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SEISMIC RISK ASSESSMENT OF RC BRIDGE

ANANDH C.S.[1], AJISHA R.[2]

[1]PG Student, M-Tech Structural Engineering, Sreepathy Institute of Management and Technology, Vavanoor, Kerala,India
[2]Assistant Professor, Department of Civil Engineering, Sreepathy Institute of Management and Technology, Vavanoor, Kerala, India

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Abstract - *Most structures are subjected to vibrations. These Vibrations may arise from wind forces, earthquake excitation, machine vibrations, or many other sources. However, for structures subjected to strong vibrations, the inherent damping in the structure is not sufficient to mitigate the structural response. In many situations, supplemental damping may be used to control the response of these structures. In this regard, researchers have studied, developed and tested supplemental damping techniques. For any system, if the resisting force is proportional to the velocity of the motion, the system can be considered viscously damped. Fluid viscous dampers operate on the principle of fluid flow through orifices. A stainless steel piston travels through chambers that are filled silicone oil. Fluid viscous dampers have the unique ability to simultaneously reduce both stress and deflection within a structure subjected to a transient. This study deals with the modelling of two types of bearings High density rubber bearing (HDRB), Friction pendulum system(FPS) of bearing with viscous dampers. Unanchored elastomeric pad bearings are free to move over substructure during an earthquake. Excessive deck displacement causes unseating and sometimes complete collapse of the deck leading to closure of the bridge for long periods. The problem is worse for an irregular bridge with significant variations in the pier/pile heights elastomeric pad bearings are free to move over substructure during an earthquake. Performance of the bridge was analytically investigated using the finite element (FE) analysis program SAP2000. Viscous dampers are provided throughout the bridge. It has been found in the study that for a bridge with supplemental dampers, the pier top displacements reduced by about 47%, compared to bridge without dampers.*

***Key Words*: RC Bridge, Bearings, Viscous dampers, HDRB, and FPS.**

1. INTRODUCTION

Bridges are important components of highway and railway transportation systems. Failure of bridges due to natural or manmade hazards may cause significant disruption of transportation system performance, and thus may result in major economic losses to the society. Therefore, safety and serviceability of bridges have always been great concerns to the civil engineering profession. The after effect of an earthquake manifests great damage due to unpredicted seismic forces striking extensive damage to innumerable structures of varying degree either full or partial or slight. It has been observed that majority of such earthquake damaged

structures may be safely reused, if they are converted into seismically resistant structures by employing a few retrofitting measures Therefore, seismic retrofitting of structures is one of the most important aspects for mitigating seismic hazards especially in earthquake-prone countries.

The need of seismic retrofitting of buildings arises under two circumstances: (i) earthquake damaged buildings and (ii) earthquake-vulnerable buildings that have not yet experienced severe earthquakes. The problems faced in retrofitting earthquake damaged buildings are: (a) lack of standards for methods of retrofitting; (b) effectiveness of retrofitting techniques since there is a considerable dearth of experience and data on retrofitted structures; (c) absence of appropriate methods for the wide range of parameters like type of structures, condition of materials, type of damage, amount of damage, location of damage, significance of damage, condition under which a damaged element can be retrofitted etc.

The need of retrofitting of existing earthquake vulnerable structures may arise due to one or more than one of the following reasons i.e. (a) the structures been designed according to a seismic code, but the code has been upgraded in later years; (b) structure designed to meet the modern seismic codes, but deficiencies exist in the design and/or construction; (c) essential structures must be strengthened like hospitals, historical monuments and architectural buildings; (d) important structures whose service is assumed to be essential even just after an earthquake; (e) structures, the use of which has changed through the years; (f) structures that are expanded, renovated or rebuilt.

Retrofitting of existing buildings and issues of their structural safety have not received adequate attention in India. Bridges are lifeline structures and their performance is critical during and after the earthquake. The RC Bridge decks, supported on unanchored elastomeric pad bearings are free to move over substructure during an earthquake. Excessive deck displacement causes unseating and sometimes complete collapse of the deck leading to closure of the bridge for long periods. The problem worsens for irregular bridge with significant variations in the pier/pile heights The seismic risk associated with exceeding different damage states in the columns, including yielding, cover spalling, bar buckling, and structural collapse (i.e., dynamic instability) is predicted. Bridges with elastomeric pad bearings have not performed well during past earthquakes. It is generally found that damage is limited to excessive displacement of bridge deck causing unseating and sometimes collapse of the superstructure. Several types bearings are available for various structures throughout the world. In this study, the use of High Density Rubber Bearing(HDRB) and Friction Pendulum System (FPS) bearing are investigated in a reinforced concrete bridge(RC) using non-linear time history analysis.

