COMPARATIVE STUDY OF FLAT SLAB AND WAFFLE SLAB BUILDING USING PUSHOVER ANALYSIS

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***Abstract*— Now a scenario, the availability of net clear ceiling height in the building is the major problem. To overcome this problem, the flat slab and waffle slab has been used. The present work is to determine the behavior of flat slab and waffle slab under pushover analysis. Three types of models of single storey flat slab and waffle slab has been taken for analysis. The models have spans of 15 m by 15 m with thickness of 150 mm, 200 mm and 250 mm. The modeling and pushover analysis has been done with the help of software ETAB version 9.5.0. The pushover analysis is a very good tool to determine the behavior of structural elements of buildings under seismic loading. Pushover analysis is very popular method of retrofitting of building. The result has been shown that the performance point of Waffle slab is much better than that of the flat slab.**

***Keywords*: Flat Slab, Waffle Slab, Pushover Analysis.**

I. INTRODUCTION

Common practice of design and construction is to support the slab by beams and support by columns. This may be called as beam –slab construction. The beams reduce the available net clear ceiling height. Hence in warehouse, office and public hall sometimes beams are avoided and slabs are directly supported by columns. These types of construction are aesthetically appealing also. These slabs which are directly supported by columns are called flat slab.
The term flat slab means a reinforced concrete slab supported directly on columns without beams. A flat slab system requires lesser head room, hence, it is very economical for use in multistory buildings. There are large bending moments and shear near the junctions with columns. Therefore, there may be a need to flare the column at its top end or thicken the slab over the column.
Waffle slab consist of closely spaced intersecting beams in two directions with monolithic slab on the top. It may be looked as a thick slab with concrete removed from tension zone and to some extent even from the compression zone. This type of flooring is known as ribbed lab/voided slab/waffle slab. The beams act as T-beams since they are cast monolithic with slab. If the beams intersect at right angles to each other then it is called ortho grid. Ortho grid may consist of square grid or rectangular grid. Sometimes beams are made to intersect at diagonals for architecture purpose. In such case it may be called as dia. grid.

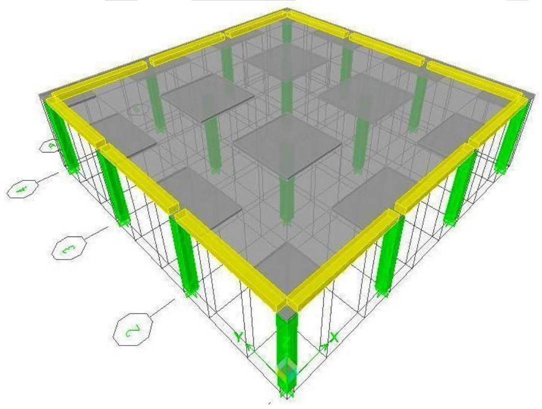
Pushover Analysis of structures is performed under permanent vertical loads and gradually increasing lateral loads. Equivalent static lateral forces are the approximate representation of earthquake induced forces, which results into a plot of total base shear versus top displacement which in turn indicates permanent failure or weakness.

II. METHODOLOGY AND MODELLING

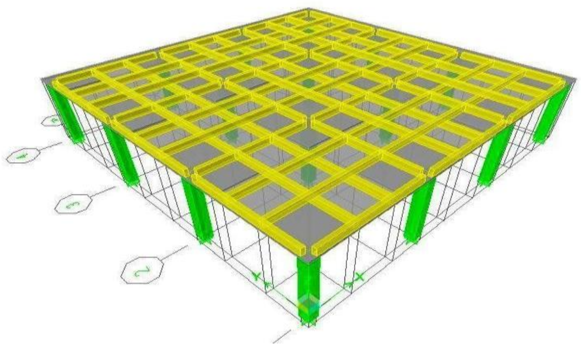
We have taken 3-models of flat slab and waffle slab and studied the behavior of both the slabs under pushover analysis. Various 3-dimensional models have been taken of 15m by 15m with different thickness of 150mm, 200mm, 250mm respectively.

