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# DEVELOPMENT OF PERIPHERALLY RESTRAINING TYPE SEISMIC ISOLATOR

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## 1. Abstract

This paper deals with the development of a peripherally restraining type seismic isolator. Experiments were carried out on a full scale model of 5400 kN rated load capacity, and on contracted models thereof with contraction ratios of 0.3 and 0.18 in dimensions in terms of horizontal and vertical properties and destructive properties.

As the results, the newly developed peripherally restraining type seismic isolator proved to have larger damping capability than that of the existing high-damping rubber bearings, and its destructive properties proved to be satisfactory in its actual application to buildings. The comparison between the data scaled up from the results with contracted models and those with the full scale model showed good agreements to convince that the performance of the contracted models might provide the good prediction of the full scale model.

## 2. Introduction

It has been regarded as very important for critical facilities such as nuclear reactors that the seismic acceleration, if it should arise, be reduced. In recent years, the high-damping rubber bearings, which have damping capability for themselves, have been attracting attention and several research works are reported(1). In general,the larger the damping capability of rubber bearings, the more effective in reducing the seismic acceleration, thus reducing the response of the upper structures in terms of displacement and acceleration. Accordingly, the development of rubber bearings having ever higher damping capability has been hoped for.

In carrying out the dynamic test of the full scale rubber bearings under the same conditions as they are actually used, a testing machine having an unrealistically large actuator will be required. In fact, most researches on full scale models have been carried out at lower frequencies than those may be encountered in the actual use, or estimations have been made from the test results with contracted models at the same frequencies as the actual use.

However, there are few reports available which focus on whether or not the results with such contracted models should correctly predict the dynamic properties of the full scale model.

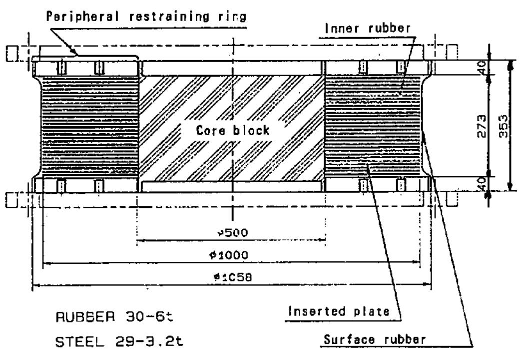
This paper deals with the development of a peripherally restraining type rubber bearing which has larger damping capability than that of the existing high-damping rubber bearings. It also refers to the experiment to study whether or not the test results with contracted models correctly provide the good prediction of dynamic properties of full scale models.

## 3. Experimental

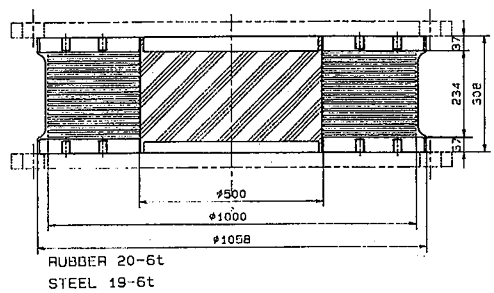
### 3.1. Specimens

The full scale model of a peripherally restraining type seismic isolator (hereinafter referred to as "PRB") of 5400 kN rated load, shown in Fig.1(a), was tested in terms of the horizontal dynamic properties and the vertical compression. The "PRB" comprises a core block made of a synthetic rubber compound ( hereinafter referred to as the "core block" ), the damping of which is even higher than that of the high-damping rubber compound used in the multilayers, and a peripherally restraining ring (hereinafter referred to as the "restraining ring") made of multilayers of alternately stacked high-damping rubber sheet bonded to a steel plate surrounding the aforesaid core block. Under the vertical load on the "PRB", the "restraining ring" effectively restrains the homogeneous "core block" from its bulging out thus making the vertical stiffness of "PRB" almost identical with that of the existing high-damping rubber bearing (hereinafter referred to as "HDB"). (This suggests that "PRB" will be usable in the same way as "HDB"). In Fig.1(b) is shown the dimensions of the "PRB" of 5400 kN rated load, which was used as the specimen for the destructive test, the number of rubber layers of which was reduced to some degree so that the specimen might successfully break down within the maximum horizontal stroke of the testing machine. The dimensions and profiles of the contracted "PRB" models with contraction ratios of 0.3 and 0.18 are shown in Figs.1(C) and 1(d).

