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CRACK BEHAVIOUR OF PRE-TENSIONED (PRT) CONCRETE BEAM AFTER RETROFITTED WITH CFRP SHEETS

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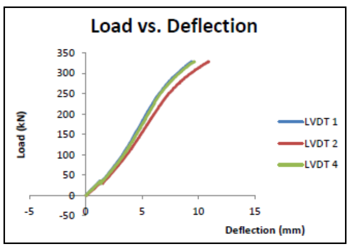
Graphical abstract



Abstract

This study concentrates on crack that occurs at PRT beam which the beam then retrofitted with carbon fibre reinforced plastic (CFRP) sheets. The beam was tested to determine crack modes and ultimate capacity before and after retrofitted. The beam was tested under static test with displacement control of 0.009 mm/sec. Once the first crack appeared, the beam was unloaded and took out for retrofitting process. The beam was loaded again to failure to evaluate the effect of CFRP on the behaviour of the long span beam. Therefore, the finding of this study will guide engineers and construction practitioners to further understand the effects of CFRP sheets used in long span beam in term of load capacity and crack behaviour after retrofitting work.

Keywords: Load capacity, crack, PRT beam, CFRP sheets, concrete retrofitting

1.0 INTRODUCTION

Degradation of concrete bridge structures happen because of several factors influenced by material constituents, applied force, design errors, construction defects and structural boundary equipment [1]. It is also can wear off as a result of normal aging, increasing traffic and impact from aggressive environment. This situation certainly gives influence to the structural strength and durability.

In bridge structural system, beam is a significant component as it roles as superstructure system supporting loads from decks and vehicles. Usually, degradation of bridge beam can be detected during periodical maintenance which is the typical damage of concrete structure such as cracks. Cracks mainly revealed as the sign of concrete deterioration [2]. In extensive condition, the structure can suffer concrete spalling, delamination, deformation, and excessive deflection [3].

The existence of cracks on the bridge beam will lead to severe failure such as steel corrosion, durability problem, shorten the service life of bridge, and thus increase the instability of bridges to static and dynamic loads [4]. Typically, the repair method at this severe defect stage is to join the steel pre-stressing strands but this method performs poorly during fatigue and also may disturb traffic when the bridge must be closed for traffic [5,6]. Therefore, it is crucial to retrofit the beam structure at early stage of crack detected to prevent severe damage on the structure which consumes more cost and time.

This study determines the effectiveness of CFRP sheets used in bridge repair when the first crack was detected. The effectiveness are determined by comparing the crack behaviour and load capacity of beams which non-retrofitted and retrofitted.

2.0 EXPERIMENTAL PROGRAM

Bridge beam is the concern in this study and focused on crack occurrence in the beam. Two specimens of pre-tensioned (PRT) concrete bridge beam were used [7] (Figure 1). A control beam named as PRTB-C is a non-retrofitted beam, while a PRTB-R is named for beam retrofitted with CFRP sheets. The control beam was tested under the static load to failure to determine the ultimate capacity and behaviour of cracks without any. Another beam is used to determine the effects of CFRP sheets as retrofit material also in a form of ultimate capacity and crack behaviour.

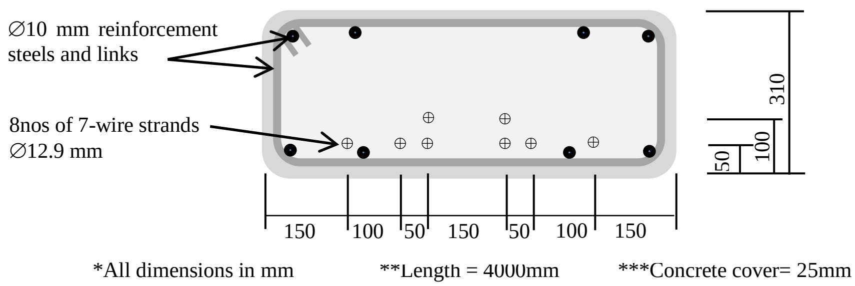


Figure 1 Tendons arrangement in PRTB-C and PRTB-R

There are limitations in this study due to laboratory constrains such as limited space of testing frame which can only accommodate 4m length specimen. Another limitation is there would some negligence in beam behaviour when the specimen has to unloaded and lift up to retrofit area as the retrofitting works cannot be prepared at the test frame.

