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RESEARCH ARTICLE

EFFECT OF REINFORCEMENT RATIO AND CROSS SECTION DIMENSIONS ON THE RELIABILITY INDEX OF SLENDER REINFORCED CONCRETE COLUMNS

***,1Saleh, I. M., 2Abdel-Hay A. S. and 3Ahmed, M. A.**

[1]Department of Civil Engineering, Faculty of Engineering, Cairo University, Egypt
[2]Department of Civil Engineering, Faculty of Engineering, Beni-Suef University, Egypt
[3]Department of Structural Engineering, Faculty of Engineering, Cairo University, Egypt

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ABSTRACT

The reliability of structure is its ability to achieve its design purpose during a specified time. The reliability index is equivalent to the probability of safety. In this study, the reliability index for the RC slender columns with rectangular cross section is studied. The variable parameters studied include the concrete compressive strength, the reinforcement yield strength, the loads, the reinforcement ratio, the dimensions of concrete cross-section, and the location of steel placement. Risk Analysis program called @Risk (Version 6.0) was used to perform the analytical study. This paper present the effect of the reinforcement ratio and the cross section dimensions on the reliability index of slender reinforced concrete columns. The results of this study indicate that the good quality control has significant effects on decreasing the coefficient of variation for the concrete compressive strength, yield steel strength and the dimension of reinforced concrete sections which in turn improve the performance of slender reinforced columns through increasing the reliability index β.

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INTRODUCTION

Structural design is concerned with the assurance of adequate safety of structures under loading conditions. Because of the statistical nature of loading, material properties, manufacturing and construction processes, safety analysis can be applied using probabilistic techniques. In an early description of probabilistic design, Freudenthal *et al*. (1966) pointed out that the term "factor of safety" is correlated with the probability of failure or, on the other hand probability of survival (reliability) of the structure. Ahmed *et al*. (2016) studied the effect of load eccentricity on the reliability index of reinforced concrete slender column. They were pointed that:

- Increasing both the loads eccentricity and the column slenderness ratio (λ), causes a decrease of the reliability index. The reliability index (β) will be slightly decreased in case of higher column thicknesses.
- Increasing the concrete compressive strength (fcu) causes an increase in reliability index (β). This effect was significant in case of columns with small reinforcement ratio.
- Increasing the yield steel strength (fy) causes an increase in reliability index (β). This effect was significant in case of columns with small reinforcement ratio.
- The good quality control has significant effects on decreasing the coefficient of variation for the concrete compressive strength and yield steel strength which in turn improve the performance of slender reinforced columns through increasing the reliability index β.

Frangopol *et al*. (1996) carried out many investigations for columns and bridges, where the reliability is shown to be affected by load correlation and loading paths. In this work, the reliability analysis is performed by using Monte Carlo simulations, using an appropriate nonlinear stress-strain relationship and a strongly simplified elastic-plastic buckling model. Frangopol *et al*. (1996) studied the reliability of reinforced concrete short columns. The reliability of RC columns with moment and axial force in random correlation using Monte Carlo method was studied by Jiang *et al*. (2011), also, Hong and Zhou (1999) proposed an improved approach to deal with the uncertainty in eccentricity. Bazant (1991), Holicky and Vrouwenvelder (1997), Mohamed *et al*. (2001), Sofia and Frangopol (2003), Youba Jiang and Weijun Yang (2013), Mostafa (1989), Jose (2001), Kwak (2006) deals with the reliability of columns. Therefore, there is a lake of study on

****Corresponding author:*** **Saleh, I. M.**
Department of Civil Engineering, Faculty of Engineering, Cairo University, Egypt.

the reliability index of slender reinforced concrete columns. The objective of this study is to introduce a Risk analysis technique via the Risk analysis program model to identify and assess the parameters that affect the reliability index of slender reinforced concrete column designed according to the Egyptian code for design and construction of concrete structures (ECP 203).The parametric study deals with the effect of reinforcement ratio and the effect of cross section dimensions on the reliability index of slender RC columns.

