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ASSESSMENT OF THE SEISMIC RESPONSE OF RIBBED SLABS AND WAFFLE SLABS IN STRUCTURAL ENGINEERING

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ABSTRACT

Slabs serve as integral flooring components in a wide range of structures, encompassing office buildings, commercial spaces, residential homes, bridges, sports arenas, and various other facilities. Their primary roles typically involve bearing vertical loads, including those from people, materials, furnishings, and vehicles. In contemporary structural design, especially for tall buildings and below-ground structures, slabs also play a crucial role as floor diaphragms, aiding in the resistance against horizontal forces like wind, seismic activity, and lateral soil pressure. The process of designing involves several description data that in cumulates the variation observed in designing field of the structure. The safety factors involve the economical designing and variations. This research presents a comparative study of R.C.C. Waffle slab and One way Ribbed Slab considering a G+11 structure. For examination purposes ETAB 15 (Coordinated Investigation, Plan and Drafting of Building Framework) programming results were into thought. Programming in Succeed is finished to get the outcomes for different boundaries of bowing second, shear force, pivotal power, removal, Stress examination and cost productivity. The design was dissected according to IS code 1893 Section I-2016. Results uncover that One-way Ribbed Piece is less expensive than RCC Waffle Section.

I. INTRODUCTION

Greater part of the structure consists of primary components, for example, radiates, segments, supports, shear walls, and floor chunks. Floor sections in multi story structures, which normally send gravity burdens to the underlying framework, are likewise expected to move sidelong latency powers to the primary framework. By and large, the models utilized for the examination of such sort of building structures are ready without the floor sections expecting that they irrelevantly affect the reaction of a construction. Consequently, the floor pieces are basically traded by unbending floor stomachs for effortlessness in the examination technique. For this situation, the flexural firmness of the floor chunks is overlooked in the examination. Furthermore, albeit the shafts are situated under the floor chunks in a construction, the logical model were created expecting that the tomahawks of floor pieces and pillars are situated on a typical plane.

The adaptability of floor stomachs fundamentally while breaking and yielding are normal, it influences the seismic reaction of structures in two significant ways:

1. The conveyance of the horizontal powers to the upward components is modified.
2. The unique attributes of the structure are impacted by nearby vibration methods of the floor frameworks.

These impacts are completely overlooked in examination when floor pieces are thought to be entirely unbending.

Consequently, in the powerful examination the scientific model which ignores the flexural firmness of the floor chunks would actuate significant logical mistakes. In this review, research on the productive demonstrating strategies which can consider the flexural solidness of the floor chunks are done. Looking at the outcomes on a similar construction as G+11 utilizing waffle chunks and one-way ribbed pieces. In building structures, the flexural firmness of the floor chunks is irrelevant in correlation with the in-plane solidness of the floor pieces.

1.1 Waffle Slab

A waffle slab is a type of slab with holes underneath, this type of slab provides great structure stability as well this provides an unique appreance of the slab beneath. 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 1.1 Waffle Slab

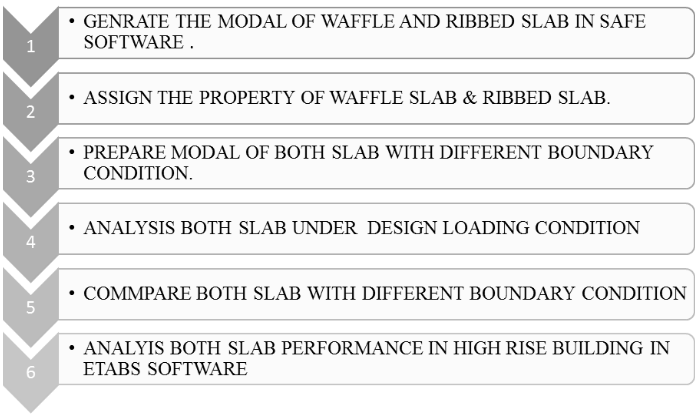
II. LITERATURE SURVEY

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.

