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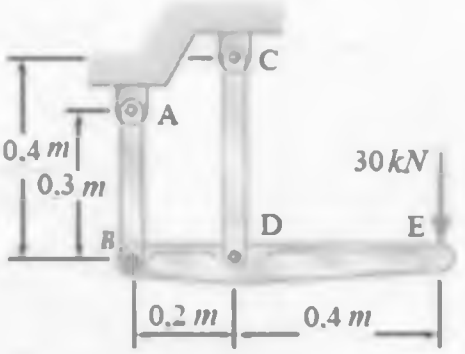

Toshkent -2019

O'ZBEKISTON RESPUBLIKASI OLIY VA O'RTA MAXSUS TA`LIM VAZIRLIGI

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Amaliy mashg'ulotlar va hisoblash – grafik ishlari uchun misollar

O'zbekiston Respublikasi Oliy va o'rta maxsus ta`lim vazirligining 2018 yil 7 dekabrdagi 1000 sonli buyrug'iga asosan 5340200-Bino va inshootlar qurilishi, 5310600-Yer usti transporti tizimlari va ularning ekspluatatsiyasi bakalavriat ta'lim yo'nalishlari talabalari uchun o'quv qo'llanma sifatida tavsiya qilingan

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Annotatsiya

Materiallar qarshiligidan tavsiya etilayotgan amaliy mashg'ulotlar uchun misollar va hisoblash grafik ishlari uchun topshiriqlar to'plami hamda ularni echish metodikasi bo'yicha o'quv qo'llanma oliy ta'lim muassasalarining mashinasozlik, qurilish, qishloq xo'jaligini va gidromeliorativ ishlarini mexanizatsiyalash xamda texnik mexanika fanini o'rganayotgan talabalari xamda yosh o'qituvchilar uchun mo'ljallangan.

O'quv qo'llanmada keltirilgan misollar materiallar qarshiligi fanining barcha bo'limlarini qamrab olgan, shundan 100 dan ortiq misollarning echimi keltirilgan. Kitob Binolar va inshootlar qurilishi, Er usti transport tizimlari va ularning ekspluatatsiyasi bakalavriat ta'lim yo'nalishlari talabalari uchun mo'ljallangan.

O'quv qo'llanmadagi misollarni tanlashda V.K.Kachurinning «Materiallar qarshiligidan masalalar to'plami » (Toshkent «O'qituvchi» 1998 yil) dan, shuningdek, M.Ergashovning "Materiallar qarshiligidan hisoblash loyihalash ishlari" (Toshkent, Moliya, 2004 yil), S.M.Hasanovning "Materiallar qarshiligidan misollar echish" (O'zbekiston nashriyoti, Toshkent, 2006 yil) kitobidan foydalanildi.

Аннотация

Примерами практических упражнений от материального сопротивления и набора задач для вычислительной графической работы и методологии их решения являются механизация, механизация, строительство, сельское хозяйство и гидромелиоративная работа высших учебных заведений для студентов, изучающих технику и молодых учителей. Примеры, представленные в справочнике, охватывают все аспекты устойчивости материала, с более чем 100 примерами. Книга предназначена для студентов бакалавриата по строительству зданий и сооружений, систем наземного транспорта и их эксплуатации.

Annotation

Examples of practical exercises from the material resistance and a set of tasks for computational graphic work and the methodology for solving them include the mechanization, mechanization, construction, agriculture and hydromeliorative work of higher education institutions for students studying technical mechanics and for younger teachers.

The examples presented in the handbook cover all aspects of material resistance, with more than 100 examples available. The book is intended for students of bachelor's degree in building of buildings and structures, surface transport systems and their exploitation.

Ayrim materiallarni cho'zilishda mustahkamlik chegarasi σ_B va uzayishi δ 1-jadval

Material	σ_B, $\frac{kg}{sm^2}$	δ, %
Bolt va parchin mix uchun po'lat	3400...5500	22 - 25
Quvma temir (po'lat)	3000...4800	8 - 16
Prokat po'lat	3800...6200	18 - 22
Nikelli po'lat	5500...6500	22 - 27
Xromnikelli po'lat	6500...7000	16 - 18
Maxsus po'lat	11000...16000	8 - 10
Cho'yon	1200...2500	-
Qizil mis	2000...2300	38
Bronza	2500	15
Alyuminiy	1000...3500	10 - 20
Qarag'ay tolalari bo'ylab	800	
Granit	30	
Qum tosh	20	
Fisht	7...30	
Beton	2,5...17,5	

Ayrim materiallar uchun cho'zilish va siqilishda ruxsat etilgan kuchlanish

Material	Ruxsat etilgan kuchlanish $\frac{kg}{sm^2}$	
	siqilish	cho'zilish
Qurilish uchun po'lat	1600	1600
Po'lat St 2	1400	1400
Sosna tola bo'ylab	100	70
Dub tola bo'ylab	130	90
Tekstolit	500 - 900	300 - 400
Kul rang cho'yon	1200...1500	
Beton $R = 110\ \frac{kg}{sm^2}$ markali	38	4,5
Beton $R = 170\ \frac{kg}{sm^2}$ markali	60	7

Ayrim materiallar mexanik xarakteristikalari

Material	Elastiklik moduli E, mPa	Puasson koeffitsienti μ	Ruxsat etilgan kuchlanish mPa	Haroratdan chiziqli kengayish koeffitsienti α^0C^{-1}	Solish-tirma og'irlik ρ, n/m^3
Po'lat	$2\cdot10^5$	0,30	160	$125\cdot10^{-7}$	78
Cho'yan	$1,2\cdot10^5$	0,25	130	$104\cdot10^{-7}$	75
Mis	$1\cdot10^5$	0,32	60	$165\cdot10^{-7}$	83
Bronza	$1\cdot10^5$	0,35	90	$170\cdot10^{-7}$	82
Shisha	$0,56\cdot10^5$	0,25			

I-BOB. "MATERIALLAR QARShILIGI" FANIDAN AMALIY MAShG'ULOTLAR

Misol echishning maqsadi. Fanni o'rganishga ajratilgan vaqtning taxminan yarmi misollar echish uchun sarflanishi kerak. Ushbu vaqtni samarali sarflash uchun maqsadli misollarni tanlash, ularni ratsional echish usulini belgilash va albatta nazariy bilim tayyorgarligi bo'lishi lozim. Misol echishning maqsadi quyidagilardan tashkil topadi:

1. Fizik hodisalarni tushunish, mustaqil ijobiy ishlash, texnikaviy o'ylash va analiz qilish qobiliyatini rivojlantirish.
2. Amaliy savollarni echishda nazariy bilimlar yangiliklarini va ko'nikmalarini tadbiq etish. Bu erda real konstruktsiyalardan nazariy izlanishlar usullari va hisoblashlarida qabul qilingan hamda ruxsat etilgan hisoblash sxemalariga o'tish tushuniladi.
3. O'rganilayotgan fandan olingan bilimlarni chuqurlashtirish va mustahkamlash.
4. Hisoblash texnikasini rivojlantirish.
5. Texnik adabiyot va ma'lumotlar bilan ishlashni rivojlantirish.
6. Texnik hisoblashlarni bajarish bilan tanishish.
7. Texnik savollarni echishda ustuvor qobiliyatni shakllantirish.

Albatta, bu maqsad mustaqil shaklga egadir. Gap shundaki, dars jarayonida ishlangan misollarga o'xshash, lekin auditoriyada ishlanmagan misollar uyga vazifa qilib berilishi mumkin. Bunda talaba mustaqil bir-biriga o'xshash misollarni tahlil qiladi, echadi. Ustuvor qobiliyat rivojlanishi yoki shakllanishi uchun talaba uyda dars davomida echilgan misolga o'xshamagan misolni echishga harakat qilsa, bunda talaba mustaqil ravishda misolni sharti bilan tanishadi, uning hisoblash sxemasini chizadi va misolni echish usullarini izlaydi. Boshqa holat ham yuzaga kelishi mumkin, ya'ni fanni o'zlashtirish boshlanishida o'qituvchi tomonidan talabaga uyga vazifa sifatida murakkab misollar topshirilsa, talaba misol ustida bosh qotirish natijasida fanga qiziqishi pasayishi mumkin.

Misollarni tanlash. Qo'yilgan maqsadni amalga oshirishda auditoriyada yoki uyda echiladigan misollarni tanlash katta ahamiyatga ega.

Materiallar qarshiligining tarkibiy qismlari bo'yicha barcha misollar to'plamida hamma mavzularni qamrab olgan juda ko'plab misollar mavjud. Ularning soni dars davomida echilishi mumkin bo'lgan

misollarning sonidan 4-5 barobar ko'p bo'lishi mumkin. Shuning uchun, har bir o'qituvchi dars beradigan mutaxassislikning ish rejasiga binoan yoki o'zining shaxsiy uslubiy xislatiga ko'ra, u yoki bu misollarni tanlashi lozim. Bu o'rinda o'qituvchining o'zi misollar to'plamini yoki variantini tuzib, darsda foydalansa qiziqarli bo'ladi.

Tanlangan misollar ushbu mavzuning barcha savollarini qamrab olishi kerak. Masalalarni tanlash va echish uchun ko'rsatilgan adabiyotlar talabalarga materiallar qarshiligi muammolarini to'liqligicha o'rganish va echimini topishga yordam beradi.

V.K.Kachurinning «Materiallar qarshiligidan masalalar to'plami» asosan masalalarni talabalarning o'zlari echishlari uchun mo'ljallangan bo'lib, amaliy mashg'ulotlarda masala echish uchun asosiy darslik.

M. Ergashevni «Materiallar qarshiligidan hisoblash – loyihalash ishlari» o'zbek tilida yozilgan va chop etilgan birinchi to'plam bo'lib, materiallar qarshiligining hamma bo'limlariga oid hisoblash – loyihalash ishlari, masalalari va ularni bajarish namunalari keltirilgan. S.Xasanov va A.Nabievlarning materiallar qarshiligidan masalalar echish qo'llanmasi lotin alifbosida chop etilgan. Bir qism savollar dars vaqtida o'rganilsa, ayrim savollar uyga vazifa tarkibida ko'rib chiqilishi mumkin.

Materiallar qarshiligi fani bo'yicha tuzilgan masalalar to'plamida ko'p variantli misollar ham keltirilgan. Bunday misollarni dars vaqtida echish samara bermaydi, ularni uy vazifasi yoki hisoblash-grafik ishi ko'rinishida bajarish qulaydir. O'qituvchilik faoliyatini boshlagan yosh pedagoglar ko'p variantli misollarni echishlari va tajriba orttirishlari mumkin. Keyinchalik boshqa turdagi mavzularni to'liq yoritadigan misollar to'plamini echishga o'tishlari lozim.

Misollarni mavzusi, ya'ni echilishi shart bo'lgan muammoni qo'yilishi murakkab emas. Lekin quyidagi fikrlarni keltirish lozim deb o'ylaymiz:

Birinchidan, bakalavrlar tayyorlaydigan oliy ta'lim muassasalarida nazariy (mutaxassislikka bog'liq) material to'liq va chuqur yoritilmasligi mumkin, ko'p vaqt talabalarning uy vazifasi yoki hisoblash-grafik ishiga yaqin mavzular bo'yicha misollar echiladi.

Ikkinchidan, ayrim vaqtlarda asosan nazariy materiallarga e'tibor beriladi va aniq bitta tahlil yoki ikkinchi formula bilan echiladigan misollar tahlil etiladi.

Tajriba shuni ko'rsatadiki, hajmi kichik yoki oddiy misollarni tanlash va nazariy materiallarni chuqur o'zlashtirmaslik natijasida, talaba tanish va oddiy misollar turkumiga o'rganib oladi va u murakkabroq misollardan

hadiksirab qoladi. Masalan, materiallar qarshiligidan misol echishni mustaqil bajara olgan talaba mashina detallari fanidan misol echishda qiyinchilikka uchrab qolishi mumkin.

Uchinchidan, amaliy mashg'ulotlarda tadbiq etilmagan nazariy bilimlar chuqur va mustahkam emas. Bunday sharoitda talaba ham, o'qituvchi ham og'ir vaziyatda qoladi.

Misollarni murakkabligi yoki boshqa ko'rsatkichlarga binoan tanlash hamma vaqt ham samarali bo'lavermasligi mumkin. Shuning uchun misollarni quyidagi guruhlarga ajratishni tavsiya etamiz:

I guruh. Bu guruhdagi misollar hech qanday qiyinchilik tug'dirmaydi, hajmi kichik va oddiy bo'lib, maqsadi formulalarni takrorlash, turli o'lchov birlikdagi kattaliklar bilan hisoblashni o'rganish. Masalan, buralishda mustahkamlik shartidan foydalanib val diametrini aniqlang.

II guruh. Bu guruhdagi misollar oddiy, savolning fizik mohiyati va echish usuli aniq.Masalan, yuklanishni har xil turlarida statik aniq misollarda mustahkamlikka hisoblash. Bu guruhdagi misollarni ham murakkabligi turlicha bo'lgan misollarga ajratish mumkin. Masalan, cho'zilish yoki siqilishda ichki bo'ylama kuchni aniqlash va epyurasini ko'rish, egilish deformatsiyasida ko'ndalang kuch va eguvchi moment epyuralarini qurishdan ancha oson. Bundan tashqari, ko'ndalang kuch va eguvchi momentini aniqlash qoidasi, bo'ylama kuchni aniqlash qoidasidan mutlaqo farq qiladi va murakkabdir.

III guruh. Bu guruh misollarning murakkabligi turlicha bo'lib, ular mavzuga bog'liq. Masalan, statik noaniq misollarda murakkablik, misolni echishni individuallashgan va uning fizik-geometrik mohiyatini aniq tushunish va tasavvur etishdadir. Misolni individuallashgan, har bir statik noaniq misolni echishning o'ziga xos usulni tadbiq etishligida. Bu guruh misollariga mo'rt materiallardan tayyorlangan balkalarni mustahkamlikka hisoblash, o'zgaruvchan balkalarda kesimni tanlash kiritilishi mumkin.

IV guruh. O'ta murakkab misollar bo'lib, ularni echish uchun nostandart usullar tadbiq etiladi. Bunday misollarga fanlar olimpiadalaridagi yoki fan to'garaklarida echiladigan misollar kiritiladi.

V guruh. Og'zaki echiladigan misollar, hozirgi vaqtda tadbiq etilayotgan oddiy ko'rinishdagi test savollari.

Misollarni tanlash to'g'risida mulohaza yuritganda shuni nazarda tutish kerakki, misollar rivojlanadigan, yangilik kiritilishi mumkin bo'lgan bo'lishi lozim. Juda katta matematik hisoblashlari bo'lgan misollarni tanlamaslik kerak. Chunki bunday misollarni echishda talaba matematik

hisoblashga e'tiborini kuchaytirib, misolning fizik yoki geometrik mohiyatini esidan chiqarib qo'yishi mumkin. Shu bilan birga, hisoblash elementi juda kam bo'lgan, faqat formulalarni yoki tenglikni hosil qilish bilan bog'liq bo'lgan misollarni ham tanlamaslik kerak. Chunki analiz qilinishi lozim bo'lgan material yoki inshoot konstruktsiyasining elementi – o'lchamlari ma'lum son qiymatlari bilan belgilanadi.

Auditoriyada misol echishni tashkillashtirish. Misol echishning shakllari va ular to'g'risida qisqa fikr bildiramiz.

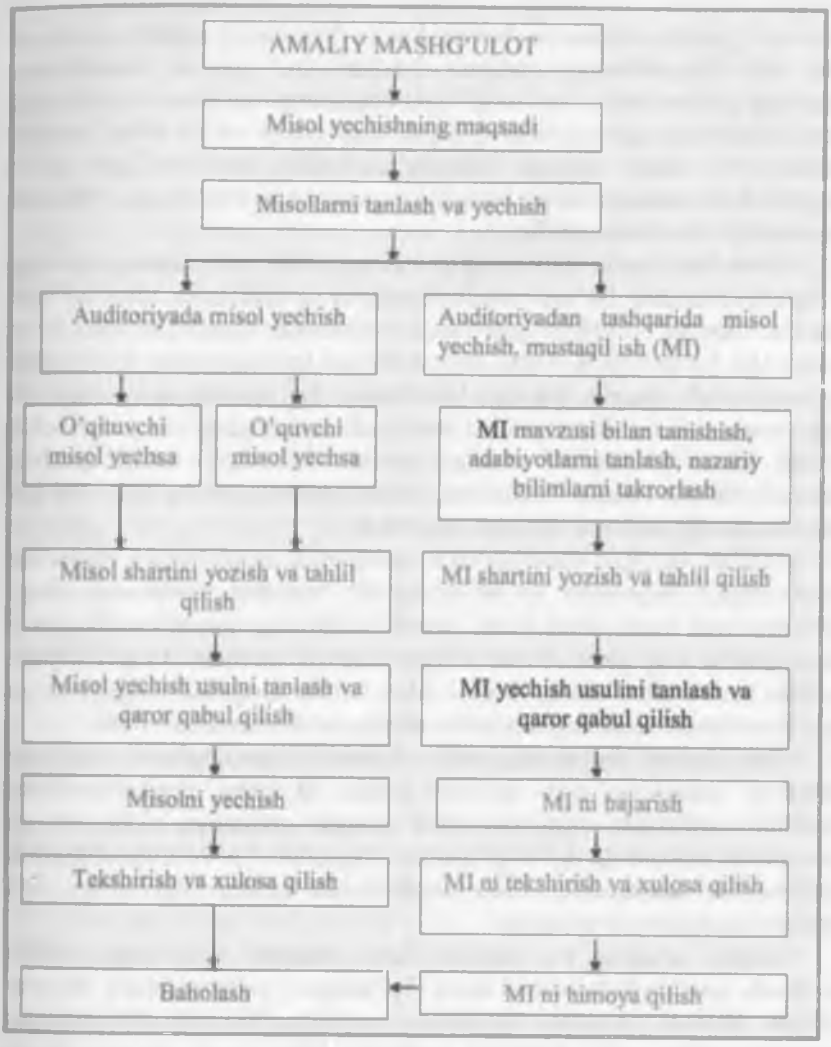
O'qituvchining o'zi misol echsa. Bu shakl fanning har bir mavzusida tadbiq etiladi. O'qituvchi doskada mavzu bo'yicha birinchi misolni qanday echsa, talabalar ushbu yoki boshqa misolni echish usulini shunday tushunib oladi.

O'qituvchi misol shartini yozib olishdan va tushunishdan boshlab, uni echish usulini to'liq yoritishi, matematik hisoblashlarni bajarib, misol natijalarini analiz etish bilan tugatishi lozim. Hech kachon o'qituvchi misolni echish davomida, uni to'liq bilishligini, shuning uchun misolni yoddan ishlab berayotganligini talabalarga bildirmasligi kerak. Balki misolni echishda o'qituvchi talabalarga savollar bilan murojaat qilib, ularni ham misol echishda qatnashayotganligini bildirishi va mustahkamlashi hamda bu vaziyatni talaba mustaqil misol echishida o'qituvchining uslubini takrorlanishini ta'minlashi lozim. O'qituvchi talabada misol echishni ijobiy shakllantirishi kerak.

Doskada talaba misol echsa. Bu shakl to'liq o'qituvchining nazoratida bo'ladi va ayrim hollarda uning yordami seziladi. Bunda barcha talabalarning faolligi talab etiladi, ulardan misol echish tartibini tushuntirishni, hisoblash natijalarini tekshirishni talab etish kerak.

Talaba o'tirgan joyida misol echsa. Bu shakl albatta misol tahlil qilingan va u doskada talaba yoki o'qituvchi tomonidan ishlanayotgan bo'lsa, tadbiq etiladi. Bunday paytda o'qituvchi talabalarning faoliyatini nazorat qilib turadi. Lekin ushbu shakl vaqtni kamligi uchun tadbiq etilishi cheklangan.

Tajriba qurilmasidan foydalanib misol echish. Talaba nazariy misolni echadi va tajribada sinab ko'radi. Nazariy va tajriba natijalari solishtiriladi. Bu shakl katta ahamiyatga ega va u tajriba ishini o'tkazish darsidir. Uning samarasini oshirish uchun tajriba qurilmalari to'liq va benuqson ishlashi kerak.



Misol shartini yozish va tahlil qilish. Qo'yilgan maqsadga erishish uchun faqat misolni tanlash va uni echish emas, balki misolning shartini muhokama va tahlil qila bilish lozim. Bu esa talabaning texnik mushohada qilish qobiliyatini yaxshilaydi. Misol tariqasida shkivlar o'rnatilgan transmission valni hisoblashni olamiz. Terminni tushuntirish, tasmalarning

taranglik kuchlari, ularning yo'nalishi va taranglik kuchlarining valga bosimi to'g'risida tushuncha berish lozim. Misolning amaliy mohiyati, balki hali o'rganilmagan mashina detallari fani asosida transmission vallarning qo'llanilish sohasi to'g'risida talabalarga ma`lumot berish usuli bilan, ularda misolga nisbatan qiziqish uyg'otiladi va bu holat misolni echishda o'z aksini topadi. Misolni echishda lozim bo'lgan ayrim qisqartirish va cheklanishlar hamda o'zgarishlarni talabalarga oldindan tushuntirish o'ta ahamiyatlidir.

Ayrim misollarda fizik jarayon qisqartirilishi yoki ahamiyatga ega bo'lmasligi mumkin. Bu vaziyatni tushuntirish va tahlil etish zarur bo`ladi. Masalan: massasi 500 N bo'lgan yuk 2 s davomida vertikal holatda 10 m balandlikka ko`tarildi. Berilgan ruxsat etilgan kuchlanishdan foydalanib, kanatning talab qilingan diametri hisoblansin. Bu misolda jarayonni fizik nuqtai nazaridan harakat xarakteri hisoblash natijasiga ta`siri juda kichik bo'ladi. Misol cheklanish evaziga echildi. Misollarni tahlil qilishda ularning shartida amaliy mohiyatini ochib berish kerak bo'ladi. Bu esa talabada misolga nisbatan qiziqish uyg'otadi.

Masalan, berilgan materialdan va o'lchamda tayyorlangan val uchun ruxsat etilgan momentni ko`rib chiqaylik: metallni kesishning yangi rejimiga o'tish munosabati bilan, stanok valikining mustahkamlik sharti uchun qanday eng katta ruxsat etilgan burovchi moment to'g'ri keladi. Metallni kesish sifati uning sirtiga ishlov berish darajasini belgilaydi, bu esa o'z navbatida valikning mustahkamligiga ta`sir etuvchi omildir.

Misol shartini muhokama qilish yoki tahlili ham rivojlanuvchan, ham tarbiyaviy xarakterga ega bo'lishi kerak. Masalan: mustahkamlikka ehtiyotlik koeffitsienti birlamchi qabul qilingan qiymatiga ko'ra 10% ga kamaytirilsa, balkaning og'irligi qanday o`zgaradi. Bu misolda ehtiyotlik koeffitsientini kamaytirish katta qurilishlarda qanday ahamiyatga ega ekanligini tushuntirish mumkin.

Misolni ortiqcha va etishmaydigan shartlari to'g'risida. Ayrim misollarda uni echish uchun kerak bo'lmagan, ya`ni ortiqcha shartlar berilgan bo'ladi. Masalan, buralishda mustahkamlikka hisoblanayotgan valning uzunligi yoki detalning materiali bilan birga ruxsat etilgan kuchlanishining qiymati berilgan.

Misolni shartida ortiqcha ma`lumot yoki qiymatlar berilishi foydalidir, chunki talabani o'ylab tahlil qilishga o'rgatadi, texnik muammoni echishda ular kerak emas, lekin konstruktsiyani to'liq tasavvur qilish uchun hamda misol echish davomida talaba tegishli formulani izlab topishida ushbu ma`lumot samara beradi.

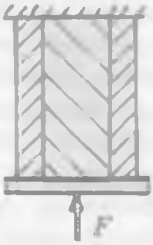
Ayrim hollarda to'liq ma'lumot bo'lmagani ma'qul, chunki real loyihalashda konstruktorning o'zi bir qancha kerak bo'lgan ma'lumotlarni tanlashini talaba bilib oladi. Bunday misollar mashina detallari fanida uchraydi. Materiallar qarshiligida qo'shimcha ma'lumotlarni kitoblardan qidirib topiladi. Bunda yuklanish xarakteri va material ko'rsatilgan, lekin ruxsat etilgan kuchlanish berilmagan. Masalan, ichi g'ovak valning uzatayotgan quvvati va uning aylanish chastotasi berilgan. Valning diametri hisoblansin. Buning uchun valning o'rtacha diametrini, uning ichki va tashqi diametrlari bilan tashkil qilgan nisbatidan foydalaniladi.

Misolni faqat sharti ahamiyatli deb tushunmaslik kerak, balki uni to'liq ma'nosini saqlagan holda qisqa yozish kerakki, talaba har daqiqa to'liq shartni tiklay olsin. Kitobda misolning shartı to'liq yozilganligi uchun, uni yozish shart emas deyish noto'g'ri. Ayrim hollarda yozish elementi deb, sxema yoki chizmani tuzish tushuniladi. Eng yomon holat chizmani yozuv asosida tushuntirish yoki uning mazmunini yoritish. Oddiy misollarda shartni o'qib, uni yozib (doskada yoki daftarda) talaba tegishli chizmani bajara olishi kerak. Murakkab misollarda bu savolni echimi juda qiyinlashadi. Chizmalarda o'lchamlarning shartli belgilarini berilishi yozuvni qisqartiradi. Konstruktiv yoki yarim konstruktiv sxemalardan hisoblash sxemalariga o'tish yozuv asosida emas, balki misolni echish elementi sifatida bajariladi. Masalan, valni buralish bilan egilishga hisoblash.

Misol echish usulining asosiy tamoyillari. Auditoriyada o'qituvchi yoki talaba tomonidan misol echishni asosiy tamoyillariga: shartni yozish, misol echishni yozishning shakli va ketma-ketligi, hisoblash ishlarining bajarilishiga rioya qilishlari kerak. Ushbu uslubiy tamoyillar ketma-ket va astoydil bajarilishi kerakki, natijada talaba uyda yoki doskada misolni mustaqil echishda quyida keltiriladigan uslubiy ko'rsatmani tadbiq etsin.

Misolni sharti yozilgan va tahlil qilingan vaziyat uchun quyidagi uslubiy tamoyillarni keltiramiz:

1. Misol «sifatli echilgan» bo'lishi kerak. Misolni echish boshlanishida, talabada «Qaysi formula bilan misolni echish mumkin» degan savol paydo bo'ladi. Agar bu savolni talabaga o'qituvchi bersa, eng yomon vaziyat sodir bo'ladi. «Sifatli echilgan» misol deganda, mohiyati tahlil qilingan va echish tartibi so'zma-so'z izohlangan misol, formula esa bildirilgan fikrning matematik ifodalanishi va u tegishli hisoblashlardan keyin sonli echimga olib keladi.



1-rasm.F- ta'siridagi sterjenlar.

Misol. Siquvchi F kuch po'lat va bronza sterjenlarga (*1-rasm*) P-detali orqali ta'sir qiladi. Sterjen ko'ndalang kesimining o'lchamlari topilsin ($A_p=2A_b$). Po'lat va bronza materiallarining elastiklik modullari bir xil emas, ya'ni po'lat materialining elastiklik moduli E_p bronza materialining elastiklik moduli E_b dan katta. Demak, po'lat sterjen bo'lmaganida bronza sterjeni F kuch ta'siridan ko'proq siqilar edi. Lekin ham bir xil uzayadi. F- siquvchi kuchning har kaysi sterjenga ta'sirini topish uchun bitta tenglama tuzish mumkin: $F_b + F_n = F$ Bitta tenglamada ikkita noma'lum kuch bor. Demak, misol statik noaniq. F_b va F_p kuchlarni topish uchun qo'shimcha deformatsiya tenglamasini tuzamiz. Tashqi siquvchi kuch ta'sirida har ikkala sterjen ham bir xil masofaga siqiladi. Guk qonuniga asosan: $\Delta\ell = \frac{F_b\ell}{E_bA_b} = \frac{F_n\ell}{E_nA_n}$

Endi muvozanat va deformatsiya tenglamalarini birgalikda echib, misolning shartiga tegishli savollariga javob topiladi.

2. Misol umumiy holda echilgandan keyin matematik hisoblashga o'tamiz. Hisoblash bandma-band ketma-ketlikda olib boriladi va har bir band uchun oldindan hisoblanishi lozim bo'lgan formula belgilanadi. hisoblash natijalari alohida ajratib yoziladi.

Murakkab va hajmi katta matematik hisoblashni bajarishda yordamchi hisoblashlar olib boriladi. Yordamchi hisoblashlar umumiylashtiriladi (mujassamlashadi) va sonli natijaviy qiymat kelib chiqadi. Bu erda misol echishni usuli va uni tashkil etish muammosi to'g'risida to'xtalib o'tamiz. Gap shundaki, mustaqil misol echishda talabalarni birdaniga oq varaqda bajarishga o'rgatish kerak, chunki birlamchi hisoblash qora qog'ozda bajarilsa, ortiqcha vaqt va ish talab etiladi. Formulaga barcha kattaliklarning son qiymatlarini qo'yishdan oldin, ularning o'lchov birliklarini bir xil sistemaga keltirilishi lozim. Buni og'zaki bajarish kerak. Masalan, 100 kN kuch bilan cho'zilayotgan sterjenning uzayishi aniqlansin, agar $l = 2m, d = 60mm, E = 2\cdot10^5 mPa$ bo'lsa, hisoblash formulasi – $\Delta l = \frac{N\cdot l}{EA}$ ni $\Delta l = \frac{100000\,N\cdot 2m}{2\cdot10^{11}\,Pa\left(3{,}14\cdot\frac{0{,}06^2}{4}\right)m^2}$

- ko'rinishda yozmaslik kerak. Hozirgi vaqtda ko'plab xorij adabiyotlardagi hisoblash formulalarida o'lchov birliklar keltiriladi

To'g'ri yozuv $\Delta l = \dfrac{100 \cdot 10^3 \cdot 2}{2 \cdot 10^5 \cdot 10^6 \cdot \dfrac{3{,}14 \cdot (60 \cdot 10^{-3})^2}{4}} = 0{,}354 m$

Sterjen kesim yuzasini alohida hisoblash shart emas, vaholanki, ayrim hollarda, masalan, murakkab shaklli kesim yuzalarining geometrik xarakteristikalari alohida hisoblanib, natijasini formulaga keltirib qo'yish mumkin. Hisoblash jarayoniga juda katta e'tibor berish bilan birga quyidagilarga amal qilish lozim:

-hisoblash natijasini juda katta aniqlik bilan yakunlashni izidan quvlamaslik. Bunga o'zingizni ham talabalarni ham o'rgatish kerak. Xususiy hollarda verguldan keyin uch xonali aniqlik bilan hisoblash amalini bajarish lozim. Asosan, yaxlitlash va yaqinroq rakamlar hisoblansa bo'ladi;

-talabalarni og'zaki hisoblashga o'rgatish kerak;

-olingan natijalarni tahlil qilishni, ularni to'g'ri ekanligini muhokama etishni o'rgatish lozim;

-hisoblash amaliga rioya qilish, ya'ni kasrni surati va maxrajini ketma-ketlikda bajarish kerak.

Hisoblashni aniqlik bilan bajarilishiga izoh berish talab etilishi mumkin. Masalan, cho'zilish yoki siqilish, egilish deformatsiyalarida statik noaniq misollarni echishda tayanch nuqtalardagi deformatsiyalarni nolga teng bo'lishini keltirib chiqarishda, nazariy hisoblash va tajriba ishlarining natijalarini taqqoslashda aniq hisoblash natijasiga erishish talab etiladi. Chunki noaniqlik bilan bajarilgan hisoblash natijasi xatolikni olib keladi.

3. Misol echimining sonli qiymatlari hisoblash natijasiga ko'ra, uni xulosa qilishni talab etadi.

Natijani tekshirish va tahlili quyidagilardan tashkil topadi:

a) echimni to'g'ri va aniqligim baholash, talabaga texnik misollarni echishni va ularning natijalarini baholashni, ayrim hollarda, tanqidiy mushohada yuritishni o'rgatadi;

b) echimni nazorat etish usullarini ishlab chiqish va mushohada qilish. Masalan, ko'ndalang kuch va eguvchi moment epyurlari asosida ular orasidagi differentsial bog'lanishlarni bajarilishi nazorati. Agar misol mustahkamlikni tekshirish nuqtai nazaridan olib borilayotgan bo'lsa, ichki kuch faktorlarining epyurlari va differentsial bog'lanishlarini tekshirishni

misol echimining natijasini kutib o'tirmasdan, balki epyura qurilishi bilan amalga oshirilishi kerak;

v) nazariy, amaliy va texnik qoidalarni tahlil qilish nuqtai nazaridan echimni mushohadasi. Masalan, val minutiga n marotaba aylanib N, kvt quvvatni uzatadi. Berilgan ruxsat etilgan kuchlanishdan foydalanib, val kesimining uch xil shakli topilsin. aylana, halqa ($c = \frac{d_1}{d}$ berilgan), kvadrat; har bir valning massalari solishtirilsin. Agar valning markaziy kesimidagi materialini olib, uning og'irligini 16% kamaytirsak, hosil bo'lgan halqasimon kesimning sirtidagi eng katta kuchlanish 26% oshar ekan. Radiusi *R=350 mm* bo'lgan halqasimon val radiusi *R=300 mm* bo'lgan valdan 53,4 % ga engildir. Shunga qaramasdan halqasimon kesim kam ishlatiladi. Kvadrat kesimli val ishlatilmaydi. Bu erda ishlatil-maslik mustahkamlik va texnologik nuqtai nazardan isbotlanmoqda;

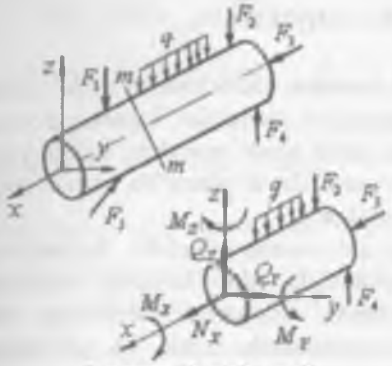
g) ayrim detal va o'lchamlarni standartlashtirilishini esdan chiqarmaslik kerak. Natijaviy qiymatlarni yaxlitlamasdan va GOST bilan solishtirmasdan qabul qilmaslik kerak. Masalan, valning diametri *d=44,2 mm*, GOST bo'yicha *d=45 mm* qabul qilamiz.

14. Yuqorida keltirilgan mulohazalar, shak-shubhasiz «Materiallar qarshiligi» fanida misol echish usullarini to'liq kamrab olmaydi. Ma'lumki, har bir misolni echishda o'zining xususiy usullarini tadbiq etishni talab etadi. Shuning uchun o'qituvchilar fanning alohida bo'limlarida misol echish usullarini ishlab chiqishlari va tadbiq etishlari mumkin.

KESISh USULI

Inshoot konstruktsiyalarini mustaxkamlikka va bikrlikka hisoblash ichki kuchlarni aniqlash usuli asosida olib boriladi.

Ichki kuch deb, tashqi kuch ta'sirida jism zarrachalarining o'zaro ta'sirlashuvining intensivlashuviga aytiladi. Ichki kuchlar kesish usuli bilan topiladi.



2-rasm. Kesish usuli

Kesish usulining tartibi.

Bir kancha kuchlar bilan yuklangan brusning ixtiyoriy kesimidagi ichki kuchni aniklash tartibi.

1.Brusni ixtiyoriy kesim yuzasidan ***m – m*** tekislik bilan fikran kesib ikkita bo'laklarga ajratamiz va bir bo'lagini tashlab yuboramiz.

2.Natijada, brusning olib kolingan qismida tashlab yuborilgan kismning ta'siri yo'qotiladi va olib qolingan qismda muvozanat holati buziladi.

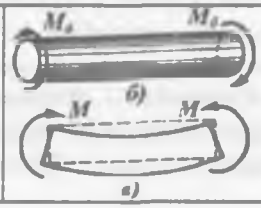
3. Olib qolingan qism muvozanatini ta'minlash uchun uning kesilgan yuzasiga tashlab yuborilgan qism ta'sirini bosh kuch vektori $\overline{R}$ va bosh moment vektori $\overline{M}$ ko'rinishida keltirilishi lozim.

4. Bosh kuch vektori va bosh moment vektori olib qolingan qism uchun ichki kuch hisoblanadi. $\overline{R}$ va $\overline{M}$ lar *X, Y, Z* o'qlarida *Nx, Qy, Qz, Mx, My, Mz* tashkil etuvchilarga ajratiladi:

Nx, Qy, Qz, Mx, My, Mz – **ichki kuch** faktorlari deyiladi

N_x – bo'ylama kuch, brusning *x* o'qi bo'ylab yo'nalgan. N_x – ichki bo'ylama kuch cho'zilayotgan yoki siqilayotgan brusning ko'ndalang kesimida hosil bo'ladi. (*a – rasm*). Q_y; Q_z – brusning *x* o'qiga perpendikulyar joylashganligi uchun **ko'ndalang** yoki **kesuvchi** (*siljituvchi*) **kuch** deyiladi.

M_x – burovchi moment buralish deformatsiyasida brusning ko'ndalang kesimida hosil bo'ladi. (*b – rasm*). M_y va M_z – eguvchi momentlari egilish deformatsiyasida brusning ko'ndalang kesimida hosil bo'ladi (*v– rasm*). Ichki kuch faktorlarini topish uchun brusning ajratilgan qismidagi barcha kuchlardan muvozanat shartlari tuziladi.

$\sum X = 0$ $\sum U = 0$ $\sum Z = 0$	$\sum M_x = 0$ $\sum M_u = 0$ $\sum M_z = 0$		

I. ChO'ZILISh VA SIQILISh

Mustahkamlikka hisoblashga oid masalani auditoriya va uyda echish uchun tanlash kerak. Darslik, qo'llanma va masalalar kamroq bo'lsa, o'qituvchinng o'zi bir nechta masalani tuzib olishi mumkin. Lekin V.K. Kachurining "Materiallar qarshiligidan masalalar to'plami"da bu mavzuga oid masalalar varianti etarli miqdorda berilgan.

Ruxsat etilgan yukni hisoblashga oid masala echishda, ko'ndalang kesim yuzalarning o'lchamlarini aniqlashda turli kesimli sterjenlar sistemasidan foydalanishni tavsiya etamiz. Sterjenlar sistemasiga oid masalani echishda kesish usulidan foydalanish kerak va siqilishga hisoblashda ularning ustuvorligi ta'minlangan bo'lishi lozim.

Ichki bo'ylama kuchni topish. Cho'zilish va siqilishda ichki bo'ylama kuch – brusning ko'ndalang kesimidagi barcha normal kuchlarning teng ta'sir etuvchisi. Bo'ylama kuch – brusning kesilgan ko'ndalang kesimidan bir tomonda olib qolingan tashqi kuchlarni ushbu sistemaning bo'ylama o'qiga proektsiyalarining algebraik yig'indisiga teng. Amaliyotda uchraydigan konstruktsiya qismlarining ko'pchiligi ko'ndalang kesimda hosil bo'ladigan ichki cho'zuvchi yoki siquvchi bo'ylama kuchlarini kesish usulidan foydalanib, sistemaning ajratilgan bo'lagini muvozanat shartidan topiladi.

$$\sum X = -F + N = 0$$

Bo'ylama kuch N deb, sterjenning ko'ndalang kesimida hosil bo'lgan normal kuchlanishlarning teng ta'sir etuvchisiga aytiladi

$$N = \int_A \sigma \cdot dA \qquad (1)$$

Cho'zilishda (siqilish) brus materialining zarrachalari bo'ylama bir xil masofaga masofaga ko'chadi . Shuning uchun, normal kuchlanish brusning kesim yuzasida teng tarqaladi.

Kuchlanish – sterjenning kesim yuzasida ichki bo'ylama kuchni tarkalish konuniyatini belgilaydi. Kuchlanish deb bir birlik yuzaga to'g'ri keladigan kuchning miqdoriga aytiladi.

Cho'zilish va siqilishda sterjenning kesim yuzasida normal kuchlanish hosil bo'ladi: $\sigma = \frac{N}{A}$, $\frac{kN}{m^2}$ (2)

Agar cho'zuvchi yoki siquvchi kuch maksimumga erishsa, ya'ni chegaraviy qiymatga chiqsa $N = N_{max}$ bo'lsa, normal kuchlanish ham maksimal chegaraviy qiymati $\sigma_{max} = \frac{N_{max}}{A}$ ga erishadi. Konstruktsiyada xavfli holat emirilish sodir bo'ladi.

Konstruktsiyada xavfli holatni cheklash uchun elementining qesim yuzasidagi eng katta normal kuchlanish σ_{max}, shu konstruktsiya materiali uchun ruxsat etilgan kuchlanishdan katta bo'lmasligi kerak, ya'ni

$\sigma_{max} \le [\sigma]$ yoki $\sigma_{max} = \frac{N_{max}}{A} \le [\sigma]$ (3)

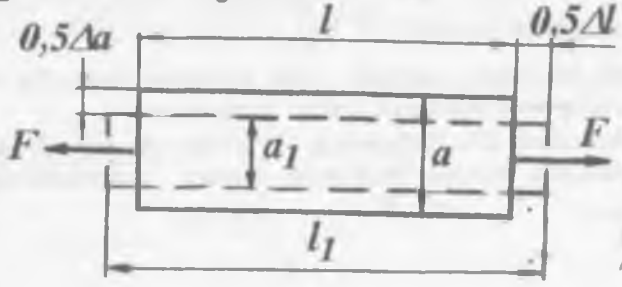
(3) formula cho'zilish yoki siqilishda mustahkamlik shart

Ruxsat etilgan kuchlanish konstruktsiyani xavfsiz ishlashini ta'minlaydi va uning qiymati konstruktsiyaning materialiga bog'liq bo'lib tajriba asosida belgilanadi. Cho'zilish va siqilishda loyihaviy hisoblashda sterjennning

kesimi tanlanadi: $A \ge \frac{F}{[\sigma]}$ (4)

Ruxsat etilgan yuk hisoblanadi: $F_{max} = [\sigma] \cdot A$ (5)

Deformatsiya. Cho'zilish va siqilish sterjennning bo'ylama va ko'ndalang o'lchamlarini o'zgarishi bilan xarakterlanadi.



Masalan, sterjenni cho'zilishida uzun-ligi ortadi, ko'ndalang kesimi esa qisqaradi. Siqilishda teskari holat, ya'ni sterjenning uzunligi qisqaradi, ko'n-dalang o'lcham esa kattalashadi

Sterjen bo'ylama va ko'ndalang o'lchamlarining o'zgarishi bo'ylama va ko'ndalang deformatsiyalar deyiladi. Absolyut va nisbiy deformatsiyalar mavjud. Absolyut uzayish (deformatsiya) sterjenni cho'zilganidan keyingi va boshlang'ich uzunliklarining farqi bilan belgilanadi. Absolyut qisqarish ko'ndalang kesimning boshlang'ich va deformatsiyadan keyingi o'lchamlar farqi bilan belgilanadi.

$\Delta\ell = \ell_1 - \ell_0$ bo'ylama va $\Delta a = a_0 - a_1$ ko'ndalang deformatsiyalar absolyut deformatsiya deyiladi.

Bir birlik uzunlikka to'g'ri keladigan absolyut uzayishga nisbiy bo'ylama uzayish deyiladi.

$\varepsilon = \frac{\Delta\ell}{\ell}$ nisbiy bo'ylama uzayish va $\varepsilon' = \frac{\Delta a}{a}$ nisbiy ko'ndalang qisqarishlar nisbiy deformatsiya deyiladi.

Nisbiy ko'ndalang deformatsiyani nisbiy bo'ylama deformatsiyaga nisbati o'zgarmas miqdor va Puasson koeffitsienti deyiladi.

$$\mu = \frac{\varepsilon'}{\varepsilon} \qquad (6)$$

Sterjenning uzunligi ham, absolyut cho'zilishi ham (mm) yoki (sm) hisobida o'lchanganligi uchun nisbiy bo'ylama deformatsiya o'lchovsiz son bo'ladi.

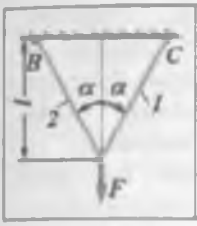
Agar, sterjenning cho'zilishi faqat elastik deformatsiya chegarasida qaralsa, cho'zuvchi kuch bilan absolyut uzayish orasida to'g'ri propoptsionallik bog'lanish bo'ladi. Bu bog'lanish inglız olimi Robert Guk qonuni deyiladi: $\Delta\ell = \frac{N\ell}{EA}$ (7)

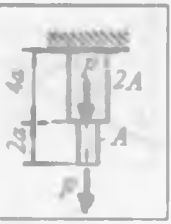
Elastik bo'ylama uzayish, ichki bo'ylama kuch va sterjenning uzunligiga to'g'ri va bikrligiga teskari proportsional.

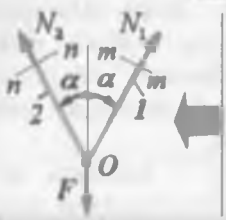
(7) formulada EA sterjenning cho'zilish yoki siqilishdagi bikrligi. Elastik jismlarda, normal kuchlanish nisbiy deformatsiyaga to'g'ri proportsional $\sigma = E \cdot \varepsilon$ (8)

Statik aniq sistemalar

Tarkibidagi noma'lum reaktsiya va ichki kuchlarining soni statikaning muvozanat tenglamalari soniga teng yoki undan kam bo'lgan sistemalar statik aniq sistemalar deyiladi.







Ichki kuchlarni aniqlash uchun kesish usulidan foydalanamiz

pastki pog'ona

yuqori pog'ona

Ichki kuchlarni aniqlash uchun olib qolingan sistemaning yuklanish sxemasiga asosan statikani muvozanat tenglamalarini tuzamiz

$$\sum x = N_1 \sin\alpha - N_2 \sin\alpha = 0$$
$$\sum y = N_1 \cos\alpha + N_2 \cos\alpha - F = 0$$

$$\sum x = N_1 - F = 0 \qquad \sum x = N_1 - F - F = 0$$

Noma'lum kuchlar soni muvozanat tenglamalari soniga teng

Birinchi tunglamadan $N_1 = N_2$

e'tiborga olsak, $N_1 = N_2 = \dfrac{F}{2\cos\alpha}$

hosil bo'ladi

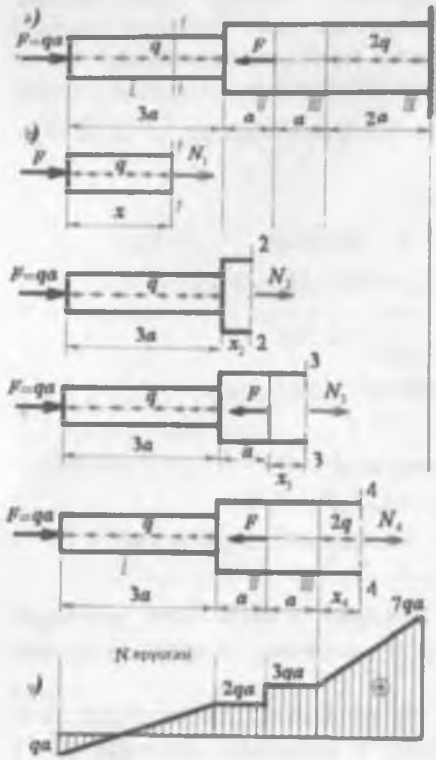
$$N_1 = F \qquad N_2 = 2F$$

Ichki kuchlarni har bir qiymati uchun normal kuchlanish va absolyut uzayishni aniqlaymiz

birinchi sterjen (pog'ona) $\sigma^{I} = \dfrac{N_1}{A_1}$ va $\Delta\ell_1 = \dfrac{N_1 \cdot \ell_1}{E \cdot A_1}$

ikkinchi sterjen (pog'ona) $\sigma^{II} = \dfrac{N_2}{A_2}$ va $\Delta\ell_2 = \dfrac{N_2 \cdot \ell_2}{E \cdot A_2}$

$$\left(\Delta\ell_2 = \Delta\ell_1 + \frac{N_2 \cdot \ell_2}{E \cdot A_2}\right)$$



IY- IY oraliq. $\sum X = 0$

$N_4 + F - q \cdot 3a - F - 2q \cdot x = 0$

$x = 0$ bo'lsa $N_4 = 3qa$

va $x = 2a$ bo'lsa

$N_4 = 7qa$

N_X - ichki bo'ylama kuchni brus o'qining uzunligi bo'ylab o'zgarishining tanlangan masshtabdagi grafikasi uning epyurasi deyiladi.

5 – rasm. Ichki kuchni aniqlash texnologik xaritasi
a) pog'onali brusni yuklanish sxemasi;
b) pog'onali brusni kesish tartibi;
v) pog'onali brus uchun ichki bo'ylama kuch epyurasi

4-misol. Po'latdan tayyorlangan sterjenlar sistemasidagi B nuqtaning to'liq ko'chishini toping (6-rasm - *a*) .

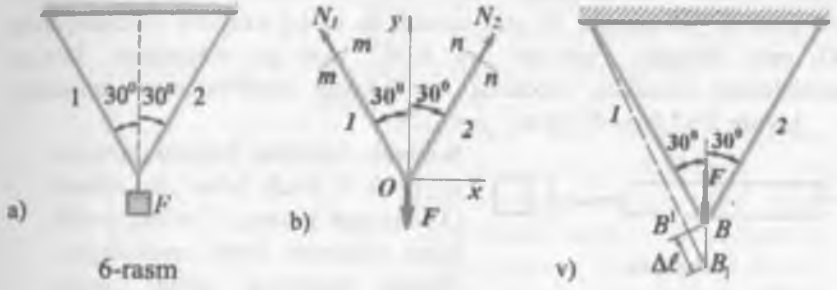
$$\ell_1 = \ell_2 = 3m, \quad A_1 = A_2 = 1 \cdot 10^{-4} m^2, F = 10kN, \qquad E = 1 \cdot 10^8 \frac{kN}{m^2}$$

echish. Ichki kuchlarni oldingi misolning echimiga asosan hisoblaymiz: $N_1 = \frac{F}{2 \cdot \cos 30^0} = \frac{10}{2 \cdot 0{,}866} = 5{,}77kN$

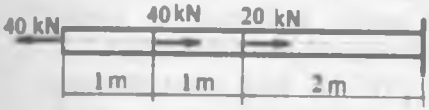
Deformatsiyani hisoblash. F kuch ta`siridan sterjenlar uzayadi (6-rasm-*v*) B nuqta B_1 nuqtaga ko'chadi. B nuqtadan birinchi sterjenni uzaygan holatiga tik chiziq o'tkazib, B^1 nuqtani hosil qilamiz. Bu erda $BB^1 \perp B_1B^1$ va ΔBB_1B^1 dan $BB_1 = \frac{B_1B^1}{\cos 30^0}$

Bu erda $B_1B' = \Delta\ell_1$ birinchi sterjenni absolyut uzayishini Guk qonuni orqali ifodalaymiz: $\Delta\ell_1 = \frac{N_1 \cdot 3}{EA} = \frac{5{,}77 \cdot 3}{1 \cdot 10^6 \cdot 1 \cdot 10^{-4}} = 17{,}31 \cdot 10^{-4} m$

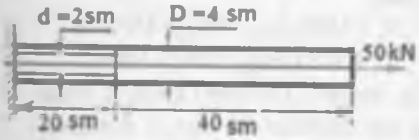
B nuqtaning to'liq ko'chishi $BB_1 = \Delta = \frac{17{,}31 \cdot 10^{-4}}{0{,}866} \approx 20 \cdot 10^{-4} m$



6-rasm



7-rasm



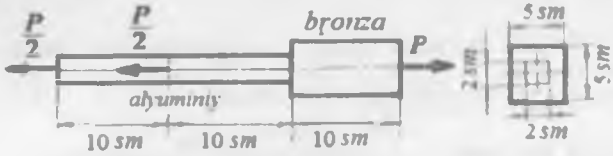
8-rasm

Javob: Chap uchastkada σ= - 53,1 MPa, o'ng uchastkada σ= - 39,7 MPa; $\Delta l = 0{,}132$

5-misol. 7-rasmda ko'rsatilgan po'lat sterjenning barcha uchast-kalaridagi kuchlanishlarni va uning to'liq deformatsiyasini toping. Sterjen ko'ndalang kesim yuzasi 5 sm^2.
Javob: Chap uchastkada σ = - 40 Mpa, $\Delta l = 0$.

6-misol. 8-rasmda tasvirlangan pulat sterjenning o'ng qismidagi kesimi yaxlit dumaloq, chap qismidagi kesimi halqasimon. Sterjenning ikkala qismidagi kuchlanishlar va to'liq uzayi-shini toping

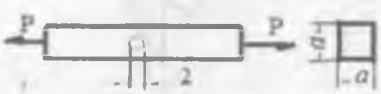
7-misol. 9-rasmda ko'rsatilgan sterjen o'ziga qo'yilgan yuk ta'sirida 0,2 mm cho'ziladi. Alyuminiyning elastiklik moduli $0{,}75 \cdot 10^{11}$ N/m^2, bronzaniki $1{,}1 \times 10^{11}$ N/m^2, qabul qilingan yuk



qiymati R aniqlansin.
javob: 36,7 kN
9-rasm

8-misol. Diametri 30 mm.li dumaloq ko'ndalang kesimli po'lat sterjen sinash mashinasida 125 kN zo'riqish bilan cho'zilgan. Tenzometrlar yordamida 50 mm uzunlikda uning uzayishi o'lchanganda 0,43 mm chiqqan, diametri esa 0,007 mm ga o'zgargan. Sterjen materialining elastiklik modulini va Puasson koeffitsientini aniqlang.

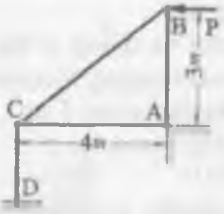
javob: $E=2,06\times10^{11}$ N/m^2 $\mu=0,271$.



10-rasm.

javob: 5 mm.

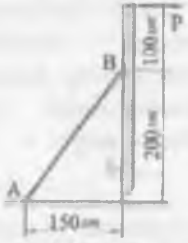
9-misol. Kvadrat kesimli ster-jen R=1500 N kuch bilan cho'zila-di (10-rasmga qarang). U ochiq teshik bilan (diametri 2mm) zaiflashgan. Sterjen materia-li uchun ruxsat etilgan kuchlanish 100 MPa bo'lganda kesimning a tomoni qanchaga teng bo'lishi lozim?



11-rasm.

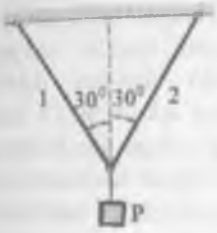
10-misol. R =100 kN kuch konstruktsiyaga 11-rasmda ko'rsatilganidek ta'sir qiladi. Barcha sterjenlarning ko'ndalang kesimi bir xil bo'lib, ikkita teng yonli burchaklik 80x80x8 dan iborat. Sterjenlardagi kuch-lanishni aniqlang.

javob: σ_{AV} = 30,5 MPa; σ_{AS} = 40,6 MPa
σ_{VS} = 50,9 MPa; σ_{CD} = 30,5 MPa;



12-rasm

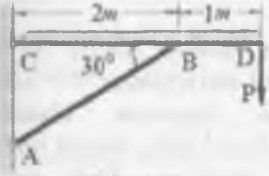
11-misol. Bikr sterjen (12-rasm) kuch R bilan yuklangan va uni diametri 20 mm.li dumaloq ko'ndalang kesimdagi qiya po'lat tortqi ag'darilib ketishdan ushlab turadi. Eng katta yo'l qo'yiladigan yuk R ni va kuch qo'yiladigan nuqtaning gorizontal ko'chish qiymatini aniqlang. Tortqi materiali uchun ruxsat etilgan kuchlanish 160 MPa . **javob:** R=20,1 kN: δ = 5mm =$5\cdot10^{-3}$ m.



13-rasm

12-misol. Yuk R ikkita sterjenga rasmda ko'rsatilgandek osilgan. Dumaloq ko'ndalang kesimining diametri 30 mm bo'lgan sterjen 1 ning materiali uchun ruxsat etilgan kuchlanish 160 MPa diametri 40 mm bo'lgan dumaloq ko'ndalang kesimli sterjen 2 materialining ruxsat etil-gan kuchlanishi 60 MPa. Bu konstruktsiya ko'pi bilan qancha yuk R ga chidashi mumkin?

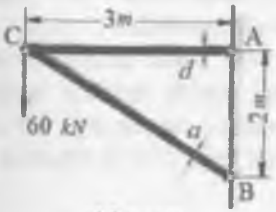
javob: 130 kN.



14-rasm

13-misol. Bikr brus SD rasmda ko'rsatilgandek yuklangan va yog'och qiya tirgak AV bilan mustahkam-langan. Brusning deformatsiyasi hisobga olinmasin. D nuqtaning kuchishi o'lchab ko'rilganda, u 3 mm ga tengligi aniqlandi. Qiya tir-gakdagi kuchlanishlar nimaga teng? Agar qiya tirgakning ko'n-dalang kesimi 20x20 sm o'lchamli kvadrat bo'lsa, nagruzka R nimaga teng?

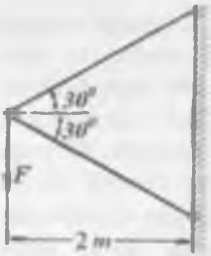
javob: $\sigma = 4{,}33$ MPa R = 57,8 kN.



15-rasm

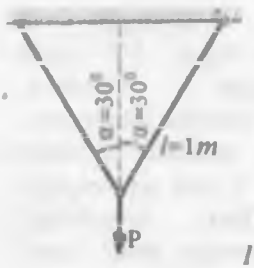
14-misol. Rasmda tasvirlangan kronshteynda sterjen AS po'lat-dan, sterjen VS esa yog'ochdan yasalgan. Ruxsat etilgan kuchlanish po'lat uchun [σ] = 4 MPa. Po'lat sterjenning duma-loq kesimi diametri d ni g'amda yog'och sterjenning kvadrat kesimi tomoni á ni tanlang, tugun S ning gorizontal, vertikal va to'liq siljıshini aniqlang.

javob: d = 27 mm; á = 16,4 sm; $\Delta_{vert} = 6{,}2$ mm; $\Delta = 6{,}64$ mm, $\Delta_{gor} = 2{,}4$ mm $= 24 \cdot 10^{-4}$ m.



16-rasm

15-misol. 16-rasmda tasvirlangan kron-shteyn R kuchi bilan yuklangan. Ikkala sterjen po'latdan yasalgan. Ustki ster-jen ikkita shveller № 12 dan, pastkisi ikkita № 24 dan iborat. Cho'zilishga yo'l qo'yilgan kuchlanish 160 MPa, siqishga yo'l qo'yilgan kuchlanish – 100 MPa. Eng katta yo'l qo'yilgan nagruzka R ni va nagruzka qo'yilgan uzelning vertikal siljishini aniqlang. **Javob:** R=348 kN, Δ= 2,70 mm



17-rasm

16-misol. Ko'ndalang kesim $A=1sm^2$ bo'lgan bir xil sterjenlarga P = 10 kN yuk osilgan. Sterjenlar elastik-lik moduli $E=1x10^5$ MPa bir xil bo'lgan materialdan yasalgan. Yuk osilgan nuqtaning ko'chishini aniq-lang. Agar burchak $\alpha = 52^0$ bo'lsa bu burchak qanday o'zgaradi?

misol – 17. Po'latdan tayyorlangan pog'onali brus $F_1 = 30\ kN$, $F_2 = 30\ kN$, $F_3 = 50\ kN$ tashqi kuchlar bilan yuklangan (18 – rasm). Pog'onali brus uchun ichki bo'ylama kuch N; normal kuchlanish σ va absolyut uzayish $\Delta\ell$ epyuralari qurilsin.

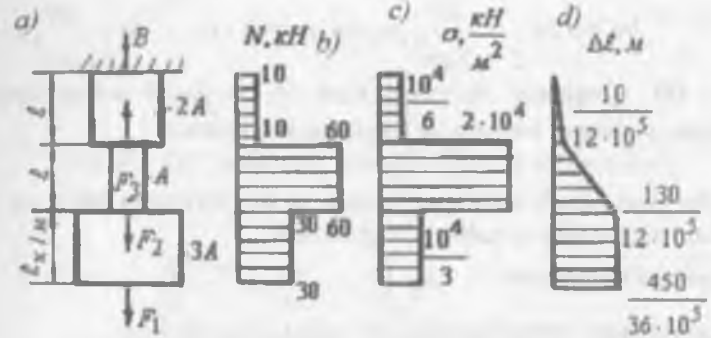
echish. Berilgan masala statik aniq yoki statik aniqmas sistema bo'lishidan qat'iy nazar bo'ylama ko'chishni topish tayanch nuqtadan boshlanishi kerak, chunki tayanch kesimdagi nuqtaning ko'chishi ($\Delta\ell_a = 0$) nolga teng. Shuning uchun, bo'ylama kuch N – ni topishni ham sterjenning tayanch nuqtasidan boshlaymiz.

Pog'onali brusni muvozanat tenglamasidan noma'lum reaktsiya kuchi V-ni topamiz (*18 – rasm*, a):

$$\sum y = B + F_3 - F_2 - F_1 = 0 \quad \text{va} \quad B = 30 + 30 - 50 = 10kN$$

Kesish usulidan foydalanib sterjenning yuqori pog'onasidan fikran ikki qismga ajratamiz va pastki qismni tashlab yuboramiz. Ajratib qoldirilgan qismning kesilgan yuzasiga pastki tashlab yuborilgan qismning ta'sirini almashtiradigan N kuchni qo'yamiz va muvozanat tenglamasini tuzamiz.

$$\sum y = B - N_1 = 0 \quad yoki \quad B = N_1 = 10kN$$



18 – rasm. Pog'onali brusni yuklanish sxemasi va bo'ylama kuch, normal kuchlanish va bo'ylama uzayish (N, σ va Δℓ) epyuralari

Tekshirilayotgan pog'onaning uzunligi bo'ylab N1 kuch o'zgarmas bo'lib miqdor jihatdan reaktsiya kuchi V-ga teng. Kesimdagi normal kuchlanishni topamiz: $\sigma_1 = \frac{N_1}{2A} = \frac{10}{2 \cdot 3 \cdot 10^{-3}} = \frac{10^4}{6}, \frac{kN}{m^2}$

Sterjenning ℓ uzunligi bo'ylab to'liq ko'chishni topamiz

$\Delta\ell_1 = \int_0^{\ell} \frac{N_1 dy}{E2A} = \frac{N_1 y_1}{E2A}$, buerda $0 \le y_1 \le 1$ m.da o'zgaradi

Agar, $y_1 = 0$ bo'lsa $\Delta\ell_1 = 0$ va $y_1 = 1m$ bo'lsa $\Delta\ell_1 = \frac{10}{12 \cdot 10^5}, m$

Demak, brusning yuqori pog'onasida bo'ylama deformatsiya to'g'ri chiziqli qonuniyat bilan o'zgarib noldan $\Delta\ell_1 = \frac{10}{12 \cdot 10^5}$ gacha ortib boradi.

II-II – qirqimdan ajratilgan qismning muvozanat tengla-masiga asosan $\sum y = 0$. $B + F_3 - N_2 = 0$ va $N_2 = 60kN$,

normal kulanish $\sigma_2 = \frac{N_2}{A} = \frac{60}{3 \cdot 10^{-3}} = 2 \cdot 10^4 \frac{kN}{m^2}$

Sterjen ajratilgan qismining to'liq uzayishini topish uchun ikkinchi oraliq uzayishiga birinchi oraliqning to'liq uzayishini qo'shib yozamiz, ya'ni: $\Delta\ell_2 = \frac{10}{12 \cdot 10^5} + \frac{N_2 \cdot y_2}{EA}$, buerda $0 \le y_2 \le 1$ m.

kelib chiqadi. $x=0$ da $\Delta\ell_1=0$., ya'ni qo'zg'almas M kesimni uzayishi nolga teng bo'ladi, $x_1=0{,}5m$. $\Delta\ell_1=1{,}224\cdot10^{-4}m$.

$x_1=1m$ $\Delta\ell_1=\Delta\ell_B=2{,}291\cdot10^{-4}m$

II – II qirqim. $a\le x_2\le 2a$.

Qo'zg'almas kesimdan x_2 masofadagi kesimni bo'ylama kuchi quyidagicha topiladi:

$$\sum x=0. \qquad N_2=M+F_3-\int_0^2 q_x dx=M+3{,}5F-\int_0^2 q\frac{x_2dx}{2a}$$

Normal kuchlanish $\sigma_2=\frac{N_2}{A}$

$x_2=1m,$ $N_2=42{,}5kN$ $\sigma_2=21{,}25\cdot10^4\frac{kN}{m^2}$

$x_2=2m.$ $N_2=35kN,$ $\sigma_2=17{,}5\cdot10^4\frac{kN}{m^2}$

I pog'onadan II pog'onaga o'tish V nuqtasida bo'ylama kuchni qiymati $F_3=3{,}5F=35kN$ ga farq qiladi. Shuning uchun V nuqta joylashgan kesimni N epyurasida 35 kN ga teng sakrash bo'ladi.

Brus $2a$ uzunligining to'liq uzayishini topamiz.

$$\Delta\ell_2=\Delta\ell_B+\int_0^{1m}\frac{N_2dx}{EA}=2{,}291\cdot10^{-4}+\int_0^1\frac{Mx_2}{EA}+\frac{3{,}5Fx_2}{EA}-F\frac{x_2^3}{12a^2EA}$$

$x_2=0,$ $\Delta\ell_2=2{,}291\cdot10^{-4}m, x_2=0{,}5m$ $,\Delta\ell=7{,}9\cdot10^{-4}m,$

$x_2=1m,$ $\Delta\ell_2=\Delta\ell_C=13{,}3\cdot10^{-4}m$ - AS uzunlikning to'liq uzayishi.

