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Comparative Study of Conventional Slab, Flat Slab and Waffle Slab by using Finite Element Method

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Abstract*— The slab is the main component of the structure. There are different types of slab used in different structure and gives better appearance to the structure. In this project, three type of slab to be used. The comparative study of Conventional slab, flat slab, and waffle slab under seismic condition to be analyzed. An effort has been made to evaluate the study between Conventional slab, flat slab, and Waffle slab for G+10 story building. This type of slab has been analyzed and designed by ETABS software. The plan of waffle slab plan is done in such a way in order to accomplish better burden dispersion. The near investigation of waffle slab with flat Slabs and conventional slab and features the benefit waffle slab have over flat Slabs and conventional slab. The parametric studies comprise maximum lateral displacement, story drift, and axial forces generated in the column due to slab.

***Keywords*— ETABS, Conventional Slab, Flat Slab, Waffle Slab, Story Displacement.**

I. INTRODUCTION

There has been an expanding interest for development of tall structures because of an always expanding urbanization and flexuous populace. Tremor is the most despicable aspect of such tall constructions. As tremor powers are erratic in nature and capricious, we wanted to sharpen the design of apparatuses for breaking down structures under the activity of these powers. In this manner a cautious demonstrating of such tremor stacks should be done, to assess the conduct of the construction with a reasonable point of view of the harm that is normal. To examine the construction for different seismic tremor powers and afterward perform checks for different rules at each level has turned into a fundamental practice for the most recent few decades. For assurance of seismic reactions, it is important to complete seismic investigation of the design utilizing diverse accessible strategies. A slab is a construction used to help the surface level. Slabs are little for private constructions while they are long in halls, homerooms, just as in numerous business structures. The plan of the long range slabs should be possible in numerous ways. There are many kinds of slabs in the development field. There are various kinds of slabs utilized for development.

A. Flat Slab

Flat slabs are shaft-less designs which are entirely usable nowadays. In flat slab structure we are just including boards the highest point of the segments and expanding the thickness of the slab, structures with flat slabs are more usable due to diminishing floor to floor tallness of the design, low sum is needed to be built and for different reasons like engineering necessities and so on. Flat slabs are perhaps the most well-known floor system utilized in private structures, vehicle leaves, and numerous different designs. Flat slabs are supported by the two, engineers and customers on account of their tasteful allure and financial reasons.

B. Conventional Slab

The slab which is upheld on beams and segments is called an ordinary slab. The thickness of the slab is little, while the profundity of the shaft is enormous, and load is moved to pillars and afterward to slabs. It requires more formwork when constructed than a flat slab. In customary sort of slab there is no need of giving slab covers.

C. Waffle Slab

Waffle slabs can be characterized as "A supported substantial slab with similarly separated ribs corresponding to the sides, having a waffle appearance from underneath". A waffle slab is a kind of building material that has two-directional support outwardly of the material, providing it with the state of the pockets on a waffle. The highest point of a waffle slab is for the most part smooth, similar to a customary structure surface, yet under has a shape suggestive of a waffle. Straight lines run the whole width and length of the slab, for the most part raised a few creeps from the surface.

II. LITERATURE REVIEW

Alaa C. Galeb, Zainab F. Atiyah, 2011

Two contextual analyses are discussed; the first is a waffle slab with strong heads, and the second is a waffle slab with a band that radiates along slab centrelines. The immediate plan technique is utilized for the primary examination and plan of slabs. The expense work addresses the expense of cement, steel, and formwork for the slab. The plan factors are taken as the successful profundity of the slab, ribs width, the dividing between ribs, the top slab thickness, the space of flexural support right now basic segments, the band radiates width, and the space of steel support of the pillars. The limitations remember the imperatives for measurements of the rib, the imperatives on the top slab thickness, the requirements on the spaces of steel support to fulfil the flexural and the base region prerequisites, the limitations on the slab thickness to fulfil flexural conduct, oblige support and give sufficient substantial cover, and the imperatives on the longitudinal support of band radiates. A PC program is composed utilizing MATLAB to play out the underlying investigation and plan of waffle slabs by the immediate plan strategy. The improvement cycle is done utilizing the underlying hereditary calculation tool stash of MATLAB.

