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Comparative Study of Waffle Slab with Bracing System and Conventional Slabs without Bracing System

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Abstract: The analysis and design of structures are influenced by earthquake ground motion. The objective of this work is to analyse a commercial building with two different slab configurations, including conventional slabs, grid/waffle slabs and structures with bracings. The bracing system allows load to be transmitted from the frame to the braces, increasing the structure's capacity to withstand lateral loads. Time history analysis is performed in order to study the impact of seismic loads on structures with two different slab layouts using ETABS software. Storey drift, stiffness, joint displacement and storey displacement are among the parameters that have an influence on a structure's performance and are vital in determining how building will respond under seismic loads and other load combinations. IS 456-2000 code is taken into consideration for designing purpose. Live loads are taken in accordance to IS 875-part 1 and earthquake analysis is performed according to IS 1893-2016 Part 1. Results are depicted in the form of graphs and tables in the research paper. The outcome demonstrates that waffle slab with bracing system in terms of displacement and drift shows better performance, in contrast to alternative slab arrangements utilized in the seismic evaluation of the buildings.

I. INTRODUCTION

An earthquake is strong shaking of the earth resulting from the energy released by tectonic plate movement. Often, earthquakes result in severe damage to life and property. The performance of the structure under gravity and lateral loads is determined by various parameters such as the structure's shape and dimension, earthquake intensity, and slab type. It is critical to ensure that the structure is capable of withstanding horizontal ground vibrations. RCC slab structure is an important part of the building that is designed to bear both vertical and horizontal loads during earthquakes. While, conventional slab is one that is supported by standard beams and columns.

In case of conventional slab, the load is transferred from slab to beam, beam to column and column to foundation. On the other hand, waffles are made to cover large span with least possible columns to provide aesthetic appearance to the structures. These kinds of slabs are used in commercial buildings such as auditoriums, airports, theatre halls, and show rooms where there is minimal or no need for columns. The strength and stability of a structure during an earthquake is governed by the intensity of the quakes and the characteristics of the structure.

Here, barcing comes into significance as it is an economical and efficient way to strengthen the frame structures against lateral loads. The steel braces are usually placed in vertically aligned spaces. Steel bracing are cost-effective, easy to install, takes up less area and provide the extra strength and stiffness. Braced frames are highly effective for structures subjected to severe lateral loads, such as earthquake loads.

Time history analysis is an adaptive method for evaluating seismic behaviour of multi-storey building for the range of seismic intensities in order to understand how parameters such as storey shear , displacement, storey stiffness etc. affects seismic performance. The primary goal of the study is to evaluate the structural behaviour of waffle slab with bracings and conventional slab without bracings in seismic zone IV.

II. LITERATURE REVIEW

Kaushal Vijay Rathod, Sumit Gupta[2020]: This research paper discusses the outcomes of a time history study performed on a ten-story building. There is a necessity to study seismic analysis in order to develop earthquake resistance structures to assure safety against seismic forces of multi-story buildings. This paper reports use of ETABS to perform a nonlinear time history analysis on a ten-story RCC building frame while taking into account the timing of the 1940 El Centro Earthquake.

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Joshi, D. D., & Murnal, P. B. [2013]: In this research, authors have described the outcomes of pushover analysis on flat slabs using SAP2000, a widely used software. Pushover analysis is performed for (G+7) frame with five different models. It has been noted that the flat slab performs better than traditional slabs.

Manoj Kumar M, Victor Samson Raj A, et al [2020]: A structure's ductility and energy dissipation capability play a key role in its ability to withstand seismic force. Bracing was utilized to increase a steel-framed structure's ability to dissipate energy. Here, a steel-framed G+14 story building was chosen for examination. The addition of the X, V, and zipper bracing increased the ability of these structures to dissipate energy. For the analytical analysis, STAAD PRO and SAP2000 are used. Pushover analysis is used to relate the performance of the various braced framed structures. For all steel frames, the positioning of the bracings on the edge structure has raised the base shear conveying limit, raised the performance point, and decreased the displacement of the roof.

