BRE Centre *for* Fire Safety Engineering

Bond Strength Degradation for CFRP Bars and Steel Prestressing Wires in Concrete at Elevated Temperature

Fire Behaviour of Novel Concrete Structural Elements

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INTRODUCTION

The desire to build more sustainable and durable structures has promoted the emergence of innovative precast structural elements which incorporate high performance self-consolidating concrete (HPSCC) with prestressed, sand coated, carbon fibre reinforced polymer (CFRP) prestressing bars.

Figure 1: Application of CFRP prestressed HPSCC L-shaped beams

RESEARCH SIGNIFICANCE

Inherent and beneficial insulating conditions of conventional ribbed steel prestressing wires is typically ensured by prescribing a minimum allowable concrete cover depth to protect the internal reinforcement from the effects of fire. The fire performance of CFRP prestressed elements, however, is not well known and two issues are critical:

1. Considerably less concrete cover is typically required for structural elements prestressed with CFRP, because of the non-corrosive properties of the CFRP prestressing bar.
2. Bond strength of the CFRP prestressing bars is given by a resin rich sand coated surface which is critically degraded at temperatures in the region of 150°C.

"there is the potential for loss of the inherent fire endurance obtained when designing with prestressed steel"

The objective of this research is to study the effects of elevated temperature on the bond strength capacity of CFRP and steel prestressing bars in HPSCC.

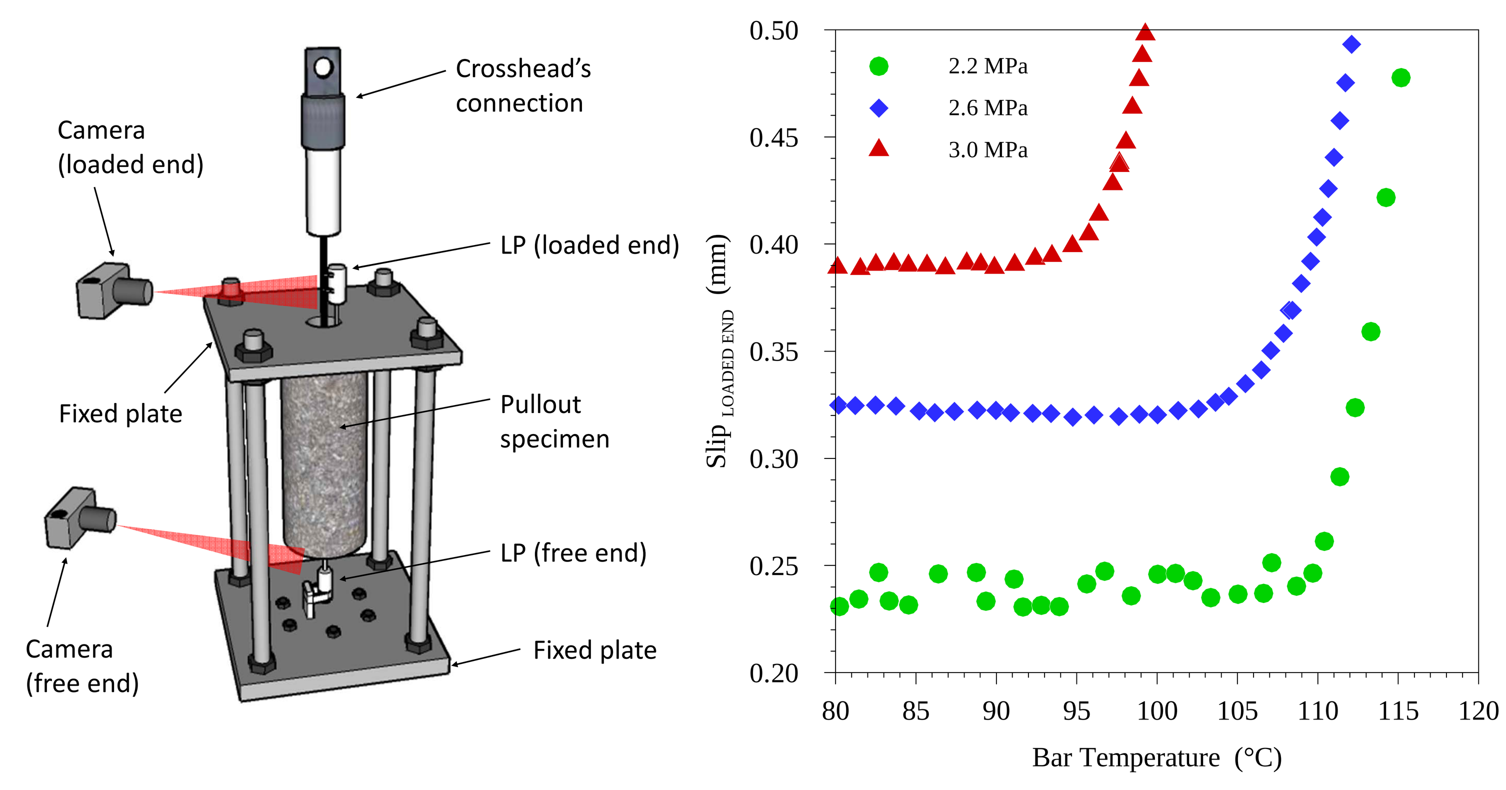

Figure 2: Bond pullout test setup and close-up view of the failure sequence for CFRP prestressing bars at sustained average bond stresses of 2.2, 2.6 and 3.0 MPa

