Seismic Retrofitting of Collapse Evaluation of Irregular Bridge with Nonlinear Curved Effects

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Abstract – *Bridges are lifeline structures. Their performance is critical during and after the earthquake. The decks of an RC bridge, which is supported on unanchored elastomeric pad bearings, are free to move from bearing during an earthquake. Excessive deck displacement cause unseating sometimes leading to complete collapse of bridge deck. This becomes a major problem in case of irregular bridges. Bridges with significant variations in pile/pier height, curvature, skewness, and inclined condition are known as irregular bridge. Under design level earthquake ground motions, the model predicted that the bridge will experience unseating of the decks and possible collapse indicating higher vulnerability of irregular bridges with unanchored elastomeric pad bearings. The present study attempted to examine how the curvature in bridge affects the seismic response. In this study partial curvature is evaluated using ANSYS. After investigating collapse seismic retrofitting method is also proposed to overcome the limit and failure.*

Key Words: **RC Bridge, ANSYS software, Earthquake, retrofitting, unanchored elastomeric pad bearings.**

1. INTRODUCTION

Bridges are lifeline structures. If a bridge has failed before achieving its lifetime, it's a great loss. So bridge design should be made as much accurately to avoid failure and to reach maximum lifetime. This project discuss about a bridge, Chengappa Bridge across Austen Strait in Andaman Island. The bridge had suffered by unseating of decks from its bearing during Sumatra Andaman earthquake at 2004. The 2D model of RC bridge is developed in AutoCAD and further modeling and analysis are done using ANSYS Workbench 19.0 software.

Dimensions of bridge are:

- Deck = 9.3 m wide
- Expansion gap = 5o mm
- RC slab = 200 mm thick
- Diameter of piers = 1.5 m
- Diameter of foundation piles = 0.8 m
- Elevation at top of pier cap = 12.7 m
- Elevation at top of pile cap = 3 m
- Elastomeric bearing pad = 500x320x52mm
- Shear modulus of elastomer = 1MPa
- Spacing of I girders = 2.3 m

1.1 Objectives of Work

To study the seismic performance of the bridge and evaluating the collapse level and stability limit of the bridges, deck displacement, base shear, unseating the deck etc. and providing the seismic retrofitting on the failure area using damper and bearing.

1.2 Scope of Work

The present study attempted to examine how the curvature in bridge affects the seismic response. For this study the curvature form evaluated is partial curvature. After investigating the collapse seismic retrofitting method is also proposed to overcome the limit and failure.

2. METHODOLOGY

The thesis is regarding the modeling and analysis of real full scale long span irregular bridge (268 m). Modeling and analysis is done using ANSYS workbench design modeler software.

The methodology adopted for the present analytical investigation is summarized as follows.

1. Modeling of real full scale long span irregular bridge (268m) as per the case study journal.
2. Modeling of bridge with curvature as per AASHTO code.
3. Analyzing the dynamic characteristics of bridge by model analysis.
4. Performing nonlinear time history analysis to evaluate failures.
5. Strengthening of bridge according to failures.
6. Finding out which one is more efficient.
7. Comparison of results by preparing graphs and charts.

3. FINITE ELEMENT MODELING

The size and properties of various components of the study bridge is taken from the available drawings. The 2D model of the study bridge is developed in AutoCAD. The piers and deck support beams are modeled as elastic beam-column elements. It is expected that plastic hinges will be developed in the piers. However, as no damage observed in the piers during the 2004 Sumatra-Andaman earthquake, no plastic hinges were modeled for the purpose of the present study.

The pier cap beam is modeled as elastic beam- column element and the deck slab is modeled as thin shell element. Foundation is assumed to provide rigid support to the pile, and hence, all six degrees of freedom at the ends of piles are restrained. The piles are founded on rock and thus, soil-structure interaction is ignored. Abutment structure is assumed rigid and not modeled. Elastomeric pads are modeled as Friction Isolator link element with the coefficient of friction as 0.2.

4. GROUND MOTION DATA

The ground motion used for the analysis of RC bridge in this project is ground motion of the event Kern Country at Taft Lincoln school in 1952 which is marked as GM3 (Ground Motion 3) in ground motion database. PGA values are taken from PEER (Pacific Earthquake Engineering Research) ground motion database. To investigate the observed behavior of the bridge the ground motions were scaled to a PGA value of 0.54*g*, which represents the Sumatra-Andaman earthquake scenario. (Zone factor Z = 0.36g × Importance factor I = 1.5 as per IS: 1893 - 2002).

