Economical Study of Variables in RC-Structures and Accumulation of their Design

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Abstract - *Millions of reinforced concrete structures are being constructed every year throughout the world. Almost all the designers are not able toadopt economical aspects related to the design and results. Hence, in this economical investigation has been tried and studied of the important parameters in design of the RC members and structures. The study has gone through simply supported rectangular slabs (SSRS), T-Beam and RC portal frames. The research gap studied of relative moment capacities along the shorter and longer directions in RC-Slab, spacing of ribs in a low-cost manner in T-Beam and influence of span, spacing of frames and the relative moments of inertia of beam and column members on the lowest cost of unit area covered in this study. The above-mentioned study has been taken limit state method for design has been adopted. The recommendations of all the relevant Indian Standard Codes of Practice have been incorporated wherever necessary. All the conclusions that have been arrived at based on this study will be very useful to the designers of RC structures to accumulation economical designs.*

Key Words: M-25 to M-50 Grade of Concrete, Ultimate moment, Economical Design.

1. INTRODUCTION

Millions of concrete structures such as dwellings units, Multistoreyed buildings, bridges, industrial structures, commercial buildings and other structures have been constructed in the past, are being constructed at present and will be continued to be constructed in the future also. Research works pertaining to concrete technology, design of concrete elements and execution of concrete structures have been carried out for the past over one hundred and fifty years. Research workers in the past have concentrated on the properties such as strength and durability of concrete. Very little information is available on the economical design of reinforced cement concrete structural members and structures made of it. A small saving effected in the design of a RC structural member will result in the huge savingwhen numbers of such elements are adopted in the whole structure. Almost all of the structural concrete designers simply follow the codal provisions and do not explore the possibility of reducing the cost within the limitations of the codal provisions. Hence, at present, a huge amount of money is being wasted in the uneconomical design of RC elements and their structures. Considering all these factors, in this theoretical investigation, an attempt has been made to arrive at economical designs for the following RC structural components/ structures.

1.1 Aims of the Investigation

The aims of the investigation can be briefly stated as follows:

To find out the effect of the relative moment capacities about the x and y axes of simply supported RC slabs on the minimum cost of these slabs. To investigate the effect of grades of concrete and steel, spacing of T-Beams and span on the lowest cost per unit area covered by simply supported T-beam and slab structure and by continuous T-Beam and slab structure. In the case of slab supported by RC Portal frames, to find outthe effect of spacing of frames, span and the relative dimensions of beam and column members on the cost per unit area covered by the structure.

1.2 In the Case of Simply Supported Slabs

Grades of concrete: M 25, M 30, M 35, M 40, M 45 and M 50

Grades of steel : Fe 250, Fe 415, Fe 500 and Fe 550.
Live load : 2.5kN/m^2
μ : 0, 0.2, 0.4, 0.6, 0.8, and 1
L/b ratio : 1 to 2.2
Method of Design: Yield line theory for analysis and limit state method for Design

1.3 In the Case of Simply Supported T-Beams

Span of beams : 8, 12, 16, 20,22m
Grades of concrete : M 25, M 30, M 35, M 40, M 45 and M50
Grades of steel : Fe 250, Fe 415, Fe 500and Fe 550.
Spacing of T-Beams : 3, 4, 5,6m
Method of Design : Limit state Design

1.4 In the Case of Portal Frames

Spacing of frames : 3.5, 4.5, 5.5, 6 and 7 m
Span of frame : 8, 12, 16, 20 and 25m
Grades of concrete : M 25, M 30, M 35, M 40, M 45 and M50
Grades of steel : Fe 250, Fe 415, Fe 500and Fe 550.
Safe bearing capacity of soil : 200kN/m^2.
Method of Design :Elastic analysis and Limit state design

2. SIMPLY SUPPORTED RC RECTANGULAR SLABS

One hundred and forty-five simply supported RC slabs have been designed adopting M 25 grade concrete and Fe 500 grade steel and using yield line theory and Bacterial Foraging Optimization Technique. A live load of 2.5kN per square metre was considered. The ratio of Ultimate moment of resistance of slab with respect to x and y axis, μ, was varied from 0 to 1. The length of the slab was varied from 3m to 6m and L/b ratio from 1 to 2.0. The value of μ that results in the most economical solution has been found out.

