e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:03/Issue:09/September-2021 Impact Factor- 6.752 www.irjmets.com

PERFORMANCE BASED ANALYSIS OF BRIDGES

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ABSTRACT

Given the geographic circumstances, bridges serve a vital function in linking two inaccessible locations. As a result, studying the seismic behavior of bridges is critical in order to equip engineers with the capacity to design structures that operate predictably and reliably in earthquakes. In this study, Performance Based Seismic design is used to guarantee that the earthquake risks caused by new construction are acceptable. Dynamic properties such as natural modes and frequencies are determined in this work. The displacements of Lead Rubber Bearings in the x, y, and z axes are presented, and the capacity versus demand curves are produced using the ATC 40 push over analysis. Midas civil software is used to do the analysis.

Keywords: Bridges, Seismic Design, Static, Dynamic, Nonlinear, Earthquake, Push Over Analysis.

I. INTRODUCTION

Bridges as one of the important man-made structures play a vital role in everyday life of the people of metropolitan city. The response of bridges when subjected to seismic excitation can be evaluated by a number of analysis method. The focus of seismic design in current bridge codes is one of life safety without the ability to consider multiple levels of structural performance from various loading conditions. For a seismic event of greater magnitude, all structures are subject to collapse. As a response to this, the development of a performance based design approach has emerged as a more complete method to predict, within a certain level of confidence, the seismic response of a structure based on the level of design imposed. In this way, the economic losses suffered in a given earthquake can be limited, and the loss of life and the emergency services necessary for post earthquake operations is reduced.

For seismic design of ordinary bridges, the basic philosophy is to prevent collapse during severe earthquakes. To prevent collapse various approaches are commonly used in design. The main purpose of performance based design is to ensure that earthquake risks posed by new construction are acceptable. To identify and correct unacceptable seismic safety conditions in existing structures. To develop and implement a rapid, effective and economic response mechanism for recovering structural integrity after damaging earthquakes. The performance requirements for a specific project must be established first, Loads, materials, analysis method, and detailed acceptance criteria are then developed to achieve the expected performance.

II. BRIDGE MODELING AND VALIDATION

In order for MIDAS civil to generate ultimate analyses using computerised instruments adapted for the demands of research, modelling, analysing and design of bridge structures will be incorporated.

For the validation of the software MIDAS civil a R.C Slab bridge problem from the text book "Essentials of Bridge Engineering" by D. Johnson Victor is considered. Details of the problem is given below.

Width of bridge: 12m
No footpath provided
Materials: Concrete grade M25
Steel- Deformed bars to IS:1786 (grade Fe 415)
Clear span: 12m
Wearing Course: 56mm thick asphaltic concrete

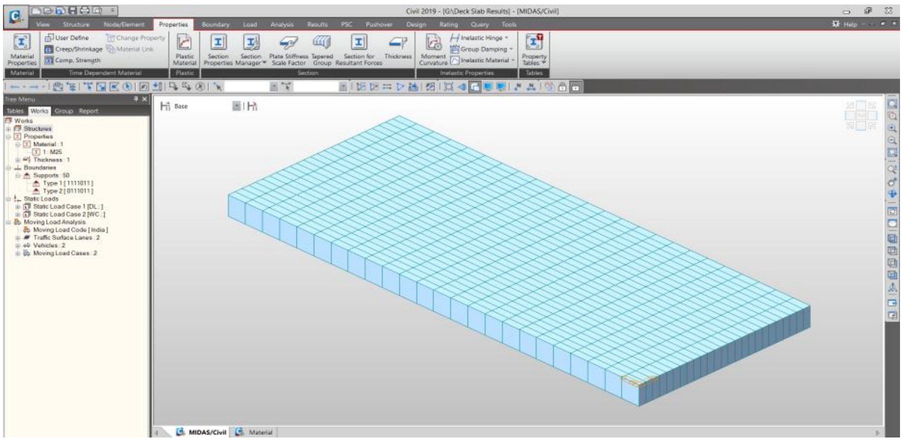

Fig 1. R.C Bridge Model

Analysis Results:

Shear Force and Bending moment diagrams for static analysis considering only static loads are as follows.

