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Test Arrangement of Small-scale Shear Tests of Composite Slabs

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Abstract

Composite slab consists of the layer of concrete above the trapezoidal sheeting. The sheeting serves as a lost formwork as well as a tension bearing member after the hardening of concrete. The interaction between the sheeting and the concrete is necessary for composite action and can be ensured by prepressed embossments in the sheeting. According to nowadays codes, full scale bending tests are required in the design of the new sheeting of this type of composite slabs. An alternative longitudinal shear tests of a small part of the slab have already been derived by many authors. However, the testing arrangement is not unified. The results of the shear tests can be influenced by the magnitude and the way of application of the clamping force, the loading speed, the interface conditions and others. This paper presents a proposal of the testing arrangement and the recommendations for the testing procedure of small-scale shear tests. The recommendations are posted based on the results of several series of performed laboratory tests.

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Keywords: composite slab; embossments; longitudinal shear; small-scale test; design method; end anchorage;

1. Introduction

Design of a new type of composite slab requires full scale laboratory bending tests of the slab in several series. The main reason why the bending resistance cannot be calculated by an analytical model is various longitudinal shear resistance of the sheeting. The resistance in longitudinal shear can be ensured by prepressed embossments, end shear studs, self-locking shape of the sheeting, deformed ends of the ribs or by a combination of these. An alternative possibility how to measure the longitudinal shear resistance of the slab is to use small scale shear tests. The shear tests, however, cannot fully simulate the real condition of the slab in bending. Several possibilities of the test arrangement

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of the small scale shear test can be found in technical literature. The results of these arrangements are used in corresponding alternative design methods to calculate the bearing resistance of the slab in bending. This paper is focused on searching of the test arrangement which is possible to be used in three alternative design methods: Slip-Block Test, Simplified Method and Built-up Bars.

The Slip-Block Test is transparent design method with the testing procedure for establishing friction line. The linear equation of this friction line describes coefficient of friction and shear resistance of mechanical interlock of the slab. The calculation of the bearing capacity in bending then follows partial connection method which is in Eurocode 4 [1].

Simplified Method uses calculation model which consider material nonlinearity, cracks in concrete and slip in the interface. The method calculates bearing capacity and rotation of the slab in three phases. A software is developed to calculate the resistance easily [2].

Built-up Bars method uses analytical solution of partial interaction of structure in layers. The method calculates the bending resistance and deflection of the slab for various levels of loading [3].

2. Small scale shear test arrangement

2.1. Test arrangements in literature

The Slip-Block Test and Built-up Bars method use similar test arrangements. The specimen is fixed to the base plate by the sheeting and concrete is pushed out of the sheeting. The clamping force *V* is applied on the top face of concrete (Slip-Block Test uses roller bearing and Built-up Bars uses a pneumatic wheel to transmit the force and enable concrete movement). The difference is also in dimensions of the specimen (Fig. 1a and Fig. 1c). The magnitude of the camping force *V* is higher in Slip-Block Test (up to 50 kN) compare to Built-up Bars method (usually 5 kN) [4, 5].

The Simplified Method uses arrangement developed by Daniels which consists of two specimens tied together back to back. The specimens are hanged by the overlapped sheeting and the concrete block is held by 2 cast screw rods per specimen. The sheeting is pulled up. The clamping force *V* is applied by two springs to simulate action of self-weight of the concrete only. The magnitude of the clamping force is 1.6 kN (Fig. 1b) [6].

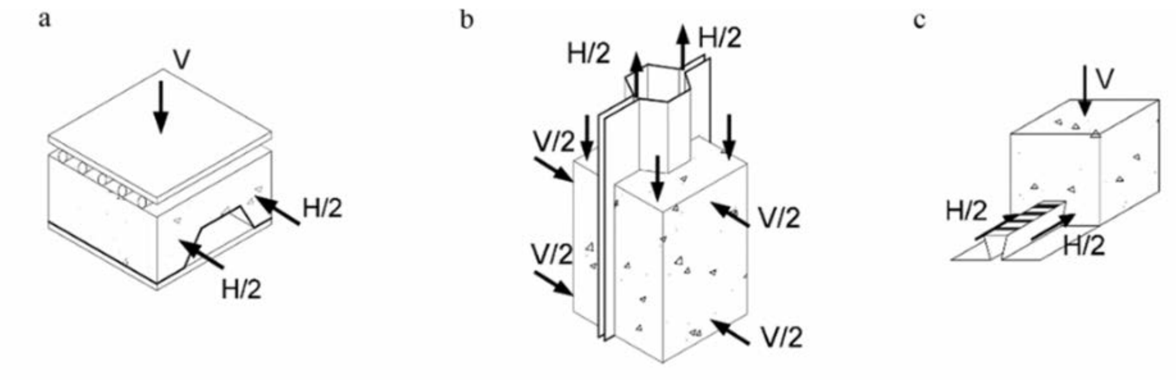

Fig. 1 Test arrangement used in (a) Slip-Block Test, (b) Simplified Method, (c) Built-up Bars [7].

