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Finite Element Analysis of Kevlar Reinforced Rubber as Seismic Isolator

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Abstract**: *The seismic isolators are one of the modern innovative solution for building protection against the seismic behaviour of earth. Using the scope of composite materials we can create better solution for engineering problems arises due to earthquakes. Nowadays, an innovative material Kevlar is used as seismic isolator. Finite element simulations were carried out using ANSYS15 for the mechanical characterization of multi-layer elastomeric isolation bearings. Conventional steel plates are replaced by the fiber reinforcement. Fiber reinforced elastomeric isolation bearings are low cost alternative to the conventional steel-reinforced bearings. Some experiments were conducted in the past to assess their effectiveness. The development of lightweight, low-cost isolator is crucial if this method of seismic protection is to be applied to a wide range of buildings such as residential, school and hospital buildings etc. in rural and urban earthquake-prone zones. The main aim of this study is to find the effect of a high strength composite material Kevlar reinforced rubber as a seismic isolator. For this, circular isolators of increasing depth ratio were modelled using ANSYS 15. Horizontal displacements were applied at different oscillations and the horizontal stiffness and damping ratios were calculated. The study reveals that damping of the structure decreases with increase in depth ratio.***

Keywords: Kevlar, Seismic Isolator, ANSYS 15, Finite Element, Depth Ratio

I. INTRODUCTION

The use of seismic isolation for structures has been gaining worldwide acceptance to a seismic design. Seismic isolation is achieved by providing suitable devices called base isolation devices between the superstructure and the foundation. The principle of base isolation is to reduce the structures natural frequency by using devices with low horizontal stiffness at the base to decouple the structure from the ground. Conventionally, steel plates are used as reinforcing material. Its function is to provide vertical stiffness to the isolator to take the weight of the structure. Bearings using steel as reinforcing material are known as steel-reinforced elastomeric bearings. Thin sheets of steel are interspersed in between layers of rubber. However, steel reinforcement has some disadvantages. Steel is heavy and makes up for most of the weight of the isolator. The process of bonding steel with the rubber involves placing steel plates between rubber layers and heating them under pressure for several hours. The entire process is complicated and expensive. All these make conventional isolators unsuitable. Many fiber materials whose stiffness is comparable to steel are now available. Kevlar is used as a base isolator since it has many advantages as compared to conventional fibers.

II. MATERIAL PROPERTIES

The material properties of Kevlar used for the analysis is depicted in Table I.

TABLE I
MATERIAL PROPERTIES OF KEVLAR

Modulus of Elasticity (Mpa)			Modulus of Rigidity (Mpa)			Poisson's Ratio		
Ex	*Ey*	*Ez*	*Gxy*	*Gyz*	*Gzx*	γ_{xy}	γ_{yz}	γ_{zx}
2.3×10^5	1.7×10^4	1.7×10^4	1.17×10^4	6.8×10^3	1.7×10^9	0.22	0.3	0.22

III. MODELLING

For modelling the structure some geometric properties are given to ANSYS 15. In this study, the depth ratio 0.2, 04, 0.6 has been taken for showing increase in damping of the Kevlar reinforced rubber using the respective displacements – 50mm, 100mm, and 120mm. To carry out finite element analysis of circular isolator by increasing depth, the geometry of isolator is chosen from the

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study conducted by Kevlar. The geometric properties corresponding to increasing depth ratio as 0.2, 0.4 and 0.6 are shown in the Table II, Table III, and Table IV respectively. Fig. 1, Fig. 2 and Fig. 3 shows the model of kevlar isolator by increasing depth ratio 0.2, 0.4 and 0.6 respectively.

TABLE II
GEOMETRIC PROPERTIES OF KEVLAR ISOLATOR BY INCREASING DEPTH RATO 0.2

Kevlar Rubber Isolator	
Diameter	305 mm
Total height	169.2 mm
Thickness of Kevlar layer	3.6 mm
Number of Kevlar fiber layer	13
Thickness of rubber layer	10.2 mm
Number of rubber layer	12
Bonded end plate diameter	320 mm
Bonded end plate thickness	20 mm

