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Deck Displacement Study on C Type Curved Bridge

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Abstract - *Curved bridges are often used to construct large and complex highway interchanges into densely populated areas to avoid traffic congestion and to increase the aesthetics of the structure. Earthquake may cause excessive deck displacement and complete collapse of bridge deck leading to shutdown of the structure for long period. The bridge was modelled in AutoCAD and exported to CSI SAP 2000 software to analytically investigate the performance of bridge. The investigation is carried on C types of curved bridges. The seismic behaviour of curved bridge is studied using non-linear time history analysis. The main objective of this project is to detect the maximum deck displacement to compare the performance of the bridge during an earthquake. A suitable retrofitting technique is proposed in the form of bearing and isolator in order to arrest the displacement of the deck slab and girders. The software used for this project is SAP 2000.*

***Key Words*: C Type Curved Bridge, SAP 2000, Deck Displacement, Non-linear Time History Analysis, Seismic Retrofitting.**

1.INTRODUCTION

Curved bridges are provided for viaducts and interchanges where divergent traffic lanes are converted into a double laned bridge or over-bridge and the other way around. Horizontally curved bridges respond to loads differently than do straight bridges because of the torsional forces induced by the curvature of the longitudinal axis. The behaviour of such bridges is more complicated than straight bridges and have more complex seismic behaviour than straight bridges and have been more vulnerable to earthquakes. The curve of the bridge and its ability to dissipate the force of the load outward along the curve reduces the effects of torsional force on the underside of the bridge.

The main advantages of curved bridges are it avoids the cost of using costly, complex construction works. Horizontally curved decks can be provided by using a series of straights or the use of curved members. A series of straight beams with angular change at discrete places may be suitable for the larger plan radii. Bridges lack structural redundancy and therefore suffer severe harm that results in failure throughout earthquakes. Pounding has been known together of the most causes of the initiation of harm and should modification the unstable response of the whole bridge. In this paper, C type curved bridge was analyzed under a severe earthquake. The analytical study is carried out by using SAP 2000 software.

The main objective of the study is to found out deck displacement using nonlinear time history analysis. Also, to propose a retrofitting method for the bridge to arrest displacement of deck slabs and avoids future disasters.

1.1 Scope and Objectives of the Study

Work is restricted to analysis of curved bridges under severe earthquake. The work is limited to modelling and analysis of curved bridge by using SAP 2000.
The main objectives of the study are follows;

- For conducting this study, C type curved bridge is modelled.
- To study the seismic behaviour of curved bridges by using nonlinear time history analysis.
- To study the deck displacement in C type during severe earthquake and retrofitting the maximum displaced deck.

1.2 Elastomeric Pad Bearing

Elastomeric pad bearings contain a wide variety of rubber layers separated by steel plates normally casted in pads and are fitted to small structures to accommodate the movements due to deformation in shear and rotations. Generally, it provides vibration isolation and are easy to install and use.

1.3 Lead Rubber Bearing

Lead rubber bearing (LRB) is mainly used for bridge construction because it is practical and cost effective for seismic isolation. Mainly LRB composed of laminated elastomeric pad bearing, top and bottom sealing and connecting plates. And there is a lead plug inserted within the middle of the bearing.

The main advantage of LRB are: It has the capacity to absorb earthquake and generated force by changing the bearing shape and it is easy to install without a separated damper. LRBs are stiff and strong in vertical direction but flexible in horizontal direction and requires low maintenance. It also reduces the ground acceleration by extending the structural vibration period.

2. MODELLING AND ANALYSIS

2.1 Geometry

In this study, A C shaped curved bridge was modelled in AutoCAD version 2017 software. The bridge is 268m span length, simply supported over 12 cast-in-place piers. The width of the bridge deck is about 9.3m wide and the length of the bridge is divided into 20.61 m individual span. It contains 200 mm thick slab, supported on four 1.35 m girders at 2.3 m spacing [8].

The length of pile varies along the length of the bridge is tabulated in table 1 and a description of the model is given in table 2.

In this study, a concrete grade of 30 N/mm² and reinforcement grade of 415 MPa is used.

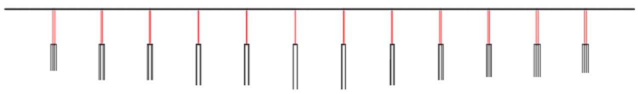

Fig -1: Elevation of C type of curved bridge

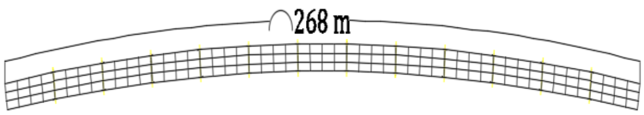

Fig -2: Plan of C type curved bridge

The length of pile varies along the length of the bridge is tabulated in table 1.