Bhautik D. Jasoliya,maulik Kakadiya 2020

In R.C.C working without a shear divider, the bar and slab size is very weighty and there is a parcel of the clog of support at the joint it is hard to put and vibrate concrete at these spots and uproot is very substantial which prompts weighty powers in part. The examination is via completion of R.C.C working with the various posting of the shear divider on the floor plan by utilizing E-TABS programming. It gives the possibility of examination of R.C.C working with the various arrangements. The primary goal of quake engineers is to plan and fabricate a construction so that harm to the design during the tremor is limited. In multi-storeyed structures flat slab and waffle, slabs are by and large connected when segment dispersing is more. Flat slabs and waffle slabs are utilized in structures as prerequisites for seriously working spaces like business structures, studios, get-together structures, and so on. The fundamental inconvenience of designs with flat slabs and waffle slabs is their absence of withstanding seismic burdens. In this study are introduced the parts of a square formed waffle slab computation, upheld dependably and having a two-way post-tensioning support arranged allegorically. It is depicted the waffle slab framework, its attributes, starter plan of forming components, mechanical viewpoints with respect to the assembling of precast boards, insights about utilized materials, the support format, and the computation of prestressing power.

Shubham Sharma, Amritansh Sharma and Dr. Pankaj Singh June 2020

Waffle slab development comprises substantial joists at right points to one another with strong heads at the segment which is required for shear necessities or with strong wide pillar areas on the slab centrelines for uniform profundity development. Waffle slab development permits an extensive decrease in the dead heap of the general design when contrasted with flat slabs and ordinary RCC slabs. The thickness of waffle slabs can be limited to an extraordinary degree when contrasted with flat slabs and RCC slabs. The base part of the waffle slab has many square projections with ribs traversing in two ways. The ribs are built up with steel to oppose flexural ductile anxieties. The plan of the waffle slab is done in such a way as to accomplish better burden circulation. This paper manages a similar investigation of Waffle slabs with flat slabs and regular RCC slabs and features the benefits waffle slabs have over flat slabs and RCC slabs. This examination is displayed with the assistance of a contextual investigation by planning waffle slabs alongside flat slabs and RCC slabs with the assistance of IS 456-2000 and displayed with a correlation of different focuses.

Aashapak Rashid Shaikh, N.C. Dubey March 2020

Timoshenko's hypothesis of plates is utilized to assess plan minutes and shears happening in the ribs of a Grid floor precisely. Notwithstanding, it includes accepting extents of boundaries like separating of ribs, the thickness of the slab, and width of the rib which have a significant impact on the general economy of the Grid floor slab. The point of this review is to systematically discover the impact of these expected boundaries on the general economy of the design. Framework floors of sizes 12 m X 16 m, 14 m X 16 m, and 16 m X 16 m were intended for different elements of the slab, rib, and distinctive separating. The expense of every slab is assessed and collaboration bends are created. From this review, it tends to be presumed that the expense of the lattice floor would be least if the least thickness of slab, least width of ribs, and greatest dividing of ribs is embraced. Further, for the run-of-the-mill case considered, the estimated technique for Ranking - the Grashoff hypothesis thinks little of the minutes by around 20 %.

Mohammed J. Hussein, Hussain A. Jabir, Thaar S. Al-Gasham 2021

For this situation, the mechanical properties of slabs amazingly diminish, and reinforcement should be applied. Along these lines, this examination proposed four strategies to recover the lost mechanical attributes of slabs inferable from openings. Six built-up substantial slabs were ready with comparable measurements, 1300*1300*120 mm. One of them was a reference without opening, while the others contained a square edge opening of 350 mm side. For slabs with openings, one example was the control left without fortifying, and the excess four were fortified using different strategies, which were Carbon Fiber

Reinforced Polymer (CFRP), steel plates, steel bars, and close surface mounted Engineered Cementations Composite (ECC) with steel network. The slabs were presented to consistently dispersed burden up to disappointment.

Jasim M. Mhalhal 2021

This work principally planned to contrast the air bubble slab tentatively and strong slabs affected by restricted rehashed four-point loads. In this manner, six slab strips were fabricated in similar structures, aside from the cross-segment type. Three were strong, and the others were voided due to putting 70 mm-distance across balls inside them. Likewise, the shear range to powerful profundity proportion (a/d) was additionally contemplated. In like manner, one slab from each kind was tried, with the a/d being either 2, 3.5, or 5. The applied burdens were rehashed ten cycles at a heap level of 25 kN, addressing 70 % of a definitive burden assessed by the ACI-19 code, and afterward endured bit by bit until the slabs fell. The outcomes recorded that the balls' quality caused slabs to flop unexpectedly because of shear mode paying little mind to the a/d. For a similar slab type, the slabs' solidarity, firmness, and sturdiness decreased as the a/d was expanded; all things considered, the flexibility showed a contrary pattern. Contrasted with strong similar, the air pocket slabs' mechanical estimations, barring the assistance solidness, dropped prominently.

