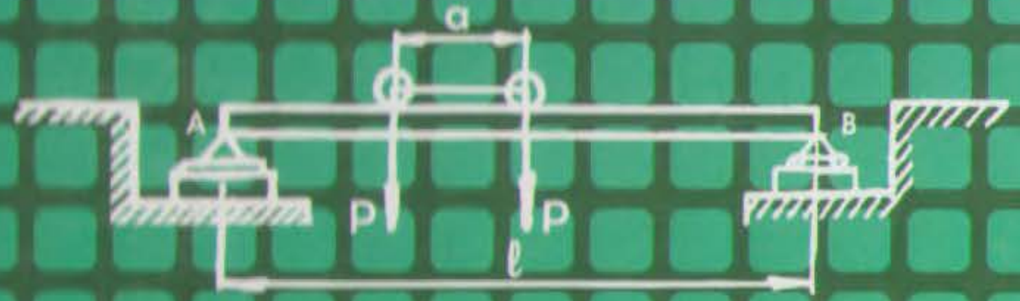
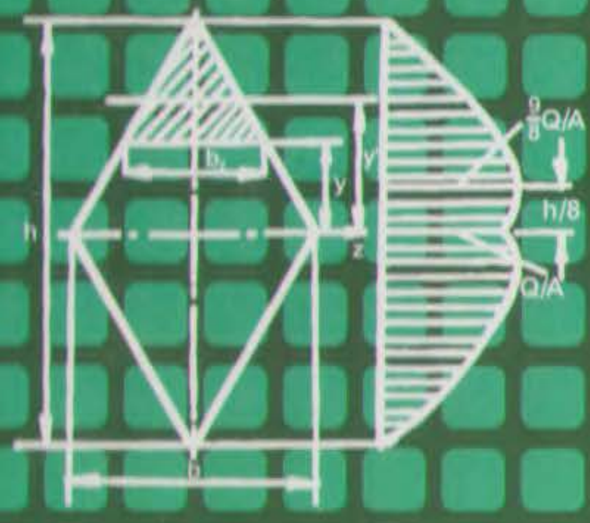
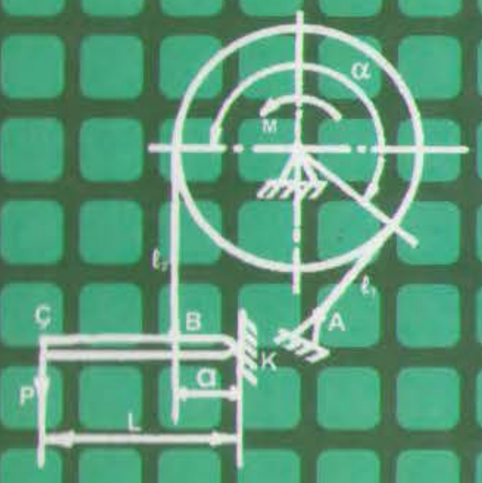
MATERIALLARYŇ GARŞYLYGY
DERSI BOÝUNÇA MESELELER ÝYGYNDYSY



$$\sigma = E\varepsilon$$

MATERIALLARYŇ GARŞYLYGY DERSI BOÝUNÇA MESELELER ÝYGYNDYSY





$$\tau = G\gamma$$

TÜRKMENISTANYŇ ILKINJI PREZIDENTI
BEÝIK SAPARMYRAT TÜRKMENBAŞY

TÜRKMENISTANYŇ DÖWLET TUGRASY

TÜRKMENISTANYŇ DÖWLET BAÝDAGY

TÜRKMENISTANYŇ DÖWLET SENASY

Janym gurban saňa, erkana ýurdum,
Mert pederleň ruhy bardyr köňülde.
Bitarap, garaşsyz topragyň nurdur,
Baýdagyň belentdir dünýäň öňünde.

Gaýtalama:

Halkyň guran Baky beýik binasy,
Berkarar döwletim, jigerim-janym.
Başlaryň täji sen, diller senasy,
Dünýä dursun, sen dur, Türkmenistanym!

Gardaşdyr tireler, amandyr iller,
Owal-ahyr birdir biziň ganymyz.
Harasatlar almaz, syndyrmaz siller,
Nesiller döş gerip gorar şanymyz.

Gaýtalama:

Halkyň guran Baky beýik binasy,
Berkarar döwletim, jigerim-janym.
Başlaryň täji sen, diller senasy,
Dünýä dursun, sen dur, Türkmenistanym!

B.Asyrow, D.Myradow

MATERIALLARYŇ GARŞYLYGY

dersi boýunça meseleler ýygyndysy

Ýokary okuw mekdepleri üçin okuw gollanmasy

Türkmenistanyň bilim ministrligi

tarapyndan hödürlenildi

Aşgabat
TDKP - neşirýaty

2009

UOK 373.167.1+539.2
A-48

Aşyrow B., Myradow D. Materiallaryň garşylygy dersi boýunça meseleler ýygyndysy. Ýokary okuw mekdepleri üçin okuw gollanmasy. – Aşgabat, 2009.

Okuw gollanmasynda ýokary okuw mekdeplerinde materiallaryň garşylygy dersi boýunça mesele çözmegiň usullary görkezilen. Gollanma iki bölümden ybarat, birinji bölümde nusgawy meseleleriň şertleri, ikinji bölümde bolsa, meseleleriň çözüwleri, görkezmeleri we jogaplary getirilýär.

Kitap tehniki ýokary okuw mekdepleri üçin tassyklanan okuw maksatnamasy esasynda taýýarlanyldy.

Meseleler ýygyndysy ýaş mugallymlar, aspirantlar we talyplar üçin niýetlenen.

TDKP 105 **KBK 22:37+ý73**

SÖZBAŞY

TÜRKMENISTANYŇ PREZIDENTI GURBANGULY BERDIMUHAMEDOW:

"Güýçli döwletde ylym esasy orny eýeleýär, diýmek, biz ylmyň iň täze gazananlary bilen aýakdaş gitmelidiris."

Türkmenistanyň Prezidenti Hormatly Gurbanguly Berdimuhamedowyň ýurdumyzyň jemgyýetçilik – önümçilik gurluşyny döwrebaplaşdyrmak boýunça işläp düzen syýasy we ykdysady maksatnamalary Beýik Galkynyşlar zamanamyzda täze kämil ýaşaýyş keşbini döretmegi baş maksat edinýän strategiýadyr. Onuň esasy sütünleriniň biri-de ýurdumyzda bilim ulgamyny kämilleşdirmäge, ylym pudagyny ösdürip, halkara derejesine çykarmaga gönükdirilen özgertmelerdir. Ol halkymyza ylmy-tehniki progresiň iň soňky gazananlary bilen aýakdaş gidip, dühýä siwilizasiýasyna sazlaşykly goşulyp gitmäge mümkinçilik berýän ýoldur.

Hormatly Prezidentimiziň öçmez-ýitmez taglymatlaryny durmuşa ornaşdyrmakda türkmen talyplaryna halkara derejesinde ylym-bilim bermek we arassa ahlakly, watançylyk ruhunda terbiýelemek iň wajyp meseleleriň biri bolup durýar.

Döwletiň ykdysady kuwwatyny pugtalandyrjak we ony has belentliklere alyp gitjek döwrebap inžener hünärmenlerini taýýarlamak hem aýratyn ähmiýete eýedir. Şu babatda hakykata akyl ýetirmek baradaky ylymlaryň esasylarynyň biri bolan "Materiallaryň garşylygy" ylmyna uly orun degişlidir. Onuň üçin tehniki ýokary okuw mekdepleriniň talyplary "Materiallaryň garşylygy" dersiniň çylşyrymly hasaplamalarynyň ajaýyp usullaryndan ýeterlik derejede baş alyp çykmalydyrlar.

"Materiallaryň garşylygy" umumy tehniki ders bolup, gelejekki inženerleri taýýarlamakda tehniki bilimleriň binýady bolup hyzmat edýär. Galyberse-de, bu kursuň amaly bölegi talyplarda inženerlik pikirlenmäniň ösmegine, olaryň dünýägaraýşynyň giňelmegine ýokary derejede ýardam berýär.

Talyplar "Materiallaryň garşylygy" kursuny öwrenende, köplenç, meseleleri çözmekde uly kynçylyklar çekýärler.

Meseleler ýygyndysynyň türkmen dilinde taýýarlanylyp, ýokary okuw mekdepleriniň talyplaryna ýetirilmegi, ýurdumyzda döwrebap inženerçilik meseleleriň çözülmegine ýardam berýär. Şeýle maksat bilen eliňizdäki ýygyndy ýurdumyzyň tehniki ýokary okuw mekdeplerinde okaýan talyplar üçin niýetlenilip, talyplara materiallaryň garşylygy dersi boýunça meseleleri çözmegiň usullaryny göwnejaý özleşdirmegi maksat edinýär. Gollanma awtorlaryň köp ýyllaryň dowamynda toplan ylmy-mugallymçylyk tejribeleri esasynda taýýarlanyldy. Ýygyndynyň köp bölegi aýdyň meseleler bolup, olaryň jogaplary, görkezmeleri we çözüwleri kitabyň ikinji böleginde ýerleşdirilendir. Şeýle hem talyplaryň işjeň pikirlenmegi we özbaşdak özleşdirmegi üçin birnäçe çylşyrymly meseleleriň çözüwi gollanmada düşündirişsiz berilýär.

Meseleler ýygyndysynyň düzümine girýän temalar tehniki ýokary okuw mekdepleri üçin tassyklanan okuw maksatnamasyna laýyklykda beýan edildi.

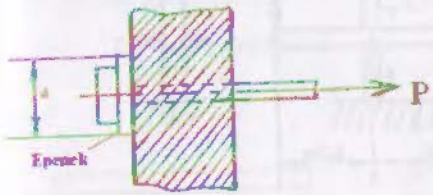
Kitabyň ilkinji gezek türkmen dilinde taýýarlanýandygy bilen baglylykda awtorlar kitapda goýberilmegi mümkin bolan käbir nogsanlyklar üçin jogapkärçiligi öz üstlerinden aýyrmaýarlar. Ýygyndy boýunça gelip gowşan bellikler we teklipler onuň geljekki neşirlerinde göz öňünde tutular. Kitap çapa taýýarlananda beren gymmatly maslahatlary üçin professor Ç.Amansähedowa, teksti redaksiýa eden dosent S.Güjükowa we tehniki taýdan ýardam eden B.Abdyrahmanowa, S.A.Nyýazow adyndaky TOHU-nyň talyplary P.Annaýewe, B.Berdiýewe, N.Artykowa, S.Paşşykowa, A.Myradowa, A.Erlekowa awtorlar uly minnetdarlyk bildirýärler.

Awtorlar şu kitabyň çykmagyna beren uly kömekleri üçin Ýewropa Birleşiginiň TASIS-TEMPUS maksatnamasynyň CD_JEP-25064 belgili "Ýewropanyň uniwersitetleri bilen hyzmatdaşlykda Türkmenistanda oba hojalyk bilimlerini ösdürmek" atly taslamasyna öz minnetdarlygyny bildirýär.

I BAP
SÜÝNME WE GYSYLMA

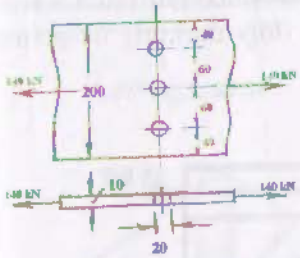
1.1 Statiki kesgitlenýän ulgamlaryň hasaby

1.1. Kese kesigi 16x16 sm^2 bolan agaç sütün gysylanda dartgynlylygy 1kN/sm^2 -dan köp bolmadyk ýagdaýynda näçe iň uly ýüki saklap biler?



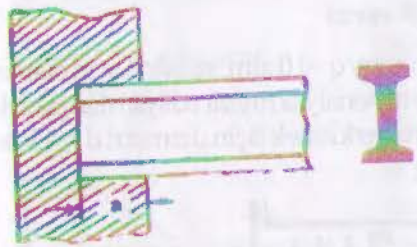
1.2-nji surat

1.2. P güýç bilen dartylan (surata seret) diametri 25 mm bolan çatyda ýüze çykýan dartgynlylyk 10 kN/sm^2. Epenegiň diwara bolan basyşy 0,14 kN/sm^2 -dan köp bolmadyk ýagdaýda epenegiň diametrini kesgitlemeli.



1.3-nji surat

1.3. Polat zolak tegelek berçin deşikler bilen gowşadylan we boý güýji bilen dartylan (surata seret). Howply kesikde dartgynlylygyň orta bahasyny kesgitlemeli.

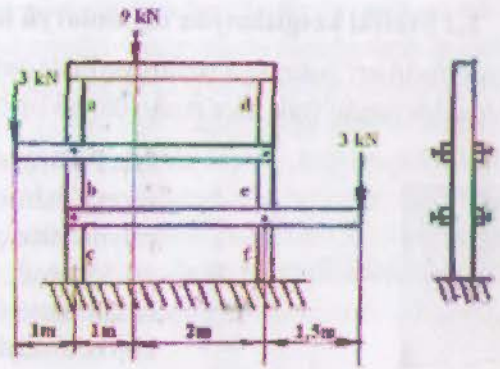


1.4-nji surat

1.4. 30 a belgili iki tawraly balka kerpiç diwara girizilen (surata seret). Balka Q=60kN basyş güýç bilen kerpiç diwary endigan basýar. Eger kerpiç örümiň rugsat edilýän dartgynlylygy $[\sigma] = 0{,}09$ kN/sm^2 bolsa, balkanyň diwara girýän uzynlygyny kesgitlemeli. Balkanyň inini kesgitlenen sortdan almaly.

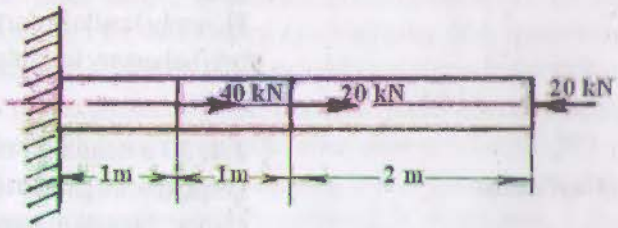
1.5. Uzynlygy birmeňzeş we ok boýunça täsir edýän birmeňzeş güýç bilen ýüklenen iki simiň biri mis, beýlekisi bolsa polat materialdan ýasalan. Mis simiň diametri 1mm. Eger iki sim hem deň uzalýan bolsalar, polat simiň diametri näçä deň bolar?

1.6. Kese kesigi 10 x 10 sm² bolan agaç diregleriň her biri suratda görkezilişi ýaly ýüklenen. Diregleriň häsiýetli kesiklerindäki dartgynlylyklary kesgitlemeli.



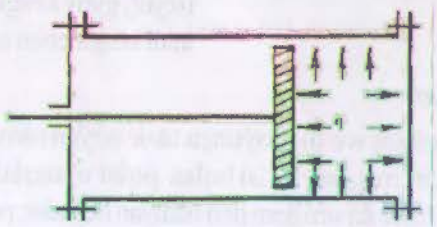
1.6-njy surat

1.7. Kese kesiginiň meýdany 10 sm² bolan polat sterženiň (surata seret) hemme böleklerindäki dartgynlylyklary we doly durkuny üýtgetmesi kesgitlemeli.

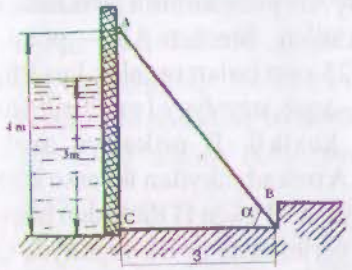


1.7-nji surat

1.8. Bug maşynynyň silindrindäki iş basyşy q =10 atm; silindriň içki diametri D=350 mm (surata seret). Eger boltuň materialyna rugsat edilýän dartgynlylyk [σ] = 4 kN/sm² bolsa, gapagy silindre berkitmek üçin diametri d = 18 mm bolan näçe bolt gerek bolar?

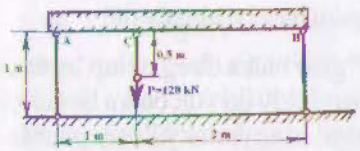


1.8-nji surat



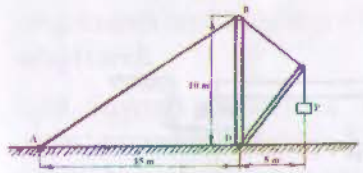
1.9-njy surat

1.9. Diametri d=15 sm bolan tegelek kesikli agaç AB direg (surata seret) suw geçirmeýän germewajy agdarylmakdan saklaýar. Diregiň materialyna rugsat edilýän dartgynlylygy 0,2 kN/sm² diýip kabul edip, diregleriň iň uly aralyklaryny kesgitlemeli.



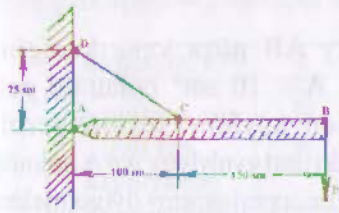
1.10-njy surat

1.10. Suratda görkezilişi ýaly ýüklenen, gaty AB balka, A we B direglere agram salýar. A diregiň materialy-polat, kese kesigi 10 sm², B diregiň materialy-agaç, kese kesigi 100 sm², Ç steržen-mis, kese kesigi 30 sm². Ýüküň asylan nokadynyň aşak süýşmesini kesgitlemeli.



1.11-nji surat

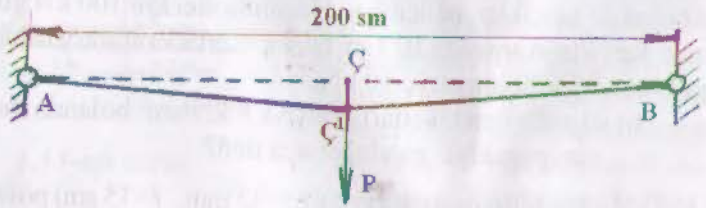
1.11. Göteriji kranyň AB dartyjysy (surat seret) 500 mm² kese kesikli tros bolup hyzmat edýär. Trosuň materialyna rugsat edilýän dartgynlylyk 4 kN/sm². Dartyjynyň berklik şerti boýunça kran näçe ýüki göterip biler?



1.12-nji surat

1.12. Gaty AB steržen (surata seret) P güýç bilen ýüklenen we diametri 20 mm bolan tegelek kese kesikli DÇ polat çekiji bilen saklanýar. Iň uly rugsat edilýän güýji we B nokadyň aşak süýşmesini kesgitlemeli. ÇD sterženiň materialyna rugsat edilýän dartgynlylyk [σ] = 16 kN/sm².

1.22. Diametri 1mm bolan polat sim gorizontal A we B (surata seret) gozganmaýan nokatlaryň arasyna dartylyp çekilen. Simiň uzynlygynyň ortasyna Ç nokatda kem-kemden artýan P ýük asylan. Simiň uzalmasy 0,5 % bolanda, ol üzülýär. Şu pursatda P ýük, Ç nokadyň aşak süýşmesi we üzülen pursatynda simiň dartgynlylygy nämä deň? Üzülme pursadyna çenli simiň durkuny üýtgetmesini maýyşgak diýip hasap etmeli.



1.22-nji surat

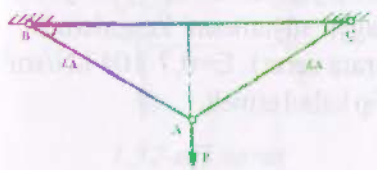
1.23. Tekiz nusgada iki tenzometr oturdylan.A tenzometr nusganyň boý oky boýunça, B tenzometr bolsa, oka perpendikulýar ýerleşdirilen. Degişlilikde, tenzometrleriň ulaltmagy K_A=950, K_B=1100. Tenzometrleriň bazalary birmeňzeş: $S_A=S_B$=20 mm:

Basgançakly ösýän ýüklenmede alnan görkezijiler tablisada getirilen. Maýyşgaklyk boý E modulyň orta bahasyny we kese durkuny üýtgetmäniň koeffisiýentini μ (Puassonyň koeffisiýentini) hasaplamaly. Nusganyň kesiginiň meýdany A=1sm^2.

1.23-nji surat

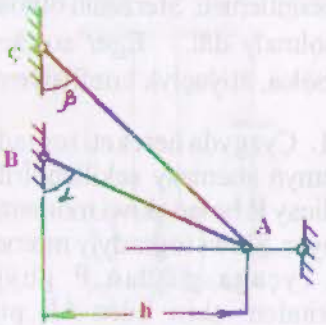
Ýüklenme P, kN	Tenzometrler boýunça hasabat	
	n_A, mm	n_B, mm
2	4,5	36
12	14,5	32,5
22	24	30
32	34,5	25,5

1.24. Içinden ýandyrylýan dwigateliň silindrini berkidýän şpilkanyň (hyrly sterženiň) diametrini saýlamaly. Şpilkalara güýçler deň ýaýran diýip hasap etmeli. Berlen: silindriň içki diametri D=100 mm; silindriň içindäki gazyň iň uly basyşy p=10MPa=1kN/sm^2, şpilkalaryň sany n=8, şpilkanyň materialyna rugsat edilýän dartgynlylyk 6 kN/sm^2-e deň.



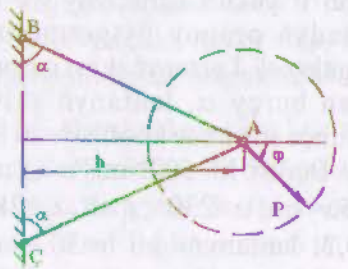
1.25-nji surat

1.25. Hemişelik göwrümleri bolan sterženler A düwne berkidilen. α burçuň haýsy ululygynda düwne goýlan rugsat edilýän güýjüň iň uly bahasy bolar? Sterženiň materialynyň rugsat edilýän dartgynlylygy [σ]deň bolanda güýjüň ululygyny kesgitlemeli.



1.26-njy surat

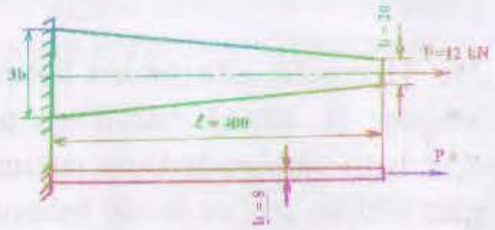
1.26. Sterženleriň materialy we gyzdyrylýan temperaturasy birmeňzeş bolanda we β burçlaryň haýsy gatnaşygynda sterženlerde temperatura dartgynlylyklary döremeýär? Direg üsti BÇ-den A düwne çenli aralyk hemişelik (h = const).



1.27-nji surat

1.27. A düwün tekizlikde ýuwaş aýlanýan ululygy boýunça hemişelik güýji kabul edýär. Sterženleriň materialynyň massasynyň minimal bahasynda α burçuň ululygyny kesgitlemeli. Sterženleriň meýdany birmeňzeş berklik şertinden kesgitlenilýär.

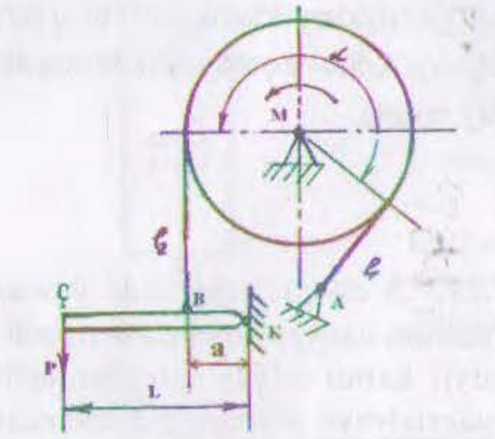
1.28. Öňünden gyzdyrylan kiçi radiusy r gurşaw, radiusy R bolan tigre geýdirilen. Eger gurşawyň kese kesiginiň meýdany A we maýyşgaklyk moduly E bolsa, gurşaw sowadylandan soň gurşawdaky dartyş güýjüni we dartgynlylygy kesgitlemeli (tigri gysylmaýan diýip hasap etmeli).



1.29-njy surat

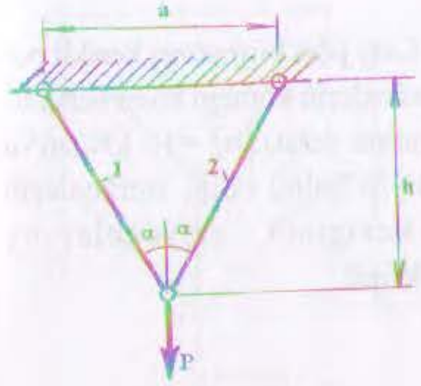
1.29. Üýtgeýän kesikli dýuralýumin zolagyň süýnmesini kesgitlemeli (surata seret). E=0,7·104 kN/sm^2 diýip kabul etmeli.

1.30. Dinamiki koeffisiýenti k_d=2 bolan birdenkä goýlan süýndüriji güýçden polat sterženiň kese kesiginiň meýdanyny kesgitlemeli. Sterženiň otnositel durkuny üýtgetmesi 1/1800-den köp bolmaly däl. Eger sterženiň materialynyň berklik çägi σ_b=42 kN/sm^2 bolsa, ätiýaçlyk koeffisiýentini kesgitlemeli.



1.31-nji surat

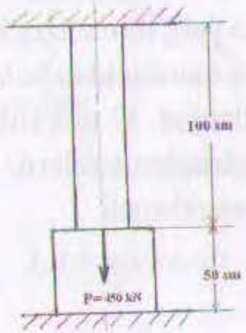
1.31. Çyzgyda hereketi togtadyjy enjamyň shemasy şekillendirilen. Radiusy R bolan şkiwi moment M aýlaýar. Şkiwi togtadyjy momenti ÇK ryçaga goýlan P güýjüň täsirinden şkiw bilen AB polat lentanyň arasynda döreýän sürtülme güýjüni döredýär. M momenti deňagramlaşdyrmak üçin gerek bolan P ýüküň agramyny we Ç nokadyň ornuny üýtgetmesini kesgitlemeli. Lentanyň şkiwi gurşap alýan burçy α, lentanyň şkiw boýunça sürtülme koeffisiýenti f-ℓ deň. Berlen: M=500Nm; R=0,2 m; L=5a=1m; α=230° ; ℓ_1=R, ℓ_2=2R; f=0,2; lentanyň ini b=30 mm; galyňlygy h=1mm. KÇ ryçagy absolýut gaty diýip hasap etmeli.



1.32-nji surat

1.32. Iki birmeňzeş steržene P güýç goýlan (surata seret). Sterženli ulgama iň az material harç bolar ýaly h aralyk nähili bolmaly?

1.2 Statiki kesgitlenmeýän sterženli ulgamlaryň hasaby

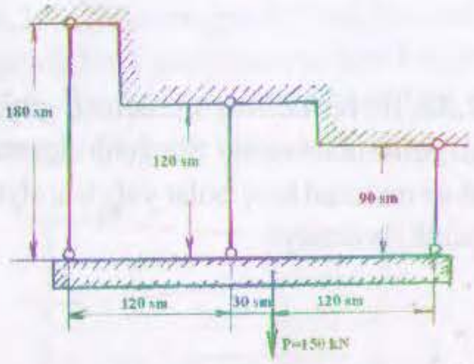


1.33-nji surat

1.33. Iki tarapy jebis berkidilen sterženiň aşaky böleginiň meýdany 40 sm^2-a, ýokarky böleginiň meýdany 10 sm^2-a deň. Sterženiň aşaky we ýokarky böleklerinin dartgynlylyklaryny kesgitlemeli.

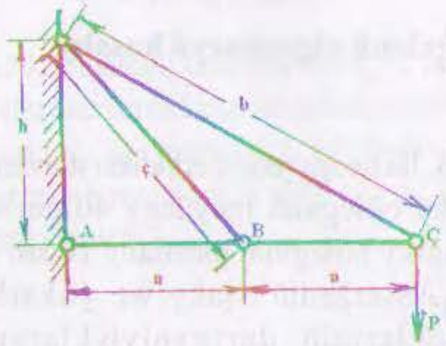
1.34. Tros merkezi böleginiň diametri d_1=5mm bolan mis simden we bu bölegi gurşap alan diametri d_2 =2,5 mm bolan dokuz polat simden ybarat. Simleri parallel hasap edip, P=5 kN ýük asylanda, trosuň simlerindäki dartgynlylygyny kesgitlemeli.

1.35. Kwadrat kese kesikli demirbeton sütün, sütüniň kesiginiň 1%-ini tutýan tegelek kese-kesikli dört polat sterženler bilen armirlenen. Betona rugsat edilýän dartgynlylyk 0,6 kN/sm^2, polat steržene rugsat edilýän dartgynlylyk 12 kN/sm^2 bolsa, sütüniň taraplary we sterženiň diametri näçe bolmaly? Poladyň maýyşgaklyk modulynyň betonyň maýyşgaklyk modulyna gatnaşygy 10-a deň. Sütüniň göterýän ýüki 1000 kN-a deň.



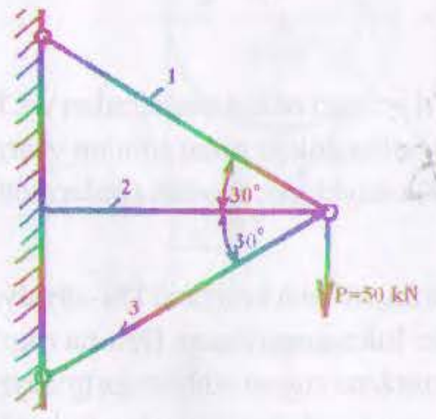
1.36-njy surat

1.36. Gaty pürs birmeňzeş kesikli polat sterženleriň kömegi bilen berkidilen (surata seret).[σ] =16 kN/sm²-a deň diýip kabul edip, sterženleriň kese-kesiginiň meýdanlaryny kesgitlemeli.



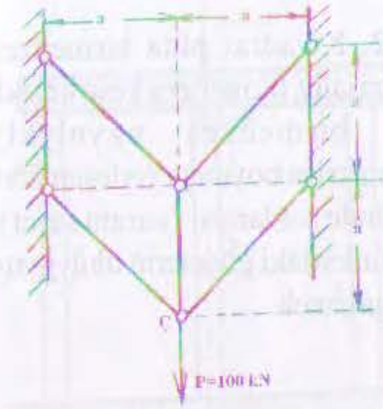
1.37-nji surat

1.37. Gaty AÇ balka, A nokatda diwara şarnirli berkidilen we suratda görkezilişi ýaly, birmeňzeş kesikli we birmeňzeş materialdan bolan iki sim bilen saklanýar. Ç nokatda goýlan ýüküň täsirinden simlerde döreýän güýçleri kesgitlemeli.



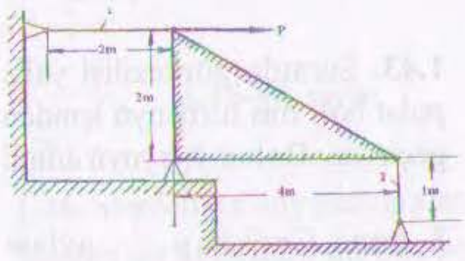
1.38-nji surat

1.38. Bir nokatda birmeňzeş materialdan üç steržen şarnirli berkidilen (surata seret). Kese-kesikleriniň meýdanlary: birinji sterženiňki 2 sm², ikinji sterženiňki 3 sm² we üçünjiniňki 4 sm² bolsa, sterženlerdäki dartgynlylyklary kesgitlemeli.



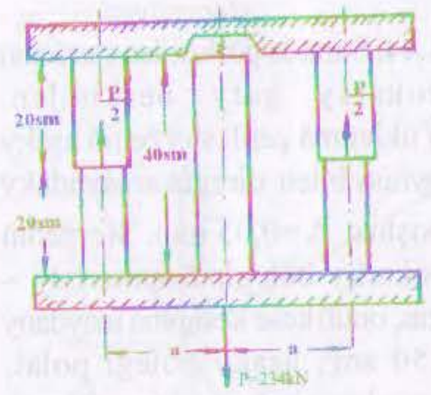
1.39-njy surat

1.39. Birmeňzeş kese-kesikli polat sterženler ulgamynyň Ç nokadynyň aşak süýşmesini kesgitlemeli (surata seret). Ölçeg a=1m, A=5 sm².



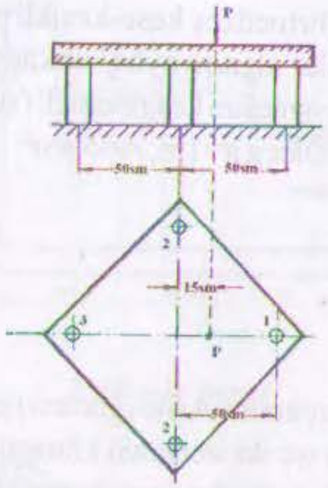
1.40-njy surat

.40. Gaty konstruksiýa (gurnaw) şarnirli diregiň we iki sterženiň kömegi bilen binýatda berkidilen (surata seret). Birinji steržen-polat ([σ_p] = 16 kN/sm²), ikinji steržen-çoýun ([$\sigma_ç$] = 10 kN/sm²). Olaryň kese kesiginiň meýdanlary $A_ç$=50 sm² -a, A_p=30 sm²-a deň. P ýüküň iň uly bahasyny kesgitlemeli.



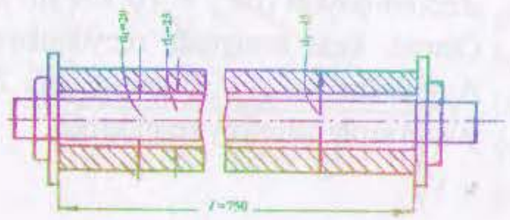
1.41-nji surat

1.41. Iki gaty pürs suratda görkezilişi ýaly üç steržen bilen birikdirilen. Çetki sterženleriň materiallary – polat, ýokarky böleginiň kese kesiginiň meýdany 16 sm², aşaky bölegińňki bolsa 10 sm², ortaky steržen-mis, kese kesiginiň meýdany 20 sm²-a deň. Ortaky sterženiň ýokarky üsti bilen ýokarky pürsüň arasynda $\alpha = 1{,}25 \cdot 10^{-4}$ sm/kN (1 kN ýükde pružiniň çökmesi) çeýelik koeffisiýenti bolan pružin goýlan. Berlen ýük boýunça pürsleri birikdirýän sterženlerdäki dartgynlylyklary kesgitlemeli.



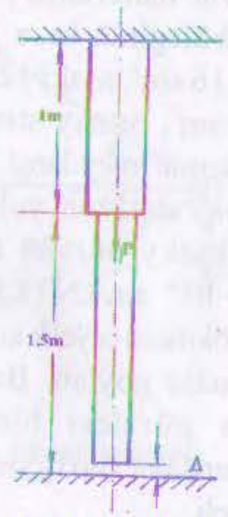
1.42-nji surat

1.42. Kwadrat plita birmeňzeş materially, birmeňzeş kese kesikli we birmeňzeş uzynlykly simmetriýa boýunça ýerleşen dört sütünde saklanýar (surata seret). Sütünlerdäki güýçleriň ululygyny kesgitlemeli.



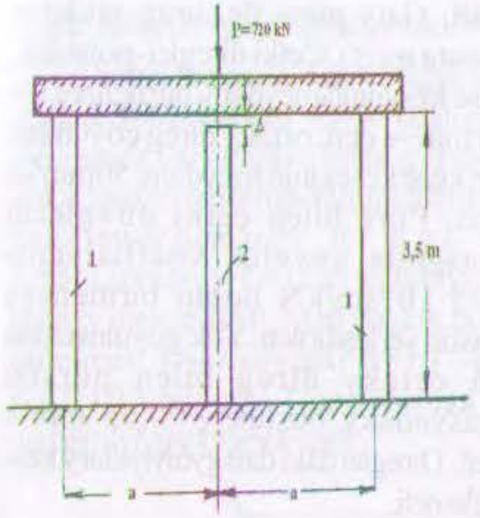
1.43-nji surat

1.43. Suratda görkezilişi ýaly, polat bolt mis turbanyň içinden geçirilen. Boltuň hyrynyň ädimi 3 mm. Gaýkany $\frac{1}{4}$ aýlaw çekdireniňde boltda we turbada nähili dartgynlylyklar döreýär?



1.44-nji surat

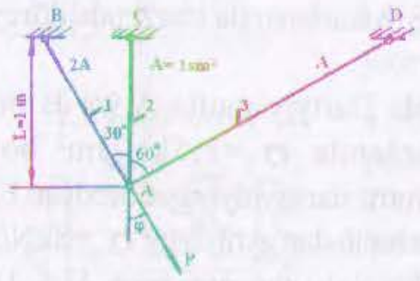
1.44. Suratda görkezilen sterženiň ýokarsy gaty berkidilen. Ýüklenmä çenli sterženiň aşaky gyrasy bilen diregiň arasyndaky boşluk Δ =0,05 mm. Sterženiň ýokarky böleginiň materialy – mis, onuň kese kesiginiň meýdany 150 sm², aşaky bölegi polat, kese-kesiginiň meýdany 50 sm². Steržen P=200 kN güýç bilen ýüklenende, onuň ýokarky we aşaky böleklerindäki dartgynlylyklary kesgitlemeli.



1.45-nji surat

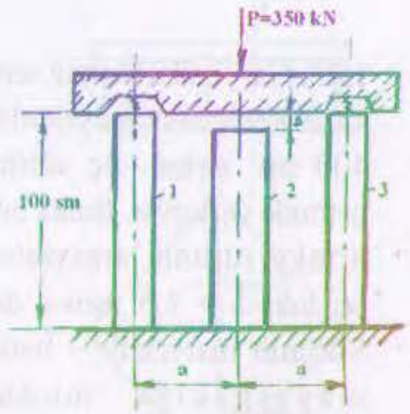
1.45. Gaty balka (surata seret) kese kesiginiň meýdanlary 400 sm² bolan üç sütüniň üstünde ýerleşýär. Balka bilen ortaky sütüniň arasyndaky boşluk Δ = 1,5 mm-e deň. Sütüniň materialy – beton, maýyşgaklyk moduly E=1400kN/sm². Sütünlerde döreýän dartgynlylyklary kesgitlemeli.

1.46. Steržen we ony gurşap alan turba bir wagtda P güýç bilen dartylýar. Steržen we turba dürli-dürli materiallardan we olaryň uzynlyklary ℓ-e deň, kese kesikleriniň meýdany bolsa, degişlilikde, A_1 we A_2deň. Maýyşgaklyk modullary E_1 we E_2. Ýüklenmeden soň bu dartgynlylyklaryň gatnaşygy m bolar ýaly, steržende we turbada nähili deslapky dartgynlylyklary σ_1^1 we σ_2^1 oýandyrmaly.



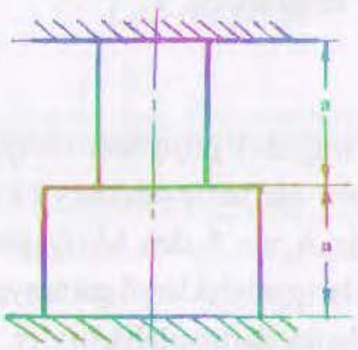
1.47-nji surat

1.47. A düwün wertikal boýunça Δ = 0,05 sm süýşýän bolsa, üç sterženli düwne goýlan güýjüň ululygyny we ugruny tapmaly. $E = 2 \cdot 10^3$ kN/sm²-a deň diýip kabul etmeli.



1.48-nji surat

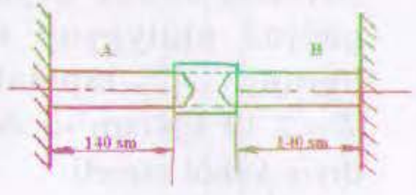
1.48. Gaty pürsi üç direg saklaýar (surata seret). Çetki diregler-polatdan, kese kesiginiň meýdany birmeňzeş we 20 mm²-a deň, ortaky direg çoýundan we kese keseginiň meýdany 50mm²-a deň. Pürs bilen çetki diregleriň arasynda çeýelik koeffisiýenti $\alpha=5\cdot10^{-4}$sm/kN bolan birmeňzeş pružin ýerleşdirilen. Ýük goýulmazdan öň ortaky direg bilen pürsüň arasyndaky boşluk Δ =0,05 mm-e deň. Direglerdäki dartgynlylyklary kesgitlemeli.



1.49-njy surat

1.49. Polat steržen (surata seret) iki tekizligiň arasynda t_1=+5°S temperaturada berkidilen; ýokarky bölegiň kese kesiginiň meýdany A_1 = 5 sm² aşaky böleginiňki bolsa A_2=10sm². Temperatura t_2=+25°S ýokarlananda sterženiň ýokarky we aşaky böleklerinde döreýän dartgynlylyklary kesgitlemeli.

1.50. Uzynlygy ℓ =2m polat sterženiň iki tarapy diwara berkidilen. Sterženiň haýsy hem bolsa bir tarapy diwaryň içinde Δ =0,05 mm boşlukda ornuny erkin üýtgedip bilýär. Temperatura 40°S ýokarlananda steržende döreýän dartgynlylygy kesgitlemeli.

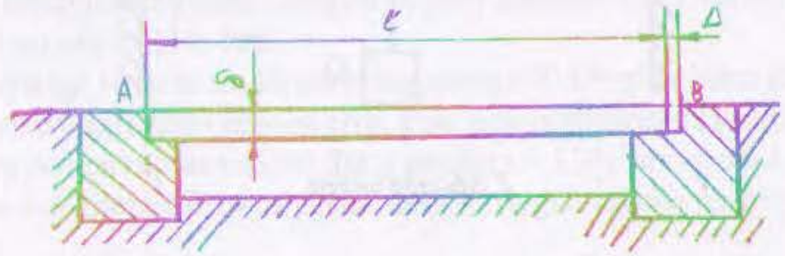


1.50-nji surat

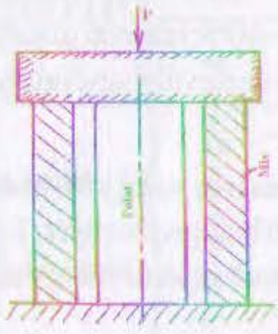
1.51. Dartyjy mufta A we B polat steržende σ_1=1,5kN/sm² bolan süýnme dartgynlylygy döredýär. Eger sterženiň dartgynlylygy σ_2=8kN/sm² bolar ýaly temperatura $\Delta t=-10^0$S üýtgedilende, muftanyň kömegi bilen sterženiň uzynlygyny näçe üýtgetmeli?

1.52. Her haýsynyň kese kesikleriniň meýdany 37,5 sm² we uzynlyklary 50 sm bolan inwar we mis turbajyklar 0°S temperaturada bir-birine seplenip goýlan. Soň bolsa olar +36,4° çenli gyzdyrylýar we olaryň umumy uzynlyklary üýtgemez ýaly P güýç bilen gysylýar. Bu güýjüň ululygy näçe bolýar we ýokarlandyrylan temperaturada turbajyklaryň her haýsynyň uzynlyklary näçä deň? Inwar üçin α_i=0 we E =2 ·10⁴ kN/sm².

1.53. Uzynlygy ℓ =12m, galyňlygy δ=40 sm bolan köpriniň demirbeton plitasy direge Δ=0,3 sm boşluk bilen goýlan. Demirbetonyň uzynlygyna giňelmek koeffisiýenti $\alpha=10^{-5}$-e deň, maýyşgaklyk moduly bolsa, $E=2\cdot10^3$kN/sm². Temperatura $\Delta t=30^0$S ýokarlananda plitadaky dartgynlylygy kesgitlemeli.

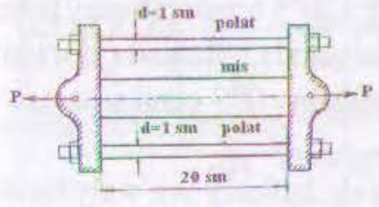


1.53-nji surat



1.54-nji surat

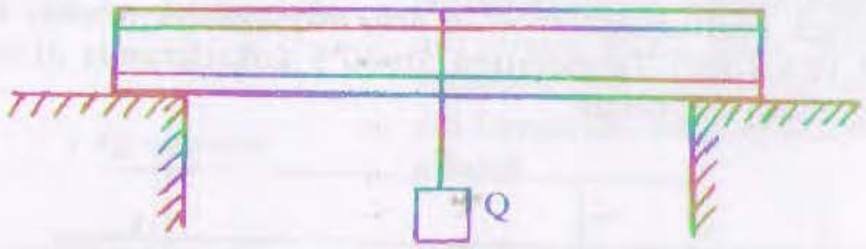
1.54. Gaty plitanyň üsti bilen 45 kN ýük meýdany 15 sm² polat silindre we meýdany 20 sm² içi boş mis silindre geçirilýär (surata seret). Güýç iki silindriň hem oklary boýunça täsir edýär. Ýük goýlandan soň temperatura 30°S ýokarlanýar. Ýüküň temperatura üýtgemezden öňki we üýtgäninden soňky ýaýraýşyny tapmaly.



1.55-nji surat

1.55. Suratda görkezilişi ýaly, iki gaty guýma polat boltlar bilen berkidilen. Uzynlygy 20,02 sm we kesekesiginiň meýdany 6 sm² bolan mis sterženi guýmanyň arasynda ýerleşdirmek üçin, şonuň ýaly-da guýmany süýşürmek üçin P güýjüň ululygyny tapmaly. P güýç aýrylan-dan soň guýmanyň arasyndaky uzynlygy tapmaly.

1.56. 16-njy belgili polat iki tawraly balka iki diregiň üstünde ýerleşdirilen we Q= 10 kN ýük bilen diregleriň ortasynda ýüklenen (surata seret). Balkanyň direginde gorizontal ornuny üýtgetmesine sürtülme güýji päsgel beryär. Balka bilen diregiň üstüniň sürtülme koeffisiýenti f=0,3-e deň. Balkada dartgynlylygyň artmagyna çenli iň uly temperaturanyň tapawudyny kesgitle-meli we temperatura dartgynlylygyny kesgitlemeli.



1.56-njy surat

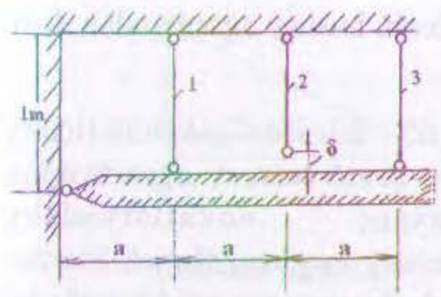
1.57. Tomus wagtynda relsde gysylma bolmaz ýaly relsleriň sepinde zerur bolan boşlugyň ululygyny kesgitlemeli. Relsler +10°S temperaturada ýerleşdirilip goýulýar; Tomusdaky iň uly temperatura +60°S; relsleriň uzynlygy 8 m-e deň. Relsler boşluksyz ýerleşdirilip goýlanda dartgynlylygyň ululygy nähili bolar?

1.58. Polat bug geçiriji turbanyň +15°S temperaturada uzynlygy 30 m deň. Bu turbadan +180°S temperatura çenli gyzdyrylan bug goýberilýär. Eger turbanyň giňelmegine hiç hili päsgelçilik bolmasa, turbanyň uzynlygy näçä deň bolar?

Eger turba uzalmaýan bolsa, turbadaky dartgynlylyk näçä deň bolar?

1.59. t_1=135°S-a çenli gyzdyrylan mis halka, t_2=20°S temperaturasy bolan polat wala geýdirilen. a) halka 20°S sowadylanda, halkada döreýän dartgynlylygy kesgitlemeli; b)waly we halkany 0°S çenli sowatsaň, halkadaky dartgynlylyk näçe ýokarlanar?

ç) halkadaky dartgynlylyk nola deň bolar ýaly halkany we waly haýsy temperatura çenli gyzdyrmaly? $E_m=10^4$kN/sm^2, $\alpha_m=1{,}6\cdot10^{-5}$, $\alpha_p=1{,}25\cdot10^{-5}$.



1.60-njy surat

1.60. Gaty pürs kese kesigi 20 sm^2 bolan birmeňzeş meýdanly üç polat sterženden asylan. Ortaky steržen taslama ölçeginden δ = 0,5 mm gysga ýerine ýetirilen (surata seret). Konstruksiýa ýygnalandan soň sterženlerdäki dartgynlylyklary kesgitlemeli.

1.3 Hususy agramy hasaba almak

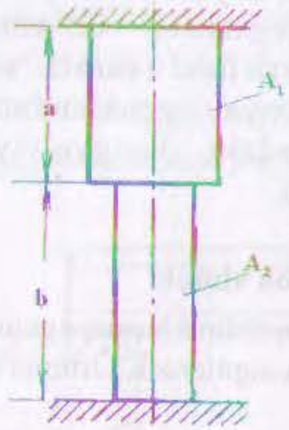
1.61. Hemişelik kese kesikli, beýikligi 8 m bolan sütüniň hususy agramyndan iň aşaky kesigindäki gysma dartgynlylygyny kesgitlemeli. Örümiň bir kub metriniň agramy 20kNa deň.

1.62. Beýikligi 10 m bolan kwadrat daş sütün 500 kN güýç bilen ýüklenen bolsa, hususy agramyny hasaba alyp, kese kesiginiň ölçegini kesgitlemeli. Örümiň gysylma rugsat edilýän dartgynlylygy 0,1 kN/sm^2-a, udel agramy bolsa 2-ä deň. Sterženiň uzynlygyna dartgynlylygyň ýaýraýşynyň epýuryny gurmaly.

1.63-nji surat

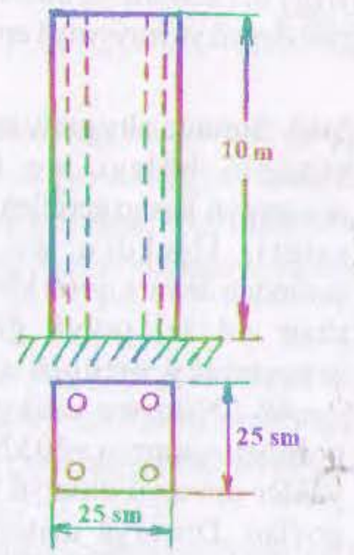
1.63. Suratda alty gatly jaýyň öň ýüzüniň bölegi we kerpiç diwarynyň kesigi getirilen (surata seret). Üçekden we jaýyň üstünden diwara q=60 kN/m ýük täsir edýär, jaýyň gatynyň arasyndaky örtügiň agramy q_2=40 kN/m we aşaky gatyň polunyň agramy q_3=30 kN/m. Bu ýükler diwaryň okunyň boýuna goýlan. Diwaryň materialynyň göwrüm agramy 20 kN/m^3-a deň. Rugsat edilýän dartgynlylyk [σ]=0,06 kN/m^2 bolsa, diwarlaryň iň kiçi galyňlygyny we binýadyň düşeginiň gumuna rugsat edilýän dartgynlylyk 0,05 kN/sm^2 bolsa, binýadyň inini kesgitlemeli.

1.64. Uzynlygy 120 m bolan polat sterženiň hususy agramyndan doly uzalmasyny kesgitlemeli.



1.65-nji surat

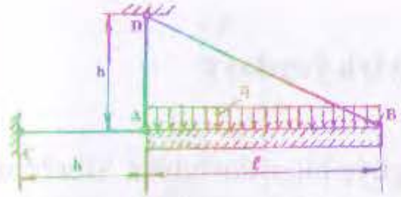
1.65. Suratda şekillendirilen sterženiň hususy agramyndan daýanç nokatlaryndaky gaýtargylary kesgitlemeli. Steržen ýokarky we aşaky böleklerіniň udel agramy γ we maýyşgaklyk moduly E bolan birmeňzeş materialdan ýasalan.



1.66-njy surat

1.66. Suratda görkezilen ölçegli demirbeton sütün diňe hususy agramy bilen ýüklenen. Demirbetonyň göwrüm agramy 25 kN/m³ bolsa, sütüniň betondaky we armaturadaky dartgyn-lylyklaryny kesgitlemeli. Polat armaturanyň we betonyň modullarynyň gatnaşygyny 15-e deň diýip kabul etmeli. Armaturanyň diametri 25 mm.

1.67. Umumy uzynlygy ℓ=1200 m, 125x125 mm kwadrat kesikli, içki deşiginiň diametri d=50 mm bolan köp basgançakly buraw ştangasy göwrüm agramy $\gamma=18\cdot10^{-6}$ kN/m² bolan suwuk toýun ergini bilen doldurylan we skwažina (guýa) çümdürilen. Ştanga skwažinadan ýokary göterilende onuň aşaky bölegine P=60 kN dartýan ýük täsir edýär. Ştangadaky iň uly dartgynlylygy we onuň absolýut durkuny üýtgetmesini kesgitlemeli.

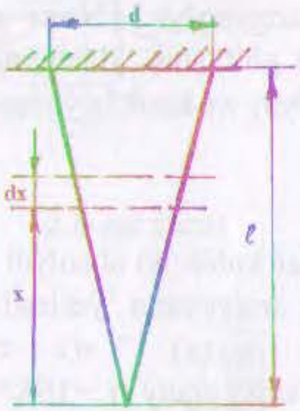


1.68-nji surat

1.68. Absolýut gaty AB pürs q=5kN/m bolan hususy agramy bilen ýüklenen. Berkidiji AÇ we AD sterženleriň jemlenen agramy iň az bolar ýaly h uzynlygy kesgitlemeli. Srterženler polatdan γ=78,5 kN/m³, süýnmä rugsat edilýän dartgynlylyk $[\sigma]_s$=16 kN/sm², gysylma $[\sigma]_g$=8kN/sm³. Sterženleriň kesikleri deň berklik şertinde saýlanylýar. ℓ=4m kabul edip, berkidiji sterženleriň iň az agramyny hasaplamaly.

1.69-njy surat

1.69. Suratda görkezilişi ýaly, uzynlygy ℓ kese kesiginiň meýdany A we udel agramy γ bolan materialdan ýasalan sterženiň ýokarsy we aşagy berkidilen. Sterženiň hususy agramyndan ýokarky we aşaky kesiklerindäki dartgynlylyklaryny kesgitlemeli we sterženiň uzynlygyna dartgynlylygyň ýaýraýşynyň epýuryny çyzmaly.



1.70-nji surat

1.70. Hususy agramynyň täsirinden konus şekilli sterženiň uzalmasyny kesgitlemeli (surata seret). Sterženiň uzynlygy ℓ, esasynyň diametri d we materialynyň göwrüm agramy γ deň.

1.71. Hususy agramy bilen ýüklenen polat steržen ýokarsyndan wertikal asylan. Eger dartgynlylyk 3 kN/sm² –dan ýokary bolmasa we poladyň udel agramy 7,85 bolsa, sterženiň rugsat edilýän iň uly uzynlygy näçä deň bolar? Sterženiň uzynlygyna dartgynlylygyň ýaýraýşynyň epýuryny gurmaly.

II bap
Çyzyk we tekiz dartgynlylyk ýagdaýy

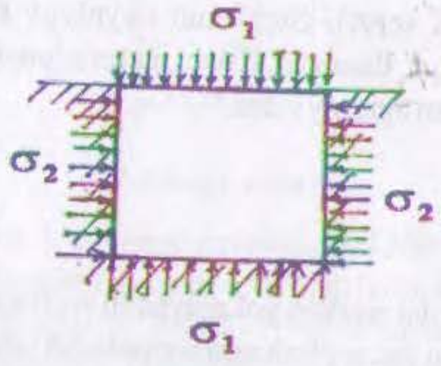
2.1. Diametri 6 sm bolan steržen 250 kN güýç bilen dartylýar. Sterženiň okuna 30° burç boýunça ýapgytlanan kesigiň normal we galtaşma dartgynlylyklaryny kesgitlemeli. Haýsy kesik boýunça galtaşma dartgynlylygyň iň uly bolýandygyny kesgitlemeli we onuň ululygyny hasaplamaly.

2.2. Diametri 7,5 sm bolan steržen 350 kN güýç bilen dartylýar. Kese kesikdäki doly dartgynlylygy kesgitlemeli. Sterženiň okuna 15° burç boýunça ýapgytlanan kesigiň doly we galtaşma dartgynlylygyny kesgitlemeli.

2.3. Tegelek kesikli steržen 150 kN güýç bilen dartylýar. Islendik kesikde galtaşma dartgynlylyk 6 kN/sm²-dan uly bolmadyk ýagdaýynda sterženiň diametrini kesgitlemeli.

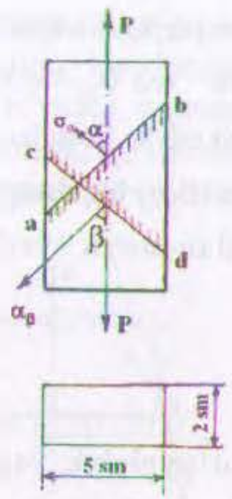
2.4. Dartylan sterženiň haýsy hem bolsa bir ýapgytlanan meýdançasynda normal dartgynlylyk 7 kN/sm²-a, galtaşma dartgynlylyk bolsa 5 kN/sm²-a deň. Iň uly normal we galtaşma dartgynlylyklary kesgitlemeli.

2.5. Dartylan sterženiň kese-kesiginde normal dartgynlylyk 5 kN/sm²-a deň. Haýsy hem bolsa bir ýapgytlanan kesikde galtaşma dartgynlylyk 1,6 kN/sm²-a deň. Ýapgytlanan kesigiň ýagdaýyny we kesik boýunça täsir edýän normal dartgynlylygy kesgitlemeli.

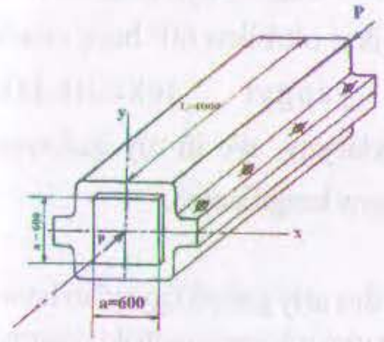


2.6-njy surat

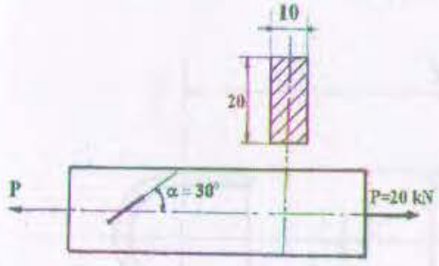
2.6. Polat kubik iki absolýut gaty diwaryň aralygynda ýerleşdirilen (surata seret) we erkin gapdalyndaky grany σ_1=16 kN/sm² dartgynlylyk döredýän gysylma sezewar bolýar. Eger μ=0,3 bolsa, kubigiň gapdal granyndaky basyşy kesgitlemeli.



2.7-nji surat



2.8-nji surat



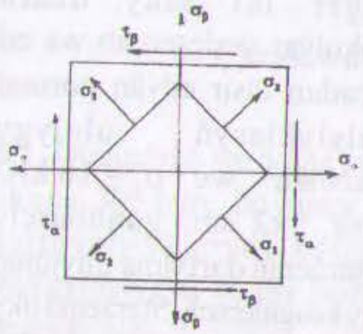
2.9-njy surat

2.7. Eger iki sany özara perpendikulýar ýerleşen ab we cd meýdançadan täsir edýän normal dartgynlylyklaryň ululygy σ_α= 16 kN/sm² we σ_β = 16 kN/sm² bolsa, 5x2 sm gönüburçly kesikli sterženiň dartylma güýjüniň ululygyny kesgitlemeli. Sterženiň oky bilen ab we cd meýdança normalyň emele getiren burçunyň ululygyny hasaplamaly.

2.8. Gaty iki bölek gurşaw sekiz bolt bilen gaýymlanan boltlardan ybarat. Puassonyň koeffisiýenti μ =0,4 bolan plastmassadan ýasalan prizma gurşawyň içinde gysylýar (surata seret). Gurşawyň oky boýunça plastmassa prizma P=100kN güýç bilen gysylýar. Boltlara talap edilýän diametri kesgitlemeli.

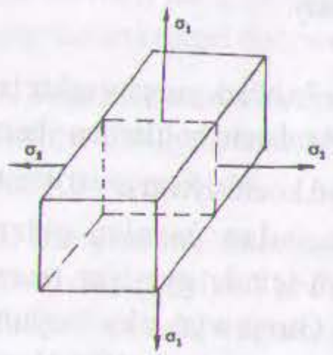
Bolt üçin $[\sigma_s]$ = 10 kN/sm² diýip kabul etmeli.

2.9. Suratda görkezilişi ýaly, süýndürilýän nusga tenzometr oturdylan. Tenzometriň bazasy S=20 mm, ulaldyş koeffisiýenti k=1000, berlen ýüklenmede tenzometriň görkezmesi Δ=6,5 mm. Eger E =2,1·10⁴ kN/sm² bolsa, nusganyň materialy üçin Puassonyň koeffisiýentini kesgitlemeli.



2.10-njy surat

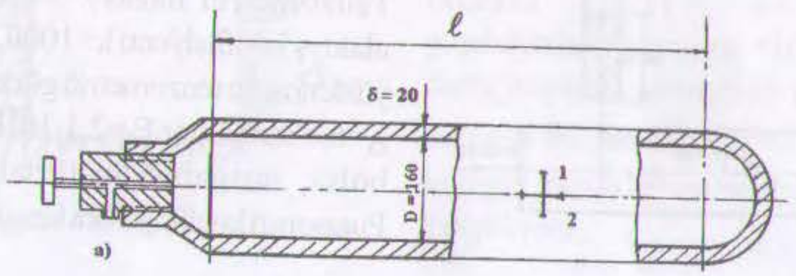
2.10. Eger iki özara perpendikulýar granlara $\sigma_\alpha = 12$ kN/sm² we $\sigma_\beta = 6$ kN/sm²; $\tau = 3$ kN/sm² täsir edýän bolsalar, suratda görkezilen element üçin baş dartgynlylygy we baş meýdançanyň ýerleşişini kesgitlemeli.



2.11-nji surat

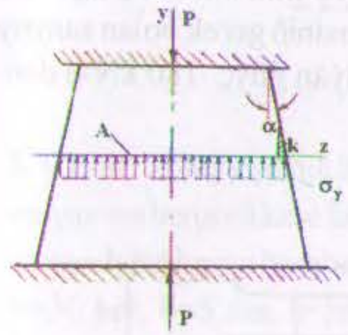
2.11. Tekiz dartgynlylyk ýagdaýyna sezewar bolan elementiň nokadyndaky baş dartgynlylyklar $\sigma_1 = 12\ kN/sm^2$-a, $\sigma_2 = 10\,\text{kN/sm}^2$-a deň (surata seret). Wertikal ok bilen 60° burç emele getirýän ýapgyt tekizlikdäki dartgynlylyklaryny we iň uly galtaşma dartgynlylygyny kesgitlemeli.

2.12. Suratda görkezilişi ýaly, silindrik ýuka diwarly gabyň (gysylan howa üçin ballon) üstüne iki datçik ýelimlenen. Eger elektriktenzometriki enjamyň kömegi bilen kesgitlenen datçigiň bazasynyň ugrundaky durkuny üýtgetme degişlilikde $\varepsilon_1 = 330\cdot10^{-6}$ we $\varepsilon_2 = 84\cdot10^{-6}$ bolsalar, ballondaky howanyň basyş ıy kesgitlemeli. Ballonyň materialy üçin $E = 2\cdot10^4$ kN/sm², =0,25.



2.12-nji surat

2.13. Bir ugra dartýan dartgynlylykdan $\sigma_y = 14$kN/sm² ölçegi b=40 sm bolan alýumin kwadrat list Δb=0,8 mm uzalýar. Eger liste şol bir ululykda we ugry boýunça σ_y perpendikulýar goşmaça dartýan σ_x dartgynlylyk täsir edýän bolsa, iki ugra uzalmany kesgitlemeli. Puassonyň koeffisiýenti μ=0,3. Eger goşmaça dartgynlylyk gysýan bolsa, durkuny üýtgetme nähili bolar?



2.14-nji surat

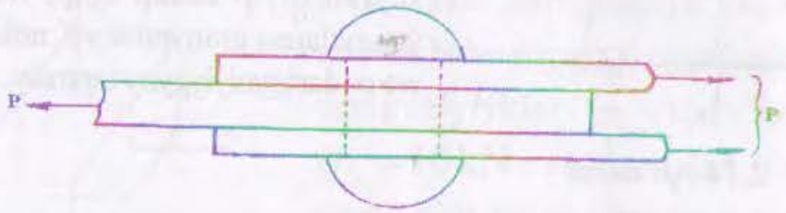
2.14 Tekiz trapesiýa görnüşli nusga presiň ýassygynyň aralygynda P güýç bilen gysylýar. Normal dartgynlylyk σ_y gorizontal tekizlik boýunça endigan ýaýran diýip hasap edip, nusganyň ýapgytlanan granyndaky K nokadyň τ_{xy} we σ_z dartgynlylygyny tapmaly.

III bap

Süýşme we towlanma

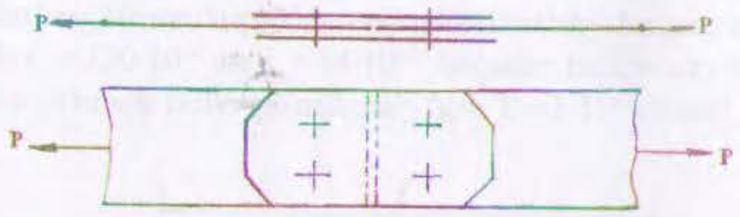
3.1. Süýşme (kesilme, ýenjilme, owranma)

3.1. Galyňlygy 5 mm bolan iki listi galyňlygy 12 mm bolan üçünji liste birikdirmek üçin, diametri 20 mm deň berçinlemäniň gerek bolan sanyny kesgitlemeli (surata seret). Birikdirmä täsir edýän güýç 180 kN-a deň. Rugsat edilýän dartgynlylyklar:
$[\tau]$= 10 kN/sm^2; $[\sigma_{ý}]$ = 28 kN/sm^2



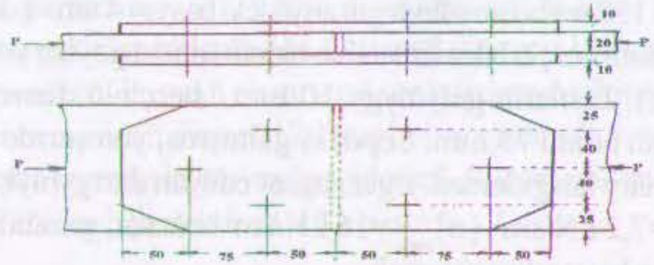
3.1-nji surat

3.2. 12 x 150 mm^2 kese kesikli list galyňlygy 6 mm bolan urna bilen örtülen (surata seret). Birikdirmede diametri 20 mm bolan berçin ulanylan. Süýndürýän güýç 120 kN. Kesilmede we ýenjilmede berçiniň, şonuň ýaly-da listiň we urnanyň howply kesiginde üzülme dartgynlylyklaryny kesgitlemeli.



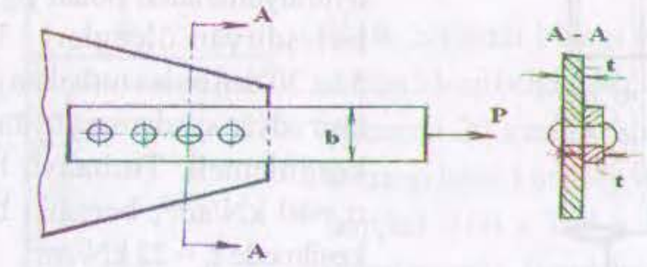
3.2-nji surat

3.3. Iki listiň sepinde diametri 26 mm bolan berçin ulanylan. Birikdirme suratda görkezilişi ýaly ýerine ýetirilen. Rugsat edilýän dartgynlylyklar: $[\tau]$ = 10 kN/sm^2; $[\sigma_{ý}]$ = 28 kN/sm^2, $[\sigma_{s}]$ =16 kN/sm^2. Sepe rugsat edilýän iň uly süýnme güýjüni kesgitlemeli.

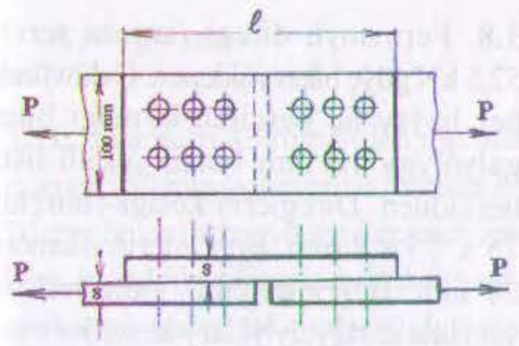


3.3-nji surat

3.4. Polat zolagy şekilli liste birikdirmek üçin (surata seret) zerur berçin sanyny we berçiniň kese kesiginiň diametrini kesgitlemeli. Berçin deşigi bilen gowşadylan kesigi hasaba alyp, polat zolagyň berkligini barlamaly. Berlen: P=30 kN, b=5 sm, t=5mm, polat zolagyň materialyna rugsat edilýän dartgynlylyk $[\sigma]$ = 16 kN/sm^2, berçiniň materialy üçin $[\tau]$ = 10 kN/sm^2 (kesmede), $[\sigma]_{ýenj.}$=26 kN/sm^2 (ýenjilmede).



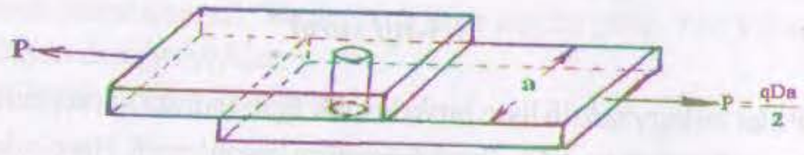
3.4-nji surat



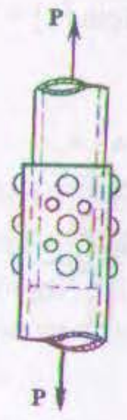
3.5-nji surat

3.5. Ölçegi 100 x 8 mm iki polat listi galyňlygy 8 mm bolan urnanyň kömegi bilen birikdirmek üçin iki setirli berçinleme tikinine näçe berçin gerek bolar. Urnanyň talap edýän uzynlygyny kesgitlemeli. Berlen: P=80kN, $[\sigma]$=26kN/sm^2, $[\tau]$=10 kN/sm^2.

3.6. Diametri 150 sm bolan silindr gazanyň içki basyşy 4 atm-e deň. Gazanyň boý tikini bir setir berçin bilen listleri bir-biriniň üstüne goýlup ýerine ýetirilen (surata seret). Listleriň galyňlygy 10 mm, berçiniň diametri 20 mm, berçinlemäniň ädimi 75 mm. Sepdäki galtaşma, ýemşerme we süýnme dartgynlylyklary kesgitlemeli. Eger rugsat edilýän dartgynlylyklar $[\sigma]=10$ kN/sm^2, $[\tau]=7{,}2$ kN/sm^2, $[\sigma]_{ýenj.}=16$ kN/sm^2 bolsalar, gazandaky aňryçäk rugsat edilýän basyşy kesgitlemeli.

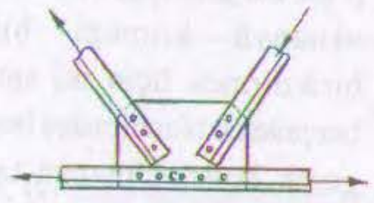


3.6-njy surat



3.7-nji surat

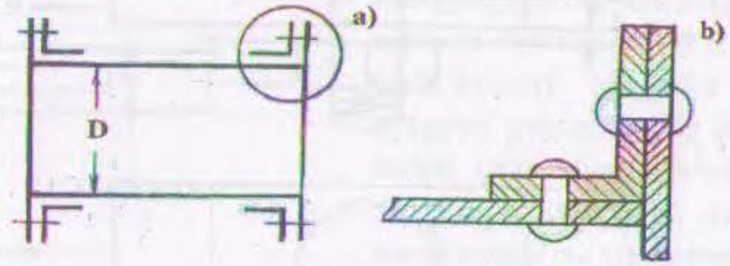
3.7. Diametri d = 3,5 mm, materialy dýuralýuminiden bolan ýigrimi berçiniň birleşdirýän ölçegleri 30 x 28 we 33 x 30 deň bolan turbalara (surata seret) täsir edýän syndyrma güýjüniň ululygyny kesgitlemeli. Turbanyň berklik çägi $\sigma_b=40$ kN/sm^2, berçiniň berklik çägi: kesilmede $\tau_b=22$ kN/sm^2, ýenjilmede $\sigma_{ýenj.}=52$ kN/sm^2.



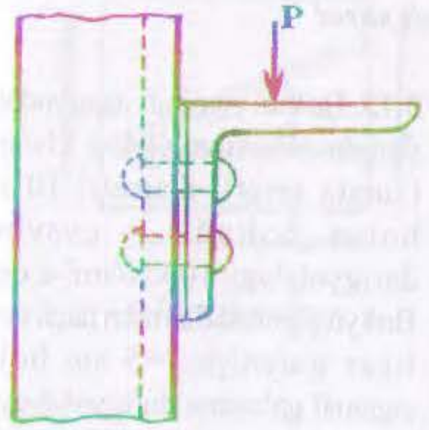
3.8-nji surat

3.8. Fermanyň diregi (surata seret) 52,5 kN güýç bilen ýüklenen. Ç düwünde her haýsy üç berçiniň kömegi bilen galyňlygy 10 mm bolan şekilli liste berkidilen. Diregleriň kesigi– burçluk 75 x 75 x 8 mm. Berçinleriň diametri 20 mm. Berçinlerdäki galtaşma we ýenjilme dartgynlylyklary kesgitlemeli.

3.9. Suratda görkezilişi ýaly, gazanyň gapagy diwar bilen berçinlenilip, burçlugyň kömegi bilen birleşdirilen. Gazanyň diametri 100 mm; gazandaky basyş 10 atm-e deň. Gazanyň diwarynyň we burçlugyň tekjesiniň galyňlygy 10 mm. Eger berçinleriň diametri 20 mm bolsa, gazanyň diwaryny burçluk bilen birikdirýän berçinleriň sanyny kesgitlemeli. Rugsat edilýän dartgynlylyk: kesilmede 7 kN/sm^2, ýenjilmede 16 kN/sm^2.



3.9-njy surat

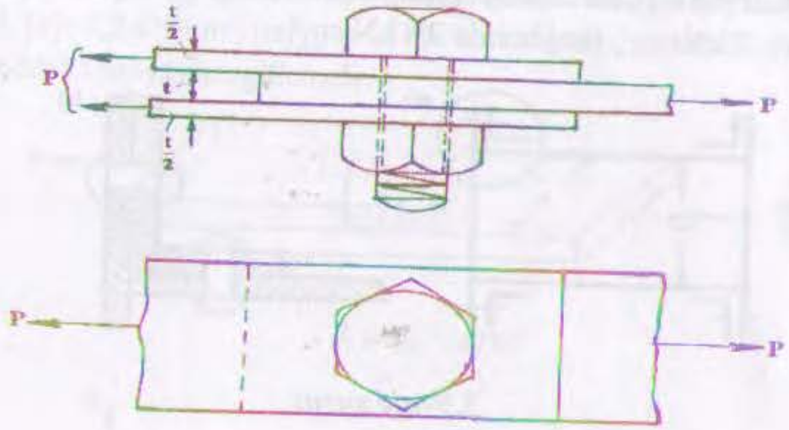


3.10-njy surat

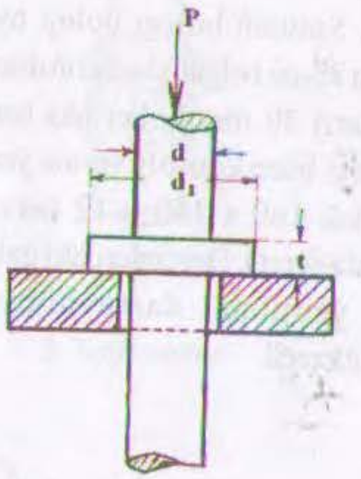
3.10. Sütüniň bölegi bolup hyzmat edýän 33-nji belgili şwelleriň diwaryna diametri 20 mm bolan bäş berçiniň kömegi bilen konsoly ýerine ýetirýän burçluk 160 x 160 x 12 berkidilen (surata seret). Berçinlerdäki galtaşma we ýenjilme dartgynlylyklary kesgitlemeli.

3.11. Diametri 40 mm bolan mis steržen örän kiçi boşluk bilen daşky diametri 60 mm bolan polat turbada goýlan. Sterženiň iki gyrasy diametri 20 mm bolan turbanyň we sterženiň içinden geçýän gaty şpilkalaryň kömegi bilen birikdirilen. Eger konstruksiýanyň gyzgynlygy 40°S ýokarlanýan bolsa, şpilkanyň galtaşma dartgynlylygyny kesgitlemeli. Şpilkanyň durkuny üýtgetmegini hasaba almaly däl.

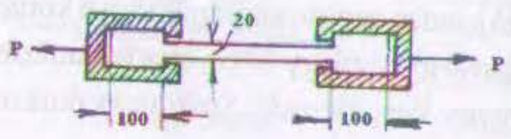
3.12. Suratda görkezilen boltuň birikdirmedäki diametrini kesgitlemeli. Süýndürme güýç P =200 kN, galyňlyk t = 2 sm. Boltuň materialy üçin rugsat edilýän dartgynlylyklar: kesilmede 8 kN/sm², ýenjilmede 20 kN/sm².



3.12-nji surat



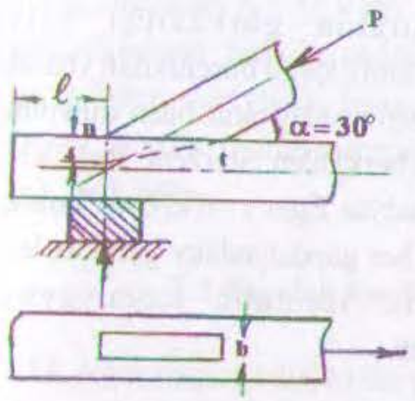
3.13-nji surat



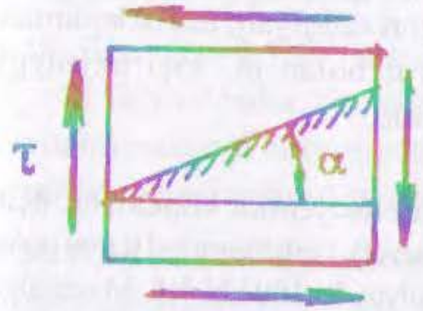
3.14-nji surat

3.13. Boltuň çigniniň aşagyndaky ýenjilme dartgynlylyk 4 kN/sm² (surata seret), diametri 10 sm bolan boltuň gysylma dartgynlylygy 10 kN/sm²-a deň. Boltyň çigniniň diametri näçä deň? Eger galyňlyk t=5 sm bolsa çigniniň galtaşma dartgynlylygyny kesgitlemeli.

3.14. Eger agajyň süýnmä rugsat edilýän dartgynlylygy [σ]=5,6 kN/sm²-a deň bolsa, kesigi 2 x 4 sm² (surata seret) bolan tekiz agaç nusga näçe dartuw güýjüni goýmak bolar? Şu dartuw güýjünde nusganyň kellesindäki owranma dartgynlylygy näçä deň bolar?



3.15-nji surat



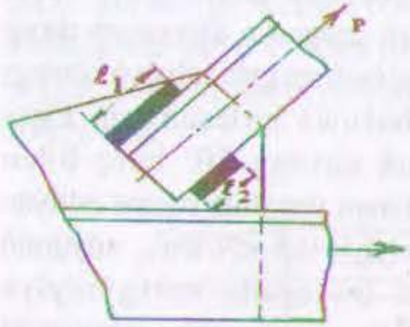
3.16-njy surat

3.15. Suratda görkezilişi ýaly, fermanyň eşegarka aýagynyň direg düwni ini b=6 sm çykyndynyň kömegi bilen dartuwa birleşdirilen. Eger süýümiň ugruna 30° burç bilen ýapgytlanan ýenjilmä rugsat edilýän dartgynlylyk 0,5 kN/sm², süýümiň ugruna owranma dartgynlylyk 0,08 kN/sm², eşegarka germewiň aýagyny gysýan güýç P = 20 kN bolsa, çykyndynyň beýikligini we dartuwyň ahyrynyň uzynlygyny kesgitlemeli. n-t çyzyk boýunça güýç täsir etmeýär diýip hasap etmeli.

3.16. Arassa süýşmä sezewar bolýan elementiň galtaşma dartgynlylygy τ=5kN/sm² deň, suratda görkezilişi ýaly süýşme tekizligine α =30° burç boýunça ýapgytlanan meýdançada dartgynlylyk tegelegini gurup, normal, galtaşma we doly dartgynlylyklary kesgitlemeli.

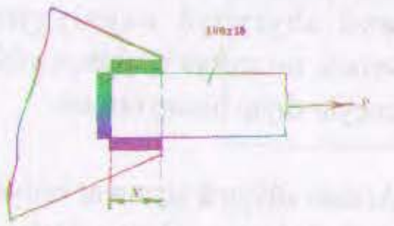
3.17. Gapyrgalarynyň ölçegi 20 sm bolan polat kubuň dört granlary τ=10kN/sm² galtaşma dartgynlylyklar bilen ýüklenen. Absolýut we otnositel süýşmeleriň ululygyny tapmaly. Süýşmede maýyşgaklyk moduly G = 8·10³ kN/sm².

3.18. Tekiz polat nusga ýüklenmä çenli nusganyň okuna α =30° burç boýunça ýapgytlanan çyzyk çyzylan. Eger nusga =12 kN/sm² dartgynlylyga çenli süýndürilse, burç näçe ululykda üýtgär? E = 2·10⁴ kN/sm², μ= 0,25.



3.19-njy surat

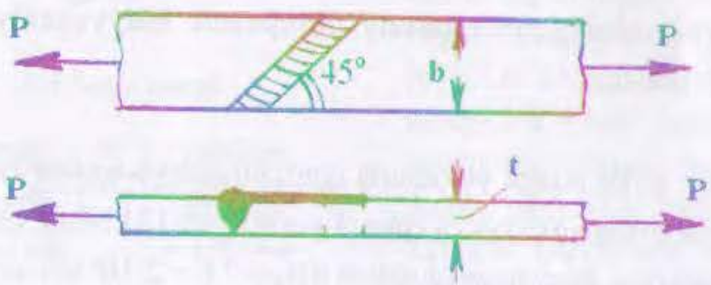
3.19. Suratda görkezilişi ýaly 80 x 80x8 mm ölçegli burçlukdan ybarat bolan steržen maňlaý tikin bilen düwnüň şekil listine berkidilen. Steržene P=62 kN güýç täsir edýär. Eger τ =8 kN/sm^2 bolsa, burçlugyň her gapdalyndaky gerek bolan kebşirleme tikin· iniň uzynlygyny kesgitlemeli.



3.20-nji surat

3.20. Eger listiň süýnme dartgynlylygy 14kN/sm^2, kebşirlemäniň kesilmä rugsat edilýän dartgytlylygy 8kN/sm^2 bolsa, suratda görkezilişi ýaly, listi birleşdirmek üçin zerur bolan iň kiçi uzynlygy kesgitlemeli.

3.21. Materialyň peýdalanylyşynyň koeffisiýentini köpeltmek üçin kebşirleme tikinleri ýapgyt edilen (surata seret). Galyňlygy t=10 mm polat listler birikdirilende süýndürýän güýjüň ululygy P=100 kN deň. Materialyň peýdalanylyşyny 100% hasap edip, listiň zerur bolan inini kesgitlemeli. Gyýa kebşirleme tikin süýndürýän güýjüň ugruna 45° burç boýunça ýerleşdirilen. Eger kebşirleme tikinine rugsat edilýän dartgynlylyklar $[\sigma]_{keb}$=10 kN/sm^2, $[\tau]_{kebş.}$=8 kN/sm^2 bolsalar, aýratynlykda normal we galtaşma dartgynlylyklar boýunça tikiniň berkligini barlamaly.



3.21-nji surat

3.22. Meýdany A = 55,9 sm^2 bolan şweller, şekilli liste iki maňlaý we bir dilik tikinleriň birikdirmedäki berkligini barlamaly. Şweller P = 800 kN güýç bilen dartylýar. Esasy materiala rugsat edilýän dartgynlylyk $[\sigma]_s$ = 16 MPa, tikiniň materialy üçin kesilmä rugsat edilýän dartgynlylyk $[\tau]_{tik}$ = 8 MPa.

3.2 Tegelek kesikli sterženleriň towlanmasy

3.23. Eger rugsat edilýän dartgynlylyk [τ] = 7 kN/sm^2 bolsa, 15 kN·m aýlaw momenti geçirýän bitewi tegelek kesikli walyň diametrini kesgitlemeli.

3.24. 300 aýl./min. we 450 a.g. geçirilýän bitewi kesikli walyň diametrini kesgitlemeli. Walyň 2 m uzynlygynda towlanma burçy 1°– dan ýokary bolmaly däl, iň uly galtaşma dartgynlylyk 4 kN/sm^2; G = 8·10^3 kN/sm^2.

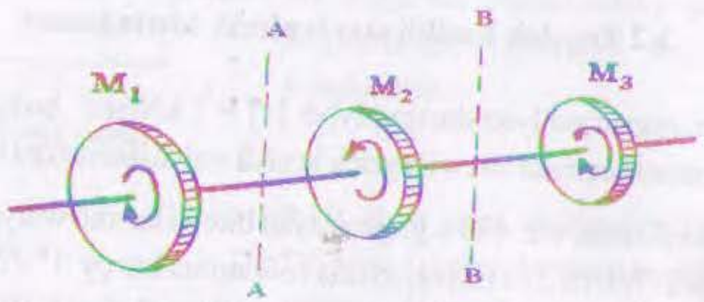
3.25. Eger G_a =2.7·10^3 kN/sm^2, G_p =8·10^3 kN/sm^2, γ_a =26kN/m^3, γ_p =78,5kN/m^3 bolsa, birmeňzeş towlanma momentinde we otnositel towlanma burçunda taslanan polat we alýumin ergininden ýasalan birmeňzeş uzynlykda bitewi wallaryň agramlaryny deňeşdirmeli.

3.26. Polat bitewi walyň gerek bolan diametrini kesgitlemek üçin rugsat edilýän galtaşma dartgynlylyk 8 kN/sm^2, 1 m uzynlykda rugsat edilýän towlanma burçy 1°-a deň. Towlanma momentiniň haýsy ululygynda diametri kesgitlemek üçin çäklenmek mümkin, rugsat edilýän dartgynlylyk boýunçamy ýa-da diňe rugsat edilýän towlanma burçy boýunça?

3.27. Uzynlygy 6 m we diametri 10 sm bitewi wal 4° burç boýunça towlanan. Eger G = 8·10^3 kN/sm^2 bolsa, iň uly galtaşma dartgynlylyk näçä deň?

3.28. Walyň diametrini kesgitlemegiň ýakynlaşdyrylan formulasy $d = 2{,}5\sqrt[3]{40\frac{N}{n}}$ görnüşe eýe. Bu ýerde d–walyň diametri, N – walyň geçirýän kuwwaty a.g., n–walyň minutdaky aýlaw sany. Bu formula süýşmede rugsat edilýän dartgynlylygyň haýsy ululygyna laýyk getirilip çykarylan?

3.29. Walyň AA we BB kesiklerinde M_1=130 kNsm, M_2=300 kNsm aýlaw momentlerden iň uly galtaşma dartgynlylyklary kesgitlemeli. AA kesikde walyň diametri 5 sm, BB kesikde bolsa 7,5 sm-e deň.



3.29-njy surat

3.30. Uzynlygy 200 mm-e, diametri 20 mm-e deň bolan polat nusga towlanma synag edilýär. Synagyň netijesi tablisada getirilen:

Towlanma momenti, kN m	0,02	0,04	0,06	0,08	0,1	0,12	0,14	0,16	0,18
Towlanma burçy, köpeldilen 2000 (radianda)	6,1	12,5	18,9	25,2	31,4	37,8	44,3	50,5	56,9
Towlanma momenti, kN m	0,2	0,22	0,24	0,26	0,28	0,3	0,32	0,34	
Towlanma burçy, köpeldilen 2000 (radianda)	63	69,5	75,8	82,1	88,5	95,4	110	148	

Towlanma burçuna baglylykda galtaşma dartgynlylygynyň diagrammasyny gurmaly we towlanmada maýyşgaklyk modulyny kesgitlemeli. Seredilýän ýagdaý üçin proporsionallyk çäginiň ululygyny tapmaly.

3.31. Materialy ýumşak polatdan bolan steržen 60 kN güýç bilen süýndürilende 0,113 mm uzalýar. Sterženiň diametri 25 mm-e, uzynlygy bolsa 20 sm-e deň. Bu steržen 20kN·sm towlanma moment bilen ýüklenende, 15 sm uzynlykda 0,55° burç bilen towlanýar. E, G we μ ululyklaryny kesgitlemeli.

3.32. Bug turbinanyň kuwwaty kesgitlenende aýlanýan walyň towlanma burçy ölçenen we 6 m uzynlykda 1,2°-a deň bolýar. Walyň daşky we içki diametrleri degişlilikde 25 sm-e we 17 sm-e deň. Walyň aýlaw tizligi 250 aýl./min; $G = 8 \cdot 10^3$ kN/sm^2. Walyň geçirýän kuwwatyny we onda döreýän galtaşma dartgynlylygyny kesgitlemeli.

3.33. Walyň geçirýän kuwwatyny kesgitlemek üçin onuň daşky emele getirijisine 45° burç boýunça ýerleşen çyzgynyň ugruna tenzometriň kömegi bilen uzalmasy ölçelýär. Ölçelen otnositel uzalma $\varepsilon = 0{,}000425$-e deň. Walyň daşky diametri 40 sm, içki diametri bolsa 24 sm. Maýyşgaklyk moduly $G = 8 \cdot 10^3$ kN/sm^2. Eger wal 120 aýl/min tizlik bilen aýlanan bolsa, onuň geçirýän kuwwatyny kesgitlemeli. Iň uly galtaşma dartgynlylyk nähili ululykda bolar?

3.34. Içki diametri daşky diametriniň 60% düzýän içi boş wal, diametri 40 sm bolan bitewi wal bilen çalşyrylýar. Iki walyň rugsat edilýän galtaşma dartgynlylyklarynyň birmeňzeşlik şertinden içi boş walyň daşky diametrini kesgitlemeli. Bitewi we içi boş wallaryň agramlaryny deňeşdirmeli.

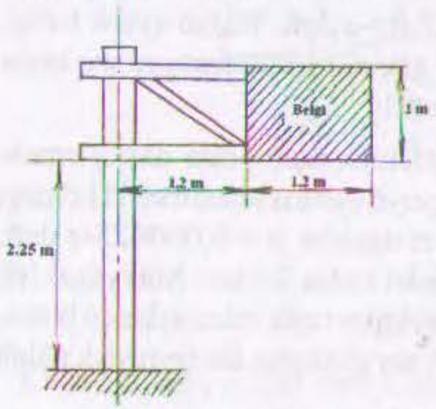
3.35. Bitewi tegelek walyň agramyny 20% azaltmak üçin, diametri içki diametrinden iki esse köp bolan içi boş wal bilen çalşyrylýar. Eger bitewi walyň galtaşma dartgynlylygy 6 kN/sm^2 deň bolsa, içi boş walyň dartgynlylygy näçe bolar?

3.36. Birmeňzeş agramly we birmeňzeş towlanma momentini geçirýän iki walyň biri bitewi, beýlekisiniň bolsa içi boş. Eger içi boş walyň içki diametri daşky diametriniň 0,6 bölegini düzýän bolsa, haýsy walda iň uly galtaşma dartgynlylyk bolar we näçe esse uly bolar?

3.37. Uzynlygy 1,8 m bolan içi boş polat wal 6 kNm towlanma moment bilen ýüklenen. Eger galtaşma dartgynlylyk 7 kN/sm^2, towlanma burçy 2° bolsa, walyň daşky we içki diametrlerini kesgitlemeli.

3.38. Abssissasy minutdaky aýlaw sany, ordinatasy – zerur diamerti bolan bitewi polat walyň egrisini gurmaly. 6 kN/sm^2 rugsat edilýän galtaşma dartgynlylygynda walyň geçirýän kuwwaty 50 a.g. Aýlaw sanyny 16...16000 aýl./min çäginde üýtgetmeli.

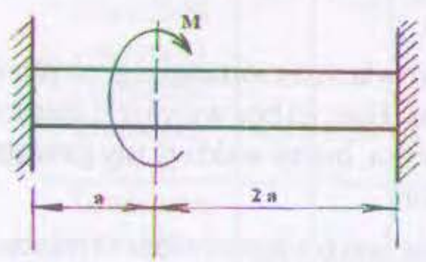
3.39. Orta diametri d_{or}=12,5 sm bolan ýuka diwarly turba M_t=625 kN sm towlanma moment goýlan. Galtaşma dartgynlylyk 7 kN/sm^2 geçmeýän ýagdaýda turbanyň diwarynyň galyňlygy nähili bolar? Eger $G = 8 \cdot 10^3$ kN/sm^2 bolsa turbanyň 1m uzynlygyndaky towlanma burçuny tapmaly.



3.40-njy surat

3.40. Suratda görkezilişi ýaly, polat turba ýol belgisini dikmek üçin sütün bolup hyzmat edýär. Ýol belgisine şemalyň iň uly basyşy 2 kN/sm^2-a deň diýip hasap etmeli. Belginiň aşaky gysgyjynda turbanyň towlanma burçy 6°-dan köp bolmaly däl. Towlanmadan turbanyň kesigindäki iň uly galtaşma dartgynlylyk 3,5 kN/sm^2 ýokary bolmaly däl. Eger turbanyň galyňlygy t = 3 mm bolsa, onuň orta diametrini kesgitlemeli. Şemalyň basyşy diňe ştrihlenen meýdana täsir edýär diýip hasaplamaly.

3.41. Turba şekilli walyň orta diametri 10 sm-e, galyňlygy 3 mm-e deň. Towlanma burçy 3,7 m uzynlykda 1°-a deň. Walyň geçirýän kuwwaty 50.a.g. bolsa, onuň aýlaw tizligini kesgitlemeli.

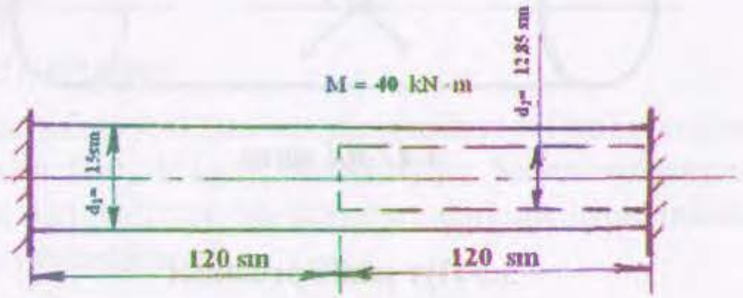


3.42-nji surat

3.42. Suratda görkezilişi ýaly, tegelek kesikli sterženiň ahyrlary gaty berkidilen. Aralyk kesikde steržene 12 kN m moment goýlan. Eger sterženiň diametri 8 sm bolsa, iň uly galtaşma dartgynlylygyny kesgitlemeli.

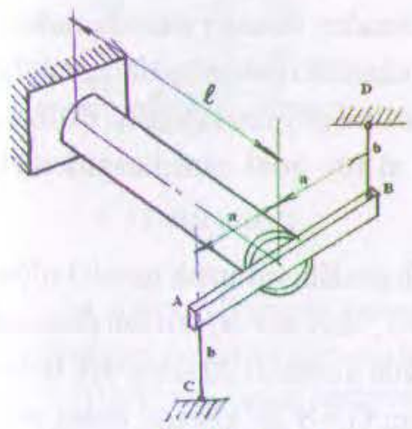
3.43. Daşky diametri 7,5 sm bolan mis turba şol bir diametrli polat turbanyň içinde ýerleşdirilen. Turbalaryň galyňlygy 3 mm-e deň. Turbalaryň ahyrlary biri-biri bilen gaty berkidilen we 1 kN m moment goýlan. Turbalardaky iň uly galtaşma dartgynlylyklary, turbalaryň aralarynda towlanma momentiň ýaýraýşyny we 3 m uzynlykda towlanma burçuny kesgitlemeli. $G = 4 \cdot 10^3$ kN/sm^2, $G_p = 8 \cdot 10^3$ kN/sm^2.

3.44. Bir bölegi bitewi, beýlekisi bolsa içi boş bolan polat steržen towlanma moment bilen ýüklenen (surata seret). Sterženiň sag we çep böleklerindäki iň uly galtaşma dartgynlylygy we ortasyndaky kesigiň towlanma burçuny kesgitlemeli.



3.44-nji surat

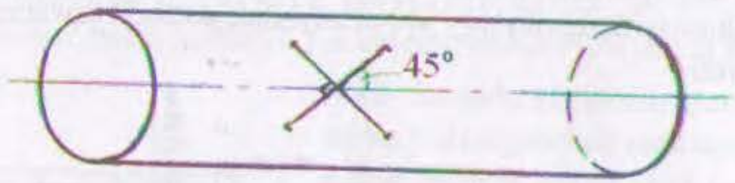
3.45. Diametri 2 r bolan tegelek kesikli pürsüň materialynyň $G_p = G\left(1 + \frac{3\rho}{r}\right)$ kanun boýunça üýtgeýän maýyşgaklyk moduly bar. Pürs M moment bilen towlananda dartgynlylygyň paýlanyşynyň aňlatmasyny we epýuryny kesgitlemeli.



3.46-njy surat

3.46. Diametri D bolan bitewi walyň bir tarapy gaty berkidilen. Walyň beýleki tarapyna keseligine goýlan gaty AB pürs berkidilen. Bu pürs birmeňzeş AÇ we BD sterženler bilen birleşdirilen (surata seret). Sterženler Δt°S-a çenli sowadylýar. Eger sterženlerdäki normal dartgynlylyklar waldaky iň uly galtaşma dartgynlylyga deň bolsa, sterženiň kese kesiginiň meýdanyny kesgitlemeli.

3.47. Diametri 50 mm bolan polat walyň üst ýüzüne oka 45° burç boýunça bir-birine perpendikulýar iki datçik ýelimlenen. Datçikleriň görkezýän otnositel durk üýtgemeleriniň alamatlary dürli-dürli, absolýut ululyklary birmeňzeş we $6{,}5 \cdot 10^{-4}$-e deň. Wala goýlan towlanma momentiň ululygyny we ugruny kesgitlemeli.



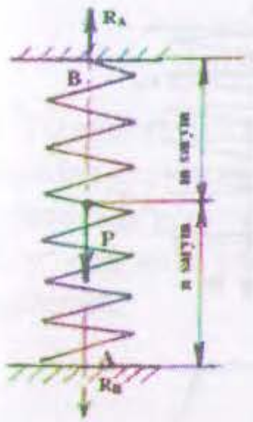
3.47-nji surat

3.3 Hyr şekilli pružinler

3.48. Diametri 18 mm bolan tegelek kesikli silindrik hyr şekilli pružin P=0,5 kN güýç bilen ýüklenen. Pružiniň sarymynyň orta diametri D=125 mm-e deň. Maýyşgaklyk moduly $G = 8 \cdot 10^3$ kN/sm^2. Pružiniň materialyndaky iň uly galtaşma dartgynlylygyny kesgitlemeli. Eger pružiniň çökmesi 6 mm-e deň bolsa, sarymynyň sanynyň näçe bolýandygyny kesgitlemeli.

3.49. Silindrik hyr şekilli pružin 6 mm-lik simden ýasalan we orta radiusy 7,5 sm bolan 20 sarymdan ybarat. Eger pružindäki galtaşma dartgynlylyk 9 kN/sm^2 bolsa, ok boýunça täsir edýän dartma güýjüni tapmaly. Pružiniň uzalmasyny we durkuny üýtgetmesiniň iň uly udel işini kesgitlemeli. $G = 8 \cdot 10^3$ kN/sm^2.

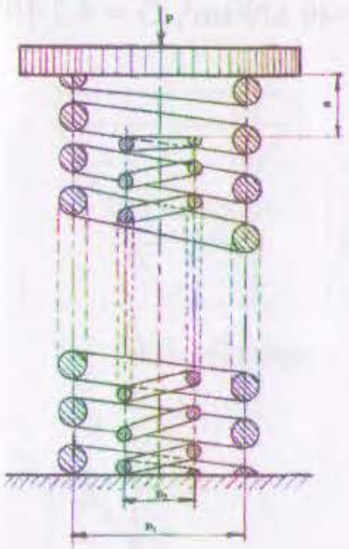
3.50. 6 kN ýükden 2 sm çökýän hyr şekilli pružin ýasamak gerek bolýar. Eger rugsat edilýän galtaşma dartgynlylyk 7,5 kN/sm^2-a, pružini ýasamak üçin silindriň töweregindäki emele getirijiniň diametri 20 sm-e deň bolsa, pružiniň simininiň diametrini kesgitlemeli. Eger $G = 8 \cdot 10^3$ kN/sm^2 bolsa, näçe mukdarda sarym gerek bolar?



3.51. Diametri d=2,2 sm we orta radiusy R=12 sm bolan silindrik polat pružiniň A we B taraplary berkidilen we Ç nokatda P=1,6 kN güýç bilen ýüklenen (surata seret). Sarymlaryň sany m=10, n=6. Berkitmedäki gaýtargylary, pružiniň iň uly dartgynlylygyny we Ç nokadyň ornuny üýtgetmesini kesgitlemeli.

3.51-nji surat

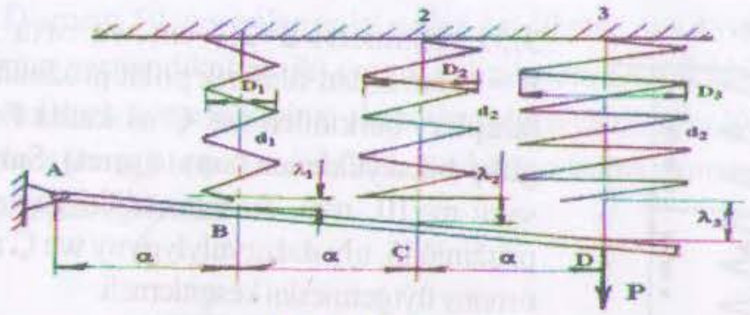
3.52. Orta radiusy R=12 sm we simininiň radiusy r=1 sm bolan silindr görnüşli polat pružin P=0,3 kN güýç bilen dartylýar. Sarymlaryň sany n=25. Iň uly galtaşma dartgynlylygy, uzalmany we durkuny üýtgetmäniň potensial energiýasyny kesgitlemeli.



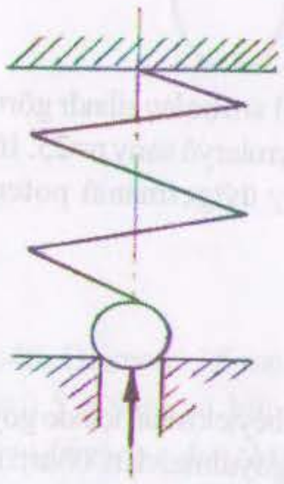
3.53. Iki pružiniň biri beýlekisiniň içinde goýlan. Plita P=1,2 kN güýç goýulmazdan, öňürti ikinji pružin birinjiden δ=2 sm gysga (surata seret). Pružiniň iň uly galtaşma dartgynlylygyny τ_{max} we plitanyň ornuny üýtgetmegini tapmaly.

