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Comparison on fire performance of unbonded post-tensioned one-way slabs depending on tendon types

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ABSTRACT

Post-earthquake fire is a potential hazard in Korea and other countries. In this paper, fire-resistance performance of three unbonded post-tensioned one-way slabs is studied. Test specimens had same variables in dimensions, cover thickness, heating length, heating time, and boundary conditions. A major difference in the experiment was tendon type: unbonded 7-wire strands tendon with duct (PF-U2), unbonded greased-sheathed-strand (GSS) tendon with duct (PF-G2), and GSS tendon without duct (PF-S2). Fire-resistance performance is evaluated using test results and compared in terms of temperature change, deflection change, and tendon force change.

1. INTRODUCTION

Post-tensioned (PT) structures are widely used for underground structures, long-span structures, and nuclear containments, as well as elevated floor structures in both high seismic and low-to-moderate seismic regions. Especially, PT floor slabs are preferred for office and residential buildings because of the advantages of crack control, deflection control, reduced slab width to depth ratio, and increased load capacity (Burns et al. 1978). Structural performance of PT structures is affected by the amount of bonded or unbonded tendons. For bonded tendons, strands are protected by duct and filled with grouts. Whereas, unbonded tendons are filled with grease or wax. Also, there is a method using GSS tendon with grouting, which however is a kind of unbonded tendon (Shin et al. 2020).

Although classified as unbonded tendon, the composition and size of GSS are different from other unbonded tendons, which would affect the fire performance of structures. Fire is a common disaster, and the probability of fire disaster is significantly increased after an earthquake. In this study, fire performance of unbonded PT one-way slab depending on the tendon type is investigated by conducting fire experiments. Input

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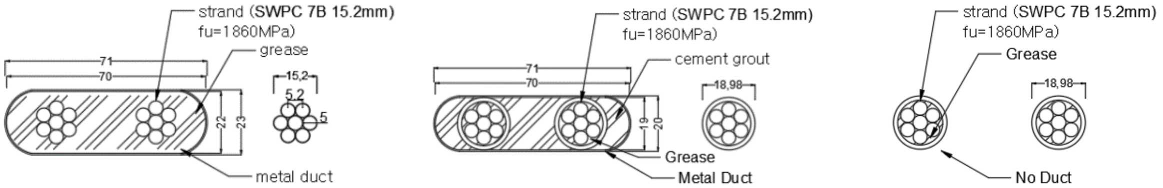
fire scenario follows the procedure in ASTM E119-20 (2020), and loads are applied on four points using an actuator. Measured experiment data are temperature change, tendon tension force change, and deflection of the slab, which are used for the evaluation of fire-resistance performance according to tendon type.

2. EXPERIMENTAL OUTLINE AND METHOD

2.1 Experimental outline

Fig. 1 presents tendon types used in the experiment. Although all of the tendon types are unbonded tendons, the coat and/or duct types used were different. In this paper, they were assumed to affect the fire performance. Specimen dimensions and heating conditions are shown in Table 1.



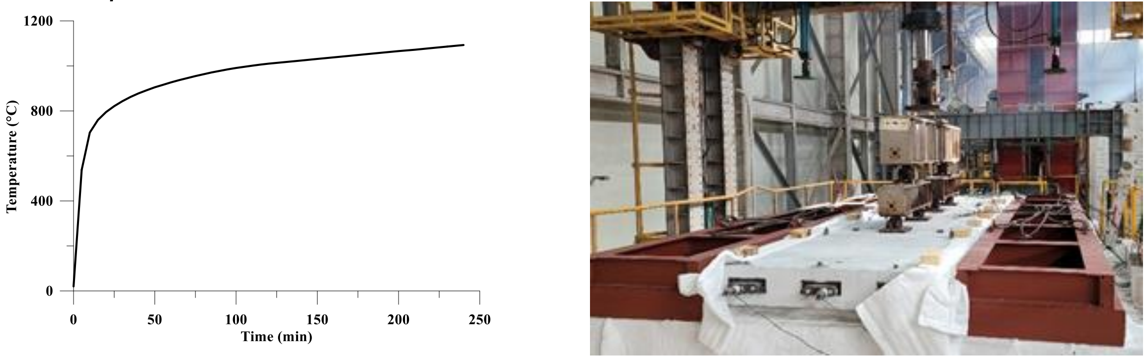
(a) PF-U2 (b) PF-G2 (c) PF-S2

Fig. 1 Unbonded tendon types

Table 1 Specimen dimensions and heating conditions

Name	PF-U2	PF-G2	PF-S2
Dimensions (mm)		6700×1500×250	
Span length (mm)		6350	
Heating length (mm)		6000	
Heating time (hr)		2	
Cover thickness (mm)		45	
Boundary conditions		Simply supported	

