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

TOSHKENT TO’QIMACHILIK VA ENGIL SANOAT INSTITUTI

«Nazariy mexanika va materiallar qarshiligi» kafedrasi

AMALIY MEXANIKA

1 qism – Materiallar qarshiligi

(Metodik qo’llanma)

(540600, 5140900, 520800, 5522300, 5540400, 5540600 bakalavriat yo’nalishlari)

Toshkent – 2010

Annotatsiya

«**Amaliy mexanika**» fanini o’rganishda talabalar ma'ruza, Amaliy mashg’ulot tinglashlari, bilan birgalikda hisoblash-loyiha ishlarini mustaqil bajaradilar. Bu ishlarni bajarishda talabalar oldiga qator masalalar qo’yiladi. Fandan hisoblash-loyiha ishlarini bajarish uchun ushbu qo’llanma tavsiya etilgan.

Uslubiy qo’llanma «Amaliy mexanika» fanining «Materiallar qarshiligi» bo’limini o’z ichiga olgan.

Qo’llanmada masalalar, ularni echish uslublari, hisoblash-loyiha ishlarini variantlari, nazorat savollari keltirilgan bo’lib, u materiallar qarshiligi fanini quyidagi bo’limlarini o’z ichiga oladi:

1. Cho’zilish va siqilish;

2. Buralish;

3. Egilish.

Bo’limlardagi masalalar *Mathcad* matematik dasturi yordamida echilgan.

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TTESI ilmiy-uslubiy kengashda tasdiqlangan
(bayonnoma № __5__ «_28__» may)

TTESI tipografiyasida «_25_» nusxada ko’paytirilgan.

Umumiy uslubiy ko’rsatmalar

Masalani echishdan oldin quyidagi ko’rsatmalarga amal qilish taklif etiladi:

1. Materiallar qarshiligi kursi (Mavzular: «Cho’zilish – siqilish, buralish va egilish») darslik va ma'ruza materiallarining nazariy bo’limlarida bajariladi. Ushbu nazariy materiallar bo’yicha to’liq savollar S.M. Stepinning «Materiallar qarshiligi» darsligida M.: Vishshaya shkola, 1998, §§7-22, 35-44,58-67 hamda boshqa darsliklar va o’quv qo’llanmalarda (1),(2),(3),(4),(5) keltirilgan.

2. Mathcad matematik dasturi bilan tanishish. Makarova E.G.ning «Mathcad da muhandislik hisoblari» nomli kitobida *Mathcad* ni qo’llash S.-P.: Piter, 2003, hamda boshqa adabiyotlarda (6),(7).

3. Berilgan har bir hisoblar o’zining shifri yoki jurnal bo’yicha tartib raqami bilan olinadi.

4. Hisoblash – loyihalash ishlarini kafedra belgilagan vaqt mobaynida tugallagan va himoya qilgan, hamma talablarni bajargan holda, o’zi bajargan bo’lishi shart.

I - CHO'ZILISH VA SIQILISH

CHO'ZILISH VA SIQILISHDAGI DEFORMATSIYA HAQIDA UMUMIY TUSHUNCHALAR

1 - topshiriqga statik aniq va statik aniqmas 4 ta masala kiradi. Ikkita sterjen o'qi bo'ylab qarama-qarshi tomonga yo'nalgan kuch ta'siridan hosil bo'lgan deformatsiyaga cho'zilish yoki siqilish deyiladi. Cho'zilish (siqilish) da sterjenning ko'ndalang kesimida faqat sterjen o'qi bo'ylab yo'nalgan N kuchi hosil bo'ladi. Bu kuch ichki normal kuchlarning teng ta'sir etuvchisini ifodalaydi.

Bo'ylama N kuchi kesish usuli bilan aniqlanadi (Rozu usuli).

Brusning ixtiyoriy ko'ndalang kesimidagi bo'ylama kuch N modul jihatdan barcha tashqi kuchlarning o'qdagi proektsiyalarining algebraik yig'indisiga teng. Bunda cho'zuvchi bo'ylama kuch musbat, siquvchi kuch esa manfiy deb qabul qilingan.

Bo'ylama kuchning brus(g'o'la) uzunligi bo'yicha o'zgarishini grafik ko'rinishida ya'ni bo'ylama kuch epyurasi tarzida ifodalanadi.

Brusning ko'ndalang kesimida faqat normal kuchlanish hosil bo'ladi.

Kuchlanish

$$\sigma = \frac{N}{A}$$

Formuladan aniqlanadi. Bu erda N - bo'ylama kuch; A - ko'ndalang kesim yuzasi.

Ko'ndalang kesimi o'zgarmas bo'lgan l uzunlikdagi brusning absolyut deformatsiyasi

$$\Delta l = \frac{N \cdot l}{E \cdot A}$$

formuladan aniqlanadi. Bu erda E – elastiklik moduli bo'lib, po'lat uchun $E = 2 \cdot 10^4 \ \kappa H / см^2$.

E·A ko'paytma cho'zilishdagi brusning mustahkamligi deyiladi.

STATIK ANIQ MASALALAR

Masala № 1. Po'lat sterjenning har xil ko'ndalang kesimlaridagi bo'ylama kuch N, kuchlanish σ, va vertikal ko'chish δ larini aniqlang. Natijalarni epyura ko'rinishida tasvirlang.

Kerakli qiymatlar 1 - jadvaldan aniqlanadi.

Мисол № 1

Berilgan: d_1=1,5 *см* == 10 *мм*, d_2=2 *см* = 20 *мм*, l_1= 100 *см*, l_2=150 *см*, l_3= 250 *см*, P_1=10 *кН*, P_2=-20 *кН*, P_3=30 *кН*.

Topish kerak: Bo'ylama kuch - N, normal kuchlanish - σ, ko'chish - δ va ularni epyuralarini qurish.

Bo'ylama kuch N ni topish uchun brusni uchta I-I, 2-2 va 3-3 kesimlari bo'ylab kesamiz (1 - rasm.). I-I kesim uchun muvozanat tenglamalarini quramiz:

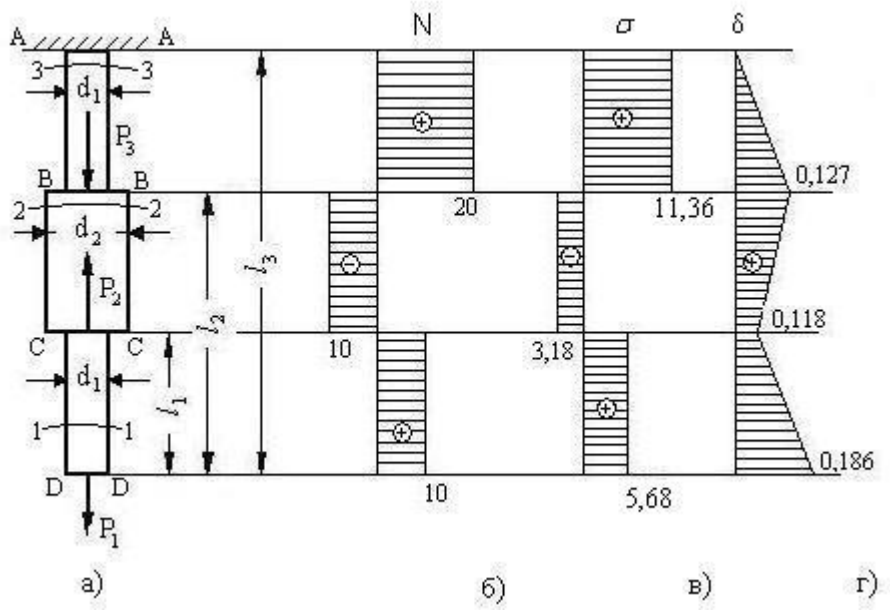
$$\sum x = 0,\ N_1 - P_1 = 0,\ \ N_1 = P_1 = 10\ кН \quad \text{(cho'zilish)}$$

Shunga o'xshab 2-2 kesim uchun:

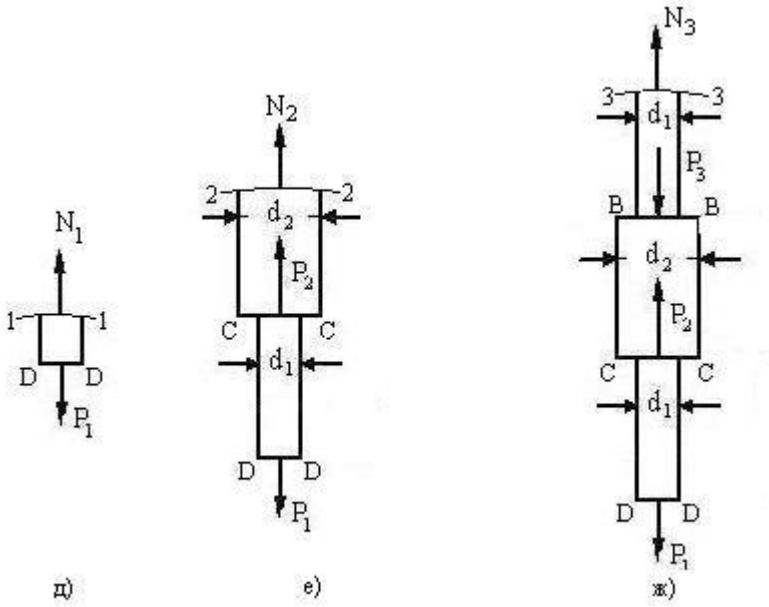
$$\sum x = 0,\quad N_2 + P_2 - P_1 = 0,\ \text{bundan}\ \ N_2 = -10\ кН,\ \text{(siqilish).}$$

3-3 kesim uchun:

$$\sum x = 0,\quad N_3 + P_2 - P_1 - P_3 = 0,\ \text{bundan}\ \ N_3 = 20\ кН,\ \text{(cho'zilish).}$$



I-I kesim 2-2 kesim 3-3 kesim



1-rasm.

Masshtab tanlab bo'ylama kuch epbrasini quramiz (1b - rasm). Buning uchun avval A_1 va A_2 ko'ndalang kesim yuzalarini hisoblaymiz:

$$A_1 = A_3 = \frac{\pi \cdot d_1^2}{4} = \frac{3{,}14 \cdot 1{,}5^2}{4} = 1{,}76\,см^2$$

$$A_2 = \frac{\pi \cdot d_1^2}{4} = \frac{3{,}14 \cdot 2^2}{4} = 3{,}14\,см^2$$

Turli kesimlardagi kuchlanishlar aniqlanadi ular mos ravishda quyidagilarga teng:

past qismdagi kesim uchun :

$$\sigma_1 = \frac{N_1}{A_1} = \frac{10}{1{,}76} = 5{,}68\ \ кН/см^2 \qquad \text{(cho'zilish),}$$

sterjenning o'rta qismi uchun:

$$\sigma_2 = \frac{N_2}{A_2} = \frac{-10}{3{,}14} = -3{,}18\ \ кН/см^2 \quad \text{(siqilish),}$$

Sterjenning yuqori qismidagi kesim uchun:

$$\sigma_3 = \frac{N_3}{A_3} = \frac{20}{1{,}76} = 11{,}36\ \ кН/см^2 \ \text{(cho'zilish).}$$

Ma'lum masshtab birligida kuchlanishning epyurasini quramiz (1v - rasm)

δ ning epyurasini qurish uchun uchta B-B, C-C va D-D kesimlardagi ko'chishlarni aniqlaymiz (A-A kesimdagi ko'chish nolga teng ($\delta_A = 0$)). B-B kesim pastga ko'chadi, chunki sterjenning yuqori qismi cho'ziladi:

$$\delta_B = \delta_A + \Delta l_3 = 0 + \frac{N_3 \cdot (l_3 - l_2)}{E \cdot A_3} = 0 + \frac{20 \cdot 100}{2 \cdot 10^4 \cdot 0{,}785} = 0{,}127 \ \ см$$

C-C kesimning ko'chishi B-B (δ_B) kesimning ko'chishi bilan ikkinchi uchastkaning absolyut deformatsiyalarning yig'indisiga teng:

$$\delta_C = \delta_B + \Delta l_2 = 0{,}127 + \frac{N_2 \cdot (l_2 - l_1)}{E \cdot A_2} = 0{,}127 + \frac{-10 \cdot 50}{2 \cdot 10^4 \cdot 3{,}14} = 0{,}118 \ \ см .$$

D-D kesimning ko'chishi C-C (δ_C) kesimning ko'chishi bilan birinchi uchastkaning absolyut deformatsiyalarining yig'indisiga teng:

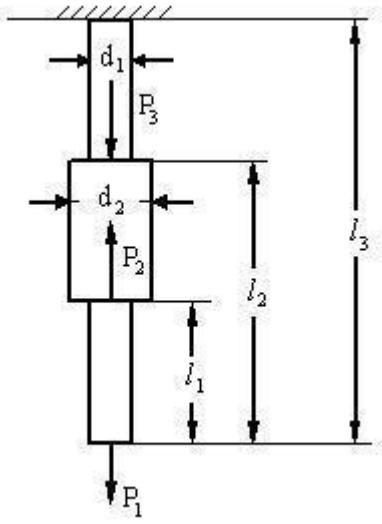
$$\delta_D = \delta_C + \Delta l_1 = 0{,}118 + \frac{N_1 \cdot l_1}{E \cdot A_1} = 0{,}118 + \frac{10 \cdot 100}{2 \cdot 10^4 \cdot 0{,}785} = 0{,}186 \ \ см .$$

Ma'lum masshtab tanlab, δ_C , δ_B, δ_D larning qiymatlarini qo'yamiz. Hosil qilingan nuqtalarni birlashtirib, ko'chishlarni epyurasini aniqlaymiz.

Shu masalani «Mathcad» matematik dasturi orqali ham echish mumkin.

Masala № 2.

Berilgan: 2 rasmda ko'rsatilgan sterjenga ta'sir etayotgan bo'ylama kuch- *N*, normal kuchlanish - σ kesimdagi ko'chishlar topilsin hamda ularning epyuralari qurilsin, agar d_1*=1 см* , d_2*=2 см* , l_1*= 100 см*, l_2*=150 см*, l_3*= 250 см* , P_1*=10 кН*, P_2*=-20 кН*, P_3*=30 кН*.



2 - rasm

Masalani echimi:

м := m см := 0.01·m кН := 1000·N $МПа := 10^6 \cdot \frac{N}{m^2}$

$E := 2 \cdot 10^5 \cdot МПа$ d1 := 1.0·см d2 := 2.0·см

$$F := \begin{pmatrix} 10 \\ -20 \\ 30 \end{pmatrix} \cdot кН \quad L_F := \begin{pmatrix} 0 \\ 100 \\ 150 \end{pmatrix} \cdot см \quad L := \begin{pmatrix} 100 \\ 150 \\ 250 \end{pmatrix} \cdot см$$

n := 3

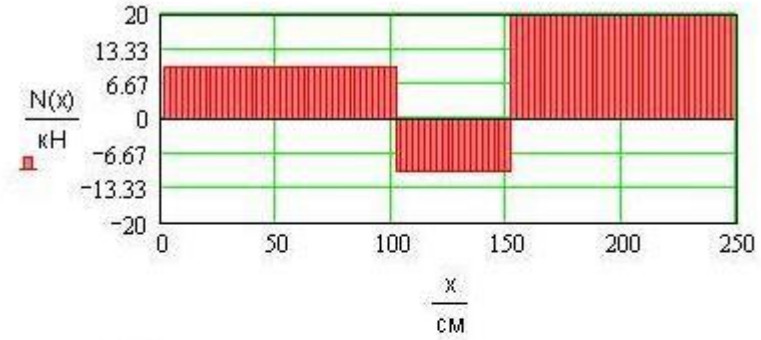
$$N(x) := \left[\sum_{i=1}^{n} F_i \cdot \left(x > L_{F_i} \right) \right]$$

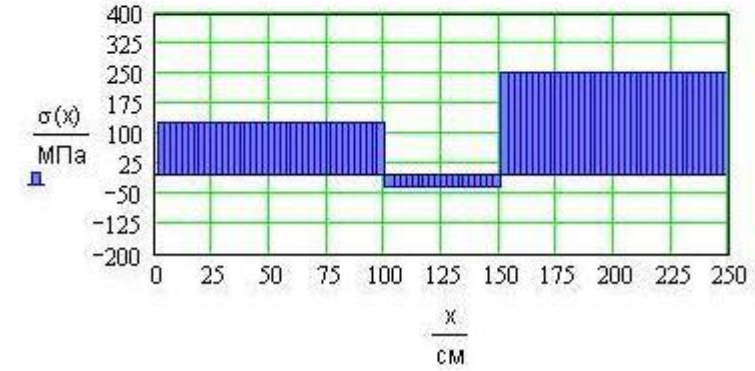
$$A(x) := \begin{cases} \left(\pi \cdot \frac{d1^2}{4} \right) & \text{if } 0 \le x < L_1 \\ \left(\pi \cdot \frac{d2^2}{4} \right) & \text{if } L_1 < x < L_2 \\ \left(\pi \cdot \frac{d1^2}{4} \right) & \text{if } L_2 < x \le L_3 \end{cases}$$

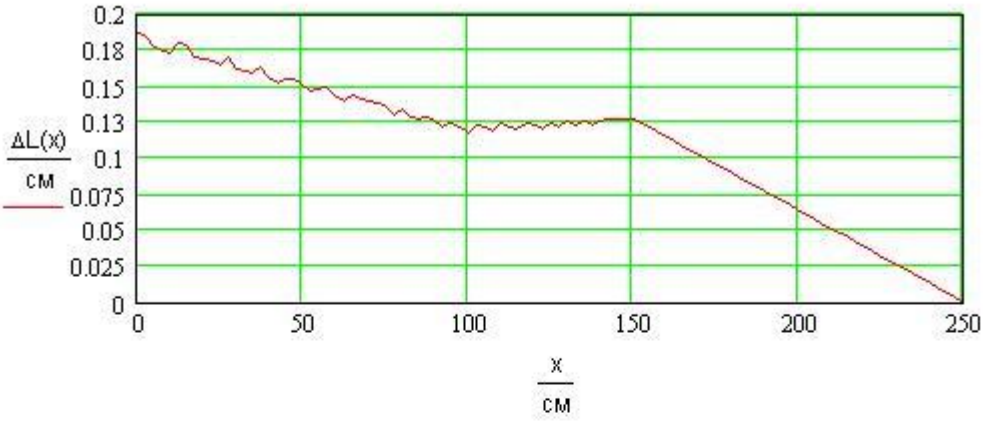
$$\sigma(x) := \frac{N(x)}{A(x)}$$

$$\Delta L(x) := \int_x^{L_3} \frac{N(x)}{E \cdot A(x)} \, dx$$

$$x := 0 \cdot см, \frac{L_3}{100} .. L_3$$







$x := 0.01\,см, \frac{L_3}{10} .. L_3$

x =		N(x) =		σ(x) =		ΔL(x) =	
$1 \cdot 10^{-4}$	m	10	кН	127.324	МПа	0.186	см
0.25		10		127.324		0.165	
0.5		10		127.324		0.154	
0.75		10		127.324		0.136	
1		10		127.324		0.118	
1.25		-10		-31.831		0.124	
1.5		-10		-31.831		0.127	
1.749		20		254.648		0.096	
1.999		20		254.648		0.064	
2.249		20		254.648		0.032	
2.499		20		254.648		$1.146 \cdot 10^{-4}$	

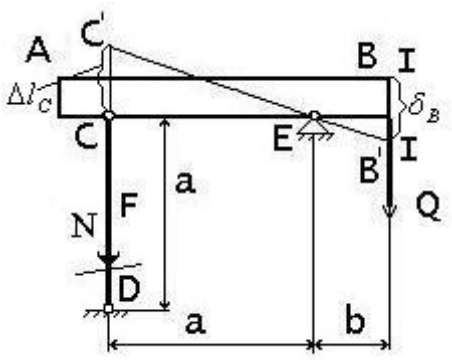
Masala № 2. Deformatsiyasini hisobga olmasligi mumkin bo'lgan AB brus(g'o'la) CB ga osib qo'yilgan yoki bir uchi bilan CB po'lat sterjenga tiralib turibdi (2-rasm). Bo'ylama kuch N, sterjendagi normal kuchlanish σ, va brusning B nuqtadagi ko'chishi δ aniqlansin hamda *d* diametr tanlansin.

