Earthquake Response Observation of Isolated Building

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1.INTRODUCTION

Base isolation system is expected to be one of the key technology for a rational design of FBR plant. In order to apply this system to important structures, accumulation of verification data is necessary.

From this point of view, the vibration test and the earthquake response observation of the actual isolated building using laminated rubber bearings and elasto-plastic steel dampers were conducted for the purpose of investigating its dynamic behavior and of proving the reliability of the base isolation system. Since September in 1986, more than thirty earthquakes have been observed. This paper presents the results of the earthquake response observation.

2.OUTLINE OF BASE ISOLATED BUILDING AND ISOLATION DEVICE

Base Isolated Building The base isolated building, an object of test and observation, is a four-story reinforced concrete building with dimensions of 15m in width, 20m in length and 14m in height as shown in Fig.1. Total floor area is 1,330m^2 and the weight is 2,250ton. Seismic isolation devices are installed between the basemat and the first floor.

Seismic Isolation Device The seismic isolation devices consist of 25 laminated rubber bearings and 12 elasto-plastic steel dampers as shown in Fig.2 and Fig.3. The average horizontal stiffness of the rubber bearing used for this isolated building is 0.82ton/cm. The stiffness of the damper before yielding is about 2.0ton/cm and the yielding displacement is about 30mm. Under the assumption that the damper behaves elasto-plastically, the design horizontal natural frequencies of this building with the isolation devices are 0.71Hz(1.4sec) and 0.48Hz(2.1sec) corresponding to pre-yielding stiffness and post-yielding stiffness,respectively.

3.EARTHQUAKE RESPONSE OBSERVATION

3.1 Observed Earthquakes

More than thirty earthquakes have been observed since September in 1986 in the base isolated building. Epicenter of each earthquake is shown in Fig.4. Observed earthquakes are classified and characterized as shown in table 2.

Fig. 5 shows the averaged acceleration fourior spectra on the basemat of each group earthquakes. Each spectrum is normalized such that a maximum spectrum value be 1.0. Low frequency components below 1.0Hz of groupIII are larger than that of group I and II .

Table 1. Classification of Obserbed Earthquakes

Group No.	Type	Epicentral Distance	Focal Depth	Magnitude*
I	Near	0 ～ 50km	50 ～ 80km	～ 6.0
II	Intermediate	50 ～ 150km	40 ～ 60km	～ 6.0
III	Far	150km ～	0 ～ 50km	6.0 ～ 7.0

