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Comparative Study of the Static and Dynamic Analysis of Multi-Storey Irregular Building

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***Abstract*—**As the world move to the accomplishment of Performance Based Engineering philosophies in seismic design of Civil Engineering structures, new seismic design provisions require Structural Engineers to perform both static and dynamic analysis for the design of structures. While Linear Equivalent Static Analysis is performed for regular buildings up to 90m height in zone I and II, Dynamic Analysis should be performed for regular and irregular buildings in zone IV and V. Dynamic Analysis can take the form of a dynamic Time History Analysis or a linear Response Spectrum Analysis.

In present study, Multi-storey irregular buildings with 20 stories have been modeled using software packages ETABS and SAP 2000 v.15 for seismic zone V in India. This paper also deals with the effect of the variation of the building height on the structural response of the shear wall building. Dynamic responses of building under actual earthquakes, EL-CENTRO 1949 and CHI-CHI Taiwan 1999 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.

***Keywords*—**Equivalent Static Analysis, Time history method, Response spectrum method, Reinforce concrete building, displacement.

I. Introduction

STRUCTURAL design of buildings for seismic loads is primarily concerned with structural safety during major ground motions, but serviceability and the potential for economic loss are also of concern. Seismic loading requires an understanding of the structural performance under large inelastic deformations.

In PayamTehrani [2006] study, he compared the nonlinear static (pushover) and nonlinear dynamic procedures in the determination of maximum displacements of an existing steel structure retrofitted with different methods [1]. In A.R.Touqan [2008] a comparison of the Response spectrum analysis and Equivalent Static Lateral Load with the more elaborate Response Spectrum Method of analysis as they apply to a repertoire of different structural models [2].In ProfDr. QaiseruzZaman Khan’s [2010] paperResponse spectrum analysis of 20 story building has been discussed in detail and comparison of static and dynamic analysis and design results of buildings up to 400 feet height (40story) in terms of percentage decrease in bending moments and shear force of beams, bending moments of columns, top story deflection and support reaction are discussed [3]. Romy Mohan [2011] paper highlights the accuracy and exactness of Time History analysis in comparison with the most commonly adopted response spectrum analysis and equivalent static analysis considering different shape of shear walls [4].

The main objective of this paper is to study the seismic behavior of concrete reinforced building. Also, analysis of structure by using equivalent static method, time history method and response spectrum method has been surveyed. The storey displacements and displacement of center of mass result have been obtained by using both static and dynamic analysis.

The pertaining structure of 20 stories residential building has been modeled. The storey plan is changing in the different floors. The building has been analyzed by using the equivalent static, response spectrum and time history analysis, based on IS codes; the results obtained are compared eventually to determine the structural performance.

II. Method of Analysis of Structure

A. Equivalent Static Analysis

All design against seismic loads must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings. It begins with an estimation of base shear load and its distribution on each story calculated by using formulas given in the code. Equivalent static analysis can therefore work well for low to medium-rise buildings without significant coupled lateral-torsional modes, in which only the first mode in each direction is considered. Tall buildings (over, say, 75 m), where second and higher modes can be important, or buildings with torsional effects, are much less suitable for the method, and require more complex methods to be used in these circumstances.

B. Time History Method

It is an analysis of the dynamic response of the structure at each increment of time, when its base is subjected to a specific ground motion time history. Alternatively, recorded ground motions database from past natural events can be a reliable source for time histories but they are not recorded in any given site to include all seismological characteristics suitable for that site. Recorded ground motions are randomly selected from analogous magnitude, distance and soil condition category (bin); three main parameters in time history generation.

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Adding more constraints to characteristics of each bin makes it to be more definite and similar to site characteristics. However, it may put serious availability limit for real records in the bin. Selected ground motions' response spectrum around fundamental period of the structure can be different than target response spectrum determined from seismic hazard analysis. Therefore, records are scaled by single-factor scales to have their mean spectral accelerations complied with target spectrum. Nevertheless, not much close agreement between the response spectrum of the record and target will be achieved with simply a single-factor scaling of the record.

