International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 7 July 2021, pp: 1452-1458 www.ijaem.net ISSN: 2395-5252

Parametric Assessment Of The Influence Of Deflection Limit On Waffle Slab With And Without Hidden Beams

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Submitted: 25-06-2021 Revised: 06-07-2021 Accepted: 09-07-2021

ABSTRACT— When a large space within a building needs to be covered without hindrance and supports, architects often deploy waffle slab to construct floor and ceiling. Waffle slab are generally used for heavy loads. An arrangement of intersecting beams placed at regular interval and interconnected to a slab of nominal thickness is known as Waffle slab. These slabs are used to when a large column free area is the main requirement. It is common to have two-way slabs in parking floors as the spans are long and they may reach about nine meters or more. Drop beams of depth that is larger than slab depth is very common especially in parking floors and industrial structures as the existence of these beams does not affect the shape or the use of the structure. Drop beams can be used in buildings that have false ceilings and decorations. In residential buildings, it is not common to have false ceilings, so the existence of drop beams in these buildings is not recommended architecturally, so hidden beams must be used.

There are various methods available for analyzing the grid slab system. In present study some of these methods are studied namely Equivalent static analysis, Response spectrum analysis,Push over analysis and Time history analysis and compared with each other. The comparison is done on the basis of flexural parameters such as bending moments, shear forces and deflection obtained from various methods. The parameters considered for study include span to depth ratio, spacing of transverse beams, thickness of web and thickness of flange.

For analysis purpose ETABS and SAFE software results will be taken into consideration.

Keywords— Waffle slab, Hidden Beam, ETABS, Seismic dynamic Analysis

I. INTRODUCTION

Over the years, the multi-storey buildings have become more slender and lighter, consequently more susceptible to vibrations .These vibrations are coming from different sources such as wind action, actions induced by people, and earthquakes.The slab is the structural element that receives the main load of the building, being in direct contact with its occupants and so subjected to vibrations. In nowadays, human activities such as walking, dancing, jumping, running and aerobic exercises are regarded the most severe excitation source in slab floors .Moreover, it canbe said that people's behavior has been adapting to modern life being very common to use residential portable gym equipment like stationary bikes, mini elastic beds, among others. The dissemination of gym centers in shopping centers, in little commercial centers and even in residential buildings is spreading worldwide. Waffle foundations are resistant to cracking and sagging and can hold a much greater amount of weight than traditional concrete slabs. A waffle slab is usually regarded as a two-way system to cover square areas in buildings, which transfers loads in two mutually perpendicular directions. It takes advantage of two-way load-bearing capacity, and the engineering demand stays high. Traditional waffle slab uses RC beams as the slab ribs.

In this work the seismic performance of 12x9m waffle slabs are modelled at varying parametres and Equivalent satatic analysis,response spectrum analysis,Time history analysis and push over analysis are done.

II. METHODOLOGY

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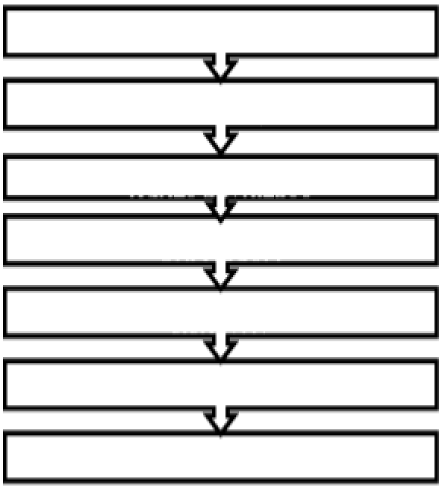

- MODELLING

In this project the waffle slab are designed at 12x9m size,and the parametres are varied,the parametres like varying rib spacing,varying live load, varyig rib width,varying L/D ratio and varying rib crossection.

TABLE 1.MODELLING INPUTS OF WAFFLE SLAB

Depth of Wwaffle Slab	**400mm**	Span to Depth Ratio = 23
Width of Rib	**150mm**	Range = 110mm to 200mm
Depth of Slab	**100mm**	Range = 85mm to 100mm
Spacing	**900mm**	Range = 600mm to 1500mm
Drop size	**2mx2m**	1/6 of longer direction

