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Pushover Analysis of Bridge Using SAP 2000

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ABSTRACT: Bridges extend horizontally with their two ends restrained and that makes the dynamic characteristics of bridges different from buildings. Non-linear static procedures, such as pushover-based ones, have been continuously refined and improved along the past few years as a complement or even as an alternative to dynamic time-history analysis. The study addresses the issue of pushover analysis of bridges sensitive to torsion, using as a case-study a straight, overpass bridge with two equal spans, whose fundamental mode is purely torsional. This chapter presents a summary of various parameters defining the computational models, the basic assumptions and the bridge geometry considered for this study. The loads and load combinations on the bridge are studied and the same bridge is modeled in SAP 2000 and conducted Linear static, Modal and Seismic Analysis (Response Spectrum) to get the maximum bending moments and dynamic properties of the bridge.

KEYWORDS: Pushover Analysis, RC Bridge, SAP 2000.

I. INTRODUCTION

India has had a number of the world's greatest earthquakes in the last century. 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. 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 zonation of some regions has also been upgraded.

There are many literatures available that present step-by-step procedures to evaluate multi-storied buildings. This procedure follows nonlinear static (pushover) analysis.

The attention for existing bridges is comparatively less. However, bridges are very important components of transportation network in any country. The bridge design codes, in India, have no seismic design provision at present. A large number of bridges are designed and constructed without considering seismic forces. Therefore, it is very important to evaluate the capacity of existing bridges against seismic force demand. There are presently no comprehensive guidelines to assist the practicing structural engineer to evaluate existing bridges and suggest design and retrofit schemes. In order to address this problem, the present work aims to carry out a seismic evaluation case study for an existing RC bridge using nonlinear static (pushover) analysis. Nonlinear static (pushover) analysis as per ATC 40 is used to verify the result.

II. LITERATURE REVIEW

R. Shreedhar & Spurti Mamadapur - T-beam bridge decks are one of the principal types of cast-in place concrete decks. T-beam bridge decks consist of a concrete slab integral with girders. The finite element method is a general method of structural analysis in which the solution of a problem in continuum mechanics is approximated by the analysis of an assemblage of finite elements which are interconnected at a finite number of nodal points and represent the solution domain of the problem. A simple span T-beam bridge was analyzed by using I.R.C. loadings as a one dimensional structure. The same T-beam Bridge is analysed as a three-dimensional structure using finite element plate for the deck slab and beam elements for the main beam using software STAAD Pro V8i. Both models are subjected to I.R.C. Loadings to produce maximum bending moments.

Parimal A. Godse - The structure remains within elastic range employing linear method and resulting forces and the displacement are quite high. By introducing ductility in bridges, the load carrying capacity can be enhanced thus bridge is to be designed for lesser forces than obtained in elastic range. This requires employing non-linear analysis (in-elastic range). Static non-linear analysis is an effective tool to evaluate the expected non-linear behavior and consequent failure pattern in different components of the bridge.

P. Fajfar - Structural response to strong earthquake ground motion cannot be accurately predicted due to large uncertainties and the randomness of structural properties and ground motion parameters. Consequently, excessive sophistication in structural analysis is not warranted. For the time being, the most rational analysis and performance evaluation methods for practical applications seem to be simplified non-linear procedures, which combine the non-linear static (pushover) analysis of a relatively simple mathematical model and the response spectrum approach.

A.Nicknam, A. Mosleh, & H. HamidiJamnani - The possibility of severe damage to bridges that are subjected to earthquake leads to the necessity of seismic evaluation of existing bridges, particularly those which have been either designed regardless of earthquake effects or according to moderate earthquake resistant consideration. The assessment of safety and stability of these bridges while passing increasingly traffic is of high importance in their seismic performance. In this study, an urban steel bridge in metropolitan Tehran which is accounted for as an important structure in the city transportation is studied using nonlinear static procedure at two hazard levels. The hazard levels were obtained by the use of probabilistic seismic hazard analysis (PSHA). Three-dimensional model of the mentioned bridge is developed and analyzed using nonlinear static procedure (NSP) thus its seismic performance is evaluated accordingly. The results show the vulnerability of this steel bridge during earthquake and the necessity of retrofitting for improving its seismic behavior.