C. Response Spectrum Method

The representation of the maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motions. The maximum response plotted against of un-damped natural period and for various damping values and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement. For this purpose Response spectrum case of analysis have been performed according to IS 1893.

III. Analysis of Structure

Two considered recorded accelerograms have been compared with standard response spectrum based on IS 1893, shown in Fig [1,2]. It is observed that, the peak ground acceleration of both earthquakes is less than standard spectrum. Hence those earthquakes can be used for time history analysis of building.

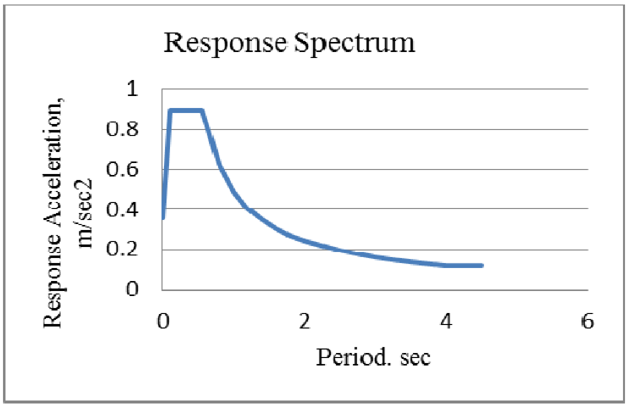

Fig. 1 Response spectrum standard of the model

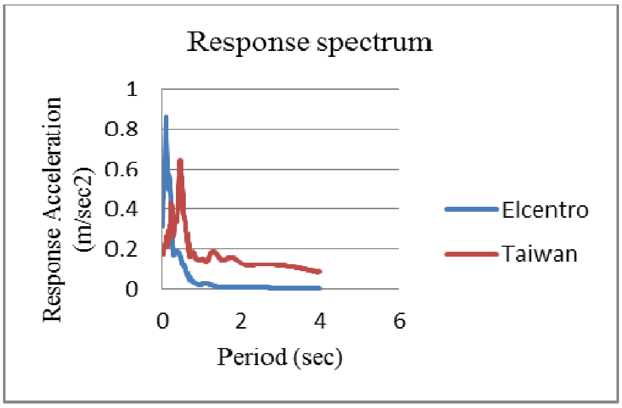

Fig. 2 Elcentro and Taiwan Response Spectrum

IV. Details of the Models

The pertaining structure of 20 stories residential building with the general form of plan shown in figure has been modeled. The storey plan is changing in the different floors as shown in figures [3–7]. The height of the first floor is 3 meter and the other floors are 3.2 meter. The plan of first five stories of the problem is given in figure 1, other stories plan is shown in figure 2 to 5. Base plan dimension in X and Y direction is 23.4 and 18.6 meter respectively. The loading which applied in this structure including dead, live and earthquake loads are according to IS 875 part 1, and part 2 and IS 1893 respectively. The sections including all beams and columns which are used in model have been arranged at storey 1 to 5 Column70*70-60Q26mm, storey 5 to 10 Column 65*65-56Q25mm, storey 10 to 20 Column 50*50-32Q25mm, storey 1 to 10 Beam65*65, storey 10 to 20 Beam 45*45. The floor slab taken as 170mm thick. The modulus of elasticity and shear modulus of concrete have been taken as E = 24855578.28 kN/m^2 and G = 10356490.95 kN/m^2.

