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Ground Motion Analysis of an Existing Bridge

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ABSTRACT: An existing RC bridge is selected for the case study. A 2-span reinforced concrete T beam girder bridge is seismically evaluated. Computer software SAP2000 is used to analyze the bridge. Response spectrum analysis method is adopted to evaluate seismic performance of a bridge. Performance of the selected bridge is found out for the Bhuj earthquake loading by the time history analysis. The bridge is analyzed for ground motion and the capacity of the bridge is checked. It is also analyzed for different loads and load combinations. Natural frequency and natural mode shapes are found. Base shear due to seismic ground motion at the base of a structure and displacement of joints due to seismic loads are compared for different load cases.

KEYWORDS: Bridges, Response Spectrum Analysis, Time History Analysis, Bhuj Earthquake.

I. INTRODUCTION

Bridges play a vital role in the economic development of the country and these are an essential part of the transportation system. They ensure smooth transportation by establishing links between cities and even between countries. The failure of bridges during an earthquake not only costs human lives but also causes a catastrophe to the transport network and the economy. In recent years several earthquakes caused significant damage to many bridges. India has a number of the world's greatest earthquakes in the last century. In fact, more than fifty percent area in the country is considered prone to damaging earthquakes. The north- eastern region of the country as well as the entire Himalayan belt is susceptible to great earthquakes of magnitude more than 8.0. After 2001 Gujarat Earthquake and 2005 Kashmir Earthquake, there is a nation-wide attention to the seismic vulnerability assessment of existing buildings. Also, a lot of efforts were focused on the need for enforcing legislation and making structural engineers and builders accountable for the safety of the structures under seismic loading. The seismic building design code in India (IS 1893, Part-I) is also revised in 2002. The magnitudes of the design seismic forces have been considerably enhanced in general, and the seismic zone of some regions has also been upgraded.

II. BRIDGE DESCRIPTION

A typical tee beam deck slab generally comprises the longitudinal girder &continuous deck slab between the tee beams. Three longitudinal girders are placed as showed in figure1. Effective span of simply supported tee beam is 22.32 m. Clear width of roadway is 7.5 m. Thickness of the deck slab providedis 300 mm. Bridge Consists of a massive single pier with cantilever caps on opposite sides resembling the head of a hammer. Height of pier is 2.8 m & circular pier of diameter is 2 m. Material used for the construction is M-30 grade concrete&Fe-415 grade HYSD steel bars.The present bridge is located in seismic zone III with a zone factor 0.16. IRC Class AA Loading is taken as Live Load.

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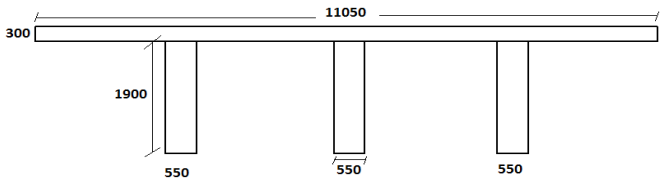

Figure 1: Cross Section of Bridge Deck

III. OBJECTIVES

This project is carried out,

- ✓ To analyze ground motion and check for capacity of the bridge.
- ✓ To analyze bridges for different loads and load combinations.
- ✓ To analyze Eigenvalue to obtain natural frequency and natural mode shapes.
- ✓ To find Base shear due to seismic ground motion at the base of a structure.
- ✓ To find Displacement of joints due to seismic loads.

IV. MODELLING OF BRIDGE

Computer software SAP2000 is used to model the bridge.

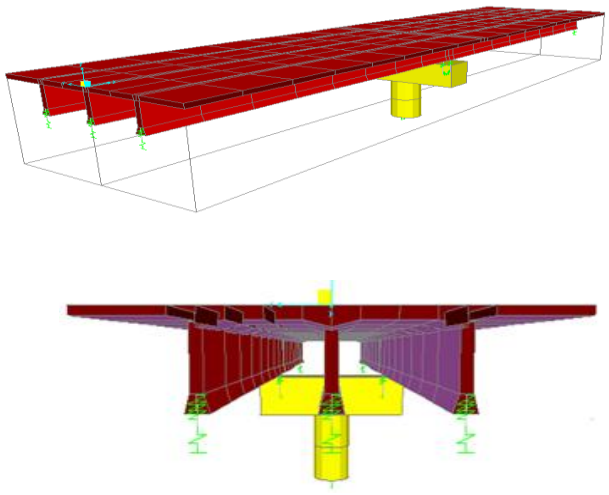

Figure 2: Extruded view of model

V. METHODOLOGY

- Selecting an existing RC bridge with geometrical and structural details.
- Modelling the selected bridge in computer software SAP2000.
- Response spectrum analysis is carried out.
- Performance of the selected bridge is found out for the Bhuj earthquake loading by the time history analysis.
- The applied moment is then compared with the moment of resistance of the deck slab which is calculated manually by working stress method.

