Seismic Performance of a Pre stressed Tied Arch bridge Fitted With Dampers

Jyothish Kiran A S[1], Krishnakumar S[2], Finny Alex[3], Nikhil Mohanan [4]

[1]Post Graduate student, Amal Jyothi College of Engineering, Kanjirappally, Kerala, India
[2]Assistant Executive Engineer, LSGD, Government of Kerala, Kerala, India
[3]Assistant Professor, Amal Jyothi College of Engineering, Kanjirappally, Kerala, India
[4] Research Engineer, FEM CFD Research and Development, Kerala, India

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Abstract - *The dynamic response of a pre stressed bowstring reinforced concrete (RC) type arch bridge under seismic loading is under investigation using finite element model. The bridge named as New Kozhencherry Bridge, Kerala, India was selected for the study. The bridge is a proposed work of the Public Works Department, Kerala. This paper deals with static analysis and seismic analysis of the bridge with and without the provision of a damping systems and comparison of the results. The studie presented in this paper are a possible suggestion for design improvements to the structure under consideration.*

Key Words:Reinforced concrete bridges, viscous dampers, finite element analysis, seismic retrofit, modal analysis, dynamic analysis, seismic analysis, transient analysis

1.INTRODUCTION

A Tied Arch Bridge is a type of arch bridge in which the outward-directed horizontal forces of the top chord, are carried as tension by the bottom chord. This elimination of horizontal forces at the abutments allows tied-arch bridges to be constructed with less robust foundations. Therefore, tied arch bridges can be situated atop elevated piers or constructed in areas having unstable soil. Since the structure do not depend on horizontal compressive forces for its integrity, tied-arch bridges can be prefabricated offsite, and subsequently assembled at site.

Of the many methods employed for the optimum performance of structures during seismic events, the use of dampers have proven to give promising results. Structures try to passively resist excitations through minor deformations, energy absorptions through plastic hinges etc. But these mechanisms cannot provide the required level of damping to resist a strong seismic vibration. Therefore we have to employ supplementary damping mechanisms: provision of dampers. Although the effect of dampers are well studied and recorded in the case of buildings, studies in the field of bridges are quite rare. Buildings and bridges excite very differently in seismic events. Studies exist on existing bridges being retrofitted with dampers, but this study focuses on a proposed governmental work.

Philippe Duflot and Doug Taylor (2008) [9] retrofitted a footbridge named The Millennium Bridge with fluid viscous dampers. Peak accelerations were reduced from 0.25 g undamped to 0.006 g damped.

Maria Q. Feng et al. (2000) [18] studied the effect of dampers in mitigating the seismic responses of bridges using a two-dimensional finite element model and found that the provision of dampers offered a practical solution to mitigate seismic vibrations.

2. STRUCTURE SELECTED FOR THE STUDY

The bridge is proposed to be constructed downstream of the the existing Kozhenchery Bridge across the Pamba River connecting Thiruvalla and Pathanamthitta under Pathanamthitta Division. The new bridge is proposed have six spans of 32.08+m and two spans of 23.40 m (Arch beams on both side). The MFL is +93.050 vertical clearance of the bridge above the MFL is proposed to be 5m for playing Beaked Boat. The total width of the bridge is 8.5 m. The carriageway has a width of 7.5 m and the superstructure consists of two prestressed tie members as bottom chords, fourteen cross girders, two bows and two bracings. Fig-1 shows the location of the proposed bridge.

Fig-1: Location of the proposed bridge.

3. FLUID VISCOUS DAMPER

A damper can be defined as an element which can be added to a system to provide forces which causes energy dissipation during vibrations.
The damping equation can be characterised as,

$$F = C \cdot V^{\alpha}$$

Where F is the output force in kN or MN, V the relative velocity across the damper in mm/s, C is the damping coefficient and α is a constant which usually has a value between 0.3 and 2.

The energy dissipation by dampers take place through fluid flow through orifices. This flow through tight orifices absorbs energy, which is dissipated into the atmosphere as heat.

Fluid viscous dampers can operate in a wide range of temperatures. The length of the damper and the required damping force are customer controlled attributes. Fig-2 is a schematic illustration of a fluid viscous damper and Fig-3 shows one under commission.

