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AN EXPERIMENTAL RESEARCH OF THE COMBINED JOINTS OF WALL PANELS FROM THE NATURAL HARDENING FOAM CONCRETE

EKSPERIMENTALNA ISTRAŽIVANJA KOMBINIRANIH SPOJEVA ZIDNIH PLOČA OD PRIRODNO OTVRDNUTE BETONSKE PJENE

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Professional paper

Abstract: *The article is dedicated to the investigation of a fracture behavior of combined horizontal joints of wallboards from natural hardening foam concrete and the influence of some factors on the ultimate loads for joints. Two of the most valuable factors that influence the ultimate loads for wallboard joints were allocated while planning the experiment: load eccentricity and indirect reinforcement. The samples consisting of three elements (top wallboard, bottom wallboard and floor slab) were made for the experiment. The typical scheme of destruction for the combined joints of wallboards with and without an indirect reinforcement was identified as a result of testing. The table of comparison of the analysis values of the ultimate loads for combined joints by the existing methods and obtained as a result of the analysis by SP "LIRA" with the received experimental data is shown in the article. Moreover, the diagrams of ultimate load relation with load eccentricity and indirect reinforcement are shown in the paper.*

Keywords: *ultimate load, combined joint, indirect reinforcement, natural hardening foam concrete, wall panels.*

Stručni članak

Sažetak: *Rad se bavi proučavanjem lomljivog ponašanja kombiniranih horizontalnih spojeva zidnih ploča od prirodno otvrdnute betonske pjene i utjecajem određenih faktora na krajnje opterećenje za spojeve. Dva najvrjednija faktora koja utječu na krajnja opterećenja za zglobove zidnih ploča dodijeljena su prilikom planiranja eksperimenta: ekscentričnost opterećenja i neizravno pojačanje. Uzorci koji se sastoje od tri elementa (vrh, dno i sredina zidne ploče) izrađeni su za eksperiment. Tipična shema uništenja kombiniranih spojeva zidnih ploča s i bez indirektnog pojačanja identificirana je kao rezultat proučavanja. Tablica usporedbe analiziranih vrijednosti krajnjih opterećenja za kombinirane zglobove na temelju postojećih metoda dobivena kao rezultat analize SP „Lira" s ostvarenim eksperimentalnim podacima prikazana je u članku. Nadalje, u radu je iskazan i odnos dijagrama krajnjeg opterećenja s ekscentričnošću opterećenja i indirektnim pojačanjem.*

Ključne riječi: *krajnje opterećenje, kombinirani spoj, indirektno pojačanje, prirodno otvrdnuta betonska pjena, zidne ploče.*

1. STATE OF THE MATTER

In contemporary civil engineering, the important place is held by cellular concrete, side by side with the heavy aggregate concrete. The physical and thermal properties of foam concrete have the best usage in the building of houses. Basically, this material is in the form of masonry blocks which lead to a longer duration of the building construction due to the need for additional work. The use of wall panels will reduce the construction time.

The existing methods of the analysis of the horizontal joints of wall panels from cellular concrete [1] are empirical and do not fully reflect the physical side of the work of wall panels with support zones.

Currently, the Laboratory of Reinforced Concrete and Masonry Structures of the Kazan State University of Architecture and Engineering is engaged in the study of the stress-strain state of the butt joints of large-panel buildings. The method of joint strength analysis, which is based on the theory of the compression resistance of anisotropic materials and which reflects the destruction mechanism of supporting the zones of wall panels from heavy concrete, is developed by the authors of [2, 3, 4]. The applicability of this theory for the determination of the ultimate loads for horizontal joints of the wall panels from cellular concrete has not been studied.

The research of the joints' stress-strain state of wall panels from natural hardening foam concrete is provided in the Odessa State Academy of Civil Engineering and Architecture. The method of the numerical study of the joints' stress state, implemented in the SC "LIRA," is described in [5].

The purpose of experimental research is to study the destructive nature of the combined horizontal joints of the wall panels from natural hardening foam concrete and the influence of various factors on the ultimate load for the joints.

2. PLANNING OF EXPERIMENTAL RESEARCH

The two most significant factors: the eccentricity of the load application and the amount of indirect reinforcement grids that may affect the ultimate load for the joint have been isolated. The coded and full-scale values of the factor are shown in Table 1. The scheme of the tests is shown in Figure 1.

Table 1. Characteristics of experimental samples

Sample code	Values of factors			
	The amount of indirect reinforcement grids X_1		The eccentricity of load application X_2	
	Coded	Full-scale, pcs.	Coded	Full-scale, mm
JCP-0-0	-1	0	-1	0
JCP-2-0	0	2	-1	0
JCP-4-0	+1	4	-1	0
JCP-0-20	-1	0	0	20
JCP-2-20(1)	0	2	0	20
JCP-2-20(2)	0	2	0	20
JCP-2-20(3)	0	2	0	20
JCP-4-20	+1	4	0	20
JCP-0-40	-1	0	+1	40
JCP-2-40	0	2	+1	40
JCP-4-40	+1	4	+1	40

The samples that consist of three parts are the overlying panel, the underlying panel and floor slab, and they were prepared for the experiment. The dimensions of the test sample elements were accepted by a geometric similarity as full-scale parameters of panels and their joints. The thickness of wall panels is accepted as 200 mm (100 mm the contact part and 100 mm the platform part). The thickness of the floor slab is accepted as 150 mm. The width of the test samples is accepted as 600 mm with a consideration of the dimensions of the support platform of press.

