Collaborative Use of FEM with DEM for Brick Joint Splitting in Strong Earthquake Ground Motion Simulation

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ABSTRACT

Masonry structures constructed just after the opening of Japan, about one hundred and fifty years ago, have been recognized as industrial heritages. Most of them are masonry warehouses made of wooden framed brick or stone walls. Though some of them are renovated for modern use, it is indispensable to preserve their original structures for their values. Our research can help renovation design to utilize their original strength.

We have been studying collapse mechanisms of masonry structures e.g., a dry masonry Angkor heritage prototype [1 and 2] and a mortar jointed brick chimney in Tokoname [3]. Our strategy constitutes micro tremor measurements, validation of finite element or discrete element models, and simulation for large disturbances. At this time, a two-story warehouse in Tomioka city, a mortar jointed brick masonry with wooden frame reinforcements, was studied for strong earthquake ground motion.

Several vibration modes were identified by micro-tremor observation and 2nd floor excitation which were accompanied with remarkable variation of out-of-plane deformation of walls. These three-dimensional vibration characteristics required us to couple three-dimensional analyses with our two-dimensional DEM software.

The three-dimensional FEM overall model was tuned for the distinctive vibration modes by closely evaluating stiffness of the wooden roof and the wooden 2nd floor structures. Analyses for static horizontal load and dynamic ground motion exhibited that the Von Mises stress was dominated at the centre bottom and at the upper corners of the longer wall in the excitation along the shorter edge direction. The former predominance implied the dominating bending stress and the latter the dominating membrane stress induced by the constraining perpendicular shorter edge wall.

Two DEM local models were constructed; one for the centre bottom of the wall by plane strain and the other for the upper corner of the wall by plane stress. For both models, time-varying dynamic displacement response obtained by the three-dimensional FEM were specified at their peripheries. At the centre bottom of the wall, DEM revealed that the joint splitting was developing horizontally in the section; at the upper corners, joint splitting was proceeding obliquely on the wall. In these analyses, FEM based overall response with intact brick walls was used regardless of the degrading status of the walls. Although this assumption will have to be justified, the results of DEM were consistent with the reported past earthquake damages.

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