Minimum Cost Design of Reinforced Concrete Flat Slab

Kiran S. Patil, N. G. Gore, P. J. Salunke

***Abstract:** Sequential unconstrained minimization technique (SUMT) is used for the solution of a comprehensive minimum cost design problem formulation. The formulation, based on Indian codes of practice (IS 456-2000), Solutions to the nonlinear programming problem are obtained with an appropriate computer program, This is used for solving a wide range of typical flat slab designs with varying span-to-depth ratios, live and dead loads, different grades of concrete and steel. A related sensitivity study enables the comparison of optimal and standard solutions. The different conditions of flat slabs are analyzed and design by using MATLAB software.*

***Keywords:** Flat slab, Reinforced concrete, Punching shear stress, slab size, drop panel size.*

I. INTRODUCTION

The slabs which are directly supported by columns are called flat slab. In ware houses, offices and public halls sometimes beams are avoided and slabs are directly supported by columns.

Flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared column heads. A flat slab may be solid slab or may have recesses formed on the soffit so that the soffit comprises a series of ribs in two directions. The recesses may be formed by removable or permanent filler blocks.

II. LITERATURE REVIEW

Ronaldo et al. (1999) proposed a theoretical model for analyzing the punching resistance of reinforced flat slabs with shear reinforcement for concentric loading. M.G. Sahab et al. (2005) had presented Cost optimization of reinforced concrete flat slab buildings according to the British Code of Practice (BS8110). Vikunj et al. (2011) presented cost comparison between flat slabs with drop and without drop in four storey lateral load resisting building. Gupta et al. (1993) described computer aided design of flat slab-column-footing structure. Galebet al. (2011) presented optimum design of reinforced concrete waffle slabs. Adedeji (2011) had presented application: simplifying design of RC flat slab using taboo search. Hadi et al. (2012) proposed a new formulation for the geometric layout optimization of flat slab floor systems in an optimization procedure.

Revised Manuscript Received on 30 January 2014.
* Correspondence Author
Mr.Kiran S. Patil*, (M.E. student) Civil Engg. Dept., M.G.M. College of Engineering & Tech., Kamothe, Navi Mumbai, India.
Prof. N. G. Gore, (Guide) Civil Engg. Dept., M.G.M. College of Engineering & Tech., Kamothe, Navi Mumbai, India.
Prof. P. J. Salunke, (Guide) Civil Engg. Dept., M.G.M. College of Engineering & Tech., Kamothe, Navi Mumbai, India.

III. METHOD FOR DESIGN

The structural analysis of flat slab systems can be carried out using the direct design method and adopted by Indian code (IS 456-2000).

In direct design method, a flat slab building having a rectangular column layout is divided into a series of longitudinal and transverse plane. Each frame consists of a row of equivalent columns and beams representing columns and strips of slabs bounded laterally by centre lines of panels adjacent to columns. In each direction, edge and middle equivalent frames are structurally analyzed to obtain the total bending moments and shear forces at different sections of slabs. These slab panels are loaded with the full uniform gravity dead and imposed loads over the width of panels. It is assumed that the width of beams is divided into two strips, namely column and middle strips. The average bending moment over each strip is obtained as a percentage of the total bending moment at each section. The required reinforcement in each slab section is calculated according to the design bending moment obtained in each section of column and middle strips.

IV. DESIGN VARIABLES AND CONSTRAINTS

A. Design variables

A design alternative option, which defines a complete design of a flat slab with drop panel, includes the following decision variables:

- Effective depth of slab.
- Overall depth of drop from top of slab=Dd.
- No. of span required in longer direction.
- No. of span required in shorter direction.

B. Constraint equations

The restrictions that must be satisfied to produce an acceptable design are called design constraints.

- No of span constraint in x direction
- No of span constraint in y direction
- Length constraint
- Minimum depth constraint
- Depth constraint
- Load constraint
- Stiffness check in y direction
- Stiffness check in x direction
- Moment constraint in slab
- Moment constraint in drop

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

- Constraint of shear check in slab
- Constraint of shear check in drop
- Constraint of check of punching

V. MINIMUM COST DESIGN PROCEDURE

The minimum cost design of Flat slab with drop panel formulated in is nonlinear programming problem (NLPP) in which the objective function as well as constraint equation is nonlinear function of design variables. In SUMT the constraint minimization problem is converted into unconstraint one by introducing penalty function. In the present work is of the form.

The optimization problem is solved by the interior and exterior penalty function method. The method is used for solving successive unconstrained minimization problems coupled with cubic interpolation methods of on dimensional search. The program developed S. S. RAO for SUMT is used for the solution of the problem. The program is written in MATLAB language.

VI. DIFFERENT CONDITIONS AND PARAMETERS FOR ANALYSIS AND DESIGN

For comparative study consideration following parameter are consider for different results.

- Fck =Characteristic strength of concrete

= M20, M25, M30.

- Fy=Characteristic strength of steel

= Fy415, Fy500.

