Numerical Studies on Seismic Motion Behaviors of Non-Structural Components in Buildings

Daigoro Isobe[1*], Koichi Kobayashi[2], Kazuki Sato[2], Kotoku Maeda[2], Hiroyuki Omura[2]

[1]University of Tsukuba
1-1-1 Tennodai, Tsukuba-shi, Ibaraki 305-8573, Japan
isobe@kz.tsukuba.ac.jp

[2]Graduate school, University of Tsukuba
1-1-1 Tennodai, Tsukuba-shi, Ibaraki 305-8573, Japan
(s1720934, s1720937, s1720973, s1820884)@s.tsukuba.ac.jp

ABSTRACT

Improperly secured furniture, especially on the upper floors of high-rise buildings under long-period ground motion, can prove dangerous to human life. Fallen items of furniture such as chairs and desks could become fatal obstacles that prevent efficient evacuation. Deformed doors could also obstruct people from evacuating. Also, ceiling collapse damages that were observed in large-space structures such as gymnasiums during big earthquakes could obstruct people from using these facilities as shelters after earthquakes. These behaviors of non-structural components in buildings have become one of the main targets of investigation to reduce number of victims during and after disasters.

In this research, an effective numerical code for analyzing the motion of non-structural components such as furniture, doors and ceilings subjected to seismic excitations was developed. The numerical code is based on the adaptively shifted integration (ASI) – Gauss technique [1], which is a finite element scheme that provides higher computational efficiency than the conventional code. The frictional contact between objects was fully considered by employing a sophisticated penalty method [2]. The numerical results were validated through a comparison with the shake-table test results of furniture, doors and ceilings. For example, the numerical results of ceiling collapse analysis were validated with those experimental results performed at the E-Defense under an input of two continuous K-NET Sendai 50% waves. The acceleration responses, the spectrum and the displacement responses obtained on the roof matched well with the experimental result. According to the results, the plaster boards near walls pattered down occasionally as the clips and screws supporting the boards detached at the first peak of the first wave. Then, the clips near roof top began to get loose due to buckling of hanging bolts caused by vertical excitation, which ends, at the first peak of the second wave, in drop of plaster boards in a wide range. The numerical result had shown the collapse of the ceilings progressed owing to the detachment of clips that connected the ceiling joists to the ceiling joist receivers. The earthquake-resistant ceilings, on the other hand, did not detach and fall at all as were in the experiment. The numerical code, the models of various non-structural components and validation results are to be shown in the presentation.

References

[1] D. Isobe, Progressive Collapse Analysis of Structures: Numerical Codes and Applications, Elsevier, eBook ISBN: 9780128130421, Paperback ISBN: 9780128129753, 2017.

[2] D. Isobe, T. Yamashita, H. Tagawa, M. Kaneko, T. Takahashi and S. Motoyui, Motion Analysis of Furniture under Seismic Excitation using the Finite Element Method. Japan Architectural Review. 2018;00:1-12. https://doi.org/10.1002/2475-8876.1015.