S.NO.	PARTICULARS	DETAILS
1	Span in X direction	15 m
2	Span in Y direction	15 m
3	Live Load	5 kN/m^2

4	Grade of Concrete	M-25
5	Type of Steel	HYSD bars
6	Column Height	5.0 m
7	Column Size	400 mm x 400 mm
8	Column Longitudinal Reinforcement	0.8 % reinforcement
9	Column Transverse Reinforcement	8d @ 175c/c
10	Column Support condition	Fixed
11	Beam Size	300 mm x 400 mm
12	Beam Reinforcement	0.39% reinforcement at top & bottom
13	Flat slab Reinforcement	10d @ 200 centre to centre in both-ways for 150 mm thickness.



15m x 15 m flat slab



15m x 15 m waffle slab

III. RESULT AND DISCUSSION

The following cases have been considered:

CASE A – 15 m x 15 m slab with 150mm thickness

- Flat slab
- Waffle slab

CASE B – 15 m x 15 m slab with 200mm thickness

- Flat slab
- Waffle slab

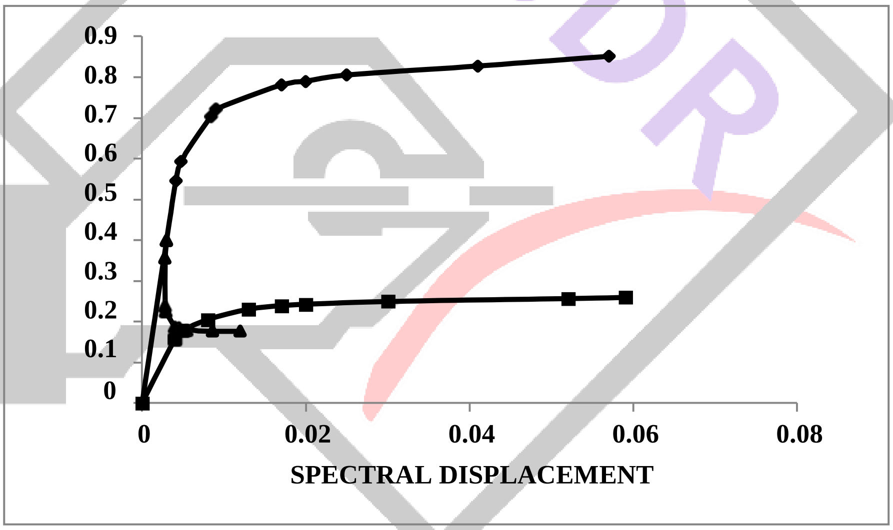
CASE C – 15 m x 15 m slab with 250mm thickness

- Flat slab
- Waffle slab

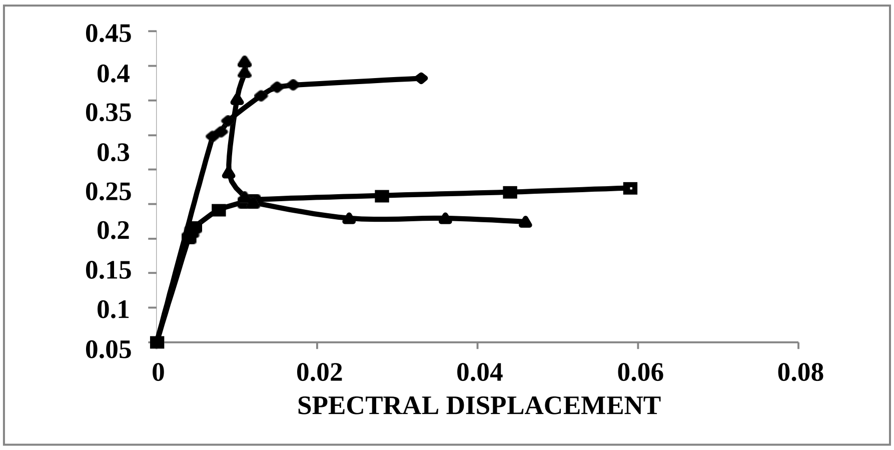
The results are divided into different categories:

1. Results of Pushover Analysis: These are further categorized as:

a) Modal Characteristics
b) Stresses in Flat Slab and Waffle Slab
c) Hinge Mechanism
d) Capacity Curves
e) Capacity-Demand Curve



Capacity demand Curve for 15 m x 15 m slab



Capacity demand Curve for 15 m x 15 m slab

Modal Characteristics

The modal participation mass factors are more than 90% in X and Y directions, for all three types of flat and waffle slab which suggests that pushover analysis gives more realistic results in the same directions.