Ccost=Cost of concrete. (Including formwork and labour charges)

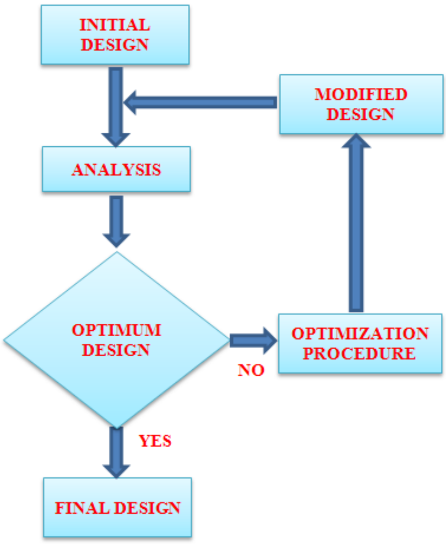

Fig.1 General Procedure of optimization

M20=7302 Rs. /m^3
M25=8580 Rs. /m^3
M30=8647 Rs. /m^3

- Scost=Cost of steel (Including labour charges) (As per District Schedule Rate)

Fy415=64 Rs. /Kg
Fy500=65.8 Rs. /Kg

- Total span= 20m X 20m, 25m X 25m, 30m X 30m, 35m X 35m, 40m X 40m.

VII. COMPARATIVE RESULTS

Comparative results for different grade of steel and concrete and different length of span are shown in tables given below. In present study results are tabulated and shown, in this results the analysis is start with some starting points (S.P.) and after analysis come towards end point which we called it as optimize point (O.P.), which gives lowest value i.e. minimum cost of structure. Formulations are done by following I.S. code 456-2000 and Results of flat slab for different grade and span are calculated by using MATLAB software.

CASE I: M20 Fy415
Grade of Concrete =20 N/mm2
Grade of Steel =415 N/mm2
Cost of Concrete =7302 Rs. /m^3
Cost of Steel =64 Rs. /Kg

Table I. Cost of Flat Slab Per m^2 For M20 Fy415

		Cost of Flat Slab Per m^2					
Span	S.P.-no. span		3X3		4X4		5X5
20x20	O.P.-no. span	4x4	2842	5x5	2249	5x5	1945
25x25		5x5	3276	6x5	2604	6x6	2207
30x30		5x6	3792	7x4	3011	7x6	2458
35x35		5x7	4339	7x6	3331	8x6	2773
40x40		5x9	4890	7x8	3702	9x6	3052

CASE II: M20 fy500
Grade of Concrete =20
Grade of Steel =500
Cost of Concrete =7302 Rs. /m^3
Cost of Steel =65.8 Rs. /Kg

Table II. Cost of Flat Slab Per m^2 For M20 Fy500

		Cost of Flat Slab Per m^2					
Span	S.P.-no. span		3X3		4X4		5X5
20x20	O.P.-no. span	4x4	2842	5x5	2250	5x5	1945
25x25		5x5	3276	6x5	2605	6x6	2209
30x30		5x6	4248	7x4	3006	7x6	2458
35x35		5x7	4339	7x6	3332	8x6	2775
40x40		5x9	4890	7x8	3707	9x6	3053

CASE III: M25 fy415
Grade of Concrete =25
Grade of Steel =415
Cost of Concrete =8580 Rs. /m^3
Cost of Steel =64 Rs. /Kg

Table III. Cost of Flat Slab Per m^2 For M25 Fy415

		Cost of Flat Slab Per m^2					
Span	S.P.-no. span		3x3		4x4		5x5
20x20	O.P.-no. span	4x4	3170	5x5	2504	5x5	2160
25x25		5x5	3680	6x5	2923	6x6	2463
30x30		5x6	4275	7x4	3376	7x6	2763
35x35		5x7	4896	7x6	3755	8x6	3118
40x40		5x9	5523	7x8	4186	9x6	3443

CASE IV: M25 fy500
Grade of Concrete =25
Grade of Steel =500
Cost of Concrete =8580 Rs. /m^3
Cost of Steel =65.8 Rs. /Kg

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Table IV. **Cost of Flat Slab Per m² For M25 Fy500**

		Cost of Flat Slab Per m²					
Span	S.P.-no. span		3x3		4x4		5x5
20x20	O.P.-no. span	4x4	3170	5x5	2504	5x5	2160
25x25		5x5	3680	6x5	2923	6x6	2463
30x30		5x6	4275	7x4	3376	7x6	2763
35x35		5x7	4896	7x6	3755	8x6	3118
40x40		5x9	5523	7x8	4186	9x6	3443

CASE V: M30 fy415

Grade of Concrete =30
Grade of Steel =415
Cost of Concrete =8647 Rs. /m³
Cost of Steel =64 Rs. /Kg

Table V. **Cost of Flat Slab Per m² For M30 Fy415**

		Cost of Flat Slab Per m²					
Span	S.P.-no. span		3x3		4x4		5x5
20x20	O.P.-no. span	4x4	3164	5x5	2497	5x5	2152
25x25		5x5	3672	6x5	2925	6x6	2455
30x30		5x6	4248	7x4	3366	7x6	2750
35x35		5x7	3113	7x6	3747	8x6	3113
40x40		5x9	5486	7x8	4160	9x6	3435

