第Ⅴ部門 **Recreation of Fire Damage on Pretensioned Prestressed Concrete on the 1-Dimensional Plain**


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## 1. Introduction

In recent years, fire damage to bridges and viaducts have been reported. In the case of estimating the residual load-carrying capacity of pre-tensioned PC girders after a fire, it is necessary to clarify the relationship between the maximum heat-receiving temperature of the PC members and the residual strength. It has been found that the heat-receiving temperature of the internal PC tendons can be determined with relatively high accuracy by analysis when there is no spalling of the cover concrete. On the other hand, when spalling of the cover concrete occurs, the heat-receiving temperature of the PC steel varies greatly depending on the depth of the spalling. Therefore, it is essential to consider the effect of spalling in the evaluation of the residual load-carrying capacity of PC structures, however, no method has been established yet.

## 2. Purpose

This study aims to recreate the effects of fire damage on a pretensioned prestressed concrete on a 1-dimensional level to get an understanding of how heat energy behaves on a 1-dimensional plane.

## 3. Specimen Outline

The PC girder details were as follows: top width 640 mm, bottom width 700 mm, total length 5300 mm, and pre-tensioned PC girder 1) (pre-tensioned PC girder (AS-05) as specified in JIS-A-5373). The design compressive strength of the concrete is 50 N/mm$^2$.

## 4. Heat test

A horizontal heating test furnace (4m x 3m) was used. For the fire curve, a heating curve (HC900) was selected, in which the maximum temperature of the hydrocarbon curve HC curve (1100°C) specified by Eurocode3 2) was modified to 900°C. The heating time was 60 minutes. Heating tests and load-bearing tests were conducted on specimen 60HC900-1. For comparison, a specimen N-2 without a heating test was used. The bottom surface of the heated PC girder is shown in Figure-3 after natural cooling and removal. The concrete has spalled to such an extent that the entire transverse stirrups and the PC steel are exposed. The maximum depth of the spalling was 61mm. The depth of the spalling was smaller in the center than at both ends.

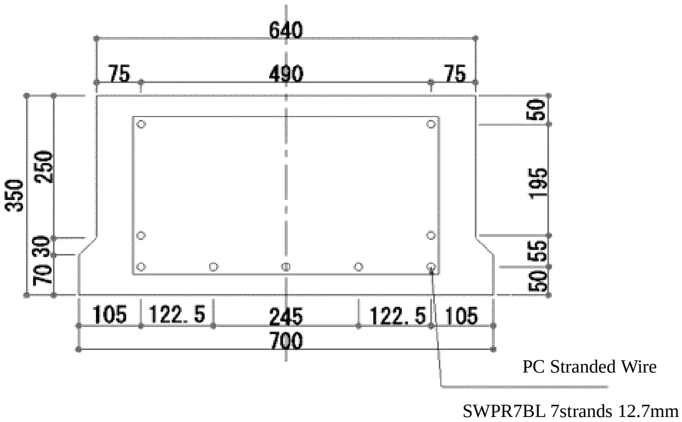


*Figure-1 Cross Section of Concrete Specimen*

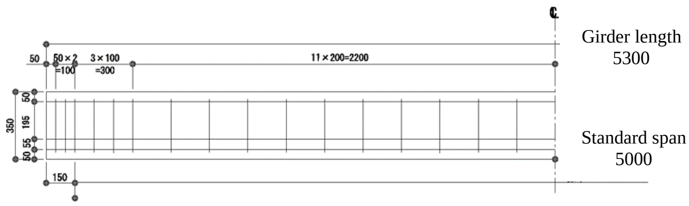


*Figure-2 Side Section of Concrete Specimen*

## 5. Simulation

The heating condition used for the 1-dimensional simulation is HC1100 modified to 900℃ which has the same heating condition as specimen 60HC900-1 under the assumption of the condition that spalling occurs at the

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temperature 650°C. In the simulation, the energy absorbed by the cover concrete is governed by convective heat transfer and radiation heat transfer, and the transfer of heat energy between the concretes is governed by the one-dimensional steady-state heat conduction. The simulation is also set so that when the cover concrete reaches the spalling temperature, the temperature doesn't rise anymore, and the next level will take in heat energy from the convective and radiation heat transfer. Table 1 shows parameters used in the simulation.

