# KONSTRUKSIYALARINI TURLI MATERIALLAR BILAN KUCHAYTIRISH BO‘YICHA HISOBLASH NAMUNALARI (TEMIRBETON USTUN MISOLIDA)

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***Annotatsiya:*** *ushbu maqolada temirbeton ustunni kompozitbeton, temirbeton, metall burchaklik va ugletolali mato xalqasi bilan kuchaytirish bo‘yicha hisob-kitob namunalari va natijalari keltirilgan. Hisob-kitoblar natijalariga ko‘ra, ushbu kuchaytirish usullarini texnik-iqtisodiy jihatdan taqqoslash amalga oshirildi.*

***Kalit so‘zlar:*** *beton, temirbeton, kompozit materiallar, ugletola, xalqa, deformatsiya, siqiluvchi elementlar.*

Ko‘ngdalang kesim yuzasi 200x200mm, ustun uzunligi 1500mm. Beton sinfi B20 ($R_b$=11,5MPa). Bo‘ylama armatura 4Ø8AIII ($A_{s,tot}$=2,01sm$^2$), ($R_{SC}$=355MPa), bo‘lgan mavjud ustunni turli xil kuchaytirish usullari orqali 1,5 barobar yuk ko‘tarish qobilyatini oshirish bo‘yicha xisoblar keltirib o‘tilgan.

$$N = 1,5 \cdot N_{byq}$$

**1. Ustun konstruksiyasini temirbeton yordamida kuchaytirish:**

Avvalambor ustun konstruksiyasining yuk ko‘tarish qobilyatini aniqlaymiz

$$N_{byq} = \varphi \cdot (R_B \cdot A + R_S \cdot A_S),$$

Ustunning egiluvchanligi:

$$\frac{l_0}{h} = \frac{1500}{200} = 7,5$$

$\varphi$=0,913

Yuqoridagi formulaga sonli qiymatlarini qo‘yib hisoblaymiz:

$$N_{byq} = 0,913 \cdot (11,5 \cdot 40000 + 355 \cdot 201) = 485,13kN,$$

$$N = 1,5 \cdot 485,13 = 727,695kN,$$

Kuchaytiruvchi xalqa beton sinfini B25 qabul qilamiz, $R_{b,RCR}$=14,5MPa; bo‘ylama armatura AIII sinfli $R_{SC,RCR}$=355MPa, ko‘ndalang armatura AI sinfli berk xomut sifatida karkas hosil qilingan, $\eta_b$=1 qabul qilamiz. Ustunni kuchaytirish butun balandligi bo‘yicha amalga oshiriladi.

Xalqa qalinligini 30mm qabul qilamiz, bunda kuchaytirilgan ustunning egiluvchanligi

$b' = b + 2 \cdot d = 20 + 2 \cdot 3 = 26sm$ ga teng.

$$\frac{l_0}{b'} = \frac{150}{26} = 5,77 \rightarrow \varphi = 0,92$$

$$A_{S,RCR} = 0,01 \cdot A_{RCR} = 0,01(26 \times 26 - 20 \times 20) = 276mm^2$$

Bo‘ylama va oddiy ko‘ndalang armatura xomuti bilan armaturalangan beton xalqaning kesim yuzasini quyidagi formula orqali aniqlaymiz

$$A_{RCR} = \frac{\frac{N}{\varphi} - \eta_b (R_b \cdot A + R_{SC} \cdot A_S)}{\eta_{RCR}(R_{b,RCR} + 0,01 \cdot R_{SC,RCR})} = \frac{\frac{727700}{0,92} - 1(11,5 \cdot 40000 + 355 \cdot 201)}{0,8(14,5 + 0,01 \cdot 355)} = 179,8sm^2$$

Talab qilinadigan temirbeton xalqa qalinligini quyidagi formula orqali aniqlaymiz

$$d = \frac{\sqrt{(b+h)^2 + 4 \cdot A_{RCR}} - b - h}{4} = \frac{\sqrt{(20+20)^2 + 4 \cdot 179,8} - 20 - 20}{4} = 2,04sm$$

Temirbeton xalqaning minimal qalinligini $d$=3sm qabul qilamiz.

