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Performance Based Seismic Analysis on the Behavior of Reinforced Concrete Frames with Different Ductility

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ABSTRACT

The recent earthquakes exhibit that the uses of seismic design codes of practice yet do not provide sufficient comprehensive safety for buildings. This means that during earthquakes all structures would behave various performances, while the design objectives in current building codes address life safety, control damage in minor and moderate earthquakes, and prevent collapse in a major earthquake. In this respect, evaluation of performance of existing buildings designed in accordance with the current seismic code of practices could improve these codes and provide ample precision related to the expected structural behavior. This paper investigates the various performances of 72 reinforced concrete moment resisting frames (RCMRF) with low and moderate ductility. These structures are designed in accordance with Iranian seismic standard 2800 and Iranian concrete code of practice. The seismic performances of all structures investigated, discussed and compared under the nonlinear static (pushover) and nonlinear dynamic analysis. The moderate ductile structures (except two stories) due to earthquake hazard level 1 exhibit life safety level of performance, which transfers to immediate occupation level by increasing the height of the structure. Among the low ductile structures, all regular six, eight and ten stories have life safety performance while the two and four stories show low level of performance expected by standard 2800. The general comparisons among all moderate and low ductile structures show the better performance for that of moderate structures.

Keywords

Nonlinear Analysis, Performance Level, Moderate Ductility, Low Ductility, Seismic Behavior.

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1 –INTRODUCTION

One of the earthquake resisting structural system in earthquake prone areas classified in most of seismic codes are Reinforced Concrete Moment Resisting Frames (RCMRF). Nonlinear responses of RCMRF particularly tend to develop inelastic deformations when subjected to strong ground motions. Accordingly, a complete assessment of the seismic resistant design of these structures often requires a nonlinear analysis. According to the Iranian standard 2800 (IS2800) for seismic design of buildings [1] and the associated concrete code of practice (ABA) [2] to provide design forces and detailing requirements for various types of RCMRF, the designer is allowed to utilize the ductile capacity of the structure and design for reduced lateral forces. In this way, the elastic design strengths can be substantially reduced on the provision of adequate ductility capacity of the structure, to sustain an appreciable amount of plastic deformation under a maximum credible earthquake condition. IS2800 specifies three levels ductility ratios for the design of RCMRFs. Its design approach is essentially the traditional strength based (SB) with overall objectives to give an acceptable performance of the structure by limiting structural damage and preventing overall collapse under the designated ultimate limit state earthquake, conventionally based on the 1 in 475 year event. In the strength based method, the structural displacements and element ductility demands are end products of the procedure which are not directly controllable by the designer. The recent earthquakes exhibit that the uses of seismic design codes of practice yet do not provide sufficient comprehensive safety for buildings. This means that during earthquakes all structures would behave various performances, while the design objectives in current building codes address life safety, control damage in minor and moderate earthquakes, and prevent collapse in a major earthquake. In this respect, evaluation of performance of existing buildings designed in accordance with the current seismic code of practices could improve these codes and provide ample precisions related to the expected structural behavior. Performance-based design seems to be more general design philosophy in which the design criteria are expressed in terms of achieving stated performance objectives when the structure is subjected to prescribed levels of seismic hazard. In the displacement-based method, by contrast, the displacements and ductility demands become fundamental design parameters and the procedure aims to ensure that the design targets or capacities set for these parameters will not be exceeded under the design-level earthquake ground motion. Since 1996 performance based design has been well developed and increasingly utilized for the evaluation and strengthening of existing buildings to resist lateral loads induced by earthquake. The performance targets may be a level of limited stress, a load, a displacement, a limit state or a target damage state [3-14]. Provided the requirements of IS2800 are met, it is assumed that the seismic performance will be adequate and accorded to the life safety level of performance. In the Applied Technology Council ATC 40 document [7], performance-based design refers to the methodology in which structural criteria are expressed in terms of achieving a performance objective for reinforced concrete buildings and emphasizes the use of the capacity spectrum method which involves determining the capacity and demand spectra. An attempt was made to develop relationships between ductility and damping using perfect, hardening and softening models [17]. The Federal Emergency Management Agency FEMA 273 document [8] presents a variety of performance objectives with associated probabilistic ground motions.

