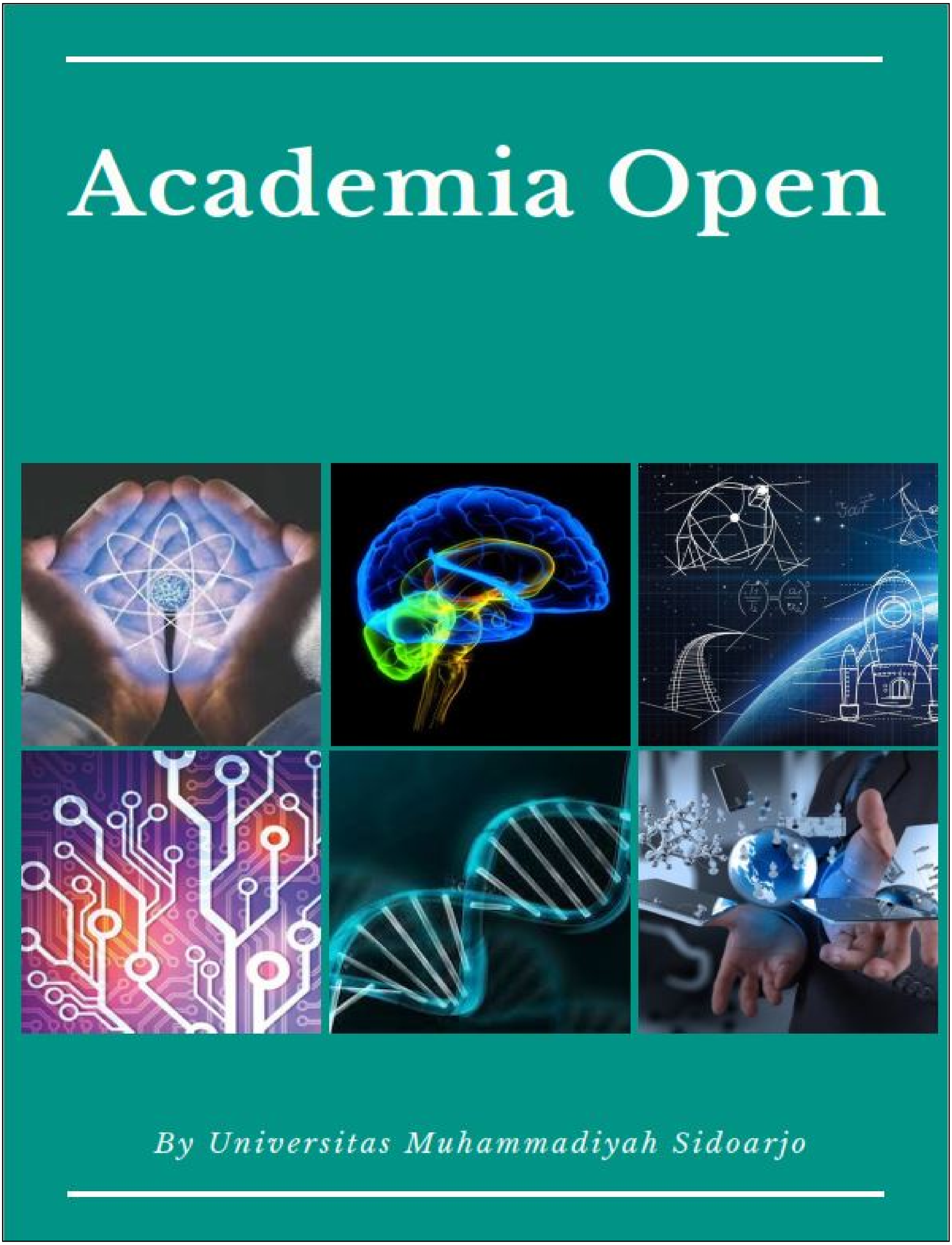
**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

# Table Of Content



ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)




ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

## Originality Statement

The author[s] declare that this article is their own work and to the best of their knowledge it contains no materials previously published or written by another person, or substantial proportions of material which have been accepted for the published of any other published materials, except where due acknowledgement is made in the article. Any contribution made to the research by others, with whom author[s] have work, is explicitly acknowledged in the article.

## Conflict of Interest Statement

The author[s] declare that this article was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Copyright Statement

Academia Open
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)



ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

# Advancing Critical Force Determination in Reinforced Concrete Columns: A Practical Approach

*Memajukan Penentuan Gaya Kritis pada Kolom Beton Bertulang: Sebuah Pendekatan Praktis*

**Kulmirzayeva Gulrabo Abduganiyevna , gkulmirzayeva@mail.ru, (1)**
*Samarkand State University of Architecture and Construction, Uzbekistan*

**Kosimov Turaboy Kosimovich , gkulmirzayeva@mail.ru, (0)**
*Samarkand State University of Architecture and Construction, Uzbekistan*

(1) Corresponding author

**Abstract**

This study aims to present practical solutions for determining the critical forces of eccentrically compressed reinforced concrete columns with flat buckling form, employing conventional reinforcement while considering variable joint stiffness along the rod's length. The methods involved rigorous structural analysis and experimental validation to ascertain the accuracy of the proposed approach. Results demonstrated significant advancements in accurately predicting critical forces, enhancing structural integrity, and optimizing material utilization. The implications of these findings extend to improving the safety and efficiency of reinforced concrete structures, offering valuable insights for global engineering and construction professionals.