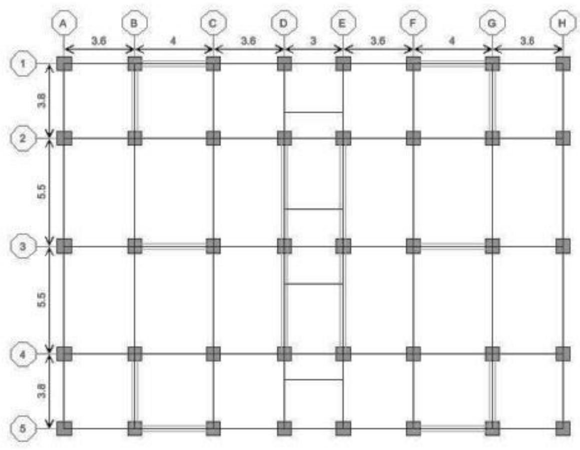

Fig. 3 First to fifth Floor Plan (ST 1 to 5)

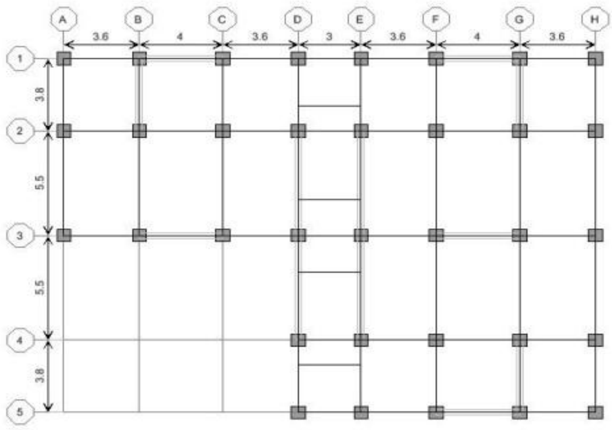

Fig. 4 Sixth to tenth Floor Plan (ST 6 to 10)

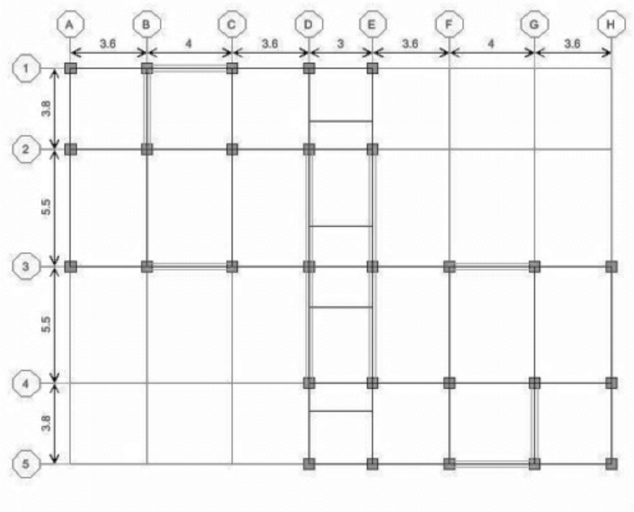

Fig. 5 Eleventh to fifteenth Floor Plan (ST 11 to 15)

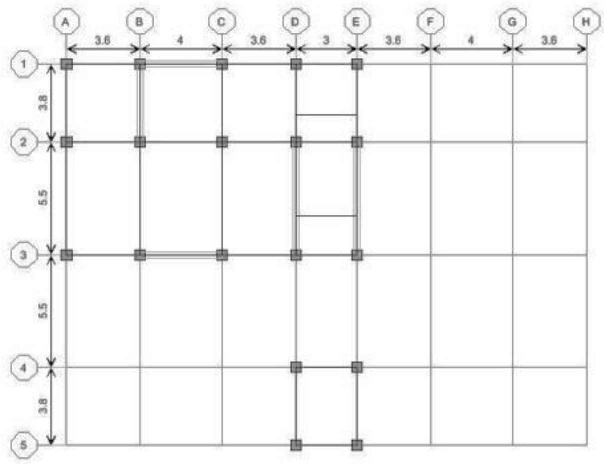

Fig. 6 Sixteenth floor plan (ST 16)

