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TIME HISTORY RESPONSE PREDICTION FOR MULTI-STOREY BUILDINGS UNDER EARTHQUAKE GROUND MOTIONS

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ABSTRACT

The earthquake code IS 1893(Part 1):2002 indicates that every structure shall be designed to seismic forces, because whole part of the country is under the seismic influence.

The seismic resistance design codes recommend the selection of at least three or seven ground motion records, for the time-history analysis purposes, which shall be compatible to the design spectrum. On the other hand, the spectrum compatible records may change the structural response because of the different characteristics in comparison with real ground motion records. Spectrum compatibility is done for real accelerograms to generate compatible accelerograms. The spectrum compatibility is done by using a programme WAVEGEN**,** by using these records response spectrums are generated using SEISMO-SIGNAL software. These response spectrums are compared with IS 1893(Part1)-2002 response spectrum. The time-history analysis is carried out by using the compatible accelerograms. The response spectrum analysis and time-history analysis is done by using ETABS, and results obtained from analysis are verified. Nonlinear time history analysis is done for studying the inelastic behaviour of the structures.

KEY WORDS: Time History, Spectrum compatible, Accelerograms, Response spectrum, Ground motion.

INTRODUCTION

The dispersion in the seismic response of structure, which defines the seismic demand and capacity, is usually high even if a large number of real ground motion records being used. That is, the time-history analysis for the design purpose shall be performed based on an appropriate suite of ground motion records. The common design code recommended selecting at least three or seven records in a way that the mean spectral acceleration covers the design spectrum. The record selection becomes, by this criterion, a little difficult, at least if the real records being of interest. For clarity of expansion, four different methods have been reviewed to satisfy the common code requirements which are follows:

1) To scale up all acceleration values of the selected record to ensure that the record spectral acceleration is above the values of design spectrum in the interest region. This method is partially impossible to use, because it will increase the spectrum amplitude significantly and the design will not be economic.
2) To select a set of records from a record database in a way that their mean response spectrum have a good compatibility with the design spectrum. This method is obviously an optimization

process which needs a relatively large record database for its input however this method may not work due to the limitations of earthquake catalogue, the scenario-based selection is of interest.

3) To use the spectrum compatible or synthetic records. The spectrum compatible records are based on some modifications on the real records characteristics. The synthetic records are usually produced based on the sinusoidal motions. The disadvantages of using the compatible or synthetic records are reported in the literature.
4) To use the limited number of real ground motion records to predict the median response of structure. This method needs a precedence list of ground motion records to be established before the time history analysis is performed. The main advantage of this method is that the selection of a few real ground motion records is possible based on a scenario earthquake.

It is concluded that using of compatible sets of records result to a concentrative prediction of structural response.

SPECTRUM COMPATIBLE

For the purpose of earthquake resistant analysis and design of structures, realistic ground motion is required. In most of the cases it may not be possible to have strong motion records at a given site. Even if such recordings are available, there is no basis to expect that a future earthquake might generate same or similar ground motion. It is, therefore, essential that for earthquake resistant time history analysis of a structure, synthetic time histories must be generated for specific sites. However, there are several uncertainties in arriving at such time histories and to overcome these uncertainties decisions are required to be taken in a scientific and purposeful manner. Some of the issues for generation of site specific synthetic accelerogram are shape of design response spectra, zero period acceleration (ZPA), duration of record, rise, strong motion and decay time (envelop function of time history), phase characteristic of record, number of zero crossings, realistic derived velocity and displacement history etc.

GROUND MOTION RECORDS

A set of five ground motion records, have been selected from Bhuj earthquake, magnitudes 7.6Ms are recorded. The real earthquake ground motion acceleration values are taken and the spectrum compatible is done for those records. The real earthquake ground motions are taken at different locations of bhuj earthquake, damping of 5% is taken for five earthquake ground motions. . The peak ground acceleration of the selected 5 earthquake ground motions are 1.108g, 1.125g, 1.170g, 1.830g and 1.832g.The response spectrums are taken by using the spectrum compatible records and compared with the IS 1893-2002(part I) as shown below.

