Seismic Behavior Evaluation of Base Isolated Structure with Different Isolators

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Abstract- In this research paper the main part of study was to check the response of the base isolation of the concrete deck slab structure under time history analysis. Base isolation is one of the most widely accepted seismic protection systems used in structures in earthquake prone areas. The base isolation system separates the sub structure from its super structure and primarily moves it relative to that of the upper structure. The aim of this study is calculate restoring forces and time period due to earthquake ground excitation, applied to the superstructure of the bridge by installing base isolation devices at the foundation level and then to compare the different performances between the fixed base condition and base-isolated condition. In this study, the bridge Structure with and without isolator is used as models. Friction base isolator and Rubber Base isolator is used as isolation system in this study. time history analysis is used on Conventional base and base isolated structure. The comparative study of the acceleration, displacement and base shear was carried out for both fixed Conventional base and base isolated structure. It is found that the displacement is increased with period of the structure in case of base isolated structure and the acceleration is reduced and vice versa.

Keywords-Base isolation, rubber bearing, friction bearing, time history method, displacement, time period

1. INTRODUCTION

A natural calamity like an earthquake cause significant loss of life and destruction to property every year. A disturbance that causes shaking of earth surface due to movement at underground along fault plane or from volcanic activity is called earthquake. The seismic forces produced are harmful and lasts only for a small duration of time. Yet, humans are confused with uncertainty in terms of its time of occurrence and its nature. However with advances made in varies areas of sciences it has been learned how to pinpoint the locations of earthquake and how to accurately measure their sizes, however, this solves only one part of the problem to protect a structure. The other part is seismic design of the structures. Since from the last century, this part of problem has taken various forms, and improvements in design philosophy and methods have been done. There are two types of methods for the seismic design of structures,

1) Conventional method: This is the traditional method to resist lateral force is by increasing the design capacity and stiffness. Ex- shear wall, Braced frames or Moment resisting frames.

2) Non conventional method: Based on reduction of seismic demands instead of increasing capacity. Ex- Base isolation, Dampers.

II. LITERATURE REVIEW

In the paper Ajay Sharma , Analytical seismic response of multi-story building supported on base isolation system is investigated under real earthquake motion. The superstructure is idealized as a shear type flexible building with lateral degree-of-freedom ateach floor. The force-deformation behavior of the isolation system is modeled by the bilinear behavior which can be effectively used to model all isolation systems in practice. He derived governing equations of motion of the isolated structural system. The response of the system is obtained numerically by step-by-method under three real recorded earthquake motions and pulse motions associated in the near-fault earthquake motion. The variation of the top floor acceleration, under story drift, base shear and bearing displacement of the isolated building is studied under different initial stiffness of the bi-linear isolation system. It was observed that the high initial stiffness of the isolation system excites higher modes in base-isolated structure and generate floor accelerations and story drift. Such behavior of the base-isolated building especially supported on sliding type of isolation systems can be detrimental to sensitive equipment installed in the building. On the other hand, the bearing displacement and base shear found to reduce marginally with the increase of the initial stiffness of the initial stiffness of the isolation system. Further, the above behaviour of the base-isolated building was observed for different parameters of the bearing and earthquake motions

In this paper by Srijit Bandyopadhyay, studied the performance of a well-designed layer of sand, geogrid, geo-textiles and composites like layer of sand mixed with shredded tyre (rubber) as low-cost base isolators is studied in shake table tests in the laboratory. The selected base isolator is placed between the block and the sand foundation. Accelerometers are placed on top of the footing and foundation sand layer. The displacement of the footing is also measured by transducers. The whole set-up is mounted on the shake table and subjected to sinusoidal motion with varying amplitude and frequency. Sand is found to be effective only at very high amplitude (>0.65 g) of motion. Among all the different materials tested, the performance of a composite consisting of sand and 50% shredded rubber tyre placed under the footing is found to be the most promising as a low-cost, effective base isolator.

In this paper by Soumya Chandran **,** has presented *Base* isolation have become a significant element of a structural system to enhance reliability during an earthquake. It is a technique developed to prevent or reduce damage to building. The principle of seismic isolation is to introduce flexibility in the structure. In this a study of base isolation, with different plan shape G+6 storey with rubber isolation and friction isolation is analyzed by using ETABS. The analysis is done using nonlinear seismic time history data for with and without base isolation. Time history analysis has been performed and performance of RC building is studied with base isolation. The result is compared with and without base isolation structures. Santa Monica is the earthquake that is imposed on the structure .C,H,L and T shapes are analyzed with fixed base, friction isolator and rubber isolator.

