Rapid Calibration of a Damaged Bridge Undergoing Rehabilitation

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Summary

Redistribution of stresses can be difficult to predict following damage in bridge structures. Such uncertainty is particularly important for designing, monitoring and decision making in relation to repair works. When continuous monitoring is deemed feasible on a damaged bridge, on-site rapid calibrations can be of significant importance in addressing these uncertainties and help in the decision making process. This paper presents a full scale example of a bridge structure damaged by impact loading and subsequently repaired in the presence of a monitoring sensor network. A site-based, rapid calibration of the damaged and undamaged beams in the bridge is presented based on full-scale experimentation and the relationship between the calibrations between the damaged and undamaged beams are investigated.

Keywords: Prestressed Concrete, Bridge, Impact Damage, Structural Health Monitoring, Vibrating Wire Strain Gauges, Rapid Calibration, Repair.

1. Introduction

This paper describes the emergency rehabilitation of a precast prestressed beam bridge following an impact event to the soffit of the bridge. The lack of knowledge relating to stress distribution around the damage was a key challenge in quantifying the actions during the various stages of repair. The structure was monitored throughout the repair works, including initial and final stages when the thermal diurnal effects on the structure were prominent. Strain data obtained from a network of strain gauges from damaged and undamaged neighbouring beams throughout the rehabilitation period was tracked and this data provided an opportunity to observe how the full scale structure behaved during the various stages of rehabilitation.

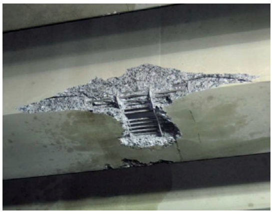

Fig. 1: Damaged area of inner beam

2. Damage and Repair Method

Brownsbarn Bridge is a two span continuous slab-girder bridge consisting of six precast prestressed U8 concrete beams connected by a continuity diaphragm. One internal beam suffered concrete crushing and significant loss of section following an impact event, although the tendons remained intact as shown in Figure 1. The assessment of the damage took the form of a visual and photographic survey of the region followed by a hammer tapping survey and impact echo testing to determine the extent of damage caused. It was established that very extensive damage had occurred over a 5m section of the beam near midspan.

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2.1 Rehabilitation Process

Rehabilitation was challenging as it included dealing with uncertainties in the stress distribution, working to a strict deadline, difficult traffic management on a major road, interaction with many third parties, hydro-demolition and the health and safety aspects related to all of the works. The rehabilitation can be divided into six significant zones of activity as indicated in Figure 2. These include the instrumentation of the gauges, application of load, concrete removal, application of repair material, shrinkage, removal of load and further strength gain.

2.2 Instrumentation

The instrumentation stage involved mounting and zeroing 16 external vibrating wire strain gauges along with three embedded gauges attached to the tendons prior to the loading period. Data was collected every minute commencing from the initial installation.

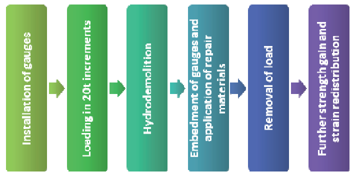

Fig. 2: Stages of rehabilitation

2.3 Rehabilitation Works

Pre-loading the bridge consisted of incrementally placing 20t bales of concrete to a total of 120t. This induced tension in the soffit of the beam thereby releasing the high prestressing forces and allowed for safer removal of the concrete through hydro-demolition. Following the repair, the removal of the pre-load restored some of the lost prestress. The repair material chosen was a ploymer fibre reinforced, sprayed mortar with a curing time of 48 hours and a 28 day compressive strength of 70MPa. Following the removal of the pre-load the strain gauges remained for a further 4 days to allow any further strength gain to be examined. Typical strain gauge responses (in microstrains) for the various stages of rehabilitation is presented in Figure 3.

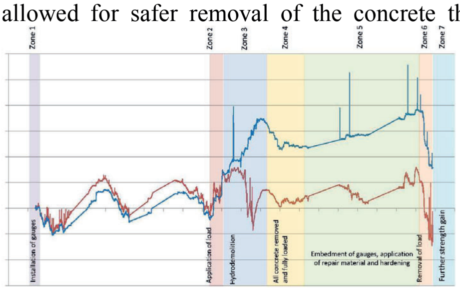

Fig. 3: Representative responses of strain gauges

3. Rapid Calibration of Beams during Monitoring

The interaction of the beams is very useful if the relationship between the damaged and the undamaged beams can be shown to be approximately linear. If an approximately linear relationship between the responses under a number of varied and fundamentally different activities can be established, the bridge-specific relation can be calibrated with a high degree of confidence. Additionally, these calibrations can cross correlate the responses of the damaged and undamaged locations. This means, the calibration is essentially a relatively robust and appropriate map of what is happening on the damaged beam but which is measured on an undamaged beam. The degree of correlation will provide the bounds on the confidence of such relationships highlighting the potentials and the limitations. It is observed that a very good linear correlation is observed. The fact that this is repeated for all of the combinations does increase the degree of confidence on this conclusion qualitatively.

4. Discussion and Conclusion

The investigations noted that, while the structural damage was observed to introduce significant local distress, the global linearity of the structure, in terms of its elastic mechanical response, remained intact. Although very different processes were carried out on the structure, the correlation between all combinations of damaged and undamaged beam locations remained linear. Due to this relatively small change in the global linearity, it is possible to establish a rapid and initial estimate of correlations between all combinations of damaged and undamaged locations. This calibration provides a very simple, on-site tool for monitoring of rehabilitation, detection of anomalous global behaviour and for the estimation of behaviour of damaged location, based on measurements at undamaged locations.