Investigating the Seismic Design Lateral Force Distribution of a Tall Steel Moment Frame Building Based on Inelastic Behaviour

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Abstract

In recent earthquakes, most of the observed collapses have been related to inappropriate distributions of strength and stiffness of structural elements. Since most building structures designed according to current code procedures are expected to undergo large deformations in the inelastic range when subjected to major earthquakes, lateral force distributions can be quite different from those given by the code formulas. One of the essential elements of performance-based seismic design of structures should be to use more realistic design lateral force distribution, which represents peak lateral force distribution in a structure in the inelastic state and includes the higher mode effects. In this paper, design lateral force distribution of the 20-story steel moment resistant frames located in Los Angeles, which was the subject of an extensive analytical study as part of the SAC project, has been investigated using dynamic time-history analyses results. The maximum story shear at each level, under twenty ground motion records at 10% and twenty at 2% probability of exceedance in 50 years, obtained from nonlinear time history dynamic analyses, and compared with the code lateral load pattern. OpenSees software has been used in this paper for modeling and performing analyses. It is concluded that code lateral force distribution does not able to accurately predict deformation and force demands that may be induced during nonlinear phase; causing structures to behave in a rather unpredictable and undesirable manner.

Keywords: Tall, Steel frame, Inelastic behavior, Lateral distribution.

1. INTRODUCTION

Since most building structures designed according to current code procedures are expected to undergo large deformations in the inelastic range when subjected to major earthquakes, lateral force distributions can be quite different from those given by the code formulas. This is due to current seismic design approach which is generally based on elastic analysis and considered inelastic behavior in an indirect manner [1]. For example, according to International Building Code [2] (IBC 2006) provisions, after selecting the member sizes for required strengths, as obtained from elastic analysis, effect of inelastic behavior is considered by multiplying the calculated drift at design force by a deflection amplification factor and limiting that to specified value.

In recent earthquakes, most of the observed collapses have been related to inappropriate distributions of strength and stiffness of structural elements. The seismic codes are generally considering the seismic effects as lateral inertia forces according to the force-based approach that was inception in the early 1900s and has not changed significantly yet [3]. The height wise distribution of these static forces and therefore, stiffness and strength seems to be based implicitly on the elastic vibration modes [4], [5]. As structures exceed their elastic limits in severe earthquakes, the use of inertia forces corresponding to elastic modes may not lead to the optimum distribution of structural properties; consequently, the structure does not response in a desirable and predictable manner.

One of the essential elements of performance-based seismic design of structures should be to use more realistic design lateral force distribution, which represents peak lateral force distribution in a structure in the inelastic state and includes the higher mode effects [6]. In this paper, shear forces that induced from earthquake excitation and the forces determined by code patterns is investigated for a 20-story tall steel moment frame that was the subject of an extensive analytical study as part of the SAC steel research program [7] (Gupta 1999) based on nonlinear dynamic time history analyses results.