- f_y is the steel reinforcement yield strength
- P_c is the column capacity in case of pure compression
- p_{ult} is the ultimate applied load (the values of p_{ult} are equal to 0.15, 0.2 and 0.25 p_c)
- e is the loading eccentricity Where $e = M_{ult}/p_{ult}$,

Table 1. The studied parameters of groups

Group ID	Concrete dimensions (mm^2)	µ%	F_{cu} (MPa)	P_{ult} (KN)	M_{ult} KN.m
1- A and 1-B	500×500	1.6	25, 30, 35	0.15,0.20,0.25 P_c	100
					200
					300
					400
		2.8	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400
		4	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400
2- A and 2-B	500×1000	1.6	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400
		2.8	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400
		4	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400
3-A and 3-B	500×1500	1.6	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400
		2.8	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400
		4	25, 30, 35	0.15,0.20,0.25 Pc	100
					200
					300
					400

Fy = 360 MPa for group A and 420 MPa for group B

Parametric study

In this study, the risk analysis simulation program called @Risk (Version 6.0) is used. This software uses Monte Carlo simulation. The conducted parametric study consists of input variables of six groups of slender reinforced concrete columns as shown in Tables (1).

Where

- µ is the steel reinforcement ratio
- f_{cu} is the concrete characteristic strength

Statistics of the basic variables

The basic Statistics of variables related to column strength and load were taken as values used in ref (Sofia *et al*., 2003)

Interaction diagram depicts all combinations of axial loads and bending moments

For each cross section and each case of loading, the interaction diagram was plotted using first principals according to the Egyptian code of reinforced concrete design, ECP203, with some simplifications as described in ref (Ahmed *et al*., 2016)

Reliability formulation (verification of the structural safety)

The structural safety and the reliability index were estimated using the method used and described in ref (Ahmed *et al.*, 2016).

RESULTS AND DISCUSSION

There are many factors that affect the reliability index of R.C long column. In the present study, the factors considered were the effect of reinforcement ratio and the effect of cross section dimensions.

Table 2. Reliability index (β) for 500*500 mm R.C. cross section, P_{ult}= 0.15 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25	360	1.6%	0.57	0.52	0.11
		2.8%	0.82	0.74	0.61
		4%	1.13	1.01	0.86
30		1.6%	0.74	0.70	0.22
		2.8%	1.07	0.94	0.78
		4%	1.37	1.23	1.22
35		1.6%	0.95	0.88	0.35
		2.8%	1.29	1.19	1.16
		4%	1.57	1.51	1.41
25	420	1.6%	0.63	0.64	0.34
		2.8%	0.97	0.87	0.74
		4%	1.29	1.25	1.04
30		1.6%	0.84	0.77	0.47
		2.8%	1.18	1.10	0.99
		4%	1.59	1.50	1.30
35		1.6%	1.04	1.01	0.65
		2.8%	1.45	1.36	1.18
		4%	1.83	1.79	1.62

Table 3. Reliability index (β) for 500*500 mm R.C. cross section, P_{ult}= 0.20 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25	360	1.6%	0.70	0.63	0.31
		2.8%	1.01	0.91	0.76
		4%	1.3	1.27	1.10
30		1.6%	0.93	0.85	0.41
		2.8%	1.28	1.16	0.99
		4%	1.71	1.54	1.34
35		1.6%	1.18	1.07	0.72
		2.8%	1.57	1.43	1.21
		4%	1.95	1.84	1.71
25	420	1.6%	0.78	0.66	0.57
		2.8%	1.18	1.07	0.96
		4%	1.64	1.52	1.69
30		1.6%	1.01	0.88	0.72
		2.8%	1.40	1.31	1.02
		4%	1.96	1.82	1.60
35		1.6%	1.28	1.14	0.98
		2.8%	1.77	1.65	1.45
		4%	2.28	2.17	1.69

Effect of reinforcement ratio on the reliability index

Tables (2) through (10) shows the reliability index at eccentricity/column thickness (e/t) = 0.05, 0.10 and 0.20 and different loading conditions for the studied columns. Also, some of these data plotted and represented in figures (1) through (6) which show the relation between the reliability index β and reinforcement steel ratio μ.

