A NEW PUSHOVER ANALYSIS TO ESTIMATE THE COLLAPSE PREVENTION PERFORMANCE LEVEL RESPONSES OF MID-RISE STEEL MOMENT RESISTING FRAMES

Mohammad Mahdi MADDAH  
Ph.D. Student, IIEES, Tehran, Iran  
mm.maddah@iiees.ac.ir

Sassan ESHGHI  
Associate Professor, Structural Engineering Research Center, IIEES, Tehran, Iran  
s.eshghi@iiees.ac.ir

Alireza GARAKANINEJAD  
Ph.D. Earthquake Engineering, Tehran, Iran  
alirezagarakani@yahoo.com

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Evaluation of the engineering demand parameters (EDPs) such as inter-story drift ratio profile has great importance in the seismic collapse assessment of structures. Nonlinear static analysis (pushover) methods have been used as approximate approaches for this aim. The previous researches show that application of advanced pushover analysis is complicated and require time consuming calculations (Guan et al., 2019). In this paper, an alternative method is introduced to produce inter-story drift profile and story displacement profile obtained from modal pushover analysis (MPA) for the collapse prevention (CP) performance level.

Also, a novel criterion is presented for detection of this performance level in the pushover analysis. In the proposed CP criterion, the onset of unloading from the stories of the structure is considered as near-collapse level. This phenomenon corresponds with the first backward form in story capacity curves in the coordinate of inter-story drift versus story shear. In the suggested pushover method, which is named optimized modal pushover analysis (OMPA), the modal pushover responses are combined using modal coefficients which are calculated from the optimizing process. The coefficients have been calculated using two optimization algorithms of particle swarm optimization (PSO) (Eberhart and Kennedy, n.d.) and colliding bodies optimization (CBO) (Kaveh and Mahdavi, 2014). These coefficients are obtained based on the incremental dynamic analysis (IDA) of three 5, 8 and 11 story steel moment resisting frames under 22 pairs of FEMA P695 guideline (FEMA, 2009).

The buildings have four 6.0 m bays and 3.1 m height in each story. The previous works showed that there is no obvious gain between three-dimensional (3D) and 2D analyses in the estimation of a collapse mechanism for regular MRFs (Lignos et al., 2013). In the current study, 2D models have been developed in the OpenSEES program (Mazzoni et al., 2006). The beams and columns are modelled by elastic beam-column element and plastic hinge rotational springs at member ends that follow the modified IMK (Ibarra-Medina-Krawinkler) model. Also, the panel zones are explicitly modelled using the proposed method by Gupta and Krawinkler (1999).

In the proposed method, the modal pushover analyses can be performed by using the force distribution corresponds to the product of the diagonal mass matrix (M) and the ith natural vibration mode $\phi_i$. The EDPs of the structure at CP performance level can be directly assessed from a combination of results of the modal pushover analysis with a modal combination rule according to Equation 1:

$$EDP_{OMPA} = \sum_{i=1}^{m} \alpha_i EDP_i$$

where $m$ is the number of the considered modes, $\alpha_i$ is modal combination coefficient of $i^{th}$ mode and $EDP_i$ is resulted from $i^{th}$ mode pushover analysis at the CP performance level. By optimization and fitting process, a simple equation for $\alpha_i$ as a function of
story numbers (N) is derived as Equation 2, Figure 1 and Table 1. Considering two and three modes in the pushover analysis are shown by OMPA-2 and OMPA-3, respectively. The OMPA method was validated on a 9-story building according to Figure 1.

\[ \alpha_i = a_i N + b_i \quad (i=1, 2, 3) \]  

(2)

<table>
<thead>
<tr>
<th>Mode Coefficient</th>
<th>3 Mode Coefficient</th>
<th>2 Mode Coefficient</th>
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<tr>
<td>Mode 1</td>
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<td>Mode 3</td>
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<tr>
<td>b</td>
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<td>-0.277</td>
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<tr>
<td>b</td>
<td>2.167</td>
<td>-0.350</td>
</tr>
</tbody>
</table>

Table 1. Obtained constant factors of a and b.

These results show the proposed method presents high accuracy in evaluating the inter-story drift profile and story displacement profile at the collapse prevention performance level of the structure.

REFERENCES


