icvleba 11.5-dan 21.5 m-mde.

TovldamWeri mudmivi Robeebis mTliani sigrZe Seadgens 4759 m-s, aqedan marjvena mxares ewyoba 2094 gr. m sigrZis Robe, simaRliT 3 m, xolo marcxena mxares 2665 gr. m simaRliT 2 m.

qvemoT moyvanil cxrilSi 24 warmodgenilia liandagebisa da nagebobebis TovliT danamqrisagan damcav saSualebaTa mosawyobad saWiro ZiriTad samuSaoTa moculobebis uwyisi, xolo naSromis **p4.3-Si** Cvens mier SemuSavebuli da rkinigzis xazis am ubanze gamoyenebuli TovldamWer nagebobaTa axali efeqturi konstruqciebi.

cxrili 21

liandagebisa da nagebobebis TovliT danamqvrisagan damcav saSualebaTa mosawyobad saWiro ZiriTad samuSaoTa moculobebis uwyisi

# r.m	**samuSaoTa dasaxeleba**	**Gganz. erT.**	**raodenoba**

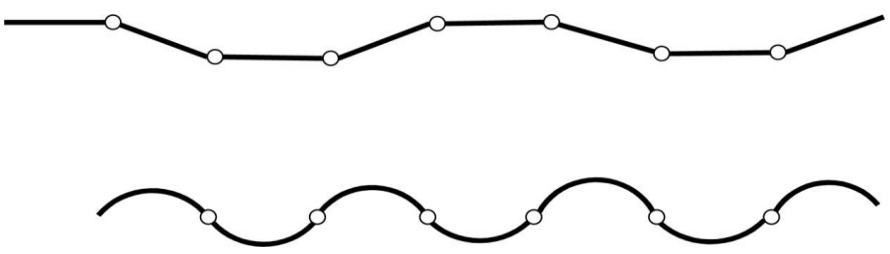
1	tyenargavebis cocxali Robeebis mowyoba: - wiwvovani nargavebi (3-5 wliani simaRliT aranakleb 100 sm); - buCqnari 60-80 sm	cali cali	85962 27856
2	antikoroziuli safari `pentalaksi~-T dafaruli TovldamWeri Robeebis muSa farTi	Km^2	9625.4
3	gadasatani gisosebiani farebi	gr. m.	7000
4	droebiTi mavTulis Robe tyenargavebis dasacavad	gr. m.	16700

4.3 TovldamWeri nagebobis axali konstruqciebi

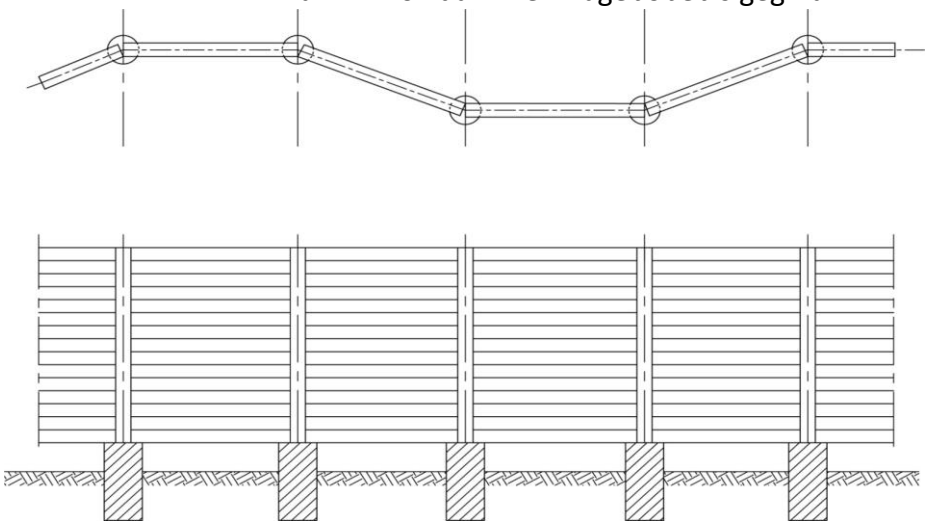
qarbuqis Teoriuli kvlevebis analizisa da TovldamWer nagebobaTa eqspluataciis mravalwliani gamocdilebis Seswavlisa da analizis Sedegad Cvens mier SemuSavebulia TovldamWer nagebobaTa axali efeqturi da ekonomiuri konstruqciebi, romelTac gaaCniaT rigi upiratesoba dRemde gamoyenebul nagebobebTan SedarebiT.

nagebobebis axali konstruqciebis damuSavebisas dasaxuli iyo nagebobis simtkicisa da mdgradobis gaumjobeseba minimaluri materialuri da SromiTi danaxarjebiT, mSeneblobis meqanizaciisa da industrializaciis uzrunvelyofa, gegmasa da sivrceSi sxvadasxva konfiguraciis nagebobaTa mosawyobad erTi da igive tipis elementebis gamoyeneba.

