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Comparative Analysis of a Ribbed and Waffle Slab Under Seismic Load Using ETABS

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ABSTRACT

When a large space within a building needs to be covered without hindrance and supports, architects often deploy waffle slabs to construct floors and ceilings. Structural designers analyse such slabs, assuming the grid work as simply supported system (all four edges) and deriving solutions based on displacement compatibility of beams or plates to arrive at an approximate solution or performing a detailed finite element analysis (FEM) of the slab beam system using any of the generalized finite element software available in the market. This is so because no analytical solution or quick computational tool exists, except for the case of slabs with all edges simply supported. In this study we are performing comparative analysis of ribbed and waffle slab to determine the most stable and distributive one in comparison.

To validate the results, selected cases are compared with finite element analysis and results are compared in terms of forces, moment, displacement and drift in both direction.

Keywords: Bending moment, Deflection, boundary condition, Plate equations, Shape functions, Shear force, Waffle slab, Ribbed slab , ETABS.

I. INTRODUCTION

Majority of the building structures consist of structural elements such as beams, columns, braces, shear walls, and floor slabs. Floor slabs in multi storey buildings, which usually transmit gravity loads to the structural system, are also required to transfer lateral inertia forces to the structural system. Generally, the models used for the analysis of such kind of building structures are prepared without the floor slabs assuming that they have negligible effects on the response of a structure. Thus, the floor slabs are simply replaced by rigid floor diaphragms for simplicity in the analysis procedure. In this case, the flexural stiffness of the floor slabs is ignored in the analysis. In addition, although the beams are located under the floor slabs in a structure, the analytical model were developed assuming that the axes of floor slabs and beams are located on a common plane.

The flexibility of floor diaphragms mainly when cracking and yielding are expected, it affects the seismic response of buildings in two major ways:

- The distribution of the lateral forces to the vertical elements is altered.
- The dynamic characteristics of the building are influenced by the local vibration modes of the floor systems.

These effects are totally ignored in analysis when floor slabs are assumed to be perfectly rigid.
Therefore, in the dynamic analysis the analytical model which disregards the flexural stiffness of the floor slabs would induce substantial analytical errors. In this study, research on the efficient modeling techniques which can consider the flexural stiffness of the floor slabs are carried out. Comparing the results on the same structure as G+11 using waffle slabs and one way ribbed slabs. In building structures, the flexural stiffness of the floor slabs is negligible in comparison with the in-plane stiffness of the floor slabs.

Waffle Slab

A waffle slab is a type of slab with holes underneath, giving an appearance of waffles. It is usually used where large spans are required (e.g auditorium) to avoid many columns interfering with space. Hence thick slabs spanning between wide beams (to avoid the beams protruding below for aesthetic reasons) are required. Since the tensile strength of concrete is mainly satisfied by the steel bar reinforcement, only the "ribs" containing the reinforcement are kept where the remaining 'unused' concrete portion below the neutral axis is removed, to reduce the self-weight of the slab. This is achieved by placing clay pots or other shapes on the formwork before casting of the concrete.

Waffle slabs provide stiffer and lighter slabs than an equivalent flat slab. The speed of construction for such slab is faster compared to conventional slab. Relatively lightweight hence economical. It uses 30% less concrete and 20% less steel than a raft slab. They provide low floor deflections. It has good finishes and robustness. Fairly slim floor depth and fire resistant. Excellent vibration control.

Waffle slabs are used where vibration is an issue and where large span slabs are to be constructed i.e areas having less number of columns. For example airport, hospitals, commercial and industrial buildings etc & where low slab deflections and high stability are required.