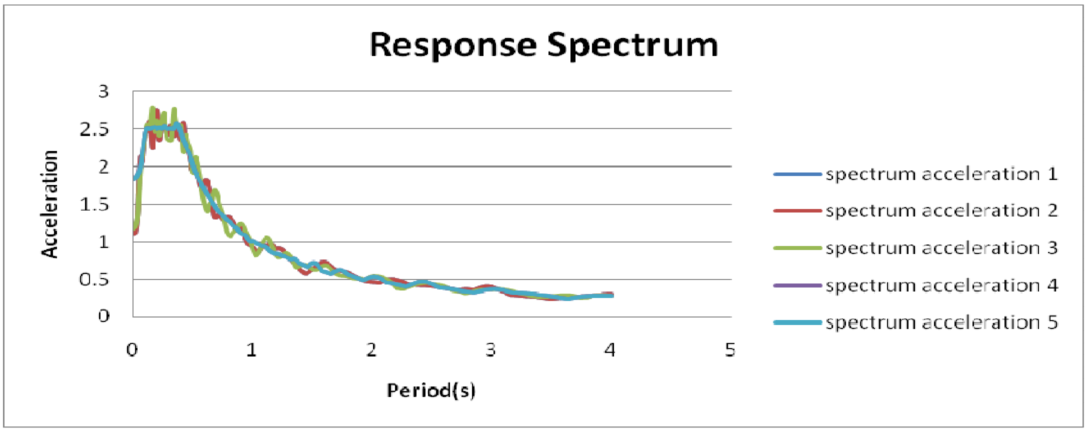


Figure 1

The 5% damped acceleration elastic response spectrum of the ground motion records are presented in Figure 1.

RESPONSE SPECTRUM

Response spectra can also be used in assessing the response of linear systems with multiple modes of oscillation (multi-degree of freedom systems), although they are only accurate for low levels of damping. Modal analysis is performed to identify the modes, and the response in that mode can be picked from the response spectrum. This peak response is then combined to estimate a total response. A typical combination method is the square root of the sum of the squares (SRSS) if the modal frequencies are not close. The main limitation of response spectra is that they are only universally applicable for linear systems.

TIME HISTORY ANALYSIS

A time dependent forcing function (earthquake accelerogram) is applied and the corresponding response–history of the structure during the earthquake is computed. That is, the moment and force diagrams at each of a series of prescribed intervals throughout the applied motion can be found. As the number of degrees of freedom of a structure increases it very quickly becomes too difficult to calculate the time history manually - real structures are analysed using non-linear finite element analysis software. Computer programs have been written for both linear elastic and non-linear inelastic material behaviour using step-by-step integration procedures.

DESCRIPTION OF THE STRUCTURE

The buildings consider for analysis are typical 3D structures which are (G+3), (G+6), (G+9), and (G+12) of RC frame.

Zone	-	III
Overall plan dimension	-	29 X 22 m
No. of stories	-	G+3, G+6, G+9 and G+12

Type of building use	-	Commercial
Zone factor, Z	-	0.16
Importance factor, I	-	1.5
Response reduction factor, R	-	5
Live load	-	$3KN/m^2$
Floor Finish	-	$1KN/m^2$
Thickness of Slab	-	0.120 m

