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EXPERIMENTAL STUDIES ON SABARMATI BRIDGE USING TRAFFIC INDUCED VIBRATION

S.G. Patel* and G.R. Vesmawala
Applied Mechanics Department, S.V. National Institute of Technology, Surat, India

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ABSTRACT

Increasing of traffic intensity due to technology advancement in heavy axle vehicles affects overall integrity of highway bridges. Along with the traffic intensity, aging of structural elements leads to distress of structure. Due to distressing in structural elements, stiffness gets reduced. Research studies based on vibration test methodology shows that change in fundamental frequency of any structures is directly related to overall stiffness of the structure. Therefore, many research studies have been carried out across the globe by researchers in the field of vibration based monitoring of the structure to identify dynamic behaviour by using properties such as natural frequencies, mode shapes and modal damping ratios. In this paper, ambient vibration test on a bridge where measurements taken with instrumentation of acceleration sensors on the bridge span. For the study, concrete I girder bridge on the ring road over Sabarmati River near Ahmedabad City is selected. The bridge is characterized by a system of post-tensioned I girder simply supported beams with span. The dynamic characteristics of the bridge were computed by using Stochastic subspace identification (SSI) method and Least squares complex frequency domain (LSCF) Method, which is further used to study fundamental frequency of bridge.

Keywords: Ambient vibration test; operational modal analysis; stochastic subspace identification, least squares complex frequency domain bridge.

1. INTRODUCTION

Frequencies of vibration gives value information for bridges, as stiffness of the bridge is related to its fundamental frequency. These fundamental frequency used to assess structural integrity or health condition [1–3]. Research study show as reduction in the frequency of vibration gives idea regarding a deterioration in the structural element of the bridge, it could be caused by any damage or failure in its component, expension joint, or support of the

*E-mail address of the corresponding author: sampatel260484@gmail.com (S.G. Patel)

bridge, or by a loss in tendon or cable forces, depending on the type of bridges considered. The structural deterioration may be caused due to ageing in materials, overloading by heavy axle loaded truck than allowable design load on the bridge, previous ground motion, settlement in bridge supports, or other damaging events such as impact loading cause due to acciedent etc.. Therefore, it is necessary that the change in frequencies of a bridge be monitored throughout its service period, so that remedial measure can be taken to ensure its safety and normal functioning.

Conventionally, a different techniques have been developed for measuring the bridge frequencies, with the use of different vibration excitations, such as ambient vibrations [4, 5], wind forces [6, 7], normal traffic loads [1, 3, 8–10], controlled traffic loads [11, 12], forced vibrations [4, 10], impact forces [13–15], among others [16]. The selection of a proper excitation method depends mainly on the dynamic properties of the bridge of interest, the type of the bridge structure and the time, effort and testing budget available for conducting the test.

In this study, I girder with post tension type of superstructure over Sabarmati River is taken to carry out vibration test to understand vibration properties of the bridge. The ambient vibration test was performed on Sabarmati Bridge (Structure no. 45/88) situated on Sardar Patel Ring Road near Bhat Village near to Ahmedabad City. Bridge is under jurisdiction of Ahmedabad Urban Development Authority, Ahmedabad, Gujarat. Ambient vibration tests were conducted on first span of the bridge from Bhat village side.The results of an ambient vibration test on the bridge are presented in this study.

2. DESCRIPTION OF THE SABARMATI BRIDGE

Sabarmati River Bridge, Structure no. 45/88 is taken to carry out vibration test to evaluate vibration properties of the bridge having I girder with post tension type of superstructure on Sabarmati River as shown in Fig. 1. It is coming under judicial of Ahmedabad Urban Development Authority, Gujarat. It is situated on Sardar Patel Ring Road near Bhat village. The bridge was instrumented with 10 accelerometers above deck besides carriageway. Ambient vibration tests were conducted on first span of the bridge. Bridge consists of 12 span of 42.50 m. Clear roadway width 7.50 m and footpath width of 1.25 m and depth of I girder is 2.350m & slab thickness of carriageway 250 mm. Geometery of the test span is shown in Fig. 2.

