LONG TERM OBSERVATION OF RC-BRIDGE USING CHANGES IN NATURAL FREQUENCY

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ABSTRACT

Laboratory tests have shown that an early indication of deterioration seems possible by observing the relative change of eigenfrequencies. A relative change of about 25% was found in the very advanced stage of deterioration. Tests have been carried out in 1986 - 88 on a 3-span RC footbridge, to evaluate the accuracy when using a simple measurement of a well defined eigenfrequency to give a long term overall indication of deterioration or crack formation. It is concluded that the technique should be considered as a tool when evaluating structural integrity in simple RC structures.

Key-words: Long term observation, RC structures, Dynamic parameters.

1. INTRODUCTION

Progressive deterioration of concrete structures due to alkali silica reactions and frost-thaw influence has become a serious problem. It has increased the importance of making observations on full scale structures in order to obtain the experimental results necessary for the development of theories for predicting service life.

Long term observation is discussed in the literature /1 - 3/. This paper describes tests carried out as a continuation of the work reported in /4/, where laboratory tests with RC-beams deteriorated by frost-thaw exposure were performed. Dynamic methods, also used by other authors (see references in /4/), were applied to correlate relative changes of material frequencies and damping with carrying capacity. It was found that the techniques used gave an early indication of incipient deterioration. The relative change of natural frequency was the same for the 3 lowest frequencies and was about 30% when the beams were fully deteriorated or mechanically overloaded. The change in damping at the same stage was about 100% but larger scattering of measured values was observed.

It has been the scope of this work to evaluate whether the relative change of a well defined natural frequency or the change of the corresponding damping observed by impulse loading can be used to give an overall indication of deterioration or crack formation. The technique is not meant to give detailed information but to be a technique simple to use to decide whether more detailed methods should be used.

One requirement for accepting the technique is that loading and recording is fast and simple to perform and this is the case. The other requirement is that contributions to changes in frequency or damping originating from other sources than deterioration or cracking, i.e. temperature, humidity, foundation etc., should be either small or predictable.

This last requirement has been investigated by tests made on a 3-span RC footbridge built in the 1960 ies and not in use and with no asphalt surface layer. There is no sign of deterioration or cracking. It is assumed that all changes in natural frequency and damping in the measuring period 1986 - 88 are solely caused by other phenomena than deterioration or cracking.

If these changes are negligible compared with the expected changes from a sound to a fully deteriorated or cracked structure (about 30% and 100%) then the technique may prove to be useful in long term observation schemes.

A theoretical prediction of the bridge behaviour and preliminary tests are reported in /5/.

2. TEST SET UP

The reinforced concrete footbridge has 3 spans of 8.9 and 10.7 and 10 m and is simply supported at one end and at the other end fixed in a motorway ramp as shown in fig. 1 and 2.

The impulse load is produced by a weight of 166 kg falling from a height of 0.10 - 0.15 m and landing on a rubber buffer. The force-time curve shows a max. load of about 30 kN and a duration of about 30 m sec. The loading system and the force-time diagram is shown in fig. 3 and 4 and the loading position in fig. 1.

A FFT analyzer (Hewlett-Packard 3582 A.) in combination with two accelerometers (Brüel & Kjær 4338, preamplifier 2626) were used to record the loading events. The accelerometers were connected in series to give response for bending modes only, by compensating for torsional modes. Measurements were made with accelerometers placed nearly midspan in midsection as shown in fig. 1. Averaged results of 4 recordings of the transfer function (ratio between acceleration and force spectra) were used in the evaluation, and the lowest natural frequency in bending only was considered. The damping was found by means of the 3dB bandwidth method and curve fitting techniques.

