Comparison of Response Spectrum, Time History and Matched Time History Method in Zone V and Zone IV Earthquake Zones of Multi Storied Building as per IS 1893-2016

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Abstract: ***Earthquake are one of the devastating natural calamities. Keeping in view of the varying effects of earthquake based on the nature of the location, IS 1893-2016 classified India into four zones namely Zone II, Zone III, Zone IV, Zone V. IS 1893-2016 has clearly stated that Equivalent static method can only be used for a regular building in Zone II whose height is within 15m, for all other structures Dynamic Analysis has to be used. The various Dynamic Analysis as per code are Response Spectrum, Time History and Modal Time History. A special method is developed by matching Time History function with Response Spectrum in both Frequency and Time Domain. The present work deals in analysing these methods in both Zone V and Zone IV when subjected with seismic excitations of Chamoli earthquake in Zone V and Uttarkashi Earthquake in Zone IV both of which occurred in year 1999 and both the earthquakes have same magnitude of 6.8 on Richter Scale. Parameters considered in the study are storey displacements, storey drifts, storey shears and base reactions. ETABS V.17.0.1 is used as the software tool for performing linear time history, response spectrum, matched time history and modal time history analysis of the regular structure.***

Index Terms: Chamoli ground motion data, Linear time history analysis, Matched Time History, Response Spectrum.

I. INTRODUCTION

Earthquake are one of the devastating natural calamities. Keeping in view of the varying effects of earthquake based on the nature of the location IS 1893-2016 classified India into four zones namely Zone II, Zone III, Zone IV, Zone V. IS 1893-2016 has clearly stated that Equivalent static method can only be used for a building whose height is within 15m and is present in Zone II for all other structures Dynamic Analysis has to be used. The various Dynamic Analysis as per code are Response Spectrum, Time History and Modal Time History. A special method is developed by matching Time History function with Response Spectrum in both Frequency and Time Domain. The present work deals in analysing these methods in both Zone V and Zone IV when subjected with seismic excitations of Chamoli earthquake in Zone V and Uttarkashi Earthquake in Zone IV both of which occurred in year 1999 and both the earthquakes have same magnitude of 6.8 on Richter Scale. Parameters considered in the study are storey displacements, storey drifts, storey shears and base reactions. ETABS V.17.0.1 is used as the software tool for performing linear time history, response spectrum, matched time history of the regular structure

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II. LITERATURE REVIEW

Dr. S.K. Dubey et.al [2015] conducted Dynamic Analysis on a G+20 building of height 60m situated in Zone IV. A comparison of Time History analysis and Response Spectrum analysis is performed. For time history analysis ground motion data of earthquake Delina (Alaska) 2002 is considered. It was observed that displacements and drifts storey wise are greater in Time History Analysis in comparison with Response Spectrum analysis and whereas in Base shear the values of Response Spectrum are higher than values of time history analysis.

Dr. P. S. Bokare et.al [2015] performed a comparative study on comparison of time history analysis and response spectrum, separately on time history analysis and response spectrum analysis is performed. The analysis is based on IS 1893-2002. In various papers different models were considered, different earthquake data in different zones and by using various simulation software some considering Finite Element Methods and some not. It was observed that the storey wise displacements are maximum in Response Spectrum and minimum in Time History and the difference in displacements in very low in lower storeys but predominant in higher storeys

III. MODEL CONSIDERED FOR STUDY

A regular square building of plan dimensions 40X40m with 15 storeys and each storey of height 3m.

Model U :15 Storied Regular Building analysed by Time History Analysis taking Uttarkashi Earthquake

Model UF :15 Storied Regular Building analysed by Uttarkashi Earthquake Time History Analysis matched to Response Spectrum in Spectral Frequency Domain.

Model UT : 15 Storied Regular Building analysed by Uttarkashi Earthquake Time History Analysis matched to Response Spectrum in Spectral Time Domain

Model RS4 : 15 Storied Regular Building analysed by Response Spectrum Analysis in Zone IV.

Model C :15 Storied Regular Building analysed by Time History Analysis taking Chamoli Earthquake

Model CF :15 Storied Regular Building analysed by Chamoli Earthquake Time History Analysis matched to Response Spectrum in Spectral Frequency Domain.

Model CT : 15 Storied Regular Building analysed by Chamoli Earthquake Time History Analysis matched to Response Spectrum in Spectral Time Domain

Model RS5 : 15 Storied Regular Building analysed by Response Spectrum Analysis in Zone V.

IV. STRUCTURAL SPECIFICATIONS

U Table 1 shows the specifications of the models considered in the work.