Cvens mier SemuSavebuli da rekomendirebulia sivrceSi gamWoli formis, gegmaSi texili moxazulobis TavlgadamWeri nagebobebi (ix. nax. 28 da 29).



nax. 27 TovldamWeri nagebobebis gegma



nax. 28 ToldamWeri nagebobebis xedebi

nagebobebi Sedgeba samkuTxa, prizmatuli (trapeciodaluri) an maTi kombinaciis formis mqone seqciebisagan, romlebic ewyoba erTidaigive topoelementis - Riobis mqone filebis an sworkuTxa Zelebisagan.

nagebobis forma da misi Semadgeneli elementebi saSualebas gvaZlevs gavzardoT nagebobis mier gadaWerili Tovlis moculoba da nagebobis simaRlis, masze mosuli datvirTvis, adgilmdebareobis, masalebis ekonomiisa da sxva pirobebis gaTvaliswinebiT ferdis daxris kuTxis cvalebadobis xarjze vcvaloT nagebobis konfiguracia misi mzidunarianobis sididis uzrunvelyofis Sesabamisad.

nageboba SeiZleba moewyos rogorc liTonis, aseve rkinabetonisa da plastmasis calkeuli mcirezomiani anakrebi filebisagan.

rekomendirebul nagebobaTa teqnikur-ekonomikur

upiratesobebs ganapirobeben:

1. texili moxazulobis sivrculi forma uzrunvelyofs gadaWerili Tovlis moculobis gazrdas da Tovlisa da Tovlgajerebuli qaris aqtiuri dawneviT gamowveul datvirTvaze nagebobis gadayiravebisa da wacurebis mimarT mdgradobis gaumjobesebas;
2. gegmaSi texili moxazulobis Sedegad nagebobaze kumSvasa da gaWimvaze upiratesi muSaobis Sedegad SesaZlebeli xdeba maRali simtkicisa da mcire sisqis elementTa gamoyeneba, riTac miiRweva mniSvnelovani sididis ekonomiuri efeqti;

3. sivrculi formis konstruqcia kargad aRiqvams ganiv Zalebs, ris gamoc mniSvnelovnad ioldeba nagebobis sayrdenTa mowyoba;
4. Tovli, romelic kontaqtSia garsacmebTan, aumjobesebs nagebobis sixistes da zrdis maT mdgradobas;
5. minimaluri tipo elementebis saWiroeba sxvadasxva konfiguraciis nagebobis mosawyobad, rac mniSvnelovnad

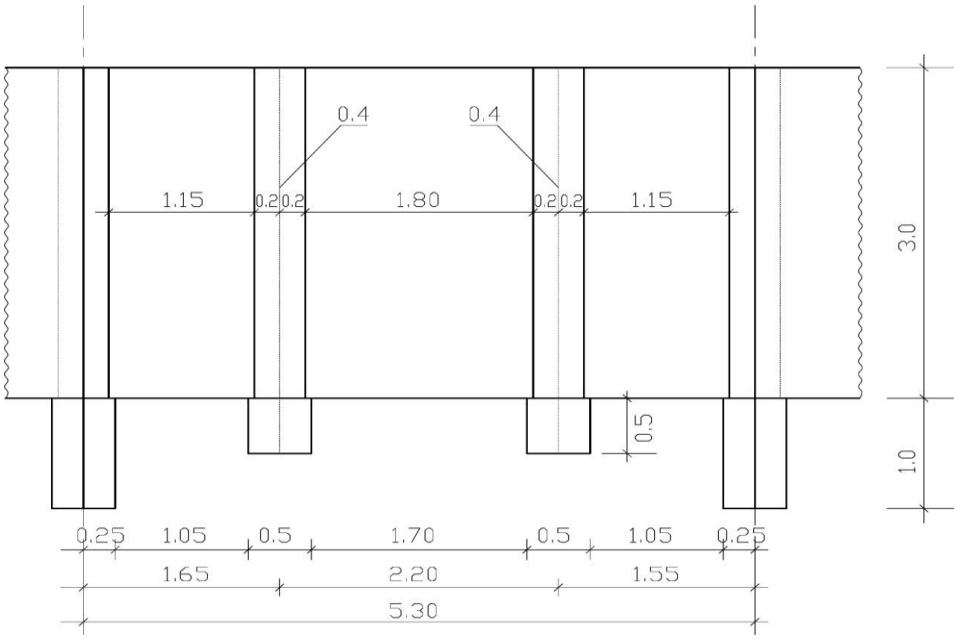
aiolebs samSeneblo-samontaJo samuSaoTa Sesrulebas;

6. nagebobas gaaCnia arqiteqturulad kargad gamoxatuli forma.