Another approach to enhance seismic performance is to increase system damping by introducing energy dissipation devices in certain area within the structure. The objective here is to have structures meet code strength requirements without the devices and reduces displacement demands through increased damping by utilizing energy dissipation devices and thus, improve seismic performance. This in turn results in safer and more cost effective structures on the long run.

Several types of energy dissipation devices have been proposed to be applied to various structures throughout the world. In study, the use and application fluid viscous dampers are investigated in a bridge by performing non-linear time history analysis.

Fig -1: Damper installed in Ok-yeo bridge

Various applications of passive viscous dampers in bridges have been reported in the past. The first use of viscous damper stoppers in a bridge application was performed on the Tokyo Metropolitan Expressway, Tokyo, Japan in 1992.it was a five span,116.9m long,16.7m wide, four cell box girder structure. The dampers were installed between the superstructure and the sub structure at both abutments ant at top of piers at bents three and four. Yamadera and Uyeman (1979) also reported the use of viscous damper stoppers in at least ten bridges in japan after Tokyo Metropolitan Expressway including the kaihoku bridge, a five span 285m long cell box girder bridge that suffered no damage during strong earthquake of Miyagi-ken-Oki in June of 1978 Damping is one of many different methods that have been proposed for allowing a structure to achieve optimal performance when it is subjected to seismic, wind storm, blast or other types of transient shock and vibration disturbances. Conventional approach would dictate that the structures must inherently dissipate the effects of transient inputs through a combination of strength, flexibility and deformability. The level of damping in a conventional elastic structures is very low. During strong motions, such as earthquakes, conventional structures usually deform well beyond their elastic limits and eventually fail or collapse. Therefore, most of the energy dissipated absorbed by the structure itself through localized damage as it fails. The concept of supplemental dampers added to a structure assumes that much of the energy input to the structure from a transient will be absorbed, not by the structure itself, but rather by supplemental damping elements. An idealized damper would be of a form such that the force being produced by the damper is of such a magnitude and function that the damper forces do not increase overall stress in the structure. Properly implemented, an ideal damper should be able to simultaneously reduce both stress and deflection in the structure.

2. LITERATURE REVIEW

Bassem Andrawes and Reginald Desroches 2004 [1] This paper presents an analytical study that was conducted to compare the efficiency of three seismic retrofit methods in limiting the relative displacement between adjacent spans and frames in bridges. In this study a simplified 2-DOF analytical model and a finite element model of a multi-frame bridge were utilized. The performance of the bridge model using the superleastic restrainers, steel restrainers, and metallic dampers was evaluated under a suite of 8 strong ground motion records. A two degree of freedom (DOF) analytical model was developed in MATLAB as a preliminary stage in studying the performance of the Super-Elastic (SE) SMA restrainers compared to other devices in bridges. The maximum relative displacement with no retrofit device installed was 160 mm. All three devices reduced the maximum response. The SE restrainer was the most effective device among the three used retrofit devices in limiting the maximum relative displacement. It reduces it to 77.7 mm, which corresponds to a reduction of approximately 52% compared to the maximum relative displacement in the as-built case. On the other hand, the metallic dampers and steel restrainers reduced the response by approximately 44% and 11%, respectively. The tension-compression behavior of the metallic dampers allowed the device to dissipate larger amount of energy compared to the other two devices. A finite element model was developed for a typical four-frame box girder bridge, which is commonly constructed in California. The model was developed using nonlinear program DRAIN-2DX. The superelastic restrainers showed better ability in reducing the relative hinge displacements in most of the ground motion records. The superelastic restrainers were also capable of eliminating the residual hinge displacements at the end of the records. In some records the metallic dampers performance was close to the superelastic restrainers due to the ability of the metallic dampers to carry tension and compression and its high energy dissipation capability. The steel restrainers showed limited capability for reducing the relative displacement due to the accumulation of residual displacement after yielding. The analysis also showed that the type of retrofit device used at the intermediate hinges of bridges has a very minor effect on the lateral drift of the bridge.