3.53-nji surat

3.54. Gaty AD ryçag birmeňzeş sarym sanly we Q = 4 kN güýç bilen ýüklenen üç pružinden asylan. Eger dartgynlylyk hemmesinde birmeňzeş τ= 50 kN/sm^2 bolsa, her pružiniň simininiň diametrini hasaplamaly. Pružinleriň sarymynyň orta diametri D_1=6 sm, D_2=8 sm, D_3=10 sm.



3.54-nji surat



3.55. Klapanyň şarigi P=0,15 kN güýç bilen pružini gysýar. Eger sarymyň diametri D=20 mm, işleýän sarymyň sany n=6 bolsa, simiň kesigini saýlamaly. Pružin bronzadan ýasalan bolsa, pružini näçe gysmaly, rugsat edilýän dartgynlylyk $[\tau]=40$ kN/sm^2, $G = 4{,}2\cdot10^3$ kN/sm^2.

3.55-nji surat

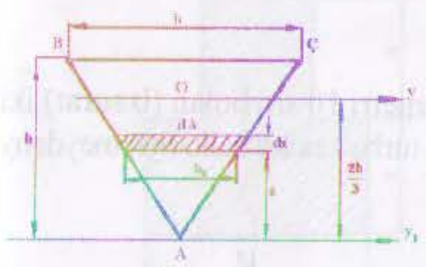
IV bap

Tekiz kesikleriň geometriki häsiýetleri

4.1. Taraplarynyň ölçegleri b x h = 12 x 20 sm bolan gönüburçlugyň esasyndan geçýän oka görä inersiýa momentini we onuň taraplaryndan geçýän oklara görä merkezden daşlaşýan inersiýa momentini hasaplamaly.

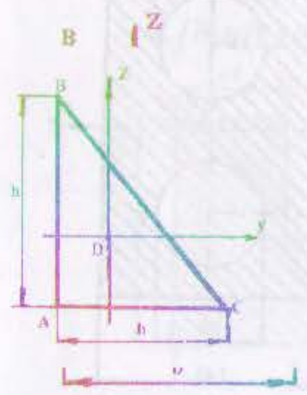
4.2. y_1 oka görä parallelogramyň (surata seret) inersiýa momentini kesgitlemeli.

4.2-nji surat



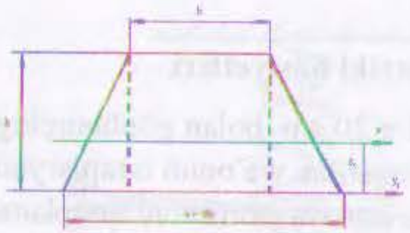
4.3-nji surat

4.3. ABÇ üçburçlugyň A depesinden geçýän, esasyna parallel y_1 oka görä inersiýa momentini hasaplamaly.



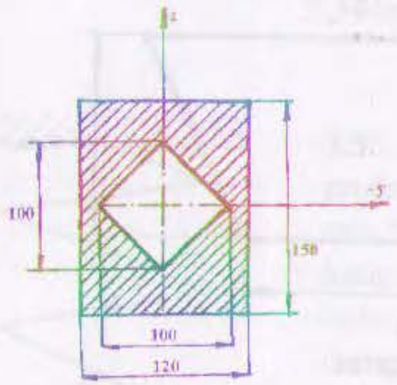
4.4-nji surat

4.4. Katetlerine parallel (surata seret) merkezi oklara Oy we Oz görä ABÇ üçburçlugyň merkezden daşlaşýan we oka görä inersiýa momentlerini kesgitlemeli, şonuň ýaly-da üçburçlugyň AB esasyndan geçýän oka görä inersiýa momentini hasaplamaly.



4.5. Esasyna parallel merkezi oka görä deň gapdally trapesiýanyň (surata seret) inersiýa momentini hasaplamaly.

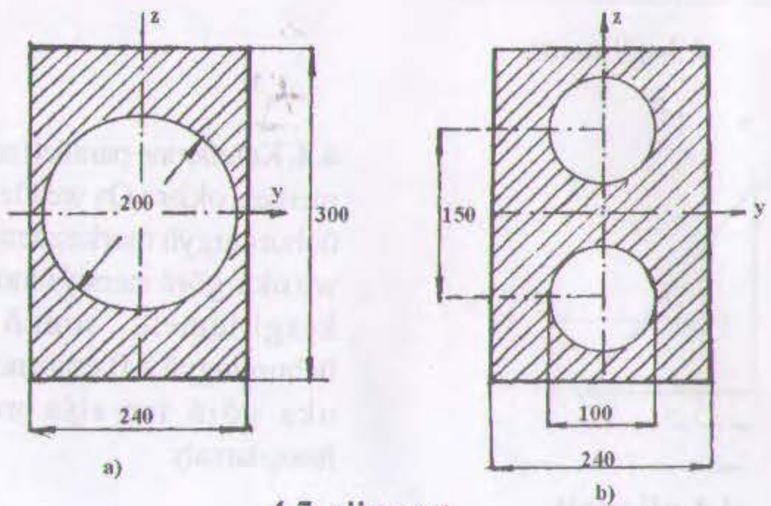
4.5-nji surat



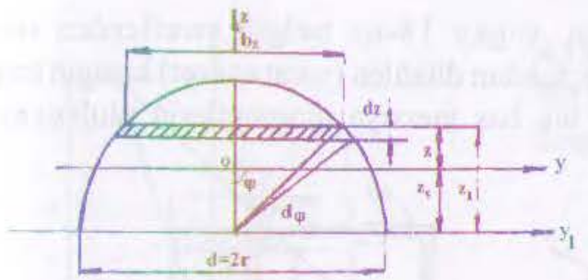
4.6. Suratda şekillendirilen kesigiň bitarap okuna görä inersiýa momentini kesgitlemeli. Ölçegler mm-de görkezilen.

4.6-njy surat

4.7. Diametri 20 sm bolan bir deşigi, diametri 10 sm bolan (b surat) iki deşik bilen çalyşsaň, suratda şekillendirilen turba kesikli balkanyň meýdany we inersiýa momenti nähili üýtgeýär?

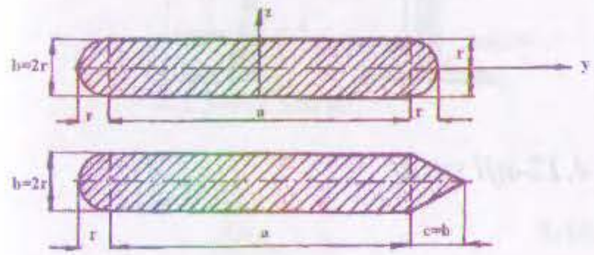


4.7-nji surat



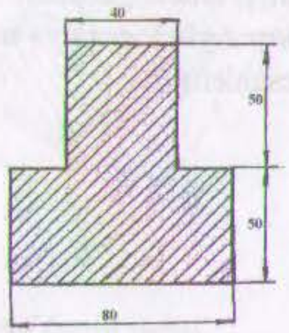
4.8. Baş merkezi inersiýa okuna görä ýarymtegelegiň (surata seret) inersiýa momentini tapmaly.

4.8-nji surat



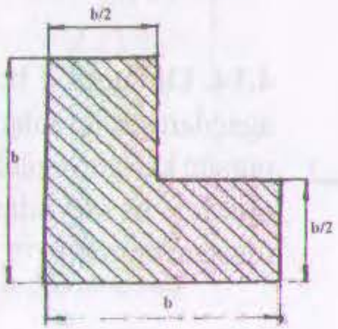
4.9. Shemada şekillendirilen köpri sütüniň kesiginiň baş inersiýa momentlerini kesgitlemeli.

4.9-njy surat



4.10. Suratda şekillendirilen tawr görnüşli kesigiň meýdanynyň Oy merkezi okuna görä inersiýa momentini tapmaly.

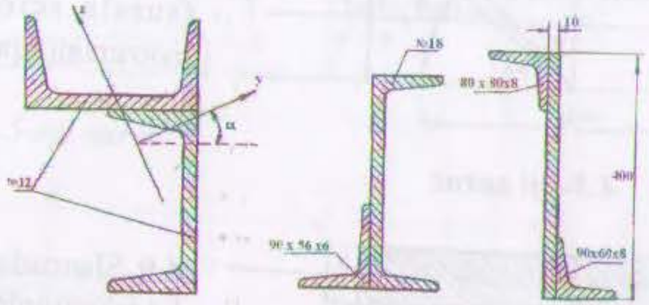
4.10-njy surat



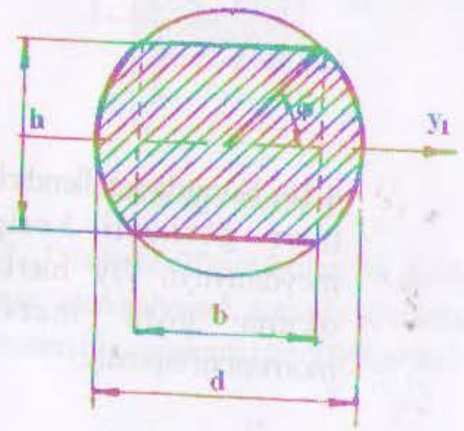
4.11. Suratda görkezilen galyň diwarly burçlugyň profiliniň baş inersiýa momentini tapmaly. Şeýle-de burçlugyň polkalaryna parallel merkezi oklara görä merkezden daşlaşýan inersiýa momentini tapmaly.

4.11-nji surat

4.12. Sozulan profillerden, ýagny 18-nji belgili şwellerden we 90x56x6 mm-e deň bolan burçlukdan düzülen (surata seret) kesigiň baş inersiýa okunyň ýagdaýyny we baş inersiýa momentleriň ululygyny kesgitlemeli.

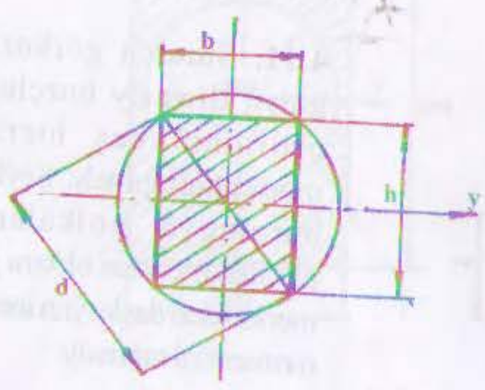


4.12-nji surat



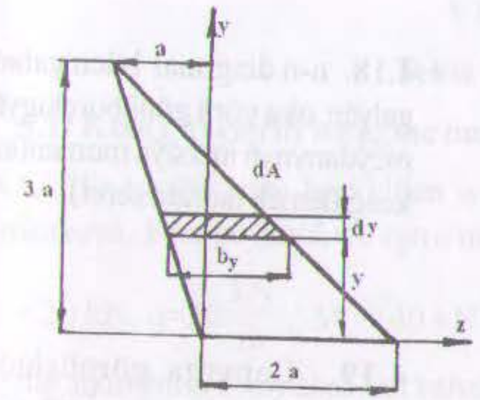
4.13. Tegelekden segment kesilip alnyp emele getirilen kesigiň y okuna görä inersiýa momentini kesgitlemeli.

4.13-nji surat



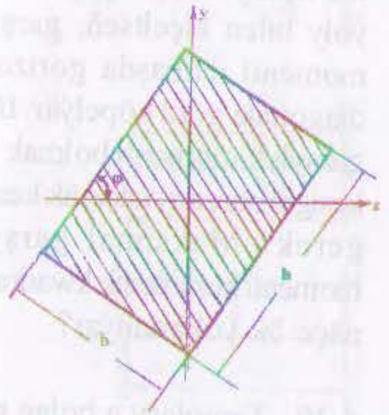
4.14. Diametri d bolan togalak agaçdan kesilip alnan gönüburçly pürsüň kesigini egilme berkliginiň nukdaý nazaryndan iň oňaýly ölçegini tapmaly.

4.14-nji surat



4.15. Baş merkezi okuň ugruny we baş merkezi inersiýa momentlerini kesgitlemeli (surata seret).

4.15-nji surat

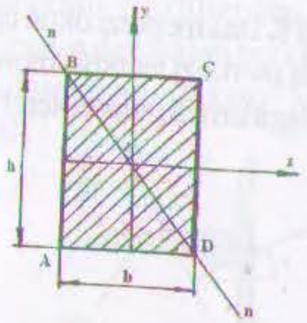


4.16. φ burç boýunça öwrülen ok üçin gönüburçlugyň merkezden daşlaşýan inersiýa momentini tapmaly (surata seret).

4.16-njy surat

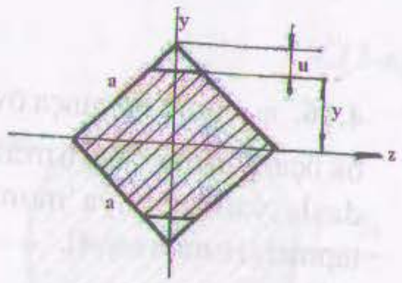
4.17. Üçburçlugyň medianasy bilen gabat gelýän BM oka görä üçburçlugyň inersiýa momentini kesgitlemeli (surata seret).

4.17-nji surat



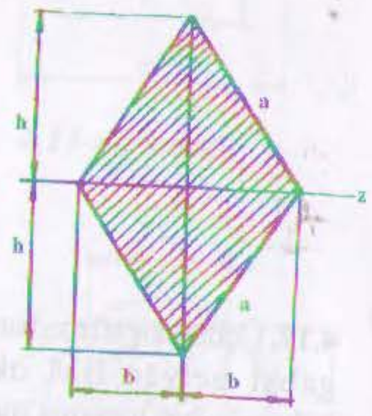
4.18-nji surat

4.18. n-n diagonal bilen gabat gelýän oka görä gönüburçlugyň meýdanynyň inersiýa momentini kesgitlemeli (surata seret).



4.19-njy surat

4.19. Gapyrga görnüşinde goýlan kwadrat kesigiň uly bolmadyk u ululyk bilen ýokarky we aşaky burçlaryny kesmek ýoly bilen kiçeltseň, garşylyk momenti ilkibaşda gorizontal diagonala görä köpelýär. Iň uly garşylyk momenti bolmak üçin kesigiň burçuny näçeräk kesmek gerek? Maksimal garşylyk momenti kesilmedik kwadratdan näçe % ýokarlanýar?



4.20-nji surat

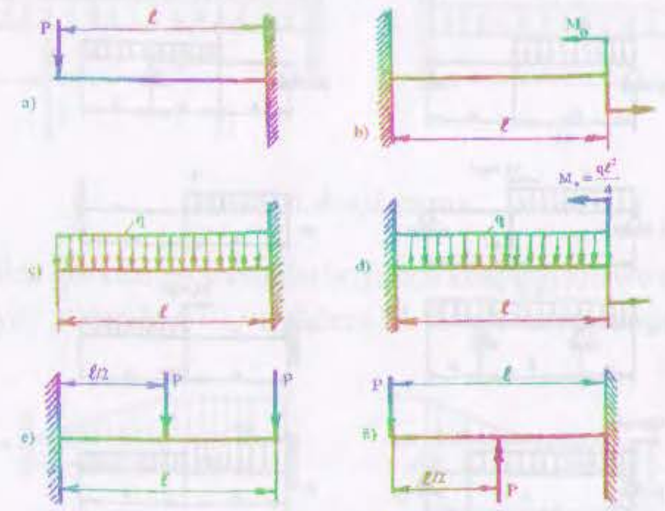
4.20. Taraplary a bolan romb görnüşli kesigiň (surata seret) b we h ölçegleriniň haýsy gatnaşyklarynda gorizontal merkezi oka görä iň uly inersiýa momenti we iň uly garşylyk momenti bolar?

V bap

Tekiz egilme

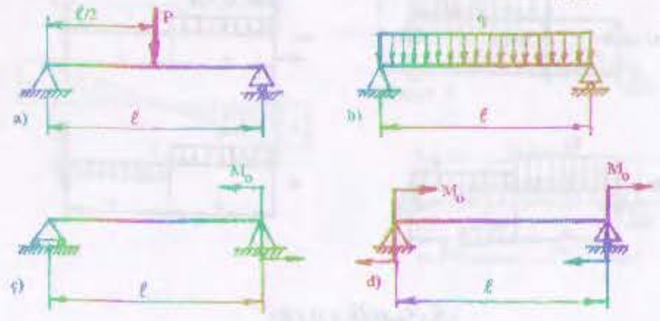
5.1. Kese güýçleriň we egme momentleriň epýurlaryny gurmak

5.1. Bir tarapy gaty berkidilen we suratda görkezilişi ýaly ýüklenen balkalaryň, kese güýjüniň we egme momentiniň epýurlaryny gurmaly. Eger $P = 20$ kN, $q = 20 \frac{kN}{m}$, $M_o = 40$ kN m we $\ell = 2$ m bolsa, kese güýjüň we egme momentiň iň uly absolýut bahalaryny hasaplamaly.



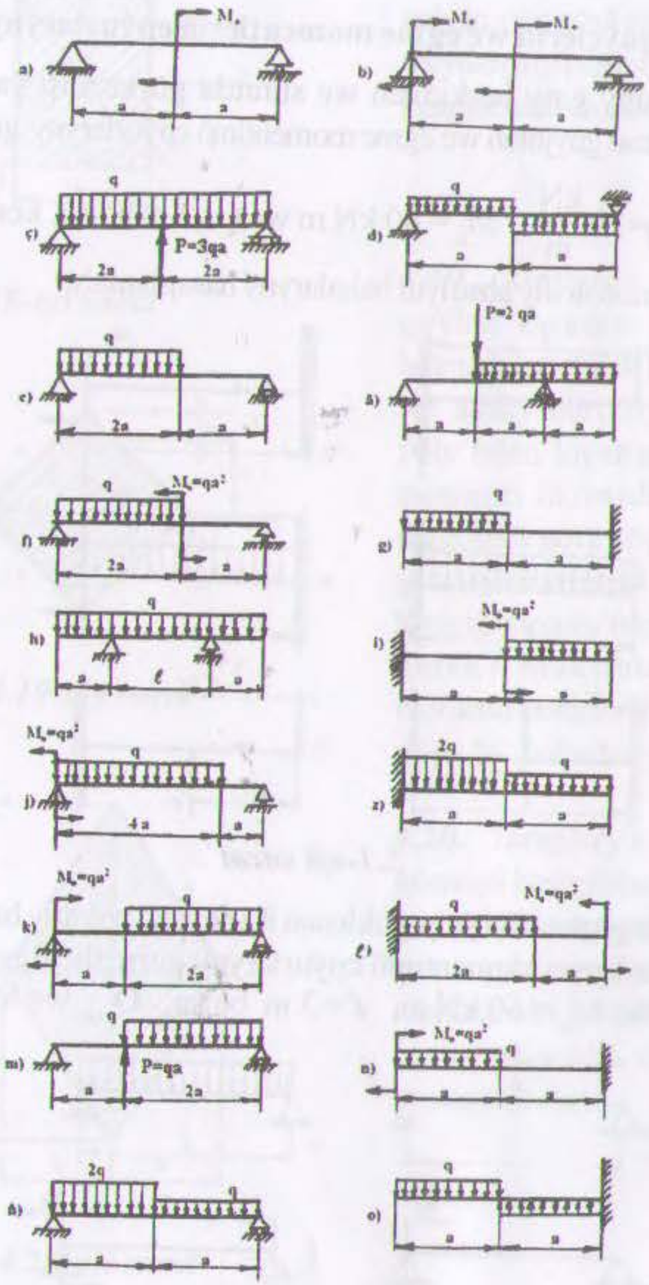
5.1-nji surat

5.2. Suratda görkezilişi ýaly, ýüklenen iki daýanç nokatly balkalaryň kese güýjüniň we egme momentiniň epýurlaryny gurmaly. Eger $P = 60$ kN, $q = 20$ kN/m, $M_o = 60$ kN m, $\ell = 3$ m bolsa, Q_{max} we M_{max} tapmaly.



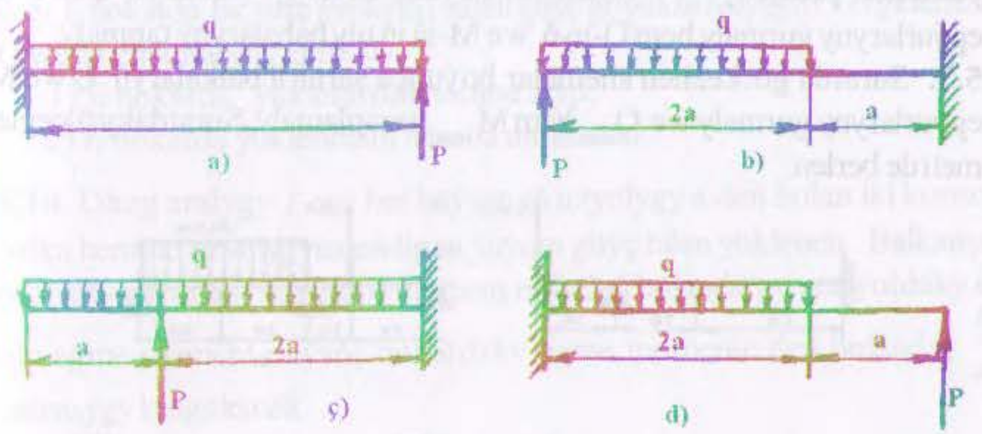
5.2-nji surat

5.3. Suratda şekillendirilen balkalaryň Q we M epýurlaryny gurmaly.



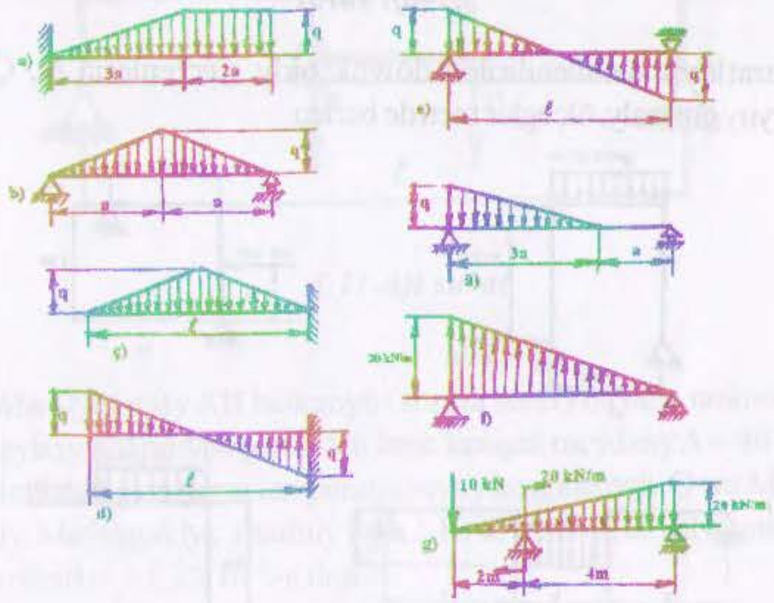
5.3-nji surat

5.4. P güýjüň haýsy bahasynda suratda şekillendirilen balkalaryň daýanç nokadyndaky kesiklerde egme moment nola deň? Güýjüň şu bahasynda Q we M epýurlaryny gurmaly.



5.4-nji surat

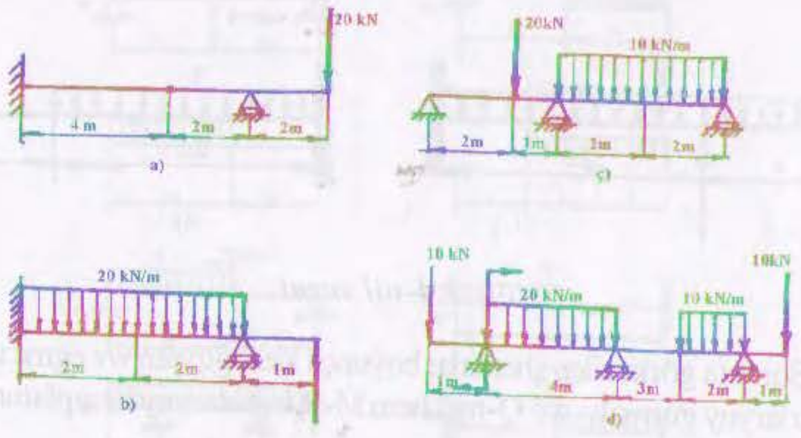
5.5. Suratda görkezilen shemalar boýunça kese güýjüň we egme momentiň epýurlaryny gurmaly we Q-nyň hem M-iň bahalaryny hasaplamaly.



5.5-nji surat

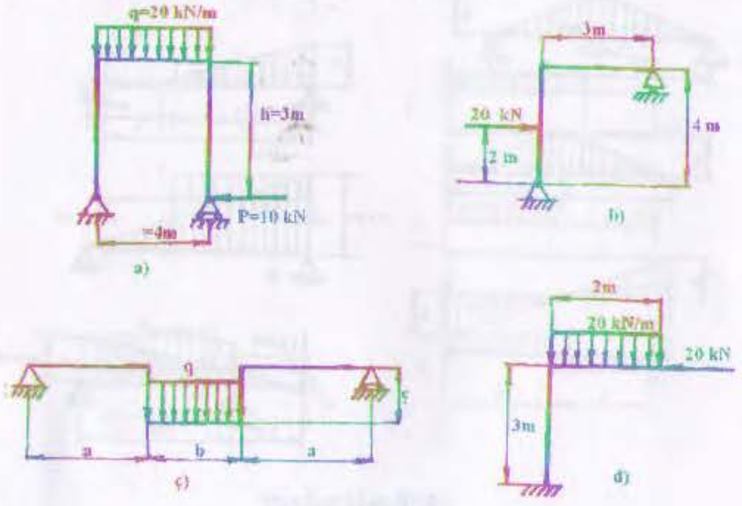
5.6. $q(x)=\frac{4}{\ell^2}q\left(\ell x-x^2\right)$ deňleme boýunça üýtgeýän ýaýran güýç bilen ýüklenen prolýoty ℓ bolan iki daýanç nokatly balkanyň Q we M epýurlaryny gurmaly hem Q-nyň we M-iň iň uly bahalaryny tapmaly.

5.7. Suratda görkezilen shemalar boýunça şarnirli balkalaryň Q we M epýurlaryny gurmaly we Q_{max} hem M_{max} hasaplamaly. Suratdaky ölçegler metrde berlen.



5.7-nji surat

5.8. Suratlarda şekillendirilen döwük okly sterženleriň N, Q we M epýurlaryny gurmaly, ölçegler metrde berlen.



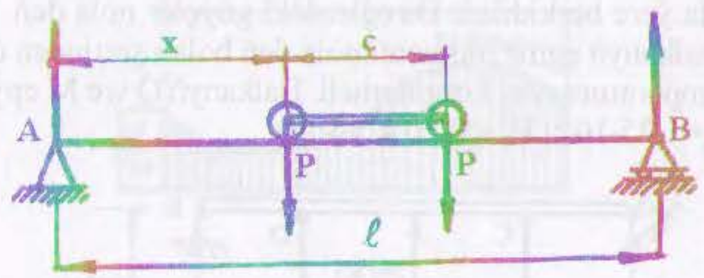
5.8-nji surat

5.9. ABÇDE balka A we D nokatlarda şarnirli berkidilen. AB = 0,6 m; BÇ = 0,6 m; ÇD = 1,8 m; DE=1m. B nokatda balka P=25 kN bir ýere jemlenen güýç bilen ýüklenen. Ç nokatda egme moment nola deň bolar ýaly, E nokatda bir ýere jemlenen nähili güýç goýulmalydygyny kesgitlemeli. Q we M epýurlaryny gurmaly:

1) E nokatda ýüklenmäni hasaba alyp;
2) E nokatda ýüklenmäni hasaba almazdan.

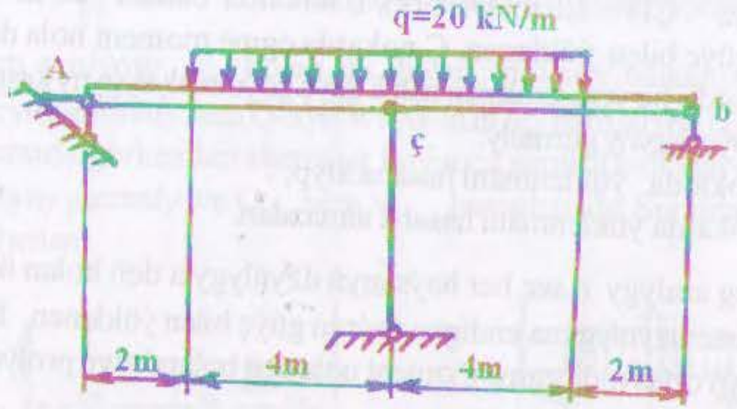
5.10. Direg aralygy ℓ we her haýsynyň uzynlygy a deň bolan iki konsol balka hemme uzynlygyna endigan ýaýran güýç bilen ýüklenen. Balkanyň prolýotynyň ortasynda egme moment nola deň bolanda we prolýotdaky iň uly egme moment daýanç nokatdaky egme momente deň bolanda, $\frac{\ell}{a}$ gatnaşygy kesgitlemeli.

5.11. Köpri kranyň balkasy boýunça her okdan P basyşy geçirýän iki okly arabajyk süýşýär. Egme momentiň iň uly bahasyny almak üçin arabajygy prolýotda nähili ýerleşdirmeli?



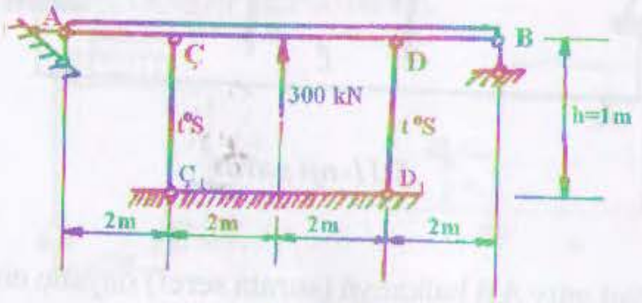
5.11-nji surat

5.12. Absolýut gaty AB balkanyň (surata seret) daýanç nokatlaryndaky gaýtargylary nol bolýan şertinden kese kesigiň meýdany A = 40 sm^2 bolan polat sterženiň gyzdyrma temperaturasyny kesgitlemeli. Q we M epýuryny gurmaly. Maýyşgaklyk moduly $E_p = 2\cdot10^4 kN/sm^2$-a, uzynlygyna giňelmek koeffisiýenti $\alpha_p = 1{,}25\cdot10^{-5}$ -e deň.



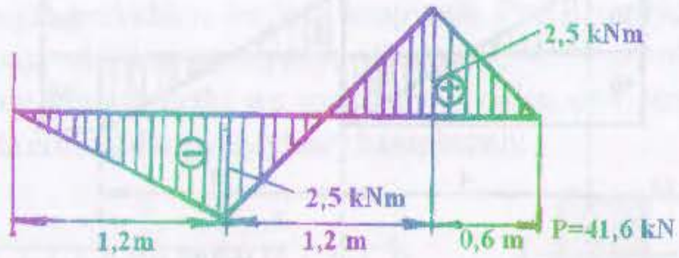
5.12-nji surat

5.13. Absolýut gaty AB balkanyň ortasyna P=300 kN ýük ýüklenen we her haýsynyň kesikleriniň meýdany A=30 sm^2 bolan polat diregler bilen Ç we D nokatlarda ýere berkidilen. Direglerdäki güýçler nola deň. Ç we D kesiklerde balkanyň egme momenti nola deň bolan şertinden direglerin sowatma temperaturasyny kesgitlemeli. Balkanyň Q we M epýurlaryny gurmaly ($\alpha_p=1{,}25\cdot10^{-5}$, $E_p=2\cdot10^4 kN/sm^2$).



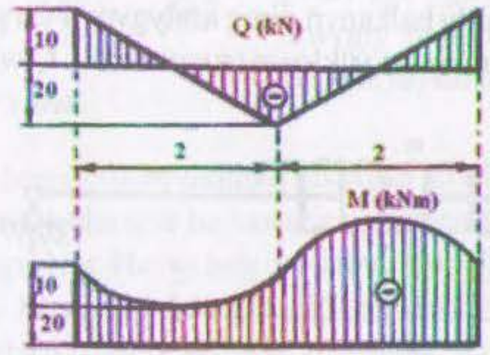
5.13-nji surat

5.14. Suratda A we Ç nokatlarda şarnirli berkidilen balkanyň epýury şekillendirlen. Ýüklenmäni, Q epýuryny şekillendirmek we direglerdäki gaýtargylary tapmak talap edilýär.

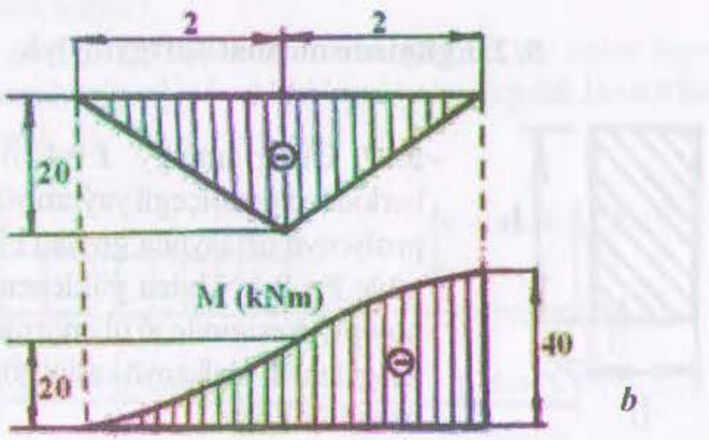


5.14-nji surat

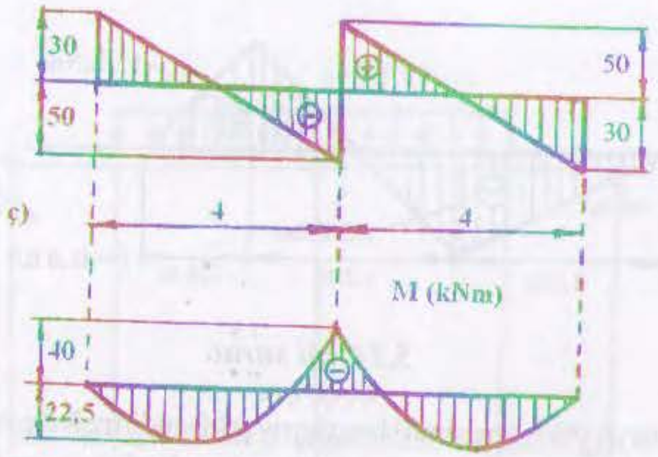
5.15. Balkalaryň ýüklenmesiniň shemasyny şekillendirmeli we suratda getirilen kese güýjüň hem-de egme momentiň epýury boýunça goýlan güýçleriň ululygyny kesgitlemeli. Uzynlyk metrde görkezilen, Q – kN, M – kNm.



a

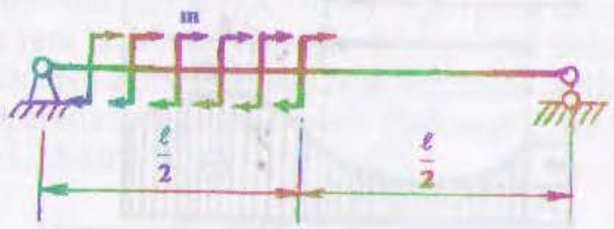


b



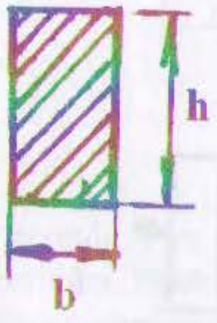
5.15-nji surat

5.16. Iki daýanç nokatly balkanyň direg aralygynyň ýarysyna hemişelik depginli ýaýran daşky moment ýüklenen (surata seret). Q we M epýurlaryny gurmaly.



5.16-njy surat

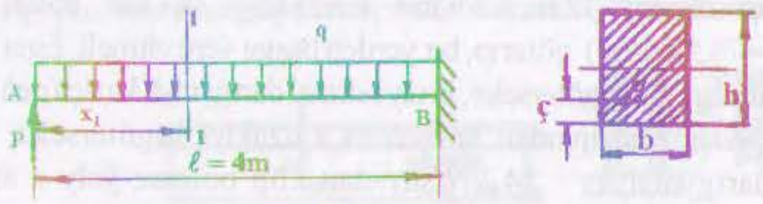
5. 2. Egilmede normal dartgynlylyk



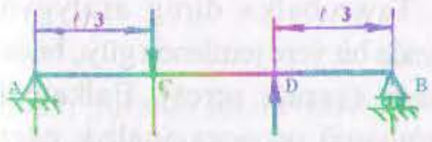
5.17-nji surat

5.17. Direg aralygy ℓ =4 m bolan şarnirli berkidilen deňölçegli ýaýran ýük q=4 kN/m we prolýotyň ortasynda goýlan bir ýere jemlenen güýç P= 2 kN bilen ýüklenen agaç balkanyň howply kesiginde iň uly normal dartgynlylygy kesgitlemeli. Balkanyň kesigi gönüburçluk ölçegi bxh=12x20sm^2.

5.18. 20x30 sm ölçegli gönüburçly kese kesikli agaç balkanyň bir tarapy diwara pugta berkidilen, beýleki tarapynda P=5 kN güýç we balkanyň uzynlygyna q = 6 kN/m ýaýran güýç ýüklenen. Q we M epýurlaryny gurmaly we howply kesigiň çetki we aşaky gyrasyndan ç=4 sm uzaklykdaky nokadynda normal dartgynlylyklary hasaplamaly.



5.18-nji surat



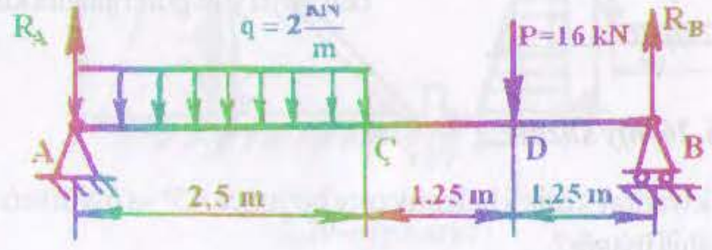
5.19-njy surat

5.19. Suratda görkezilen prolýoty 6 m, P=60 kN güýç bilen ýüklenen iki tawraly balkanyň DÖST boýunça kesigini saýlamaly.

5.20. Diwaryň hemişelik beýikligini saklaýan iki sany 20 a belgili sozulyp ýasalan iki tawraly balka setir boýunça ýerleşdirilen. Olar bir sany iki tawraly balka bilen çalşyrylýar. Haýsy belgili iki tawraly balkany çalşyp bolar?

5.21. Uzynlygy 12 m, daşky diametri 25 sm we diwarynyň galyňlygy 1 sm bolan çoýun turba iki daýanç nokatlaryň üstünde ýerleşdirilen we suw bilen doldurylan. Eger çoýnuň udel agramy 7,8 bolsa, turbadaky iň uly normal dartgynlylyk nähili bolýar?

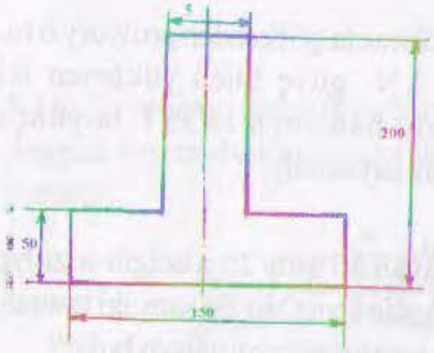
5.22. Suratda görkezilen balka üçin kese güýjüň we egme momentiň epýurlaryny gurmaly. Eger [σ] = 11 kN/sm^2 bolsa, tegelek kesikli balkanyň diametrini tapmaly.



5.22-nji surat

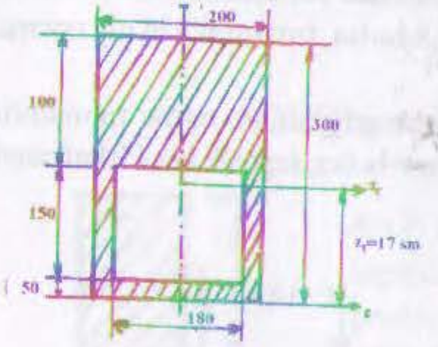
5.23. Birmeňzeş uzynlygy, meýdany we materialy bolan iki balkanyň birinin kese kesigi kwadrat, beýlekisiniňki bolsa tegelek. Tegelek kesikli balka üçin balkanyň direg aralygynyň ortasynda goýlan howpsuz güýjiň ululygy 10 kN-a deň. Direg aralygynyň ortasynda goýlan howpsuz güýjüň ululygy kwadrat kesikli balka üçin nähili bolar?

5.24. Iki işçi uzynlgy 12 m, kwadrat kese kesigi 3x3 sm^2 bolan polat sterženi (γ=78,5kN/m^2) göterip, bir ýerden başga ýere eltmeli. Eger işçiler sterženiň ujundan tutup göterseler, iň uly normal dartgynlylyk näçä deň bolar? Eger her işçi sterženiň ujundan birmeňzeş a uzaklykda göterseler, iň uly normal dartgynlylyk 14 kN/sm^2-dan köp bolmaz ýaly a aralygy kesgitlemeli.



5.25-nji surat

5.25. Tawr balka direg aralygyň ortasynda bir ýere jemlenen güýç bilen ýüklenen (surata seret). Balkanyň materialynyň proporsionallyk çägi süýnmede – 3 kN/sm^2 we gysylmada – 6 kN/sm^2. Balkanyň ortasyndaky kesikde iň uly süýnme we gysylma dartgynlylyklary kesgitlemeli we proporsionallyk çägine görä ätiýaçlyk koeffisiýenti tapmaly.

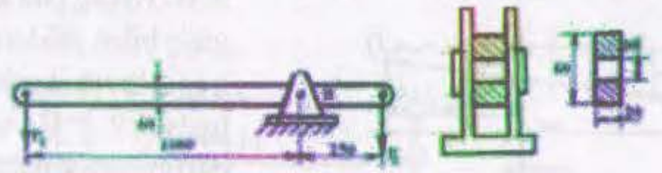


5.26-njy surat

5.26. Eger süýnmede rugsat edilýän dartgynlylyk 1,2 kN/sm^2-a, gysylmada bolsa 5 kN/sm^2-a deň bolsa, suratda kese kesigi şekillendirilen çoýun balkanyň ýük göterijiligini kesgitlemeli.

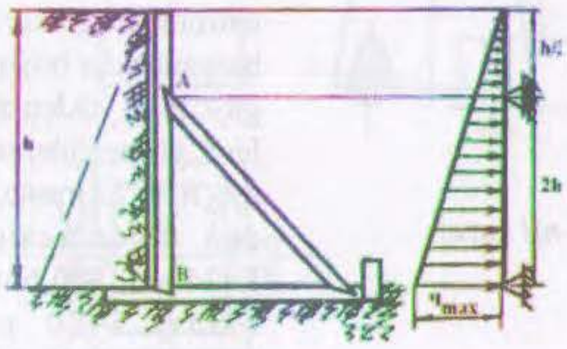
5.27. Eger kwadrat kesikli balkany oky boýunça 45° -a öwürseň, onuň ýük göterjiligi nähili üýtgär?

5.28. Štanganyň deşiginiň içinden geçirilen şarnirli bolta, B nokatda (surata seret) direnýän, gönüburçly kese kesikli 20 x 60 mm štanga, togtadyjy enjamyň polat ryçagy bolup hyzmat edýär. Deşigiň merkezi štanganyň okunda ýerleşýär, onuň diametri d=30 mm. Boltuň deşiginiň kesigi gowşadýandygyny hasaba alyp we rugsat edilýän dartgynlylyk [σ] = 14 kN/sm^2 bolsa, ryçagyň soňuna goýlan howpsuz güýçleri tapmaly. Suratdaky ölçegler mm-de berlen.



5.28-nji surat

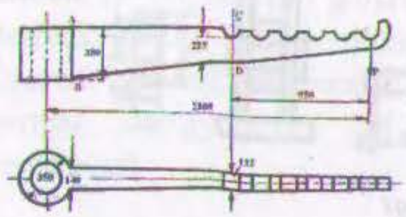
5.29. Suratda şekillendirilen direg diwarynyň kwadrat kesigini we tagta örtüginiň galyňlygyny saýlap almaly. Her 2 m-den goýlan sütün kese goýlan purse direlen we söýeg bilen saklanýar, her sütüni A we B nokatlarda şarnirli diregi bolan balka hökmünde seredip bolýar. Sütünler tagta örtügiň üsti bilen geçirilýän topragyň basyşy bilen ýüklenen. Sütünde döreýän boý güýç hasaba alynmaýar. Ini b=20 sm bolan tagta örtügini diregde kesilen şarnirli daýanç nokatlary bolan balka diýip hasap etmeli. Gum üýşmeginiň beýikligi 1,5 m. Topragyň basyşy çyzyk kanuny boýunça 0-dan q_{max} = 13 kN/m^3-a çenli artýar. Egilmede rugsat edilýän dartgynlylyk [σ]=1 kN/sm^2.



5.29-njy surat

5.30-njy surat

5.30. Eger balkanyň oky töweregiň dugasy boýunça egilýän bolsa, hemişelik h beýiklikli (kesigiň ini üýtgeýär) gönüburçly kesigi bolan balka haýsy şekilde bolmaly?



5.31-nji surat

5.31. Ryçag (surata seret) P= 80kN güýç bilen ýüklenen. AB ýa-da ÇD kesikleriň haýsysy „howply" bolýar? Howply kesikde dartgynlylyk näçä deň?

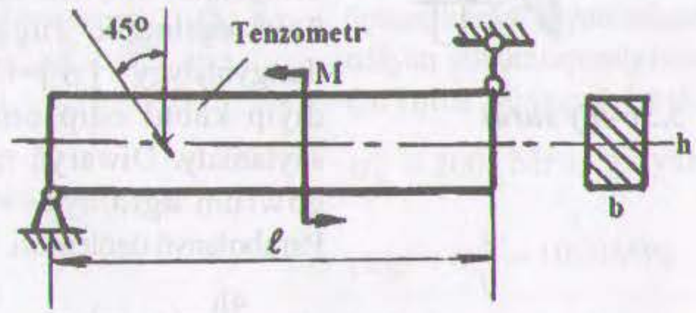
5.32-nji surat

5.32. Konsol egilmede deň garşylykly balka görnüşinde taslanýar. Konsolyň kese kesigi, beýikligi hemişelik h deň bolan gönüburçluk. Kesigiň ininiň üýtgemek kanunyny b = b(x) anyklamaly. Konsolyň her kesiginde maksimal dartgynlylyk $[\sigma]$- rugsat edilýäne deň.

5.33-nji surat

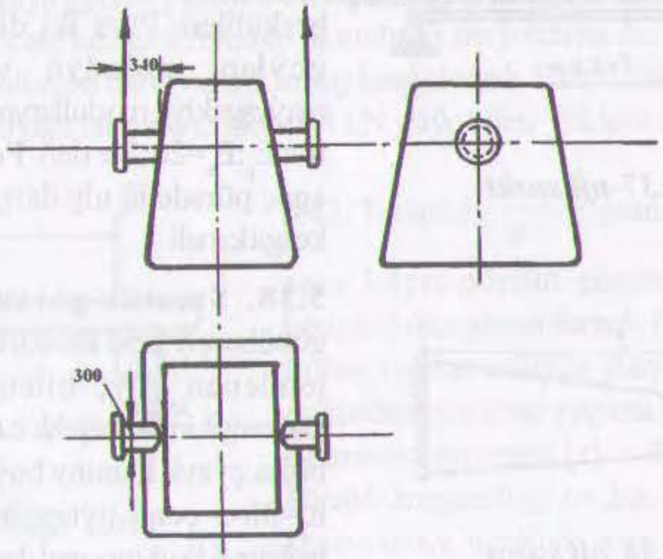
5.33. Çoýun balka ($E=1{,}2\cdot10^4$kN/sm^2) synag edilende, suratda görkezilen shema boýunça 1 we 2 tenzometriň görkezijileri, ölçenilen basgançaklar boýunça P = 50 kN güýç bilen ýüklenende tenzometrleriň görkezijileriniň orta artmasy Δn_1= -15 mm-e, Δn_2= 5mm-e deň. Eger kesigiň beýikligi h=24 sm, a=0,6m, tenzometriň bazasy ℓ=20 mm, ulaltma koeffisiýenti K=1000 bolsa, baş merkezi oka görä kesigiň inersiýa momentiniň ululygyny kesgitlemeli.

5.34. Suratda şekillendirilişi ýaly, balkanyň bitarap okunda kesekesigine 45° burç boýunça tenzometr ýerleşdirilen. Balka ýüklenenden soň B bazasy bolan tenzometr ΔB uzalma görkezýär. Abzalyň görkezen bahasynda momentiň ululygyny nähili kesgitläp bolýar? Balkanyň kese-kesiginiň ini b we beýikligi h, maýyşgaklyk moduly E we Puassonyň koeffisiýenti μ-e deň bolan materialdan ýerine ýetirilen.

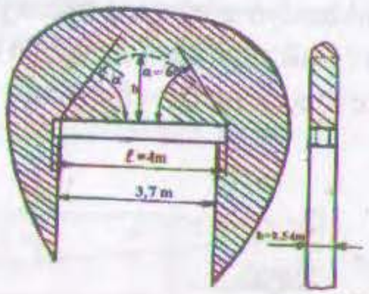


5.34-nji surat

5.35. Eredilip galyba guýlan poladyň galyp bilen bilelikdäki agramy 430 kN (surata seret). Galybyň sapfasynyň boýnundaky dartgynlylygy tapmaly.



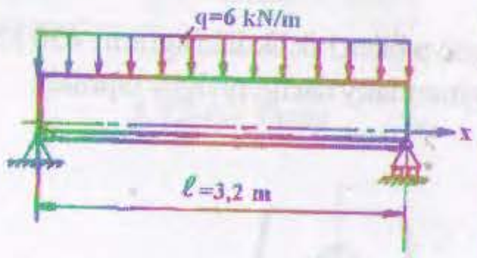
5.35-nji surat



5.36-njy surat

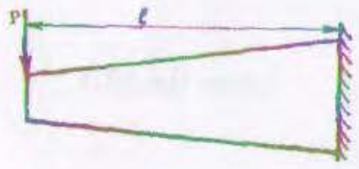
5.36. Diwarynyň galyňlygy b = 54 sm bolan gapy ýere iki birmeňzeş tawra bilen basyrylan. Balkanyň hasaplaýyş uzynlygy ℓ =4 m. Balka düşýän ýük diregde α=60° burç boýunça ýapgytlanan parabola boýunça çäklenen diwaryň böleginiň agramyna deň (surata seret). Balkanyň materialy üçin egilmede rugsat edilýän dartgynlylygy $[\sigma]$=15kN/sm² deň diýip kabul edip onuň kesigini saýlamaly. Diwaryň materialynyň göwrüm agramy γ =16kN/sm³. Parabolanyň deňlemesi.

$$y = \frac{4h}{\ell^2} x(\ell - x).$$



5.37-nji surat

5.37. Uzynlygy ℓ=3,2 m, ini b=12 sm, galyňlygy b=0,6 sm (surata seret) polat list kesigi bxh=12x18 sm agaç pürse berkidilen. Pürs iki diregde erkin goýlan, poladyň we agajyň maýyşgaklyk modullarynyň gatnaşygy $n = E_p : E_a$ =20:1-e deň. Polat listde we agaç pürsde iň uly dartgynlylyklary kesgitlemeli.

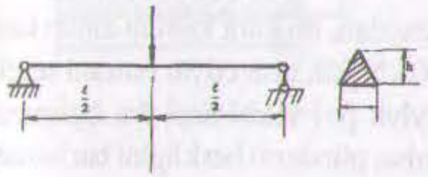


5.38-nji surat

5.38. Suratda görkezilişi ýaly, gönüburçly kese kesikli balka bir ýere jemlenen güýç bilen ýüklenen. Balkanyň ini hemişelik b deň, beýikligi bolsa çyzyk kanuny boýunça h_1-den h_2=3h-a çenli üýtgeýär. Egilmede balkanyň iň uly normal dartgynlylygyny kesgitlemeli.

5.39-nji surat

5.39. Uzynlygy –! we agramy G=q–ℓ bolan bir jynsly göni balka gaty tekizlikde ýatyr. Balkanyň ujunda M= qℓ^2/8 moment goýlanda, onuň ýokary göterilýän böleginiň uzynlygyny kesgitlemeli.

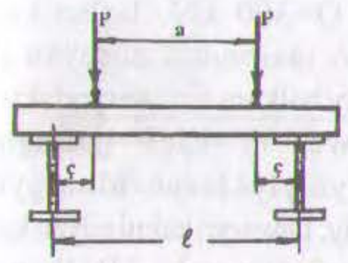


5.40-njy surat

5.40. Uzynlygy ℓ =1m, beýikligi h=5 sm, esasynyň ini b=h bolan üçburç kesikli çoýun balkanyň rugsat edilýän ýüküni tapmaly (surata seret). Çoýnuň süýnmä berklik çägi σ_b^s = 200 MPa, gysylma berklik çägi $\sigma\frac{g}{b}$ = 1000MPa, berklik ätiýaçlygy n=3-e deň.

5.3. Egilmede galtaşma dartgynlylyk

5.41. Uzynlygy 2 m, ini 7,5 sm we beýikligi 15 sm bolan gönüburçly kese kesikli balkanyň gyralary şarnirli berkidilen. Çep diregden 75sm uzaklykda ýerleşen we kese kesiginiň bitarap okundan 5 sm ýokarda duryan nokadyň normal we galtaşma dartgynlylyklaryny kesgitlemeli. Balka direg aralygynyň ortasynda goýlan bir ýere jemlenen 4 kN güýç bilen ýüklenen.



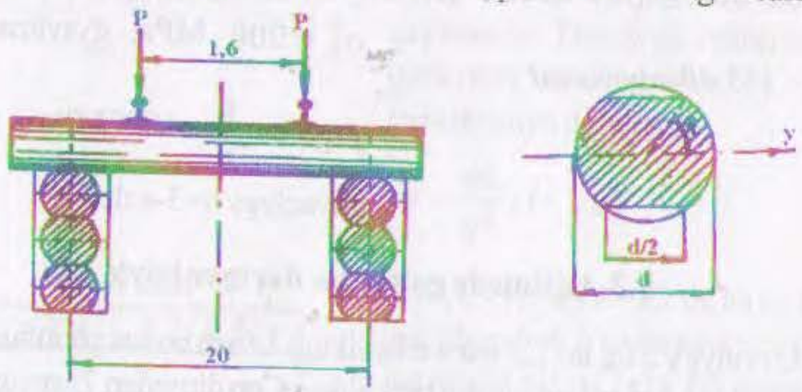
5.42-nji surat

5.42. Taraplary $\frac{h}{b} = \frac{4}{3}$ gatnaşykda bolan agaç köpri pürsüň gönüburçly kese-kesiginiň ölçegini saýlamaly (surata seret). Pürse rugsat edilýän dartgynlylyklar: egilmede süýnme we gysylma $[\sigma]$=1kN/sm², egilmede owranma $[\tau]$ = 0,25 kN/sm². Pürsüň direg aralygy ℓ = 2m, relsiň okunyň arasyndaky uzaklyk a=1,6 m. Relsiň üstünden hereket edýän düzümiň tigriniň brusa geçiryän basyşy P=9,8 kN.

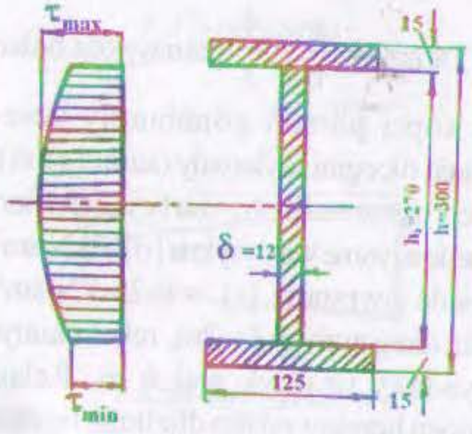
5.43. Diregde erkin ýatan direg aralygy 4 m-e deň 18-nji belgili iki tawraly balkanyň iň uly galtaşma dartgynlylygyny kesgitlemeli. Balka 14 kN/sm² iň uly normal dartgynlylyk döredýän direg aralygyň hemme ýerine goýlan endigan ýaýran güýç bilen ýüklenen.

5.44. Eger kese güýç Q=60 kN-e deň bolsa, daşky diametri D=20sm we içki diametri d=18 sm bolan tegelek turbanyň egilmede iň uly galtaşma dartgynlylygyň ululygyny kesgitlemeli.

5.45. Diametri d=25 sm bolan togalak agaçdan, iki kant kesilip alnan kese köpri pürslerine parowozyň tigrinden P=60 kN ýük täsir edýär (surata seret). Eger egilmede rugsat edilýän dartgynlylyk [σ]=1kN/sm² we egilmede owranma dartgynlylyk [τ] =0.2 kN/sm² bolsa, pürsleriň berkligini barlamaly.

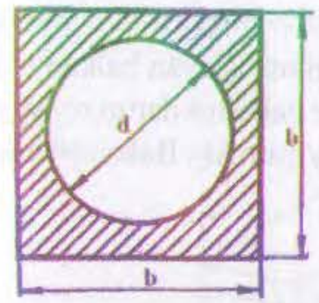


5.45-nji surat



5.46. Q=300 kN bolan kese güýjüň täsirinden döreýän iki tawraly balkanyň diwaryndaky iň uly we iň kiçi galtaşma dartgynlylyklaryň ululygyny tapmaly. Diwaryň kabul edýän kese güýjüni tapmaly. Balkanyň suratdaky kese kesiginiň ölçegleri mm-de görkezilen.

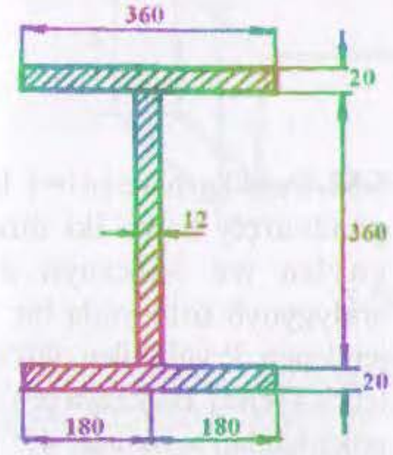
5.46-njy surat



5.47-nji surat

5.47. Iki diregde erkin ýatan turba kesikli çoýun balka, diregden a=0,7 m aralykda goýlan iki deň simmetriýaly ýerleşen P=60 kN güýç bilen ýüklenen. Eger kesigiň ölçegleri b=24 sm we d=20 sm, direg aralygy ℓ=3 m (surata seret) bolsa, balkanyň howply kesigindäki iň uly normal we galtaşma dartgynlylyklaryň ululyklaryny tapmaly.

5.48. Ululygy Q=60 kN bolan wertikal kese güýjüň täsirinden gönüburçly turba görnüşli balkanyň diwarynda ýüze çykýan iň uly galtaşma dartgynlylygyň ululygyny kesgitlemeli. Kesigiň haýsy diwarynda galtaşma dartgynlylygy uly bolýar? Kesigiň beýikligi we ini boýunça galtaşma dartgynlylygyň ýaýraýşynyň epýuryny gurmaly.

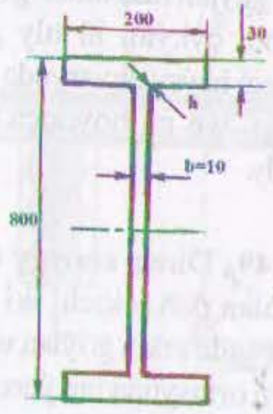


5.49-njy surat

5.49. Direg aralygy ℓ = 3 sm bolan deň tekjeli iki tawra iki diregde erkin goýlan we prolýotyň ortasynda bir ýere jemlenen P güýç bilen ýüklenen. Normal dartgynlylyk boýunça berklik şertinden balkanyň ýük göterijiligini kesgitlemeli. Iň uly galtaşma dartgynlylygy hasaplamaly we diwaryň beýikligine we tekjäniň inine galtaşma dartgynlylygyň ýaýraýşynyň epýuryny gurmaly. Rugsat edilýän dartgynlylyklary [σ]=16 kN/sm², [τ] =10 kN/sm² deň diýip kabul etmeli.

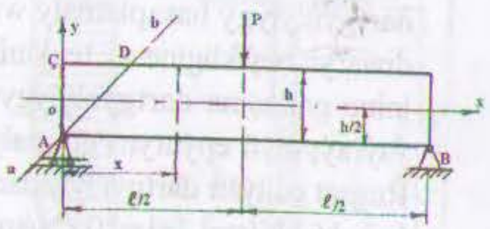
5.50-nji surat

5.50. Egilmä işleýän balkanyň kese kesiginde galtaşma dartgynlylygyň τ_{xy} epýuryny gurmaly. Balkanyň kesigi – romb.



5.51-nji surat

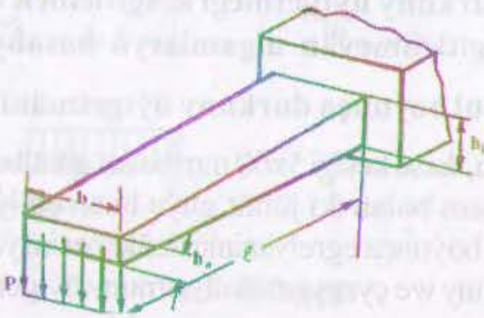
5.51. Kebşirlenen iki tawraly balkanyň tikininiň galyňlygyny kesgitlemeli. Balkanyň kesigindäki kese güýç Q=300 kN. Kebşirleme tikinine rugsat edilýän dartgynlylyk [τ] = 50 Mpa.



5.52-nji surat

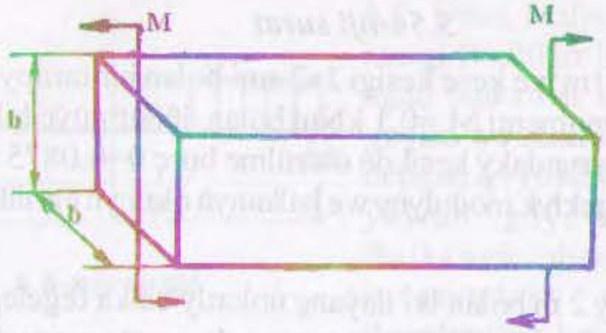
5.52. Beýikligi h we ini b=1 bolan gönüburçly balka iki diregde goýlan we balkanyň direg aralygynyň ortasynda bir ýere jemlenen P ýük bilen ýüklenen (surata seret). Balkanyň çep direg nokadyndan x okuna 45° burç boýunça geçirilen a-b kesikdäki normal we galtaşma dartgynlylyklaryň epýurlaryny gurmaly.

5.53. Üýtgeýän galyňlygy h bolan pürsüň kese kesiginde galtaşma dartgynlylygynyň ýaýraýyş kanunyny kesgitlemeli.



5.53-nji surat

5.54. Rezinden edilen gönüburçly kesikli pürsüň üstüne süýnmeýän ýuka lenta ýelmenen. Eger synagda lentanyň üzülme güýji P-e deň bolsa, tekiz kesik çaklamasy esasynda pürsi egýän momentiň ululygyny kesgitlemeli. Lentanyň galyňlygyny h beýiklige görä ujypsyz diýip hasap etmeli.



5.54-nji surat

5.55. Direg aralygy ℓ =4m bolan iki konsolly balka suratda görkezilişi ýaly ýüklenen. Konsolyň uzynlygy a=0,5 m. Eger Ç nokatda galtaşma dartgynlylyk $\tau_ç$ = 1 kN/sm² bolsa, balkanyň howply kesiginde iň uly normal we galtaşma dartgynlylyklaryň ululyklaryny kesgitlemeli. Kesigiň ölçegleri mm-de görkezilen.

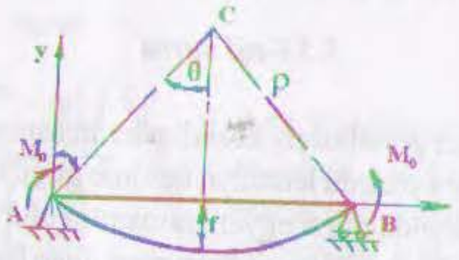
5.56. Deňýanly üçburçluk şekili bolan balkanyň kesiginiň beýikligine galtaşma dartgynlylygyň wertikal düzüjisiniň ýaýraýşynyň epýuryny gurmaly. Kese güýç Oz okuň boýy boýunça ugrukdyrylan.

VI bap

Egilmede durkuny üýtgetmegi kesgitlemek we statiki kesgitlenmeýän ulgamlaryň hasaby

6.1. Analitik usul boýunça durkuny üýtgetmäni kesgitlemek

6.1. Uzynlygy ℓ =1m, kese kesigi 5x60 mm bolan gönüburçly polat çyzgyç, momenti M_o=1kN sm bolan iki jübüt güýç bilen egilýär (surata seret). Çyzgyjyň haýsy egri boýunça egrelýäniniň deňlemesini ýazmaly we kesigiň iň uly öwrülme burçuny we çyzgyjyň iň uly ornuny üýtgetmesini tapmaly.



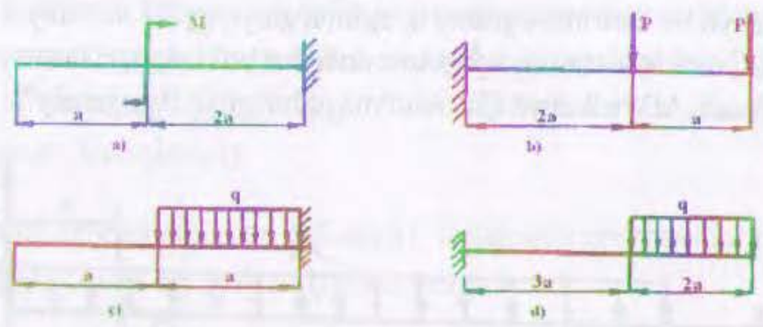
5.54-nji surat

6.2. Uzynlygy ℓ =1m we kese kesigi 2x2 sm² bolan bir tarapy berkidilen balkanyň ujunda momenti M_o=0,1 kNm bolan jübüt güýç bilen egilýär. Eger balkanyň ahyryndaky kesikde öwrülme burç θ=0,0875 rad. bolsa, materialyň maýyşgaklyk modulyny we balkanyň okunyň egrilik radiusyny tapmaly.

6.3. Direg aralygy 2 m bolan iki daýanç nokatly balka tegelegiň dugasy boýunça egrelýär. Direg aralygynyň ortasynda onuň ornuny üýtgetmesi 0,5 sm deň. E=2,1·10⁴ kN/sm² we I=230 sm⁴ bahalarynda egme momentiň ululygyny we balkanyň egrelen okunyň egrelmesiniň radiusyny kesgitlemeli.

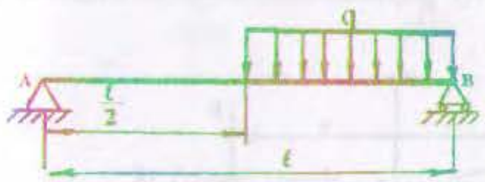
6.4. Togtaýjy güýjüň T=240 kN täsirinden köpri sütüniniň kerpiç örüminiň materialynyň maýyşgaklyk modulyny kesgitlemek üçin onuň ýokarky kesiginiň gorizontal ornuny üýtgetmesi ölçelýär we bu ululyk 8,75 mm-e deň bolýar. Eger binýadyň erňeginden sütüniň beýikligi h=12 m bolsa, materialyň maýyşgaklyk modulyny kesgitlemeli. Ölçegleri suratda görkezilen.

6.5. Maýyşgak çyzygyň differensial deňlemesini integrirlemek ýoly bilen suratdaky ýaly ýüklenen, bir tarapy berkidilen balkanyň erkin kesiginiň burç we çyzyk ornuny üýtgetmelerini tapmaly.



6.5-nji surat

6.6. Balkanyň ujundaky rugsat edilýän ornuny üýtgetme $[f]=\frac{\ell}{450}$ -den köp bolmadyk ýagdaýynda, uzynlygy ℓ=2m, bir tarapy berkidilen we hemme uzynlygyna endigan ýaýran güýç q=10 kN/m bilen ýüklenen balkanyň ikitawraly kesigini saýlamaly. Eger [σ]=14 kN/sm² bolsa, balkanyň berkligini saýlanan iki tawra kanagatlandyrýarmy?



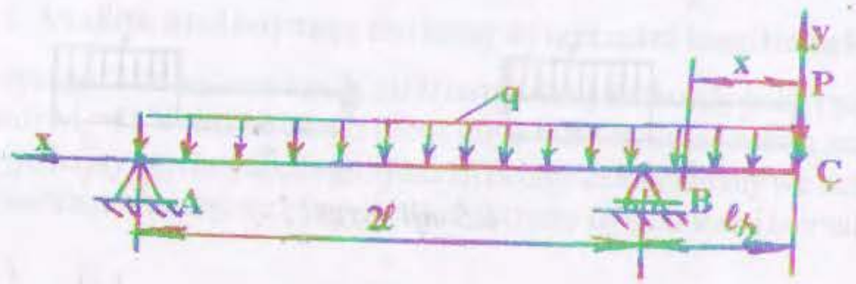
6.6-njy surat

6.7. Direg aralygy ℓ =4 m, kese kesigi 18x20 sm bolan gönüburçly agaç balkanyň soňy iki diregde goýlan we suratda görkezilişi ýaly depgini q=10 kN/m bolan endigan ýaýran güýç bilen ýüklenen. Balkanyň direg aralygynyň ortasyndaky egrelmäni we direglerdäki kesikleriň öwrülme burçlaryny tapmaly.

6.8. Sag diregi M moment bilen ýüklenen balkanyň iň uly egrelmesini kesgitlemeli we balkanyň direg aralygynyň ortasyndaky kesigiň egrelmesi bilen deňeşdirmeli.

6.8-nji surat

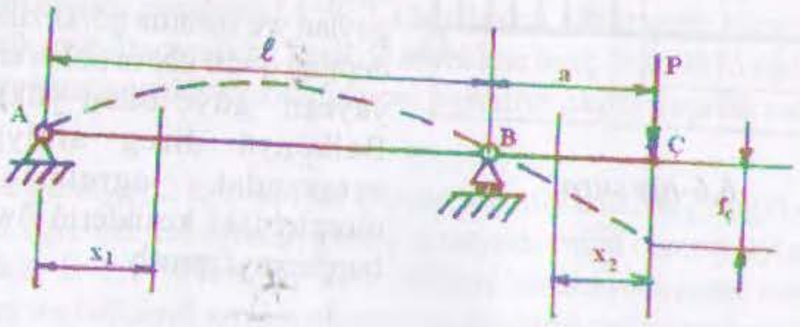
6.9. Balkanyň bir metriniň agramy q, egilmä gatylygy EI we uzynlygy 2ℓ-e deň bolsa, Ç nokatda ornuny üýtgetme nola deň bolmak üçin hususy agramy bilen ýüklenen AB balkanyň Ç nokadyna nähili güýç P goýmaly?



6.9-njy surat

6. 2. Energetiki usullar bilen sterženli ulgamlaryň durkuny üýtgetmegini kesgitlemek

6.10. Suratda şekillendirilen balkanyň egilmede durkunyň üýtgedilmeginiň potensial energiýasynyň aňlatmasyny peýdalanyp, erkin tarapyndaky egrelmesini kesgitlemeli.

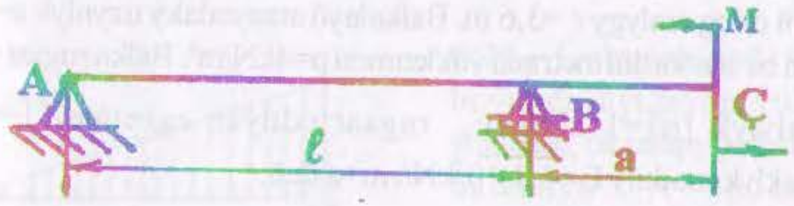


6.10-njy surat

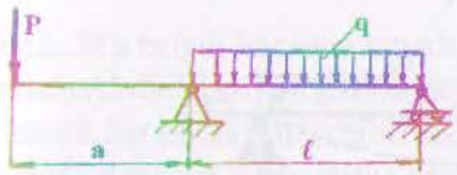
6.11. Diametri d = 12 sm bolan tegelek kesikli wal, M_{eg}=6 kNm hemişelik moment bilen egilýär we M_i=8 kNm moment bilen towlanýar. Walyň 1 metrinde durkuny üýtgetmäniň toplan potensial energiýasyny kesgitlemeli. Walyň materialynyň maýyşgaklyk modullary E =2,1·10⁴kN/sm², G =8,5·10³kN/sm² .

6.12. Gönüburçly kese kesikli balka hemişelik egme moment bilen ýüklenen; iň uly normal dartgynlylygy σ deň, normal maýyşgaklyk moduly E, kese kesiginiň meýdany A, uzynlygy ℓ bolan balkanyň toplan potensial energiýasyny hasaplamaly.

6.13. Suratda şekillendirilen balkanyň Ç kesiginiň egrelmesini we öwrülme burçuny Makswell-Moruň usuly bilen kesgitlemeli.

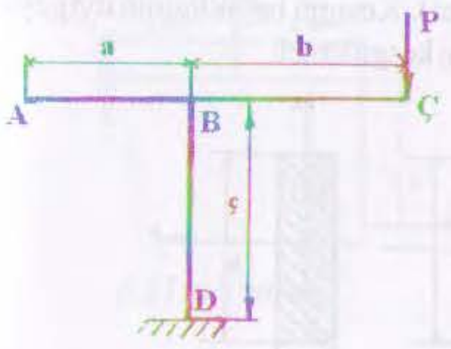


6.13-nji surat



6.14-nji surat

6.14. Suratda görkezilişi ýaly, ýüklenen polat balkanyň konsolynyň ahyryndaky kesikde Makswell-Moruň usuly bilen egrelmesini we öwrülme burçuny kesgitlemeli. P=20 kN, q=30 kN/m, ℓ =4 m, a=1m, I=3500 sm⁴.



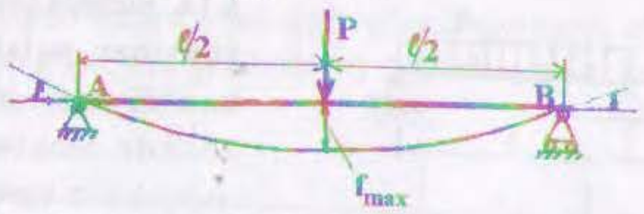
6.15-nji surat

6.15. Suratda şekillendirilen ABÇD çarçuwanyň sag konsolynyň ahyrynda goýlan P ýüküň täsirinden çep konsolynyň ahyrynda ýerleşen A nokadyň egrelmesini Makswell-Moruň usuly bilen kesgitlemeli.

6.16. Suwy akdyrmak üçin niýetlenen gorizontal ýerleşen polat turba ℓ =2,4 m uzynlykda diwardan çykyp duryar. Turbanyň içki diametriniň daşkysyna bolan gatnaşygy d:D=0,85. Poladyň göwrüm agramy γ_p = 78,5kN/m³ -a, suwuňky bolsa γ_s = 10kN/m³ -a deň. Turbanyň materialynyň maýyşgaklyk moduly E =1,96·10⁴kN/sm². Turbanyň erkin tarapyna rugsat edilýän egrelme [f] = 0,003ℓ . Turbanyň içki we daşky diametrlerini kesgitlemeli.

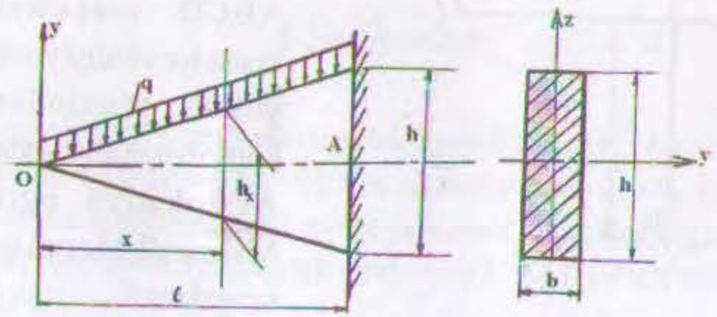
✓ **6.17.** Berklik we gatylyk şertlerinden agaç örtgüli balkany hasaplamaly. Balkanyň direg aralygy ℓ =3,6 m. Balkalnyň arasyndaky uzynlyk a=1,2 m, örtüginiň bir inedördül metriniň ýüklenmesi p=4kN/m². Balka rugsat edilýän dartgynlylyk [σ]=1 kN/sm², rugsat edilýän egrelme $[f]=\frac{1}{350}\ell$ maýyşgaklyk moduly E =1,1·10³kN/sm²-a deň.

6.18. Uzynlygy ℓ we hemişelik beýikligi (h=const) hem üýtgeýän ini bolan iki daýanç nokatly balka P güýç bilen ýüklenen (surata seret). Maýyşgaklyk moduly E deň bolsa, θ_{max} we f_{max} tapmaly.

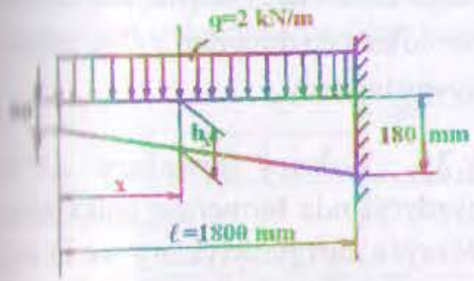


6.18-nji surat

6.19. Uzynlygy ℓ we hemişelik ini bolan gönüburçly kesikli, hemme kesiklerinde deň garşylyk görkezýän bir tarapy berkidilen balka endigan ýaýran ýük bilen ýüklenen (surata seret). Kesigiň beýikliginiň üýtgeýän kanunyny we balkanyň iň uly egrelmesini kesgitlemeli.

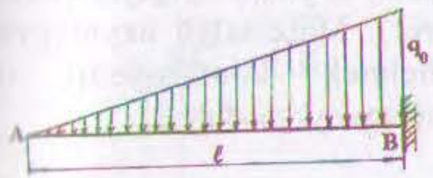


6.19-njy surat



6.20-nji surat

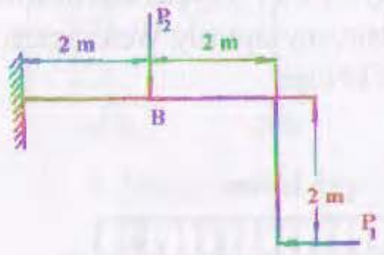
6.20. Suratda şekillendirilen gönüburçly kesikli balkanyň iň uly egrelmesini kesgitlemeli. Pürsüň materialy sosna, sosnanyň maýyşgaklyk moduly E=10³ kN/sm². Kesigiň ini b=60 mm.



6.21-nji surat

6.21. Üçburçlugyň kanuny boýunça üýtgeýän ýük bilen ýüklenen, bir tarapy berkidilen AB balkanyň A nokadynyň egrelmesiniň we öwrülme burçunyň ululygyny kesgitlemeli (surata seret).

6.22. 20 a belgili iki tawra kesikli, direg aralygy 6 m-e deň balkanyň bir tarapynyň diregi şarnirli gozganmaýan, beýleki tarapy diametri 10 sm bolan silindrik hyr şekilli pružin bilen saklanýar. Pružiniň sarymynyň sany n=10, siminiň diametri 2 sm. Balka we pružin polatdan ýasalan, materialyň maýyşgaklyk modullary E =2·10⁴kN/sm²-a we G =8·10³kN/sm²-a deň. Balkanyň ortasynda goýlan wertikal güýjüň täsirinden toplanan potensial energiýany kesgitlemeli.



6.21-nji surat

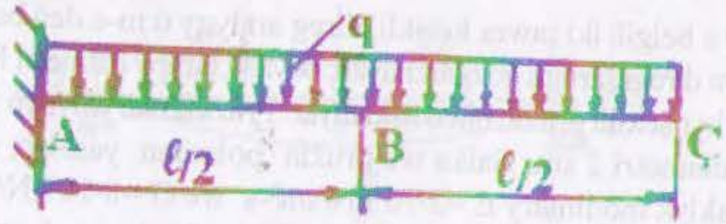
∨ **6.23.** Suratda görkezilişi ýaly, döwük oky bolan balka P_1=10 kN we P_2=20 kN güýçler bilen ýüklenen. Kesigiň inersiýa momenti 3000 sm⁴-e deň we balkanyň hemme uzynlygyna hemişelik. Maýyşgaklyk moduly E =2·10⁴kN/sm²-a deň. P_1 güýjüň ugry boýunça A kesigiň ornuny üýtgetmesini we B kesigiň öwrülme burçuny kesgitlemeli.

6.24. Iki daýanç nokatda ýatan balka, sagat diliniň ugry boýunça aýlanýan iki jübüt güýçler bilen egilýär. Eger epme nokat çep diregden $\ell/3$ aralykda ýerleşen bolsa, bu momentleriň gatnaşygyny tapmaly.

6.25-nji surat

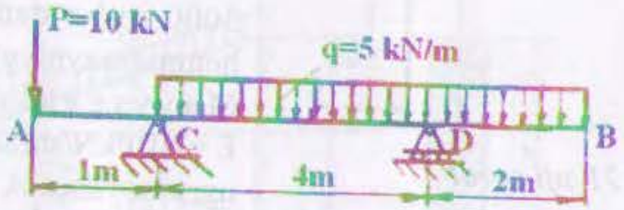
6.25. Ýokary granlary $\Delta t°S$ gyzdyrylanda birmeňzeş balkalarda döreýän dartgynlylyklary we iň uly egrelmeleri deňeşdirmeli. Balkanyň galyňlygyna temperatura çyzyk kanuny boýunça üýtgeýär (surata seret). Materialyň uzynlygyna giňelmek koeffisiýenti α, maýyşgaklyk moduly E.

6.26. Suratda görkezilen endigan ýaýran ýük bilen ýüklenen balkanyň B kesiginiň öwrülme burçuny kesgitlemeli. Wereşaginiň usulyny ulanmaly.



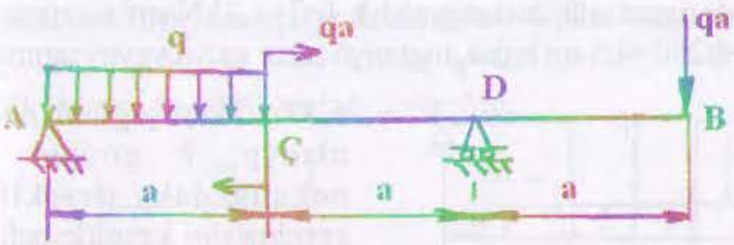
6.26-njy surat

6.27. Suratda görkezilen AB balkanyň q we P güýçleriniň täsirinden çep konsolyň ahyryndaky kesiginiň öwrülme burçuny tapmaly. Wereşaginiň usulyny ulanmaly. Balkanyň gatylygy $EI = 4 \cdot 10^7 kN/sm^2$.



6.27-nji surat

6.28. Wereşaginiň usulyny ulanyp, balkanyň B nokadynyň egrelmesini we diregdäki A nokadyny öwrülme burçuny kesgitlemeli.

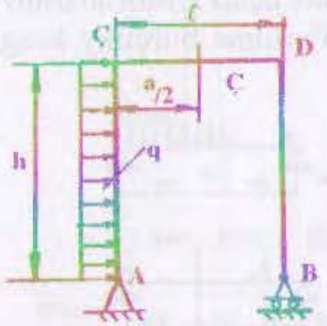


6.28-nji surat

6.29-njy surat

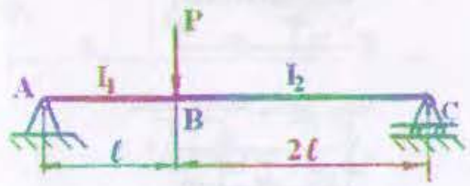
6.29. Suratda şekillendirilen çarçuwanyň Wereşaginiň düzgünini ulanyp, erkin tarapyndaky wertikal ornuny üýtgetmesini kesgitlemeli.

6.30. Suratda görkezilen endigan ýaýran ýük bilen ýüklenen çarçuwanyň B diregindäki gorizontal ornuny üýtgetmesini kesgitlemeli. Şonuň ýaly-da Wereşaginiň usulyny ulanyp, Ç kesiginiň wertikal ornuny üýtgetmesini, D kesiginiň öwrülme burçuny kesgitlemeli.



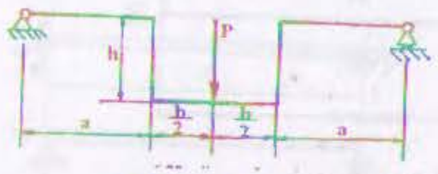
6.30-njy surat

6.31. Suratda şekillendirilen polat balkanyň P güýjüň goýlan ýerinde, AB we BÇ böleklerin inersiýa momentleriniň I_1 we I_2 haýsy gatnaşygynda iň uly ornuny üýtgetmesi bolar? Eger P=6,25 kN, ℓ=0,24 m, I_1=16 sm^4 bolsa bu ornuny üýtgetmäni tapmaly.



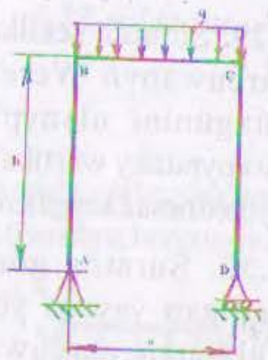
6.31-nji surat

6.32. Direg aralygy ℓ=1,25 m bolan tagta pol metal balkanyň üstünde goýlan we P=8,5kN/m^2 ýük bilen ýüklenen (poluň agramy + peýdaly ýük). Eger egilmede rugsat edilýän dartgynlylyk [σ]=1,2 kN/sm^2 we rugsat edilýän egrelme [f]=l/250=0,5 sm bolsa, tagtanyň zerur galyňlygyny tapmaly.



6.33-nji surat

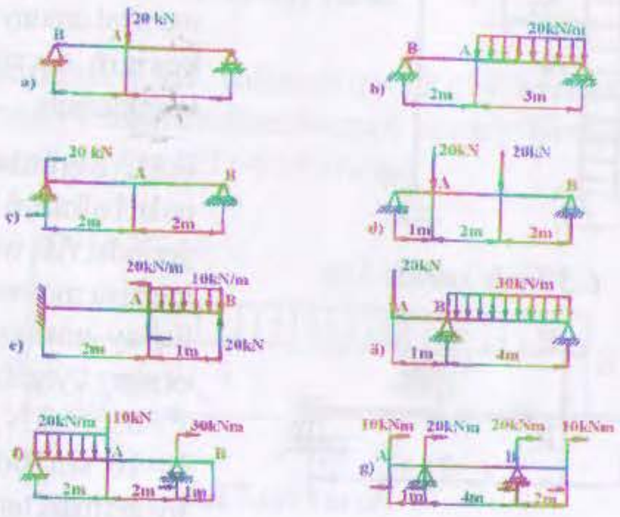
6.33. Wereşaginiň düzgünini ulanyp, P güýjüň goýlan nokadyndaky tirsekli walyň egrelmesini kesgitlemeli. Walyň kesigi hemme böleklerinde hemişelik.



6.34-nji surat

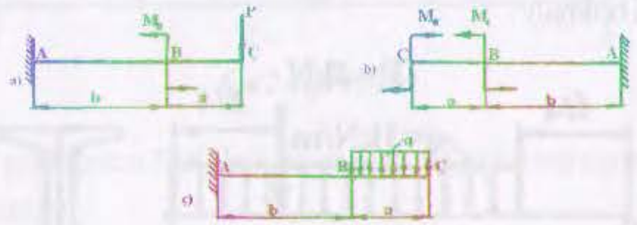
6.34. Suratda görkezilen rigelde endigan ýaýran ýük bilen ýüklenen simmetriýaly çarçuwanyň D şarniriniň gorizontal ornuny üýtgetmesini Wereşaginiň usuly bilen kesgitlemeli. Rigeliň we çarçuwanyň aýaklarynyň kese kesikleri birmeňzeş.

6.35. Çyzgyda getirilen balkalaryň shemalary üçin O. Moruň usuly bilen A nokadynyň egrelmesini we B kesigiň öwrülme burçuny kesgitlemeli E = 2·10^{4}kN/sm^2.



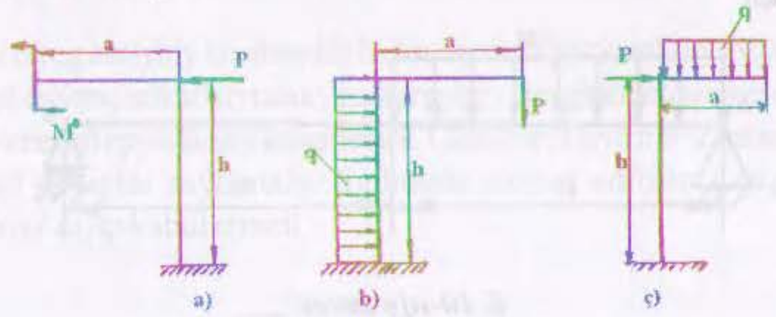
6.35-nji surat

6.36. Shemalarda görkezilen bir tarapy berkidilen we dürli güýçler bilen ýüklenen hemişelik kesikli ABÇ balkanyň Ç kesiginiň Simpson-Karnouhowyň usulyny ulanyp egrelmesini we öwrülme burçuny kesgitlemeli. Berlen: P=20 kN; M_0=40 kNm; q=20 kN/m; b=3m, a=2m; E=2·10^{4}kN/sm^2; I=4800 sm^4; ℓ=a+b=5m.

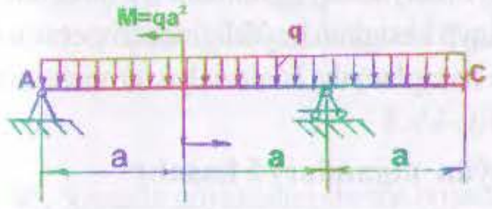


6.36-njy surat

6.37. Suratda görkezilen shemalar boýunça ýüklenen hemişelik kesikli polat çarçuwanyň erkin kesigindäki wertikal f, gorizontal Δ ornuny üýtgetmelerini we öwrülme burçuny θ matrisa usuly bilen kesgitlemeli (E = 2·10^{4}kN/sm^2.).



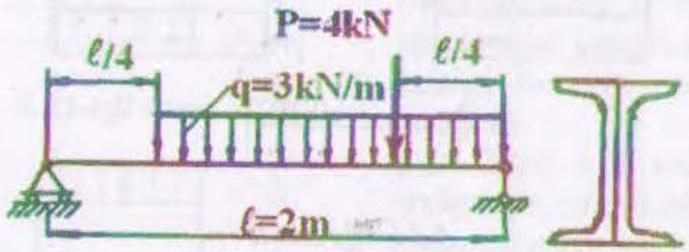
6.37-njy surat



6.38-nji surat

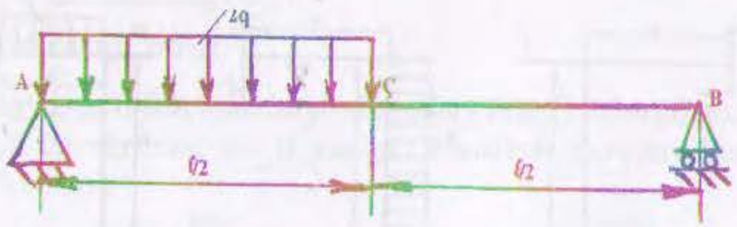
6.38. Matrisa usulyny ulanyp, suratda görkezilen balkanyň Ç nokadyndaky egrelmesini we öwrülme burçuny kesgitlemeli.

6.39. 16-njy belgili Pr. 106 tipli iki şwellerden (bir şwelleriň inersiýa momenti I=51,98 sm^4) ybarat bolan dýural balka, suratda görkezilişi ýaly, ýük bilen ýüklenen. Matrisa usulyny ulanyp, balkanyň ortasyndaky egrelmäni kesgitlemeli. E = $7{,}5\cdot10^3 kN/sm^2$. Balkanyň ortasyndaky egrelmesi $\ell/200$-den ýokary geçmedik ýagdaýynda, balkanyň kesiginiň inersiýa momenti nähili bolmaly?



6.39-njy surat

6.40. Uzynlygy ℓ, depgini 2 q bolan endigan ýaýran ýük bilen çep direginden ortasyna çenli ýüklenen iki daýanç nokatly balkanyň ortasyndaky egrelmäni kesgitlemeli.

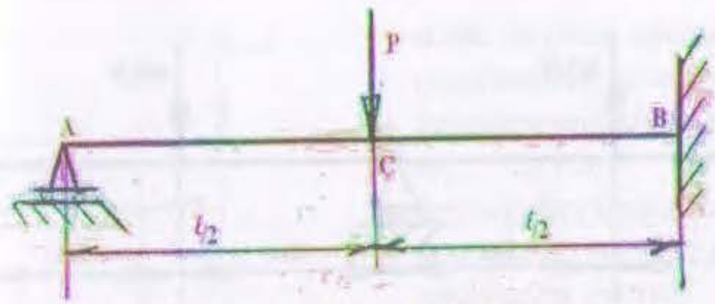


6.40-njy surat

6.41. Uzynlygy ℓ deň bolan hemişelik kesikli ýönekeý balkanyň $\Delta t°S$ bilen aşagy gyzdyrylanda, direg aralygynyň ortasyndaky egrelmäni we diregdäki öwrülme burçuny kesgitlemeli. Balkanyň kesiginiň beýikligine temperatura çyzyk kanuny boýunça üýtgeýär diýip hasaplamaly. Materialyň temperatura giňelmek koeffisiýenti α deň.

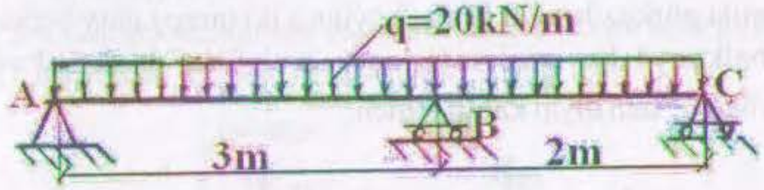
6.3. Statiki kesgitlenmeýän ulgamlaryň hasaby

6.42. AÇB balkanyň B gyrasy gaty we A gyrasy gozganýan şarnirli direg bilen berkidilen. Balkanyň ortasyna P=40 kN güýç goýlan, kese güýjüniň we egme momentiniň epýurlaryny gurmaly.



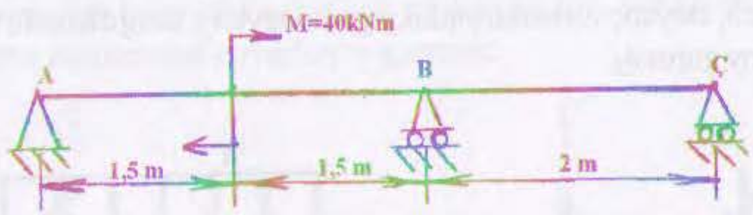
6.42-nji surat

6.43. Suratda görkezilen ABÇ balkanyň kese güýjüniň we egme momentiniň epýurlaryny gurmaly.



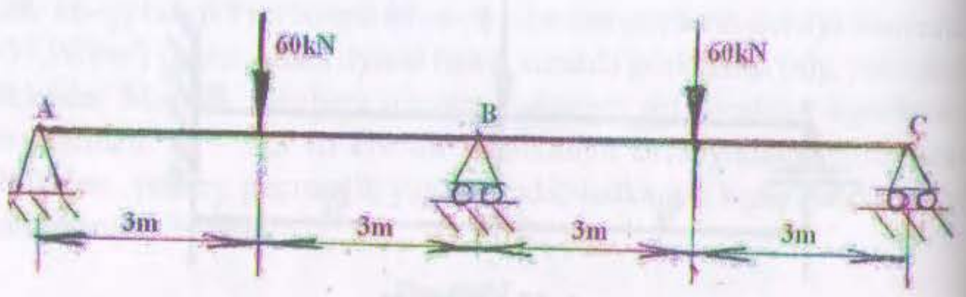
6.43-nji surat

6.44. Iki direg aralykly kesilmedik balka suratda görkezilişi ýaly ýüklenen. Balkanyň daýanç nokatlaryndaky gaýtargylary kesgitlemeli we kese güýjüň, egme momentiň epýurlaryny kesgitlemeli. Gönüburçlugyň h:b=2 gatnaşygynda balkanyň kesigini saýlamaly. Egilmede rugsat edilýän dartgynlylyk 1,1 kN/sm^2 diýip kabul etmeli.



6.44-nji surat

6.45. Suratda görkezilen shema boýunça balkanyň daýanç nokatlaryndaky gaýtargylary we iň uly hem iň kiçi egme momentlerini kesgitlemeli. Rugsat edilýän dartgynlylyk 16 kN/sm^2 bolanda, iki tawranyň belgisini saýlamaly.



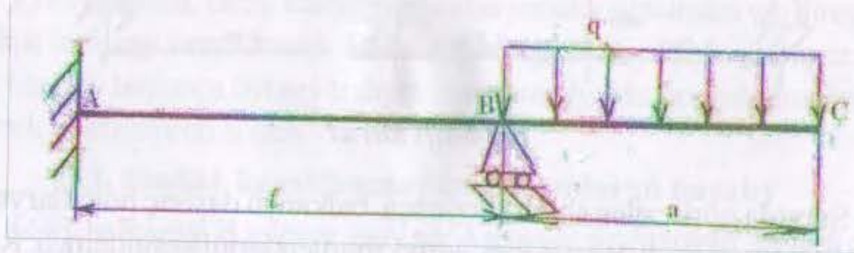
6.45-nji surat

6.46. Shemada görkezilen çarçuwalaryň kese güýjüniň we egme momentiniň epýurlaryny gurmaly.

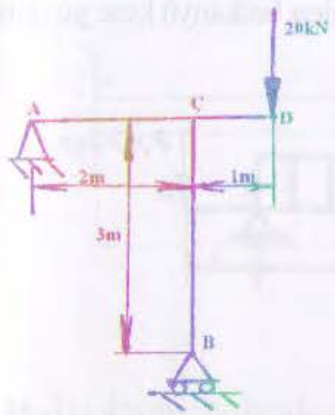
6.47. Suratda görkezilen ýüklenme boýunça iki tarapy gaty berkidilen iki tawraly balkanyň kesigini saýlamaly. a=1,5 m, b=3m, P=60 kN, $[\sigma]$=16 kN/sm² deň diýip kabul etmeli.

6.47-nji surat

6.48. Islendik usul bilen balkanyň statik kesgitlenmeýändigini açyp görkezmeli, daýanç nokatlaryndaky gaýtargylary kesgitlemeli, Q we M epýurlaryny gurmaly.



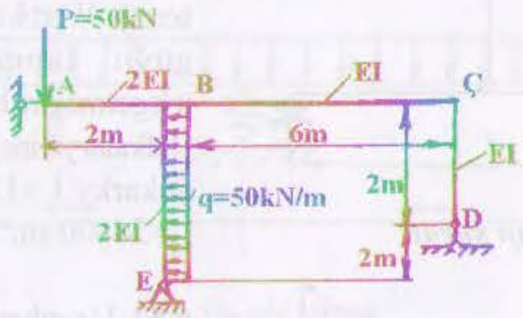
6.48-nji surat



6.49-njy surat

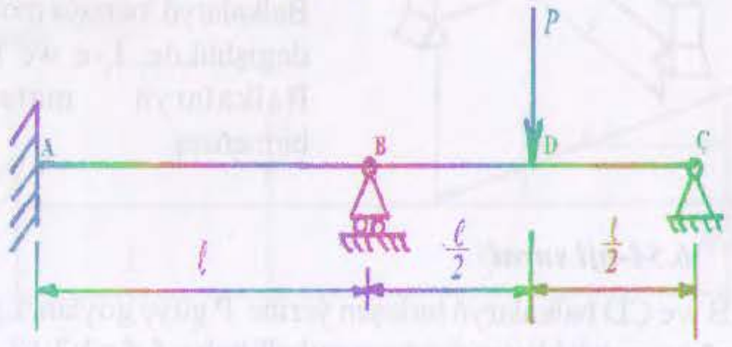
6.49. Suratda shemasy görkezilen çarçuwanyň güýç usulyny ulanyp, statik kesgitlenmeýändigini açyp görkezmeli we daýanç nokatlaryndaky gaýtargylary kesgitlemeli. Normal we kese güýçleriniň we egme momentiniň epýurlaryny gurmaly.

6.50. Suratda şekillendirilen çarçuwanyň normal we kese güýçleriniň hem egme momentiniň epýurlaryny gurmaly.



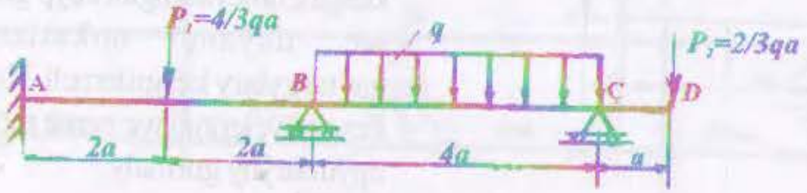
6.50-nji surat

6.51. Iki direg aralykly balka sag direg aralygynyň ortasynda bir ýere jemlenen güýç bilen ýüklenen. Güýç usulyny ulanyp, balkanyň kese güýjüniň we egme momentiniň epýurlaryny gurmaly.

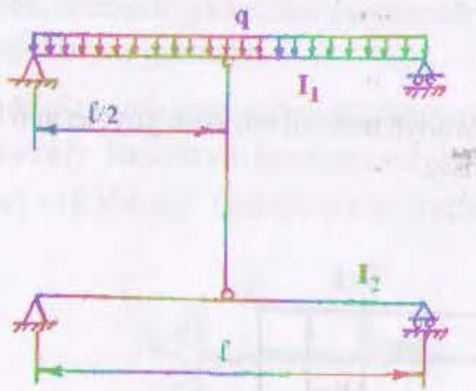


6.51-nji surat

6.52. Matrisa usulyny ulanyp, suratda şekillendirilen balkanyň kese güýjüniň we egme momentiniň epýurlaryny gurmaly.

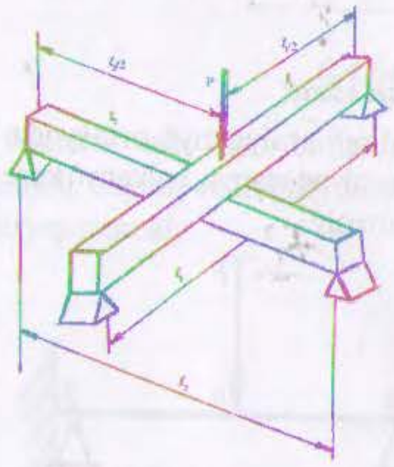


6.52-nji surat



6.53-nji surat

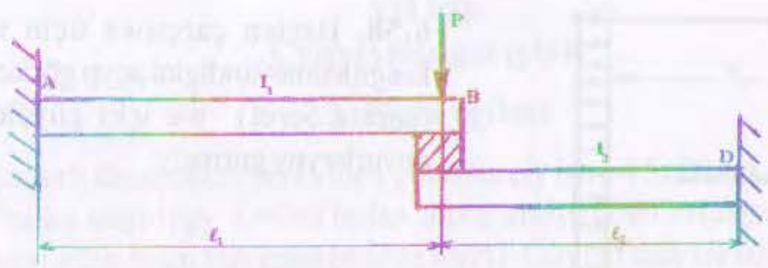
6.53. Uzynlygy ℓ=1m bolan birmeňzeş materialdan ýasalan iki balka wertikal steržen bilen ortasynda birikdirilen (surata seret). Wertikal steržene düşýän güýji tapmaly (durkuny üýtgetmegini hasaba almazdan). Balkalaryň inersiýa momentleri: ýokarky I_1=12560 sm^4; aşaky I_2=54400 sm^4.



