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NON-LINEAR STATIC ANALYSIS OF TEE-BEAM BRIDGE

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ABSTRACT: This paper performs the static analysis which is commonly known as 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, analysing 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.

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

1 INTRODUCTION

India is one of the countries to experience number of the world's greatest earthquakes in the last century. 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 enhanced in general, and 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. This procedure follows nonlinear static (pushover) analysis. The attention for existing bridges is comparatively less. The bridge design codes, in India, have less seismic design provision at present. Therefore, it is very important to evaluate the capacity of existing bridges against seismic force demand based on EURO codes.

2 NONLINEAR STATIC ANALYSIS

It is mainly to determine strength, drift capacity and seismic demand for a structure subjected to design earthquake. Lateral load is increased monotonically by a predefined distribution pattern along the height of the

Structure which is displaced till it reaches "target displacement" or structure collapses. The sequence of cracking, plastic hinging and failure of the structural components throughout the procedure is observed. Base shear vs displacement graph is plotted for the pushover analysis. This curve is also known as capacity curve. The seismic demand is then compared with the corresponding structural capacity or predefined performance limit state to know what performance the structure will exhibit. Below are the two methods to be followed

2.1 Capacity spectrum method (CSM)

It is a reliable tool to predict seismic performance and seismic demands of structures subjected to design earthquake. This method by means of a graphical procedure compares the capacity of the structure with the demands of earthquake ground motion on the structure. The intersection of capacity spectrum and demand spectrum provides an estimate of inelastic acceleration and displacement demand.

2.2 N2 method

N stands for nonlinear analysis and 2 for two mathematical models. It combines the pushover analysis of a MDOF model with the response spectrum analysis of an equivalent SDOF system. This method is formulated in the acceleration-displacement format, which enables the visual representation of the capacity spectrum method with the sound basis of the inelastic demand spectra. The inelastic demand spectra are determined from a typical smooth elastic design spectrum.

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 analysed 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. 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.

