MECHANICAL CHARACTERISTICS OF CIRCULAR ELASTOMERIC HOLLOW RUBBER BEARING

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ABSTRACT: The isolation system reduces the effect of the horizontal components of the ground acceleration by interposing structural elements with low horizontal stiffness between the structure and the foundation. This gives the structure a fundamental frequency that is much lower than both its fixed-base frequency and the predominant frequencies of the ground motion. The isolation system does not absorb the earthquake energy, but deflects it through the dynamics of the system. One of these devices of isolator appears as the laminated rubber bearing. Structural Earthquake Engineering Research (SEER) has been developing the hollow base isolator in order to reduce the horizontal stiffness of the isolator and to increase the effectiveness of the conventional one. Finite element models were studied the mechanic behaviour of elastomeric bearing under compressions and shear loads. The previous programs assumed the isolator as an elastic material. In contrast, the isolator is made from elastomeric rubber bearing which is not an elastic material. Therefore, the previous programs should be clarified or modified to obtain more reliable results.

Keywords: Base isolator, elastomeric rubber bearing, hollow base isolator, horizontal stiffness, vertical stiffness.

1. INTRODUCTION

In recent years, base isolation techniques were actively adopted in the construction of building, bridges, and other structures. The basic principles of base isolation are to reduce the input earthquake energy with soft bearing, and to restrain excessive displacement by damping. Code provisions for base isolated buildings and bridges have been developed in many countries and utilized for actual structures such as in Armenia, Chile, China, Indonesia, Malaysia, Italy, Japan, New Zealand, the United States and Uzbekistan.

The isolation system reduces the effect of the horizontal components of the ground acceleration by interposing structural elements with low horizontal stiffness between the structure and the foundation. This gives the structure a fundamental frequency that is much lower than both its fixed-base frequency and the predominant frequencies of the ground motion. The isolation system does not absorb the earthquake energy, but deflects it through the dynamics of the system.

Most recent examples of isolated buildings use multilayered laminated rubber bearings with steel reinforcing layers as the load-carrying component of the system. Because of the reinforcing steel plates, these bearings are very stiff in the vertical direction but soft in the horizontal direction, thereby producing the isolation effect. These bearings are easy to manufacture, have no moving parts, are unaffected by time, and resist environmental degradation.

In seismic protection it is beneficial to have different stiffness in two plane directions to provide a better protection of dynamic characteristic structures. Therefore a special design of base isolators with hollow is investigated, where the diameter of the hole is 20% of the outer diameter.

2. FINITE ELEMENT MODELING

Elastomeric rubber bearings have finite vertical stiffness that affects the vertical response of the isolated structure. The vertical stiffness, k_v, of an elastomeric rubber bearing can be obtained using the following formula.

$$k_v = \frac{P}{\delta} = \frac{E_c A}{nt} \qquad (1)$$

where P is the vertical load, δ is the vertical displacement, A is the cross sectional area of the bearing, n is the number of elastomeric layers, t is the thickness of each layers and E_c is the compression modulus of elastomer. Although some approximations using empirical method have been proposed for calculating the compressions modulus, the most acceptable expressions for circular bearings is proposed by Kelly (1993) as follow.

$$E_c = \left(\frac{1}{6G_{eff} S^2} + \frac{4}{3K} \right)^{-1} \qquad (2)$$

where K is the bulk modulus (typically assumed to have a value of 2000 MPa) and S is the shape factor, which is defined as the ratio of the loaded area to the bonded perimeter of a single rubber layer. For a circular bearing of bonded diameter Φ and rubber layer thickness t, the shape factor is given by

$$S = \frac{\Phi}{4t} \qquad (3)$$

A similar approach leads to the horizontal stiffness, k_h, is expressed as

$$k_h = \frac{F}{\Delta} = \frac{GA}{nt} \qquad (4)$$

where F is the horizontal load, Δ is the horizontal displacement, and G is the shear modulus of elastomer. Considering an elastomeric bearing design G_{eff} = 0.7 MPa, and K = 2000 MPa..