2.1 Calculation of dead load moments

Assuming b/d =35 for simply supported two way slab as perIS456:2000, to satisfy stiffness criterion 4200/d=35
Therefore d=4200/35=120mm, Assuming 10mm diameter bars and clear cover of 20mm, Overall depth,
D = effective depth +clear cover + (□/2)=120+20 + (10/2) =145mm,
Dead Load of slab = 0.145*1*1*25 =3.625kN/m^2Live load =2.5kN/m^2,
Total load =6.125kN/m^2
Factored design load =1.5*6.125=9.187 kN/m^2.

2.1 Cost Estimation of cost of RC-Slab

Estimation of steel cost:

Volume of steel, V_S = $(284.37/10^6)*6*4.2$ + $(174/10^6)*4.2*6$ =0.01155m^3. Cost of steel = 0.01155*280614=Rs 3236.7.

Estimation of concrete cost:

Volume of concrete for the whole length of the slab = (L*b*D) - V_S=(6*4.2*0.145)-0.01155=3.64m^3.

Cost of concrete of slab =3.64*4015=Rs 14624.43

Estimation of formwork cost:

Perimeter area= 2(L+b)*D= 2(6+4.2)*0.145= 2.958m^2 Formwork area for bottom of slab = 6*4.2=25.2m^2 Total formwork area = 2.958+25.2=28.158m^2

Cost of formwork for slab = 28.452*350=Rs 9855.3

Total cost of Slab = Concrete cost +steel cost+ formwork cost

= 14624.43+3236.7+9855.3= Rs.27716.3

Table -1: Comparison of cost for a span 3m

S.no	Length of slab, m	a	μ	D in mm	Ast in shorter direction in mm^2/m	Ast in longer direction in mm^2/m	Cost in Rs
1	3	1	0	67.86	199.1817	51.42857	3266
2			0	67.86	152.2164	51.42857	3197
3			0	67.86	136.4324	53.25361	3205
4			1	67.86	125.5613	73.93517	3214.8
5			1	67.86	117.1574	92.42261	3224.9
6			1	67.86	110.2862	109.2057	3234.8
7	3	1	0	76.43	251.8841	61.71429	4181.2
8			0	76.43	182.409	61.71429	4065.9
9			0	76.43	160.0722	62.54785	4071.7
10			1	76.43	145.03	85.521	4081.3
11			1	76.43	133.6075	105.5673	4091.6
12			1	76.43	124.4093	123.3919	4102

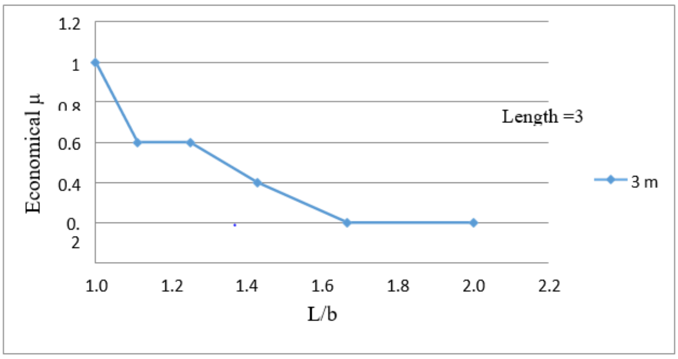

Chart -1: Variation of economical μ for various L/b ratios

The various values of μ that results in the least cost of simply supported slabs for different L/b ratios are graphically given in above Chart.

When the L/b ratio is 1 the economical value of μ is one. Nowwhen L/b ratio is 2, i.e., when the slab becomes one way slab the economical value of μ is not zero because a minimum reinforcement of 0.12% of bD is provided and this gives rise to certain value of moment of resistance.

3. SIMPLY SUPPORTED RC T-BEAMS

3.1 The Table below gives the results obtained by using BacterialForaging optimization technique.

Table -2: Comparison of Depth of the section

Span of Beam, m	Total Depth of the sectionas per BFO in mm
8	476.2
12	699.7
16	921.4
20	1143.1
22	1255.9

Table -3: Comparison of Area of tension steel in beam when Fe 250 gradesteel is adopted

Span of Beam,m	Total Depth of the sectionas per BFO in mm
8	2516.5
12	4506.298
16	7243.286
20	11376.47
22	13849.32

Table -4: Comparison of Area of tension steel in beam when Fe 415 gradesteel is adopted

Span of Beam, m	Total Depth of the section as per BFO in mm
8	1519.09
12	2681.197
16	4314.17
20	6773.052
22	8257.18

Table -5: Comparison of Area of tension steel in beam when Fe 500 gradesteel is adopted

