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A Review on Non-Linear Analysis of Arch Bridge Subjected To Ground Motion

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ABSTRACT— Arch bridge construction has re-emerged around the world thanks to the cantilever lowering method, and today these structures are one of the three main types of long-span bridges, the other two types being suspension and cable-stayed bridges. The arch rib is an element that is mainly subjected to a large axial compressive force caused by self-load, and therefore arch bridge structures exhibit complex behavior during strong earthquakes. This paper deals with the nonlinear dynamic analysis of an arch bridge using STAAD.Pro V8i software subjected to earthquake loading. Currently, the construction of short and medium span arch bridges for traffic bypass is extensive due to their easy load-bearing properties. Therefore, it is necessary to verify its stability against a strong earthquake. In this research, a nonlinear time history analysis of an arch bridge modeled in STAAD.Pro is performed. Bhuj-2001 earthquake data is used for time history analysis and Rudramata bridge which failed during Bhuj earthquake is studied for reference. This study mainly focuses on the study of displacement, time-velocity and time-acceleration of an arch bridge against lateral loading. And the results show that the displacement in all three directions for the arch bridge is less than that for the Rudramata bridge.

KEYWORD: Non-linear Dynamic analysis, Time History- Bhuj , Arch Bridge , STAAD.Pro.

I. INTRODUCTION

A bridge is a structure built to cross a physical obstacle, such as a body of water, a valley, or a road, in order to provide passage over the obstacle. Nonlinear analysis is required due to geometric irregularities of the bridge structure, including curves, long spans or significant overall length, multiple expansion joints, massive substructure components, or unstable soil conditions (Krishnakanth, 2015). Of the above irregularities, this work mainly focuses on geometrical irregularities such as curves and long spans. Studying the time-history loading behavior of Arch Bridge is important for earthquake-prone areas. The STAAD.Pro software version V8i is also the leading software in the field of structural analysis. Nonlinear analysis allows us to account for stiffness changes with load application. Depending on the nature of the problem, the loads should be applied in steps, while the stiffness is adjusted multiple times within a load step to reach a converged solution. The objective of a field inspection of damage to a bridge structure is to evaluate the properties of the structure, identify actual and potential sources of damage at the earliest possible stage, explain whether the weather in the Member State is safe or unsafe, classify the damaged parts in the bridge elements and identify any maintenance, repair and strengthening that needs to be done. Degradation of the bridge structure is often manifested by visible signs of damage. Damage information is provided by a detailed investigation. Various tests can be used to supplement the results of the visual examination. Test techniques and equipment should be determined in relation to the amount and type of damage and the importance of the structure. The objective of bridge design is to evaluate the performance of the structure, identify actual and potential sources of damage at the earliest possible stage, explain whether the weather in the Member State is safe or unsafe, classify the damaged parts of the bridge elements and identify any maintenance, repair and strengthening that needs to be done using AASHTO 1986, (Robert 2005). Degradation of the bridge structure is often manifested by visible signs of damage. Damage information is provided by a detailed investigation. Various tests can be used to supplement the results of the visual examination. Test techniques and equipment should be determined in relation to the amount and type of damage and the importance of the structure. The purpose of damage assessment of a bridge structure is not only to determine the effect of damage on its remaining service life and bearing capacity, but also to determine the causes of defects. In general, the damage that occurs in concrete bridges under unacceptable loading can be classified into girder and slab cracks, additional settlement of the bridge slab, extreme vibration under transient loads, corrosion of steel reinforcement, and spalling of concrete (Sadeghi and Fathali 2007). In this study, Longtan concrete truss bridge is inspected by the inspection team at School of



Transportation Science and Engineering/ Bridge and Tunnel Engineering/ Harbin Institute of Technology (HIT). The objective of this study is to investigate and classify the damage of the Longtan truss concrete bridge structure and to evaluate the structural properties of the bridge structure elements using a static load test.

II. STATE OF DEVELOPMENT

Dai Yu-wena, Wang You-yuana This paper presents an optimization calculation method for optimizing the initial cable force of a suspended arch bridge when erecting an arch rib. The cantilever assembly of the arch rib of the cable-stayed arch bridge has a cable removal design process. It is different with a cable-stayed or arched bridge. Therefore, the joint influence matrix cannot be used directly. And the optimization method in the paper was developed by modifying the influence matrix. The article also develops a program using the ANSYS APDL language. The program was applied in Lian-cheng Bridge. The calculation result was similar to the sequential forward algorithm. Finally, the deviation of the closure of the arch rib was up to 5 mm. The entire arc curve meets the design requirements.

T. E. Ford et al. This paper deals with the Numerical Models of Masonry Arch Bridges needed to accurately determine ultimate failure loads. Finite element analysis (FEA) has been surprisingly underutilized in this field, perhaps because the main features of masonry behavior, namely the highly non-linear stiffness loss by cracking and arch failure by mechanism formation, are difficult to model using conventional continuum elements familiar to industrial users. This paper describes masonry arch bridge models built within a basic FEA package, with numerical results based on field data from tests to destruction on arch bridges.