5. GEOMETRY AND MATERIAL PROPERTIES

Analyzing models are:

a) Straight bridge without damper

b) Straight bridge with damper

c) Curved bridge without damper

d) Curved bridge with damper

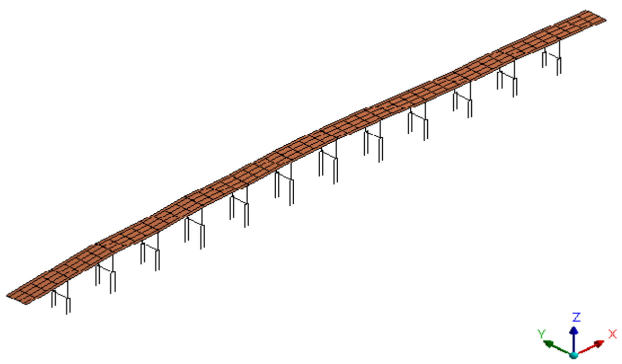

Fig-1: Geometry of straight bridge

Fig -2 Geometry of curved bridge

Table -1: Material properties of concrete

Properties	Description
Density (kg/m^3)	2450
Young's modulus (MPa)	23000
Poisson's ratio	0.18
Bulk modulus (Pa)	1.979E+10
Shear modulus (Pa)	9.7458E+09

6. LOADING

Seismicity of the region indicates that the bridge site can experience earthquake from variety of sources with distance ranging from as near as 15 km to as far as 1200 km. Earthquake may occur in the region with thrust type or strike slip type fault mechanism. The bridge is founded on rock and hence, records shall be selected such that it represents the appropriate scenario for which the response of structure is to be studied. For the present study ground GM3 (Ground Motion 3) was selected, from ground motion records, having major and minor PGA of 0.178g and 0.156g respectively.To investigate the cause of unseating of deck in the transverse direction, the nonlinear time history analysis is performed such that the major component of the pair of records is applied along transverse direction and the minor component is applied along longitudinal direction simultaneously.

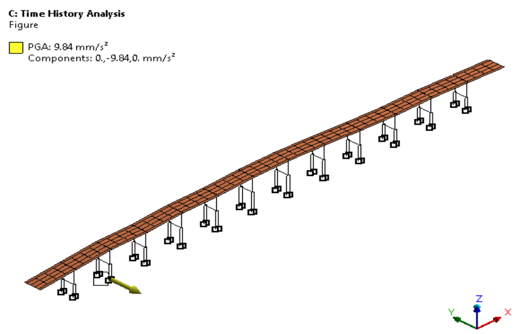

Fig- 3: Earthquake loading in ANSYS

7. MODELING AND ANALYSIS

In this section straight bridge i.e. Chengappa Bridge, is used to evaluate the effect of seismic force on it. 2D model of bridge is developed in AutoCAD and its 3D form is analyzed in ANSYS software. After analyzing the bridge, values of time periods in transverse and longitudinal direction, frequency, deck displacement etc are obtained. Elastomeric pad was placed such that the 500 mm side was parallel to the transverse direction of the bridge. Hence, bearing instability will occur when the displacement exceeds half the size of pad, i.e., 250 mm. Here, the deck displacement exceeds 260 mm. Therefore, it needs strengthening to avoid failure. Here,

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viscous damper is used as a retrofitting method. Then the bridge with damper is again analyzed by applying the same load and note down the results.

In this section, the shape of Chengappa Bridge is changed and considering as a new RC bridge having same dimensions. Now an RC bridge with single curvature is formed by applying a rise of 10m at the middle of straight bridge. As in case of straight bridge, its 2D modeling is developed in AutoCAD and time history analysis is performed in ANSYS. The values of time periods in transverse and longitudinal direction, frequency, deck displacement, total deformation etc are obtained. Then after checking bearing stability retrofitting method is adopted if needed. Viscous damper is used or strengthening.

8. STRENGTHENING

The bridge is strengthened by viscous damper provided by the manufacturing company Taylor Device Inc. The damping coefficient and velocity exponent are 810kN-s/m and 0.3 respectively.