Nicos Makris and Jian Zhang 2004[2] This paper presents a case study on the seismic response of a recently constructed freeway overcrossing located in southern California, which is equipped with elastomeric bearings and fluid dampers at its end abutments. The analysis employs the substructure method and a reduced order stick model. The newly constructed 91/5 Overcrossing is a continuous two span, cast-in-place, prestressed concrete, box-girder bridge supported by an outrigger bent at midspan and equipped with four fluid dampers at each end abutment (eight dampers total). At each abutment, the deck rests on four elastomeric pads. The stick model is a collection of beam elements with cross section properties adjusted from geometric data without considering any cracked section reduction. At each end, a massless rigid link preserves the skewed geometry of the bridge and serves as the connecting element between the bridge deck and the end abutments. In this paper, the dynamic response of three configurations are compared the as-built configuration where the deck is supported at both ends by elastomeric pads and is equipped with fluid dampers, same configuration as case 1 but without fluid dampers and finally the bridges deck is rigidly connected to integral abutments. The time history response analysis is conducted on the bridge with elastomeric pads and nonlinear fluid dampers (Case 1), the bridge with elastomeric pads (Case 2), and the bridge with integral abutment (Case 3), subjected to the ground motions listed. The increased mobility of the deck ends due to the elastomeric bearings results in high acceleration which can be suppressed with supplemental damping. The response at the end abutments of an isolated bridge appears to underperform the response of the same bridge with integral abutments.

Thomas P. Murphy and Kevin R. Collins 2004 [3] In this paper a Suspension bridges in the Central and Eastern United States (CEUS) was analysed with a retrofit strategy. Damping devices are provided throughout the suspended truss structure in order to reduce the bridge response. Three different damping devices were considered in this investigation: Friction devices; metallic hysteresis devices; and fluid viscous dampers. The bridge has three suspended spans, with a large main span flanked by two smaller side spans. The span lengths are 229 m–655–229 m. ANSYS was used for the numerical modeling of the bridge. Several different retrofit configurations were investigated. From the initial results, placement locations which more efficiently and effectively utilize the damping devices were identified. It was found that the chords and lateral members were best suited to damper installation, because of the higher stress levels experienced during seismic events and also because of the ease of installation in these locations. The demand capacity ratios were compared along with the distance along the bridge. The effects of the retrofit on the foundation forces, as well as the effects of including spatial variations in the ground motions, were evaluated. It was found that by locating the dampers both in the truss chord and lateral members, large amounts of energy could be dissipated.

Durgesh C. Rai, et.al. 2006 [4] The Andaman Islands have a larger population, and hence more roads and bridges, than the Nicobar Islands. In general, the superstructures of bridges in the A&N islands are of three types: reinforced concrete RC, steel truss e.g., Bailey bridge, and wooden sleeper semi-permanent. In general, the substructures are made of either RC or masonry. Under earthquake shaking, the steel truss-type systems performed reasonably better. However, the RC bridges showed varied damage. The largest bridge in the A&N islands is over the Austen Strait, which connects the North and Middle Andaman Islands on the ATR. This is a newly constructed 268 m long 7.5-m carriageway RC bridge. Two of the authors had visited this region two years ago after an Mw=6.5 earthquake on 14 September 2002 and had expressed the following concerns about this bridge in published reports. Inadequate seating of bridge deck over piers and abutments is a serious concern for its safety during a stronger earthquake in future. The bearings are simple neoprene pads which are far from satisfactory for a bridge located in seismic zone V. Bridge deck restrainers are the minimum that need to be provided to ensure that the spans are not dislodged from the piers in future earthquakes. The use of conventional neoprene pad bearings in bridges must be thoroughly reviewed before such bearings are used in new construction. The addition of a few really simple earthquake-resistant features in bridges, such as lateral restrainers for bridge decks, can be critically useful in the event of strong shaking.

Jamie Ellen Padgett, et.al. 2010 [5] conducted a study incorporating an inventory analysis of the about 375 bridges in the Charleston territory. The second half of the article will assess the effect of uncertainty on the resulting bridge damage distribution and estimated losses in Charleston, South Carolina. The risk assessment approach in this study is limited to an assessment of the bridge damage due to ground shaking, and considers only the economic losses due to physical damage, rather than indirect losses due to operation losses or time delay in the transportation system. The bridges studied in this paper are classified with the methodology, according to material and construction type.