Table 1: Specifications

Specifications	For all Models
Height of Building	45m
Column size	500mmx500mm
Clear Cover for Column	40mm
Beam size	300mmx450mm
Clear Cover for Beam	25mm
Slab thickness	150mm
Thickness of wall	220mm
Grade of concrete for Column & Beam	M-35
Grade of concrete for Slab	M-25
Grade of concrete for Wall	M-20
Grade of steel in Longitudinal bars	Fe-550
Grade of steel in Confinement bars	Fe-415
Unit weight of concrete	25kN/ m^3
Live load	3kN/m^2
Floor finish	1.5kN/m^2

The Zone considered for analysis is Zone V and Zone IV and the soil type is Type II. The structure considered was Ordinary Moment Resisting Frame (OMRF) therefore the Response Reduction factor is 3. The structure considered was not an Important building but with occupancy of more than 200 persons therefore, Importance factor is 1.2. As per the code the damping value considered is 5% of critical damping.

For slab and wall membrane sections are considered.

V. EARTHQUAKE DATA

The earthquake data considered for the Zone V analysis is Chamoli Earthquake of intensity 6.8 on Richter Scale which occurred on 29th March 1999 in Chamoli District of Uttar Pradesh state.

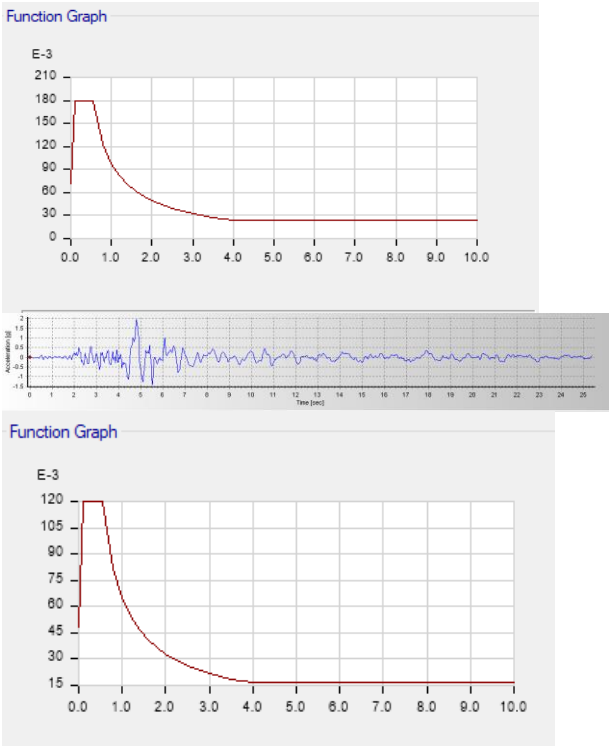

Fig 1: Acceleration(g) vs Time (sec) graph of Chamoli Earthquake

The earthquake data considered for the Zone IV analysis is Uttarkashi Earthquake of intensity 6.8 on Richter Scale which occurred on 20th October 1999 in Uttarkashi and Garhwal Regions of Uttarakhand State.

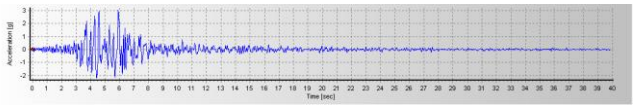

Fig 2: Acceleration(g) vs Time (sec) graph of Uttarkashi Earthquake

VI. METHOD OF ANALYSIS

The Analysis is performed in Response Spectrum, Time History, Time history matched to Response Spectrum methods. The method of Analysis is Linear Dynamic Modal Analysis. The Spectral Matching is done in Time domain and Frequency Domain. And the Modal Case type considered is Modal-Ritz. Maximum number of modes considered is 12. The analysis is done in ETABS V17.0.1.

A.Time History Analysis

Time-history analysis is performed by either linear or non-linear dynamic analysis by taking the seismic ground acceleration as a function of time. Direct Integration or Fourier transform techniques are used to analyse a model by time history analysis. For modal analysis Fourier transform is used.

B.Response Spectrum Analysis

Response-spectrum analysis (RSA) measures the contribution from each natural mode of vibration and gives the values of likely maximum response of the elastic

structure. It is a linear dynamic analysis. Response-spectrum analysis gives an idea about dynamic behaviour by analyzing pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given earthquake data and value of damping.

