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Seismic Analysis of Box Girder Bridge using CSiBridge Software

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ABSTRACT

Roads are the modern network lifelines and the bridges are the most important elements of transport networks. When their structural defects are unnoticed, they are vulnerable to failure. Following the large and catastrophic earthquakes in recent years, a great deal of attention has been given to assessing the seismic vulnerability of the existing structures. Bridge analysis and design requires a lot of complexity but nowadays, their durability and serviceability during the earthquake are more relevant. A significant number of bridges built around the world were constructed during the time when there were no seismic safety requirements on the bridge codes, or when those requirements were inadequate according to current standards. In addition, several existing bridges in India are experiencing degradation due to ageing and increasing vehicle loads in magnitude and volume. The Box Girder Bridge nowadays is a worldwide widely used bridge network. In addition, the Box Girder Bridge is widely used for ignoring the heavyweight over the other bridge girder network for the long span. CSiBridge v 21.1.0 is used in the study of Box Girder Bridge's dynamic response. The main objective of this study is to evaluate and examine multi-span seismic output with up to five spans of 100 meter long Girder Bridge frame. Box Girder Bridge's seismic performance is very complex and the performance is based on the intensity of peak ground motion and ground motion acceleration. This is achieved using the nonlinear time history analysis approach. In this study, the three dimension model and the data of Bhuj earthquake are used for dynamic characteristics and showing the maximum response of box girder deck. Response results indicate in terms of deformed shape, relative acceleration, relative velocity, base shear, base reaction, shear force, stresses, base moment, torsion and relative displacement.

Keywords: Bhuj earthquake, Box Girder Bridge, CSiBridge, Deformed shape, Seismic response

INTRODUCTION

The continuing expansion of highway network throughout the world is essentially the results of great increase in traffic, population and extensive growth of metropolitan urban areas. This expansion has cause many changes within the use and development of varied sorts of bridges. The bridge type is said to providing maximum efficiency of use of material and construction practice, for particular span and applications. Adoption of design philosophy and therefore the lack of attention within the design detail cause the unexpectedly poor performance of the bridges. Numbers of bridges were designed round the world during the period, when there have been no provisions for the seismic loads within the bridge codes.

Unlike buildings, the failure of one structural element or connection between the components within the bridges is more susceptible to cause the collapse of the entire bridge structure. Structural damage and failure of bridges under recent earthquake had created an awareness to develop new guidelines and therefore the retrofit measures to style and evaluate the structural vulnerability of the bridges. When span increases, the load will rise during a substantial factor. To scale back the load, unnecessary material, which isn't utilized to its full capacity, is removed out of section, this leads to the form of box girder or cellular structures, depending upon whether the shear deformations are often neglected or not. A box beam bridge may be a bridge during which the most beams comprise girders within the shape of a hollow box. The box beam normally comprises either prestressed concrete, steel or a composite of steel and reinforced concrete. Box girders, have gained wide acceptance in freeway and bridge systems thanks to their structural efficiency, better stability, serviceability, economy of construction and pleasing aesthetics. Analysis and design of box-girder bridges are very complex due to its 3-D behaviours consisting of torsion, distortion and bending in longitudinal and transverse directions. In our country, the road bridges are designed consistent with specification and recommendation laid by Indian Road Congress (IRC).

Galuta and Cheung (1995) developed a hybrid analytical solution that mixes the boundary element method with the finite-element method to research box-girder bridges. The finite-element method was used to model the webs and bottom flange of the bridge, while the boundary element method was employed to model the deck. The bending moments and vertical deflection were found to be in good agreement in comparison with the finite element solution. Zasiah Tafheem and Khan Mahmud Amanat (2011) presented the results of a search under seismic loading to evaluate a three-span concrete deck girder bridge. A finite element model to research the deck girder bridge had been developed by using finite element software ANSYS. Based on overall findings, it can be suggested that the response spectrum method should be performed for seismic load analysis of the bridge to realize more reliable and safer design.

Bridges were a crucial component of all sort of modern transport system. Within the half the past decade technical knowledge of earthquake engineering increased considerably. Bridge results were of critical significance prior to and during an earthquake occurrence. Hence it must remain functional even after dissipation of seismic event to endure relief also as security purpose [Godse P.A. (2013)]. Ghosh et al. (2014) studied the influence of combined seismic and live load on the seismic reliability assessment of the highway bridges. Author first derived the probabilistic seismic demand model developed from statistical analysis of non-linear time history response of bridge to determine the connection between median of peak seismic response of bridge component and therefore the intensity of the seismic excitation. Secondly, bridge fragility curve was developed by assuming the bridge as a series of system which suggests failure of its single component results in collapse of structure. Free flowing traffic was assumed within the model and analyzed because the assumption that at a time there's just one vehicle present within the deck. Results of this study showed that bridges were queasier in traffic loading under seismic event.