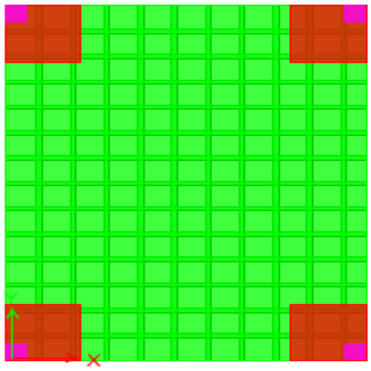

Figure 1: Plan view of waffle slab

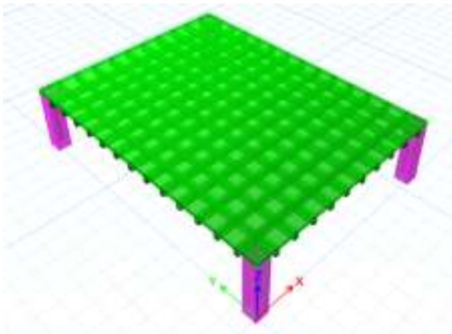

Figure 2: 3Dview of waffle slab

TABLE 1.MODELLING INPUTS OF WAFFLE SLAB
In this project the modeling are done by waffle slab with hidden beams and then th e parametres are varied

TABLE 2.MODELLING INPUTS OF WAFFLE SLAB WITH HIDDEN BEAMS

Depth of Waffle Slab (Slab + Rib)	**200mm**	
Width of Rib	**150mm**	Range = 110mm to 200mm
Spacing	**900mm**	Range = 600mm to 1500mm
Drop size	**2mx2m**	1/6 of longer direction

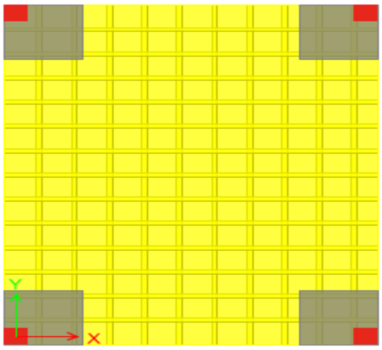

Figure 3: Plan view of waffle slab with hidden beams

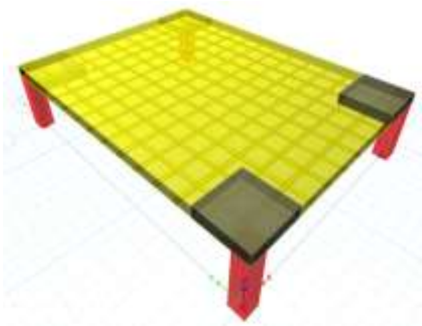

Figure 4:3D view of waffle slab with hidden beams

VARYING RIB SPACING

In this project consist of waffle slabs are Modelled at varying rai spacing ,the rib spacing is range from 6mm,900mm,1200mm and 1500mm,Tha same variations are done in waffle slab with hidden beams

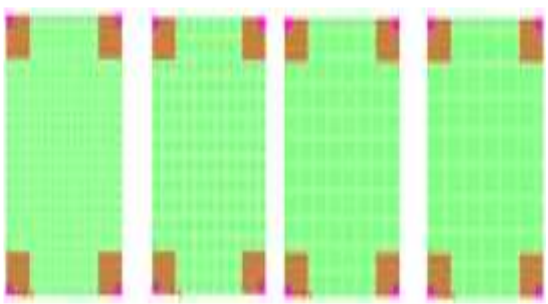

Figure 5: Varying rib spacing

VARYING L/D RATIO

In this project consist of waffle slabs are modelled at varying L/D ratio ,it ranges from 2,23,26,29 and 32. The design of waffles can be done as normal slab/ Flat slab.Perimeter beams can have depth same as waffle depth. For 2 way slabs, the shorter of the two spans should be used for calculating the span to effective depth ratios.The values of span to effective depth ratios of continuous slab for spans up to 10m is 26.For spans above 10m, the value should be multiplied by 10/span in meters .For high strength deformed bars, the values should be multiplied by 0.8.The maximum deflection should not normally exceed span/250 or 20mm

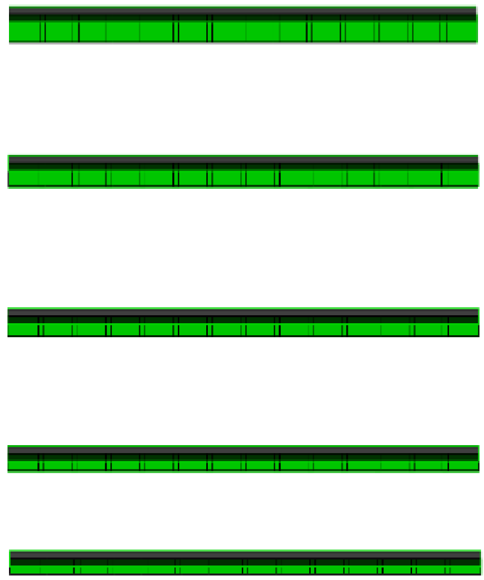

Figure 6: varying L/D ratio

- ANALYSIS
- Equivalent static analysis

Equivalent static analysis are conducted to determine the seismic capacity of structure can support prior to instability or Collapse.The analysis are conducted in normal waffle slab and waffle slab with hidden beams,so the variations are plotted