Fig 3: Response Spectrum for Zone V

Fig 4: Response Spectrum for Zone IV

C.Time History Matched to Response Spectrum

Seismic input to nonlinear dynamic analyses of structures is usually defined in terms of acceleration time series (time-history function) whose response spectra are compatible with a specified target response spectrum. Various methods have been developed to modify a reference time series so that its response spectrum is compatible with a specified target spectrum. Two of the most widely used methods, namely the Frequency Domain Method and the Time Domain Method

D.Frequency Domain Method

Frequency Domain method maintains the Fourier phase of the reference time history fixed and adjusts the Fourier Amplitude spectrum. It adjusts based on the ratio of target response spectrum to the time-series response spectrum.

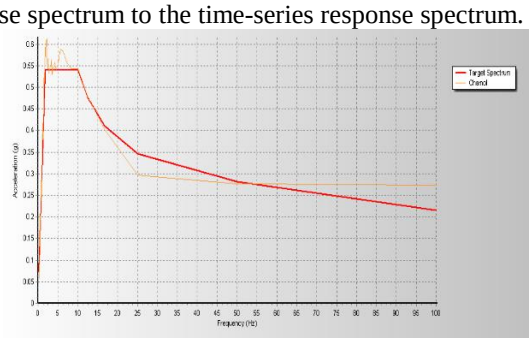

Fig 5: Chamoli Frequency Domain Method

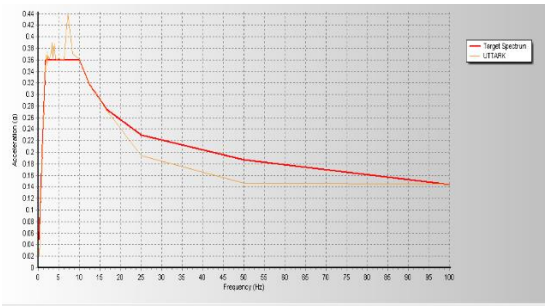

Fig 6: Uttarkashi Frequency Domain Method

E.Time Domain Method

Time Domain method by the addition of wavelets adjusts the time history accelerations in time domain.

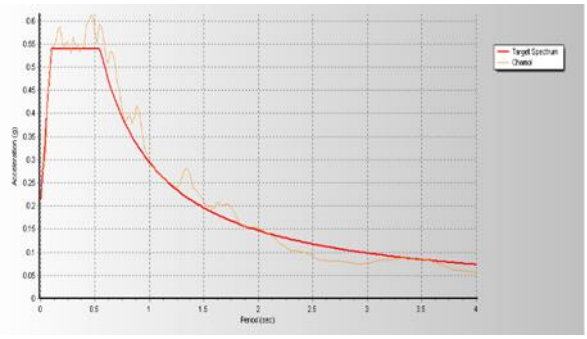

Fig 7: Chamoli Time Domain Method

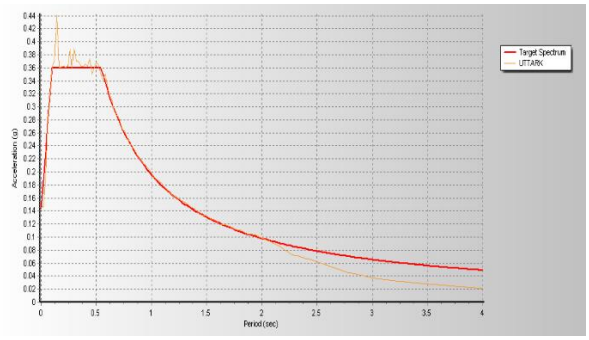

Fig 8: Uttarkashi Time Domain Method

VII. RESULTS

A. Maximum Story Displacement

It is total displacement of nth storey with respect to ground.

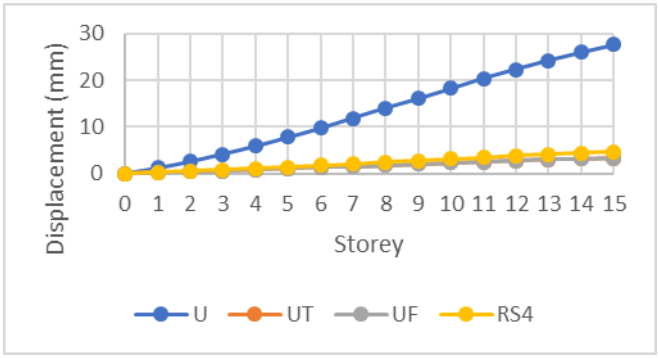

Fig 9: Uttarkashi Storey Displacement

- Maximum results were observed in Time History case followed by Response Spectrum.
- Time history matched to Response Spectrum in both Time domain and Frequency domain the results are same.

