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COMBINATIONS OF CONJUNCTION OF TRADITIONAL AND ENERGY-SAVING MATERIALS IN CONSTRUCTIONS OF MODERN BUILDINGS

The article is devoted to particularly important contemporary problems, namely usage of energy-saving and ecological materials in load-bearing structures of buildings. This issue is discussed in the paper in respect of floor slabs. We propose to combine traditional materials (concrete and steel reinforcement) with energy-efficient material (non-autoclaved foamed concrete) in floor slabs structure. It is assumed that employment of precast-monolithic reinforced concrete floor slab with usage of non-autoclaved foamed concrete can afford to decrease dead weight of floor and foundation loading, and to guarantee good thermal and acoustic insulation between storeys.

Keywords: **precast-monolithic reinforced concrete floor slab, non-autoclaved foamed concrete, assembly mounting, exploitation, polypropylene fibre**

INTRODUCTION

Development of building and high requirements of present time with regard to energy-saving and ecological impact on the environment require usage of building structure materials, which have high heat-insulated properties and afford economic effect by their utilization [1-3]. Cellular concrete, i.e. foamed concrete, aerated concrete belong to such materials. However, we think that they should be used in construction not only as thermal insulating, but also as both constructional and thermal insulating materials. Nevertheless, taking into consideration present high electricity charges for making autoclaved foamed concrete, we propose to use non-autoclaved foamed concrete in building. Coupling non-autoclaved foamed concrete with reinforcement in structures is little [4], but their thermal insulation and sound insulation characteristics are rather high [5, 6]. Therefore, we propose to use non-autoclaved foamed concrete in floor constructions in conjunction with normal concrete and steel reinforcement. This conjunction allows to create floor slab structures, which will have many advantages in comparison with traditional structures, particularly from energy-efficient, ecological and economic points of view [7].

1. MATERIALS AND METHODS

Experimental models were made in quantity of fourteen pieces, of overall dimensions in scheme L x B = 4200 x 500 mm. In dependence on floor slab type, they are divided into 7 series:

– series I - plates of grades P-1 and P-2 - reinforced concrete deck form floor slabs. Before the laboratory test, in plate of grade P-2, transversal steel reinforcement was cut off in overhead part on apart 1/4 span of seats, in order to experimentally validate enough distance between points of welding transversal reinforcement to top erection rebar from the point of view of guarantee their stability. The construction of slabs of grades P-1 and P-2 is shown in Figure 1.

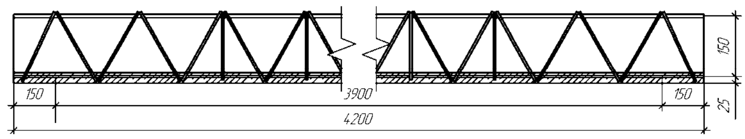

Fig. 1. The construction of reinforced concrete deck form floor slabs of grades P-1 and P-2

– series II - plates of grades P-3 and P-4 - reinforced concrete deck form floor slabs, that had different direction of transversal steel reinforcement than in plates of grades P-1 and P-2, which is shown in Figure 2:

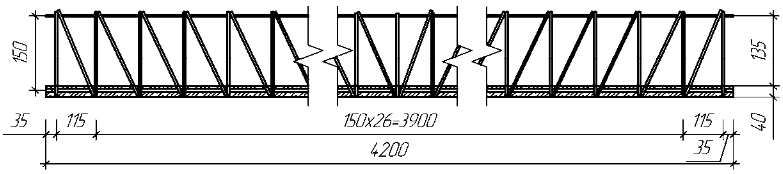

Fig. 2. The construction of reinforced concrete deck form floor slabs of grades P-3 and P-4

– series III - plates of grades PP-1 and PP-2 - precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete project grade D800 with additional reinforcement of polypropylene fibre, length of fibre L = 12 mm;
– series IV - plates of grades PP-3 and PP-4 - precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete project grade D1000 without any additional reinforcement of polypropylene fibre;
– series V - plates of grades PP-5 and PP-6 - precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete project grade D800 without any additional reinforcement of polypropylene fibre;

Precast-monolithic reinforced concrete floor slabs of grades PP-1 - PP-6 had transversal steel reinforcement as in reinforced concrete deck form floor slabs of grades P-1 and P-2.

Experimental models of grades P-1 and P-2 were unloaded after laboratory tests, and in places, where we observed loss of stability of the top erection bars of spatial framework, additional reinforcing bars of the same diameter as the diameter of these top bars were welded. Whereupon, on plates of grades P-1 and P-2 top layer of non-autoclaved foamed concrete of the height of 160 mm was concreted. In consequence, we got two precast-monolithic reinforced concrete floor slabs of grade PP-5 and PP-6 (series V). Realization of the procedure, as stated above, is associated with the fact that we aspired to investigate experimentally the behaviour of slabs in case that reinforced concrete deck form floor slabs are damaged during transportation, but defects are inconsiderable and their influence on strength and deformation properties of slab is not significant.

