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1 Design of reinforced areas of concrete column using quadratic polynomials

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Abstract. Designing of reinforced concrete columns mostly carried out by a simple planning method which uses column interaction diagram. However, the application of this method is limited because it valid only for certain compressive strength of the concrete and yield strength of the reinforcement. Thus, a more applicable method is still in need. Another method is the use of quadratic polynomials as a basis for the approach in designing reinforced concrete columns, where the ratio of neutral lines to the effective height of a cross section (ξ) if associated with ξ in the same cross-section with different reinforcement ratios is assumed to form a quadratic polynomial. This is identical to the basic principle used in the Simpson rule for numerical integral using quadratic polynomials and had a sufficiently accurate level of accuracy. The basis of this approach to be used both the normal force equilibrium and the moment equilibrium. The abscissa of the intersection of the two curves is the ratio that had been mentioned, since it fulfill both of the equilibrium. The application of this method is relatively more complicated than the existing method but provided with tables and graphs (N vs ξ_y) and (M vs ξ_m) so that its used could be simplified. The uniqueness of these tables are only distinguished based on the compressive strength of the concrete, so in application it could be combined with various yield strength of the reinforcement available in the market. This method could be solved by using programming languages such as Fortran.

1. Introduction

If a normal force acted on a column then it could be described as a normal force relationship with the moment in a diagram as below. The column interaction diagram was divided into 3 regions:

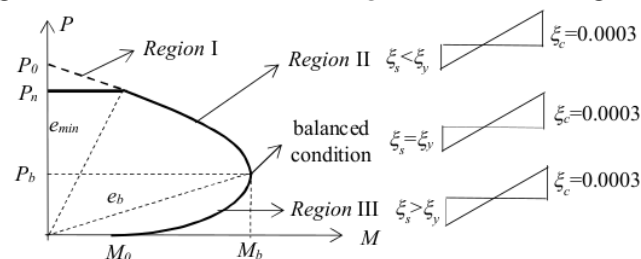


Figure 1. The division of region in the column interaction diagram

1.1 The assumption of the stresses of the concrete and steel

1.1.a Assumption of concrete stresses

1. Strain on reinforcement and concrete should be assumed to be proportional to the distance from the neutral axis. (Bernoulli - Navier)
2. The maximum strain that could be utilized in the outermost compression concrete was assumed to be 0.003.



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3. Strength at the reinforcing value smaller than the strength of f_y should be taken by E_s multiplied by the steel strain (Law of Hook). For strains of greater than ϵ_y associated with f_y , the stress on the reinforcement should be taken equal to f_y .
4. In axial and bending calculations, concrete tensile strength should be ignored.
5. The relationship between the distribution of compressive stresses of concrete and concrete strain may be assumed to be square, trapezoidal, parabolic or other shaped, resulting in a good reasonably when compared to the compression test results.
6. The above conditions could be simplified by an equivalent square distribution defined as follows:
- A stress of concrete average of $0.85 f'_c$, was assumed to be uniformly distributed over an equivalent compressive area bounded by a cross-sectional edge and a straight line parallel to a neutral axis of $a = \beta_1 c$ of fiber with maximum compressive strain.
 - The distance from the fiber with maximum strain to the neutral axis c should be measured in the direction perpendicular to the neutral axis.
 - For f'_c between 17 and 28 MPa, β_1 must be taken at 0.85. For f'_c above 28 MPa, β_1 must be reduced by 0.05 for any 7 MPa over 28 MPa, but β_1 should not be taken less than 0.65 or could be written in mathematical form as:

$$\beta_1 = 0.85 - \frac{1}{140}(f'_c - 28) \geq 0.65 \quad (1)$$

1.1.b The assumption of steel stress

The idealization of steel stress with strain to be used as commonly used in structural analysis was bi-linear as shown below :