III. METHODOLOGY

3.1 Flow chart of the methodology



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IV. DYNAMIC ANALYSIS

The Dynamic analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. A plot of complete base shear versus top relocation in a structure is received by this examination that would show an untimely disappointment or shortcoming. Every one of the bars and segments which arrive at yield or have encountered smashing and even break are recognized. A plot of entire base shear versus between story float is likewise gotten. A Dynamic investigation is performed by exposing a structure to a monotonically expanding example of sidelong load that demonstrates the inertial powers which would be experienced by the structure when exposed to ground movement. Under gradually expanding burdens numerous auxiliary components may yield successively. In this manner, at every occasion, the structure encounters a diminishing in firmness. Utilizing a Dynamic analysis, a representative non- linear force-displacement relationship can be obtained.

Most researchers recommend using the normalized displacement profile at target displacement level as a shape vector, but since this displacement is not known beforehand, an iteration is needed. Therefore, by most of the approaches, a fixed shape vector, elastic first mode, is utilized for simplicity without regarding higher modes. The target displacement is found by the roof displacement at mass center of the structure.

The accurate estimation of the target displacement associated with particular performance objective, has an effect on accuracy of the seismic demand predictions of Dynamic analysis. Furthermore, hysteretic characteristics of MDOF must be incorporated into the equivalent SDOF model, in case displacement demand is affected from stiffness degradation or pinching, strength deterioration, P- effects. Foundation uplift, torsional effects as well as semi-rigid diaphragms may also affect target displacement.

However, in Dynamic analysis, usually an invariant lateral load pattern is utilized that the distribution of the inertia forces is assumed to be not changing during earthquake and deformed configuration of the structure under the action of invariant lateral load pattern is likely to be similar to that which is experienced in the design earthquake. As response of the structure, therefore the capacity curve is highly sensitive to the lateral load distribution selected choice of lateral load pattern is more critical as compared to the accurate estimation of the target displacement. The invariant load patterns cannot explain the redistribution of inertia forces because of progressive yielding and resulting variations in dynamic properties of structure. Also, fixed load patterns have inadequate capability to foretell higher mode effects in post-elastic range. These restrictions have led many researchers to suggest adaptive load patterns that consider the variations in inertia forces corresponding to the level of inelasticity. The basic approach of this technique is to restructure the lateral load shape with the degree of inelastic deformations. Although better predictions have been found from adaptive load patterns, they make Dynamic analysis computationally hard and theoretically complicated. The measure of improvement has been a topic of discussion that simple invariant load patterns are preferred widely at the expense of accuracy. We have used an invariant triangular loading pattern here.

4.1 Comparative Results

Maximum Storey Displacement (mm):

Table 4.1: Storey Displacement

Storey Displacement mm		
Storey	Waffle	Ribbed
Story11	21.82	19.298
Story10	18.732	16.204
Story9	15.284	13.893
Story8	12.84	10.927
Story7	9.375	8.395
Story6	7.384	6.284
Story5	5.828	4.849

