EVALUATION OF SEISMIC-RESISTANT CAPACITY OF EXISTENT HIGH-RISE BUILDINGS UNDER EXTREMELY STRONG EARTHQUAKE EXCITATIONS TAKING VARIOUS DETERIORATION EFFECTS

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論　文　内　容　の　要　旨

The researches addressed in this thesis are mainly about the evaluation on the seismic-resistant capacity of various existent high-rise buildings subjected to extremely strong earthquake ground motions. In particular, we specifically incorporate the influences of P-Δ effect and member deteriorations induced by local failure.

Six chapters are included in this dissertation, beside the Chapter 1 for introduction and Chapter 6 for summary and conclusions, the core of the thesis consists of two parts, Chapters 2~3 are expected to calibration the accuracy of unified constitutive models for concrete and steel members by incorporating strength and stiffness deteriorations. Chapter 4~5 focus on the seismic safety and collapse capacity of various existent high-rise buildings subjected to severe seismic excitation. Details of these four chapters are introduced below.

In Chapter 2, the unified constitutive models for steel and concrete fiber materials for fiber element analysis are developed or modified in accordance with the fully calibrated and recognized models as mentioned above. Due to the effects of geometric-nonlinear and material-nonlinear ought to be fully considered in the assessment of the seismic-resistant capacity and collapse behavior of high-rise buildings under severe seismic excitations. The unified constitutive models incorporating the strength and stiffness deteriorations of structural components are respectively quantified and evaluated on the basis of an extensive database of the experimental results on H-shaped steel members, hollow steel tubular members and concrete filled steel tubular members. Calibrated results in this chapter are expected to prove the feasibility and accuracy of such deteriorating constitutive models, and support the reliability of the dynamic analyses on the seismic-resistant capacity of various existent high-rise steel and concrete filled steel tubular buildings that tend to be conducted the Chapters 4~5.

In Chapter 3, a full-scale shaking table test of 4-story steel moment-resistant frames subjected to incremental earthquake loadings was used for the calibration of stress fiber model analysis employing the stress-strain models incorporating strength and stiffness deteriorations, in order to predict the collapse capacity of the steel frame under severe seismic excitation. An E-Defense shaking table test of a high-rise steel building subjected to long-period ground motions is also used for the validation of the unified constitutive model. In addition, a CFT frame specimen subjected to cyclic horizontal loadings with constant axial loading is also simulated. Although differences are included in the modelling of three dimensional frame specimen by two-dimensional plan frame model, the two dimensional frame models by adopting the unified constitutive models are reliably capable to predict the collapse and seismic responses of low-rise and high-rise steel and concrete filled steel tubular frame buildings.

In Chapter 4, the seismic-resistant capacity of existent high-rise steel buildings with various story levels subjected to long-period ground motions, near-fault ground motions and artificial ground motions are

numerically investigated. The deterioration behavior of such building models is evaluated by using the unified constitutive models and taking the *P-Δ* effect into account. The deterioration criteria are also quantified on the basis of maximum and residual story drift angles, structural component ductility and energy dissipation. Various high-rise building models incorporating and ignoring deterioration effect are compared with each other to further assess the safety margin until collapse. The P-Δ effect and member deterioration have been proved very significantly influence the seismic-resistant capacity and collapse behaviour of high-rise steel buildings.

In Chapter 5, we replace the square hollow steel tubular columns in high-rise steel building with the associated square concrete filled steel tubular columns by equivalent flexural stiffness, in order to assess the seismic-resistant capacity of the existent high-rise concrete filled steel tubular building that is analogous to the associated high-rise steel buildings. Extreme earthquake waves with long-period ground motions (i.e. Art-Hachi) are selected because of the larger seismic responses have been obtained in Chapter 4. In comparison with the analogous high-rise steel buildings, the safety margin until collapse of concrete filled steel tubular building structures is assessed. Larger safety margin until collapse of high-rise CFT buildings than that of high-rise steel building is obtained.

Finally, summary and conclusive remarks of the findings in Chapter 2~5 are respectively achieved in Chapter 6. According to above achieved findings, by considering the influences of *P-Δ* effect and strength and stiffness member deterioration effect, the existent high-rise buildings have higher probability of collapse when under long-period ground motions and pulse-like ground motions, than under earthquake waves which are used in structural design so far. *P-Δ* effect tends to reduce the seismic resistant capacity of the building with higher story level based on Uetani theory. Strength and stiffness member deterioration make the high-rise building suddenly collapse and reduce the safety margin until collapse of the high-rise buildings. Hence, the influences of P-Δ effect and member deterioration effect should be incorporated not only for the seismic evaluation on various existent building structures, but also for the performance-based seismic design of new constructing building structures in the future.

論 文 審 査 の 結 果 の 要 旨

本論文は、PΔ効果を考慮すると共に部材の局部損傷による耐力劣化を精度よく解析できる構成則モデルを提案し、これを用いて既存の鉄骨造およびCFT造の超高層建築物を対象として、その年代では考慮されていなかった長周期地震動等に対する耐震性能評価を行い、長周期地震動等への配慮が不可欠であることを明らかにすると共に、新たな指標として安全余裕度を導入し、超高層建築物の耐震性能をより適切に評価する方法を提案したもので、建築構造学について重要な知見を得たものとして価値ある業績と認める。