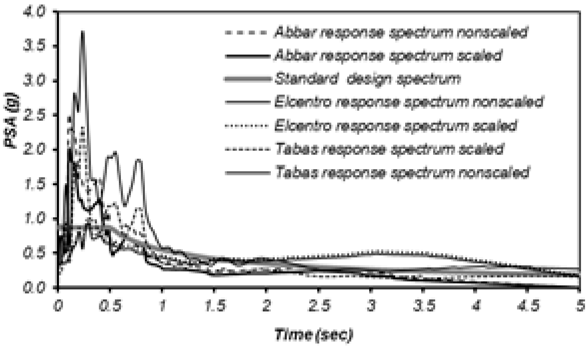

FIG.1: PERFORMANCE POINT OF FRAME

2- BRIEFING ANALYSIS AND RESULTS

This paper investigates the performances of 72 RCMRFs with low and moderate ductility. These structures are designed in accordance with IS2800 and ABA in tow regular and irregular groups for the medium, high and very high seismicity areas. All frames nominated with six digits as FIJASN. Character “F” is the first character of frame and “I” stands for regular and irregular frames indicating by “1” and “0” respectively. “J” represents “M” for moderate ductility and “L” for low ductile frames. The fourth character “A” represent three relative hazard levels as a=0.35g, b=0.3g and c=.25g. The remaining digits “S” and “N” represent the number of spans and number of stories respectively. This study is then presented for frames to assess the performance levels and the yielding mechanisms, using the well-known El Centro (NS), Tabas and Abbar earthquake ground motions as the seismic input for nonlinear dynamic analysis. The spectral characteristics of this earthquake are known to match closely the design spectral shapes adopted in the IS2800 earthquake codes for earthquakes (Figure 1). The seismic performances of all structures investigated, discussed and compared under the nonlinear static (pushover) and nonlinear dynamic analysis. Figures 2 and 3 illustrate the performance point and maximum drift ratio for one of the frames. The moderate ductile structures (except two stories) due to earthquake hazard level 1 exhibit life safety (LS) level of performance, which transfers to immediate occupation (IO) level by increasing the height of the structure. Among the low ductile structures, all regular six, eight and ten stories have LS performance while the two and four stories show low level of performance expected by IS2800. The general comparisons among all moderate and low ductile structures show the better performance for that of moderate ductile structures. Overall ductility demands have also been computed for the analyses conducted on the frames. Table 1 provides the results of some of the frames under nonlinear dynamic analysis with their performances.

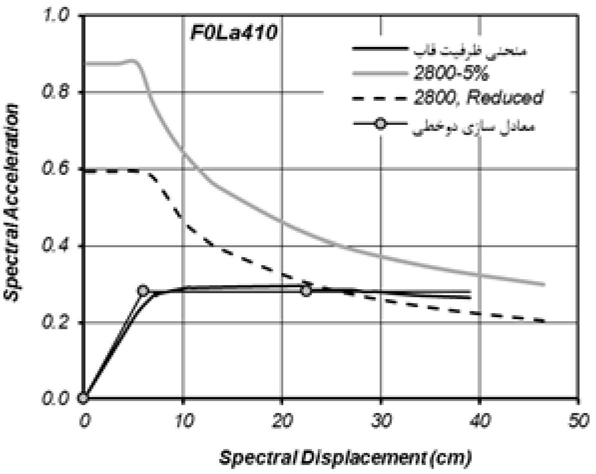

FIG.2: PERFORMANCE POINT OF FRAME, "F0LA410"

