Analysis of Flat Slab and Waffle Slab in Multistorey Buildings using ETABS

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Abstract— In multistoried buildings flat slab and waffle slab are generally engaged when column spacing is more. Flat slabs and waffle slabs are used in buildings in requirement of more working space like commercial buildings, workshops, assembly buildings, etc. The main disadvantage of structures with flat slab and waffle slab are there lack of withstanding seismic loads. Special features like shear walls are used to help the building to resist the lateral loads caused due to high winds and seismic loads. In this paper, an attempt has been made to investigate the seismic effect on multi storey building of G+9, G+14 and G+19 floors with waffle slab and flat slab using the software ETABS 2013. The seismic evolution is performed by response spectrum analysis as per IS 1893 (2002). It is observed that waffle slabs are advisable for structure with a height less than 40m, whereas for structures of height above 40m it is advisable to go with flat slab.

Key words: ETABS 2013, Earthquake, Waffle Slab, Flat Slab, Seismic Analysis, Storey Drift, Maximum Displacement

I. INTRODUCTION

In general normal frame construction utilizes columns, beams and slabs. However it may be possible to undertake construction without providing beams, in such a case the frame system would consist of slab and column without beams. These types of slabs are called flat slabs. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. Flat slabs have been widely used in building construction due to their advantages in reducing storey height and construction period (compared with RC frames with beams and columns), leading to a reduction of construction costs.

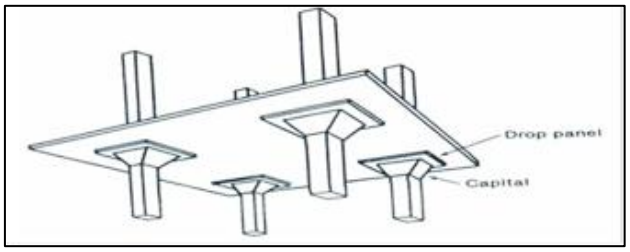


Fig. 1: Flat Slab

A waffle slab is a type of building material that has two-directional reinforcement on the outside of the material, giving it the shape of the pockets on a waffle. This type of reinforcement is common on concrete, wood and metal construction. A waffle slab gives a substance significantly more structural stability without using a lot of additional material. This makes a waffle slab perfect for large flat areas like foundations or floors. The most common material for a waffle slab is concrete. These slabs are used as the foundation for many different types of buildings and structures, but are most commonly used in commercial or industrial buildings. Waffle foundations are resistant to cracking and sagging and can hold a much greater amount of weight than traditional concrete slabs.

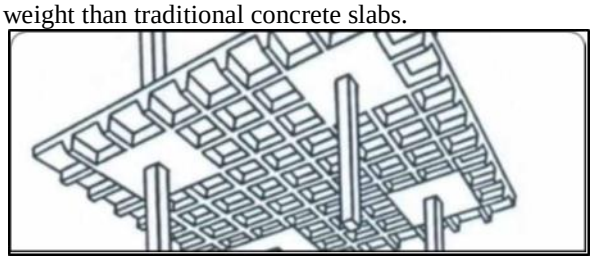


Fig. 2: Waffle Slab

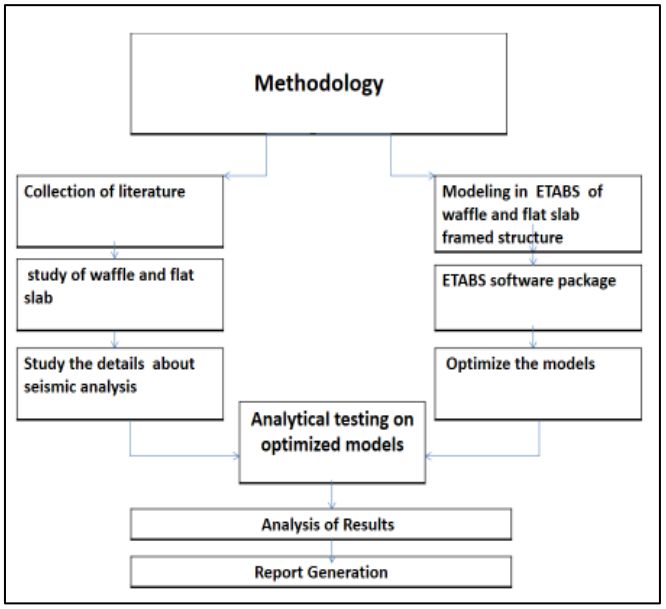
II. RESEARCH OBJECTIVES

To obtain the storey drift and maximum displacement of multi storey building subjected to seismic loads by applying response spectrum analysis for buildings of G+9, G+14 and G+19 floors with waffle slab and flat slab using the software ETABS 2013.

