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Spalling of Concrete in Actual Fire

Eclatement du béton dans un incendie réel

Ausplatzen von Beton bei einem echten Brand

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Spalling experiment conducted with fifty-two 1m x 1m test panels of reinforced concrete has shown a prominent effect of free water in concrete on spalling phenomenon of both lightweight and ordinary aggregate concrete, as we have reported in the preliminary report. The result shows that spalling is liable to occur when the amount of free water in concrete is increased above the range of 120 to 130kg per cubic meter of concrete. 1)

Fig. 1 and fig. 2 show the examples of test panels exposed to fire. The test panel in fig. 1 made of ordinary aggregate concrete and having 140kg/m^3 of free water shows a remarkable spalling, while the panel in fig. 2 made of lightweight aggregate concrete shows a slight spalling on the exposed surface, the amount of free water being 120kg/m^3.

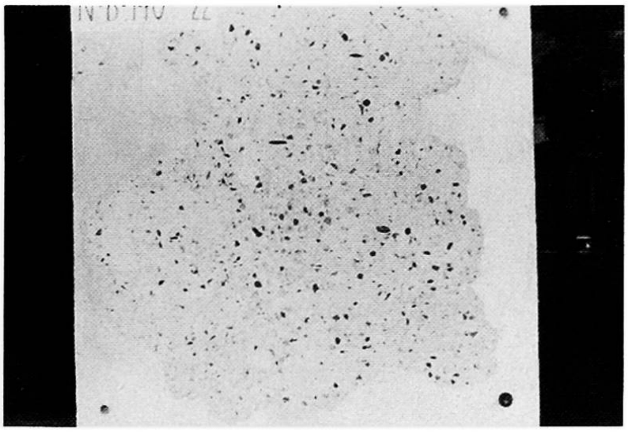

Fig.1

Ordinary aggregate concrete test panel having 140 kg/m^3 of free water

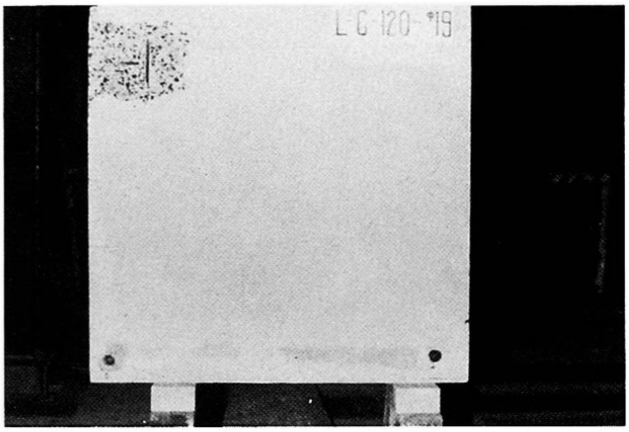

Fig.2

Lightweight aggregate concrete test panel having 120 kg/m^3 of free water

An investigation is now under consideration to make clear what amount of free water exists in realized concrete structures. A preliminary study for this investigation on the loss of free water from ∅15 x 30cm cylinder made of lightweight aggregate concrete in the course of atmospheric drying in the room shows that lightweight aggregate concrete has about 100 to 120kg/m^3 of free water at the age of 3 months, and the amount of free water of air dried concrete seems to be in equilibrium within this level (fig. 3).

We can consider that the amount of free water in the light-weight aggregate concrete in realized structures also decreases to this level after the age of 3 months or more, according to the size and exposure conditions of the concrete elements. For ordinary concrete, the initial and the equilibrium amount of free water is less than those for lightweight aggregate concrete.

