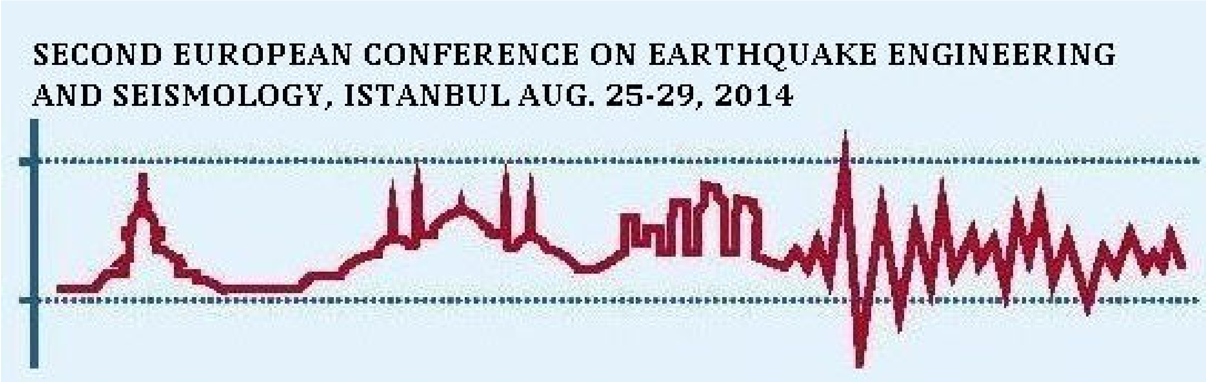

SEISMIC PERFORMANCE OF R/C SPECIAL MOMENT FRAMES IN LOW AND MODERATE TO HIGH SEISMICITY REGIONS

Rehber AKDOĞAN [1] and Nuri ÖZHENDEKCİ [2]

ABSTRACT

Two of the definitions utilized in order to define hazard region during the preparation of NEHRP Provisions Seismic Hazard Maps are "Low and Moderate to High Seismicity" and "High Seismicity Near Known Faults" regions. For the "High Seismicity Near Known Faults" regions, near fault earthquakes are determinative and the hazard is generally determined with deterministic approach. On the other hand, the earthquake hazard is generally determined via probabilistic procedures in "Low and Moderate to High Seismicity" regions. However there are transition regions between these two zones. Namely, near fault earthquakes can be effective in hazard determination in "Low and Moderate to High Seismicity" regions. Thus, during the selection of earthquake records, those matching design spectrum; near fault earthquake records can also be used. However, since the number of recorded earthquakes is not adequate, the selection can be carried out not specific to a location, the records satisfying the particular criteria can be selected from all around the world. Moreover, scaling near fault records can ruin the inherent impact effects and the analyses with scaled near-fault records shall cause an additional dispersion. In order to investigate such a transition region, two earthquake record sets, one from Turkey and one from different locations of the world are used. These record sets are scaled to fit 1.5 times the design spectrum provided in Turkish Seismic Design Provision. A 10-story special R/C moment model frame is designed along with the strength and capacity based design principles provided by TS500 and Turkish Seismic Design Provision. The model frame is analyzed under the effects of above mentioned two record sets with PERFORM-3D software and seismic performance assessment is carried out with nonlinear dynamic procedure per ASCE 41-06 for collapse prevention structural performance level. The analyses results are compared for two record sets via the median and mean values, separately.

INTRODUCTION

According to NEHRP Commentary for Seismic Regulations for New Buildings and Other Structures (BSSC, 2003) there are zones between the regions of "Low and Moderate to High Seismicity" and "High Seismicity Near Known Faults". For these zones records can be selected from near fault earthquakes matching to a target design spectrum for seismic performance assessment of a structure. However the effects of the selection of the earthquakes from local events or from all around the world have not been investigated yet as known to the authors. In order to investigate the effects of record selection on the seismic performance of a 10-storey R/C special moment frame, two sets of near fault earthquakes matching the design spectrum are selected. One set is from local events and the second set is from all around the world. The response spectra of these sets along with the design spectrum are provided.

