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EMERGENCY REHABILITATION OF BROWNSBARN BRIDGE

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Abstract
This paper outlines the repair methodology of Brownsbarn Bridge situated over the N7 near Dublin. The repair strategy was formulated following impact damage to the soffit from a low- loader carrying an excavator passing underneath the bridge. Significant damage was observed to one of the beams. The repairs were carried out as emergency works over a bank holiday weekend in Ireland successfully. The rehabilitation methodology is based on preloading the bridge before repair followed by a removal of load to ensure the reestablishment of some of the lost prestress. This paper outlines the various stages of rehabilitation and establishes the timelines of significant events along with practical discussions on the execution of the rehabilitation methodology. The bridge was continuously monitored throughout the refurbishment process. This case study is expected to be of topical interest to researchers, practicing engineers, bridge owners and end-users alike.

Keywords: Bridge, Repair Methods, Durability, Impact Damage, Emergency Works

1. General

An emergency rehabilitation was required to be carried out on Brownsbarn Bridge situated over the national road N7, following an impact damage to its soffit on from a low-loader carrying an excavator passing underneath the bridge. The rehabilitation posed a number of theoretical and practical engineering challenges in terms of uncertainty in the stresses, lack of time, liaison among a number of groups working on disparate aspects of the project, the practical execution of rehabilitation strategy and the health and safety aspects of a number of high risk activities. The works were carried out by Roughan & O'Donovan Consulting Engineers for South Dublin County Council on behalf of the National Roads Authority.

The Brownsbarn Bridge is a two span continuous slab – girder bridge comprising six precast prestressed U8 concrete beams connected by a continuity diaphragm. The reinforced concrete piers are integral to the deck and the ends of the bridge are simply supported. The abutments are made of reinforced concrete. The continuity diaphragm is connected to the U8 beams through steel plates of dimension 300x30x1700 (in mm). These U8 beams date from one of the earliest of their kind of design in the Republic of Ireland.

The impact damage affected two of the prestressed U8 beams the bridge consists of. The edge of the outer beam was damaged in a relatively benign fashion than a more extensively damaged inner beam. The main requirements of the rehabilitation involved

detailed repair of both beams including the introduction of some of the lost prestress into the damaged location of the inner beam. Although one of the prestressing strands wass severed on the outer beam, it was computed that apart from this isolated severing of a strand, the prestressing tendons are essentially unaffected in both of the damaged beams. Under these circumstances, it was not envisaged that the damaged prestressing strand will be replaced.

Impact damage in bridges is an important (Mallett, 1996), but often academically overlooked problem (Zobel et.al, 1997). Although a number of studies exist on the theoretical aspects of repairs, analysis of partially prestressed beams, exposed tendons, web openings (Zobel and Jirsa,1998; Russo et.al, 2000; Chern et.al, 1992,Au and Du, 2004; Abdala and Kennedy, 1995; Yoo et.al, 2007; Withers and Bhadeshia,2001) or even the response of prestressed concrete beams to impact loads, (Fujikake et.al, 2009,Ishikawa et.al, 1993) relatively few studies directly attempt to negotiate the problem of vehicle related impact damage to bridges(Zobel et.al, 1997; Civjan et.al, 1995; Zobel and Jirsa,1998).

This paper outlines a successfully executed repair strategy based on a similar strand to (Zobel et.al, 1997) under a number of additional constraints and uncertainties and revisits and revives the problem from a research viewpoint of full scale experimental mechanics and a commercial viewpoint of project management. This section provides the background to the problem. Section 2 discusses the broad scope of works and the practical ramifications of such a rehabilitation process. Section 3 outlines the emergency rehabilitation in detail and delineates the time zones of significant events through continuous structural health monitoring and Section 4 provides a brief summary of this project of topical interest.

