Test on Large-Scale Seismic Isolation Elements

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ABSTRACT

Demonstration test of seismic isolation elements is considered as one of the most important items in the application of seismic isolation system to Fast Breeder Reactor (FBR) plant. Facilities for testing seismic isolation elements are built in Abiko Research Laboratory of CRIEPI, and various tests for full-scale laminated rubber bearing and reduced scale models are conducted.
From the result of the tests, the laminated rubber bearings turn out to satisfy the specification. Their basic characteristics are confirmed from the tests with full-scale and reduced scale models. And the ultimate capacity of the bearings under the condition of ordinary temperature are evaluated.

INTRODUCTION

Recently the seismic isolation has become one of the notable methods in the seismici design of important structures or equipment. And the research for the application of seismic isolation system to FBR plant has been conducted since 1987. This research program has various technical issues to be investigated. One of the most significant issues is to estimate the characteristics of seismic isolation element. In this test, The main objectives are followings. One is to clarify the basic characteristics of full-scale seismic isolation element under actual loading condition. And the other is to clarify the failure characteristics of reduced scale models under actual loading condition. Based on the above recognition. Facilities for testing seismic isolation elements were built, and by using these facilities various static tests were conducted.

OUTLINE OF FACILITIES AND SEISMIC ISOLATION ELEMENT

Facilities for Testing Element

Facilities for testing seismic isolation element was built in Abiko Research Laboratory of CRIEPI. Two actuators can apply both horizontal load and vertical load on the element, the actuators are controled in load control mode and displacement control mode.
Maximum availabe load of each actuator is 600 tonf. Maximum achievable horizontal displacement is ±600 mm or 1200 mm, and maximum achievable vertical displacement is ±350 mm or 700 mm. Maximum velocity of loading of each actuator is 0.5 cm/sec. Fig 1 shows the facilities.

Seismic Isolation Element

In this program, concept of base isolation of FBR building was selected as the most feasible system. In this concept, natural rubber bearing, lead rubber bearing and high damping rubber bearing are regarded as the promising seismic isolation element of the FBR building. Natural rubber bearing was tested at first. Because natural rubber bearing with damper is considered to be the most feasible system of the base isolation in Japan, and the scattering of the basic characteristics of the bearing are relatively small in comparison with other bearings.

Fig. 2 shows the natural rubber bearing consisting of thin natural rubber sheets and insert steel plates. One full-scale model and two kinds of reduced scale models were submitted for the test.

The full-scale model is designed to behave linearly up to the displacement of 500 mm, and designed to provide the 500 ton rated mass with the horizontal natural frequency of 0.5Hz and the vertical one of 20Hz.

Parameters of the bearings are summarized in Table 1.

RESULTS OF TESTS

Horizontal Stiffness Tests

The objectives of these tests are to estimate the horizontal stiffness and damping of the bearing and to confirm the similarity between a full-scale model and reduced scale models. The tests were performed under the conditon of low frequency cyclic loading.(under 0.01Hz)

Four cycles of sinusoidal horizontal displacement was applied under constant vertical load. The amplitude of horizontal displacements are varied from shear strain of rubber ±25% to shear strain of rubber ±400%. And the amplitude of vertical loads are varied from -20% to +200% of design vertical load, and the record of third cycle was adopted as a data.

Fig. 3 shows the relationship between horizontal load and horizontal displacement of each model and Fig. 4 shows the relationship between normalized horizontal spring constant and shear strain of rubber.

From these results, the horizontal stiffness of the all bearings turned out to behave almost linearly within shear strains of 200%. But over shear strains of 300%, restoring force (horizontal load) increases sharply as shear strain increases.

Equivalent horizontal spring constant obtained by the tests of the bearings agree approximately with the design value within shear strain of 200%, but at shear strain of 400% the equivalent horizontal spring constant increases about 30% of the design value owing to the hardening of rubber.

Fig. 5 shows the relationship between equivalent damping ratio and shear strain of rubber. The equivalent damping ratio for the full-scale model in horizontal direction is between 1% and 2% within shear strain of 200%. But from the test result of 200ton model, it was made clear that the equivalent damping ratio is larger at shear strain over 300% by material non-linearity of rubber.

Differrences of these characteristics between models of the same scale were small.

Vertical Stiffness Tests

The objectives of these tests are to evaluate the vertical stiffness and damping of the bearing and to investigate the similarity between a full-scale model and reduced scale models. The tests were performed under the condition of low frequency cyclic loading in the same way as horizontal stiffness tests. In the first test, four cycles of sinusoidal vertical load was applied under initial static vertical load and constant shear strain.

Amplitude of sinusoidal vertical load was ±50% of design vertical load. The initial vertial loads were varied from 50% to 150% of the design vertical load. And the constant shear strain of the bearing were varid from 0% to 200%. In the second test, vertical load was increased gradually from 0% to 200% of the design vertical load .