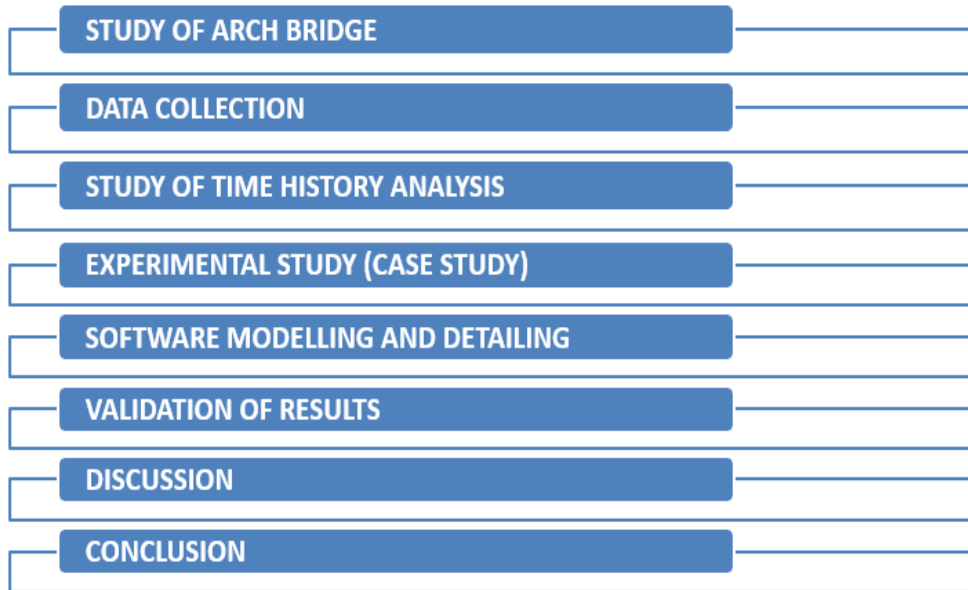
E.C. Kandemira et al. They investigated the process of retrofitting an existing upper deck steel arch bridge located in Ground Type I, which includes good diluvial soil and rock. Since the bridge was designed under the old 1980 law, it needed retrofitting. As the first step of the dynamic response analysis, the dynamic characteristics in the longitudinal and transverse directions were analyzed by eigenvalue analysis to determine the natural self-loading behavior. The nonlinear dynamic response analysis is performed under the Hyogo Ken Nanbu earthquake that occurred in 1995. After identifying the critical sections as abutment, viscous dampers are installed to increase the seismic performance of the bridge under strong earthquakes. Comparative results between undamped and damped designs are presented in terms of acceleration and displacement values at critical points to evaluate the advantages of the dampers. This research presents the application of seismic retrofitting and isolation methods.

José de Jesús et al. They studied the seismic response of a concrete platform arch bridge with linear and nonlinear fluid viscous dampers (FVD) subjected to ground motions in terms of time accelerations including near-field effects using 2D analytical models. FDVs were placed at both ends of the deck connecting the superstructure to the foundation. Force-velocity relationship for FDVs Can be expressed as $f = c \dot{v} + n$; a parametric study aimed at identifying optimal dampers was carried out. The most effective devices were non-linear dampers with c equal to 15 MN/ (meter per second) $l/4$ and n equal to 1 to 4 reduced the longitudinal displacement of the superstructure by 72%.

P. K. Chatterjee et al. They performed a dynamic analysis of arch bridges undergoing a single moving load using a mixed approach in which I combined the advantages of the continuum and concentrated mass methods. The bridge deck is idealized by a flat plate supported by struts of the same stiffness. The applicability of the method is investigated by comparing the results with those obtained by the mass accumulation method. The results in this study indicate that for a relatively stiff arch carrying a flexible plate, the proposed method and the lumped mass method show good agreement. The variation of DAF with velocity parameter shows that for higher velocity parameters, a fluctuating pattern with higher peaks is generally obtained. DaF generally increases with increasing h/L Arch ratio. Keeping all other parameters equal d and f is greater for a steeper arch bridge.



III. METHODOLOGY



3.1 Rudramata Bridge

Many researchers have studied the nonlinear elastic or elastic behavior of a bridge structure subjected to an earthquake, but none of them have performed a nonlinear time history analysis for an existing failed bridge. Hence this report containing the analysis of Rudramata Bridge in Bhuj which failed during Bhuj-2001 Earthquake. And then it will be replaced by an arch bridge of the same size under the same load to check its response. Built in 1966, Rudramata Bridge is located on National Highway 45, 16 km north of Bhuj.