The classifications simply identify the bridges by both their span configuration simply supported (SS), multi-span simply supported (MSSS), multi-span continuous (MSC) as well as by their girder material type concrete or steel. Three types are used selected based on recommendations from South Carolina department of transportation SCDOT: earthquakes of magnitude Mw 4.0, 5.5, and 7.0 located at 32.9_ N, 80.0_ W, which is approximately 14.5 km outside of the Charleston city center near Summerville, South Carolina. These hazards produce maximum ground motion intensities of 0.28 and 0.62 g peak ground acceleration for Mw 4.0 and Mw 7.0, respectively, the levels of damage are qualitatively described as slight, moderate, extensive, and complete damage. The seismic risk assessment was performed for three different hazards, Mw 4.0, 5.5, and 7.0 (epicenter in Summerville, South Carolina), using the MAEViz platform. The results show that for the Mw 7.0 event, over 85% of the bridges are damaged, with 73% of the bridges having moderate to complete damage. For the Mw 5.5 event, approximately 60% of the bridges are damaged, with nearly 50% of the bridges having moderate to complete damage. Finally, the Mw 4.0 earthquake results in only 17% of the bridges having damage, and less than 9% have moderate or greater damage.

Pilate moyo 2011 [6] This paper reports on successful practical application of vibration based condition assessment of two reinforced concrete bridges. The bridges exhibited signs of structural distress indicating limitations at serviceability state. Full-scale vibration tests were used for structural system identification and finding out the defects on the bridge. Structural performance of the bridges was assessed using the parameters position of the neutral axis of the beams, bridge impact factors and load redistribution between the beams. Retrofitting conducted at Van der Kloof Bridge includes replacement of all bearings with reinforced elastomeric bearing pads, installation of two transverse beams at third points and installing a 100mm thick fully bonded concrete pavement. Bridge retrofitting work at Gariep Bridge includes retrofitting of outer beams, using 250x5mm grade 300WA steel plates, replacement of all bearing with reinforced elastomeric bearing 300x200x22mm elastomeric bearings. And providing 60mm thick existing asphalt left in place. Dynamic testing was conducted by an instrumented 12lb sledge hammer and a long stroke shaker electro-dynamic shaker. Accelerations were measured using a suite of force balance and piezoelectric accelerometers. Signal conditioning was provided by custom made and commercial signal analysers. Natural frequencies and mode shapes were recovered using both a MATLAB base non-commercial software and a commercial modal analysis software.

The bridges were modeled using 3D beam elements and shell elements in a commercial FEM code. Dynamic based condition assessment was also showed that the retrofitting interventions were successful with significant improvements such as overall functioning and performance of both bridges. Also structural stiffness and bearing functioning of both bridges improved. Load distribution improved in only van der kloof bridge.

Thimothy Wright et. al. 2011 [7] conducted a detailed review of the seismic hazard, inventory, bridge vulnerability and bridge retrofitting practices in central and southern united states (CSUS). After analysis of the bridge inventory in the CSUS, it was found the 12,927 bridges are exposed to 7% probability of exceedance (PE) in 75year peak ground acceleration (PGA) of greater than 0.20g and nearly 3.5% of bridges in CSUS have a 7% PE in 75 year PGA of greater than 0.50g. Retrofit practices in the region indicates that the most common retrofit approaches in the CSUS include the use restrainer cables, isolation bearings, column jacketing, shear keys, and seat extenders. Use of seismic isolation bearings, column jacketing, and other measures of column confinement, restraining devices to prevent unseating, and the use of shear keys and keeper brackets to limit transverse deck movement.

