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Comparative Analysis of Flat Slab and Grid Slab in Different Seismic Zones

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ABSTRACT- Because of ever-increasing urbanization and a flexuous population, there has been an increasing call for the construction of tall buildings. Earthquakes are the bane of such tall buildings. Because earthquake forces are haphazard in nature and unpredictable, we want to develop engineering tools for studying systems under the influence of those forces. Thus, careful modeling of such earthquake loads is required in order to examine the behavior of the structure with a clear perspective of the harm that is expected. Examining the structure for different earthquake intensities, followed by exams for various criteria at each level, has become an essential exercise over the last two decades. [9]Earthquake-resistant design (ERD) of construction has advanced significantly since the preliminary thoughts took form in the early 20th century. The invention of accelerofigure and introduction of response spectrum are the crucial steps in the history of ERD. The other essential development was the know-how of ductility and hysteretic damping. Gradually, the earthquake-resistant design has advanced considerably in the form of capacity design, displacement based design, and performance-based design. Earthquakes cause varying degrees of shaking in different locations, and the damage caused to buildings in these locations is also unique. As a result, it is critical to build an earthquake-resistant structure that can withstand a certain level of shaking and absorb the impact of an earthquake. Because of the varying depths of earthquakes, identical magnitudes of earthquakes occur, resulting in varying destructive effects in various regions. As a result, the seismic behavior of buildings with comparable layouts must be understood under various earthquake intensities. It is critical to perform seismic evaluation of the structure using various available methods in order to determine seismic responses. [2]

KEYWORDS- Base shear, Bending moment, Gridslab, Nodal displacement, Shear force.

I. INTRODUCTION

Earthquake is sudden shaking of the surface of Earth as a result of release of energy in earth's lithosphere which creates seismic waves. Earthquakes range in size from the ones which may be so feeble that they cannot be felt to the ones that are violent enough to wreak havoc in cities[1]. Seismic activity, in a place is the frequency, type and size of earthquakes that have occurred a lifetime. The seismic zoning map of India divides India into four seismic zones (zones 2, 3, 4 and 5). As per the existing zoning map, Zone five has the highest degree of seismicity and Zone 2 is related as the lowest degree of seismicity (Wikipedia).

In this evaluation of G+4 construction slabs namely flat slab and grid slab are used.

Flat slab is an R.C.C. floor resting directly on concrete pillars without using beams. To provide sufficient shear strength and to reduce negative reinforcement at the support, the flat slab is frequently thickened near the columns[2]. Flat slabs appear trim and fit, resulting in fewer duct and conduit limitations and lower floor heights. They are, however, weak in shear. The flat slab arrangement of building is one wherein the beam is used in the traditional techniques of construction as well as the weight from the slabs is directly conveyed to the columns and from the column to the footing[3]. Various advantages of flat slabs are in the form of architectural flexibility, space usage, simple formwork, and shorter time required. Flat slabs are getting used mainly in workplace because of decreased formwork cost, speedy excavation, and smooth establishment[4].

A grid slab or a waffle slab is a concrete slab fabricated from R.C.C.with ribs going in two directions from the bottom. The grid pattern created by the reinforcing ribs inspired the waffle's name[5]. Waffle slabs are preferred for spans greater than forty feet (12 m) because they are stronger than flat slabs, two-way joist slabs, and one-way joist slabs. A waffle slab is flat from top to bottom, with beams forming a grid-like surface at the bottom. After the concrete has hardened, the grid is formed by removing the mould[6]. When used on longer spans and with heavier loads, this structure is designed to be more stable. Because of its rigidity, this type of structure is generally recommended for structures that require minimal vibration, such as laboratories and manufacturing plants. It is also used in structures that require large open spaces, such as theatres and train stations[7]. Waffle slabs are built using complex formwork and can be more expensive than other slabs; however, depending on the project and the amount of concrete required, they may be less expensive to build.