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The ten story reinforced concrete special moment frame is designed along with the strength and capacity based design principles provided by TS500 (TSI, 2000) and Turkish Seismic Design Provision (MPWS, 2007). For the analyses PERFORM-3D (CSI, 2013) software is used. Nonlinear Dynamic Procedure of ASCE/SEI 41-06 (ASCE, 2007) is used for performance assessments. For the collapse prevention performance level earthquake hazard is represented by 1.5 times the design spectra as advertised in MPWS (2007).

It is widely known that the use of median values is more appropriate for seismic performance assessment of building structures. Moreover median values are not affected by the results of near collapse buildings, generally. However design codes propose the use of mean values. Reyes and Akkar (2012) has reported that the mean values are higher than the median values of inelastic response of single degree of freedom systems. Hence in addition to investigating the effects of earthquake selection, the effects of using mean or median values on the seismic performance of the model MDOF system are also investigated.

DESIGN OF THE MODEL FRAME

A ten story reinforced concrete special moment frame (Fig.1) is designed along with the strength and capacity based design principles provided by TS500 (TSI, 2000) and Turkish Seismic Design Provision (MPWS, 2007). Its plan and elevation views are given in Figure 1. Materials used for concrete and reinforcement steel are C25 having 25Mpa characteristic strength and S420 having 365MPa yield stress, respectively. The design spectrum is also given in the figure. Site class of the spectrum is equivalent to class "C" of United States Geological Survey (USGS).