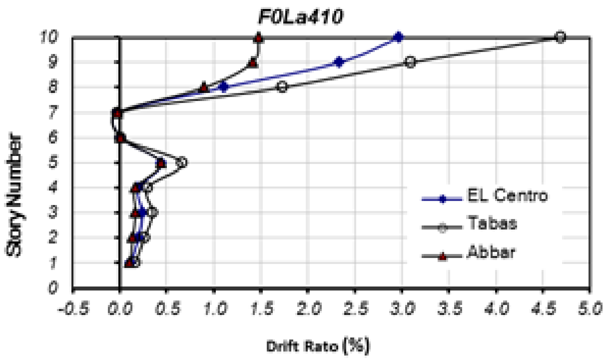

FIG.3: MAXIMUM LATERAL DRIFT RATIO, FRAME FOLA410

TABLE 1: RESULTS OF NONLINEAR DYNAMIC ANALYSIS OF SOME SELECTED FRAMES WITH THEIR PERFORMANCE LEVEL

Frmae	Maximum Lateral Displacement (cm)			Maximum Drift ratio (%)	Performance Level
	EL Centro	Tabas	ABbar		
F1Ma32	7.45	4.59	1.55	1.16	LS
F1Mb34	7.39	8.25	2.19	0.64	IO
F1Mc36	6.08	7.91	2.32	0.41	IO
F1Ma46	19.17	8.25	4.40	1.00	IO
F1Mb38	6.74	9.64	2.33	0.38	IO
F1Mc48	8.03	6.59	2.00	0.31	IO
F1Ma310	12.18	10.89	6.46	0.38	IO
F1Ma410	33.70	18.65	8.55	1.05	LS(*)
F1Mb410	13.02	9.25	4.99	0.41	IO
F1Mc410	10.41	7.68	4.03	0.33	IO
F1La410	26.34	29.21	6.01	0.91	IO
F0Mb36	20.28	10.56	8.65	1.06	LS
F0Mc38	11.89	6.98	3.28	0.46	IO
F0Ma310	13.06	14.39	6.62	0.45	IO
F0Mb410	11.52	15.39	5.39	0.48	IO
F1Lc48	6.44	6.95	7.20	0.28	IO

3- MAIN REFERENCES

[1] Iranian Code of Practice for Seismic resistant Design of Buildings (standard 2800), Building and Housing research center (BHRC), PN. S 465, 2007.

[2] Iranian Concrete Code of Practice (ABA), Planning and Management Organization, PN. 120, 2001.

[3] Moehle JP. Displacement-based seismic design criteria. In: Proceedings of 11th World Conference on Earthquake Engineering, Acapulco, Mexico. Paper no. 2125. Oxford: Pergamon, 1996.

[4] Krawinkler, H., "Chalenges and Progress in Performance–Based Earthquake Engineering", International Seminar on Seismic Engineering for Tomorrow, Tokyo, Japan, November, 1999.

[5] Holmes Consulting Group Ltd., "Performance Based Evaluation of Buildings, Nonlinear Push Over and Time History Analysis", Reference Manual, Wellington, New Zealand, 2001.

[6] SEAOC. Vision 2000, Performance based seismic engineering of buildings, vols. I and II: Conceptual framework. Sacramento (CA): Structural Engineers Association of California, 1995.

[7] ATC 40, Seismic evaluation and retrofit of existing concrete buildings. Redwood City (CA): Applied Technology Council, 1996.

[8] FEMA 273, NEHRP guidelines for the seismic rehabilitation of buildings; FEMA 274, Commentary. Washington (DC): Federal Emergency Management Agency, 1996.

[9] Krawinkler H. New trends in seismic design methodology. In: Proceedings of 10th European Conference on Earthquake Engineering, Vienna, Austria, vol. 2. Rotterdam: AA Balkema, pp. 821–830, 1995.

[10] Ghobarah Ahmed, “Performance-based design in earthquake engineering: state of Development”, Engineering Structures, vol 23, pp. 878– 884, 2001.

[11] Krawinkler, H. & Seneviratna, G.D.P.K. (1998), “Pros and Cons of Push Over analysis of seismic performance evaluation”, Engineering Structures, Vol 20, Nos.4-6, PP. 452- 464, 1997.

[12] Bertero V. State of the art report on: design criteria. In: Proceedings of 11th World Conference on Earthquake Engineering, Acapulco, Mexico. Paper no, 2005, 1996.

[13] Rojahn C, Whittaker A. Proposed framework for performance based design of new buildings. In: Proceedings of 6th US National Conference on Earthquake Engineering, Oakland (CA): Earthquake Engineering Research Institute, [CD-Rom], 1998.

[14] Fajfar P. Trends in seismic design and performance evaluation approaches. In: Proceedings of 11th European Conference on Earthquake Engineering. Rotterdam: AA Balkema, pp. 237– 49, 1998.

[15] Tassios TP. Seismic design: state of practice. In: Proceedings of 11th European Conference on Earthquake Engineering. Rotterdam: AA Balkema, pp. 255– 67, 1998.

[16] Priestley MJN. Displacement-based approaches to rational limit states design of new structures. In: Proceedings of 11th European Conference on Earthquake Engineering. Rotterdam: AA Balkema, pp. 317–35, 1998.

[17] Borzi B, Elnashai AS. Assessment of inelastic response of buildings using force and displacement based approaches, Struct Design Tall Bldgs, vol. 9 (2), pp. 251– 77, 2000.