SEISMIC VULNERABILITY ANALYSIS OF CHENGAPPA BRIDGE USING ANSYS

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Abstract - *In December 2004 Great Sumatra earthquake, the decks of 268 m long Chengappa Bridge across Austen Strait in Andaman Islands which had taller piers in the middle for navigational purposes was damaged. The Damage was mainly due to unseating and collapse of the bridge deck. The maximum deck displacement observed was 700 mm after that earthquake. The reason was due to non-installation of isolators or supplementary devices. Therefore, in the seismic response analysis, it is important to include the effect of isolators and dampers. To study the seismic response analysis six models of the same bridge was made. Each model is analyzed incorporating an isolator with and without a damper. Performance of the bridge was analytically investigated using the finite element analysis program Ansys. The isolators used for the study were Lead Rubber Bearing, High Damping Rubber Bearing and Frictional Pendulum Bearing. Viscous Damper is the supplementary device used. Each of the models was analyzed under earthquake load including the Dead Load and Live Load conditions. Both the Modal Analysis and the Time History Analysis were done. The time history data of El Centro earthquake which has an intensity of 3129.39 mm/s^2 is used for the study. Analysis results show that by using isolators, an average deck displacement reduction of 68% was obtained by using Lead Rubber Bearing, 2% with High Damping Rubber Bearing and 87% with Frictional Pendulum Bearing. And in comparison Frictional Pendulum Bearing is the most effective and High Damping Rubber Bearing is the least effective in reducing displacements and base shears. Dampers were also proven to be very effective as a supplementary device in reducing both the deck displacements and base shears.*

Key Words: **seismic vulnerability, Chengappa Bridge, Lead Rubber Bearing, High Damping Rubber Bearing, Frictional Pendulum Bearing, Viscous damper.**

1. INTRODUCTION

The purpose of earthquake prevention of structures is to provide the structural safety and comfort by controlling the internal forces and displacement within the particular limits. The common method for protecting the structures against the destructive effects of earthquakes is to damp the seismic energy thus providing the resistance against the earthquake. Another method for protection of the structures against the earthquake is to isolate the building from the ground and to install seismic energy dissipating elements at the appropriate places of the structure. With this method, better protection could be provided.

The earthquakes have been considered to be an important factor that threatens the social and economic future of the countries, as we can observe the results of them. Thus, it is insisted on the resolutions that minimize the seismic effects of the structures should demonstrate a high performance level in the expected earthquakes. The seismic isolators and energy dissipating devices are seen to be effective solutions within this context, which are placed in the building appropriately to damp the seismic energy or placed between the foundation and vertical structural systems, damping the seismic energy under the ground of the structure, thus decreasing the effects of loads on the structure.

1.1 SEISMIC VULNERABILITY

Seismic vulnerability of a structure is defined as their proneness to manifest damage in occurrence of a seismic event. It is also defined as the inability of a building to withstand the effects of seismic forces.

The aim of a vulnerability assessment is to obtain the probability of a given level of damage to a structure due to a scenario earthquake. There are various methods for vulnerability assessment that have been proposed in past and can be divided into two main categories: empirical or analytical, both of which can be used in hybrid methods.

1.2 SEISMIC ISOLATION SYSTEMS

All the operations that are developed in order to protect the structures against the earthquakes thus providing the security and comfort conditions under service loads and that include placing certain kind of additional elements in the building are named seismic isolation in general.

The kinds of seismic isolation devices that are placed in the structures are usually energy dissipating mechanisms. Two types of classification of the devices can be done in accordance to their location and operation principles. According to the classification of devices by their location in the isolators can be classified as two types, external and internal. Devices of external type are located outside the structures. Devices of internal type are the energy dissipating mechanisms. All response control systems are classified in accordance to their operation principles as active, passive and hybrid systems.

1.2.1 COMMONLY USED ISOLATION SYSTEMS

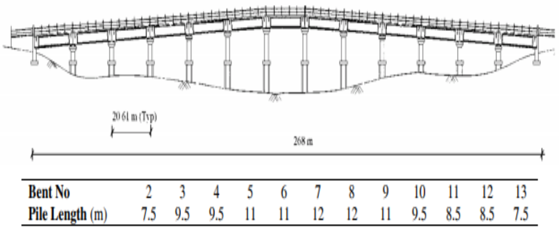
There are various types of bearings used in the base isolation systems, which vary according to their behavior and to the material they are made of. The most extensively used ones are the ones which belong to elastic systems class such as Rubber Bearing (RB), High Damping Natural Rubber Bearing (HDNR) and Steel Laminated Rubber Bearing (SLR). The ones belonging to elasto-plastic systems class is Lead Rubber Bearing (LRB) and the ones belonging to kinematic systems class and friction pendulum systems class is Friction Pendulum Bearing (FPB).

