Assessment of Response Reduction Factor of Flat Slab Structures by Pushover Analysis

Ajinkya M. Balate, H. R. MagarPatil

Abstract: ***India is rapidly developing in every aspect now. As a result of which number of smart cities are now arising. while building such smart cities major role is played by infrastructural development. In this infrastructures, speedy and economical constructions are expected to make them more effective. Among such effective construction systems, Flat slab system is the one and is being widely applied on large scale. Flat slabs are thin solid reinforced concrete slabs which are supported directly by columns without beams. Flat slab system is now well adopted for constructions of high rise multi- storied commercial, residential, institutional buildings. They have adventitious constructive, architectural and economical features including easier formwork, speed of construction, spaciousness, etc. The purpose of this project is to study the seismic behavior of Flat Slab Structure for different seismic zones by assessment of Response Reduction Factor using Pushover analysis. Response reduction factor is the factor by which intensity of seismic waves produced during earthquake (maximum elastic base shear) can be reduced to calculate the design base shear. In the project parameters such as base shear, shear and bending stresses and deflection check in flat slab structure are examined by using ETABS Software.***

Keywords: Base Shear, ETABS Software, Flat Slab, Pushover analysis and Response Reduction Factor.

I. INTRODUCTION

The tern Flat Slab denotes the slab with or without drop panels and generally beamless is directly resting upon the columns with or without column capitals (heads). Flat slabs are proving more effective over the traditional slab-beam-column structure system and are being used in the constructions where large amount of free space is demanded as theatres, auditoriums, showrooms and complex. During the seismic activities of earthquake, lateral forces act upon the building. And these lateral forces generate the base shear within the slab structure. High intensity of such forces which leads to the direct or indirect effect on structures and damage to structural and non-structural members. Flat slab structures may face the failures such as flexural failure, punching shear failure, etc. So as to reduce the intensity of such lateral forces response reduction factor(R) is useful. Response reduction factor is ratio of elastic base shear to the design base shear. It is also stated as product of ductility factor, strength factor, structural redundancy and damping associated with the structural behavior.in other way R factor reflects capacity of slab structure to dissipate energy due to above mentioned forces by its inelastic behavior.

R factor goes on decreasing as the number of stories increases. but R factor for Flat slab system is not stated in Indian Standard (IS) code. Here in this paper the assessment of response reduction factor is done for behavior of flat slabs at seismic zones II, III and IV by pushover analysis. ETABS software is used to analyse the flat slab structure.

II. OBJECCTIVES

- The present article represents analytical study to evaluate the response reduction factors of eight storey flat slab building by using ETABS software.
- To analyse the flat slab building using pushover analysis method for different response reduction factors and seismic zones.
- To determine the base shear for different R values using ETABS and manual for calculation validation.
- Also comparative examination of bending stress and to check the deflection in serviceability case for flat slab building.

III. LITURATURE REVIEW

Literature survey stated below is comprised of summary of research papers presented in various popular journals on the topic similar to current field of study.

Kunal P. Shukla[1],This paper related to evaluation of response reduction factor of RCC building based on plastic design methodology and limit state method. The prevention of the total collapse of structure can be performed based on plastic design method, which uses pre-selected target drift & yield mechanism, it is criteria for performance of structure. In this paper author select a fifteen storey RCC frame structure was designed using performance based plastic design methodology and now currently used limit state design which is force based method. The comparative study of seismic performance evaluation of frames was then carried out by determining Response reduction factor as well as failure pattern. Abhijit Salunkhe[2],Flat slabs are system of construction is one in which the beams used in the conventional methods of constructions are done away with, Flat slab structure have advantages over conventional structure such as economy in construction, its architectural appearance, flexibility and speed of the construction. However, because of extraction of beams from flat slab system, reduction in lateral stiffness, hence flat slab structure more flexible to seismic loading as compare with conventional structure.

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The aim of this work is to compare the seismic behavior of flat slab structure with conventional frame structure. R. P. Apostolska. and G. S. Necevska- Cvetanovska [3],They work on Seismic Performance of Flat-Slab Building Structural Systems and conclude that the purely flat-slab RC structural system is considerably more flexible for horizontal loads than the traditional RC frame structures which contributes to the increase of its vulnerability to seismic effects.