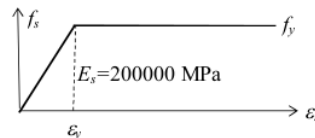


Figure 2. Stainless-steel strain idealization

1.2 Balanced condition

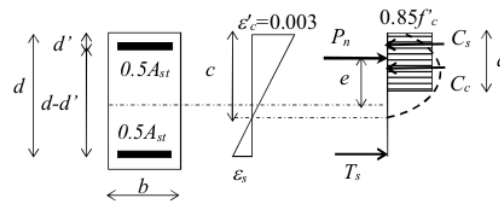


Figure 3. Cross section of columns and the stresses

From the drawing, obtained the relationship:

$$\frac{c}{d} = \frac{\epsilon'_c c}{\epsilon'_c c + \epsilon_s} \rightarrow \xi = \frac{\epsilon'_c c}{\epsilon'_c c + \epsilon_s} \quad (2)$$

For the balanced condition :

$$\xi_b = \frac{\epsilon'_c c}{\epsilon'_c c + \epsilon_y} = \frac{0.003}{0.003 + \frac{f_y}{E_s}} = \frac{0.003}{0.003 + \frac{f_y}{200000}} = \frac{600}{600 + f_y} \quad (3)$$

$$\sum H = 0$$

$$C_c + C_s - T_s - P_b = 0 \quad (4)$$

$$\text{Where: } C_s = T_s \rightarrow P_b = C_c = 0.85\beta_1 f'_c b c_b \quad (5)$$

1.3 Region II

$$P_b < P < P_n$$

Compression forces :

$$C_c = 0.85f'_c ab = 0.85\beta_1 f'_c bc \quad (6)$$

$$C_s = 0.5A_{st}f_y = 0.5\rho_t bdf_y \quad (7)$$

Tensile forces :

$$T_s = 0.5A_{st}f_s = 0.5\rho_t bde_s E = 300\rho_t bd \left(\frac{d}{c} - 1\right) \quad (8)$$

$$\sum H = 0$$

$$C_c + C_s - T_s - P_n = 0$$

$$0.85\beta_1 f'_c bc^2 + \{\rho_t bd(0.5f_y + 300) - P_n\}c - 300\rho_t bd^2 = 0 \quad (9)$$

$$\sum M = 0$$

$$-C_c \left(d - \frac{a}{2}\right) - C_s(d - d') + P_n \left(e + \frac{d-d'}{2}\right) = 0 \quad (10)$$

$$0.85\beta_1^2 f'_c bc^2 - 1.7\beta_1 f'_c bdc - \rho_t bdf_y(d - d') + P_n(2e + d - d') = 0 \quad (11)$$

From the above two squares equations (9 & 11) it is seen that the value of c depended on ρ and vice versa so it was difficult to solve.

1.4 Region III

$$P < P_b$$

$$C_c = 0.85f'_c ab$$

$$C_s = 0.5A_{st}f_y = 0.5\rho_t bdf_y$$

$$T_s = 0.5A_{st}f_y = 0.5\rho_t bdf_y$$

$$\sum H = 0$$

$$C_c + C_s - T_s - P_n = 0$$

$$P_n = C_c = 0.85f'_c ab \rightarrow a = \frac{P_n}{0.85f'_c b} \quad (12)$$

$$\sum M = 0$$

$$-P_n \left(d - \frac{a}{2}\right) - C_s(d - d') + P_n \left(e + \frac{d-d'}{2}\right) = 0$$

$$A_{st} = \frac{P_n \left(2e - h + \frac{P_n}{0.85f'_c b}\right)}{f_y(d-d')} \quad (13)$$

From this equation (13) it could be seen that the designed of reinforced concrete columns for region III could be calculated directly so that the discussion needed not be elaborated further.