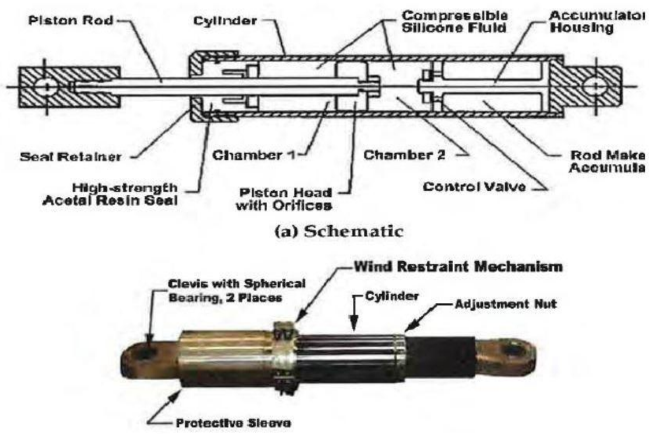

Fig-2: Schematic diagram of a Fluid Viscous Damper

Fig-3:A fluid viscous damper installed on a bridge

4. MODELLING OF THE STRUCTURE

The bridge was modelled using Design Modeller of ANSYS 16.2 Workbench platform according to the data as shown in table 1.

Member	Dimensions
Deck slab thickness	225 mm
Tie member dimension	600 X 600 mm
End Cross girder dimension	600 X 950 mm
Intermediate Cross girder dimension	300 X 850 mm
Bow dimension	600 X 1000 mm
Bracing dimension	300 X 600 mm
Hanger diameter	72 mm
Pier Diameter	1500 m

Table-1: Section Properties

Diameter of rebars used are 32 mm, 25 mm, 20 mm, 12 mm, 10 mm and 8 mm. 12 T 13 strands were used for pre stressed members. The deck slab consists of 12 mmdiabars @ 200 mm c/c+16 mm dia bars @ 200 mm c/c as top and bottom steel and 10 mm dia bars as distributors.

The Bow consists of 36 no.s of 25 mm dia bars with 10 mm dia bars at 150 mm c/c as shear reinforcements. The bracings are 8 no's of 25 mm dia bars. The cross beams with 8 no's of 25 mm dia bars at top and 4 no's of 25 mm dia bars at bottom and shear reinforcement of 10 mm dia bars.

The pier consists of 34 no.s of 32 mm dia bars with a shear reinforcement of 8 mm dia bars at 200 mm c/c.The damper was modelled to have a length of 0.7 m as a longitudinal damper connecting the pier to the deck.

The models are shown in Fig-4 and Fig-5.

