ISSN 2348 – 7968

Study of Seismic Behaviour of RC Bridges and Control Measures for Seismic Pounding

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Abstract

Bridges lack structural redundancy and hence suffer severe damage which leads to failure during earthquakes. Pounding has been identified as one of the main causes of the initiation of Damage and may change the seismic response of the entire bridge. Pounding occurs when the closing girder movement at an expansion joint exceeds the expansion joint gap. In this study, two span simply supported RC highway bridges is considered. The bridge is modelled and analyzed to investigate the effect of use of magneto rheological (MR) dampers in reducing the pounding effect using the structural analysis and design software SAP2000. Using IRC Class A loading bridge responses such as Bending Moment and deflection are obtained to assess the serviceability. Further, with the help of SAP2000 software dynamic analysis is done by Nonlinear Time History Analysis. The results includes dynamic parameters such as displacement and acceleration with and without Magneto Rheological (MR) dampers.

Keywords: *Seismic pounding, RC Bridges, Non-Linear Time History Analysis, Magneto Rheological (MR) damper, SAP2000.*

1. Introduction

Bridges are considered one of the most critical components of highway transportation networks, as closure of a bridge due to partial damage or collapse can disrupt the total transportation system. Past earthquake studies shows that the major bridge failures are due to pounding effect. This is because the gap between adjacent girders or between a girder and an abutment is usually only a few centimetres to ensure a smooth traffic flow, which is not big enough to accommodate the closing relative displacement between the adjacent components.

Pounding is a result of relative movement of adjacent bridge superstructures. Sometimes the pounding force become more compared to the force for which the bridge was designed, which may lead to major bridge local failures. Pounding is a very complicated phenomenon, involves plastic deformations in the materials at the location of pounding, energy dissipation during contact etc.

In general, bridges lack structural redundancy and hence suffer severe damage which leads to failure during earthquakes. A more robust bridge design is not considered economical or even effective, unless earthquake induced forces in the structure are reduced by means of seismic isolation. Seismic isolation devices generally used in the bridge decouple the bridge deck from the bridge substructure and hence reduce seismic forces transmitted to abutments and piers.

Generally, structures are subjected to two types of load: static and dynamic. However, the majority of civil engineering structures are designed with the assumption that all applied loads are static. This feature of neglecting the dynamic forces may sometimes become the cause of disaster, particularly in the case of earthquake. In present scenario where earthquakes are occurring frequently, dynamic force cannot be neglected. Because, it provides an accurate measure of expected structural response for a given earthquake or any kind vibrations. One of the aspects to be considered while assessing the dynamic response of bridges subjected to live loads is the problem of vibration. The passage of any load over a bridge causes the span to deflect from the equilibrium position, causing a series of oscillations. This phenomenon continues till either the structure comes back to its equilibrium position or is again activated by the passage of another load. Therefore, "dynamic behaviour of bridge deck" needs to be studied.

Using IRC Class A loading bridge responses such as Bending Moment (BM) and deflection are obtained to assess the serviceability. Further, with the help of SAP2000 software dynamic analysis is done by Time History Analysis to obtain dynamic parameters such as displacement and acceleration with and without Magneto Rheological (MR) dampers.

2. Structural Modelling

The software SAP2000 is adopted to create a finite element model of a two span simply supported bridge. The bridge used is a 2 lane reinforced concrete bridge with overall length 60m and of width 7.56m and its each spans of length 30m. IRC Class A loading is used as live load. The piers of the bridge are columns of size 1.75m×4.2m with 12m height and M40 concrete and Fe500 steel is adopted. Concrete box girder of width 7.56m and height 2.1m is used and deck slab thickness is selected as 0.18m. Figure below shows typical plan and 3D view of two span simply supported bridge.