As per previous study by Mirza Mahaboob Baig, Abdul Rashid, Y Pavan Sai Durga Reddy et.al 2020: The purpose of their study is to determine behaviour of waffle slab constructions when the obstructing columns have been removed from the building's hall and room. This study concludes that ribbed/waffle slab structures are more susceptible to lateral loads than conventional slab structures because of an increase in self-weight. The research was carried out in seismic zone III and it was found that, in high seismic zones, ribbed slab structures perform less than conventional slab buildings because they have fewer columns, but that performance can be improved by structural retrofitting.

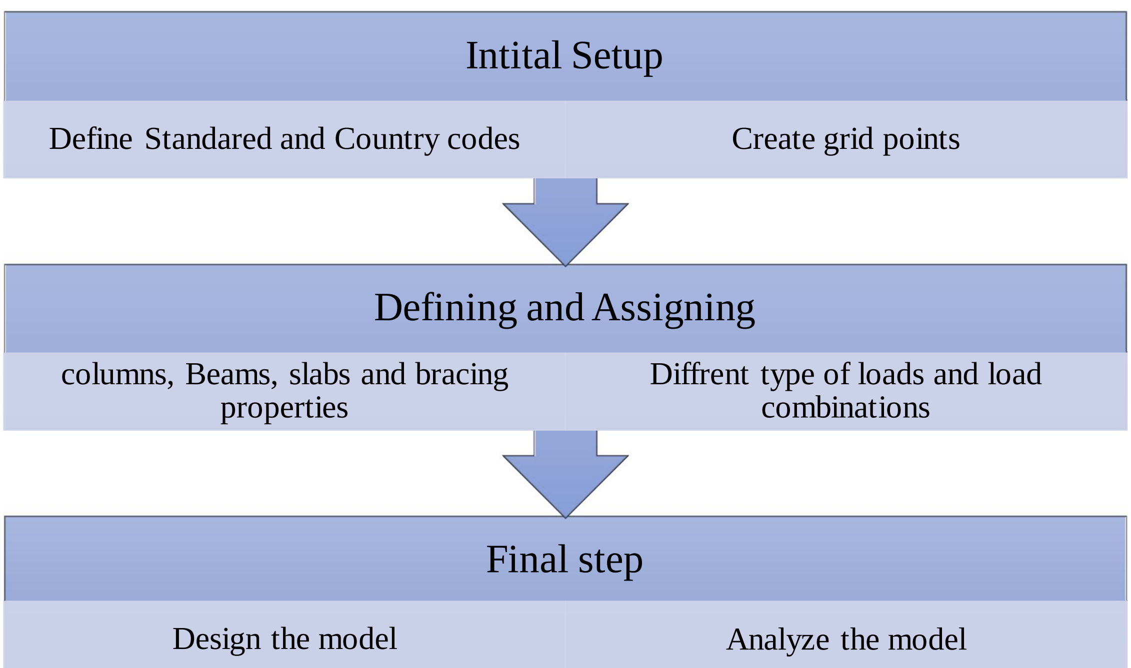
CH. Lokesh Nishanth, Y. Sai Swaroop, Durga Chaitanya Kumar Jagarapu, Pavan Kumar Jogi [2020]: The goal of the project was to examine and develop a commercial building adopting a variety of slab arrangements, including grid slabs, traditional slabs, flat slabs with drop panels, and load-bearing walls. The main purpose was to evaluate the cost effect of different slab arrangements. They concluded that grid slab is more cost-effective and safer than other building slab arrangements.

III. RESEARCH SIGNIFICANCE

The present study is conducted to evaluate the behaviour of G+4 reinforced concrete structure with conventional slab without any bracings and waffle slab with cross bracings in corners and central frame in each elevation face, subjected to earthquake forces in zone IV. The reinforced concrete structures are analysed using time history method taking Chamoli earthquake in reference. It shows the performance levels, behaviour of the components and failure mechanism in a building.

