Non-linear Static Analysis of Tee-beam Bridge

Abisheik A[1], Dr R. Sathyanarayan Sridhar[2]

[1] Post Graduate student, M.E. Computer Methods and Applications in Structural Engineering, Coimbatore Institute of Technology
[2] Associate Professor, Department of Civil Engineering,
Coimbatore Institute of Technology, Coimbatore-04, Tamil Nadu, India

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Abstract: *This paper deals with Non-linear static analysis (pushover analysis). This had been used for seismic analysis of high-rise buildings to determine ultimate load and deflection capability of structure. Particularly in bridges the seismic analysis is carried out by using nonlinear dynamic analysis and nonlinear static analysis. Under nonlinear static analysis Capacity spectrum method and N2 method has been used widely for the high-rise buildings. The main aim of the paper is to imply the concepts of Capacity spectrum method and N2 method of seismic analysis in T-beam Bridge. This is achieved by modelling, analyzing the T-beam Bridge in CSiBridge and SAP2000 software and comparing the output from both the software and verify the concepts of analysis with the code provision.*

Key word: capacity spectrum, N2, Tee-beam Bridge, non-linear, nsp, static analysis.

1. INTRODUCTION

India is one of the country to experience number of the world's greatest earthquakes in the last century. Hence the seismic building design code in India (IS 1893, Part-I) is also revised in 2002. As per the records of the previous earthquake the magnitudes of the design seismic forces has raised up and so the seismic zone of some regions has also been upgraded. Whereas the Zone I is combined with Zone II and declared it as Low intensity zone. However, bridges are very for transportation network in any country. The bridge design codes in India doesn't meet the seismic design demand at present based on the earthquake records. Therefore, it is now liable to evaluate the capacity of existing bridges against seismic force demand based on EURO codes.

2. NONLINEAR STATIC ANALYSIS

This analysis used to determine the strength of the structure, drift capacity of existing structure and the seismic demand of the new structure or existing structure subjected to selected earthquake and also can be used for checking the adequacy of new structural design as well. The lateral load is increased sequentially with the distribution pattern along the translational direction of the new or existing Structure. It is displaced till target displacement is reached or structure collapses. Once the elastic limit is reached the structure is further loaded which results in formation of cracks, plastic hinge and failure of the structural components. The relation between base shear VS displacement is plotted. This curve is also called as pushover curve or capacity curve. The main aim of capacity curve is to determine performance point for a desired seismic demand. Below are the two methods to be followed.

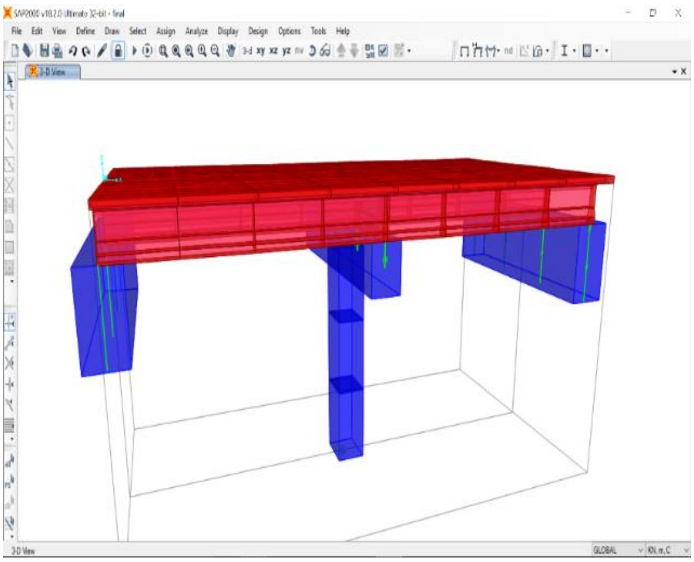

Fig-1: Model of the T-beam Bridge.

2.1 Capacity spectrum method (CSM)

This method is used to predict seismic performance and demands of structures subjected to design earthquake. This method compares the capacity of the structure with the demands of earthquake ground motion on the structure by means of graphical representation. The intersection point of capacity and displacement demand spectrum provides an estimate of acceleration beyond its elastic spectrum in terms of Performance point. This performance point is fed as the input for the N2 method.