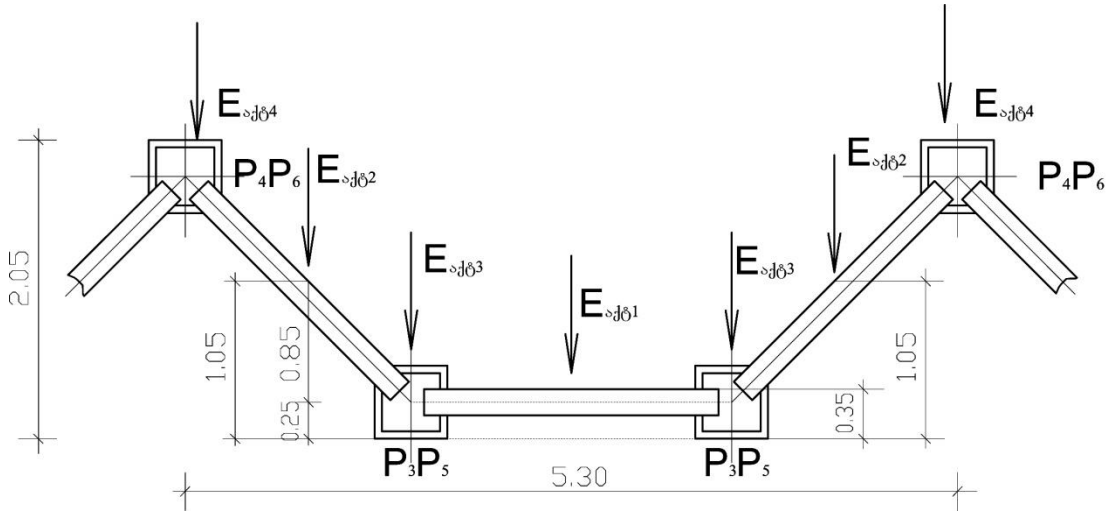
nagenobaTa gaangariSebis Tanamimdevrobebi Semdegnairia:

1. iniSneba nagebobis geometriuli zomebi, simaRle, seqciebis biji, gamoyenebuli masalis tipi da klasi;
2. damaxasiaTebel wertilebSi ganisazRvreba nagebobaze mosuli aqtiuri da pasiuri dawnevebi;
3. ganisazRvreba nagebobaze mosuli yvela saangariSo da normatiuli Zalebi gadatvirTvis koeficientebis gaTvaliswinebiT;
4. gaiangariSeba nagebobis mdgradoba wacurebasa da gadayiravebaze;
5. mowmdeba fuZis simtkice da tolqmedi Zalis adgilmdebareoba;
6. gaiangariSeba filebisa da sayrdenebis armireba da maTi simtkice;
7. konstruirdeba kvanZebi da gaiangariSeba maTi simtkice.