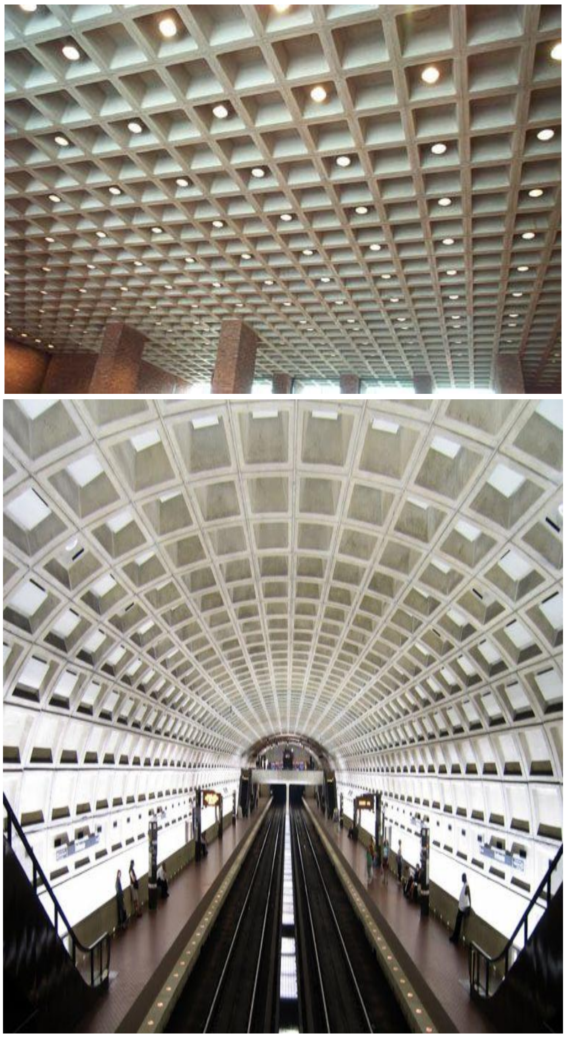


Fig 1. Waffle Slab

Ribbed Slab

Ribbed or waffle slab is a slab system which consists of series of parallel reinforced concrete T beams framing into reinforced concrete girders. The slab is the flange of the beam and the extended part is the web. The extended part is known as ribs. The spacing between the ribs should be in general 20-30 inch. The ribs are tapered in cross-section in its lower part.

In this type of slab, the tension stress is eliminated in the tension side of the slab. The strength of concrete in tension is very small and so elimination of much of the tension concrete is done by the use of pan forms. Economical where the live loads are fairly small such as apartment houses, hotels. Long slab spans can be constructed through ribbed and waffle Slabs. In many cases, long spans are desirable in the building. Ribbed or waffle slabs are an easy solution for this purpose. Provide architectural advantages. All the Electrical appliances can be installed easily in the gap of the ribs which can be architecturally aesthetic.

Fig 2 One way and Two way Ribbed Slab

Objectives of the study

The main aim of this study are as follows:

1. To evaluate performance of waffle & Ribbed slab under the design loading condition with different boundary condition.
2. To check performance of Waffle & Ribbed slab with multistory building system with seismic loading performance.
3. To compare the behavior Waffle and Ribbed slab system under lateral load and review the performance.
4. To study advantages/disadvantages of waffle & ribbed slab in the form of cost stability & strength.
5. To study the effect of stiffness of floor slab on the behavior of building when subjected to seismic loading.

II. LITERATURE REVIEW

Atif Zakaria et al (2019) this research paper presented assessment on two different slabs namely Grid slab and Ribbed Slab constituting of ribs to evaluate seismic response as they were highly suitable and economical for construction of long span structures. The considered models in this examination were OMRF outline with sheer walls along with the selection of 4,6,8 number of the story by utilizing ETABS programming for investigating and structure, the pursued examination techniques were Equivalent static strategy, reaction range, and time history. The criteria for the analytical comparison were story float, base shear, time-period, story shear and axial force in the columns.

As per the acquired results, the ends were expressed as the suitable determination of the slab framework assumed a significant job in the structure solidness against both sidelong and gravity forces. Grid slab building has a superior seismic reaction than ribbed slab building. At the point when the complete stature of the structure builds the base shear, uprooting, Story shear and float increments at the same time. In OMRF building shear walls takes the tremendous level of the base shear and the storey shear. Around above 95% from the load would-be withstood by shear walls.

