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A Review Performance Evaluation of Ribbed Slab and Waffle Slab Systems Under Lateral Loading

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ABSTRACT

This study examines the role of slab stiffness in reinforced concrete structures during seismic events. Typically, slab panels are neglected in structural analysis due to their complex behavior. However, slabs significantly increase lateral load resistance during earthquakes due to their in-plane stiffness.

Slabs distribute loads in structures and come in types like ribbed and waffle, used for large spans and high loads. These slabs reduce reinforcement needs and provide stiffer, lighter floors, ideal for areas requiring minimal columns.

The study emphasizes uniform distribution of mass, stiffness, and strength to improve earthquake resistance. It also identifies a gap in research on the suitability of these slabs for tall structures, aiming to evaluate their performance and assess their cost, stability, and strength advantages.

KEYWORDS: *Bending moment, Deflection, boundary condition, Plate equations, Shape functions, Shear force, Waffle slab, Ribbed slab*

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INTRODUCTION

GENERAL

The primary function of floor and roof systems is to support gravity loads and to transfer these loads to other structural members such as columns and walls. Furthermore, they play a central role in the distribution of wind and seismic forces to the vertical elements of the lateral load resisting system. The effect of the slab panels is not considered in reinforced concrete structural analysis because designers neglect their contribution in lateral load resistance. Their contribution is neglected in the structural analysis because they show large complexity in structural behavior. Mostly, the construction carried out is reinforced concrete with slabs providing the useable floor area. During an earthquake, these slabs will increase the lateral earthquake load resistance significantly. As they form a large part of structural system, therefore designers should get benefit from their large in plane stiffness. So in this study the response of two essentially same structures, with and without consideration of stiffness of slabs were evaluated and compared on the basis of different structural parameters. Reinforced concrete slabs are widely used in the concrete constructions. In structural analysis, the torsional stiffness of slab is ignored in common. When this stiffness is taken into account, the exact theory of bending of elastic plates shows that the twisting moment relieve the bending moments about 25 percent and this decreases the reinforcement requirement of the structure.

In our study we have taken two different cases i.e. ribbed slab and waffle slab for a G+10 symmetrical structure considering seismic force (Zone-II) medium soil condition using ETABS and studied the variations in Frame forces, nodal displacements and support reactions also comparing the designing of both to determine the most effective and economical frame.

SLAB

Slabs are the auxiliary components that convey the extra dead and live loads in various structures. They are utilized in buildings, ways and extensions. For the most part, they can be ordered to one way and two different ways frameworks. One path slabs with

beams in a single heading are usually utilized for little ranges up to six meters. Two-path slabs with beams and without beams are utilized for bigger ranges. Two-way slab frameworks are for the most part used to oppose high loads or they are utilized when there are enormous ranges to limit the slab thickness and to diminish the inner powers in the slab and to restrict the slab diversion. It isn't unexpected to have two-route slabs in stopping floors as the ranges are long and they may reach around nine meters or more. Drop beams of profundity that is bigger than slab profundity is normal particularly in stopping floors and mechanical structures as the presence of these beams doesn't influence the shape or the utilization of the structure. Drop beams can be utilized in buildings that have bogus roofs and enhancements. In private buildings, rarely to have bogus roofs, so the presence of drop beams in these buildings isn't suggested compositionally, so concealed beams must be utilized. Two way ribbed slabs will be slabs with solid squares while waffle slabs will be slabs with removable structures. Two-way ribbed slabs are usually utilized in private and places of business. Waffle slabs can be utilized in lobbies, modern buildings and stopping floors. It is entirely expected to have two-way ribbed slabs with ranges from six to nine meters. Waffle slabs can be utilized for ranges that may reach up to twelve meters. Two- path slabs with shrouded beams are simple and basic in development as there is no extra drop formwork. A slab with smooth level with no drops is very basic by and by.

As indicated by IS-1893:2002: Diaphragms with sudden discontinuities or varieties in solidness, which incorporates those having removed or open zones more noteworthy than 50 percent of the gross encased stomach region, or changes in successful stomach firmness of in excess of 50 percent from one story to the following. In basic designing, a stomach is an auxiliary framework used to move parallel burdens to shear dividers or casings essentially through in-plane shear pressure. Horizontal burdens are normally wind and tremor loads. Two essential sorts of stomach are unbending and adaptable. Adaptable stomachs oppose horizontal powers relying upon the region, regardless of the adaptability of the individuals that they are moving power to. Unbending stomachs move burden to casings or shear dividers relying upon their adaptability and their area in the structure. Adaptability of a stomach influences the conveyance of horizontal powers to the vertical parts of the parallel power opposing components in a structure.

