COMPARISON OF SEISMIC DEMAND COMPUTED FROM LINEAR MODAL (THA) USING CMS AND UHS SPECTRAL MATCHING GROUND MOTIONS

Aftab Ahmad[1], Prof T. K. DUTTA[2]

[1]*P.G. Student, Department of Civil Engineering, Jamia Millia Islamia, New Delhi, India*
[2]*Professor, Dept. of Civil Engineering, IIT Delhi, New Delhi, India*

Abstract - *Current seismic design practice often relies on the use of uniform hazard spectrum UHS, which implicitly include motion from multiple earthquake sources and envelopes possible spectra, yet does not represent a single event. Each spectral value on the UHS corresponds to a particular hazard level individually. But the likelihood that an actual earthquake will produce spectral response values that exceeds the design hazard level across all periods simultaneously is almost negligible. Therefore an alternative termed as conditional mean spectrum is presented by baker and Cornell. The CMS provides the mean spectrum conditioned on occurrence of a target spectral acceleration value at the period of interest. In this study comparison of responses computed using multiple sets of CMS ground motions are compared with those computed using a single set of UHS spectral matching ground motions, where the period of interest T* were considered at the periods closest to the periods of the first three translational modes of the building in the direction of excitation. A 15 story tall building is considered for this purpose which is a model structure located in Kathmandu, Nepal. After analysis various important dynamic characteristics of the building namely, story displacement, story drift, overturning moment, and story forces are compared. It was found that for story drift and story displacement the CMS conditioned at fundamental period of the structure is sufficient for evaluation. As it provides larger results than CMS conditioned at higher mode periods throughout the height of the building.*

Key Words: Uniform Hazard Spectrum, Conditional Mean Spectrum, Time History Analysis, Story Displacement, Story Drift, Story Forces and Overturning Moment.

1. INTRODUCTION

The goal of dynamic analysis is to predict the response of a structure subjected to ground motions having a specified spectral acceleration at a given period. For this purpose various methods can be used. In this study linear modal time history is considered for comparing the responses of 15 story model building for CMS and UHS selected and modified ground motions. Ideally it should be done for non-linear response history analysis which plays a major role in performance based earthquake engineering of buildings [1]. By performing RHAs of computer model of the building subjected to an input ground motion, seismic demands can be computed to determine seismic demand hazard curves. The computed seismic demands are used as inputs to fragility functions for predicting both structural and non-structural damage. By predicting the demand as a function of the seismic demand instead of the ground motion intensity (e.g., peak ground acceleration, etc.), the resulting estimate of the damage is more informative because of variability in the estimates is reduced. Similarly, losses due to earthquakes (e.g., repair costs, business downtime, casualties, etc.) may be better predicted with the knowledge about the damage in the buildings. Thus, non-linear RHAs of building models are an important step in estimation of losses due to earthquakes. However, one of the key challenges in this approach is the selection and scaling of ground motions to serve as input excitation for nonlinear RHAs. Researchers have proposed many different ways to select the ground motions. Some have proposed to select on the basis of matching seismological parameters for a given earthquake scenario whereas others have suggested to select on the basis of spectral shape. Current seismic design practice often relies on the use of the uniform hazard response spectrum (UHS), which is widely used as a target spectrum for selecting and scaling of ground motions to be used in RHAs [2]. UHS implicitly include motion from multiple earthquake sources and envelopes possible spectra, yet does not represent a single event. Therefore when performing dynamic structural analysis using UHS as a target spectrum for selecting and scaling ground motions it is unlikely for one ground motion from the earthquake scenario contributing to the UHS at a period of interest to have a large spectral values as the UHS at all other periods. Each spectral value on the UHS corresponds to a particular hazard level individually but the likelihood that an actual earthquake will produce spectral response values that exceeds the design hazard level across all the periods simultaneously is almost negligible. Therefore using UHS as target spectrum would be overly conservative to estimate responses to an earthquake scenario on the other hand an alternative termed as conditional mean spectrum is presented by BAKER and CORNELL [3]. The CMS provides the mean spectrum conditioned on occurrence of a target spectral acceleration value at the period of interest. However the choice of interest when using CMS with tall buildings is not definite as higher modes could be more significant for some response parameters such as base shear force and overturning moment [1,13]. There are several challenges with choosing a target spectrum for an explicit design check of tall building. First, a single UHS leads to overly conservative estimates of demands whereas a single CMS lead to un-conservative estimates of demand [14]. Moreover the choice of conditioning period for a single CMS is sometimes unclear. These challenges can be overcome by employing multiple CMS conditioned at different vibration periods and defining seismic demands as the maximum value among estimates from different CMS [10, 14]. However the computational effort associated with this approach can be substantial. Recently, a generalized CMS has been proposed to provide demands that are as accurate as multiple CMSs and with less computational effort. However, tools for developing this spectrum are not widely available. This study aimed at investigating seismic demand of 15 story tall building computed from linear modal time history analysis using CMS ground motions at multiple conditioning periods and compared to those computed from linear modal time history analysis suing ground motions selected, scaled, and modified to match UHRS at all periods.

