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Comparative Study on Analysis and Design of Flat Slabs with Conventional Slabs

B. P. R. V. S. Priyatham, Er. D. V. S. K. Chaitanya

Abstract— Flat Slabs are highly adaptable elements widely used in construction, providing minimum depth, fast construction. In flat slabs, the beams used in conventional slabs are no more and the slab is made to rest directly over the columns. A drop panel or a column head is provided in case of higher loads to reduce the load intensity. Flat slabs are particularly suitable for areas where, for acoustic or fire reasons, tops of partitions need to be sealed to the slab soffit. This study concerns mainly the comparison of conventional and flat slab with and without slab drops by comparing the quantity of steel and bending moment in slabs of various spans 20 x 20m, 40 x 40m, 60 x 60m. Each slab is sub divided into different panels of sizes 5x5m, 10x10m, 15x15m.

Index Terms— Flat slab, Interior Panel, Exterior Panel, Column strip, Middle strip, Slab drop.

I. Introduction

Flat slabs construction system is the one in which the beams used in the conventional construction methods are eliminated. The slab rests directly on the column and the slab load is transferred directly to the columns and then to the foundation. The thickness of the slab near the support with the column is increased in order to support heavy loads and these are called slab drops and generally supplied with enlarged heads called column heads or capitals. Absence of beam gives a plain ceiling, thus giving better architectural appearance than in usual cases where beams are used.

Flat slab construction can significantly decrease floor to floor height, particularly in the lack of a false ceiling, since flat slab construction acts as a limiting factor in the positioning of horizontal services and partitions [1]. This can prove gainful in case of lower building height, decreased cladding expense and pre-fabricated services.

In case the client plans changes in the interior and wants to use the accommodation to suit the need, flat slab construction is the perfect choice as it offers that flexibility to the owner.[6]

Types of Flat slabs:

- Typical Flat Slab
- Slab without drop and column with column head
- Slab with drop and column without column head
- Slab with drop and column with column head

Components of a Flat Slab

- Slab Drop
- Column Head
- Middle Strip
- Column Strip

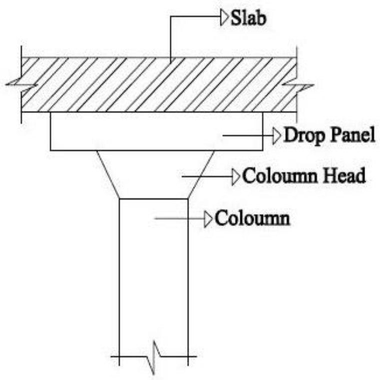

Fig.1 .Typical Components of a Flat Slab

Drop: The drops are nothing but the enlarged part below the slab at the intersection of column and slab. The main aim is to resist the punching shear which is predominant at the contact of slab and column Support. One of the most important criteria to be followed without fail is that the drop dimension should not be less than one -third of panel length in that direction.[2]

Column Head: Column Head is the bulged area over the column constructed to resist the slab load coming on to it. The column head is usually provided under the slab drop if necessary or as per the design requirement. Some amount of negative moment at the support is transferred from the slab to the column. The area at the support must be increased in order to resist this negative moment.

S.S.Patil, Rupali Sigi [7] said that in every code book it suggests any of the two methods as Direct Design Method and Equivalent Frame Method for gravity load analysis of flat slab. Design of Flat slab by Direct Design Method has some restrictions that (a) It should have minimum three spans in each directions. (b) It should not have staggered column orientation. Hence Equivalent Frame Method is adopted.

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B. P. R.V. S. Priyatham, *Department of Civil Engineering, GMR Institute of Technology, Rajam.*
Er. D. V. S. K. Chaitanya*, Department of Civil Engineering, ANU College of Engineering and Technology, Guntur.*

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II. DESIGN METHODS AND METHODOLOGY

The design of flat slab consists of two approximate methods namely Direct Design Method and Equivalent Frame Method.

- **Step1:** Finding the depth of slab.
- **Step2:** Finding the depth of slab drop.
- **Step3:** Finding the diameter of the column head.
- **Step4:** Finding the width of middle strip and column Strip.
- **Step5:** Consideration of the loads as per requirements.
(In the case of exterior panel calculation of the stiffness factor is compulsory)
- **Step6:** Calculation of the Factored Bending Moment.
- **Step7:** Calculation of negative and positive bending moments of column strip and middle strip.
- **Step 8:** calculation of shear stresses and check for the permissible shear.
- **Step 9:** calculation of reinforcements of all the column and middle strips.
- **Step 10**: check for the deflection.