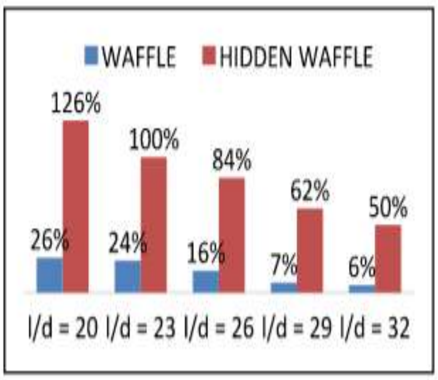

Figure 7: Deflection vs varying L/D ratio in normal waffle slab and waffle slab with hidden beams

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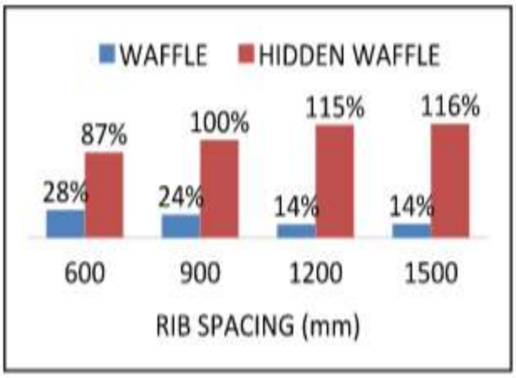

Figure 8: Deflection vs varying rib spacing in normal waffle slab and waffle slab with hidden beams

Hidden waffle shows a higher percentage of deflection than normal waffle slab when both rib spacing and live loads were varied. Hidden waffle shows a higher percentage of deflection than normal waffle slab when both span to depth ratio and width of rib were varied.

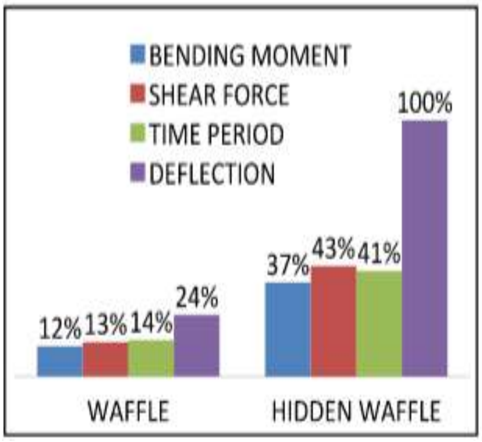

Figure 9: Reactions on normal waffle slab and waffle slab with hidden beams

The percentage increment of deflection along Y- axis exceeds X- axis in all the analysis .As discussed in the previous section, lesser stiffness possessed by the Hidden waffle slab in comparison with the normal Waffle slab, induced more deflection .On comparing with the Normal slab, both Waffle and Hidden Waffle slab exhibits more deflection.For reducing vibration and where large span slabs are to be constructed with less number of columns, waffle slabs are used. So further analysis of waffle slab is essential

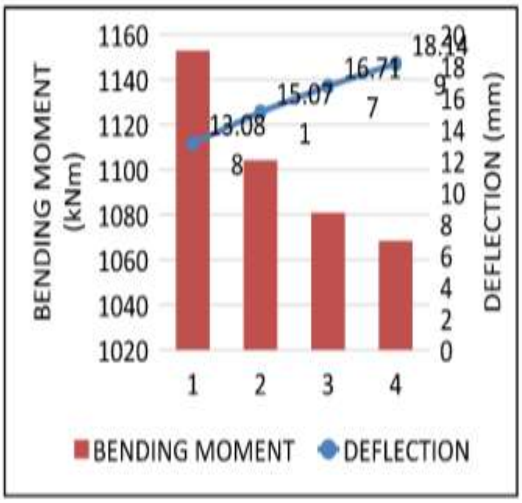

Figure 10: Rib spacing vsBending moment and Deflection diagram

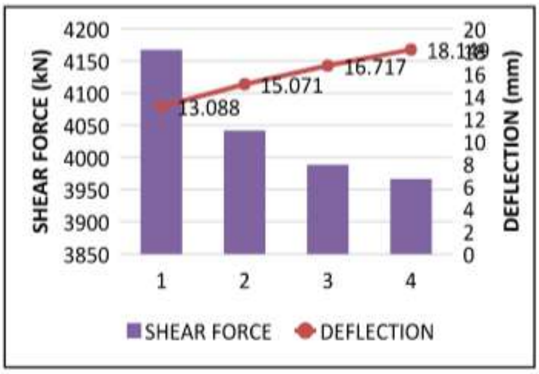

Figure 11: Rib spacing vs SF and Deflection diagram

Bending Moment and shear force decreases with increase in rib spacing.When Bending moment and Shear force decreases, deflection increases.Fundamental Time period is minimum for rib spacing between 900mm to 1200mm