Story4	4.172	3.73
Story3	2.974	2.374
Story2	1.663	1.432
Story1	0.61	0.598

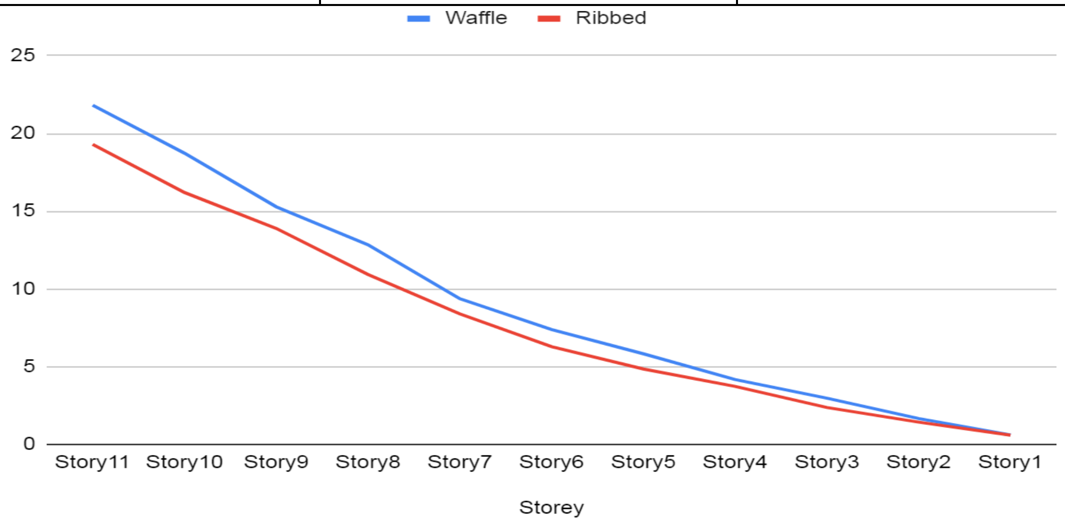

Fig 4.1: Storey Displacement

4.2 Discussion:

As observed in fig 6.1, it can be said that displacement in waffle slab is comparatively more in comparison to ribbed slab and a variation of 16.1% is visible in the top storey in the comparison. Ribbed slab is in permissible limit as per I.S. 1893-I:2016.

Storey Drift:

Table 4.2: Storey Drift

Storey Drift mm		
Storey	Waffle	Ribbed
Story11	0.379	0.371
Story10	0.57	0.559
Story9	0.732	0.726
Story8	0.858	0.844
Story7	0.952	0.936
Story6	1.015	0.999
Story5	1.053	1.037
Story4	1.069	1.053
Story3	1.024	1.048
Story2	0.729	1.008
Story1	0.82	0.713

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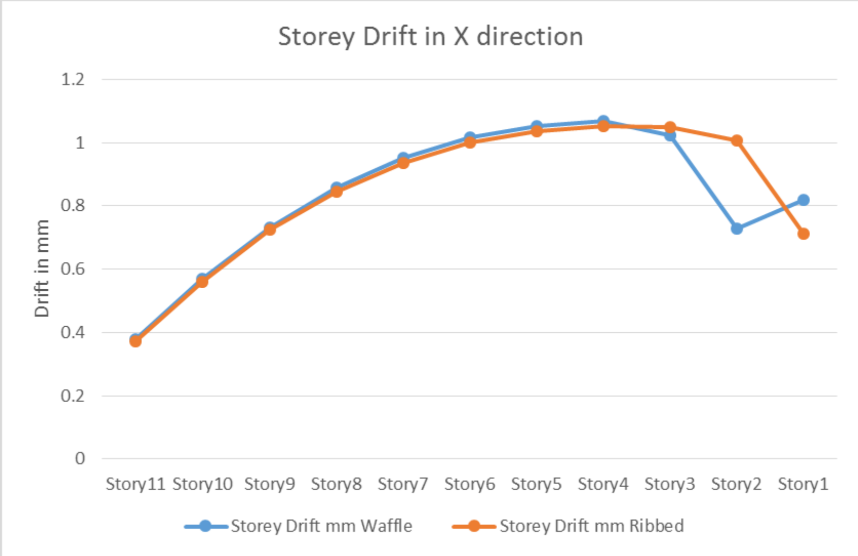

Fig 4.2: Storey drift in X direction

Table 4.3: Storey Drift in Y direction

Storey Drift in Y direction mm		
Storey	Waffle	Ribbed
Story11	0.455	0.476
Story10	0.684	0.726
Story9	0.879	0.944
Story8	1.03	1.115
Story7	1.142	1.243
Story6	1.218	1.332
Story5	1.264	1.387
Story4	1.282	1.412
Story3	1.229	1.408
Story2	0.874	1.342
Story1	0.82	0.882