Data Analysis

In this study, Bhuj Earthquake ground motion was used for the seismic analysis. A strong motion seismograph, IMD recorded earthquake with a magnitude of 7.7 and the intensity of the affected region ranged up to X (Extreme) on the MSK scale of intensity. The tremor lasted for 22 seconds and the focus of the earthquake was 16 km beneath its epicenter of Kutch district of Gujarat, India in 2001. The earthquake killed between 13,805 and 20,023 people, injured another 167,000 and destroyed nearly 340,000 buildings.

Methodology

To carry out the seismic analysis of 100 m Concrete Box Girder Bridge, CSiBridge v 21.1.0 Software was used. Seismic response of the box girder bridge are analyzed in terms of deformed shape, relative acceleration, relative velocity, base shear, base reaction, shear force, stresses, base moment, torsion and relative displacement. In order to evaluate the seismic response of the bridge structure, there are various approaches to use. They are response spectrum method, equivalent static seismic force method, time history analysis method and pushover analysis. In our research, the non linear time history analysis technique is used. The seismic response of the five spans Box Girder Bridge is discussed in this study. The 100 m long Box Girder Bridge model using 3-D and Bhuj Earthquake are used as dynamic input to evaluate the maximum seismic response of the box girder deck.

Nonlinear Time History Analysis

Nonlinear time history analysis is adopted when a high degree of accuracy is required within the analysis of structure. During this technique, the structure is exposed on to real earthquake ground motions and response of the structure is studied in terms of deformations or forces developed within the structure. Incremental dynamic forces working on the structure must be remain in equilibrium is that the basic analysis requirement during this analysis. The characteristic of the displacement-dependent lateral resisting forces within the structure defines the essential difference between the linear time history analysis and nonlinear time history analysis. Lateral resisting forces within the elastic systems are represented as one valued function of the displacement whereas lateral resisting forces in inelastic systems are hooked in to the prior history of the motion. To solve the differential equation, a numerical integration method is used, results of which gives the time history of the response. The benefits of the nonlinear dynamic time-history analysis include the power to explain nonlinear inelastic response and to represent the time-history of the seismic response of the structure.

CSiBridge Software

Modeling, analysis and design of bridge structures are integrated into CSiBridge to make the last word in computerized tools tailored to satisfy the requirements of the engineering professional. The convenience with which all of those tasks are often accomplished makes CSiBridge the foremost versatile and productive software program within the industry.

Bridge structure model and analysis

The model of the box girder bridge having five spans has been shown in Fig. 1. The geometric properties and material properties used for modeling the bridge are given in table 1.

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Table 1: Geometric and Material properties for the box girder bridge

Parameters	**Unit**	**Value**
Total span length	m	100
No. of span	--	5
No. of girders		1
Length of each span	m	20
Bridge width	m	10
Bridge depth	m	1.6
Concrete slab thickness	m	0.225
Abutment (a) Depth (b) Width	 m m	 4.2 1.6
Diameter of circular column	m	1.6
Height of column	m	10
Live Load	IRC class A	
Regulations	IRC-5, IRC-6, IRC-18, IRC-112 and IRC-SP-114	
Seismic loading	IS:1893-2016, IS:1893 (Part-3)	
Material Properties for the Bridge		
Modulus of Elasticity (M40)	N/m^2	$31x10^9$
Density	N/m^3	25000
Untensioned steel HYSD bars grade Fe415 conforming IS:1786, controlled concrete M40		
Poisson's ratio		0.2
Damping ratio		5 %

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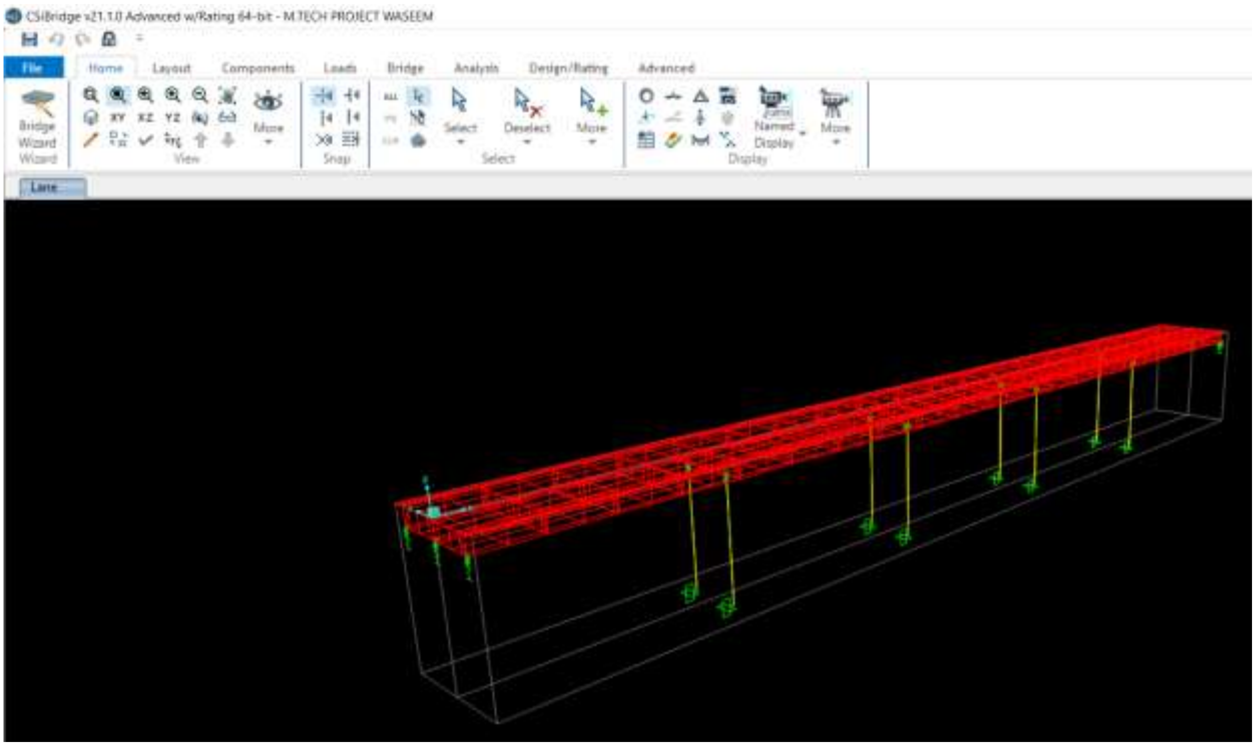
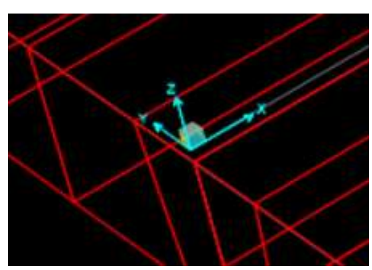


