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(Research Article)

Study on non-linear analysis of arch bridges subjected to ground motion

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Abstract

Thanks to the cantilever launching technique, arch bridge building has once again become popular throughout the world. Today, these structures are one of the three main types of long-span bridges, along with suspension and cable-stayedbridges. Arch bridge structures have a complex behavior duringpowerful earthquakes because the arch rib is an element that is primarily susceptible to a large axial compression force brought on by dead loads. The nonlinear dynamic analysis of an arch bridge using STAAD Pro V8i software with earthquake loading isthe subject of this research. Due to their easy load bearing qualities, arch bridges with short and medium spans are currentlybeing constructed frequently for traffic bypass. Therefore, it is necessary to assess its stability in the event of a powerful earthquake. The STAAD-modeled arch bridge's nonlinear, time history analysis. The research in this study uses pro. For Time History analysis, data from the Bhuj Earthquake of 2001 is used, and the Rudramata Bridge, which collapsed during the BhujEarthquake, is researched. The primary focus of this study is on the analysis of the displacement, time-velocity, and time-acceleration responses of an arch bridge to lateral loads. And the results demonstrate that the displacement for the arch bridge is less than that for the Rudramata Bridge in all three directions.

Keyword: Non-linear Dynamic analysis; Time History- Bhuj; Arch Bridge; STAAD.Pro

1. Introduction

Arch curve at the process of the arch cantilever erection. Therefore cable force optimizing calculation is needed to attain the goal of arch curve accuracy. There are permanent stayed cables and temporary stayed-buckle cables in the arch cantilever erection processes of cable-stayed arch bridge. It is different with common arch bridge which has temporary stayed-buckle cables only. And also it is different with commoncable-stayed bridge which has permanent stayed-cables only. So the influence matrix method mentioned above cannot be used in cable-stayed arch bridge's cable force optimizing calculation without any modification.

The purpose of evaluating the bridge structure damage is not only to determine the effect of damage to its remaining servicelife and load-carrying capacity, but also to determine the causesof defects. Generally, the damages occur in concrete bridges under unacceptable loads can be classified into cracks beneath the beam and slab. Additional settlement of bridge slab, extra vibration due to upcoming loads, corrosion of reinforcement, and spalling of concrete (Sadeghi and Fathali, 2007). In the present study, Rudramata concrete bridge is inspected for the Lateral loading in terms of Time-History Analysis. The objectives of this study are to investigate is there any kind of reduction in displacement, and to compare the results of Bridgeby considering the Arch bridge models with various radius of curvature. Arch curve at the process of the arch cantilever erection. Arch bridge is a bridge with abutments at each end shaped as a curved arch. Arch bridges work by transferring theweight of the bridge and its loads partially into a

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horizontal thrust restrained by the abutments at either side. A viaduct (a long bridge) may be made from a series of arches, although other more economical structures are typically used today.

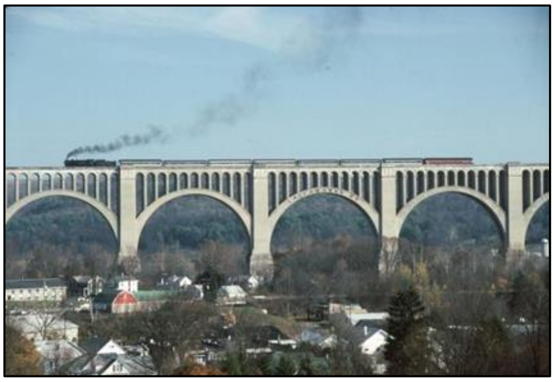

Figure 1 Deck Arch Bridge

The Romans also introduced segmental arch bridges into bridge construction. The 330 m-long Limyra Bridge in southwestern Turkey features 26 segmental arches with an average span-to- rise ratio of 5.3:1, giving the bridge an unusually flat profile unsurpassed for more than a millennium. Trajan's bridge over the Danube featured open-spandrel segmental arches made of wood (standing on 40 m-high concrete piers). This was to be the longest arch bridge for a thousand years both in terms of overall and individual span length, while the longest extant Roman Bridge is the 790 m-long long Puente Romano atMérida.