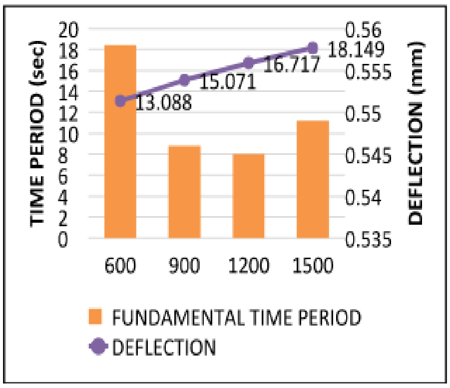

Figure 12: Rib spacing vs Time period and Deflection diagram

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Maximum stiffness for the case of both Waffle and Hidden Waffle are exhibited with L/D= 20 .For L/D= 23, Waffle slab observed as safe in deflection, but Hidden Waffle came up with exceeding deflection limit All other L/D ratio is estimated as unsuitable due to exceeding deflection limit

The Rib Width of B=D seemed satisfactory result on both Waffle and Hidden Waffle, the dimensional equality of width and depth implies the improved stability for Hidden waffles .When the width had been reduced as half of the depth, only the Waffle slab are able to show good stiffness characteristics while Hidden Waffles suffered an exceeding deflection limit

B= D/3 and D/4 conceived as not at all good for both Waffle slab and Hidden Waffle slab

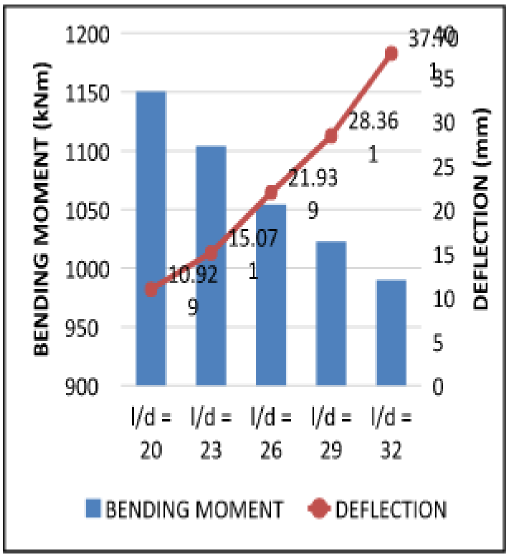

Figure 13: l/d ratio vsBending moment and Deflection diagram

Bending Moment and shear force decreases with increase in L/D ratio

Fundamental Time period increases with increase in L/D ratio

TABLE 3.ECONOMIC SECTIONS

Type of Floor	**Economic Span to Depth Ratio and Rib Spacing**
Roof	L/D = 32 @ 900mm spacing
Residential	L/D = 26 @ 600mm spacing
Educational	L/D = 23 @ 600mm spacing
Office/Merca	L/D = 20 @ 600mm

ntile	spacing
Industrial	Waffle slabs are not suitable

VARYING RIB CROSSECTION

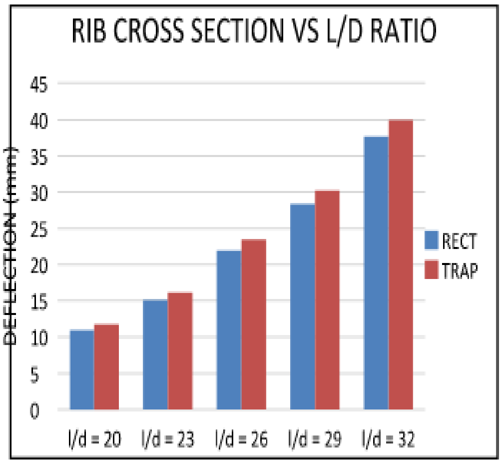

Figure 14: l/d ratio vs Rib crossection and Deflection diagram

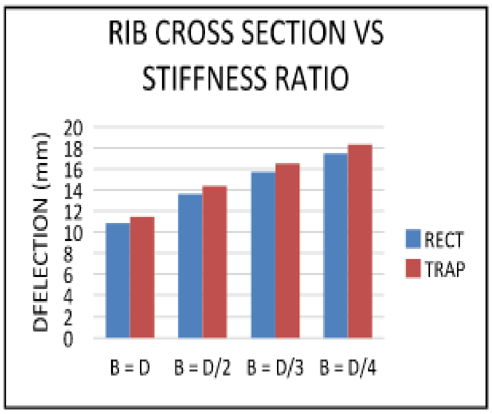

Figure 15: B/D ratio vs Rib crossection and Deflection diagram

Ribs with trapezoidal cross section shows more deflection

For both cross sections, deflection increases with increase in L/D ratio and increases with decrease in rib width