II. LITERATURE REVIEW

"Navyashree and Sahana (2014) compared the performance of multi-story industrial buildings with flat slabs and traditional RC frames to that of two-way slabs with beams, as well as the impact of construction height on the overall performance of these types of buildings under seismic forces[8]

Makode et al. (2014) discussed the overall seismic performance of flat slab and grid slab buildings. The authors designed a 12-story building with a flat slab and a grid slab in their paper, and the building was analyzed using the Response spectrum method. The results of axial force, base shear, and storey drift are plotted[9].

Mohamed A A El-Shaer (2013) reviewed the lateral analysis for tall structures due to the seismic performance of various R.C.C.slab structures in his paper. The author investigated three structures: flat slab, ribbed slab, and paneled beam slab. The three structures are the most appealing and commonly used floor structures, particularly in high-rise buildings. The declared non-ductile flat slab structure poses a significant risk in high seismicity areas; brittle punching failure results from the transfer of shearing forces and unbalanced moments between slab and columns, which can cause a collapse."[10]

III. OBJECTIVE

- Carry out a dynamic evaluation for seismic loading of multistory RCC structures with flat slabs and grid slabs in different earthquake zones in accordance with Indian Standard code IS 1893-2002 part-I.
- Compare the seismic behavior of a multistory RCC structure with a flat slab and a grid slab for various earthquake intensities in terms of nodal displacement, shear force, bending moment, and base shear.
- To discover the connection among earthquake intensities and responses.

IV. METHODOLOGY

Seismic evaluation is a subset of structural analysis and is the calculation of the reaction of a construction to earthquakes [7]. It is a part of the procedure of structural layout, or structural evaluation and retrofit in areas wherein earthquakes are prevalent. The evaluation can be carried out based on the concept of external action, the behavior of the structure or structural materials, and the type of structural model chosen [8]. The evaluation can be classified similarly based on the type of external action and structure behavior, as shown below:

Equivalent static analysis 2. Nonlinear Static Analysis 3. Response Spectrum Method 4. Time History Method.

The tool used for the evaluation is staad .pro. STAAD or (STAAD.Pro) is a structural evaluation and design software application firstly developed by Research Engineers International in 1997[9-11]. In late 2005, Research Engineers International was sold to Bentley Systems. STAAD.Pro is one of the broadly used structural evaluation and design software products worldwide. It helps over ninety worldwide steel, concrete, timber & aluminum design codes(Wikipedia) [12-13]. In modeling all dimensions of structural elements like Slabs, Beams, and Columns, are assumed and modeled. Dead load / Self weight are assumed [14]. In this analysis G+four constructing are analyzed the use of flat slab and grid slab [15-16]. The structures are of square geometry. These constructions are then analyzed for seismic loading in different zones (II, III, IV, and V) [17].

The details of modeled building are given below:

1. The building is modeled as a frame structure with bays of Length = 5m, Width = 5m, Height = 4m
2. Overall length of the building = 5 × no. of bays = 5 × 5 = 25m
3. Overall width of the building = 5 × no. of bays = 5 × 3 = 15m
4. Overall height of the building = 4 × no. of bays = 4 × 5 = 20m
5. Size of columns = 0.5 × 0.5m
6. Size of beams = 0.5 × 0.5m
7. Size of ribs = 0.3 × 0.3m
8. Spacing of ribs = 1m
9. Thickness of slab = 0.2m
10. Thickness of drop panel = 0.2m
11. Support type = Fixed
12. Soil type = Medium
13. Loading conditions:
    a) Self weight of the building
    b) Seismic weight of the building = Total dead load + Appropriate amount of imposed load = 8 + 2 = 10 KN/m2 (IS 1893-2002 Clause 7.4.1)

(Dead load = 8 KN/m2, Live load = 4 KN/m2

As per IS 1893-2002 Clause 7.3.1 Table 8 if imposed loads exceed 3 KN/m2 then percentage imposed loads is 50 [18-20]. Also, imposed loads on the roof need not be considered. As per IS 1893-2002 (Clause 7.3.2.)

V. RESULTS AND DISCUSSION

In this present work, STAAD Pro. is used to analyze G+4 structures with flat slab and grid slab in different seismic zones. Seismic analysis of these structures, particularly those built in high seismic zones, is absolutely necessary for the safety of the people who live in these buildings.