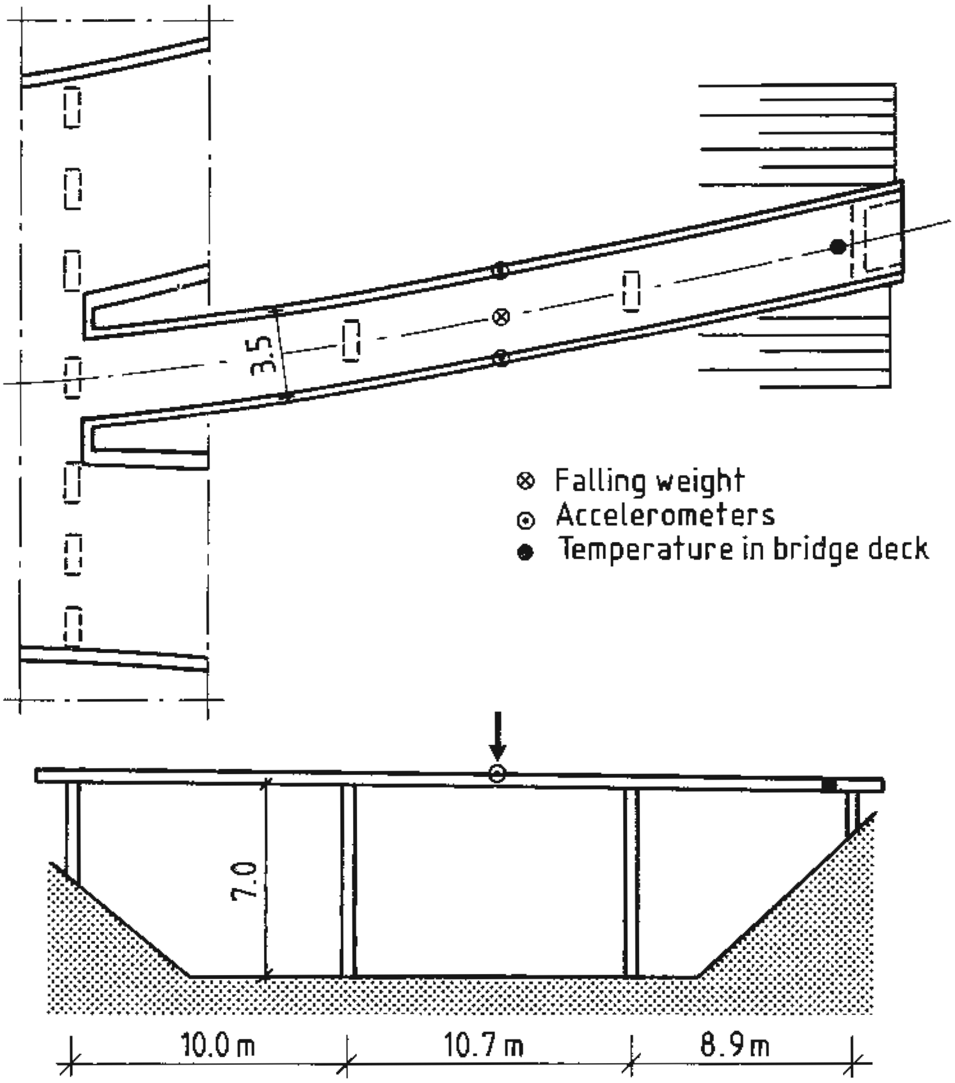

Fig. 1. Sketch of RC footbridge.

An averaged recording of the transfer function is seen in fig. 5 and the full experimental set-up is shown diagrammatically in fig. 6.

The measuring system was calibrated occasionally during the measuring period and the inaccuracy of the frequency in the actual frequency range corresponded to a coefficient of variations less than 0.01. It was also found that the recording was insensitive to changes in the ambient temperature, which was measured.

In the last part of the measuring period the temperature distribution through the bridge deck was measured by temperature sensors (Analog Devices AD 590) placed at 8 levels in a borehole in the position shown in fig. 1.

Fig. 2. Footbridge with loading arrangement.