Vinit P.Thakor and Tushar N. Patel (2019) the research paper valuated the behavior of reinforced concrete waffle slab attributable to rhythmatic activities of human beings and resonance. The specimen Waffle slab was modelled with the use Element Meshing Method using analytical programming "ETAB's" with various aspect ratios. The analysis included two different dynamic procedures namely, Free Vibration analysis so as to attain natural frequencies and Mode Shapes and force Vibration was use to attain Maximum Displacement.

The results concluded that as soon as the ratio of span increases, the mass raises leading to reduction in fundamental frequency.

Ayad Abdulhameed Sulaibia and Dhifaf Natiq (2017)

This research paper introduces the consequences of finite element investigation for two test apparatus (considered from other research works). This examination was based on the utilization of the Finite Element Method (FEM) by utilizing ANSYS (v.15) programming to investigate the rationality of experiments to confirm the legitimacy of FEM by correlation with exploratory outcomes. Besides, some parametric investigations on these works were done to cover the impact of some significant factors on ultimate load capacity and deflection which were not shrouded in the test work. The analytical reports of ANSYS programming for defined models presented great concurrence with the test results. Load-diversion curve for ANSYS models was found higher than the experimental curves. The normal estimation of the relationship factor was (98.85%) for the primary model and (73.7%) for the subsequent one. Results have demonstrated that the level of increment in firmness increments with an increase in the thickness of the slab, however, this expansion was administered by the separating between ribs.

The results stated that the rate of increment in Stiffness expanded with the expansion of slab thickness. Such expansion was monitored by the dispersing between ribs. The two-way ribbed (waffle) slab without a strong part in the area of loading has higher solidness the two-way ribbed (waffle) slab with a strong bit up to a similar farthest point. Past this breaking point, the solidness for this model was marginally diminished.

III. METHODS AND MATERIAL

Step-1 : To configure Indian Provisions and unit data in ETABS

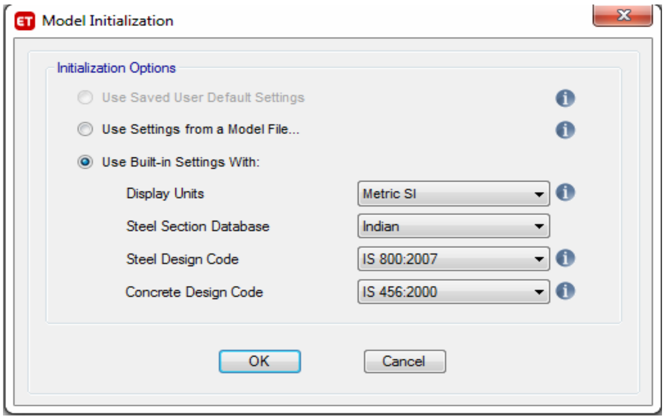


Fig 3 : Selection of Indian units and codal provisions

Step-2 : To Assign Grid data using analysis tool ETABS.

