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Dynamic Analysis of Multi-storey RCC Building

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***Abstract*—The important objective of earthquake engineers is to design and build a structure in such a way that damage to the structure and its structural component during the earthquake is minimize. This report aims towards the dynamic analysis of a multi-storey RCC building with symmetrical configuration. For the analysis purpose model of ten storey RCC with symmetrical floor plan is consider. The analysis is by carried by using finite element based software SAP 2000. Various response parameters such as lateral force, base shear , story drift , story shear can be determined. For dynamic analysis time history method or response spectra method can be used .Time-history analysis is a step-by-step analysis of the dynamical response of a structure to a specified loading that may vary with time. The analysis may be linear or non-linear. Dynamic analysis can be performed for symmetrical as well as unsymmetrical building. Dynamic analysis can be in the form of nonlinear dynamic time history analysis."**

"In this seminar report, a nonlinear time history analysis is performed on a ten storey RCC building frame considering time history of el centro earthquake 1940 using SAP 2000. The main parameters of the seismic analysis of structures are load carrying capacity, ductility, stiffness, damping and mass. The various response parameters like base shear, storey drift, storey displacements etc are calculated. The storey drift calculated is compared with the minimum requirement of storey drift as per IS 1893:2002.

***Index Terms*—Base Shear, Finite Element, Storey Drift, Time history analysis**

I. INTRODUCTION

"All over world, there is 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 those 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 analyzing structures under the action of these forces. Earthquake loads are required to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. Analyzing the structure for past earthquakes of different intensities and checking for multiple criteria at each level has become essential and pivotal these days."

"The main parameters of 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 appropriate 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 controlled using nonlinear methods. Dynamic analysis should be performed for symmetrical as well as unsymmetrical building. Due to unsymmetrical section of building the major parameter to be considered is Torque. The structural engineers perform for both regular as well as irregular buildings."

"The current version of the IS: 1893 - 2002 requires that practically all multistoried buildings be analyzed as three-dimensional systems. This is due to the fact that the buildings have generally irregularities in plan or elevation or in both. Further, seismic intensities have been upgraded in weaker zones as compared to the last version IS: 1893-1984. It has now indirectly become mandatory to analyze all multistoried buildings in the country for seismic forces."

II. SEISMIC METHODS OF ANALYSIS

"For the determination of seismic responses there is necessary to carry out seismic analysis of structure. The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected.

Based on the type of external action and behavior of structure, the analysis can be further classified as: (1) Linear Static Analysis, (2) Nonlinear Static Analysis, (3) Linear Dynamic Analysis; and (4) Nonlinear Dynamic Analysis. Linear static analysis or equivalent static method can be used for regular structure with limited height. Linear dynamic analysis can be performed by response spectrum method. The significant difference between linear static and linear dynamic analysis is the level of the forces and their distribution along the height of structure. Nonlinear static analysis is an improvement over linear static or dynamic analysis in the sense that it allows inelastic behavior of structure. A nonlinear dynamic analysis is the only method to describe the actual behavior of a structure during an earthquake. The method is based on the direct numerical integration of the differential equations of motion by considering the elasto-plastic deformation of the structural element."

Equivalent Static Analysis

"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-it requires less computational efforts and is based on formulate given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individuals lateral load resisting elements."

Linear Dynamic Analysis

"Linear dynamic analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method. This analysis will produce the effect of higher modes of vibration and the actual distribution of forces in the elastic range in a better way. They represent an improvement over linear static analysis. The significance difference between linear static and linear dynamic analysis is the level of force and their distribution along the height of the structure."

Non linear static analysis

"Non linear static analysis is an improvement over linear static or dynamic analysis as it allows the inelastic behavior of the structure. The method still assumes a set of static incremental lateral load over the height of the structure. The method is relatively simple to be implemented and provides information on the strength, deformation and ductility of the structure and the distribution of demands. This permit to identify critical members likely to reach limit states during the earthquake, for which attention should be given during the design and detailing process. But this method contains many limited assumptions, which neglects the behavior of loading patterns, the influence of higher modes, and the effect of resonance. Push over analysis has acquired a great deal of popularity nowadays in spite of these deficiencies this method provides reasonable estimation of the global deformation capacity, especially for structures which primarily respond according to the first mode."