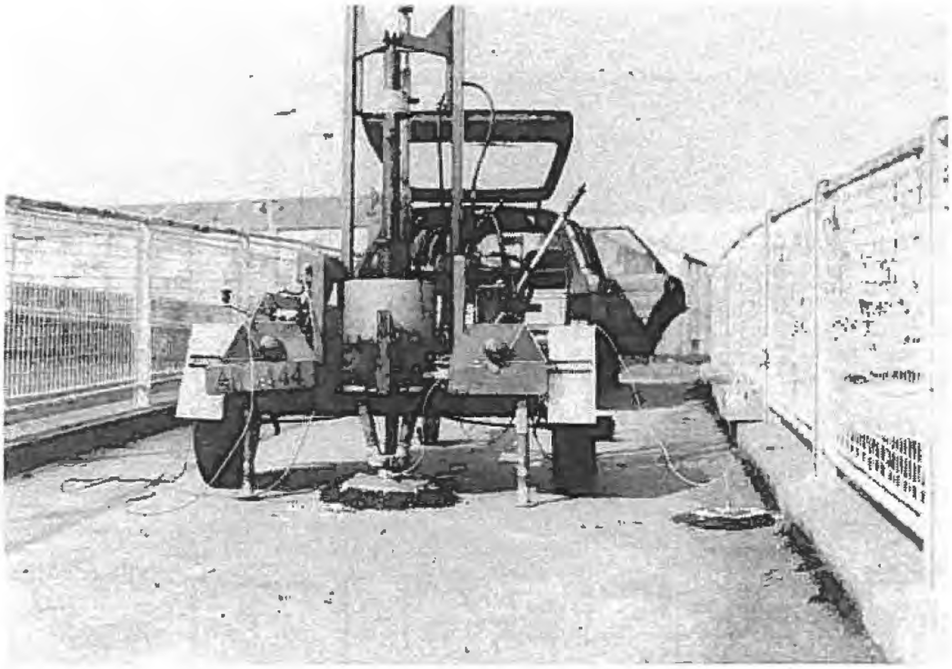

Fig. 3. Falling weight load arrangement.

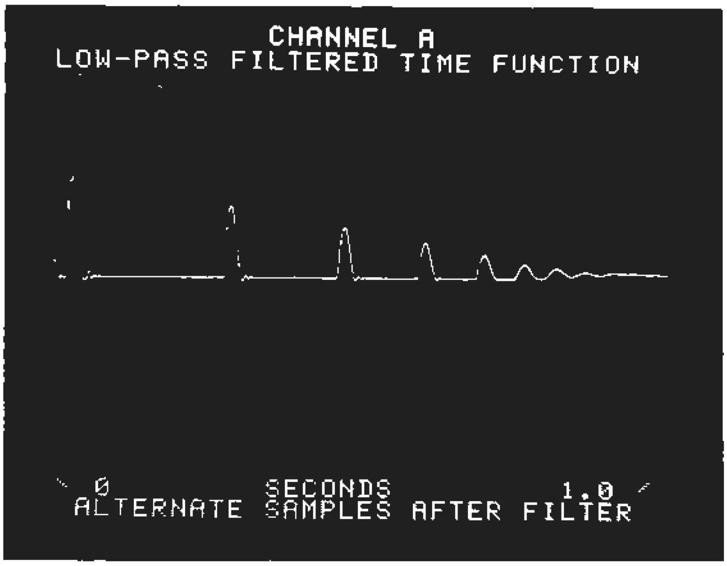

Fig. 4. Force-time diagram.