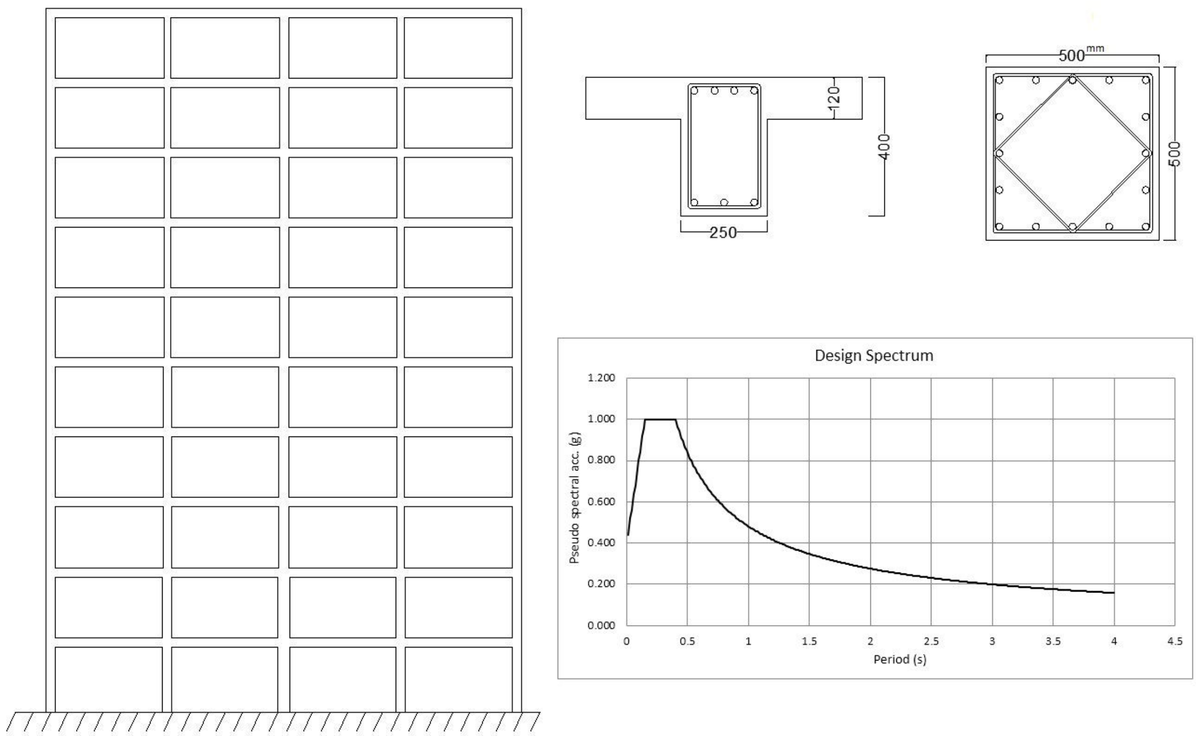

Figure 1. Designed special R/C moment resisting model frame and design spectrum

GROUND MOTIONS

It is argued above that near fault earthquakes can be effective in hazard determination in "Low and Moderate to High Seismicity" regions too. Hence near fault earthquakes can be used for design spectrum matching. First set (set-NF) is selected among near fault records within Turkey. For all the earthquakes in this set scale factor of 1.5 is used. Response spectra of the earthquakes and 1.5 times design spectrum used are given in Figure 2. The factor of 1.5 is used for design spectrum in order to represent %2 probability of exceedance in 50 years, approximately.

For the second set (set-NFW) near fault records from all around the world are used. Both the target design spectrum and the pseudo acceleration response spectra of the earthquakes are given in Figure 3.

Turkish Seismic Design Provision (MPWS, 2007) allows mean values as low as 90% of the design spectrum. However it should be noted that descending portion of the design spectrum is proportional to $1/T^{0.8}$. This is similar to the design spectrum of UBC (1994) which is increased in order to take into account higher mode effects by using a descending branch proportioning to $1/T^{0.75}$. Where T is natural period. The list of the earthquakes used are given in Table 1 (PGMD, 2010). Since there are not enough number of earthquakes some of the earthquakes with a different site class are also selected in some cases. The response spectra of the earthquake sets of NF and NFW are given in Figure 2.

Table 1. Earthquake record sets, NF and NFW

Set	Event	NGA No	Station	Comp	Magnitude, M_w	Distance
NF	Dinar, Turkey, 1995	1141	Dinar	FN	6.40	0.0
	Dinar, Turkey, 1995	1141	Dinar	FP	6.40	0.0
	Erzincan, Turkey, 1992	821	Erzincan	FN	6.69	0.0
	Kocaeli, Turkey, 1999	1176	Yarımca	FN	7.51	1.4
	Düzce, Turkey,1999	1605	Düzce	FP	7.14	0.0
	Düzce, Turkey,1999	1602	Bolu	FN	7.14	12.0
	Düzce, Turkey,1999	1602	Bolu	FP	7.14	12.0
NFW	Northridge-01, 1994	1085	Sylmar	FN	6.69	0.0
	Chi-Chi, Taiwan, 1999	1182	CHY006	FN	7.62	9.8
	Loma Prieta, 1989	779	LGPC	FP	6.93	0.0
	Gazli, USSR, 1976	126	Karakyr	FP	6.80	3.9
	Düzce, Turkey, 1999	1602	Bolu	FP	7.14	12.0
	Superstition Hills-02, 1987	723	Parachute Test Site	FP	6.54	0.9
	Kobe, Japan, 1995	1106	KJMA	FP	6.90	0.9

SEISMIC PERFORMANCE ASSESSMENT

Analyses are performed by PERFORM-3D (CSI, 2013). Lumped plasticity approach is used and the hinges at the element ends are modeled according to ASCE41-06 (ASCE, 2006). Performance assessments for collapse prevention level are made by nonlinear dynamic procedure (NDP) of ASCE41-06 (ASCE, 2006).

Obtained results for each of the sets NF and NFW are given in Table 2. Design codes usually require the use of mean values however median values are also given for the assessments. Although the earthquake hazard level is accordant to the collapse performance (CP) assessment, results are also reported if they are below the other performance level limits such as life safety (LS) or immediate occupancy (IO) in order to better represent the level of the demands.