III. DESIGN CALCULATIONS

In the present study we are comparing bending moments and area of steel for conventional slab, flat slab with drop and flat slab without drop having slab sizes of 20m*20m, 40*40m, 60m*60m each slab is further divided into panels of sizes 5m*5m, 10m*10m, 15m*15m with exterior and interior panels.

The following are the considerations made in this design.
Dead load = 25kN/m^3
Live load = 4.5kN/m^2
Floor finish = 1.5kN/m^2
Column dia in case of flat slab with drop = 400mm
Column size in case of flat slab without drop = 300mm*450mm
Diameter of primary reinforcing bar = 16mm, 10mm
Diameter of secondary reinforcing bar = 8mm

CASE I: DESIGN OF FLAT SLAB WITHOUT SLAB DROP OF SIZE 20 x 20m

Design of Interior Panel 5 x 5m

Column size = 300*400mm
Live Load = 4.5kN/m^2
Floor Finish = 1.5kN/m^2
Height of column is 4m above & below the slab. M_{20} & Fe_{415}

Depth of slab

L/d = 32 (Clause 31.2)
5000/32 = d
d = 156.25mm ~ 160
Provide Overall depth, D = 185mm

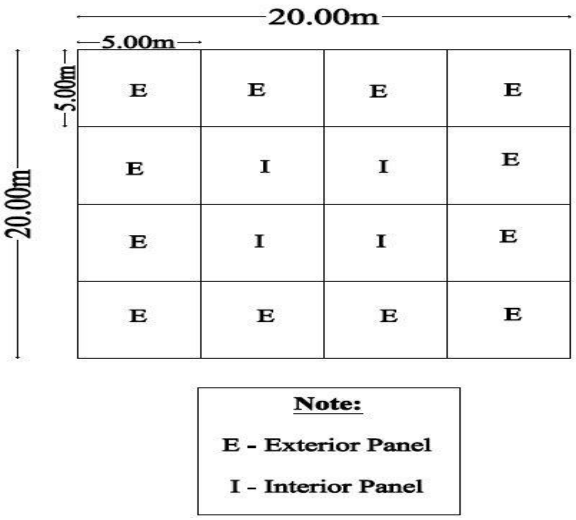

Fig.2 .Plan of Flat Slab without Slab Drop (20 x 20m)

Load Calculations

Self-weight of slab = 0.185*25 = 4.625kN/m^2
Floor Finish = 1.5kN/m^2
Live Load = 4.5kN/m^2
Total Factored Load = 15.93kN/m^2
Dead Load = 4.625 + 1.5 = 6.125kN/m^2
Live Load = 4.5kN/m^2

Along Longer direction

For Slab
$K_S = 4EI/l = 2.11*10^6E$
For Column
$K_C = 4EI/l = 1.6*10^6E$
$\alpha_c = \Sigma K_C/\Sigma K_S = 0.758$

Along Shorter direction

For Slab
$K_S = 4EI/l = 2.11*10^6E$
For Column
$K_C = 4EI/l = 0.9*10^6$
$\alpha_c = \Sigma K_C/\Sigma K_S = 0.426$

Check for correction due to pattern loading

(IS 456-2000, Clause 31.4.6) **[5]**
Ratio = Live Load/ Dead Load = 4.5/6.125 = 0.734 > 0.5
Check for pattern loading is required

Check along longer direction

$l_2/l_1 = 5000/5000 = 1.0$
Live Load / Dead Load = 0.734
$w_l/w_d = 0.5$; $\alpha_{cmin} = 0$
$w_l/w_d = 1.0$; $\alpha_{cmin} = 0.7$
$\alpha_{Calculated} > \alpha_{cmin}$ (0.9 > 0.7)
No correction is required.
Check for pattern loading is same along shorter span also

