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Experimental study on the shear behaviour of precast concrete hollow core slabs with concrete topping

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ABSTRACT

In typical precast construction practice of floor slabs using precast concrete hollow core unit (HCU), in-situ concrete is cast on top of the HCU to obtain smooth and even floor finish. The surface of the HCU is seldom given proper treatment prior to casting the concrete topping. The texture and surface moisture condition of the HCU just before receiving concrete topping may affect the overall strength of the slabs when the concrete topping and the HCU act compositely during service. This paper presents the experimental study on shear-flexure capacity of composite slabs using HCU and concrete topping. Full scale three point load test are carried out on 14 composite slab specimens with different surface roughness and surface condition of the HCU before casting the concrete topping. The surface roughness considered is smooth and rough, while the moisture conditions are dry, ponded and optimum wet. The effect of the longitudinal joint between the HCU panels is also considered. The experimental results are also compared with predicted values using the available equation in Eurocode 2 and an equation published by a previous researcher. The results of the experiment show that the HCU surface condition and longitudinal joint affect the stiffness and shear-flexure strength of the slabs. The optimum HCU surface condition which can produce highest stiffness and shear strength is rough and wet conditions, while the longitudinal joint between HCU panels reduces the slab shear strength. The interfacial horizontal shear is not the factor that governs the strength and behaviour of the slabs. The equation available in Eurocode 2 gives non-conservative prediction of the shear strength. In contrary, the equation published by the previous researcher gives conservative prediction of the shear strength.

1. Introduction

Precast concrete slab system for buildings that is widely available in the market includes hollow core unit, double-tee, solid composite plank & beam, and composite plank. They offer speedy construction, reliable and reduce construction cost particularly for the construction of suspended floors. The system can be made with variable lengths and is suitable for used in all types of buildings. In most construction practices, cast in-situ concrete toppings are added onto the concrete precast slab for the purpose of making smooth and even floor finish. Besides, the concrete topping can also enhance the structural performance of the precast slab by producing a composite structural system. Typically, the in-situ concrete toppings are 40–100 mm in thickness, and contain a small amount of steel reinforcement, usually a prefabricated welded mesh to control shrinkage. The concrete topping with the strength ranges from 25 to 40 N/mm^2 are laid onto the aged precast slab units. The most popular precast concrete slab system is the prestressed precast Hollow Core Units (HCUs). The HCU is manufactured using automated semi-dry extrusion where the final product is high strength concrete.

Each year the UK industry constructs around £30 m of composite hollow core floors slabs with no bona fide information about their design, surface preparation and construction. Relative movement between the wet cast concrete topping and the HCU, the injudicious placement of mesh reinforcement, and the presence of construction joints may cause delamination, edge restraint, curvature and loss of serviceability (see Fig. 1). Ultimate failure modes could be brittle, especially on the precast prestressed floors that have a high strength-stiffness ratio.

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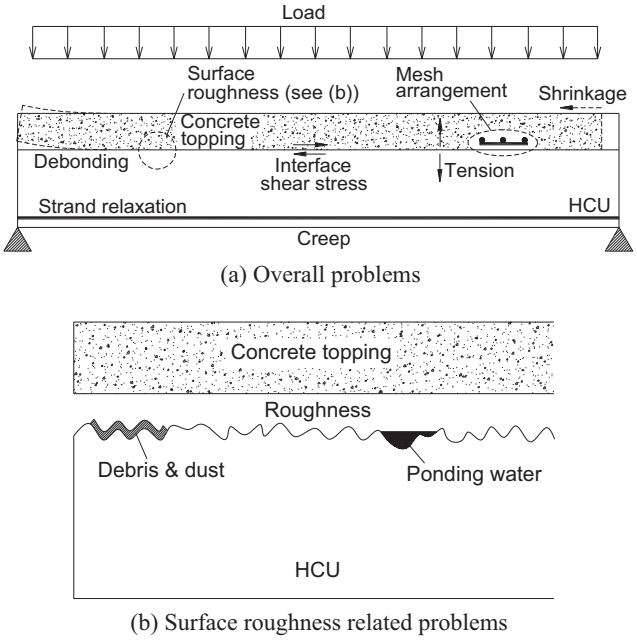

Fig. 1. Problems related to concrete topping construction.

Typical work specification does not address the proper surface preparation of the HCU before casting of the concrete topping. Delays can also occur by not knowing when the conditions are right for laying the concrete topping. Consequently, the contractor often neglects the surface preparation of the HCU during concrete topping construction. Improper surface preparations may cause problems to the interaction between the concrete topping and the HCUs. This may affect the overall structural behaviour and strength when composite action is expected from both. Some attempts to quantify surface textures on its relation with the interfacial shear in the composite floor structures are given in the Fédération Internationale de la Précontrainte (FIP) [1] document.