III. SCOPE

This paper deal with the parametric study of G+9, G+14, G+19 storey buildings with flat-slab and waffle slab which is designed according to the standards given in the codes. The structure is subjected to response spectrum analysis for which the values are to be calculated, to obtain the storey drift and maximum displacement of the structure. The obtained results are compared.

IV. METHODOLOGY



V. MODELLING

In this paper, the structures with waffle slab and flat slab for various heights are modelled using the software ETABS 2013. To obtain the results for the effect of seismic force on flat slab and waffle slab framed structures different load combinations, as per IS: 1893 (2002) are considered for the analysis. The parameters studied here are storey drift and maximum displacement.

A. Description of Load:

The following parameters are considered for seismic analysis in this research. Different loads are considered as per the following calculations:

Loads	References
Finishing load	As per IS: 875(Part 1)1987
Live load	As per IS: 875(Part 2)1987
Earthquake load	As per IS: 1893(2002)

Table 1: Description of Loads

Response Reduction factor	5
Importance Factor	1.5
Damping Ratio	0.05

Table 2: Other Parameters

B. Description of Geometry Adopted In Building:

This table shows the description of framed structure adopted for modelling:

Type of Structure	Ordinary moment resisting frame
Type of building	Office Building/ Business Building
Total number of building	6
Total area of building	25*25 = 625m^2
Number of column in X direction	5
Number of column in Y direction	5
Height of basement	4m
Height between the floors	3m
Total height of the building (G+9)	31m
Total height of the building (G+14)	46m
Total height of the building (G+19)	61m

Table 3: Description of Model

C. Description of Different Slabs Adopted In Building:

This table shows the details of the slabs adopted for modelling:

Waffle Slab	Details
Slab thickness	200 mm
Size of Rim Beam	200 mm × 350 mm

Table 4: Description of Waffle Slab

Flat Slab	Details
Slab thickness	200 mm
Density of concrete	25kN/m^3
Modulus of Elasticity of Concrete	5000√fck (As per IS 456:2000)

Table 5: Description of Flat Slab

D. Plan View for Given Structure:

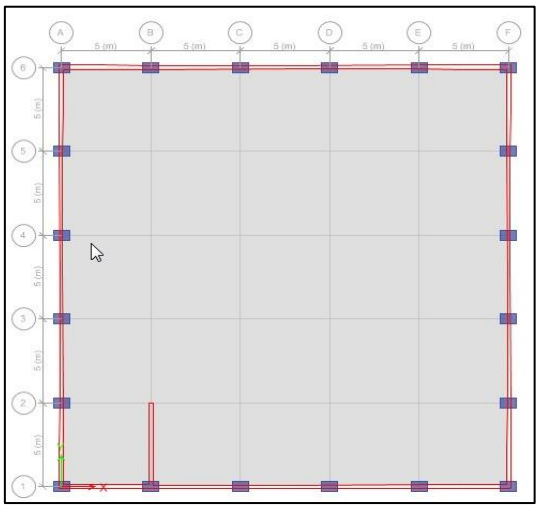


Fig. 3: Flat Slab

For the study, given plan is used for G+9, G+14 and G+19 storey building.

VI. RESULTS AND DISCUSSION

Seismic analysis is done on waffle slab and flat slab. After seismic analysis changes in parameters such as maximum displacement and storey drift of the structure are noticed.