Fig. 1: 3-Dimensional Bridge Model



The span of bridge is of continuous in nature and it is integral bridge type. For this study, only IRC class A loading is taken into account. The Peak Ground Acceleration (PGA) for Bhuj Earthquake was recorded 1.0382 m/s^2 at 46.940 s and it is considered for seismic analysis of present study. In this study, vehicles loading are taken from IRC: 6 and geometry from IRC: 112. In this bridge analysis, the maximum bending moment to loading A is analyzed. Seismic loading considered from IS: 1893-2016. Permissible stresses have been taken as per section IRC: 18.

Seismic Property of the Site:

Seismic zone = V, Zone factor = 0.36, Response reduction factor = 3, Importance factor = 1.2, Soil type = Rock or Hard soil

Results and Discussion

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The seismic response of the five spans Box Girder Bridge is discussed in this study. The 100 m long Box Girder Bridge model using 3-dimensional and Bhuj Earthquake are used as dynamic input to calculate the maximum seismic response of the box girder deck. Seismic response of the box girder in the term of relative acceleration, relative displacement, relative velocity, torsion, forces, stresses, base moments and base shear shows in the comparative diagrams are shown below.

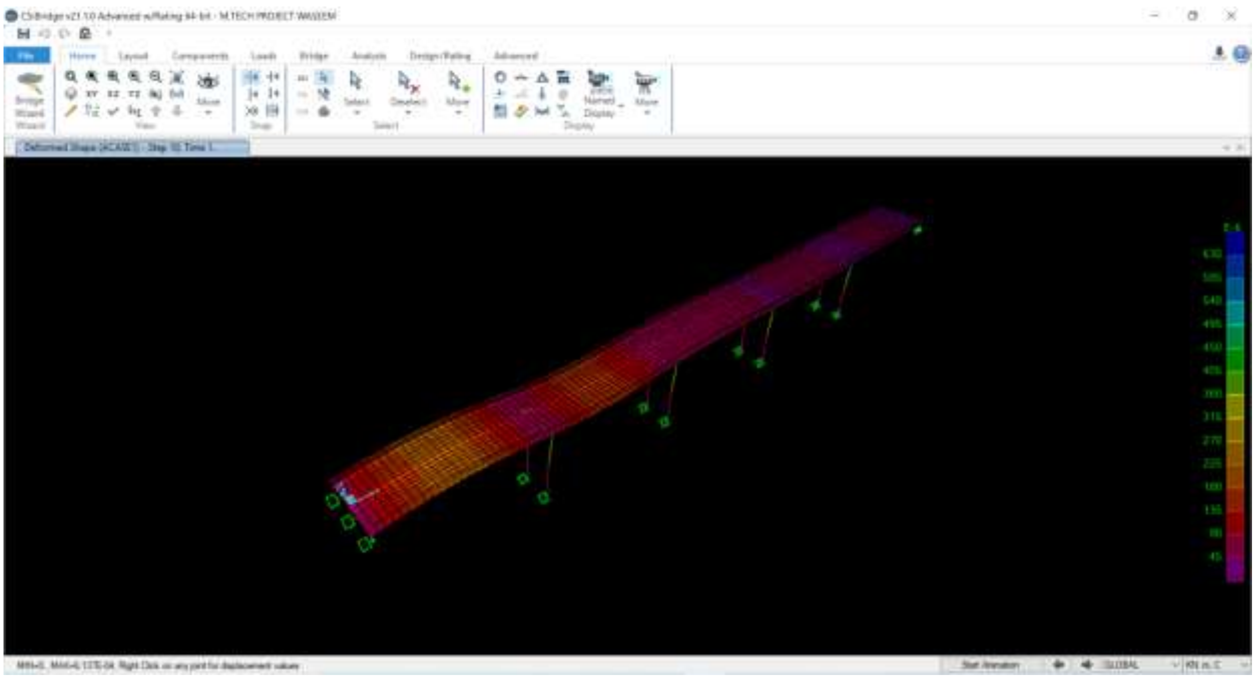

Fig. 2: Relative Displacement diagram of Deformed Bridge Section

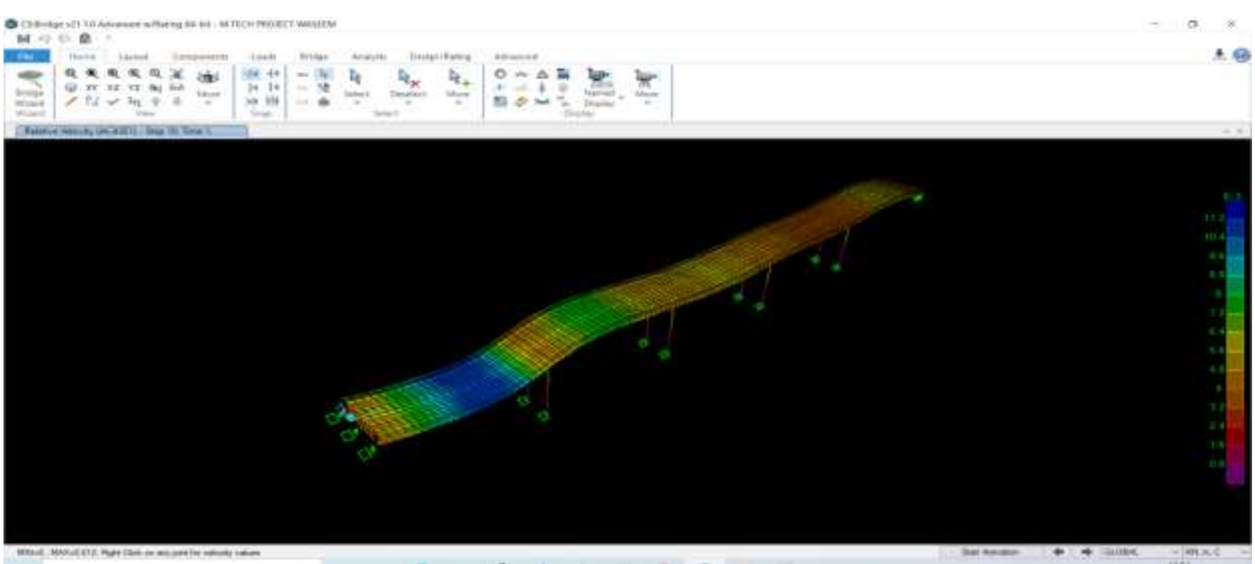

Fig. 3: Relative Velocity diagram of Deformed Bridge Section

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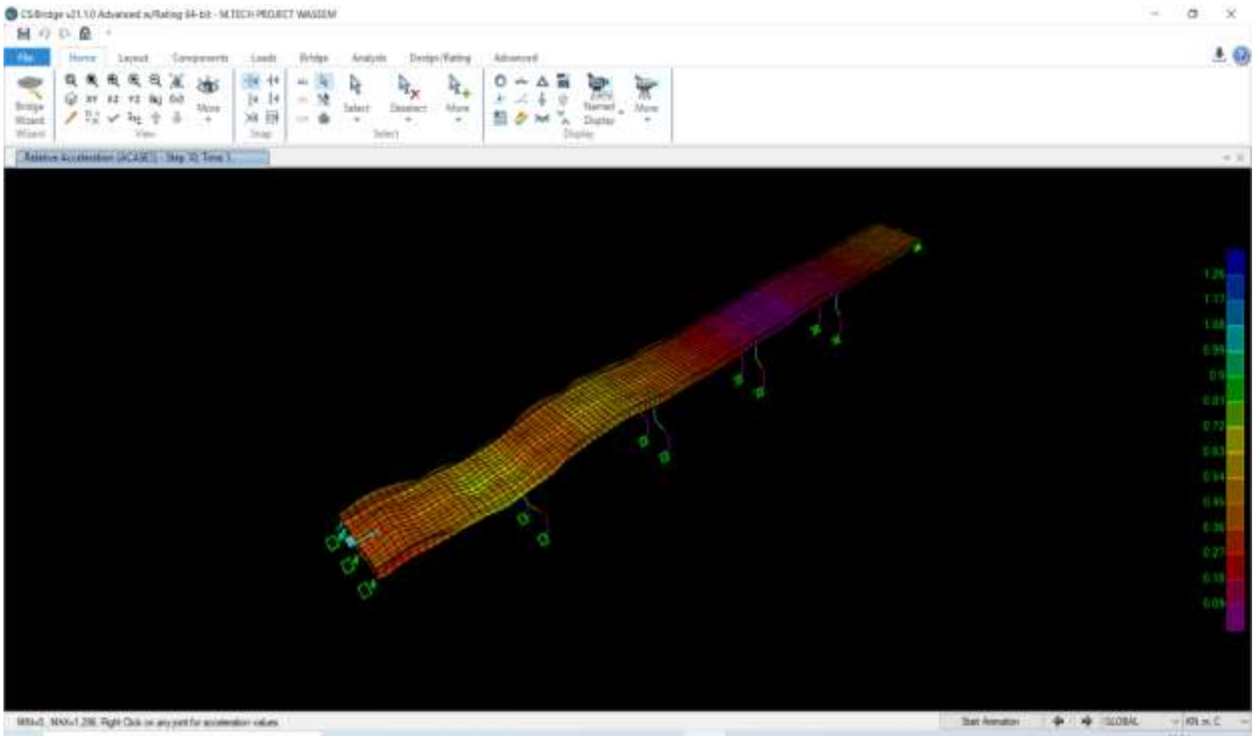