Total design moment

Along Longer direction

$M_u = Wl_n/8$
$W = wl_2l_n$
$l_n = 5 - 0.2 - 0.2 = 4.6m$

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$M_u = 15.9375*5*4.6^2/8$
M_u = 210.77 kNm
Along Shorter direction
$M_u = Wl_2l_n^2/8$ = 210.77 kNm
Column Strip and Middle Strip
Along Longer direction (page no:53, Clause 1.31.1.1)
2*0.25*5000 = 2500
2*0.25*5000 = 2500
Provide Smaller of two values.
Width of column strip = 2500mm
Width of middle Strip = 5000-1250-1250 = 2500mm
Along Shorter direction
Width of Column strip = 2500mm
Middle Strip = 2500mm
Reinforcement in both directions
Column Strip
M_u (-ve) = 0.65*0.75*210.77 = 102.75kNm
A_{st} (-ve) = 1983.6mm^2
M_u (+ve) = 0.5*0.6*210.77 = 44.26kNm
A_{st} (+ve) = 799.7mm^2
Middle Strip
M_u (-ve) = (0.65*210.77) – 102.75 = 34.25kNm
A_{st} (-ve) = 612.6mm^2
M_u (+ve) = (0.35*210.77) – 102.75 = 28.81kNm
A_{st} (+ve) = 512.9mm^2
Check for two-way shear
d/2 = 160/2 = 80mm
V_u = 394.332kN
b_u = 2(560+460) = 2040mm
$T_v = V_u/b_{u*}d$ = 1.208N/mm^2 IS 456:2000 (Clause 31.6.3.1)
$T_c^{'} = K_sT_c$, K_s= 0.5+300/400 = 1.25>1.0
$T_c = 0.25\sqrt{fck}$ =1.11
$T_c^{'}$ = 1.11N/mm^2, $T_v > T_c^{'}$
Hence Shear Reinforcement is Required.
Design of shear Reinforcement
Consider 8ϕ Stirrups, 8 legged Fe_{415}
$S_v = 0.87*415*A_{sv}*d/V_{us}$
A_{sv} =402m^2
$V_{us} = V_u - 0.5T_cb_odK_s = 213.830*10^3$N
$S_v = 108.93 \approx 110$mm

Table I BENDING MOMENT AND AREA OF STEEL FOR INTERIOR PANEL WITHOUT DROP

Panel Sizes (m)	Column Strip		Middle Strip	
	Bending Moment (kNm)	Area of Steel (mm^2)	Bending Moment (kNm)	Area of Steel (mm^2)
5*5	102.75(-ve)	1983.6	34.25(-ve)	612.65
	44.26(+ve)	799.2	28.81(+ve)	512.98
10*10	1242.15(-ve)	12927.8	414.18(-ve)	3771.07
	535.48(+ve)	4953.23	356.6(+ve)	3319.53
15*15	5406.85(-ve)	42521.87	1802.28(-ve)	11389.79
	2329.10(+ve)	15068.89	1489.74(+ve)	9291.62

Design of Exterior Panel 5 x 5m

In the design of exterior panel preliminary data is same as of interior panel design and so the total design moments along the longer and shorter directions are considered from that and the moment distribution should be done. Also the width of column and middle strips is also same.
Total design moment M_u = 210.77kNm
Moment Distribution
Interior negative design moment = 0.75 - $0.10/(1+\frac{1}{\alpha c})$ = 0.702
Positive design moment = 0.63 - $0.28/(1+\frac{1}{\alpha c})$ = 0.497
Exterior negative design moment = $0.65/(1+\frac{1}{\alpha c})$ = 0.31
Based on the moment distribution the area of steel can be calculated in both the directions and the check for two way shear is same as for interior panel.
Reinforcement in both directions
Column Strip
M_u (-ve) = 0.31*210.77 = 65.33kNm
A_{st} (-ve) = 1207mm^2
M_u (+ve) = 0.6*0.497*210.77 = 62.85kNm
A_{st} (+ve) = 1158.08mm^2
Middle Strip
M_u (+ve) = (0.497*210.77) – 61.37 = 41.92kNm
A_{st} (+ve) = 755.6mm^2

TABLE II BENDING MOMENT AND AREA OF STEEL FOR EXTERIOR PANEL WITHOUT DROP

Panel Sizes (m)	Column Strip		Middle Strip	
	Bending Moment (kNm)	Area of Steel (mm^2)	Bending Moment (kNm)	Area of Steel (mm^2)
5*5	65.33(-ve)	1207	-	-
	62.85(+ve)	1158.08	41.92(+ve)	755.6
10*10	163.12(-ve)	1446.6	-	-
	884.8(+ve)	8583.4	618.7(+ve)	5792.93
15*15	262.85(-ve)	1564.18	-	-
	3501.3(+ve)	24047.02	2859.41(+ve)	18917.2

CASE II: DESIGN OF FLAT SLAB WITH SLAB DROP OF SIZE 20 x 20m

Design of Interior Panel 5 x 5m

Materials: M20 Grade and Fe415
Design of Interior panel dimension 5m*5m
(l/d) = 32
Two-way Continuous Slab as per IS 456: 2000
Thickness of slab at mid span (5000/32) = 156.25 ≈ 160mm
Adopt Effective Depth, d = 160mm
Overall Depth, D = 185mm