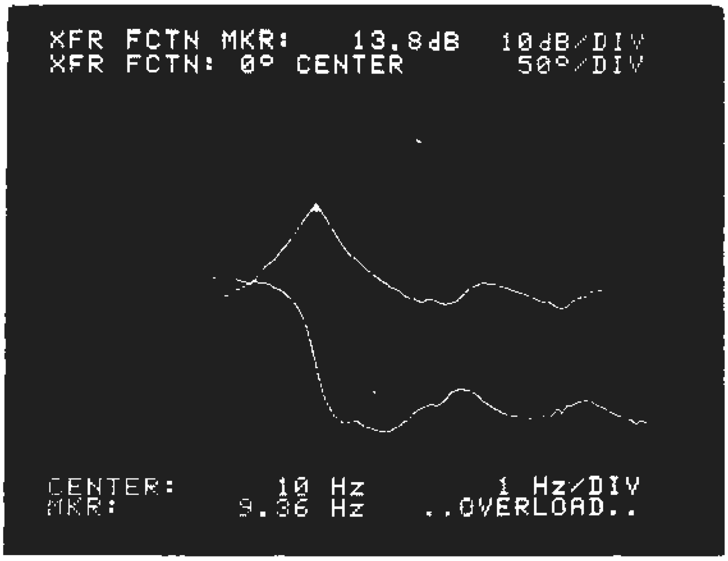

Fig. 5. Transfer function (amplitude and phase) average of 4 loadings.

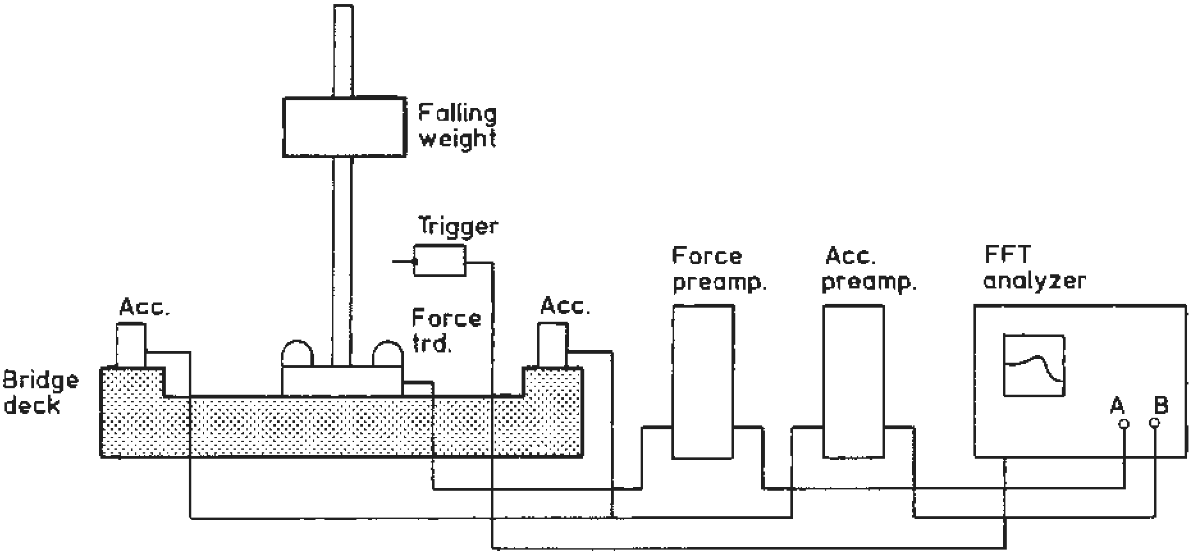

Fig. 6. Diagram of instrumentation.

3. TEST RESULTS

Results giving frequency and damping for the lowest natural frequency in bending and ambient temperature throughout the whole measuring period are shown in fig. 7. A 10% change in frequency is observed during a year but it is systematic from one year to the next and is partly due to changes in ambient temperature. By measuring the frequency at the same time of year the changes from year to year are small and not systematic and correspond to a coefficient of variation of about 0.01. This may be considered negligible compared with the changes in natural frequency of about 30% corresponding to advanced deterioration observed in /4/.

There is not the same systematic change of damping and the scattering of results is big. The loss factor (3dB band width technique) may change about 30% from measurement to measurement which is not small compared with the changes of about 100% caused by advanced deterioration as found in /4/. The damping may even change by a factor of two during a day as seen in fig. 8.