Nonlinear Dynamic Analysis

"A nonlinear dynamic analysis of inelastic time history analysis is the only method to describe the actual behavior of the structure during an earthquake. Time history analysis is a step-by step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake. This method is based on the direct numerical integration of the differential equations of motions by considering the elasto-plastic deformation of the structure element. This method capture the effect of amplification due to resonance, the variation of displacements at diverse levels of a frame, an increase of motion duration and a tendency of regularization of movements result as far as the level increases from bottom to top."

III. LITERATURE REVIEW

Baldev D. Prajapati (2013), discussed the analysis & design procedure that may be adopted for the evaluation of symmetric multi-storey building under effect of Wind and earthquake forces. Structures are designed to resist moderate and frequently occurring earthquakes & wind and must have sufficient stiffness and strength to control displacement and to prevent any possible damage. It is inappropriate to design a structure to remain in the elastic region, under severe earthquakes & wind lateral forces, because of the economic constraints. The inherent damping of yielding structural elements can advantageously be utilized to lower the strength requirement, leading to a more economical design. This yielding usually provides the ductility or toughness of the structure against the sudden brittle type structural failure.

Dj. Ladjinovic et al., (2012) presented an overview of modeling methods and results of the analysis obtained for the designed model of multi-storey frame using the programme SAP2000. The paper presents different possibilities for modelling plastic hinges for the nonlinear static analysis of reinforced concrete frame. The real behaviour of a structure during an earthquake can be the best simulated using the nonlinear dynamic time-history analysis (THA). The strength and deformation capacity of ductile concrete elements of the multi-storey frame structure is determined by the analysis of moment-curvature based on the expected (adopted) material properties. The nonlinear behaviour of structural elements is idealized by plastic hinges set in pre-selected locations. Since, THA is still too complicated for practical application, the calculation methods based on nonlinear static pushover analysis are used.

Mayuri D. Bhagwat et al., (2014): Dynamic analysis of multistoried practiced RCC building considering for Koyna and Bhuj earthquake is carried out by time history analysis and response spectrum analysis and seismic responses of such building are comparatively studied and modeled. Two time histories (i.e. Koyna and Bhuj) have been used to develop different acceptable criteria (base shear, storey displacement, storey drifts).

Reinforced concrete buildings have been damaged on a very large scale in Bhuj earthquake of Jan 26th 2001, Even though these buildings are analyzed and designed as per IS code. The damages are caused by inconsistence seismic response, irregularity in mass and plan, soft storey and floating columns etc. Hence it becomes necessary to evaluate actual seismic performance of building subjected to earthquake forces. Time History analysis gives more realistic seismic behavior of the building. It gives more accurately seismic responses than response spectrum analysis because of it incorporates material nonlinearity and dynamic nature of earthquake.

A S Patil et al.: In this paper, study of nonlinear dynamic analysis of ten storied RCC building considering different seismic intensities is carried out and seismic responses such as base shear and displacements of such building are studied. The building under consideration is modeled with the help of SAP2000-15 software. The software is able to predict the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. Five different time histories have been used considering seismic intensities V, VI, VII, VIII, IX and X on Modified Mercalli's Intensity scale (MMI) for establishment of relationship between seismic intensities and seismic responses. The values of seismic responses namely base shear, storey displacement and storey drifts for all the Time Histories and both the models are found to be of the increased order for seismic intensities varying from V to X. From this study it is recommended that analysis of multistoried RCC building using Time History method becomes necessary to ensure safety against earthquake force. It provides a better check to the safety of structures analyzed and designed by method specified by IS code.

A.R. Chandrasekaran and D. S. Prakash Rao: some of the poor planning and construction practices of multistoried buildings in Peninsular India in particular, which lead to irregularities in plan and elevation of the buildings are discussed in this paper. The large scale collapse of reinforced concrete multi-storied buildings (RCMS) in Gujarat (January 2001) could have been avoided by suitable planning, and good constructional practices. Inadequate detailing of columns, seismically unfavourable layouts and weak story at the ground floor appear to be the primary causes of the structural damage and collapses; ignorance of structural behaviour and non-compliance with building regulations may be the contributory causes.