A.Kanchanadevi& C. Umarani - The increased traffic demand, material ageing, cracking of bridge components, physical damages incurred by concrete, corrosion of reinforcement and inadequate maintenance of bridges necessitate the assessment of bridges periodically for their performances. The accuracy of analytical assessment of bridges depends on the ability of the tool to simulate the problem. The nonlinear analysis is one such tool to simulate the exact material behavior, to evaluate strength in inelastic range and to identify the potential of high load carrying capacity through redistribution, tensile and shear strength. An attempt has been made to perform nonlinear finite element analysis to analyze the component of a selected road bridge.

III.METHODOLOGY

- a) A thorough literature review to understand the seismic evaluation structures and application of pushover analysis.
- b) Selection of the dimensions of Existing RC Bridge.
- c) Model the selected bridge in computer software SAP2000.
- d) Carry out modal analysis to obtain the dynamic properties of the bridges and input parameters for nonlinear analysis of the bridge.
- e) Carry out nonlinear static analysis of the bridge model and arrive at a conclusion.

IV. PROBLEM DEFINITION

A 4 Span RC Slab Bridge existed at a chainage 12+334 in State Highway (SH-12) from Bijapur-Athani Section across Done River is taken as a case study. The loads and load combinations on the bridge are studied and the same bridge is modeled in SAP 2000 and conducted Linear static, Modal and Seismic Analysis (Response Spectrum) to get the maximum bending moments and dynamic properties of the bridge. Afterwards the FEMA 356 Hinges are defined in the model and conducted Nonlinear Static (Pushover) Analysis using ATC-40 to calculate Base Shear vs. Displacements, Effective time, Spectral Displacement Capacity & Spectral Displacement Demand and to find out Performance points of Bridge.



Bridge Details		
Sr. No.	Description	
1	Span of Bridge	20m X 4
2	Width of Bridge	8.6 m
3	Lanes	2 Lanes
4	Number of Main Girders	3 No's
5	Total depth	2.495 m
6	Slab thickness (average)	0.26m
7	Type of Loading	IRC class A Train
8	Loads	DL+LL+IL+EQ
9	Compressive Strength of Concrete (fck) (M30)	30000 KN/m ²
10	Modulus of Elasticity $E=5000\sqrt{fck}$ $E=5000\sqrt{30} = 30000 \text{ N/mm}^2$	27386128 KN/m ²
11	Poisson's Ratio of Concrete	0.18
12	Type of Analysis	Linear & Nonlinear

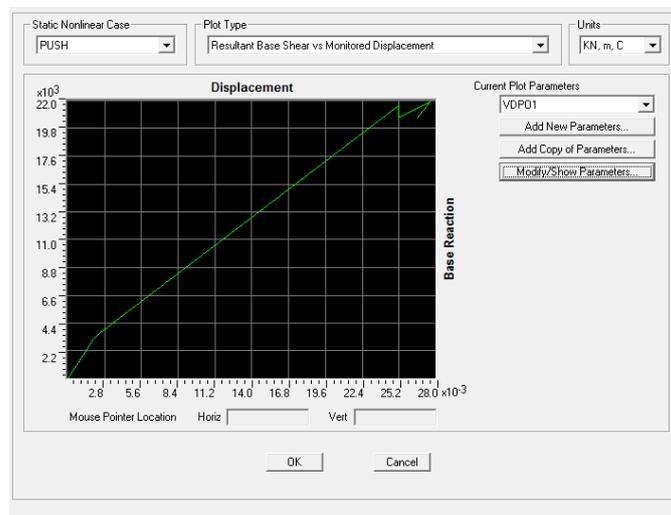
Input Data for Analysis		
Sr. No.	Particulars	
1)	Density of Reinforced Concrete	25 KN/m ³
2)	Grade of Concrete	M-30
3)	Type of live load	IRC Class A Train
4)	Impact Factor (i) $\frac{4.5}{6 + L}$	0.173
5)	Importance Factor (I)	1.2
6)	Response Reduction Factor (R)	3.0
7)	Poisson's Ratio of Concrete	0.18
8)	Seismic Zone	Zone III
9)	Seismic Zone Factor	0.16
10)	Soil Type	Type II