6.54-nji surat

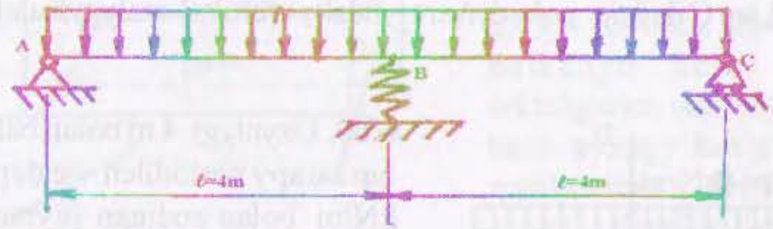
6.54. Uzynlygy ℓ_1 we ℓ_2 bolan iki atanaklaýyn ýatan balkalar P güýç bilen ýüklenen (surata seret). Balkalaryň arasynda güýjüň ýaýraýşyny tapmaly. Balkalaryň inersiýa momentleri, degişlilikde, I_1-e we I_2-ä deň. Balkalaryň materiallary birmeňzeş.

6.55. Iki AB we ÇD balkalaryň birleşen ýerine P güýç goýlan. Eger direg aralyklarynyň we gatylyklarynyň gatnaşygy belli bolsa: $\ell_1:\ell_2$=3:2; $EI_1:EI_2$=4:5, P güýjüň balkalaryň arasyndaky paýlanylyşyny tapmaly.



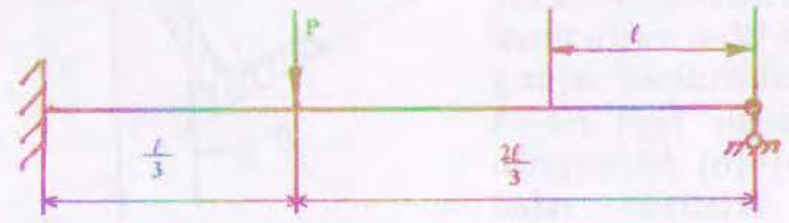
6.55-nji surat

6.56. Iki daýanç nokatda goýlan 24-nji belgili iki tawraly polat balkanyň ortasynda gatylygy $c=10$ kN/sm bolan pružin goýlan (surata seret). Durkuny üýtgetmegi deňeşdirmek usuly bilen ortaky diregiň gaýtargysyny kesgitlemeli.

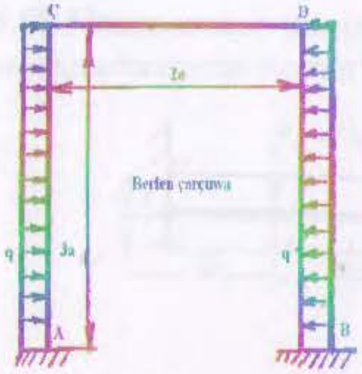


6.56-njy surat

6.57. Polat balkanyň okuna parallel edilip datçik ýelimlenen (surata seret). Eger elektrotenzometrik ölçeýjileriň görkezmesi boýunça datçigiň bazasynyň ugruna alnan durkuny üýtgetme $\varepsilon_A = -1 \cdot 10^{-4}$ bolsa, P güýjüň ululygyny kesgitlemeli.



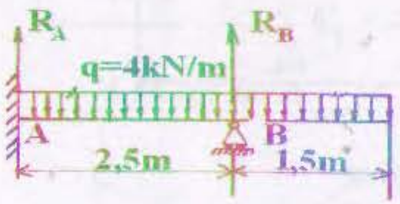
6.57-nji surat



6.58-nji surat

6.58. Berlen çarçuwa üçin statik kesgitlenmeýändigini açyp görkezmeli (surata seret) we içki güýçleriniň epýurlaryny gurmaly.

6.59. Direg aralary ℓ bolan iki direg aralykly ABÇ balka, depgini q bolan endigan ýaýran ýük bilen ýüklenen. Ortaky daýanç nokadyň gaýtargysy $q\ell$-e deň. A we Ç daýanç nokadyň arasyndaky wertikal aralygyň ululygyny tapmaly.



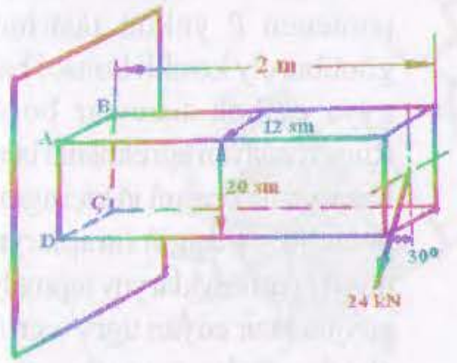
6.60-njy surat

6.60. Uzynlygy 4 m bolan balkanyň bir tarapy berkidilen we depgini 4 kN/m bolan endigan ýaýran güýç bilen ýüklenen; balkanyň berkidilen A nokadyndan 2,5 m aralykda direg bilen goldaw berlende, berkidilen A nokatda egme moment nola deň bolýar. Goldaw beriji direge düşýän basyşy tapmaly we balkanyň kese güýjüniň we egme momentiniň epýurlaryny gurmaly.

VII bap
Çylşyrymly garşylyk

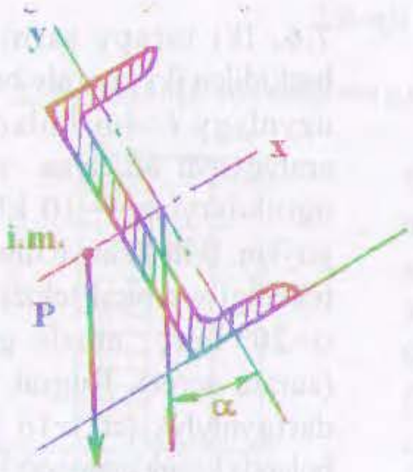
7.1. Gyýa egilme

7.1. Şarnirli direg bilen berkidilen gönüburçly bxh=15x20 sm kese kesikli agaç balka uzynlygy ℓ=3m bolan direg aralygynyň ortasynda bir ýere jemlenen güýç bilen ýüklenen (surata seret). Güýjüň täsir tekizligi balkanyň okundan geçýän wertikal tekizlik bilen $\varphi=15^{\circ}$ burç boýunça ýapgytlanan. Balkanyň kese kesiginde bitarap okunyň ýagdaýyny we gysylma dartgynlylygyny kesgitlemeli. Balkanyň ortasyndaky kesigiň doly egrelmäniň ululygyny we ugruny kesgitlemeli.



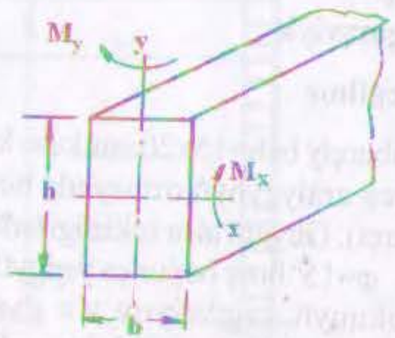
7.2-nji surat

7.2. Uzynlygy ℓ=2m, kese kesigi 12x20 sm bolan gönüburçly agaç balkanyň bir tarapy gaty berkidilen, beýleki tarapy bolsa, 2,4 kN ýük bilen ýüklenen. Güýç balkanyň kese kesiginiň tekizliginden täsir edýär we onuň täsir çyzygy kesigiň agyrlyk merkezinden geçýär (surata seret). Berkidilen kesigiň gapdallary boýunça normal dartgynlylygyň epýuryny gurmaly we balkanyň erkin tarapynda doly egrelmäni kesgitlemeli.



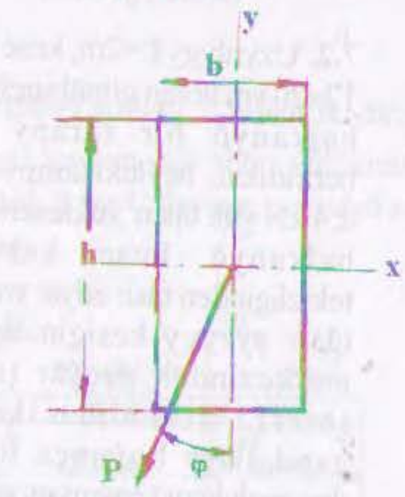
7.3-nji surat

7.3. Iki tarapy şarnirli berkidilen şweller endigan ýaýran wertikal täsir edýän q=5 kN/m güýç bilen ýüklenen. Şwelleriň diwary wertikal bilen $\alpha=30^{\circ}$ burç emele getirýär. Şwelleriň direg aralygy ℓ=4m. Eger rugsat edilýän dartgynlylyk $[\sigma]=16$ kN/sm^2 bolsa, şwelleriň belgisini saýlamaly.



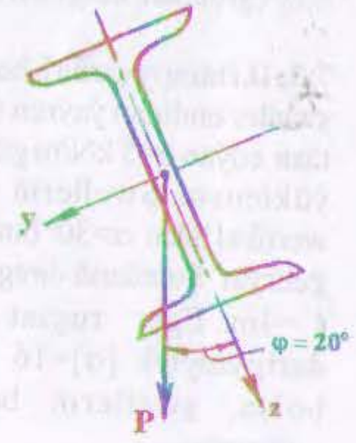
7.4-nji surat

7.4. Gönüburçly kesikli brus M_x we M_y egme momentlerden gyýa egilmä sezewar bolýar. Brusuň iň az agramynda $k = \frac{h}{b}$ oňaýly gatnaşygyny kesgitlemeli.



7.5-nji surat

7.5. Erkin tarapyndan bir ýere jemlenen P ýüküň täsirinden gönüburçly kesikli konsol balka gyýa egilmä sezewar bolýar. Rugsat edilýän egrelmäniň berlen bahasynda brusuň iň kiçi agramy bolar ýaly kesigiň taraplarynyň oňaýly gatnaşyklaryny tapmaly. P güýjüň täsir edýän ugry wertikal ok bilen α burçy emele getirýär.

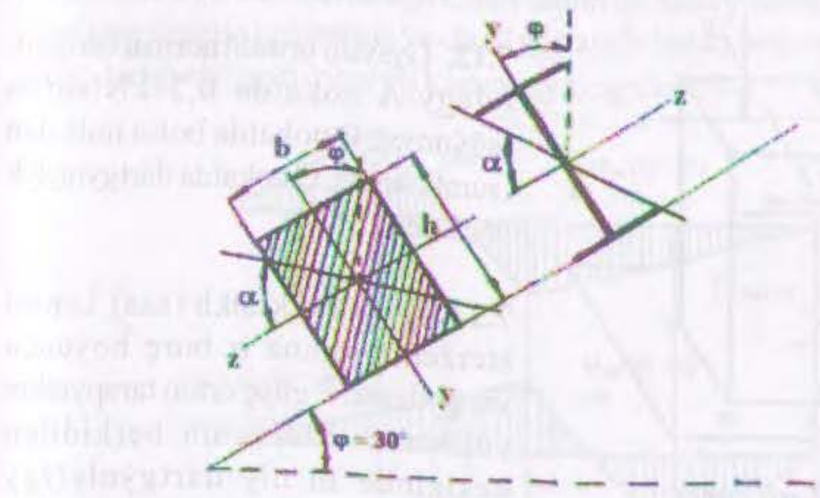


7.6-njy surat

7.6. Iki tarapy şarnir bilen berkidilen iki tawraly balkanyň uzynlygy ℓ=4m bolan direg aralygynyň ortasyna wertikal ugrukdyrylan P=10 kN güýç goýlan. Ikitawranyň diwarynyň tekizligi wertikal tekizlik bilen α=20° burç emele getirýär (surata seret). Rugsat edilýän dartgynlylyk $[\sigma]$ =16 kN/sm^2 bolanda kesgitlenen sort boýunça balkanyň kesigini saýlamaly.

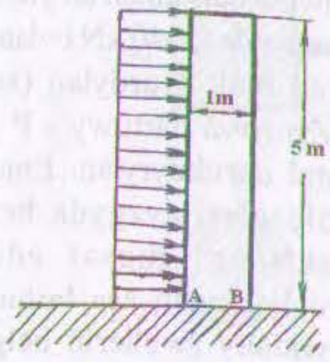
7.7. Uzynlygy 1.6 m, ölçegi 80 x 80 x 7mm bolan ugolok bir tarapy gaty berkidilen balka görnüşinde işleýär; kesigiň egilme merkezinden geçýän bir ýere jemlenen P=1kN güýç balkanyň erkin tarapynda goýlan. Balkanyň howply kesiginde bitarap okuň ýagdaýyny we A,B we Ç nokatlarda normal dartgynlylyklary kesgitlemeli. Ugologyň iň uly egrelmesiniň ululygyny we ugruny kesgitlemeli.

7.8. Jaýyň üçeginiň gapyrgasynyň (p=3,2 kN/m^2 wertikal ýüki göteryän bolsa) kesiginiň ölçeglerini iki görnüşde saýlamaly: gönüburçluk $[\sigma]$=1,25 kN/sm^2 (agaç) we ikitawra ($[\sigma]$=16 kN/sm^2) Gapyrganyň direg aralygy ℓ =4m; gapyrgalaryň özara aralygy a=1,25 m deň.



7.8-nji surat

7.2. Egilmäniň süýnme we gysma bilen bilelikdäki täsiri

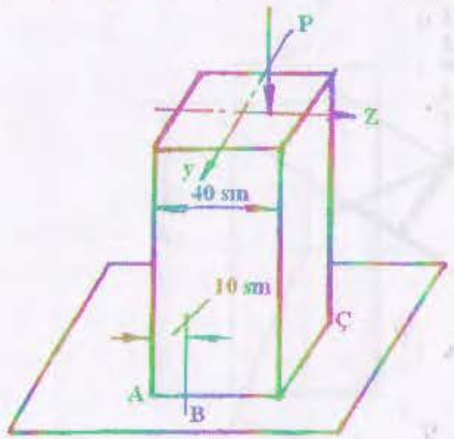


7.9-njy surat

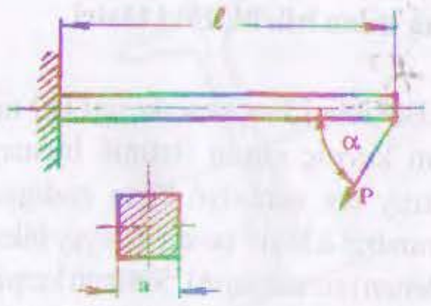
7.9. Beýikligi 5 m, kese-kesigi 1x1 m^2 bolan kerpiç sütün özüniň hususy agramy we şemalyň kese endigan ýaýran 0,8 kN/m^2 bolan basyşy bilen ýüklenen (surata seret). Sütüniň kerpiç örüminiň udel agramy 1,6. Sütüniň esasyndaky iň uly we iň kiçi gysylma dartgynlylyklaryny kesgitlemeli.

7.10. Kesilen kesigi suratda shematiki görkezilen daşdan edilen söýeg diwary ýeriň gum üýşmegini saklaýar. Örümiň udel agramy 1,8-e deň. Ýeriň basyşy q gorizontal ugrukdyrylan we diwaryň beýikligine üçburçlugyň kanuny boýunça ýaýraýar; diwaryň esasyndaky iň uly basyş 1,5 kN/m² deň. Diwaryň esasyndaky iň uly we iň kiçi gysylma dartgynlylyklaryň ululygyny kesgitlemeli.

7.11. Gönüburçly 15x20 sm kese kesikli agaç direg baş inersiýa oklaryň her haýsyndan 3 sm uzaklykda ýerleşen N nokatda 90 kN deň gysýan boý güýji bilen ýüklenen. Bitarap okuň ýagdaýyny kesgitlemeli we gönüburçlugyň taraplary boýunça normal dartgynlylygyň ýaýraýşynyň epýuryny gurmaly.



7.12-nji surat

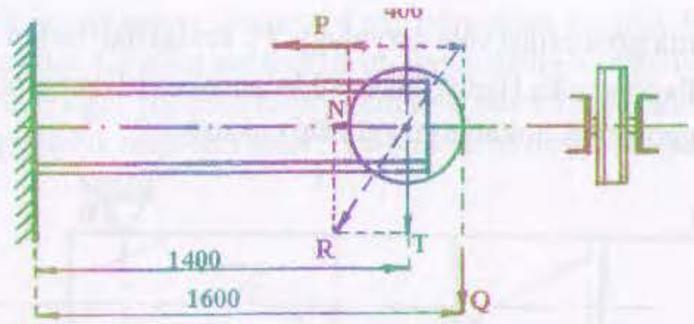


7.13-nji surat

7.12. Gysylan brusuň normal dartgynlylygy A nokatda 0,2 kN/sm²-a (süýnme), B nokatda bolsa nola deň (surata seret). Ç nokatda dartgynlylyk näçä deň?

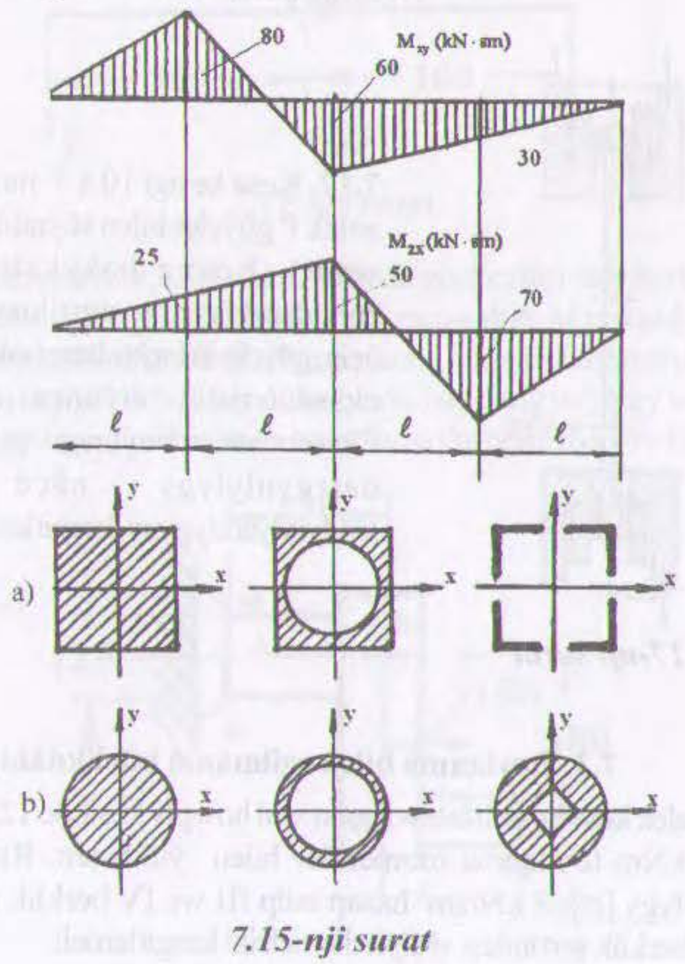
7.13. Kwadrat kesikli (axa) konsol sterženiň okuna α burç boýunça ýapgytlanan P güýç erkin tarapyndan ýüklenen. Sterženiň berkidilen kesiginde iň uly dartgynlylygy kesgitlemeli we α burçuň haýsy bahasynda dartgynlylyk iň uly baha deň bolýar.

7.14. Diwara berkidilen iki şwelleriň erkin tarapynda Q=40 kN bolan ýüki galdyrýan blok oturdylan (surata seret). Zynjyryň dartuwy - P güýç gorizontal ugrukdyrylan. Enjamyň esasy ölçegleri çyzgyda berlen. [σ]=8 kN/sm² rugsat edilýän dartgynlylygyndan aşa bolmadyk ýagdaýyndaky şwelleriň belgisini kesgitlemeli.



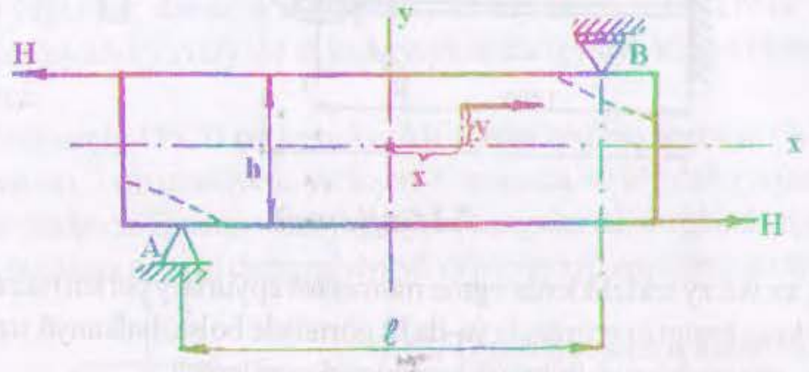
7.14-nji surat

7.15. zx we zy tekizliklerde egme momentiň epýurlary berlen (surata seret). Eger kese kesigi a) görnüşde ýa-da b) görnüşde bolsa, balkanyň uzynlygyna iň uly dartgynlylygyň üýtgeýiş kanunyny kesgitlemeli.



7.15-nji surat

7.16. Suratda görkezilişi ýaly uzynlygy ℓ, kesigi hxb bolan iki diregde goýlan gönüburçly balka H güýç bilen ýüklenen. Normal dartgynlylygyň nola deň bolýan geometrik nokatlaryny gözläp tapmaly.



7.16-njy surat

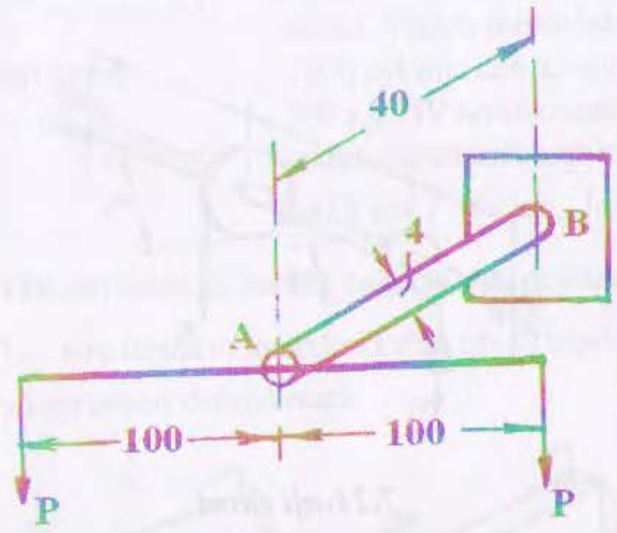
7.17. Kese kesigi 10 x 5 mm bolan polat zolak P güýçler bilen süýndürilýär (surata seret). Emma hakykatdan gysýan enjamlardaky uly sürtülme bolýandygy üçin, güýçleriň haýsy hem bolsa biri 0,1 mm ekssentrisitet boýunça täsir edýär. Ekssentrisitet boýunça goýlan güýjüň dartgynlylygy näçe göterim galdyrylýandygyny kesgitlemeli.

7.17-nji surat

7.3. Towlanma bilen egilmäniň bilelikdäki täsiri

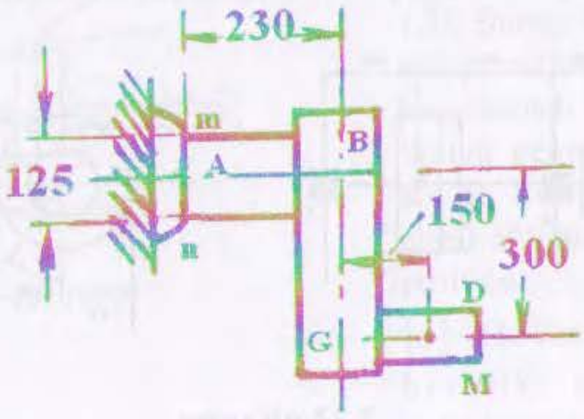
7.18. Tegelek kese kesikli bitewi polat wal howply kesikde 12,5 kNm egme we 12,5 kNm towlanma momentler bilen ýüklenen. Rugsat edilýän dartgynlylygy $[\sigma]=8$ kN/sm^2 hasap edip III we IV berklik nazaryýetleri boýunça berklik şertinden walyň diametrini kesgitlemeli.

7.19. Uzynlygy 40 sm we diametri 4 sm, birmeňzeş iki güýç P=1kN bilen ýüklenen, tegelek AB polat sterženiň iň uly hasap dartgynlylygyny kesgitlemeli (surata seret). Eger ýükleriň haýsy hem bolsa birini aýyrsaň, sterždäki hasap dartgynlylyk näçä deň bolar? IV berklik nazaryýetini peýdalanmaly.



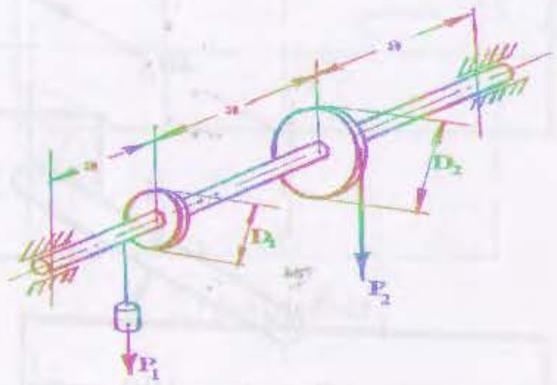
7.19-njy surat

7.20. Polat tirsekli ABÇD steržen, suratda görkezilişi ýaly berkidilen. AB bölegiň kese kesigi tegelek, diametri 125 mm-e deň. M nokatda çyzgynyň tekizligine perpendikulýar 20kN güýç goýlan. Galtaşma dartgynlylygy hasaba almazdan mn kesigiň iň howply nokadynda baş dartgynlylygy we II, III we IV berklik nazaryýetleri boýunça hasaplama dartgynlylyklary kesgitlemeli.



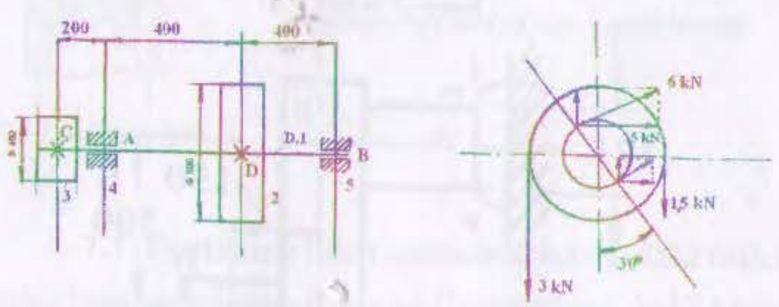
7.20-nji surat

7.21. Diametrleri D_1=20 sm we D_2=50 sm bolan iki tigir, suratda görkezilişi ýaly wala oturdylan, tigirlere P_1 we P_2 wertikal güýçler täsir edýärler. P_1=5 kN we $[\sigma]$=10 kN/sm², a=120 sm şertlerde III berklik nazaryýeti boýunça walyň diametrini kesgitlemeli. Podşipniklerdäki sürtülmäni hasaba almaly däl.

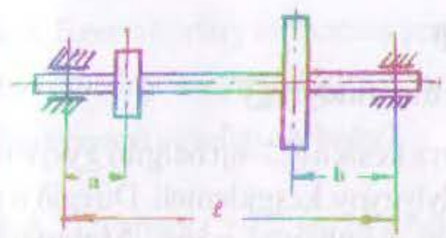


7.21-nji surat

7.22. Waldan-1, şkiwlerden-2 we 3, podşipniklerden-4 we 5 ybarat hereketi geçirijiniň walynyň diametrini kesgitlemeli. Şkiwleriň diametrleri D_1=800 mm, D_2=400 mm. Çekiniň şahalaryndaky güýçler suratda görkezilen. Walyň materialy üçin egilmede rugsat edilýän normal dartgynlylyk $[\sigma]$=9 kN/sm²-a deň. Hasap üçin iň uly galtaşma dartgynlylygyň berklik nazaryýetini peýdalanmaly. Şkiwleriň agramyny hasaba almaly däl.



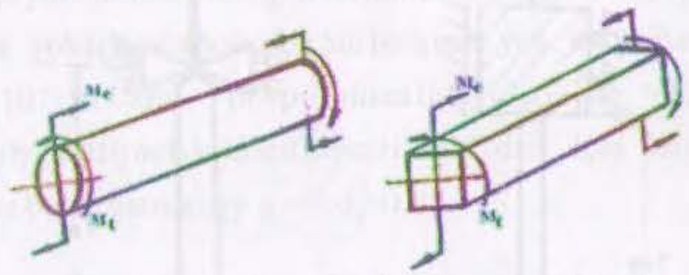
7.22-nji surat



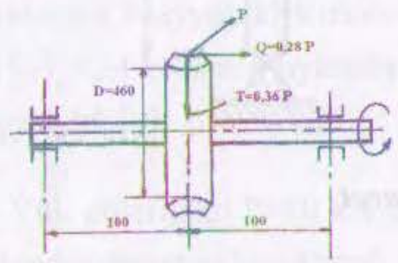
7.23-nji surat

7.23. Radiuslary r_1=6 sm we r_2=12 sm bolan aýlanýan polat wala iki dişli tigirler oturdylan. Töwerekleýin täsir edýän güýçler wertikal oklara α_1=45°we α_2=30° burç bilen ýapgytlanan (surata seret). Walyň minutdaky aýlaw sany 1000 aýl/min deň. Geçirýän kuwwaty 500 a.g.. IV berklik nazaryýeti boýunça walyň diametrini kesgitlemeli. a=10 sm, b=15 sm, ℓ=50 sm, $[\sigma]$=12 kN/sm².

7.24. Deň berklik şertinden III berklik nazaryýetini peýdalanyp, $M_\ell$egme we $M_1 = \frac{1}{3} M_\ell$ towlanma momentleri kabul edýän tegelek we kwadrat kesikli bruslaryň agramyny deňeşdirmeli.



7.24-nji surat



7.25-nji surat

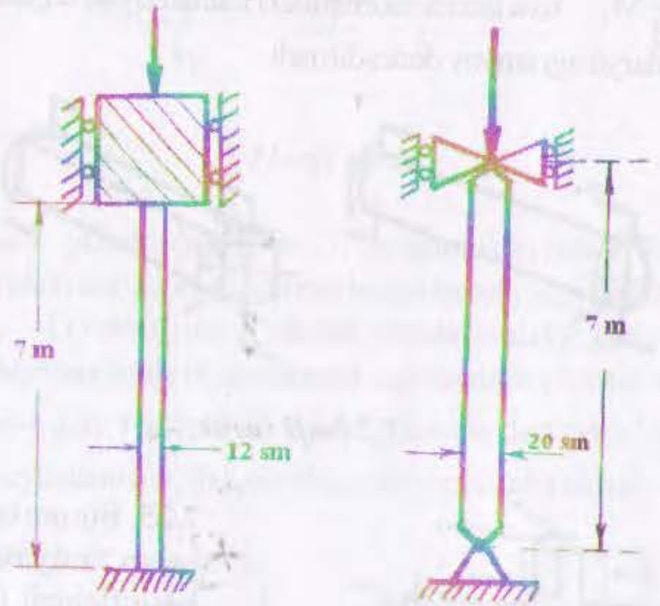
7.25. Burum tigriniň walynyň talap edýän diametrini kesgitlemeli (surata seret). Walyň geçirýän kuwwaty N=12 kwt; aýlaw sany n=80 aýl/min; wala rugsat edilýän dartgynlylyk $[\sigma]$=4 kN/sm². Hasapda IV berklik nazaryýetini peýdalanmaly.

VIII bap

Gysylan sterženleriň durnuklylygy

8.1. Eýleriň formulasyny ulanyp iki tawra kesikli (22-nji belgili) gysylan diregiň kritiki güýjüni we kritiki dartgynlylygyny kesgitlemeli. Diregiň iki tarapy hem şarnirli berkidilen. Sütüniň uzynlygy ℓ =5m. Materialy proporsionallyk çägi $[\sigma]_{ps}$ =20kN/sm² bolan polat.

8.2. Uzynlygy 7 m, gönüburçly kese kesikli 12x20 sm² agaç diregiň kritiki güýjüniň we kritiki dartgynlylygynyň ululygyny kesgitlemeli. Maýyşgaklyk moduly E =0,9·10³kN/sm² deň. Iň kiçi gatylykdaky tekizlikde diregiň iki tarapy hem berkidilen, oňa perpendikulýar tekizlikde – iki tarapy şarnirli berkidilen (surata seret).



8.2-nji surat

8.3. Eger diregleriň biri tegelek, beýlekisi turba görnüşli, kese kesikleriniň meýdanlary deň ululykda bolsa, Eýleriň formulasyny peýdalanyp, birmeňzeş şertlerde işleýän diregleriň kritiki güýçleriniň gatnaşygyny tapmaly. Turba görnüşli kesigiň diametrleriniň gatnaşygy $d_d : d_i = 1{,}25$ -e deň.

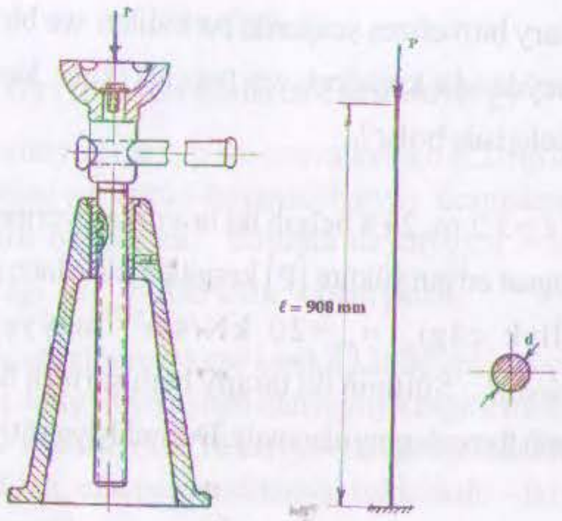
8.4. Eger ahyrlary birmeňzeş şertlerde berkidilen we birmeňzeş ýüklenen bir ululykly meýdanda kwadrat we tegelek kese kesikli sterženleriň haýsysynyň çeýeligi uly bolar?

8.5. Uzynlygy ℓ =3,2 m, 24 a belgili iki tawradan ýerine ýetirilen sütüniň durnuklylyga rugsat edýän ýüküni $[P]$ kesgitlemeli. Materialy – polat 3, onuň proporsionallyk çägi $\sigma_{p\cdot s}$=20 kN/sm², maýyşgaklyk moduly $E = 2\cdot10^4$ kN/sm². Sütüniň iki tarapy hem şarnirli berkidilen. Mesele çözülende Eýleriň formulasyny ulanmaly. Durnuklylyga ätiýaçlyk koeffisiýenti n_d=2,8-e deň.

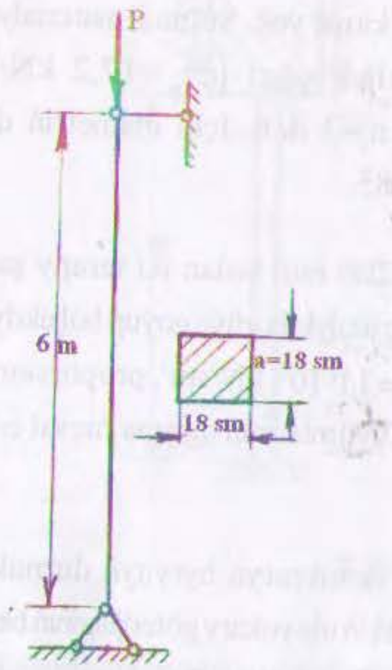
8.6. $[P_d] = 300$ kN güýç bilen gysylýan, uzynlygy ℓ =3,2 m bolan içi boş tegelek çoýun sütüniň kesigini saýlamaly. Sütüniň aşaky tarapy gaty berkidilen, ýokarsynda bolsa hiç hili berkitme ýok. Sütüniň materialy üçin $E = 1{,}15\cdot10^4$ kN/sm², proporsionallyk çägi $[\sigma]_p$ =17,2 kN/sm². Durnuklylyga ätiýaçlyk koeffisiýenti n_d=3 deň. Içki diametriň daşky diametrine bolan gatnaşygy $\alpha = d_i : d_d = 0{,}85$.

8.7. Uzynlygy ℓ =2,7 m, diametri d=200 mm bolan iki tarapy şarnirli berkidilen tegelek kesikli agaç direge näçe ululykda güýç goýup boljakdygyny kesgitlemeli. Maýyşgaklyk moduly $E = 1{,}1\cdot10^3$ kN/sm², proporsionallyk çägi $[\sigma]_p$=2,1 kN/sm² gysylmada boý süýümleriniň ugruna rugsat edilýän dartgynlylyk $[\sigma] = 0{,}6$ kN/sm².

8.8. Ýük göterijiligi P=50 kN bolan domkratyň hyrynyň durnuklylyk hasabyndan diametrini kesgitlemeli. Ýüküň iň uly ýokary göterijiliginiň beýikligi ℓ =900 mm; durnuklylyga ätiýaçlyk koeffisiýenti n_d=4,0. Hyryň materialy polat 30; maýyşgaklyk moduly $E = 2{,}1\cdot10^4$ kN/sm².



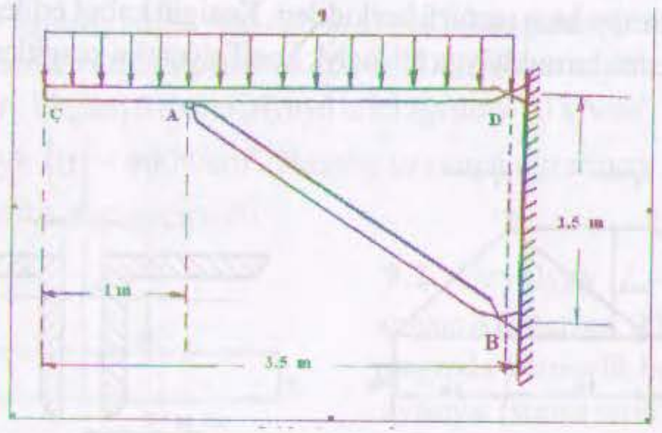
8.8-nji surat



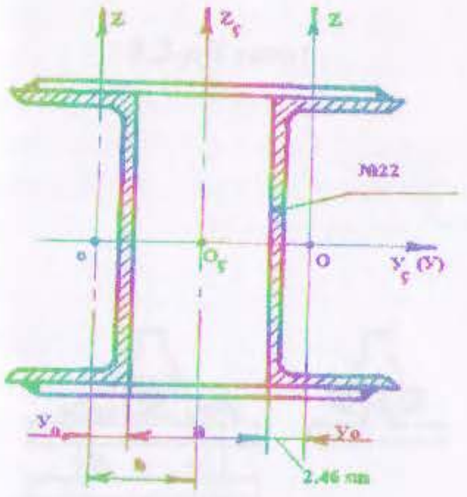
8.9-njy surat

8.9. Beýikligi 6 m kwadrat kesekesikli agaç diregiň kritiki we rugsat edilýän güýjüni, şonuň ýaly-da esasy rugsat edilýän dartgynlylygy azaldýan koeffisiýenti tapmaly. Diregiň iki tarapy hem şarnirli berkidilen. Kwadratyň taraplary a=18 sm. Ätiýaçlyk koeffisiýenti n_d=3. Gysylma rugsat edilýän dartgynlylyk $[\sigma]=1\,kN/sm^2$.

8.10. Esasy rugsat edilýän dartgynlylygy $[\sigma]=1,1kN/sm^2$ bolan AB kronşteýniň agaçdan söýeginiň diametrini kesgitlemeli. Söýegiň iki tarapyny hem şarnirli berkidilen diýip hasap etmeli. ÇD balka täsir edýän endigan ýaýran güýç q=60 kN/m-e deň.



8.10-njy surat

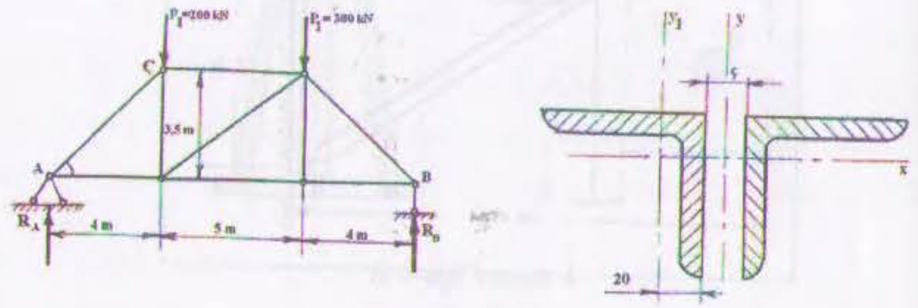


8.11-nji surat

8.11. Uzynlygy ℓ =5 m bolan sütün 22 a belgili iki şwelleri birikdirýän plankadan ybarat. Şwelleriň materialy polat 3, onuň üçin $[\sigma]=16\ kN/sm^2$. Sütüniň iki tarapy şarnirli berkidilen. Sütüne iň uly rugsat edilýän güýji kesgitlemeli. $I_{y_0}=I_{z_1}$ şertden şwellerleriň aralygyny kesgitlemeli.

8.12. Eger: a) göwrüm agramy $\gamma=80\cdot10^{-6}\,kN/sm^3$ we maýyşgaklyk moduly $E=2\cdot10^4\,kN/sm^2$ bolan polatdan, b) $\gamma=26\cdot10^{-6}\,kN/sm^3$ we $E=0,7\cdot10^4\,kN/sm^2$ duraldan, ç) $\gamma=6\cdot10^{-6}\,kN/sm^3$ we $E=1\cdot10^3\,kN/sm^2$ agaçdan ýasalan tegelek kese kesiginiň diametri 10 sm, bir tarapy berkidilen, beýleki tarapy berkitmeden erkin bolan sterženiň hususy agramyndan ýitiryän kritiki uzynlygyny kesgitlemeli.

8.13. Suratda şekillendirilen fermanyň gysylan AÇ elementiniň (surata seret) kesigini saýlamaly. Elementiň kesigi suratda görkezilişi ýaly, iki burçlukdan ybarat we bir steržen ýaly işleýär. Materialy polat 3, $[\sigma]=16$ kN/sm^2. Sterženiň iki tarapy hem şarnirli berkidilen. Kesigiň kabul edilen ölçegleri boýunça sterženiň durnuklylyga ätiýaçlyk koeffisiýentini kesgitlemeli.

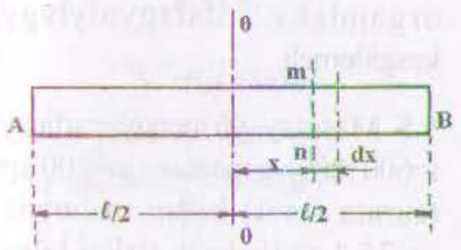


8.13-nji surat

IX bap
Dinamiki we dowamly ýüklenmeler.

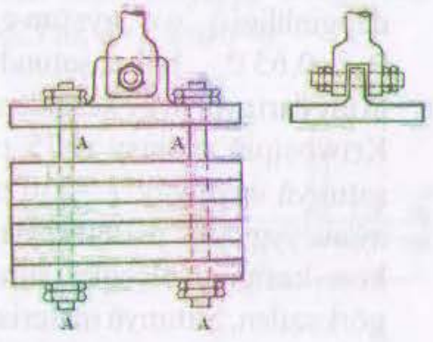
9.1. Inersiýa güýçlerini hasaba almak

9.1. 50 kN agramy bolan ýüki deň tizlenme bilen galdyrýan uzynlygy 60 m urganyň diametrini kesgitlemeli. Birinji üç sekuntda ýük 9 m beýiklige galdyrylýar. Urganyň materialynyň udel agramy 70 kN/m^3, rugsat edilýän dartgynlylyk $[\sigma]=6$ kN/sm^2. Hasaby urganyň agramyny hasaba alman hem-de hasaba alyp geçirmeli.



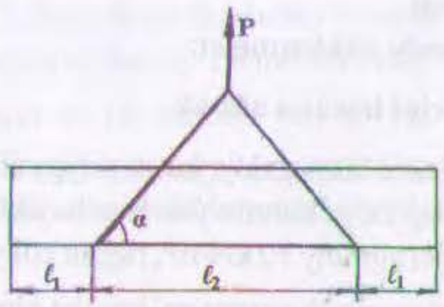
9.2-nji surat

9.2. Uzynlygy $\ell=1{,}8$ m bolan çoýun AB steržen, 00 wertikal okuň daşynda hemişelik burç tizligi bilen aýlanýar (surata seret). Eger çoýnuň göwrüm agramy $\gamma=74$ kN/m^3, süýnmä rugsat edilýän dartgynlylyk $[\sigma]=4$ kN/sm^2 bolsa, sterženiň aňryçäk minutdaky aýlaw sanyny kesgitlemeli. Eger $E=1{,}6\cdot10^4$ kN/sm^2, aýlaw sany 1000 aýl/min bolsa, sterženiň uzalmasyny kesgitlemeli.



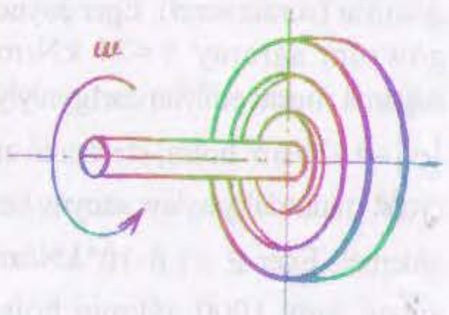
9.3-nji surat

9.3. Göterijiniň garşylyk agramy 42 kN deň (surata seret). Göterijini galdyrýan togtadylanda aşak goýberilýän garşylyk agramyň tizlenmesi 1,5 m/s^2-a deň. Eger boltuň materialy üçin $[\sigma]=3{,}2$ kN/sm^2 we $[\tau]=2$ kN/sm^2 bolsa, A we B garşylyk agramynyň boltunyň diametrini kesgitlemeli. Boltlaryň sany A-iki, B-bir.



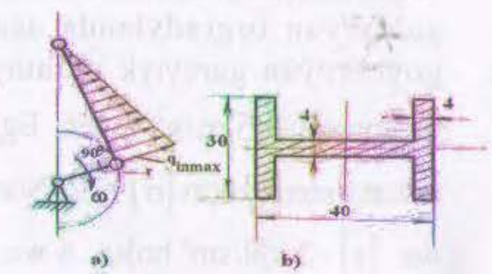
9.4-nji surat

9.4. Tizlenmesi a=6 m/s² bolan beton balka kran bilen ýokary göterilýär (surata seret). Eger balkanyň kese kesigi – taraplary b=20 sm bolan kwadrat, betonyň udel agramy γ =24 kN/m³ bolan balkanyň dartgynlylygyny kesgitlemeli. Polat urganyň kese kesiginiň meýdany A=1,27 sm², α=45°, ℓ_1=1m, ℓ_2=4m bolsa, urgandaky dartgynlylygy kesgitlemeli.



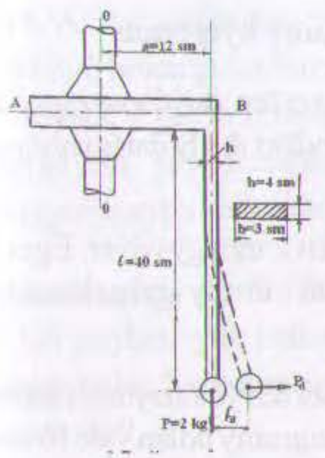
9.5-nji surat

9.5. Massasynyň inersiýa radiusy i=600 mm we massasy m=200 kg (surata seret) bolan mahowik ω=75,4 rad/s burç tizligi bilen aýlanýar. Deňölçegli haýallanýan togtamada mahowik 20 aýlawdan soň durýar. Mahowik oturdylan walyň diametri d=50 mm bolsa, walyň iň uly galtaşma dartgynlylygyny kesgitlemeli.



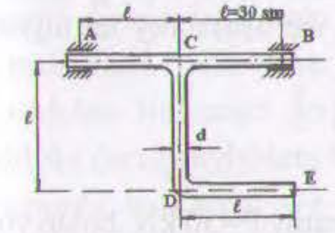
9.6-nji surat

9.6. Şatuny egýän inersiýa güýjüň depginliligi q_{in} we gysýan güýç P_{90}^{0}=0,65 P_{max} bolsa, şatundaky iň uly dartgynlylygy kesgitlemeli. Kriwoşipiň radiusy r=75 mm, şatunyň uzynlygy ℓ =250 mm, aýlaw ýygylygy n=2800 aýl/min, kese-kesiginiň ölçegleri suratda görkezilen. Şatunyň materialy – polat 45 Г 2, rugsat edilýän dartgynlylyk [σ]=0,25,σ_b=850MPa, P_{max}=30 kN.



9.7-nji surat

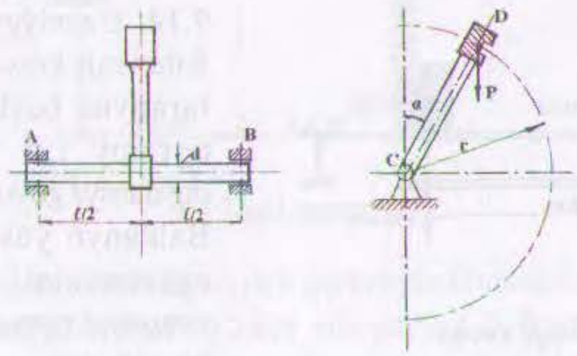
9.7. Regulýator (sazlaýjy) 00 okuň daşyndan hemişelik burç tizligi bilen aýlanýar (surata seret). Regulýatoryň aňryçäk aýlaw sanyny tapmaly we eger [σ]=18 kN/sm² bolsa, şol aýlaw sanda BÇ polat sterženiň erkin tarapynyň egrelmesini kesgitlemeli. AB steržen absolýut gaty diýip hasap etmeli. BÇ sterženiň inersiýa güýjüni hasaba almaly däl.



9.8-nji surat

9.8. Tegelek kese kesikli (d=18 mm) döwük brus AB okuň daşyndan endigan aýlanýar. Eger γ =78 kN/m³, [σ]=10 kN/sm² bolsa, iň uly rugsat edilýän burç tizligini kesgitlemeli.

9.9. Nusgany urga synag edýän AB kopýor okuň daşynda aýlanýan ÇD maýatnikden ybarat. Synagdan öň maýatnik suratda görkezilişi ýaly ýagdaýda saklanýar we agram güýjüniň täsirinden aşak gaçmaga mejbur edilýär. Maýatnigiň inersiýa güýjünden AB okda döreýän egilmeden iň uly normal dartgynlylygy kesgitlemeli. Berlen: P=0,25 kN, r=0,75m , ℓ=0,25 m, d=2 sm, α=0.



9.9-njy surat

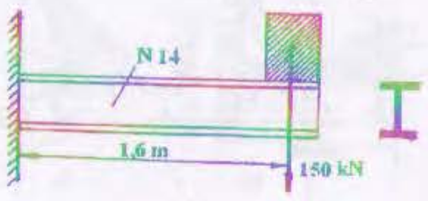
9.2. Urguda dartgynlylyk we durkuny üýtgetme

9.10. Diametri 25 mm we uzynlygy 1,5 m polat steržen duýdansyz goýlan hemişelik güýç P=25 kN bilen dartylýar. Steržendäki iň uly dartgynlylygy we durkuny üýtgetmäni kesgitlemeli.

9.11. Statiki goýlan P güýç bilen wertikal steržen 2 mm gysylýar. Eger P ýük 1mm beýiklikden gaçýan bolsa, sterženiň iň uly gysgalmasyny kesgitlemeli.

9.12. Uzynlygy 5 m bolan tegelek kesikli polat steržen ýokarsyndan asylan we aşaky tarapynda halka çykyntgysy bar. 8 kN agramy bolan ýük 16 mm beýiklikden sterženiň boýuna gaçýar we bu ýüki çykyntgy saklaýar. Rugsat edilýän dartgynlylyk 16 kN/sm^2 bolsa, sterženiň diametrini kesgitlemeli. Urguda dartgynlylygy hasaplamagyň takyk we aşakdaky takmynan formulasyny $\sigma_d = \sigma_{st}\sqrt{\frac{2H}{\Delta_{st}}}$ peýdalanmaly:

9.13. Polat trosuň (urganyň) bir tarapynda agramy P=50 kN bolan ýük berkidilen, beýleki tarapyny lebýodkanyň barabanyna oralan ýük v = 1,6 m/s hemişelik tizlik bilen aşak goýberilýär. Lebýodka birdenkä togtadylanda, ýük şol bada saklanýar. Saklanan pursatda trosuň ýük bilen lebýodkanyň arasyndaky uzynlygy ℓ =240 m deň. Trosyň kese kesginiň meýdany A=10 sm^2. Trosuň agramyny hasaba alyp we hasaba almazdan, iň uly dartgynlylyklaryny kesgitlemeli.



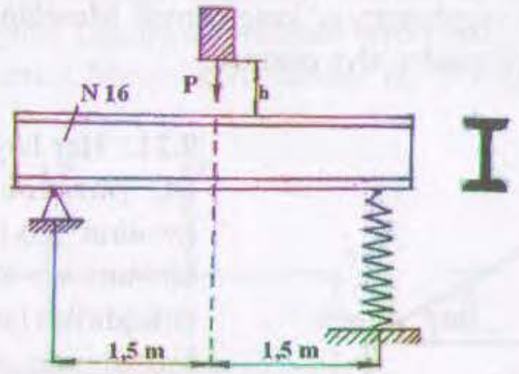
9.14-nji surat

9.14. Uzynlygy ℓ=1,6 m bolan ikitawraly konsol balkanyň erkin tarapyna başlangyç tizliksiz, agramy 1,5 kN bolan ýük duýdansyz goýulýar (surata seret). Balkanyň ýüküň aşagyndaky egrelmesini we berkidilen tarapynyň normal dartgynlylygyny kesgitlemeli.

9.15. Aýlaw tizligi n=150 aýl/min, diametri D=600 mm we galyňlygy t=40 mm bolan polat bitewi disk diametri d=100 mm bolan polat walda oturdylan. Eger wal diskden ℓ=2,5 m uzaklykdaky kesikde birdenkä togtadylsa, towlanmadan walyň kese kesigindäki iň uly galtaşma dartgynlylygyny kesgitlemeli. Walyň massasyny hasaba almaly däl.

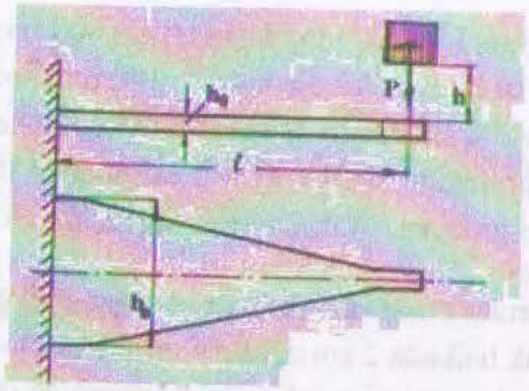
9.16. Ahyrlary şarnirli berkidilen balkanyň direg aralygynyň ortasynda 45 kN goýlan, ýük balkada 2 sm egrelme döredýär. Şu balka 5 kN ýük gaçýan bolsa, 2 sm-den uly bolmadyk egrelme döredýän ýüküň iň uly tizligi näçe bolar?

9.17. Uzynlygy 3 m bolan 16-njy belgili ikitawraly balkanyň bir tarapy gaty şarnirli diregde berkidilen. Beýleki tarapy simiň diametri 20 mm, sarymyň orta diametri 10 sm we sarymynyň sany 10-a deň bolan hyr şekilli pružinde oturdylan. Balkanyň $[\sigma]$=16 kN/sm^2, pružiniň $[\tau]$=20 kN/sm^2 rugsat edilýän dartgynlylyklary bolanda, agramy 2 kN ýük nähili beýiklikden gaçanda balkanyň we pružiniň dartgynlylyklary rugsat edilýän dartgynlylyklardan ýokary bolmaz?



9.17-nji surat

9.18. Hemme kesiklerinde deň garşylyk görkezýän konsolyň erkin tarapyna h=20 sm bolan beýiklikden P=0,2 kN ýük gaçýar. Balkanyň massasyny hasaba alyp, konsolyň ahyryndaky egrelmesini we iň uly dartgynlylygyny hasaplamaly.

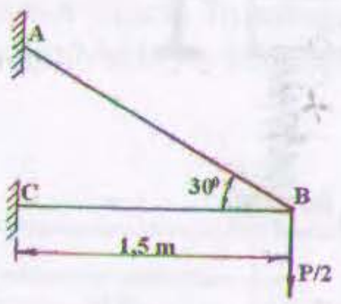


9.18-nji surat

9.19. Eger sterženiň kese kesiginiň meýdanyny iki gezek azaltsaň, h beýiklikden gaçýan ýük sterženi boý urga sezewar edýän bolsa, sterżende döreýän dartgynlylyk näçe göterim köpeler?

9.3. Yrgyldydan dartgynlylyk we durkuny üýtgetme

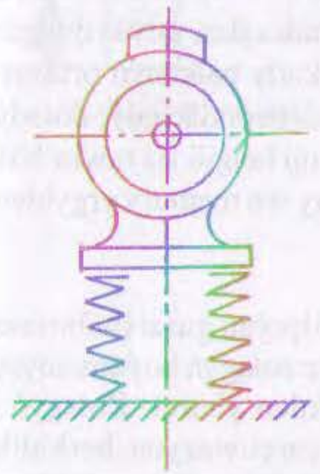
9.20. Uzynlygy 80 sm we diametri 5 sm, 100 kN boýuna gysýan güýç bilen ýüklenen tegelek kesikli polat diregiň boý hususy yrgyldysynyň periodyny t_o we ýygylygyny ω_o kesgitlemeli. Meseläni diregiň massasyny hasaba alman we hasaba alyp çözmeli.



9.21-nji surat

9.21. Her haýsy iki agaç AB we BÇ pürsden ýerine ýetirilen kwadrat 10x10 sm^2 kese kesikli biri-biri we diwar bilen şarnirli birleşdirilen (surata seret) iki ABÇ kronşteýne agramy P=100 kN bolan elektrodwigatel berkidilen. Hususy wertikal yrgyldynyň periodyny we yrgyldynyň ýygylygyny kesgitlemeli. $E=10^3$ kN/sm^2.

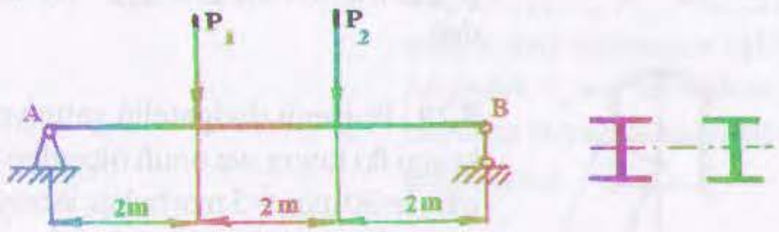
9.22. Kronşteýne berkidilen elektrodwigatel (öňki meselä seret) 1300 aýl/min ýygylykda aýlanýar. BÇ sterženiň okuna perpendikulýar tekizlikde aýlanýan dwigateliň böleklerineň doly däl deňagramlaşmagy netijesinde 1,6 kN deň merkezden daşlaşýan inersiýa güýçleri döreýär. Ulgamyň diňe wertikal mejbury yrgyldysyna seredip, kronşteýniň pürslerindäki yrgyldynyň ösme koeffisiýentini, dinamiki koeffisiýentini we iň uly normal dartgynlylygynyň ululygyny hasaplamaly. Garşylyk güýçleri hasaba almaly däl.



9.23-nji surat

9.23. Massasy m=1kN bolan elektrodwigatel dört silindrik hyr şekilli pružinde oturdylan. Pružiniň häsiýetnamalary: d=12 mm, D=10 mm, sarymyň sany n=7 (surata seret). Elektrodwigateliň aýlaw ýygylygy n=240 aýl/min. Rotoryň deňagramlaşmadyk massasy m_o=10 kg, massanyň ekssentrisiteti r=0,02 m deň. Ulgamy rezonansa barlamaly, iň uly galtaşma dartgynlylygy we pružiniň çökmesini kesgitlemeli.

9.24. Uzynlygy ℓ=6 m, inersiýa momenti I_x=945 sm^4 iki ikitawraly balkada oturdylan iki maşynlar ulgamynyň (surata seret) hususy yrgyldysynyň ýygylygyny kesgitlemeli. Maşynlaryň massasy: m_1=500 kg, m_2=1500 kg.

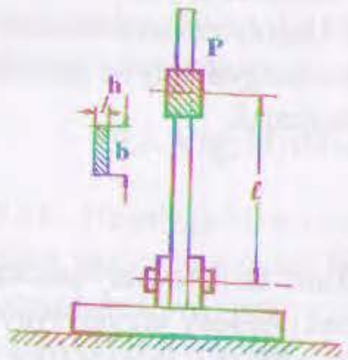


9.24-nji surat

9.25. Uzynlygy ℓ=1,5 m, diametri d=5 sm bolan wala inersiýa momenti I_m = 0,31kN·sm.s^2 bolan mahowik oturdylan. Walyň aýlaw tizligi 950 aýl/min-a deň. Waly rezonansa barlamaly. Walyň agramyny we mahowigiň agramynyň döredýän egrelmesini hasaba almaly däl.

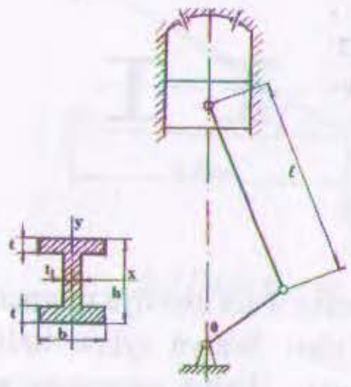
9.26. Wagonyň ressory sarymyň orta radiusy R=60 mm, pružiniň siminiň radiusy r=15 mm, sarymynyň sany n=8 deň bolan sekiz sany silindr görnüşli spiral pružinden durýar; simiň materialynyň süýşmede maýyşgaklyk moduly $G=9{,}5\cdot10^3$kN/sm^2, wagonyň gabynyň agramy Q=50 kN, peýdaly ýük S=3,5 kN. Relsleriň sepgitleriniň arasy ℓ =8 m. Wagonyň rezonans hadysasynyň boljak hereketiniň kritiki tizligini kesgitlemeli.

9.27. Agramy Q = 25 kN bolan we n=540 aýl/min aýlaw edýän dwigatel, uzynlygy ℓ =3,5 m deň bolan iki daýanç nokatly balkanyň ortasynda berkidilen. Dwigatel $P_1=P\sin\omega t$ deň bolan wertikal periodiki güýç döredýär. Bu ýerde P=8 kN. Eger balkanyň kesigi 27-nji belgili iki tawra bolsa, howply kesikdäki iň uly dinamiki dartgynlylygy we mejbury yrgyldynyň amplitudasyny tapmaly. $[\sigma]$=13 kN/sm^2 deň.



9.28-nji surat

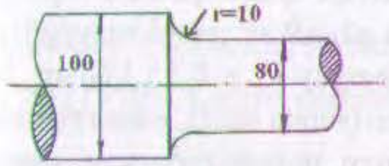
9.28. Titremäni ölçeýän gural (wibrometr) polat zolakdan we zolagyň boýuna süýşýän P=0,001 kN ýükden ybarat. Zolagyň bir tarapy abzalyň çarçuwasyna berkidilen. Yrgyldyny ýazmak üçin wibrometr titreýän konstruksiýa berkidilýär, ýük bolsa zolak ýük bilen konstruksiýa bilen bilelikde güýçli titräp başlar ýaly ℓ aralykda berkidilýär. Eger ℓ =20sm bolsa, konstruksiýanyň ýygylygyny kesgitlemeli. Zolagyň Kese kesiginiň ölçegleri: b=5 sm, h=0,3 sm, $E=2{,}2\cdot10^4$ kN/sm^2–a deň.



9.29-njy surat

9.29. Porşenli dwigateliň şatunynyň kese kesigi iki tawra we onuň ölçegleri: h=50 mm, b=30 mm, t=5 mm bolup, inersiýa güýjüň täsirinden yranma tekizliginde kese yrgyldy ýagdaýynda bolýar. Şatunyň hususy yrgyldysynyň ýygylygyny we periodyny, şonuň ýaly-da dwigateliň kritiki aýlaw sanyny kesgitlemeli.

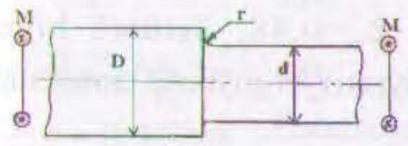
9.4. Dowamly ýüklenmeler



9.30-njy surat

9.30. Aýlanýan tegelek basgançakly wal hemişelik moment M bilen egilýär. Uglerodly polatdan ýasalan walyň berklik çägi σ_b =45kN/sm^2 we egilmede çydamlylyk çägi σ_{-1}^{ℓ}=22 kN/sm^2 (simmetriýa sikli). Walyň diametrleri D=100 mm we d=80 mm; galteliň radiusy r=10 mm (surata seret).

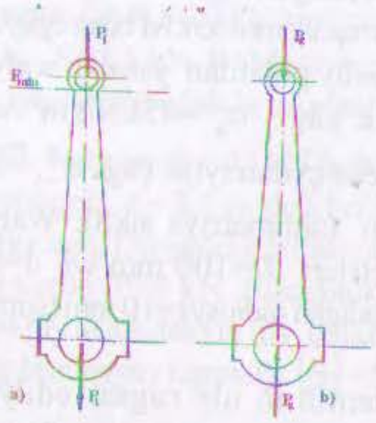
Momentiň iň uly rugsat edilýän ululygyny kesgitlemeli. Şaýyň berkliginiň ätiýaçlyk koeffisiýenti onuň çydamlylyk çägine bolan gatnaşygy k=2.



9.31-nji surat

9.31. M=0,64 kN·m moment bilen ýüklenen basgançakly wal (surata seret) hemişelik burç tizligi bilen aýlanýar. Walyň ölçegleri: D=50 mm; d=40 mm; r=2 mm; materialy-legirlenen polat; σ_b =75kN/sm^2; σ_a =42kN/sm^2; σ_{-1} =32,5kN/sm^2 walyň üsti ýylmanan (şlifowka). Akyjylyk n_a we döwülme n_d çägi boýunça ätiýaçlyk koeffisiýentlerini kesgitlemeli.

9.32. Üýtgeýän egilme bilen towlanma sezewar bolýan diametleri d=40 mm we D=50 mm basgançakly walyň berklige ätiýaçlyk koeffisiýentini kesgitlemeli. Galteliň radiusy r=2 mm, normal dartgynlylyk σ_{max} =5kN/sm^2, σ_{min} =–5kN/sm^2 çenli üýtgeýär, galtaşma dartgynlylyk - τ_{max} =4kN/sm^2, τ_{min} =2kN/sm^2 walyň materialy uglerodly polat σ_b =50kN/sm^2, σ_{-1} = 22kN/sm^2 τ_{-1} = 12kN/sm^2, σ_a = 30kN/sm^2, $_a$ = 18kN/sm^2, ψ_σ = 0,05 ψ_τ =0.



9.33-nji surat

9.33. Polat 45-den ýasalan awtomobil dwigateliniň şatunynyň statiki we sikl berkliginiň ätiýaçlyk koeffisiýentini kesgitlemeli. Şatun-porşen toparynyň inersiýa güýji P we gazyň basyş güýji P_g, gazyň basyşy $P_ž = 0{,}55$ kN/sm^2 bilen ýüklenen (surata seret). Silindriň diametri D=78 mm, porşen toparynyň massasy m_p=0,005 kN, şatunyň ýokarky böleginiň massasy $m_{ý.ş}$ =0,002 kN. Kriwoşipiň radiusy r=40 mm, $\lambda = \frac{r}{\ell_s} = 0{,}28$, aýlaw ýygylygy n_{max} = 6000 aýl/min, şatunyň iň kiçi kesigi suratda görkezilen. Şatunyň başjagazyndan sterženine geçýän ýeriniň konsentrasiýa koeffisiýenti K_σ=1,27, masştab faktory (h = 23 mm üçin), ε_σ=0,88, üstüniň hiliniň koeffisiýenti (ýel goýberip tämizlemek) β_σ=1,3.

9.34. Walyň kesigi şponka (pahna) dilkaw bilen gowşadylan we howply kesiginde pulşirleýji sikl boýunça üýtgeýän iň uly towlanma moment M_t=64 kN sm we simmetriýa sikli boýunça üýtgeýän egme moment M_e =80 kN sm täsir edýär. Walyň diametri d=50 mm, walyň materialy–polat, onuň mehaniki häsiýetnamalary: $\sigma_{-1} = 28$ kN/sm^2, $\sigma_a = 35$ kN/sm^2. Howply kesik üçin berklige ätiýaçlyk koeffisiýentini kesgitlemeli.

Jogaplar , görkezmeler, çözüwler

I bap. Süýnme we gysylma

1.1. P =256 kN. Berklik şertinden $P = [\sigma] \cdot A = 1 \cdot 256 = 256$ kN.

1.2. d=213 mm. Çatyny dartýan güýç

$$P = \sigma \cdot A_ç = 10 \cdot \frac{3{,}14 \cdot 2{,}5^2}{4} = 49{,}06 \text{ kN}.$$

Berklik şertinden epenegiň meýdany:

$$A_e = \frac{P_ç}{\sigma_e} = \frac{49{,}06}{0{,}14} = 350{,}45 \text{sm}^2$$

ýa-da $A_e = \frac{\pi}{4}(d^2 - d_ç^2)$, onda

$$d^2 = \frac{4A_e}{\pi} + d_ç^2 = \frac{4 \cdot 350{,}45}{3{,}14} + 2{,}5^2 = 452{,}68,$$

$d = 21{,}28$ sm ≈ 213 mm.

1.3. $\sigma = 10$ kN/sm^2. Zolagyň gowşadylan kesiginiň meýdany

$A = 20 \cdot 1 - 3 \cdot 1 \cdot 2 = 14$ sm^2,

orta dartgynlylygyň ululygy $\sigma = \frac{P}{A} = \frac{140}{14} = 10$ kN/sm^2.

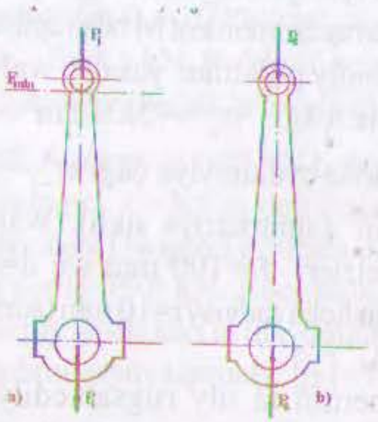
1.4. a=46 sm. Berklik şertinden $A = \frac{Q}{[\sigma]} = \frac{60}{0{,}09} = 666{,}7 \text{sm}^2$.

Iki tawranyň diwara galtaşýan meýdany $A = b \cdot a$,

kesgitlenen sortdan 30 a belgili iki tawra üçin,

onda $b \cdot a = 666{,}7$, $a = \frac{666{,}7}{14{,}5} = 46$ sm.

1.5. d_p=0,71 mm. Meseläniň şerti boýunça $\Delta\ell_p$ =



9.33-nji surat

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Iki tawranyň diwara galtaşýan meýdany $A = b \cdot a$, b=14,5 sm – kesgitlenen sortdan 30 a belgili iki tawra üçin,

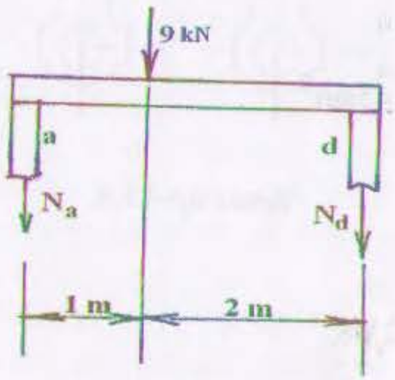
onda $b \cdot a = 666{,}7$, $a = \frac{666{,}7}{14{,}5} = 46$ sm.

1.5. d_p=0,71 mm. Meseläniň şerti boýunça $\Delta\ell_p = \Delta\ell_m$;

onda $d_p = \sqrt{\frac{E_m}{E_p}} \cdot d_m = \sqrt{\frac{10^4}{2 \cdot 10^4}} \cdot 0{,}1 = 0{,}071\text{sm} = 0{,}71\text{mm}.$

1.6. $\sigma_a = -0{,}06\,\text{kN/sm}^2$, $\sigma_b = -0{,}1\,\text{kN/sm}^2$, $\sigma_ç = -0{,}085\,\text{kN/sm}^2$, $\sigma_e = -0{,}02\text{kN/sm}^2$; $\sigma_f = -0{,}065\text{kN/sm}^2$; $\sigma_d = -0{,}03\,\text{kN/sm}^2$, Kesmek usulyny ulanyp, ilki direglerdäki içki güýçleri, soň bolsa degişli dartgynlylyklaryny kesgitleýäris.

ad kesik



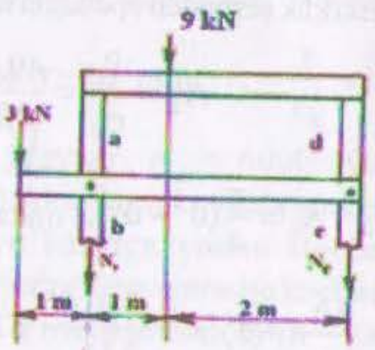
1) $\sum M_a = N_d \cdot 3 + 9 \cdot 1 = 0$,
$N_d = -3\text{kN}$;

$\sigma_d = -\frac{3}{100} = -0{,}03\text{kN/sm}^2$;

2) $\sum M_d = -N_a \cdot 3 - 9 \cdot 2 = 0$,
$N_a = -6$ kN,

$\sigma_a = -\frac{6}{100} = -0{,}06\text{kN/sm}^2$

be kesik



1) $\sum M_b = 0$,
$N_e \cdot 3 + 9 \cdot 1 - 3 \cdot 1 = 0$,

$N_e = -\frac{6}{3} = -2\text{kN}$,

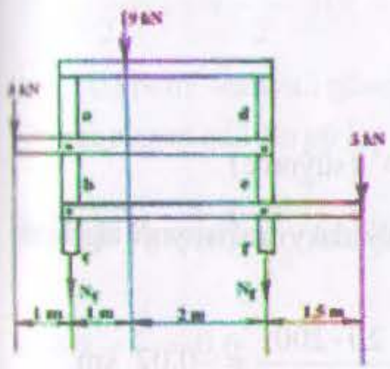
$\sigma_e = -\frac{2}{100} = -0{,}02\text{kN/sm}^2$;

2) $\sum M_e = 0$,
$N_b \cdot 3 + 9 \cdot 2 + 3 \cdot 4 = 0$,

$N_b = -\frac{-30}{3} = -10\,\text{kN}$,

$\sigma_b = -\frac{N_b}{100} = -\frac{10}{100} = -0{,}1\,\frac{\text{kN}}{\text{sm}^2}$

çf kesik



1.6-njy surat

1) $\Sigma M_ç = 0$,
$N_f \cdot 3 + 9 \cdot 1 - 3 \cdot 1 + 3 \cdot 4{,}5 = 0$,

$N_f = -\frac{19{,}5}{3} = -6{,}5\text{kN}$,

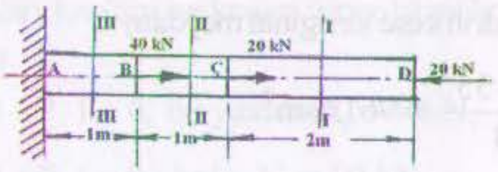
$\sigma_f = -\frac{6{,}5}{100} = -0{,}065\text{kN/sm}^2$

2) $\sum M_f = 0$,
$N_ç \cdot 3 + 9 \cdot 2 + 3 \cdot 4 - 3 \cdot 1{,}5 = 0$

$N_ç = -\frac{25{,}5}{3} = -8{,}5\,\text{kN}$,

$\sigma_ç = \frac{-8{,}5}{100} = -0{,}085\text{kN/sm}^2$.

1.7. $\sigma_{AB} = 4\,\text{kN/sm}^2$, $\sigma_{BÇ} = 0$, $\sigma_{CD} = -2\,\text{kN/sm}^2$, $\Delta\ell = 0$.



1.7-nji surat

DÇ bölegiň I-I kesiginde N_1 boý güýji döreýär. I-I kesiginiň bölünip alnýan sag böleginiň deňagramlylygyna seredýäris: $\sum X = -N_1 - 20 = 0$, bu ýerden $N_1 = -20$ kN (gysylma). BÇ bölegiň II-II kesigindäki N_2 boý güýji deňagramlylygyň deňlemesinden tapýarys:

$\sum X = -N_2 - 20 + 20 = 0$, bu ýerden $N_2 = 0$. Şonuň ýaly-da BA bölegiň III-III kesiginde $\sum X = -N_3 - 20 + 20 + 40 = 0$, $N_3 = 40$ kN (süýnme). Sterženiň hemme böleklériniň kese kesiginde normal dartgynlylyk döredýär.

DÇ böleginde: $\sigma_{ÇD} = \frac{N_1}{A} = -\frac{20}{10} = -2\text{kN/sm}^2$ (gysylma).

ÇB böleginde: $\sigma_{ÇB} = \frac{N_2}{A} = -\frac{0}{10} = 0$

BA böleginde: $\sigma_{BA} = \frac{N_3}{A} = -\frac{40}{10} = 4\text{kN/sm}^2$ (süýnme)

Sterženiň doly uzalmasy, onuň her böleginiň aýratynlykdaky uzalmasynyň algebraik jemine deň.

DÇ bölegiň gysylmasy: $\Delta\ell_{DÇ} = \frac{N_1 200}{EA} = -\frac{20 \cdot 200}{2 \cdot 10^4 \cdot 10} = -0{,}02$ sm.

ÇB böleginde içki güýç N_2 nola deň, şonuň üçin hem $\Delta-!_{ÇB}=0$

BA bölegindäki uzalma: $\Delta\ell_{BA} = \frac{N_3 100}{EA} = \frac{40 \cdot 100}{2 \cdot 10^4 \cdot 10} = 0{,}02$ sm.

Sterženiň doly uzalmasy

$\Delta-l=\Delta-l_{DÇ}+\Delta-l_{BA} = -0{,}02+0{,}02=0.$

1.8. n=10 bolt. Silindriň kese kesiginiň meýdany

$$A_S = \frac{\pi D^2}{4} = \frac{3{,}14 \cdot 35^2}{4} = 961{,}6\text{sm}^2.$$

Gapaga täsir edýän güýç $P = A_S \cdot q = 961{,}6 \cdot 0{,}1 = 96{,}16\text{kN}$.

Boltlaryň kese kesiginiň meýdany

$$A = nA_b = n \cdot \frac{\pi d_b^2}{4} = n \cdot \frac{3{,}14 \cdot 1{,}8^2}{4} = 2{,}54n$$

n–berkitmedäki boltlaryň sany

Boltlaryň berklik şerti $\sigma = \frac{P}{A} \le [\sigma_b]$, onda

$$n = \frac{P}{2{,}54[\sigma]} = \frac{96{,}16}{2{,}54 \cdot 4} = 9{,}5 \approx 10 \text{ bolt.}$$

1.9. ℓ =1,88 m. Uzynlygy ℓ deň germewajyň bölegine seredýäris. Bu uzynlyga bir direg düşýär. Seredilýän bölege suwuň gidrostatiki basyşy

$$P = \frac{3 \cdot 3}{2}\gamma \cdot \ell = \frac{3 \cdot 3}{2} \cdot 10\ell = 45\ell$$

$\gamma = 10\ \text{kN/m}^3$ – suwuň göwrüm agramy.

Direge rugsat edilýän güýç

$$[P] = [\sigma]A = [\sigma] \cdot \frac{\pi d^2}{4} = 0{,}2 \cdot \frac{3{,}14 \cdot 15^2}{4} = 35{,}33\ \text{kN},$$

$$\cos\alpha = \frac{3}{5} = 0{,}6$$

$$\sum M_c = [P]4\cos\alpha - P \cdot 1 = 0$$

$$4[P]\cos\alpha = 45\ell$$

$$\ell = \frac{4[P]\cos\alpha}{45} = \frac{4 \cdot 35{,}33 \cdot 0{,}6}{45} = 1{,}88\text{m}.$$

1.10. Δ=0,6mm. A we B diregleriň içki güýçlerini tapmak üçin hyýaly pikirde olary kesýäris we kesilen ýerine häzirlikçe bize näbelli güýçleri goýýarys.

$\sum M_A = N_B \cdot 3 + P \cdot 1 = 0$, bu ýerden N_B=-40kN,

$\sum M_B = N_A \cdot 3 + P \cdot 1 = 0$, onda N_A=-80 kN.

Ortaky sterždendäki içki güýçden N=P=120 kN ýüküň asylan nokadynyň aşak ornuny üýtgetmesi

$\Delta = \Delta\ell_Ç + \Delta\ell$ dir,

$\Delta\ell_Ç = \frac{N_Ç \ell_Ç}{E_m A_m} = \frac{120 \cdot 50}{10^4 \cdot 30} = 2 \cdot 10^{-2}$ sm – ortaky sterženiň uzalmasy.

Gyraky diregleriň gysylmasy.

$$\Delta\ell_A = \frac{N_A \ell_A}{E_p A_p} = \frac{-80 \cdot 100}{2 \cdot 10^4 \cdot 10} = -4 \cdot 10^{-2}\text{sm},$$

$$\Delta\ell_B = \frac{N_B \ell_B}{E_a A_a} = \frac{-40 \cdot 100}{10^3 \cdot 100} = -4 \cdot 10^{-2}\,\text{sm},$$

Direglerdäki $\Delta\ell_A = \Delta\ell_B$ we bu durkuny üýtgetmeler P güýjüň goýlan nokadyny aşak süýşürýärler, şonuň üçin hem

$$\Delta = 2 \cdot 10^{-2} + 4 \cdot 10^{-2} = 6 \cdot 10^{-2}\,\text{sm} = 0{,}6\text{mm}.$$

1.11. P=33,3kN. AB dartyjynyň uzynlygy $\ell_{AB} = \sqrt{15^2 + 10^2} = 18{,}03\text{m}$,

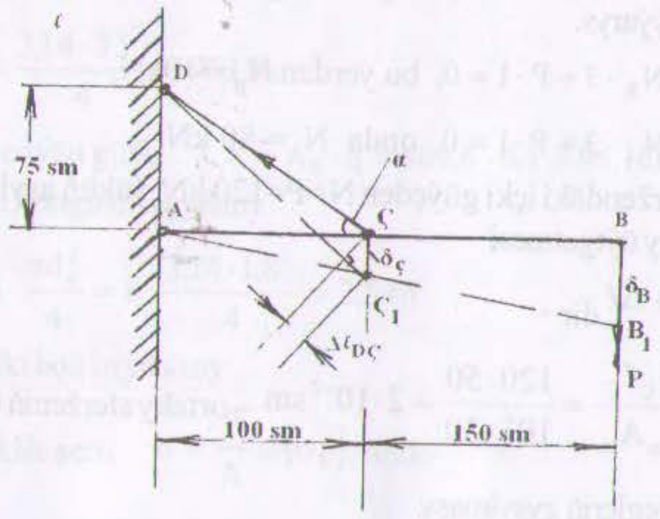
, $\sin\alpha = \frac{10}{18{,}03} = 0{,}554$, $\cos\alpha = \frac{15}{18{,}03} = 0{,}832$

$$\sum M_D = N_{AB} \cdot 10\cos\alpha - P \cdot 5 = 0\,, \qquad P = \frac{N_{AB} \cdot 10 \cdot \cos\alpha}{5}$$

$N_{AB} = [\sigma] \cdot A_{AB} = 4 \cdot 5 = 20$ kN,

onda $P = \frac{20 \cdot 10 \cdot 0{,}832}{5} = 33{,}3$ kN.

1.12. P=12 kN, δ_B=4,17 mm. Çyzgydan $\ell_{DÇ} = \sqrt{100^2 + 75^2} = 125\,\text{sm}$



1.12-nji surat

$$\Delta AÇD - \text{den}\sin\alpha = \frac{\ell_{DA}}{\ell_{DÇ}} = \frac{75}{125} = \frac{3}{5} = 0{,}6$$

$$\sum M_A = P \cdot 2{,}5 - N_{DÇ} \cdot 1{,}0 \sin\alpha = 0$$

$$P = \frac{N_{DÇ} \cdot 1 \cdot \sin\alpha}{2{,}5} \quad (1)$$

Berklik şertinden

$$N_{DÇ} = [\sigma] \cdot A_{DÇ} = [\sigma] \cdot \frac{\pi d^2}{4} = 16 \cdot \frac{3{,}14 \cdot 2^2}{4} = 50{,}24 \text{ kN}.$$

Onda (1) aňlatmadan $P = \frac{50{,}24 \cdot 1 \cdot 0{,}6}{2{,}5} = 12$ kN

çyzgydan

$$\delta_B = 2{,}5\delta_Ç = 2{,}5 \cdot \frac{\Delta\ell_{DÇ}}{\sin\alpha} = 2{,}5 \cdot \frac{N_{DÇ} \cdot \ell_{DÇ}}{EA \cdot \sin\alpha} = 2{,}5 \cdot \frac{50{,}24 \cdot 125}{2 \cdot 10^4 \cdot 3{,}14 \cdot 0{,}6} =$$

$$= 0{,}417\,\text{sm} = 4{,}17\,\text{mm}.$$

1.13. x=0,081 m, P=414 kN, σ_{AD}=2,347 kN/sm², σ_{BE}=1,01 kN/sm².
Birinji sterženiň uzynlygy

$$\ell_1 = \sqrt{2^2 + 3^2} = \sqrt{13} = 3{,}6\text{m}.$$

$$\sin\alpha = \frac{3}{3{,}6} = 0{,}833; \quad \cos\alpha = \frac{2}{3{,}6} = 0{,}555$$

$$A_1 = \frac{\pi d^2}{4} = \frac{3{,}14 \cdot 2{,}5^2}{4} = 4{,}9\text{sm}^2$$

Ulgamyň deňagramlylygynyň deňlemesi

$$\sum M_B = N_1 (2 + 1{,}5) \sin\alpha - P \cdot x = 0$$

$$\sum M_A = N_2 3{,}5 - P(3{,}5 - x) = 0$$

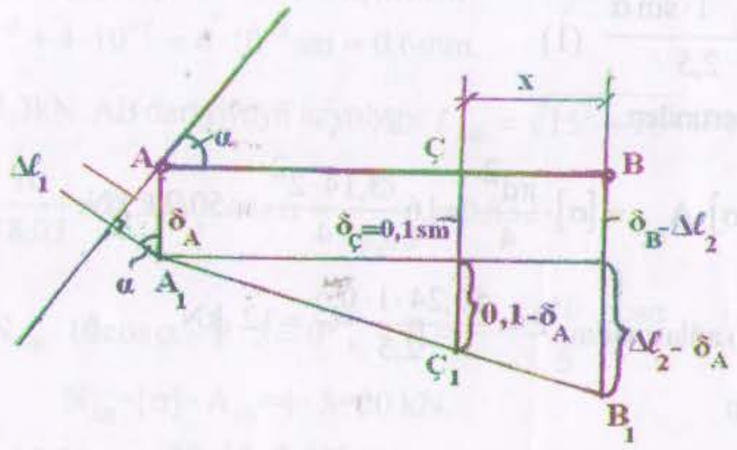
$$\sum Y_i = N_1 \sin\alpha + N_2 - P = 0.$$

Bu ýerden $3{,}5\, N_1 \sin\alpha = P \cdot x$, (1)

$$3{,}5\,N_2 = P\,(3{,}5-x), \qquad (2)$$

$$0{,}833\,N_1 + N_2 = P. \qquad (3)$$

Görşümiz ýaly üç deňlemäniň dört näbellesi bar. Ulgamyň durkuny üýtgeden ýagdaýyna seredýäris.



1.13-nji surat

Meseläniň şertinden $\delta_B = 2\delta_A$, çyzgydan $\delta_A = \dfrac{\Delta\ell_1}{\sin\alpha}$, $\delta_B = \Delta\ell_2$,

$\Delta\ell_2 = \dfrac{2\Delta\ell_1}{\sin\alpha}$ – durkuny üýtgetmäniň bilelikdäki deňlemesi.

Gukuň kanunyny ulanyp alarys. $\dfrac{N_2\ell_2}{E_2A_2} = \dfrac{2\cdot N_1\ell_1}{E_1A_1\sin\alpha}$, bu ýerden onda

$N_2 = 35{,}4\,N_1$ (4)

(4) aňlatmany (3) deňlemä goýup alarys $0{,}833\,N_1 + 35{,}4\,N_1 = P$,

$N_1 = \dfrac{P}{36{,}23}$, (1) aňlatma goýup alarys.

$3{,}5\cdot\dfrac{P}{36{,}23}\cdot 0{,}833 = Px$, bu ýerden x=0,081 m, çyzgydan

$$\frac{0{,}1-\delta_A}{3{,}5-0{,}081} = \frac{\Delta\ell_2-\delta_A}{3{,}5}$$

$$\frac{0{,}1-\dfrac{\Delta\ell_1}{0{,}83}}{3{,}419} = \frac{\Delta\ell_2-\dfrac{\Delta\ell_1}{0{,}833}}{3{,}5} \Rightarrow 3{,}5\left(0{,}1-\frac{N_1\ell_1}{E_1A_1\sin\alpha}\right) =$$

$$= 3{,}419\left(\frac{N_2\ell_2}{E_2A_2} - \frac{N_{1\ell_1}}{E_1A_1\cdot 0{,}833}\right)$$

Soňky aňlatmany (4) bilen bilelikde işläp alarys N_2=404 kN

(2) deňlemeden $3{,}5\cdot 404 = P\cdot 3{,}419$, bu ýerden P=414 kN

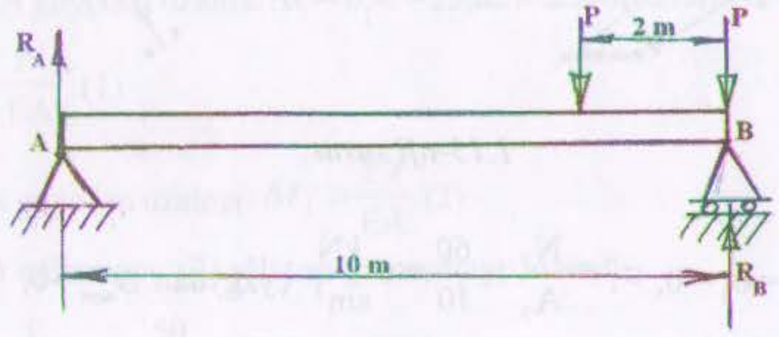
(1) deňlemeden $N_1 = \dfrac{Px}{3{,}5\cdot\sin\alpha} = \dfrac{414\cdot 0{,}081}{3{,}5\cdot 0{,}833} = 11{,}5\text{kN}$, onda

sterženlerdäki dartgynlylyklar:

$\sigma_1 = \dfrac{N_1}{A_1} = \dfrac{11{,}5}{4{,}9} = 2{,}347$ kN/sm²

$\sigma_2 = \dfrac{N_2}{A_2} = \dfrac{404}{400} = 1{,}01$ kN/sm².

1.14. Ýüküň iň oňaýsyz ýagdaýy A ýa-da B diregleriň üstünde goýlan ýagdaýda bolýar.



1.14-nji surat

$$\sum M_A = R_B \cdot 10 - P \cdot 10 - P \cdot 8 = 0$$

$$R_B = \frac{18P}{10} = \frac{18 \cdot 150}{10} = 270\text{kN}$$

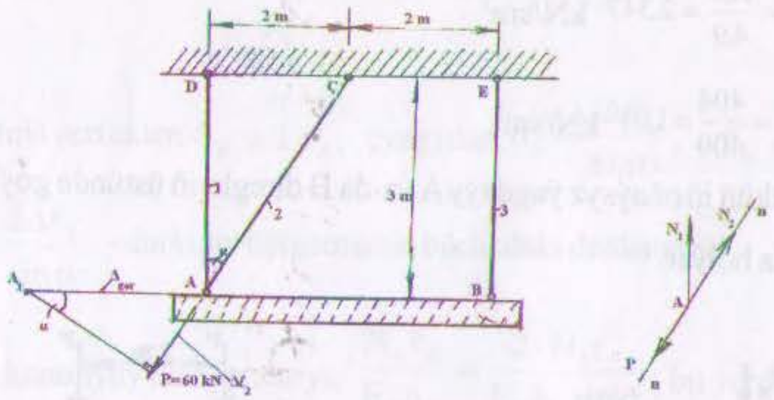
Berklik şertinden $\sigma = \frac{R_B}{A} \le [\sigma]$ gerek bolan ölçegleri kesgitleýäris:

$$A = \frac{R_B}{[\sigma]} = \frac{270}{0{,}1} = 2700\text{sm}^2, \quad a = \sqrt{A} = \sqrt{2700} = 52\text{sm} \cdot$$

Kwadrat kesigiň ölçegleri 52 x 52 sm.

1.15. $\sigma_1 = \sigma_3 = 0, \quad \sigma_2 = 6\frac{\text{kN}}{\text{sm}^2} \quad \Delta_{wert} = 0, \ \Delta_{gor} = 1{,}946$ mm.

A düwüniň deňagramlylygyna seredýäris. Düwne täsir edýän güýçleri n-n oka proýektirläp alarys N_2=P=60 kN, N_1=0, N_3=0.



1.15-nji surat

Onda $\sigma_1 = \sigma_3 = 0, \ \sigma_2 = \frac{N_2}{A_2} = \frac{60}{10} = 6\frac{\text{kN}}{\text{sm}^2}$ çyzgydan $\Delta_{wert} = 0,$

$$\Delta_{gor} = \frac{\Delta\ell_2}{\sin\alpha},$$

$$\ell_2 = \sqrt{3^2 + 2^2} = 3{,}6\text{m}; \quad \Delta\ell_2 = \frac{N_2\ell_2}{EA_2} = \frac{60 \cdot 360}{2 \cdot 10^4 \cdot 10} = 10{,}8 \cdot 10^{-2}\text{sm};$$

$$\sin\alpha = \frac{2}{3{,}6} = 0{,}555, \text{ onda } \Delta_{gor} = \frac{10{,}8 \cdot 10^{-2}}{0{,}555} = 0{,}1946\text{sm},$$

Δ_{gor}=1,946 mm.

1.16. E=1,15·10⁴kN/sm². Gukuň kanuny boýunça polat we mis sime täsir edýän güýçler:

Polat sime $P = \frac{\Delta\ell E_p A_p}{\ell}, \quad A_p = \frac{\pi d^2}{4} = \frac{3{,}14 \cdot 0{,}16^2}{4} = 0{,}002\text{sm}^2$

Mis sime

$$P_1 = \frac{\Delta\ell_1 E_m A_m}{\ell_1}, \quad A_m = \frac{\pi d_1^2}{4} = \frac{3{,}14 \cdot 0{,}32^2}{4} = 0{,}008\text{sm}^2$$

Meseläniň şertine görä, $P=P_1$.

onda $\frac{\Delta\ell E_p A_p}{\ell} = \frac{\Delta\ell_1 E_m A_m}{\ell_1}$, bu ýerden

$$E_m = \frac{\Delta\ell E_p A_p \ell_1}{\Delta\ell_1 A_m \ell} = \frac{0{,}15 \cdot 2 \cdot 10^4 \cdot 0{,}002 \cdot 300}{0{,}039 \cdot 0{,}008 \cdot 180} = 1{,}15 \cdot 10^4\text{kN/sm}^2$$

1.17. ℓ_1 = 25,0135 sm, ℓ_1'=25,0106 sm, E = 1,88·10⁴kN/sm².
100 kN güýçden uzalma $\Delta\ell = \ell_1 - \ell$=25,027–25=0,027sm ýa-da

$$\Delta\ell = \frac{P\ell}{EA} \quad (1)$$

50 kN güýçden uzalma $\Delta\ell_1 = \frac{P_1\ell}{EA}$ (2)

(1) aňlatmany (2) aňlatma gatnaşdyryp, olaryň

$$\Delta\ell_1 = \frac{P_1}{P}\Delta\ell = \frac{50}{100} \cdot 0{,}027 = 0{,}0135\text{sm}$$ – bu uzalma bolsa steržene

50 kN güýçden bolýar, ℓ_1 = 25,0135 sm.

(1) aňlatmadan

$$E=\frac{P\ell}{A\cdot\Delta\ell}=\frac{100\cdot25\cdot4}{3{,}14\cdot2{,}5^2\cdot0{,}027}=1{,}88\cdot10^4\,kN/sm^2$$ sterżendäki dartgynlylyk

$\sigma=8kN/sm^2$ bolanda, uzalmany kesgitleýäris.

$$\Delta\ell_1=\frac{\sigma\ell}{E}=\frac{8\cdot25}{1{,}88}=0{,}0106\,sm,$$

$$\ell_1^1=\ell_1+\Delta\ell_1^1=25+0{,}0106=25{,}0106\,sm.$$

1.18. $E=2{,}1\cdot10^4kN/sm^2$, $\mu=0{,}2425$. 5 sm uzynlykda sterżeniň uzalmasy 0,004 sm bolsa, Gukuň kanunyny ulanyp, sterżeniň materialynyň maýyşgaklyk modulyny kesgitleýäris.

$E=\frac{P\ell_1}{A\cdot\Delta\ell}$, bu ýerde $\ell_1=5$ sm, $A=\frac{\pi d^2}{4}=\frac{3{,}14\cdot3{,}2^2}{4}=8{,}04sm^2$

onda $E=\frac{135\cdot5}{0{,}004\cdot8{,}04}=2{,}1\cdot10^4\,kN/sm^2$.

Otnositel boý durkuny üýtgetme $\varepsilon=\frac{\Delta\ell}{\ell_1}=\frac{0{,}004}{5}=0{,}0008$, otnositel kese durkuny üýtgetme $\varepsilon^1=\frac{\Delta d}{d}=\frac{0{,}00062}{3{,}2}=0{,}000194$, kese durkuny üýtgetmäniň koeffisiýenti

$$\mu=\left|\frac{\varepsilon^1}{\varepsilon}\right|=\frac{0{,}000194}{0{,}0008}=0{,}2425.$$

1.19. $\Delta V=3\ sm^3$. Sterżeniň otnositel göwrümini üýtgetmesi

$$\theta=\frac{\Delta V}{V}=\frac{1-2\mu}{E}\cdot\sigma,\quad \sigma=\frac{P}{A},\quad V=A\ell$$

onda sterżeniň göwrüminiň artmagy

$$\Delta V=V\frac{1-2\mu}{E}\sigma=A\ell\frac{1-2\mu}{E}\cdot\frac{P}{A}=\frac{1-2\mu}{E}P\ell=\frac{1-2-0{,}25}{2\cdot10^4}\cdot200\cdot600=3sm^3.$$

1.20. $2\cdot10^4\,kN/sm^2$.

Şaýyň hakyky absolýut uzalmasy

$$\Delta\ell=\frac{\Delta}{K}=\frac{2{,}5}{500}=0{,}005sm.$$

Şaýyň otnositel uzalmasy

$$\varepsilon=\frac{\Delta\ell}{S}=\frac{0{,}005}{10}=5\cdot10^{-4}.$$

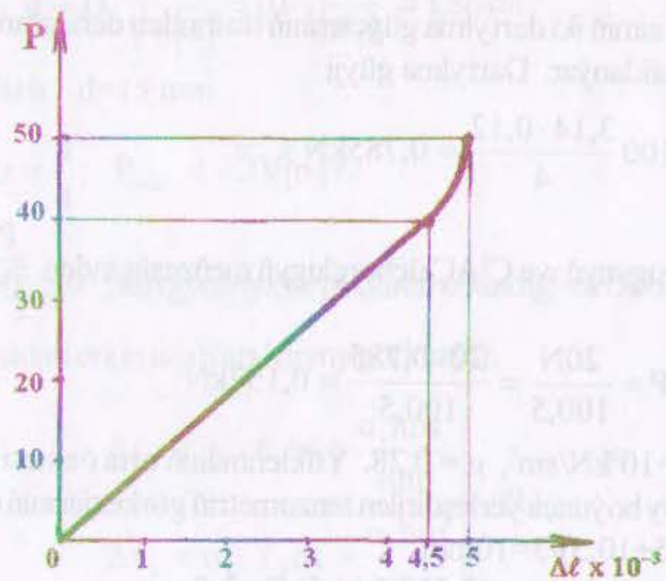
Şaýyň normal dartgynlylygy

$$\sigma=\frac{P}{A}=\frac{100}{10}=10kN/sm^2.$$

Dartgynlylyk üçin Gukuň kanunyndan

$$E=\frac{\sigma}{\varepsilon}=\frac{10}{5\cdot10^{-4}}=2\cdot10^4\,kN/sm^2.$$

1.21. $E=1{,}78\cdot10^3kN/sm^2$. $P-\Delta\ell$ gysma diagrammany guryarys.



1.21-nji surat

Meseläniň şertine görä, σ=0,4kN/sm^2 bolanda, otnositel durkuny

üýtgetme $\varepsilon = \frac{\Delta\ell}{\ell} = \frac{4{,}5\cdot10^{-3}}{20} = 0{,}225\cdot10^{-3}$,

onda $E = \frac{\sigma}{\varepsilon} = \frac{0{,}4}{0{,}225\cdot10^{-3}} = 1{,}78\cdot10^{3}$ kN/sm^2.

1.22. ÇÇ^1=10 sm, σ=100 kN/sm^2, P=0,157 kN.

Simiň absolýut uzalmasy

$$\Delta\ell = \varepsilon\ell = 0{,}005\cdot200 = 1\text{sm}.$$

Onda simiň ortasyndaky Ç nokatdan çep ýa-da sag böleginiň uzynlygy

$$\ell_1 = 100 + \frac{\Delta\ell}{2} = 100 + 0{,}5 = 100{,}5\text{sm}.$$

AÇÇ^1 üçburçlukdan

$$ÇÇ^1 = \sqrt{\ell_1^2 - \left(\frac{\ell}{2}\right)^2} = \sqrt{100{,}5^2 - 100^2} = 10\text{sm}.$$

Simdäki dartgynlylyk $\sigma = E\varepsilon = 2\cdot10^4\cdot0{,}005 = 100$kN/sm^2.

Ç nokat P we simiň iki dartylma güýçleriniň täsirinden deňagramlylyk ýagdaýynda saklanýar. Dartylma güýji

$$N = \sigma\cdot A = 100\frac{3{,}14\cdot0{,}12}{4} = 0{,}785\text{kN}.$$

Güýç üçburçlugynyň we Ç^{1}AÇ üçburçlugyň meňzeşliginden $\frac{P}{2N} = \frac{10}{100{,}5}$

bu ýerden, $P = \frac{20N}{100{,}5} = \frac{20\cdot0{,}785}{100{,}5} = 0{,}157\text{kN}$.

1.23. E= 1,9·10^{4}kN/sm^2, μ = 0,28. Ýüklenmäniň orta ösmesi ΔP=10kN, nusganyň boýy boýunça ýerleşdirilen tenzometriň görkezijisiniň orta ösmesi Δn_A= (10+9,5+10,5)/3=10mm,

kese tenzometr üçin Δn_A=(3,5+2,5+4,5) /3=3,5 mm.