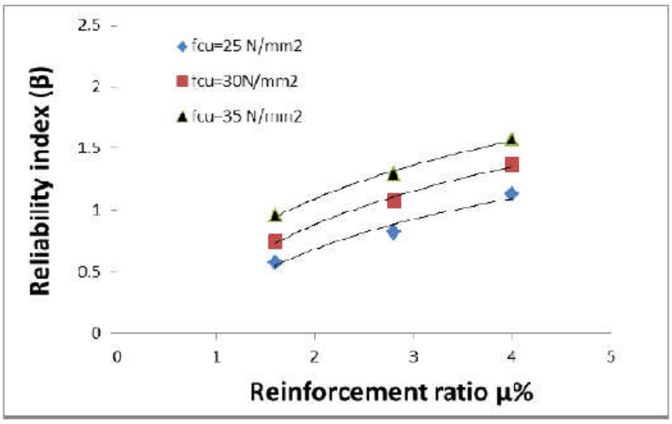

Figure 1. Relation between reliability index (β) and reinforcement ratio (μ%) for 500*500 mm^2 Concrete cross section, e/t = 0.05 , fy= 360 MPa. and Pult = 0.15 Pc

Table 4. Reliability index (β) for 500*500 mm R.C. cross section, P_{ult}= 0.25 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25	360	1.6%	0.81	0.64	0.43
		2.8%	1.20	1.03	0.82
		4%	1.85	1.44	1.12
30		1.6%	1.07	0.88	0.64
		2.8%	1.47	1.33	1.08
		4%	1.98	1.74	1.56
35		1.6%	1.37	1.16	0.88
		2.8%	1.85	1.65	1.37
		4%	2.34	2.13	1.90
25	420	1.6%	0.89	0.74	0.67
		2.8%	1.45	1.22	0.97
		4%	1.92	1.76	1.51
30		1.6%	1.18	0.98	0.76
		2.8%	1.69	1.53	1.30
		4%	2.34	2.09	1.99
35		1.6%	1.46	1.28	1.03
		2.8%	2.07	1.89	1.59
		4%	2.71	2.48	2.30

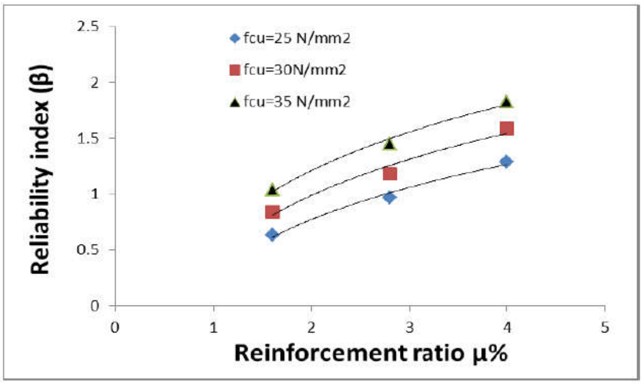

Figure 2. Relation between reliability index (β) and reinforcement ratio (μ%) for 500*500 mm^2 Concrete cross section, e/t = 0.05 , fy= 420 MPa. and Pult = 0.15 Pc

From the above results, it can be noticed that:

- Reliability index increased when the reinforcement ratio increased
- For the reinforcement yield stress Fy = 360 Mpa, increasing the reinforcement ratio from (1.6% to 2.8%) causes an increase in reliability index by range of (35% to 45%) in most cases of studied columns.
- For the reinforcement yield stress Fy = 360 Mpa, increasing the reinforcement ratio from (2.8% to 4%)

causes an increase in reliability index by range of (20% to 35%) in most cases of groups 1 and 3and range of (35% to 65%) in most cases of groups 2.