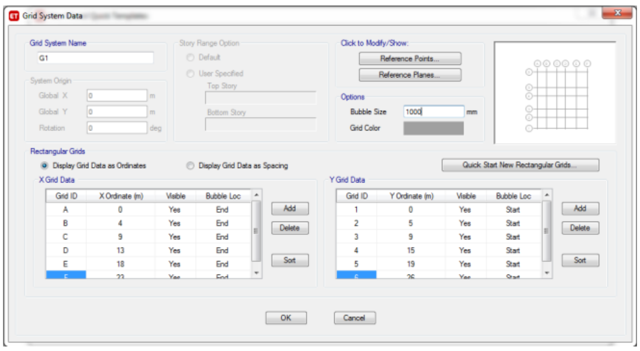


Fig 4: Geometrical grid

Step-3 : To Create materials as per Indian standards

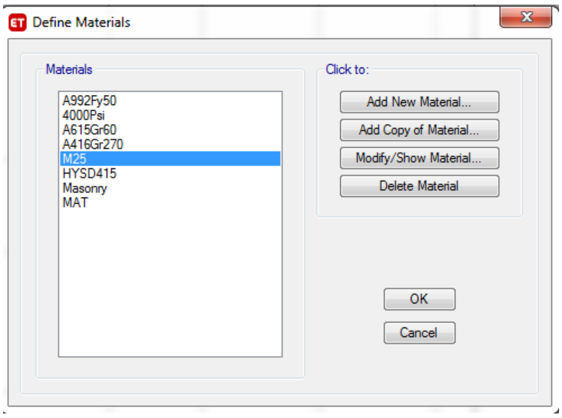


Fig 5: Define materials

Step-4 : To Define sectional data

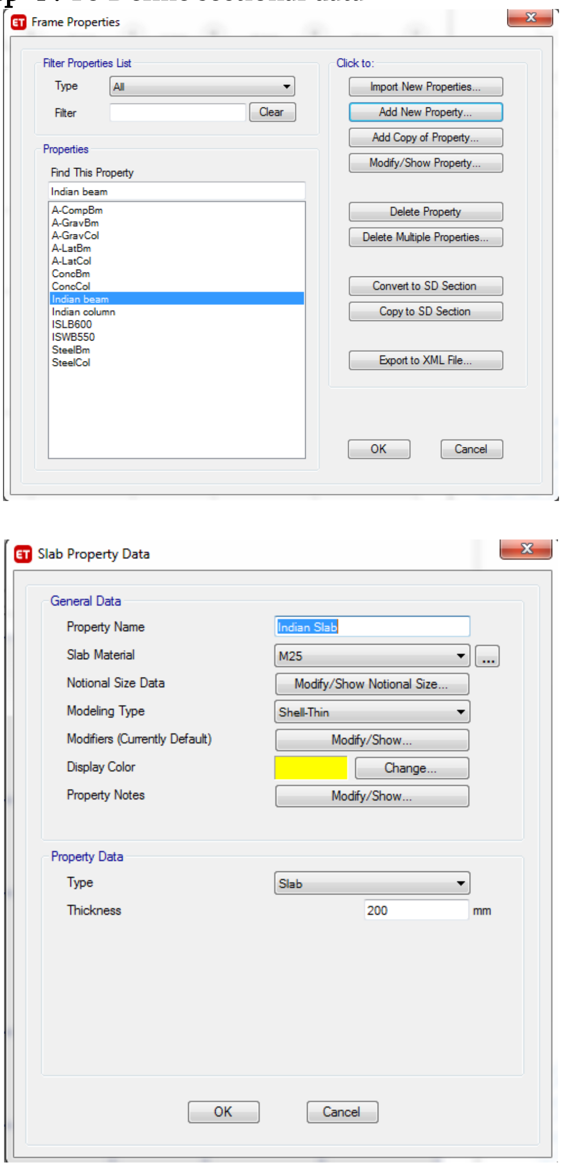