* Magnitude of Japan Meteorological Agency

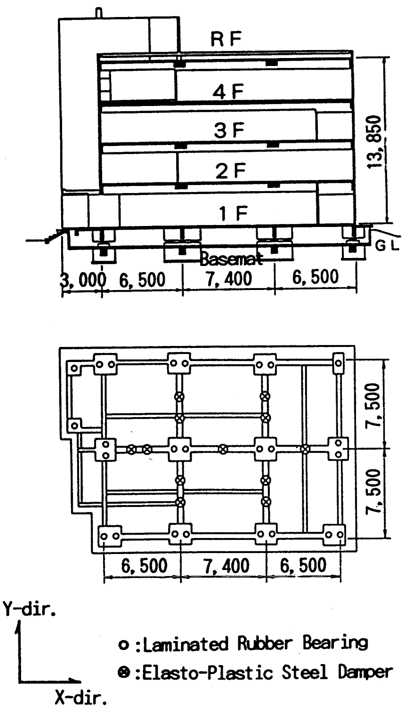

Fig. 1 Section and Plan of Building

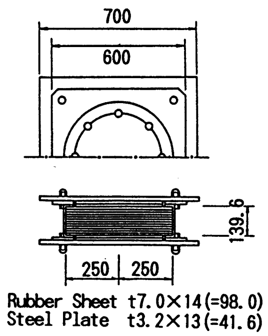

Fig. 2 Laminated Rubber Bearing

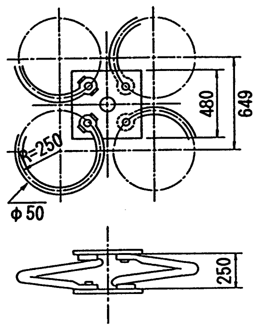

Fig. 3 Elasto-Plastic Steel Damper

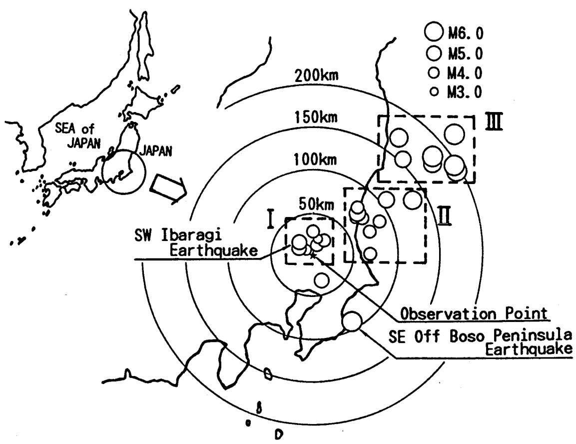

Fig. 4 Epicenter of Observed Earthquakes

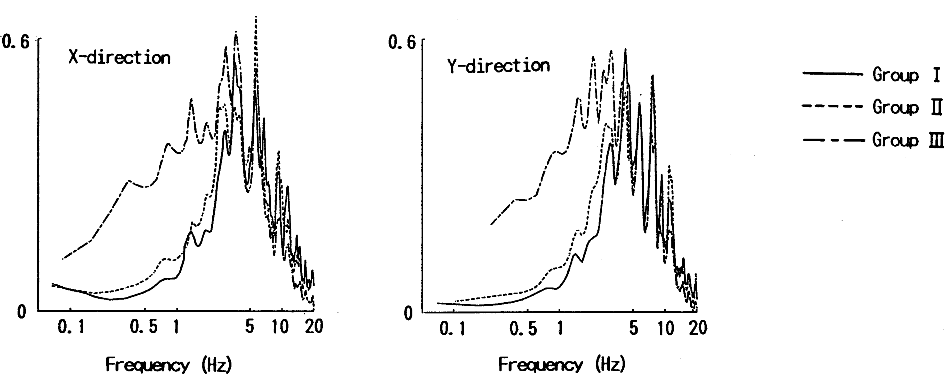

Fig. 5 Normalized Acceleration spectra on Basemat

3.2 Responce of the building

Fig. 6 shows the relationship between the ratio of the maximum acceleration (1st floor / basemat) and the maximum acceleration on the basemat. It can be seen that the horizontal acceleration ratio of both group Ⅰ and Ⅱ arthquakes are less than 0.5,that is ,the acceleration on first floor is reduced sufficiently. But,in case of groupⅢ earthquakes,acceleration is not so reduced. This is because they contain much low frequency componens as is shown in Fig.5. The average ratio is around 0.6 in both X and Y-direction. On the other hand,the vertical acceleration ratio is almost constant and the average ratio is 1.24.

Fig.7 shows the relationship between the maximum relative displacement (basemat~1F) and the maximum acceleration and velocity on the basemat, respectively. Strong correlation is observed between displacement of the isolation device and input velocity. This suggests that the deformation of the isolation device can be predicted by the velocity of input earthquakes.

It must be noted here that the relative displacement of the isolation device in these earthquakes are all less than yielding displacement of the dampers of 30mm, so in these cases, dampers do not work as damping devices for any observed earthquakes.

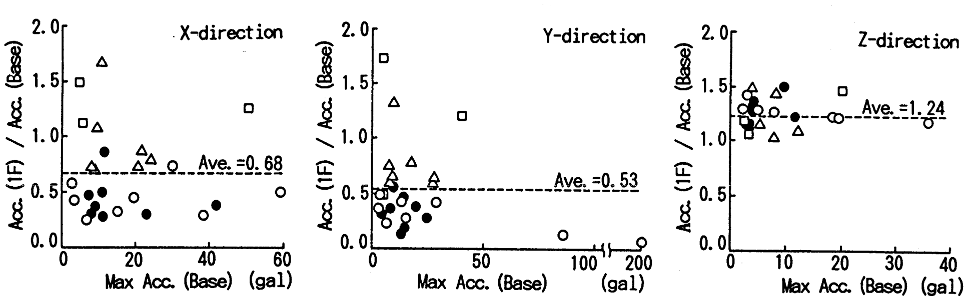

Fig. 6 Relationship between Acceleration Response Ratio of First Floor and Maximum Acceleration on Basemat