Boshlang'ich qiymatlar 2- jadvaldan olinsin.

Misol № 3.

Berilgan: $a = 1\ м,\ в = 3\ м,\ Q = 150\ кН,\ [\sigma] = 16\ kH/см^2$

Aniqlansin: bo'ylama kuch - *N*, *d* –diametr tanlansin, δ - ko'chish aniqlansin



3-rasm

Echish:

Bo'ylama kuchni topish uchun statikaning muvozanat tenglamalarini tuzamiz:

$$\sum M_E = -N \cdot a + Q \cdot b = 0,$$

bundan : $$N = \frac{Q \cdot b}{a} = \frac{150 \cdot 3}{1} = 450\ \ кН$$

Kesimni tanlash uchun esa cho'zilishdagi mustahkamlik shartidan foydalanamiz.

Shartga asosan: $$\sigma = \frac{N}{A} \le [\sigma]$$

$$A = \frac{\pi \cdot d^2}{4} \ge \frac{N}{[\sigma]}$$

$$\text{bunda} \rightarrow \quad d = \sqrt{\frac{N \cdot 4}{\pi \cdot [\sigma]}} = \sqrt{\frac{450 \cdot 4}{3{,}14 \cdot 16}} = 5{,}9\,см$$

Normal kuchlanishni aniqlaymiz σ:

$$\sigma = \frac{N}{A} = \frac{450}{28} = 16{,}07\ \ кН/см^2$$

СД sterjenning absolyut cho'zilishini aniqlaymiz

$$\Delta l_c = \frac{N \cdot a}{E \cdot A} = \frac{450 \cdot 3 \cdot 100}{2 \cdot 10^4 \cdot 28} = 0{,}24\ \ см$$

B nuqtadagi ko’chishni aniqlash uchun 3-rasmda keltirilgan sistema deformatsiyasini qaraymiz. Uchburchaklar o’xshashligidan kesimdagi (δ_B) ko’chishni topamiz

$\Delta ECC' \infty \Delta EBB'$ bunda $EB = b,\ EC = a,\ CC' = \Delta l_C,\quad BB' = \delta_B$

$$\frac{\delta_B}{b} = \frac{\Delta l_C}{a} \Rightarrow \quad \delta_B = \frac{b}{a} \cdot \Delta l_C = \frac{100}{300} \cdot 0{,}24 = 0{,}08 \ \text{см}$$

2. CHO’ZILISH VA SIQILIShDAGI STATIK ANIQMAS MASALALAR

Agar konstruktsiyaga ta'sir etuvchi noma'lum kuchlar soni muvozaat tenglamalar sonidan ko’p bo’lsa, bunday masalalar statik aniqmas masalalar deyiladi. Statik aniqmas masalalarni echish uchun muvozanat tenglamalariga elastik deformatsiya tenglamalari qo’shiladi.

Deformatsiya tenglamalarini hosil qilishda qaralayotgan sistemani deformatsiyalangan holatini geometrik tasavvur qilinadi hamda sistemaning turli qismlaridagi deformatsiyalarini bog’liqligi aniqlanadi.

STATIK ANIQMAS MASALALARNI ECHISh REJASI

1. Noma'lumlarni aniqlab, statik aniqmaslik darajasini belgilaymiz.
2. Asosiy sistemani tanlaymiz.
3. Muvozanat tenglamalarini tuzamiz.
4. Deformatsiyalar tenglamalarini tuzamiz.
5. Statika va deformatsiya tenglamalarini birgalikda echib, noma'lum miqdorlarni aniqlaymiz
6. Echimning davomi statik aniq masalalarini echishga o’xshaydi.

MASALA № 3

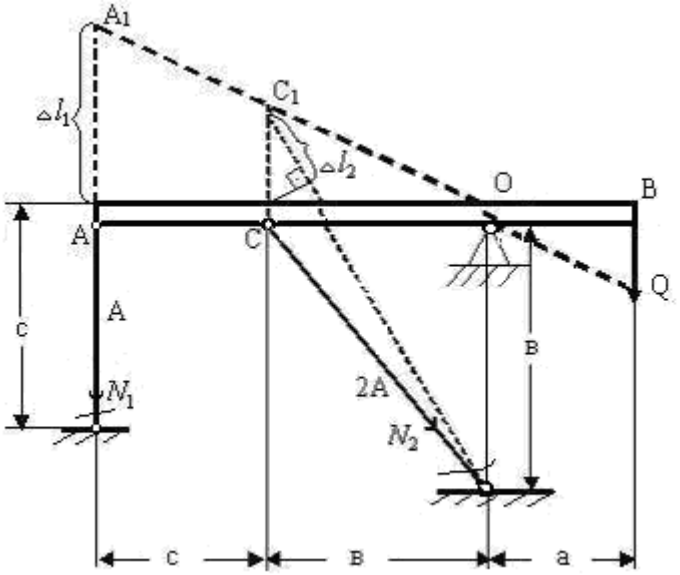
Absolyut qattiq brus(go'la) qo'zg'almas sharnirli tayanchga tiralgan holda ikki po'lat sterjenga sharnir vositasida bog'langan (4-rasm). N va σ larni topish talab etiladi.

Masala № 4.

ECHISh: qiymatlarni quyidagicha tanlaymiz:

$Q = 120\,кН$, $F = 6{,}0 \quad см^2$, $a = 2{,}0 \quad м$, $b = 3{,}0 \quad м$, $c = 1{,}0 \quad м$

1. AE va СД sterjenlardagi zo'riqishlarni mos ravishda N_1 va N_2 bilan belgilaymiz va ularni yo'nalishlarini chizmada tasvirlaymiz.



4-rasm

2.Qaralayotgan masala uchun statika tenglamalarini tuzamiz

$$\sum M_o(P_i) = 0 \qquad -N_1 \cdot (b+c) - N_2 \cdot b \cdot \sin 45^0 + Q \cdot a = 0 \qquad (1)$$

3.Konstruktsiyani olohida elementlari uchun deformatsiyaning geometrik bog'liqligini ifodalovchi tenglamalarni tuzamiz.

Sterjenning deformatsiyasini tekshirishda, AB qattiq g'o'la yangi A_1 ва B_1 holatga o'tadi. Bunda A ва C нуқталар AB qattiq g'o'la yo'nalishiga yuqoridan tik(perpendikulyar) yo'nalgan bo'ladi. AB qattiq g'o'la qo'zqalmas tayanch «O» nuqta atrofida aylanadi. Bundan, o'xshash uchburchaklar A_1AO ва C_1CO dan quyidagilarni keltiramiz:

$$\frac{AA_1}{CC_1} = \frac{в + c}{в} \qquad (2)$$

4.(2)dan Guk qonuni yordamida deformatsiya tenglamasini tuzamiz:

$$\Delta l_{AE} = AA_1 = \frac{N_1 \cdot a}{E \cdot A}$$

$$CC_1 = \frac{CK}{\sin 45^0} = \frac{\Delta l_{CD}}{\sin 45^0} = \frac{N_2 \cdot \sqrt{b^2 + b^2}}{E \cdot 2A \cdot \frac{\sqrt{2}}{2}} = \frac{N_2 \cdot \sqrt{2} \cdot b}{\sqrt{2} \cdot E \cdot A} = \frac{N_2 \cdot b}{E \cdot A}$$

AA_1 ning qiymatini (2) tenglikka qo'yamiz

$$\frac{N_1 \cdot a}{E \cdot A} : \frac{N_2 \cdot b}{E \cdot A} = \frac{b + c}{b}$$

bundan

$$\frac{N_1 \cdot a}{N_2 \cdot b} = \frac{4}{3} \qquad \text{ёки} \qquad \frac{N_1}{N_2} = 2 \qquad (3)$$

5.Olingan tenglamalarni birgalikda echamiz. (3) dan

$$N_1 = 2N_2$$

ekanligi kelib chiqadi. Olingan qiymatni (1) tenglamaga qo'yamiz:

$$-2N_2(b + c) - N_2 \cdot b \cdot \sin 45^0 + Q \cdot a = 0$$

bundan $N_2 = 24 \ \ кН$

(3) tenglamadan $N_1 = 48 \ \ кН$ ekanligi kelib chiqadi.

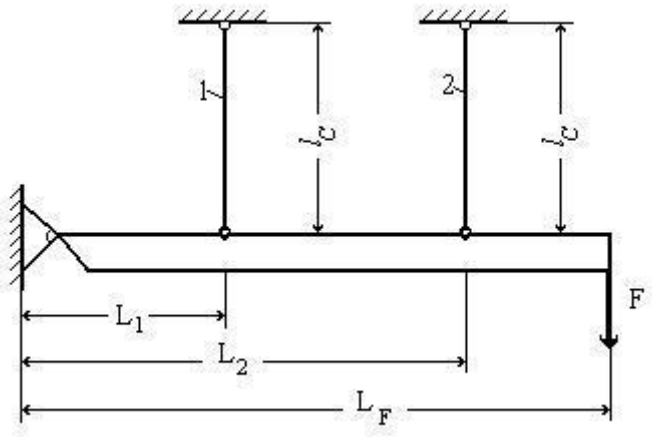
Sterjenlardagi kuchlanishlar quyidagicha aniqlanadi:

$$\sigma_1 = \frac{N_1}{A} = \frac{48}{6} = 8 \ \ кН/см^2; \qquad \sigma_2 = \frac{N_2}{2A} = \frac{24}{2 \cdot 6} = 2 кН/см^2$$

Bunday turdagi masalalarni «Mathcad» matematik dasturi yordamida ham echish mumkin (5-rasm).

Masala № 5. Sterjenlardan tashkil topgan sistema berilgan (5-rasm).

Sterjenlardagi zo'riqish va ko'chishlarni aniqlash talab qilinadi.



5-rasm

Boshlang'ich qiymatlar quyidagicha berilgan:

град := deg мм := 0.001·m см := 0.01·m кН := 1000·N $МПа := 10^6 \cdot \frac{N}{m^2}$

$E := 2 \cdot 10^5 \cdot МПа$ $\sigma_{доп} := 160 \cdot МПа$

$F := 10 \cdot кН$ $L_F := 100 \cdot см$

ECHISH:

$L := \begin{pmatrix} 60 \\ 80 \end{pmatrix} см$ $\phi := \begin{pmatrix} 90 \\ 90 \end{pmatrix} \cdot град$ $A := \begin{pmatrix} 1 \\ 2 \end{pmatrix} \cdot см^2$ $L_{ст} := \begin{pmatrix} 30 \\ 30 \end{pmatrix} \cdot см$ $k := \begin{pmatrix} 1 \\ 1 \end{pmatrix}$

$\Delta L(N,i) := \frac{N \cdot L_{ст_i}}{E \cdot A_i}$ $\Delta(N,i) := \frac{\Delta L(N,i)}{\sin(\phi_i)}$ $m := rows(A)$ $i := 1..m$

$N := \begin{pmatrix} 1 \\ 1 \end{pmatrix} \cdot кН$ Given $F \cdot L_F - \sum_{i=1}^{m} k_i \cdot N_i \cdot L_i \cdot \sin(\phi_i) = 0$ $\frac{\Delta(N_1,1) \cdot k_1}{L_1} = \frac{\Delta(N_2,2) \cdot k_2}{L_2}$

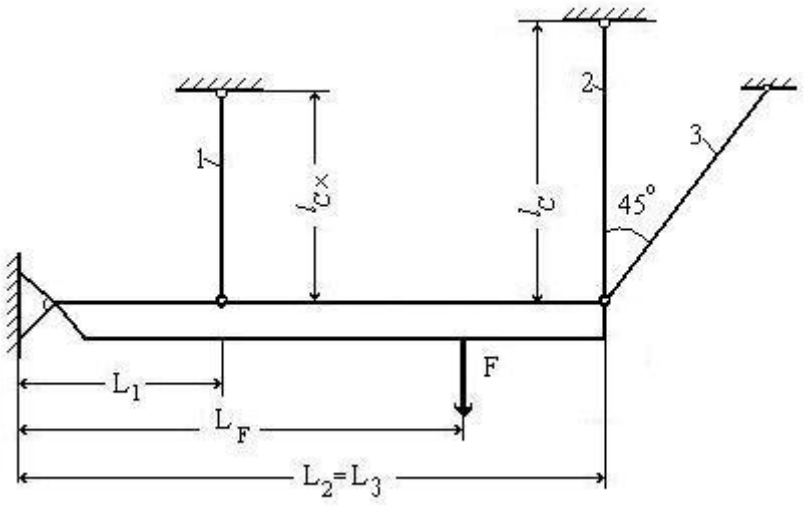
$N := Find(N_1, N_2)$ $N = \begin{pmatrix} 3.659 \times 10^3 \\ 9.756 \times 10^3 \end{pmatrix} N$ $\sigma := \frac{\vec{N}}{A}$ $\sigma = \begin{pmatrix} 3.659 \times 10^7 \\ 4.878 \times 10^7 \end{pmatrix} Pa$

$\Delta L(N_i,i) = \begin{pmatrix} 0.055 \\ 0.073 \end{pmatrix} мм$

Masala № 6.

Sterjenlardan tashkil topgan sistema berilgan (6-rasm).

Sterjenlardagi zo'riqish va ko'chishlarni aniqlash talab qilinadi.



6-rasm

Boshlang'ich qiymatlar:

$$\text{град} := \text{deg} \quad \text{мм} := 0.001\cdot\text{m} \quad \text{см} := 0.01\cdot\text{m} \quad \text{кН} := 1000\cdot\text{N} \quad \text{МПа} := 10^6\cdot\frac{\text{N}}{\text{m}^2}$$

$$E := 2\cdot10^5\cdot\text{МПа} \qquad \sigma_{\text{доп}} := 160\cdot\text{МПа}$$

$$F := 20\cdot\text{кН} \qquad L_F := 100\cdot\text{см}$$

ECHISH:

$$L := \begin{pmatrix}50\\150\\150\end{pmatrix}\cdot\text{см} \quad \phi := \begin{pmatrix}90\\90\\45\end{pmatrix}\cdot\text{град} \quad A := \begin{pmatrix}1\\1\\1\end{pmatrix}\cdot\text{см}^2 \quad L_{ст} := \begin{pmatrix}40\\60\\\frac{40}{\sin(\phi_3)}\end{pmatrix}\cdot\text{см} \quad k := \begin{pmatrix}1\\1\\1\end{pmatrix}$$

$$\Delta L(N,i) := \frac{N\cdot L_{ст_i}}{E\cdot A_i} \qquad \Delta(N,i) := \frac{\Delta L(N,i)}{\sin(\phi_i)} \qquad m := \text{rows}(A) \qquad i := 1..m$$

$$N := \begin{pmatrix}1\\1\\1\end{pmatrix}\cdot\text{кН} \qquad \text{Given} \quad F\cdot L_F - \sum_{i=1}^{m} k_i\cdot N_i\cdot L_i\cdot\sin(\phi_i) = 0 \quad \frac{\Delta(N_1,1)\cdot k_1}{L_1} = \frac{\Delta(N_2,2)\cdot k_2}{L_2}$$

$$\frac{\Delta(N_2,2)\cdot k_2}{L_2} = \frac{\Delta(N_3,3)\cdot k_3}{L_3}$$

$$N := \text{Find}(N_1,N_2,N_3) \qquad N = \begin{pmatrix}3.929\times10^3\\7.857\times10^3\\5.893\times10^3\end{pmatrix}\text{N} \qquad \sigma := \frac{\overrightarrow{N}}{A} \qquad \sigma = \begin{pmatrix}3.929\times10^7\\7.857\times10^7\\5.893\times10^7\end{pmatrix}\text{Pa}$$

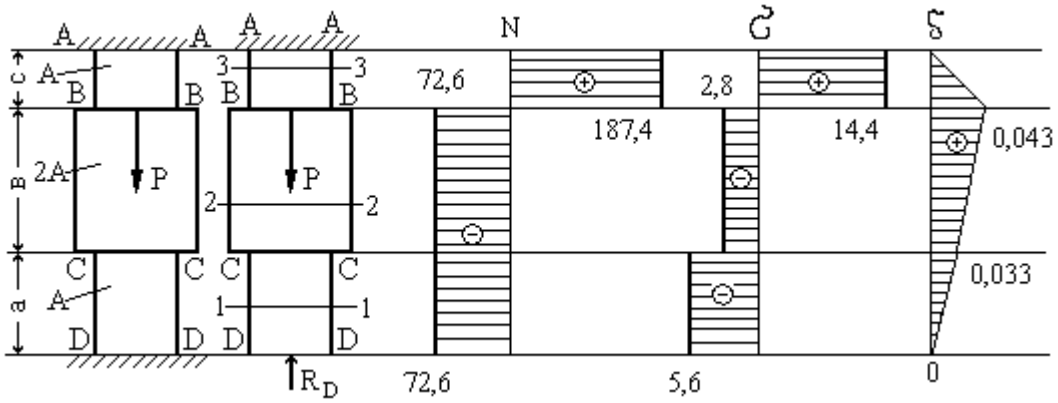
$$\Delta L(N_i,i) = \begin{pmatrix}0.079\\0.236\\0.167\end{pmatrix}\text{мм}$$

Masala № 4.