III – III qirqim. $0\le x_3\le 1m$. Oraliq uzunligi bo'yicha taqsimlangan kuch intensivligining teng ta'sir qiluvchisi $\frac{1}{2}q\cdot2a=qa=\frac{F}{a}\cdot a=F$ teng

Brusni ajratilgan qismini muvozanat tenglamasi quyidagicha yoziladi $\sum x=N_3+F_2+F-F_3-M=0$ va $N_3=5kN$

Normal kuchlanish $\sigma=2{,}5\ 10^4\frac{kN}{m^2}$. Oraliq uzunligi bo'ylab N_3 va σ_3 teng tarqalgan, absolyut uzayish $\Delta\ell_3$ esa x_3 masofaga propor-tsional

bog'lanishda bo'lib to'g'ri chiziqli qonuniyat bilan o'zgaradi. *AD* oraliqning uzayishi $\Delta\ell_D = \Delta\ell_C + \frac{N_2 1}{EA} = 14{,}55\cdot10^{-4}, m$

IV – IV qirqim. $0 \le x_4 \le 1m$ oraliqda ajratilgan brus qismining muvozanat sharti

$$\Sigma x = N_4 + F_1 + \int_0^A q_x dx + F_2 - F_3 - \frac{1}{2} q2a - M = 0 \quad \text{yoki}$$

$$N_4 = -F - q\frac{x^2}{2a} - 3F + 3{,}5F + \frac{F}{a}\cdot a + F = 1{,}5F - F\frac{x_4^2}{2a^2}$$

Normal kuchlanish $\sigma_4 = \frac{N_4}{A}$ va absolyut uzayishi

$$\Delta\ell_4 = \Delta\ell_D + \int_0^A \frac{N_4 dx}{EA} = 14{,}55\cdot10^{-4} + \int_0^A \frac{\left(1{,}5F - F\frac{x_4^2}{2a^2}\right)}{EA} dx =$$

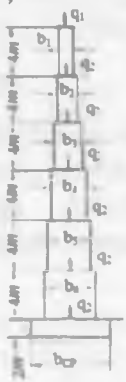
$$= 14{,}55\cdot10^{-4} + \frac{1{,}5Fx_4}{EA} - F\frac{x_4^3}{6a^2EA}$$

$x_4 = 0 . N_4 = 15kN;\ \sigma_4 = 7{,}5\cdot10^4\frac{kN}{m^2};\qquad \Delta\ell_4 = 14{,}55\cdot10^{-4}m$

$x_4 = 0{,}5m \qquad N_4 = 13{,}875kN; \qquad \sigma_4 = 6{,}937\cdot10^4\frac{kN}{m^2};$

$x_4 = 1m \qquad N_4 = 10kN; \qquad \sigma_4 = 5\cdot10^4\frac{kN}{m^2};\ \Delta\ell_4 = 17{,}88\cdot10^{-4}m$

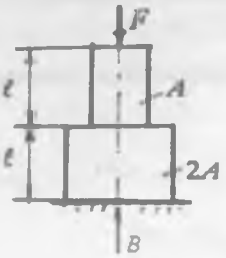
Brusning to'liq uzayishi $\Delta\ell = 17{,}88\cdot10^{-4}m$ ga teng



20-rasm

19-misol. 20 - rasmda olti qavatli bino g'ishtli devorining ko'ndalang qirqimi ko'rsatilgan. Cherdak va tomdan devorning har pogon metriga q_1 = 60 kN/m, qavatlar-aro yopmalardan q_2 = 40 kN/m va paskti qavat polidan q = 30 kN/m kuch ta'sir qiladi. Bu kuchlar devor o'qi bo'ylab yo'nal-gan. Devor va poydevor materialining hajmiy og'irligi 20 kN/m^3. Agar ruxsat etilgan kuchlanish [σ] = 0,6 MPa bo'lsa, har bir qavatdagi devorning eng kichik qalinligini va agar erda ruxsat etilgan bosim 0,5 MPa bo'lsa, poydevor enini aniq olish mumkin?

javob: b_1 = 11,5 sm; b_2 = 21 sm; b_3 = 32 sm;



21– rasm

20-misol. G' kuch va xususiy og'irligi bilan yuklangan pog'onali brusni (21– rasm) to'liq qisqarishi topilsin. Brus materialining hajmiy og'irligi ρ va elastiklik moduli – E.

echish. Brus har bir pog'onasining xususiy og'irligi $\sigma_1 = \rho A\ell$ va $\sigma_2 = \rho 2A\ell$ va G' kuch ta`siridan – tayanch kesimida V reaktsiya kuchi hosil bo'ladi. Reaktsiya kuchini topamiz. $\sum x = B - F - \rho A\ell - \rho 2A\ell = 0$

yoki $B = F + 3\rho A\ell$

I – I qirqim $0 \le x_1 \le \ell$ oraliqda, ya`ni brusni pastki pog'onasidagi ichki bo'ylama kuchni kesish usulidan foydalanib topamiz: $\sum x = N_1 + B - \rho 2Ax_1 = 0$ va $N_1 = \rho 2A \cdot x_1 - F - 3\rho A\ell$

Brus ajratilgan qismining deformatsiyasini topamiz.

$$\Delta\ell_1 = \int_0^{\ell} \frac{N_1 dx}{E2A} = \int_0^{\ell} \frac{(\rho 2Ax_1 - F - 3\rho A\ell)dx}{E2A} = \left| \frac{\rho x_1^2}{2E} - \frac{(F + 3\rho A\ell)x_1}{E2A} \right|_0^{\ell}$$

Agar, $x_1 = 0$ bo'lsa $\Delta\ell_1 = \Delta\ell_B = 0$, ya`ni tayanch kesimida deformatsiya nolga teng: $x_1 = \ell$; $\Delta\ell_1 = -\frac{F\ell}{E2A} - \frac{\rho\ell^2}{E}$

II – II qirqim. $0 \le x_2 \le \ell$ oraliqda bo'ylama kuchni topamiz:

$\sum x = N_2 + B - \rho 2A\ell - \rho Ax_2 = 0$ va $N_2 = -F - \rho A\ell + \rho Ax_2$

Ajratilgan qismning to'liq ko'chishini topamiz.

$$\Delta\ell_2 = \Delta\ell_1 + \int_0^{x_2} \frac{N_2 dx}{EA} = \Delta\ell_1 + \int_0^{x_2} \frac{(-F - \rho A\ell + \rho Ax_2)dx}{EA} = \Delta\ell_1 + \left[\frac{\rho Ax_2^2}{2EA} - \frac{(F + \rho A\ell)x_2}{EA} \right]_0^{\ell}$$

$x_2 = 0$, $\Delta\ell_2 = \Delta\ell_1$ va $x_2 = \ell$, $\Delta\ell_2 = -\frac{3F\ell}{2EA} - \frac{3\rho \cdot \ell^2}{2E}$

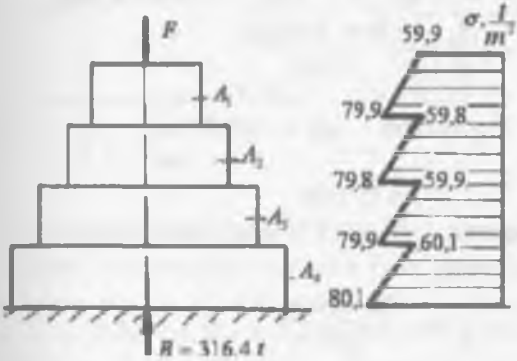
21-misol. Vertikal osilgan po`latdan tayyorlangan sterjen qancha xususiy og'irligida emiriladi. Po'lat materialining mus-tahkamlik chegarasi $30\ kg/mm^2$, xususiy og'irligi $\rho = 7800\ kg/m^3$ **echish.** Faqat xususiy og'irligi bilan yuklangan sterjenni mustahkamlik shartini yozamiz: $\sigma_{max} = \rho\ell \le \sigma_B$ bu erdan kritik

uzunlik $\ell_K = \frac{\sigma_B}{\rho} = \frac{50 \cdot 10^6}{7800} = 6410m$

22-**misol.** Uzunligi $40m$ bo'lgan pog'onali brus $G' = 100\ t$ kuch va xususiy og'irligi bilan yuklangan. Pog'onali brus to'rtta bir xil uzunlikdagi oraliqdan iborat. Brus materialining solishtirma og'irligi $2\frac{t}{m^3}$, ruxsat etilgan kuchlanish $[\sigma]=80\frac{t}{m^2}$

echish. Pog'onali brus yuqori qismining kesim yuzasini topamiz:

$$A_1=\frac{F}{[\sigma]-\rho\ell_1}=\frac{100}{80-2\cdot10}=1{,}67m^2$$



22 – rasm. Tashqi kuch va xususiy og'irlik ta'siridagi pog'onali brus normal kuchlanish epyurasi

A_2 kesimga tashqi G' kuch va yuqori qismni xususiy og'irligi ta'sir qiladi:

$$A_2=\frac{F-\rho A_1\ell_1}{[\sigma]-\rho\ell_2}=\frac{100+2\cdot1{,}67\cdot10}{80-2\cdot10}=2{,}23t^2$$

Pog'onali brusni uchinchi qismi G' kuch, birinchi va ikkinchi pog'onalarni xususiy og'irliklari ta'sirida:

$$A_3=\frac{A+\rho\ell(A_1+A_2)}{[\sigma]-\rho\ell_3}=\frac{100+2\cdot10(1{,}67+2{,}23)}{80-2\cdot10}=2{,}97t^2$$

Pog'onali brusni eng pastki qismi G' kuch va undan yuqori qismlarini xususiy og'irliklari ta'sirida bo'ladi:

$$A_4=\frac{F+\rho\ell(A_1+A_2+A_3)}{[\sigma]-\rho\ell_4}=\frac{100+2\cdot10(3{,}9+2{,}97)}{80-2\cdot10}=3{,}95t^2$$

Pog'onali brusni tayanch kuchini topamiz:

$$\sum x=-F-\pi\cdot\ell(A_1+A_2+A_4)+B=0 \qquad \text{bu erdan}$$

$$B=100+2\cdot10(1{,}67+2{,}23+2{,}97+{,}95)=316{,}4\ t$$

Pog'onali brusning uzunligi bo'ylab kuchlanish epyurasini qurish uchun, uni har bir pog'onasidagi ichki bo'ylama kuchlarini kesish usulidan foydalanib topamiz.

yoki $\Delta\ell_1 = \frac{Cx_1}{EA} - \frac{\rho \cdot x_1^2}{2E}$

Yuqoridagi tenglamalarga asosan $0 \le x_1 \le 1.м$ oraliqda N va σ to'g'ri chiziqli va $\Delta\ell$ egri chiziq qonuniyati bilan o'zgaradi.

$$x_1 = 0\, bo'lsa\, N_1 = 16{,}3kN; \qquad \sigma_1 = 81{,}5\frac{kN}{m^2}; \qquad \Delta\ell_1 = 0$$

$$x_1 = 1m \qquad N_1 = 0{,}7kN \qquad \sigma_1 = 3{,}5\frac{kN}{m^2} \qquad \Delta\ell_1 = 21{,}25\cdot 10^{-8}m$$

II – II qirqim. Brusni qo'zg'almas kesimidagi x_2 masofada joylashgan 2-2 kesimi uchun bo'ylama kuch $N_2 = c + F - \rho A x_2$ normal kuchlanish: $\sigma_2 = \frac{N_2}{A}$

$$x_2 = 1m \qquad N_2 = 1{,}2kN \qquad \sigma_2 = 6\frac{kN}{m^2}$$

$$x_2 = 2m, \qquad N_2 = -14{,}4kN \qquad \sigma_2 = -7{,}2 \quad \frac{kN}{m^2}$$

Brusning ajratilgan qismini to'liq uzayishi quyidagicha topiladi:

$$\Delta\ell_2 = \Delta\ell_1 + \int_0^{\ell} \frac{N_2 dx}{EA} = \Delta\ell_1 + \int_0^{\ell} \frac{(C + F_3 - \rho A x_2)dx}{EA}$$

Hosil bo'lgan tenglamani integrallasak

$$\Delta\ell_2 = \Delta\ell_1 + \frac{(C + F_3)x_2}{EA} - \frac{\rho \cdot x_2^2}{2E}$$

$x_2 = 0$ da $\Delta\ell_2 = 21{,}25\cdot 10^{-8}m$ va $x_2 = 1m.$ da $\Delta\ell_2 = 43{,}75\cdot 10^{-8}m$

III – III qirqim. Uzunligi x_3 ga teng bo'lgan brusni muvozanat tenglamasi quyidagicha yoziladi.

$$\sum x = 0. \quad N_3 = C + F_3 + F_2 - \rho A x_3$$

normal kuchlanish $\sigma_3 = \frac{N_3}{A}$

$$x_3 = 2m \qquad bo'lsa\, N_3 = 5{,}6kN \qquad \sigma_3 = 28 \quad \frac{kN}{m^2}$$

$$x_3 = 3m \qquad bo'lsa\, N_3 = -10 \quad kN \qquad \sigma_3 = -50 \quad \frac{kN}{m^2}$$

Brusni to'liq uzayishini topamiz:

$$\Delta\ell_3 = \Delta\ell_2 + \int_0^{\ell} \frac{N_3 dx}{EA} = \Delta\ell_2 + \int_0^{\ell} \frac{(c + F_3 + F_2 - \rho A x_3)dx}{EA} =$$

$$= 43,75 \cdot 10^{-8} + \frac{36,8x_3}{EA} - \frac{\rho \cdot x_3^2}{2E}$$

$x_3 = 3m;$ $\Delta\ell_3 = 43,75 \cdot 10^{-8} m$ va $x_3 = 1m$ $\Delta\ell_3 = 116,5 \cdot 10^{-8} m$

Statik noaniq sistemalar. Statik noaniq sistemalar deb, noma'lum kuchlarni (reaktsiya kuchlari, ichki kuchlar) aniqlash uchun kesish usuli yoki statika tenglamalari etarli bo'lmagan sistema-larga aytiladi.

Tarkibidagi noma'lum reaktsiya va ichki kuchlarining soni statikaning muvozanat tenglamalari sonidan ko'p bo'lgan sistema-lar statik noaniq sistemalar deyiladi.

Tashqi va ichki statik noaniq sistemalar mavjud. Masalan, sterjenlar sistemasida ichki bo'ylama kuchlarni aniqlash ichki statik noaniq; ikki tomoni bikr mahkamlangan brus tashqi statik noaniq sistema.

Har ikkala statik noaniq sistemalarda ham noma'lum kuchlarni aniqlash masalasi – statik noaniq masala deyiladi. Statik noaniq sistemalarni statik noaniqlik darajasi mavjud. $S = n - 3$

Bu erda n - sistemadagi noma'lum kuchlar soni.

Statik noaniq masalalarni echish metodikasi ikki xil variantda olib boriladi. Masalan, sterjenlar sistemasida noma'lum ichki bo'ylama kuchlarni aniqlash uchun kesish usulidan foydalanib, sterjenlarni kesamiz. Sterjenlardagi ichki bo'ylama kuchlarni ko'rsatib, sistemani olib qolingan qismi uchun muvozanat tenglamalarini tuzamiz. Tuzilgan muvozanat tenglamalarida noma'lum ichki kuchlar bilan birga noma'lum reaktsiya kuchlari qatnashadi. Reaktsiya kuchlarini aniqlash yoki aniqlamaslik, masalani mohiyatini belgilamaydi. Shuning uchun reaktsiya kuchlarini aniqlamaymiz va ular qatnashadigan muvozanat tenglamalarini e'tiborga olmasak ham bo'ladi. Unda uchta muvozanat tenglamasidan faqat bittasi qoladi va unda ikkita noma'lum ichki kuchlar va tashqi kuch qatnashadi.

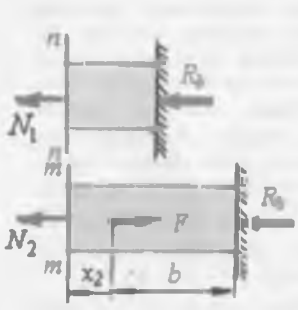
Pog'onali brus uchun bitta muvozanat tenglamasi tuziladi Bu tenglamada ikkita noma'lum reaktsiya kuchlari qatnashadi. Har ikkita statik noaniq sistemalarni echish metodikasiga oid bir nechtadan masalalar echilgan.

Ushbu mavzuga oid talabalarni mustaqil ishi sifatida hisob-lash grafik ishi uyga vazifa beriladi. Variantlarni M. Ergashevni "Materiallar qarshiligidan hisoblash – loyihalash ishlari" yoki V.K. Kachurinning "Materiallar qarshiligi masalalar to'plami" kitoblaridan olish mumkin

$\Delta\ell_{BF}$ ko'chish brus a – uzunlikdagi qismining F kuch ta'siridan absolyut uzayishiga teng bo'ladi (*24– rasm, v*) $\Delta_a = \Delta\ell_{BF} = \frac{Fa}{EA}$.

Ikkinchi faraz, deformatsiyalangan brusning B_1 (24 – rasm, g) nuqtasiga qo'yilgan. R_B reaktsiya kuchi ta'siridan B_1 nuqta B vaziyatga ko'chadi, ya'ni brus uzunligi bo'ylab siqiladi, unda brus-ning absolyut qisqarishini Guk formulasi bilan quyidagicha ifodalanadi: $\Delta\ell_{BB} = -R_B\frac{a+e}{EA}$. Unda B nuqtaning to'liq ko'chishi $\Delta\ell_B = \frac{F\cdot a}{EA} - \frac{R_B(a+e)}{EA} = 0$ Bu erdan $R_B = F\frac{a}{a+e}$ hosil bo'ladi va ushbu tenglikni muvozanat tenglamasiga qo'ysak: $R_A = F\frac{e}{a+e}$.

Kesish usulidan foydalanib ichki bo'ylama kuch, normal kuchlanish va bo'ylama deformatsiyani aniqlaymiz (*24 - rasm* - d).



$n-n$ **qirqim**: $\sum x = -N_1 - R_B = 0$ muvozanat shartidan ichki bo'ylama kuch $N_1 = -R_B$ (minus ishorasi bu oraliqda siqilish bo'lishini bildiradi)

Normal kuchlanish $\sigma_1 = \frac{N_1}{A}$ va bo'ylama deformatsiya: B tayanch nuqtada nolga teng va tashqi kuch qo'yilish nuqtasida $\Delta\ell_1 = \frac{N_1\cdot b}{EA}$ ga teng.

$m-m$ **qirqim**: $\sum x = -N_2 - R_B + F = 0$ tenglamadan $N_2 = -R_B + F$ hosil bo'ladi.

Normal kuchlanish $\sigma_2 = \frac{N_2}{A}$ va to'liq bo'ylama deformatsiya

$\Delta\ell_2 = \frac{N_2\cdot x_2}{EA} - \frac{R_B b}{EA}$, bu erda $0 \le x_2 \le a$ oraliqda o'zgaradi.

Agar $x_2 = 0$ bo'lsa, $\Delta\ell_2 = -\frac{R_B b}{EA}$ va $x_2 = a$ bo'lsa,

$\Delta\ell_2 = \frac{(-R_B + F)\cdot a}{EA} - \frac{R_B b}{EA} = \frac{Fa}{EA} - R_B\frac{(a+b)}{EA} = 0$ bo'ladi.

25-misol. Ikki uchi qistirib mahkamlangan brusning uzun-ligi bo'ylab N, σ va $\Delta\ell$ epyuralarini quring. Ko'ndalang kesim-lari $A_1 = A_3 = 2A_2 = 4 \cdot 10^{-3} m^2$ bo'lgan brus $G'_1 = 20$ va $G'_2 = 10\ kN$ tashqi kuchlar bilan yuklangan (25–rasm).

echish. Tashqi kuchlar ta'sirida brus uzayishga va siqilishga qarshilik ko'rsatadi va K va V tayanchlarga tayanadi. Tayanch nuqtalaridan brusga reaktsiya kuchlari ta'sir qiladi. Reaktsiya kuchlarini yo'nalishini va qiymatini aniqlash uchun tuzilgan muvozanat sharti ikkita noma'lum K va V ni beradi, ya'ni:

$$\sum x = K + B - F_1 + F_2 = 0$$

Sistemadagi noma'lumlar soni statikani muvozanat tenglamalaridan ortiqcha. Shuning uchun, konstruktsiya statik aniqmas masalalarga kiradi. Bunday masalalarni qo'shimcha deformatsiya (deformatsiyani taqqoslash) tenglamalarini tuzish usuli bilan echiladi. Deformatsiyani taqqoslash tenglamasini tuzish tashqi kuchlar ta'sirida tayanchlar oralig'i masofasi o'zgarmasdan (brusni to'liq deformatsiyasi nolga teng bo'ladi), faqat brusni pog'onalari uzunligi o'zgarishi, ya'ni sistemani tashqi kuchlar ta'siridagi to'liq uzayishining absolyut qiymati K reaktsiya kuchi ta'siridagi to'liq qisqarishni absolyut miqdoriga tengligiga asoslangan.

$\Delta\ell_K = \Delta\ell_{F_1} - \Delta\ell_{F2}$ bu erda $\Delta\ell_1 = \frac{F_1 \cdot 1}{EA}$; $\Delta\ell_{F2} = \frac{F_2 \cdot 1}{EA_2} + \frac{F_2 \cdot 1}{EA_1}$

va $\Delta\ell_K = K\left[\frac{1}{EA_1} + \frac{1}{EA_2} + \frac{1}{EA_3}\right] = \frac{2A}{EA_2}$

Demak $\frac{2K}{EA_2} = \frac{F_1 \cdot 1}{E2A} - F_2\left(\frac{1+1}{EA_2}\right)$ *yoki* $K = -\frac{F_2}{4} = -2500N$

Minus ishorasi, K reaktsiya kuchini yo'nalishi noto'g'ri qabul qilinganligini bildiradi. Demak, K reaktsiya kuchini yo'nalishini teskariga yo'naltiramiz va keyingi tenglamalarda minus ishorasini hisobga olmaymiz. K tayanch kuchining qiymatini sistemaning muvozanat tenglamasiga keltirib qo'ysak, ya'ni

$-\frac{F_2}{4} + B - F_1 + F_2 = 0$ bu erdan $V = 12{,}5\ kN$

Statik aniqmaslik yo'qotilgandan keyin brusni oraliq pog'onalarida N; σ va $\Delta\ell$larni o'zgarishini topamiz va epyurasini quramiz. Buning uchun brusni oraliqlarga bo'lamiz. Qirqimlar chegaralari tashqi kuchlar qo'yilgan nuqtadan va brusni kesim yuzasi o'zgarishi oraliqlaridan o'tgan.

Demak, $\Delta_n > \Delta$ yoki 0,002375 > 0,002 m, natijada N va A kesimlar tutashadi va A tayanchda reaktiv kuch hosil bo'lib, sistema statik noaniq bo'ladi. Masalani echish uchun sistemani muvozanat tenglamasini tuzamiz:

$$\sum y = A + B + F_2 - F_1 = 0 \qquad \text{yoki} \qquad A + B = F_1 - F_2$$

Sistemani aniqmaslik darajasini ochish uchun qo'shimcha deformatsiya tenglamasini tuzamiz: $\Delta_H - \Delta = \Delta_A$

Bu erda $\Delta_A = A\frac{1}{EA_1} + \frac{A \cdot 1}{EA_2} + \frac{A \cdot 1}{EA_3}$ brusni A reaktsiya kuchi ta'siridan uzayishi $0{,}002375 = A\left(\frac{1}{EA_1} + \frac{1}{EA_2} + \frac{1}{EA_3}\right) + \Delta$ yoki

$$A = \frac{(0{,}002375 - 0{,}002) \cdot 2 \cdot 10^{11} \cdot 2 \cdot 10^{-3}}{2} = 7500N$$

$$B = F_1 - F_2 - A = 20000 - 10000 - 7500 = 2500N$$

Brusni oraliqlarga bo'lib $N; \sigma$ va $\Delta\ell$ larni hisoblaymiz.

1 – 1 qirqim.

$N_1 = B - 2500N$ va $\sigma_1 = \frac{N_1}{A_1} = \frac{2500}{2 \cdot 2 \cdot 10^{-3}} = 625 \cdot 10^3 \frac{N}{m^2}$

V kesimning ko'chishi nolga teng, ya'ni $\Delta\ell_s = 0$. S kesimning ko'chishi VS masofani to'liq uzayishiga teng, ya'ni:

$$\Delta\ell_C = \frac{N_1 \cdot 1}{EA_1} = \frac{2500 \cdot 1}{2 \cdot 10^{11} \cdot 2 \cdot 2 \cdot 10^{-3}} = 312{,}5 \cdot 10^{-8} m$$

II-II – qirqim.

Bo'ylama kuch $N_2 = B - F_1 = 2500 - 20000 = -17500N$ va normal kuchlanish $\sigma_2 = \frac{N_2}{A_2} = -\frac{17500}{2 \cdot 10^3} = -8750 \cdot 10^3 \frac{N}{m^2}$

VD oraliq masofasini to'liq uzayishi quyidagicha topiladi:

$$\Delta\ell_D = 312{,}5 \cdot 10^{-8} + \frac{N_2 \cdot 1}{EA_2} + \alpha \cdot \Delta t \cdot 1 = 312{,}5 \cdot 10^{-8} - \frac{17500 \cdot 1}{2 \cdot 10^{11} \cdot 2 \cdot 10^{-3}} +$$

$$125 \cdot 10^{-7} \cdot 20 \cdot 1 = 0{,}00209375m$$

III-III qirqim

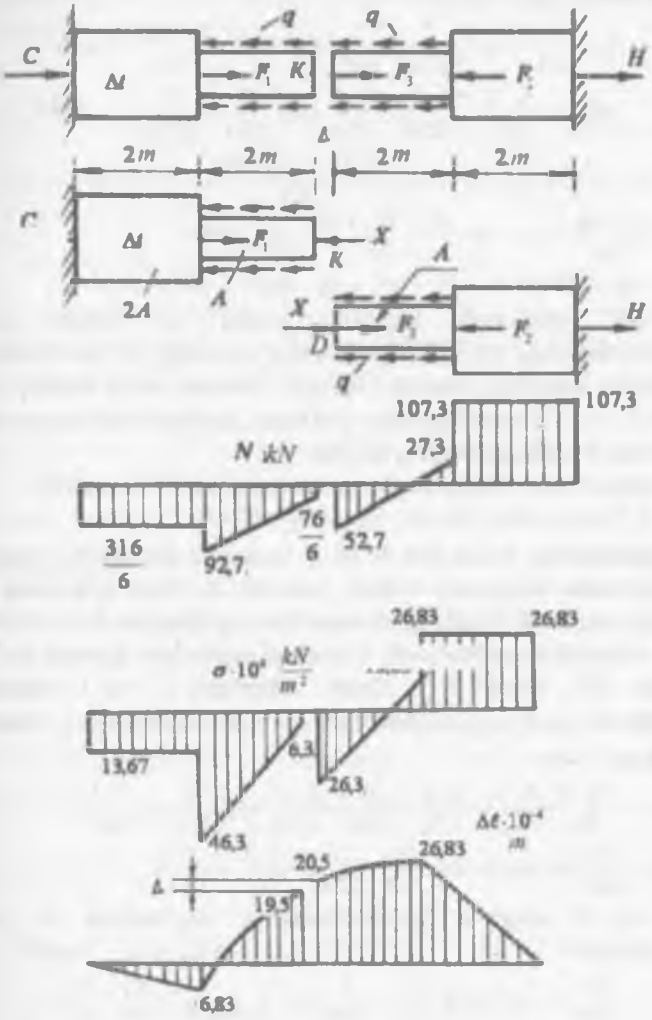
$$N_3 = B - F_1 + F_2 = 2500 - 20000 + 10000 = -7500N$$

$$\sigma_3 = \frac{N_3}{A_3} = -\frac{7500}{2 \cdot 2 \cdot 10^{-3}} = -1875 \cdot 10^3 \frac{N}{m^2}$$

N kesimning ko'chishi yoki brusning to'li uzayishi

$$\Delta\ell_H = 0{,}00209375 + \frac{N_3}{EA_3} = 0{,}00209375 - \frac{7500 \cdot 1}{2 \cdot 10^{11} \cdot 2 \cdot 2 \cdot 10^{-3}} = 0{,}002m$$

27-misol. Brusning pastdan birinchi va ikkinchi pog'onalari orasida $\Delta = 0{,}001$ m. masofa bor. Δ masofa yopilgunga qadar, tashqi kuch ta'sirida brusning har bir bo'lagi alohida deformatsiyalanadi (27 a – rasm).



27– rasm. Statik noaniq pog'onali brus uchun bo'ylama kuch, normal kuchlanish va absolyut uzayish epyurlari

echish: Sistemani $\Delta = 1\cdot10^{-4}m$ masofani yopilish yoki yopilmasligini tekshirish uchun D va K nuqtalarni deformatsiyasini Δga tenglashtiramiz: $\Delta_K + \Delta_D = \Delta$

$$\Delta_K = \frac{F_1\cdot 2}{E2A} - q\cdot 2\left(\frac{2}{E2A}+\frac{2}{2EA}\right) + \alpha\cdot 2\cdot\Delta t = \frac{F_1-4q}{EA} + 2\cdot\alpha\cdot\Delta t$$

$$\Delta_D = -\frac{F_3\cdot 2}{EA} - \frac{F_3\cdot 2}{E2A} + \frac{F_2\cdot 2}{E2A} + 2q\left(\frac{2}{2EA}+\frac{2}{E2A}\right) \quad \text{yoki}$$

$$\Delta_D = \frac{-3F_3+F_2+4q}{EA}$$

Unda $\frac{F_1-4q}{EA} + 2\cdot\alpha\cdot\Delta t + \frac{F_2-3F_3+4q}{EA} = \Delta$ yoki

$F_1 - 4q + 2EA\alpha\cdot\Delta t + F_2 - 3F_3 + 4q = \Delta EA; \quad 80 \succ \Delta EA$

Demak, pog'onali brusning pastki va yuqori qismlarini deformatsiyalarining yig'indisi pog'onalar orasidagi Δ dan katta ekan. D va K nuqtalar orasidagi masofa yopiladi. Sistema statik noaniq sistemaga aylanadi, S va N tayanchlardagi reaktsiya kuchlari sistemaga qo'yilgan barcha tashqi kuchlarga bog'liq bo'ladi.

Sistemani muvozanat tenglamasini tuzamiz (27 a – rasm)

$$\sum x = c + F_1 - 2q + F_3 - F_2 - 2q + H = 0$$

Tenglamadagi noma'lum S va N reaktsiya kuchlarini topish uchun asosiy sistemani tanlaymiz. Asosiy sistema, berilgan sistemani K va D nuqtalariga pog'onali bruslarni Δ masofasi yopilgandan keyin bir-birlariga o'zaro ta'sirlarini almashtiruvchi X kuchini noma'lum qiymati ko'rsatilgan sxemasidir (27– rasm, *b*). Asosiy sistemani K va D nuqtalarining ko'chishlarini $F_1; F_2; F_3; q; x$ kuchlari va Δt harorati farqi orqali ifodalaymiz.

$$\Delta_{DX} = -\frac{F_3\cdot 2}{EA} - \frac{F_3\cdot 2}{E2A} - x\left(\frac{2}{EA}+\frac{2}{E2A}\right) + \frac{F_2\cdot 2}{E2A} + 2q\left(\frac{2}{E2A}+\frac{2}{E2A}\right)$$

$$\Delta_{KX} = \frac{F_1 2}{2EA} + \alpha\cdot\Delta t\cdot 2 - 2q\left(\frac{2}{2EA}+\frac{2}{2EA}\right) - x\left(\frac{2}{EA}+\frac{2}{2EA}\right)$$

K va D nuqtalar ko'chishlarining yig'indisini Δ masofaga tenglashtiramiz. $\Delta_{KX} + \Delta_{DX} = \Delta$ yoki

$$\frac{F_1 2}{2FA} + \alpha\cdot\Delta t\cdot 2 - 2q\left(\frac{2}{2FA}+\frac{2}{E2A}\right) - x\left(\frac{2}{EA}+\frac{2}{2EA}\right) - \frac{2F_3}{FA} - \frac{2F_3}{E2A} -$$

$$-x\left(\frac{2}{EA}+\frac{2}{E2A}\right) + \frac{2F_2}{E2A} + 2q\left(\frac{2}{E2A}+\frac{2}{E2A}\right) = \Delta \quad \text{bu erdan}$$

$F_1 + 2EA\cdot\alpha\cdot\Delta t - 4q - 3x - 3F_3 - 3x + F_2 + 4q = \Delta EA$ yoki

$-6x + 40 - 120 + 80 + 2\cdot 2\cdot 10^8\cdot 2\cdot 10^{-4}\cdot 125\cdot 10^{-7}\cdot 80 = \Delta EA$

$6x = 80 - \Delta EA$ va $x = \frac{80 - 1\cdot 10^{-4}\cdot 2\cdot 10^8\cdot 2\cdot 10^{-4}}{6} = \frac{76}{6}, kN$

Sistemaning har ikkala qismlarini muvozanat shartlaridan foydalanib S va N reaktsiya kuchlarini topamiz

$\sum x = 0;\quad C + F_1 - 2q - x = 0$ yoki $C = \frac{316}{6}, kN$

$\sum x = 0;\quad H + x + F_3 - F_2 - 2q = 0$ yoki $H = -\frac{76}{6} - 40 + 80 + 80 = \frac{644}{6}, kN$

Topilgan reaktsiya kuchlarining to'g'ri aniqlanganligini tekshiramiz:

$\sum x = C + F_1 - 2q + F_3 - F_2 - 2q + H = 0$ yoki

$\frac{316}{6} + 40 - 80 + 40 - 80 - 80 + \frac{644}{6} = 0;\quad 960 - 960 = 0$

Endi, sistemani oraliqlarga bo'lib har bir pog'onadagi ichki bo'ylama kuch N, normal kuchlanish σ, bo'ylama deformatsiya $\Delta\ell$ larni topamiz.

1 – 1 qirqim. $\sum x = C + N_1 = 0$ yoki $N_1 = -\frac{316}{6}, kN$ (siquvchi)

$$\sigma_1 = \frac{N_1}{2A} = -\frac{316}{6\cdot 2\cdot 2\cdot 10^{-4}} = -13{,}167\cdot 10^4, \frac{kN}{m^2}$$

x_1 - oraliqdagi brus C - reaktsiya kuchi va Δt haroratlar farqi ta'sirida deformatsiyalanadi: $\Delta\ell_1 = \frac{N_1 x_1}{E2A} + \alpha\cdot\Delta t\cdot x_1$

$x_1 = 0$ *bo'lsa* $\Delta\ell_1 = 0$

$x_1 = 2м$ *bo'lsa* $\Delta\ell_1 = 6{,}83\cdot 10^{-4}\, m$

II – II qirqim. Ajratilgan qismning muvozanat shartidan $\sum x = c + N_2 + F - qx_2 = 0$ bo'ylama kuch $N_2 = -c - F_1 + qx_2$ normal kuchlanish $\sigma_2 = \frac{N_2}{A}$, bo'ylama deformatsiya

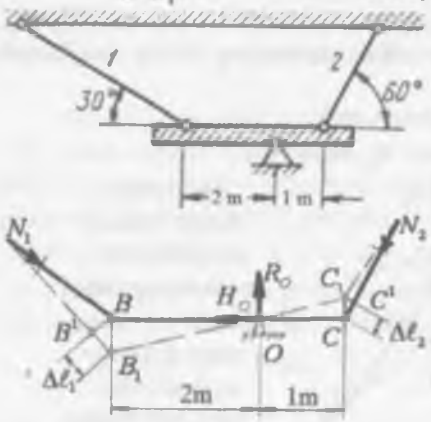
$$\Delta\ell_2 = \Delta\ell_1 + \int_0^2 \frac{N_2 dx}{EA} = \Delta\ell_1 + \int_0^2 \frac{(-C - F_1 + qx_2)dx}{EA} = \Delta\ell_1 - \frac{(c + F_1)x_2}{EA} + q\frac{x_2^2}{2EA};$$

$x_2 = 0;\quad N_2 = -92{,}7kN;\quad \sigma_2 = -46{,}3\cdot 10^4\,\frac{kN}{m^2}\quad \Delta\ell_2 = 6{,}8310^{-4} m$

$x_2 = 2m;\quad N_2 = -\frac{76}{6}kN;\quad \sigma_2 = -6{,}3\cdot 10^4\,\frac{kN}{m^2};$

$\Delta\ell_2 = -19{,}5\cdot 10^{-4} m$

yoki $\sigma_1 = \frac{N_1 \cdot 4}{\pi \cdot d_1^2} \le [\sigma]$ buerdan $d_1 = \sqrt{\frac{4N_1}{\pi[\sigma]}} = \sqrt{\frac{4 \cdot 80}{3{,}14 \cdot 160 \cdot 10^3 \cdot 5{,}96}} = 0{,}0103m$



47 – rasm. Temperatura ta'siridagi statik noaniq sterjenlar sistemasi va sterjenlar deformatsiyalarining o'zaro bog'lanish sxemasi

45-misol. Ko'ndalang kesim yuzalari o'zaro teng bo'lgan ($A_1 = A_2 = 40 \cdot 10^{-4} m^2$) 1 va 2 sterjenlar (*47 – rasm*) $\Delta t = 20^0$ ga qizdirilgan. Sterjenlardagi kuchlanishlar topil sin.

echish. Sterjenlarning qizdirilishi natijasida *VS* brus *O* sharnir atrofida aylanib V_1S_1 holatga o'tadi, 1 stejen N_1 kuch ta'sirida siqiladi va Δt harorat ta'sirida uzayadi, 2 sterjen siqiladi R_0 va N_0 reaktsiya-larining ta'sirini hisobga olmaslik uchun, sistemani muvozanat tenglamasi sifatida O sharnirga nisbatan momentlar tenglamasini tuzamiz, ya'ni: $\sum M_0 = -2N_1 \cos 60^0 + N_2 \cos 30^0 = 0$ yoki

$$N_2 = 2N_1 \frac{\cos 60^0}{\cos 30^0} = 1{,}1547 N_1 \quad (a)$$

(*a*) tenglamadan ko'rinishicha, sistemadagi noma'lumlar soni N_1 va N_2 statikaning muvozanat shartidan ko'p ekan. Masala statik noaniq Masalani echish uchun qo'shimcha deformatsiya tenglamasini tuzamiz. Sxemadan (47 – rasm) ko'rinishicha 1 va 2 sterjenlarning deformatsiyalari quyidagi nisbatda bog'liqdir: $BB_1 = 2CC_1$

$$\frac{\Delta\ell_1}{\cos 60^0} = 2\frac{\Delta\ell_2}{\cos 30^0} \quad \text{bu erdan} \quad \Delta\ell_1 = 1{,}1547\Delta\ell_2 \qquad (б)$$

Sterjenlarning deforma tsiyalarini Guk qonuni bilan ifodalaymiz

$$\Delta\ell_1 = -\frac{N_1 h}{EA \sin 30^0} + \alpha \cdot \Delta t \frac{h}{\sin 30^0}; \quad \Delta\ell_2 = -\left(\frac{N_2 h}{EA \sin 60^0} + \alpha \cdot \Delta t \frac{h}{\sin 60^0}\right)$$

Unda (*b*) tenglama quyidagicha yoziladi:

$$\frac{h}{\sin 30^0}\left(-\frac{N_1}{EA}+\alpha\cdot\Delta t\right)=1{,}1547\frac{h}{\sin 60^0}\left[-\frac{N_2}{EA}-\alpha\cdot\Delta t\right] \quad \text{yoki}$$

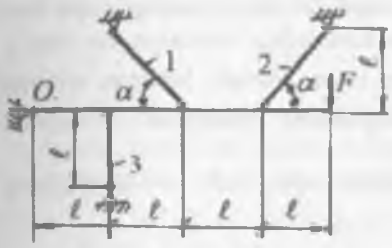
$$-\frac{N_1}{EA}+\alpha\cdot\Delta t=1{,}1547\frac{\sin 30^0}{\sin 60^0}\left(-\frac{N_2}{EA}-\alpha\cdot\Delta t\right)$$

bu erdan $-N_1+0{,}6667N_2=EA(-0{,}667\alpha\cdot\Delta t-\alpha\cdot\Delta t)$

(a) tenglamani hisobga olsak $1{,}7698N_1=1{,}667\alpha EA\Delta t$ hosil bo'ladi unda $N_1=18834kg$ va $N_2=21747kg$

1 sterjendagi kuchlanish $\sigma_1=\frac{N_1}{A_1}=\frac{18834}{40}=470\frac{kg}{sm^2}$

2 sterjendagi kuchlanish $\sigma_2=\frac{N_2}{A_2}=\frac{21747}{40}=543\frac{kg}{sm^2}$



48 – rasm. Statik noaniq sterjenlar sistemasi

46-misol. OD balka kesim yuzalari $A=1\cdot10^{-3}m^2$ bo'lgan po'latdan tayyorlangan sterjenlar bilan bog'langan. Sistemaga qo'yilishi mumkin bo'lgan rux-sat etilgan kuch $[F]$ ni sterjen-lardagi eng katta kuchlanishini $[\sigma]=160\ mPa$ ga tenglashti-rib topilsin; oquvchanlik chegarasidagi kuchlanishdan $\sigma_{oc}=240\ mPa$ foydalanib chekli yuk G'_{chek} topilsin.

$\ell=1M;\ \alpha=45^0;$

echish: OD balka G' kuch ta'sirida O sharnir atrofida aylanadi 1 va 2 sterjenlarni cho'zilishga va 3 sterjen siqilishga qarshilik ko'rsatadi deb qabul qilamiz. Sterjenlarning deformatsiyadan keyingi holati va hisoblash sxemasi 48 – rasmda ko'rsatilgan.

Sistemaning muvozanat holatini ifodalovchi statikaning tenglamalarini tuzamiz:

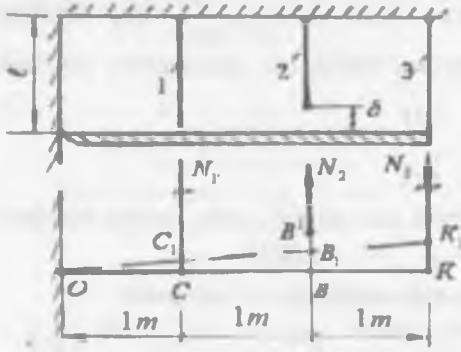
$$\sum x=0;\quad x_0-N_1\cos\alpha+N_2\cos\alpha=0 \qquad (a)$$

$$\sum y=0;\qquad y_0+N_3+N_1\sin\alpha+N_2\sin\alpha-F=0 \quad (б)$$

$$\sum M_0=0;\qquad 2N_1\sin\alpha+3N_2\sin\alpha+N_3-4F=0 \quad (в)$$

$\sum M_0 = 0$ tenglamani tuzamiz.

$$\sum M_0 = N_1 \cdot 1 - N_2 \cdot 2 + N_3 \cdot 3 = 0$$



50–rasm. Statik noaniq sterjenlar sistemasi va sterjenlar deformatsiyalarining o'zaro bog'lanish sxemasi

Bitta tenglamada uchta $N_1; N_2$ va N_3 ma'lum ichki kuchlar bor ekan. Bu masala statik noaniqdir. Noma'lumlar soni muvozanat tenglamasidan ikkitaga ko'p. Shun ing uchun, tanlangan masala ikki marotaba noaniq. Masalaning aniqmaslik darajasini ochish uchun ikkita qo'shimcha deformatsiya tenglamalarini tuzish kerak (50 – rasm). Konstruktsiyaning deformatsiyasini o'rganamiz. 1 va 3 sterjenlarning siqilishda, birinchi sterjen $CC_1 = \Delta\ell_1 = \frac{N_1\ell}{EA}$ masofaga, uchinchi sterjen $KK_1 = \Delta\ell_3 = \frac{N_3\ell}{EA}$ masofaga qisqaradi. Natijada V nuqta V_1 ga ko'chadi. 2 sterjenni brus bilan tutashtirish uchun, uni $\Delta\ell_2 = \frac{N_2\ell}{EA}$ masofaga uzaytirish kerak.

Konstruktsiyadagi sterjenlarning deformatsiyasi natijasida uchburchaklar hosil bo'ladi: $\Delta KK_1O \infty \Delta BB_1O \infty \Delta CC_1O$

Unda $\frac{KK_1}{KO} = \frac{CC_1}{CO}$ yoki $\frac{\Delta\ell_3}{3} = \frac{\Delta\ell_1}{1}$ va $\Delta\ell_3 = 3\Delta\ell$

bu erdan $\frac{N_3\ell}{EA} = 3\frac{N_1\ell}{EA}$, $N_3 = 3N_1$ (*b*)

$\frac{BB_1}{BO} = \frac{CC_1}{CO}$ $\frac{\delta - \Delta\ell_2}{2} = \Delta\ell_1$ va $\delta - \Delta\ell_2 = \Delta\ell_1$

bu erdan $\delta - \frac{N_2\ell}{EA} = 2\frac{N_1\ell}{EA}$ va $N_2 = \frac{\delta EA - 2N_1\ell}{\ell}$ (*v*)

hosil bo'ladi. (*b*) va (*v*) tengliklarni (*a*) tenglamaga keltirib qo'yamiz:

$$N_1 \cdot 1 - 2\frac{\delta \cdot EA - 2N_1\ell}{\ell} + 9N_1 = 0, \quad 10N_1\ell - 2\delta \cdot EA + 4N_1\ell = 0$$

va $N_1 = \frac{\delta \cdot EA}{7\ell} = \frac{0{,}5 \cdot 10^{-4} \cdot 2 \cdot 10^8 \cdot 20 \cdot 10^{-4}}{7} = \frac{20}{7} kN$

Birinchi sterjendagi kuchlanish:

$$\sigma_1 = \frac{N_1}{A} = \frac{20}{7 \cdot 20 \cdot 10^{-4}} = 0{,}143 \cdot 10^4 \frac{kN}{m^2}$$

(v) tenglikdan N_1-ni topamiz: $N_2 = \frac{100}{7} kN$

Ikkinchi sterjendagi kuchlanish:

$$\sigma_2 = \frac{N_2}{A} = \frac{100}{7 \cdot 20 \cdot 10^{-4}} = 0{,}715 \cdot 10^4 \frac{kN}{m^2}$$

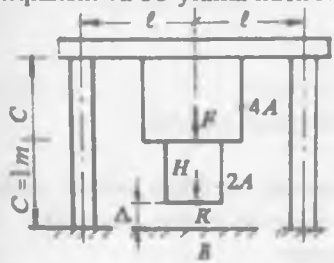
(b) tenglikdan N_1-ni topamiz: $N_3 = 3\frac{20}{7} = \frac{60}{7} kN$

va kuchlanish $\sigma_3 = \frac{N_3}{A} = \frac{60}{7 \cdot 20 \cdot 10^{-4}} = 0{,}429 \cdot 10^4 \frac{kN}{m^2}$

48-misol. Pog'onali brus kesim yuzasi A va asosi qo'zg'almas bo'lgan po'latdan tayyorlangan ikkita sterjenlarga bikr mahkamlangan.

1) qo'zg'almas tayanch bilan pog'onali bruslar orasidagi masofa $\Delta = 1 \cdot 10^{-4} m$ kuchni qancha qiymatida yopiladi;

2) o'rta sterjenni pastki asosidagi reaktsiya kuchi V berilgan kuch N orqali aniqlansin va bo'ylama kuch N epyurasi qurilsin



51 – rasm. Statik noaniq masala

echish. Birinchi savolga javob berish uchun pog'onali brusni N kuchdan deformatsiyasini Δ masofaga tenglashtiramiz

$$\Delta = \frac{HC}{4E4} + \frac{HC}{4E4} + \frac{HC}{2EA} + \frac{H2C}{EA} = \frac{3HC}{EA} \qquad (a)$$

$$\Delta = \frac{3H}{2 \cdot 10^8 \cdot 2 \cdot 10^{-3}} \qquad yoki \quad H = \frac{40}{3} kN$$

Bu erda: $E = 2 \cdot 10^8 \frac{kN}{m^2}$ va $A = 2 \cdot 10^{-3} m^2$

a) tenglama asosida topilgan N kuchi, masalani shartida berilgan $N = 50$ *kN* kuchdan kichik. Demak, brus bilan tayanch oralig'idagi masofa

yopiladi. Masofa yopilishini aniqlash uchun berilgan $N = 50\ kN$ kuch ta`sirida (a) tenglama asosida topilgan pog'onali brusning to'liq deformatsiyasi Δ_k-ni $\Delta = 1 \cdot 10^{-4}$ m bilan taqqoslaymiz:

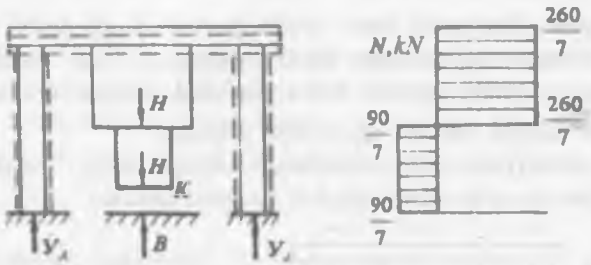
$$\Delta_k = \frac{3HC}{EA} = \frac{3 \cdot 50 \cdot 1}{2 \cdot 10^5 \cdot 2 \cdot 10^{-3}} = 3{,}75 \cdot 10^{-4} m \qquad yoki \quad \Delta_k \succ \Delta$$

Demak, Δ-masofa yopiladi. Brusni K kesimi V tayanchga kelib tayanadi. Sistema- ni hisoblash sxemasi 2.45 – rasmda ko'rsatilgan. Reaktsiya kuchlari Y_A va V larning sistemani muvozanat shartidan topamiz:

$$\sum Y = 2Y_A + B - 2H = 0 \qquad (b)$$

(b) tenglamadan ko'rinishicha, sistemada noma`lum reaktsiya kuchlari statikani muvozanat tenglamasidan ikkitaga ko'p. Demak, sistema bir marotaba statik aniqmas ekan.

Noma`lum Y_A va V reaktsiya kuchlarini topish uchun (b) tenglama yoniga qo'shimcha deformatsiya tenglamasini tuzishimiz kerak.



52 – rasm. Asosiy sistema va ichki kuch epyurasi

Buning uchun ikki pog'onali brusni va ikkita chetki sterjenlardan bittasini berilgan N kuchidan deformatsiyasini reaktsiya kuchlari ta`siridagi deformatsiyaga tenglashtiramiz:

$$\frac{HC}{2EA} + \frac{HC}{4EA} + \frac{HC}{4EA} + \frac{H2C}{EA} - \frac{BC}{4EA} - \frac{BC}{E2A} - \frac{Y_A 2C}{EA} = \Delta \quad (a)$$

Agar, $Y_A = \frac{B}{2}$ deb qaralsa (v) tenglamani

$12HC - 7BC = 4\Delta EA$ ko'rinishga keltiramiz. Bu erdan:

$$B = \frac{12HC - 4\Delta EA}{7C} = \frac{12 \cdot 50 \cdot 1 - 4 \cdot 10^{-4} \cdot 2 \cdot 10^5 \cdot 2 \cdot 10^{-3}}{7 \cdot 1} = \frac{440}{7} \hat{e}\hat{I}$$

B reaktsiya kuchini (b) tenglamaga keltirib qo'ysak Y_A reaktsiya kuchini topamiz: $Y_A = \frac{2H-B}{2} = H - \frac{B}{2} = 50 - \frac{440}{7} = \frac{130}{7} kN$

Pog'onali brusni oraliqlarga bo'lib, ichki bo'ylama kuch N ni topamiz

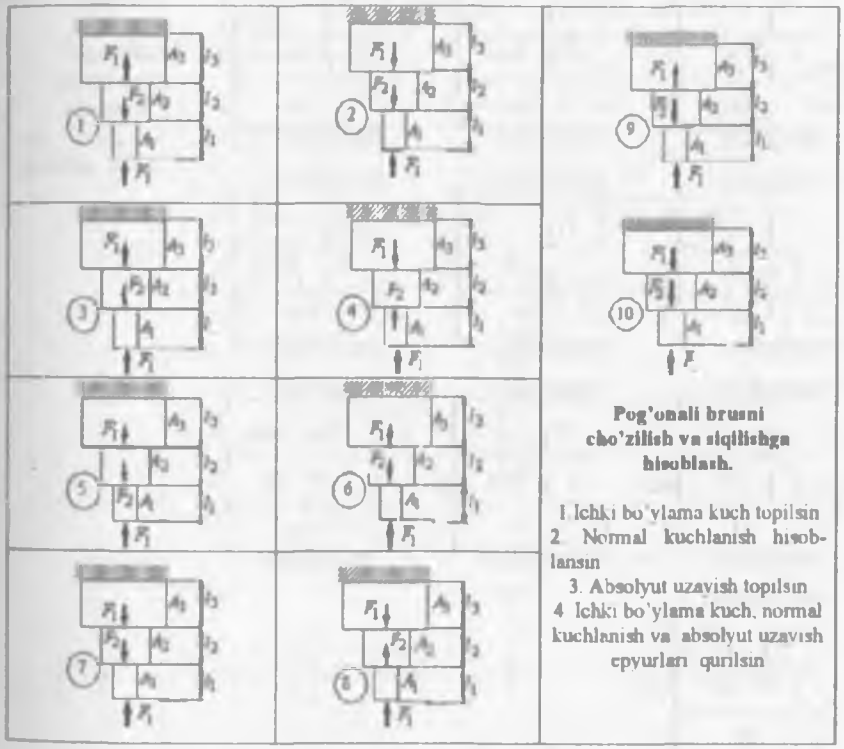
1 – 1qirqim. $\sum Y = N_1 - H + B = 0$ yoki

$N_1 = H - B = 50 - \frac{440}{7} = -\frac{90}{7}$ (siquvchi kuch)

2 – 2 qirqim. $\sum Y = N_2 - 2H + B = 0$

$N_2 = 2H - B = 2 * 50 - \frac{440}{7} = \frac{260}{7} kN$ (cho'zuvchi kuch)

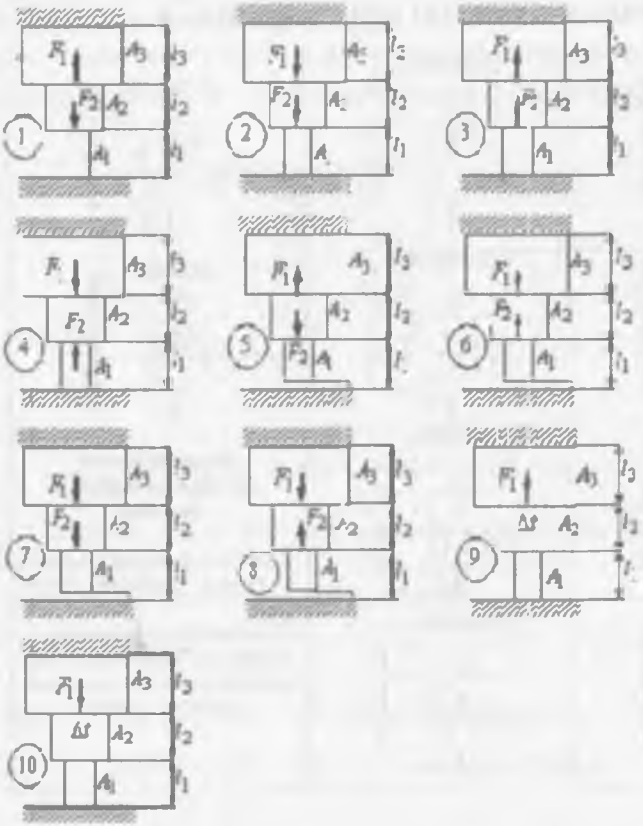
HISOBLASh - GRAFIK ISh UChUN TOPShIRIQLAR



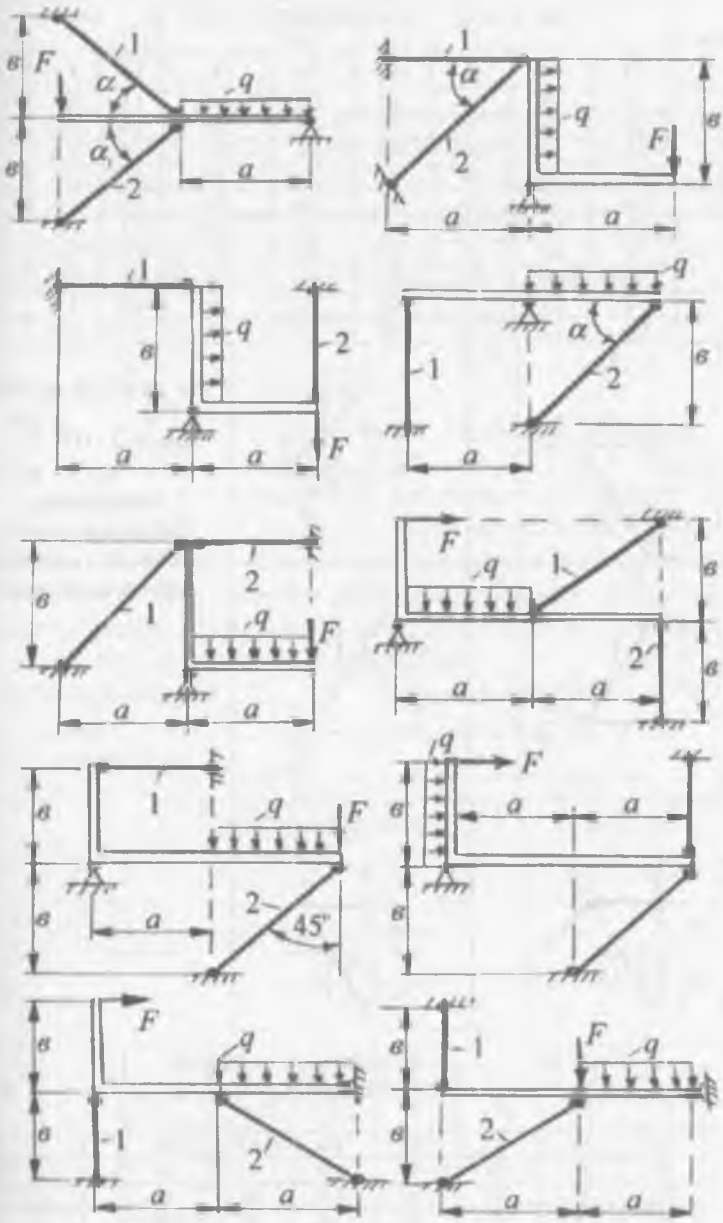
Pog'onali brusni cho'zilish va siqilishga hisoblash.

1. Ichki bo'ylama kuch topilsin
2. Normal kuchlanish hisoblansin
3. Absolyut uzayish topilsin
4. Ichki bo'ylama kuch, normal kuchlanish va absolyut uzayish epyurlari qurilsin

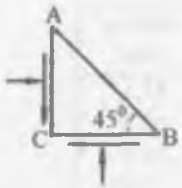
Variant	Kuchlar, kN		Kesim yuza, m			Uzunlik, m		
	F_1	F_2	A_2	A_3	A_1	l_1	l_2	L_3
1	10	100	50	60	100	5.0	1.0	1.0
2	20	90	40	70	80	4.0	2.0	2.0
3	30	80	30	80	60	3.0	3.0	3.0
4	40	70	20	90	40	2.0	4.0	4.0
5	50	60	10	100	20	1.0	5.0	5.0
6	60	50	50	100	100	1.0	1.0	1.0
7	70	40	40	90	80	2.0	2.0	2.0
8	80	30	30	80	60	3.0	3.0	3.0
9	90	20	20	70	40	4.0	4.0	4.0
10	100	10	10	60	20	5.0	5.0	5.0



Statik noanik pogonali brus chuzilish va siqilishga hisoblansin Chizmada $\Delta t = 20°$ va $\delta =$ qabul qilinsin



(chizmada a = v = 1m qabul qilinsin)



2.6-misol. Rasmda tasvirlangan uchburchak elementning AS va SV yoqlari bo'yicha bir xil qisuvchi normal kuchlanishlar – 50 MPa va urinma kuchlanishlar ta'sir qiladi, AV yoqqa esa yuk qo'yilmagan. AS va SV yoqlar bo'yicha urinma kuchlanishlar qiymatini hamda asosiy kuchlanishlarning qiymati va yunalishini aniqlang.

javob: $\tau = 50$ MPa; $\sigma_1 = 0$; $\sigma_3 = -100$ MPa.

2.7-misol. Bosim balandligi 100 m bo'lganda diametri 120 sm li cho'yan vodoprovod trubasining devori qalingligini aniqlang. Cho'yan uchun cho'zilishga ruxsat etiladigan kuchlanish 20 MPa deb oling.

javob: 30 mm = $3 \cdot 10^{-2}$ m.

2.8-misol. Tashqi diametri 54 mm va ichki diametri 50 m li viniplast vodoprovod trubasida bosimning maksimal balandligi qancha bo'lishi mumkin? Viniplast uchun uzoq cho'zilishga ruxsat etiladigan kuchlanishni 80 MPa deb oling.

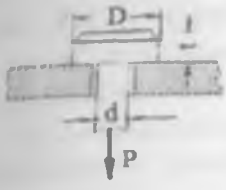
javob: 61,5 m.

2.9-misol. Ish bosimi 10 at ta'sirida bo'lgan diametri 250 sm li po'lat qozon devorining mustahkamligini tekshiring. Devorning qalinligi 12 mm, uchun ruxsat etiladigan kuchlanish 90 MPa ga teng. IV mustahkamlik nazariyasini qo'llang.

javob: $\sigma_{IV} = 90$ MPa.

III. SILJISh

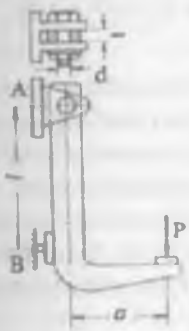
Parchin mixli birikmani qirqilishga va ezilishga hisoblash bilan birga, har bir detal cho'zilishga ham hisoblanadi, parchin mix o'rni va soni to'g'ri hisoblanganmi – yo'qmi tahlil qilinadi. Birikmaga qo'yilishi mumkin bo'lgan kuchni ruxsat etilgan qiymati, biriktiriluvchi detallar kesimining o'lchamlari–eni va qalinligi hisoblanadi. Bunday masalalar [4] da ko'plab keltirilgan. Masalan, echish sifatini doskada aniq va ravon, chiroyli chizilgan sxemasi ham belgilaydi, bunday ayrim detallarni akseonometrik ko'ri-nishlari berilishi kerak. [12] to'plamdan 3,1; 3,4; 3,5; 3,9; 3,10; 3,12; 3,15; 3,16; 3,19; 3,20 masalalar tavsiya etiladi.



3.1-rasm

3.1-misol. Kuch R = 120 kN bilan yuklangan tirsakli richagni A nuqtada sharnirli po'lat bolt va V nuqtada rolikli tayanch tutib turadi. Po'lat uchun ruxsat etiladigan qirqish va ezish kuchlanishlari $[\tau]$ = 120 MPa va $[\sigma_e]$ = 250 MPa bo'lsa, boltning zarur diametrini aniqlang. Richag tayanch lari orasidagi masofa l = 75 sa, o'lcham a=50 sm, qalinlik t = 3 sm. Ko'rsatma. Boltga tushadigan bosimni richagning muvozanatlik shartidan kelib chiqib A nuqtadagi to'liq reaktsiya sifatida aniqlang.

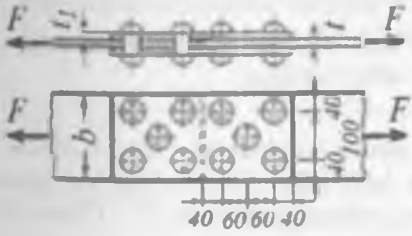
javob: d = 2,8 sm.



3.2-rasm

3.2-misol. Cho'zilishga ishlaydigan d = 100 mm diametri bolt kallagi listga tayanib turibdi (3.2-rasmga qarang). Agar bolt kesimidagi cho'zuvchi kuchlanish σ = 100 MPa, kallak tayangan yuzadagi ezish kuchlanishi σ_e = 40 MPa va kallakni qirqish kuchla-nishi τ = 50 MPa bo'lsa, kallak diametri D ni va balandligi t ni aniqlang.

Javob: D = 187 mm; t =50 mm.



3.3-rasm

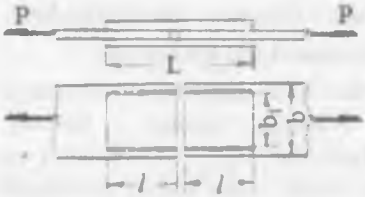
3.3-misol. Qalinligi t = 10 mm bo'lgan va har birining qalin-ligi t_1 = 6 mm.li ikki ust qo'yma bilan yopilgan ikki listning tutashgan joyi R = 240 kN kuch bilan cho'ziladi. (3.3-rasm). Agar ruxsat etiladigan kuchlanishlar: parchin mixlar uchun – qirqi-lishga $[\tau]$ = 100 MPa, ezilishga $[\sigma_e]$ = 240 Mpa va listlarni

echish. Old choklarning mustahkamligi qirqimga shartli ravishda tekshiriladi. Barcha choklar qabul qiladigan kuch ularning ish kesimi bo'yicha bir tekis taqsimlanadi deb qabul qilingan.

Demak, bundan yon choklarning uzunligi hisoblanadi.

$$l_h \geq \frac{1}{2}\left(\frac{P}{2\cdot 0{,}7t[\tau_E]} - b\right) = \frac{1}{2}\left(\frac{15\cdot 10^4}{0{,}7\cdot 0{,}01\cdot 9\cdot 10^7} - 0{,}1\right) = 0{,}069 \text{ m}.$$

Chokning loyihadagi uzunligini (chokning faat bir tomonida payvandlanmay qolgan joy bor deb hisoblab) quyidagicha olish kerak:



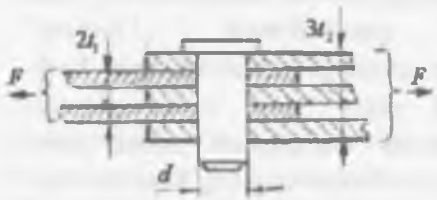
3.7-rasm

3.7-misol. Ikkita ustqo'yma bilan yopilgan ikki listning tutashgan joyi P= 240 kN kuch bilan cho'ziladi (3.7-rasmga qarang).

a) Agar listlarning qalinligi t = 10 mm, ustqo'ymalarning qalinligi t_1 = 8 mm, choklarning qirqimiga ruxsat etiladigan kuchlanishi $[\tau_e]$ = 100 MPa bo'lsa, ustqo'ymalarni biriktirish uchun zarur yon choklarning uzunligini aniqlang.

Har bir chokning faqat bir uchidagi 5 mm uzunlikda payvandlanmay qolgan joyni o'lchamlarini (ustqo'ymaning eni va uzunligini parchinmixli birikma o'lchamlariga (3.7- masaladagi ma`lumotlarga qarang solishtiring. Parchin mixli birikma o'rniga payvand birikmadan foydalanganda qancha metall tejalishini chamalab ko'ring.

javob: a) l= 112 mm; b) payvand chok uchun a=150 mm, b_1 = 130 mm, L = 225 mm, parchinmixli birikma uchun b_1 = 190 mm va L = 400 mm) . Faqat listlarning asosiy metalini tejash 21 % ni tashkil qiladi.



3.8-rasm

3.8-misol. Boltli birikma dagi po`latdan tayyorlangan valik orqali 480 *kN* kuch uzatiladi. Valikni qirqilishga va ezilishga mustahkamlik shartidan foydalanib, uning diametrini va ulanuvchi elementlarni o`lchamlari topilsin.

$$[\tau]=95\cdot10^3\frac{kN}{m^2}$$

Ruxsat etilgan kuchlanish: qirqilishga ezilishga

$[\sigma]=95\cdot10^3\frac{kN}{m^2}$ $[\sigma]=160\cdot10^3\frac{kN}{m^2}$

va cho`zilishga

echish: Boltli birikmani mustahkamlik shartidan foydalanib valikning diametrini topamiz: $\tau=\frac{F}{4A}\le[\tau]$

bu erda: $A=\frac{\pi\cdot d^2}{4}$ - valikni bitta qirqilish yuzasi, 4 – qirqi-lish yuzalarining soni

$$d=\sqrt{\frac{4\cdot F}{4\cdot\pi[\tau]}}=\sqrt{\frac{480}{3{,}14\cdot95\cdot10^3}}=40mm$$

Unda valikni diametri:

t_1 - qalinliklardagi elementlarning ezilishga mustahkamlik shartidan foydalanib t_1 qalinlikni topamiz. $\sigma_{.}=\frac{F}{ntd}\le[\sigma]_{.}$ bu erdan

$$t_1=\frac{F}{2d[\sigma]}=\frac{480}{2\cdot0{,}04\cdot250\cdot10^3}=0{,}024m$$

Ikkita bir xil t_1 - qalinlikdagi va eni bir xil bo`lgan elementlarni cho`zilishga mustahkamlik shartidan foydalanib

b ni topamiz. $\sigma=\frac{F}{2t_1(v-md)}\le[\sigma]$, bu erda $m=1$.

$$b=\frac{F}{2t_1[\sigma]}+d=\frac{240}{160\cdot10^3\cdot0{,}024}+0{,}04=0{,}1025m$$

Unda

Birikmadagi qolgan 3 ta elementning qalinligi t_2 topamiz.

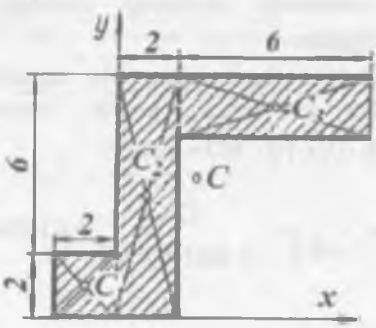
$$\sigma=\frac{F}{3t_2(v-md)}\le[\sigma]$$

$$t_2=\frac{F}{3(b-d)[\sigma]}=\frac{480}{3(0{,}1025-0{,}04)\cdot160\cdot10^3}=0{,}016m$$

Bu erdan

3.9-misol. Qalinligi $t=10mm$ bo`lgan ikkita element diametrlari $d=20mm$ bo`lgan 6 ta parchin mix bilan ustma-ust ulangan. Ruxsat etilgan cho`zuvchi kuch va elementlarni eni topilsin

IV. GEOMETRIK XARAKTERISTIKALAR



4.1-rasm.

4.1-misol. 4.1- rasmdagi jism yuzasining og'irlik markazi aniqlansin. Barcha o'lchamlar santimetrda.

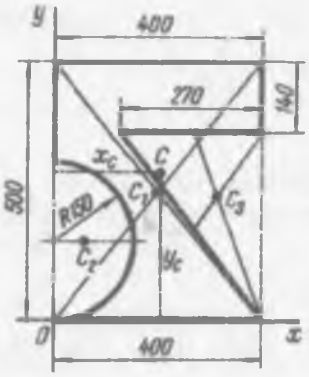
echish. Koordinata o'qlarini o'tkazib, jism yuza-sini uchta to'rtburchakka bo'lamiz (bo'lish chiziqlari shtrix bilan ko'rsatilgan). Har bir bo'lagi og'irlik markazining koordinatalarini va yuzalarini aniqlaymiz: C_1 (— 1; 1); C_2 (1; 4),

C_3 (5; 7), $A_1 = 4\ sm^2$, $A_2 = 16\ sm^2$, $A_3 = 12\ sm^2$.

Shaklning og'irlik markazini aniqlaymiz:

$$x_c = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3} = \frac{4\cdot(-1) + 16\cdot 1 + 12\cdot 5}{4 + 16 + 12} = \frac{9}{4}\ sm$$

$$y_c = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3} = \frac{4\cdot 1 + 16\cdot 4 + 12\cdot 7}{4 + 16 + 12} = \frac{19}{4}\ sm$$



4.2 - rasm

4.2-misol. 4.2 - rasmda ko'rsatilgan bir jinsli plastinka og'irlik markazining vaziyati aniqlansin.

echish. Plastinkani XOY koordinata sistemasiga joylashtiramiz va kesim yuzasini oddiy yuzalarga ajratamiz: to'g'ri burchak – 400 x 500, yarim aylana va uchburchak. Unda

$$X_c = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3};$$

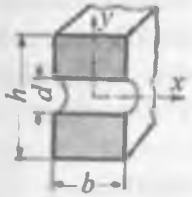
$$Y_c = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$A_2 = -\frac{\pi}{2}(15)^2 = -353 \quad sm^2; \qquad A_1 = 40 \times 50 = 2000 \quad sm^2; \qquad x_1 = 20 sm$

$x_2 = \frac{4 \cdot 15}{3\pi} = 6{,}37 \ sm \quad A_3 = -\frac{1}{2} \cdot 27 \cdot 36 = -486 \ sm^2;$

$x_3 = 13 + \frac{2}{3} \cdot 27 = 31 \ sm; \quad y_1 = 25 \ sm; \quad y_2 = 15 \ sm; \quad y_3 = \frac{2}{3} \cdot 36 = 24 \ sm$

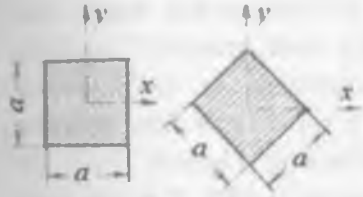
Og'irlik markaz koordinatalari: $X_c = 19{,}5 \ sm$ va $Y_c = 28{,}4 \ sm$



4.3-rasm

4.3-misol. Dumaloq teshik bilan kuchsizlangan to'g'ri to'rtburchak brus kesimining bosh markaziy inertsiya momentlari va qarshilik momentlari kattaligini aniqlang (4.3-rasmga qarang). O'lchamlar quyidagicha: b = 12 sm, h=20 sm, d=5 sm.

