IJSRD - International Journal for Scientific Research & Development| Vol. 6, Issue 02, 2018 | ISSN (online): 2321-0613

Comparative Analysis of Performance of RCC Framed Building with Flexible & Rigid Slabs under Seismic Loads

Madhulika Malviya[1] **Dushyant Kumar Sahu**[2]
[1,2]Assistant Professor
[1,2]Government Engineering College, Jagdalpur, India

Abstract— A reinforced concrete slab is one of the most important components in a building. Geometry of a reinforced framed building plays an important role in its structural behavior under lateral loads. The objective of the present study is to perform the critical study of three RCC framed buildings, to perform the parametric and comparative analysis of structure for rigid and flexible condition. A total of 18 number of RCC framed structure with different number of floors has been considered for this study. The material has been kept constant for all the cases. Percentage of steel in columns, area of steel in columns and section of the columns has been compared. Maximum deflection, support reaction, bending moments, shear forces for both rigid and flexible slab for all the cases has been also calculated for lateral loads as per IS 4998-1: 1992 , IS 1893: 2002 & IS 4928: 1993 using STAAD.Pro V8i software. Parametric study has been performed for zones III, IV&V and different structural parameters.

Key words: Flexible and Rigid Slab, Seismic Analysis, RCC Frame, STAAD. Pro V8i, Percentage Reduction of Reinforcement

I. INTRODUCTION

A Reinforced Concrete Slab is a structural element of modern buildings supported by Columns and Beams. A slab is a flat, two dimensional, planar structural element having thickness small compared to its other two dimensions. It supports mainly transverse loads and transfers them to support primarily by bending element just like beam.

The fixed slab is a thin concrete slab placed on a rigid foundation with infinite plane dimensions. Due to the restraint of the rigid foundation, the horizontal displacements and turn of the slab are zero. The free slab is free of external restraint and can deform freely in all directions.

The Evolution of the computation software has made it possible to analyze and design structures at an accelerated pace. This has facilitated the development of the projects with reduced time and cost. The finite element method and codes of calculation provides the engineers, the possibility of modeling and analysis, as well as the ability to control the model of calculation and to interpret the results. Simplified elastic methods of calculation were systematically used in dimensioning structures based on stick model, with concentrated masses and equivalent stiffness's. However, this approach suffers with the limitation that comprehension of the real seismic behavior is not possible. The response of the structure with flexible floors under seismic forces in terms of displacement has been largely unexplored.

Using codes of calculation based on the finite element methods, this paper deals with analyzing the structural response of a building with and without diaphragms, when subjected to seismic forces using specific methods based on the principle of finite elements which could give good indications on the seismic behavior of the structure. This paper deals with the comparative analysis of performance of RCC framed buildings with different number of floors in terms of the reinforcement requirement.

II. OBJECTIVE OF THE WORK

The objective of the present study is defined as follows:

a) The main objective of this thesis is to perform the critical study of three RCC framed buildings with increasing number of floors under seismic zones III, IV & V under rigid and flexible slab conditions.
b) To perform the parametric and comparative analysis of structures for rigid and flexible conditions i.e. to compare percentage of steel in columns, area of steel in columns and sections of the columns.

III. LITERATURE REVIEW

Daniel et. al. (2000) analyzed the structures subjected to earthquakes to discern the best way to reinforce the buildings so that they suffer the least damage possible. They determined that the vertical resisting system with triangulations have the greatest influence on performance.

Dong- Guen Lee et. al. (2004) conducted the structural analysis using an analytical model which disregards the flexural stiffness of the floor slabs and considering the T-section beam effect for the simplification and efficiency of the structural analysis. In this study, to resolve the problems, efficient analytical modeling methods employing the sub structuring techniques, super-elements, and rigid diaphragms are adapted. They computed the analytical results of time history analysis and the computational time of various analyses.

Monotti (2004) Mustapha et. al. (2012) proposed that the structure of a building can be regarded as composed of several vertical systems bounded by horizontal diaphragms. They assumed a rigid diaphragm for the modeling of floor slab. The floor can have a significant influence on the lateral response of the structures, if the flexibility of the floor slab is completely ignored then the lateral rigidity can be appreciably underestimated .Within the framework of this study, they examined the deformability of the floor in their plan, under the effect of horizontal seismic actions.

Augustssonet.al.(2010) performed the comparison of the generated results and concluded that the reliability for the SDOF analyses, assuming elastic response, is good for both beams and slabs. The analysis approached the FE-analysis when increased load duration is used, but is not a reliable method for impulse loaded structures. However, the results are conservative and can be used for preliminary design. To design such structures with linear elastic FE analysis, the concentrated shear forces gained must be distributed within larger parts of the structure in order to describe the real behavior of the slab since occurrence of cracking leads to stress redistributions.

Hakimi (2012) recommended the methodology to perform the stress distributions and also to investigate the influence of flexural cracking on the redistribution of shear forces. The results showed that the shear stress along the support of a cantilever reinforced concrete slab becomes more evenly distributed when the non-linear flexural response is taken into account in the structural analysis.

Jennings et. al. (2013) presented the semi-automatic method for the rigid-plastic yield-line analysis of slabs to predict the mechanisms which are most likely to cause collapse. Linearized constraint equations were developed analytically and used with the conjugate gradient method in order to overcome problems due to the existence of discontinuities in slope of the optimizing function.

Koliou, M., Filiatrault, A., Kelly, D., and Lawson, J. (2015) conducted a study on buildings having rigid walls and flexible roof diaphragms (RWFD). The results of the study indicate that codal provisions for this type of building do not satisfy the collapse objective requirements of FEMA P695 under maximum considered earthquake ground motions. This is because the provisions are based on assumed yielding of the walls rather than the roof diaphragm. To assist with creating provisions that take into account large flexible diaphragm deformations, a semi-empirical formula to estimate the fundamental period of RWFD buildings that accounts for roof diaphragm flexibility is derived in this paper.

IV. DESCRIPTION OF SLABS

In the structural analysis of buildings, floor slabs are usually assumed to be rigid in their planes. At the mass centre of each rigid floor, there is a master node having three degrees of freedom to represent the two in-plane translations and one out of- plane rotation of all the other nodes or so-called slaved nodes in this floor. These slaved nodes contain three degrees of freedom two in-plane rotations and one out-of-plane translation. In this assumption, no deformation in the plane of building floors, is used widely in the structural analysis of building systems.

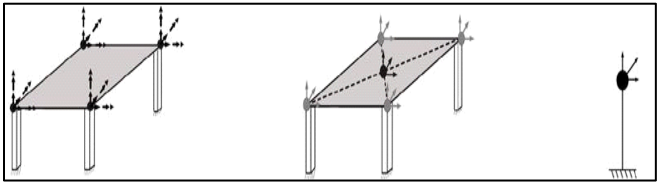

Fig. 1: Stick Model

V. MODELS OF BUILDING ANALYSIS

For building analyses under the rigid-floor assumption, master and slaved nodes are used. Each rigid floor contains a master node with three degrees of freedom at the mass center of the floor to control the two in plane translations and one out-of-plane rotation of all the slaved nodes in this rigid floor. The slaved nodes include three additional degrees of freedom-two in-plane rotations and one out-of-plane translation. Thus, the total number of degrees of freedom is equal to three times the total number of slaved nodes and master nodes in the mesh for a three-dimensional (3D) building analysis. The numerical model of the master-slaved-node algorithm can be performed using a constraint matrix.

For building analyses under the flexible-floor assumption, each node contains six degrees of freedom-three translations and three rotations. Thus, the number of degrees of freedom for the flexible-floor mesh is about twice as large as that for the rigid-floor mesh. The membrane elements were also used to model the shear walls of the buildings under the rigid- or flexible- floor assumption.

In the analysis of building structures, the stick model which has 3 in-plane DOF`s per floor is usually used in commercial software, such as STAAD.Pro, ETAB etc., by applying the rigid diaphragm assumption. But if the rigid diaphragm assumption is applied, the story shear forces in the basement may be significantly overestimated since the flexibility of the floor system is ignored.

VI. METHODOLOGY ADOPTED

The analysis of R.C.C. frames carried out when it is subjected to earthquake forces and rigid slab conditions at various sections along its height. The vertical cross-sections for P + 8 building frame from one of the cases are given below:

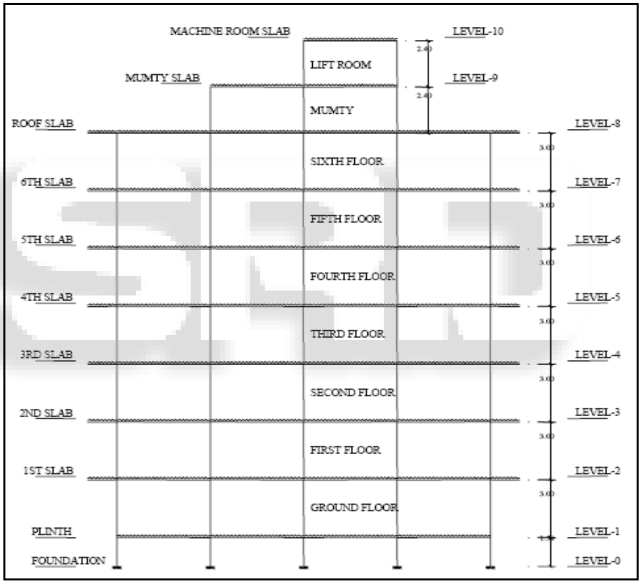

Fig. 2: Building Frame

A. *Steps for Analysis*

In order to achieve the objectives of the study the following methodology is proposed:

a) Understand the design procedure of a RCC frame structure as per Indian Standard IS-456:2002, IS-1893:2002.
b) Select frame geometry.
c) Modeling of a frame in STAAD.Pro V8i.
d) Selection of earth quake zones for different case for analysis.
e) Application of lateral loads on the structures

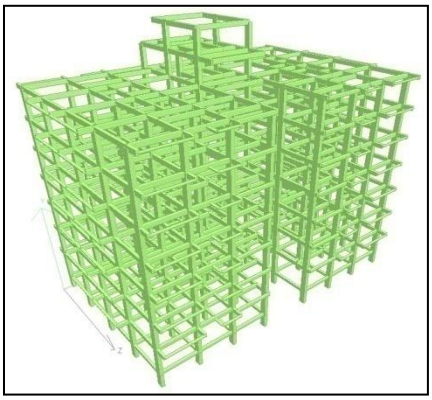

Fig. 3: Model of the RCC Frame in Staad.Pro V8i.

f) Analysis considering different diaphragm models (18 possible cases)
g) Results will be presented in the form of graphs and tables.
h) Parametric and comparative study of all cases in terms of Support Reaction, support moments, sizes of members, percentage steel required and overall economy.

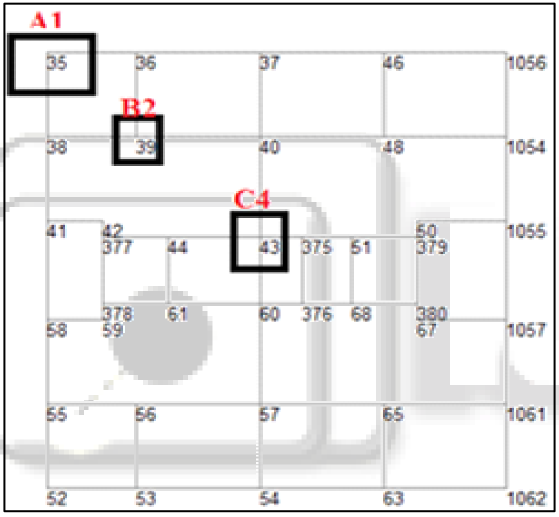

Fig. 4: Column Grid

B. *Problem Formulation*

This paper includes comparative study of behavior of structures with different RCC frame structures (18cases) by changing the height of the building (number of floors), earthquake zones and type of slab (Flexible or Rigid). A comparison in results of deflection, Support Reactions, Moments, percentage of steel in columns, area of steel in columns and sections of the columns.

Details of the constant parameters taken for RCC frames are as follows:

1) Grade of concrete - M20
2) Grade of Steel - Fe-415
3) Modulus of elasticity (M20 Concrete)- 2.23 x 10^4 N/mm^2
4) Modulus of elasticity (Fe-415 Steel) - 2 x 10^5 N/mm^2
5) Poisson's Ratio - 0.17
6) Dampness Ratio - 0.05
7) Foundation Type - RCC Footing

1) Description of Loading

1) Concrete : 25 KN/m^3
2) Insulation : 1 KN/m^3
3) Dead Loads : 4 KN/m^2
4) Live Loads : 2 KN/m
5) Wall Loads : 5.2 KN/m (100mm thick wall)
6) 10.4 KN/m (200mm thick wall)
7) Parapet Loads : 2 KN/m
8) Staircase Loads : 2 KN/m^2
9) Sunken Loads : 4 KN/m^2

2) Seismic Parameters

– Zone factor (z) as per IS-1893:2002 Part -1 for different. Zone as per clause 6.4.2.

Seismic Zone	II	III	IV	V
z	0.1	0.16	0.24	0.36

– Importance factor (I)- depending upon the fundamental use:
– For Structure and economic importance, I = 1.0
– For Importance service and community building as I = 1.5
– R-Response reduction factor:-Depending on the perceived seismic damage performance of the structure:
– For ordinary RC moment resisting Frame (OMRF) R = 3
– For Special RC moment resisting Frame (SMRF) R = 5
– (Here R=3 for the chimney structure)
– Average Response acceleration:

Coefficient S_a/g	Time Period for medium soil site
$S_a/g = 1+15T$	$0.00 \le T \le 0.1$
$S_a/g = 2.5$	$0.1 \le T \le 0.55$
$S_a/g = 1.36/T$	$0.55 \le T \le 4.00$

– Design horizontal seismic coefficient :

$$A_h = \frac{z}{2}\frac{I}{R}\frac{S_a}{g}$$

C. *Cases for Analysis*

All possible combinations have been worked out considering P+6, P+8, P+10 type of RCC framed buildings in seismic zones III, IV and V for both flexible and rigid slabs. The required reinforcement has been computed. Comparison of results has been represented in the form of tables and graphs.

D. *Results*

ZONES	FLEXIBLE SLAB (mm^2)	RIGID SLAB (mm^2)	PERCENTAGE REDUCTION
ZONE-III	38170	35867	6.93%
ZONE-IV	29238	25006	14.47%
ZONE-V	21623	17086	20.98%

Table 1: Total Percentage Reduction of Reinforcement for P+6 Building

ZONES	FLEXIBLE SLAB (mm^2)	RIGID SLAB (mm^2)	PERCENTAGE REDUCTION
ZONE-III	52704	45494	13.68%
ZONE-IV	59462	48688	18.01%
ZONE-V	68737	53794	21.73%

Table 2: Total Percentage Reduction of Reinforcement for P+8 Building

ZONES	FLEXIBLE SLAB (mm^2)	RIGID SLAB (mm^2)	PERCENTAGE REDUCTION
ZONE-III	72595	58280	19.71%
ZONE-IV	86094	64072	25.58%
ZONE-V	102804	69704	32.19%

Table 3: Total Percentage Reduction of Reinforcement for P+10 Building

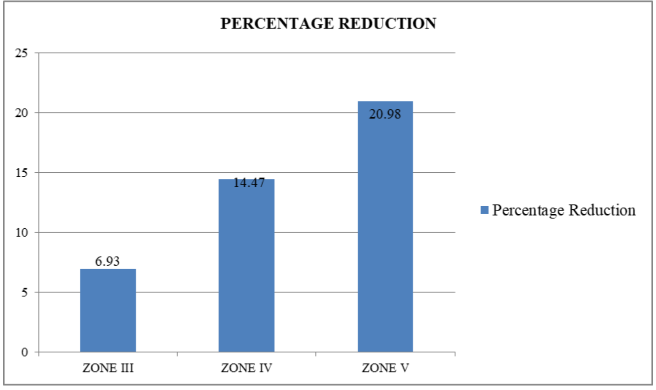

Fig. 5: Total Percentage Reduction of Reinforcement for P+6 Building

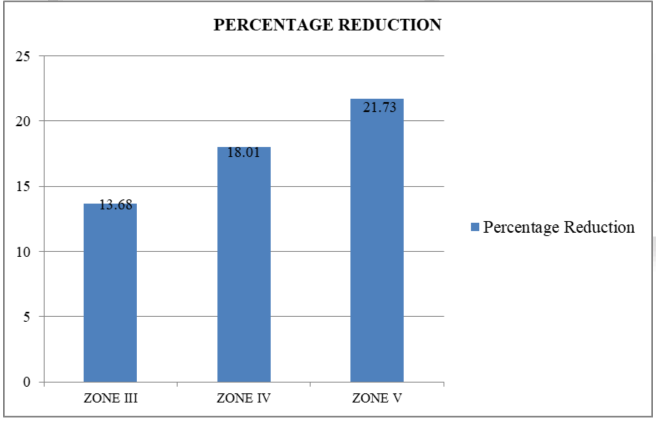

Fig. 6: Total Percentage Reduction of Reinforcement for P+8 Building

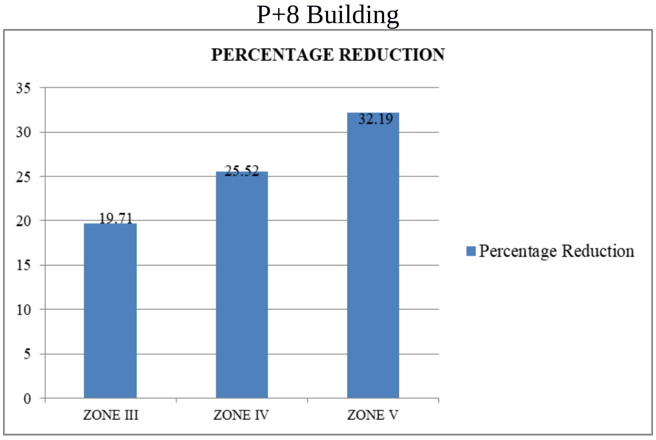

Fig. 7: Total Percentage Reduction of Reinforcement for P+10 Building

VII. CONCLUSION

a) Size and reinforcement of heavy columns of structure were reduced to a great extent by using master slave command which induces Rigid Diaphragm behavior in STAAD.Pro model. Whereas size and reinforcement of relatively lighter columns of structure were increased resulting in an overall balanced structure.

b) In all RCC Framed Buildings especially residential buildings, higher sizes of columns become obstruction in proper furniture layout of residence and also are an eyesore and heavy costs are incurred to conceal those columns with interior facade. By using Rigid Diaphragm Modeling, column sizes become uniform and easy to manage in interiors.

c) Reinforcement in columns increased by increasing number of floors from P+6 to P+8 and P+10, as expected.

d) Reinforcement in columns increased tremendously by changing Seismic Zones (III, IV and V) by changing Seismic Zone Coefficients from 0.1 to 0.16 to 0.24.

e) Slab openings in floor systems may cause irregularities in the horizontal plane according to the earthquake code.

f) In high seismic risk regions, beam-slab systems having high lateral rigidity should be preferred.

g) System lateral rigidity is biggest in beam-slab systems

VIII. SCOPE OF THE STUDY

a) This study can be extended to structures with greater number of floors i.e. P+12, P+14, P+16, and so on.

b) Behavior of beams by considering Rigid Diaphragm behavior can also be analyzed thus.

c) Slab openings in floor systems may cause irregularities in the horizontal plane. This aspect can also be included in this study.

d) Analysis of the case in which the slab openings are formed very close to the vertical load carrying elements can also be included in this study.

ACKNOWLEDGMENTS

If words are considered as symbols of approval and token of acknowledge, then the words play the heralding role of expression of our gratitude. I express my sincere and profound gratitude to our Director, SIRTS for his valuable suggestion and ample resources at all stages of the research work.

I also wish to thanks all my respected teachers, for their constant support and guidance during my research work. I extend my gratitude to all staff member of department of C.E. and colleagues, who have always been by my side, through thick and thin during these years and helped me in several ways.

REFERENCES

[1] Koliou. Maria; Filiatrault, Andre; Kircher, (2017) Assessing Modeling Complexities on the Seismic Performance of an Instrumented Short-Period Hospital Source: Journal of structural engineering

[2] M Koliou, A Filiatrault, DJ Kelly, J Lawson. (2015) Journal of Structural Engineering 142 (3), 04015166, 2016. 7, 2016. Evaluating existing and proposing new seismic design provisions for rigid wall-flexible diaphragm buildings. J Lawson, D Kelly, M Koliou,

AFiliatrault. 83rd SEAOC Annual Convention Proceedings: Indian Well,

[3] Knapton(2014) Ground bearing concrete slabs London : Telford, 2003. , Single Pour Industrial Floors London: Telford, 1999. In-Situ Industrial Hard standings London: Telford, 1999.

[4] Hakimi (2012) Master of Science Thesis in the Master's Programme Structural Engineering and Building Performance Design and analysis of continuous beams and columns. Chalmers University of Technology, Göteborg, 2012.

[5] Augustssonet.al. (2010) in particular transforming a reinforced concrete beam or slab into a Single Degree of Freedom .The SDOF simplification has been shown to describe the elastic behavior of steel structures. Structural Response of Reinforced Concrete Frames Subjected to Explosions.

[6] Monotti (2004) Mustapha et. al. (2012) Applications of Approximation Theory of various diaphragms in earthquake engineering .Department of Civil and Environmental Engineering, University of Perugia, Italy.

[7] Dong-Guen Lee, Hyun-Su Kim. (2002) efficient seismic analysis of high-rise building structures with the effects of floor slabs, Engng. Struct., 24, n. 5, 613-623.

[8] Daniel et. al.(2000) .and Coelho, E. Shaking table tests of 1:3 reduced scale models of four unreinforced masonry buildings. Proceedings of the 13th World Conference on Earthquake Engineering. Vancouver, Canada. University of Vancouver.

[9] M. Dolce, V. D. Lorusso, A. Masi. (1994)Seismic response of building structures with flexible inelastic diaphragms, Struct. Des. Of Tall Buildings, 3, 87-106.

[10] S. K. Jain, P. Jennings. (1985) Analytical models for low-rise buildings with flexible floor diaphragms, Earth. Engng. Struct. Dynam, 13, 225-241.

[11] Cook, R. D., Malkus, D. S., and Plesha, M. E. (1989). Concepts and applications of finite element analysis, Wiley, 3rd Ed., Wiley, New York, 370– 376.

[12] Jain, S. K. (1984). Seismic response of buildings with flexible floors. J. Engrg. Mech., ASCE, 110(1), 125–129.

[13] Muto, K. (1974). A seismic design analysis of buildings. Maruzen, Ltd., Tokyo, 241–260.

[14] DhimanBasu and Sudhir K. Jain "Seismic Analysis of Asymmetric Buildings with Flexible Floor Diaphragms. Journal of structural engineering ASCE, August 2004, 1169. RPA 2003, Algerian earthquake resistant regulations, DTR, MHU CGS, 2003.

[15] Ju, S. H., and Lin, M. C, Comparisons of building analyses assuming rigid or flexible floors, J. Struct. Eng, 125- 1, Pages 25-31, 1999.

[16] Lee DG, Kim HS, The effect of the floor slabs on the seismic response of multi-story building structures, Proceedings of APSEC 2000, Malaysia, 2000.

[17] Matthew Spooner, Gregory A. Mac Rae, Bruce Deam, Debra Gardiner and Vinod Sadashiva, Quantifying the dynamic response of flexible floor diaphragms, NZEEE, 2009.

[18] Fox, E.N., "Limit analysis for plates: a simple loading problem involving a complex exact solution", Philosophical Transactions of the Royal Society, London, Vol. 272 Series A, 1972, pp. 463-492.