Xalqadagi bo‘ylama ishchi armaturaning kesim yuzasini aniqlaymiz

$A_{S,RCR} = 0,01 \cdot A_{RCR} = 0,01(260^2 - 200^2) = 276mm^2$

Konstruktiv talablarga ko‘ra 4Ø 8AIII $A_s$=2,01sm$^2$ qabul qilamiz.

Kuchaytirilgan ustunning mustahkamligini tekshiramiz

$$\frac{l_0}{b'} = \frac{150}{26} = 5,77 \rightarrow \varphi = 0,92$$

$$N = N \le \varphi \cdot (\eta_b (R_b \cdot A + R_{SC} \cdot A_S) + \eta_g \cdot (R_{b,RCR} \cdot A_{RCR} + A_{S,RCR} \cdot R_{SC,RCR})) =$$

$$727,69 = 0,92(1(11,5 \cdot 200 \cdot 200 + 355 \cdot 201) + 0,8(0,9 \cdot 14,5 \cdot 27600 + 355 \cdot 201) = 806,46kN$$

***727,69kN ≤806,46kN***

Ustunning yuk ko‘tarish qobilyati ta’minlandi.

**2. Ustun konstruksiyasini kompozitbeton yordamida kuchaytirish:**

Kuchaytiruvchi xalqa beton sinfini B25 qabul qilamiz, $R_{b,RCR}$=14,5MPa; bo‘ylama armatura ShKA $R_{SC,RCR}$=1200 MPa, ko‘ndalang armatura ShKA, $\eta_b$=1 qabul qilamiz. Ustunni kuchaytirish butun balandligi bo‘yicha amalga oshiriladi.

Xalqa qalinligini 30mm qabul qilamiz, bunda kuchaytirilgan ustunning egiluvchanligi

$b' = b + 2 \cdot d = 20 + 2 \cdot 3 = 26sm$ ga teng.

$$\frac{l_0}{b'} = \frac{150}{26} = 5,77 \rightarrow \varphi = 0,92$$

$$A_{S,RCR} = 0,01 \cdot A_{RCR} = 0,01(26 \times 26 - 20 \times 20) = 276mm^2$$

Bo‘ylama va oddiy ko‘ndalang armatura xomuti bilan armaturalangan beton xalqaning kesim yuzasini quyidagi formula orqali aniqlaymiz

$$A_{RCR} = \frac{\frac{N}{\varphi} - \eta_b (R_b \cdot A + R_{SC} \cdot A_S)}{\eta_{RCR}(R_{b,RCR} + 0,01 \cdot R_{SC,RCR})} = \frac{\frac{727700}{0,92} - 1(11,5 \cdot 40000 + 1200 \cdot 113)}{0,7(14,5 + 0,01 \cdot 1200)} = 105,3sm^2$$

Talab qilinadigan temirbeton xalqa qalinligini quyidagi formula orqali aniqlaymiz

$$d = \frac{\sqrt{(b+h)^2 + 4 \cdot A_{RCR}} - b - h}{4} = \frac{\sqrt{(20+20)^2 + 4 \cdot 105,3} - 20 - 20}{4} = 1,24sm$$

Temirbeton xalqaning minimal qalinligini $d$=3sm qabul qilamiz.

Xalqadagi bo‘ylama ishchi armaturaning kesim yuzasini aniqlaymiz

$A_{S,RCR} = 0,01 \cdot A_{RCR} = 0,01(260^2 - 200^2) = 276mm^2$

Konstruktiv talablarga ko‘ra 4Ø 6ShKA $A_s$=1,13sm$^2$ qabul qilamiz.