Absolýut uzalma: $\Delta S_A = 10/950 = 1{,}05\cdot10^{-2}$ mm

$$\Delta S_B = \frac{3{,}5}{1190} = 2{,}9\cdot10^{-3}\text{mm},$$ bu ýerden

$$E = \frac{\Delta P\cdot S_A}{A\Delta S_A} = \frac{10\cdot2}{1\cdot0{,}105\cdot10^{-2}} = 1{,}9\cdot10^4\text{kN/sm}^2$$

Puassonyň koeffisiýenti

$$\mu = \frac{\varepsilon_B}{\varepsilon_A} = \frac{\Delta S_B/S_B}{\Delta S_A/S_A} = \frac{\Delta S_B}{\Delta S_A} = \frac{0{,}29\cdot10^{-3}}{0{,}105\cdot10^{-2}} = 0{,}28.$$

1.24. d=15 mm. Karterden silindri ýolup aýyrjak bolýan güýjiň ululygy

$$P = p\frac{\pi D^2}{4}.$$

Eger şpilkalara ýokarky güýç endigan ýaýran bolsa, rugsat edilýän güýç

$$P = n\frac{\pi d^2}{4}\cdot[\sigma].$$

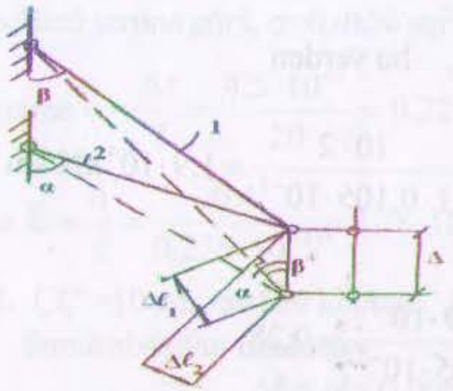
Bu ýerden $d = D\cdot\sqrt{\frac{P}{n[\sigma]}} = 10\cdot\sqrt{\frac{1}{8\cdot6}} = 1{,}86\text{sm}$;

kabul edýäris d=15 mm

1.25. $\alpha = \frac{\pi}{4}$; $P_{max} = \sqrt{2}V[\sigma]/\ell$.

1.26. $\beta = \frac{\pi}{2} - \alpha$ Dartgynlylyklaryň döremeýändigi sterženleriň gyzdyrylmadan erkin uzalýandygyny görkezýär.

$$\left.\begin{aligned}\Delta\ell_1 &= \alpha_t\cdot\ell_1\Delta t = \frac{\alpha_t h\Delta t}{\sin\beta}\\ \Delta\ell_2 &= \alpha_t\cdot\ell_2\Delta t = \frac{\alpha_t h\Delta t}{\sin\alpha}\end{aligned}\right\}\ (1),$$



1.26-njy surat

Bu ýerde: $\ell_1 = \dfrac{h}{\sin\beta}$,

$$\ell_2 = \frac{h}{\sin\alpha}$$

α_t -sterženiň materialynyň temperatura koeffisiýenti ölçeg-leriň üýtgemezlik ýörelgesine esaslanyp, çyzgydan

$$\Delta = \frac{\Delta\ell_1}{\cos\beta} = \frac{\Delta\ell_2}{\cos\alpha}, \quad (2)$$

Soňky aňlatmany (1) formula goýup alarys:

$$\frac{\alpha_t h\Delta t}{\sin\beta\cos\beta} = \frac{\alpha_t h\Delta t}{\sin\alpha\cos\alpha}$$

ýa-da $2\sin\beta\cos\beta = 2\sin\alpha\cos\alpha$; $\sin2\beta = \sin2\alpha$

$$\sin2\beta - \sin2\alpha = 0 \Rightarrow 2\sin\frac{\beta-\alpha}{2}\cdot\cos\frac{\beta+\alpha}{2} = 0.$$

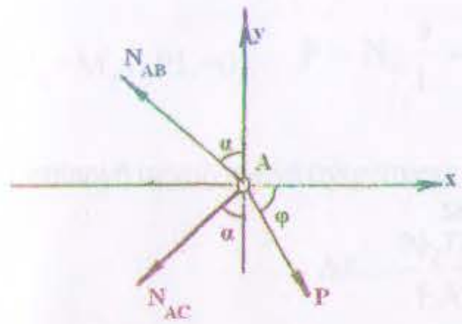
Bu ýerden, $\beta - \alpha = n\cdot180°$ $(n = 0,1,2,3\ldots)$

$$\beta + \alpha = \frac{\pi}{2} + n\cdot180° \quad (n = 0,1,2,3,\ldots).$$

Çyzgyda α we β burçlar $\dfrac{\pi}{2}$-den kiçi (diýmek n=0) we meseläniň şerti

boýunça $\alpha \neq \beta$, onda $\beta + \alpha = \dfrac{\pi}{2}$ ýa-da $\beta = \dfrac{\pi}{2} - \alpha$.

1.27. $\alpha = \dfrac{\pi}{4}$. Ilki bilen P güýjüň sterženlerde iň uly güýjüni döredýäň φ burçy tapýarys.



1.27-nji surat

$\sum X = P\cos\varphi - N_{AB}\sin\alpha - N_{AÇ}\sin\alpha = 0$;

$\sum Y = P\sin\varphi - N_{AB}\cos\alpha - N_{AÇ}\cos\alpha = 0$.

Bu ýerden

$$N_{AB} = \frac{P}{2}\cdot\frac{\cos\varphi}{\sin\alpha} + \frac{\sin\varphi}{\cos\varphi},$$

$$N_{AÇ} = \frac{P}{2}\cdot\frac{\cos\varphi + \sin\varphi}{\sin\alpha + \sin\alpha}.$$

Görşümiz ýaly, $N_{AB} > N_{AÇ}$ we N_{AB} iň uly bahasy $\alpha = \varphi$ bolanda bolýar.

1.28. $\sigma = \left(\dfrac{R}{r} - 1\right)E$ Gurşaw bilen tigriň töwereklerіniň uzynlyklarynyň tapawudy

$\Delta\ell = 2\pi(R-r)$ (1)

Şeýle-de Gukuň kanunyna esaslanyp absolýut uzalma

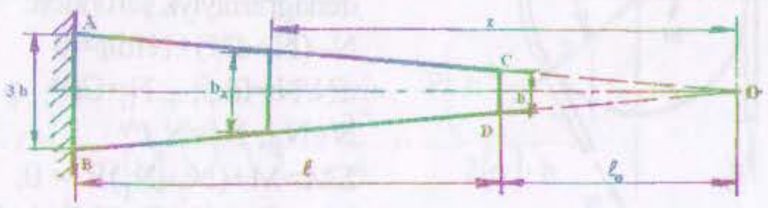
$$\Delta\ell = \frac{N\ell}{EA} = \frac{N\cdot2\pi r}{EA} \quad (2)$$

(1) we (2) aňlatmalaryň sag taraplaryny deňläp alarys.

$$2\pi(R-r) = \frac{N2\pi r}{EA} \Rightarrow N = \left(\frac{R}{r} - 1\right)EA$$

Gurşawdaky dartgynlylyk $\sigma = \left(\dfrac{R}{r} - 1\right)E$.

1.29. $\Delta\ell = 21{,}6\cdot10^{-3}$ sm.



1.29-njy surat

$\Delta ABO \infty \Delta ÇDO$ alarys

$$\frac{b}{\ell_o}=\frac{3b}{\ell+\ell_o}\Rightarrow \ell_o=\frac{1}{2}\ell.$$

Çyzgydan $\frac{b_z}{z}=\frac{b}{\ell_o}$, $b_z=\frac{bz}{\ell_o}=\frac{2bz}{\ell}$.

Üýtgeýän kesikli sterženiň uzalmasy

$$\Delta\ell=\int_0^{\ell}\frac{Ndz}{EA}=\frac{P}{E}\int\frac{dz}{A}=\frac{P}{E}\int_{0,5\ell}^{1,5\ell}\frac{\ell dz}{2b\delta z}=\frac{P\ell}{2E\delta b}\ln 3=\frac{12\cdot 40}{2\cdot 0,7\cdot 10^4\cdot 2\cdot 0,8}\ln 3=21,6\cdot 10^{-3}\text{sm}.$$

ln3 = 1,0986,

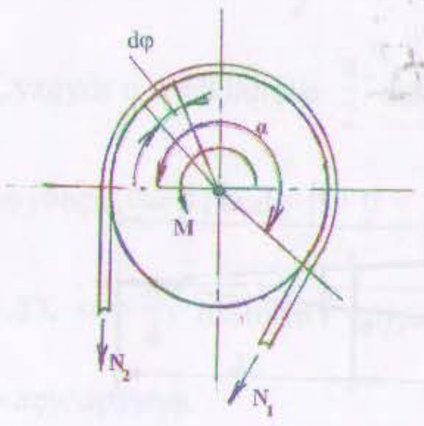
1.30. K=3,78 , A=2,7 sm². Gukuň kanunyny ulanyp birdenkä ýüklenmedäki dartgynlylygy kesgitleýäris.

$$\sigma_d=E\varepsilon=2\cdot 10^4\cdot\frac{1}{1800}=11,11\text{kN/sm}^2$$

$$\sigma=\sigma\cdot K_d=\frac{PK_d}{A}\Rightarrow A=\frac{PK_d}{\sigma_d}=\frac{15\cdot 2}{11,11}=2,7\text{sm}^2.$$

Ätiýaçlyk koeffisiýenti

$$K=\frac{\sigma_b}{\sigma_d}=\frac{42}{11,11}=3,78.$$



1.31-nji surat

1.31. P=0,406 kN; δ=3,52 mm.
Lentanyň elementiniň deňagramlylyk şertinden:
$N-(N+dN)+Nfd\varphi=0$
$dN/N=fd\varphi$; $N=C\ell^{f\varphi}$ $\varphi=0$,
$N=N_2$, $N_1=N_2\ell^{f\varphi}$
$\Sigma M=M+(N_2-N_1)R=0$,
$M=+(N_1-N_2)R=N_2R(1-\ell^{fa})$
onda $N_2=M/R(\ell^{fa}-1)$;

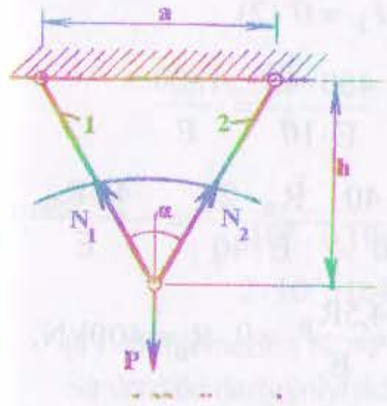
$M_K=M_2a-PL=0$, $P=N_2\frac{a}{L}=\frac{a}{L}\cdot\frac{M}{R(e^{fa}-1)}$.

Lentanyň uzynlygynyň üýtgetmesi:

$$\Delta\ell=\frac{N_2\ell_2}{EA}+\int_0^a\frac{N_2e^{f\varphi}R}{EA}d\varphi$$

$$\delta=\Delta\ell\cdot\frac{L}{a}=3,52\text{mm}.$$

1.32. $h=\frac{a}{2}$



1.32-nji surat

Statikanyň deňlemesinden

$$N_1=N_2=\frac{P}{2\cos\alpha}$$

$$\cos\alpha=\frac{h}{\sqrt{h^2+\frac{a^2}{4}}}$$

Kesigiň zerur meýdany.

$$A=\frac{N}{|\sigma|}=\frac{P\cdot\sqrt{h^2+\frac{a^2}{4}}}{2[\sigma]\cdot h}$$

Kesigiň göwrümi

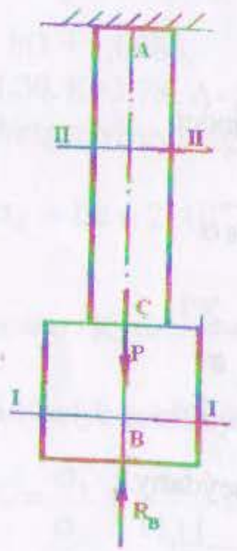
$$V=A\cdot\ell=\frac{P\sqrt{h^2+\frac{a^2}{4}}}{2[\sigma]\cdot h}\sqrt{h^2+\frac{a^2}{4}}=\frac{P\left(h^2+\frac{a^2}{4}\right)}{2[\sigma]\cdot h}.$$

Sterženiň göwrüminden h boýunça ösme alyp we alnan aňlatmany nola deňläp alarys.

$$V^1 = \frac{P}{2[\sigma]} \cdot \left(\frac{h^2 + \frac{a^2}{4}}{h} \right) = 0,$$

Bu ýerden $h = \frac{a}{2}$ ýa-da $\alpha = \frac{\pi}{4}$.

1.33. $\sigma_{ýok} = 5kN/sm^2$, $\sigma_{aş} = -10kN/sm^2$,



1.33-nji surat

Deňagramlylygyň deňlemesi

$\Sigma Y = R_A + R_B - P = 0$ (1)

Durkuny üýtgetmäniň deňlemesi

$$\Delta\ell = \Delta\ell_{R_B} + \Delta\ell_P = 0 \quad (2)$$

$$\Delta\ell_P = \frac{P \cdot 40}{E \cdot 10} = \frac{450 \cdot 40}{E \cdot 10} = \frac{1800}{E}$$

$$\Delta\ell_{R_B} = \frac{-R_B \cdot 40}{E \cdot 10} - \frac{R_B \cdot 20}{E \cdot 40} = -\frac{4{,}5R_B}{E}.$$

Onda $\frac{1800}{E} - \frac{4{,}5R_B}{E} = 0$, $R_B = 400kN$,

$R_A = P - R_B = 450 - 400 = 50kN$

I–I kesikde $N_{aş} = -R_B = -400kN$, $\sigma_{aş} = \frac{N_{aş}}{40} = -\frac{400}{40} = -10kN/sm^2$,

II–II kesikde $N_{ýok} = R_A = 50kN$,

$$\sigma_{yok} = \frac{N_{yok}}{10} = \frac{50}{10} = 5kN/sm^2.$$

1.34. $\sigma_m = 4{,}6kN/sm^2$; $\sigma_p = 9{,}29kN/sm^2$.

Deňagramlylygyň deňlemesinden $N_m + N_P = P$ (1)

Durkuny üýtgetmäniň deňlemesinden $\varepsilon_m = \varepsilon_p$ (2)

ýa-da $\frac{N_m}{E_m A_m} = \frac{N_p}{E_p A_p} \Rightarrow N_m = \frac{E_m A_m}{E_p A_p} N_p$ (3)

(3) aňlatmany (1) deňlemä goýup alarys

$$N_p = \frac{P}{1 + \frac{E_m A_m}{E_p A_p}};$$

Bu ýerde $E_m = 10^4 kN/sm^2$,
$E_p = 2 \cdot 10^4 kN/sm^2$.

$$A_m = \frac{\pi d_1^2}{4} = \frac{3{,}14 \cdot 0{,}5^2}{4} = 0{,}196sm^2,$$

$$A_p = \frac{\pi d_2^2}{4} \cdot 9 = \frac{3{,}14 \cdot 0{,}25^2}{4} \cdot 9 = 0{,}44sm^2,$$

onda $N_p = \frac{5}{1 + \frac{10^4 \cdot 0{,}196}{2 \cdot 10^4 \cdot 0{,}44}} = 4{,}09kN$

(1) Deňlemeden $N_m = P - N_p = 5 - 4{,}09 = 0{,}91kN$

Simlerdäki dartgynlylyklar:

$$\sigma_m = \frac{N_m}{A_m} = \frac{0{,}91}{0{,}196} = 4{,}64kN/sm^2,$$

$$\sigma_p = \frac{N_p}{A_p} = \frac{4{,}09}{0{,}44} = 9{,}29kN/sm^2.$$

1.35. a=39 sm, d=22 mm.

$N_b + N_a = P$; $\frac{N_b}{E_b A_b} = \frac{N_a}{E_a A_a}$; $\frac{N_b}{E_b A_b} = \frac{N_a}{10E_b \cdot 0{,}01A_b}$; $N_b = 10N_a$;

$11N_a = P$, $N_a = \frac{P}{11} = \frac{1000}{11} = 91kN$, $N_b = 909kN$. .

$$A_b=\frac{N_b}{[\sigma]_b}=\frac{909}{0,6}=1516sm^2,\ a=\sqrt{A_b}=\sqrt{1516}=39sm.$$

Şerte görä:

$$A_a=0,01A_b,\ A_a=0,01\cdot1516=15,16\ sm^2,\ A_a^1=\frac{A_a}{4}=\frac{15,16}{4}=3,79sm^2$$

$$A_a^1=\frac{\pi d^2}{4}\Rightarrow d=\sqrt{\frac{4\cdot A_a^1}{\pi}}=\sqrt{\frac{4\cdot3,79}{3,14}}=2,2sm=22mm$$

Kabul edýäris: d=22mm.

1.36 A= 4,3 sm².

Deňagramlylygyň deňlemesi:

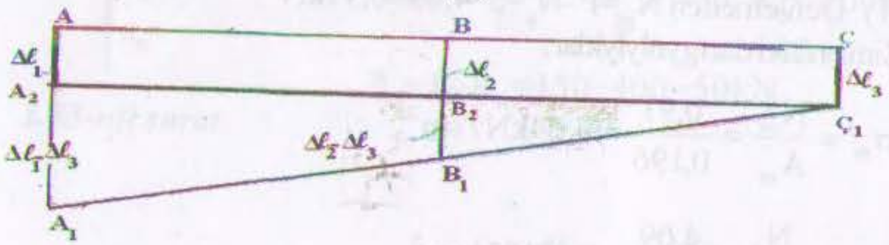
1).$\Sigma Y=N_1+N_2+N_3-P=0;\ \Sigma M_A=N_2\cdot1,5+N_3\cdot3-P\cdot1.125=0.$

Durkuny üýtgetmäniň deňlemesi:

$$\Delta A_1A_2Ç_1\infty\Delta B_1B_2Ç_1$$

$$\frac{\Delta\ell_1-\Delta\ell_3}{3}=\frac{\Delta\ell_2-\Delta\ell_3}{1,5};\quad \Delta\ell_1=2\Delta\ell_2-\Delta\ell_3,\ (3)$$

ýa-da $N=2N-N$ (4)



1.36-njy surat

(1), (2) we (3) aňlatmalary bilelikde işläp alarys: N_1=6,97 kN, N_2=50 kN, N_3=30,3 kN.

$$A_1=\frac{N_1}{[\sigma]}=\frac{69,7}{16}=4,3sm^2,\ A_2=\frac{N_2}{[\sigma]}=\frac{50}{16}=3,125sm^2,$$

$$A_3=\frac{N_3}{[\sigma]}=\frac{30,3}{16}=1,89sm^2,\ \text{kabul edýäris } A=4,3\ sm^2.$$

1.37. $N_1=\frac{2P}{h}\cdot\frac{çb^3}{b^3+4ç^3}$, $N_2=\frac{4P}{h}\cdot\frac{bç^3}{b^3+4ç^3}$.

Cyzgydan $\sin\alpha=\frac{h}{ç}$, $\sin\beta=\frac{h}{b}$.

Deňagramlylygyň deňlemesi

$$\Sigma M_A=N_1\cdot a\sin\alpha+N_2\cdot2a\sin\beta-P\cdot2a=0.\qquad(1)$$

Durkuny üýtgetmäniň bilelikdäki deňlemesi

Çyzgydan $\frac{\Delta\ell_1}{a\sin\alpha}=\frac{\Delta\ell_2}{2a\sin\beta}\Rightarrow2\Delta\ell_1\sin\beta=\Delta\ell_2\sin\alpha$ (2)

ýa-da $2\Delta\ell_1ç=\Delta\ell_2b$;

onda $\frac{2N_1\ell_1ç}{E_1A_1}=\frac{2N_2\ell_2b}{E_2A_2}\Rightarrow2N_1ç^2=N_2b^2;$

bu ýerden $N_2=\frac{2N_1ç^2}{b^2}$.

Bu aňlatmany (1) deňlemä goýup,

$$N_1\sin\alpha+\frac{4N_1ç^2}{b^2}\cdot\sin\beta=2P\Rightarrow N_1\frac{h}{ç}+4N_1\frac{ç^2}{b^2}\cdot\frac{h}{b}=2P$$

$N_1hb^3+4N_1ç^3h=2P\cdot çb^3$ alarys.

Bu ýerden $N_1=\frac{2P}{h}\cdot\frac{çb^3}{b^3+4ç^3}$

onda $N_2=\frac{4P}{h}\cdot\frac{bç^3}{b^3+4ç^3}$

1.38. σ_1=21,05kN/sm², σ_2=4,3kN/sm², σ_3=14,4kN/sm².

Çyzgydan

$$\sin\alpha=\frac{Ç_2Ç_5}{\delta_y},\quad \sin\alpha=\frac{ÇÇ_6}{\delta_x},\quad \sin\alpha=\frac{Ç_2Ç_7}{\delta_y},\quad \sin\alpha=\frac{Ç_2Ç_8}{\delta_x}.$$

Deňagramlylygyň deňlemesi

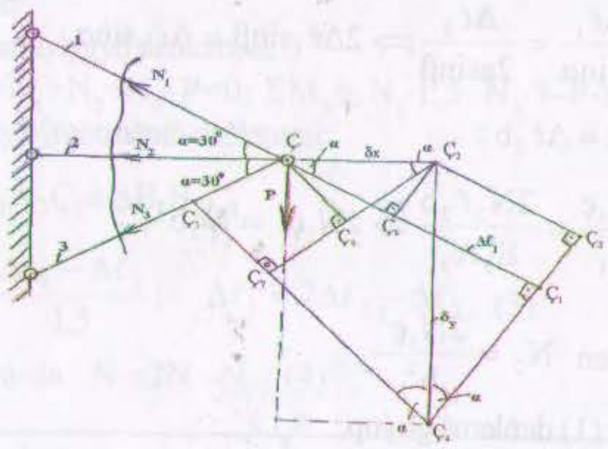
1) $\Sigma X_i=-N_1\cos\alpha-N_2+N_3\cos\alpha=0$

$$0{,}86\ N_2+N_2=0{,}86\ N_3, \quad (1)$$

2) $\Sigma Y_i=N_1\sin\alpha+N_3\sin\alpha-P=0$

$$0{,}5\ (N_1+N_3)=P. \quad (2)$$

Çyzgydan $\ell_1=\ell_3=\dfrac{\ell_2}{\cos\alpha}$.



1.38-nji surat

Durkuny üýtgetmäniň deňlemesi:

Ulgamyň durkuny üýtgeden ýagdaýyna seredip alarys:

$$\begin{cases}\Delta\ell_1=Ç_2Ç_5+ÇÇ\\ \Delta\ell_3=Ç_7Ç_2-Ç_2Ç_8\end{cases}$$

$\Delta\ell_2=ÇÇ_2$

$Ç_2Ç_5=\delta_y\sin\alpha,\ ÇÇ_6=\delta_x\cos\alpha,\ Ç_2Ç_7=\delta_y\sin\alpha,\ Ç_2Ç_8=\delta_x\cos\alpha,$

$$\text{Onda}\begin{cases}\Delta\ell_1=\delta_y\sin\alpha+\delta_x\cos\alpha\\ \Delta\ell_3=\delta_y\sin\alpha-\delta_x\cos\alpha\end{cases}$$

bu ýerden $\Delta l_1-\Delta l_3=2\delta_x\cos\alpha$ (3)

$$\frac{N_1\ell_2}{EA_1\cos\alpha}-\frac{N_3\ell_2}{EA_3\cos\alpha}=2\frac{N_2\ell_2}{EA_2}\cos\alpha$$

$$\frac{N_1}{2\cdot0{,}86}-\frac{N_3}{4\cdot0{,}86}=2\frac{N_2}{3}0{,}86\Rightarrow N_2=N_1-0{,}506N_3$$

(1) deňleme boýunça $N_1=0{,}73\ N_3$

(2) deňleme boýunça $N_3=\dfrac{P}{0{,}866}=\dfrac{50}{0{,}866}=57{,}7\text{kN}$

$N_1=0{,}73\cdot N_3=0{,}73-57{,}7=42{,}1\text{kN}$,

$N_2=N_1-0{,}506N_3=42{,}1-0{,}506\cdot57{,}7=12{,}9\text{kN}$,

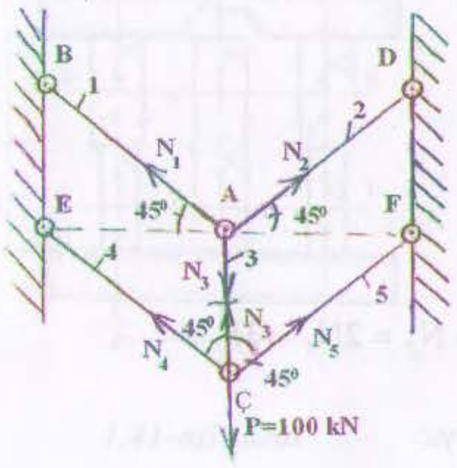
Degişlilikde, sterženiň dartgynlylyklary

$$\sigma_1=\frac{N_1}{A_1}=\frac{42{,}1}{2}=21{,}05\text{kN/sm}^2\quad\text{(süýnme)}$$

$$\sigma_2=\frac{N_2}{A_2}=\frac{12{,}9}{3}=4{,}3\text{kN/sm}^2\quad\text{(süýnme)}$$

$$\sigma_3=\frac{N_3}{A_3}=\frac{57{,}7}{4}=14{,}4\text{kN/sm}^2\quad\text{(gysylma)}$$

1.39. $\Delta_ç=0{,}894\text{sm}$



Statikanyň deňlemelerini düzýäris.

A düwün üçin

$\Sigma X=-N_1\cos45°+N_2\cos45°=0$,

$N_1=N_2$;

$\Sigma Y=N_1\sin45°+N_2\sin45°-N_3=0$,

$2N_1\sin45°=N_3\Rightarrow N_3=\sqrt{2}N_1$

Ç düwün üçin

$\Sigma X=-N_4\sin45°+N_5\sin45°=0$,

$N_4=N_5$;

$\Sigma Y=N_3+2N_4\cos45°-_P=0$,

$N_3+\sqrt{2}N_4=P$

Durkuny üýtgetmäniň bilelikdäki deňlemesi

$$\Delta_Ç=\Delta_A+\Delta-\ell_Ç;\quad \Delta_Ç=\frac{\Delta\ell_4}{\cos45°},\quad \Delta_A=\frac{\Delta\ell_1}{\cos45°}$$

onda $$\frac{N_4a\sqrt{2}}{EA\cos\alpha}=\frac{N_1a\sqrt{2}}{EA\cos\alpha}+\frac{N_3a\sqrt{2}}{EA}$$

$$\begin{cases}2N_4=2N_1+N_3\\ N_3=\sqrt{2}N_1\\ N_3+\sqrt{2}N_4=P\end{cases}$$

Bu ýerden $N_4=44,7$ kN

onda

$$\Delta_Ç=\frac{\Delta\ell_4}{\cos45°}=\frac{N_4a\sqrt{2}}{EA\cdot\cos45°}=\frac{2N_4a}{EA}=\frac{2\cdot44,7\cdot100}{2\cdot10^4\cdot5}=0,894\text{sm}$$

1.40. [P] = 1250kN

Deňagramlylygyň deňlemesi

$\Sigma M_A=N_1\cdot2+N_2\cdot4-P\cdot2=0$

$N_1+2N_2=P$

Durkuny üýtgetmäniň deňlemesi

$BB_1=\Delta\ell_1$, $ÇÇ_1=\Delta\ell_2$

$\Delta ABB_1\infty\Delta AÇÇ_1$

$$\frac{\Delta\ell_1}{2}=\frac{\Delta\ell_2}{4}\Rightarrow\Delta\ell_2=2\Delta\ell_1\quad(2)$$

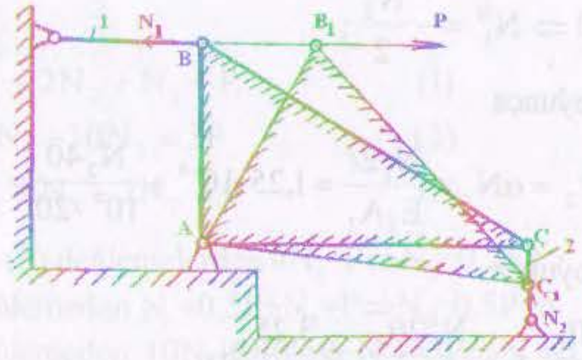
Onda $$\frac{N_2\cdot100}{1,2\cdot10^4\cdot50}=2\frac{N_1\cdot200}{2\cdot10^4\cdot30}\Rightarrow N_2=2N_1\quad(3)$$

(3) aňlatmany (1) deňlemä goýup alarys:

$N_1=0,2$ P, $N_2=0,4$ P

Sterženlerdäki dartgynlylyklar

$$\sigma_1=\frac{N_1}{A_1}=\frac{0,2}{30}=0,00667P,\quad \sigma_2=\frac{0,4}{50}=0,008P,$$

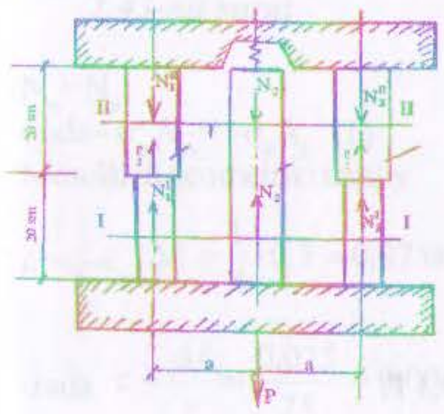


1.40-njy surat

$\sigma_2>\sigma_1$, şonuň üçin hem çoýun sterženiň berklige çydamlylygyndan rugsat edilýän güýji kesgitleýäris.

$$\sigma_2=0,008[P]=[\sigma]_ç\Rightarrow[P]=\frac{[\sigma]_ç}{0,008}=\frac{10}{0,008}=1250\text{kN}$$

1.41. $\sigma_1^I=-0,9\text{kN}/\text{sm}^2$, $\sigma_1=10,26\text{kN/sm}^2$, $\sigma_2=1,44\text{kN/sm}^2$.



1.41-nji surat

Deňagramlylygyň deňlemesi

I–I kesik

1) $N_1^I+N_2+N_3^I=P$, $N_1^I=N_3^I$

II–II– kesik

2) $N_1^{II}+N_2+N_3^{II}=0$, $N_1^{II}=N_3^{II}$

Durkuny üýtgetmäniň deňlemesi

3) $\Delta\ell_2^{II}=\Delta\ell_2+\alpha N_2=\Delta\ell_1$

4) $\Delta\ell_1=\Delta\ell_1^{II}+\Delta\ell_1^I$ $\Delta\ell_2=\dfrac{N_2 2\ell}{E_2A_2}$

(1) deňleme boýunça

$$2N_1^I + N_2 = P \Rightarrow N_1^I = \frac{P - N_2}{2};$$

(2) deňleme boýunça

$$2N_1^{II} + N_2 = 0 \Rightarrow N_1^{II} = -\frac{N_2}{2};$$

(3) deňleme boýunça

$$\Delta\ell_1 = \alpha N_2 + \Delta\ell_2 = \alpha N_2 + \frac{N_2 2\ell}{E_2 A_2} = 1{,}25\cdot 10^{-4} + \frac{N_2 40}{10^4 \cdot 20} = \frac{3{,}25}{10^4} N_2;$$

(4) deňleme boýunça

$$\Delta\ell_1 = \frac{N_1^{II} 20}{2\cdot 10^4 \cdot 20} + \frac{N_1^I 20}{2\cdot 10^4 \cdot 16} = \frac{3{,}25}{10^4} N_2,$$

$$N_1^{II} + \frac{N_1^I}{1{,}6} = 3{,}25N_2 \Rightarrow \frac{P - N_2}{2} - \frac{N_2}{2\cdot 1{,}6} = 3{,}25N_2 \Rightarrow N_2 = 28{,}8\text{kN}$$

$$N_1^I = \frac{P - N_2}{2} = \frac{234 - 28{,}8}{2} = 102{,}6\text{kN},$$

$$N_1^{II} = -\frac{N_2}{2} = -\frac{28{,}8}{2} = -14{,}4\text{kN}.$$

Degişli dartgynlyklar:

$$\sigma_1^{II} = \frac{N_1^{II}}{A_1^I} = \frac{-14{,}4}{16} = -0{,}9\text{kN/sm}^2,$$

$$\sigma_1^I = \frac{N_1^I}{A_1} = \frac{102{,}6}{10} = 10{,}26\text{kN/sm}^2,$$

$$\sigma_2 = \frac{N_2}{A_2} = \frac{28{,}8}{20} = 1{,}44\text{kN/sm}^2 \ldots$$

1.42. N_1=0,4 P, N_2=0,25 P, N_3=0,1 P.

Meseläniň statiki tarapy

1)$\Sigma Y = N_1 + 2N_2 + N_3 - P = 0$;

1.42-nji surat

2) $\Sigma M_Y = N_3\cdot 50 + P15 - N_1 50 = 0$.

Meseläniň geometriki tarapy

$$\Delta\ell_2 = \frac{\Delta\ell_1 + \Delta\ell_3}{2} \Rightarrow 2\Delta\ell_2 = \Delta\ell_1 + \Delta\ell_3,$$

$2N_2 = N_1 + N_3$.

Onda
$$\begin{cases} N_1 + 2N_2 + N_3 - P & (1) \\ 10N_1 - 10N_3 = 3P & (2) \\ N_1 + N_3 - 2N_2 = 0 & (3) \end{cases}$$

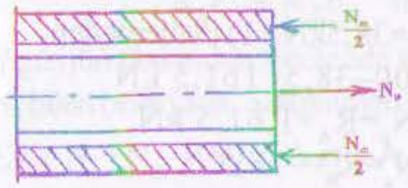
(1) we (3) deňlemelerden $4N_2 = P \Rightarrow N_2 = 0{,}25P$

(1) deňlemeden $N_1 + 0{,}5P + N_3 = P \Rightarrow N_3 = 0{,}5P - N_1$

(2) deňlemeden $10N - 10(0{,}5P - N_1) = 3P \Rightarrow N_1 = 0{,}4P$

$N_3 = 0{,}5P - N_1 = 0{,}5P - 0{,}4P = 0{,}1P$.

1.43. σ_p=12,74kN/sm², σ_m=–3,636kN/sm².



1.43-nji surat

$$A_p = \frac{\pi d_1^2}{4} = \frac{3{,}14\cdot 2^2}{4} = 3{,}14\text{sm}^2,$$

$$A_m = \frac{\pi}{4}\left(d_3^2 - d_2^2\right) = \frac{3{,}14}{4}\left(4{,}5^2 - 2{,}5^2\right) = 11\text{sm}^2$$

Meseläniň statiki tarapyna seredýäris.

$N_m = N_p$

onda $-\sigma_m A_m = -\sigma_p A_p$ (1)

Meseläniň geometriki tarapy

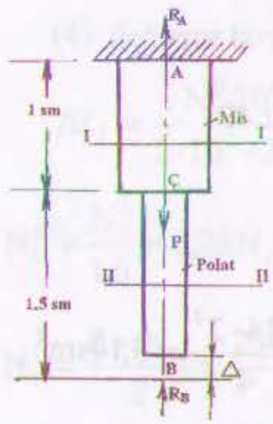
$$\varepsilon = \varepsilon_p - \varepsilon_m;\ \Delta\ell = \frac{1}{4}\cdot 0{,}3 = 0{,}075\text{sm},$$

onda $\varepsilon = \frac{\Delta\ell}{\ell} = \frac{0{,}075}{75} = 0{,}001$, $\varepsilon_m = \frac{-\sigma_m}{E_m}$, $\varepsilon_p = \frac{\sigma_p}{E_p}$,

$$\begin{cases} \dfrac{\sigma_p}{E_p} - \dfrac{\sigma_m}{E_m} = 0{,}001 \\ -\sigma_m A_m = \sigma_p A_p \end{cases}$$

$$\frac{\sigma_p}{E_p} + \frac{A_p}{A_m}\cdot\frac{\sigma_p}{E_m} = 0{,}001 \Rightarrow \sigma_p = 12{,}74\text{kN/sm}^2 \text{ , } \sigma_m\text{=-6,636kN/sm}^2.$$

1.44. σ_y=1,07kN/sm², σ_a=–0,77kN/sm².



1.44-nji surat

Meseläniň statik tarapy.
$\Sigma Y=R_A+R_B-P=0$ (1)
Meseläniň geometrik tarapy
$\Delta\ell_p - \Delta\ell_{R_B} = \Delta$ (2)

$$\frac{P\cdot 100}{E_y\cdot A_y} - \frac{R_B\cdot 100}{E_y\cdot A_y} - \frac{R_B\cdot 150}{E_a\cdot A_a} = \Delta$$

Bu ýerden R_B=38,5kN (1) deňlemeden
$R_A=P-R_B+200-38{,}5+161{,}5$ kN
AÇ bölekde $N_ý=R_A$=1,61,5 kN
BÇ bölekde $N_a=R_B$=–38,5

Bu böleklerdäki dartgynlylyklar

$$\sigma_ý = \frac{N_ý}{A_ý} = \frac{161{,}5}{150} = 1{,}076\text{kN/sm}^2,$$

$$\sigma_a = \frac{N_a}{A_a} = -\frac{38{,}5}{50} = -0{,}77\text{kN/sm}^2.$$

1.45. σ_1= –0,8kN/sm², σ_2=–0,2kN/sm².
Statikanyň deňagramlylygynyň deňlemesi
$\Sigma Y=2N_1+N_2-P=0$; (1)
Durkuny üýtgetmäniň deňlemesi

$$\Delta l_1 - \Delta l_2 = \Delta \text{ (2)}$$

ýa-da $\dfrac{N_1 350}{1400\cdot 400} - \dfrac{N_2 350}{1400\cdot 400} = 0{,}15 \Rightarrow N_1 - N_2 = 240$ (3)

(3) aňlatmany (1) deňlemä goýup alarys:
$2N_1+(N_1-240)=720\Rightarrow N_1$=320kN, N_2=80kN.
Sütünlerdäki dartgynlylyklar:

$$\sigma_1 = \frac{-N_1}{A} = \frac{-320}{400} = -0{,}8\text{kN/sm}^2;$$

$$\sigma_2 = \frac{-N_2}{A} = \frac{-80}{400} = -0{,}2\text{kN/sm}^2.$$

1.46. $\sigma_1^1 = -\dfrac{PA_2}{A_1E_1+A_2E_2}\cdot\dfrac{E_1-mE_2}{mA_1+A_2}$,

$$\sigma_2 = \frac{PA_1}{A_1E_1+A_2E_2}\cdot\frac{E_1-mE_2}{mA_1+A_2}.$$

P güýjüň täsirinden steržende we turbada döreýän dartgynlylyklary σ_1 we σ_2 bilen belleýäris. Statikanyň deňlemesini ýazýarys
$\Sigma X=N_1+N_2-P=0\Rightarrow A_1\sigma_1+A_2\sigma_2=P$. (1)
Durkuny üýtgetmäniň deňlemesi

$$\frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2} \qquad (2)$$

Alnan deňlemeleri bilelikde işläp taparys:

$$\sigma_1 = \frac{PE_1}{A_1E_1+A_2E_2} \text{ we } \sigma_2 = \frac{PE_2}{A_1E_1+A_2E_2}.$$

P güýç bilen ýüklenmedik ýagdaýynda steržen we turba üçin statika bize aşakdaky deňlemäni berýär.

$$A_1\sigma_1^1 + A_2\sigma_2^1 = 0\text{ ,} \qquad (3)$$

Başga tarapdan meseläniň şertine görä

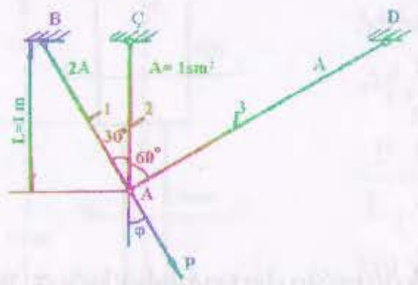
$$\frac{\sigma_1+\sigma_1^1}{\sigma_2+\sigma_2^1}=m. \qquad (4)$$

Ýokardaky deňlemeleri bilelikde işläp taparys:

$$\sigma_1^1=\frac{PA_2}{A_1E_1+A_2E_2}\cdot\frac{E_1-mE_2}{mA_1+A_2},$$

$$\sigma_2^1=\frac{PA_1}{A_1E_1+A_2E_2}\cdot\frac{E_1-mE_2}{mA_1+A_2}.$$

1.47. P=24,8kN, φ=12,4° .



1.47-nji surat

$\ell_1=\ell_2/\cos30°$, $\ell_3=\ell_2/\cos60°$.
Statikanyň deňlemesinden

$$\begin{cases}0{,}866N_3-0{,}5N_1=-P\sin\varphi,\\ N_2+0{,}866N_1+0{,}5N_3=P\cos\varphi\end{cases} (1).$$

Durkuny üýtgetmäniň deňlemesiinden
$\Delta\ell_2=\Delta=0{,}05$sm

$\Delta\ell_1=\Delta l_2\cos30°$, $\Delta\ell_3=\Delta\ell_2\cos60°$.

Gukuň kanuny ulanyp, soňky aňlatmadan

$$N_1=\frac{\Delta\ell_1EA_1}{\ell_1},\ N_2=\frac{\Delta\ell_2EA_2}{\ell_2},\ N_3=\frac{\Delta\ell_3EA_3}{\ell_3},$$

Bu ýerden N_1=14,8 kN, N_2=10 kN, N_3=2,5 kN.
Bu bahalary (1) deňlemelere goýup alarys:

$$\begin{cases}0{,}866\cdot2{,}5-0{,}5\cdot14{,}8=-P\sin\varphi\\ 10+0{,}866\cdot14{,}8+0{,}5\cdot2{,}5=P\cos\varphi\end{cases}$$

Bu ýerden φ=12,4°, P=24,8kN.

1.48. $\sigma_p=-5$kN/sm², $\sigma_ç=-3$kN/sm².
Meseläniň statiki tarapyndan $N_1=N_3$, $2N_1+N_2=P$
Meseläniň geometriki tarapy
$\Delta\ell_1=\Delta\ell_3$, $\Delta+\Delta\ell_2=\Delta_{pr}+\Delta\ell_1$, $\Delta_{pr}=N\cdot\alpha$.

Soňky deňlemelerdäki durkuny üýtgetmeleri Gukuň kanuny boýunça aňladyp alarys:

$$\Delta+\frac{N_2\ell_2}{E_2A_2}=\Delta_{pr}+\frac{N_1\ell_1}{E_1A_1},\ \ell_1=100\text{ sm},\ \ell_2=99{,}95\text{ sm}.$$

$$\Delta+\frac{(P-2N_1)\ell_2}{E_2A_2}=\Delta_{pr}+\frac{N_1\ell_1}{E_1A_1}\Rightarrow N_1=100\text{kN}.$$

Onda $N_2=P-2N_1=350-2\cdot100=150$kN.
Çetki we ortaky direlgelerdäki dartgynlylyklar

$$\sigma_1=\sigma_p=-\frac{N_1}{A_1}=-\frac{100}{20}=-5\text{kN/sm}^2$$

$$\sigma_2=\sigma_ç=-\frac{N_2}{A_2}=-\frac{150}{50}=-3\text{kN/sm}^2$$

1.49. $\sigma_ý=-6{,}66$kN/sm², $\sigma_a=-3{,}33$kN/sm².
Statikanyň deňlemesinden $R_A=R_B$
Meseläniň geometrik tarapyndan $\Delta l_1=\Delta l_{R_B}$

ýa-da $\alpha\Delta_t 2a=\frac{R_Ba}{EA_1}+\frac{R_Ba}{EA_2}\Rightarrow R_B=33{,}33\text{kN}$, $R_A=33{,}33$ kN.

$N_a=-R_B=-33{,}33$kN, $N_ý=-R_A=-33{,}33$kN.

Onda $\sigma_a=-\frac{N_a}{A_2}=\frac{-33{,}33}{10}=-3{,}33\text{kN/sm}^2$,

$$\sigma_ý=-\frac{N_ý}{A_1}=-\frac{33{,}33}{5}=-6{,}66\text{kN/sm}^2$$

1.50-nji surat

1.50. $\sigma=-9{,}50$kN/sm².
Statikanyň deňlemesi
$R_A=R_B$ (1)

Durkuny üýtgetmäniň bilelikdäki deňlemesi

$$\Delta\ell_t - \Delta\ell_{R_B} = \Delta \quad (2)$$

$$,\alpha\Delta_t\ell - \frac{R_A\ell}{EA} = \Delta \Rightarrow 1{,}25\cdot10^{-5}\cdot40\cdot200 - \frac{R_A\cdot200}{2\cdot10^4\cdot A} = 0{,}005.$$

Bu ýerden R_A=9,5A, R_A=R_B=9,5A kN, N=$-R_A$=–9,5A.

$$\sigma = \frac{N}{A} = \frac{-9{,}5A}{A} = -9{,}5kN/sm^2.$$

1.51. Δ=+0,056 sm (iki sterženiňki).

$$\Delta\ell = \frac{N\ell}{EA} = \frac{\sigma_1\ell}{E}$$

Temperatura dartgynlylygy $\sigma_t=\pm E\alpha\Delta t$, $\Delta t=-10°S$ temperatura sterženlerde süýnme dartgynlylyklaryny döredýär, onda

$\sigma_t=E\alpha\Delta t=2\cdot10^4\cdot1{,}25\cdot10^{-5}\cdot10=2{,}5kN/sm^2$,

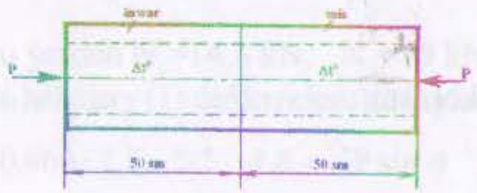
$$\sigma_1^1 = \sigma_1 + \sigma_t = 2{,}5 + 1{,}5 = 4kN/sm^2,$$

$$\sigma_2^1 = \sigma_2 + \sigma_1^1 = 8 - 4 = 4kN/sm^2.$$

Onda $\Delta_1 = \frac{\sigma_2^1\ell}{E} = \frac{4\cdot140}{2\cdot10^4} = 0{,}028sm$.

Umumy uzalma

$\Delta=\Delta_1+\Delta_2=0{,}028+0{,}028=0{,}056$ sm.



1.50-nji surat

1.52. P=150 kN, ℓ_m=50,01 sm, ℓ=49,99 sm.

$\varepsilon_t=\varepsilon_i+\varepsilon_m$ (1) $N_i=N_m$;

$\varepsilon_t=(\alpha_m+\alpha_i)t$,

$$\alpha_m t° = \frac{N_i}{E_iA_i} + \frac{N_m}{E_mA_m},$$

Bu ýerden $N_m=N_i=150kN\Rightarrow P=150kN$.

Misiň we inwaryň erkin durkuny üýtgetmesi

$$\Delta\ell_m = \frac{N_m 50}{E_mA_m} = \frac{150\cdot50}{10^4\cdot37{,}5} = 0{,}02sm,$$

$$\Delta\ell_i = \frac{N_i 50}{E_iA_i} = \frac{150\cdot50}{2\cdot10^4\cdot37{,}5} = 0{,}01sm.$$

Onda ℓ_m=50+($\Delta\ell_m$–$\Delta\ell_i$)=50+(0,02–0,01)=50,01 sm,

ℓ_i=50–($\Delta\ell_m$–$\Delta\ell_i$)=50–0,01=49,99 sm.

1.53. σ = –0,1kN/sm².

Plitada döreýän boý güýji direglerdäki gaýtargylara deň we bu güýji durkuny üýtgetmäniň deňlemesinden tapýarys. $\Delta\ell_t-\Delta\ell_N=\Delta$ ýa-da $\alpha\Delta t\ell - \frac{N\ell}{EA} = \Delta$.

Bu ýerden $N = \frac{EA(\alpha\Delta t\ell - \Delta}{\ell}$ – plitanyň bir inindäki güýç, N=–400kN.

Plitanyň kesigindäki dartgynlylyk

$$\sigma = \frac{N}{A} = -\frac{400}{100\cdot40} = -0{,}1kN/sm^2.$$

1.54. Temperatura üýtgeýänçä P_p=27 kN, P_m=18 kN.

Temperatura üýtgände P_p=1,26 kN, P_m=32,4 kN.

Statikanyň deňlemesi $N_p+N_m=P$ (1).

Durkuny üýtgetmäniň deňlemesi $\varepsilon_p=\varepsilon_m$ (2).

(1) we (2) deňlemäni bilelikde işläp, N_p=27 kN, N_m=18 kN.

Diregler $\Delta t = 30°S$ gyzdyrylanda,

$$N_p^1 = N_m^1 \quad (1) \quad \varepsilon_m^t - \varepsilon_m^N = \varepsilon_p^t + \varepsilon_p^N. \quad (2)$$

Bu deňlemeleri işläp alarys.

$$N_p^1 = N_m^1 = 14{,}4kN$$

$$\text{Onda } P_p = N_p - N_p^1 = 27 - 14{,}4 = 12{,}6kN,$$

$$P_m = N_m + N_m^1 = 18 + 14{,}4 = 32{,}4kN.$$

1.55. P=31,4 kN, ℓ=20,011sm.

Statikanyň deňlemesinden $P=2N_b$

$$A_b = \frac{\pi d^2}{4} = \frac{3{,}14 \cdot 1^2}{4} - 0{,}785 sm^2,$$

$\Delta\ell=(\ell_2 - \ell_1) = 20{,}02 - 20 = 0{,}02$sm,

onda

$$\frac{N_b \ell_1}{E_b A_b} = 0{,}02 \Rightarrow N_b = \frac{0{,}02 \cdot E_b \cdot A_b}{\ell_1} = \frac{0{,}02 \cdot 2 \cdot 10^4 \cdot 0{,}785}{20} = 15{,}7kN,$$

$P=2N_b=2 \cdot 15{,}7=31{,}4$kN.

P güýç aýrylandan soň, boltlardaky dartuw güýçleriniň bir bölegini mis steržen kabul edýär.

Statikanyň deňlemesinden $2N_b=N_m=31{,}4$ kN.

Durkuny üýtgetmäniň deňlemesi $\varepsilon_m=\varepsilon_b$

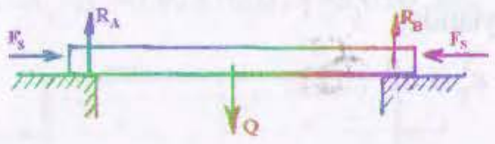
$$\frac{N_m}{E_m A_m} = \frac{N_b}{E_b A_b} \Rightarrow N_m = \frac{E_m A_m}{E_b A_b} N_b,$$

$$\Delta = \Delta\ell_b^1 - \Delta\ell_m^1,$$

onda

$$\Delta = \frac{N_b \cdot \ell_1}{E_b A_b} - \frac{N_m \cdot \ell_2^1}{E_m A_m} = \frac{15{,}7 \cdot 20{,}02}{2 \cdot 10^4 \cdot 0{,}785} - \frac{31{,}4 \cdot 20{,}02}{10^4 \cdot 6} = 0{,}0095sm,$$

$\ell = \ell_2 - \Delta = 20{,}02 - 0{,}0095 = 20{,}011$sm.



1.56-njy surat

1.56. $\Delta t = \pm 2{,}97°S$,

$\sigma = \pm 0{,}743$ kN/sm^2

$$R_A = R_B = \frac{Q}{2} = \frac{100}{2} = 50kN$$

$F_s = f \cdot R_A = 0{,}3 \cdot 50 = 15$kN,

$$\sigma = \Delta t \alpha E = \frac{F_s}{A} \Rightarrow \Delta t = \frac{F_s}{\alpha E A}$$

16-njy belgili iki tawra üçin $A=20{,}2$ sm^2

onda $\Delta t = \pm \dfrac{15}{20{,}2 \cdot 1{,}25 \cdot 10^{-5} \cdot 2 \cdot 10^4} \cong \pm 2{,}97°S$

bu ýerden $\sigma = \alpha \cdot \Delta t \cdot E = \pm 1{,}25 \cdot 10^{-5} \cdot 12 \cdot 10^4 \cdot 2{,}97 = \pm 0{,}743$kN/sm^2

1.57. $\Delta_t = 5$mm, $\sigma_t = 12{,}5$kN/sm^2.

Zerur bolan boşlugyň ululygy ($\Delta t=50°S$)

$\Delta_t = \alpha \Delta t \ell = 1{,}25 \cdot 10^{-5} \cdot 50 \cdot 800 = 0{,}5$sm

Boşluk bolmadyk ýagdaýynda relsde döreýän gysma dartgynlylyk

$\sigma_t = -\alpha \Delta t E = -1{,}25 \cdot 10^{-5} \cdot 50 \cdot 2 \cdot 10^4 = -12{,}5$kN/sm^2

1.58. $\ell_1 = 30{,}062$m, $\sigma = -41{,}25$kN/sm^2.

Polat turbanyň temperaturanyň ýokarlanmagy sebäpli erkin uzynlygyna giňelmegi

$\Delta\ell_t = \alpha \Delta t \ell = 1{,}25 \cdot 10^{-5} \cdot 165 \cdot 3000 = 6{,}2$sm,

onda $\ell_1 = \ell + \Delta\ell_t = 30 + 0{,}062 = 30{,}062$m.

Meseläniň ikinji şerti aşakdaky formula bilen tapylýar.

$\sigma_t = -\alpha \Delta t E = -1{,}25 \cdot 10^{-5} \cdot 165 \cdot 2 \cdot 10^4 = -41{,}25$kN/sm^2.

1.59. a) $\sigma = 18{,}4$kN/sm^2, b) $\sigma_1 = 0{,}7$kN/sm^2, ç) $t_2 = 545°S$.

a) Halkadaky dartgynlylyk

$\sigma = E \cdot \varepsilon = \alpha_m (t_1 - t_0) E_m = 1{,}6 \cdot 10^{-5} (135 - 20) \cdot 10^4 = 18.4$kN/sm^2.

b) Waly we halkany bir wagtda $0°S$-a çenli sowadylanda halkada döreýän goşmaça dartgynlylyk

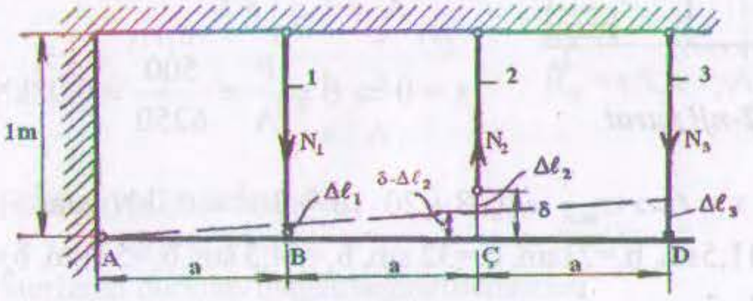
$\sigma_1 = (\alpha_m - \alpha_p) t_0 E_m = (1{,}6 \cdot 10^{-5} - 1{,}25 \cdot 10^{-5}) \cdot 20^0 \cdot 10^4 = 0{,}7$kN/sm^2.

Halkadaky doly dartgynlylyk $\sigma = \sigma + \sigma_1 = 19{,}1$kN/sm^2.

ç) Halkadaky dartgynlylyk nola deň bolmak üçin aşakdaky şert ýerine ýetirilmeli

$\sigma_2 = (\alpha_m - \alpha_p) E_m t_2$, bu ýerden $t_2 = \dfrac{\sigma_2}{(\alpha_m - \alpha_p) E_m} = 545°S.$

1.60. $\sigma = -1\ 43$kN/sm^2 $\sigma = 715$kN/sm^2 $\sigma = -4\ 29$kN/sm^2.



1.60-njy surat

Statikanyň deňlemesi $\Sigma M_A = N_1 a - N_2 2a + 3N_3 = 0$ (1)

Durkuny üýtgetmäniň deňlemesi

$$\frac{\Delta\ell_1}{a} = \frac{\delta - \Delta\ell_2}{2a} \text{ we } \frac{\Delta\ell_1}{a} = \frac{\Delta\ell_3}{3a} \Rightarrow 3N_1 = N_3 \quad (2)$$

$$2\frac{N_1 100}{2\cdot 10^4 \cdot 20} = 0{,}05 - \frac{N_2 100}{2\cdot 10^4 \cdot 20} \Rightarrow N_1 + 0{,}5N_2 = 100 \quad (3)$$

(1), (2) we (3) deňlemeleri bilelikde işläp alarys:

N_1=28,5 kN, N_2=143 kN, N_3=85,5 kN .

Degişli dartgynlylyklary

$$\sigma_1 = \frac{-N_1}{A} = -\frac{28{,}5}{20} = -1{,}43 kN/sm^2;$$

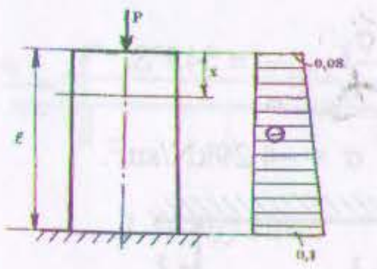
$$\sigma_2 = \frac{N_2}{A} = \frac{143}{20} = 7{,}15 kN/sm^2;$$

$$\sigma_3 = -\frac{N_3}{A} = -\frac{85{,}5}{20} = -4{,}29 kN/sm^2.$$

1.61. $\sigma = 0{,}016 kN/sm^2$.

$\sigma = \gamma\ell = 20\cdot 8 = 160 kN/m^2 = 0{,}016 kN/sm^2$.

1.62. 79×79 sm^2.



1.62-nji surat

$$A = \frac{P}{[\sigma] - \gamma\ell} = \frac{500}{0{,}1 - 20\cdot 10^{-6}\cdot 10^3} = 6250 sm^2$$

a×a = 79×79 sm^2

$$\sigma = \frac{P}{A} + \gamma x$$

$$x = 0 \Rightarrow \sigma = \frac{P}{A} = \frac{500}{6250} = 0{,}08 kN/sm^2$$

$$x = \ell \Rightarrow \sigma_{max} = 0{,}08 + 20\cdot 10^{-6}\cdot 10^3 = 0{,}1 kN/sm^2$$

1.63. b_1=11,5sm, b_2=21sm, b_3=32 sm, b_4=44,5 sm, b_5=54 sm, b_6=76 sm, b_7=125sm.

Hasap ýokarky diwardan başlanýar.

$$b_1 = \frac{q_1}{[\sigma] - \gamma\cdot 4} = 11{,}5sm,$$

$$b_2 = \frac{q_1 + q_2 + \gamma b_1 \cdot 4}{[\sigma] - \gamma\cdot 4} = 21sm,$$

$$b_3 = \frac{q_1 + 2q_2 + \gamma b_1 \cdot 4 + \gamma b_2 \cdot 4}{[\sigma] - \gamma\cdot 4} = 32sm,$$

$$b_4 = \frac{q_1 + 3q_2 + \gamma b_1 \cdot 4 + \gamma b_2 \cdot 4 + \gamma b_3 \cdot 4}{[\sigma] - \gamma\cdot 4} = 44{,}5sm,$$

$$b_5 = \frac{q_1 + 4q_2 + \gamma b_1 \cdot 4 + \gamma b_2 \cdot 4 + \gamma b_3 \cdot 4 + \gamma b_4 \cdot 4}{[\sigma] - \gamma\cdot 4} = 59sm,$$

$$b_6 = \frac{q_1 + 5q_2 + \gamma b_1 \cdot 4 + \gamma b_2 \cdot 4 + \gamma b_3 \cdot 4 + \gamma b_4 \cdot 4 + \gamma b_5 \cdot 4}{[\sigma] - \gamma\cdot 4} = 76sm,$$

$$b_7 = \frac{q_1 + 5q_2 + q_3 + \gamma\cdot 4(b_1 + b_2 + b_3 + b_4 + b_5 + b_6)}{[\sigma] - \gamma\cdot 4} = 1{,}25sm.$$

1.64. $\Delta\ell = 2{,}8mm$

$$\Delta\ell = \frac{\gamma\ell^2}{2E} = \frac{78\cdot 10^{-6}\cdot 120^2\cdot 10^4}{2\cdot 2\cdot 10^4} 0{,}28sm = 2{,}8mm.$$

1.65. $$R_A = \frac{\gamma A_1 a}{2}\cdot\frac{1 + \frac{b^2}{a^2} + 2\frac{b}{a}\cdot\frac{A_1}{A_2}}{1 + \frac{b}{a}\cdot\frac{A_1}{A_2}}, \quad R_B = \gamma A_1 a + \gamma A_2 b - R_A.$$

Statikanyň deňlemesinden

$R_A + R_B = \gamma A_1 a + \gamma A_2 b$ (1)

Sterženiň durkuny üýtgetmeginiň deňlemesi

$\Delta\ell_{R_A} = \Delta\ell_Q$ (2)

R_A gaýtargydan sterženiň uzalmasy

$$\Delta\ell_{R_A} = \frac{R_A a}{EA_1}\left(1+\frac{b}{a}\cdot\frac{A_1}{A_2}\right).$$

Sterženiň hususy agramyndan gysgalmasy

$$\Delta\ell_Q = \frac{\gamma a^2}{2E}\left(1+\left(\frac{b}{a}\right)^2+2\frac{b}{a}\cdot\frac{A_1}{A_2}\right).$$

Soňky aňlatmalary (2) deňlemä goýup alarys:

$$\frac{R_A a}{EA_1}\left(1+\frac{b}{a}\cdot\frac{A_1}{A_2}\right)=\frac{\gamma a^2}{2E}\left(1+\left(\frac{b}{a}\right)^2+2\frac{b}{a}\cdot\frac{A_1}{A_2}\right).$$

Bu ýerden $$R_A=\frac{\gamma A_1 a\left(1+\dfrac{b^2}{a^2}+2\dfrac{b}{a}\cdot\dfrac{A_1}{A_2}\right)}{2\left(1+\dfrac{b}{a}\cdot\dfrac{A_1}{A_2}\right)}$$

(1) deňlemeden $R_B=\gamma A_1 a+\gamma A_2 b-R_A$.

1.66. $\sigma_b=-0{,}0187\text{kN/sm}^2$, $\sigma_a=-0{,}28\text{kN/sm}^2$.

Sütüniň aşaky kesigi üçin statikanyň deňlemesi

$N_a+N_b=(\gamma_a A_a+\gamma_b A_b)\ell$; ýöne $N_a=\sigma_a A_a$, $N_b=\sigma_b A_b$,

$A_b=25\times25=625\text{sm}^2$ $n=15$ onda $\sigma_a A_a+\sigma_b A_b=(\gamma_a A_a+\gamma_b A_b)\ell$

$A_b=25\times25=625\text{sm}^2$ $n=15$ onda $\sigma_a A_a+\sigma_b A_b=(\gamma_a A_a+\gamma_b A_b)\ell$ (1)

Durkuny üýtgetmäniň bilelikdäki deňlemesi

$$\varepsilon_a=\varepsilon_d,\ \text{ýa-da}\ \frac{\sigma_a}{E_a}=\frac{\sigma_b}{E_b}\Rightarrow\sigma_a=\sigma_b\frac{E_a}{E_b}=n\sigma_b \quad (2)$$

(1) we (2) deňlemeleri bilelikde işläp alarys:

$$\sigma_b=\frac{(\gamma_a A_a+\gamma_b A_b)}{nA_a+A_b}=\frac{\left(78{,}5\cdot10^{-6}\cdot19{,}6+25\cdot10^{-6}\cdot625\right)\cdot10^3}{15\cdot19{,}6+625}=$$

$$=0{,}0187\text{kN/sm}^2$$

$$\sigma_a=15\cdot0{,}0187=0{,}28\text{kN/sm}^2$$

1.67. $\sigma_{max}=8{,}87\text{kN/sm}^2$, $\Delta\ell=28{,}03$ sm.

Ştanganyň ýokarky kesigindäki dartgynlylyk

$$\sigma=\frac{P}{A_ş}+\gamma\ell$$

Toýun ergini hasaba alyp, ştanganyň göwrüm agramyny kesgitleýäris:

$$\gamma=\frac{A_ş\gamma_ş+A_t\gamma_t}{A_ş+A_t}=\frac{136{,}6\cdot78{,}5\cdot10^{-6}+19{,}6\cdot18\cdot10^{-6}}{156{,}2}=70{,}3\cdot10^{-6}\text{kN/sm}^2$$

onda $\sigma_{max}=\dfrac{50}{136{,}2}+70{,}3\cdot10^{-6}\cdot0{,}12\cdot10^6=8{,}87\text{kN/sm}^2$.

Gukuň kanuny esasynda absolýut durkuny üýtgetme

$$\Delta\ell=\frac{P\ell}{E_ş A_ş}+\frac{\gamma\ell^2}{2E_ş}=\frac{50\cdot0{,}12\cdot10^{-6}}{2\cdot10^4\cdot136{,}6}+\frac{70{,}3\cdot10^{-6}\cdot\left(0{,}12\cdot10^{-6}\right)}{2\cdot2\cdot10^4}=28{,}03\text{sm}$$

1.68. $\alpha=35°20'$, $G=0{,}19$ kN.

Pürsüň deňagramlylygynyň şertinden

$$N_{AD}=\frac{q\ell}{2},\quad N_{BD}=\frac{q\ell}{2\sin\alpha},\quad N_{AÇ}=\frac{q\ell}{2\text{tg}\alpha}.$$

Berklik şertinden sterženleriň kese kesiginiň meýdanlaryny kesgitleýäris:

$$A_{AD}=\frac{N_{AD}}{[\sigma]_s}=\frac{q\ell}{2[\sigma]_s},\quad A_{BD}=\frac{N_{BD}}{[\sigma]_s}=\frac{q\ell}{2[\sigma]_s\cdot\sin\alpha},$$

$$A_{AÇ}=\frac{N_{AÇ}}{[\sigma]_s}=\frac{q\ell}{2[\sigma]_s\cdot tg\alpha}.$$

onda sterženleriň agramlarynyň jemi

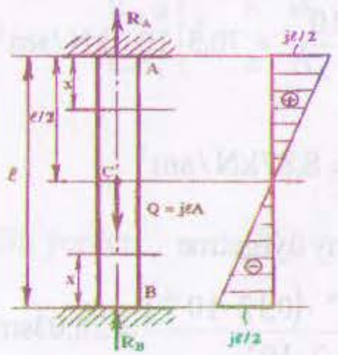
$$G=G_{AD}+G_{BD}+G_{AÇ}=\frac{\gamma g\ell^2}{2[\sigma]_s}\left(tg\alpha+\frac{1}{\sin\alpha\cos\alpha}+\frac{[\sigma]_s}{[\sigma]g}\right).$$

Soňky aňlatmanyň α görä birinji önümini nola deňläp, iň kiçi agramyň şertini tapýarys.

$3\sin^2\alpha-1=0\Rightarrow\alpha=35°20'$

Bu bahany umumy agramynyň aňlatmasyna goýup alarys G=0,19 kN.

1.69. $\sigma_ý=\frac{\gamma\ell}{2}$, $\sigma_a=\frac{\gamma\ell}{2}$.



1.69-njy surat

Statikanyň deňlemesi

$R_A+R_B-Q=0$ (1)

Durkuny üýtgetmäniň deňlemesi

$\Delta\ell_Q-\Delta\ell_{R_B}=0$ (2)

Gukuň kanunyny ulanyp

$$\frac{\gamma\ell A\cdot\ell}{2EA}=\frac{R_B\ell}{EA}\Rightarrow R_B=\frac{\gamma\ell A}{2}$$

onda $R_A=Q-R_B=\frac{\gamma\ell A}{2}$

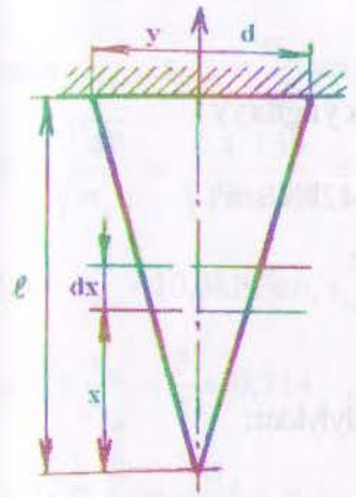
$$\sigma_ý=\frac{R_A}{A}=\frac{\gamma\ell A}{2A}=\frac{\gamma\ell}{2}$$

Aşakdaky deňlemelerden dartgynlylygyň epýuryny gurýarys:

AÇ bölek üçin $\sigma=\frac{R_A}{A}-\gamma x$,

BÇ bölek üçin $\sigma=-\frac{R_B}{A}+\gamma x$

1.70. $\Delta\ell=\frac{\gamma\ell^2}{6E}$.



1.70-nji surat

Sterženiň agramy $Q=\frac{\pi d^2}{4}\cdot\frac{\ell}{3}\cdot\gamma$

Sterženiň aşaky tarapynda x aralykdaky kese kesikdäki dartuw güýji aşaky böleginiň agramyna deň

$$\frac{Qx^3}{\ell^3}=\frac{\pi d^2}{4}\cdot\frac{x^3}{3\ell^2}\cdot\gamma$$

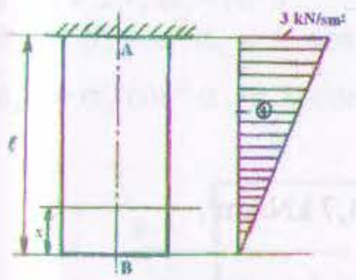
dx uzynlykdaky elemente prizma görnüşinde seredip, elementiň

uzalmasyny alarys: $\Delta dx=\frac{\gamma x^3}{3E}dx$

we sterženiň doly uzalmasy $\Delta\ell=\frac{\gamma}{3E}\int_o^\ell x dx=\frac{\gamma\ell^2}{6E}$.

Bu uzalma prizmatik sterženiň uzalmasynyň üçden birine deň.

1.71. $\ell=382$ m.



1.71-nji surat

Berklik deňlemesinden

$$\ell=\frac{[\sigma]}{\gamma}=\frac{3}{78{,}5\cdot10^{-6}}=382\cdot10^2\,sm$$

ýa-da $\ell=382$m.

Dartgynlylygyň epýury

$\sigma=\gamma x$

$x=0\Rightarrow\sigma_B=0$

$x=\ell\Rightarrow\sigma_A=\gamma\ell=78{,}5\cdot10^{-6}\cdot382\cdot10^2=$

$=3kN/sm^2$

II bap

Çyzyk we tekiz dartgynlylyk ýagdaýy

2.1. σ_α=6,63kN/sm, τ_α=3,38kN/sm², τ_{max}=4,42kN/sm².

Sterženiň kese kesigindäki normal dartgynlylyk:

$$\sigma_o = \frac{4P}{\pi d^2} = \frac{4 \cdot 250}{3{,}14 \cdot 6^2} = 8{,}84 kN/sm^2 .$$

Ýapgyt kesikdäki normal we galtaşma dartgynlylyklar:

$\sigma_\alpha = \sigma_o \cdot \cos^2\alpha = 8{,}84 \cdot \cos^2 30° = 6{,}63 kN/sm^2$,

$$\tau_\alpha = \frac{\sigma_o}{2} \sin 2\alpha = \frac{8{,}84}{2} \sin 60° = 3{,}83 kN/sm^2 .$$

Iň uly galtaşma dartgynlylyk sterženiň okuna 45° boýunça ýapgytlanan kesikde bolýar.

$$\tau_\alpha = \frac{\sigma_o}{2} = \frac{8{,}84}{2} = 4{,}42 kN/sm^2 .$$

2.2. σ_o=8,15kN/sm, p_α=5,13kN/sm², τ_α=2,075kN/sm².

Kese kesikdäki dartgynlylyk:

$$\sigma_o = \frac{4P}{\pi d^2} = \frac{4 \cdot 350}{3{,}14 \cdot 7{,}5^2} = 8{,}15 kN/sm^2 .$$

Ýapgyt kesikdäki dartgynlylyklar:

$\sigma_\alpha = \sigma_o \cdot \cos^2\alpha = 8{,}15 \cdot \cos^2 15° = 8{,}15 \cdot 0{,}759^2 = 4{,}7$ kN/sm²,

$$\tau_\alpha = \frac{\sigma_o}{2} \sin 2\alpha = \frac{8{,}15}{2} \sin 30° = 2{,}075 kN/sm^2 .$$

Doly dartgynlylyk:

$$P_\alpha = \sqrt{\sigma_\alpha^2 + \tau_\alpha^2} = \sqrt{4{,}7^2 + 2{,}075^2} = 5{,}13 kN/sm^2 .$$

2.3. d=4 sm

α =45° deň bolanda, τ_{max}=6kN/sm² deň,

onda $\tau_{max} = \frac{\sigma_o}{2} \Rightarrow \sigma_o = 2\tau_{max} = 12 kN/sm^2$

$$d = \sqrt{\frac{4P}{\sigma_o \pi}} = \sqrt{\frac{4 \cdot 150}{12 \cdot 3{,}14}} = 4 sm .$$

2.4. σ_{max}=10,6kN/sm, τ_{max}=5,01kN/sm².

$$tg\alpha = \frac{\tau_\alpha}{\sigma_\alpha} = \frac{5}{7} = 0{,}714 , \quad \alpha \approx 35°30'.$$

$$\text{onda } \sigma_{max} = \frac{\sigma_\alpha}{\cos^2\alpha} = \frac{7}{\cos^2 35°30'} = \frac{7}{0{,}814^2} = 10{,}6 kN/sm^2$$

$$\text{we } \tau_{max} = \frac{\sigma_{max}}{2} \sin 2\alpha = \frac{10{,}6}{2} \sin 71° = 5{,}3 \cdot 0{,}9455 = 5{,}01 kN/sm^2$$

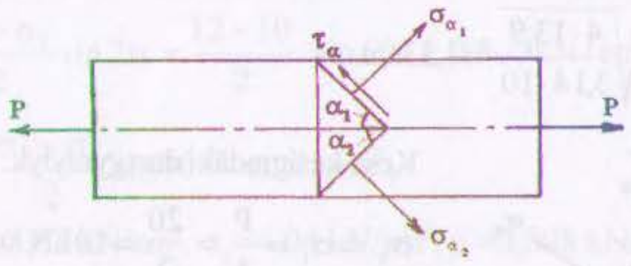
2.5. α_1=19°55', α_2=70°5', $\sigma_{\alpha_1} = 4{,}42 kN/sm^2$, $\sigma_{\alpha_2} = 0{,}58 kN/sm^2$.

$$\sin 2\alpha = \frac{2\tau_\alpha}{\sigma_o} = \frac{2 \cdot 1.6}{5} = 0{,}64 ,$$

α_1 =19°55', α_2=70°5',

$\sigma_{\alpha_1} = \sigma_o \cos^2 \alpha_1 = 5 \cdot \cos 19°55' = 5 \cdot 0{,}94^2 = 4{,}42 kN/sm^2$,

$\sigma_{\alpha_2} = \sigma_o \cos^2 \alpha_2 = 5 \cdot \cos 70°5' = 5 \cdot 0{,}34^2 = 0{,}58 kN/sm^2$.



2.5-nji surat

2.6. q_2 =–4,8kN/sm² .

Durkuny üýtgetmäniň deňlemesi $\varepsilon_2 = \frac{1}{E}(\sigma_2 - \mu\sigma_1) = 0$,

Bu ýerden $q_2 = \sigma_2 = \mu\sigma_1 = -0{,}3 \cdot 16 = -4{,}8 kN/sm^2$.

2.7. P =80kN, $\alpha = 60°$, $\beta = 30°$.

$\sigma_\alpha = \sigma_o \cdot \cos^2\alpha$, $\sigma_\beta = \sigma_o \cdot \cos^2\beta = \sigma_o \cdot \sin^2\alpha$.

Jemläp alýarys: $\sigma_\alpha + \sigma_\beta = \sigma_o = 8$ kN/sm².

Dartyjy güýç

$P = \sigma_o \cdot A = 8 \cdot 2 \cdot 5 = 80$ kN/sm².

$$tg^2\alpha = \frac{\sigma_\alpha}{\tau_\alpha} = \frac{6}{2} = 3 \Rightarrow \alpha = 60° \text{ we } \beta = 30°.$$

2.8. d_1=13,33 mm

$\varepsilon_x = \varepsilon_y = 0$; $\sigma_x = \sigma_y$ – simmetriýa şertinden,

$$\text{Onda } \varepsilon_x = \varepsilon_y = \frac{1}{E}\left[\sigma_x - \mu(\sigma_z + \sigma_y)\right] = 0,$$

$\sigma_x(1-\mu) = \sigma_z\mu \Rightarrow \sigma_x = \mu\sigma_z/(1-\mu)$,

$$\sigma_z = \frac{-P}{a^2} = \frac{100}{60^2} = -0{,}028 \text{kN/sm}^2,$$

$$\sigma_x = \frac{-0{,}4 \cdot 0{,}028}{(1-0{,}4)} = -0{,}0185 \text{kN/sm}^2.$$

Boltlara täsir edýän güýç

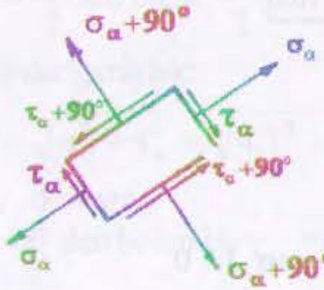
$Q = a \cdot \ell(\sigma_x) = 60 \cdot 100 \cdot 0{,}0185 = 111$ kN.

Bir bolta düşýän güýç $Q_b = Q/8 = 13{,}9$ kN.

Berklik şertinden boltuň kesiginiň diametri

$$d = \sqrt{\frac{4Q_b}{\pi[\sigma_s]}} = \sqrt{\frac{4 \cdot 13{,}9}{3{,}14 \cdot 10^3}} = 1{,}33 \text{sm}.$$

2.9. $\mu = 2{,}272$.



2.9-njy surat

Kese kesigindäki dartgynlylyk

$$\sigma_x = \sigma_1 = \frac{P}{A} = \frac{20}{2} = 10 \text{kN/sm}^2,$$

$\alpha = 30°$ burç boýunça ýapgytlanan elementiň granlaryndaky dartgynlylyklar

$\sigma_\alpha = \sigma_1 \cos^2\alpha = 7{,}5$kN/sm²;

$\sigma_{\alpha+90°} = \sigma_1 \sin^2\alpha = 2{,}5$kN/sm².

Tenzometriň bazasynyň ugruna çyzyk durkuny üýtgetmäni kesgitlemek üçin aşakdaky aňlatmany düzýäris.

$$\varepsilon_\alpha = \frac{1}{E}(\sigma_\alpha - \mu\sigma_{\alpha+90°}); \quad \varepsilon_\alpha = \frac{\Delta}{SK} = \frac{6{,}5}{20 \cdot 1000} = 3{,}25 \cdot 10^{-4}.$$

$$\text{Onda } \mu = \frac{\sigma_\alpha - E\varepsilon_\alpha}{\sigma_{\alpha+90°}} = \frac{7{,}5 - 2{,}1 \cdot 10^4 \cdot 3{,}25 \cdot 10^{-4}}{2{,}5} = 0{,}272.$$

2.10. σ_{max}=13,24kN/sm², σ_{min}=4,76 kN/sm², $\alpha_1 = 67{,}5°$, $\alpha_2 = -22{,}5°$.

Baş dartgynlylyklar

$$\sigma_{\substack{max \\ min}} = \frac{\sigma_\alpha + \sigma_\beta}{2} \pm \frac{1}{2}\sqrt{(\sigma_\alpha - \sigma_\beta)^2 + 4\tau^2}.$$

Bu ýerden σ_{max}=13,24 kN/sm², σ_{min}=4,76 kN/sm².

Baş meýdançanyň ugry

$$tg2\alpha = -\frac{2\tau}{\sigma_\alpha - \sigma_\chi} = -\frac{2 \cdot 3}{12 - 6} = -1$$

$2\alpha_1 = 135° \Rightarrow \alpha_1 = 67°30'$, $2\alpha_2 = -45°$, $\alpha_2 = -22°30'$.

2.11. σ_α=11,5kN/sm², $\tau_\alpha = 0{,}5\sqrt{3}$kN/sm², $\tau_{\alpha(max)}$=1kN/sm².

Tekiz dartgynlylyk ýagdaý üçin

$\sigma_\alpha = \sigma_1 \cdot \cos^2\alpha + \sigma_2 \cdot \sin^2\alpha = 12 \cdot \cos^2 30° + 10\sin^2 30° = 11{,}5$ kN/sm²,

$$\tau_\alpha = \frac{\sigma_1 - \sigma_2}{2} \sin 2\alpha = \frac{12 - 10}{2} \cdot \sin 60° = 0{,}5\sqrt{3}\text{kN/sm}^2$$

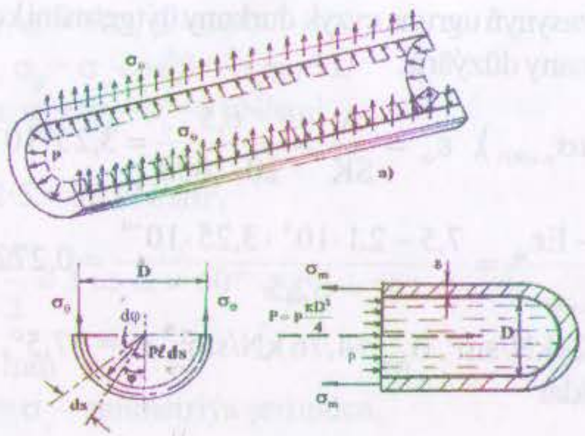
$$\tau_{\alpha(max)} = \frac{\sigma_1 - \sigma_2}{2} \sin 90° = 1\text{kN/sm}^2.$$

2.12. σ_1=8,08 kN/sm², σ_2=4,04 kN/sm², p =0,808 kN/sm².

Belleýäris: σ_θ – töwerekleýin dartgynlylyk, σ_m – meridional dartgynlylyk

Hemme güýçleri σ_θ ugruna proýektirläp alarys:

$$2\sigma_\theta \ell\delta = 2\int_0^{\pi} p\ell \frac{D}{2} \cos\varphi d\varphi \Rightarrow \sigma_\theta = \frac{pD}{2\delta}$$



2.12-nji surat

σ_m ugruna proýektirläp alarys: $\sigma_m \pi D\delta = p\frac{\pi D^2}{4} \Rightarrow \sigma_m = \frac{pD}{4\delta}$

onda $\sigma_1 = \sigma_\theta = \frac{pD}{2\delta}$, $\sigma_2 = \sigma_m = \frac{pD}{4\delta}$, $\sigma_3 = 0$.

σ_1 we σ_2 Gukuň baýlaşdyrylan kanuny esasynda tapýarys

$$\varepsilon_1 = \frac{1}{E}(\sigma_1 - \mu\sigma_2), \quad \varepsilon_2 = \frac{1}{E}(\sigma_2 - \mu\sigma_1).$$

Bu aňlatmalardan: $\sigma_1 = \frac{E(\varepsilon_1 + \mu\varepsilon_2)}{1-\mu^2} = 8{,}08 kN/sm^2$,

$$\sigma_2 = \frac{E(\varepsilon_2 + \mu\varepsilon_1)}{1-\mu^2} = 4{,}04 kN/sm^2.$$

Onda $p = \frac{\sigma_1 \cdot 2\delta}{D} = 0{,}808 kN/sm^2$.

2.13. Meseläniň şertine görä $\sigma_x = \sigma_y = \sigma$ we süýnme iki tarapa hem birmeňzeş bolýar

$$\Delta b_x = \Delta b_y = \varepsilon b = \frac{b}{E}(\sigma_x - \mu\sigma_y) = \frac{\sigma b}{E}(1-\mu) \qquad (1)$$

Maýyşgaklyk moduly $E = \frac{\sigma_y}{\varepsilon} = \frac{\sigma \cdot b}{\Delta b}$ (2)

(2) aňlatmany (1) aňlatma goýup alarys:

$\Delta b_x = \Delta b_y = \Delta b(1-\mu) = 0{,}56$ mm.

Ikinji ýagdaýda σ_x gysýan dartgynlylyk bolany üçin, diňe alamaty üýtgeýär we (1) aňlatmany ulanyp alarys.

$\Delta b_y = \Delta b(1+\mu) = 1{,}04$ mm (süýnme),

$\Delta b_x = -\Delta b(1+\mu) = -1{,}04$ mm (gysylma).

2.14. $\tau_{zy} = \frac{P}{A}\operatorname{tg}\alpha$; $\sigma_z = \frac{-P}{A}\operatorname{tg}^2\alpha$.

III bap

Süýşme we towlanma

3.1. Dört berçin.

Kesme şertinden berçinleriň sany

$$n \geq \frac{4P}{\pi d^2 \cdot [\tau] \cdot m} = \frac{4 \cdot 180}{3{,}14 \cdot 2^2 \cdot 10 \cdot 2} = 2{,}86 \approx 3$$

Ýemşerme şertinden

$$n \geq \frac{P}{d \cdot \delta [\sigma]_{ý}} = \frac{180}{2 \cdot 1 \cdot 28} = 3{,}2 \approx 4,$$

n = 4 kabul edýäris.

3.2. τ_k=9,55kN/sm², $\sigma_ý$=25N/sm², σ_u=9,09kN/sm².

$$\tau_k = \frac{4P}{n \cdot \pi d^2 \cdot m} = \frac{4 \cdot 120}{2 \cdot 3{,}14 \cdot 2^2 \cdot 2} = 9{,}55 kN/sm^2,$$

bu ýerde n=2–berçinleriň sany, m=2–kesme sany

$$\sigma_ý = \frac{P}{n \cdot \delta \cdot d} = \frac{120}{2 \cdot 1{,}2 \cdot 2} = 25 kN/sm^2,$$

Listiň dartgynlylygy

$$\sigma_ł = \frac{P}{(b \cdot \delta - 2d \cdot \delta)} = \frac{120}{(15-4) \cdot 1{,}2} = 9{,}09 kN/sm^2.$$

Urnanyň dartgynlylygy

$$\sigma_u = \frac{P}{(b - 2d) \cdot 2 \cdot \delta_1} = \frac{120}{(15 - 2 \cdot 2) \cdot 2 \cdot 0{,}6} = 9{,}09 kN/sm^2.$$

3.3. P=250 kN.

$$P_k \leq \frac{n \cdot \pi d^2 \cdot m[\tau]_k}{4} = \frac{3 \cdot 3{,}14 \cdot 2{,}6^2 \cdot 2 \cdot 10}{4} = 318{,}4 kN$$

$P_ý \leq \delta d[\sigma_ý] \cdot n = 2 \cdot 2{,}6 \cdot 28 \cdot 3 = 436{,}8 kN,$

$P_I \leq (b–d)\,\delta\,[\sigma]_s = (13–2{,}6) \cdot 2 \cdot 16 = 364{,}8 kN,$

$P_{II} \leq (b–n \cdot d)\,\delta\,[\sigma]_s = (13–2 \cdot 2{,}6) \cdot 2 \cdot 16 = 249{,}6 kN.$

3.4. n=4, d=1 sm.

d=2t=1 sm kabul edýäris.

Kesmä berklik şertinden

$$n \geq \frac{4P}{\pi d^2 [\tau]_k} = \frac{4 \cdot 30}{3{,}14 \cdot 1^2 \cdot 10} \geq 3{,}8,$$

Ýemşermä berklik şertinden

$$n \geq \frac{P}{dt[\sigma]_ý} = \frac{30}{1 \cdot 0{,}5 \cdot 26} \geq 2{,}3,$$

n =4 berçin kabul edýäris.

Zolagyň gowşak kesiginde listiň üzülmä berkligini barlaýarys,

$$\sigma_{uz} = \frac{P}{(b-d) \cdot t} = \frac{30}{(5-1) \cdot 0{,}5} = 15 < 16 kN/sm^2.$$

3.5. d =1,6 sm, n =4 (bir tarapynda), ℓ= 22sm. Kesmä we ýemşermä berklik şertinden berçinleriň sanyny tapýarys (d =2t kabul edýäris).

$$n_k = \frac{4P}{[\tau]_k \cdot \pi d^2} = \frac{4 \cdot 30}{10 \cdot 3{,}14 \cdot 1{,}6^2} = 3{,}8 \approx 4$$

$$n_{ýem} = \frac{P}{d \cdot \delta [\sigma]_ý} = \frac{80}{1{,}6 \cdot 0{,}8 \cdot 26} = 2{,}4$$

n =4 berçin kabul edýäris.

3.6. τ_k=7,17kN/sm², $\sigma_ý$=11,25N/sm², σ_s=4,09kN/sm².

$$P = \frac{q \cdot Da}{2} = \frac{4 \cdot 150 \cdot 7{,}5}{2} = 2250 kg = 22{,}5 kN.$$

Gazandan iki berçinlemäniň ädimine deň bolan elementi kesip alýarys (surata seret). Dartgynlylyklary kesgitleýäris:

$$\tau_k = \frac{4P}{\pi d^2} = \frac{4 \cdot 22{,}5}{3{,}14 \cdot 2^2} = 7{,}17 kN/sm^2,$$

$$\sigma_{ý} = \frac{P}{dt} = \frac{22,5}{2 \cdot 1} = 11,25 kN/sm^2,$$

$$\sigma_s = \frac{P}{(a-d)t} = \frac{22,5}{(7,5-2) \cdot 1} = 4,09 kN/sm^2.$$

Kesilmä hasap dartgynlylyk rugsat edilýän dartgynlylyga iň golaýy şonuň üçin hem rugsat edilýän basyşy galtaşma dartgynlylygyň üstünden kesgitleýäris. τ basyşa göni proporsional, onda rugsat edilýän basyş

$$[q] = q\frac{[\tau]_k}{\tau_k} = 4 \cdot \frac{7,2}{7,17} = 4,02 atm.$$

3.7. P=30,8 kN.

Turbanyň berklik şertinden syndyrma güýjüň ululygyny kesgitleýäris.

$$P_s = [\sigma]_s \cdot \left[\frac{\pi}{4}(D^2 - d^2) - d_b \cdot t \cdot n\right] = 40\left[\frac{3,14}{4}(3^2 - 2,8^2) - 0,35 \cdot 0,1 \cdot 4\right] = 30,8 kN$$

Berçinlemäniň berklik şertlerinden syndyrma güýjüň ululygyny kesgitleýäris:

$$P_k = \frac{\pi d_e^2}{4}[\tau]_k \cdot n = \frac{3,14 \cdot 0,35^2}{4} \cdot 22 \cdot 20 = 42,25 kN.$$

$P_{ý} = dt[\sigma]_{ý} \cdot n = 0,35 \cdot 0,1 \cdot 52 \cdot 20 = 36,4 kN.$

Kabul edýäris P_s=30,8 kN.

3.8. τ =5,57kN/sm², $\sigma_{ý}$=10,93kN/sm².

Galtaşma dartgynlylyk

$$\tau = \frac{4P}{\pi d^2 \cdot n} = \frac{4 \cdot 52,5}{3,14 \cdot 2^2 \cdot 3} = 5,57 kN/sm^2.$$

Normal dartgynlylyk

$$\sigma_{ý} = \frac{P}{dt \cdot n} = \frac{52,5}{2 \cdot 0,8 \cdot 3} = 10,93 kN/sm^2.$$

3.9 . n=36 berçin.

Kesilmä berklik şertinden

$$n = \frac{4P}{\pi d^2 \cdot [\tau]_k} = \frac{4 \cdot 785}{3,14 \cdot 2^2 \cdot 7} = 35,6 \approx 36 sany,$$

Bu ýerde $P = q\frac{\pi D^2}{4} = 10 \cdot 0,785 \cdot 10^4 = 785 kN.$

Ýenjilme şertinden

$$n = \frac{P}{dt[\sigma]_{ý}} = \frac{785}{2 \cdot 1 \cdot 16} = 24,5 \approx 25 sany.$$

Kabul edýäris n=36 berçin.

3.10. τ =7,64kN/sm², $\sigma_{ý}$=17,14kN/sm².

$$\tau = \frac{4P}{\pi d^2 \cdot n} = 7,64 kN/sm^2,$$

$$\sigma_{ý} = \frac{P}{d \cdot t_{min} \cdot n} = 17,14 kN/sm^2.$$

3.11. τ_k =2,29kN/sm².

$$\varepsilon_m = \varepsilon_p (1) \Rightarrow \alpha_m \Delta t - \frac{N}{E_m A_m} = \alpha_p \Delta t + \frac{N}{E_p A_p}, \quad (2)$$

$$A_p = \frac{\pi}{4}(D^2 - d^2) = \frac{3,14}{4}(6^2 - 4^2) = 15,7 sm^2,$$

$$A_m = \frac{\pi d^2}{4} = \frac{3,14 \cdot 4^2}{4} = 12,56 sm^2.$$

(2) aňlatmadan

$$N = \frac{\Delta t \cdot A_m E_p A_p (\alpha_m \alpha_p)}{2A_p + A_m} = 14,35 kN,$$

$$\tau = \frac{4P}{\pi d^2 \cdot m} = \frac{4 \cdot 14,35}{3,14 \cdot 2^2 \cdot 2} = 2,29 kN/sm^2,$$

m =2 – kesme meýdanynyň sany.

3.12. d=5 sm.

Kesilme şertinden

$$d=\sqrt{\frac{4P}{\pi[\tau]\cdot n}}=\sqrt{\frac{4\cdot 200}{3{,}14\cdot 8\cdot 2}}=3{,}99\text{sm}.$$

Ýenjilme şertinden

$$d=\frac{P}{\tau[\sigma]}=\frac{200}{2\cdot 20}=5\text{sm}.$$

Kabul edýäris d=5 sm.

3.13. d_1=18,7 sm, τ=5 kN/sm².

Bolty gysýan güýjüň ululygy

$$P=\sigma_g\cdot A_b=10\cdot\frac{3{,}14\cdot 10^2}{4}=785\text{kN}.$$

Ýemşerme dartgynlylykdan

$$\sigma_{ý}=\frac{4P}{\pi\left(d_1-d^2\right)},$$

Bu ýerden $d_1=\sqrt{\frac{4P+\pi d^2\sigma_{ý}}{\pi\sigma_{ý}}}=\sqrt{\frac{4\cdot 785+3{,}14\cdot 10^2\cdot 4}{3{,}14\cdot 4}}=18{,}7\text{sm}.$

Galtaşma dartgynlylyk

$$\tau=\frac{P}{\pi dt}=\frac{785}{3{,}14\cdot 10\cdot 5}=5\text{kN/sm}^2.$$

3.14. P=44,8 kN, σ=0,56 kN/sm².

Üzüji güýç

P=[σ]·A=5,6·2·4=44,8kN/sm².

Nusganyň kellesinde döreýän owranma dartgynlylygy

$$\sigma=\frac{P}{A_{öwr}}=\frac{44{,}8}{2\cdot 10\cdot 4}=0{,}56\text{kN/sm}^2.$$

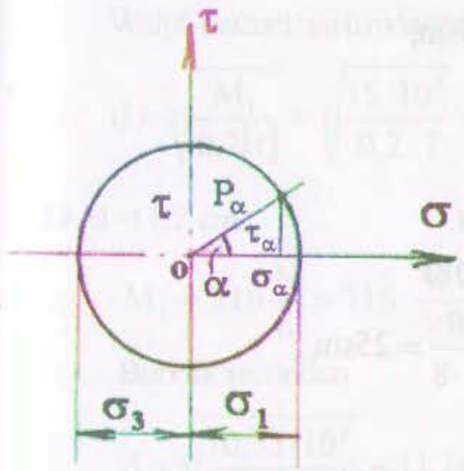
3.15. h=6 sm, ℓ=36 sm.

Ýenjilmä berklik şertinden

$$t\ge\frac{P\cos\alpha}{b[\sigma]_{ý}}\ge\frac{20\cdot 0{,}866}{6\cdot 5}\ge 5{,}77\text{sm}\cong 6\text{sm}.$$

Owranma berklik şertinden

$$\ell\ge\frac{N\cos\alpha}{b[\tau]}\ge\frac{20\cdot 0{,}866}{6\cdot 0{,}08}=36\text{sm}.$$



3.16-njy surat

3.16. σ_α=4,33kN/sm², τ_α=2,5kN/sm², p_α=5kN/sm².

Çyzgydan

τ_α=2,5kN/sm², σ_α=4,33kN/sm².

$$p_\alpha=\sqrt{\sigma_\alpha^2+\tau_\alpha^2}=\sqrt{4{,}33^2+2{,}5^2}=5\text{kN/sm}^2$$

3.17. $\Delta S=0{,}25$ mm, $\gamma=0{,}00125$.

Süýşmede Gukuň kanunyny ulanyp alarys:

$$\gamma=\frac{\tau}{G}=\frac{10}{8\cdot 10^3}=0{,}00125.$$

Absolýut süýşme $\Delta S=\gamma\cdot S=0{,}00125\cdot 200=0{,}25\text{mm}$.

3.18. $\gamma=0{,}00065$rad.

Süýşme burçuň üýtgemeginiň ululygy

$$\gamma=\frac{\sigma}{E}(1+\mu)\sin 2\alpha=\frac{12}{2\cdot 10^4}(1+0{,}25)\cdot\sin 60^\circ=0{,}00065\text{rad}.$$

3.19. $\ell_1=9{,}88$sm, $\ell_2=3{,}92$sm.

Tikiniň umumy uzynlygy

$$\ell = \ell_1 + \ell_2 = \frac{P}{0{,}7t[\tau_e]} = \frac{6^2}{0{,}7 \cdot 0{,}8 \cdot 8} = 13{,}8\text{sm}.$$

Başga tarapdan

$$\frac{\ell_2}{\ell_1} = \frac{z_o}{h - z_o} = \frac{2{,}27}{8 - 2{,}27} = 0{,}396,\ \ell_2 = 0{,}396\ell_1,\ z_o = 2{,}27\text{sm}$$ – tablisadan alýarys

onda $\ell_1 + 0{,}396\ell_1 = 13{,}8 \Rightarrow \ell_1 = 9{,}88\text{sm}$,

$\ell_2 = 0{,}396 \cdot 9{,}88 = 3{,}92\text{sm}$.

3.20. x =7,5 sm.

Liste rugsat edilýän güýç

$P \le [\sigma] \cdot A_t = 14 \cdot 10 \cdot 1 = 140\text{kN}$.

Kebşirleme tikiniň umumy uzynlygy

$$\ell = 2x + 10 = \frac{P}{0{,}7 \cdot 1 \cdot [\tau]} = \frac{140}{0{,}7 \cdot 8} = 25\text{sm},$$

Bu ýerden x =7,5 sm .

3.21. b = 7,2 sm, σ_{tik}=7,7kN/sm², τ_{tik}=7,7kN/sm².

Zolagyň zerur bolan inini süýnmä berklik şertinden tapýarys:

$$b \ge \frac{P}{t[\sigma]} = \frac{100}{1 \cdot 14} \Rightarrow b \ge 7{,}14 \approx 7{,}2\text{sm} \cdot$$

Gyýa tikiniň uzynlygy

$$\ell_{tik} = \frac{b}{\sin 45^\circ} - 1 = \frac{7{,}2}{0{,}707} - 1 = 9{,}2\text{sm}.$$

Tikiniň berkligini barlaýarys

$$\sigma_{tik} = \frac{10}{9{,}2 \cdot 1} \cdot 0{,}707 = 0{,}77 < 10\text{kN/sm}^2,$$

$$\tau_{tik} = \frac{10}{9{,}2 \cdot 1} \cdot 0{,}707 = 0{,}77 < 8\text{kN/sm}^2.$$

3.22. Berklik şerti kanagatlandyrylýar. Şwelleriň üzülmä berkligini barlaýarys.

$$\sigma_s = \frac{P}{A} = \frac{800}{55{,}9} = 14{,}3 < 16\text{kN/sm}^2,$$

Tikiniň kesilmä berkligini barlaýarys.

$$\tau_k = \frac{P}{1{,}4 \cdot 60 + 2 \cdot 20} = 6{,}45 < 8\text{kN/sm}^2.$$

3.23. d =10,3 sm

Walyň diametrini towlanma berklik şertinden tapýarys:

$$d = \sqrt[3]{\frac{M_t}{0{,}2[\tau]}} = \sqrt[3]{\frac{15 \cdot 10^2}{0{,}2 \cdot 7}} = 10{,}3\text{sm}.$$

3.24. d=11,2 sm.

$$M_t = 716\frac{N}{n} = 716 \cdot \frac{450}{300} = 1075\text{kgm} = 10{,}75\text{kNm},$$

Berklik şertinden

$$d = \sqrt[3]{\frac{10{,}75 \cdot 10^2}{0{,}2 \cdot 4}} = 11{,}2\text{sm}.$$

Gatylyk şertinden

$$d = \sqrt[4]{\frac{M_t \ell}{G \cdot 0{,}1 \cdot [\varphi]}} = \sqrt[4]{\frac{10{,}75 \cdot 10^2 \cdot 2 \cdot 10^2}{8 \cdot 10^3 \cdot 0{,}1 \cdot 0{,}01744}} = 11{,}54\text{sm}.$$

d=11,2 sm kabul edýäris.

3.25. $Q_p = 1{,}75Q_a$.

$$\varphi_p = \varphi_a \Rightarrow \frac{1}{G_p I_p} = \frac{1}{G_a I_a},\ Q_p = \gamma_p A_p \ell_p,\ Q_a = \gamma_a A_a \ell_a,$$

$$\frac{Q_p}{Q_a} = \frac{d_p^2 \gamma_p}{d_a^2 \gamma_a};\ G_p 0{,}1d_p^4 = G_a 0{,}1d_a^4 \Rightarrow \frac{d_p}{d_a} = \sqrt[4]{\frac{G_a}{G_p}};$$

$$\frac{Q_p}{Q_a}=\sqrt{\frac{G_a}{G_p}}\cdot\frac{\gamma_p}{\gamma_a}=\sqrt{\frac{2{,}7\cdot10^3}{8\cdot10^3}}\cdot\frac{78{,}5}{26}=1{,}75.$$

3.26. Eger $M_t > 23{,}6$ kNm – rugsat edilýän dartgynlylyk boýunça,
$M_t < 23{,}6$ kNm – rugsat edilýän towlanma burçy boýunça.

$$\tau=\frac{M_t}{I}\cdot\frac{d}{2}\le[\tau]\Rightarrow M_t=\frac{[\tau]\cdot I\cdot 2}{d}$$ – berklik şertinden

$$M_t=\frac{\varphi GI}{\ell}$$ – gatylyk şertinden

$$\frac{\varphi GI}{\ell}=\frac{[\tau]I\cdot 2}{d}\Rightarrow d=11{,}46\text{sm}.$$

$$M_t\ge\frac{[\tau]\cdot\pi d^4\cdot 2}{32\cdot d}=8\cdot0{,}196\cdot d^3=2{,}6\text{kNm}.$$

3.27. $\tau = 4{,}66\text{kN/sm}^2$.

$$\tau=\frac{\varphi\pi Gd}{180\cdot\ell\cdot 2}=\frac{4\cdot3{,}14\cdot8\cdot10^3\cdot10}{180\cdot600\cdot2}=4{,}66\text{kN/sm}^2.$$

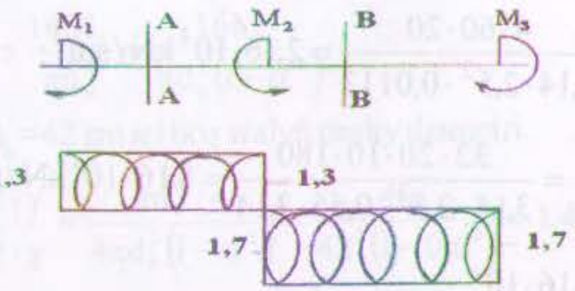
3.28. $\tau = 6\text{kN/sm}^2$.

$$\tau=\frac{M_t}{W_p}\Rightarrow M_t=71620\frac{N}{n};$$

$$W_p=\frac{\pi d^3}{16}=\frac{\pi}{16}\cdot2{,}5^3\cdot40\cdot\frac{N}{n}=119{,}3\frac{N}{n};$$

$$\tau=\frac{71620\dfrac{N}{n}}{119{,}3\dfrac{N}{n}}=600\text{kg/sm}^2=6\text{kN/sm}^2$$

3.29. $\tau_A = 5{,}3\text{kN/sm}^2$, $\tau_B = 2{,}05\text{kN/sm}^2$.