AB brus ikala tomondan mahkamlangan (7-rasm). Brusning barcha q1ismlaridagi zo'riqishlarni aniqlab, N , σ ва δ larning epyuralari qurilsin.

Masala № 7.

Echish: Berilgan: *A=13 см^2, a=1,2 м, в=0,7 м, c=0,6 м, P=260 кН.*



7-rasm

Ko'pincha P kuch sterjenning biriktirilgan yuqori yoki pastki qismlariga qo'yiladi. Biriktirilgan joylarda ikkita no'malum reaktsiya kuchlarini muvozanat tenglama yordamida aniqlab bo'lmaydi. Deformatsiya tenglamasini tuzish uchun: biriktirilgan joyning bir tomonini tashlab yuborib, masalan pastki qismi o'rniga noma'lum Dreaktsiya kuchini qo'yamiz. Bu holatdagi sistemada (ya'ni asosiy sistema deb ataladi) pastki ko'chishini nolga teng deb olinadi.

Bo'ylama N kuchni aniqlash uchun kesish usulidan foydalanib, muvozanat tenglamalarini tuzamiz:

1-1 kesim $N_1 + R_D = 0$;

$$N_1 = -R_D \qquad (1)$$

2-2 kesim $N_2 + R_D = 0$;

$$N_2 = -R_D \qquad (2)$$

3-3 kesim $N_3 + R_D - P = 0$;

$$N_3 = P - R_D \qquad (3)$$

Qo'shimcha tenglamalar:

$$\delta_D = \Delta l_1 + \Delta l_2 + \Delta l_3 = 0 \qquad (4)$$

Deformatsiyani aniqlash uchun Guk qonunidan foydalanamiz:

$$\Delta l_1 = \frac{N_1 \cdot a}{E \cdot A}, \qquad \Delta l_2 = \frac{N_2 \cdot b}{E \cdot 2A}, \quad \Delta l_3 = \frac{N_3 \cdot c}{E \cdot A} \qquad (5)$$

(5) ifodani (4) ga qo'yib,

$$\frac{N_1 a}{EA} + \frac{N_2 b}{E2A} + \frac{N_3 c}{EA} = 0 \ ,$$

Ifodani hosil qilamiz. Bundan

$$2N_1 a + N_2 b + 2N_3 c = 0 \qquad (6)$$

(6) ga (1,2,3) larni qo'yamiz

$$-2{,}4R_D - 0{,}7R_D + 312 - 1{,}2R_D = 0$$

$$312 = 4{,}3R_D$$

$$R_D = 72{,}6\,kH$$

Natijada zo'riqish kuchlari aniqlanadi. $N_1 = -72{,}6\,kH,\ N_2 - 72{,}6\ kH,\ N_3 = 187{,}4\,kH$.

Kuchlanishlarni hisoblaymiz $\sigma_1 = \frac{N_1}{A} = \frac{-72{,}6}{13} = -5{,}6\,kH/см^2$

$$\sigma_2 = \frac{N_2}{2A} = \frac{-72{,}6}{13 \cdot 2} = -2{,}8\,kH/см^2$$

$$\sigma_3 = \frac{N_3}{A} = \frac{187{,}4}{13} = 14{,}4\,kH/см^2$$

Bo'ylama kuch N va normal kuchlanish σ epyuralarini quramiz.

B-B, C-C va D-D (A-A kesimning ko'chishi nolga teng ($\delta_A = 0$)) kesimlarga epyura qurish uchun δ ko'chishni aniqlaymiz. Yuqori qismi cho'zilganligi sababli, B-B kesim pastga ko'chadi:

$$\delta_B = \delta_A + \Delta l_3 = 0 + \frac{N_3 \cdot c}{E \cdot A_3} = 0 + \frac{187{,}4 \cdot 60}{2 \cdot 10^4 \cdot 13} = 0{,}043\ см \ ,$$

Kesimlarning pastga ko'chishini musbat, yuqoriga ko'chishini manfiy deb hisoblaymiz. C-C kesim ko'chishining albegraik yig'indisi, B-B (δ_B) kesim ko'chishi va sterjenni qisqarishi:

$$\delta_C = \delta_B + \Delta l_2 = 0{,}043 + \frac{N_2 \cdot b}{E \cdot 2A_2} = 0{,}043 - \frac{72{,}6 \cdot 70}{2 \cdot 10^4 \cdot 2 \cdot 13} = 0{,}033\ см \ ,$$

D-D kesim ko'chishining albegraik yig'indisi, B-B (δ_B) kesim ko'chishi va sterjenni cho'zilishi:

$$\delta_D = \delta_C + \Delta l_1 = 0{,}033 + \frac{N_1 \cdot a}{E \cdot A_1} = 0{,}033 - \frac{72{,}6 \cdot 120}{2 \cdot 10^4 \cdot 13} = 0$$

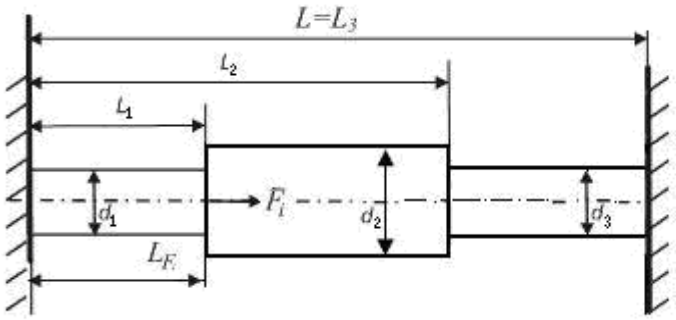
Epyurada δ_C , δ_B, δ_D ko'rsatkichlari aniq masshtab bo'yicha tuziladi va xosil bo'lgan nuqtalar tutashtirilganda to'g'ri chiziq, ya'ni ko'chish chiziqli va undagi kesim ko'chishining abtsissasiga bog'liq.

Ushbu masalalarni «Mathcad»matematik dasturi orqali echamiz.

Masala № 8.

ORIGIN := 1 м := m см := 0.01·m кН := 1000·N МПа := $10^6 \cdot \frac{N}{m^2}$

Sterjenni yuklash sxemasi



Berilgan:

E := $2 \cdot 10^7$·МПа d1 := 4·см d2 := 6·см LL := 13600·см

$$F := \begin{pmatrix} 0 \\ -260 \\ 0 \end{pmatrix} \cdot кН \quad L_F := \begin{pmatrix} 0 \\ 60 \\ 0 \end{pmatrix} \cdot см \quad L := \begin{pmatrix} 60 \\ 130 \\ 250 \end{pmatrix} \cdot см$$

$$A(x) := \begin{cases} \left(\pi \cdot \frac{d1^2}{4}\right) & \text{if } 0 \le x < L_1 \\ \left(\pi \cdot \frac{d2^2}{4}\right) & \text{if } L_1 \le x < L_2 \\ \left(\pi \cdot \frac{d1^2}{4}\right) & \text{if } L_2 \le x \le L_3 \end{cases}$$

Sterjendagi bo'ylama kuch

n := rows(F)

$$N(x,R) := R + \sum_{i=1}^{n} F_i \cdot \left(x > L_{F_i}\right)$$

Kuchlanish

$$\sigma(x,R) := \frac{N(x,R)}{A(x)}$$

Sterjenni uzayishi

$$\Delta L(x,R) := \int_0^x \frac{N(x,R)}{E \cdot A(x)}\, dx$$

$$x := 0 \cdot см, \frac{L_3}{100} .. L_3$$

$\Delta(L,R) = 0$

Deformatsiya tenglamasini echish:

R := 10·кН

$$R := root\left(\Delta L\left(L_3, R\right), R\right)$$

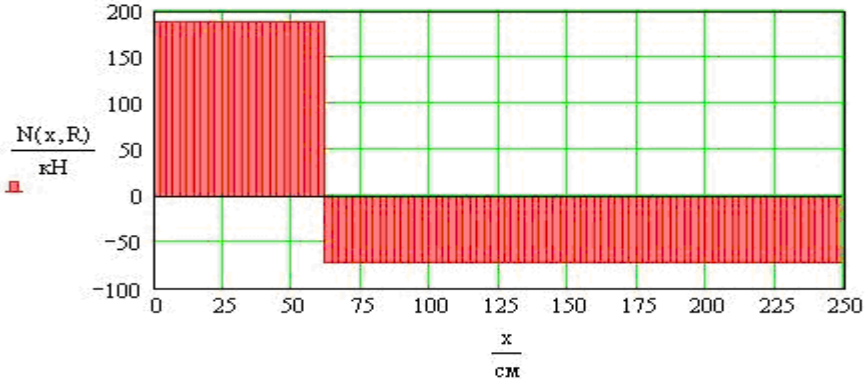
R = 188.143 кН

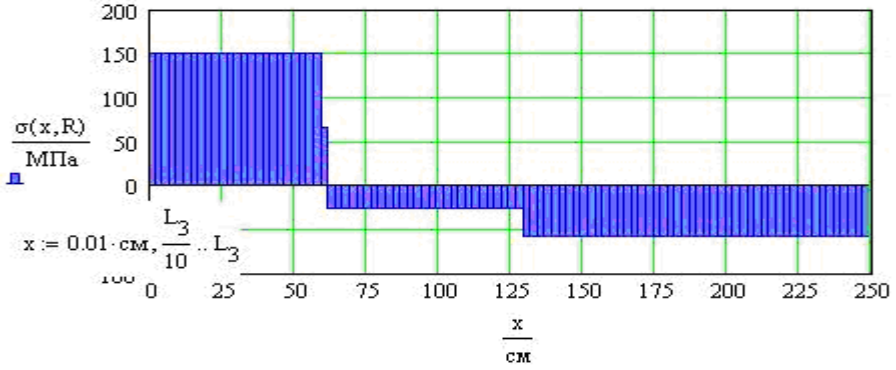
x=0 и x=LL

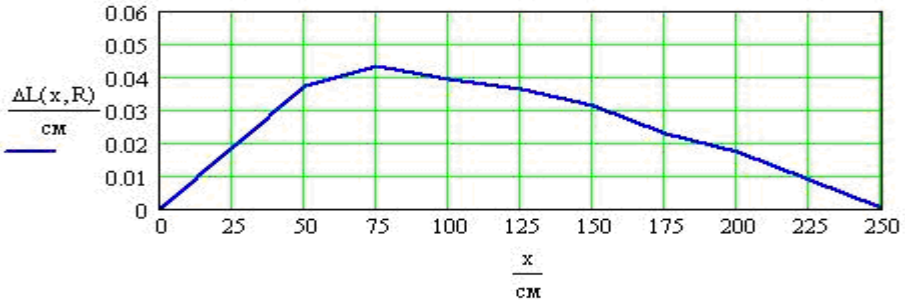
$\Delta L\left(L_3, R\right) = 0$см

$\Delta L(0 \cdot см, R) = 0$ см

Hisoblash natijalari







$x := 0.01 \cdot см, \frac{L_3}{10} .. L_3$

x =		N(x,R) =		σ(x,R) =		ΔL(x,R) =	
0.01	см	188.1	кН	150	МПа	0	см
25		188.1		150		0.02	
49.99		188.1		150		0.04	
74.98		-71.9		-25		0.04	
99.97		-71.9		-25		0.04	
124.96		-71.9		-25		0.04	
149.95		-71.9		-57		0.03	
174.94		-71.9		-57		0.02	
199.93		-71.9		-57		0.02	
224.92		-71.9		-57		0.01	
249.91		-71.9		-57		0	

KALIT SO’ZLAR:

1. Cho’zilish
2. Siqilish
3. Deformatsiya
4. Uzayish
5. Qisqarish
6. Absolyut deformatsiya
7. Nisbiy deformatsiya
8. Kuchlanish
9. Cho’zilish va siqilishdagi mustahkamlik sharti
10. Mustahkamlik
11. Kesim
12. Guk qonuni

O’Z-O’ZINI NAZORAT QILISH SAVOLLARI (CHO’ZILISH-SIQILISH)

1. Kesish usulini afzalligi nimadan iborat?
2. Guk qonunini ifodalang
3. Elastiklik moduli deganda nimani tushunasiz?
4. Qanday sistemalar statik aniq sistemalar deyiladi?
5. Qanday sistemalar statik aniqmas sistemalar deyiladi?
6. Statik aniqmas sistemalarning echishni qanday usullari mavjud?
7. Statik aniqmas sistemalarni echish tartibi qanday?
8. Statik aniq va statik aniqmas sistemalarning farqlovchi parametrlari nimalardan iborat?
9. Cho’zilish va siqilishda deformatsiya.

Asosiy belgilashlar

N - Bo'ylama kuch
l - Uzunlik
x - Diskrit o'zgaruvchi
P, F - Kuch
σ - Normal kuchlanish
ΔL - Sterjenning cho'zilishi

TOPSHIRIQLARNI BAJARISH UCHUN BERILGAN MIQDORLAR
(1,2,3,4 - jadvallar)

Jadval № 1

№	Sxe-ma	A (sm^2)	l_1 (m da)	l_2 (m да)	P_1 (kN da)	P_2 (kN da)
1	**I**	**10**	**2,0**	**1,0**	**10**	**30**
2	**II**	**11**	**2,1**	**1,1**	**11**	**31**
3	**III**	**12**	**2,2**	**1,2**	**12**	**32**
4	**IV**	**13**	**2,3**	**1,3**	**13**	**33**
5	**V**	**14**	**2,4**	**1,4**	**14**	**34**
6	**VI**	**15**	**2,5**	**1,5**	**15**	**35**
7	**VII**	**16**	**2,6**	**1,6**	**16**	**36**
8	**VIII**	**17**	**2,7**	**1,7**	**17**	**37**
9	**IX**	**18**	**2,8**	**1,8**	**18**	**38**
10	**X**	**19**	**2,9**	**1,9**	**19**	**40**

Jadval № 2

№	Sxe-ma	**a** (m da)	**в** (m da)	**c** (m da)	**Q** (kN da)
1	**1**	**2,1**	**0,5**	**0,6**	**110**
2	**2**	**2,2**	**0,6**	**0,7**	**120**
3	**3**	**2,3**	**0,7**	**0,8**	**130**
4	**4**	**2,4**	**0,8**	**0,9**	**140**
5	**5**	**2,5**	**0,9**	**0,5**	**150**
6	**6**	**2,6**	**0,6**	**0,6**	**160**
7	**7**	**2,7**	**0,7**	**0,7**	**170**
8	**8**	**2,8**	**0,8**	**0,8**	**180**
9	**9**	**2,9**	**0,9**	**0,9**	**190**
10	**10**	**3,0**	**1,0**	**2,0**	**200**