Fig 6: Sectional data

Step-5: To Create building design

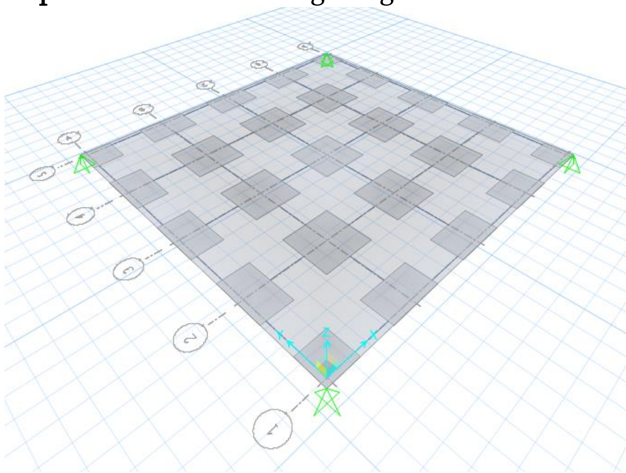
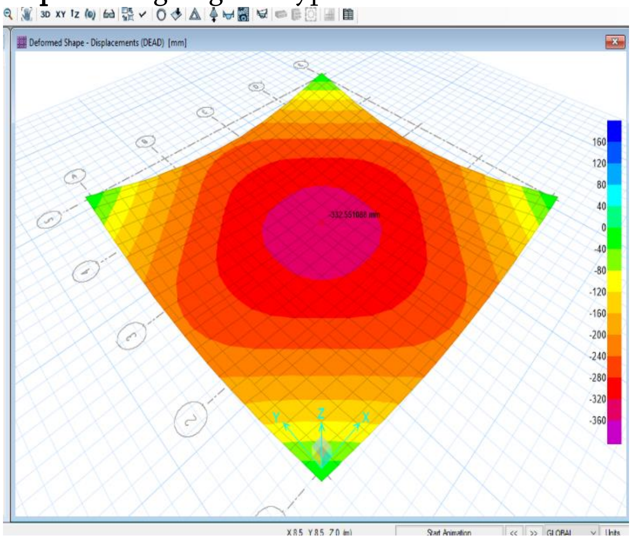
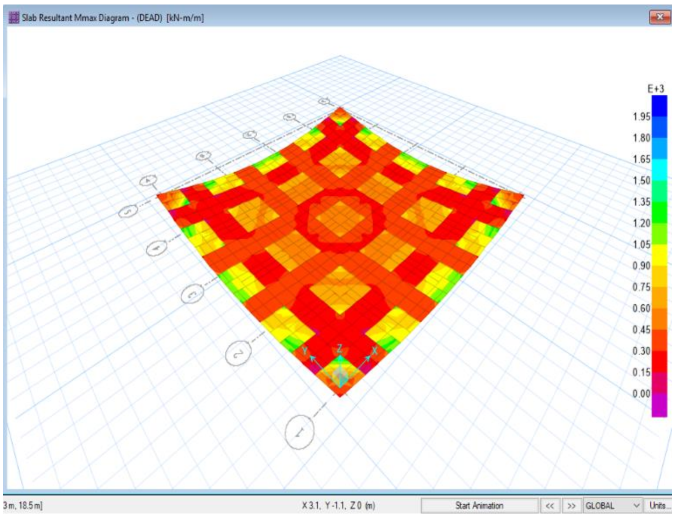


Fig 7: Unsymmetrical frame

Step-6 : Assigning slab type i.e. waffle and ribbed.