Fig 1 the Rudramata Bridge

Table 1 Bridge Details (Case Study)

No	Description	
1	Span of Bridge	1. 166 m span 2. 83 m span
2	Width of Bridge	10 m
3	Lanes	2 Lanes
4	Number of Main Girders	10 No's
5	Total depth	20 m



6	Slab thickness (average)	0.3 m
7	Type of Loading	IRC class AA Train
8	Loads	DL+LL+EQ(Time History)
9	Compressive Strength of Concrete (fck) (M30)	30N/mm ²
10	Modulus of Elasticity $E=5000\sqrt{fck}$ $E=5000\sqrt{30} = 27,386.128 \text{ N/mm}^2$	27386128 N/mm ²

IV. MODELING IN STAAD PRO

Bridge models were analyzed using STAAD. Software version Pro v8i. The project above contains the modeling of a 166m span straight and arched bridge found in the problem statement. The results obtained from the models are summarized below. The table below shows the different models considered for calculating results in STAAD. For.

Model	Type Of Bridge	Total Span	Height	Width	No of spans
Model no.1	Straight bridge	166m	20 m	10 m	10 no
Model no.2	Arch bridge	166m	20 m	10 m	10 no
Model no.3	Straight bridge	83 m	20 m	10 m	5 no
Model no.4	Arch bridge	83 m	20 m	10 m	5 no

4.1. Straight bridge 166m

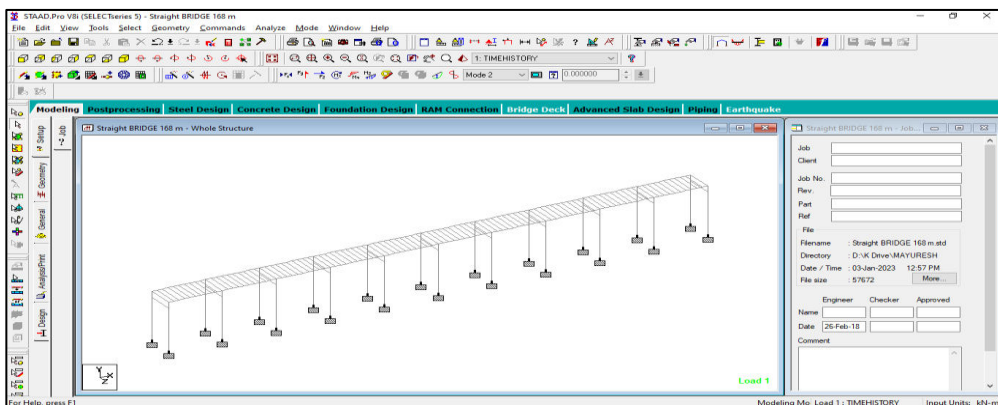


Fig. 2: Typical Model for Arch Bridge

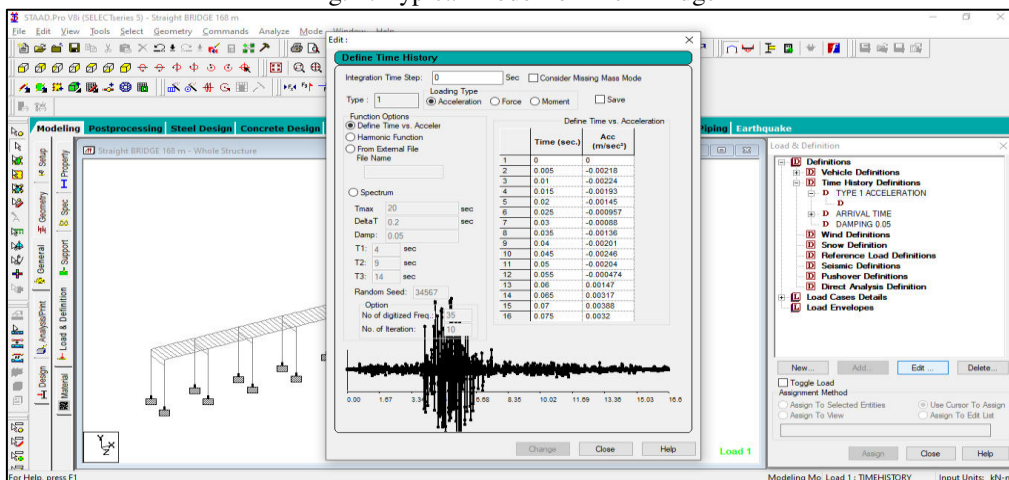


Fig. 3: Apply Time History Load on Bridge

Table 2 Time Period for Straight Bridge 166m

Mode	Time Period
1	0.36
2	0.352
3	0.341
4	0.327
5	0.314
6	0.311

V. CONCLUSION & FURTHER STUDY

This article focuses only on a literature review of previously published studies. From the research study, analysis is done using software like STAAD Pro, ETABS, ANSYS, etc. In this research, non-linear analysis of the bridge will be done and the report covers all the important aspects of the analysis. This study includes analysis of the results of time shifts, time velocities and time accelerations for the given models. The future content of the work is the preparation of bridge models according to the data presented in the above chapters in the staad pro program and their analysis for IRC loads and time history analysis of the bridge using software.

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