A. Conclusion from literature review

1) The slab analysis is to be done by various software such as MATLAB, STADD-Pro, etc.
2) The variation of slab thickness leads to the deformation of the structure. The stability of the structure depends on the column and beam likewise it also depends on the slab thickness.
3) The slab is designed by various codes with different standards.

III. OBJECTIVE

A. To analyse and compare the responses of a structure subjected to seismic excitation
B. To investigate the pushover curve of the conventional slab, waffle slab, and flat slab.
C. To analyse the punching shear, base shear, deflection, and displacement of the conventional slab, waffle slab, and flat slab and compare them.
D. To compare the estimated cost of all types of slabs with their reinforcement detail.

IV. METHODOLOGY

A. Create a New Model

We will begin the model utilizing the accompanying advances:

- Set the units to kN and meter, "kN-m", utilizing the dropdown enclose the lower right corner of the ETABS screen.
- Select the File menu > New Model order.
- Click the No button in the New Model Initialization structure. This demonstrates that we don't wish to involve a past model as the beginning stage for this model.
- This currently opens the Building Plan Grid System and Story Data Definition structure, where a significant part of the meaning of the design happens.
- Following are particular buildings.

Grade of concrete- M 20
Zone factor (Z) -0.36
Grade of steel -Fe 500
Response reduction factor (R)- 5.0
Floor to floor height -3 m
Importance factor (I) -1.0
Ground floor height -0.750 m
Soil type Medium soil- II
Dead load- 2 kN/m2
Slab thickness -200 mm
Slab Type: 1. Flat Slab 2. Waffle Slab 3. Conventional Slab
Columns -450 × 450 mm
Beams -350 × 450 mm
Live load on all floors -3 kN/m2
Damping ratio- 5%

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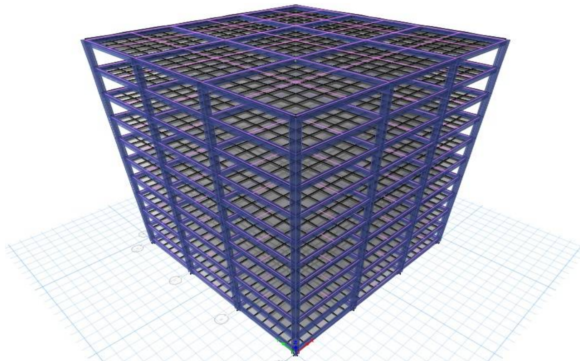

Fig. 1 Conventional Slab

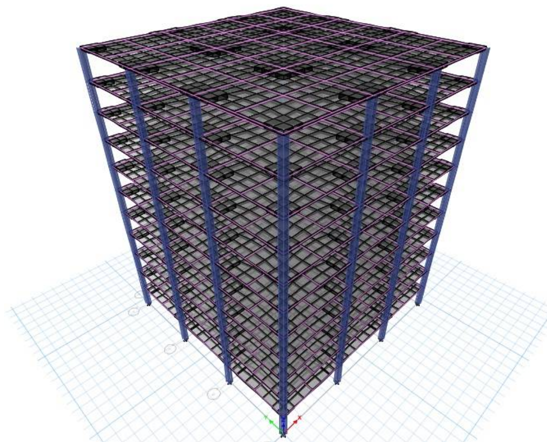

Fig. 2 Flat Slab

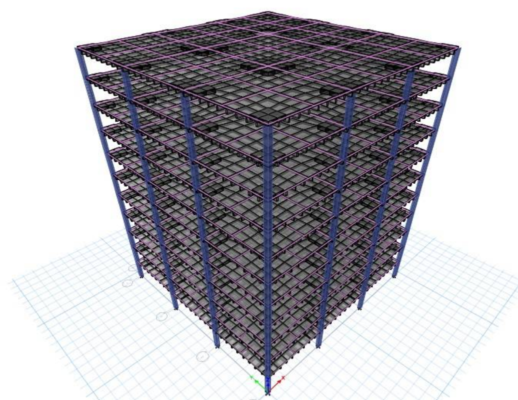

Fig. 3 Waffle Slab

B. Fractional Safety Factors

The arrangement quality for concrete and fortress is procured by parcelling the brand-name nature of the material by a deficient prosperity factor, γm. The assessments of γm used in the program are according to the accompanying:

Fragmentary security factor for steel, γs = 1.15 (IS 36.4.2.1)

Fragmentary security factor for concrete, γc = 1.5 (IS 36.4.2.1)

These factors are at this point merged into the arrangement conditions and tables in the code. These characteristics can be overwritten; regardless, an alert is provoked.

C. Slab Design

ETABS Slab plan framework incorporates portraying sets of strips in two usually inverse directions. The spaces of the strips are commonly addressed by the spaces of the segment reinforces. The centre power, minutes, and shears for a specific strip are

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recovered from the examination (in view of the Wood Armer method), and a flexural design is finished ward on a conclusive quality construction strategy.

