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Different Structural Analysis Scheme for Optimal Design Study of Structural Slab

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Abstract:

This research is for the study of different type of structural scheme of structural slab considering architectural aesthetic, functional requirement with optimal design solution. Most of the time the architect wishes to fit aesthetic appearance of his design in structural scheme, with other services for functional requirement. A few architects don't bother about structural scheme, by considering hiding the structure with other cosmetic treatment, false ceiling. These cosmetic treatments are additional expenses in the project cost. A structural design can be said to be unique design, which will fulfil the requirement of architectural appearance, other services/ functional requirement without other expenses.

An alternative of conventional beam slab can be with flat slab, waffle slab, wide beam slab.

This paper describes the analysis of a commercial building with different types of structural slab design. The study of different type if slabs has been considered based on aesthetic appearance, economical, ease in construction. The behaviour of building was investigated using STAAD Pro connect software. For modelling and analysis of old Traditional slab flat slab, Waffle slab and one-way ribbed slab structural, STAAD Pro connect. The dead load, live load Seismic and wind load considered as per Indian codes IS 456: 2000 IS 1893 & IS 875: 1987 (all parts). Study result will be summarized in conclusion part of this paper.

Keywords —Conventional beam Slab system, Flat Slab system, Onaway ribbed slab system, Multi Storey Building, Staad pro connect, Cost Comparison.

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I. INTRODUCTION

This study is focused on the Comparative Study of different type of slab diaphragms i.e., conventional beam slab system, flat slab system, waffle slab and one-way ribbed slab system. The configuration involves the conventional frame structures which acting on different loading circumstances. All these schemes are having different conditions in framework so, they are performing different way on different loading circumstances.

For development plan, or expansion of metro cities, land cost is increasing day by day. With rapid growth in population along with development of industrial and commercial activities rapid urbanization has taken place which has resulted into continues influx of rural

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people to metro cities. So obviously the horizontal space constraint is reaching an alarming situation for metros. To cope with the situation maximum utilization of space vertically calls for the construction of multi-storey buildings in large numbers but the question of affordability of the target customers mainly the middle-income group of our country necessitates efficient and cost effect design of such buildings.

1.1 Conventional Beam Slab System

In this scheme, the slab will be supported on wall or r.c.c. beams. Slab panel in general will be square, rectangular in plan shape, but it can be of any shape such as triangular, circular, trapezoidal, etc. Loads are transferred by the slab through flexural, shear and torsion to the supports. When slab width is very small when comparing to length of panel, such slabs supported on two parallel sides carry loads by bending in the direction perpendicular to the supports are one-way.

Figure 1-1 – Conventional Beam Slab

1.2 Flat Slab System

In this scheme, the slab will be supported on column. Slab panel will be continuous, and load will be transferred to columns through slab itself or from slab to column capital. Load transfer mechanism is through concealed beam (column strip and middle strip). Flat slabs require continuous span, otherwise the design thickness of slab will be much more. From Architectural and services point of views, flat slab is preferable, because it allow service duct in any direction.

Figure 1-2 – Flat slab with column capital

1.3 Waffle Slab System

Waffle slab system is like Flat slab system. Slab panel will be continuous, and load will be transferred to columns through waffle (ribs) to column capital. Load transfer mechanism is through ribs (column strip and middle strip). Waffle slabs require continuous span, otherwise the design thickness of slab will be much more. From Architectural aesthetic point of views, waffle slab is preferable, false ceiling may not require.

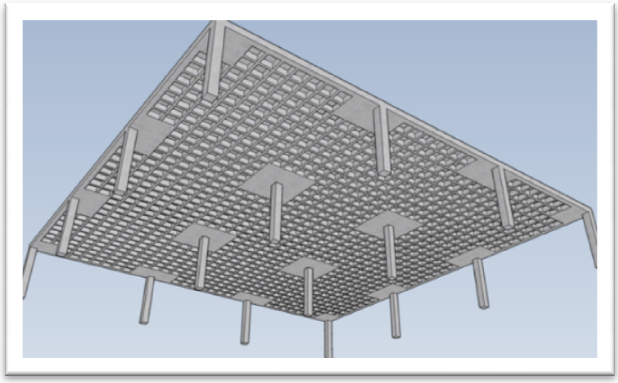

Figure 1-3 – Waffle slab system

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1.4 One Way Beam Slab System

One-way ribbed slab system is another option, where thin slab will be supported on small ribs, spanning on main beam. From main beam, load will be directly transferred to supporting columns. From Architectural aesthetic point of views, one-way ribbed is preferable, false ceiling may not require.