In the above study it is concluded that:

The nodal deflections (deflection of the node points in a structure) in case of structure with flat slab in different seismic zones i.e. zone II, zone III, zone IV and zone V are much more than in structures with grid slab (Figure 1, Figure 2 and Figure 3).

Shear force for flat slab is more than grid slab in zone II but in all other zones the shear force is less in flat slab than grid slab. In general, structures with flat slab are weaker in shear as compared to the structures with grid slab (Figure 4, Figure 5 and Figure 6).

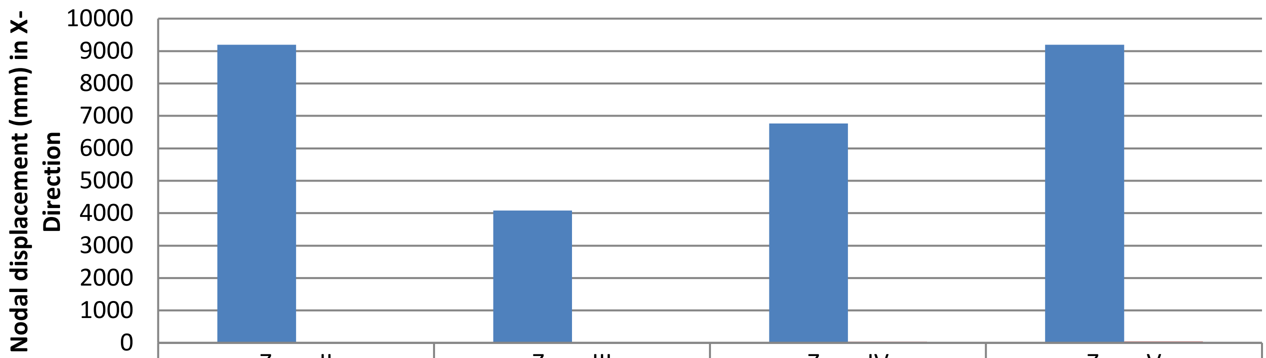
Bending moment in flat slab is comparable to Grid slab. Grid slabs are known to resist bending moment more efficiently (Figure 7, Figure 8 and Figure 9).

Base shear i.e. maximum expected lateral force on the base of the structure due to seismic activity, is less in flat slab than in grid slab (Figure 10).

It is evident that concrete required in flat slab is less than that required in grid slab as more concrete will be required to fill the ribs of grid slab.

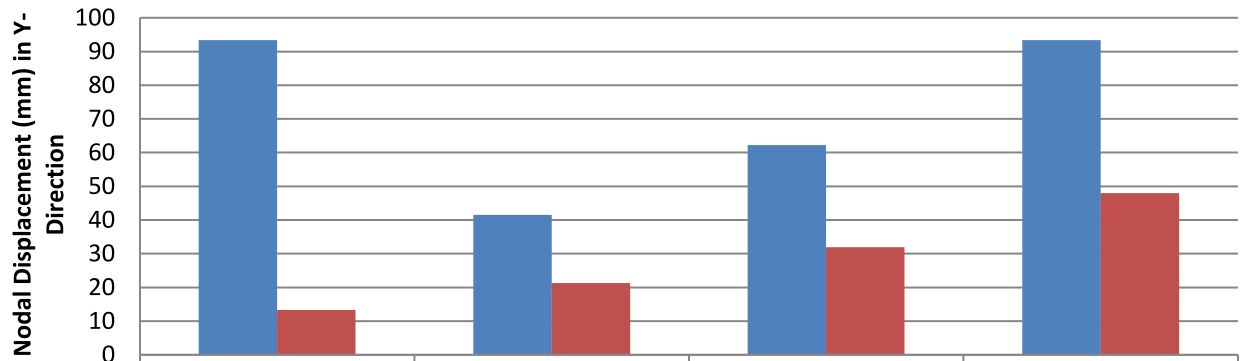
A. Nodal Displacements

Figure 1, Figure 2 & Figure 3 shows the nodal displacements for flat slab in x,y & z directions.