2. Scope of Works

The analytical background to the proposed refurbishment works were constrained to a line beam model and a two dimensional finite element model to qualitatively assess the potential stress hotspots, to distinguish non-structural cracks from structural ones with a high degree of confidence and to establish guidance for monitoring of strains during rehabilitation. Under damaged condition, the bridge was deemed safe under Ultimate Limit State (ULS) but was observed to violate Serviceability Limit State(SLS). Figure 1 provides the as-manufactured drawings of the tendons of the prestressed beam obtained from the design archives of Roughan & O'Donovan Consulting Engineers.

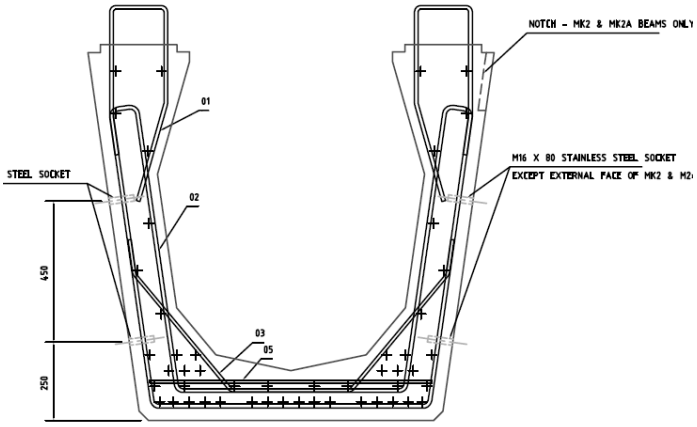


Figure 1 – As Manufactured Tendon Arrangement

The damage extent was assessed and estimated by a number of techniques including an initial visual, photographic and hammer tapping condition survey. The extent was further investigated by incorporating an impact echo test (Tinkey et.al, 2005). In addition, a 3-D visualization was made available through laser scanning. Figure 2 and Figure 3 show the impact damage photograph and the 3-D visualization respectively. Significant damage was established to be extending at least 1.5m on either side of the visually apparent damage.



Figure 2 – Photograph of Impact Damage

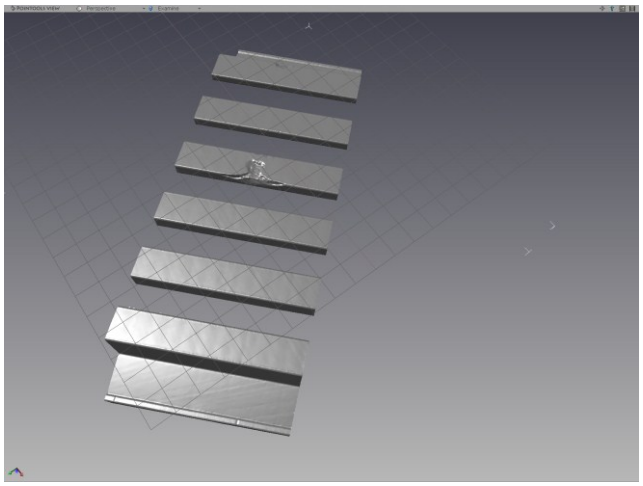


Figure 3 – 3-D Laser Scanning Visualisation made Available by Coastway Ltd.

The main elements of the works comprised of site clearance, protective fencing, construction of temporary and permanent safety barriers and guardrails, traffic management, hydrodemolition of damaged concrete, preloading of damaged beam to induced prestrain, repair of concrete beam using an appropriate material and the real time monitoring of the rehabilitation process.

These works were inspired from the fact that the preload in the form of vertical loading from the top surface on the two sides of the damage would release high prestressing forces at the bottom and will introduce compressive stresses at the top. This situation was deemed favourable since a significant section was lost from damage and the hydrodemolition would temporarily increase the stresses even further. With uncertainty of the retained stresses within fractured concrete and the redistribution of stresses and the participation of adjacent beams, the prestressing forces alone can be significant. Under such circumstances, the external loads are beneficial.