V. RESULTS AND DISCUSSIONS

Table 5.1 Base Shear vs Displacement

Pushover Curve - PUSH		
Step	Base Shear	Displacement
	KN	m
0	0	0
1	3105.297	0.00199
2	3606.609	0.002397
3	21609.991	0.02516
4	20626.293	0.02517
5	21960.929	0.027578
6	20547.83	0.02653

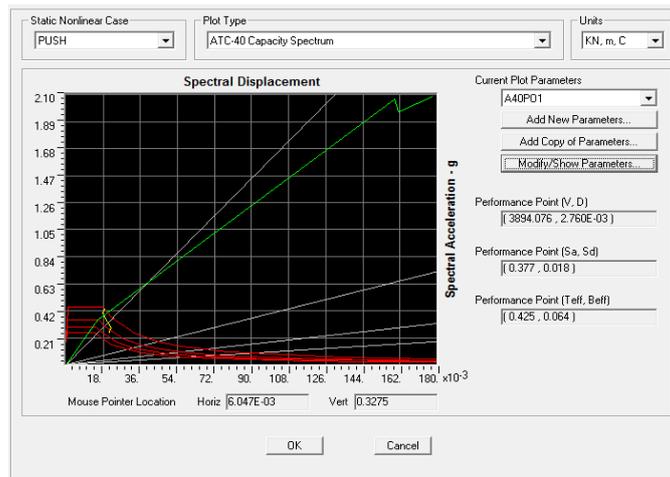


Graph 5.1 Base Shear vs. Displacement

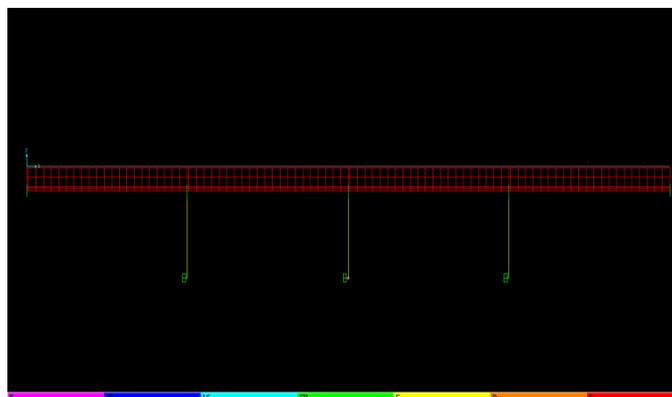


Table 5.2 Pushover Demand Capacity Curve

Pushover Demand Capacity Curve - ATC40 - PUSH						
Step	Teff	Beff	Sd Capacity (m)	Sa Capacity	Sd Demand (m)	Sa Demand
1	0.414959	0.05	0	0	0.018554	0.433778
2	0.414959	0.05	0.012881	0.301159	0.018554	0.433778
3	0.422873	0.063618	0.015547	0.350003	0.017778	0.400216
4	0.557828	0.081033	0.15941	2.062309	0.021952	0.283991
5	0.574937	0.108421	0.161382	1.965413	0.020765	0.25289
6	0.585788	0.114581	0.178023	2.088502	0.020797	0.243985



Graph 5.2 Pushover Demand Capacity Curve (ATC 40)