1.5 Region II for 4 sided reinforcement

With each $0.25 A_{st}$ reinforcement on each side. ($P_b < P < P_n$)

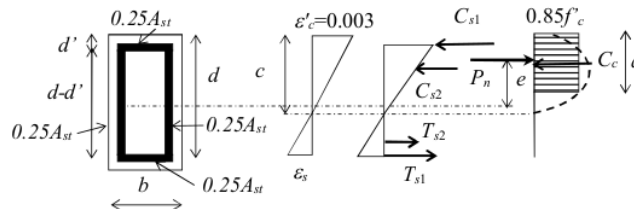


Figure 4. Cross section for 4 sided reinforcement

The forces acting on the cross section :

Compression forces :

$$C_c = 0.85f'_c ab = 0.85\beta_1 f'_c bc$$

$$C_{s1} = 0.25\rho_t bdf_y \quad (14)$$

$$C_{s2} = \frac{c-d'}{c} 0.5A_{st} \frac{2}{3} f'_s = 200\rho_t \frac{bd}{c^2} (c-d')^2 \quad (15)$$

Tensile forces :

$$T_{s1} = 0.25\rho_t b d \varepsilon_s E_s = 150\rho_t b d \left(\frac{d}{c} - 1\right) \quad (16)$$

$$T_{s2} = \frac{d-c}{c} 0.5A_{st} \frac{2}{3} f'_s = 200\rho_t \frac{bd}{c^2} (d-c)^2 \quad (17)$$

$$\sum H = 0$$

$$C_c + C_{s1} + C_{s2} - T_{s1} - T_{s2} - P_n = 0 \quad (18)$$

$$\text{If: } \frac{d'}{d} = R \quad (19)$$

$$0.85\beta_1 f'_c c^3 + \left\{ \rho_t d (0.25f_y + 150) - \frac{P_n}{b} \right\} c^2 + 250\rho_t d^2 (1 - 1.6R)c - 200\rho_t d^3 = 0 \quad (20)$$

$$\sum M = 0$$

$$-C_c \left(d - \frac{a}{2} \right) - C_{s1} (d - d') - C_{s2} \left\{ \frac{2}{3} (c - d') + d - c \right\} + T_{s2} \frac{1}{3} (d - c) + P_n \left(e + \frac{d-d'}{2} \right) = 0 \quad (21)$$

$$0.85\beta_1 f'_c c^4 - 1.7\beta_1 f'_c d c^3 - \left\{ 0.5\rho_t d f_y (d - d') - \frac{P_n}{b} (2e + d - d') \right\} c^2 - \frac{400}{3} \rho_t d \left\{ (c - d')^2 \left[3d \left(1 - \frac{2}{3}R \right) - c \right] - (d - c)^3 \right\} = 0 \quad (22)$$

2. Research methods

In this research the normal force equilibrium equation, the form was converted to equation with $\xi_N = \left(\frac{c}{d}\right)$ as a variable :

$$0.85\beta_1 f'_c \xi_N^2 + \left\{ \rho_t (0.5f_y + 300) - \frac{P_n}{bd} \right\} \xi_N - 300\rho_t = 0 \quad (23)$$

This equation could not be solved because the value ξ_N depended on ρ_t and vice versa so that there was a solution it was determined ρ_t first so that ξ_N could be determined. While the other value was a known factor of a column.

Therefore this equation would be solved by taking the value of the column reinforcement ratio ρ_{t1} , ρ_{t2} and ρ_{t3} which had the same difference it would be obtained three pairs of numbers $\{\rho_{t1}, \xi_{N1}\}$, $\{\rho_{t2}, \xi_{N2}\}$ and $\{\rho_{t3}, \xi_{N3}\}$ which were assumed to satisfy **quadratic polynomial**.

Similarly, the moment equilibrium equation, the form was converted to equation with $\xi_M = \left(\frac{c}{d}\right)$ as variable :

$$0.85\beta_1 f'_c \xi_M^2 - 1.7\beta_1 f'_c \xi_M - \rho_t f_y (1 - R) + \frac{P_n}{bd^2} (2e + d - d') = 0 \quad (24)$$

In the same way above, taking the values of the column ratios of ρ_{t1} , ρ_{t2} dan ρ_{t3} that had the same difference would be obtained three pairs of numbers $\{\rho_{t1}, \xi_{M1}\}$, $\{\rho_{t2}, \xi_{M2}\}$ dan $\{\rho_{t3}, \xi_{M3}\}$ which were assumed to satisfy **quadratic polynomial**.