Swagata Banerjee and Gautham G. Prasad 2011 [8] carried out assess the joined impact of earthquake and flood initiated scour on the performance of bridges situated in areas having moderate to high seismic and flood hazards. For the investigation California is picked as the bridge site where the probabilities of having these two natural hazards are sensibly high. Two cases of reinforced concrete (RC) bridges one 2-span and another 3-span were studied. A 100-year flood occasion with discharge rate of 158.6 m^3/s, speed of 0.8 m/s and upstream depth of 11.9 m is taken to represent the flood hazard. Finite element model of the two types is developed with and without flood induced scour using SAP2000 and analyzed under several ground motions that represent regional seismicity. Bridge piers are modeled as double column bents by introducing nonlinear hinges at top and bottom of bridge piers. Nonlinear time history analyses of these bridges are performed under three sets of earthquake ground motions having annual exceedance probabilities as 2%, 10% and 50% in 50 years. The ground motions considered were originally generated for FEMA/SAC project. A parametric study was performed to determine the effect of number of span, scour depth(S), diameter of equivalent pile (d_{eq}) and combined effect of earthquake and flood induced scour on the seismic performance of concrete bridges.Finite element analyses are performed by taking combinations of (i) number of bridge span: two and three (ii) scour depths as 0m,0.6m,1.5m and 3.0m so that the ratio of scour depth to pier diameter (S/D) becomes 0,0.25,0.625and 1.25, (iii) d_{eq} as 1.0m (for sway motion),1.2m,1.6m,2.4m and 4.2m (for rocking motion) that yield D/d_{eq} to be 2.5,2.0,1.5,10 and0.57 and (iv) earthquake ground motions with varying hazard levels. An axial force is developed at girder abutment interfaces when the horizontal translation of bridge girder exceeds the initially provided gap at locations eventually leads to bridge failure. Such failure increases as the bridge loses its base support due to scour. The present study represented the bridge seismic damage by tracking the displacement of bridge girder when the lateral restrains at abutments in the longitudinal direction are removed. Push over analysis is performed to determine the yielding and plastic displacements at the top of pier which correspond to the yield and plastic rotations of pier bottom. The analysis result showed that for all values S/D the displacement at top of pier is always higher for 2 span bridges than that of 3 span bridges. Thus in presence of scour, effect of seismic events on bridges can amplify to great extent. The effect of D/d_{eq} for 2 span and 3 span bridge is observed that increase in D/d_{eq} ratio, the bridge response increases. Hence bridge will be more sensitive to combined effect of earthquake and flood induced scour depth. The effect of ground motion the bridge response is at highest level under strong motion. It is concluded that 3D modelling and uncertainty analysis should be conducted to identify all possible failure modes.

Ashish R. Akhare and Tejas R.Wankhade (2014) [9] The aim of this study is the use of High density rubber bearing (HDRB) and friction pendulum system (FPS) as an isolation device and then to compare various parameters between fixed base condition and base isolated condition by using SAP2000v14 software. In this study the (G+12) storey hospital building is used as a test model. Nonlinear time history analysis is carried out for both fixed base and base isolated structure. The results of the research show that the response of the structure can be reduced by the use of High Density Rubber Bearing (HDRB) and Friction Pendulum System (FPS) isolators.

Waseem Khan et.al. 2014[10], This research paper describes the results of an extensive study on the seismic behavior of a structure with damper and without damper under different earthquake acceleration frequency like EQ Altadena, EQ Lucerne, EQ Pomona, EQ Smonica and EQ Yormo. The proposed procedure is placed the dampers on the floors of the ninth-floor and five-floor of a ninth story building frame then compare the different performance of structure with damper up to Ninth-floors, damper up to Fifth-floors and without damper of ninth-story building frame using SAP2000 V15. As per IS-1893 2002 non-linear time-history analyses of frame structure indicate that maximum displacement, maximum base shear and maximum acceleration effectively reduce by providing the damper in building frame from base support to fifth- floor and base support to ninth-floor comparison to as usual frame. The following conclusions are made seismic performance of building can be improved by providing energy dissipating device (damper), which absorb the input energy during earthquake. The frame is more safe when damper is provided up to top floor from base. Due to absolute displacement reduction the structure has not require more ductility to resisting earth-quake forces. This paper considers only nonlinear time history analysis. It can be extended to P-delta dynamic analysis and response spectrum dynamic analysis.

Nirav Thakkar and Durgesh C. Rai 2014 [11] This study is conducted on RC bridge in the Andaman Islands. The bridge is 268 m long Chengappa bridge. The RC Bridge decks, supported on unanchored elastomeric pad bearings are free to move over substructure during an earthquake. Performance of the bridge was analytically investigated using the finite element (FE) analysis program SAP2000. A set of 7 ground motion records were used for time-history analysis. Ground motions were scaled to a PGA value of 0.2g, which represents the Sumatra-Andaman earthquake scenario. Similarly, for design earthquake scenario, the ground motions were scaled to PGA of 0.54g. In this study bridge when subjected to two selected ground motions,