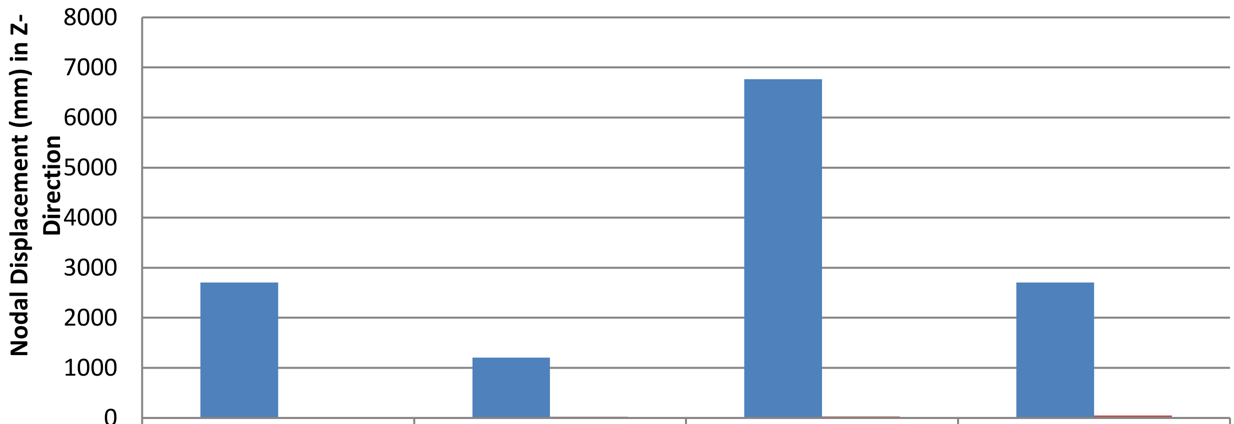
	Zone II	Zone III	Zone IV	Zone V
Flat Slab	9190.236	4084.55	6768.691	9190.236
Grid Slab	12.692	20.307	30.46	45.69

Figure 1: Comparison of nodal displacements (x-direction) for flat slab and grid slab in different seismic zones



	Zone II	Zone III	Zone IV	Zone V
Flat Slab	93.344	41.486	62.229	93.332
Grid Slab	13.32	21.312	31.968	47.953

Figure 2: Comparison of nodal displacements (y-direction) for flat slab and grid slab in different seismic zones



	Zone II	Zone III	Zone IV	Zone V
Flat Slab	2705.726	1202.545	6768.691	2705.726
Grid Slab	13.32	21.312	31.968	47.951

Figure 3: Comparison of nodal displacements (z-direction) for flat slab and grid slab in different seismic zones

B. Shear Force

Figure 4, Figure 5 & Figure 6 shows the Comparison of shear force (x, y & z direction) for flat slab and grid slab in different seismic zones