This was identical to the assumption used by Simpson in numerical integration that using three points as the basis of calculation assuming it met the quadratic polynomial and given quite accurate results. The value of $\{\rho_t, \xi\}$ occurring was that which satisfies the normal force equilibrium curve and the moment equilibrium curve or, in other words, the point of intersection of the two curves.

2.1 Determining the value of ξ from the normal force and moment equilibrium equations

The normal force equilibrium equation could be written as:

$$0.85\beta_1 f'_c \xi_H^2 + N \xi_H - 300 \rho_t = 0 \quad (25)$$

$$\text{where : } N = \rho_t (0.5 f_y + 300) - \frac{P_n}{bd} \quad (26)$$

By solving the quadratic equation, it was obtained :

$$\xi_N = \frac{1}{1.7\beta_1 f'_c} (-N + \sqrt{N^2 + 1020 \rho_t \beta_1 f'_c}) \quad (27)$$

From the above equation it can be seen that ξ_H depended on N and the compressive strength of the concrete. Of the three values of $N_{1.0}$, $N_{1.5}$ dan $N_{2.0}$ were determined by three variation $\rho_{1.0} = 1.0\%$, $\rho_{1.5} = 1.5\%$ and $\rho_{2.0} = 2.0\%$ so that the value $\xi_{N1.0}$, $\xi_{N1.5}$ and $\xi_{N2.0}$ could be obtained.

So that the three points obtained $\{(0.01, \xi_{N1.0}), (0.015, \xi_{N1.5}) \text{ and } (0.02, \xi_{N2.0})\}$

The moment equilibrium equation could be written as :

$$0.85\beta_1^2 f'_c \xi_M^2 - 1.7\beta_1 f'_c \xi_M + M = 0 \quad (28)$$

$$\text{where : } M = -\rho_t f_y (1 - R) + \frac{P_n}{bd^2} (2e + d - d') \quad (29)$$

By solving the quadratic equation, it was obtained :

$$\xi_M = \frac{1}{\beta_1} \left(1 - \sqrt{1 - \frac{M}{0.85 f'_c}} \right) \quad (30)$$

From the equation above showed that ξ_M depended on M and the compressive strength of the concrete. Of the three values of $M_{1.0}$, $M_{1.5}$ dan $M_{2.0}$ could be determined with three variations $\rho_{1.0} = 1.0\%$, $\rho_{1.5} = 1.5\%$ dan $\rho_{2.0} = 2.0\%$ so the value $\xi_{M1.0}$, $\xi_{M1.5}$ and $\xi_{M2.0}$ could be obtained. Thus, there were three points $\{(0.01, \xi_{M1.0}), (0.015, \xi_{M1.5}) \text{ and } (0.02, \xi_{M2.0})\}$

2.2 Determining the reinforcement ratio on the basis of $\rho_{1.0}$, $\rho_{1.5}$ and $\rho_{2.0}$

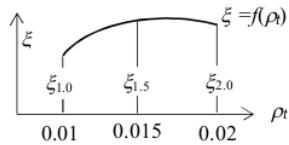


Figure 5. Quadratic equation curve

$$\xi = 20000(\xi_{2.0} - 2\xi_{1.5} + \xi_{1.0})\rho_t^2 + 100(-5\xi_{2.0} + 12\xi_{1.5} - 7\xi_{1.0})\rho_t + 3\xi_{2.0} - 8\xi_{1.5} + 6\xi_{1.0} \quad (31)$$

Forms of quadratic equations on the basis of $\xi_{N1.0}$, $\xi_{N1.5}$ and $\xi_{N2.0}$ or $\xi_{M1.0}$, $\xi_{M1.5}$ and $\xi_{M2.0}$

The ρ_t value that occurs was the abscissa value of the intersection of the curve of normal force and the curve moment equilibrium and as an illustration saw the picture below in figure 6.