Fig. 4: Relative Acceleration diagram of Deformed Bridge Section

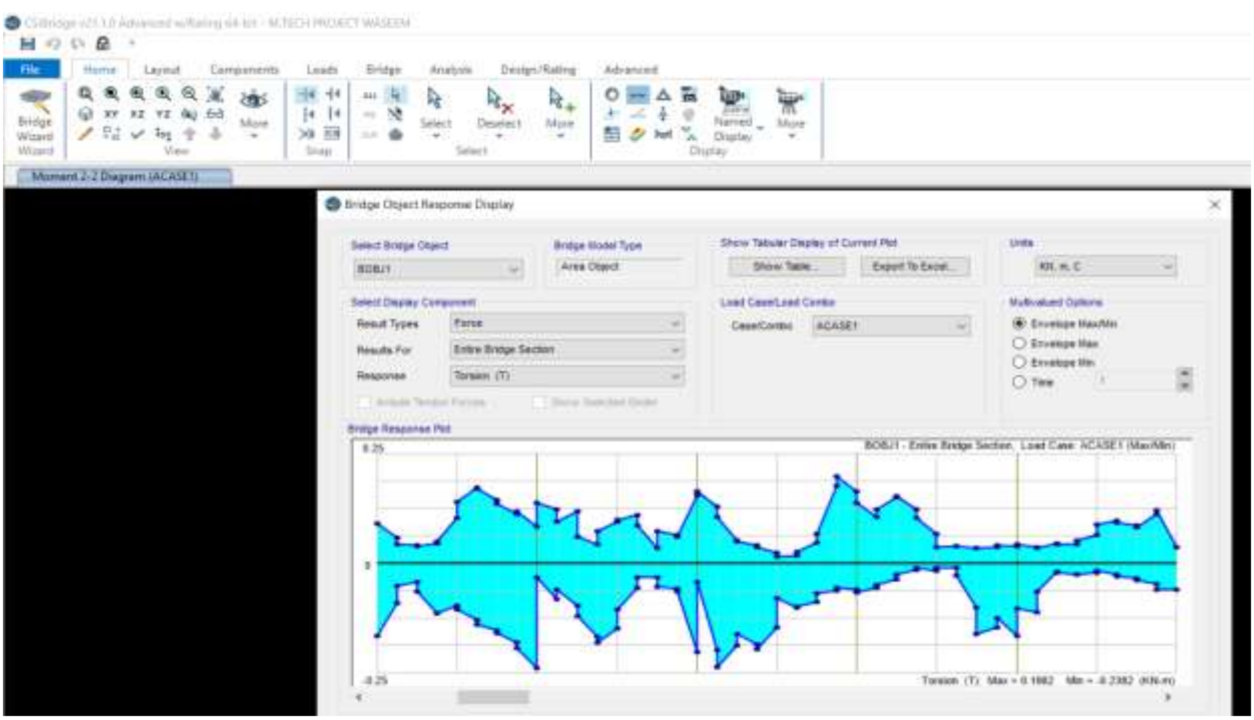

Fig. 5: Torsion diagram due to Seismic action

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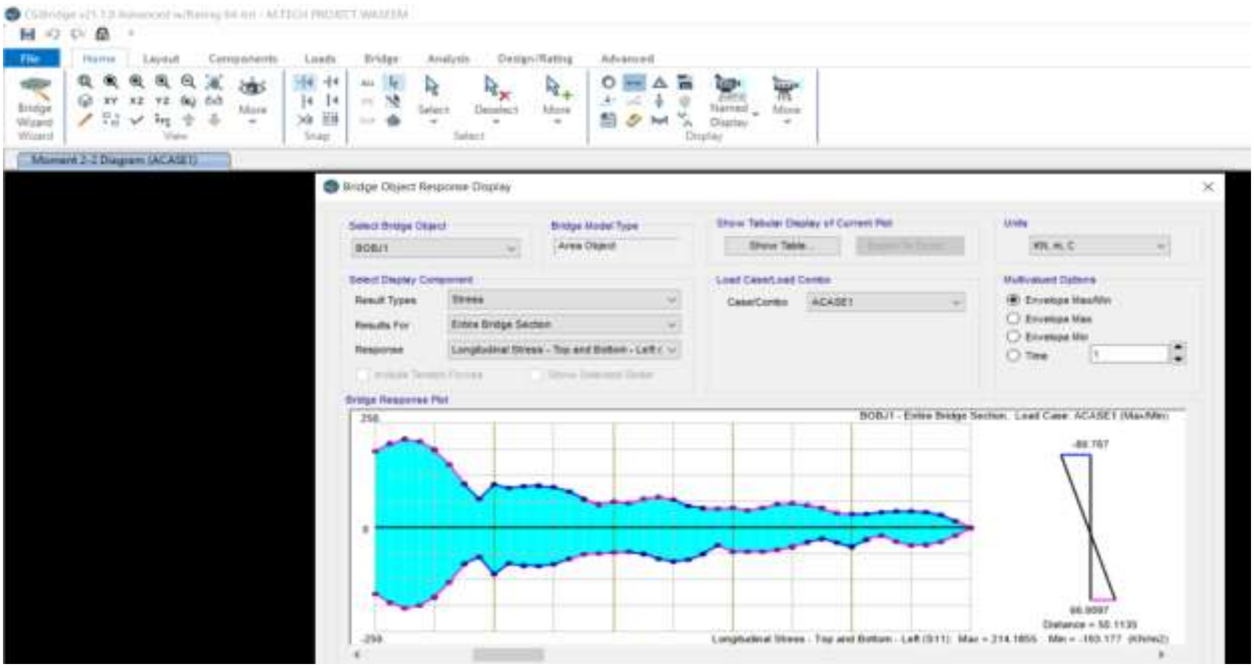