III. MODELING OF STRUCTURE

In present study, bridge Model 2 and bridge Model 3 is modeled and analyzed with conventional bridge model 1 and results found then this bearings are replaced with rubber isolated bearing and friction isolated bearings and analysis is made and results compared. The difference between conventional bearings and isolation bearing is that isolation bearing are more flexible in horizontal direction than that of conventional bearing and same vertical stiffness. The horizontal flexibility and damping characteristics of the bearing provide the desired isolation effects in the system .The horizontal flexibility transmits relatively limited earthquake forces from the piers to the superstructure. On the other hand, the damping of the bearing dissipates the seismic energy, thereby reducing the design displacement of the bridge. The following assumptions are made for the earthquake analysis of the isolated bridges under consideration.

- The bridge superstructure and piers are assumed to remain in the elastic state during the earthquake excitation. This is a reasonable assumption, as the isolation attempts to reduce the earthquake response in such a way that the structure remains within the elastic range.
- The deck of bridge is straight. Deck and abutments of bridge are assumed to be rigid.
- The bridge piers are assumed to be rigidly fixed at the foundation level.
- The bridge is founded on firm soil or rock and soil structure interaction effect is ignored.
- The bearings provided at abutment and pier has same dynamic properties

Table -1: Model description

Parameter	Value
No of Spans	2
Each Span Length	25 m
Bent Beam Length	10 m
Total Width of Flat slab	7.5 m
Flat Slab thickness	0.3 m
Grade of concrete	M35
Grade of Rebar	Fe 500

Table -2: Preliminary load considerations

Parameter	Value
Live load	IRC CLASS AA LOADING
Future wearing finish	1.43kN/m2

Table -3: Seismic data required for analysis

Parameter	Value
Seismic zone	III
Zone factor	0.16
Type of soil	Medium
Importance factor	1
Response reduction factor	5

Seismic response of bridge is found by time history analysis. five earthquake ground motion record is used for time history analysis of bridge. This bridge is then modelled
and analysed with conventional bridge bearing and then this rubber and frictional bearing replaced with conventional bearings . Stiffness properties of rubber isolator bearing and frictional isolator bearing are used in analysis of bridge are as follows

Table -4: Properties of Rubber isolator

	U1	U2	U3
Linear effective stiffness (KN/m)	1500000	800	800
Non - Linear effective stiffness (KN/m)	-	2500	2500
Yield Strength (KN	-	80	80
Post yield stiffness	-	0.1	0.1

Table 5 : Properties of Friction Isolator

	U1	U2	U3
Linear effective stiffness (KN/m)	15000000	750	750
Non - Linear effective stiffness (KN/m)	-	15000	15000
Friction Coefficient, Slow	-	0.03	0.03
Friction Coefficient , Fast	-	0.05	0.05
Rate parameter	-	40	40
Radius of Sliding Surface	-	2.23	2.23

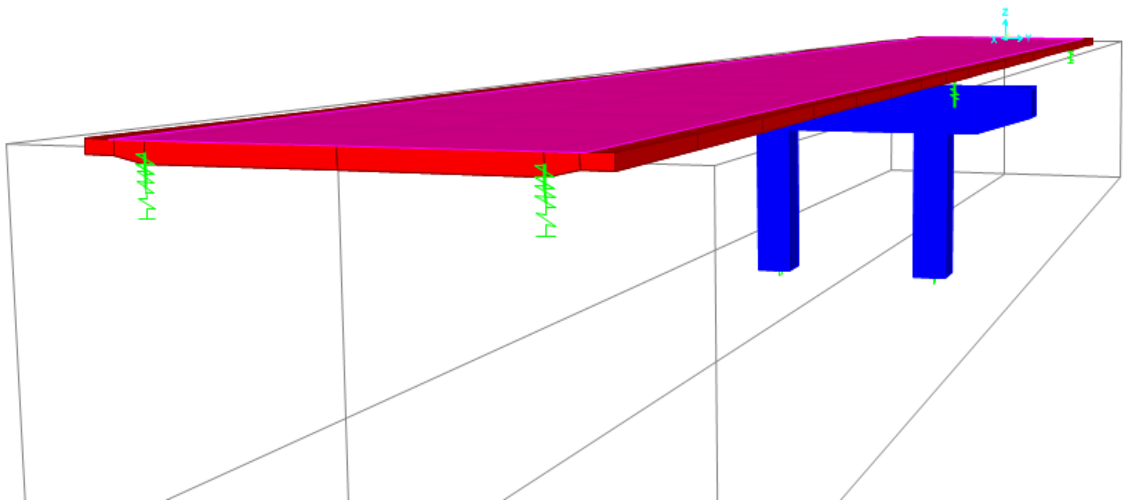

Fig- 1: model 1 (conventional model)