Figure 1.1 Structure with Slab element

Waffle Slab

WAFFLE SLAB: A waffle slab is a kind of slab with gaps underneath, giving an appearance of waffles. It is typically utilized where enormous ranges are required (e.g assembly room) to maintain a strategic distance from numerous sections meddling with space. Thus thick slabs traversing between wide beams (to keep away from the beams jutting underneath for stylish reasons) are required. Since the rigidity of cement is mostly fulfilled by the steel bar fortification, just the "ribs" containing the support are kept where the staying 'unused' solid bit underneath the unbiased hub is evacuated, to diminish oneself load of the slab. This is accomplished by putting mud pots or different shapes on the formwork before throwing of the solid.

Motivation behind WAFFLE SLAB: Waffle slabs give stiffer and lighter slabs than a comparable level slab. The speed of development for such slab is quicker contrasted with traditional slab. Moderately lightweight thus affordable. It utilizes 30% less concrete and 20% less steel than a pontoon slab. They give low floor redirections. It has great completions and strength. Genuinely thin floor profundity and fireproof. Phenomenal vibration control.

Utilization OF WAFFLE SLAB It is utilized where vibration is an issue and where huge range slabs are to be developed i.e zones having less number of sections. For instance air terminal, emergency clinics, business and mechanical buildings and so on and where low slab avoidances and high steadiness are required.

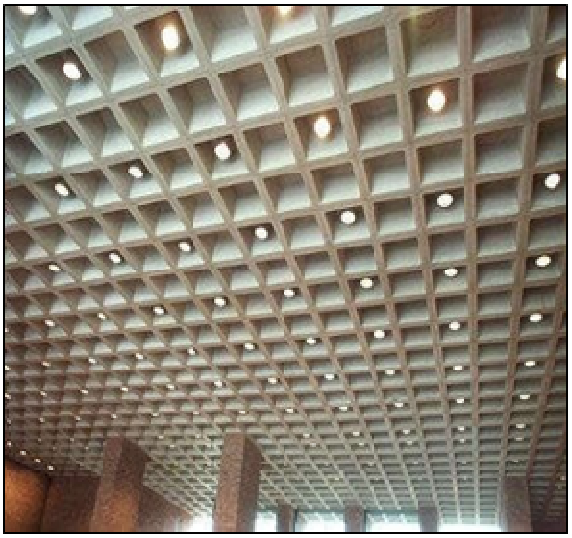

Figure 1.2 Waffle Slab

Ribbed Slab

RIBBED SLAB: Ribbed or waffle slab is a slab framework which comprises of arrangement of parallel fortified solid T beams encircling into strengthened solid braces. The slab is the spine of the beam and the all-encompassing part is the web. The all- inclusive part is known as ribs. The separating between the ribs ought to be by and large 20-30 inch. The ribs are decreased in cross-area in its lower part.

Utilization OF RIBBED SLAB: In this kind of slab, the strain pressure is dispensed with in the strain side of the slab. The quality of cement in pressure is extremely little thus disposal of a great part of the strain cement is finished by the utilization of skillet structures. Prudent where the live loads are genuinely little, for example, condos, inns. Long slab ranges can be built through ribbed and waffle Slabs. By and large, long ranges are alluring in the building. Ribbed or waffle slabs are a simple answer for this reason. Give compositional points of interest. All the Electrical machines can be introduced effectively in the hole of the ribs which can be structurally tasteful.

Figure 1.3 Ribbed Slab

SEISMIC ANALYSIS

In multi-storeyed surrounded building, harms from earthquake for the most part starts at areas of auxiliary shortcomings present in the horizontal burden opposing edges. This conduct of multi-story confined buildings during solid earthquake movements relies upon the conveyance of mass, solidness, quality in both the level and vertical planes of buildings. In not many cases, these shortcomings might be made by discontinuities in solidness, quality or mass along the stomach. Such discontinuities between stomachs are frequently connected with unexpected varieties in the edge geometry along the length of the building. Auxiliary specialists have created trust in the plan of buildings in which the dispersions of mass, solidness and quality are pretty much uniform. There is a less certainty about the plan of structures having unpredictable geometrical arrangements.

