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THREE-DIMENSIONAL SEISMIC ISOLATION FLOOR SYSTEM USING AIR SPRING AND ITS INSTALLATION INTO A NUCLEAR FACILITY

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1. INTRODUCTION

As high-precision equipments such as computer systems have been highly advanced in the nuclear field, it is important to protect them from earthquakes. The use of seismic isolation system may provide a practical solution for the object [1].

Research on the use of laminated rubber bearings as seismic isolators has been primarily focused on the development of base-isolated buildings. The laminated rubber bearing shows excellent seismic isolation performance to horizontal directions. However, it cannot reduce the response due to vertical seismic motion. Strength of buildings is usually sufficient to vertical earthquake motion, but high-precision equipments inside of buildings are easily resonant to vertical motion as well as horizontal one. Hence, the use of three-dimensional isolators is necessary to protect them from earthquakes.

Development of three-dimensional isolators for base-isolated buildings may not be practical because of its high cost and of the difficulty in suppressing a rocking motion. One of the practical methods for protecting these equipments may be use of a three-dimensional seismic floor isolation system, on which they are set up.

A three-dimensional seismic isolation floor system has been developed, where the isolator is constructed by the combination of an air spring and a laminated rubber bearing [2,3]

In genaral, isolated structure should be sufficiently stiff relative to an isolator. In three-dimensinal seismic isolation floor systems, however, vertical stiffness of floor structure is limited as compared with an isolator, and load distribution on the isolated floor is non-uniform. Therefore, bending deformations of floor structure is easily caused by vertical seismic motion. The use of air springs as vertical isolators enables to attain uniform vertical motion without bending deformations, because its vertical stiffness is propotional to air pressure i.e. its suppoting load.

The present three-dimensional seismic isolation floor system has been installed into a part of the central control room of the Tokai Vitrification Facility (TVF) of Power Reactor and Nuclear Fuel Development Corporation (PNC). In this paper, we discribe an outline of the above system, the design conditions and the results of performance test using a three-dimensional shaking table.

2.BASIC CONCEPT OF THE PRESENT SYSTEM

2.1 OUTLINE OF THE SYSTEM

The system consists of three-dimensional isolators, viscous dampers and automatic floor level controller and so on, as shown in Fig.1.

The three-dimensional isolator, the main device of the system, is constructed by the combination of an air spring and a laminated rubber bearing. Vertical vibration is absorbed by the air spring, while horizontal one is primarily by the laminated rubber bearing. Fig.2 shows a cross-section of the isolator.