1.2.2 DAMPERS

Dampers are devices which are used to absorb or dissipate the vibration caused by the earthquake to the structure. Their Function is to increase the damping and stiffness of the structure. There are many types of dampers. Most commonly used are (a) Tuned mass damper (TMD), (b) Tuned liquid mass damper (TLD), (c) Friction damper, (d) Metallic damper. (e) Elastoplastic damper and (f) viscous damper.

2. MODELING

For the seismic vulnerability assessment study the Chengappa Bridge which is constructed over Austen Strait at Mayabander is taken into consideration. It is the longest bridge in the Andaman Islands which is 268 m long RC bridge, simply supported over 12 cast-in-place piers. The length of pile varies along the length of the bridge. The bridge deck is made of pre-cast girders and cast-in-situ slab. The elevation of Chengappa Bridge is shown in the fig 1 below.



Bent No	2	3	4	5	6	7	8	9	10	11	12	13
Pile Length (m)	7.5	9.5	9.5	11	11	12	12	11	9.5	8.5	8.5	7.5

Fig -1: Elevation of CHENGAPPA Bridge

There are a total of six models made for the study. Each model is analyzed under earthquake load for two loading conditions. ie, condition one in which Dead Load and Earthquake Load is only considered and condition two in which both Dead Load, Live Load and Earthquake Load is also considered. In each model different type of isolators are installed. Along with isolators supplementary devices like dampers are also provided in order to improve the dynamic characteristics. The isolators used here are Lead Rubber Bearing, High Damping Rubber Bearing and Frictional Pendulum Bearing respectively. The Damper used here is Viscous Damper. Each model is described as following:

MODEL 1: Bridge with Lead Rubber Bearing (LRB) without Damper.

MODEL 2: Bridge with Lead Rubber Bearing (LRB) with Damper.

MODEL 3: Bridge with High Damping Rubber Bearing (HDRB) without Damper.

MODEL 4: Bridge with High Damping Rubber Bearing (HDRB) with Damper.

MODEL 5: Bridge with Frictional Pendulum Bearing (FPB) without Damper.

MODEL 6: Bridge with Frictional Pendulum Bearing (FPB) with Damper.

Following table shows the details of the Chengappa Bridge used for the analysis:

Table -1: Description of model

DESCRIPTION	DIMENSIONS
Length	268m
Width of bridge deck	9.3m
Span	20.61m
No. of span	12
Expansion gap	50mm
Thickness of deck slab	200mm
Diameter of Pier	1.5m
Size of Pier cap	1.8m x 0.8m
Diameter of pile	0.8m
Elevation at top of pier cap	12.7m
Elevation at top of pile cap	3.0m

The three dimensional view and meshed view of the full bridge is shown in fig 2 and fig 3 respectively.

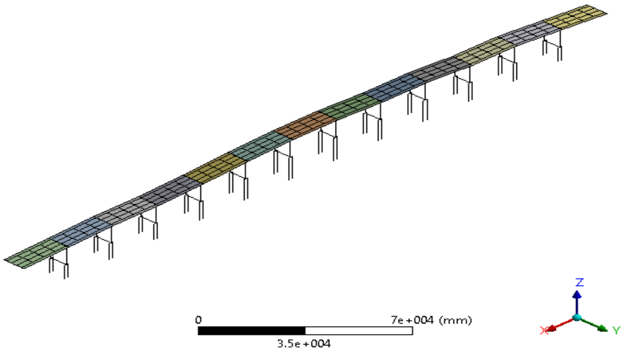


Fig -2: Full Three Dimensional View of the Chengappa Bridge modelled in ANSYS

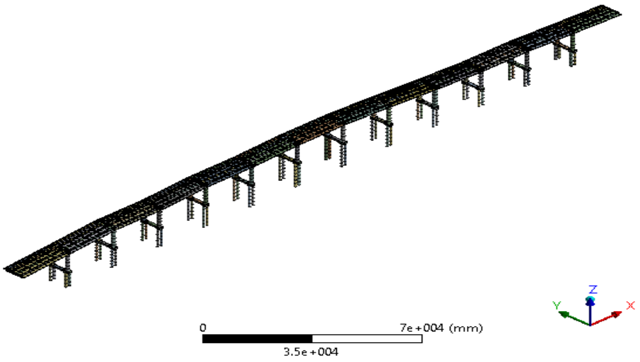


Fig -3: The meshed view after Modelling

Properties of each of the isolators and viscous damper are tabulated below below:

Table -2: Properties of isolators

Properties	HDRB	FPB
Length	50mm	50mm
Breadth	320mm	320mm
Height	500mm	500mm
Area	160000mm^2	160000mm^2
Stiffness	2812845 N/mm	29000000 N/mm

Table -3: Properties of Damper

Properties Of Viscous Damper	
Damping coefficient	810 kN-s/m
Stiffness	595238.0953 kN/m

3. ANALYSIS

A total of twelve analyses were done here. Both modal analysis and time history analysis were done on each model. Analysis was done using finite element program ANSYS WORKBENCH 16.1. The Bridge is first modelled with Lead Rubber Bearing and is analyzed for Dead Load and Earthquake Load in the absence of damper. Then the same model of Bridge with LRB with Damper is analyzed for both Dead Load and Live Load combinations. The same analyses were done for other models with High Damping Rubber Bearing and Frictional Pendulum Bearings.

Following table shows the total analyses involved in the study.

Table -4: Total analyses involved in the study

ISOLATOR	DAMPER	LOADING CONDITION
LRB	Without Damper	Dead Load
		Dead Load + Live Load
	With Damper	Dead Load
		Dead Load + Live Load
HDRB	Without Damper	Dead Load
		Dead Load + Live Load
	With Damper	Dead Load
		Dead Load + Live Load
FPB	Without Damper	Dead Load
		Dead Load + Live Load
	With Damper	Dead Load
		Dead Load + Live Load

4. RESULTS AND DISCUSSIONS

The results are based on the Time History Analysis that was conducted on the study bridge. The analytical study gives different results for each model. In all analyses there were variations in both deck displacements as well as base shears. The results obtained from the analyses are listed below and compared by graphical representation. From the obtained results, charts has been drawn in X direction, similar variations is observed in Y directions also

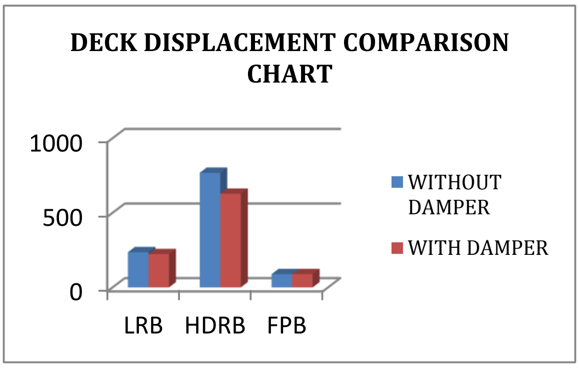


Chart -1: Comparison of Deck Displacement of three of the isolators with and without damper under Dead Load condition

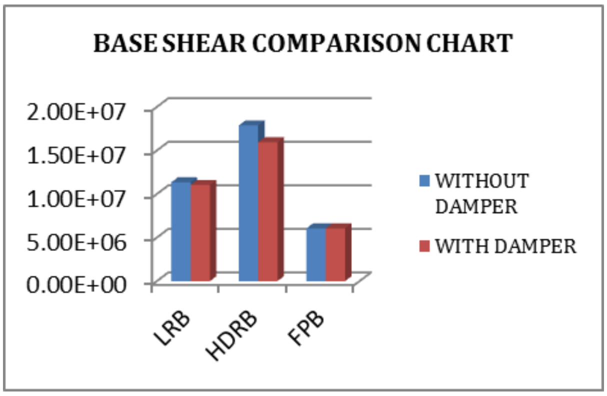


Chart -2: Comparison of base shear of three of the isolators with and without damper under Dead Load condition

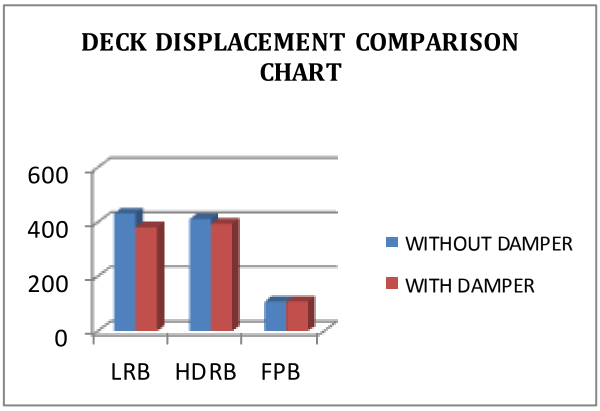


Chart -3: Comparison of Deck Displacement of three of the isolators with and without damper under Dead Load + Live Load condition