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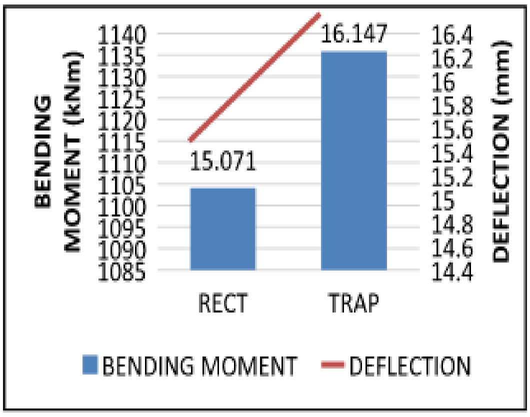

Figure 16:Crossection of ribs vs BM and Deflection

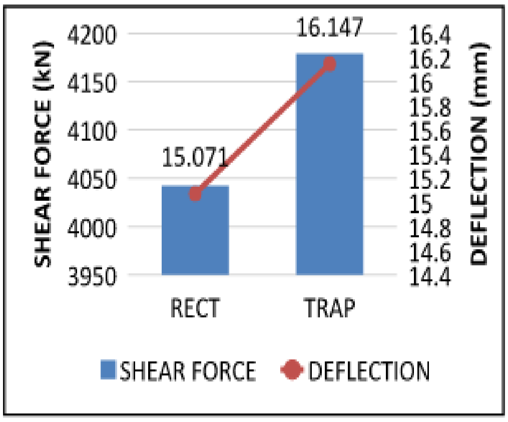

Figure 17:Crossection of ribs vs SF and Deflection

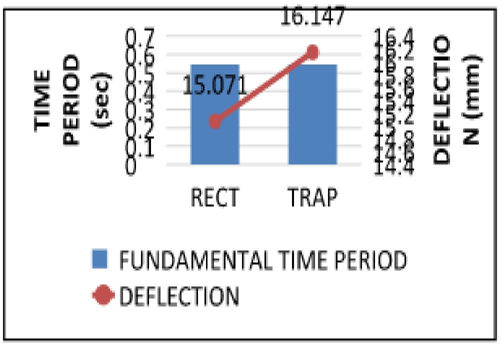

Figure 18:Crossection of ribs vs Time period and Deflection

Bending Moment and shear force is higher for trapezoidal rib cross section.Bending moment and Shear forces are proportional to to deflection.Fundamental time period is irrespective of cross section

TABLE 4.ECONOMIC CROSS SECTIONS

Parameters	Cross section with min value
Bending Moment	**Rectangle**
Shear Force	**Rectangle**
Time period	**Rectangle & Trapezoidal**

III. CONCLUSION

The percentage increment of deflection along Y- axis exceeds X- axis in all the analysis .As discussed in the previous section, lesser stiffness possessed by the Hidden waffle slab in comparison with the normal Waffle slab, induced more deflection .On comparing with the Normal slab, both Waffle and Hidden Waffle slab exhibits more deflection.For reducing vibration and where large span slabs are to be constructed with less number of columns, waffle slabs are used. So further analysis of waffle slab is essential. Maximum stiffness for the case of both Waffle and Hidden Waffle are exhibited with L/D= 20 .For L/D= 23, Waffle slab observed as safe in deflection, but Hidden Waffle came up with exceeding deflection limit .All other L/D ratio is estimated as unsuitable due to exceeding deflection limit Increase in rib spacing and stiffness ratio decreases bending moment, shear force and time period.Increase in span to depth ratio decreases bending moments and shear forces but increases the time period.Increase in live load increases bending moments and shear forces but it is irrespective of fundamental time period.Using trapezoidal ribs deflection, bending moment and shear force get increased .Shape of rib cross section is irrespective of time period.Ribs oriented 90degree to the waffle slab shows least deflection, bending moment and shear forces but shows higher time period.Waffle slab possessed more stiffness than Hidden Waffle slab, but when both these slabs are compared with the Normal slab, got the drawback of more deflection susceptibility

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