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SEISMIC ANALYSIS OF A MULTI STORIED BUILDING

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Abstract: Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls. Furthermore, they play a key role in distributing earthquake-induced loads to the lateral load resisting systems by diaphragm action. When building structures are subjected to earthquake loadings, the induced inertial forces are transmitted through floor slabs and resisted by vertical structural components such as shear walls and frames. In this situation, the floor slabs function as diaphragms placed between the vertical components. In analysis and design of three dimensional structures under seismic loading, the diaphragms are frequently assumed to be perfectly rigid. In certain type of structures, however, this assumption is found to create significant discrepancy on the lateral load distribution. This discrepancy frequently occurs in frame-wall structures, in which the vertical components consist of shear walls with high storey stiffness's and relatively flexible frames. Therefore, in the present work analytical parametric studies are done on high rise structures with simple frame and plate frame structures. To resolve the problems, efficient analytical modeling tactics are done employing the super-elements, and rigid diaphragms are proposed in this study. In the present work, an efficient method is proposed to analyze multistorey building considering the effects of floor slabs. The objective of the present study is to evaluate how a structure behaves when the reinforced concrete slab are included in the structural analysis. Two distinct analyses are carried out namely, Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) using STAAD. Pro software. The load combinations are considered as per IS 1893(Part-1): 2002. The results in terms of design base shear, displacements, reactions, and time period in simple frame structure and plate frame structures are compared for Zone III considered in this investigation. It was found that considering the effect of slabs in the structural analysis of case study buildings will give smaller values of displacement and greater values of reaction and base shear. The results also show that the slabs can slightly increase the lateral stability of bare frame.

Key Words: Earth quake, Seismic Analysis, Multi-storied building, base shear, Structural model

I. INTRODUCTION

Majority of the building structures consist of structural elements such as beams, columns, braces, shear walls, and floor slabs. Floor slabs in multi storey buildings, which usually transmit gravity loads to the structural system, are also required to transfer lateral inertia forces to the structural system. Generally, the models used for the analysis of such kind of building structures are prepared without the floor slabs assuming that they have negligible effects on the response of a structure. Thus, the floor slabs are simply replaced by rigid floor diaphragms for simplicity in the analysis procedure. In this case, the flexural stiffness of the floor slabs is ignored in the analysis. In addition, although the beams are located under the floor slabs in a structure, the analytical model were developed assuming that the axes of floor slabs and beams are located on a common plane.

The flexibility of floor diaphragms mainly when cracking and yielding are expected, it affects the seismic response of buildings in two major ways:

- The distribution of the lateral forces to the vertical elements is altered.
- The dynamic characteristics of the building are influenced by local vibration modes of the floor systems.
- These effects are totally ignored in analysis when floor slabs are assumed to be perfectly rigid.

Therefore, in the dynamic analysis the analytical model which disregards the flexural stiffness of the floor slabs would induce substantial analytical errors. In this study, research on the efficient modeling techniques which can consider the flexural stiffness of the floor slabs are carried out. In building structures, the flexural stiffness of the floor slabs is negligible in comparison with the in-plane stiffness of the floor slabs. Therefore, the analytical efficiency for a large building structure can be improved by applying the rigid diaphragm assumption.

OBJECTIVES OF THE STUDY

The objectives of the study are

- Generation of 3D building model for elastic method of analysis.
- To perform lateral load analysis on different building models.
- To evaluate these building models under static and dynamic analysis that are designed for different load combinations as given in IS: 1893 (2002) code.
- To compare the variation of the performance levels of the building with Seismic analysis and Response spectrum analysis.
- To compare the maximum displacement, Reactions, Base Shear and Time Period of the simple frame and plate frame structures for various zones.
- To study the effect of stiffness of floor slab on the behavior of building when subjected to seismic loading.

II. SEISMIC NATURE OF EARTH

EARTHQUAKE is the disturbance that happens at some depth below the ground level which causes vibrations at the ground surface. These vibrations happen in all the directions and are totally uncertain. The location, time, duration, magnitude and frequency of earthquake are totally unknown. Also, these vibrations are momentary, happening for a short while. It should be noted that earthquakes are totally unpredictable. Earthquake is the shaking or trembling caused by the sudden release of energy below the ground. It is usually associated with faulting or breaking of rocks. Continuing adjustment of position results in aftershocks

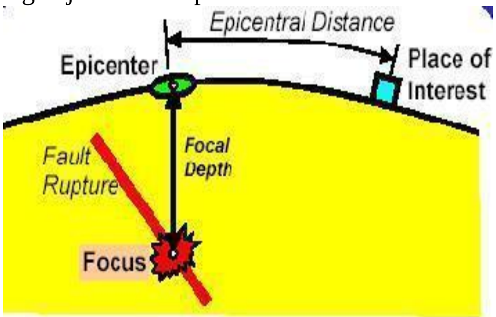


Fig.1: Terminologies in Earthquake Engineering

Focus or Hypocenter: It is the location from where earthquake originates. The point within Earth where faulting begins is the focus, or hypocenter. It may be a point, line or a plane. It will be deep below the earth surface.
Epicenter: It is the projection of focus on the surface of earth. It is a point which is closest to point of release of energy. The point directly above the focus on the surface is the epicenter.
Focal Depth: Distance between focus and epicenter is the focal depth. The closer the focal depth, more damaging is the earthquake.
Epicentral Distance: Distance between point of interest and epicenter is called Epicentral Distance.

SEISMIC WAVES
When the energy is released at the hypocenter or focus, it translates in to waves and travels through the body of earth. A similarity can be brought with a pebble thrown in to still water in a lake developing rings of waves in all directions. These waves attenuate after some distance and time due to material damping of earth. There are two types of waves, namely,
Body waves: Primary and secondary waves
Surface waves: Raleigh and love waves

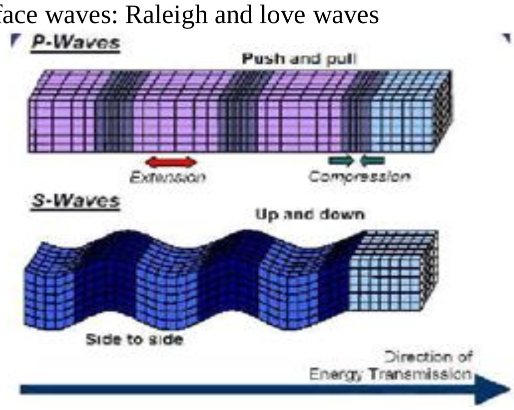


Fig. 2(a): Illustration of Seismic Waves

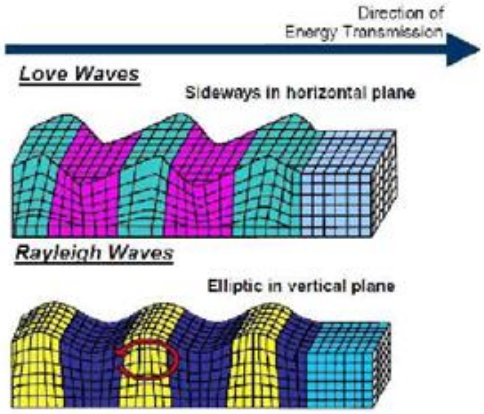


Fig. 2(b): Illustration of Seismic Waves

India is seismically active and has experienced many earthquakes in the past. Fig. 2 and Table 3 present some of the past earthquakes and their effects on Indian soil. More than 60 % of the country is considered to be in seismically active regions. Based on the past experience, geologic activities, presence of active faults and closeness to plate boundary, the country is divided in to 4 zones - Zone 2 to Zone 5. Zone 2 is seismically least active and zone 5 is seismically most active. In seismically very active zone, the frequency of big earthquake and possibility of strong shaking are more. Over years, Indian codal provisions are evolved and the following are the important modifications in the recent version of IS 1893 – Part 1 – 2002.
Major modifications in the recent I S code

- Zone I is merged with Zone II
- Values of seismic zone factors are changed considering MCE & service life of structure.
- Response spectra are specified for THREE types of soils - Rock & Hard Soil, Medium Soil and Soft Soil.
- Empirical equations for time period of multi storey buildings are revised

III. METHODOLOGY

The present work is carried out to study the effects of floor slab of RCC building models by performing seismic analysis. Here, analysis is carried on symmetric building models. In the analysis, different models considered.

The finite element method approach is adopted for modeling RC multistory building with and without slabs in the analysis. Seismic evaluation of the building models is performed by Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) as per IS 1893 (Part-1): 2002[12]. Also the buildings are considered to be in zone III.
The parameters considered in the performance evaluation are as under.

1. Analysis method Equivalent static analysis (ESA)
2. Response spectrum analysis (RSA)in STAAD.Pro.

DETERMINATION OF DESIGN LATERAL FORCE

The procedures to determine lateral forces in the code, IS 1893 (Part-1): 2002[14] are based on the approximation effects, yielding can be accounted for linear analysis of the

building using the design spectrum. This analysis is carried out either by modal analysis procedure or dynamic
Analysis procedure. A simplified method may also be adopted that will be referred as lateral force procedure or equivalent static procedure. The main difference between the equivalent static analysis procedure and dynamic analysis procedure lies in the magnitude and distribution of lateral forces over the height of the buildings. In the dynamic analysis procedure, the lateral forces are based on properties of the natural vibration modes of the building, which are determined by distribution of mass and stiffness over height. In the equivalent lateral force procedure, the magnitude of forces is based on an estimation of the fundamental period and on the distribution of forces as given by a simple formula that is appropriate only for regular building. The following sections will discuss in detail the above mentioned equivalent static and dynamic analysis procedure to determine the design lateral forces in detail.
In this study, the lateral design forces are determined by the equivalent static method and the response spectrum method as per the provisions of IS 1893 (Part -1): 2002[14], for the building models to be considered for the study. The buildings are analyzed by results of the building for different zones for the different load combinations to arrive at a conclusion regarding the importance of carrying out seismic analysis.
The present work is expanded to study these effects on our building models by performing lateral load analysis. The present work also includes the effect of floor slab on building models Which are considered in Zone III
Two buildings with equal number of storeys, with 6(G+5) storey having same floor plan of 60m x 45 m dimensions were considered for this study. The floor plans were divided into8 x6 bays in such a way that center to center distance between two grids is 7.5 meters on both the sides respectively as shown in Figure .1 and .2. The floor height of the building was assumed as 3.2 meters for all floors and plinth height is 4 meters above from foundation base as shown in Figure .3.
DESCRIPTION OF BUILDING

Type of structure	: Multi-storey RC frame structure
Number of stories	: 5 (G+4)
Ground storey height	: 4.2 m
Intermediate storey height	: 3.2 m
Depth of foundation	: 4 m
Location	: Vijayawada
Type of Soil	: Medium Soil
Earthquake Zone	: III
Building type	: School Building
Earthquake load	: As per IS1893 (Part 1)-2002

Beam Size: 230mm x 450 mm
Column Size: 230mm x 600 mm
Slab Thickness: 100 mm
Wall Thickness: 230 mm.

IV. STRUCTURAL MODELING FOR ANALYSIS

The floor slabs of multistorey building were modeled using plate elements available in structural analysis program STAAD. Pro V8i to obtain the stiffness/rigidities of floor slab using finite element method (FEM). To study the effect of floor slab in high rise building on seismic responses of buildings, three dimensional (3D) geometric models of the buildings were developed in software. Beams and columns were modeled as beam elements. Floor slabs were modeled as plate elements.
The loads of slab, periphery wall and parapet wall were incorporated in the modeling of structure. Due to time limitations, it was impossible to account accurately for all aspects of behavior of all the components and materials even if their sizes and properties were known. Thus, for simplicity, following assumptions were made for the structural modeling:

- The materials of the structure were assumed as homogeneous, isotropic and linearly elastic.
- The effects of secondary structural components and non-structural components such as staircase, masonry infill walls were assumed to be negligible.
- Foundation for analysis was considered as rigid .

STAAD Views

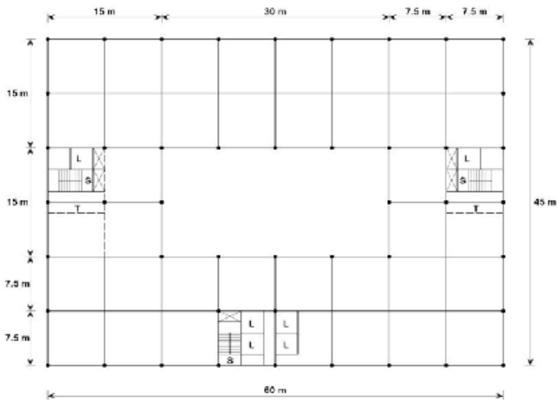


Fig.1 Typical Floor Plan

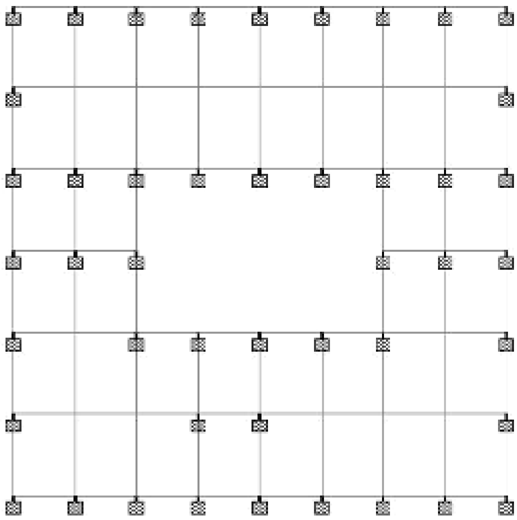


Fig.2 Typical Floor Plan

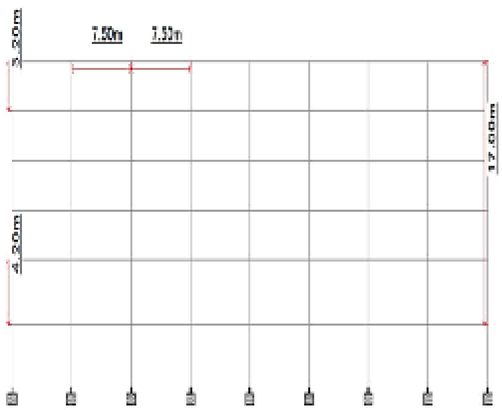


Fig.3 Elevation of the Building

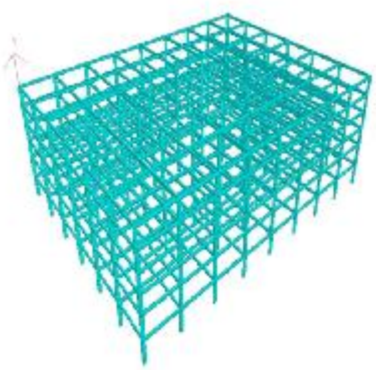


Fig.4 3D Model of the Building

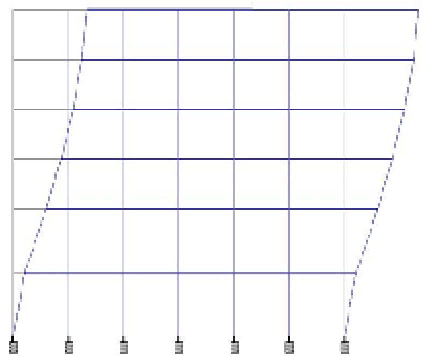
V. RESULTS AND DISCUSSION

The results obtained for different building models for Zone III are considered for different types of analysis carried out namely Equivalent Static analysis and Response Spectrum Analysis are presented. The analysis is carried out in STAAD. Pro software. After performing the static and dynamic analysis of models considered, their behavior will be analyzed and compared in terms of following parameters of tables:

1. Base shear
2. Time Period

The comparison of results in terms of the above parameters will be given in terms of tables and graphs and discussed in details.

Mode shapes



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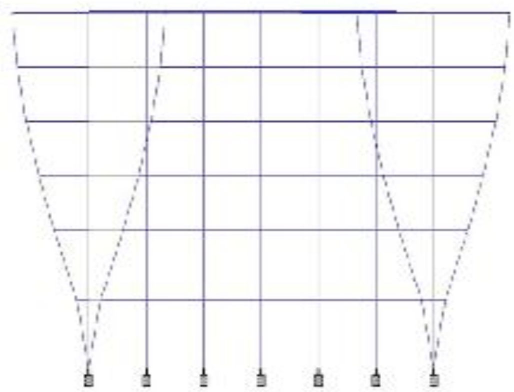

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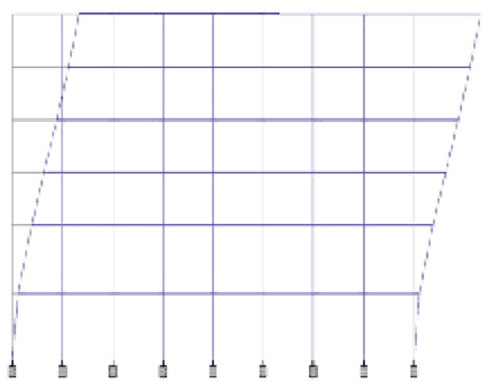

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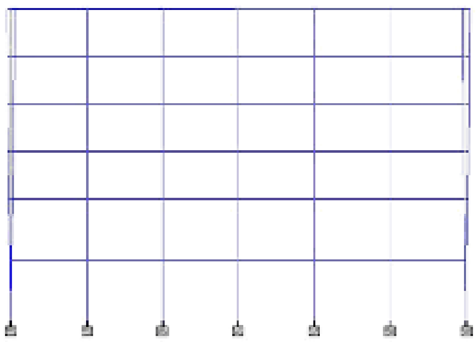

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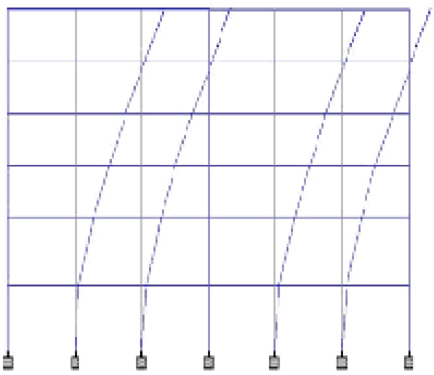

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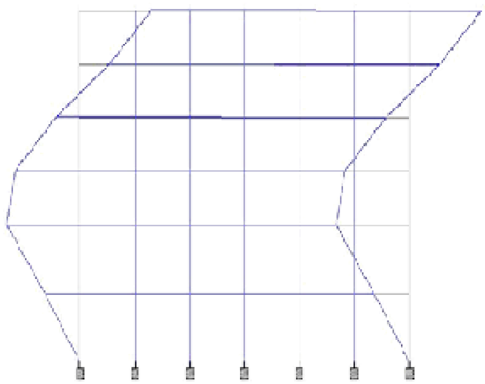

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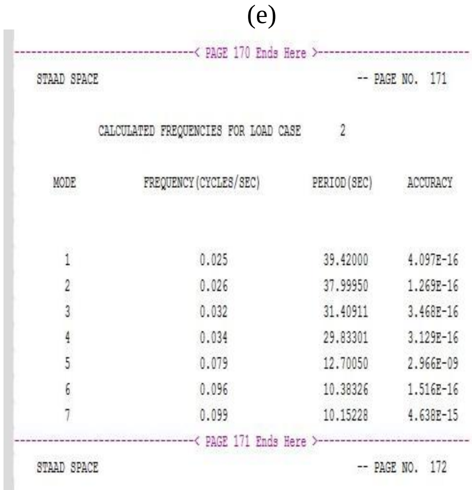

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CALCULATED FREQUENCIES FOR LOAD CASE 2

MODE	FREQUENCY(CYCLES/SEC)	PERIOD(SEC)	ACCURACY
1	0.025	39.42000	4.097E-16
2	0.026	37.99950	1.269E-16
3	0.032	31.40911	3.468E-16
4	0.034	29.83301	3.129E-16
5	0.079	12.70050	2.966E-09
6	0.096	10.38326	1.516E-16
7	0.099	10.15228	4.638E-15

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(f)

Table.1 Analysis output

MODE	Frequency (cycles/sec)	Period(sec)	Accuracy
1	0.025	39.42000	4.097E-16
2	0.026	37.99950	1.269E-16
3	0.032	31.40911	3.468E-16
4	0.034	29.83301	3.129E-16
5	0.079	12.70050	2.966E-09
6	0.096	10.38326	1.516E-16
7	0.099	10.15228	4.638E-15

Table.2 Shear calculations

FLOOR	PEAK STOREY SHEAR IN KN(X)	PEAK STOREY SHEAR IN KN(Z)
7	1645.03	0.00
6	4929.27	0.00
5	6451.28	0.00
4	7539.14	0.00
3	8197.00	0.00
2	8388.22	0.00
1	8288.22	0.00

VI. CONCLUSIONS

- The numerical model that considers the stiffness of the floor of a building allows to obtain more accurate results of the real behavior of the structure. Hence it can be concluded that the stiffness of slabs yield economical design.
- The displacements for the structure with slabs are lower as compared to structure without slab, but the difference can be ignored if the designer wants to, provided the displacements obtained are within permissible limits. The lower value of displacements in case of model with slabs indicates the effect of higher stiffness of slabs in structure.
- For the case of model with slab, the support reactions are more as compared to model without slabs. Therefore, for safe design of foundations, slabs should be considered in the analysis and

design of structure.

- Time period in Z direction is greater compared to X direction for all models as length in Z direction is greater.
- Base shear of the structure modeled with slabs are slightly greater compared to structure modeled without slabs. Thus, the model without slabs will give the critical results.
- As can be seen from the study, the slabs can increase the lateral stability of bare frames

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