A. Max Displacement in X-direction:

1) G+9 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	3	2.6
2	5.6	4.8
3	8.2	7
4	10.8	9.2
5	13.3	11.4
6	15.6	13.3
7	17.6	15.1
8	19.4	16.6
9	20.8	17.9
10	21.9	18.8

Table 6: Max Displacement in X-direction (mm) for (G+9) Storey Building

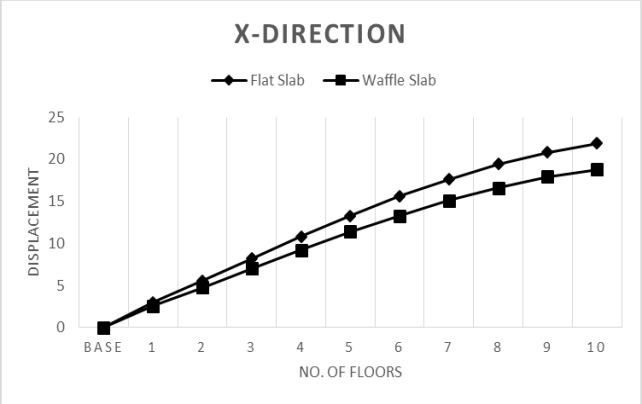


Fig. 4: Max Displacement In X-Direction For (G+9) Storey Building

2) G+14 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	2.3	4.4
2	4.4	8.3
3	6.6	12.6
4	9	17
5	11.3	21.5
6	13.8	26.1
7	16.2	30.6
8	18.5	35.1
9	20.8	39.4
10	20.3	43.5
11	25	47.4
12	26.9	50.9
13	28.6	54.2
14	30.1	57.1
15	31.5	59.6

Table 7: Max Displacement In X-Direction (Mm) For (G+14) Storey Building

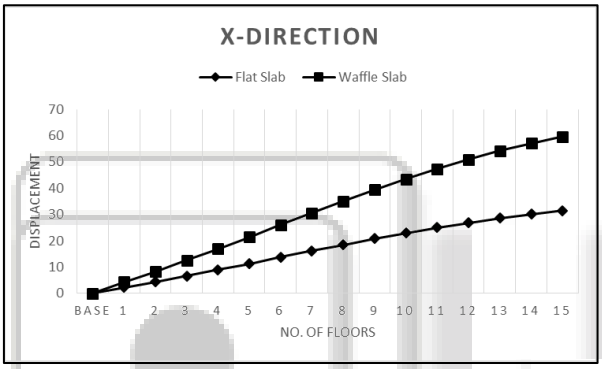


Fig. 5: Max Displacement In X-Direction For (G+14) Storey Building

3) G+19 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	4.3	4.4
2	8.3	8.4
3	12.7	12.8
4	17.4	17.5
5	22.3	22.5
6	27.5	27.8
7	32.8	33.1
8	38.1	38.6
9	43.6	44.1
10	49.1	49.7
11	54.5	55.2
12	59.9	60.7
13	65.2	66.1
14	70.3	71.3
15	75.3	76.4
16	80.1	81.3
17	84.6	86
18	88.9	90.4
19	92.9	94.6
20	96.7	98.4

Table 8: Max Displacement In X-Direction (Mm) For (G+19) Storey Building

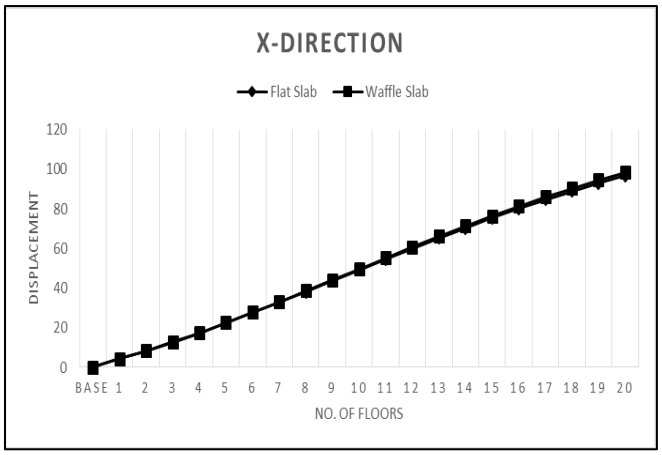


Fig. 6: Max Displacement In X-Direction For (G+19) Storey Building

B. Max Displacement in Y-direction:

1) G+9 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	2.9	2.5
2	5.5	4.7
3	8.2	7
4	10.9	9.3
5	13.5	11.5
6	15.9	13.5
7	18	15.4
8	19.9	17
9	21.5	18.4
10	22.7	19.5

