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CSST: a screening tool to assist concrete mix design

N. Valiante & F. Martelozzo - Webuild
R. Felicetti & F. Lo Monte - PoliMi

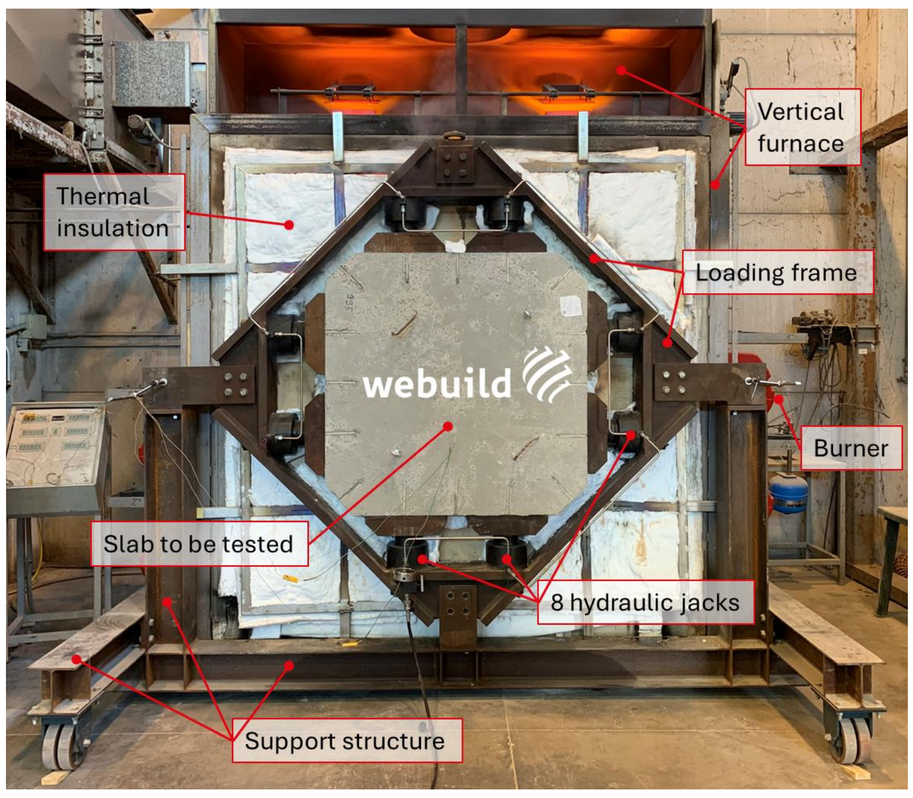
Introduction

In 2022, Webuild Group addressed the need to develop an easy while representative and widely applicable fire test method that could be adopted to estimate the depth of explosive spalling associated with a given concrete mix design, before that tunnel geometry and production processes are completely defined.
Webuild Group and PoliMi started a collaboration and succeeded in developing this type of fire test method, called the **Confined Slab Spalling Test (CSST)**.
Over the past three years, **more than 30 tests** have been carried out to assess the fire resistance of numerous **SFRC concrete mixtures for precast tunnel linings**.
Aiming at both representativeness and cost/time effectiveness, the CSST solution allows to merge a configuration close to the real fire scenario to the flexibility and repetitiveness of intermediate-scale testing.

The CSST experimental setup

The CSST setup includes:

- **Specimen** - a square concrete slab with 1.3x1.3m^2 in-plane dimension and a thickness ranging from 0.2 to 0.3m. Concrete could either be SFRC or reinforced with rebars. Considering the heated area is 1.0x1.0m^2, the cold rim has a width of 0.15m, whose confinement effect is smoothed down by the application of perimetral slits. Three internal “K-type” thermocouples record the temperature of different inner concrete layers.
- **Loading frame** - an octagonal steel restraining frame which works mainly under tension. The system is completed by 8 hydraulic jacks with a capacity of 1.5MN each being able to apply an equivalent average compression stress up to 10- 15MPa in the slab.
- **Thermal insulation** - a stainless-steel frame lined with three layers of ceramic fiber blankets reduces the vertical furnace opening to the required exposed area.
- **Surveying** - the erosion undergone by the tested specimens is surveyed by means of a 3D laser scanner.

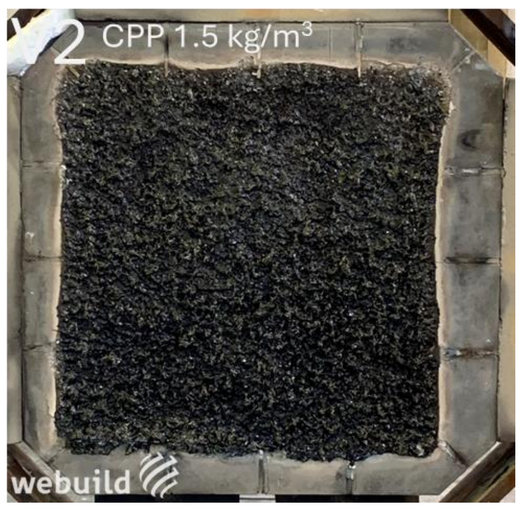


Initial experimental results

Here, the results are reported from the first 4 CSST fire tests aimed at investigating the sensitivity to spalling of one SFRC mix for precast tunnel lining applications classified as C45/55 4C.
Two different types of PP fibers were tested, characterized by different geometry and Melt Mass-Flow Rate:

- Conventional PP fiber (CPP) with low MFR
- High-performance PP fiber (HPP) with high MFR

One test has been performed on a reference specimen made of SFRC with no PP fibers and another test was performed on plain reinforced concrete (without any fibre).
The applied fire curve is the well-known RWS120 curve, as prescribed by the Italian railway infrastructure management (RFI) design specifications with T_{max} of 1350°C.



Specimen code	Reinforcement	Fire curve	PP fibers [kg/m3]	Sample age [days]	Average spalling [mm]
F03	SFRC	RWS 120	0	336	87
V2	SFRC	RWS 120	1.5 CPP	85	40
F27	SFRC	RWS 120	1.5 HPP	337	3
F08	Rebars (RC)	RWS 60	0	366	>150

Conclusions

A comparison among the initial CSST tests confirmed that:

- Addition of PP fibers to the mix proved to be the most effective way to reduce the likelihood of fire spalling.
- Spalling depth was lower in SFRC than in conventional RC, demonstrating the beneficial effect given by steel fibers.

Further tests are underway to evaluate the fire resistance of several SFRC concrete mixtures for precast tunnel linings of the principal Italian high-speed railways projects.

R. Felicetti et al. “Confined Slab Spalling Test (CSST): a screening tool to assist concrete mix design in tunnel projects”. *SiF 2024 – The 13th International Conference on Structures in Fire*