2.1 Test Setup and Instrumentation

The preparation of beam specimen for static test includes surface preparation, placing of strain gauges, and LVDTs. 60 mm gauge length were used for each specimen and placed at both sides of the beam. For retrofitting purpose, CFRP sheets were used to wrap cracked beam.

2.2 Test Procedure

Both PRT were tested under static load using 2500kN capacity of Universal Testing Machine at the Heavy Structures Laboratory, *Universiti Teknologi MARA (UiTM)*. The 4 metres long beams were simply supported 200 mm from both ends and loaded by 2 points located at the middle of the beam. There are six (6) strain gauges (SG) were attached at the both sides of beam near the tension zone. Whilst, four (3) transducers were placed at possibility points that maximum displacement will occur. The display control rate of the static load is 0.009mm/s. The 4 metres long beams were simply supported 200 mm from both ends and loaded by 2 points located at the middle of the beam (Figure 2).

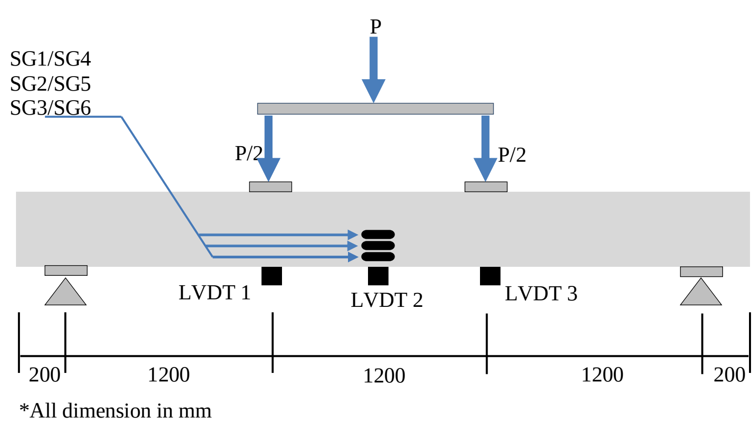


Figure 2 Experiment setup

The PRTB-C was loaded non-stop to failure and concurrently observed the crack load and, propagation of crack size and displacement. The ultimate capacity then determined when the beam is totally damaged.

The PRTB-R was loaded up to crack load which determined from the control beam test. The PRTB-R then unloaded and moved out from testing frame to wrap with CFRP sheets in 2 layers (Figure 3). In order to ensure good adhesion between beam surface and

CFRP sheet, the beam was only test after 5 days of relaxation period.

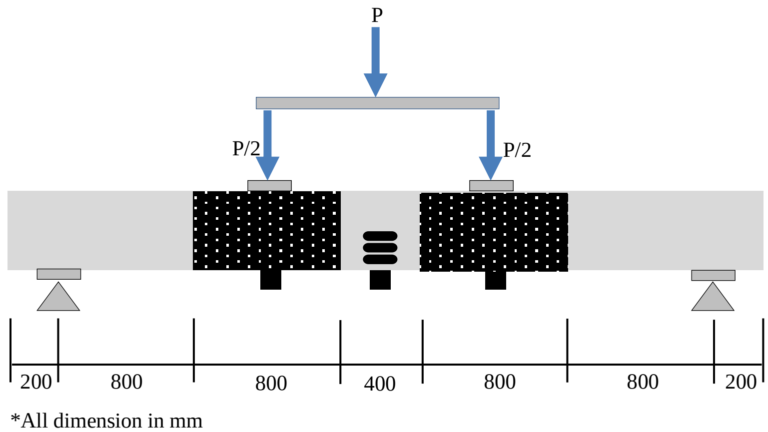


Figure 3 Application of CFRP on BRTB-R

3.0 RESULTS AND DISCUSSION

The result of load-deflection response and crack behaviour for PRTB-C and PRTB-R were recorded individually. Then, the results were compared to determine the effects of the retrofitted work to cracked beam.