Since elastomeric bearings experience large deformations and the elastomer behaves nonlinearly, the Finite Element Modeling (FEM) must include geometric and material nonlinearities in order to obtain the reliable results. The elastomer and its material properties are usually significant problems in analyzing the isolator using FEM. It is difficult to determine these parameters experimentally; therefore in this study the parameters are determined based on parameter analysis using computer software.

2.1 Three Dimensional Model

There are two geometric types of elastomeric are designed and analyzed in this study; the conventional isolator and the elastomeric hollow rubber bearing. The dimensions of both the elastomeric can be shown in Figures 1 and 2. The modulus of elasticity of the steel is 20 x 10^6 kN/m^2 and 14 x 103 kN/m^2 for rubber. The poison ratio for the steel and the rubber are 0.3 and 0.6 respectively. The design parameters of both elastomeric rubber bearings can be shown at *Table 1*.

The devices were analyzed under two directions of loading, i.e. vertical and horizontal directions. *Table 2* shows the loading values for load directions. *Figures 3 and 4* show the mesh of the base isolator's model.

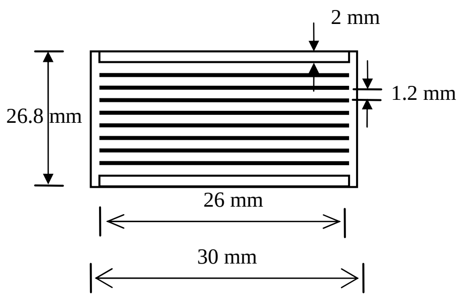

Figure 1. The conventional elastomeric rubber bearing

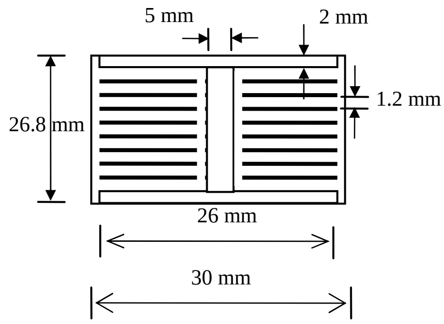

Figure 2. Elastomeric hollow rubber bearing

Table 1. The design parameters of the elastomeric rubber bearings

Parameters	Conventional Elastomeric Rubber Bearing	Elastomeric Hollow Rubber Bearing
Vertical design load (kN)	25	25
Nominal shear stiffness (kN/mm)	0.082	0.078
Nominal vertical stiffness (kN/mm)	13.256	13.234
Nominal vertical natural frequency (Hz)	5.79	5.79
Safety factor	3.59	2.05
Critical load (kN)	89.82	50.2
Rollout instability (mm)	26	21

Table 2. Loading value on both directions

Load Number	Vertical Loading (P) kN	Horizontal Loading (H) kN
Load 1	5	5
Load 2	10	10
Load 3	15	15
Load 4	20	20

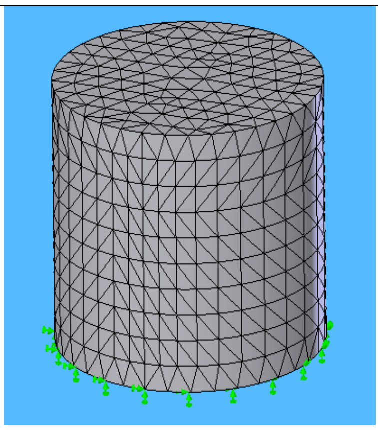

Figure 3. The mesh of the conventional elastomeric rubber bearing.

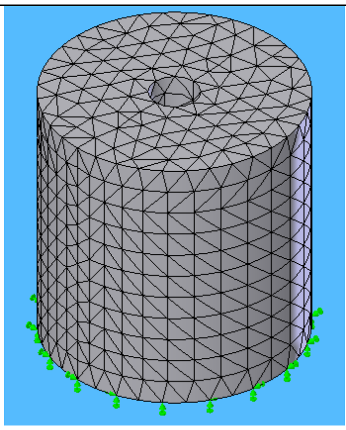

Figure 4. The mesh of the elastomeric hollow rubber bearing.