Table -1: Pile Length Details

Bent no	Pile length (m)
2	7.5
3	9.5
4	9.5
5	11
6	11
7	12
8	12
9	11
10	9.5
11	8.8
12	8.5
13	7.5

The table below shows the details of C type curved bridge.

Table -2: Description of model

DESCRIPTON	DIMENSIONS
Span Length	268 m
Width of bridge deck	9.3 m
Span	20.61 m
Expansion gap	50mm
Thickness of deck slab	200mm
Diameter of pier	1.5m
Size of pier cap	1.8mx0.8m
Diameter of pile	0.8m
Elevation at top of pier cap	12.7m
Elevation at top of pile cap	3.0m
Length of cross girder	2.3 m
Length of long girder	20.61 m

Properties of elastomeric pad bearing and lead rubber bearing are tabulated below.

Table -3: Properties of bearing and isolator

PROPERTIES	ELASTOMERIC PAD BEARING	LEAD RUBBER BEARING
Length (mm)	500	650
Breadth (mm)	320	650
Height (mm)	52	81.3
Area (mm²)	160000	422500
Horizontal Stiffness (KN/m)	1538.5	2598.40
Vertical stiffness (KN/m)	949635.38	3207793.57

2.2 Modelling

The bridge structure has been modelled using AutoCAD software and exported to SAP 2000 software. Dynamic analysis is carried out using nonlinear time history analysis. The detailed description of the model is given on the table 2. There is a total of 3 models made for the study. Each model is analyzed under Dead load and earthquake load condition. In model 1, the elastomeric pad bearing is installed. The elastomeric pad bearing is replaced with lead rubber bearing, i.e., model 2. After studying model 1 and 2, the maximum displaced deck is studied using the combination of elastomeric pad bearings and lead rubber bearing. Each model is explained below.

Model 1: A C type curved bridge with Elastomeric Pad bearing(el).

Model 2: A C type curved bridge with Lead Rubber Bearing (LRB).

Model 3: A C type curved bridge with el + LRB at maximum displaced deck.

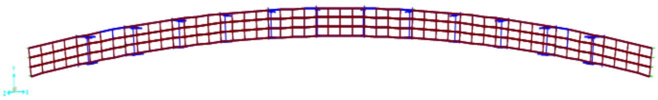

Fig -3: Plan of C type curved bridge from SAP 2000

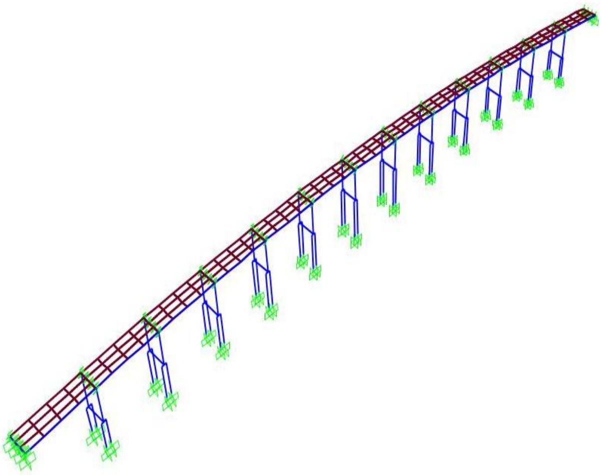

Fig -4: 3D view of C type curved bridge with elastomeric pad bearing

The figure shows the 3D view of C type curved bridge with elastomeric pad bearings and lead rubber bearing.

