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Original Research Article

EXPERIMENTAL TESTS OF THE VECTOR II SLAB IN FIELD CONDITIONS, SLAB AND STRIP MODEL

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Abstract

Vector II slab was tested on a natural scale (a slab with a dimension of 6.30 × 6.30 m) and a strip 6.30 m long and 1.20 m wide. The Vector II slab is built by precast panel 60 cm wide, 4 cm thick and 14-20 cm thick concrete overtopping on the construction site. The main purpose of the slab tests on a natural scale was to observe the "faulting" effect and temporary deflections. During the tests, the displacements in the area of the panel joints in the middle of the slab span were recorded. The maximum difference in displacement between adjacent panels of the slab model was 0.16 mm, and the vertical displacement was 1.9 mm. The strip model had no cracks that could indicate a interface cracks between the precast element and the concrete overlay. After completion of the field tests, the load was left on the slab model to verify long-term effects.

Keywords: crack pattern, flexural analysis, interface, precast, slab, short term load

1. INTRODUCTION

Field tests of the Vector II slab, belonging to the conventionally called family of panel slabs, were carried out. The construction of the Vector slabs refers to the already existing, partially precast solutions, such as block and beam or Filigran

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slabs [1-3]. The Vector slabs are unidirectional structures, consisting of 600 mm wide panels (Fig. 1). The panels have a specially prepared upper surface that meets the requirements of the notched surface [6]. The significant thickness of the concrete overlay concerning the precast element is responsible for the transfer of shear forces between the panels. This provides the basis for drawing adjacent panels into cooperation, similar to the other described prefabricated solutions [4, 7-9].
The research aimed to check the possibility of faulting subjected to unevenly distributed load on the slab surface. Both the slab model with a square plan and the strip model was tested. Additionally, the possibility of interface crack was checked on the strip model. The results of tests under short-term loading are presented; however, the loading of the slab model is planned for 12 months.

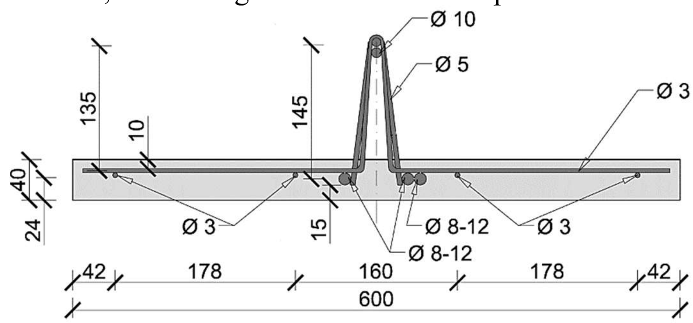


Fig. 1. Vector II cross-section [1]

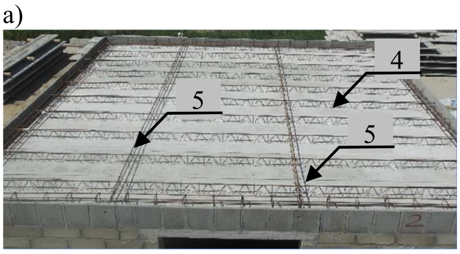
2. RESEARCH DESCRIPTION

2.1. Slab model

The tests were carried out on a full-size model of the Vector II slab. The model was made on walls made of 240 mm concrete blocks. Precast ring beam elements are placed on the walls (Fig. 2). Two openings were made in the walls, covered with prestressed concrete system lintels SBN 7.2/12/180 and SBN 12/12/210. The dimensions of the model are 6.30 × 6.30 m, and the total height is 2.24 m (Fig. 4). The slab was designed following the producer guidelines as Vector II 20/60 4.81, where the symbol defines the type and reinforcement of the precast element. The total thickness of the slab was 200 mm (160 mm of concrete overtopping). Both the precast element and the concrete topping were made of C20/25 class concrete. There are two distribution ribs, consisting of an upper and lower bar ø10 mm (class C) and stirrups type S ø6 mm (made of steel class A), spaced every 300 mm. The distribution ribs were placed on the precast plate (Fig. 3). In the axis of the lattice, support reinforcement was made of one ø10 mm rebar ended with a straight hook in the ring beam.