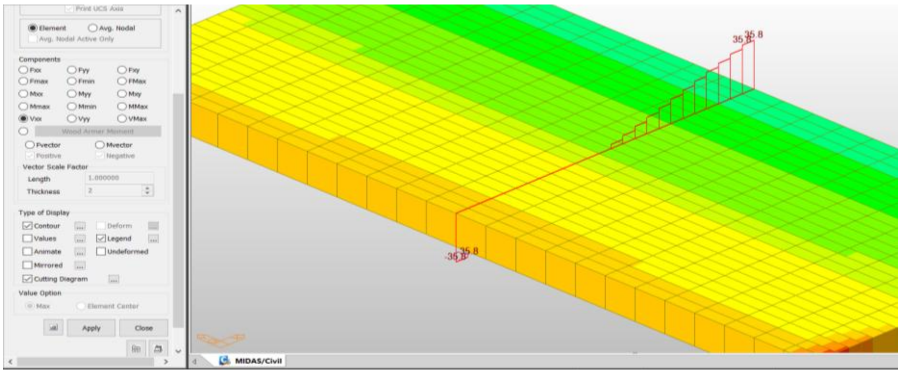

Fig 2. Dead Load SFD of R.C Bridge Model

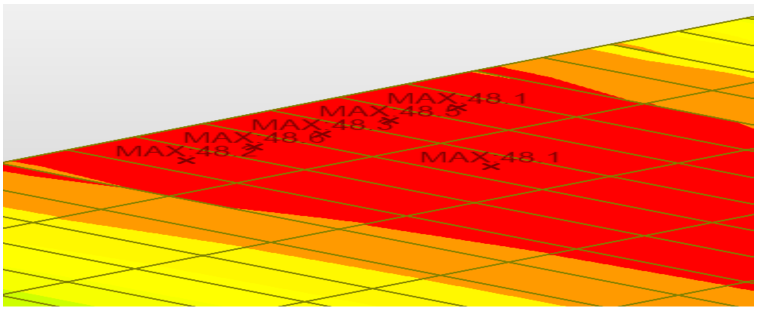

Fig 3. Dead Load BMD of R.C Bridge Model

Bending Moment Diagram for static analysis considering Class AA and Class A loadings are as follows.

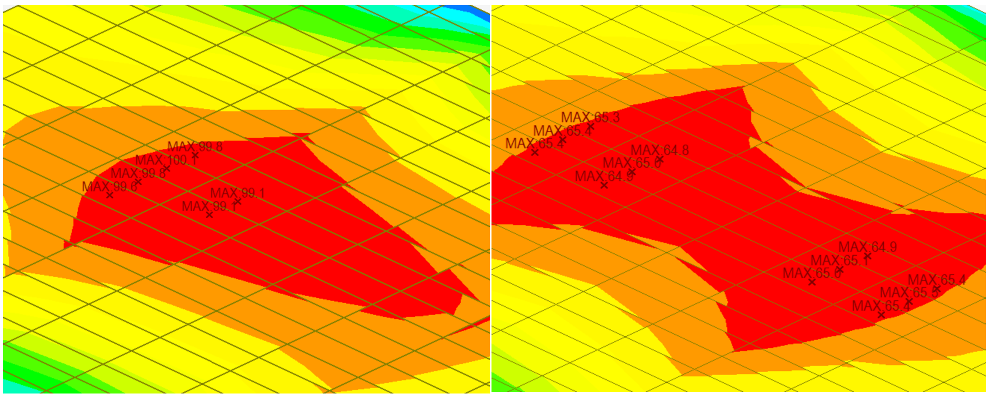

Fig 4. BMD of Class AA & Class A loading for R.C Bridge Model

Table below shows the comparison of the results of validation problem with text book results:

Table 1. BM and SF Dead Loads comparison for R.C Bridge

Results	MIDAS Civil (Present study)			Johnson Victor (2007) Result	Percentage variation
	Self-weight	Wearing coat	Total DL		
Shear force (kN)	31.10	4.80	35.80	36.20	1.10%
Bending moment (kN-m)	41.70	6.40	48.10	48.80	1.43%

Table 2. BM comparison for Class A and Class AA loading for R.C Bridge Model

Results Bending moment (kN-m)	MIDAS Civil	Johnson Victor (2007)	Percentage variation
Class A loading	99.10	96.20	3.01%
Class AA loading	67.20	70.20	4.27%

From the comparison of results it is observed that the software results are in good agreement with manual results.

