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Evaluation of the YPS method for Regular RC Buildings Designed Based on the Iranian Standard 2800

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ABSTRACT: The performance-based design method has received the attention of researchers and engineers in recent two decades. In this regard, different methods have been proposed by the codes to design and assess the performance of structures. The main purpose of this study is the evaluation of the Iranian seismic code's efficiency. For this research, three 1, 5, and 10-storey buildings having moderate concrete moment frames are designed based on the criteria of the Iranian code. Then, the seismic performance of these structures is evaluated according to the yield point spectrum (YPS), ATC-40, and Iranian seismic rehabilitation instructions method through nonlinear static analysis. There are two different approaches in the YPS method which include evaluating the performance point location relative to the performance boundary and comparing the response modification factor demand with the one used for design. However, ATC-40 and Iranian seismic rehabilitation instructions methods evaluate the structure's response at the performance point and target displacement, respectively. Results showed that the studied structures satisfy life safety performance levels according to the YPS and Iranian seismic rehabilitation instruction methods, while the 10-storey building satisfies the immediate occupancy performance level based on the ATC-40 criteria. Moreover, in the case of the examined structures, the Iranian seismic rehabilitation instructions are more strict than the other methods and the buildings designed based on the Iranian codes are evaluated as seismically safer based on ATC-40 and YPS in comparison with the Iranian seismic rehabilitation instructions.

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1. INTRODUCTION

The performance-based design methodology has been suggested in recent years for seismic evaluation and rehabilitation of existing buildings. Some of the main reference documents to be noted in this context are Instructions for seismic rehabilitation of existing buildings, ASCE 41-17, and ATC-40 [1, 2]. A different method for seismic evaluation of existing buildings is a spectral method of calculating seismic demands for seismic design of structures or retrofit of existing structures that are called the yield point spectrum (YPS). Since exact determining the collapse point is very difficult, the YPS method unlike the existing procedures resorts to the yield displacement. This is the main advantage of YPS. In this method, the nonlinear response of an equivalent SDOF (single degree of freedom) system is calculated. The YPS method was presented in 2000 by Aschheim with developing a new form of inelastic response spectra for seismic design or evaluation of buildings using the yield point [3]. Then Aschheim and Black extended the YPS approach to estimating the target displacement for use in nonlinear static methods of FEMA-273 [4] and ATC-40 [5]. Aschheim and Montez studied P-Δ effects on the estimation of the yield displacement of tall buildings using the YPS spectrum and showed that this method may increase the accuracy of performance-based design of such buildings [6]. Irani and Naji assessed the P-Δ effects in steel structures with a similar approach for examining the lateral resistance of structures with a constant-ductility demand [7]. Tjhin and Aschheim used the yield spectrum in the design of concrete buildings with shear walls [8]. In this paper, the accuracy of the YPS method is evaluated in comparison to the existing code-based methodologies mentioned above.

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2. DESCRIPTION OF THE METHOD

Three moment resisting reinforced concrete frame buildings having 1, 5, and 10 stories are considered for the current study. These buildings were designed based on the Iranian seismic design code (i.e., standard 2800). The seismic performance of the buildings was evaluated based on three different methods: YPS, ATC-40, and the Iranian seismic rehabilitation manual (ISRM). In the YPS method, evaluation of buildings was carried out through two alternatives:

1. Direct use of YPS curves.
2. Calculation of the response modification factor of each structure and comparing these values with the standard 2800 ones.

Table 1. Comparing response modification factors of the buildings

No. of Stories	R_μ	R_S	Y	$R=R_SR_\mu Y$	Performance Level
1	1.5	2.6	1.0	3.9	LS
5	2.8	1.8	1.0	4.9	LS
10	2.6	1.8	1.0	4.7	LS

Table 2. The evaluation results based on ATC-40

No. of Stories	Performance Point	Overall Drift Ratio	Performance Level
1	$S_a = 0.4359g$ $S_d = 3.27cm$	1.09%	LS
5	$S_a = 0.177g$ $S_d = 17.6cm$	1.17%	LS
10	$S_a = 0.148g$ $S_d = 29.06cm$	0.97%	IO

Table 3. The evaluation results based on the Iranian Seismic Rehabilitation Manual

No. of Stories	δ_t (cm)	Overall Drift Ratio	Performance Level
1	3.1	1.03%	LS
5	24.5	1.63%	LS
10	49.1	1.63%	LS

In the first alternative, the equivalent yield point and its associated lateral capacity required for the buildings were determined and compared to the existing capacities using the nonlinear static analysis (NSA). In the second approach, values of the modification factor (R) were calculated for structures. The resulting R should not be more than that the values presented in standard 2800 for the initial design of the building, otherwise the lateral resistance of the building should be increased.

3. RESULTS AND DISCUSSION

The results of calculating response modification factors of the buildings are presented in Table 1. According to the YPS method, the calculated modification factors are smaller than the design value 5, and therefore all three structures designed based on standard 2800 satisfy the life safety performance level.

The results of evaluating the buildings' performance level based on the ATC-40 and ISRM methods are summarized in Tables 2 and 3, respectively. By calculating the capacity spectra based on ATC-40 and determining the target displacements using ISRM, the performance level of each frame was attained using again the NSA. The results showed that the structures under study are evaluated as seismically safer based on ATC-40 and YPS and less safe based on the ISRM.

4. CONCLUSION

Seismic performance levels of three different moment resisting reinforced concrete frame buildings designed based on the Iranian seismic design code (i.e., standard 2800) were evaluated using the YPS, ATC-40, and ISRM methods. In ATC-40, the performance point is at the intersection of the capacity and demand spectra while in the YPS method yield point of structures shall be provided. The performance point in the ISRM was determined by a prescribed formula called the displacement coefficient method. According to YPS, all of the frames analyzed were at the life safety performance level. The results showed that the structures under study are evaluated as seismically safer based on ATC-40 and YPS and less safe based on the ISRM.

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