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FIRE-INDUCED COLLAPSE ANALYSES OF HIGH-RISE TOWERS USING ASI-GAUSS TECHNIQUE

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ABSTRACT

The 9/11 terrorist attack on the New York World Trade Center (WTC) towers caused an unprecedented tragedy in the history of architecture. The twin towers WTC 1 and 2 stood in flames caused by jet fuel until finally, both collapsed totally to the ground with thousands of people trapped in the buildings. Both towers collapsed at an unnaturally high speed, which was observed to be nearly equal to that of free fall. Official statements have already been released by the Federal Emergency Management Agency (FEMA) in 2002 [1], and also by the National Institute of Standards and Technology (NIST) in 2005 [2], regarding the incident. FEMA [1] concluded that the heat of burning jet fuel induced additional stresses into the damaged structural frames while simultaneously softening and weakening these frames, and this additional loading and the resulting damage were sufficient to induce the collapse of both structures. Many detailed numerical analyses were carried out in [2], and the report was concluded by stating "the WTC towers likely would not have collapsed under the combined effects of aircraft impact damage and the extensive, multifloor fires, if the thermal insulation had not been widely dislodged or had been only minimally dislodged by aircraft impact." But how wide should the fire be spread in the towers to cause such perfect destruction? How high should the heat be to reduce the structural strengths of core beams and columns? What really caused the free-fall total collapse? Many questions still remain unresolved.

Isobe and his collaborators are seeking for the true cause of the total collapse by conducting several numerical simulations, including the full model aircraft impact analysis of the WTC tower [3]. Isobe suggested in the paper that the spring-back phenomenon due to rapid unloading caused by aircraft impact possibly have destructed member joints in the core structure, which might have caused the towers to become brittle and unstable. However, it does not give answers to the total collapse of WTC tower 7, which collapsed, reportedly, only by fire.

In this study, the investigation is made from a different point of view and the influence of fire and heat is taken into account. The main objective of this study is to conduct

some fire-induced collapse analyses using the ASI-Gauss technique [4], to investigate how the structural strength reduction of member joints gives influence on the collapse phenomena. It is to be noted that the region of New York City rarely has earthquakes and high-rise towers only need structural design to withstand wind loads. To investigate the influence of how the structures are designed, the base-shear coefficient which is the general index to indicate the earthquakeproof strength of buildings is taken into consideration in the numerical analyses. Member-joint strengths of the models are also expressed by changing the coefficients in the yield functions. Fracture points of axial tensile strain, shear strain, and rotational angle estimated from some experimental data are used in the criterion of member fracture. Reduction rate curves of elastic modulus and yield stress related to temperature shown by NIST [2] are adopted. The results of the fire-induced collapse analyses of high-rise towers show a clear difference between the models with strong and weak member-joint strengths. The strongly designed model withstands high temperature without any sign of collapse, whereas the weak model initiates its collapse when the temperature reaches nearly to the highest, and ends, eventually in a total collapse.

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