2. NUMERICAL MODEL OF STRUCTURE USING SOFTWARE (ETABS)

The purpose of this study is to compare the seismic demand computed from linear modal time history analysis using CMS at multiple conditioning periods and computed from linear modal time history analysis using four ground motions selected, scaled, and modified to match UHS at all periods. G+14 story simple moment resisting frame building is considered

Table -1: details of model structure

No. of stories		15
Top height(m)		3
Typical story height(m)		3
Column size (m x m)		0.5 x 0.5
Beam size (m x m)		0.3 x 0.6
First three translational modes in X- direction	T_1	1.596
	T_2	0.531
	T_3	0.293

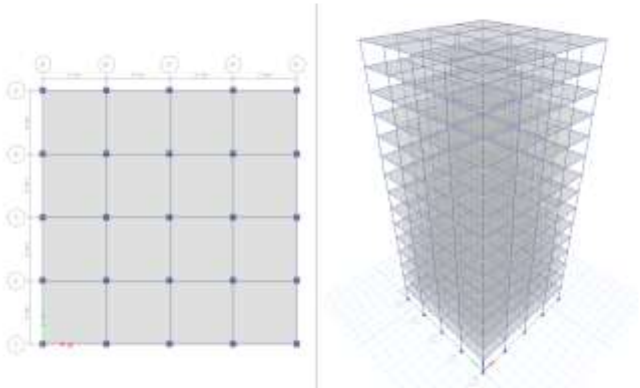


Fig -1: 3D & plan for G+14 story model structure

3. EARTHQUAKE GROUND MOTIONS

The maximum considered earthquake (MCE) ground motions having 2% probability of exceedence in 50 years were employed. The UHRS at bedrock site in Kathmandu was obtained from probabilistic seismic hazard analysis (PSHA) which was carried out by Rahman bai et al [15]. the CMs at the bedrock site for four periods of interest (T*): 0.2, 0.5, 1.0, and 1.5 seconds were determined using the procedure proposed by baker. It should be noted that for the bedrock site, a CMS matches UHRS only at its conditioning period and is lower than the UHRS at other periods. These bedrock ground motions were used as target spectra to select appropriate bedrock ground motions to be used as input for linear modal time history analysis. PEER [26] recommends using a minimum of three CMS conditioned at the first three translational modes of the building. So in our case CMS ground motions conditioned at the period of 1.5, 0.5, and 0.2 sec were used for 15 story building whose periods of first three translational modes in x direction are 1.59, 0.53, and 0.29. to obtain the UHRS spectral matching ground motions, CMS ground motions for the set of conditioning periods were matched spectrally in ETABS to have the shape fitted to the UHRS for four CMS conditioned at 1.5, 1.0, 0.5, and 0.2 are used.

Table 2 List of ground motions for the four periods of interest: 0.2, 0.5, 1.0, and 1.5 sec.