2.2 N2 method

N stands for nonlinear analysis and 2 for two mathematical models. It combines the pushover analysis and capacity spectrum method obtained. Whereas the performance point is defined for the analysis. In which the analysis is carried out by linearization of the capacity spectrum curve. At the end of linearization the target displacement is determined for the earthquake forces defined as per EURO code: 8 Part-2: Bridges. And the value of Target displacement is verified as per code provision.

2.3 TEE BEAM BRIDGE

- Span – 20m
- Number of lanes - 2
- Slab thickness – 0.7m
- Carriageway width - 7.5m
- Abutment - 2.5m x 1.5m
- Approach slab thickness – 0.7m
- Type of bearing- Fixed bearing
- Soil type- II
- Site Class- B

3. MODELLING OF TEE BEAM BRIDGE

Initially the bridge is modelled and analyzed in both the **CSiBRIDGE** and **SAP2000** (**Fig-1**) for dead load, super imposed dead load, moving load (based on IRC 6 code provisions). Later for seismic analysis only the dead load and superimposed dead load alone is considered. As per **IRC 6 for a carriage width between 5.3m and 9.6m the load combination is of one lane of Class 70R or two lanes of Class A**. Hence the load combination of Class 70R (L, M, N type) and Class A along two lanes are added to existing load cases. At first the analysis has been performed with all the load cases and deflection is shown in the **Fig-2**. Then to obtain static pushover curve a new load case (PUSH) has been defined by entering the inputs as per the code. Then the dead load and PUSH load case are considered for the upcoming analysis to obtain the pushover curve, capacity spectrum curve (**Fig-3**) and the target displacement.

Once the performance point is obtained the point has been linearized **(Fig-4)** and taken as the input for N2 method **(Fig-5**) to determine the target displacement. For the better continuity and clear representation the screenshots of SAP2000 software has been used.

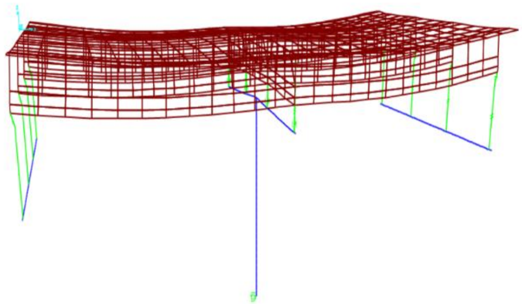

Fig-2 Deflection of bridge

During the pushover analysis in the bridge a plastic hinge is formed at the bottommost point where the pier is attached with the superstructure (deck). But these seismic forces act on either sides. Hence the PUSH load case is subjected horizontally and then vertically. When the load case is applied vertically the displacement obtained is minimum when compared to the displacement obtained during the load applied horizontally. And hence the load case is applied along horizontal direction to get maximum target displacement.

