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Design of 3-D earthquake isolation floor applied to a large room housing computers

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ABSTRACT: This paper is concerned with a 3-D isolation floor. This floor is a partial 3-D isolation floor in which a vertical isolated component is incorporated in a section of a horizontal isolated part with a direction converter of vertical vibration.

Vibration tests were carried out to check this mechanism. The vibration tests were designed to simulate seismic motions of subjective floors of building. This paper shows a summary of the vibration tests and an example of this floor to applied a large computer room. The plan dimensions of the computer room is 91.8 m * 25.8 m. And maximum area of 3-D isolated part is 126 m^2 and total area of this 3-D isolation floor is 710 m^2.

1 INTRODUCTION

Computers are playing an increasingly important role in society and in economy, and therefor techniques to protect computer equipment from earthquake damage are becoming indispensable. At present, the most advanced and effective aseismic device for the protection of computer equipment is the earthquake isolation floor system.

A number of concepts for earthquake isolation floor systems have been developed in Japan; however, most of these systems are unable to reduce the vertical vibration component were not sufficiently effective in reducing vertical accelerations due to the high natural frequency (approximately the lowest 2.0 Hz) of the vertical isolation systems.

We have developed a 3-D isolation floor based on a new concept and have succeeded in reducing to a very high degree the forces of earthquake motions in 3 dimensions. The new concept involves the conversion of vertical vibrations, and the effectiveness of this system has been demonstrated through vibration tests.

There are many examples to applied this system for a room housing computers. One of them is an application for a large computer room. This report shows the vibration test and the example.

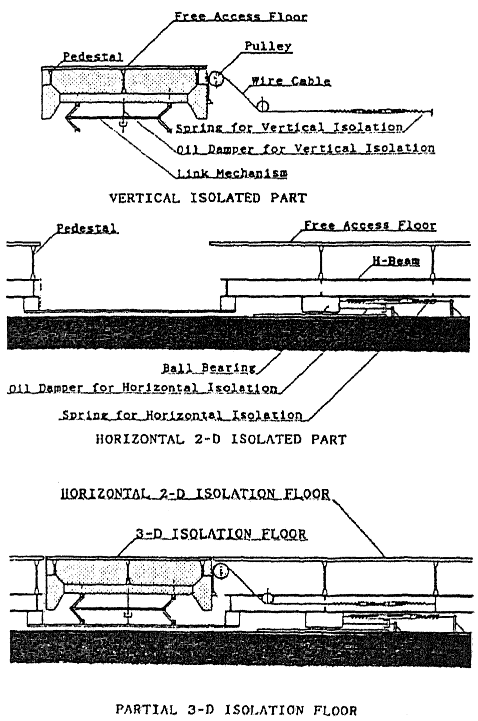


Fig.1 Basic concept of the partial 3-d isolation floor

2 BASIC CONCEPT OF THE ISOLATION FLOOR

The basic concept and fundamental mechanisms of the 3-D isolation floor are as shown in Fig.1. This is a partial 3-D isolation floor system in which a vertical isolation floor is incorporated in a section of a horizontal 2-D isolation system.

The vertical isolation floor is suspended by a vibration converter which is consist of wire cables, coil springs and pulleys. This vibration converter can achieve a far lower natural frequency compared to conventional vertical isolation devices. Oil dampers are used to absorb vertical vibration energy, and link mechanisms are installed to resist rocking motion.

The new isolation floor has an direction converter of vibration for vertical isolation, and has the following advantages:

1. Ease in lowering the natural frequency in the vertical direction.
2. Complete resistance to rocking vibration of the 3-D isolation floor.
3. Installable in ordinary buildings, even in rooms not having high ceilings.

3 SUMMERY OF THE VIBRATION TESTS

The plan dimensions of the 3-D isolation floor for the vibration tests was 2.11*4.05m, as shown in Fig.2. The area of the 3-D isolation part was 0.81 m^2. The first natural frequency of the horizontal isolation system was 0.25 Hz, and that of the vertical isolation system was 0.5 Hz. The critical damping ration of the horizontal system was 0.18, and that of the vertical system was 0.30. A computer was positioned on the 3-D isolation part of the system.