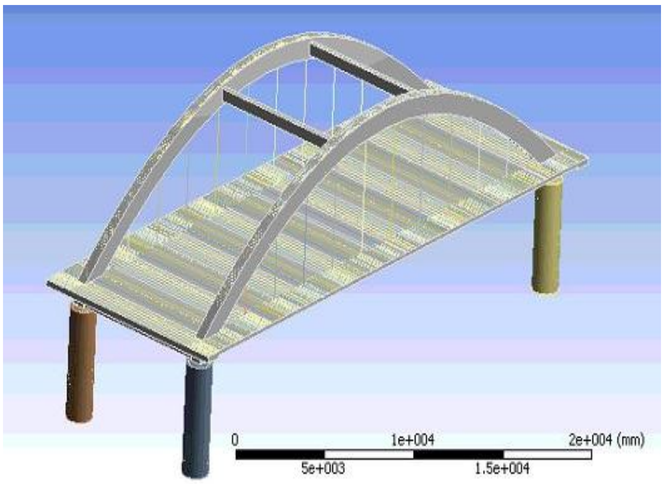

Fig-4: Model of the bridge in ANSYS 16.2

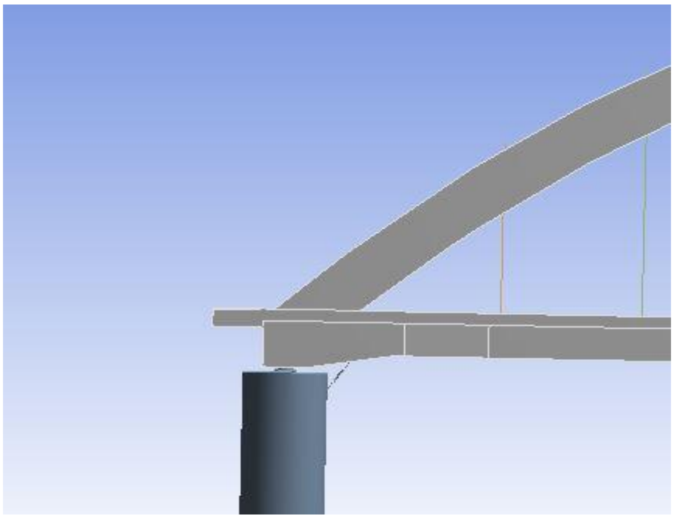

Fig-5: Damper provided between pier and deck

4.1 Material Data

M40 grade concrete is designated to be used for construction of the bridge along with Fe500 grade steel bars. The concrete is modelled using solid elements and the rebars, hangers and pre stressing cables are modelled as beam elements. The hangers used are Macalloy tension rods M76 of 72 mm nominal diameter. A brief material description is given in Table-2.

Table-2: Material description

Concrete	
Compressive strength	40 MPa
Density	24 kN/m^3
Poissons Ratio	0.17
Structural Steel	
Tensile Strength	500 N/mm^2

The hangers have a minimum yield load of 1756 kN and a minimum breaking load of 2329 kN.

5. ANALYSIS

Coupled Static, modal and transient structural analysis of the models are completed. Two different earthquake ground acceleration data namely The North-Ridge Earthquake and The Kashmir Earthquake are used for the seismic model. The analyses of the structure are done with and without the provision of dampers and the deformation values and resultant acceleration are compared. ANSYS Workbench 16.2 offers a wide selection of solvers. The Sparse MAPDL solver was used for the FE analyses.

A final mesh of 228387 nodes and 128216 elements were generated during the user controlled meshing process. Further fine meshing proved unnecessary since required convergence criteria were met after the initial trials.

The ground acceleration data of North-ridge earthquake and Kashmir Earthquake are as shown in Fig-6 and Fig-7.

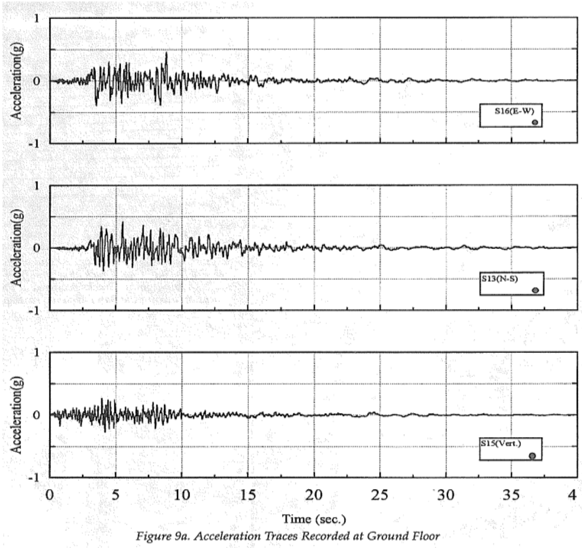

Fig-6: North-Ridge earthquake ground motion data

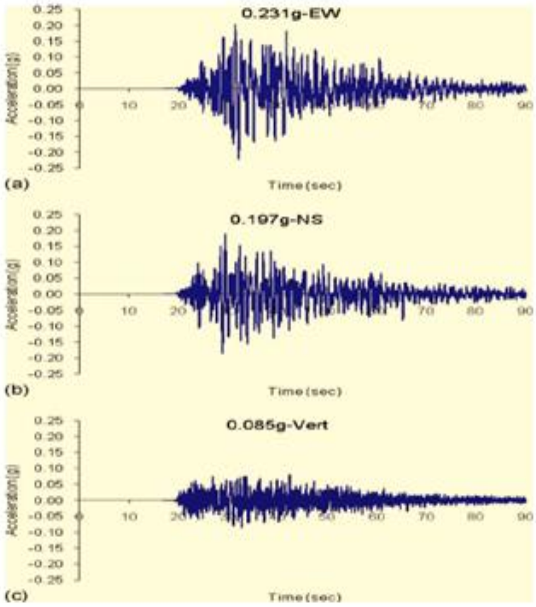

Fig-7: Ground motion data of Kashmir earthquake

The North-Ridge earthquake 0f 1994 January 17 is of magnitude 6.7. The Kashmir earthquake of October 8th 2015 is of magnitude 7.6.