Figure 1. Location & Overview of Shilaj Rail Over Bridge taken for study

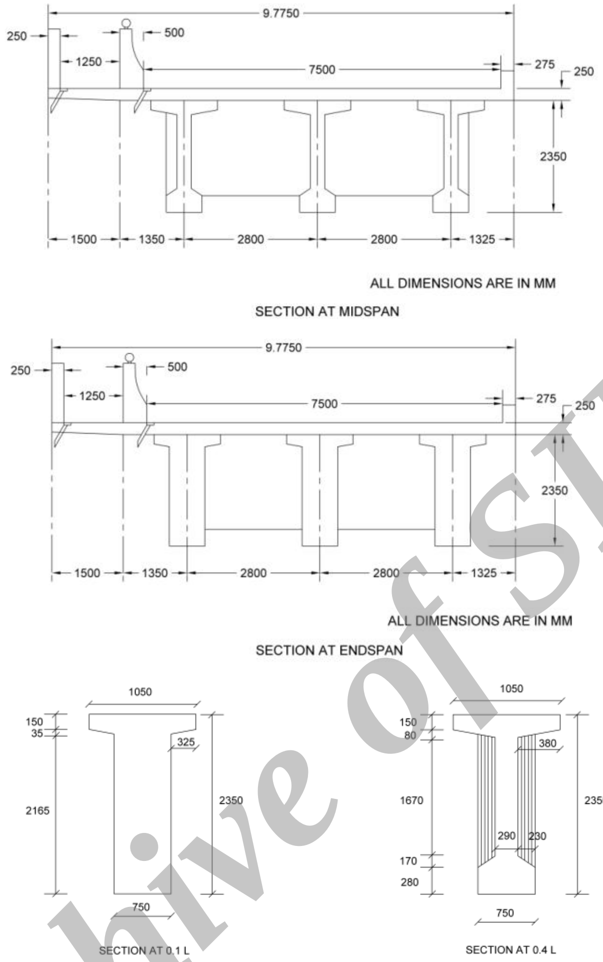

Figure 2. Geometrical sections of structural elements of Sabarmati Bridge

During the visiual inspection, severe damage or deterioration in structural elements and bearings was not found and overall health of the structure was observed in good conditions. Therefore, the purpose of testing of bridge to collect the vibration data to extract its dynamic characteristics of the bridge in good condition for future comparsion of same or similar type of bridges.

3. TEST INSTRUMENTATION

3.1 Sensors

We are using accelerometers to measures of vibration, shock, acceleration, and motion for monitoring, control, and testing acceleration. As per the acceleration measurement in particular direction we have to use the accelerometer accordingly. For experimental study, uniaxial accelerometers having a sensitivity 100mV/g and measurement range ±50g were used. To record acceleration in vertical direction measurement range between ±5g and sampling frequency of 100 Hz. At predefine location, accelerometer fixed on the test span of the bridge as shown in Fig. 3. For attachment of accelerometers to object mounting pads are used which are fixed with the bee wax or adhesives directly on the structure.

