Pushover Analysis of Bridge

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Abstract- *Bridges extends horizontally with its two ends restrained and that makes the dynamic characteristics of bridges different from building.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 in 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 presents 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.

A. Types Of Bridges

A bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed may be a river, a road, railway or a valley.

According to the form or type of superstructure as arch, girder/beam, truss, slab, rigid frame or suspension and cable stayed bridges

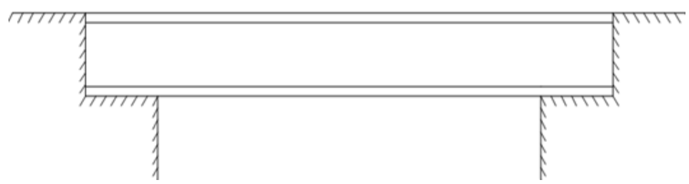


Fig.1 Beam Bridge

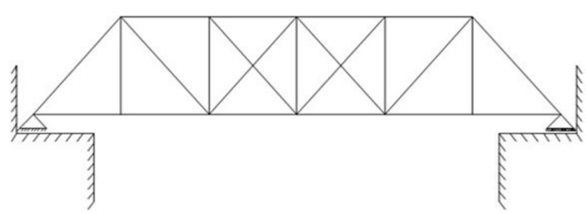


Fig 2 Truss Bridge

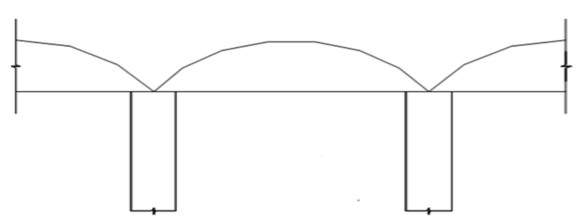


Fig .3 Arch Bridge

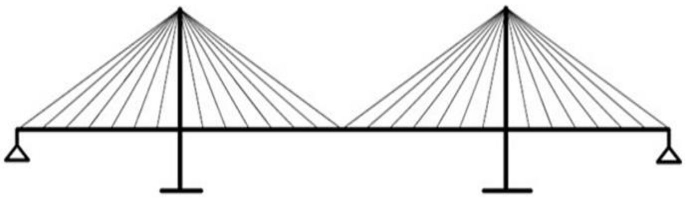


Fig 4 Cable stayed bridge

B. Problem Statement

This chapter presents a summary of various parameters defining the computational models, the basic assumptions and the bridge geometry considered for this study.A 4 Span **RC Slab Bridge** existed at a chainage 12+334 in State Highway (SH-12) from Bijapur-Athani Section across Done Rivers taken as a case study. The loads and load combinations on the bridge are studied and the same bridge in modelled 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.

Table 1 Bridge Details

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/m²
10	Modulus of Elasticity E=5000√fck E=5000√30 = 30000 N/mm²	27386128 KN/m²
11	Poisson"s Ratio of Concrete	0.18
12	Type of Analysis	Linear & Nonlinear

C. Aim

- To Study Behaviour of Bridge By using Pushover Analysis

D. Objectives

- To study the loads and load combinations on the RCBridge.
- To understand the nonlinear static (pushover) analysis procedures available in literature.
- To carry out a detailed case study of pushover analysis of a reinforced concrete bridge.
- To study the structural response of bridge elements by conducting nonlinear static analysis.
- To study the performance levels of bridge & arrive atconclusion.

II. MATERIALS & METHODOLOGY

A. *General*

- A thorough literature review to understand the seismic evaluation structures and application of pushoveranalysis.
- Selection of the dimensions of Existing RCBridge.
- Model the selected bridge in computer softwareSAP2000.
- Carry out modal analysis to obtain the dynamic properties of the bridges and input parameters for nonlinear analysis of thebridge.
- Carry out nonlinear static analysis of the bridge model and arrive at aconclusion.

III. RESULTS AND OBSERVATIONS

A. Linear Analysisresults

Linear analysis is conducted under Dead load, Live load, Impact load & Seismic Load is conducted as a result Maximum Bending Moments are calculated.

Table 2 Maximum Bending Moments (Linear Analysis)

Sr.No	Load Case / Combo	Maximum Bending Moment (KN-m)
1)	Deal Load (DL)	3931.009
2)	Live + Impact Load (LL+IL)	3425.085
3)	Seismic Load (EQ)	209.239
4)	DL+LL+IL	7356.094
5)	DL+LL+IL+EQ	7458.461