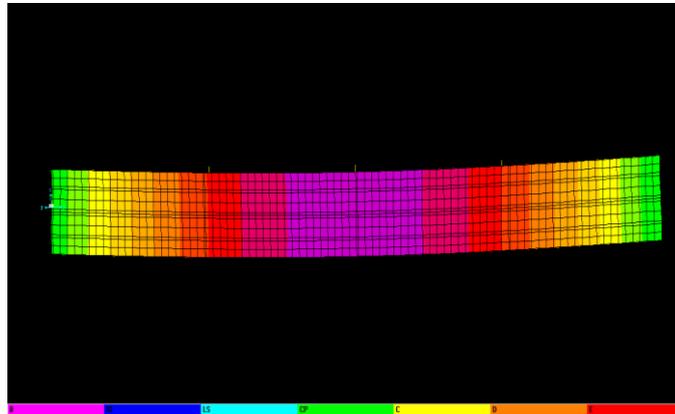


Fig 5.1 Pushover Step 1

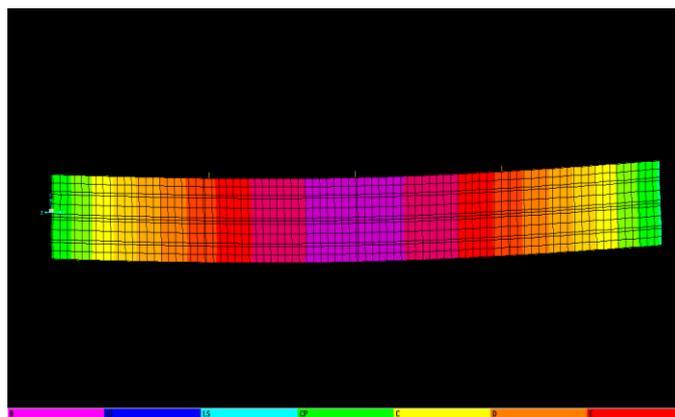
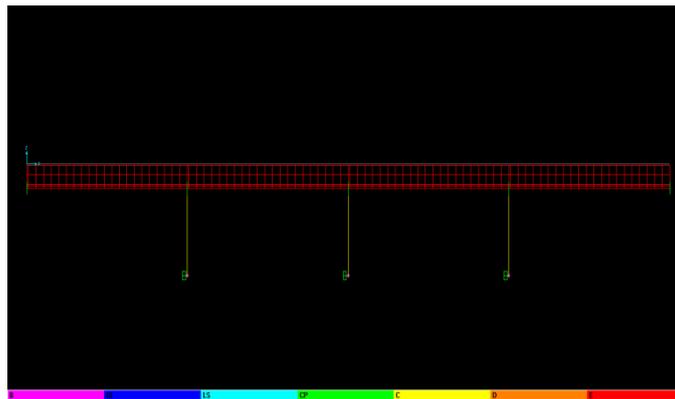


Fig 5.2 Pushover Step 2

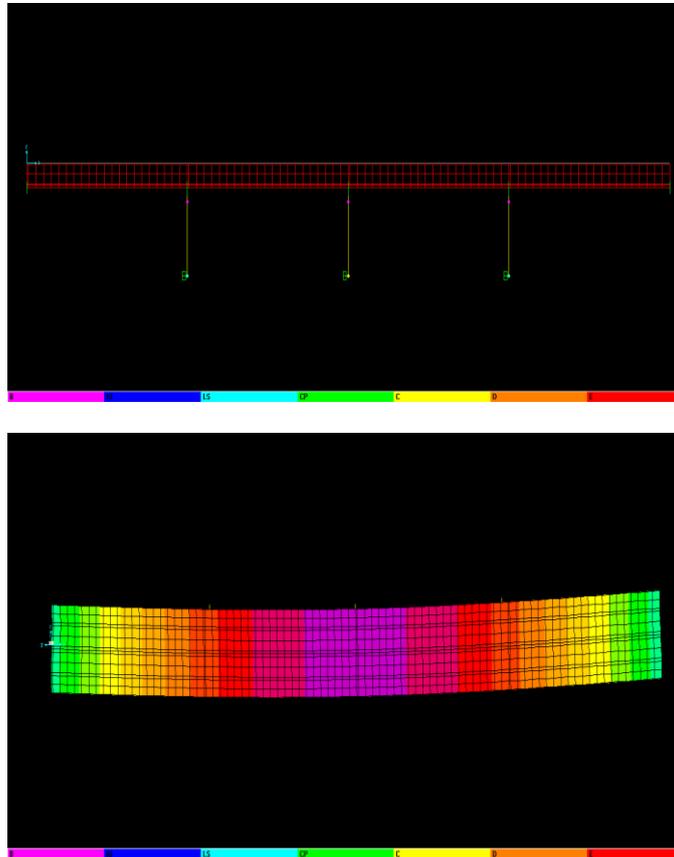
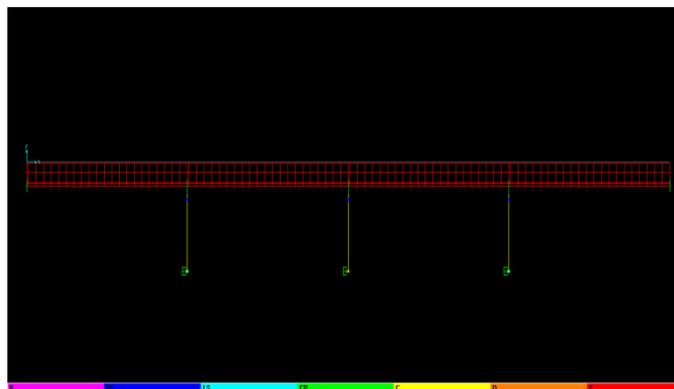


