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Seismic Performance of Base Isolated RCC Structure using Fibre Reinforced Elastomeric Isolator

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ABSTRACT: In 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. Various analytical and experimental studies have been done on the mechanical properties of FREI namely, horizontal and vertical stiffness. But so far no work has been reported on the seismic performance of a RC structure is base isolated with a FREI. In present study a FREI is designed as per UBC-97 for a G+6 RC building. The FREI manufactured in this study uses glass fibres in place of steel plates. The FREI is of $450 \times 450 \times 339$ mm consisting of alternate layers of rubber and glass fibre with rubber thickness as 4mm and glass fibre as 0.5 mm, it also consists of 28 mm thick top and bottom steel plate. The mechanical properties viz. vertical stiffness and horizontal stiffness are obtained experimentally. Considering the values from the test results the seismic performance of the RCC building base isolated with FREI is compared with the fixed base RCC building and building base isolated with SREI (Steel Reinforced Elastomeric Isolator) by using ETABS-2016 software and the parameters considered for comparison are base shear, story displacement, story drift, and overturning moment. Comparison of the behavior of the FREI under various zones as per IS 1893:2016 is also been done.

KEYWORDS: base isolation, FREI, elastomeric isolator

I. INTRODUCTION

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.

II. RELATED WORK

1 N. Torunbalci et. al. (2008) studied earthquake response analysis of mid story buildings isolated with various seismic isolation techniques. As a numerical example, a six story structure analyzed with four different seismic protection alternatives as fixed base, rubber bearing, friction pendulum bearing, and viscous damper is studied. Three dimensional nonlinear time history analysis is performed on RC building model for fixed base case with respect to the seismic isolation, the main objective here is to make a comparison between the seismic isolation and fixed based building, rather than comparing the seismic isolation alternatives within themselves. In the analysis, total base shear forces, story shear forces, maximum absolute accelerations and relative story drifts are compared. The natural period of the structure being 0.58 in the fixed base situation is increased to 2 sec. in the systems containing base isolators. It is seen that the alternative containing viscous dampers did not have that much influence on the natural period. In the base shear forces,

the results of the rubber and friction pendulum alternatives are very close to each other, and they provided approximately 71 % reduction in the x direction and 74% reduction in the Y direction. This reduction in the forces indicates that the performance of the base isolation under the influence of earthquake is extremely good. [23]

From the research done by Andrea Mordini et. al. (2008) an innovative earthquake isolation system using fibre reinforced rubber bearings was studied. In this contribution, a new innovative isolation system for structures in earthquake regions is presented. The system consists of high damping rubber bearings strengthened with glass fibre fabrics. A wide parametric numerical investigation through Finite Element Analysis is carried out in order to develop and verify analytical models for these new isolation devices. Experimental investigations provided useful information for numerical modelling and derivation of analytical approaches. Comparisons with simplified formulations are reported as well. In order to demonstrate the effectiveness of the proposed solution and to verify the reliability of the numerical simulations, the new devices are applied to the seismic analysis of a liquid storage tank. [03]

In the research conducted by M. J. Tait et. al. (2008) the influence of end geometry of fibre reinforced elastomeric isolator bearings was studied. The isolators investigated in this paper comprises of a base isolation system developed specifically for the seismic mitigation of ordinary low-rise buildings. This base isolation system employs “Stable Unbonded Fibre Reinforced Elastomeric Isolators” (SU-FREI). A fibre reinforced elastomeric isolator utilizes fibre fabric, such as carbon fibre, as the reinforcement material instead of solid steel plates. In an unbonded application, the FREI bearings are placed between the superstructure and substructure with no bonding or fastening required between the contact surfaces. An experimental study is conducted on model scale prototype FREI bearings constructed using unfilled soft Neoprene rubber as the elastomer, and bi-directional carbon fibre fabric as the reinforcement. Three different end geometries are considered and the influence of the different end configurations on the response behaviour of the isolators is investigated by means of cyclic testing. FREI bearings have a number of advantages over SREI bearings including superior energy dissipation capability, potential low manufacturing cost, light-weight, and the prospect of being produced in long rectangular strips and modified to the required size locally. As a result of using a reinforcing material with no bending stiffness and an unbonded installation technique, an SU-FREI bearing has a unique Stable Rollover (SR) deformation characteristic. This SR characteristic has been found to improve the effectiveness of this seismic isolation device. Four SU-FREI bearings with different end geometries are experimentally investigated and the results are compared to evaluate the influence of this parameter on the lateral force-displacement properties of SU-FREI bearings. The unbonded application permits the contact boundary surfaces of the SU-FREI bearing to change as the bearing is displaced laterally. As a result, a new parameter, namely the geometry of the contact surfaces, can be modified to alter the response behavior of the bearings. Changes to the surrounding contact surfaces and vertical faces of the bearing will influence the horizontal force that develops as the bearing is displaced laterally. A comparison of the lateral force-displacement hysteresis loops showed that end geometry can significantly modify the lateral force-displacement response behavior of an SU-FREI bearing. The lateral stiffness of an SU-FREI bearing was found to decrease if material was removed from the end faces of the bearing and to increase if material was added to the end faces of the bearing. Additionally, the shape of the end face was found to affect the response behavior of the bearing. These preliminary findings indicate that the end geometry of an SU-FREI bearing is a parameter that can be modified to obtain the desired lateral force-displacement response behavior. Additional studies are needed to determine optimal end geometries that maximize theseismic mitigation efficiency of SU-FREI bearings. [20]

II. METHODOLOGY

The step by step procedure adopted for achieving the aim and objective of the present study is shown in the flow chart below.