Figure 4 shows the result of the 1-dimensional simulation. Where the two-dash line is the heating curve condition used for the experiment, the dashed line is the temperature of the simulated concrete at the position of 50mm from the cover concrete, the thick line is the data gathered at the beam end, and the normal line is the data gathered at the beam center. As shown in Figure 4, spalling depth of the beam end reached the position where the heat sensor is set (50mm from the cover concrete) at the 15-minute mark. The simulation data and experimental results for the beam end have the same temperature rise until the 15-minute mark. On the other hand, the beam center indicates that the heat sensor is not directly exposed to the fire due to having a spalling depth of less than 50mm.

## 6. Conclusion

The conclusions obtained in this study are as follows. The concrete has spalled to such an extent that the entire transverse stirrups and the PC tendons are exposed. The maximum depth of the spalling was 61mm. The result of the 1-dimensional simulation has the same temperature rise until the 15-minute mark.

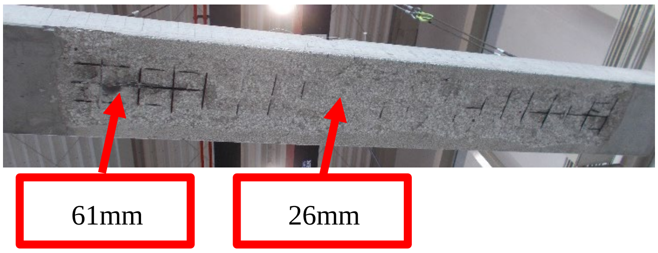


*Figure 3 Explosion Spalling Condition after Heat Test*


*Figure 4 Spalling Depth*

*Table 1 Parameters Used in the Simulation*

| Symbol | Name | Value |
|---|---|---|
| $\alpha'_c$ | Coefficient of convective heat transfer | 25(W/m$^2$) |
| $\Phi$ | Configuration Factor | 1.0 |
| $\sigma$ | Stefan-Boltzmann constant | 5.67x10$^{-8}$ (W/m$^2$K$^4$) |
| $\varepsilon_m$ | Emissivity of concrete | 0.8 |
| $\varepsilon_f$ | Emissivity of fire | 1.0 |
| $\lambda_c$ | Thermal conductivity of concrete | 1.77 (W/mK) |

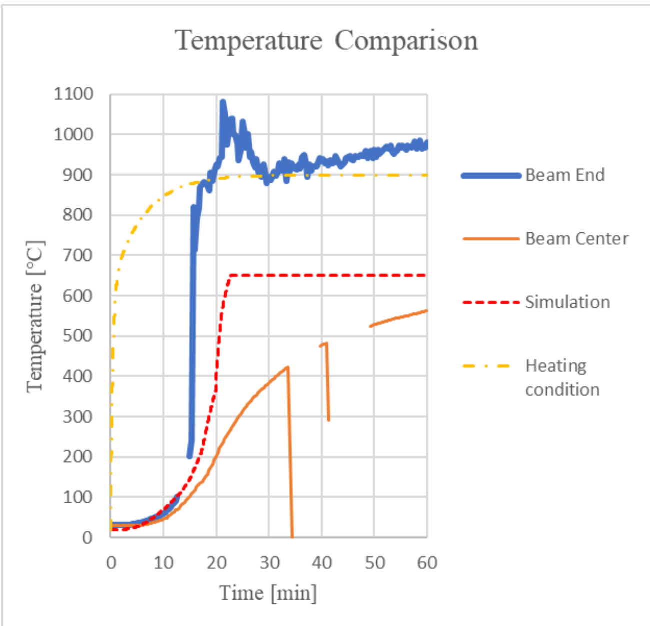


*Figure 5 Results of 1-Dimensional Simulation*

### Acknowledgment

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### References

1) Susumu Inoue, Yosuke Tabuchi: Effect of Fire Damage on the Residual Prestress and Load Carrying Capacity of Pre-tensioned Prestressed Concrete Bridge Girders, Proc. Of the 5th International fib Congress, ID81,2018.10

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