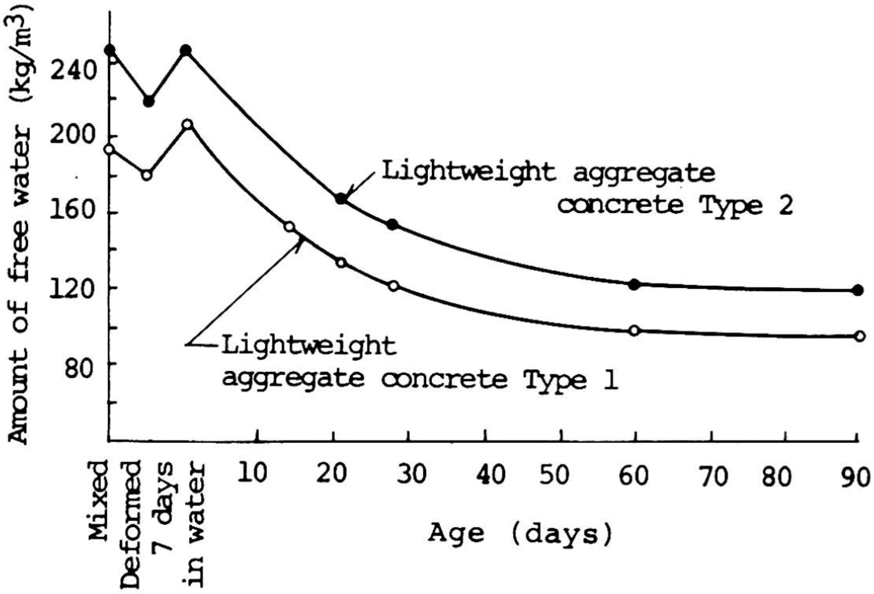

Fig. 3 Loss of free water from lightweight aggregate concrete (∅15 x 30 cylinder)

The following are some examples of spalling phenomenon in actual fire which seem to represent different levels of the amount of free water and different types of aggregate used. The examples are limited but we could recognize an effect of the amount of free water in concrete on spalling in actual fire, as in the experiment.

Example 1: Explosive Spalling Occurred in Fire of a Reinforced Concrete Structure Building under Construction

This example, reported by K. Kizawa and S. Ohgishi in 1967, shows a remarkable spalling in concrete during hardening. A five-story reinforced concrete shop building having 2,200m^2 total floor area was under construction when fire spread from the 3rd to the 5th floor, 5 days after concreting in the 4th story and floor slab of the 5th story. It was 17th day after concreting in the 3rd story.

Spalling was so much intensitive as to be explosive at the 5th story floor slab and at the bearing wall around the elevator shaft in the 3rd and 4th story. The concrete was of ordinary aggregate and the amount of free water should have been very high because of early ages of concrete (fig. 4).

Fig.4
Spalling at the wall of the elevater shaft

Example 2: Spalling in Fire of a Reinforced Concrete and Steel Structure Building Nearing Opening

The building was a six-story steel structure with a basement of reinforced concrete, having 60,000m^2 total floor area. The floor slab of each story was of reinforced lightweight aggregate concrete except that ordinary aggregate concrete was used in the basement.

Fire occurred at the basement, just before the opening of the building, spread from the 2nd to the 4th floor, the 1st floor remaining undestroyed, and continued for 15 hours smoldering. It was about 6 months after concreting.

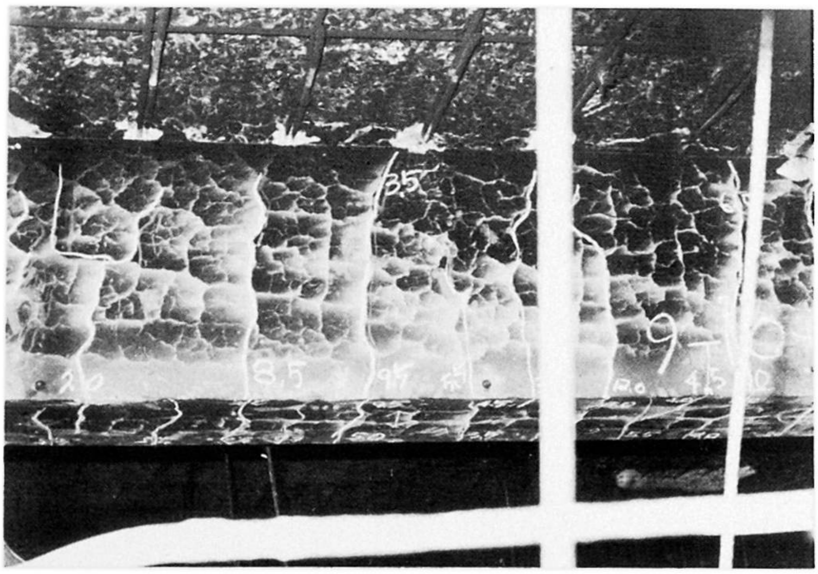

Fig.5
Spalling at the under side of floor slab

Spalling of concrete was observed at the under side of each floor slab and at the reinforced concrete beam and girdir of the basement. It was so much remarkable in severely attacked slabs that the lower reinforcing bars of the slabs were entirely bared out (fig. 5).

It was considered that the cause of this remarkable spalling could be a fairly high content of free water in the concrete, especially in that of the basement, and the long duration of fire due to the abandance of combustibles.