The supporting areas in the contact and platform parts of the overlying panel are located close to each other, which is why we can assume that the load on the sample is applied to its full width l_c = 200 mm. The height of the overlying panel is accepted as $3l_c$ = 600 mm. The maximum possible width of the support in the platform part of the underlying panel is 100 mm. The required height of the underlying panel is $3l_c$ = 300 mm. The ledge height of the underlying panel is accepted as 160 mm. Finally, the height of the underlying panel with the ledge is accepted as 600 mm with a consideration of the production conditions. The cantilevered ledge of the floor slab fragment is 510 mm.

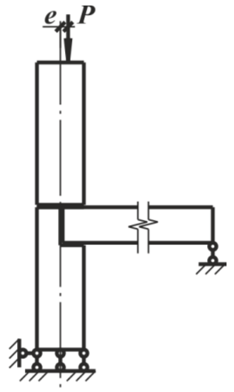

Figure 1. Scheme of tests

The wall panels of test samples are made of natural hardening foam concrete with a density from 700 to 1000 kg/m^3. The floor slab is made of a concrete class C20/25. The indirect reinforcement of the wall panels is made of grids from reinforcement wires Ø3 mm, class Bp-I with a characteristic yield strength f_y = 608 MPa and modulus of elasticity $E = 20.51 \times 10^5$ MPa.

The model of a test sample with the main dimensions and scheme of the instrumentation layout is presented in Figure 2. The tensoresistors are installed at the levels of the first and fourth grids of indirect reinforcement. The general view of test samples is shown in Figure 3.

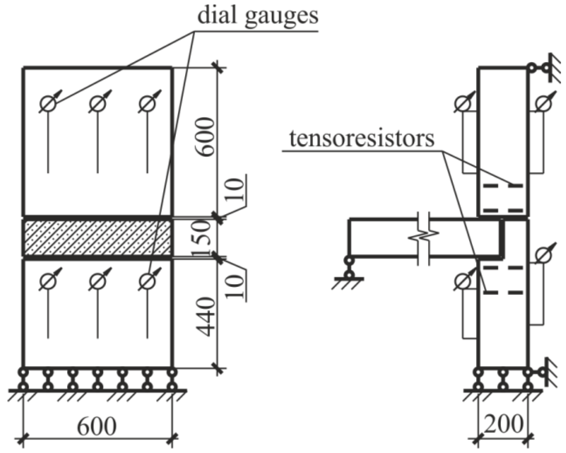

Figure 2. Model of test sample with a scheme of an instrumentation layout

Figure 3. The general view of test sample, which is mounted on a press platform

All samples were exposed to a static load. At each stage, the load on the sample of a combined joint was applied by 0.1 of the expected destructive value.

3. MAIN RESULTS OF THE EXPERIMENT

The characteristic schemes of destruction that were identified on the testing results of the horizontal joints of the wall panels from natural hardening foam concrete are shown in Figure 4.

The destruction of the test samples without indirect reinforcement occurred in accordance with the diagram shown in Figure 4(a). The formation of the first vertical crack was observed near the cement mortar joint on the boundary between the contact and platform parts of the wall panel. The development of vertical cracks at the height of wall panels took place with the load increasing. The destruction of the samples occurred as a result of the split of panels on the conditional boundary between the contact and platform part.

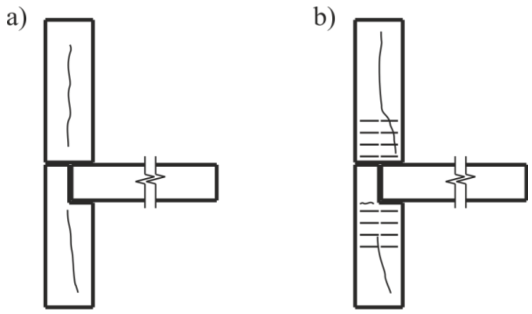

Figure 4. Characteristic scheme of destruction
a) samples without indirect reinforcement;
b) samples with indirect reinforcement.

The destruction of test samples with indirect reinforcement occurred in accordance with the diagram shown in Figure 4(b). The character of cracking on the visible surfaces of samples with indirect reinforcement is generally consistent with the cracking of samples without indirect reinforcement. At the same time, the presence of grids had prevented the development of vertical cracks. The destruction of samples occurred as a result of the crushing of the foam concrete of wall panels in the locations of resting on the concrete floor slab and support platform of press. The spalling of the underlying panel ledge occurred in the samples onto which load was applied with the eccentricity.