CASE VI: M30 fy500

Grade of Concrete =30
Grade of Steel =500
Cost of Concrete =8647 Rs. /m³
Cost of Steel =65.8/ Rs. /Kg

Table VI. **Cost of Flat Slab Per m² For M30 Fy500**

		Cost of Flat Slab Per m²					
Span	S.P.-no. span		3x3		4x4		5x5
20x20	O.P.-no. span	4x4	2150	5x5	2498	5x5	2152
25x25		5x5	3671	6x5	2926	6x6	2458
30x30		5x6	4865	7x4	3360	7x6	2750
35x35		5x7	4798	7x6	3748	8x6	3113
40x40		5x9	5486	7x8	4164	9x6	3435

The problem of cost optimization of flat slab with drop panel has been formulated as mathematical programming problems. The resulting optimum design problems are constrained non-linear programming problems and have been solved by SUMT. Parametric study with respect to different type of spans and grade of concrete combinations of flat slab sections has been carried out.

VIII. GRAPHICAL REPRESENTATION

As graph shown below, as we increase no. of span from 3mX3m to 4mX4m per meter cost is decrease and also as we again go from 4mX4m to 5mX5m again per meter cost of slab decrease, so as a no. of span increase the cost of flat slab decrease. (Typical graph for

Grade of Concrete =20 N/mm²
Grade of Steel =415 N/mm²
Cost of Concrete =7302 Rs. /m³
Cost of Steel =64 Rs. /Kg.)

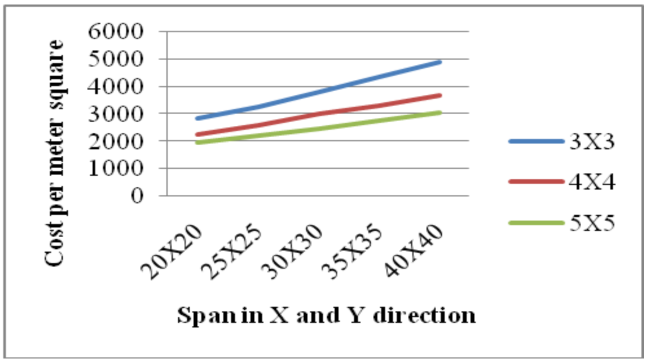

Fig.2 Cost-Span graph

IX. CONCLUSION

The result of optimum design for flat slabs have been compared and conclusions drawn.

- The optimum cost for a flat slab is achieved in M20 grade of concrete and fe415 grade of steel.
- The cost of flat slab unit increased rapidly with respect grade of concrete increases and grade of steel increases whereas cost of flat slab decreases as the number of span increases by keeping total length of slab constant.
- It is possible to formulate and obtain solution for the minimum cost design for flat slab
- Maximum cost savings of 33.91% over the normal design is achieved in case of flat slab.
- The percent reduction in optimum cost for a flat slab is directly proportion to number of span increases.

REFERENCES

1. M.G. Sahab, A.F. Ashour, And V.V. Toropov "Cost optimisation of reinforced concrete flat slab buildings", Engineering Structures.Vol.27 pp.313–322. 2005.
2. N. Subramanian "Evaluation and enhancing the punching shear resistance of flat slabs using HSC", The Indian Concrete Journal, Vol. 79(5), pp.31-37. 2005.
3. Ronaldo B. Gomes and Paul E. Regan,"Punching Resistance of RC Flat Slabs with Shear Reinforcement", Journal of Structural Engineering, Vol.125 (6), pp- 684-692. 1999.
4. K.M.A. Hossain, And O. Olufemi "Design optimization of simply supported concrete slabs by finite element modeling", Struct. Multidisc Optimization.Vol.30, pp.76–88. 2005.
5. Adeola A Adedeji "Application: simplifying design of RC flat slab using taboo search", Trends in applied science research (Academic Journals Inc.)Vol.6 (4) pp 375-385.2011.
6. S.S.F. Mehanny, B.M. Sobhy and M.M. Bakhoum "Strength versus drift limitation effects on code compliant seismic-resistant flat slab buildings", The Indian Concrete Journal .vol.36 (6) pp.-1-2. 2008.
7. M.A. Eder, R.L. Vollum, A.Y. Elghazouli, T. Abdel-Fattah "Modelling and experimental assessment of punching shear in flat slabs with spearheads", Engineering Structures.Vol.32, pp.3911–3924. 2010.
8. H.S. Kim, And D.G.Lee "Efficient analysis of flat slab structures subjected to lateral loads" Engineering Structures Vol.27 pp.251–263. 2005.
9. Vikunj k.Tilva Prof. B.A.Vyas and Assit.Prof. Parth Thaker "Cost comparison between flat slabs with drop and without drop in four storey lateral load resisting building", National Conference on Recent Trends in Engineering & Tech. pp1-5. 2011.
10. R.C.Gupta and Dr. M.R.Sethia "computer aided design of flat slab-column-footing structure", The Bridge and Structural Engineering. Vol.23 (1) pp.39-54. 1993.
11. I.S: 456-2000.
12. "Engineering Optimization" by S.S. Rao

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)