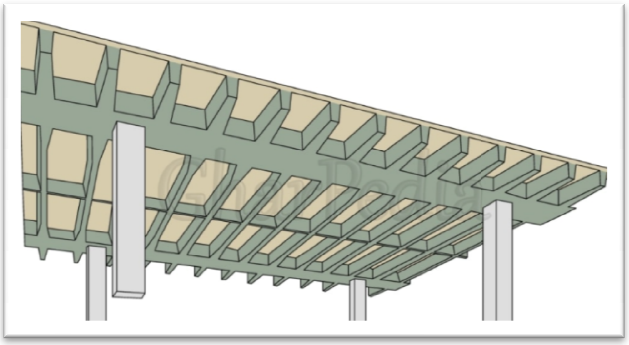

Figure 1-4 – One-way beam slab system

2METHODOLOGY

For the study, a commercial building G+1 considered. Structural analysis carried out using STAAD Pro connect software. Floor height taken as 3.65 m. Properties are defined as per IS. 456 :2000

2.1 Material Properties

Properties of material considered are as tabulated below –

Table 2-1 Material Properties

Description	Properties
Grade of concrete	M-25
Density Of Concrete	25 kN/M3
Modulus of Elasticity Of Concrete	2x105 N/mm2
Grade Of Steel	Fe-500 (HYSD)

2.2 Model Description

Structural slab systems are as below -

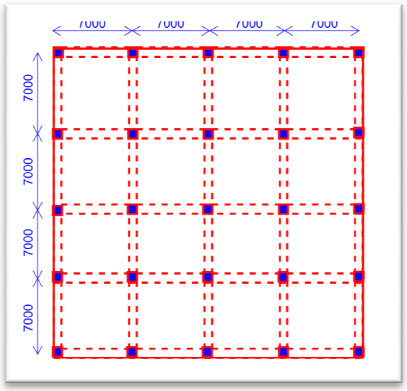

Figure 2-5 – Typ Floor Plan (Beam Slab)

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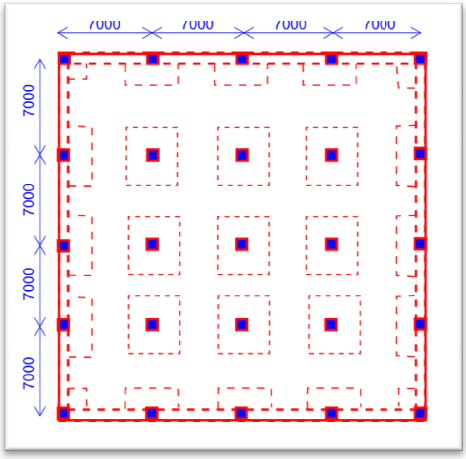

Figure 2-6 – Typ Floor Plan (Flat Slab)

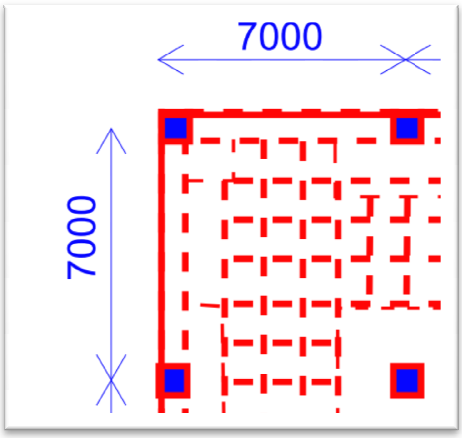

Figure 2-7 – Typ Floor Plan (Waffle Slab)