Mohammed yousuf, P.M. shimpale (2013): This paper aims towards the dynamic analysis of reinforced concrete building with plan irregularity. Four models of G+5 building with one symmetric plan and remaining irregular plan have been taken for the investigation. The analysis of R.C.C. building is carried out with the FE based software ETABS 9.5.

Estimation of response such as; lateral forces, base shear, storey drift, storey shear is carried out. . Four cross sectional variation in columns section are considered for studying effectiveness in resisting lateral forces. The paper also deals with the effect of the variation of the building plan on the structural response building.

Pralobh S. Gaikwad and Kanhaiya K. Tulani (2015): The paper aims towards the dynamic analysis of RCC and Steel building with unsymmetrical configuration. For the analysis purpose models of G +9 stories of RCC and Steel with unsymmetrical floor plan is consider. The analysis is by carried by using F.E based software E TABS. Various parameter such as lateral force, base shear , story drift , story shear can be determined .For dynamic analysis time history method or response spectra method is used. .If the RCC and Steel building are unsymmetrical, torsional effect will be produce in both the building and thus are compared with each other to determine the efficient building under the effect of torsion.

Hugo Batchmann et al. presented a dynamic nonlinear analysis method for R/C building subjected to earthquake action is presented. Nonlinear elements for modeling of plastic hinges in walls, beams and columns are explained. In numerical example, a capacity designed frame wall building subjected to different ground motion is analyzed, and an evaluation of the ductility demand of the plastic hinges in walls, beams and in slender columns is made.

Romy Mohan and C Prabha: In this, two multi storey buildings, one of six and other of eleven storey have been modeled using software package SAP 2000 12 for earthquake zone V in India. Six different types of shear walls with its variation in shape are considered for studying their effectiveness in resisting lateral forces. The paper also deals with the effect of the variation of the building height on the structural response of the shear wall. Dynamic responses under prominent earthquake, El-Centro have been investigated. This paper highlights the accuracy and exactness of Time History analysis in comparison with the most commonly adopted Response Spectrum Analysis and Equivalent Static Analysis.

A.M. Mwafy, A.S. Elnashai: In this paper, the applicability and accuracy of inelastic static pushover analysis in predicting the seismic response of RC buildings are investigated. The dynamic pushover' idealised envelopes are obtained from incremental dynamic collapse analysis. This is undertaken using natural and artificial earthquake records imposed on 12 RC buildings of different characteristics. The results of over one hundred inelastic dynamic analyses using a detailed 2D modelling approach for each of the twelve RC buildings have been utilised to develop the dynamic pushover envelopes and compare these with the static pushover results with different load patterns.

IV. STRUCTURAL MODELING AND ANALYSIS

The finite element analysis software SAP 2000 is used to create 3D model and run all analyses. The software is able to predict the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. In this report, a nonlinear time history analysis will be performed on a multi storey RCC building frame considering time history of el centro earthquake 1940.

Problem statement: A 10 storey RCC masonry infilled RCC building is considered. The geometry and dimension of plan are shown below:

Live Load on Typical floors - 3.5 KN/m2

Live Load on Terrace – 1.5 KN/m2

Column size - 0.5 m X 0.5 m; Beams size - 0.23 m X 0.45 m

Slab Thickness - 0.150 m; Brick wall thickness – 0.23m

Density of concrete- 25 kN/m3; Density of brick wall- 20kN/m3

Floor to floor height- 3.1 m. Height of parapet wall- 1m

Use M25 concrete and Fe415 steel.

Load calculations:

Dead load (self wt.) of slab= 0.15x1x25= 3.75kN/m

Wall load intensity= 0.23 x (3.1-0.45) x 20= 12.19kN/m

Parapet wall load intensity= 0.23 x 1 x 20= 4.6kN/m

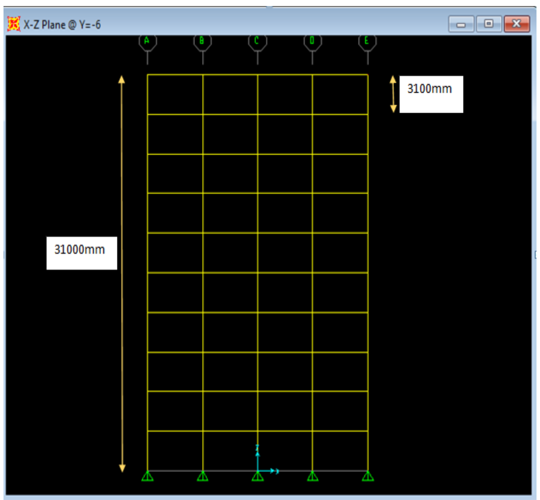


Fig a: Elevation of the building

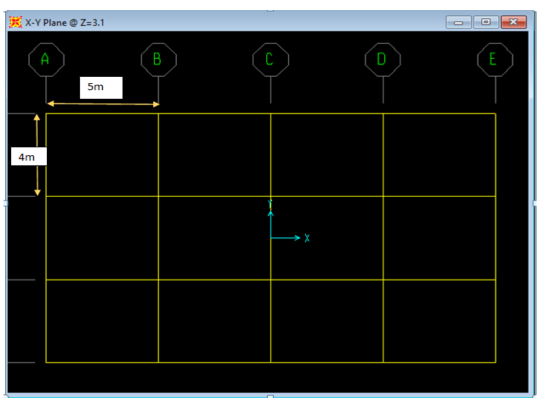


Fig b: Plan of the building

After modelling, nonlinear time history analysis is performed using el centro time history. Download the time history of the ground acceleration

Location: Imperial Valley

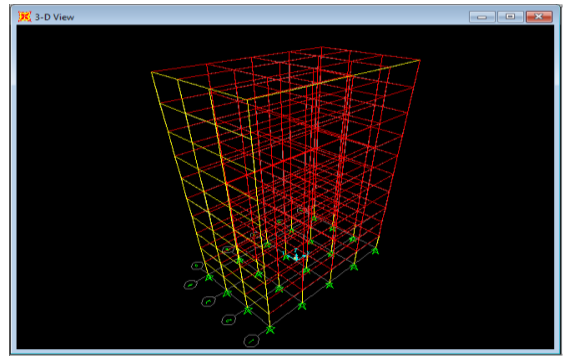
Date: 19th May 1940

Time: 4:39am

Station: El Centro Array

Units of acceleration: g= 9.81 m/s2 (acceleration of gravity); Sampling time: Δt= 0.02 s

The building is modeled as shown below:



V. RESULTS AND DISCUSSION

Number of modes considered =12

Frequency (cycle/sec) = $\frac{1}{T}$

Other things can be also calculated using formulae,

Circular frequency, ω (rad/sec) = $\frac{2\pi}{T}$

Eigen value = ω^2

Table 1: mode number with its respective period and frequency

OutputCase Text	StepType Text	StepNum Unitless	Period (sec)	Frequency (cycle/sec)
MODAL	Mode	1	1.756	0.5692
MODAL	Mode	2	1.343	0.7444
MODAL	Mode	3	1.145	0.8726
MODAL	Mode	4	0.462	2.1618
MODAL	Mode	5	0.425	2.3483
MODAL	Mode	6	0.366	2.7277
MODAL	Mode	7	0.234	4.2687
MODAL	Mode	8	0.228	4.3725
MODAL	Mode	9	0.205	4.8596
MODAL	Mode	10	0.153	6.5092
MODAL	Mode	11	0.145	6.8952
MODAL	Mode	12	0.136	7.3202

Table 2: Results of Base Shear

Case	Fx (kN)	Fx (kN)	Fx (kN)	Mx (kNm)	Mx (kNm)	Mx (kNm)
Time History	2528	184	0.00	3535	55298	4280

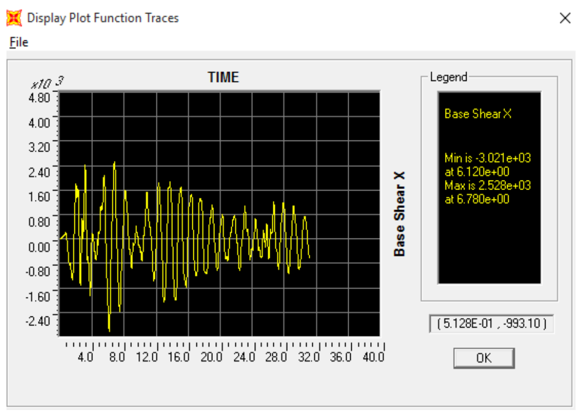


Fig c: The plot of variation of base shear in x-direction w.r.t time(sec)