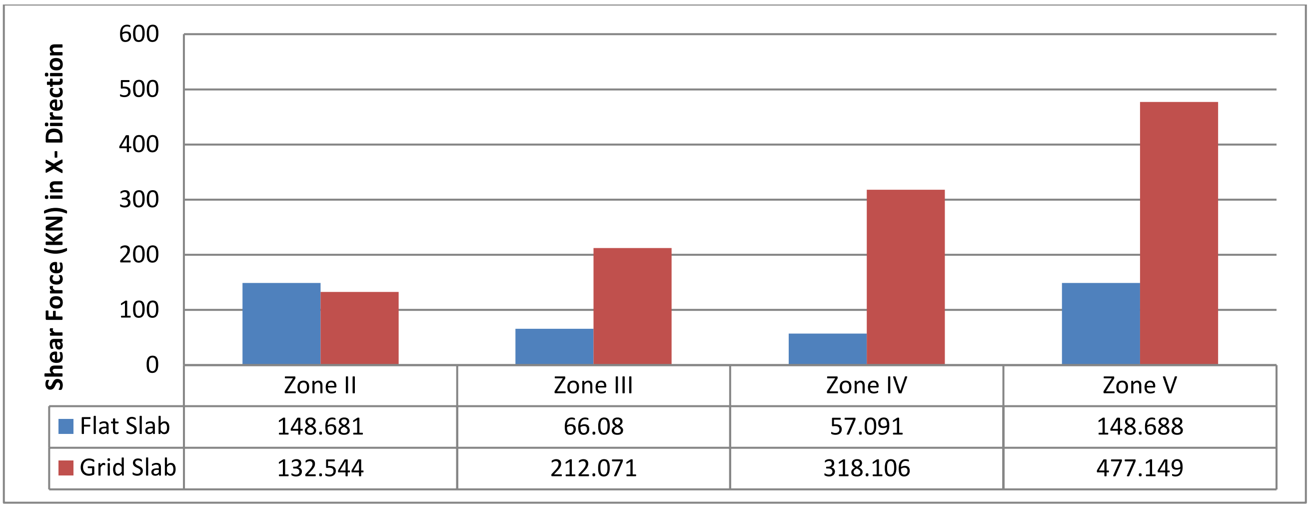


Figure 4: Comparison of shear force (x-direction) for flat slab and grid slab in different seismic zones

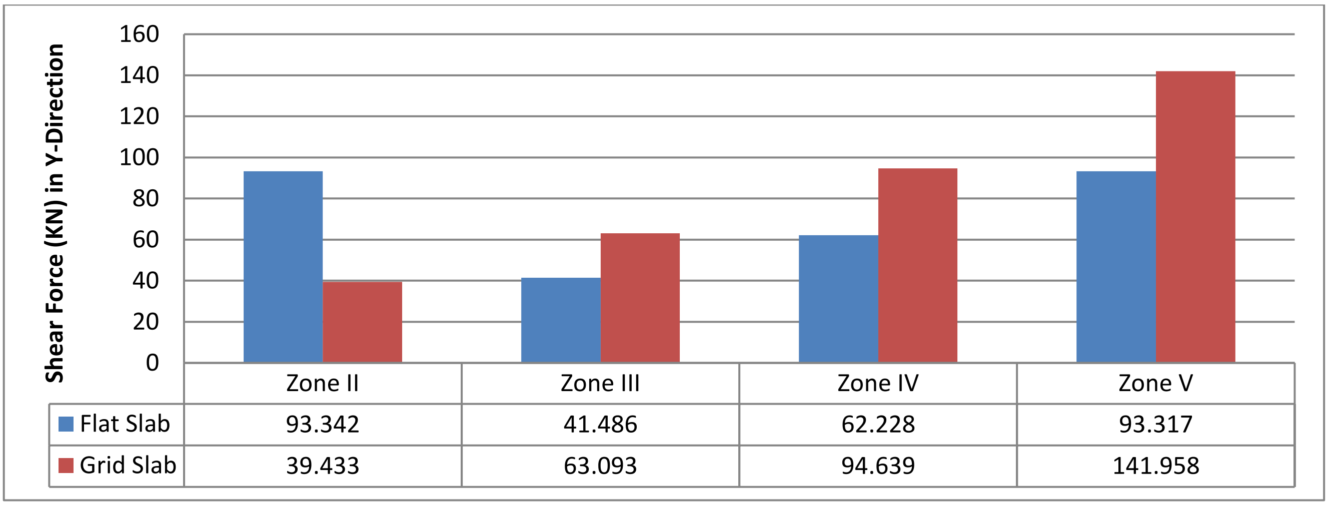


Figure 5: Comparison of shear force (y-direction) for flat slab and grid slab in different seismic zones