Fig. 6: Longitudinal Stress (Top and Bottom) diagram due to Seismic action

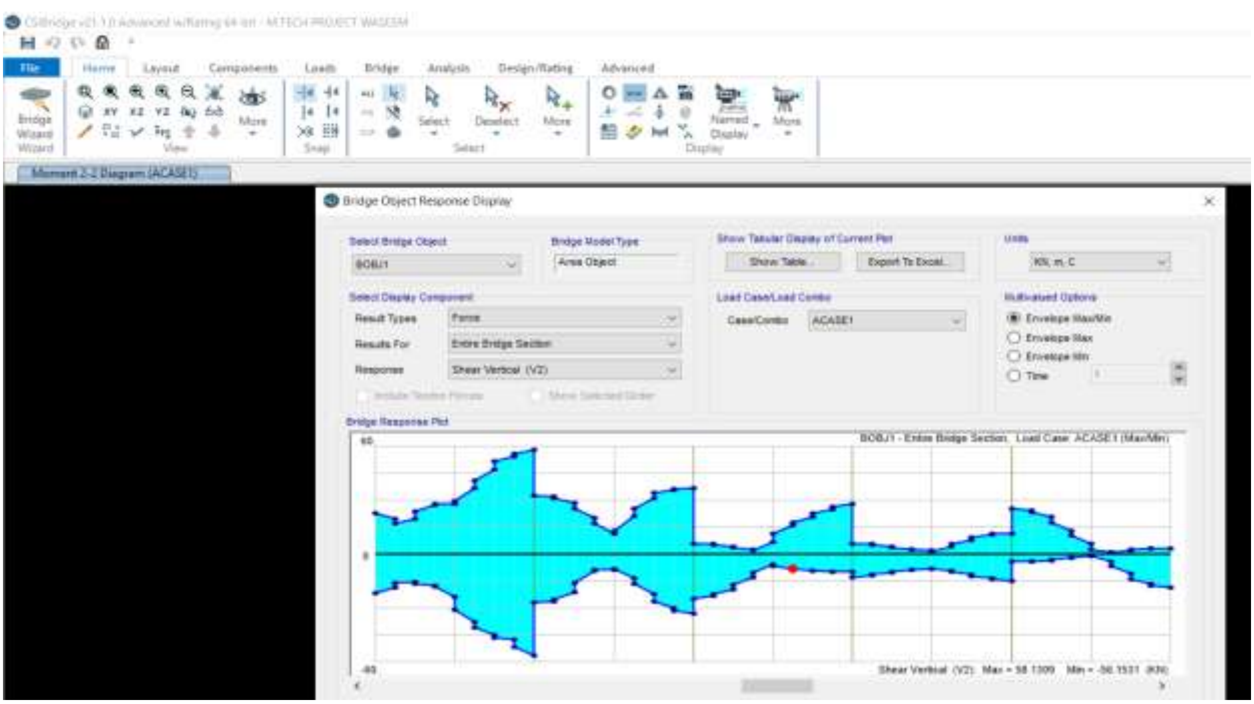

Fig. 7: Shear Vertical diagram due to Seismic action

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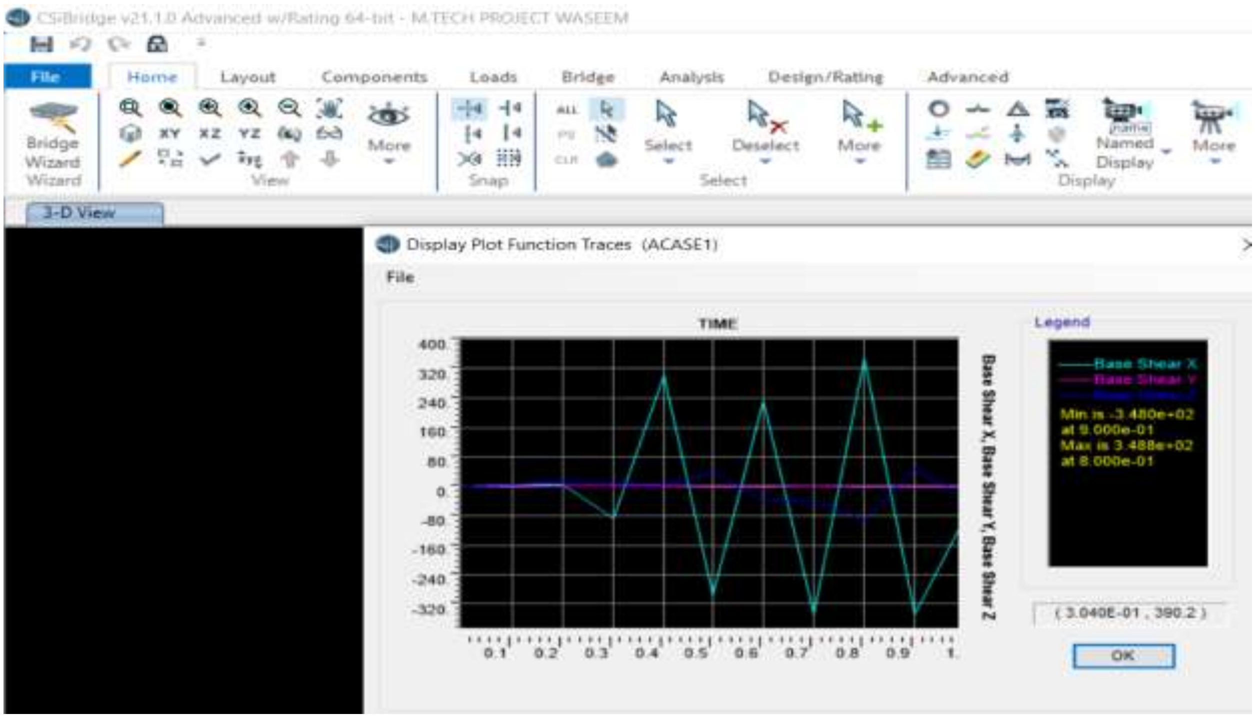