Fig. 5 shows the relationship between vertical load and vertical displacement for each model, and Fig. 6 shows the relationship between normalized vertical spring constant and shear strain of rubber.

From these results, the vertical stiffnesses of all bearings around design vertical load without shear strain turned out to be almost linear. And it was proved that the equivalent vertical spring constant agree approximately with the design value. However, the equivalent vertical spring constants decrease as shear strain increases, and are 50% of the design value at shear strain of 200%.

Breaking Tests

The objectives of these tests are to evaluate the strength of the bearings and the deformation characteristics around the breaking point and to confirm the similarity rule of two reduced scale models around the breaking point.

Fig. 7 shows the relationship between horizontal displacement and horizoontal load of each reduced scale model up to the breaking point.

From these results, breaking points of each model were approximately between shear strain of 450% and 500%, and between shear stress of 50$\mathrm{kgf/cm^2}$ and 75$\mathrm{kgf/cm^2}$.

CONCLUSION

Horizontal stiffness tests, vertical stiffness tests and breaking tests for both full-scale model and reduced scale models were conducted.

As a result, followings were obtained.

i) Characteristics of a full-scale model used in design were made clear and agreed approximately with the design value.

ii) Charateristics of reduced scale models around breaking point are clarified and the similarity rule between a full-scale model and reduced scale models were verified.

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REFERENCES

Sawada Y. et al., 1989, " Seismic Isolation Test Program ", Trans. 10th SMiRT, to appear.

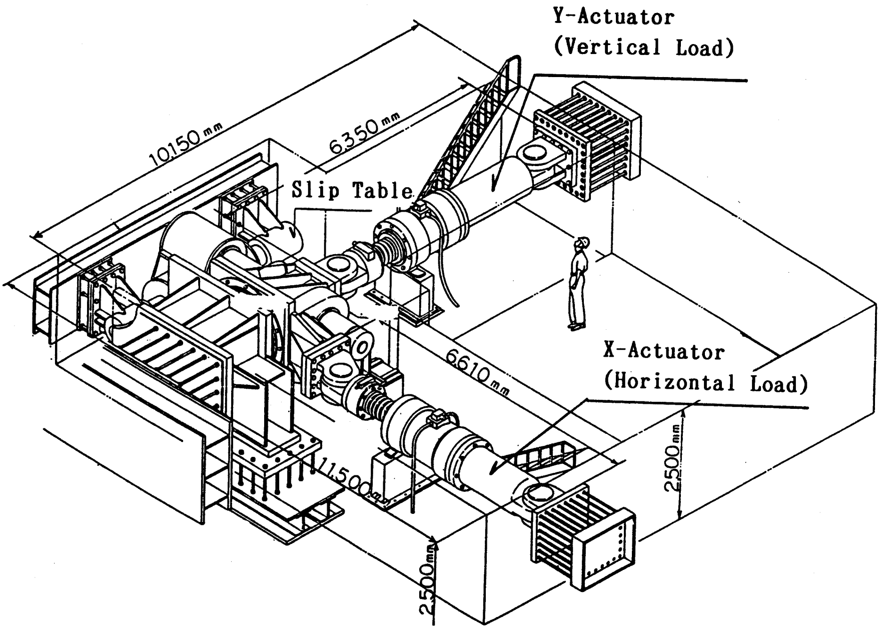


Fig. 1 Facilities for Testing Element

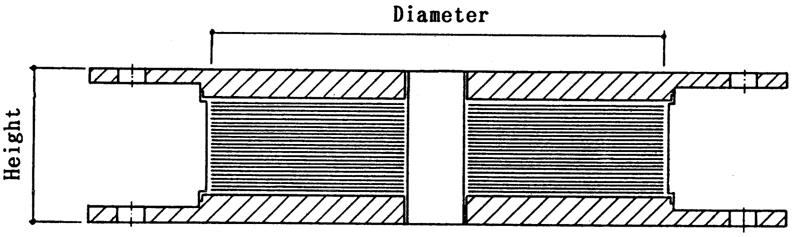
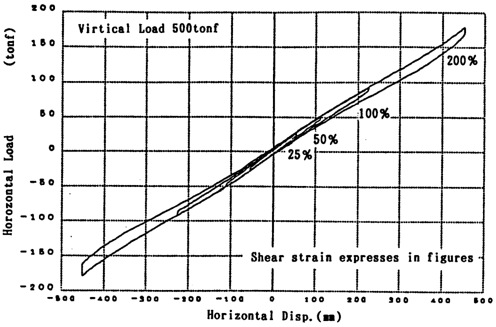