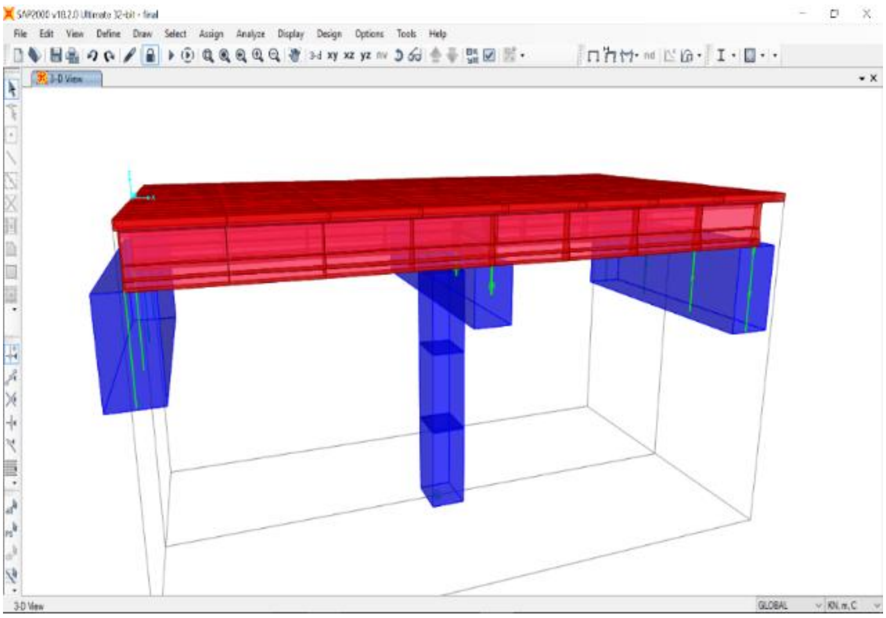

Figure 1. Model of the T-beam bridge

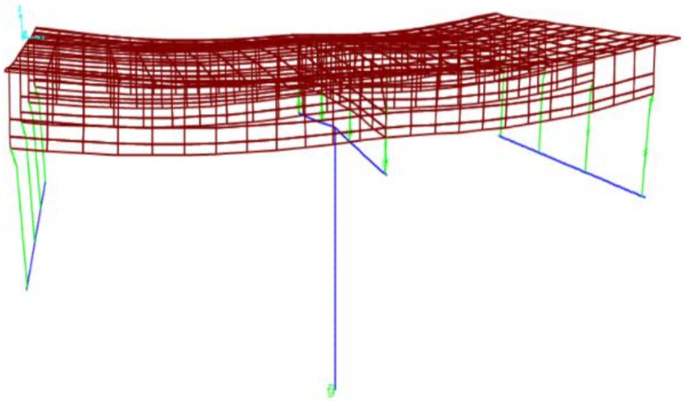

Figure 2. Deflection of bridge

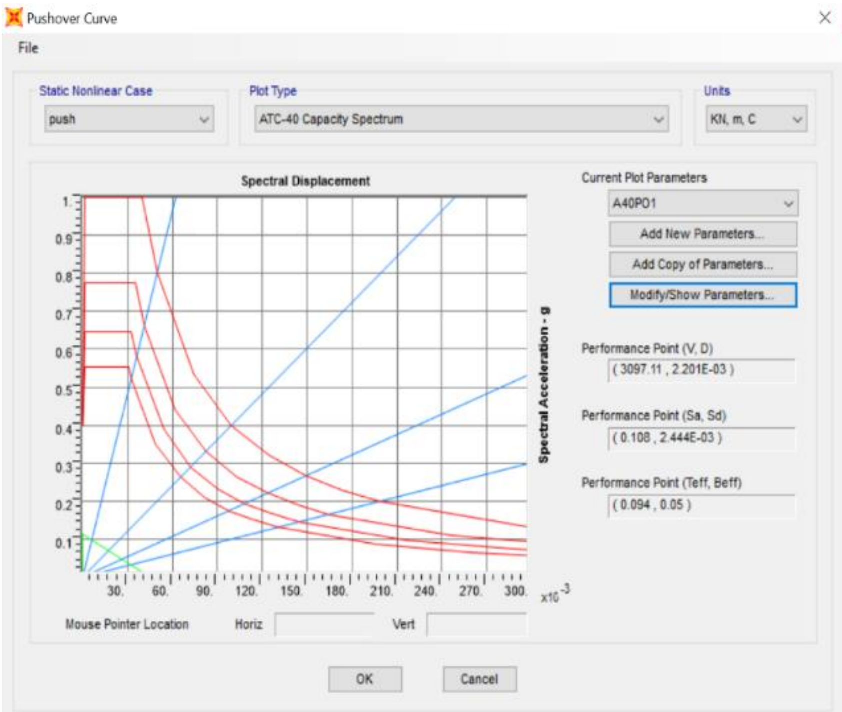

Figure 3. Capacity spectrum curve

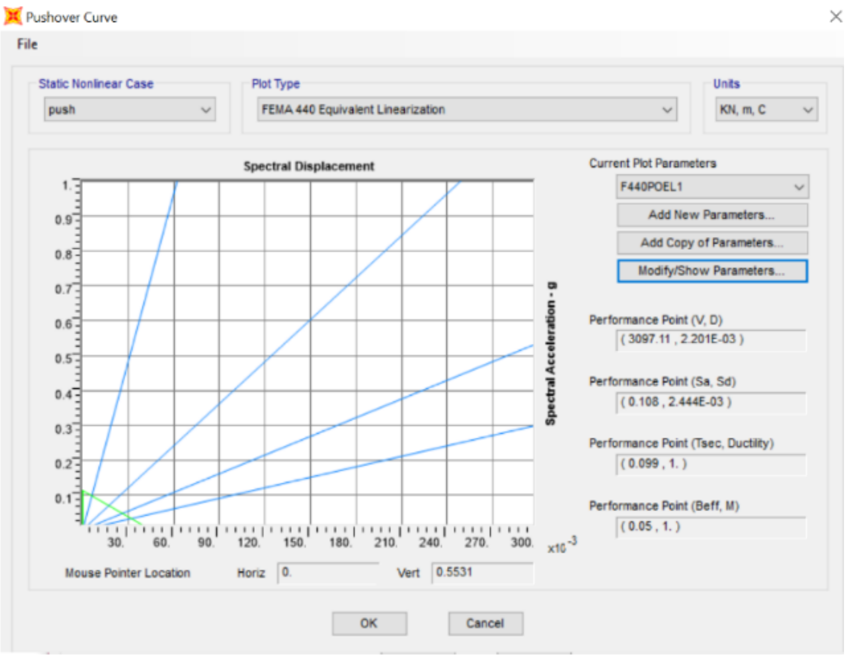

Figure 4. Linearization

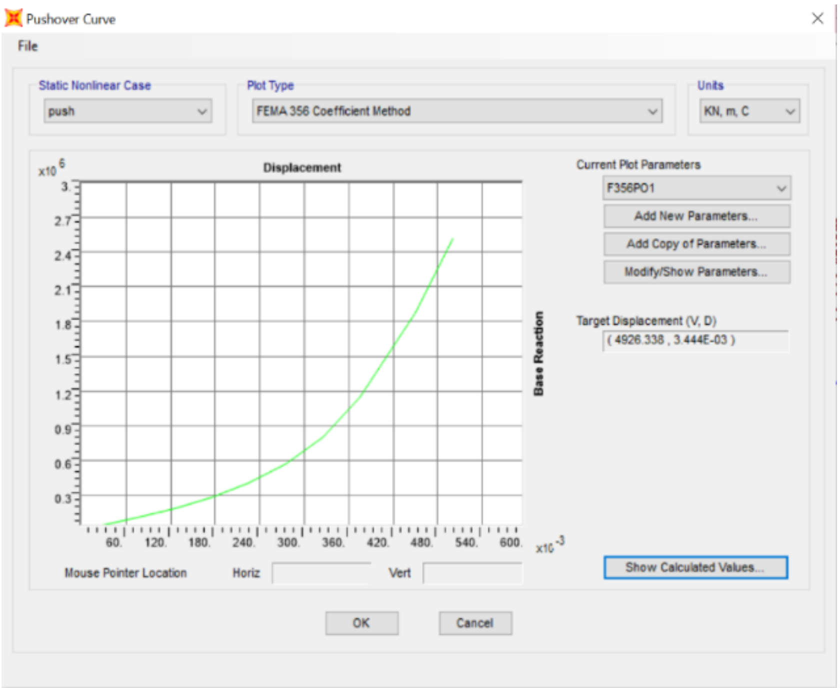

Figure 5. N2 curve

4 RESULTS AND DISCUSSION

The values from the curves are noted and are taken for the analysing 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).

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

Figure 6. Displacement limit as per EURO code 8

Table 1. Result for Push over analysis

Displacement	Base Force
m	KN
0.000005812	0
0.000005842	-0.609
0.045036	63536.491
0.075036	107539.273
0.105036	154237.528
0.135036	205034.079
0.165036	261693.65
0.195036	326533.531
0.225036	402684.504
0.255036	494415.718
0.300006	673941.259

5 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. The feasibility of employing simplified assessment procedures for the performance-based seismic evaluation of bridges has been only recently under investigation. Thus a well-established knowledge consisted an important gap in the field of bridge engineering, given that current performance-based trends require, as a matter of necessity to estimate seismic demand (accurate), without resorting to more complex nonlinear time-history analyses. And thus the gap has been tried to bridge up with this paper.

REFERENCES

1. Y.Chen "An Effective and Efficient Approach for Nonlinear Seismic Analysis of Bridges" , June 1993
2. IRC 6-2010, "Standard Specifications and Code of Practice for Road Bridges", Section II, loads and stresses, The Indian Roads Congress, New Delhi, India, 2010.
3. Euro code 8(2004), "Design of Structures for Earthquake Resistance, Part-1: General Rules, Seismic Actions and Rules for Buildings".
4. Eurocode 8 - Design of structures for earthquake resistance Part 2: Bridges
5. ATC 40, 1996, Seismic evaluation and retrofit of concrete buildings, Volume1
6. FEMA 273, NEHRP Guidelines for the Seismic Rehabilitation of Buildings.
7. FEMA 440, Improvement Of Nonlinear Static Seismic Analysis Procedures
8. FEMA 356, Prestandard And Commentary For The Seismic Rehabilitation Of Buildings