- For the reinforcement yield stress Fy = 420 Mpa, increasing the reinforcement ratio from (1.6% to 2.8%) causes an increase in reliability index by range of (34% to 55%) in most cases of studied columns.
- For the reinforcement yield stress Fy = 420 Mpa, increasing the reinforcement ratio from (2.8% to 4%) causes an increase in reliability index by range of (26% to 44%) in most cases of groups 1, (48% to 67%) in most cases of groups 2 and (26% to 37%) in most cases of groups 3.

Table 5. Reliability index (β) for 1000*500 mm R.C. cross section, P_{ult}= 0.15 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25		1.6%	2.37	2.26	2.25
		2.8%	3.00	2.70	2.52
		4%	3.57	3.46	3.28
30		1.6%	3.20	3.03	3.00
	360	2.8%	3.70	3.70	3.42
		4%	4.50	4.40	4.33
35		1.6%	4.07	3.92	3.08
		2.8%	5.00	4.50	4.43
		4%	5.44	5.38	5.24
25		1.6%	2.71	2.42	2.38
		2.8%	3.80	3.60	3.53
		4%	4.18	4.10	3.79
30		1.6%	3.50	3.25	3.01
	420	2.8%	4.40	4.00	4.00
		4%	5.15	4.98	4.65
35		1.6%	4.35	4.18	4.09
		2.8%	5.60	5.46	5.00
		4%	6.05	6.04	5.91

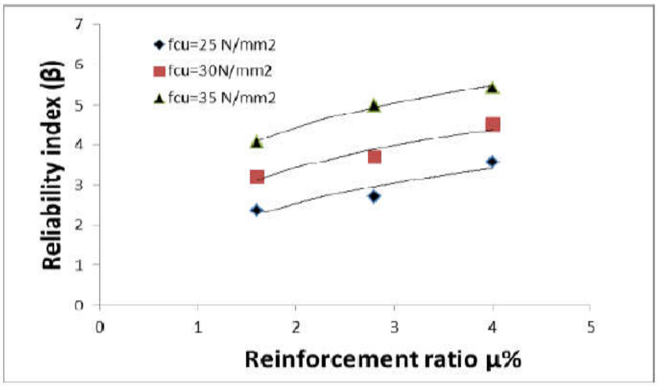

Figure 3. Relation between reliability index (β) and reinforcement ratio (µ%) for 500*1000 mm^2 Concrete cross section, e/t = 0.05 , fy= 360 MPa. and Pult = 0.15 Pc

Table 6. Reliability index (β) for 1000*500 mm R.C. cross section, P_{ult}= 0.20 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25		1.6%	2.78	2.61	2.54
		2.8%	3.50	3.50	3.30
		4%	4.55	4.54	4.39
30		1.6%	3.77	3.58	3.33
	360	2.8%	4.60	4.53	4.32
		4%	5.58	5.53	4.98
35		1.6%	4.88	4.70	4.18
		2.8%	6.00	6.00	6.15
		4%	6.92	6.69	6.32
25		1.6%	3.44	3.31	2.47
		2.8%	4.60	4.30	4.25
		4%	5.28	5.02	4.62
30		1.6%	4.00	3.80	3.35
	420	2.8%	5.50	5.00	4.90
		4%	6.41	6.24	5.62
35		1.6%	5.18	4.94	4.68
		2.8%	6.50	6.30	6.25
		4%	7.82	7.68	7.03