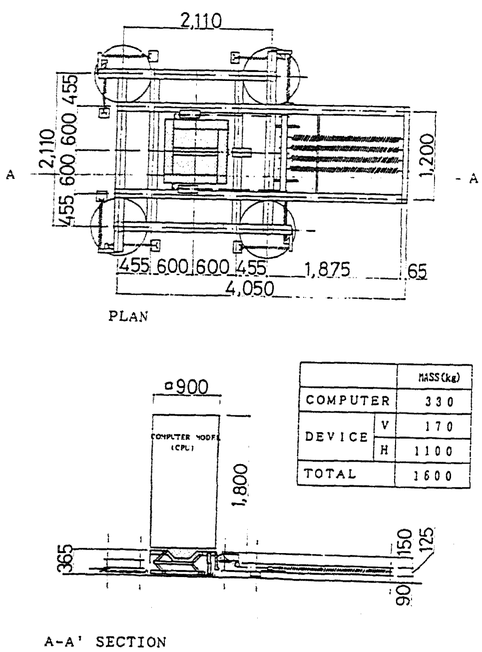


Fig.2 Specimens of the test model

The vibration tests were designed to simulated seismic motions of subjective floors of buildings when the buildings are accelerated by the following 3 recorded earthquake motions:

1. EL CENTRO (Imperial Valley, 1940)
2. Touhoku University, 1st Floor (Miyagi-ken-Oki, 1970)
3. Hachinohe (Tokachi-Oki, 1968)

The combinations of seismic directions were NS + UD and EW + UD for each earthquake wave. In addition, two types of response spectra were considered for each wave. One of the response spectra assumed that the isolation floor would be set up on the first floor of a 5-story RC building. In this case, the waves

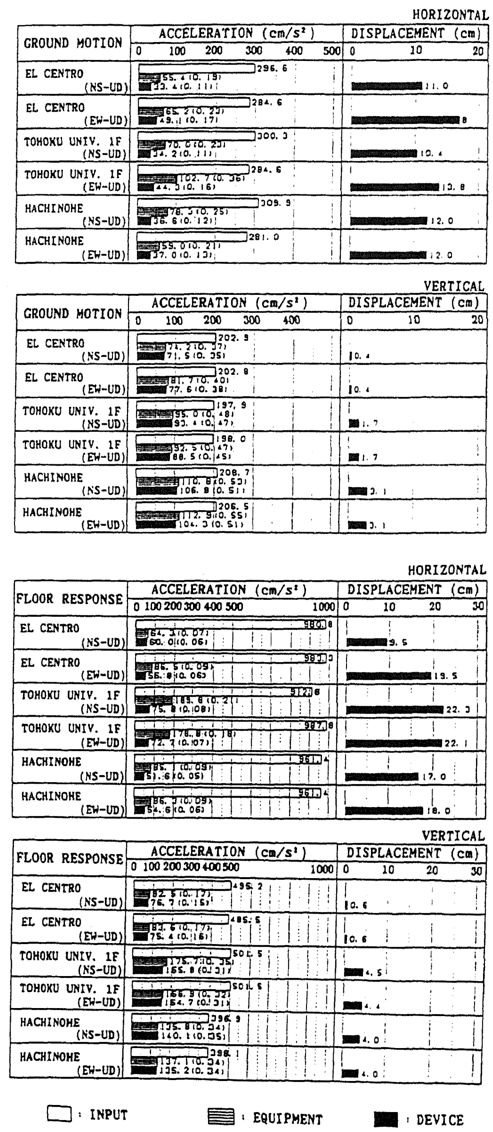


Fig.3 Aseismic effect

simulated the recorded waves (GROUND MOTION). The other type assumed that this system would be installed on the 5th floor on the same building. The waves in this case were obtained by a seismic response analysis on the building (FLOOR RESPONSE).

In the case of "GROUND MOTION", the maximum acceleration was 300 cm/s^2 (horizontal) and 200 cm/s^2 (vertical). In the case of the "FLOOR RESPONSE", the maximum horizontal acceleration was adjusted to 1000 cm/s^2 and the maximum vertical acceleration was adjusted 500 cm/s^2. The results of the vibration tests are represented in Figure 3 which shows the maximum accelerations and displacements of the shaking table, the isolation device, and the computer.

By comparing the magnitudes of the accelerations and the displacements, it is clear that this 3-D isolation floor can sufficiently reduce not only the horizontal acceleration, but also the vertical acceleration.

4 APPLIED TO A LARGE COMPUTER ROOM

4.1 SUMMARY OF THE LARGE COMPUTER ROOM

The 3-D isolation floor is installed in a computer room (of which size is 13.2*53.6 m) of a computer building (of which size is 25.8*91.75 m). Figure 4 shows 4th floor plan of the computer building and figure 5 shows a X-Z section and Y-Z section. The building is a 5 stories building and made of reinforced concrete. The plan dimension of the building is 25.8*91.8 m and the height is 17.2 m. Basic characteristics are shown in Table-1.