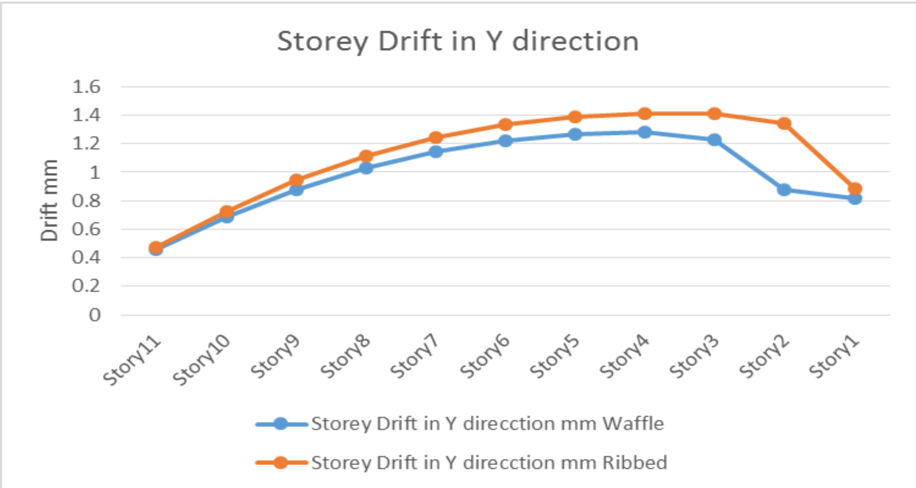

Fig 4.3: Drift in Y direction

4.3 Discussion:

Drift can be defined as a relative consecutive displacement of two storey, in this study it can be said that up to 6 storey waffle slab has less drift increment but after 6th storey ribbed slab is observed as more stable.

Axial Force KN

Table 4.4: Axial Force KN

Axial Force KN		
Storey	Waffle	Ribbed
Story11	3762.98	3010.11
Story10	8293.92	5987.021
Story9	11216.82	8983.92
Story8	14363.89	12845.23
Story7	18274.93	15987.85
Story6	21284.25	18370.81
Story5	25317.58	22103.93
Story4	28842.95	22753.76
Story3	32368.32	28972.09
Story2	35287.83	32982.93
Story1	40982.94	35820.39

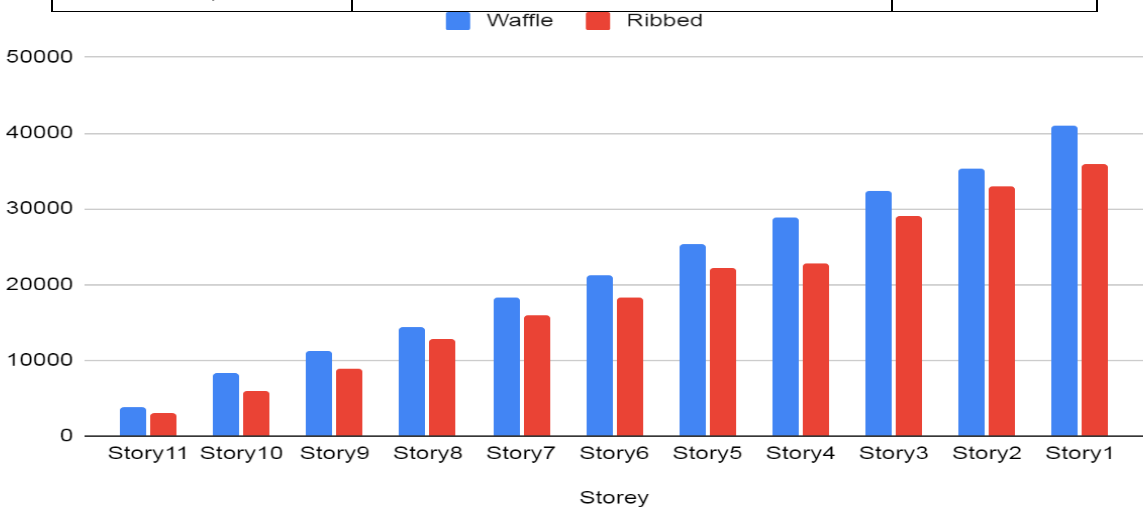

Fig 4.4: Axial Force

Discussion:

As observed in fig 4.4 it can be said that vertical force is generating more in waffle slab in comparison which is more resistable in ribbed slab case.