Table 9: Max Displacement In Y-Direction (Mm) For (G+9) Storey Building

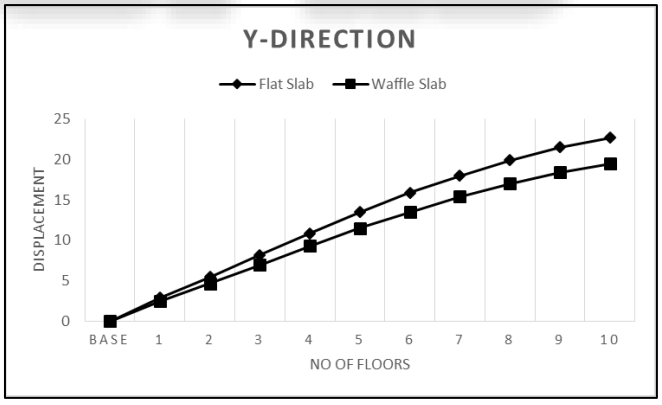


Fig. 7: Max Displacement In Y-Direction For (G+9) Storey Building

2) G+14 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	2.3	4.3
2	4.4	8.2
3	6.7	12.5
4	9.1	17.1
5	11.6	21.8
6	14.2	26.5
7	16.7	31.3
8	19.2	35.9

9	21.6	40.4
10	23.9	44.7
11	26.1	48.7
12	28.1	52.4
13	29.9	55.8
14	31.6	58.9
15	33.1	61.6

TABLE 10: Max Displacement In Y-Direction (Mm) For (G+14) Storey Building

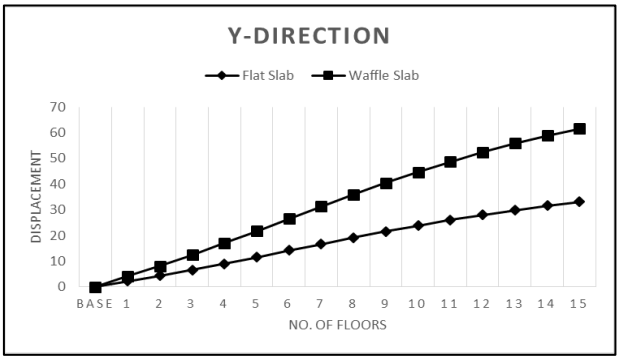


Fig. 8: Max Displacement In Y-Direction For (G+14) Storey Building

3) G+19 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	4.1	4.2
2	8.1	8.2
3	12.7	12.7
4	17.4	17.6
5	22.5	22.7
6	27.8	28.1
7	33.3	33.7
8	38.9	39.3
9	44.5	45
10	50.2	50.7
11	55.8	56.4
12	61.3	62
13	66.7	67.6
14	72	73
15	77.1	78.2
16	82	83.3
17	86.7	88.1
18	91.1	92.6
19	95.3	96.9
20	99.2	100.9

TABLE 11: Max Displacement In Y-Direction (Mm) For (G+19) Storey Building

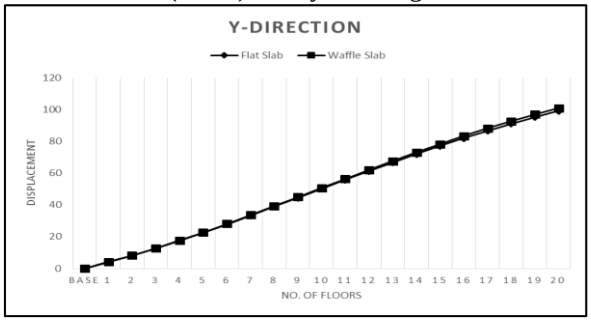


Fig. 9: Max Displacement In Y-Direction For (G+19) Storey Building

C. Storey Drift in X-direction:

1) G+9 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	0.000755	0.000642
2	0.000862	0.000739
3	0.000875	0.000756
4	0.000865	0.000747
5	0.000829	0.000717
6	0.00077	0.000669
7	0.000691	0.000604
8	0.000596	0.000523
9	0.000486	0.000428
10	0.000369	0.000323