Kuchaytirilgan ustunning mustahkamligini tekshiramiz

$$\frac{l_0}{b'} = \frac{150}{26} = 5,77 \rightarrow \varphi = 0,92$$

$$N = N \leq \varphi \cdot (\eta_b (R_b \cdot A + R_{SC} \cdot A_S) + \eta_g \cdot (R_{b,RCR} \cdot A_{RCR} + A_{S,RCR} \cdot R_{SC,RCR})) =$$

$$727,69 = 0,92(1(11,5 \cdot 200 \cdot 200 + 355 \cdot 201) + 0,7(0,9 \cdot 14,5 \cdot 27600 + 1200 \cdot 113) = 841,6kN$$

***727,69kN ≤841,6kN***

Ustunning yuk ko‘tarish qobilyati ta’minlandi.

**3. Ustun konstruksiyasini metal xalqa yordamida kuchaytirish:**

Avvalambor ustun konstruksiyasining yuk ko‘tarish qobilyatini aniqlaymiz

$$N_{byq} = \varphi \cdot (R_B \cdot A + R_S \cdot A_S),$$

Ustunning egiluvchanligi:

$$\frac{l_0}{h} = \frac{1500}{200} = 7,5$$

$\varphi$=0,913

yuqoridagi formulaga sonli qiymatlarini qo‘yib hisoblaymiz:

$$N_{byq} = 0,913 \cdot (11,5 \cdot 40000 + 355 \cdot 201) = 485,13kN,$$

$$N = 1,5 \cdot 485,13 = 727,695kN,$$

$$N_0 = N - N_{byq} = 727,7 - 485,1 = 242,6kN$$

Ustun bir tomonining talab qilingan kuchaytirish yuzasi:

$$A_0 = \frac{N_0}{2 \cdot \varphi \cdot m_0 \cdot R_y} = \frac{242,6 \cdot 10^3 N}{2 \cdot 0,913 \cdot 0,9 \cdot 210MPa} = 702,9mm^2 = 7,03sm^2,$$

bunda $m_0$-iShKAsh sharoitini hisobga oluvchi koeffisent;

$R_y$- C235 sinfli po‘latning hisobiy qarshiligi.

Ustunning qarama-qarshi tomonida joylashgan har bir rasporkalarni 2ta burchakliklardan qabul qilamiz va 63x40x4;

$A_{2bur63x40x4}=A_0$=8,08 sm$^2$ > 7,03 sm$^2$

2ta 63x40x4 burchaklik uchun sortament jadvalidan quyidagi xususiyatlarni qabul qilamiz:

$A$=4,04 sm$^2$; $t_{qal}$=4 mm; $i_x$=2,01 sm;

$i_y$=1,13 sm; $x_0$=0,91 sm; $y_0$=2,03 sm;

*Burchakliklarni bog‘lovchi plankalar hisobi*

Plankalarga shartli ko‘ndalang kuchlar ta’sir etadi. A240 sinfli metal uchun:

$Q_p$=0,2*$A_0$=0,2*8,08 sm$^2$=16,16 kN.

“Metal konstruksiyalar” ga asosan ustundagi plankalarning egilishi 40 dan yuqori bo‘lmasligi talab etiladi.

Plankalar qadami $l_n = \lambda \cdot i_u = 40 \cdot 0,87 = 33,6sm.$

Plankalar qadamini $l_n$=35sm qabul qilamiz.

Plankalarni qirquvchi kuch $l_n$=35sm da quyidagiga teng:

$$T = \frac{Q_p \cdot l_n}{c} = \frac{1,62kN \cdot 0,35m}{0,19} = 2,98kN,$$

bunda c-burchaklik og‘irlik markazi orasidagi masofa:

$$c = b + 2 \cdot t_{qal} - 2 \cdot x_0 = 200mm + 2 \cdot 4mm - 2 \cdot 9,1mm = 189,8mm = 0,19m$$

Planka tekisligidagi eguvchi moment:

$$T = \frac{Q_p \cdot l_n}{2} = \frac{1,62kN \cdot 0,35m}{2} = 0,28kN \cdot m,$$

$$W_{NT} = \frac{M}{R_y} = \frac{0,28 \cdot 10^6 N \cdot m}{210} = 1333mm^3 = 1,5sm^3,$$

Planka qalinligini burchaklik profiliga yaqin qabul qilamiz $\delta$=6 mm.

$$h_{pl} = \sqrt{\frac{W_{NT} \cdot 6}{\delta}} = \sqrt{\frac{1333 \cdot 6}{6}} = 36,5mm \approx 37mm.$$

Plankani 40x6 qabul qilamiz.