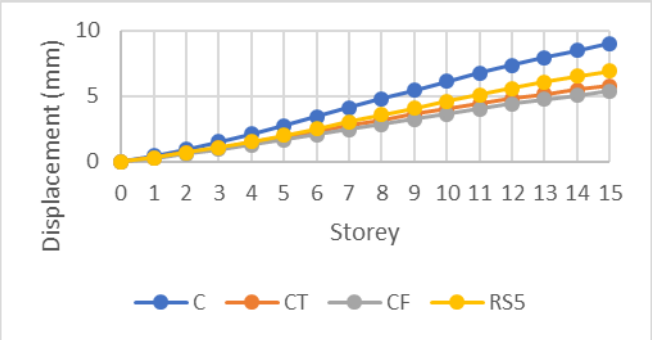

Fig 10: Chamoli Storey Displacement

- Maximum results were observed in Time History case followed by Response Spectrum.
- The Response Spectrum values are followed by Time History matched to Response Spectrum in Time Domain.

B.Storey Drift

It is defined as ratio of displacement of two consecutive stories.

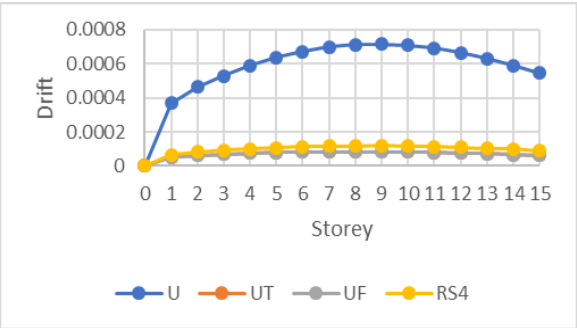

Fig 11: Uttarkashi Storey Drift

- Maximum results were observed in Time History case followed by Response Spectrum.
- Time history matched to Response Spectrum in both Time domain and Frequency domain the results are same.

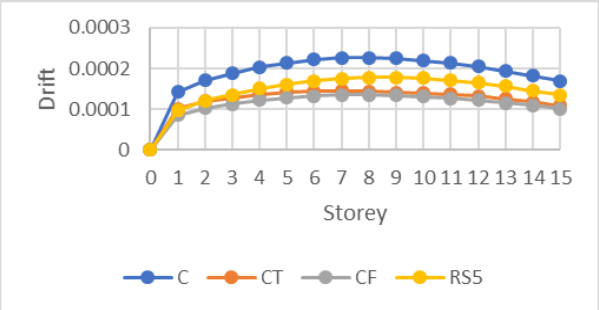

Fig 12: Chamoli Storey Drift

- Maximum results were observed in Time History case followed by Response Spectrum.
- The Response Spectrum values are followed by Time History matched to Response Spectrum in Time Domain.

C.Base Reaction

Maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

Fig 13: Uttarkashi Base Reaction

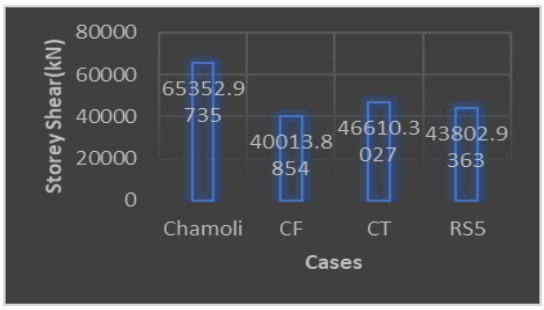

Fig 14: Chamoli Base Reaction

D.Uttarkashi (Zone IV)

- Maximum results were observed in Time History case followed by Response Spectrum.
- Time history matched to Response Spectrum in both Time domain and Frequency domain the results are same.

E.Chamoli (Zone V)

- Maximum results were observed in Time History case followed by Time History matched to Response Spectrum in Frequency Domain.
- Time History matched to Response Spectrum in Time Domain value is followed by Response Spectrum value.

Storey Shear

Storey Shear is defined as the lateral seismic force applied at each storey.

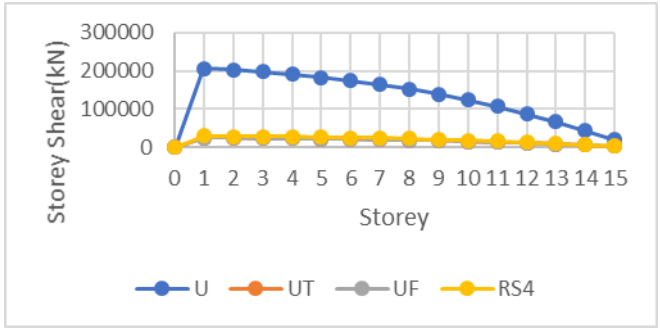

Fig 15: Uttarkashi Storey Shear

- Maximum results were observed in Time History case followed by Response Spectrum.