Table 2. Results of the performance assessments

Technique	Earthquake Set	Element	Satisfied Performance Level Limit (number of elements)				Max. Story Drift Ratio
			IO	LS	CP	Collapse	
Median	NF	Beam	20	20	-	-	1.85
		Column	50	-	-	-	
	NFW	Beam	16	20	4	-	2.07
		Column	45	5	-	-	
Mean	NF	Beam	20	16	4	-	1.94
		Column	45	5	-	-	
	NFW	Beam	16	16	8	-	2.12
		Column	45	5	-	-	

Regarding the median values, all the elements are within the collapse performance level limits for both of the sets. Selecting the records within the earthquakes from the nearby (NF) or from all around the world (NFW) does not have a dramatic effect on the performance assessment. For the use of set-NFW number of the columns exceeding the limits of IO performance level is only 5. Median value of the maximum story drift ratio is increased from 1.85 to 2.07 with the use of set-NFW.

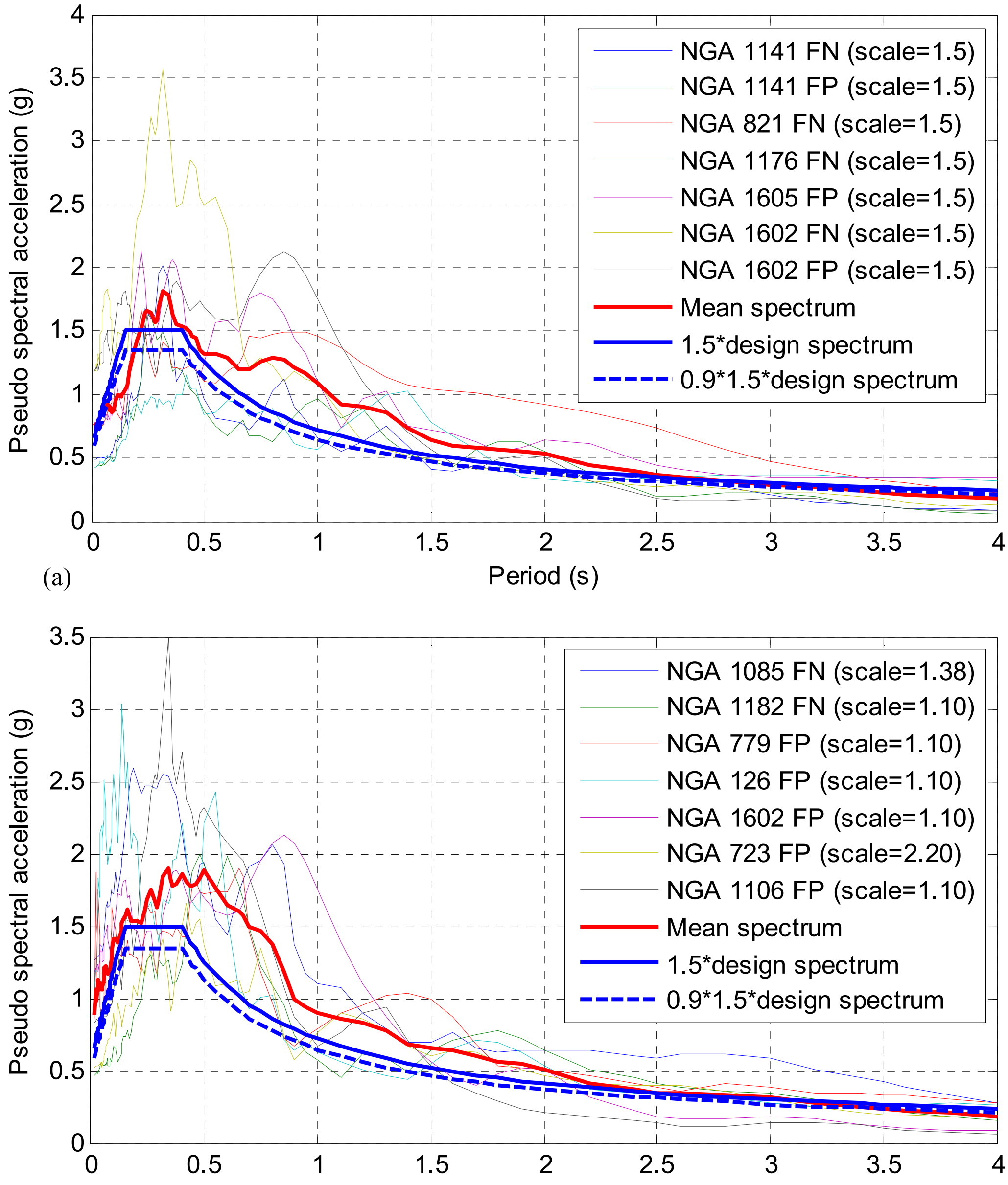

Figure 2. The design spectrum and pseudo acceleration response spectra of the earthquakes of (a) set-NF (b) set-NFW

Considering the mean values, story drift ratio increased from 1.94 to 2.12 with the use of set-NFW. And 4 number of the beams exceeded the limit of LS performance level. It can be said that selecting the records within the earthquakes from the nearby or from all around the world creates similar effects for both median or the mean values.

The use of mean values instead of median values increased the drift ratio demands as 5% and 2.5% for the sets NF and NFW, respectively.

Although the obtained results are similar it is also dependent on the sophistication of the analysis method used. In this study the analysis is stopped if the element hinge limit or the story drift ratio limit is exceeded. If progressive collapse analysis was done instead of the method used here higher inelastic demands would have been obtained. Although a progressive analysis is not performed, in order to give an idea the same analyses are performed without any limit value. Obtained drift demands are 0.0312 and 0.0341 for the sets NF and NFW, respectively. The use of these results are not proper since they may belong to an already collapsed building. However the results obtained from the analysis stopped at 3% drift limit or at hinge rotation limits may also belong to a building which will collapse. Both of the cases do not seem rational to use for mean value calculations. However, since the use of mean values did not change the results of seismic performance assessment dramatically, the use of the results from the analyses with story drift limit and hinge rotation limits are appropriate to use for mean value calculations.

Story drift demands for each earthquake can be seen in Figure 3. The use of mean values provided higher results than median values, generally. However for upper stories slightly lower values are also obtained.