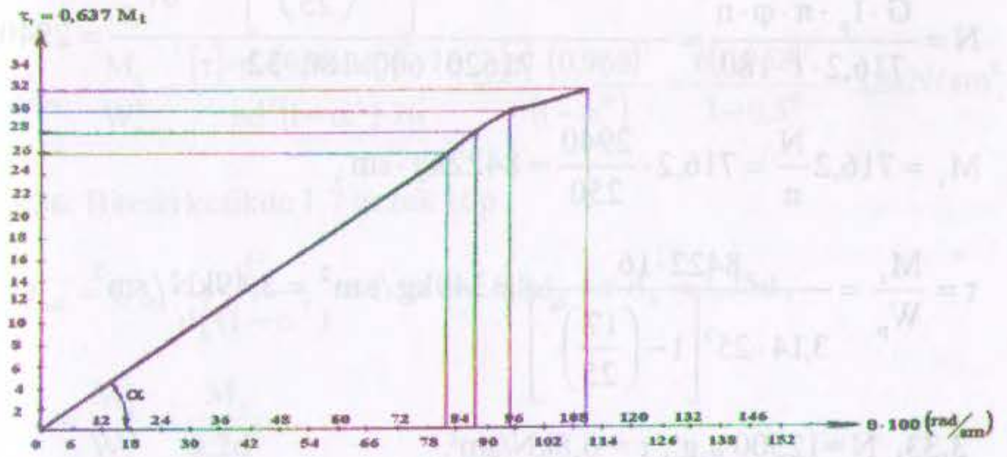


3.29-njy surat

$M_{AA}=1{,}3$ kN m $\qquad$ $M_{BB}=1{,}7$ kN m

$$\tau_{AA}=\frac{16M_{AA}}{\pi d_A^3}=5{,}3\text{kN/sm}^2,\quad \tau_{BB}=\frac{16M_{BB}}{\pi d_B^3}=2{,}05\text{kN/sm}^2.$$

3.30. $\tau_t = 063M_t$, $\tau_t=\dfrac{M_t}{W_p}=\dfrac{16M_t}{\pi d^3}=\dfrac{16}{3{,}14\cdot8}M_t=0{,}637M_t$.



3.30-njy surat

$$\theta=\frac{\varphi}{\ell}=\frac{1}{20}\cdot\varphi=0{,}05\text{rad/sm};$$

$$G=\frac{\tau}{\gamma}=\text{tg}\alpha;\ \gamma=\frac{d\varphi}{dx}\rho.$$

3.31. $E = 2{,}16\cdot10^4$ kN/sm²; $G = 8{,}16\cdot10^3$ kN/sm²; $\mu = 0{,}32$.

$$E=\frac{4P\ell}{\pi d^2\cdot\Delta\ell}=\frac{4\cdot60\cdot20}{3{,}14\cdot2{,}5^2\cdot0{,}0113}=2{,}16\cdot10^4\,kN/sm^2;$$

$$G=\frac{32M_t\ell\cdot180}{\pi d^4\cdot\varphi\pi}=\frac{32\cdot20\cdot10\cdot180}{3{,}14\cdot2{,}5^4\cdot0{,}55\cdot3{,}14}=8{,}16\cdot10^3\,kN/sm^2;$$

$$\mu=\frac{E}{2G}-1=\frac{2{,}16\cdot10^4}{2\cdot8{,}16\cdot10^3}-1=0{,}32.$$

3.32. N = 2940 a.g., τ = 3,49kN/sm².

$$N=\frac{M_t n}{7{,}162};\ \varphi=\frac{M_t\ell\cdot180}{G\cdot I_p\cdot\pi}(grad);\ M_t=\frac{G\cdot I_p\cdot\pi\cdot\varphi}{\ell\cdot180};$$

$$N=\frac{G\cdot I_p\cdot\pi\cdot\varphi\cdot n}{716{,}2\cdot\ell\cdot180}=\frac{8\cdot10^5\cdot3{,}14^2\cdot25^4\left[1-\left(\frac{17}{25}\right)^4\right]\cdot1{,}2\cdot250}{71620\cdot600\cdot180\cdot32}=2940a.g.$$

$$M_t=716{,}2\frac{N}{n}=716{,}2\cdot\frac{2940}{250}=8422kg\cdot sm,$$

$$\tau=\frac{M_t}{W_p}=\frac{8422\cdot16}{3{,}14\cdot25^3\left[1-\left(\frac{17}{25}\right)^4\right]}=349kg/sm^2=3{,}49kN/sm^2$$

3.33. N =12500 a.g., τ = 6,8kN/sm².

$\tau_{max}=2\varepsilon G=2\cdot10^4\cdot4{,}25\cdot8\cdot10^3=6{,}8kN/sm^2$

$$N=\frac{\tau_{max}\cdot W_p\cdot n}{71620}=\frac{680\cdot3{,}14\cdot40^3\cdot\left[1-\left(\frac{24}{40}\right)^4\right]\cdot120}{71620\cdot16}=12500a\cdot g.$$

3.34 d_h =42 sm; Q_b/Q_h = 1,41.

$$[\tau]_b=[\tau]_h\Rightarrow\frac{16M_t}{\pi d_b^3}=\frac{16M_t}{\pi d_h^3\left(1-\alpha^4\right)},$$

Bu ýerden d_h =42 sm içi boş walyň daşky diametri.

$$\frac{Q_b}{Q_h}=\frac{A_b\cdot\ell\cdot\gamma}{A_h\cdot\ell\cdot\gamma}=\frac{\pi d^2\cdot4}{4\pi d_h^2\left(1-\alpha^2\right)}=\frac{40^2}{42^2\left(1-0{,}6^2\right)}=1{,}41.$$

3.35. $\tau_{max}^h=5{,}8kN/sm^2$.

$$Q_h=0{,}8Q_b\Rightarrow\frac{Q_b}{Q_h}=1{,}25=\frac{d^2}{d_h^2\left(1-\alpha^2\right)},$$

$$d=d_h\sqrt{\left(1-\alpha^2\right)\cdot1{,}25}=0{,}968d_h,$$

$$M_t=[\tau]\frac{\pi d^3}{16},$$

$$\tau_{mzx}^h=\frac{M_t}{W_p^h}=\frac{[\tau]\cdot\pi\cdot(0{,}968d_h)^3\cdot16}{\pi d^3\left(1-\alpha^4\right)\cdot16}=\frac{[\tau]\cdot(0{,}968)^3}{\left(1-\alpha^4\right)}=\frac{6(0{,}968)^3}{1-0{,}5^4}=5{,}8kN/sm^2.$$

3.36. Bitewi kesikde 1,7 gezek köp.

$$Q_{hal}=Q_{bütin}\frac{d^2}{d_h^2(1-\alpha^2)}=1\Rightarrow d=0{,}8d_h\Rightarrow d_h=1{,}25d,$$

$$\tau_b=\frac{M_t}{W_p^b}=\frac{M_t}{0{,}2d^3},$$

$$\tau_h=\frac{M_t}{0{,}2d_h^3\left(1-\alpha^4\right)}=\frac{M_t}{0{,}2(1{,}25d)^3\left(1-0{,}6^4\right)}=\frac{M_t}{0{,}2\cdot1{,}7d^3},$$

$$\frac{\tau_b}{\tau_h}=\frac{M_t\cdot0{,}2\cdot1{,}7d^3}{0{,}2d^3M_t}=1{,}7gezek.$$

3.37. D=9,04 sm, d=7,24 sm.

$$W_p = \frac{\pi D^3}{16}\left(1-\alpha^4\right),\quad I_p = \frac{\pi}{32}\left(1-\alpha^4\right) \Rightarrow \frac{I_p}{W_p} = \frac{D}{2}.$$

Berklik şertinden

$$W_p = \frac{M_t}{[\tau]}.$$

Gatylyk şertinden

$$I_p = \frac{M_t \ell \cdot 180}{G\varphi \cdot \pi},$$

onda $\frac{I_p}{W_p} = \frac{180\ell[\tau]}{G\varphi\pi} = \frac{D}{2}$,

bu ýerden $D = \frac{2 \cdot 180 \cdot \ell[\tau]}{G\varphi\pi} = 9{,}04\text{sm}$

Başga tarapdan

$$W_p = \frac{M_t}{[\tau]} = \frac{\pi D^3}{16}\left(1-\alpha^4\right),$$

bu ýerden $\alpha = 0{,}8$.

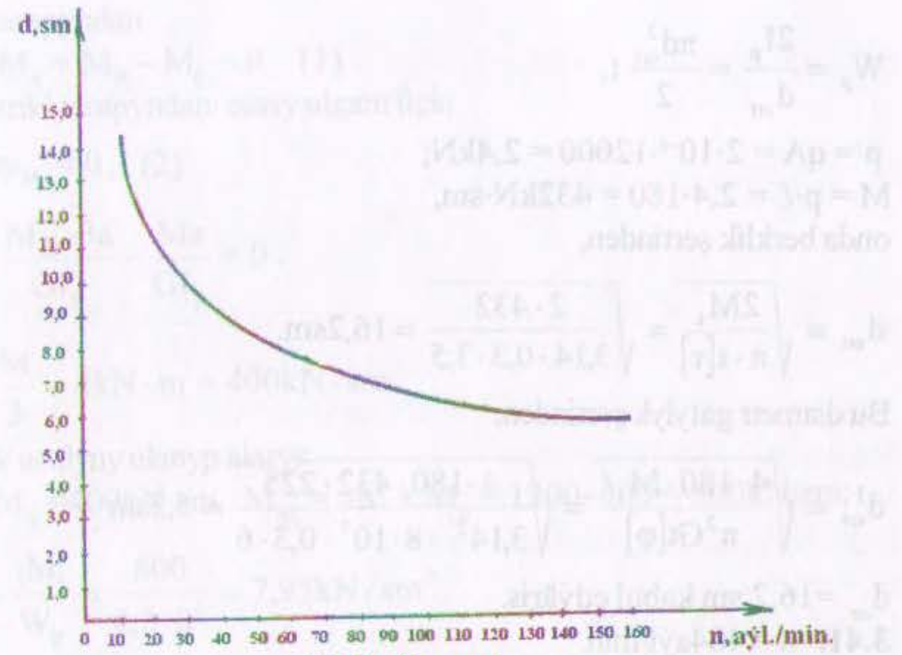
Onda $d = \alpha D = 0{,}8 \cdot 9{,}04 \approx 7{,}24\text{sm}$.

3.38. $d = \frac{31{,}2}{\sqrt[3]{n}}$.

Berklik şertinden

$$d = \sqrt{\frac{16 \cdot M_t}{\pi[\tau]}},\quad M_t = 71620\frac{N}{n},$$

onda $d = \sqrt[3]{\frac{16 \cdot 71620 \cdot N}{\pi n[\tau]}} = \sqrt[3]{\frac{16 \cdot 71620 \cdot 50}{3{,}14 \cdot n \cdot 600}} = \frac{31{,}2}{\sqrt[3]{n}}$.



3.38-nji surat

3.39. $\varphi = 0{,}016\text{rad}$, $t = 0{,}318$ sm.

Ýuka diwarly sterženlerde galtaşma dartgynlylyk, diwaryň galyňlygyndaky orta bahasyna deň diýip kabul edýäris:

$$\tau = \frac{M_t d_{ort}}{2I_p}$$

$$I_p = \int_A \rho^2 dA = \pi d_{ort} \cdot t \cdot \frac{d_{ort}^2}{4} = \frac{\pi d_{ort}^3}{4} \cdot t,$$

onda $\tau = \frac{2M_t}{\pi d_{ort}^2 \cdot t} \le [\tau]$

bu ýerden $t = \frac{2M_t}{\pi d_{ort}^2[\tau]} = \frac{2 \cdot 625}{\pi \cdot 12{,}5^2 \cdot 8} = \frac{1}{\pi} = 0{,}318\text{sm}$

Towlanma burçuny adaty formuladan tapýarys:

$$\varphi = \frac{M_t \ell}{GI_p} = \frac{4M_t \ell}{G\pi d_{ort}^3 \cdot t} = \frac{4 \cdot 625 \cdot 100}{810^3 \cdot 3{,}14 \cdot 12{,}5^3 \cdot 0{,}318} = 0{,}016\text{rad}.$$

3.40. $d_{ort} = 16{,}2$sm.

$$W_p = \frac{2I_p}{d_{ort}} = \frac{\pi d_{ort}^2}{2} t,$$

$p = qA = 2\cdot10^{-4}\cdot12000 = 2{,}4\text{kN};$
$M = p\cdot\ell = 2{,}4\cdot180 = 432\text{kN}\cdot\text{sm},$
onda berklik şertinden,

$$d_{ort} = \sqrt{\frac{2M_t}{\pi\cdot t[\tau]}} = \sqrt{\frac{2\cdot432}{3{,}14\cdot0{,}3\cdot3{,}5}} = 16{,}2\text{sm}.$$

Bu diametr gatylyk şertinden,

$$d_{ort}^1 = \sqrt[3]{\frac{4\cdot180\cdot M_t\ell}{\pi^2 Gt[\varphi]}} = \sqrt[3]{\frac{4\cdot180\cdot432\cdot225}{3{,}14^2\cdot8\cdot10^3\cdot0{,}3\cdot6}} = 5{,}3\text{sm},$$

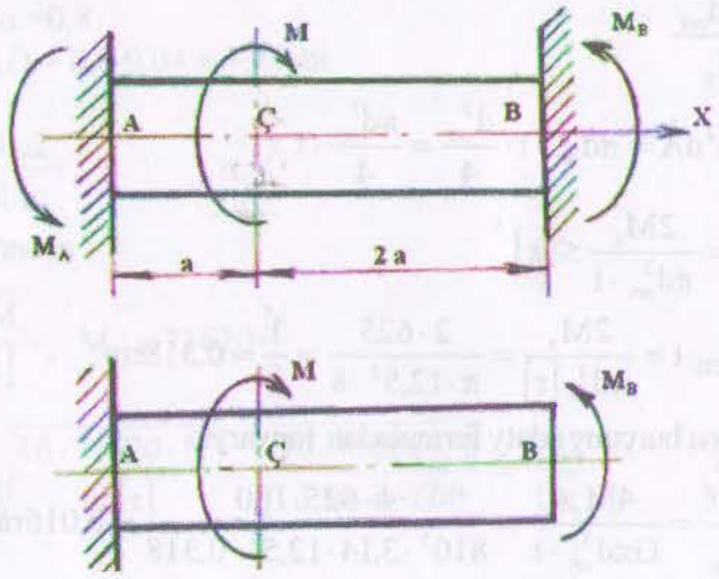
d_{ort} =16,2 sm kabul edýäris.

3.41. n = 404aýl/min.

Gatylyk şertinden walyň aýlaw tizligini tapýarys:

$$n = \frac{71620\cdot N\cdot4\cdot180\cdot\ell}{Gt\pi^2 d_{ort}^3[\varphi]} = \frac{71620\cdot50\cdot4\cdot180\cdot370}{8\cdot10^3\cdot0{,}3\cdot3{,}14^2\cdot10^3\cdot1} = 404\text{aýl/min}$$

3.42. $\tau = 7{,}95\text{kN/sm}^2$.



3.42-nji surat

Statiki tarapyndan

$$\Sigma M_x = M_A + M_B - M_Ç = 0 \quad (1)$$

Geometriki tarapyndan esasy ulgam üçin

$$\varphi_{M_B} + \varphi_M = 0, \quad (2)$$

$$\varphi_{M_B} = \frac{M_B\cdot3a}{GI_p} - \frac{Ma}{GI_p} = 0;$$

$$M_B = \frac{M}{3} = 4\text{kN}\cdot\text{m} = 400\text{kN}\cdot\text{sm}.$$

Kesmek usulyny ulanyp alarys:

$M_{ÇB} = M_B$ =400kN·sm, $M_{AÇ} = -M + M_B$ = 1200–400=–800kN·sm;

$$\tau_{max} = \frac{|M|}{W_p} = \frac{800}{0{,}2\cdot8^3} = 7{,}95\text{kN/sm}^2.$$

3.43. $\tau_p = 2{,}5\text{kN/sm}^2$, $\tau_m = 1{,}15\text{kN/sm}^2$, $M_p = 0{,}718\text{kNm}$, $M_m = 0{,}282\text{kNm}$, $\varphi = 1{,}353°$.

Statikanyň deňlemesi: $M_p + M_m = M$ (1)

Durkuny üýtgetmäniň deňlemesi: $\theta_m = \theta_p$ (2)

Gukuň kanuny esasynda:

$$\frac{M_m}{G_m I_p^m} = \frac{M_p}{G_p I_p^p} \Rightarrow M_p = \frac{G_p I_p^p}{G_m I_p^m}\cdot M_m \quad (3)$$

(3) we (1) aňlatmalardan $M_m = \dfrac{M}{1 + \dfrac{G_p I_p^p}{G_m I_p^m}} = 0{,}282\text{kN}\cdot\text{m}$ onda

$$M_p = M - M_m = 0{,}718\text{kNm}$$

$$I_p^p = 0{,}1\cdot d_p^4\left(1-\alpha_p^4\right) = 114\text{sm}^4, \quad d_p = 7{,}5 + 2t, \quad \alpha_p = \frac{7{,}5}{d_p};$$

$$I_p^m = 0{,}1\cdot d_m^4\left(1-\alpha_m^4\right)=90sm^4,\quad d_m=7{,}5,\quad \alpha_m=\frac{d_m-7{,}5}{d_m};$$

$$\tau_m=\frac{M_m}{W_p^m}=1{,}15kN/sm^2,\quad \tau_p=\frac{M_p}{W_p^p}=2{,}5kN/sm^2,$$

$$\varphi=\frac{M_t^p\ell}{G_pI_p}=\frac{71{,}8\cdot 300}{810^3\cdot 114}=0{,}0236rad=0{,}0236\cdot\frac{180}{3{,}14}=1{,}353^\circ.$$

3.44. $\tau_ç = 3{,}07kN/sm^2$, $\tau_s = 3{,}07kN/sm^2$, $\varphi = 0{,}33^\circ$.

Statikanyň adaty deňlemesinden

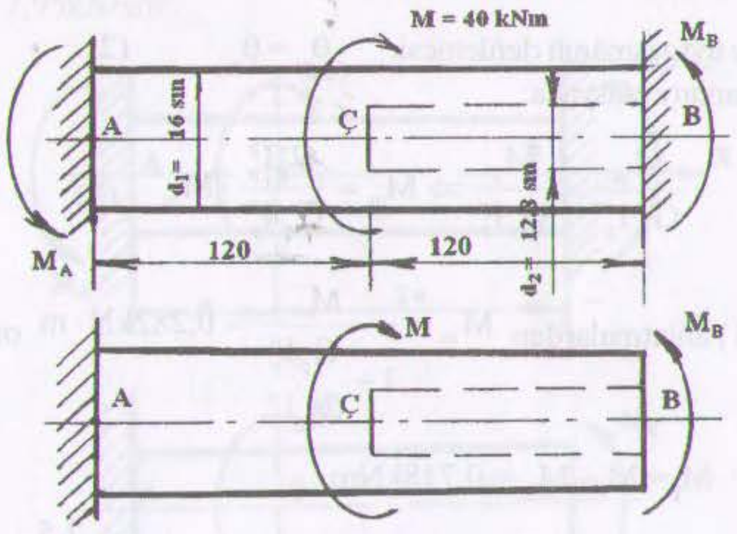
$M_A + M_B = M.$ (1)

Durkuny üýtgetmäniň deňlemesinden

$\varphi_B = \varphi_M + \varphi_{MB} = 0,$

$I_{p1} = 0{,}1'''16^4 = 6553sm^4,$

$$I_{p2}=0{,}1\cdot 16^4\left[1-\left(\frac{12{,}8}{16}\right)^4\right]=3866sm^4.$$



3.44-nji surat

$$\varphi_A=\frac{M\cdot 120}{GI_{p1}}-\frac{M_B\cdot 120}{GI_{p1}}-\frac{M_B\cdot 120}{GI_{p2}}=0;$$

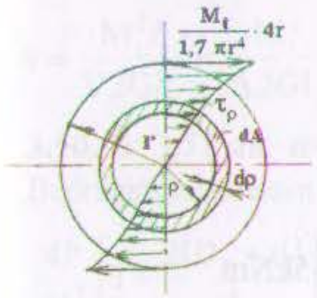
$$M_B = 13{,}84kNm,\ M_A = 25{,}16kNm;$$

$$\tau_ç=\frac{M_A}{I_{p1}}\cdot\frac{d_1}{2}=\frac{2516}{6553}\cdot 8=3{,}07kN/sm^2;$$

$$\tau_s=\frac{M_B}{I_{p2}}\cdot\frac{d_1}{2}=\frac{1484}{3866}\cdot 8=3{,}07kN/sm^2;$$

$$\varphi_ç=\frac{M_A\cdot 120}{GI_{p1}}=\frac{2516\cdot 120}{8\cdot 10^3\cdot 6553}=0{,}0058rad=0{,}33^\circ.$$

3.45. $$\tau=\frac{M_t}{1{,}7\pi r^4}\left(1+\frac{3\rho}{r}\right)\rho.$$



3.45-nji surat

$\gamma_\rho = \gamma\frac{\rho}{r}$ –bu ýerde, γ_ρ–ρ daşlykdaky süýşme burçy,

γ– daşky gatlakdaky süýşme burçy,

onda, $\tau_p = G_p\gamma_p = G\left(1+\frac{3\rho}{r}\cdot\frac{\gamma\rho}{r}\right)$.

Statikanyň deňlemesinden

$$M_t=\int_A^r\tau_p\rho\cdot dA=\int_0^r\tau_p\cdot\rho(2\pi\rho d\rho)=2\pi\int_0^r\tau_p\rho^2 d\rho,$$

τ_p – nyň bahasyny goýup we integrirläp alarys:

$$M_t=\frac{2\pi\gamma G}{r}\int_0^r\left(1+\frac{3\rho}{r}\right)\rho^3 d\rho=\frac{1{,}7\pi\lambda Gr^4}{r},$$

ýa-da $\frac{G\gamma}{r}=\frac{M_t}{1{,}7\pi r^4}$, onda $\tau=\frac{M_t}{1{,}7\pi r^4}\left(1+\frac{3\rho}{r}\right)\rho$ bolar.

3.46. $A = \dfrac{\pi D^3}{32a}$.

$N = E\alpha\Delta tA$, $N_{BD} = N_{AÇ}$.

$M = N_{BD}\cdot a + N_{AÇ}\cdot a = N\cdot 2a$,

$$\tau = \frac{M}{W_p} = \frac{2a\cdot E\alpha\Delta tA\cdot 16}{\pi D^3};\ \tau = \sigma = E\alpha\Delta t,$$

onda $A = \dfrac{\pi D^3}{32a}$.

3.47. $M_t = 2{,}45$ kNm.

$\sigma_1 = -\sigma_2 = \tau$,

$$\varepsilon = \frac{1}{E}(\sigma_1 - \mu\sigma_2) = \frac{\tau}{E}(1+\mu)$$

$E = 2G(1+\mu)$,

onda $\varepsilon = \dfrac{\tau}{2G} \Rightarrow \tau = 2G\varepsilon$.

$$\tau = \frac{M_t}{W_p} = \frac{16M_t}{\pi d^3};\quad \frac{16M_t}{\pi d^3} = 2G\varepsilon,$$

$$M_t = \frac{G\varepsilon\pi d^3}{8} = \frac{8\cdot 10^3\cdot 6{,}5\cdot 10^{-4}\cdot 3{,}14\cdot 5^3}{8} = 2{,}55\text{kNm}$$

$$\tau = \frac{E\cdot\varepsilon}{1+\mu} = \frac{2\cdot 10^4\cdot 6{,}5\cdot 10^{-4}}{1+0{,}3} = 10\text{kN/sm}^2.$$

3.48. $\tau_{max} = 2{,}93\text{kN/sm}^2$, $n = 7$ sarym.

Pružiniň iň uly dartgynlylygy

$$\tau_{max} = \frac{P}{A} + \frac{M_t}{W_p} = \frac{8\rho D}{\pi d^3}\left(1 + \frac{d}{2D}\right) = 2{,}93\text{kN/sm}^2.$$

Pružiniň çökmesi

$$\lambda = \frac{8\rho D^3 n}{Gd^4},$$

Bu ýerden $n = \dfrac{\lambda Gd^4}{8\rho D^3} = 6{,}46 \approx 7$sarym.

3.49. $P = 0{,}0489$ kN, $\lambda = 25{,}46$sm, $a = 23\cdot 10^{-4}\text{kN/sm}^2$.

Pružiniň berklilk şertinden

$$P = \frac{\pi d^3[\tau]}{8D\left(1 + \dfrac{d}{2D}\right)} = 0{,}0489\text{kN}$$

Pružiniň süýnmesi

$$\lambda = \frac{8\rho D^3 n}{Gd^4} = 25{,}46\text{sm}.$$

Durkuny üýtgemäniň iň uly udel potensial energiýasy

$$a = \frac{M_t^2\ell}{V2GI_p} = \frac{M_t^2}{A2GI_p} = \frac{P^2D^2}{4A2GI_p} = 23\cdot 10^{-4}\text{kNsm/sm}^3.$$

3.50. $d = 3{,}51$ sm, $n = 5$ sarym.

Berkligiň deňlemesini ýazýarys:

$$\frac{4P}{\pi d^2}\left[1 + \frac{2(D_0 + d)}{d}\right] \le [\tau].$$

Bu deňlemäni özgerdip, aşakdaky aňlatmany alarys.

$$d^2 = \frac{8\rho D_o}{\pi[\tau]d} + \frac{3\rho}{\pi[\tau]}$$

San bahalaryny goýup alarys:

$$d^2 = \frac{40{,}64}{d} + 0{,}764.$$

Bu deňlemäni seçmek ýoly bilen çözmek amatly bolýar.

Eger: d=4 sm 16>10,92

d=3,6 sm 12,96>12,05

d=3,5 sm 12,25<12,37
d=3,51 sm 12,32≈12,34
d=3,51 sm kabul edýäris.

Sarymyň sany

$$n=\frac{\lambda Gd^4}{8PD_0^3}=\frac{2\cdot 8\cdot 10^3\cdot 3{,}51^4}{8\cdot 6\cdot 21{,}75^2}=4{,}92\approx 5\text{sarym}.$$

3.51. $R_A=0{,}6\text{kN}$, $R_B=1\text{kN}$, $\tau_{max}=6{,}45\text{kN/sm}^2$, $\lambda_c=3{,}265\text{sm}$.

Statikanyň deňlemesi:

$R_A+R_B-P=0$ (1).

Durkuny üýtgetmäniň deňlemesi

$\lambda_1=\lambda_2$ (2)

$$\lambda_1=\frac{8R_AD^3m}{Gd^4},\ \lambda_2=\frac{8R_BD^3n}{Gd^4}.$$

Bu ýerden $R_A=\frac{n}{m}R_B$.

Onda $R_A=0{,}6\text{kN}$, $R_B=1\text{kN}$.

Pružindäki iň uly dartgynlylyk

$$\tau_{max}=\frac{8R_BDk}{\pi d^3}=\frac{8\cdot 1\cdot 24\cdot 1{,}12}{3{,}14\cdot 2{,}2^3}=6{,}45\text{kN/sm}^3.$$

Bu ýerde $k=\dfrac{4\frac{D}{d}+2}{4\frac{D}{d}-3}=1{,}12$.

Ç nokadyň ornuny üýtgetmesi

$$\lambda=\frac{8R_AD^3m}{GD^4}=\frac{8\cdot 0{,}6\cdot 24^3\cdot 10}{8\cdot 10^3\cdot 2{,}24}=3{,}265\text{sm}.$$

3.52. $\tau_{max}=2{,}38\text{kN/sm}^2$, $\lambda=6{,}5\text{sm}$, $U=9{,}7$ joul.

Iň uly galtaşma dartgynlylyk

$$\tau_{max}=\frac{2PR}{\pi r^3}\left(1+\frac{r}{2R}\right)=\frac{2\cdot 0{,}3\cdot 12}{3{,}14\cdot 1^3}\left(1+\frac{1}{2\cdot 12}\right)=2{,}38\text{kN/sm}^2.$$

Pružiniň uzalmasy

$$\lambda=\frac{4PR^3}{Gr^4}=\frac{4\cdot 0{,}3\cdot 12^3\cdot 25}{8\cdot 10^3\cdot 1^4}=6{,}5\text{sm}.$$

Potensial energiýany aşakdaky formula boýunça kesgitleýäris.

$$U=\frac{\pi R^3nP^2}{GI_p}=\frac{3{,}14\cdot\left(12\cdot 10^{-2}\right)^3\cdot 25\cdot 300^2\cdot 2}{80\cdot 10^9\cdot 3{,}14\left(1\cdot 10^{-2}\right)^4}=9{,}7\text{joul}.$$

3.53. $\tau_{max1}=5{,}8\text{kN/sm}^2$, $\tau_{max2}=11{,}6\text{kN/sm}^2$, $\lambda=6\text{sm}$.

Birinji pružini δ ululyga çenli gysýan güýji tapýarys.

$$P_0=\frac{\delta Gd_1^4}{8D_1^3n_1}=0{,}534\text{kN}<P=1{,}2\text{kN}.$$

Şonuň üçin hem P=1,2 kN güýjüň täsirinden iki pružin ýüklenen; şonuň ýaly-da

$\lambda_1=\delta+\lambda_2$.

Plita üçin deňagramlylygyň deňlemesi

$P_1+P_2=P=1{,}2$ (1);

$$\frac{8P_1D_1^3n_1}{Gd_1^4}=\delta+\frac{8P_2D_2n_2}{Gd_2^4}\quad(2);$$

(1) we (2) aňlatmalary bilelikde işläp alarys $P_1=0{,}8$ kN, $P_2=0{,}4$ kN.

Pružinlerdäki galtaşma dartgynlylyklar

$$\tau_{max}=\frac{8P_1D_1k_1}{\pi d_1^3}=\frac{8\cdot 0{,}8\cdot 20\cdot 1{,}14}{3{,}14\cdot 2^3}=5{,}8\text{kN/sm}^2.$$

$$k_1=\frac{4\cdot\frac{20}{2}+2}{4\cdot\frac{20}{2}-3}=1{,}14=k_2;$$

$$\tau_{max\,2}=\frac{8P_2D_2k_2}{\pi d_2^3}=\frac{8\cdot 0{,}4\cdot 10\cdot 1{,}14}{3{,}14\cdot 1^3}=11{,}6\text{kN/sm}^2.$$

Plitanyň ornuny üýtgetmesi birinji pružiniň çökmesine deň

$$\lambda_1 = \frac{8P_1D_1^3n_1}{Gd_1^4} = \frac{8\cdot 0{,}8\cdot 20^3\cdot 15}{8\cdot 10^3\cdot 2^4} = 6\text{sm}.$$

3.54. d_1=1,02 sm, d_2=0,907 sm, d_3=0,944 sm.
Mesele iki gezek statiki kesgitlenmeýän statikanyň deňlemesi

$\Sigma M_A = Q_1a + Q_2 2a + Q_3 3a = P\cdot 3a$,

$Q_1 + 2Q_2 + 3Q_3 = 3P = 12\text{kN}$. (1)

Ornuny üýtgetmäniň deňlemesi, çyzgydan

$\lambda_1 : \lambda_2 : \lambda_3 = 1 : 2 : 3$

ýa-da $\frac{8Q_1D_1^3n}{Gd_1^4} : \frac{8Q_2D_2^3n}{Gd_2^4} : \frac{8Q_3D_3^3n}{Gd_3} = 1 : 2 : 3$.

Bu ýerden $\frac{27Q_1}{d_1^4} = \frac{64Q_2}{2d_2^4} = \frac{125Q_3}{3d_3^4}$, (2)

Pružinleriň deňberklik şertinden

$\tau_{1max} = \tau_{2max} = \tau_{3max} = [\tau]$,

ýa-da $\frac{8Q_1D_1}{\pi d_1^3} = \frac{8Q_2D_2}{\pi d_2^3} = \frac{8Q_3D_3}{\pi d_3^3}$.

Bu ýerden $\frac{3Q_1}{d_1^3} = \frac{4Q_2}{d_2^3} = \frac{5Q_3}{\pi d_3^3}$ (3)

(1), (2), (3) aňlatmalary işläp alarys

Q_1=1,9Q_2=2,1Q_3,

Q_1=3,45kN.

Onda $d_1 = \sqrt[3]{\frac{8Q_1D_1}{\pi[\tau]}} = \sqrt[3]{\frac{8\cdot 3{,}45\cdot 6}{3{,}14\cdot 50}} = 1{,}02\text{sm}$,

$d_2 = \frac{8}{9}d_1 = 0{,}907\text{sm}$, $d_3 = \frac{25}{27}d_1 = 0{,}944\text{sm}$.

3.55. d=3 mm, λ=17 mm.
Pružiniň siminiň diametri

$$d_1 = \sqrt[3]{\frac{8PD}{\pi[\tau]}} = \sqrt[3]{\frac{8\cdot 0{,}15\cdot 2}{3{,}14\cdot 40}} = 0{,}267\text{sm} \approx 3\text{mm}.$$

Pružini gysmasynyň ululygy

$$\lambda = \frac{8PD^3n}{Gd^4} = \frac{8\cdot 0{,}15\cdot 2^3\cdot 6}{4{,}2\cdot 10^3\cdot 0{,}3^4} = 1{,}7\text{sm}.$$

IV bap

Tekiz kesikleriň geometriki häsiýetleri

4.1. $I_{y_1} = 32000\text{sm}^4$, $I_{y_1z_1} = 14400\text{sm}^4$.

Parallel oklara görä inersiýa momentleriň formulasyny peýdalanýarys.

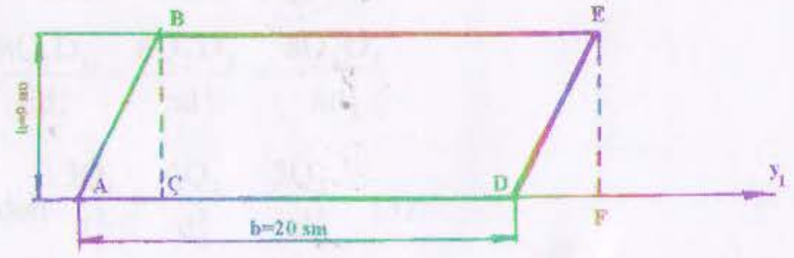
$$I_{y_1} = I_y + \left(\frac{h}{2}\right)^2 \cdot A = \frac{bh^3}{12} + \frac{bh^3}{4} = \frac{bh^3}{3} = \frac{12 \cdot 20^3}{3} = 32000\text{sm}^4,$$

$$I_{y_1z_1} = A\left(\frac{h}{2}\right)\left(\frac{b}{2}\right) = \frac{b^2h^2}{4} = \frac{20^2 \cdot 12^2}{4} = 14400\text{sm}^4.$$

4.2. $I_{y_1} = 4860\text{sm}^4$.

$\Delta ABC = \Delta DEF$

onda $I_{y_1} = \frac{bh^3}{12} + \left(\frac{h}{2}\right)^2 \cdot A = \frac{bh^3}{3} = \frac{20 \cdot 9^3}{3} = 4860\text{sm}^4$.



4.2-nji surat

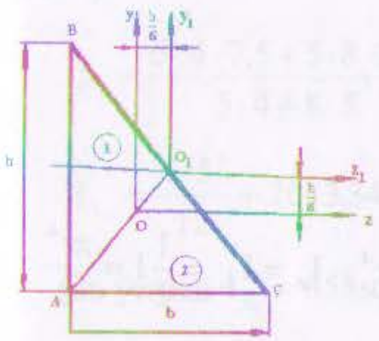
4.3. $I_{y_1} = \frac{bh^3}{4}$, $I_y = \frac{bh^3}{36}$.

$$b_z = b\frac{z}{h}, \quad dA = b_z \cdot dz = b\frac{z}{h}dz,$$

Onda $I_{y_1} = \int_0^h z^2 dA = \int_0^h z^2 b \cdot \frac{z}{h} dz = \frac{bh^3}{4}$;

$$I_y = \frac{bh^3}{4} - \left(\frac{2h}{3}\right)^2 \cdot \left(\frac{b}{2}\right) \cdot h = \frac{bh^3}{36}.$$

4.4. $I_{yz} = -\frac{b^2h^2}{72}$, $I_{AÇ} = \frac{bh^3}{12}$.



4.4-nji surat

AO_1 kesim ABÇ üçburçlugyň medianasy. z_1 ok ABO_1 üçburçlugyň simmetriýa oky bolany üçin,

$I_{(z_1y_1)_1} = 0$, Şonuň ýaly-da $I_{(z_1y_1)_2} = 0$,

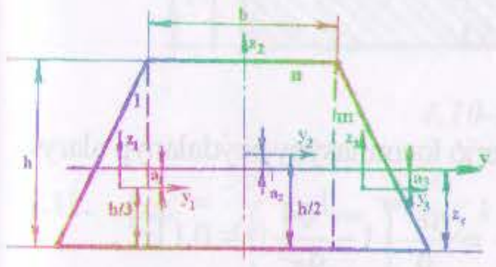
onda $I_{z_1y_1} = I_{(z_1y_1)_1} + I_{(z_1y_1)_2} = 0$.

Parallel oklaryň baglanyşygyndan

$$I_{z_1y_1} = I_{zy} + A\left(-\frac{h}{6}\right)^2\left(-\frac{b}{6}\right) = 0$$

Bu ýerden $I_{zy} = -A\frac{hb}{36} = -\frac{bh}{2} \cdot \frac{bh}{36} = \frac{-b^2h^2}{72}$,

$$I_{AÇ} = I_z + A\left(\frac{h}{2}\right)^2 = \frac{bh^3}{36} + \frac{bh}{2} \cdot \frac{h^2}{9} = \frac{bh^3}{12}$$



4.5-nji surat

4.5. $I_y = \frac{13bh^3}{108}$.

Adaty usul bilen $z_ç = \frac{4}{9}h$,

$a_1 = a_3 = -\frac{h}{9}$, $a_2 = \frac{h}{18}$.

Onda $I_y = 2\frac{bh^3}{72} + \frac{bh}{2}\left(\frac{-h}{9}\right)^2 + \frac{bh^3}{12} + bh\left(\frac{h}{18}\right)^2 = \frac{13bh^3}{108}$.

4.6. $I_y = 3167sm^4$.

$I_y = I_y^{gön} - I_y^{kw} = 3167sm^4$.

4.7. Meýdan 38,6% köpelýär, inersiýa momenti 4,3% azalýar.

$I_y^o = 46150sm^4$, $I_y^{oo} = 44187{,}5sm^4$, $A^o = 406sm^2$, $A^{oo} = 563sm^2$.

$$\frac{A^{oo}}{A^o} = \frac{563}{406} = 1{,}386 \Rightarrow 38{,}6\%\ \text{köpelýär}$$

$$\frac{I_y^{oo}}{I_y^o} = \frac{44187{,}5}{46150} = 0{,}957 \Rightarrow 4{,}3\%\ \text{azalýar.}$$

4.8. $z_ç = \frac{4r}{3\pi}$; $I_y = \frac{\pi r^4}{8}\left(1 - \frac{64}{9\pi^2}\right) \approx 0{,}11r^4$; $I_z = I_{y_1} = \frac{1}{2}I = \frac{\pi r^4}{8}$.

$$z_ç = \frac{S_{y_1}}{A} \Rightarrow S_{y_1} = \int_A y_1 dA = \int_0^r b_y \cdot y_1 dy,\quad A = 0{,}5\pi r^2,$$

$b_y = 2r\sin\varphi$, $y_1 = r\cos\varphi$, $dy_1 = -r\sin\varphi d\varphi$.

Onda $S_{y_1} = -2r^3 \int_{\frac{\pi}{2}}^{0} \sin\varphi\cos d\varphi = 2r^3 \frac{\sin^3\varphi}{3}\Big|_0^{\frac{\pi}{2}} = \frac{2}{3}r^3$,

$$z_ç = \frac{\frac{2}{3}r^3}{0{,}5\pi r^2} = \frac{4r}{3\pi}.$$

Parallel oklara görä inersiýa momentleriň formulasyny peýdalanyp alarys:

$$I_y = I_{y_1} - A \cdot z_ç^2 = \frac{\pi r^4}{8} - \frac{\pi r^2}{4} \cdot \frac{16r^2}{9\pi^2} = \frac{\pi r^4}{9}\left(1 - \frac{64}{9\pi^2}\right) \cong 0{,}11r^4.$$

Bu ýerde $I_{y_1} = \frac{\pi r^4}{8}$ – ýarym töweregiň oka görä inersiýa momenti

Beýleki baş oka görä inersiýa momenti,

$$I_{z_ç} = 0{,}5 \cdot \frac{\pi r^4}{4} = \frac{\pi r^4}{8} \cong 0{,}39r^4.$$

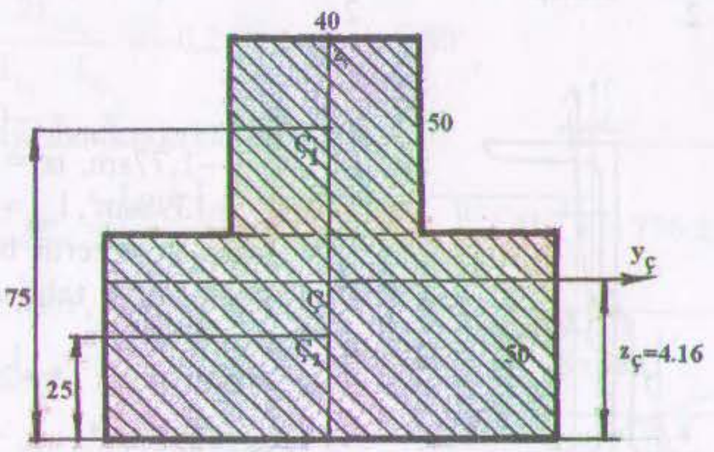
4.9. $I_y = \frac{ab^3}{12} + \frac{\pi b^4}{64}$, $I_z = \frac{ab}{12}\left(a^2 + 2b^2\right) + \frac{\pi b^4}{64}\left(b^2 + 4a^2\right)$.

4.10. $I_{y_ç} = 458sm^4$.

$$z_ç = \frac{5 \cdot 4 \cdot 7{,}5 + 5 \cdot 8 \cdot 2{,}5}{5 \cdot 4 + 8 \cdot 5} = 4{,}16sm,$$

$$I_{y_ç} = \frac{4 \cdot 5^3}{12} + 20 \cdot 3{,}34^2 + \frac{8 \cdot 5^3}{12} + 40(1{,}66)^2.$$

Bu ýerden $I_{y_ç} = 458sm^4$.



4.10-njy surat

4.11. $I_{max} = \frac{5b^4}{64}$; $I_{min} = \frac{7b^4}{192}$; $I_{z_ç y_ç} = -0{,}022b^4$.

$$z_ç = y_ç = \frac{b \cdot \frac{b}{2} \cdot \frac{b}{4} + \frac{b}{2} \cdot \frac{b}{2} \cdot \frac{3}{4}b}{b \cdot \frac{b}{2} + \frac{b}{2} \cdot \frac{b}{2}} = \frac{5b}{12};$$

$$I_{z_ç} = I_{y_ç} = \frac{b^4}{16\cdot 12} + \frac{b}{2}\cdot\frac{b}{2}\cdot\left(-\frac{b}{6}\right)^2 + b\cdot\frac{b}{2}\cdot\left(\frac{b}{12}\right)^2 + \frac{b\cdot b^3}{8\cdot 12} = \frac{5b^4}{192},$$

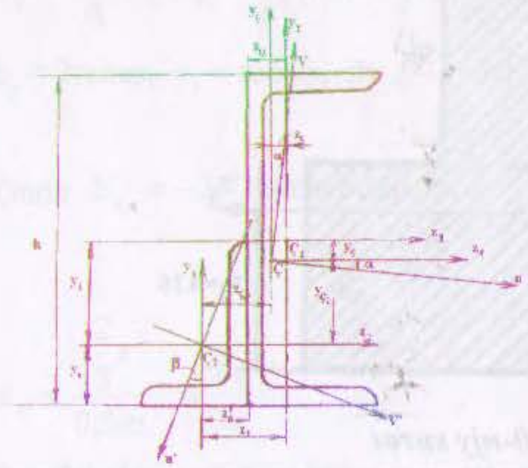
$$I_{z_ç y_ç} = b\cdot\frac{b}{2}\cdot\left(\frac{b}{12}\right)\left(-\frac{b}{6}\right) + \frac{b}{2}\cdot\frac{b}{2}(0{,}334b)(-0{,}166b) = -0{,}02b^4,$$

$$\operatorname{tg}2\alpha = -\frac{I_{z_ç y_ç}}{I_{z_ç} - I_{y_ç}} = +\infty \Rightarrow \alpha = +45°,$$

$$I_{max(min)} = \frac{I_{z_ç} + I_{y_ç}}{2} \pm \frac{1}{2}\sqrt{\left(I_{z_ç} - I_{y_ç}\right)^2 + 4I_{z_ç y_ç}^2},$$

Bu ýerden $I_{max}=0{,}077b^4$, $I_{min}=0{,}037b^4$.

$$I_{z_ç y_ç} = \frac{I_{max} - I_{min}}{2}\sin 2\beta = \frac{0{,}077b^4 - 0{,}037b^4}{2}\sin(-90°) = -0{,}02b^4.$$



4.12-nji surat

4.12. $z_ç = -0{,}94$sm, $y_ç = -1{,}77$sm, $\alpha = -6°30'$, $I_{max} = 1398$sm^4, $I_{min} = 154$sm^4.

Hasap üçin zerur berlenleri goşmaçanyň tablisasyndan göçürip alýarys.

Şweller üçin: $A_ş=20{,}7$ sm^2, $I_{z_1}=1090$ sm^4, $I_{y_1}=86$ sm^4, $z_o=1{,}94$ sm, $h=18$ sm.

Burçluk üçin: $A_b=8{,}54$ sm^2, $I_{z_2}=70{,}6$ sm^4, $I_{y_2}=21{,}2$ sm^4, $I_{v_1}=79{,}1$ sm^4, $I_{u_1}=12{,}2$ sm^4,

$\operatorname{tg}\beta = 0{,}384$, $z_0^1 = 1{,}28$sm, $y_0=2{,}95$ sm.

Şwelleriń merkezi okuna görä kesigiń agyrlyk merkezini kesgitleýäris:

$$z_ç = \frac{A_ş\cdot 0 + A_b\cdot z_1}{A_ş + A_b} = -0{,}94\text{sm},$$

$$y_ç = \frac{A_ş\cdot 0 + A_b\cdot y_1}{A_ş + A_b} = -1{,}77\text{sm}.$$

Baş inersiýa okuň yagdaýyny kesgitleýäris:

$$I_{z_ç} = I_{z_1} + A_ş\cdot y_ç^2 + I_{z_2} + A_b\cdot y_{ç_1}^2 = 1382\text{sm}^4,$$

$$I_{y_ç} = I_{y_1} + A_ş\cdot z_ç^2 + I_{y_2} + A_b\cdot z_{ç_1}^2 = 170\text{sm}^4,$$

$$I_{z_ç y_ç} = A_ş\cdot z_ç y_ç + \frac{I_{v_1} - I_{u_1}}{2}\cdot\sin 2\beta + A_b\cdot y_{ç_1}\cdot z_{ç_1} = 140\text{sm}^4,$$

$$\operatorname{tg}2\alpha = \frac{2I_{z_ç y_ç}}{I_{y_ç} - I_{z_ç}} = -0{,}231 \Rightarrow \alpha = -6°30'.$$

Baş inersiýa momentlerini kesgitleýäris.

$$I_{u,v} = I_{max(min)} = \frac{I_{z_ç} + I_{y_ç}}{2} \pm \frac{1}{2}\sqrt{\left(I_{z_ç} - I_{y_ç}\right)^2 + 4I_{z_ç y_ç}^2} = 776 \pm 622,$$

$I_{max} = 1398$sm^4, $I_{min} = 154$sm^4.

Barlagy: $I_{max} + I_{min} = I_{z_ç} + I_{y_ç}$; 1382+170=1398+154

1552=1552

$$I_{u,v} = \frac{I_{z_ç} + I_{y_ç}}{2}\cdot\sin 2\beta + I_{z_ç y_ç}\cdot\cos 2\alpha =$$

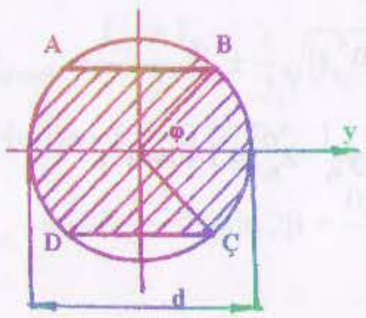
$$= \frac{1382 - 170}{2}\cdot\sin(-13°) + 140\cdot\cos(-13°) = 0.$$

Ýokardaky hasaplar dogry ýerine ýetirilen.

4.13. $I_y = \frac{d^4}{32}\cdot\left(\varphi - \frac{\sin 4\varphi}{4}\right)$.

$$I_y = 2\frac{b\left(\frac{h}{2}\right)^3}{4} + 2\cdot\frac{d\varphi}{128}(2\varphi - \sin 2\varphi);\quad b = d\cos\varphi,\ h = d\sin\varphi.$$

Onda



4.13-nji surat

$$I_y = \frac{d^4\sin^3\varphi\cos\varphi}{16} + \frac{d^4(2\varphi - \sin 2\varphi)}{64} =$$

$$= \frac{d^4}{32}\left[\varphi - \left(0{,}5\sin 2\varphi - 2\sin^3\varphi\cos\varphi\right)\right] =$$

$$= \frac{d^4}{32}\left[\varphi - \frac{1}{2}\left(\sin 2\varphi - 4\cos\varphi\sin^3\varphi\right)\right] =$$

$$= \frac{d^4}{32}\left[\varphi - \frac{1}{2}\left(\sin 2\varphi - 2\cdot 2\sin\varphi\cos^2\varphi\sin^2\varphi\right)\right] =$$

$$= \frac{d^4}{32}\left(\varphi - \frac{\sin 4\varphi}{4}\right).$$

4.14. $W_y = \frac{b}{6}\left(d^2 - b^2\right)$; $b = \frac{d}{\sqrt{3}} = 0{,}577d$; $h = \frac{d\sqrt{2}}{\sqrt{3}} = 0{,}816d$.

$$W_y = \frac{bh^2}{6};\quad d^2 = h^2 + b^2 \Rightarrow h^2 = d^2 - b^2,\ W_y = \frac{b\left(d^2 - b^2\right)}{6},$$

$$W_y' = \left[\frac{b\left(d^2 - b^2\right)}{6}\right]' = \frac{d^2 - 3b^2}{6},$$

bu ýerden $b = \frac{d}{\sqrt{3}}$, onda $h = \frac{d\sqrt{2}}{\sqrt{3}}$.

4.15. $\alpha = 25°$, $I_{max} = 1{,}73sm^4$, $I_{min} = 0{,}43sm^4$.
Merkezi inersiýa momentlerini integrirlap tapýarys.

Çyzgydan $b_y = \frac{2}{3}(3a - y)$,

$$dA = \frac{2}{3}(3a - y)dy,$$

$$I_z = \int_0^{3a} y^2\cdot\frac{2}{3}(3a - y)dy = 4{,}5a^4,$$

$$I_{z_ç} = I_z - A\cdot\left(\frac{3a}{3}\right)^2 = 4{,}5a^4 - \frac{3a\cdot 2a}{2}\left(\frac{3a}{3}\right)^2 = \frac{3a^4}{2},$$

$$I_{y_ç} = I_y - A\cdot\left(\frac{2a}{3}\right)^2 = \frac{3a\cdot(2a)^3}{12} - \frac{3a\cdot 2a}{2}\left(\frac{2a}{3}\right)^2 = \frac{2a^4}{3},$$

$$I_{z_ç y_ç} = I_{zy} - A\cdot\left(\frac{3a}{3}\right)\left(\frac{2a}{3}\right) = \frac{(3a)^2\cdot(2a)^2}{24} - \frac{3a\cdot 2a}{2}\cdot\frac{2}{3}a^2 = -\frac{a^4}{2}.$$

Baş okuň ugruny kesgitleýäris:

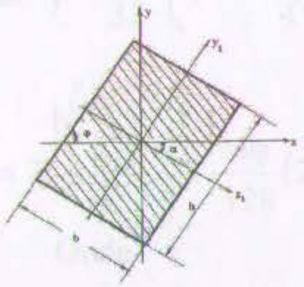
$$\operatorname{tg}\alpha = \frac{2I_{z_ç y_ç}}{I_{z_ç} - I_{y_ç}} = \frac{2\left(-\frac{a^4}{2}\right)}{\frac{3}{2}a^4 - \frac{2}{3}a^4} = 1{,}2.$$

Bu ýerden $\alpha = 25°$.
Baş inersiýa momentleri:

$$I_{max(min)} = \frac{1}{2}\left[I_{z_ç} + I_{y_ç} \pm \sqrt{(I_{z_ç} - I_{y_ç})^2 + 2I_{z_ç y_ç}^2}\right] =$$

$$= \frac{1}{2}\left[\frac{3}{2}a^4 + \frac{2}{3}a^4 \pm \sqrt{\left(\frac{3}{2}a^4 - \frac{2}{3}a^4\right)^2 + 4\left(-\frac{a^4}{2}\right)^2}\right],$$

Bu ýerden $I_{max} = 1{,}73sm^4$, $I_{min} = 0{,}43sm^4$.



4.16-njy surat

4.16. $I_{zy} = \dfrac{bh^3}{12}\left(h^2 - b^2\right)\sin\alpha\cos\alpha,$

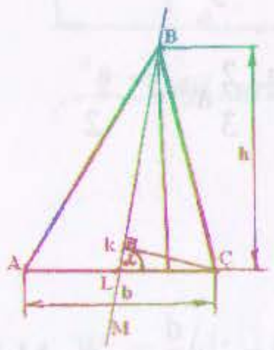
$$I_{z_1} = \frac{bh^3}{12},\ I_{y_1} = \frac{b^3h}{12},\ I_{z_1y_1} = 0.$$

$$\alpha = 90° - \varphi$$

$$I_{zy} = \frac{I_{z_1} - I_{y_1}}{2}\sin 2\alpha + I_{z_1y_1}\cos 2\alpha =$$

$$= \frac{\dfrac{bh^3}{12} - \dfrac{b^3h}{12}}{2}\sin 2\alpha =$$

$$= \frac{hb}{12}\left(h^2 - b^2\right)\sin\alpha\cos\alpha.$$



4.17-nji surat

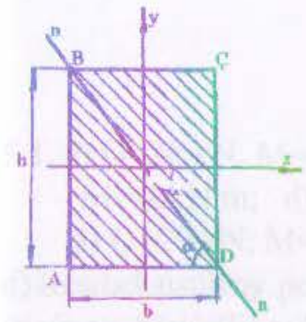
4.17. $I_x = \dfrac{hb^3 \cdot \sin^2\alpha}{48}$.

BM - mediana

$$\sin\alpha = \frac{KÇ}{\frac{b}{2}},\quad KÇ = \frac{b}{2}\sin\alpha,$$

$$BL = \frac{h}{\sin\alpha},\qquad I_x = \frac{hb^3}{12},$$

$$I_x = 2\left[\frac{h}{\sin\alpha}\cdot\frac{\left(\frac{b}{2}\sin\alpha\right)^3}{12}\right] = \frac{2hb^3\sin^2\alpha}{8\cdot 2} = \frac{hb^3\sin^2\alpha}{48}$$



4.18-nji surat

4.18. $I_n = \dfrac{b^3h^3}{6(h^2+b^2)}$.

$$\cos\alpha = \frac{b}{\sqrt{b^2+h^2}},\ \sin\alpha = -\frac{h}{\sqrt{b^2+h^2}},$$

$$I_n = I_z\cos^2\alpha + I_y\sin^2\alpha =$$

$$= \frac{bh^3}{12}\cos^2\alpha + \frac{b^3h}{12}\sin^2\alpha =$$

$$= \frac{b^3h^3}{6(h^2+b^2)}.$$

4.19. $u = \dfrac{a}{9\sqrt{2}};\ W_z^{max} = \dfrac{64\sqrt{2}}{729}a^3;\ \dfrac{W_z^{max}}{W_z} = \dfrac{256}{243}.$

Ştrihlenen meýdanyň garşylyk momenti:

$$W_z = \frac{2u(2y)^2}{6} + \frac{(y\sqrt{2})^4}{12y}.$$

Çyzgydan $u = \dfrac{a}{\sqrt{2}} - y;$

özgertmeden soň:

$$W_z = \frac{2\sqrt{2}}{3}ay^2 - y^3,$$

$$W_z' = \frac{4\sqrt{2}}{3}ay - 3y^2 = 0.$$

Bu ýerden: $y = \dfrac{4\sqrt{2}\cdot a}{9}$.

$$W_z^{max} = \frac{2\sqrt{2}}{3}a\left(\frac{4\sqrt{2}}{9}a\right)^2 - \left(\frac{4\sqrt{2}}{9}a\right)^3 = \frac{64\sqrt{2}}{729}a^3,$$

$$W_z = \frac{a^3}{6\sqrt{2}},$$

Onda: $\frac{W_z^{max}}{W_z} = \frac{64\sqrt{2}a^3 6\sqrt{2}}{729a^3} = \frac{256}{243}.$

4.20. $\frac{h}{b} = \sqrt{3}$, $\frac{h}{b} = \sqrt{2}$.

Rombuň dörtden bir bölegi üçin - $I_z^1 = \frac{bh^3}{12}$,

Onda: $I_z = \frac{bh^3}{3}$; $W_z = \frac{I_z}{h} = \frac{bh^2}{3}$.

Çyzgydan $h^2 = a^2 - b^2$

$W_z = \frac{b(a^2 - b^2)}{3}$ we $\frac{dW_z}{db} = 0$,

$W_z' = \left[\frac{b(a^2 - b^2)}{3}\right]^1 = \frac{a^2 - 3b^2}{3} = 0 \Rightarrow a = b\sqrt{3}$.

Onda: $h = b\sqrt{2}$ – garşylyk momenti iň uly.

Çyzgydan: $b = \sqrt{a^2 - h^2}$, $I_z = \frac{\sqrt{a^2 - b^2}\cdot h^3}{3}$ we $\frac{dI_z}{db} = 0$.

$I_z^1 = \left(\frac{\sqrt{a^2 - b^2}\cdot h^3}{3}\right)^1 = -h^4 + 3h^2(a^2 - h^2) = 0$,

$a = \frac{2h}{\sqrt{3}}$, $b^2 = a^2 - h^2 = \frac{4h^2}{3} - h^2 = \frac{h^2}{3}$,

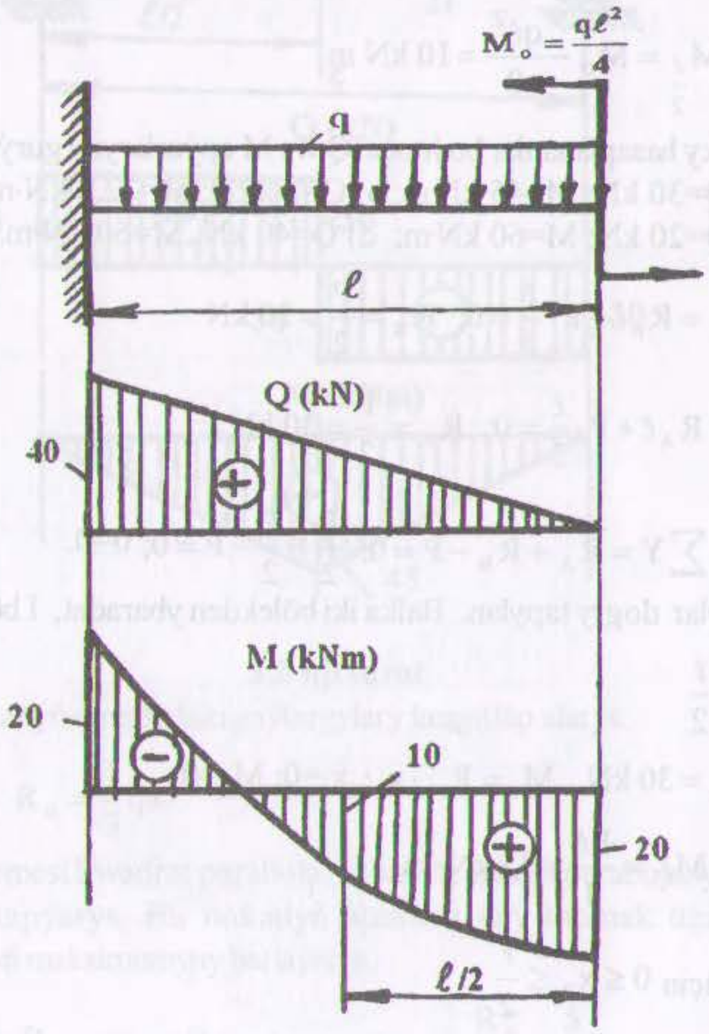
$\frac{h}{b} = \sqrt{3}$ – inersiýa momenti iň uly.

V bap

Tekiz egilme

5.1. a) Q=20 kN; M=40kN·m; b) Q=0; M=40kN·m; ç) Q=40 kN; M=40kN·m; d) Q=40 kN; M=20kN·m; g) Q=40; M=20kN·m; ä) Q=20 kN; M=20kN·m.

d) Kesmek usulyny peýdalanyp, balkanyň içki güýçleriniň aňlatmalaryny ýazýarys, häsiýetli kesiklerde bahasyny kesgitleýäris we olaryň epýurlaryny gurýarys.



5.1-nji surat

I-I kesik üçin

$Q_1 = qx, M_1 = M_o - q\frac{x_1^2}{2}$ bu ýerde $0 \le x_1 \le \ell$

Eger $x_1 = 0 \Rightarrow Q_B = 0, M_B = M_o = 20$ kN m,

Eger $x_1 = \ell \Rightarrow Q_A = 40$ kN, $M_A = -40$ kN m.

Egme momentiň aňlatmasyndan onuň parabolanyň çyzygy boýunça üýtgeýändigini anyklap, egme momentiň aralyk bahasyny hasaplaýarys.

$x_1 = \frac{\ell}{2}, M_{\frac{\ell}{2}} = M_o - \frac{q\ell^2}{8} = 10$ kN m

Ýokardaky hasaplananlar boýunça Q we M epýurlaryny guryarys.

5.2. a) Q=30 kN; M=45 kN·m; b) Q=30 kN; M=22,5 kN·m;
ç) Q=20 kN; M=60 kN·m; d) Q=40 kN; M=60 kN·m.

a) $\sum M_A = R_B\ell - P\cdot\frac{\ell}{2} = 0;\ R_B = \frac{P}{2} = 30$ kN

$\sum M_B = R_A\ell + P\cdot\frac{\ell}{2} = 0;\ R_A = \frac{P}{2} = 30$ kN.

Barlagy: $\sum Y = R_A + R_B - P = 0;\ \frac{P}{2} + \frac{P}{2} - P = 0;\ 0=0.$

Gaýtargylar dogry tapylan. Balka iki bölekden ybaradat, I bölek üçin

$0 \le x_1 \le \frac{\ell}{2}$

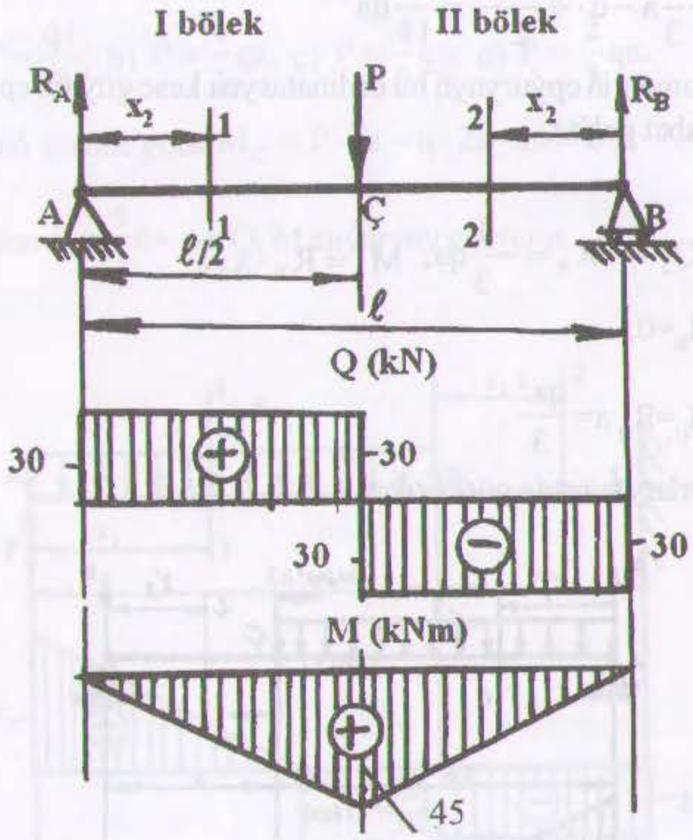
$Q_1 = R_A = 30$ kN, $M_1 = R_A\cdot x_1;\ x_1=0;\ M_A=0$

$x_1 = \frac{\ell}{2},\ M_Ç = \frac{P\ell}{4} = 45$ kN·m.

II bölek üçin $0 \le x_2 \le \frac{\ell}{2}$

$Q_2 = -R_B = -30$ kN, $M_2 = R_B\cdot x_2;\ x_1=0,\ M_B=0;\ x_2 = \frac{\ell}{2},$

$M_Ç = \frac{P\ell}{4} = 45$ kN·m



5.2-nji surat

5.3. f) Balkanyň diregindäki gaýtargylary kesgitläp alarys:

$R_A = \frac{5}{3}$qa, $R_B = \frac{1}{3}$qa.

M_1–iň deňlemesi kwadrat parabola, şonuň üçin hem parabolanyň üçünji nokadyny tapýarys. Bu nokadyň abssissasyny tapmak üçin M_1–iň aňlatmasynyň maksimumyny barlaýarys.

$\frac{dM_1}{dx_1} = Q_1 = R_A - qx_1 = 0$ bu ýerden $x_{max} = \frac{R_A}{q} = \frac{5}{3}$a,

x_{max} bahasyny M_1 goýup alarys.

$$M_{max}=\frac{5qa}{3}\cdot\frac{5}{3}a-q\cdot\frac{\left(\frac{5}{3}a\right)^2}{2}=\frac{25}{18}qa^2.$$

Egme momentiň epýurynyň bu ordinatasyna kese güýjüň epýurynyň nol nokady gabat gelýär.

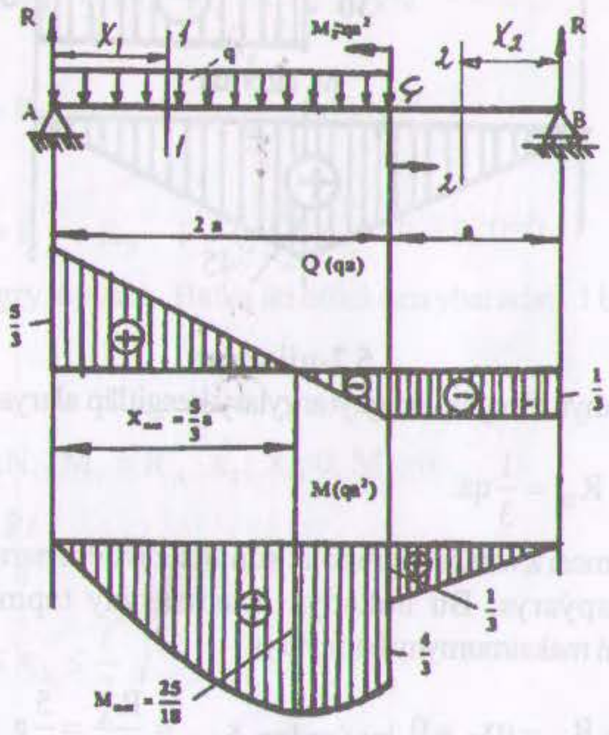
II bölek üçin

$$0\le x_2\le a,\ Q_2=-R_B=-\frac{1}{3}qa,\ M_2=R_B\cdot x_2,$$

Eger x_2=0, M_B=0,

Eger x_2=a, $M_Ç$=R_B a=$\frac{qa^2}{3}$,

Q we M epýurlary suratda görkezilen.



5.3-nji surat

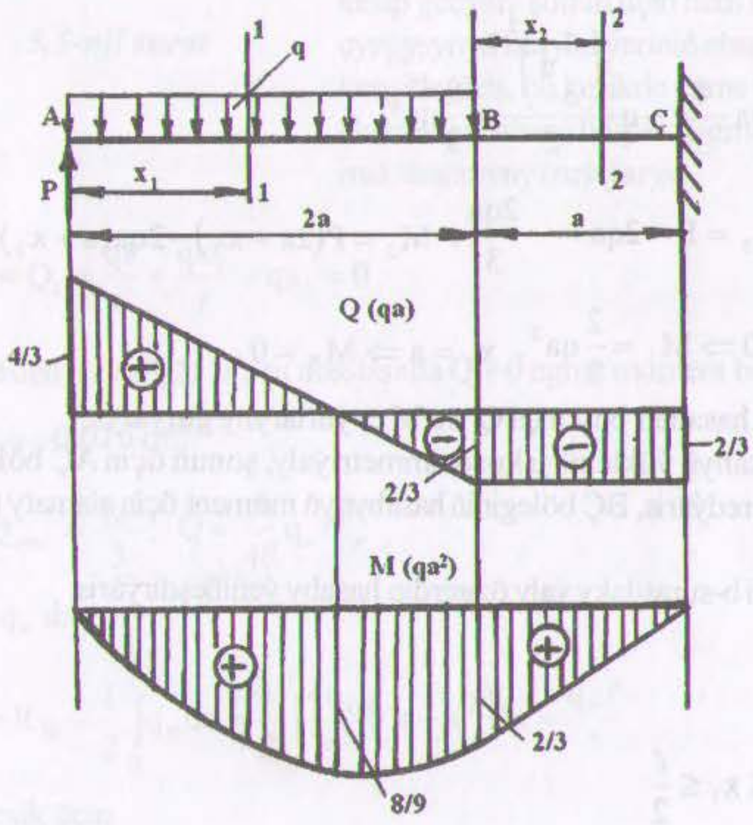
Epýurlardan görünýär Q we M absolýut maksimal bahalary:

$$Q_{max}=\frac{5}{3}ga,\ M_{max}=\frac{25}{18}qa^2$$

5.4. a) $P=\frac{q\ell}{2}$; b) $P=\frac{4}{3}qa$; ç) $P=\frac{4}{9}qa$; d) $P=\frac{2}{3}qa$.

Meseläniň şertine görä $M_Ç=P\cdot 3a-q\cdot 2a\cdot 2a=0$.

Bu ýerden $P=\frac{4}{3}qa$ we Q, M epýuryny gurýarys.



5.4-nji surat

I bölek: $Q_1 = P - qx_1 \;\; 0 \le x_1 \le 2a \;\; M_1 = Px_1 - q\frac{x_1^2}{2}$;

Eger $x_1 = 0 \Rightarrow Q_A = P = \frac{4}{3}qa,\; M_A = 0$

$x_1 = 2a \Rightarrow Q_B = \frac{2}{3}qa,\; M_B = \frac{2}{3}qa^2$

M_1 maksimumyny tapýarys.

$$\frac{dM_1}{dx_1} = P - qx_1 = 0 \Rightarrow x_{max} = \frac{4}{3}a$$

$$M_{max} = \frac{4}{3}qa \cdot \frac{4}{3}a - q \cdot \frac{\left(\frac{4}{3}a\right)^2}{2} = \frac{8}{9}qa^2$$

II bölek: $Q_2 = P - 2qa = -\frac{2qa}{3}$, $M_2 = P(2a + x_2) - 2qa(a + x_2)$

Eger $x_2 = 0 \Rightarrow M_2 = \frac{2}{3}qa^2$, $x_2 = a \Rightarrow M_B = 0$.

Ýokardaky hasaplar boýunça Q we M epýurlaryny guryarys.

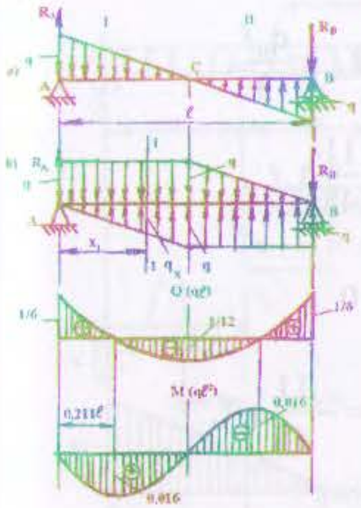
5.5. e) Balkanyň ýüklenilişi kososimmetriýaly, şonuň üçin AÇ böleginiň hasabyna seredýäris, BÇ böleginiň hasabynyň moment üçin alamaty tersine bolýar.

Berlen güýji b-suratdaky ýaly özgerdip hasaby ýeňilleşdiryäris.

$$q_x = q\frac{2x}{\ell}$$

I bölek: $0 \le x_1 \le \frac{\ell}{2}$

$$Q_1 = R_A + q \cdot \frac{x_1}{\ell} \cdot \frac{x_1}{2} - qx_1 = \frac{q\ell}{6} + \frac{qx_1^2}{\ell} - qx_1$$



5.5-nji surat

$$M_1 = \frac{q\ell}{6} \cdot x_1 + \frac{qx_1^3}{3\ell} - q\frac{x_1^2}{2}$$

Eger $x_1 = 0 \Rightarrow Q_A = \frac{q\ell}{6}$, $M_A = 0$

$$x_1 = \frac{\ell}{2} \Rightarrow Q_Ç = \frac{q\ell}{6} + \frac{q\ell}{4} - q\frac{\ell}{2} = -\frac{1}{12}q\ell$$

$$M_Ç = \frac{q\ell}{6} \cdot \frac{\ell}{2} + \frac{q\ell^3}{24\ell} - \frac{q\ell^2}{8} = 0$$

Kese güýjüň epýury, epýuryň bazasyny kesip geçýär, şonuň üçin hem epýuryň çyzgysynyň kesýän ýeriniň abssissasyny kesgitleýäris, bu kesikde egme momentiň ekstremal bahasy bolýar. Egme momentiň maksimumyny barlaýarys:

$$\frac{dM_1}{dx_1} = Q_1 = \frac{q\ell}{6} + \frac{qx_1^2}{\ell} - qx_1 = 0.$$

Bu ýerden $x_1 = 0{,}211\ell$, şu abssissada $Q_1 = 0$ egme moment bolsa,

$M_{max} = -0{,}016\, q\ell^2$

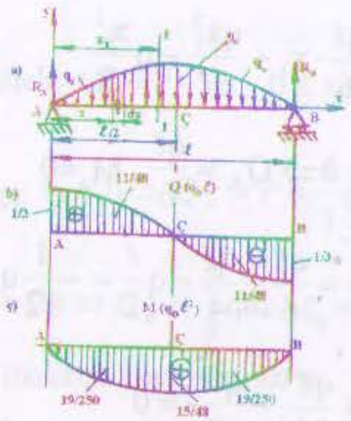
5.6. $Q_{max} = \frac{q_o\ell}{3}$; $Q = \frac{5}{48}q_o\ell^2$.

$d\omega = q_x\, dx$

$$R_A = R_B = \frac{1}{2}\int_0^\ell q_x dx = \frac{1}{2}\int_0^\ell \frac{4q_o}{\ell^2}(\ell x - x^2)dx = \frac{q_o\ell}{3}$$

1-1 kesik üçin

$$Q_x = \frac{q_o\ell}{3} - \int_o^x \frac{4q_o}{\ell^2}(\ell x - x^2)dx = \frac{q_o\ell}{3} - \frac{4q_o}{\ell^2}\left(\frac{\ell x^2}{2} - \frac{x^3}{3}\right)$$



5.6-njy surat

Eger $x=0\Rightarrow Q_A=\frac{q_o\ell}{3}$,

$x=\frac{\ell}{4}\Rightarrow Q_{\frac{\ell}{4}}=\frac{11}{48}q_o\ell$,

$x=\frac{\ell}{2}\Rightarrow Q_Ç=0$

$x=\frac{3\ell}{4}\Rightarrow Q_{\frac{3\ell}{4}}=-\frac{11}{48}q_o\ell$,

$x=\ell\Rightarrow Q_B=-\frac{q_o\ell}{3}$.

Q_x epýury b suratda görkezilen.

M_x aňlatmasyny ýazmak üçin balkany çep diregden x_1 aralykda kesýäris we 1-1 kesik üçin egme momentiň deňlemesini düzýäris.

$$M_{x_1}=\frac{q_o\ell}{3}x_1-\int_0^{x_1}\frac{4q_o}{\ell^2}(\ell x-x^2)dx\cdot(x_1-x)=\frac{q_o\ell}{3}x_1-\frac{q_o}{3\ell^2}(2\ell x_1^3-x_1^4)$$

Eger: $x_1=0\Rightarrow M_A=0$, $x_1=\frac{\ell}{4}\Rightarrow M_{\frac{\ell}{4}}=\frac{19}{256}q_o\ell^2$,

$x_1=\frac{\ell}{2}\Rightarrow M_Ç=\frac{5}{48}q_o\ell$, $x_1=\frac{3}{4}\ell\Rightarrow M_{\frac{3\ell}{4}}=\frac{19}{256}q_o\ell^2$

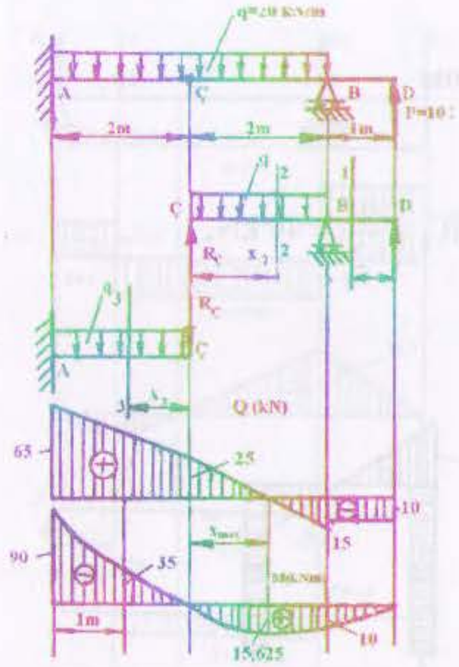
$x_1=\ell\Rightarrow M_B=0$

5.7. a) M=80 kN m; Q=20 kN; b) M=-90 kN m; Q=65 kN;
d) M=-20 kN m; Q=30 kN; g) M=70 kN m;Q=-66,2 kN.

b) B nokada görä sag balka täsir edýän güýçlerden momentiň deňlemesini düzýäris.

$$\sum M_B=P\cdot1+q\cdot\frac{2^2}{2}-R_Ç\cdot2=0,$$

$R_Ç=25$ kN



5.7-nji surat

Ýokarky balkanyň hasaby

1-1 kesik üçin $0\le x_1\le 1$m.

$Q_1=-P=10$kN

$M_1=P\,x_1$, $x_1=0\Rightarrow M_D=0$

$x_1=1$m$\Rightarrow M_B=10$ kN m

2-2 kesik üçin $0\le x_2\le 2$m.

$Q_2=R_Ç-q_2x_2$

$$M_2=R_Ç\cdot x_2-q\frac{x_2^2}{2}$$

$x_2=0\Rightarrow Q_Ç=R_Ç=25$kN,

$M_Ç=0$

$x_2=2$m; $Q_B=-15$kN, $M_B=10$kNm

M_2 maksimimyny barlaýarys.

$$\frac{dM_2}{dx_2}=Q_2=R_Ç-qx_2=$$

$$=0\Rightarrow x_{max}=x_2=\frac{R_Ç}{q}=1{,}25\text{ m}$$

onda $M_{max}=R_Çx_{max}-q\frac{x_{max}^2}{2}=15{,}625\text{ kN}\cdot\text{m}$

Esasy balkanyň hasaby

3-3 kesik üçin $0\le x_2\le 2$ m

$Q_Ç=R_Ç+qx_2$, $M_B=-R_Çx_3-q\frac{x_3^2}{2}$

$x_2=0\Rightarrow Q_Ç=R_Ç=25$ kN, $M_Ç=0$

$x_2=2\text{m}\Rightarrow Q_A=R_Ç+q\cdot2=25+40=65$ kN

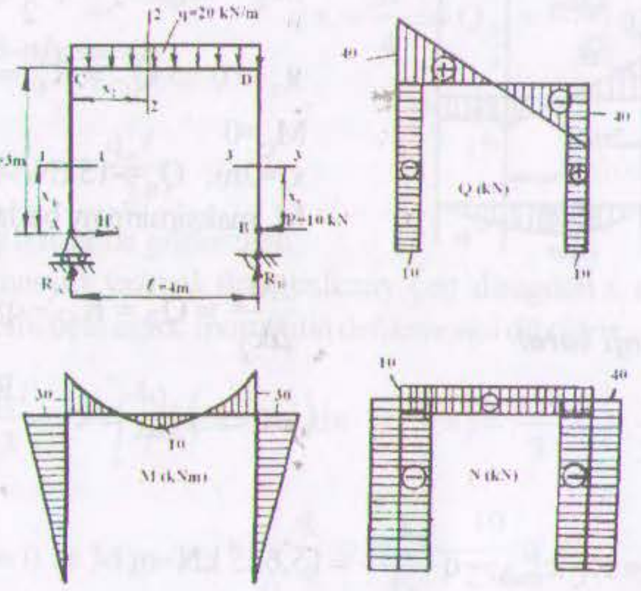
$M_A=-25\cdot2-20\cdot\frac{2^2}{2}=90$ kN m

x_2=1m, $M_3 = -25\cdot 1 - 20\cdot\frac{1^2}{2} = 35$ kN m.

Q we M epýurlary suratda görkezilen.

5.8. a)statikanyň deňlemesinden $R_A = R_B = \frac{q\ell}{2} = 40$ kN,

$H_A = P = 10$ kN, q=20 kN/m.



5.8-nji surat

AÇ direg $Q_{AÇ} = -H_A = -10$ kN, $M_1 = -H_A\, x_1$,

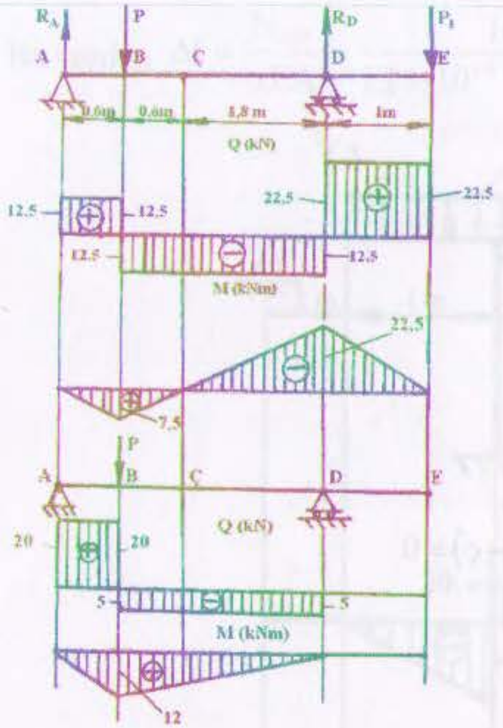
$N_{AÇ} = -R_A = -40$ kN

ÇD rigel $Q_2 = R_A - qx_2$, $M_2 = R_A\, x_2 - q\frac{x_2^2}{2}$,

$N_{ÇD} = -H_A = -10$ kN

BD direg $Q_{BD} = P = 10$ kN, $M_3 = -P\, x_3$, $N_{BD} = -R_B = -40$ kN

Q, M, N epýurlary suratda görkezilen.



5.9. P_1=22,5 kN.Statikanyň deňlemesinden

$$R_A = \frac{4}{5}\cdot P - \frac{P_1}{3}.$$

Onda

$$M_Ç = R_A\cdot 1{,}2 - P\cdot 0{,}6 =$$

$$= \left(\frac{4P}{5} - \frac{P_1}{3}\right)\cdot 1{,}2 - P\cdot 0{,}6 = 0$$

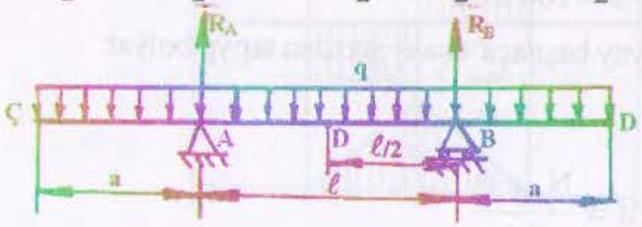
Bu ýerden P_1=22,5 kN
Q we M epýurlary, E nokatdaky güýjüň ululygy hasaba alnyp we hasaba almazdan suratda görkezilen.

5.9-njy surat

5.10. $a = \frac{\ell}{2}$; $a = \frac{\sqrt{2}\ell}{4}$.

1) $R_A = R_B = \frac{q(\ell + 2a)}{2}$,

$$M_D = R_A\cdot\frac{\ell}{2} - q\frac{\left(a+\frac{\ell}{2}\right)^2}{2} = \frac{q(1+2a)}{2}\cdot\frac{\ell}{2} - q\frac{\left(a+\frac{\ell}{2}\right)^2}{2} = 0$$



5.10-njy surat

Bu ýerden $a=\frac{\ell}{2}$

2) $M_A = M_D \Rightarrow q\frac{a^2}{2} = \frac{q(\ell+2a)}{2}\cdot\frac{\ell}{2} - q\frac{\left(a+\frac{\ell}{2}\right)^2}{2}$

Bu ýerden $a=\frac{\sqrt{2}\ell}{4}$

5.11. $x=\frac{\ell}{2}-\frac{ç}{4}$.

$\sum M_B = R_A\ell - P(\ell-x) - P(\ell-x-ç) = 0$

$R_A = 2P - 2P\frac{x}{\ell} - P\frac{ç}{\ell}$

$M_x = R_A x = 2Px - 2P\frac{x^2}{\ell} - P\frac{ç}{\ell}x$

$\frac{dM_x}{dx} = 2P - 2P\frac{x}{\ell} - P\frac{ç}{\ell} = 0$

Bu ýerden $x=\frac{\ell}{2}-\frac{ç}{4}$.

5.12. $\Delta t = 16^0S$.

Meseläniň şertine görä R_A=R_B=0, onda ÇA steržene düşýän güýç hemme ýüki kabul edýär.

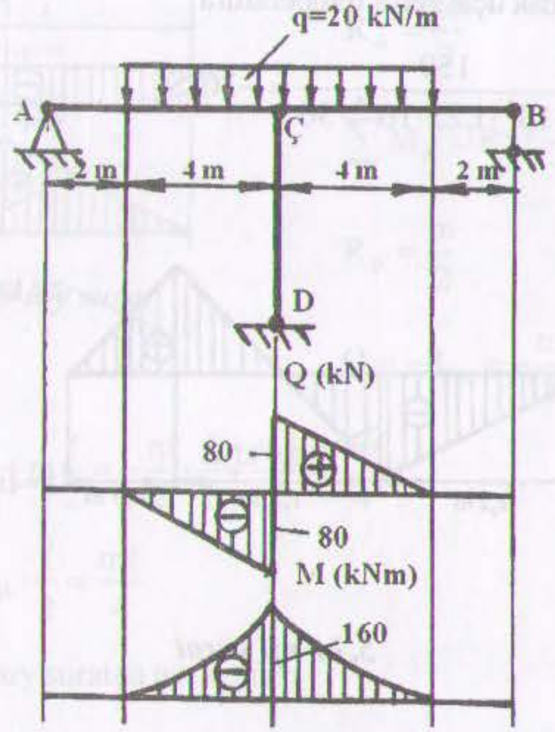
$N_{ÇD} = q\cdot 8 = 20\cdot 8 = 160\ kN$

Bu güýjüň ululygyny başgaça aşaky şertden tapyp bolýar.

$\Delta\ell_t = \Delta\ell_{N_{ÇD}}$

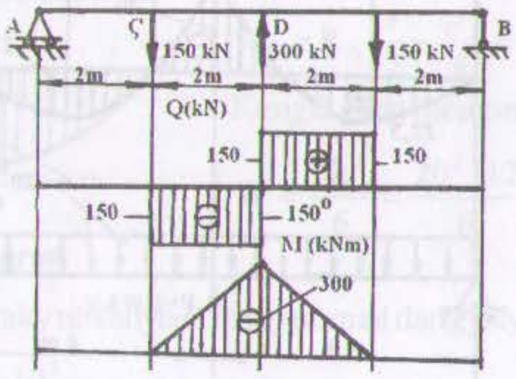
Ýa-da $\alpha\cdot\ell_{ÇD}\cdot\Delta t = \frac{N_{ÇD}\cdot h}{EA}$

Bu ýerden $\Delta t = \frac{N_{ÇD}}{\alpha EA} = \frac{160}{1{,}25\cdot 10^{-5}\cdot 2\cdot 10^4\cdot 40} = 16^0S$



5.12-nji surat

5.13. $\Delta t = -20^0S$.



5.13-nji surat

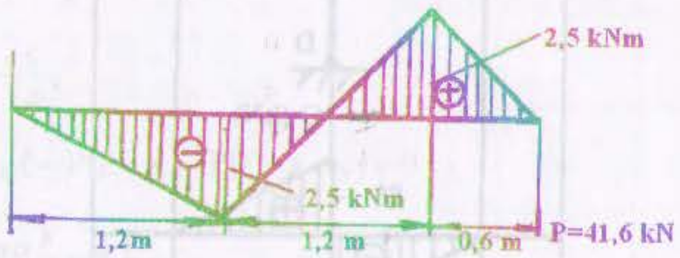
Her direge düşýän güýç

$N_{ÇÇ_1} = N_{DD_1} = 150$ kN

Diregleri sowatmak üçin zerur temperatura

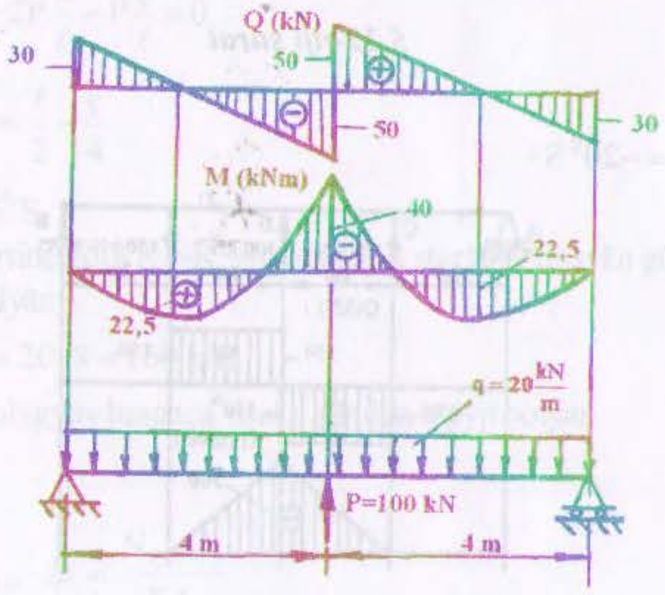
$$\Delta t = \frac{N_{ÇÇ_1}}{E\alpha A} = \frac{150}{2\cdot 10^4 \cdot 1{,}25\cdot 10^{-5}\cdot 30} = -20^0 S.$$

5.14.

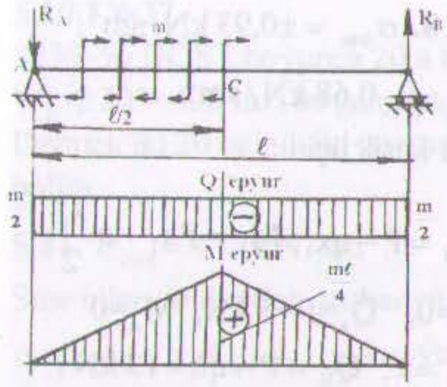


5.14-nji surat

5.15. ç)



5.15-nji surat



5.16-njy surat

5.16. $\sum M_B = R_A \cdot \ell - \frac{m\ell}{2} = 0,$

$$R_A = \frac{m}{2}$$

$$\sum M_A = R_B \ell - \frac{m\ell}{2} = 0,$$

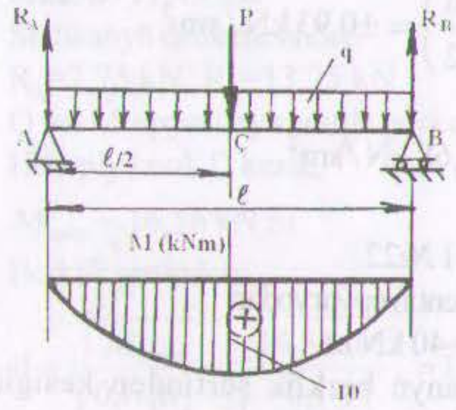
$$R_B = \frac{m}{2}$$

$$Q = -R_A = -\frac{m}{2}$$

$$M_Ç = -R_A \cdot \frac{\ell}{2} + m\frac{\ell}{2} = -\frac{m}{2}\cdot\frac{\ell}{2} + \frac{m\ell}{2} = \frac{m\ell}{4}$$

ýa-da $M_Ç = R_B \cdot \frac{\ell}{2} = \frac{m\ell}{4}$

Q we M epýurlary suratda görkezilen



5.17-nji surat

5.17. $\sigma_{max} = 1{,}25$ kN/sm^2.

$$R_A = R_B = \frac{P}{2} + \frac{q\ell}{2} = 9 \text{ kN}$$

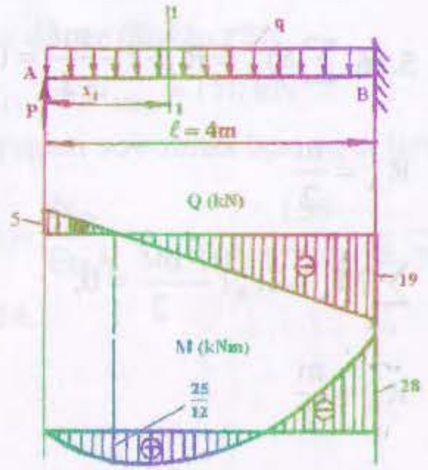
$$M_Ç = R_A \cdot \frac{\ell}{2} - \frac{q\ell^2}{8} = 18 - 8 = 10 \text{ kN m}$$

Kesigiň garşylyk momenti

$$W = \frac{bh^2}{6} = \frac{20^2\cdot 12}{6} = 800 \text{ sm}^3$$

Howply kesigiň gyraky nokadynda iň uly normal dartgynlylyk

$$\sigma_{max} = \frac{M_{max}}{W} = \frac{10\cdot 10^2}{800} = 1{,}25 \text{ kN/sm}^2$$



5.18-nji surat

5.18. $\sigma_{max} = \pm 0{,}93\ kN/sm^2$,

$\sigma_{Ç} = -0{,}68\ kN/sm^2$.

1-1 kesik üçin

$$Q_1 = P - qx_1,\ M_1 = Px_1 - q\frac{x_1^2}{2}$$

$x_1=0$, $Q_A=P=5$ kN, $M_A=0$

$x_1 = \ell$, $Q_B = P - q\ell = 19$ kN,

$$M_B = P\ell - q\frac{\ell^2}{2} = -28\ kN\ m$$

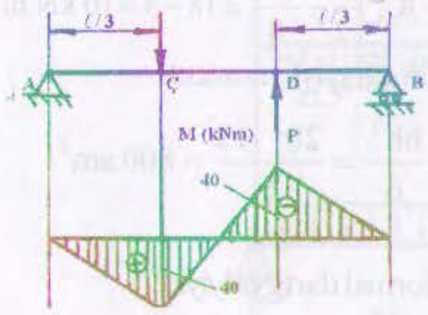
$$\frac{dM_1}{dx_1} = P - qx_1 = 0,\quad x_1 = x_{max} = \frac{5}{6}m$$

$$M_{max} = P\cdot\frac{5}{6} - q\cdot\frac{5^2}{6^2\cdot 2} = \frac{25}{12}\ kN\ m$$

Howply kesigi we M_B=-28 kN m

$$\sigma_{max} = \frac{M_B}{I_Z}\cdot y_{max} = \frac{12\cdot M_B}{bh^3}\left(\pm\frac{h}{2}\right) = \pm 0{,}93\ kN/sm^2$$

$$\sigma_Ç = \frac{M_B}{I_Z}\cdot y_Ç = \frac{12\cdot M_B}{bh^3}(-y_Ç) = -0{,}68\ kN/sm^2.$$



5.19-njy surat

5.19. I №22.

Momentiň epýuryndan

M_{max}=40 kN m.

Balkanyň berklik şertinden kesigiň garşylyk momenti

$$W_Z = \frac{M_{max}}{[\sigma]} = \frac{40\cdot 10^2}{16} = 250\ sm^3.$$

Tablisadan I № 22 kabul edýäris.

5.20. I №27

8239-56 DÖST boýunça 20 a belgili iki iki tawranyň garşylyk momenti W_Z=2·203=406 sm^3, bu garşylyk moment 27a belgili ikitawra gabat gelýär. Diýmek iki 20 belgili iki tawrany bir 27a belgili iki tawra bilen çalşyryp bolýar.

5.21. $\sigma_{max} = 4{,}12\ kN/sm^2$.

Suw bilen doldurylan turbanyň 1 m uzynlygyna getirilen hususy agramy $q = \gamma_1 A_1 + \gamma_2 A_2$; γ_1, γ_2 - çoýun turbanyň we suwuň udel agramlary, A_1, A_2 – turbanyň diwarynyň kese kesiginiň we suw bilen doldurylan meýdanlary. Iki diregli balkanyň endigan ýaýran q ýükden iň uly egme momenti

$$M_{max} = \frac{q\ell^2}{8},\ \text{onda}$$

$$\sigma_{max} = \frac{q\,\ell^2}{8\cdot W_Z} = \frac{\gamma_1\cdot 0{,}785\,D^2\left(1-\alpha^2\right)+\gamma_2\cdot 0{,}785\cdot d^2}{8\cdot 0{,}1\,d^3\left(1-\alpha^4\right)} = 4{,}12\frac{kN}{sm^2}.$$

Bu ýerde $d = D - 2t$, $\alpha = \frac{d}{D}$, t – turbanyň diwarynyň galyňlygy.

5.22. d=11,45 sm.

Statikanyň deňlemesinden

R_A=7,75 kN, R_B=13,25 kN.

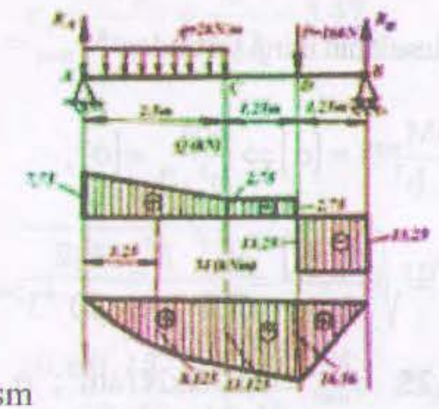
Q we M epýurlary suratda görkezilen

Howply kesik D kesik,

M_{max} = 16,56 kN m

Berklik şertinden

$$d = \sqrt[3]{\frac{M_{max}}{0{,}1\cdot[\sigma]}} = \sqrt[3]{\frac{16{,}56\cdot 10^2}{0{,}1\cdot 11}} = 11{,}45\ sm$$



5.22-nji surat

5.23. P_2=11,80 kN.

$$A_1 = A_2 \Rightarrow \frac{\pi d^2}{4} = b^2 \Rightarrow d = \frac{2b}{\sqrt{\pi}},$$

$$W_1=\frac{\pi d^3}{32}=\frac{\pi 8b^3}{32\pi\sqrt{\pi}}=\frac{b^3}{4\sqrt{\pi}},\quad W_2=\frac{b^3}{6},$$

$$\frac{M_2}{M_1}=\frac{W_2}{W_1}\Rightarrow\frac{P_2\ell\cdot 4}{4\cdot P_1\ell}=\frac{W_2}{W_1}\Rightarrow\frac{P_2}{P_1}=\frac{b^3\cdot 4\sqrt{\pi}}{6\cdot b^3}=1{,}18,$$

Bu ýerden kwadrat kesikli balkanyň howpsuz ýüki

$P_2=P_1\cdot 1{,}18=11{,}80$ kN m .

5.24. 1) $\sigma_{max}=28{,}26\ kN/sm^2$; 2)a=4,22 m.

Meseläniň birinji şertinden $M_{max}=\frac{q\ell^2}{8}$; q=γA.

Onda $\sigma_{max}\frac{M_{max}}{W_Z}=\frac{\sigma\gamma A\ell^2}{8\cdot b^3}=\frac{6\gamma b^2\ell^2}{8b^3}=\frac{6\gamma\ell^2}{8b}=$

$$=\frac{6\cdot 78{,}5\cdot 10^{-6}\cdot 12^2\cdot 10^4}{8\cdot 3}=28{,}26\ kN/sm^2.$$

Meseläniň ikinji şertinden $M_{max}=\frac{qa^2}{2}$.

$$\frac{6M_{max}}{b^3}=[\sigma]\Rightarrow\frac{6qa^2}{b^3\cdot 2}=[\sigma],$$

$$a=\sqrt{\frac{2b^3[\sigma]}{6\gamma A}}=\sqrt{\frac{3^3\cdot 14\cdot 2}{6\cdot 78{,}5\cdot 10^{-6}3^2}}=422\ sm=4{,}22\ m.$$

5.25. $\sigma_{max}=0{,}576\ kN/sm^2$; $\sigma_{min}=-1{,}73\ kN/sm^2$, n_2=3,47.

Balkanyň maksimal egme momenti

$$M_{max}=\frac{P\ell}{4}=\frac{8\cdot 3{,}6}{4}=7{,}2\ kN\ m.$$

$$z_ç=\frac{75\cdot 2{,}5+75\cdot 7{,}5}{15\cdot 5+15\cdot 5}=5\ sm,$$

$$I_{z_ç}=\frac{5^3\cdot 15}{12}+15\cdot 5\left(-2{,}5^2\right)+\frac{15^3\cdot 5}{12}+15\cdot 5\cdot 7{,}5^2=$$

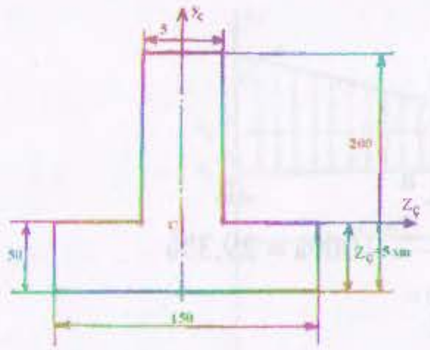
$$=156{,}25+468{,}75+1406{,}25+4216{,}5=6247{,}75\ sm^4.$$

Iň uly süýnme dartgynlylyk

$$\sigma_{max}=\frac{M_{max}}{I_{Zç}}\cdot y_1=\frac{7{,}2\cdot 10^2}{6247{,}75}\cdot 5\cong 5{,}576\ kN/sm^2.$$

Iň uly gysylma dartgynlylyk

$$\sigma_{min}=\frac{M_{max}}{I_{Z_Ç}}\cdot y_2=\frac{7{,}2\cdot 10^2}{6247{,}75}\cdot(-15)=-1{,}73\ kN/sm^2$$



5.25-nji surat

Proporsionallyk çägindäki ätiýaçlyk koeffisiýentleri

$$n_1=\frac{\sigma^s_{pç}}{\sigma_{max}}=\frac{3}{0{,}576}=5{,}2,$$

$$n_2=\frac{\sigma^s_{pç}}{\sigma_{min}}=\frac{6}{1{,}73}=3{,}47$$

5.26.