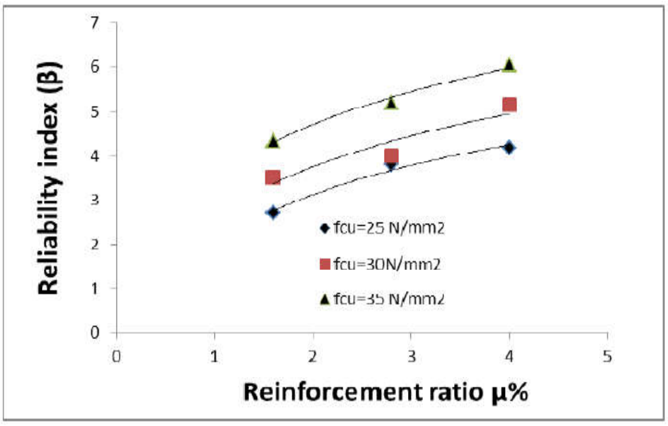

Figure 4. Relation between reliability index (β) and reinforcement ratio (µ%) for 500*1000 mm^2 Concrete cross section, e/t = 0.05 , fy= 420 MPa. and Pult = 0.15 Pc

Table 7. Reliability index (β) for 1000*500 mm R.C. cross section, P_{ult}= 0.25 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25		1.6%	2.98	2.76	2.59
		2.8%	4.80	3.86	3.64
		4%	5.34	5.23	4.87
30		1.6%	4.12	3.91	3.56
	360	2.8%	5.90	5.12	4.68
		4%	6.68	6.39	6.09
35		1.6%	5.41	5.17	4.58
		2.8%	7.00	6.31	6.28
		4%	8.13	7.93	7.12
25		1.6%	3.12	2.89	2.65
		2.8%	4.54	4.11	4.36
		4%	6.17	6.10	5.62
30		1.6%	4.33	4.07	3.55
	420	2.8%	5.67	5.24	5.12
		4%	7.60	7.48	6.95
35		1.6%	5.68	5.39	4.77
		2.8%	7.48	7.23	7.13
		4%	8.94	8.95	8.26

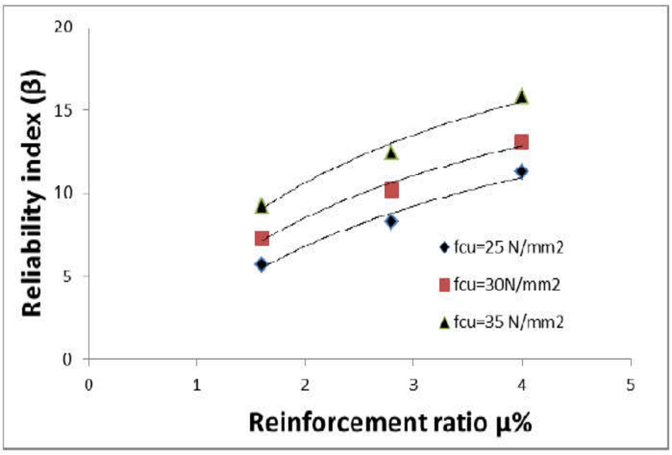

Figure 5. Relation between reliability index (β) and reinforcement ratio (µ%) for 500*1500 mm^2 Concrete cross section, e/t = 0.05 , fy= 360 MPa. and Pult = 0.15 Pc

Table 8. Reliability index (β) for 1500*500 mm R.C. cross section, P_{ult}= 0.15 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25	360	1.6%	5.70	5.57	5.36
		2.8%	8.28	8.11	8.59
30		1.6%	7.31	7.24	6.91
		2.8%	10.20	10.18	10.29
		4%	13.11	13.09	12.98
35		1.6%	9.24	9.13	8.54
		2.8%	12.50	12.24	11.23
		4%	15.85	15.35	13.96
25	420	1.6%	6.28	6.17	6.11
		2.8%	9.47	9.36	8.97
		4%	13.91	12.97	12.24
30		1.6%	8.07	7.84	7.50
		2.8%	11.48	11.38	10.64
		4%	15.53	15.45	15.14
35		1.6%	10.07	9.97	9.51
		2.8%	13.94	13.71	13.56
		4%	18.38	17.60	16.88