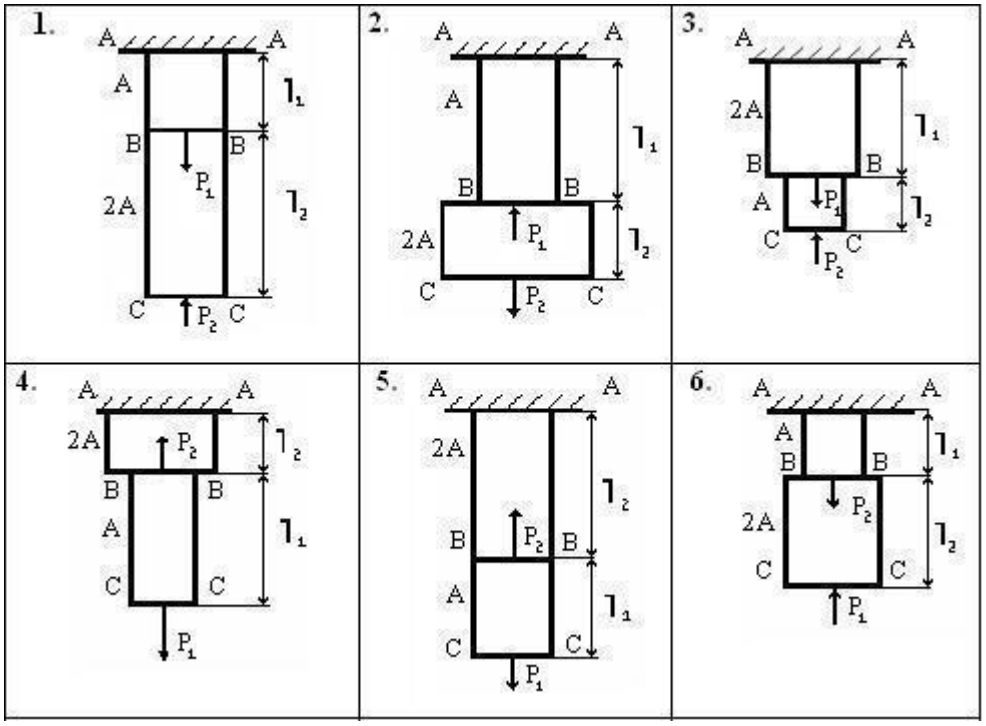
Jadval № 3

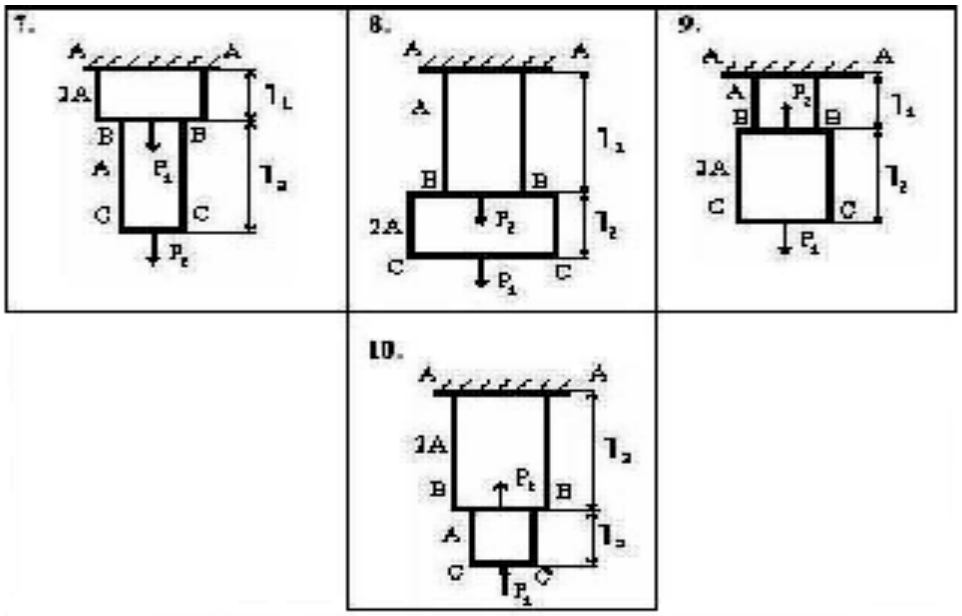
№	Sxema	***A*** **(sm^2)**	**a (m da)**	**в (m da)**	**c (m da)**	**Q (kN da)**
1	I	5	2,1	2,1	1,1	110
2	II	6	2,2	2,2	1,2	120
3	III	7	2,3	2,3	1,3	130
4	IV	8	2,4	2,4	1,4	140
5	V	9	2,5	2,5	1,5	150
6	VI	10	2,6	2,6	1,6	160
7	VII	11	2,7	2,7	1,7	170
8	VIII	12	2,8	2,8	1,8	180
9	IX	13	2,9	2,9	1,9	190
0	X	14	3,0	3,0	2,0	200

Jadval № 3

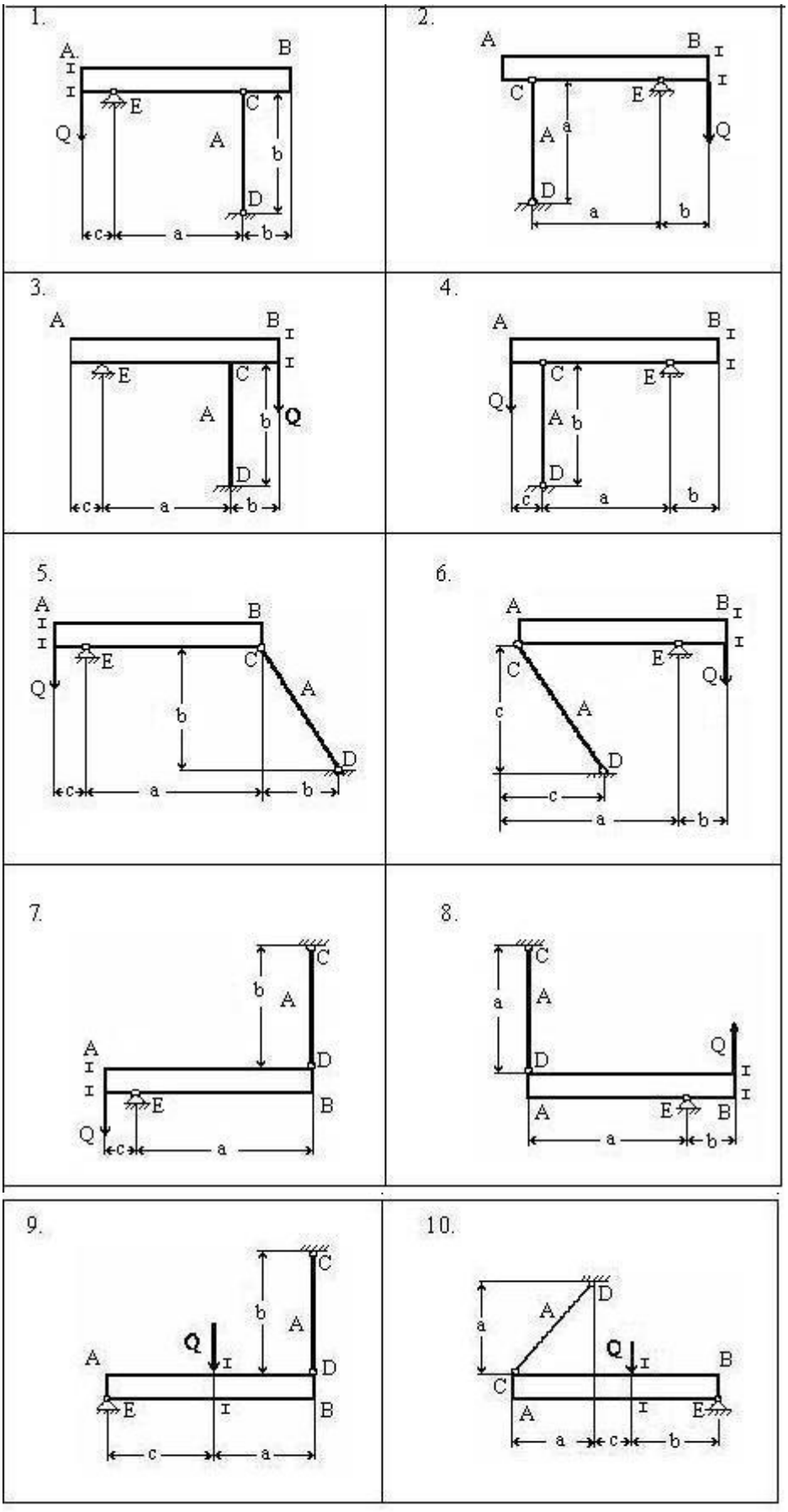
№	Sxema	***A*** **(sm^2)**	**a (m da)**	**в (m da)**	**c (m da)**	P **(kN da)**
1	I	11	1,0	0,5	0,4	220
2	II	12	1,1	0,6	0,5	240
3	III	13	1,2	0,7	0,6	260
4	IV	14	1,3	0,8	0,8	280
5	V	15	1,4	0,9	1,0	300
6	VI	16	1,5	1,0	1,2	320
7	VII	17	1,6	1,2	1,4	340
8	VIII	18	1,7	1,3	1,6	360
9	IX	19	1,8	1,4	1,8	380
0	X	20	2,0	1,6	2,0	400

№ 1 - topshiriq sxemasi

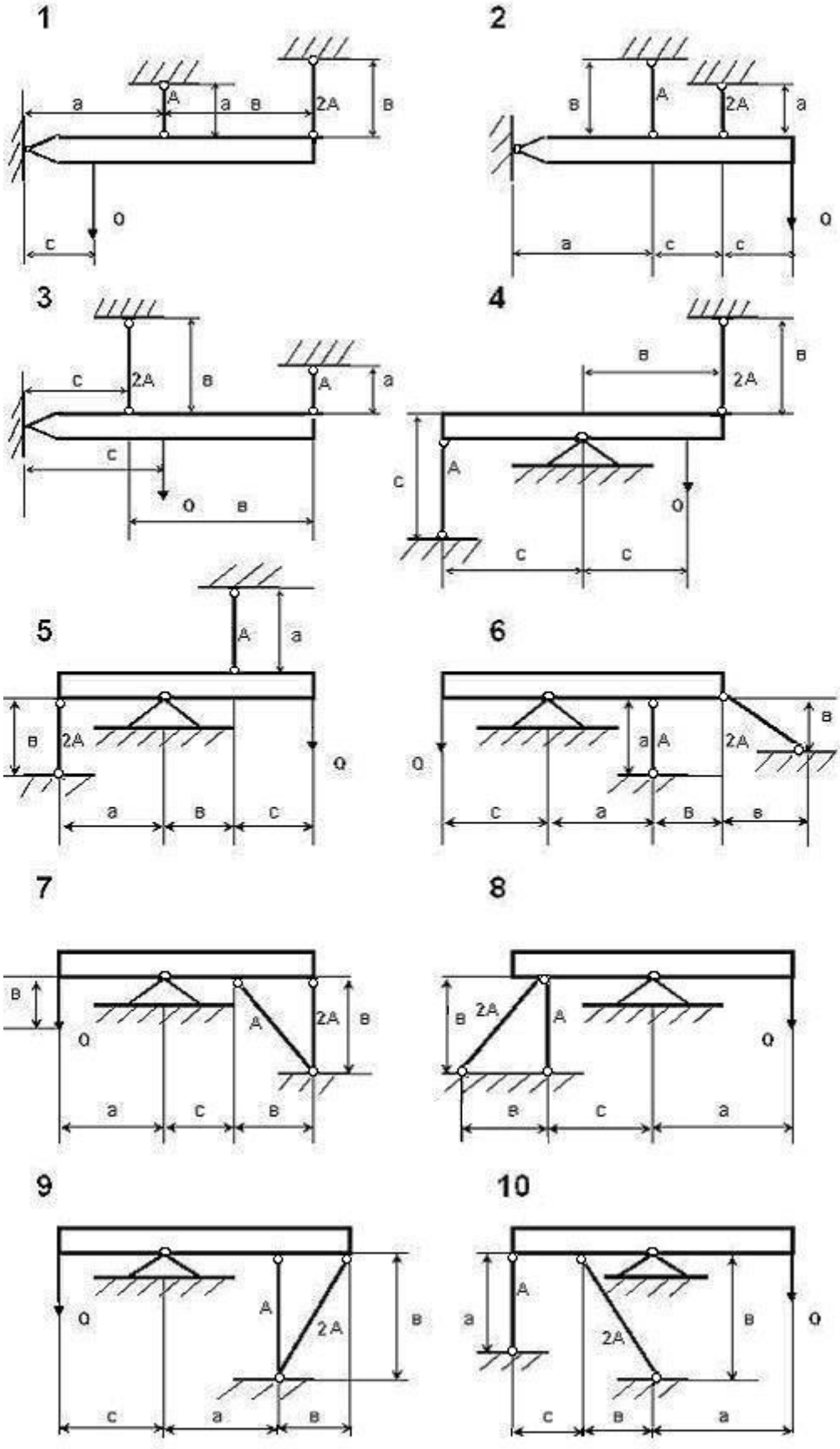




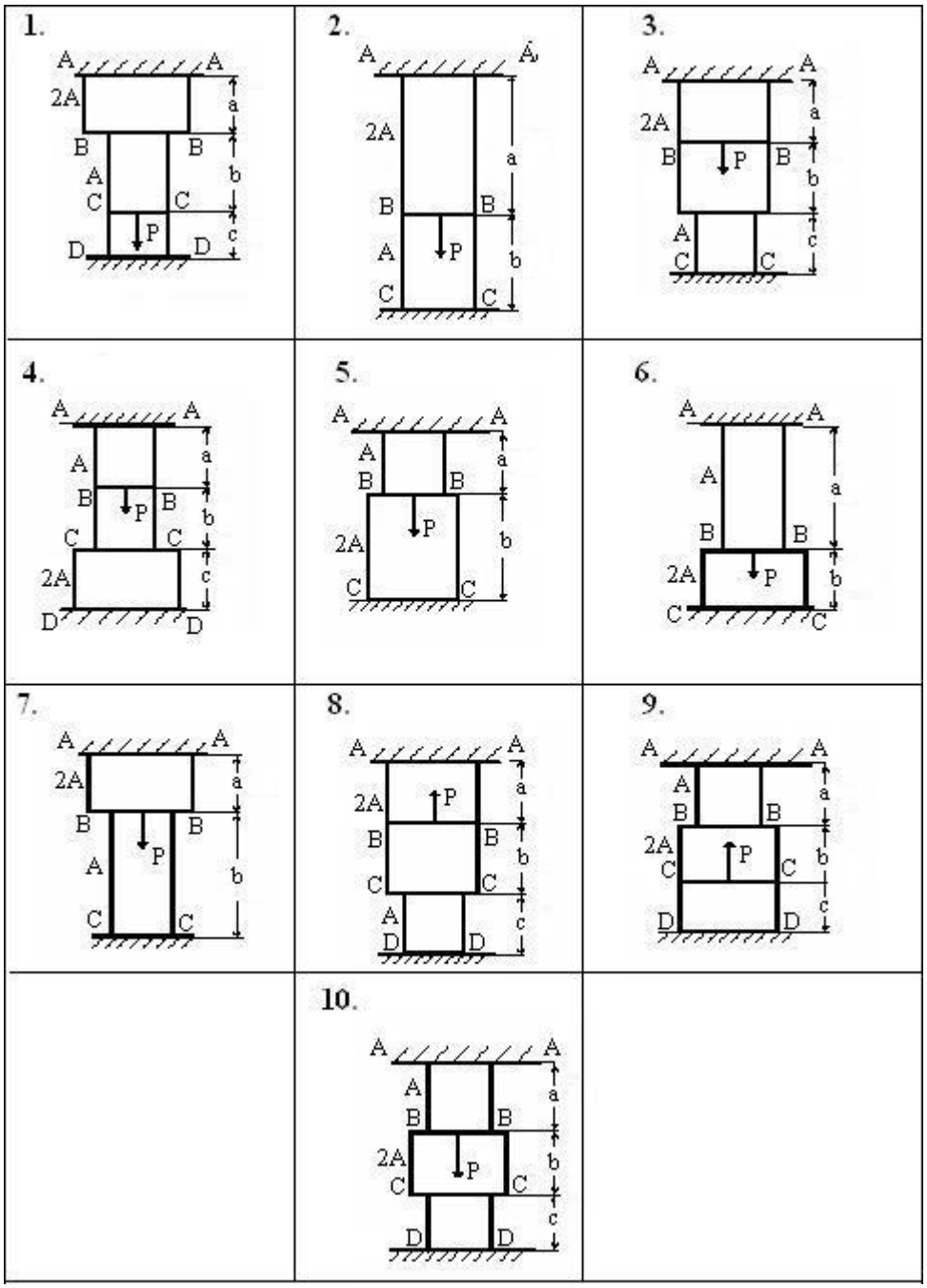
№ 2 - topshiriq sxemasi



№ 3 - topshiriq sxemasi



№ 4 - topshiriq sxemasi



II – BURALISH

UMUMIY TUShUNChALAR

Buralish deb – o’qiga tik tekisliklarda uchlariga teng va qarama-qarshi yo’nalgan kuchlar jufti qo’yilgan g’o’lacha (brus)ning deformatsiyalanishiga aytiladi. Buralishga vallar, vintli prujinalar va boshqalar ishlaydi.

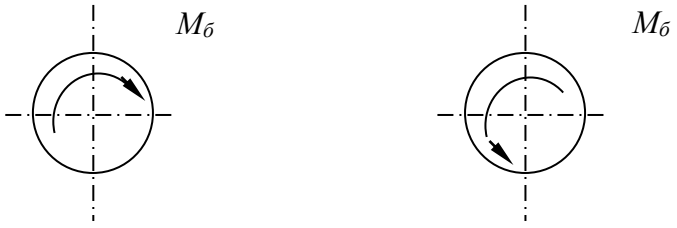
Buralishda – g’o’lacha (brus)ning ko’ndalang kesimlarida burovchi momentlar $M_б$ вужудга келади.

G’o’lachaning ixtiyoriy kўndalang kesimidagi burovchi moment kesimning bir tomonida g’o’lacha qo’yilgan tashqi burovchi momentlar (o’qqa nisbatan) albegraik yig’indisiga teng.

Epyuralarni yasashni soddalashtirish uchun quyidagi ishoralar qonunini qabul qilamiz

Mustahkamlik va bikrlikka hisoblashda, $M_б$ burovchi momentning epyuralarini yasashni soddalashtirish uchun quyidagi ishoralar qonunini qabul qilamiz: agar g’o’lachaning kesib olingan qismining yon tomoni (torets)ga qaraganda burovchi moment soat mili bo’yicha yo’nalgan bo’lsa, burovchi moment musbat, agar aksincha yo’nalgan bo’lsa, manfiy ishorali bo’ladi.

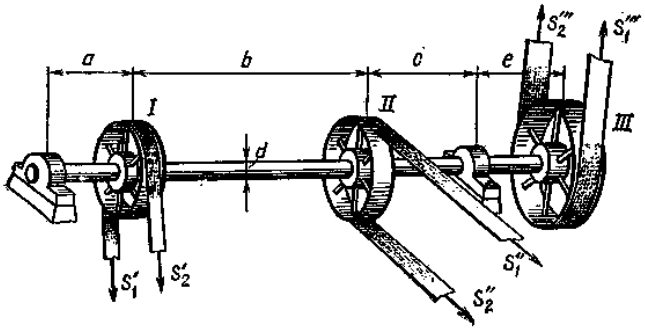
8-Rasm.



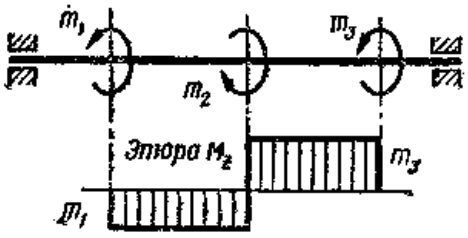
8-rasm. Burovchi moment ishoralari

Nazariy jihatdan doiraviy kesimli g’o’lachaning buralishida ko’pincha har xil vallarning hisobi qilinadi.