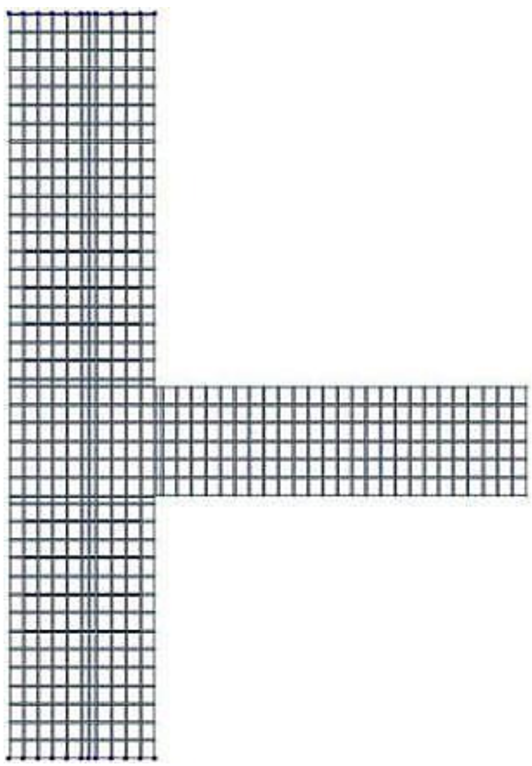

Figure 5. General view of the joint that was built for the analysis in the SC "LIRA"

Moreover, a combined joint was modeled in the software complex "LIRA 9.4" [5] which implements the finite elements method (Figure 5).

The finite elements, which allow for the building of the plane model, were used for modeling:

223 – physically non-linear universal rectangular finite element of a plane problem (beam-wall), which simulates the body of foam concrete and the mortar;

210 – physically non-linear universal spatial rod finite element, which simulates the indirect reinforcement of the joint.

The analysis was performed in the nonlinear formulation with a stepwise increment of the load. The physical and mechanical characteristics of the materials were set according to the results of cubes' and prisms' tests in compression and reinforcing bars in tension. A significant increment of the nodes' displacement of the design scheme at the current stage of load was assumed as a destruction criterion.

The values of the foam concrete cube strength, as well as the values of the joint ultimate load obtained from tests, analysis by the formulas given in the normative literature [1] and studies carried out under the guidance of B.S. Sokolov [2, 3, 4], and numerical studies [5] are given in Table 2.

Charts of ultimate loads for the combined horizontal joints of the wall panels from natural hardening foam concrete depending on the studied factors are shown in Figure 6.

Table 2. Ultimate loads for the combined horizontal joints

Sample code	Cube strength $f_{cd,cube}$, MPa	Ultimate load, kN			
		by test results	by [1]	by [4]	by numerical study results
JCP-0-0	2,39	60,00	141,3	380,9	53,33
JCP-2-0	0.89	33.33	66.3	-	20.00
JCP-4-0	1.99	46.67	192.0	-	53.33
JCP-0-20	1.42	33.33	78.7	147.0	26.67
JCP-2-20(1)	2.95	73.33	198.1	-	66.67
JCP-2-20(2)	2.84	46.67	130.3	-	40.00
JCP-2-20(3)	4.16	86.67	372.3	-	80.00
JCP-4-20	3.26	46.67	163.6	-	53.33
JCP-0-40	2.14	33.33	93.9	427.4	46.67
JCP-2-40	1.66	53.33	89.3	-	40.00
JCP-4-40	4.61	73.33	216.9	-	80.00

Note: The method [4] does not allow taking into account the indirect reinforcement of the wall panel support zones

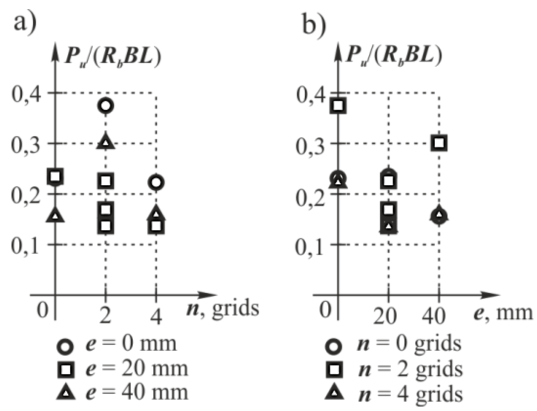

Figure 6. Ultimate load depending on:
a) the quantity of indirect reinforcement grids;
b) the eccentricity of loads application

4. CONCLUSION

The next conclusions could be made according to the analysis of the test results:

- the ultimate loads of the horizontal joints of the wall panels from natural hardening foam concrete, that has been calculated according to the normative literature [1] and propositions of the authors [2, 3, 4], is significantly overtaken compared to the results of the numerical and natural experiments;
- an increase in the load application eccentricity leads to the decrease of the ultimate load for the joint;
- an indirect reinforcement of the wall panels that end by two grids leads to the increase of the joint bearing the capacity; indirect reinforcement of the wall panels that end by four grids does not influence on the joint bearing the capacity.

5. REFERENCES

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