Example 3: Spalling in Fire after Gas Explosion of a Precast Concrete Structure Apartment House

The building was of a composite structure of H section steel frame and precast concrete large panels. The large panels were made of lightweight aggregate concrete and manufactured by steam curing. Fire occurred after gas explosion in an apartment on the 6th floor and spread to adjoining 5 apartments.

Though the damage by the gas explosion was so heavy as to destroy the walls and slabs (fig. 6), spalling was observed only at the lower corner of the beams and around the ventiration opening penetrating them (fig. 7). The cause of the slight spalling might be a fairly low content of free water in the concrete due to steam curing.

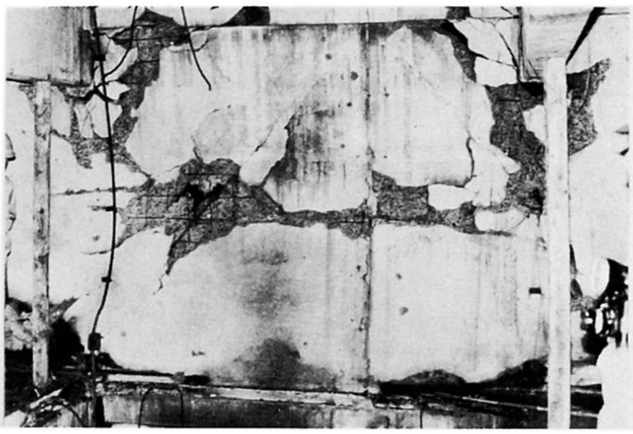

Fig.6
A wall destroyed by gas explosion

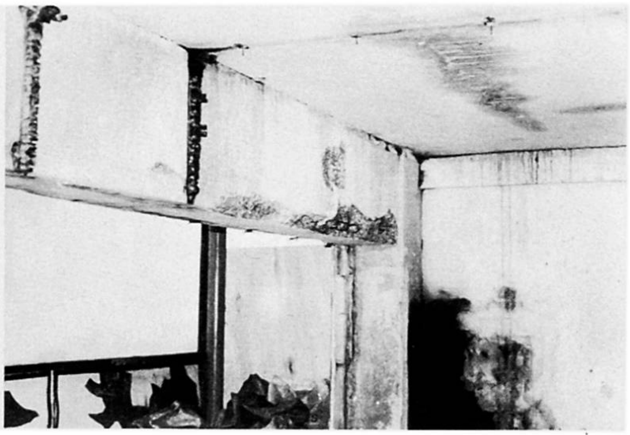

Fig.7
Spalling at the beam

Example 4: Spalling in Fire of a Reinforced Lightweight Aggregate Concrete Apartment House

The apartment house is of a composite structure of lightweight aggregate concrete cast-in-situ, having 11 stories. Fire occurred in March 1976, i.e. 6 years after completion, in an apartment on the 8th floor and this apartment was fully burnt out.

Spalling could scarcely be observed except at the under side of balcony slab of the upper story. The spalled part was about 80cm x 50cm, depth about 2cm, and its appearance was as same as that of test panels spalled in our experiment. This part has been attacked directly by the flame going out from the broken window, and the amount of free water in the slab should have been higher than in interior elements (fig. 8).

Fig.8
Spalling at the under side of balcony slab

SUMMARY

Four examples of spalling of concrete in actual fire representing different levels of the amount of free water and different types of aggregates used are shown. An effect of the amount of free water in concrete on spalling could be significant in actual fire as in the experiment, the amount of free water in realized concrete structures being to be investigated.

RESUME

On présente 4 exemples d'éclatement du béton dans un incendie réel, avec des bétons correspondant à différentes quantités d'eau libre et à des agrégats différents. L'effet d'une certaine quantité d'eau libre pourrait être déterminant pour l'éclatement du béton, dans des incendies réels comme en laboratoire, mais il reste à déterminer la quantité d'eau libre se trouvant en réalité dans le béton des structures existantes.

ZUSAMMENFASSUNG

Vier Beispiele des Ausplatzens von Beton bei einem echten Brand werden gezeigt; die Betons werden mit verschiedenen Mengen Freiwasser und mit verschiedenen Aggregaten vorbereitet. Die Wirkung einer gewissen Menge Freiwasser auf das Ausplatzen des Betons könnte sowohl bei wirklichen Bränden wie auch im Labor entscheidend sein, es wäre aber noch notwendig, die Menge Freiwasser im Beton von bestehenden Bauwerken festzustellen.

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