2.2 Discussion and Result

Figure 5 shows the displacements of the bearings at the maximum loading 25 kN on vertical and horizontal direction. *Figure 6* shows the stresses of the bearings and *Figure 7* shows the stress of the bearings. It is recognized that displacements, stresses and strains of two bearing are different even each bearing is applied in the same vertical and horizontal loadings. The graphs loading versus displacement with different direction of loadings were plotted at *Figures 8* and *9* for each bearing. Summarized responses of the bearing can be shown at *Table 3*.

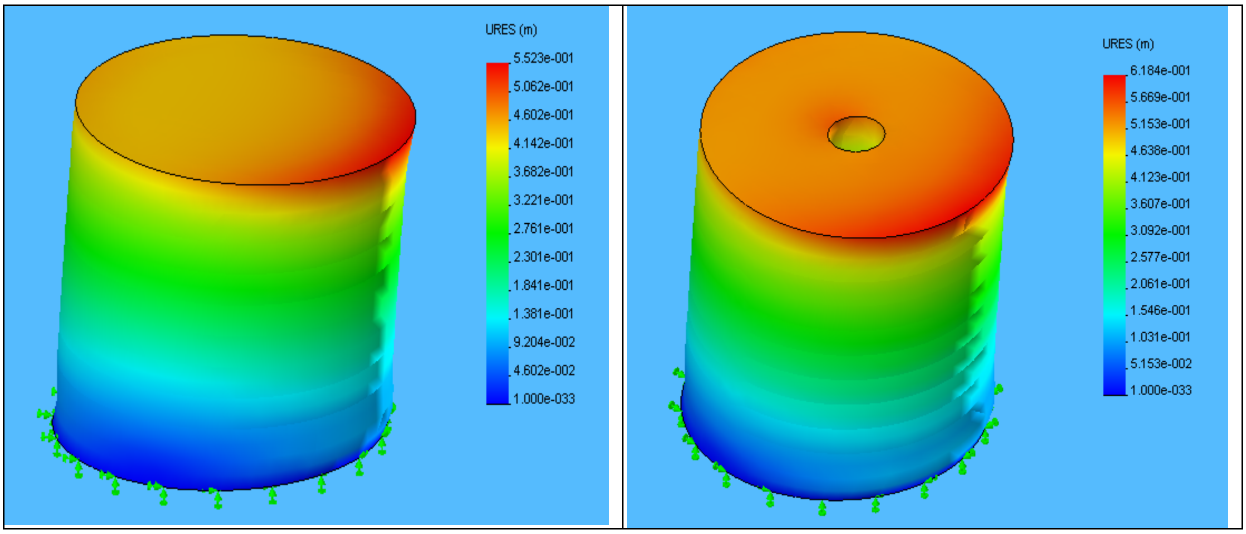

Figure 5. Displacement of base isolators

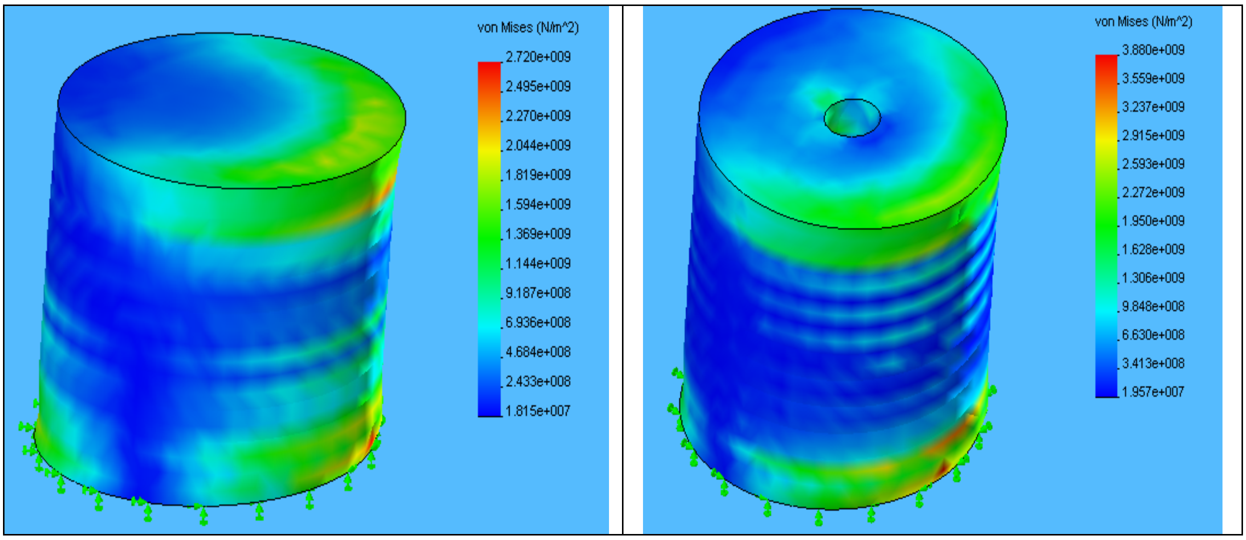

Figure 6. Stress of base isolators

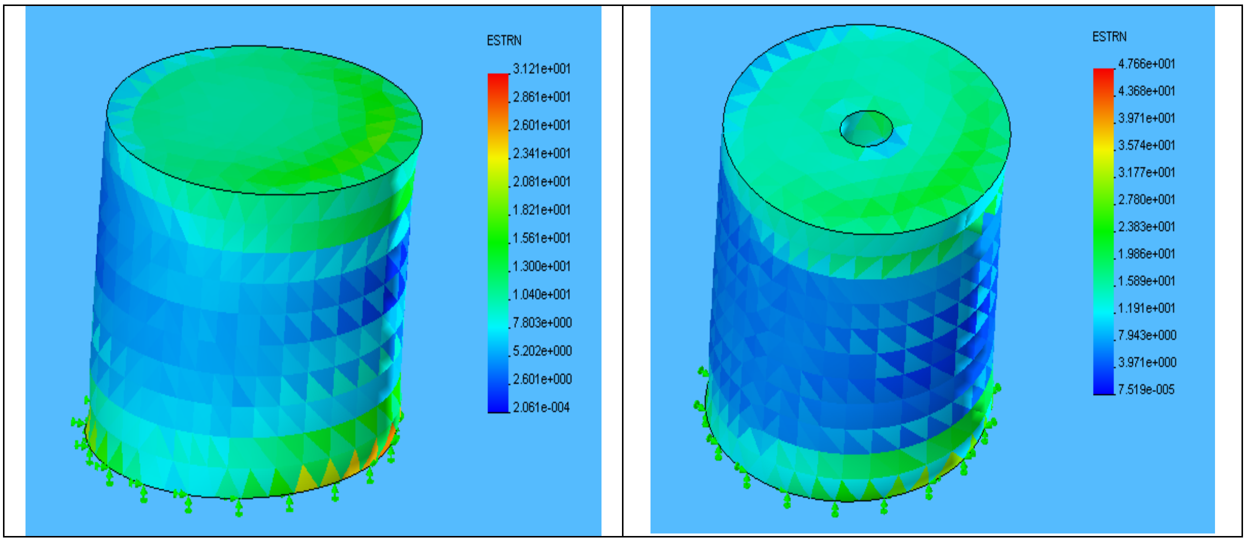

Figure 7. Strain of base isolators

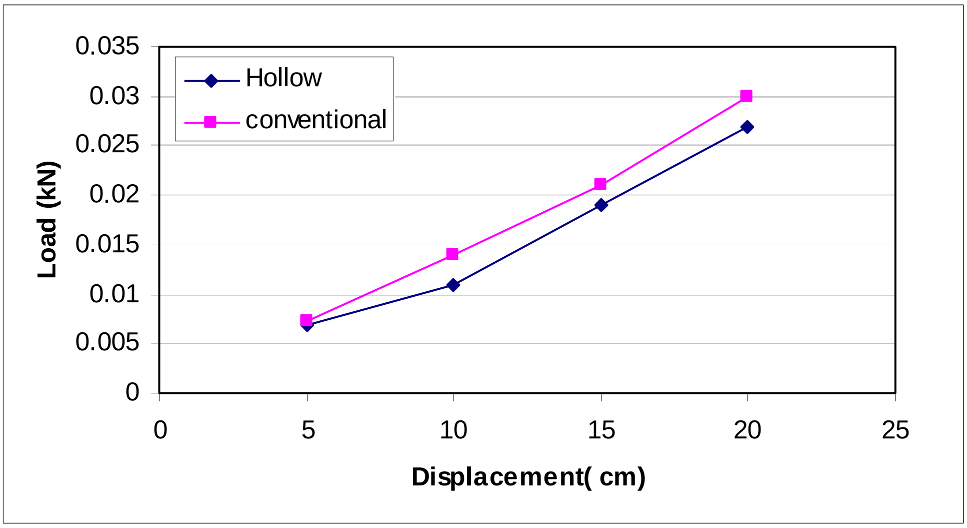

Figure 8. Horizontal load versus displacement of the bearings