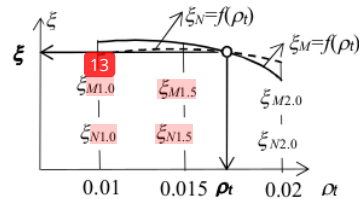


Figure 6. Illustration of intersection of two curves normal force and moment

For easy writing, next

$$[\xi_{N2.0} - \xi_{M2.0}] = Y_{2.0} \quad (32)$$

$$[\xi_{N1.5} - \xi_{M1.5}] = Y_{1.5} \quad (33)$$

$$[\xi_{N1.0} - \xi_{M1.0}] = Y_{1.0} \quad (34)$$

So the quadratic equation to be solved was:

$$20000(Y_{2.0} - 2Y_{1.5} + Y_{1.0})\rho_t^2 + 100(-5Y_{2.0} + 12Y_{1.5} - 7Y_{1.0})\rho_t + 3Y_{2.0} - 8Y_{1.5} + 6Y_{1.0} = 0 \quad (35)$$

$$\text{Or: } 20000A_{1.5}\rho_t^2 + 100B_{1.5}\rho_t + C_{1.5} = 0 \quad (36)$$

$$A_{1.5} = Y_{2.0} - 2Y_{1.5} + Y_{1.0} \quad (37)$$

$$B_{1.5} = -5Y_{2.0} + 12Y_{1.5} - 7Y_{1.0} \quad (38)$$

$$C_{1.5} = 3Y_{2.0} - 8Y_{1.5} + 6Y_{1.0} \quad (39)$$

$$\rho_t = \frac{B_{1.5}}{400A_{1.5}} \left(-1 + \sqrt{1 - 8 \frac{A_{1.5}C_{1.5}}{B_{1.5}^2}} \right) \quad (40)$$

2.3 Determining the reinforcement ratio on the basis of $\rho_{2.0}$, $\rho_{2.5}$ and $\rho_{3.0}$

In case $\rho_t > 0.02$ then it was better to use $\rho_{2.0} = 2.0\%$, $\rho_{2.5} = 2.5\%$ dan $\rho_{3.0} = 3.0\%$, as the based of the analysis.

$$\xi = 20000(\xi_{3.0} - 2\xi_{2.5} + \xi_{2.0})\rho_t^2 + 100(-9\xi_{3.0} + 20\xi_{2.5} - 11\xi_{2.0})\rho_t + 10\xi_{3.0} - 24\xi_{2.5} + 15\xi_{2.0} \quad (41)$$

$$[\xi_{N2.5} - \xi_{M2.5}] = Y_{2.5} \quad (42)$$

$$[\xi_{N3.0} - \xi_{M3.0}] = Y_{3.0} \quad (43)$$

So the quadratic equation to be solved was :

$$20000(Y_{3.0} - 2Y_{2.5} + Y_{2.0})\rho_t^2 + 100(-9Y_{3.0} + 20Y_{2.5} - 11Y_{2.0})\rho_t + 10Y_{3.0} - 24Y_{2.5} + 5Y_{2.0} = 0 \quad (44)$$

$$\text{Or: } 20000A_{2.5}\rho_t^2 + 100B_{2.5}\rho_t + C_{2.5} = 0 \quad (45)$$

$$A_{2.5} = Y_{3.0} - 2Y_{2.5} + Y_{2.0} \quad (46)$$

$$B_{2.5} = -9Y_{3.0} + 20Y_{2.5} - 11Y_{2.0} \quad (47)$$

$$C_{2.5} = 10Y_{3.0} - 24Y_{2.5} + 15Y_{2.0} \quad (48)$$

$$\rho_t = \frac{B_{2.5}}{400A_{2.5}} \left(-1 + \sqrt{1 - 8 \frac{A_{2.5}C_{2.5}}{B_{2.5}^2}} \right) \quad (49)$$

