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A Review - Comparison between Response Spectrum Method and Time History Method for Dynamic Analysis of Multistoried Building

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Abstract: ***The Indian subcontinent is particularly visited by earthquake of severe to medium intensities almost once a decade. This earthquake causes severe damage to properties in general and multistoried building in particular. Hence all the building constructed in Indian subcontinents and particularly situated in earthquake prone zones as defined by IS 1893:2002 should be designed for loads and stresses, resulting out of earthquake. The multistory building can be analyzed for stresses arising out of earthquake by using method of dynamic analysis. Various methods of dynamic analysis include Response Spectrum Method, Time History Method and Seismic Coefficient Method out of these Response spectrum method and Time history method are widely used for dynamic analysis of multistoried building. However the researchers are always at the crossroads while choosing the proper method of dynamic analysis for multistoried building. This paper therefore attempts to document the various research input available so far, for the use of Response spectrum method and Time history method for the analysis of multistoried building. Study suggests that the Time History Method of dynamic analysis of multistoried building is better than Response Spectrum Method.***

Keywords: Response Spectrum Method**,** Time History Method, Earthquake, Dynamic analysis.

1. Introduction

Dynamic Analysis is analyzing a code or structure of a program while running the program. Structural dynamic it is the response analysis for structure subjected to dynamic loading like wind or earthquake. In this study we focus on only one kind of dynamic load that is earthquake load. Ground motion in earthquake load varies in its magnitude, direction and position with time. This motion causes the structure to vibrate or shake in all three directions. Generally structures we designed for vertical shaking, which may not be able to safely sustain the effect of horizontal shaking[1].Therefore it is necessary to ensure that the structure is adequately resistant to horizontal earthquake shaking too. In most structural engineering calculations, dead loads, live loads and wind loads can be evaluated with fair degree of accuracy. However, the situation with regard to earthquake forces is entirely different. Earthquake Loads are inertia forces whose magnitude is function of mass, stiffness, and energy absorbing capacity (e.g., damping and ductility) of elements. Earthquake response also depends on over all geometry of structure[2].Various methods available for Dynamic analysis of structure include *Response Spectrum Method*[3], *Seismic Coefficient Method* and*Time History Method*[4].Present study discusses the THM and RSM.

Time History Method

This method calculates response of structure subjected to earthquake excitation at every instant of time (hence the name Time History). Various seismic data are necessary to carry out the seismic analysis i.e. acceleration, velocity, displacement data etc., which can be easily procured from seismograph data's analysis for any particular earthquake. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear[5].

Response Spectrum Method

This method is derived from time history analysis. A designer is not often bothered about the structure's response at every instance of time, maximum response is enough information to design adequately strong structure. In this method graph between maximum spectral acceleration and various time period of structure is prepared for some ground acceleration and structures response at every instance of time is not calculated. Response spectrum method, it is the linear dynamic analysis method[6].This method involves the calculation of only the maximum values of displacements and member forces in each mode of vibration. This method uses smooth design spectra that are the average of several earthquake motions. Different earthquake will have different response spectra but for ease of structural engineer IS 1893:2002 has given a general purpose response spectra which is derived by considering few big earthquake from past.

This study aims at reviewing few of the available research report on analysis of multistoried building using Response Spectrum Method and Time History Method and carrying comparative study of both method.

2. Review of Literature on Dynamic Analysis

Lot of studies in past have been conducted comparing various approaches of dynamic analysis on various parameters. With increased availability and demand of Finite element method and non FEM based software in market, researchers have also compared this methods on ground of usability in performing computers based model analysis and programing such software. Following a few of important papers in this context.

The available research reports are classified in three parts:-

1) Review of researchers report on response spectrum method.
2) Review of researchers report on time history method.
3) Comparison of response spectrum method and time history method.

A. Literatures on response spectrum method-

- **S.S. Patil et al.2013**[7]presented seismic analysis of high rise building using different lateral load resisting system that are 1) bare frame, 2)brace frame, 3) shear wall frame. This analysis is done with Response Spectrum Method, and using STAAD Pro software. Test result is based on parameters like base shear, story drift and story deflection. They concluded that shear wall model gives less story deflection and story drift than bare frame and braced frame.
- **Hassaballa A.E. et al.2013**[8] studied the seismic analysis of a RC building, and investigate the performance of existing building if exposed to seismic loads. This building frame was analyzed by Response Spectrum Method and frame is computed through STAAD Pro software. For seismic analysis of multistory building they used static load and seismic load and get result that design based on response spectrum method required large dimension of to resist large displacement. And concluded that drift resulting from nodal displacement due to combination of static load and seismic loads were about 2 to 3 times the allowable drifts.
- **Mindaye et al, 2016**[9]studied the seismic response of residential G+10 RC frame building is analyzed by the linear analysis approaches of equivalent static lateral forces and Response spectrum method using ETAB ultimate 2015 software as per IS 1893:2002 part1. Different response like lateral force, overturning moment, story drift, displacement, base shear are plotted in order to compare the result of the static and dynamic analysis. They concluded that dynamic story shear is less than story shear for all cases. Equivalent static lateral force method gives higher value of force and moments which make building uneconomical hence consideration of response spectrum method is also needed.