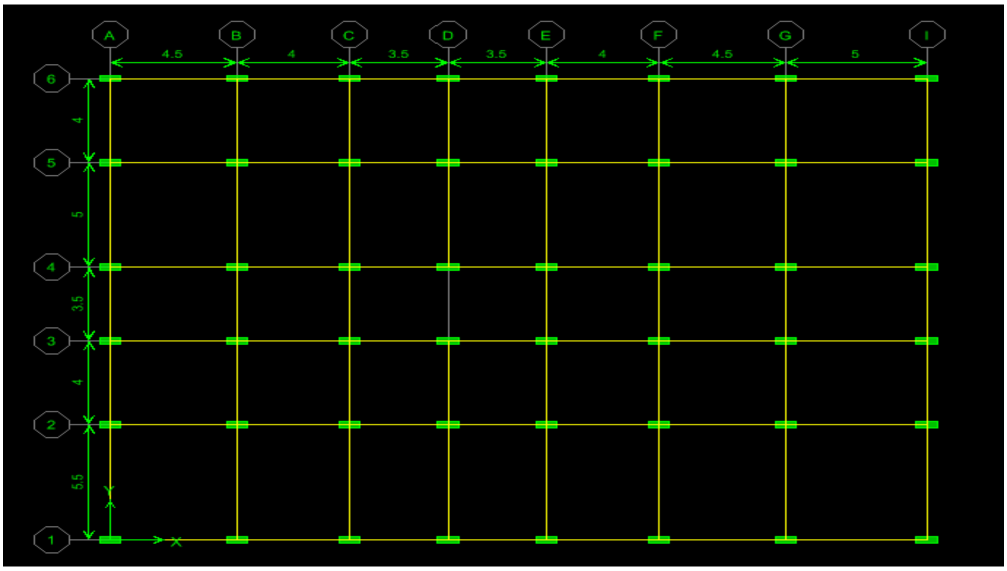
Table 1 : Dimensions of Beam & Column

Structures	Beam size	Column size
(G+3)	0.23X0.3m	0.3X0.3m
(G+6)	0.25X0.35m	0.3X0.45m
(G+9)	0.3X0.4m	0.3X0.7m
(G+12)	0.3X0.4m	0.3X0.75m

Material properties are assumed to be 25MPa for concrete compressive strength and 415MPa for unit strength of longitudinal and shear reinforcement.

MODELLING APPROACH

A three dimensional RC frames are modelled in ETABS to perform analysis. The response spectrum analysis and time history analysis are carried out for these models.



RESULTS AND DISCUSSION

Response spectrum and time history analysis were considered for seismic performance evaluation. The response spectrum analysis is carried out according to IS 1893-2002(part1). The base shear forces and the displacements are observed at the floor levels. The time history analysis is a step by step analysis of the dynamical response of the structure to a specified loading that may vary with time. A set of 5 strong ground motions having a magnitude of 7.6Ms are selected from time history evaluation. The peak displacements obtained in time history analysis don't correspond to the ultimate displacements of the response spectrum analysis. A conventional technique is to scale ground motions such that the spectral acceleration at the fundamental period matches a given design spectrum. The earthquake motions are taken for analysis and the scale factors corresponding to target displacement at DBE and MCE level.

The scale factor taken for DBE is 0.784

The scale factor taken for MCE is 1.569

BASE SHEAR

The base shear obtained at DBE and MCE levels from time history analysis are compared with response spectrum analysis.

- For the structure (G+3) the results from time history analysis gives 78% and 256% higher values of DBE and MCE than the response spectrum analysis.
- For the structure (G+6) the results from time history analysis gives 116% and 313% higher values of DBE and MCE than the response spectrum analysis.
- For the structure (G+9) the results from time history analysis gives 81% and 262% higher values of DBE and MCE than the response spectrum analysis.
- For the structure (G+12) the results from time history analysis gives 121% and 316% higher values of DBE and MCE than the response spectrum analysis.

INTERSTOREY DRIFT

The Interstorey drift has long been recognized as an important indicator of building performance. Interstorey drift is defined as the ratio of relative horizontal displacement of two adjacent floors and corresponding storey height. The drift allowable is of 0.4% according to IS1893-2002(part1).

- For the structure (G+3) the results from time history analysis gives 0.11% and 0.22% at DBE and MCE.
- For the structure (G+6) the results from time history analysis gives 0.11% and 0.22% at DBE and MCE.

- For the structure (G+9) the results from time history analysis gives 0.076% and 0.15% at DBE and MCE.
- For the structure (G+12) the results from time history analysis gives 0.089% and 0.17% at DBE and MCE.

INELASTIC BEHAVIOUR OF STRUCTURES

The nonlinear time history analysis is carried out on the structures using the spectrum compatible data. The inelastic behaviour of structure is studied at the MCE condition, hinges formed at this condition shows the inelastic behaviour of the structure.

