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# Three-dimensional base isolation system for assumed FBR reactor building

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**ABSTRACT** : A three-dimensional base isolation system for an assumed FBR reactor building is proposed, where a horizontally isolated building by laminated rubber bearings is supported by an intermediate slab which is vertically isolated by using air springs of high pressure. From some fundamental investigations on the above system, it is concluded that the system can be sufficiently practical by using the current industrially available techniques.

## 1. INTRODUCTION

Many works on seismic isolation of nuclear reactor facilities have been reported, where the majority deals with the use of horizontal isolation system only. In case of FBR, the use of vertical isolation is expected to result in significant benefits in the seismic design of thin walled structures due to severe thermal conditions. Because of the magnificent weight of reactor building, however, sufficiently flexible vertical isolator for reactor building has been considered to be unpractical.

The published works on the application of vertical isolation techniques to FBR seem to be confined to local isolation of the primary systems in reactor building. The most critical problem to be solved in the above local isolation method lies in the allowance of relative displacement between the isolated primary systems and the other non-isolated secondary ones. From this point of view, vertical as well as horizontal isolation of reactor building is the ideal one.

In the present paper, a three-dimensional base isolation system for an assumed FBR reactor building is proposed as shown in Fig.1. Here the horizontally isolated building using laminated rubber bearings is supported by an intermediate slab. Then, the above system is vertically isolated by using air springs of high pressure arranged under the intermediate slab.

A work of spring support system of buildings was reported (Huffmann,1988), where an example of 16,000 tons building is supported by metal coil springs. However, this application is for vibration isolation from environmental disturbances such as traffic ones in areas of low frequent earthquake attack.

The use of air springs as vertical isolator is promising from the view point of its potentially large loading capacity. The present authors developed a three-dimensional seismic isolation floor system using air springs and laminated rubber bearings (Uriu et al,1993).

The weight of FBR reactor building is supposed to be about 200,000 tons with base support area of 64m x 64m. Fundamental studies were carried out to investigate the feasibility of high pressure air spring with such loading capacity under the current industrially available techniques. It is found that such an air spring is feasible by suppressing its horizontal deformation. This can be realized by using vertically flexible horizontal stopper for the intermediate slab. The existing technique of laminated rubber bearing suffices to the above objective.

Furthermore, seismic response of the above system was also evaluated by using an equivalent mass-spring model taking rocking motion into account. It is found that the rocking response under here used seismic input (Ishida et al,1989) is sufficiently small and vertical response can be reduced significantly.

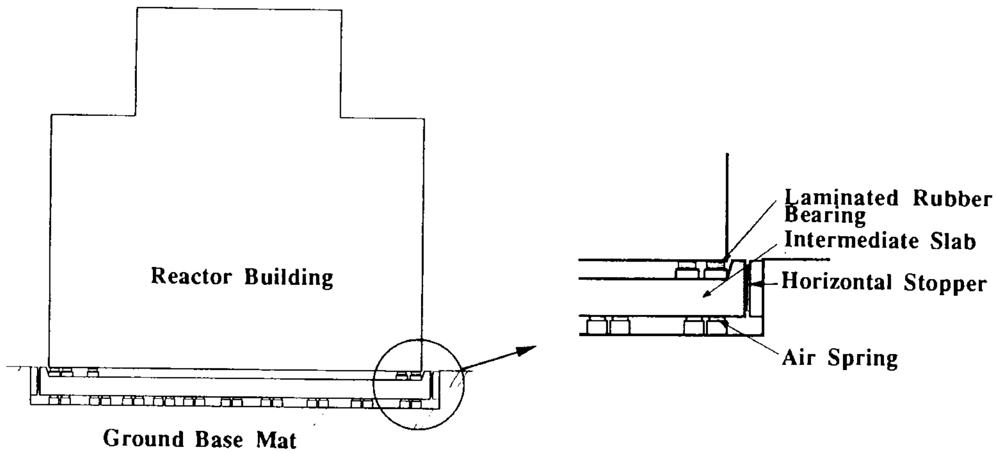


**Fig.1 Three-Dimensional Base Isolation System for FBR Building**

## 2 DESCRIPTION OF THE ISOLATION SYSTEM

### 2.1 General arrangement

As was mentioned, the fundamental structure of here proposed three-dimensional seismic isolation system for FBR reactor building is shown in Fig.1.

1.FBR reactor building is horizontally isolated by using laminated rubber bearing which are arranged under the base slab of the building and assumed to be very stiff in the vertical direction. This horizontal isolation system has been technically well established.

