Behavior of Prestressing Steels after Fire

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Summary

Even if a fire does not give rise to apparent damage in a prestressed structure, mechanical properties of materials as well as load distribution can be affected. A verification of residual load bearing capacity after fire is necessary to determine if the structure can be maintained in use. Mechanical properties of structural steels at high temperatures have been extensively studied. However, no attention has been paid to the behavior of steel wires after fire. This paper seeks to give a simplified estimation of the non-visible fire-induced damages produced in steel wires, with the hope that this information can be useful for engineers in the structural evaluation after a fire. Two aspects should be considered when assessing the security of the structures: The reduction of the prestressing loads due to the increment in the stress relaxation losses during the exposure to high temperatures and the permanent damage of the residual mechanical properties of steel wires produced by the fire.

Keywords: fire; prestressed concrete; structural steel; prestressing tendons; mechanical properties; structural safety.

1. Introduction

Following a fire, if no collapse happens, there is a possibility of fire-induced damage. Then, the question which unavoidably arises is if the structure is still safe; what the load bearing capacity of the structure is and how it has been affected by the fire. Appropriate knowledge of the behavior of construction materials after a fire is of major importance for answering these questions; For this end, the behavior of prestressing steel wires after a fire is the subject of this work. Measurements on loaded steel wires used for prestressed concrete during and after several simulated fires have been performed. This paper seeks to give a comprehensive and extensive explanation and a simplified estimation of the non-visible fire-induced damages produced in steel wires, with the hope that this information can be useful for engineers in the structural evaluation after a fire.

2. Experimental: Characterization of prestressing steel behavior after fire

A detailed study of the prestressing steel behavior was performed, examining the two principal aspects that could affect the performance of the structure after fire:

- The residual mechanical properties of the wires after fire: Extensive literature is available on the mechanical properties of structural steel at high temperatures. However no attention has been paid to the mechanical residual properties after fire. In this work, wires were subjected to a complete cycle of heating and cooling while loaded. Figure 1-a shows the variation of tensile strength at room temperature after fire, for the different maximum temperatures reached during the fire simulations.

- The stress relaxation losses produced during fire: Temperature has a great influence on the stress relaxation; an increment of temperature produces a large increase in stress relaxation losses and, consequently, the prestressed compressive load provided to concrete decreases. In Figure 1-b, an example of the time-stress relaxation losses curves obtained in this work is depicted as a function of temperature.

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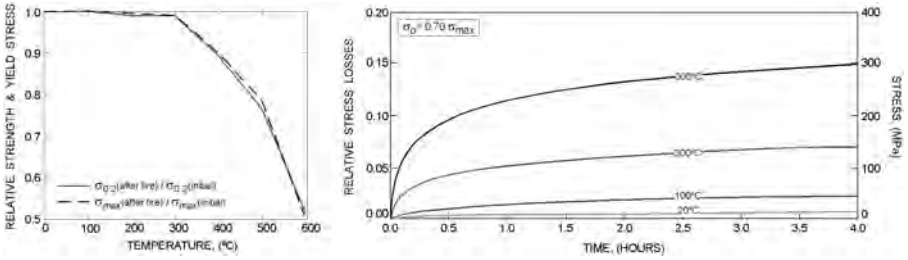

Fig. 1: a) Relative residual strength and yield stress at room temperature, after heating at different temperatures. b) Stress-relaxation losses (lost load/maximum load) as a function of temperature, for an initial stress of 70% of the wire strength.

3. Discussion: Estimation of fire-induced damage in prestressing steel

Figure 2 shows the experimental results of the evolution of the prestressed load before, during and after a simulated fire scenario. During the fire there is a significant reduction of the bearing load, as a consequence of the restrained dilatation and the increase of stress relaxation at high temperatures. When cooling, the part of this lost load due to the constrained dilatation is recovered, but not the stress relaxation losses. Thus, although the wire has successfully supported the fire without any visible damage, the prestressed load after fire has been considerable reduced, due to stress relaxation. Additionally, as the wire has suffered 500ºC (see Fig. 1-a) the residual strength has been affected (20% less than the original value).

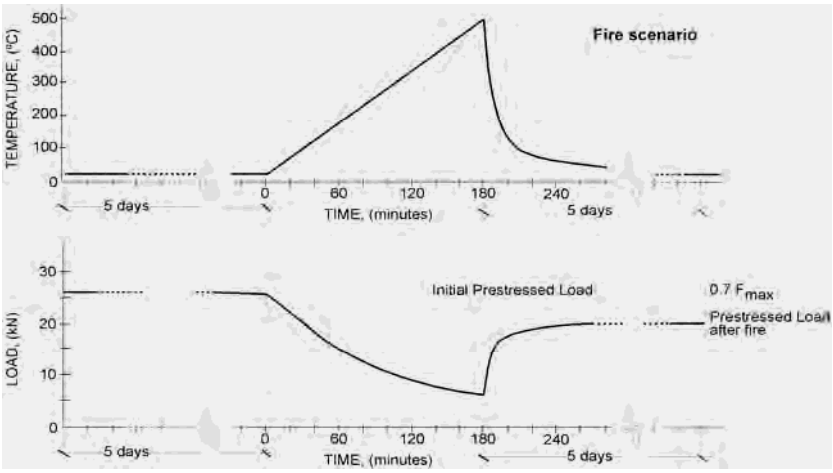

Fig. 2: Evolution of prestressed load before, during and after a fire scenario.

Fire safety should consider not only the performance of the structure during the fire but also the behavior of the structure after cooling. Even if a fire does not give rise to apparent damage in the prestressed structure, mechanical properties of materials as well as load distribution can be affected. The extent of damage in prestressing steels depends on the intensity and duration of the fire, the temperatures reached in the wires, as well as the load intensity they bear during a fire. A conservative estimation of the fire-induced damage can be obtained from the results presented in this work (as shown in Figure 1).