results in maximum elastomeric pad displacement of 365 mm and 445 mm, with an average of 405 mm, along transverse direction of the bridge. The size of the elastomeric bearing pad used is 500 mm×320 mm and 52 mm thick. Elastomeric pad was placed such that the 500 mm side was parallel to the transverse direction of the bridge. Hence, bearing instability is occurring when the displacement exceeds half the size of pad, i.e., 250 mm. It is also observed that central six spans of the bridge deck will lose contact with elastomeric pad, as indicated by positive axial displacements in the bearing and the deck beam will slip over the bearing pad due to lack of contact. There is also a displacement in transverse direction which is due to the uneven distribution of pier stiffness. The uneven distribution of stiffness is caused due to the increase of height of piers from abutment to mid span pier while the cross section of pier is kept same. In order to study the effect of restrainer on seismic performance of the bridge, the adjacent slabs are assumed to be connected together with two 20 mm diameter rod to arrest relative movement of deck slabs with no positive connection with the pier cap. It is also assumed that the elastomeric pad is anchored using two 20 mm diameter rod shear pin, to arrest transverse movement of the deck. Under design level earthquake ground motions, the bridge will experience unseating of the decks and possible collapse of decks, indicating the higher vulnerability of irregular bridges with elastomeric pad bearings. Due to absence of displacement arresters, there is greater likelihood that the bridge will experience problems like unseating and collapse of more than one decks.

Puneeth Sajjan and Praveen Biradar 2016 [12] In this study an 8 storey structures which is symmetrical in plan is modelled and analyzed using the ETABs 2015 software. The earthquake loads are defined as per IS1893-2002 (Part 1). To control the seismic response and to increase the stiffness of structures viscous dampers are provided the structure with and without damper was modelled and analysed. The model was analysed for gravity load and seismic loads. The seismic behavior of the reinforced concrete structure is judged by observing the parameters such as displacement, storey drift and storey shear. The displacement value of structure was reduced about 60% to 85% when viscous damper is applied. The storey drift at mid stories is reduced by 70% when compared with base model. The viscous dampers play a vital role in reducing and controlling the seismic response of structure.

3. SEISMIC ANALYSIS

Seismic analysis is a subset of structural analysis and is the calculation of the response of a structure subjected to earthquakes. It is part of the process of earthquake engineering or structural assessment, structural design, retrofit in regions where earthquakes are prevalent and the vulnerability of structures. Based on the type of external action and behavior of structure, the analysis can be classified as:

1. Linear static Analysis
2. Linear dynamic Analysis
3. Non-linear static Analysis
4. Non-linear dynamic Analysis

As stated above, linear and nonlinear analyses are the two basic methods. Static analysis is performed by considering the structure as stationary and the loads acting on the structure as constant and not time dependent. The effects of all kinds of loads are idealized and simplified in this approach. In contrast to static analysis, dynamic analysis is based on the behavior of the structural system in a time domain. The response spectrum method and the time history method are the dynamic analysis methods most commonly suggested by earthquake codes. paragraph, The entire document should be in cambria font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes. The entire document should be in cambria font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes.

4. GROUND MOTION DATA

Ground motion data can be collected from number of databases such as COSMOS virtual center, PEER etc. Among all those most reliable one is Pacific Earthquake Engineering Research (PEER). Ground motion data for this thesis was collected from "NGA strong motion record" database of Pacific Earthquake Engineering Research (PEER) center. PEER is most popular among the all earthquake research who sought data for the analysis and design of complex structures. PEER database consist of a large number of ground motion data from the world wide tectonic areas. The database has most comprehensive sets of data, including different distance measures, various site characterizations, and earthquake source data.

4.1 SELECTION CRITERIA

For the present study, a set of 7 ground motion records were used for time-history analysis. All ground motions were recorded at soft rock (Site Class C) arising due to thrust or strike slip fault mechanism with no directivity effect and thus can be considered to represent the design earthquake scenario appropriate for the site of the study bridge. In order to investigate the cause of failure of the study bridge during the 2004 Sumatra-Andaman earthquake, it is required to perform nonlinear time-history analysis with the actual ground motion. The digital instruments used to record ground motion at the nearest station in Port Blair failed to record the motion during the event. Hence, two ground motions (GM6 and GM7 of Table 1) are used which have similar characteristics of the 2004 seismic event.

