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Seismic Response of a Secondary Structure by Mass Eccentricity of a Base-isolated Primary Structure

Tae Myung Shin [a*], Kyeong Hye Koo [b]
[a]*National Univ. of Transportation, Daehakro 50, Chungju, Korea*
[b]*KAERI, Daedukdaero 989 Gil 111, Daejeon, Korea*

[*]*Corresponding author: tmshin@ut.ac.kr*

1. Introduction

As a part of research projects for enhancement of seismic capacity of operating nuclear power plants, design development of small-sized laminated rubber bearings has been performed for seismic isolation of equipment or small structures. For the purpose, the small-sized laminated rubber bearing (LRB) with 10kN vertical design load and 2.3 Hz seismic isolation frequency has been developed with the lead plug inserted to make damping effects. It is mainly concerned to apply to the safety-related facility components such as control cabinet, emergency diesel generator, remote shutdown console, battery pack, spent fuel rack, and so on. Some components have nonuniform mass distribution and it is questioned how they affect the seismic response of the isolated super structure. Up to date, there have been few studies on shaking table tests on full-size LRBs for nuclear power plant (NPP) facilities or equipment models.

In the study, shaking table tests of the real-scale LRB are carried out for some base-isolated equipment models having mass eccentricity. Through the test of models with different shape, the seismic response effects by mass eccentricity are investigated with their dynamic characteristics.

2. Design Description of LRBs for Equipment

Analysis of the bearing designs confirmed that the low-damping small-sized LRB was less effective in dissipating seismic energy than the larger bearings for buildings. This is mainly because of the manufacturing difficulty of the thin rubber plate for small-sized isolation bearings. In this study, 1-ton capacity small-sized LRB is designed to have the fundamental natural frequency to be approximately 2.3 Hz. The cross-sectional shape and design specifications of the LRB used in this study are compared in Figure 1 and Table 1, respectively.

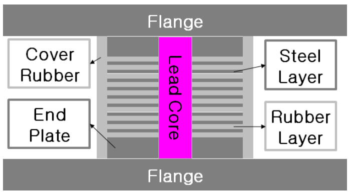


Figure 1. Cross-sectional shape of the LRB.

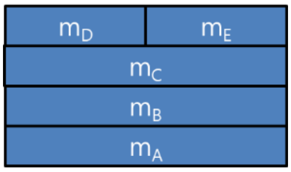
Table 1: Design of LRB for Equipment

Properties	**Design Value**
Design Load [ton]	1
Outer Diameter [mm]	100
Design Hori. Freq. [Hz]	2.3
Shape Factor, S1	9.9
Shape Factor, S2	5.0

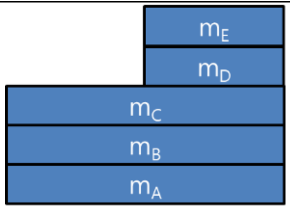
3. Seismic Test for Mass Eccentricity Models

3.1 Test Model Description

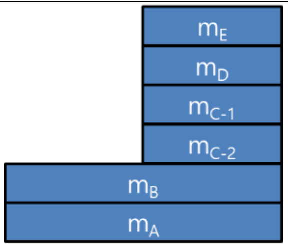
For the test efficiency, the models are designed to have three different shapes easy to change and assemble by reusing the dummy mass blocks between the tests. And the design mass eccentricities are 0%, 6.25% and 12.5%, The models are depicted in Fig.2 for reference.



(a) Model I : 0% Eccentricity



(b) Model II : 6.25% Eccentricity



(c) Model III : 12.5% Eccentricity

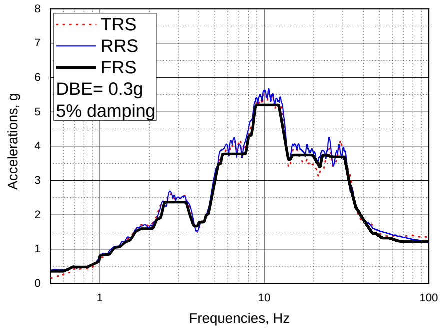
Figure 2. Schematic Shape of the Test Models.