IV. METHODOLOGY

This paper includes modelling G+4 building by creating a plan of dimension 45m*45m and assigning material properties, RC sectional properties and load conditions using ETABSv16 software. Then we define time history function taking Chamoli earthquake data as reference for the analysis& the study is performed in seismic zone IV.



V. MODELLING PARAMETERS

Area of the building	45*45 m^2
Height of the building	25m
Columns	C1 450*450mm^2 C2 450*350 mm^2 C3 450*600 mm^2
Beams	B1 350*400 mm^2 B2 350*500 mm^2
Slab Type	Conventional and Waffle slab
Slab thickness	90mm for waffle slab, 125mm for conventional slab
Spacing of ribs	1500mm
Width of ribs	200mm
Overall depth	800mm
Bracings	X-type (ISA200*200*15)

VI. LOADING CONDITIONS

Seismic Loads	(IS 1893:2016)
Live load	5 KN/m^2 (IS 875-Part 2)
Dead load	6.8 KN/m^2 (IS 875-Part 1)
Seismic zone	IV
Seismic Zone Factor Z	0.24
Response Reduction Factor(R)	5
Importance factor (I)	1.5
Soil Type	II-(medium)
Scale factor (I.g/R)	1.962

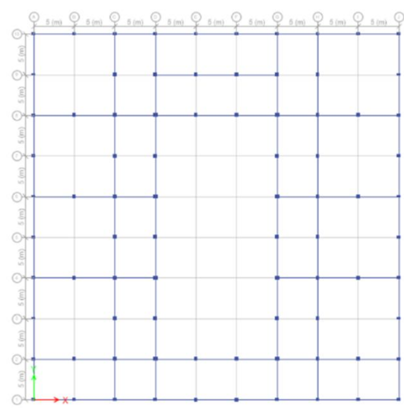


Fig: plan view of the slab

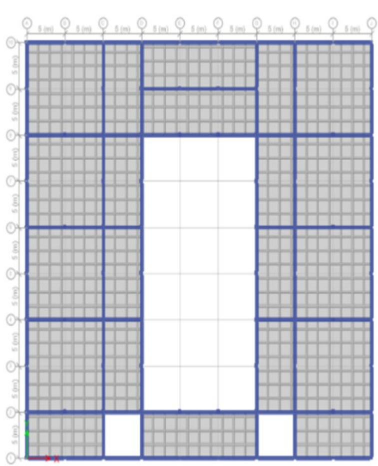


Fig: waffle slab

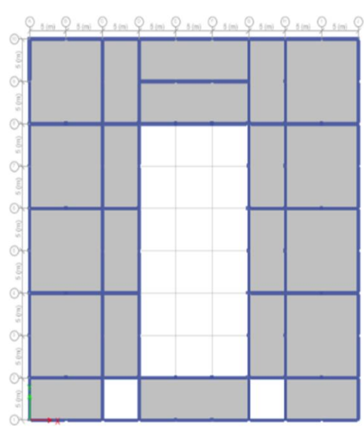


Fig: conventional slab

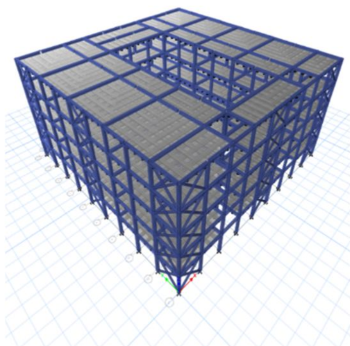


Fig: Waffle Slab with X-bracing

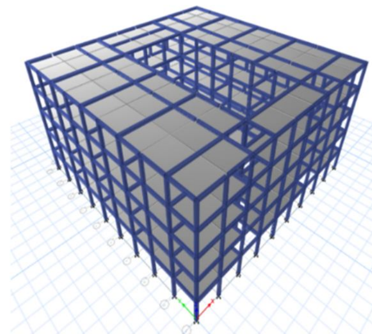


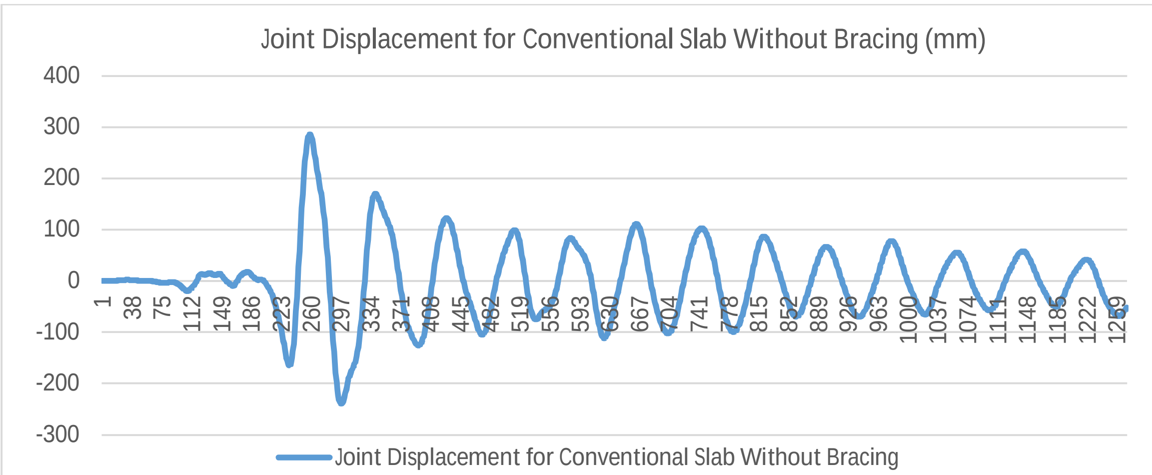
Fig: Conventional Slab without bracing

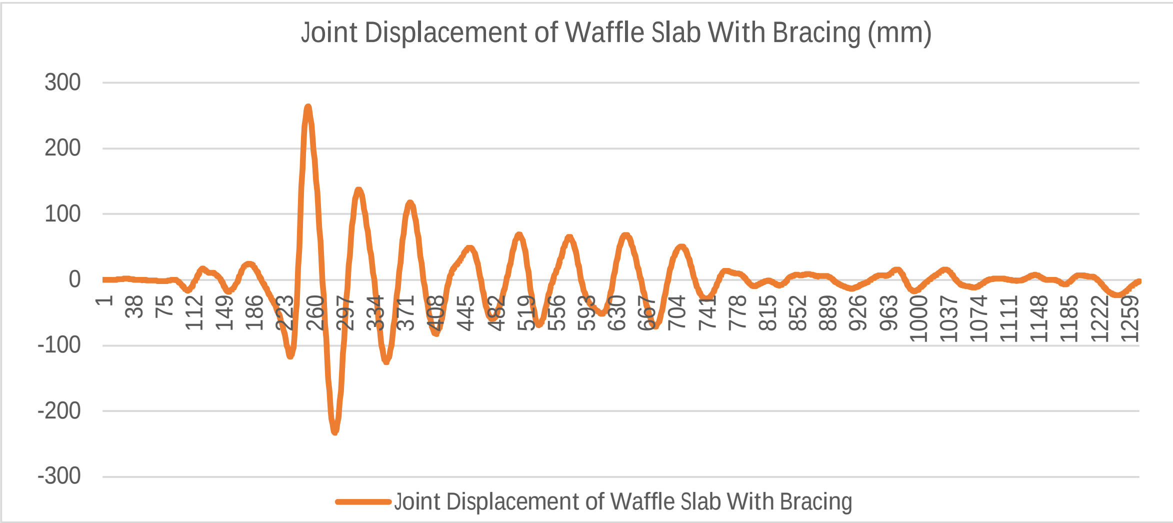
VII. RESULTS AND DISCUSSION

As a result of comparison between the braced and non- braced G+4 structure, following inferences has been made:

VIII. JOINT DISPLACEMENT

The maximum joint displacement at 5.14 sec. is found to be 286.025 mm in conventional slab without bracing. Similarly, the maximum value of joint displacement for waffle slab with bracing is found to be 263.666 mm at 5.02 sec. The value for waffle slab with bracing is observed to be approx. 8% less than that of conventional slab without bracing.