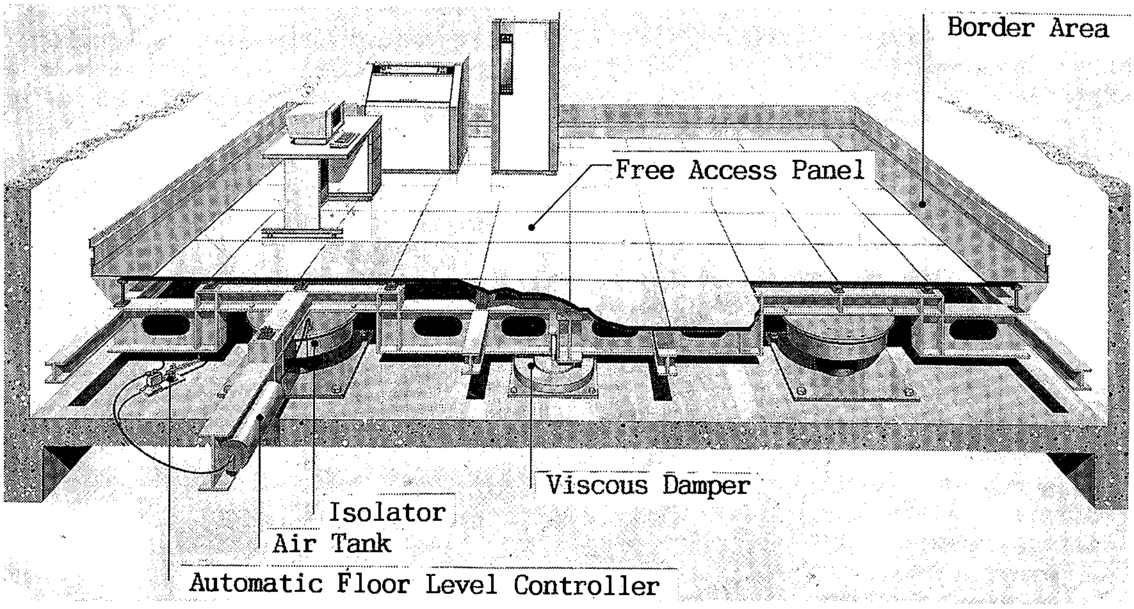

Fig.1 Three-dimensional Isolation Floor System

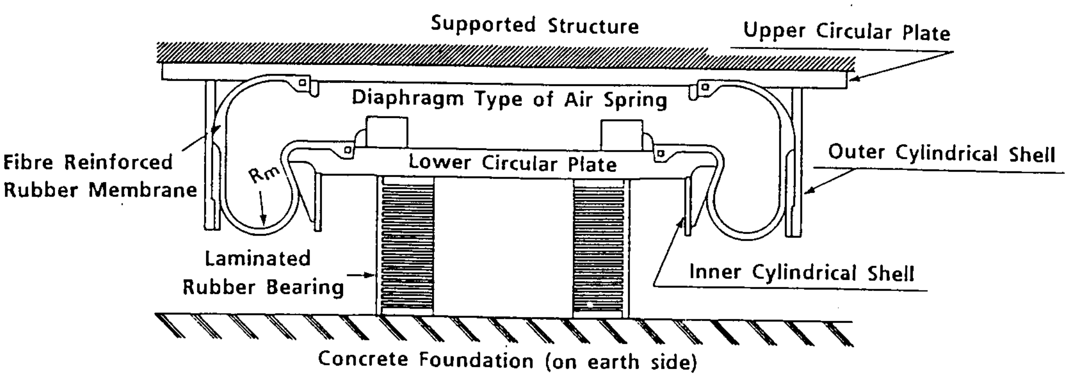

Fig.2 Three-dimensional Isolator

A viscous damper is adopted to reduce horizontal response displacement. It utilizes the shear resistance of highly viscous material located in the gap beetween the base plate of the vessel of the damper and the sliding plate. And an air damper utilizing the feature of an air spring is adopted to vertical damper, which will be discribed later.

2.2 MERIT IN USE OF AIR SPRING

One of the technical difficulty in three-dimensional seimic floor isolation system may be to attain the response in uniform translational motion to vertical seismic motion. In general, supporting load of each isolator varies due to non-uniform load distribution on the isolated floor, i.e. non-uniform arrangement of equipments. And vertical stiffness of floor structure is not sufficintly stiff so that bending deformations of floor structure are easily caused by vertical seismic motion. The use of air springs as vertical isolators enables to attain uniform vertical motion without bending deformations, because its vertical stiffness is propotional to air pressure i.e. its suppoting load. It should be noted that this specific feature of the air spring cannot be given by the use of a conventional coil spring.

Another merit of an air spring is to utilize air damping as a vertical damper with the auxiliary use of air tank. The air damping force is obtained from the resistance generated at an orifice equiped with the connecting part of the air spring with the air tank. The mechanism of air damper is simple as shown in Fig.3, and provides riliable high damping performance, which is independent of temprature.

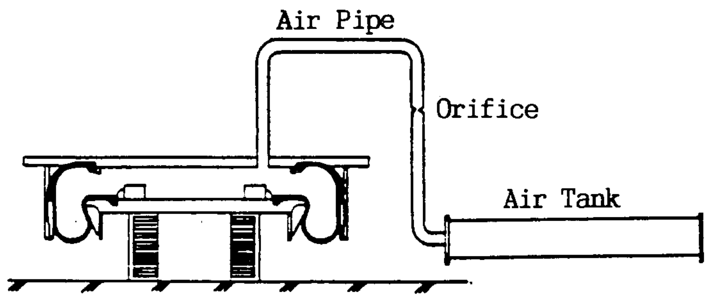

Fig.3 Air Damper

3.ISOLATION FLOOR SYSTEM INSTALLED INTO TVF

The present three-dimensional isolation floor system has been installed into TVF of PNC, in Tokai, Japan. TVF was constructed in 1992, to bear the mission of demonstrating the technology of radioactive liquid waste vitrification. The isolation floor system is installed into a part of the central control room on the second floor of the Technical Developement Building in TVF (Fig.4), with the aim of further increasing the reliability of contral equipments.

The TVF's isolation floor system is shown in Fig.5. The floor area of system is about $100m^2$, supported by four isolators. Natural frequencies, damping ratios and maximum allowable displacements of the system are shown in Table 1.