5.26-njy surat

$$M_{max}=\frac{q\ell^2}{2}=\frac{q\cdot 220^2}{2}=2{,}42q\cdot 10^4$$

$$z_ç=\frac{20\cdot 30\cdot 15-15\cdot 18\cdot 12{,}5}{20\cdot 30-15\cdot 18}=17\ sm$$

$$I_{z_ç}=\frac{20\cdot 30^3}{12}+20\cdot 30\cdot(-2)^2-\frac{18\cdot 15^3}{12}-$$

$$-18\cdot 15\cdot(-4{,}5)^2=36870\ sm^4$$

Berklik şertinden

Süýnme

$$\frac{M_{max}}{I_{z_ç}} \cdot y_1 = [\sigma]_s \Rightarrow q = \frac{[\sigma]_s \cdot I_{z_ç}}{10^4 \cdot 2{,}42 \cdot y_1} = \frac{1{,}2 \cdot 36870}{2{,}42 \cdot 13 \cdot 10^4} = 1{,}41 \frac{kN}{sm},$$

Gysylma

$$\frac{M_{max}}{I_{z_ç}} \cdot y_2 = [\sigma]_g \Rightarrow q = \frac{[\sigma]_s \cdot I_{z_ç}}{2{,}42 \cdot 10^4 \cdot y_2} = \frac{5 \cdot 36870}{2{,}42 \cdot 10^4 \cdot 17} = 0{,}448 \frac{kN}{sm}.$$

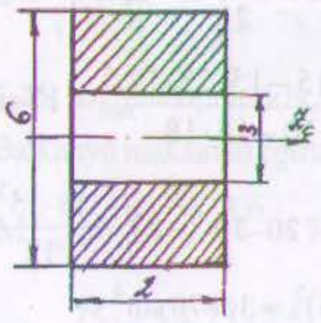
$$I_{z_1} = I_{z_2} = \frac{a^4}{12};\ y_1 = \frac{a}{\sqrt{2}};\ M_{max_1} = M_{max_2},$$

$$\sigma_1 = \frac{M_{max_1}}{I_{z_1}} \cdot y_1,\ \sigma_2 = \frac{M_{max_2}}{I_{z_2}} \cdot y_2$$

$$\frac{\sigma_2 - \sigma_1}{\sigma_2} \cdot 100\% = \frac{y_2 \cdot y_1}{y_2} \cdot 100\% = \frac{\frac{a}{\sqrt{2}} - \frac{a}{2}}{\frac{a}{\sqrt{2}}} \cdot 100\% = 29{,}3\%$$

5.28. P_1=1,47 kN, P_2=5,88 kN.

$$I_{z_ç} = 2\left(I_z + A \cdot y^2\right) = 2\left(\frac{2 \cdot 1{,}5^3}{12} + 2 \cdot 1{,}5 \cdot 2{,}25^2\right) = 31{,}5\ sm^4,$$



5.28-nji surat

$$M^I_{max} = P_1 \cdot 100,\ M^{II}_{max} = P_2 \cdot 25,$$

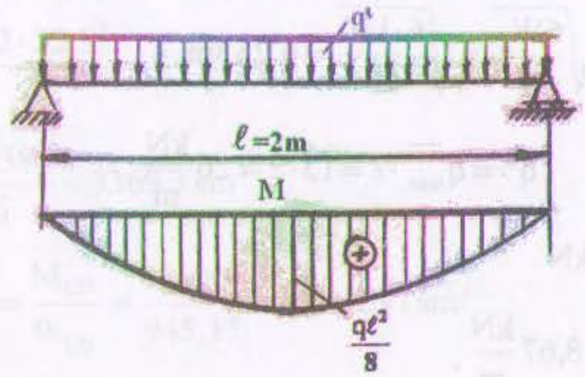
$$\sigma = \frac{M_{max}}{I_{z_ç}} \cdot y \le [\sigma].$$

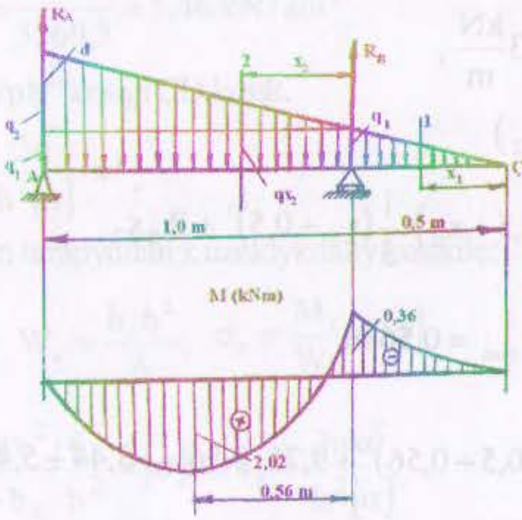
Onda $P_1 = \frac{I_{z_ç} \cdot [\sigma]}{y \cdot 100} = \frac{31{,}5 \cdot 14}{3 \cdot 100} = 1{,}47$ kN,

$$P_2 = \frac{I_{z_ç}[\sigma]}{y \cdot 25} = \frac{31{,}5 \cdot 14}{3 \cdot 25} = 5{,}88 \text{ kN}.$$

5.29. Direg üçin 16 x 16sm^2, örtük üçin t = 6,25sm.

$q^t = q_{max} \cdot b = 0{,}0013 \cdot 20 = 0{,}026$ kN/sm.





5.29-njy mesele

Tagtanyň galyňlygyny kesgitleýäris:

$$M_{max} = \frac{q^t \cdot \ell^2}{8} = \frac{0{,}026 \cdot 200^2}{8} = 130 \text{ kN} \cdot \text{sm}.$$

Berklik şertinden $\sigma_{max} = \frac{M_{max}}{W_z} \le [\sigma].$

Bu ýerden $W_Z = \frac{M_{max}}{[\sigma]} = \frac{130}{1} = 130\ sm^3$,

$W_Z = \frac{bt^2}{6} \Rightarrow t = \sqrt{\frac{6W_Z}{b}} = \sqrt{\frac{6\cdot 130}{20}} = 6{,}25\ sm.$

$$q^d = q_{max} \cdot \ell = 13 \cdot 2 = 26 \frac{kN}{m}.$$

$R_A = R_B = 9{,}75\ kN.$

$\frac{q_1}{0{,}5} = \frac{q^d}{1{,}5} \rightarrow q_1 = 8{,}67 \frac{kN}{m}$,

$q_2 = q^d - q_1 = 17{,}33 \frac{kN}{m}$,

$q_{x_2} = 17{,}34(0{,}5 + x_2)$

$M_{x_2} = -\frac{1}{2} \cdot 17{,}34(0{,}5 + x_2) \cdot \frac{1}{3}(x_2 + 0{,}5)^2 + R_B x_2$,

$\frac{dM_2}{dx_2} = 0 \Rightarrow x_2 = x_{max} = 0{,}56\ m$,

$M_{max} = -\frac{1}{6} \cdot 17{,}34(0{,}5 + 0{,}56)^3 + 9{,}75 \cdot 0{,}56 = -3{,}44 + 5{,}46 = 2{,}02\ kN \cdot m$

5.30. $b = \frac{BX}{\ell}$.

$b_x = B\frac{x}{\ell}$, $\frac{1}{\rho} = \frac{M}{EI_Z}$, $M = Px$, $I_Z = \frac{b_x h^3}{12} = \frac{bxh^3}{12\ell}$,

$\frac{1}{\rho} = \frac{Px}{B} \cdot \frac{12\ell}{xh^3 E} = \frac{P}{EB} \cdot \frac{12\ell}{h^3} \rightarrow$ hemişelik

Onda ρ=hemişelik, diýmek: $b = \frac{BX}{\ell}$.

5.31. $\sigma_{CD} = 8{,}04\ kN/sm^2$.

$M_{ÇD} = -P \cdot 95 = -7600\ kN \cdot sm$, $M_{AB} = -P \cdot 230 = -18400\ kN \cdot sm$,

$W_{ÇD} = \frac{11{,}2 \cdot 22{,}5^2}{6} = 945{,}35\ sm^3$,

$W_{AB} = \frac{14 \cdot 38^2}{6} = 3369{,}3\ sm^3$.

Onda $\sigma_{ÇD} = \frac{M_{ÇD}}{W_{ÇD}} = \frac{7600}{945{,}35} = 8{,}04\ kN/sm^2$,

$\sigma_{AB} = \frac{M_{AB}}{W_{AB}} = \frac{18400}{3369{,}3} = 5{,}46\ kN/sm^2$.

Ryçagyň „howply“ kesigi ÇD kesik.

5.32. $b_x = \frac{3q}{h^2[\sigma]} \cdot x^2$.

Balkanyň erkin tarapyndan x uzaklykdaky kesikde:

$M_x = -\frac{qx^2}{2}$, $W_x = \frac{b_x h^2}{6}$, $\sigma_x = \frac{M_x}{W_x} \le [\sigma]$

Bu ýerden $\frac{qx^2 \cdot 6}{2 \cdot b_x \cdot h^2} = [\sigma] \Rightarrow b_x = \frac{3qx^2}{h^2[\sigma]}$.

5.33. $I_x = 6000\ sm^4$.

$\sigma_{gys} = E\varepsilon_1 = E \cdot \frac{\Delta n_1}{\ell \cdot k} = -1{,}2 \cdot 10^4 \cdot \frac{1{,}5}{2 \cdot 1000} = -9\ kN/sm^2$,

$\sigma_{süýnme} = E \cdot \varepsilon_2 = E\frac{\Delta n_2}{\ell \cdot k} = 1{,}2 \cdot 10^4 \cdot \frac{0{,}5}{2 \cdot 1000} = 3\ kN/sm^2$,

$M_{max} = P \cdot a = 50 \cdot 60 = 3000\ kN \cdot sm$,

$\frac{h-y_ç}{15}=\frac{y_ç}{5}$ $y_ç=\frac{h}{4}$, $y_{gys}=18$ sm, $y_{süýnme}=6$ sm.

Gysylma berklik şertinden $I_x=\frac{M_{max}}{\sigma_{gys}}\cdot y_g=\frac{3000}{9}\cdot 18=6000\ sm^4$

Süýnmeden $I_x=\frac{M_{max}}{\sigma_{süýnme}}\cdot y_s=\frac{3000\cdot 6}{3}=6000\ sm^4$

5.34. $M=\frac{2}{3}\cdot\frac{\ell bh}{1-\mu}\cdot\frac{\Delta B}{B}$.

Balkanyň ýüklenmesinden $Q=\frac{M}{\ell}$,

Žurawskiniň formulasyndan $\tau=\frac{3}{2}\cdot\frac{Q}{bh}=\frac{3}{2}\cdot\frac{M}{\ell bh}$. (1)

Tenzometr 45° boýunça goýlan we bu kesikde $\sigma_1=\tau=-\sigma_3$.

Gukuň kanunyna laýyklykda

$\varepsilon=\frac{1}{E}(\sigma_1-\mu\sigma_3)=\frac{\tau}{E}(1+\mu)$, bu ýerde $\varepsilon=\frac{\Delta B}{B}$.

Onda $\tau=\frac{E\,\Delta B}{(1+\mu)B}$ (2)

(1) we (2) aňlatmalaryň sag tarapyny deňläp alarys:

$M=\frac{2}{3}\cdot\frac{E\,\ell\,b\,h}{1+\mu}\cdot\frac{\Delta B}{B}$.

5.35. $\sigma=2{,}71\ kN/sm^2$.

Sapfa düşýän güýç $R_S=\frac{G}{2}=\frac{430}{2}=215$ kN.

Sapfanyň boýnundaky egme moment

$M_{max}=R_S\cdot 0{,}34=215\cdot 0{,}34=73{,}1$ kN m,

Sapfanyň boýnundaky dartgynlylyk

$\sigma_{max}=\frac{M_{max}}{W_Z}=\frac{M_{max}}{0{,}1d_S^3}=\frac{73{,}1\cdot 10^2}{0{,}1\cdot 30^3}=2{,}71\ kN/sm^2$.

5.36. I №14.

Balka düşýän ýük $G=\frac{2}{3}\ell\ b\ h\ \gamma$,

$\frac{dy}{dx}=\frac{4h}{\ell^2}(\ell-2x)$,

Eger $x=0\Rightarrow\frac{dy}{dx}=tg\alpha=\frac{4h}{\ell}$, $\alpha=60^0$, $h=0{,}43\ell$.

Balkany basýan diwaryň böleginiň agramy

$G=\frac{2}{3}\cdot 0{,}43\,\ell^2\ B\,\gamma$.

Iň uly egme moment balkanyň ortasynda bolýar.

$M_{max}=\frac{G}{2}\left(\frac{\ell}{2}-\frac{3}{16}\ell\right)=\frac{5\,G\,\ell}{32}$,

$W_Z=\frac{M_{max}}{2[\sigma]}=\frac{5\,G\,\ell}{2\cdot 32[\sigma]}=\frac{4{,}3}{48}\cdot\frac{\ell^3 b\gamma}{2\cdot[\sigma]}=86\ sm^3$,

Tablisadan $W_Z=81{,}7\ sm^3$ I №14.

5.37. $\sigma_A=-0{,}73\ kN/sm^2$, $\sigma_B=6{,}68\ kN/sm^2$.

Polat listi ekwibalent agaç bilen çalşyrýarys, şonuň üçin listiň inini n=20 esse ulaldýarys, ýagny $B_{ekw}=nb=20\ b$.

Ekwiwalent kesigiň agyrlyk merkezini tapýarys.

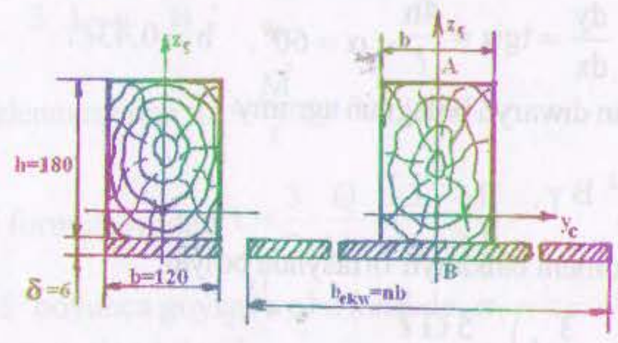
$$Z_ç=\frac{A^\ell Z^\ell+A^a Z^a}{A^\ell+A^a}=\frac{b_{ekw}\cdot\delta\cdot\frac{\delta}{2}+b\cdot h+\left(\delta+\frac{h}{2}\right)}{b_{ekw}\cdot\delta+b\,h}=5{,}88\ sm,$$

$$I_{Z_Ç} = \frac{b_{ekw}\cdot\delta^3}{12} + b_{ekw}\cdot\delta\cdot 5{,}58^2 + \frac{b\,h^3}{12} + b\cdot h\cdot 3{,}72^2 = 13310\ sm^4.$$

A we B nokatdakylary dartgynlylyklar.

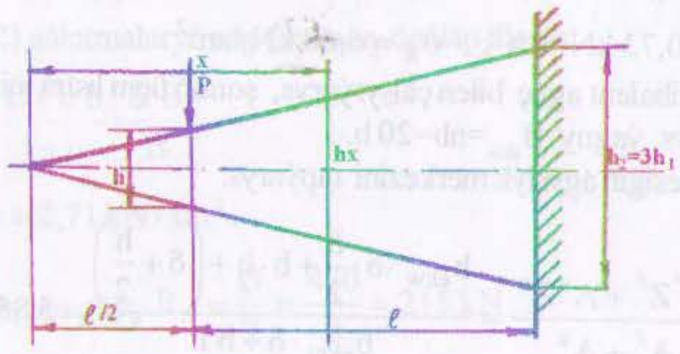
$$\sigma_B = \frac{M_{max}}{I_{Z_Ç}}\cdot Z_B = \frac{q\ell^2}{81_{Z_Ç}} Z_B = 0{,}334\ kN/sm^2,$$

$$\sigma_A = \frac{q\ell^2}{8I_{Z_3}}\cdot Z_A = 0{,}734\ kN/sm^2 \text{ onda } \sigma_B^{list} = \sigma_B\cdot n = 6{,}68\ \frac{kN}{sm^2}.$$



5.37-nji surat

5.38. $\sigma_{max} = \frac{3}{4}\cdot\frac{P\ell}{b\,h_1^2}$ - balkanyň oratasyndaky kesikde.



5.38-nji surat

Çyzgydan $h_x = \frac{2\,h_1}{\ell}\cdot x$,

$$W_Z = \frac{b}{6}\cdot h_x^2 = \frac{b}{6}\cdot\frac{4h_1^2}{\ell^2}x^2, \qquad M_x = -P\left(x - \frac{\ell}{2}\right).$$

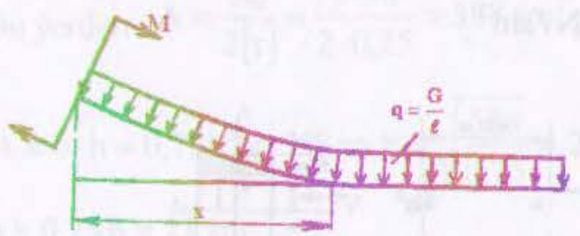
$$\sigma_x = \frac{M_x}{W_Z} = -\frac{P\left(x-\frac{\ell}{2}\right)}{\frac{b}{6}\cdot\frac{4h_1^2}{\ell^2}x^2} = -\frac{3P\ell^2}{2bh_1^2}\left[x^{-2}\cdot\left(x-\frac{\ell}{2}\right)\right].$$

Bu aňlatmanyň maksimumyny barlaýarys:

$$\frac{d\sigma_x}{dx} = -\frac{3P\ell^2}{2bh_1^2}\left[x^{-2}\cdot\left(x-\frac{\ell}{2}\right)\right]^1 = 0$$

Bu ýerden $x_{max} = \frac{\ell}{2}$.

Onda $\sigma_{max} = \frac{3\,P\,\ell^2}{2\,b\,h_1^2}\cdot\frac{1}{\ell^2}\cdot\frac{\ell}{2} = \frac{3}{4}\cdot\frac{P\,\ell}{b\,h_1^2}$.



5.39-njy surat

5.39. $x = 0{,}5\,\ell$.

$M_B^{zer} = M - q\frac{x^2}{2} = 0$,

Bu ýerden $\frac{q\,x^2}{2} = \frac{q\,\ell^2}{8}$,

onda $x = 0{,}5\,\ell$.

5.40. $P_{r.e} = \sigma_{wagt}\,b^3/(3\,n\,\ell)$.

Berklik şerti: $\sigma_{max} = \frac{M_{max}}{I_Z}\cdot y_{max} \le [\sigma]$.

Hasaby balkanyň süýnýän gatlagy üçin geçiriýäris, $y = \frac{h}{3}$.

$[\sigma]=\sigma_{wagt}/n$ we $M=\frac{P\ell}{4}$,

$I_Z=\frac{b\,h^3}{36}$ hasaba alyp,

$$\frac{P_{r.e}\ell}{4}\frac{36}{bh^3}\cdot\frac{h}{3}=\frac{\sigma_{wagt}}{n}$$

Bu ýerden $P_{r.e}=\frac{\sigma_{wagt}\cdot b^3}{3\,n\,\ell}$.

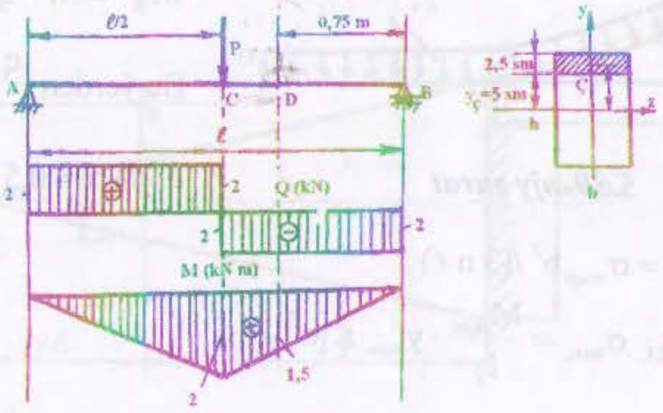
5.41. $\sigma_Ç=0{,}355\ kN/sm^2$, $\tau_Ç=0{,}015\ kN/sm^2$.

$$\sigma_Ç=\frac{M_D}{I_Z}\cdot y_Ç=\frac{12M_D}{b\,h^3}\cdot y_Ç=\frac{12\cdot1{,}5\cdot10^2}{7{,}5\cdot15^3}\cdot5=0{,}355\frac{kN}{sm^2}.$$

$$\tau_Ç=\frac{Q\cdot S_Z^{kes}}{I_Z\cdot b},$$

$S_Z^{kes}=A^{kes}\cdot y=7{,}5\cdot2{,}5\cdot6{,}25=117\ sm^3$,

$$\tau_Ç=\frac{2\cdot117}{7{,}5\cdot15^3\cdot7{,}5}=0{,}015\ kN/sm^2.$$



5.41-nji surat

5.42. b x h = 21 x 28 sm^2.

$Q_{max}=P=98\ kN$, $M_{max}=P\cdot Ç=98\cdot0{,}2=19{,}6\ kN\cdot m$.

Normal dartgynlylyk boýunça berklik şertinden

$$\sigma_{max}=\frac{M_{max}}{W_Z}\le[\sigma],\qquad W_Z=\frac{0{,}75\,h^3}{6}=0{,}125\,h^3.$$

Onda $h=\sqrt[3]{\frac{M_{max}}{0{,}125\cdot[\sigma]}}=\sqrt[3]{\frac{19{,}6\cdot10^2}{0{,}125\cdot1}}=25\ sm$,

$b=0{,}75\cdot25=18{,}75\ sm$.

Galtaşma dartgynlylyk boýunça barlaýarys:

$$\tau=\frac{3}{2}\cdot\frac{Q}{A}=\frac{3}{2}\cdot\frac{98}{25\cdot18{,}75}=0{,}31\ kN/sm^2>[\tau]=0{,}25\frac{kN}{sm^2}$$

$\tau>[\tau]$, şonuň üçin kesigi galtaşma dartgynlylygyň berklik şertinden saýlaýarys.

$$\tau=\frac{3}{2}\cdot\frac{Q}{A}\le[\tau],$$

Bu ýerden $A=\frac{3Q}{2[\tau]}=\frac{3\cdot98}{2\cdot0{,}25}=588\ sm^2$,

$A=b\cdot h=0{,}75h^2=558\Rightarrow h=\sqrt{\frac{588}{0{,}75}}=28\ sm$,

$b=0{,}75h=21\ sm$.

5.43. q=10 kN/m, τ_{max}=2,48 kN/sm².

Berklik şertinden $M_{max}=\frac{q\ell^2}{8}$, W_Z=143 sm^3,

$$\sigma=\frac{M_{max}}{W_Z}\le[\sigma]\Rightarrow\frac{q\,\ell^2}{8.\,W_Z}\le q=\frac{8W_Z[\sigma]}{\ell^2}=10kN/m,$$

Galtaşma dartgynlylyk d=0,51sm, I_Z=1290 sm^4,

S_Z=81,4sm³, $Q=\frac{q\,\ell}{2}=20\,kN$,

$$\tau_{max}=\frac{Q\cdot S_Z}{d\cdot I_Z}=\frac{20\cdot 81,4}{0,51\cdot 1290}=2,48\,kN/sm^2.$$

5.44. $\tau_{max}=2\,kN/sm^2$.

Žurawskiniň formulasyny ulanýarys.

$$\tau_{max}=\frac{Q\cdot S_Z^{max}}{b\,I_Z};\quad S_Z^{max}=S_{Z_1}^{max}=A_1\cdot Z_{Ç_1}-A_2\cdot Z_{Ç_2}=\frac{1}{6}\left(D^3-d^3\right),$$

$I_Z=0,1D^4\left(1-\alpha^4\right)$, α=0,9, b=2(D-d),

$$\tau_{max}=\frac{Q\left(D^3-d^3\right)}{6\cdot 2(D-d)\cdot 0,1D^4\left(1-\alpha^4\right)}=\frac{60\cdot\left(20^3-18^3\right)}{1,2(20-18)\cdot 20^4\left(1-0,9^4\right)}=2\frac{kN}{sm^2}.$$

5.45. $\sigma_{max}=0,86\,kN/sm^2$, $\tau_{max}=0,18\,kN/sm^2$.

Çyzgydan $\varphi=60^0=1,0466rad$, $M_{max}=P\cdot 3=12\,kN\,m$.

$$I_Z=\frac{d^4}{32}(\varphi-0,25\sin 4\varphi)=\frac{25^4}{32}(1,0466-0,25\cdot(-0,866))=15454\,sm^4,$$

$$\sigma_{max}=\frac{M_{max}}{I_Z}\cdot y,\qquad y=\sqrt{\frac{d^2}{4}-\frac{d^2}{16}}=\frac{\sqrt{3}}{4}d=10,83\,sm,$$

Onda $\sigma_{max}=\frac{12\cdot 10^2}{15454}\cdot 10,83=0,86\,kN/sm^2<[\sigma]$.

$$S_Z=\frac{d^3}{12}(1-\cos 3\varphi)=\frac{25^3}{12}\left(1-0,5^3\right)=1139,3\,sm^3,$$

$$\tau_{max}=\frac{P\cdot S_Z}{I_Z\cdot d}=\frac{60\cdot 1139,3}{15454\cdot 25}=0,18\,kN/sm^2<[\tau].$$

5.46. $\tau_{max}=9,8\,kN/sm^2$, $\tau_{min}=6,98\,kN/sm^2$,

Q =288kN, $\frac{Q_{diw}}{Q}=0,96$.

$$I_{Z_Ç}=\sum\left(I_{Z_i}+A_i\cdot y_i^2\right)=9590\,sm^4,$$

$S_{Z_Ç}=\sum A_i y_C=376,5\,sm^3$ –ýarym kesigiň statiki momenti,

$S_{Z_Ç}^I=A\cdot y=267,2\,sm^2$ –polkanyň merkezi oka görä statiki momenti.

Onda $\tau_{max}=\frac{Q\cdot S_{Z_Ç}}{I_{Z_Ç}\cdot d}=9,8\,kN/sm^2$, $\tau_{min}=\frac{Q\cdot S'_{Z_Ç}}{I_{Z_Ç}\cdot d}=6,98kN/sm^2$

$$Q_{diw}=\tau_{min}\cdot A_{diw}+\frac{2}{3}(\tau_{max}-\tau_{min})A_{diw}=288\,kN;$$

$$\frac{Q_{diw}}{Q}=\frac{288}{300}=0,96.$$

5.47. $\sigma_{max}=2,54\,kN/sm^2$, $\tau_{max}=0,8\,kN/sm^2$.

$Q=P=60\,kN$, $M_{max}=Pa=60\cdot 70=4200\,kN\,sm$,

$$I_Z=\frac{b^4}{12}-\frac{\pi d^4}{64}=\frac{24^4}{12}-\frac{3,14\cdot 20^4}{64}=19798\,sm^4,$$

$$\sigma_{max}=\frac{M_{max}}{I_Z}\cdot y_{max}=\frac{4200}{19798}\cdot 12=2,54\,kN\,sm^2,\quad y_{max}=\frac{b}{2}=12\,sm.$$

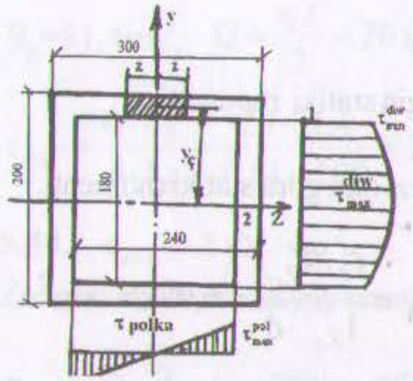
Ýarym kesigiň statiki momenti

$$S_Z=b\cdot\frac{b}{2}\cdot\frac{b}{4}-\frac{\pi d^2}{8}\cdot\frac{2d}{3\pi}=\frac{24^3}{8}-\frac{20^3}{12}=1061,33\,sm^3,$$

$$\tau_{max}=\frac{Q\cdot S_Z}{I_Z(b-d)}=\frac{60\cdot 1061,33}{19798\cdot 4}=0,8\,kN/sm^2.$$

5.48. $\tau_{max}=3,3\,kN/sm^2$ bu bolsa diwardaky dartgynlylykdan 30% ýokary.

$$I_Z=\frac{30\cdot 20^3}{12}-\frac{24\cdot 18^3}{12}=8336\,sm^4,$$



5.48-nji surat

$$S_{Z_1}^{diw} = 30\cdot 1\cdot 9{,}5 = 285\ sm^3,$$

$$S_{Z_1}^{diw} = S_{Z_1}^{diw} + 2\cdot 9\cdot 3\cdot 4{,}5 = 528\ sm^3,$$

$$\tau_{Z_1}^{diw} = \frac{Q\,S_{Z_1}^{diw}}{I_Z\cdot 2\cdot 3} = \frac{240\cdot 285}{8336\cdot 6} = 1{,}36\ kN/sm^2,$$

$$\tau_{Z_1}^{diw} = \frac{Q\,S_{Z_2}^{diw}}{I_Z\cdot 6} = \frac{240\cdot 528}{8336\cdot 6} = 2{,}53\ kN/sm^2,$$

$$S_Z^{pol} = t\cdot z\cdot y_ç = 9{,}5\,z,$$

$z=0,\quad \tau=0,\qquad z=12$ sm,

$$\tau_{max}^{pol} = \frac{Q\cdot S_Z^{pol}}{I_Z\cdot t} = \frac{240\cdot 9{,}57}{8336\cdot 1} = \frac{240\cdot 9{,}5\cdot 12}{8336} = 3{,}3\ \frac{kN}{sm^2}.$$

5.49. P=605 kN, τ_{max}=6,95 kN/sm².

$$I_Z = \left(\frac{36\cdot 2^3}{12} + 36\cdot 2\cdot 19^2\right)\cdot 2 + \frac{1{,}2\cdot 36^3}{12} = 56697{,}6\ sm^4,$$

$$S_Z = 36\cdot 2\cdot 19 + 1{,}2\cdot 18\cdot 9 = 1562{,}4\ sm^3.$$

1) Normal dartgynlylyk boýunça berklik şertinden

$$\frac{P\ell}{4W_Z} \le [\sigma] \Rightarrow P = \frac{4W_Z[\sigma]}{\ell} = \frac{4\cdot 2834{,}88\cdot 16}{300} = 605\ kN.$$

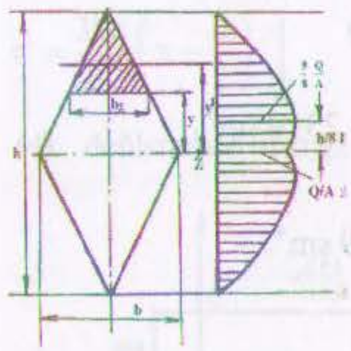
2) Galtaşma dartgynlylyk boýunça berklik şertinden

$$\tau_{maü} = \frac{Q\cdot S_Z}{I_Z\cdot D} \le [\tau], \qquad Q = \frac{P}{2}$$

$$\frac{Q\cdot S_Z}{2I_Z\cdot d} \le [\tau] \Rightarrow P = \frac{2I_Z d[\tau]}{S_Z} = \frac{2\cdot 56697{,}6\cdot 1{,}2\cdot 10}{1562{,}4} = 871\frac{kN}{sm^2}.$$

Kabul edýäris: P=605kN.

Onda $\tau_{max} = \dfrac{Q\cdot S_Z}{I_Z\cdot d} = \dfrac{605\cdot 1562{,}4}{2\cdot 56697{,}6\cdot 1{,}2} = 6{,}95\ kN/sm^2$.



5.50-nji surat

5.50. $\tau_{max} = \dfrac{9}{8}\cdot\dfrac{Q}{A}$,

$$\tau = \frac{2Q}{bh^3}(h-2y)\cdot(h+4y).$$

Žurawskiniň formulasyndan

$$\tau = \frac{Q\cdot S_Z^{kes}}{I_Z\cdot b_z}$$

Çyzgydan alarys:

$$S_Z^{kes} = \frac{1}{2}\cdot b_Z\left(\frac{h}{2}-y\right)\cdot\frac{h+4y}{6} = \frac{1}{4}\cdot\frac{b}{h}(h-2y)^2\cdot\frac{h+4y}{6},$$

$$I_Z = 2\cdot\frac{b\left(\frac{h}{2}\right)^3}{12} = \frac{bh^3}{48},$$

Onda:

$$\frac{Q\cdot 48}{bh^3}\cdot\frac{b(h-2y)^2(b+4y)}{24h}\cdot\frac{h}{b(h-2y)} = \frac{2Q}{bh^3}(h-2y)(h+4y),$$

Eger: $y = \pm\dfrac{h}{2} \Rightarrow \tau = 0$,

Eger: $y = 0 \Rightarrow \tau = \dfrac{Q}{A}$.

Galtaşma dartgynlylygyň iň uly bahasyny tapýarys:

$$\frac{d\tau}{dy} = \left[\frac{2Q}{bh^3}\cdot(h-2y)(h+4y)\right]' = 0 \Rightarrow y = \frac{h}{8},$$

$$\tau_{max}=\frac{2Q}{bh^3}\left(h-2\cdot\frac{h}{8}\right)\left(h+4\cdot\frac{h}{8}\right)=\frac{9}{8}\cdot\frac{Q}{A}.$$

5.51. h=0,3 sm.

Polka bilen diwaryň sepgidindäki dartgynlylyk

$$\tau=\frac{Q\cdot S_z}{I_z\cdot\delta};\quad S_z^{pol}=3\cdot20\cdot38{,}5=2310\ sm^3,$$

$$I_z=2\left(3\cdot20\cdot38{,}5^2+\frac{203^3}{12}\right)+\frac{1\cdot74^3}{12}=211729\ sm^4$$

$$\tau=\frac{300\cdot2310}{211729\cdot1}=3{,}27\ kN/sm^2;\quad T=\tau\cdot\delta\cdot1=3{,}27\ kN.$$

Tikiniň meýdany $A=\frac{T}{[\tau]}=\frac{3{,}27}{5}=0{,}654\ sm^2$,

$A=2\cdot1\cdot0{,}7\,h_t=0{,}654$, h_t=0,47 sm.

5.52. $\sigma^1=\frac{3Px}{2h^3}(3h-4x)$, $\tau^1=\frac{3Px}{h^3}\left(x-\frac{h}{2}\right)$.

Diregden x uzaklykdaky balkanyň çep böleginiň kese kesigindäki σ we τ ańlatmalary aşakdaky ýaly ýazylýar (b=1):

$$\sigma=-\frac{6Pxy}{h^3},\qquad \tau=\frac{3P\left(\frac{h^2}{4}-y^2\right)}{h^3}.$$

a-b kesik boýunça dartgynlylyk aşakdaky formula bilen tapylýar:

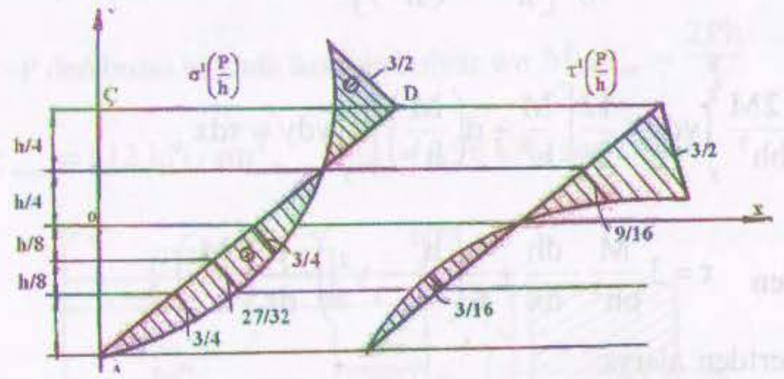
$$(2)\quad\begin{cases}\sigma^1=\frac{\sigma}{2}(1-\cos2\alpha)-\tau\sin2\alpha, & 1-\cos2\alpha=2\cos^2\alpha\\ \tau^1=\frac{\sigma}{2}\sin2\alpha-\tau\cos2\alpha, & \text{bu yerde}\quad \alpha=135^0\end{cases}$$

σ^1 we τ^1 meýdançasy a-b gönüde ýatyr, onuň deňlemesi $y=x-\frac{h}{2}$ (3)

(1), (2) we (3) ańlatmalary bilelikde çözüp alarys:

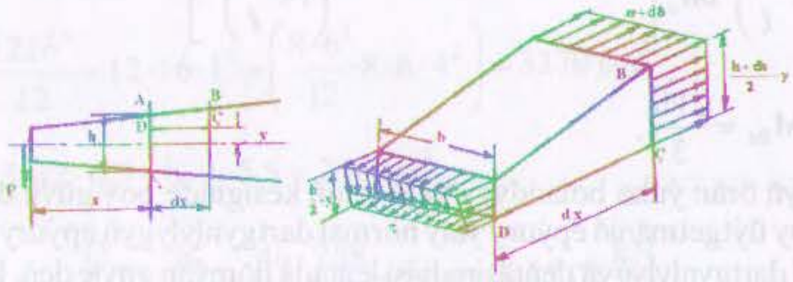
$$\left.\begin{aligned}\sigma^1&=\frac{3Px}{2h^3}(3h-4x)\\ \tau^1&=\frac{3Px}{h^3}\left(x-\frac{h}{2}\right)\end{aligned}\right\}\qquad(4)$$

(4) deňlemeleri ulanyp, aşakdaky epýurlary alarys.



5.52-nji surat

5.53. $\tau=6P\left[\left(1+\frac{x}{\ell}\right)^2bh_0\right]^{-1}\cdot\left[\frac{x}{2\ell}+\frac{1}{h_0^2}\left(\frac{h^2}{4}-y^2\right)\cdot\frac{1-\frac{2x}{\ell}}{\left(1+\frac{x}{\ell}\right)^2}\right]$



5.53-nji surat

Uzynlygy dx bolan elementar bölegi bölüp alýarys we onuň deňagramlylygyna seredýäris.

$$\sum X = -\int_{y}^{\frac{h}{2}} \sigma\, b\, d\, y + \int_{y}^{\frac{h+dh}{2}} (\sigma + d\,\sigma)\, d\, y = \tau\, b\, d\, x\,, \quad \sigma = \frac{12\, M}{b\, h^3} \cdot y\,.$$

Bu ýerde $\sigma + d\sigma_1 = \frac{12y}{b}\left[\frac{M}{h^3} + d\left(\frac{M}{h^3}\right)\right]$,

Onda $\frac{12M}{bh^3}\int_{y}^{\frac{h}{2}} ydy + \frac{12}{b}\left[\frac{M}{h^3} + d\left(\frac{M}{h^3}\right)\right]\int_{y}^{\frac{h+dh}{2}} ydy = \tau dx$,

Bu ýerden $\tau = 3\frac{M}{bh^2}\cdot\frac{dh}{dx} + \frac{6}{6}\left(\frac{h^2}{4} - y^2\right)\cdot\frac{d}{dx}\left(\frac{M}{h^3}\right)$,

$h_1=2h_o$ şertden alarys:

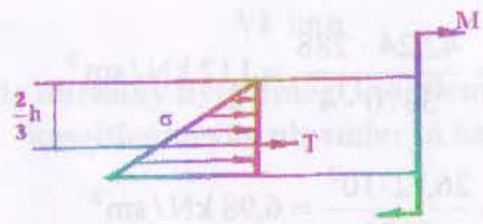
$h = h_o\left(1 + \frac{x}{\ell}\right)$, M=Px.

Onda ýerine goýup aşakdaky aňlatmany alarys:

$$\tau = \frac{6P}{\left(1+\frac{x}{\ell}\right)^2 bh_o}\left[\frac{1}{2}\cdot\frac{x}{\ell} + \frac{1}{h^2}\left(\frac{h^2}{4} - y^2\right)\cdot\frac{1-\frac{2x}{\ell}}{\left(1+\frac{x}{\ell}\right)^2}\right].$$

5.54. $M_{üz} = \frac{2Ph}{3}$.

Lentanyň örän ýuka bolandygy üçin onuň kesiginde boý güýji döreýär. Durkuny üýtgetmäniň epýury ýaly normal dartgynlylygyň epýury bolýar. Normal dartgynlylygyň deňtäsiredijisi lentada döreýän güýje deň. Hemme güýçler bir jübüt güýje $\left(T\cdot\frac{2h}{3}\right)$ getirilýär.

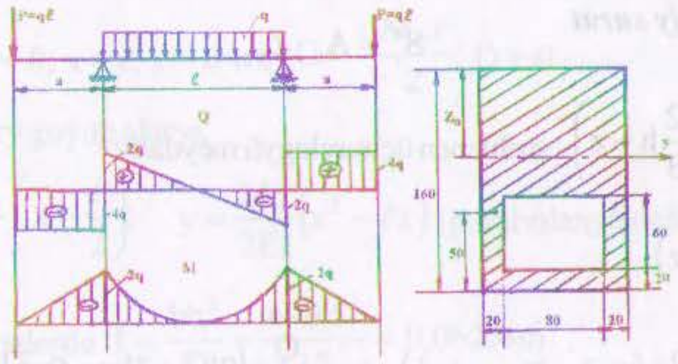


5.54-nji surat

Deňagramlylyk şertinden $M = T2h/3$,

Eger T=P deň bolsa lentada üzülme bolýar we $M_{üzülme} = \frac{2Ph}{3}$

5.55. $\tau_{max} = 1{,}12\ kN/sm^2$, $\sigma_{max} = 6{,}98\ kN/sm^2$.



5.55-nji surat

$$Z_o = \frac{16\cdot12\cdot8 - 8\cdot6\cdot11}{16\cdot12 - 8\cdot6} = 7\ sm,$$

$$I_y = \frac{1216^3}{12} + 12\cdot16\cdot1^2 - \left(\frac{8\cdot6^3}{12} 8\cdot6\cdot4^2\right) = 3370\ sm^4,$$

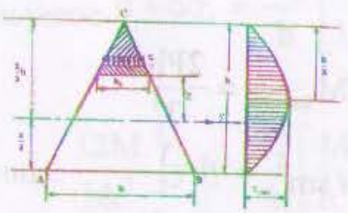
$$S_y^{ç} = 5\cdot12\cdot6{,}5 - 8\cdot3\cdot5{,}5 = 258\ sm^3.$$

Onda $\tau_ç = \frac{Q_{max}\cdot S_y^ç}{I_y\cdot\delta_3} = \frac{4q\cdot258}{3370\cdot4} = 1 \Rightarrow q = 13{,}06\frac{kN}{sm}$

$S_y^{max} = 12\cdot8\cdot5 - 6\cdot8\cdot4 = 288\ sm^3$

$$\tau_{max} = \frac{Q_{max} \cdot S_y^{max}}{I_y \cdot \delta} = \frac{42{,}24 \cdot 288}{3370 \cdot 4} = 1{,}12\ kN/sm^2$$

$$\sigma_{max} = \frac{M_{max}}{I_y} \cdot y_{max} = \frac{26{,}12 \cdot 10^2}{3370} = 6{,}98\ kN/sm^2.$$



5.56-njy surat

5.56. $\tau_{max} = \frac{3}{2} \cdot \frac{Q}{A}$.

Žurawskiniň formulasy boýunça

$$\tau = \frac{Q \cdot S_y^0}{I_y \cdot b_z},$$

$$S_y^o = A_0 \cdot Z_0,$$

$A_0 = \frac{1}{2} b_z \left(\frac{2}{3} h - z \right)$ - ştrihlenen üçburçlugyň meýdany

$$Z_0 = \frac{2}{3}(h + z)$$

Onda $S_y^o = \frac{b_z}{27}\left(2h^2 + 3hz - 9z^2\right)$, $\tau = \frac{Q}{27I_y}\left(2h^2 + 3hz - 9z^2\right)$

$$\frac{d\tau}{dz} = 3h - 18z = 0 \Rightarrow z = \frac{h}{6};$$

Diýmek $\tau = \tau_{max}$, eger $z = \frac{h}{6}$ ýa-da üçburçlugyň orta çyzygynda iň uly galtaşma dartgynlylyk bolýar, ýagny $\tau_{max} = \frac{3Q}{bh} = \frac{3}{2} \cdot \frac{Q}{A}$.

Eger $z = 0 \Rightarrow \tau = \frac{4}{3} \cdot \frac{Q}{A}$, $z = \frac{2}{3}h \rightarrow \tau = 0$ we $z = \frac{h}{3} \rightarrow \tau = 0$; τ epýury suratda görkezilen.

VI bap

Egilmede durkuny üýtgetmegi kesgtlemek we statiki kesgitlenmeýän ulgamlaryň hasaby

6.1. $\theta_{max} = 0{,}04rad$; $y_{max} = f = 1sm$.

$EJy^{II} = M_x = M_o$ egrelen okuň differensial deňlemesini integrirläp, burç we çyzyk ornuny üýtgetmeleriniň bahalaryny alarys.

Iki gezek integrirläp alarys:

$$EJy^I = M_o x + C; \quad EJy = M_o \frac{x^2}{2} + Cx + D.$$

Balkany berkitmek şertinden C we D hemişelikleri tapýarys.

$x = 0; y = 0; x = \ell; y = 0$ we $C = -\frac{M_o \ell}{2}, D = 0.$

Bu bahalary goýup alarys.

$$y^I = \frac{M_o}{EI}\left(x - \frac{\ell}{2}\right); \quad y = \frac{M_o}{2EI}\left(x^2 - \ell x\right)$$ (parabolanyň deňlemesi).

Bu deňlemelerde $I = \frac{bh^3}{12} = \frac{6 \cdot 0{,}5^3}{12} = 0{,}0625sm^4$.

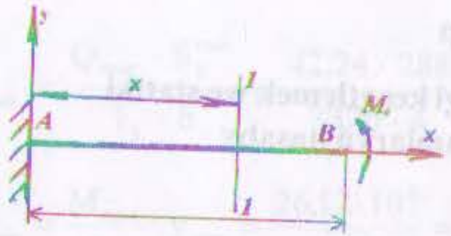
Iň uly öwrülme burçy ($x = 0$ ýa-da $x = 1m$)

$x = 0 \Rightarrow \theta_A = \frac{-M_o \ell}{2EI} = -0{,}04rad$ (minus alamaty A diregde kesik sagat diliniň ugruna öwrülýär).

Iň uly progib prolýotyň ortasynda bolýar.

$$x = \frac{\ell}{2} \Rightarrow f = -\frac{M_o \ell^2}{EI} = -1sm$$ (progibiň ugry **y** okuň ugruna gapma-garşy).

6.2. $E = 2 \cdot 10^4 km/sm^2$, $\rho = 26{,}75m$.



6.2-nji surat

$$EIy^{II} = M_{x_1} = M_o,$$

$$EJy^{I} = M_o x + C;$$

$$EJy = M_o \frac{x^2}{2} + Cx + D,$$

$$x = 0;\ C = 0;\ D = 0;\ x = \ell;$$

$$EI\theta_{max} = M_o \ell;$$

$$E = \frac{M_o \ell}{I\theta_{max}} = \frac{10 \cdot 100 \cdot 12}{2^4 \cdot 0{,}075} = 2 \cdot 10^4 \text{kN/sm}^2.$$

Egrelmäniň radiusy $\rho = \frac{EI}{M_o} = \frac{2 \cdot 10^4 \cdot 2^4}{12 \cdot 10} = 2675\text{sm} = 26{,}75\text{m}$.

6.3. $\rho = 100\text{m}$, $M = 23\text{kN}\cdot\text{sm}$,

Egrelmäniň deňlemesi $y = \frac{M_o}{2EI} x^2 + Cx + D$.

Bu ýerde $D = 0$, $C = -\frac{M_o \ell}{2EI}$

Onda $y = \frac{Mx^2}{2EI} - \frac{M\ell}{2EI} x$.

Eger $x = \frac{\ell}{2} \Rightarrow y_{max} = -\frac{M\ell^2}{8EI} \Rightarrow M = \frac{8EI \cdot y_{max}}{\ell^2} = 23\text{kN} \cdot \text{sm}$.

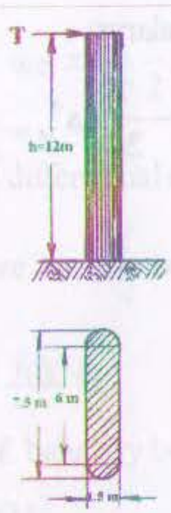
Egilmäniň esasy deňlemesinden:

$$\rho = \frac{EI}{M_o} = \frac{10^3 \cdot 230}{23} = 10^4\text{sm} = 100\text{m}.$$

6.4. $E = 8{,}08 \cdot 10^2 \text{kN/sm}^2$.

Konsol balkanyň T güýçden iň uly egrelmesi

$$y_{max} = \frac{T\ell^3}{3EI} \Rightarrow E = \frac{T\ell^3}{3Iy_{max}} = \frac{240 \cdot 12^3 \cdot 10^6}{3 \cdot 0{,}875 \cdot 19553 \cdot 10^4} = 8{,}08 \cdot 10^2 \text{kN/sm}^2.$$



6.4-nji surat

Bu ýerde

$$I = \frac{600 \cdot 150^3}{12} + \frac{3{,}14 \cdot 150^4}{64} = 19553 \cdot 10^4 \text{sm}^4$$

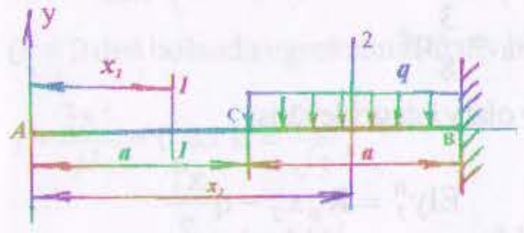
6.5. a) $\theta = \frac{2M_o a}{EI}$, $f = \frac{4M_o a^2}{EI}$;

b) $\theta = \frac{13Pa^2}{2EI}$, $f = -\frac{41Pa^3}{3EI}$;

ç) $\theta = \frac{qa^3}{6EI}$, $f = -\frac{7qa^4}{24EI}$;

d) $\theta = \frac{49qa^3}{3EI}$, $f = -\frac{59qa^4}{EI}$

ç) Balkanyň birinji bölegi üçin:



6.5-nji surat

$$EIy_1^{II} = 0,\ EIy_1^{I} = C_1,$$

$$EIy_1 = C_1 x_1 + D_1.$$

Balkanyň ikinji bölegi üçin:

$$EIy^{II} = -q\frac{(x_2 - a)^2}{2}$$

$$EIy^{I} = -q\frac{(x_2 - a)^3}{6} + C_2,\ EIy = -q\frac{(x_2 - a)^4}{24} + C_2 x + D_2.$$

Eger $x_1 = x_2 = a$,

$\theta_c = y_1^I = y_2^I$ we $y_c = y_1 = y_2$.

Onda ýokardaky deňlemelerden alarys:

$C_1 = C_2 = C$, $D_1 = D_2 = D$.

C we D hemişelikleri balkany berkitmek şertinden alarys:

$x_2 = 2a$ bolanda $y_2' = 0$, $y_2 = 0$, $C = \frac{qa^3}{6}$, $D = -\frac{7}{24}qa^4$,

Eger $x_1 = 0$,

$\theta_A = \frac{qa^3}{6EI}$ we $y_A = -\frac{7}{24EI}qa^4$.

6.6. IN22, σ_{max} =8,62kN/sm².

$y_{max} = \frac{q\ell^4}{8EI} = \frac{\ell}{450} \Rightarrow I = \frac{459q\ell^3}{8E} = 2250sm^4$.

8239-56 DÖST boýunça $I_z = 2250sm^4$, $W_z = 232sm^3$.
22-nji belgili iki tawra gabat gelýär.
Iň uly normal dartgynlylyk:

$\sigma_{max} = \frac{M_{max}}{W_z} = \frac{q\ell^2}{2W_z} = 8,62kN/sm^2 < 14kN/sm^2$.

6.7. f=–1,39sm; θ_A =–0,0097rad; θ_B = 0,0125rad.

$q = \frac{2Q}{\ell} = 10kN/m$; $R_A = \frac{q\ell}{8}$; $R_B = \frac{3}{8}q\ell$.

Differensial deňlemeleri düzýäris we olary integrirleýäris:

$EIy_1'' = R_A x_1$, $EIy_2'' = R_B x_2 - q\frac{x_2^2}{2}$

$EIy_1' = R_A\frac{x_1^2}{2} + C_1$; $EIy_2' = R_B\frac{x_2^2}{2} - q\frac{x_2^3}{6} + C_2$;

$EIy_1 = R_A\frac{x_1^3}{6} + C_1x_1 + D_1$. $EIy_2 = R_B\frac{x_2^3}{6} - q\frac{x_2^4}{24} + C_2x_2 + D_2$.

Deňlemelere giryän dört hemişelikleri kesgitlemek üçin aşakdaky şertleri ulanýarys:

a) $x_1 = 0$; $y_1 = 0$; b) $x_2 = 0$; $y_2 = 0$;

ç) $x_1 = \frac{\ell}{2}$ we $x_2 = \frac{\ell}{2}$; $\theta_Ç = -y_1' = y_2'$;

d) we ; $f_ç = y_1 = y_2$.

Bu şertleri differensial deňlemelere goýup, C_1, C_2, D_1, D_2 bahalaryny tapýarys we $x = \frac{\ell}{2}$ bolanda $f = -\frac{5Q\ell^3}{384EI} = -1,39sm$, bu ýerde

$Q = \frac{q\ell}{2} = 20kN$.

$x = 0$, $x = \ell$ bahalary berip θ_A we θ_B tapýarys:

$\theta_A = -\frac{7Q\ell^2}{192EI} = -0,0097rad$, $\theta_B = -\frac{9Q\ell^2}{192EI} = 0,0125rad$.

6.8. $y_{max} = 0,0641\frac{M\ell^2}{EI}$, $y_{\frac{\ell}{2}} = 0,0625\frac{M\ell^2}{EI}$.

θ we y deňlemeler aşakdaky ýaly aňladylýar:

$y_x = \frac{M\ell^2}{6EI}\left(\frac{x}{\ell} - \frac{x^3}{\ell^3}\right)$, $\theta_x = \frac{M\ell}{6EI}\left(1 - \frac{3x^2}{\ell^2}\right)$,

$\theta_x = 0$ deň bolanda egrelmäniň iň uly bahasy bolýar:

$1 - \frac{3x^2}{\ell^2} = 0 \Rightarrow x = \frac{\ell}{\sqrt{3}}$.

Onda $y_{max} = \frac{\ell}{9\sqrt{3}}\frac{M\ell^2}{EI} = 0,0641\frac{M\ell^2}{EI}$.

Balkanyň ortasyndaky egrelme:

$y_{\frac{\ell}{2}} = \frac{M\ell^2}{15EI} = 0,0625\frac{M\ell^2}{EI}$.

6.9. $P = \frac{3}{5}q\ell$.

BÇ bölek üçin differensial deňleme düzýäris we ony integrirleýäris:

$EIy^{II} = -Px - q\frac{x^2}{2}$, $EIy^{I} = -P\frac{x^2}{2} - q\frac{x^3}{6} + C$,

$EIy = \frac{Px^3}{6} - q\frac{x^4}{24} + Cx + D$.

C we D hemişelikleri aşakdaky şertlerden tapýarys:

$x = 0{,}5\ell$, $y = 0$, $EIy = -\frac{P(2{,}5\ell)}{6} - q\frac{(0{,}5\ell)^4}{24} + 0{,}5C\ell + D = 0$,

$x = 2{,}5\ell$, $y = 0$, $EIy = -\frac{P(2{,}5\ell)}{6} - q\frac{(2{,}5\ell)^4}{24} + 0{,}5C\ell + D = 0$.

Bilelikde işläp alarys:

$C = \frac{31}{24}P\ell^2 + \frac{13}{16}q\ell^3$, $D = -\frac{5}{8}P\ell^3 + \frac{3}{8}q\ell^4$.

Hemişelik D, koordinatlar okunyň başlangyjyndaky egrelme, şerte görä $D = 0$

Onda $\frac{5}{8}P\ell^3 = \frac{3}{8}q\ell^4 \Rightarrow P = \frac{3}{5}q\ell$.

6.10. $f_ç = \frac{Pa^2(\ell + a)}{3EI}$.

$R_A = -\frac{Pa}{\ell}$, $M_{x_1} = -\frac{Pa}{\ell}x_1$, $M_{x_2} = -Px_2$.

Onda $U = \int_0^{\ell}\frac{M_{x_1}^2 dx}{2EI} + \int_0^{a}\frac{M_{x_2}^2 dx}{2EI} = \frac{P^2a^2(\ell + a)}{6EI}$.

Daşky güýjüň işi $A = A_{R_A} + A_P = A_P = \frac{1}{2}Pf_Ç$, $(A_{R_A} = 0)$.

Daşky güýjüň işi balkanyň durkuny üýtgetmesiniň doly potensial energiýasyna geçýär we $A = U$, onda

$\frac{1}{2}Pf_ç = \frac{P^2a^2(1 + a)}{6EI}$,

Bu ýerden $f_ç = \frac{Pa^2(\ell + a)}{3EI}$.

6.11. $U = 2{,}7\text{kN}\cdot\text{sm}$.

$I_z = \frac{\pi d^4}{64} = \frac{3{,}14\cdot 12^4}{64} = 1017\text{sm}^4$, $I_p = 2I_z = 2034\ \text{sm}^4$.

Onda

$U = \frac{M_k^2\ell^2}{2GI_p} + \frac{M_\ell^2\ell^2}{2EI_z} = \frac{800^2\cdot 10^2}{2\cdot 8{,}5\cdot 2034} + \frac{600^2\cdot 10^2}{2\cdot 2{,}1\cdot 10^4\cdot 1017} = 2{,}7\text{kN}\cdot\text{sm}$.

6.12. $U = \frac{\sigma^2 A\ell}{6E}$.

Balkada toplanan potensial energiýa

$U = \frac{M^2\ell}{2EI_z}$, bu ýerde $M = \sigma W_z$; $W_z = \frac{bh^2}{6}$; $I_z = \frac{bh^3}{12}$.

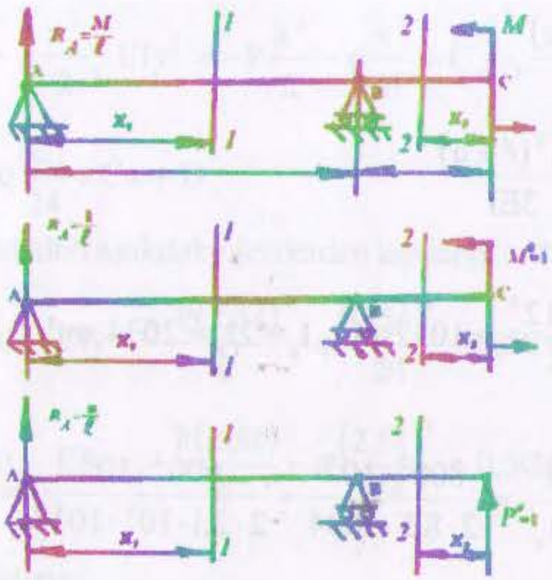
Onda $U = \frac{\sigma^2 W_z^2\ell}{2EI_z} = \frac{\sigma^2 A\ell}{6E}$; $A = bh$.

6.13. $\theta_ç = \frac{M}{3E\ell}(\ell + 3a)$, $f_ç = \frac{Ma}{6EI}(2\ell + 3a)$.

Makswell – Mor boýunça balkanyň islendik kesigindäki ornuny üýtgetme aşakdaky formulalar bilen kesgitlenilýär:

$\theta = \frac{1}{EI}\int_0^{\ell} M_x M_x^o dx$, $y = \frac{1}{EI}\int_0^{\ell} M_x M_x^o dx$

M_x^o – birlik ýagdaýdaky egme moment (birlik güýçden ýa-da birlik momentden ýüklenme).



6.13-nji surat

Balkanyň hakyky ýüklenmesinden $M_{x_1} = \frac{M}{\ell} x_1$, $M_{x_2} = M$.

Birlik momentiň ýüklenmesinden $M_1^o = \frac{1}{\ell} x_1$, $M_2^o = 1$.

Onda gözlenýän öwrülme burç:

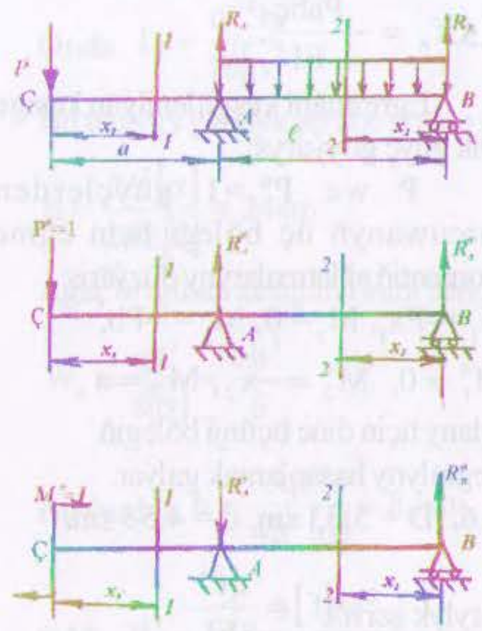
$$\theta_ç = \frac{1}{EI}\left(\int_0^\ell \frac{M}{\ell} x_1 \cdot \frac{1}{\ell} x_1 dx_1 + \int_0^a M \cdot 1 dx_2\right) = \frac{M}{3EI}(\ell + 3a).$$

Balkanyň egrelmesini tapmak üçin birlik güýç bilen balkany Ç kesikde ýükleýäris we egme momentiň aňlatmasyny ýazýarys:

$$M_1^o = \frac{1 \cdot a}{\ell} x_1, \; M_2^o = 1 \cdot x_2.$$

Onda idelýän egrelme:

$$f_ç = \frac{1}{EI}\left(\int_0^\ell \frac{M}{\ell} x_1 \cdot \frac{1 \cdot a}{\ell} x_1 dx_1 + \int_0^a M \cdot 1 \cdot x_2 dx_2\right) = \frac{Ma}{6EI}\ell(2\ell + 3a).$$



6.14-nji surat

6.14. y = –0,667sm,
θ= 0,0062rad.

$$R_B = \frac{q\ell}{2} - P\frac{a}{\ell}$$

Berlen güýçden

$M_{x_1} = -Px_1$,

$$M_{x_2} = \left(\frac{q\ell}{2} - P\frac{a}{\ell}\right)x_2 - q\frac{x_2^2}{2}.$$

Birlik güýçden $R_B^o = \frac{a}{\ell}$,

$M_1^o = -1 \cdot x_1$, $M_2^o = -\frac{a}{1}x_2$.

Birlik momentden $R_B^o = \frac{1}{\ell}$, $M_1^o = 1$, $M_2^o = -\frac{x_2}{\ell}$.

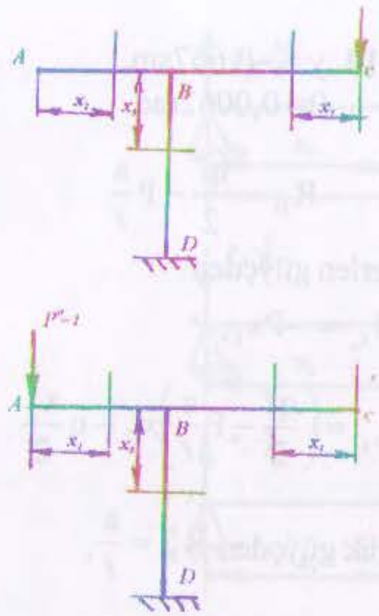
$$y = \frac{1}{EI}\left[\int_0^a M_{x_1} \cdot M_1^o dx + \int_0^\ell M_{x_2} \cdot M_2^o dx\right] =$$

Onda $\frac{1}{EI}\left[\int_0^a (-Px)\cdot(-x)dx + \int_0^\ell \left(\frac{q\ell x}{2} - \frac{Pax}{\ell} - \frac{qx^2}{2}\right)\left(-\frac{ax}{2}\right)dx\right] =$

$$= \frac{P\alpha^2(a+\ell)}{3EI} - \frac{qa\ell^3}{24EI} = -0{,}667\text{sm},$$

$$\theta = \frac{1}{EI}\int_0^a (-Px)\cdot 1 \cdot dx + \int_0^\ell \left(\frac{q\ell x}{2} - \frac{Pax}{\ell} - \frac{qx^2}{2}\right)\frac{x}{\ell}dx =$$

$$= \frac{1}{EI}\left[-P\frac{a}{6}(3a+2\ell) + \frac{q\ell^3}{24}\right] = 0{,}0062\text{rad}$$



6.15-nji surat

6.15. $f_A = -\dfrac{Pabç}{EI}$.

Egrelmäni kesgitlenilýän kesige birlik güýç goýýarys:

P we $P^0 = 1$ güýçlerden çarçuwanyň üç bölegi üçin egme momentiň aňlatmalaryny düzýäris:

$M_1 = -Px_1$, $M_2 = 0$, $M_3 = -Pb$,

$M_1^0 = 0$, $M_2^0 = -x_2$, $M_3^0 = a$

bolany üçin diňe üçünji bölegiň integralyny hasaplamak galýar.

6.16. D = 5,33 sm, d = 4,53 sm.

Gatylyk şerti $[f] = \dfrac{q\ell^4}{8EI_z}$.

$I_z = \dfrac{\pi D^4}{64}(1-\alpha^4)$. Turbanyň ýüküniň depgini

$$q = \frac{\pi D^2}{4}(1-\alpha^4)\gamma_{Pol} + \frac{\pi(\alpha D)^2}{4}\gamma_s.$$

Onda $D = \ell\sqrt{\dfrac{[(1-\alpha^2)\gamma_p + \alpha^2\gamma_s]2\ell}{0{,}003E(1-\alpha^4)}} = 5{,}33\text{sm}$,

we $D = d\alpha = 5{,}33 \cdot 0{,}85 = 4{,}53\text{sm}$.

6.17. b = 8,1sm, h = 24sm.

Gatylyk şerti $[f] = \dfrac{5q\ell^4}{384EI}$.

Berklik şerti $[\sigma] = \dfrac{M_{max}}{W_z} = \dfrac{q\ell^2}{8W_z}$, $W_z = \dfrac{I_z \cdot 2}{h}$.

Onda $I_z = \dfrac{q\ell^2 h}{16[\sigma]}$.

Bu ululygy gatylyk şertine goýup alarys:

$h = \dfrac{5\ell^2[\sigma]}{24E[f]} \cong 24\text{sm}$.

Agaç örtgüniň kesiginiň inini berklik şertinden tapýarys:

$W_z = \dfrac{q\ell^2}{8[\sigma]} = \dfrac{bh^2}{6}$.

Bu ýerden $b = \dfrac{3q\ell^2}{4h^2[\sigma]} = 8{,}1\text{sm}$.

6.18. $\theta_{max} = -\dfrac{3}{2}\cdot\dfrac{P\ell^2}{Eh^3b}$ we $f_{max} = -\dfrac{3}{8}\cdot\dfrac{P\ell^3}{Eh^3b}$.

$M_x = \dfrac{P}{2}x$; $I_x = \dfrac{b_x h^2}{12}$; $W_x = \dfrac{b_x h^2}{6} = \dfrac{Px}{2[\sigma]} \Rightarrow b_x = \dfrac{3Px}{h^2[\sigma]}$,

$x = 0 \Rightarrow b_x = 0$; $x = \dfrac{\ell}{2} \Rightarrow b = \dfrac{3}{2}\cdot\dfrac{P\ell}{h^2[\sigma]} \Rightarrow [\sigma] = \dfrac{3}{2}\cdot\dfrac{P\ell}{h^2[\sigma]}$.

Onda $I_x = \dfrac{b_x h^2}{12} = \dfrac{Phx}{4[\sigma]}$.

$Ey^{II} = \dfrac{M_x}{I_x} = \dfrac{2[\sigma]}{h} \Rightarrow \dfrac{Eh}{2[\sigma]}y^{II} = 1$,

$\dfrac{Eh}{2[\sigma]}y^{I} = x + C$ we $\dfrac{Eh}{2[\sigma]}y = \dfrac{x^2}{2} + Cx + D$,

$x = 0$, $y = 0 \Rightarrow D = 0$; $x = \dfrac{\ell}{2}$, $y^I = 0 \Rightarrow C = -\dfrac{\ell}{2}$.

Şonuň üçin hem

$$\theta_{max} = \theta_A = -\theta_B = \left(y^1\right)_{x=0} = \frac{2C[\sigma]}{Eh} = -\frac{\ell[\sigma]}{Eh}$$

$$f_{max} = (y)_{x=\frac{\ell}{2}} = -\frac{\ell^2[\sigma]}{4Eh},$$

[σ]-yň ýokarda tapylan bahasyny goýup alarys:

$$\theta_{max} = -\frac{3}{2}\cdot\frac{P\ell^2}{Eh^3b} \quad \text{we} \quad f_{max} = -\frac{3}{8}\cdot\frac{P\ell^3}{Eh^3b}.$$

6.19. $EIy = -\frac{q\ell^3}{2}(x\ln x - x - x\ln\ell + \ell)$, $f_{max} = -\frac{q\ell^4}{2EI_o}$.

Deň garşylykly balkanyň islendik kesiginde

$$\sigma_{max} = \frac{6M_x}{bh_x^2} = \text{const},$$

$$h_x = h\cdot\frac{x}{\ell}.$$

Onda balkanyň erkin tarapyndan x we ℓ uzaklykdaky kesiklerde $\sigma_x = \sigma_\ell$

we $\frac{qx^2\cdot 6}{2bh_x^2} = \frac{q\ell^2\cdot 6}{2bh^2}$.

Onda $EI_o y^{II} = -\frac{q\ell^3}{2}\cdot\frac{1}{x}$,

$$EI_o y^I = -\frac{q\ell^3}{2}\ln x + C.$$

Eger $x = \ell \to y^I = 0 \Rightarrow C = \frac{q\ell^3}{2}\ln\ell$.

Onda $EI_o y^I = -\frac{q\ell^3}{2}\ln x + \frac{q\ell^3}{2}\ln\ell$.

Ikinji gezek integrirläp alarys:

$$EIy = -\frac{q\ell^3}{2}x\ln x + \frac{q\ell^3}{2}x\ln\ell + D,$$

$x = \ell$, $y = 0 \Rightarrow D = \frac{q\ell^4}{2}$.

Onda $EIy = -\frac{q\ell^3}{2}(x\ln x - x - x\ln\ell + \ell)$,

$x = 0$, $f_{max} = -\frac{q\ell^4}{2EI_o}$.

6.20. $f_{max} = -1{,}2$sm.

Islendik kesikde $M_x = -x^2$, $h_x = 9 + 0{,}05x$,

$I_x = 0{,}5(9 + 0{,}05x)^3$

Onda $y^{II} = -\frac{2x^2}{E(9+0{,}05x)^3}$.

Belleýäris: $a = \frac{2}{E}$; $b = 9$, $ç = 0{,}05$ onda $y^{II} = -\frac{ax^2}{(b+çx)^3}$.

Bir gezek integrirläp alarys:

$$y^I = -\frac{a}{ç^3}\left[\ln(b+çx) + \frac{2b}{b+çx} - \frac{b^2}{2(b+çx)^2}\right] + C,$$

$x = \ell$, $y^I = 0$.

Onda $C = -\frac{a}{ç^3}\left[\ln(b+ç\ell) + \frac{2\ell}{b+ç\ell} - \frac{b^2}{2(b+ç\ell)^2}\right]$.

Ikinji gezek integrirläp alarys:

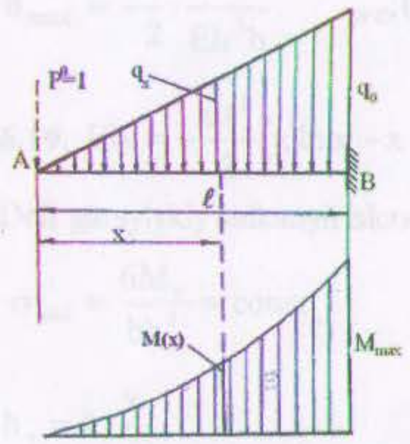
$$y = -\frac{a}{ç^3}\left[\left(x + \frac{3b}{ç}\right)\ln(b+çx) - x + \frac{b^2}{2ç(b+çx)}\right] + Cx + D,$$

$x = \ell$, $y = 0$,

$$D=-\frac{a}{ç^3}\left[\left(\ell+\frac{3b}{ç}\right)\ln(b+ç\ell)-\ell+\frac{b^2}{2ç(b+2ç)}\right]-ç\ell.$$

a, b, c, C we D bahalaryny goýup we $x=0$ baha berip alarys:

$$f_{max}=-\frac{a}{ç^3}\left(\frac{3b}{ç}\ln b+\frac{b}{2ç}\right)+D=1{,}2sm.$$



6.21-nji surat

6.21. $f_A=\frac{q_o\ell^4}{30EI}, \theta_A=\frac{q_o\ell^3}{24EI}.$

$$M_x=-q_o\frac{x^3}{6\ell},$$

$$M_1^o=-x,\ M_2^o=-1,$$

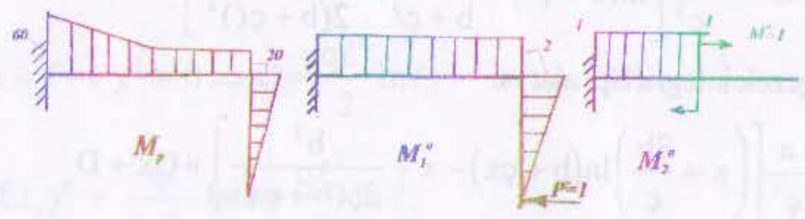
$$f_A=\frac{1}{EI}\int_o^\ell -\frac{q_o x^3}{6\ell}(-x)dx=\frac{q_o\ell^4}{30EI},$$

$$\theta_A=\frac{1}{EI}\int_o^\ell -\frac{q_o x^3}{6\ell}(-1)dx=\frac{q_o\ell^3}{24EI}.$$

6.22. U = 53,40kN·sm.

$$U=A=\frac{1}{2}P\left(f+\frac{1}{2}\lambda\right)=\frac{P^2\ell^2}{96EI}+\frac{P^2R^3n}{2Gr^4}=53{,}40kN\cdot sm.$$

6.23. $f_A=4{,}45sm,\ \theta_A=0{,}0133rad.$



6.23-nji surat

Wereşaginiň usulyny peýdalanyp alarys:

$$\Delta_{ip}=\sum\frac{\omega_p\cdot M_ç^o}{EI}.$$

Onda $f_A=\frac{\left[\frac{1}{2}\cdot 20\cdot 2\cdot\frac{2}{3}\cdot 2+20\cdot 2\cdot 2\cdot 2+\frac{1}{2}\cdot 40\cdot 2\cdot 2\right]10^6}{2\cdot 10^4\cdot 3000}=4{,}45sm,$

$$\theta_A=\frac{\left[20\cdot 2\cdot 1+\frac{1}{2}\cdot 40\cdot 2\cdot 1\right]10^4}{2\cdot 10^4\cdot 3000}=0{,}0133rad.$$

6.24. $M_2=2M_1.$

6.25. a) $y=\frac{\alpha t}{h}\cdot\frac{\ell^2}{2}$, b) $y=\frac{\alpha t}{h}\cdot\frac{\ell^2}{8}.$

Moruň integralyny ulanýarys: $y=\int_\ell\frac{M_x M^o}{EI_x}dx.$

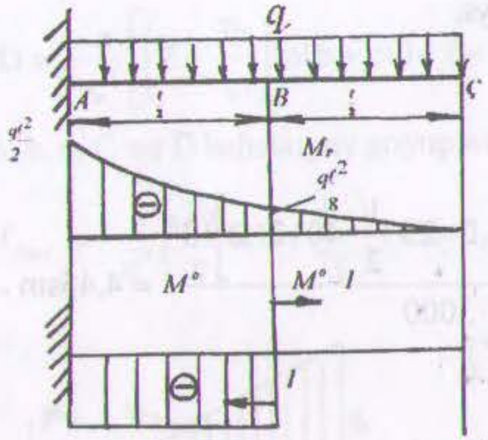
Egilme nazaryýetinden $\frac{M_x}{EI_x}=\frac{1}{\rho}$, ýöne $\frac{1}{\rho}=\frac{\varepsilon_t}{y}$, $\varepsilon_t=\alpha t$, $y=\frac{h}{2}$.

Onda $y=\int_\ell\frac{\alpha t}{h}\cdot M^o dx.$

Birinji balka üçin $M_1^o=x$,

$$y_1=\frac{\alpha t}{h}\int_o^\ell x dx=\frac{\alpha t}{h}\cdot\frac{\ell^2}{2}.$$

Ikinji balka üçin $M_2^o=\frac{x}{2}$, onda $y_2=\frac{\alpha t}{h}\cdot 2\int_o^\ell\frac{x}{2}dx=\frac{\alpha t}{h}\cdot\frac{\ell^2}{8}.$



6.26-njy surat

6.26. $\theta_B = \frac{1}{8} \cdot \frac{q\ell^2}{EI}$.

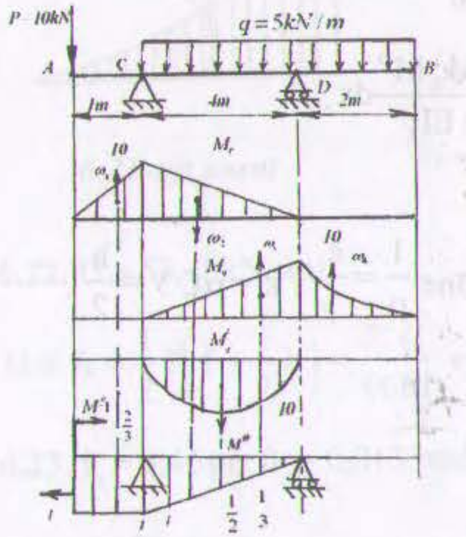
Wereşaginiň formulasy:

$$\theta = \sum \frac{\omega_P \cdot M_Ç^o}{EI},$$

$$\omega_p = -\frac{q\ell^2}{8} \cdot \frac{\ell}{2} \cdot \frac{1}{3} \cdot \frac{3q\ell^2}{8} \cdot \frac{\ell}{2} = -\frac{q\ell^3}{8},$$

$$M_Ç^o = -1.$$

Onda $\theta_B = \frac{q\ell^2}{8EI}$.



6.27-nji surat

6.27. $\theta_A = -\frac{7}{2400}$ rad.

Güýçleriň täsirini goşmak ýörelgesini ulanyp, balka täsir edýän güýçleriň egme momentiniň epýurlaryny aýratynlykda guryarys.

Berlen güýçlerden gurlan epýurlaryň meýdanlary:

$$\omega_1 = \frac{1}{2} \cdot 10 \cdot 1 = 5\,\text{kN} \cdot \text{m}^2,$$

$$\omega_2 = \frac{1}{2} \cdot 10 \cdot 4 = 20\,\text{kN} \cdot \text{m}^2,$$

$$\omega_3 = \frac{1}{2} \cdot 10 \cdot 4 = 20\,\text{kN} \cdot \text{m}^2,$$

$$\omega_4 = \frac{1}{3} \cdot 10 \cdot 2 = \frac{20}{3}\,\text{kN} \cdot \text{m}^2,$$

$$\omega_5 = \frac{2}{3} \cdot 10 \cdot 4 = \frac{80}{3}\,\text{kN} \cdot \text{m}^2.$$

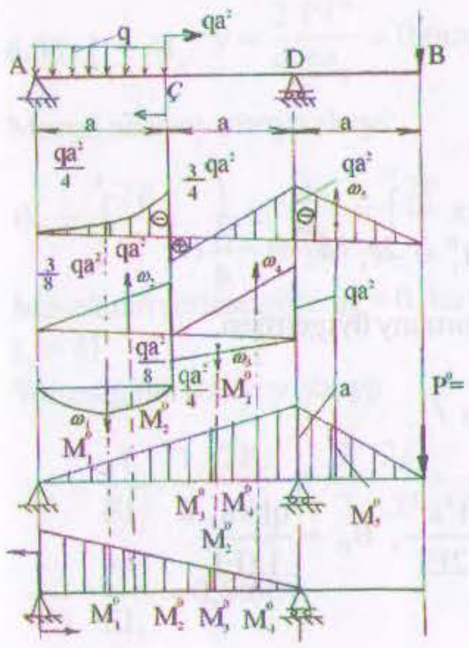
Birlik momentden epýur gurup, $M_Ç^o$ ordinatalaryny belleýäris.

Hasaplama geçiryäris:

$$EI\theta_A = -5 \cdot 1 - 20 \cdot \frac{2}{3} - 20 \cdot \frac{1}{3} + \frac{80}{3} \cdot \frac{1}{2} = -\frac{35}{3}\,\text{kN} \cdot \text{m}^2,$$

$$\theta_A = -\frac{35}{3EI} = -\frac{35 \cdot 10^4}{32 \cdot 10^4 \cdot 2 \cdot 10^3} = -\frac{35}{12000} = -\frac{7}{2400}\,\text{rad}.$$

6.28. $y_B = \frac{37}{48} \cdot \frac{qa^4}{EI}$, $\theta_B = \frac{11}{48} \cdot \frac{qa^3}{EI}$.



6.28-nji surat

AB we ÇD böleklerde egme momentiň epýuryny ýönekeý epýurlara dargadýarys we olaryň meýdanlaryny kesgitleýäris:

$$\omega_1 = \frac{qa^3}{12}, \quad \omega_2 = -\frac{3}{8}qa^3,$$

$$\omega_3 = -\frac{1}{8}qa^3, \quad \omega_4 = -\frac{1}{2}qa^3,$$

$$\omega_5 = \frac{1}{2}qa^3.$$

Ýokarky meýdanlaryň agyrlyk merkezine degişli birlik güýçden gurlan egme momentleriň ordinatalary:

$$M_1^0 = -\frac{1}{3}a, \quad M_2^0 = -\frac{1}{4}a,$$

$$M_3^0 = -\frac{2}{3}a,\quad M_4^0 = -\frac{5}{6}a,\ M_5^0 = -\frac{2a}{3}.$$

B nokatdaky gözlenýän egrelme:

$$y_B = \sum \frac{\omega_p M_c^o}{EI} = \frac{1}{EI}\left(\omega_1 M_1^0 + \omega_2 M_2^0 + \ldots + \omega_5 M_5^0\right) = \frac{37}{48}\cdot\frac{qa^4}{EI}.$$

M_2^0 epýuryndan alarys:

$$M_1^0 = -\frac{2}{3},\ M_2^0 = -\frac{3}{4},$$

$$M_3^0 = -\frac{1}{3},\quad M_4^0 = -\frac{1}{6}.$$

Onda gözlenýän öwrülme burçy:

$$\theta_A = \frac{1}{EI}\left(\omega_1 M_1^0 + \omega_2 M_2^0 + \omega_3 M_3^0 + \omega_4 M_4^0\right) = \frac{11}{48}\cdot\frac{qa^3}{EI}.$$

6.29. $y_ç = \frac{q\ell^3}{8EI}(4h + \ell)$.

Epýurlardan alarys:

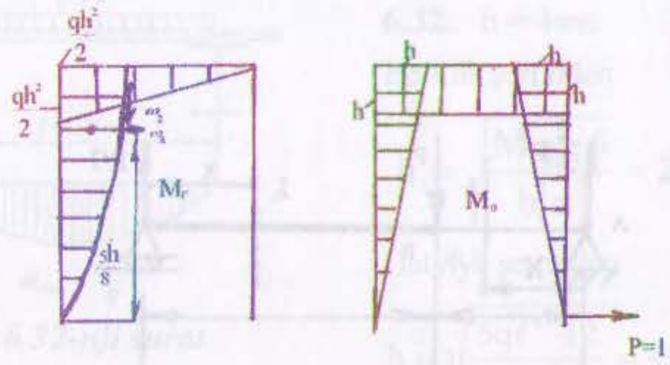
$$\omega_1 = -\frac{q\ell^2 h}{2},\ \omega_1 = -\frac{q\ell^3}{6},\ M_1^0 = -\ell,\ M_2^0 = -\frac{3}{4}\ell.$$

Onda çarçuwanyň Ç kesiginiň wertikal ornuny üýtgetmesi.

$$y_ç = \frac{1}{EI}\left(\omega_1 M_1^0 + \omega_2 M_2^0\right) = \frac{q\ell^2}{8EI}(4h + \ell).$$

6.30. $\Delta_B = \frac{qh^3}{24EI}(5h + 6a);\ y_ç = \frac{qh^2a^2}{32EI},\ \theta_D = \frac{qh^2a}{12EI}.$

Epýurlardan $\omega_1 = \frac{qh^3}{3},\ \omega_2 = \frac{qh^2a}{4},$



6.30-njy surat

Onda $\Delta_B = \frac{1}{EI}\left(\frac{qh^3}{3}\cdot\frac{5}{8}h + \frac{qh^2a}{4}\right) = \frac{qh^3}{24EI}(5h + 6a).$

Kesgitlemek talap edilýän beýleki ornuny üýtgetmeler ýokardaky yzygiderlilikde hasaplanylýar.

6.31. $I_2 = 4I_1,\ y = \frac{2}{9}\frac{P\ell^3}{EI_1} = 0{,}6\text{mm}.$

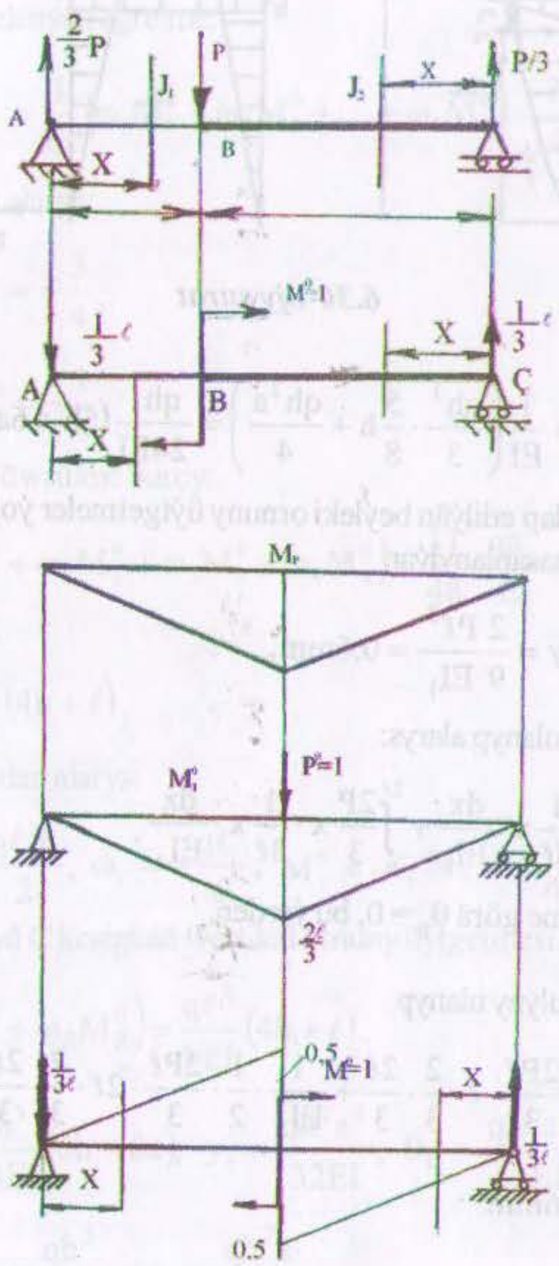
Moruň usulyny ulanyp alarys:

$$\theta_B = \int_0^{\ell}\frac{2P}{3}x\cdot\frac{1}{3\ell}x\cdot\frac{dx}{EI_1} + \int_0^{2\ell}\frac{2P}{3}x\cdot\frac{1}{3\ell}x\cdot\frac{dx}{EI_2}.$$

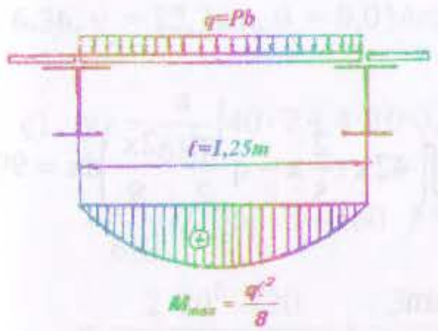
Meseläniň şertine görä $\theta_B = 0$, bu ýerden,
$I_2 = 4I_1$.
Weraşaginiň usulyny ulanyp

$$y_B = \frac{1}{EI_1}\cdot\frac{1}{2}\cdot\frac{2P\ell}{3}\cdot\ell\cdot\frac{2}{3}\cdot\frac{2\ell}{3} + \frac{1}{EI_2}\cdot\frac{1}{2}\cdot\frac{2P\ell}{3}\cdot 2\ell\cdot\frac{2}{3}\cdot\frac{2\ell}{3} =$$

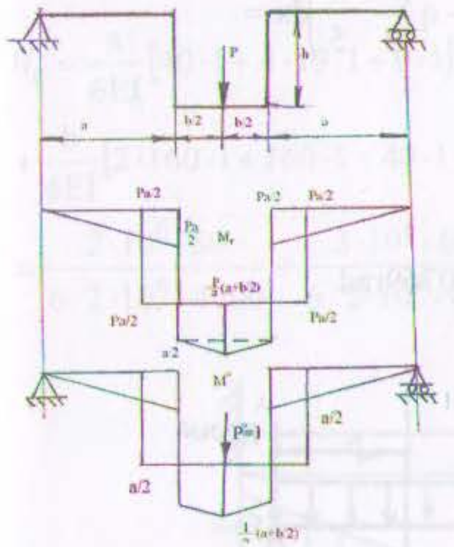
$$= \frac{2}{9}\cdot\frac{P\ell^3}{EI_1} = 0{,}6\text{mm}.$$



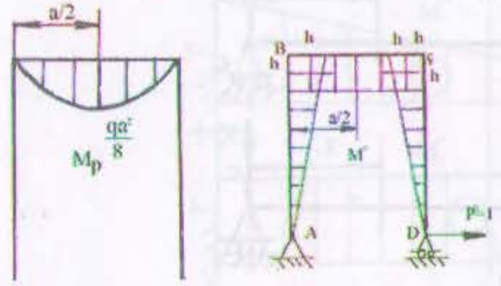
6.31-nji surat



6.32-nji surat



6.33-nji surat



6.34-nji surat

6.32. h = 4sm.

Berklik şertinden

$$h = \sqrt{\frac{M_{max}\,6}{b[\sigma]}} = 2{,}9 \text{ sm}\cdot$$

Gatylyk şertinden

$$h = \sqrt[3]{\frac{5q\ell^4 \cdot 12}{384E[f]b}} = 4\text{sm},$$

h = 4 sm kabul edýäris.

6.33. $f = \dfrac{P(2a+b)^3}{48EI} + \dfrac{Pa^2h}{2EI}$.

$$f = 2\frac{1}{EI}\left(\frac{Pa}{2}\cdot a\cdot\frac{2}{3}\cdot\frac{a}{2} + 2\frac{Pa}{2}\cdot h\cdot\frac{a}{2}\right) +$$

$$+\frac{1}{EI}\cdot\frac{Pa}{2}\cdot b\cdot\frac{1}{2}\left(a+\frac{b}{2}\right) +$$

$$+2\frac{Pb}{4}\cdot\frac{b}{2}\cdot\frac{b}{4}\cdot\frac{2}{3} = \frac{P(2a+b)^3}{48EI} + \frac{Pa^2h}{2EI}.$$

6.34. $\Delta_B = \dfrac{qa^3h}{12EI}$.

$$\Delta_B = \frac{\omega_p M_ç^0}{EI} = \frac{2}{3}\cdot\frac{qa^2}{8}\cdot a\cdot\frac{h}{EI} =$$

$$= \frac{qa^3h}{12EI}$$

6.35. y_A=1,2375 sm, θ_B=0,00769 rad.
Moruň usulyny ulanýarys:

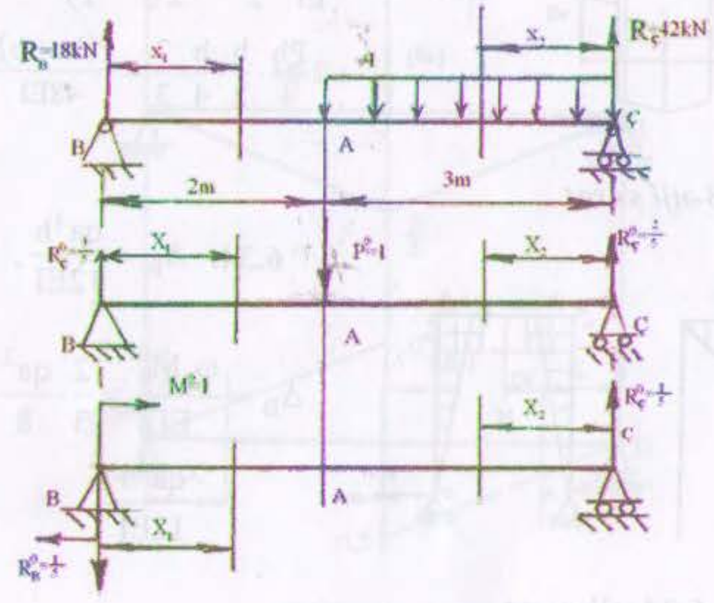
$$EIy_A = \int_0^{\ell} M_p \cdot M^{\circ} d[= \int_0^2 18x \cdot \frac{2}{5}x \cdot dx + \int_0^3 \left(42x \cdot \frac{2}{5}x - q\frac{x^2}{2} \cdot \frac{2x}{5} \right) dx = 99;$$

$$y_A = \frac{99}{EI} = \frac{99 \cdot 10^6}{2 \cdot 10^4 \cdot 4000} = \frac{99}{80} = 1{,}2375 sm,$$

$$EI\theta_A = \int_0^2 18x \cdot \left(1 - \frac{x}{5}\right) dx + \int_0^3 \left(42x \cdot \frac{x}{5} - q\frac{x^2}{2} \cdot \frac{x}{5} \right) dx =$$

$$= \left| 9x^2 - \frac{6}{5}x^3 \right|_0^2 + \left| \frac{14}{5}x^3 - \frac{x^4}{2} \right|_0^3 = 615;$$

$$\theta_B = \frac{615}{EI} = \frac{615 \cdot 10^4}{2 \cdot 10^4 \cdot 400} = \frac{61{,}5}{8000} = 0{,}00769 rad.$$



6.35-nji surat

6.36. $y_ç$ = 12,3sm, $\theta_ç$ = 0,034rad.

ç) $$y_ç = \frac{a}{6EI}[40 \cdot 2 + 4 \cdot 10 \cdot 1 + 0 \cdot 0] +$$

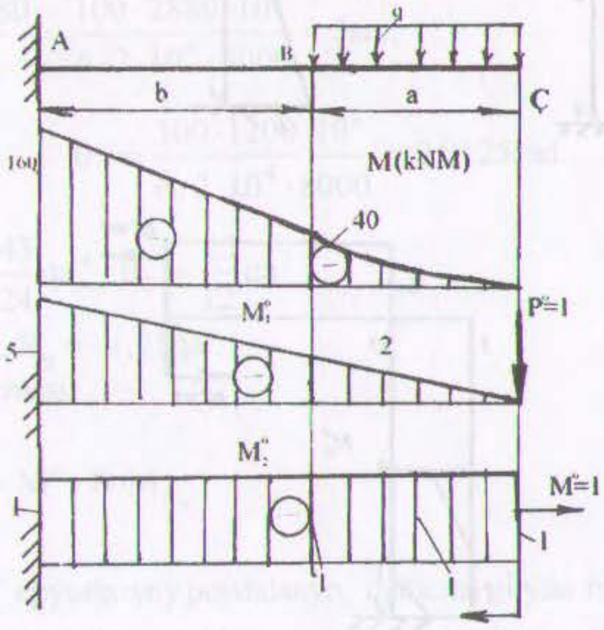
$$+ \frac{b}{6EI}[2 \cdot 160 \cdot 5 + 160 \cdot 2 + 40 \cdot 5 + 2 \cdot 40 \cdot 2] =$$

$$= \frac{2 \cdot 10^6 \cdot 120}{6 \cdot 2 \cdot 10^4 \cdot 4800} + \frac{3 \cdot 10^6 \cdot 2280}{6 \cdot 2 \cdot 10^4 \cdot 4800} = 12{,}3 sm,$$

$$\theta_ç = \frac{a}{6EI}[40 \cdot 1 + 4 \cdot 10 \cdot 1 + 0 \cdot 1] +$$

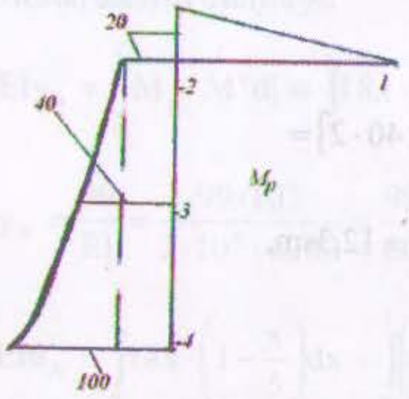
$$+ \frac{b}{6EI}[2 \cdot 160 \cdot 1 + 160 \cdot 1 + 40 \cdot 1 + 2 \cdot 40 \cdot 1] =$$

$$= \frac{2 \cdot 10^6 \cdot 80}{6 \cdot 2 \cdot 10^4 \cdot 4800} + \frac{3 \cdot 10^6 \cdot 600}{6 \cdot 2 \cdot 10^4 \cdot 4800} = 0{,}034 rad.$$



6.36-njy surat

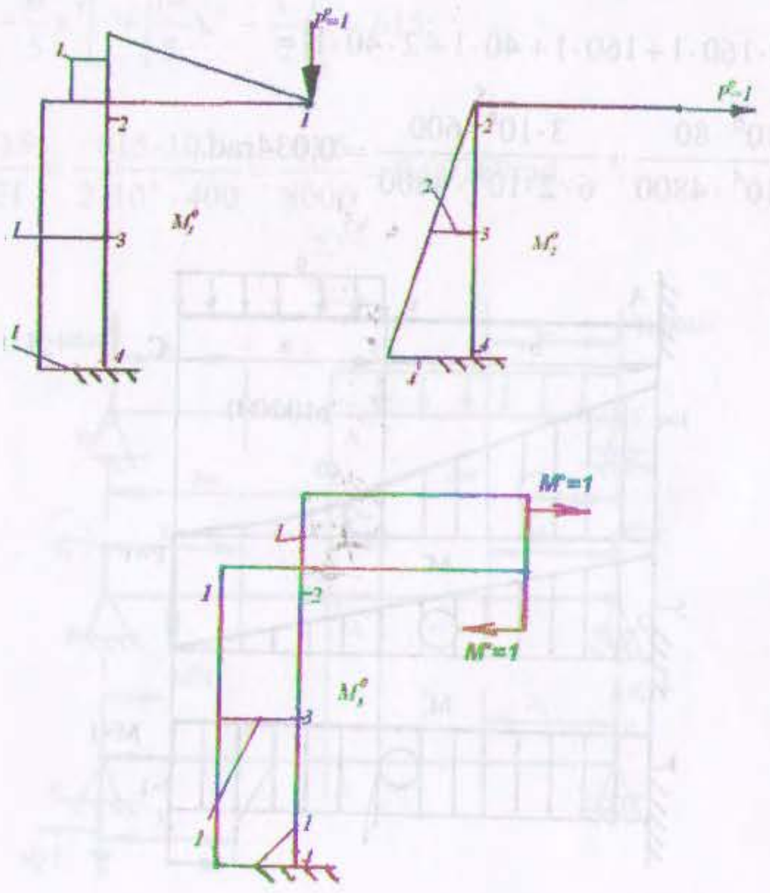
6.37. y_{wert} =1,21sm, y_{gor} =3sm, θ = 0,0125rad.



Matrisa deňlemesi

$$\Delta_{ip} = M_i^o \cdot B \cdot M_p,$$

$$M_p = \begin{bmatrix} 0 \\ 20 \\ 40 \\ 100 \end{bmatrix}; \quad M_i^o = \begin{bmatrix} 0 & 2 & 2 & 2 \\ 0 & 0 & 2 & 4 \\ 1 & 1 & 1 & 1 \end{bmatrix}.$$



6.37-nji surat

Ýumşaklyk matrisasy

$$B = \begin{bmatrix} b_I & 0 \\ 0 & b_{II} \end{bmatrix} = \frac{a}{6E} \begin{bmatrix} 2 & 1 & 0 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 \\ 0 & 0 & 0 & 16 & 0 \\ 0 & 0 & 0 & 0 & 4 \end{bmatrix} = \frac{a}{6EI} \begin{bmatrix} 2 & 1 & 0 & 0 \\ 1 & 6 & 0 & 0 \\ 0 & 0 & 16 & 0 \\ 0 & 0 & 0 & 4 \end{bmatrix}$$

$$\Delta_{ip} = \begin{bmatrix} y_{wert} \\ y_{gor} \\ \theta \end{bmatrix} = \begin{bmatrix} 0 & 2 & 2 & 2 \\ 0 & 0 & 2 & 4 \\ 1 & 1 & 1 & 1 \end{bmatrix} \frac{a}{6EI} \begin{bmatrix} 2 & 1 & 0 & 0 \\ 1 & 6 & 0 & 0 \\ 0 & 0 & 16 & 0 \\ 0 & 0 & 0 & 4 \end{bmatrix} \begin{bmatrix} 0 \\ 20 \\ 40 \\ 100 \end{bmatrix} = \frac{a}{6EI} \begin{bmatrix} 1160 \\ 2880 \\ 1200 \end{bmatrix},$$

Bu ýerden $y_{wert} = \dfrac{a \cdot 1160}{6EI} = \dfrac{100 \cdot 1160 \cdot 10^4}{6 \cdot 2 \cdot 10^4 \cdot 8000} = 1{,}21\text{sm},$

$$y_{gor} = \frac{a \cdot 2880}{6EI} = \frac{100 \cdot 2880 \cdot 10^4}{6 \cdot 2 \cdot 10^4 \cdot 8000} = 3\text{sm},$$

$$\theta = = \frac{100 \cdot 1200 \cdot 10^2}{6 \cdot 2 \cdot 10^4 \cdot 8000} = 0{,}0125\text{rad}.$$

6.38. $y_Ç = \dfrac{43}{24} qa^4$, $\theta_Ç = \dfrac{25}{12} qa^3$.

$R_A = 2{,}25qa^2$, $R_B = -1{,}25qa^2$.