3.1 Bending of PRTB-C

The load-deflection curves and crack length for PRTB-C three different locations of is visualised at in graph plot (Figure 4)

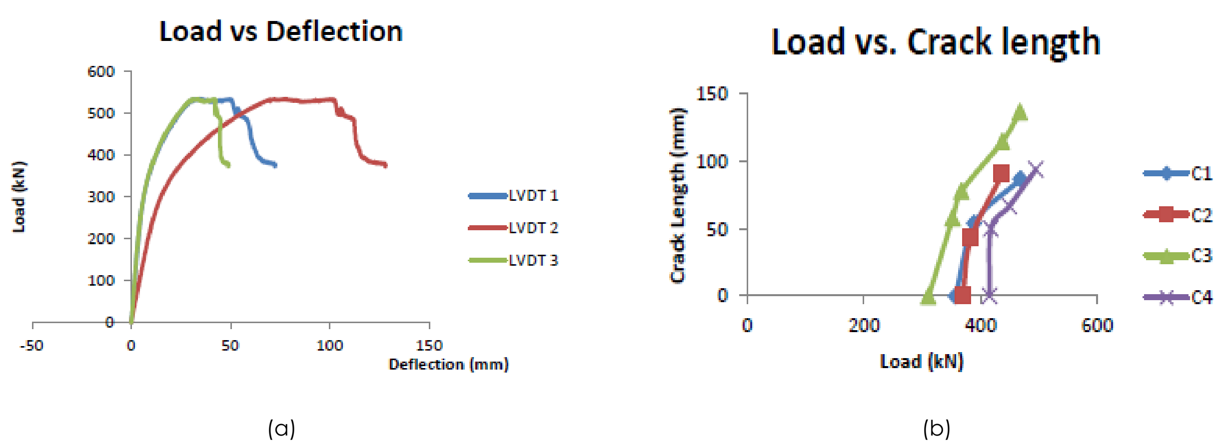


Figure 4 (a) Load-deflection curves of PRTB-C (b) Load-crack length curves of PRTB-C

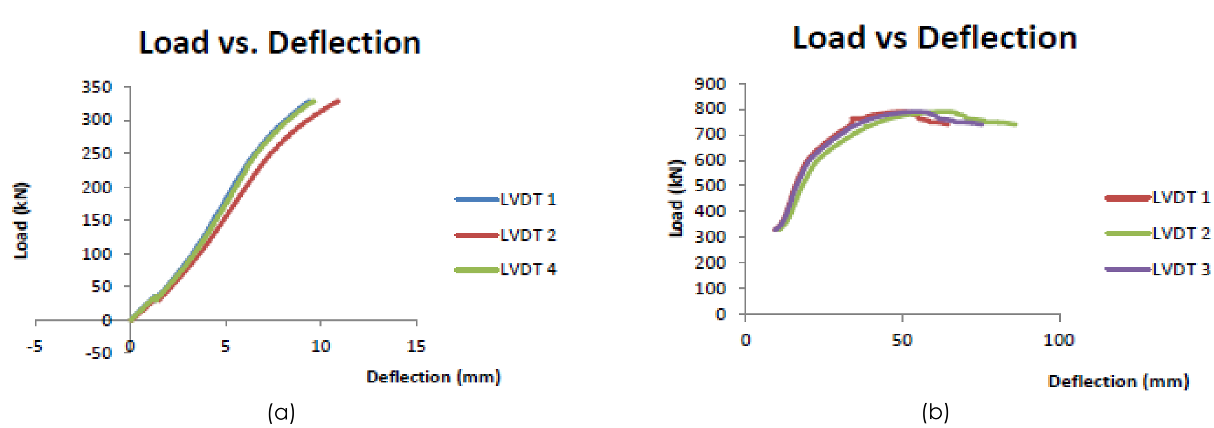


Figure 5 (a) Load-deflection of PRTB-R before retrofit (b) Load-deflection of PRTB-R before retrofit