The segment structure strategy incorporates the going with progress:

- Structure flexural support
- Arrangement shear support
- Punching check

V. RESULT

The main purpose of the slab design is to find out the seismic behaviour of the structure and also find out the deflection under the loading condition. In this analysis, dead load, live load, and seismic load in x and y directions are applied. Due to this analysis, the following results are found.

A. Slab Finite Element Design of Top Rebar's Intensity

In this analysis, the top rebar intensity is calculated for the conventional slab, flat slab, and waffle slab. In this analysis, the measurement scale to be provided and reading is given to that scale due to which the intensity of the rebar in the slab is found.

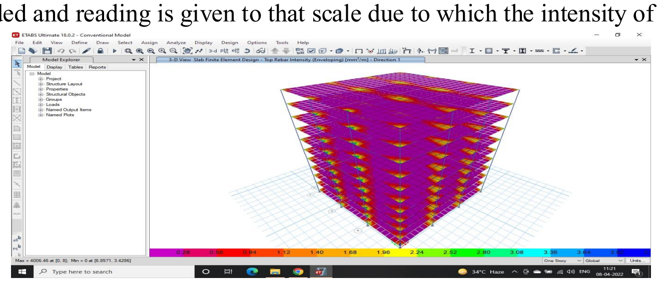

Fig. 4 Top Rebar of Conventional Slab

In this slab, the middle portion has a required greater intensity of rebar due to which the slab portion does not bend due to loading. The Violet colour portion has satisfies the loading condition but the yellow portion required a maximum number of rebar for which it satisfied all the condition.

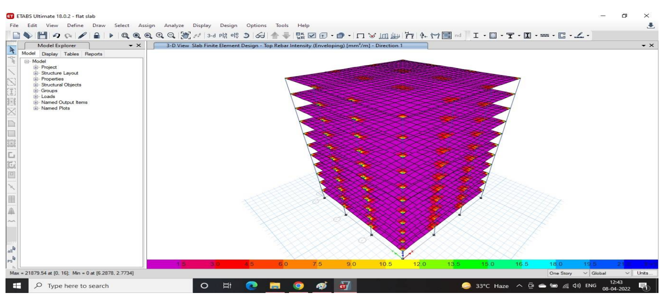

Fig. 5 Top Rebar of Flat Slab

In the flat slab, the drop panel is introduced and the top rebar intensity is maximum in that drop panel so that it requires a maximum number of top bars for the stability of the slab.

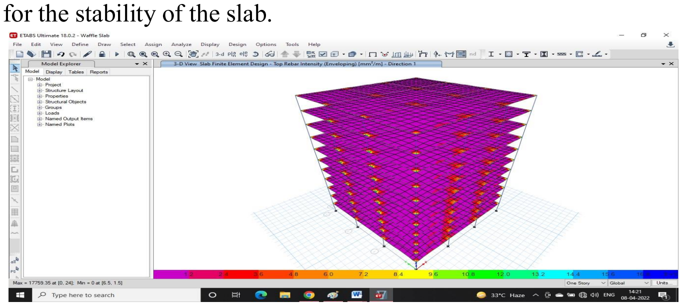

Fig. 6 Top Rebar of Waffle Slab

In this slab, in the drop panel, the yellowish portion is found out which shows that the intensity of the rebar is less and around the yellow portion the intensity is increased.

B. Displacement of Model due to EQx

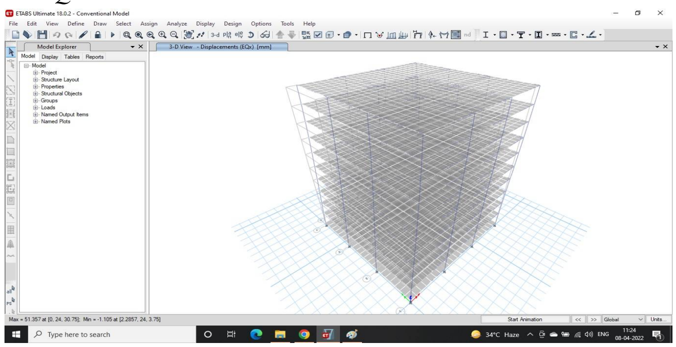

Fig. 7 Model Displacement due to Earthquake in x-Direction of Conventional slab Building