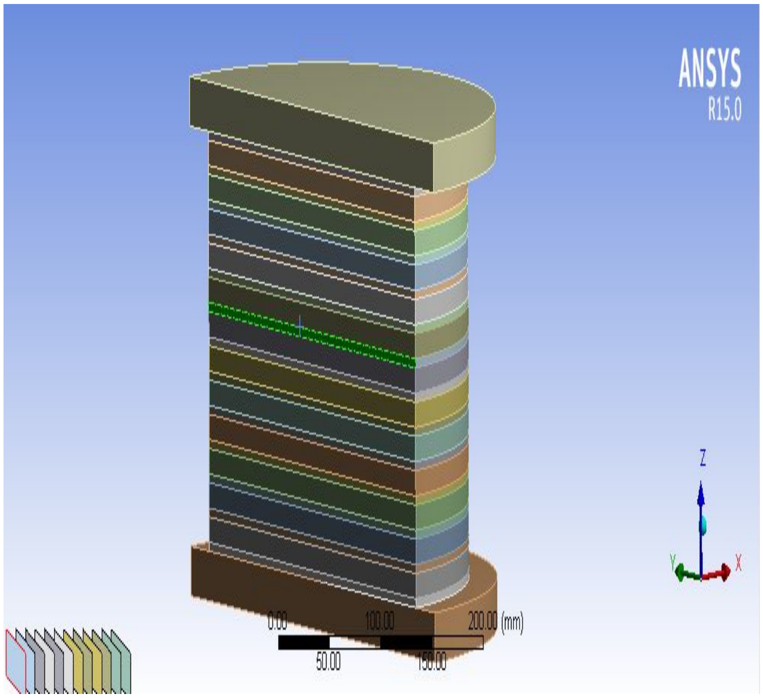

Fig. 1 Model of kevlar isolator by increasing depth ratio 0.2

TABLE III
GEOMETRIC PROPERTIES OF KEVLAR ISOLATOR BY INCREASING DEPTH RATO 0.4

Kevlar Rubber Isolator	
Diameter	305 mm
Total height	197.4 mm
Thickness of Kevlar layer	4.2 mm
Number of Kevlar fiber layer	13
Thickness of rubber layer	11.9 mm
Number of rubber layer	12
Bonded end plate diameter	320 mm
Bonded end plate thickness	20 mm

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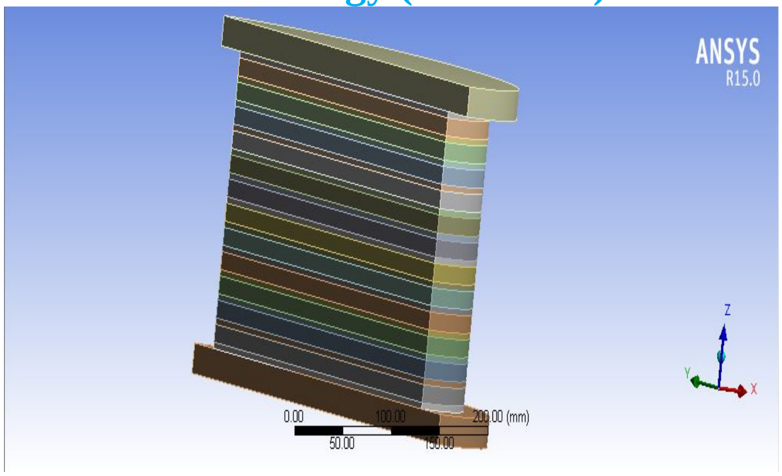

Fig. 2 Model of kevlar isolator by increasing depth ratio 0.4

TABLE IV
GEOMETRIC PROPERTIES OF KEVLAR ISOLATOR BY INCREASING DEPTH RATO 0.6

Kevlar Rubber Isolator	
Diameter	305 mm
Total height	225.6 mm
Thickness of Kevlar layer	4.8 mm
Number of Kevlar fiber layer	13
Thickness of rubber layer	13.6 mm
Number of rubber layer	12
Bonded end plate diameter	320 mm
Bonded end plate thickness	20 mm

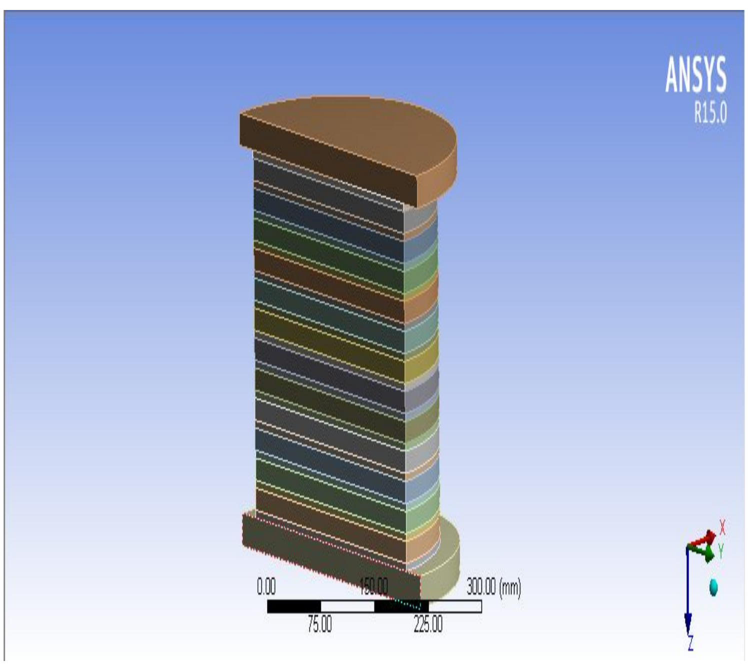

Fig. 3 Model of kevlar isolator by increasing depth ratio 0.6

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IV.RESULTS AND DISCUSSIONS

From this parametric study, it can be concluded that using the displacement 50mm in each of the depth ratios 0.2, 0.4, 0.6 there is an increase in stiffness and decrease in damping. Similarly, there exists the same condition while using the displacements 100mm and 120mm. The Fig. 4, Fig. 5, and Fig. 6 shows the hysteresis curve obtained by increasing the depth ratio by 0.2, 0.4 and 0.6 at different displacement cyclic loads. At 50mm displacement less area obtained compared to the other displacements 100mm and 120mm. From the experimental theory, it can be said that more energy dissipation occurs under large area. Thus high dissipation energy occurs under the curve obtained at 120mm displacement. Hence, in every case, it can be seen that with increase in displacement, there is an increase in damping also.