**Highlights:**

- Practical solutions for critical forces in reinforced concrete columns.
- Utilization of conventional reinforcement for cost-effectiveness.
- Consideration of variable joint stiffness for accurate predictions.

**Keywords:** Critical Force, Eccentric Compression, Loss of Stability

Published date: 2024-12-01 00:00:00

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

# Introduction

It is important to take into account the age of the concrete and the load shoulder and time of loading and the limit value of the amount of critical force in ensuring the priority of columns made of reinforced concrete acting in eccentric compression. The superiority of a reinforced concrete column depends on the amount of high critical force applied to it [1].

# Methods

In the current normative rules, the calculation of the deformation due to the longitudinal force is not required in cases where the elements acting on eccentric compression are elastic [2]. However, in many cases, the longitudinal bending of reinforced concrete columns subjected to eccentric compression increases from the amount of bending moment at the loaded shoulder to the amount of bending moment resulting from longitudinal bending. Column priority according to the applicable standard provided when available.

$$\frac{l_0}{i} \le 14; \left(\frac{l_0}{h} \le 4\right) \; and \; \frac{l_0}{i} > 14; \left(\frac{l_0}{h} > 4\right) M_e = N(e) M_{(e+f)} = N \cdot (e+f)$$
$$Ne \le M_u = R_b bx(h_0 - 0{,}5x) + R_{sc} A'_s (h_0 - a')$$

**Figure 1.**

while, the structural structure of column concrete changes and the slip property increases. Therefore, it is important to determine the critical strength of reinforced concrete columns.