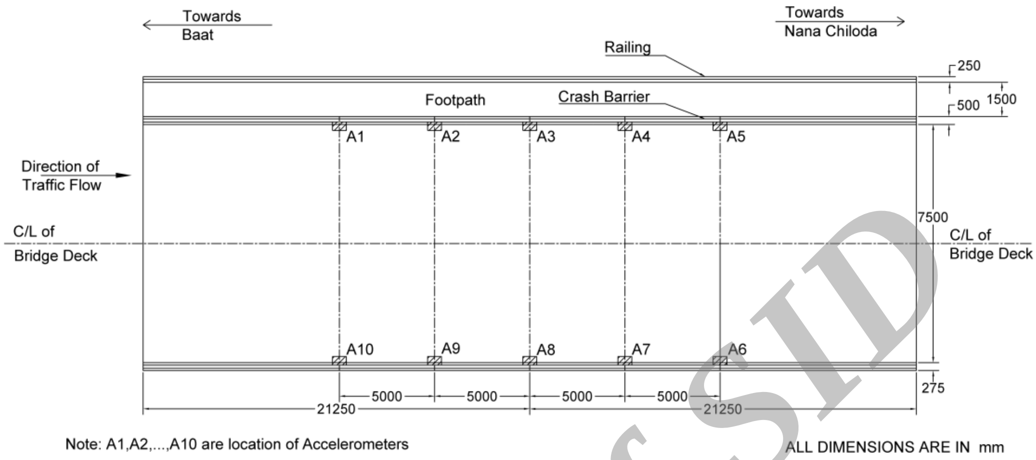

Figure 3. Location of sensor implementation on test span of bridge

3.2 Data acquisition board

NI compactDAQ NI cDAQ – 9174 and NI Data acquisition (DAQ) Modules (National Instruments, USA) are used for data acquisition system. NI CompactDAQ system consists of a chassis, NI C Series I/O modules, and software. Chassis can connect to a host computer over USB and 4-slot chassis which support NI DAQ card NI9234. NI CompactDAQ provides a flexible, expandable platform for sensor measurement system. The NI 9234 is a four-channel C Series dynamic signal acquisition module for making high-accuracy vibration frequency measurements from sensors with NI CompactDAQ or CompactRIO systems. The NI 9234 delivers 102 dB of dynamic range and incorporates software-selectable AC/DC coupling and IEPE signal conditioning for accelerometers and microphones. The four input channels simultaneously digitize signals at rates up to 51.2 kHz per channel with built-in anti- aliasing filters that automatically adjust to our sampling rate.

3.3 Data processing

Regardless of the hardware, we must send information to the hardware and receive information from the hardware. We send configuration information to the hardware (the sampling rate etc.) and receive information from the hardware such as data, status messages, and error messages. We might also need to supply the hardware with information so that we can integrate it with other hardware and with computer resources. LabVIEW Signal Express Tool to acquire acceleration data. These data are recorded in hard drive in form of .lvm file format and ASCII file format. For processing the recorded data for identify modal parameters we are using ModalVIEW software tool. After obtaining a set of time histories, Modal parameters can estimate the response of a structure. It helps to extract and visualize useful modal parameters information from acquired time and frequency domain experimental data.

4. TECHNIQUES USED FOR OPERATION MODAL ANALYSIS

The Stochastic Subspace Identification (SSI) technique, is becoming a consolidating method, being one of those methods more indicated for identification of systems submitted to natural excitation condition [17]. This method identifies a stochastic state space model from output-only measurements. Since it is practically impossible to measure the operational forces, output-only system identification techniques are required in the system identification analysis of such vibration response data. Among the different system identification techniques proposed for civil engineering monitoring applications the stochastic subspace identification (SSI) method is a reliable output-only identification technique which compares favourably to other available methodologies. For a more in-depth look at the SSI method the reader may refer to the work by Peeters and De Roeck [18] or Peeters [19].

The least-squares complex frequency-domain (LSCF) estimation method was introduced to find initial values for the iterative maximum likelihood method. The method estimates common denominator transfer function model. Lately it was found that these “initial values” yielded already very accurate modal parameters with a very small computational effort. A thorough analysis of different variants of the common-denominator LSCF method can be found in [20]. A complete background on frequency-domain system identification can be found in [21]. LSCF method was applied to the preprocessed experimental signals of tested bridge. The frequencies and damping ratios are related to the discrete-time eigenvalues. The mode shapes were estimated with the linear least squares method and stabilization diagram shows stable poles by considering the user define criteria are 1 % for frequencies, 3% for both damping and operational reference factor. The concentrated stable poles at particular frequencies represents corresponding modal frequencies of the structure.

5. EXPERIMENTAL RESULTS

The bridge was tested for 24 hours so that the distribution of averaged acceleration amplitude from accelerometer can be determined, which is as shown in Fig. 4. Throughout the duration of testing, peak accelerations across the structure ranges from approx. less than ±0.225 m/s2. Acceleration amplitudes from all the accelerometers are averaged to obtain a global indicator or the vibration levels in every hour. It is clearly observed that during peak day time hour’s 10.00 am to 4.00 pm acceleration amplitude varies between 0.145 m/s2 - 0.215 m/s2 and during night time 10.00 pm to 04.00 am pm acceleration amplitude varies between 0.135 m/s2 - 0.221 m/s2. Recorded acceleration time histories were used to extract modal parameters.

Fig. 5 shows typical acceleration time history recorded during ambient vibration testing. Using stochastic subspace identification (SSI) method, fundamental frequency of 1.88 Hz were identied and corresponging modal frequencies upto 10 Hz were identified as shown in Fig. 6. Similarly, from least-squares complex frequency-domain (LSCF) method, fundamental frequency of 1.84 Hz were identified and corresponging modal frequencies upto 10 Hz were identified as shown in Fig. 7. Results of first fundamental frequency of bridge identified by both methods give close value. From Fig. 8, it was concluded that hourly based natural frequency of bridge varies from 1.59 Hz to 1.88 Hz. Modal frequencies upto 8 modes can be identified upto 10 Hz using both mehods were given in Table 1. The bridge frequency will be blurred due to the involvement of high-frequency components resulting from the cart structure and pavement roughness. The existence of ongoing traffic is considered beneficial since it tends to intensify the track response. The fundamental frequency of the bridge represents first bending mode. Higher modal frequency represents mode shape of the bridge are corresponds to the bending, tortional or combine effect as shown in Fig. 9.

