

A STUDY IN DETECTING THE DAMAGE CONDITIONS IN CONCRETE BRIDGES BY USING NON- LINEAR VIBRATION TECHNIQUES

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ABSTRACT:

The aim of the work presented here was to investigate the change of exploitation changes within the non-linear vibration characteristics to observe injury in concrete bridges. These changes within the non-linear vibration characteristics were studied by conducting impact excitation vibration tests on concrete beams. The non-linearity's were detected by examining the changes in first harmonic over time many time-frequency distribution estimation tools area unit mentioned together with linear vibrations against theoretical values and also the illustration of a non-linear mechanism exploitation the model was compared with experimental knowledge. Static load tests were conjointly conducted on the beams at varied damage levels. They concerned the employment of vibratory wire strain gauges to analyze the moment-rotation behavior over the cracked region many doable non-linear crack mechanisms are mentioned and 2 of them are assessed victimization the vibration and therefore the static load tests. Future experimental work is proposed to study the possible non-linear mechanisms further. The beam tests incontestable that there's a modification in non-linear vibration behavior with harm. The modification is greatest at low levels and once the beam has been loaded to half-hour of the failure load in three-point loading there's a reversal within the trend and a small reduction in non-linearity with any damage.

Keywords: concrete bridges, Static load tests.

INTRODUCTION

Using Non-linear Vibration Techniques .to discover injury in Concrete Bridges There has been abundant work printed in recent years on the utilization of vibration characteristics to discover injury in bridges. the majority of this work has been supported the idea that the vibration is linear, i.e. the natural frequencies don't seem to be passionate about the amplitude of oscillation The aim of the work bestowed here was to

research the chance of victimization changes within the non-linear vibration characteristics to discover injury in concrete bridges These changes within the non-linear vibration characteristics were studied by conducting impact excitation vibration tests o ferroconcrete beams. The non-linearity's were detected by examining the changes in harmonic over time (and thus over amplitude of vibration). many time-frequency distribution estimation tools area unit mentioned as well as the separate Fourier rework moving window, the auto-regressive model moving window, harmonic wavelets and samples of the Cohen category of linear time-frequency distributions. Static load tests were additionally conducted on the beams at varied harm levels. They concerned the employment of vibratory wire strain gauges to research the moment-rotation behavior over the cracked region. many potential non-linear crack mechanisms square measure mentioned and 2 of them square measure assessed mistreatment the vibration and also the static load tests. Future experimental work is planned to review the potential non-linear mechanisms more.

Technology based on smart elements:

With this vision in mind, a pursuit effort has been launched, at the University of urban center, to develop an economical construction system supported good ready-made concrete parts for life-long period condition watching of bridges. the concept is to supply formed RC parts embedding a affordable high sturdiness sensing system: sensors square measure expected to be

created within the kind of standardized packages, formed as associate integral a part of the ready-made component. betting on the sort of instrument used, a sensible component are going to be doubtless capable of self-detecting purpose to purpose physical quantities such as: strain and stress distribution; vibration response; cracking location and extension; temperature; moisture; pH; chloride concentration.

Dynamic tests and damage detection procedure:

During the experimental dynamic tests, the acceleration responses were non-heritable considering because the force excitation vibrations caused by wind, micro-earthquakes, pedestrians passing for the bridge, cars passing within the section of the bridges, etc. this method of acting dynamic tests is understood as close Vibration Tests (AVTs). Because it wasn't doable to record Associate in Nursing excitation force exploitation; modal parameters were obtained using Operational Modal Analysis (OMA) strategies that don't need, for his or her application, data concerning the input force. Specifically, the improved Frequency Domain Decomposition (EFDD) and therefore the random topological space Identification (SSI) strategies were used for the concrete and timber arch overcrossing, severally. Before starting During the experimental dynamic tests, the acceleration responses were innate considering as a result of the force excitation vibrations caused by wind, micro-earthquakes, pedestrians passing for the bridge, cars passing inside the section of the bridges, etc. this technique of acting dynamic tests is known as shut Vibration Tests (AVTs).