Statistics of Plastic Hinges

Hinges are formed in column and not in beams.

For, two types of flat slab and one types of waffle slab, hinges are formed up to CP state in X-directions, whereas, in 15 m x 15 m flat slab and waffle slab with 150mm thickness, hinges are formed up to LS.

Deflection in flat slab and waffle slab

The permissible deflection in flat slab and waffle slab (as per IS 456) is span/250, i.e 60mm for 15m slabs. The actual deflections of all the slabs are given below:

For 15m x15m flat and waffle slab with 150mm thickness – 59 mm, 58.6 mm For 15m x 15m flat and waffle slab with 200mm thickness– 58 mm, 57 mm

For 15m x 15m flat and waffle slab with 250mm thickness – 57.5 mm, 56 mm Which are in permissible limits.

Stresses in flat slab and waffle slab

The permissible stresses in flat slab and waffle slab (as per IS 456) are- Permissible Stress in Concrete is 0.446*fck i.e 11.15 N/mm².

The actual maximum stresses of all the slab are within the permissible limits

Capacity Curve:

On applying modal load pattern in X directions, the structure will yield at the following loads:

For 15m x 15m flat slab and waffle slab with 150mm thickness in X-direction: 666kN, 802kN respectively.

For 15m x 15m flat slab and waffle slab with 200 mm thickness in X- direction: 657kN, 500kN respectively.

For 15m x 15m flat slab and waffle slab with 250 mm thickness in X- direction: 653kN, 487kN respectively.

Performance Point:

The performance points for all the slabs are obtained at:

For 15m x 15m flat slab with 150mm thickness: Sa= 0.254 g, Sd= 0.049 m For 15m x 15m waffle slab with 150mm thickness: Sa= 0.664 g, Sd= 0.07 m For 15m x 15m flat slab with 200mm thickness: Sa= 0.22 g, Sd= 0.056 m

For 15m x 15m waffle slab with 200mm thickness: Sa= 0.383 g, Sd= 0.034 m For 15m x 15m flat slab with 250mm thickness: Sa= 0.230 g, Sd= 0.054 m For 15m x 15m waffle slab with 250mm thickness: Sa= 0.279 g, Sd= 0.045 m These performance points show the capacity of the structure.

IV. CONCLUSION

The flat slab and waffle slab has been modeled with equal span and with different thickness, so it has become possible to observe the results in all models. The pushover analysis is a simpler way to identify the nonlinear behavior of structures and same is here applied for flat slab and waffle slab structures. Hinges are formed in columns in almost every case.

In 15 m x 15 m flat slab and waffle slab with 150mm thickness:

a) The deflection of flat slab and waffle slab are within the permissible limit. According to IS CODE 456:2000, the permissible deflection is L/250, i.e 60 mm for 15 m span and the actual deflection for flat slab is 59 mm and for waffle slab is 58.6 mm.

b) The maximum and minimum stresses are within the permissible limits for both flat and waffle slab.

c) Maximum hinges have been formed in the columns.

In 15 m x 15 m flat slab and waffle slab with 200mm thickness:

d) The deflection of flat slab and waffle slab are within the permissible limit. According to IS CODE 456:2000, the permissible deflection is L/250,i.e 60 mm for 15 m span and the actual deflection for flat slab is 58 mm and for waffle slab is 57 mm.

e) The maximum and minimum stresses are within the permissible limits for both flat and waffle slab.

f) Maximum hinges has been formed in the columns.

On the basis of the above observation and results obtained the following conclusions can be made

The performance point of waffle slab is more as compared to flat slab..

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