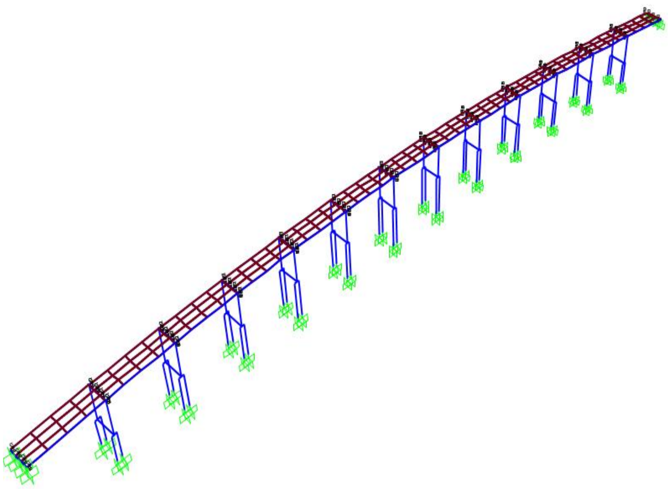

Fig -5: 3D view of C type curved bridge with lead rubber bearing isolator

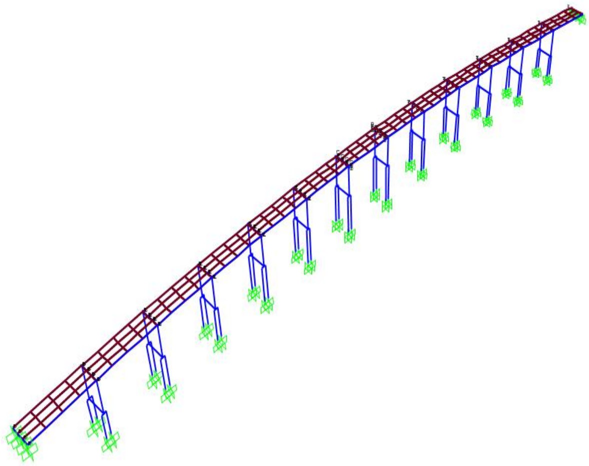

Fig -6: 3D view of C type curved bridge with elastomeric pad + lead rubber bearing isolator

2.3 Analysis

A total of three models and three analysis were done here. Both modal and nonlinear time history analysis were done on each model. The analysis was done using SAP2000 software. El Centro earthquake data was used for the analysis which was obtained from PEER NGA database. The bridge was first modelled with elastomeric pad bearing and analyzed using earthquake load. Then, the same model was analyzed with LRB. Comparing both the models, the maximum displaced deck was retrofitted with the combination of elastomeric pad bearings and LRB.

3. RESULT AND DISCUSSIONS

The deck displacement details of each models are given below. The deformed shape of C type curved bridges using elastomeric pad bearings, LRB and el +LRB are shown in the figures respectively.

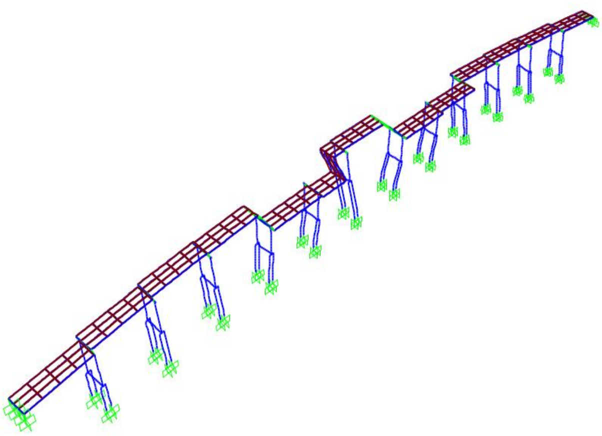

Fig -7: Deformed shape of C type curved bridge with elastomeric pad bearing

The deck displacement of C type curved bridge with elastomeric pad bearing is tabulated below.

Table -4: Deck-Displacement details of el

DECK NUMBER	DISPLACEMENT (in m)
1	0.0265
2	0.0933
3	0.1317
4	0.1242
5	0.153
6	0.1852
7	0.2105
8	0.1858
9	0.1297
10	0.1196
11	0.1321
12	0.1044
13	0.037

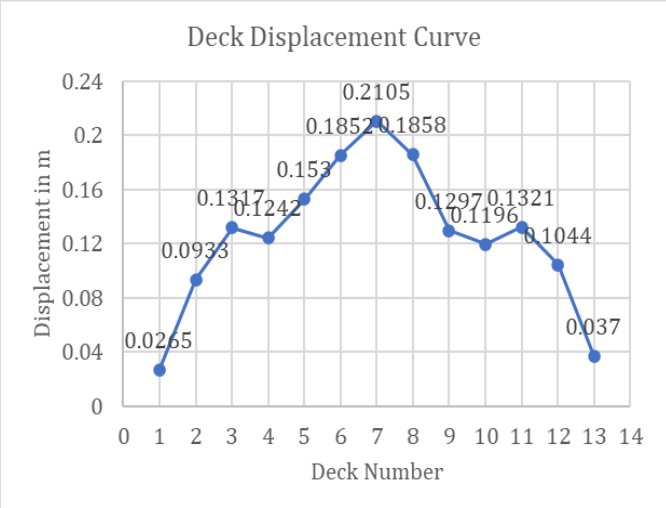

Chart- 1: Deck-Displacement curve of el

Table 4. shows the deck displacement details of el after earthquake and chart 1 shows the graphical representation of the deck displacement. The maximum deck displacement under earthquake is found out to vary from 26.5 mm to 37mm. The maximum deck displacement is found at 7th deck of 210.5 mm.