4.2 DESIGN OF THE LARGE 3-D ISOLATION FLOOR

A floor beam plan of a large 3-D isolation floor is shown in Fog.6. A whole size of this floor is 8.9*50.9 m. A 3-D isolated area

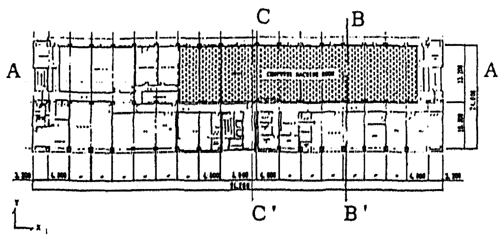
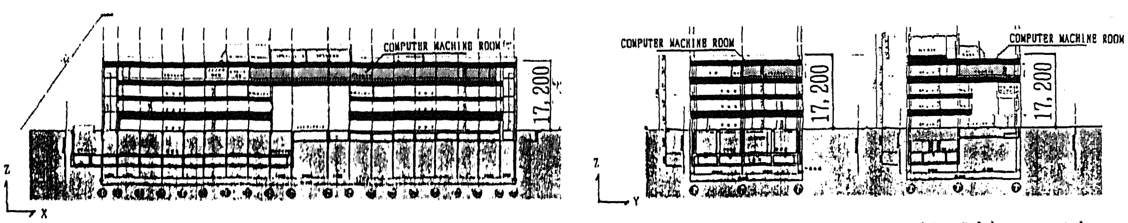


Fig.4 The 4th Floor Plan

Table-1 Basic characteristics of the building

DIRECTION	1st NATURAL FREQ.	DAMPING RATIO
X (LONG)	2.30	0.05
Y (SHORT)	4.90	0.05
Z (VERT.)	16.40	0.05



X-Z(A-A') section Y-Z(B-B') section Y-Z(C-C') section

Fig.5 Sections of the building

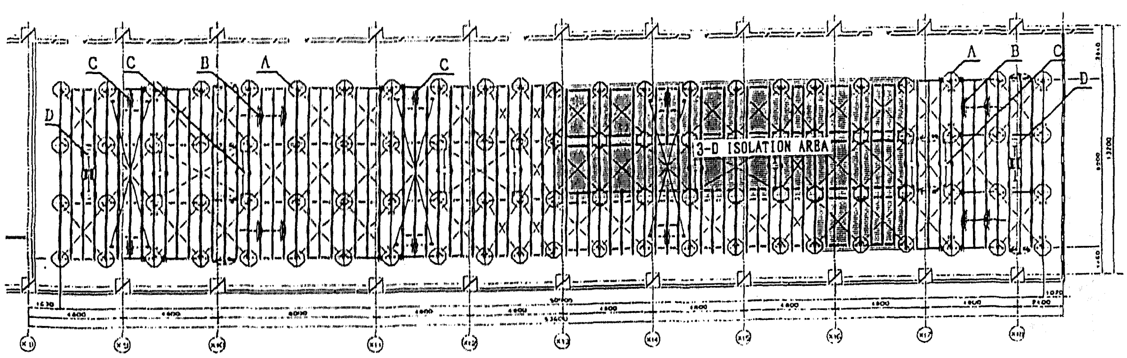


Fig.6 Beam plan of the horizontal isolation floor

which are patched in the figure is 126 m^2. This area is the area that a vertical isolated floor is put on horizontal 2-D isolated floor. A 3-D earthquake isolation is achieved by means of the combination of the vertical floor and the horizontal one.

Numerical analysis is carried out to design horizontal springs, horizontal dampers, vertical springs and vertical dampers of the isolation floor. Input acceleration data for analysis are calculated by floor response analysis of the computer building. The first natural frequencies of X,Y and Z direction at 4th floor are respectively 2.3 Hz, 4.9 Hz and 16.4 Hz. Both horizontal and vertical damping ratio are assumed 0.05.

Figure 7 shows a whole appearance of frame works of the 3-D isolation floor. Figure 8 shows a frame of the vertical isolated floor on the horizontal isolated floor. The coil springs for vertical isolation are also shown in Fig.8.

Figure 9 shows a supporting unit which consists of a ball bearing and a tempered steel plate. The supporting units are set up at intervals of about 2.4 m in X direction and about 3.0 m in Y direction.