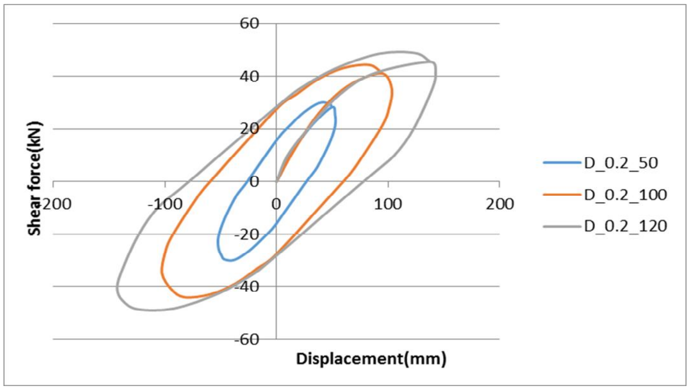

Fig. 4 Shear force v/s Displacement curve for increasing depth ratio by 0.2

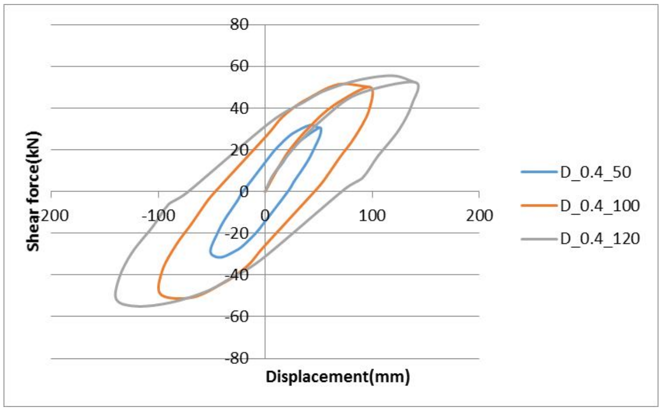

Fig. 5shear force v/s displacement **c**urve for increasing depth ratio by 0.4

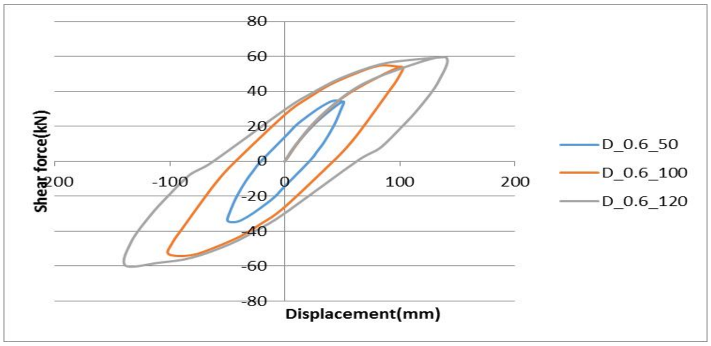

Fig. 6 shear force v/s displacement curve for increasing depth ratio by 0.6

From this parametric study, the damping of each isolator is recorded with different depth ratio under different displacement cyclic loads which is shown in the Table V.

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TABLE V
RESULTS OF THE DAMPING OF INCREASING DEPTH OF ISOLATOR

Cases	Maximum Displacement (mm)	Stiffness K (kN/m)	Damping (%)
Depth increasing by 20%	50	570.47	26.56
	100	428.51	30.47
	120	341.69	24.87
Depth increasing by 40%	50	617.90	21.95
	100	522.17	25.73
	120	396.79	23.69
Depth increasing by 60%	50	692.76	20.73
	100	535.09	21.78
	120	429.19	21.80

V. CONCLUSIONS

In modern Engineering design, the safety features of mega structures are very important against seismic behaviour of the earth. We have to take good amount of safety measures for the protection of our buildings and constructions against these natural phenomenon. Seismic isolators is one of the modern Engineering solution against seismic issues. The commonly available natural rubber elastomer have a better capability against seismic effects. Because of the extended usage of these materials there is an improvised usage in modern composite materials. There are lots of researches being done on composite materials to with stand seismic loads. Some of the materials used for making better rubber composite are CFRP, Kevlar etc. There are lot of experiments being conducted around the world to create a better solution for seismic isolation of mega structures.

In the present study, Kevlar reinforced rubber composite is taken as a solution for seismic isolator. Kevlar is one of the strongest material available with a high durability against heavy tensile loading. From the current study it is found that kevlar showing more damping and much better bonding with hyperelastic material like rubber. A parametric study was conducted on depth by increasing depth ratio by 0.2, 0.4, and 0.6 at different displacements. From the study it is revealed that damping decreases and stiffness increases at different displacements.

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