Solving problems in structural dynamics using beam elements: From collapse behaviors of buildings to torque cancelling of robots

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Abstract

In this lecture, several finite element approaches to solve various problems in structural dynamics, all using beam elements for numerical modelling, are presented.

First, a brief outline of the Adaptively Shifted Integration (ASI)-Gauss code [1] incorporated with linear Timoshenko beam elements is introduced. This code provides higher computational efficiency than the conventional code in those problems with strong nonlinearities including phenomena such as member fracture and elemental contact. Several results obtained by using the numerical code are shown in this lecture. One of them are an aircraft impact analysis of a high-rise tower, conducted to identify the specific structural cause of the high-speed total collapse of the World Trade Center (WTC) towers, which occurred during the 9.11 terrorist attacks. It is followed by a seismic pounding analysis of the Nuevo Leon buildings, a 14-story apartment consisted of three similar buildings connected with narrow expansion joints, in which two out of the three collapsed completely during the 1985 Mexican earthquake. Furthermore, outcomes of a one-way coupling analysis of a steel frame building subjected under tsunami wave and debris collision [2] is described. Finally, some numerical results obtained from motion behavior analyses of indoor non-structural components such as ceilings and furniture are compared with experimental results [3].

Next, a torque cancelling system (TCS) [4] that stabilizes mechanical sway in quick-motion robots is described. The TCS computes reaction moments generated by motors in robots by considering the precise dynamics of the whole system. The reaction moments can be computed using the parallel solution scheme of inverse dynamics [5], which handles the dynamics of complex robotic architectures by modelling them with Bernoulli-Euler beam elements. In contrast to the conventional schemes based upon dynamic equations, the developed scheme can handle different types of configurations and can also consider the elasticity of constituted links or passive joints by only changing the input numerical model. Once the reaction moment is known, it can be cancelled by applying an anti-torque to a torque generating device. Some experimental results of torque cancelling are presented in this lecture.

Keywords: Structural dynamics, FEM, Beam element, Collapse behaviors, Torque cancelling system, Inverse dynamics, Robot

References

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