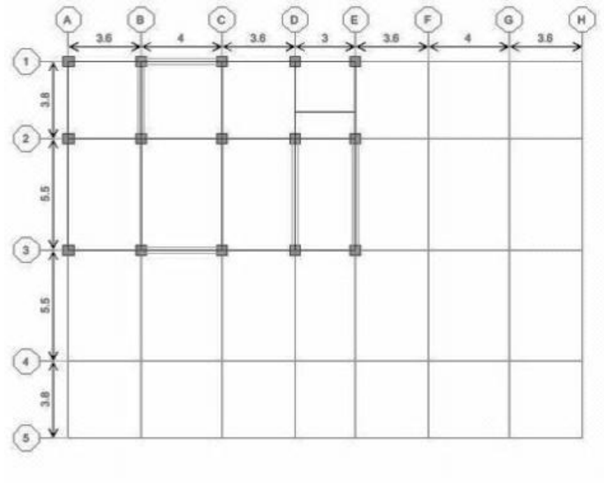

Fig. 7 Seventeenth to twentieth Floor Plan (ST 17 to 20)

V. Results and Discussions

The maximum displacements of building in different stories in both X and Y direction for all methods of analysis have been compared and shown in figures [8, 9]. Also, the maximum displacement of center of mass is considered to indicate the difference between all methods; the results obtained have been shown in figures [10, 11].

From the diagrams below, it is observed that, in first five stories, the difference between the results obtained with different methods is insignificant. With increasing the height of building, the difference between the displacements (calculated by those methods) is gradually increased, by considering the maximum displacement of each storey and displacement of center of mass.

It is observed that, the maximum displacement is increasing from first storey to last one. However, the maximum displacement of center of mass, obtained by time history analysis for both earthquakes at 16th floor is less than 15th floor which is against the general trend line. It is as a result of plan properties in those stories where the location of center of mass is changed in X and Y directions.

As a matter of fact response spectrum analyses represent maximum response of structure during earthquake ground motion. It is seen from the diagrams below, the storey displacements obtained by response spectrum analysis and static analyses are close to each other.

It’s clear that the static analysis gives higher values for maximum displacement of the stories in both X and Y directions rather than other methods of analysis, especially in higher stories. Although in Y direction these difference is much less than X direction appears (Because of less differences which exist between center of mass and center of stiffness).