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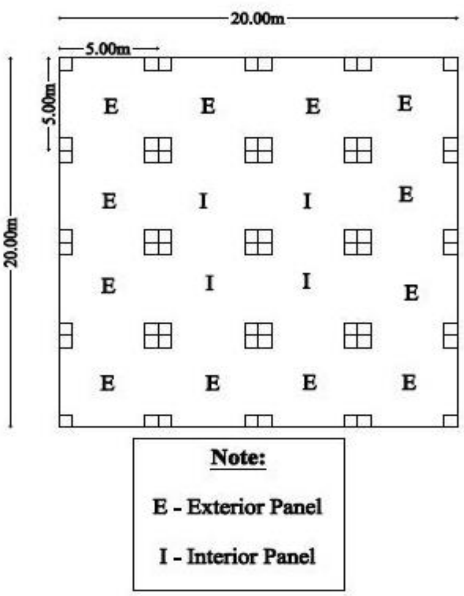

Fig.3 .Plan of Flat Slab with Slab Drop (20 x 20m)

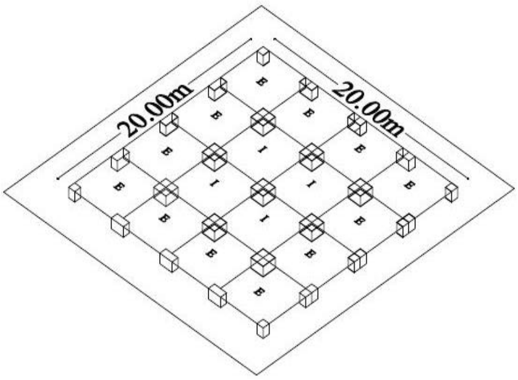

Fig.4 .Isometric View of Flat Slab with Slab Drop (20 x 20m)

According to Code ACI 318 the projection below slab drop should not be less than 1/4(Slab Thickness) and also should be less than or not equal to 100mm.

Hence thickness of slabs at drops (185+100) = 285mm

Column Head Diameter not greater than 0.25L = 0.25*5000 = 1250mm

Length of Drop should not less than (L/3) = 5000/3 = 1666.6mm

Adopt Drop Width = 2500mm

Column Strip = Drop width = 2500mm

Width of middle Strip = 2500mm

Loading Specifications

Live Load of slab = 4.5kN/m^2

Dead Load of slab = 5.5625kN/m^2

Floor Finishers = 1.5kN/m^2

Total Service Load = 11.5625kN/m^2

Factored Load = 17.34kN/m^2

Factored Bending Moment

As per the IS 456-2000 Clause 31.4.2.2 the total moment is calculated as follows

$M_o = Wl_n/8$

$L_n = 5 - 1.25 = 3.75$m

$L_1 = L_2 = 5$m

$W = w_u L_2 l_n = 325.125$kN

$M_o = 152.40$kNm

Reinforcement

Column Strip

M_u (-ve) =49% M_o = 0.49*152.40 = 74.67kNm

$M_u = 0.89*415*A_{st}*d*(1-A_{st}f_y/b*d*f_{ck})$

$74.67*10^6 = 0.89*415*A_{st}*260*(1-415A_{st}/2.5*10^3*260*20)$

A_{st} (-ve) = 817.15mm^2

M_u (+ve) = 21% M_o = 0.21*152.40 = 32kNm

A_{st} (+ve) = 344.89mm^2

Middle Strip

M_u (-ve) = 15% M_o = 0.15*152.40 = 22.86kNm

A_{st} (-ve) = 406mm^2

M_u (+ve) = 15% M_o = 0.15*152.40 = 22.86kNm

A_{st} (+ve) = 406mm^2

Check For thickness of slab

For balanced section $M_u = 0.138f_{ck}bd^2$

Thickness of slab near drops (Column strip)

$d = \sqrt{\frac{74.6*10^6}{0.138*20*2.5*10^3}} = 104.02$mm

Thickness of slab in middle strips

$d = \sqrt{\frac{22.86*10^6}{0.138*20*2.5*10^3}} = 52.54$mm

Overall depth near drops = 285mm

Effective depth near drop = 250mm

Overall depth (Middle Strip's) = 185mm

Effective depth (Middle Strip) = 160mm

Check for Shear Stress

Shear Stress is checked near the column head at section (D + d) near column head.