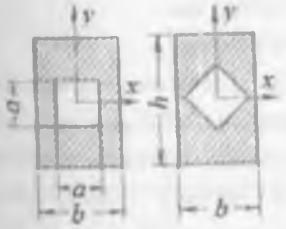
javob: $J_x = 7875$ sm^4; $J_y = 2160$ sm^4; $W_x = 787{,}5$ sm^3; $W_y = 360$ sm^3.



4.4-rasm

4.4-misol. x - o'qni gorizontal qoldirgan holda (4.4-rasmga qarang) kesimini 45 ° burchakka burilsa, tomonlari α ga teng bo'lgan kvadratning x o'qqa nisbatan inertsiya momenti va qarshilik momenti qanday o'zgaradi?

javob: Inertsiya momenti o'zgarmaydi, qarshilik momenti 41 % kamayadi.



4.5-rasm

4.5-misol. 4.5-rasmda ko'rsatilgan ichi bo'sh to'g'ri to'rtburchak kesimning bosh markaziy inertsiya momentlari, bosh inertsiya radiuslari va qarshilik momentlarini hisoblang. O'lchamlar: b=12 sm, h=20 sm, α = 6 sm. Agar rasm, b da ko'rsatilganidek ichki kvadrat bo'shliq 45 ° burchakka burilsa,

kesimning bu xarakteristikalari qanday o'zgaradi?

Javob: a) J_x =7892 sm^4; J_y = 2772 sm^4; i_x = 6,16 sm. W_x =789,2 sm^3; W_y =462 sm^3; i_y = 3,69 sm.

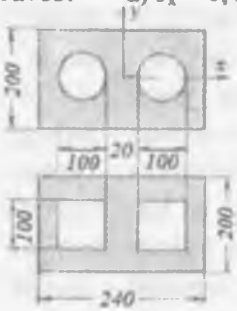
b) o'zgarmaydi

4.6-rasm

4.6-misol. Agar uchchala kesim yuzasi bir xil bo'lsa (rasmga qarang) to'g'ri to'rtburchak kvadrat va doiraning kesimlari inertsiya momentlari kattaligini markaziy *x* o'qga nisbatan taqqoslang.

Ko'rsatma. Shakllarning inertsiya momentlarini kesim yuzasi orqali ifodalang.

Javob: a) $J_x = 0,167 \cdot F^2$; b) $J_x = 0,0833 \cdot F^2$; v) $J_x = 0,797 \cdot F^2$



4.7-rasm

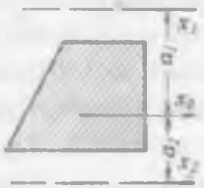
4.7-misol. Quyidagi ikki variantda loyixalangan to'g'ri to'rtburchak shaklli ikki kanalli trubaning bosh markaziy inertsiya momentlarini xisoblang: a) har birining diametri d = 10 sm bo'lgan ikki dumaloq teshikli, b) har birining o'lchami 10x10 sm bo'lgan ikki kvadrat teshikli. Kesimlarining o'lchamlari rasmda mm da berilgan.

Javob: a) $J_x \approx 15000$ sm^4,

$J_u \approx 16400$ sm^4,

b) $J_x \approx 14300$ sm^4,

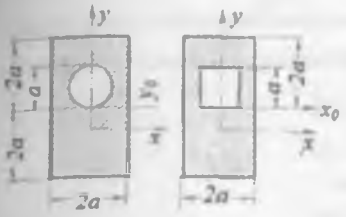
$J_u \approx 14200$ sm^4.



4.8-rasm

4.8-misol. Yuzasi A bo'lgan kesimning x_2 o'qqa nisbatan inertsiya momenti kattaligini aniqlang. Uning x_1 o'qiga nisbatan inertsiya momenti berilgan (4.8-rasmga qarang). Kesimlarning og'irlik markazidan x_1 va x_2 o'largacha bo'lgan masofa a_1 va a_2 larga teng.

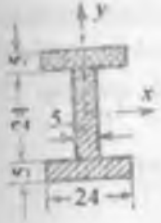
javob: $J_{x2} = J_{x1} + F(a_2^2 - a_1^2)$.



4.9-rasm

4.9-misol. Quyidagi ikki variantda loyixalangan to'g'ri to'rtburchak kesimli trubaning bosh markaziy inertsiya momentlarini va bosh inertsiya radiuslarini taqqoslang :

a) dumaloq teshikli va b) kesim balandligi bo'yicha bir xil joylashgan kvadrat teshigli. Kesimlarning eng kichik qarshiliklaar momentlarini markaziy *x* o'qga nisbatan xisoblang.

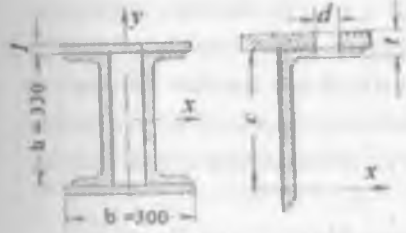


4.10-rasm

4.10-misol. Yog'och balka bir-biriga dvutavr ko'rinishida elimlangan bir xil taxtadan iborat (4.10-rasmga qarang) Agar har qaysi taxta kesimining o'lchamlari 5x24 sm bo'lsa, dvutavr yuzasining bosh markaziy inertsiya momentlari va qarshilik momentlarini aniqlang

javob: $J_x = 56660\ sm^4$. $J_y = 11770\ sm^4$;

$W_x = 3330\ cm^3$; $W_u = 980\ cm^3$.



4.11-rasm

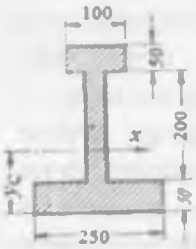
4.11-misol. Ikkita shveler № 33 dan iborat bo'lgan va 300x14 mm o'lchamli listlar bilan yopilgan yig'ma balka (rasmga qarang) ikki variantda loyixalanadi: a) payvandlab – listlar shvellerlar tochkasiga yon choklar bilan payvandlanadi, b) parchinlab – listllar shvellerlar tokchasiga diametri d= 23 mm li parchin mixlar yordamida payvandlanadi. Ikkala variant uchun kesimning x o'qqa nisbatan inertsiya momentini va qarshilik momentini hisoblang va natijalari taqoslang.

Ko'rsatma. Kesimning parchin mixlar uchun ochilgan teshiklardan kuchsizlanishini xisoblash maqsadida rasm, b da shtrixlanmagan to'rta

teshikning x o'qqa nisbatan inertsiya momentini ushbu formuladan xisoblang: $\Delta J_x=4\ (\frac{dt3}{12}+dtc2)$. teshiklarning xususiy inertsiya momentlarini ($\frac{dt3}{12}$) xisobga olmasa ham bo'ladi.

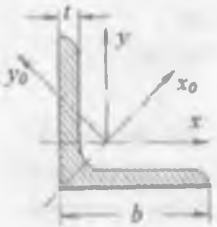
Butun kesimning inertsiya momenti $J_H = J_{br} - \Delta J$.

javob: a) $J_x = 40800$ sm^4. $W_x = 2280$ sm^3;
$J_x = 34300$ sm^4; $W_x = 1920$ sm^3.



4.12-misol. Tokchasining eni har xil bo'lgan qo'shtavr (rasmgga qarang, mm) uchun kesimning ogirlik markazi vaziyatini aniklang xamda shakl yuzasining markaziy x o'qqa nisbatan inertsiya momentini va eng kichik qarshilik momentini xisoblang. Devorning qalinligi 22 mm.

javob: $U_g = 10,8$ sm; $J_x = 25470$ sm;
$W_x = 1330$ sm^3



4.13-rasm.

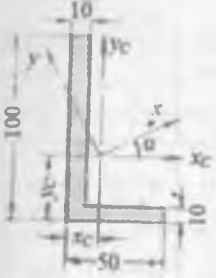
4.13-misol. O'lchamlari 125x125x10 bo'lgan teng yonli prokat burchakligi kesimi yuzasining burchaklik tokchalariga parallel bo'lgan markaziy o'qlar x va u ga nisbatan markazdan qochma inertsiya momenti kattaligini toping. Agar kesimni vertikal o'q atrofida 180° burilsa (gorizontal tokchasini chapga qilib) markazdan qochma inertsiya momentining iymati qanday o'zgaradi?

Agar burchaklikni ikki to'g'ri to'rtburchakga ajratib va dumaloqlangan joylarni xisobga olmay xisoblansa, J_{xy} kattalikni aniqlashdagi xatolik qancha bo'lishini aniqlang.

javob: 1) $J_{xy} = \frac{J_{x0}-J_{y0}}{2}\sin 2\,a = -211$ sm^4 (a<0);
2) J_{xy} =211 sm^4 (α burchakni ishorasi uzgaradi).
3) J_{xy} = - 215 sm^3 xatolik 1.9,%.

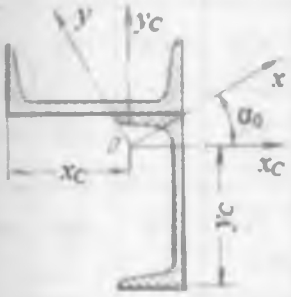
4.14-misol. Rasmda kursatilgan teng yonli burchaklikning kesimi ogirlik markazi koordinatalarini aniklang, shakl yuzasining bosh markaziy

inertsiya uklari vaziyatini toping va shu uklarga nisbatan inertsiya momentlarini xisoblang. Kesimni (ulchamlari rasmda mm da berilgan) ikkita tugri turtburchakdan iborat deb karang (dumaloklangan joylarni xisobga olmang).



javob:X_C = 1,2 sm; Y_c = 3,7 sm; α =14°23.J_x = I_{max} = 150 sm^4 ; J_y =15,7 sm^4.

4.14-rasm



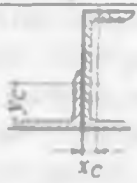
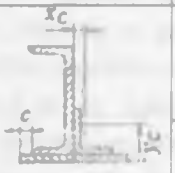
4.15-rasm

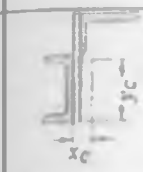
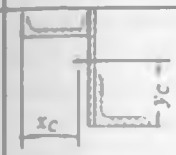
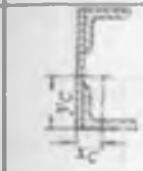
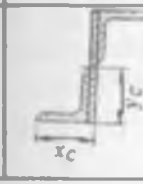
4.15-misol. Ikkita shveller №12 dan iborat kesimning og'irlik markazi koordinatalarini niklang,shaklning usha kesim tomonlariga parallel markaziy uklar (J_{xS}, J_{uO}, J_{SuS})ga nisbatan inertsiya momentlarini xisoblang va analitik xamda grafik usullarda bosh uklarning uklar X_s ·U_s ga kiyalik burchagi α_0 ni toping, shaklning bosh inertsiya momentlari va va bosh inertsiya radiuslari kattaligini aniklang.

javob: x_s =8,23 sm, U_s =9,77 sm^4, J_{US} = 467 sm^4, J_{USxS} = - 223 sm^4 α_0 = 30°15, J_{MAX}= 845 sm^4, J_{Min}= 332 sm^4, J_{MAX}= 5,63 sm, i_{max} = 3,54 sm.

4.16-misol. Prokat profillardan yasalgan yigma nosimmetrik kesimlar uchun 1)shaklning og'irlik markazi koordinatalarini toping, 2) bosh markaziy inertsiya uklari vaziyatini aniklang,
3) analitik va grafik usullarda (Mor doirasini yasab) kesimining bosh inertsiya momentlari, bosh inertsiya radiuslarini aniklang va inertsiya ellipsini yasang. Kesimlarining shakllari va mm dagi ulchamlari jadvaldagi rasmlarda keltirilgan.

javob: Jadvalga qarang (raqamlar yaxlitlangan, 4.16-rasm).

Sxema nomeri	Kesim sxemasi	variant	Kesim tarkibi	javob				
				Og'irlik markaz koordinatalari		burchak	Bosh inertsiya momentlari	
				x_S	u_S	α	I_{max}	I_{min}
1	2	3	4	5	6	7	8	9
1		a	Shveller №18 burchak 80x80x8	-0,37	11,51	$-11^{0}40^{1}$	1565	245
		b	Shveller №24 burchak 125x125x12	-1,95	16,10	$-15^{05}0^{1}$	4300	1155
2		a	Shveller №18 burchak 90x90x8	0,33	6,50	$-13^{0}30^{1}$	1730	320
		b	Shveller №24 burchak 100x100x10	0,40	8,40	-11^{0}	4200	580
3		a	Shveller №24 l. 200x10 100x100x10 s=12	0,48	5,45	$17^{01}0^{1}$	2885	1065
		b	Shveller №30 l. 260x12 140x140x12	0.84	8,0	$11^{0}55^{1}$	11700	3000
4		a	Shveller №14 l. 240x10 125x80x10	0,93	11,35	$-28^{0}50^{1}$	6175	855
		b	Shveller №16 l. 240x10 160x100x12	0,21	10,	$-34^{0}05^{1}$	7070	2060
5		a	Shveller №20 l. 180x10 80x80x8	16,55	7,5	$35^{0}05^{1}$	4660	1080
		b	Shveller №14 l. 180x10 110x110x8	13,4	8,8	-40^{0}	3300	600
6		a	Shveller №30 l. 200x10 100x100x10	12,05	9,15	$-21^{0}25^{1}$	10980	3020

		b	Shveller №24 L 240x10 100x100x8	13,9	6,67	44^0	7500	3300
7		a	Shveller №16 L 240x10 125x80x10	1,30	14,0	$-17^0 15^1$	4370	520
		b	Shveller №20 L 300x12 140x140x10	1,21	17,3	$-13^0 10^1$	8870	790
8		a	Shveller №16 L 240x10 125x80x10	16,0	10,7	$37^0 15^1$	6310	1180
		b	Shveller №14 L 240x10 125x125x10	14,2	10,7	$31^0 10^1$	5380	910
9		a	L 240x10 100x100x10 160x100x10	3,55	11,0	$9^0 30^1$	5580	1140
		b	L 240x10 90x90x8 180x110x10	3,85	9,9	$16^0 05^1$	5420	1280
10		a	L 400x12 140x140x12	14,6	15,0	$20^0 05^1$	13350	1080
		b	L 400x12 160x160x12	16,6	20,0	$16^0 25^1$	28500	1680

4.17-misol. Tekis kesim yuzalarining geometrik tasniflarini hisoblash. Berilgan:

$$v_L \times h_L = 180 \times 25$$

1. List *(mm)*.;
2. Shveller №20
3. Teng tomonli burchak $80 \times 80 \times 6$ *(mm)*
4. Teng tomonsiz burchak $100 \times 63 \times 8$ *(mm)*

Murakkab shaklli tekis kesimni tarkibidagi har bir kesimni geometrik tasniflarni yozib olamiz.

- shveller №20: $h_{sh} = 200\,mm$; $v_{sh} = 76mm$; $z_0 = x_{sh} = 2,07sm$; $I_{x_{sh}} = 1520sm^4$; $I_{y_{sh}} = 113sm^4$; $A_{sh} = 23,4sm^2$;

- teng tomonli burchak $80 \times 80 \times 6$ *(mm)*

$A_b = 9{,}38sm^2$ $h_b = v_b = 88mm^2$ $x_b = y_b = 2{,}19sm^2$

; ;

$I_{xb} = 57sm^4$ $I_{xo\max} = 90{,}4sm^4$ $I_{yo\min} = 23{,}5sm^4$

; ;

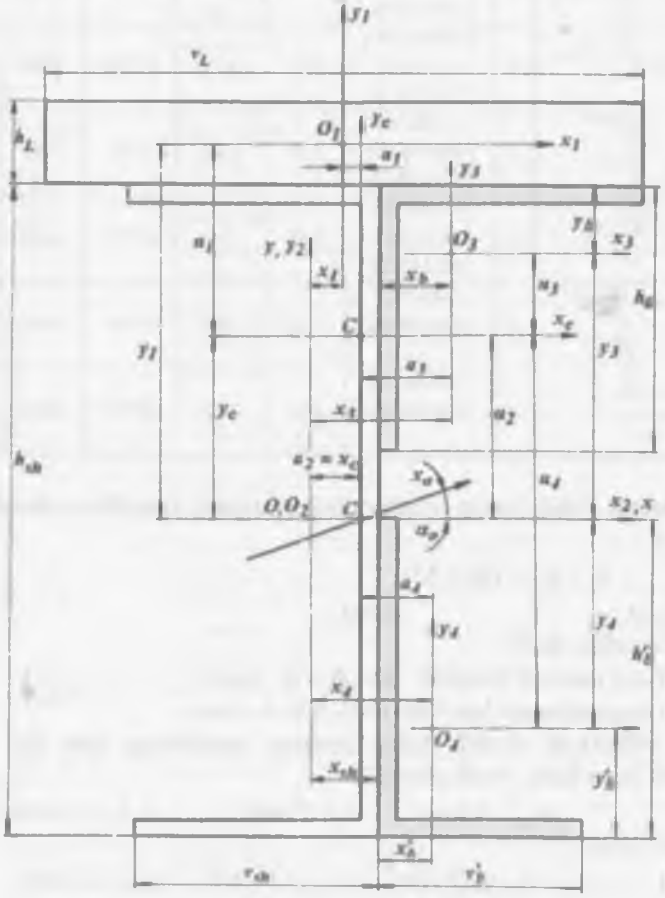
- teng tomonli burchak $100 \times 63 \times 8$ (mm) $tg\alpha = 0{,}391$

$h'_b = B = 100mm$ $v'_b = v = 63mm$ $A'_b = 12{,}6sm^2$

; ;

$I'_{xb} = 127sm^4$ $I'_{yb} = 39{,}2sm^4$ $x_0 = x_b = 3{,}32sm$ $Y_o = x'_b = 1{,}5sm$

; ;



4.17 – rasm. Kesim yuzaning markaziy o'qlariga nisbatan inertsiya momentlarini hisoblash sxemasi.

- 180×25 (mm) list uchun geometrik tasniflar quyidagicha

$$A_1 = v_1 h_1 = 18 \cdot 2{,}5 = 45 sm^2$$

hisoblanadi:

$$I_{x1} = \frac{v_1 h_1^3}{12} = \frac{18(2{,}5)^3}{12} = 23{,}4375 sm^4 \qquad I_{y1} = \frac{h_1 v_1^3}{12} = \frac{2{,}5(18)^3}{12} = 1215 sm^4$$

;

Kesimni *M1:2* masshtabda chizamiz va uning tarkibidagi har bir kesimni og'irlik markazlarini (0_1, 0_2, 0_3, 0_4 – nuqtalari) va ularning markaziy o'qlarini x_1 va u_1 ; x_2 va u_2; x_3 va u_3; x_4 va u_4; koordinata sistemasiga joylashtiramiz. Ayni masalada *xou* koordinata o'qi bilan x_2, 0_2 , u_2 koordinata o'qi ustma – ust qabul qilindi. Tanlangan *xou* - koordinata o'qi bilan x_1 0_1 u_1; x_2 0_2 u_2; x_3 0_3 u_3 va x_4 0_4 u_4 – koordinata o'qlari orasidagi masofalarni hisoblaymiz. (4.17 - rasm);

$$x_1 = \frac{v_1}{2} - (v_b + x_{sh}) = \frac{18}{2} - (8{,}0 + 2{,}07) = 1{,}07 sm$$

xou koordinata o'qi bilan x_2 0_2 u_2 – koordinata o'qi ustma – ust tushganligi uchun $x_2 = 0$ va $y_2 = 0$ bo'ladi, ya`ni shvellarning og'irlik markazi *xou* koordinata sistemasining markazi bilan bitta nuqtada joylashadi.

$$x_3 = x_{sh} + x_b = 2{,}07 + 2{,}19 = 4{,}26$$

sm.

$$x_4 = x_{sh} + x_b' = 2{,}07 + 1{,}5 = 3{,}57$$

sm.;

$$y_1 = \frac{h_{sh} + h_1}{2} = \frac{20 + 2{,}5}{2} = 11{,}25$$

sm.

$$y_3 = \frac{h_{sh}}{2} - y_b = \frac{20}{2} - 2{,}19 = 7{,}81$$

sm.

$$y_4 = -\left(\frac{h_{sh}}{2} - y_b'\right) = -\left(\frac{20}{2} - 3{,}32\right) = -6{,}68$$

sm

Kesim og'irlik markazining koordinatalarini hisoblaymiz.

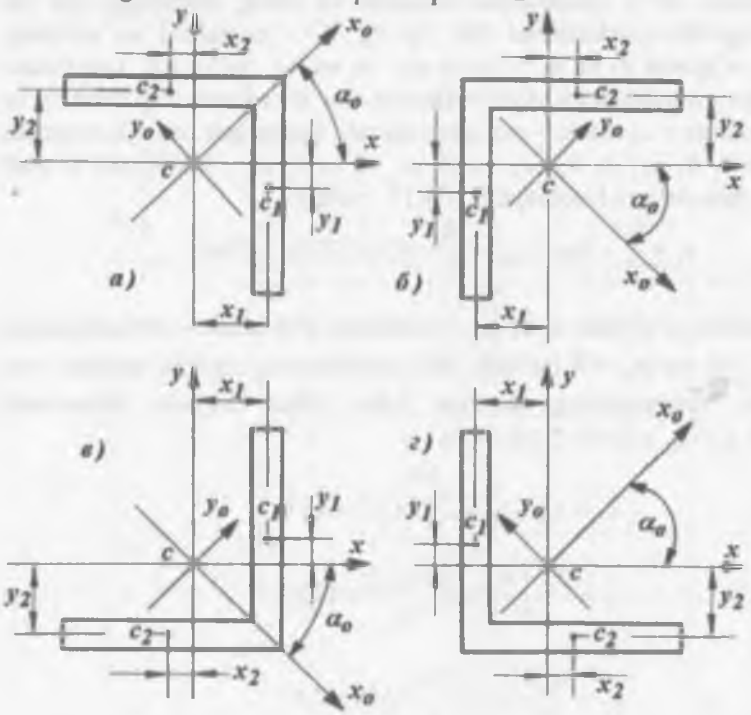
$$X_c = \frac{A_1 * x_1 + A_{sh} * x_2 + A_b * x_3 + A_b' * x_4}{A_1 + A_{sh} + A_b + A_b'} =$$

$$= \frac{45 * 1{,}07 + 9{,}38 * 4{,}26 + 12{,}6 * 3{,}57}{45 + 23{,}4 + 9{,}38 + 12{,}6} = 1{,}47\ sm$$

$$y_c = \frac{y_1 \cdot A_1 + A_{sh} \cdot y_2 + A_b \cdot y_3 + A_b' \cdot y_4}{A_1 + A_{sh} + A_b + A_b'} =$$

$$= \frac{45 \cdot 11{,}25 + 9{,}38 \cdot 7{,}81 - 12{,}6 \cdot 6{,}68}{45 + 23{,}4 + 9{,}38 + 12{,}6} = 5{,}48 sm$$

$X_c = 1{,}47 sm$ va $X_c = 5{,}48$ *sm*-ni *xoy* koordinata o'qida joylashtirib kesimni og'irlik markazi *S* nuqtani topamiz. *S*



4.18 – rasm. Markazdan qochma inertsiya momentining ishorasini tanlashga oid

nuqtadan X_c va Y_c o'qlarini o'tkazamiz va bu o'qlar bilan x_1, x_2, x_3 va x_4, hamda y_1, y_2, y_3 va y_4 - o'qlari orasidagi masofalarni belgilaymiz va topamiz

$a_2 = -X_c = -1{,}47 sm;\ a_1 = -(x_c - x_1) = -(1{,}47 - 1{,}07) = -0{,}4 sm$

$a_3 = x_3 - x_c = 4{,}26 - 1{,}47 = 2{,}79 sm;$

$a_4 = x_4 - x_c = 3{,}57 - 1{,}47 = 2{,}10\ sm;$

$U_1 = y_1 - y_c = 11{,}25 - 5{,}48 = 5{,}77\ sm;\quad U_2 = y_c = 5{,}48\ \ sm;$

$U_3 = y_3 - y_c = 7{,}81 - 5{,}48 = 2{,}33\ \ sm;$

$U_4 = -(y_4 + y_c) = -(6{,}68 + 5{,}48) = -12{,}16\ \ sm;$

Parallel o'qlarga nisbatan kesimni inertsiya momentlari formulasidan foydalanib, berilgan kesimni X_c va Y_c o'qlarga nisbatan inertsiya momentlarini hisoblaymiz.

$$I_{Xc} = I_{X1} + U_1^2 A_1 + I_{xsh} + U_2^2 A_{sh} + I_{xb} + U_3^2 A_b + I'_{xb} + U_4^2 A'_b =$$

$$= 23{,}4375 + (5{,}77)^2 \cdot 45 + 1520 + (5{,}48)^2 \cdot 23{,}4 + 57 + (2{,}33)^2 \cdot 9{,}38 +$$

$$+ 127 + (12{,}16)^2 \cdot 12{,}16 = 5842{,}359 sm^4$$

$$I_{yc} = I_{y1} + a_1^2 A_1 + I_{sh} + a_2^2 A_{sh} + I_{xb} + a_3^2 A_b + I'_{yb} + a_4^2 A_b =$$

$$= 1215 + (0{,}4)^2 \cdot 45 + 113 + (1{,}47)^2 \cdot 23{,}4 + 127 + (2{,}79)^2 \cdot 9{,}38 +$$

$$+ 39{,}2 + (2{,}1)^2 \cdot 12{,}6 = 1680{,}546 sm^4$$

Markazdan qochma inertsiya momenti.

$$I_{xcyc} = I'_{xy} + a_1 u_1 A_1 + I^{sh}_{xy} + a_2 u_2 A_{sh} + I^{b}_{xy} + a_3 u_3 A_b + I^{1b}_{xy} + a_4 u_4 A^1_b$$

Kamida bitta simmetriya o'qi bo'lgan kesim yuzalarining markazdan qochma inertsiya momentlari nolga teng. Demak, $I^{sh}_{xy} = 0$ va $I^{1}_{xy} = 0$

Teng tomonli va tomonlari teng bo'lmagan burchakli profillarni markazdan qochma inertsiya momentlarini hisoblaymiz.

- teng tomonli burchak (4.18 –rasm) $I_{xy} = \dfrac{I_{x0\max} - I_{y0\min}}{2} \sin 2\alpha_0$

buerda: $I_{x0\max}$ va $I_{y0\min}$ - burchak kesimining markaziy bosh inertsiya momentlari. $\alpha_0 = \dfrac{\pi}{4}$ - markaziy bosh inertsiya o'qlarini (x_0 va y_0) profilni X va U o'qlariga nisbatan og'ishgan burchagi (4.18 –rasm) $\alpha_0 = \dfrac{\pi}{4}$ - burchakda $\sin 2\alpha_0 = 1$ hosil bo'ladi.

Markazdan qochma inertsiya momentining ishorasi $-\alpha_0$ - burchakni x –o'qiga nisbatan joylashishiga bog'liq holda aniqlanadi. Masalan, 4.18-rasm, *a,g* –larda α_0 - burchak musbat ishorali, chunki – u x_0 va y_0 - o'qlarini x va u o'qlariga nisbatan soat strelkasining harakat yo'nalishiga teskari yo'nalishda aylantirganda hosil bo'ladi. α_0-burchakni musbat

ishorali qiymatida kesimni xu - o'qlariga nisbatan markazdan qochma inertsiya momenti – manfiy ishorali bo'ladi.

4.18 - rasm $-b,v$ – larda α_0-burchak manfiy, chunki x_0 va y_0 - o'qlarini x va u – o'qlariga nisbatan soat strelkasining harakat yo'nalishiga mos aylantirganda hosil bo'ldai. Bu holda - I_{xy} - markazdan qochma inertsiya momenti musbat ishorali.

I_{xy} - markazdan qochma inertsiya momentining ishorasini tanlash uchun qo'yidagi qoidani ishlatsa ham bo'ladi: agar burchak supachalarining og'irlik markazlari x va u koordinata o'qlarining birinchi va uchinchi choraklarida joylashsa - I_{xy} - musbat; agar supachalarning og'irlik markazlari ikkinchi va to'rtinchi choraklarda joylashsa – manfiy ishorali bo'ldai. Burchak profilining berilgan vaziyatlari uchun α_0 - burchak va I_{xy} - markazdan qochma inertsiya momentining ishoralari 1 - jadvalda berilgan

1 –jadval

Burchak profilining vaziyati	C_1 va C_2 nuqta koordinatalarining ishorasi				α_0 va I_{xy} ishoralari	
	X_1	Y_1	X_2	Y_2	α_0	I_{xy}
a	+	-	-	+	+	-
b	-	-	+	+	-	+
v	+	+	-	-	-	+
g	-	+	+	-	+	-

Teng tomonli burchakni markazdan qochma inertsiya momenti:

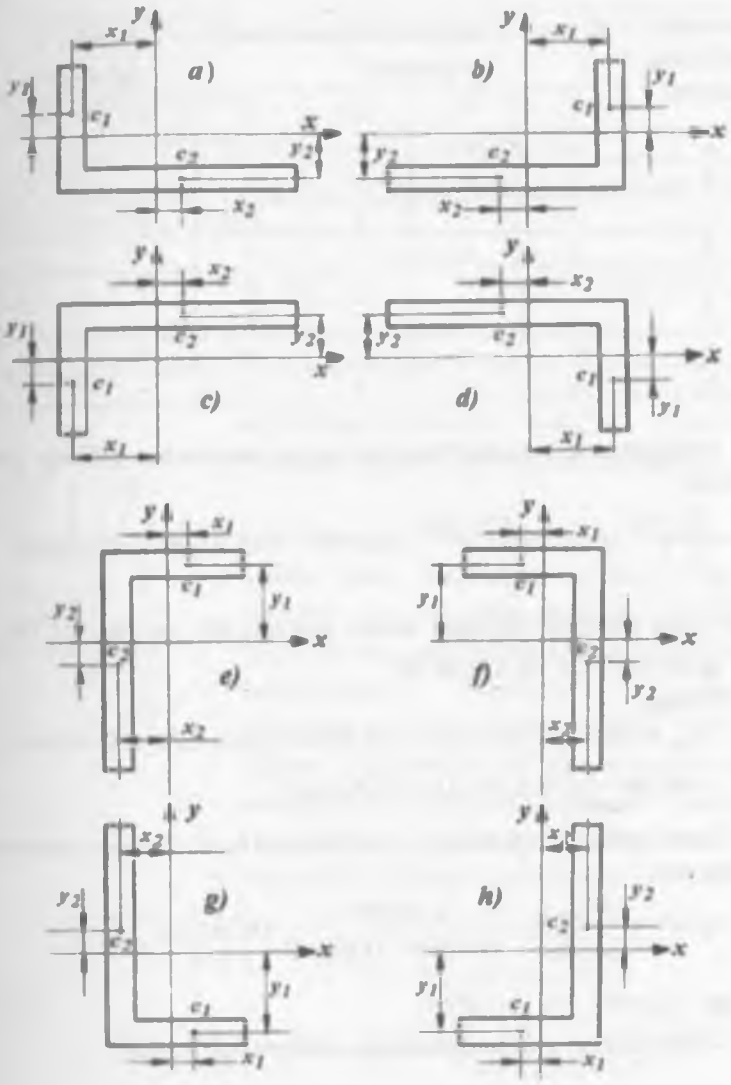
$$I_{xy}^{b} = -\frac{I_{x0\max} - I_{y0\min}}{2} = -\frac{90,4 - 23,5}{2} = -33,45 \quad sm^4$$

Teng tomonli bo'lmagan burchakni (4.19 - rasm) markazdan qochma inertsiya momenti $I_{xy} = \frac{I_y - I_x}{2} tg2\alpha_0$ formula bilan hisoblanadi.

α_0 - burchak teng tomonsiz burchak uchun $\frac{\pi}{4}$ qiymatdan kichik

4.19 - rasmda ko'rsatilgan teng tomonsiz burchaklarning – a,b,v,g – ko'rinishlarida $I_y > I_x$ yoki $I_y = I_{\max}$; d,e,j,z –ko'rinish-larida $I_x > I_y$

yoki $I_x = I_{max}$. 2- jadvalda teng tomonsiz burchakni turli vaziyatlari uchun - α_0, I_{xy} - kattaliklarning ishorali keltirilgan.



4.19 –rasm. Teng tomonsiz burchakda markazdan qochma inertsiya momentining ishorasini tanlash

2 –jadval

Burchak profilining vaziyati	C_1 va C_2 nuqta koordinatalarining ishorasi				α_0 va I_{xy} ishoralari	
	X_1	Y_1	X_2	Y_2	α_0	I_{xy}
a	-	+	+	-	+	-
b	+	+	-	-	-	+
c	-	-	+	+	-	+
d	+	-	-	+	+	-
e	+	+	-	-	-	+
f	-	+	+	-	+	-
g	+	-	-	+	+	-
h	-	-	+	+	-	+

Berilgan teng tomonsiz burchak uchun markazdan qochma inertsiya momenti

$$I_{xy} = -\frac{I_{ab}^1 - I_{ab}^1}{2} tg2\alpha_0 = -\frac{127 - 39,2}{2} \text{tg } 42^0 36' = -43,9 \cdot 0,9195 \approx -40,366 sm^4$$

bu erda – teng tomonsiz burchak uchun $\text{tg}\alpha = 0,391$ va $\alpha = 21^0 18'$, unda

$$tg2\alpha = tg2 \cdot 21^0 18' = tg42^0 36'$$

Demak,

$$I_{xyc} = -0,4 \cdot 5,77 \cdot 45 - 1,47 \cdot 5,48 \cdot 23,4 - 33,45 + 2,79 \cdot 2,33 \cdot 9,38 -$$

$$- 40,366 - 2,10 \cdot 12,16 \cdot 12,6 = -626,95 sm^4$$

Bosh inertsiya o'qlarining yo'nalishini va bosh inertsiya momentlarni hisoblaymiz.

$$\text{tg}2\alpha = -\frac{2I_{xyc}}{I_{xc} - I_{yc}} = \frac{2 \cdot 626,95}{5842,359 - 1680,546} \approx 0,303 rad$$

buerdan $2\alpha_0 = 17^0$, va $\alpha_0 = 8^0 30'$

- Bosh inertsiya momentlarining ekstremal qiymatlari.

$$I_{\substack{max\\min}} = \frac{1}{2}\left[(I_{xc} + I_{yc}) \pm \sqrt{(I_{xc} - I_{yc})^2 + 4I_{xcyc}^2}\right] =$$

$$= \frac{1}{2}\left[(5842,36 + 1680,54 \pm \sqrt{(5842,36 - 1680,54)^2 + 4(626,95)^2}\right] =$$

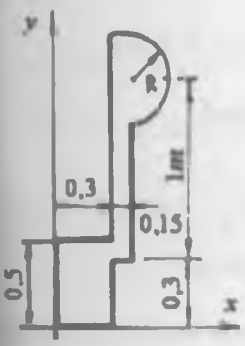
$$= \frac{1}{2}(7522,9 \pm 4346,6);$$

$I_{max} = 5934,75\ sm^4$ va $I_{min} = 1588,15\ sm^4$

Bosh inertsiya o'qlariga nisbatan kesimni markazdan qochma inertsiya momentini topamiz.

$$I_{x0y0} = \frac{I_{xc} - I_{yc}}{2}\sin 2\alpha_0 + I_{xcyc}\cos 2\alpha_0 = \frac{5842,36 - 1680,54}{2}\sin 2\cdot 8^0 30' -$$

$$- 626,954\cdot\cos 2\cdot 8^0 30' = 2080,9\cdot 0,2920 - 626,95\cdot 0,9563 \approx 8,9 sm^4$$



4.18-misol. Murakkab shaklli kesim yuzaning gemetrik tasniflarini hisoblash.

O'lchamlar metrda berilgan. Murakkab shaklni oddiy shakllarga bo'lamiz (4.20-rasm) va har bir oddiy yuzaning og'irlik markazlarini belgilaymiz, u nuqtalardan kesimlarning markaziy o'qlarini o'tkazamiz, ushbu o'qlardan *XOU* koordinata o'qlarigacha bo'lgan masofalarni aniqlaymiz. Hisoblash murakkab shaklning ixtiyoriy o'qlar sistemasida og'irlik markazini topishdan boshlanadi.

$$x_C = \frac{A_1x_1 + A_2x_2 + A_3x}{A_1 + A_2 + A_3} = \frac{50\cdot 30\cdot 15 + 120\cdot 15\cdot 37,5 + 628\cdot 53,5}{50\cdot 30 + 120\cdot 15 + \frac{\pi(20)^2}{2}}$$

$$y_c = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3} = \frac{50\cdot 30\cdot 25 + 120\cdot 15\cdot 90 + 628\cdot 130}{1500 + 1800 + 628};$$

bu erda: $A_1 = 0,3\cdot 0,5 = 0,15 m2$ $A_2 = 1,2\cdot 0,15 = 0,18 m2$

$$A_3 = \frac{\pi R^2}{2} = \frac{3{,}14(0{,}2)^2}{2} = 0{,}0628m^2, \quad \Sigma A = A_1 + A_2 + A_3 = 0{,}3928m^2$$

$$x_1 = \frac{0{,}3}{2} = 0{,}15m \qquad y_1 = \frac{0{,}5}{2} = 0{,}25m \qquad x_2 = 0{,}3 + \frac{0{,}15}{2} = 0{,}375\,m$$

;

$$y_2 = \frac{1+R}{2} + 0{,}3 = 0{,}9m \qquad x_3 = 0{,}3 + 0{,}15 + \frac{4R}{3\pi} = 0{,}535m$$

$$y_3 = 0{,}3 + 1 = 1{,}3m \qquad x_c = 0{,}31467m; \qquad y_c = 0{,}71474\,m$$

va

Parallel o`qlarga nisbatan inertsiya momentlari formulasidan foydalanib kesimning $x_C$ va $u_C$ o`qlarga nisbatan inertsiya momentlarini topamiz (4.20 – rasm).

$$I_{x_c} = \frac{0{,}3(0{,}5)^3}{12} + (y_c - y_1)^2 0{,}3 \cdot 0{,}5 + \frac{0{,}15(1{,}2)^3}{12} + (y_2 - y_c)^2 \cdot 0{,}18 +$$

$$+0{,}393R^4 + (y_3 - y_c)^2 + \frac{3{,}14R^2}{2} = 0{,}085455\,m^4$$

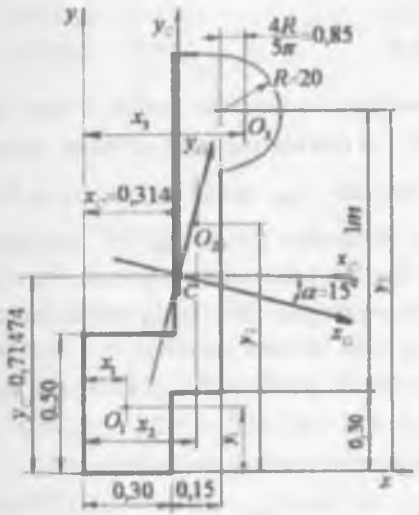
$$I_{y_c} = \frac{0{,}5(0{,}3)^2}{12} + (x_c - x_1)^2 \cdot 0{,}15 + \frac{1{,}2(0{,}15)^3}{12} + (x_2 - x_c)^2 \cdot 0{,}18 +$$

$$+0{,}11R^4 + (x_3 - x_c)^2 \cdot 0{,}0628 = 0{,}01246\,m^4$$

Markaziy o`qlarga nisbatan markazdan qochma inertsiya momentini topamiz:

$$I_{x_c y_c} = [-(y_c - y_1)][-(x_c - x_1)] \cdot 0{,}15 + (y_2 - y_c)(x_2 - x_c) \cdot 0{,}18 +$$

$$+(y_3 - y_c)(x_3 - x_c) \cdot 0{,}0628 = 0{,}02154\,m^4$$



4.20– rasm. Bosh va markaziy inertsiya o'qlarining vaziyatiga oid

Bosh inertsiya momentlarini topamiz

$$I_{\substack{\max\\ \min}} = \frac{I_{xc}+I_{yc}}{2} \pm \frac{1}{2}\sqrt{(I_{xc}-I_{yc})^2+4\cdot I^2_{xy}} = \frac{0,08545+0,01246}{2} \pm$$

$$\pm\frac{1}{2}\sqrt{(0,08545-0,01246)^2+4\cdot(0,02154)^2};$$

$$I_{\max}=0; \qquad I_{\min}=0,006575m^4$$

$$I_{xc}+I_{yc}=I_{\max}+I_{\min} \qquad 0,0854+0,01246=0,04895+0,006575$$

Bosh inertsiya o'qlarining og'ishgan burchagini topamiz:

$$tg2\alpha_0 = -\frac{2I_{xc}}{I_{xc}-I_{yc}} = -\frac{2\cdot 0,02154}{0,08545-0,01246} = -0,59\,rad$$

$$2\alpha_0 = -30^\circ \qquad \text{yoki} \qquad \alpha_0 = -15^\circ$$

$I_{xc} > I_{yc}$ bo'lganligi uchun x_c o'qqa nisbatan inertsiya momenti maksimal qiymatga erishadi. α_0 burchagi manfiy ishorali bo'lgani uchun qiymatini x_c o'qidan soat strelkasining harakat yo'nalishi bo'ylab joylashtiramiz. α_0 burchak bosh inertsiya o'qining holatini belgilaydi. Inertsiya radiuslarini topamiz:

$$i_{max} = \sqrt{\frac{0,09133}{0,3928}} = 0,48m, \qquad i_{max} = \sqrt{\frac{0,00657}{0,3928}} = 0,129m$$

Shaklning inertsiya radiuslarini yarim o'qlar sifatida qabul qilib, x_0cy_0 koordinata o'qlarida inertsiya ellipsini quramiz (4.20 – rasm). Bunda cx_0 o'qi bo'ylab i_{min} radiusini, cy_0 o'qi bo'ylab i_{max} inertsiya radiusini qo'yamiz. Ellipsdan gorizontga 45^0 burchak ostida joylashgan x_α o'qqa nisbatan inertsiya momentini topamiz. Bu o'q x_0 o'qqa nisbatan 60^0 burchak ostida yo'nalgan. Bu o'qqa parallel ravishda ellipsga urinma o'tkazamiz. x_0 o'q bilan urinma orasidagi $h = 0,265m$ masofani o'lchab olamiz. Inertsiya momenti grafik usulda quyidagicha topiladi.

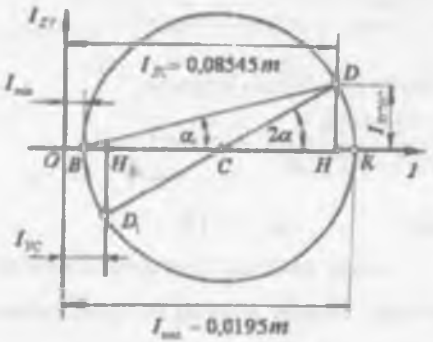
$$I_k = h^2 A = (0,265)^2 \cdot 0,3928 = 0,0276м^4$$

Ushbu inertsiya momentini analitik usulda topamiz:

$$I_k = I_{max} \cdot \cos^2 \alpha + I_{min} \cdot \sin^2 \alpha = 0,091339\cos^2 60^0 +$$

$$+0,006575 \cdot \sin^2 60^0 = 0,0277.м^4$$

Bosh inertsiya momentlarini grafik usulda topamiz (4.21 – rasm), buning uchun kesimning x_c va y_c o'qlariga nisbatan inertsiya momentlari $I_{xc} = 0,08545m^4$ va $I_{yc} = 0,01246m^4$ va markazdan qochma inertsiya momenti $I_{xoc} = 0,02154m^4$ dan foydalanamiz.



4.21 – rasm. Mor yoki inertsiya doirasini qurish tartibi.

IOI_{xy} koordinata sistemasini tanlaymiz. I_{xc}, I_{yc} va I_{xcyc} inertsiya momentlarini masshtabda IO va I_1O o'qlarida joylashtiramiz.

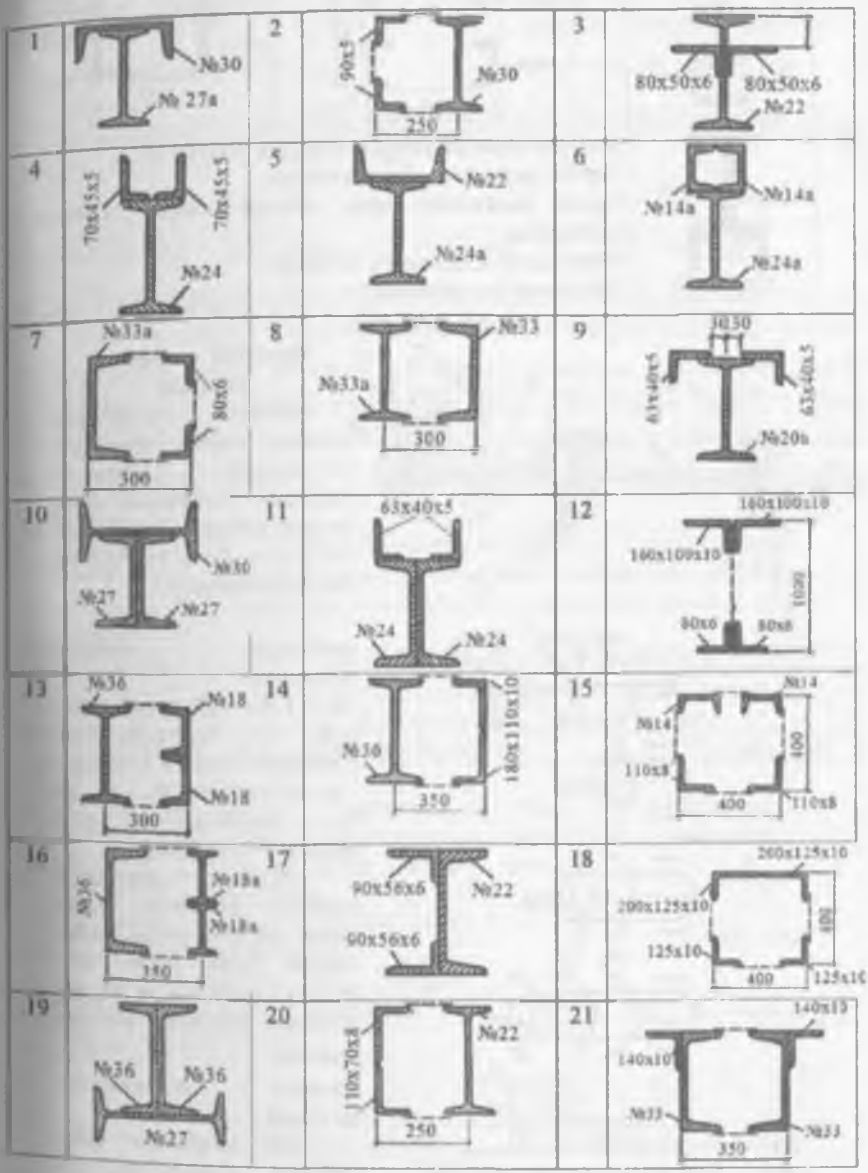
Masshtab: $1mm = 0,00122m$, unda

$$OH = \frac{0,08545}{0,00122} = 70mm,$$

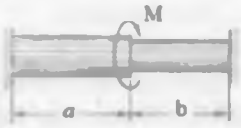
$$OH_1 = \frac{0,01246}{0,00122} = 10,2mm,$$

$$HD = \frac{0,02154}{0,00122} = 17,6mm$$

Tekis kesim yuzalarning geometrik xarakteristikalari xisoblansin.



javob: 8,27 sm; 0.

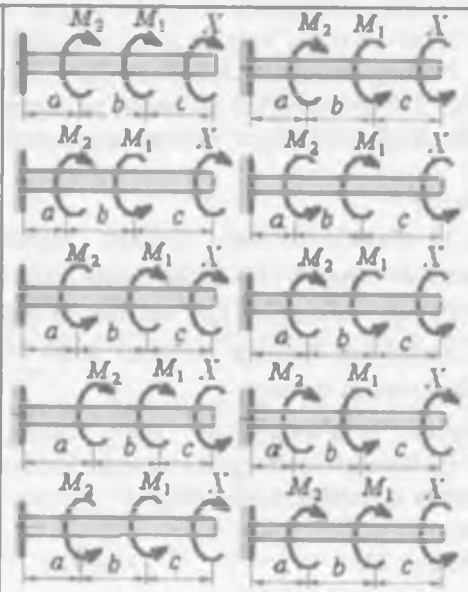


5.6 -rasm

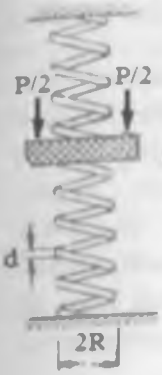
javob: a=1,8 m;
b=1,5 m

bo'lsa, sterjenning diametrini aniqlang. Sterjen o'rta kesimining buralish burchagi nimaga teng.

5.13-misol. Uchlaridan qisilgan sterjen chap qismining diametri 6 sm, o'ng qisminiki 5 sm. Sterjenning umumiy uzunligi a+b = 3,3 m (rasmga qarang). Sterjenning diametri o'zgargan joyga qo'yilgan burovchi moment sterjenning har qaysi qismida bir xil eng katta urinma kuchlanish hosil qilishi shartiga ko'ra *a* va *b* o'lchamlarini aniqlang.

1		6	**5.14-misol.** Berilgan bruslarda noma'lum X momenti qo'yilgan kesimning buralish burchagini nolga tenglashtirib, moment X-ning qiy-mati hisoblansin. $a = 1m$ $b = 2m$ $c = 2m$ $M_1 = 10kNm$ $M_2 = 20kNm$
2		7	
3		8	
4		9	
5		10	

5.7-rasm



5.8-rasm

5.15-misol. O'ramlarining o'rtacha oadiussi bir xil (R=10 sm) bo'lgan ikki prujina doira kesimining diaametri d=2 sm li po'lat simdan yasalgan. Prujinalar ikki qo'zg'almas tekisliklar orasiga qo'yilgan. Prujinalar orasiga nagruzka plitasi qo'yilgan bo'lib,u prujinalarning uchlariga qattiq maxkamlangan. Plita orqali prujinalarga pastga yo'nalgan nagruzka R=4500 N uzatiladi. Plita og'irligini hisobga olmay turib, prujinalar orasida nagruzka qanday taqsimlanganligini aniqlang. Yuqoridagi prujinada to'rtta o'ram, pastdagisida beshta o'ram bor. Plitaning vertikal siljishi qanchaga teng? Har qaysi prujina sterjenidagi urinma kuchlanish anday kattalikka erishadi?

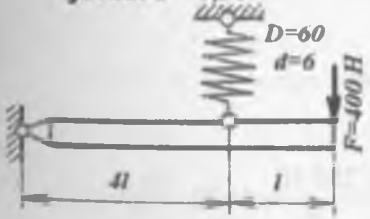
javob:2500 va 2000 N; 5 sm; 1672 va 13380 N/sm^2.

5.16-misol. Diametrlari D=32 *mm*; d=4 *mm* bo'lgan prujina F =300 N kuch bilan siqiladi. τ_{max} kuchlanish aniqlansin.

javob: τ_{max} =450 $\frac{N}{mm^2}$

5.17-misol. Diametrlari D=80 *mm*; d=8 *mm* bo'lgan prujina materialining ruxsat etilgan kuchlanishi $[\tau]$=600 $\frac{N}{mm^2}$. Ruxsat etilgan kuchni hisoblang.

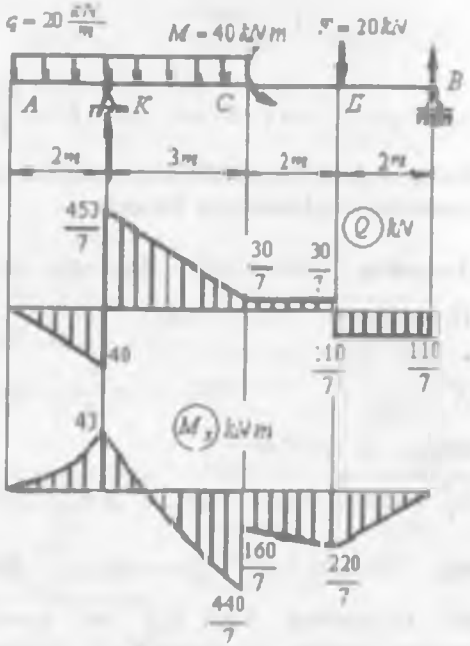
javob: F=1,31 *kN*



5.18-misol. $[\tau]$=500 $\frac{N}{mm^2}$ ruxsat etilgan kuchlanishdan foydalanib prujina mustahkamligi tekshirilsin

javob: τ_{max} =406 $\frac{N}{mm^2}$

5.19-misol. Ўrtacha radiuslari R = *10 sm*, o'ramning diametri d = *2 sm* bo'lgan po'latdan tayyorlangan ikkita prujinalar S va V nuqtalarda tayanchlarga tayangan. Yuqori prujinada n_1 = *4* ta va pastki prujinada n_2 = *5* ta o'ramlari bor. Ikkala prujinalar o'rtasiga G' = *450 kg* kuch qo'yilgan plita o'rnatilgan. Prujinalarga taqsimlangan kuchning



6.5 – rasm. Balkani yuklanish sxemasi va ko'ndalang kuch va eguvchi moment epyurlari

6.3-misol. Balkaning eguvchi moment (M) va ko'ndalang kuch (Q) lari aniqlansin epyuralari qurilsin (6.6 - rasm).

Berilgan:

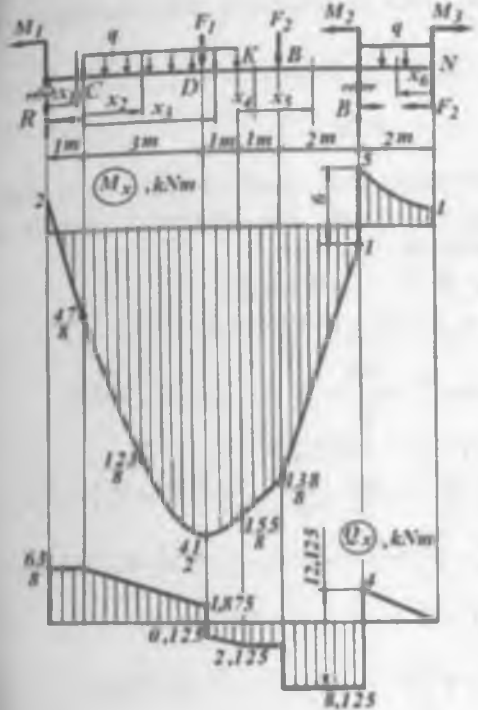
$M_1=2kNm,\quad M_2=6kNm,\quad M_3=1kNm,\quad q=2\frac{kN}{m};\quad F_1=9kN,\quad F_2=6kN$

echish. Reaktsiya kuchlarini balkaning muvozanat shartlaridan foydalanib topamiz:

$$\Sigma M_A=-M_1+4q\left(\frac{4}{2}+1\right)+F_1 4+F_2\cdot 6-M_2+q\cdot 2\left(\frac{2}{2}+8\right)++M_3-B\cdot 8=0;$$

$$\Sigma M_B=-M_1-q4\left(\frac{4}{2}+3\right)-F_1 4+F_2\cdot 2-M_2+q2\cdot\frac{2}{2}+M_3+R\cdot 8=0;$$

$$B=12{,}125kN \quad \text{va} \quad R=\frac{63}{8}kN$$



Balkani 6 ta oraliq qirqim-larga bo'lib, har bir oraliq uchun eguvchi moment va ko'nadalang kuch tenglamala-rini tuzamiz (6.6 – rasm).

6.6–rasm. Balkani yuklanish sxemasi va ko'ndalang kuch va eguvchi moment epyuralari

1 – 1 oraliq (R - S). $0 \le x_1 \le 1m$

$$M_{x_1} = Rx_1 - M_1 \qquad \text{va} \qquad Q_1 = R = \frac{63}{8}kN$$

I – I oraliqda Q = *constanta,* shuning uchun ko'ndalang kuch epyurasi abstsissaga parallel chiziq bo'ladi. M_X epyurasi abstsissaga qiya to'g'ri chiziq bo'lib, uni $x_1 = \frac{M_1}{R} = \frac{16}{63}m$ masofada kesib o'tadi, ya'ni nolga teng bo'ladi.

II – II oraliq (S – D). $0 \le x_2 \le 3m$

$$M_{x_2} = R(1 + x_2) - M_1 - q\frac{x_2^2}{2} \qquad va \qquad Q_2 = R - qx_2$$

II – II oraliqda ko'ndalang kuch epyurasi $\frac{63}{8}kN$. dan 1,875 kN gacha kamayadi, ya'ni Q abstsissaga qiya to'g'ri chiziq bo'ladi, M_X esa botiq parabola qonuniyatida o'sadi. Q va M_X - bu oraliqda musbat

ishorali. M_X epyurasi balka materialining cho'ziluvchan tolasiga quriladi.

III – III oraliq (D - K) $3 \le x_3 \le 4m$ $Q_3 = R - qx_3 - F_1$

va $M_{x3} = R(1 + x_3) - M_1 - q\frac{x_3^2}{2} - F_1(x_3 - 3)$

III – III oraliqda ko'ndalang kuch manfiy ishorali va u abstsissaga qiya to'g'ri chiziq qonuniyatida o'sadi, M_X esa musbat ishorali va botiq parabola qonuniyatida kamayadi.

IV – IV oraliq (K - B). $0 \le x_4 \le 1M$

$$M_{x_4} = R(5 + x_4) - M_1 - q4(2 + x_4) - F_1(1 + x_4)$$

$$Q_4 = R - q \cdot 4 - F_1 = \frac{63}{8} - 2 \cdot 4 - 2 = -2,125kN$$

V-V oraliq (B - V). $0 \le x_5 \le 2m$

$$M_{x_5} = R(6 + x_5) - M_1 - q4(2 + 1 + x_5) - F_1(2 + x_5) - F_2 x_5$$

$$Q_5 = R - q \cdot 4 - F_1 - F_2 = \frac{63}{8} - 2 \cdot 4 - 2 - 6 = -8,125kNm$$

VI – VI oraliq (V - N) $0 \le x_6 \le 2m$

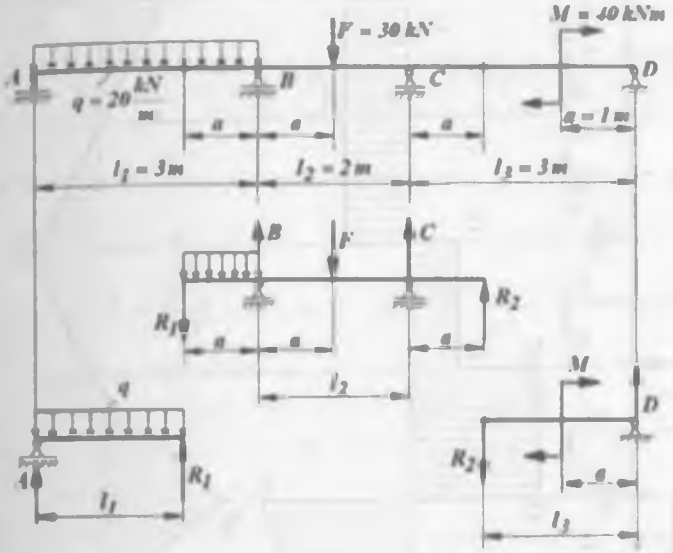
$$M_{x_6} = -M_3 - q\frac{x_6^2}{2}; \qquad Q_6 = qx_6$$

Balkani R nuqtasida ($R = \frac{63}{8}kN$), D nuqtasida ($F_1 = 2kN$), B nuqtasida ($F_2 = 6kN$), V tayanch nuqtasida ($B = 12,125kN$) kuchlar ta'sir qiladi. Mos ravishda Q epyurasining mazkur nuqtalarida qo'yilgan kuchlarga teng miqdorda sakrash mavjud. Masalan, R nuqtada sakrash $\frac{63}{8}kN$ ga teng, D nuqtada 1,875 + 0,125 = 2 kN, B nuqtada 8,125 – 2,125 = 6 kN, V tayanch nuqtada 8,125 + 4 = 12,125 kN. SD oraliqda taqsimlangan kuch ta'sir qiladi. Q epyurasida ushbu oraliqda o'zgarish (kamayish) $\frac{\frac{63}{8} - 1,875}{3} = q$ ga teng.

Balkani R tayanch va N nuqtalarida eguvchi moment mos ravishda 2 kNm va 1 kNm. ga teng va manfiy ishorali. V tayanch nuqtasiga

$M_2 = 6kNm$ juft kuch momenti qo'yilgan, shuning uchun M_x epyurasining shu nuqtasida $5+1=6$ kNm sakrash mavjud.

6.4-misol. Sharnirli balkani ko'ndalang kuch va eguvchi moment-larining epyuralari qurilsin.



6.7 – rasm. Sharnirli balka

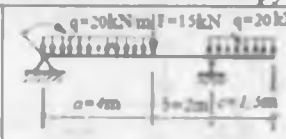
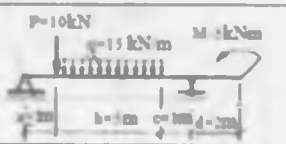
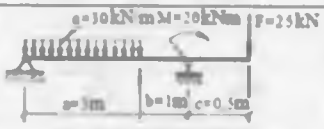
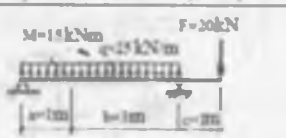
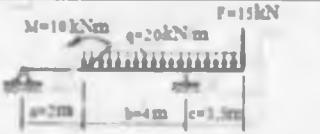
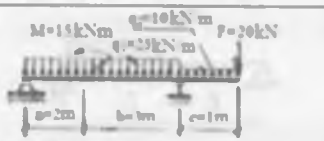
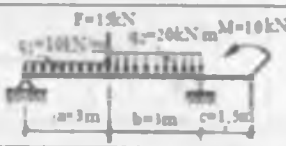
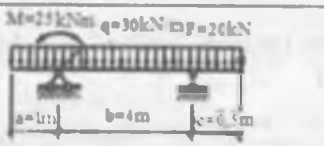
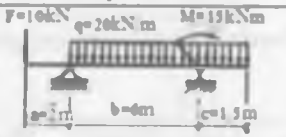
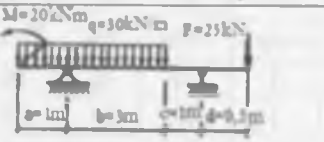
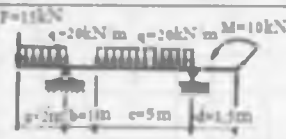
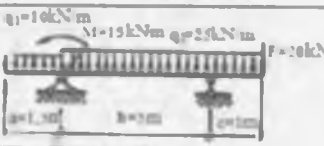
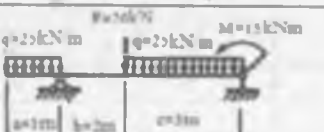
Sharnirlar momentni uzatmaydi, shuning uchun sharnirlarda momentlar nolga teng bo'lishidan foydalanib balkani ikkita asosiy va bitta konsol balkalarga ajratamiz (6.7 - rasm, b). Sharnirlardagi bosim kuchini R_1 va R_2 reaktsiya kuchlari bilan almashtiramiz. Hosil bo'lgan har bir balkalar uchun Q va M_x - epyuralarini quramiz.

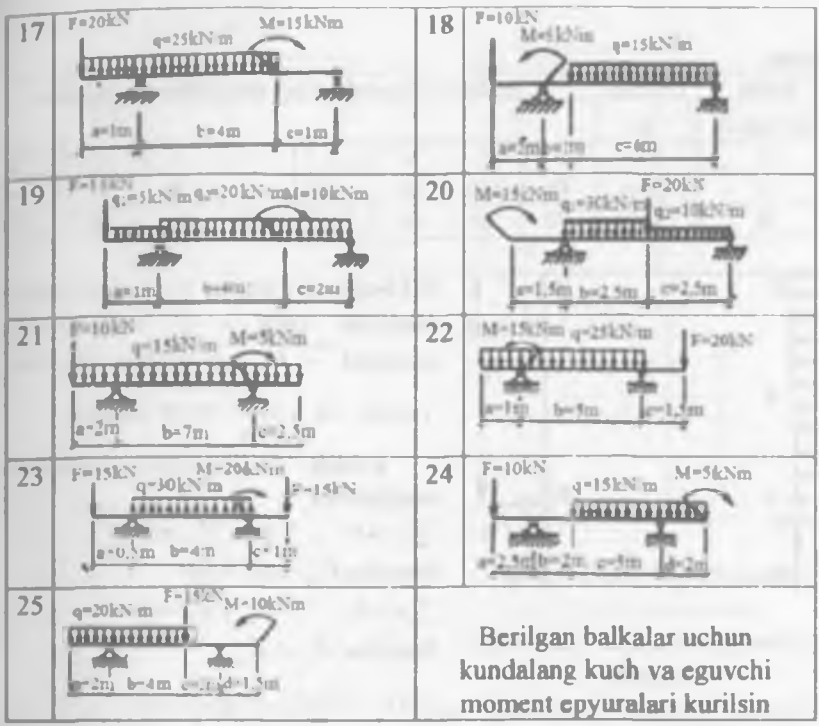
1-balka. Reaktsiya kuchlarini hisoblaymiz:

$$\sum M_A = -q\frac{\ell_1^2}{2} + R_1\ell_1 = 0 \quad va \quad R_1 = q\frac{\ell_1}{2} = \frac{20\cdot 3}{2} = 30kN$$

$$\sum M_1 = -A\cdot\ell_1 + q\frac{\ell_1^2}{2} = 0 \quad va \quad A = q\frac{\ell_1}{2} = \frac{20\cdot 3}{2} = 30kN$$

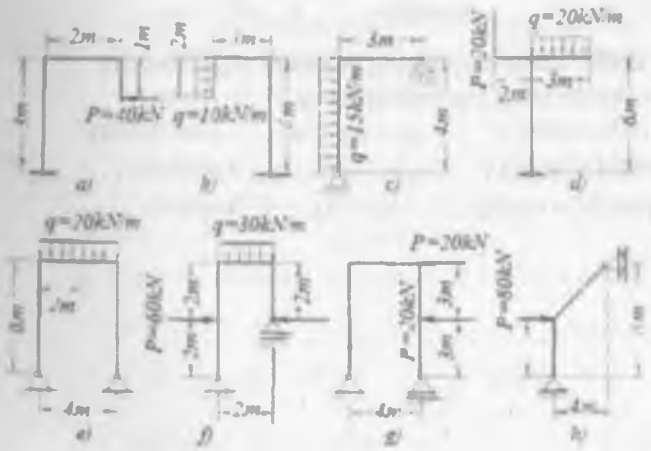
6–12-misol. Balkalarda (*6.16-rasm*) ko'ndalang kuch va eguvchi momentlar hisoblansin va epyuralari qurilsin

1		2	
3		4	
5		6	
7		8	
9		10	
11		12	
13		14	
15		16	



6.16-rasm

6.13-misol. Sxemalari 6.17-rasmda ko'rsatilgan ramalar uchun ko'ndalang va bo'ylama kuchlar va eguvchi momentlar epyuralarini kuring..



6.17-rasm. Ramalarda ichki kuch faktorlarini aniklash

$y_2 = 0$ bo'lsa $M_{x_3} = 0$ va $y_2 = \ell$ bo'lsa $M_{x_3} = -32m$

6.15-misol. Berilgan rama uchun (*6.20 – rasm*, a) $N,Q,,M$ epyuralari qurilsin.

echish. Ramani S,V,D tayanchlarida to'rtta S, V, D_X, D_U - reaktsiya kuchlari hosil bo'ladi. Agar ramada K-sharnir o'rnatilmaganida masala statik noaniq ko'rinishda bo'lar edi. K- sharnirdan bir tomonda joylashgan barcha kuchlarni K nuqtaga nisbatan kuch momentlarining yig'indisi nolga teng, chunki sharnirlardan momentlar uzatilmaydi.

Muvozanat shartlari:

$$\sum y = B + D_y - q \cdot 1{,}5 = 0 \qquad \text{(a)}$$

$$\sum x = -C - D_x + q \cdot 3 = 0 \qquad \text{(b)}$$

$$\sum M_C = D_y \cdot 5{,}5 - D_x \cdot 3 - M + q \cdot 3 \cdot 1{,}5 - q \cdot 1{,}5 \cdot 4{,}75 = 0 \qquad \text{(e)}$$

DBK qismning K nuqtasiga nisbatan kuch momenti

$$\sum M_k = D_y \cdot 1{,}5 - D_x \cdot 2 - M - q \cdot 3 \cdot 1{,}5 = 0 \qquad \text{(u)}$$

a,b,e,u – tenglamalar sistemasini echib quyidagilarni topamiz: $D_y = 59{,}4kN$; $D_x = 27{,}6kN$; $C = 32{,}4kN$

Ramani to'rtta oraliqga bo'lamiz va har bir oraliq uchun N,Q,M tenglamalarini tuzamiz.