III. DESIGN OF ABUTMENTS

At either end the single span bridges feature an abutment that provides vertical and lateral support for the span, and acts as retaining walls to prevent the lateral motion of the earth filling approach to the bridge. A 4m height abutment is designed for T beam bridges of span 14m, 16m and 18m as per IS codes. Following are the IRC clauses which are used to select the dimensions of various components in Abutments.

Height of the Abutment: IRC SP13 2004 (clause 12.2) is used to find the height of the abutment.

Top width of the Abutment: IRC SP13 2004 (clause 13.5.8, Table 13.1) is used to find the top width of the abutment.

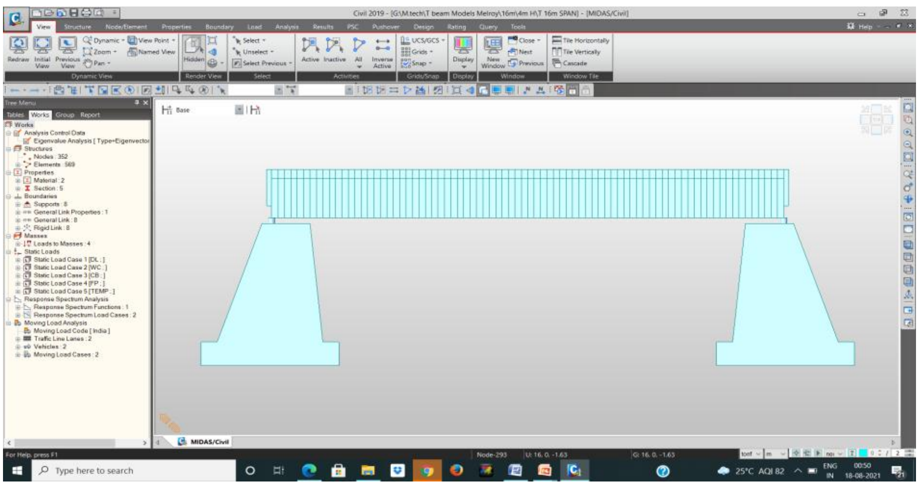

Fig 5. T Beam Bridge with Abutment & lead rubber bearings

IV. STATIC ANALYSIS

The T beam bridge models are analyzed and the design is checked for bending moment and shear. The following tables give the reinforcements required at the top and bottom and cross girder and T beam.

Table 3. Required reinforcement for Cross Girders in KN,m

Span		End- I	Mid	End-J
14m	Top	0.0007	0.0004	0.0007
	Bottom	0.0014	0.0009	0.0014
16m	Top	0.0007	0.0005	0.0007
	Bottom	0.0014	0.0009	0.0014
18m	Top	0.0007	0.0008	0.0007
	Bottom	0.0013	0.0009	0.0013

Table 4. Required reinforcement for T beam in KN,m

Span		End- I	Mid	End-J
14m	Top	0.0007	0.0007	0.0007
	Bottom	0.0068	0.0068	0.0068
16m	Top	0.0008	0.0008	0.0008
	Bottom	0.0078	0.0078	0.0078
18m	Top	0.0009	0.0009	0.0009
	Bottom	0.0088	0.0088	0.0088

From the analysis it was found that the structures were safe against shear and bending moment.

V. DYNAMIC ANALYSIS

Eigen value analysis: It is carried out for 14m, 16m and 18m span T beam bridges and natural modes and natural frequencies are obtained. Modes of these models are compared by plotting a graph of modes vs. frequency.