6. RESULTS AND DISCUSSIONS

The results and inferences of the analysis are as described below.

6.1 Static Analysis Results

The static analysis is used to find the deformation under the dead load of the structure. The only load applied in this case is the Earth's gravity. Fig-8 and Fig-9 shows the static analysis results.

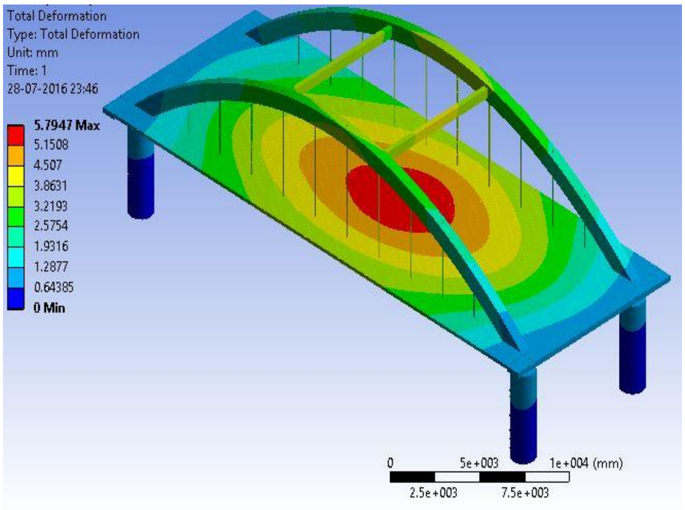

Fig-8: Deformation of the bridge without dampers

The maximum deformation is found out to be 5.7947 mm at the middle portion of the deck slab.

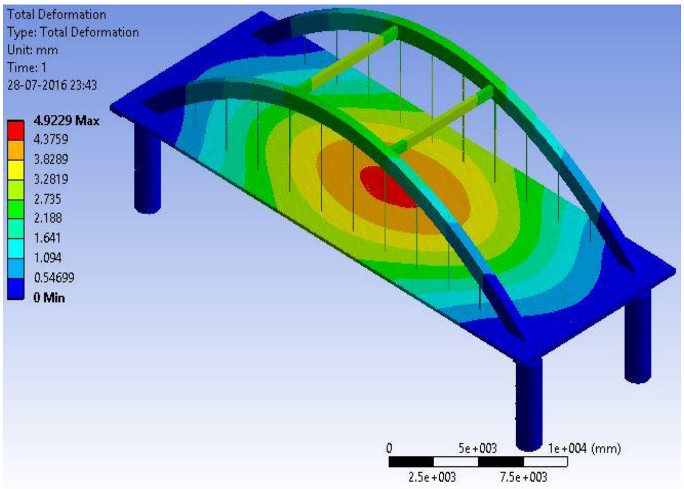

Fig-9: Deformation of the bridge with dampers

Here maximum deflection is found out to be 4.9230 mm and the deflection values have decreased to almost zero near the supports.

6.2 Modal analysis

A total of ten modes were identified prior to the transient analysis through a modal analysis. The mode numbers and respective frequencies and maximum deformations are given in Table-3. A mode shape is shown in Fig-11.

