Study of methods to evaluate and test external forces to verify structural performance of architectural structural members

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1. Background of the study

This study aims to develop technical references for structural performance verification by targeting non-structural members of buildings which are damaged by earthquakes, the field that have not been explored so much in past studies, and by examining methods to evaluate external forces that are generated during earthquakes. The study also aims to test structural performances of applicable members. The target of this study is the glass screen. Past studies have examined effects of forced deformation in the in-plane direction that is parallel to the glass surface. The damage probably caused by the effect of inertial force of resonance with swings in the off-plane direction that was orthogonal to the glass surface was reported in recent earthquakes. The study conducted an actual-scale vibration table test using glass screens and strong-motion earthquake measurement of a building that caused the force applied to the glass screen during an earthquake.

2. Examination of the vibration characteristics of glass screens

One test piece shown in Photo 1 was created for the actual-scale vibration table test. Types of vibrations applied in the off-plane direction included the sine wave excitation, random wave excitation to check vibration characteristics, and excitation with the wave observed during earthquakes. (Waves observed were on the ground-level floors because many reported damages were on ground-level floors of low-rise steel-frame buildings.)

The maximum excitation with observed waves was set at 250% of the north-south wave observed in Sendai by Japan Meteorological Agency during the 2011 Great East Japan Earthquake. Figure 1 is the plotting of the excitation level and maximum responses on the glass surface. The excitation level and maximum responses are mostly proportional up to about 10 mm of the maximum responses. The peak of the Fourier amplitude ratios of the responses is clearly shown at 6.1 Hz in ranges with small responses. Meanwhile, two peaks are seen for 250% excitation at 6.2 Hz and 6.6 Hz. The test indicated that the vibration characteristics on the glass surface changed with excitation levels.

3. Strong-motion earthquake measurement of low-rise steel frame building

Strong-motion earthquake measurement was conducted using a low-rise steel-frame building (one-story building with a two-story section in Ushiku, Ibaraki) to examine the vibration characteristics of a building that could generate force on the glass screens. Figure 2 shows the Fourier amplitude ratio observed during an earthquake (occurred at 14:28, May 25, 2015). The peaks in two orthogonal directions were at 3.30 Hz (0.30 seconds) and 2.77 Hz (0.36 seconds). The test found that the vibration characteristic had a natural period that was considerably greater than the natural period (0.12 seconds for a steel-frame building with the height of 4 meters) calculated using the simplified formula used for architectural designs.

4. Conclusion

The series of experiments and observations in this test were obtained targeting glass screens produced with certain specifications and low-rise steel-frame buildings. The team will apply these tests to more generalized targets in future studies.

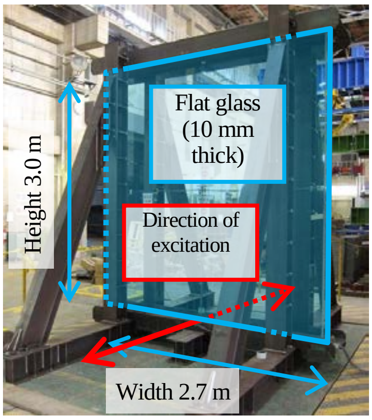

Photo 1. Test piece used for actual-scale vibration table test

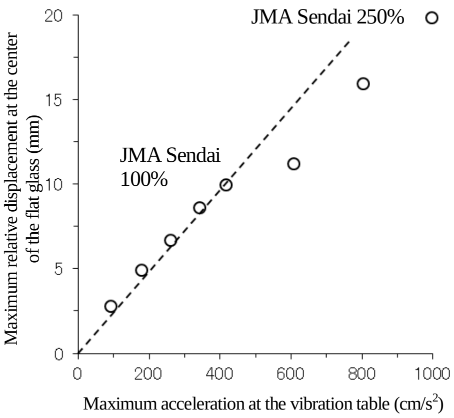

Figure 1. Relationship between excitation level and responses

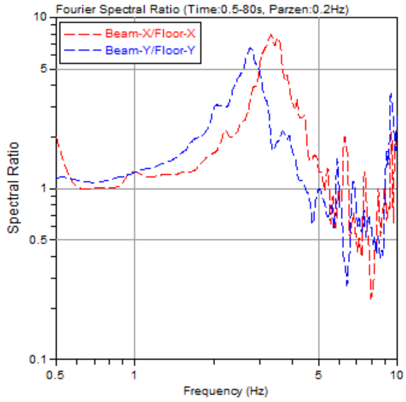

Figure 2. Responses of low-rise steel-frame building during an earthquake