This 3-D isolation floor has the other 2 mechanisms which the previous isolation floor for vibration test did not have. One of them is a trigger mechanism which make the isolat-

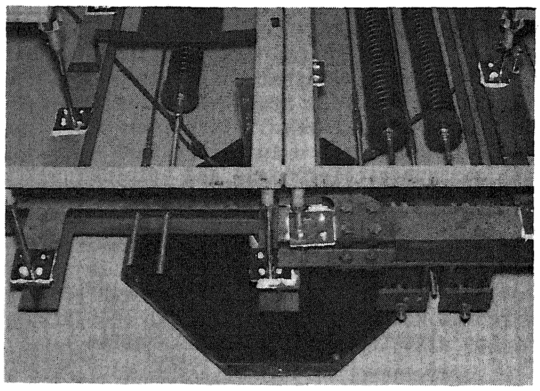


Fig.9 The supporting unit

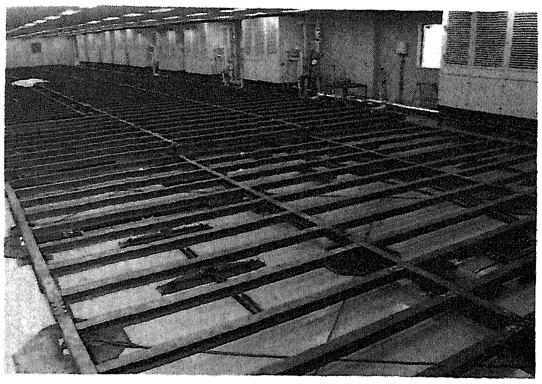


Fig.7 Appearance of the framing works of the 3-d isolation floor

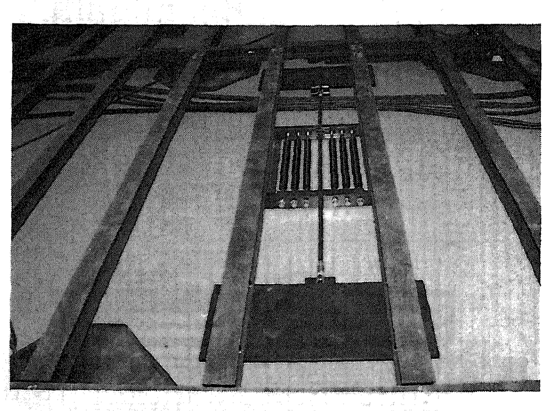


Fig.10 The trigger mechanism

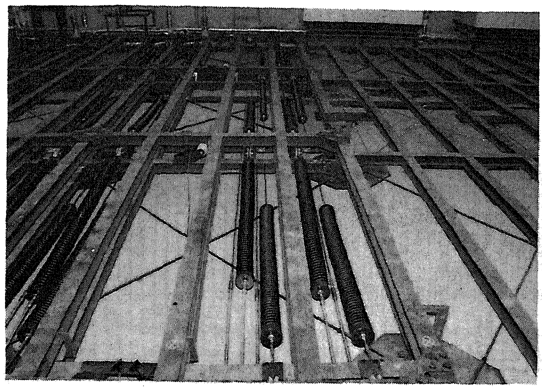


Fig.8 The vertical isolation floor and the vertical springs

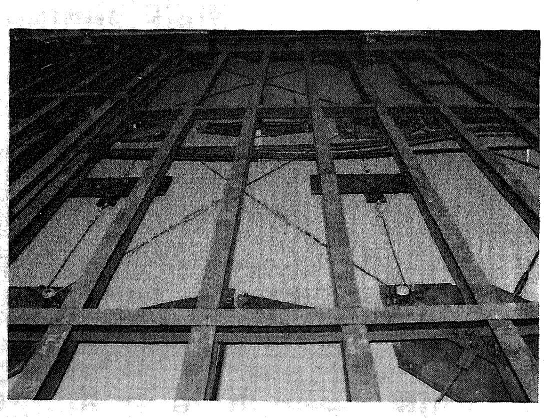


Fig.11 The resistance system to yawing motion

ion floor start only in seismic events. The trigger mechanism is shown in Fig.10. Another one is a resistance system to yawing motion.

Figure 11 shows the resistance system to yawing motion. The other 6 devices are installed in the horizontal isolation floor. Rocking protection devices of which mechanism is the same as the yawing resistance device are also installed between vertical isolation floor and the horizontal isolation floor.

CONCLUSION

We demonstrate the effectiveness of the 3-D isolation floor with the vibration converter by means of the vibration tests. And we also show the example of this floor which is applied to the large computer room. In this application, trigger mechanisms and yawing resistant devices are newly installed in this system. The trigger mechanisms are installed in order not to disturb users who work in computer room in ordinary time. According to install the yawing resistant devices, it can protect computers from earthquake including the vibration of any directions.

The computer building is in Tokyo and the computer room has been already used. Accelero meters are set now. We have a plan continuing the study of the 3-D isolation floor using results of the observations.

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