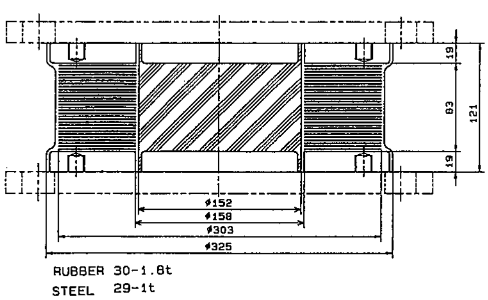
The dimensions and profiles of "HDB" models, used for the comparison with "PRB" models, are shown in Figs.2(a),2(b),2(c) and 2(d); for the model sizes of full scale (5400 kN rated load), 0.3 contraction ratio, and 0.18 contraction ratio, respectively.



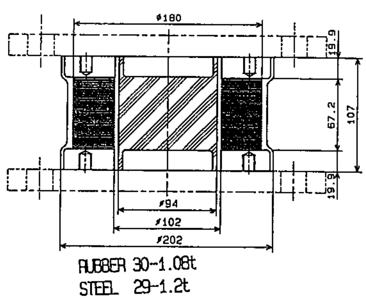

(a) Full scale model ( $\phi$ 1000-500 PRB)




(b) Full scale model for the destructive test ( $\phi$ 1000-500 PRB/L)

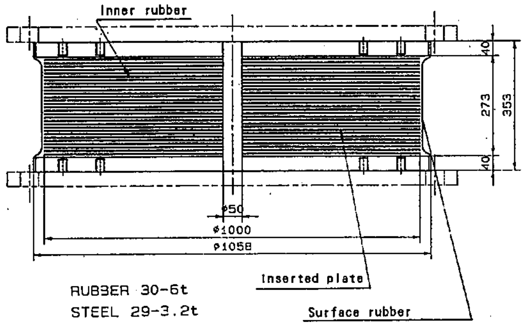



(c) 0.3 contraction ratio model ( $\phi$ 303-152 PRB)

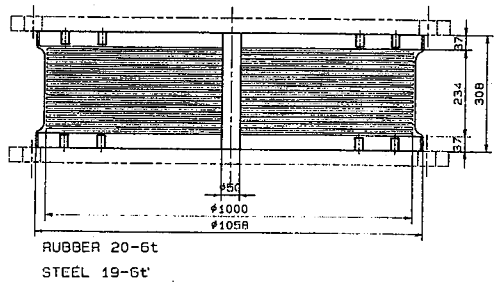



(d) 0.18 contraction ratio model ( $\phi$ 180-94 PRB)

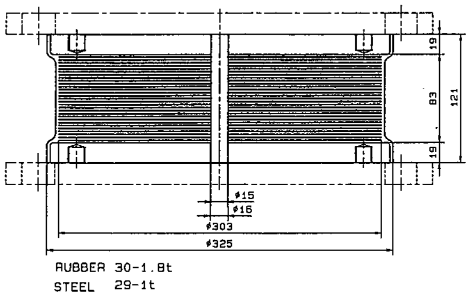
Fig.1 Dimension of the "PRB"



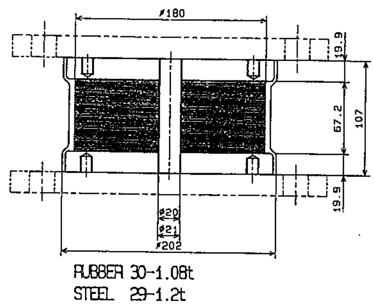

(a) Full scale model (φ 1000 HDB)




(b) Full scale model for the destructive test (φ 1000 HDB/L)




(c) 0.3 contraction ratio model (φ 303 HDB)




(d) 0.18 contraction ratio model (φ 180 HDB)

Fig.2 Dimension of the "HDB"

### 3.2. Loading Facilities And Loading Method

The large biaxial testing machine used for the full scale models is shown in Fig.3. The small biaxial testing machine as used for the contracted models is shown in Fig.4.