Fig. 2. General view of the model

a)



b)

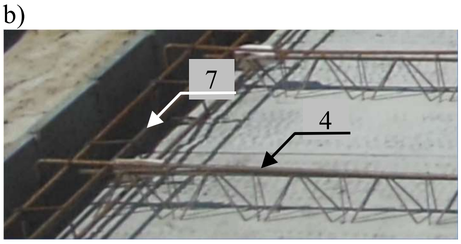


Fig. 3. Research model: (a) Lattice girder panel laying, (b) Lattice girder panel support reinforcement

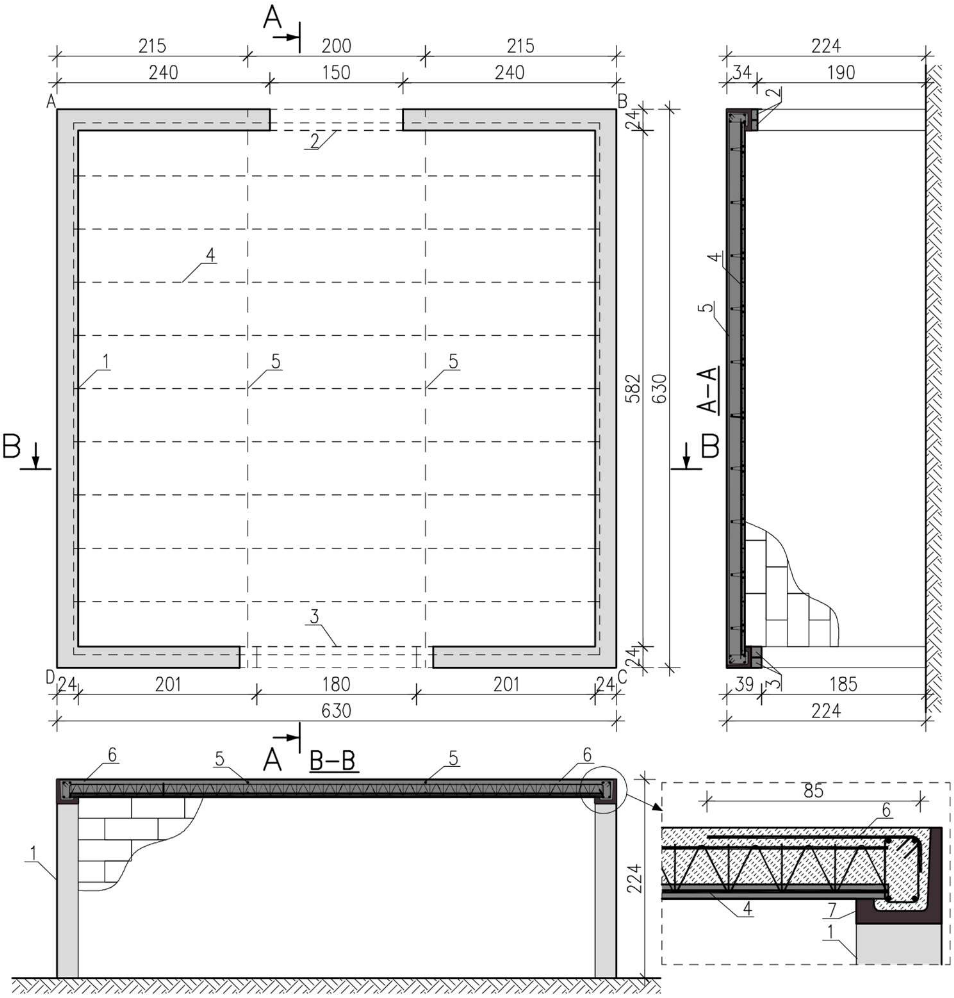


Fig. 4. Geometric dimensions: top view, A-A cross-section, B-B cross-section (1-wall, 2- lintel 2 × SBN 7,2/12/210, 3- lintel 2 × SBN 12/12/180, 4- Lattice girder panel, 5- distribution ribs, 6- support reinforcement, 7- precast form)

2.2. Strip model

The same type of Vector II panels was used to make the strip model. The strip model is based on two edges (Fig. 5), achieving a one-way work, consistent with the producer design tables. The total length of the panel was 6.30 m and a width of 1.20 m - two Vector II panels. A 160 mm thick concrete overlay was made. Different support reinforcement was used, one of the supports had bars anchored from the top surface in the rim (Fig. 6a) with the upper bar ended with a hook in the rim, and the other U-type bar (Fig. 6b) played onto the surface of the precast element. The panels did not rest on the ring beams but ended up touching them.