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

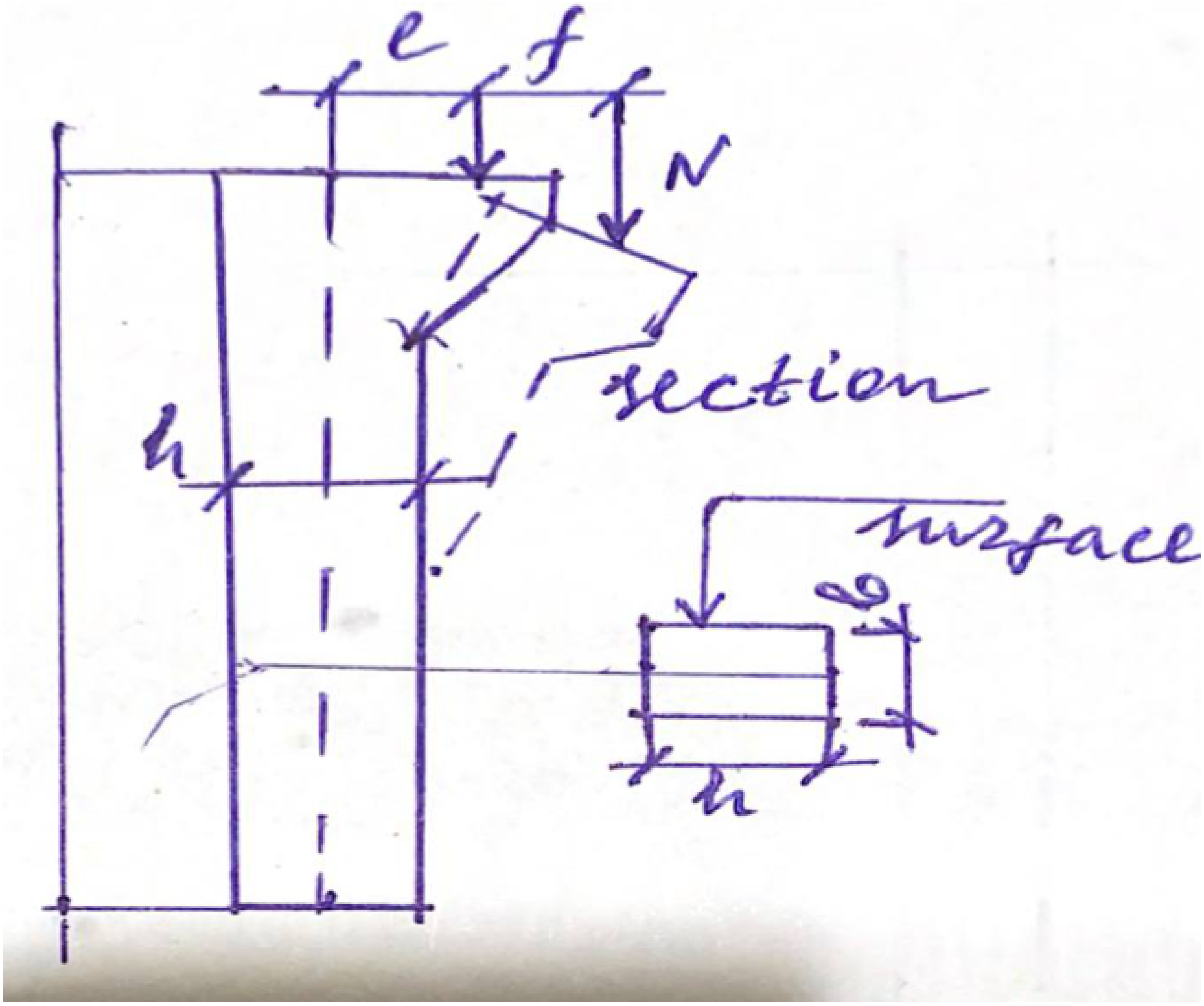



**Figure 2.** *Report and structural schemes of reinforced concrete columns operating in non-central compression: a) the cross – sectional surface of the column is in full compression; b) the case where ¼ of the upper cross – sectional surface is compressed; c) the case where ¾ of the cross – sectional surface of the column works in compression.*

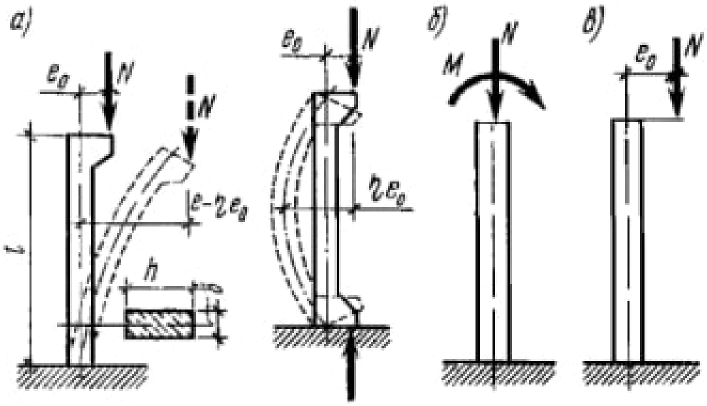



**Figure 3.** *Report and structural schemes of reinforced concrete columns operating in non-central compression: a) the cross – sectional surface of the column is in full compression; b) the case where ¼ of the upper cross – sectional surface is compressed; c) the case where ¾ of the cross – sectional surface of the column works in compression.*

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

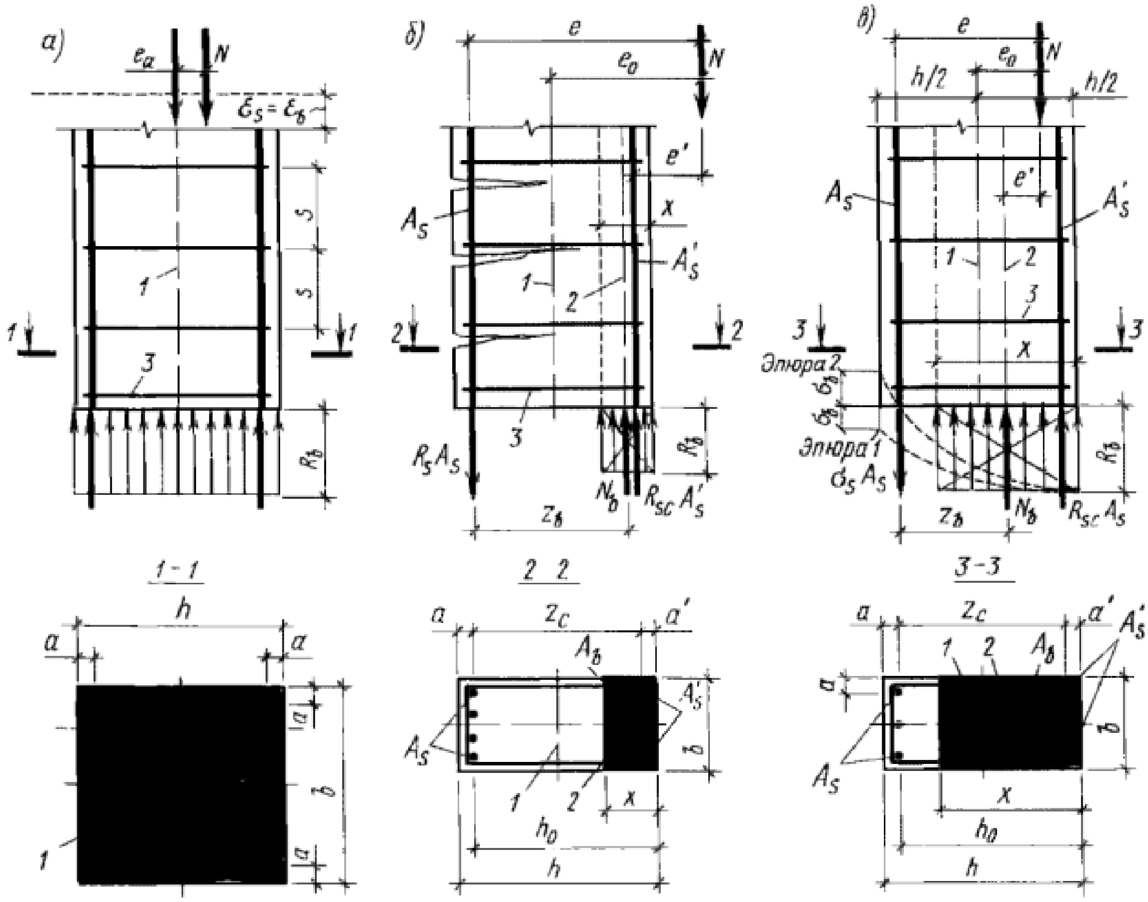


**Figure 4.** *Report and structural schemes of reinforced concrete columns operating in non-central compression: a) the cross – sectional surface of the column is in full compression; b) the case where ¼ of the upper cross – sectional surface is compressed; c) the case where ¾ of the cross – sectional surface of the column works in compression.*