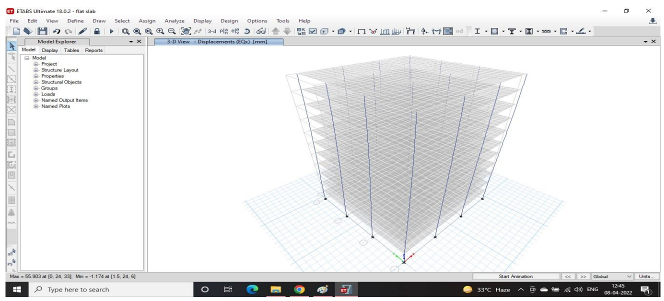

Fig. 8 Model Displacement due to Earthquake in x-Direction of Flat slab Building

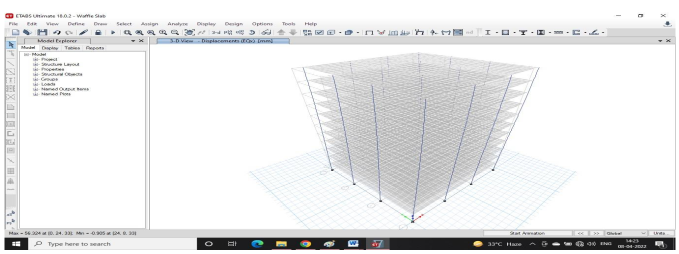

Fig. 9 Model Displacement due to Earthquake in x-Direction of Waffle slab Building

The above Figures show the displacement of the structure due to earthquake loading in the x-direction. The below graph shows the displacement of the structure.

TABLE I
DISPLACEMENT OF MODEL DUE TO EQX (MM)

Story	Conventional Slab	Flat Slab	Waffle Slab
	mm	mm	mm
Story11	0.002	0.009	0.006
Story10	0.002	0.009	0.005
Story9	0.002	0.008	0.005
Story8	0.002	0.008	0.005
Story7	0.001	0.007	0.004
Story6	0.001	0.006	0.004
Story5	0.001	0.005	0.003
Story4	0.001	0.004	0.003
Story3	4.77E-04	0.003	0.002
Story2	2.17E-04	0.002	0.001
Story1	1.19E-05	0.001	0.00049
Base	0	0	0

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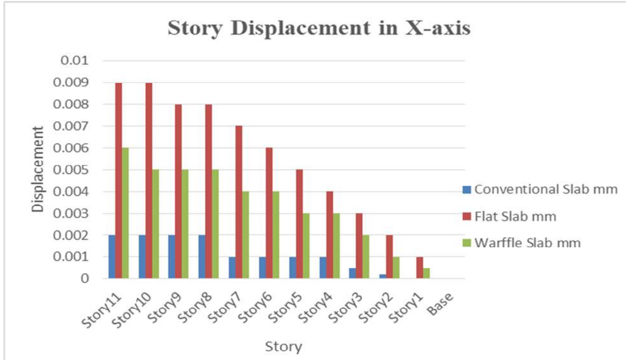

Fig. 10 Comparative story displacement in X direction

The above graph shows that the story displacement due to the earthquake in the X-direction is displayed in the above graph. In this graph, the displacement of the flat slab is more as compared to the waffle slab and conventional slab. In the 11th story the maximum displacement occurs i.e. 0.009mm in flat slab and in conventional slab it is 0.002mm and in waffle slab, it is 0.006mm.

C. Displacement of Model due to EQy

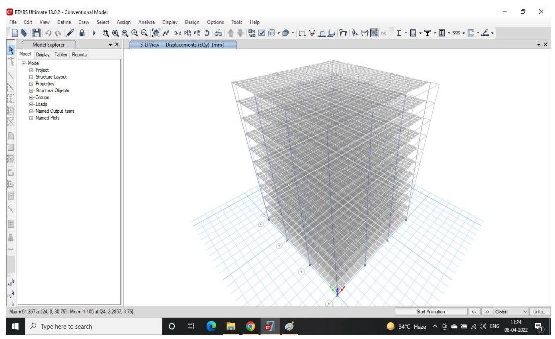

Fig. 11 Model Displacement due to Earthquake in Y-Direction of Conventional slab Building

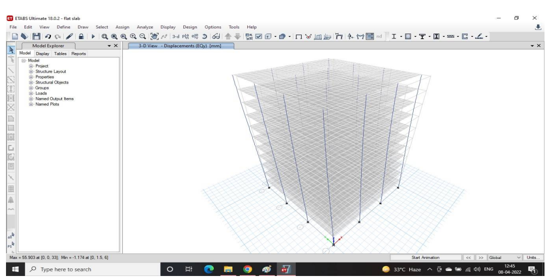

Fig. 12 Model Displacement due to Earthquake in Y-Direction of Flat slab Building

