ABSTRACT

Use of Super Elements and Substructures for Efficient Analysis of Building Structures

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Flat plate system has been adopted in many buildings constructed recently because of the advantage of reduced floor heights to meet the economical and architectural demands. Structural engineers commonly use Effective Beam Width Model (EBWM) in practical engineering for the analysis of flat plate structures. However, in many cases, when it is difficult to use the EBWM, it is necessary to use a refined finite element model for an accurate analysis. But it would take significant amount of computational time and memory if the entire building structure was subdivided with finer meshes. An efficient analytical method is proposed in this study to obtain accurate results in significantly reduced computational time.

Regarding the proposed analytical method, additional researches about vibration analysis of floors in shear wall building structures were performed. Many high-rise apartment buildings have been constructed, especially in Asian region, using the box system which consists of only reinforced concrete walls and slabs. In residential buildings such as apartments, vibrations may be induced by various sources and these vibrations are transferred to neighboring residential units through walls and slabs. It is necessary to use a refined finite element model for an accurate vibration analysis of a shear wall building structure because a large number of modes are involved in the dynamic responses. But it would take significant amount of computational time and memory if the entire building structure were represented by a finer mesh model.

In this study, an efficient analytical method about these structures is proposed. Though mentioned structural systems are not the same kind, the analytical method is commonly applicable to them.

In case of the flat plate structures, the proposed method employs super elements developed using the matrix condensation technique and fictitious beams are used in the development of super elements to enforce the compatibility at the interfaces of super elements. The stiffness degradation of flat plate system considered in the EBWM was taken into account by reducing the elastic modulus of floor slabs in this study. Static and dynamic analyses of example structures were performed and the efficiency and accuracy of the proposed method were verified by comparing the results with those of the refined finite element model and the EBWM.

In the case of vibration analysis of floors in shear wall building structures, the efficient analytical method which can provide accurate vibrational responses of a shear wall building structure in a significantly reduced computational time. The number of degrees of freedom can be minimized without deteriorating the accuracy in the results if all the DOFs except those associated with translation perpendicular to walls or slabs in the shear wall structure are eliminated. If a large number of DOFs are condensed at once, the computational time for the matrix condensation would be significant. Thus, the modeling technique using super elements and substructures is proposed to reduce the computational time for the matrix condensation. Shear wall example structures with 3- and 5-story were used to verify the accuracy and efficiency of the proposed method. It was confirmed that the natural frequencies, mode shapes and time histories from the proposed method are very close to those of a refined finite element model based on the analyses of example structures. However, the computational time for the proposed method was significantly reduced because the number of DOFs used in the proposed model was only 5 % of that of a refined finite element model for the analysis of example structures. And the time and the effort for the modeling of a shear wall structure can be significantly reduced using super elements and substructures when identical residential unit plans are repeatedly used in many floors in a shear wall structure. Therefore, the floor vibration analysis of a high-rise shear wall building could be efficiently performed in the practical engineering if the proposed method were used.