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Initial estimate of short and long-term prestress losses of BFRP pretensioned RC beams

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Abstract

The drive for technological advancement in the construction industry and more durable structures has brought more attention to Fibre Reinforced Polymers (FRPs), due to their excellent strength-to-weight ratio, resistance to corrosion and other benefits. However, application of FRPs as internal reinforcement, especially GFRP and BFRP, has been limited by poor serviceability performance of such elements. Prestressing has been shown to be a viable method for improving the cracking and deformability of FRP reinforced concrete elements. Hence, this paper aims to provide insight into prestress losses of pretensioned BFRP reinforced concrete beams.
The experimental program includes long-term analysis of BFRP pretensioned concrete beams. Six samples were produced, with pairs of different prestress levels; namely, 20%, 30% and 40% of the ultimate tensile capacity of the BFRP bars. Strain levels in the BFRP bars were continuously monitored during prestressing, concrete casting and curing, as well as releasing of the samples from the prestressing rig. This paper presents the results of the initial 3 months of monitoring.

Keywords: BFRP, pretensioned, prestress losses, long term, RC beams

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Introduction

Glass and, more recently, basalt fibre reinforced polymers are widely used in civil engineering as a more economic substitute for carbon FRP. On the other hand, GFRP and BFRP have a much lower Young's modulus in comparison with CFRP, which results in poor performance as per Serviceability Limit State criteria, with larger deflections at lower levels of loading. To overcome this issue, prestressing of the FRP reinforcement has been developed as a possible solution.

Encouraging results regarding pretensioned BFRP reinforced beams were published by Mirshekari [1, 2]. The study was conducted on reinforced concrete beams of same dimensions, with varying levels of prestressing, which were submitted to a four-point bending test until failure. The cross-analysis of the results confirmed that prestressing BFRP improves the serviceability performance of the elements to a level comparable to that of a steel reinforced element.

Similarly, Thorhallson and Jonsson [3] conducted an experimental study with BFRP prestressed members, with no shear reinforcement. This study did not observe increase in capacity with prestressing of the member; nonetheless, it did agree with the conclusion that the deformation performance of PT samples was improved (in terms of lower deflections).

Furthermore, the superior performance of prestressed BFRP beams versus reinforced beams was highlighted in [4] in terms of more favourable SLS/Ultimate Limit State ratio, as well as increased capacity. Additionally, viability of prestressed BFRP for civil engineering applications was confirmed in a study [5], which produced a large-scale precast fibre reinforced SCC slab pretensioned with BFRP. The results of the testing and numerical investigation confirmed that the element's structural performance under bending is satisfactory.

However, prestress losses of BFRP PT RC elements remain under-researched. Hence, this experimental program aims to give insight into time dependant losses of stress in BFRP bars.

Methodology

Six concrete beams, with a rectangular 130x180mm cross section, 1200 mm long were produced for this experiment. The reinforcement cages were constructed with two N6 steel top reinforcement bars and R6 mild steel shear links with 100 mm spacing, except for the mid 300 mm of the span, which had no shear links. As main (bottom) reinforcement, BFRP bars with 6mm nominal diameter were used.

Additionally, steel sleeve bonded anchorage was installed on either end of the bars, in accordance with the recommendations given in ACI440R [6]. The sleeve was used as a connection between BFRP bars and steel threaded bars, which were utilised during the prestressing process. Initial prestress force was applied using a manual hydraulic jack on both bars simultaneously as shown in *Figure 1* and monitored using Vishay 120±0.3% Ω foil strain gauges.

After prestressing of bars was completed, three pairs of beams were cast using the same concrete mix with target class C30/35 to produce six samples. The following alphanumerical labelling system was adopted for all samples: BFRPnα; where n={20;30;40} depending on the degree of prestress as a percentage of the ultimate tensile capacity of bars, and α={A;P} depending on whether the beams was cast at the active (A) or passive (P) end of the prestressing rig.

After 28 days curing of concrete, the prestress was gradually released from the external anchorage and transferred to concrete by unscrewing the anchor nuts, whilst clamping the anchor sleeves to prevent any torsional effects.

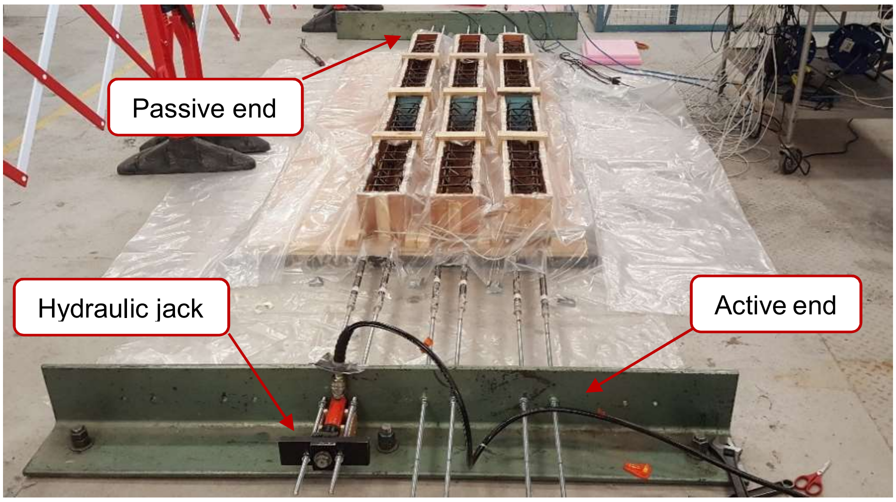

Figure 1: Samples in the prestressing rig during the application of the prestressing force

Throughout the application of prestress, casting and curing of concrete, until release and transfer of prestress strains of the BFRP bars at the midspan and close to supports were monitored and continuously recorded using VPG System 8000 data acquisition system at a 1Hz rate.

