ON THE DIVERSITY OF DESIGN CRITERIA IN SEISMIC DESIGN

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Abstract

In Japan, the earthquake of M7 or more since the Kobe earthquake in 1995 occurred at a rate of almost one year. At the Kumamoto earthquake in 2016, several production facilities suffered a large operating loss. The modern latest production system is established with IT-advanced production equipment and inter-company network. Therefore, the influence of earthquake shaking on non-structural members and production equipment rather than damage to structures is important. In the future seismic design, protection of human life is essential, performance targets corresponding to individual buildings such as business activities are required.

1. Introduction

Non-structural members such as ceilings, partition walls, OA floors, and equipment have been designed for small and medium-sized earthquakes, and they cannot help breaking for large earthquakes It has been thought. The seismic isolation structure has greatly contributed to the maintenance of the function of the facility, such as disaster prevention hubs and hospitals, whose functions are required immediately in the event of an earthquake. In general, however, it is not easy to realize a seismic isolation structure in a production facility consisting of several buildings with a large scale at a lower level, and in most cases there are cases where it is unavoidable to plan with conventional structural system. Therefore, considering the Kumamoto earthquake as an example, consider the seismic design of non-structural members

2. 2016 Kumamoto Earthquakes

Kumamoto earthquake was a series of earthquakes, magnitude 7.0 mainshock which struck beneath Kumamoto City of Kumamoto Prefecture in Kyushu Region, Japan, at a depth of about 10 km (6.2 mi),and a foreshock earthquake with a magnitude 6.2. Kumamoto district is over 1000 km away from Tokyo, but many plants were located because of abundant water resources and few earthquakes.

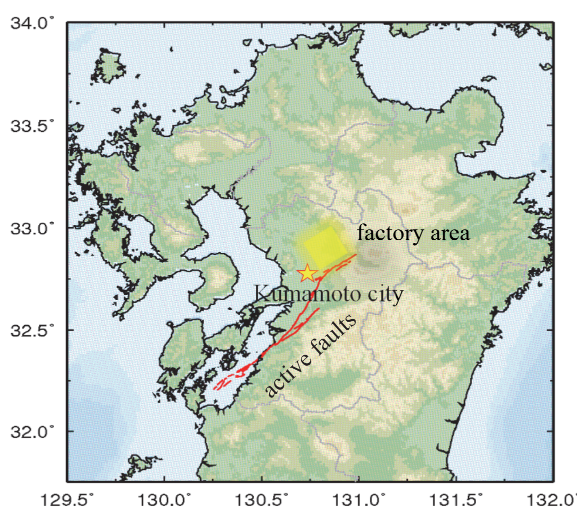

Figure 0. Map of Kumamoto earthquakes.

3. Damage Status of Non-Structural Members

3-1 Ceiling. In general ceilings used in Japan, ceiling materials are received by sub-beam, main-beam, as shown in Fig. 1, and hanging them from the upper floor slab is often used. Since these two kinds of beams are clamped with a clip of a fit type, many cases occurred in which the ceiling material dropped due to the shaking of the clip due to the shaking at the time of the earthquake. In addition, cases where the ceiling material was only suspended from the slab, sufficient horizontal rigidity was lacking enough to vibrate, and cases of falling after the deformation were also seen.

Figure 1. Damage of ceilings

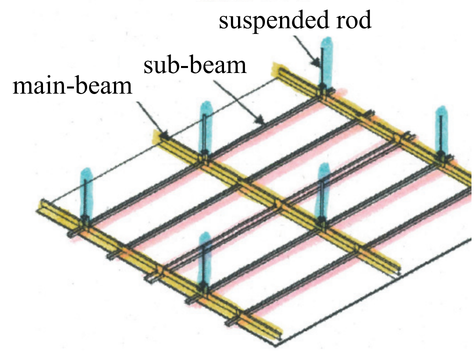

Figure 2. Structure of ceilings.

3-2 Partitions. Figure 4 shows the structure of a typical dry partition wall used in Japan. A lightweight steel frame post is fitted at regular intervals between the slabs above and below the layer, or between the slab and the ceiling, as shown in Figure 1, and constitutes the base material of the wall plate. Experiments have confirmed that the underlying material can move horizontally along the socket and follow the interlayer deformation to some extent. In the Kumamoto earthquake, many posts were detached from the sockets due to deformation of the surface which could not follow the interlaminar deformation of the building and many were seen.

Figure 3. Damage of dry partition.