Shear Force

Table 4.5: Shear Force

Shear Force KN		
Storey	Waffle	Ribbed
Story11	-92.3552	-80.4545
Story10	-178.082	-151.837

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Story9	-247.808	-209.657
Story8	-304.994	-255.342
Story7	-351.12	-290.319
Story6	-387.661	-316.017
Story5	-416.093	-333.862
Story4	-437.889	-345.284
Story3	-454.524	-351.708
Story2	-468.474	-354.563
Story1	-479.211	-355.277

Fig 4.5: Shear force

Discussion:

As observed in above fig 4.5, it can be said that unbalance forces generating in both the cases are in negative i.e. opposite direction due to geometry of slab, here values observed in ribbed slab is comparatively less than waffle slab.

Torsion

Table 4.6: Torsion

Torsion Kn		
Storey	Waffle	Ribbed
Story11	786.18	650.28
Story10	1401.63	1157.21
Story9	1896.1	1637.95
Story8	2286.79	2014.29
Story7	2585.91	2303.84
Story6	2805.68	2516.19
Story5	2958.29	2664.38
Story4	3055.98	2758.94
Story3	3110.91	2812.14
Story2	3135.32	2835.78
Story1	3141.23	2841.69

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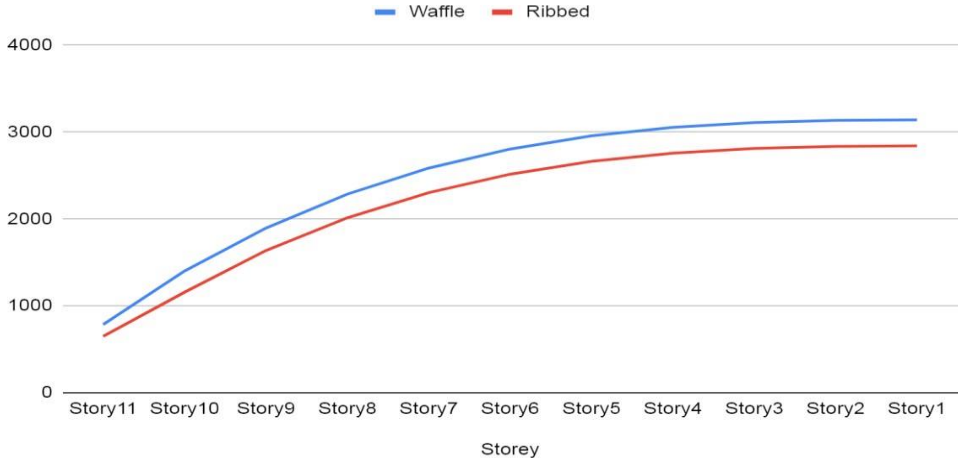

Fig 4.6: Torsion

Discussion:

As observed in table 4.6 torsion developing in structural component is observed more in waffle slab.

Bending Moment KN-m

Table 4.7: Bending Moment kN-m

Bending Moment kN-m		
Storey	Waffle	Ribbed
Story11	24740.96	21440.08
Story10	51181.12	46576.36
Story9	77621.29	71718.64
Story8	113061.4	96857.93
Story7	139501.6	121997.2
Story6	165941.8	138136.5
Story5	192381.9	163275.8
Story4	218822.1	188415.1
Story3	245262.3	213554.3
Story2	271702.4	238693.6
Story1	298142.6	263832.9