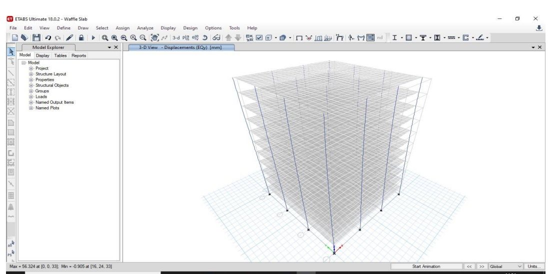

Fig. 13 Model Displacement due to Earthquake in Y-Direction of Waffle slab Building

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TABLE II
DISPLACEMENT OF MODEL DUE TO EQY (MM)

Story	Conventional Slab	Flat Slab	Waffle Slab
	mm	mm	mm
Story11	0.022	0.021	0.023
Story10	0.022	0.021	0.023
Story9	0.021	0.02	0.022
Story8	0.019	0.019	0.02
Story7	0.017	0.017	0.019
Story6	0.015	0.015	0.016
Story5	0.012	0.013	0.014
Story4	0.009	0.01	0.011
Story3	0.006	0.007	0.008
Story2	0.003	0.004	0.005
Story1	1.46E-04	0.002	0.002
Base	0	0	0

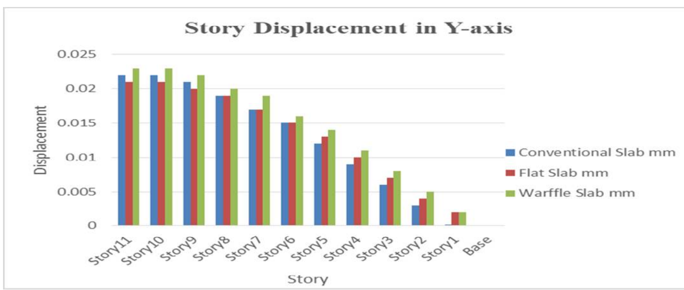

Fig. 13 Comparative story displacement in Y direction

In the above graph, the displacement occurs due to earthquakes in Y-direction. The displacement of the waffle slab is more as compared to the conventional and flat slab. The maximum displacement in the waffle slab in the 11th story is 0.023mm and that of base displacement is negligible.

D. Story Drift

The lateral displacement of the floor with respect to the below floor is known as story drift. In this the story drift is taken out form the model.

TABLE III
STORY DRIFT IN X-DIRECTION (MM)

Story	Conventional Slab	Flat slab	Waffle Slab
Story11	1.70E-08	7.46E-08	4.39E-08
Story10	2.96E-08	1.26E-07	7.74E-08
Story9	4.25E-08	1.80E-07	1.11E-07
Story8	5.45E-08	2.32E-07	1.43E-07
Story7	6.52E-08	2.79E-07	1.72E-07
Story6	7.43E-08	3.20E-07	1.97E-07
Story5	8.16E-08	3.54E-07	2.18E-07
Story4	8.65E-08	3.79E-07	2.35E-07
Story3	8.67E-08	3.92E-07	2.45E-07
Story2	6.83E-08	3.71E-07	2.43E-07
Story1	1.58E-08	2.17E-07	1.64E-07
Base	0	0	0.00E+00

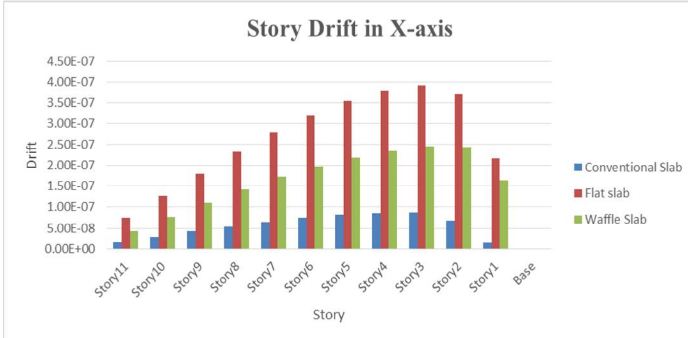

Fig. 14 Comparative Story Drift of the structure

In this comparative graph the lateral displacement of the story 3 has greater value. This graph pattern shows form the upper story to downward, the drift increases and at the base it is negligible. This story drift are calculated by the earthquake in X-direction.