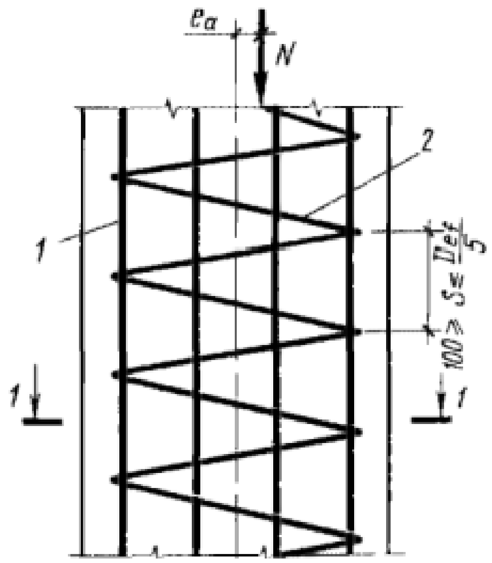


**Figure 5.** *Report and structural schemes of reinforced concrete columns operating in non-central compression: a) the cross – sectional surface of the column is in full compression; b) the case where ¼ of the upper cross – sectional surface is compressed; c) the case where ¾ of the cross – sectional surface of the column works in compression.*

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

# Results and Discussions

Determination of the critical force of a reinforced concrete column with a rectangular cross-sectional surface subjected to centrifugal compression.

**a. Given**

The dimensions of the cross-sectional surface of the column b = 15 sm, h = 24 sm, a = 2 sm. Column concrete grade is B30, dried under natural conditions. B(28) = 30 MPa = 30; value of conical subsidence is 3-4sm; the column is symmetrical in shape 4F20AIII (75; equipped with class armature; the calculated length of the column is the load falling on the transverse surface of the column, acting from the center of gravity along the shoulder, the relative humidity of the outside air during operation of the column is W=75% [3].

$$(R_s = R_s' = 375\ \text{МПа} = 3{,}75 \cdot 10^6\ H/m^2;\ \ E_s = 2 \cdot 10^{11} H/m^2),$$
$$A_s = A_s' = 6{,}28 \cdot 10^{-4} m^2\ ; L_0 = 4{,}65\ m\ ; l_0 = 0{,}115\ m = 11{,}5\ sm$$

**Figure 6.**

**b. Objective**

The column is loaded at full age and is required to determine the continuous critical force with respect to the moment of time

$$\bar{M} = \frac{2(b+h)}{b \cdot h} = 2\frac{0{,}24+0{,}15}{0{,}24 \cdot 0{,}15} = 21{,}67 m^{-1}$$

**Figure 7.**

**c. Solution**

The open surface modulus of the column is determined as follows [4].

The working height of the section surface affected by the bending moment is equal to the following value:

$h_0=h-a=0{,}15-0{,}02=0{,}13m=13$ sm

1. we can determine the strength of concrete with age from the table. From this.

$t_0=60$ sutka $t\to\infty$ $R_b^G(60)=33{,}9$ МПа ; $R_b^G(\infty)=39{,}1$ МПа

From table 2, we determine the modulus of elasticity of concrete according to the above values.$E_b(60)=33{,}87 \cdot 10^3$ МПа$=3{,}387 \cdot 10^{10}$ $H/m^2$

$E_b(\infty)=35{,}69 \cdot 10^3$ МПа$=3{,}56 \cdot 10^{10}$ $H/m^2$

From tables 11 and 12, we determine the values of the indicators of the continuous deformation function of concrete:

$\gamma=0{,}012$ $sut^{-1}$; $\gamma_1=0{,}006 sut^{-1}$; $c=0{,}50$; $d=0{,}7$.

Based on these equations, we define the following functions.

$\Omega(t_0)=C+de^{-\gamma t_0}=\Omega(60)=C+de^{-\gamma 60}=0{,}5+0{,}7e^{-0{,}012 \cdot 60}=0{,}841;$

$f(t-t_0)=1-ke^{-\gamma(t-t_0)}=f(\infty-60)=1-ke^{-\gamma_1(\infty-60)}=$

$=1-0{,}8 \cdot e^{-0{,}006(\infty-60)}=1{,}0$

2. from the table

$C^N=(\infty,28)=79 \cdot 10^{-6}$ МПа$^{-1}=7{,}9 \cdot 10^{-11}$ $m^2/H$,

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

we select values from table 6 and table 7. $\xi_{2c}=0,946$ ;$\xi_{3c}=0,8$

Based on the values determined above, we determine the threshold value of the linear slippage rate according to the formula (5a).