B. Literatures on Time History Method-

- **Padol S. et al.2015**[10]studiedthe seismic analysis of multistoried RCC building with mass irregularity at different floor level are carried out. This paper highlights the effect of mass irregularity on different floor in RCC building with Time History Method and analysis is done by ETABS software. They concluded that whenever structure has different irregularity the effect of earthquake on structure can be minimize by providing shear wall, base isolation etc.
- **Patil A. S, (2013)**[11]studied nonlinear dynamic analysis of 10 storied RCC building considering different seismic intensities and also studied seismic response of such building. The building under consideration is modeled with the help of SAP 2000-15 software and 5 different time histories have been used. The result of the study shows similar variations pattern in seismic response such as base shear and storey displacements and concluded that time history is realistic method used for seismic analysis. It provides a better check to the safety of structure analyzed and designed.

C. Comparison of response spectrum method and time history method -

- **Bhagwat et al.2014**[12] studied dynamic analysis of G+12 multistoried practiced RCC building considering for Koyna and Bhuj earthquake is carried out. The Time History Analysis and Response Spectrum Analysis and seismic responses of the building are comparatively studied. The modeled with the help of ETABS9.7.2 software. Two time histories (i.e. Koyna and Bhuj) have been used to develop different criteria (base shear, storey displacement, storey shear), and concluded that, the value of base shear for Bhuj earthquake is 49.11% more than the Koyna earthquake, and Response Spectrum method gives 50% more result than Time History Analysis.
- **Dubey et al. 2015**[13]presented design of multistoried irregular building with 20 stories and modeled it using software STAAD-PRO for seismic zone IV in India, dynamic response of building under actual earthquake, DELINA (ALASKA)2000 have been considered. This paper highlights the comparison of Time History Method and Response Spectrum Method. The story displacement result has been obtained by using both method of dynamic analysis, and Concluded that Time History Analysis is found to be 2 to 8% higher than that of Response Spectrum Analysis in both type of building i.e. regular and irregular, For high rise building it is necessary to provide dynamic analysis because of nonlinear distribution of force. Storey displacement is found greater in THM as compared to RSM ,and observed that the base shear is greater in RSM compared to THM. Thus it can be concluded that time history analysis is economically better for designing.
- **Rampure et al. 2016**[14] studied the dynamic time history analysis and response spectrum analysis of a concrete gravity dam by using STAAD-PRO. Finite element approach is used to analyze the dam and a concrete gravity dam model is prepared in STAAD-PRO to perform the time history analysis and response spectrum analysis and comparison is done between both these methods. They concluded that STAAD-PRO is most convenient and less tedious for dynamic analyses and it provides a computing environment to investigate modelling assumption and computational processes related to the static and seismic structural stability of gravity dam. It is necessary to analyze the structure by dynamic analysis of both these method for below the height of dam 100m and above the height of dam 100m.
- [15]**Hawaldar et al. 2015**[15]presented G+12 storey building model with and without infill the time history analysis used for Bhuj and Koynaearthquake function it is carried out in ETABS 2013 software. The seismic responses of story displacements, storey drifts are observed. Time history plots of base force v/s time and roof displacement v/s time for both time history functions are compared and studied. They concluded that the displacement values for bhuj function are higher than the displacement value for koyna function and those for infill building are less than that without in filled building and drift value of bhuj function were more in comparison with drifts for koyna function and infill drift values are comparatively less than for without infill drift values for both time history function.

- **Bahador et al. (2012)**[16]studied 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. And 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. And concluded that time history analysis is an elegant tool to visualize the performance level of building under a given earthquake and static analysis is not sufficient for high rise building, the result of equivalent static analysis are approximately uneconomical because values of displacement are higher than dynamic analysis.
- **Harshita et al. (2014)**[17]studied the dynamic behavior of multistoried symmetrical building frame using IS1893-2002 code recommended response spectrum method and time history method. The time history analysis, two earthquake data such as from previous earthquakes corresponding to Bhuj (2001) and Spitak (1988). Study focuses to evaluate the base shear, response spectra at different story levels, bending moment diagram, shear force diagram variation in the building. Analysis has been carried out using the STAAD-PRO software based on the matrix analysis. Based on the result it is found that the base shear obtained from time history analysis is slightly higher compared to response spectrum analysis, this may be due to variation in amplitude and frequency content of the ground motion.

3. Discussion

Above studies results boils down to following-

- Top displacement values from time history analysis is 10% to 20% lesser than the displacement from response spectrum analysis.
- For important structure time history method should be used over response analysis as it predicts structure behavior more accurately.
- Difference in structure displacement is very small in lower stories in both the methods both result predicts almost same result for lower stories.
- Difference in structural displacement by both methods become large for higher stories only.
- Design based on response spectrum analysis are uneconomical as large dimension of beam are required to resist large displacement.
- Time history method is accurate but very resource consuming on the other hand response spectrum is quick but marginally uneconomical.

4. Conclusion

Although fundamentally both method are derived from same principle but in comparison Time history analysis is a more precise in description of the structure under dynamic load and it can give a more precise approximation of the interior stresses and also the time and position of the cracks emerging in the structure. On the other handResponse Spectrum analysis over estimates the stresses, but it saves lot of resources and time.

From the above work, for dynamic analysis, time history method is best suited compare to response spectrum method. Response spectrum analysis should be strictly avoided in case of tall, irregular or important structure.

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