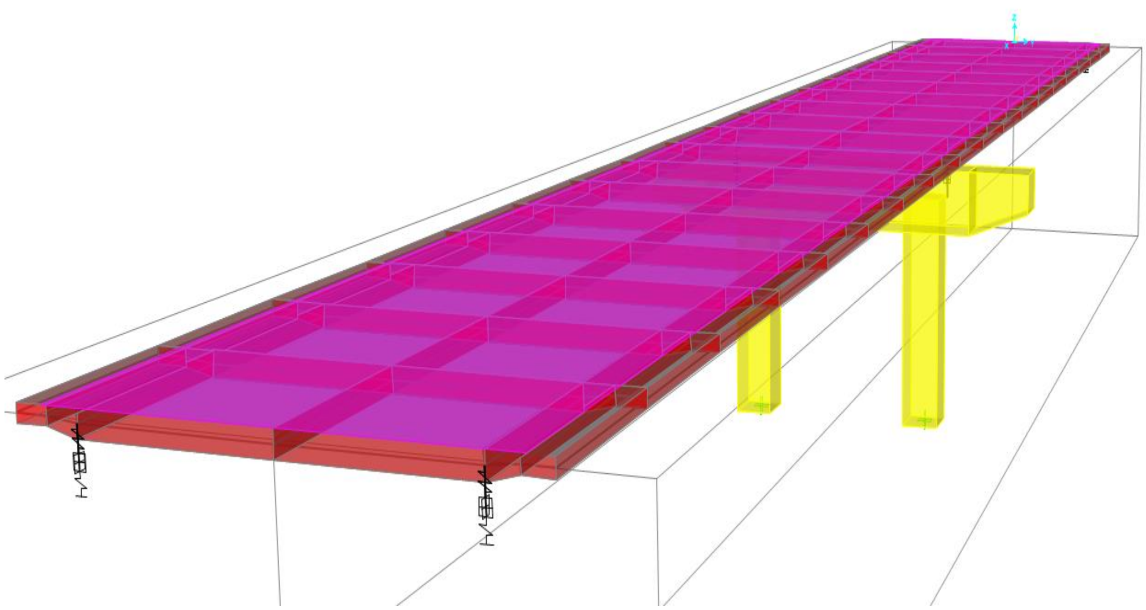

Fig- 2: model 2 (rubber isolator)