I – I qirqim (VS- oraliq) $\quad 0 \le z \le 3m$

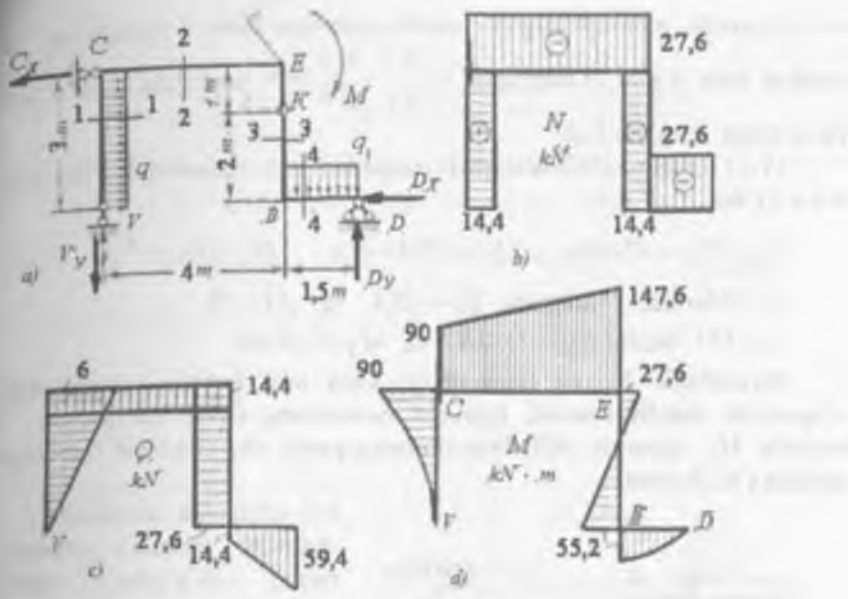
$$N_1 = B = 14{,}4kN \qquad Q = -q \cdot z \qquad M_1 = -\frac{q \cdot z^2}{2}$$

N_1 musbat ishorali va o'zgarmas. Q_1 kuch to'g'ri chiziqli qonuniyat bilan M_1 esa parabola qonuniyati bilan o'zgaradi.

$z_1 = 0$ bo'lsa $Q_1 = 0$ va $M_1 = 0$

$z_1 = 3m$ bo'lsa $Q_1 = 60kN$ va $M_1 = -90kNm$

Moment M_1 vertikal brus o'qi bo'yicha parabola qoidasi bilan o'zgaradi va V nuqtada nolga teng, S nuqtada minus 90 kNm. Eguvchi moment VS brusning tashqi tomonini cho'zadi, shuning uchun $M_1 = -90kNm$ momentni vertikal brus S nuqtasidan chap tomonda joylashtiramiz.



6.20 – rasm. Ramada ichki kuch faktorlarini aniqlash: a) ramani yuklanish sxemasi; b) ichki bo'ylama kuch epyurasi; v) ko'ndalang kuch epyurasi: g) eguvchi moment epyurasi

II – II qirqim (*SE*-oraliq). *S* nuqtadan *z* masofada o'tkazi-ladi $0 \le z \le 4m$

$$N_2 = -C + 3q = 27,6kN \quad Q_2 = -B = -14,4kN \quad \text{va} \quad M_2 = -B \cdot z - \frac{q \cdot 3^2}{2}$$

Bu oraliqda N_2 va Q_2 kuchlar o'zgarmas. N_2 kuch cho'zuvchi va Q_2 kuch manfiy ishorali. $z_1 = 0$ bo'lsa $M_2 = -90kNm$ va $z_1 = 4i$ bo'lsa $M_2 = -147,6kNm$

III – III qirqim (*BE*-oraliq) *BE* vertikal brusda *B* nuqtadan *z* masofada o'tkaziladi $0 \le z \le 3m$

$$N_3 = -D_y + 1,5q = -14,4kN \quad Q_2 = D_x = 27,6kN$$

$$M_3 = D_y \cdot 1,5 - D_x \cdot z - \frac{q \cdot 1,5^2}{2} = 55,2 - D_x \cdot z$$

N_3 va Q_3 kuchlar o'zgarmas. N_2 kuch siquvchi va Q_2 kuch musbat ishorali.

Eguvchi moment to'g'ri chiziqli qonuniyat bilan o'zgaradi va BE vertikal brus o'qini B nuqtadan $z=\frac{55,2}{\Pi_X}=\frac{55,2}{27,6}=2m$ masofada kesib o'tadi, ya'ni nolga teng bo'ladi.

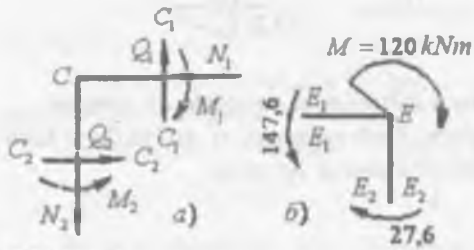
IY-IY qirqim (DB-oraliq). D nuqtadan z masofada o'tkaziladi $0 \le z \le 1,5m$

$$N_4=-D_X=-27,6kN \qquad Q_4=-59,4+q\cdot z \qquad M_4=D_y\cdot z-\frac{q\cdot z^2}{2}$$

$z_4=0$ bo'lsa, D nuqtada $Q_4=-59,4$ va $M_4=0$

$z_1=1,5i$ bo'lsa $Q_4=-14,4kN$ va $M_4=55,2kNm$

Bu oraliqda N_4 va siquvchi. Q_4 kuch to'g'ri chiziq qonuniyatida o'zgara di manfiy ishorali. Eguvchi momentning ekstremal qiymati B nuqtada. M_4 epyurasi BD brus o'qining pastki cho'ziladigan tomoniga quriladi (6.20-rasm).



6.21-rasm

M – epyurasini tekshirish.

Eguvchi moment epyurasining to'g'riligi rama uzellarining muvozana- tini tekshirish bilan baholanadi (*6.21-rasm*) .

S-uzel. Ushbu uzelga cheksiz yaqin bo'lgan C_1-C_1 va C_2-C_2 kesimlardagi N_1,Q_1,M_1 va N_2,Q_2,M_2 ichki kuch faktorlari ko'rsatilgan C_1-C_1 va C_2-C_2 kesimlarni tashqi tomonlari cho'ziladi, shuning uchun M_1 va M_2 momentlar S uzelni ichki tomoniga yo'naladi. Uzelni muvozanat tenglamasi $\sum M_C=0$ va $M_1-Q_1\cdot dz-Q_2\cdot dz-M_2=0$

Buerda $-Q_1\cdot dz$ va $-Q_2\cdot dz$ - lar cheksiz kichik miqdor bo'lganligi uchun ularni tenglamadan chiqarib tashlaymiz. Unda $M_1-M_2=90-90=0$ muvozanat shart bajarildi.

E- uzel. Ushbu uzelni E_1-E_1 kesimda 147,6 *kNm* moment va E_2-E_2 kesimiga 27,6 *kNm* moment ta'sir qiladi. E - uzelni tashqi tomoni cho'ziladi va bu uzelga tashqi 120 *kNm* moment qo'yilgan.

$$\sum M_E=-M-M_3+M_2=0 \quad \text{va} \quad -120-27,6+147,6=0$$

6.16-misol. Berilgan rama uchun M va Q epyuralari qurilsin. *(6.22-rasm)*

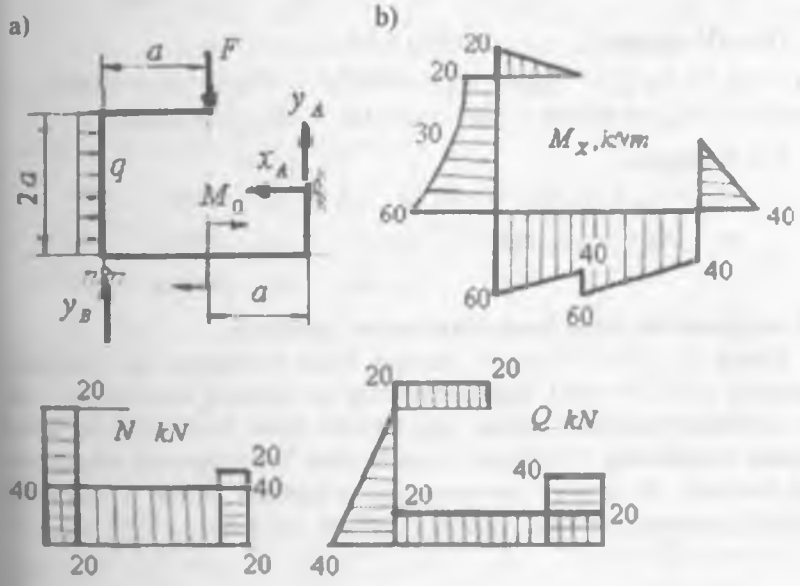
$$F=20kN; \qquad M_0=20kNm, \quad a=1m, \quad q=20\frac{kN}{m}$$

echish. Reaktsiya kuchlarini topamiz (*6.22 – rasm*, a).

$$\sum x = -x_A + q \cdot 2a = 0 \quad \text{yoki} \quad x_A = 2qa = 40kN$$

$$\sum M_B = F \cdot a + q \cdot 2a \cdot \frac{2a}{2} + M - y_A \cdot 2a - x_A \cdot a = 0 \quad \text{va} \quad y_A=20kN$$

$$\sum M_A = y_B \cdot 2a + M - F \cdot a = 0 \quad \text{va} \quad y_B = 0$$



6.22 – rasm . Ramada ichki kuch faktorlarini aniqlash:
a) ramani yuklanish sxemasi;
b) ichki bo'ylama kuch, ko'ndalang kuchva eguvchi moment epyuralari

M va Q tenglamalarini tuzamiz:

1 – 1 qirqim. $0 \le x_1 \le 1m$

$M_{x1} = F \cdot x_1$ va $Q_1 = F = 20kN$

$x_1 = 0; \quad M_{x1} = 0 \quad va \quad x_1 = 1m; \quad M_{x1} = 20kNm$

$M_B = q \cdot \frac{a^2}{2}$ ga teng. Mustahkamlik shart cho'ziladigan material uchun quyidagicha yoziladi

$$\sigma_{\max.ch} = \frac{M_B}{I_X} \cdot y_L \le [\sigma]_{ch} \quad \text{yoki} \quad \sigma_{\max.ch} = \frac{q \cdot a^2}{2 \cdot I_X} \cdot y_L \le [\sigma]_{ch}$$

buerdan $$q = \frac{2 \cdot [\sigma_{ch}] I_X}{a^2 \cdot y_L} = \frac{2 \cdot 918 \cdot 10^4}{16 \cdot 110} = 6{,}68 \frac{N}{mm}$$

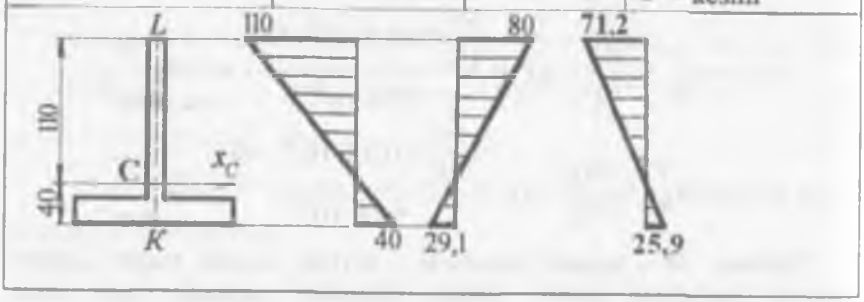
B – kesimdagi siquvchi va cho'zuvchi kuchlanishlar:

$$\sigma_s = \sigma_k^B = \frac{M_B}{I_X} \cdot y_k = \frac{6{,}68 \cdot 10^6 \cdot 40}{918 \cdot 10^4} \approx 29{,}1 \frac{N}{mm^2}$$

$$\sigma_{ch} = \sigma_L^B = \frac{M_B}{I_X} \cdot y_L = \frac{6{,}68 \cdot 10^6 \cdot 110}{918 \cdot 10^4} \approx 80 \frac{N}{mm^2}$$

Ushbu nuqtalardagi kuchlanishlarni $q = 10{,}33 \frac{N}{mm}$ kuch ta'sirida hisoblansa $\sigma_L^B = 123{,}75 \frac{N}{mm^2} > [\sigma_s]$ va $\sigma_k^B = 45 \frac{N}{mm^2} > [\sigma_{ch}]$ hosil bo'ladi. Ruxsat etilgan yukni $q = 6{,}68 \frac{N}{mm}$ qabul qilamiz.

Normal kuchlanish epyurlari			
Tavr profili	T - kesim	B - kesim	$q = 6{,}68 \frac{N}{mm}$ yukda T - kesim



6.39-rasm.

3.Qo'shtavr profilining polkasini yuqorida joylashgan holati uchun ruxsat etilgan yukni hisoblaymiz.

Cho'ziladigan tola bo'yicha ruxsat etilgan yukni hisoblaymiz:

$$\sigma_{\max.ch}=\sigma_L=\frac{M_T}{I_X}\cdot y_L\le[\sigma]_{ch} \qquad \sigma_{\max.ch}=\frac{16q\cdot a^2}{18\cdot I_X}\cdot y_L\le[\sigma]_{ch}$$

buerdan $q=\frac{18\cdot[\sigma_{ch}]I_X}{16\cdot a^2\cdot y_L}=\frac{18\cdot40\cdot918\cdot10^4}{16\cdot(1000)^3\cdot110}=3,76\frac{N}{mm}$

T – kesimdagi siquvchi va cho'zuvchi kuchlanishlar:

$$\sigma_s=\sigma_k^T=\frac{M_T}{I_X}\cdot y_k=\frac{\frac{16}{18}\cdot3,76\cdot10^6\cdot40}{918\cdot10^4}=14,56\frac{N}{mm^2}$$

$$\sigma_{ch}=\sigma_L^T=\frac{M_T}{I_X}\cdot y_L=\frac{\frac{16}{18}\cdot3,76\cdot10^6\cdot110}{918\cdot10^4}=40\frac{N}{mm^2}$$

Balkani B - tayanch kesimida neytral o'qdan yuqori qatlam materiali cho'ziladi. Unda polka cho'ziladigan material tomonida joylashadi. Mustahkamlik shart cho'ziladigan material uchun quyidagicha yoziladi

$$\sigma_{\max.ch}=\frac{M_B}{I_X}\cdot y_k\le[\sigma]_{ch} \text{ yoki } \sigma_{\max.ch}=\frac{q\cdot a^2}{2\cdot I_X}\cdot y_k\le[\sigma]_{ch}$$

buerdan $q=\frac{2\cdot[\sigma_{ch}]I_X}{a^2\cdot y_k}=\frac{2\cdot918\cdot10^4}{16\cdot40}=18,36\frac{N}{mm}$

– kesimdagi siquvchi va cho'zuvchi kuchlanishlar:

$$\sigma_{ch}=\sigma_k^B=\frac{M_B}{I_X}\cdot y_k=\frac{18,36\cdot10^6\cdot40}{918\cdot10^4}\approx80\frac{N}{mm^2}\succ[\sigma_{ch}]$$

$$\sigma_s=\sigma_L^B=\frac{M_B}{I_X}\cdot y_L=\frac{18,36\cdot10^6\cdot110}{918\cdot10^4}\approx220\frac{N}{mm^2}\succ[\sigma_s]$$

bu erda

$$I_{OTB} = 4d(h_P+t_B)\left[\left(\frac{h}{2}+h_P\right)-\frac{1}{2}\left(\frac{h}{2}+t_B\right)\right]^2 + 2d\cdot\delta(15^2+30^2+45^2) =$$

$$4\cdot 2\cdot 1{,}8\cdot(50{,}1)^2 + 2\cdot 2\cdot 0{,}8\cdot 3150 = 46200\,sm^4$$

buerda b_i, h_i, t_i - teng tomonli burchakning o'lchamlari

Ushbu inertsiya momentini hisoblashda teng tomonli burchakning vertikal qirrasidagi teshik kesim yuzasi e'tiborga olinmadi, chunki bu teshik yuzasining markaziy o'qida normal kuchlanishning qiymati tarkibiy balka xavfli kesimidagi kuchlanishdan kichik. Zaiflashgan kesimning qarshilik momenti:

$$W = \frac{I_{netto}}{\frac{h}{2}+h_P} = \frac{290416}{\frac{100}{2}+1} = 5694sm^3$$

Balka xavfli nuqtasidagi eng katta kuchlanish

$$\sigma_{\max} = \frac{M_{\max}}{W} = \frac{8190000}{5694} = 1564 \prec 1600\frac{kg}{sm^2}$$

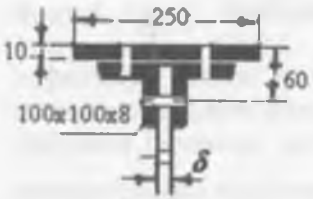
Balka kesimning devoridagi urinma kuchlanishni tekshiramiz. Buning uchun balka kesimining neytral o'qidan bir tomonda joylashgan yuzasining brutto statik momentini xisoblaymiz:

$$S_{OB} = b\cdot h_P\left(\frac{h+h_P}{2}\right)+2A_B\left(\frac{h}{2}-z_O\right)+\delta\cdot\frac{h}{2}\cdot\frac{h}{4} =$$

$$= 25\cdot 1\cdot 50{,}5 + 2\cdot 15{,}6\cdot 47{,}2 + 50\cdot 0{,}8\cdot 25 = 3735sm^3$$

Neytral qatlamdagi urinma kuchlanish

$$\tau_{\max} = \frac{Q\cdot S_{OB}}{I_{brutto}\cdot\delta} = \frac{540000\cdot 3735}{336616\cdot 0{,}8} = 745\frac{kg}{sm^2}$$



6.43-rasm.

Parchin mixlar qadamini hisoblaymiz. Balkani egilishida gorizontal listlar va teng tomonli burchaklar devorga nisbatan harakatlanishiga ezilishga ishlovchi gorizontal (devordagi) parchin mixlar qarshilik ko'rsatadi. Balkani $1sm$ uzunligiga to'g'ri keluvchi kuch

$$t_F = \frac{Q\cdot S_1}{I}$$ formuladan topiladi.

Parchin mix qadamini a - bilan belgilaymiz. Balkaning chetki oraliqlarida ko'ndalang kuch o'zgarmas bo'lganligi uchun, kesuvchi kuch gorizontal kesimda –tokchada teng taqsimlanadi. Bitta parchin mixdagi kesuvchi kuch $T = t_F \cdot a = 438{,}75kg$. Bu shart parchin mixni qirqilishiga va ezilishga qarshilik kuchidan ortib ketmasligi kerak. a -ni hisoblash uchun 2 ta shartdan foydalanamiz:

1) $T \le 2 \cdot \frac{\pi \cdot d^2}{4}[\tau]$ - ikki qirqimli parchin mixni qirqilishga

2) $T \le d \cdot \delta \cdot [\sigma]sm$ - ezilishga

Birinchi shartdan $a \le 2 \cdot \frac{3{,}14 \cdot 2^2}{438{,}75 \cdot 4} \cdot 1000 = 14{,}31sm$

Ikkinchi shartdan $a \le \frac{2 \cdot 0{,}8 \cdot 2800}{438{,}75 \cdot 4} = 10{,}21sm$

Gorizontal va vertikal parchin mixlar uchun $a = 100mm$ qabul qilamiz. Bosh kuchlanishlarni tekshirish balka devorini teng tomonli burchak bilan biriktirilgan kesimida bajariladi, chunki shu kesimda tokchadan devorga kesuvchi kuch uzatiladi.

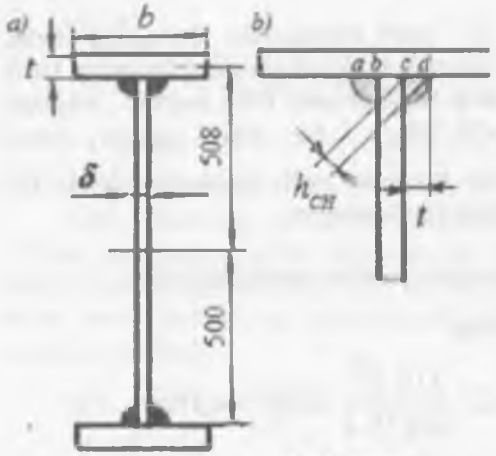
Normal kuchlanish $\sigma = \frac{M \cdot y}{I_{netto}} = \frac{8910000 \cdot 45}{290416} = 1380\frac{kg}{sm^2}$

Urinma kuchlanish $\tau = \frac{Q \cdot S}{I_{brutto} \cdot \delta} = \frac{540000 \cdot 2925}{336616 \cdot 0{,}8} = 586\frac{kg}{sm^2}$

$S = 2735 + 0{,}8 \cdot 5 \cdot 47{,}5 = 2925sm^3$ - bosh kuchlanishlarni tekshi-rish nutasidan yuqorida qolgan balka kesim yuzasini neytral o'qga nisbatan statik momenti. Bosh kuchlanish

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{(\frac{\sigma}{2}) + \tau^2} = \frac{1380}{2} + \sqrt{(\frac{1380}{2})^2 + (586)^2} = 1595\frac{kg}{sm^2}$$

Payvand balkalar. Payvand balkalarni tokchasi qalinligi kataroq bo'lgan gorizontal list tayyorlanib, devor bilan ikkita burchakli chok yordamida payvandlanadi. Payvand balkalarda kesimni tanlash parchin mixli balkalardagi kesimni zaiflashmagan. 6.44-rasmda ko'rsatilgan balka uchun



6.44-rasm

payvand tarkibli kesim tanlansin.

Balkani devori $1000x8mm$ inertsiya momenti $I_{ST}=66700sm^4$

Gorizontal listni qalinligini h_P=16mm qabul qilamiz, uning eni -b -ni topish uchun tokchani inertsiya momen-tini hisoblaymiz:

$$I_{LP}=\frac{1}{2}(I_{netto}-I_{ST}=\frac{1}{2}(290416-66700)=111858sm^4$$

Polka kesim yuzasini neytral o'qga nisbatan inertsiya momenti formulasidan (o'zining markaziy o'qiga nisbatan inertsiya momentini e`tiborga olmasdan) polka kesim yuzasining enini topamiz:

$b\cdot h_P\cdot(50,8)^2=111858\,sm^4$ va b=27,0sm.

Balkani inertsiya momenti

$$I=2\cdot b\cdot h_P\cdot(\frac{h}{2}+\frac{h_P}{2})^2+\frac{\delta\cdot h^3}{12}=2\cdot 27\cdot 1,6\cdot(50,8)^2+\frac{0,8\cdot(100)^3}{12}=289634\,sm^4$$

va qarshilik momenti $W=\dfrac{I}{\frac{h}{2}+h_P}=\dfrac{289634}{51,6}=5613sm^3$

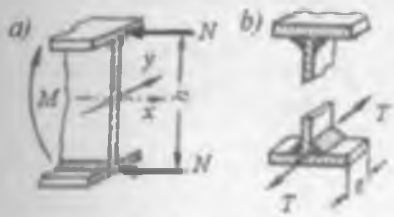
$$\sigma_{\max}=\frac{M_{\max}}{W}=\frac{8190000}{5613}=1587\frac{kg}{sm^2}$$

Chok kalinligini payvand uchun $[\tau]=800\dfrac{kg}{sm^2}$ ruxsat etilgan kuchlanishdan foydalanib topamiz. Tokcha bilan devor orasidagi bir birlik uzunlikka to'g'ri keluvchi kesuvchi kuch $t_F=\dfrac{Q\cdot S_1}{I}$. Tokcha

kesim yuzasining statik momenti

$$S_P = b \cdot h_P \left(\frac{h+h_P}{2}\right) = 27 \cdot 1{,}6 \left(\frac{100+1{,}6}{2}\right)^3 = 2195\, sm^3$$

$t_F = \frac{54000 \cdot 2195}{289634} = 409 \frac{kg}{sm}$ .Bu kuch chokni ab, cd yuzalarida ta`sir etadi



6.45 - rasm

Burchakli choklar uchun hisoblashda $h = 0{,}7 \cdot t$ o'lcham ishlatiladi. Shuning uchun chokni qalinligi h-ni $t_F = 1{,}4 \cdot h \cdot [\tau]$ tenglikdan topamiz:

$$h_{ch} = \frac{409}{1{,}4 \cdot 800} = 0{,}365 sm$$

Amalda burchakli chokni qalinligi $6mm$ dan kichik olinmaydi. Payvand balkalarda bosh kuchlanishlar chok qatlamida tekshiriladi. Normal kuchlanish $\sigma = \frac{M \cdot y}{I} = \frac{8910000 \cdot 50}{289634} = 1538 \frac{kg}{sm^2}$

Urinma kuchlanish $\tau = \frac{t_F}{\delta} = \frac{409}{0{,}8} = 511 \frac{kg}{sm^2}$

Bosh kuchlanish

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right) + \tau^2} = \frac{1538}{2} + \sqrt{\left(\frac{1538}{2}\right)^2 + (511)^2} = 1692 \frac{kg}{sm^2}$$

O'ta kuchlanish 5.75% ni tashkil etadi, bunga yo'l qo'yish mumkin emas. Buning uchun tokcha (list) qalinligini to'g'ri tanlash lozim.

Tokcha kesimning o'lchamlarini taxminiy belgilash uchun tokchalarga eguvchi moment elkasi h-ga teng bo'lgan (80-85%) juft kuchlar – N tarzda ta`sir qiladi deb taxmin qilinadi (*6.45–rasm*). Demak, $N = \frac{0{,}8 \cdot M}{h}$. Kuch tokchalarni cho'zilishiga va siqilishiga sabab buladi. Shuning uchun tokcha kesimining yuzasi

$$A_{tokcha} \geq \frac{N}{[\sigma]} = \frac{0{,}8 \cdot M}{h \cdot [\sigma]} = \frac{0{,}8 \cdot 8910000}{100 \cdot 1600} = 44{,}6 sm^2$$

Konstruktiv mulohazalarga ko'ra tokchalarning enini $b = (0{,}3...0{,}4)h$ deb olinadi. Bizda b=(0,3...0,4)·100=100...25sm yoki $b = 27 sm$ deb olib

tokchaning qalinligini topamiz $h_P = \frac{A_{tokcha}}{b} = \frac{44,6}{27} = 1,65sm$

$h_P = 1,8sm$ qabul qilamiz, belgilangan o'lchamlar asosida kesimning markaziy o'qqa nisbatan inertsiya momentini hisoblaymiz:

$$I = 2 \cdot b \cdot h_P \cdot (\frac{h+h_P}{2})^2 + \frac{\delta \cdot h^3}{12} = 2 \cdot 27 \cdot 1,8 \cdot (50,9)^2 + 66667 = 318494\, sm^4$$

Balka kesimining karshilik momenti $W = \frac{I}{\frac{h}{2} + h_П} = \frac{318494}{51,8} = 6148 sm^3$

Kuchlanish $\sigma = \frac{8910000}{6148} = 1450 \frac{kg}{sm^2}$

Tokcha kesim yuzasiing statik momenti

$S_P = 27 \cdot 1,8 \cdot (\frac{100+1,8}{2})^3 = 2473 sm^3$ urinma kuch

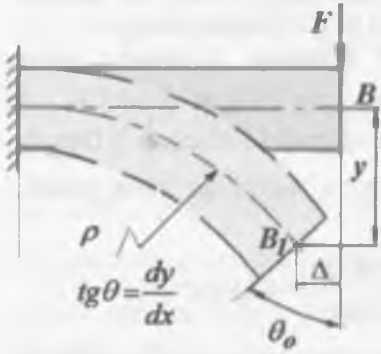
$$t_F = \frac{54000 \cdot 2473}{318494} = 419 \frac{kg}{sm}$$ va kuchlanish

$$\tau = \frac{t_F}{\delta} = \frac{419}{0,8} = 524 \frac{kg}{sm^2}$$

Chokni qalinligi $h_{ch} = \frac{419}{1,4 \cdot 800} = 0,374sm$

Normal kuchlanish $\sigma = \frac{M \cdot y}{I} = \frac{8910000 \cdot 50}{318494} = 1400 \frac{kg}{sm^2}$

VI. EGILISHDA KO'CHISHNI ANIQLASH



Balka biror inertsiya o'qi tekisligida tashqi kuch bilan yuklansa, uning o'qi shu tekislikda egrilanadi, tekis egilish sodir bo'ladi. Balka egilgan o'qining tenglamasi

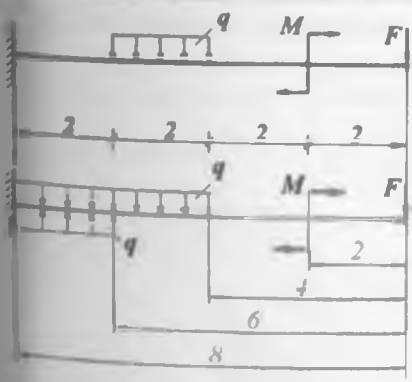
$$y = f(x)$$

B nuqta B_1 holatga ko'chadi. Bu ko'chish *F* kuch yo'nalishida sodir bo'lib, balkaning salqiligi (y) deyiladi

Egilishgacha tekis bo'lgan balkaning kesimi, deformatsiyadan keyin ham tekisligicha qolib, o'zining boshlang'ich holatiga nisbatan θ burchakka aylanadi. θ burchak balka kesining aylanish burchagi deyiladi.

Salqilik va kesimni aylanish burchagini aniqlash usullari	- balka egilish o'qining takribiy differentsial tenglamasini uzluksiz integrallash
	- boshlangich parametrlar usuli
	- grafoanalitik usul
	- energetik usul: Mor integralini tadbiq etish
tajribaviy	- maxsus tajriba qurilmalarida bajariladi

Boshlang'ich parametrlar usulini tadbik etish tartibi	1) balkani *XOU* koordinata sistemasiga joylashti-ramiz, balkani boshlang'ich nuqtasini belgilaymiz; 2) balkaning oraliq masofalarini, koordinata boshidan joylashtiramiz. 3) balkaning biror oraliqidagi taqsimlangan kuch intensivligini ta'siri, balkaning oxirigacha davom etmasa. balkani shu oraliqlarini o'zaro teng va qarama-qarshi yo'nalgan taqsimlangan kuch intensivligi bilan to'ldiramiz. 4) balkani oxirgi oraliki uchun takribiy differen-tsial tenglamani tuzamiz va uni ketma-ket ikki marotaba integrallaymiz $$EIy'' = -F \cdot x - M(x-2)^0 - q\frac{(x-4)^2}{2} + q\frac{(x-6)^2}{2}$$



5)Juft kuch momentini $M \cdot x^0$ - ko'rinishda yozamiz;

6) Differentsial tenglamani integrallashda – qavslarni ochmaymiz. Integrallash quyidagi tartibda bajariladi

$$\int (x-a)^n dx = \frac{(x-a)^{n+1}}{n+1}$$

7) balka boshlangich kesimi-ning aylanish burchagi va salqiligini, balka uchlarini tayanchlarga

tokchaning qalinligini topamiz $h_P = \frac{A_{tokcha}}{b} = \frac{44,6}{27} = 1,65sm$

$h_P = 1,8sm$ qabul qilamiz, belgilangan o'lchamlar asosida kesimning markaziy o'qqa nisbatan inertsiya momentini hisoblaymiz:

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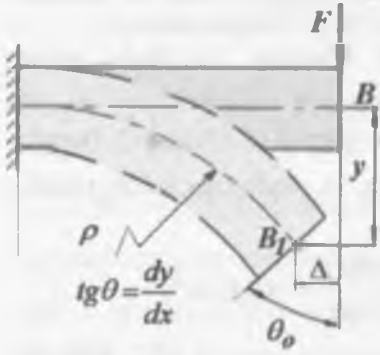
VI. EGILISHDA KO'CHISHNI ANIQLASH



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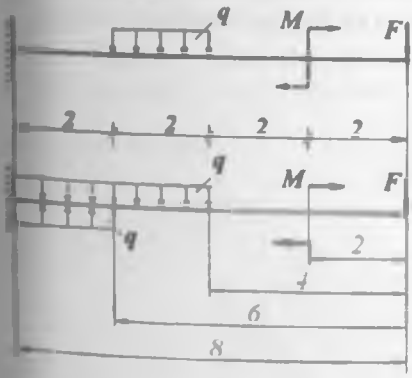
	- energetik usul: Mor integralini tadbiq etish
tajribaviy	- maxsus tajriba qurilmalarida bajariladi

Boshlang'ich parametrlar usulini tadbik etish tartibi	1) balkani *XOU* koordinata sistemasiga joylashti-ramiz, balkani boshlang'ich nuqtasini belgilaymiz; 2) balkaning oraliq masofalarini, koordinata boshidan joylashtiramiz. 3) balkaning biror oraliqidagi taqsimlangan kuch intensivligini ta`siri, balkaning oxirigacha davom etmasa, balkani shu oraliqlarini o'zaro teng va qarama-qarshi yo'nalgan taqsimlangan kuch intensivligi bilan to'ldiramiz. 4) balkani oxirgi oraliki uchun takribiy differen-tsial tenglamani tuzamiz va uni ketma-ket ikki marotaba integrallaymiz $$EIy'' = -F \cdot x - M(x-2)^0 - q\frac{(x-4)^2}{2} + q\frac{(x-6)^2}{2}$$



5)Juft kuch momentini $M \cdot x^0$ - ko'rinishda yozamiz;

6) Differentsial tenglamani integrallashda – qavslarni ochmaymiz. Integrallash quyidagi tartibda bajariladi

$$\int (x-a)^n dx = \frac{(x-a)^{n+1}}{n+1}$$

7) balka boshlangich kesimi-ning aylanish burchagi va salqiligini, balka uchlarini tayanchlarga

tayanish shartlaridan topiladi.

8) boshlangich marametrlar usuliga asosan balka ixtiyoriy kesimining aylanish burchagi va salqiligi quyidagi universal formuladan hisoblanadi:

kesimni aylanish burchagini hisoblash formulasi

$$\theta = \theta_0 + \frac{1}{EI}\left[-F\frac{x^2}{2} - M(x-2)^{/} - q\frac{(x-4)^3}{6} + q\frac{(x-6)^3}{6}\right]$$

salqilik formulasi

$$y = y_0 + \theta_0 x + \frac{1}{EI}\left[-F\frac{x^3}{6} - M\frac{(x-2)^2}{2} - q\frac{(x-4)^4}{24} + q\frac{(x-6)^4}{24}\right]$$

buerda:

y_0, θ_0 - balka boshlang'ich nuqtasining salqiligi va boshlang'ich kesimining aylanish burchagi bo'lib, balka uchlarini tayanchlarga tayanish shartlaridan topiladi

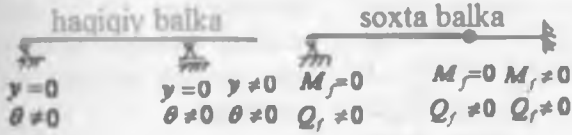
Kesimning aylanish burchagi va salqilik formulalariga $x = 8м$ qiymat qo'yilsa formulalarni chap tomoni nolga teng bo'ladi ($\theta = 0, y = 0$), chunki balkani qistirib mahkamlangan kesimi absolyut qo'zg'almas. Unda, balka kesimining aylanish burchagi formulasidan hosil bo'lgan $\theta_0 = -\frac{1}{EI}\left[-32F - 6M - q\frac{56}{6}\right]$ ifodani $x = 8м$ qiymatda salqilik formulasiga keltirib qo'yib $y_0 = -\frac{1}{EI}\left[F\frac{664}{6} + 30M + q\frac{282}{3}\right]$ ifodani hosil qilamiz. Topilgan y_0, θ_0 ifodalarini kesimni aylanish burchagi va salqilik formu-lalariga keltirib qo'yib, hosil bo'lgan formulalardan balka ixtiyoriy kesimining aylanish burchagi va salqiligini hisoblash mumkin.

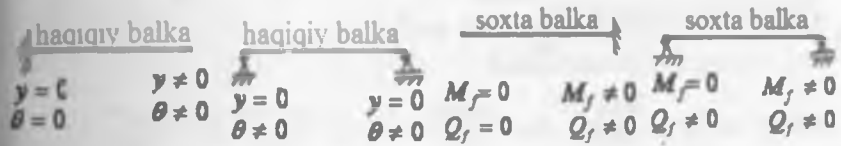
Egilishda ko'chishni grafoanalitik usulda aniqlashning tartibi.

1. Berilgan balka uchun tashqi kuch ta'siridan eguvchi moment epyurasi quriladi.

2. Berilgan balka uchun soxta balka tanlanadi:

3. Soxta balka berilgan balkaning eguvchi momentiga miqdor jihatdan teng bo'lgan $M = q_f$ soxta kuch bilan yuklanadi, soxta kuch intensivligi





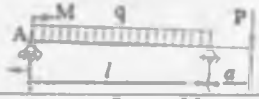
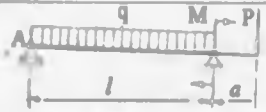
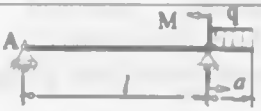
q_f - haqiqiy balkaning eguvchi momenti qonuniyati bilan bir xil o'zgaradi.

4. Haqiqiy balka ixtiyoriy kesimining aylanish burchagi - θ, soxta balkani shu kesimidagi ko'ndalang kuchni haqiqiy balkaning bikrligiga bo'linmasiga teng: $\theta = \frac{Q_f}{EI}$

5. Haqiqiy balka ixtiyoriy nuqtasining salqiligi - u, soxta balkaning shu nuqtasidagi eguvchi moment M_f - ni haqiqiy balkaning bikrligiga bo'linmasiga teng: $y = \frac{M_f}{EI}$

burchagini aniqlang (jadvaldagi rasmlarda ko'rsa-tilgan). Balkalarning qulochi $l = 4a=4$ *m*, konsolning uzunligi $a=1$ *m*. Ruxsat etiladigan kuchlanish 160 MPa uchun balka kesimining qo'shtavrni tanlang. Balkaning har qaysi sxemasi uchun yuklanish ikki variantda beriladi: 1) *q=2 kN/m, P = 40 kN, M=60 kNm;*

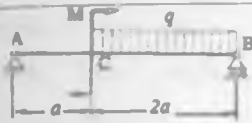
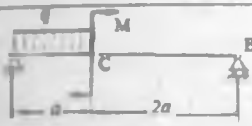
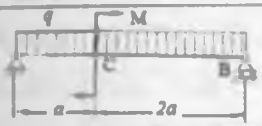
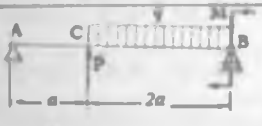
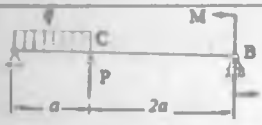
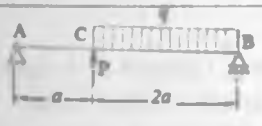
2) q=40 kN/m, R= 60 kN, M = 20 kNm.

6.37-misol uchun sxemalar	vari-ant	qo'sh-tavr	deformatsiya		
			y_1,sm	y,sm	θ,rad
	1	27	-0,866	0,266	-0,01067
	2	27	-0,931	0,196	-0,0031
	1	33	0,169	-0,474	0,00068
	2	30a	-0,343	-0,129	-0,00343
	1	27	-0,067	-0,566	-0,00133
	2	30	-0,799	0,494	-0,00659
	1	27	-0,498	2,413	-0,00732
	2	18	0	-0,711	-0,00518
	1	24a	-0,658	0,844	-0,00438
	2	18	0	-0,194	0

6.38-misol. Rasmda ko'rsatilgan ikki tayanchga tiralgan balkalar uchun S kesimdagi salkilik va o'ng tayanch V dagi aylanish burchagini aniklang. Ruxsat etilgan kuchlanish 16000 N/sm^2 bo'lganda mustahkamlik shartidan har bir qo'shtavrli balkaning kesimini tanlang. Balka yuklashning ikki varianti beriladi:

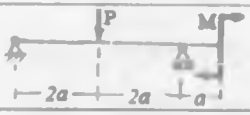
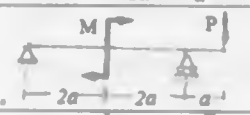
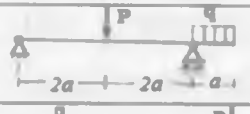
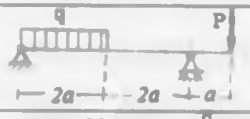
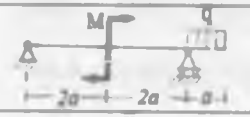
1) *q=20 kN/m, P = 40 kN, M=60 kNm; 2) q=40 kN/m, R= 60 kN, M = 30 kNm*. Balkalar qulochi $l= 3\ a = 6$ *m*. Agar har qaysi balkaning

xususiy og'irligini xisobga olinsa, ularning salkiligi qanday Δ_{U_0} qiymatga o'zgaradi?

6.38-misol uchun sxemalar	va-ri-ant	qo'sh -tavr	deformatsiya		
			y_C,sm	θ_B,rad	Δy_C,sm
	1	33	-1,355	0,00926	-0,031
	2	40	-1,197	0,00806	-0,022
	1	27a	-1,212	0,00707	-0,045
	2	30	-1,319	0,00675	-0,038
	1	36	-1,295	0,00822	-0,027
	2	45	-1,117	0,00692	-0,017
	1	27	-0,355	-0,0049	-0,046
	2	30	-1,130	0,00832	-0,038
	1	27	-0,444	0,00866	-0,046
	2	20	0	0,00785	-0,084
	1	27a	-1,858	0,01192	-0,0445
	2	36	-1,046	0,00775	-0,027

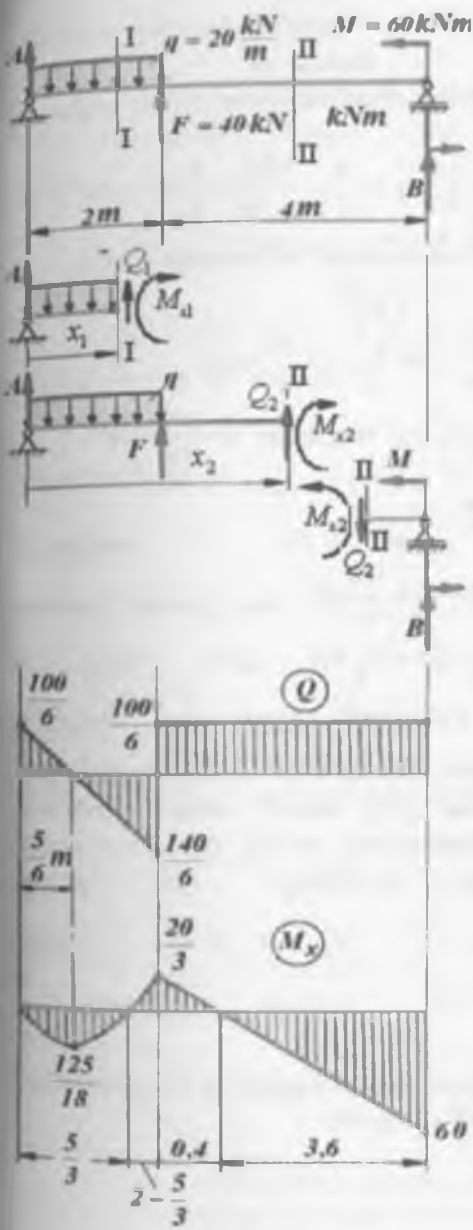
6.39-misol. Qo'shtavr kesimli balkalar rasmda ko'rsatilganidek yuklangan. Quloch o'rtasidagi (u_o) va konsol uchidagi (u_u) salkiliklar, shuningdek o'ng tayanchdagi aylanish burchagini aniqlang. Uchastka uzunligi $a=2$ *m*, har qaysi balka sxemasi uchun yuklanish ikki variantda beriladi: *1) M=20 kNm, P = 30 kN, q=10 kN/m. 2) M=30 kNm, R= 20 kN, q = 2 kN/m*. Qo'shtavr nomerini ruxsat etiladigan kuchlanish 160 MPa bo'lgandagi mustahkamlik shartidan aniqlash kerak. Qo'shtavr nomerini jadvaldan ham olish mumkin. (3-grafa). Kuchishlar kattaliklarining sonli

iymatlarini aniqlagandan so'ng balka o'rtasidagi eng katta egilish 1,6 sm dan oshmasligi uchun qanday nomerli qo'shtavr olish kerakligini ham xisoblang.

6.39-misol uchun sxemalar	vari-ant	qo'sh-tavr	javob			
			y_1 ,sm	y ,sm	θ_A,rad	qo'sh-tavr
	1	24a	-3,16	1,23	0,00878	30a
	2	20	-2,54	-1,63	0	24
	1	27	2,4	-3,87	-0,0153	40
	2	22a	2,87	-4,42	-0,0173	36
	1	24a	-3,16	1,49	0,00878	30a
	2	22a	-0,96	-1,67	-0,0048	27
	1	27	-0,27	-2,13	-0,0067	36
	2	30	-2,64	0,75	0,008	36
	1	18	3,10	-4,40	-0,0180	27a
	2	22a	2,87	-4,18	-0,0173	36
	1	20a	-4,61	2,30	0,01642	30
	2	30	-2,92	1,84	0,01120	36

6.51-rasm

6.40-misol. Qulochi $2l$ = 80 sm bo'lgan yog'och balka chap uchidan qisilgan. Balkaning erkin o'ng uchiga R=2000 N kuch qo'yilgan. Balka bir qismining diametri 12 sm, ikkinchisiniki 10 sm (6.51-rasmga qarang). I-I , II-II kesimlarda eng katta normal kuchlanishlar nimaga teng? Balka erkin uchining salqiligini toping. Kuchlanishlar kontsentratsiyasi ta`sirini hisobga olmang.



6.52 - rasm

6.41-misol. Balkani egilishga to'liq hisoblash

echish. Balkani reaktsiya kuchlarini hisoblaymiz (6.52–rasm). $\Sigma M_B = 0;$

$$-6A + q \cdot 2\left(\frac{2}{2} + 4\right) - 4F + M = 0$$

$$\Sigma M_A = 0;$$

$$2F - q \cdot \frac{(2)^2}{2} + M + 6B = 0$$

$$A = \frac{100}{6} kN \quad \text{va} \quad B = -\frac{100}{6} kN$$

Tekshirish:

$$\Sigma Y = A + F + B - 2q = 0 \quad \text{va}$$

$$\frac{100}{6} + 40 - \frac{100}{6} - 2 \cdot 20 = 0$$

Balkani eguvchi moment va kundalang kuch epyurala-rini quramiz.

I-I qirqim. $0 \le x_1 \le 2m$

$$Q_1 = A - qx;$$

$$M_{x1} = A_{x1} - q\frac{x_1^2}{2}$$

$x_1 = 0$ bo'lsa $Q_1 = \frac{100}{6}, kN$

va $M_{x1} = 0$

$x_1 = 2m$ da $Q_1 = -\frac{140}{6}, kN$

va $M_{X1} = -\frac{20}{3} kNm$ hosil bo'ladi. $0 \le x_1 \le 2m$ oraliqda ko'ndalang kuch to'g'ri chiziqli qonuniyat bilan o'zgaradi va ishorasini

o'zgartirdi. Demak to'g'ri chiziq x_1-ni

qandaydir qiymatida abstsissani kesib o'tadi va kesib o'tish nuqtasida nolga tenglashadi.

$Q_1 = A - qx_1 = 0$ tenglikdan $x_1 = \frac{A}{q} = \frac{100}{6 \cdot 20} = \frac{5}{6} m$

$Q_1 = 0$ bo'lganda nuqtada M_{x_1} eguvchi moment maksimumga erishadi.

$$M_{x1\max} = \frac{100}{6} \cdot \frac{5}{6} - 20 \frac{\left(\frac{5}{6}\right)^2}{2} = \frac{125}{18}, kNm$$

Birinchi oralikda $M_{x_1} = A_{x_1} - q\frac{x_1^2}{2} = 0$ tenglikdan $x_1 = \frac{100}{60} = \frac{5}{3} m$

II - II qirqim. $2 \le x_2 \le 4m$

Ko'ndalang kuch tenglamasi $Q_1 = A - q2 + F = \frac{100}{6} - 20 \cdot 2 + 40 = \frac{100}{6} kN$ va eguvchi moment tenglamasi $M_{x2} = Ax_2 - q \cdot 2(x_2 - 1) + F(x_2 - 2)$. Ushbu tenglamani $M_{x2} = A(2 + x_2) - q \cdot 2(\frac{2}{2} + x_2) + Fx_2$ ko'rinishda ham tuzish mumkin, buning uchun oraliqni o'zgarishi $0 \le x_2 \le 2m$ sohada belgilanishi kerak. Agar balkani II–II qirqimdan o'ng tomoni uchun ko'ndalang kuch va eguvchi moment tenglamalari tuzilsa, ular $0 \le x_2 \le 4m$ o'zgarish sohasida quyidagi ko'rinishga ega bo'ladi

$Q_2 = B = \frac{100}{6} kN$ va $M_{x2} = M - B \cdot x_2$ yoki

$M_{x2} = A(2 + x_2) - q \cdot 2(\frac{2}{2} + x_2) + Fx_2 = 0$ $x_2 = 0{,}4m$ nuqtalarda M_x ishorasini o'zgartiradi.

2. Balkani xavfli kesimi uchun normal kuchlanish bo'yicha mustahkamlik shartidan qo'shtavrli profil tanlaymiz.

$$\sigma_{\max} = \frac{M_{\max}}{W_x} \le [\sigma]$$

Bu erda. $M_{max} = 60kNm$ - balkani V xavfli kesimidagi eguvchi moment;

$[\sigma] = 160\ mPa$,- balkani materiali uchun ruxsat etilgan kuchlanish,

Mustahkamlik shartdan xavfli kesimni talab etilgan qarshilik momentini hisoblaymiz: $W_x = \frac{M_{max}}{[\sigma]} = \frac{60}{160 \cdot 10^3} = 0{,}375 \cdot 10^{-3} m^3$

Qo'shtavrli kesimning qarshilik momentini hisoblab tartib raqamini tanlaymiz: $W_T = 0{,}371 \cdot 10^{-3} m^{-3}$

qarshilik momentli №27 va $W_T = 0{,}407 \cdot 10^{-3} m^{-3}$ qarshilik momentli - №27 a – raqamli qo'shtavrlar.

Tanlangan - W_T qarshilik momentlar asosida mustahkamlik shartni tekshiramiz. $\sigma_{max}^{27} = \frac{M_{max}}{W_x} = \frac{60}{0{,}371 \cdot 10^{-3}} = 161{,}725 \cdot 10^{-3} \frac{kN}{m^2} > [\sigma]$

$$\sigma_{max}^{27a} = \frac{60}{0{,}407 \cdot 10^{-3}} = 147{,}42 \cdot 10^{-3} \frac{kN}{m^2} < [\sigma]$$

№ 27 – raqamli qo'shtavr - $\frac{161{,}725 - 160}{160} \cdot 100\% = 1{,}08\%$ yuqori kuchlanishda va № 27a – raqamli qo'shtavr $\frac{147{,}42 - 160}{160} \cdot 100\% = -7{,}86\%$ to'liq yuklanmagan vaziyatda ishlaydi.

Qo'shtavrlar mustahkamligini balkani ko'ndalang kuch bo'yicha xavfli kesimidagi urinma kuchlanishlar asosida tekshiramiz.

$$\tau_{max}^{27} = \frac{Q_{max} \cdot S_{max}}{I_x} = \frac{\frac{140}{6} \cdot 100 \cdot 210}{5010 \cdot 0{,}6} = 163 \frac{kg}{sm^2} < [\tau]$$

$$\tau_{max}^{27a} = \frac{Q_{max} \cdot S_{max}}{I_x \cdot d} = \frac{\frac{140}{6} \cdot 100 \cdot 229}{5500 \cdot 0{,}6} = 162 \frac{kg}{sm^2} < [\tau]$$

Bu erda $Q_{max} = \frac{140}{6} \cdot 100$ - balkadagi eng katta ko'ndalang kuch;

S_{max}, I_{max} va d – qo'shtavrli kesimni tegishli geometrik xarakteristikalari

Balkani xavfli kesimida mustahkamlikni ta'minlash uchun № 27a – qo'shtavrni tanlaymiz va uning geometrik xarakteristikalarini yozamiz:

$h = 270mm$, $a = 135mm$, $d = 6mm$, $t = 10,2mm$ $I_X = 5500sm^3$
$S_X = 229sm^3$ $W_T = 407sm^3$

Qo'shtavrli kesimni balandligi bo'yicha normal - σ - va τ - urunma kuchlanishlarini hisoblaymiz.

- normal kuchlanish: $\sigma = \frac{M_{max}}{I_x} \cdot y$ formula bilan hisobla- nadi

buerda y qushtavrli kesimni x neytral o'qidan tegishli nuqtalargacha bo'lgan masofa.

1 -nuqta - $y_1 = y_9 = \frac{h}{2} = \frac{270}{2} = 135mm = 13,5sm$;

$$\sigma_1 = -\frac{60 \cdot 10^5}{5510} 13,5 = -1472,7 \frac{kg}{sm^2}$$

2 – nuqta - $y_{2,3} = y_{7,8} = \frac{h}{2} - t = \frac{27}{2} - 1,02 = 12,48sm$

$$\sigma_2 = -\frac{60 \cdot 10^5}{5510} 12,48 = -1361,45 \frac{kg}{sm^2}$$

4- nuqta. $y_{4,6} = \frac{1}{2}(\frac{h}{2} - t) = \frac{1}{2}(\frac{27}{2} - 1,02) = 6,24sm$

$$\sigma_4 = -\frac{60 \cdot 10^5}{5510} 6,24 = -680,73 \frac{kg}{sm^2}$$

5- nuqta - $y_5 = 0$; $\sigma_5 = 0$

Balka kesimining neytral o'qidan yuqorida joylashgan mate-riali siqilishga va pastki qatlam materiali cho'zilishga qarshilik ko'rsatganligi uchun 1, 2, 3 va 4 nuqtalarda normal kuchlanish ishorasi manfiy

Urinma kuchlanish $\tau = \frac{Q_{max} \cdot S_x^0}{I_x \cdot b(d)}$ formula bilan hisoblanadi

Buerda S_x - qushtavrli kesimning chetki va kuchlanishi hisoblanishi lozim bo'lgan – tanlangan nuqtalar orasidan ajratilgan yuzani neytral o'qga nisbatan statik momentni va u quyidagicha hisoblanadi

1-nuqta - $S_x^{01} = 0$; demak $\tau_{1,9} = 0$

2-nuqta - $S_x^{02}=\left(\frac{h-t}{2}\right)\cdot t\cdot b=\left(\frac{27-1,02}{2}\right)1,02\cdot 13,5=178,9 sm^3$

Qushtavrni 2 va 3 nuqtalari joylashga kesimining eni $b=13,5\ sm$ dan $d=0,6\ sm$ ga qadar kichiklashadi. Shuning uchun bu nuqtalardagi kuchlanishlar bir – biridan tubdan farq qiladi:

$$\tau_2=\frac{14000\cdot 1787,9}{6\cdot 5500\cdot 13,5}=5,62\frac{kg}{sm^2} \quad \text{va} \quad \tau_3=\frac{14000\cdot 178,9}{6\cdot 5500\cdot 0,6}=126,5\frac{kg}{sm^2}$$

4 – nuqta uchun $S_x^{04}=178,9+\frac{d}{2}\left(\frac{h_C^2}{4}-y^2\right)$, bu erda

$h_C=h-2t=27-2\cdot 1,02=24,96 sm$ va $y=y_4=\frac{h_C}{4}=6,24 sm$.

Unda, $S_X^{04}=213,9 sm^3$ va $\tau_4=\frac{14000\cdot 213,9}{6\cdot 5500\cdot 0,6}=151,2\frac{kg}{sm^2}$

5 – nuqta uchun $S_x^{05}=S_{max}=229 sm^3$; va $\tau_{max}=162\ \ kg/sm^2$

Ko'rsatma. Salqilikni aniqlash uchun Kastilyano teoremasidan foydalangan maqul. Nisbat $J_2:J_1 = 2,86$. Salqilik uchun ifoda quyidagi ko'rinishni oladi:

$$f=\int_0^l Px^2\,dx+\frac{1}{2}\int_0^{2l} Px^2\,dx=\frac{Pl^3}{3EJ_1}\left(1+\frac{7}{2,86}\right).$$

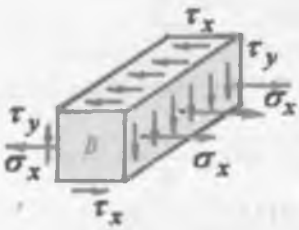
Javobdagi musbat ishora egilish yo'nalishi R kuch yo'nalishi bilan mos kelganligini ko'rsatadi.

Javob: $\sigma_{II}=0,91\ \sigma_I$; $\sigma_I=810\ N/sm^2$; $f\approx 0,3$ sm.

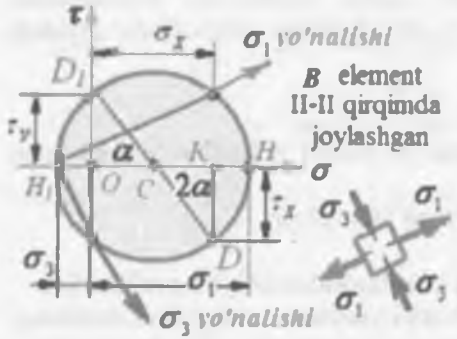
4. Balka mustahkamligini bosh kuchlanishlar bo'yicha tekshirish. Egilayotgan balkaning ko'ndalang kesim yuzasida normal kuchlanishning eng katta qiymati balka kesimining neytral o'qidan eng uzoqda joylashgan chetki nuqtalarida hosil bo'ladi. Bu nuqtalarda urinma kuchlanish nolga teng. Shuning uchun bu materialning mustahkamligi normal kuchlanish bo'yicha ta'minlanadi: $\boxed{\sigma_{max}=\frac{M_{max}}{W}\le[\sigma]}$

Urinma kuchlanish eng katta qiymatga erishgan neytral qatlamdagi materialda normal kuchlanish nolga teng. Shuning uchun bu materialning mustahkamligi urinma kuchlanishlar bo'yicha ta'minlanadi: $\boxed{\tau_{max}=\frac{Q_{max}\cdot S_{max}}{I_x d}\le[\tau]}$

Balka kesimining neytral o'qidan u masofada joylashgan materialning mustahkamligini normal va urinma kuchlanishlar bo'yicha ta`minlash mumkin emas. Chunki bu matertialda normal σ va urinma τ kuchlanishlar noldan farqli. Shuning uchun bu elementning mustahkamligi normal va urinma kuchlanishlar buyicha mustahkamlik shartlariga bo'ysunmaydi.



Ushbu materialdan ajratilgan kubik shaklidagi elementning old qismi – balkaning yon sirtiga ustma - ust tushadi. Bu yuza normal va urinma kuchlanishlardan ozod, shuning uchun bu yuzacha bosh yuza, elementni vertikal yuzalari normal σ_x va τ_y urinma kuchlanishlar, gorizontal yuzasi esa faqat τ_x urinma kuchlanish ta`sirida. Ikkita kuchla-nishlar ta`siridagi yuzalar tekis kuchlanganlik holatida bo'ladi.



6.53 rasm

B element II-II qirqimda joylashgan

Tekis kuchlanganlik holatidagi elementda uchta bosh normal kuchlanishlardan bittasi (masalan $\sigma_2 = 0$) nolga teng. σ_1 va σ_3 bosh normal kuchlanishlarni, berilgan $\sigma_x; \tau_x = -\tau_y$ kuchlanishlari yordamida Mor doirasini qurish usuli bilan topamiz (6.53-rasm). Buning uchun $\sigma O \tau$ koordinata sistemasini olamiz. Koordinata boshidan (O nuqtadan) kuchlanishlar masshtabida cho'zuvchi normal kuchlanishni $\sigma_x = OK$ kesma –masofa bilan belgilaymiz. K nuqtadan σ o'qiga perpendikulyar tekislikda musbat ishorali urinma kuchlanish $\tau_x = KD$ joylashtiriladi. Elementning gorizontal yuzasiga qo'yilishi mumkin bo'lgan vertikal tekislikdagi normal kuchlanish nolga teng ($\sigma_y = 0$) chunki egilishda balkaning yuqori qatlam materiali pastki material qatlamiga vertikal tekislikda bosim ta`sirini o'tkazmaydi)

bo'lganligi uchun bu kuchlanish $\sigma o\tau$ koordinata sistemasining O nuqtasida joylashadi. O nuqtadan τ o'qining manfiy tomoniga $\tau_y = OD_1$ kuchlanishni joylashtirsak D va D_1 nuqtalar kelib chiqadi. D va D_1 nuqtalarni birlashtirsak Mor doirasining markazi S nuqta hosil bo'ladi. D va D_1 nuqtalar Mor doirasining chetki nuqtalari bo'lganligi uchun kuchlanishlar doirasi $CD = R$ radiusi bilan chiziladi (6.53– rasm).Mor doirasi σ o'qining N va N_1 nuqtalarda kesib o'tadi. Kuchlanishlar masshtabida ON masofa σ_1 - eng katta bosh normal kuchlanishga, ON_1 masofa esa- σ_3 bosh normal kuchlanishga teng.

Qushtavrli kesimni har bir nuqtasidagi bosh normal kuchlanishlar topiladi:

$$\sigma_{1,3} = \frac{1}{2}\left[\sigma \pm \sqrt{\sigma^2 + 4\tau^2}\right].$$

1 – nuqta uchun $\sigma_1 = 0$ va $\sigma_3 = -1472{,}7\frac{kg}{sm^2}$

2 – nuqta. $\sigma_{1,3} = \frac{1}{2}\left[-1361{,}4 \pm \sqrt{(1361{,}4)^2 + 4\cdot(5{,}62)^2}\right] = \frac{1}{2}(-1361{,}4 \pm 1361{,}44)$

buerdan $\sigma_1 = 0{,}02\ kg/sm^2$ va $\sigma_3 = -1361{,}42\ kg/sm^2$

3 – nuqta. $\sigma_{1,3} = \frac{1}{2}\left[-1361{,}4 \pm \sqrt{(1361{,}4)^2 + 4\cdot(126{,}5)^2}\right] = \frac{1}{2}(-1361{,}4 \pm 1384{,}7);$

buerdan $\sigma_1 = 11{,}7\frac{kg}{sm^2}$ $\sigma_3 = -1373{,}4\frac{kg}{sm^2}$

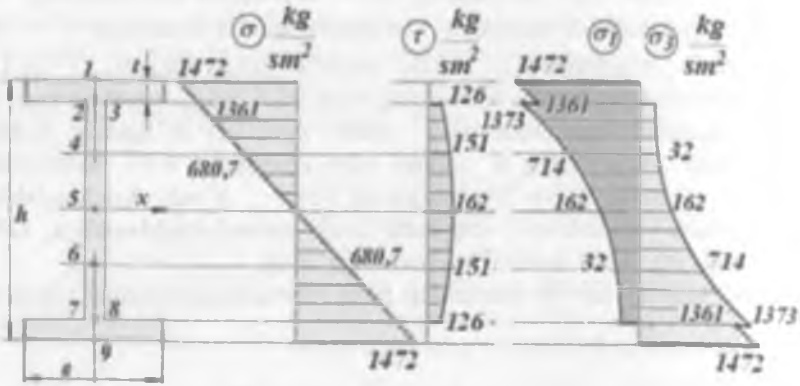
4 – nuqta. $\sigma_{1,3} = \frac{1}{2}\left[-681{,}7 \pm \sqrt{(681{,}7)^2 + 4\cdot(151{,}2)^2}\right] = \frac{1}{2}(-681{,}7 \pm 745{,}8);$

buerdan $\sigma_1 = 32\frac{kg}{sm^2}$ va $\sigma_3 = -713{,}8\frac{kg}{sm^2}$

5 – nuqta $\sigma_{1,3} = \pm 162\frac{kg}{sm^2}$

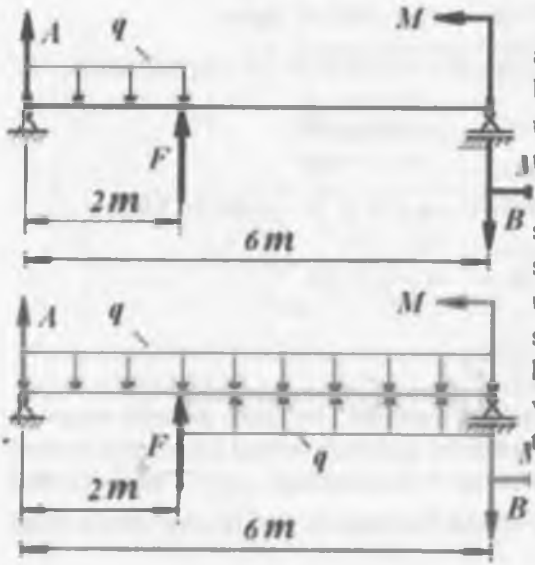
Neytral o'qdan pastki qatlam materiali cho'zilish deforma-tsiyasiga qarshilik ko'rsatadi, shuning uchun bu qatlamda normal kuchlanish musbat ishorali bo'ladi. Demak, 6,7,8 va 9 nuqtalardagi $\sigma_{1,3}$ - bosh normal kuchlanishlarini hisoblashda normal kuchlanish - σ musbat ishora bilan olinadi.

Bosh urinma kuchlanishni maksimal va minimal qiymati kesimni har bir nuqtasi uchun $\tau_{\substack{max\\min}} = \pm\frac{1}{2}\sqrt{\sigma^2 + 4\tau^2}$ formula bilan hisoblanadi. Bosh normal kuchlanishlarni yo'nalishlari $tg2\alpha_0 = -\frac{2\tau}{\sigma}$



6.54-rasm. Normal va urinma kuchlanishlar, bosh normal kuchlanish

5.Egilishda salkilik va kesimning aylanish burchagini xisoblashga oid misollar.



6.55 - rasm

Salkilik va kesimning aylanish burchagini boshlang'ich parametrlar usuli bilan hisoblash tartibi:.

1.balka berilgan sxemasini 6.55-rasmda ko'rsatilganidek chizamiz va universal formulani tuzish shartlari asosida kesimni aylanish burchagi va salkilik tenglamalarini tuzamiz:

-Kesimni aylanish burchagining formulasi:

$$\theta = \theta_0 + \frac{1}{EI}\left[A\frac{x^2}{2} - q\frac{x^3}{6} + F\frac{(x-2)^2}{2} + q\frac{(x-2)^3}{6}\right]$$ va salqilik

formulasi $$y = y_0 + \theta_0 x + \frac{1}{EI}\left[A\frac{x^3}{6} - q\frac{x^4}{24} + F\frac{(x-2)^3}{6} + q\frac{(x-2)^4}{24}\right]$$

Balka boshlang'ich kesimining aylanish burchagi θ_0 va sal-qiligi y_0- larni balka uchlarining tayanch turlariga bog'liq ravishda aniqlaymiz.

Masalan, $x_0 = 0; \theta = \theta_A = \theta_0 \neq 0; y = y_A = y_0 = 0$, ya'ni A tayanch kesimining aylanish burchagi nolga teng emas, lekin vertikal ko'chishi cheklangan. Shuning uchun bu tengliklardan $y_0 = 0$ va θ_0 -ni topib bo'lmaydi. $x = 6\ m$. bo'lsa $\theta = \theta_B \neq 0$ va $y = y_B = 0$

Unda ikkinchi tenglamadan

$$6\theta_0 + \frac{1}{EI}\left[\frac{100}{6}\frac{6^3}{6} - 20\frac{6^4}{24} + 40\frac{(4)^3}{6} + 20\frac{(4)^4}{24}\right] = 0 \quad \text{yoki} \quad \theta_0 = \frac{-26,7}{EI}$$

Balka kesimining aylanish burchagi

$$\theta = -\frac{26,7}{EI} + \frac{1}{EI}\left[A\frac{x^2}{2} - q\frac{x^3}{6} + F\frac{(x-2)^2}{2} + q\frac{(x-2)^3}{6}\right]$$

salqilik tenglamasi

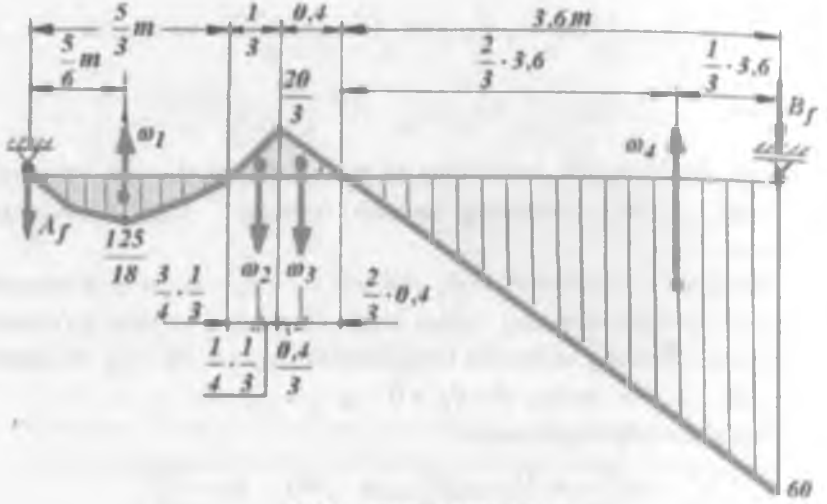
$$y = \frac{-3840}{144EI}x + \frac{1}{EI}\left[A\frac{x^3}{6} - q\frac{x^4}{24} + F\frac{(x-2)^3}{6} + q\frac{(x-2)^4}{24}\right]$$

Balkani turli kisimlar uchun y va θ ni hisoblaymiz.

$$x = 2m, \qquad y = \frac{-3840 \cdot 2}{144EI} + \frac{1}{EI}\left[\frac{100}{6}\frac{8}{6} - 20\frac{16}{24}\right] = \frac{44,4}{EI}$$

$$x = 6\ m, \quad \theta_B = \frac{-3840}{144EI} + \frac{1}{EI}\left[\frac{100}{6}\frac{36}{2} - 20\frac{216}{6} + 40\frac{16}{2} + 20\frac{64}{6}\right] = \frac{86,63}{EI}$$

6. Balkani egilishdagi ko'chishini grafoanalitik usul bilan hisoblaymiz. Balkani berilgan sxemasi uchun soxta balka tanlaymiz. Soxta balkani berilgan balka uchun qurilgan eguvchi moment epyurasi bilan yuklaymiz (6.56-rasm)



6.56 – rasm. Soxta balka.