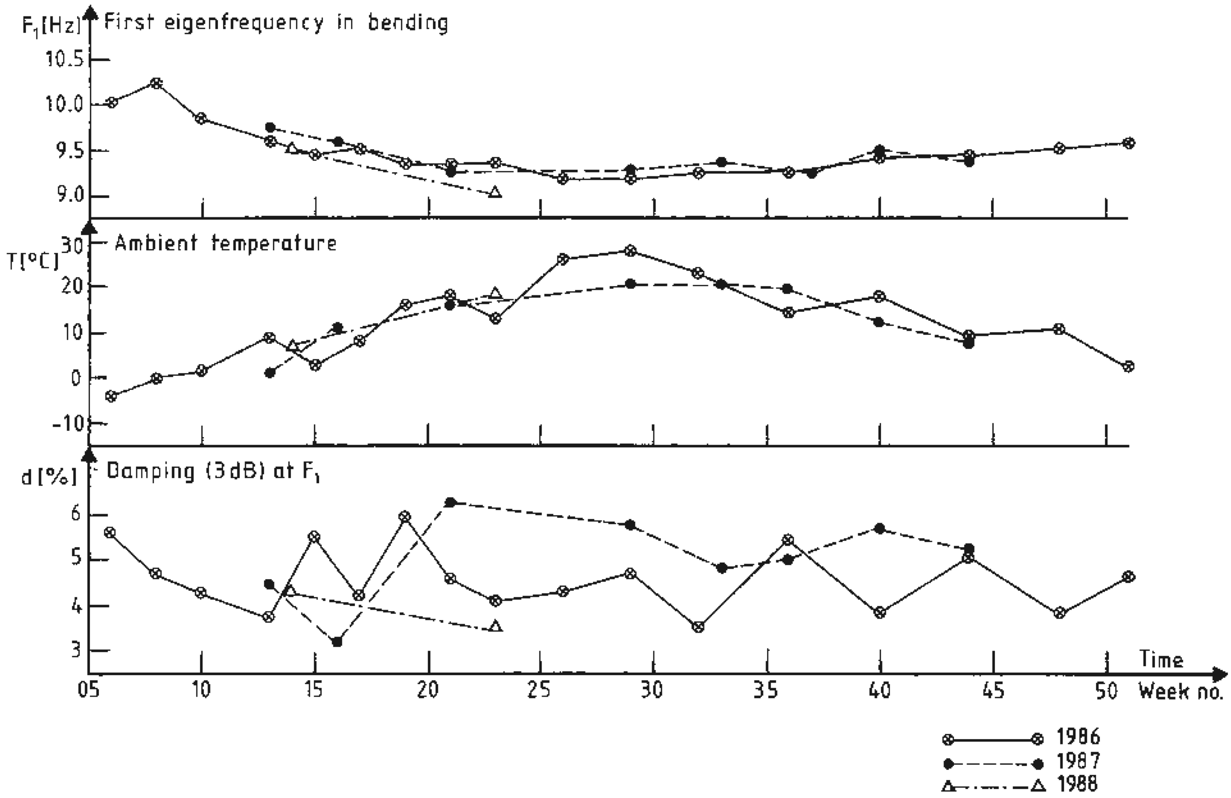

Fig. 7. Changes in relative frequency, damping and temperature 1986 - 1988.