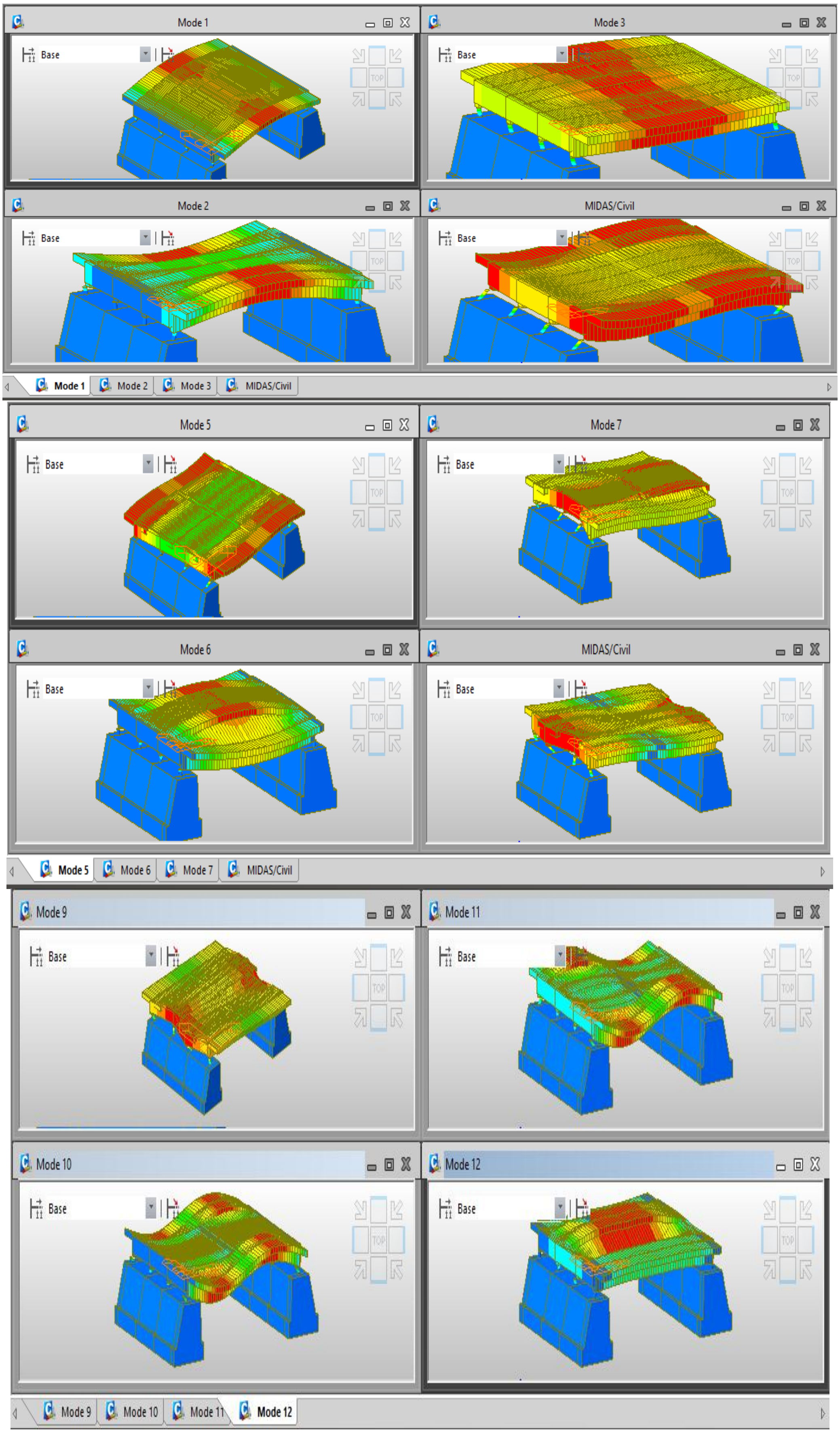

Fig 6. Mode shapes from 1-12 of 14m span bridge

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Table 5. Eigen Value analysis of 14m T beam bridge

Mode	Frequency		Period	Tolerance
No	(rad/sec)	(cycle/sec)	(sec)	
1	65.563151	10.4347	0.095834	0
2	67.65173	10.767107	0.092875	0
3	76.620708	12.194564	0.082004	0
4	116.779138	18.585977	0.053804	1.0455E-107
5	122.104517	19.433537	0.051457	1.5615E-104
6	125.916632	20.040254	0.0499	9.8848E-103
7	164.31209	26.151081	0.038239	5.2923E-85
8	178.534164	28.414595	0.035193	2.9191E-80
9	198.238133	31.550579	0.031695	1.7869E-71
10	207.394678	33.007888	0.030296	8.1723E-69
11	209.518744	33.345944	0.029989	5.1112E-69
12	220.684522	35.123033	0.028471	1.3035E-66