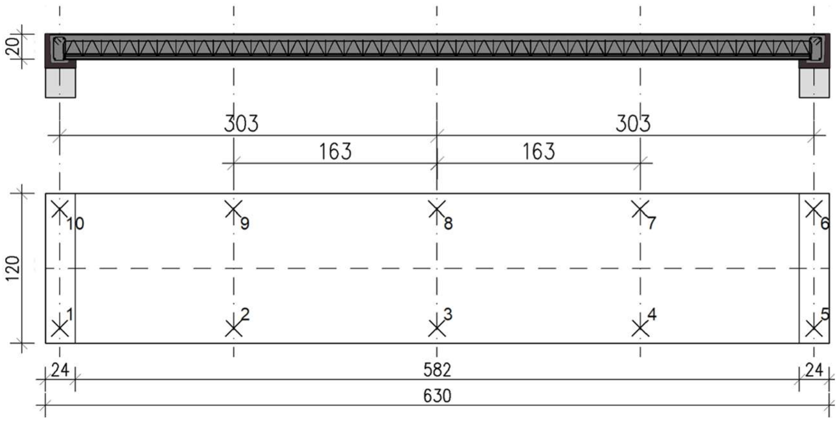


Fig. 5. Cross-section of the strip model with measurement points

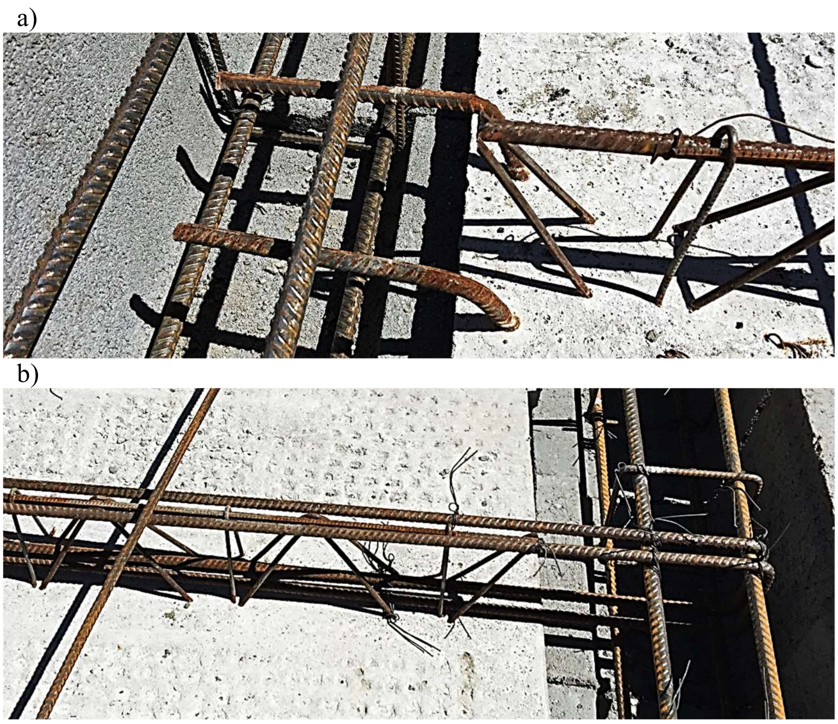


Fig. 6. Support reinforcement: a) rebars anchored from the top surface, b) U-type rebars

3. MEASURING APPARATUS

Short-term displacements were recorded using linear displacement transducers (LVDT) of the PJX-10 and PJX-20 type with the accuracy of indications equal to 0.002 mm. The sensors were attached to a steel frame support on a reinforced concrete slab (Fig. 7). Fig. 8 shows the arrangement of the sensors along the axis of the door openings and the joint of the middle panels. The sensors were placed approximately 25 mm from the panel joint; the distance between adjacent sensors was about 50 mm. In the strip model, displacements were measured in a geodetic manner in points located on the upper surface of the model (Fig. 5). The accuracy of the measurements was 0.5 mm.

Fig. 7. Overall view of inductive sensors arrangement: 1- steel frame, 2- LVDT sensor, 3- geodetic marker