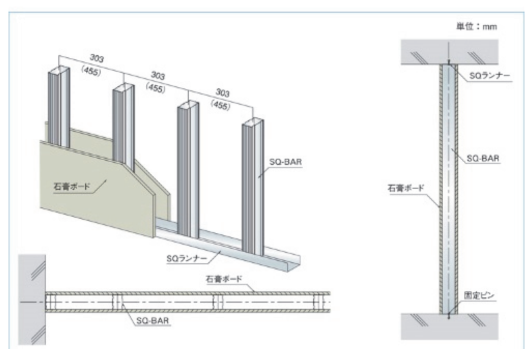

Figure 4. Structure of partition.

3-3 Expansion Joints. In the conventional thinking, expansion joints follow the relative deformation between buildings during the middle earthquake, and at the time of a large earthquake, in many cases, the criteri is not to collide with each other even if the hardware is damaged. Therefore, as the damage of the expansion joint, expansion joint joint hardware cannot keep up with the building deformation at the time of the large earthquake, and there are many cases where the finish around the expansion joint is damaged.

Figure 5. Damage of expansion joints.

3-4 Building Facilities. Damage to equipment in the past earthquake is always seen irrespective of its magnitude, and depending on the damaged part, it is an important element forced to stop the building function for a long time.

Figure 6. Damage of equipment.

The horizontal seismic intensity for the design for the facility is based on design codes, equipment has a value according to the earthquake class / , Earthquake support interval and seismic support specification are set for piping / duct.

On the other hand, however, a seismic performance of "structural body", "building non-structural member" and "facility" is set independently and many buildings are not consistent. For that reason, damage cases such as breakage and dropout of support members designed with underestimated stress, mutual interference and collision due to excessive deformation are also seen.

4. Response of Non-Structural Component During Earthquakes

Seismic responses of non-structural members were examined by a factory as a model. The analysis model was steel structure with 3 stories above the ground and 30 m in height, response analysis was performed with the phase characteristics of the earthquake motion, the damping of the building model (including escape soil-structure interaction, etc.), the building floor number, the structural form, etc. as parameters . The analysis model is shown in fig.9. In addition, the phase characteristics of the seismic motion were set to 6 types in total, including 2 random phases and 4 actual phases. The earthquake ground motion of the 500 years return period level specified by the Building Standard in Japan in the engineering foundation is input. Amplification due to the influence of the surface soil from the engineering foundation to the base of the building base is evaluated according to the ground type 1:hard to 3:soft. Also, in accordance with the amplification of the surface soil, damping to the ground was taken into consideration.

Here, in addition to the internal damping of the building, the hysterical damping, and the damping of the surface soil, such as damping to be considered in the building model, can be considered. Among them, the internal viscous damping is generally set to 2% in steel-framed buildings in many cases. On the other hand, the hysterical damping is a value that varies depending on the structure type and the amount of deformation, and varies depending on the building. In addition, it is known that there is soil-structure interaction, input loss, etc. to the ground when earthquake ground motion is input to the building, but this also changes according to the structural form and basic form of the building. In this paper, the time history response analysis was performed by evaluating these damping collectively as 5%, 10%, 15% (evaluated as internal viscous damping in analysis)).

Fig. 11 shows the response acceleration and the response displacement of the non-structural member fixed to the floor of the upper floor from the basement of the building.

Among the response values, red represents damping 5%, blue: 10%, green: 15%, and the results of six kinds of phase characteristics are superimposed.

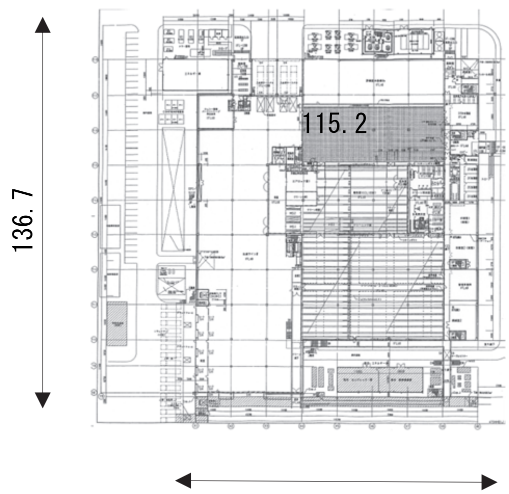

Figure 7. Plan of model building.