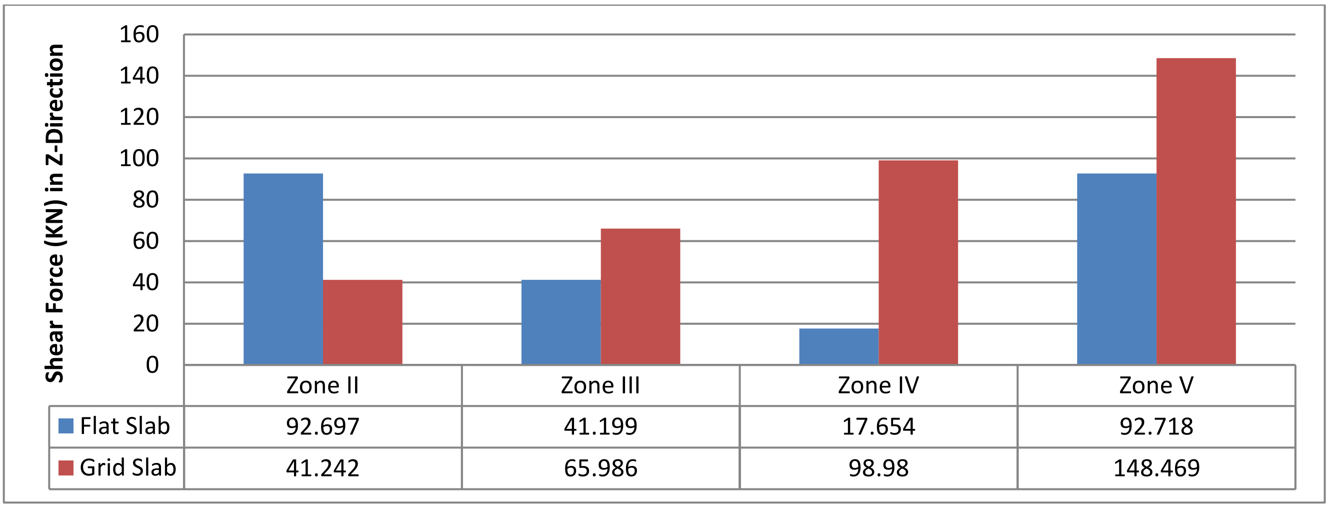
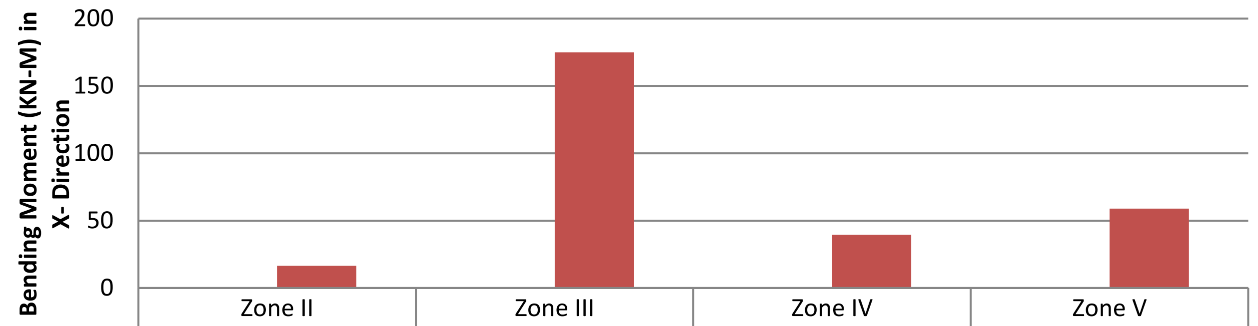


Figure 6: Comparison of shear force (z-direction) for flat slab and grid slab in different seismic zones

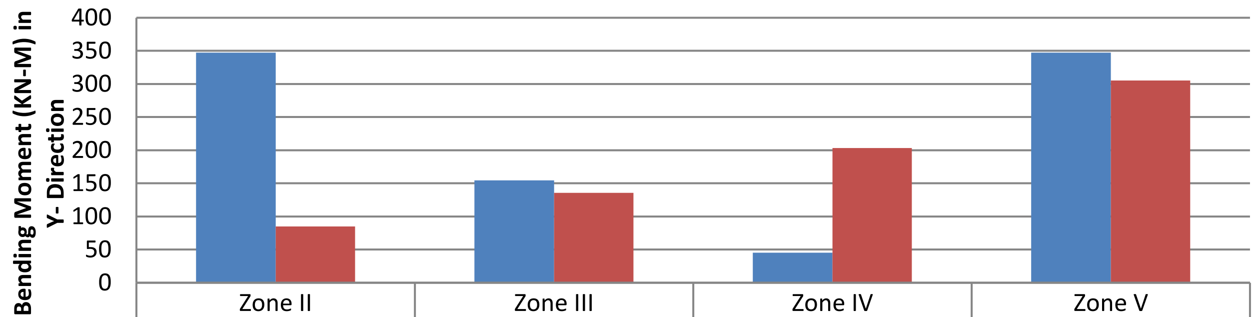
C. Bending Moment

Figure 7, Figure 8 & Figure 9 shows the Comparison of Bending moment in (x,y & z direction) for flat slab and grid slab in different seismic zones