The dynamic horizontal loading tests were carried out under the conditions as given in Table 1. The loading in these tests were given from the smaller shear strain to the larger one, with three waves for each strain, and the overall test was repeated twice.

It has been known that the properties of high-damping rubbers are affected by the history of the shear strains experienced. Therefore, following discussions are based on the data of the second loading cycle above because the data in the horizontal direction were more stable in that cycle.

Table 1. The dynamic horizontal loading test conditions.

| | Contraction ratio | Pressure (MPa) | Frequency (Hz) * |
|---|---|---|---|
| Full scale models | —— | 5.6 | 0.01 |
| Contracted models (1) | 0.3 | 3.2 | 0.01 |
| Contracted models (2) | 0.18 | 5.6 | 0.01 |
| | | 7.4 | 0.5 |

* sinusoidal

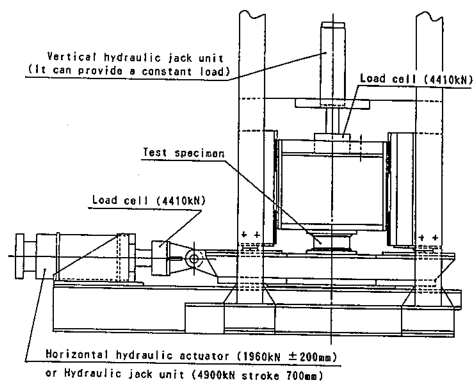



Fig.3 The large biaxial testing machine

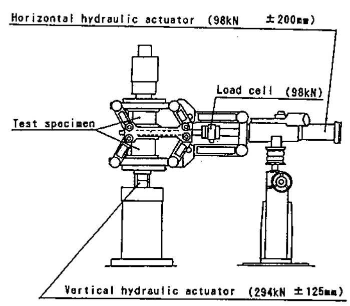



Fig.4 The small biaxial testing machine

## 4. Results and Discussion

### 4.1. Static Compressive Tests

The vertical compressive test results of full scale models of "PRB" and "HDB" are shown in Fig.5. The vertical spring constant of "PRB" proved to belower than that of "HDB" by only 9%, which may be defined as almost identical.

### 4.2. Dynamic Horizontal Loading Tests

Fig.6 shows the horizontal restoring forces of the "PRB" models with full scale and 0.3 contraction ratio in which the data are taken from the third waves. These data were used for the calculation of the horizontal spring constants and the equivalent damping ratios of "PRB" models, and the results are shown as a function of shear strains in Fig.7; however, it should be noted that the calculation results shown for the contracted models are the scaled up ones to equate with the full scale models. The horizontal spring constants and the equivalent damping ratios of "HDB" are shown in Fig.8 as a function of shear strains wherein again the results shown for the contracted models are the scaled up ones to equate with the full scale models. With regard both to "PRB" and "HDB", the scaled up data of the contracted models are in good agreement with those of the full scale models.

As regards the shear strain dependence of the horizontal spring constants, the scaled up data of the contracted models seem of provide the good prediction of the full scale models.