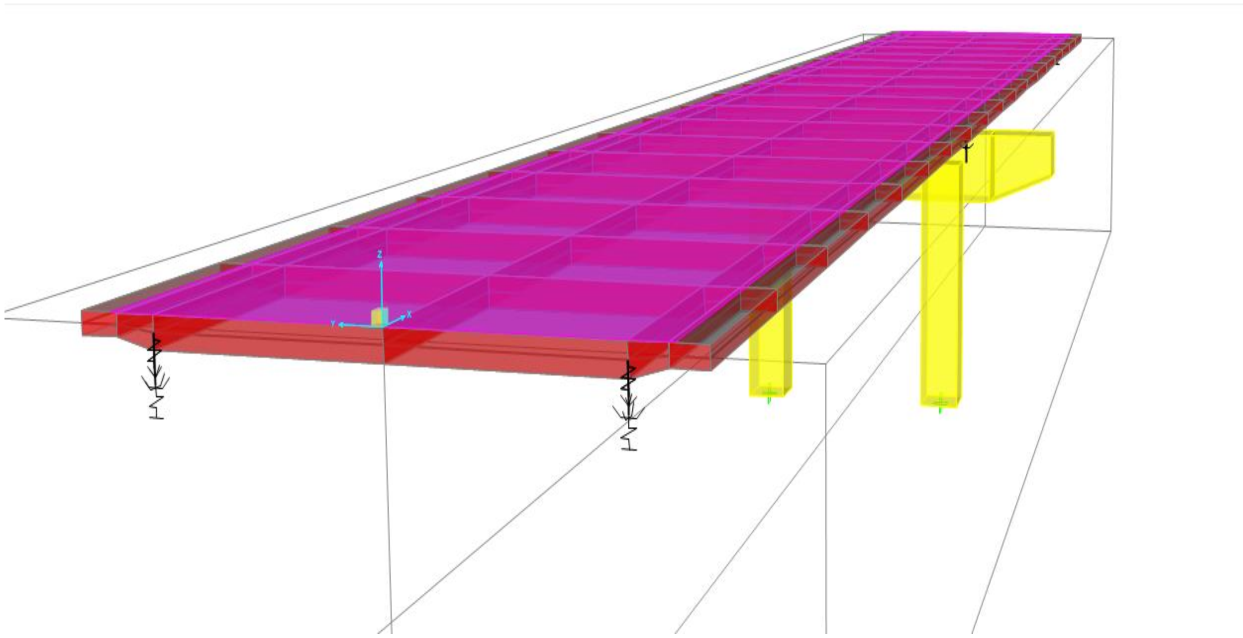

Fig- 3: C model 3 (friction isolator)

IV. INPUT GROUND ACCELERATION

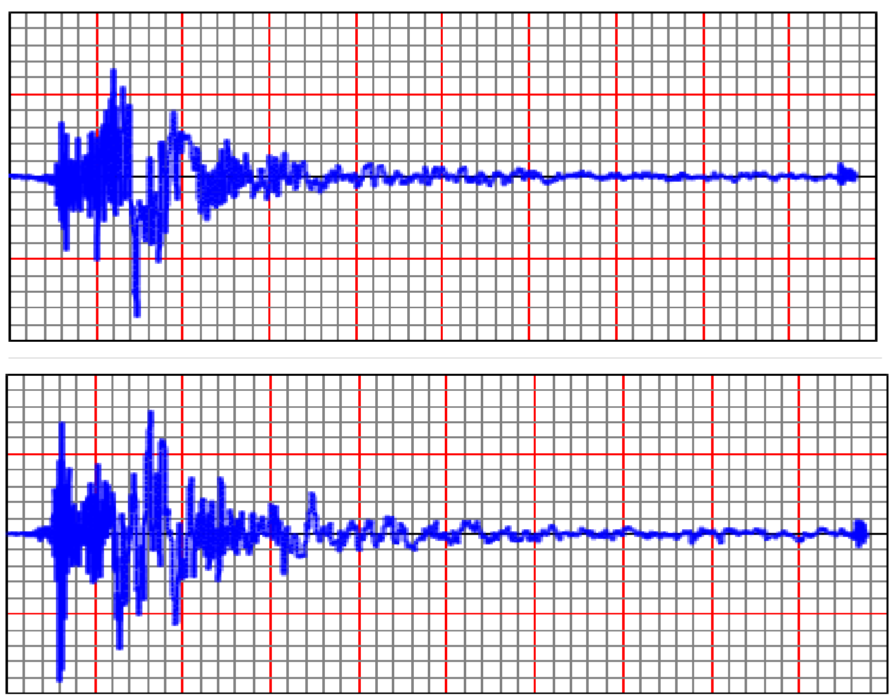

FIG 4 Ground acceleration Vs. Time record of Array earthquake for direction 1 and 2