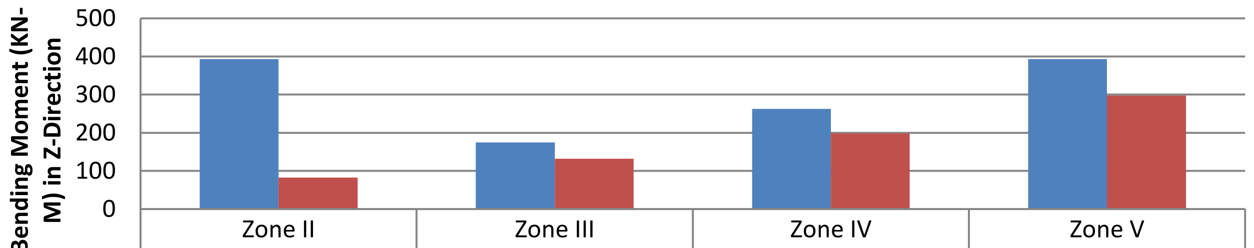
	Zone II	Zone III	Zone IV	Zone V
Flat Slab	0.473	0.21	0.042	0.494
Grid Slab	16.403	174.912	39.367	59.05

Figure 7: Comparison of bending moment (x-direction) for flat slab and grid slab in different seismic zones



	Zone II	Zone III	Zone IV	Zone V
Flat Slab	347.336	154.372	45.458	347.41
Grid Slab	84.796	135.674	203.511	305.267

Figure 8: Comparison of bending moment (y-direction) for flat slab and grid slab in different seismic zones

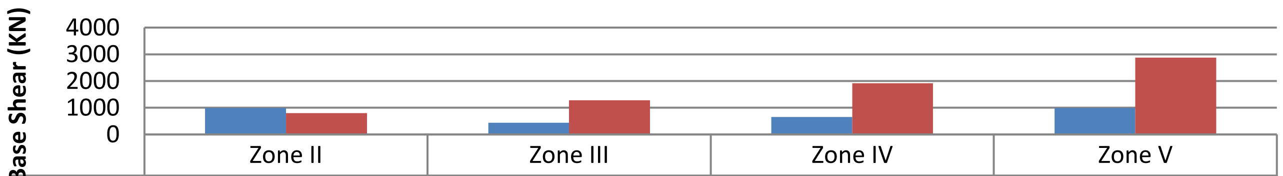


	Zone II	Zone III	Zone IV	Zone V
Flat Slab	393.552	174.912	262.368	393.461
Grid Slab	82.702	132.324	198.486	297.729

Figure 9: Comparison of bending moment (z-direction) for flat slab and grid slab in different seismic zones

D. Base Shear

Figure 10 shows the Comparison of Base shear for flat slab and grid slab in different seismic zones



	Zone II	Zone III	Zone IV	Zone V
Flat Slab	985.96	438.03	657.04	985.56
Grid Slab	798.02	1276.83	1915.24	2872.86

Figure 10: Comparison of base shear for flat slab and grid slab in different seismic zones

VI. CONCLUSION

The nodal deflections in case of structure with flat slab in different seismic zones, i.e. zone II, zone III, zone IV and zone V are much more than in structures with grid. Shear force for flat slab is more than grid slab in zone II but in all other zones the shear force is less in flat slab than grid slab. In general, structures with flat slab are weaker in shear as compared to the structures with grid slab. Bending moment in flat slab is comparable to Grid slab. Grid slabs are known to resist bending moment more efficiently.

Base shear i.e. maximum expected lateral force on the base of the structure due to seismic activity, is less in flat slab than in grid slab. It is evident that concrete required in flat slab is less than that required in grid slab as more concrete will be required to fill the ribs of grid slab.

CONFLICTS OF INTEREST

The authors, Ainain Wantt and Anuj Sachar declare that they have no conflicts of interest.

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