In Fig.9 is shown, as a function of

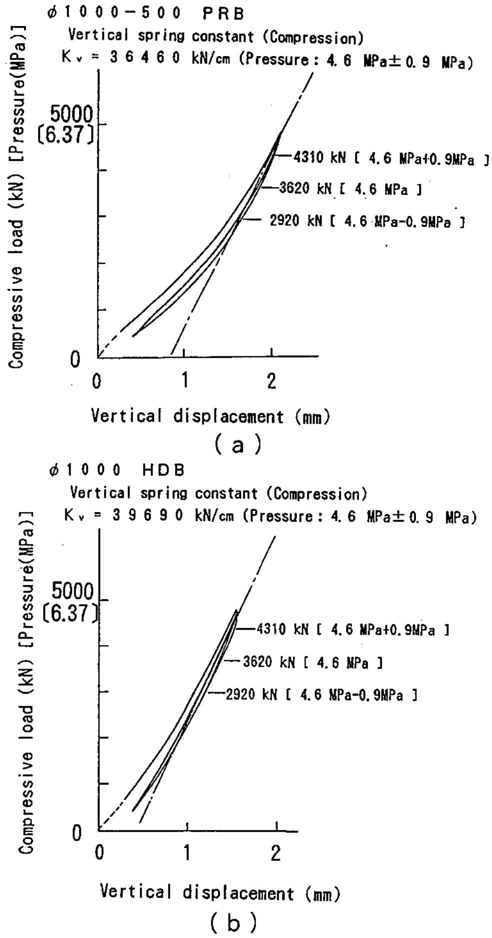



Fig.5 Compressive load vs. vertical displacement
(a) Full scale model ($\phi$ 1000-500 PRB)
(b) Full scale model ($\phi$ 1000 HDB)

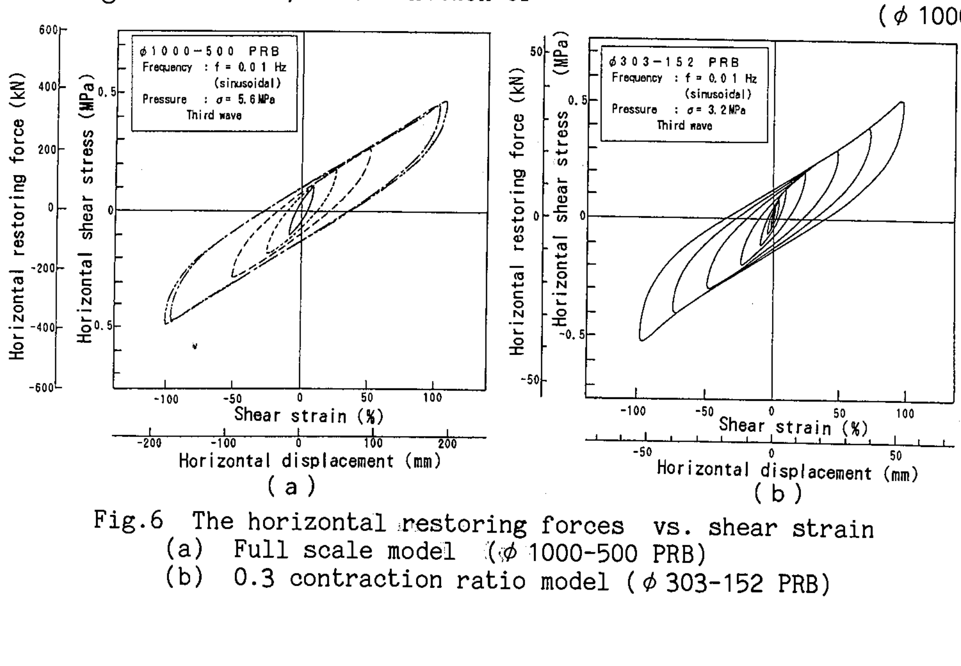
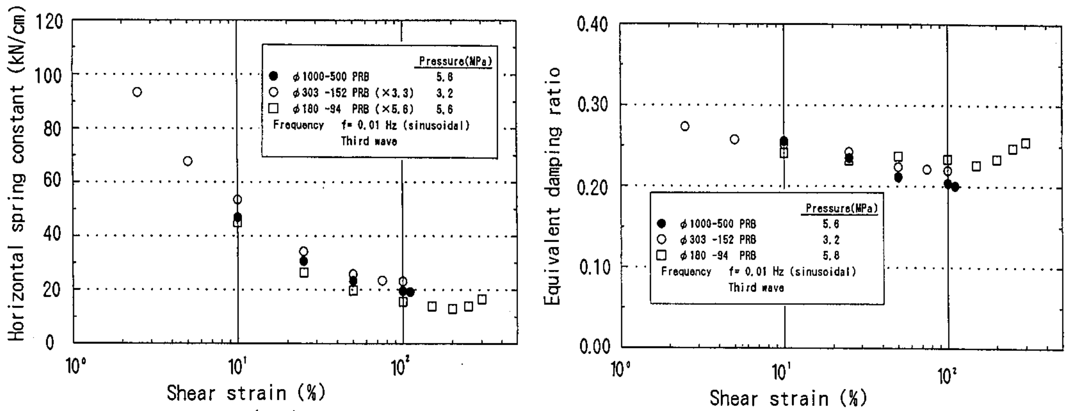
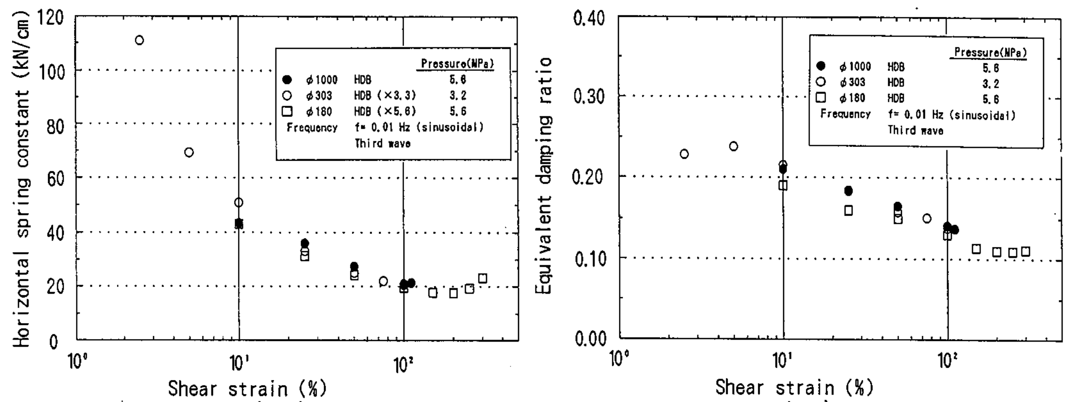