Fig 5.3 Pushover Step 3



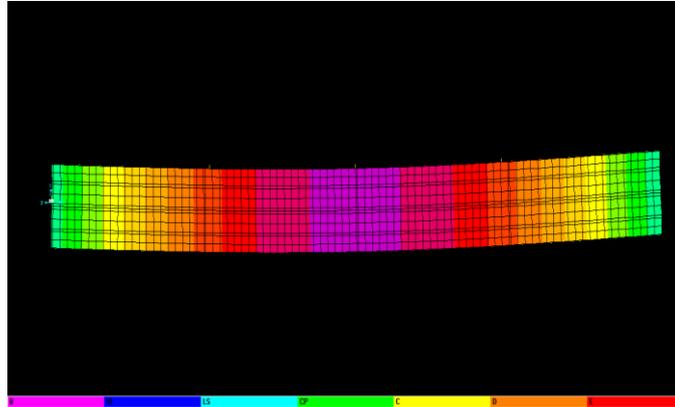


Fig 5.4 Pushover Step 4

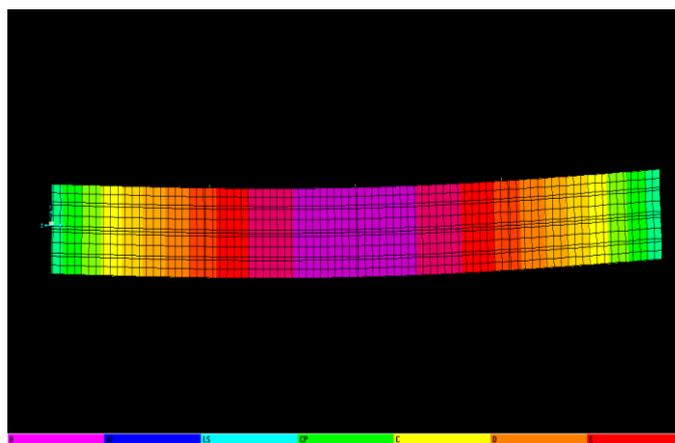
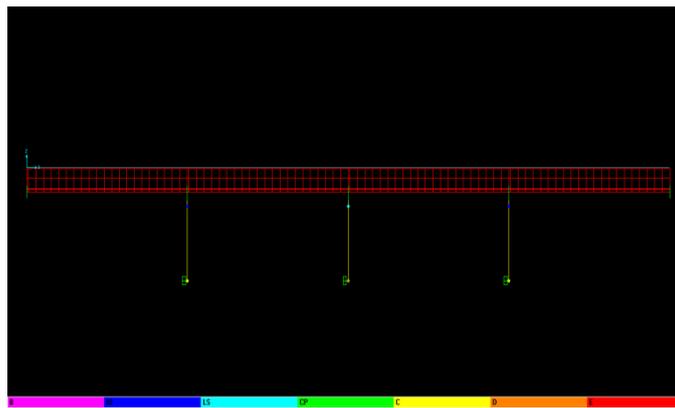


