Comportement des bétons en situation d'incendie

> JOURNEE DES DOCTORANTS
> CSTB - PARIS

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PROBLEM

Fire poses one of the most severe environmental conditions that can act on concrete structures as an external load which could induce severe damages like cracks, spalling or even lead to the collapse. Fire spalling reduces the cross-sectional area and can lead to the direct exposure of rebars to flames and then reduce the structure load bearing capacity.

CSTB fire test

OBJECTIVE

The objective is to study the factors influencing fire spalling behaviour of concrete, mainly focusing on the role of mechanical loading and cement types.

EXPERIMENTAL TEST METHODS

In order to gain a better understanding of the fundamental physics behind the fire spalling of concrete, several tests have been carried out on two ordinary concretes (B40-II and B40-III: fc_{28days} ≈ 40 MPa), for example, permeability [1-2], porosity [2], pore pressure-temperature-mass loss (PTM) [2], fire spalling tests under different levels of uniaxial and biaxial mechanical loading [3-4, 6].

RESULTS

Effect of uniaxial loading on spalling

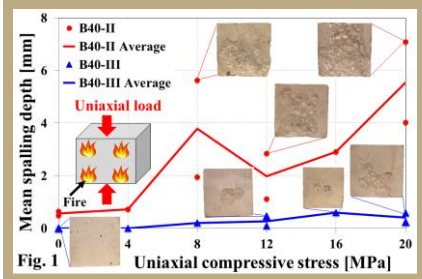

Fig. 1

▲ An increasing trend of the fire spalling depth was observed for the increased uniaxial compressive stress, except scattered at 8 MPa of B40-II.

▲ Spalling depth:
B40-II >> B40-III.
This could be due to higher pore pressure caused by lower permeability (K_{int}) and porosity of B40-II at high temperatures (Fig. 5).

▲ Low permeability reduces transport of water vapour inside the concrete, which induces higher pore pressure.

Effect of biaxial loading on spalling

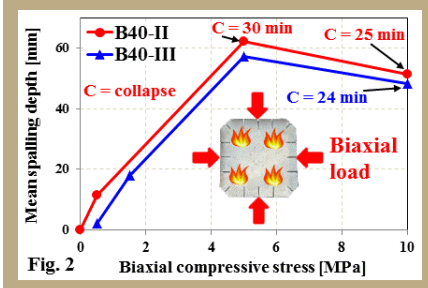

Fig. 2

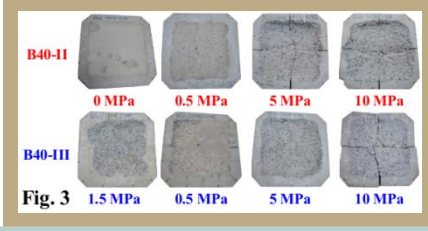

Fig. 3

▲ B40-II: very small load (0.5 MPa) is enough to trigger spalling, while no spalling in unloaded test (Fig. 2-3).

▲ Load up to 5 MPa: spalling increased with the increased load in both concretes.

▲ At 10 MPa: lower spalling due to early collapse (hence, lower fire duration).

▲ Spalling depth:
B40-II > B40-III (Fig. 2-3)

▲ Good agreement with the uniaxial test results (Fig. 1-2).

Comparison: Uniaxial tests vs Biaxial tests

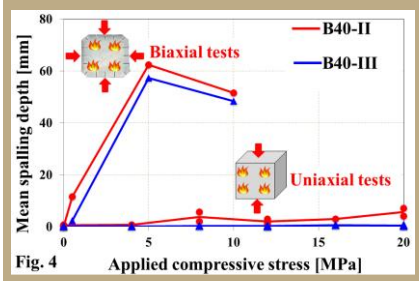

Fig. 4

▲ Spalling depth:
Biaxial >>> Uniaxial tests

▲ Uniaxial tests: cracks tend to open vertically in all the directions along the loading axis.

▲ Biaxial tests: cracks only generated parallel to the heated surface .

▲ Permeability:
Uniaxial >> Biaxial test

▲ Uniaxial test:
increase permeability → decrease pore pressure and decrease internal stresses → less risk of fire spalling.

Effect of loading (confining pressure) on permeability

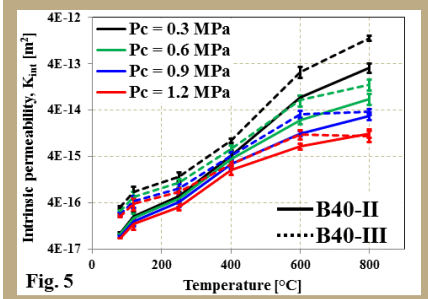

Fig. 5

▲ Permeability decreased with the increased confining pressure (P_c) due to the partial closure of heat induced microcracks (Fig. 7).

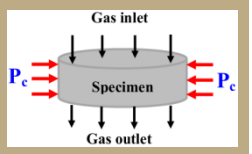

Fig 6. Cembureau test

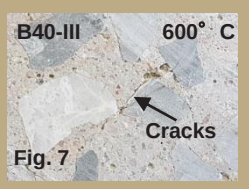

Fig. 7

CONCLUSIONS

1. **Loaded specimens (uniaxial and biaxial) are more susceptible to spalling than unloaded specimens, with increasing amounts of spalling for higher values of applied load. External load increase stresses and increase pore pressure due to decreased permeability (Fig. 5), which could increase the risk of fire spalling.**
2. **The amount of spalling is much higher in biaxial tests than uniaxial tests. Probably, in biaxial tests, the cracks are mainly orientated parallel to the heated surface, which help to induce spalling, while in uniaxial tests, the cracks tend to open vertically in all the directions along the loading axis, therefore, less risk of spalling due to the higher permeability of uniaxial tests.**
3. **Concrete made with CEM III cement (B40-III: 43% of slag) exhibited less spalling than CEM II cement (B40-II: 3% of slag). This behaviour is attributed to lower pore pressure caused by higher permeability and porosity of B40-III than B40-II at high temperatures (Fig. 5).**

Publication papers:

[1] Miah et al. (2015). "Effect of cement type on pore pressure, temperature, and mass loss of concrete heated up to 800 °C", 33èmes RUGC, May 27-29, 2015, Bayonne, France
[2] Miah et al. (2015). "Fire Spalling of Concrete: Effect of Cement Type", Proceedings of 4th IWCS, October 8-9, 2015, Leipzig, Germany.
[3] Miah et al. (2015). "Effect of Uniaxial Mechanical Loading on Fire Spalling of Concrete", Proceedings of 4th IWCS, October 8-9, 2015, Leipzig, Germany.
[4] Miah et al. (2016). "Effect of Biaxial Mechanical Loading and Cement Type on the Fire Spalling Behaviour of Concrete", Pro. of the 9th SIF June 8-10, 2016, USA.
[5] Miah et al. (2016). "A Thermo Mechanical Experimental Investigation on 3 Loaded Concrete Walls Exposed to ISO 834-1 Fire", Pro. of the 9th SIF June 8-10, 2016, USA.
[6] Miah et al. (2016). "Fire Spalling Behaviour of Concrete: Role of Mechanical Loading (Uniaxial and Biaxial) and Cement Type", Pro. of the 8th CONSEC, Sept 12-14, 2016, Italy
[7] Carré, Miah et al. (2016). "Durability of ordinary concrete after heating at high temperature", Pro. of the 8th CONSEC, Sept. 12-14, 2016, Italy
[8] Bamonte, Miah et al. (2016). "On the structural behavior of reinforced concrete walls exposed to fire", Pro. of the 8th CONSEC, Sept. 12-14, 2016, Politecnico di Milano, Italy

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