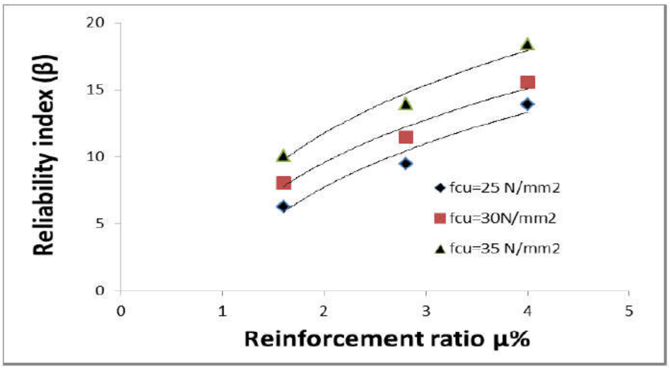

Figure 6. Relation between reliability index (β) and reinforcement ratio (μ%) for 500*1500 mm^2 Concrete cross section, e/t = 0.05 , fy= 420 MPa. and Pult = 0.15 Pc

Table 9. Reliability index (β) for 1500*500 mm R.C. cross section, P_{ult}= 0.20 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25	360	1.6%	7.10	7.07	6.44
		2.8%	10.49	10.46	9.66
		4%	13.99	13.81	12.75
30		1.6%	9.22	9.12	8.88
		2.8%	12.86	12.72	12.33
		4%	16.77	16.62	16.27
35		1.6%	11.74	11.61	11.52
		2.8%	15.86	15.67	14.70
		4%	19.60	19.06	17.66
25	420	1.6%	7.92	7.77	7.39
		2.8%	11.94	11.74	11.64
		4%	16.23	16.20	16.05
30		1.6%	10.11	10.00	9.59
		2.8%	14.69	14.49	13.33
		4%	19.36	19.38	17.84
35		1.6%	12.77	12.49	11.70
		2.8%	17.98	17.38	15.93
		4%	23.06	23.05	22.41

Effect of concrete column thickness on the reliability index

The effect of concrete column thickness on the reliability index was explained in tables (11) through (18). These tables show the reliability index at eccentricity/column thickness (e/t) = 0.05, 0.10 and 0.20, for a reinforcement ratios 1.6% , 2.80% and 4.0% at different loading conditions , different concrete compression strength and steel yield strength fy of 360 and 420 MPa.

Table 10. Reliability index (β) for 1500*500 mm R.C. cross section, P_{ult}= 0.25 Pc

fcu MPa	fy MPa	μ	β for e/t= 0.05	β for e/t= 0.10	β for e/t= 0.20
25	360	1.6%	8.43	8.26	8.06
		2.8%	12.19	12.14	11.71
		4%	16.30	16.10	15.08
30		1.6%	11.05	10.70	9.89
		2.8%	15.18	15.03	13.90
		4%	20.10	19.90	19.19
35		1.6%	13.77	13.55	12.87
		2.8%	18.33	18.16	17.57
		4%	23.39	22.97	21.20
25	420	1.6%	9.37	9.12	8.90
		2.8%	14.35	14.00	13.14
		4%	19.56	19.53	17.92
30		1.6%	11.98	11.75	11.58
		2.8%	17.30	17.36	17.08
		4%	22.80	22.38	22.20
35		1.6%	14.86	14.62	13.88
		2.8%	20.72	20.66	20.06
		4%	27.12	26.74	24.36

Table 11. Reliability index (β) for different concrete cross section, e/t=0.05, μ= 1.6%

fcu MPa	fy MPa	t mm	β for p=0.15 pc	β for p=0.20 pc	β for p=0.25 pc
25	360	500	0.57	0.70	0.81
		1000	2.47	3.11	3.66
		1500	5.70	7.10	8.43
30		500	0.74	0.93	1.07
		1000	3.20	4.00	4.76
		1500	7.31	9.22	11.05
35		500	0.95	1.18	1.37
		1000	4.07	5.03	6.03
		1500	9.24	11.74	13.77
25	420	500	0.63	0.78	0.89
		1000	2.71	3.44	4.04
		1500	6.28	7.92	9.37
30		500	0.84	1.01	1.18
		1000	3.50	4.48	5.15
		1500	8.07	10.11	11.98
35		500	1.04	1.28	1.46
		1000	4.36	5.55	6.48
		1500	10.07	12.77	14.86