$C^* (t,t_0 )=[1/(E_b (t_0))]-[1/(E_b (t) )]+C(\infty,28)\Omega(t_0 )f(t-t_0 )=$

$=C^* (\infty,60)=[1/(3,387\bullet 10^{10} )]-[1/(3,569\bullet 10^{10} )]+5,979\bullet 10^{-11}\bullet 0,841\bullet 1,0=0,518 m^2/H$

[ ] We determine the parameters of the nonlinear function from table 10.

$V_k=1,3$; $V_c=1,6$.

We determine the modulus of continuous deformation according to the following formula.

$E_b^f (\infty,60)=\{(1+V_k)/(E_b (\infty))+(1+V_e ) C^* (\infty,60)\}^{-1}=$

$=[(1+1,3)/(3,569\bullet 10^{10} )+(1+1,6)0,518\bullet 10^{-10} ]^{-1}=0,502\bullet 10^{10} H/m^2$

(25) from the table. $f_0=0,13$

Using the following formula, we determine the effective deformation modulus of the compressive part of the column concrete [5].

The limit height of the compression zone on the transverse section of a reinforced concrete column operating in non-central compression is determined using the following formulas.

$$\xi_R=\left\{1+\frac{R_s E_b^f(\infty,60)}{R_b(28)E_s}\right\}^{-1}=\left[1+\frac{3,75\cdot 10^8\cdot 0,502\cdot 10^{10}}{17\cdot 10^6\cdot 2\cdot 10^{10}}\right]=0,645;$$

$$\xi_R'=\left(\frac{a}{h_0}\right)\left\{1-\frac{R_s F_b^f(\infty,60)}{R_b(28)E_s}\right\}=\frac{0,02}{0,13}\left[1-\frac{3,75\cdot 10^8\cdot 0,502\cdot 10^{10}}{17\cdot 10^6\cdot 2\cdot 10^{11}}\right]^{-1}=0,345$$

**Figure 8.**

here is the calculated compressive strength of concrete $R_b (28)$;

$R_b (28)=(R_{bn} (28))/\gamma_{bc} =(22\bullet 10^6)/1,3=17\bullet 10^6 H/m^2$

here $R_{bn}=22\bullet 10^6$ ,$\gamma_{bc}=1,3$.

In the matter under consideration □□= 0.645 > □□R = 0,345 the height of the compressive part of the column cross-section surface is selected according to the values determined by the following formula [6].

DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

$$A = 0; \quad B = \left[\frac{R_b(28)b}{1+f_0}\right] = \frac{17 \cdot 10^6 \cdot 0{,}24}{1+0{,}13} = 3{,}61 \cdot 10^6$$

$$C = R_s A_s - R'_s A'_s = 3{,}75 \cdot 10^8 \cdot 6{,}28 \cdot 10^{-4} - 3{,}75 \cdot 10^8 \cdot 6{,}28 \cdot 10^{-4} = 0$$

Thus, A = 0; when $B = 3{,}61 \cdot 10^6$; $C = 0$ that is $X_{min}(\infty, 60) - 0 = 0$ . $X_{min}(\infty, 60) = 0$
So,

$$\xi = \frac{X_{min}(\infty, 60)}{h_0} = 0 < \xi'_R$$

$X_{min}(\infty, 60)$ we re-determine the values based on the table (27).

$$A = \frac{R_b(28)}{1+f_0} = \frac{17{,}0 \cdot 10^6 \cdot 0{,}24}{1+0{,}13} = 3{,}61 \cdot 10^6;$$

$$\epsilon_b^f(\infty, 60) = \frac{R_b(28)}{E_b^f(\infty, 60)} = \frac{17 \cdot 10^6}{0{,}502 \cdot 10^{10}} = 33{,}86 \cdot 10^{-4}$$

$$B = \epsilon_b^f(\infty, 60) E'_s A'_s - R_s A_s = 33{,}86 \cdot 10^{-4} \cdot 2 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4} - \\ -3{,}75 \cdot 10^8 \cdot 6{,}28 \cdot 10^{-4} = 1{,}898 \cdot 10^5;$$

$$C = \epsilon_b^f(\infty, 60) E'_s A'_s a' = 33{,}86 \cdot 10^{-4} \cdot 2 \cdot 10^{-11} \cdot 6{,}28 \cdot 10^{-4} \cdot 0{,}02 \\ = 8{,}505 \cdot 10^3;$$

$$A \cdot x_{min}^2(\infty, 60) + B x_{min}(\infty, 60) - C = 0;$$

$$3{,}61 \cdot 10^6 \cdot x_{min}^2(\infty, 60) + 1{,}898 \cdot 10^5 x_{min}(\infty, 60) - 8{,}505 \cdot 10^3 = 0;$$

**Figure 9.**

From the solution of this quadratic equation, we determine the following value.

x_min (∞,60)=[1/2A] √(B^2+4AC)-B=

=[1/(2•3,61•10^6 )] √((1,898•10^5 )^2+4•3,61•10^6•8,505•10^3 )-1,898•10^5=

=0,0289 m = 2,89 sm.

q_0 (∞,60) We determine its value according to the following equation.