Table-3: Modal analysis results

Mode Number	Frequency(Hz)	Deformation(mm)
1	4.0998	0.09549
2	4.482	0.089641
3	6.3421	0.09384
4	6.6588	0.09072
5	6.9986	0.1096
6	7.6317	0.145
7	8.4496	0.1158
8	9.0376	0.11297
9	10.739	0.7234
10	10.96	2.3916

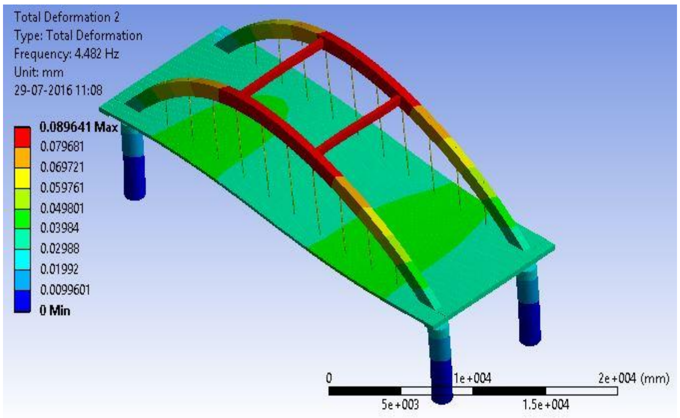

Fig-10: Second mode shape for frequency 4.482 Hz

6.3 Dynamic analysis results for North-Ridge earthquake

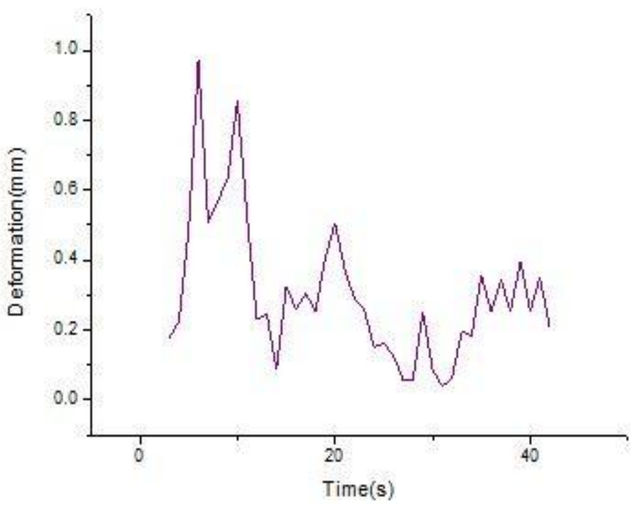

Chart-1: North-Ridge earthquake Deformation

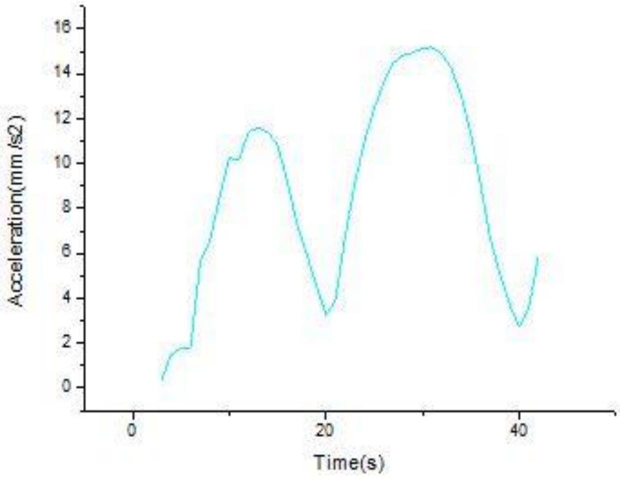

Chart-2: Northridge earthquake acceleration

6.4 Dynamic analysis results for Kashmir earthquake

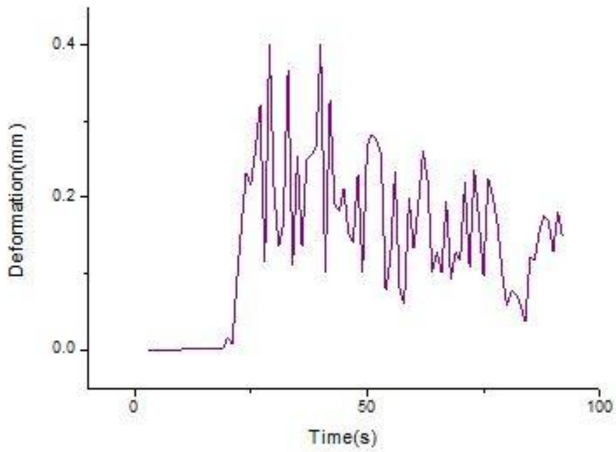

Chart-3: Kashmir earthquake deformation

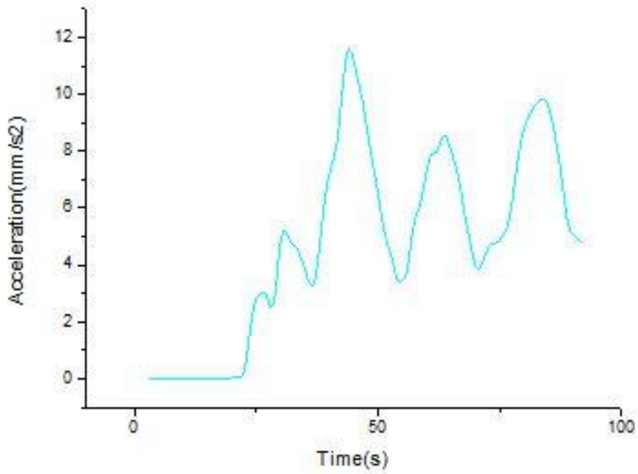

Chart-4: Kashmir earthquake acceleration