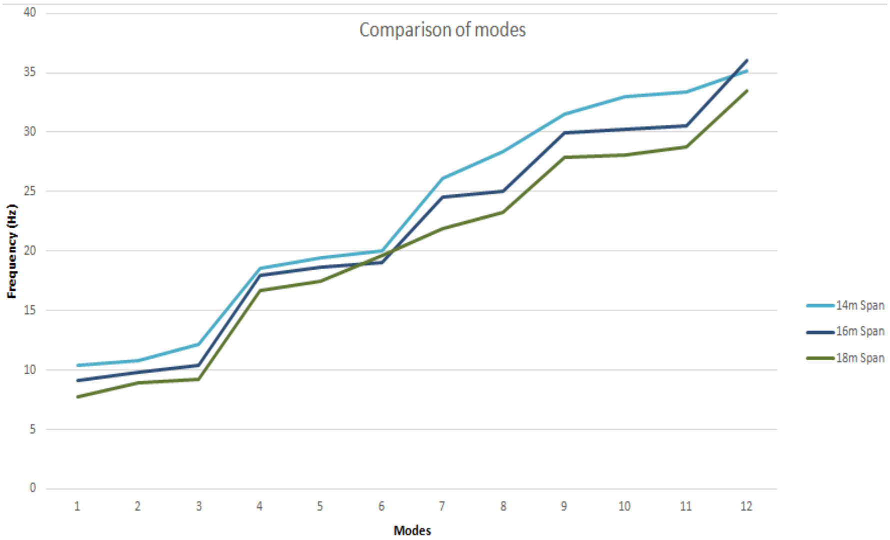

Fig 7. Modes vs. Frequency graph of 14m, 16m & 18m span bridges

Time history analysis: It is used to do a dynamic study of a structure that has been exposed to seismic excitation. In this research, the response spectra of the El-Centro, 1940 earthquake ground motion in both X and Y directions are employed.