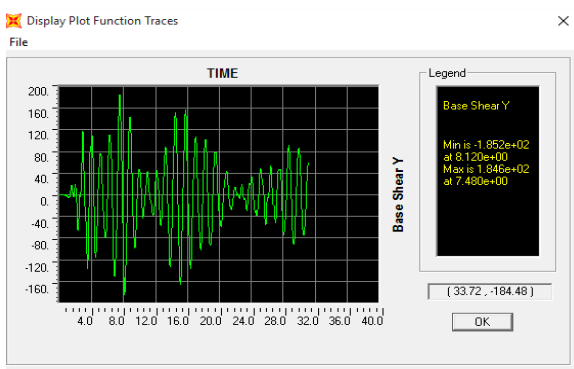


Fig d: Plot of variation of base shear in y-direction w.r.t time (sec)

Results of storey drift

Table 3: Storey drift in x and y directions

Floor	Storey drift in X-dir (m)	Storey drift in y-dir (m)
1st	0.026	0.006
2nd	0.0428	0.011
3rd	0.055	0.014
4th	0.067	0.017
5th	0.076	0.019
6th	0.085	0.021
7th	0.093	0.023
8th	0.099	0.025
9th	0.103	0.026
10th (roof)	0.106	0.027

Maximum roof displacement= 0.106 m

As per is 1893:2002, clause 7.11.1, the storey drift in any storey due to the design lateral force shall not exceed 0.004 times the storey height.

Maximum permissible storey drift= 0.004 x 31m = 0.124m

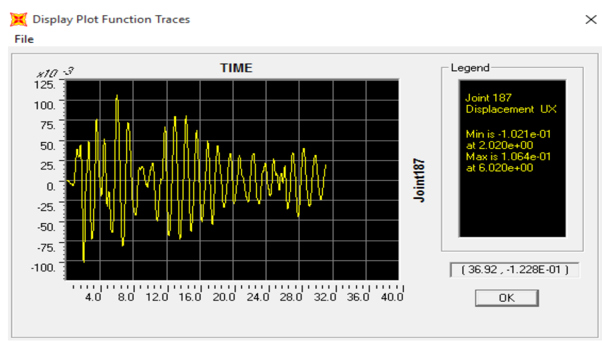


Fig e: Plot of variation of roof displacement in X-dir w.r.t time (sec)

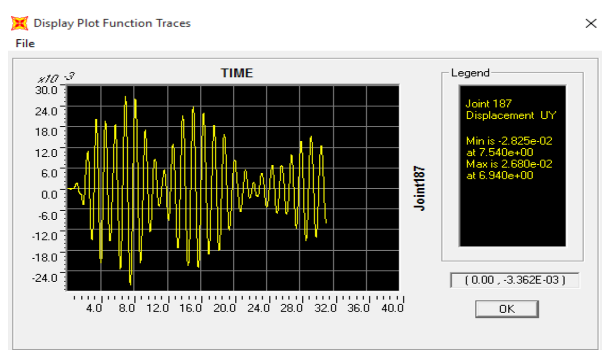


Fig f: plot of variation of roof displacement in Y-dir w.r.t time (sec)

VI. CONCLUSION

We can observe that storey drift increases from base to top floor. Maximum storey drift is found to be within permissible storey drift range as per IS 1893:2002. The maximum drift obtained for a ten storey building was 0.106m while permissible drift is approximately 0.124m. The maximum base shear in x and y direction was found to be 2528.2 kN and 184.59 kN respectively. I have concluded that lot of research has been carried on the dynamic effect on the building with symmetrical configuration in the past. For the analysis purpose basic parameter taken are lateral force, base shear, storey drift, storey shear and results are interpreted. It is recommended that time history analysis should be performed as it predicts the structural response more accurately than the response spectrum analysis.

The numbers of mode shapes considered are 12 and for each mode number the time period, frequency and eigen values are mentioned above. The variation of base shear in X and Y direction with respect to time history of el centro earthquake is plotted and similarly the variation of storey drift in X and Y direction with respect to time history is also plotted.

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