The effect of corrosion on the natural frequency and modal damping of reinforced concrete beams

H. Abdul Razak , F.C. Choi

Past investigations and surveys have revealed that deterioration caused by reinforcement corrosion causes the design life span of structures to be shortened. As reported by Wallbank [1], of 200 concrete highway bridges examined, 25 had minor blemishes, 114 classed as fair and 61 were categorised as being in poor condition. The primary reason for this deterioration was caused by corrosion of reinforcement. This phenomenon has been confirmed by other researchers worldwide. Transport Research Laboratory, UK [2] studied the effects of corrosion deterioration on concrete bridges. The results showed that severe general corrosion can cause a complete breakdown of the bond between concrete and the reinforcement. Yoshihiro et al. [3] found that a reduction in stiffness and load carrying capacity occurred in corrosion damaged beams.

This paper is concerned with the reduction in strength of deteriorated beams caused by corrosion of reinforcement. The primary objective of the experimental study is to establish a relationship between the degree of corrosion damage in beams and the changes in natural frequencies and modal damping. Visual inspection and changes in load carrying capacity were adopted to assess the state of reinforcement corrosion. Modal tests on the beams were conducted to determine the modal parameters. By comparing the data obtained, the effect of corrosion damage on the modal parameters such as natural frequencies and damping ratio can be investigated.

Experimental programme

In this investigation, three reinforced concrete beams were cast. Two of the beams were subjected to different states of reinforcement corrosion while the other acted as

Fig. 1. Overview of crack on side of the test beam.

a control. The details of the test beams and the technique adopted to induce corrosion in the reinforcement are described elsewhere [4]. Signs of corrosion, cracking and crack pattern were recorded through visual inspection. Longitudinal crack widths on the side of the beam were measured using a crack microscope. Modal tests were performed on all the test beams prior to load testing the beams to failure to ascertain the load carrying capacity. The extent and severity of the damage on one of the corroded beams is illustrated in Fig. 1.

Modal test

Two methods of modal testing were adopted to obtain the modal parameters; the transfer function and the normal mode methods. The transfer function method is based on the use of digital signal processing techniques and the fast Fourier transform (FFT) algorithm to measure the transfer function between different points on the test structure. In this investigation, white noise was used as the excitation signal for the vibration shaker which was permanently positioned at the soffit of the beam and coincident with reference point number 72 as shown in Fig. 2. The input force was measured by means of a force transducer mounted on to the soffit of the beam and connected to the shaker by means of a flexible drive rod. The sine wave rated force of the vibration shaker is 294 N.

The response signal was picked up using a single general purpose low impedance accelerometer having a sensitivity of 100 mV/g. The accelerometer was moved from point to point until all the measurement locations were covered. The measurement points which were located on the top surface of the beam are also shown in Fig. 2. It can be seen that points 1, 56, 57, 112, 113 and 168 were located at the supports. The distance between each point was 40 mm and 50 mm in the longitudinal and transverse directions of the beam, respectively.

Initially, the transfer function spectrum within a 4 kHz frequency span was obtained in order to locate roughly the resonant frequency peaks of all the flexural modes within the band. Subsequently, zooming within a 100 Hz span of the resonant frequency peak of a particular mode was carried out. The measurements were made using a block size of 400 lines, thus giving a resolution of 0.25 Hz per spectral line. By using modal analysis software, the curve fitting process was performed on the transfer function spectrums obtained to extract the natural frequencies, damping ratios and mode shapes. The software estimates damping using the half-power points bandwidth.

In modal testing, the normal mode method is normally conducted to establish the damping characteristics of the structural system. This method excites the undamped or ‘normal’ modes of the test structure one at a time. Typically this is done by using multiple shakers to excite a single mode of vibration. In order to measure damping, a particular mode would have to be properly excited initially and then the shakers are simultaneously shut off. This would simulate an impulse response of the structure at a single frequency that is the frequency of the excited mode, and ideally should exhibit a damped sinusoidal response at all points on the structure. Thus, the damping of the structure at the modal frequency can be measured from the envelope of the damped sinusoidal response. In general the method is difficult, time consuming and expensive to implement.

However, in this study a modification was applied to the method using a single shaker. The first three modes of vibration were investigated by exciting the test beam at the anti-node points ascertained from the transfer function method. The response amplitudes were picked up using 16 accelerometers positioned at points along the centreline on the top surface of the beam and by using a high speed, multichannel digitizer with dynamic signal conditioning, the data were sampled and acquired simultaneously. The excitation signal and frequency were acquired from a sine wave generator and the modes were excited at a reasonable amplitude between 0.5 and 1 Vpp. Referring to Fig. 2, the excitation point for modes 1 and 3 was point number 84 while for mode 2 it was at point number 73. Once a mode was properly excited and a steady state of vibration was achieved, the shaker was shut down and the vibration of the beam allowed to decay freely. The amplitudes of vibration at all the points were recorded during the decay period. From these data, an algorithm known as the logarithmic decrement,

d_n, as given in Eq. (A1), was used to extract the
value of z, which is the damping ratio [5].

Load test

modal testing is shown in Fig. 3. A concentrated line load was applied across the beam at mid span using a load actuator controlled by a servo hydraulic pump. The loading rate was controlled and maintained at a constant rate until the beam failed. Displacement transducers positioned at the beam soffit at mid span and a load cell placed directly above the load actuator measured displacements and applied loads, respectively. These measurements were then acquired using the high speed, multichannel digitizer thus enabling the load–deflection plot to be displayed while the test was being conducted. Finally, the failure mode, crack width and crack pattern were recorded.

Full text available at :

http://www.sciencedirect.com/science/article/pii/S0141029601000050

http://ac.els-cdn.com/S0141029601000050/1-s2.0-S0141029601000050-main.pdf?_tid=6f59f448-781f-11e3-8709-00000aacb35d&acdnat=1389156395_fe9cc521987889353e8edfd6467acda4