9-rasmda ko’rinib turibdiki, buralishda g’o’lachaning deformatsiyasi tavsifi ko’ndalang kesimi shakliga bog’liq. Materiallar qarshiligida buralishga doir masalalar, faqat ko’ndalang kesimi doiraviy yoki xalqali shakldagi g’o’lalar uchun bajariladi. 9-rasmda transmission val ko’rsatilgan



9-rasm



10-rasm

Ko’pincha vallar, buralish bilan birga egilish deformatsiyasi ta'sirida bo’ladi. Agar egilish deformatsiyasi inobatga olinmasa, ***xisobiy sxema*** quydagicha bo’ladi (10-rasm).

Buralishdagi asosiy formulalar:

Buralishda maksimal urinma kuchlanish:

$$\tau_{\max} = \frac{M_б}{W_\rho},$$

bunda: $M_б$ - burovchi moment, birligi $[кН \cdot м]$

W_ρ - Qutb qarshilik momenti

Dumaloq kesim uchun qutb qarshilik momenti:

$$W_\rho = \frac{\pi \cdot d^3}{16}, \text{ birligi } [см^3]$$

Buralishda mustahkamlik sharti:

$$\tau_{\max} = \frac{M_б}{W_\rho} \le [\tau]$$

Buralishda buralish burchagi:

$$\varphi = \frac{M_б \cdot l}{G \cdot J_\rho} \text{ ,birligi } [рад]$$

Buralishda bikrlik sharti:

$$\varphi_{\max} = \frac{M_б \cdot l}{G \cdot J_\rho} \cdot \frac{180}{\pi} \le [\varphi]$$

bunda: $l = 100 \ \ см$ - valning uzunligi

G - siljishdagi elastiklik moduli, $[G = 8 \cdot 10^3 кН/см^2]$

J_ρ - Qutb inertsii momenti, $J_\rho = \frac{\pi \cdot d^4}{32}$, $\left[см^4\right]$,

Buralishda g'o'laning bikrligi , $G \cdot J_\rho$

1 metr(100 см) val uchun ruxsat etilgan buralish burchagining o'rtacha qiymati $[\varphi] = 0{,}5^0$.

Masala.

Po'lat valga uchta M_1, M_2, M_3 moment qo'yilgan. Quyidagilarni aniqlaymiz:

1. Burovchi momentlarni aniqlaymiz va ularning epyuralarini quramiz;

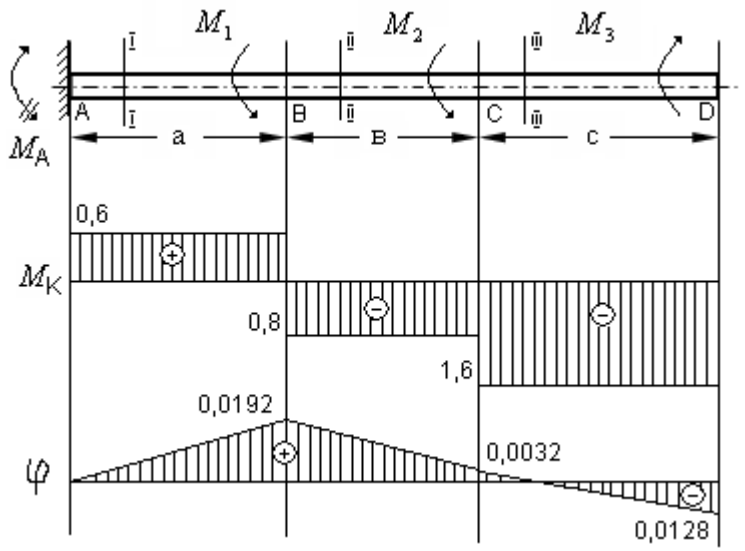
2. Berilgan $[\tau]$ orqali valning diametri d aniqlanib, xisobiy mustahkamlik shartidan standartga yaqini tanlanadi (30,35,40,45,50,60,70,80,100,110,120 мм);

3.Buralish burchagi epyurasini quramiz;

4. Валнинг мустаҳкамлигидан, агар $[\varphi] = 0{,}5^0$ $l = 1\ м$ да φ.

Мисол № 9:

Berilgan: $M_1 = 1{,}4\ кН \cdot м$, $M_2 = 0{,}8\ кН \cdot м$, $M_3 = 1{,}6\ кН \cdot м$, $[\tau] = 8\ кН/см^2$, $a = 1{,}6\ м$, $в = 1 м$, $c = 1{,}4 м$



11- rasm.

Echish:

1. Statik muvozanat tenglama tuzamiz va M_A ni aniqlaymiz:

$$\sum M_A = 0$$

$$M_1 + M_2 - M_3 + M_A = 0 \quad \Rightarrow \qquad M_A = 1{,}6 - 1{,}4 - 0{,}8 = -0{,}6\ кН \cdot м$$

2. Burovchi momentlar epyuralarini quramiz:

Burovchi momentlarni aniqlash uchun kesish usulidan foydalanamiz:

1 kesim $M_{б1} = M_A = 0{,}6\ кН \cdot м$

2 kesim $M_{б2} = M_A - M_1 = 0{,}6 - 1{,}4 = -0{,}8\ \ кН \cdot м$

3 kesim $M_{б3} = M_A - M_1 - M_2 = 0{,}6 - 1{,}4 - 0{,}8 = -1{,}6\ \ кН \cdot м$

Valning mustahkamlik shartidan foydalanib, uning diametrini aniqlaymiz: $d - ?$

$$\tau_{\max} = \frac{M_K}{W_\rho} \le [\tau] \quad \text{и} \quad W_\rho = \frac{\pi \cdot d^3}{16}$$

$$d = \sqrt[3]{\frac{16 \cdot M_K}{\pi \cdot \{\tau\}}} = \sqrt[3]{\frac{16 \cdot 1{,}6 \cdot 100}{3.14 \cdot 8}} = 4{,}8\ см,\ \text{diametr}\ d = 50\ мм\ \text{deb olamiz.}$$

Inertsiya momentini aniqlaymiz: $J_\rho = \frac{\pi \cdot d^4}{32} = \frac{3{,}14 \cdot 5^4}{32} = 62{,}5\ см^4$

3. Buralish burchagi epyurasini quramiz: $\varphi = \frac{M_{KP} \cdot l}{G \cdot J_\rho}$

$\varphi_A = 0$

$$\varphi_B = \varphi_A + \varphi_{AB} = 0 + \frac{M^1_{KP} \cdot a}{G \cdot J_\rho} = 0 + \frac{0{,}6 \cdot 160 \cdot 100}{8 \cdot 10^3 \cdot 62{,}5} = 0{,}0192\ \ рад$$

$$\varphi_C = \varphi_B + \varphi_{BC} = 0 + \frac{M^2_{KP} \cdot в}{G \cdot J_\rho} = 0{,}0192 - \frac{0{,}8 \cdot 100 \cdot 100}{8 \cdot 10^3 \cdot 62{,}5} = 0{,}0032\ \ рад$$

$$\varphi_D = \varphi_C + \varphi_{CD} = 0 + \frac{M^3_{KP} \cdot c}{G \cdot J_\rho} = 0{,}0032 - \frac{0{,}8 \cdot 140 \cdot 100}{8 \cdot 10^3 \cdot 62{,}5} = -0{,}0128\ \ рад$$

Buralish burchagi epyurasi qurildi 11- rasm.

4. Buralish burchagini aniqlaymiz va valning mustahkamlik shartini tekshiramiz:

$$\varphi_{\max} = \frac{M_K \cdot 100}{G \cdot J_\rho} \cdot \frac{180}{\pi} \le [\varphi]$$

$$\varphi_{\max} = \frac{M_K \cdot 100}{G \cdot J_\rho} \cdot \frac{180}{\pi} = \frac{180}{\pi} \cdot \frac{1{,}6 \cdot 100 \cdot 100}{8 \cdot 10^3 \cdot 62{,}5} = 1{,}8^0$$

Agar yo'l qo'yilgan buralish burchagi $[\varphi] = 0{,}5^0$ bўlsa, 1 metr val uchun mustahkamlik sharti bajarilmaydi. Valning diametrini tanlaymiz va $d = 70\ мм$ ga teng deb qabul qilamiz, bundan, qutb inertsiya momenti

$$J_\rho = \frac{\pi \cdot d^4}{32} = \frac{3{,}14 \cdot 7^4}{32} = 236\ см^4$$

$$\varphi_{\max} = \frac{M_K \cdot l}{G \cdot J_\rho} \cdot \frac{180}{\pi} = \frac{180}{3{,}14} \cdot \frac{1{,}6 \cdot 100 \cdot 100}{8 \cdot 10^3 \cdot 236} = 0{,}48^0$$

Valning mustahkamlik sharti bajarildi.

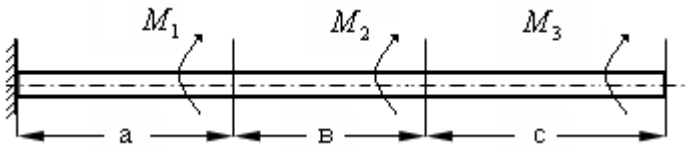
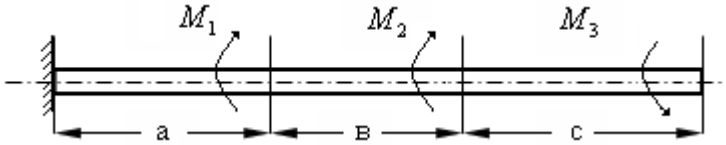
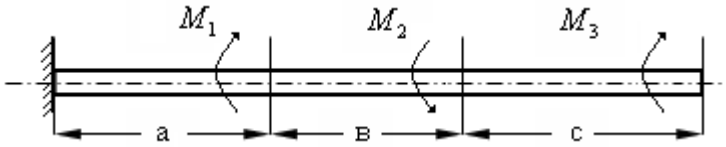
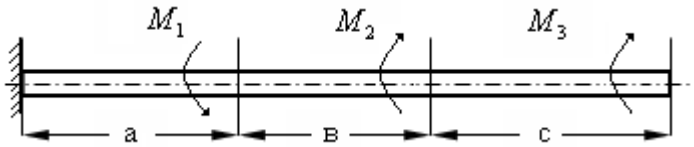
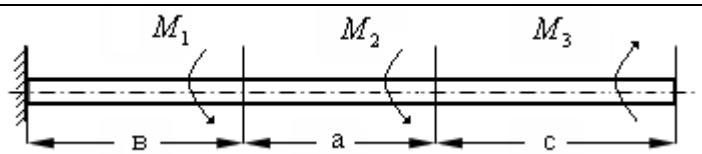
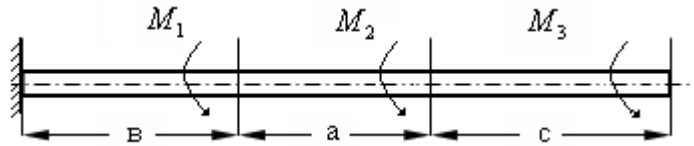
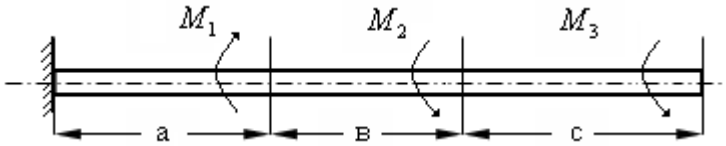
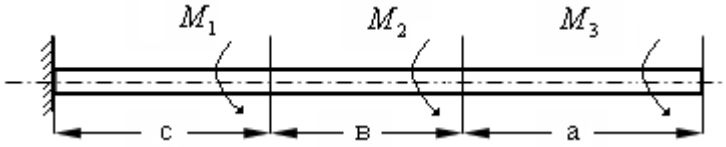
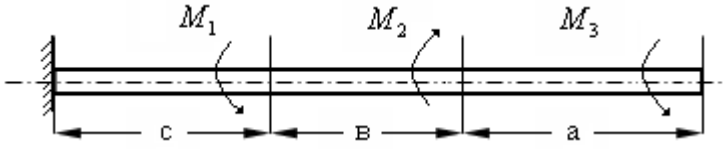
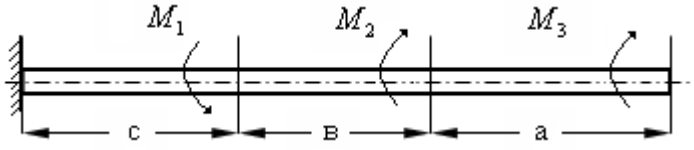
Kalit so’zlar:

1. Buralish
2. Sof siljish
3. Val
4. Deformatsiya
5. Statika tenglamalari
6. Vintli prujinalar
7. Kuchlanish
8. Ruxsat etilgan urinma kuchlanish
9. Buralishda mustahkamlik sharti
10. Epyura
11. Bikrlik
12. Kesim
13. Qarshilik momenti
14. Inertsiya momenti
15. Qutb inertsiya momenti
16. Qutb qarshilik momenti
17. Buralish burchagi
18. Maksimal urinma kuchlanish

Tekshirish savollari

1. Buralishda kўndalang kesimi dumaloq sterjenga qanday kuchlanishlar ta'sir qiladi?
2. Ularning o’lchamlari ko’ndalang kesimning ixtiyoriy nuqtasida qanday aniqlanadi?
3. Buralishda normal kuchlanish ta'sir qiladimi?
4. Dumaloq kesimning qutb qarshilik momenti nimaga teng?
5. Buralishda qutb qarshilik momenti deb nimaga aytiladi?
6. Valning quvvati va aylanishlar soniga qarab moment qanday hisoblanadi?
7. Buralish burchagi qanday aniqlanadi?
8. Valning mustahkamlik va bikrlik sharti qanday hisoblanadi?

Jadval - 1

1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Jadval(Buralish)

№	№ sxemalar	Masofalar, *м*			Momentlar, N · *м*			
		a	*в*	*c*	M_1	M_2	M_3	$[\tau]$, *MPa*
1	I	1,1	1,2	1,3	1100	1000	1200	80
2	II	1,2	1,3	1,4	1200	1100	1300	75
3	III	1,3	1,4	1,5	1300	1200	1400	70
4	IV	1,4	1,5	1,6	1400	1400	1500	65
5	V	1,5	1,6	1,7	1500	1500	1600	60
6	VI	1,6	1,7	1,8	1600	600	1000	60
7	VII	1,7	1,8	1,9	1700	700	1100	65
8	VIII	1,8	1,9	2,0	1800	800	1200	70
9	IX	1,9	2,0	1,1	1900	900	1300	75
10	X	2,0	1,1	1,2	2000	1000	1100	80
	в	***г***	***д***	***е***	***г***	***д***	***е***	***в***

III - EGILISh

UMUMIY TUSHUNCHALAR

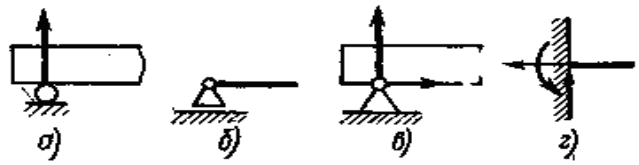
Egilish deb bo'ylama o'qqa perpendikulyar(tik) yuklar yoki shu o'q orqali o'tuvchi kuchlar jufti ta'sirida go'lachaning deformatsiyalanishiga aytiladi. Ikki uchi tayanchlarda yotadigan g'o'lacha(brus) to'sin(balka) deb ataladi.

Egilish bu shunday deformatsiyaki, to'sinning ko'ndalang kesimida eguvchi momentlar hosil bo'ladi. Ko'p hollarda, bir vaqtning o'zida to'sin eguvchi momentlar va ko'ndalang kuchlar ta'sirida bo'ladi; bunday egilish ***ko'ndalang egilish*** deb ataladi; agar ko'ndalang kuchlar ta'sir qilmasa, bunday egilish ***sof egilish*** deb ataladi. Agar eguvchi momentni ta'sir tekisligi bosh o'qlarning birortasidan o'tsa, bunday egilish tekis egilish deyiladi. To'sin tayanchlari tekis sistemalar uchun uch xil bo'ladi:

1. **Sharnirli-qo'zg'aluvchan tayanch** (12a-rasm). Bunday tayanch to'sin uchlarining burilishiga va tayanch sirti bo'yicha ilgarilanma harakat qilishiga yo'l qo'yadi. Bunda bitta reaktsiya kuchi paydo bo'lib, tayanch markazidan o'tadi va shu sirtga tik (perpendikulyar) yo'naladi. Sharnirli-qo'zgaluvchan tayanchning 12b-rasmda sxematik tasviri chizilgan.

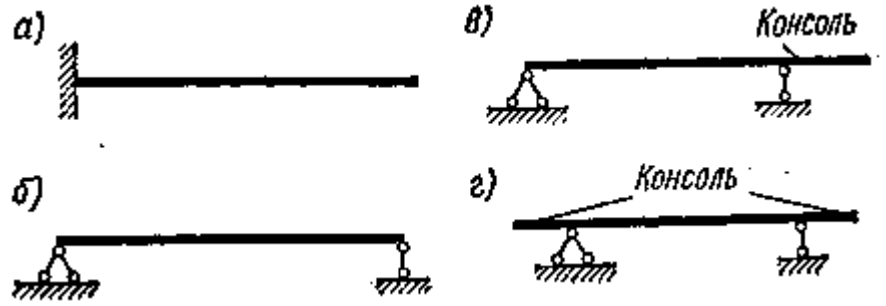
2. **Sharnirli-qo'zgalmas tayanch** (12v-rasm). Bunday tayanch to'sin uchlarining burilishiga yo'l qo'yadi va uning istalgan yo'nalishida ilgarilanma harakat qilishiga to'sqinlik qiladi. Hosil bo'ladigan to'liq reaktsiya vertikal va gorizontal tekisliklarda ta'sir qiladigan reaktsiyalardan tashkil etadi.