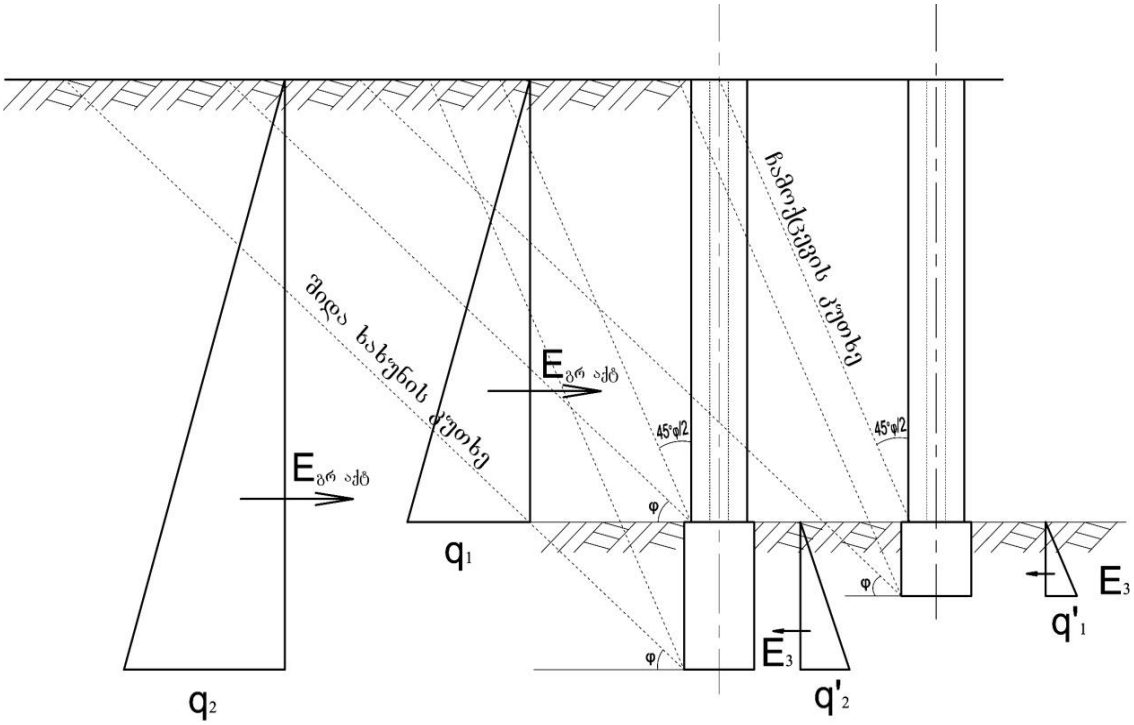
rk. betonis nagebobis saangariSo sqema warmodgenilia 30-e, naxaze.



sqema #1



sqema #2



sqema #3

nax. 29 rkinabetonis Robeebis saangariSo sqemebi

garsacmis simtkice SeiZleba ganvsazRvroT zRvruli wonasworobis meTodis kinematikuri xerxiT, garsacmis faqtiuri rRvevis sqemis gaTvaliswinebiT.

zRvruli mRunavi momenti

$$m_t = \frac{\ell_1^2}{240}\left[\frac{\sigma_{ar1}(1 + 2_{ar1}/\sigma_{ar2}) + \sigma_{ar2}(2 + \sigma_{ar1}/\sigma_{ar2})}{1 + \sigma_{ar1}/\sigma_{ar2}}\right]$$

gaWimul zonaSi vertikaluri armaturis farTi gaiangariSeba rogorc texili kveTis Runvadi konstruqciisaTvis

$$\mathrm{M} = \frac{100}{6} H^2(\sigma_{ar1} + \sigma_{ar2})$$

$$\mathrm{M} \le R_b b \times \left(h_0 - \frac{1}{2}\alpha\right) \qquad \mathrm{M} = A_0 b h_0^2\, Re$$

$$\mathrm{M} \le R_0 A \times \left(h_0 - \frac{1}{2}\alpha\right) \qquad \mathrm{M} = \mathrm{M}(\eta h h_0)$$

$$A_0 = \xi(1 - 0.5\,\xi) \qquad \eta = 1 - 0.5\,\xi \qquad \xi = \frac{x}{h_0}$$

$$\alpha' = \alpha - \frac{2}{3} + \qquad \alpha = \frac{R_s A_s}{R_e b} + \frac{1}{2}t$$

sadac: $\mathrm{M_y}$ - mRunavi momentia nebismier kveTSi;

M - maqsimaluri momenti elementis safuZvelSi;

A_s - gaWimul zonaSi vertikalur Tavmoyril Seyursuli armaturis kveTis farTobi;

R_s - armaturis saangariSo winaRoba;

R_e - betonis saangariSo nawilis Tovlis aqtiuri dawneva;

σ_{ar} - horizontaluri mdgeneli.

horizontaluri armaturis farTi gaingariSeba rogorc uWri mravalmaliani filisaTvis

$\mathrm{M} = \sigma_{\mathrm{ag\,saS}}\,\ell^2/12$ sadac $\ell = \ell_1\ an\ \ell = \ell_2$;

$\mathrm{M_{ai}} = \mathrm{M_{mal}} = \mathrm{M}$; $\mathrm{M} = A_0 b h_0^2 R_{b;}$ $A_s = \mathrm{M}(\eta_1\, h_0 R_s)$;

$A_s = \frac{\mathrm{M}}{0.9\,б_0 R_s}$; $б_0 = б - a$

sadac: M, $\mathrm{M_{ai}}$, $\mathrm{M_{mal}}$ - nagebobis malisa da sayrden kveTebSi Runvis momentebia;

$\sigma_{\mathrm{ag\,saS}}$ - aqtiuri dawnevis horizontaluri mdgeneli saSualo sidide;

б - filis sisqe;

a - damcavi Sris sisqe.

daxrili kveTis simtkice

$$Q \le \varphi_{b_1} R_{b_+} b h_0^2 / c; \qquad c \le 2h_0; \qquad \varphi_{b_1} = 15;$$

$$\varphi_{b_1} R_{b_+} b h_0 < \frac{\varphi_{b_2} R_{b_+} b h_0^2}{c} < 2.5 b_1 b h_{0;} \qquad \varphi_{b_2} = 0.6$$

sadac: Q - Sida datvirTvis ganivi Zalaa; R_{b_+} - betonis

RerZuli gaWimvis saangariSo winaRobaa;

h_0 - elementis muSa simaRlea ($h_0 = h - a$).