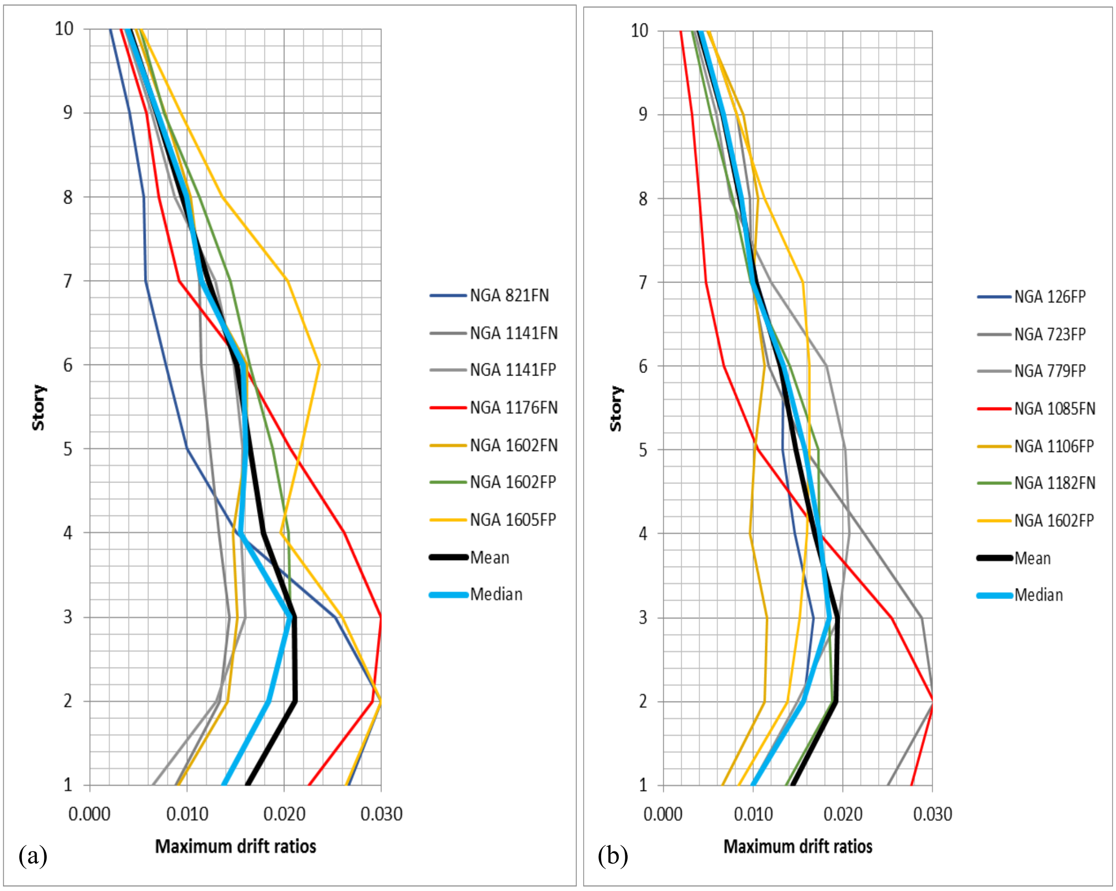

Figure 3. Story drift demands for the sets (a) NF (b) NFW

CONCLUSIONS

The model frame satisfied the conditions of collapse prevention performance level.

For the transition zones between the regions of "Low and Moderate to High Seismicity" and "High Seismicity Near Known Faults", selection of the earthquakes through the regional near fault events or from all around the world did not make an important effect on the performance assessment. Hence the earthquake set can be selected from regional events or from all around the world. It should be noted that this results is valid for Turkey region, for other regions calculations should be repeated.

The use of the results from the analyses with story drift limit and hinge rotation limits for mean value calculations did not change the satisfied CP performance level.

Although the mean values are affected by the results of near collapse buildings, The use of mean values provided higher results than median values for lower stories and slightly lower values for some of the upper stories. This result should be further investigated for other hazard levels also.

REFERENCES

American Society Of Civil Engineers (ASCE) (2007) Seismic Rehabilitation of Existing Buildings, ASCE/SEI 41-06, ASCE, Virginia

Building Seismic Safety Council (BSSC) (2003) NEHRP Recommended Provisions and Commentary for Seismic Regulations for New Buildings and Other Structures, Part-2, prepared for Federal Emergency Management Agency, FEMA 450, BSSC National Institute Of Building Sciences, Washington, D.C.

Computers and Structures, Inc. (CSI) (2013) PERFORM-3D, ver 5, Computers and Structures Inc.

International Conferences of Building Officials (ICBO) (1994) Uniform Building Code - Structural Engineering Design Provisions, Whittier, California

Ministry of Public Works and Settlement (MPWS) (2007) Specifications for Structures to Be Built in Disaster Areas, Ankara, Turkey (in Turkish)

PEER Ground Motion Database (PGMD) (2010) Pacific Earthquake Engineering Research Center Ground Motion Database, Beta ver., available at http://peer.berkeley.edu/peer_ground_motion_database

Reyes JC and Kalkan E (2012) "How Many Records Should Be Used in an ASCE/SEI-7 Ground Motion Scaling Procedure?", *Earthquake Spectra*, 28(3):1223-1242

Turkish Standards Institute (TSI) (2000) TS500 Requirements for Design and Construction of Reinforced Concrete Buildings, Ankara, Turkey (in Turkish).