01. A Fibre Reinforced Elastomeric Isolator (FREI) is designed as per UBC-97 and then manufactured and tested for mechanical properties such as vertical stiffness and horizontal stiffness.

02. A G+6 RCC structure is analysed by considering standard Response Spectrum Analysis as per IS 1893: 2016, in ETABS-2016 software to find its seismic performance with fixed base condition and base isolated condition using Steel Reinforced Elastomeric Isolator and Fibre Reinforced Elastomeric Isolator.



III. EXPERIMENTAL RESULTS

Story Shear

The comparison of Story Shear of SREI, FREI and Fixed Base Structures for all the zones considered is described in this section.

Table 5.4: Story Shear in different Zones

| Story Shear (kN) | | | | | | | | |
|------------------|-------|---------|---------|---------|---------|---------|---------|---------|
| Zones | | Base | Story 1 | Story 2 | Story 3 | Story 4 | Story 5 | Story 6 |
| Zone V | Fixed | 1806.43 | 1690.36 | 1494.23 | 1253.78 | 955.41 | 553.62 | 553.62 |
| | SREI | 485.73 | 410.88 | 333.81 | 254.59 | 171.94 | 85.18 | 85.18 |
| | FREI | 455.63 | 384.71 | 311.93 | 237.58 | 159.53 | 79.75 | 79.75 |
| Zone IV | Fixed | 1204.26 | 1126.88 | 996.13 | 835.83 | 763.92 | 369.07 | 369.07 |
| | SREI | 323.8 | 273.9 | 223.62 | 169.71 | 114.16 | 57.26 | 57.26 |
| | FREI | 303.78 | 256.49 | 207.97 | 158.39 | 106.36 | 52.82 | 52.82 |
| Zone III | Fixed | 808.87 | 751.28 | 664.11 | 557.24 | 424.63 | 246.05 | 246.05 |
| | SREI | 215.91 | 182.64 | 149.12 | 113.17 | 76.12 | 37.86 | 37.86 |
| | FREI | 202.54 | 171.02 | 138.66 | 105.61 | 70.91 | 35.22 | 35.22 |
| Zone II | Fixed | 501.82 | 469.58 | 415.09 | 348.29 | 265.41 | 153.79 | 153.79 |
| | SREI | 134.95 | 114.15 | 92.74 | 70.73 | 47.58 | 23.86 | 23.86 |
| | FREI | 126.54 | 106.84 | 86.63 | 65.88 | 44.3 | 22 | 22 |

From the table 5.4 it can be seen that the shear force of fixed base structure is more than the base isolated structure. And by comparing the shear force in SREI and FREI, it can be understood that the shear force is less for FREI as compared to that of SREI for all the zones considered. The shear force represented in the tabular format above is also represented in graphical format below for each zone individually.



Story Overturning Moment

The comparison of Overturning Moment of SREI, FREI and Fixed Base Structures for all the zones is shown below.

Table 5.5: Overturning Moment in different Zones

| Overturning Moments (kN.m) | | | | | | | | |
|----------------------------|-------|---------|---------|---------|---------|---------|---------|---------|
| Zones | | Base | Story 1 | Story 2 | Story 3 | Story 4 | Story 5 | Story 6 |
| Zone V | Fixed | 24364.2 | 18741 | 13483.6 | 8783.27 | 4799.02 | 1753.89 | 0 |
| | SREI | 0 | 3773.23 | 2532.49 | 1534.94 | 773.17 | 257.7 | 0 |
| | FREI | 0 | 3526.14 | 2361.84 | 1429.26 | 718.82 | 239.25 | 0 |
| Zone IV | Fixed | 16242.4 | 12493.7 | 8988.87 | 5855.38 | 3199.28 | 1169.24 | 0 |
| | SREI | 0 | 2515.29 | 1688.19 | 1023.22 | 515.41 | 171.79 | 0 |
| | FREI | 0 | 2350.94 | 1574.68 | 952.91 | 479.25 | 159.51 | 0 |
| Zone III | Fixed | 10828.6 | 8329.44 | 5992.78 | 3903.72 | 2132.92 | 738.16 | 0 |
| | SREI | 0 | 1677.25 | 1125.72 | 682.3 | 343.68 | 114.55 | 0 |
| | FREI | 0 | 1567.49 | 1049.92 | 635.36 | 319.54 | 106.36 | 0 |
| Zone II | Fixed | 6768.27 | 5206.19 | 3745.69 | 2439.96 | 1333.15 | 461.38 | 0 |
| | SREI | 0 | 1048.28 | 703.58 | 426.44 | 213.65 | 71.59 | 0 |
| | FREI | 0 | 979.32 | 657.24 | 396.95 | 199.64 | 66 | 0 |

IV. CONCLUSION

01. From the manufacturing of FREI it can be concluded that the FREI is a light in weight replacement of SREI. From the testing it is seen that the vertical stiffness of FREI is at par with that of SREI and the horizontal stiffness of FREI is lower than that of SREI, thus giving a layer of lateral stiffness between ground and superstructure further less than that of SREI which will reduce the seismic loads transferred to the structure above.

02. From the study of seismic analysis it can be concluded that the seismic responses decrease when the building is base isolated. As we compare the performance of SREI and FREI we can see that the performance of FREI is comparatively better than that of SREI, thus making FREI an efficient replacement of SREI.

03. The FREI is found out to be efficient in all the zones considered. From section 5.4.5 we can see that the seismic response decreases as we go from higher zones to lower zone.

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