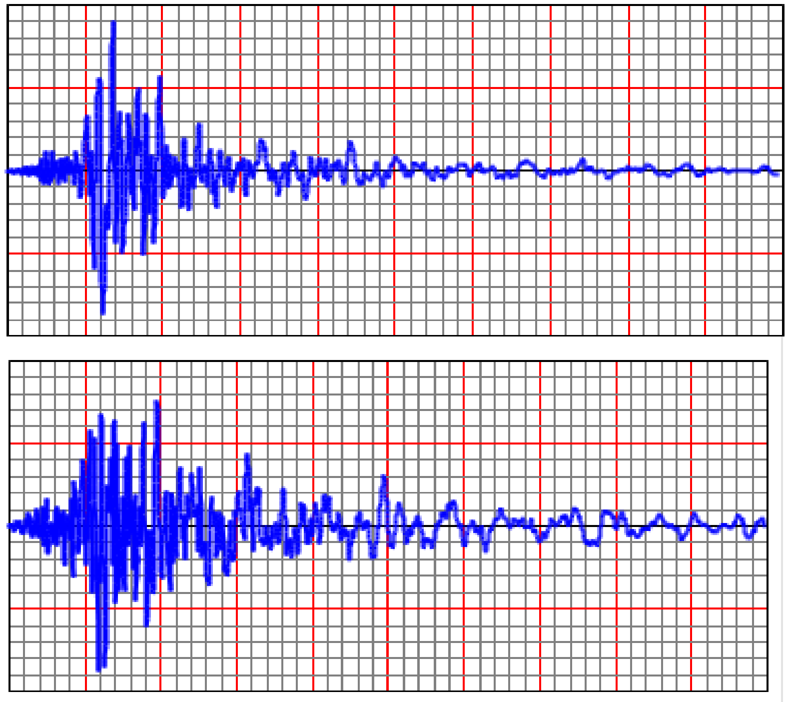

FIG 5 Ground acceleration Vs. Time record hollister earthquake for direction 1 and 2

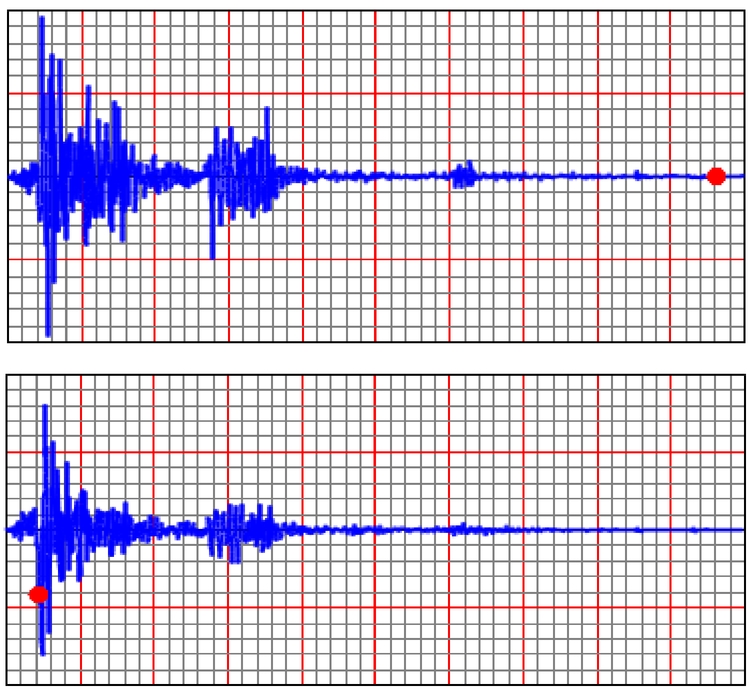

FIG 6 Ground acceleration Vs. Time record of petrolia earthquake for direction 1 and 2

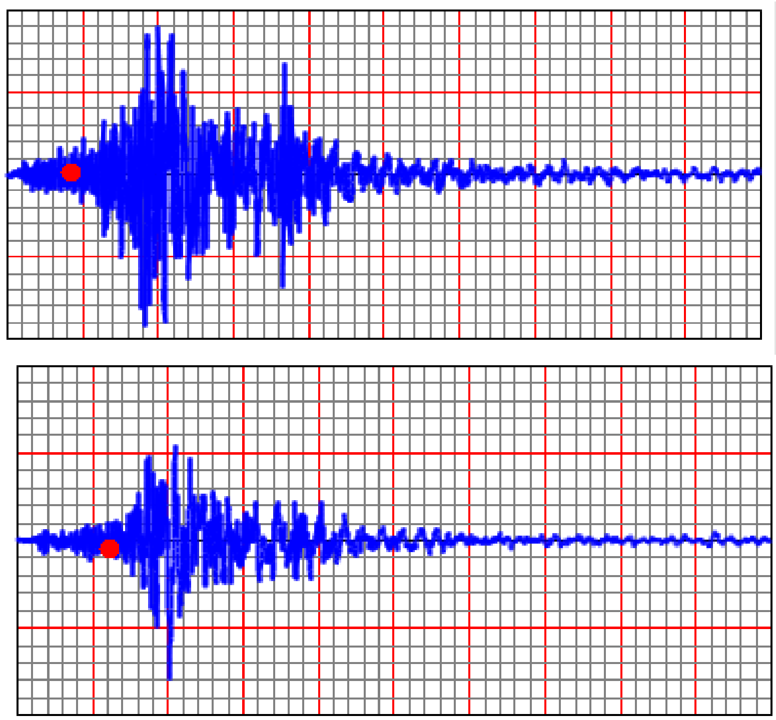

FIG 7 Ground acceleration Vs. Time record of yermo earthquake for direction 1 and 2

V. RESULTS AND DISCUSSION

After performing time history analysis of bridge, seismic response of bridge is scrutinized and compiled results are presented in following

- **Time period**

Modal period of fixed base, Rubber Isolator & Friction isolators structures were compared.