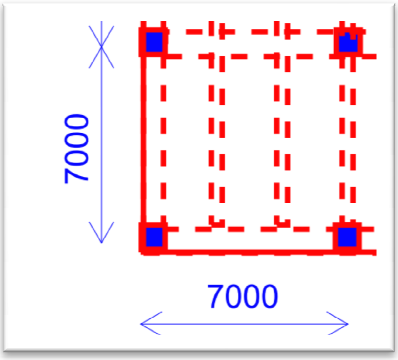

Figure 2-8 – Typ Floor Plan (One way Beam Slab)

Table 2-2Structural Scheme

Description	Description
Number of Floor	2
Floor to Floor Height	3.65m
Total Height of Building	2000+7300mm = 9300mm from foundation
Number of bay's along X	4 number @ 7000mm ctc
Number of bay's along Z	4 number @ 7000mm ctc
RCC Columns	400x400mm
RCC Beams (Conventional Beam Slab)	300x550mm
Flat Slab	250mm
Drop Flat Slab	250mm (2250x2250)
Conventional Slab	250mm
Waffle Slab	200x400 @ 1167mm with 100 thk slab
One way beam slab Main Beam	550x550
One way beam slab Secondary Beam	250x550 @ 2334mm ctc with 100 thk slab

2.3 Loading

Dead Load

Self-weight of slab with concrete density 25kN/M^3+ Floor Finish 1.0kN/M^2 + Service0.5kN/M^2

Live Load 3 kN/M^2

Seismic

Zone IV, R = 5, I = 1.0

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Load Case
1 = EQx
2 = EQz
3 = EQy
4 = DL
5 = LL