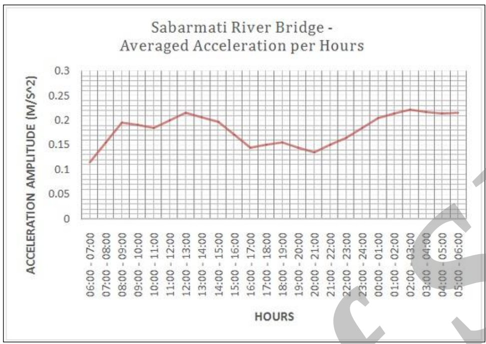

Figure 4. Averaged acceleration per hours

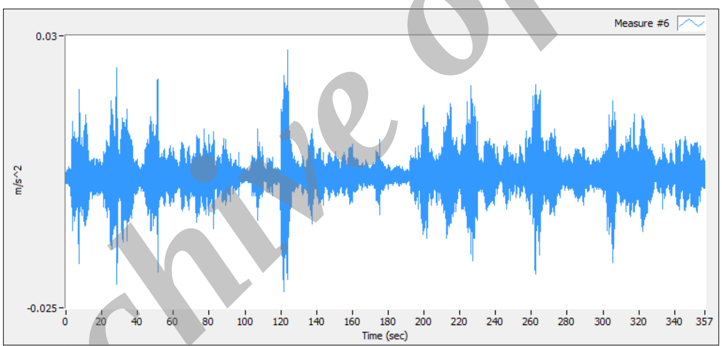

Figure 5. Typical acceleration time history recorded during ambient vibration testing