Fig.6 The horizontal restoring forces vs. shear strain
(a) Full scale model ($\phi$ 1000-500 PRB)
(b) 0.3 contraction ratio model ($\phi$ 303-152 PRB)



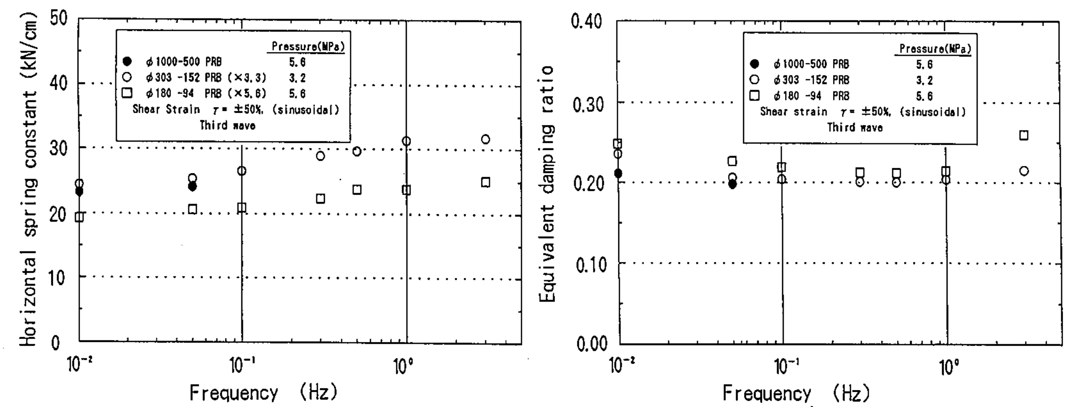

(a) (b)

Fig.7 (a) Horizontal spring constant vs. shear strain (PRB)
(b) Equivalent damping ratio vs. shear strain (PRB)




(a) (b)

Fig.8 (a) Horizontal spring constant vs. shear strain (HDB)
(b) Equivalent damping ratio vs. shear strain (HDB)




(a) (b)