Table 12: Storey Drift In X-Direction (Mm) For (G+9) Storey Building

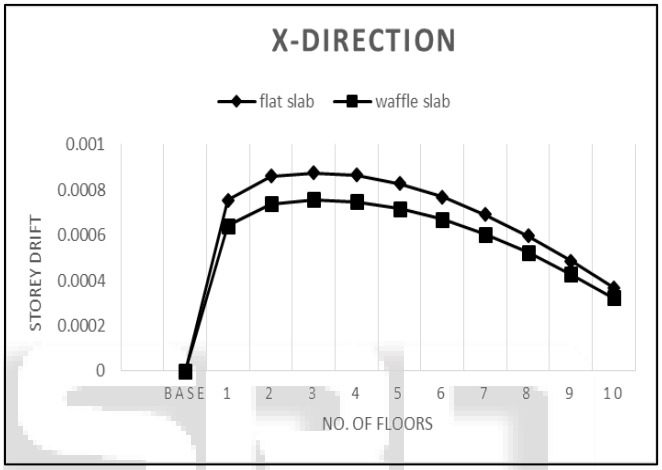


Fig. 10: Storey Drift In X-Direction For (G+9) Storey Building

2) G+14 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	0.000579	0.001098
2	0.000693	0.001214
3	0.000742	0.001408
4	0.000779	0.001476
5	0.0008	0.001514
6	0.000808	0.001529
7	0.000805	0.001522
8	0.000791	0.001494
9	0.000766	0.001446
10	0.000732	0.001382
11	0.000689	0.001301
12	0.000638	0.001205
13	0.000581	0.001096
14	0.000518	0.000978
15	0.000455	0.000858

TABLE 13: Storey Drift In X-Direction (Mm) For (G+14) Storey Building

Fig. 11: Storey Drift In X-Direction for (G+14) Storey Building

3) G+19 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	0.001074	0.00109
2	0.001329	0.001342
3	0.00146	0.001474
4	0.00157	0.001586
5	0.001657	0.001674
6	0.001725	0.001745
7	0.001776	0.001799
8	0.001813	0.001839
9	0.001844	0.001876
10	0.001844	0.001876
11	0.00184	0.001875
12	0.001822	0.00186
13	0.001791	0.001831
14	0.001747	0.00179
15	0.001691	0.001736
16	0.001623	0.001669
17	0.001544	0.001591
18	0.001456	0.001503
19	0.001362	0.001408
20	0.001267	0.001312

Table 14: Storey Drift In X-Direction (Mm) For (G+19) Storey Building

Fig. 12: Storey Drift In X-Direction For (G+19) Storey Building

D. Storey Drift in Y-direction:

1) G+9 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	0.000737	0.00063
2	0.000866	0.00074
3	0.000901	0.000767
4	0.000901	0.000768
5	0.000869	0.000743
6	0.000812	0.000698
7	0.000734	0.000636
8	0.000638	0.000557
9	0.000531	0.000468
10	0.000419	0.000372

Table 15: Storey Drift In Y-Direction (Mm) For (G+9) Storey Building

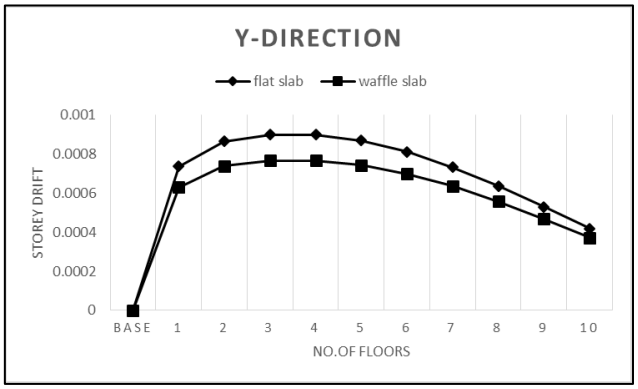


Fig. 13: Storey Drift In Y-Direction For (G+9) Storey Building

E. G+14 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	0.000564	0.001066
2	0.000706	0.001323
3	0.000774	0.001448
4	0.000819	0.001529
5	0.000843	0.001574
6	0.000853	0.001592
7	0.00085	0.001584
8	0.000834	0.001555
9	0.000809	0.001506
10	0.000773	0.001439
11	0.000728	0.001354
12	0.000676	0.001255
13	0.000617	0.001144
14	0.000555	0.001026
15	0.000495	0.000911