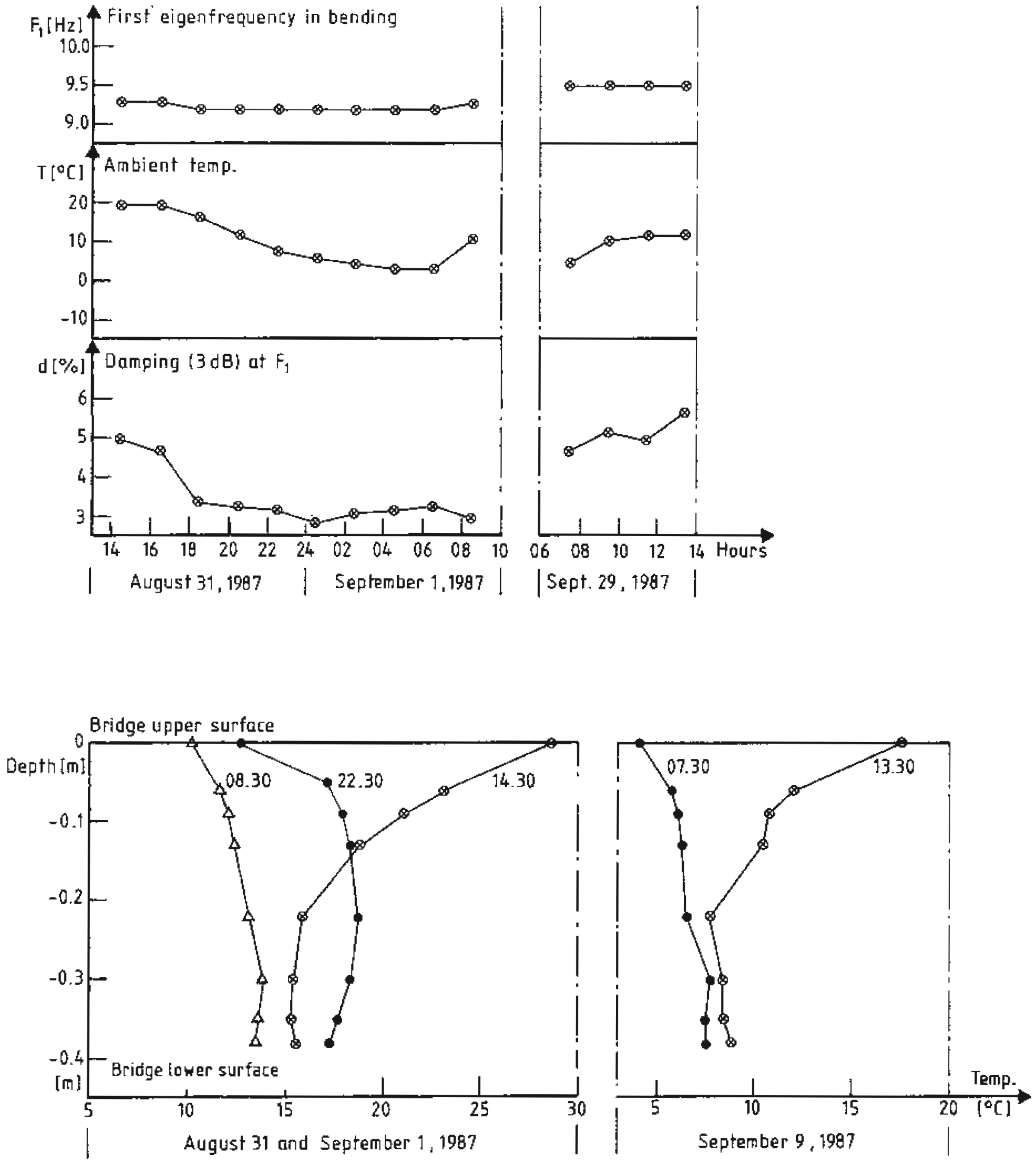

Fig. 8. Changes in relative frequency, damping and temperature in short term tests.

What causes these changes is not clarified. There are changes in the temperature profiles through the bridge deck during the day as shown in fig. 8. This may give changes in length and curvature of bridge which can influence support conditions and thereby damping. Windspeed, ambient relative humidity and temperature and temperature gradients through the deck all influence humidity transport in the bridge deck, in particular at the surface, and may thereby also change damping /6/.

4. CONCLUSION

The test results show that the relative change of a well defined natural frequency seems to be very little influenced by changes in temperature, humidity, support conditions,etc. in a fully hardened not deteriorated RC structure of simple geometry, if measurements to be compared are made at the same time of the year. This indicates that the technique may prove useful by giving an idea of the overall development of long term deterioration and cracking in RC structures. The technique may not be considered a substitute but a supplement to other observation techniques.

The change in structural damping can so far not be used in a similar way because changes not due to deterioration or cracking are relatively big compared to the change expected in a fully deteriorated structure.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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