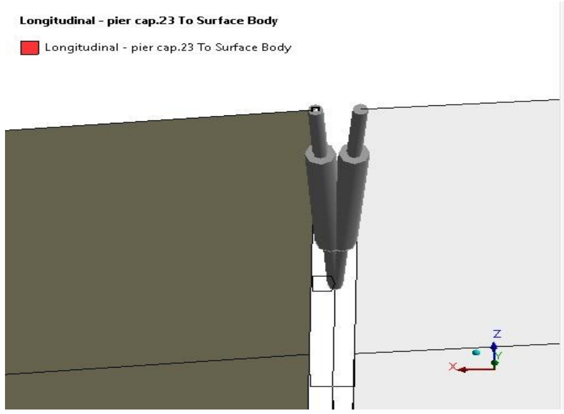

Fig- 4: Viscous damper in ANSYS view

9. RESULTS AND DISCUSSION

9.1 Straight Bridge

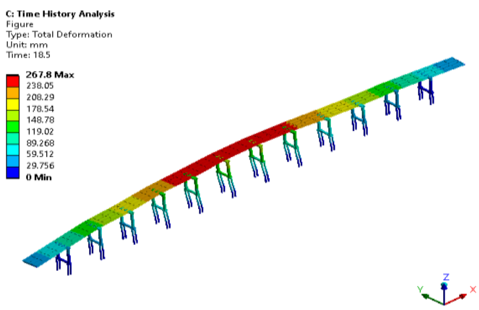

Fig- 5: Total deformation of straight bridge without damper

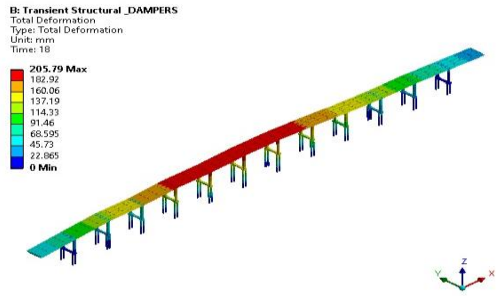

Fig- 6: Total deformation of straight bridge with damper

9.2 Curved Bridge

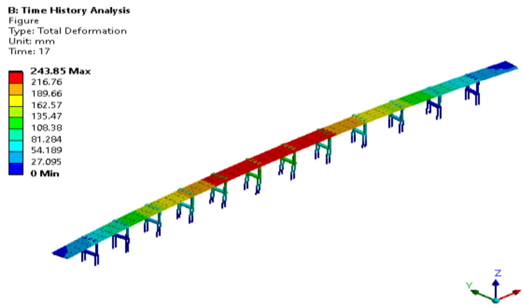

Fig- 7: Total deformation of curved bridge without damper

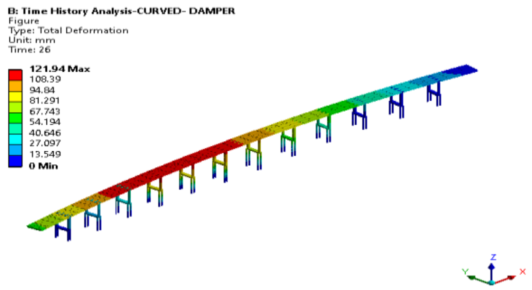

Fig- 8: Total deformation of curved bridge with damper

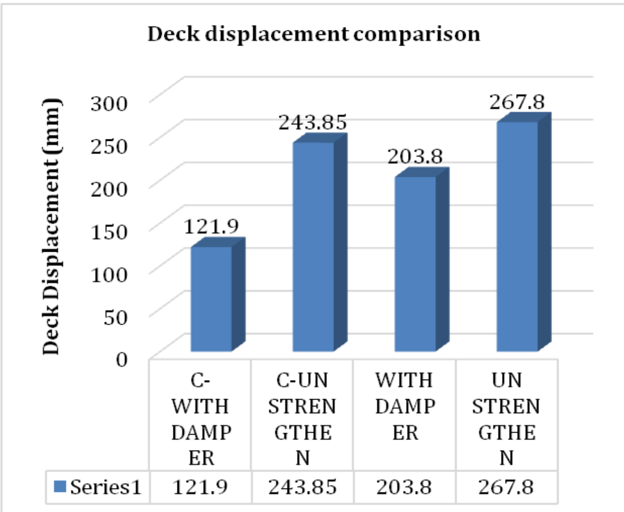

Chart-1: Comparison of deck displacement

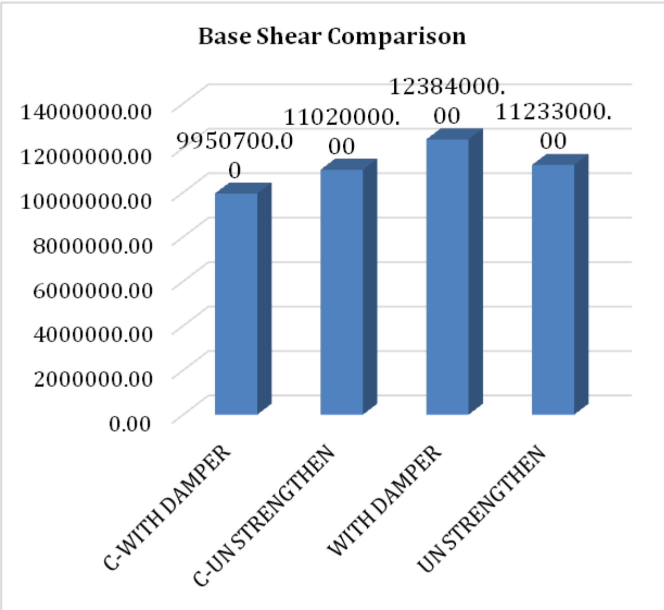

Chart-2: Comparison of base shear

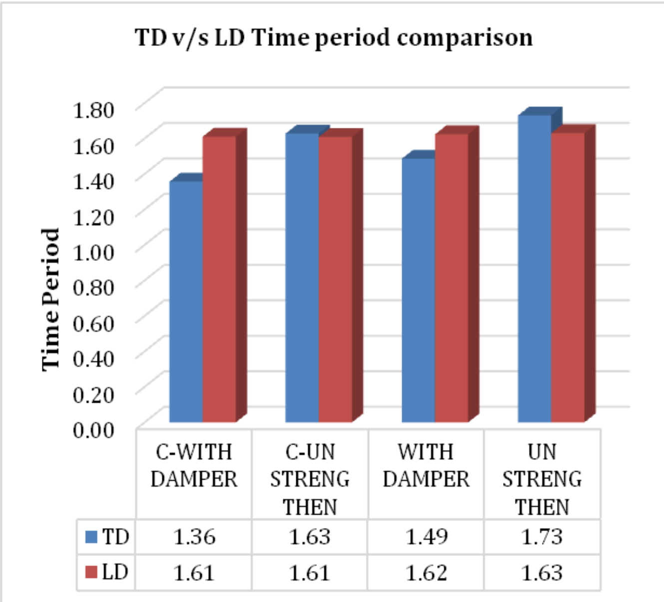

Chart-3: Comparison of time period in transverse & longitudinal direction

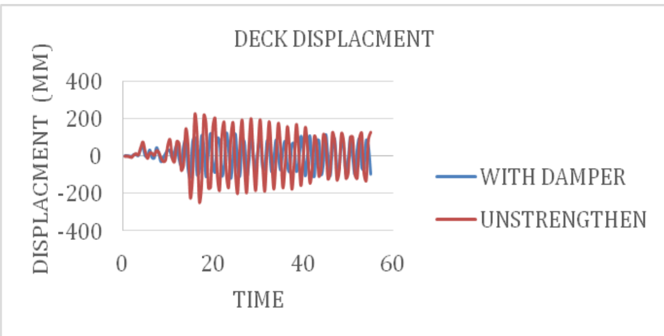

Chart-4: Time history analysis of deck displacement (curved bridge)

10. CONCLUSIONS

The work deals with seismic performance evaluation of an RC bridge whose decks are supported on unanchored elastomeric pad bearings. After the structural analysis of bridge it is obtained that the bridge experience unseating of deck during the application of load GM3. To rectify this problem the bridge is strengthened with viscous damper. After strengthening, the bridge had achieved 23.90% decrease in deck displacement and 11.10% decrease in acceleration. To improve the performance of bridge, the bridge is reformed with a single curvature and seismic performance is evaluated with and without damper. With curvature the bridge showed great improvement in its performance than straight one. Also curved bridge with damper could reduce deck displacement, base shear and acceleration of about 50%, 9.7% and 32.54% respectively. Finally, on comparing irregular straight bridge with curved one, curved bridge with damper could give seismic performance much better than a straight one.

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