EXPERIMENTS

- Transient elevated temperature bond pullout tests on CFRP and steel prestressing bars
  - Slip measured by digital image correlation analysis (Figure 2)
  - Temperature measured at the specimens' surface and over the bonded length
- Transient elevated temperature tensile strength tests on CFRP and steel prestressing bars
- Micromechanical analysis of the CFRP prestressing bars
  - Dynamic mechanical analysis (DMA)
  - Thermogravimetric analysis (TGA)

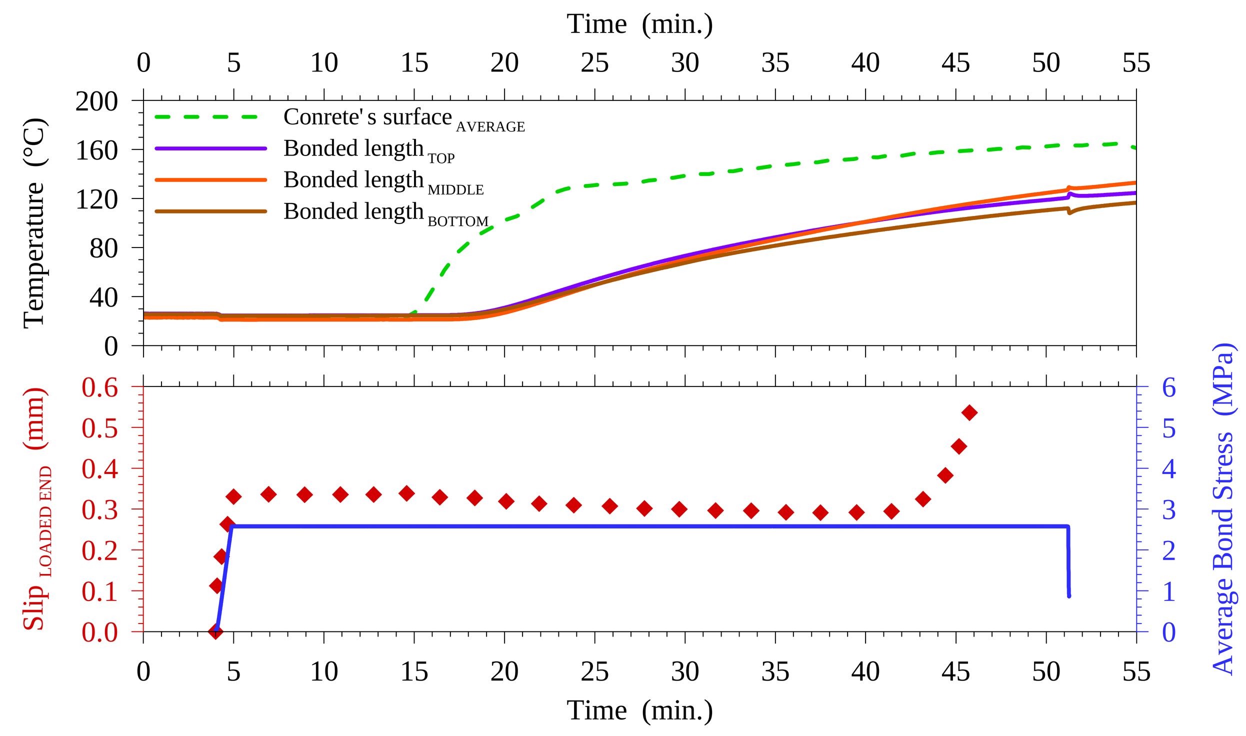

Figure 3: Typical thermal and mechanical behaviour of a bond pullout test

PULLOUT TESTS

- Loaded at ambient temperature, load was then sustained as the temperature of the sample was increased at 24 °C/min until failure occurred (Figure 3).
- CFRP prestressing bars loaded at 2.2, 2.6 and 3.0 MPa average bond stress failed at the bond interface.
- Steel prestressing wires loaded at 9.1 Mpa average bond stress failed by splitting crack of concrete.
- Significant differences were observed between the remnant bond strength after failure at elevated temperatures (Figure 4).