The figure below shows the deformed shape of LRB isolator.

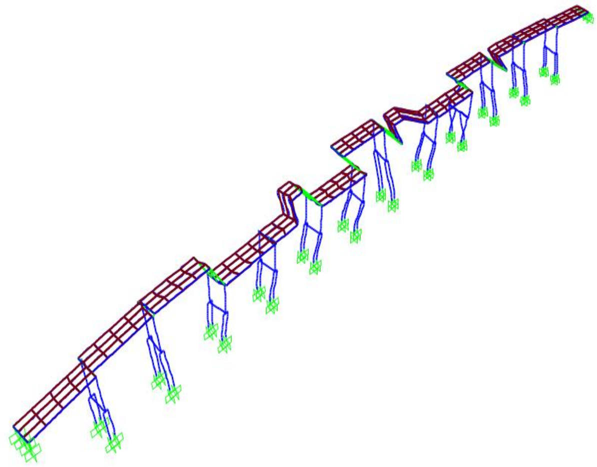

Fig -7: Deformed shape of C type curved bridge with lead rubber bearing

The deck displacement of C type curved bridge with Lead rubber bearing is tabulated below.

Table -5: Deck-Displacement details of LRB

DECK NUMBER	DISPLACEMENT (in m)
1	0.0263
2	0.0899
3	0.1156
4	0.1064
5	0.1095
6	0.1284
7	0.1522
8	0.1161
9	0.1102
10	0.1084
11	0.1048
12	0.0997
13	0.0423

Table 5. shows the deck displacement details of LRB after earthquake and chart 2 shows the graphical representation of the deck displacement. The maximum deck displacement under earthquake is found out to vary from 26.3 mm to 42.3 mm. The maximum deck displacement is found at 7th deck of 152.2 mm.

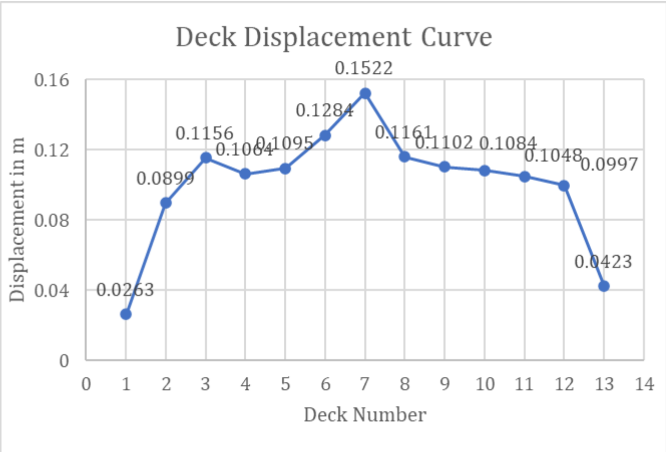

Chart- 2: Deck-Displacement curve of LRB

From the results, it was clear that LRB can be effectively reduce deck displacement compared to elastomeric pad bearing. Since LRB reduces displacement, retrofitting will be done on the deck which shows maximum displacement on elastomeric pad bearing.

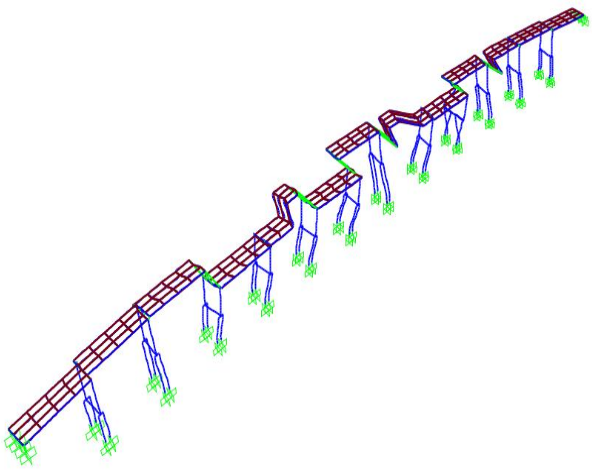

Fig -8: Deformed shape of C type curved bridge with el + LRB

The deck displacement of C type curved bridge with elastomeric pad bearing and lead rubber bearing is tabulated below.