T* (sec)	Pair no.	Earthquake event	year	Station	Magnitude (M_w)	Distance(m)
0.2	1 2 3	San Fernando. Loma prieta. San simeon.	1971. 1989. 2003.	Castaic-old ridge route Apeel skyline San Luis Obispo-Lopez lake grounds	6.61 6.93 6.52	21 42 48
0.5	1 2 3	Kern county. Landers. Loma prieta.	1952. 1992. 1989.	Pasadena CIT Athenaeum Chats worth devan shire featherly Apeel skyline	7.36 7.28 6.93	125 172 42
1.0	1 2 3	Tabs Iran. Kern county. Montenegro Yugoslavia.	1978. 1952. 1979.	Bajestan Pasadena CIT Athenaeum Debar skubstina opstine	7.35 7.36 7.1	120 125 118
1.5	1 2 3	Trinidad. Tabs Iran. Kern county.	1980. 1978. 1952.	Rio dell overpass Bajestan Pasadena CIT Athenaeum	7.2 7.35 7.36	76 120 125

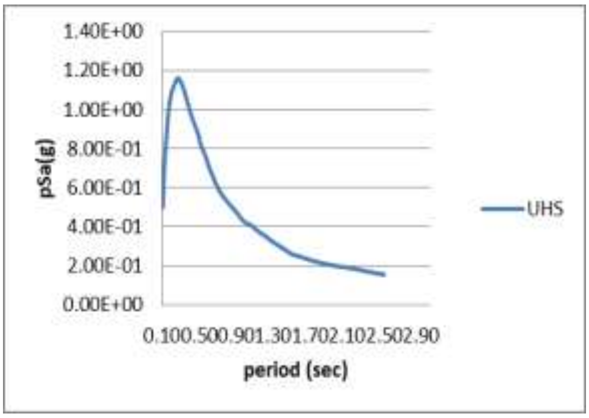


Figure 1 uniform hazard spectrum

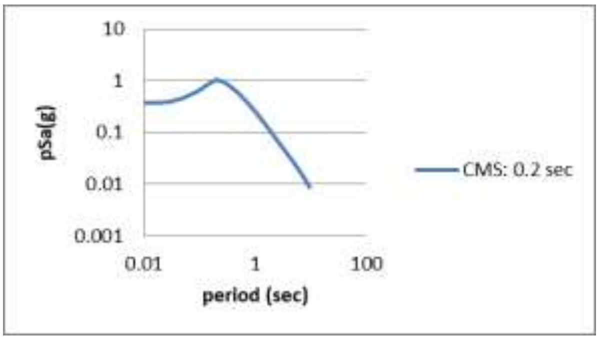


Figure 2 conditional mean spectrum for 0.2 sec spectral period

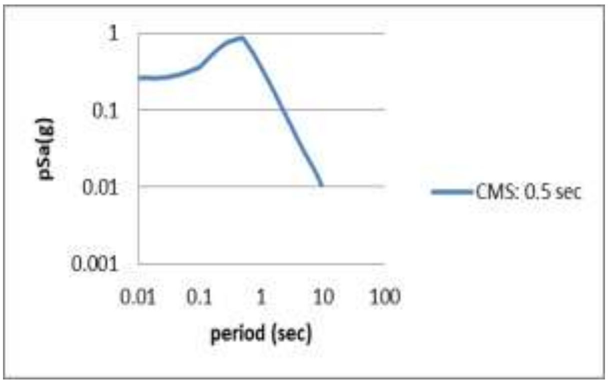


Figure 3 conditional mean spectrum for 0.5 sec spectral period

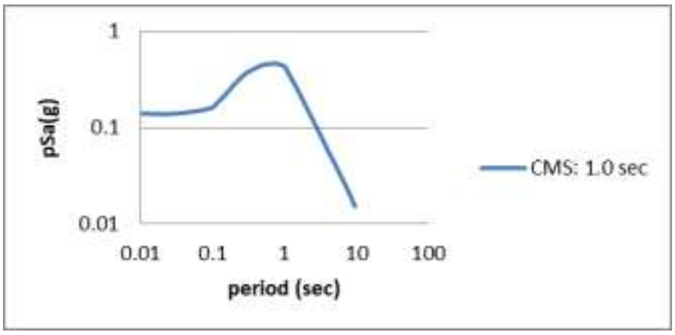


Figure 4 conditional mean spectrum for 1.0 sec spectral period

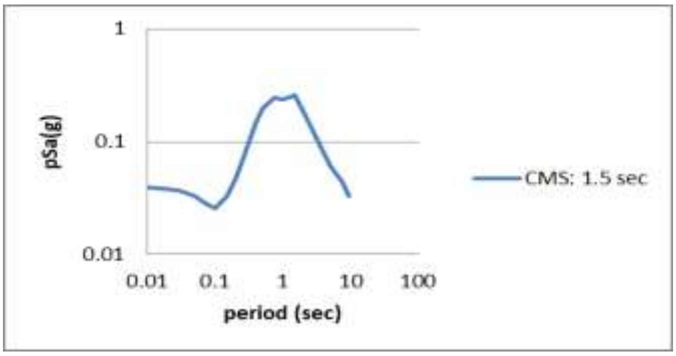


Figure 5 conditional mean spectrum for 1.5 sec spectral period

4. RESULTS

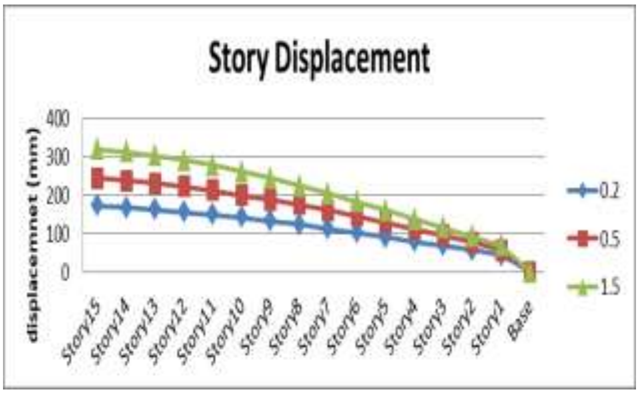
The results presented are the maximum values of the peak responses considered. Shear force, story overturning moment, floor displacement, floor drift. Response to excitation in the X-direction are presented here only because the responses in the Y-direction somewhat is going to be similar.

4.1 comparisons of results from analysis using three sets of CMS ground motions

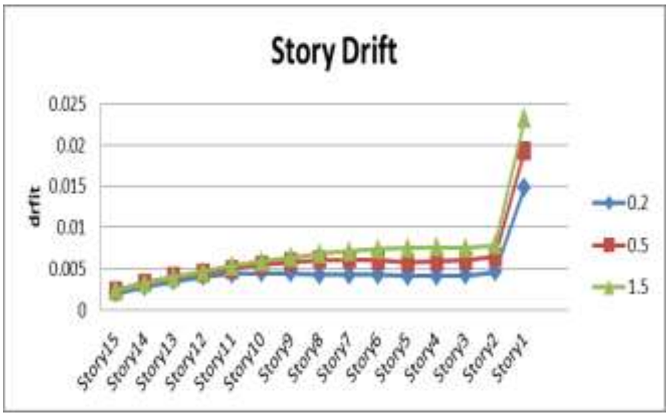