Table 2: Design of LRB for Equipment

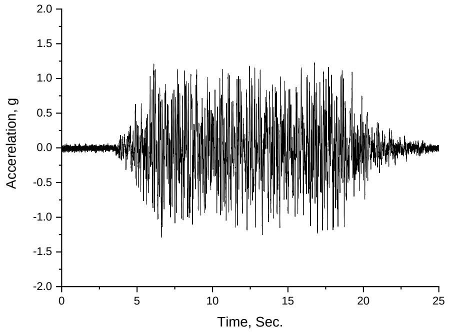
Models	Mass Eccentricity [%]	Deviation from Geo. Center [mm]
Model-I	0	0
Model-II	6.25	77
Model-III	12.5	154

3.2 Input Seismic Data

The design earthquake for a domestic export-type NPP, APR1400, was used to investigate seismic response characteristics of the isolation bearing through dynamic test. The floor response spectra (FRS) of the 137 ft high Safe Shutdown Earthquake (SSE) in the auxiliary building are selected because safety-related devices are mostly located at about the level. The seismic input shown in Fig.3 is largely amplified from design basis Earthquake (DBE) of 0.3g at ground level.



(a) FRS



(b) Time History

Figure 3. Seismic Input (SSE 0.3g, 5% damp., 137ft).

3.3 Review of Shaking Table Test Results

Figure 4 shows a comparison of the acceleration response measured on the shaking table for the DBE 0.3 g (ZPA of FRS: 1.3 g) test with the response measured on the isolated dummy mass in no eccentricity case. As expected, the peak of acceleration response of the dummy mass appears around 2.3 Hz, which is the design frequency of the LRB. The maximum acceleration of the dummy mass as a super-structure largely decreased in the range of about 5Hz to 60 Hz by seismic isolation, as expected.

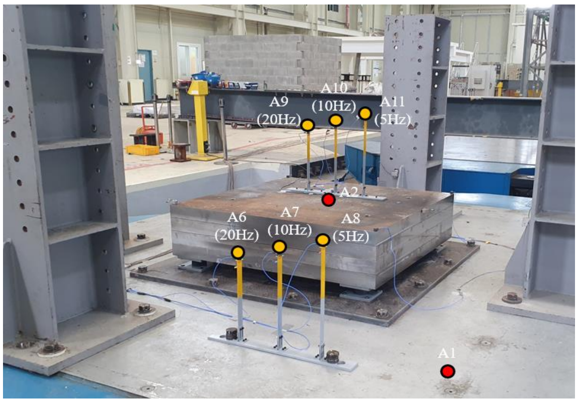


Figure 4. Schematics of 3D shaking table test.

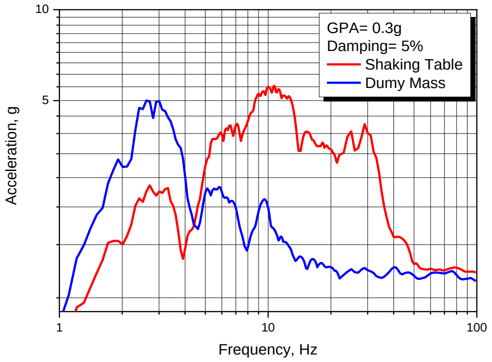
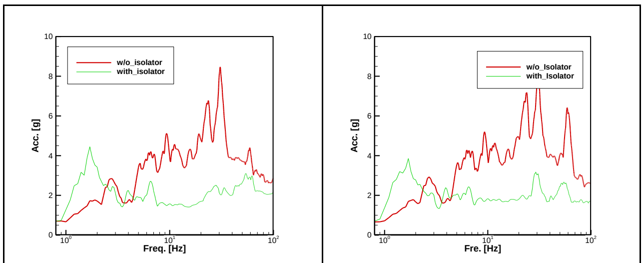


Fig. 5. Seismic Response by Base-isolation (SSE, 137ft)

Figure 6 a, b shows a representative case for the comparison of acceleration response effect of secondary structure with natural frequency of 50Hz by mass eccentricity of isolated primary structure. It is recognized that the seismic response effect by mass eccentricity seems almost negligible.



(a) No Eccentricity **(b)** Eccentricity

Fig. 6. Seismic Response Effect by Mass Eccentricity

4. Conclusions

The effect on the seismic responses of base-isolated equipment by mass eccentricity is investigated by dynamic tests of some different models in the paper. It can be concluded that the acceleration and displacement responses of the super structure both are not much dependent upon the eccentric mass distribution, and rather decreased in some cases of increased eccentricity. And it is considered to be caused by the increased contribution of rotational modes in seismic response.

5. Acknowledgements

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