An adaptive finite element code for impact and collapse analyses of buildings

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Catastrophic disasters of large-scale framed structures occurred recently are mainly caused by sudden, extreme external loads such as aircraft collision, explosion, large seismic excitation, and big fire. Dynamic codes are generally used to investigate such phenomena. However, strong nonlinearity in the deformation of structures and rapidness of the external loads often generate higher hurdle in the analyses. The authors have developed an adaptive finite element code with the use of an ASI (Adaptively Shifted Integration)-Gauss technique, which provides higher computational efficiency than the conventional code in such analyses, and enable us to cope with dynamic behavior with strong nonlinearities including phenomena such as member fracture and elemental contact. The code has been applied to various collapse analyses of buildings. Contact release and re-contact algorithms are also developed and implemented in the code to realize complex behaviors of structural members during impact and collapse sequence.

One of the various collapse simulations to be presented is a fire-induced collapse analysis of a high-rise tower, which is carried out for an investigation seeking for the true cause of the total collapse of New York World Trade Center (WTC) towers, which collapsed in 2001. The results clearly show the effect of the weak member joints, which were reported to be 20 to 30 % of the strength of the members in WTC towers, as well as the effect of the strength reduction due to elevated temperatures. The effect of outrigger truss system on roof top is also verified. The models with outrigger truss systems tend to withstand longer in time by catenary action only if their load paths are protected. Other simulation results to be presented include some controlled demolition analyses of a high-rise building, and impact collapse analyses of neighboring buildings under long-period seismic excitation.

The adaptive finite element code with the ASI-Gauss technique can be effectively used to investigate various collapse problems of framed structures. It is confirmed that the contact release and re-contact algorithms developed in this study also help us to understand complex behaviors of structural members during impact and collapse sequence.

References

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