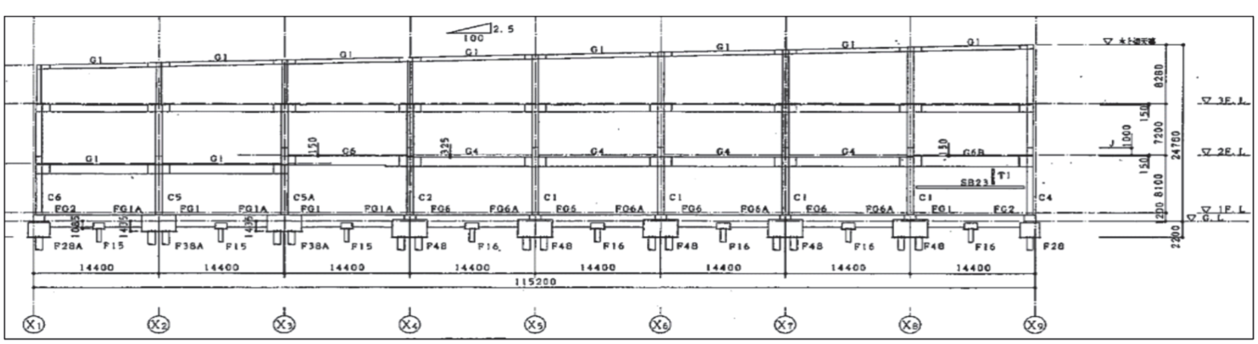

Figure 8. Elevation of model building.

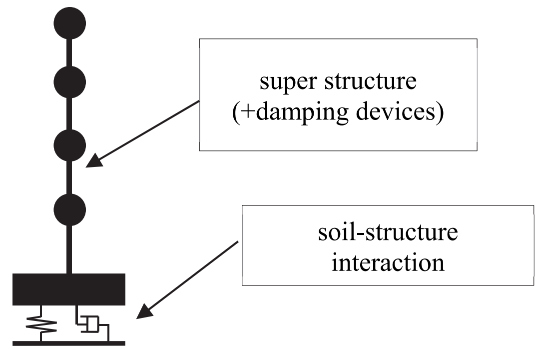

Figure 9. Analysis model.

1. From the analysis results the following can be seen. A large response (resonance) occurs in the acceleration / displacement near the building primary period (T1 = 1.14 seconds).
2. There is a slight difference in response value due to phase characteristics.
   The response value varies depending on the damping, and the response value decreases as the damping amount increases.
3. The difference in responses due to the difference between the 2 types and 3 types of ground did not show a big difference and the response of the 2 types of ground was slightly smaller than the response of the 3 types of ground.
4. If the natural period of the non-structural member is set to 0.3 seconds or less, for example, the amplification of the response acceleration is limited to some extent and the response displacement becomes small.
5. Even if the period of nonstructural members is increased to avoid resonance with buildings, large response deformation cannot be avoided.

5. A Case Study for Deformation Control

In order to reduce the damage of non-structural members from past damage cases, it is considered important to suppress story deformation in accordance with securing sufficient rigidity of nonstructural member. We compare earthquake response when oil damper is inserted as a method to reduce interlaminar deformation. The input earthquake ground motion was the actual earthquake ground motion recorded near the factory affected by the Kumamoto earthquake. The building model assumes the installation of a 7% damping device in the same model as above. As for the maximum response deformation, it is only about a 30% reduction effect compared with the case without damper, but it is understood that the response characteristics are greatly different when compared in response in time history. Especially, the effect after the maximum response is more than 50% is seen. This discussion is only an analysis case using one observed seismic motion and cannot be concluded as a general theory. However, considering that the damage to the nonstructural members in the past is not so large at the time of the short-time large acceleration earthquake, considering that the damage to the seismic motion for a long time is large, the dry partition due to the story deformation It can be inferred that the vibration damping structure has utility against damage to non-structural members such as expansion joints.

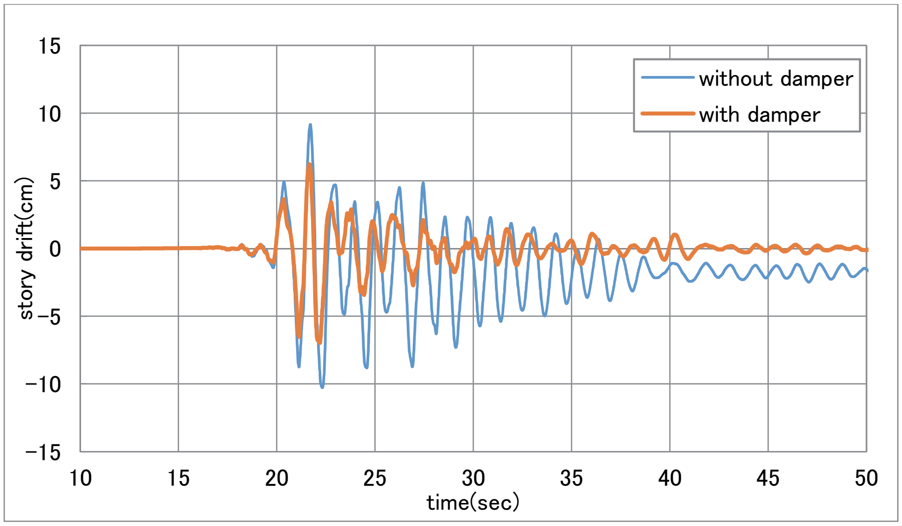

Figure 10. Story drift of 1st floor.