They have also proved themselves to have been an extremely durable structural form and are generally considered aesthetically pleasing. In recent years, considerable effort has been put into gaining a greater understanding of the behaviour of masonry arch bridges to improve efficiency when assessing a bridge’s ultimate strength.

2. Loads on bridge

The following are the various loads to be considered for thepurpose of analysis.

- Dead load
- Live load
- Moving Load
- Seismic load

2.1. Dead Load

It is a gravity loading due to the structure simply calculated as the product of volume of bridge and material density of the bridge.

2.2. Live Load

Road bridge decks have to be designed to withstand the live loads specified by Indian Roads Congress (I.R.C: 6-2010 Section II).

In India, highway bridges are designed in accordance with IRC bridge code. IRC: 6 - 2010 – Section II gives the specificationsfor the various loads and stresses to be considered in bridge design. There are three types of standard loadings for which thebridges are designed namely, IRC class AA loading, IRC classA loading and IRC class B loading.

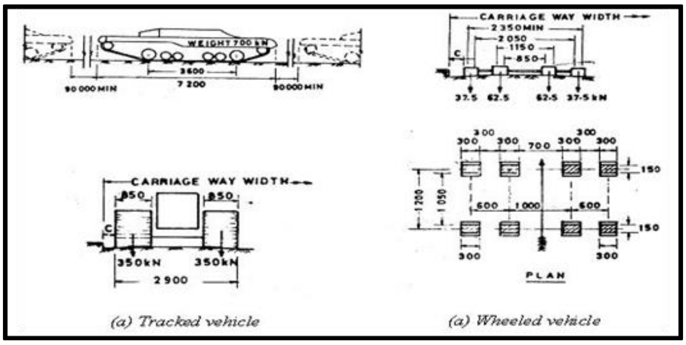

Figure 2 IRC Class AA loading

IRC class AA loading consists of either a tracked vehicle of 70tonnes or a wheeled vehicle of 40 tonnes with dimensions as shown in Figure.3.2. The units in the Figure 3 are mm for length andtonnes for load. Normally, bridges on national highways and state highways are designed for these loadings. Bridges designed for class AA loading should be checked for IRC classA loading also, since under certain conditions, larger stresses may be obtained under class A loading. Sometimes class 70 R can be used for IRC class AA loading. Class 70R loading is notdiscussed further here.

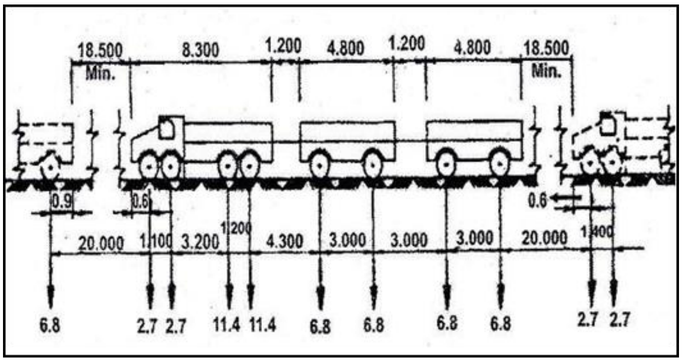

Figure 3 IRC Class A loading

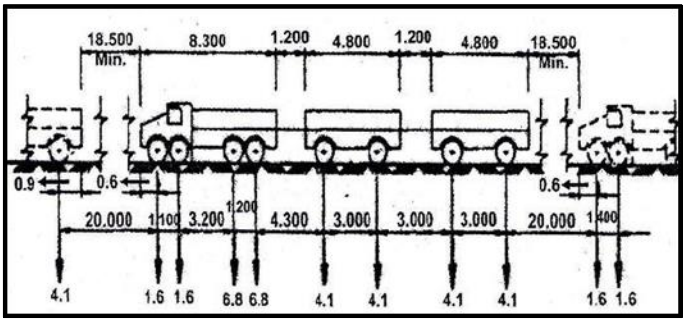

Figure 4 IRC Class B loading

Class A loading shown in Figure 3 consists of a wheel load train composed of a driving vehicle and two trailers of specified axlespacing. This loading is normally adopted on all roads on whichpermanent bridges are constructed. Class B loading shown in Figure 4 is adopted for temporary structures and for bridges in specified areas