$$q_0(\infty, 60) = \frac{0{,}5 E_b(\infty,60) b x_{min}^2(\infty,60) + \beta_s E_s + A_s h_0 + \beta'_s E'_s A'_s a'}{E_b(\infty,60) b x_{min}(\infty,60) + \beta_s E_s A_s + \beta'_s E'_s A'_s} =$$

$$= \frac{0{,}5 \cdot 0{,}696 \cdot 10^{10} \cdot 0{,}24 \cdot 0{,}0289^2 + 1{,}0 \cdot 2{,}0 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4} \cdot 0{,}13 + 1{,}0 \cdot 2 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4} \cdot 0{,}02}{0{,}696 \cdot 10^{10} \cdot 0{,}24 \cdot 0{,}0289 + 1{,}0 \cdot 2{,}0 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4} + 1{,}0 \cdot 2 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4}}$$

$$= 0{,}065\text{m} = 6{,}52\text{sm}$$

$\beta_s$ $va$ $\beta'_s$ $\quad \beta_s = \beta'_s = 1$ here,

**Figure 10.**

DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

the coefficients are assumed to be values. We determine the stiffness of a reinforced concrete column operating in non-central compression according to the limit stress state in the following order [7].

x_(min,e) (∞,60) we calculate the limit value of the bending moment generated in a reinforced concrete column operating in non-central compression, based on the height of the compression part of the cross-sectional surface [8].

$$D_{\min b,c}(\infty,60) = E_b(\infty,60)\left\{\left[\frac{bx^3_{min}(\infty,60)}{12} + \frac{bx_{\min}(\infty,60)}{q_0(\infty,60)} - \frac{x_{min}(\infty,60)}{2}\right]^2\right\}$$

$$=$$

$$=0{,}696 \cdot 10^{10} \cdot \left[\frac{0{,}24 \cdot 0{,}0289^3}{12} + 0{,}24 \cdot 0{,}0289 \left(\frac{0{,}0652-0{,}0289}{2}\right)^2\right] = 1{,}277 \cdot 10^5 H \cdot m^2$$

$$D_{bc}(\infty,60) = \beta_s' E_s' A_s' [q_0(\infty,60) - a']^2 =$$

$$= 1{,}0 \cdot 2 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4} \cdot (0{,}0652 - 0{,}02)^2 = 2{,}57 \cdot 10^5 H \cdot m^2$$

$$D_{s,t}(\infty,60) = \beta_s E_s A_s [h_0 - q_0(\infty,60)]^2 =$$

$$=1{,}0 \cdot 2 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4}(0{,}13 - 0{,}0652)^2 = 5{,}274 \cdot 10^5 H \cdot m^2$$

$$D_{min}(\infty,60) = D_{\min b,c}(\infty,60) + D_{s,c}(\infty,60) + D_{s,t}(\infty,60) =$$

$$=1.277 \cdot 10^5 + 2{,}57 \cdot 10^5 + 5{,}274 \cdot 10^5 = 9{,}121 \cdot 10^5 H \cdot m^2$$

$\xi_R > \xi_R'$ , $x_{min,e}(\infty,60)$ given that found from Eq.

**Figure 11.**

The height of the compressive part of the cross-sectional surface of the column

x_min (∞,60)

$$A' x_{min,e}(t,t_0) + B' x'_{min,e}(t,t_0) + C' x_{min,e}(t,t_0) - D = 0$$

is determined by recalculation based on the solution of the equation.

$$A x^2_{min,e}(\infty,60) + B x_{min,e}(\infty,60) - C = 0$$

here

$$A = \left[\frac{R_b(28)b}{1+f_0}(2+f_0)\right] = \frac{17 \cdot 10^6 \cdot 0{,}24}{(1+0{,}13)(2+0{,}13)} = 1{,}695 \cdot 10^6;$$

$$B = \left[\frac{e_0 - \frac{h}{2}}{1+f_0}\right] R_b(28)b = \left[\left(\frac{0{,}115 - \frac{0{,}15}{2}}{1+0{,}13}\right)\right] 17 \cdot 10^6 \cdot 0{,}24 = 0{,}144 \cdot 10^6$$

$$e = e_0 + \frac{h}{2} - a = 0{,}115 + \frac{0{,}15}{2} - 0{,}02 = 0{,}17m\ ;$$

$$e' = e_0 - \frac{h}{2} + a' = 0{,}115 - \frac{0{,}15}{2} + 0{,}02 = 0{,}06m;$$

$$C = R_s A_{se} - R_s' A_s' e' =$$

$$= 3{,}75 \cdot 10^8 \cdot 6{,}28 \cdot 10^{-4} \cdot 0{,}17 - 3{,}75 \cdot 10^8 \cdot 6{,}28 \cdot 10^{-4} \cdot 0{,}06 = 2{,}59 \cdot 10^4$$

**Figure 12.**

We define the root of the initial equation as follows.

x_(min,e) (∞,60)=[1/2A](√(B^2+4AC)-B)=[1/(2•1,695•10^6 )]•

•(√((0,144•10^6 )^2+4•1,695•10^6•2,59•10^4 )-0,144•10^6 )=0,088 m

We check the condition of the problem as follows.

DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

$$\xi = \frac{x_{min,e}(\infty,60)}{h_0} = \frac{0{,}088}{0{,}13} = 0{,}677 > \xi_R = 0{,}645$$

$$A' = \frac{R_b(28)b}{(1+f_0)(2+f_0)} = \frac{17 \cdot 10^6 \cdot 0{,}24}{(1+0{,}13)(2+0{,}13)} = 1{,}695 \cdot 10^6$$

$$B' = \frac{e_0 - \frac{h}{2}}{(1+f_0)R_b(28)b} = \frac{0{,}115 - \frac{0{,}15}{2}}{(1+0{,}13)17 \cdot 10^6 \cdot 0{,}24} = 0{,}144 \cdot 10^6$$

$$C' = R'_s A'_s e' + e_b^f(\infty,60)E_s A_s e = 3{,}75 \cdot 10^8 \cdot 6{,}28 \cdot 10^{-4} \cdot 0{,}06 + \\ +33{,}86 \cdot 10^{-4} \cdot 2 \cdot 10^{11} \cdot 6{,}28 \cdot 10^{-4} \cdot 0{,}17 = 86{,}428 \cdot 10^3$$

$$D' = e_b^f(\infty,60)E_s A_s h_0 e = 33{,}86 \cdot 10^{-4} \cdot 6{,}28 \cdot 10^{-4} \cdot 2 \cdot 10^{11} \cdot 0{,}13 \cdot 0{,}17 = \\ = 9{,}399 \cdot 10^3$$

**Figure 13.**

And so, [9]

1,695•10^6 •x_(min,e)^3 (∞,60)+0,144•10^6•x_(min,e)^2 (∞,60)+ +86,428•10^3•x_(min,e) (∞,60)-9,399•10^3=0

or after contraction

1695•x_(min,e)^3 (∞,60)+144•x_(min,e)^2 (∞,60)+86,428•x_(min,e) (∞,60)-9,399=0

Let's solve this equation according to Newton's method [10].

x_(min,e)^n (∞,60)=x_(min,e)^(n-1) (∞,60)-{F[x_(min,e)^(n-1) (∞,60)]/F'[x_(min,e)^(n-1) (∞,60)] },

here

$$F\left[x^{n-1}_{min,e}(\infty,60)\right] \\ = A' x^{n-1}_{min,e}(\infty,60) + B x^{(n-1)^2}_{min,e}(\infty,60) + C'F\left(x^{(n-1)}_{min,e}(\infty,60)\right) - D';$$

$$F\left[x^{n-1}_{min,e}(\infty,60)\right] = 3A x^{(n-1)^2}_{min,e}(\infty,60) + 2B'\left(x^{\square}_{min,e}\right)(\infty,60) + C'$$

**Figure 14.**

We choose the following parameters as initial values.

$$x^{n-1}_{min,e}(\infty,60) = x^0_{min,e} = \xi_R h_0 = 0{,}645 \cdot 0{,}13 = 0{,}0839\ m$$

$$F\left(x^0_{min,e}\right) = 1695 \cdot 0{,}0839^3 + 144 \cdot 0{,}0839^2 + 86{,}428 \cdot 0{,}0839 - 9{,}399 = \\ = -0{,}133;$$

$$F'\left(x^{(0)}_{min,e}\right) = 3 \cdot 1695 \cdot 0{,}0839^2 + 2 \cdot 144 \cdot 0{,}0839 + 86{,}428 = 146{,}39$$

**Figure 15.**

and the value is equal to the first approximation x_(min,e) (∞,60)

x_(min,e)^((1))=(0,0839-(-0,133))/146,39=0,0848 m

x_(min,e) (∞,60) The second approximation value of is determined as follows.

F(x_(min,e)^((1)) )=1695•0,0848^3+144•0,0848^2+86,428•0,0848-9,399= -7,486•10^(-4);

F(x_(min,e)^((1)) )=3•1695•0,0848^2+2•144•0,0848+86,428=147,42;

x_(min,e)^((2))=(0,0848-(-7,846•10^(-4)))/147,42=0,0848

We take the value of the height of the compression zone of the cross-sectional area of the column determined by the double approximation as follows [11].

**Academia Open**
Vol 9 No 2 (2024): December
DOI: 10.21070/acopen.9.2024.8807 . Article type: (Engineering)

x_(min,e) (∞,60)=0,0848 m

Now, we determine the stresses produced in compression and tension reinforcements using the following formulas:

$$\sigma_s(\infty,60) = \varepsilon_b^f(\infty,60)E_s\left\{\frac{h_0 - x_{min,e}(\infty,60)}{x_{min,e}(\infty,60)}\right\} =$$
$$= \frac{33{,}86\cdot 10^{-4}\cdot 2\cdot 10^{11}(0{,}13-0{,}0848)}{0{,}0848} = 3{,}6\cdot 10^{8}H/m^2 < R_s' =$$
$$=3{,}75\cdot 10^{8}H/m^2$$
$$\sigma_s' = \varepsilon_b^f(\infty,60)E'_s\left[\frac{1-\alpha'}{x_{min,e}(\infty,60)}\right] = 33{,}86\cdot 10^{-4}\cdot 2\cdot 10^{11}\frac{1-0{,}02}{0{,}0848} =$$
$$= 5{,}175\cdot 10^{8} > R'_s = 3{,}75\cdot 10^{8}H/m^2$$

**Figure 16.**

We accept the following values for the account.

$$\sigma_s' = R_s' = 3{,}75\cdot 10^{8}\,\frac{H}{m^2} \qquad \sigma_s = 3{,}61\cdot 10^{8}\,\frac{H}{m^2}$$

**Figure 17.**

The limiting value of the bending moment generated in a reinforced concrete column operating in eccentric compression [12].

