MONITORING FATIGUE DAMAGE IN REINFORCED CONCRETE BEAM

Kyoto University Member of JSCE Koichi ONO
Kyoto University Student Member of JSCE ○Phongthon THARACHAI
Kyoto University Student Member of JSCE Shingo GOTO

1. INTRODUCTION

Reinforced Concrete Bridge slabs experience damage from passing heavy traffic. One way to reduce stress in the steel reinforcement of this kind of structure is by applying an externally bonded steel or fiber plastic plate to its tension face. Thus, in general, the externally bonded plate RC slabs are previously damaged structures. Consequently, the fatigue life of this kind of structure divides into two parts which are a condition before strengthening and a condition after strengthening. The remaining life of the structure before strengthening must also take in to consideration. Thus, the simple and yet precise measuring method of such fatigue damage is important.

In this paper, monitoring a degradation process by changing natural frequency of unstrengthened concrete beam, carbon fiber sheet strengthened beam and steel plate strengthened beam is discussed. Beams are monitored during the test in laboratory for their change in mid-span deflection; strain in concrete, steel reinforcement and external plate; and natural frequency.

2. TEST PROGRAM

Series of twelve RC beams with a rectangular cross-section of 100 mm width and 200 mm height were test under a four-point bending test over a span of 1400 mm under a fatigue load. A shear span to depth ratio, a/d, equals 3.5. All beams have the same steel reinforcements and same load setup in fatigue test as shown in figure 1.

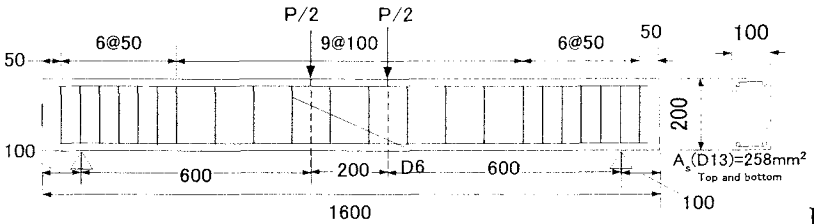

Figure 1: Detail of Test Beam

Beams are divided in to four main groups, namely unstrengthened beam, 2 layers of CFS strengthened beam, steel plate strengthened beam with anchor bolts and steel plate strengthened beam without anchor bolt. CFS was attached all over a tension face of beam by epoxy resin. Therefore, CFS is extended beyond the supported in loading stage.

The fatigue loading has a sinusoidal load history at a frequency of 1 Hz with minimum applied load of 0.6 tons and the varied maximum load from 3.6 to 7.0 tons. The static test was also performed to find the maximum load that each type of beam could resist.

Beams were periodically measured. Loading was stopped during each measurement. The accelerometer used has a nominal voltage acceleration sensitivity of 0.2040 V/ (m/s^2). Measuring signal was 4096 points per time and the measuring frequency was 1000 Hz.

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3. TEST RESULTS AND DISCUSSION

Figure 2 and 3 show measurement from and unstrengthened beam, FU series. FU-1, FU-2 and FU-3 are beam loaded with maximum fatigue load of 58%, 78% and 83% of their maximum static load respectively. Figure 4 shows degradation from the CFS strengthened beam, FC series. FC-1 and FC-2 are beams loaded with maximum fatigue load of 46% and 58% of their maximum static load respectively. FC-2.3-wo is the beam strengthened with steel plate with maximum load of 58%. In this research, ratio of residual stiffness and initial stiffness, EI_x/EI_0, will be defined as a square of a ratio of beam natural frequency after x cycles and initial frequency, $(f_x/f_0)^2$.

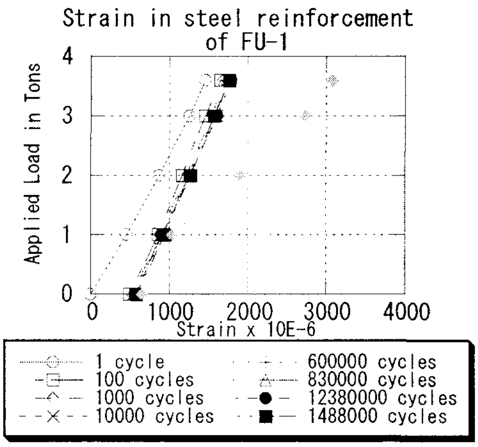

Figure2: Steel strain from unstrengthened beam

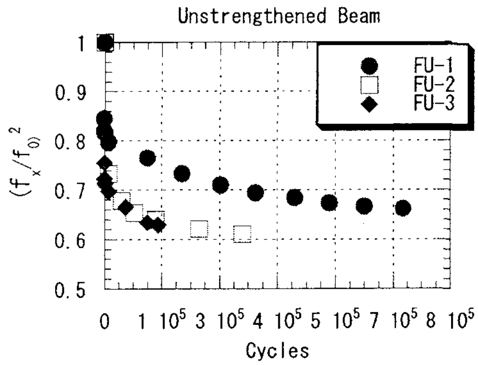

Figure 3: Degradation of unstrengthened beam

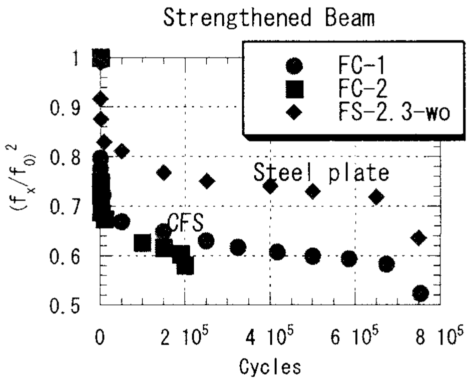

Figure 4: Degradation of strengthened beam

The deflection and strain of all beams do not change in its slope until near the failure of beams. On the other hand, natural frequency of beam, change as soon as the first load cycle started. All beams show great drop in their natural frequencies during the first cycles. When applied load to ultimate load ratio (S_{max}) is higher, dropping during first cycles is also bigger. The reduction in natural frequency per load cycle is gradually smaller when loading cycles is bigger i.e., when the beam has more damage. Despite the different maximum load, all unstrengthened beams failed when stiffness dropped to about 60 % that of undamaged beams. In case of plate strengthened beam, natural frequency dropped sharply again near failure due to the delamination of the plate.

4. CONCLUSION

From the observation found in this test, it could be concluded that by measure deflection and strain, the degradation state of beam and the failure indication can not be known until in the last stage just before failure. In the other hand, change in natural frequency can sensitively indicate the change in stiffness of beam. Measuring the change in natural frequency of RC structure is a simple, yet, reliable method to monitor fatigue damage in this kind of structure.