Table -1: Set of Earthquake

No.	Event	Station	Magnitude (M_w)
GM 1	Northridge-01, 1994	Pacific Palisades – Sunset	6.69
GM 2	Tabas, Iran, 1978	Dayhook	7.35
GM 3	Kern County, 1952	Taft Lincoln School	7.36
GM 4	Taiwan SMART1, 1986	SMART1 E02	7.30
GM 5	Denali, Alaska, 2002	TAPS Pump Station #09	7.90
GM 6	Kocaeli, Turkey, 1999	Manisa	7.51
GM 7	San Fernando, 1971	San Diego Gas & Electric	6.61

To investigate the observed behavior of the bridge the ground motions were scaled to a PGA value of 0.54g, which represents the Sumatra-Andaman earthquake scenario. (Zone factor Z = 0.36g × Importance factor I = 1.5 as per IS: 1893 - 2002).

5.MODELLING AND ANALYSIS

The foremost purpose of structural analysis is to know the displacement of decks of a structure and to identify the critical condition of the structure under given seismic conditions. The program SAP2000 was used for the modeling and analysis in this paper.

5.1 BEARINGS AND DAMPERS

High density rubber bearing (HDRB) is another type of elastomeric bearing which consist of thin layers of high damping rubber and steel plates in alternate layers. The rubber used is either natural rubber or synthetic rubber which provide a sufficient amount of damping. The cross-sectional view of HDRB is as shown in Fig. 6.7 Non-linear Stiffness (U2 & U3) 2069.24 kN/m [1]

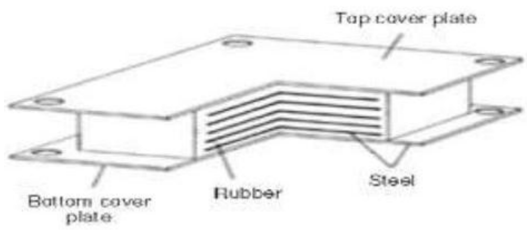

Fig -2: High density rubber bearing (HDRB)

The friction pendulum system (FPS) is a sliding type isolation system and consists of a spherical stainless steel surface and an articulated slider, covered by Teflon based composite material. It works on the principal of simple pendulum. Friction Pendulum bearings are seismic isolators that are installed between a structure and its foundation to protect the supported structure from earthquake ground shaking. The cross-sectional view of FPS is as shown in Fig. 6.8 Non-linear Stiffness (U2 & U3) 29000 kN/m [1]

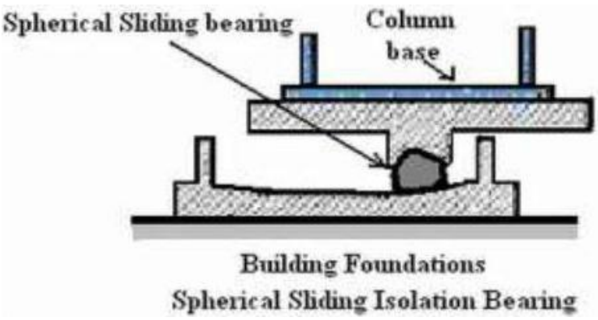

Fig -3: Friction Pendulum System

The Viscous dampers are passive energy dissipation device which is added to structure to increase the effective stiffness of new and existing structures. They are very robust material and energy is transferred by piston and absorbed or vanishes by silicone-based fluid flowing between the piston-cylinder arrangement.

The properties of the Viscous Damper are considered as provided by the manufacturing company Taylor Device Inc.,

Damping coefficient: 810 kN-s/m

Velocity exponent: 0.3

The stiffness value of the viscous damper is calculated by the following formula by considering the force and displacement of the bare structure.

Force = Stiffness * Displacement

i.e., $F=K*\delta$

K = 5,95,238.0953 kN/m [8]

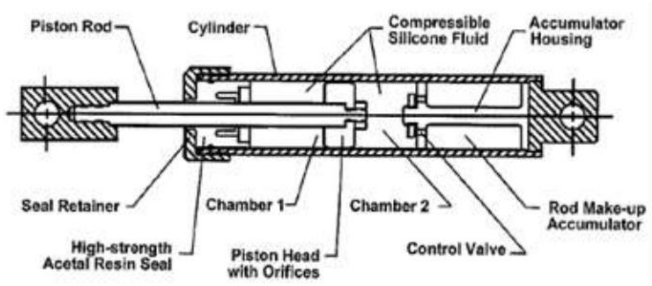

Fig -4: Detail of viscous damper

6. RESULTS AND DISCUSSIONS

Nonlinear Time history analysis is carried out to obtain the deck displacement with two different scaled ground motions (0.54g) for FPS and HDRB. The following are the models considered:

Table -2: Models Considered

HDRB without damper (w/o)	FPS without damper (w/o)
HDRB with damper throughout the bridge (wd f)	FPS with damper throughout the bridge (wd f)

Analyzed result of damper provided throughout the bridge is compared with without damper case for two bearings. The displacement and percentage of decrease when the damper is provided throughout the bridge for HDRB and FPS bearing is considered.

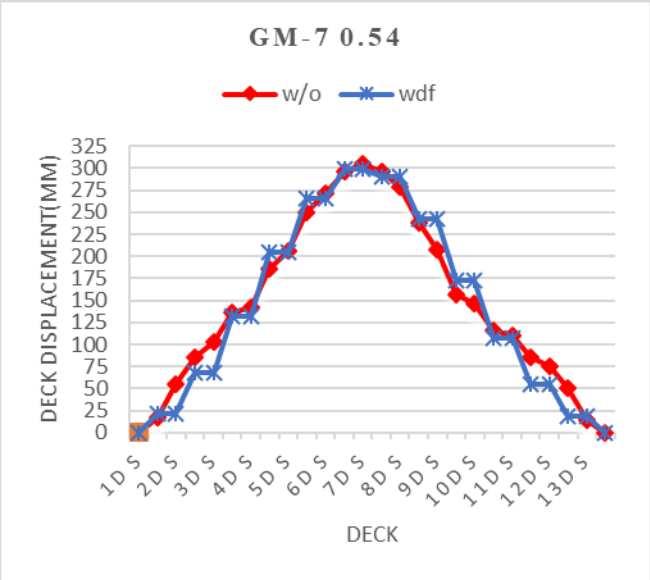

Chart -1: Deck displacement for HDRB for GM7

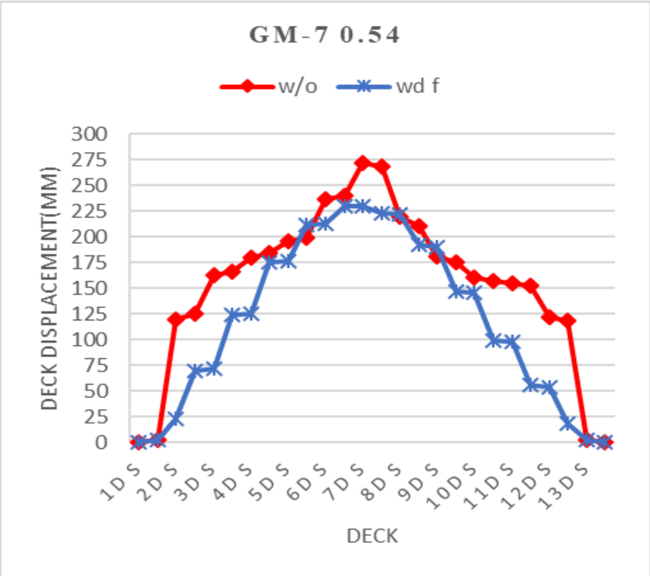

Chart -2: Deck displacement for FPS for GM7

7. CONCLUSIONS

The seismic analysis helps to study about the behavior of building under earthquakes. This works includes the seismic response of RC bridge with two type of bearing with viscous damper provide throughout the bridge. The findings are listed below:

- There is a significant reduction in the displacement response of a bridge subjected to ground accelerations with the use of viscous dampers.
- An average reduction of up to 47% can be achieved by incorporating an overall system of damping.
- In FPS the center deck displacement has been reduced to max 30% in every earthquake
- Despite widespread use of viscous dampers in rehabilitation or retrofitting of bridge structures as well as in new bridges, there are no standards available to calculate damper forces and limit states
- Bridge codes should emphasize on requirement of anti-dislodgement devices, such as, shear keys and links or cables to arrest excessive displacement of the bridge deck.

Fluid viscous dampers are effective in improving bridge performance under dynamic conditions by dissipating energy. They introduce damping in the system and consequently, reduce force and displacement demands. This could even elimination of structural damage as well as traffic loss could be achieved after a seismic event, yielding substantial economic benefits

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