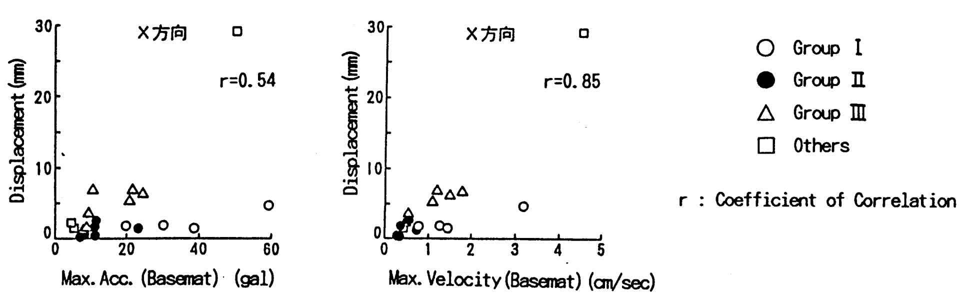

Fig. 7 Relationship between Maximum Displacement (1F-Basemat) and Maximum Acceleration and Velocity on Basemat

3.3 Typical Responce Records

Two typical response records are introduced. One is the response for the SW Ibaraki Earthquake on June 30, 1987, the epicenter of it is very close to the observation point. Another is for the SE Off Boso Peninsula on Dec. 17, 1987 which includes much low frequency components compared with the other earthquakes. Data of both earthquakes are shown in table 2. The maximum acceleration distribution, time histories and acceleration response spectrum for 5% damping on each floor level are shown in Fig.8,9 and 10 respectively.

SW Ibaraki Earthquake, June 30, 1987 This is a typical high-frequency earthquake as seen in the time history and the acceleration response spectrum on the basemat. The maximum horizontal acceleration of 269gal was recorded on the ground surface at the begining of a main shock. On the other hand, those in the building were around 20gal, showing a remarkable seismic isolation effect, especially in y-direction. The response spectrum on the first floor and the roof have a peak at the frequency around 7.0Hz(0.15sec), due to the second mode excitation. However, the acceleration responce spectra in the building are reduced compared with that on the basemat in higher range than 1.5Hz.

SE Off Boso Peninsula Earthquake, December 17,1987 The maximum horizontal ground surface acceleration is 83gal and those in the building are around 60gal in x-direction. In this case,acceleration reduction effect is not so large as the case of June 30,1987 earthquake, however, the acceleration is not amplified in the building, which differ from the case of non-isolated building. As for the acceleration responce spectra, the first mode frequency of 0.83Hz(1.2sec) is especially predominated. It is because the ground motion has a peak at this frequency. However, at the higher range than 1.5Hz (0.67sec), acceleration responce spectra in the building are not higher than that on the basemat.

Table 2 Data of the Earthquakes

NAME	DATE	Magnitude	Focal Distance	Epicentral Distance	Depth
SW Ibaragi	June 30, 1987	5.1	56km	11km	55km
SE Off Boso Peninsula	Dec. 17, 1987	6.6	125km	104km	70km