6. Conclusion

Although it is an analysis as an example, it is considered important to ensure sufficient rigidity not to resonate with the swing of the building in order to reduce the damage of the non-structural member, that is, to reduce the response. In addition, it seems that there is a possibility of damage suppression effect of damping system for low-rise building. Due to the sophistication of building functions and production facilities, various structural performances are required, and future structural design needs to respond to it.

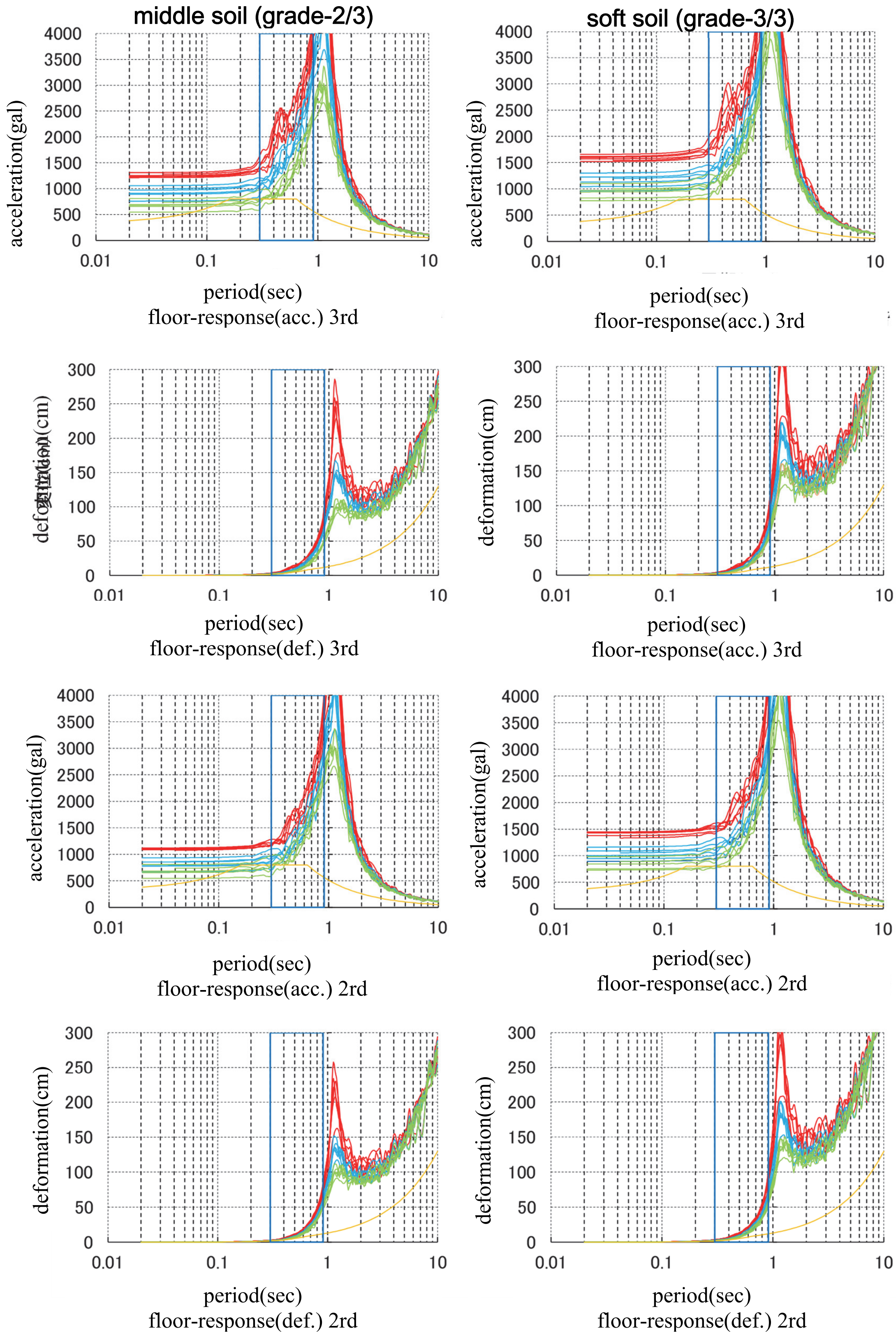

Figure 11. Floor-response for 2nd&3rd floor.