Fire performance of hollowcore floors

A preliminary BRANZ study into the fire performance of hollowcore concrete floors suggests that conventional fire design requirements for precast floors may need to be reviewed.

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SINCE 2006, many seismic requirements have been introduced to hollowcore floor practice, including a link slab between the hollowcore unit and the adjacent beam (see Figure 1).

Following these changes, concerns have been raised about the fire adequacy of hollowcore floors.

Recently, BRANZ undertook a fire experiment on a precast hollowcore floor system as part of an investigation into the effect of the link slab on the fire performance of hollowcore floors. This is the result from one experiment, and further work will be carried out to explore these observations.

Fire design of concrete floors

Fire design of buildings around the world usually takes an elemental approach. Fire resistance rating (FRR) demands are determined based on a building's characteristics. All of the structural elements necessary for load carrying or separation are required to have a fire rating not less than the fire resistance rating demands.

Fire rating of an element is usually determined by a fire resistance test (usually AS 1530.4 in New Zealand) and is defined as the ability of the element to fulfil its designed function for a period of time in the event of a fire. Three numbers (representing the time in minutes) are used to define fire ratings:

- Structural adequacy - the ability of the element to carry an applied load.
- Integrity - the ability to prevent fire spread by flaming on the non-fire side or the creation of gaps to allow the passage of hot gases.
- Insulation - the ability to limit the average temperature rise to 140 K on the non-fire side.

Concrete floors are load-carrying elements as well as fire-separating elements. Fire design of concrete floors follows NZS 3101:2006 *Concrete structures standard,* which specifies two paths for evaluating the FRRs of concrete floors - a tabulated method and a calculation method. The tabulated method is commonly used because NZS 3101:2006 does not specify an appropriate calculation method.

The data for the tabulated method is produced by conducting standard fire tests using AS 1530.4 on individual floor elements without allowing for the interactions between floors and frame members within the building.

According to the tabulated method in NZS 3101:2006, the criterion for integrity is considered to be met if the member meets the criteria for both insulation and structural adequacy for that period. The insulation rating of concrete floors is determined by the effective thickness of the slabs, and the structural adequacy rating is dependent on the axis distance from the bottom reinforcement and tendons.

BRANZ fire test of a hollowcore floor system

BRANZ carried out the fire resistance experiment on a hollowcore floor system rather than an individual floor element.

The experimental specimen had concrete beams on the four sides. The surrounding

Table 1

FRRs of 200 series hollowcore floor components (minutes)

	BARE HOLLOWCORE UNITS	75 MM TOPPING
Insulation	105	60
Structural adequacy	180	225

concrete beams were 500 mm deep, the topping was 75 mm concrete cast in situ and the hollowcore units were 200 mm thick. The relevant NZS 3101:2006 requirements were followed.

Theoretical fire resistance ratings

The fire resistance ratings of the hollowcore floor specimen were assessed using the tabulated methods in NZS 3101:2006. The assessed fire ratings of the floor system are listed in Table 1.

The insulation rating was 60 minutes, limited by the thickness of the link slab. The structural adequacy rating was 180 minutes, limited by the hollowcore floor units.

According to the NZS 3101:2006 tabulated method, the integrity rating is considered satisfactory if the member meets the criteria for both insulation and structural adequacy for that period. As such, the integrity rating of the tested hollowcore floor systems experiment was at least 60 minutes.

Hollowcore floor units in real buildings often span 7–8 m, which is about twice the span of the test. Therefore, the structural adequacy of the experimental specimen should be maintained for much longer than 180 minutes in theory.

Premature hollowcore web failure

The experiment used the furnace conditions required by AS 1530.4 with a live load of 5.5 kPa. Vertical deflections were measured at mid-span and quarter-span points. Temperatures at multiple locations and different depths were measured throughout the experiment.

The experiment was terminated soon after the 140 K average temperature rise insulation criterion measured on the unexposed surface was reached at 116 minutes.

Floor system deflections were insignificant throughout the entire 120 minute furnace exposure duration. However, premature web failure and high strength reinforcing steel wire exposure in the hollowcore unit adjacent to the link slab was observed only 29 minutes into the experiment. At the completion of the test, all the strands were exposed, and damage spread to the entire unit (see Figure 2).

This observation is a concern for the structural adequacy of hollowcore floor systems using the greater spans typically found in buildings.

What did we find?

Preliminary findings point to some potential issues and related future actions.

Review fire rating test for floor systems

The conventional fire resistance test for precast floors should be reviewed to ensure adequate allowance for system effects on the fire performance of the floor systems. This is especially true for the floor systems that are thin and/or susceptible to torsional failure.

The traditional fire resistance test for floor systems is performed on individual floor elements – an elemental test. This arrangement allows the hollowcore floor units exposed to fire to expand freely along two orthogonal horizontal directions.

