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On the modal incremental dynamic analysis of reinforced concrete structures, using a trilinear idealization model

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ABSTRACT

In order to estimate the seismic demands at the performance level, the inelastic behavior of concrete structures should be considered. Incremental dynamic analysis (IDA) based on a nonlinear response time history analysis (NL-RHA) is considered to be the most accurate method in seismic demand calculations. However, modal incremental dynamic analysis (MIDA), based on the equivalent single-degree-of-freedom (SDF) oscillator, is also often used in studying structural engineering performances. As the MIDA method has usually not been applied to reinforced concrete (RC) structures, in this study an attempt is made to investigate the performances of RC frames and to compare the results obtained through the MIDA against those obtained from exact IDA. Furthermore, an innovative suggestion on approximated pushover curves of the corresponding SDF model, by means of a trilinear idealization representation, is also offered. For this purpose, an eight-story concrete frame subjected to 30 different earthquake records is studied with the trilinear idealization model, and the damage measures, important for the seismic vulnerability of buildings, such as the maximum displacement and the interstory drift ratio, are considered. Comparison of the results has shown reasonable and/or acceptable precision and reveals good agreement of the MIDA method with the new idealization behavior model for concrete frames.

1. Introduction

Estimating seismic demands at low performance levels, such as life safety and collapse prevention, requires explicit consideration of the inelastic behavior of structures. Although nonlinear response time history analysis (NL-RHA) is one of the most accurate methods for seismic demand calculations, nonlinear static processes are also used in the ordinary performance evaluation of structural engineering. The pushover analysis method gives reliable results in low-rise buildings that respond primarily in the fundamental mode of vibration and have inelastic actions uniformly distributed over their heights. In this method, the contribution of modes, higher than the first mode, is not considered. Therefore, researchers have been increasingly interested in developing new pushover analysis techniques. Bracci, Gupta and Kunnath have presented an adaptive pushover technique, which accounts for the effects of higher modes and time-varying structural stiffness [1]. Elnashai and his co-workers have conducted extensive comparisons between dynamic and pushover analyses in order to identify the domain where a pushover analysis is valid [2]. Chopra and Chintanapakdee determined the seismic demands of irregular frames with high stiffness and strength for 20 earthquakes comparing two methods, modal pushover analysis (MPA) and nonlinear time history analysis [3]. Hernández-Montes et al. observed that the roof was displaced in the reverse direction of the lateral load in a multimodal pushover analysis. This phenomenon is a potential impediment to MPA procedure application for curves of higher pushover modes. To overcome this difficulty an energy-based pushover analysis (EB-PA) technique was suggested by Hernández-Montes et al. [4], which is recommended in FEMA-440, and the EB-PA formulation has been extended to adaptive pushover analysis by Kunnath [5]. Then in 2006, a new method was presented by Tjhin et al. They considered another feature (displacement upon energy) for studying single-degree-of-freedom (SDF) systems instead of roof displacement [6].

Similar to the process of the linear static analysis method moving forward to become the nonlinear static pushover analysis method, the idea of promoting the dynamic analysis method to an incremental dynamic analysis (IDA) method was raised. Apparently, this concept was put forward for the first time by Bertero, in 1977 [7], and he was followed by many other scientists and engineers such as Luco and Cornell [8], Bazzurro and Cornell [9], Yun et al. [10], Mehanny and Deierlein [11], Dubina et al. [12], Nassar and Krawinkler [13], Psycharis et al. [14], Vamvatsikos and Cornell [15]. Aschheim et al. [16] and Mander et al. [17], who worked extensively on this afterwards.

Recently, a new technique for the dynamic response of structures has been investigated. This applied procedure can evaluate and predict the approximate seismic demands of structures,

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