LITERATURE REVIEW

Chaojun Huang and SatishNagarajaiah, (2014)This article examines the natural frequencies and associated modes of bridge construction .it compares field observations with theoretical idealizations and finds that

the idealization wide used is correct solely in regard to sure styles of bridges, and plenty of bridges need a lot of elaborated analysis. He developed a simplified methodology to accurately estimate the elemental frequency of bridge sculptresque as a grid, the paper additionally discusses the importance of the support rigidity, and also the dynamic modulus of snap of concrete, within the estimation of natural frequencies vibration.

Bruno, D., Greco, F., Lonetti, P., (2009)In the gift work the Finite Prism technique was used for the dynamic analysis of bridges below moving vehicles. during this method, employing a combination of finite parts representing the cross section of the prism and also the main side of Fourier during this work is that the coupling of technique of express resolution of the equation of motion with the harmonic resolution consistent with the strategy of finite prism to the matter of the moving vehicle, having thought that the dynamic interaction between the series fittingly chosen to represent the behavior of the pris m within the longitudinal direction, that satisfies merely supported boundary conditions at the ends.

D.p.Thambiratnam and G.H. brameld (1995): This paper investigates the natural frequencies and associated mode shapes of bridge structure .it compares field observations with theoretical idealizations and finds that wide used idealization square measure correct solely in reference to bound varieties bridges, which several bridges need a lot of elaborate analyses. It then develops a simplified technique for accurately estimating the basic frequency of bridge sculptured as a grillage, the paper additionally debates the importance of support stiffness and also the dynamic modulus of snap of concrete, in estimating the natural frequencies of vibration.

Moni and Alam (2010):Have no text to check thought of the many retrofitting

provisions on three column concrete bridge bent in North yank nation that was designed before 1965 with inadequate unstable description. as a result of the bridge bent designed only for gravity load did not meet the unstable standards, several retrofiting techniques like steel jacketing, CFRP jacketing and steel bracing were thought of to spice up the unstable performance.

METHODOLOGY

First, it is necessary to discuss the estimation of the frequency content of a discrete finite time signal using the discrete Fourier transform and modifications that can be made to it including the auto-regressive method of predicting the frequency content. Then the analysis of a time-frequency relationship for a signal victimization the moving-window technique is going to be given. the utilization of harmonic wavelets in estimating the time-frequency relationship also will be investigated. Self-weight of the cable a stayed bridge could be a major portion of dead hundreds and it affects the stiffness of the cable stayed bridges. therefore it effects is enclosed by acting the static analysis (linear or non-linear) underneath burden before going towards the dynamic analysis of research underneath live hundreds. The aim of static analysis is to induce the initial malformed form of the cable stayed bridges.

Linear Modal Methods:

the idea of using vibration measurements to detect damage was proposed by It is based on the fact that damage will reduce the local stiffness of the structure, which in turn reduces the natural frequencies of the whole structure. Most studies into using vibration measurements to detect damage examine changes in modal properties and assume that these properties are linear, i.e. they are not related to the amplitude of oscillation. The types of indicators can be split into several main groups, each of which is briefly described below with some examples of

their application. For further details there are several review papers on vibration damage detection method

Modes of vibrations:

As cable stayed bridges square measure terribly versatile as compare to alternative sort of bridges therefore the massive displacement response of the bridge is incredibly necessary to watch once dynamic hundreds square measure applied. Frequencies and modes shapes square measure the most effective representative of the dynamic behavior of the cable stayed bridges. By playacting modal analysis mode shapes and frequencies square measure obtained that square measure then accustomed study the modal behavior of the cable stayed bridges.

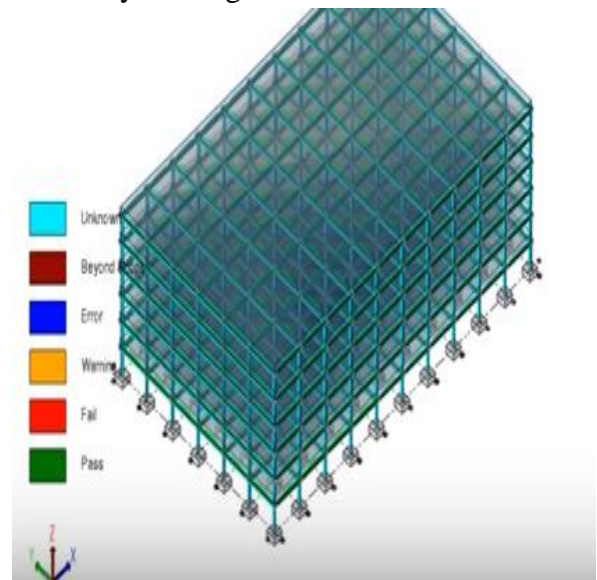


Figure: linear, non-linear and free vibration analysis

Damage Loading:

Applying Loads the beam was damaged using three-point loading. The damage levels were in steps of 1500 N, approximately 10% of the failure load. Failure was defined as the point where the beam could sustain no further increase in load. The load was applied using a small hydraulic jack and measured using a MIL 5000 kgf load cell



Damage indexes-1

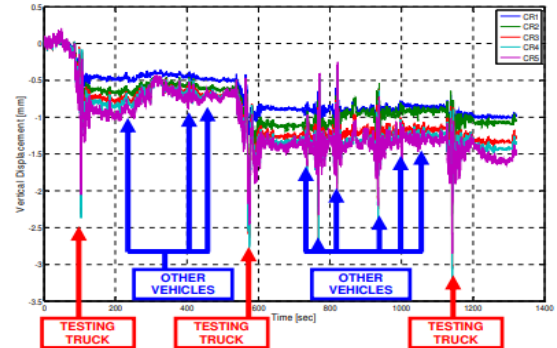
Table: Vibration intensity damage index for buildings

Intensity (vibrars)	Effect	Intensity (vibrars)	Effect
<20	No damage	<17.5	No damage
20–30	Damage likely	17.5–40	Possibility of plaster cracks
30–40	Small damage	40–72.5	Damage to load-bearing components
40–50	Cracking of load-bearing wall	72.5	Damage to load-bearing components and destruction
>50	Building liable to collapse	-	-

Natural Frequencies:

It is clear from the literature that looking for changes in natural frequency is a very insensitive method of detecting damage. Farrar and conducted tests on a steel plate girder bridge and reported only minimal changes in frequency even at extreme damage states. When the stiffness of 1 of the most plate girders had been reduced by

ninety six.4% (reducing the native bending stiffness of the bridge by 21%) the most modification in natural frequency was simply seven-membered. At lower harm levels no important modification in frequency may be determined.



Modeling a Vibrating Beam:

The derivation of a time-stepping model of a transversely vibrating simply-supported beam which allows the inclusion of non-linear damage such as a breathing crack is now presented. This model allows inclusion of damage in the form of a moment-rotation relationship over a region of the beam spanning the crack, and will allow a better understanding of the non-linear behavior exhibited by the beam during vibration. Existing methods use a rotational spring to represent damage combined with Timoshenko or Euler-Bernoulli beams between cracks to represent bending and shear deformation present if the beam was undamaged This idea is extended here, with the intention of representing the bending and shear deformation of the undamaged sections using springs, as well as the damaged regions. The beam is divided into short rigid blocks joined using rotational and transverse springs which represent bending and shear deformation respectively. Any stiffness reduction due to a crack is represented by adjusting the rotational spring stiffness at that spring position. It is then possible to derive equations for the displacement and rotation of each rigid block in terms of the accelerations (both transverse and rotational) of the blocks and

use these equations in a time-stepping method to find the response of the beam to a set of initial conditions.

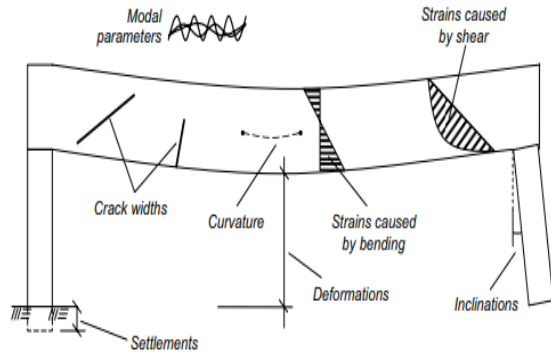


Figure: Bridge Modeling a Vibrating Beam structure

RESULTS

Table: Experimental natural frequencies for four-span bridges of different ages:

mode	bridge age /years				
	frequency/Hz				
1	0	5	12	18	25
2	2153	2091	2012	1970	1861
3	7203	1702	6021	1458	5442
4	1863	3022	1425	4132	1476
5	4848	4451	1432	4184	2638
	1	0	0	1	7