Table 16: Storey Drift In Y-Direction (Mm) For (G+14) Storey Building

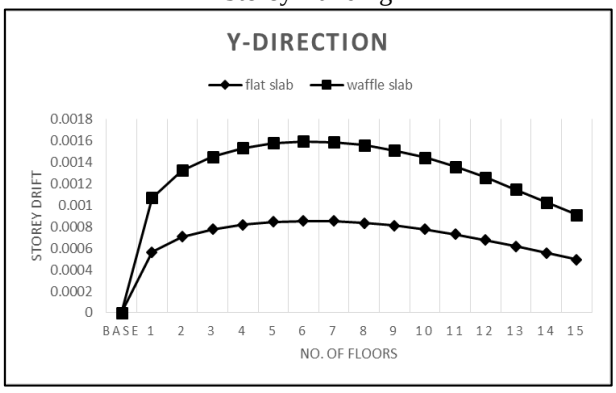


Fig. 14: Storey Drift In Y-Direction for (G+14) Storey Building

F. G+19 Storey Building:

No. of floors	Flat Slab	Waffle Slab
Base	0	0
1	0.001036	0.001054
2	0.001335	0.001348
3	0.001497	0.001509
4	0.00162	0.001634
5	0.001712	0.001728
6	0.001783	0.001802
7	0.001835	0.001857
8	0.001872	0.001896
9	0.001893	0.001921
10	0.001901	0.001931
11	0.001894	0.001928
12	0.001874	0.001911
13	0.001841	0.00188
14	0.001795	0.001837
15	0.001736	0.00178
16	0.001665	0.001711
17	0.001584	0.00163
18	0.001494	0.001541
19	0.001401	0.001448
20	0.001311	0.001356

Table 17: Storey Drift In Y-Direction (Mm) For (G+19) Storey Building

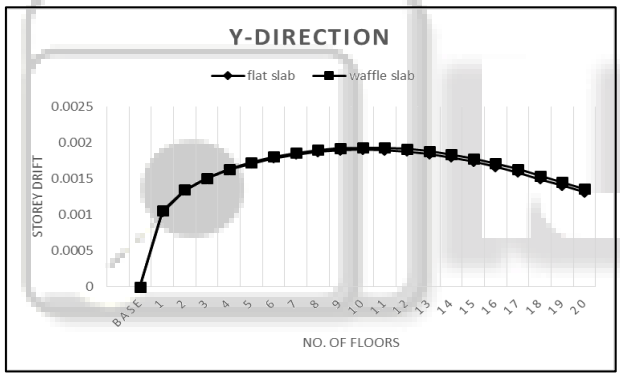


Fig. 15: Storey Drift In Y-Direction for (G+19) Storey Building

VII. CONCLUSION

Based on the results obtained it can be said that the maximum displacement value of flat slab is about 16% higher compared to waffle slab in both X and Y direction for G+9 storey building. In G+14 storey building, maximum displacement value of waffle slab is 89% higher compared to flat slab in X direction whereas in Y direction it increases upto 86%.In G+19 storey building, maximum displacement is constant in both flat and waffle slab in both X and Y direction with a slight variation. Whereas as for G+9 storey building, storey drift value of flat slab varies from 11% to 14% both in X and Y direction from waffle slab. In G+14 storey building, storey drift value of waffle slab is 45% to 47% higher compared to flat slab both in X and Y direction. In G+19 storey building variation of waffle slab is 1% to 3% higher than flat slab, both in X and Y direction. From the above obtained result it can be observed that for structure with a height less than 40m it is advisable to use waffle slab other than flat slab, whereas for structures of height above 40m it is advisable to use flat slab.

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