Soxta balkani (*6.56–rasm*) reaktsiya kuchlarini topamiz $\sum M_b = 0$.

$$A_f \cdot 6 - \omega_1\left(6 - \frac{5}{6}\right) + \omega_2\left(4 + \frac{1}{12}\right) + \omega_3\left(3{,}6 + \frac{0{,}8}{3}\right) - \omega_4 \frac{3{,}6}{3} = 0$$

buerda $\omega_1 = \frac{2}{3} \cdot \frac{4}{3} \cdot \frac{125}{18} = 7{,}71605 \ \frac{kN}{m^2}$ $\omega_2 = \frac{1}{3} \cdot \frac{20}{3} \cdot \frac{1}{3} = \frac{20}{27} \ \frac{kN}{m^2}$

$$\omega_3 = \frac{1}{2} \cdot \frac{20}{3} \cdot 0{,}4 = \frac{4}{3} \ \frac{kN}{m^2} \qquad \omega_4 = \frac{1}{2} \cdot 60 \cdot 3{,}6 = 108 \ \frac{kN}{m^2}$$

$$A_f \cdot 6 - \frac{156770}{972} = 0; \qquad A_f = \frac{156770}{6 \cdot 972} = 26{,}9 \ \frac{kN}{m^2}$$

y va θ larni aniqlaymiz $y_k = \frac{M_f^k}{EI} = \frac{-44{,}8}{EI}$ va $\theta_B = \frac{Q_f^B}{EI} = \frac{B_f}{EI} = \frac{86{,}76}{EI}$

$M_f^k = -A_f \cdot 2 + \omega_1\left(\frac{5}{6} + \frac{1}{3}\right) - \omega_2 \frac{1}{12} = -26{,}9 \cdot 2 + 7{,}716 \cdot \frac{7}{6} - 0{,}74 \frac{1}{12} = -44{,}8 kNm^3$ Soxta balkaning V tayanch reaktsiya kuchini aniqlaymiz.

$$\sum M_A = -\omega_1 \cdot \frac{5}{6} - \omega_2\left(\frac{5}{3} + \frac{3}{4}\frac{1}{3}\right) - \omega_2\left(2 + \frac{0{,}4}{3}\right) + \omega_1\left(2{,}4 + \frac{2}{3}3{,}6\right) - B_f 6 = 0$$

6.42-misol. Berilgan balka (*6.57-rasm*) tayanch kesimlarining aylanish burchaklari,S va D nuqtalarning salqiliklari topilsin. $EI = 4 \cdot 10^3 kNm^2$

echish. Balkaning reaktsiya kuchlarini topamiz.

$$\sum M_A = -F\cdot 1 - R_B\cdot 4 + F\cdot 5 = 0; \qquad R_B = F = 40kN$$

$$\sum M_B = -F\cdot 5 - R_A\cdot 4 + F\cdot 1 = 0; \qquad R_A = 40kN$$

Eguvchi moment tenglamalarini tuzamiz va epyurasini quramiz.

I – I qirqim $0 \le x_1 \le 1m$ $\quad M_{x_1} = -Fx_1;$

II – II qirqim $1 \le x_2 \le 5m$ $\quad M_{x_2} = -F_{x_2} + R_A(x_2 - 1)$

III – III qirqim $5 \le x_3 \le 6m$ $\quad M_{x_3} = -Fx_3 + R_A(x_3 - 1) + R_B(x_3 + 5)$

Universal formulani tuzamiz: Kesimning aylanish burchagi

$$\theta = \theta_0 + \frac{1}{EI}\left[-F\frac{x^2}{2} + R_A\frac{(x-1)^2}{2} + R_B\frac{(x-5)^2}{2}\right] \quad (a)$$

va salqilik tenglamasi

$$y = y_0 + \theta_0 x + \frac{1}{EI}\left[-F\frac{x^3}{6} + R_A\frac{(x-1)^3}{6} + R_B\frac{(x-5)^3}{6}\right] \quad (b)$$

Universal formuladagi noma`lum θ_0 va y_0 larni topish uchun balka uchlarining tayanish shartidan foydalanamiz:

$x = 1m$ bo'lsa, $\theta = \theta_A \neq 0;$ $\quad y = y_a = 0$ unda (b) tenglamadan

$y_a + \theta_a\cdot 1 - \frac{F\cdot 1^3}{6EI} = 0$ (v) hosil bo'ladi.

$x = 5м$ bo'lsa, $\theta = \theta_B \neq 0;$ $\quad y = y_B = 0$ unda (b) tenglamadan

$y_0 + 5\theta_0 + \frac{1}{EI}\left[-F\frac{125}{6} + R_A\frac{64}{6}\right] = 0$ tenglama hosil bo'ladi. *(v)* va *(g)*

Tenglamalarni sistema qilib echamiz:

$$y_0 + \theta_0 - \frac{F}{6EI} = 0;$$

$$y_0 + 5\theta_0 - \frac{125F}{6EI} + \frac{64R_A}{6EI} = 0$$

Yuqoridagi tenglamani - 1ga ko'paytirib, hosil bo'lgan tenglamani pastki tenglamaga qo'shamiz: $\quad 4\theta_0 - \frac{124F}{6EI} + \frac{64R_A}{6EI} = 0$

bu erdan $\quad \theta_a = \frac{124F - 64R_A}{24EI} = \frac{124\cdot 40 - 64\cdot 40}{24EI} = \frac{100}{EI}$

$\theta_a = \frac{100}{EI}$ ifodani *(v)* tenglamaga qo'yib $\quad U_0$ - ni topamiz

$$Y_a = \frac{F}{6EI} - \theta_0 = \frac{40}{6EI} - \frac{100}{EI} = -\frac{560}{6EI}$$

Topilgan θ_0 va Y_0 larni universal formulaga keltirib qo'yamiz:

$$\theta = \frac{100}{EI} + \frac{1}{EI}\left[-F\frac{x_1}{EI} + R_A\frac{(x-1)^2}{2} + R_B\frac{(x-5)^2}{2}\right]$$

$$Y = -\frac{560}{6EI} + \frac{100x}{6EI} + \frac{1}{EI}\left[-F\frac{x^3}{6} + R_A\frac{(x-1)^3}{6} + R_B\frac{(x-5)^3}{6}\right]$$

Balkaning A tayanch kesimining aylanish burchagi:

$$\theta = \theta_A = \frac{100}{EI} - \frac{F\cdot 1^2}{2EI} = \frac{100}{EI} - \frac{20}{EI} = \frac{80}{EI} = \frac{80}{4\cdot 10^3} = 0{,}02 rad$$

V tayanch kesimining aylanish burchagi

$$\theta = \theta_B = \frac{100}{EI} + \frac{1}{EI}\left[-F\frac{25}{5} + R_A\frac{16}{2}\right] = \frac{100}{EI} - \frac{80}{EI} = -\frac{20}{4\cdot 10^3} = -0{,}02 rad$$

S nuqtaning salqiligini topamiz $X = 3\ m$

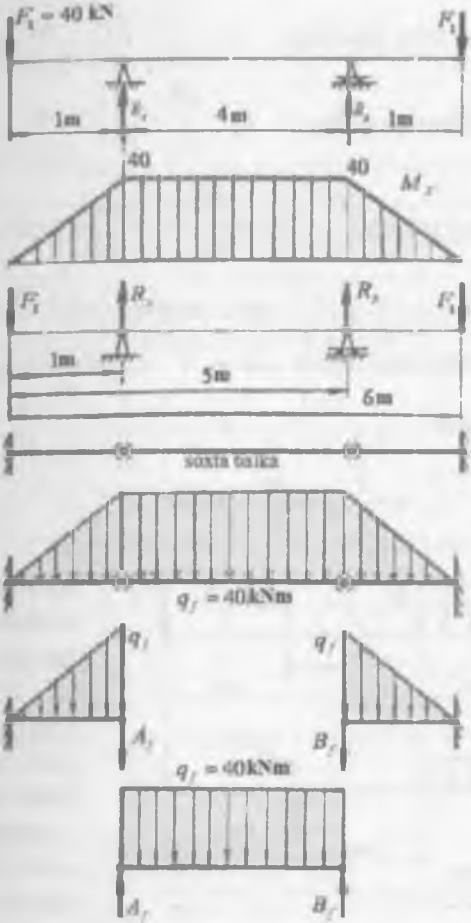
$$Y_C = -\frac{560}{6EI} + \frac{100\cdot 3}{EI} - \frac{27F}{6EI} + \frac{8R_A}{6EI} = \frac{-560 + 1800 - 1080 + 320}{6EI} = \frac{480}{24\cdot 10^3} = 0{,}02 m$$

D nuqtaning salqiligini topamiz: ($x = 6\ m$)

$$Y_D = -\frac{560}{6EI} + \frac{100\cdot 6}{EI} + \frac{1}{EI}\left[-F\frac{216}{6} + R_A\frac{125}{6} + R_B\frac{1}{6}\right] =$$

$$= \frac{-560 + 3600 - 8640 + 5000 + 40}{24\cdot 10^3} = -\frac{560}{24\cdot 10^3} = -0{,}0233 m$$

Balkaning deformatsiyasini grafoanalitik usul bilan aniqlash uchun, haqiqiy balkadan soxta balkani tanlaymiz (*6.57 – rasm*) va uni soxta kuch bilan yuklaymiz. Haqiqiy konsol balkaning tayanch nuqtalari soxta balkada sharnirlar bilan almashtiriladi.



6.57 rasm

Sharnirli kesimlarda momentni ta'siri nolga teng bo'lganligi uchun, soxta balkaning uchta oddiy balkalarga ajratamiz. O'rta soxta balkaning reaktsiya kuchlarini topamiz.

$$\sum M_A = q_f \cdot \frac{4^2}{2} - B_f \cdot 4 = 0 \qquad yoki \quad B_f = 2 \cdot 40 = 80 kNm^2$$

$$\sum M_B = -q_f \cdot 8 + A_f \cdot 4 = 0 \qquad yoki \quad A_f = 80 kNm^2$$

Topilgan θ_0 va Y_0 larni universal formulaga keltirib qo'yamiz:

$$\theta = \frac{100}{EI} + \frac{1}{EI}\left[-F\frac{x_1}{EI} + R_A\frac{(x-1)^2}{2} + R_B\frac{(x-5)^2}{2}\right]$$

$$Y = -\frac{560}{6EI} + \frac{100x}{6EI} + \frac{1}{EI}\left[-F\frac{x^2}{6} + R_A\frac{(x-1)^3}{6} + R_B\frac{(x-5)^3}{6}\right]$$

Balkaning A tayanch kesimining aylanish burchagi:

$$\theta = \theta_A = \frac{100}{EI} - \frac{F\cdot 1^2}{2EI} = \frac{100}{EI} - \frac{20}{EI} = \frac{80}{EI} = \frac{80}{4\cdot 10^3} = 0{,}02 rad$$

V tayanch kesimining aylanish burchagi

$$\theta = \theta_B = \frac{100}{EI} + \frac{1}{EI}\left[-F\frac{25}{5} + R_A\frac{16}{2}\right] = \frac{100}{EI} - \frac{80}{EI} = -\frac{20}{4\cdot 10^3} = -0{,}02 rad$$

S nuqtaning salqiligini topamiz $X = 3\ m$

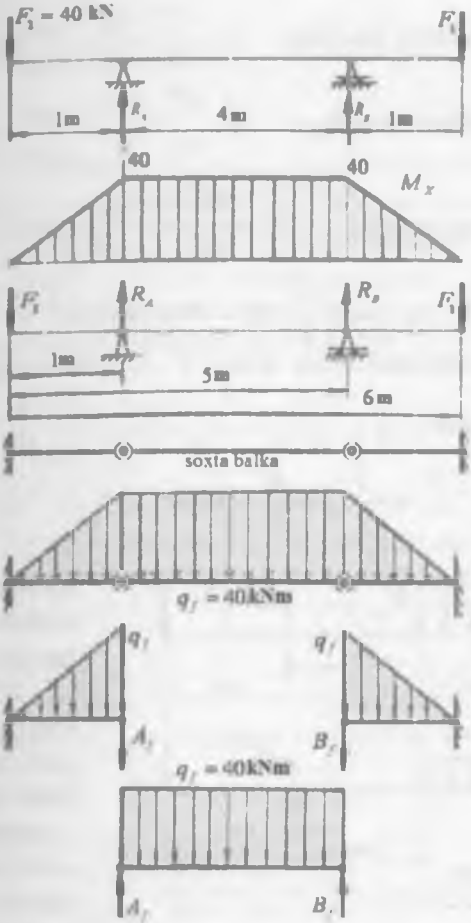
$$Y_C = -\frac{560}{6EI} + \frac{100\cdot 3}{EI} - \frac{27F}{6EI} + \frac{8R_A}{6EI} = \frac{-560 + 1800 - 1080 + 320}{6EI} = \frac{480}{24\cdot 10^3} = 0{,}02 m$$

D nuqtaning salqiligini topamiz: ($x = 6\ m$)

$$Y_D = -\frac{560}{6EI} + \frac{100\cdot 6}{EI} + \frac{1}{EI}\left[-F\frac{216}{6} + R_A\frac{125}{6} + R_B\frac{1}{6}\right] =$$

$$= \frac{-560 + 3600 - 8640 + 5000 + 40}{24\cdot 10^3} = -\frac{560}{24\cdot 10^3} = -0{,}0233 m$$

Balkaning deformatsiyasini grafoanalitik usul bilan aniqlash uchun, haqiqiy balkadan soxta balkani tanlaymiz (*6.57 – rasm*) va uni soxta kuch bilan yuklaymiz. Haqiqiy konsol balkaning tayanch nuqtalari soxta balkada sharnirlar bilan almashtiriladi.



6.57 rasm

Sharnirli kesimlarda momentni ta'siri nolga teng bo'lganligi uchun, soxta balkaning uchta oddiy balkalarga ajratamiz. O'rta soxta balkaning reaktsiya kuchlarini topamiz.

$$\sum M_A = q_f \cdot \frac{4^2}{2} - B_f \cdot 4 = 0 \qquad yoki \quad B_f = 2 \cdot 40 = 80 kNm^2$$

$$\sum M_B = -q_f \cdot 8 + A_f \cdot 4 = 0 \qquad yoki \quad A_f = 80 kNm^2$$

A kesimning aylanish burchagi: $\theta_A = \frac{\theta_f^A}{EI} = \frac{A_f}{EI} = \frac{80}{4 \cdot 10^3} = 0{,}02 rad$

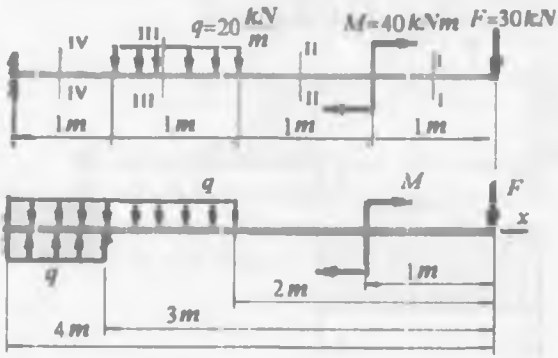
V kesimning aylanish burchagi: $\theta_B = \frac{\theta_f^B}{EI} = \frac{B_f}{EI} = -\frac{80}{4 \cdot 10^3} = -0{,}02 rad$

S nuqtaning salqiligi: $yC = \frac{M_f^C}{EI} = \frac{80}{4 \cdot 10^3} = 0{,}02 m$

bu erda $M_f^C = A_f \cdot 2 - q_f \frac{2^2}{2} = 80 \cdot 2 - 40 \cdot 2 = 80 kNm^3$

D nuqtaning salqiligini topish uchun $V - D$ uzunlikdagi soxta balkani o'rganamiz: $y_D = \frac{M_f^D}{EI} = \frac{-\omega \frac{2}{3} \cdot 1 - B_f \cdot 1}{EI} = \frac{-\frac{40}{3} - 80}{4 \cdot 10^3} = -0{,}023 m$

bu erda $\omega = \frac{1}{2} q_f \cdot 1 = \frac{40}{2} = 20 kNm^2$



6.58-rasm.

6.43-misol. Bir uchi kistirib maxkamlangan balkaning θ va V nuktalarining salkiligi boshlangich parametrlar usuli bilan toping

echish: Balkaning oraliqlarga bo'lib eguvchi momentning tenglamalarini tuzamiz

1 – 1 qirqim $0 \le x_1 \le 1m \quad M_{x_1} = -Fx_1;$

II – II qirqim $1 \le x_2 \le 2m \quad M_{x_2} = -Fx_2 - M;$

III – III qirqim $2 \le x_3 \le 3m \quad M_{x3} = -Fx_3 - M - q\frac{(x_3 - 2)^2}{2};$

IV – IV qirqim $3 \le x_4 \le 4m \quad M_{x_4} = -Fx_4 - M - q \cdot 1(x_4 - 2{,}5);$

Balka uchun universal formulani tuzamiz:

$$\theta = \theta_0 + \frac{1}{EJ}\left[-F\frac{x^2}{2} - M(x-1)^1 - q\frac{(x-2)^3}{6} + q\frac{(x-3)^3}{6}\right]$$

$$y = y_0 + \theta_0 x + \frac{1}{EJ}\left[-F\frac{x^3}{6} - M\frac{(x-1)^2}{2} - q\frac{(x-2)^4}{24} + q\frac{(x-3)^4}{24}\right]$$

Universal formuladagi θ_0 va y_0 noma'lumlarni balka uchla-rining tayanish shartidan foydalanib topamiz. $x = 0$ nuqta tayanch-dan ozod, bu kesimda $\theta = \theta_0 \neq 0$ va $y = y_0 \neq 0$ Shuning uchun, $x = 0$ shartdan foydalanib bo'lmaydi. $x = 4$ *m*. masofadagi tayanch kesimning barcha yo'nalishdagi harakatlari chegaralangan. Shuning uchun $x = 4$ m. bo'lsa θ va y tenglamalaridan quyidagini hosil qilamiz:

$\theta = 0$ va $y = 0$

$$\theta_0 = \frac{1}{EJ}\left[F\frac{16}{2} + M\cdot 3 + q\frac{8}{6} - q\frac{1}{6}\right] = \frac{2300}{6EJ};$$

$$y_0 = -\frac{2300\cdot 4}{6\cdot EJ} + \frac{1}{EJ}\left[F\frac{64}{6} + M\cdot\frac{9}{2} + q\frac{16}{24} - q\frac{1}{24}\right] = -\frac{24500}{24EJ}$$

Topilgan θ_0 va y_0 – larni universal formulaga keltirib qo'yamiz.

$$\theta = \frac{2300}{6EJ} + \frac{1}{EJ}\left[-F\frac{x^2}{2} - M(x-1)^1 - q\frac{(x-2)^3}{6} + q\frac{(x-3)^3}{6}\right]$$

$$y_x = -\frac{24500}{24EJ} + \frac{2300}{6EJ}\cdot x + \frac{1}{EJ}\left[-F\frac{x^3}{6} - M\frac{(x-1)^2}{6} - q\frac{(x-1)^4}{24} + q\frac{(x-3)^4}{24}\right]$$

O nuqtani salqiligi $x = 0$ nuqtaga to'g'ri kelib $y = y_0$ hosil bo'ladi.

$$y_0 = -\frac{24500}{24\cdot 10^5} = -0{,}0102m$$

V nuqtaning salqiligini topamiz ($x = 2$ *m*)

$$y_B = -\frac{24500}{24EJ} + \frac{2300\cdot 2}{6EJ} - \frac{240}{6EJ} - \frac{40}{2EJ} \approx -3{,}14\cdot 10^{-3} m$$

6.44-misol . Ikkita sharnirli tayanchga tayangan, uzunligi $\ell = 1$. Balkaning o'rta kesimida salqilik $f = 6{,}25$ *mm*. Balkaning kesimi, tomonlari $b = 0{,}06$ *m* va $h = 0{,}04$ *m* bo'lgan to'g'ri burchakli. Balka materialining elastiklik moduli va bo'ylama o'qining egrilik radiusi topilsin. $\sigma_{max} = [\sigma] = 10\cdot 10^3 \frac{kN}{m^2}$

echish: Balkaning normal kuchlanish bo'yicha mustahkamlik shartini yozamiz: $\sigma_{max} = \frac{M\cdot y_{max}}{I_x} = [\sigma]$. Bu erda $y_{max} = \frac{h}{2}$ va M balkaning

xavfli kesimidagi eguvchi momenti M - momentli balkaning eng katta salqiligini f bilan belgilaymiz. $f=\frac{M\ell^2}{8EI_x}$ va $M=\frac{fEI_x\cdot 8}{\ell^2}$, unda

mustahkamlik shart quyidagicha yoziladi: $\frac{fEI_x\cdot 8\cdot\frac{h}{2}}{I_x\cdot\ell^2}=[\sigma]$

va $$E=\frac{[\sigma]\ell^2}{f\cdot 8\cdot\frac{h}{2}}=\frac{1\cdot 10^4}{6{,}25\cdot 10^{-3}\cdot 8\cdot\frac{0{,}04}{2}}=1\cdot 10^7\ \frac{kN}{m^2}$$

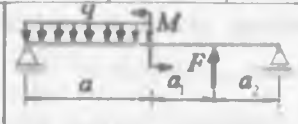
Egrilik radiusi ρ bilan M va balkaning egilishdagi bikr-ligi EI_x orasidagi bog'lanishni yozamiz: $\frac{1}{\rho}=\frac{M}{EI_x}$ bu erdan

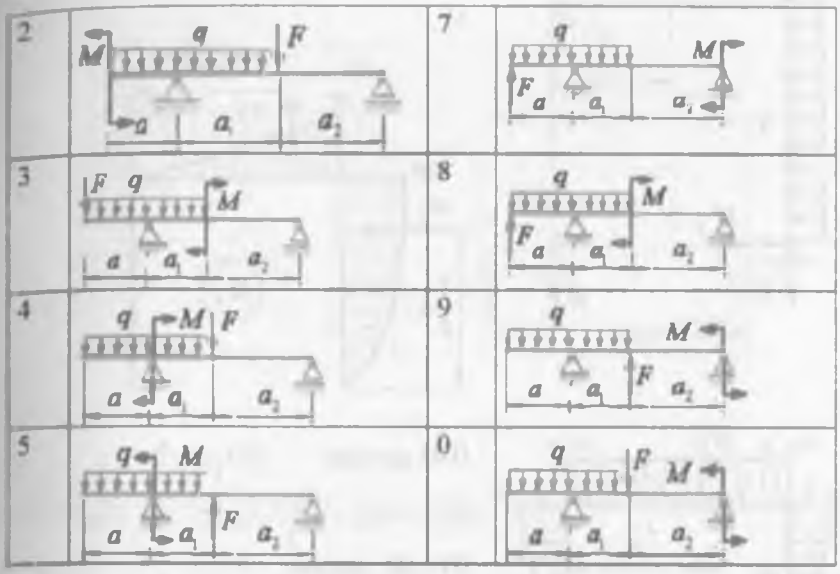
$$\rho=\frac{EI_x}{M}=\frac{EI_x\ell^2}{fEI_x\cdot 8}=\frac{\ell^2}{f\cdot 8}=\frac{1^2}{6{,}25\cdot 10^{-3}\cdot 8}=20m$$

6.45-misol. Balkani to'liq xisoblashga oid mustaqil ish uchun misollar (6.59-rasm)

Balkani xavfli kesimi uchun qo'shtavr profili tanlansin.
Balkani mustaxkamligi bosh kuchlanishlar bo'yicha tekshirilsin.
Balkani deformatsiyasi xisoblansin

Variant	Masofalar, m			M, kNm	F, kN	$q,\frac{kN}{m}$
	a	a_1	a_2			
1	1	9	1	10	10	10
2	2	8	2	20	20	20
3	3	7	3	3	3	3
4	4	6	4	4	4	4
5	5	5	5	5	5	5
6	6	6	1	6	6	6
7	7	7	2	7	7	7
8	8	8	3	8	8	8
9	9	9	4	9	9	9
10	10	10	5	10	10	10

1		6	



6.59-rasm. Balkani to'liq xisoblashga oid

Ramalarda ko'chishlarni hisoblashga oid misollar.

6.46-misol. Berilgan ramani B tayanchining gorizontal ko'chishi, C nuqtani vertikal kuchishi va D kesimni aylanish burchagi topilsin (6.60 – rasm). Berilgan: $q=20\ kN/m;\ a=2\ m;\quad n=3m;\ EI=const$

echish: 1. Ramani tayanch kuchlarini aniqlaymiz.

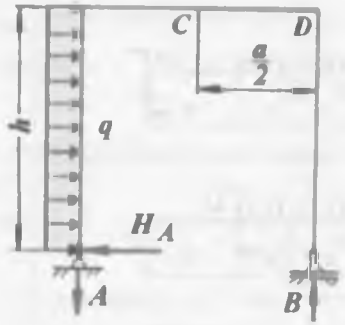
$$\sum x=-H_A+qh=0;\ H_A=60\ kN;$$

$$\sum M_A=0;\quad Ba-q\frac{h^2}{2}=0 \qquad \text{va} \qquad B=q\frac{h^2}{2a}=45kN$$

$$\sum M_B=0 \qquad Aa-q\frac{h^2}{2}=0 \qquad \text{va} \qquad A=q\frac{h^2}{2a}=45kN$$

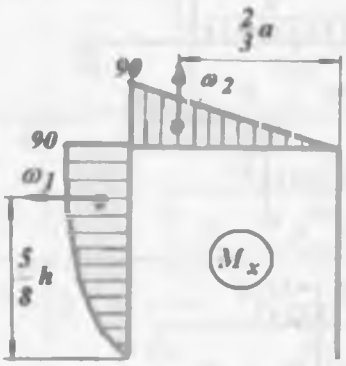
2. Eguvchi moment tenglamalarini tuzamiz va epyuralarini quramiz.

I-I qirqim . $0\le y_1\le h=3m \qquad M_{x_1}=H_A\cdot y_1-q\frac{y_1^2}{2}$

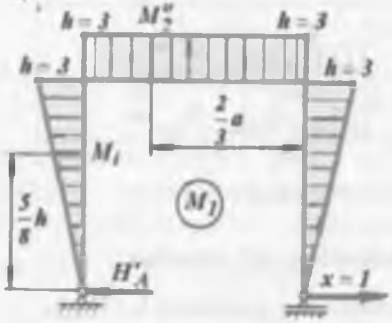


6.60 - rasm

a)



b)



II-II qirqim. $0 \le x_1 \le a = 2m$.

$$M_{x_1} = -Ax_1 - q\frac{h^2}{2} + A_A h = -Ax_1 + 90$$

III - III qirqim. $0 \le y_2 \le h$;

$$M_{x_3} = 0$$

6.61 - rasm

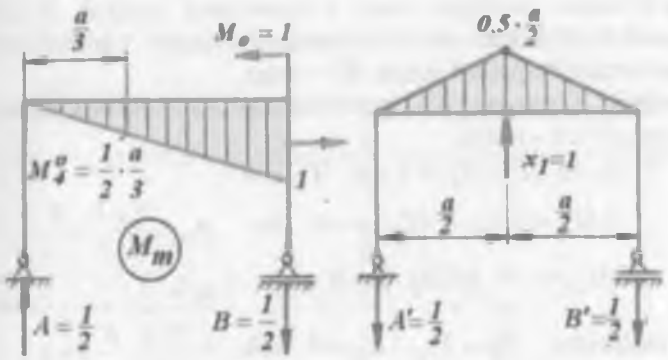
Rama eguvchi momenti epyurasining yuzalarini hisoblaymiz (*6.61–rasm,a*).

$$\omega_1 = \frac{2}{3} \cdot 90 \cdot 3 = 180 kNm^2; \quad \omega_2 = \frac{1}{2} \cdot 90 \cdot 2 = 90 kNm^2;$$

Ramani $x=1$ birlik kuch ta'siridan eguvchi moment epyurasini quramiz. ω_1 va ω_2 kuch yuzalarining og'irlik markaziga to'g'ri keluv-chi birlik kuch momenti epyurasining ordinatasini topamiz. $M_1^0 = \frac{5}{8}h$ va $M_2^0 = h = 3$ (*6.61– rasm,b*). B nuqtani gorizontal ko'chishi

$$\Delta_B = \frac{\omega_1 M_1^0}{EI} + \frac{\omega_2 M_2^0}{EI} = \frac{180 \cdot \frac{5}{3} \cdot 3}{EI} + \frac{90 \cdot 3}{EI} = \frac{4860}{8EI}$$

C nuqtani vertikal ko'chishini aniqlash uchun, ramani shu nuqtasiga $x_1 = 1$ birlik kuchini qo'yamiz va eguvchi moment epyurasini quramiz.(*6.62-rasm*). $x_1 = 1$ birlik kuch rama gorizontal



6.62 – rasm

qismining o'rtasida ta'sir qilganligi uchun $A' = B' = \frac{1}{2}$. Unda

$$M_c = -A' \frac{a}{2} = -\frac{1}{2} \cdot \frac{a}{2} = -\frac{1}{2}\ m$$

C nuqtani vertikal ko'chishi $\Delta_C = \frac{\omega_2 M_3^0}{EI} = \frac{\omega_{x_1} M_q^0}{EI}$

buerda $\omega_{x1} = \frac{1}{2} \cdot 0{,}5 \cdot \frac{a}{2} \cdot a = \frac{1}{2} \cdot 0{,}5 \cdot \frac{2}{2} \cdot 2 = \frac{1}{2}\ m^2$

$M_q^0 = B' \cdot \frac{a}{2} = 45 \cdot \frac{2}{2} = 45$ kNm – berilgan ramaning gorizontal qismidagi eguvchi moment epyurasini $x_1 = 1$ birlik kuchi momenti epyurasining yuzi ω_{x1}ni og'irlik markaziga to'g'ri keluvchi ordinatasi. Unda

$$\Delta_C = \frac{\frac{1}{2} \cdot 45}{EI} = \frac{22{,}5}{EI}$$

D kesimni aylanish burchagini aniqlash uchun ramani shu nuqtada $M_0 = 1$ birlik momenti bilan yuklaymiz (6.62 – rasm) va reaktsiya kuchlarini aniqlaymiz: $A = -B = \frac{M}{a} = \frac{1}{2}\left(\frac{1}{m}\right)$ birlik momenti (M_m) epyurasini quramiz. D kesimni aylanish burchagi:

$$\theta_D = \frac{\omega_2 \cdot M_4^0}{EI} = \frac{90 \cdot \frac{1}{2} \cdot \frac{2}{3}}{EI} = \frac{30}{EI}$$

6.47-misol. Berilgan rama A kesimining vertikal, V kesimi-ning gorizontal ko'chishlari va S kesimining aylanish burchaklari topilsin. Ramani barcha sterjenlari uchun $EI = sonst$.

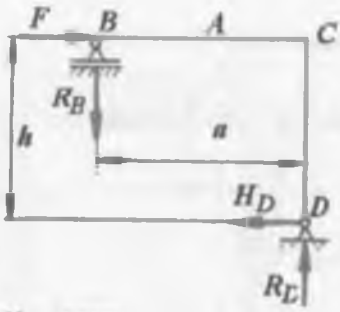
echish: Ramani D va V tayanchlaridagi R_D va R_B reaktsiya kuchlarini aniklaymiz (*6.63 – rasm*).

$$\Sigma x = 0 \quad F - H_D = 0 \text{ va } H_D = F$$

$$\Sigma M_B = -H_D \cdot h + R_D \cdot a = 0 \quad \text{va} \quad R_D = \frac{H_D \cdot h}{a} = \frac{F \cdot h}{a}$$

$$\Sigma M_D = -F \cdot h + R_B \cdot a = 0 \quad \text{va} \quad R_B = \frac{Fh}{a}$$

Tekshirish.: $\Sigma y = R_D - R_B = 0$ yoki $\frac{F \cdot h}{a} - \frac{F \cdot h}{a} = 0$



6.63 - rasm

Ramani eguvchi momenti epyuralarini quramiz.

Ramani har bir oraliqidagi eguvchi momenti epyuralarining yuzalarini hisoblaymiz va ularning og'irlik markazlari-ni topamiz.

$$\omega_1 = \frac{1}{2} \cdot R_B \cdot a \cdot a = F \cdot h \cdot a \cdot \frac{1}{2};$$

$$\omega_2 = \frac{1}{2} \cdot H_D \cdot h \cdot h = \frac{1}{2} Fh^2$$

Ramaning tegishli kesimlaridagi salqilik va aylanish burchaklarini Vereshagin formulasi bilan aniqlaymiz.

$$\Delta = \frac{\omega \cdot M^0}{EI}$$

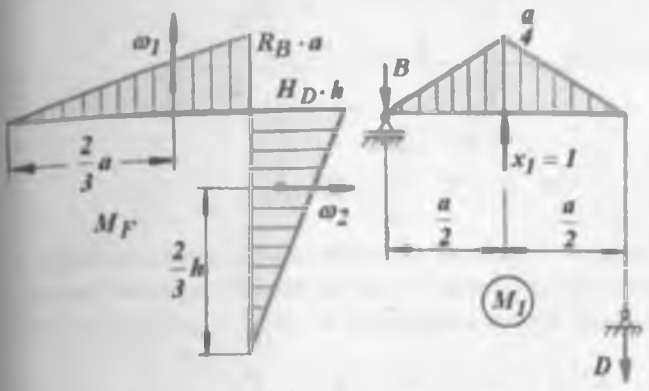
A kesimni vertikal ko'chishini aniqlash uchun ramani shu nuq-tasidan $x_1 = 1$ birlik kuch bilan yuklangan soxta ramaning reaktsiya kuchlarini aniqlaymiz va birlik kuch eguvchi momenti epyurasini quramiz (*6.64 – rasm*).

$$\sum M_D = Ba - x_1 \frac{a}{2} = 0 \text{ va } B = \frac{x_1}{2} \text{ Unda } M_A = -B\frac{a}{2} = \frac{-x_1 a}{4} = -\frac{a}{4}$$

A kesimni vertikal ko'chishi $\Delta_A = \frac{\omega_1' M_F^0}{EI} = \frac{\frac{1}{2} \cdot a \cdot \frac{a}{4} \cdot \frac{Fh}{2}}{EI} = \frac{Fha^2}{16EI}$

buerda $\omega_1' = \frac{1}{2} \cdot a \cdot \frac{a}{4} = \frac{a^2}{8}$ birlik kuch eguvchi momenti epyurasining yuzasi;

$M_F^0 = R_B \cdot a = \frac{Fh}{2}$ - birlik kuch eguvchi momenti epyurasi yuzasining og'irlik markaziga to'g'ri keluvchi tashqi kuch eguvchi momentning ordinatasi.



6.64 - rasm

B kesimni gorizontal ko'chishini aniqlash uchun ramani shu nuqtasiga gorizontal $x_2 = 1$ birlik kuchini joylashtira- miz va soxta ramani $x_2 = 1$ birlik kuchi eguvchi momenti epyurasini quramiz

- Reaktsiya kuchlari $\sum x = x_2 - H_D' = 0;$ $\quad H_D' = x_2 = 1$

$$\sum M_B = -H_D' \cdot h + R_D' \cdot a = 0 \quad \text{va} \quad R_D' = \frac{H_D' h}{a} = \frac{x_2 h}{a} = \frac{h}{a}$$

$$\sum M_D = -x_2 \cdot h + R_B' \cdot a = 0 \quad \text{va} \quad R_B' = \frac{h}{a}$$

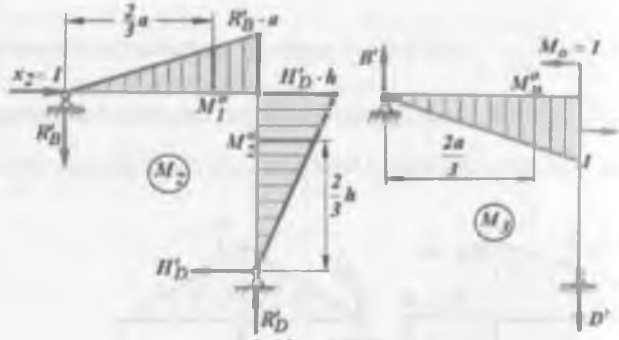
V kesimni gorizontal ko'chishini Vereshagin formulasi bilan aniqlaymiz.

$\Delta_B = \frac{\omega_1 M_1^0 + \omega_2 M_2^0}{EI}$ bu erda $\omega_1 = \frac{Fha}{2}$ va $\omega_2 = \frac{Fh^2}{2}$ -

tashqi kuch eguvchi momenti epyuralarining yuzalari (*6.65 - rasm*)

M_1^0 va M_2^0 - tashqi kuch eguvchi momenti epyuralari yuzalarining (ω_1 va ω_2) og'irlik markazlariga to'g'ri keluvchi $x_2 = 1$ birlik kuchi eguvchi momenti epyurasining ordinatasi. $\quad M_1^0 = R_B^1 \cdot \frac{2}{3}a = \frac{h}{a} \cdot \frac{2a}{3} = \frac{2h}{3};$

$M_2^0 = H_D^1 \cdot \frac{2h}{3} = 1 \cdot \frac{2h}{3} = \frac{2h}{3}$



6.65 - rasm

Unda $$\Delta_B = \frac{1}{EI}\left(\frac{Fha}{2}\cdot\frac{2h}{3}+\frac{Fh^2}{2}\cdot\frac{2h}{3}\right)=\frac{Fh^2}{3}(a+h)$$

S kesimni aylanish burchagini Vereshagin usuli bilan aniqlash ramani shu nuqtasini $M_0 = 1$ birlik momenti bilan yuklaymiz va eguvchi moment epyurasini quramiz (6.65 - rasm). Soxta ramani tayanch nuqtalaridagi V' va D' – reaktsiya kuchlarini hisoblaymiz. $$\Sigma M_D = -B'\cdot a + M^0 = 0 \quad \text{va} \quad B' = \frac{M^0}{a} = \frac{1}{a}$$

$$\Sigma M_D = -B'\cdot a + M^0 = 0 \quad \text{va} \qquad D' = \frac{M^0}{a} = \frac{1}{a}$$

tekshirish: $\Sigma y = B' - D' = 0$ yoki $\frac{1}{a} - \frac{1}{a} = 0$

S nuqtadagi eguvchi momenti $M_c = B'\cdot a = \frac{1}{a}\cdot a = 1$

Kesimni aylanish burchagining formulasi $\theta_C = \frac{\omega_1 \cdot M_m^0}{EI}$

Buerda $\omega_1 = \frac{Fha}{2}$ - tashqi kuch eguvchi momenti epyurasining yuzasi (*6.65 - rasm*),;

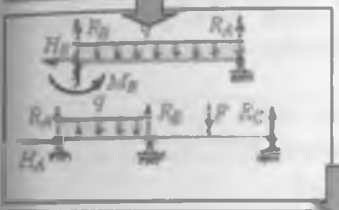
M_M^0 - tashqi kuch eguvchi momenti epyurasi yuzasining (ω_1) og'irlik markaziga to'g'ri keluvchi M_0=1 birlik momenti epyurasining ordinatasi,

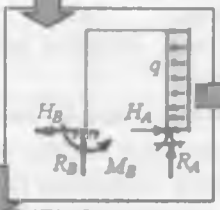
$$M_M^0 = B'\cdot\frac{2}{3}\cdot a = \frac{1}{a}\cdot\frac{2a}{3} = \frac{2}{3},$$

Unda $$\theta_C = \frac{F\cdot h\cdot a\cdot 2}{2\cdot EI\cdot 3} = \frac{F\cdot h\cdot a}{3\cdot EI}$$

EGILISHDA STATIK NOANIQ MASALALAR

Real ob'ekt – ko'prikli yuk ko'tarish kranlari, ko'p qavatli uylaming, ko'priklar, mashina va mexanizmlaming ramalari





Tekislikda joylashgan kuchlar sistemasi uchun muvozanat tenglamalarini tuzamiz: $\sum x = 0$;

$$\sum y = 0$$

$$\sum M = 0$$

Balkalardagi noma'lum reaksiya kuchlari soni muvozanat tenglamalari sonidan ko'p, masala statik noaniq

Masalaning statik noaniqlik daraiasi: $S = n - m$

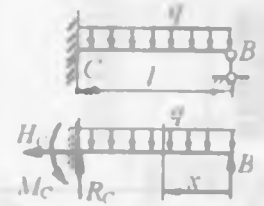
Statik noaniqlikni ochish usullari

- egilgan o'q taqribiy differensial tenglamasi $EI \cdot y'' = M_x$
- deformatsiyani taqqoslash
- Mor integralini tadbiq etish $\Delta = \int \frac{M \cdot M_1 \cdot dx}{EI}$
- Vereshagin qoidasini tadbiq etish $\Delta = \frac{\omega \cdot M_1}{EI}$
- uch moment nazariyasini tadbiq etish

$$M_1\ell_1 + 2M_2(\ell_1 + \ell_2) + M_3\ell_2 = -6\left(\frac{\omega_1 a_1}{\ell_1} + \frac{\omega_2 a_2}{\ell_2}\right)$$

-kanonik tenglamani tuzish $x_1\delta_{11} + \Delta_{1F} = 0$

Oddiy statik noaniq masala



Real ob'ekt - B nuqtada qo'zg'aluvchan sharnirli va S nuqtada bikr mahkam-langan tayanchga tayanuvchi balka:

- muvozanat tenglamalari

$$\sum X = -H_A = 0 \qquad a)$$

$$\sum Y = -R_c - q\ell + B = 0 \qquad б)$$

$$\sum M_C = -M_C + q\frac{\ell^2}{2} - B\ell = 0 \qquad в)$$

Balkaning tayanchlaridagi reaktsiya kuchlarining soni, ularni aniqlash uchun tadbiq etiladigan statikaning muvozanat tenglamalari sonidan kup. Balkani statik noaniqlik darajasi $S = n - m = 4 - 3 = 1$. Noma'lum reaktsiya kuchlarini aniqlash uchun bitta qo'shimcha tenglama tuziladi.

Qo'shimcha tenglamalar tuzish usuli. Balka egilgan o'qining taqribiy differentsial tenglamasini tadbiq etishda balkadan ajratilgan x oraliq uchun deformatsiya tenglamasi tuziladi:

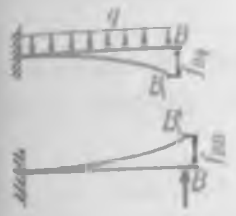
$$EI \cdot y'' = Bx - q\frac{x^2}{2} \quad (g) \qquad \text{(qo'shimcha tenglama)}$$

Taqribiy differentsial tengla-mani birinchi tartibli integ-ral balka kesimining aylanish burchagi tenglamasini beradi	Taqribiy differentsial tenglamani ikkinchi tartibli integrali balkaning salqilik tenglamasini hosil qiladi
$EI \cdot y' = B\frac{x^2}{2} - q\frac{x^{43}}{6} + C \quad (d)$	$EI \cdot y = B\frac{x^3}{6} - q\frac{x^4}{24} + CX + D \, (e)$

bu erda, C va D - integrallash doimiyliklari , balka uchlarini tayanchlarga tayanish shartlaridan topiladi. Masalan, $x = 0$ bo'lsa *(e)* tenglamaning chap tomonida $y = y_B = 0$buladi, chunki balkani B qo'zg'aluvchan sharnirli tayanch nuqtasida vertikal ko'chish chegaralangan. Unda *(e)* tenglamadan $D = 0$ hosil bo'ladi. $x = l$ bo'lsa, *(d)* va *e)* tenglamalarning chap tomonlari nolga tenglashadi, chunki balkani C kesimi bikr mahkamlanganligi uchun $y' = \theta_C = 0$ va $y = y_C = 0$. Unda *(d)* va *e)* tenglamalar ikki noma'lumli ikkita tenglamalar sistemasi ko'rinishiga keltiriladi:

$B\frac{l^2}{2} - q\frac{l^3}{6} + C = 0$ $B\frac{l^3}{6} - q\frac{l^4}{24} + C \cdot l = 0$	Tenglamalar sistemasidan $B = \frac{3}{8}q\ell$ topiladi va statik aniq balka hosil qilinadi.

Deformatsiyalarni taqqoslash usuli

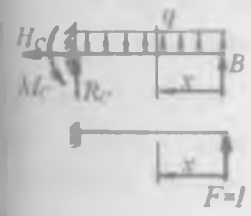


Balkani statik aniqmaslik darajasi ni ochish uchun deformatsiyalarni taqqoslash usulini tadbiq etish – balkani B qo'zg'aluvchan sharnirli tayanch nuqtasida vertikal ko'chishni chegaralanganligiga asoslanadi, ya'ni $f_B = 0$. Bu shart bajarilishi uchun, B nuqtani tashqi q kuch va noma'lum B reaktsiya kuchlari ta'siridan ko'chishlarining yig'indisi nolga teng bo'lishi kerak: $f_B = f_{Bq} + f_{BB} = 0$

buerda, $f_{Bq} = -\frac{q\ell^4}{8EI}$ - balka B nuqtasini tashqi q kuch intensivligi ta'siridan ushbu kuch yo'nalishidagi ko'chishi;

$f_{BB} = \frac{B\ell^3}{3EI}$ - balka B nuqtasini noma'lum reaktsiya kuchi ta'siridan ushbu kuch yo'nalishidagi ko'chishi

Unda ko'chishlar yig'indisida $B = \frac{3}{8}q\ell$ hosil qilinadi.



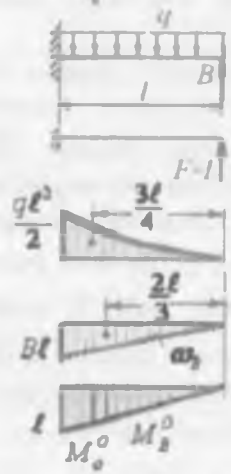
Mor integralini tadbiq etish

Balkani statik aniqmaslik dara-jasini ochishda Mor integralini tadbiq etish uchun berilgan balkani yoniga, qiymati va yo'nalishi noma'lum bo'lgan reaktsiya kuchi qo'yilgan nuqtada $F = 1$ birlik kuch bilan yuklangan balka tanlanadi.

Berilgan balka B nuqtasining ko'chishini Mor integrali bilan ifodalaymiz: $f_B = \int_0^\ell \frac{M_x M_o dx}{EI} = 0$

buerda, $M_x = Bx - q\frac{x^2}{2}$ - eguvchi moment va $M_o = Fx = 1 \cdot x = x$- birlik kuch momenti.

Unda $f_A = \int_0^{\ell} \frac{(Bx - q\frac{x^2}{2})dx}{EI} = 0$ tenglamadan $B = \frac{3}{8}q\ell$ hosil qilinadi.



Mor integralini Vereshagin qoidasini tadbiq etib echish. Buning uchun tashqi va birlik kuchlar ta'siridan alohida – alohida moment epyuralari quriladi.

Berilgan balka B nuqtasining ko'chishi Vereshagin qoidasiga asosan quyidagicha topiladi:

$$f_B = \frac{\omega_q \cdot M_q^o + \omega_B \cdot M_B^0}{EI} = 0$$

Buerda, $\omega_q = \frac{1}{3}q\frac{\ell^2}{2}\ell$ - tashqi kuchdan qurilgan eguvchi moment epyurasining yuzasi

$M_q^o = \frac{3}{4}\ell$ - tashqi kuchdan qurilgan eguvchi moment epyurasi yuzasining og'irlik markaziga to'g'ri keluvchi birlik kuch momenti epyurasining ordinatasi;

$\omega_B = \frac{1}{2}B\ell \cdot \ell$ -noma'lum reaktsiya kuchidan qurilgan eguvchi moment epyurasining yuzasi va $M_B^o = \frac{2}{3}\ell$ ushbu yuzaning og'irlik markaziga to'g'ri keluvchi birlik kuch momenti epyurining ordinatasi

Barcha ifodalarni Vereщagin qoidasiga qo'yib, $B = \frac{3}{8}q\ell$-hosil qilinadi. Noma'lum reaktsiya kuchlari hisoblangan balka uchun kundalang kuch va eguvchi moment tenglamalari tuziladi va epyuralari quriladi.

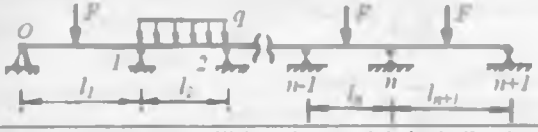
Kundalang kuch $Q = -B + qx$ va eguvchi moment $M_x = Bx - q\frac{x^2}{2}$

buerda $0 \le x \ge \ell$ $x = 0$ bulsa, $Q = -B = -\frac{3}{8}q\ell$ va $M_x = 0$

$x = \ell$ bulsa $Q = \frac{5}{8}q\ell$ va $M_x = -\frac{q\ell^2}{2}$

Balkani uzunligi buylab kundalang kuch tug'ri chiziqli va

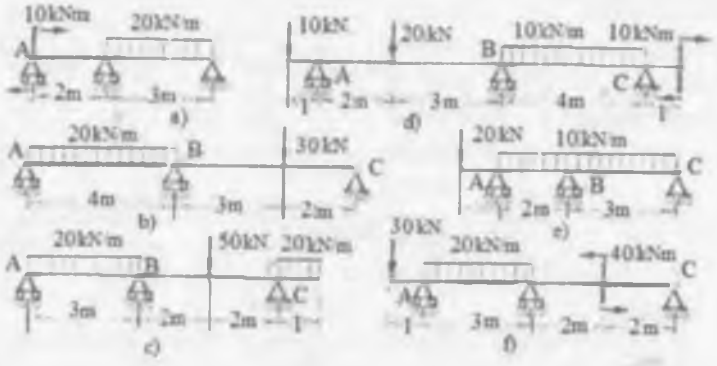
eguvchi moment parabola qonuniyatida uzgaradi. $x = \frac{3\ell}{8}$ qiymatda kundalang kuch nolga teng va eguvchi moment maksimumga erishadi.

Uzluksiz balkalar. Statik aniqmas konstruktsiyalarning asosiy ko'rinishlaridan biri uzluksiz balkalardir	
ta'rifi va taxminiy ko'rinishi	Uzluksiz deb, kamida uchta tayanchga tayanuvchi va oraliq sharnirlar bo'lmagan balkaga aytiladi. 
tayanchlarga qo'yilgan talablar	Bo'ylama kuchni qabul qilish uchun uzluksiz balkaning bitta tayanchi qo'zg'almas sharnirli bo'lishi kerak. Harorat ta'si-rida uzunligini o'zgartirishi uchun uzluksiz balkaning qolgan tayanchlarini qo'zg'aluvchan sharnirli qabul qilinadi. Uzluksiz balkaning tayanchlari chapdan o'ngga qarab *0; 1; 2; 3...n-1* va *n +1* sonlari , tayanchlar orasidagi masofalar ℓ_1, $\ell_2 \ell_3,\ldots$ ℓ_n va ℓ_{n+1} bilan belgilanadi. Har bir oraliq uzunligining indeksi o'ng tayanch nomeriga to'g'ri keladi
statik noaniqlik darajasi	Agar balka *n + 1* ta sharnirli tayanchga tayansa, unda gori-zontal reaktsiya kuchini hisobga olmaganda, shuncha vertikal yo'nalgan reaktsiya kuchlari hosil bo'ladi. Noma'lum reaktsiya kuchlarini aniqlash uchun ikkita muvozanat shartini tuzish mumkin. Unda uzluksiz balka *n –1* marotaba noaniqdir. Uzluksiz balkaning aniqmaslik darajasini ochishda asosiy sistemani tanlab, uch moment teoremasidan foydalanamiz.
asosiy sistema-sharnirlar-ga tayangan, tashqi kuch va noma`lum momentlar bilan yuklangan oddiy – balkalar	Uzluksiz balkaga ekvivalent bo'lgan asosiy sistemada sharnirli tayanchlar o'rniga oraliq sharnirlari, noma'lum reaktsiya kuchlari o'rniga esa noma'lum tayanch momentlari qabul qilinadi  Oraliq sharnirlari uzluksiz balkani bir nechta oddiy balkalarga ajratish imkoniyatini beradi, chunki sharnir bosim ta'sirini uzatmaydi

Asosiy sistemada har bir tashqi kuch, o'zi qo'yilgan oraliqqa ta'sir qiladi, ya'ni tashqi kuch balkaning boshqa oraliqlariga ta'siri noma'lum tayanch momentida ifodalanadi

i) 45 kN, -30 kNm; -15 kN; 15 kNm;
j) -2,5 kN; -5 kNm; 25 kN; 7,7 kNm; 17,5 kN;
k) -2,8 kN; -5,6 kNm, 20,6 kN; 12,2 kNm; 12,2 kN;
l) 1,25 kN; 2,5 kNm; -22,5 kN; -191+21 kNm; 21,25 kN.

6.50-misol. 6.68-rasmda ko'rsatilgan ikki qulochli balkalarning statik aniqmasligini oching. tayanch reaktsiyalarni aniqlang, ko'ndalang kuch va eguvchi moment epyuralarini yasang.



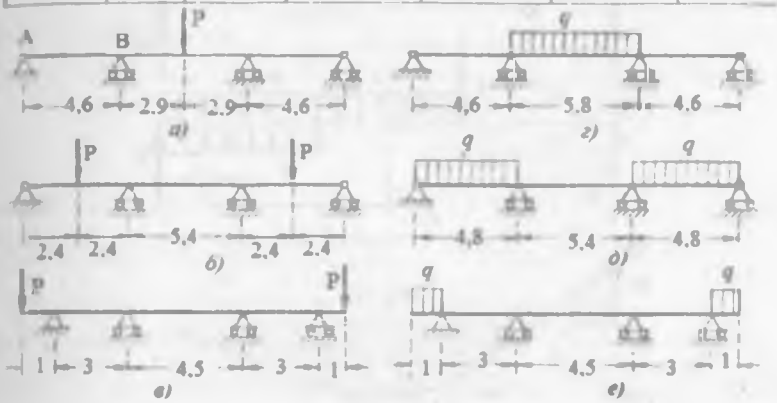
6.68-rasm

Sxema	Tayanch reaktsiyalar, kN			Ko'ndalang kuch		Eguvchi moment	
	A	V	S	maks.	min.	maks.	min.
a	-12,7	47,9	24,8	35,2	-24,8	15,4	-15,5
b	32,1	66,3	11,6	32,1	-47,9	25,7	-31,8
v	20,6	68,9	40,5	29,5	-39,4	31,0	-28,2
g	21,4	29,4	19,2	20,8	-19,2	12,7	-13,2
d	37,6	19,0	13,4	17,6	-20	0,90	-20
e	39,9	42,7	-12,6	29,9	-30,1	14,8	-25,2

6.51-misol. Qirqilmagan qo'shtavr balkalar 6.69-rasmda ko'rsatilgandek simmetrik yuk bilan yuklangan. R=60 kN, q=40 kN/m. Istalgan usulda statik aniqmaslikni oching, tayanch reaktsiyalarni xisoblang, Q va M epyuralarni kuring, [σ] = 160 MPa bo'lganda qo'shtavr nomerini tanlang va balkaning o'rta kesimidagi salkilikni xisoblang.

javob:

Sxema	a, kN	V, kN	M_{min}, kNm	M_{max}, kNm	Qo'shtavr	u, sm
a	6,2	36,2	-28,5	58,5	N 27	-1,23
b	25,8	34,2	-20,1	61,9	N 27	0,72
v	83,1	-23,1	-60	9,2	N 27	-0,23
g	16,0	13,20	-73,4	94,8	N 33	-1,4
d	87,1	104,9	-42,9	94,9	N 33	0,79
e	47,7	-7,7	-20	3,1	N 18	-0,30



6.69-rasm.

6.52-misol.

1) Berilgan statik aniqmas balkaning V tayanchdagi reaktiv moment M_B topilsin.

2) M_x va Q_x epyuralari qurilsin

3)Balkani uzunligi bo'ylab salqilik epyurasi qurilsin $\alpha = 1,0$

echish: Berilgan sistemaning ekvivalent sxemasini tanlaymiz. (*6.70–rasm*). Agar balkaning A tayanchdan keyingi oralig ida taqsim-langan kuch intensivligi ta sir qilmasa, asosiy (ekvivalent) sxemani tanlashda, balkaning shu qismi bir-biriga teng va qarama-qarshi yo'nalgan q - kuchlar bilan to'ldiriladi. Birinchi savolga javob topish uchun barcha kuchlardan A tayanch nuqtaga nisbatan olingan momentlar yig'indisini nolga tenglashtiramiz: $\sum M_A = M_B + B \cdot 2\ell - P\ell - P\ell - q\ell^2 + q\frac{\ell^2}{2} = 0$

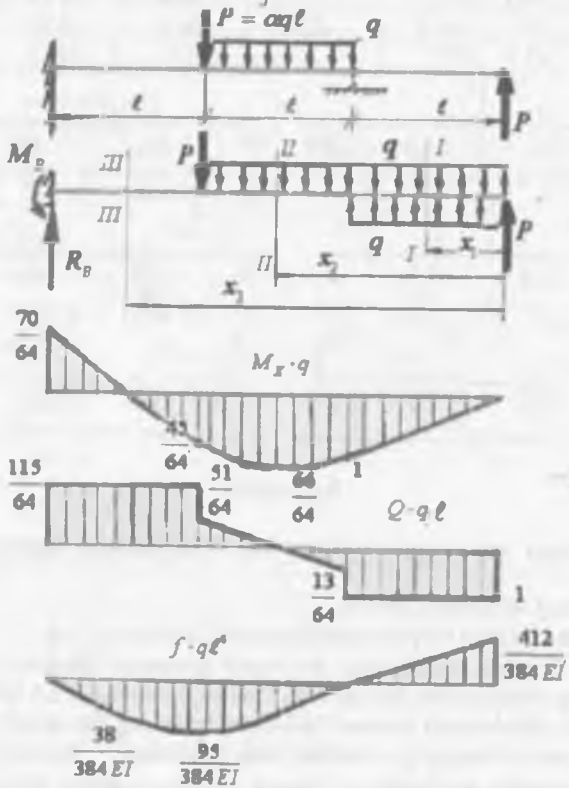
yoki $$M_B = 2B\ell - 2P\ell - q\frac{\ell^2}{2} \qquad (a)$$

(*a*) tenglamada ikkita noma'lum bo'lib, B-ni topish uchun qo'shimcha tenglama tuzishga to'g'ri keladi. Qo'shimcha tenglama sifatida balkaning istalgan

kesimini salqiligini ifodolovchi universal formulani tuzamiz.

$$f = y_0 + Q_0 x + \frac{1}{EJ}\left[B\frac{x^3}{6} - M_B\frac{x^2}{2} - q\frac{(x-\ell)^4}{24} + A\frac{(x-2\ell)^3}{6} + \right.$$

$$\left. + q\frac{(x-2\ell)^4}{24} - P\frac{(x-\ell)^3}{6}\right] \qquad (6)$$



6.70-rasm

U_0 va Q_0 balkaning boshlang'ich B kesimining salqiligi va aylanish burchagi *(b)* tenglamadagi $x = 0$ va balkaning B kesimda tayanishiga asosan nolga teng, $x = 2\ell$ bo'lsa balkaning A tayanchida salqilik nolga teng.

Demak, $f = f_A = \frac{1}{EI}\left[B\frac{8\ell^3}{6} - M_B\frac{4\ell^2}{2} - q\frac{\ell^4}{24} - P\frac{\ell^3}{6}\right] = 0$, buerda $\frac{1}{EI} \neq 0$, shuning uchun $M_B = \frac{1}{2}\left(\frac{8B\ell^3}{6} - q\frac{\ell^3}{6} - q\frac{\ell^2}{24}\right) = \frac{4B\ell}{6} - \frac{5 \cdot q \cdot \ell^2}{48}$ (*e*)

(a) va *(v)* tenglamalarni o'zaro tenglashtirib V reaktsiya kuchini topamiz:

$$2B\ell - 2P\ell - q\frac{\ell^2}{2} = 4B\ell - \frac{5q\ell^2}{48}$$

bu erdan $B = \frac{115 \cdot 6}{48 \cdot 8} q\ell^2 = \frac{115}{64} q\ell$ ifodani *(a)* tenglamaga qo'ysak, M_e momentni topamiz: $M_B = 2 \cdot \frac{115}{64} q\ell^2 - 2q\ell^2 - q\frac{\ell^2}{2} = \frac{70}{64} q\ell^2$

Endi barcha kuchlardan V nuqtaga nisbatan moment tenglamasini tuzamiz va A tayanch kuchini topamiz:

$$\Sigma M_B = -M_B + P\ell + q2\ell\left(\frac{2\ell}{2} + \ell\right) - A \cdot 2\ell - P \cdot 3\ell - q\ell\left(\frac{\ell}{2} + 2\ell\right) = 0$$

$$A = \frac{-M_B + P\ell + 4q\ell^2 - 3P\ell - 2{,}5q\ell^2}{2\ell} = -\frac{102}{128} q\ell$$

tekshirish: $\Sigma y = B - P - 2q\ell + A + q\ell - P = 0$ yoki

$$B + A - q\ell = \frac{115}{64} - \frac{102}{128} - 1 = 0; \qquad 0 = 0$$

Balkani uchta oraliqga bo'lib M_x va Q_x epyuralarni quramiz:

I–I qirqim $0 \le x_1 \le \ell$ -da $M_{x_1} = Px_1 = q\ell x_1$ va $Qx_1 = -P = -q\ell$

M_x va Q_x tenglamalarini tuzishda balkaning $0 \le x_1 \le \ell$ oraliqdagi taqsimlangan kuch intensivligi q - ning ta'sirini hisobga olmadik. Chunki q kuch faqat (δ) tenglamani keltirib chiqarishda va f salqilikni topishda ishlatiladi.

$x_1 = 0$ bo'lsa $Mx_1 = 0$ va $x_1 = \ell$ da $M_{x_1} = q\ell^2$

II – II qirqim $\ell \le x_2 \le 2\ell$

$$M_{x2} = P \cdot x_2 + A(x_2 - \ell) - q\frac{(x_2 - \ell)^2}{2} \quad \text{va} \quad Q_{x_2} = -P - A + q(x_2 - \ell)$$

III – III qirqim $2\ell \le x_3 \le 3\ell$

$$\dot{I}_{x3} = P_{x_3} + A(x_3 - \ell) - q\ell\left[x_3 - \left(\ell + \frac{\ell}{2}\right)\right] - P(x_3 - 2\ell)$$

$$Q_{x3} = -P - A + q\ell + P = \frac{51}{64} q\ell + q\ell = \frac{115}{64} a\ell$$

III – III qirqimda ko'ndalang kuch o'zgarmas qiymatga ega

$M_{\max}$ - ni II – II qirqimdagi $Q_{x2} = 0$ kesimdan aniqlaymiz

$$O = -P - A + q(x_2 - 2) \quad \text{yoki} \quad O = -q\ell + \frac{51}{64} q\ell + qx_2 - q\ell$$

tenglamadan $x_2 = \dfrac{2q\ell - \dfrac{51}{64}\cdot q\ell}{q} = \dfrac{77}{64}q \approx 1{,}2\ell$

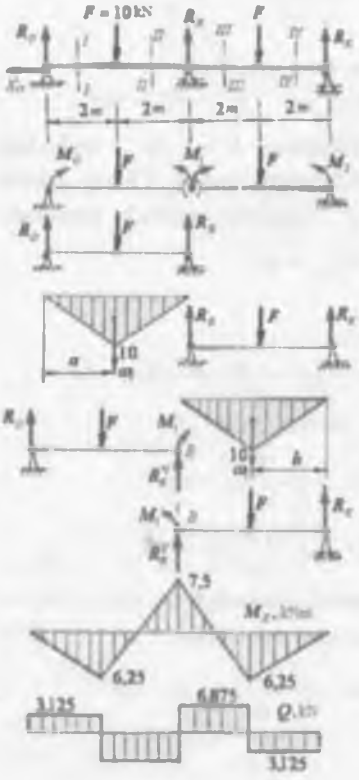
$$M_{x_2} = M_{\max} = q\ell \cdot 1{,}2\ell - \frac{51}{64}q \cdot 0{,}2\ell^2 - q\frac{0{,}04\ell^2}{2} = \frac{65{,}5}{64}q\ell^2$$

Uchinchi savolga javob berish uchun (δ) tenglamadan foydalanamiz

$$f = \frac{1}{EI}\left[B\frac{x^3}{6} - P\frac{(x-\ell)^3}{6} - M_B\frac{x^2}{2} - q\frac{(x-\ell)^4}{24} + A\frac{(x-2\ell)^3}{6} + q\frac{(x-2\ell)^4}{24}\right]$$

$x = 0{,}5\ell,\ f = -\dfrac{38{,}1q\ell^4}{384EI}$ $\quad x = \ell,\ \ f = -\dfrac{95q\ell^4}{384EI}$

$x = 1{,}5\ell,\ f = -\dfrac{93{,}37q\ell^4}{384EI};$ $\quad x = 2\ell;$ $\quad f = 0;\ \ x = 3\ell;\ \ f = \dfrac{412}{384}q\ell^4$



6.53-misol Ikki oraliqli balka, sxemada ko'rsa-tilganidek yuklangan Balkaning statik noaniqlik darajasi topilsin: reaktsiya kuchlari aniqlansin: M va Q epyuralari qurilsin va $h:b=2$ nisbatdan foydalanib balka kesimining o'lchamlari topilsin.

Balkaning materiali - po'lat $[\sigma] = 160mPa$

6.71-rasm. Berilgan va asosiy balkalar, oddiy va berilgan balkalar uchun eguvchi moment epyuralari

echish. Berilgan uzluksiz balka uchun statikaning tenglamalaridan quyidagilarni hosil qilamiz (*6.71– rasm*).

$$\sum x = -x_0 = 0 \qquad (1)$$

$$\sum y = R_0 - F + R_B + R_c - F = 0 \qquad (2)$$

$$\sum M_0 = -F \cdot 2 - R_B \cdot 4 + F \cdot 6 - R_c \cdot 8 = 0 \quad (3)$$

Uchta tenglamada to'rtta noma'lum. Demak, uzluksiz balka bir marotaba statik noaniq. Uzluksiz balkaning statik noaniqlik darajasini ochish uchun uch moment tenglamasidan foydalanamiz. Uzluksiz balkadagi noma'lum reaktsiya kuchlarini noma'lum tayanch momentlari bilan almashtirib, asosiy sistemani hosil qilamiz. Asosiy sistemada o'rta (1) tayanchni ortiqcha bog'lanish deb sharnir bilan almashtiramiz. Sharnir uzluksiz balkani 2 ta oddiy balkalarga ajratadi. Oddiy balkalar uchun eguvchi moment epyuralarini quramiz va ularni kuch yuzalari deb qabul qilamiz. $\omega_1 = \omega_2 = \frac{1}{2} 10 \cdot 4 = 20 kNm^2$ va ω_1 va ω_2 - dan balkalarning chetki tayanch-larigacha bo'lgan masofalarni $-a, b$ deb qabul qilamiz

Keyin uch moment tenglamasini tuzamiz (*6.71 – rasm*)

$$M_0 \cdot \ell_1 + 2M_1(\ell_1 + \ell_2) + M_2 \cdot \ell_2 = -6\left(\omega_1 \frac{a}{\ell_1} + \omega_2 \frac{b}{\ell_2}\right)$$

Uch moment tenglamasida

$M_0 = 0;$ $M_2 = 0;$ $\ell_1 = 4m;$ $\ell_2 = 4m$

$a = 2m,$ $b = 2m$ unda, $M_1 = -7{,}5 kNm$

Oddiy balkalarni M_1- momenti bilan yuklaymiz har bir oddiy balkaning G' tashqi kuchi va M_1 momenti ta'siridan reaktsiya kuchlarini topamiz.

