Incremental Dynamic Analysis Applied to Collapse Margin Assessment of High-Rise Buildings

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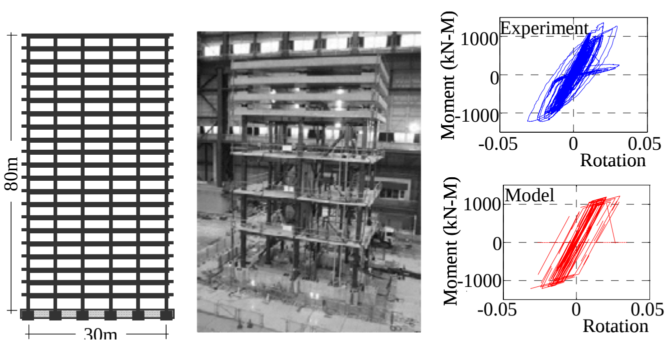
1. Introduction

A series of full scale shake table tests that represented typical high-rise construction in the 1970's (Fig. 1 (a) (b)) examined the capacity of high-rise building when subjected to the long-period ground motions. The test results indicated that beam-to-column connections of high-rise steel structures deteriorate and eventually facture due to cumulative damage from a large number of inelastic cycles of long period ground motions. Consequently, there is a need to investigate the effect of component deterioration and ductile fracture on the seismic capacity of high rise steel buildings. As part of the efforts, behavior of the fractured beam-to-column connections obtained from the E-Defense test was modeled numerically. Parameters of the model, such as the strength and stiffness deterioration ratio, and cumulative plastic deformation capacity up to fracture, were applied to the connections of a 21-story numerical model. A serious of incremental dynamic pushover analysis was also conducted up to the fracture of the 21-story model..

2. Incremental Dynamic Analysis

The model was built in the Open System for Earthquake Engineering Simulation (OpenSees, 2009) which is able to represent the deterioration and fractures behaviors. Hysteretic loops obtained from the tested and model connections are shown in (Fig. 1 (c)). The 21-story building was developed as a 2D numerical model. The fracture connection model was inserted at each beam end.

El Centro wave and two synthesized long-period ground motions, Hog and San waves, were adopted as the input waves. Their acceleration response spectrum values at the first model period of the building (2.3 sec) were scaled to the level of 0.2g. The intensity was increased by 0.2g in each analysis up to the collapse of the building. Fig. 2 shows the input wave intensity and the corresponding maximum drift angle response of the building. Fractures occurred at the intensity of 1.6g under the El Centro wave loading. For the long-period ground motions, fractures occurred at the intensity of 0.6g. The building collapsed at 2.6g intensity of the El Centro wave. For the long-period ground motions, collapse occurred at 1.4g intensity. Long-period ground motion generated significantly large cumulative plastic deformations and accelerated the occurrence of fractures and collapse.



(a) (b) (c)

Figure 1 E-Defense test specimen: (a) Prototype building; (b) Test specimen; (c) Hysteretic loop of beam-to-column connection

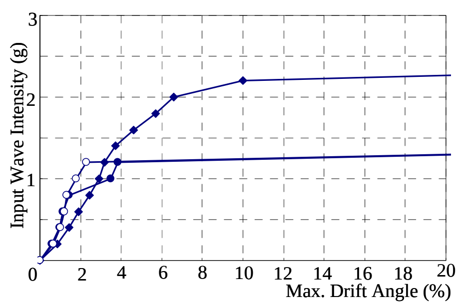


Figure 2 Incremental Dynamic Pushover