Fig 5.5 Pushover Step 5

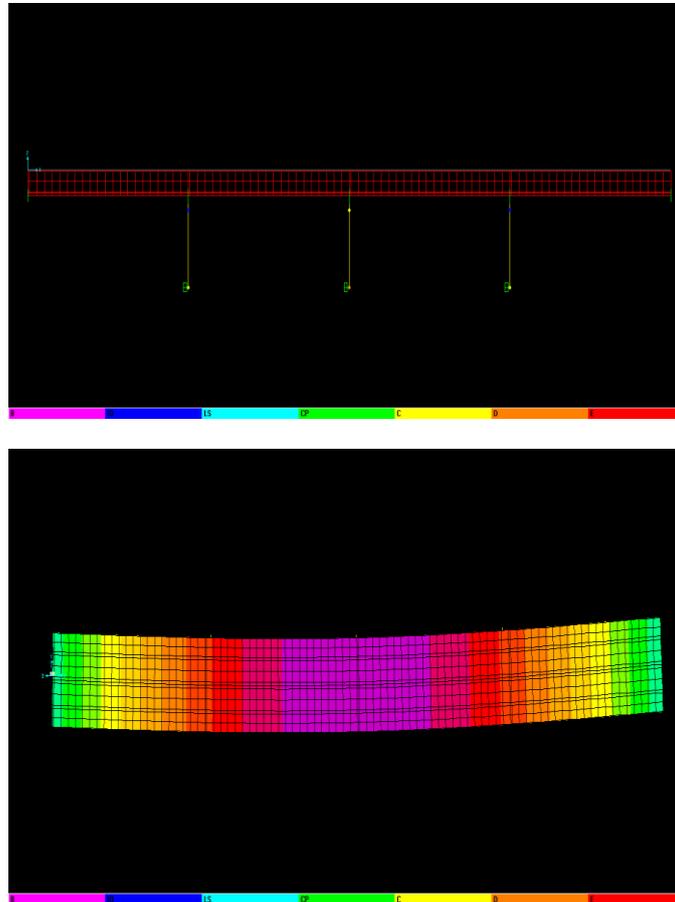
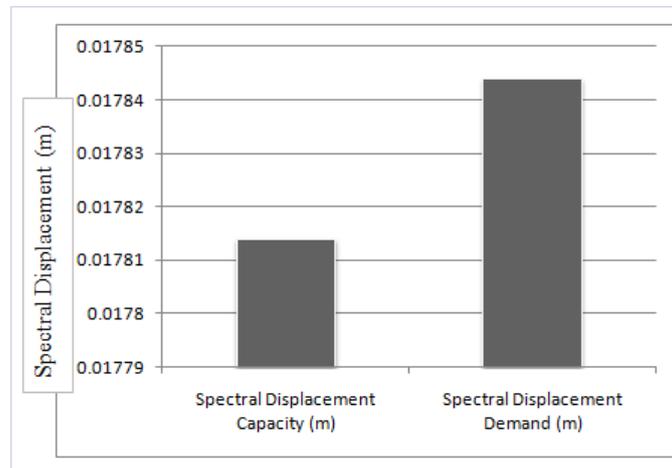


Fig 5.6 Pushover Step 6

The effective time is 0.425; it is in between pushover step 3 and step 4. At effective time the Spectral Displacement Capacity (m) and Spectral Displacement Demand (m) is calculated by interpolating values in the Table 4.2. The table 4.3 shows the Spectral Displacement Capacity and Spectral Displacement Demand values according to Capacity Spectrum Method ATC 40 at effective time 0.425 sec's.

Table 5.3 Comparison between Capacity & Demand (ATC 40)

Pushover Step	Effective Time, T _{eff} (Sec)	Spectral Displacement Capacity (m)	Spectral Displacement Demand (m)
Between 3 & 4	0.425	0.017814	0.017844



Graph 5.3 Comparison between S_d Capacity & S_d Demand

VI. CONCLUSION

- 1) Under Seismic Load, Base Shear v/s Displacement and By Pushover Analysis the performance levels of bridge are studied.
- 2) Spectral Displacement Demand & Spectral Displacement Capacity is calculated by conducting Nonlinear Static (Pushover) Analysis.
- 3) From the Analysis, Spectral Displacement Demand is more than the Spectral Displacement Capacity in the analyzed Bridge. So the analyzed bridge requires retrofitting

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