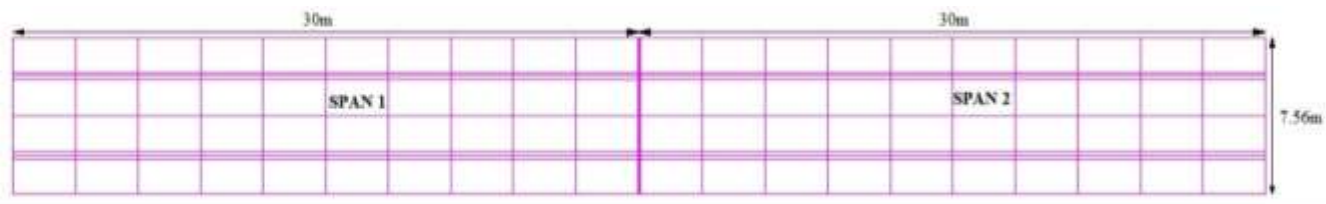

Fig. 1: Typical plan of bridge

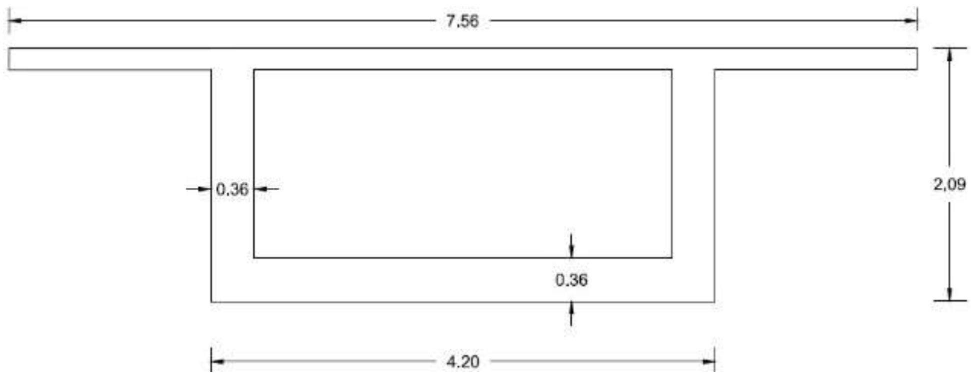

Fig. 2: Cross section of bridge

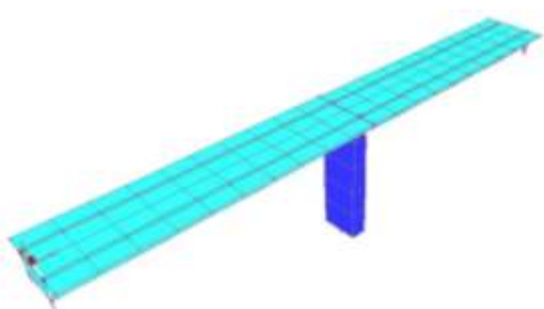

Fig. 3: 3D view of model

3. Determination of Earthquake Ground Motion

For numerical study of seismic pounding effect on simply supported bridges different types of earthquake ground motions can be considered. Here El Centro wave is selected for the analysis. The main characteristics of the earthquake motion is described in the table below.

Table 1: Main characteristics of the selected earthquake ground motion

Earthquake motion	***Direction***	***Amplitude***	***Predominant periods (sec)***
El Centro wave	E-W	216.5	0.507
	N-S	344.4	0.560
	V	209.3	0.110

4. Analysis of structures

IRC Class A loading is used. Load case is selected as moving loads. Then nonlinear time history case is defined.

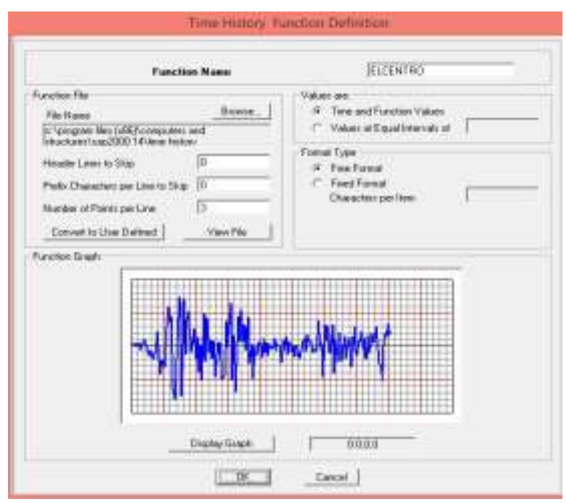

Fig. 4: Time History definition

5. Results and Discussions

5.1 Pounding Force

The peak pounding forces at pier are obtained as shown in table. When comparing the result the pounding force is decreased when damper is provided. The peak pounding forces are obtained at short time and then it decreased considerably.