2.The above laminated rubber bearings in turn are supported on the upper surface of intermediate slab.

3.The weight of FBR reactor building is supposed to be 200,000 tons including the weight of intermediate slab. This weight is supported by using air springs arranged under the intermediate slab. The support area is assumed to be 64m x 64m.

4.The arrangement of air springs is shown in Fig.2. The support area of 64m x 64m is divided into 1024 small block areas of 2m x 2m. Keeping the maintenance path with 2m width and the spaces for support columns necessary during construction period or periodical inspection, 484 to 505 small block areas are available for the arrangement of air springs. In the following, 484 block areas for air springs is assumed.

5.From the view point of construction and maintenance works, the effective diameter of air springs to be stored in the small block area 2m x 2m is supposed to be 1.6m. In order to support 200,000 tons weight by 484 such air springs, the required loading capacity is about 410 tons per an air spring with its air pressure of 2.0 MPa.

6. In order to design the required air spring of the above high pressure, it is desirable to

suppress the horizontal deformation of air spring as small as possible. From this point of view, 84 horizontal stoppers are arranged along the side surface of intermediate slab. The stoppers are supported at the wall of ground base mat as shown in Fig.2. This stopper is required to be very stiff in the horizontal direction and deformable in the vertical direction. The existing technique of laminated rubber bearing suffices to the above objective.

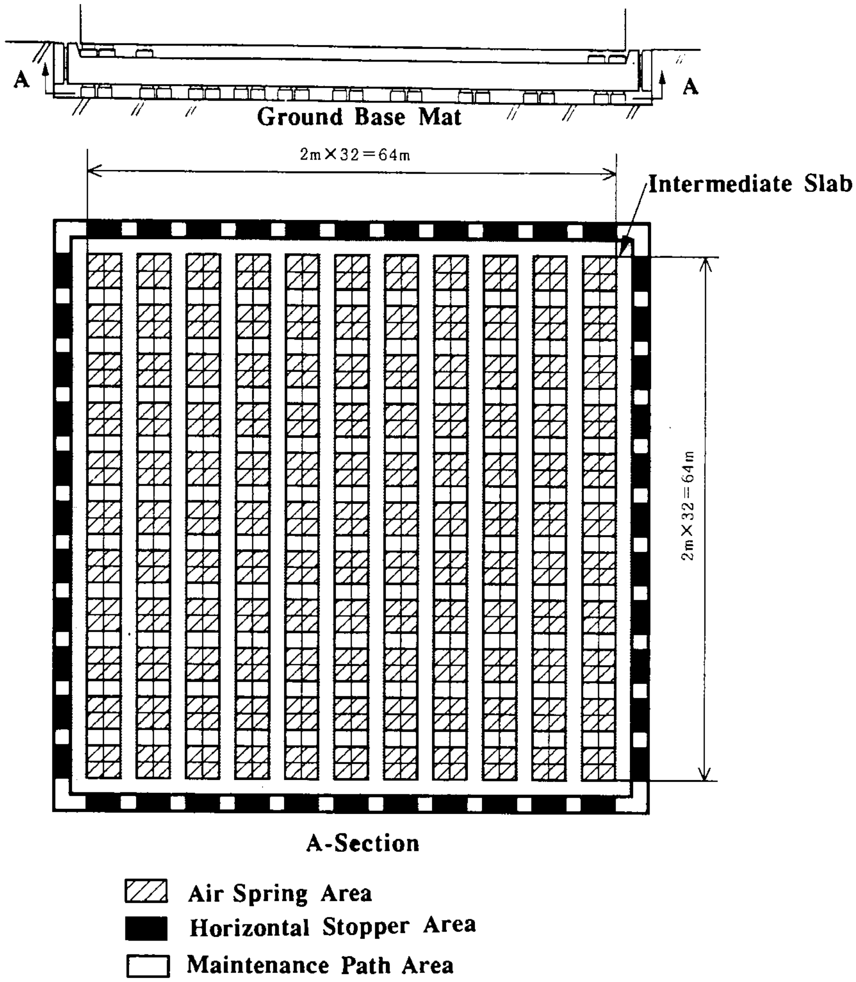


**Fig.2 Arrangement of Air Springs and Horizontal Stoppers**

## 2.2 Air spring

The air spring is schematically shown in Fig.3. The air spring is composed of outer and inner cylindrical shells, upper and lower circular plates and fiber reinforced rubber membrane. The components except for rubber membrane are made of steel.