Plankalar qadamini 150mm qabul qilamiz.

Metal burchaklik bilan kuchaytirilgan ustunning yuk ko‘tarish qobilyati quyidagiga teng:

$$N_{0ult} = \varphi \cdot [R_b \cdot A_b + R_{SC} \cdot A_{s,tot} + \varphi_1 \cdot R_{sc,ad} \cdot A_{sad,tot}] =$$
$$0,913 \cdot [11,5 \cdot 40000 + 355 \cdot 201 + 0,913 \cdot 210 \cdot 1616] = 768,0kN;$$

***727,69kN ≤768,0kN***

Ustunning yuk ko‘tarish qobilyati ta’minlandi.

**4. Temirbeton ustun konstruksiyasini kompozit materiallar bilan kuchaytirish:**

Murakkab kuchlanish holatida ishlovchi betonning talab qilingan mustahkamlik qiymatini aniqlaymiz:

$$R_{b3}^{talab} = \frac{\frac{N}{\varphi} - R_{SC} \cdot A_{stot}}{A_b} = \frac{\frac{729670}{0,913} - 3550 \cdot 2,01}{384} = 2062,7 kg * kuch / sm^2$$

bunda $A_b = b \cdot b - 2 \cdot r \cdot r = 20 \cdot 20 - 2 \cdot 2 \cdot 2 = 384 sm^2$

yaxlit xalqa hosil qilinganda beton mustahkamligining oshishi.

$$R_{bf} = R_{b3}^{talab} - R_b = 2062,7 - 1150 = 910,7 kg * kuch / sm^2$$

ko‘ngdalang kompozit armaturalash koeffisenti:

$$\mu_f = \frac{R_{bf}}{k_{ef} \cdot k_b \cdot R_f} = \frac{910,7}{0,36 \cdot 1 \cdot 30000} = 0,084;$$

bunda; $k_{ef} = 1 - \frac{(b-2r)^2 + (h-2r)^2}{2b \cdot h} = 1 - \frac{(20-2 \cdot 2)^2 + (20-2 \cdot 2)^2}{2 \cdot 20 \cdot 20} = 0,36;$

yaxlit xalqa uchun xalqadagi mavjud uzilishlarni hisobga oluvchi koeffisent $k_b = 1,0$

kompozit materialning cho‘zilishdagi hisobiy qarshiligi $y_{f2} = 1,0$ koeffisentda

$$R_f = \frac{\gamma_{f1} \cdot \gamma_{f2} \cdot R_{fn}}{\gamma_f} = \frac{0,95 \cdot 1 \cdot 3790}{1,2} = 3000 kg * kuch / sm^2;$$

kompozit material kesim yuzasi maydoni:

$$A_f = \mu_f \cdot A = 0,084 \cdot 384 = 32,3 sm^2$$

kuchaytirish kerak bo‘ladigan ishchi kesim yuzasi perimetri:

$$U_f = 2(b + h - 4r) = 2(20 + 20 - 4 \cdot 2) = 64 sm$$

Armoshel KB500 li t=0,27 sm li xalqadagi qatlamlar soni

$$n_f = \frac{A_f}{U_f t_f} = \frac{32,3}{64 \cdot 0,27} = 1,87;$$

2 qatlamli xalqa qabul qilamiz.

Armoshel KB900 li t=0,48 sm li material qo‘llanilganda:

$$n_f = \frac{A_f}{U_f t_f} = \frac{32,3}{64 \cdot 0,48} = 1,05;$$

1 qatlamli xalqa qabul qilamiz.