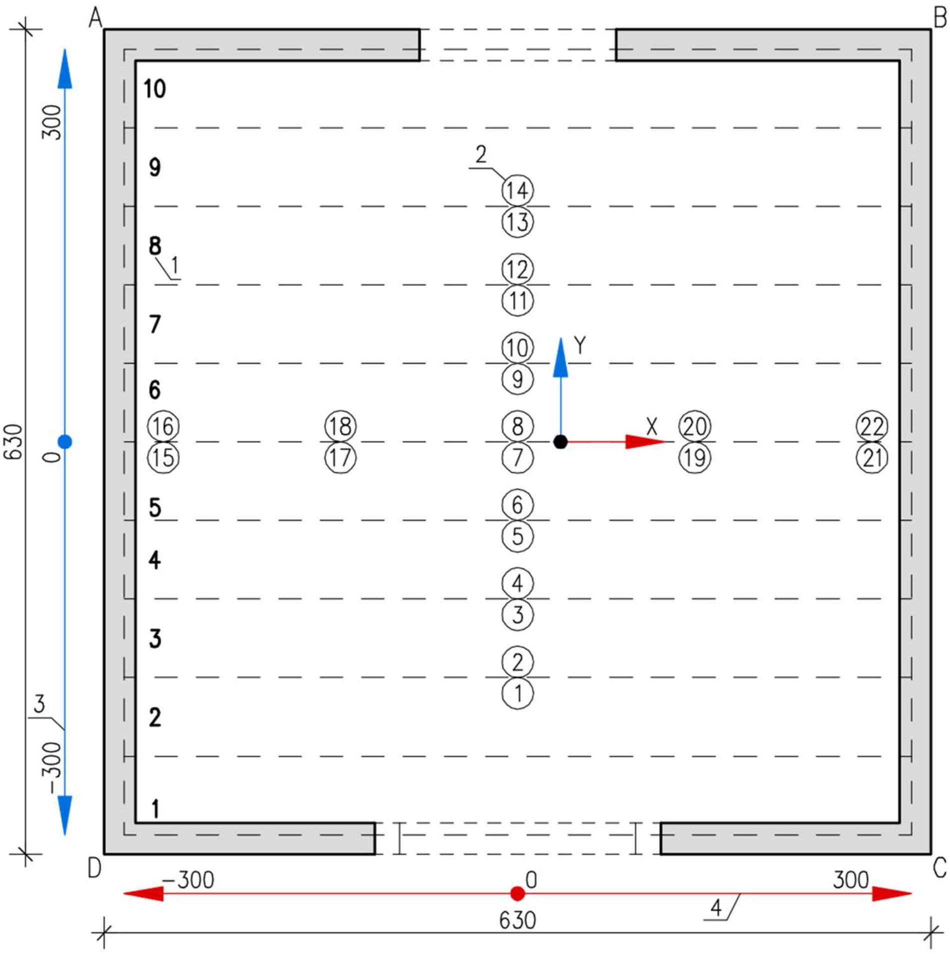


Fig. 8. Arrangement of the transducer and geodetic sensors for measuring vertical displacements on the lower surfaces of the tested slabs: 1- plate number, 2- sensor number, 3- measurement direction transverse to the main direction of the panels (Y-axis), 4- measurement direction along the length of the central panels joint (X-axis)

4. MODEL LOADING

The model was loaded by concrete blocks according to the established schedule. The total load above the self-weight of the slab with a value of 4.7 kN /m^2 was divided into two parts: 1.7 kN/kN^2 (concrete blocks) and 3.0 kN/m^2 (pallets with concrete blocks). The load was applied, as shown in Fig. 9. The view of selected load schemes is shown in Fig. 10. Displacement readings were performed each time 15 minutes after the load was placed. Schemes F and L were a continuation of the earlier schemes E and K, with the displacement readout being carried out in an hour interval. The last scheme was left for one year to verify long-term effect impacts.

