Study of Seismic Performance of Base Isolated RCC Structure using Fibre Reinforced Elastomeric Isolator – A Review

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Abstract - *Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements and to some structural members in the building. This may render the building non-functional after the earthquake, which may be problematic in some structures, like hospitals, which need to remain functional during the earthquake. Special techniques are required to design buildings such that they remain practically undamaged even in a severe earthquake. Base isolation is one such techniques of designing an earthquake resistant building. The idea behind base isolation is to detach the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least get greatly reduced. It has become evident in recent times that base isolation can be very effective in the event of an earthquake. But the cost of installing base isolation system has been so great that it is for important buildings and in developed nations only. In a developing country like India, base isolation technique is as good as non-existent. Fibre Reinforced Elastomeric Isolator (FREI) is a low cost base isolation system. It is a rubber bearing reinforced with fibre instead of steel, which reduces the weight and cost of the bearings with great extent. It can also lead to a much lesser labour intensive manufacturing process. Past study shows that the behaviour of the fibre reinforced elastomeric isolator is very similar to that of the steel reinforced specimen with regard to shear deformation and dynamic and mechanical characteristics including vertical stiffness, effective horizontal stiffness and damping. Therefore, this type of fibre reinforced isolator can be used in seismic isolation of structures.*

***Key Words*: Base Isolation, Seismic Performance, Fibre Reinforced Elastomeric Isolator.**

1. INTRODUCTION

The earthquakes in the recent past have provided enough evidence of performance of different type of structures, earthquake conditions and foundation conditions to be taken as a food for thought to the engineers and scientists. This has given birth to different type of techniques to save the structures from the earthquake effects. Base Isolation is a passive vibration control system. It partially reflects and partially absorbs input seismic energy before it gets transmitted to the superstructure. The idea behind base isolation is to detach the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least get greatly reduced. The basic difference between dampers and base isolators is that dampers are provided in the superstructure while base isolators are provided between superstructure and foundation. Isolation system introduces a layer of low lateral stiffness between the structure and the foundation. With this isolation system the structure has a natural time period which is much longer than its fixed base natural time period. This lengthening of time period can reduce the acceleration and hence the earthquake induced forces in the structure.

It has become evident in recent times that base isolation is a very efficient measure to design an earthquake resistant structure but due to the cost involved in manufacturing and installing base isolation systems it is generally only used for emergency centers, historical buildings, and buildings with very expensive and sensitive equipment and is limited to developed nations only and in a developing country like India, base isolation technique is as good as non-existent. Therefore to enable its use for ordinary structures and in countries like India it is important to develop low cost devices, one such low cost device is Fibre Reinforced Elastomeric Isolator (FREI). Therefore the main focus of this study is to understand the seismic response of a base isolated RC structure where a low cost device i.e. FREI is used as a base isolation device.

2. DETAILED REVIEW

A review of some of the research done by some researchers around the world on the base isolation and on Fibre Reinforced Elastomeric Isolator is presented below.

James M. Kelly (2001) et. al. studied analytical and experimental study of fibre-reinforced elastomeric isolators. Theoretical and experimental analyses are carried out for the mechanical characteristics of multi-layer elastomeric isolation bearings where the reinforcing elements, normally steel plates, are replaced by a fibre reinforcement. The fibre-reinforced isolator, in contrast to the steel-reinforced isolator (which is assumed to be rigid both in extension and flexure), is assumed to be flexible in extension, but completely without flexure rigidity. The influence of fibre flexibility on the mechanical properties of the fibre reinforced isolator, such as the vertical and horizontal stiffness, is studied, and it is shown that it should be possible to produce a fibre-reinforced isolator that matches the behaviour of a steel-reinforced isolator. [5]

Hsiang Chuan Tsai (2001) et. al. studied the stiffness analysis of fibre reinforced elastomeric isolators. This report deals with theoretical approaches for analysing the compressive and bending stiffness of fibre reinforced isolators having three types of geometry, infinitely long strip, rectangular, and circular. The stiffness formulae of fibre reinforced isolators is studied, and it is shown that it should be possible to produce a fibre reinforced isolators that equals the advantageous behaviour of steel reinforced isolator. [4]

Byung Young Moon (2002) et. al. studied design and manufacturing of fibre reinforced elastomeric isolator for seismic isolation. In this study three kinds of comparison tests have been performed. In case 1, four kinds of elastomeric isolators are compared in terms vertical stiffness and shear modulus in which fibres used are Polyester-200, Nylon-200, FIBP-01, FIBP-05. In case 2, Carbon fibre and glass fibre is compared for vertical stiffness. The results show that vertical stiffness of carbon fibre reinforcement is higher than that of glass fibre reinforcement. But the cost of glass fibre being very less as compared to carbon fibre, therefore can be used for ordinary buildings. In case 3, FREI with Carbon fibre is compared with SREI for vertical and horizontal stiffness and the test and comparison results show that, carbon can be replaced with steel of SREI. [1]