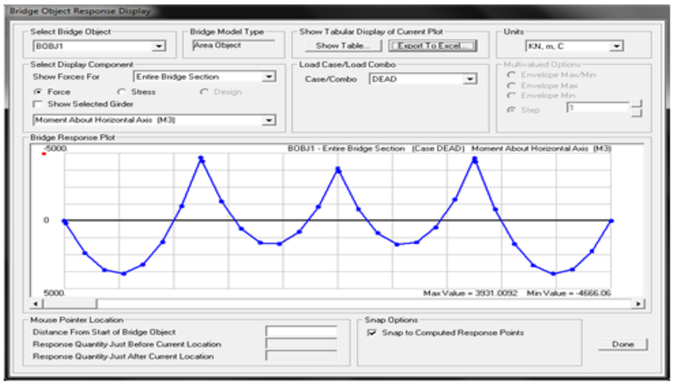


Fig 5 Dead Load Bending Moment

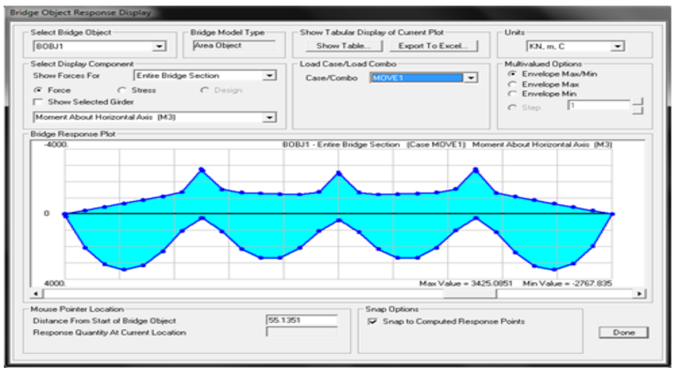


Fig 6 Live Load + Impact Load Bending Moment

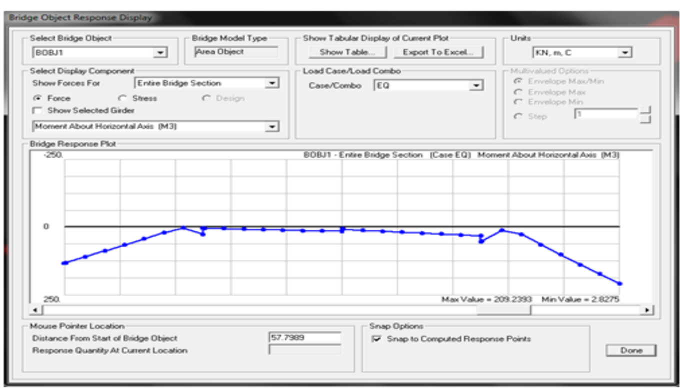


Fig 7 Seismic Load Bending Moment (Response Spectrum)

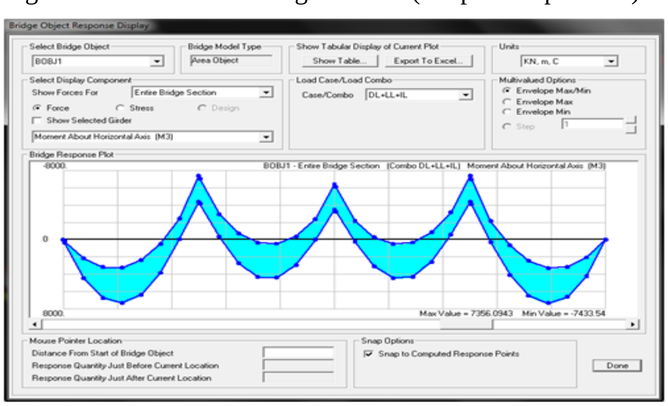


Fig 8 Bending Moment Due to DL+LL+IL

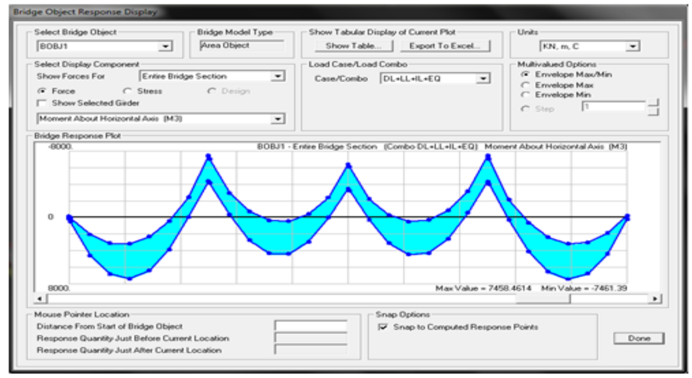


Fig 9 Bending Moment Due to DL+LL+IL+EQ

B. Nonlinear Static (Pushover) Analysis

Nonlinear Static (Pushover) Analysis permits to identify critical members likely to reach limit states during the earthquake. Nonlinear Static Analysis is carried out after assigning flexural hinges (FEMA 356 Auto hinges) using ATC 40Capacity Spectrum Method. As a result performance points& levels (IO, LS, and CP) are found in different pushover steps and Base shear vs. Displacement Graph & Spectral Acceleration vs. Spectral Displacement Graph is drawn and Spectral Displacement Demand & Spectral Displacement Capacity is calculated.