A serious earthquake is one of the most destructive wonders of nature. It is very difficult to correctly foresee and counteract an earthquake , yet the harm to a structure can be decreased by its appropriate plan. Subsequently it is judicious to do the seismic investigation and configuration to avert structures against any disaster. The seriousness of the harm relies upon the blend of a few factors, for example, earthquake extent, vicinity to focal point, and the neighborhood topographical conditions, which influence the seismic wave proliferation. The horizontal powers because of earthquake cause the greatest issue for structures. Earthquake safe plan is in this manner principally worried about constraining the seismic hazard related with man-made structures to socio-monetarily worthy levels. It expects to predict the potential results of an earthquake on common infrastructure and to guarantee the plan and development of buildings conforms to configuration codes so as to keep up a sensible degree of execution with some acknowledged degree of harm during an earthquake presentation .The malleability of a structure demonstrations like a safeguard and aides in disseminating a specific measure of seismic vitality.

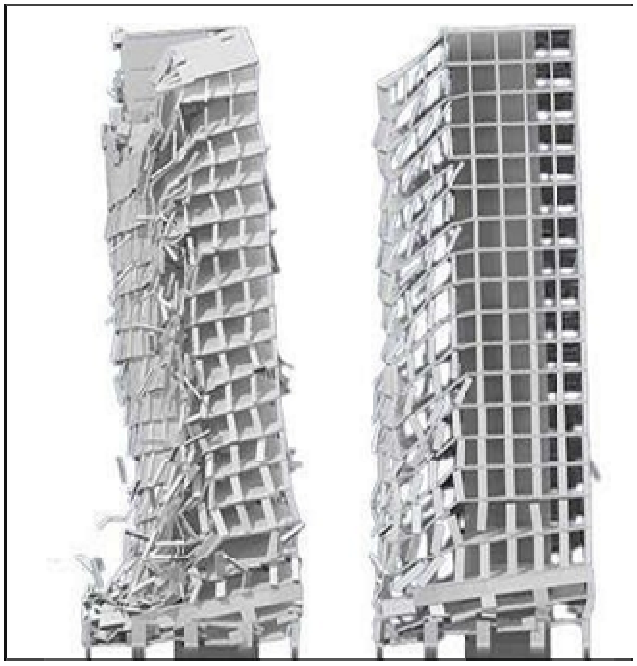

Figure 1.4 Seismic Analysis

LAYOUT OF THE THESIS

Chapter 1: Introduction
This chapter provide overview of diaphragm, seismic load, structural analysis and Objectives of the study.

Chapter 2: Literature review
This chapter provide literature survey of past researches related to Diaphragm, slab types, lateral forces and analysis method.

Chapter 3: Problem Identification and objectives
This chapter provide Identification of problem and objectives of the study

Chapter 4: Methodology
This Section provide Flow chart of the study with step by step process of working model.

Chapter 5: Problem formulation
In this chapter, the geometry and properties to be allocated and sectional measurements have been examined. Load calculations and material description is provided.

Chapter 6: Results & Discussion
In this Chapter Analysis results are elaborated with discussions as per observations are provided.

Chapter 7: Conclusion & Future scope
In the last section conclusion as per results observed in chapter 5 is explained with a possible future scope of the study.

LITERATURE REVIEW

GENERAL

Slab is the main distributive part of the structure, this component of structural frame transmit the live load which act at the slab. In spite of the way that there has been an impressive proportion of work exhibited as totally unbendable spaces in fortified solid structures running from examination doubts to diagram recommendations – no one offer start to finish appreciation of the seismic response of strengthened cement (RC) structures responsibilities related to slab and past tries most immovably related to the necessities of the present work. A succinct review on slab versatility and code course of action of past assessments is shown here. This composing overview around versatility of slab in fortified solid structures and some code courses of action will be would in general by zone.

LITERATURE REVIEW

Atif et. al. (2019) [4] 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.

Vinit and Patel (2019)[17] 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.

Abdulhameed et. al. (2017)[5] 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.

Mohammed et. al. (2017)[12] this research paper was subjected to investigation of various stresses non-linear analysis of a one way ribbed reinforced slab of a ten storey structure when addressed to seismic loads The structures are generally designed so as to resist any form of lateral loads (seismic loading) with the use of elastic investigation considering all the about all experience significant inelastic distortions when exposed to intense earthquake tremors. The results led to the conclusion that one way ribbed slab reduces the stress and maximum displacement in comparison to traditional solid slabs and such reduction decreases simultaneously with increase in number of stories on the structure. Besides, even the value of stress in ribbed slab was less than that of stresses in traditional solid slabs.