Fig. 8: Graphical representation of Base Shear along three directions

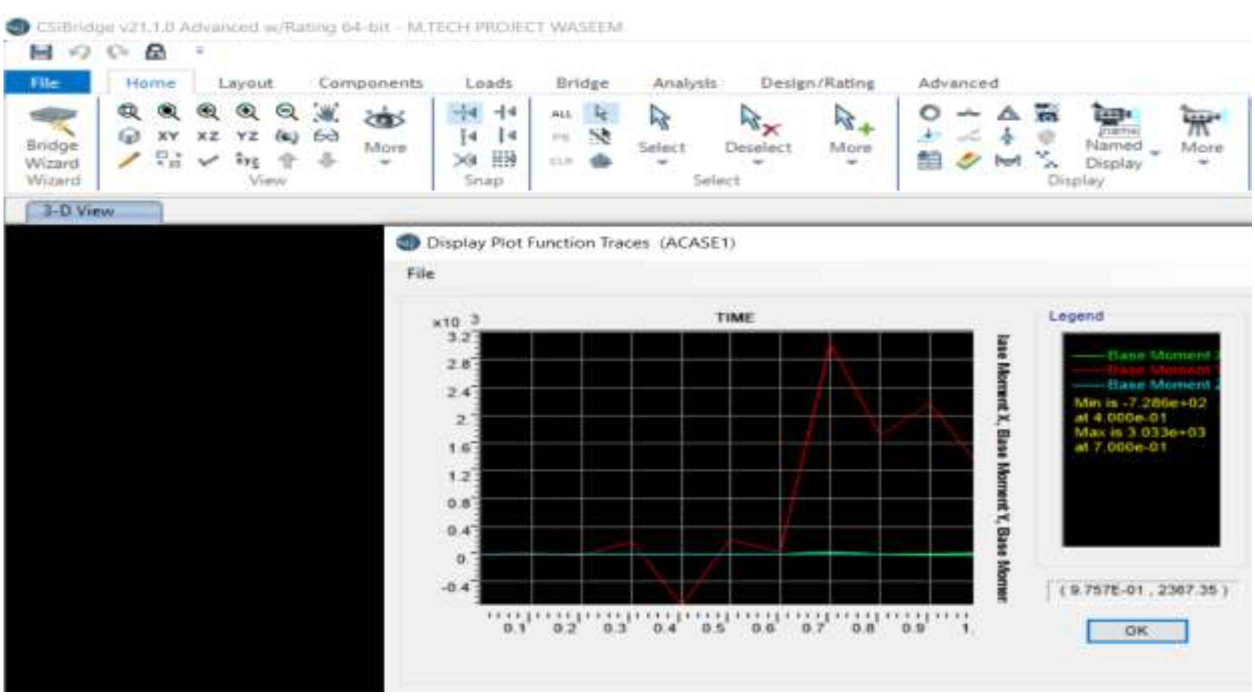

Fig. 9: Graphical representation of Base Moment along three directions

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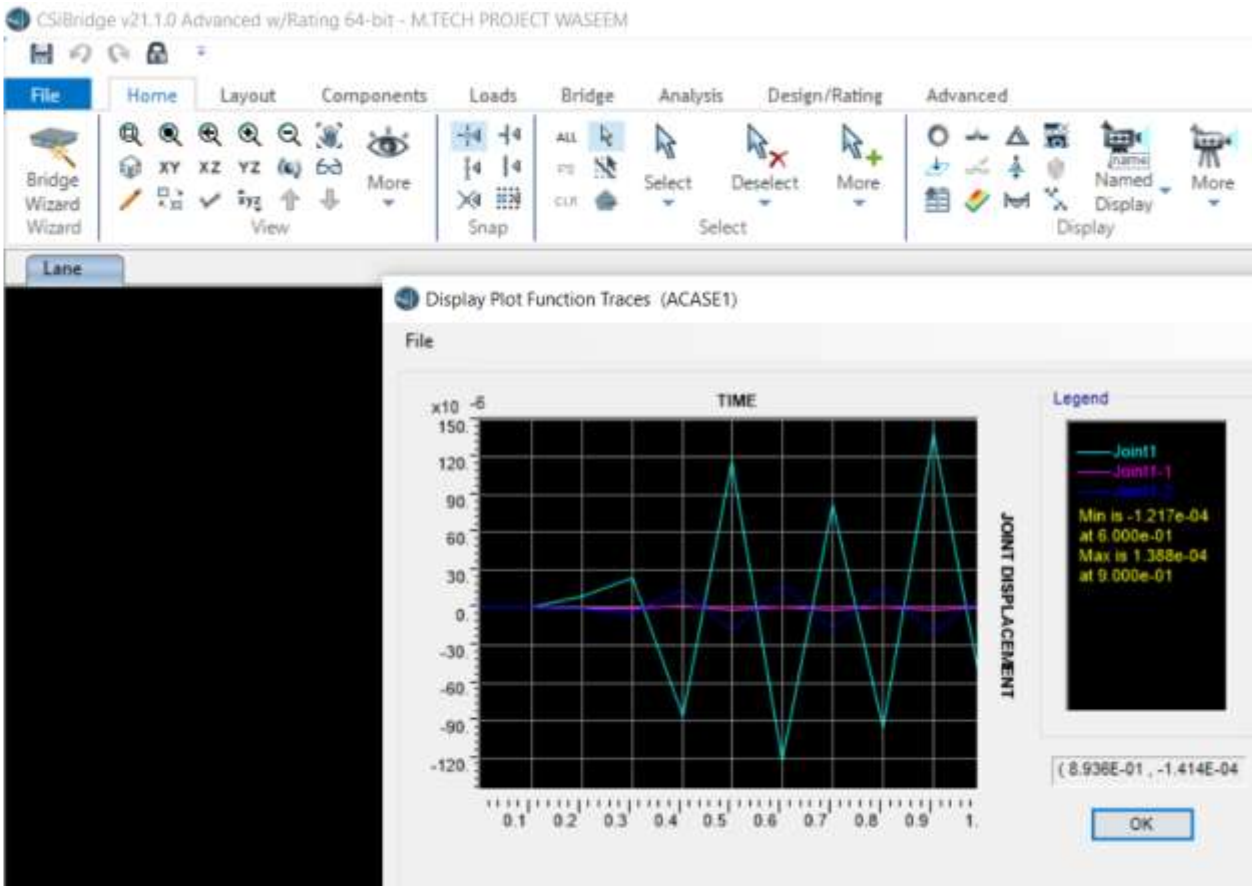

Fig. 10: Graphical representation of Joint Displacement along three directions

Conclusions

From this study, the value of the acceleration, base shear, base moment, torsion, velocity and displacement have been analyzed in three directions i.e. X, Y and Z of the bridge structure. The longitudinal stresses are also analyzed. The results are represented in a comparative diagram. According to the analyzed result, the following conclusions can be drawn:

- The value of the acceleration, displacement, velocity, and base shear with respect to time in the x-direction is higher than the acceleration, displacement, velocity and base shear with respect to time in both directions, while the base moment with respect to time in the y-direction is higher than the remaining two directions.
- The bridge deck's acceleration response depends on bridge characteristics and applied ground motion.
- Results show that the seismic response of the superstructure good agreements with recorded

ground motion data in the term of the acceleration, base shear, velocity, moment, torsion, stresses and displacement in the three directions.

- It is also the indication that the base shear has played a significant role in the bridge deck's seismic response. It provides resistance to lateral load.

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