$W_1 = \Pi/4(D+d)^2 Wu = 30.626$kN

Shear Force = (total load) – (Load on circular Area)

= (17.34*5*5) - 30.62 = 402.88kN

Shear force per meter of perimeter = $[Shearforce/\pi(D+d)]$ = 85.537kN

Shear Stress = $85.537*10^3/(1000*250) = 0.34$N/mm^2

As per IS 456:2000 Clause 31.6.3.1

Permissible shear stress = K_sT_c

$K_s = (0.5+ \boldsymbol{\beta}_c)$, $\boldsymbol{\beta}_c = L/L_2 = 1$

K_s = (0.5+1) = 1.5 But should not be greater than 1.0

$T_c = 0.25\sqrt{fck} = 0.25\sqrt{20} = 1.118$N/mm^2

K_sT_c = 1.118N/mm^2 = 0.342<1.118N/mm^2

Check for Deflection Control

According to the IS 456:2000, Clause 23.2.1

$P_t = 100A_{st}/bd$

= (100*406/1000*160) = 0.254

Figure:4 of IS 456:2000 modification factor for tension reinforcement

$K_t = 1.8$

$(L/d)_{max}$ = (1.8*32) = 57.6//1.1*32 = 35.2

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$(L/d)_{provided}$ = 5000/160 = 31.25
31.25<57.6
The designed Slab satisfies deflection limit.

Table III BENDING MOMENT AND AREA OF STEEL FOR INTERIOR PANEL WITH SLAB DROP

Panel Sizes (m)	Column Strip		Middle Strip	
	Bending Moment (kNm)	Area of Steel (mm^2)	Bending Moment (kNm)	Area of Steel (mm^2)
5*5	74.67(-ve)	817.15	22.86(-ve)	406
	32(+ve)	344.89	22.86(+ve)	406
10*10	826.87(-ve)	5786.4	253.12(-ve)	2258.09
	354.37(+ve)	2394.76	253.12(+ve)	2258.09
15*15	5703.49(-ve)	33020	1745.96(-ve)	8869.95
	2444.35(+ve)	12661.14	1745.96(+ve)	8869.95

Design of Exterior Panel 5 x 5m

Loading class = 4.5kN/m^2, M20, Fe415
Height of Story = 3m
Thickness of slab in column strip = 285m
Thickness of slab in middle strip = 185mm
Dimensions of Flat slab
Width of middle strip = Width of column =
Drop width = 2.5m

Stiffness Computation

$K_c = 4E_cI_c/l = 1.67*10^6E_c$
Assuming columns both at top and bottom
$K_c = 2(1.67*10^6)E_c$

Stiffness of slab

$K_s = 4*5000*300^3/12*5000 = 21.33*10^6E_c$
$\boldsymbol{\alpha}_c = \boldsymbol{\Sigma}K_c/\boldsymbol{\Sigma}K_s = 0.156$
$\boldsymbol{\alpha}_c(\min) = 0.7$ for $(L_2/L_1) = 1.0$
$(1+1/\boldsymbol{\alpha}_c) = 7.41$
$L_n = 5 - 1.25 = 3.75$m

Bending Moment

Total Load = W = $w_ul_2L_n$ = 325.125kN
Bending Moment M_o = (325.125*3.75)/8 = 152.40kNm

Interior Negative design moment

$\left(0.75 - \frac{0.10}{1+1/\alpha c}\right)M_o = 112.24$kNm

Positive design moment

$\left(0.63 - \frac{0.28}{1+1/\alpha c}\right)M_o = 78.45$kNm

Exterior Negative design moment

$\left(\frac{0.65}{1+1/\alpha c}\right)M_o = 13.36$kNm

Interior Negative design moment

Column strip = 0.75*112.24 = 84.18kNm
Middle strip = 0.25*112.24 = 28.06kNm

Exterior Negative design moment

Column strip = 13.36kNm
Middle Strip = 0

Positive moment in column strip

0.60*84.18 = 50.508kNm

Positive moment in Middle strip

0.40*84.18= 33.672kNm

Thickness of Slab near Drops

d= $\sqrt{Mu/0.138fckb}$ = 110.45mm

Thickness of Slab in middle Strip

d = $\sqrt{Mu/0.138fckb}$ = 69.85mm

Reinforcement

Column Strip Interior Negative Bending moment

$= 0.87f_yA_{st}d\left(1 - \frac{Astfy}{bdfck}\right)$

$84.18*10^6 = 0.87*415*A_{st}*260*\left(1 - \frac{415Ast}{2.5*10^3*260*20}\right)$