2.2. Proposed test arrangement

The proposed test arrangement is similar to Slip-Block Test arrangement. The overlapped part of the sheeting is bolted to the base plate. The concrete block is being pushed out of the specimen by shear force. The specimens have the width of two ribs so that the shear force *H* can be applied in one point (Fig. 2a). The clamping force is applied on the top of the specimen. The concrete block movement is enabled by roller bearing (Fig. 2b).

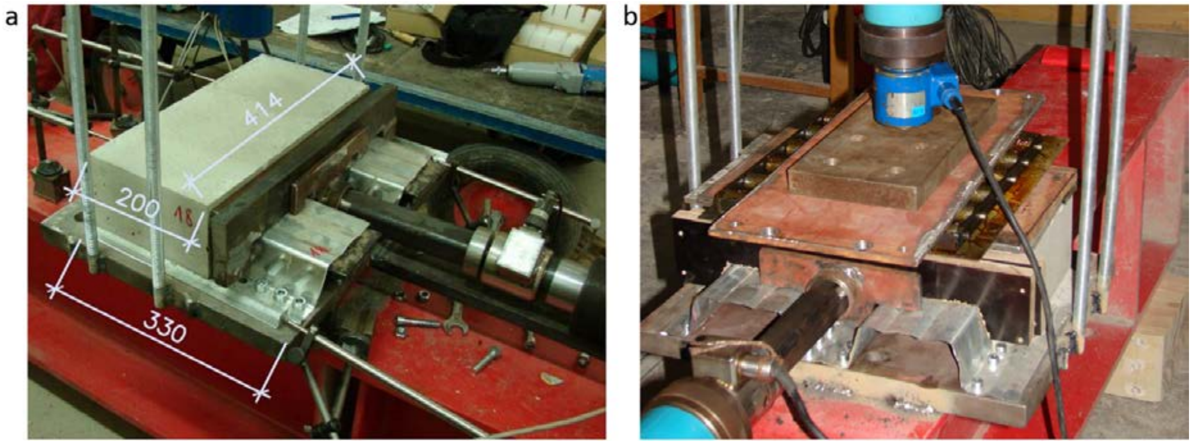

Fig. 2 (a) The specimen bolted to the base plate and loaded by the shear force in the mid rib; (b) Test arrangement with massive steel base and hand operated hydraulic cylinders.

2.3. Laboratory experiments

The laboratory experiments have been performed in several series.

The initial test series were performed using massive steel section with welded base plate and supporting structure was used to fix hydraulic cylinders. Hand operated hydraulic cylinders were used in this arrangement (Fig. 2b).

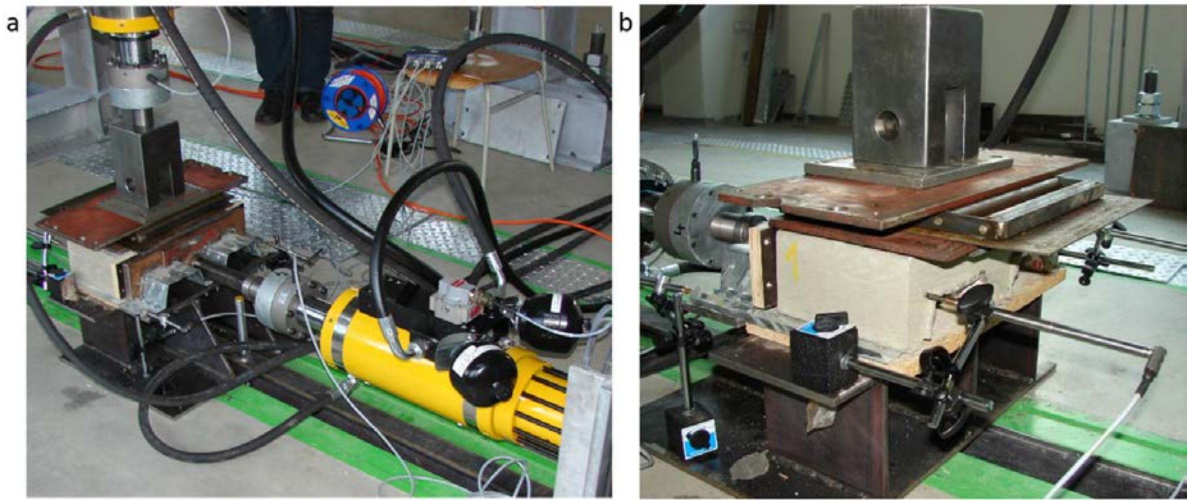

Fig. 3 (a) Test arrangement with electrohydraulic loading system; (b) Concrete block measuring devices.