6.4 Comparison of results of Bridge with and without dampers for North-ridge earthquake

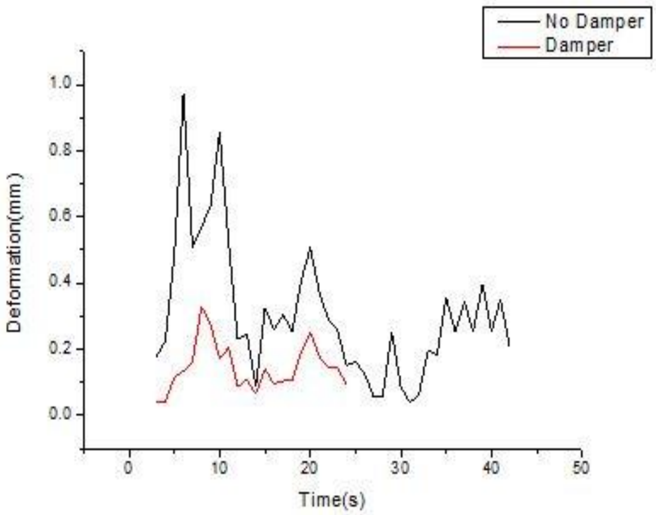

Chart-5: Deformation comparison for North-Ridge earthquake

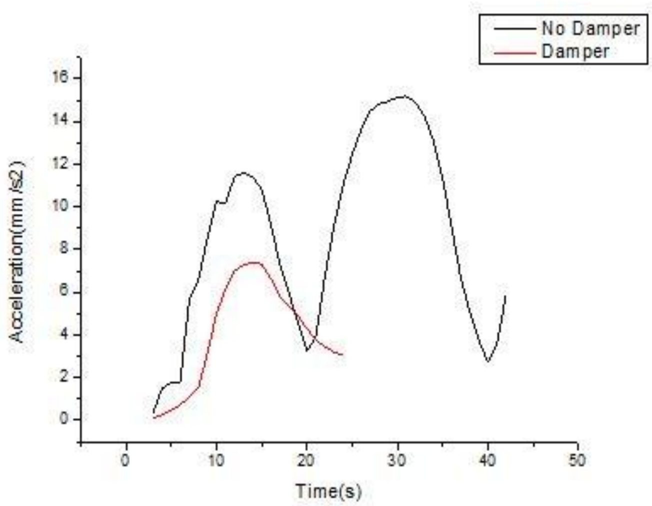

Chart-6: Acceleration comparison for Northridge earthquake

The deformations and accelerations became negligible after 20 seconds when the analysis was done on the damped structure.

6.4 Force dissipated by the damper during Northridge earthquake excitation

A significant amount of force was found to be dissipated by the damper. As mentioned above this energy will have been dissipated as heat energy. The energy dissipation characteristics of a single damper is depicted in chart-7. The result is obtained from the North-Ridge earthquake analysis.