In contrast, the recent BRANZ experiment was on a hollowcore floor system that included precast hollowcore units, a topping slab and beams around the floor. The experiment ➤

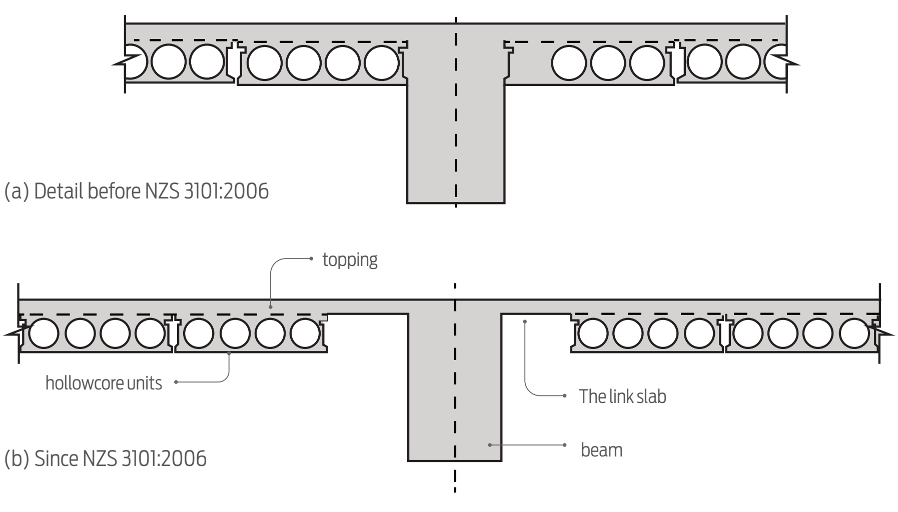

Figure 1: Details in NZS 3101 for hollowcore units adjacent to a beam.

showed that fire resistance of a hollowcore element, when tested at the systems level, could be significantly less than the tabulated fire rating in the current NZS 3101:2006.

Negative impact from restraining elements

Restraining actions by floor frame elements could potentially have a negative impact on the fire performance of hollowcore units.

When hollowcore floors are heated, they expand differentially with the hotter part expanding more than the cooler part. When there is no restraining action, the hollowcore units can expand in all directions except upwards. However, when the restraining actions are present at both ends, the expansion is limited to a sideways and/or downwards movement.

The sideways expansion of hollowcore units is like a twisting action and is more damaging than the downward expansion-like normal loading action. The distortion of the hollowcore units potentially caused horizontal web cracking at the uppermost web level, leading to partial failure of the units. The presence of the link slab is likely to exacerbate such a failure mode, leading to the significantly compromised structural adequacy of the floors.

Issue with link slabs in hollowcore floors

Preliminary experimental results show that inserting link slabs to hollowcore floor systems as required by the current concrete structures standard may compromise the structural adequacy fire resistance of the hollowcore floor units. Further work will explore this phenomenon and provide recommendations to improve fire resistance assessment.

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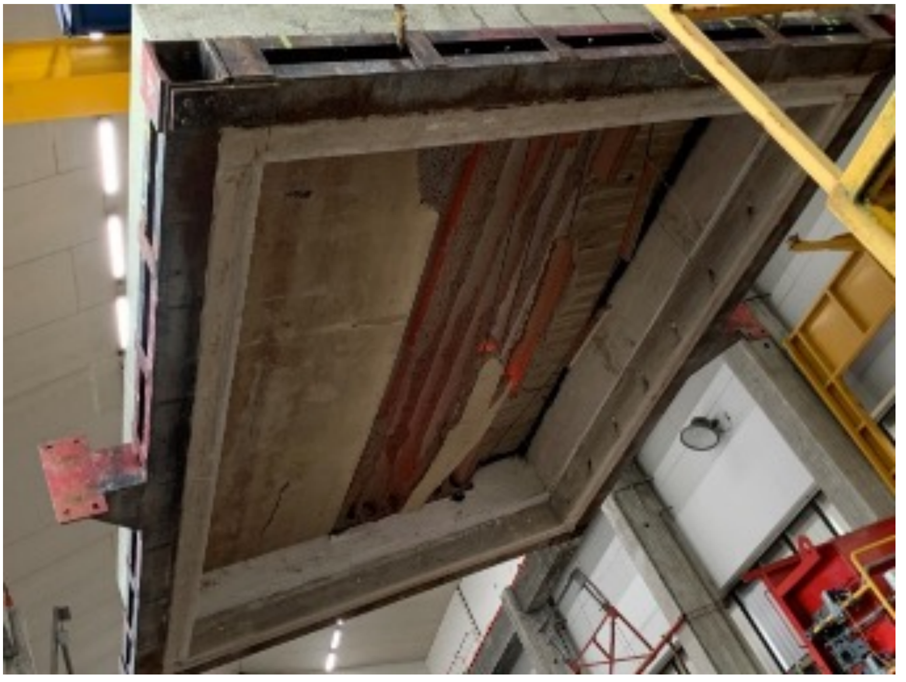

Figure 2: Damage to the underside of the floor after the fire experiment. Close-up in the bottom photo.