The outer diameter of slackened part of rubber membrane is designed to be 40mm from the view point of its strength for required air pressure of 2MPa at its nominal condition. The allowable vertical stroke of air spring is designed to be 100mm considering the vertical deformation due to vertical and rocking motions under earthquake loading.

The air damping is utilized as a vertical damper with the auxiliary use of air tank, where the damping force is inducted from the air resistance generated at an orifice. By the parallel use of lead rubber bearing or high damping rubber bearing as horizontal stopper, the vertical damping ratio of 20% is easily ensured.

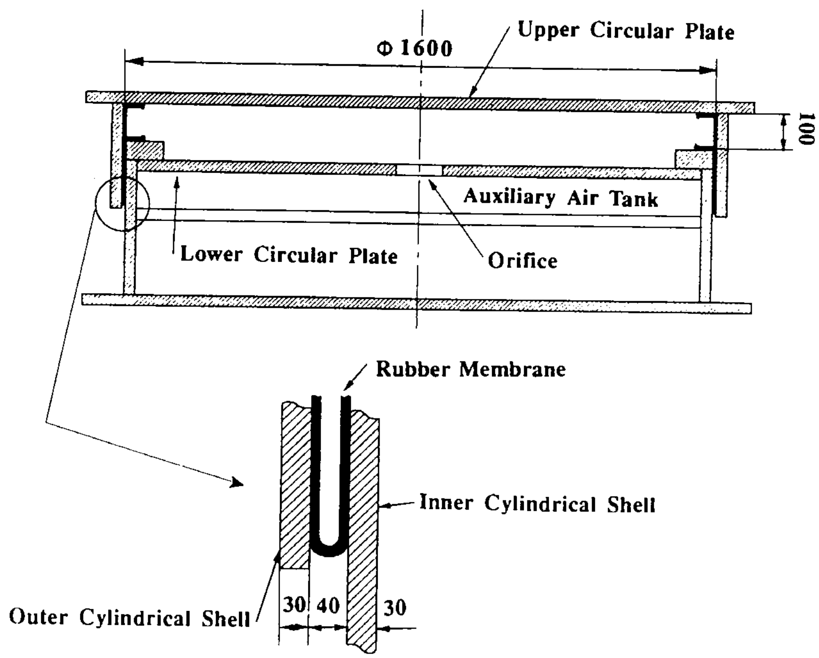


**Fig.3 Air Spring**

### 2.3 Horizontal stopper

Fig.4 schematically shows the horizontal stoppers. The laminated rubber bearings arranged lengthwise are used as horizontal stoppers, which are installed between the side surface of intermediate slab and the wall of ground base mat.

Their compressive (horizontal) stiffness can be very large so as to suppress horizontal deformation of air springs. The vertical stiffness of the above air springs is not sufficient for suppressing rocking motion. From this point of view, the vertical (shear) stiffness of the horizontal stopper is designed to keep sufficiently large. The allowable vertical displacement is designed to be 100mm, same as that of air springs.

The earthquake horizontal force should be supported by the compressive sides of horizontal stoppers alone, considering their low tensile strength. Therefore, for the installation of horizontal stopper between the intermediate slab and the ground base mat, the Dowel Pin method is adopted.

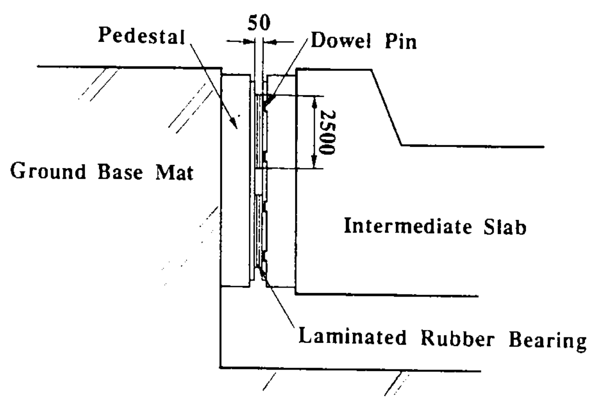


**Fig.4 Horizontal Stopper**

### 2.4 Intermediate slab

The intermediate slab is required to be keep sufficient bending stiffness by being made of steel or prestressed concrete.

## 3 EARTHQUAKE RESPONSE EVALUATION

### 3.1 Analysis Model

To evaluate earthquake response of the present three-dimensional isolated FBR reactor building, the response spectrum method was used. Fig.5 exhibits analytical model representing horizontal, vertical and rotational motions. The building was assumed to be rigid body and simple mass distribution. And the height of the center of gravity from the horizontal spring was supposed to be 20m.

