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ADAPTIVE PUSHOVER ANALYSIS OF REINFORCED CONCRETE STRUCTURES

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The effectiveness of nonlinear static analysis and its computational simplicity has recently brought this procedure into several seismic guidelines and design codes. However, many researches have shown that conventional methods which are usually based on load patterns restricted to the fundamental mode shape include many deficiencies that can result in responses totally different from those obtained through dynamic analyses (Goel and Chopra, 2004). Therefore, various procedures as well as load patterns have been proposed in order to overcome some of these shortcomings. Moghadam and Tso (2002) provided a multimode approach in which the seismic response of the structure corresponding to each mode was calculated and the overall responses were then obtained on the basis of modal participation factors for each mode. Chopra and Goel (2002) developed another method of analysis named modal pushover analysis. In this method, a series of independent analyses was performed with the lateral load patterns consistent to the mode shapes. The produced modal responses were then combined together using quadratic modal combination rules. Despite the higher mode effect considerations, however, the continuing changes in the dynamic properties of the structure due to the inelastic behaviour are not considered in computing the applied load pattern in this type of pushover analysis.

In order to overcome this defect, the adaptive pushover procedure was introduced where the lateral force distribution is evaluated and adjusted as necessary based on the nonlinear behaviour of the structure (Antoniou and Pinho, 2004; Abbasnia et al., 2013). Besides, many researchers have also developed improved modal methods in which the structures are pushed with combined modal forces. In other words, the modal combination conception is used to identify the load pattern rather than to combine the nonlinear responses for each mode. In addition, adaptive forms of these methods have been proposed, wherein the load pattern is defined by the combination of instantaneous modal loads, and is then applied to the structure through a single pushover analysis (Antoniou and Pinho, 2004).

In this research, four samples of 10- and 15-story [two- and four-bay] reinforced concrete frames were studied. All frames have story height of 3.2 m and equal bays of 5.0 m. Gravity and seismic loads were assigned to the frames based on the criteria in the 6th section of the Iranian National Building Code and the Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard No. 2800, third edition). Moreover, the frames were designed according to the design criteria for special moment resisting frames according to the 9th section of the Iranian National Building Code. The buildings are characterized as an ordinary building having residential occupancy, and are supposed to be built in a site with conditions matching ground type II. The construction site is also located in a region of high seismicity. This is also noteworthy that in order to simulate the nonlinear behaviour of materials, the Takeda Model has been adopted. The lateral load distribution patterns recommended in FEMA 273/356 guidelines were applied to the sample models in order to perform pushover analyses. The results were then compared to the results obtained from several nonlinear incremental dynamic analyses for a range of earthquakes. Finally, a lateral load distribution pattern was proposed for pushover analysis of medium-rise reinforced concrete buildings based on the results of nonlinear static and dynamic analyses. The lateral load distribution pattern which is derived from the summation of the first three modes (Equation 1) and the general shape of this proposed load pattern applied to the 10- and 15-story frames are shown in Figures 1 and 2, respectively.

$$\Delta F_i = \left\{\frac{L_1^{\,2}}{M_1}\right\} * \Delta F_{1i} + \left\{\frac{L_2^{\,2}}{M_2}\right\} * \Delta F_{2i} + \left\{\frac{L_3^{\,2}}{M_3}\right\} * \Delta F_{3i} \qquad (1)$$

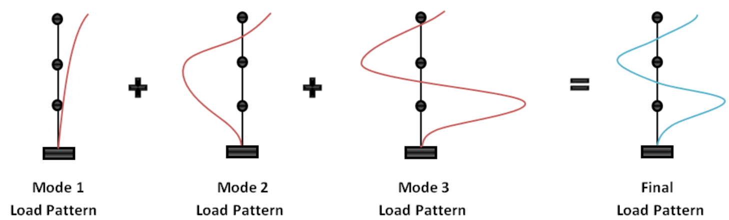

Figure 1. The process of determining the proposed lateral load pattern during nonlinear behavior of the structure

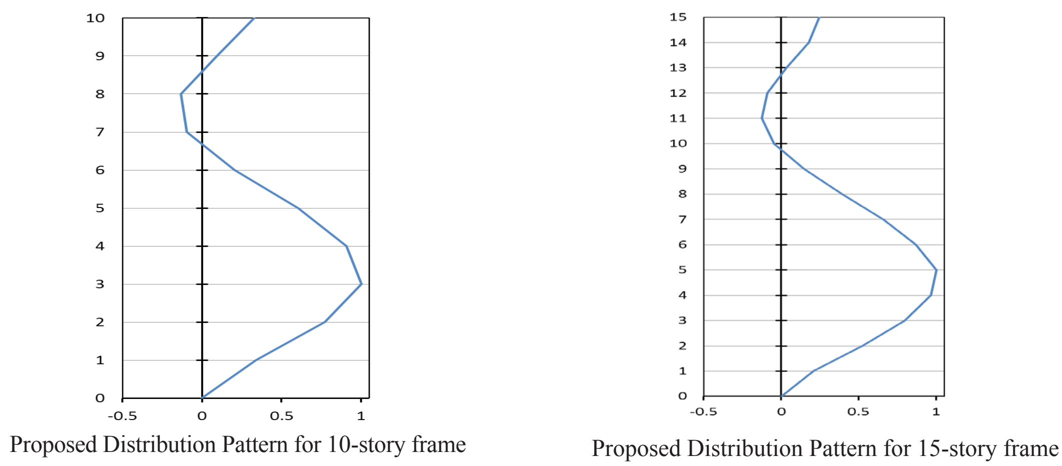

Figure 2. General shape of proposed load distribution patterns applied to the 10- and 15-story frames

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