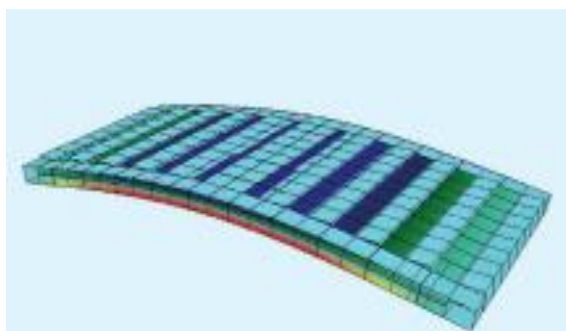


Figure: bending Mode-1

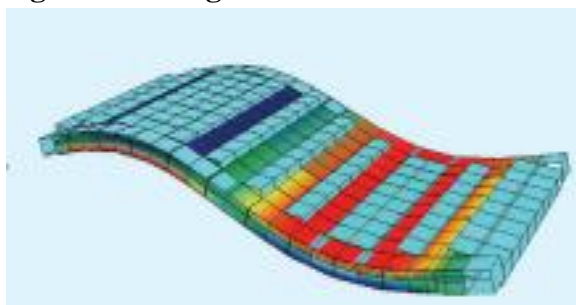


Figure: bending Mode-2

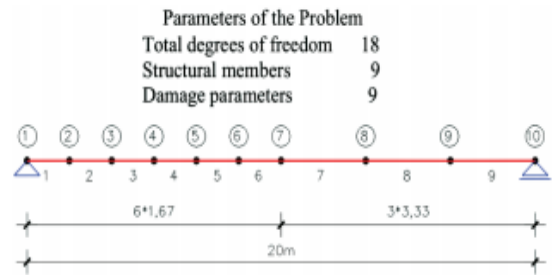


Figure: One-span (of four-spans) girder bridge, divided in 9 non-symmetric finite elements with 10 nodes

Table: Frequencies and damping ratios for the first damage test

mode	frequency(Hz)		damping ratio	
	mean	σ	mean	σ_{ξ}
2	6.33	0.05	2.88	1.72
3	15.48	0.10	1.11	0.71
4	18.64	0.09	2.22	1.47

Modal identification after the damage tests:

As mentioned before, only ambient vibration was the force excitation during the dynamic data acquisition in Övikbridge. Therefore, an OMA technique which can determine the modal parameters of the structure with just information of the dynamic response was used. In this case study, the EFDD Method, was applied to the obtained history of accelerations for calculating the modal parameters of the bridge after the two damage tests.

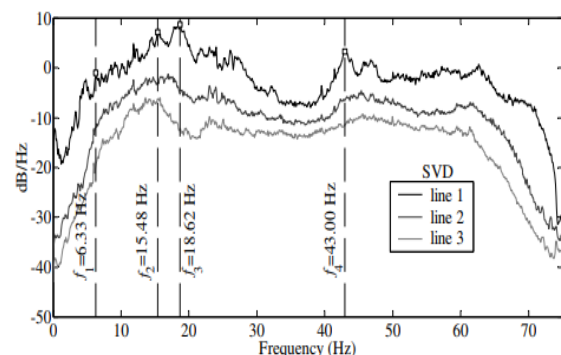
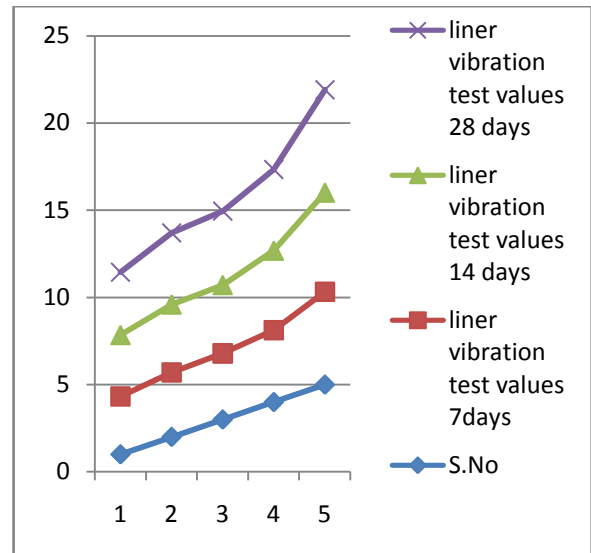


Figure: Singular Values of the Spectral Density Function for all setups in the first damage test.