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- Model period and frequency are tabulated.
- The deformed shape and mode shapes are determined.
- Base shear due to seismic ground motion at the base of a structure and displacement of joints due to seismic loads are compared for different load cases.

VI. RESULTS AND DISCUSSION

COMPARISON BETWEEN APPLIED MOMENT AND MOMENT OF RESISTANCE.

The selected bridge consists of 2 span reinforced concrete slab deck. The moment induced due to the various combination of loads i.e., dead load, live load and earthquake loads are tabulated. The different combinations of loads are taken from IS: 1893. The maximum BM is taken at mid of each span. The applied moment is then compared with the moment of resistance of the deck slab which is calculated manually by working stress method. Graph is plotted for the obtained result.

COMB NO	LOAD COMBINATION	Applied Moment (kN-m)	Moment ofResistance (kN-m)
1	1.5 (DL + LL)	14839	20707
2	1.2 (DL + LL + EQ X)	11939	20707
3	1.2 (DL + LL + EQ Y)	11870	20707
4	1.5 (DL + EQ X)	9210	20707
5	1.5 (DL + EQ Y)	9123	20707
6	0.9 DL + 1.5 EQ X	5560	20707
7	0.9 DL + 1.5 EQ Y	5474	20707

Table 1: Comparison between Applied Moment and Moment of Resistance

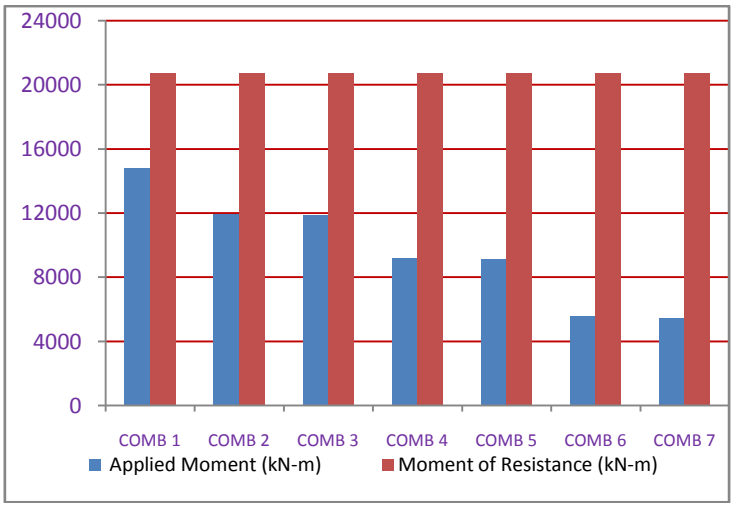

Figure 3 Graph of Applied Moment Applied Moment vs. Moment of Resistance

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The above graph shows the variation of applied moment and moment of resistance of T-girder. The applied moment values are obtained from SAP 2000 and Moment of resistance of the deck is manually calculated by working stress method. Moment of resistance of the bridge is found greater than the moment induced due to the various combinations of loads. Therefore the selected bridge can withstand the earthquake load without collapse. The DL and LL combination produces maximum moment compared to other combinations.

MODAL ANALYSIS RESULTS

Modal analysis is a linear dynamic-response procedure which evaluates and superimposes free-vibration mode shapes to characterize displacement patterns. Mode shapes describe the configurations into which a structure will naturally displace. A structure with N degrees of freedom will have N corresponding mode shapes. Each mode shape is an independent and normalized displacement pattern which may be amplified and superimposed to create a resultant displacement pattern. Mode shapes of low-order tend to provide the greatest contribution to structural response. The dynamic analysis may be either a response spectrum analysis or an elastic time history analysis. Sufficient number of modes must be considered to have a mass participation of at least 90%.

TABLE: Period ,Frequency and Modal mass				
StepNum	Period	Frequency	SumUX	SumUY
Unitless	Sec	Cyc/sec	Unitless	Unitless
1	0.263179	3.7997	2.80E-17	0.76338
2	0.184243	5.4276	3.71E-17	0.76338
3	0.154237	6.4835	0.12239	0.76338
20	0.04506	22.193	0.96085	0.88589
21	0.042556	23.498	0.96085	0.93781

Table 2: Modal Periods and Frequencies

For the selected bridge mode 1 which provide the greatest contribution to the structural response has a time period 0.26 seconds and frequency 3.79 Cycle/sec. The Bridge takes 21 modes to get its 90% of the mass to the exited state so the first 21 modes are considered for the analysis. Out of these modes first three are major modes and their deformed shapes are shown below.