Ramkrishna V. Darji (2009) et. al. studied Design of Base Isolator for RCC Building and Performance Evaluation. The study include design of different types of base isolators namely Lead Rubber Bearing (LRB), High Damping Rubber bearing (HDR) and Friction Pendulum System (FPS). A G + 4 symmetric R.C.C. building has been taken for the study. The analysis of the R.C.C. building has been carried out with the commercially available software ETABS 8.11. The design of base isolators has been carried out broadly based on the guidelines of IBC 2000. It was found in the study that the time period for base isolated buildings are approximately 2.25 times higher compared to fixed base building, the base shear value for fixed base building is approximately 2.5 to 3.5 times lower compared to base isolated building. Based on the values obtained for base shear and story drifts, it is recommended that, the base isolated system is not effective for buildings with time period more than 1 sec. [10]

Md. Arman Chowdhury (2013) et. al gave comparative study of the dynamic analysis of multi-story irregular building with or without base isolator. A 20 storyed residential building is modeled to analyse with story plan changing in different floors. For isolated structure Lead Rubber Bearing (LRB) is used which were connected to all column and foundation of the building. Results of comparison between isolated and non-isolated building under different earthquake show that the displacement obtained by non-isolated building is much higher than isolated structure. [7]

Farshad Hedayati (2014) et. al. studied sensitivity analysis of carbon fibre-reinforced elastomeric isolators based on experimental tests and finite element simulations. This research work deals with the study of the performance of rectangular carbon FREIs (C-FREIs) produced through a simple and cost-effective manufacturing process. Additionally, the effect of different factors including the number and the thickness of rubber layers, as well as the thickness of carbon fibre reinforced sheets are investigated on the performance of C-FREIs through sensitivity analyses based on the results obtained from finite element simulations. The results show that by increasing the number and thickness of rubber layers, the efficiency of C-FREIs degrades in terms of vertical strength and damping capacity, however, the performance improves in terms of lateral flexibility. Another important observation is that the increasing thickness of fibre-reinforced layers can increase the vertical rigidity of the base isolator. The vertical stiffness has the most sensitivity to the thickness of elastomeric layers and the thickness of CFR sheets while, when the number of rubber layers increases, the effective lateral stiffness is mostly affected. [3]

S. Keerthana (2015) et. al. studied Seismic Response Control of Structures Using Base Isolation with a case study of three storyed building modelled in SAP-2000 software. Base isolation is one of the reliable techniques for earthquake resistant design of structures. The acceleration time history of the structure gets controlled if base isolation is used but it increases the displacement of the structure. The large displacements observed in the isolated structure can be controlled by designing the isolator in the nonlinear form which can be adopted easily. 58% reduction in the acceleration and 85% increase in displacement were observed. Further 38% reduction in displacement could be observed when the nonlinear properties of the isolators were considered. [9]

Dhananjay A. Chikhalekar (2015) et. al. studied different types of G+10 structures with fixed base and isolated with rubber bearing. These structures are modelled in SAP2000. The results of analysis are compared in terms of story displacements, story acceleration, and story drift. The comparative study shows that these parameters are greatly reduced for base isolated structure. [2]

James M. Kelly (2015) et. al. studied single series solution for the rectangular fibre reinforced elastomeric isolator compression modulus. Fibre-reinforced elastomeric bearings were originally proposed as an alternative to conventional steel-reinforced elastomeric bearings for seismic isolation applications. The flexible fibre reinforcement is a light-weight and potentially cost-saving alternative to steel reinforcement, which is assumed rigid in the design process. The variety of fibre materials available also serves as an additional parameter for designers to tailor the vertical stiffness of the bearing. In this report, a further cost reduction is visualized by manufacturing the bearing in a large sheet that can be cut to the required size such that the ideal shape for the bearing will be rectangular. An analytical solution for the vertical compression modulus of a rectangular elastomeric pad including the effects of the elastomer bulk compressibility and extensibility of the fibre reinforcement is given here in the form of a rapidly convergent single series. This solution is computationally efficient and allows for a rapid calculation of the stiffness for both design and analysis purposes. [6]

S. D. Darshale (2016) et. al. studied Seismic Response Control of RCC Structure Using Base Isolation and showed that base isolation reduces the responses such as lateral displacement, shear forces etc. as compared to the conventional fixed base structure, using ETABS. [8]

3. CONCLUSIONS

Base isolation is an efficient method to reduce the earthquake induced forces. It reduces the responses such as lateral displacement, shear forces, bending moments, base shear, story acceleration, inter-story drift as compared to the conventional fixed base structure. It is evident from the above literature survey that base isolation devices are costly, since the cost involved in manufacturing and installing is more. Therefore a cost efficient device should be developed for developing countries like India and for ordinary buildings. Fibre Reinforced Elastomeric Isolator (FREI) is a cost efficient, light in weight replacement of Steel Reinforced Elastomeric Isolator (SREI). So far the work has been done on finding the mechanical properties of scaled down FREI, the future work done on this topic can be of designing a FREI for actual structure and finding its mechanical properties and studying the seismic performance of the structure when base isolated with FREI.

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