Permanent Damages of Structural Components in Existing High-Rise Steel Buildings Subjected to Rare Earthquakes

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Summary

Severe ground motions generate permanent damages and residual deformations on various existing high-rise steel buildings, due to the effects of local-failure in steel and CFT members on the seismic damages have not been accounted in the provisions of current performance-based seismic design. In this study, component deterioration after local buckling of steel beam and columns is incorporated in dynamic analysis of existing high-rise steel moment frames subjected to long period ground motions. Performance-based earthquake damages are numerically investigated and compared in terms of the extent and distribution of plastic deformation ratios in beam and column components. Analytical results indicate that the characteristics of synthetic long period ground motions excited significantly different plastic deformations over the height of building structures. The component deterioration is not influential to the maximum responses of plastic deformation under the original scale of seismic excitations. The plastic deformation ratio of beams initiate and grow from the mid-floors, and the exterior connections sustained excessive damages.
Keywords: Permanent damage, high-rise buildings: deterioration; earthquakes; plastic deformation.

1. Introduction

Tokachi-oki Earthquake (Mw=8.0) on September 26th of 2003 generated serious fire disasters on oil-tanks, due to resonance effects at long-period branch of structures (oil-tanks) and the earthquake ground motions [1]. Afterwards, new understanding on the threat of severe earthquakes with long period components are recognized on the seismic safety of building structures with long natural periods such as high-rise buildings. The 2011 Great East Japan earthquake and induced Tsunami have taken devastating losses on human life, buildings and infrastructures near seismic epicentre, and simultaneously, long period ground motions are observed at Tokyo, Nagoya and Osaka regions, where high-rise buildings resonate over five minutes [2]. Meanwhile, high probability of severe earthquakes with magnitude class over 8.0 along the Tokai, Tonankai and Nankai sea troughs of Japan have also been predicted, in next certain years. Particularly, high-rise buildings located in basin area whose period margin between 3 sec and 6 sec are expected to face extreme challenges and damages by severe earthquakes occurring nearby.

According to the nearly 40-year constructional history of high-rise buildings, destructive severe earthquake has rarely been experienced. Thus, various extensive existent high-rise buildings face urgent challenges of seismic safety under probable severe ocean-ridge earthquakes and near-fault earthquakes. For the high-rise buildings under earthquake excitations, the permanent damages induced by local buckling of steel components and/or crush of concrete could lead to excessive residual deformations or even collapse, especially when it resonates with long period ground motions generated by severe earthquakes with high level magnitude. In this chapter, typical existent

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