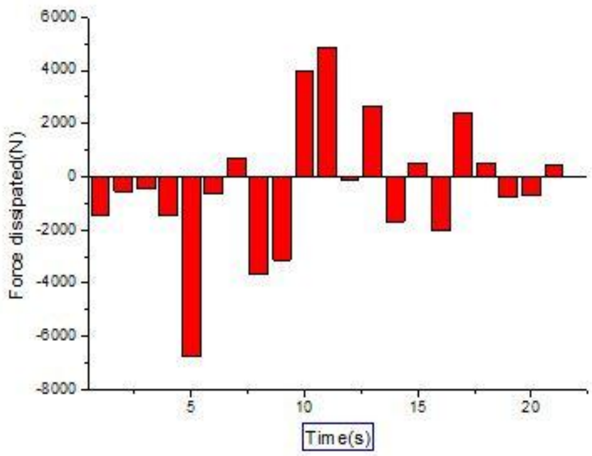

Chart-7 Force dissipated by a single damper

6.5 Comparison of results of Bridge with and without dampers for Kashmir earthquake

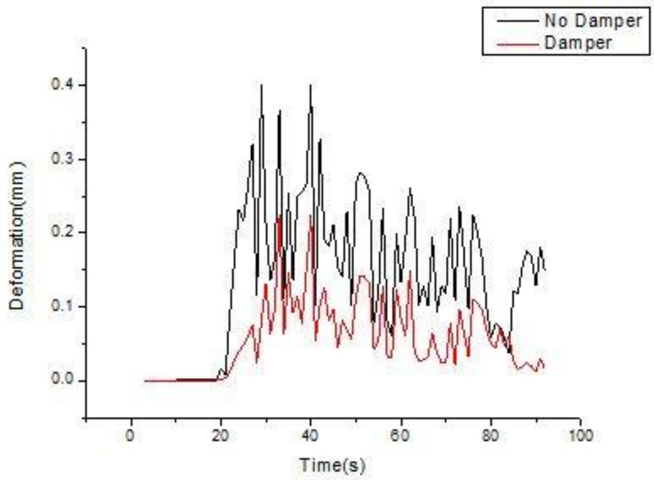

Chart-8: Deformation comparison for Kashmir earthquake

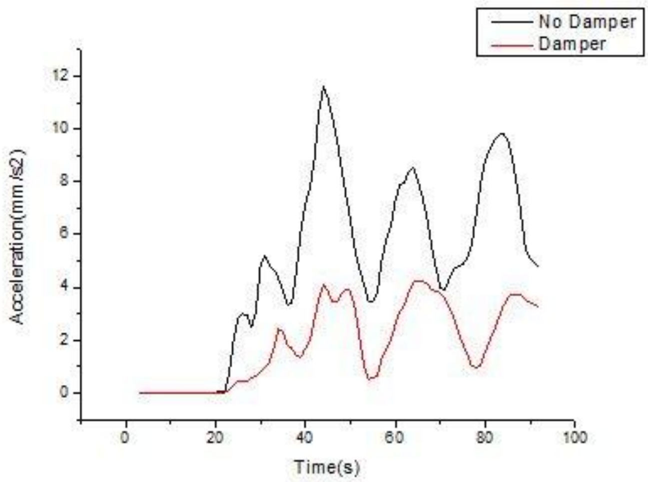

Chart-9: Acceleration comparison for Kashmir earthquake

7. DISCUSSIONS

[1]. Significant reduction in response can be obtained by the implementation of supplementary damping devices.
[2]. Buildings sometimes tend to exhibit increased acceleration due to extra stiffening effect caused by dampers but no such trend is observed in this case.
[3]. The response and acceleration are significantly reduced.
[4]. The passive damping device tested has significantly enhanced the energy dissipation in the structure.
[5]. Due to the architectural peculiarity of the bridge only a longitudinal configuration of dampers would be effective.
[6]. Although the installation of dampers will incur extra costs, on the long run they will protect the bridge from de-commissioned due to vibrational hazards.
[7]. The installation of dampers can also result in a more economic design of the structure
[8]. A decrease of about 40% was recorded in the response of the bridge fitted with dampers

8. CONCLUSION

The results and discussions show that displacement and acceleration are significantly reduced with the application of dampers. The longitudinal configuration can be chosen as the optimum configuration of damping devices. For improved results the effects of type and number of dampers should also be investigated.

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