3. Problem statement: bridge

3.1. Rudramata Bridge

Many researchers have studied the non-linear elastic or in elastic behavior of the bridge structure subjected to earthquakeloading, but none of them have carried out the Non-Linear timehistory analysis for the existing failed bridge.

So that’s why thisreport containing the analysis of Rudramata bridge situated in Bhuj which was failed during Bhuj-2001 earthquake.

Figure 5 The Rudramata Bridge

Table 1 Bridge Details

Sr.No	Description	
1	Span of Bridge	1. 10 X 16.8m span 2. 20m, 30m and 40m span
2	Width of Bridge	7.3 m
3	Lanes	2 Lanes
4	Number of MainGirders	10 No's
5	Total depth	20 m
6	Slab thickness(average)	0.3m
7	Type of Loading	IRC class AA Train
8	Loads	DL+LL+EQ(Time History)
9	Compressive Strength of Concrete(fck) (M30)	30000 KN/m^2
10	Modulus of Elasticity $E=5000\sqrt{fck}$ $E=5000\sqrt{30}$ = 27,386.128 N/mm^2	27386128 KN/m^2

The Bridge models have been analyzed using STAAD Pro v8i version software. Above project is containing the modelling ofstraight and arch bridge of span 166 m which was found in problem statement. The results obtained from the models havebeen summarized below.

Table 2 Various models considered forresults calculation in STAAD Pro

Model	Type Of Bridge	TotalSpanc/c	TotalSpan	Heig ht	Width	Noof spans
Modelno.1	Straight bridge	166m	168m	20 m	10 m	10 no
Modelno.2	Arch bridge	166m	168m	20 m	10 m	10 no
Modelno.3	Straigh t bridge	83 m	84 m	20 m	10 m	5 no
Modelno.4	Arch bridge	83 m	84 m	20 m	10 m	5 no

4. Results and discussion

4.1. Results for Bridge 166m

For the model of a 168 and 84-metre span of bridge, we appliedthe time history acceleration of the Bhuj earthquake and analysed it for straight and arch bridges. The results of the analysis are as follows.