The comparison of seismic demands computed from linear modal time history analysis using three sets of CMS conditioned at three different periods closest to the periods of the first three translational modes of the building in X-direction is shown in fig. 5. It was found that the CMSs conditioned at short periods (higher mode periods) results larger force demands than the CMS conditioned at long period (first-mode period) for some location along the height of the building shown in fig. 5(d), and they cause larger overturning moment at the bottom half of the building shown in fig.5(C), compared to CMS conditioned at long period. This is because the base shear and overturning moment in a tall building are significantly contributed from higher-mode response. Therefore design demand values should conservatively consider the envelope of force demands from linear modal time history analysis using CMS ground motions conditioned at multiple periods. For story drift and floor displacement the CMS conditioned at fundamental mode is sufficient for conducting the evaluation as it provides larger results than the CMS conditioned at higher-modes periods throughout the height of the building because the floor displacement and story drift are dominantly contributed from the first mode response.

4.2 comparisons of results from analysis using CMS and UHS as target spectrum

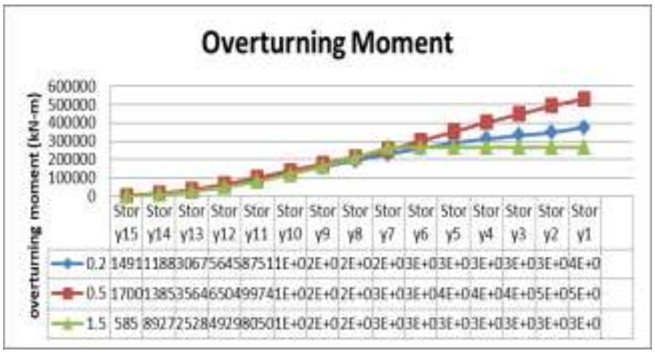
The comparison of seismic demands computed from linear modal time history analysis using CMS and UHS as target spectrum is shown in fig. 6. The envelope of results from analysis using CMS as target spectrum from linear modal time history analysis using three sets of CMS ground motions. When using UHS as target spectrum, maximum values of peak responses computed from linear modal time history analysis using four spectral matching ground motions. It was found that using UHS ground motions results of analysis was slightly larger values compared to the envelope of results from linear modal time history analysis using CMS conditioned at multiple periods.