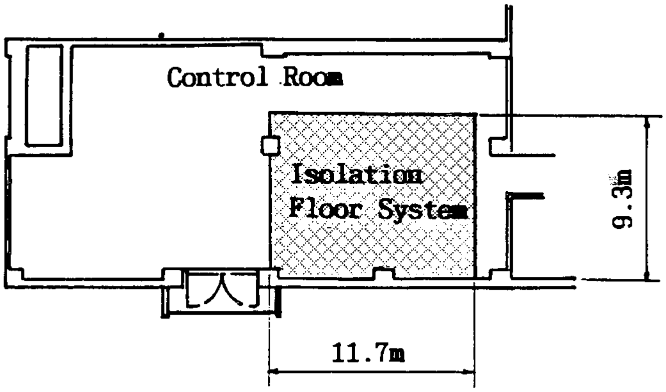

Fig.4 Arrangement of Isolation Floor System

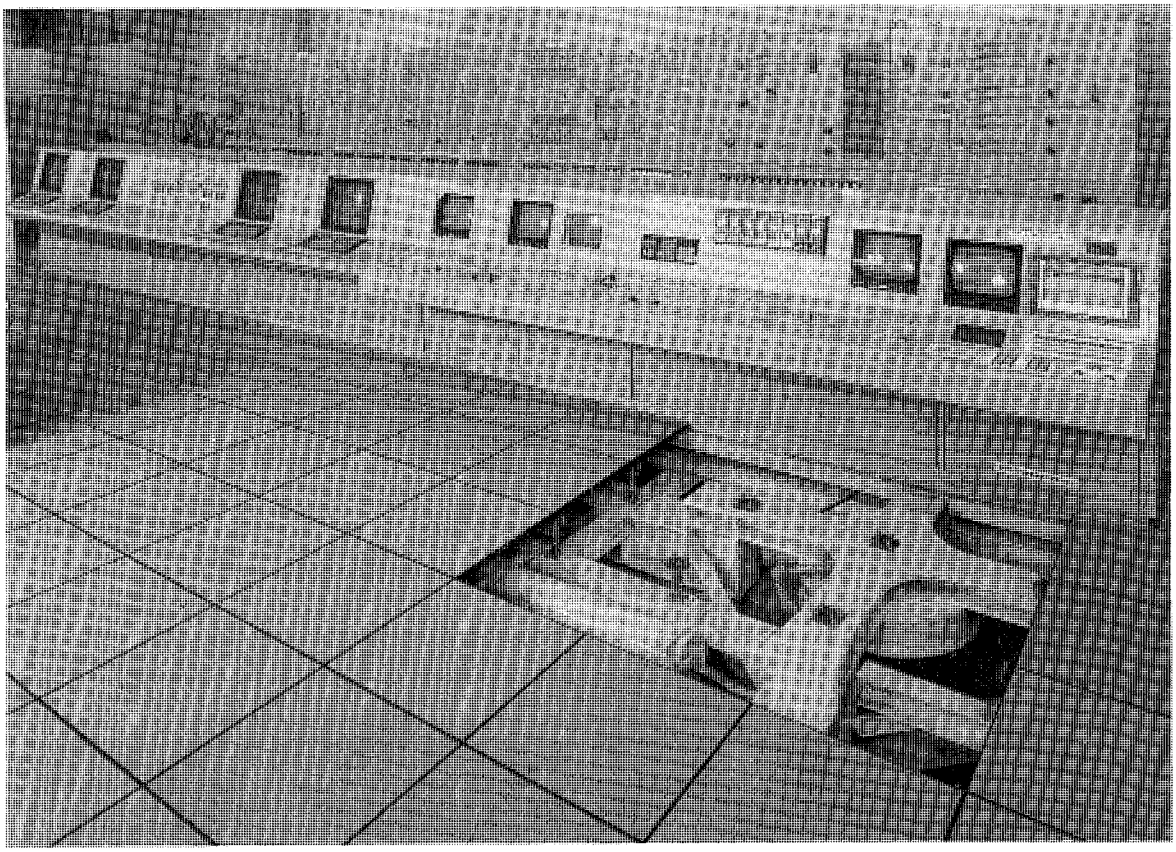

Table 1 Characteristics of TVF's Isolation System

	Natural Frequency	Damping Ratio	Allowable Displacement
Horizontal	0.7 Hz	20 %	± 150 mm
Vertical	1.2 Hz	20 %	± 40 mm

In floor isolation systems it is important to compromise reducing the response acceleration and suppressing large displacement relative to non-isolation part, as compared with the base isolation system. Because available area in control room is reduced by the increase of the border area which absorbs the above displacement smoothly. From the point of view, the frequency of 0.7Hz and damping ratio of 20% in horizontal direction were designed, respectively. Under these conditions, response displacement caused by the design base seismic motion is about 50mm. Maximum allowable displacement is ensured to be about three times of response displacement, which it may be sufficient under the design base earthquake.

Moreover, for the purpose of preventing serious damages under the seismic motion over the design base, a stopper device is adopted to the TVF's system. The stopper is made of rubber block, which suppresses the excessive displacement.

4.PERFORMANCE CONFIRMATION TEST

With the purpose to verify performance of the present system, shaking tests were performed using a floor model. A three-dimensional shaking table of 35tf in IHI Earthquake-Proof Engineering Laboratory was used for seismic isolation performance test. General view of the test model is shown in Fig.6. Four isolators of real size were used in the test model, while its floor area was reduced due to the restriction of the size of the shaking table.