Horizontal and vertical natural periods of isolation system were determined to be 2sec and 0.5sec, respectively, and every modal damping ratio were set to be 20%. To simplify the calculation, the weight of intermediate slab was added to that of building.

As the horizontal earthquake force, the response spectrum proposed by the Ishida et al (Fig.6) was used. And vertical input force was supposed to be a half of horizontal one without changing period characteristics.

To calculate the response of the FBR building (damping ratio of 20%) from the response spectrum by Ishida et al (damping ratio of 5%), the correction coefficient of 0.56 (MITI,1981) was used.

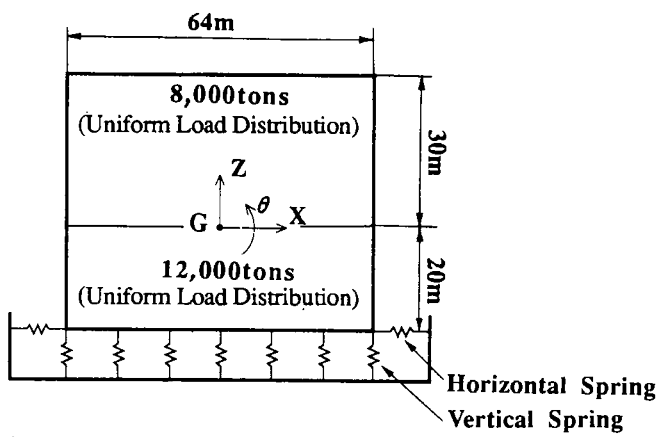


**Fig.5 Evaluation Model for Earthquake Response**

### 3.2 Evaluation

The earthquake response of building is represented by three vibration modes. One is the vertical translatory motion excited by vertical earthquake motion. And the other two are the so called rocking motions under horizontal excitation.

Table 1 shows the calculated responses of three vibration modes. According to the rocking motion, the maximum vertical response displacement occurs at the side edges of building. The absolute summation of maximum vertical displacements of air springs in Table 1 amounts to 30mm, which is less than a half of allowable vertical displacements of air spring (100mm). And horizontal and vertical response acceleration at the center of gravity are 0.2G and 0.18G, respectively.

From these results, excellent three dimensional isolation performance are found.

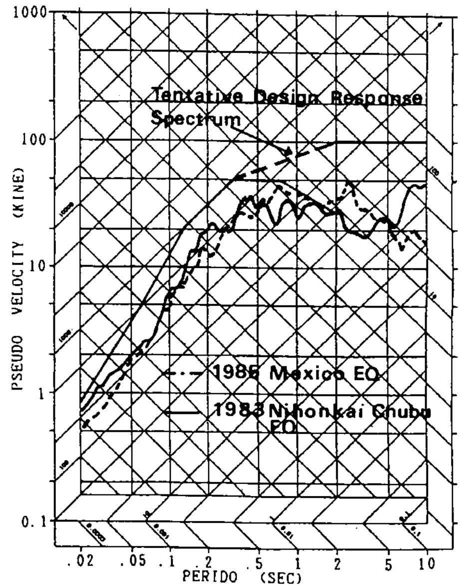


**Fig.6 Response Spectrum (Ishida,1989)**

**Table 1 Calculated Responses by Response Spectrum Method**

| | | |
|---|---|---|
| Vertical Translatory Mode | Natural Period<br>Vertical Displacement<br>Vertical Acceleration | 0.5sec<br>14mm<br>0.18m/sec |
| Rocking Mode Dominated by Horizontal Motion | Natural Period<br>Horizontal Displacement<br>Horizontal Acceleration<br>Vertical Displacement at Side Edge | 2.1sec<br>181mm<br>0.20m/sec<br>14mm |
| Rocking Mode Dominated by Rotational Motion | Natural Period<br>Vertical Displacement at Side Edge | 0.5sec<br>2mm |
| | Absolute Summation of Vertical Displacement | 30mm |

## 4 CONCLUDING REMARKS

A three-dimensional base isolation system for an assumed FBR reactor building is proposed, where high pressure air springs are used as vertical isolator. Through the fundamental investigations on the above system, it is concluded that the present system can be sufficiently practical by using the current industrially available techniques.

Another merit of air spring is that it can play a role of a jack, which is very attractive from the view point of construction and maintenance works.

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