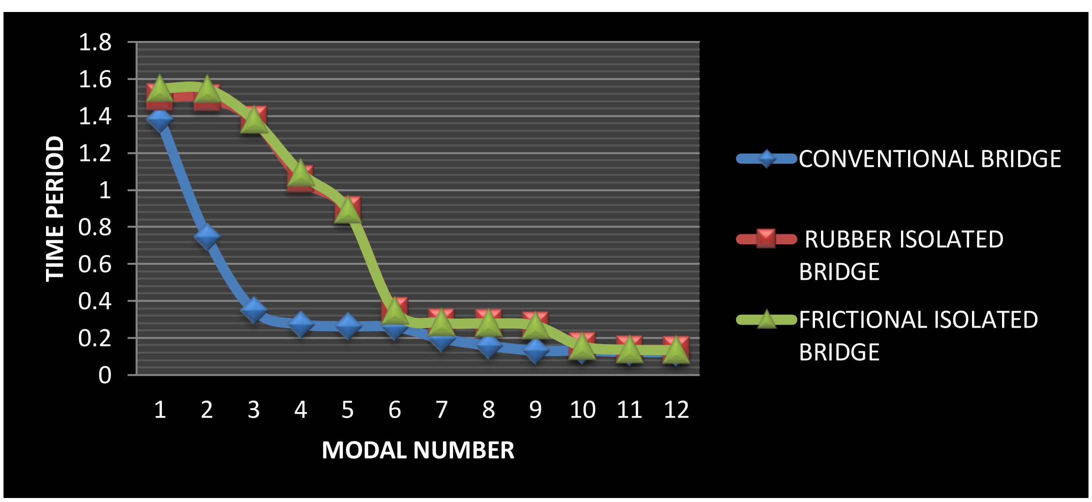

FIG 8 Comparison of Time Period in conventional bridge and isolated bridge

- **Restoring force**

Nodal forces of fixed base, Rubber Isolator & Friction isolator's structures were compared and Restoring force computed

For Model (Rubber Isolator)

Table 6: Forces in Rubber Isolator

	Abutment		Pier	
	F2	F3	F2	F3
Dead Load	0.28	-9.74	82.6	0
Live Load	-1.25	-18.08	62.57	19.27
Total Load	-0.97	-27.82	145.17	19.27

For Model (Friction Isolators)

Table 7: Forces in Friction Isolator

	Abutment		Pier	
	F2	F3	F2	F3
Dead Load	-0.26	-9.13	82.59	0
Live Load	-1.17	-16.97	62.56	18.09
Total Load	-1.43	-26.1	145.15	18.09

VI . conclusion

From the study it is concluded that rubber and frictional isolator bearing can be replaced with conventional bearings as it reduces significant amount of the time period. and dissipated amount of energy So the reduction in size and amount of reinforcement in bridges can be achieved and ultimately economy of structure. From the tables and graphs of displacement of isolated and conventional bridge model, it is clear that the storey displacements are much higher for isolated buildings. The isolator with friction has more displacement compared to rubber isolator and restoring forces are given below ,

A. Restoring Force for Rubber Isolators

- Abutment
    - Restoring Force provided by Rubber isolators in X direction i.e. Longitudinal direction is 1016.87 KN
    - Restoring Force provided by Rubber isolators in Y direction i.e. Transverse direction is 5196.77 KN

- Piers
    - Restoring Force provided by Rubber isolators in X direction i.e. Longitudinal direction is - 8.75 KN

- Restoring Force provided by Rubber isolators in Y direction i.e. Transverse direction is – 19.27 KN

B..Restoring Force for Friction Isolators

- Abutment
  - Restoring Force provided by Friction isolators in X direction i.e. Longitudinal direction is 1017.33 KN
  - Restoring Force provided by Friction isolators in Y direction i.e. Transverse direction is 5195.05
- Piers
  - Restoring Force provided by Friction isolators in X direction i.e. Longitudinal direction is - 8.75 KN
  - Restoring Force provided by Friction isolators in Y direction i.e. Transverse direction is 18.09 KN

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