Chap balka, $\sum M_0 = F \cdot 2 - R_B^{ch} \cdot 4 + M_1 = 0;$ $R_B^{ch} = \frac{27{,}5}{4}, kN.$

$$\sum M_B = R_0 \cdot 4 - F \cdot 2 + M_1 = 0; \qquad R_0 = \frac{12{,}5}{4}, kN$$

O'ng balka, $\sum M_B = -M_1 + F \cdot 2 - R_c \cdot 4 = 0;$ $R_c = \frac{12{,}5}{4} kN.$

$$\sum M_c = -M_1 + R_B^y \cdot 4 - F \cdot 2 = 0; R_B^y = \frac{27{,}5}{4}, kN$$

Uzluksiz balkaning reaktsiya kuchlarini yozamiz:

$$R_0 = \frac{12{,}5}{4} = 3{,}125 kN; \qquad R_c = \frac{12{,}5}{4} = 3{,}125 kN$$

Ikkinchi balka: (6.72 – rasm) balkada faqat B va C tayanchlar qoladi va Mo – juft kuch momenti bilan yuklangan.

$$\Sigma M_B = -M_0 + R_C \cdot 2{,}5 = 0; \qquad R_C = 16kN$$

$$\Sigma M_C = -M_0 + R_B \cdot 2{,}5 = 0; \qquad R_B = 16kN$$

Oddiy balkalar uchun eguvchi moment epyuralarini quramiz

Ikkita oddiy balkalardagi kuch yuzalarining teng ta`sir etuvchilarini topamiz.

$$\omega_q = \frac{2}{3}\cdot 10\cdot \ell_1 = \frac{2}{3}\cdot 10\cdot 2 = \frac{40}{3}\,kNm^2; \qquad a_q = 1m$$

$$\omega_1^1 = \frac{1}{2}\cdot 16\cdot 1 = 8kNm^2; \qquad b^1 = \frac{1}{3}\cdot 1 + 1{,}5 = \frac{5{,}5}{3}m;$$

$$\omega_1^{11} = \frac{1}{2}\cdot 24\cdot 1{,}5 = 18kNm^2; \qquad b^{II} = \frac{2}{3}\cdot 1{,}5 = 1m;$$

Uch moment tenglamasini tuzamiz

$$\begin{cases} M_k\ell_1 + 2M_1(\ell_1+\ell_2) + M_2\ell_2 = -6\left(\dfrac{\omega_q\cdot a_q}{\ell_1} + \dfrac{\omega_1^1 b_1^1 + \omega_1^{11} b^{II}}{\ell_2}\right) \\ M_1\ell_2 + 2M_2(\ell_2+\ell_3) + M_3\ell_3 = -6\left(\dfrac{\omega^1\dfrac{2}{3}\cdot 1 - \omega^{II}\left(1+\dfrac{1{,}5}{3}\right)}{\ell_2} + \dfrac{\omega_3\cdot a_3}{\ell_3}\right) \end{cases}$$

Bu erda: $M_k = -F\cdot 0{,}5 = -10kN; \quad M_3 = 0, \quad \omega_3 = 0;$

$$a_3 = 0; \qquad \ell_3 = 0$$

Unda $-10\cdot 2 + 9M_1 + 2{,}5M_2 = -6\left(\dfrac{40\cdot 1}{6} + \dfrac{8\cdot\dfrac{5{,}5}{3} - 18\cdot 1}{2{,}5}\right)$

$$M_1 2{,}5 + 5M_2 = -6\left[\frac{16}{7{,}5} - \frac{18-1{,}5}{2{,}5}\right] \qquad \text{va}$$

$$\left.\begin{aligned} -20 + 9M_1 + 2{,}5M_2 &= -32 \\ 2{,}5M_1 + 5M_2 &= 52 \end{aligned}\right\} \qquad \text{yoki} \qquad \left.\begin{aligned} 9M_1 + 2{,}5M_2 &= -12 \\ 2{,}5M_1 + 5M_2 &= 52 \end{aligned}\right|$$

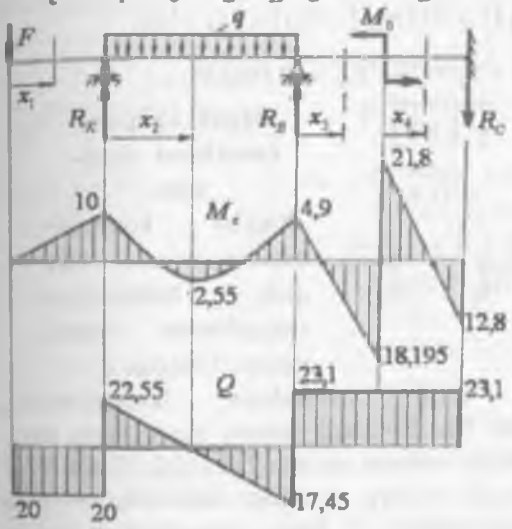
Ikki noma`lumli, ikkita tenglamalar sistemasidan: $M_1 = -4{,}9kNm$ va $M_2 = 12{,}84kNm$, hosil bo'ladi. M_1 va M_2 - momentlarning qiymatlarini va ishoralarini hisobga olib, oddiy ikki tayanchli balkalarning reaktsiya kuchlarini topamiz (6.72 – rasm).

Chap balka $\sum M_k = -F \cdot 0{,}5 + q\frac{\ell_1^2}{2} + M_1 - R_B^{II} \cdot \ell_1 = 0;\quad R_B^{II} = 17{,}45kN$

$$\sum M_B = -F \cdot (0{,}5 + \ell_1) - q\frac{\ell_1^2}{2} + M_1 - R_k \cdot \ell = 0;\qquad R_k = 42{,}25kN$$

O'ng balka $\sum M_B^y = -M_1 - M_0 - M_2 + R_c \cdot \ell_2 = 0;\qquad R_c = 23{,}096kN$

$\sum M_c = -M_1 - M_0 - M_2 + R_B^y \cdot \ell_2 = 0;\qquad R_B^y = 23{,}096kN$



6.73 – rasm

Uzluksiz balkaning reaktsiya kuchlari:

$R_k = 42{,}55kN$

$R_C = 23{,}096kN$

$R_B = R_B^{II} + R_B^{I}$

$R_B = 17{,}45 + 23{,}096$

$R_B = 40{,}545kN$

Uzluksiz balkaning S qo'zg'almas tayanch nuqtasidagi reaktsiya kuchi

$R_S = 23{,}096kN$

va tayanch momenti

$M_2 = M_S = 12{,}84kNm$

Balkani (6.73 – rasm) oraliqlarga bo'lib M va Q tenglamalarini tuzamiz.

I – I qirqim. $0 \le x_1 \le 0{,}5m\quad M_{x_1} = -Fx_1;\quad Q_1 = -F = -20kN;$

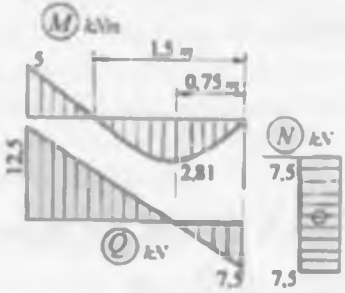
II – II qirqim. $0 \le x_2 \le 2m$

$$M_{x_2} = -F(0{,}5 + x_2) + R_k x_2 - q\frac{x_2^2}{2};\quad Q_2 = -F + R_k - qx_2$$

Q - ko'ndalang kuch abtsissa o'qini kesib o'tish nuqtasida nolga teng, $-F + R_k - qx_2 = 0$ yoki $x_2 = \frac{R_k - F}{q} = 1{,}1275m$. Shu nuqtada balkaning ikkinchi qirqimdagi cho'ziladigan tolalarida eguvchi moment eng katta qiymatga erishadi.

$$0 \le x_1 \le 2m$$

$$M_{e_2} = Bx_1 - q\frac{x_1^2}{2}; \qquad Q_2 = -B + qx_2; \quad va \quad N_2 = 0$$



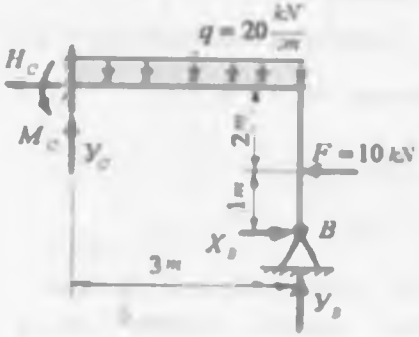
6.78 – rasm.

SA - oraliqda eguvchi moment M_{eg} egri chiziqli Q_2 to'g'ri chiziqli qonuniyat bilan o'zgaradi Q_2 kuch S nuqtada manfiy ishorali, A nuqtada musbat ishorali qiymatga ega. Ko'ndalang kuch abstsissa o'qini kesib o'tish nuqtasida, ya'ni $Q_2 = 0$ nuqtada M_{eg} ekstremal qiymatga erishadi:

$$Q_2 = -B + qx_1 = 0$$

yoki $x_1 = \frac{B}{q} = 0{,}75m$ $\qquad M_2 = 7{,}5 \cdot 0{,}75 - 10\frac{(0{,}75)^2}{2} = 2{,}8125kNm$

$M_{eg} = 0$ nuqtani topamiz: $M_{eg} = 7{,}5x_1 - 10\frac{x_1}{2} = 0;\ x_1 = 1{,}5m$



6.79 – rasm

6.56-misol. Statik noaniq rama uchun *M, Q* va *N* epyurlari qurilsin (*6.79 – rasm*).

echish: Ramaning *S* tayanch nuq-tasida uchta va *V* nuqtasida ikkita reaktsiya kuchlari hosil bo'ladi. Ramaning aniqmaslik darajasi $S = n - 3 = 5 - 3 = 2$

Masala ikki marotaba noaniq. Noma'lum kuchlarni aniqlash uchun ramani ikkita bog'lanishdan ozod etib, ularning o'rniga birlik kuchlar qo'yiladi.

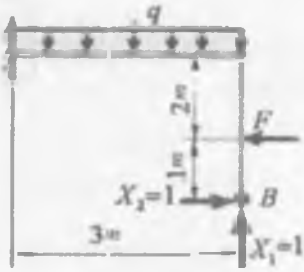
V tayanch ta'sirini $x_1 = 1$ va $x_2 = 1$

birlik kuchlar bilan almashtirib asosiy sistemani hosil qilamiz (*6.80– rasm*). Kanonik tenglama:

$$x_1\delta_{11} + x_t\delta_{12} + \Delta_{1F} + \Delta_{1q} = 0$$

$$x_1\delta_{12} + x_2\delta_{22} + \Delta_{2F} + \Delta_{2q} = 0$$

Kanonik tenglamaning koeffitsientlarini Vereshagin formulasidan foydalanib topamiz:



6.80 – rasm

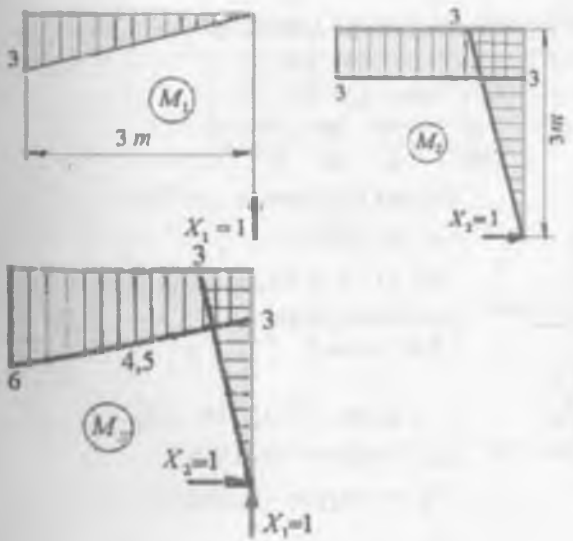
$$\delta_{11} = \frac{\omega_1 \cdot M_1}{EI} \quad \text{va} \quad \delta_{1a} = \frac{\omega_1 \cdot M_s}{EI}$$

$$\delta_{11} = \frac{1}{EI}\cdot\frac{1}{2}\cdot 3\cdot 3\cdot\frac{2}{3}\cdot 3 = \frac{9}{EI};\quad \delta_{12} = \frac{1}{EI}\left(\frac{1}{2}\cdot 3\cdot 3\frac{2}{3} + 3\cdot 3\cdot 3\right) = \frac{36}{EI}$$

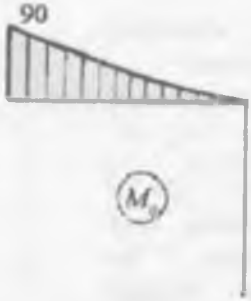
$$\delta_{12} = \delta_{21} = \frac{1}{EI}\left(\frac{1}{2}\cdot 3\cdot 3\cdot 3\right) = \frac{27}{2EI} \quad \text{va} \quad \Delta_{1F} = \frac{\omega_2 \cdot \overline{M_1}}{EI} = -\frac{20\cdot 3\cdot\frac{3}{2}}{EI} = -\frac{90}{EI};$$

$$\Delta_{2F} = \frac{\omega_F \cdot M_2}{EI} = -\frac{1}{EI}\left(\frac{1}{2}\cdot 20\cdot 2\cdot\frac{7}{3} + 20\cdot 3\cdot 3\right) = -\frac{680}{3EI}$$

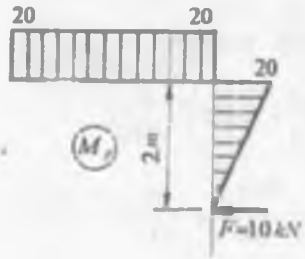
$$\Delta_{1q} = \frac{\omega_q \cdot \overline{M_1}}{EI} = -\frac{\frac{1}{3}\cdot 90\cdot 3\cdot\frac{3}{4}\cdot 3}{EI} = -\frac{810}{4EI} \quad \Delta_{2q} = \frac{\omega_q \cdot \overline{M_2}}{EI} = -\frac{\frac{1}{3}\cdot 90\cdot 3\cdot 3}{EI} = -\frac{270}{EI}$$



Birlik va tashqi kuchlar momentlarining epyurlari- ni quramiz (*6.81 – rasm*): M_1-birlik x_1 kuch momentining epyurasi; M_2- birlik kuch x_2 momentining epyurasi; M_s - birlik $x_1 = 1$ va $x_2 = 1$ kuchlar momentla- rining epyuralari



6.81 – rasm



Tekshirish:

$$\delta_{11}+\delta_{12}-\delta_{21}+\delta_{22}=\delta_S$$

$$\frac{9}{EI}+\frac{27}{2EI}+\frac{27}{2EI}+\frac{36}{EI}=\frac{72}{EI},\quad \frac{72}{EI}=\frac{72}{EI}$$

$$\delta_s=\frac{1}{EI}\left[\frac{1}{2}\cdot 3\cdot 3\cdot\frac{2}{3}\cdot 3+3\cdot 3\cdot 4{,}5+\frac{1}{2}\cdot 3\cdot 3\left(3+\frac{2}{3}\cdot 3\right)\right]$$

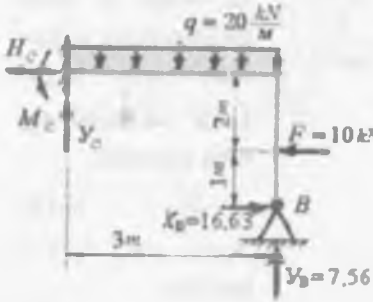
$$\Delta_{1q}+\Delta_{1F}+\Delta_{2F}+\Delta_{2q}=-\frac{202{,}5}{EI}-\frac{90}{EI}-\frac{680}{3EI}-\frac{270}{EI}=-\frac{789{,}1}{EI}$$

$$\Sigma\frac{M_i(M_q+M_F)}{EI}-\frac{1}{EI}\left(-\frac{1}{2}\cdot 20\cdot 2\frac{7}{3}-20\cdot 3\cdot 4{,}5-\frac{1}{3}\cdot 90\cdot 3\frac{21}{4}\right)$$

$$\Sigma\frac{M_s(M_q+M_F)}{EI}=-\frac{789{,}17}{EI}$$

Topilgan koeffitsientlarni kanonik tenglamaga keltirib qo'yamiz va x_1, x_2 noma`lumlarni topamiz:

$$\left.\begin{aligned} x_1\frac{9}{EI}+x_2\frac{27}{2EI}-\frac{90}{EI}-\frac{810}{4EI}=0\\ -x_1\frac{27}{2EI}+x_2\frac{36}{EI}-\frac{680}{3EI}-\frac{270}{EI}=0\end{aligned}\right\}$$



6.82 – rasm

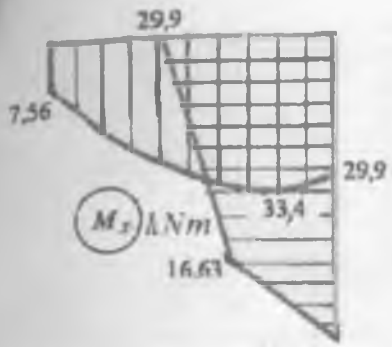
Kanonik tenglamadan $x_1 = 7{,}56kN$ va $x_2 = 16{,}63kN$.

M_1, Q va N tenglamalarni tuzamiz va epyurlarini quramiz. (*6.82 – rasm*)

1 – 1 qirqim. $0 \le x_1 \le 1m$ $Mx_1 = x_B \cdot x_1$

$$Q_1 = -x_B = -16{,}63kN$$

$$N_1 = -y_B = -7{,}56kN$$



II – II qirqim.

$$Mx_2 = x_B \cdot x_2 - F(x_2 - 1)$$

$$Q_2 = -x_B + F = -6{,}63kN;$$

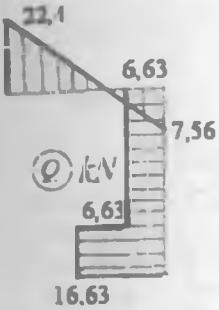
$$N_2 = -y_B = -7{,}56kN$$

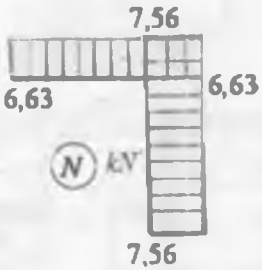
III – III qirqim. $0 \le x_3 \le 3m$;

$$Mx_3 = y_B \cdot x_3 - q\frac{x_3^2}{2} + x_B \cdot 3 - 2F$$

va $Q_3 = -y_B + qx_3$;

$$N_3 = x_B - F = 6{,}63kN$$



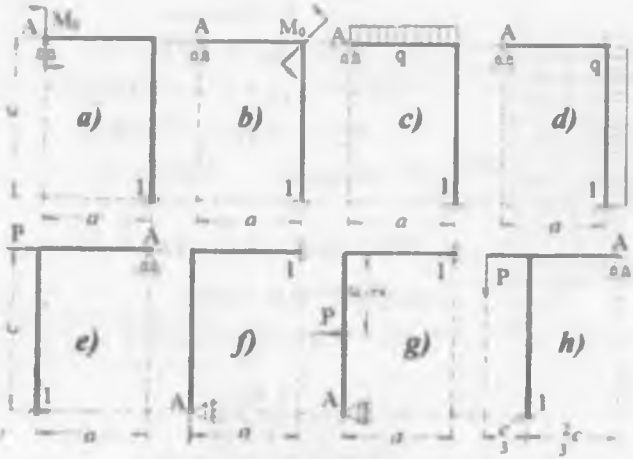


6.83 – rasm

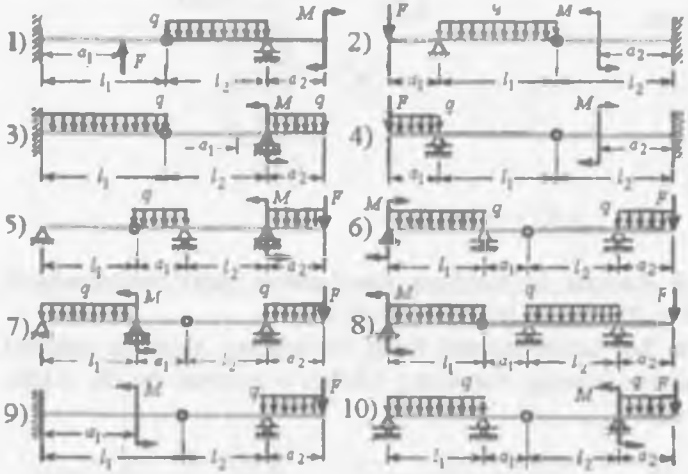
6.57-misol. Rasmda ko'rsatilgan ramalarning statik aniqmasligini ko'rsating va R = 40 kN, M= 40 kNm, q= 20 kN/m,
a= 2 m, s=3 m hol uchun normal kuch, ko'ndalang kuch va eguvchi moment epyuralarini kuring. Ramaning bikrligi o'zgarmas bo'lib, ikkala uchastkada bir xil.

javob:

Sxema	A, kN	M_1 kNm	Sxema	A, kN	M_1 kNm
a	$\frac{3M_0(a+2c)}{2a(a+3c)} = 21{,}82$	3,64	d	$\frac{3Pc^2}{2a\cdot(a+3c)} = 24{,}5$	-71
b	$\frac{3M_0c}{a\cdot(a+3c)} = 16{,}36$	-7,28	e	$\frac{3Pa^2}{2c\cdot(3a+c)} = 8{,}9$	-53,3
v	$\frac{3qa\cdot(a+4c)}{8(a+3c)} = 19{,}09$	-1,82	j	$\frac{P((24a+5c)}{16\cdot(3a+c)} = 17{,}5$	-7,5
g	$\frac{qc^3}{2a\cdot(a+3c)} = 12{,}27$	-65,46	z	$-\frac{9P}{22} = -16{,}4$	-7,2

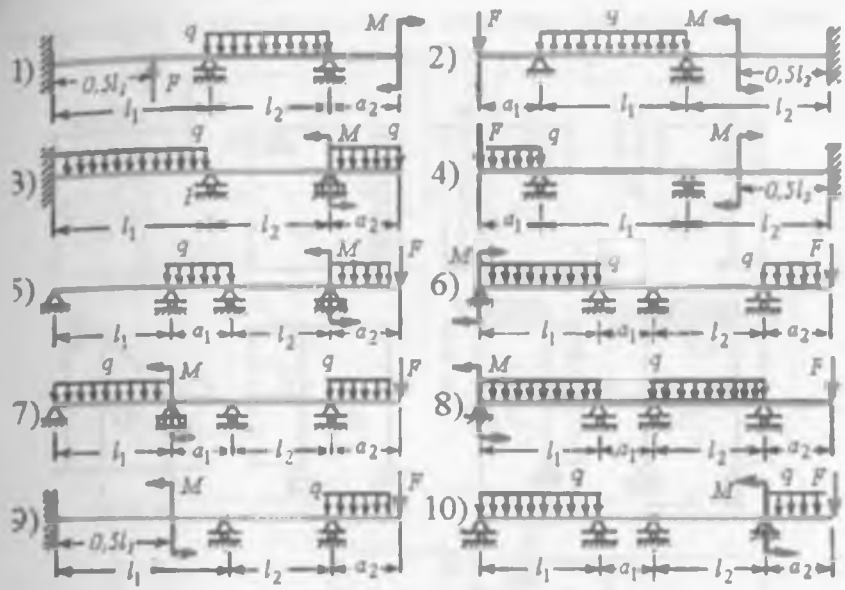


6.84-rasm



6.85-rasm Sharnirli balkalarda ichki kuch faktorlarini aniklash

Uzluksiz balkalarda ichki kuch faktorlarini aniqlashga oid mustaqil ish

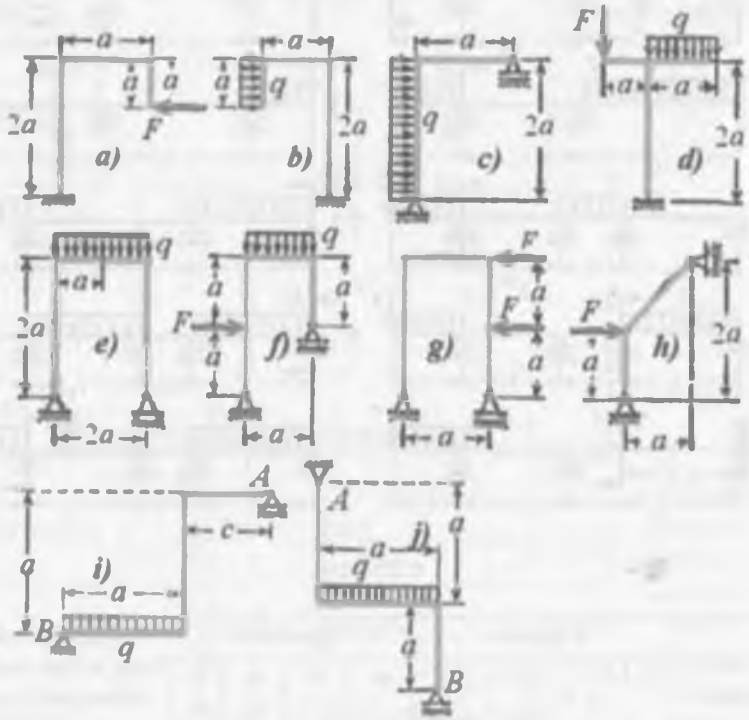


6.86-rasm

Tartib raqam	Kuchlar			Masofalar			
	F, kN	q, $\frac{kN}{m}$	M, kNm	a_1	a_2	l_1, m	l_2, m
1	10	10	5	1	2	1	3
2	15	15	6	2	1	2	4
3	20	20	7	1	2	3	5
4	25	25	8	2	1	4	3
5	10	10	9	1	2	5	2
6	14	14	5	2	1	6	1
7	12	12	6	1	2	2	6
8	8	8	7	2	1	4	7
9	6	6	8	1	2	6	2
10	30	30	9	2	1	8	3

1.Sharnirli balkalar uchun ko'ndalang kuch va eguvchi moment epyurlari qurilsin.
2.Uzluksiz balkalarning statik noaniqlik darajasi ochilsin va kundalang kuch, eguvchi moment epyurlari qurilsin.

Statik aniq va noaniq ramalarda ichki kuch faktorlarini aniqlashga oid mustakil ish

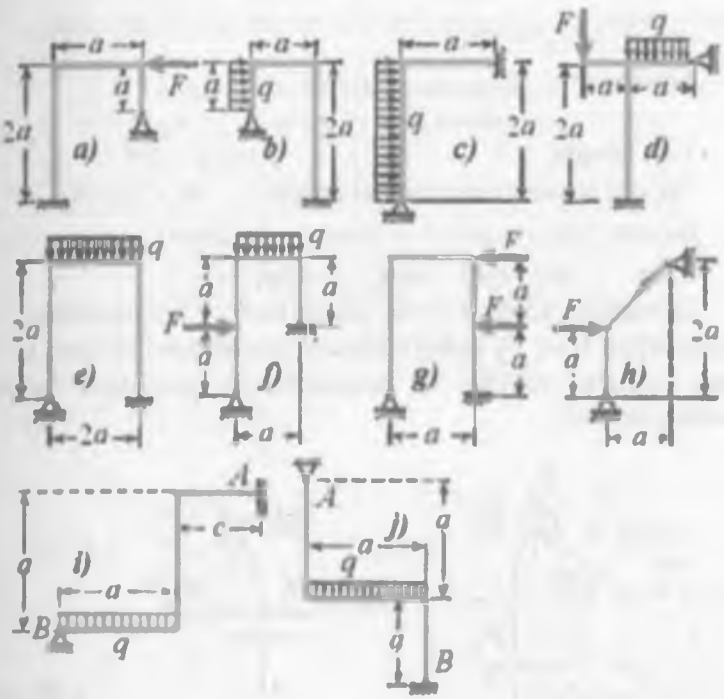


6.87-rasm

Tartib raqam	Kuchlar		Masofa
	F, kN	q, $\frac{kN}{m}$	a, m
1	10	10	1
2	15	15	2
3	20	20	1
4	25	25	2
5	10	10	1
6	14	14	2
7	12	12	1
8	8	8	2
9	6	6	1
10	30	30	2

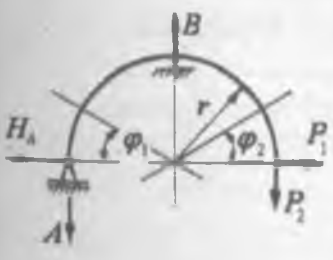
1.Statik aniq ramalar (*6.87-rasm*) uchun buylama va kundalang kuch xamda eguvchi moment epyurlari qurilsin.

2.Ikki marotaba statik aniq ramalarni (*6.88-rasm*) noaniqlik darajasi kanonik tenglamalar tuzish usulida ochilsin, buylama va kundalang kuch hamda eguvchi moment epyuralari qurilsin.



6.88-rasm

6.55-misol. Doiraviy kesimli egri sterjenni xavfli kesimining normal kuchlanishini toping (*6.89 – rasm*)



6.89 – rasm

Berilgan:

$P = 1100N$; $d = 5,0sm$

$r = 16sm$`; $P_1 = P_2 = P$

echish: Egri sterjen A va V tayanchlarga tayanadi.Reaktsiya kuch-larini topamiz:

$\sum x = 0;\quad -H_A + P_1 = 0$

yoki $H_A = P_1 = 1100N; \sum M_A = 0$

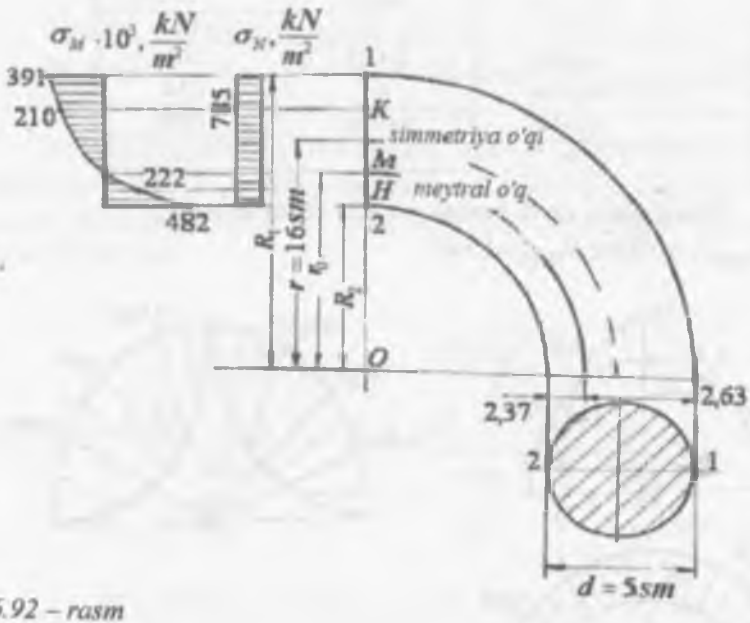
$P_2 \cdot 2r - Br = 0$

bu erdan $B = 2P_2 = 2200N$

$\sum M_B = 0;\qquad H_A \cdot r - A \cdot r + P \cdot r - P_1 r = 0$ bu erdan

kesim yuzasi. Neytral o'qning egrilik radiusini topamiz:

$$r_0 = \frac{d}{\ell n \frac{R_1}{R_2}} = \frac{5}{\ell n \frac{18,5}{13,5}} = \frac{5}{0,315} = 15,87sm$$



6.92 – rasm

Simmetriya o'qi $-u$ - bilan neytral o'q orasidagi masofa:

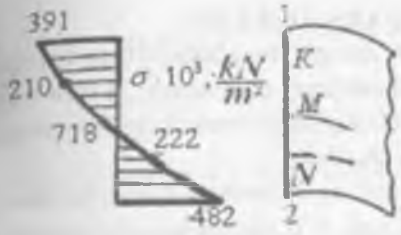
$$Z_0 = r - r_0 = 16 - 15,87 = 0,13sm$$

Kesimning neytral o'qga nisbatan statik momenti:

$$S = F \cdot Z_0 = 19,625 \cdot 0,13 \approx 2,55sm^3$$

Xavfli kesimning M va N ta siridan hosil bo'lgan to'liq normal kuchlanishini quyidagi formuladan topamiz:

$$\sigma = \frac{N_{max}}{F} - \frac{M_{max} \cdot Z_i}{S \cdot \rho_i}$$



Bu erda Z_i - kuchlanishi tekshirilayotgan nuqta bilan neytral o'q orasidagi masofa. *sm*

ρ_i - kuchlanishi tekshirilayotgan nuqta bilan sterjenning egrilik markazi Q nuqta orasidagi masofa.

Sterjen kesimining diametri bo'ylab σ epyurali egri chiziq bo'ladi.

Shuning uchun kesimning diametri bo'ylab 1KMN2 nuqtalaridagi to'liq kuchlanishni topamiz.

Nuqtalarning koordinatalari:

1 nuqta $Z_1 = R_1 - r_0 = 18{,}5 - 15{,}87 = 2{,}63sm; \quad \rho_1 = R_1 = 18{,}5sm$

K nuqta

$$Z_k = \frac{Z_1}{2} = \frac{2{,}63}{2} = 1{,}315sm; \qquad \rho_k = R_1 - \frac{Z_1}{2} = 18{,}5 - \frac{2{,}63}{2} = 17{,}185sm$$

M nuqta $Z_M = 0$ (nuqta neytral o'q ustiga joylashgan)

$$\rho_M = r_0 = 15{,}87sm$$

2 nuqta $Z_2 = r_0 - R_2 = 15{,}87 - 13{,}5 = 2{,}37sm; \quad \rho_2 = R_2 = 13{,}5sm$

N nuqta

$$Z_H = \frac{Z_2}{2} = 1{,}185sm; \qquad \rho_H = r_0 - \frac{Z_2}{2} = 15{,}87 - 1{,}185 = 14{,}685sm$$

Nuqtalarning kuchlanishlarini topamiz:

$$\sigma_1 = -\frac{1{,}54}{19{,}625 \cdot 10^{-4}} - \frac{0{,}07 \cdot 10^2 \cdot 2{,}63 \cdot 10^{-2}}{2{,}55 \cdot 10^{-6} \cdot 18{,}5 \cdot 10^{-2}} = -391 \cdot 10^3 \frac{kN}{m^2}$$

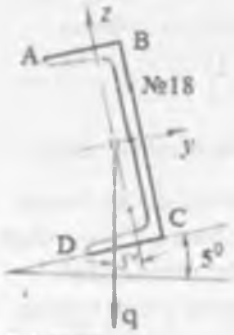
$$\sigma_A = -\frac{1{,}54}{19{,}625 \cdot 10^{-4}} - \frac{0{,}07 \cdot 10^2 \cdot 1{,}315 \cdot 10^{-2}}{2{,}55 \cdot 10^{-6} \cdot 17{,}185 \cdot 10^{-2}} = -210{,}84 \cdot 10^3 \frac{kN}{m^2}$$

$$\sigma_m = -\frac{1{,}54}{19{,}625 \cdot 10^{-4}} = -784{,}7 \frac{kN}{m^2}$$

$$\sigma_A = -\frac{1{,}54}{19{,}625 \cdot 10^{-4}} - \frac{0{,}07 \cdot 10^2 \cdot 1{,}185 \cdot 10^{-2}}{2{,}55 \cdot 10^{-6} \cdot 14{,}685 \cdot 10^{-2}} = -222{,}3 \cdot 10^3 \frac{kN}{m^2}$$

$$\sigma_F = -\frac{1{,}54}{19{,}625 \cdot 10^{-4}} - \frac{0{,}07 \cdot 10^2 \cdot 2{,}37 \cdot 10^{-2}}{2{,}55 \cdot 10^{-6} \cdot 13{,}5 \cdot 10^{-2}} = -482{,}7 \cdot 10^3 \frac{kN}{m^2}$$

Mustahkamlik shartdan valning kesimi topiladi $W = \frac{M_{ye.t}}{[\sigma]}$ yoki agar $W = \frac{\pi \cdot d^3}{32}$ bo'lsa, valning diametri: $d = \sqrt[3]{\frac{32M_{ye.t}}{\pi \cdot [\sigma]}}$



7.1-rasm

7.1-misol. Uchlari sharnirli tiralgan 4 m uzunlikdagi balkaga q=5 kN/m intensivlikdagi teng tarqalgan yuk ta'sir qiladi. Balkaning ko'ndalang kesimi № 18li shveller. Shvellerning devori yuklanish ta'sir ta'sir qiladigan tekislikka $\alpha=5^0$ qiya (7.1-rasmga qarang). Balkaning xavfli kesimidagi A, B, C va D nuqtalardagi normal kuchlanishlarni aniqlang va AB, BC va DC chiziqlar bo'yicha shu kuchlanishlar epyuralarini yasang. Balkaning eng katta egilish qiymati va yo'nalishini ham toping. Shvellerning buralishi xisobga olinmaydi.

javob: $\sigma_A = -309 \cdot 10^5$ N/m^2, $\sigma_B = -1019 \cdot 10^5$ N/m^2; $\sigma_c = 626 \cdot 10^5$ N/m^2; $\sigma_D = +1336 \cdot 10^5$ N/m^2; f= 1,14 sm, $\alpha = 47^0 57$ (devor tekisligiga).

7.2-rasm

7.2-rasm. Uchlari sharnirli tiralgan qo'shtavr balka qulochi l = 5 m o'rtasiga to'plangan kuch P= 8000 N qo'yilgan. Qo'shtavr devori tekisligi yuk ta'sir qiladigan tekislik bilan $\alpha = 20$ burchak tashkil qiladi (rasmga qarang). Yo'l qo'yilgan kuchlanish $[\sigma] = 16 \cdot 10^7$ N/m^2 bo'lganda balka kesimini tanlang

echimi: Bu holda mustahkamlik sharti quyidagi ko'rinishni oladi:

$$M_{max} = \frac{8000 \cdot 500}{4 \cdot 16 \cdot 10^3} + \frac{21,38}{23,1} = 0,319 + 0,925 = 1,244 > 1$$

Mustahkamlik sharti qoniqarli bo'lmaydi, maksimal kuchlnish yo'l qo'yiladigan kuchlanishdan 24,4 % katta chiqadi. Shuning uchun qo'shtavrning nomerini kattalashtirish kerak. Endi № 22 li qo'shtavrni olib ko'ramiz, unda $W_u = 232$ sm^3 va $W_z = 28,6$ sm^3. Endi quyidagi xosil

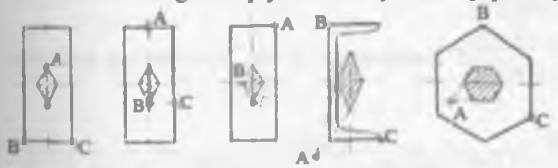
bo'ladi: O'ta kuchlanish 0,1 % ga yo'l qo'yish mumkin. Demak, № 22 li qo'shtavrni tanlaymiz.

7.3-rasm

7.3-misol. Tomning stropila tiraklari bir-biridan 3 m narida bo'lib, gorizontga 30 burchak ostida qiya. Ularga № 20 shvellerdan 2 m nari joylashgan. Tom tekisli-giga perpendikulyar yo'nalgan shamol yuklanishining intensivligi q= 750 N/m, tomning vertikal ta'sir qiladigan o'z og'irligi intensivligi q_2 = 500 N/m (rasmga qarang). Xavfli kesimda A, B, C va D nuqtalardagi normal kuchlanishlarni aniqlang va AB, AD va DC chiziqlari bo'yicha bu kuchlanishlar epyuralarini yasang. Shvellerning buralishi hisobga olinmaydi.

javob: $\sigma_A = -273 \cdot 10^5$ N/m^2; $\sigma_V = +105 \cdot 10^5$ N/m^2, $\sigma_S = +446 \cdot 10^5$ N/m^2; $\sigma_D = +67 \cdot 10^5$ N/m^2.

7.4-misol. Rasmda to'g'ri to'rtburchak, shvellar va oltiburchakli ko'ndalang kesimlar, shuningdek ularning kesim yadrolari tasvirlangan. Agar kesim tekisligiga perpendikulyar kuch A nuqtaga qo'yilgan bo'lsa, bu kesimlarning har qaysisida neytral o'q qanday o'tadi?



javob: V va S nuq-talar orqali o'tadi

7.4-rasm

7.5-misol. Berilgan: P=15kN; ℓ=2m; h:b=2,5

Balka kesimining o'lchamlari aniqlansin va xavfli nuqtalardagi kuchlanishlar topilsin. Balkaning tayanch kesimidagi M_x va M_y eguvchi momentlarni aniqlaymiz va epyurasini quramiz.

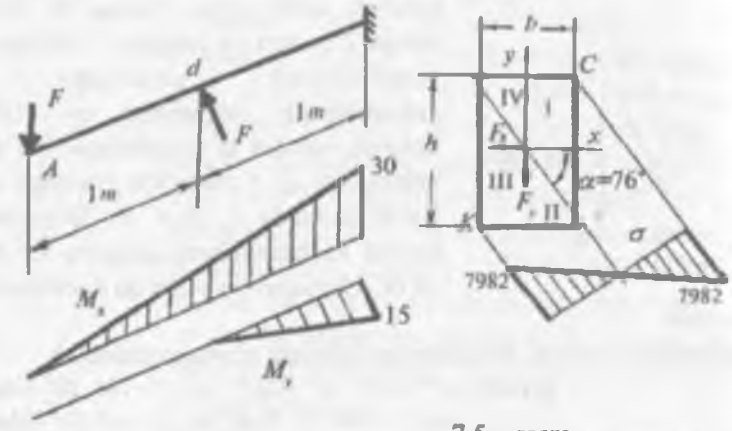
$M_x = 2R = 30\ kNm$; va $M_y = R = 15\ kNm$.

Balkaning mustahkamlik shartini yozamiz

$$\sigma_{max} = \frac{M_x}{W_x} + \frac{M_y}{W_y} \le [\sigma] \quad \text{va} \quad \frac{6M_x}{bh^2} + \frac{6M_y}{b^2h} \le [\sigma]$$

Agar $h = 2,5\ b$ ni va M_x va M_y momentlarning qiymatlarini hisobga olsak, mustahkamlik shartidan kesimning eni b-ni topamiz:

$$b = \sqrt[3]{\frac{405}{6,25 \cdot 8 \cdot 10^3}} \approx 0.2m$$



7.5 – rasm

Kesimning balandligi $h = 2,5 \cdot 0,2 = 0,5m$. Neytral o'qning holatini aniqlaymiz: $|tg\varphi| = \left|\frac{M_y}{M_x} \cdot \frac{I_x}{I_y}\right| = tg\beta \frac{I_x}{I_y}$

Bu erda $I_x = \frac{bh^3}{12}$ va $I_y = \frac{b^3 h}{12}$ kesimning x va u o'qlariga nisbatan inertsiya momentlari;

$$I_x = \frac{0,2 \cdot (0,5)^3}{12} = 2,1 \cdot 10^{-3} m^4;\ I_y = \frac{0,5 \cdot (0,2)^3}{12} = 3,4 \cdot 10^{-4} m^4$$

$$tg\varphi = \frac{2,1 \cdot 10^{-3}}{3,4 \cdot 10^{-4}} \cdot 0,5 = 4,242 \qquad yoki \quad \varphi = 76^0$$

Neytral o'q kuchning ta'sir chizig'i joylashgan chorakga qarama-qarshi chorakdan o'tadi. Kesimning S neytral o'qdan eng uzoqda joylashganligi uchun unda normal kuchlanish katta qiymatga erishadi. S nuqtaning koordinatlari:

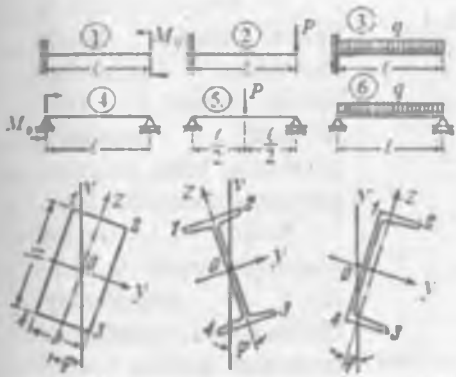
$$x_c = \frac{b}{2} = 0,1m,\ \ y_c = \frac{h}{2} = 0,25m$$

$$\sigma_c = \frac{M_x}{I_x} \cdot y_c + \frac{M_y}{I_y} \cdot x_c \cdot \quad \text{va} \quad \sigma_c = -7982 \frac{kN}{m^2}$$

Balka erkin uchining (A nuqta) to'liq salqiligini topamiz

$$f=\sqrt{f_x^2+f_y^2}=\sqrt{\left(\frac{P\ell^3}{3E8I_y}\right)^2+\left(\frac{P\ell^3}{3EI_x}\right)^2}=\frac{P\ell^3}{3E}\sqrt{\frac{1}{(8I_y)^2}+\frac{1}{(I_x)^2}}=$$

$$=\frac{15\cdot 8}{3\cdot 2\cdot 10^8}\sqrt{\frac{1}{(8\cdot 0{,}00034)^2}+\frac{1}{(0{,}0021)^2}}=33{,}34\cdot 10^{-5}m.$$



7.6-rasm.

7.6-misol. Rasmda ko'rsatilgan balkalar uchun neytral o'q vaziyati aniqlansin (u o'qi bilan α burchak), xavfli kesimdagi eng katta normal kuchlanish hisoblansin epyuralari qurilsin, eng katta salqilik topilsin.

Kuchni ta'sir chiziqi kesimni egilish markazi O nuqtadan o'tuvchi B o'qi tekisligi bilan mos tushadi. To'g'ri burchakli Kesimli balkalarning materiali yog'och, boshqalarining materiali po'lot.

№	Balka va kesim sxemasi	Prolet m	yuklanish	Kesimning o'lchamlari	Burchak φ	javoblar		
						burchak, α	f_{max} sm	σ_{max} kG/sm^2
1	1-A	1,5	M_0=0,4 *mm*	12x20 sm	60^0	$78^0 16^1$	1,38	97,2
2	1-B	1,4	M_0=0,2 *mm*	qt №12	30^0	$82^0 8^1$	1,77	1443
3	1-C	2,0	M_0=0,6 *mm*	shv. №27	60^0	$87^0 55^1$	1,98	1492
4	2-A	2,0	F=80 *kG*	10x15sm	45^0	$66^0 2^1$	1,32	75,4
5	2-B	1,5	F=200 *kG*	qt №16	30^0	$83^0 22^1$	0,97	1273
6	2-C	1,4	F=300 *kG*	shv. №22	60^0	$87^0 38^1$	0,79	1552
7	3-A	2,0	q = 2 *kG/sm*	10x25sm	45^0	$80^0 55^1$	1,37	95,0
8	3-B	1,2	q = 3 *kG/sm*	qt №14	30^0	$82^0 46^1$	0,47	1108
9	3-C	2,4	q = 2 *kG/sm*	shv. №24	45^0	$85^0 54^1$	1,41	1481

To'liq eguvchi momentni M_e^B va M_e^G momentlarning yig'indisi sifatida topamiz. $M_x^2 = \left(M_e^B\right)^2 + \left(M_e^G\right)^2$

$$M_{xA} = 0; \quad M_{xB} = \sqrt{0 + \left(M_e^G\right)} = 3245 Nm;$$

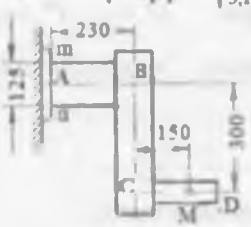
$$M_{xC} = \sqrt{(2164)^2 + (1870.8)^2} = 2862 Nm;$$

$$M_{xO} = \sqrt{(2701)^2 + (935.3)^2} = 2862 Nm; \quad M_{xk} = 0.$$

Eguvchi va burovchi moment epyuralariga asosan V tayanch kesimi xavfli holatda bo'ladi.

III – mustahkamlik nazariyasiga asosan, keltirilgan momentni topamiz: $M_{kel} = \sqrt{M_x^2 + M_e^2} = \sqrt{(3245)^2 + (324.5)^2} = 3261.2 Nm$

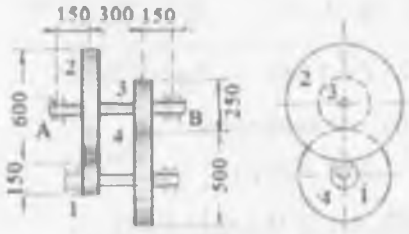
$$d = \sqrt[3]{\frac{32 M_{kel}}{\pi [\sigma]}} = \sqrt[3]{\frac{32 \cdot 3261.2}{3.14 \cdot 8 \cdot 10^7}} = 0.0746 = 74.6 mm \quad d = 80 mm \text{ qabul qilamiz}$$



7.11-rasm

7.11-misol. Po'lat tirsakli sterjen AVS rasmda ko'rsatilgandek mahkamlangan. AV kesimining dumaloq ko'ndalang kesimi diametri 125 mm. 2 kN kuch M nuqtada chizma tekisligiga perpendikulyar qo'yilgan. Ko'n-dalang kuchlarning urinma kuchlanishlari-ni xisobga olmay, eng xavfli nuqta M dagi bosh kuchlanishlarni hamda uchinchi va to'rtinchi mustahkamlik nazariyalari bo'yicha xisobiy kuchlanishlarni aniqlang.

javob: $\sigma_1 = 451$ N/sm^2; $\sigma_2 = 54$ N/sm^2; $\sigma_{h\,III} = 505$ N/sm^2, $\sigma_{h\,IV} = 480$ N/sm^2.



7.12-rasm

7.12-misol. Tsilindrik tishli uzatma vali AV ning diamet-rini aniqlang (rasmga qarang). Tishli g'ildirak 1 dagi burov-chi moment 30 N ga teng. To'r-tinchi mustahkamlik nazariya-sidan foydalaning. Tishli g'ildiraklarning xususiy og'ir-liklarini xisobga olmang. Yo'l qo'yiladigan kuchlanish

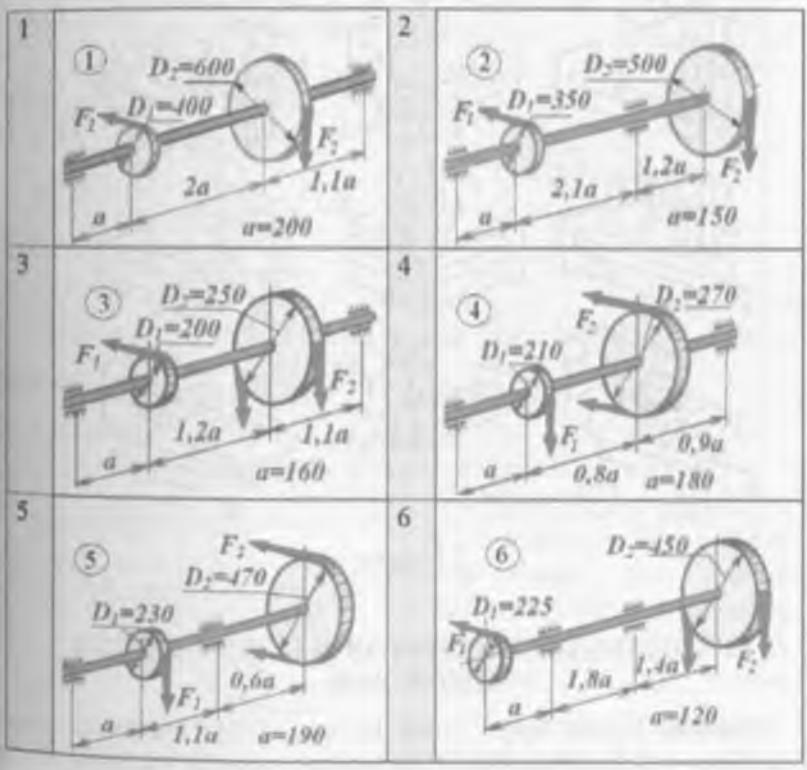
$[\sigma]$ =800 N/sm^2. Uchinchi mustahkamlik nazariyasi asosida valning diametrini qancha olish kerak edi?

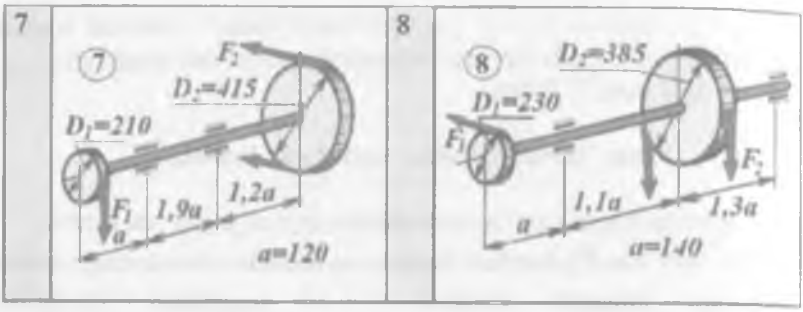
javob: 56,2 mm; 57,8 mm.

Valni buralish bilan egilishga hisoblash

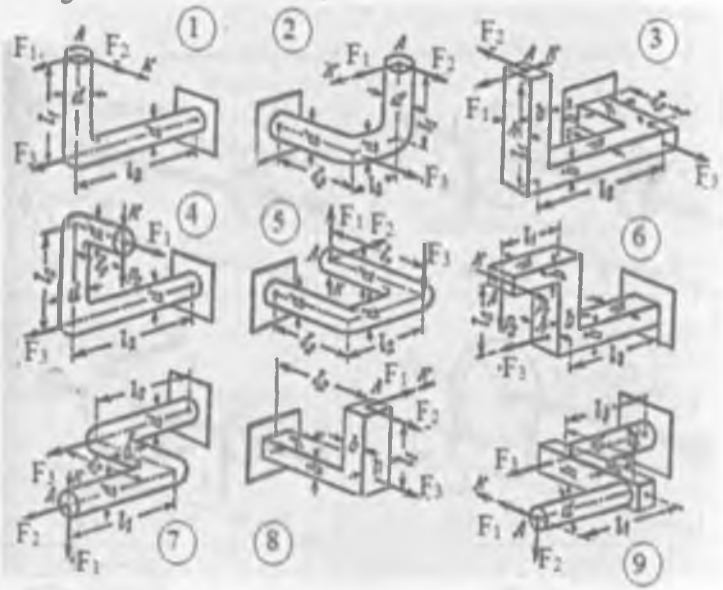
O'zgarmas kesimli po'lat materialidan tayyorlangan val uchun:

1. $F_1 = 5kN$ va F_2 kuchlar birinchi va ikkinchi shkivlardagi etakchi tasmalarning taranglik kuchlari. $F_1 = 2F_2$ tenglikdan foydalanib, burovchi va eguvchi moment epyuralari qurilsin Uchinchi mustahkamlik nazariyasidan foydalanib, valning diametri hisoblansin.





7.13-misol. Pulot kolen vallarlar uchun buylama kuch, burovchi va eguvchi momen epyuralari qurilsin, uchinchi mustahkamlik nazariyasi buyicha eng katta kuchlanishlar topilsin, A kesim markazining K strelka yunalishdagi kuchishi xisoblansin.



7.13-rasm

VIII. SIQILGAN STERJENLARNI USTUVORLIKKA HISOBLASH

8.1-misol. Kesimi teng yonli bo'lmagan ikki burchakni o'zaro biriktirishdan tarkib topgan ferma sterjenidagi siquvchi kuchning ruxsat

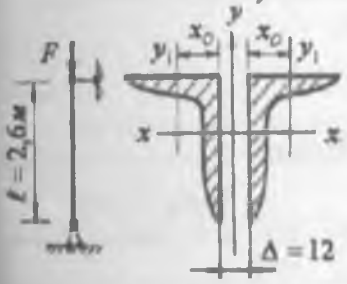
etilgan miqdori aniqlansin. Sterjen st.3 markali po'latdan tayyorlangan (8.1 - rasm). 140 x 90 x 6 teng tomonsiz burchak uchun: $I_{y_\delta}=120sm^4$ $I_{x\delta}=364sm^4$ $x_0=2{,}03sm$; $A=18sm^2$

echish: Ruxsat etilgan kuchni sterjenning ustuvorlik shartidan foydalanib yozamiz: $\sigma_y=\frac{F}{\varphi A}\le[\sigma]$,unda $[N]=\varphi A[\sigma]$

φ - koeffitsient miqdorini topish uchun sterjenning egiluvchanligini aniqlash kerak. Bu esa o'z navbatida sterjen kesimini minimal inertsiya momenti va inertsiya radiusini topishni talab etadi. $I_x=2I_{x\delta}=2\cdot364=728sm^3$

$$I_y=2\left[I_{y_1\delta}+(x_0+0{,}5\cdot\Delta)^2\cdot A\right]=2\left[120+(2{,}03+0{,}5\cdot1{,}2)^2\cdot18\right]=489sm^2$$

Shunday qilib, $I_y<I_x$ va minimal inertsiya radiusi



8.1 – rasm

$$i_{min}=\sqrt{\frac{I_y}{A}}=\sqrt{\frac{489}{2\cdot18}}=3{,}68sm$$

Sterjenning egiluvchanligini aniqlaymiz:

$$\lambda=\mu\frac{\ell}{i_{min}}=1\cdot\frac{260}{3{,}68}=70{,}65$$

Jadvaldan :

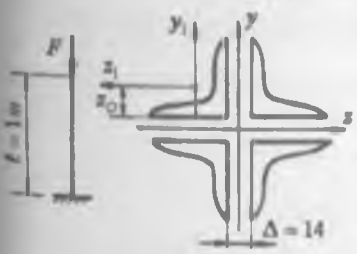
$\lambda=70$ $\varphi'=0{,}81$

$\lambda=80$ $\varphi''=0{,}75$

Qiymatlarni interpolyatsiyalab $\lambda=70{,}65$ egiluvchanlikka to'g'ri keladigan koeffitsient φ - ni qiymatini topamiz: $\varphi=0{,}81-\frac{0{,}81-0{,}75}{10}\cdot0{,}65=0{,}806$

Siquvchi kuchning ruxsat etilgan qiymati

$[N]=0{,}806\cdot2\cdot18\cdot1600=46425{,}6kg=464{,}256kN$



8.2 – rasm

8.2-misol. Kesimni to'rtta 90 x 90 x 2 teng tomonli burchakdan tashkil topgan st.3 markali po'latdan tayyorlangan ustunning ustuvorlikka ehtiyotlik koeffitsienti $[n_y]=2$ uchun siquvchi kuchning ruxsat etilgan qiymati topilsin.

90 x 90 x 2 teng tomonli burchak uchun $Z_0=2,55sm;\quad I_{y_1}=118sm^4;\quad A=15,6sm^2$

echish: Kesimning inertsiya momentini topamiz:

$$I_z=I_y=4\left[I_{z_1}+a^2\cdot A\right]=4\left[118+(3,25)^2\cdot 15,6\right]=1131,1sm^4$$

Bu erda $a=Z_0+0,5\cdot\Delta=2,55+0,5\cdot 1,4=3,25sm$

Inertsiya radiusi $i_z=i_y=i_{\min}=\sqrt{\frac{I_z}{\sum A}}=\sqrt{\frac{1131,1}{4\cdot 15,6}}=4,25sm$

Ustunning egiluvchanligi $\lambda=\mu\frac{\ell}{i_{\min}}=\frac{2\cdot 100}{4,25}=47,05$

$\lambda\angle\lambda_{chek}$ bo'lgani uchun kritik kuchni Eyler formulasidan topib bo'lmaydi. Kritik kuchni Yasinskiy formulasidan aniqlaymiz.

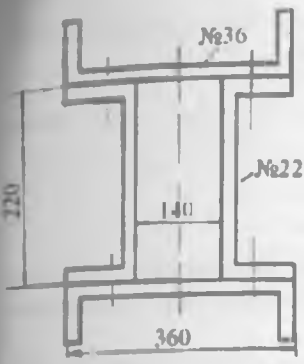
$F_{kr}=\sigma_{kr}\cdot A=(a-b\lambda)\sum A=(3100-11,4\cdot 47,05)\cdot 4\cdot 15,6=159970,5kg$

Ustunga ta'sir etuvchi ruxsat etilgan kuch

$$[F]=\frac{F_{kr}}{[n_y]}=\frac{159,97}{2}=79,985kN$$

Koeffitsient φ-ning kiymati

$\lambda=\mu\frac{\ell}{i_{min}}$	φ-ning kiymati				$\lambda=\mu\frac{\ell}{i_{min}}$	φ-ning kiymati			
	St.3 St.4	St.5	chuyon	yogoch		St.3 St.4	St.5	chuyon	yogoch
0	1,0	1,0	1,0	1,0	110	0,52	0,43	-	0,25
10	0,99	0,98	0,97	0,99	120	0,45	0,37	-	0,22
20	0,97	0,96	0,91	0,97	130	0,40	0,32	-	0,18
30	0,95	0,93	0,81	0,93	140	0,36	0,28	-	0,16
40	0,92	0,89	0,69	0,87	150	0,32	0,25	-	0,14
50	0,89	0,85	0,57	0,80	160	0,29	0,23	-	0,12
60	0,86	0,80	0,44	0,71	170	0,26	0,21	-	0,11
70	0,81	0,74	0,34	0,60	180	0,23	0,19	-	0,10
80	0,75	0,67	0,26	0,48	190	0,21	0,17	-	0,09
90	0,69	0,59	0,20	0,39	200	0,10	0,16	-	0,08
100	0,60	0,50	0,15	0,31					



8.3 – rasm

8.3-misol. Quyidagi ikkita 36 va 22 profilli shvellerlar birikmasidan tayyorlangan kolonnani sxemasi ko'rsatilgan birikmani ikkita uchlari ham sharnirli tayanchda..

Ustuvorlik va mustahkamlik shartlaridan foydalanib kolonnaga qo'yilishi mumkin bo'lgan siquvchi kuchni toping. Material.St.3. $[\sigma]=160mPa$, $\ell=9m$; $\mu=1$

echish: Kesimdagi shvellerlarni tavsiflarini yozib olamiz. Kesimning o'lchamlarini masshtabda ifodalaymiz. Kalonnaning kesim yuzasini topamiz: $A=2(53,4+26,7)=160,2sm^2$

Kesimning minimal inertsiya momentini parallel o'qlarga nisbatan inertsiya momenti formulasidan topamiz:

$$I_x=2\left[513+\left(\frac{22}{2}+2,68\right)^2\cdot 53,4\right]+2\cdot 2110=25232,808sm$$

$$I_y=2\cdot 10820+2\left[151+(7+2,21)^2\cdot 26,7\right]=26471,607sm^4$$

$$I_x=I_{\min}=25232,808sm^4$$

Kesimning minimal inertsiya radiusini topamiz

$$i_{\min}=\sqrt{\frac{I_{\min}}{A}}=\sqrt{\frac{25232,808}{160,2}}=12,55sm$$

Kolonnaning egiluvchanligi: $\lambda=\mu\frac{\ell}{i_{\min}}=1\cdot\frac{900}{12,55}=71,713$

Jadvaldan foydalanib φ –ni qiymatini topamiz:

$\lambda=70;\quad \varphi'=0,81$

$\lambda=80;\quad \varphi''=0,75$

$$\varphi=0,81-\frac{0,81-0,75}{10}\cdot 1,713=0,7997$$

Ruxsat etilgan siquvchi kuchni topamiz:

$[F]=\varphi[\sigma]\cdot A=0,7997\cdot 1600\cdot 160,2=206979kg$

Kolonnaning kesimi to'rtta parchin mix o'rni bilan zaiflash-tirilgan.

$$A_H = A - 4d(0{,}95 + 0{,}75) = 160{,}2 - 4 \cdot 2 \cdot 1{,}7 = 146{,}6 sm^2$$

Kolonnaning mustahkamlik sharti $\sigma_{max} = \frac{F}{A_H} \le [\sigma]$ dan ruxsat etilgan siquvchi kuchni topamiz.

$$F \le [\sigma] \cdot A_H = 1600 \cdot 146{,}6 = 234560 kg$$

misol-8.4. Ustuvorlik va mustaxkamlik shartlaridan foydalanib kolonkaga qo'yilishi mumkin bo'lgan siquvchi kuchning eng katta qiymati hisoblansin.

Bitta kesimda 4 ta zaklepka bor deb qabul qilinsin. Material St.3, ruxsat etilgan kuchlanish 1600 kG/sm^2 qabul qilinsin.

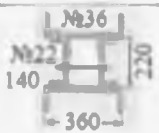
Kolonnalar oxirining mahkamlanish turlari:

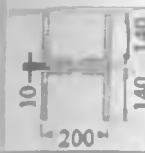
a) ikki tomoni sharnirli tayanchda

b) bir tomoni sharnirli va ikkinchi tomoni bikr mahkamlangan tayanch;

v) ikki tomoni ham bikr mahkamlangan tayanch;

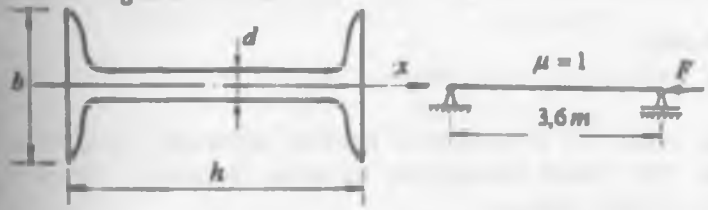
g) bir tomoni tayanchlan ozod va ikkinchi tomoni bikr mahkamlangan tayanch;

№	Kundalang kesim sxemasi	Kesimning tarkibi	Zaklepka-ning diametri, mm	Tayanch turi	Kolonka-ning uzunligi	Javob: ruxsat etilgan yuk, t
1		ikkita №16 shveller, ikkita list 250x8 mm	17	a b v g	5,5 6,6 7 3,5	96,6 104,0 104,1 80,8
2		4 ta ugolok 70x70x7 2 ta list 200x6 2 ta list 290x6	14	a b v g	6 8 10 2	125,0 128,6 133,5 138,9
3		ikkita №36 shveller, ikkita №22 shveller	20	a b v g	9 12 6 5	205,0 211,5 234,6 192,7

4		ikkita №1 kushtavr 2 ta list 240x8	17	a b v g	3 7 11 3	100,3 91,8 85,4 79,7
5		4 ta ugolok 100x100x10 2 ta list 300x10 1 ta list 240x10 mm	20	a b v g	7 5 10 4	126,8 212,5 190,9 102,7
6		4 ta ugolok 140x90x10 1 ta list 200x10 mm	20	a b v g	6 6 10 3,5	107,4 142,2 128,8 85,1

8.5-misol. Po'latdan tayyorlangan sterjen F = 28 t kuch bilan siqilayapti. Sterjenning uzunligi $\ell = 3{,}6m$ va ikkita sharnirli tayanchga tayanadi. Sterjenning ustuvorlik shartidan foydalanib kesimi tanlansin.

Ruxsat etilgan kuchlanish $[\sigma] = 1600 \frac{kg}{sm^2}$



8.5 – rasm

echish: I hisoblash sterjenning hisoblangan kesim yuzasini topamiz: $A = \frac{F}{\varphi[\sigma]} = \frac{28000}{\varphi \cdot 1600} = \frac{17{,}5}{\varphi}$; $\varphi = 0{,}5$; $A = \frac{17{,}5}{0{,}5} = 35 sm^2$.

Kesim yuzasi $A = 35\ sm^2$ bo'lgan qo'shtavrni katalogdan tanlaymiz. Qo'shtavr 24: $A = 34{,}8\ sm^2$ va $I_y = 198\ sm^4$

Kesimning minimal inertsiya radiusi: $i_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{198}{34{,}8}} = 2{,}385 sm$

Sterjenning egiluvchanligi: $\lambda = \mu \frac{\ell}{i_{min}} = 1 \cdot \frac{360}{2{,}385} = 150{,}94$

Jadvaldan st.3 materiali uchun φ – ni qiymatini topamiz:

$\lambda = 150;$ $\varphi' = 0,32$

$\lambda = 160;$ $\varphi'' = 0,29$

Interpolyatsiya usuli bilan $\varphi_1 = 0,32 - \frac{0,32-0,29}{10} \cdot 0,94 = 0,317$

va $\varphi_2 = \frac{\varphi + \varphi_1}{2} = \frac{0,5 + 0,317}{2} = 0,4085$ - ni topdik $\varphi \succ \varphi_2$

II – hisoblash. $A = \frac{17,5}{0,4085} = 42,84 sm^2$. Kesim yuza 27 a qo'shtavrni kesim yuzasiga yaqin: $A = 43,2 sm^2$; $I_y = I_{\min} = 337 sm^4$.