The health and safety aspects of the project were of paramount importance. The rehabilitation involved high risk activities like hydrodemolition. Another important aspect within the management of this project was the severe constraint of time (and of space during the execution of works) where a number of sub-consultants and sub-contractors had to liaise with each other to ensure smooth transition and successful completion of works in a safe and efficient fashion. The works were carried out over the bank holiday weekend of May in the Republic of Ireland. Significantly detailed traffic management was required for the completion of the project as one lane of the National Road N7 had to be taken under possession throughout the refurbishment and during the installation and de-installation of monitoring devices.

Real-time online monitoring of strains and deflections were another important aspect of the project. This required a full instrumentation of the bridge and the monitoring of strain and deflection data in time while the rehabilitation was going on.

3. Rehabilitation Process

The emergency rehabilitation process on Brownsbarn Bridge can be divided into seven significant zones of activity distributed chronologically in time. Figure 4 provides a flow chart indicating these stages. The first stage comprises of the installation of gauges. These gauges corresponded to monitoring points of the damaged beam and the two adjacent beams. In total, five monitoring points were selected. Each monitoring point comprised of a number of strain gauges, including sacrificial strain gauges and targets for the measurement of deflection. A vibrating wire strain gauge was used in this regard. The instrumentation and real time remote data logging was provided by Datum Geotechnical and Structural Monitoring.

The two ends of the damage were patch loaded in 20t increments on each side, quasistatically and equally, using bales of concrete blocks. This loading provided the prestrain in the beam. The loading was carried up to 60t on each side. Consequently, the bridge was preloaded to 120t in total before hydrodemolition

was carried out. The organisation of hydrodemolition, including the erection of safety fencing and scaffolding was carried out during this time by Structural Concrete Bonding. Figure 5 shows a photograph of the removal of concrete through hydrodemolition. Although this method is a high risk activity and should only be carried out by experts, the process was chosen to be the best for the current project due to its precision and low impact on the existing strands.

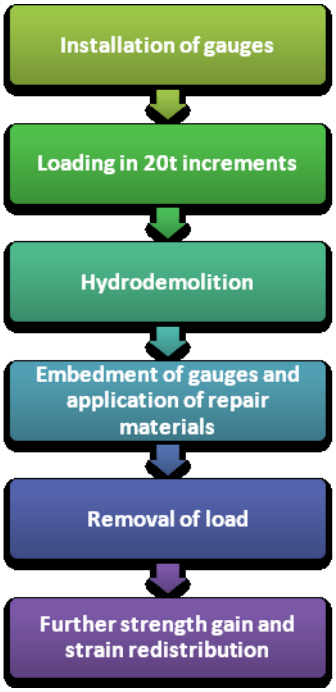


Figure 4 – Brownsbarn Bridge Rehabilitation Flowchart



Figure 5 – Removal of Concrete through Hydrodemolition

Hydrodemolition was followed by the installation of embedded strain gauges within the existing tendons and the application of high strength repair material. The material was expected to gain adequate strength within 12 hours and can take significant tension as well.

The preload was removed from the top of the bridge after the repair material gained adequate strength and some amount of prestress was reinstated following the removal of prestrain. The repaired section is shown in Figure 6 while the removal of preload is shown in Figure 7. A sample photograph of the traffic management provided by Complete Highway Maintenance throughout the rehabilitation is provided as Figure 8.



Figure 6 – Repaired Section of Damaged Beam



Figure 7 – Removal of Preload



Figure 8 – Traffic Management Provided during Rehabilitation

Figure 9 provides the example of two strain gauges from adjacent beams (damaged and undamaged) results during the entire rehabilitation process and zones them into the main activities along the timeline. The strains are in multiples of 10^{-6}. This graph creates the departure point of detailed structural health monitoring analyses including the effects of thermal oscillations, shrinkage characteristics, redistributions of strains, release of entrapped strains, participation and energy flow of adjacent beams and the real mechanics of structures similar to Brownsbarn Bridge. Such analyses are beyond the scope of the current paper.