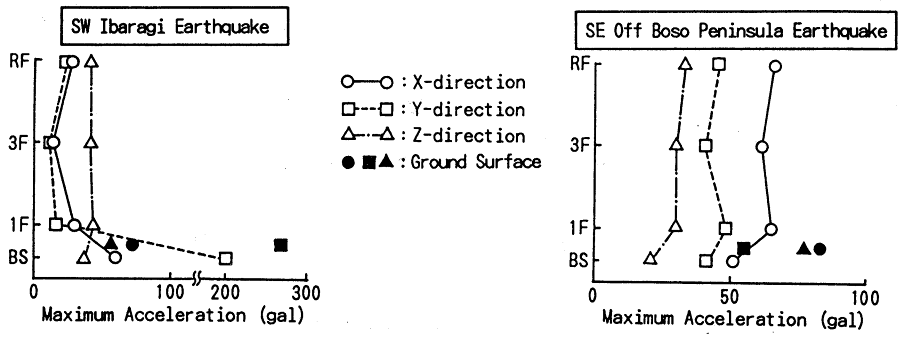

Fig. 8 Distribution of Maximum Acceleration

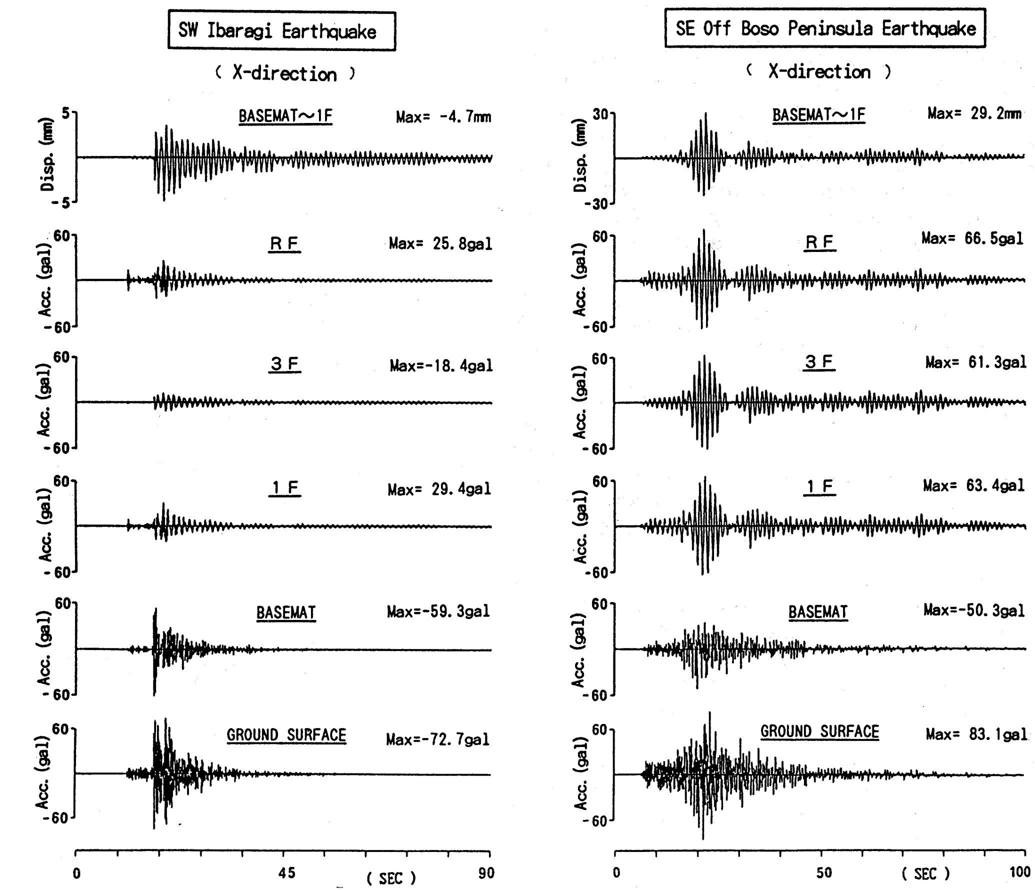

Fig. 9 Time Histories of Acceleration and Displacement

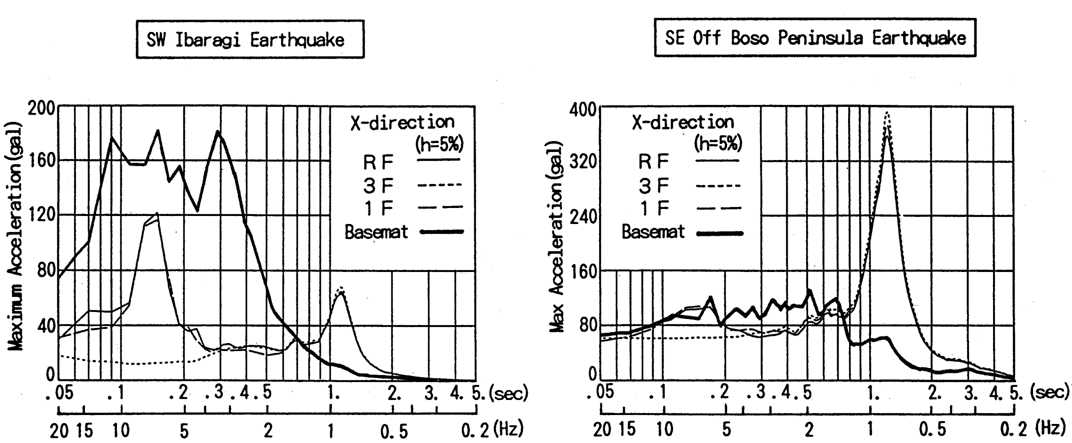

Fig. 10 Acceleration Response Spectra

3.4 Torsional Behavior of the Building

The base isolated building is supposed to perform the torsional behavior due to the eccentricity during earthquake. In this building, the eccentric distance between the stiffness center of the isolation devices and the gravity center of the upper structure is about 30cm. Fig.11 shows the time histories of the translational displacement and the torsional angle at the center of the gravity on the first floor in the case of Dec.17,1987 earthquake. The maximum horizontal displacement due to torsional motion is about 3.0mm at the edge of the building which corresponds 15% of the recorded displacement. This is not so large as to make influence on the base isolation devices. And if needed, the torsional behavior can be reduced by adequate arrangement of the isolation devices.

Fig.12 shows the time history of the relative torsional angle between the first and the roof floor which indicates torsional behavior in the upper structure. Maximum torsional angle of 7×10^{-5} rad. is an order smaller than that of the first floor of 3×10^{-4} rad. in fig.14. This means that the torsional deformation of the base isolated building concentrate at the isolation devices and that of the upper structure is very small.

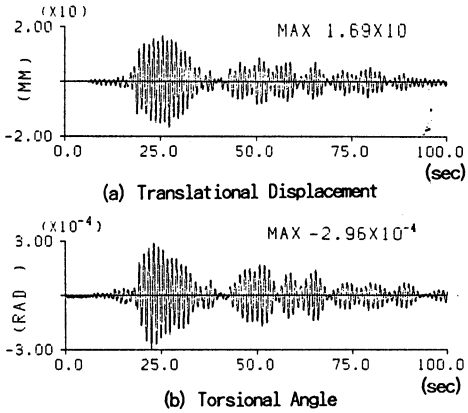

Fig. 11 Translational Displacement and Torsional Angle at the Center of Gravity on First Floor

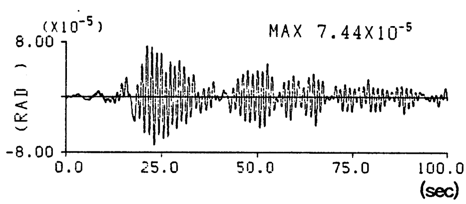

Fig. 12 Relative Torsional Angle between First Floor and Roof Floor

4.CONCLUSIONS

Through the earthquake responce observation of the base isolated building,the followings are confirmed.

i) Acceleration response during earthquake is strongly influenced by the frequency characteristics of the ground motion, especially, intensity of the component around the first natural frequency of the base isolated building. However, for any earthquake, it is sufficiently reduced in comparison with that of the ground surface.

ii) The maximum relative displacement of the isolation device is almost in proporsion to the maximum velocity of input eartquake.

iii) Torsinal deformation of the base isolated building is concentrated at the isolation devices and that of the upper structure is very small.

REFERENCES

1. S. Aoyagi, T. Mazda, O. Harada, M. Takeuchi et al., Experimental Study on the Dynamic Behavior of the Base Isolated Building, 9th SMIRT(1987), pp.687-692.
2. S.Aoyagi, T.Mazda, O.Harada, S.Ohtsuka, Vibration Test and Earthquake Responce Observation of Base Isolated Building. 9th WCEE(1988).