Sterjenning egiluvchanligi $\lambda = \frac{360}{\sqrt{\frac{337}{43,2}}} = \frac{360}{2,793} = 128,89$

Jadvaldan $\lambda = 120;$ $\varphi' = 0,45$

$\lambda = 130;$ $\varphi'' = 0,4$

Unda $\varphi_3 = 0,45 - \frac{0,45-0,4}{10} \cdot 8,89 = 0,406.$

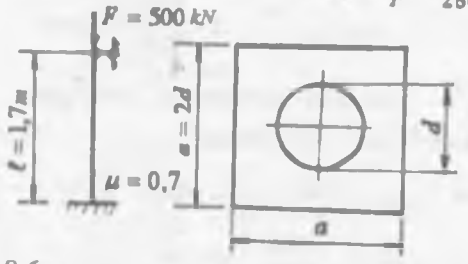
Haqiqiy kuchlanishni topamiz: $\sigma_x = \frac{28000}{43,2} = 648,15 \frac{kg}{sm^2}$ Ruxsat etilgan kuchlanish:

$[\sigma]_y = \varphi_3 \cdot [\sigma] = 0,406 \cdot 1600 = 649,6 \frac{kg}{sm^2}$; $\sigma_x \prec [\sigma]_y$

Shuning uchun 27 a qo'shtavrli kesimni tanlaymiz. Sterjenning egiluvchanligi 100. Kritik kuchni Eyler formulasi yordamida topamiz:

$F_{kp} = \frac{\pi^2 E I_{\min}}{\ell^2} = \frac{(3,14)^2 \cdot 2 \cdot 10^6 \cdot 337}{(360)^2} = 52006 kg$

Koeffitsient: $K_y = \frac{F_k}{F} = \frac{52006}{28000} = 1,86$



8.6 – rasm

8.6-misol. Po'latdan tayyorlangan sterjen G' kuch bilan siqilayapti:

1)$[\sigma] = 160 mPa$ kuchlanishdan foydalanib sterjen ko'ndalang kesimining geometrik o'lchamlarini toping;

2)kritik kuch aniqlansin

echish: Sterjen ko'ndalang kesimining yuzasi: $A = a \cdot a - \frac{\pi \cdot d^2}{4} = 2d \cdot 2d - \frac{\pi \cdot d^2}{4} = 3{,}215d^2$

Minimal inertsiya momenti

$$I_{min} = I = \frac{a^4}{12} - \frac{\pi \cdot d^4}{64} = \frac{(2d)^4}{12} - \frac{\pi \cdot d^4}{64} = 5{,}27d^4$$

va inertsiya radiusi $i_{min} = \sqrt{\frac{5{,}27d^4}{3{,}215d^2}} = \sqrt{\frac{5{,}27(0{,}041)^2}{3{,}215}} = 0{,}0564m$

1 – hisoblash $(\varphi = 0{,}5)$: $A \geq \frac{P}{\varphi[\sigma]} = \frac{500}{0{,}5 \cdot 160 \cdot 10^3} = 0{,}00625m^2$ bo'ladi,

unda $d = \sqrt{\frac{0{,}00625}{3{,}215}} = \sqrt{0{,}001944} = 0{,}0441m$, sterjenning egiluvchanligi

$\lambda = 0{,}7\frac{1{,}7}{0{,}0564} = 21{,}1$

jadvaldan po'lat material uchun:

$\lambda = 20$ $\varphi = 0{,}96$

$\lambda = 30$ $\varphi = 0{,}94$ topamiz.

interpolyatsiya usuli bilan $\lambda = 21{,}1$ egiluvchanlik uchun φ–ning qiymatini topamiz. $\varphi_1 = 0{,}96 - \frac{0{,}96 - 0{,}94}{10} \cdot 1{,}1 = 0{,}9578;$

$\varphi_1 = 0{,}9578$ – birinchi marotaba qabul qilingan $\varphi = 0{,}5$ dan farq qiladi

2 hisoblash $\varphi_2 = \frac{\varphi + \varphi_1}{2} = \frac{0{,}5 + 0{,}9578}{2} = 0{,}7289;$

$$A \geq \frac{P}{\varphi_2[\sigma]} = \frac{500}{0{,}7289 \cdot 160 \cdot 10^3} = 0{,}042872m^2$$

$$d = \sqrt{\frac{F_1}{3{,}215}} = \sqrt{\frac{0{,}0042872}{3{,}215}} \approx 0{,}036m;$$

$$i_{min} = \sqrt{\frac{5{,}27d^4}{3{,}215d^2}} = \sqrt{\frac{5{,}27 \cdot 0{,}001296}{3{,}215}} = 0{,}046.$$

Sterjenning egiluvchanligi $\lambda = 0{,}7\frac{1{,}7}{0{,}046} = 25{,}87$

Jadvaldan sterjenning materialiga va egiluvchanligiga qarab

$\lambda = 20$ $\varphi = 0{,}96$

$\lambda = 30$ $\varphi = 0{,}94$ - ni topamiz,

$$\sigma_{max}=\frac{N_{max}}{F}+\frac{M_{max}}{W}=\frac{N_{max}}{F}+\frac{32\cdot M}{\pi d^3}\le[\sigma]\quad yoki$$

$$\frac{5\gamma A\omega^2\ell^2}{2Ag}+\frac{32\cdot 5\gamma A\omega^2\cdot\ell^2}{2\pi d^3 g}\le[\sigma]\quad \frac{5\gamma A\omega^2\ell^2}{2g}+\frac{8\cdot 5\gamma A\omega^2\cdot\ell^3}{2dg}=[\sigma]$$

Bu erdan $\omega_p=\omega=\sqrt{\frac{[\sigma]}{\frac{5\gamma\ell^2}{2g}+\frac{20\gamma\ell^3}{dg}}}=\sqrt{\frac{100\cdot10^3}{\frac{5\cdot78\cdot0{,}25}{2\cdot9{,}81}+\frac{20\cdot78\cdot0{,}125}{9{,}81\cdot0{,}02}}}=10\frac{1}{sek}$

Bir minutda valikning aylanish soni

$$n=\frac{60\cdot\omega_p}{2\pi}=\frac{60\cdot\omega_p}{2\cdot3{,}14}=95{,}54$$

9.7-misol. Mustahkamlik chegarasi $\sigma_B=600MPa$; oquvchanlik chegarasi $\sigma_T=300MPa$; po'latdan tayyorlangan, diametri $d = 50$ *mm* bo'lgan valni xavfli kesimda $M_\delta=320Nm$ burovchi va $M_e=320Nm$ eguvchi momentlar ta'sir qiladi. Egilishdagi normal kuchlanishning simmetrik tsikldagi: buralishdagi urinma kuchlanishning tepkili (pulsiruyuvchi) tsikldagi kuchlanishga teng deb qaralib, xavfli kesim uchun ehtiyotlik koeffitsienti topilsin.

echish. Eng katta normal kuchlanish:

$$\sigma_{max}=\frac{M_e}{W}=\frac{32M_e}{\pi d^3}=0{,}026\cdot10^3\frac{N}{mm^2}$$

Eng katta urinma kuchlanish : $\tau_{max}=\frac{M_\delta}{W}=\frac{16\cdot M_\delta}{\pi d^3}=0{,}013\cdot10^3\frac{N}{mm^2}$

Buralishda oquvchanlik chegarasi: $\tau_{-1}=0{,}25\sigma_T=0{,}25\cdot300=75MPa$

Chidamlilik (bardosh berish) chegarasi:

Buralishda $\sigma_{-1}=0{,}25\sigma_b=0{,}25\cdot600=150MPa$

Egilishda $\sigma_{-1}=0{,}43\sigma_b=0{,}43\cdot600=258MPa$

Kuchlanishlar kontsentratsiyasi

$$K=1{,}2+0{,}2\frac{\sigma_b-40}{110}=1{,}2+0{,}2\frac{600-40}{110}=2{,}2$$

Masshtab koeffitsienti

$$\beta_m=1{,}2+0{,}1(d-3)=1{,}2+0{,}1(5-0{,}3)=1{,}67$$

σ va τ bo'yicha ehtiyotlik koeffitsienti $n_\tau=\frac{\tau_{max}}{2}=\frac{13}{2}=6{,}5$

$$n_\sigma=\frac{\sigma_{-1}}{\sigma_{max}}=\frac{\sigma_{-1}}{k\beta_m\cdot\sigma_{max}}=\frac{250}{2{,}2\cdot1{,}67\cdot26}=2,$$

Charchashdan emirilishdagi va oquvchanlikning boshlanishidagi umumiy ehtiyotlik koeffitsientlarini topamiz:

$$n_{\tau_0} = \frac{\tau_{-1}}{k \cdot n_\tau + \beta_m n_\tau} = \frac{75}{2{,}2 \cdot 6{,}5 + 1{,}67 \cdot 6{,}5} = 2{,}9$$

$$k_{TM} = \beta_m \cdot \kappa = 1{,}67 \cdot 2{,}2 = 3{,}674$$

buralishdagi oquvchanlikka ehtiyotlik koeffitsienti

$$n_\tau = \frac{\tau_T}{\tau_{max}} = \frac{75}{13} = 5{,}77$$

Mustahkamlikning umumiy ehtiyotlik koeffitsienti

$$n = \frac{n_\sigma \cdot n_\tau}{\sqrt{n_\sigma^2 + (n_\tau)^2}} = \frac{2{,}7 \cdot 5{,}77}{\sqrt{(2{,}7)^2 + (5{,}77)^2}} = 2{,}99$$

Charchashdan emirilishga ehtiyotlik koeffitsienti

$$n = \frac{n_\sigma \cdot k_{TM}}{\sqrt{n_\sigma^2 + K^2{}_{TM}}} = \frac{2{,}7 \cdot 3{,}674}{\sqrt{(2{,}7)^2 + (3{,}674)^2}} = 2{,}17$$

II- BOB. MATERIALLAR QARShILIGI FANIDAN AMALIY MAShGULOTLAR BO'YIChA METODIK TAVSIYaLAR

Kesish metodi. Bu mavzuni yaxshi o'rganish materiallar qarshiligi fanini samarali o'zlashtirish uchun zamin yaratadi. Shuning uchun kesish metodini chuqurroq va shoshilmasdan kengaytirilgan holda ixtiyoriy jismni yuklanishi shaklida tushuntirish tavsiya etiladi. Bunda, kesish usuli – ichki kuchlar bosh vektori va bosh momentini aniqlash imkonini beradi; kuchlanishlarni aniqlash uchun esa ularni kesim yuzada tarqalish qonuniyatini bilish kerak. Kesish usulini tushuntirishda, ayrim hollarda (РОЗУ-режим, отбрасываем,заменяем, уравновешиваем), ya'ni KAAM – kesamiz, ajratimiz, almashtiramiz, muvozanatlaymiz - degan usul ishlatiladi.

Statikadan aniqki, har qanday kuchlar sistemasi biror nuq-taga, masalan kesimni og'irlik markaziga keltirilishi va ekvivalent sistema – bosh vektor va bosh moment bilan almashtirilishi mumkin.

Ichki kuch faktorlari – bosh vektor va bosh momentni koordina-ta o'qlaridagi tashkil qiluvchilari bo'lib vektor kattalikdir. Shuning uchun ichi kuch faktorlari biror jismni kesilgan yuzasiga tasir qiladi deb tushuntirmaslik kerak, balki ushbu yuzada tashqi kuch tasiridan hosil bo'ladi. Bu holat absolyut qattiq jism bog'lanishlarida (tayanch nuqtalari) tashqi kuch tasiridan bog'lanish kuchlarini hosil bo'lishiga o'xshaydi.

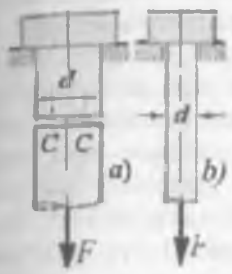
Brus ichki kuch faktorlari deformatsiyaning turi bo'yicha beriladi va uni maruzada to'liq bayon etish kerak. Ichki kuchlarni tushun-tirishda terminologiyaga etibor berish shart. Masalan, N_x kuchni tushuntirishda termin "bo'ylama kuch" – to'g'ri bo'ladi, "normal kuch" – termini noto'g'ri, Q_y, Q_z kuchlarni tushuntirishda "kesuvchi kuch" termini – noto'g'ri, uni faqat "ko'ndalang kuch" deb aytish kerak. Shunga o'xshash ichki kuch tasirida, masalan, "bo'ylama kuch" tasirida brusda cho'zilish yoki siqilish hosil bo'ladi deb tushuntirmaslik kerak. Balki prof. V.I.Feodosev tarifiga asosan, "Ko'ndalang kesim yuzida faqat bo'ylama kuch hosil bo'ladigan, boshqa barcha ichki kuch faktorlari nolga teng bo'lgan brusni yuklanish turida cho'zilish va siqilish hosil bo'ladi" deb tushunishni tavsiya etamiz.

Materiallar qarshiligidan yozilgan darsliklarda ichki kuch faktorlarini aniqlash mavzusini mustahkamlash uchun misollar keltirilmaydi. Ushbu traditsiyani ozroq o'zgartirishni tavsiya etamiz va turli oddiy va murakkab deformatsiya turlarida bir ikkita misollar echilsa maqsadga muvofiq bo'lar edi. [5] darslikda kesish metodi va ichki kuch foktorlarini aniqlash bo'yicha bir qancha misollar keltirilganki, bu amaliy mashg'ulotlarni birinchi soatlarida tekislikda joylashgan kuchlar sistemasining muvozanat shartlarini tadbiq etib, reaktsiya kuchlarini yoki ichki kuchlarni aniqlashga oid misol echish imkonini beradi.

Konstruktsiya elementlarini hisoblashning turlari.

Mashina va muxandislik inshootlarini mustahkamlikka hisoblash, ularning ishonchliligiga qo'yilgan talablarni qanoatlantiradimi degan savolga javob berishdan iborat. Aks holda qo'yilgan maqsadga erishilmaydi, ya'ni konstruktsiyada xavfli holat yuzaga kelib, u yoki ishlash layoqatini yo'qotadi, yoki xatolik bilan ishlaydi.

Shuning uchun, konstruktsiyani hisoblash usulini to'g'ri tanlash kerak bo'ladi. Mashina detallari yoki inshoot elementlarini kuchlanishlar bo'yicha mustahkamlikka hisoblash usuli keng tarqalgan. Bu usulga asosan, konstruktsiyani ishonchlilik kriteriysi deb kuchlanish, ya'ni nuqtaning kuchlanganlik holati qabul qilingan. Bu usulda - konstruktsiyani tahlili asosida jismdagi eng katta kuchlanish hosil bo'lgan nuqta aniqlanadi. Bu hisobiy kuchlanish berilgan material uchun chegaraviy kuchlanish bilan taqqoslanadi va mustahkamlik to'g'risida xulosa qilinadi.



1 – rasm

Ishonchlilikni baholashda nuqta kuchlanishini hisoblash usuli ayrim konstruktsiyalar uchun tadbiq etilmaydi. Masalan, ma'lum kesimida kanalcha tayyorlangan sterjenni cho'zilishida S nuqtasida-gi kuchlanish (1–rasm, *a*), shunday kuch bilan cho'zilayotgan silliq sterjendagi (1 – rasm, *b)* kuchlanishdan katta bo'ladi. Bunday holat kam uglerodli po'lat, shisha, tosh va ayrim materiallarda kuzatiladi. Mis, bronza, alyuminiydan tayyorlangan shunday ikkita sterjenlardan, masalan kanavka tayyorlangani ko'proq yukni ko'tarishi mumkin. Shuning uchun nuqta kuchlanish hamma vaqt ham konstruktsiyani emirilish shartini belgilamaydi. Emiruvchi kuch asosida hisoblash usuli. Bunda konstruktsiya emirilmasdan yoki shaklini o'zgartirmasdan chegaraviy kuchni qabul qilishi kerak. Chegaraviy kuch ishchi kuch bilan taqqoslanadi va konstruktsiyani mustahkamligi to'g'risida xulosa qilinadi. Bu usul oddiy konstruktsiyalarda tadbiq etiladi. Ruxsat etilgan ko'chish, ustuvorlik shart, dinamik va davriy o'zgaruvchan kuchlanishlar bo'yicha hisoblash usullari mavjud. Materiallar qarshiligi kuchlanish, deformatsiya, chegaraviy kuchlarni amaliy hisoblash va tajribada aniqlash usullarini o'rgatadi.

Real ob'ekt va hisoblash sxemasi. Tabiiy fanlardagi kabi, materiallar qarshiligida ham, real ob'ektni izlanishi, uning hisoblash sxemasini, ya'ni hisoblash modelini tanlashdan boshla-nadi.

Konstruktsiyani hisoblashga horshlashdan oldin echilishi lozim bo'lgan muammoni sxemasini (rejasini) tuzish kerak. Buning uchun qo'yilgan masalani muhim tomonini belgilab, muhim bo'lmaganlarini tashlab yuborish kerak bo'ladi, chunki real ob'ektga qo'yilgan talablarni qanoatlantiradigan xususiyatlarini va ularga ta'sir qiladigan faktorlarni hammasini e'tiborga olib bo'lmaydi va mumkin ham emas.

Muhim bo'lmagan faktorlardan ozod bo'lgan real ob'ekt hisoblash sxema deyiladi. Qo'yilgan masalaga ko'ra, hisoblash sxemani bir nechta variantda qabul qilish mumkin. Masalan, liftni harakatida, faqat tros mustahkamlikka hisoblansa, kabina bilan yuk absolyut qattiq jism deb olinadi va kuch trosni pastki nuqtasiga qo'yiladi. Agar kabinaning

mustahkamligi hisoblanishi lozim bo'lsa, kabina konstruktsiyasining xususiyatlari alohida tahlil qilinadi va hisoblash sxemasi tuziladi.

Bitta real ob'ektga bir nechta hisoblash sxema variantlari to'g'ri kelsa, bitta hisoblash sxemadan ko'plab real ob'ekt hosil qilish mumkin, ya'ni hisoblash sxemani tahlili asosida bir nechta real masalalarni echimi kelib chiqadi. Masalan, lift trosining yuklanish sxemasi juda keng tarqalgan hisoblash sxemasi bo'lib hisoblanadi. Hisoblash sxemani tuzishda material birjinsli, elastik va izotrop deb qabul qilinadi, real ob'ektni geometriyasi (inshoot elementining shakli) va qo'yilgan kuchning turi e'tiborga olinadi.

Cho'zilish va siqilish. Masalani qo'yilishiga qarab mustahkamlikka hisoblashni uch xil turi mavjud: 1.Tekshirish; 2.Loyihaviy; 3.Ruxsat etilgan yukni hisoblash.

Tekshirish hisoblashda ayrim holarda hisobiy ehtiyotlik koeffitsenti talab qilingan qiymati bilan taqqoslanadi. Mustahkamlikka hisoblashga oid misolni auditoriya va uyda echish uchun tanlash kerak. Darslik, qo'llanma va masalalar kamroq bo'lsa, o'qituvchinng o'zi bir nechta masalani tuzib olishi mumkin. Lekin, V.K. Kachurining "Materiallar qarshiligidan masalalar to'plami"da bu mavzuga oid masalalar varianti etisharli miqdorda berilgan.

Ruxsat etilgan yukni hisoblashga oid masala echishda – sterjenlar sistemasidan yoki har xil materiallardan tayyorlangan sterjenlar sistemasidan foydalanish lozim. Ko'ndalang kesim yuzalarining o'lchamlarini aniqlashda turli kesimli sterjenlar sistemasidan foydalanishni tavsiya etamiz. Sterjenlar sistemasiga oid misolni echishda kesish usulidan foydalanish kerak. Sterjenlar sistemasini siqilishga hisoblashda ularni ustuvorligi tamin-langan bo'lishi eozim.

Statik noaniq sistemalar. Statik noaniq sisitemalar deb, nomalum kuchlarni (reaktsiya kuchlari, ichki kuchlar) aniqlash uchun kesish usuli yoki statika tenglamalari etisharli bo'lmagan sistemalarga aytiladi.

Tashqi va ichki statik noaniq sistemalar to'g'risida tushuncha berish kerak. Masalan, sterjenlar sistemasida sterjenlarda ichki bo'ylama kuchlarni aniqlash ichki statik noaniq sistemaga misol bo'ladi; ikki tomoni bikr mahkamlangan brus tashqi statik noaniq sistema. Har ikkala statik noaniq sistemalarda ham noma'lum kuchlarni aniqlash masalasi – statik noaniq masala deyiladi. Statik noaniq sistemalarni statik noaniqlik darajasi mavjud.

Statik noaniq masalalarni echish metodikasi ikki xil variantda olib boriladi. Masalan, sterjenlar sistemasida no'malum ichki bo'ylama kuchlarni aniqlash uchun kesish usulidan foydalanib sterjenlarni kesamiz. Sterjinlardagi ichki bo'ylama kuchlarni ko'rsatib, sistemani olib qolingan qismi uchun muvozanat tenglamalarini tuzamiz. Tuzilgan muvozanat tenglamalarida no'malum ichki kuchlar bilan birga no'malum reaktsiya kuchlari qatnashadi. Lekin, reaktsiya kuchlarini aniqlash yoki aniqlamaslik masalani mohiyatini belgilamaydi. Shuning uchun reaktsiya kuchlarni aniqlamaymiz va ular qatnashadigan muvozanat tenglamalarini e'tiborga olmasak ham bo'ladi. Unda uchta muvozanat tenglamasidan faqat bittasi qoladi va unda ikkita no'mulum ichki kuchlar va tashqi kuch qatnashadi.

Pog'onali brus uchun bitta muvozanat tenglamasi tuziladi Bu tenglamada ikkita no'malum reaktsiya kuchlari qatnashadi. Har ikkita statik noaniq sistemalarni echish metodikasiga oid bir nechtadan masalalar echilgan.

Ushbu mavzuga oid talabalarni mustaqil ishi sifatida hisoblash – grafik ishi uyga vazifa beriladi. Variantlarni M. Ergashevni "Materiallar qarshiligidan hisoblash – loyihalash ishlari" yoki V.K. Kachurinning "Materiallar qarshiligi masalalar to'plami" kitoblaridan olish mumkin

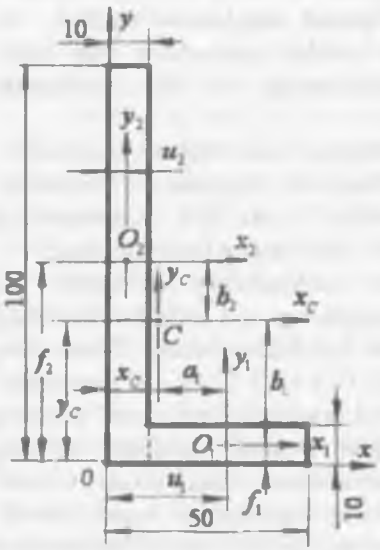
Kuchlanganlik holatlari. Bosh kuchlanishlar yo'nalishi va qiymatini analitik yoki grafik usulda aniqlashga oid turli ko'rinishdagi misollar echish lozim. Bunday masalalar V.K.Kachurinning "Materiallar qarshiligidan masalalar to'plami"da 2-8,2-11,2-12,2-13 va h.k. masalalari; M.Ergashevning "Materiallar qarshiligidan hisoblash loyihalash" kitobida ko'p sonli masalalar variantlari keltirilgan. Bunday misollarni ko'proq qurilish mutaxassisligi-da tahsil olayotgan talabalar echishi lozim. Chunki bunday masalalar balkani egilishga to'liq hisoblashda kerak buladi. To'qimachilik mutaxassisligi talabalariga esa ingichka ipni mustahkamligi bilan bog'liq masalalarni echish lozim. Mashinasozlik mutaxassis-ligida valni buralish bilan egilishga hisoblashda tekis kuchlan-ganlik holatidan foydalaniladi

Siljish. Parchin mixli birikmani qirqilishga va ezilishga hisoblash bilan birga, har bir detal cho'zilishga ham hisoblanadi, parchin mix o'mi va soni to'g'ri hisoblanganmi – yo'qmi tahlil qilinadi. Birikmaga qo'yilishi mumkin bo'lgan kuchni ruxsat etilgan qiymati, biriktiriluvchi detallar kesimining o'lchamlari eni va qalinligi hisoblanadi. Misolni echish sifatini doskada aniq va ravon chiroyli chizilgan sxemasi ham belgilaydi, bunday ayrim detallarni aksonometrik ko'rinishlari berilishi kerak. [12]

to'plamdan 3,1; 3,4; 3,5; 3,9; 3,10; 3,12; 3,15; 3,16; 3,19; 3,20 masalalar tavsiya etiladi.

Tekis kesim yuzalarining geometrik xarakteristikalari.

Amaliy mashg'ulotga talabalar ma'ruzada eshitgan va konspektlashtirib olgan mavzusini o'rganib kelishi shartligi eslatib qo'yiladi. Amaliy mashg'ulotda echiladigan masalalar ikkita nosimmetrik, imkoni boricha prokat profillaridan tashkil topgan, murakkab shaklli kesimlar tanlab olinadi. Bunday masalalar [4,5,7,8] kitoblarda ko'plab uchraydi. Dars davomida echilgan misollarni mustahkamlash uchun talabalarni mustaqil ishi sifatida, ularga hisoblash-grafik ishi mo'ljallanadi



2 -rasm

misol. Rasmda ko'rsatilgan teng yonli bo'lmagan burchakning og'irlik markazi koordinatalarini aniqlang, shakl yuzasining bosh markaziy inertsiya o'qlari vaziyatini toping va shu o'qlarga nisbatan inertsiya momentlarini hisoblang.

echish. Kesimni M 1:1 masshtabda chizamiz va ikkita to'g'ri to'rtburchakdan tashkil topgan deb, har bir yuzaning og'irlik markazlaridan $x_1O_1y_1$ va $x_2O_2y_2$ koordinata o'qlarini o'tkazamiz (*2-rasm*). Kesim alohida yuzalarining geometrik xarakteristikalarini hisoblaymiz

1. Kesim yuza:

$$A_1=10\cdot(50-10)=400mm^2=4sm^2$$

$$A_2=100\cdot10=100mm^2=10sm^2$$

2.Xususiy inertsiya momentlari:

$$I_{X1}=\frac{40\cdot(10)^3}{12}=\frac{1}{3}sm^4 \quad I_{y1}=\frac{1\cdot(4)^3}{12}=\frac{16}{3}sm^4 \quad I_{X2}=\frac{1\cdot(10)^3}{12}=\frac{250}{3}sm^4$$

$$I_{y2}=\frac{10\cdot(1)^3}{12}=\frac{5}{6}sm^4$$

3. Yordamchi o'qlar X,Y-ni tanlab, kesimning statik momentlarini hisoblaymiz: $\sum S_X = A_1 \cdot f_1 + A_2 \cdot f_2 \quad \sum S_Y = A_1 \cdot u_1 + A_2 \cdot u_2$

buerda $f_1 = \frac{10}{2} = 5mm = 0{,}5sm$ va $f_2 = \frac{100}{2} = 50mm = 5sm$

$u_1 = 10 + \frac{50-10}{2} = 30mm = 3sm$ va $u_2 = \frac{10}{2} = 5mm = 0{,}5sm$

Kesim og'irlik markazining koordinatalarini hisoblaymiz:

$$x_C = \frac{\sum S_Y}{A_1 + A_2} = \frac{17}{4+10} = 1{,}2sm; \quad y_C = \frac{\sum S_X}{A_1 + A_2} = \frac{52}{4+10} = 3{,}71sm$$

4. Kesimning topilgan og'irlik markazi C nuqtadan yangi X_c, Y_c o'qlarni o'tkazamiz. Kesimni shu o'qlarga nisbatan o'q va markazdan qochma inertsiya momentlarini parallel o'qlarga o'tish formulalaridan foydalanib hisoblaymiz:

$$I_{XC} = I_{X1} + b_1^2 A_1 + I_{X2} + b_2^2 A_2 = \frac{1}{3} + (3{,}21)^2 4 + \frac{250}{3} + (1{,}29)^2 10 = 141{,}53sm^4$$

$$I_{YC} = I_{Y1} + a_1^2 A_1 + I_{Y2} + a_2^2 A_2 = \frac{16}{3} + (1{,}8)^2 4 + \frac{5}{6} + (0{,}7)^2 10 = 23{,}19sm^4$$

$$I_{XCYC} = I_{X1Y1} + a_1 b_1 A_1 + I_{X2Y2} + a_2 b_2 A_2 = 1{,}8(-3{,}21)\cdot 4 + (-0{,}7)1{,}29\cdot 10 = -32{,}14sm^4$$

buerda: $I_{X1Y1} = 0$ va $I_{X2Y2} = 0$

$b_1 = -(y_C - f_1) = -(3{,}71 - 0{,}5) = -3{,}21sm$; $b_2 = f_2 - y_C = 5 - 3{,}71 = 1{,}29sm$

$a_1 = u_1 - x_C = 3 - 1{,}2 = 1{,}8sm$; va $a_2 = -(x_C - u_2) = -(1{,}2 - 0{,}5) = -0{,}7sm$

5. x_c va y_c o'qlarga bosh o'qlarning qiyalik burchagini aniqlaymiz $tg2\alpha_0 = -\frac{2I_{XCYC}}{I_{XC} - I_{YC}} = -\frac{2(-32{,}14)}{141{,}53 - 23{,}19} = 0{,}543$

bundan $2\alpha_0 = 28^\circ 30^1$ va $\alpha_0 = 14^\circ 15^1$,

$Sin\alpha_0 = 0{,}247$ $Sin2\alpha_0 = 0{,}4772$ $cos\alpha_0 = 0{,}969$ $cos2\alpha_0 = 0{,}8788$

6. Og'ishgan o'qlarga o'tish formulalaridan foydalanib bosh markaziy inertsiya momentlarini hisoblaymiz:

$$I_{XO} = I_{XC} \cdot \cos^2 \alpha_0 + I_{YC} \cdot \sin^2 \alpha_0 - I_{XCYC} \cdot \sin 2\alpha_0 = 149{,}64sm^4$$

$$I_{yO}=I_{yC}\cdot\cos^2\alpha_0+I_{xC}\cdot\sin^2\alpha_0+I_{xC\cdot yC}\cdot\sin 2\alpha_0=15{,}08\,sm^4$$

$$I_{xoyo}=\frac{I_{xC}-I_{yC}}{2}\sin 2\alpha_0+I_{xCyC}\cdot\cos 2\alpha_0=\frac{141{,}53-23{,}19}{2}0{,}4772-32{,}14\cdot 0{,}8788$$

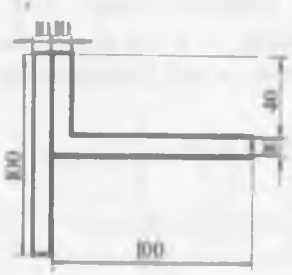
Bosh inertsiya momentlarining bittasi maksimal, ikkinchisi esa minimal qiymatga erishadi.

$$I_{\substack{max\\min}}=\frac{1}{2}\left[(I_{xC}+I_{yC})\pm\sqrt{(I_{xC}+I_{yC})^2+4\cdot I_{xCyC}^2}\right]\text{ yoki}$$

$$I_{max}=\frac{164{,}72+134{,}67}{2}=149{,}69\,sm^4\quad\text{va}\quad I_{min}=\frac{164{,}72-134{,}67}{2}=15\,sm^4$$

Arifmetik amallarni tekshirish: $I_{xO}+I_{yO}=I_{xC}+I_{yC}=const$

$$149{,}64+15{,}08=141{,}53+23{,}19=154{,}72\,sm^4$$



3-rasm

Keyingi amaliy mashg'ulotda quyidagi misolni echish mumkin. 3-rasmda ko'rsatilgan teng yonli bo'lmagan burchak $(100x50x10)mm$ bilan $(100x10)mm$ o'lchamdagi to'g'ri to'rtburchak birikma hosil qilgan. Birik-ma kesimining geometrik xarakteristikalari hisoblansin.

Buralish. 4,2; 4,3; 4,4; 4,9 [12] – masalada burovchi moment epyuri quriladi, brusning xavfli kesimi tanlanib mustahkamlik shartdan uning diametri hisoblanadi va standart qiymatga qadar yaxlitlanadi, brus ko'ndalang kesim yuzasining qutb inertsiya momenti hisoblanib brusning uzunligi bo'ylab buralish burchagining o'zgarish qonuniyati aniqlanadi va epyuri quriladi. Bir tomoni qistirib mahkamlangan pog'onali brusni hisoblash tavsiya etiladi (masala 4,11 [12]). Bu masalada burovchi moment epyuri quriladi, har bir pog'onaning ko'ndalang kesimidagi urinma kuchlanish formulasi yoziladi, lozim bo'lsa buralish burchaginin epyuri ham quriladi. [12] masalalar to'plamidan 4,15; 4,19; 4,20 masalalar taklif etiladi, 4,24; 4,25; 4,26; 4,29; 4,30 va boshqa bir qancha masalalarni [7,8] echish tavsiya etiladi.

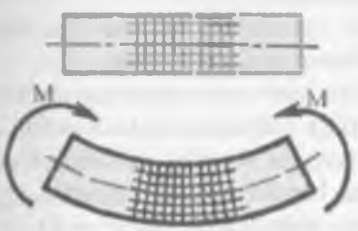
Buralishda statik noaniq masalalarga oid 2-3 ta [12]- 4,33; 4,34; 4,35 masalalarni echilish metodikasini ko'rsatish kerak Kronshteyn bilan

ustunni o'zaro 3-4-5 ta parchin mix yoki bolt yorda-midagi birikmasi berilgan masalalar mavjud [12]. Bu birikmadagi ayrim parchin mixlar bir vaqtda ham qirqilishga, ham buralishga qarshilik ko'rsatadi. Imkoniyat darajasida amaliy mashg'ulot davomida bunday masaladan echish tavsiya etiladi.(4,64; 4,65-masalalar)

Egilish. Ko'ndalang kesimida eguvchi moment va ko'ndalang kuch hosil bo'ladigan brusning yuklanishiga egilish deyiladi Konstruktsiyani egilishga ishlovchi elementlari balka, konsol, rama ko'rinishida bo'ladi Tashqi kuch ta'sirida balkaning to'g'ri chiziqli o'qi egrilanadi.

Balkani bosh tekisligi tushunchasi kiritiladi. Bosh tekislik balkani bo'ylama o'qi va ko'ndalang kesimining birorta bosh markaziy o'qlaridan o'tadi (4- rasm).

Agar, eguvchi moment bosh tekislikda va ko'ndalang kuch birorta bosh markaziy o'qlarda hosil bo'lsa to'g'ri egilish deyiladi.To'g'ri egilish tekis egilish deb ham yuritiladi. Agar, balka o'qining egilish yo'nalishi tashqi kuchning ta'sirchizig'i bilan mos tushsa tekis egilish bo'ladi



4 - rasm

Oddiy qilib tushuntirilganda tashqi kuch balkani qaysi tomonga egiltirsa, u shu tomonga egiladi. Balkani egilish xarakterini ustiga setka shaklida to'g'ri chiziq chizilgan rezinani egilishida tasvirlash mumkin.(*4-rasm*).

Plastik materiallardan tayyorlangan balkalarda mustahkamlik shart asosida uch xil masala echilishi mumkin.

1.Konstruktsiyaga qo'yilishi mumkin bo'lgan yuk $M_{max} = [\sigma] \cdot W_z$

2.Konstruktsiyaning kesimi tanlanadi $W_z \geq \frac{M_{max}}{[\sigma]}$

3.Mustahkamlik shart tekshiriladi $\sigma_{max} \leq [\sigma]$

Plastik materialdan tayyorlangan simmetrik kesimli balka-larning qanday shaklli kesimi ratsional va ratsionallik kriteriy-si nima degan savolni echimini aniqlash lozim. Balka minimal massaga va yuqori mustahkamlikka ega bo'lishi kerak. Balkani berilgan materiali va

darajasi ochilgan har qanday statik noaniq sistema – statik aniq sistemadir. Sistemani aniqmaslik darajasi qo'shimcha tenglamalar tuzilishi bilan ochiladi.

Egilishda statik noaniq sistemalar mavzusiga oid masala qurilish mutaxassisligida echiladi, mashinashunoslik mutaxassisligida esa bunday masalalarga zaruriyat yo'q. Shunday bo'lsa ham mavzuga ajratilgan soat etisharli bo'lsa statik noaniq balkalarni hisoblash metodiga oid 2-3 ta masala echish mumkin. Qurilish mutaxassisligida uzluksiz balkalar va statik noaniq ramalarni hisoblashga oid auditoriyada va talabalarni mustaqil ishida jami 4-5 tadan masala echish tavsiya etiladi. Har qanday statik noaniq masala echimining nazorati mavjud. Statik noaniq ramalarda bunday tekshirishda quyidagi tenglik bajarilishi shart:

$\delta_{11} + \delta_{12} + \delta_{21} + \delta_{22} = \delta_s$, buerda $\delta_s = \frac{\omega_s M_s}{EJ}$ birlik kuchlarni asosiy ramaga bir vaqtda ta`sir qilgandagi V nuqtani ko'chishi, ω_s mazkur kuchlardan qurilgan moment epyurining yuzasi. Amaliy mashg'ulotlarda quyidagi masalalarni [12] echish tavsiya etiladi: 1) Uzluksiz balkalar 9.8; 9.9; 9.10; 9.17; 9.22; 9.30; 9.33; 2) Statik noaniq ramalar 9.37; 9.38; 9.43; 9.44;

Kiyshik egilish. Birinchi bo'lib 10.5 va 10.7 masalalarni [4], keyin fazoviy qiyshiq egilishga oid 10.24 masala [12], vaqt etarli bo'lsa 10.16 masala [12] echib ko'rsatilsa bo'ladi. 10.16 va 10.24 masalalar variant ko'rinishida berilgan. Shuning uchun bu masalalardan talabalarni mustaqil ishi sifatida ham foyda-lanish mumkin.

Markazlashmagan siqilish (cho'zilish). Amaliy mashg'ulotda birinchi masala [12] engilroq ko'rinishda 10-27 misol bo'lishi kerak. Mashinasozlik mutaxassisligi uchun 10-33 masala [12] va barcha ta`lim yo'nalishlari uchun 10-48 masala [12] echilishini tavsiya etamiz. Bir juftlik soatda 2-3 ta masala echilsa maqsadga muvofiq bo'ladi.Ayrim masalalarni talabalarni mustaqil ishi (10.48- masala) sifatida tavsiya etilishi mumkin. 10-52 va 10-53 masalalar [12] kesim yadrosiga oid. O`qituvchini o`zi ham darsga masala tuzib kelishi mumkin.

**Buralish bilan egilishni birgalikdagi ta`siri**. Valni buralish bilan egilishga hisoblashga oid talabalarni mustaqil ishi shaklidagi hisoblash – grafik ishi (mashinasozlik mutaxassisligi uchun) mavjud. Amaliy mashg`ulotlarda 10.77; 10.80; 10.101 va hokazo masalalarni [12] echishni tavsiya etamiz. Hisoblash – grafik ishining variantlari kafedra

tomonidan tuziladi yoki [7] –qo'llanmadan olinadi. Mavzuga oid masala echish asosida talaba valni hisoblash va loyihalash asoslarini o'rganadilar.

Siqilgan sterjenlarning ustuvorligi. Nazariy mate-riallarni o'rganib masala echishga o'tish kerak. Bu mavzuga oid qurilish mutaxassisligida 4 soat va mexanik mutaxassisliklarda 2 soat vaqt ajratiladi. Materiallar qarshiligidan asosiy masalalar to'plamining [12] rus tilida nashr qilinganida ko'proq masala berilgan. Shuning uchun o'zbek tilida nashr qilingan boshqa masalalar to'plami [7,8] dan foydalanish mumkin. [12] masalalar to'plamida 11.13 va 11.15 masalalar variant shaklida berilgan masalalar turiga kiradi.

Birinchi masala ruxsat etilgan kuchni aniqlashga oid bo'lsa maqsadga muvofiq. Bunda shveller, qo'shtavr profillari va listdan tashkil topgan nosimmetrik kesimlar tadbiq etilishi mumkin.

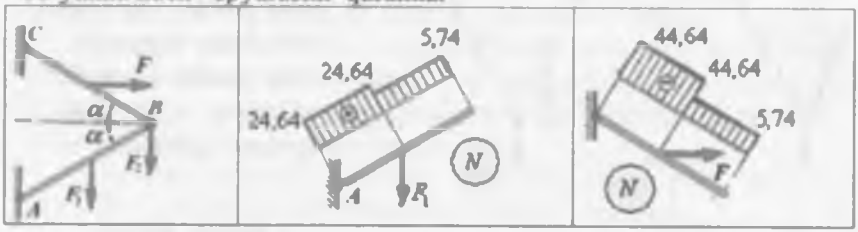
Loyihaviy hisoblashga oid masala echish samarali bo'ladi. Bunda turli tayanchli va kesim shakli har xil bo'lgan, turli materiallardan tayyorlangan sterjenlar tadbiq etilsa, masala turi ko'p bo'ladi. Lekin, bunday masalalarni dars davomida echish ko'p vaqtni talab etadi va ozroq zerikarli bo'lishi mumkin. Shuning uchun loyihaviy hisoblashga oid masalalarni talabalarga uyga vazifa sifatida mustaqil ish tarkibida mo'ljallash mumkin. Bir – ikkita masala siqilayotgan sterjen ko'ndalang kesimining ratsional shakliga oid bo'lishi mumkin.

Dinamik kuchlanishlar. Dinamik kuchlanishlar mavzusiga oid masala echish uchun, mutaxassislikga qarab 2-4 soat vaqti ajratilishi mumkin. [12] masalalar to'plamida jami 6 ta masala berilgan, bo'lib, ulardan 12.1; 12.3; 12.4; 12.5 va 12.6 masalalarni echish mumkin. [19]-adabiyotda 17.1. va 18.1 masalalar ko'p variantli masalalar turkumiga kiradi. Bu masalalarni birinchisida tebranma harakatda qo'shtavr kesimli sterjenda eng katta normal kuchlanishni topish talab etilsa, ikkinchisida zarb ta'sirida konsol balkani zaif kesimidagi dinamik normal kuchlanish ikki xil variantda hisoblanishi talab etiladi: 1 – variantda konsol-balka sharnirli tayanchga tayanadi va 2 – variantda o'ng tayanch ustiga prujina o'rna-tiladi.

O'zgaruvchan kuchlanishlar. Bu mavzuga oid masala echish uchun hamma mutaxassisliklarda ham etarliga vaqt ajratilmaydi, lekin mashinasozlik mutaxassisligida albatta 2-3 ta masala echilishi kerak.

3. Brusni har bir pog'onasini kesish usulidan foydalanib kesamiz va ajratib olingan qismining muvozanat tenglamasini tuzib, ichki bo'ylama kuchni hisoblaymiz.

4. Sterjenni (pog'onali brusni) uzunligi bo'ylab ichki bo'ylama kuch epyurasini quramiz.



7-rasm.Sterjenlarda ichki buylama kuch epyurasi.

echish. Sterjenlarni kesish usuli asosida bog'lanishdan ozod etib, kesilgan yuzalarga ichki kuchlarni qo'yamiz, tenglamalarini tuzamiz:

I-I qirqim: $N_1 = -N_2 - \frac{F}{\cos\alpha}$ va $N_2 = \frac{1}{2\sin\alpha}(-F\frac{\sin\alpha}{\cos\alpha} - F_1 - F_2)$

II-II qirqim: $N_1 = -N_2$ va $N_2 = -\frac{F}{2\sin\alpha}$

javoblar

№	kuch	1	2	3	4	5	6	7	8	9	0
1-1 qirqim	N_1	311,7	150,7	92,7	59,4	32,9	24,6	23,6	27	36,9	61,1
	N_2	-322	-171	-127	-111	-110	44,6	54,7	66,2	83,1	-114
2-2 qirqim	N_1	28,8	29,2	30	31,1	32,6	5,74	13	23,3	40	73,1
	N_2	-28,8	-29,2	-30	31,1	32,6	5,74	-13	23,3	-40	73,1

Pog'onali brusda ichki kuchlar hisoblansin.

1. Reaktsiya kuchini hisoblaymiz.

$$\sum y = R_C - F + F_1 - F = 0 \quad \text{va} \quad R_C = F - F_1 + F_2$$

2. Brusni har bir pog'onasi uchun N_X tengla-malarini tuzamiz: Yuqori pog'ona $\sum y = -N_1 + R_C = 0$ va $N_1 = R_C$

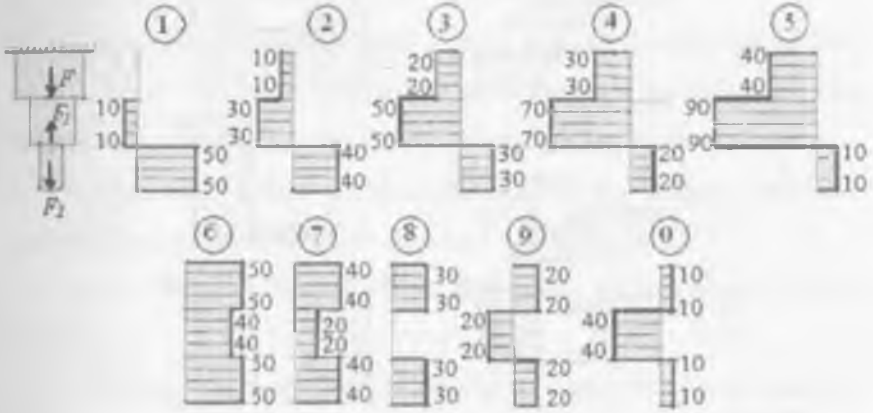
O'rta pog'ona $\sum y = -N_1 + R_C - F = 0$ va $N_1 = R_C - F$

Pastki pog'ona $\sum y = -N_1 + R_C - F + F_1 = 0$ va $N_1 = R_C - F + F_1$

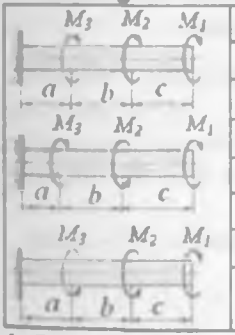
Tenglamalarda kuchlaming qiymatlari 1-jadvaldan olindi	№	R_C	N_1	N_2	N_3
	1	0	-	-10	50
	2	-10	-10	-30	40
	3	-20	-20	-50	30
	4	-30	-30	-70	20
	5	-4-	-40	-90	10
	6	50	50	40	50
	7	40	40	20	40
	8	30	30	0	30
	9	20	20	-20	20
	10	10	10	-40	10

Talabalar berilgan masala uchun tuzilgan tenglamalar yordamida pog'onali brusning ichki kuchlarini hisoblab, natijasini ushbu jadvaldagi javoblar bilan tekshiradilar.

Bo'ylama kuch epyuralari.



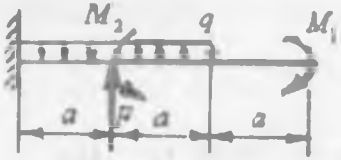
2-kichik guruh: **Buralishga oid misol.**



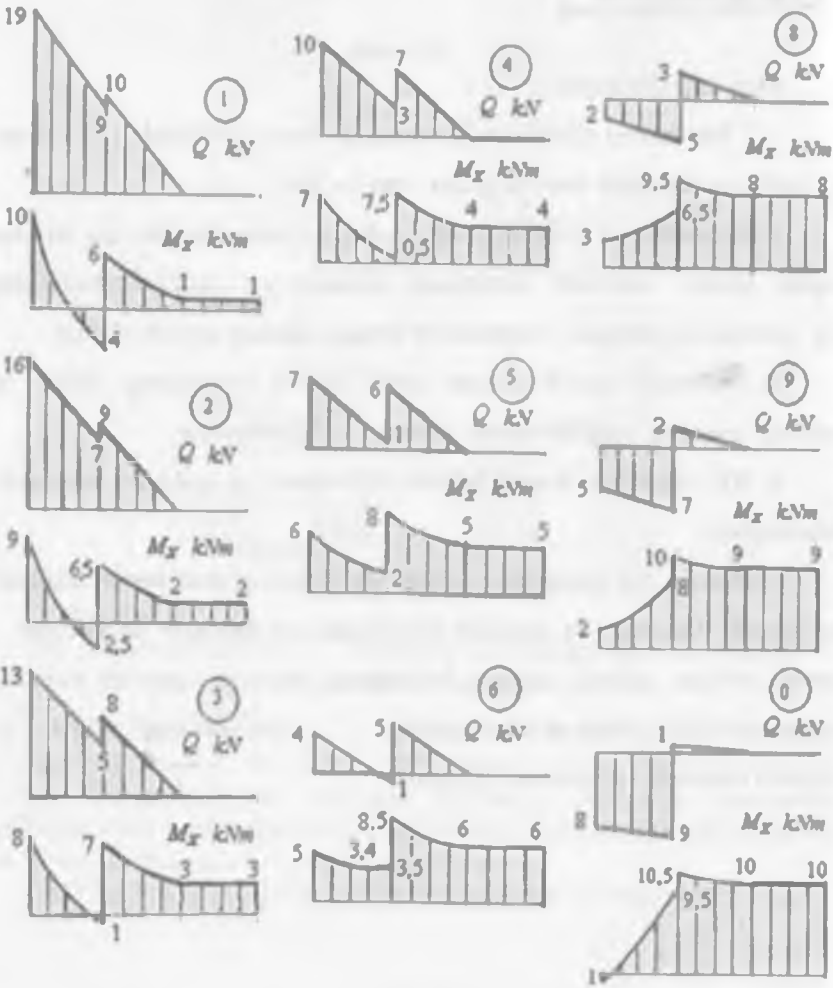
№	1	2	3	4	5	6	7	8	9	0
M_{1c}	10	20	30	40	50	60	70	80	90	100
M	100	90	80	70	60	50	40	30	100	100
M_3	10	20	30	40	50	60	70	80	90	100
a	1	2	3	4	5	5	4	3	2	1
b	5	4	3	2	1	1	2	3	4	5
s	1	2	3	4	5	6	7	8	9	10

8 – rasm. 2 - jadval

1. Sterjenni har bir oraliq kesimidagi burovchi moment topilsin.



Ko'ndalang kuch va eguvchi moment epyuralari.



11-rasm.

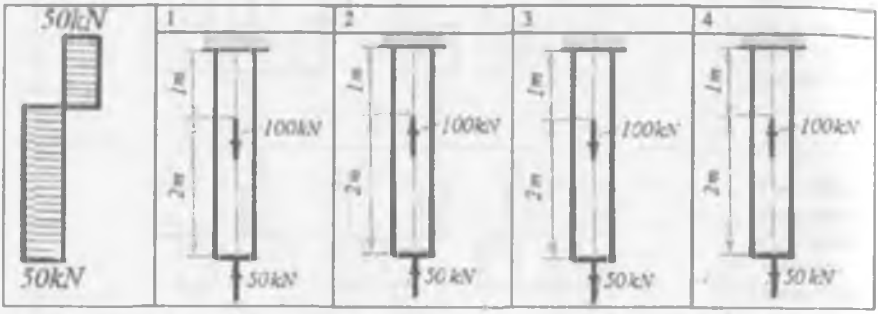
Xulosa chiqarish. Talabalar bajargan topshiriqlarini, o'qituvchi tahlil qilib yakuniy suhbat o'tkazadi va keyingi mashg'ulotda nimalarga e'tibor berish kerakligini aytib o'tadi.

2 – 3 mashg'ulot (80 daqiqa). Kesish usuliga asoslanib inshoot element-laridagi ichki kuch faktorlarini aniqlash bo'yicha ijodiy topshiriqlarni bajaradilar. O'qituvchi tomonidan oldingi mashg'ulotda ushbu mavzuga oid masala echishda yuzaga kelgan ayrim muammolar to'g'risida to'xtalib o'tadi va ularni takrorlamaslik uchun tavsiyalar beradi. Bu vaziyatda iqtidorli talabalarning fikrlarini ham tinglash lozim bo'ladi. Kichik guruhlarning har biriga ijodiy topshiriqlar beriladi va ular topshiriqni bajaradilar. Bunda oldingi mashg'ulotda topshiriqni bajargan talabalar yangi masalani echish tartibi va uslubini fikrlashishlari mumkin. O'qituvchi talabalar ishini kuzatib turadi. Har bir guruh talabalari masalani belgilangan vaqtda bajarishlari lozim. O'qituvchi bajarilgan masalani tekshirib, ularni ma'lum mezon asosida baholaydi. Topshiriqni bajarishda ijodiy yondashuv ham alohida baholanishi lozim. Talabalar bajargan ishini baholash orqali ularning mustaqil va ijodiy qobiliyatlari haqida ham ma'lumotga ega bo'lish mumkin.

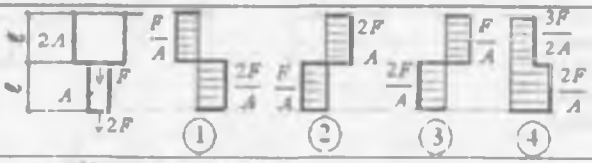
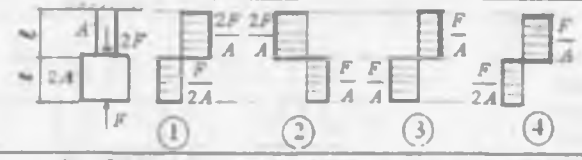
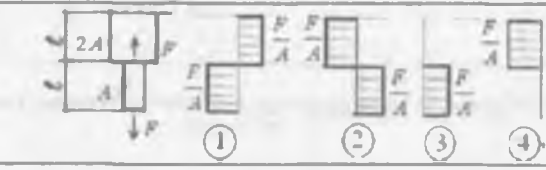
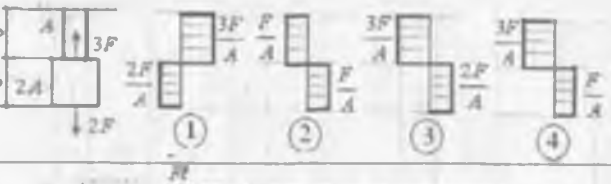
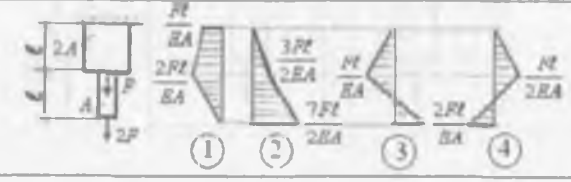
Baholash mezonlari.

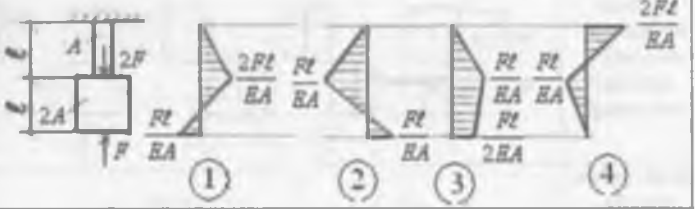
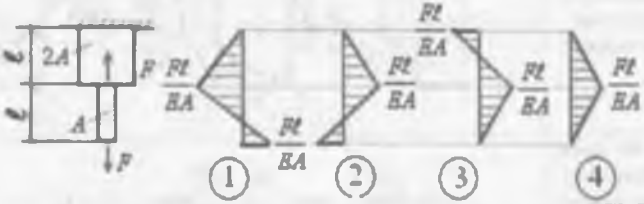
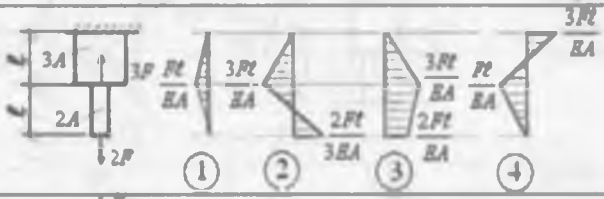
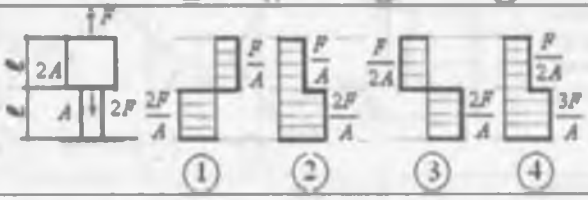
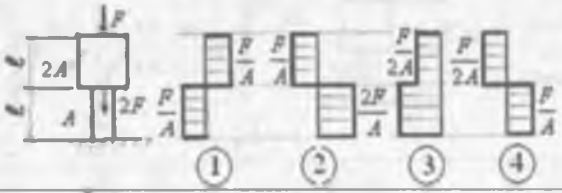
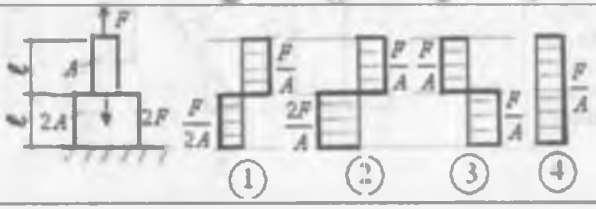
Ball	Baho	Talabalarning bilim darajasi
86-100%	A'lo	- kesish usulining mohiyati va tartibini bilish; - brusni yuklanish sxemasiga ko'ra qanday ichki kuch faktori hosil bo'lganini aniqlash; - ikki tayanchli balkalarda reaktsiya kuchlarini aniqlash; - brusni (balkani) ajratib olingan qismi uchun muvozanat tenglamalarini tuzish; - ichki kuch faktorini hisoblash va uning ishorasini tanlash; - ichki kuch faktorining epyurasini qurish.
71-85%	Yaxshi	- kesish usulining mohiyati va tartibini bilish; - ikki tayanchli balkalarda reaktsiya kuchlarini aniqlash; - brusni (balkani) ajratib olingan qismi uchun muvozanat tenglamalarini tuzish; - ichki kuch faktorini hisoblash va uning ishorasini tanlash; - ichki kuch faktorining epyurasini qurish.
55-70%	Qoniqarli	- kesish usulining mohiyati va tartibini bilish; -ikki tayanchli balkalarda reaktsiya kuchlarini aniqlash; - brusni (balkani) ajratib olingan qismi uchun muvozanat tenglamalarini tuzish; - ichki kuch faktorini hisoblash va uning ishorasini tanlash.
0-54%	Qoniqarsiz	- kesish usulining mohiyati va tartibini bilmaslik.

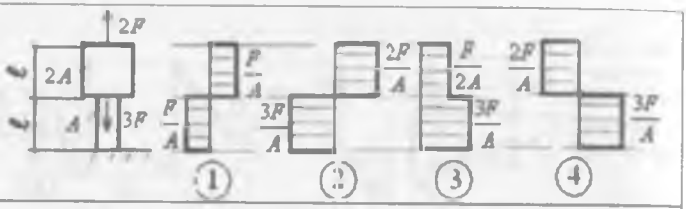
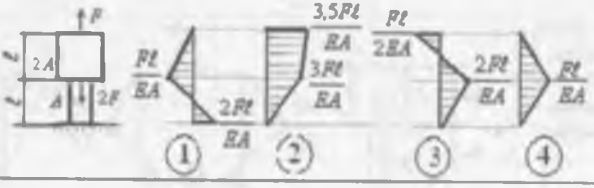
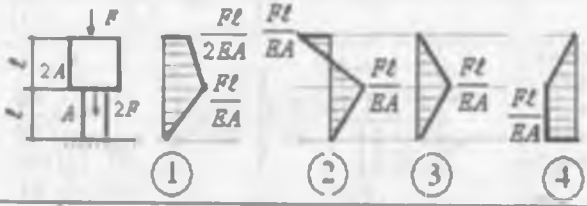
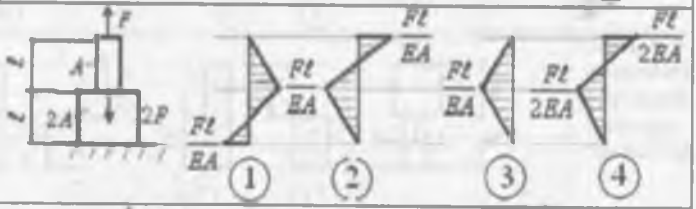
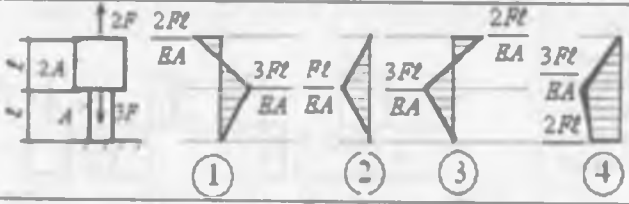
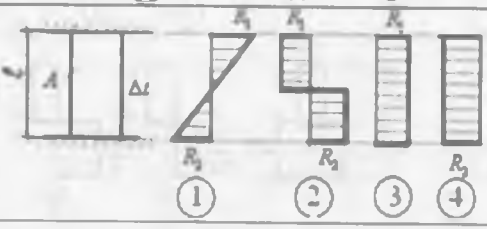
11. Ichki bo'ylama kuchning epyurasiga mos keluvchi brusning yuklanish sxemasini ko'rsating?

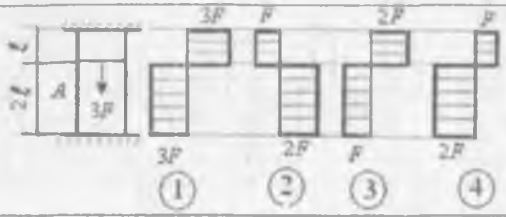
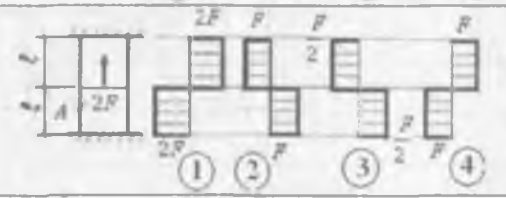
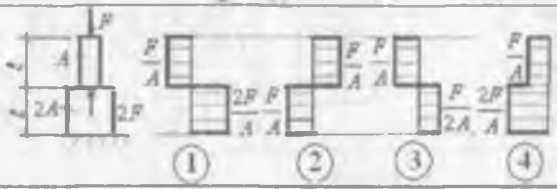
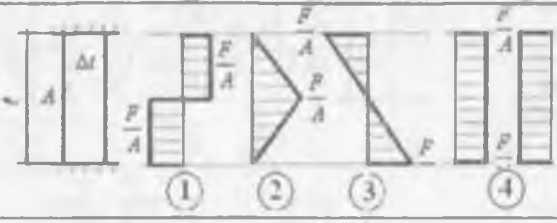
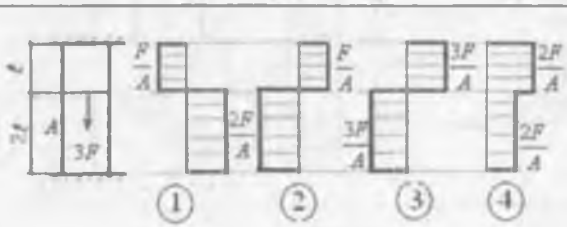


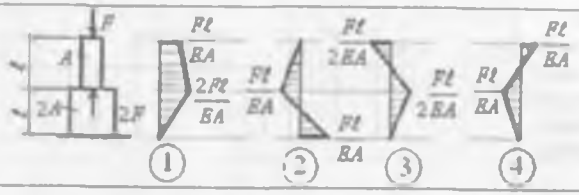
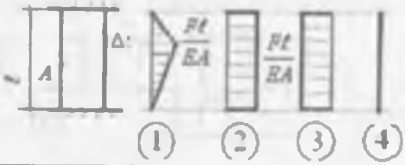
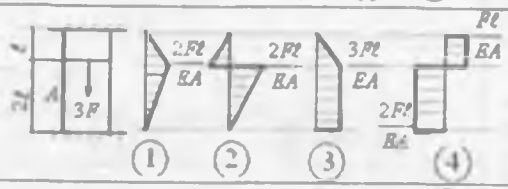
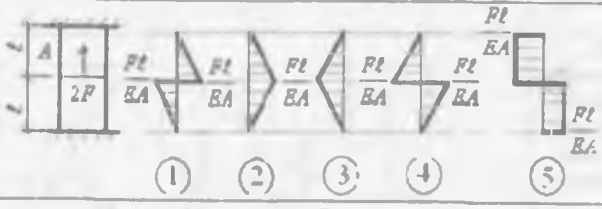
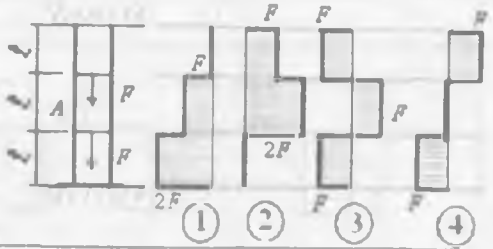
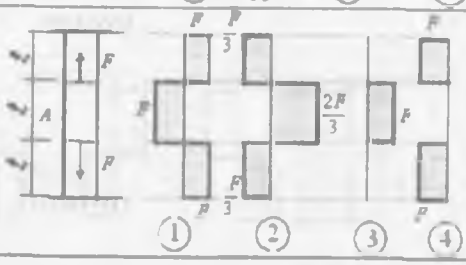
2. Cho'zilish va siqilishda normal kuchlanish va bo'ylama uzayishni aniqlashga oid testlar

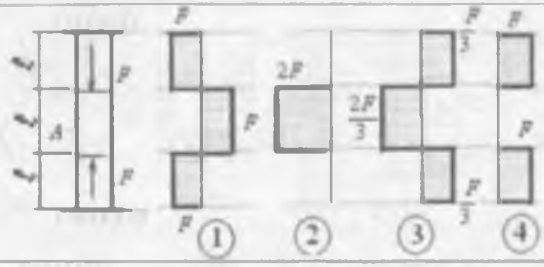
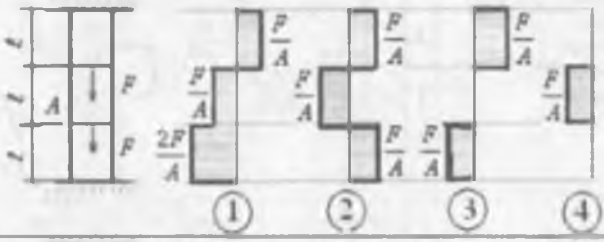
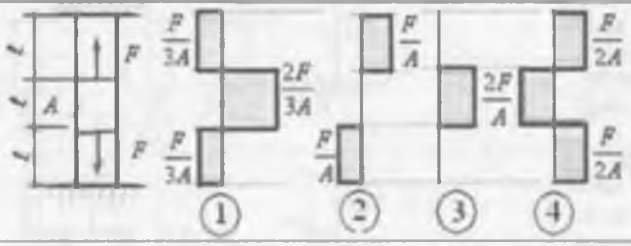
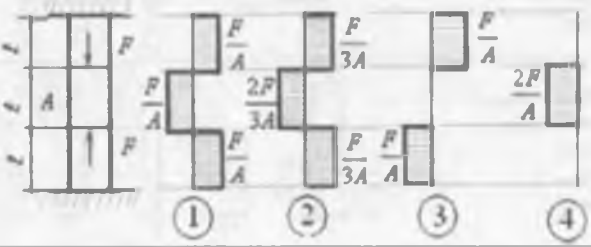
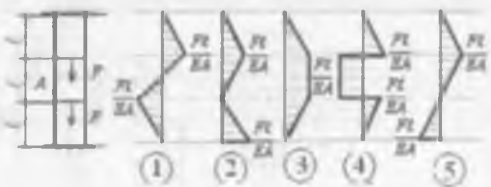
1.Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	
2.Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	
3. Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	
4. Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	
5. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	

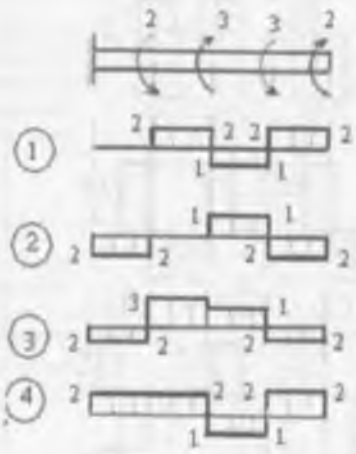
6. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	
7. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	
8. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	
9. Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	
10. Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	
11. Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	

12. Normal kuchlanish-ning to'g'ri epyurini ko'rsating?	
13. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	
14. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	
15. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	
16. Bo'ylama uzayish-ning to'g'ri epyurini ko'rsating?	
17. Ichki bo'y-lama kuch-ning to'g'ri epyurini ko'rsating?	

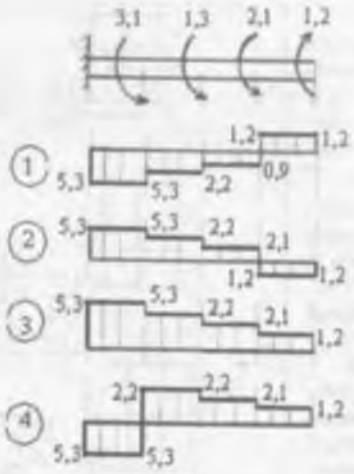
18. Ichki bo'ylama kuchning to'g'ri epyurini ko'rsating?	
19. Ichki bo'ylama kuchning to'g'ri epyurini ko'rsating?	
20. Normal kuchlanishning to'g'ri epyurini ko'rsating?	
21. Normal kuchlanishning to'g'ri epyurini ko'rsating?	
22. Normal kuchlanishning to'g'ri epyurini ko'rsating?	
23. Normal kuchlanishning to'g'ri epyurini ko'rsating?	

24. Bo'ylama uzayishning to'g'ri epyurini ko'rsating?	
25. Bo'ylama uzayishning to'g'ri epyurini ko'rsating?	
26. Bo'ylama uzayishning to'g'ri epyurini ko'rsating?	
27. Bo'ylama uzayishning to'g'ri epyurini ko'rsating?	
28. Ichki bo'ylama kuchning to'g'ri epyurini ko'rsating?	
29. Ichki bo'ylama kuchning to'g'ri epyurini ko'rsating?	

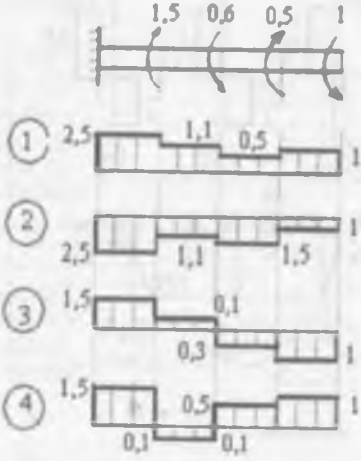
30. Ichki bo'ylama kuchning to'g'ri epyurini ko'rsating?	
31. Normal kuchlanishning to'g'ri epyurini ko'rsating?	
32. Normal kuchlanishning to'g'ri epyurini ko'rsating?	
33. Normal kuchlanishning to'g'ri epyurini ko'rsating?	
34. Bo'ylama uzayishning to'g'ri epyurini ko'rsating?	



3. Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?



4. Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?



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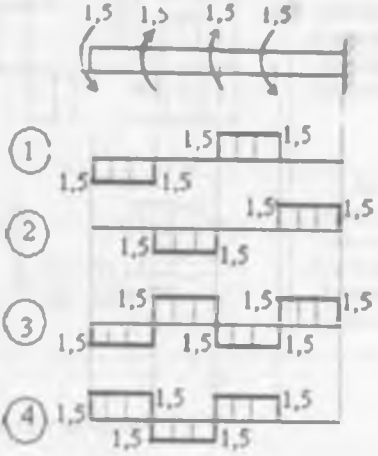
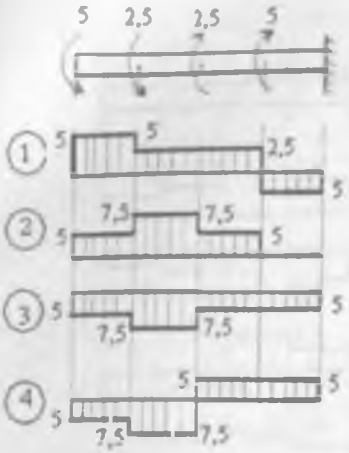
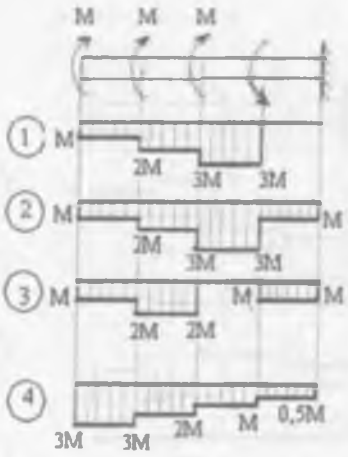


6 Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?