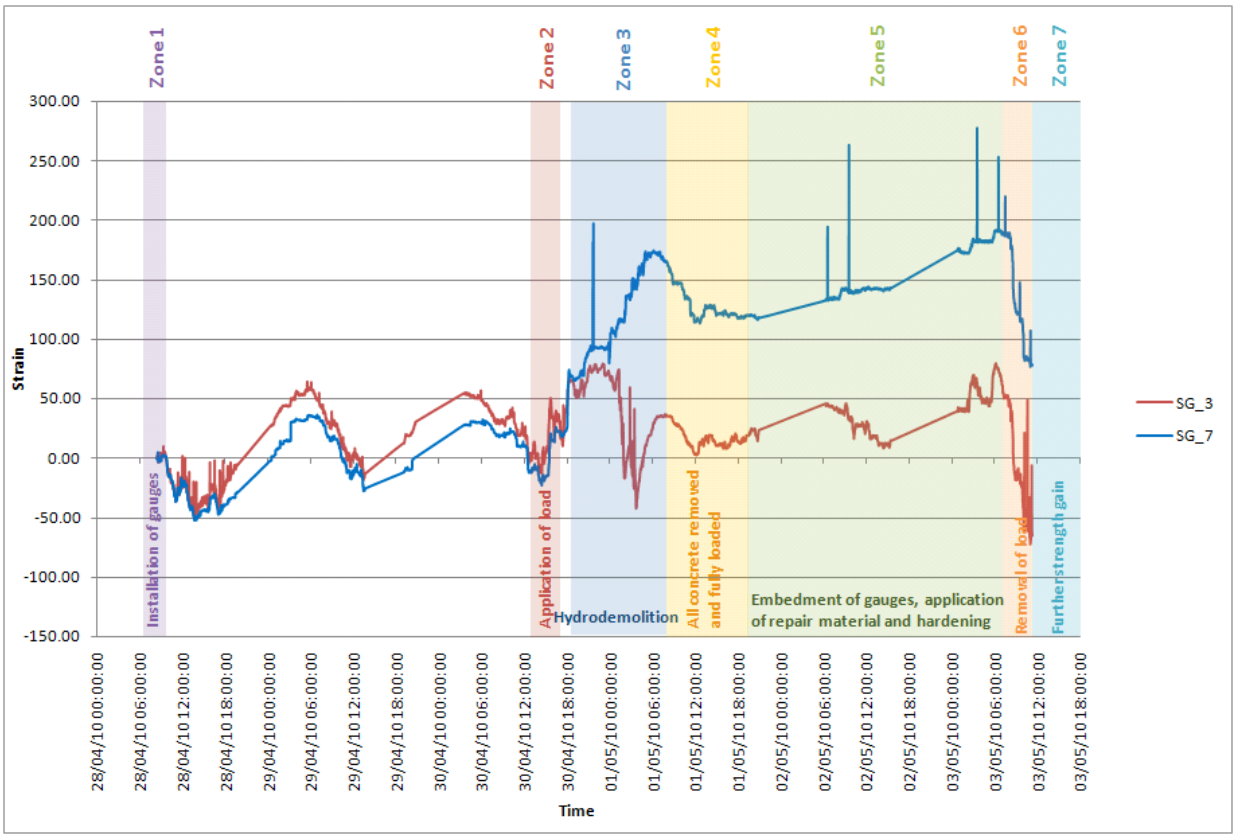


Figure 9 – Activity Footprints in Strain Gauge Monitoring Data and Event Hotspots

4. Conclusons

This paper outlines the emergency rehabilitation of impact damaged Brownsbarn Bridge. The methodology of the emergency repair is discussed along with the theoretical and practical challenges. The various steps of the rehabilitation are detailed and their implications are stated. The footprints of the various stages of the methodology are observed in monitored strain data and are accordingly delineated. These results create a departure point for a more general and theoretical study in the field of structural health monitoring and experimental engineering mechanics. On the other hand, the general outline of the project is expected to be topical, important and of considerable interest to the engineering committee in general, including academics, engineers and bridge – owners.

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