A PROCEDURE FOR HARMONIZING DESIGN BASED ON STANDARD 2800 AND SEISMIC EVALUATION OF DOCUMENT 360

Farhad BEHNAMFAR
Department of Civil Engineering, Isfahan University of Technology, Esfahan, Iran
farhad@cc.iut.ac.ir

Hossein DASTAN MIRAK
Senior Earthquake Engineer, Tehran, Iran
hosein.dastan@yahoo.com

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A procedure for matching the outcome of design of a seismic resistant structure and its nonlinear performance level according to the seismic evaluation process using a nonlinear dynamic analysis is presented in this paper. In this simple method, the design response modification factor is corrected such that the average nonlinear response of the designed structure satisfies the life safety performance level in all members (Document 360, 2014). Buildings being 2-10 stories high with moment resisting frames are considered and designed based on version 4 of Standard 2800 (BHRC, 2014). Then the same structures are modeled nonlinearly in OpenSees and analyzed under a consistent suit of ten scaled earthquake records. The analysis results are presented as plastic hinge rotations for displacement controlled actions in structural members. Because of some members being unacceptable, the structure is again designed using a smaller response modification factor to arrive at an acceptable seismic behavior. Since this procedure may need several trial and errors that is not desirable, an analytical procedure is derived based on fundamentals of nonlinear analysis to estimate the response modification factor in a single stage without iteration. Finally, the modified response modification factors are suggested for moment resisting frames.

In order to give a short glance at the analytical procedure derived in this study for calculation of the corrected response modification, or behaviour factor, Eq. (1) is mentioned that is the final relation derived in this study for the renewed factor:

$$\frac{R'_\mu}{R_\mu} \cong \frac{\delta'_u}{\delta_u}\,\frac{S'_a}{S_a} \qquad (1)$$

In Eq. (1), R_μ is the ductilty-related part of the behavior factor, δ_u is the maximum roof displacement during the nonlinear dynamic response, and S_a is the spectral acceleration, all for the original structure. The corresponding parameters shown with a prime, refer to the building designed with the corrected behavior factor.

Tables 1 and 2 show the performance levels of beams and columns of the 10-story building, as an example, before and after its response modification factor is corrected according to the above procedure. It is observed that while the code-based building suffers from inadequacy of some of its columns under the mean of earthquakes consistent with the design spectrum, the modified structure satisfies the life safety performance level.

In Tables 1 and 2, the abbreviations B, IO, LS, CP, and C refer to the performance levels of minor yielding, Immediate Occupance, Life Safety, Collapse Prevention, and Failure, respectively. A dash shows no nonlinear behavior.

Table 1. Mean performance levels of structural members of the 10-story building before correction

Floor	Beam						Column							
	1		2		3		1		2		3		4	
	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end
1	B	B	-	-	-	B	IO	-	B	-	IO	-	-	IO
2	B	B	-	B	B	IO	-	-	B	B	B	B	-	-
3	IO	IO	IO	IO	IO	IO	-	-	IO	LS	IO	-	B	-
4	IO	B	B	B	B	IO	-	-	B	IO	B	IO	-	-
5	IO	-	-	B	-	IO	-	-	IO	IO	IO	IO	-	-
6	IO	B	-	B	IO	IO	B	-	IO	IO	CP	C	B	-
7	IO	-	-	-	B	IO	-	B	IO	IO	LS	IO	B	B
8	IO	B	B	B	B	IO	-	-	IO	IO	IO	IO	-	-
9	IO	B	B	B	B	IO	B	-	IO	IO	IO	IO	B	-
10	-	-	-	-	-	-	-	-	B	B	B	B	-	-

Table 2. Mean performance levels of structural members of the 10-story building after correction

Floor	Beam						Column							
	1		2		3				2		3			
	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end	Right end	Left end
1	B	B	-	-	-	B	B	-	B	-	B	-	B	-
2	IO	B	-	B	B	IO	-	-	B	B	B	B	-	-
3	IO	IO	IO	IO	IO	B	-	-	LS	LS	IO	B	B	-
4	IO	IO	IO	IO	IO	IO	-	-	B	B	B	B	-	-
5	IO	-	-	B	-	B	-	-	B	IO	B	IO	-	-
6	IO	B	B	B	B	IO	B	-	IO	IO	LS	LS	B	-
7	IO	B	-	-	-	IO	-	B	IO	IO	IO	IO	-	B
8	IO	B	B	B	B	IO	-	-	IO	IO	IO	IO	-	-
9	IO	B	B	B	B	IO	-	-	IO	IO	IO	IO	-	-
10	-	-	-	-	-	-	-	-	B	B	B	B	-	-

In Table 3, the corrected response modification factors (R) of all buildings of this study are presented along with their critical performance levels.

Table 3. Corrected response modification factors and critical performance levels (PL)

No. of stories	Old R	New R	Critical PL before correction	Critical PL after correction
2	7	6	C	IO
4		6	C	IO
6		6.1	CP	LS
8		6.4	C	LS
10		6.5	C	LS

The above results clearly show the effectiveness of the proposed procedure.

REFERENCES

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