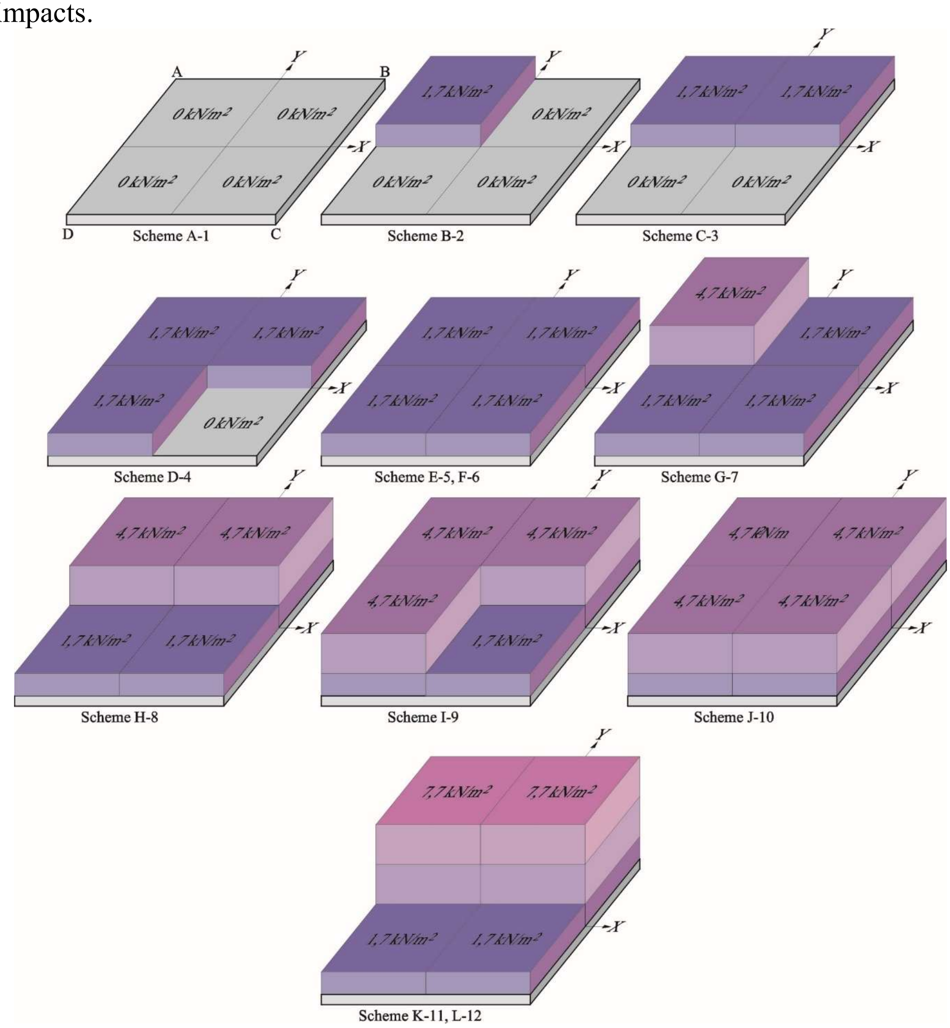


Fig. 9. Load schemes

a)

b)

Fig. 10. Load scheme: a) E, b) K, L

The load of the strip model was carried out by concrete blocks (Fig. 11). In the first six schemes, the layers of blocks were arranged, achieving a total uniform load equal to 13.2 kN/m^2. Then, in Scheme 7, pallets with blocks were placed, obtaining a total uniform load of 17.3 kN/m^2. In scheme 8, additional pallets were placed next to one of the model's support zones.

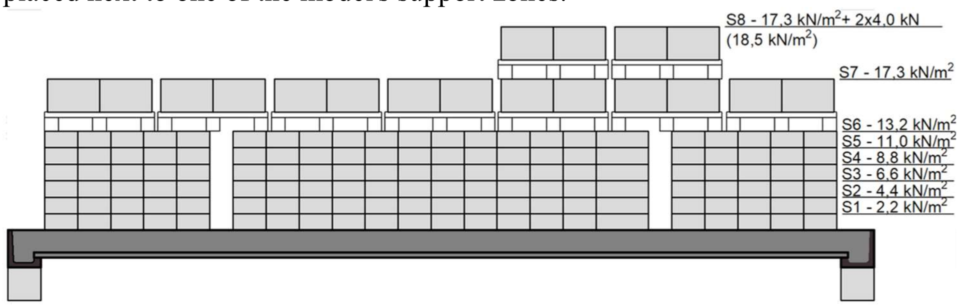


Fig. 11. Strip model load schemes

5. RESULTS

5.1 Slab model

The results of the test were presented in the form of diagrams of displacements in measurement locations, the location of which is shown in Fig. 8. Fig. 12 shows the values of slab displacements along the Y-axis from each load scheme. Along with increasing the value of the load, the displacements gradually increased. Despite the significant relief of the slabs 1-5 and the transfer of part of the load (diagram K, L) to the slabs 6-10, no reduction of the lightened part of the slab was observed. With the last load scheme, the maximum displacement was 1.9 mm, and the difference in displacement between adjacent sensors was 0.16 mm for the scheme I (Fig. 13).