Following series of the shear tests were performed with both the shear and the clamping forces induced by electrohydraulic system acting in position control. The loading speed was 0.2 mm/min up to cylinder head displacement 2.5 mm; 0.8 mm/min up to the displacement 10 mm and then 5 mm/min up to the end of the test. The loading speed in the previous series of the tests used to be more than 10 times higher. The specimens in these series were cast and tested with supporting slabs to prevent deformation of the specimens during transport and setting. The effect of these slabs was also investigated (Fig. 3a).

Mutual slip between concrete block and sheeting together with both forces acting on the specimen were measured in all the test series (Fig. 3b).

3. Results and Discussions

3.1. Application of clamping force

Clamping force tends to grow up in higher values of slip. This can be caused by prying of concrete block and by the geometry of the embossments. Using the hand operated cylinders it is difficult to maintain the constant level of clamping force. The level of clamping force was varied between test series. Fig. 4 displays the results completely without clamping force and with very low level of clamping with the cylinder held in its position to measure the development of the clamping force during the test. Fig. 5 displays the results with initially 5 kN clamping force by hand operated hydraulic cylinders..

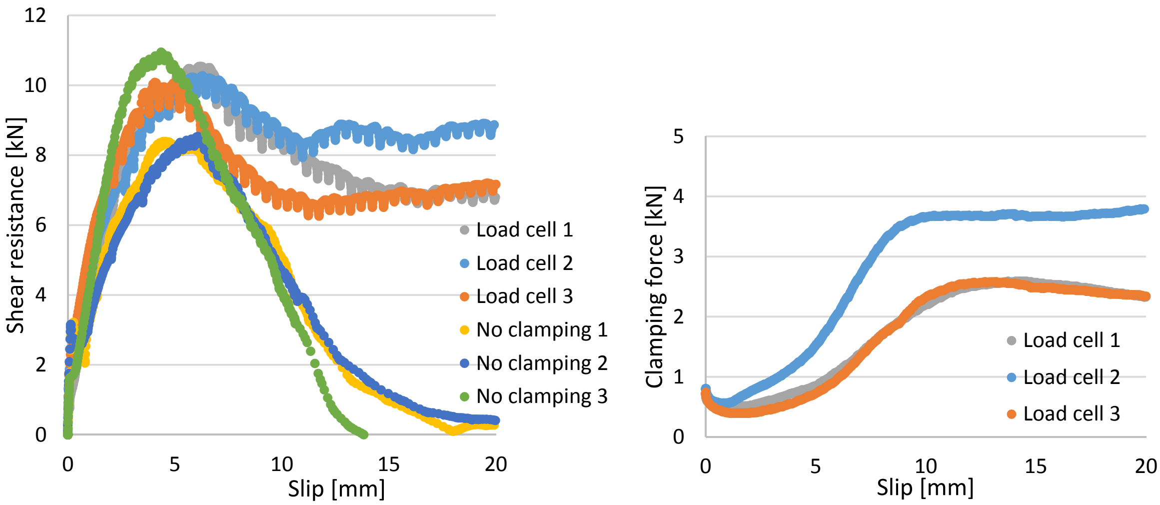

Fig. 4 (a) Shear resistance of specimens with zero clamping force (no clamping) and with very low level of clamping at the beginning of the test; (b) Level of the clamping force during the test without corrections.