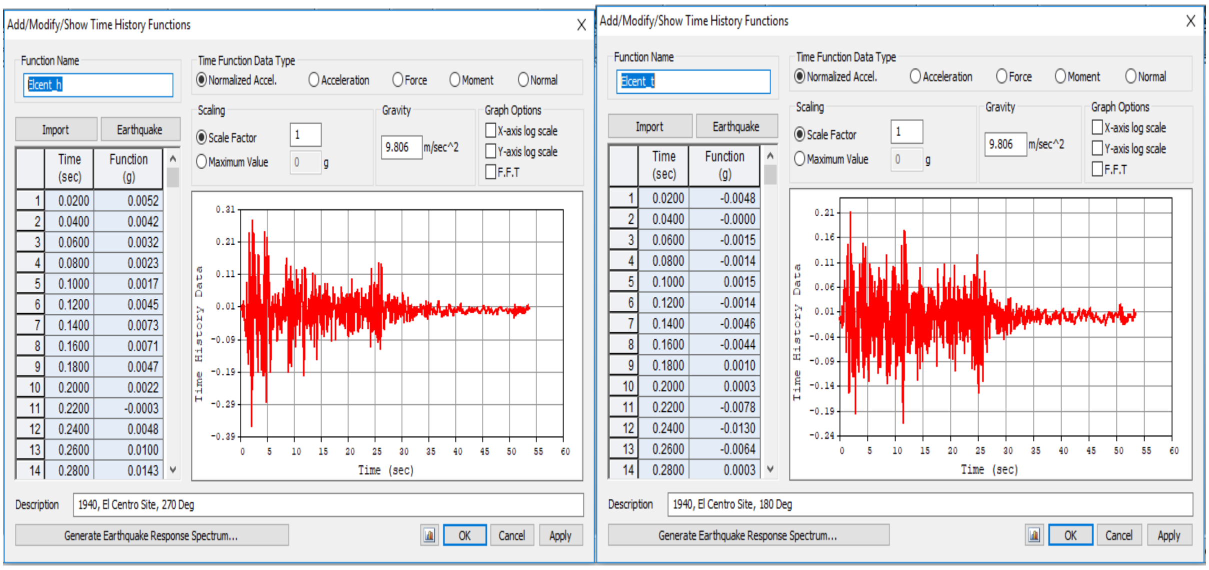

Fig 8. El-Centro earthquake data in X & Y direction

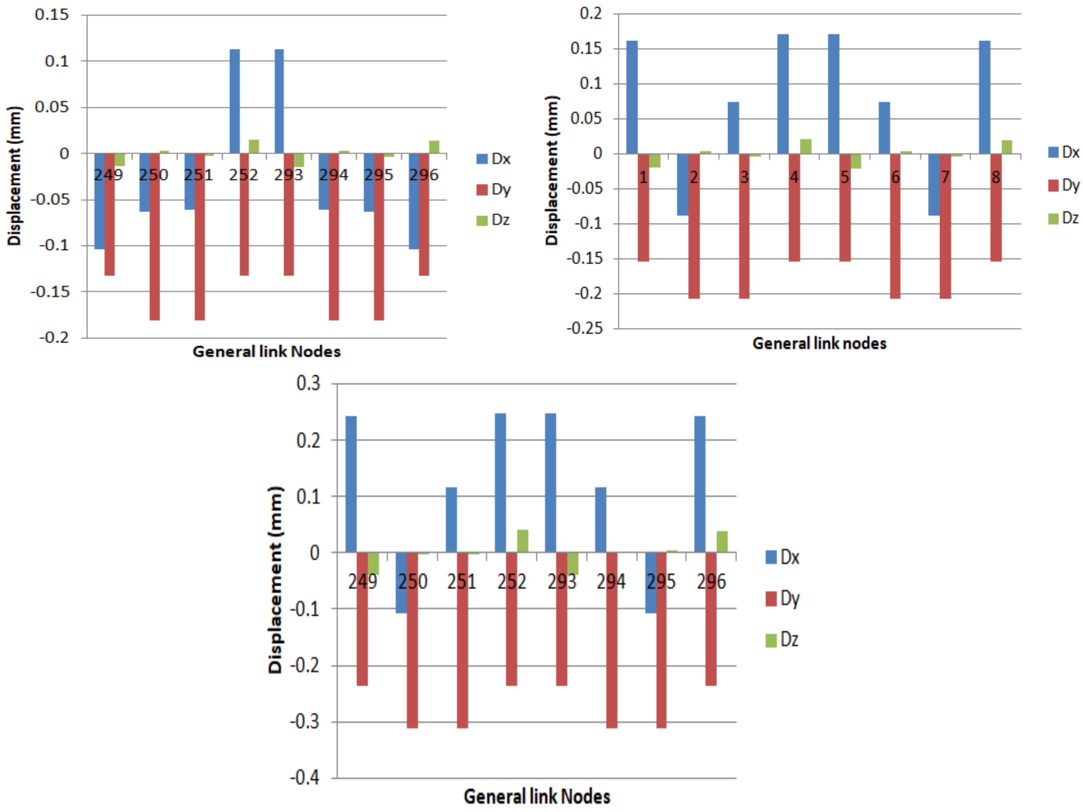

Fig 9. LRB displacement in x, y & z direction of 14, 16 & 18m span bridge subjected to earthquake

From the bar graphs it was observed that the deflection appears to be greater in the y direction. As a result, the structure's stiffness in the y direction is lower than in the x and z directions.

Push over analysis: Pushover Analysis (PA) is a simple method to predict the non-linear behaviour of a structure under seismic loads. By carrying out push over analysis capacity vs. demand curves are obtained. .

