GeoWatch

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Keynote:

Scope:

GeoSIG has supplied several instruments that are being used by researchers on several occasions in cooperation with each other. In this issue we present a very recent coordinated measurement effort performed by experts from University of Sheffield, University of Porto and City University Hong Kong, on one of the fifth longest span cable supported bridges of the world, The Humber Bridge in England.

Ambient Vibration Testing Of The Humber Bridge, England

This article is provided as a courtesy of Prof. James Brownjohn of the University of Sheffield, Department of Civil and Structural Engineering, Vibration Engineering Research Section.

Figure 1. Location and general view of the bridge

The Humber Bridge is the fifth-largest single-span suspension bridge in the world with a centre span of 1'410 metres and a total length of 2'220 metres. It was opened in 1981.

An international team comprising:

Prof. JMW Brownjohn	University of Sheffield, UK
Dr. Paul Reynolds	University of Sheffield, UK
Mr. Chris Middleton	University of Sheffield, UK
Mr. Filipe Magalhaes	FEUP Porto, Portugal
Prof. Elsa Caetano	FEUP Porto, Portugal
Prof. Ivan Au	City University Hong Kong
Prof. Paul Lam	City University Hong Kong

with support from Dr. Ivan Munoz Diaz, Prof. Aleksandar Pavic, Dr. Stana Zivanovic, Mrs. Eunice Lawton, Mrs. Tuan Norhayati Tuan Chik and Mr. Mohammad Muaz Aldimashki from Sheffield, Prof. Alvaro Cunha from FEUP and Mr John Cooper, Mr Peter Hill and Mr Ian Allenby from Humber Bridge Board Tested the bridge during the week 14th-18th July 2008 as part of EPSRC funded research project:

EP/F035403/1, Novel Data Mining and Performance Diagnosis Systems for Structural Health Monitoring of Suspension Bridges.

The exercise had several purposes:

- To re-evaluate the modal properties of the bridge and provide a modal model in digital form, that would be used as a baseline for calibration of a finite element model of the bridge
- To evaluate the viability of using standalone recorders with precision timing (via GPS) to provide time histories of response that could be used for operational modal analysis of such an extended open-space structure
- To evaluate the difficulties of operational modal analysis procedures in estimating modal parameters for super-low frequency structures with short data lengths and to evaluate the effect of non-stationary structural (hence modal) parameters on the procedure of gluing mode shape pieces.
- To establish collaborative links and share expertise among University of Sheffield, FEUP and City University.

The bridge was tested in 1985 by a team from the University of Bristol:

Brownjohn, J. M. W., Dumanoglu, A. A., Severn, R. T. and Taylor, C. A. (1987) Ambient vibration measurements of the Humber Suspension Bridge and comparison with calculated characteristics. Proceedings of the Institution of Civil Engineers, Vol. 83, Part 2, 83, pp. 561-600.

The 1985 test used only three Schaevitz LSOC accelerometers, about 2 km of cable, a two channel spectrum analyzer and a four-channel analog tape recorder. The testing lasted two weeks, and data processing to identify the modes, replaying data tapes through the spectrum analyzer and using the procedure known as 'peak picking' lasted about 6 months. The analog tapes can no longer be read and the digital modal description did not survive migration between storage formats in the last 23 years. Hence while the mode frequencies and general form of most of the mode shapes are useful these are not available digitally. Also the resolution was poorer, the damping ratio estimates are known to be heavily biased due to the crude technology, the signal to noise ratios of the sensors are poor and, made worse by the poor dynamic range of the tape recorder, the torsional mode shapes could not be resolved using only three sensors and it was not possible to measure simultaneously points on towers, main span and side spans. So there are several reasons to need an up to date study.

The new study involved new instruments consisting of ten GSR-24's utilising internal or external accelerometers, all brought together from FEUP and Sheffield.

Figure 2. Instrumentation used during measurements

The testing was divided into 28 measurements spanning five days: For example on day 2, measurements concentrated on the southern part of the bridge, in the direction of the town of Barton. Each of the box sections of the bridge, are identified by an odd number with prefix b (for Barton, south) or h (for Hessle, north). Recordings were made mainly at alternate hanger locations, in each case maintaining at least one fixed (reference) location on the main span. The set of seven measurements on day 2 listed below used a reference pair (21h) on the Hessle side and one (49b) on the Barton side, with the remaining three pairs of recorders roving on the Barton side with 10-minutes to relocate between one-hour recordings. Measurements included one at the Barton tower (78b) with including locations 77b/79b across the bearings, then moved into the Barton side span. Measurement setup 14a was a short recording to cross-check calibrations (as shown in Figure 3).

	S7/8		S9/A		S1/2		S3/4		S5/6				
measurement	Ref1		Ref2		pair 1		pair 2		pair 3		delay	duration	total
8	21	h	49	b	39	b	43	b	47	b	10	60	70
9	21	h	49	b	51	b	55	b	59	b	10	60	70
10	21	h	49	b	63	b	67	b	71	b	10	60	70
11	21	h	49	b	**77**	**b**	**78**	**b**	**79**	**b**	10	60	70
12	21	h	49	b	75	b	83	b	87	b	10	60	70
13	21	h	49	b	91	b	95	b	99	b	10	60	70
14	21	h	49	b	103	b	107	b	111	b	10	60	70
14a	21	h	49	b	49	b	49	b	49	b	10	15	25

Figure 3. Sample Measurement Setup

The configuration for measurement setup 9 is shown in Figure 4, the red dots indicate the 10 recorder locations.