$A_{st} = 924.47mm^2$

A_{st} for positive Bending Moment

$50.508*10^6 = 0.87*415*A_{st}*160*\left(1 - \frac{415Ast}{2500*160*20}\right)$

$A_{st} = 918.52mm^2$

Middle Strip

$33.672*10^6 = 0.87*415*A_{st}*160*\left(1 - \frac{415Ast}{2500*160*20}\right)$

$A_{st} = 601.97mm^2$

Column Strip

$13.36*10^6 = 0.87*415*A_{st}*260*\left(1 - \frac{415Ast}{2500*260*20}\right)$

$A_{st} = 143.04mm^2$

TABLE IV BENDING MOMENT AND AREA OF STEEL FOR EXTERIOR PANEL WITH SLAB DROP

Panel Sizes (m)	Column Strip		Middle Strip	
	Bending Moment (kNm)	Area of Steel (mm^2)	Bending Moment (kNm)	Area of Steel (mm^2)
5*5	84.18(-ve)	924.47	-	-
	50.5(+ve)	918.52	33.67(+ve)	601.97
10*10	932.13(-ve)	6577	-	-
	559.28(+ve)	5192	372.85(+ve)	3376.65
15*15	6429.5(-ve)	6577	-	-
	3857.7(+ve)	5192	2571.82(+ve)	3376.65

CASE III: DESIGN OF CONVENTIONAL TWO WAY SLAB OF SIZE 20 x 20m

Materials: Adopt M20&Fe415.
L_x = 5m
L_y = 5m $(L_y/L_x=1)$
$F_{ck} = 20N/mm^2$
$F_y = 415N/mm^2$

Depth of slab

As the span more than 3.5m adopt a span/depth ratio of 25
Depth = Span/25 = 5000/25 = 200mm
Adopt effective depth, d = 175mm

Effective Span

Effective span = Clear span + Effective depth = 4.87m

Loads

Self-weight of slab = (0.2*2.5) = 5kN/m^2
Live load on slab = 4kN/m^2
Floor finish = 1.5kN/m^2

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Total working load = $10.5kN/m^2$
Design ultimate load = $15.75kN/m^2$

i) Interior Panel

Ultimate Design moments & Shear forces

For, $(L_y/L_x=1)$ $\alpha_x = 0.032$, $\alpha_y = 0.024$
$M_{ux} = \alpha_x w_u L_x^2 = 11.95kNm$
$M_{uy} = \alpha_y w_u L_y^2 = 8.96kNm$
$V_{ux} = 0.5 w_u L_x = 32.60kNm$

Area of reinforcement

$$A_{st} = 0.5f_{ck}/f_y\left[1 - \sqrt{1 - \frac{4.6Mu}{fckbd\string^2}}\right]bd = 193.67mm^2$$

$A_{st}min = 0.0012*175*1000 = 210mm^2$
$A_{st} < A_{st}min$
Hence provide minimum reinforcement

Reinforcements Along Short span

$$A_{st} = 0.5f_{ck}/f_y\left[1 - \sqrt{1 - \frac{4.6Mu}{fckbd\string^2}}\right]bd = 145mm^2$$

A_{st} min = $210mm^2$
Hence provide minimum reinforcement

ii) Two Adjacent Edges Discontinuous

Ultimate Design moments & Shear forces

As per the codebook the ratio $(L_y/L_x=1)$
$M_{ux\,(-ve)} = (\alpha_x w_u L_x^2) = 0.047*15.75*4.87^2 = 17.55kNm$
$M_{ux(+ve)} = (\alpha_x w_u L_y^2) = 0.035*15.75*4.87^2 = 13.07kNm$
$M_{uy(-ve)} = (\alpha_x w_u L_y^2) = 0.042*15.75*4.87^2 = 15.668kNm$
$M_{uy(+ve)} = (\alpha_x w_u L_y^2) = 0.035*15.75*4.87^2 = 13.07kNm$

Area of reinforcement

$$A_{st}(-ve) = 0.5f_{ck}/f_y\left[1 - \sqrt{1 - \frac{4.6Mu}{fckbd\string^2}}\right]bd = 287.7mm^2$$