Table 2: Peak pounding forces

Location	***EI Centro***		
	Time (s)	***Pounding force (×10^7) N***	
		Without damper	***With damper***
Interior Pier	1	0.04643	0.04626
	2	0.2116	0.1858
	3	0.3792	0.1937
	4	0.01204	0.01092
	5	0.02113	0.02039

5.2 Displacement and Acceleration Responses

Fig. 5 shows the response of the bridge when no damper is provided. It is found that when pounding occurs, acceleration of the deck will increase. The large increase of acceleration can result in damage of deck ends and supports. The values from acceleration and displacement responses are quite large due to seismic pounding. Pounding results in a strong coupling of nonlinearity in piers.
To mitigate the pounding effect, supplemental damping can be provided using Magneto Rheological damper. Fig.6 shows the response of the bridge when MR damper is provided. The values from acceleration and displacement responses are decreased due to the effect of damper. Comparing with the deck response when damper is provided, it is found that the displacement and acceleration values are reduced considerably than the case of no damper is provided.

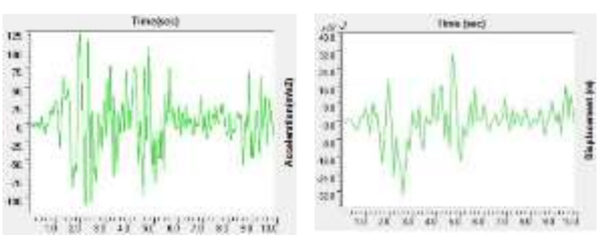

Fig.5: Response of bridge without damper (a) acceleration (b) displacement

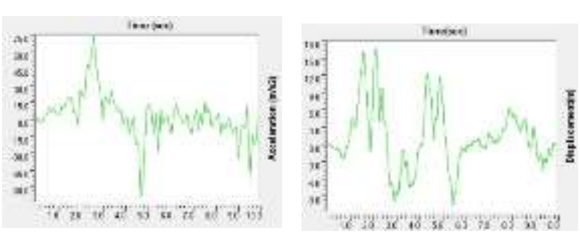

Fig.6: Response of bridge with MR damper (a) acceleration (b) displacement

5.3 Deflection With and Without Damper

Table.3: Displacement of deck with and without damper

Joint	***Displacement of deck (mm)***	
	Without damper	***With damper***
981	25.3	13.62
1109	32.44	8.3
1253	22.62	9.31
1239	38.27	12.44

6. Conclusions

1. Pounding between superstructure segments is considered one of the main reasons for damage and collapse of multi-span RC highway bridges.
2. Analysis of a two-segment bridge shows that pounding can generate significant force which may cause damage at the point of collision.
3. The two span simply supported RCC Bridge is modelled using SAP2000.
4. Numerical study of pounding effect of RC bridge under different earthquake simulations was done
5. A simplified analytical model in conjunction with MR dampers for pounding between adjacent superstructure segments has been developed
6. It has been observed that the seismic pounding effect can be effectively reduced by MR dampers
7. The pounding force, displacement &acceleration responses effectively reduced.
8. Acceleration of superstructure segment due to pounding has been observed to be amplified by several times.

Acknowledgments

I wish to express my sincere gratitude to Ms. Minu Anna Johny, (Assistant Professor and Head of the Department of Civil Engineering, IIET) for her valuable encouragement to carry out this work. Also, I have been fortunate in having Mrs. Teena Joy as my guide, whose timely guidance, advices and inspiration helped me in the preparation and presentation of this work in time. I express my sincere gratitude for his invaluable guidance in spite of his almost overpowering schedule. Her views on many matters have inspired me a lot. I would like to extent my special thanks to my parents and friends.

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