Now let's determine the continuous critical force according to the following equation.

$$P_{cr}(t,t_0) = \frac{P_{eil}^0(t,t_0)}{\left(1+\frac{\pi}{8}\sqrt{\frac{2}{3}}l_0k_e + l_0k_e\right)}$$
$$P_{eil}^0(\infty,60) = \left(\frac{\pi}{l_0}\right)^2 D_0(\infty,60) = \left(\frac{\pi}{1{,}65}\right)^2 16{,}058\cdot 10^5 = 7{,}33\cdot 10^5H;$$
$$P_{eil}^{min}(\infty,60) = \left(\frac{\pi}{l_0}\right)^2 D_{min}(\infty,60) = \left(\frac{\pi}{4{,}65}\right)^2 9{,}121\cdot 10^5 = 4{,}16\cdot 10^5H;$$
$$k_e = \frac{\left[P_{eil}^0(\infty,60) - P_{eil}^{min}(\infty,60)\right]}{M_{max}(\infty,60)} = \frac{7{,}33\cdot 10^5 - 4{,}16\cdot 10^5}{0{,}3339\cdot 10^5} = 9{,}494m^{-1};$$
$$P_{cr}(\infty,60) = \frac{P_{eil}^0(\infty,60)}{\left[1+\frac{8}{\pi}\sqrt{\frac{2}{3}}l_0k_0 + l_0k_e\right]} =$$
$$= \frac{7{,}33\cdot 10^5}{\left[1+\frac{8}{\pi}\sqrt{\frac{2}{3}}0{,}115\cdot 9{,}494+0{,}115\cdot 9{,}494\right]} = 171890\ H$$

**Figure 18.**

## Conclusion

As a result of longitudinal bending of reinforced concrete columns operating in eccentric compression, the value of the initial bending moment increases. Therefore, the load-bearing capacity of the column decreases, and the slip property of the concrete increases. In this case, the strength of the column is calculated according to its deformed state. The priority of the column depends on the critical amount of permanent load placed on it.

# References

1. V.M. Bondarenko and D.G. Suvorkin, "Reinforced Concrete and Column Structures," Textbook, Higher School, Moscow, Russia, 1987, p. 382.
2. V.F. Usmanov, "Theory of Reinforced Concrete Resistance," Monograph, Samarkand, Uzbekistan, 2021, pp. 108.
3. V.M. Bondarenko and S.V. Bondarenko, "Engineering Methods of Nonlinear Theory of Reinforced Concrete," Moscow, Russia, 1982, pp. 287.
4. H.A. Reid,"Concrete and Reinforced Concrete Constructions," KMK 2.03.01. - 96, Publisher: 1907.
5. S. Kholmirzayev, I. Akhmedov , A. Khamidov, "Concrete and Reinforced Concrete Structures," SP63.13330.2018, Publisher: 2018.
6. P. Acker, F.J. Ulm, "Recommendation for Taking into Account Creep and Shrinkage of Concrete When Calculating Concrete and Reinforced Concrete Structures," Moscow, Russia, 1988.
7. I.E. Prokopovich and V.A. Zadgenidze, "Applied Theory of Creep," Stroyizdat, Moscow, Russia, 1980, pp. 240.
8. T.K. Kosimov, "Stress-Strain State of Reinforced Concrete Creep," Monograph, Samarkand, Uzbekistan, 2019, p. 128.
9. T.K. Kasimov and Sh.R. Yakhasboyev, "Practical Solution of Tension Reduction Due to the Slip Property of Concrete in a Reinforced Concrete Structure with Reinforced Concrete Tensioned to a Symmetrical Shape," Problems of Architecture and Construction, vol. 3, 2022.
10. T.K. Kasimov and Sh.R. Yakhasboyev, "Calculation of the Strength of Reinforced Concrete Column Based on the State of Nonlinear Slip of Concrete," Architecture and Construction Problems, vol. 1, 2023.
11. T.K. Kasimov and G.A. Kulmirzayeva, "A Practical Solution for Calculating the Straightness and Bending of a Reinforced Concrete Beam with a Rectangular Cross-Section Surface According to the Slipability of Concrete (1-Issue)," Architecture and Construction Problems, vol. 4, 2023.
12. T.K. Kasimov and G.A. Kulmirzayeva, "A Practical Solution for Calculating the Straightness and Bending of a Reinforced Concrete Beam with a Rectangular Cross-Section Surface According to the Slipability of Concrete (2-Issue)," Architecture and Construction Problems, vol. 1, 2024.

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo