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SEISMIC ANALYSIS OF REINFORCED CEMENT CONCRETE AND COMPOSITE (P.T.) STRUCTURES

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Abstract —In the seismic design of buildings, reinforced concrete structural walls, or shear walls, act as major earthquake resisting members. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the walls appropriately. In this present study, main focus is to determine the solution for shear wall location in multi-storey building An earthquake load is applied to a building of B+G+14 stories located in zone III. Parameters like Lateral displacement, story drift. The response of building when subjected to seismic excitation can be evaluated in a number of ways. Structural analysis methods can be mainly divided into four categories Equivalent Static Analysis, Linear dynamic analysis, Nonlinear Static Analysis, Nonlinear dynamic analysis. Equivalent Static Analysis method or linear static analysis, defines a series of forces acting on a building to represent the effect of earthquake ground motion. In this method, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The response spectrum analysis determines the natural frequencies and mode shapes via eigen value analysis. It is used to estimate the peak response whereas the time history analysis provides a method for obtaining the exact response of a structure as a function of time.

Index Terms— Story drift, story shear, shear wall, flat slab with drop

1 INTRODUCTION

All over the world, there is a high demand for construction of tall buildings due to increasing urbanization and spiraling population, and earthquakes have the potential for causing the greatest damages to tall structures. Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. Usually, they are modeled as two-dimensional or three-dimensional frame systems using finite beam elements. Since earthquake forces are random in nature and unpredictable, the engineering tools need to be sharpened for analysing structures under the action of these forces. Earthquake loads are required to be carefully modeled so as to assess the real behaviour of structure with a clear understanding that damage is expected but it should be regulated. Analysing the structure for previous earthquakes of different intensities and checking for multiple criteria at each level has become essential and pivotal these days. The main parameters to be checked in the seismic analysis of structures are load carrying capacity, ductility, stiffness, damping and mass. The design can be divided into two main steps. First, a linear analysis is conducted with dimensioning of all structural elements, ensuring the functionality of the structure after minor earthquakes, and then the behaviour of structures during strong earthquakes has to be conducted using nonlinear methods. Dynamic analysis should be performed for symmetrical as well as unsymmetrical buildings. In unsymmetrical building structures the major parameter to be considered is torque. For the determination of seismic responses it is necessary to carry out seismic analysis of the structure. The analysis can be performed on the basis of external action, the behaviour of structural materials, structure and the type of structural model selected. Based on the type of external action and behaviour of structure, the analysis can be further classified as:

(1) Linear Static Analysis
(2) Nonlinear Static Analysis
(3) Linear Dynamic Analysis
(4) Nonlinear Dynamic Analysis

1) Linear Static Analysis

This method is also known as Equivalent Static Analysis method. This procedure does not require dynamic analysis, however, it account for the dynamics of building in an approximate manner. The static method is the simplest one among all the other analysis procedures. It requires less computational efforts and is based on formulas given in the code of practice. First, the design base shear is computed for the entire building and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individual lateral load resisting elements. The equivalent static analysis procedure involves the following steps:

- Calculation of the Design Seismic Base Shear
- Vertical distribution of base shear along the height of the structure
- Horizontal distribution of the forces across the width and breadth of the structure
- Determination of the drift and overturning moment

2) Nonlinear Static Analysis

Nonlinear static analysis also known as Pushover Analysis procedure is mainly used to estimate the strength and drift capacity of existing structure and the seismic demand for this structure subjected to selected earthquake. This analysis procedure can be used for checking the adequacy of new structural design as well. The effectiveness of pushover analysis and its computational simplicity brought this analysis procedure in to several seismic guidelines (ATC 40 and FEMA 356) and design codes (Eurocode 8 and PCM 3274).

- **Pushover Analysis Procedure**

The magnitude of the lateral load to be applied is increased monotonically maintaining a predefined distribution pattern along the height of the building (Fig. 1.a) for the pushover analysis procedure. Building is displaced till the "control node" reaches the "target displacement" or building collapses. The sequence of cracking, plastic hinging and failure of the structural components is observed throughout the procedure. The relation between base shear and control node displacement is plotted for all the pushover analysis.

3) Linear Dynamic Analysis

Response spectrum method is a linear dynamic analysis method. In this method the peak response of structure during an earthquake is obtained directly from the earthquake response, but this is quite accurate for structural design applications. In this approach multiple mode shapes of the building are taken into account. Computer analysis can be used to determine the different modes for a structure. Based on the modal frequency and the modal mass, for each mode a response is read from the design spectrum, and they are then combined to provide an estimate of the total response of the structure using modal combination methods. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following:

- Square Root Sum of Squares (SRSS)
- Complete Quadratic Combination (CQC)
- Absolute Sum method

4) Nonlinear Dynamic Analysis

Nonlinear dynamic analysis is also referred as Time history analysis. It is an important method for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform this analysis, a representative earthquake time history data is required for a structure being evaluated. Time history analysis is a step-by step analysis procedure of the dynamic response of a structure for a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading for a representative earthquake.

2. Objective Study

The objectives of this research can be summarized briefly as follows:

1. In the present work, PT composite, and R.C.C. options are considered for comparative study of B+G+14 multistorey building which is situated in earthquake zone III. Response Spectrum Method of Analysis is used.
2. Study of Linear and Non-linear Dynamic Analysis of structure having using STAAD PRO computer programming according to IS 1893 (part-1):2016.
3. To study the seismic response of buildings in terms of storey shear, storey drift, storey displacement, time period, base shear, base moments, storey displacement, etc. find out compared R.C.C and composite structure by using STAAD PRO software.
4. Case study of Bhuj earthquake is done to understand the effects of earthquake on RCC structures.
5. Summarize the advantage of using composite structure in construction.
6. To choose a best building model from alternatives
7. Study the behaviour of reinforced concrete, steel and composite structure under the effect of seismic loading.

3 Literature Survey

Krishna G Nair, Akshara S P had worked on the response of building when subjected to seismic excitation can be evaluated in a number of ways. Structural analysis methods can be mainly divided into four categories Equivalent Static Analysis, Linear dynamic analysis, Nonlinear Static Analysis, Nonlinear dynamic analysis. Equivalent Static Analysis method or linear static analysis, defines a series of forces acting on a building to represent the effect of earthquake ground motion. In this method, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The response spectrum analysis determines the natural frequencies and mode shapes via eigen value analysis.

Anusha. I. Koti, Dr. S. B. Vanakudre has studied on As we know that in the present scenario buildings with post-tensioned flat slab are gaining more popularity than conventional RCC buildings for flooring system due to its increased number of floors and even due to its capability to the resistance during earthquake. In this paper a plan of residential building with post-tensioned flat slab with drop considering seismic effect is considered for the analysis using CSI SAFE 2016 software. A floor system of post-tensioned flat slab with drop model is considered for the analysis. The modeling and analysis is done using CSI SAFE 2016 software. An attempt is made to study the parameters such as moments, stresses, time period, frequency and behavior of flat slab under seismic effect for Equivalent Frame method and strip base method

"SEISMIC ANALYSIS OF RC STRUCTURES TECHNIQUE" was studied by Shameena Khannavar et.al. In the seismic design of buildings, reinforced concrete structural walls, or shear walls, act as major earthquake resisting members. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the walls appropriately. In this present study, main focus is to determine the solution for shear wall location in multi-storey building. Effectiveness of shear wall has been studied with the help of four different models. Model one is bare frame structural system and other three models are dual type structural system. An earthquake load is applied to a building of ten stories located in zone II, zone III, zone IV and zone V. Parameters like Lateral displacement, story drift and total cost required for ground floor are calculated in both the cases replacing column with shear wall. Changing the position of shear wall will affect the attraction of forces, so that wall must be in proper position. If the dimensions of shear wall are large then major amount of horizontal forces are taken by shear wall. Providing shear walls at adequate locations substantially reduces the displacements due to earthquake.

4 METHODOLOGY

R.C.C. options are considered for comparative study of B+G+14 Floor multistorey building which is situated in earthquake zone III. Response Spectrum Method of Analysis is used. Floor height provided as 3.2 m. And also, properties are defined for the frame structure. Models are created in Etabs software. Various types of load are considered. For static behavior dead load of the building is considered as per IS 875 Part 1 and live load is considered as per IS 875 Part III, lateral load confirming IS 1893(part 1)2016. The three-dimensional reinforced concrete structures with G+15 storey was analyzed by Response spectrum analysis using STAAD PRO software. To study the seismic response of buildings in terms of storey shear, storey drift, storey displacement, time period, base shear, base moments, storey displacement, etc. find out compared R.C.C and composite structure by using Etabs software

4.1. Problem statement of Rectangular Geometry Analysis of RCC and Composite Structure

In the present work, steel concrete composite and R.C.C. options are considered for comparative study of G+15 storey multistorey building which is situated in earthquake zone III. The plan selected is Rectangular in shape. It is not the plan of any existing or proposed building but is an architectural plan. The structure has been analysed for both static and dynamic wind and earthquake forces. Hard soil condition has been selected for the structure. Study the behaviour of reinforced concrete, steel and composite structure under the effect of seismic loading

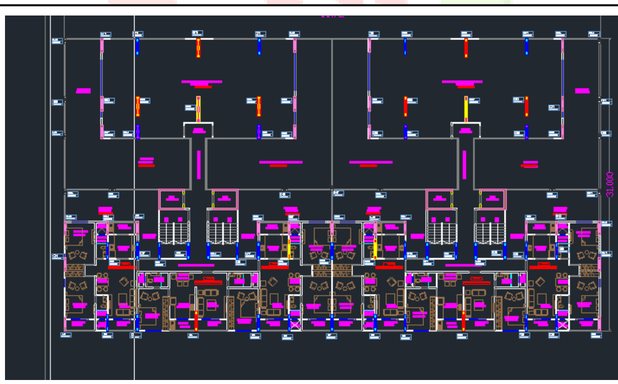

Fig. 2. Working Plan in Autocad.

4.1.1. Building details:-

- Location of site:- Ahmednagar
- Total number of Storeys :- 16 (B+G+14)
- Type of building :- Residential
- Structure type :- plan regular type
- Height of each storey:- 3m
- Total height of structure:- 49.5m
- Material Properties
- Grade of concrete: - M35
- Grade of steel: - FE500
- All wall thickness:- 150 mm
- Interior beam sizes:- 230mm X 600mm
- Exterior beam sizes:- 230mm X 600mm
- Slab thickness:- 150mm

4.1.2. Gravity loads:-

Dead load (slab) = 25X0.15X13.5X8.5
= 430KN (3.75KN/M2)
Live load = 2 KN/M2
Floor finish load = 1.5 KN/M2
Beam load = 150 KN/M
Wall load = 20X0.15X2.7=7.9 KN/M
Parapet load = 20X0.15X1.2= 3.6 KN/M

Calculation of various design parameters

Table 1:- Seismic design parameters

Sr. no.	Parameter	Values as per Is 1893	Reference
1	Type of structure	Special RC moment resisting frame	Table 9, Clause 7.2.6
2	Seismic zone	III	Table 3, Clause 6.4.2
3	Location	Ahmednagar	Annex E
4	Zone factor	0.16	Table 2, Clause 6.4.2
5	Type sof soil	Hard soil	Clause 6.4.2.1
6	Damping	5%	Clause 7.2.4
7	Response spectra	As per IS 1893 (part 1):2016	Figure 2, Clause 6.4.6
8	Response Reduction factor	5	Table 9, Clause 7.2.6
9	Importance Factor	1	Table 8, Clause 7.2.3

Table 2:- Wind load design parameters

Sr. no.	Parameter	Values as per Is 875(part3)-2015	Reference
1	Basic wind speed (Vb)	Pune =39m/sec,	Annex A
2	Risk coefficient k1	1	Table 1, Clause 6.3.1
3	Terrain Roughness Factor k2	1.22	Table 2, Clause

			6.3.2.2
4	Topography Factor k3	1	Table 3
5	Importance Factor k4	1	Clause 6.3.4
6	Windward coefficient cp	0.8	Clause 7.3.3
7	Leeward coefficient cp	0.5	Clause 7.3.3

5 ANALYSIS OF RCC BUILDING

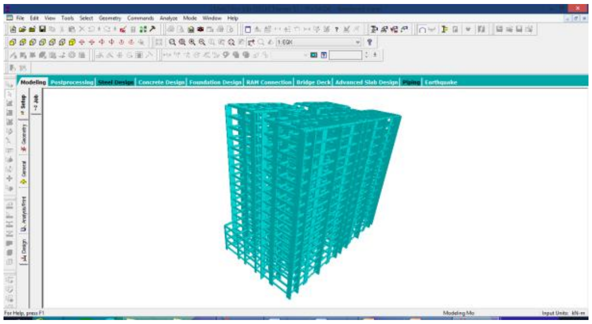

Fig. 3. RENDERED 3D VIEW OF THE MODEL

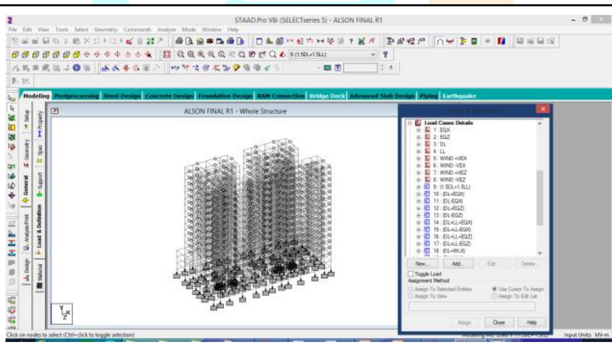

Fig. 4. LOAD COMBINATIONS

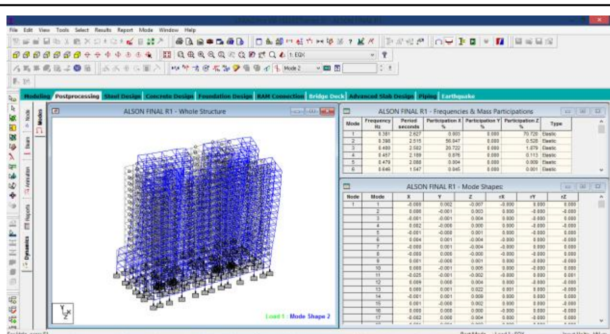

Fig. 5 DISPLACEMENT OF BUILDING FOR VARIOUS MODE SHAPES

As loading is applied there will some shear force generated at the base. This shear forces are result of loading from all the floors above and there individual floor load. The shear load generated by the software as shown below. There are loads pre calculated by the software according to pre-defined IS parameters.

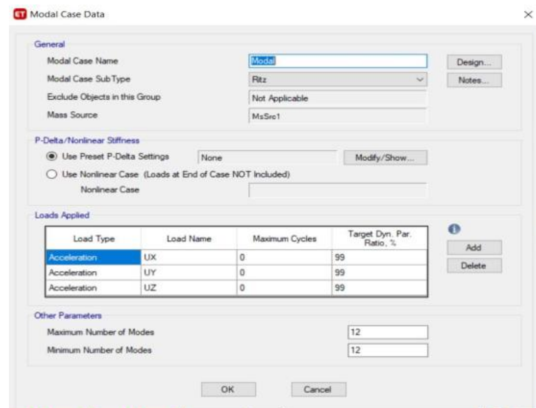

Fig. 6. Assigning flat slab in Etab model

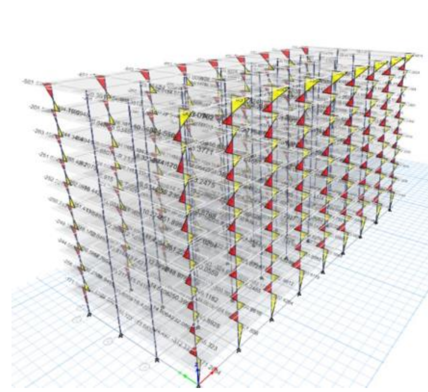

Fig. 7. Mode with fixed base made in ETABS

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...codes IS 1893 (Part 1): 2016 and IS: 13920: 1993.

2) Performance of Flat (P.T.) slab is better than conventional slab for spans ranging between 10-12 m. cost reduction is nearly 20% as compared to conventional slab.
3) Inclusion of shear wall in the building improves the performance of building subjected to seismic loading.
4) Geometry of building plays vital role in resisting seismic forces. Buildings without mass, stiffness and vertical irregularities should be preferred.
5) Formation of soft storey, weak storey, pounding effect should be avoided.
6) Maximum displacement, force, bending moment, storey shear are least for flat P.T. slab as compared to conventional slab.
7) On comparison of both RCC and composite structure, it is observed that storey drift is reduced by 20%, Storey shear is reduced by 15% and displacement is reduced by 16% in composite structure.
8) If float column is required to be started from floor slab level then it should start from P.T. beam. Deflection of P.T. beam is very less as compared to RCC beam.

9) For smaller spans Conventional slabs resting on beams are found economical and efficient.
10) In multi-storey buildings base isolation techniques should be used for enhancing the performance of building subjected to seismic loads.
11) for larger spans flat P.T. slabs should be prefered against conventional slab both from economy and stability perspective.

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