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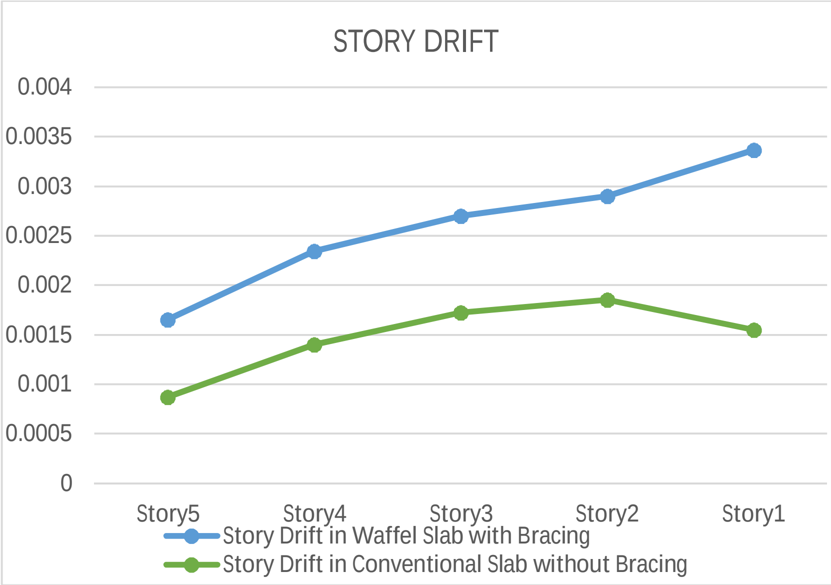
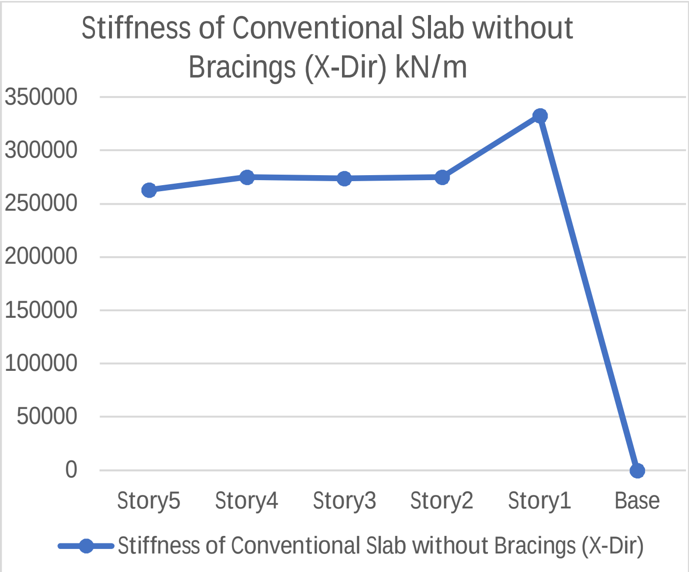
A. Storey Drift