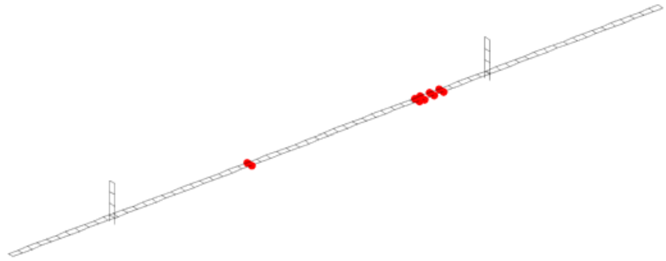

Figure 4. Recorder location schematic for measurement setup 9

The following are some highlights from the measurements.

Figure 5. Performing cross-calibration and synchronization check on east side of bridge

Figure 6. Surviving British weather on the upper portal of one of the towers

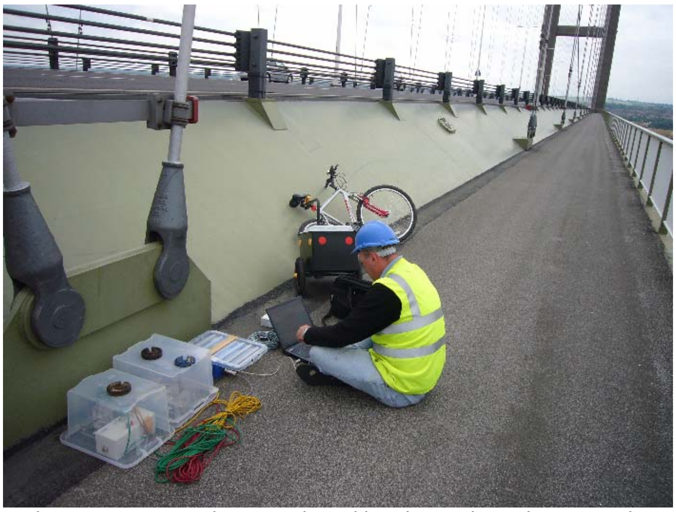
Figure 7. Programming recorder, with enhanced weather protection


Figure 8. Checking recorder while measuring relative motion across the tower bearing


Figure 9. Continuously recording 4-channel recorder inside the deck at h21

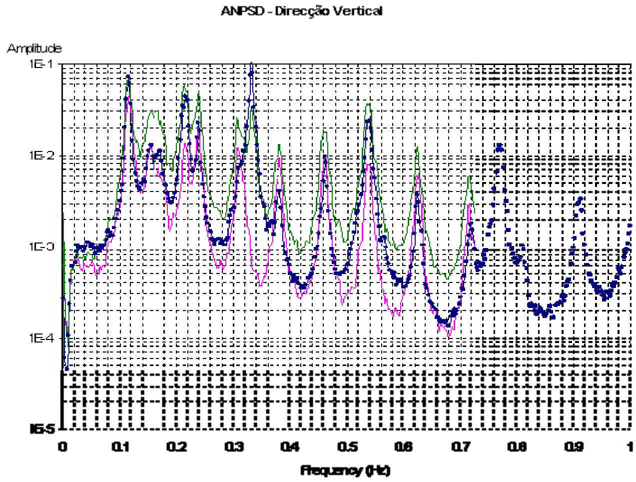

Figure 10. Aggregate normalized PSD for vertical acceleration response.

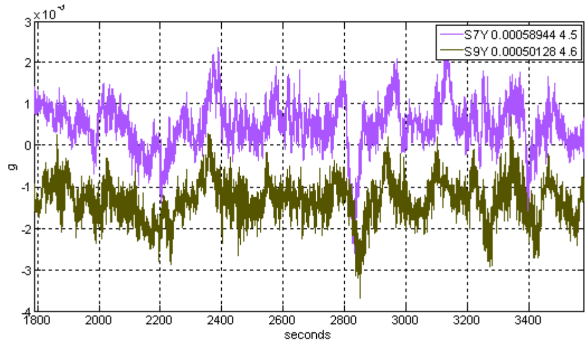

Figure 11. Lateral response at h21 and b49 showing common but time-shifted deck rotation with lateral vibration superimposed

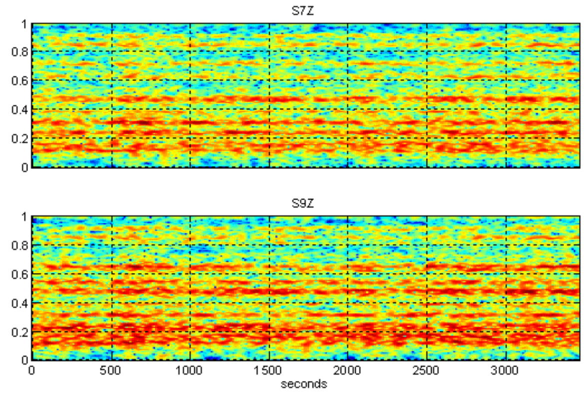

Figure 12. Spectrogram of vertical response at h21/b49

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