2.4 Determining the reinforcement ratio on the basis of $\rho_{3.0}$, $\rho_{3.5}$ and $\rho_{4.0}$

In case $\rho_t > 0.03$ then it was better to use $\rho_{3.0} = 3.0\%$, $\rho_{3.5} = 3.5\%$ and $\rho_{4.0} = 4.0\%$, as the base of the analysis.

$$\xi = 20000(\xi_{4.0} - 2\xi_{3.5} + \xi_{3.0})\rho_t^2 + 100(-13\xi_{4.0} + 28\xi_{3.5} - 15\xi_{3.0})\rho_t + 21\xi_{4.0} - 48\xi_{3.5} + 28\xi_{3.0} \quad (50)$$

$$[\xi_{N3.5} - \xi_{M3.5}] = Y_{3.5} \quad (51)$$

$$[\xi_{N4.0} - \xi_{M4.0}] = Y_{4.0} \quad (52)$$

So the quadratic equation to be solved was :

$$20000(Y_{4.0} - 2Y_{3.5} + Y_{3.0})\rho_t^2 + 100(-13Y_{4.0} + 28Y_{3.5} - 15Y_{3.0})\rho_t + 21Y_{4.0} - 48Y_{3.5} + 28Y_{3.0} = 0 \quad (53)$$

$$\text{Or: } 20000A_{3.5}\rho_t^2 + 100B_{3.5}\rho_t + C_{3.5} = 0 \quad (54)$$

$$A_{3.5} = Y_{4.0} - 2Y_{3.5} + Y_{3.0} \quad (55)$$

$$B_{3.5} = -13Y_{4.0} + 28Y_{3.5} - 15Y_{3.0} \quad (56)$$

$$C_{3.5} = 21Y_{4.0} - 48Y_{3.5} + 28Y_{3.0} \quad (57)$$

$$\rho_t = \frac{B_{3.5}}{400A_{3.5}} \left(-1 + \sqrt{1 - 8 \frac{A_{3.5}C_{3.5}}{B_{3.5}^2}} \right) \quad (58)$$

17 Research of region II for 4-sided reinforcement

The normal force equilibrium equati [15](#)

As in the above of this research the normal force equilibrium equation, changed to the equation $\xi_N = \left(\frac{c}{d}\right)$ as a variable :

$$0.85\beta_1 f_c' \xi_N^3 + \left\{ \rho_t (0.25f_y + 150) - \frac{P_n}{bd} \right\} \xi_N^2 + 250\rho_t (1 - 1.6R)\xi_N - 200\rho_t = 0 \quad (59)$$

$$\text{Where : } N_4 = \rho_t(0.25f_y + 150) - \frac{P_n}{bd} \quad (60)$$

The above equation (59) was in the form of a cubic polynomial so that ξ_N was obtained with the aid of the Newton-Raphson method.

This equation would be solved by taking the value of the column reinforcement ratio ρ_{t1} , ρ_{t2} and ρ_{t3} which have the same difference it would be obtained three pairs of numbers $\{\rho_{t1}, \xi_{N1}\}$, $\{\rho_{t2}, \xi_{N2}\}$ and $\{\rho_{t3}, \xi_{N3}\}$ assumed to satisfy **quadratic polynomial**.

The moment equilibrium equation :

As in the above section of this research the the moment equilibrium equation, changed to the equation

$\xi_N = \left(\frac{c}{d}\right)$ as a variable:

$$0.85\beta_1^2 f_c' \xi_M^4 - 1.7\beta_1 f_c' \xi_M^3 - \left\{0.5\rho_t f_y (1-R) - \frac{P_n}{bd^2} (2e + d - d')\right\} \xi_M^2 - 400(1-R)^2 \rho_t \xi_M + \frac{400}{3} \rho_t (2R^3 - 3R^2 + 1) = 0 \quad (61)$$

$$\text{Where : } M_4 = -\left\{0.5\rho_t f_y (1-R) - \frac{P_n}{bd^2} (2e + d - d')\right\} \quad (62)$$

The above equation (61) was in the form of a quartic polynomial so that ξ_M was obtained with the aid of the Newton-Raphson method.