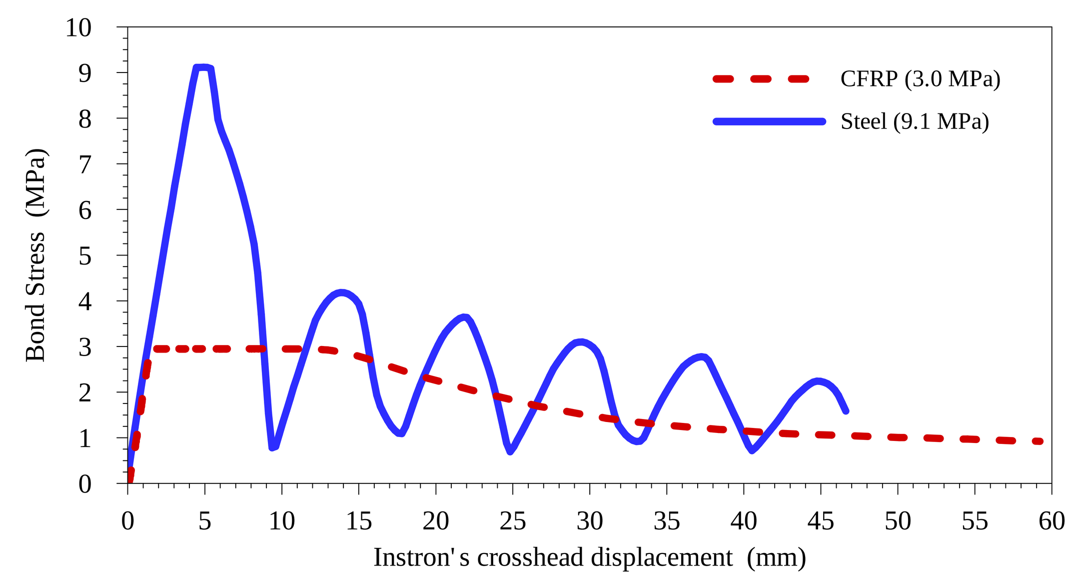

Figure 4: Typical remnant bond stress behaviour of bond pullout tests

TRANSIENT TENSILE STRENGTH, DMA & TGA (Figure 5)

- The tensile strength of CFRP prestressing bars was slightly more sensitive to elevated temperature then that of steel prestressing wires.
- DMA indicated that a drop (150°C) in the elastic modulus of the CFRP's resin matrix is in the range of temperatures for which bond pullout tests presented evidence of failure.
- TGA indicated that a first drop (340°C) in the mass of the CFRP sample is in the range of loss of the tensile strength, evidence of matrix degradation, and a second drop (650°C) is evidence of fibre oxidation.

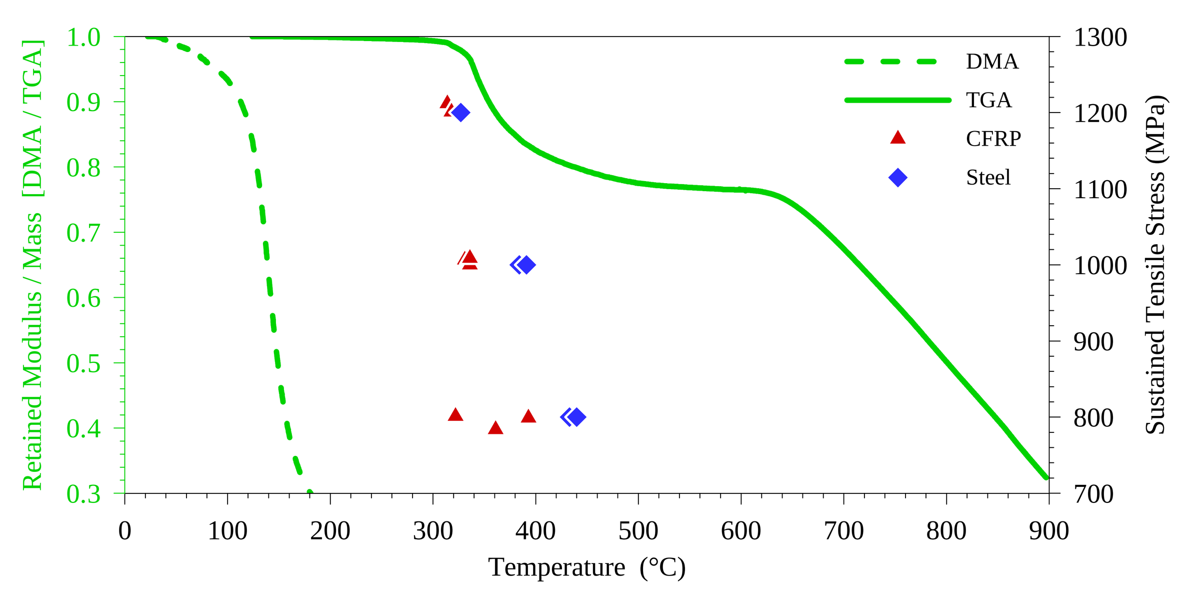

Figure 5: DMA, TGA for CFRP and transient elevated temperature tensile strength test results for CFRP and steel

CONCLUSIONS

1. Thermal and mechanical conditions in the bond between prestressing bars and concrete were found to be far more complex than shown by previous studies.
2. For CFRP prestressing bars bond reduction is more critical than loss of tensile strength.
3. For steel prestressing wires, bond strength is less sensitive to elevated temperatures, but is susceptible to concrete splitting cracking with high sustained loading during the early stages of heating; this is due to a summation of the mechanical and thermal stresses which become critical.
4. Many aspects of bond performance, for CFRP and steel at elevated temperature, remain poorly understood and additional research is needed.

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