Salman I. Khan and Ashok R. Mundhada.[4],The objective of the study is to achieve the comparative seismic performance of flat slab buildings with grid slab buildings. Dynamic analysis of three different high-rise buildings having 12, 15 & 18 stories is performed using response spectrum method for all four seismic zones of India, as categorized by the Indian code for earthquake resistant structures. The assessment of the seismic response is based on the maximum inter-story drift, roof displacement, Time period and the base shear. E-TAB v9.7.3 software is used for the analysis. It is observed that the seismic performance of grid slab buildings was better performance against earthquake load case as compared to that of flat slab buildings. P. Srinivasulu,[5],The flat slab system is currently widely used in commercial building construction. It permits flexibility in architecture, clear height is more, lowers the building height, easier formwork, and speedy construction. Flat slab building structures are naturally more flexible than conventional concrete structures as beams are absent. They are becoming more vulnerable to earthquakes. The objective of this paper is to investigate the behavior of flat slab in 4 different cases as I). Flat slab structure without drop, II). Flat slab structure with column drop, III). Flat slab structure with shear wall, IV). The flat slab structure with column drop and structural shear wall combination, by response spectrum method, by using ETABS software. The behavior of the flat slab is worked out in terms of story displacements, frequency of structure, base shear of building, story level accelerations. And also, most major problem in flat slabs is punching shear failure around the column head.

Mohan H. S.[6] Now a days, construction activity the use of flat slab is absolutely common which helps to weight reduction, speedy construction and economical. Its's capacity is similar from the earlier conventional slab providing features like more stiffness, higher the load carrying capacity & safe also. This paper based on G+5 commercial multistoried building having flat slab & conventional slab have been analyzed for the parameters like base shear, storey drift, axial forces & the displacement. The performance and the structural behavior of both the system in all seismic zones of India have been studied. The conclusion of work was the storey shear of flat slab gives 5% more than the conventional slab structure, axial forces are nearly 6% more than conventional building. Pradip S. Lande,[7],In this paper the parametric investigation was carried out to study seismic response of the system which are as flat slab building, flat slab with perimeter beam, flat slab with shear wall, flat slab with drop panel & conventional building hypothetical systems were studied for two different storey heights located in sever zone V and analysis was carried out in ETABS nonlinear.

Mohammad Hossain1, Tahsin Hossain,[8],They investigated in their research the effect of column on flat plate structure. Also, they have studied the effect of other parameter in different flat plat model in ETABS software. The different parameter is used in study are Height of column, Column have different cross-section with three different panel sizes for gravity and environmental load. They have investigated critical buckling load variation and ultimate load to critical buckling load variation along with non-sway moment magnification factor variation, sway moment magnification factor variation for different location of column. Navyashree K,[9]They study for conventional R.C.C building and flat slab building for different floor height in the seismic regions. The effect of seismic load on structure has been studied for the two types of building with different height. They conclude that the moments are maximum at plinth, first and second level. After second level it decreases and increases at the top storey level. The column behavior changes as height of the building structure increases. Storey drift in building with flat slab construction is significantly more as compared to regular R.C.C building. As a result of this, additional moments are developed there. Therefore, the columns of such buildings should be designed by considering additional moments caused by the drift effect. The difference between the two varies from 28-60 percent. Micallef K., Sagaseta J,[10]They worked on punching shear failure in RCC flat slab subjected to impact loading. They had studied the dynamic behavior of slab for different parameter like with and without transverse reinforcement in it. In this study they have presented different experimental work on flat slab for evaluate punching shear in flat slab subjected to impact loadings. They have presented stiffness and response of slab during experiments. From their result it has been seen that increase in stiffness due to variation in slab span.

IV. METHODOLOGY

A. Modelling of structure

Building model purposed project is having G + 7 storey with floor to floor 3.5 m. A simple 37.1m X 26.5 m plan was prepared for flat slab structure. Panel size of this structure is 5.3 m X 5.3 m .The fixed supports are used as end conditions to all the columns. Brick material of siporex block of grade 1 with density 9 kN/m^3 is used for partition wall. Steel and concrete used have grades Fe415 and M25 respectively. ETABS software is used here for all designs and model analysis. Models having different response reduction factor are created using ETABS. Modulus of elasticity of steel is 2 X105 N/mm^2.

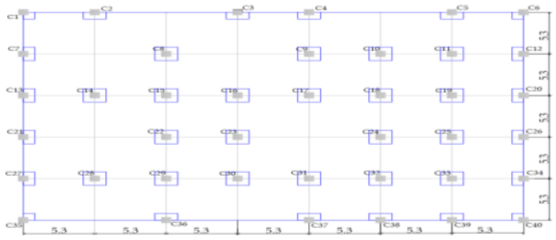

Fig. 1.Floor plan of Flat slab building.

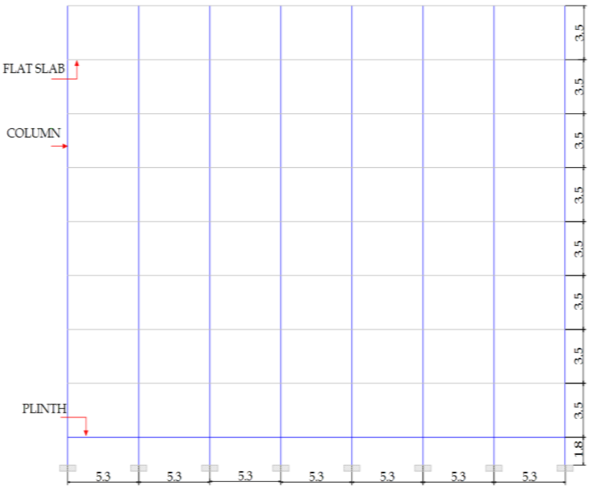

Fig. 2. Elevation of Flat slab building.

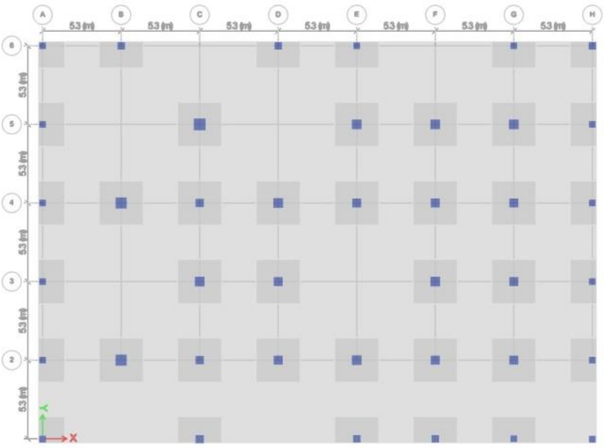

Fig. 3. Model plan drop view for Flat slab building.

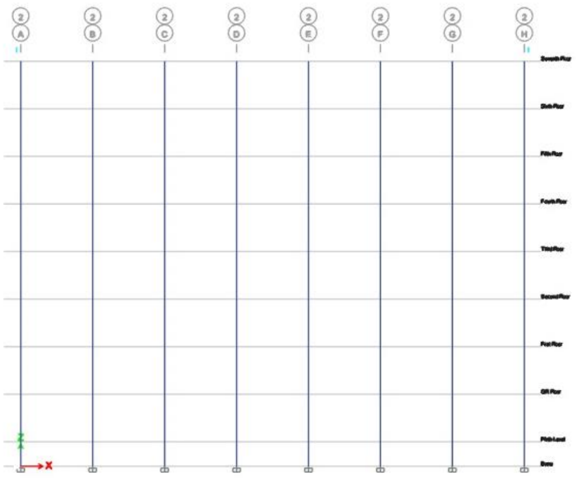

Fig. 4. Model elevation view for Flat slab building.

Table- I: Flat slab Structure element details

Flat slab (thickness)	250mm
Drop size	1.7m x1.7m
Drop thickness	125mm
Thickness of wall	150mm
Plinth beam	300mm x 450mm

Table- II: Flat slab column details

Column size (mm)	Column size
450X450	C1,C4,C5,C7,C12,C13,C20,C21,C26, C27,C34,C35,C39,C40
500X500	C2,C3,C6,C37,C38
550X550	C15,C29,C36
600X600	C17,C18,C19,C23,C25,C30,C32,C33
650X650	C9,C10,C11,C16,C22,C24,C31
750X750	C14,C28
800X800	C8

B. Earthquake and other loads

Table- III: Earthquake and loads

Seismic zone	II,III,IV
Response reduction factor R	1,2,3,4,5
Importance factor I	1
Damping ratio	5%
Type of soil	Hard
Live load	3 kN/m^2
Dead load	
Flat slab	6.5 kN/m^2
Floor finish	1 kN/m^2
Wall load	2.28 kN/m^2
Parapet wall load	0.16 kN/m^2

C. Loading combination

Loading combination as per IS: 1893 are given below-

- 1.5DL + 1.5LL
- 1.5DL ± 1.5EQx
- 1.5DL ± 1.5EQz
- 1.2DL + 1.2LL ± 1.2EQx
- 1.2DL + 1.2LL ± 1.2EQz
- 0.9 DL ± 1.5EQx
- 0.9 DL ± 1.5EQz

As per IS: 456 Load combination used for limit state of serviceability to check the deflection of structure-

- DL+LL
- DL+EQx
- DL+EQz
- DL+0.8LL+0.8EQx
- DL+0.8LL+0.8EQz

Where, EQX and EQZ are Earthquake loads DL is Dead load and LL is Live load.

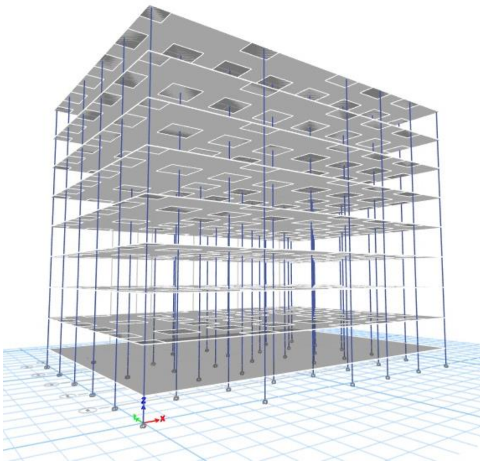

Fig. 5. Isometric view for Flat slab building in ETABS.

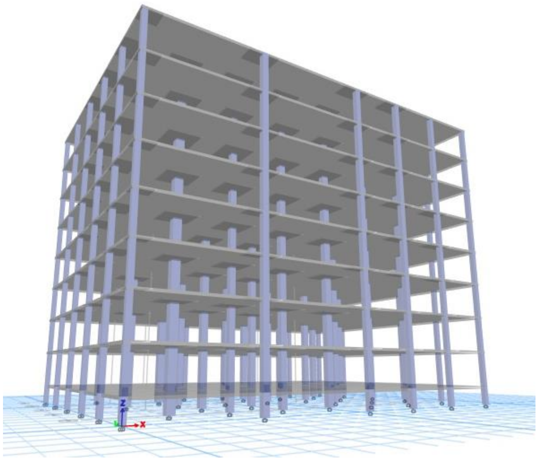

Fig. 6. Model 3D view for Flat slab building in ETABS.

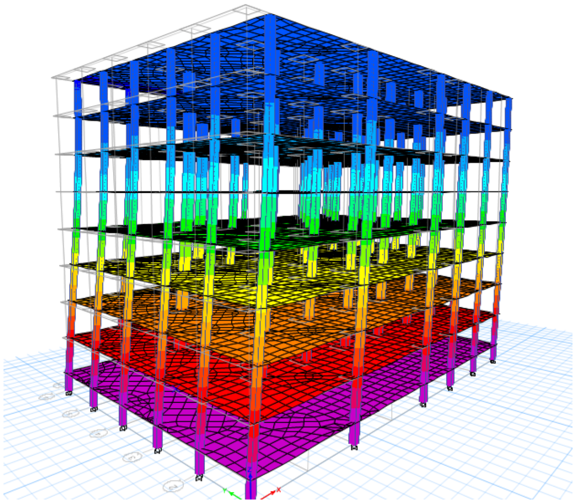

Fig. 7. Seismic load view for Flat slab building.

V. RESULT AND DISSCUSION

A. Result graph comparison

Graphs are plotted by comparing the bending moment in the slab with bending moment and similar comparison are plotted for R=1, 2,3,4,5 and zone II, III, IV.

1. Graphical comparison of bending moment of flat slab for load case 1.5(DL+LL) with 1.5(DL+Eq.X) which is critical load case for R=1, 2, 3, 4, 5 considering zone II

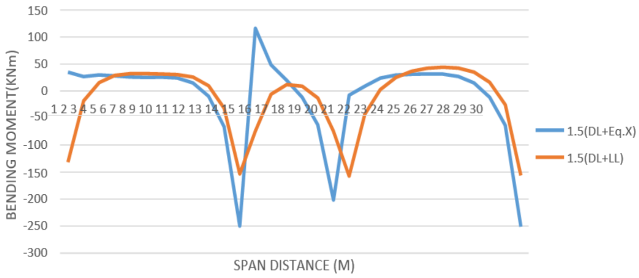

Fig. 8. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=1.

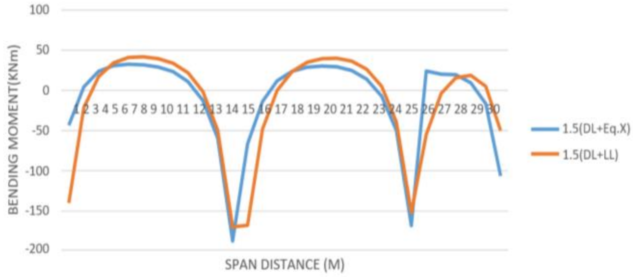

Fig. 9. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=2.

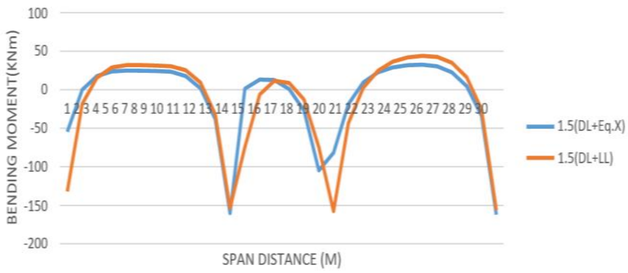

Fig. 10. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=3.

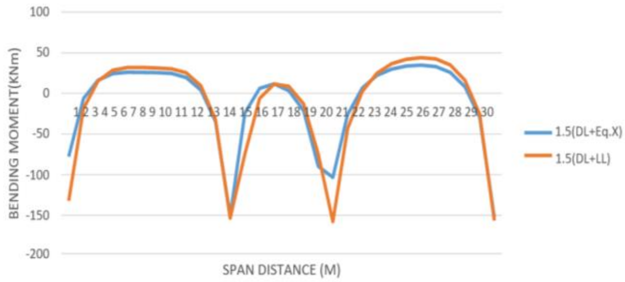

Fig. 11. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=4.

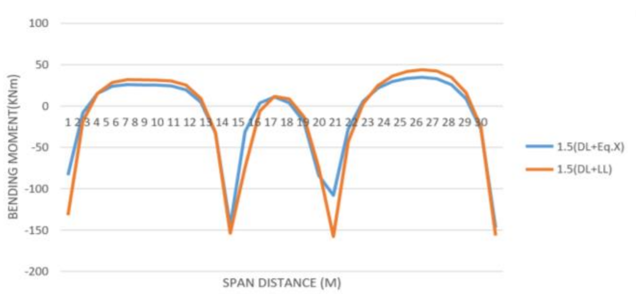

Fig. 12. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=5.

2. Graphical comparison of bending moment of flat slab for load case 1.5(DL+LL) with 1.5(DL +Eq.X) which is critical load case for R=3 considering zone III

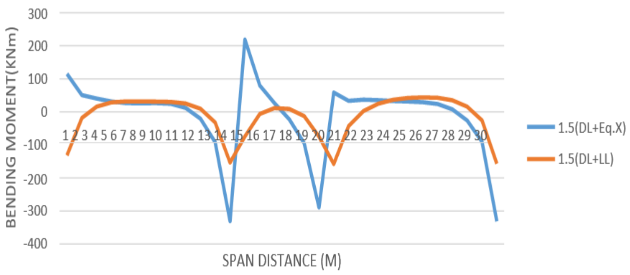

Fig. 13. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=3.

3. Graphical comparison of bending moment of flat slab for load case 1.5(DL+LL) with 1.5(DL +Eq.X) which is critical load case for R=1 Vs R=3, 5 considering zone II

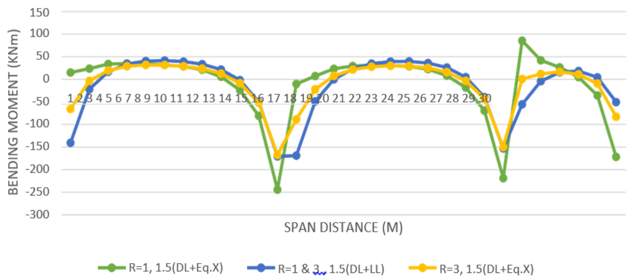

Fig. 14. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=1 Vs R=3.

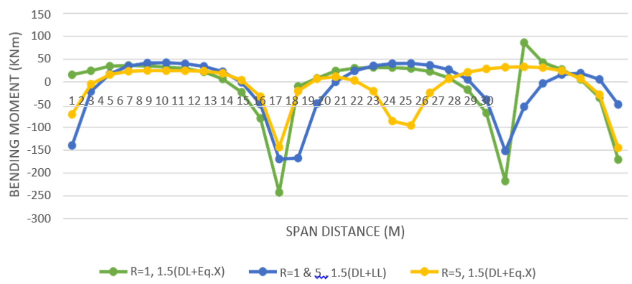

Fig. 15. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=1 Vs R=5.

4. Graphical comparison of bending moment of flat slab for load case 1.5(DL+LL) with 1.5(DL +Eq.X) which is critical load case for R=3, 5 considering zone II,III,IV

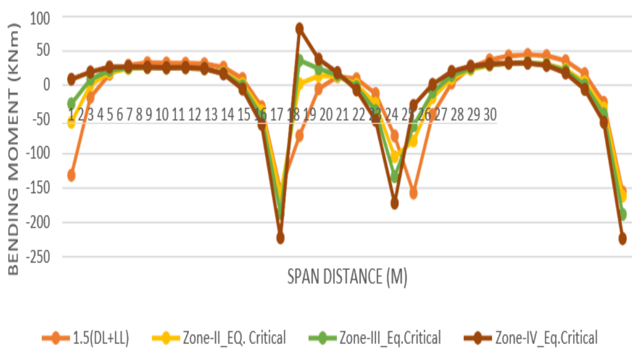

Fig. 16. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=3, Zone-II, III, IV.

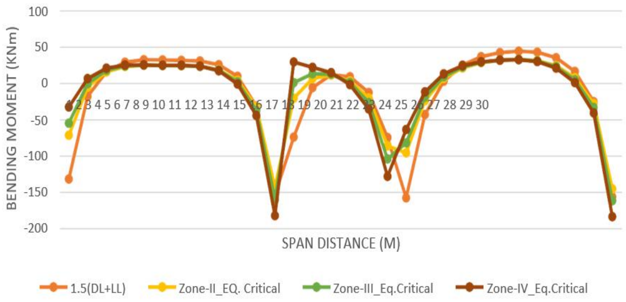

Fig. 17. For flat slab 1.5(DL+Eq.X) with 1.5(DL+LL) for R=5, Zone-II, III, IV.

B. Deflection graph for flat slab system

For stability of slab structure deflection check is necessary, to check the allowable deflection as per IS 456 serviceability load case is considered, as per the final deflection due to loads on structure including temperature, shrinkage and creep should not exceed Span/350 or 20mm whichever is lesser. For this flat slab case span are 5.3m and 10.6m allowable deflections 15.14mm and 30.28mm respectively

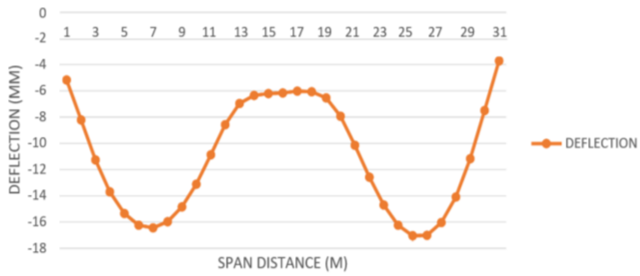

Fig. 18. For flat slab deflection Vs span dist. For R-3 & zone-II.

In deflection graph we observed that maximum vertical deflection in the slab is 16.63mm which is lesser than 20mm, so the slab is safe against the deflection during serviceability condition.

C. Lateral deflection for flat slab system

Lateral stability of the building deflection check is necessary for serviceability load case, as per codal provision the lateral allowable deflection is 0.4% of the height of storey. The height of flat slab building is 29.80m and allowable deflections 119.20mm.

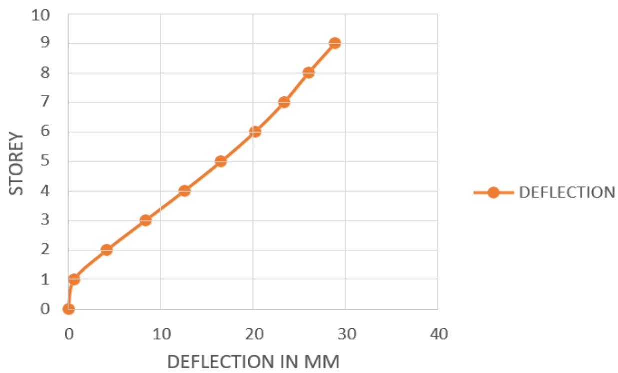

Fig. 19. For flat slab column deflection Vs span dist. For R-3 & zone-II.

D. Base shear and horizontal acceleration spectrum for flat slab

1. Design horizontal acceleration spectrum for Flat Slab

Table- IV: Design horizontal acceleration spectrum Ah for Flat Slab

Seismic zone	Response reduction factor-R				
	1	2	3	4	5
Zone II	0.0608	0.0312	0.0224	0.0154	0.0119
Zone III	0.0787	0.0387	0.0258	0.0197	0.0153
Zone IV	0.0987	0.0589	0.0378	0.0282	0.0208

2. Design base shear for Flat Slab

Base shear means lateral forces acting to the base of a structure due to seismic waves, following are the results of base shear (kN) of all models for various R factors

Table- V: Design Base shear V_B ETABS with manual validation for Flat slab structure

Seismic zone		Response reduction factor-R				
		1	2	3	4	5
Zone II	ETABS	4102.69	2139.53	1243.01	973.68	732.83
	Manual	4076.79	2133.89	1269.37	963.44	726.39
Zone III	ETABS	6334.58	3279.86	2192.07	1529.56	1268.32
	Manual	6328.87	3259.47	2239.28	1533.63	1274.62
Zone IV	ETABS	9324.39	5139.27	3089.27	2763.03	1827.25
	Manual	9333.51	5129.34	3127.49	2748.12	1813.38

VI. SUMMURY AND CONCLUSION

Above comparative results have shown clearly the comparison of flat slab structure having different response reduction factors.

Among the graphs stated above, better results are given by the flat slab structure of zone II having R factor of 3. In this design, earthquake case can be considered as critical load case, because the difference between ultimate load case excluding earthquake and ultimate load case of earthquake is minimum or the same value.

The moment which gives safe depth check as per provided depth is considered as ultimate moment, for the design purpose. Similarly, the design moment of above case governs earthquake case is safe under depth check.

It is observed by the above graph, the flat slab gives maximum bending moment at end corner as it behaves similarly to cantilever slab.

Earthquake cases for Zone III and IV, the maximum bending moment is given which gives more difference. In these cases provide more depth then the slab depth. It is also necessary to construct peripheral beam as well as to provide shear wall at the corner of building design so as to improve sustainability of it and will also provide extra bottom steel for slab. Earthquake intensities for zone III and zone IV are more. for that, avoid the multistoried flat slab type of building.

For flat slab structure having R-3, we get safe serviceability deflection check.

Flat slab structure for R-4 reduces the intensity of earthquake by 40 % while for R-5 reduces it by 50 % which means lateral forces directing upon the building are also reduced. But for that ductile detailing is necessary. As there is no beam construction in pure flat slab so, it can be a problem for providing ductile dealing steel.

It is clarified from all above observations that flat slab structure for R-3 reduces the earthquake intensity by 30 % so that it can sustain the building structure during seismic vibrations produce by earthquake. Also, against the limit serviceability and limit state of collapse this structure is safe.

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