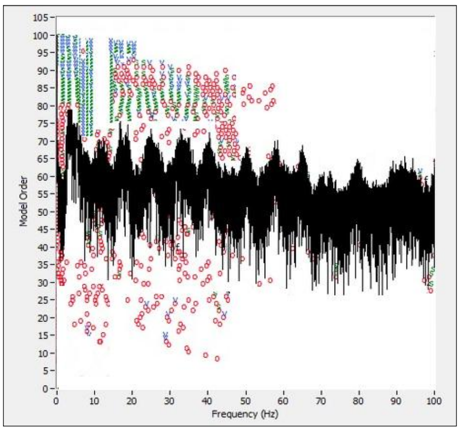

Figure 6. Modal frequencies identification by SSI Method

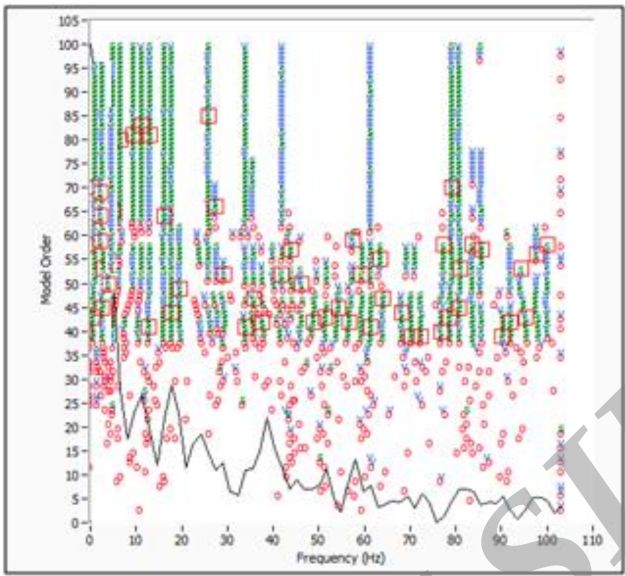

Figure 7. Modal frequencies identification by LSCF Method

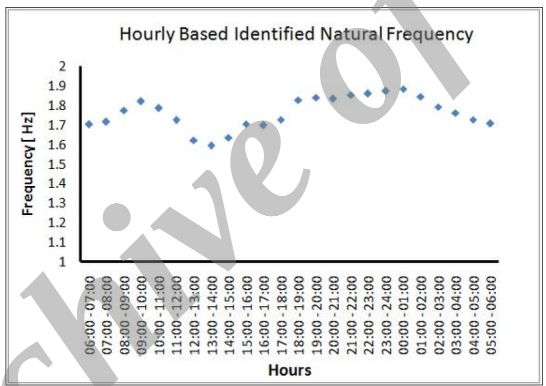

Figure 8. Hourly Based Identified Natural frequency

Table 1: Modes and modal frequencies and damping ratio of ambient vibration test

Mode	**Identified modal parameters**			
	Frequency (Hz)		**Damping Ratio (%)**	
	SSI Method	**LSCF Method**	**SSI Method**	**LSCF Method**
1	1.88	1.84	1.09	1.06
2	3.10	3.04	3.45	2.96
3	3.83	3.76	2.12	2.21
4	5.08	5.11	2.13	2.17
5	6.19	6.09	1.73	1.77
6	6.52	6.56	1.9	1.85
7	7.15	7.09	2.52	2.68
8	8.93	8.97	2.57	2.74

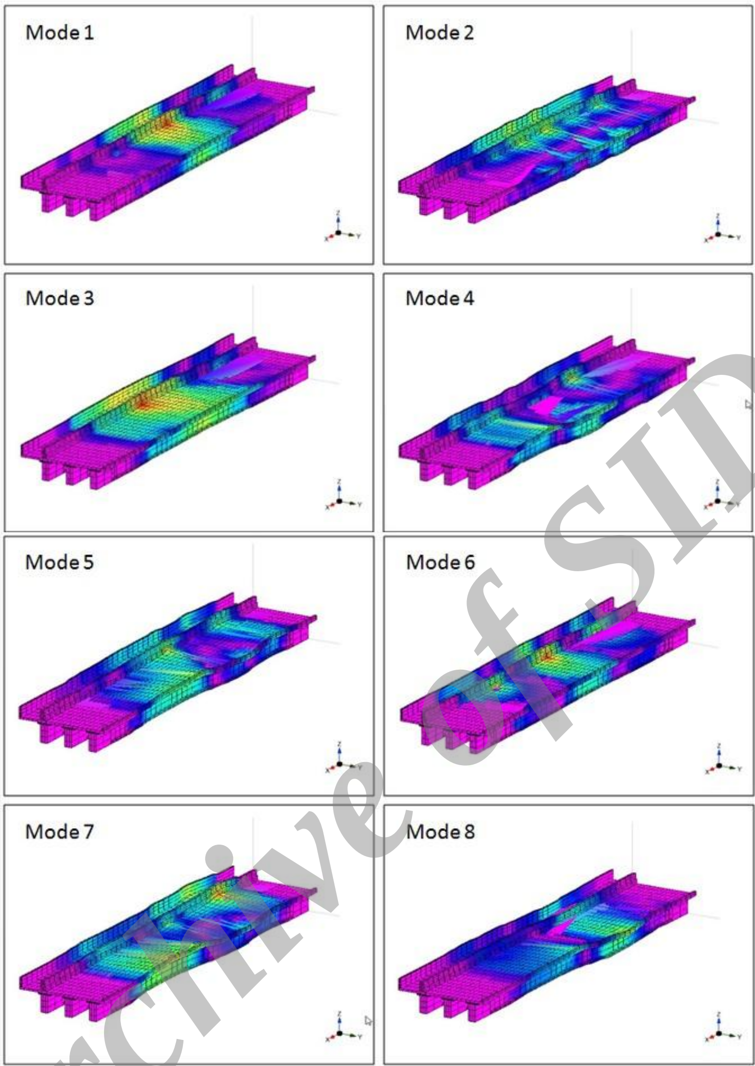

Figure 9. Mode shape of the test bridge

6. CONCLUSION

Ambient vibration testing was conducted on Sabarmati Bridge to estimate its dynamic characteristics and its results will use for future comparision of the same or similar kind of bridge structures. From experimental study, vibration data were processed using Bandpass filter is applied on the acceleration analog signal between 0.05 Hz to 50 Hz. First modal frequency of the bridge is evaluated with ambient loading is 1.88 and 1.84 Hz (Frequency corresponding values are obtained by SSI method & LSCF method respectively). Remaining modal frequencies are obtained below 10 Hz. Total 8 mode shapes are obtained in study below frequency of 10 Hz. The fundamental frequency of the bridge represents first bending mode. Higher modal frequency represents mode shape of the bridge are corresponds to the bending, tortional or combine effect. Statistical analysis of frequency results shows that the maximum relative difference of frequency estimates of bridge with ambient vibration data using SSI and LSCF methods varies from 1% to 3% and damping ratio also varies from 0.5% to 5%.

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