Where β = reliability index, μ% = reinforcement steel ratio, e = eccentricity (M/P), t = column thickness

Table 12. Reliability index (β) for different concrete cross section, e/t=0.10, μ= 1.6%

fcu MPa	fy MPa	t mm	β for p=0.15 pc	β for p=0.20 pc	β for p=0.25 pc
25	360	500	0.52	0.63	0.64
		1000	2.42	2.99	3.54
		1500	5.57	7.07	8.26
30		500	0.70	0.85	0.88
		1000	3.14	3.91	4.59
		1500	7.24	9.12	10.70
35		500	0.88	1.07	1.16
		1000	3.92	4.98	5.76
		1500	9.13	11.61	13.55
25	420	500	0.64	0.66	0.74
		1000	2.60	3.31	3.91
		1500	6.17	7.77	9.12
30		500	0.77	0.88	0.98
		1000	3.49	4.29	5.04
		1500	7.84	10.00	11.75
35		500	1.01	1.14	1.28
		1000	4.15	5.39	6.31
		1500	9.97	12.49	14.62

Table 13. Reliability index (β) for different concrete cross section, e/t=0.20, μ= 1.6%

fcu MPa	fy MPa	t mm	B for p=0.15 pc	B for p=0.20 pc	B for p=0.25 pc
		500	0.11	0.31	0.43
25		1000	2.25	2.54	2.59
		1500	5.36	6.44	8.06
		500	.22	.41	.64
30	360	1000	3.00	3.33	3.56
		1500	6.91	8.88	9.89
		500	.35	.72	.88
35		1000	3.08	4.18	4.58
		1500	8.54	11.52	12.87
		500	.34	.57	.67
25		1000	2.38	2.47	2.65
		1500	6.11	7.39	8.90
		500	.47	.72	.76
30	420	1000	3.01	3.35	3.55
		1500	7.50	9.59	11.58
		500	.65	.98	1.03
35		1000	4.09	4.68	4.77
		1500	9.51	11.70	13.88

Table 14. Reliability index (β) for different concrete cross section, e/t=0.05, μ= 2.80%

fcu MPa	fy MPa	t mm	B for p=0.15 pc	B for p=0.20 pc	B for p=0.25 pc
		500	0.82	1.01	1.16
25		1000	3.00	4.55	4.80
		1500	8.28	10.49	12.19
		500	1.07	1.28	1.47
30	360	1000	4.60	5.58	5.90
		1500	10.20	12.86	15.18
		500	1.29	1.57	1.81
35		1000	5.44	6.92	8.13
		1500	12.50	15.86	18.33
		500	0.97	1.18	1.38
25		1000	4.18	5.28	6.17
		1500	9.47	11.94	14.35
		500	1.18	1.40	1.69
30	420	1000	5.00	6.41	7.60
		1500	11.48	14.69	17.30
		500	1.45	1.77	2.07
35		1000	5.60	7.82	8.94
		1500	13.94	17.98	20.72

Table 15. Reliability index (β) for different concrete cross section, e/t=0.10, μ= 2.80%

fcu MPa	fy MPa	t mm	B for p=0.15 pc	B for p=0.20 pc	B for p=0.25 pc
		500	0.74	0.91	1.03
25		1000	2.70	4.54	3.86
		1500	8.11	10.46	12.14
		500	0.94	1.16	1.33
30	360	1000	4.40	4.53	5.12
		1500	10.18	12.72	15.03
		500	1.19	1.43	1.65
35		1000	5.38	6.69	7.93
		1500	12.24	15.67	18.16
		500	0.87	1.07	1.22
25		1000	4.12	5.02	6.10
		1500	9.36	11.74	14.00
		500	1.10	1.31	1.53
30	420	1000	4.49	6.24	7.48
		1500	11.38	14.49	17.36
		500	1.36	1.65	1.89
35		1000	5.46	7.68	8.95
		1500	13.71	17.38	20.66