5(a)



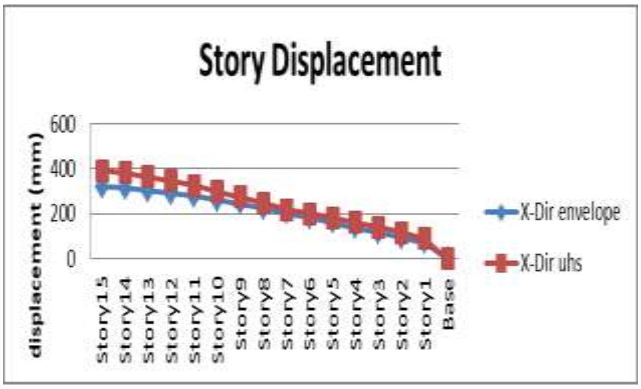
5(b)



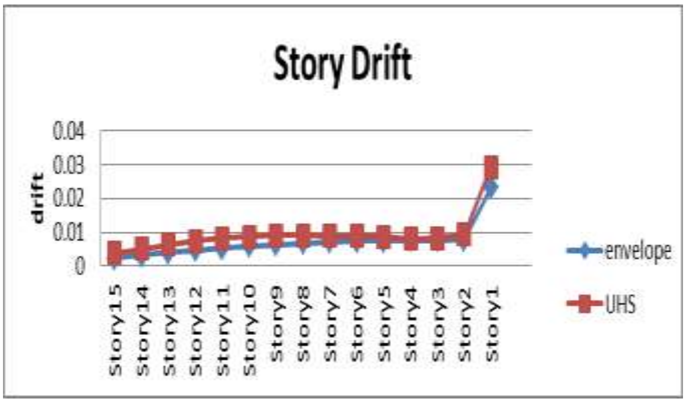
5 (c)

5(d)

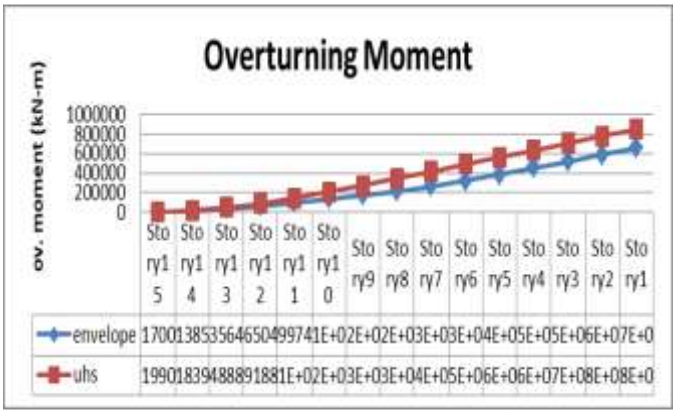
Figure 5 (a) Story displacement; (b) story drift; (c) Overturning Moment; and (d) story shear forces computed from linear modal time history analysis for X-direction seismic excitation using three sets of CMS ground motions. CMS (T1), CMS (T2), and CMS (T3) refer to the computed results using CMS conditioned at periods closest to the periods of the 1st, 2nd, and 3rd translational modes of the building in the direction of seismic excitation, respectively.



6(a)



6(b)



6(c)

6(d)

Figure 6. (a) Story displacement; (b) story drift; (c) overturning moment; and (d) Story shear force computed from linear modal time history analysis for X-direction seismic excitation using CMS and UHS as the target spectrum.