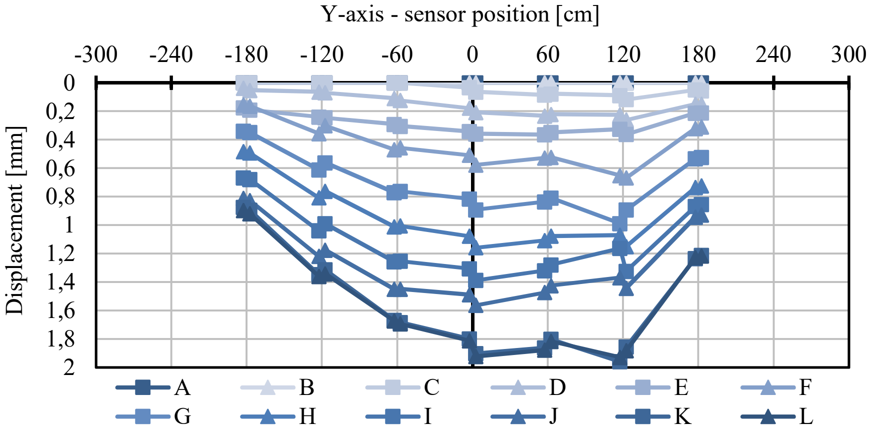


Fig. 12. Displacements in the Y axis - transverse to the plates

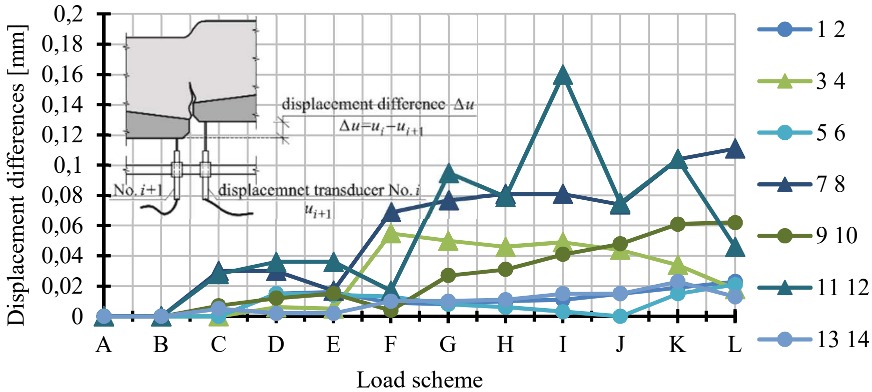


Fig. 13. Displacement difference between sensor pairs

Fig. 14 shows a comparison of the charts of displacements in the X and Y axis (plate no. 6) for the scheme J - uniform load on the entire surface. The curve of the displacements in two perpendicular directions undoubtedly indicates a two-way operation of the slab, even in the absence of transverse reinforcement of panels and joints.

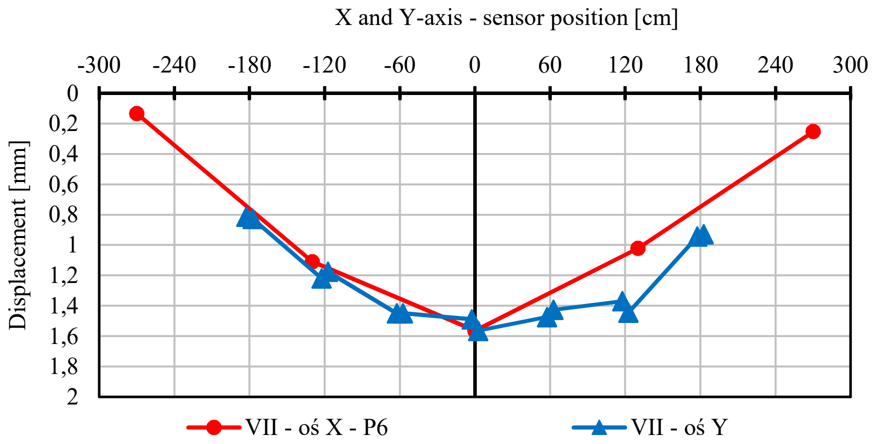


Fig. 14. Comparison of displacements of the X and Y axis (plate 6) - scheme J

Before starting the tests, the lower surface of the Vector II floor had single cracks with an opening of less than 0.05 mm (Fig. 15). At a load of 1.7 kN/m^2, no changes were observed on the lower surface. After increasing the load (diagram J), the appearance of new cracks on panels 6 and 8 was noticed. The last control was carried out after transferring the load (diagram L) to half of the slab (panel 6-10), new scratches were observed (panel no.5) and the opening of the existing ones were increased (panels no. 4 and 8). There were no scratches wider than 0.3 mm. A complete inventory of the roof scratches, including the upper surface, and possible interface crack (by drilling the cores) was planned after the second phase of the research, under long-term loading. During the research, measurements of wall deformation and lintel displacement were also performed. The measured values of deflection of the lintels did not exceed 0.1 mm. No impact of openings in the walls supporting the ceiling on the scratch pattern in the floor slabs was found.