Load Combination Service case (SLS) =
LOAD COMB 101 1DL+1LL

4 1.0 5 1.0

LOAD COMB 102 1DL+1LL+1EQX

1 1.0 2 0.3 3 0.2 4 1.0 5 1.0

LOAD COMB 103 1DL+1LL+1EQZ

1 0.3 2 1.0 3 0.2 4 1.0 5 1.0

LOAD COMB 104 1DL+1LL+1EQY

1 0.3 2 0.3 3 0.67 4 1.0 5 1.0

LOAD COMB 105 1DL+1LL+1EQX

1 -1.0 2 -0.3 3 -0.2 4 1.0 5 1.0

LOAD COMB 106 1DL+1LL+1EQZ

1 -0.3 2 -1.0 3 -0.2 4 1.0 5 1.0

LOAD COMB 107 1DL+1LL+1EQY

1 -0.3 2 -0.3 3 -0.67 4 1.0 5 1.0

Load Combination Strength case (ULS) =
LOAD COMB 201 1.5DL+1.5LL

4 1.5 5 1.5

LOAD COMB 202 1.2DL+1.2LL+1.2EQX

1 1.2 2 0.36 3 0.24 4 1.2 5 0.6

LOAD COMB 203 1.2DL+1.2LL+1.2EQZ

1 0.36 2 1.2 3 0.24 4 1.2 5 0.6

LOAD COMB 204 1.2DL+1.2LL+1.2EQY

1 0.36 2 0.36 3 0.8 4 1.2 5 0.6

LOAD COMB 205 1.2DL+1.2LL+1.2EQX

1 -1.2 2 -0.36 3 -0.24 4 1.2 5 0.6

LOAD COMB 206 1.2DL+1.2LL+1.2EQZ

1 -0.36 2 -1.2 3 -0.24 4 1.2 5 0.6

LOAD COMB 207 1.2DL+1.2LL+1.2EQY

1 -0.36 2 -0.36 3 -0.8 4 1.2 5 0.6

LOAD COMB 208 1.5DL+1.5EQX

1 1.5 2 0.45 3 0.3 4 1.5

LOAD COMB 209 1.5DL+1.5EQZ

1 0.45 2 1.5 3 0.3 4 1.5

LOAD COMB 210 1.5DL+1.5EY

1 0.45 2 0.45 3 1.0 4 1.5

LOAD COMB 211 1.5DL+1.5EQX

1 -1.5 2 -0.45 3 -0.3 4 1.5

LOAD COMB 212 1.5DL+1.5EQZ

1 -0.45 2 -1.5 3 -0.3 4 1.5

LOAD COMB 213 1.5DL+1.5EQY

1 -0.45 2 -0.45 3 -1.0 4 1.5

LOAD COMB 214 0.9DL+1.5EQX

1 1.5 2 0.45 3 0.3 4 0.9

LOAD COMB 215 .9DL+1.5EQZ

1 0.45 2 1.5 3 0.3 4 0.9

LOAD COMB 216 .9DL+1.5EQY

1 0.45 2 0.45 3 1.0 4 0.9

LOAD COMB 217 .9DL+1.5EQX

1 -1.5 2 -0.45 3 -0.3 4 0.9

LOAD COMB 218 .9DL+1.5EQZ

1 -0.45 2 -1.5 3 -0.3 4 0.9

LOAD COMB 219 .9DL+1.5EQY

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1 -0.45 2 -0.45 3 -1.0 4 0.9

3 STRUCTURAL ANALYSIS AND DESIGN

Structural Analysis carried out using STAAD Pro Connect edition. Structural Design calculated as per BIS norms (IS 456:2000).

Before analysis all the required elements of the structure need to be defined earlier like material properties, loads, load combinations, size of members, response spectrum etc. once the analysis has been done the forces can be extracted for all the results like displacement, storey shear, bending moment, drift ratio, axial forces for comparing the performance of selected structural schemes.

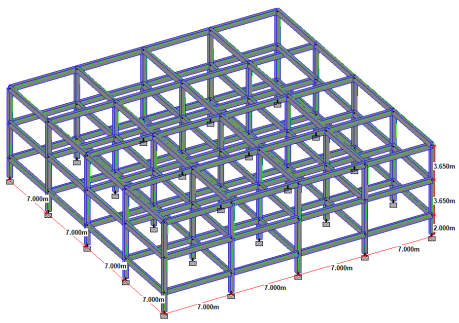


Figure 3-1 – Structural Analysis Model (Beam Slab)

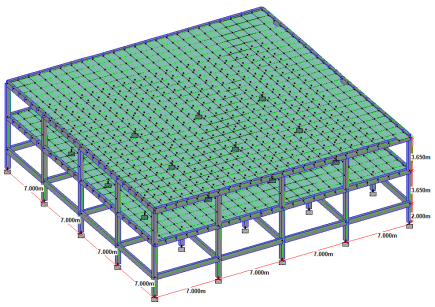


Figure 3-2 – Structural Analysis Model (Flat Slab)

Figure 3-3 – Structural Analysis Model (Waffle Slab)

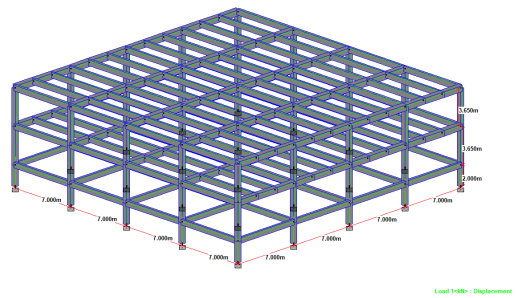


Figure 3-4 – Structural Analysis Model (One way Beam Slab)

4 RESULT AND DISCUSSION

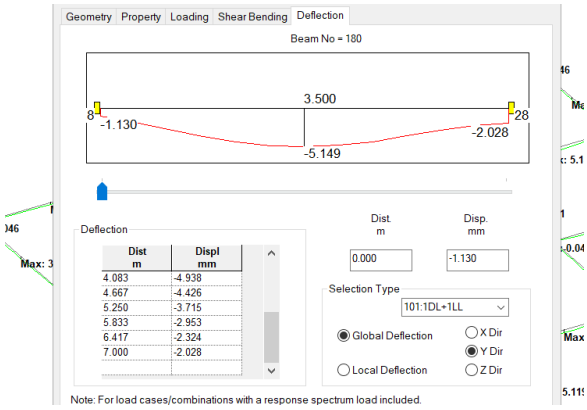
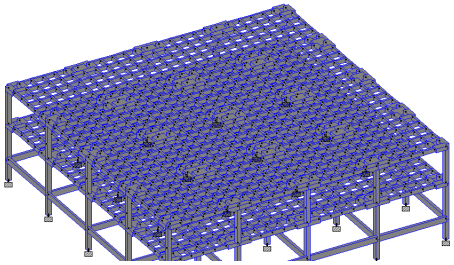