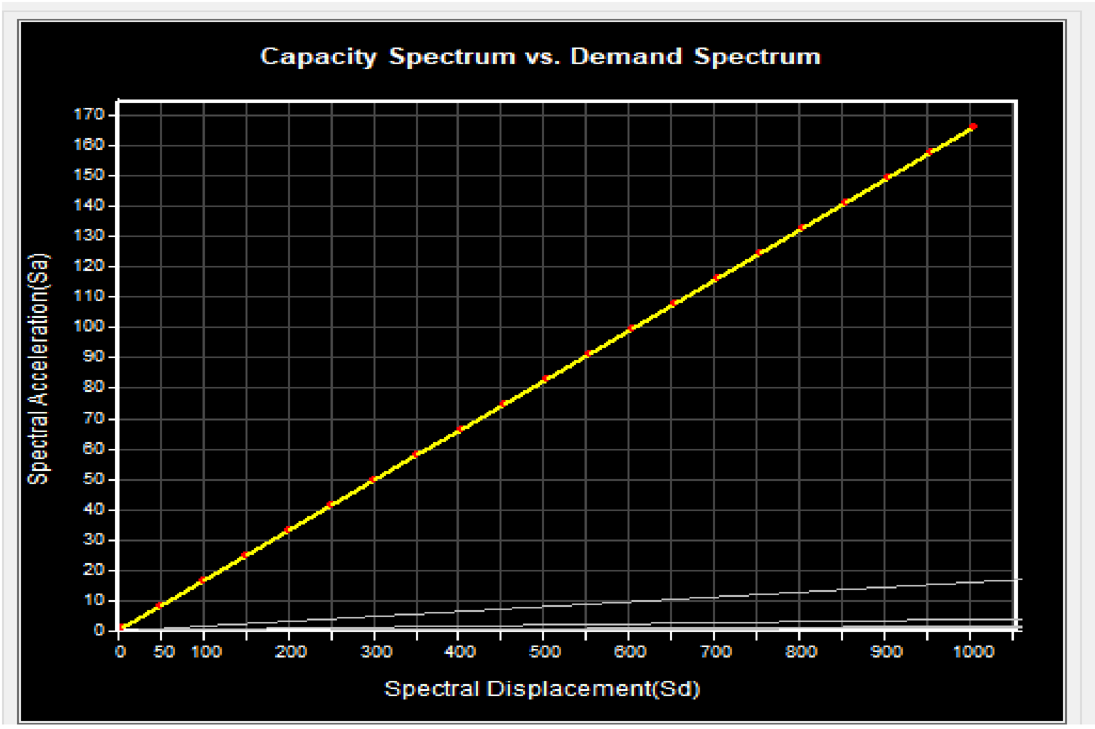

Fig 10. Capacity vs Demand graph for 14m span bridge

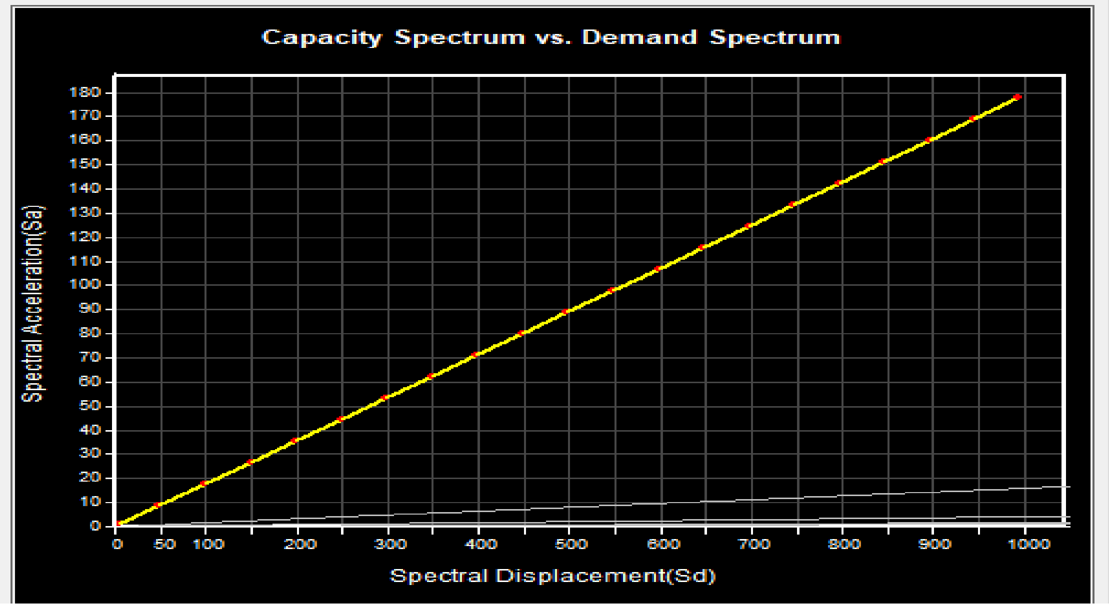

Fig 11. Capacity vs Demand graph for 16m span bridge

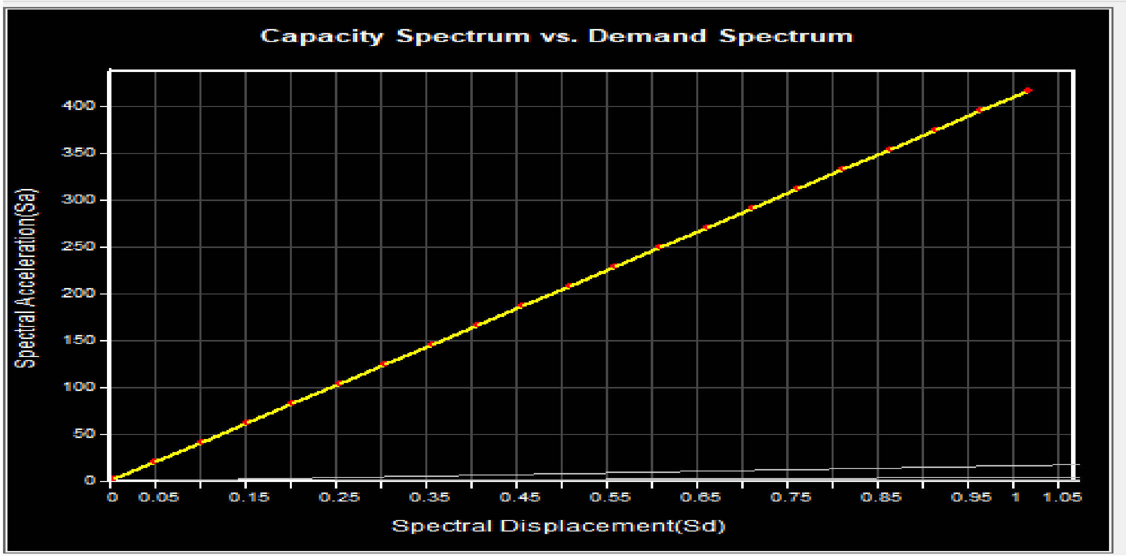

Fig 12. Capacity vs Demand graph for 18m span bridge

From the push over curves, it can be seen that the structure's capacity is quite high in comparison to its demand. As a result, the structure's performance during an earthquake is extremely high.

VI. CONCLUSION

The following findings are drawn from the work done on bridges of various spans and modeling them in the Midas civil software:

1. Software was validated by modeling a bridge problem from D. Johnson Victor's book "Essentials of Bridge Engineering," and the comparison of results revealed that the software results are in good agreement with manual results, with a percentage variation of 1.10% for shear force and 1.43% for bending moment.
2. T beam bridge types with spans of 14m, 16m, and 18m, abutments were constructed according to IS regulations. The design was tested for bending moment and shear using a static analysis. The models were judged to be safe against both shear and bending moments based on the results.
3. Dynamic characteristics such as natural modes (or mode shapes) and natural periods (or frequencies) are determined via eigen value analysis. The frequencies of 12 modes of T beam bridges with spans of 14m, 16m, and 18m is displayed in a graph of Modes vs Frequency(Hz).

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4. The displacements of Lead Rubber Bearings in the x, y, and z axes exposed to seismic excitations are displayed in bar graphs using Response spectrum and Time history analysis. The deflection appears to be greater in the y direction, based on the bar graphs. As a result, the structure's stiffness in the y direction is lower than in the x and z directions.
5. The non-linear behavior of the structure is anticipated using the push over analysis, and capacity versus demand curves are generated. From the push over curves, it can be seen that the structure's capacity is quite high in comparison to its demand. As a result, the structure's performance during an earthquake is extremely high.

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