2. Related works

When concrete topping is cast onto the HCU without mechanical devices to strengthen the interfacial connection, the system in flexure may behave either partially of fully composite. Partial composite is obtained when the slippage occurs at the interface of the two concrete components in the horizontal direction as shown in Fig. 2. The incomplete interfacial interaction may occur in the system where the two concrete components are cast at different time and surface condition of the HCU is not sufficient to provide resistance to horizontal shear force. Horizontal shear transfer along the interface between the HCU and the in-situ concrete topping is an essential requirement to ensure composite action of the two members.

Codes of Practice such as ACI 318 [2], BS 8110 [3] and Eurocode 2 [4] specify that the interface shear strength between the concrete topping and the precast unit depends on two fundamental parameters; (i) the surface roughness of the precast unit and (ii) the quantity of shear steel. In common construction practice using HCU, there is usually no shear steel or mechanical device provided to connect between the concrete topping and the HCU surface. In such a case, the interface shear strength relies on the surface roughness of the HCU which provides natural friction between the two materials. Fig. 3 shows comparison of interface shear strength from different codes of practices, namely BS 8110, FIP and Eurocode 2. It can be seen from the figure that all codes consider the interface shear strengths to vary depending on the concrete strength as well as on the different types of surface roughness of the precast units. The ACI 318 code specifies the minimum interface shear strength value for 6.4 mm roughened surface as 1.79 N/mm^2, a far higher value compared to other international codes. Furthermore, ACI 318 does not consider the concrete compressive strength as a factor influencing the interface shear strength.

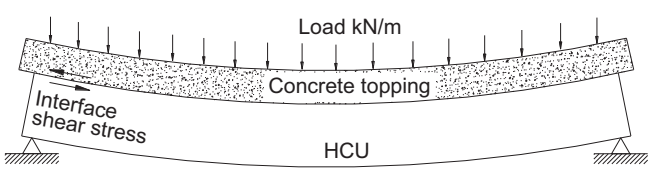

Fig. 2. Horizontal shear stress along the interface of a composite member bent in flexure.

Another significant difference between the codes is the categorisation of the degrees of roughness. BS 8110 merely states the type of instrument used to create the roughness, whereas Eurocode 2 assigns measurable properties, i.e. 3 mm for rough surfaces and 5 mm or greater for indented surfaces.

The FIP Guide to Good Practice [1] identifies ten categories of the type of surface which a precast unit may have, prior to receiving the in-situ concrete. The categorise are based on the end production of the precast unit in terms of "smooth" and "rough" surface despite of the difficulties in distinguishing the two cases. Within the FIP Commission itself there is a popular theory that the smooth but clean surfaces have better overall bond than roughened which is often dusty and dirty surfaces where localised bond failures occur. FIP [1] recommends that contaminants should be removed either by water flushing, compressed air or vacuum cleaning. Sweeping is not sufficient as it could not remove the dust completely especially on rough surface. Surface treatment is also needed to control the moisture of the precast surface, because;

(a) If the surface of the precast member is very dry before receiving the concrete topping, it will absorb water from the in-situ concrete. As a result, the concrete near the interface that govern the interfacial shear capacity may have degraded.
(b) If the surface is very wet, i.e. ponding, the water-cement ratio at the interface will be very high, resulting in weak bond strength in the immediate strata.

When the surface pores are fully treated, it is said to be surface-dry and saturated (wet condition). If the precast surface unit was

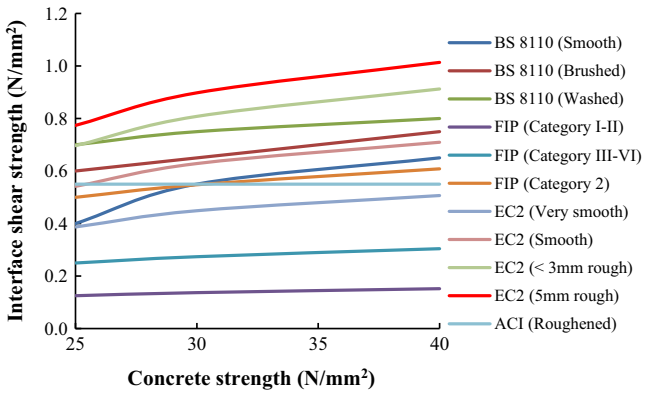

Fig. 3. Comparison of interface shear strength with various codes of practice.