Saketh et. al. (2017)[11] the research paper introduced the data of conduct punching shear in waffle slabs at slab segment joint exposed to concentric punching shear. Even though it was seen that waffle slabs are fundamentally the same as that of flat slabs, the shear load was moderately decreased because a portion of the potential surfaces was lost when it reached out into the waffle section. The current IS code of practice don't consider the punching shear component of waffle slabs. The scientific part was finished utilizing Finite Element programming ANSYS, by applying the concentric load at the piece segment joint on waffle sections, waffle slabs of various sizes and contrasting the investigative results and traditional RC slab.

Jemal et. al. (2017)[10] this research paper presented comparative analysis in between solid slab frame and composite slab under seismic loading, besides, gravity load was analyzed in two procedures, firstly it was valuated manually and lastly with the use of software application STAAD.Pro v8 so as to ensure the stability, ecomic aspects and their capability to resist designed loads as per the assumed life span. The results stated that the correlation frame of the private structure built from solid slab required a lesser amount of material (steel and cement) by 5.512% than structure developed from rib slab. The general conduct and story relocation of the strong slab structure has lower in both x-and z-course when contrasted with ribbed section structures. Structures produced using ribbed slab become prevalent and monetary under medium to long-length and lightweight structures. Acquainting voids with the soffit of a slab lessens dead weight and expands the proficiency of the solid area. A marginally more profound area is required however these stiffer floors encourage longer ranges and arrangement of openings. The base bending moment of the strong slab structure has lower an incentive because of horizontal and gravity loads when contrasted similarly as with ribbed slab structures.

Raut and Riyaz (2016)[2] here the author presented a comparative analysis in between RCC Waffle Slab and Pre-stressed Waffle Slab. At the point when a huge space inside a structure should be secured without block and supports, structural designer frequently conveys waffle slabs to build floor and roof. Waffle slabs are commonly utilized for substantial loads. The analytical work incorporated the investigation and plan of R.C.C. Waffle slabs and Pre-stressed Waffle section for small span, medium span and long-span ranging from 10m to 40m. For investigation reason ETAB 15 (Integrated Analysis, Design and Drafting of Building System) and SAFE 14 (Integrated Design of Slabs, Mat and Footing) programming results were embraced into thought for R.C.C. Waffle section and Pre-stressed waffle piece and manual computation were out for both.

Sarita et. al. (2016)[16] the research paper presented comparative analysis of Waffle slabs with Flat slabs against the traditional RCC slabs, focusing attention towards its advantages of waffle slabs over Flats slabs and RCC slabs. The comparison was presented with the use of a case study through a design of Waffle Slabs with Flat slabs and RCC slabs as per IS 456-2000 and the comparison was done on various parameters.

The calculus stated that waffle slabs are progressively favourable when contrasted with different sections, for example, flat slabs and RCC slabs, in terms of loading, large spans, aesthetic appearance, etc.

Pushpa et. al. (2015) [3] this research paper investigated seismic performance on a multi storey structure of three different tunes such as G+9, G+14 and G+19 floors using Waffle slabs and Flat slabs and the designing and modelling of the structure was done using computer program ETAB'S 2013. The seismic advancement was performed using response range investigation according to IS 1893 (2002). It was seen that waffle slabs were fitting for structure with tallness under 40m, though for structures of stature above 40m it was prudent to go with the flat slab.

The obtained results presented that the maximum displacement estimation of the flat slab was about

16% higher contrasted with a waffle slab in both X and Y directions for G+9 storey building.

Ibrahim et. al. (2014) [7] this research paper was focused towards analysis of a two way ribbed slab and waffle slabs with hidden beams. Numerous strategies were utilized to dissect two-way slabs and the efficiency of these techniques change contingent upon strategy decision. In this investigation, the ACI direct plan technique was utilized as manual or hand strategy for estimation and the end strategy was contrasted against the examination consequences of the three-dimensional basic models done by the analytical system program SAP2000.

Naziya and Chitra V. (2014)[13] the research paper described various approaches those are accessible for the analysis of waffle slab system and their comparison was done on flexural parameters such as bending moment and shear forces. Experimental apparatus included size with contant width 10.00m and varying ratio of hall dimensions (L/B) from 1 to 1.5 was considered in the examination.

Tian et. al. (2012)[9] the research paper presented experimental and numerical analytical results of Multi-Ribbed Slab Structure (MRSS) which is a type of composite structural system composed of prefabricated multi-ribbled composite wall slabs. The results were extracted from four scaled model constituting three one and half scale two storey two Bay models and one third scale three storey two bay models executing pseudo static investigation on all the specimen.