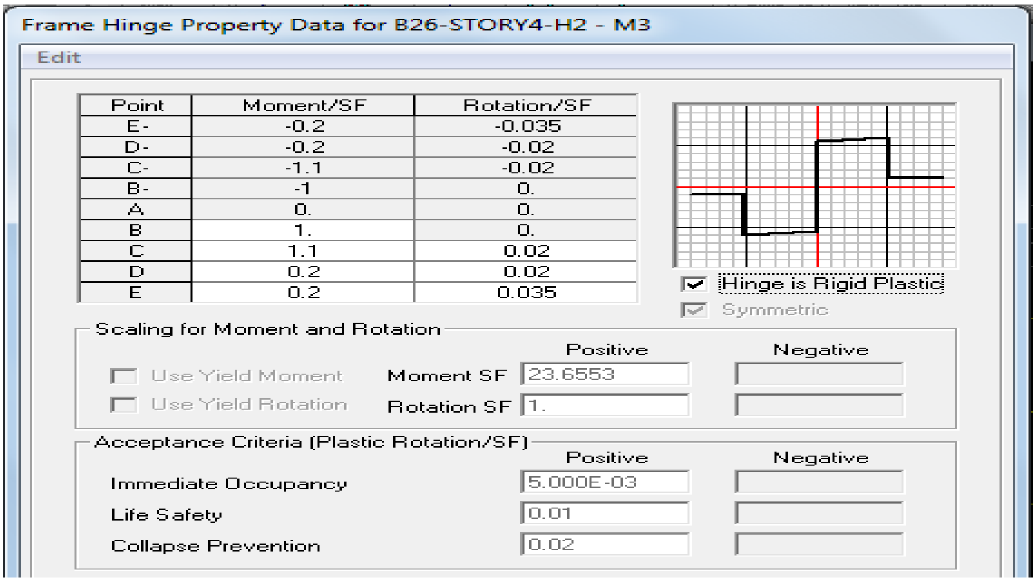


Figure 1 : Behaviour of Hinge in beam

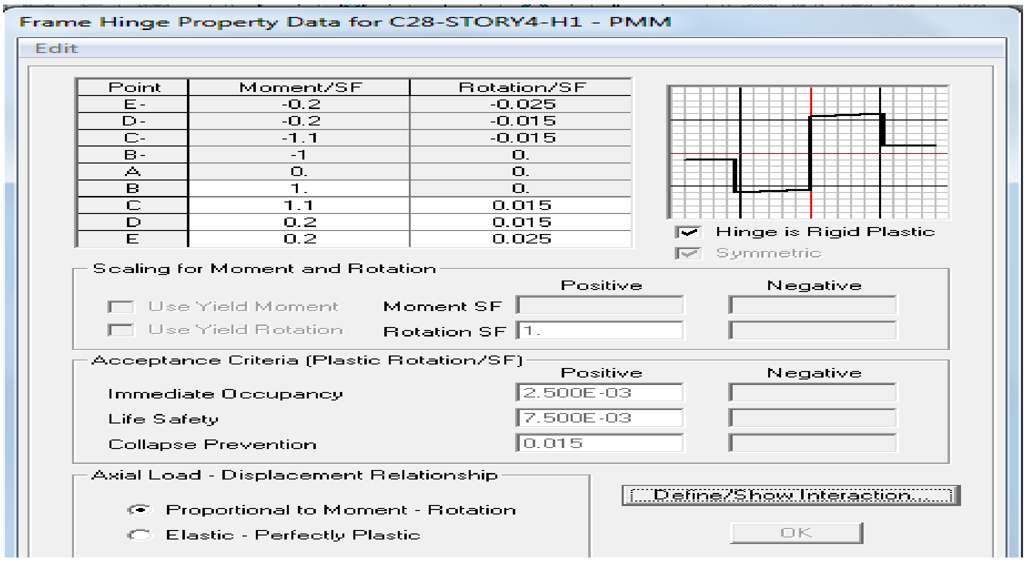


Figure 2 : Behaviour of hinge in column

By seeing the above hinge properties the behaviour of the structure when subjected to the strong ground motions at MCE condition is shown that the structure is in the life safety and collapse prevention condition, this says that the structure is still in the life safety condition even after subjecting to the strong ground motions.

CONCLUSIONS

A three dimensional RC frames analysis done for gravity loads and lateral loads were considered and the response spectrum analysis and time history analysis were carried out to evaluate seismic performance of frame. The following findings were observed:

1) The time history analysis gave higher value of base shear at DBE and MCE conditions than response spectrum analysis as follows:
   a) For the structure (G+3) 78% and 256%.
   b) For the structure (G+6) 116% and 313%
   c) For the structure (G+9) 81% and 262%
   d) For the structure (G+12) 121% and 316%
2) The floor drifts of frames at DBE and MCE levels indicates that the frame satisfies as per IS 1893(Part 1)-2002 as follows:
   a) For the structure (G+3) 0.11% and 0.22%
   b) For the structure (G+6) 0.11% and 0.22%
   c) For the structure (G+9) 0.076% and 0.15%
   d) For the structure (G+12) 0.089% and 0.17%
3) From the response spectrum and time history analysis, it is seen that 2nd storey experienced the maximum interstorey drift ratio at the both DBE and MCE levels. Time history analysis gave higher interstorey drift when compared to the response spectrum analysis.
4) From the nonlinear analysis of the structures it is seen that the structure is in between the Life safety and Collapse prevention state at MCE Condition.

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