Matrisa deňlemesi

$$\Delta_{ip} = \begin{bmatrix} y_ç \\ \theta_ç \end{bmatrix} = M^0 \cdot B \cdot M_p,$$

M_p, M_1^0, M_2^0 epýurlaryny peýdalanyp, deňlemä giryän matrisalary we balkanyň böleklerineň ýumşaklyk matrisasyny düzýäris:

M_1^0, M_2^0 matrisalary transponirläp ýazýarys.

$$M^{\circ}=\begin{bmatrix}0 & 0{,}25a & 0{,}5a & 0{,}5a & 0{,}75a & 0{,}5a & 0\\ 0 & 0{,}25 & 0{,}5 & 0{,}5 & 0{,}75 & 0{,}5 & 0\end{bmatrix};$$

$$b_I = b_{II} = b_{III} = \frac{a}{6EI}\begin{bmatrix}1 & 0 & 0\\ 0 & 4 & 0\\ 0 & 0 & 1\end{bmatrix};$$

$$M_p = \begin{bmatrix}1\\1\\1{,}75\\0{,}75\\1{,}25\\1{,}5\\0{,}875\\0\end{bmatrix} qa^2;\quad B=\frac{a}{6EI}\begin{bmatrix}1&0&0&0&0&0&0&0&0\\0&4&0&0&0&0&0&0&0\\0&0&1&0&0&0&0&0&0\\0&0&0&1&0&0&0&0&0\\0&0&0&0&4&0&0&0&0\\0&0&0&0&0&1&0&0&0\\0&0&0&0&0&0&1&0&0\\0&0&0&1&0&0&0&4&0\\0&0&0&0&0&0&0&0&1\end{bmatrix};$$

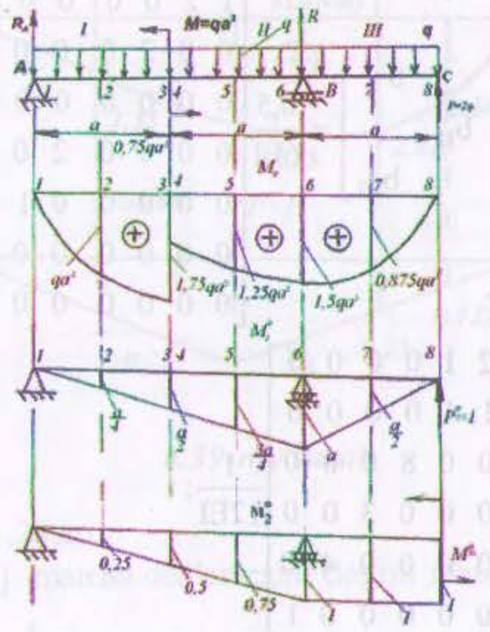
$$B=\frac{a}{6EI}\begin{bmatrix}1&0&0&0&0&0&0&0\\0&4&0&0&0&0&0&0\\0&0&1&0&0&0&0&0\\0&0&0&1&0&0&0&0\\0&0&0&0&4&0&0&0\\0&0&0&0&0&2&0&0\\0&0&0&0&0&0&4&0\\0&0&0&0&0&0&0&1\end{bmatrix}.$$

Matrisa deňlemesine goýup alarys:

$$\Delta_{ip}=\begin{bmatrix}y_Ç\\ \theta_Ç\end{bmatrix}=\frac{qa^3}{6EI}\begin{bmatrix}0&0&25a&0{,}5a&0{,}5a&0{,}75a&0{,}5a&0\\0&0&25&0{,}5&0{,}5&0{,}75&0{,}5&0\end{bmatrix}.$$

$$\begin{bmatrix}1\\1\\1{,}75\\0{,}75\\1{,}25\\1{,}5\\0{,}875\\0\end{bmatrix}\begin{bmatrix}1&0&0&0&0&0&0&0\\0&4&0&0&0&0&0&0\\0&0&1&0&0&0&0&0\\0&0&0&1&0&0&0&0\\0&0&0&0&4&0&0&0\\0&0&0&0&0&2&0&0\\0&0&0&0&0&0&4&0\\0&0&0&0&0&0&0&1\end{bmatrix}=\frac{qa^3}{6EI}\begin{bmatrix}\frac{43a}{4}\\ \frac{25}{2}\end{bmatrix},$$

onda $y_Ç=\frac{43}{24}qa^4$, $\theta_Ç=\frac{25}{12}qa^3$.



6.38-nji surat

6.39. $y_{ort} = 1,28sm$, $I \geq 66,5 \cdot 2 = 133sm^4$.
Berlen:
$P = 4kN$, $q = 3kN/m$, $\ell = 2m$, $I = 51,98sm^4$.

$E = 7,5 \cdot 10^3 kN/sm^2$, $[y] = \dfrac{\ell}{200}$.

$R_A = 2,7kN$, $R_B = 5,8kN$.
$M^o = [0 \;\; 0,25 \;\; 0,5 \;\; 0,25 \;\; 0,125 \;\; 0]$;

$$M_p = \begin{bmatrix} 0 \\ 1,35 \\ 2,325 \\ 2,525 \\ 1,36 \\ 0 \end{bmatrix}; \; \ell_1 = \ell_3 = \frac{\ell_2}{2} = 0,5m, \; \ell_2 = 1m.$$

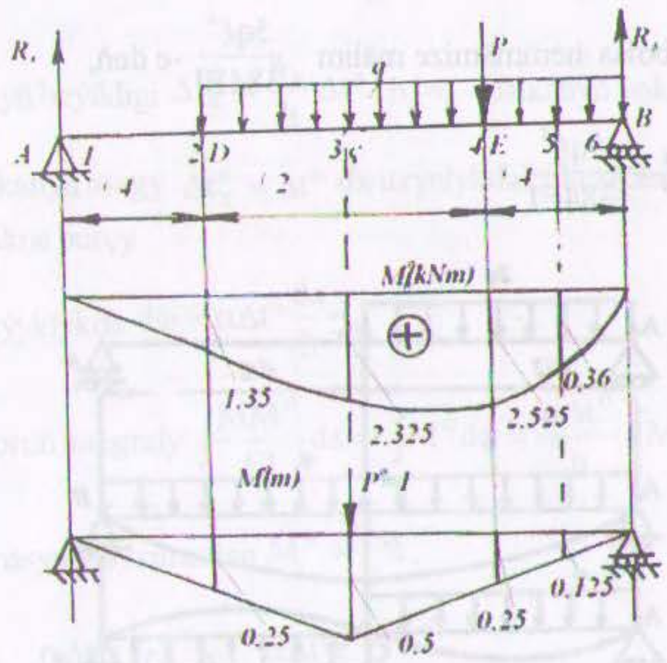
$$B = \begin{bmatrix} b_I & & 0 \\ & b_{II} & \\ 0 & & b_{III} \end{bmatrix} = \frac{0,5}{6EI} \begin{bmatrix} 2 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 8 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 1 & 0 & 0 & 0 & 0 \\ 1 & 4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \frac{1}{12EI};$$

$$y_{ort} = \frac{10^6}{2 \cdot 3,75 \cdot 10^3 \cdot 2 \cdot 51,98} [0 \;\; 0,25 \;\; 0,5 \;\; 0,25 \;\; 0,125 \;\; 0] x$$

Onda

$$x \begin{bmatrix} 2 & 1 & 0 & 0 & 0 & 0 \\ 1 & 4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 1,35 \\ 2,325 \\ 2,525 \\ 1,36 \\ 0 \end{bmatrix}$$



6.39-njy surat

Bu ýerden $y_{ort} = 1,28sm$.
$y_{ort} = [M^o][B][M_p]$ matrisa deňlemesine degişli matrisalaryň bahalaryny goýup we $y_{ort} = \dfrac{\ell}{200} = 1sm$ kabul edip, matrisa deňlemesinden balkanyň

kesiginiň gerek bolan inersiýa momentini tapýarys: $I = 66{,}5sm^4$ - bir şwelleriň inersiýa momenti.

6.40. $y_ç = \dfrac{5q\ell^4}{384EI}$.

Bu de berlen ýüki özgerdip hasaplamak çözüwi has ýeňilleşdiryär. Şol maksat bilen berlen ýüki b) we ç) suratlarda görkezilişi ýaly, simmetriýa we simmetriýa ters bolan ýüklere dargadýarys.

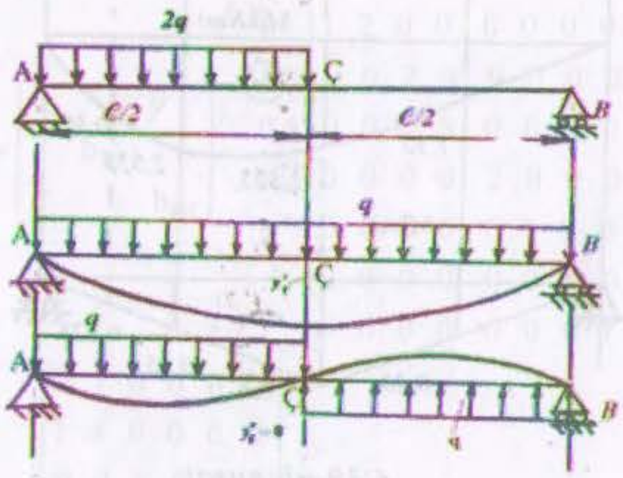
Umumy egrelme

$$y_ç = y_ç^I + y_ç^{II};$$

ýöne $y_ç^{II} = 0$.

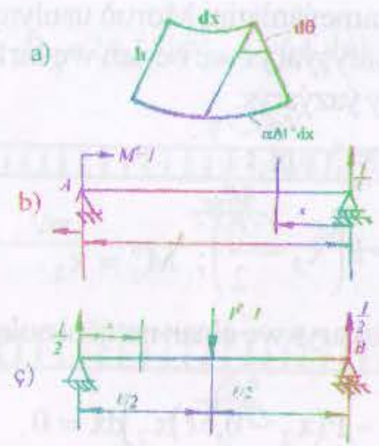
$y_ç^I$ bahasy bolsa hemmämize mälim $\dfrac{5q\ell^4}{384EI}$-e deň,

onda $y_ç = y_ç^I = \dfrac{5q\ell^4}{384EI}$.



6.40-njy surat

6.41. $\theta_A = \dfrac{\alpha\Delta t^\circ \ell}{2h}$, $f = \dfrac{\alpha\Delta t^\circ \ell^2}{8h}$.



6.41-nji surat

h – halkanyň beýikligi $\Delta t_x^o = \dfrac{h_x}{h}\Delta t^\circ$, h_x=0 – balkanyň ýokarsy Δt_x=0.

h_x=h – balkanyň aşagy $\Delta t_x^o = \Delta t^\circ$ dx uzynlykdaky kesikleriň biri-birine görä öwrülme burçy.

a)çyzga laýyklykda $d\varphi = \alpha\Delta t^\circ \dfrac{dx}{h}$.

Onda Moruň integraly $\int \dfrac{MM^o}{EI}dx = \int M^o d\varphi = \dfrac{\alpha\Delta t^o}{h}\int M^o dx$

M^o aňlatmasyny: b) suratdan $M^o = \dfrac{1}{\ell}x$.

Onda $\theta_A = \dfrac{\alpha\Delta t^\circ \ell}{h}\int_0^\ell \dfrac{x}{\ell}dx = \dfrac{\alpha\Delta t^\circ \ell}{2h}$.

Balkanyň ortasyny P^0=1 birlik güýç bilen ýükleýäris.

Onda $M^o = \dfrac{x}{2}$ we $f = \dfrac{\alpha\Delta t^\circ}{h}\cdot 2\int_0^{\frac{\ell}{2}} \dfrac{x}{2}dx = \dfrac{\alpha\Delta t^\circ \ell^2}{8h}$.

6.42. $Q_{max} = 30kN$, $M_{max} = 2{,}75kN/m$.

Meseläniň statiki kesgitlenmeýänligini Moruň usulyny ulanyp açýarys. A diregi R_A gaýtargy bilen çalyşýarys we berlen we birlik güýçlerden egme momentleriň aňlatmalaryny ýazýarys:

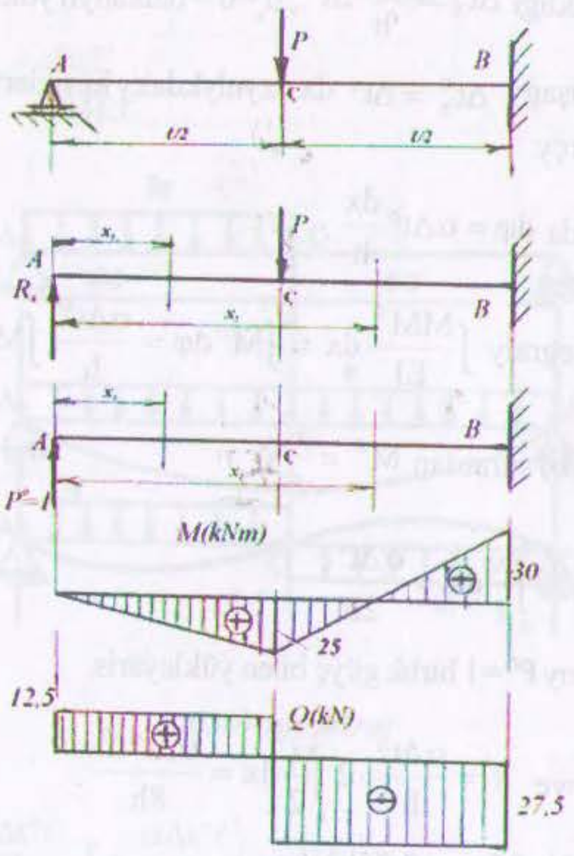
I bölek $M_{x_1} = R_A \cdot x_1;\ M_1^0 = x_1;$

II bölek $M_{x_2} = R_A \cdot x_2 - P\left(x_2 - \frac{\ell}{2}\right);\ M_2^0 = x_2.$

Moruň integralyny hasaplaýarys we alnan netijäni nola deňleýäris:

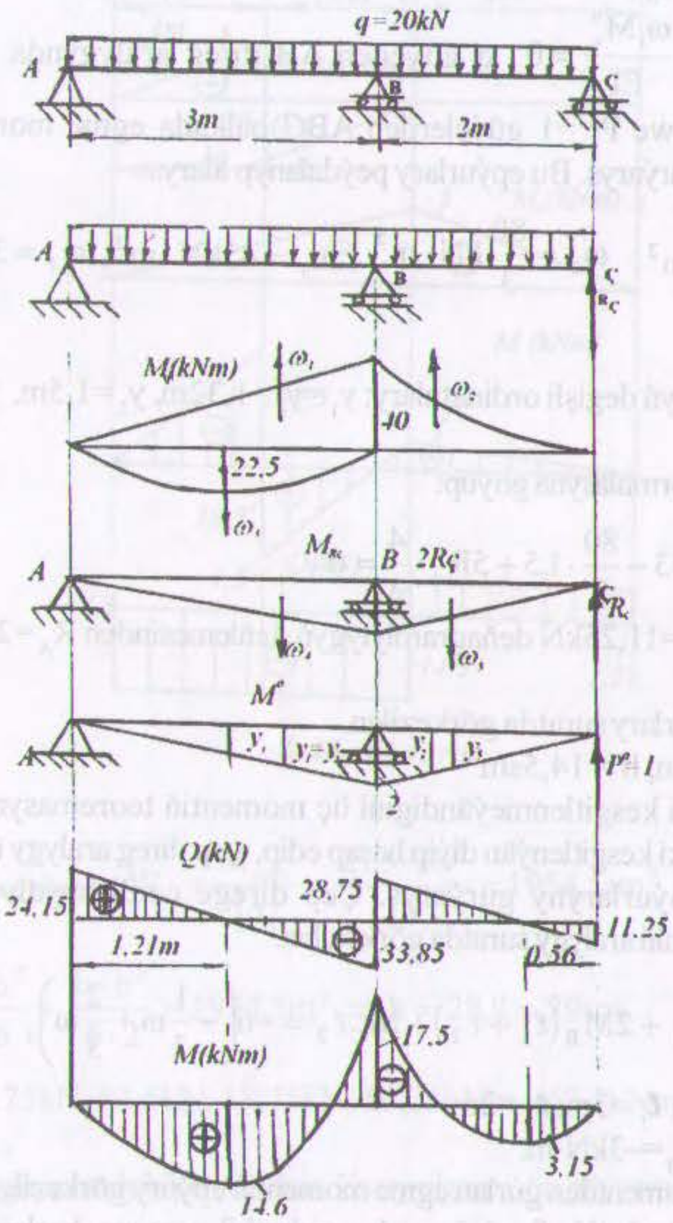
$$\int_0^{0,5\ell} R_A \cdot x_1^2 dx + \int_{0,5\ell}^{\ell} \left[R_A x_2^2 - P(x_2 - 0,5\ell)x_2\right]dx = 0.$$

Bu ýerden $R_A = \frac{5\ell}{16}$ alarys: Q we M epýurlaryny adaty usul bilen guryarys.



6.42-nji surat

6.43. $R_ç$=11,25kN, R_A=24,15kN, ℓ=64,46kNm.



6.43-nji surat

Balkanyň statiki kesgitlenmeýändigini Wereşaginiň usuly boýunça açýarys. Artykmaç berkitme hökmünde sag diregi alýarys:

onda $f_ç = \sum \frac{\omega_i M_ç^o}{EI} = 0$, q güýçden AB direg aralygynda we BÇ konsolda, $R_ç$ we $P^o = 1$ güýçlerden ABÇ balkada egme momentleriň epýurlaryny guryarys. Bu epýurlary peýdalanyp alarys:

$\omega_1 = 60\text{kN}\cdot\text{m}^2$, $\omega_2 = \frac{80}{3}\text{kN}\cdot\text{m}^2$, $\omega_3 = 45\text{kN}\cdot\text{m}^2$, $\omega_4 = 3R_ç$,

$\omega_5 = 2R_ç$.

Bu meýdanlaryň degişli ordinatalary: $y_1 = y_4 = 1{,}32\text{m}$, $y_2 = 1{,}5\text{m}$, $y_3 = 1\text{m}$, $y_5 = 1{,}33\text{m}$.

Wereşaginiň formulasyna goýup:

$$45\cdot 1 - 60\cdot 1{,}33 - \frac{80}{3}\cdot 1{,}5 + 5R_ç\cdot\frac{4}{3} = 0.$$

Bu ýerden $R_ç = 11{,}25\text{kN}$ deňagramlylygyň deňlemesinden $R_A = 24{,}15\text{kN}$, $R_B = 64{,}6\text{kN}$.

Q we M epýurlary suratda görkezilen.

6.44. h = 29sm, b = 14,5sm.

Statiki kesgitlenmeýändigini üç momentiň teoremasyny ulanyp açýarys. Statiki kesgitlenýän diýip hasap edip, çep direg aralygy üçin egme momentiň epýurlaryny guryarys. Çep direge çenli hyýaly ýükleriň deňtäsiredijisiniň aralygy suratda görkezilen.

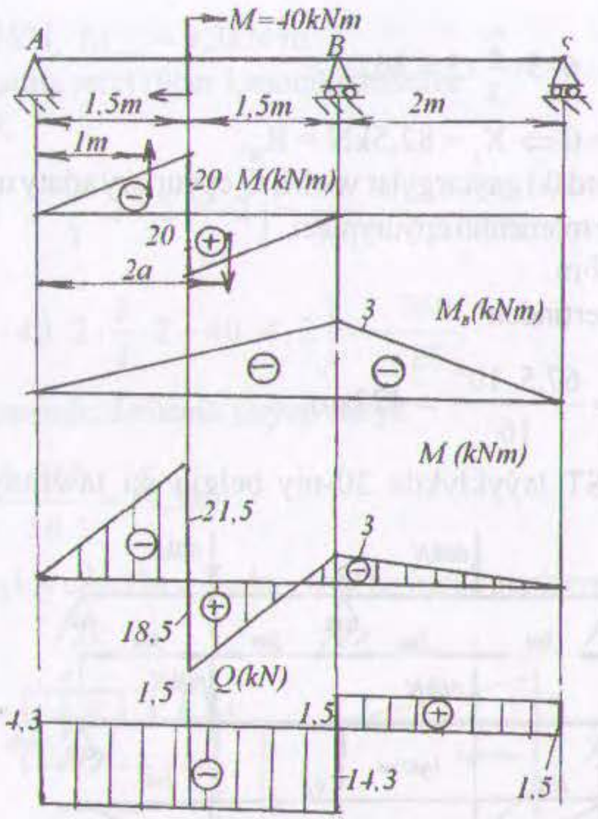
$$M_A\ell_1 + 2M_B(\ell_1 + \ell_2) + M_Ç\ell_2 = -6\left(-\frac{1}{3}\omega + \frac{2}{3}\omega\right),$$

$M_A = M_Ç = 0$, $\ell_1 = 3\text{m}$, $\ell_2 = 2\text{m}$.

Bu ýerden $M_B = -3\text{kN}\cdot\text{m}$.

Suratda bu momentden gurlan egme momentiň epýury görkezilen. Bu epýury çep ýönekeý balka üçin gurlan epýur bilen goşup, berlen balka üçin egme momentiň epýuryny alarys.

Direglerdäki gaýtargylary kesgitläp, kese güýjüň epýuryny gurarys (surata seret):



6.44-nji surat

Berklik şertinden $W_z = \frac{M_{max}}{[\sigma]} = \frac{21{,}5\cdot 10^2}{1{,}1} = 1954{,}5\text{sm}^3$;

$W_z = \frac{bh^2}{6} = \frac{h\cdot h^2}{6\cdot 2} = 1954{,}5\text{m}^2 \Rightarrow h = 28{,}8 \approx 29\text{sm}.$

6.45. 18,75kN, 82,5kN, 18,75kN, 56,25kNm – 67,5kNm, 30-njy belgili iki tawra .

Meseläni güýç usuly bilen çözýäris. Esasy ulgam üçin güýç usulynyň kanoniki deňlemesi:

$X_1\delta_{11} + \Delta_{1p} = 0$,

$EI\Delta_{1p;} = -2\cdot\frac{1}{2}\cdot 180\cdot 3\cdot\frac{2}{3}\cdot 1{,}5 - 2\cdot 180\cdot 3\cdot 2{,}25 = -2970;$

$$EI\delta_{11} = -2\cdot\frac{1}{2}\cdot 6\cdot 3\cdot\frac{2}{3}\cdot 3 = 36;$$

$36X_1 - 2970 = 0 \Rightarrow X_1 = 82{,}5\text{kN} = R_B$.

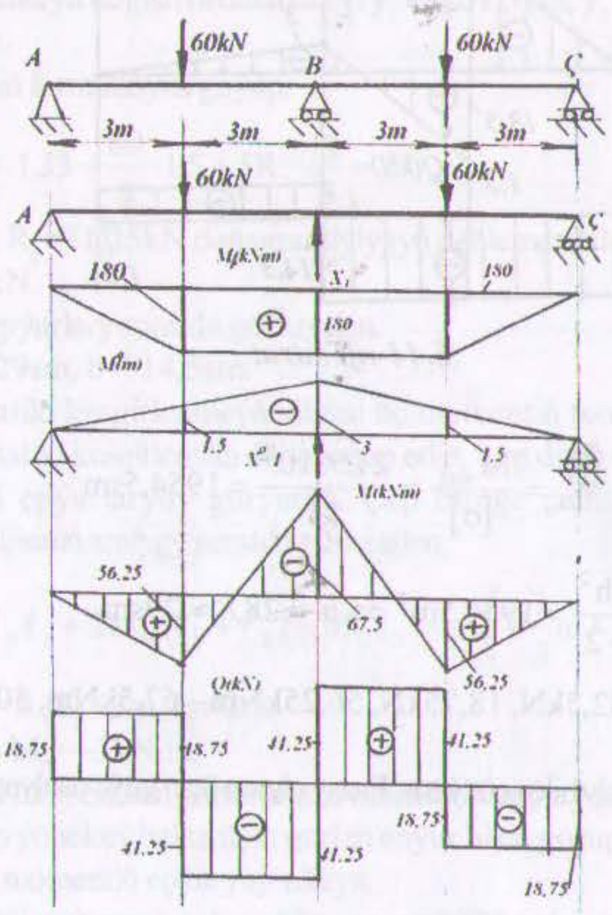
A we Ç direglerdäki gaýtargylar we M, Q epýurlary adaty usul bilen ýerine ýetirilen. Egme momentiň epýuryndan

$M_{max} = 67{,}5\text{kN}\cdot\text{m}$.

Onda berklik şertinden

$$W_z \geq \frac{M_{max}}{[\sigma]} = \frac{67{,}5\cdot 10^2}{16} = 422\text{sm}.$$

8239-56 DÖST laýyklykda 30-njy belgili iki tawrany saýlaýarys.



6.45-nji surat

6.46. $R_A = 19{,}3\text{kN}$, $M_{max} = 9{,}3\text{kN}\cdot\text{m}$.

Esasy ulgam (surata seret) üçin kanoniki deňleme:

$X_1\delta_{11} + \Delta_{ip} = 0$,

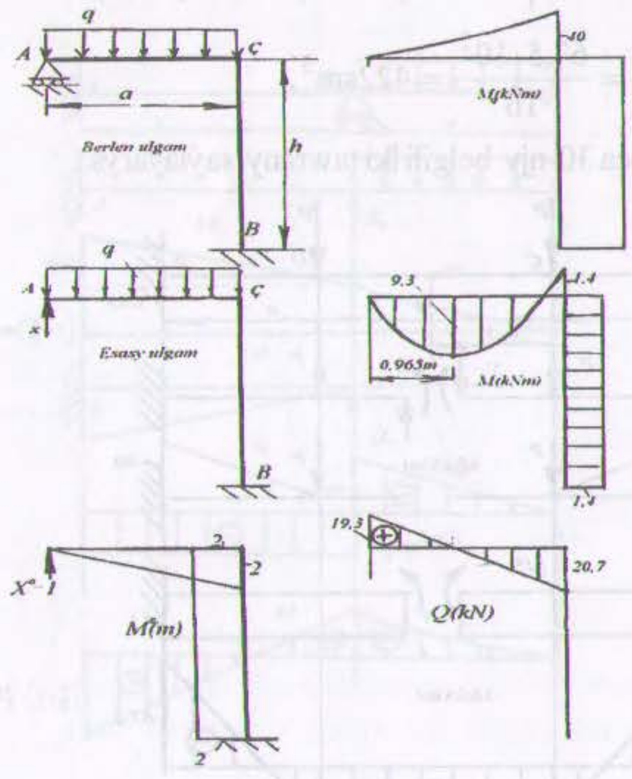
$$\delta_{11} = \frac{1}{EI}\left(\frac{1}{2}\cdot 2\cdot 2\cdot\frac{2}{3}\cdot 2 + 2\cdot 4\cdot 2\right) = \frac{56}{3EI},$$

$$\Delta_{ip} = \frac{1}{EI}\left(-\frac{1}{3}\cdot 40\cdot 2\cdot\frac{3}{4}\cdot 2 - 40\cdot 4\cdot 2\right) = -\frac{360}{EI}.$$

Bu ululyklary kanoniki deňlemä goýup alarys:

$$X_1 = -\frac{\Delta_{ip}}{\delta_{11}} = \frac{3\cdot 360}{56} = 19{,}3\text{kN}.$$

Q we M gutarnykly epýurlaryny adaty usul boýunça guryarys (surata seret).



6.46-njy surat

6.47. $M_A = -67{,}5\text{kN}\cdot\text{m}$, $M_C = 22{,}5\text{kN}\cdot\text{m}$, 30-njy belgili iki tawra.
Statiki kesgitlenmeýändigini açmak üçin, balkanyň we ýükleriň simmetriýalygyny, peýdalanýarys. Balkanyň we daşky güýçleriň simmetriýaly X_2 güýjüň tersleýin
Simmetriýaly bolany üçin, δ_{22}, δ_{21}, δ_{12}, Δ_{2p} nola deň we kanoniki deňleme aşakdaky ýaly ýazylýar:

$$X_1\delta_{11} + \Delta_{ip} = 0,$$

$$\Delta_{ip} = \left(-\frac{1}{2}\cdot 90\cdot 1{,}5\cdot\frac{2}{3}\cdot 90\right)\cdot 2 = -135.$$

$$\delta_{11} = 2\cdot 6\cdot 1 = 12,$$

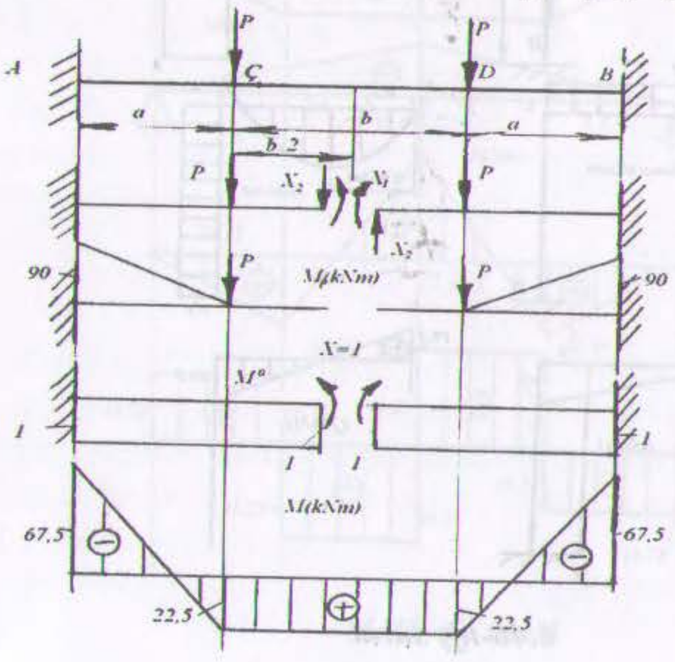
$$X_1 = -\frac{\Delta_{ip}}{\delta_{11}} = \frac{135}{12} = 22{,}5\text{kN}\cdot\text{m}.$$

Onda

$$M_B = M_A = -P\cdot a + X_1 = -60\cdot 1{,}5 + 22{,}5 = -67{,}5\ \text{kN},$$

$$W_z \geq \frac{M_{max}}{[\sigma]} = \frac{67{,}5\cdot 10^2}{16} = 422\text{sm}^3.$$

DÖST boýunça 30-njy belgili iki tawrany saýlaýarys.



6.47-nji surat

6.48. Bu ýerde güýç usulyny ulanmak amatly bolýar.

$$X_1\delta_{11} + \Delta_{ip} = 0,$$

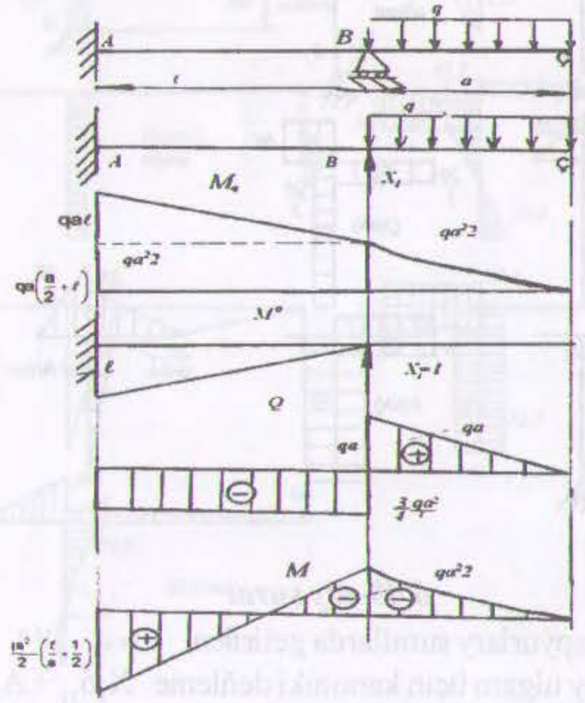
$$\delta_{11} = \frac{1}{2}\cdot\ell\cdot\ell\cdot\frac{2\ell}{3} = \frac{\ell^3}{3},$$

$$\Delta_{ip} = -\frac{qa^2}{2}\cdot\ell\cdot\frac{1}{2}\cdot\ell - qa\ell\cdot\frac{1}{2}\cdot\ell\cdot\frac{2}{3}\cdot\ell = -qa\ell^2\left(\frac{a}{4}+\frac{\ell}{3}\right),$$

$$X_1 = -\frac{\Delta_{ip}}{\delta_{11}} = \frac{qa\ell^2\cdot 3}{\ell^3}\left(\frac{a}{4}+\frac{\ell}{3}\right) = qa\left(1+\frac{3}{4}\cdot\frac{a}{\ell}\right),$$

$$M_A = M_q^A - X_1\cdot M_A^0 = qa\left(\frac{a}{2}+\ell\right) - qa\left(1+\frac{3}{4}\cdot\frac{a}{\ell}\right)\cdot\ell = -\frac{qa^2 2}{2}\left(\frac{1}{2}+\frac{\ell}{a}\right)$$

M we Q epýurlary suratda görkezilen.



6.48-nji surat

6.49. Esasy ulgamyň kanoniki deňlemesi.

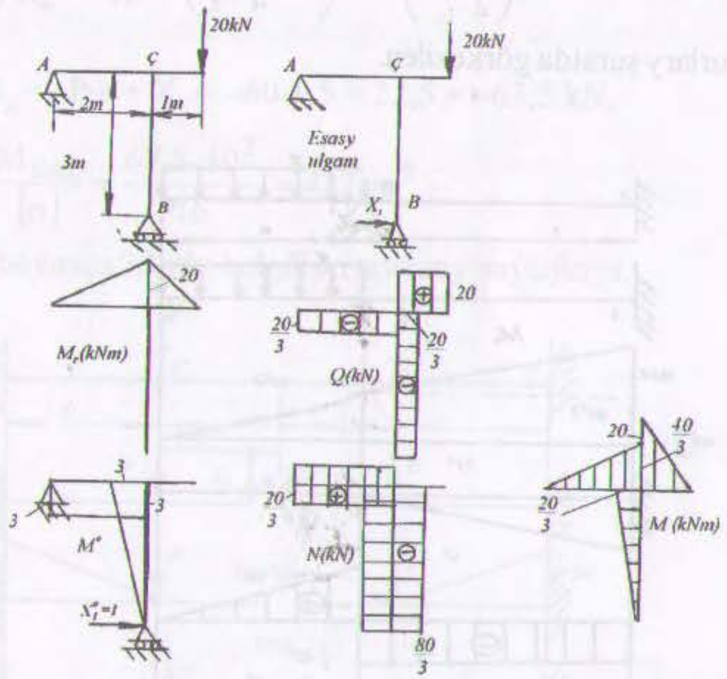
$X_1\delta_{11} + \Delta_{1P} = 0,$

$\delta_{11} = \frac{1}{2}\cdot 3\cdot 3\cdot\frac{2}{3}\cdot 3 + 3\cdot 3\cdot 2 = 27,$

$\Delta_{1P} = -\frac{1}{2}\cdot 20\cdot 2\cdot 3 = -60,\ X_B = X_1 = \frac{60}{27} = \frac{20}{9}\text{kN},$

$X_A = X_B = \frac{20}{9}\text{kN},\ R_A = \frac{20}{3}\text{kN},\ R_B = \frac{80}{3}\text{kN}.$

M, Q we N epýurlary suratda görkezilen.



6.49-njy surat

6.50. Q, M we N epýurlary suratlarda getirilen.

Kabul edilen esasy ulgam üçin kanoniki deňleme $X_1\delta_{11} + \Delta_{1P} = 0,$

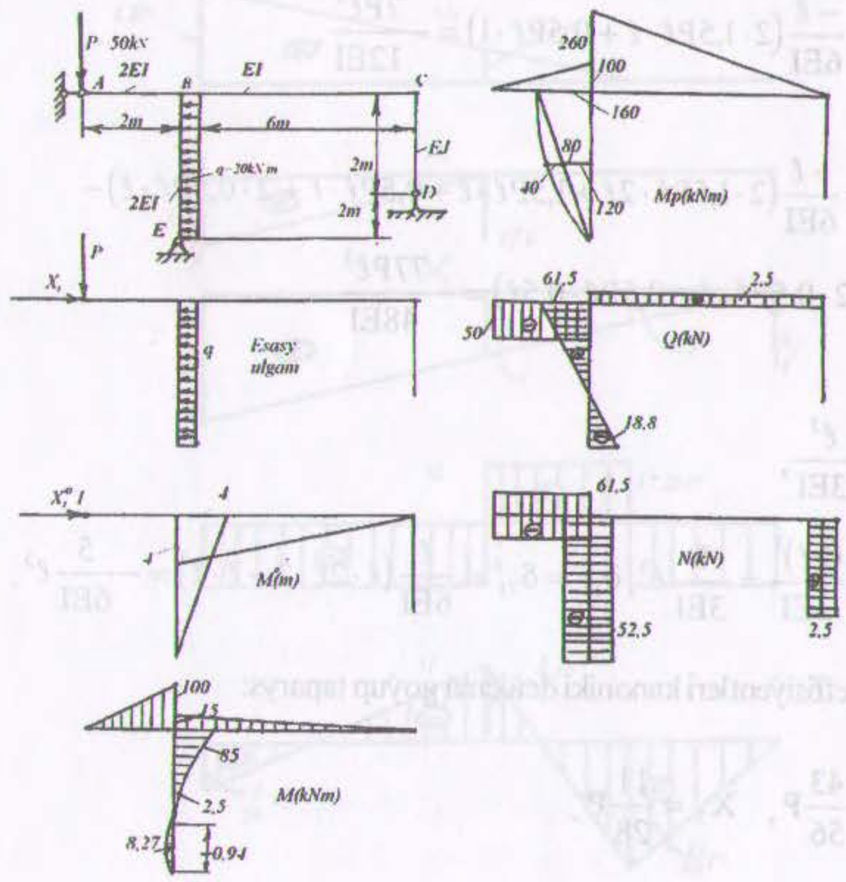
$\delta_{11} = \frac{1}{EI}\cdot\frac{1}{2}\cdot 4\cdot 6\cdot\frac{2}{3}\cdot 4 + \frac{1}{2EI}\cdot\frac{1}{2}\cdot 4\cdot 4\cdot\frac{2}{3}\cdot 4 = \frac{128}{3EI},$

$\Delta_{1P} = \frac{1}{EI}\cdot\frac{1}{2}\cdot 260\cdot 6\cdot\frac{2}{3}\cdot 4 - \frac{2}{3}\cdot 40\cdot 4\cdot 2\cdot\frac{1}{2EI} - \frac{1}{2}\cdot 160\cdot 4\cdot\frac{2}{3}\cdot 4\cdot\frac{1}{2EI} = -\frac{7840}{3EI}$

Kanoniki deňlemeden $X_1 = -\frac{\Delta_{1P}}{\delta_{11}} = \frac{7840}{128} = 61{,}25\text{kN}.$

Berlen statiki kesgitlenmeýän çarçuwanyň häsiýetli kesiklerindäki egme momentiň gutarnykly epýurlarynyň ordinatalaryny aşakdaky formula bilen kesgitleýäris: $M = M_p + M^o X_1$

Kese we boý güýçleriň epýurlary adaty usul bilen gurlan.



6.50-nji surat

6.51. Esasy ulgam üçin balkanyň kanoniki deňlemesi:

$$\begin{cases} X_1\delta_{11} + X_2\delta_{12} + \Delta_{1p} = 0 \\ X_1\delta_{21} + X_2\delta_{22} + \Delta_{2p} = 0 \end{cases}$$

X_1, X_2 – näbelli gaýtargylar. Kanoniki deňlemäniň koeffisiýentlerini Simpson–Karnouhowyň usuly bilen tapýarys:

$$\Delta_{1p} = \frac{-\ell}{6EI}\left(2\cdot 1{,}5P\ell\cdot\ell + 0{,}5P\ell\cdot 1\right) = -\frac{7P\ell^3}{12EI},$$

$$\Delta_{2p} = \frac{-\ell}{6EI}\left(2\cdot 1{,}5P\ell\cdot 2\ell + 1{,}5P\ell\cdot\ell + 0{,}5P\ell\cdot\ell + 2\cdot 0{,}5P\ell\cdot\ell\right) -$$

$$\frac{0{,}51}{6EI}\left(2\cdot 0{,}5P\ell\cdot\ell + 0{,}5P\ell\cdot 0{,}5\ell\right) = -\frac{77P\ell^3}{48EI}$$

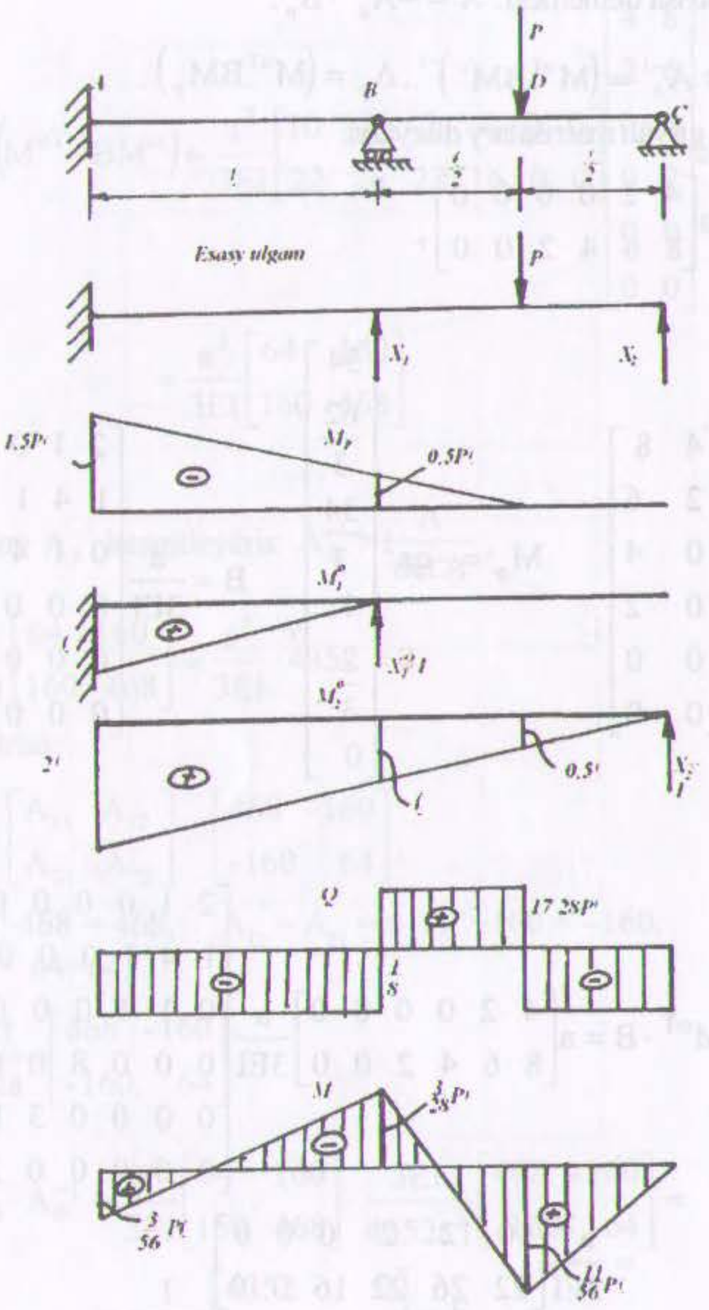
$$\delta_{11} = \frac{\ell^3}{3EI},$$

$$\delta_{22} = \frac{(2\ell)^3}{3EI} = \frac{8}{3EI}\ell^3, \delta_{12} = \delta_{21} = \frac{\ell}{6EI}\left(\ell\cdot 2\ell\cdot 2 + \ell\cdot\ell\right) = -\frac{5}{6EI}\ell^3.$$

Bu koeffisiýentleri kanoniki deňlemä goýup taparys:

$$X_1 = \frac{43}{56}P, \quad X_2 = \frac{11}{28}P.$$

Q we M epýurlary adaty usul bilen gurlan.



6.51-nji surat

6.52. Matrisa deňlemesi: $X = -A_{\delta}^{-1} \cdot \Delta_p$.

Bu ýerde $A_{\delta}^{-1} = \left(M^{oT} B M^{o}\right)^{-1}$, $\Delta_p = \left(M^{oT} B M_p\right)$.

Deňlemä giryän matrisalary düzýäris:

$$M^{oT} = a\begin{bmatrix} 4 & 2 & 0 & 0 & 0 & 0 \\ 8 & 6 & 4 & 2 & 0 & 0 \end{bmatrix},$$

$$M^{o} = a\begin{bmatrix} 4 & 8 \\ 2 & 6 \\ 0 & 4 \\ 0 & 2 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}; \quad M_p = -qa^2 \begin{bmatrix} 34 \\ \frac{62}{3} \\ \frac{34}{3} \\ 4 \\ \frac{2}{3} \\ 0 \end{bmatrix}, \quad B = \frac{a}{3EI}\begin{bmatrix} 2 & 1 & 0 & 0 & 0 & 0 \\ 1 & 4 & 1 & 0 & 0 & 0 \\ 0 & 1 & 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 3 & 1 \\ 0 & 0 & 0 & 0 & 0 & 2 \end{bmatrix}.$$

$$M^{oT} \cdot B = a\begin{bmatrix} 4 & 2 & 0 & 0 & 0 & 0 \\ 8 & 6 & 4 & 2 & 0 & 0 \end{bmatrix}\frac{a}{3EI}\begin{bmatrix} 2 & 1 & 0 & 0 & 0 & 0 \\ 1 & 4 & 1 & 0 & 0 & 0 \\ 0 & 1 & 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 3 & 1 \\ 0 & 0 & 0 & 0 & 0 & 2 \end{bmatrix} =$$

$$= \frac{a^2}{3EI}\begin{bmatrix} 10 & 12 & 2 & 0 & 0 & 0 \\ 22 & 26 & 22 & 16 & 0 & 0 \end{bmatrix}$$

Birlik güýçlerden ornuny üýtgetmäniň matrisasy

$$A_{\delta} = \left(M^{oT} \cdot BM^{o}\right) = \frac{a^2}{3EI}\begin{bmatrix} 10 & 12 & 2 & 0 & 0 & 0 \\ 22 & 26 & 22 & 16 & 0 & 0 \end{bmatrix}\begin{bmatrix} 4 & 8 \\ 2 & 6 \\ 0 & 4 \\ 0 & 2 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} a =$$

$$= \frac{a^3}{3EI}\begin{bmatrix} 64 & 160 \\ 160 & 468 \end{bmatrix}$$

Ters matrisany A_{δ}^{-1} kesgitleýäris: $A_{\delta}^{-1} = \frac{\breve{A}}{\det A}$,

$$\det A = \frac{a^3}{3EI}\begin{bmatrix} 64 & 160 \\ 160 & 468 \end{bmatrix} = \frac{a^3}{3EI} \cdot 4352 \neq 0$$

Baglaýjy matrisa:

$$\breve{A} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} = \begin{bmatrix} 468 & -160 \\ -160 & 64 \end{bmatrix},$$

$A_{11} = (-1)^{1+1} \cdot 468 = 468$, $A_{12} = A_{21} = (-1)^{1+2} \cdot 160 = -160$,
$A_{22} = (-1)^{2+2} \cdot 64 = 64$,

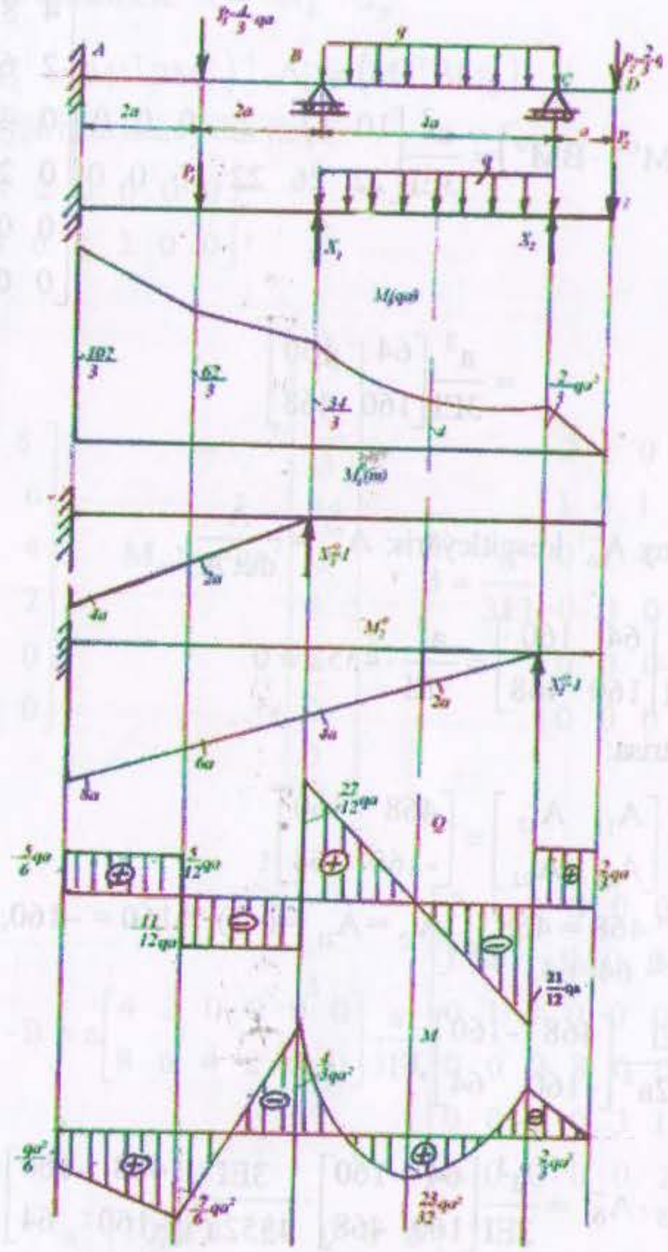
$$A_{\delta}^{-1} = \frac{3EI}{4352a^3}\begin{bmatrix} 468 & -160 \\ -160 & 64 \end{bmatrix},$$

$$A_{\delta} \cdot A_{\delta}^{-1} = \frac{a^3}{3EI}\begin{bmatrix} 64 & 160 \\ 160 & 468 \end{bmatrix} \cdot \frac{3EI}{4352a^3}\begin{bmatrix} 468 & -160 \\ -160 & 64 \end{bmatrix} =$$

Barlagy

$$= \frac{1}{4352}\begin{bmatrix} 4352 & 0 \\ 0 & 4352 \end{bmatrix} = E$$

Ters matrisa dogry hasaplanan.



6.53-nji surat

$$\Delta_p = -\frac{a^2}{3EI}\begin{bmatrix}10 & 12 & 2 & 0 & 0 & 0\\ 22 & 36 & 22 & 16 & 0 & 0\end{bmatrix}\cdot\begin{bmatrix}34\\ \frac{62}{3}\\ \frac{34}{3}\\ 4\\ \frac{2}{3}\\ 0\end{bmatrix}qa^2 = -\frac{qa^4}{9EI}\begin{bmatrix}1764\\ 6416\end{bmatrix}$$

Onda $X = \begin{bmatrix}X_1\\ X_2\end{bmatrix} = \frac{3EI}{4352a^3}\begin{bmatrix}468 & -160\\ -160 & 64\end{bmatrix}\cdot\frac{qa^4}{9EI}\begin{bmatrix}1764\\ 5416\end{bmatrix} = \begin{bmatrix}3{,}14\\ -4{,}93\end{bmatrix}qa$

$X_1 = 3{,}14qa$, $X_2 = -4{,}93qa$.

6.53. N = 1,06kN.

$q\ell = q_1\ell + P_2$ (1), $f_1 = f_2$,

$$f_1 = \frac{5q_1\ell^4}{384EI_1},\quad f_2 = \frac{P_2\ell^3}{48EI_2};$$

$$\frac{5q_1\ell}{384I_1} = \frac{P_2}{48I_2} \Rightarrow \frac{5q_1\ell}{8I_1} = \frac{P_2}{I_2};$$

$$q_1 = \frac{8}{5\ell}\cdot\frac{I_1}{I_2}P_2, \qquad (2).$$

(2)ańlatmany (1) goýup alarys:

$$q\ell = P_2\left(1+\frac{8}{5}\cdot\frac{I_1}{I_2}\right),$$

$$P_2 = \frac{q\ell}{1+\frac{8}{5}\cdot\frac{I_1}{I_2}} = \frac{5\cdot 1}{1+\frac{8}{5}\cdot\frac{12{,}56\cdot 10^3}{5{,}44\cdot 10^3}} = \frac{5}{4{,}7} = 1{,}06\text{kN}.$$

6.54. $P_1 = \dfrac{\ell_2^3 I_1}{\left(\ell_2^3 I_1 + \ell_1^3 I_2\right)} \cdot P$, $P_2 = \dfrac{\ell_1^3 I_2}{\left(\ell_2^3 I_1 + \ell_1^3 I_2\right)} \cdot P$.

Goý, ýokarky we aşaky balkalar, degişlilikde, P_1 we P_2 güýçleri kabul edýän bolsunlar, onda

$$P = P_1 + P_2 , \qquad (1).$$

Balkalaryň ortasyndaky egrelmeleriň deňligi üçin

$$\frac{P_1 \ell_1^3}{48EI_1} = \frac{P_2 \ell_2^3}{48EI_2} \qquad (2).$$

(1) we (2) aňlatmalardan

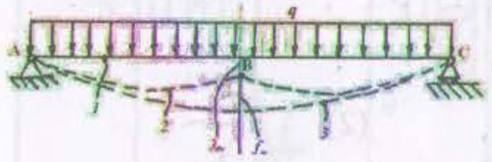
$$P_1 = \frac{\ell_2^3 I_1}{\left(\ell_2^3 I_1 + \ell_1^3 I_2\right)} \cdot P, \quad P_2 = \frac{\ell_1^3 I_2}{\left(\ell_2^3 I_1 + \ell_1^3 I_2\right)} \cdot P.,$$

6.55. $P_1 = 0{,}19P$, $P_2 = 0{,}81P$.

$$P_1 + P_2 = P, \quad \frac{P_1 \ell_1^3}{3EI_1} = \frac{P_2 \ell_2^3}{3EI_2}$$

Bu ýerden $P_1 = 0{,}19P$, $P_2 = 0{,}81P$.

6.56. R_{pr}=30,32kN.



6.56-njy surat

Durkuny üýtgetmäniň bilelikdäki deňlemesi:

$$f_q = f_B + \lambda_{pr} \text{ ýa-da } \frac{5q(2\ell)^4}{384EI} = \frac{R_B}{c} + \frac{R_B(2\ell)^3}{48EI};$$

Bu ýerden $R_B = R_{pr} = \dfrac{5cq\ell^4}{4\left(6EI + c\ell^3\right)} = 30{,}32\text{kN}$.

6.57. P = 0,55kN.

$X_1\delta_{11} + \Delta_{1p} = 0$, $\delta_{11} = \dfrac{\ell^3}{3}$,

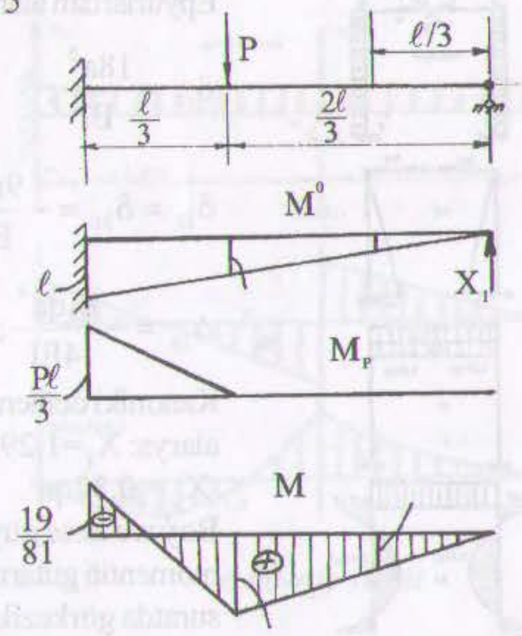
$$\Delta_{1p} = \frac{-\ell}{18EI}\left(2\frac{P\ell}{3}\cdot\ell + \frac{P\ell}{3}\cdot\frac{2\ell}{3}\right) = \frac{-4P\ell^3}{81},$$

$$X_1 = \frac{4P\ell^3 \cdot 3}{81\cdot\ell^3} = \frac{4}{27}P,$$

$\sigma = E\varepsilon = 2\cdot10^4\cdot10^{-4}$=2kN/sm^2,

$$\sigma = \frac{M\cdot y}{I} = \frac{4\cdot150\cdot12\cdot3}{81\cdot4\cdot12^3}P = 2.$$

Bu ýerden $P = \dfrac{41}{75}\text{kN} = 0{,}55\text{kN}$.



6.57-nji surat

6.58. Berlen çarçuwa üç gezek statiki kesgitlenmeýän. Çarçuwany ok simmetriýasy boýunça kesýäris.
Kanoniki deňlemeler:

Kanoniki deňlemeler:

$$\begin{cases} X_1\delta_{11} + X_2\delta_{12} + X_3\delta_{13} + \Delta_{1p} = 0 \\ X_1\delta_{21} + X_2\delta_{22} + X_3\delta_{23} + \Delta_{2p} = 0 \\ X_1\delta_{31} + X_2\delta_{32} + X_3\delta_{33} + \Delta_{3p} = 0 \end{cases}$$

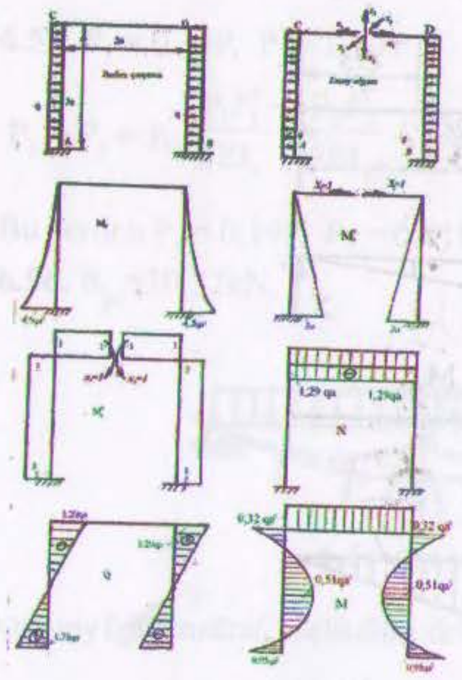
M_1^0, M_3^0 – simmetriýaly epýurlar, M_2^0 – ters simmetriýaly epýur.

Şonuň üçin hem $\delta_{12} = \delta_{21} = 0$; $\delta_{23} = \delta_{32} = 0$.

M_p epýur simmetriýaly, onda $\Delta_{2p} = 0$.

Kanoniki deňlemeler aşakdaky ýaly görnüşe geçýär:

$$\begin{cases} X_1\delta_{11} + X_3\delta_{13} + \Delta_{1p} = 0 \\ X_1\delta_{31} + X_3\delta_{33} + \Delta_{3p} = 0 \end{cases}$$



Epýurlardan alarys:

$$\delta_{11} = \frac{18a^3}{EI};$$

$$\delta_{13} = \delta_{31} = -\frac{9a^2}{EI}; \delta_{33} = \frac{8a}{EI};$$

$$\Delta_{1p} = -\frac{81qa^4}{4EI}; \Delta_{3p} = \frac{9qa^3}{EI}.$$

Kanoniki deňlemeleri işläp alarys: $X_1 = 1{,}29qa$, $X_3 = 0{,}32qa^2$.

Boý we kese güýçleriň we egme momentiň gutarnykly epýurlary suratda görkezilen.

6.58-nji surat

6.59. $f_B = \frac{q\ell^4}{24EI}$.

Ortaky diregi aýryp, B nokatdaky egrelmäni tapýarys:

$$f_{B_q} = \frac{5q\ell^4}{24EI},$$

B nokatdaky R_B güýçden egrelme

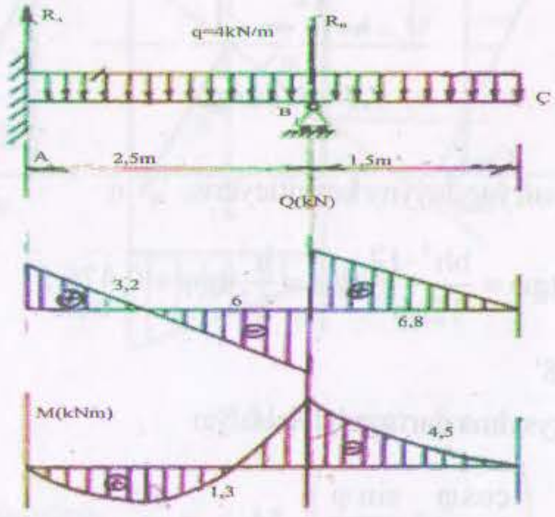
$$f_{BR_B} = \frac{q\ell^4}{6EI},$$

Onda B kesigiň mümkin bolan egrelmesi:

$$f_B = f_{B_q} - f_{BR_B} = \frac{q\ell^4}{24EI}.$$

Bu ýerden çetki direglere garanyňda ortaky direg $\frac{q\ell^4}{24EI}$ deň ululykda aşakda ýerleşen.

6.60. $R_B = 12{,}8$kN.



6.60-njy surat

$$\sum M_A = q\frac{4^2}{2} - R_B \cdot 2{,}5 = 0, \quad R_B = 12{,}8\text{kN}.$$

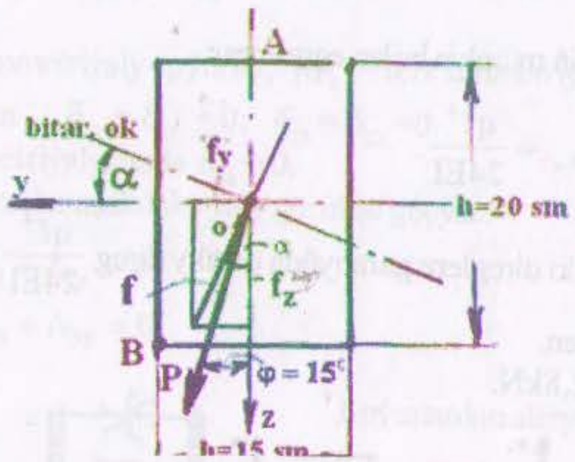
$R_A = q \cdot 4 - R_B = 16 - 12{,}8 = 3{,}2$kN.

Q we M epýurlary adaty usul bilen gurlan we suratda görkezilen.

VII bap

Çylşyrymly garşylyk

7.1. $\alpha = 25^0 28'$; $f = 0{,}605$ sm; $\sigma_A = -0{,}98 kN/sm^2$.



7.1-nji surat

Bitarap okuň ýagdaýyny kesgitleýäris.

$$tg\alpha = \frac{I_y}{I_z} tg\varphi = \frac{bh^3 \cdot 12}{12hb^3} tg\varphi = \frac{h^2}{b^2} tg\varphi = 0{,}476;$$

$$\alpha = 25^\circ 28'$$

A nokatda iň uly gysylma dartgynlylyk bolýar.

$$\sigma_A = -M_{max}\left(\frac{\cos\varphi}{w_z} + \frac{\sin\varphi}{w_y}\right);\ M_{max} = \frac{P\ell}{4}$$

$$\sigma_A = -\frac{P\ell}{4}\left(\frac{6\cos\varphi}{bh^2} + \frac{6\sin\varphi}{b^2 h}\right) = -0{,}98 kN/sm^2,$$

z we y oklaryň ugry boýunça iň uly progib

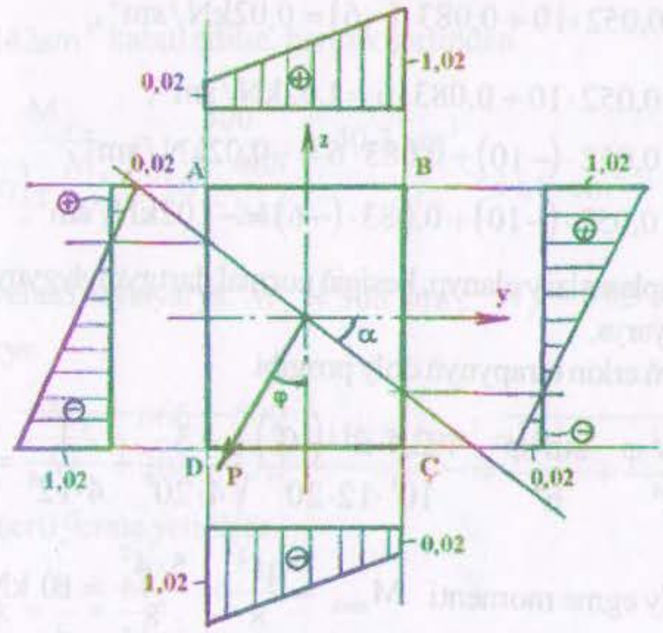
$$f_z = \frac{P_z \ell^3}{48EI_y};\quad f_y = \frac{P_y \ell^3}{48EI_z};\quad I_y = \frac{bh^3}{12};\quad I_z = \frac{b^3 h}{12},$$

onda $f = \sqrt{f_z^2 + f_y^2} = \sqrt{\left(\frac{P\ell^3 \sin\varphi}{48EI_z}\right)^2 + \left(\frac{P\ell^3 \cos\varphi}{48EI_y}\right)^2} = 0{,}605$ sm.

Progibiň ugry z ok bilen $\alpha = 25°28'$ burç boýunça ugrukdyrylan.

7.2. $\sigma_A = 0{,}02 kN/sm^2$, $\sigma_B = 1{,}02 kN/sm^2$,

$\sigma_ç = 0{,}02 kN/sm^2$, $\sigma_D = -1{,}02 kN/sm^2$, $f = 1{,}31$ sm.



7.2-nji surat

Bitarap okuň ýagdaýy

$$tg\alpha = \frac{I_z}{I_y} \cdot tg\varphi = \frac{h^2}{b^2} tg30^\circ = 1{,}58,$$

$$\alpha = 57^\circ 42'$$

Iň uly egme moment $M = P\ell$.

Kesigiň islendik nokadyndaky doly dartgynlylyk

$$\sigma = M\left(\frac{\cos\varphi}{I_z}\cdot y + \frac{\sin\varphi}{I_y}\cdot z\right) =$$

$$= 2{,}4\cdot 200\left(\frac{\cos 30^0\cdot 12}{12\cdot 20^3}\cdot y + \frac{\sin 30^0\cdot 12}{20\cdot 12^3}\cdot z\right) =$$

$$= 0{,}052y + 0{,}083z.$$

onda $\sigma_A = 0{,}052\cdot 10 + 0{,}083\cdot(-6) = 0{,}02 kN/sm^2$,

$\sigma_B = 0{,}052\cdot 10 + 0{,}083\cdot 6 = 1{,}02 kN/sm^2$,

$\sigma_C = 0{,}052\cdot(-10) + 0{,}083\cdot 6 = -0{,}02 kN/sm^2$,

$\sigma_D = 0{,}052\cdot(-10) + 0{,}083\cdot(-6) = -1{,}02 kN/sm^2$.

Ýokardaky hasaplamalary ulanyp, kesigiň normal dartgynlylygynyň epýurlaryny gurýarys.

Balkanyň erkin tarapynyň doly progibi

$$f = \frac{4P\ell^3}{Ebh}\sqrt{\frac{\cos^2\varphi}{h^4} + \frac{\sin^2\varphi}{b^4}} = \frac{4\cdot 2{,}4\cdot 2^3\cdot(10^6)}{10^3\cdot 12\cdot 20}\sqrt{\frac{3}{4\cdot 20^4} + \frac{1}{4\cdot 12^4}} = 1{,}31 sm$$

7.3. Iň uly doly egme momenti $M_{max} = \frac{q\ell^2}{8} = \frac{5\cdot 4^2}{8} = 10$ kNm.

Baş oklar boýunça egme momentler

$M_x = M_{max}\cdot\cos 30^0 = 8{,}66 kNm$, $M_y = M_{max}\cdot\sin 30^0 = 5$ kNm.

Berklik şerti $\sigma = \frac{M_x}{W_x} + \frac{M_y}{W_y} \le [\sigma]$.

Diňe M_x täsirinden talap edilýän garşylyk moment

$$W_x = \frac{M_x}{[\sigma]} = \frac{8{,}66\cdot 10^2}{16} = 54\ sm^3,$$

DÖST 8240-56 boýunça N12 şweller gabat gelýär.

M_y täsirinden

$$W_y = \frac{5\cdot 10^2}{16} = 31{,}2\ sm^3 \Rightarrow$$ N24 şweller degişli.

Diýmek, şweller N24 kiçi bolmaly däl.

Meseläni yzygiderli ýakynlaşdyrma usuly bilen işleýäris.

Birinji ýakynlaşmada 24-nji belgili şwelleri saýlaýarys. DÖST 8240-56 boýunça $W_x = 242\ sm^3$, $W_y = 31{,}6\ sm^3$.

$W_x = 242 sm^3$ kabul edilse, berklik şertinden

$$W_y = \frac{M_y}{[\sigma] - \frac{M_x}{W_x}} = \frac{500}{16 - \frac{866}{242}} = 40.3\ sm^3 > 31{,}6\ sm^3$$

№27 şwelleri saýlaýarys: $W_x = 308\ sm^3$; $W_y = 37{,}3\ sm^3$.

Barlaýarys:

$$\sigma = \frac{M_x}{W_x} + \frac{M_y}{W_y} = \frac{866}{308} + \frac{500}{37{,}3} = 16 kN/sm^2 = [\sigma].$$

Berklik şerti ýerine ýetirilýär.

7.4. $k = \frac{h}{b} = \frac{M_x}{M_y}$.

Berklik şertinden

$$\frac{M_x}{W_x} + \frac{M_y}{W_y} \le [\sigma]; \quad W_x = \frac{k^2b^3}{6}; \quad W_y = \frac{kb^3}{6}.$$

$$b = \sqrt[3]{\frac{6M_x + 6M_y k}{[\sigma]^2 k}}; \quad A = h\cdot b = \sqrt[3]{\frac{36(M_x + kM_y)^2}{[\sigma]^2 k}}.$$

Iň kiçi meýdan $\frac{dA}{dk} = 0$.

onda $k = \frac{h}{b} = \frac{M_x}{M_y}$.

7.5. $k = \frac{1}{\sqrt{tg\varphi}}$.

Konsolyň erkin tarapyndaky progibiň deňlemesinden,

$$[f] = \sqrt{\left(\frac{P\ell^3 \cos\varphi}{3EI_x}\right)^2 + \left(\frac{Pl^3 \sin\varphi}{3EI_x}\right)^2}$$

Balkanyň kesiginiň meýdanyny tapýarys.

$$A = \sqrt{\frac{144P^2\ell^6\left(k^4\cos^2\varphi + \sin^2\varphi\right)}{9k^2E[f^2]}}; \qquad \frac{dA}{dk} = 0 \text{ şertden,}$$

$k = \frac{1}{\sqrt{tg\varphi}}$.

7.6. №22 iki tawra.

Gyýa egilmäniň berklik şertinden alarys:

$$W_z = \frac{P\ell}{4[\sigma]}\left(\cos\varphi + \frac{W_z}{W_y}\sin\varphi\right) = 58{,}75 + 21{,}38\frac{W_z}{W_y};$$

Yzygiderli çemeleşme ýoly arkaly kesigi saýlaýarys. W_z/W_y gatnaşyk iki tawra balka üçin 6-15 aralygynda $\frac{W_z}{W_y} = 6$ kabul edýäris.

Onda $W_z \geq 58{,}75 + 21{,}38 \cdot 6 = 185\ sm^3$,

Eger $\frac{W_z}{W_y} = 15$ bolsa, onda $W_z \geq 58{,}75 + 21{,}38 \cdot 15 = 380\ sm^3$.

$W_z = 184 sm^3$ N20 iki tawra, $W_z = 371 sm^3$ N27 iki tawra degişli.

N22 saýlaýarys, $W_z = 232 sm^3$; $W_y = 28{,}6\ sm^3$

$\frac{W_z}{W_y} = \frac{232}{28{,}6} = 8{,}11$

Bu belgidäki iki tawranyň iň uly normal dartgynlylygy

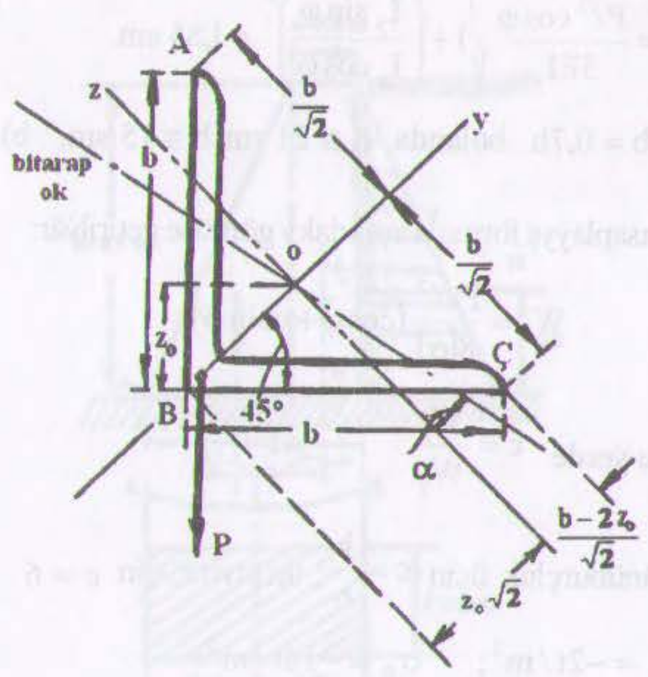
$$\sigma_{max} = \frac{P\ell}{4W_z}\left(\cos\varphi + \frac{W_z}{W_y}\sin\varphi\right) = 16{,}01 kN/sm^2 \approx [\sigma].$$

№22 iki tawrany saýlaýarys.

7.7. $\sigma_A = 16{,}64 kN/sm^2$; $\sigma_B = -13{,}32 kN/sm^2$; $\sigma_Ç = 4{,}33 kN/sm^2$; $f = 1{,}85$ sm.

Burçlugyň howply kesiginiň islendik nokadyndaky normal dartgynlylyk

$$\sigma = M_{max}\left(\frac{\sin\varphi}{I_z}\cdot y + \frac{\cos\varphi}{I_y}\cdot z\right) = 419y + 108{,}8z \quad (1),\ \varphi = 45^\circ.$$



7.7-nji surat

Bu deňlemeden bitarap okuň ugruny kesgitleýäris:

$$\operatorname{tg}\alpha = \frac{y}{z} - \frac{108{,}8}{419} \approx -0{,}26 = \operatorname{tg}\left(-14^{\circ}33'\right),$$

A,B we Ç nokatlaryň koordinatlary

$$y_A = y_Ç = \frac{b - 2z_o}{\sqrt{2}} = 2{,}5\text{sm};$$

$$z_A = -z_Ç = \frac{b}{\sqrt{2}} = 5{,}66\ \text{sm}.$$

$y_B = -z_o\sqrt{2} = -3{,}15\text{sm}; \quad z_B = 0.$

(1) deňlemä goýup alarys:

$\sigma_A = 16{,}64\text{kN/sm}^2; \ \sigma_B = -13{,}32\ \text{kN/sm}^2; \ \sigma_Ç = 4{,}33\text{kN/sm}^2.$

Burçlugyň iň uly progibi

$$f = \frac{P\ell^3\cos\varphi}{3EI_y}\sqrt{1+\left(\frac{I_y\sin\varphi}{I_z\cos\varphi}\right)^2} = 1{,}85\ \text{sm}.$$

7.8. a) $b = 0{,}7h$ bolanda, $h \cong 21$ sm, $b \cong 15$ sm. b) N20a ikitawra.

Hasaplaýyş formula aşakdaky görnüşe getirilýär:

$$W_z = \frac{Pa\ell^3}{8[\sigma]}(\cos\varphi + c\sin\varphi);$$

Bu ýerde $c = \dfrac{W_z}{W_y}$

gönüburçluk üçin $c = \dfrac{h}{b}$; iki tawra üçin $c = 6 \ldots 8$.

7.9. $\sigma_A = -2\text{t/m}^2; \quad \sigma_B = -14\text{t/m}^2.$

$\sigma = \dfrac{Q}{A} \pm \dfrac{M_{max}}{W}$ – sütüniň esasyndaky dartgynlylyk

A nokatdaky dartgynlylyk, $Q = \gamma \cdot \ell A; \quad A = 1\text{m}^2;$

$W = \dfrac{1}{6}\text{m}^3.$

$$\sigma_A = -\gamma\ell + \frac{q\ell^2}{2W} = -1{,}6\cdot 5 + \frac{0{,}08\cdot 5^2\cdot 6}{2\cdot 1} = -8 + 6 = -2\text{t/m}^2;$$

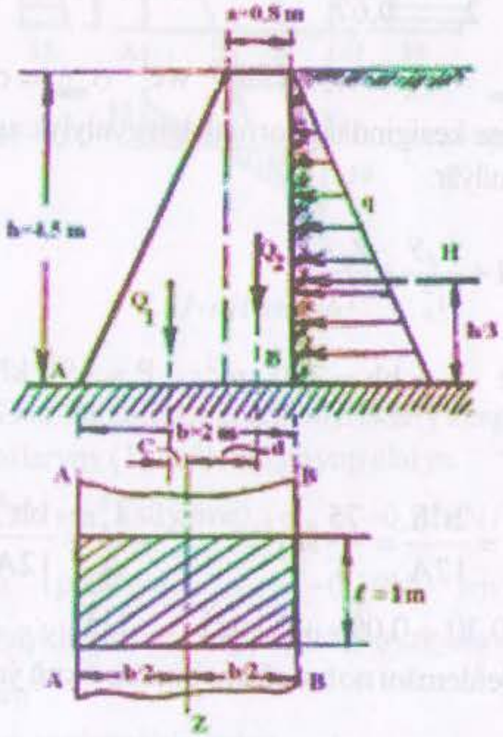
B nokatdaky dartgynlylyk

$$\sigma_B = -\gamma A - \frac{q\ell^2}{2W} = -8 - 6 = -14\text{t/m}^2.$$

7.10. $\sigma_A = 8{,}89\text{t/m}^2; \quad \sigma_B = 2{,}45\ \text{t/m}^2.$

Diwaryň 1m uzynlygyna seredýäris.

Diwaryň esasyndaky kesikde iň uly we iň kiçi dartgynlylyk aşakdaky formula boýunça kesgitlenýär:



7.10-njy surat

$$\sigma_{\substack{max\\min}} = \frac{N}{A} \pm \frac{M}{W};$$

$N = Q_1 + Q_2$. $Q_1 = \frac{1}{2} h(b-a)\gamma\ell = 4{,}86\,t$ – diwaryň 1m uzynlygynyň üçburçluk böleginiň agramy,

$Q_2 = ha \cdot \gamma\ell = 6{,}48\,t$ – diwaryň 1m uzynlygynyň prizma böleginiň agramy.

Diwaryň esasynyň merkezi okuna görä egme momenti

$$M_z = Q_1\left(a + \frac{b-a}{3} - \frac{b}{2}\right) + Q_2\left(\frac{b}{2} - \frac{a}{2}\right) + \frac{q_{max}h}{2} \cdot \frac{h}{3} = 2{,}15\ tm.$$

$$A = b\ell = 2m^2; \quad W_z = \frac{\ell b^2}{6} = 0{,}67\ m^2;$$

Onda $\sigma_{\substack{max\\min}} = \frac{11{,}34}{2} \pm \frac{2.,5}{0{,}67} = 5{,}67 \pm 3{,}22\ t/m^2$.

Bu ýerden, $\sigma_{max} = \sigma_A = 8{,}89\ t/m^2$ we $\sigma_{min} = \sigma_B = 2{,}45\ t/m^2$.

7.11. Diregiň kese kesigindäki normal dartgynlylyk aşakdaky formula boýunça kesgitlenilýär.

$$\sigma = \frac{P}{A}\left(1 + \frac{y_p y}{i_z^2} + \frac{z_p z}{i_y^2}\right);$$

bu ýerde $A = bh = 300\ sm^2$; $P = -90\ kN$;

$y_p = z_p = 3$ sm.

$$i_y^2 = \frac{I_y}{A} = \frac{b^3 h}{12A} = \frac{75}{4} sm^2; \quad i_z^2 = \frac{I_z}{A} = \frac{bh^3}{12A} = \frac{100}{3}.$$

Onda $\sigma = -0{,}3(1 + 0{,}09y + 0{,}16z)$ (1)

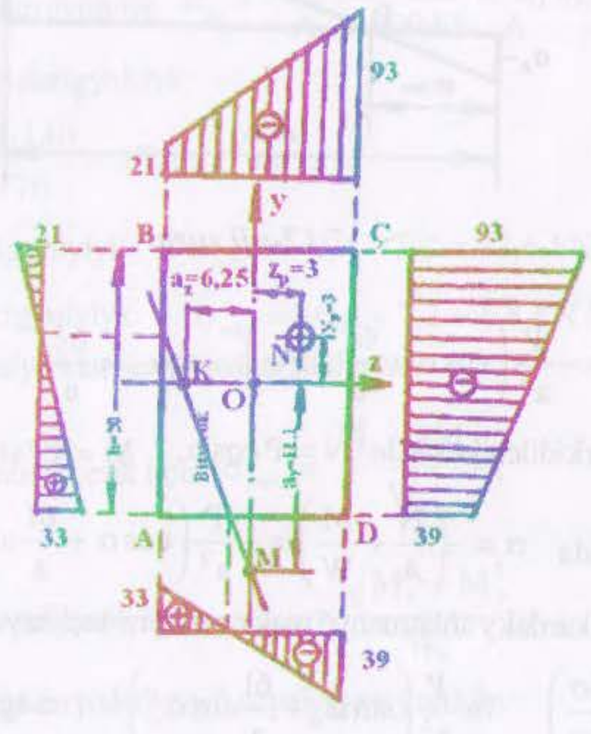
Soňky deňlemäni nola deňläp, bitarap okuň ýagdaýyny kesgitleýäris.

$$1 + 0{,}09y_o + 0{,}16z_o = 0;$$

Eger $z_o = 0$; $a_y = -11{,}1$ sm. (M nokat)

$y_o = 0$; $a_z = -\frac{1}{0{,}16} = -6{,}25$ sm. (K nokat)

Bitarap ok M we K nokatlaryň üstünden geçýär.



7.11-nji surat

A, B, Ç we D nokatlardaky dartgynlylyklary kesgitleýäris. Bu nokatlaryň koordinatlaryny (1) deňlemä goýup alarys.

$\sigma_A = 0{,}33 kN/sm^2$ (süýnme), $\sigma_B = -0{,}21 kN/sm^2$ (gysylma),

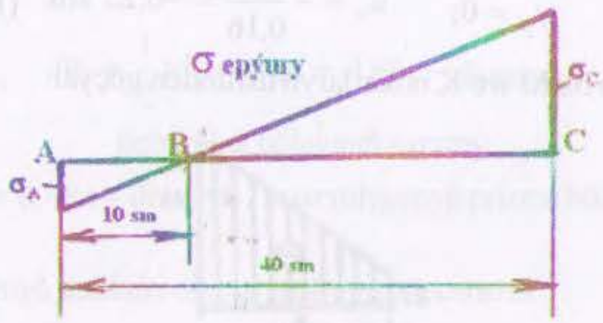
$\sigma_Ç = -0{,}93 kN/sm^2$ (gysylma), $\sigma_D = -0{,}39 kN/sm^2$ (gysylma).

Bu dartgynlylyklaryň bahalary boýunça çyzgyda epýurlar gurlan.

7.12. $\sigma = 0{,}6 kN/sm^2$.

Üçburçluklaryň meňzeşliklerinden

$$\frac{\sigma_A}{10}=\frac{\sigma_C}{30}\Rightarrow\sigma_C=3\sigma_A=3\cdot0{,}2=0{,}6\text{kN/sm}^2$$



7.12-nji surat

7.13. $\sigma=-\frac{P}{a^2}\left(\cos\alpha+\frac{6\ell}{a}\sin\alpha\right);\quad \text{tg}\alpha_o=\frac{6\ell}{a}.$

Berkidilen kesikde $N=P\cos\alpha,\quad M=P\ell\sin\alpha$

Onda $\sigma=-\left(\frac{N}{A}+\frac{M}{W}\right)=-\frac{P}{a^2}\left(\cos\alpha+\frac{6\ell}{a}\sin\alpha\right).$

Ýokardaky aňlatmanyň maksimumyny tapýarys.

$$\left(\frac{d\sigma}{d\alpha}\right)_{\alpha=\alpha_o}=\frac{P}{a^2}\left(\sin\alpha_o+\frac{6l}{a}\cos\alpha_o\right)=0\Rightarrow\text{tg}\alpha_o=\frac{6\ell}{a}$$

onda $\sigma=-\frac{P}{a^2}\cdot\frac{\cos(\alpha-\alpha_o)}{\cos\alpha_o}.$

7.14. 26-njy belgili şweller.

Zynjyryň dartuwy P = Q, onda bu güýçleriň deňtäsiredijisi bloguň okundan geçýär we dargadylandan soň $N=T=Q=40\text{kN}$ balka gysylma we egilmä sezewar bolýar.

Ilki bilen gysylmany hasaba alman, şwelleriň belgisini kesgitleýäris.

$$W=\frac{M}{[\sigma]}=\frac{40\cdot140}{8}=700\text{ sm}^3$$

Goşmaça gysylmany hasaba alyp, garşylyk momentiň bahasyny artdyryp alarys.

N26 iki şweller degişli.

$W_x=2\cdot388=776\text{ sm}^3;\quad A=2\cdot49{,}95=99{,}85\text{ sm}^2$

Gysylma dartgynlylyk $\sigma_g=-\frac{N}{A}=-\frac{40}{99{,}85}=-0{,}4\text{kN/sm}^2.$

Egilmedäki dartgynlylyk

$$\sigma_e=\pm\frac{M}{W}=\pm\frac{40\cdot140}{776}=\pm7{,}2\text{kN/sm}^2.$$

Iň uly dartgynlylyk $\sigma_{max}=-0{,}4-7{,}2=-7{,}6\text{ kN/sm}^2.$

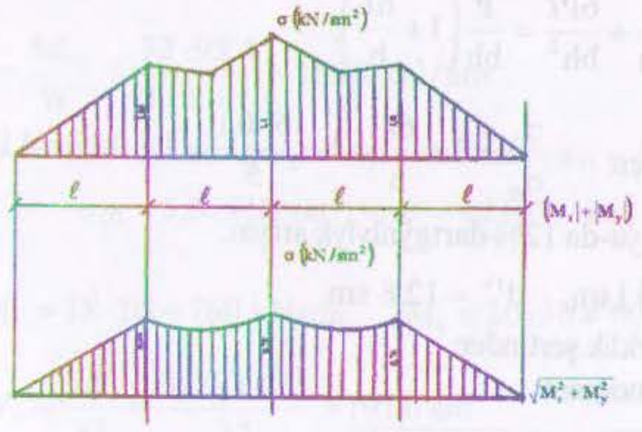
Iň kiçi dartgynlylyk $\sigma_{min}=-0{,}4+7{,}2=6{,}8\text{ kN/sm}^2.$

Bu dartgynlylyklar şerti kanagatlandyrýar.

7.15. Birinji görnüşli kesik üçin $\sigma_{max}=\frac{|M_x|+|M_y|}{W_x};$

Ikinji görnüşli kesik üçin $\sigma_{max}=\frac{\sqrt{M_x^2+M_y^2}}{W_x}.$

Dartgynlylyklaryň balkanyň uzynlygyna ýaýraýşy:



7.15-nji surat

7.16. $xy = \frac{h\ell}{12}$ – giperbolanyň deňlemesi.

Direglerdäki gaýtargylar

$$R_A = R_B = H \cdot \frac{h}{\ell};$$

Takmynan alnan nokatdaky dartgynlylyk

$$\sigma = \frac{H}{A} + \frac{H \cdot \frac{h}{2} \cdot y}{I} + \frac{R_B\left(\frac{1}{2} - x\right) \cdot y}{I};$$

bu aňlatma $\sigma = 0$, $I = \frac{bh^3}{12}$ goýup alarys $xy = \frac{1}{12} h\ell$.

Bu asimptotlar ox we oy deň bolan deňgapdally giperbolanyň deňlemesi

Bu egri çyzgyda punktir bilen görkezilen.

7.17. 12%

Ýük takyk goýlandaky dartgynlylyk

$$\sigma_o = \frac{P}{bh};$$

Çyzgyda görkezilen ýüklenme boýunça

$$\sigma_1 = \frac{P}{bh} + \frac{6P\ell}{bh^2} = \frac{P}{bh}\left(1 + \frac{6\ell}{h}\right);$$

bu ýerden $\frac{\sigma_1}{\sigma_0} = 1 + \frac{6\ell}{h} = 1 + \frac{6 \cdot 0{,}1}{5} = 1 + 0{,}12 = 1{,}12$ esse,

ýa-da 12% dartgynlylyk artýar.

7.18. $d^{III} = 13{,}1$ sm, $d^{IV} = 12{,}8$ sm.

III – berklik şertinden

Hasap moment

$$M_{III} = \sqrt{M_e^2 + M_t^2} = \sqrt{12{,}5^2 + 12{,}5^2} = 17{,}625 \text{kN m}.$$

onda $d_{III} = \sqrt[3]{\frac{32M_{III}}{\pi[\sigma]}} = \sqrt[3]{\frac{32 \cdot 17{,}625 \cdot 10^2}{3{,}14 \cdot 8}} = 13{,}1$ sm.

IV – berklik şertinden

$$M_{IV} = \sqrt{12{,}5^2 + 0{,}75 \cdot 12{,}5^2} = 16{,}53 \text{ kNm}.$$

$$d_{IV} = \sqrt[3]{\frac{32 \cdot 16{,}53 \cdot 10^2}{3{,}14 \cdot 8}} = 12{,}8 \text{ sm}.$$

7.19. $\sigma_1 = 12{,}73 \text{kN/sm}^2$; $\sigma_2 = 15{,}18 \text{kN/sm}^2$.

1) Sterženiň berkidilen kesiginde egme moment

$M_e = 2P \cdot 40 = 2 \cdot 1 \cdot 40 = 80 \text{kNsm}.$

Towlanma moment $M_t = 0$,

onda $\sigma_1 = \frac{M_e}{W_z} = \frac{32M_e}{\pi d^3} = \frac{32 \cdot 80}{3{,}14 \cdot 4^3} = 12{,}73 \text{kN/sm}^2$;

2) Haýsy hem bolsa bir güýç aýrylan ýagdaýynda

$M_e = P \cdot 40 = 40$ kNsm,

$M_t = P \cdot 100 = 100$ kNsm,

onda $M_{IV} = \sqrt{M_e^2 + 0{,}75 \cdot M_t^2} = \sqrt{40^2 + 0{,}75 \cdot 100^2} = 95{,}4$ kNsm,

we $\sigma_2 = \frac{M_{IV}}{W_z} = \frac{32 \cdot 95{,}4}{3{,}14 \cdot 4^3} = 15{,}18 \text{ kN/sm}^2$.

7.20. $\sigma_1 = 4{,}51 \text{ kN/sm}^2$; $\sigma_3 = -0{,}56 \text{ kN/sm}^2$; $\sigma_{II} = 4{,}67 \text{ kN/sm}^2$;

$\sigma_{III} = 5{,}06 \text{ kN/sm}^2$; $\sigma_{IV} = 4{,}81 \text{ kN/sm}^2$.

$M_e = 38 \cdot 20 = 760$ kNsm; $M_t = 20 \cdot 30 = 600$ kNsm.

$$W_z = \frac{\pi d^3}{32} = \frac{3{,}14 \cdot 12{,}5^3}{32} = 191{,}6 \text{ sm}^3$$

$$\sigma = \frac{M_e}{W_z} = \frac{760}{191,3} = 3,97\ \text{kN/sm}^2;$$

$$\tau = \frac{M_t}{2W_z} = \frac{600}{2\cdot 191,3} = 1,57\text{kN/sm}^2$$

Baş dartgynlylyklary belli formula boýunça kesgitleýäris.

$$\sigma_{1,3} = \frac{\sigma}{2} \pm \frac{1}{2}\sqrt{\sigma^2 + 4\tau^2} = \frac{3,97}{2} \pm \frac{1}{2}\sqrt{3,97^2 + 4\cdot 1,57^2} = 1,985 \pm 2,53$$

onda $\sigma_1 = 4,51\ \text{kN/sm}^2;\ \ \sigma_3 = -0,56\ \text{kN/sm}^2.$

II – berklik nazaryýeti boýunça

$$\sigma_{II} = \sigma_1 - \mu\sigma_3 = 4,51 + 0,3\cdot 0,56 = 4,67\ \text{kN/sm}^2.$$

III – berklik nazaryýeti boýunça

$$\sigma_{III} = \sqrt{\sigma^2 + 4\tau^2} = \sqrt{3,97^2 + 4\cdot 1,57^2} = 5,06\text{kN/sm}^2.$$

IV – berklik nazaryýeti boýunça

$$\sigma_{IV} = \sqrt{\sigma^2 + 3\tau^2} = \sqrt{3,97^2 + 3\cdot 1,57^2} = 4,81\text{kN/sm}^2.$$

7.21. d = 6,3 sm.

Deňagramlylyk şertinden

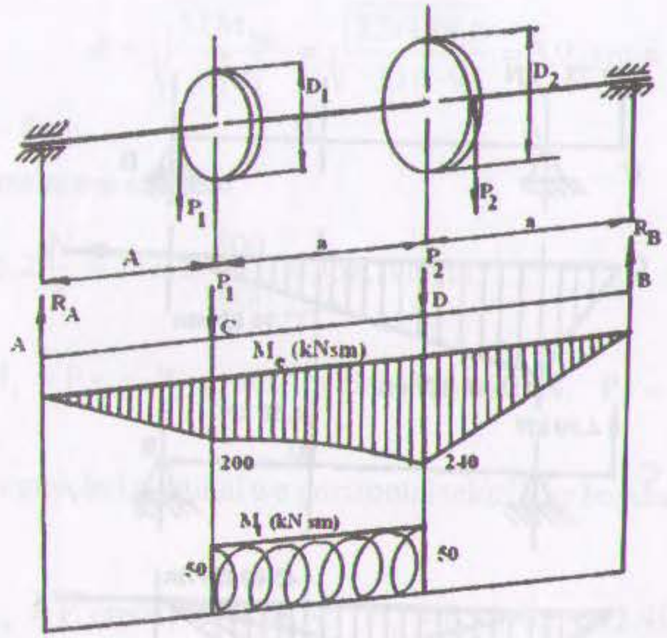
$$P_2 = \frac{R_1}{R_2}P_1 = \frac{10}{25}\cdot 5 = 2\,\text{kN} \quad \text{onda} \quad M_t = P_1R_1 = 5\cdot 10 = 50\text{kNsm}.$$

Howply kesik D kesik bolýar. $M_e = 240\ \text{kN sm};\ \ M_t = 50\ \text{kN sm}.$

III- berklik nazaryýeti boýunça

$$M_{III} = \sqrt{M_e^2 + M_t^2} = \sqrt{240^2 + 50^2} = 245\ \text{kNsm},$$

Walyň talap edýän diametri $d = \sqrt[3]{\frac{32\cdot M_{III}}{\tau\cdot[\sigma]}} = \sqrt[3]{\frac{32\cdot 245}{3,14\cdot 10}} = 6,3\ \text{sm}.$



7.21-nji surat

7.22. d = 6 sm.

Wala täsir edýän güýçleriň düzüjilerini gorizontal we wertikal tekizlikler boýunça dargadýarys.

Gorizontal tekizlikde $H_Ç = (6+3)\cos 30^\circ = 7,79\text{kN};$

$H_D = 3 + 1,5 = 4,5\text{kN}.$

Wertikal tekizlikde $R_Ç = (6+3)\sin 30^\circ = 4,5\text{kN}.$

Gorizontal tekizlikde iň uly egme moment A kesikde

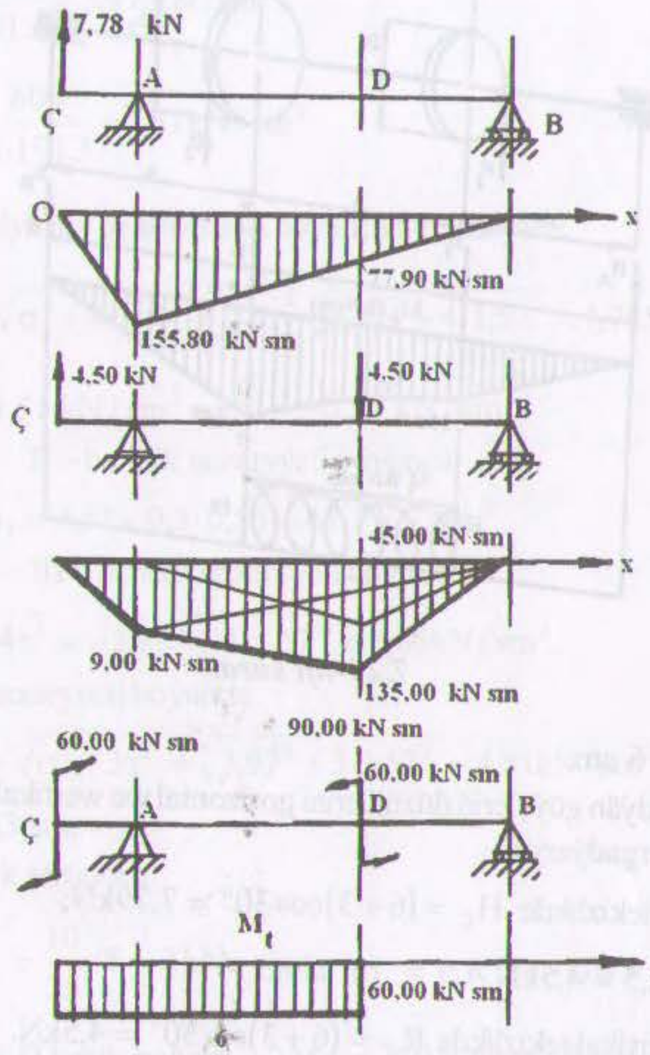
$M_A^{gor} = 7,79\cdot 20 = 155,8\text{kNsm}$ (surata seret).

Wertikal tekizlikde

$$M_A^{wert} = R_Ç\cdot 20 = 4,5\cdot 20 = 90\text{kNsm},$$

$$M_D^{wert} = \frac{R_D\cdot 80}{4} + \frac{R_Ç\cdot 20}{2} = 135\text{kNsm}.$$

Towlanma moment $M_t = (3-1,5)\cdot 40 = 60\text{kNsm}$



7.22-nji surat

D kesikdäki jemleýji egme moment

$$M_{jeml} = \sqrt{155,8^2 + 90^2} = 179,9 kN \cdot sm$$

III – berklik nazaryýeti boýunça D kesikdäki hasaplaýjy moment

$$M_{has} = \sqrt{(179,9)^2 + 60^2} = 189,6 kN \cdot sm,$$

Walyň diametri

$$d = \sqrt[3]{\frac{32M_{has}}{\pi[\sigma]}} = \sqrt[3]{\frac{32 \cdot 189,6}{3,14 \cdot 9}} = 5,97sm \approx 6sm.$$

7.23. d = 8 sm.

Towlanma moment

$$M_t = 716,2\frac{N}{n} = 716,2\frac{500}{1000} = 358,1 kNsm.$$

$M_t = P_1 r_1 = P_2 r_2$ aňlatmadan $P_1 = 60kN$; $P_2 = 30kN$.

Bu güýçleri wertikal we gorizontal tekizlikler boýunça dargadyp alarys:

$P_{1w} = P_1 \cos\alpha_1 = 42,4kN$; $P_{1g} = P_1 \sin\alpha_1 = 42,4kN$.

$P_{2w} = P_2 \cos\alpha_2 = 25,9kN$; $P_{2g} = P_2 \sin\alpha_2 = 15kN$.

Bu güýçlerden aýratynlykda wertikal we gorizontal tekizliklerde egme momentleriň epýurlaryny guryarys (surata seret).

Häsiýetli kesiklerdäki jemleýji egme momentler

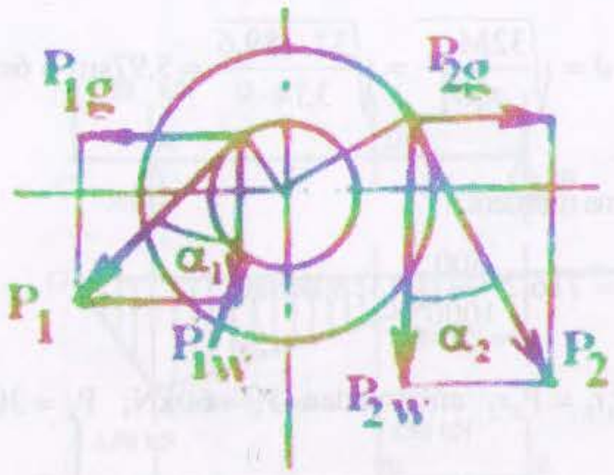
$$M_I = \sqrt{(M_I^w)^2 + (M_I^g)^2} = \sqrt{418^2 + 295^2} = 510 kNsm;$$

$$M_2 = \sqrt{(M_2^w)^2 + (M_2^g)^2} = \sqrt{398^2 + 31,5^2} = 400 kNsm.$$

Howply kesik 1-nji kesik we $M_{IV} = \sqrt{M_I^2 + 0,75 \cdot M_t^2} = 600 kNsm$.

Walyň diametri

$$d = \sqrt[3]{\frac{32M_{IV}}{\pi[\sigma]}} = \sqrt[3]{\frac{32 \cdot 600}{3,14 \cdot 12}} = 8sm.$$



7.23-nji surat

7.24. Kwadrat kesik 6% tegelek kesikden ýeňil.

Tegelek kesikli pürs üçin

$$\left(\sigma_{teg}^{III}\right)^2=\left(\frac{32M_e}{\pi d^3}\right)^2+4\left(\frac{16M_t}{\pi d^3}\right)^2=55{,}8\frac{M_e^2}{A_{teg}^3};$$

Kwadrat kesik üçin

$$\left(\sigma_{kw}^{III}\right)^2=\left(\frac{6M_e}{a^3}\right)^2+4\left(\frac{M_t}{0{,}208a^3}\right)^2=46\frac{M_e^2}{A_{kw}^3};$$

A_{teg}, A_{kw} - tegelek we kwadrat kesikleriň meýdanlary.

Ýokardaky dartgynlylyklary deňeşdirip alarys:

$A_{kw}=0{,}94A_{teg}$, diýmek, kwadrat kesik tegelekden 6% ýeňil.

7.25. d = 7 sm.

Walyň geçirýän towlanma momentini kesgitleýäris.

$$M_t=973{,}8\frac{N}{n}=973{,}8\cdot\frac{12}{80}=146\ \text{kNsm}.$$

Töwerekleýin täsir edýän güýç $P=\frac{2M_t}{D}=\frac{2\cdot146}{46}=6{,}35\text{kN}.$

Wala radial we ok boýunça täsir edýän güýçler

$P_r=0{,}36P=2{,}28$ kN; $P_{ok}=0{,}28P=1{,}78$ kN.

Suratda wertikal we gorizontal tekizliklerde gurlan egme momentleriň epýurlary görkezilen.