Méndez et. al. (2012)[6] the research paper presented the study of five full sized Post- tensioned Flat Slab-column connections which were subjected to axial and flexural moment in order to determine their mode of failure, strength and ductility. The factors that were examined were first, the arrangement of stirrups or stud shear reinforcement; furthermore, separating between stirrups or shear studs; and thirdly, connection between the applied axial loads, Vu, and the punching shear quality of the slab with hub load and without shear fortification, VcR. In this examination, waffle pieces were utilized, being more utilized in Mexico than strong chunks for financial reasons. The pliability of the associations was of extraordinary enthusiasm since this sort of structures was generally considered of low or medium malleability because of the punching shear failures was fragile. It has been discovered that the most extreme IDR (between story float proportions) came to in structures with level piece section associations relied upon the connection among Vu and VcR, so this was one of the primary factors in the exploration.

Alaa C. and Atiyah (2011)[1] this research paper demonstrated the complications associated to optimal design of Two-way ribbed or generally termed as Waffle slabs with the use of genetic algorithms. This research paper included two case studies, one was a waffle slab with solid heads and another was waffle slabs with band beams running along the centerlines. Structural analysis and slab designing was done using Direct Design methodology. The conclusion derived from the results stated that the expansion in the proportion of concrete cost comparative with the steel cost caused a diminishing in the rib spacing and the cross-sectional territory of the ribs. While the expansion in the steel unit cost comparative with the solid unit cost causes an increment in the cross-sectional zone of the ribs. The expense of formwork of the slab was seen as (85%-137%) of the overall cost of the section for slabs with strong heads and sections with the band beams was (30%- 64%). For a similar range length, it was discovered that the absolute expense of waffle section with band pillars along segments centerlines was (10%-112%) higher than the all over cost of waffle piece with strong heads.

Shabbar et. al. (2010)[15] this research paper aimed to presented the utility of one way ribbed slabs along with light weight foam concrete in reduction of the dead load on concrete slab structures. The final conclusion states Foam concrete could be intended to meet the criteria of compressive strength of load-bearing cement besides, it's an appropriate arrangement in the development of multi-story structures. Foamed concrete has been distinguished as appropriate material to swap the typical cement utilized for this reason. Simultaneously, the thickness of formed concrete can be structured and controlled by the proportion of the blend and the solidness of the foam utilized. Moreover, the development cost of the one-way ribbed slab with pillars was more practical than that of the two-way solid slabs with bars. Besides, The ESTTEM® programming proved, by all accounts, to be a productive and exact instrument that was dependable to be utilized in the preparation of the examination and calculus.

Indrajit and Singh (2010) [8] the research paper proposed a semi analytical procedure to analyze the waffle slabs with arbitrary boundary conditions whether they are fixed, or free or just simple supported. The selected cases were compared under Finite Element Method (FEM) so as to validate the results. The conclusion proposed a computationally efficient method which was comparable to Finite Element Method (FEM) analysis which could be adopted for the analysis of Waffle slabs for

generalized boundary conditions. The weighted residual technique proposed in the test examination gave sensible outcomes without turning to an expound FEM investigation.

Schwetz et. al. (2009)[14] the primary objective of the research work was to analyze the sustainability of various designing procedures most widely used in modelling of all waffle slabs so as to represent the behavior of the slabs. Real scale waffle slab when subjected to load in a confined region was instrumented with strain gages and diversion gages for estimating explicit strain and deflection in various points. The conclusion derived from the observation stated the measured vertical displacement and found strains were found adequate to numerical predictions, demonstrating a satisfactory reaction of the numerical model utilized in the examination.

OUTCOME OF THE STUDY

The researchers have tried to find the variation in forces which occurs due to waffle and ribbed slab, following are the outcomes of literature review:

1. Determine that frames with different slab types shows variations as per structural geometry.
2. That structure considering diaphragm is more stable and symmetric.
3. Difference in frame without slab, flat slab and other diaphragm types.

PROBLEM IDENTIFICATIONS AND OBJECTIVES

Problem Identification

No detailed study on suitability of structure with ribbed and waffle slab technique has been done in past researches were conducted on different materials including RCC, flyash cement concrete and panels (glass and aluminum) however information on techno economic feasibility of vibrational induced structure to be used in tall structures is lacking.

- This study will provide a suitability criteria for tall structures with these slab providing economical design.
- This study will provide a reference to designer for providing suitability and lateral load resisting technique using induced structures.

OBJECTIVES OF THE STUDY

The main aims 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.

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