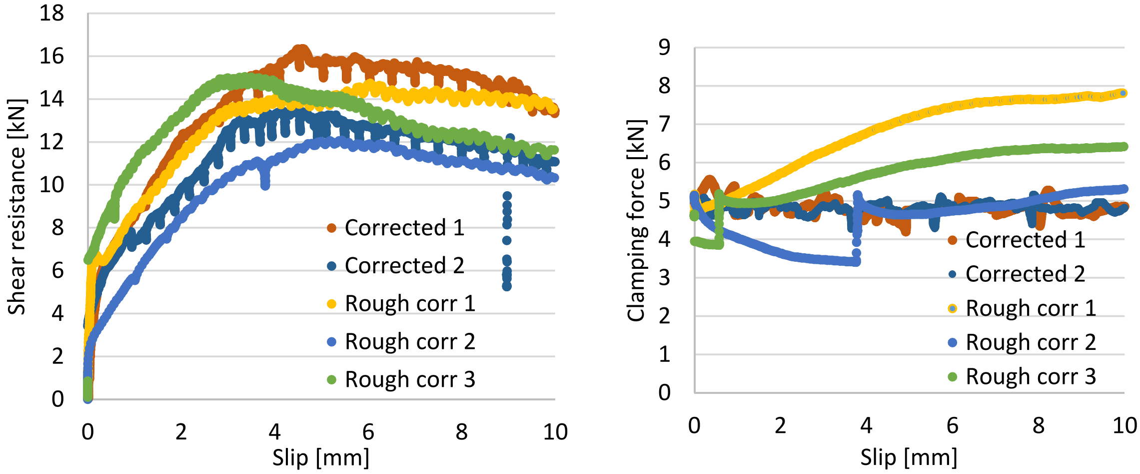

Fig. 5 (a) Shear resistance of specimens with clamping force 5 kN; (b) Level of the clamping force during the test.

The magnitude of clamping force was consistently corrected during the test in first specimens and only roughly corrected in following specimens. The shear resistance of the roughly corrected specimens displayed in the diagram was reduced by the difference in clamping forces multiplied by coefficient of friction 0.46 (this value was obtained by Slip-Block Test).

Fig. 6 displays results of specimens using electrohydraulic loading system. The charts display results of specimens with and without supporting slab. The shear resistance at the initiation of the slip is significantly better described by the specimens with the supporting slab. The maximum shear resistance is reached in smaller values of slip in this case.

The comparison of the specimens without supporting slab with the previous series enable to assess the effect of loading speed on the shear resistance. The shear resistances using slow loading speed show slightly lower dispersion in results.

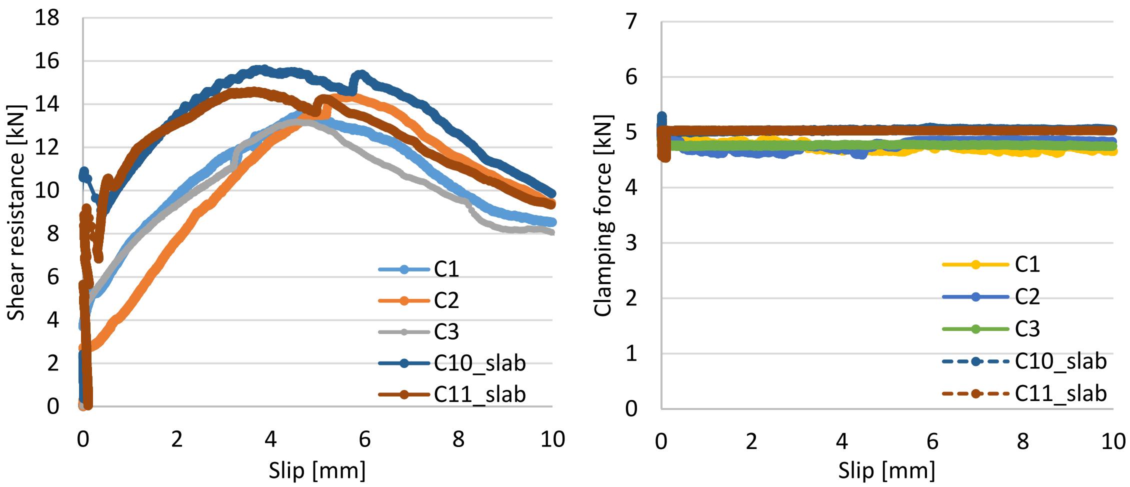

Fig. 6 (a) Shear resistances and (b) clamping forces of specimens with or without fixing slab for the series using electrohydraulic loading system.

4. Conclusions

The small-scale shear test arrangement was proposed. In order to decrease the results dispersion following recommendations are posted: Each specimen should have the supporting plate fixed to the bottom of the specimen from the casting up to the testing. The loading system which is able to act in position control manner is recommended. The minimum recommended loading speed is 0.2 mm/min up to 2.5 mm displacement, 0.8 mm/min up to 10 mm displacement and 5 mm/min up to the end of the test. The displacement of concrete block as well as displacement of the fixed sheeting should be measured on both sides of the specimen.

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