Fig. 2 Natural Rubber Bearing

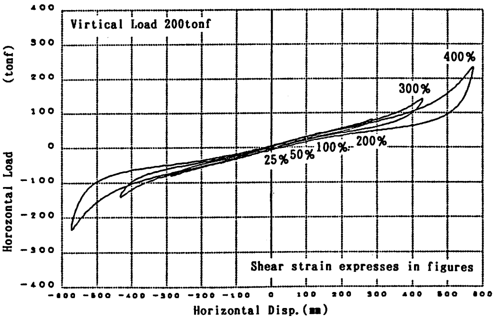
Table 1. Design Parameters of Bearings

Parameter \ Type	full-scale model	1/1.58 reduced scale model	1/3.16 reduced scale model
Diameter (mm)	1600	1000	500
Height (mm)	560	340	160
Thickness of Rubber Sheet(mm)	9.0	5.7	2.8
№ of Rubber Sheet	25	25	25
Thickness of Steel Plate(mm)	5.8	3.1	1.6
№ of Steel Plate	24	24	24
Rated Virtical Load (tonf)	500	200	50
Horizontal Spring Constant(tonf/cm)	5.036	3.19*	1.59*
Horizontal natural frequency(Hz)	0.5	——	——
Virtical Spring Constant(tonf/cm)	8057	5099*	2550*
Virtical natural frequency(Hz)	20	——	——

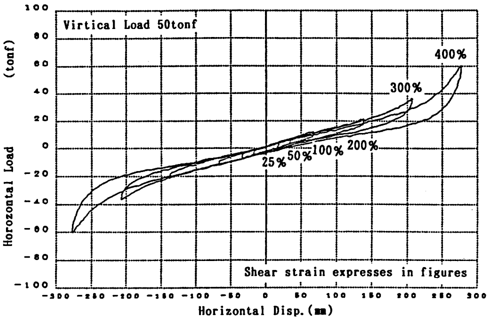
* : Value is fixed from similality



(i) Full-Scale Model(500tonf)

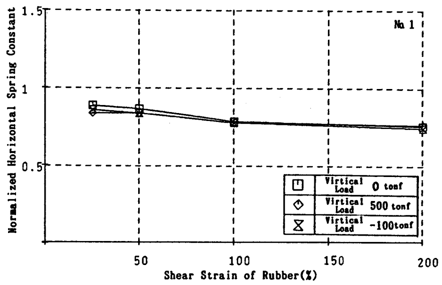


(ii) Reduced Scale Model(200tonf)

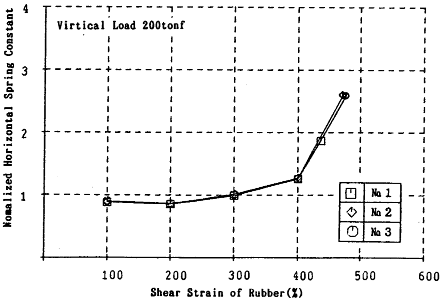


(iii) Reduced Scale Model(50tonf)

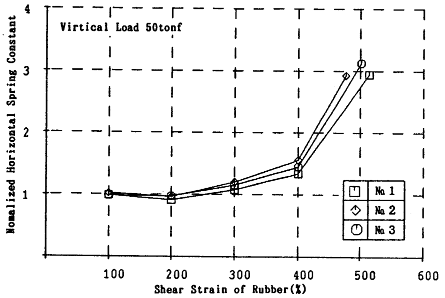
Fig.3 Relationship between Horizontal Load and Horizontal Displacement



(i) Full-Scale Model(500tonf)

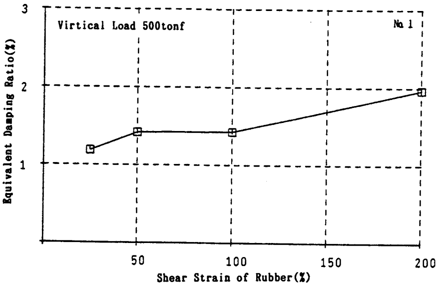


(ii) Reduced Scale Model(200tonf)

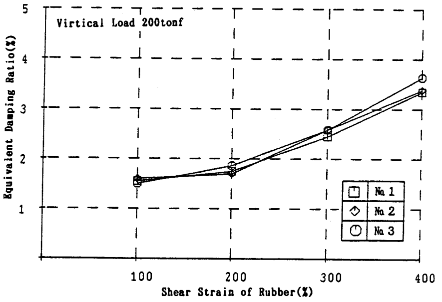


(iii) Reduced Scale Model(50tonf)

Fig.4 Relationship between Normalized Horizontal Spring Constant and Shear Strain of Rubber

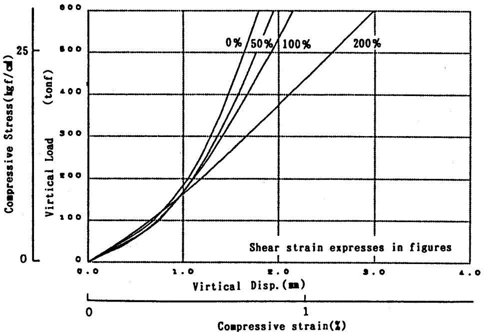


(i) Full-Scale Model(500tonf)