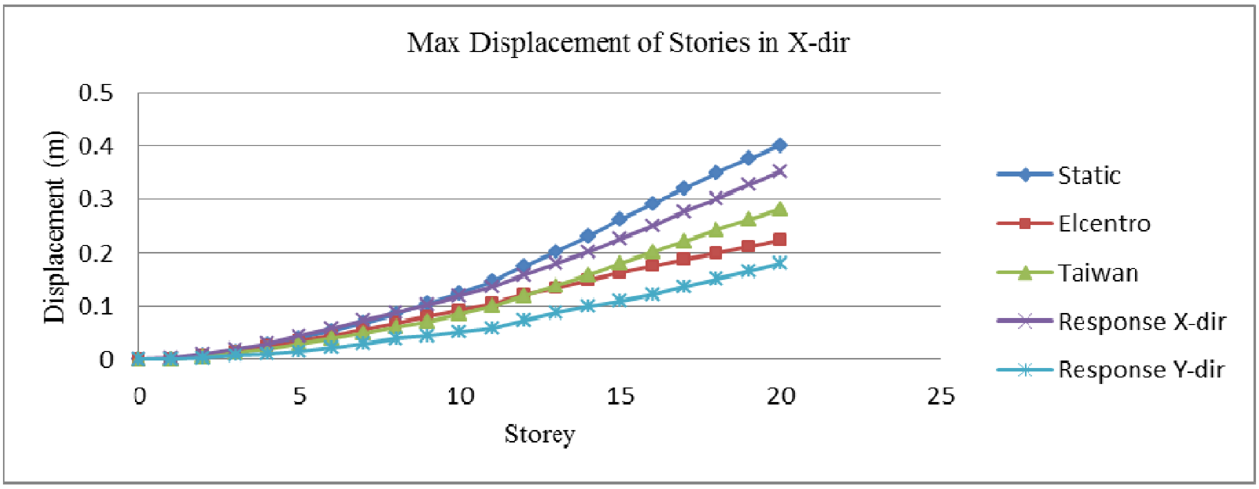

Fig. 8 Maximum Displacement of Stories in all method in X direction

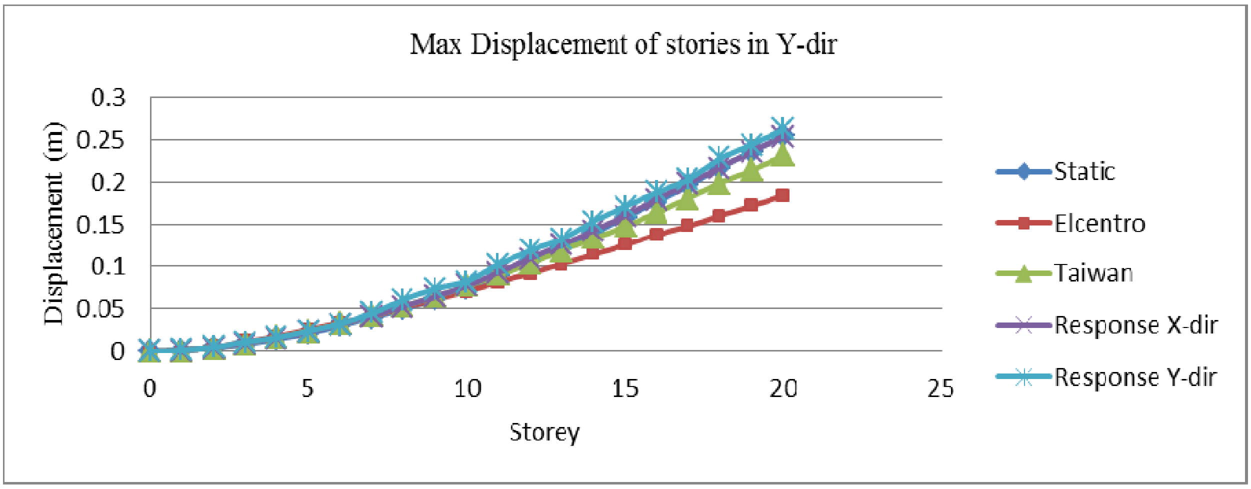

Fig. 9 Maximum Displacement of Stories in all method in Y direction

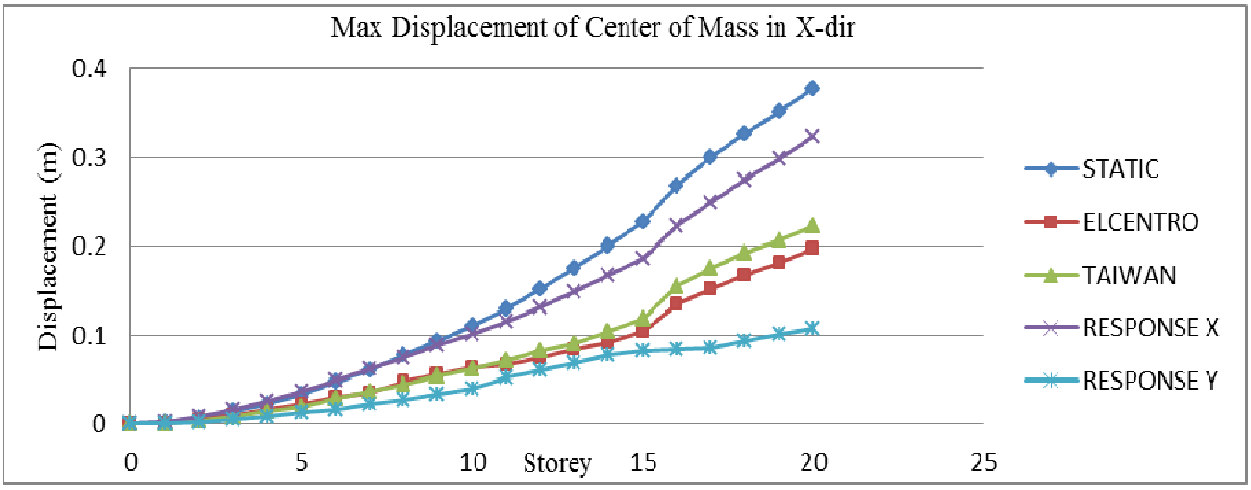

Fig. 10 Maximum Displacement of Center of Mass in all method in X direction

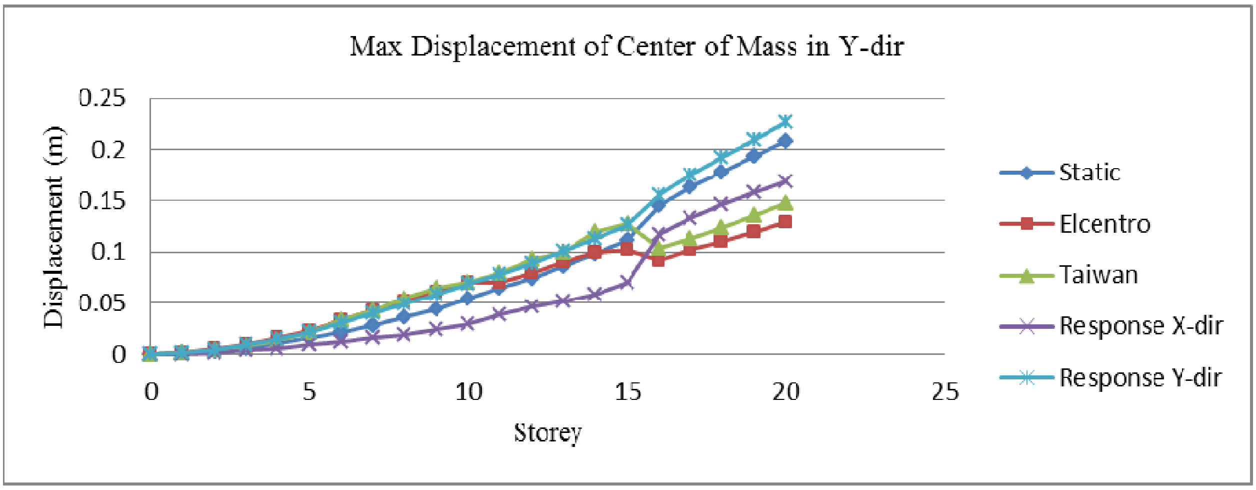

Fig. 11 Maximum Displacement of Center of Mass in all method in Y direction

VI. Conclusion

From the above work the following conclusions can be drawn out.

[1] As a result of comparison between three mentioned analysis it is observed that the displacements obtained by static analysis are higher than dynamic analysis including response spectrum and time history analysis

[2] Time history Analysis is an elegant tool to visualize the performance level of a building under a given earthquake. Seismic performance of structure can be obtained by selecting an adequate recorded ground motion for time history analysis.

[3] Static analysis is not sufficient for high-rise buildings and it's necessary to provide dynamic analysis (because of specific and nonlinear distribution of force).

[4] For important structures time history analysis should be performed as it predicts the structural response more accurately in comparison with other two methods.

[5] The difference of displacement values between static and dynamic analysis lower stories are insignificant but it increased in higher stories reached at its peak in top story or roof.

[6] The displacement of each storey at center of mass is lower compare to those at the joint of maximum displacement.

[7] The results of equivalent static analysis are approximately uneconomical because values of displacement are higher than dynamic analysis.

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