Figure 4-1 – Deflection in beam (Beam Slab)



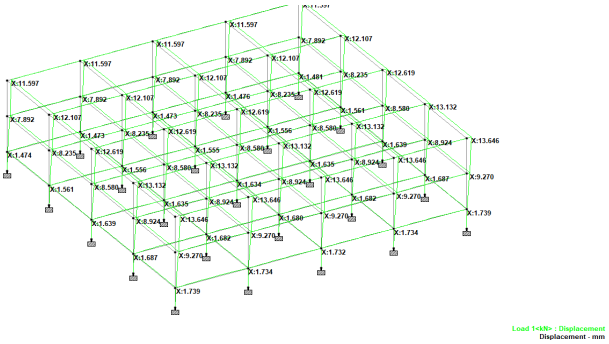


Figure 4-2 – Sway Eqx (Beam Slab)

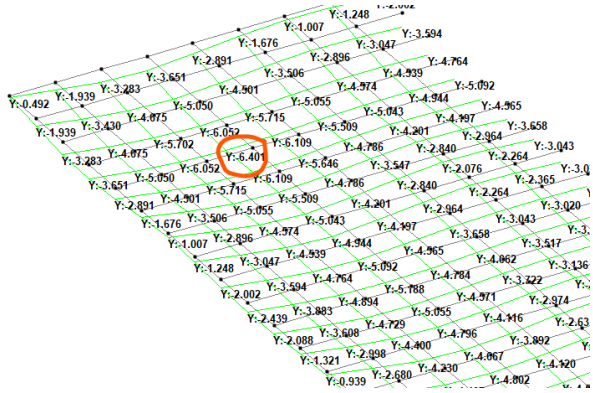


Figure 4-5 – Deflection in beam (Waffle Slab)

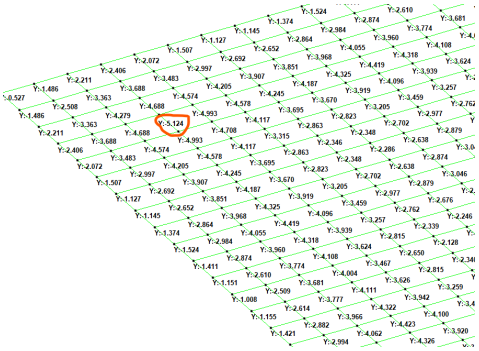


Figure 4-3 – Deflection in beam (Flat Slab)

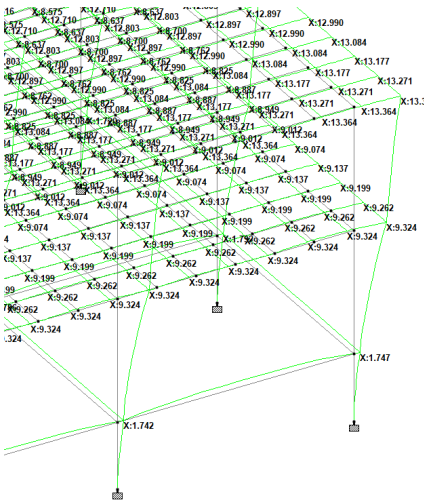


Figure 4-6 – Sway Eqx (Waffle Slab)