3. CONCLUSIONS

From the results following conclusion were arrived

- A 15 story model building on bedrock site in Kathmandu were used in this study to compare the results of seismic demands computed from linear modal time history analysis using CMS and UHS as target spectrum for selecting and scaling of ground motions.
- When using CMS as target spectrum, higher mode periods found to be significant for response parameters dominated by higher modes such as base shear forces and overturning moments.
- When using CMS ground motions conditioned at multiple periods envelope of the demand values should be undertaken before used as design demand values.
- For response quantities dominated by the fundamental mode such as floor displacements and story drift CMS ground motions at fundamental period sufficient to be used in the analysis

REFERENCES

[1] E. I. Katsanos, A. G. Sextos, and G. D. Manolis, "Selection of earthquake ground motion records: A state-of-the-art review from a structural engineering perspective," Soil Dynamics and Earthquake Engineering, vol. 30, no. 4, pp. 157-169, 2010.

[2] C. B. Haselton, J. W. Baker, J. P. Stewart, A. S. Whittaker, N. Luco, A. Fry, R. O. Hamburger, R. B. Zimmerman, J. D. Hooper, F. A. Charney, and R. G. Pekelnicky, "Response history analysis for the design of new buildings in the NEHRP provisions and ASCE/SEI 7 standard: Part I - Overview and specification of ground motions," Earthquake Spectra, vol. 33, no. 2, pp. 373-395, 2017.

[3] J. W. Baker, "Conditional mean spectrum: Tool for ground-motion selection," Journal of Structural Engineering, vol. 137, no. 3, pp. 322-331, 2011.

[4] R. Klemencic, J. A. Fry, J. D. Hooper, and B. G. Morgen, "Performance-based design of ductile concrete core wall buildings—Issues to consider before detailed analysis," The Structural Design of Tall and Special Buildings, vol. 16, no. 5, pp. 599-614, 2007.

[5] J. W. Wallace, "Modelling issues for tall reinforced concrete core wall buildings," The Structural Design of Tall and Special Buildings, vol. 16, no. 5, pp. 615-632, 2007.

[6] National Institute of Standards and Technology, "Recommended modeling parameters and acceptance criteria for nonlinear analysis in support of seismic evaluation, retrofit, and design," The Applied Technology Council, Gaithersburg, Maryland, NIST GCR 17-917-45, 2017.

[7] National Institute of Standards and Technology, "Recommended modeling parameters and acceptance criteria for nonlinear analysis in support of seismic evaluation, retrofit, and design," The Applied Technology Council, Gaithersburg, Maryland, NIST GCR 17-917-45, 2017.

[8] M. E. Koopaee, R. P. Dhakal, and G. MacRae, "Effect of ground motion selection methods on seismic collapse fragility of RC frame buildings," Earthquake Engineering and Structural Dynamics, vol. 46, no. 11, pp. 1875-1892, 2017.

[9] M. E. Koopaee, R. P. Dhakal, and G. MacRae, "Effect of ground motion selection methods on seismic collapse fragility of RC frame buildings," Earthquake Engineering and Structural Dynamics, vol. 46, no. 11, pp. 1875-1892, 2017.

[10] N. Lazar Sinković, M. Dolšek, and J. Žižmond, "Impact of the type of the target response spectrum for ground motion selection and of the number of ground motions on the pushover-based seismic performance assessment of buildings," Engineering Structures, vol. 175, pp. 731-742, 2018.

[11] K. Khy and C. Chintanapakdee, "Evaluation of seismic shear demands of RC core walls in Thailand determined by RSA Procedure," Engineering Journal, vol. 21, no. 2, pp. 151-172, 2017.

[12] National Institute of Standards and Technology, "Selecting and scaling earthquake ground motions for

performing response-history analyses," The NEHRP Consultants Joint Venture, Gaithersburg, Maryland, NIST GCR 11-917-15, 2011.

[13] B. Carlton and N. Abrahamson, "Issues and approaches for implementing conditional mean spectra in practice," Bulletin of the Seismological Society of America, vol. 104, no. 1, pp. 503-512, 2014.

[14] Pacific Earthquake Engineering Research, "Tall Buildings Initiative—Guidelines for performancebased seismic design of tall buildings," Berkeley, California, PEER-2010/05, 2010

[15] Rahman M. M., and Bai L. (2018). Probabilistic seismic hazard assessment of Nepal using multiple seismic source models. Earth Planet. Phys., 2(4), 327–341.