An example of seismic isolation performances to El Centro-NS floor response waves is shown in Fig.7. The input waves were floor response wave at the second floor of the Technical Developement Building. Ground level motion is normalized to a maximum acceleration of $180cm/sec^2$. The seismic isolation performance for the other typical seismic waves were also confirmed in the test.

5.CONCLUDING REMARKS

A three-dimensional isolation floor system has been developed, where the three-dimensional seismic isolator combining an air spring and a laminated rubber bearing is used. And it has been installed into the central control room of PNC's TVF. By using an air spring, the system has various practical specific features including excellent seismic isolation performance. We plan to observe the seismic behavior of the system to confirm the seismic isolation performance from the results of these observation.

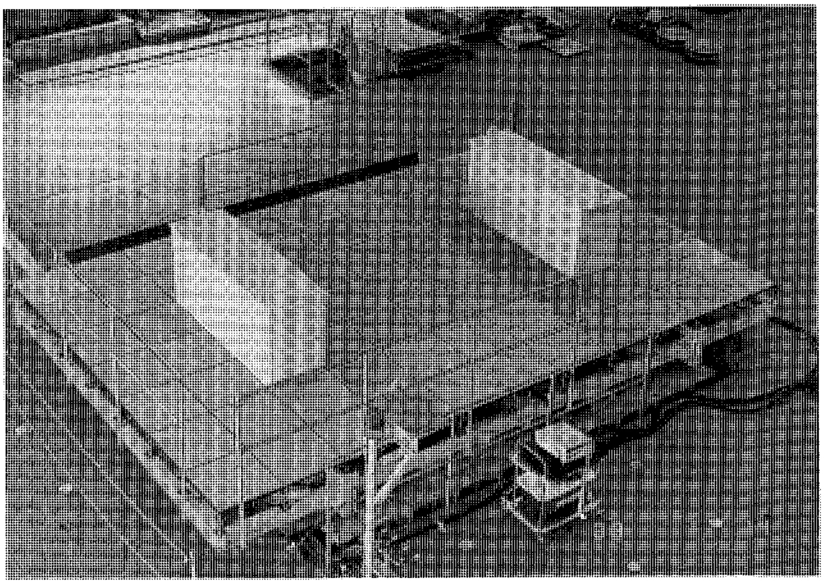

Fig.6 Test Model

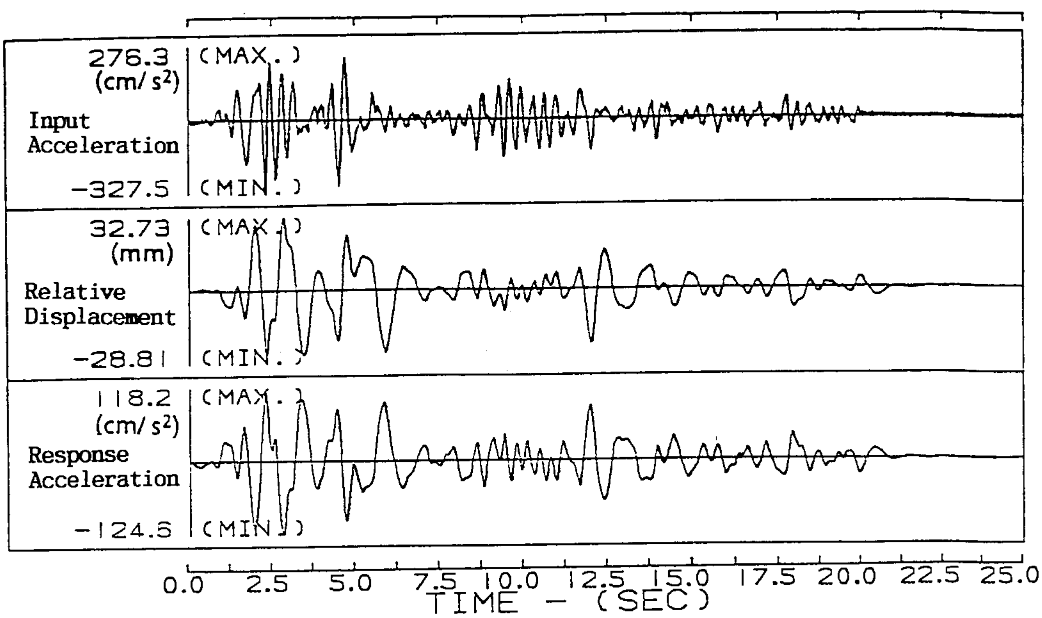

Fig.7 Example of Test Results (El Centro-NS Floor Response Wave)

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