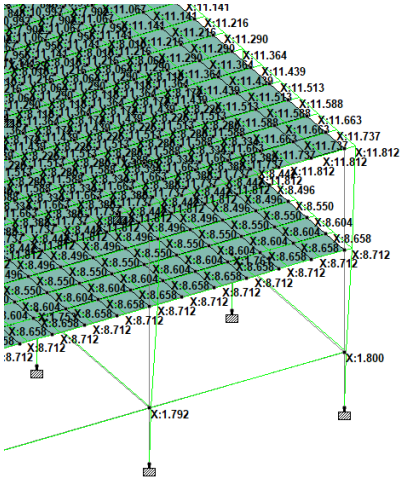


Figure 4-4 – Sway Eqx (Flat Slab)

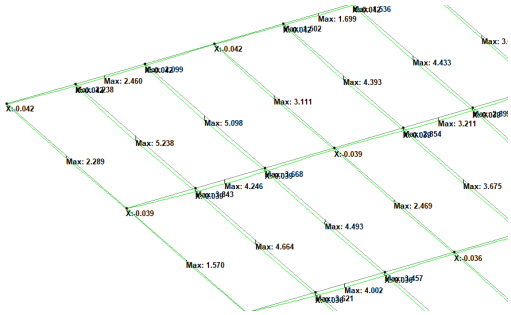


Figure 4-7 – Deflection in beam (Flat Slab)

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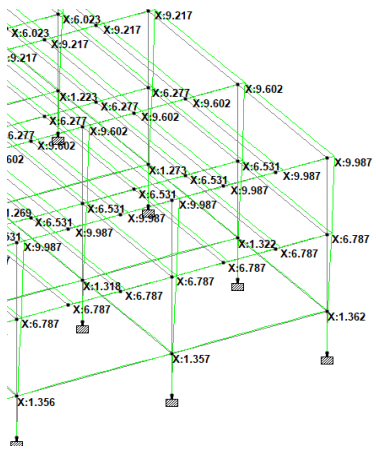

Figure 4-8 – Sway Eqx (Flat Slab)

Summary of results are as tabulated below -

Table 4-1Result of Slab panel Deflection.

Description	Traditional Slab	Flat Slab	Waffle Slab	One-way Slab
Story 2	5mm	5.12mm	6.4mm	5.24mm
Story 1	5mm	5.12mm	6.4mm	5.24mm

Table 4-2Result of Sway.

Description	Traditional Slab	Flat Slab	Waffle Slab	One-way Slab
Story 2	12.4mm	11.82mm	13.37mm	9.98mm
Story 1	8.5mm	8.70mm	9.32mm	6.79mm
Story 0	1.6mm	1.80	1.75mm	1.36mm

Table 4-3Result of Story drift.

Description	Traditional Slab	Flat Slab	Waffle Slab	One-way Slab
Max between floor	6.9mm	6.90mm	7.57mm	5.43mm

5 COST COMPARISON

Summary of costings are as tabulated below -

Table 5-1Bill of Quantities.

Description	Traditional Slab	Flat Slab	Waffle Slab	One-way Slab
Concrete M3	520.56	564.16	523.36	383.36
Steel Reinforcement kG	46200	101000	93840	68600
Shuttering				
False Ceiling			Not required	

Table 5-2Costing.

Description	Traditional Slab	Flat Slab	Waffle Slab	One-way Slab
Concrete	4575374	4958588	4599984	3369478
Steel Reinforcement	4556013	9960115	9254032	6764989
Shuttering				
False Ceiling			Not required	
Total Cost (INR)	9131387	14918703	13854015	10134467
Cost/M2 (INR)	9317.741	15223.17	14136.75	10341.29

6 CONCLUSIONS

Followings are the conclusion of the work -

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The displacement result shows that the One-way beam slab gets least, and waffle slab get maximum deflection. Conventional beam slab and one way slab are safer than Flat slab and waffle slab.

The story drift result shows that the conventional beam slab and one way beam slab system are safer than waffle slab and flat slab system.

The result shows that the structural cost of conventional slab is optimal and flat slab system is more expensive, however below mentioned point can further influence overall cost of project-.

1) Shuttering cost + false ceiling cost in one way and traditional slab might be more, whereas flat slab will be economical. Waffle slab can be carried out with modular permanent shutter, which will be much economical than other scheme.
2) Flat slab is most preferable for utilities and service.
3) Waffle slab's aesthetic appearance is good.

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