Fig.9 (a) Horizontal spring constant vs. frequency (PRB)
(b) Equivalent damping ratio vs. frequency (PRB)

frequencies, the horizontal spring constants and the equivalent damping ratios of "PRB" in the shear strain range of ±50%. The data of the full scale models, although not so many in number, seem to show a similar tendency to the contracted models. In Fig.10 are shown the restoring forces of "PRB" of the 0.18 contracted model as measured at 0.5Hz (equivalent to the frequency which may be experienced by a full scale model during an earthquake) under the pres-

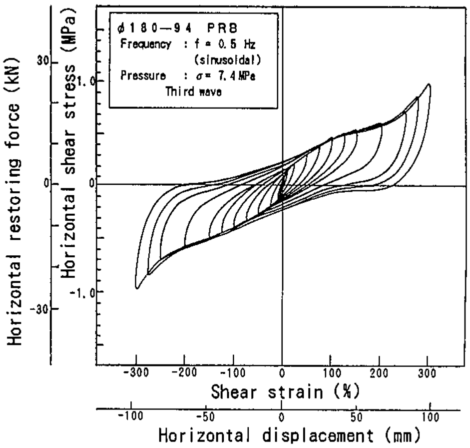



Fig.10 The horizontal restoring forces of the 0.18 contracted "PRB" model

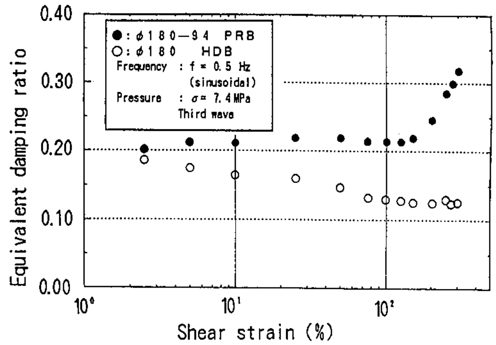



Fig.11 Equivalent damping ratio vs. shear strain for the 0.18 contracted model

sure of 7.4MPa , wherefrom the equivalent damping ratios were calculated and the results are shown in Fig.11 as a function of the shear strains. And also the equivalent damping ratios of the 0.18 contraction model of "HDB" are shown in Fig.11. The equivalent damping ratios of "PRB" was about 0.2, in the shear strain range of ±50% , which was higher than thatof "HDB".

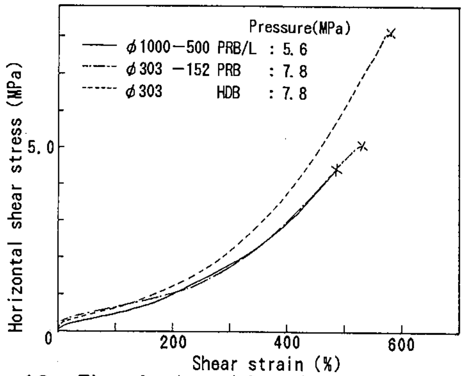



Fig.12 The destructive test results of full scale "PRB" model, 0.3 contracted models of "PRB" and "HDB"

## 4.3. Destructive Tests

The destructive test results of full scale "PRB" model are shown in Fig.12 wherein the results of 0.3 contracted models of both "HDB" and "PRB" are also shown. The relationship of the shear strain and the horizontal load of the full scale "PRB" model were in good agreement with that of the contracted model. The shear strain at the failure of "PRB" was smaller than that of "HDB", however, this critical strain is more than twice as large as about 170% strain (about 30cm in the horizontal displacement) which equates with the Level 2. Therefore,"PRB" will be satisfactory in the actual use without any problem.

## 5. Conclusions

From these results, it is concluded that:

(1) The vertical spring constant of "PRB" is on the equivalent level to that of an existing "HDB".

(2) The equivalent damping ratios of "PRB" is higher than that of an existing "HDB".

(3) The rather lower critical shear strain of "PRB" than that of "HDB" will have no problem in its actual use.

(4) The performance of dimensionally contracted models might provide the prediction of that of the full scale model.

## 6. References

1. T.Fujita et al., Proceedings of a post-conference seminar of the 10th SMIRT, 268-295 (1989)