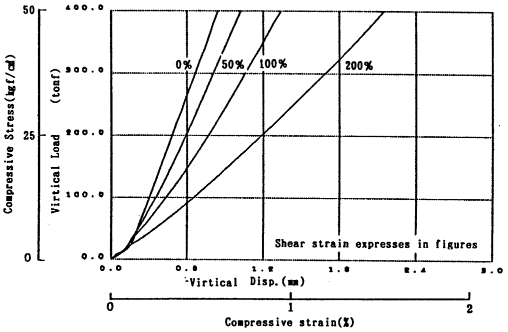


(ii) Reduced Scale Model(200tonf)

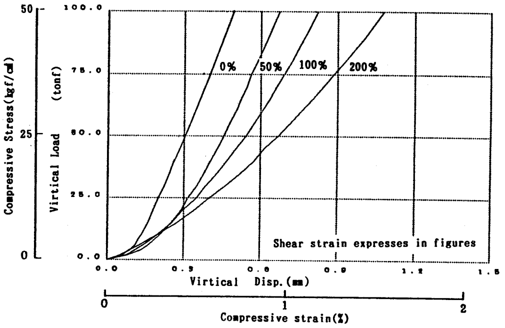
Fig.5 Relationship between Equivalent Damping Ratio and Shear Strain of Rubber



(i) Full-Scale Model(500tonf)

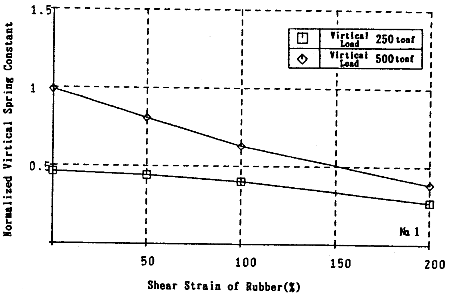


(ii) Reduced Scale Model(200tonf)

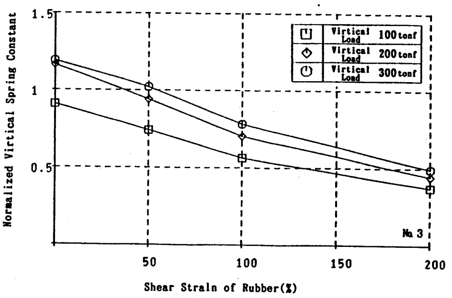


(iii) Reduced Scale Model(50tonf)

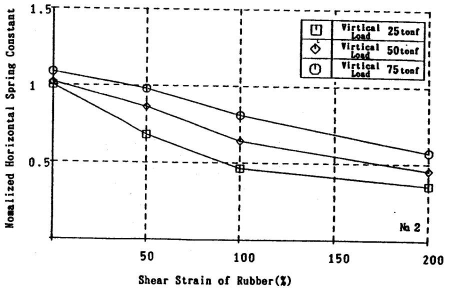
Fig.6 Relationship between virtical Load and Virtical Displacement



(i) Full-Scale Model(500tonf)

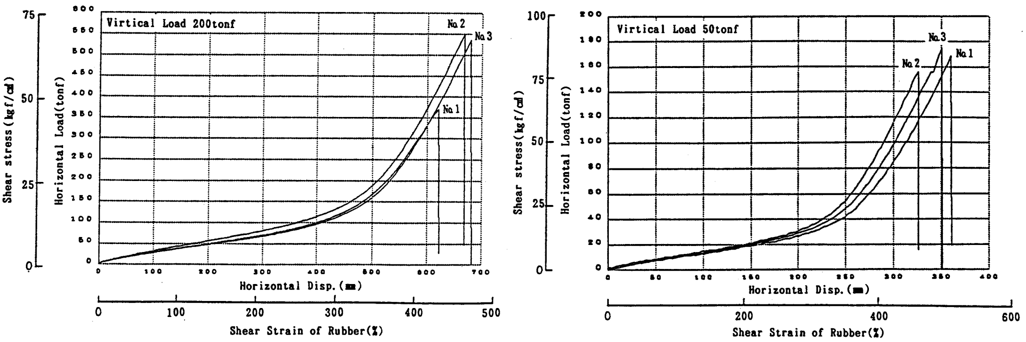


(ii) Reduced Scale Model(200tonf)



(iii) Reduced Scale Model(50tonf)

Fig.7 Relationship between Normalized Virtical Spring Constant and Shear Strain of Rubber



(i) Reduced Scale Model(200tonf)

(ii) Reduced Scale Model(50tonf)

Fig.8 Relationship between Horizontal Load and Horizontal Displacement