3**. Qistirib-mahkamlangan tayanch** (12g-rasm). Qattiq-qisilgan tayanch yoki mahkamlash, to'sin uchlarining burilishiga va istalgan yo'nalishda ilgarilanma harakat qilishiga yo'l qo'ymaydi. Tayanchda to'liq reaktsiya vujudga keladi, u vertikal va gorizontal tashkil etuvchilarga hamda tўsinning burilishiga yўl qo'ymaydigan reaktiv momentga ajraladi.

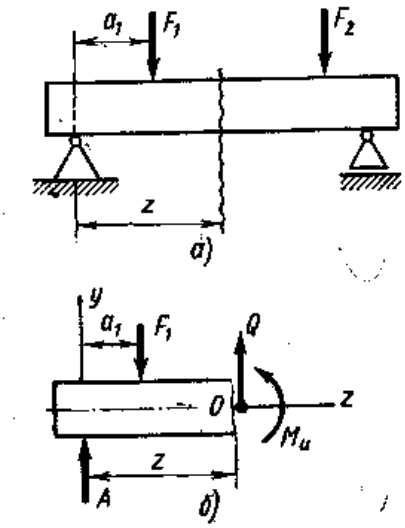


12-rasm

Bir uchi qistirilgan (mahkamlangan) to’sin (balka) konsol to’sin yoki oddiy konsolli (13a-rasm), konsolsiz ikki tayanchli to’sin (13b-rasm) yoki bir qulochli (prolet) tayanch, ikki tayanchli bir konsoli bor to’sin (13v-rasm), ikki tayanchli ikki konsoli bor to’sin (13g-rasm) deb ataladi.



13-rasm.



Tekis egilishda to’sinning ko’ndalang kesimlarida eguvchi momentlar $M_б$ va ko’ndalang kuchlar Q vujudga keladi. Ularni aniqlash uchun kesish metodini qo’llaymiz (metod Rozu). To’sinning ixtiyoriy joyidan xayolan kesib olamiz, masalan: chap tayanchdan ***z*** masofada tekislik bilan kesamiz va o’ng qismini tashlab yuboramiz.

14-rasm

Yassi ko’ndalang egilishda to’sinning ko’ndalang kesimlarida ikkita ichki kuch: eguvchi moment $Mэг$ va ko’ndalang kuch Q paydo bo’ladi (14-rasm). Ushbu kattaliklarni $Mэг$ va Q quyidagi ikkita tenglama yordamida aniqlaymiz:

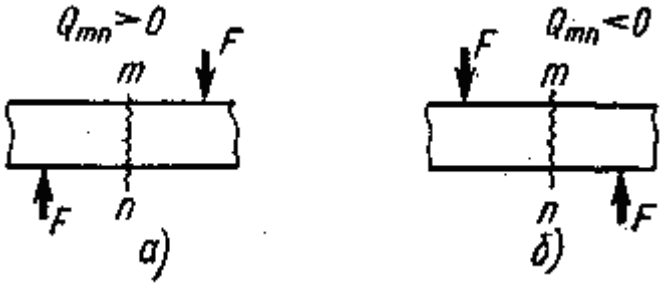
1. $\sum Y = 0;\quad A - F_1 + Q = 0;\quad Q = F_1 - A,\quad Q = \sum (F_i)_y$

2. $\sum M_0 = 0;\quad A \cdot z - F_1 \cdot (z - a_1) - M_{эг} = 0;\quad M_{эг} = A \cdot z - F_1(z - a_1);\quad M_{эг} = \sum m_0(F_i)$

Shunday qilib,

1. *Kesimdan bir tomonga yo'nalgan, ko'ndalang kuch Q, to'sinning ko'ndalang kesimi tekisligidagi barcha ichki kuchlar proektsiyalarining algebraik yig'indisiga teng;*
2. *Berilgan kesimdan bir tomonga yo'nalgan, to'sinning ko'ndalang kesimi ichki kuchlar momentlari (kesim og'irlik markazini hisobga olgan holda) algebraik yig'indisiga teng.*

Ko'ndalang kuch va eguvchi moment uchun ishoralar qoidasi



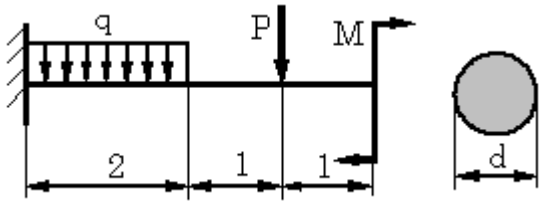
15-rasm

Agar to'sinning *mn* (15-rasm) chap qismi o'ng qismiga nisbatan yuqoriga surilsa yoki to'sinning o'ng qismi chap qismiga nisbatan pastga surilsa, ko'ndalang kuch ***musbat***, teskari holda ***manfiy*** hisoblanadi.

Рис. 16

Eguvchi moment shu paytda musbat hisoblanadi, agar to'sinning qabariq tomoni pastga qarasa(16a-rasm) yoki chap qismidagi moment soat mili bo'yicha bo'lsa, o'ng tomonidagi soat miliga teskari bo'lsa, aksincha yoki qabariq tomoni yuqoriga qarasa (16b-rasm) eguvchi moment manfiy hisoblanadi.

Misol № 10



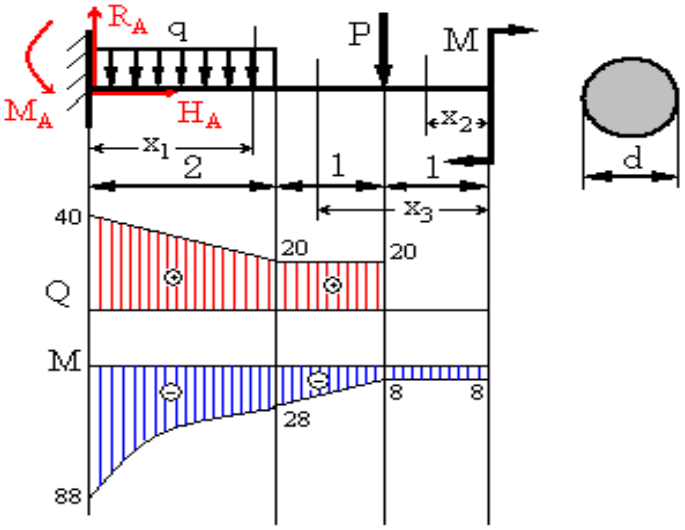
Berilgan:

$P = 20\kappa\text{N},\ q = 10k\text{N}/м,\quad M = 8\kappa\text{N}\cdot м$

Topish kerak: Kesuvchi kuch Q ,

eguvchi moment $M_{эг}$ epyuralarini qurish va kesim tanlash.

Echish: 1. Tayanch reaktsiya kuchlarini aniqlash:



Muvozanat tenglamasini tuzamiz: $\sum Y = 0;\quad R_A - q\cdot 2 - P = 0$

$R_A = q\cdot 2 + P = 10\cdot 2 + 20 = 40\ kH$

$\sum Z = 0;\quad H_A = 0$

$\sum M_A = 0;$

$-M_A + q\cdot 21 + P\cdot 3 + M = 0\ ;$

$M_A = 10\cdot 2\cdot 1 + 20\cdot 3 + 8 = 88\ kH\cdot м$

2. Uchastkalar bo'yicha Q va $M_{эг}$ aniqlaymiz:

1- uchastka $0 \le x_1 \le 2$

$$Q_1 = R_A - q\cdot x_1$$

$$M_1 = R_A\cdot x_1 - q\cdot\frac{x_1^2}{2} - M_A$$

$x_1 = 0 \quad Q_1 = 40\ kH \quad M_1 = -88kH\cdot м$

$x_1 = 2 \quad Q_1 = 20kH \quad M_1 = -28\kappa H\cdot м$

2 - uchastka $0 \le x_2 \le 1$

$Q_2 = 0 \quad M_2 = -M = -8\ \kappa H\cdot м$

3 - uchastok $1 \le x_3 \le 2$

$$Q_3 = P = 20kH$$

$$M_3 = -M - P\cdot(x_3 - 1)$$

$x_3 = 1 \quad M_3 = -8\ \kappa H\cdot м$

$x_3 = 2 \qquad M_3 = -28\ кН \cdot м$

Olingan natijalardan Q va $M_{эг}$ epyurasini quramiz.

3. Kesim tanlaymiz:

Egilishda mustahkamlik sharti: $\sigma_{\max} = \dfrac{M_{u\,\max}}{W_y} \le [\sigma]$

Dumaloq kesim uchun qarshilik momenti: $W_y = \dfrac{\pi \cdot d^3}{32}$

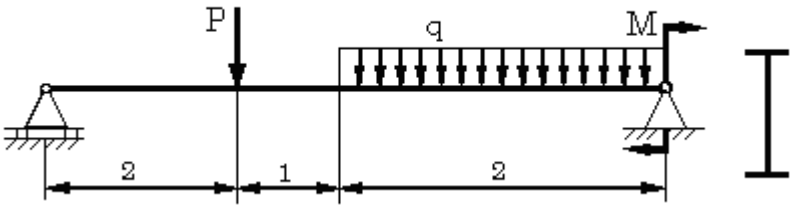
$$W_y = \frac{M_{u\,\max}}{[\sigma]} = \frac{88 \cdot 100}{1} = 8800\ см^3$$

$$d = \sqrt[3]{\frac{W_y \cdot 32}{\pi}} = \sqrt[3]{\frac{8800 \cdot 32}{3{,}14}} = 45\ см$$

Masala № 11

Berilgan: $P = 40 кN, \quad M = 20\ кN \cdot м, \quad q = 10 kN/м$

Topish kerak: Kesuvchi kuchlar Q, M_u eguvchi momentlarni va ularning epyuralarini qurish. Shuningdek qo'shtavr(dvutavr) ning ko'ndalang kesimi tanlanadi.



1. Таянч реакция кучларини аниқлаш:

Мувозанат тенгламаларини тузамиз:

$$\sum M_A = 0; \qquad P \cdot 2 + q \cdot 4 \cdot 2 + M - R_B \cdot 5 = 0$$

$$R_B = \frac{P \cdot 2 + q \cdot 4 \cdot 2 + M}{5} = \frac{80 + 80 + 20}{5} = 36\ \ kH$$

$$\sum M_B = 0; \qquad -P \cdot 3 - q \cdot 2 \cdot 1 + M + R_A \cdot 5 = 0$$

$$R_A = \frac{P \cdot 3 + q \cdot 2 \cdot 1 - M}{5} = \frac{120 + 20 - 20}{5} = 24\ \ kH$$

Tekshirish: $\sum Y = 0; \qquad R_A + R_B - P - q \cdot 2 = 0$

$$24 + 36 - 40 - 20 = 0$$

$$60 - 60 = 0$$

2. Uchastkalar bўyicha Q va $M_{эг}$ larni aniqlaymiz:

1- uchastka $0 \le x_1 \le 2$

$$Q_1 = R_A = 24\ kH$$

$$M_1 = R_A \cdot x_1$$

$x_1 = 0;$ $M_1 = 0$

$x_1 = 2\,м;$ $M_1 = 48\ kH \cdot м$

2 - uchastka $2 \le x_2 \le 3$

$$Q_2 = R_A - P = -16\ \ kH$$

$$M_2 = R_A \cdot x_2 - P \cdot (x_2 - 2)$$

$x_2 = 2\,м;$ $M_2 = 48\ kH \cdot м$

$x_2 = 3\,м;$ $M_2 = 32\ kH \cdot м$

3 - uchastka $0 \le x_3 \le 2$

$$Q_3 = -R_B + q \cdot x_3$$

$$M_3 = R_B \cdot x_3 - q\frac{x_3^2}{2} - M$$

$x_3 = 0;$ $Q_3 = -36\ \ kH;$ $M_3 = -20\ kH \cdot м$

$x_3 = 2;$ $Q_3 = -16\ \ kH;$ $M_3 = 32\ \ kH \cdot м$

Olingan qiymatlar orqali Q va M_u larning epyuralarini quramiz.

3. Qo’shtavr(dvutavr) ning kesimini tanlash:

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

Bu erda: $M_{\max}$ – Maksimal eguvchi moment, epyuradan topiladi;

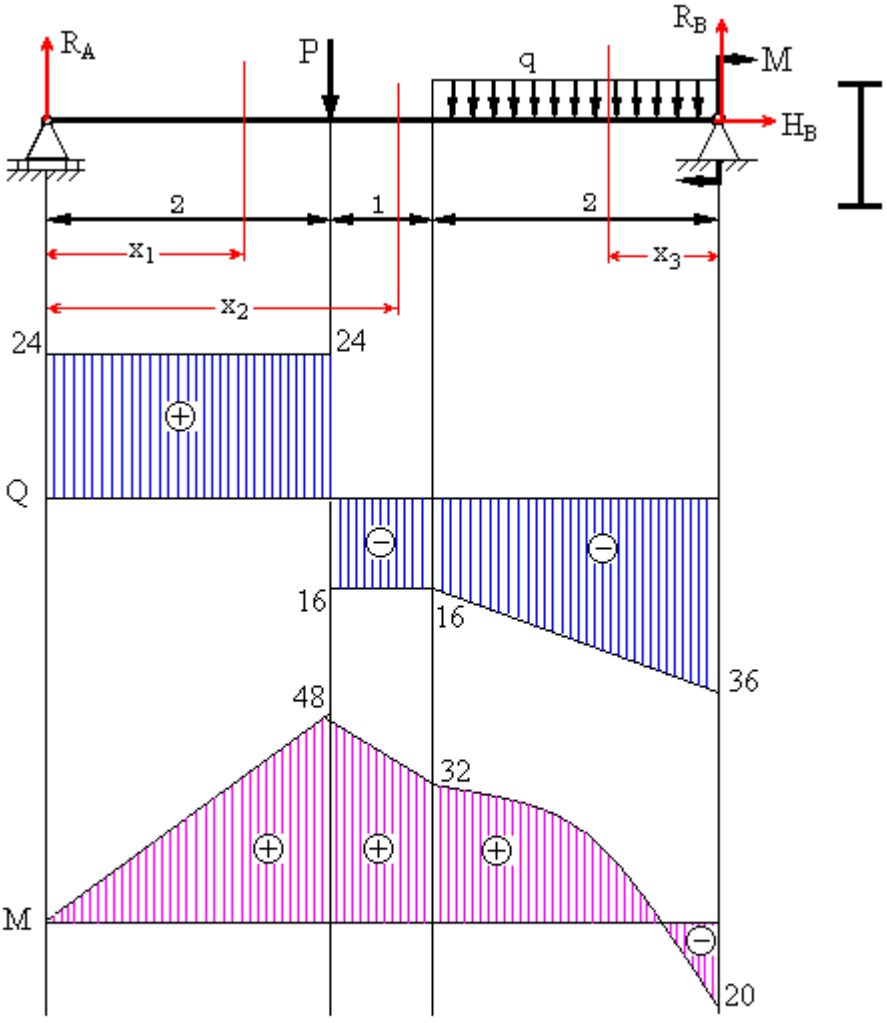
W_y – o’qqa nisbatan qarshilik momenti;

$[\sigma]$ – ruxsat etilgan normal kuchlanish.

$$W_y = \frac{M_{\max}}{[\sigma]} = \frac{48 \cdot 100}{16} = 300\ см^3$$

Jadvaldan qo’shtavr(dvutavr) ning nomerini tanlaymiz:

$W_y = 317\ см^3$ bo'lganda, qo'shtavr(dvutavr) - № 24a

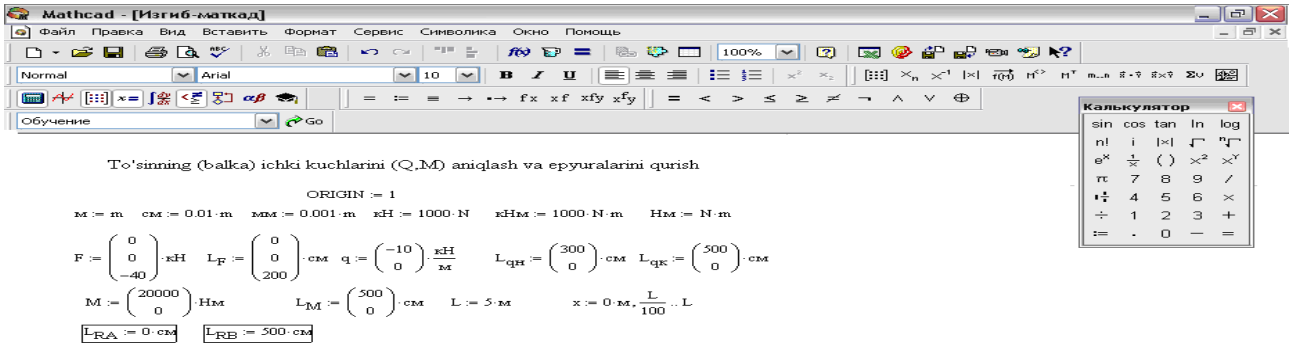


№ 12 - Misol

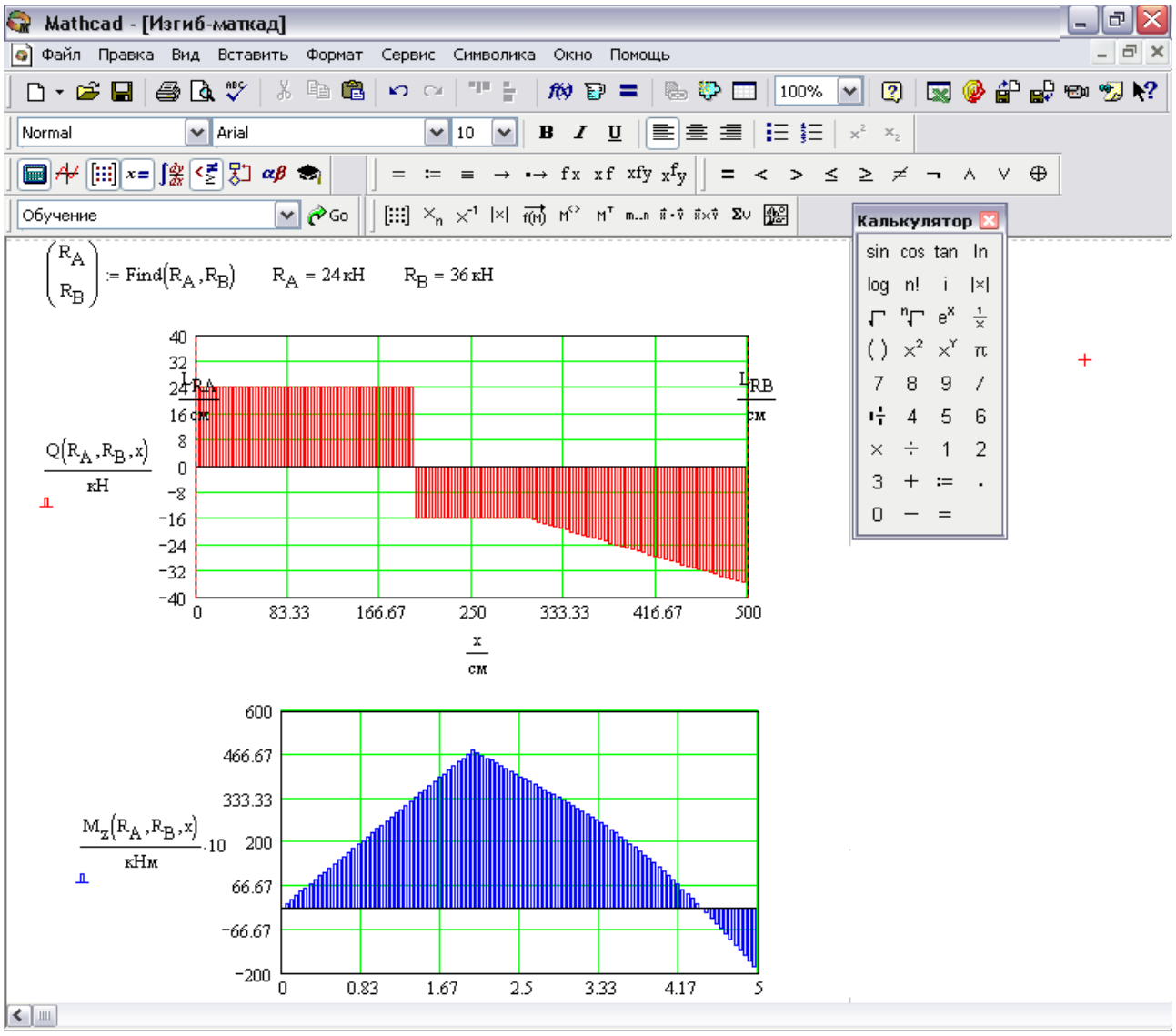
Yuqoridagi masalani «Mathcad» matematik dasturi orqali echamiz:

Berilgan: $P = 40\kappa\text{N}$, $M = 20\ \kappa\text{N}\cdot м$, $q = 10k\text{N}/м$

Berilgan qiymatlarni kiritamiz :

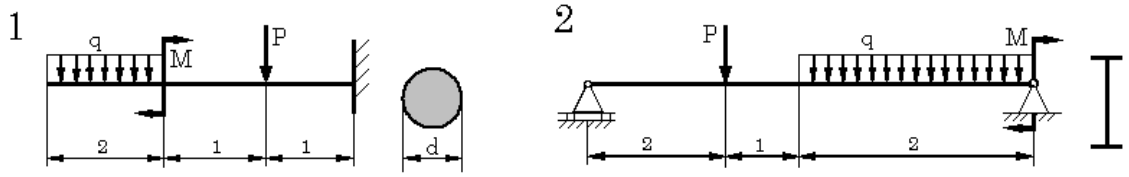


Q va *M* larning tayyor epyuralarini hosil qilamiz:



№1 jadval - Egilish

1



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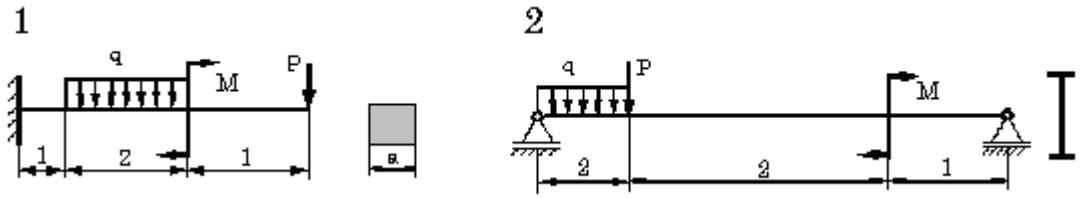

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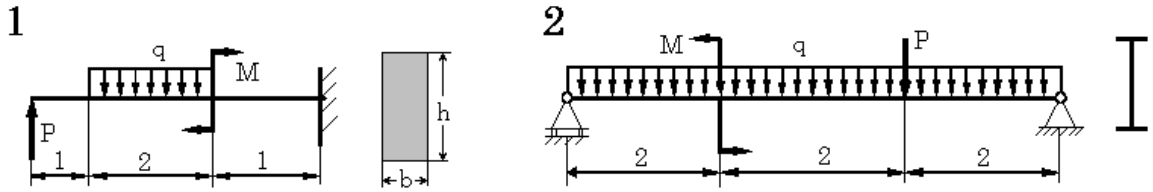

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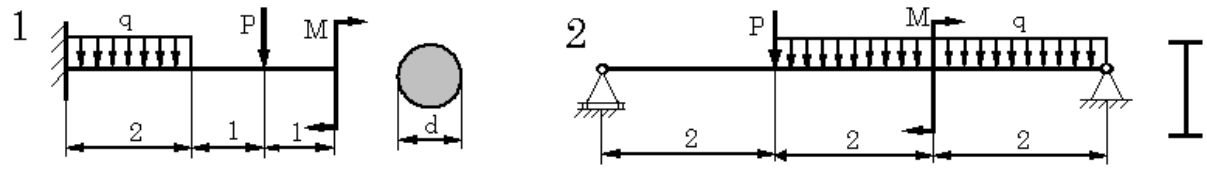

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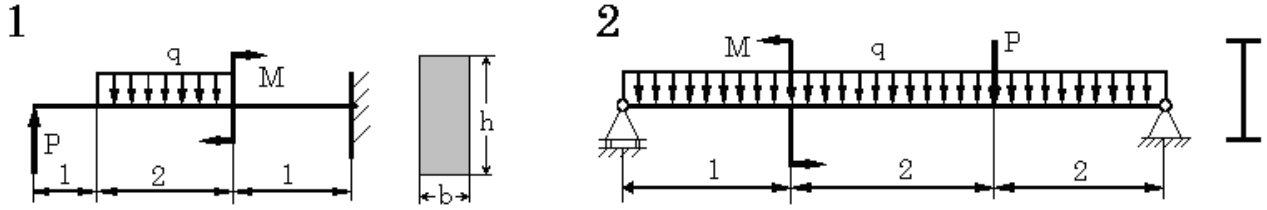

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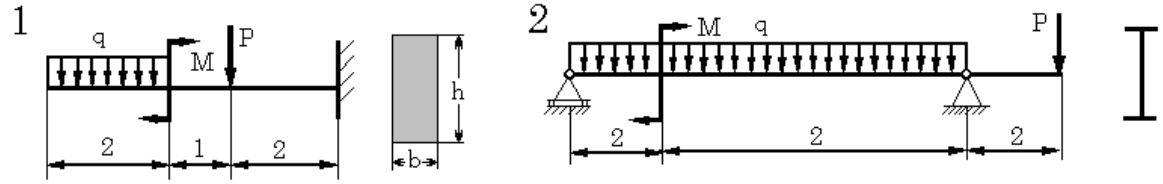

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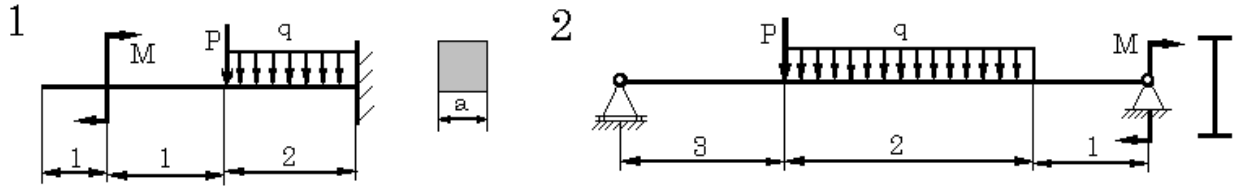
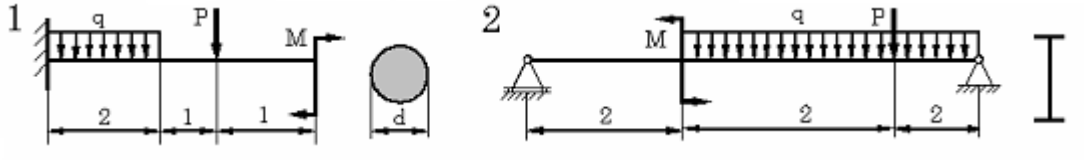
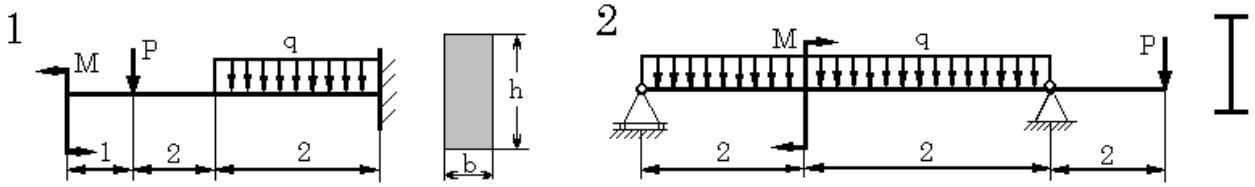

1
M
P
q
a
1
1
2
2
P
q
M
3
2
1

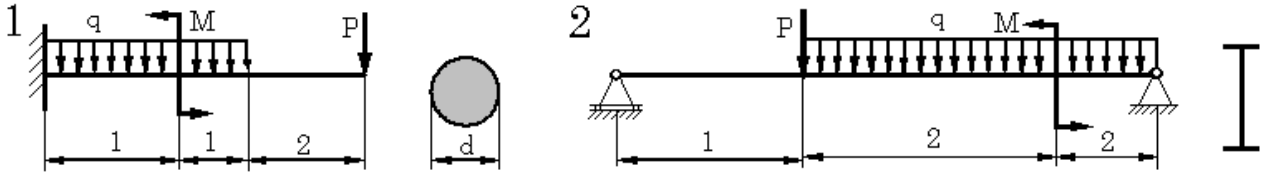
8


1
q
P
M
2
1
1
d
2
M
q
P
2
2
2

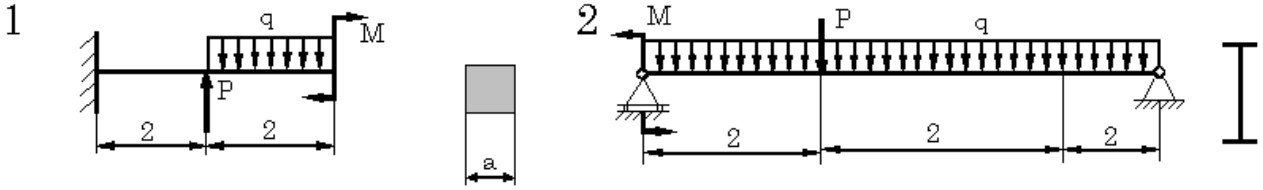
9


1
M
P
q
h
b
1
2
2
2
M
q
P
2
2
2

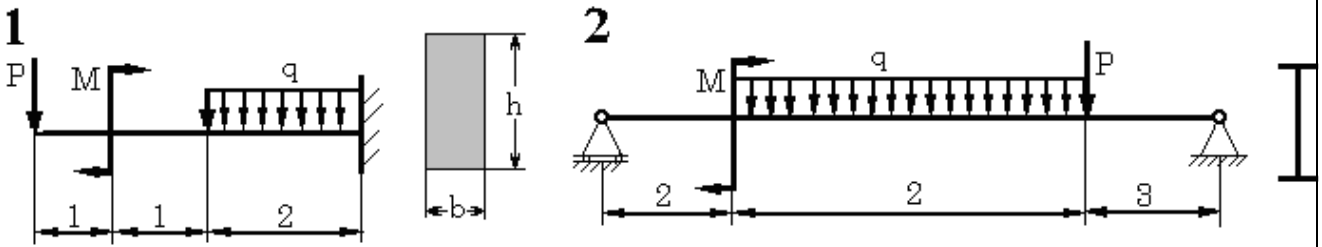
10


1
q
M
P
d
1
1
2
2
P
q
M
1
2
2

11

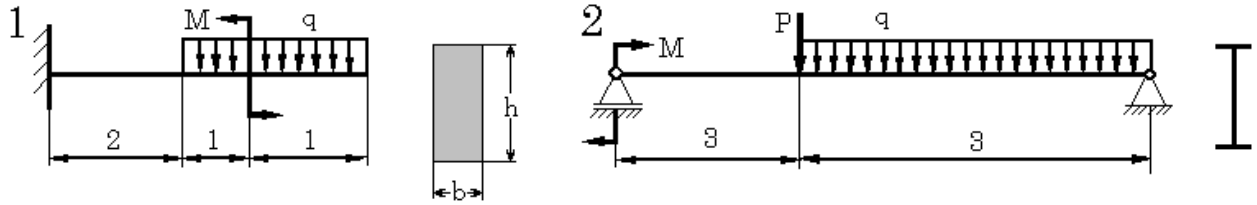

1
q
M
P
a
2
2
2
M
P
q
2
2
2

1


P
M
q
h
b
1
1
2
2
M
q
P
2
2
3

12

13



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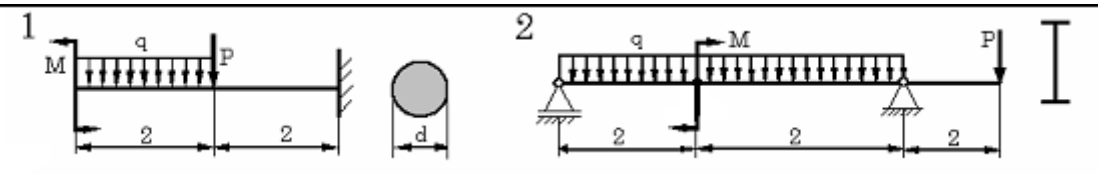

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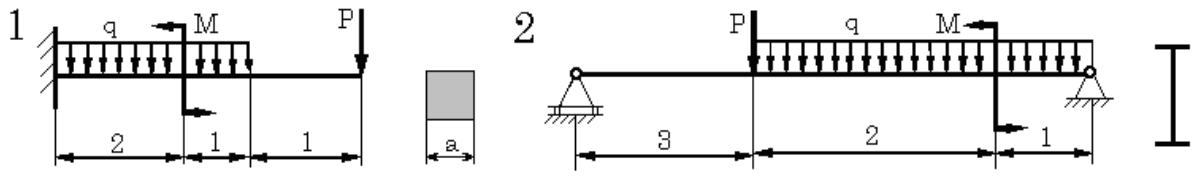

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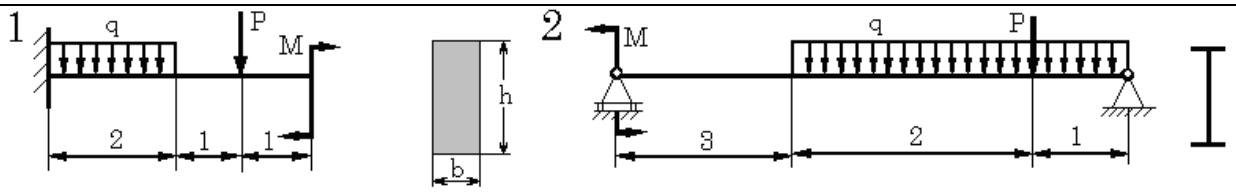

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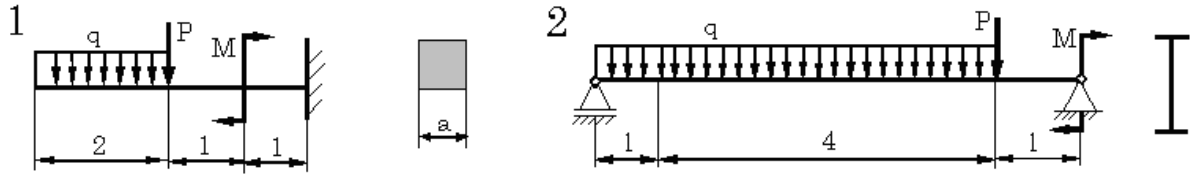

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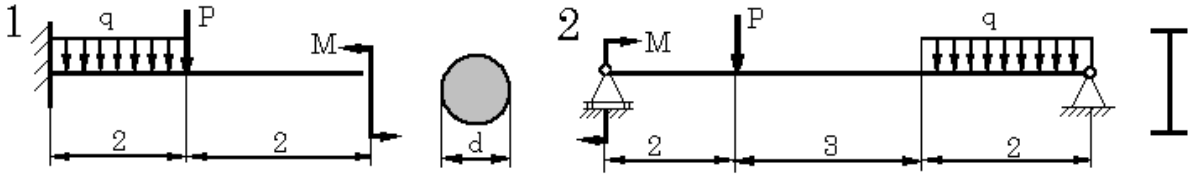

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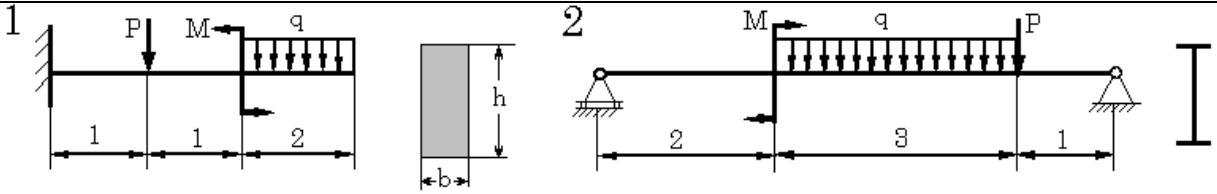