This equation was solved by taking the values of the column ratios of ρ_{t1} , ρ_{t2} and ρ_{t3} which had the same difference then there would be three pairs of numbers $\{\rho_{t1}, \xi_{M1}\}$, $\{\rho_{t2}, \xi_{M2}\}$ and $\{\rho_{t3}, \xi_{M3}\}$ which is assumed to satisfy **quadratic polynomial**.

The value of $\{\rho_t, \xi\}$ occurring was that which satisfies the equilibrium the normal force curve and equilibrium the moment curve or, in other words, the point of intersection of the two curves.

3. Result

The case of double-sided reinforcement with the following data : $f_c' = 40$ MPa, $f_y = 420$ MPa, $b = 0.8$ m, $d = 0.85$ m, $d' = 0.15$ m and $e = 0.3$ m

Estimate $A_{st} = 2\%bd$ (Tied column)

$$P_0 = 0.85f_c' (A_g - A_{st}) + f_y A_{st} = 26.207 \text{ MN}$$

$$P_n = 0.8P_0 = 28.37 \text{ MN}$$

$$P = \frac{P_u}{0.65} = 16.2 \text{ MN}$$

$$c_b = \frac{600}{600 + 420} \cdot 0.72 = 0.424$$

$$P_b = 0.85\beta_1 f_c' b c_b = 9.36 \text{ MN}$$

$$P_b < P < P_n \rightarrow \text{region II}$$

f_c'	=	40	MPa	
f_y	=	420	MPa	
P_u	=	10,53	MN	
b	=	0,8	m	
d	=	0,85	m	
d'	=	0,15	m	
e	=	0,3	m	
β_1	=	0,764		
ρ		1,00	1,50	2,00
N		-18,724	-16,174	-13,624
ξ_N		0,856	0,831	0,81
M		32,977	31,248	29,518
ξ_M		1,082	0,937	0,834
Y		-0,226	-0,106	-0,024
$A_{1,5}$	=	-0,038		
$B_{1,5}$	=	0,43		

$$C_{1,5} = -0,58$$

$$\rho = 0,022196$$

That mean not cut between the two curves were at $0.01 \leq \rho_t \leq 0.02$ then recalculated with $\rho_{2,0}$, $\rho_{2,5}$ and $\rho_{3,0}$ as the basis :

ρ	2,00	2,50	3,00
N	-13,624	-11,074	-8,524
ξ_N	0,81	0,791	0,775
M	29,518	27,789	26,060
ξ_M	0,834	0,749	0,676
Y	-0,024	0,042	0,099
$A_{2,5} =$	-0,009		
$B_{2,5} =$	0,213		
$C_{2,5} =$	-0,378		
$\rho_t =$	0,021741		

Results from the fortran program : $\rho_t = 0.0217$ and validation by the iteration method : $\rho_t = 0,0219$ (taken from the analysis but not shown)

Analysis method	ρ_t	Ratio to the iteration method
Manual	0.021741	99.27%
Fortran program	0.0217	99.09%
Iteration Gauss-Seidel	0.0219	100%

4. Conclusion

The most unique of these approaches was that the tables or graphs (N vs ξ_N) and (N vs ξ_M) were only distinguished on the basis of the compressive strenght of the concrete alone while the yield strenght of the reinforcement could be adjusted to the available market. To ensure the accuracy of this method used $\rho_{1,0}$, $\rho_{1,5}$ and $\rho_{2,0}$ or $\rho_{2,0}$, $\rho_{2,5}$ and $\rho_{3,0}$ or $\rho_{3,0}$, $\rho_{3,5}$ and $\rho_{4,0}$ as a basis for calculation two sides and calculation with 4 sided of reinforcement. If with the help of fortran program all combination of concrete and reinforcement could be completed so that the application was very flexible.

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