7 Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?



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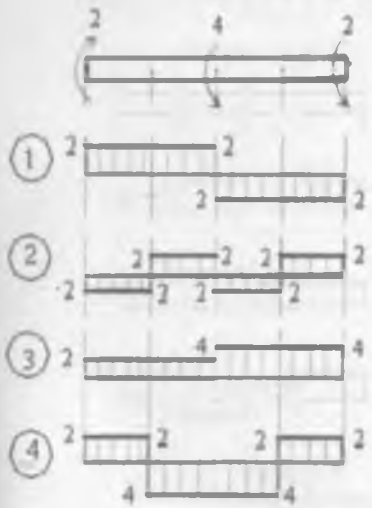
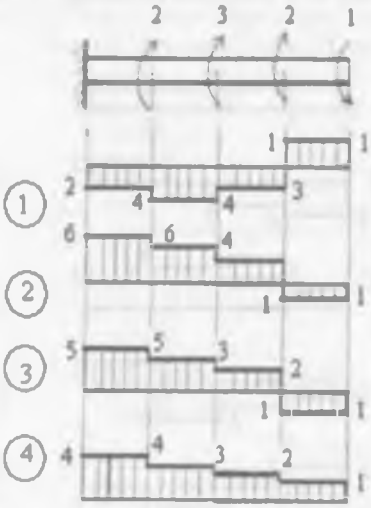
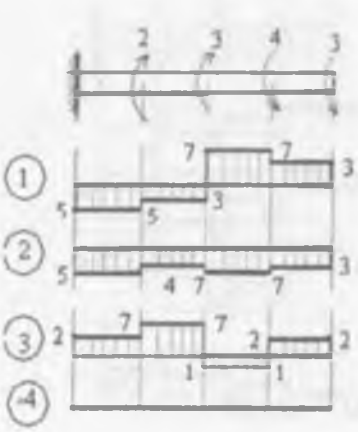


9 Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?



10 Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?



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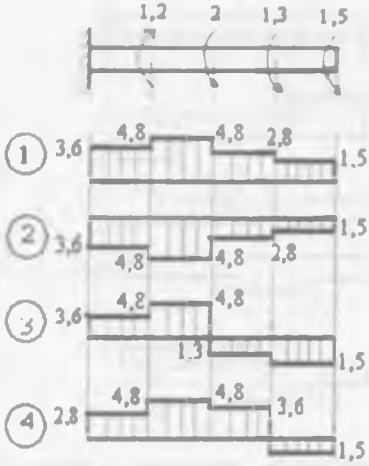
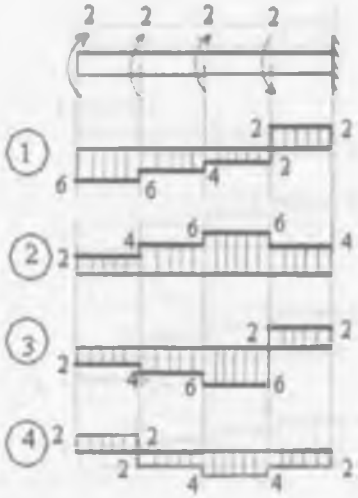
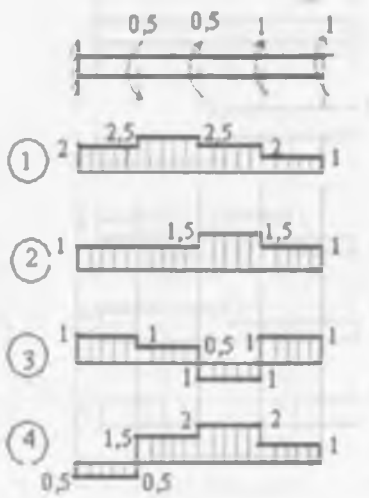


12 Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?

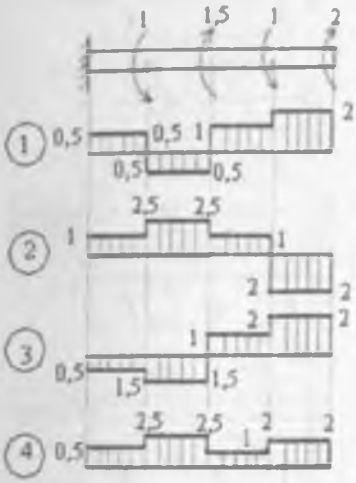


13 Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi

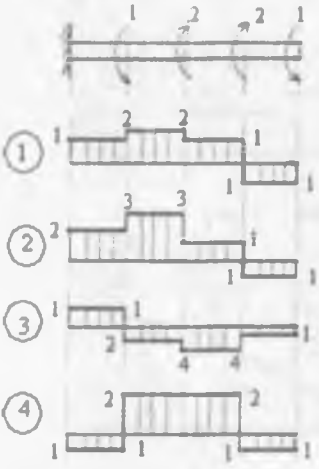


14 Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni

moment to'g'ri epyurini ko'rsating?



burovchi moment to'g'ri epyurini ko'rsating?



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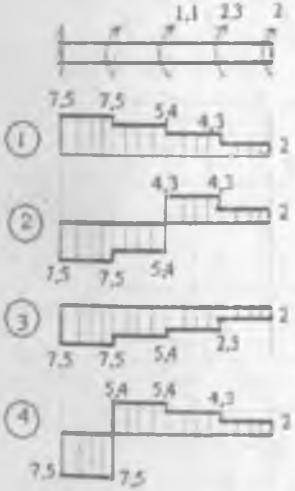
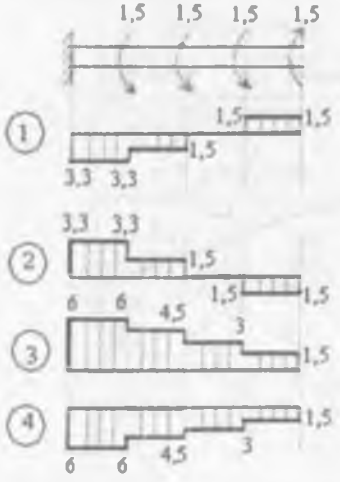
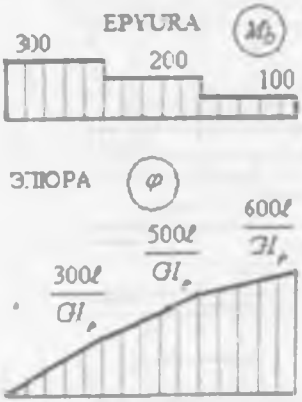


Aylantiruvchi momentlar (*kN.m*) bilan yuklangan sterjenni burovchi moment to'g'ri epyurini ko'rsating?



4. Doiraviy kesimli sterjenlarni buralishiga oid testlar

1. Burovchi moment (*kN.M*) va buralish burchagi epyurlari asosida sterjenni yuklanish sxemasini ko'rsating?



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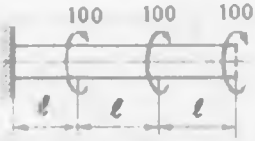

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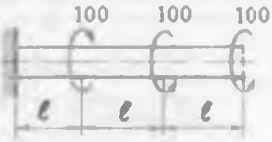

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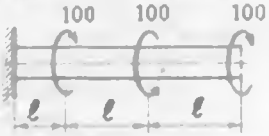

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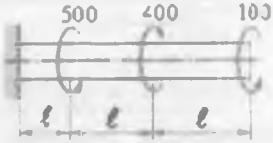

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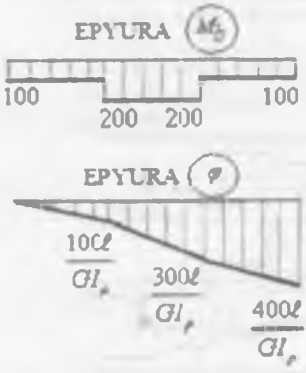

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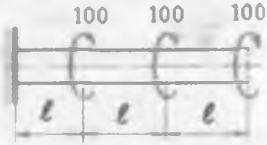

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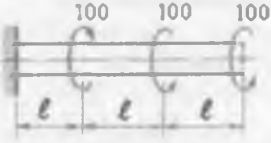

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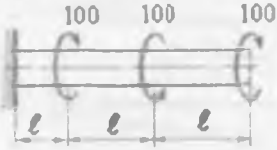

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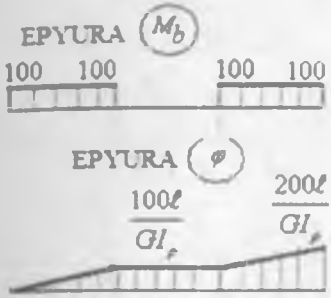

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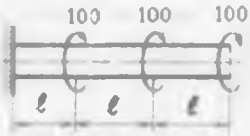

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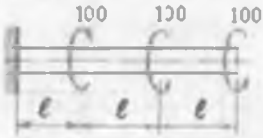

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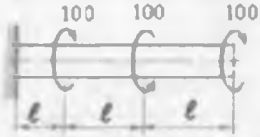

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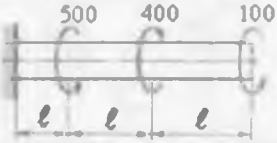
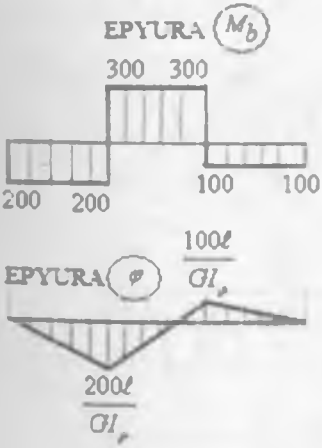


4. Burovchi moment (*kN.M*) va buralish burchagi epyurlari asosida sterjenni yuklanish sxemasini ko'rsating?



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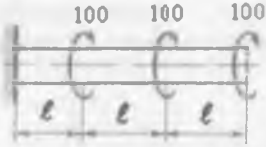

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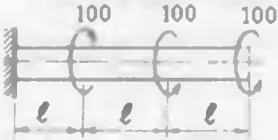

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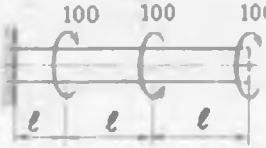

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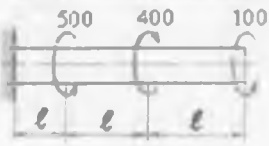
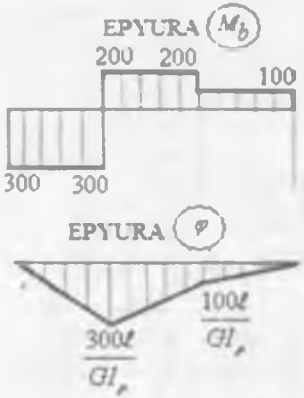


5 .Burovchi moment (*kN.M*) va buralish burchagi epyurlari asosida sterjenni yuklanish sxemasini ko'rsating?



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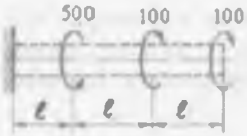

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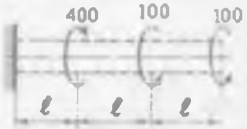

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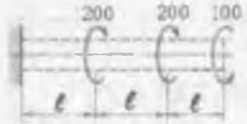

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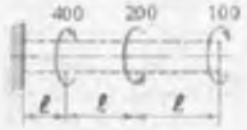
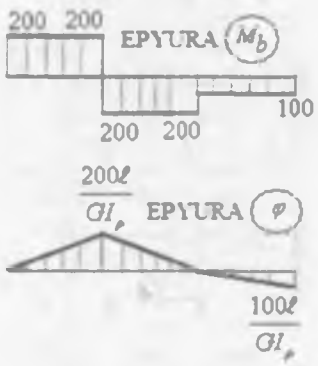


6.Burovchi moment (*kN.M*) va buralish burchagi epyurlari asosida sterjenni yuklanish sxemasini ko'rsating?



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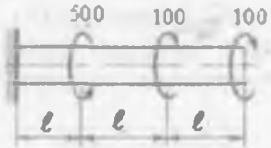

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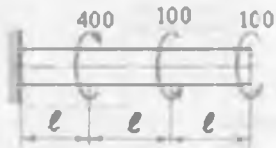

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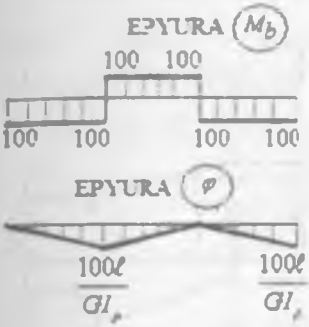

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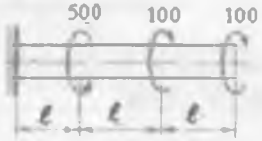

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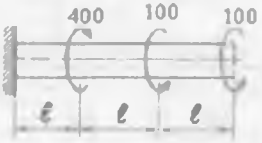

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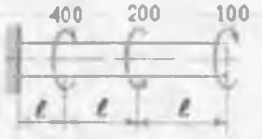
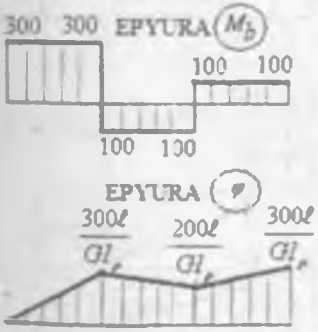


8 .Burovchi moment (*kN.M*) va buralish burchagi epyurlari asosida sterjenni yuklanish sxemasini ko'rsating?



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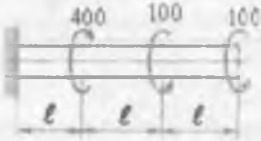

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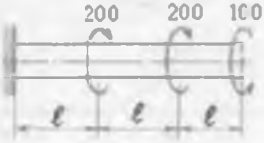

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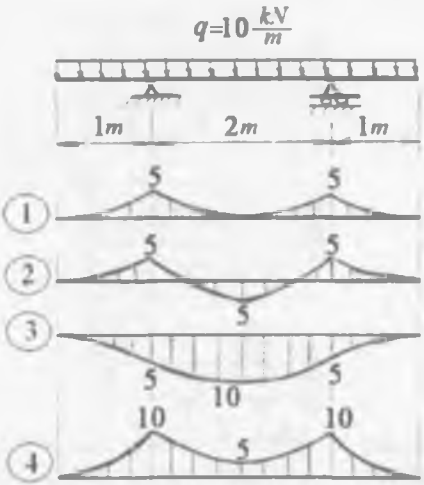
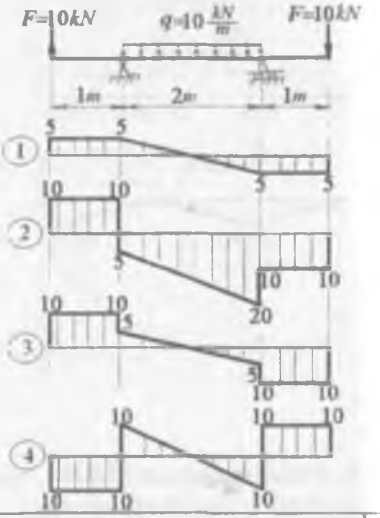
5. Ko'ndalang kuch va eguvchi momentni aniqlash

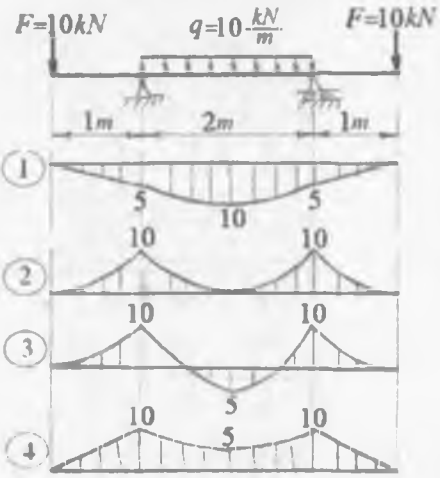
1. Balka eguvchi momentining (*kNm*) to'g ri epyurini ko'rsating?



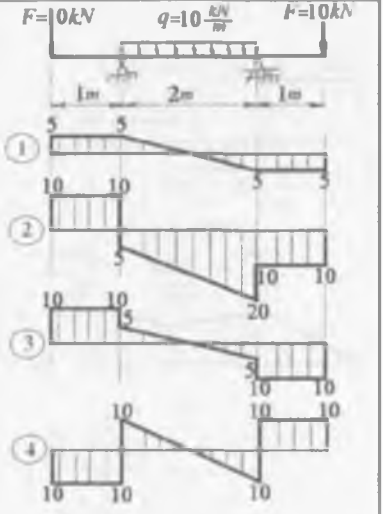
2. Balka ko'ndalang kuchining (*kN*) to'g'ri epyurini ko'rsating?

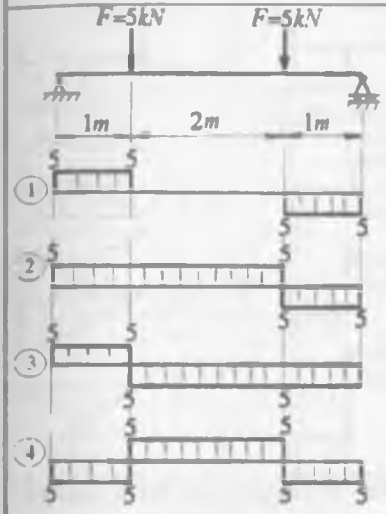
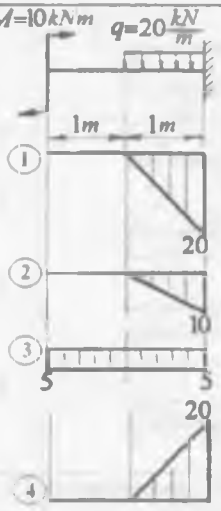
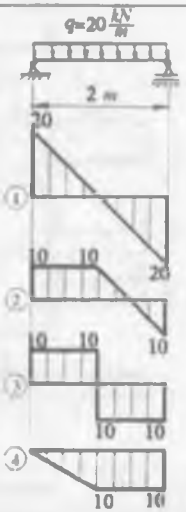
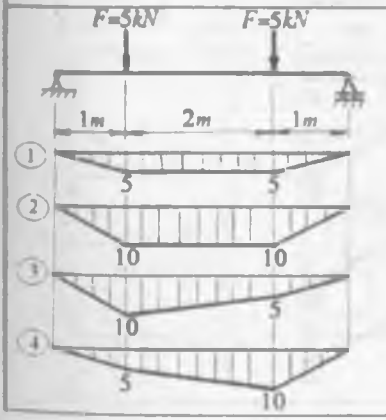
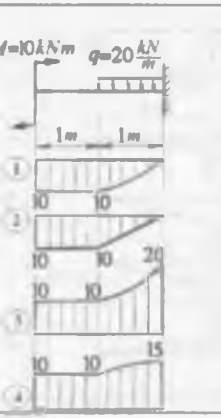
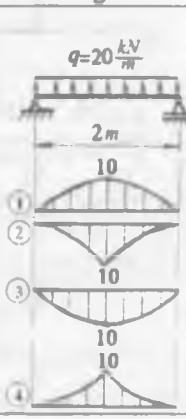


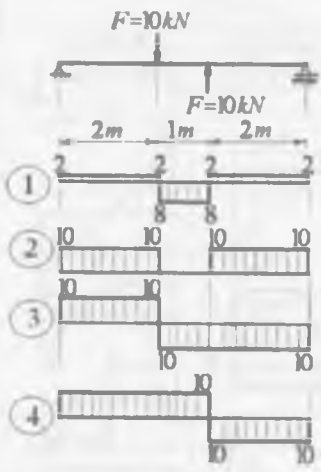
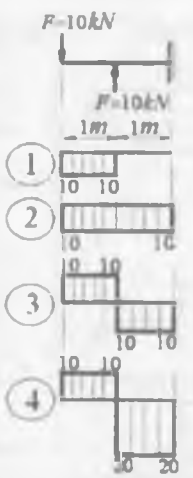
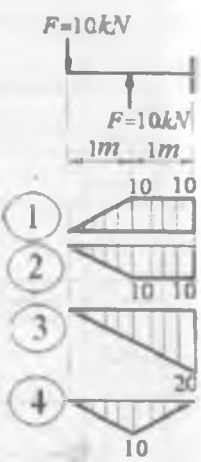
3. Balka eguvchi momentining (*kNm*) to'g'ri epyurini ko'rsating?



4. Balka ko'ndalang kuchining (*kN*) to'g'ri epyurini ko'rsating?



5. Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?	6. Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?	7. Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?
		
8. Balka eguvchi momentining *(kNm)* to'g'ri epyurini ko'rsating?	9. Balka eguvchi momentining *(kNm)* to'g'ri epyurini ko'rsating?	10. Balka eguvchi momentining *(kNm)* to'g'ri epyurini ko'rsating?
		

11. Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?	12. Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?	13. Balka eguvchi mo-mentining *(kNm)* to'g' -ri epyurini ko'rsating?
		
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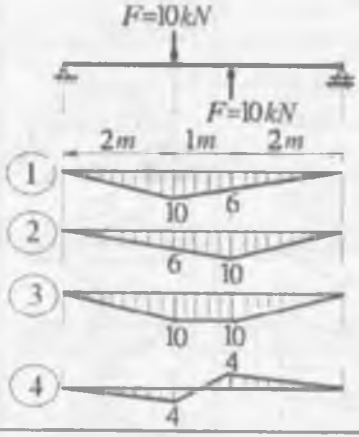	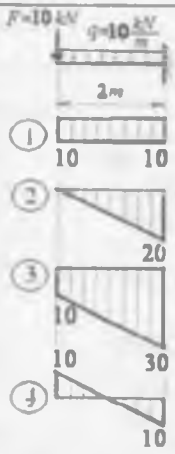	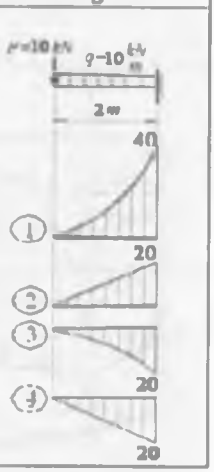

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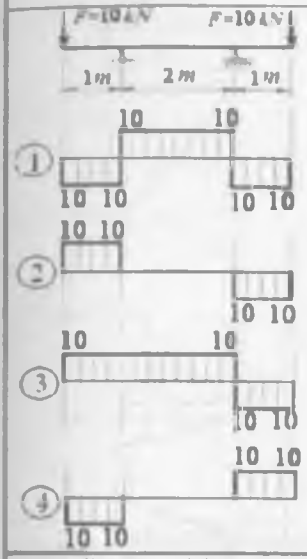

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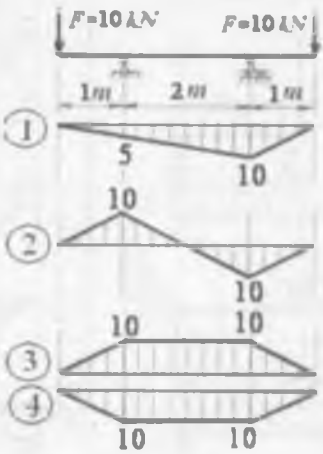

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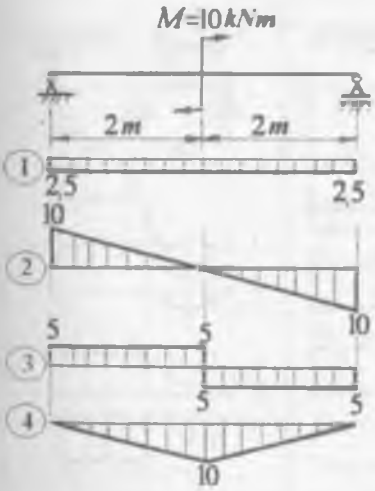

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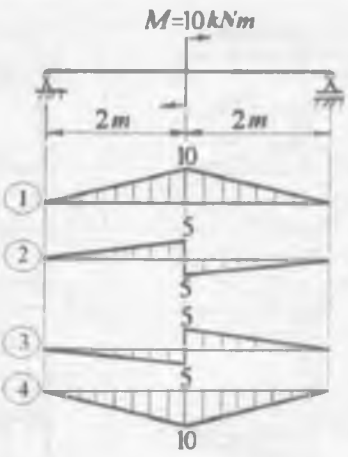
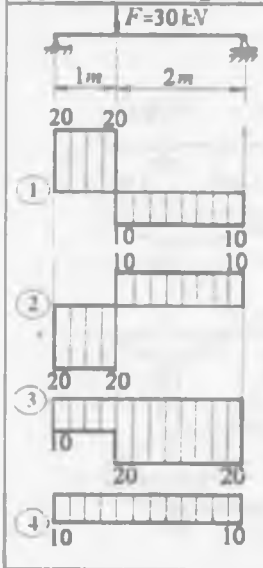
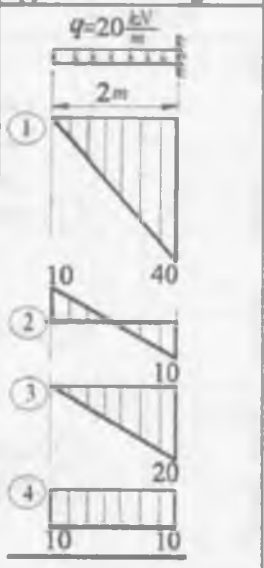
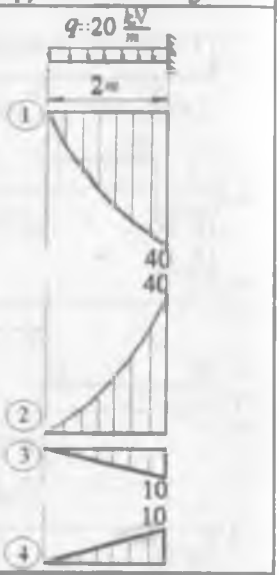
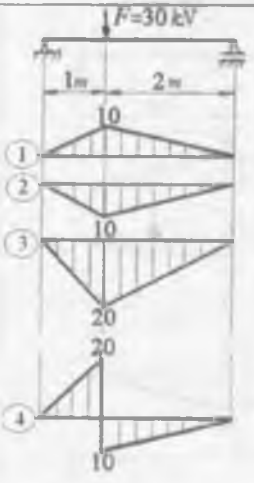
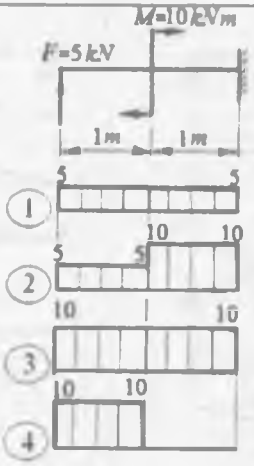
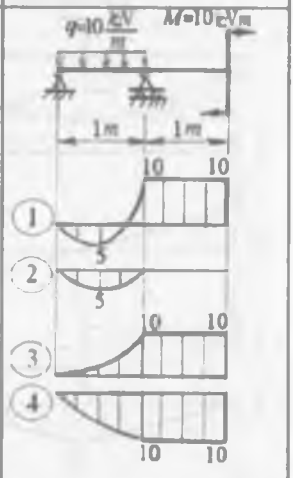
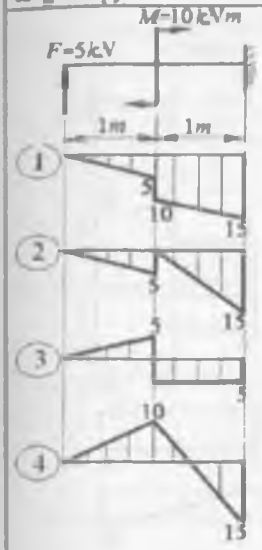
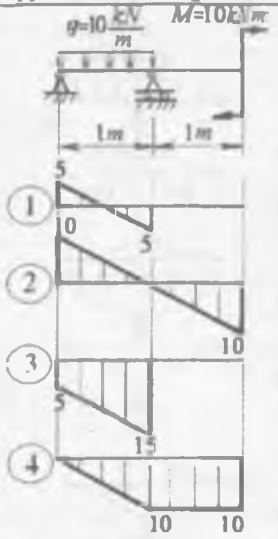
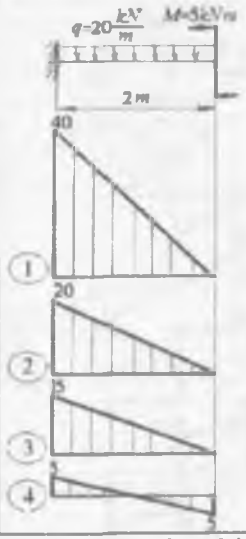
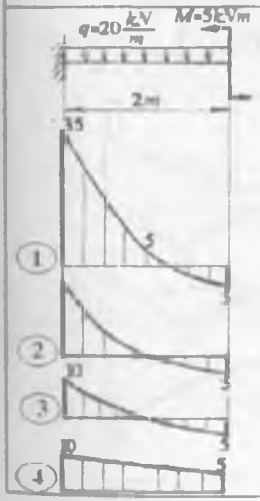
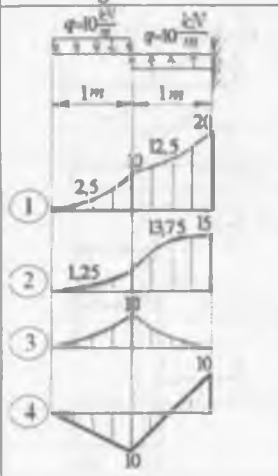
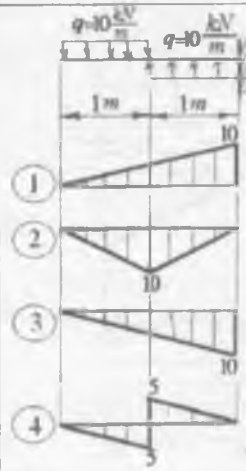
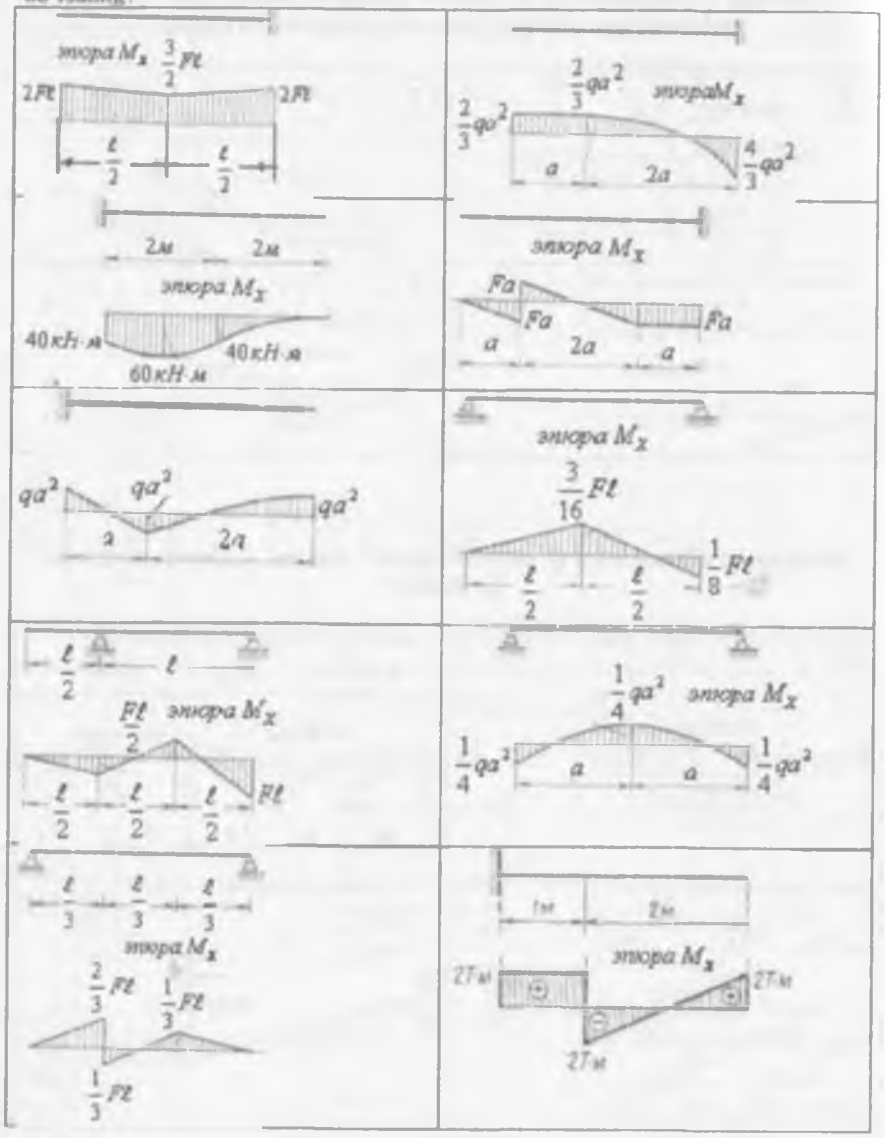
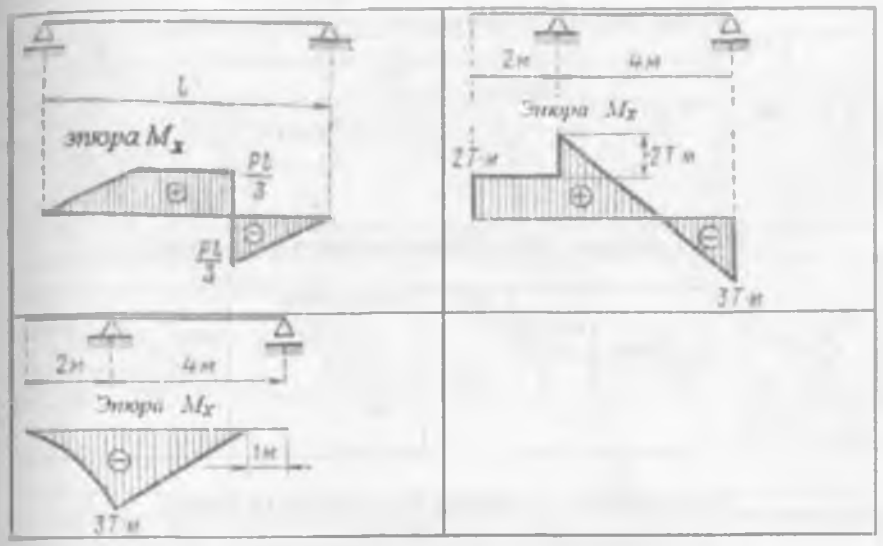


21 Balka eguvchi momentining (*kNm*) to'g'ri epyurini ko'rsating?	22 Balka ko'ndalang kuchining (*kN*) to'g'ri epyurini ko'rsating?	23. Balka eguvchi momentining (*kNm*) to'g'ri epyurini ko'rsating?
		
24. Balka eguvchi momentining (*kNm*) to'g'ri epyurini ko'rsating	25 Balka ko'ndalang kuchining (*kN*) to'g'ri epyurini ko'rsating?	26. Balka eguvchi momentining (*kNm*) to'g'ri epyurini ko'rsating?
		

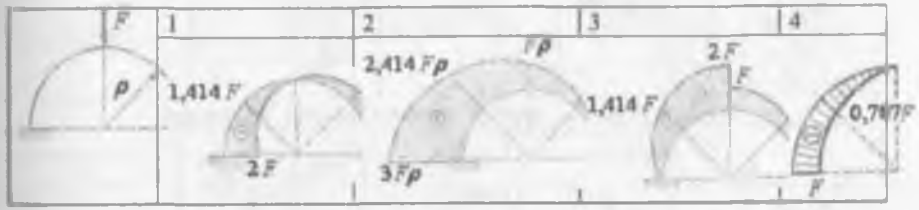
27. Balka eguvchi moment ining *(kNm)* to'g'ri epyurini ko'rsating	28 Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?	29 Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?
		
30 Balka eguvchi momentining *(kNm)* to'g'ri epyurini ko'rsating	31 Balka eguvchi momentining *(kNm)* to'g'ri epyurini ko'rsating	32 Balka ko'ndalang kuchining *(kN)* to'g'ri epyurini ko'rsating?
		

Berilgan eguvchi moment M_X epyurasi asosida balkani yuklanish sxemasini ko'rsating?

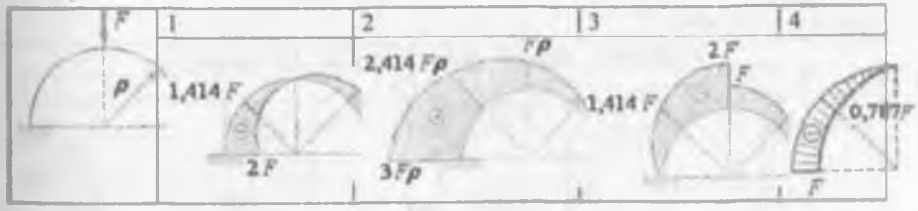




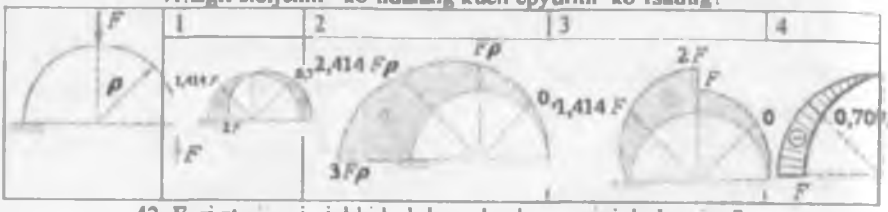
39. Egri sterjenni eguvchi moment epyurini ko'rsating?



40. Egri sterjenni ichki bo'ylama kuch epyurini ko'rsating?



41.Egri sterjenni ko'ndalang kuch epyurini ko'rsating?



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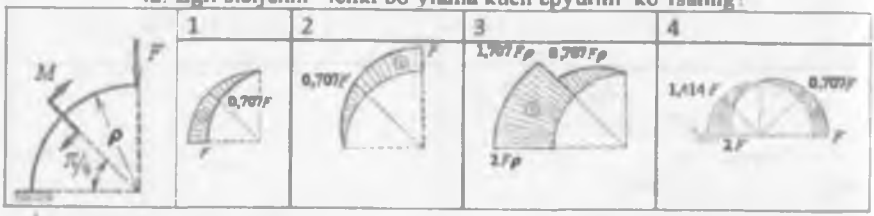

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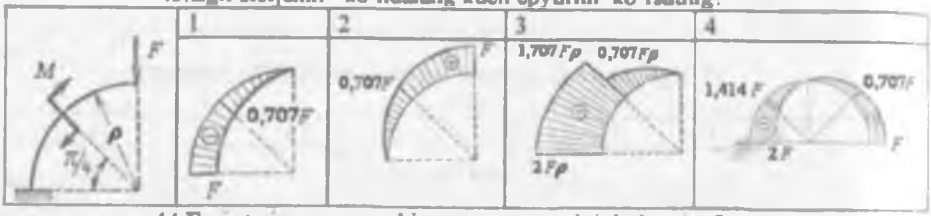
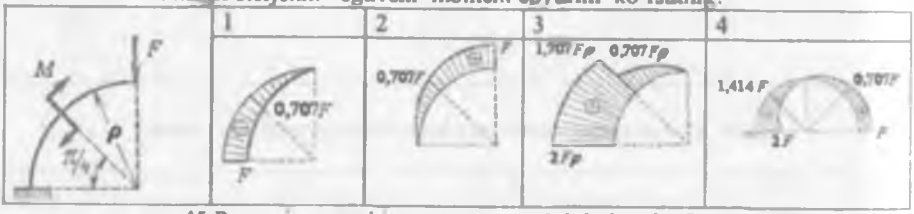
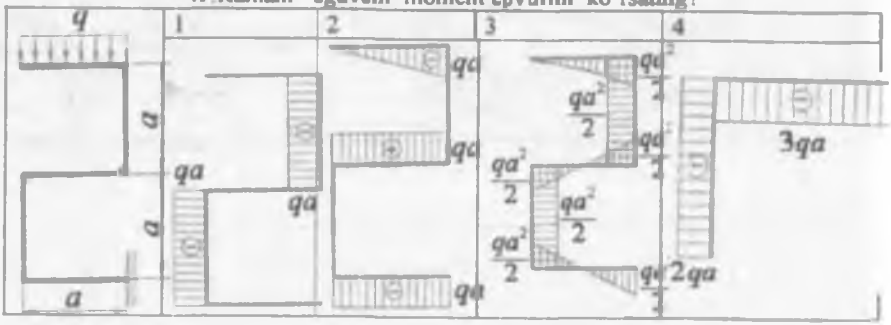


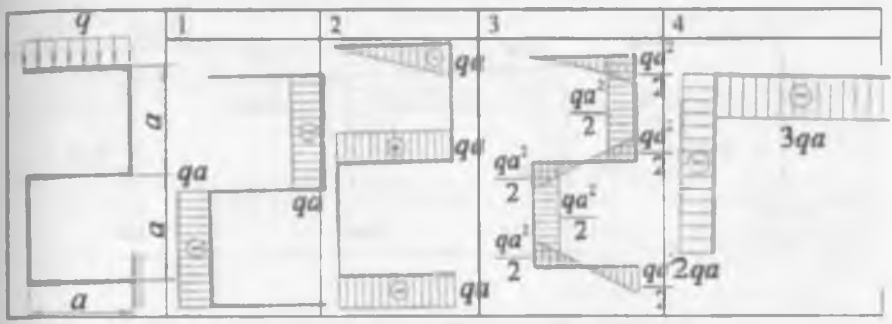
44.Egri sterjenni eguvchi moment epyurini ko'rsating?



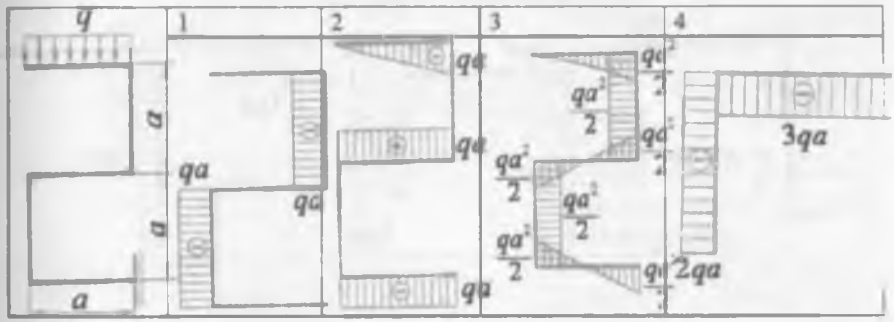
45.Ramani eguvchi moment epyurini ko'rsating?



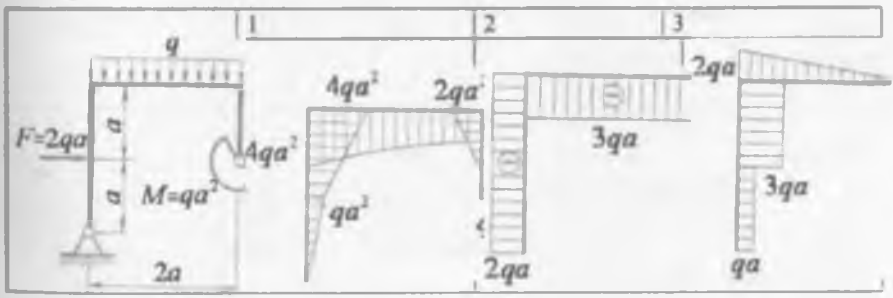
46.Ramani ichki bo'ylama kuch epyurini ko'rsating?



47.Ramani ko'ndalang kuch epyurini ko'rsating?



48.Ramani eguvchi moment epyurini ko'rsating?



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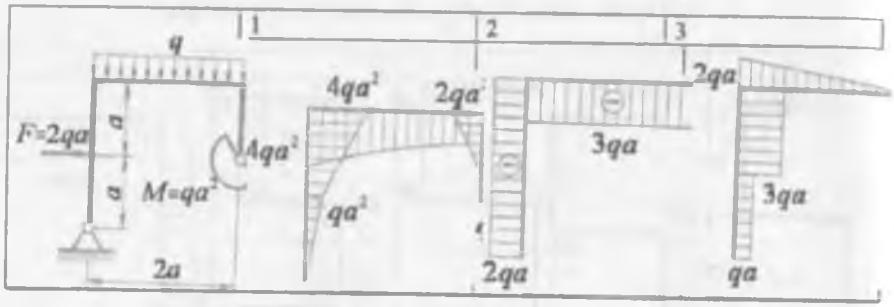

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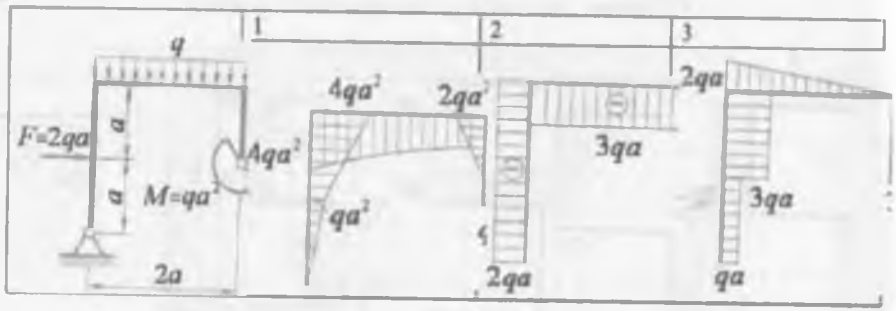

GLOSSARIY

№	Atamaning o'zbek tilida nomlanishi	Atamaning ingliz tilida nomlanishi	Atamaning rus tilida nomlanishi	Atamaning ma'nosi
1	Mexanika	Mechanics	Механика	Moddiy jismlarni ta'sirlashuvi va mexanik harakati to'g'risidagi fan
2	Texnika	technics	Техника	Ishlab chiqarishda tadbiq etiladigan va uni boshqarishda qatnashadigan mehnat qurollari, jihozlari , mashinalar
3	Muxandislik inshootlari	engineering structure	Инженерные сооружения	Mashina va mexanizmning ishchi organi harakat-lanadi. Bu faktor mashina yoki mexanizmni muxandislik inshootidan farqini belgilaydi. Binolar,ko'priklar, tonnellar, rezervuar va h.k– muxandislik inshootlari
4	Val	shaft	Вал	Aylanma harakat va quvvatni uzatadigan, burilishi va egilish deformatsiyalariga uchraydigan pog'onali brus
5	O'q	axis	Ось	Aylanuvchi g'ildiraqlar bilan harakatni uzatishda qatnashadigan, egilish deformatsiyasiga uchraydigan brus
6	Brus	beam	Брус	Uzunligi qolgan o'lchamlaridan katta bo'lgan jism
7	Sterjen	bar	Стержен	Ingichka brus
8	Balka	beam	Балка	Egilishga qarshilik ko'rsatadigan brus
9	Rama	frame	Рама	Siniq chiziqli brus
10	Plastinka	tablet	Пластинка	Qalinligi qolgan o'lchamlaridan kichik bo'lgan jism
11	Qobiq	casing, cover	Оболочка	Egri shaklli plastinka

				Tayanch kesim bitta erkinlik darajaga ega va unda ikkita reaktsiya kuchi hosil bo'ladi.
29	Qistirib mahkamlangan tayanch	built-in support	Защемленная опора	Uch bog'lanishli tayanch, hamma erkinlik darajani cheklaydi. Tayanch kesim jism bilan birgalikda biror tekislikda harakatlana-olmaydi Tayanchda uchta reaktsiya kuchi hosil bo'ladi
30	Reaktsiya kuchi	force of reactions	Сила реакции	Jismga ta'sir qiladigan bog'lanish kuchi. Jismni harakatlanishiga qarshilik ko'rsatadigan kuch.
31	Aktiv kuch	active force	Активная сила	Jismni harakatlantiradigan kuch.
32	Kuchning o'qdagi proektsiyasi	the projection of forces on the axis	Проекция сил на ось	Kuch vektorining boshi va ohiridan o'qqa tushirilgan ikkita perpendikulyar orasidagi kesma uzunligi
33	Kuchni nuqtaga nisbatan momenti	moment force about particle	Момент сил по отношении точки	Kuchni aylantiruvchi - tavsifi Kuchning nuqtaga nisbatan momenti – kuch modulini uning elkasiga kupaytmasiga teng.
34	Moment markazi	center of moment	Центр момента	Kuch momenti qaysi nuqtaga nisbatan olinsa, shu nuqta moment markazi
35	Kuch elkasi	arm of force	Плечо силы	Moment markazidan kuchning ta'sir chizig'igacha bo'lgan eng qisqa oraliq
36	Juft momenti	Moment pair of force	Момент парных сил	Juftni tashkil etuvchi kuchlardan birining modulini uning elkasiga ko'paytmasi
37	Muvozanat shart	conditions of equilibrium	Условия равновесия	Jismga ta'sir etuvchi fazoda ixtiyoriy joy-lashgan kuchlar sistemasining Dekart koordinata o'qlarining har biridagi proektsiyalarining algebraik yig'indisini nolga teng bo'lishi va kuchlarning

				har bir o'qga yoki ixtiyoriy tanlangan nuqtaga nisbatan momentlarining algebraik yig'indisini nolga teng bo'lishini aniqlovchi tenglamalar
38	Jismning og'irlik markazi	body center of gravity	Центр тяжести тела	Jismga tegishli barcha elementar zarrachalar parallel og'irlik kuchlarining markazi
39	Geometrik tavsif	geometrical definition	Геометрическое определение	Geometrik – bog'lanishni nazariyasi
40	Statik moment	static moment	Статический момент	Kesim yuza bilan o'q orasidagi masofa ko'paytmasining integrali
41	Kesim yuzaning og'irlik markazi	center of figure	Цент тяжести сечения	Kesim yuzadan hisoblab topilgan shunday nuqtaki, bu nuqta atrofida aylangan kesim yuza nuqtalarining chizgan traektoriyasi aylana bo'ladi.
42	Inertsiya momenti	moment of inertia	Момент инерции	Kesim yuza bilan o'q orasidagi masofa kvadratining ko'paytmasining integrali Kesim yuzani biror o'qga nisbatan inertsiya momenti
43	Markazdan qochma inertsiya momenti	product of iner-tia,Centrifugal moment of inertia	Центробежный момент инерции	Kesim yuza bilan ikkita o'q orasidagi masofa ko'paytmasining integrali
44	Qutb inertsiya momenti	polar moment of inertia	Полярный момент инерции	Kesim yuza bilan qutb nuqtasi orasidagi masofa kvadratining ko'paytmasi
45	Qarshilik momenti	resisting moment	Момент сопротивления	Kesim o'lchamlarining bog'lanishi, mustah kamlikni ifodalaydigan geometrik tavsif
46	Bosh inertsiya o'qi	The main axis of inertia	Главный ось инерции	Bosh inertsiya o'qlariga nisbatan kesimni markazdan qochma inertsiya momenti nolga teng
47	Bosh inertsiya momenti	principal moment of inertia	Главный момент инерции	Bosh inertsiya o'qlariga nisbatan kesimni inertsiya momenti

48	Inertsiya radiusi	radius of inertia	Радиус инерции	Kesimning biror o'qga nisbatan inertsiya momentini kesim yuzasiga nsbati bilan topiladi
49	Material	material	Материал	Mexanik va plastiklik xossasiga, ishlov berilish xususiyatiga ega bo'lgan konstruktsiya va inshoot qismlarini tayyorlash mumkin bo'lgan narsa
50	Qarshilik	Resistance	Сопротивление	Har qanday tashqi ta'sirga ichki aks ta'sirini ko'rsata olishlik
51	Deformatsiya	deformation	Деформация	Tashqi kuch ta'siridan jismda o'lcham yoki shakl o'zgarishi
52	Oddiy deformatsiya	simple deformation	Простая деформация	Tashqi kuch yo'nalishida jismning o'lcham yoki shaklini o'zgarishi
53	Murakkab deformatsiya	hard deformation	Сложная деформация	Bir vaqtda ikkita va undan ko'proq oddiy deformatsiyalarni hosil bo'lishi
54	Elastik deformatsiya	elastic deformation	Эластическая деформация	Tashqi kuch ta'sir yo'qotilgandan keyin jismning boshlang'ich o'lcham va shaklini tiklanishi
55	Plastik deformatsiya	plastic deformation	Пластическая деформация	Qoldiq deformatsiya, ya'ni tashqi kuch ta'sir yo'qotilgandan keyin jismning boshlang'ich o'lcham va shaklini tiklanmasligi
56	Absolyut deformatsiya	absolute strain	Абсолютная деформация	Bir birlik uzunlikka to'g'ri keluvchi uzayish
57	Nisbiy deformatsiya	relative deformation	Относительная деформация	Bir birlik uzunlikka to'g'ri keluvchi absolyut uzayish
58	Chiziqli deformatsiya	linear strain	Линейная деформация	Tashqi kuch ta'sirida jismda o'lcham yoki shakl o'zgarishi bir chiziq bo'ylab sodir bo'ladi
59	Burchakli deformatsiya	angular deformation	Угловая деформация	Tashqi kuch ta'siridan jismda o'lcham yoki shakl o'zgarishi burchak ostida sodir bo'ladi

				jismni kesimi aylanadi
60	Kuchlanish	tension	Напряжение	Ichki kuchni kesim yuzada tarqalish qonu-niyatini ifodalaydi, ya'ni bir-birlik yuzaga to'g'ri keluvchi kuch.
61	Normal kuchlanish	normal tension	Нормальное напряжение	Kesim yuzaga tik yo'naladigan kuchlanish
62	Urinma kuchlanish	tangential stress	Касательное напряжение	Kesim yuzaga urinma yo'naladigan kuchlanish
63	To'liq kuchlanish	combined stress	Полное напряжение	Normal va urinma kuchlanishlarni geometrik yig'indisi.
64	Ruxsat etilgan kuch-lanish	working stress	Допускаемое напряжение	Konstruktsiya qismlarining elastik deformatsiya mustaxkamligi va xavfsiz ishlashini ta'minlash uchun brus materialiga xos bo'lgan cheklangan kuchlanish
65	Kontaktli kuchlanish	contact stress	Контактное напряжение	Tishli g'ildiraklarni ilashish nuqtasida (chiziqda) hosil bo'lgan kuchlanish
66	Kuchlanishlar kontsentratsiyasi	stress concentration	Концентрация напряжений	Teshik, kanavka yoki defekt atrofidagi kuch-lanishlar to'plami
67	Qattiqlik	hardness	Твердость	Sirtiga singdirilgan detalga qarshilik ko'rsata olish qobiliyati
68	Konstruktsiya	construction	Конструкция	Detal, mexanizm, mashina qurilma,inshoot
69	Kesish usuli	sectioning method	Метод сечений	Tashqi kuch ta'sirida bo'lgan jismning ixtiyoriy kesim yuzasidagi ichki kuch faktorlarini ko'rish va hisoblash usuli
70	Bo'ylama kuch	longitudinal force	Продольная сила	Brusning kesilgan ko'ndalang kesimidan bir tomonda olib qolingan tashqi kuchlarni ushbu kesimning normal yoki bo'ylama o'qiga proektsiyalarining algebraik yig'indisi

71	Burovchi moment	twisting moment	Крутящий момент	Sterjenning kesilgan kesim yuzasidan bir tomonda joylashgan tashqi momentlaming algebraik yig'indisi
72	Ko'ndalang kuch	transverse force	Поперечная сила	Balkaning ajratib olingan qismidagi barcha kuchlarni balkani kesilgan yuzasidagi kuch chiziqiga proektsiyalarining algebraik yig'indisi
73	Eguvchi moment	bending moment	Изгибающий момент	Balkani ajratib olingan qismidagi barcha kuchlaming balka kesilgan yuzasining kesim markaziga nisbatan kuch momentlarining algebraik yig'indisi
74	Epyura	diagram	Эпюра	Ichki kuch faktorlarini brusning o'qi bo'ylab o'zgarishini ifodalovchi ma'lum qonuniyat asosida qurilgan grafikasi
75	Kuch tekisligi	plane of force	Плоскость силы	Egilishda barcha tashqi va reaktsiya kuchlari ta'sir qiladigan yagona tekislik
76	Kuch chiziqi	force line	Линия силы	Kuch tekisligini brusning ko'ndalang kesim yuzasi bilan kesishish chiziqi
77	Neytral qatlam	neutral plane	Нейтральный слой	Balkani egilishida cho'zilmaydigan va siqil-maydigan, o'zining boshlang'ich uzunligini o'zgartirmaydigan material qatlami
78	Neytral o'q	neutral axis	Нейтральная ось	Balkaning ko'ndalang kesim yuzasi bilan neytral qatlamni kesishish chiziqi
79	Cho'zilish	elongating	Растяжение	Tashqi kuch ta'sirida brus uzunligini ortishi va ko'ndalang o'lchamini qisqarishi

80	Siqilish	pressing	Сжатие	Tashqi kuch ta'sirida brus uzunligini qisqarishi va ko'ndalang o'lchamini ortishi
81	Markaziy cho'zilish va siqilish	axial tension and pressing	Центральное растяжение и сжатие	Tashqi kuch ta'siridan brusning kesim yuzasidagi material zarrachalari bir xil masofaga ko'chadi, ya ni brusning kesim yuzasi o'q bo'ylab chiziqli qisqaradi yoki ortadi
82	Guk qonuni	Hooke's law	Закон Гука	Kuch bilan deformatsiya bog'lanishining grafikasi to'g'ri chiziq qonuniyatga bo'ysuni-shini tavsiflovchi nazariya
83	Bo'ylama deformatsiya	longitudinal strain	Продольная деформация	Tashqi kuch ta'siridan brus uzunligini o'q bo'ylab chiziqli uzayishini nisbiy (absolyut) miqdori
84	Ko'ndalang deformatsiya	lateral deformation	Поперечная деформация	Tashqi kuch ta'siridan brus ko'ndalang kesim yuza-sining o'zgarishini absolyut (nisbiy) miqdori.
85	Elastiklik moduli	modulus of elasticity	Модуль эластичности	Fizik konstanta, materialni turiga bog'liq
86	Puasson koeffitsienti	Poisson ratio	Коэффициент Пуассона	Brus ko'ndalang kesim yuzasining qisqarishini tavsiflaydi
87	Diagramma	Diagram	Диаграмма	Kuch bilan deformatsiya bog'lanishini koor-dinata o'qlarida grafikaviy usulda ifodalanishi
88	Mexanik xossa	mechanical properties	Механическая свойства	Material mustahkamligini xarakterlovchi kuchlanishlar to'plami
89	Elastiklik chegara	border of elasticity	Предел эластичности	Brus materialining elastiklik xossasida – deformatsiya so'nuvchan bo'ladi
90	Proportsionallik chegara	border of propotion	Предел пропорциональности	Kuch bilan deformatsiya bog'lanishining grafikasi to'g'ri chiziq, ya'ni Guk qonuniyatiga bo'ysunadi.

91	Oquvchanlik chegara	liquid limit	Предел текучести	Taxminan o'zgarmas kuchlanish ta'sirida brusni uzayishi tez o'sadi
92	Mustahkamlik chegara	The boundary strength	Предел прочности	Eng katta kuchga to'g'ri keluvchi kuchlanish
93	Mahalliy uzayish	local elongation	Местное удлинение	Brus uzayishini ma'lum bir oraliqda to'planishi yoki sodir bo'lishi
94	Mustahkamlik shart	strength condition	Условия прочности	Xavfli kesimdagi emirilishni cheklaydigan matematik ifoda
95	Ruxsat etilgan yuk	safe load	Допускаемая нагрузка	Konstruktsiya ko'tara olishi mumkin bo'lgan yukning miqdori
96	Kesimni tanlash	Selection of cross-sections	Выбор сечений	Tashqi kuch ta'siriga emirilmasdan qarshilik ko'rsata oladigan, uning mustahkamligini ta'minlaydigan kesimning o'lchami.
97	Plastiklik xossa	Plastic properties	Пластические свойства	Materialni deformatsiyalanish xususiyatini belgilovchi xossa
98	Plastiklik	Plasticity	Пластичность	Brusni cho'zilish (siqilish) ga egilishga va h.k larga moyilligi, katta qoldiq deformatsiya hosil qilish xususiyati
99	Mo'rtlik	Brittleness	Хрупкость	Materialning plastiklikiga teskari xossasi
100	Puxtalanish	Hardening	Упрочнение	Birlamchi uzayish evaziga proportsionallik chegarani o'sishi
101	Relaksatsiya hodisasi	Relaxation	Релаксация	Vaqt o'tishi bilan kuchlanish miqdorini kamayishi
102	Kuchlanganlik holat	stressed state	Напряженное состояние	Kubikni tomonlarida va qiya kesim yuzalarida kuchlanishlami xilma-xilligi va o'zgarishini tahlili
103	Chiziqli kuchlangan-lik	linear stresses	Линейная напряженность	Chiziq bo'ylab kubikni ko'ndalang va qiya kesim yuzalarida kuchlanishlami tahlili

104	Tekis kuchlanganlik	plane tensity	Плоская напряженность	Kubikni o'zaro perpendikulyar uchta qirralaridan ikkitasining bir vaqtda cho'zilish va siqilishini tahlili
105	Bosh yuza	principal cross-section	Главная площадь	Urinma kuchlanishlar ta siri nolga teng bo'lgan yuzalar
106	Bosh kuchlanishlar	principal stresses	Главные напряжения	Bosh yuzalarga qo'yilgan kuchlanishlar
107	Bosh kuchlanish yo'na-lishi	principal stress direction	Направление главного напряжения	Cho'zuvchi va siquvchi kuchlanishlar yo'nalishini aniqlash
108	Hajmiy deformatsiya	volumetric deformation	Объемная деформация	Kubikni o'zaro perpendikulyar uchta qirralari ning bir vaqtda cho'zilish va siqilishini tahlili
109	Hajm o'zgarishi	strain energy due to change of volume	Изменения объема	Kubikni deformatsiyalanishida barcha qirrala rini bir xil miqdorga uzayishi yoki qisqarishi, ya'ni kubik kubikligicha qoladi.
110	Shakl o'zgarishi	mode change	Изменение форм	Kubikni deformatsiyalanishida uning qirralarining o'lchamlari bir xil o'zgarmaydi, kubik parallelogramm shaklini egallaydi
111	Gukni hajmiy qonuni	Hooks volumetric law	Объемный закон Гука	Elastik hajmiy deformatsiyani tavsiflovchi qonuniyatni matematik ifodasi
112	Hajmiy elastiklik modul	Modulus of extensional elasticity	Модуль объемной эластичности	Elastikhajmiy deformatsiyadagi fizik konstanta
113	Mustaxkamlik nazariya	theory of strength	Теория прочности	Konstruktsiyalarning mustahkamligi to'g'risidagi turli nazariy va tajribaviy mulohaza va g'oyalarni mujassamlashgan holatini matematik ifodasi
114	Mo'rt emirilish	brittle damage	Хрупкий износ	Materiallami elastiklik xossasidan tashqarida darz yorilishi
115	Plastik emirilish	plastic damage	Пластический износ	Materiallami elastiklik xossasidan tashqaridagi qoldiq

				deformatsiya
116	Xavfli kesim	dangerous section	Опасное сечение	Eng katta kuchlanish ta'siridan kesim yuzada emirilish sodir bo'lishi mumkin
117	Xavfli nuqta	dangerous point	Опасная точка	Kuchlanishni eng katta qiymati hosil bo'lgan nuqta.
118	Siljish	shift	сдвиг	Tashqi kuch ta'siridan brus kesim yuzalarini bir-biriga nisbatan ko'chishi
119	Absolyut siljish	absolute shear	Абсолютный сдвиг	Bir-birlik o'lchamga to'g'ri keluvchi siljish
120	Nisbiy siljish	relative shear	Относительный сдвиг	Bir-birlik o'lchamga to'g'ri keluvchi absolyut siljish
121	Qirqilish	section	Срезь	Xavfli siljish kesimida kesilishga qarshilik ko'rsatish qobiliyati
122	Ezilish	crushing	Смятие	Siljish tekisligiga perpendikulyar yuzada material zarrachalarini ko'chishi
123	Siljish moduli	modulus of rigidity	Модуль сдвига	Siljishda fizik konstanta, ikkinchi tartibli elastiklik moduli
124	Birikma	Compound	Соединение	Ikkita jismni tutashtirish yuzasi va usuli
125	Payvand birikma	welded joint	Сварное соединение	Ikkita element materiallarini suyuq holatda biriktirish usuli
126	Parchin mixli bi-rikma	rivet connection	Заклепочное соединение	Ikkita elementni parchin mix vositasida biriktirish usuli
127	Buralish torsion	torsion	Кручение	Parallel joylashgan ikkita doiraviy kesimlarni bir o'q atrofida va bir-biriga isbatan aylanishi
128	Buralish burchagi	The angle of torsion	Угол кручения	Valning ko'ndalang kesim yuzasini o'q atrofida aylanish burchagini belgilaydi
129	Bikrlik shart	Conditions stiffness	Условие жесткости	Brus deformatsiyasini cheklangan qiymatini belgilovchi matematik ifoda
130	Ko'chish	displacement	Перемещение	Nuqtaning tashqi kuch ta'sirida shu kuch yo'nalishida bir

				chiziq bo'ylab ko'chishi
131	Differentsial bog'-lanish	Differential bond	Дифференциальная связь	Balka kesimining aylanish burchagi bilan salqilik orasidagi bog'lanish
132	Differentsial teng-lama	Differential equation	Дифференциальное уравнение	Balka egilgan o'qini tashqi kuch va bikrlik bilan bog'lanishining matematik ifodasi
133	Universal formula	Universal formula	Универсальная формула	Balka ixtiyoriy kesimining aylanish burchagi va salqiligini aniqlash formulasi
134	Grafoanalitik usul	semigraphical method	Графоаналитический метод	Balka tanlangan kesimining aylanish burchagi va salqiligini aniqlashni analitik va grafikaviy usullarini mujassamlangan ko'rinishi
135	Murakkab qarshilik	Complex resistance	Сложное сопротивление	Konstruktsiyani ikkita va undan ortiq oddiy deformatsiyalar ta'sirida bo'lishi
136	Qiyshiq egilish	Oblique bending	Косой изгиб	Tashqi kuchning ta'sir chizig'i bo'ylama o'qiga perpendikulyar joylashib ko'ndalang kesimi-ning birorta ham bosh inertsiya o'qlari tekisligi-dan o'tmaydigan sterjenning deformatsiyasi
137	Markazlashmagan siqilish	eccentric compression	Внецентренное сжатие	Bo'ylama o'qiga parallel kuch ta sirida cho'zilish (siqilish)ga uchraydigan va ko'ndalang kesimining birorta ham bosh inertsiya o'qlari tekisligida egilmaydigan (egiladigan) brusning deformatsiyasi
138	Buralish bilan egi-lishni birgalikdagi ta'siri	Twisting and bending	Кручение с изгиб	Valning kesim yuzasida burovchi va eguvchi momentlarni hosil bo'lishi ya'ni valni buralish bilan egilish deformatsiyalarining birgalikdagi ta'sirida bo'lishi
139	Keltirilgan	The above point	Приведенный	Turli mustahkamlik

	moment		момент	nazariyalari asosida hisoblangan burovchi va eguvchi moment-larning yig'indisi
140	Noustuvorlik	Instability	Неустойчивость	Siquvchi kuch ta'sirida sterjenning to'g'ri chiziqli shaklini saqlab qola olmasligi
141	Kritik kuch	Critical force	Критическая сила	Sterjen ustuvorligini yo'qolishiga sabab bo'luvchi kuch
142	Egiluvchanlik	eligibility	Избирасмость	Turli uzunlik va o'lchamdagi sterjenlarni to'g'ri chiziqli shaklini elastik o'zgartirish xususiyatini ifodalovchi konstanta
143	Ustuvorlik sharti	The stability condition	Условие устойчивости	Ingichka va uzun sterjenlar ustuvor holati- ni ta'minlovchi shartni matematik ifodasi
144	Dinamik kuch	dynamic force	Динамическая сила	Qisqa vaqt oralig'ida qiymatini o'zgartiruvchi kuch
145	Dinamik deformatsiya	dynamic deformation	Динамическая деформация	Dinamik kuch ta'sirdagi brusni shakl yoki o'lchamlarini o'zgarishi
46	Zarb ta'siri	Influence of Shot	Влияние удара	Ma'lum balandlikdan tushgan yukni jismga ta'siri
147	Zarbga sinash	Impact test	Испытание на удар	Zarb ta'sirida material xossalarini o'rganish
148	O'zgaruvchan kuchlanish	AC voltage	Переменное напряжение	Vaqt oralig'ida qiymati va ishorasini o'zgartiradigan kuchlanish
149	Materialni toliqishi	Fatigue material	Усталость материала	Ўzgaruvchan kuchlanish ta'sirida materialni darz yorilishi
150	Chidamlilik chegara	Stamina border	Граница выносливости	Materiallarning toliqishini cheklaydigan chegara
151	Birikma	joint	Соединение	Detallarni yig'ish vositasi (usuli).

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MATERIALLAR QARShILIGI
Amaliy mashg'ulotlar va
hisoblash – grafik ishlari uchun misollar

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Texnik muharrir: Xakimov M.

Nashriyot lisenziyasi № AI 170.23.12.2009
Nashriyot manzili: Toshkent. A. Temur ko'chasi, 19-uy
Bosishga 15.03.2019 yil ruxsat etildi.

Ofset qog'ozi. Bichimi 60x84 1/16.
Times garniturasida ofset usulida bosildi.
Shartli b.t. 21,25. Nashir tabog'I 22,1. Adadi 100 nusxa.

"DUNA POLGRAF" Xususiy korxonasida chop etilgan.
Buxoro shaxri O'zbekiston Mustaqilligi ko'chasi 28-uy 9-xona