- Time history matched to Response Spectrum in both Time domain and Frequency domain the results are same.

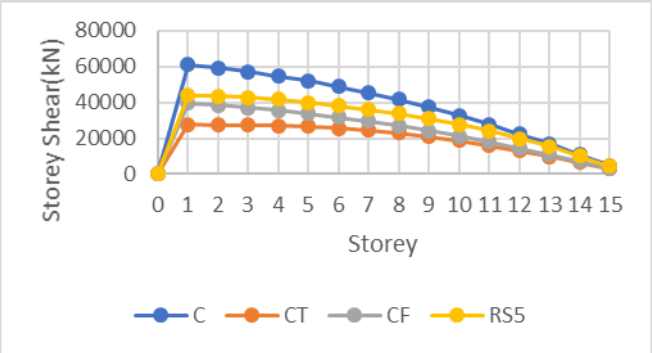

Fig 15: Chamoli Storey Shear

- Maximum results were observed in Time History case followed by Response Spectrum.
  - The Response Spectrum values are followed by Time History matched to Response Spectrum in Frequency Domain.

Figures 9 and 10 show the storey wise displacement of a regular building analysed by various methods by both Uttarkashi and Chamoli Earthquake data similarly figures 11 and 12 show the storey wise variation of drift and figures 15 and 16 show storey wise variation of storey shear where as figures 13 and 14 show the base reactions of the regular building when analysed by various methods.

VIII. CONCLUSION

1) Factors vary with the variation of Earthquake data as the frequency of earthquake differ.

2) Maximum results in all cases were obtained during Time History Analysis in both Zones.

3) Observed Results are:

A.Storey Displacement

a)Uttarkashi (Zone IV)

- With taking Time History matched to Response Spectrum in Frequency domain taken as reference the Time History Storey displacement and drift values are 6.26%-7.36% more than the reference taken values and they are increasing storey wise.
- The Response Spectrum values are 0.27%-0.40% more than the reference storey displacement and drift values and they are increasing storey wise.
- With taking Time History matched to Response Spectrum in Frequency domain taken as reference the Time History Storey shear values are 7.37%-6.75% more than the reference taken values and they are decreasing with increase in height.
- The Response Spectrum values are 0.18%-0.23% more than the reference storey shear values and they are increasing with increase in height.
- With taking Time History matched to Response Spectrum in Frequency domain taken as reference the Time History base reaction value is 7.37% more than the reference taken value.
- The Response Spectrum value is 0.174% more than the reference base reaction value.

b)Chamoli (Zone V)

- With taking Time History matched to Response Spectrum in Frequency domain taken as reference the Time History Storey displacement and drift values are 0.67% more than the reference taken values.
- The Response Spectrum values are 0.18%-0.07% more than the reference storey displacement and drift values and they are decreasing with increase in height of building.
- The Time History matched to Response Spectrum in Time Domain values are 0.14%-0.28% more than the reference storey displacement and drift values and they are increasing with increase in height.
- With taking Time History matched to Response Spectrum in Time domain taken as reference the Time History Storey shear values are 1.18%- 0.67% more than the reference taken values and they are decreasing with increase in height.
- The Response Spectrum values are 0.57%-0.59% more than the reference storey shear values and they are increasing with increase in height.
- The Time History matched to Response Spectrum in Frequency Domain values are 0.42%-0.08% more than the reference storey shear values and they are decreasing with increase in height.
- With taking Time History matched to Response Spectrum in Frequency domain taken as reference the Time History base reaction value is 0.63% more than the reference taken value.
- The Response Spectrum values is 0.09% more than the reference base reaction value.

- The Time History matched to Response Spectrum in Frequency Domain values are 0.16% more than the reference base reaction value.

4) Except in Chamoli (Zone V) base reaction case and Storey Shear case in all other cases a common trend is followed.

5) The results of Storey Displacement and Storey Drift are same.

6) In both the cases the storey shear values of Time History case are decreasing in comparison with the reference values along the increase in height of the structure whereas the Response Spectrum results are increasing.

7) The results obtained in the Response Spectrum and the Matched time history to Response Spectrum in both cases are nearly same.

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