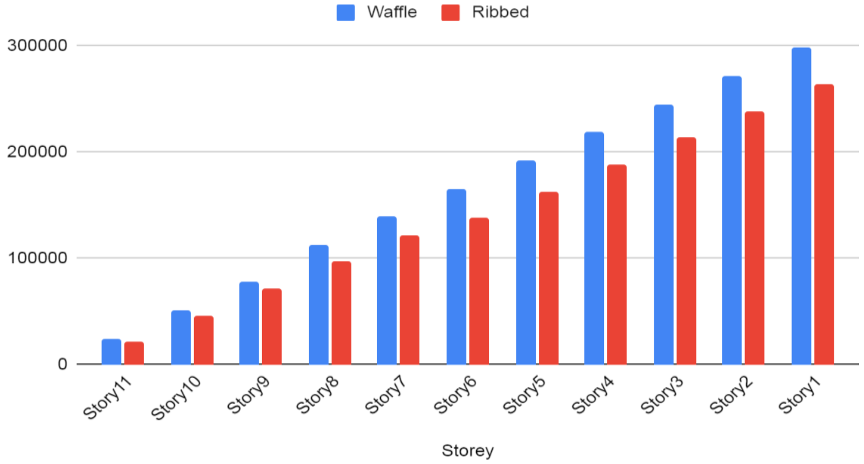

Fig 4.7: Bending Moment KN-m

Discussion:

As shown in fig 4.7 it can be said that bending moment is observed more in waffle slab case that it can be stated the ribbed slab case is comparatively more stable and cost effective.

Stress Analysis

The maximum values of stress analysis in x and y direction are stated in the table below

Table 4.8: Stress Analysis

Waffle Slab				Ribbed Slab			
FX KN-m	FY KN-m	My mm	My mm	FX KN-m	FY KN-m	My mm	My mm
735	525	3.6	3.6	540	510	2.4	2.4

Cost Analysis

Table 4.9: Quantity of Slab Work used in the Structure

Description	Unit	Waffle Slab	One Way Ribbed Slab
Concrete Quantity	Cum	4611.16	4548.75
Steel Quantity	MT	276..67	363.9
Weld Mesh Quantity	Sqm	1332.985	Nil
Shuttering Quantity	Sqm	33662.3	21327.76

Table 4.10: Amount of Slab Work

Description	Unit/ Rate	Waffle slab (Rs)	One-way Ribbed Slab (Rs)
Concrete	Rs/ Cum	19,920,211	19,650,600
Steel	Rs/ MT	16,686,244	21,947,172
Weld Mesh	Rs/ Sqm	194,615	Nil
Shuttering	Rs/ Sqm	13,767,880	67,18,244
Total		50,568,952	48,316,017
Rate per Sqm		2,768	2,522

V. CONCLUSION

In conclusion of this study it can be said that on the basis of results observed in comparison in above chapter this can be said that ribbed slab structure is capable of maintaining the structure stable and more resistible in earthquake load.

Following observations are made in above chapter are as follows:

Storey Displacement:

In terms of Storey Displacement it can be conclude that displacement in waffle slab is comparatively more in comparison to ribbed slab and a variation of 16.1% is visible in the top storey in the comparison. Ribbed slab is in permissible limit as per I.S. 1893-I:2016.

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 12.21% 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 24740.96 KN-m whereas ribbed slab observed 21440.08 KN-m.

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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 3762.98 KN and ribbed slab shows 3010.11 KN with a variation of 17.91%.

Shear Force`:

In terms of shear force ribbed slab shows 92.3552 KN whereas waffle slab shows 80.4545 KN of unbalance forces over horizontal members i.e. beam. Thus it can be said that waffle slab is observing 14.6 % less unbalanced forces.

Stress Analysis:

While conducting stress analysis in the X and Y direction, stresses did not exceeded more than 540 kN m in x direction in case of One way Ribbed slab whereas waffle slab posted values as 786.18 kN in x direction. Whereas marginal difference was seen in y direction with a gap of 17.32 % in the results.

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