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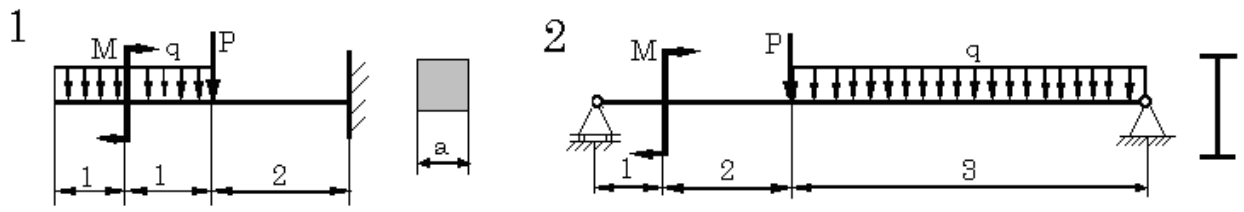

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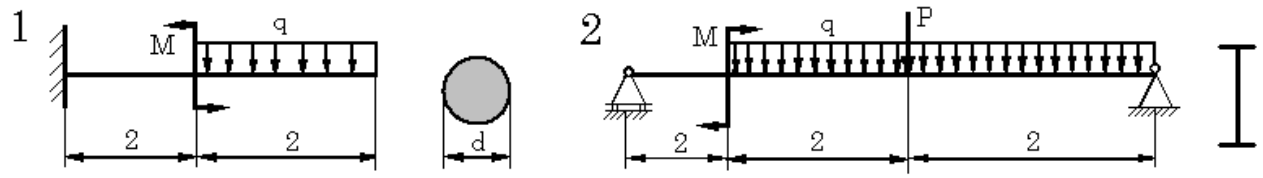

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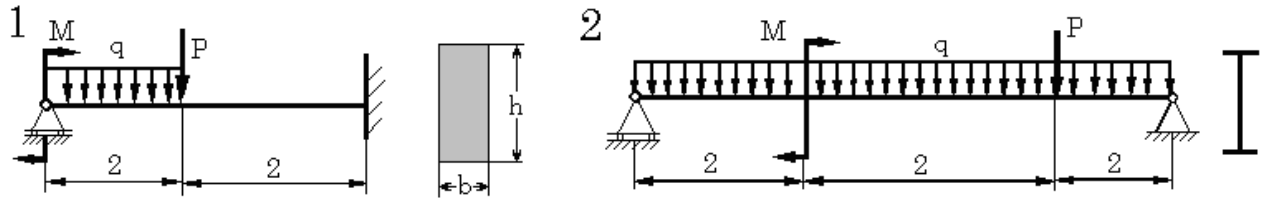

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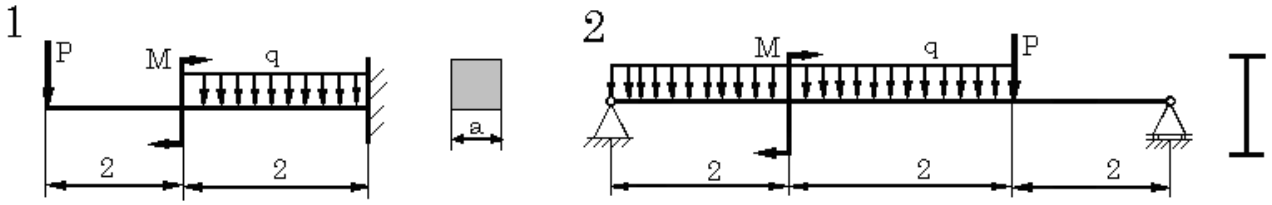

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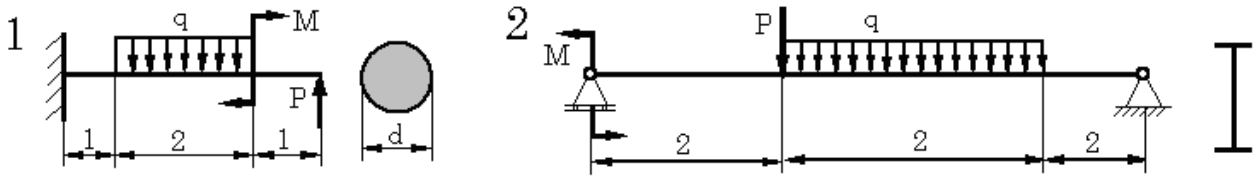

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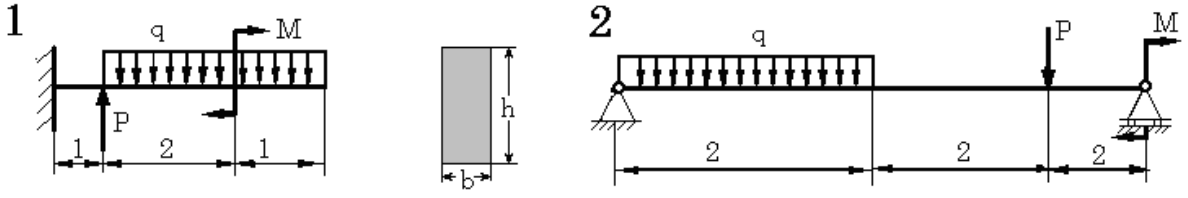


№ Vari-antlar	Yuklar					
	1masala			2 masala		
	P, кН	q, кН/м	M, кН·м	P, кН	q, кН/м	M, кН·м
1	10	5	10	50	20	10
2	15	10	15	40	10	20
3	20	15	10	30	20	30
4	20	20	10	20	10	30
5	15	5	20	10	20	20
6	10	10	10	50	10	10
7	10	15	10	40	20	20
8	15	20	5	30	10	30
9	20	10	10	20	20	30
10	20	10	20	10	10	20
11	15	5	10	50	20	10
12	10	10	15	40	10	20
13	10	15	10	30	20	20
14	20	20	10	20	10	30
15	15	5	20	10	20	30
16	10	5	10	50	20	10
17	10	10	15	40	10	20
18	15	15	10	30	20	30
19	20	20	10	20	10	30
20	20	5	20	10	20	20
21	15	10	10	50	10	10
22	10	15	10	40	20	20
23	10	20	5	30	10	30
24	20	10	10	20	20	30
25	15	10	20	10	10	20

Kalit so’zlar:

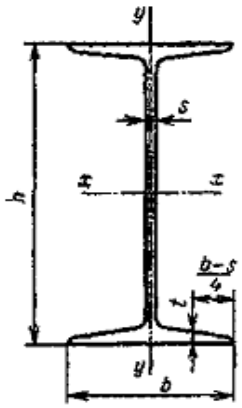
1. Egilish
2. Sof egilish
3. Ko’ndalang egilish
4. Qiyshiq egilish
5. Balkalarning turlari
6. Ikki tayanchli balka
7. Konsol balka
8. Epyura
9. Ko’ndalang kuch
10. Eguvchi moment
11. Normal kuchlanish
12. Ruxsat etilgan normal kuchlanish
13. Egilishdagi mustahkamlik sharti
14. Qarshilik momenti
15. Kesimlarni tanlash
16. Qo’shtavr (dvutavr)

O’z-o’zini tekshirish savollari:

1. Tekis va qiyshiq egilish deb nimaga aytiladi?
2. Sof egilish deb nimaga aytiladi?
3. Ko’ndalang egilish deb nimaga aytiladi?
4. To’sinning ko’ndalang kesimida qanday ichki kuchlar hosil bo’ladi?
5. Ichki kuchlar uchun qanday ishoralar qabul qilingan?
6. Tayanchlarning qanday turlari bor?
7. Tayanch reaktsiya kuchlarini aniqlashda qanday tenglama tuziladi?
8. Tayanch reaktsiya kuchlari to’g’ri topilganligini qanday aniqlanadi?
9. Eguvchi momentning ekstrimal qiymati qanday aniqlanadi?
10. To’singa to’plangan ichki moment qo’yilganda, kesimda egilish momenti qanday o’zgaradi?
11. To’singa to’plangan ichki kuch to’sin o’qiga tik qo’yilganda kesimda ko’ndalang kuch qanday o’zgaradi?
12. Nima uchun ko’ndalang kuch va eguvchi momentga epyura quriladi?
13. Egilishda normal kuchlanishlar nimaga teng?
14. Egilishda normal kuchlanishlar mustahkamlik sharti qanday yoziladi?

Issiqprokatli Qo’shtavr (Dvutavro`)lar sortamentlari

Jadvali (GOST 8239-89)



h — высота двутавра; J_x, J_y — моменты инерции;
b — ширина полки; W_x, W_y — моменты сопротивления;
d — толщина стенки; S_x — статический момент полусечения;
t — средняя толщина полки; i_x, i_y — радиусы инерции.
A — площадь поперечного сечения;

h -qo’shtavr balandligi, b -tokcha eni, d -devor qalinligi, t -tokchaning o’rtacha qalinligi, A – ko’ndalang kesim yuzasi, J_x, J_y –inertsiya momentlari, W_x, W_y -qarshilik momentlari, S_x –kesimning statik momenti, I_x, I_y – inertsiya radiuslari.

№ Qo’sh -tavr	Massa 1m, kg	Ўlchamlari, mm				A, $sм^2$	J_x, $sм^4$	W_x, $sм^3$	i_x, $sм$	S_x, $sм^3$	J_y, $sм^4$	W_y, $sм^3$	i_y, $sм$
		h	b	d	t								
10	9,46	100	55	4,5	7,2	12	198	39,7	4,06	23	17,9	6,49	1,22
12	11,5	120	64	48	7,3	14,7	350	58,4	4,88	33,7	27,9	8,72	1,38
14	13,7	140	73	4,9	7,5	17,4	572	81,7	5,73	46,8	41,9	11,5	1,55
16	15,9	160	81	5	7,8	20,2	873	109	6,57	62,3	58,6	14,5	1,7
18	18,4	180	90	8,1	8,1	23,4	1290	143	7,42	81,4	82,6	18,4	1,88
18a	19,9	180	100	5,1	8,3	25,4	1340	159	7,51	89,8	114	22,8	2,12
20	21	200	100	5,2	8,4	26,8	1840	184	8,28	104	115	23,1	2,07
20a	22,7	200	110	5,2	8,6	28,9	2030	203	8,37	114	155	28,2	2,32
22	24	220	110	5,4	8,7	30,6	2550	232	9,13	131	157	28,6	2,27
22a	25,8	220	120	5,4	8,9	32,8	2790	254	9,22	143	206	34,3	2,50
24	27,3	240	115	5,6	9,5	34,8	3460	289	9,97	163	198	34,5	2,37
24a	29,4	240	125	5,6	9,8	37,5	3800	317	10,1	178	260	41,6	125
27	31,5	270	125	6	9,8	40,2	5010	371	11,2	210	260	41,5	2,54
27a	33,9	270	135	6	10,2	43,2	5500	407	11,3	229	337	50	2,80
30	36,5	300	135	65	10,2	46,5	7080	472	12,3	268	337	49,9	2,69
30a	39,2	300	145	6,5	10,7	49,9	7780	518	12,5	292	436	60,1	2,95
33	42,2	330	140	7	11,2	53,8	9840	597	13,5	339	419	59,9	2,79
36	48,6	360	145	7,5	12,3	61,9	13380	743	14,7	423	516	71,1	2,89
40	57	400	155	8,3	13	72,6	19062	953	16,2	545	667	86,1	3,03

№ Qo'sh-tavr	Massa 1m, kg	Ўlchamlari, mm				A, $см^2$	J_x, $см^4$	W_x, $см^3$	i_x, $см$	S_x, $см^3$	J_y, $см^4$	W_y, $см^3$	i_y, $см$
		h	b	d	t								
45	66,5	450	160	9	14,2	84,7	27696	1231	18,1	708	808	101	3,09
50	78,5	500	170	10	15,2	100	39727	1589	19,9	919	1043	123	3,23
55	92,6	550	180	11	16,5	118	55962	2035	21,8	1181	1356	151	3,39
60	108	600	190	12	17,8	138	76806	2560	23,6	1491	1725	182	3,54

Testdan namunalar:

CHO'ZILISH-SIQILISH:

1. Ko'ndalang va bo'ylama deformatsiyalar orasidagi munosobat qaysi formula orqali aniqlanadi?

1. $\varepsilon = \mu \cdot \varepsilon^1$ 2. $\varepsilon = \frac{\Delta l}{l}$ 3. $\varepsilon = \frac{\sigma}{E}$ 4. $\varepsilon = \frac{E}{\sigma}$ 5. $\varepsilon^{-1} = -\mu \cdot \varepsilon$

2. Cho'zilish (siqilish) dagi mustahkamlik shartini ko'rsating?

1. $\sigma = \frac{N}{A} \le [\tau]$ 2. $\sigma = \frac{Q}{A}$ 3. $\sigma = \frac{N}{A}$ 4. $\sigma = \frac{N}{A} \le [\sigma]$

5. $\sigma = \frac{M_u}{J_y} \le [\sigma]$

3. Cho'zilish (siqilish) dagi mustahkamlik nimaga teng?

1. EG **2.** FG **3.** EI_y **4.** GI_P **5.** EF

4. Guk qonunini ko'rsating?

1. $\tau = \frac{N}{A}$ 2. $\varepsilon = \frac{\sigma}{l}$ 3. $\varepsilon = \frac{\sigma}{E}$ 4. $\varepsilon = \frac{E}{\sigma}$ 5. $\varepsilon^{-1} = -\mu \cdot \varepsilon$

5. Nisbiy deformatsiyaning o'lchov birligi nima?

1. $кг$ 2. $см$ 3. ўлчамсиз 4. $кг/см^2$ 5. $т/м$

BURALISH:

1. Buralishdagi kesimning bikrligi deganda nimani tushunasiz?

l. $E \cdot Iy$-ko'paytmani 2. $E \cdot I_P$- ko'paytmani 3. $G \cdot I_p$-ко'paytmani

4. $G \cdot W_P$-ko'paytmani 5. $E \cdot F$-ko'paytmani

2. Qaysi formula orqali buralishdagi burilish burchagi aniqlanadi?

1. $\varphi = \frac{M_к \cdot l}{G \cdot I_P}$; 2. $\varphi = \frac{M_u \cdot l}{E \cdot I_P}$; 3. $\varphi = \frac{M_к \cdot l}{G \cdot I_y}$; 4. $\varphi = \frac{M_к \cdot l}{E \cdot I_y}$; 5. $\varphi = \frac{M_u \cdot l}{G \cdot I_P}$

3. Buralishda mustahkamlik sharti qanday yoziladi?

1. $\tau = \frac{M_к}{I_p} \cdot \rho$; 2. $\tau_{\max} = \frac{M_к}{W_y} \le [\tau]$; 3. $\tau_{\max} = \frac{M_к}{I_p} \le [\tau]$;

4. $\tau_{\max} = \frac{M_к}{W_P} \le [\tau]$ 5. $\tau_{\max} = \frac{M_к}{I_p} \cdot \rho \le [\tau]$

4. Buralishda bosh kuchlanishlar nimaga teng?

1. $\sigma_{\max} = \tau_{\max} = \frac{M_к}{I_p}$; 2. $\sigma_{\max} = \tau_{\max} = \frac{M_к}{I_y}$;

3. $\sigma_{\max} = \tau_{\max} = \frac{M_u}{W_p}$; 4. $\sigma_{\max} = \tau_{\max} = \frac{M_к}{I_y} \cdot \rho$;

5. $\sigma_{\max} = \tau_{\max} = \frac{M_к}{W_p}$

5. Buralishda g'o'la (brus)ni mustahkamlikka tekshirishda qaysi formuladan foydalaniladi?

1. $\tau_{\max} = \frac{M_к \cdot l}{G \cdot W_p} \le [\varphi]$; 2. $\varphi_{\max} = \frac{M_u \cdot l}{G \cdot I_y} \le [\varphi]$; 3. $\varphi_{\max} = \frac{M_к \cdot l}{E \cdot I_p} \le [\varphi]$;

4. $\varphi_{\max} = \frac{M_к \cdot l}{E \cdot I_y} \le [\varphi]$; 5. $\varphi_{\max} = \frac{M_к \cdot l}{G \cdot I_p} \le [\varphi]$

EGILISH:

Ko’ndalang egilishda g’o’la (brus) kesimida qanday ichki kuchlar hosil bo’ladi?

1. faqat M_{eg} 2. Q, M_{eg} 3. N, M_{eg}

4. faqat Q 5. Q, N

Eguvchi moment va kesuvchi kuch o’rtasida qanday differentsial bog’lanish mavjud?

1. $q = \frac{d^2M}{dx^2}$ 2. $Q = \frac{dM_u}{dx}$ 3. $q = \frac{dQ}{dx}$ 4. $q = \frac{dN}{qx}$ 5. $Q = \frac{d^2M_u}{dx}$

Eguvchi moment va taqsimlangan kuch o’rtasida qanday differentsial bog’lanish mavjud?

1. $q = \frac{d^2M}{dx^2}$ 2. $Q = \frac{dM_u}{dx}$ 3. $q = \frac{dQ}{dx}$ 4. $q = \frac{dN}{qx}$ 5. $Q = \frac{d^2M_u}{dx}$

Egilishda urinma kuchlanish nimaga teng?

1. $\tau = \frac{Q \cdot S_y}{J_y \cdot b}$ 2. $\tau = \frac{Q \cdot S_y}{J_y \cdot E}$ 3. $\sigma = \frac{M_u S_y}{E \cdot b}$ 4. $\sigma_{\max} = \frac{M_u}{J_y} z$ 5. $\tau = \frac{Q_{\max} S_y}{J_y}$

5. Egilishda normal kuchlanish qaysi formuladan aniqlanadi?

1. $\sigma = \frac{Q_{\max}}{J_y} z$ 2. $\sigma = \frac{M_u}{W_y} z$ 3. $\sigma = \frac{M_u}{J_y} z$ 4. $\sigma = \frac{M_u}{J_\rho} \rho$ 5. $\sigma = \frac{Q_{\max}}{J_\rho} z$

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Mundarija