Span of Beam, m	Total Depth of the section as per BFO in mm
8	1262.531
12	2223.558
16	3585.242
20	5629.142
22	6921.343

Table -6: Comparison of Area of tension steel in beam when Fe 550 gradesteel is adopted

Span of Beam, m	Total Depth of the section as per BFO in mm
8	1146.222
12	2023.085
16	3255.237
20	5110.575
22	6230.417

3. RC-PORTAL FRAMES

RC slab supported by RC Portal frames re-widely used in industries, community halls and shopping complexes. In this investigation the effects of span of the frames, spacing of the frames and relative dimensions ofbeam and column members to cover one square metre area of the building is studied and conclusions useful for the economical design of such structures will be useful for the future designers.

Totally ten frames were designed and the cost of each frames including that of foundation has been estimated. The effect of spacing of frames on the cost per unit area covered has been found out. Further, the effect of the ratio of the moment of inertia of beam with that of column on the cost has been found out and the most economical ratio has been identified.

Load on beam: As the spacing between the portal frame is 3.5m, the load transmitted by the slab on one metre length of the beam is calculated.

The portal frame is assumed to be fixed at the ends and is analyzed bymoment distribution method

Table -7: Calculation of Distribution Factors

Joint	Member	k	Sk	D.F
B	BA	$393.99*10^3$	$648.3*10^3$	0.78
	BC	$108.3*10^3$.		0.22
C	CB	$108.3*10^3$.	$648.3*10^3$	0.22
	CD	$393.99*10^3$		0.78

Table -8: Moment Distribution Method

Joint	A	B		C		D
Member	AB	BA	BC	CB	CD	DC
DF		0.78	0.22	0.22	0.78	
FEM			-129.69	129.69		
Balance		101.72	27.97	-27.97	-101.72	
CO	50.86		-13.98	13.97		-50.86
Balance		10.97	3.02	-3.02	-10.97	
CO	5.49		-1.51	1.51		-5.49
Balance		1.18	0.33	-0.33	1.18	
CO	0.59		-0.16	0.16		-0.59
Balance		0.13	0.035	-0.035	-0.13	
CO	0.06		-0.0175	0.0175		-0.06
Balance	57	114	-114	114	-114	-57

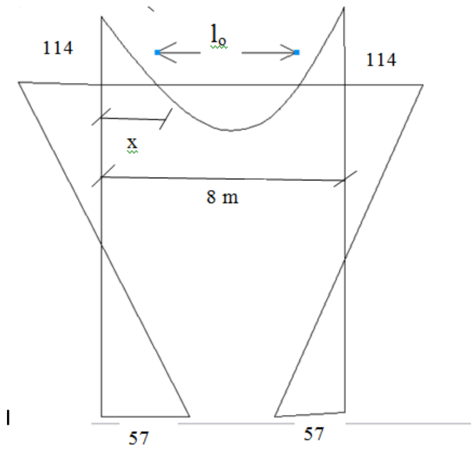

Fig -1: BMD drawn on tension side values in kNm

4. CONCULSION

4.1 Simply supported RC T- beams

The variation of cost with D/b_W ratio. It can be concluded that as D/$b_W$ratio increases the cost gets reduced and the variation is non- linear. The reduction in cost is due to increase in quantity ofsteel required because of increase in lever arm. Also it is clear that, as the grade of concrete increases the cost increases. The cost decreases with increase in grade of steel. Above Fe 415 grade, the variation is small. Here also it is clear that, as the gradeof concrete is increased, the total cost gets increased.

4.2 Simply Supported RCrectangular slabs

When the L/b ratio is 1, the economical value of μ is one. Now when L/bratio is 2, i.e., when the slab becomes one way slab, the economical value ofμ is not zero because a minimum reinforcement of 0.12% of bD is provided and this gives rise to certain value of moment of resistance. The variation of Cost with grade of steel is graphically shown for slabs having L=3m and L=6m respectively. From these figures itis clear that as the grade of steel is increased, the total cost of the slab gets reduced. The variations of cost with μ are shown. It is clear that,as the value of ratio, μ, increases the cost decreases for different grades of steel except for Fe 250.

4.3 RC-Portal Frames

The analysis and design of 113 RC Portal frames supporting RC slab, the following conclusions could be drawn. As the span of the frame increases, the cost per unit area covered in planalso increases. When the spacing between frames is 5m the cost per unit area covered isthe least for all spans of the frames. As the ratio of I_1/I_2 increases, the cost gets reduced as shown.

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