Results

Data acquired during the initial monitoring phase of this experimental programme is presented in this section. *Figure 2* presents the recorded strain values measured on the BFRP bars at the midspan of the beams, starting from the pretensioning of the bars, including concrete casting and curing, release of external pretension and transfer of the prestressing force to the cured concrete, for a total period of 86 days.

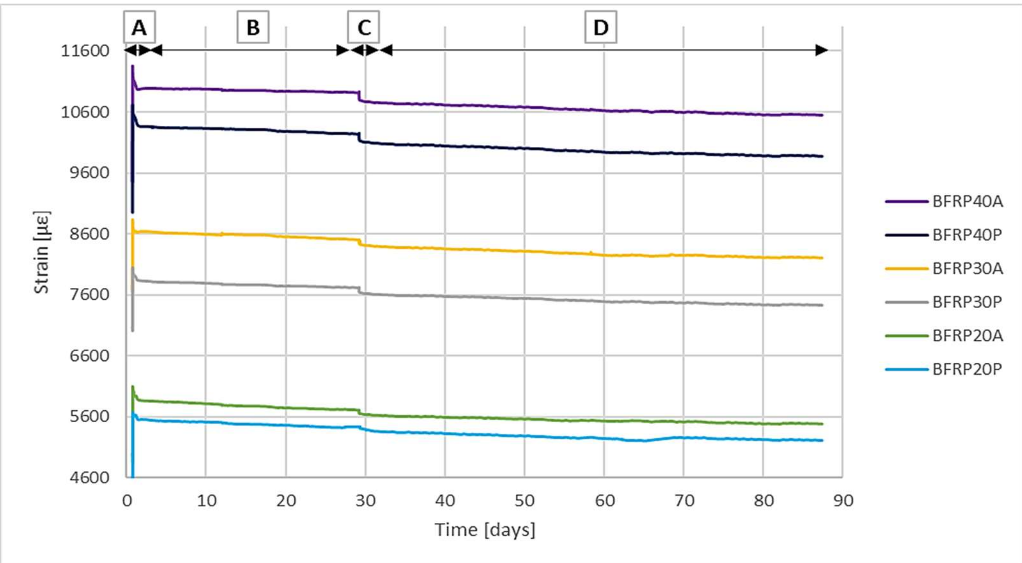

Figure 2: Strain [με] over time [days] at midspan

As shown in Figure 2 the strain values were decreasing over the entire monitored period. The observed decrease of strain in the investigated period can likely be attributed to combined influence of concrete shrinkage and elastic deformation of concrete upon release of prestress. In the initial 24h from the application of external prestress (section A), the strain dropped by an average of 1.86%, at a rate of 0.08% per hour. After casting of concrete, the strain decrease was more gradual, at an approximate average rate of 0.06% per day (section B). This was followed by a more sudden drop of strain (section C), on average 0.8%, which was a result of release of externally applied prestress and transfer to the cured concrete. The subsequent period (section D) was characterised by a steadier rate of decrease of about 0.05% per day. At the end of the monitored period, an average strain decrease of 7.0% was observed for all samples, and did not vary significantly with the level of prestress.

Conclusions

According to the analysed change of strain over time, the following can be concluded:

- Total decrease of the strain during the investigated period was on average approximately equal to 7.0%
- About 0.8% of the decrease can be attributed to the process of release of externally generated prestress
- No evident correlation was observed between level of prestress and percentage of decrease of strain

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References

[1] Mirshekari, M., Donchev, T., Petkova, D., and Limbachiya, M., 2015, "Influence of the Degree of Prestressing on the Behaviour of BFRP Reinforced Beams", The 12th International Symposium on Fiber Reinforced Polymers for Reinforced Concrete Structures (FRPRCS-12) & The 5th Asia-Pacific Conference on Fiber Reinforced Polymers in Structures (APFIS-2015) Joint Conference, 14-16 December 2015, Nanjing, China

[2] Mirshekari, M., Donchev, T., Petkova, D., and Limbachiya, M., 2016, "Deformability of Pretensioned PC Beams with BFRP Reinforcement", The 8th International Conference on Fibre-Reinforced Polymer (FRP) Composites in Civil Engineering (CICE 2016), 14-16 December 2016, Hong Kong, China

[3] Thorhallsson E.R., and Jonasson, B., 2012, "Test of Prestressed Concrete Beams with BFRP tendons, The 6th International Conference on Fibre-Reinforced Polymer (FRP) Composites in Civil Engineering (CICE 2012), 13-15 June 2012, Rome, Italy

[4] Crossett, P., Taylor, S., Robinson, D., Sonebi, M., Garcia-Taengua, E., Deegan, P., and Ferrara, L., 2015, "The Flexural Behaviour of SCC Beams Pre-stressed with BFRP", Proceedings of the 7th Beinnial Conference on Advanced Composites in Construction (ACIC 2015), 09-11 September 2015, Cambridge, UK

[5] Lago, B., Taylor, S., Deegan, P., Ferrara, L., Sonebi, M., Crosset, P., and Pattarini, A., 2017, "Full-scale testing and numerical analysis of a precast fibre reinforced self-compacting concrete slab pre-stressed with basalt fibre reinforced polymer bars", Composites Part B, issue 128 (2017), pp. 120-133

[6] ACI Committee 440, 2004, "Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures", ACI 440.3R-04 Technical Report – Appendix A