MODE SHAPES

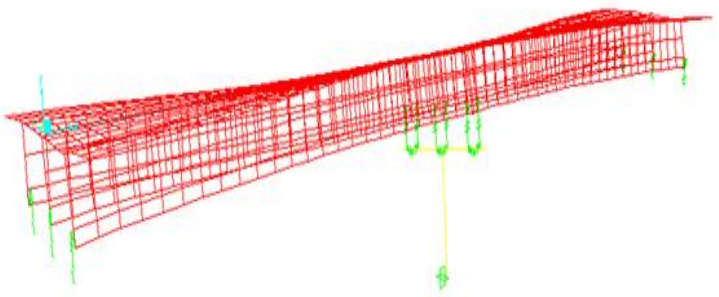

Figure 4 Mode Shape 1 (T= 0.26 sec, F= 3.79 Cycle/sec)

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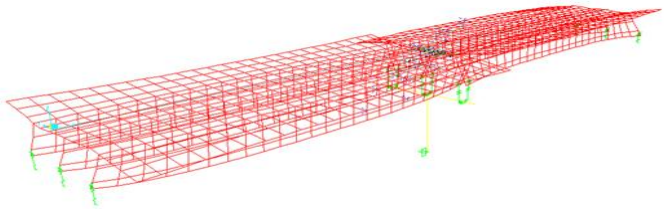

Figure 5 Mode Shape 2 (T= 0.18 sec, F= 5.42 Cyc/sec)

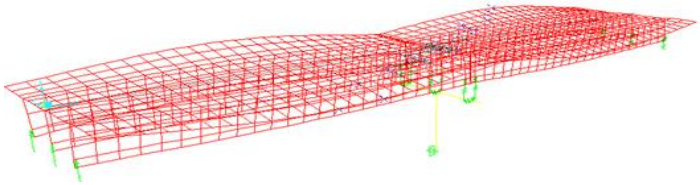

Figure 6 Mode Shape 3 (T= 0.15 sec, F= 6.48 Cyc/sec)

COMPARISON OF BASE SHEAR FOR DIFFERENT LOAD CASES

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Factors affecting Base Shear are:

- Soil conditions at the site.
- Proximity to potential sources of seismic activity (such as geological faults).
- Probability of significant seismic ground motion.
- The level of ductility and over strength associated with various structural configurations and the total weight of the structure.
- The fundamental (natural) period of vibration of the structure when subjected to dynamic loading.

In this study, Base Shear for different cases are found out using SAP2000 software and are compared between each other graphically as shown below.

Load Case	Base Shear (kN)
Earthquake X	256.659
Response Spectrum X	172.635
Bhuj Earthquake X	799.091

Table 3 Base Shear for Different Load Cases in X direction

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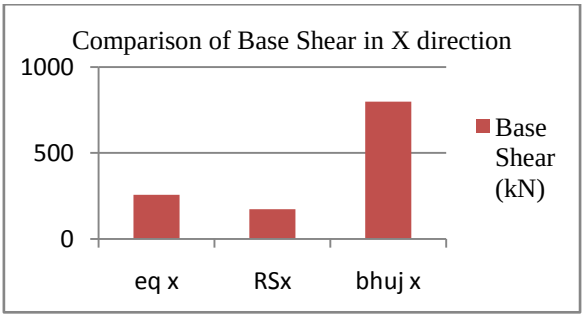

Figure 7 Graph of Base Shear for Different Load Cases in X direction.

Among the different load cases considered bhuj earthquake produces maximum base shear of 799.09 KN and theresponse spectrum load case produces least base shear of 172.635 KN in X direction. From the above graph it is seen that base shear in Bhuj X is greater than response spectrum X, hence bridge is not safe for earthquake similar to bhuj earthquake in X direction.

Load Case	Base Shear (kN)
Earthquake Y	256.659
Response Spectrum Y	140.587
Bhuj Earthquake Y	52.807

Table 4 Base Shear for Different Load Cases in Y direction

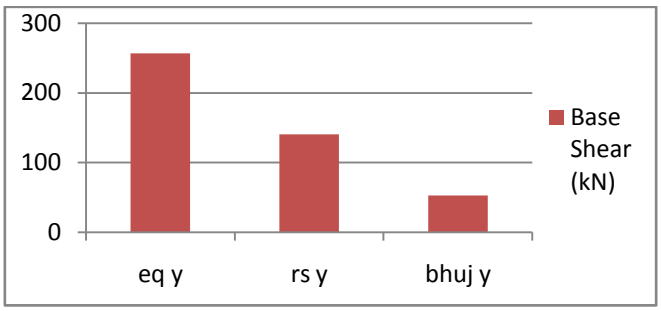

Figure 8: Graph of Base Shear for Different Load Cases in Y direction.