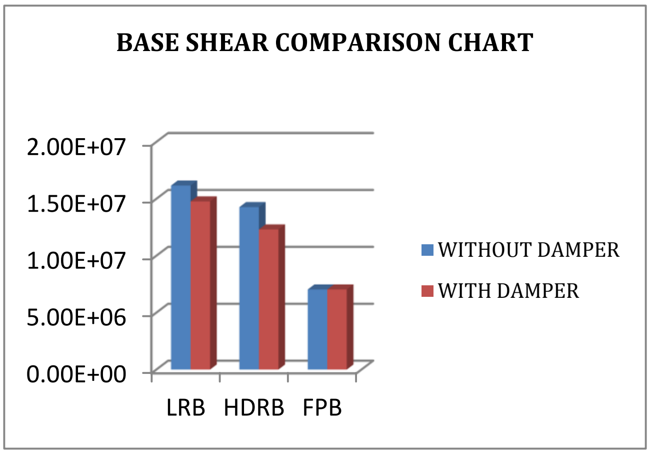


Chart -4: Comparison of base shear of three of the isolators with and without damper under Dead Load + Live Load condition

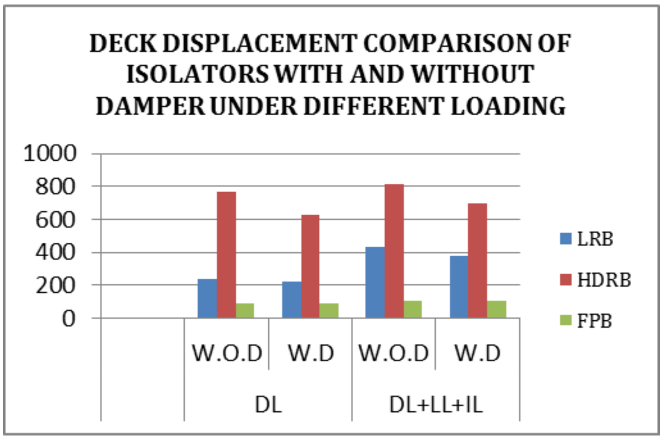


Chart -5: Deck displacement comparison of isolators with and without damper under different loading

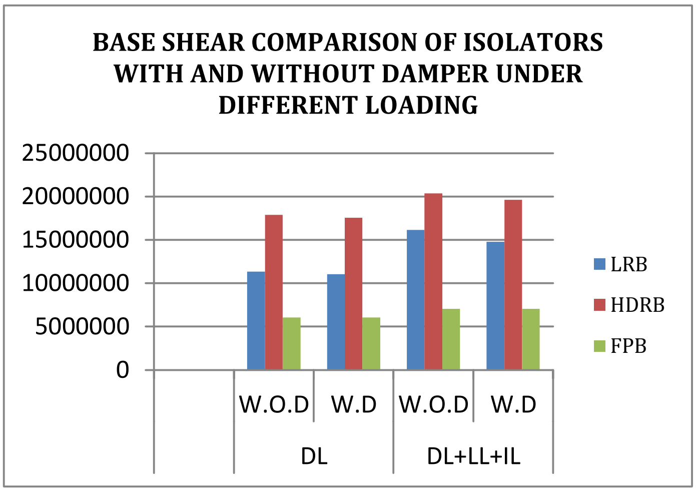


Chart -6 Base shear comparisons of isolators with and without damper under different loading

5. CONCLUSIONS

After comparing the results, the deck displacement and base shear were found to be reduced when isolators were used. 700mm was the deck displacement on the bridge without isolators. An average deck displacement reduction of 68% was seen with LRB, 2% with HDRB and 87% with FPB. And in comparison FPB is the most effective and HDRB is the least effective in reducing displacements and base shears.

Also Dampers are found to be very effective in reducing both the Deck displacements and Base Shears. As the load and seismic intensity increases, the deck displacements as well as base shears over the bridge also increases. In case of frictional pendulum bearings work done by Damper is found to be zero. The reason for this is frictional pendulum bearings are already very effective in reducing the deck displacements and base shears. So in such a case there is no need of using Damper unless a high intensity earthquake is struck on the structure. The Frictional Pendulum Bearing is found to be the most effective isolator on Chengappa Bridge with lesser deck displacements and base shears.

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