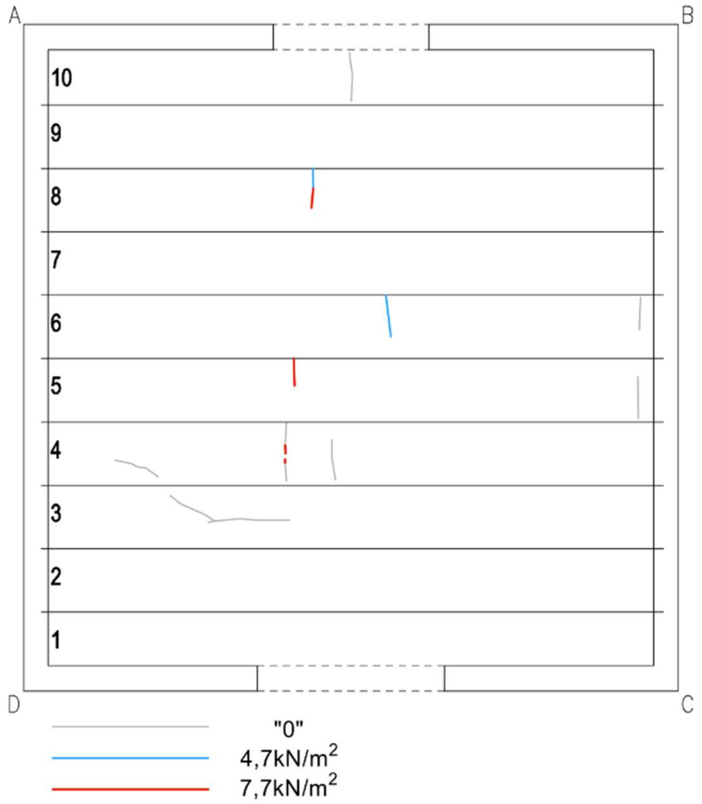


Fig. 15. Crack patterns on the bottom surface

5.2 Strip model

The results are presented for the edge covering measurement points number 1-5. The difference in displacements between the edges was not more than 3 mm. The increase was proportional to the load, up to the value of 51 mm at 13.2 kN/m^2 (Fig. 16). After this step, the crack width exceeded 0.2 mm (Fig. 17a). The last complete reading was taken in scheme 7, where the displacement of 87 mm was recorded. The maximum load was over 18.5 kN/m^2, and its distribution along the panel length was not even. There was a sharp increase in the crack opening in the middle of the panel span (Fig. 17b). With the load under the diagram 8, the maximum displacement of 122 mm was recorded. There were no cracks of the joint between the precast element and the concrete topping in the zone above the support - Fig. 17c. The image of the cracks on the side edge of the model after destruction is shown in Fig. 17d.

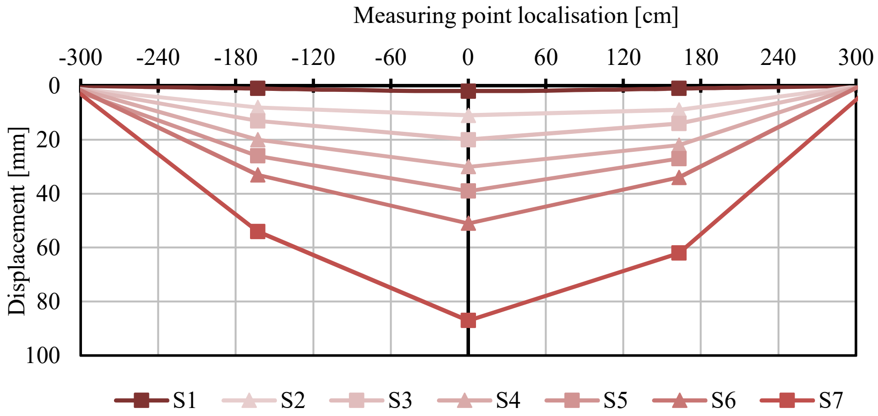


Fig. 16. Displacement of points 1-5 in each of the schemes

Due to the field tests, it was not possible to determine the exact value of the displacement and the limit load (panel resting on the ground). After the test, the slab was broken up, and the primary bar reinforcement did not break.

a)

b)

c)

d)