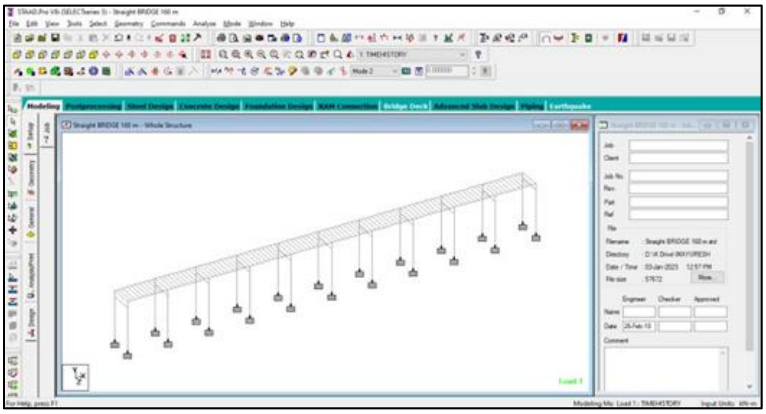

Figure 6 Typical Model for Straight Bridge

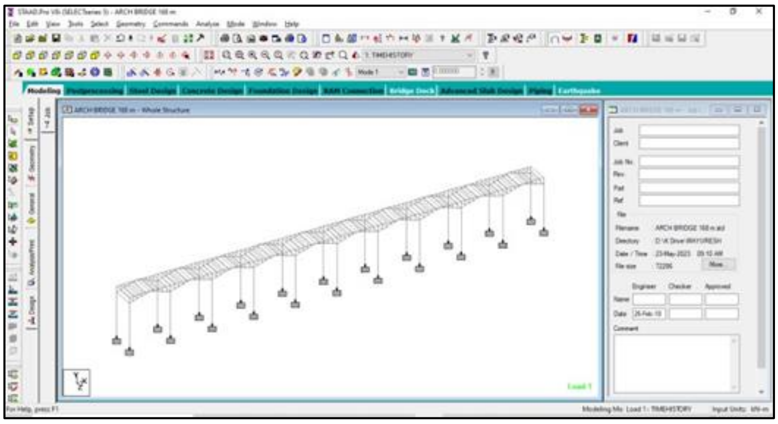

Figure 7 Typical Model for Arch Bridge

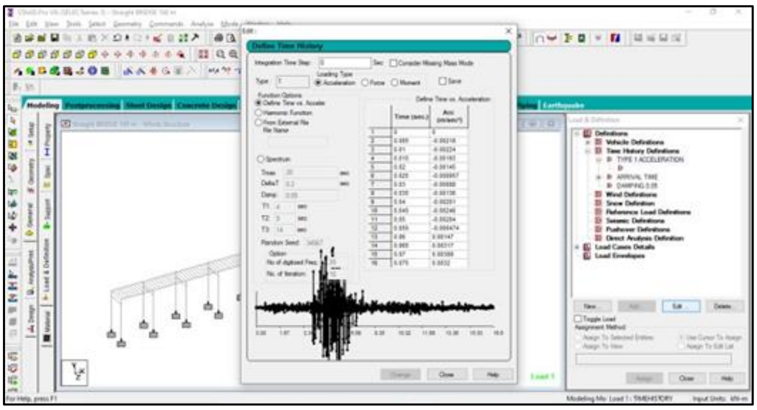

Figure 8 Apply Time History Load on Bridge

Table 3 Time Period for Straight And Arch Bridge 168m

Time Period		
Mode	**Straight Bridge 168m**	**Arch Bridge 168m**
1	0.36	0.294
2	0.352	0.266
3	0.341	0.235
4	0.327	0.221
5	0.314	0.172
6	0.311	0.167

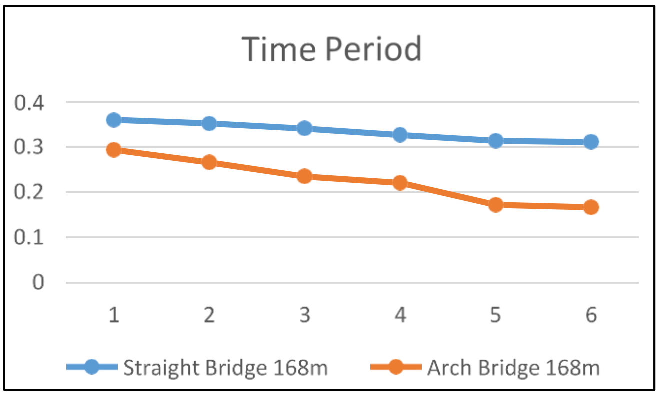

Figure 9 Time Period for Straight And Arch Bridge 168m

The above graph shows the results of a straight bridge and anarch bridge of 168 m of span for the Bhuj earthquake. Theresults for the time period show economic results for the archbridge in excess of the straight bridge by 20–25%

4.2. Results for Bridge 84m

Table 4 Time Period for Stright And Arch Bridge 84m

Time Period		
Mode	**Straight Bridge 84m**	**Arch Bridge 84m**
1	0.355	0.16
2	0.335	0.154
3	0.31	0.144
4	0.306	0.139
5	0.296	0.119
6	0.277	0.116