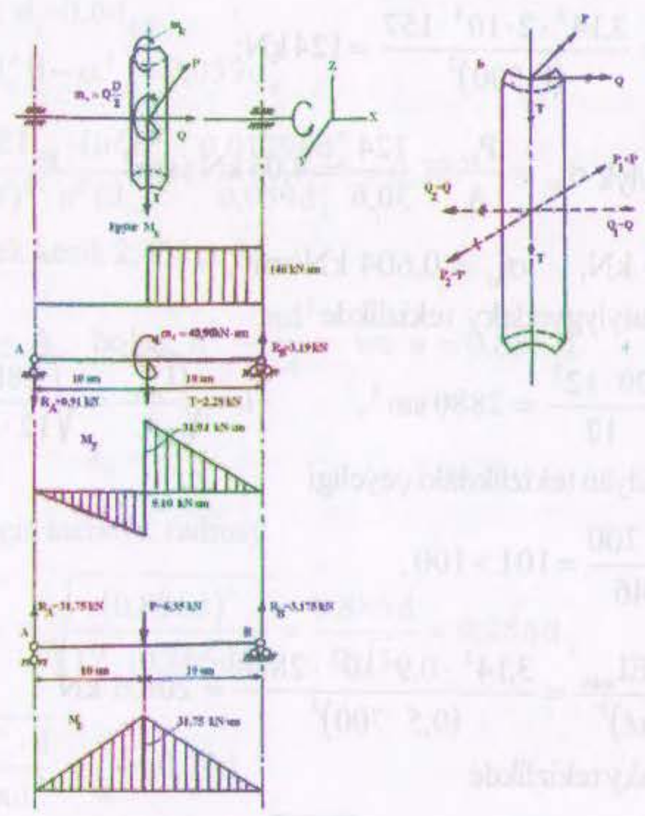
Jemleýji egme moment howply kesik üçin

$$M_{jeml}=\sqrt{M_w^2+M_g^2}=\sqrt{31{,}94^2+31{,}75^2}=37\ \text{kNsm}.$$

IV – berklik nazaryýeti boýunça

$$M_{IV}=\sqrt{M_{jeml}^2+0{,}75M_t^2}=\sqrt{37^2+0{,}75\cdot146^2}=133\,\text{kNsm},$$

onda $d=\sqrt[3]{\frac{32M_{IV}}{\pi[\sigma]}}=\sqrt[3]{\frac{32\cdot133}{3{,}14\cdot4}}=6{,}99\text{sm}\approx7\,\text{sm}.$



7.25-nji surat

VIII bap

Gysylan sterženleriň durnuklylygy

8.1. $P_{kr} = 124$ kN, $\sigma_{kr} = 4{,}05$ kN/sm^2.

22-nji belgili iki tawra üçin

$I_{min} = 157$ sm^4, $A = 30{,}6$ sm^2, $i_{min} = 2{,}27$ sm

sterženiň getirilen çeýeligi $\lambda = \dfrac{\mu\ell}{i_{min}} = \dfrac{1\cdot 500}{2{,}27} = 220 > \lambda_ç = 100$.

Şonuň üçin hem Eýleriň formulasyny ulanyp bolýar.

$$P_{kr} = \frac{\pi^2 EI_{min}}{(\mu\ell)^2} = \frac{3{,}14^2\cdot 2\cdot 10^4\cdot 157}{(1\cdot 500)^2} = 124\,\text{kN};$$

Kritiki dartgynlylyk $\sigma_{kr} = \dfrac{P_{kr}}{A} = \dfrac{124}{30{,}6} = 4{,}05\,\text{kN/sm}^2$.

8.2. $P_{kr} = 145$ kN, $\sigma_{kr} = 0{,}604$ kN/sm^2.

Iň kiçi gatylygyndaky tekizlikde

$$I_{min} = \frac{20\cdot 12^3}{12} = 2880\,\text{sm}^4, \qquad i = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{2880}{12\cdot 20}} = 3{,}46\ \text{sm}$$

Sterženiň seredilýän tekizlikdäki çeýeligi

$$\lambda = \frac{\mu\ell}{i_{min}} = \frac{0{,}5\cdot 700}{3{,}46} = 101 > 100.$$

Onda $P_{kr} = \dfrac{\pi^2 EI_{min}}{(\mu\ell)^2} = \dfrac{3{,}14^2\cdot 0{,}9\cdot 10^3\cdot 2880}{(0{,}5\cdot 700)^2} = 208{,}6$ kN

Iň uly gatylykdaky tekizlikde

$$I = \frac{20^3\cdot 12}{12} = 8000\,\text{sm}^4, \qquad i = \sqrt{\frac{8000}{240}} = 5{,}7\ \text{sm},$$

$$P_{kr} = \frac{3{,}14^2\cdot 0{,}9\cdot 10^3\cdot 8000}{(1\cdot 700)^2} = 145\ \text{kN}$$

Kabul edýäris $P_{kr} = 145$ kN;

Kritiki dartgynlylyk

$$\sigma_{kr} = \frac{P_{kr}}{A} = \frac{145}{240} = 0{,}604\ \text{kN/sm}^2.$$

8.3. $P_{teg} : P_{tur} = 0{,}22$

$n_\sigma = \dfrac{\sigma_{ak}}{\sigma_m + \sigma_a} = \dfrac{30}{5} = 6$, bu ýerde $\alpha = \dfrac{d_i}{d_d} = 0{,}8$

bu ýerden $d_i = 0{,}6 d_d$,

$I_{tur} = 0{,}1 d_d^4 \left(1 - \alpha^4\right) = 0{,}059 d_d^4$

$$\frac{P_{teg}}{P_{tur}} = \frac{\pi^2 EI_{teg}\cdot(\mu\ell)^2}{(\mu\ell)^2\cdot\pi^2 EI_{tur}} = \frac{0{,}01296 d_d^4}{0{,}059 d_d^4} = 0{,}22.$$

8.4. Tegelek kesik 2,4% çeýe.

Eger $A_\Diamond = A_o$ bolsa, $a^2 = \dfrac{\pi d^2}{4}$ we $a = 0{,}886\,d$,

$I_\Diamond = \dfrac{a^4}{12}$ $\qquad I_o = \dfrac{\pi d^4}{32}$

Onda kesigiň inersiýa radiusy

$$i_\Diamond = \sqrt{\frac{I_\Diamond}{A_\Diamond}} = \sqrt{\frac{(0{,}886d)^4}{12\cdot(0{,}866d)^2}} = \frac{0{,}886\,d}{2\sqrt{3}} = 0{,}256\,d,$$

$$i_o = \sqrt{\frac{\pi d^4\cdot 4}{64\pi d^2}} = \frac{d}{4} = 0{,}25d$$

Çeýeligiň gatnaşygyny tapýarys

$$\frac{\lambda_o}{\lambda_\Diamond}=\frac{i_\Diamond}{i_o}=\frac{0{,}256d}{0{,}25d}=1{,}024$$

8.5. $[P_d]=178{,}5$ kN.

Iki tawranyň berlen belgisi boýunça tablisadan alarys:

$I_{min}=260\ sm^4,\qquad i_{min}=2{,}63\ sm,\qquad A=37{,}5\ sm^2.$

Sütüniň çeýeligi $\lambda_1=\dfrac{\mu\ell}{i_{min}}=\dfrac{1\cdot 320}{2{,}63}=122.$

Polat 3 üçin Eýleriň formulasyny ulanmagyň aşaky çägini tapýarys.

$$\lambda_2=\sqrt{\frac{\pi^2E}{\sigma_{p\cdot s}}}=\sqrt{\frac{3{,}14^2\cdot 2\cdot 10^4}{20}}=99{,}3$$

$\lambda_1>\lambda_2$, şonuň üçin hem Eýleriň formulasy boýunça kritiki güýji hasaplamaga rugsat edilýär.

$$P_{kr}=\frac{\pi^2E\,I_{min}}{(\mu\ell)^2}=\frac{3{,}14^2\cdot 2\cdot 10^4\cdot 260}{(1\cdot 320)^2}=500\ \text{kN}.$$

Rugsat edilýän ýük $[P_d]=\dfrac{P_{kr}}{n_d}=\dfrac{500}{2{,}8}=178{,}5$ kN.

8.6. $d_2=20\,sm,\qquad d_1=17$ sm.

Ilki Eýleriň formulasyny ulanyp, soň barlap görýäris.

$$P_{kr}=[P_d]\,n_d=\frac{\pi^2E\,\pi d_2^4\left(1-\alpha^4\right)}{(\mu\ell)^2\cdot 64};$$

bu ýerden $d_2=\sqrt[4]{\dfrac{64[P_d]n_d\cdot\mu^2\ell^2}{\pi^3E\left(1-\alpha^4\right)}}=19{,}3$ sm kabul edýäris.

$d_2=20$ sm, $\quad d_1=0{,}85\cdot d_2=17\,sm.$

Barlagy: $\lambda=\dfrac{\mu\ell}{i},\quad i=\dfrac{d_2}{4}\sqrt{1+\alpha^2}=7{,}57$ sm, onda

$$\lambda=\frac{2\cdot 320}{7{,}57}=97{,}5.$$

Sütüniň materialyna Eýleriň formulasyny peýdalanmagyň aşaky çägi

$$\lambda=\sqrt{\frac{\pi^2E}{\sigma_{p\cdot s}}}=\sqrt{\frac{3{,}14\cdot 2\cdot 10^4}{17{,}2}}=81{,}2.$$

Saýlanan sütüniň çeýeligi bu çäkden ýokary, şonuň üçin hem Eýleriň formulasy dogry ulanylan.

8.7. $[P_d]=144$ kN.

Tegelegiň inersiýa radiusy

$$i=\frac{d}{4}=\frac{20}{4}=5\,sm,\quad \text{onda}\quad \lambda=\frac{\mu\ell}{i}=\frac{1\cdot 270}{5}=54.$$

Eýleriň formulasyny ulanmagyň aşaky çägi

$$\lambda=\sqrt{\frac{\pi^2E}{\sigma_{p\cdot s}}}=\sqrt{\frac{3{,}14^2\cdot 1{,}1\cdot 10^3}{2{,}1}}=71{,}8.$$

Eýleriň formulasyny ulanyp bolmaýar.

Boý egilmäniň koeffisiýentiniň kömegi bilen hasaplaýarys. Tablisadan $\lambda=54$ çeýelikdäki diregiň koeffisiýentiniň interpolýasiýany ulanyp tapýarys.

$\lambda=50\ \Rightarrow\ \varphi=0{,}8,$

$\lambda=60\ \Rightarrow\ \varphi=0{,}71,$

$\Delta\lambda=10\qquad\Delta\varphi=0{,}09,$

$$\lambda=54\ \Rightarrow\ \varphi=0{,}8-\frac{0{,}8-0{,}71}{10}(54-50)=0{,}764.$$

Durnuklylyga rugsat edilýän dartgynlylyk

$[\sigma_d]=\varphi[\sigma]=0{,}764\cdot 0{,}6=0{,}458\ \text{kN}/\text{sm}^2.$

Direge rugsat edilýän güýç $[P_d] = A[\sigma_d] = \frac{3{,}14 \cdot 20^2}{4} \cdot 0{,}458 = 144$ kN.

8.8. $d_1 = 5{,}2$ sm.

Eýleriň formulasyny ulanyp, nurbatyň içki diametrini kesgitleýäris.

$$d_1 = \sqrt[4]{\frac{64 \cdot P[n_d](\mu\ell)^2}{\pi^3 E}} = \sqrt[4]{\frac{64 \cdot 50 \cdot 4 \cdot (2 \cdot 90)^2}{3{,}14^3 \cdot 2{,}1 \cdot 10^4}} = 5{,}04 \text{ sm},$$

Bu ýerde $\mu = 2$ -nurbat bir tarapy gaty berkidilen direg görnüşinde seredilen.

Kabul edýäris: d_1=5,2sm, bu bolsa daşky diametri d=6 sm we ädimi t=0,8 mm (9484-60 DÖST boýunça) trapeseidal hyra gabat gelýär.

Ýokarky hasaby barlaýarys.

$$i = \frac{d_1}{4} = 1{,}3 \text{ sm}, \quad \text{onda} \quad \lambda = \frac{\mu\ell}{i} = \frac{2 \cdot 90}{1{,}3} = 138 > \lambda_ç = 90 \text{ (polat 30)}.$$

Şonuň üçin hem hasap Eýleriň formulasynyň ulanylýan çäginde geçirilen.

8.9. $P = 81$ kN, $[\sigma]_d = 0{,}25$ kN/sm^2, $\varphi = 0{,}25$.

Kwadrat kesik üçin $i = \frac{a}{2\sqrt{3}} = \frac{18}{2\sqrt{3}} = 5{,}2$ sm, onda

$\lambda = \frac{\mu\ell}{i} = \frac{1 \cdot 600}{5{,}2} = 115 > 100$ we kritiki güýji Eýleriň formulasy boýunça kesgitleýäris:

$$P_{kr} = \frac{\pi^2 EI}{(\mu\ell)^2} = \frac{3{,}14^2 \cdot 10^3 \cdot 18^4}{12 \cdot 600^2} = 243 \text{ kN}.$$

Kritiki dartgynlylyk $\sigma_{kr} = \frac{P_{kr}}{A} = \frac{243}{18 \cdot 18} = 0{,}75$ kN/sm^2.

Onda $[\sigma]_d = \frac{\sigma_{kr}}{n_d} = \frac{0{,}75}{3} = 0{,}25$ kN/sm^2,

$[P]_d = \frac{P_{kr}}{n_d} = \frac{243}{3} = 81$ kN.

Rugsat edilýän dartgynlylygy azaldýan koeffisiýent

$\varphi = \frac{[\sigma]_d}{[\sigma]} = \frac{0{,}25}{1} = 0{,}25$.

8.10. $d = 19.75$ sm.

Ulgamyň deňagramlylyk şertinden $N = 238$kN – söýegdäki boý güýji.

Inersiýa radiusy $i = \frac{d}{4}$.

Meseläni çemeleşme ýoly bilen işleýäris.

1-nji çemeleşme $\varphi_1 = 0{,}5$,

$[\sigma]_d = 0{,}5 \cdot 1{,}1 = 0{,}55$kN/sm^2.

Kesigiň meýdany $A = \frac{N}{[\sigma]_d} = \frac{238}{0{,}55} = 432{,}7\,\text{sm}^2$.

Bu ýerden $d = \sqrt{\frac{4A}{\pi}} = 23.5\text{sm} \rightarrow i = \frac{d}{4} = 5{,}87$ sm,

$\lambda = \frac{\mu l}{i} = \frac{1 \cdot 291{,}5}{5{,}87} \cong 50 \Rightarrow$ tablisadan $\varphi_1' = 0{,}8$,

$[\sigma]_d = 0{,}8 \cdot 1{,}1 = 0{,}88 > 0{,}55\text{kN/sm}^2$ – kesigi kiçeltmeli.

2-nji çemeleşme $\varphi_2 = \frac{\varphi_1 + \varphi_1'}{2} = \frac{0{,}5 + 0{,}8}{2} = 0{,}65$;

$[\sigma]_d = 0{,}65 \cdot 1{,}1 = 0{,}715\text{kN/sm}^2$.

Hasaplardan alarys: $A = 332{,}86$ sm^2; $d = 20{,}6$sm;

$i = 5{,}15$sm; $\lambda = 56.6$

Interpolýasiýany ulanyp alarys.

$\lambda = 50 \to \varphi = 0{,}8;\quad \lambda = 60 \to 0{,}71,$

onda $\varphi_2' = 0{,}8 - \dfrac{0{,}09}{10} \cdot 6{,}6 = 0{,}7406,$

$[\sigma]_d = 1{,}1 \cdot 0{,}7406 = 0{,}815 > 0{,}715 \text{kN/sm}^2.$

Kesigiň ölçegi ýene-de uly

3-nji çemeleşme $\varphi_3 = \dfrac{\varphi_2 + \varphi_2'}{2} = \dfrac{0{,}65 + 0{,}7406}{2} = 0{,}6953,$

$[\sigma]_d = 0{,}6953 \cdot 1{,}1 = 0{,}765$

$A = 311{,}11 \text{ sm}^2;\ d = 19{,}93 \text{ sm};\ i = 4{,}98 \text{ sm};\ \lambda = 58{,}5$

onda $\varphi_3' = 0{,}8 - \dfrac{0{,}09}{10} \cdot 8{,}5 = 0{,}7235$

$[\sigma]_d = 1.1 \cdot 0{,}7235 = 0{,}796 > 0{,}765 \text{kN/sm}^2.$

4-nji çemeleşme $\varphi_4 = \dfrac{\varphi_3 + \varphi_3'}{2} = 0{,}71,$

$[\sigma]_d = 0{,}71 \cdot 1{,}1 = 0{,}78 \text{kN/sm}^2,$

$A = 305 \text{ sm}^2;\ d = 19{,}74 \text{ sm};\ i = 4{,}93 \text{ sm};\ \lambda = 59.$

$\varphi_4' = 0{,}8 - \dfrac{0{,}09}{10} \cdot 9 = 0{,}719,$

$[\sigma]_d = 1.1 \cdot 0{,}719 = 0{,}79 \approx 0{,}78 \text{ kN/sm}^2$

Diýmek, $d = 19{,}75\text{sm}$ kabul edýäris.

8.11. $[P]_d = 689\text{kN};\ a = 12{,}4 \text{ sm}.$

Tablisadan alarys: $I_y = 2330 \text{ sm}^4;\ I_z = 187 \text{ sm}^4;$

$A = 28{,}8 \text{ sm}^2;\ y_o = 2{,}46 \text{ sm}.$

Iň kiçi inersiýa radiusy

$i_{min} = i_{y_ç} = \sqrt{\dfrac{I_{y_ç}}{A}} = \sqrt{\dfrac{2330}{2 \cdot 28.8}}, = 8{,}99 \text{ sm}.$

Sütüniň çeýeligi $\lambda_{max} = \dfrac{\mu\ell}{i_{min}} = \dfrac{1 \cdot 500}{8{,}99} = 55{,}7$

Interpolýasiýany ulanyp, tablisadan tapýarys $\varphi = 0{,}749$

Rugsat edilýän ýük $[P]_d = A\varphi[\sigma] = 28{,}8 \cdot 0{,}749 \cdot 16 = 689\text{kN}$

Şwelleriň aralygyny $I_{y_ç} = I_{z_ç}$ şertden tapýarys.

$2 \cdot 2330 = 2\left(187 + b^2 \cdot 28{,}8\right);\quad b = 8{,}64 \text{ sm}.$

onda $a = 2b - 2y_ç = 2 \cdot 8{,}46 - 2 \cdot 2{,}46 = 12{,}36 \approx 12{,}4 \text{ sm}.$

8.12. a) 23,1m; b)23,7m; ç)20,2m.

Sterženiň kritiki uzynlygyny kesgitlemek üçin Ýasinskiniň formulasyny peýdalanýarys:

$(q\ell)_{kr} = \dfrac{\pi^2 EI_{min}}{(\mu\ell)^2};\quad$ bu ýerde $\mu = 1{,}12;\quad q = \gamma A$

1)

$\ell_{kr}^3 = \dfrac{\pi^2 EI_{min}}{\gamma A \mu^2} = \dfrac{\pi^2 E \pi d^4 \cdot 4}{64 \cdot \gamma \pi d^2 \cdot \mu^2} = \dfrac{3.14^2 \cdot 2 \cdot 10^4 \cdot 10^2}{16 \cdot 80 \cdot 10^{-6} \cdot 1.12^2} = 0{,}0123 \cdot 10^{12}$

$\ell_{kr} = 10^2 \sqrt[3]{12300} = 23{,}1 \cdot 10^2 \text{sm} = 23{,}1\text{m};$

2) $\ell_{kr}^3 = \dfrac{3{,}14^2 \cdot 0{,}7 \cdot 10^4 \cdot 10^2}{16 \cdot 26 \cdot 10^{-6} \cdot 1{,}12^2} = 0{,}0132 \cdot 10^{12} \Rightarrow \ell_{kr} = 23{,}7\text{m};$

3) $\ell_{kr}^3 = \dfrac{3{,}14^2 \cdot 10^3 \cdot 10^2}{16 \cdot 6 \cdot 10^{-6} \cdot 1{,}12^2} = 0{,}00822 \cdot 10^{12} \Rightarrow \ell_{kr} = 20{,}2\text{m}.$

8.13. $140 \times 140 \times 9$ burçluk, $A = 24{,}7 \text{ sm}^2;\ i_x = 4{,}34 \text{ sm};$

$n_d = 1{,}95$

Fermanyň gaýtargylary $R_A = 231$ kN; $R_B = 269$ kN;

$$N_{AC} = \frac{R_A}{\sin\beta} = 352 \text{ kN}.$$

$\sin\beta = 0{,}657$; sterženiň uzynlygy $\ell = \frac{4}{\cos\beta} = 5{,}31\text{m}$; $A = \frac{N}{\varphi[\sigma]}$;

$\cos\beta = 0{,}753$.

Boý egilmäniň koeffisiýenti boýunça hasap geçiryäris.

1-nji çemeleşme $\varphi_1 = 0{,}6$; onda $A = 36{,}7\text{sm}^2$; $A_1 = \frac{A}{2} \cong 18{,}4\text{sm}^2$.

DÖST boýunça $100\times100\times10$ burçluk $A_1 = 19{,}2\ \text{sm}^2$;

$i_{min} = 3{,}05$ sm; $\lambda = 174$.

$$\varphi_1' = 0{,}26 - \frac{0{,}26 - 0{,}23}{10}\cdot 4 = 0{,}248; \quad \varphi_1 = 0{,}6 - \text{dan köp}$$

tapawutlanýar.

2-nji çemeleşme $\varphi_2 = \frac{\varphi_1 + \varphi_1'}{2} = 0{,}424$

$$A = 51{,}9\ \text{sm}^2; \quad A_1 \cong 26\ \text{sm}^2$$

DÖST boýunça $125\times125\times12$, $A_1 = 28.9\ \text{sm}^2$; $i_{min} = 3{,}82$ sm;

$$\lambda = \frac{531}{3{,}82} = 139; \qquad \varphi_2' = 0{,}36.$$

3-nji çemeleşme $\varphi_3 = \frac{\varphi_2 + \varphi_2'}{2} = 0{,}392$; $A = 56{,}2\ \text{sm}^2$;

$A_1 = 28{,}1\ \text{sm}^2$.

$140\times140\times9$ burçlugy kabul edýäris.

$$A_1 = 24{,}7\ \text{sm}^2; \quad i_x = 4{,}34\ \text{sm}.$$

onda $\sigma = \frac{N}{A} = \frac{352}{2\cdot24.7} = 7.12\text{kN/sm}^2$; $\lambda = \frac{531}{4{,}34} = 122$;

$\varphi_{tabl} = 0{,}44$,

$$[\sigma]_d = \varphi_{tabl}\cdot[\sigma] = 0.44\cdot16 = 7.04\text{kN/sm}^2.$$

Aşa ýüklenme 1%-den hem köp däl.

Kabul edilen kesigiň ölçegleri boýunça durnuklylyga ätiýaçlyk koeffiýsiýentini kesgitleýäris.

$n_d = \frac{\sigma_{kr}}{\sigma}$ $\lambda > \lambda_c$; Eýleriň formulasyny ulanýarys

$$\sigma_k = \frac{\pi^2 E}{\lambda^2} = \frac{3{,}14^2\cdot2{,}1\cdot10^4}{122^2} = 13{,}9\text{kN/sm}^2;$$

$$n_d = \frac{13.9}{7{,}12} = 1{,}95.$$

IX bap

Dinamiki we dowamly ýüklenmeler.

9.1. 3,58 sm; 3,74sm.

Ýüki galdyrmagyň tizlenmesi $a = \frac{2h}{t^2} = \frac{2 \cdot 9}{3^2} = 2 m/s^2$.

Urganyň hususy agramyny hasaba almazdan berklik şerti

$$A[\sigma] = P\left(1 + \frac{a}{g}\right).$$

Bu ýerden $A = \frac{P}{[\sigma]}\left(1 + \frac{a}{g}\right) = \frac{50}{6}\left(1 + \frac{2}{9,81}\right) = 10,03 sm^2$,

onda $d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 \cdot 10,03}{3,14}} = 3,58 sm$

Urganyň hususy agramyny hasaba alarys:

$$[\sigma] = \frac{P}{A}\left(1 + \frac{a}{g}\right) + \gamma \ell \left(1 + \frac{a}{g}\right).$$

Bu ýerden

$$A = \frac{P\left(1 + \frac{a}{g}\right)}{[\sigma] - \gamma \ell \left(1 + \frac{a}{g}\right)} = \frac{50\left(1 + \frac{2}{9,81}\right)}{6 - 70 \cdot 10^{-6} \cdot 60 \cdot 10^2 \left(1 + \frac{2}{9,81}\right)} = 11 sm^2.$$

Onda $d = \sqrt{\frac{4 \cdot 11}{3,14}} = 3,74 sm.$

9.2. $[n] = 1090$ aýl/min, $\Delta \ell = 0,251$ mm.

0-0 okdan x uzaklykda uzynlygy dx elementi bölüp alyp, onuň inersiýa güýjüni kesgitleýäris:

$$dP_d = \frac{\gamma A dx}{g} \omega^2 x$$

mn kesigiň süýnme dartgynlylygy

$$\sigma = \frac{P_d}{A} = \frac{1}{A} \int_x^{\ell/2} dP_d = \int_x^{\ell/2} \frac{\gamma \omega^2 x dx}{g} = \frac{\gamma \omega^2}{2g}\left(\frac{\ell^2}{4} - x^2\right).$$

Iň uly süýnme dartgynlylyk $x = 0$ deň bolanda bolýar:

$$\sigma_{max} = \frac{\gamma \omega^2 \ell^2}{8g} \le [\sigma] \Rightarrow [\omega] = \sqrt{\frac{8g[\sigma]}{\gamma \ell^2}} = \frac{\pi [n]}{30} \Rightarrow [n] = 1090 ayl/min.$$

Uzynlygy dx bolan sterženiň uzalmasy

$$d\Delta \ell = \frac{\sigma dx}{E} = \frac{\gamma \omega^2}{2gE}\left(\frac{\ell^2}{4} - x^2\right) dx.$$

Sterženiň uzalmasy

$$\Delta \ell = 2 \int_0^{\ell/2} \frac{\sigma dx}{E} = 2 \int_0^{\ell/2} \frac{\gamma \omega^2}{2gE}\left(\frac{\ell^2}{4} - x^2\right) dx =$$

$$= \frac{\gamma \omega^2 \ell^2}{12gE} = \frac{\gamma \pi^2 n^2 \ell^2}{12 \cdot 30^2 \cdot gE} = 0,0251 sm = 0,251 mm.$$

9.3. $d_A = 3,1 sm$, $d_B = 3,93 sm$.

Inersiýa güýji goşulanda garşylyk agramyň boltlara täsiri

$$P_d = P\left(1 + \frac{a}{g}\right) = 42\left(1 + \frac{1,5}{9,81}\right) = 48,42 kN$$

A boltlaryň kese kesiginiň meýdany $A_a = \frac{P_d}{2[\sigma]} = \frac{48,42}{2 \cdot 3,2} = 7,56 sm^2$ (iki bolt).

Onda onuň diametri $d_A = \sqrt{\frac{4A_A}{\pi}} = \sqrt{\frac{4 \cdot 7,56}{3,14}} = 3,1 sm.$

B boltuň kese kesiginiň meýdany

$$A_B = \frac{P_d}{[\tau]} = \frac{48{,}42}{2 \cdot 2} = 12{,}10\,\text{sm}^2 \text{ (iki kesme).}$$

$$d_B = \sqrt{\frac{4 \cdot 12{,}10}{3{,}14}} = 3{,}93\,\text{sm}.$$

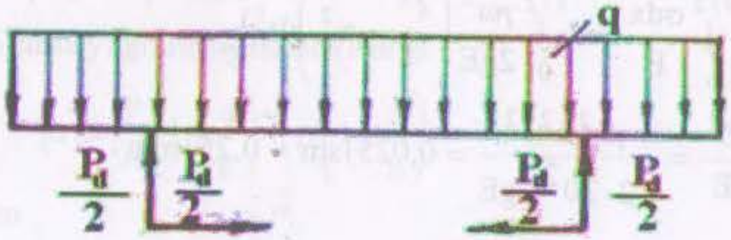
9.4. $\sigma_{max} = 0{,}149\ \text{kN/sm}^2$, $\sigma_{urg} = 2{,}56\ \text{kN/sm}^2$.

Balkanyň agramy $G = \gamma A \ell = 24 \cdot 10^{-6} \cdot 20^2 \cdot 600 = 5{,}76\,\text{kN}$,

Inersiýa güýjünden balkanyň dinamiki ýüklenmesi

$$P_d = \left(1 + \frac{a}{g}\right) G = 1{,}6 \cdot 5{,}76 = 9{,}2\ \text{kN}$$

Balkanyň 1 metrine düşýän ýüklenme $q = \frac{P_d}{\ell} = \frac{9{,}2}{6} = 1{,}53\ \text{kN/m}$



9.4-nji surat

Balkanyň egme momentlerini kesgitleýäris.

Urganyň berkidilen kesiginde $M_1 = 0{,}77\,\text{kN} \cdot \text{m}$

Balkanyň ortasyndaky kesikde $M_2 = -1{,}83\,\text{kN} \cdot \text{m}$

Balkanyň maksimal dartgynlylygy

$$|\sigma_{max}| = \sigma_\ell + \sigma_g = \frac{M_2}{W} + \frac{P_d}{2A} = \frac{1{,}83 \cdot 10^2}{1333} + \frac{9{,}2}{2 \cdot 400} = 0{,}149\ \text{kN/sm}^2.$$

Bu ýerde $W = \frac{b^3}{6} = 1333\,\text{sm}^3$, $A = b^2 = 400\,\text{sm}^2$.

Urgandaky dartgynlylyk $\sigma_{urg} = \frac{\sqrt{2}P_d}{4A} = \frac{\sqrt{2} \cdot 9{,}2}{4 \cdot 1{,}27} = 2{,}56\,\text{kN/sm}^2$.

9.5. $\tau = 10{,}9\,\text{kN/sm}^2$.

Deň haýallanýan hereketde mahowigiň burç tizlenmesi

$$\varepsilon = \omega^2 / 2\varphi = 75{,}4^2 / 2 \cdot 2 \cdot 20 \cdot 3{,}14 = 22{,}6\,\text{rad/s}^2.$$

Towlandyryjy momenti

$$M_t = mi\varepsilon = 200 \cdot 0{,}6 \cdot 22{,}6 = 2716\ \text{Nm} = 2{,}716\ \text{kNm}.$$

Galtaşma dartgynlylyk $\tau = \frac{M_k}{W_p} = \frac{2{,}716 \cdot 10^2}{25} = 10{,}9\,\text{kN/sm}^2$,

bu ýerde $W_P = 0{,}2 \cdot 5^3 = 25\,\text{sm}^3$.

9.6. $\sigma_{max} = 21{,}78\,\text{kN/sm}^2$.

Kriwoşipiň burç tizligi $\omega = \frac{\pi n}{30} = \frac{3{,}14 \cdot 2800}{30} = 293\,\text{rad/s}$,

Normal tizlenme $a_n = \omega^2 r = 293^2 \cdot 0{,}075 = 6441\,\text{m/s}^2$.

Şatunyň kese kesiginiň meýdany $A = 2 \cdot 30 \cdot 4 + 32 \cdot 4 = 368\,\text{mm}^2$,

Inersion ýüküň depgini

$$q_{in\,max} = \gamma A a_n \cdot \frac{1}{g} = 78 \cdot 10^{-6} \cdot 3{,}68 \cdot 6441 \cdot 10^2 \cdot \frac{1}{981} =$$

$$= 0{,}188\,\text{kN/sm} = 1{,}91 \cdot 10^{-2}\ \text{kN/m}$$

Şatunyň iň uly egme momenti

$$M_{max} = \frac{q_{max} \ell^2}{15{,}6} = \frac{1{,}91 \cdot 10^{-2} \cdot 0{,}25^2}{15{,}6} = 0{,}75\,\text{kN} \cdot \text{m}.$$

Kesigiň inersiýa momenti

$$I_x = \frac{30 \cdot 40^3}{12} - \frac{26 \cdot 32^3}{12} = 8{,}9\,\text{sm}^4,$$

Kesigiň garşylyk momenti

$$W_x = \frac{I_x}{b} \cdot 2 = \frac{8,9}{4,0} \cdot 2 = 4,45\,sm^3.$$

Iň uly dartgynlylyk

$$\sigma_{max} = \frac{M_{max}}{W_x} + \frac{P_{90^o}}{A} = \frac{75}{4,45} + \frac{0,65 \cdot 30}{3,68} = 21,78\,kN/sm^2.$$

9.7. $n = 106$ ayl/min, $f_d = 2,4$ sm.

Steržen BÇ aýlananda, merkezden daşlaşýan inersiýa güýjüň P_d täsirinden egilýär.

$P_d = \frac{P}{g}\omega^2 r$, bu ýerde $r = a + f_d$, $f_d = \frac{P_d \ell^3}{3EI}$ – BÇ sterženiň P_d güýçden iň uly progibi,

bu ýerde $I = \frac{bh^3}{12}$.

Onda $P_d = \frac{P}{g}\omega^2 r = \frac{P}{g}\left(\frac{\pi n}{30}\right)^2 (a + f_d) = \frac{\pi^2 n^2}{30^2 g} P\left(a + \frac{P_d \ell^3}{3EI}\right)$.

Bu ýerden $P_d = \frac{Pa}{\frac{30^2 g}{\pi^2 n^2} - \frac{P\ell^3}{3EI}}$ (a)

BC sterženiň berklik şerti $\sigma_{max} = \frac{M_{max}}{W} = \frac{P_d \ell}{W} \le [\sigma]$, $W = \frac{bh^2}{6}$.

Onda P_d güýjüň aňryçäk bahasy $P_d = \frac{[\sigma]W}{\ell}$ (b)

(a) we (b) aňlatmalary deňeşdirip alarys:

$$n = \frac{30}{\pi}\sqrt{\frac{gbh^2}{6P\ell\left(\frac{a}{[\sigma]} + \frac{2\ell^2}{3Eh}\right)}} = 106 \text{ayl/min}$$

BÇ sterženiň iň uly progibi

$$f_d = \frac{P_d \ell^3}{3EI} = \frac{[\sigma]W\ell^2}{3EI} = \frac{2[\sigma]\ell^2}{3Eh} = \frac{2 \cdot 18 \cdot 40^2}{3 \cdot 2 \cdot 10^4 \cdot 0,4} = 2,4\,sm.$$

9.8. $[\omega] = 32,4 rad/s.$

Deňölçegli aýlawda merkezden daşlaşýan inersiýa güýjüň depgini aşakdaky ýaly bolýar.

DE bölekde $q_{in} = m\omega^2\ell = \frac{\gamma A}{g} \cdot \omega^2 \ell$

ÇD bölekde noldan (Ç nokatda), q_{in} (D nokatda) çenli çyzyk kanuny esasynda ýaýraýar.

Direglerdäki gaýtargylar $R_A = \frac{q_{in}\ell}{2}$, $R_B = q_{in} \cdot \ell$.

Statiki kesgitlenýän tekiz çarçuwanyň egme momentiniň epýury suratda görkezilen.

Epýurdan $M_{max} = q_{in} \cdot \ell^2$

AB bölegiň berklik şertinden iň uly rugsat edilýän burç tizligini kesgitleýäris,

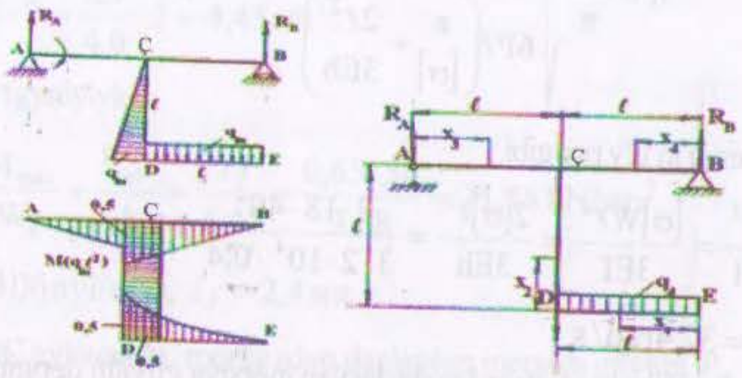
$$\sigma = \frac{M_{max}}{W} \le [\sigma] \Rightarrow [M_{max}] = [\sigma]W = [\sigma] \cdot \frac{\pi d^3}{32} =$$

$$= 10 \cdot \frac{3,14 \cdot 1,8^3}{32} = 5,72\,kN \cdot sm$$

Başga tarapdan

$$M_{max} = \frac{\gamma A}{g}\omega^2 \ell^3 = \frac{78 \cdot 10^{-6} \cdot 3,14 \cdot 1,8^2}{981 \cdot 4} \cdot 30^3 \cdot \omega^2 = 0,545 \cdot 10^{-2}\omega^2.$$

Onda $0{,}545\cdot10^{-2}[\omega]^2=5{,}72$, Bu ýerden $[\omega]=32{,}4\text{rad/s}$.



9.8-nji surat

9.9. $\sigma_{max}=10\,\text{kN/sm}^2$.

Oka täsir edýän güýç

$$P_1=P+\frac{mv^2}{r}=P+\frac{P}{rg}\cdot 2gH=P\left(1+\frac{2H}{r}\right)=P\left(1+\frac{2\cdot 2r}{r}\right)=$$

$$=0{,}25(1+4)=1{,}25\text{ kN}$$

Maýatnigiň okunyň iň uly egme momenti

$$M_{max}=\frac{P\ell}{4}=\frac{1{,}25\cdot 25}{4}=7{,}8\text{kN}\cdot\text{sm},$$

onda $\sigma_{max}=\dfrac{32\cdot M_{max}}{\pi d^3}=\dfrac{32\cdot 7{,}8}{3{,}14\cdot 2^3}=10\text{kN/sm}^2$.

9.10. $\sigma_{max}=10{,}2\text{kN/sm}^2$, $\Delta\ell_d=0{,}765$ mm.

Birdenkä goýlan güýç steržende $k_d=2$ deň bolan dinamiki güýji döredýär, ýagny $P_d=2P$.

Iň uly dartgynlylyk $\sigma_{max}=\dfrac{P_d}{A}=\dfrac{8P}{\pi d^2}=\dfrac{8\cdot 25}{3{,}14\cdot 2{,}5^2}=10{,}2\text{kN/sm}^2$,

Dinamiki durkuny üýtgetme $\Delta\ell_d=k_d\cdot\Delta\ell_{st}=2\cdot\dfrac{P\ell}{EA}=0{,}0765$ sm.

9.11. $\Delta_d=4{,}83$ mm.

Urguda dinamiki koeffisiýent $k_d=1+\sqrt{1+\dfrac{2h}{\Delta_{st}}}$.

Bu ýerde $h=1\text{mm}$, $\Delta_{st}=2\text{mm}$ we $k_d=1+\sqrt{1+\dfrac{2\cdot 1}{2}}=2{,}414$,

$\Delta_d=k_d\cdot\Delta_{st}=2{,}41\cdot 2=4{,}83$ mm.

9.12. d=2,53sm, d'=2,26sm.

1) Takyk çözüw $\sigma_d=\sigma_{st}\left(1+\sqrt{1+\dfrac{2h}{\Delta_{st}}}\right)\le[\sigma]$

$$\left(\frac{[\sigma]}{\sigma_{st}}-1\right)^2=\left(\sqrt{1+\frac{2h}{\Delta_{st}}}\right)^2\Rightarrow\left(\frac{[\sigma]}{\sigma_{st}}\right)^2-2\cdot\frac{[\sigma]}{\sigma_{st}}+1=1+\frac{2h}{\Delta_{st}}$$

$$\left(\frac{[\sigma]A}{P}\right)^2-2\frac{[\sigma]A}{P}=\frac{2h\cdot EA}{P\ell}\Rightarrow A=5\text{sm}^2\Rightarrow d=2{,}53\text{ sm};$$

2) Ýakynlaşdyrylan çözüw $\sigma_d=\sigma_{st}\sqrt{\dfrac{2h}{\Delta_{st}}}\le[\sigma]$

$$\left(\frac{[\sigma]}{\sigma_{st}}\right)^2=\frac{2h}{\Delta_{st}}\Rightarrow\left(\frac{[\sigma]A}{P}\right)^2=\frac{2hEA}{P\ell}\Rightarrow A=4\text{sm}^2\Rightarrow d'=2{,}26\text{ sm}.$$

9.13. $\sigma_d=15{,}43\,\text{kN/sm}^2$, $\sigma_d^i=16{,}7\,\text{kN/sm}^2$.

1) Urganyň agramyny hasaba almazdan, lebýodka birden togtadylan ýagdaýynda $k_d=1+\sqrt{\dfrac{v^2EA}{gP\ell}}$, onda

$$\sigma_d = \sigma_{st} \cdot k_d = \frac{P}{A}\left(1+\sqrt{\frac{v^2 EA}{gP\ell}}\right) = \frac{50}{10}\left(1+\sqrt{\frac{160^2 \cdot 2 \cdot 10^4 \cdot 10}{981 \cdot 50 \cdot 24000}}\right)$$

bu ýerden $\sigma_d = 15{,}43\ \text{kN/sm}^2$.

2) Urganyň agramy hasaba alnan ýagdaýynda

$k_d^i = 1+\sqrt{\frac{v^2 EA}{gP\ell(1+\beta)}}$, β – urganyň göterilen massasynyň $\frac{Q_{urg}}{3g} = \frac{\gamma A\ell}{3g}$

uryan jisimiň massasyna P/g bolan gatnaşygy $\beta = \frac{\gamma A\ell}{3P} = 0{,}125$.

Urganyň hususy agramyndan döreýän dartgynlylyk $\sigma_{st}^i = \gamma\ell$,

Lebýodka togtadylandaky dartgynlylyk $\sigma_d{}'' = \sigma_{st} \cdot k_d^i$.

Onda
$$\sigma_d^{/} = \sigma_{st}^{/} + \sigma_d^{//} = \gamma\ell + \frac{P}{A}\left(1+\sqrt{\frac{v^2 EA}{gP\ell(1+\beta)}}\right) =$$
$$= 1{,}87 + 14{,}83 = 16{,}7\ \text{kN/sm}^2.$$

9.14. $f_d = 0{,}355\text{sm}$, $\sigma_{max} = 5{,}87\ \text{kN/sm}^2$.

Güýç duýdansyz goýlanda dinamiki koeffisiýent $k_d = 2$, 14-nji belgili balka üçin $I_x = 572\text{sm}^4$, $W_x = 81{,}7\text{sm}^3$.

Statiki goýlan güýçden balkanyň iň uly progibi

$$f_{st} = \frac{P\ell^3}{3EI} = \frac{1{,}5 \cdot 160^3}{3 \cdot 2 \cdot 10^4 \cdot 572} = 0{,}1755\ \text{sm}.$$

Dinamiki progib $f_d = f_{st} \cdot k_d = 0{,}1775 \cdot 2 = 0{,}355$ sm.

Dinamiki dartgynlylyk $M_{max} = P\ell = 1{,}5 \cdot 1{,}6 = 2{,}4\ \text{kN} \cdot \text{m}$.

$$\sigma_d = \sigma_{st} \cdot k_d = \frac{M_{max}}{W} \cdot k_d = \frac{2{,}4 \cdot 10^2}{81{,}7} \cdot 2 = 5{,}87\ \text{kN/sm}^2.$$

9.15. $\tau_{max} = 9\text{kN/sm}^2$.

Walyň kesigindäki towlanma momenti energiýanyň balansyndan tapýarys. Birden togtadylanda $T = U$

$T = \frac{I_0\omega^2}{2}$ – hereketiň kinetiki energiýasy

$U = \frac{M_k^2\ell}{2GI_P}$ – durkuny üýtgetmäniň potensial energiýasy

$$\frac{I_0\omega^2}{2} = \frac{M_k^2\ell}{2GI_P} \Rightarrow M_k = \omega\sqrt{\frac{I \cdot GI_P}{\ell}};$$

$I_0 = \frac{QD^2}{8g}$ – diskiň massasynyň inersiýa momenti

Q – diskiň agramy.

Onda $\tau_{max} = \frac{M_k}{W_P} = \omega_0\sqrt{\frac{I_0 GI_P}{\ell w_P^2}} = \omega\sqrt{\frac{2I_0 G}{\ell A}}$.

Bu ýerde $\frac{I_P}{W_P^2} = \frac{\pi d^4}{32} \cdot \frac{16^2}{(\pi d^3)^2} = \frac{2 \cdot 4}{\pi d^2} = \frac{2}{A}$; $Q = \gamma\frac{\pi D^2}{4} \cdot t = 0{,}88\ \text{kN}$;

$$I_o = \frac{QD^2}{8g} = \frac{0{,}88 \cdot 60^2}{8 \cdot 981} = 0{,}403\ \text{kN} \cdot \text{sm} \cdot \text{s}^2;$$

$$\omega = \frac{\pi n}{30} = \frac{3{,}14 \cdot 150}{30} = 15{,}7\text{s}^{-1};$$

$$A = \frac{\pi d^2}{4} = \frac{3{,}14 \cdot 10^2}{4} = 78{,}5\text{sm}^2,$$

$$\tau_{max} = \omega \cdot \sqrt{\frac{2I_0 G}{\ell A}} = \omega \cdot \sqrt{\frac{2 \cdot 0{,}403 \cdot 8 \cdot 10^3}{250 \cdot 78{,}5}} = 9\ \text{kN/sm}^2.$$

9.16. $v = 117\text{sm/s}$.

Balkanyň statiki progibi, 5 kN güýçden

$$f_{st} = \frac{P_2}{P_1} \cdot f_d = \frac{5}{45} \cdot 2 = 0{,}222 \text{sm},$$

Onda $k_d = \frac{f_d}{f_{st}} = \frac{2}{0{,}222} = 9$; ýöne $k_d = 1 + \sqrt{1 + \frac{v^2}{g f_{st}}} = 9$.

Bu ýerden $v = \sqrt{\left[(9-1)^2 - 1\right] \cdot 981 \cdot 0{,}222} = 117 \text{sm/s}.$

9.17. $h = 4$ sm.

16-njy belgili iki tawra balka üçin

$I_x = 873 \text{ sm}^4$, $W_x = 109 \text{ sm}^3$.

Balkanyň statiki progibi $f_{st} = \frac{P\ell^3}{48EI} = \frac{2 \cdot 300^3}{48 \cdot 2 \cdot 10^4 \cdot 873} = 0{,}0644$ sm.

Balka ýüküň gaçýan ýerinde pružiniň çökmesi

$$\lambda_{st} = \frac{\lambda_{pr}}{2} = \frac{4PR^3 \cdot n}{2 \cdot Gr^4 \cdot 2} = \frac{4 \cdot 2 \cdot 5^3 \cdot 10}{2 \cdot 8 \cdot 10^3 \cdot 1^4 \cdot 2} = 0{,}3125 \text{ sm}.$$

Balkanyň berklik şertinden

$$\sigma_d = \sigma_{st} \cdot k_d \le [\sigma] \Rightarrow \frac{P\ell}{4w_x} \cdot k_d = [\sigma],$$

$$k_d = \frac{4w_x[\sigma]}{P\ell} \Rightarrow 1 + \sqrt{1 + \frac{2h}{f_{st}}} = \frac{4 \cdot 109 \cdot 16}{2 \cdot 300} \Rightarrow 10{,}6 = \sqrt{1 + \frac{2h}{0{,}0644}},$$

Bu ýerden $h = 3{,}586$ sm.

Pružiniň berklik şertinden $\tau_d = \tau_{st} \cdot k_d \le [\tau]$,

$$k_d \cdot \frac{2PR}{2 \cdot \pi r^3} = [\tau] \Rightarrow k_d \cdot \frac{2 \cdot 2 \cdot 5}{2 \cdot 3{,}14 \cdot 1^3} = 20 \Rightarrow k_d = 6{,}28,$$

$$1 + \sqrt{1 + \frac{2h}{0{,}3125}} = 6{,}28 \Rightarrow h = 4 \text{sm}.$$

9.18. $f_{max} = 9{,}25$sm, $\sigma_d = 37 \text{ kN/sm}^2$.

Balkanyň egrelen okunyň deňlemesi $y'' = \frac{P\ell}{EI_o}$.

Iki gezek integrirläp we hemişelikleri kesgitläp alarys:

$$y = \frac{P\ell}{EI_o}\left(\frac{x^2}{2} - \ell x + \frac{\ell^2}{2}\right), \quad f_{st} = \frac{P\ell^3}{2EI_o} = \frac{0{,}2 \cdot 100^3 \cdot 12}{2 \cdot 2 \cdot 10^4 \cdot 5 \cdot 2^3} = 1{,}5 \text{sm},$$

$$y = \frac{f_{st}}{\ell^2}(\ell - x)^2.$$

Balkanyň kinetiki energiýasy

$$T = \int_o^\ell \frac{P}{2g} V_0^2 \frac{(\ell - x)^4}{\ell^4} dx = \frac{P\ell}{2g} V_0^2 \int_o^\ell \frac{(\ell - x)^4}{\ell^5} dx = \frac{P\ell}{2g} V_0^2 \frac{1}{5};$$

Massanyň getirilen koeffisiýenti $k = 0{,}2$.

Balkanyň agramy $Q = \frac{1}{2} 5 \cdot 2x100 \cdot 78{,}5 \cdot 10^{-6} = 0{,}0393 \text{ kN}.$

Dinamiki progib

$$f_d = f_{st}\left[1 + \sqrt{\frac{2h}{f_{st}\left(1 + \frac{kQ}{P}\right)}}\right] =$$

$$1{,}5\left[1 + \sqrt{\frac{2 \cdot 20}{1{,}5\left(1 + \frac{0{,}2 \cdot 0{,}0393}{0{,}2}\right)}}\right] = 9{,}25 \text{ sm}.$$

$$\sigma_d = \frac{2y_{max} E f_d}{\ell^2} = \frac{2 \cdot 1 \cdot 2 \cdot 10^4 \cdot 9{,}25}{100^2} = 37 \text{kN/sm}^2.$$

9.19. 41% dartgynlylyk köpelýär.

1) $\lambda_d = \lambda_{st} \cdot k_d = \sqrt{2h\lambda_{st}}$, $k_d = \dfrac{\sqrt{2h\lambda_{st}}}{\lambda_{st}}$,

$$\sigma_d = \sigma_{st} \cdot k_d = \frac{P}{A} \cdot \frac{\sqrt{2h\lambda_{st}}}{\lambda_{st}} = \frac{P \cdot \sqrt{2h}}{A} \cdot \frac{\sqrt{\lambda_{st}}}{\lambda_{st}} = \frac{P\sqrt{2h}}{A\sqrt{\lambda_{st}}}.$$

2) Eger meýdany iki gezek azaltsaň

$$\sigma_d^{/} = \frac{2P\sqrt{2h}}{A\sqrt{\lambda_{st}^{'}}}$$

Onda $\dfrac{\sigma_d^{'}}{\sigma_d} = 2 \cdot \sqrt{\dfrac{\lambda_{st}}{\lambda_{st}^{/}}} = 2 \cdot \sqrt{\dfrac{P\ell \cdot EA}{EA \cdot 2P\ell}} = \dfrac{2}{\sqrt{2}} = 1{,}41$.

9.20. 1) $\omega_o = 219{,}4s^{-1}$, $t_o = 0{,}02863s$; 2) $\omega_o = 219{,}3s^{-1}$, $t_o = 0{,}02864s$.

1) Diregiň agramyny hasaba almazdan, yrgyldynyň ýygylygy

$$\Delta\ell_{st} = \frac{P\ell}{EA} = \frac{100 \cdot 80 \cdot 4}{2 \cdot 10^4 \cdot 3{,}14 \cdot 5^2} = 0{,}0204 \text{ sm}$$

$$\omega_o = \sqrt{\frac{g}{\Delta\ell_{st}}} = \sqrt{\frac{gEA}{P\ell}} = \sqrt{\frac{gE\pi d^2}{4P\ell}} =$$

$$= \sqrt{\frac{981 \cdot 2 \cdot 10^4 \cdot 3{,}14 \cdot 5^2}{4 \cdot 100 \cdot 80}} = 219{,}4s^{-1};$$

onda period $t_o = \dfrac{2\pi}{\omega_o} = \dfrac{3{,}14 \cdot 2}{219{,}4} = 0{,}02863\,s.$

2) Diregiň agramyny hasaba alýarys:

$$\Delta\ell_{st}^{'} = \Delta\ell_{st} + \frac{\gamma\ell^2}{2E} = 0{,}0204 + \frac{78 \cdot 10^{-6} \cdot 80^2}{2 \cdot 10^4} = 0{,}02;$$

onda $\omega_o = \sqrt{\dfrac{g}{\Delta\ell_{st}^{'}}} = \sqrt{\dfrac{981}{0{,}02}} = 219{,}3s^{-1}$,

$$t_o = \frac{2\pi}{\omega_o} = \frac{2 \cdot 3{,}14}{219{,}3} = 0{,}02864s.$$

9.21. $t_0 = 0{,}048$ s, $\omega_0 = 131$ s^{-1}.

9.22. 9.21 meseleden $\omega_o = 131s^{-1}$

Mejbury yrgyldynyň ýygylygy

$$\omega = \frac{\pi n}{30} = \frac{3{,}14 \cdot 1300}{30} = 136{,}2s^{-1}$$

Yrgyldynyň ösme koeffisiýenti

$$\beta = \frac{1}{\left(\dfrac{\omega}{\omega_o}\right)^2 - 1} = \frac{1}{\left(\dfrac{136{,}2}{131}\right)^2 - 1} = 12{,}35.$$

Dinamiki koeffisiýent $k_d = 1 + \dfrac{\delta_H}{\delta_Q} \cdot \beta = 1 + \dfrac{H}{Q}\beta = \dfrac{80}{500} \cdot 12{,}35 = 2{,}98.$

$\dfrac{\delta_H}{\delta_Q} = \dfrac{H}{Q}$, δ_Q - dwigateliň ýarym agramyndan kronşteýniň statiki deformasiýasy.

δ_H - mejbury güýjüň ýarysyndan kronşteýniň statiki deformasiýasy.

lň uly dartgynlylyk AB pürsde döreýär.

$$\sigma_{max} = \frac{P_{AB}}{A} \cdot k_d = \frac{10 \cdot 2{,}98}{10 \cdot 10} = 0{,}298kN/sm^2.$$

9.23. $\Delta\omega = 35{,}7\%$, τ_d=4,72 kN/sm², λ_d=10,8 mm.

9.24. $\omega = 23{,}4 s^{-1}$.

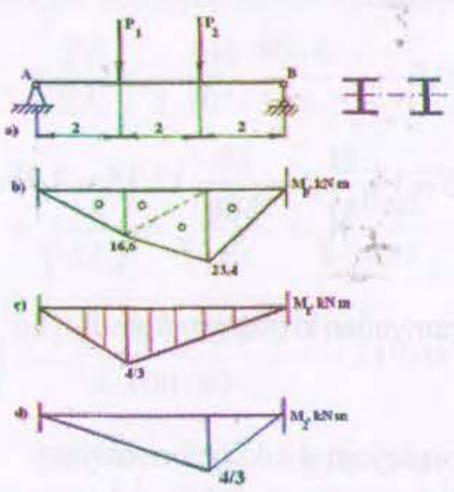
Maşynlaryň agramy bilen balkany ýükleýäris. $P_1 = m_1 g = 5kN$, $P_2 = m_2 g = 15kN$. Direglerdäki gaýtargylary $R_A = 8{,}3kN$, $R_B = 11{,}7kN$ kesgitläp, berlen güýçlerden egme momentiň M_P epýuryny guryarys (surata seret).

Güýçleriň goýlan nokatlaryna birlik güýçleri goýup, birlik güýçlerden $\overline{M}_1$ we $\overline{M}_2$ momentleriň epýurlaryny guryarys (surata seret).

Epýurlary köpeltmek usulyny ulanyp a_1 we a_2 ornuny üýtgetmeleri kesgitleýäris:

$$a_1 = \frac{1}{EI}\left[\frac{1}{2}\cdot 2\cdot 16{,}6\cdot\frac{8}{9}+\frac{1}{2}\cdot 2\cdot 16{,}6\cdot\frac{10}{9}+\frac{1}{2}\cdot 2\cdot 23{,}4\cdot\frac{8}{9}+\frac{1}{2}\cdot 2\cdot 23{,}4\cdot\frac{4}{9}\right];$$

onda $a_1 = \frac{64{,}4}{EI} = 17{,}03\cdot 10^{-3}$ m.



9.25-nji surat

Şonuň ýaly-da

$$a_2 = \frac{69}{EI} = 18{,}2\cdot 10^{-3}\text{ m}.$$

a_1 we a_2 bahalaryny Releýiň formulasyna goýup alarys:

$$\omega = \sqrt{\frac{\sum m_i a_i}{\sum m_i a_i^2}\cdot g} = 23{,}4 s^{-1}.$$

9.25. $\omega_o = 16{,}4$, $\omega = 99{,}5\ s^{-1}$, diýmek, rezonans hadysasy bolmaýar.

Birlik momentden walyň towlanma burçy

$$\delta = \frac{1\cdot\ell}{GI_P} = \frac{1\cdot\ell\cdot 32}{G\cdot\pi d^4} = 3{,}05\cdot 10^{-6}.$$

Walyň erkin yrgyldysynyň periody

$$t = 2\pi\sqrt{I_m\cdot\delta} = 2\cdot 3{,}14\sqrt{31\cdot 3{,}05\cdot 10^{-6}} = 0{,}061 s.$$

Walyň erkin yrgyldysynyň ýygylygy

$$\omega_o = \frac{1}{t} = \frac{1}{0{,}061} = 16{,}4 s^{-1};$$

Walyň mejbury yrgyldysynyň ýygylygy

$$\omega = \frac{\pi n}{30} = \frac{3{,}14\cdot 950}{30} = 99{,}5 s^{-1},$$

$\omega > \omega_o$; rezonans hadysasy bolmaýar.

9.26. $v_{kr} = 117 km/sag$.

Pružiniň çökmesi $\lambda = \frac{4PR^3 n}{Gr^4} = 1{,}53 sm.$

Bu ýerde $P = \frac{Q+S}{8} = \frac{50+35}{8} = 10{,}62$ kN.

Wagonyň erkin yrgyldysynyň periody

$$t_o = 2\pi\sqrt{\frac{\lambda}{g}} = 6{,}28\sqrt{\frac{1{,}53}{981}} = 0{,}247 s.$$

Onda yrgyldynyň ýygylygy

$$\omega_o = \frac{1}{t_o} = \frac{1}{0{,}247} = 4{,}05 s^{-1} = 243\frac{1}{min}.$$

Wagonyň hereketiniň kritiki tizligi $\omega = \omega_o$ ýagdaýynda bolýar we

$$V_{kr} = \frac{\omega \cdot 60\ell}{1000} = \frac{243 \cdot 60 \cdot 8}{10^3} = 117 km/sag.$$

9.27. $c = 0{,}255sm$, $\sigma_{max} = 1265kg/sm^2$.

Dwigateliň massasy $m = \frac{Q}{g} = \frac{2500}{981} = 2{,}55kg \cdot s^{-2}/sm$,

Birlik güýçden ýüküň aşagyndaky balkanyň progibi

$$\delta = \frac{1 \cdot \ell^3}{48EI} = \frac{1 \cdot 350^3}{48 \cdot 2 \cdot 10^6 \cdot 5010} = 8{,}91 \cdot 10^{-5} sm/kg,$$

Erkin yrgyldynyň ýygylygy

$$\omega_o = \frac{1}{\sqrt{m\delta}} = \frac{1}{\sqrt{2{,}55 \cdot 8{,}91 \cdot 10^{-5}}} = 66{,}5s^{-1}.$$

Mejbury yrgyldynyň ýygylygy

$$\omega = \frac{\pi n}{30} = \frac{3{,}14 \cdot 540}{30} = 56{,}5s^{-1},$$

Mejbury yrgyldynyň amplitudasy

$$c = \frac{P}{m} \cdot \frac{1}{\omega_0^2 - \omega^2} = \frac{800}{2{,}55} \cdot \frac{1}{66{,}5^2 - 56{,}5^2} = 0{,}255sm.$$

Bu amplituda ekwiwalent statiki güýç degişli

$$P_{st} = \frac{c}{\delta} = \frac{0{,}255}{8{,}91 \cdot 10^{-5}} = 2860kg = 28{,}6kN.$$

Bu güýjüň egilmeden döredýän dartgynlylygy

$$\sigma = \frac{M}{W} = \frac{P_{st}\ell}{4W} = \frac{2860 \cdot 350}{4 \cdot 371} = 675kg/sm^2.$$

Dwigateliň agramyndan döreýän dartgynlylyk

$$\sigma = \frac{M}{W} = \frac{Q\ell}{4W} = \frac{2500 \cdot 350}{4 \cdot 371} = 590kg/sm^2,.$$

Normal dartgynlylyk aşakdaky çäkde üýtgeýär,

$\sigma_{min} = 590 - 675 = -85kg/sm^2$,

$\sigma_{max} = 590 + 675 = 1265kg/sm^2$.

9.28. $\omega = 302s^{-1}$.

Konstruksiýanyň statiki progibi

$$\Delta_{st} = \frac{P\ell^3}{3EI} = \frac{0{,}01 \cdot 20^3 \cdot 12}{3 \cdot 2{,}2 \cdot 10^4 \cdot 0{,}3^3 \cdot 5} = 1{,}08 \cdot 10^{-2} sm.$$

Konstruksiýanyň ýygylygy

$$\omega = \sqrt{\frac{g}{\Delta_{st}}} = \sqrt{\frac{981}{1{,}08 \cdot 10^{-2}}} = 302s^{-1}.$$

9.29. $\omega = 1070s^{-1}$, $T = 0{,}00587s$, $n_{kr} = 10223$aýl/min.

Şatunyň yrgyldysynyň ýygylygyny aşakdaky takyk formula boýunça kesgitleýäris,

$$\omega = \frac{\pi^2}{\ell^2}\sqrt{\frac{EI \cdot g}{P}};$$

Şatunyň kesiginiň inersiýa momenti

$$I_x = 2\left[\frac{bt^3}{12} + bt\left(\frac{h}{2} - \frac{t}{2}\right)^2\right] + \frac{t_1 \cdot (h-2t)^3}{12} =$$

$$= 2\left[\frac{3 \cdot 0{,}5^3}{12} + 3 \cdot 0{,}5 \cdot 2{,}25^2\right] + \frac{0{,}4 \cdot 4^3}{12} = 17{,}37\ sm.$$

Onda $\omega = \frac{3{,}14^2}{30^2}\sqrt{\frac{2 \cdot 10^4 \cdot 17{,}37 \cdot 981}{0{,}035}} = 1070s^{-1}$.

Şatunyň hususy yrgyldysynyň periody,

$T = 0{,}00587s^{-1}$;

Dwigateliň kritiki aýlaw sany,

$$\omega_{kr} = \frac{\pi n_{kr}}{30} = 1070,$$

$$n_{kr} = \frac{1070 \cdot 30}{3{,}14} = 10223 \text{aýl/min}.$$

9.30. $M_{max} = 300\ \text{kN} \cdot \text{sm}$.

Şaýyň çydamlylyk çägi $\sigma^{\ell}_{-1s} = \dfrac{\sigma^{\ell}_{-1}}{\alpha_{kh}\alpha_m}$

$\alpha_{kh} = 1 + q(\alpha_{kt} - 1)$ - konsentrasiýanyň hakyky koeffisiýenti,

α_{kt} - konsentrasiýanyň nazary koeffisiýenti,

q- materialyň ýerli dartgynlylyga duýgurlyk koeffisiýenti,

$\alpha_{kt} = 1{,}5$ bahasyny $r/d = 0{,}125$ baglylykda tablisadan alýarys,

$q = 0{,}36$ bahasy $\sigma_B = 45\ \text{kN/sm}^2$ baglylykda grafikden alynýar.

Onda $\alpha_{kh} = 1 + 0{,}36(1{,}5 - 1) = 1{,}18.$

$\alpha_m = 1{,}56$ - masştab koeffisiýenti, walyň diametrine baglylykda grafikden alynýar.

Onda $\sigma^{\ell}_{-1s} = \dfrac{22}{1{,}18 \cdot 1{,}56} = 11{,}95 \text{kN/sm}^2$

Rugsat edilýän dartgynlylyk $\left[\sigma^{e}_{-1s}\right] = \dfrac{\sigma^{\ell}_{-1s}}{k} = \dfrac{11{,}95}{2} = 5{,}97 \text{kN/sm}^2$.

Berklik şertinden $M_{max} = \dfrac{\left[\sigma^{e}_{-1s}\right] \cdot \pi d^3}{32} = \dfrac{5{,}97 \cdot 3{,}14 \cdot 8^3}{32} = 300 \text{kN} \cdot \text{sm}.$

9.31. $n_a = 4{,}1$; $n_d = 1{,}5$.

Hasapda kabul edilen: $\psi_\sigma = 0{,}06$, $\alpha_\sigma = 2$, $\beta = 0{,}92$,

şaýyň konsentrasiýasynyň effekt koeffisiýenti $k_{\sigma s} = \dfrac{k_\sigma}{\varepsilon_\sigma \beta}$.

9.32. $n = 2{,}1$, $n_a = 3{,}5$.

Gatnaşyk $r/d = 0{,}05$. Grafikden $(k_\sigma)_{\frac{D}{d}=2} = 1{,}9$, $(k_\tau)_{\frac{D}{d}=2} = 1{,}5$.

$\dfrac{D}{d} = \dfrac{50}{40} = 1{,}25$ üçin

$$k_\sigma = 1 + \xi\left[(k_\sigma)_{\frac{D}{d}=2} - 1\right] = 1 + 0{,}85[1{,}9 - 1] = 1{,}77;$$

$$k_\tau = 1 + \xi\left[(k_\tau)_{\frac{D}{d}=2} - 1\right] = 1 + 0{,}8[1{,}5 - 1] = 1{,}4.$$

Grafikden $\varepsilon_\tau = \varepsilon_\sigma = 0{,}85$

Normal dartgynlylyk boýunça çydamlylyk çäginiň berklik koeffisiýenti

$$n_\sigma = \frac{\sigma_{-1}}{\psi_a \sigma_m + \dfrac{k_\sigma}{\varepsilon_\sigma}\sigma_a} = \frac{22}{0{,}05 \cdot 0 + \dfrac{1{,}77}{0{,}85} \cdot 5} = 2{,}2;$$

Galtaşma dartgynlylyk boýunça

$$n = \frac{\tau_{-1}}{\psi_\tau \tau_m + \dfrac{k_\tau}{\varepsilon_\tau} \cdot \tau_a} = \frac{12}{0{,}05 \cdot 0 + \dfrac{1{,}4}{0{,}85} \cdot 1} = 7{,}3.$$

Çydamlylyk çägi boýunça ätiýaçlyk koeffisiýenti

$$n = \frac{n_\sigma n_\tau}{\sqrt{n_\sigma^2 + n_\tau^2}} = \frac{2{,}2 \cdot 7{,}3}{\sqrt{2{,}2^2 + 7{,}3^2}} = 2{,}1;$$

Akyjylyk çägi boýunça ätiýaçlyk koeffisiýenti,

$$n_\sigma = \frac{\sigma_{ak}}{\sigma_m + \sigma_a} = \frac{30}{5} = 6, \quad n_\tau = \frac{\tau_{ak}}{\tau_m + \tau_a} = \frac{18}{4} = 4{,}5;$$

Onda $n_a = \dfrac{6 \cdot 4{,}5}{\sqrt{6^2 + 4{,}5^2}} = 3{,}5.$

9.33. $n_\sigma = 1{,}29$, $n_a = 2{,}13$.

Iň uly tizlenme $a_{max} = \omega^2 r(1+\lambda) = \left(\frac{3{,}14 \cdot 6000}{30}\right)^2 \cdot 0{,}04(1+0{,}28) =$

$$= 2{,}02 \cdot 10^4 \, m \cdot s^{-2}$$

Şatuny dartýan inersiýa güýji $P_{in} = (m_P + m_{y\cdot s}) \cdot a_{max} = 14{,}1kN$.

Gazyň basyş güýji

$$P_g = P_{\bar{z}} \cdot A_P = 5{,}5 \cdot \frac{3{,}14 \cdot 78^2}{4} = 26270N = 26{,}27\,kN.$$

Bu güýç şatuny gysýar, şonuň üçin hem tersin bahasyny alýarys. Şatuna täsir edýän ok güýji $P_{max} = 14{,}1kN$; $P_{min} = -26{,}27kN$.

Assimmetriýa koeffisiýenti $\rho = \frac{P_{min}}{P_{max}} = -1{,}86$.

Dartgynlylyklary kesgitleýäris $\left(A = 1{,}555sm^2\right)$

$$\sigma_{max} = \frac{P_{max}}{A} = \frac{14{,}1}{1{,}555} = 9{,}07kN/sm^2,$$

$$\sigma_{min} = \frac{P_{min}}{A} = \frac{-26{,}27}{1{,}555} = -16{,}89kN/sm^2.$$

Sikliň häsiýetleri: Amplituda $\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = 12{,}99kN/sm^2$,

Orta dartgynlylyk $\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = -3{,}91kN/sm^2$.

Ätiýaçlyk koeffisiýenti

$$n_\sigma = \frac{\sigma_{-1}}{k_\sigma \sigma_a + \psi_\sigma |\sigma_m|} = \frac{20}{1{,}11 \cdot 12{,}99 + 0{,}286 \cdot 3{,}91} = 1{,}29 < [n];$$

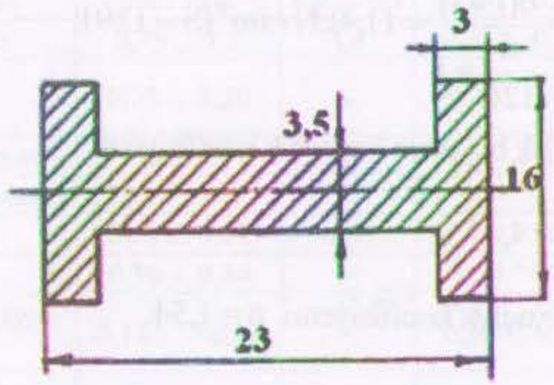
bu ýerde $k_\sigma = \frac{k_\sigma}{k_d \cdot k_V} = \frac{1{,}27}{0{,}88 \cdot 1{,}3} = 1{,}11$,

Polat üçin $\sigma_{-1s} = 20kN/sm^2$, $\sigma_a = 36kN/sm^2$, $\sigma_b = 70kN/sm^2$.

Onda $\psi_\sigma = \frac{\sigma_{-1s}}{\sigma_a} = \frac{20}{70} = 0{,}286$,

Statiki berklige ätiýaçlyk koeffisiýenti

$n_a = \frac{\sigma_a}{|\sigma|_{max}} = \frac{36}{16{,}89} = 2{,}13$ - rugsat edilýär.



9.33-nji surat

9.34. $n = 1{,}54$.

Iň uly normal we galtaşma dartgynlylyklar

$$\sigma_{max} = \frac{M_\ell}{W_x} = \frac{80}{0{,}1 \cdot 5^3} = 6{,}4kN/sm^2;$$

$$\tau_{max} = \frac{M_1}{W_P} = \frac{64}{0{,}2 \cdot 5^3} = 2{,}56kN/sm^2.$$

Normal dartgynlylyk boýunça ätiýaçlyk koeffisiýenti

$$n_\sigma = \frac{\sigma_{-1D}}{\sigma_{max}} = \frac{\sigma_{-1}}{k_\sigma \beta \cdot \varepsilon_m \cdot \sigma_{max}} = \frac{28}{1{,}8 \cdot 1{,}38 \cdot 1{,}07 \cdot 6{,}4} = 1{,}65.$$

Bu ýerde $k_\sigma = 1{,}8$, $\beta = 1{,}07$, $\varepsilon_m = 1{,}38$ (tablisadan).

τ_{-1} we τ_a kesgitleýäris:

$$\tau_{-1} = 0{,}58\sigma_{-1} = 0{,}58 \cdot 28 = 16{,}25 \text{kN/sm}^2.$$

$$\tau_a = 0{,}58\sigma_a = 0{,}58 \cdot 35 = 20{,}3 \text{kN/sm}^2.$$

Towlanmada çydamlylyk çägi (simmetriýa sikli)

$$\tau_{-1D} = \frac{\tau_{-1}}{k_\tau \cdot \varepsilon_m \cdot \beta} = \frac{16{,}25}{1{,}8 \cdot 1{,}38 \cdot 1{,}07} = 6 \text{kN/sm}^2.$$

Pulsirleýji siklde towlanmada çydamlylyk çägi (k = 1)

$$\tau_{rD} = \frac{\tau_{-1D}(1+k)}{\frac{\tau_{-1D}}{S}+1} = \frac{6(1+1)}{\frac{6}{120}+1} = 11{,}4 \text{kN/sm}^2 (S = 120);$$

Galtaşma dartgynlylyk boýunça ätiýaçlyk koeffisiýenti

$$n_\tau = \frac{\tau_{rD}}{\tau_{max}} = \frac{11{,}4}{2{,}56} = 4{,}45.$$

Berklige umumy ätiýaçlyk koeffisiýenti n = 1,54.

GOŞMAÇALAR

1-nji goşmaça

Materiallaryň fiziki-mehaniki häsiýetnamalary

Material	Maýyşgaklyk moduly $E \cdot 10^5$, MPa	Süýşme moduly $G \cdot 10^4$, MPa	Kese durkuny üýtgetmäniň koeffisiýenti, μ	Udel agram, γ kN/sm^3
Polat:				
Uglerodly	2,0 ... 2,1	8,0 ... 8,1	0,24 ... 0,33	78,5
Legirlenen	2,0 ... 2,2	8,0 ... 8,1	0,25 ... 0,30	77,5 ... 78,5
Çal çoýun	0,78 ... 1,5	4,4	0,23 ... 0,27	68 ... 76
Bürünçli galaýy	0,75 ... 1,20	-	0,32 ... 035	87,6 ... 88,2
Sozulan mis	1,0 ... 1,1	4,3	0,28 ... 0,34	89,4
Garyndylar:				
Alýumin	0,69 ... 0,71	2,7	0,33	26,4 ... 28,0
Magniý	0,39 ... 0,44	-	0,34	17,6 ... 18,0
Berklik çägi 20 MPa	0,182 ...0,232	-	0,16 ... 0,18	-
Agaç boý süýümine	0,09 ... 0,15	0,055	-	4,8 ... 5,4 (sosna)
Tekstolit	0,04 ... 0,06	-	-	13 ... 14,5
Winiplast	0,03 ... 0,04	-	0,35 ... 0,37	13,8 ... 14,3
Kapron	0,014 ... 0,020	0,045 ... 0,048	0,35 ... 0,38	11,0 ... 11,4
Aýna süýümi	0,35	-	0,29	17,0 ... 18,0
Polietilen ND	0,005 ... 0,008	-	0,39	9,2 ... 9,7
Kauçuk	0,00008	-	0,47	-

2-nji goşmaça

Materiallaryň mehaniki häsiýetnamalary

Material	Berklik çägi σ_B, MPa	Akyjylyk çägi σ_a, σ_T, MPa	Otnositel uzalma δ, %	Çydamlylyk çägi, MPa		
				δ_{-1s}	δ_{-1c}	δ_{-1t}
1	2	3	4	5	6	7
Adaty hilli uglerodly polat						
St 2 kp	330 ... 420	200 ... 220	30 ... 33	120…160	170...220	80...130
St 2 ps (sp)	340 ... 440	210 ... 230	29 ... 32			
St 3ps	370 ... 470	220 ... 240	24 ... 27	120…160	170...220	100...130
St 3ps (sp)	380 ... 490	230 ... 250	23 ... 26			
St 4ps	410 ... 520	240 ... 260	22 ... 25	-	190...250	-
St 4ps (sp)	420 ... 540	250 ... 270	21 ... 24			
St 5ps (sp)	500 ... 640	270 ... 290	17 ... 20	170...220	220...300	130...180
St 6ps (sp)	600	300 ... 320	12 ... 15	190...250	250...340	150...200
Hili ýokarlandyrylan uglerodly polat (kadalaşdyrylan)						
10	340 ... 420	210	31	120 ... 150	160 ... 220	80 ... 120
20	420 ... 500	250	25	120 ... 160	170 ... 220	100...130
30	500 ... 600	300	21	170 ... 210	200 ... 270	110...140
40	580 ... 700	340	19	180 ... 240	230 ... 320	140...190
45	610 ... 750	360	16	190 ... 250	250 ... 340	150...200
50	640 ... 800	380	14	200 ... 260	270 ... 350	160...210
60	690 ... 900	410	12	220 ... 280	310 ... 380	180...220

2-nji goşmaçanyň dowamy

1	2	3	4	5	6	7
Legirlenen polat						
20H	720 ... 850	400 ... 650	12	-	310 ... 380	170...230
40H	730 ... 1050	650 ... 900	15,5	240 ... 340	320 ... 480	210...260
45H	850 ... 1060	700 ... 950	9	-	310 ... 380	170...230
40HN	1000...1450	800...1300	-	310 ... 420	460 ... 600	-
30 HGSA	1100...1700	850 ... 1500	7	-	480 ... 700	280...400
60 G	710	420	11	250 ... 320	-	-
Çal we ýokary berklikdäki çoýun						
ÇÇ18-36	süýnme	-	-	35	90	-
	180					
	Egilme					
	360					
	Gysma					
	700					
ÇÇ 24-44	süýnme	-	-	65	120	100
	240					
	Egilme					
	440					
	Gysylma					
	1000					
ÇÇ 21-40	Süýnme		-	-	100	80
	210					
	Egilme					
	400					
	Gysylma					
	950					
AÇ 45-5	Süýnme	330	5	-	180 ... 200	-
	450 ... 550					
	Egilme					
	650 ... 750					
	Gysylma					
	1800...2000					

1	2	3	4	5	6	7
AÇ 50-2	Süýnme	380	2	-	200..220	170...210
	500 ... 600					
	Egilme					
	900 ... 1000					
	Gysylma					
	1700...1800					
Durkuny üýtgedýän alýumin garyndylary						
АМЦ	100	50	20	-	50	
АД-31						
Tebigy könelişmek	140	70	13	-	90	
Emeli könelişmek	200	150	8	-	-	-
АМ г5	270	120	15	-	110	-
АМ г6	320	160	15	-	130	-
Д16Т	400…430	280 …300	10	-	115	-
Mis garyndylary						
Latun L 68:						
Ýumşak	300 ... 380	-	42	-	120	-
Gaty	440 ... 550	-	10	-	150	-
Bürünç:						
Бр.АМц						
9-2	480… 550	-	20 … 12	-	-	-
Бр.АжМц						
10-3-1,5	60	-	12	-	-	-

1	2	3	4	5	6	7
Metal däl materiallar						
Agaç:						
sosna	Süýnme					
	93 ... 115					
	Egilme					
	74 ... 88	-	-	-	-	-
	Gysylma					
	45					
Dub	Süýnme					
	130					
	Egilme					
	95	-	-	-	-	-
	Gysylma					
	52					
Tekstolit	Süýnme					
	90 ... 100	70 ... 80	-	-	-	-
	Egilme					
	140 ... 150					
	Gysylma					
	230 ... 250					
Winiplast	Süýnme					
	40 ... 60	-	10 ... 25	-	-	-
	Egilme					
	80 ... 120					
	Gysylma					
	80 ... 160					

2-nji goşmaçanyň dowamy

1	2	3	4	5	6	7
Kapron	Süýnme					
	50 ... 60					
	Egilme					
	90 ... 100	-	-	-	-	-
	Gysylma					
	85 ... 100					
Epoksid smolasy	Süýnme					
	70 ... 80					
	Egilme					
	120 ... 130					
	Gysylma					
	145 ... 155					
Ftoreplat -3	Süýnme					
	30 ... 37	-	50 ... 70	-	-	-
	Egilme					
	60 ... 80					
	Gysylma					
	50 ... 60					

3-nji goşmaça

Ikitawraly balkalar DÖST 8239-72

Balkanyň belgisi	h, mm	b, mm	s, mm	t, mm	Kesgiň meýdany A, sm^2	Massa 1m, kg	Sprawoçnik ululyklary						
							x-x y-y						
							J_x, sm^4	W_x, sm^3	i_x, sm	S_x, sm^3	J_y, sm^4	W_y, sm^3	I_y, sm
10	100	55	4,5	7,2	12,0	9,46	198	39,7	4,06	23,0	17,9	6,49	1,22
12	120	64	4,8	7,3	14,7	11,5	350	58,4	4,88	33,7	27,9	8,72	1,38
14	140	73	4,9	7,5	17,4	13,7	572	81,7	5,73	46,8	41,9	11,5	1,55
16	160	81	5,0	7,8	20,2	15,9	873	109	6,57	62,3	58,6	14,5	1,70
18	180	90	5,1	8,1	23,4	18,4	1290	143	7,42	81,4	82,6	18,4	1,88
18a	180	100	5,1	8,3	25,4	19,9	1430	159	7,51	89,8	114	22,8	2,12
20	200	100	5,2	8,4	26,8	21,0	1840	184	8,28	104,	115	23,1	2,07
20a	200	110	5,2	8,6	28,9	22,7	2030	203	8,37	114	155	28,2	2,32
22	220	110	5,4	8,7	30,6	24,0	2550	232	9,13	131	157	28,6	2,27
22a	220	120	5,4	8,9	32,8	25,8	2790	254	9,22	143	206	34,3	2,50
24	240	115	5,6	9,5	34,8	27,3	3460	289	9,97	163	198	34,5	2,37
24a	240	125	5,6	9,8	37,5	29,4	3800	317	10,10	178	260	41,6	2,63
27	270	125	6,0	9,8	40,2	31,5	5010	371	11,20	210	260	41,5	2,54
27a	270	135	6,0	10,2	43,2	33,9	5500	407	11,30	229	337	50,0	2,80
30	300	135	6,5	10,2	46,5	36,5	7080	472	12,30	268	337	49,9	2,69
30a	300	145	6,5	10,7	49,9	39,2	7780	518	12,50	292	436	60,1	2,95
33	330	140	7,0	11,2	53,8	42,2	9840	597	13,50	339	419	59,9	2,79
36	360	145	7,5	12,3	61,9	48,6	13380	743	14,70	423	516	71,1	2,89
40	400	155	8,3	13,0	72,6	57,0	19062	953	16,2	545	667	86,1	3,03
45	450	160	9,0	14,2	84,7	66,5	27696	1231	18,10	708	808	101,	3,09
50	500	170	10,0	15,2	100	78,5	39727	1589	19,9	919	1043	123,	3,23
55	550	180	11,0	16,5	118	92,6	55962	2035	21,8	1181	1356	151,	3,39
60	600	190	12,0	17,8	1380	108	76806	2560	23,6	1491	1725	182,	3,54

Şweller DÖST 8240-72

Şwelleriň belgisi	h, mm	b, mm	s, mm	t, mm	Kesigiň meýdany A, sm^2	Massa 1m, kg	Sprawoçnik ululyklary							
							x-x				*y-y*			
							J_x, sm^4	W_x, sm^3	i_x, sm	S_x, sm^3	J_y, sm^4	W_y, sm^3	I_y, sm	z_0,*sm*
5	50	32	4,4	7,0	6,16	4,84	22,8	9,1	1,92	5,59	5,61	2,75	0,954	1,16
6,5	65	26	4,4	7,2	7,51	5,90	48,6	15,0	2,54	9,00	8,70	3,68	1,080	1,24
8	80	40	4,5	7,4	8,98	7,05	89,4	22,4	3,16	13,3	12,80	4,75	1,190	1,31
10	100	46	4,5	7,6	10,90	8,59	174,0	34,8	3,99	20,4	20,40	6,46	1,370	1,44
12	120	52	4,8	7,8	13,30	10,40	304,0	50,6	4,78	29,6	31,20	8,52	1,530	1,54
14	140	58	4,9	8,1	15,60	12,30	491,0	70,2	5,50	40,8	45,40	11,0	1,700	1,67
14a	140	62	4,9	8,7	17,00	13,30	545,0	77,8	5,66	45,1	57,50	13,3	1,840	1,87
16	160	64	5,0	8,4	18,10	14,20	747,0	93,4	6,42	54,1	63,30	13,8	1,870	1,80
16a	160	68	5,0	9,0	19,50	15,30	823,0	103	6,49	59,4	78,80	16,4	2,010	2,00
18	180	70	5,1	8,7	20,70	16,30	1090,0	121,	7,24	69,8	86,00	17,0	2,040	1,94
18a	180	74	5,1	9,3	22,20	17,40	1190,0	132	7,32	76,1	105,0	20,0	2,180	2,13
20	200	76	5,2	9,0	23,40	18,40	1520,0	152	8,07	87,8	113,0	20,5	2,200	2,07
20a	200	80	5,2	9,7	25,20	19,80	1670,0	167	8,15	95,9	139,0	24,2	2,350	2,28
22	220	82	5,4	9,5	26,70	21,00	2110,0	192	8,89	110,	151,0	25,1	2,370	2,21
22a	220	87	5,4	10,2	28,80	22,60	2330,0	212	8,99	121,	187,0	30,0	2,550	2,46
24	240	90	5,6	10,0	30,60	24,00	2900,0	242	9,73	139,	208,0	31,6	2,600	2,42
24a	240	95	5,6	10,7	32,90	25,80	3180,0	265	9,84	151,	254,0	37,2	2,780	2,67
27	270	95	6,0	10,5	35,20	27,70	4160,0	308	10,9	178,	262,0	37,3	2,730	2,47
30	300	100	6,5	11,0	40,50	31,80	5810,0	387	12,0	224,	327,0	43,6	2,840	2,52
33	330	105	7,0	11,7	46,50	36,50	7980,0	484	13,1	281,	410,0	51,8	2,970	2,59
36	360	110	7,5	12,6	53,40	41,90	10820	601	14,2	350,	513,0	61,7	3,100	2,68
40	400	115	8,0	13,5	61,50	48,30	15220	761	15,7	444,	642,0	73,4	3,230	2,75

Sozma polatdan ýasalan deňgapdally burçluk DÖST 8509-72

Profiliň belgisi	B, mm	d, mm	Kesigiň meýdany A, sm^2	Sprawoçnik ululyklary								Massa 1m, kg
				x-x		*o-x₀*	*y₀-y₀*		*x₁-x₁*			
				J_x, sm^4	i_x, *sm*	J_{x0} *max*, sm^4	i_{x0},*max*, *x, sm*	J_{y0} *min*, sm^4	J_{y0},*min*, *n, sm*	J_{x1}, sm^4	z_0,*sm*	
1	2	3	4	5	6	7	8	9	10	11	12	13
2	20	3	1,13	0,40	0,59	0,63	0,75	0,17	0,39	0,81	0,60	0,89
		4	1,46	0,50	0,58	0,78	0,73	0,22	0,38	1,09	0,64	1,15
2,5	25	3	1,43	0,81	0,75	1,29	0,95	0,34	0,49	1,57	0,73	1,12
		4	1,86	1,03	0,74	1,62	0,93	0,44	0,48	2,11	0,76	1,46
2,8	28	3	1,62	1,16	0,85	1,84	1,07	1,48	0,55	2,20	0,80	1,27
3,2	32	3	1,86	1,77	0,97	2,80	1,23	0,74	0,63	3,26	0,89	1,46
		4	2,43	2,26	0,96	3,58	1,21	0,94	0,62	4,39	0,94	1,91
3,6	36	3	2,10	2,56	1,10	4,06	1,39	1,06	0,71	4,64	0,99	1,65
		4	2,75	3,29	1,09	5,21	1,38	1,36	0,70	6,24	1,04	2,16
4	40	3	2,35	3,55	1,23	5,63	1,55	1,47	0,79	6,35	1,09	1,85
		4	3,08	4,58	1,22	7,26	1,53	1,90	0,78	8,53	1,13	2,42
		5	3,79	5,53	1,20	8,75	1,54	2,30	0,79	10,7	1,17	2,97
4,5	45	3	2,65	5,13	1,39	8,13	1,75	2,12	0,89	9,04	1,21	2,08
		4	3,48	6,63	1,38	10,50	1,74	2,74	0,89	12,1	1,26	2,73
		5	4,29	8,03	1,37	12,70	1,72	3,33	0,88	15,3	1,30	3,37
5	50	3	2,96	7,11	1,55	11,30	1,95	2,95	1,00	12,4	1,33	2,32
		4	3,89	9,21	1,54	14,60	1,94	3,80	0,99	16,6	1,38	3,05
		5	4,80	11,2	1,53	17,80	1,92	4,63	0,98	20,9	1,42	3,77
5,6	56	4	4,38	12,1	1,73	20,80	2,18	5,41	1,11	23,3	1,52	3,44
		5	5,41	16,0	1,72	25,40	2,16	6,59	1,10	29,2	1,57	4,25
6,3	63	4	4,96	18,9	1,95	29,90	2,45	7,81	1,25	33,1	1,69	3,90
		5	6,13	23,1	1,94	36,60	2,44	9,52	1,25	41,5	1,74	4,81
		6	7,28	27,1	1,93	42,90	2,43	11,2	1,24	50,0	1,78	5,72
7	70	4,5	6,20	29,0	2,16	46,0	2,72	12,0	1,39	51,0	1,88	4,87
		5	6,86	31,9	2,16	50,7	2,72	13,2	1,39	56,7	1,90	5,38
		6	8,15	37,6	2,15	59,6	2,71	15,5	1,38	68,4	1,94	6,39
		7	9,42	43,0	2,14	68,2	2,69	17,8	1,37	80,1	1,99	7,39
		8	10,70	48,2	2,13	76,4	2,68	20,0	1,37	91,9	2,02	8,37

5-nji goşmaçanyň dowamy												
1	2	3	4	5	6	7	8	9	10	11	12	13
7,5	75	5	7,39	39,5	2,31	62,6	2,91	16,4	1,49	69,6	2,02	5,80
		6	8,78	46,6	2,30	73,9	2,90	19,3	1,48	83,9	2,06	6,89
		7	10,10	53,3	2,29	84,6	2,89	22,1	1,48	98,3	2,10	7,96
		8	11,50	59,8	2,28	94,9	2,87	24,8	2,47	113	2,15	9,02
		9	12,80	66,1	2,27	105,0	2,86	27,5	1,46	127	2,18	10,1
8	80	5,5	8,63	52,7	2,47	83,6	3,11	21,8	1,59	93,2	2,17	6,78
		6	9,38	57,0	2,47	94,0	3,11	23,5	1,58	102	2,19	7,36
		7	10,80	65,3	2,45	104,0	3,09	27,0	1,58	119	2,23	8,51
		8	12,30	73,4	2,44	116,0	3,08	30,3	1,57	137	2,27	9,65
9	90	6	10,60	82,1	2,78	130,0	3,50	34,0	1,79	145,0	2,43	8,33
		7	12,30	94,3	2,77	150,0	3,49	38,9	1,78	169,0	2,47	9,64
		8	13,90	106,	2,76	168,0	3,48	43,8	1,77	194,0	2,51	10,9
		9	15,60	118,	2,75	186,0	3,46	48,6	1,77	219,0	2,55	12,2
10	100	6,5	12,80	122,	3,09	193,0	3,88	50,7	1,99	214,0	2,68	10,1
		7	13,80	131,	3,08	207,0	3,88	54,2	1,98	231,0	2,71	10,8
		8	15,60	147	3,07	233,0	3,87	60,9	1,98	265,0	2,75	12,2
		10	19,20	179	3,05	284,0	3,84	74,1	1,96	333,0	2,83	15,1
		12	22,80	209	3,03	331,0	3,81	86,9	1,95	402,0	2,91	17,9
		14	26,30	237	3,00	375,0	3,78	99,3	1,94	472,0	2,99	20,6
		16	29,70	264	2,98	416,0	3,74	112,0	1,94	542,0	3,06	23,3
11	110	7	15,20	176	3,40	279,0	4,29	72,7	2,19	308,0	2,96	11,9
		8	17,20	198	3,39	315,0	4,28	81,8	2,18	353,0	3,00	13,5
12,5	125	8	19,7	294	3,87	467	4,87	122	2,49	516	3,36	15,5
		9	22,0	327	3,86	520	4,86	135	2,48	582	3,40	17,3
		10	24,3	360	3,85	571	4,84	149	2,47	649	3,45	19,1
		12	28,9	422	3,82	670	4,82	174	2,46	782	3,53	22,7
		14	33,4	482,	3,80	764	4,78	200	2,45	916	3,61	26,2
		16	37,8	539	3,78	853	4,75	224	2,44	1051	3,68	29,6
14	140	9	24,7	466	4,34	739	5,47	192	2,79	818	3,78	19,4
		10	27,3	512	4,33	814	5,46	211	2,78	911	3,82	21,5
		12	32,5	602	4,31	957	5,43	248	2,76	1097	3,90	25,5
16	160	10	31,4	774	4,96	1229	6,25	319	3,19	1356	4,30	24,7
		11	34,4	844	4,95	1341	6,24	348	3,18	1494	4,35	27,0
		12	37,4	913	4,94	1450	6,23	476	3,17	1633	4,39	29,4
		14	43,3	1046	4,92	1662	6,20	431	3,16	1911	4,47	34,0
		16	49,1	1175	4,89	1866	6,17	485	3,14	2191	4,55	38,5
		18	54,8	1299	4,87	2061	6,13	537	3,13	2472	4,63	43,0
		20	60,4	1419	4,85	2248	6,10	589	3,12	2756	4,70	47,4

5-nji goşmaçanyň dowamy												
1	2	3	4	5	6	7	8	9	10	11	12	13
18	180	11	38,8	1216	5,60	1933	7,06	500	3,59	2128	4,85	30,5
		12	42,2	1317	5,59	2093	7,04	540	3,58	2324	4,89	33,1
20	200	12	47,1	1823	6,22	2896	7,84	749	3,99	3182	5,37	37,0
		13	50,9	1961	6,21	3116	7,83	805	3,98	3452	5,42	39,9
		14	54,6	2097	6,20	3333	7,81	861	3,97	3722	5,46	42,8
		16	62,0	2363	6,17	3755	7,78	970	3,96	42,64	5,54	48,7
		20	76,5	2871	6,12	4560	7,72	1182	3,93	5355	5,70	60,1
		25	94,3	3466	6,06	5494	7,63	1438	3,91	6733	5,89	74,0
		30	111,5	4020	6,00	6351	7,55	1688	3,89	8130	6,07	87,6
22	220	14	60,4	2814	6,83	4470	8,60	1159	4,38	4941	5,93	47,4
		16	68,6	3175	6,81	5045	8,58	1306	4,36	5661	6,02	53,8

6-njy goşmaça

Sozma polatdan ýasalan deň däl gapdally burçluk
DÖST 8510 – 72

Profiliň belgisi	B, mm	b, mm	d, mm	Kesigiň meýdany A, sm^2	Massa 1m, kg	Sprawoçnik ululyklary										
						x-x		*y-y*		x_1-x_1		y_1-y_1		*u -u*		
						J_x, sm^4	i_x, *sm*	J_y, sm^4	i_y, *sm*	J_{x1}, sm^4	Agyrlyk merkeziniň aralygy y_0, sm	J_{y1}, sm^4	Agyrlyk merkeziniň aralygy x_o, sm	J_u min, sm^4	i_u min, sm	Ýapgyt burçy
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2,5/1,6	25	16	3	1,16	0,91	0,70	0,78	0,22	0,44	1,56	0,86	0,43	0,42	0,13	0,34	0,392
3,2/2	32	20	3	1,49	1,17	1,52	1,01	0,46	0,55	3,26	1,08	0,82	0,49	0,28	0,43	0,382
			4	1,94	1,52	1,93	1,00	0,57	0,54	4,38	1,12	1,12	0,53	0,35	0,43	0,374
4/2,5	40	25	3	1,89	1,48	3,06	1,27	0,93	0,70	6,37	1,32	1,58	0,59	0,56	0,54	0,385
			4	2,47	1,94	3,93	1,26	1,18	0,69	8,53	1,37	2,15	0,63	0,71	0,54	0,381
4,5/2,8	45	28	3	2,14	1,68	4,41	1,43	1,32	0,79	9,02	1,47	2,20	0,64	0,79	0,61	0,382
			4	2,80	2,20	5,68	1,42	1,69	0,78	12,1	1,51	2,98	0,68	1,02	0,60	0,379

6-njy goşmaçanyň dowamy

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
5/3,2	50	32	3	2,42	1,90	6,17	1,60	1,99	0,91	12,4	1,60	3,26	0,72	1,18	0,70	0,403
			4	3,17	2,49	7,98	1,59	2,56	0,90	16,6	1,65	4,42	0,76	1,52	0,69	0,401
5,6/3,6	56	36	3,5	3,16	2,48	10,1	1,79	3,30	1,02	20,3	1,80	5,43	0,82	1,95	0,79	0,407
			4	3,58	2,81	11,4	1,78	3,70	1,02	23,2	1,82	6,25	0,84	2,19	0,78	0,406
			5	4,41	3,46	13,8	1,77	4,48	1,01	29,2	1,86	7,91	0,88	2,66	0,78	0,404
6,3/4,0	63	40	4	4,04	3,17	16,3	2,01	2,16	1,13	33,0	2,03	8,51	0,91	3,07	0,87	0,397
			5	4,98	3,91	19,9	2,00	6,26	1,12	41,4	2,08	10,8	0,95	3,73	0,86	0,396
			6	5,90	4,63	23,3	1,99	7,28	1,11	49,9	2,12	13,1	0,99	4,36	0,86	0,393
			8	7,68	6,03	29,6	1,96	9,15	1,09	66,9	2,20	17,9	1,07	5,58	0,85	0,385
7/4,5	70	45	4,5	5,07	3,98	25,3	2,23	8,25	1,28	51,0	2,25	13,6	1,03	4,88	0,98	0,407
			5	5,59	4,39	27,8	2,23	9,05	1,27	56,7	2,28	15,2	1,05	5,34	0,98	0,406
7,5/5	75	50	5	6,11	4,79	34,8	2,39	12,5	1,43	69,7	2,39	20,8	1,17	7,24	1,09	0,436
			6	7,25	5,69	40,9	2,38	14,6	1,42	83,9	2,44	25,2	1,21	8,48	1,08	0,435
			8	9,47	7,43	52,4	2,35	18,5	1,40	112,0	2,52	34,2	1,29	10,90	1,07	0,430
8/5	80	50	5	6,36	4,99	41,6	2,56	12,7	1,41	84,6	2,60	20,8	1,13	7,58	1,09	0,387
			6	7,55	5,92	49,0	2,55	15,8	1,40	102,0	2,65	25,2	1,17	8,88	1,08	0,386

6-njy goşmaçanyň dowamy

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
9/5,6	90	56	5,5	7,86	6,17	65,3	2,88	19,7	1,58	132	2,92	32,2	1,26	11,8	1,22	0,384
			6	8,54	6,70	70,6	2,88	21,2	1,58	145	2,95	35,2	1,28	12,7	1,22	0,384
			8	11,18	8,77	90,9	2,85	27,1	1,56	194	3,04	47,8	1,36	16,3	1,21	0,380
10/6,3	100	63	6	9,59	7,53	98,3	3,20	30,6	1,79	198	3,23	49,9	1,42	18,2	1,38	0,393
			7	11,1	8,70	113	3,19	35,0	1,78	232	3,28	58,7	1,46	20,8	1,37	0,392
			8	12,6	9,87	127	3,18	39,2	1,77	266	3,32	67,6	1.50	23,4	1,36	0,391
			10	15,5	12,10	154	3,15	47,1	1,75	333	3,40	85,8	1,58	28,3	1,35	0,387
11/7	110	70	6,5	11,4	8,98	142	3,53	45,6	2,00	286	3,55	74,3	1,58	26,9	1,53	0,402
			7	12,3	9,64	152	3,52	48,7	1,99	309	3,57	80,3	1,60	28,8	1,53	0,402
			8	13,9	10,90	172	3,51	54,6	1,98	353	3,61	92,3	1,64	32,2	1,52	0,400
12,5/8	125	80	7	14,1	11,0	227	4,01	73,7	2,29	452	4,01	119	1,80	43,4	1,76	0,407
			8	16,0	12,5	256	4,00	83,0	2,28	518	4,05	137	1,84	48,8	1,75	0,406
			10	19,7	15,5	312	3,98	100	2,26	649	4,14	173	1,92	59,3	1,74	0,404
			12	23,4	18,3	365	3,95	117	2,24	781	4,22	210	2,00	69,5	1,72	0,400

6-njy goşmaçanyň dowamy

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
14/9	140	90	8	18,0	14,1	364	4,49	120	2,58	727	4,49	194	2,03	70,3	1,98	0,411
			10	22,2	17,5	444	4,47	146	2,56	911	4,58	245	2,12	85,5	1,96	0,409
16/10	160	100	9	22,9	18,0	606	5,15	186	2,85	1221	5,19	300	2,23	110	2,20	0,391
			10	25,3	19,8	667	5,13	204	2,84	1359	5,23	335	2,28	121	2,19	0,390
			12	30,0	23,6	784	5,11	239	2,82	1634	5,32	405	2,36	142	2,18	0,388
			14	34,7	27,3	897	5,08	272	2,80	1910	5,40	477	2,43	162	2,16	0,385
18/11	180	110	10	28,3	22,2	952	5,80	276	3,12	1933	5,88	444	2,44	165	2,42	0,375
			12	33,7	26,4	1123	5,77	324	3,10	2324	5,97	537	2,52	194	2,40	0,374
20/12,5	200	125	11	34,9	27,4	1449	6,45	446	3,58	2920	6,50	718	2,79	264	2,75	0,392
			12	37,9	29,7	1568	6,43	482	3,57	3189	6,54	786	2,83	285	2,74	0,392
			14	43,9	34,4	1801	6,41	551	3,54	3726	6,62	922	2,91	327	2,73	0,390
			16	49,8	39,1	2026	6,38	617	3,52	4264	6,71	1061	2,99	367	2,72	0,388
25/16	250	160	12	48,3	37,9	3147	8,07	1032	4,62	6212	7,97	1634	3,53	604	3,54	0,410
			16	63,6	49,9	4091	8,02	1333	4,58	8308	8,14	2200	3,69	781	3,50	0,408
			18	71,1	55,8	4545	7,99	1475	4,56	9358	8,23	2487	3,77	866	3,49	0,407
			20	78,5	61,7	4987	7,97	1613	4,53	10410	8,31	2776	3,85	949	3,48	0,405

7-nji goşmaça

Çeýelik λ	Boý egilmäniň koeffisiýenti				
	Adaty hilli polat		Ýokarlandyrylan hilli polat $\sigma_a \geq 320$ MPa	Çoýun	Agaç
	polat 1, polat 2, polat 3, polat 4	Polat 5			
0	1,00	1,00	1,00	1,00	1,00
10	0,99	0,98	0,97	0,97	0,99
20	0,96	0,95	0,96	0,91	0,97
30	0,94	0,92	0,91	0,81	0,93
40	0,92	0,89	0,87	0,69	0,87
50	0,89	0,86	0,83	0,57	0,80
60	0,86	0,82	0,79	0,44	0,71
70	0,81	0,76	0,72	0,34	0,60
80	0,75	0,70	0,65	0,26	0,48
90	0,69	0,62	0,55	0,20	0,38
100	0,60	0,51	0,43	0,16	0,31
110	0,52	0,43	0,35	-	0,25
120	0,45	0,37	0,30	-	0,22
130	0,40	0,33	0,26	-	0,18
140	0,36	0,29	0,23	-	0,16
150	0,32	0,26	0,21	-	0,14
160	0,29	0,24	0,19	-	0,12
170	0,26	0,21	0,17	-	0,11
180	0,23	0,19	0,15	-	0,10
190	0,21	0,17	0,14	-	0,09
200	0,19	0,16	0,13	-	0,08

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