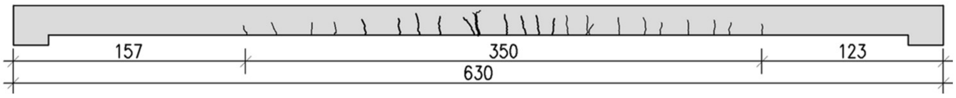


Fig.17. Cracks of the strip model: a) load 17.3 kN/m^2, b) crack in the middle of the span after failure, c) cracks near the support, d) view of cracks along the length of the slab after failure

Fig. 18 shows the dependence of the displacement of the midpoint no. 3 on the applied load. The model was destroyed in diagram No. 8 - after adding pallet with a weight of 4 kN in the middle of the span. Above the load of 13.2 kN/m^2, a significant decrease in the stiffness of the panel was visible, related to the appearance of bending cracks with an openness exceeding 0.3 mm.

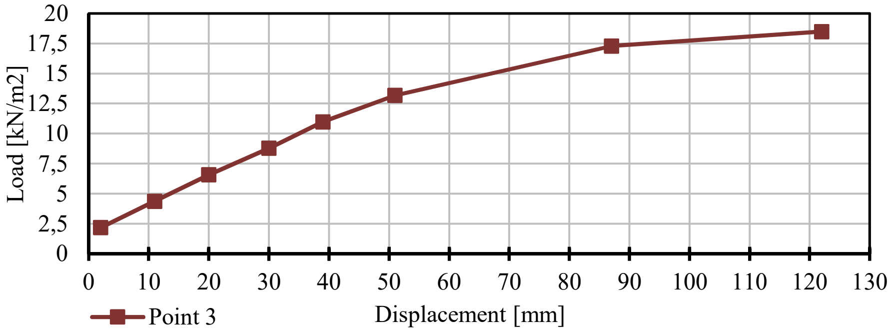


Fig. 18. Displacement of point no. 3

After completion of the tests, five core samples were taken from the panels, which were used for the internal visual inspection of the joint between the precast element and the concrete topping and to determine the compressive strength of the overlay. Based on the performed visual inspection, no interface cracking was found at any point in the model (Fig. 19). Strength tests and then qualification carried out following PN-EN 13791: 2008 showed that the characteristic compressive strength was $f_{ck,is} = 29.5$ N/mm^2. On this basis, the concrete overlay can be classified to the strength class C30/37 (against the designed C20/25).

Fig. 19. Cores from the mid-span and support zones

6. CONCLUSION

The tests of the Vector II slabs showed that the panels did not undergo faulting under short-term load without additional reinforcement of the joint. The maximum differences in displacements between adjacent panels did not exceed 0.16 mm, and the deflection was 1.9 mm. On the upper surface of the slabs, no scratches were noticed, proving that the vertical crack in the joint had not passed through the entire height of the slab. The deflection characteristics indicate the cooperation of the panels in taking over surface loads. This gives grounds to state that the concrete overlay layer connecting the panels allows the distribution of transverse forces between the elements in the range of the applied load and the slab geometry. The last load scheme of the slab model was left for one year in order to verify long-term effects. The measurements performed so far do not indicate cracks, which confirms the observations from the tests under temporary load. The study of the separated panel strip showed no damage caused by interface crack even with loads causing flexural damage to the model. The favourable effect of the interface was obtained thanks to a specially prepared surface with notches. The use of the load capacity of the interface calculated according to the formula 6.24 (1) and 6.25 (2) from PN-EN 1992-1-1 in the test situation was 34%. The actual values of material parameters were used in the calculations.

$$v_{Edi} = \beta \frac{V_{Ed}}{z b_i} \tag{6.1}$$

where: β-ratio of the longitudinal force acting on the cross-section of the new concrete to the total longitudinal force (equal to 1), V_{Ed}-transverse force, z-ray of internal forces, b_i-width of the interface (600 mm), v_{Edi}-shear in the interface

$$v_{Rdi} = c\, f_{ctd} + \mu\, \sigma_n + \rho\, f_{yd}(\mu\, sin\alpha + cos\alpha) \tag{6.2}$$

where: c and μ-coefficients of the roughness of the bond plane (equal to 0.5 and 0.9), σ_n-normal stresses to the interface area, ρ-ratio of the reinforcement area to the interface area, α-angle of the truss reinforcement, v_{Rdi}-shear interface capacity

The study of strip models will be continued in the laboratory conditions. Cooperation of panels without additional joint reinforcement and transverse reinforcement will be the subject of further analyzes. The tests will be carried out on other types of panel slabs with different shapes of the transverse connection.

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