2.2 Experimental method



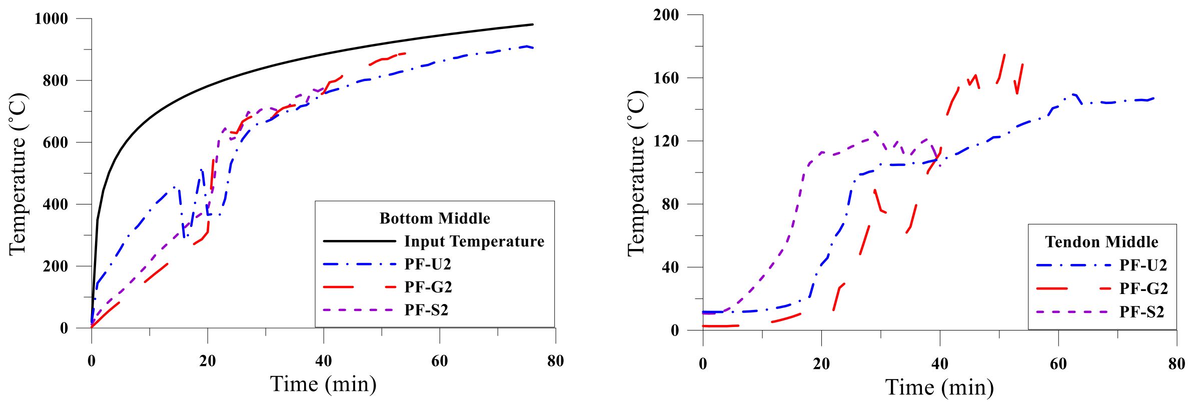
(a) Input fire scenario (b) Actuator setting

Fig. 2 Experiment method

Experiment was conducted by applying four point loads on the top of the slab and heating the bottom of the slab. A total of 12.1 tons were applied using an actuator and fire input scenario followed ASTM E119-20 standard time to temperature curve (Fig. 2).

3. EXPERIMENTAL RESULTS

Experimental results are compared in the sense of temperature change, displacement change, and tendon tension force change (see Figs. 3 to 5). Since input temperature was designed to be the same in all experiments, the rise rate of temperature at the bottom middle of the slab resembled each other. Also, after about 20 minutes since the experiment started, severe fluctuations occurred, resulting in concrete spalling. Tendon temperature increased sharply until it reached 100°C. After reaching 100°C, temperature rise rate became slower and remained its tendency until the experiment ended.



(a) Bottom (middle) (b) Tendon (middle)

Fig. 3 Time-temperature curve

The temperature to displacement curve shows that steady-state of displacement increase differs for tendon types (Fig. 4). PF-U2 had a short steady-state stage at a displacement of 30 mm, whereas PF-G2 and PF-S2 had a long steady-state stage. PF-G2 had the stage at a displacement of 40 mm with bottom temperature of 300°C to 600°C, and PF-S2 had it at a displacement of 30 mm with bottom temperature of 400°C to 700°C. The time vs. tension force curve shows that PF-U2 and PF-S2 had similar force change in range of 10 kN (Fig. 5). However, PF-G2 experienced more dynamic tension force change in the range of 30 to 40 kN.

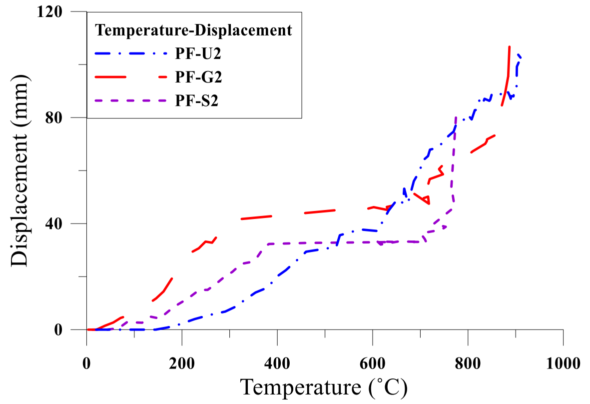


Fig. 4 Temperature-displacement curve

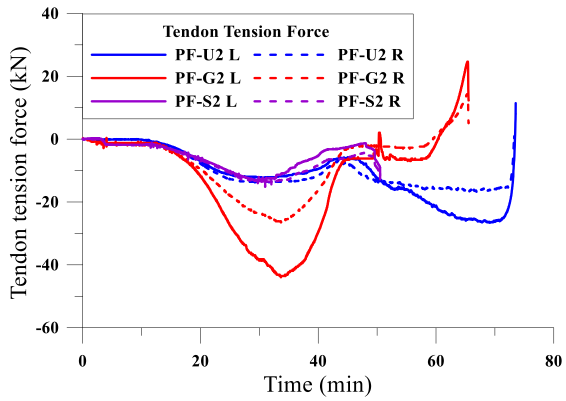


Fig. 5 Time-tension force curve

4. CONCLUSIONS

Fire-resistance performance of one-way slab in a simply supported condition was experimentally investigated. The input fire scenario followed the ASTM E-119 20 standard time-temperature curve and loading. A total of 12.1 tons were applied on the top of the slab. All specimens experienced collapse before reaching the target experiment time (2 hours). The following has been observed so far:

(1) Temperature change of bottom surface had a similar trend throughout all specimens. Overall, the specimens showed severe temperature rise after 20 minutes since the experiment started, while concrete spalling occurred. The tendon temperature also rose sharply until it reached 100°C, followed by a steady-state stage of the curve.
(2) The temperature to displacement relationship, however, showed different tendencies for different tendon types. PF-U2 had a short steady-state stage and its displacement increased until the experiment ended. PF-G2 had the stage at a displacement of 40 mm in the temperature range of 300°C to 600°C, whereas PF-S2 had it at 30 mm displacement in the range of 400°C to 700°C.
(3) The time vs. tendon tension force curves showed some difference according to the tendon type. PF-U2 and PF-S2 had similar trends with the tendon force increment of 10 kN. However, PF-G2 had the increase in tendon force of 30 kN to 40 kN.

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