a. Ribbed Slab



b. Waffle Slab

Fig 8 : Slab configuration

Step-7: Assigning fixed end conditions

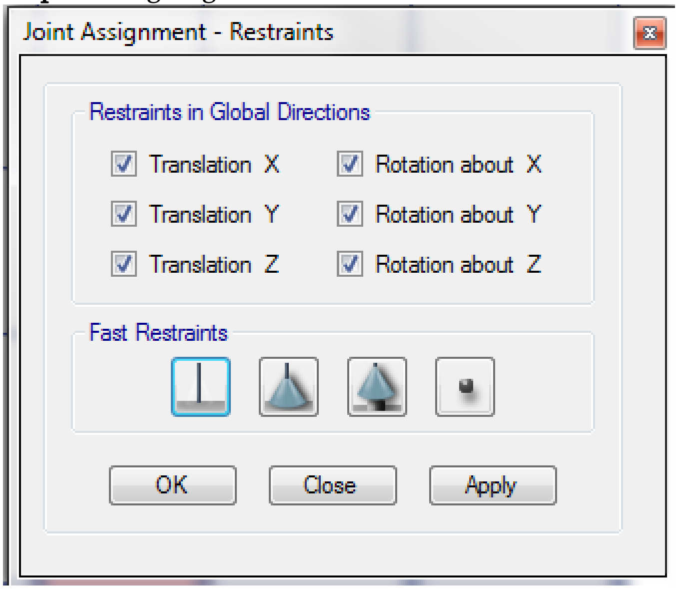


Fig 9: End conditions

Step-8: Define Loading Conditions

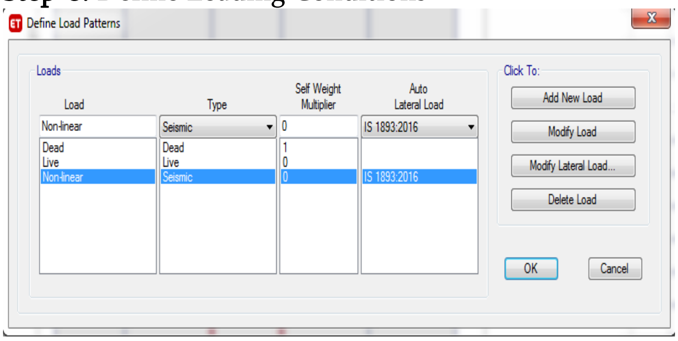


Fig 10: Loading Conditions

Step-9: Assigning Load combination:

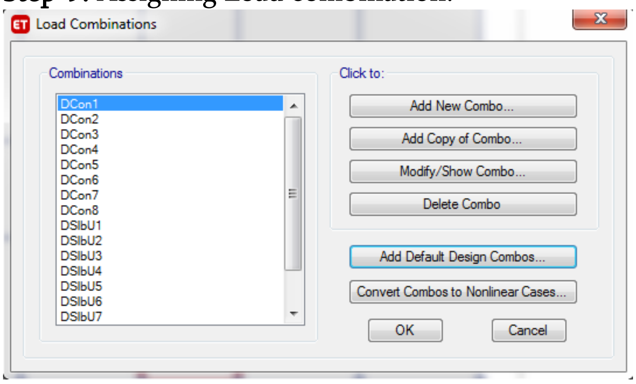


Fig 11: Load Combinations

Step-10: Check complete modelling and boundary conditions of the structure and analyze the programme

Step-11: Analysis considering boundary conditions and cases:

a. Analysis of Waffle Slab

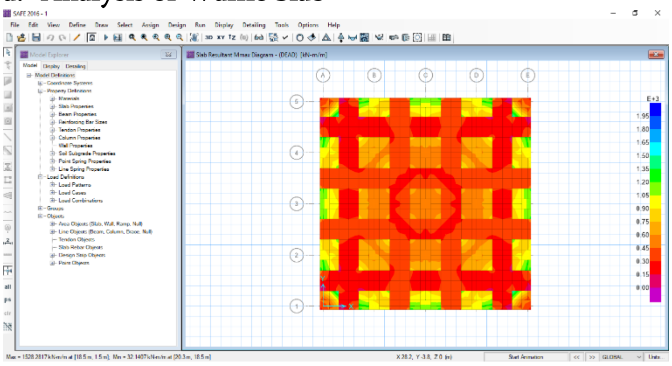


Fig 3.12 : Analysis

b. Analysis of Ribbed Slab

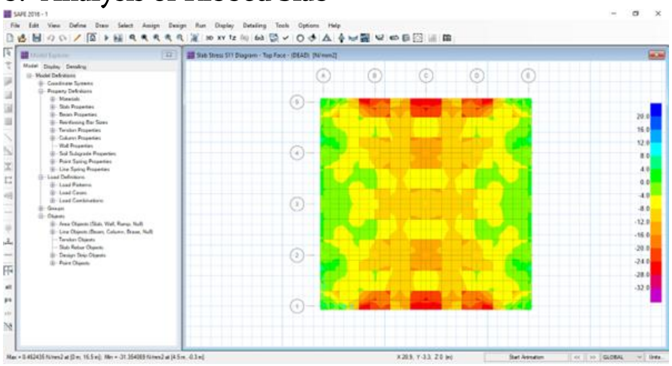


Fig 12: Analysis of both Cases

Table 1 : Geometrical Details

SR .NO.	PARAMETER	SIZES
1.	SURFACE AREA OF SLAB	400 m^2
2.	FLOOR HEIGHT	3 m
3.	LIVE LOAD	3 Kn / m^2
4.	FLOOR FINISH	1 Kn / m^2
5.	SIZE OF COLUMN	500x500 mm
6.	SIZE OF BEAM	150x500 mm
7.	DEAPTH OF SLAB	150 mm

8.	**DROP THICKNESS**	**500 mm**
10.	**ZONE**	**V**
11.	**IMPORTANCE FACTOR**	**1.2**
12.	**SOIL PROPERTY**	**MEDIUM SOIL**