Reinforcement along Short span

$A_{st}(-ve) = 255.668mm^2$
$A_{st}(+ve) = 212mm^2$

iii) One Edge Discontinuous

Ultimate Design moments & Shear forces

For, $(L_y/L_x=1)$ $\alpha_x = 0.047$, $\alpha_y = 0.035$
$M_{ux\,(-ve\,)} = \alpha_x w_u L_x^2 = 0.037*15.75*4.87^2 = 13.82kNm$
$M_{ux(+ve)} = \alpha_x w_u L_y^2 = 0.028*15.75*4.87^2 = 13.07kNm$
$M_{uy(-ve)} = \alpha_x w_u L_y^2 = 0.037*15.75*4.87^2 = 15.668kNm$
$M_{uy(+ve)} = \alpha_x w_u L_y^2 = 0.028*15.75*4.87^2 = 13.07kNm$
$V_{ux} = 0.5 w_u L_x = 0.5*15.75*4.87 = 38.35kNm$

Area of reinforcement

$$A_{st}(-ve) = 0.5f_{ck}/f_y\left[1 - \sqrt{1 - \frac{4.6Mu}{fckbd\string^2}}\right]bd = 224.8mm^2$$

$A_{st}(+ve) = 212mm^2$

Reinforcement Along Short span

$A_{st}(-ve) = 224.8mm^2$
$A_{st}(+ve) = 212mm^2$

Check for shear stresses

Tv = Vu/bd = $0.186N/mm^2$
$P_t = 100A_{st}/bd = 0.135N/mm^2$
From IS 456 Table 19, Tc = $0.28N/mm^2$
Tv < Tc
Hence no shear reinforcement is required.

Check for deflection

As per IS 456:2000 the ratio of $(L/d)_{basic} = 20$
$P_{t\,=}\,0.135$
$K_{t\,=}\,1.8$
$(L/d)_{max\,=}\,20*1.8$
$(L/d)_{provided} = 5000/170 = 28.5 < 36$
Hence deflection control is satisfied

Check for cracking

Steel provided is more than the minimum % of reinforcement
Spacing of main steel < 3d = 3*175 = 525mm
Diameter of reinforcement < D/8 = 200/8 = 25mm
Hence cracks are within permissible limits.

Torsion reinforcement at corners

Area of reinforcement in each 4 layers = (0.25*210) = $157.5mm^2$
Distance over which torsion reinforcement is provided = 1/5(short span) = 1/5(50000) = 1000mm
Provide 6mm diameter at 1000mm centers for a length of 1000mm@all 4 layers in 4 corners.

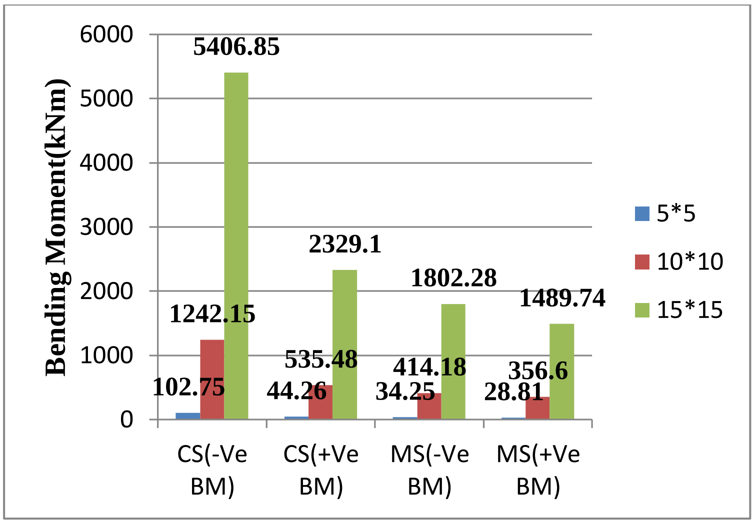

Fig.5 .Variation of Interior Panel Bending Moments for different panel sizes for flat slab without drop

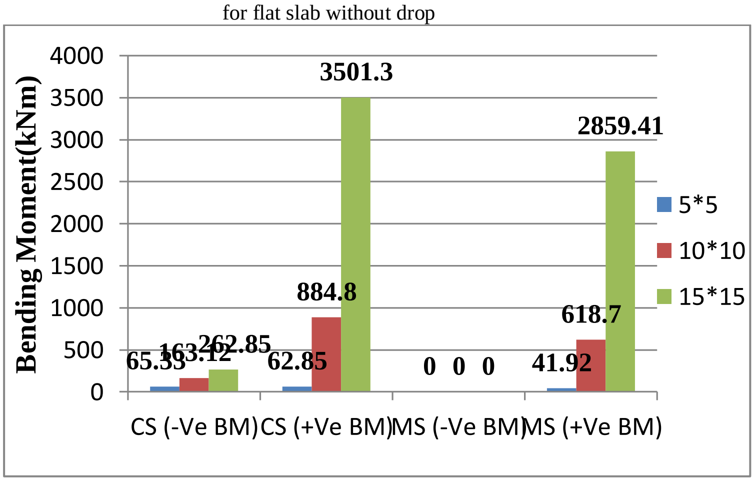

Fig.6 .Variation of Exterior Panel Bending Moments for different panel sizes for flat slab without drop