From these results it can be noticed that:

- Reliability index increased when concrete column thickness increased
- Increasing concrete column thickness from 500 to 1000 mm causes an increase in reliability index up to 400% to 450% for steel yield strength = 360 MPa and 430% to 500% for steel yield strength = 420 MPa.
- Increasing concrete column thickness from 1000 to 15000 mm causes an increase in reliability index up to 450%to 520% for steel yield strength = 360 MPa and 530% to 580% for steel yield strength = 420 MPa.

Table 16. Reliability index (β) for different concrete cross section, e/t=0.20, μ= 2.80%

fcu MPa	fy MPa	t mm	β for p=0.15 pc	β for p=0.20 pc	β for p=0.25 pc
		500	0.61	0.31	0.43
25		1000	2.52	3.30	3.64
		1500	8.59	6.44	8.06
		500	.78	.41	.64
30	360	1000	3.42	4.32	4.68
		1500	10.29	8.88	9.89
		500	1.16	.72	.88
35		1000	4.43	6.15	6.28
		1500	11.68	11.52	12.87
		500	.72	.57	.67
25		1000	3.53	4.25	4.36
		1500	8.97	7.39	8.90
		500	.99	.72	.76
30	420	1000	4.00	4.90	5.12
		1500	10.64	9.59	11.58
		500	1.18	.98	1.03
35		1000	5.00	6.25	7.13
		1500	13.56	11.70	13.88

Table 17. Reliability index (β) for different concrete cross section, e/t=0.05, μ= 4.0%

fcu MPa	fy MPa	t mm	β for p=0.15 pc	β for p=0.20 pc	β for p=0.25 pc
		500	1.13	1.36	1.62
25	360	1000	2.37	2.78	2.98
		1500	11.26	13.99	16.30
		500	1.57	1.95	2.34
35	360	1000	4.08	4.88	5.41
		1500	15.85	19.60	23.39
		500	1.29	1.95	1.92
25	420	1000	2.56	2.97	3.12
		1500	13.91	16.23	19.56
		500	1.83	1.95	2.71
35	420	1000	4.35	5.18	5.68
		1500	18.38	23.06	27.12

Table 18. Reliability index (β) for different concrete cross section, e/t=0.10, μ= 4.0%

fcu MPa	fy MPa	t mm	β for p=0.15 pc	β for p=0.20 pc	β for p=0.25 pc
25	360	500	1.01	1.27	1.44
		1000	2.26	2.61	2.76
		1500	10.92	13.81	16.10
35	360	500	1.51	1.84	2.13
		1000	3.92	4.70	5.17
		1500	15.35	19.06	22.97
25	420	500	1.25	1.84	1.76
		1000	2.42	2.77	2.89
		1500	12.97	16.20	19.53
35		500	1.79	1.84	2.48
	420	1000	4.18	4.94	5.39
		1500	17.60	23.05	26.74

Conclusion

The following conclusions could be obtained from the work done in this study:

- Increasing the column reinforcement ratio (μ) causes an increase in reliability index. This effect was significant in case of columns with small thickness, also in case of columns subjected to high eccentricity.
- Increasing the concrete column thickness (t) causes an increase in reliability index (β).
- Increasing the concrete compressive strength (fcu) causes an increase in reliability index (β). This effect was significant in case of columns with small reinforcement ratio.
- Increasing the yield steel strength (fy) causes an increase in reliability index (β). This effect was significant in case of columns with small reinforcement ratio.
- The good quality control has significant effects on decreasing the coefficient of variation for the concrete compressive strength, yield steel strength and the dimension of reinforced concrete sections which in turn improve the performance of slender reinforced columns through increasing the reliability index β.

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