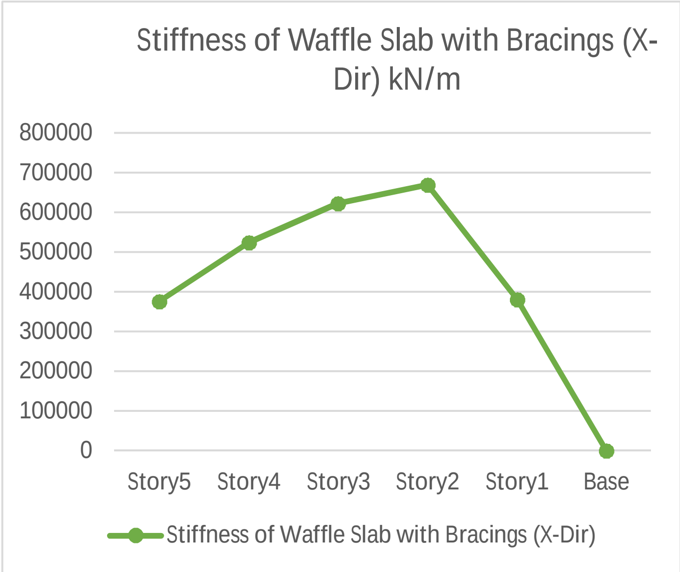
As per IS-1893 (Part 1): 2002 CI. 7.11. 3, When using a partial load factor of 1.0, the maximum storey drift caused by the minimum specified design lateral force is limited to 0.004 times the storey height and according to the graphs obtained maximum drift is 0.001816 with bracings on waffle slab and 0.001857 on conventional slab without bracings which is within the permissible limits.



B. Storey Stiffness

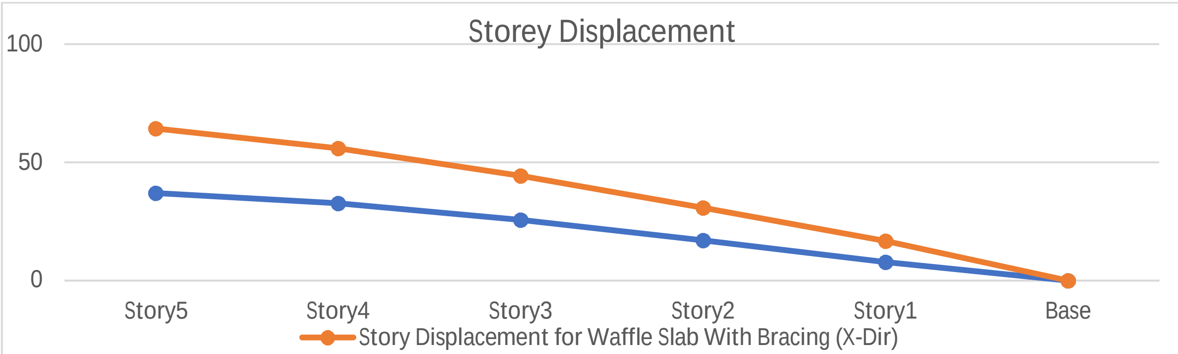
Storey stiffness is a lot more for waffle slab with bracing structure in comparison to conventional slab without bracing structure. The value gradually increases moving from bottom to top storey reaches peak and suddenly fall. The greatest values obtained for conventional slab without bracings and waffle slab with bracings are 332405 kN/m & 668863 kN/m. Waffle Slab with Bracing Stiffness is approx. double than that for Conventional Slab without Bracing.





C. Storey Displacement

Story displacement is greatest at the top storey (36.991 mm) for conventional slab without bracing and lowest at the structure's base. While for waffle slab with bracing the maximum displacement is (27.26 mm). Max value of storey displacement for waffle slab is approx. 26% less than the maximum value of displacement in the other.



IX. CONCLUSIONS

Comparative study of waffle slab with bracing and conventional slab without bracing system using time history analysis shows various parameters waffle slab shows approx 8% less joint displacement than conventional slab i.e, waffle slab performs better when it comes to lateral joint displacement of joint label 1, Storey 5. While the values of Storey Drift concludes that waffle slab shows lower drift i.e. approx 2% higher than conventional slab storey drift values. According to IS-1893 Part 1: 2002 Cl. 7.11.3, any storey's storey drift caused by the specified minimum design lateral force, with a partial load factor of 1.0, must not be greater than 0.004 times the storey height. The maximum drift calculated from the graphs is 0.02 and is within permissible limits. Moreover, conventional slab shows much less storey stiffness as compared to waffle slab. However, storey displacement values conclude that conventional slab displaces 26% more than the other slab. Waffle Slab perform better in every aspect during earthquake as compared to conventional slab. Bracings along with waffle slab will make firmly rigid frames in the building and light weight structure.

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