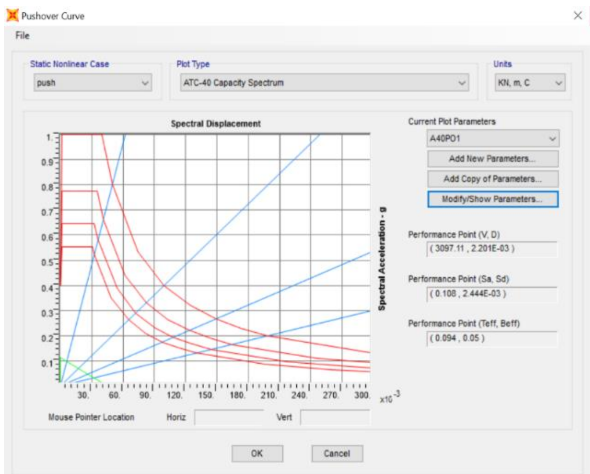

Fig-3 Capacity spectrum curve

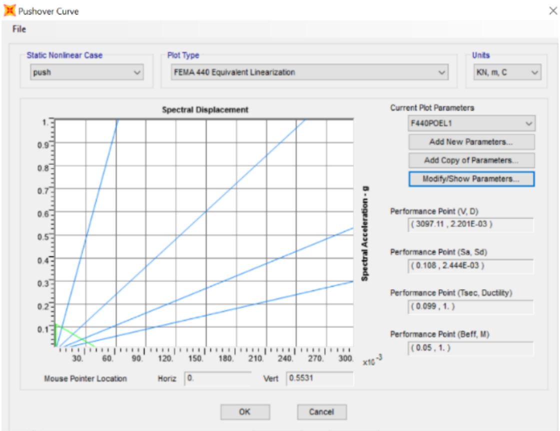

Fig-4 Linearization of the pushover curve

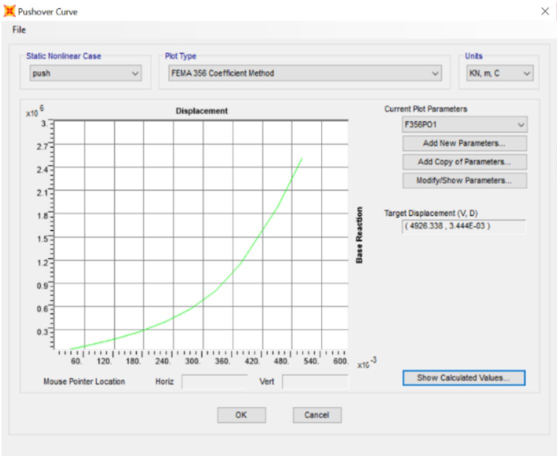

Fig-5 N2 curve

3. RESULTS AND DISCUSSION

The values from the curves are noted and are taken for the analyzing purpose for the performance based design. Where the performance point and target displacement are taken into account for the design purpose. Hence with this value the design is made simpler, economical and reliable when compared to the conventional manual method. From the capacity spectrum curve the performance point where the capacity and demand point is arrived. The target displacement obtained from the graph is **0.00344m** for a base reaction of **4926.44KN** from table 1. And hence the target displacement is well below the limit. Hence the obtained values are said to reliable and within the limits when compared with the code provision (refer Fig 6).

Table-1 Result for Push over analysis.

Steps	**Displacement** m	**BaseForce** KN
Step1	0.000005812	0
Step2	0.000005842	-0.609
Step3	0.045036	63536.491
Step4	0.075036	107539.273
Step5	0.105036	154237.528
Step6	0.135036	205034.079
Step7	0.165036	261693.65
Step8	0.195036	326533.531
Step9	0.225036	402684.504
Step10	0.255036	494415.718
Step11	0.300006	673941.259

Fig-6 Displacement limit as per EURO code 8

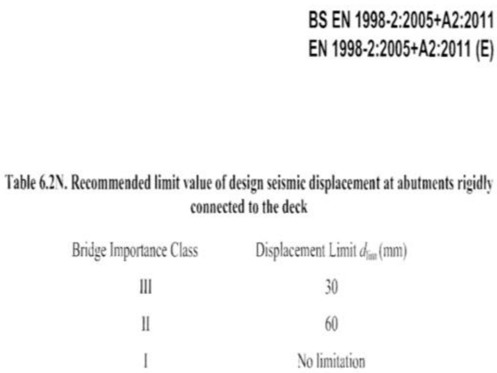
BS EN 1998-2:2005+A2:2011
EN 1998-2:2005+A2:2011 (E)

Table 6.2N. Recommended limit value of design seismic displacement at abutments rigidly connected to the deck

Bridge Importance Class	Displacement Limit d_{lim} (mm)
III	30
II	60
I	No limitation

4. CONCLUSION

The values are calculated from software and verified with code provisions Eurocode 8: Design of structures for earthquake resistance – Part 2 Bridges. Applied technology council for seismic damage and retrofit of RC structure- ATC 40.Improvement of Nonlinear Static Seismic Analysis Procedures - FEMA 440. Hence with this paper it has been proved that the analysis results can be obtained without involving in complex time-history analyses. And thus the gap has been tried to bridge up with this paper. Hence this type of analysis can be adopted for designing the bridge on Performance-based design approach.

5. REFERENCES

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