Flow chart outlining a procedure using static push-over analysis in seismic design and retrofit evaluation.

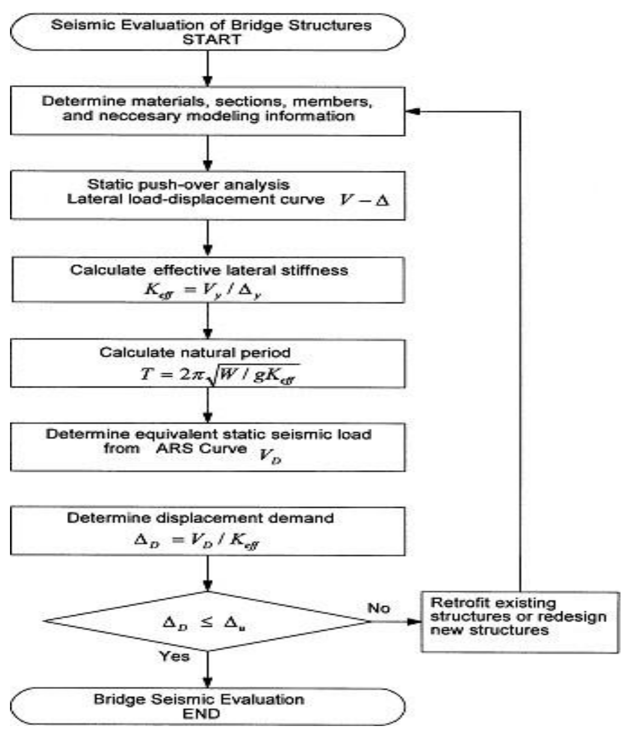
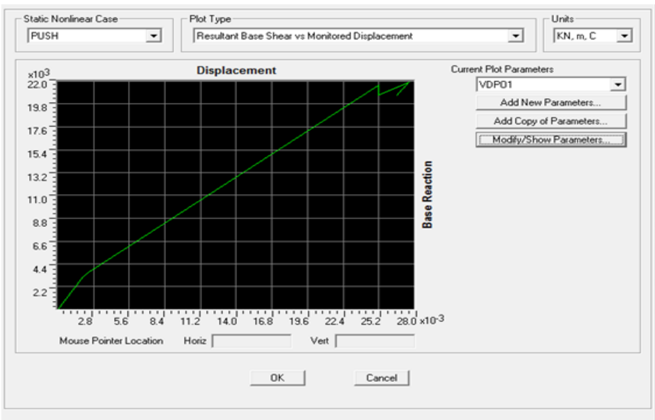


Fig 10 Flowchart of Static Pushover Analysis

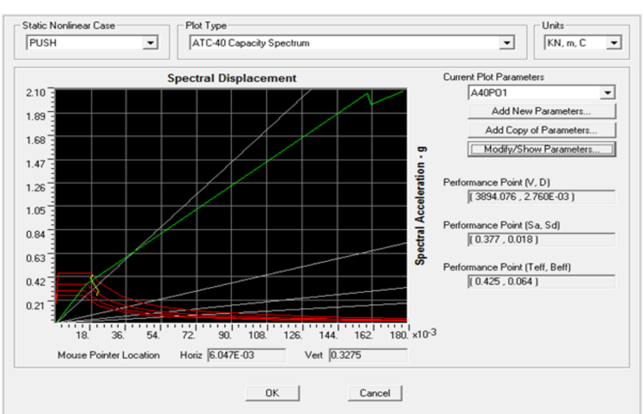
Table 3 Base Shear vs. Displacement

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 1 Base Shear vs. Displacement

Pushover Curve Demand Capacity - ATC40 - PUSH						
Step	Teff	Beff	SdCapacity (m)	Sa Capacity	SdDemand (m)	SaDemand
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

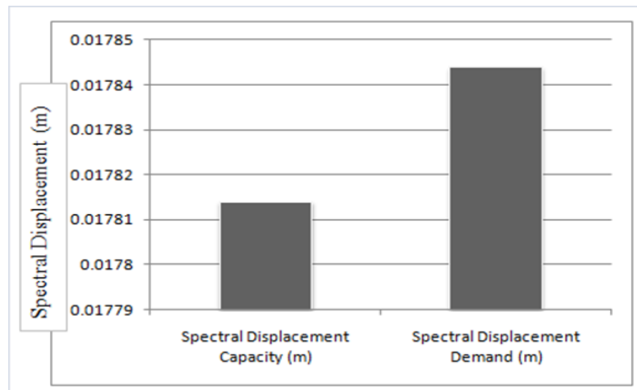


Graph 2 Pushover Demand Capacity Curve (ATC 40)

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 6.5. The table 6.6 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 4 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 3 Comparisons between S_d Capacity &S_d Demand

IV. 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.

V. ACKNOWLEDGEMENT

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