Among the different load cases considered earthquake in Y direction produces maximum base shear of 256.65 KN and the bhuj earthquake load case produces least base shear of 52.80 KN in Y direction. This shows that Khadiyangad Bridge is safe for the bhuj earthquake in Y direction.

COMPARISON OF DISPLACEMENT FOR DIFFERENT LOAD CASES

Displacement of a joint in vertical (U_1), normal to the layout line (U_2) and along the layout line (U_3) due to various load cases when applied in x and y directions are tabulated and graphically compared.

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Case	Displacement U1 (mm)	Displacement U2 (mm)	Displacement U3 (mm)
EQ x	0.147	0.00005116	0.001709
RS x	0.09	0.000713	0.044
Bhuj EQ X	0.238	0.001423	0.21

Table 5: Displacement of a Joint for Different Load Cases in X direction.

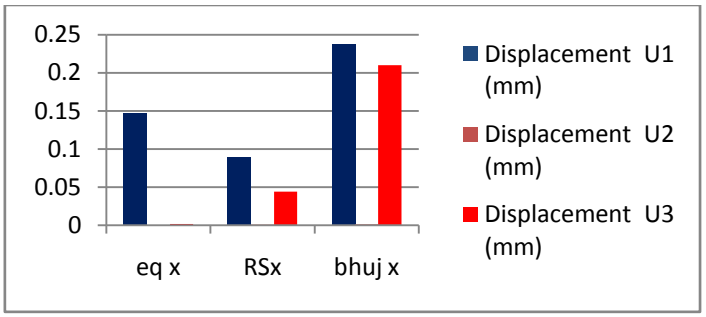

Figure 9 Graph of Displacement of a Joint for Different Load Cases in X direction

The above result shows that maximum displacement is towards vertical direction (U1) and least in the direction normal to the layout line (U2). This proves that when the load is acted in X direction the displacement is more in vertical direction.

Case	Displacement U1 (mm)	Displacement U2 (mm)	Displacement U3 (mm)
EQ y	0.118	0.464	0.222
RS y	0.098	0.252	0.154
Bhuj EQ Y	0.045	0.116	0.075

Table 6Displacement of a Joint for Different Load Cases in Y direction.

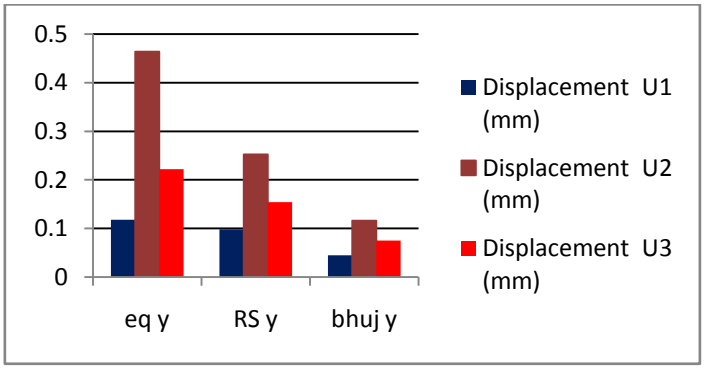

Figure 10 Graph of Displacement of a Joint for Different Load Cases in Y direction

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The above result shows that maximum displacement is in the direction towards the layout line (U3) and least in the vertical direction (U1). This proves that when the load is acted in Y direction the displacement will be more in the direction towards the layout line.

VII. CONCLUSION

Many of the bridges constructed in south interior region are not been designed for earthquake forces. Therefore in this work, an existing bridge has been evaluated for the seismic analysis as per Indian standard codes.

1. A bridge is selected and modelled and analyzed using SAP-2000. Bending moment values for various load combinations are determined from software and these values are compared with moment of resistance of the deck section. It is found that Moment of resistance is greater than moment induced due to the different combination of loads hence the bridge can withstand the equivalent earthquake load without collapse.
2. Modal analysis is carried out for the bridge and time period, natural frequency and natural mode shapes are obtained.
3. Base shear due to seismic ground motion at the base of a structure for different load cases are found out and the results are compared with each other. From the result obtained it is concluded that, the Khadiyangad Bridge is not safe for the earthquake similar to Bhuj earthquake load in x direction.
4. Displacements of joints due to various load cases when applied in X and Y directions are tabulated and graphically compared. From the result obtained it isconcluded that when the load is acted in X direction the displacement is more in vertical direction and when the load is acted in Y direction the displacement is more in the direction of the layout line.

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