Table -6: Deck-Displacement details of el +LRB

DECK NUMBER	DISPLACEMENT (in m)
1	0.0306
2	0.1018
3	0.1334
4	0.1250
5	0.1664
6	0.1803
7	0.1277
8	0.1750
9	0.1441
10	0.1098
11	0.1318
12	0.1132
13	0.0423

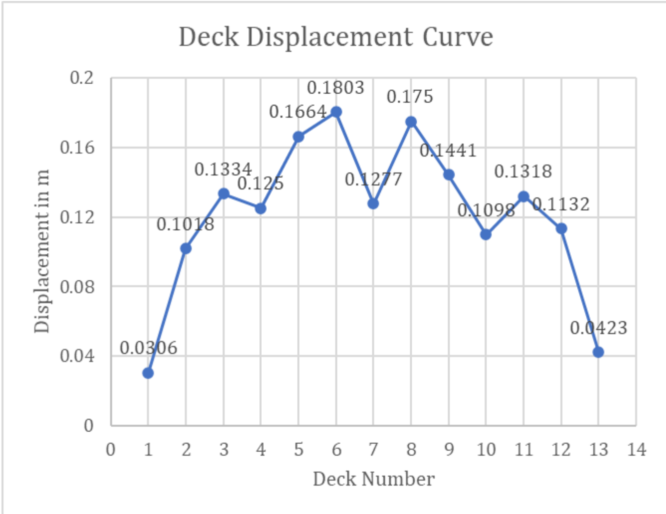

Chart- 3: Deck-Displacement curve of el+ LRB

From the chart 3, the maximum displaced deck is retrofitted. This indicates that the overall performance of the model is improved.

4. CONCLUSIONS

In this study, investigation on performance of C type curved bridge using various type of bearing and isolator was done. The behaviour of curved bridge is more complicated than straight bridges. Thus, to improve the performance of curved bridge during an earthquake, damage is detected and retrofitted. Different types of bearing and isolators are considered and study the performance by varying the types. Mainly two types of studies were considered, which include three models. The maximum displaced deck during a severe earthquake with elastomeric pad bearing and LRB isolator is the 7th deck. The maximum deck displacement in the 7th deck is about 210mm with elastomeric bearing and 152.2 mm with LRB. Therefore, LRB can be effectively reduce deck displacement compared to elastomeric pad bearing. Since LRB reduces displacement, retrofitting will be done on the deck which shows maximum displacement on elastomeric pad bearing. Overall performance of deck also increased. After the retrofitting techniques done, it was observed that the deck displacement reduced to a great extent.

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REFERENCES

[1] Mahmood Minavand and Mohsen Ghafory Ashtiany (2019), "Seismic evaluation of horizontally curved bridges subjected to near field ground motions", Latin American Journal of Solids and Structures, Volume 16, Page No. 1-15.

[2] Abey E Thomas (2018), "Effects of irregular bridge columns and feasibility of seismic regularity", Journal of The Institution of Engineers, Volume 99, Pages 579-585.

[3] Woo Seok Kim, Jeffrey A. Laman and Daniel G. Linzell (2015), "Live load radial moment distribution for horizontally curved bridges", Journal of Bridge Engineering, volume 12, pages 727-736.

[4] M. N. Haque, A. R. Bhuiyan and M. J. Alam (2010)," "Seismic response analysis of base isolated highway bridge: Effectiveness of using laminated rubber bearings", Joint Conference on Advances in Bridge Engineering-II, Page No. 336-343.

[5] Kashif Quamar Inqualabi, Rajeev Kumar Garg and K. Balaji Rao (2017), "Seismic vulnerability of urban bridges due to liquefaction using nonlinear pushover analysis and assessing parameters for damage detection", Procedia Engineering, Volume 173, 1739-1749.

[6] M. J. Levi, D. H. Sanders and I. G. Buckle (2015), "Seismic response of columns in horizontally curved bridges", International Efforts in Lifeline Earthquake Engineering, Page No. 1-9.

[7] Easa Khan, Mervyn J. Kowalsky and James M. Nau(2014), "Comparison of the seismic performance of equivalent straight and curved bridges due to transverse seismic excitation", World Conference on Earthquake Engineering, Page No. 425-431.

[8] Sadic Azeez and Rincy P M (2018), "Seismic mitigation performance analysis study of irregular bridge", International Journal of Civil and Structural Engineering Research, Volume 6, Pages 44-48.

[9] Anurag Deshpande, H M Jagadisha and Aravind Galagali (2018), "Parametric Study on Curved Bridge Subjected to Seismic Loading", International Research Journal of Engineering and Technology, Volume 04, Page No. 1883-1889.

[10] Ricardo Alvarez-Acosta and Jesus Valdes-Gonzalez (2017), "Structural response of plan curved steel i girder bridges from an equivalent straight bridge analysis", Journal of Bridge Engineering, Volume 23, Page No. 1-12.