TABLE IV
STORY DRIFT IN Y-DIRECTION (MM)

Story	Conventional slab	Flat Slab	Waffle Slab
Story11	2.09E-07	1.82E-07	1.84E-07
Story10	3.63E-07	3.07E-07	3.24E-07
Story9	0.000001	4.39E-07	4.66E-07
Story8	0.000001	0.000001	1.00E-06
Story7	0.000001	0.000001	1.00E-06
Story6	0.000001	0.000001	1.00E-06
Story5	0.000001	0.000001	1.00E-06
Story4	0.000001	0.000001	1.00E-06
Story3	0.000001	0.000001	1.00E-06
Story2	0.000001	0.000001	1.00E-06
Story1	1.94E-07	0.000001	1.00E-06
Base	0	0	0.00E+00

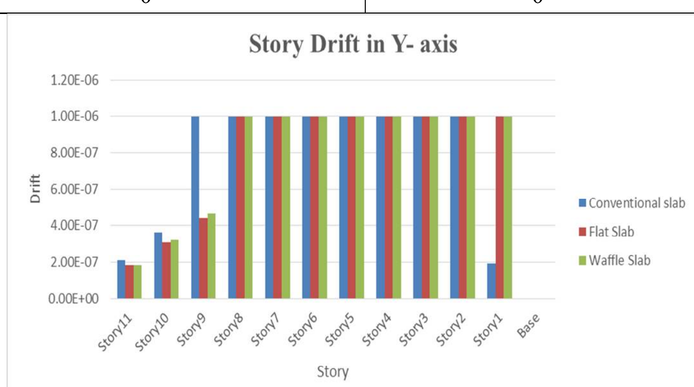

Fig. 15 Comparative Story Drift of the structure

The above graph shows the comparative story drift due to earthquake in Y-direction. In this the drift are found to be similar from story 8 to story 2. So that the drifting are formed.

E. Response Spectrum

A response spectrum is a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock.

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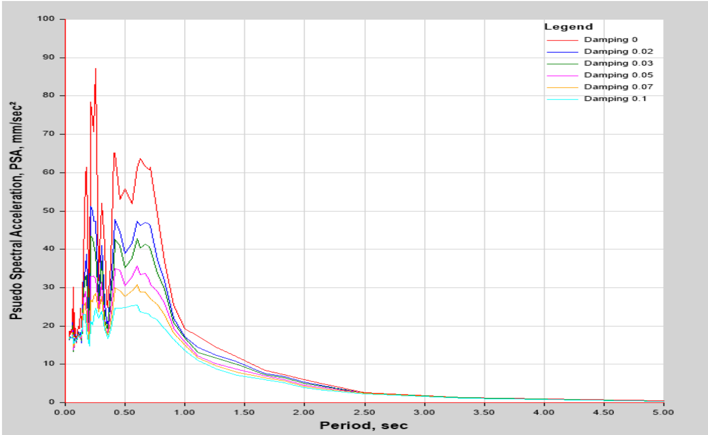