5. daskvna

1. samTo rkinigzebze moZraobis usafrTxoebaze gavlenas axdens rigi faqtorebi, romlebic ganpirobebulia cicabo qanobian monakveTze matareblis moZraobis TaviseburebebiT da adgilmdebareobis bunebrivi movlenebiT;
2. cicabo qanobian monakveTze matareblebis moZraobis Taviseburebebs miekuTvneba: grZel daRmarTebze samuxruWe xundebis gadaxureba da cveTa, sahaero magistralSi wnevis normaze dabla dacema, gaWianurebul aRmarTebze elmavlis wevis Zravebis gadaxureba. bunebriv movlenebs miekuTvneba: Tovlis namqerebi da zvavebi, kldovani Camoqcevebi, Svavebi, kurumebi, mewyerebi, Rvarcofebi da sxva;
3. rogorc gamokvlevebma gviCvenes, moZraobis usafrTxoebis TvalsazrisiT cicabo daRmarTis zRvruli sigrZe izRudeba xundebis gadaxurebisa da magistralSi haeris daSretis pirobiT;
4. xundebis gadaxurebis temperatura damokidebulia xundis masalaze, moZraobis siCqaresa da daRmarTis qanobis sidideze. magistralis daSretis maqsimaluri dro uwyveti damuxruWebisas qanobisagan damokidebulebiT ar unda aRematebodes 30÷35 wT. am pirobebis erTdrouli gaTvaliswineba gvaZlevs daRmarTis zRvrul sigrZesa da moZraobis siCqaris optimalur sidideebs, romlis drosac uzrunvelyofili iqneba matareblis usafrTxo moZraoba;
5. samTo rkinigzebze satvirTo matareblebis saangariSo wonis dadgenisas, garda lokomotivis simZlavrisa da qanobebis sididisa, unda gaviTvaliswinoT Semdegi faqtorebi: mcireradiusiani mrudebi, relsis Tavis mdgomareoba, vagonebs Soris gadasabmel mowyobilobaTa simtkice, wevis Zravebis gadaxureba. am faqtorebis gaTvaliswinebiT dadgenil iqna marabda-axalqalaqis rkinigzis xazze satvirTo matareblis wonis saangariSo normebi: zafxulis periodSi - 1700 t, xolo zamTris sezonze - 1300 t (ormagi wevisaTvis).

   Tbowevis SemTxvevaSi unda gaviTvaliswinoT dizelis Zravis simZlavris Semcireba atmosferuli wnevisa da temperaturis cvalebadobasTan dakavSirebiT;
6. matareblebis usafrTxo moZraobis uzrunvelyofis mizniT Cvens mier Seswavlili iqna marabda-axalqalaqis monakveTze yvelaze rTuli xuTi gadasarbeni.

davadgineT, rom aqedan or gadasarbenze _ TeTriwyaro-nadarbazevi da winwyaro-TeTriwyaro ar aris damakmayofilebeli damuxruWebis pirobebi. Cveni rekomendaciiT TeTriwyaro-nadarbazevis gadasarbenze gaixsna damatebiTi asaqcevi, xolo winwyaro-TeTriwyaros gadasarbenze moewyo e.w. `dasasvenebeli~ moedani;

7. bunebrivi movlenebidan erT-erT mTavar faqtors, romelic gavlenas axdens matareblebis Seuferxebel da usafrTxo moZraobaze, warmoadgens liandagis TovliT danamqra;
8. Sedgenilia rkinigzis trasisa da profilis daproeqtebis pirobebi axalmSenebare rkinigzis xazis TovliT danamqris Tavidan asacileblad;
9. SemuSavebulia liandagis TovliT danamqrisagan damcavi RonisZiebebi axalmSenebare rkinigzis ubanze axalqalaqi-karwaxi-TurqeTis respublikis sazRvari;
10. SemuSavebulia TovldamWeri nagebobebis axali konstruqciebi da maTi gaangariSebis meTodika.

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