IV. Analysis Result

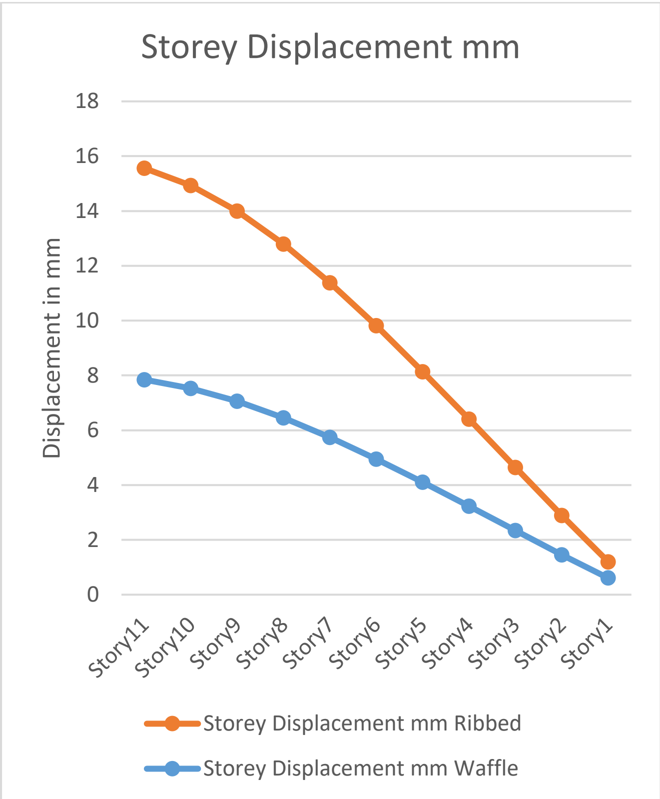


Fig 13 : Storey Displacement

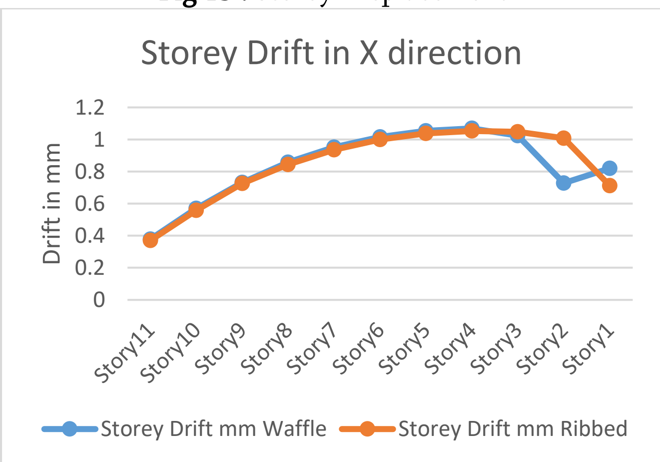


Fig 14 : Storey Drift

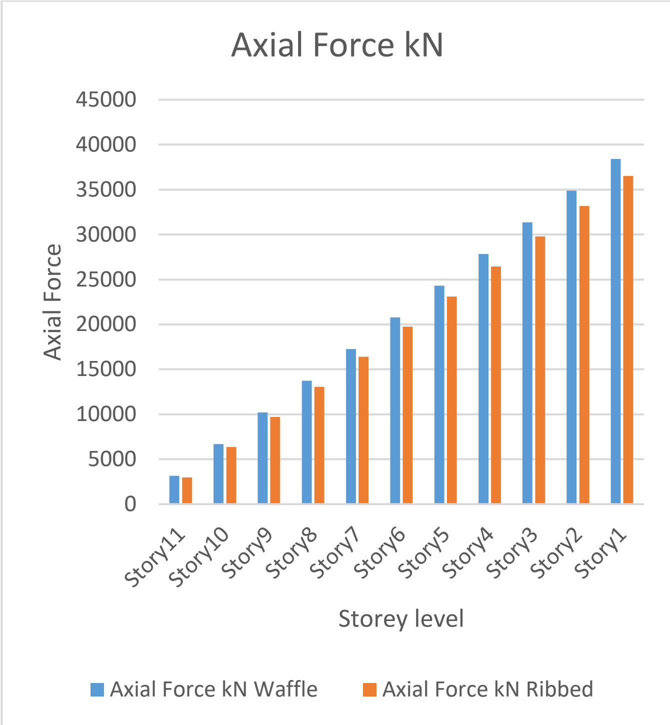


Fig 15 : Axial force

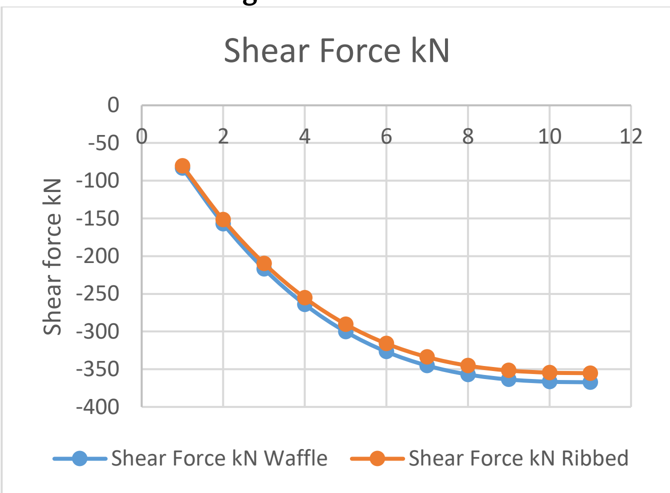


Fig 16 : Shear Force

V. CONCLUSION

Following observations are made in above chapter are as follows:

Storey Displacement:

In terms of Storey Displacement it can be conclude that ribbed slab is more stable in resisting lateral deformation of the structure due to seismic forces. As observed in analysis waffle slab shows 7.8 mm displacement whereas ribbed slab shows 7.711 mm displacement.

Drift:

Drift can be defined as the relative displacement of two consecutive floors. It is observed that upto 6th storey waffle slab is working more stable but as floors are increasing ribbed slab become more resisting and stable. Maximum drift observed in waffle slab is 1.069 mm whereas in ribbed 1.053 mm is observed.

Bending Moment:

In terms of bending moment it can be said that ribbed slab is more effective as it is retraining moment by 6% which can be said as more economical and cost effective than waffle slab. As less moment results in less area of steel required. Waffle slab is showing 23740.96 KN-m whereas ribbed slab observed 22440.08 KN-m.

Axial Force:

In terms of Axial forces it is observed that the distribution of load become uniform and linear it case of ribbed slab whereas in waffle slab it is comparatively unstable. In terms waffle slab shows 3165.461 KN and ribbed slab shows 2992.011 KN.

Shear Force`:

In terms of shear force ribbed slab shows 83.47 KN whereas waffle slab shows 80.45 KN of unbalance forces over horizontal members i.e. beam. Thus it can be said that waffle slab is observing 4.6 % less unbalanced forces.

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