Fig. 16 Response Spectrum for Conventional Slab

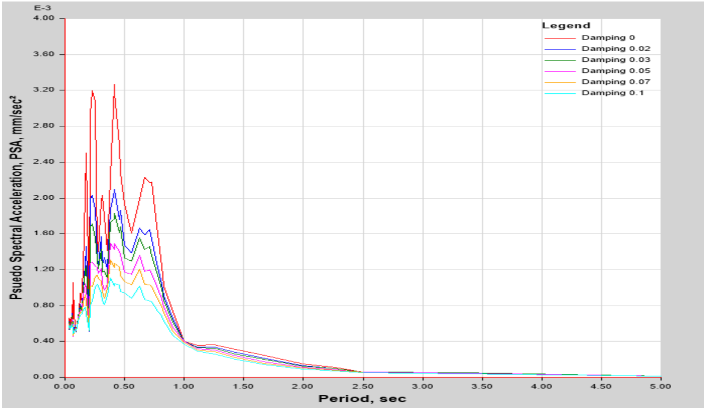

Fig. 17 Response Spectrum for Flat Slab

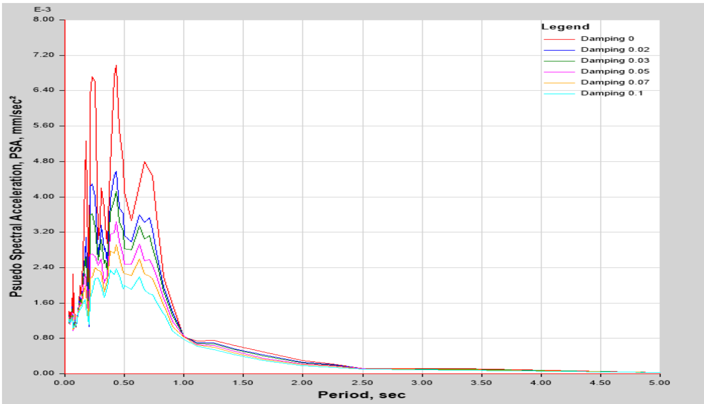

Fig. 18 Response Spectrum for Waffle Slab

VI. CONCLUSION

A. The top rebar intensity of the waffle slab is more as compared to the conventional slab and flat slab.
B. The modal displacement in the X direction is higher in the flat slab as compared to the conventional and waffle slab.
C. The modal displacement in the y-direction is increased in the waffle slab as compared to the Conventional slab and flat slab.
D. The story drift in the x-direction is greater in the flat slab as compared to the conventional slab and waffle slab.
E. The story drifts in the y-direction is the same in all slabs so that all structures behave in a similar manner.
F. The response spectrum for various damping ratios is shown in the above graph in which at damping ratio 0 the graph increases.

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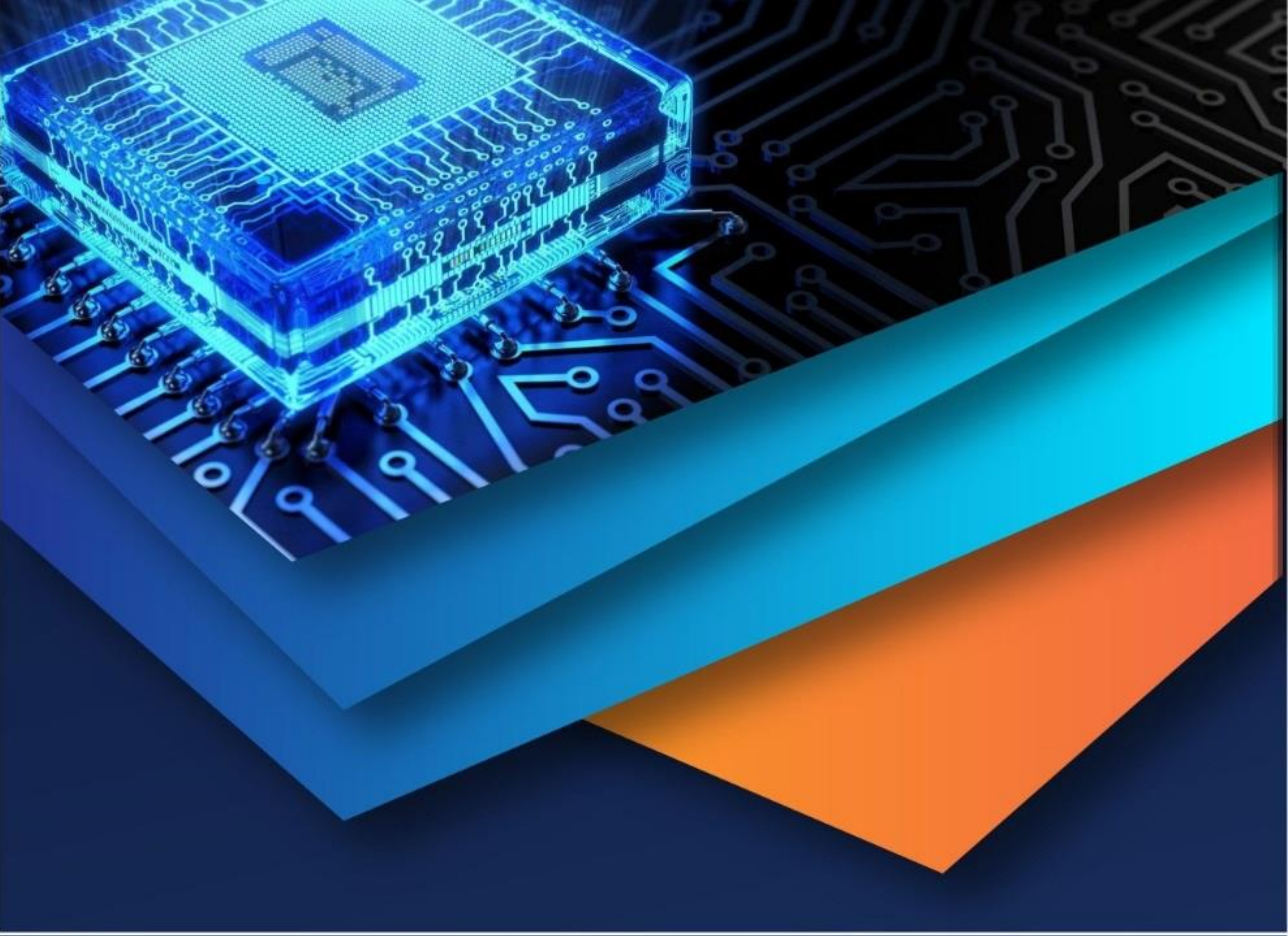

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