Structural Design with Seismic Energy-Dissipation Concept

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Summary

This paper introduces the concept of structural design using energy-dissipating members for elegant structures in seismic areas. Various example applications designed by the author are discussed.

Keywords: Elegant design, Seismic design, Energy dissipation, Grid-shell

1. Introduction

To enhance the resilience of major cities after large earthquakes, damage-controlled design using various energy-dissipating devices or seismic isolation techniques for buildings and city facilities is gaining popularity in high seismic zones as in Japan. In the energy-dissipation concept, the input seismic energy is concentrated into replaceable high-ductility structural members, keeping the main structure undamaged and minimizing residual deformation after an earthquake. In this paper, this concept introduced to various façade structures is defined as "energy-dissipating grid-skin structures", and various detailed applications are presented and discussed.

2. Various applications of grid-skin structures

A "grid-skin structure" is defined as a structural system with vertical and diagonal grid-shell frames utilized in perimeter zones as seismic or wind resistant elements in this paper. Fig.1 shows a grid-skin structure applied to the University Library at the Tokyo Institute of Technology. The perimeter frame of the three-story superstructure is composed of vertical and horizontal grids with supporting diagonal columns. The grid-skin structure can also be applied to RC frames. Fig. 2 shows a research building with checker-patterned shear walls distributed on the surface of the building. To obtain structural robustness against a large seismic input, additional ductile, internal moment-frames supporting each floor are placed at the back of the checker walls.

Fig. 1: Steel grid-skin supported by diagonals

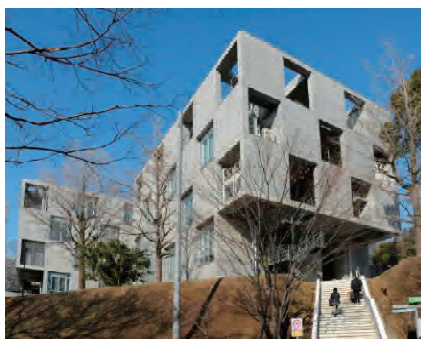


Fig.2: RC grid-skin with checkered wall

3. Grid-skin structures with energy dissipation

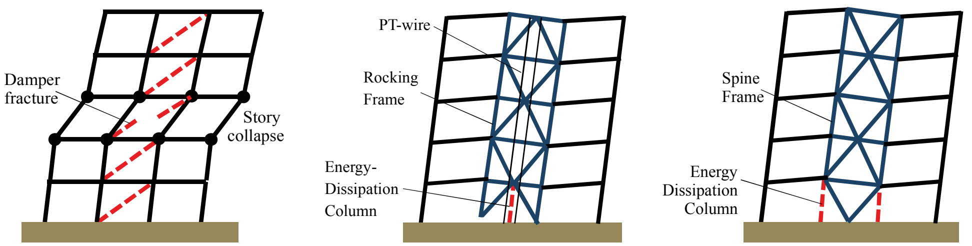
If the perimeter grid-skin structures are composed of energy-dissipating members, they will help provide high robustness without additional ductile frames. Fig. 3 shows the seismic retrofit of a 45-year old RC building by attaching a new façade composed of energy-dissipating braces, louvers, and glass. As an example of "Integrated Façade Engineering", this new façade is designed to improve not only seismic performance, but building appearance and thermal conditions as well. The same concept was used for a new research building as in Fig. 4, which is covered with 4,560 solar cells. Aside from high seismic performance, this building produces 650 kW/h of electric power on sunny days, achieving zero-emission building status and reducing CO_2 emission by 62%.

Fig. 3: Retrofit with energy-dissipating grid-skin

Fig.4: Grid-skin supporting solar cells

4. Energy-dissipating skins with spine frames

Although the energy-dissipating grid-frame structures are effective in realizing seismic-proof and elegant structures, there is still some risk of the energy-dissipating members fracturing under the maximum-considered earthquake level. To avoid such risk, introduction of spine frames through the stories is considered to be effective. The three structural systems as shown in Fig. 5 were studied in this paper, and (c) non lift-up system was applied to an actual building.



(a) Shear dumper system *(b) Lift-up spine system* *(c) Non lift-up spine system*

Fig.5: Concept of controlled spine frame systems

5. Conclusions

The concept of the "grid-skin structure" for steel and RC buildings to ensure open interior spaces and elegant façades was proposed, and application examples were introduced. Introducing diagonal energy-dissipating braces into grid-skin structures is effective in keeping the main structure in the elastic range even under large earthquakes, and applied for retrofit of existing building and new construction. These examples achieve not only high seismic performance but also improved energy efficiency and building appearance.

For avoiding possible damage concentration at weak stories and residual drift ratio, introducing spine frames with energy-dissipating members is effective. Aside from self-centering systems using PT-wires, perimeter elastic moment frames were proved to provide enough self-centering.