Heating-Induced Prestress Variation in Unbonded Post-Tensioned (UBPT) Construction

Potential Consequences for Post-Fire Performance

Luke Bisby[a], Kevin MacLean[b], Colin MacDougall[c], John Gales[c]

[a] University of Edinburgh, BRE Centre for Fire Safety Engineering, Edinburgh, Scotland, UK
[b] Read Jones Christoffersen Ltd., Toronto, Canada
[c] Queen's University, Department of Civil Engineering, Kingston, Canada

BRE Centre *for* Fire Safety Engineering

INTRODUCTION

UBPT flat plate concrete slabs are widely used in continuous multiple bay floor assemblies in multi-storey construction:

- Allow for **increased span to depth ratios** and **elimination of beams**
- Excellent **deflection control** (as compared with RC slabs)
- **Efficient**, **rapid** and **sustainable** construction

"Inherent fire endurance"

is assumed by most designers based on satisfactory results in standard tests performed during the 1960s, and ensured using concrete cover to the tendons

Much remains unknown about the true structural behavior of continuous multi-bay UPT *structures* during or after a localized fire (Figure 1). The multi-bay continuity of the unbonded tendons has potentially important implications, but has never been accounted for in tests

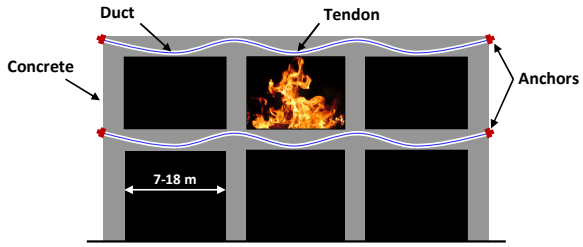

Figure 1: Single bay fire in a multi-bay structure

RESEARCH OBJECTIVES

What are the potential consequences of localized tendon heating on the global response of the tendon, both during and after fire?

1. Understand and model **creep of prestressing tendons** at elevated temperature subjected to **time-varying stress** and **non-uniform heating**
2. **Study** effects of varying the **concrete cover and heated length ratio** on the observed/ predicted **reductions in prestressing force** for a typical UBPT slab
3. Identify **potential concerns** for performance of **real UBPT structures** during/after a **real fire**

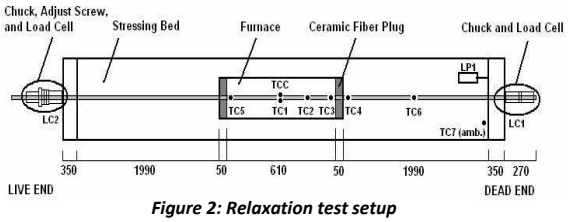

Figure 2: Relaxation test setup

EXPERIMENTS

Numerous **high temperature transient relaxation tests on stressed tendons** under various localized ramp-soak-cool heating regimes (Figures 2 and 3) to evaluate magnitude of irrecoverable prestress loss. Also tests for residual characterization of mechanical properties of tendons after heating and cooling. Results used to validate a predictive numerical model.

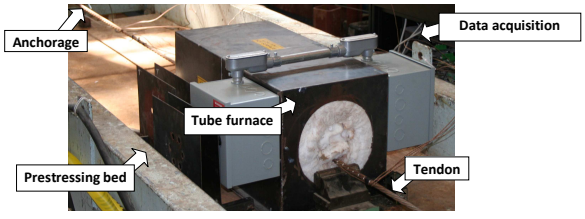

Figure 3: Localized heating relaxation tests on stressed tendons

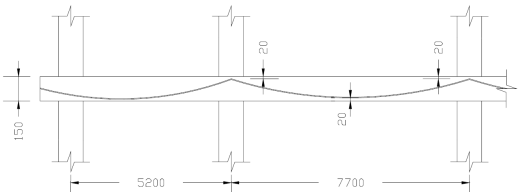

Figure 4: Example flat plate UBPT Structure used in analyses

MODELLING HIGH TEMPERATURE CREEP

A model has been developed based on previous work by others (Dorn, Harmathy, Anderberg, Hertz) to **predict transient creep at high temperature** in a locally-heated steel tendon. The model has subsequently been applied to study the effects of localized heating on a typical multi-bay UBPT flat plate concrete structure (ignoring interactions with the concrete) – Figure 4

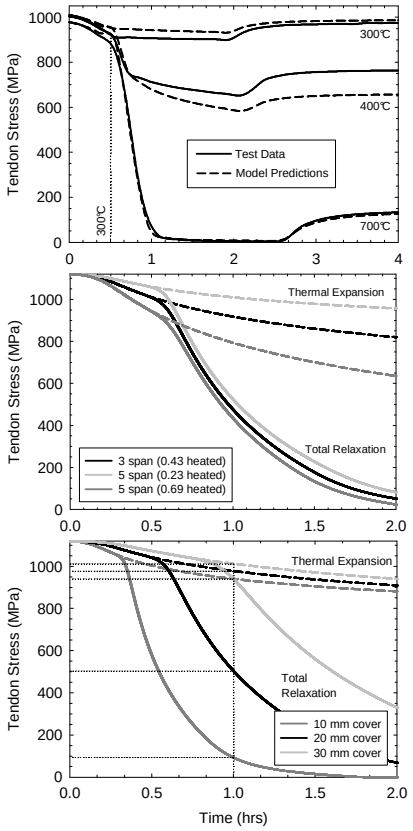

Figure 5: (a) Observed and predicted prestress relaxation for a locally-heated tendon and (b) effect of heated length ratio and (c) concrete cover at midspan on prestress relaxation during heating at 10°C/min to a predetermined temp.

RESULTS

1. At temperatures above 300°C, stress reductions accelerate (due to creep), causing considerable reductions in effective prestress. The irrecoverability of effective prestress for exposure temperatures above 300°C is also apparent
2. A model has been developed that can predict prestress relaxation due to high temp. creep
3. Larger heat length ratios may be more critical during a fire, but smaller heated length ratios may be more important in for residual prestress loss after a fire
4. Careful consideration of the effects of localized heating of prestressing tendons and properly accounting for creep deformations at high temperature appear to be important for realistic modelling (or testing) of UBPT structures in fire

The Authors would like to acknowledge the support of the Natural Sciences and Engineering Research Council of Canada, Queen's University (Canada), Dr Ivan Campbell, the Ove Arup Foundation, and the Royal Academy of Engineering