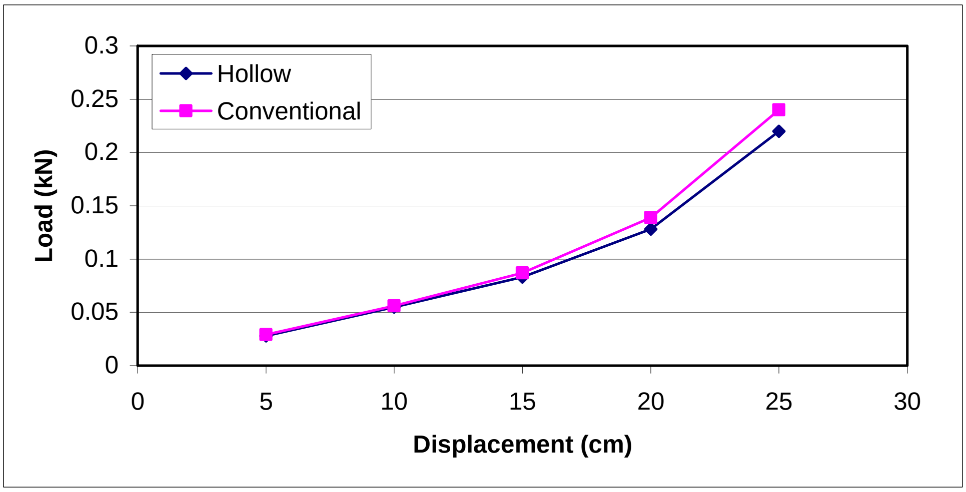

Figure 9. Vertical load versus displacement of the bearings

Table 3. Responses of base isolator

Load (kN)	Max. Deflection (m)		Strain			Stress (MN/m^2)		
	Original	Hollow		Original	Hollow		Original	Hollow
5	0.011	0.012	Max	6.2	9.5	Max	540	770
			Min	0.000041	0.000015	Min	3.6	3.9
10	0.022	0.024	Max	12	19.1	Max	1100	1500
			Min	0.000082	0.000031	Min	7.2	7.8
15	0.033	0.037	Max	18.7	28.6	Max	1600	2300
			Min	0.00012	0.00044	Min	11	12
20	0.044	0.049	Max	24.9	38.1	Max	2100	3100
			Min	0.00016	0.00062	Min	14	16

Table 4 shows that Vertical Stiffness values are larger than the Horizontal Stiffness values. These results are expected so that the design rules for bearing or base isolator that the vertical stiffness has to be greater than the horizontal stiffness. This is to ensure that the rocking and other unwanted modes can be minimized.

Table 4. Vertical and horizontal stiffness for both base isolators

Type	Description	Stiffness
Conventional	Vertical stiffness Horizontal stiffness Ratio	13.256 MN/m 0.082 MN/m 162
Hollow	Vertical stiffness Horizontal stiffness Ratio	13.234 MN/m 0.078 MN/m 170

The ratios of vertical stiffness to the horizontal stiffness were calculated for both base isolators as shown in *Table 4*. The ratio is calculated in order to know the efficiency of the base isolator. It can be seen that the hollow base isolator has larger ratio than the conventional base isolator.

3. CONCLUSIONS

From the study, it can be concluded that by changing the geometries of the base isolators, the stiffness values would also change. The hollow base isolator is efficient compared to the conventional base isolator because the ratio of the stiffness of the hollow base isolator is higher than the conventional one.

4. AKNOWLEGMENT

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5. REFFERENCES

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