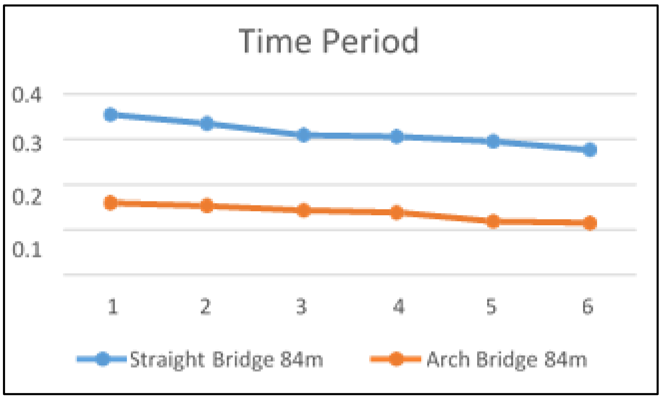

Figure 9 Time Period for Straight And Arch Bridge 84m

The above graph shows the results of a straight bridge and anarch bridge of 84m of span for the Bhuj earthquake. The resultsfor the time period show economic results for the arch bridge inexcess of the straight bridge by 50-60%

4.3. Results for Bridge 166m and 84m

Table 5 Time Period for 166m and 84m

Time Period				
Mode	**StraightBridge168m**	**StraightBridge84m**	**Arch Bridge168m**	**Arch Bridge84m**
1	0.36	0.355	0.294	0.16
2	0.352	0.335	0.266	0.154
3	0.341	0.31	0.235	0.144
4	0.327	0.306	0.221	0.139
5	0.314	0.296	0.172	0.119
6	0.311	0.277	0.167	0.116

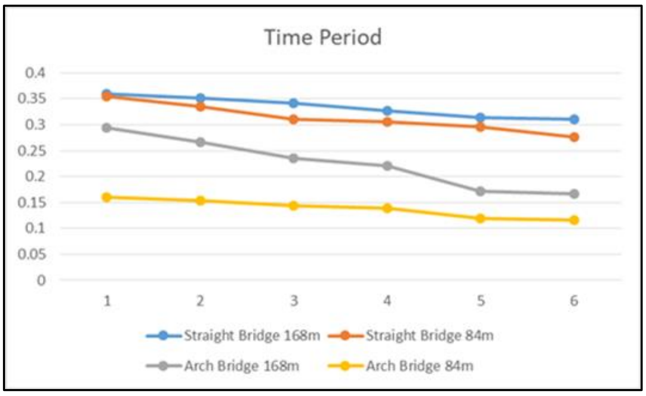

Figure 10 Time Period for Stright And Arch Bridge for 168mand 84m

The above graph shows the results of a straight bridge and an arch bridge of 168m and 84m of span for the Bhuj earthquake.The results for the time period show economic results for the arch bridge in both span of bridge

5. Conclusion

In this report non-linear analysis of bridge is carried out and report covers the every important aspect of the analysis. This study includes the analysis of time-displacement, time- acceleration results for the given models. For the model of a 168 and 84-metre span of bridge, we applied the time history acceleration of the Bhuj earthquake and analysed it for straight and arch bridges. The results obtained in this study are representing that the arch bridge is having more stability if used with proper geometry. The models used in this study gives response for the given time history analysis proves that arch bridge is having more rigidity under dynamic loading condition. In that research models analyzed for two spans 168m and 84m for the various span of arch bridge it can be stated that as the span of bridge increases the results also increases with respect to span in percentage. The all above results are conclude by following points

- The results for 168m, the time period show economicresults for the arch bridge in excess of the straight bridge by 20–25%.
- The results for 84m, the time period show economic results for the arch bridge in excess of the straight bridge by 50-60%.
- The results of a straight bridge and an arch bridge of 168m and 84m of span for the Bhuj earthquake. The results for the time period show economic results for the arch bridge in both span of bridge.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in publishing the paper.

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