Uglekompozit material bilan kuchaytirilgan ustunning yuk ko‘tarish qobilyati quyidagiga teng:

$N_{0ult} = \varphi \cdot [R_b \cdot A_b + \varphi_1 \cdot R_f \cdot A_{sad,tot}] =$

$0,913 \cdot [11,5 \cdot 40000 + 0,913 \cdot 300 \cdot 1230] = 727,6kN;$

***727,69kN ≤727,6kN***

Ustunning yuk ko‘tarish qobilyati ta’minlandi.

| № | Kuchaytirish usullari | Kuchaytirilmagan ustun yuk ko‘tarish qobilyati, kN | Kuchaytirilgan ustun yuk ko‘tarish qobilyati, kN |
|---|---|---|---|
| 1 | Ustun konstruksiyasini temirbeton yordamida kuchaytirish | 727,69 | 806,46 |
| 2 | Ustun konstruksiyasini kompozitbeton yordamida kuchaytirish | 727,69 | 841,6 |
| 3 | Ustun konstruksiyasini metal xalqa yordamida kuchaytirish | 727,69 | 768,0 |
| 4 | Temirbeton ustun konstruksiyasini kompozit materiallar bilan kuchaytirish | 727,69 | 727,6 |

Shishakompozit va po‘lat armatura narxlarini taqqoslash jadvali

| Kompozit armatura ishlab chiqaruvchi “UNIVERSAL FRP SYSTEMS” MChJ | | | Taqqoslash uchun AIII sinfli armatura narxlari | | |
|---|---|---|---|---|---|
| Nomlanishi | 1m uchun kompozit armatura narxi | Iqtisodiy tejamkorlik bo‘yicha koeffisent % | Teng kesim yuzali o‘rnini bosuvchi armatura | 1m uchun po‘lat armatura narxi | 1 tonna uchun metal narxi |
| ShKA-Ø4mm | 1064 | 60 | BP-1 | 2664 | 12000000 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Ø6mm | | |
| ShKA-Ø5mm | 1736 | 52 | BP-1 Ø7mm | 3624 | 12000000 |
| ShKA-Ø6mm | 2352 | 32 | AIII-Ø8mm | 3476 | 8800000 |
| ShKA-Ø7mm | 2632 | 52 | AIII-Ø10mm | 5430 | |
| ShKA-Ø8mm | 3248 | 58 | AIII-Ø12mm | 7814 | |
| ShKA-Ø10mm | 5208 | 51 | AIII-Ø14mm | 10648 | |
| ShKA-Ø12mm | 7616 | 45 | AIII-Ø16mm | 13904 | |
| ShKA-Ø14mm | 10752 | 39 | AIII-Ø18mm | 17600 | |
| ShKA-Ø16mm | 14224 | 35 | AIII-Ø20mm | 21736 | |

Olingan ma’lumotlar va tahlillarga ko‘ra, quyidagi xulosalarni chiqarish mumkin:

1. Ushbu tadqiqot ishida tasvirlangan barcha kuchaytirish usullari 1,5 kuchaytirish koeffisentida ustun mustahkamligini oshirishga imkon beradi.

2. Kuchaytiruvchi materiallarining narxiga ko‘ra, eng arzoni kompozitbeton xalqalar bilan kuchaytirish usuli bo‘lib chiqdi, uglekompozit materiallar bilan kuchaytirish boshqa kuchaytirish yuqori narx sababli boshqa usullardan sezilarli darajada farq qiladi.

3. Kuchaytirish ishlari nafaqat materiallarni, balki ishlarni, shuningdek, materiallarni obyektga yetkazib berishni, qoliplarning ijara haqqini, kran va boshqa xarajatlarni o‘z ichiga oladi.

4. Tadqiqot ishida 1,5 kuchaytirish koeffisentida bitta ustunni hisoblash misoli ko‘rib chiqildi. Ushbu usulni to‘liq ko‘z o‘ngimizga keltirishimiz uchun kuchaytirish koeffisient miqdorini ko‘paytirishimiz va ko‘p sonli

konstruksiyalarni iqtisodiy jihatdan taqqoslashni amalga oshirish kerak.

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