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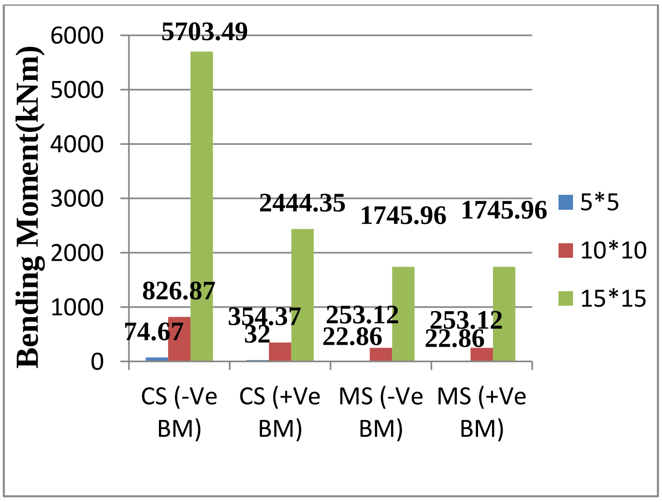

Fig.7 .Variation of Interior Panel Bending Moments for different panel sizes for flat slab with Slab Drop

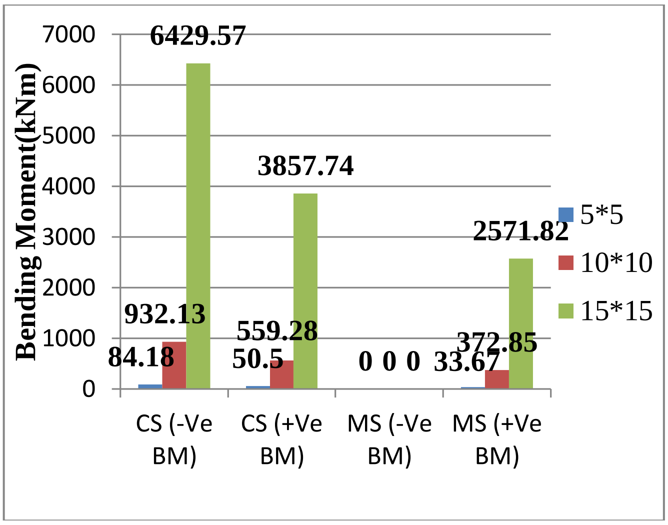

Fig.8 .Variation of Exterior Panel Bending Moments for different panel sizes for flat slab with Slab Drop

IV. CONCLUSION

1. It was observed that the value of the bending moment of flat slab without drop increases when compared to flat slab with drop of equal dimensions.
2. It was observed that the value of the bending moment of flat slab is higher when compared to conventional slab of equal dimensions.
3. When a flat Slab with drop is considered it was observed that there is an increase in the percentage of bending moment of 44.65, 54.42 for panel dimensions of 5*5m, 10*10m respectively when compared with flat slab without drop and there is a decrease in the percentage of bending moment of 3.90 for panel dimensions 15*15m.
4. When a flat Slab with drop is considered it was observed that there is an increase in the percentage of bending moment of 56.45, 67.06 for panel dimensions of 5*5m, 10*10m respectively when compared with flat slab without drop and there is a decrease in the percentage of bending moment of 4.70 for panel dimensions 15*15m.
5. When a flat Slab with drop is considered it was observed that there is a decrease in the percentage of bending moment of 18.97, 82.50, and 95.91 for panel dimensions of 5*5m, 10*10m, and 15m*15m respectively.

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AUTHORS PROFILE

B. P. R. V. S. Priyatham is an Assistant Professor at GMR Institute of Technology, Rajam. He has graduated in Masters of Engineering from Andhra University and his research area is Coldformed Steel Structures.

Er D. V. S. K. Chaitanya is an Assistant Professor at ANU College of Engineering and Technology, Acharya Nagarjuna University, Guntur. He has graduated in Masters of Engineering from Andhra University and is currently pursuing his PhD in Civil Engineering. He is a member of professional bodies like ICI and IIID.

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