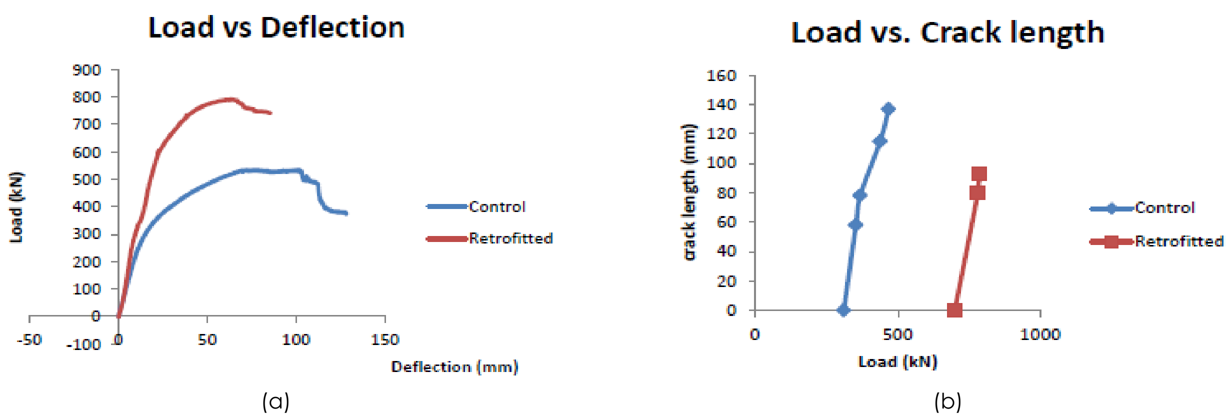


Figure 6 (a) Comparison of Load-Deflection curve of PRTB-C and PRTB-R (b) Comparison of significant crack length of PRTB-C and PRTB-R

3.2 Bending of PRTB-R

A load-deflection curve is plotted for 3 different locations. The pattern of relationship is similar to PRTB-C where the curve is linearly increased until the first crack appeared at load 328kN (Figure 5(a)). At this point, the biggest displacement 11.5mm was determined occurred at the middle point of the beam which recorded by LVDT2. The beam then unloaded for retrofitting process and put back on the testing frame to continue the test to failure. At the end of this testing, it observed that the maximum deflection retrofitted beam was 84.4 mm recorded by LVDT2 (Figure 5(b)) at load 791kN.

The CFRP sheets are used to bond the existing crack and to prevent it from propagate further. The sheets was bonded well to the concrete surface, thus during the test after retrofitted there is no physical changes of the CFRP sheets. It shows that, the material defeats the propagation of the existing crack because it slowed down the crack length increment until load 700kN. After that length of the most significant cracks started increased slowly up to 90mm at 791kN ultimate load.

3.3 Comparison behavior of PRTB-C and PRTB-R

Load capacity of cracked beam can be restored and even increased if the fast action of retrofit is carried out. The observation of this study found that a cracked beam can carry load up to 791kN if the beam is retrofitted compare to non-retrofitted beam only sustain until load 530kN (Figure 6(a)). Therefore, by using CFRP sheets in retrofitting technique the capacity of beam can be increased 32%. Nevertheless, displacement of beam also reduced 34% from 128mm for PRTB-C beam to 84mm for PRTB-R.

The length of significant crack on PRTB-R also shows some improvement. The length is 34% shorter than PRTB-C. It is evidence that CFRP sheets defeats the crack propagation if the cracked beam is repaired early.

4.0 CONCLUSION

From the experimental study, the following conclusion can be made:

a) Retrofit cracked beam with CFRP sheets 32% load capacity.
b) Displacement improved 34% for retrofitted beam compare to non-retrofitted beam.
c) Crack length also shorter 34% for retrofitted beam compare to non-retrofitted beam.
d) Retrofitting technique using CFRP sheets wrapping improve structural behaviour of cracked beam.

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