Table: testing the non-linear vibration test values

S.No	non-linear vibration test values		
	7days	14 days	28 days
1	37.91	56.14	62.44
2	39.81	56.59	66.82
3	37.78	54.66	67.34
4	41.78	56.14	62.22
5	40.15	52.87	61.93



Graph: Concrete bridge liner vibration TEST VALUES

The developed method of vibration diagnostics enables one to assess the degree of efficiency of measures for the restoration and strengthening of the structure. The obtained data provide a general algorithm for creating and performing procedures for vibration diagnostics of cracking in reinforced concrete structures. Model identification of the bridge structure was obtained by using measurement data from the dynamic and the static tests. Linear model of the bridge was generated based on test results and this model is used for structural assessment and evaluation of the bridge structure. They involved the use of vibrating wire strain gauges to investigate the moment-rotation behavior over the cracked region. Several possible non-linear crack mechanisms are discussed and two of them are assessed using the vibration and the static load tests. Future experimental work is proposed to study the possible non-linear mechanisms further. The beam tests demonstrated that there is a change in non-linear vibration behavior with damage.

CONCLUSION

An investigation into the possibility of using non-linear vibration characteristics to detect damage in reinforced concrete bridges has been presented here. A time-stepping model

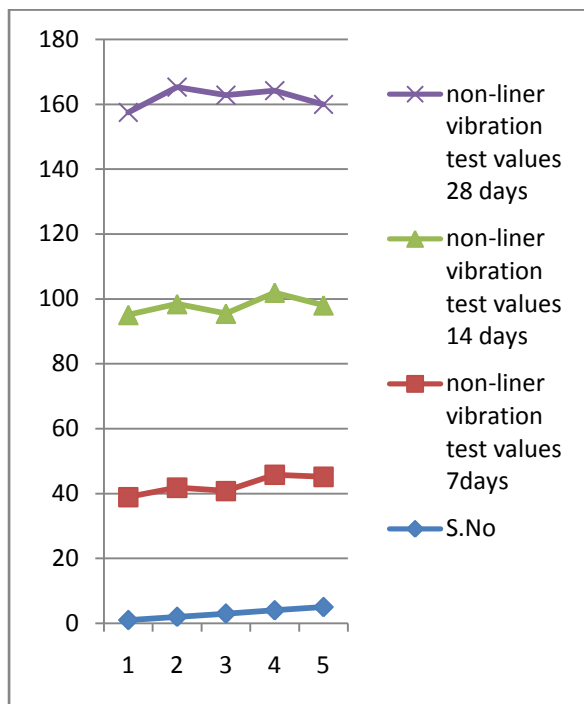


Figure: non-linear vibration test variations Table: concrete bridge liner vibration test values

S.No	liner vibration test values		
	7days	14 days	28 days
1	3.32	3.52	3.6
2	3.70	3.89	4.10
3	3.79	3.92	4.23
4	4.12	4.56	4.65
5	5.32	5.69	5.89

has been derived to aid the understanding of non-linear crack mechanisms present in damaged beams. A literature review has revealed much work has been conducted on the use of vibration tests to detect damage and non-linear vibration properties of concrete beams. An investigation into the possibility of using non-linear vibration characteristics to detect damage in reinforced concrete beams under simply supported and free conditions were focused. Forced vibration testing of reinforced concrete beam has been carried out using small hammer and random loadings to identify the changes in the vibration characteristics under different damage conditions. Along with the dynamic characteristics, the static response of the beam during application of the loading is also obtained to evaluate the damage state. Dynamic characteristics (frequencies and mode shapes) have been evaluated from the FRF matrices based on the responses measured through accelerometers.

- Studying non-linearity's in the response to impact excitation is unlikely to be a useful damage detection tool for concrete bridges
- The crack closure mechanism is not a realistic mechanism for cracked concrete.
- To improve the method of measuring the moment-relative rotation relationship using static load tests, it is recommended that modifications be made to the vibrating wire strain gauges and to the beam
- Additional work is required to assess the possible non-linear damage mechanisms. To confirm the conclusion, drawn from a model of the cracked concrete region, that the increase in stiffness due to cracked concrete strength is insignificant compared to the overall stiffness of a section of cracked concrete beam, it

is proposed that static load tests on a beam with a pre-cast plate be conducted.

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