- series VI - plates of grades PP-7 and PP-8 - precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete project grade D700 without any additional reinforcement of polypropylene fibre;
- series VII - plates of grades PP-9 and PP-10 - precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete project grade D900 without any additional reinforcement of polypropylene fibre.

Precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete of grades PP-7 - PP-10 had transversal steel reinforcement as reinforced concrete deck form floor slabs of grades P-3 and P-4.

Reinforcement of all experimental models was executed in the shape of spatial framework with reinforcement bars form A-400C in the shape of trihedral prism. Top longitudinal reinforcement bars ø12 mm and bottom longitudinal reinforcement bars of spatial framework were joined between themselves intermediately with transversal reinforcement bars ø8 mm, creating orthogonal or triangular cells. Joining reinforcement bars of spatial framework were realized by electric arc welding. In plates of grades P-1, P-2, and PP-1 - PP-6, bottom longitudinal reinforcement bars were executed of ø8 mm, and in plates of grades P-3, P-4, PP-7 - PP-10, they were executed of ø10 mm.

The height of bottom layer of concrete class B20 was 40 mm in all floor slabs. It was produced of cement, broken stone fraction 5-20, sand, concrete admixture and water. Bottom layer of concrete and spatial framework were realized in concrete product plant.

After gathering projective concrete strength by reinforced concrete deck form floor slabs, they were put into wooden decking and the top layer of slab was concreted of non-autoclaved foamed concrete, height 160 mm. Non autoclaved foamed concrete was made cement, of sand and foam. Foam was formed with help of frothing agent by BAUCHEMI company, grade Centripor SK 120. Additional reinforcement of non-autoclaved foamed concrete was carried of polypropylene fibre of RETHMEIER company in quantity 900 g/m^3. Curing of concrete and foamed concrete of models were conducted from time of laying in concrete and foamed concrete compositions. Hardening of concrete and foamed concrete were happened in normal temperature and damp conditions. After 28 days hardening of models, decking was demolished.

Experimental models of all grades were tested how beams supported on two seats to bend - joint fixed and joint moved. Structural loading on every experimental models were added by step by means of hydraulic jack, and were dealt out symmetrically in the third part of span, dimension in 0.5 P through distributive traverse (Fig. 3a, b). Value of every rate of structural loading was made 1 kN. In order to put load on reinforced concrete deck form floor slabs, little tables of cement-sandy mortar were executed in the third part of span (Fig. 3a). Structural loads on plates of grades PP-1 - PP-10 were put, through steel plates, which were mounted on layer of gypseous mortar (Fig. 3b).

a) b)

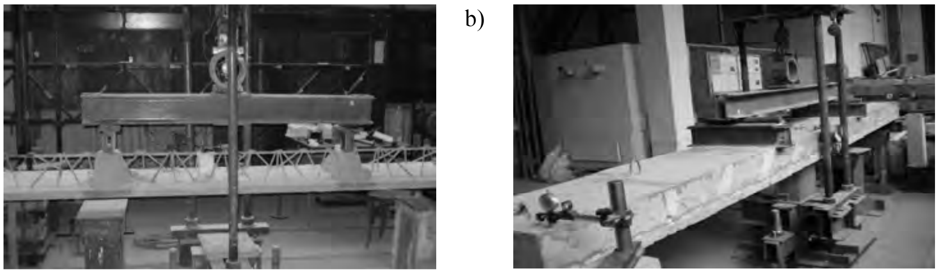

Fig. 3. Appearance of research set for test:
a) plates of grades P-1 - P-4; b) plates of grades PP-1 - PP-10

2. RESULTS AND DISCUSSION

By carrying out experiments, precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete worked as solid one-layer floor slabs. Concrete, in experimental models, was located always in tension zone. In experimental models, we watched compatible work of lower longitudinal reinforcement and concrete, in lower zone of concrete, that proved good adhesion of reinforcement and concrete. By carrying out experiments, shear in contact of reinforced concrete and non-autoclaved foamed concrete were not fixed, that confirmed the adequacy of transverse reinforcement for joining two type concrete.

The appearance of experimental models after destruction, is shown in Figure 4. The destruction of experimental models plates of grades P-1 - P-4 happened in consequence of loss of stability of top erection steel reinforcement, namely in plates of grades P-1, P-3, P-4 - in the middle of span, but in plate of grade P-2 - in places, where transversal sloping reinforcement bars were previously cut off, i.e. on apart 1/4 span of seat. The destruction of experimental models plates of grades PP-1 - PP-4 and PP-7 - PP-10 happened in scene of the maximum bending moment. By carrying out experiments plates of grades PP-5 and PP-6, we detected, that on first degrees of structural loading repeatedly, the fissures, which were received in reinforced concrete part of slabs along test of plates of grades P-1 and P-2, were opened. With increase of structural loading, the fissures occurred on overhead compression zone of foamed concrete: in plate of grade PP-5 - in the middle of span, and in plate of grade PP-6 - on application places of load point.

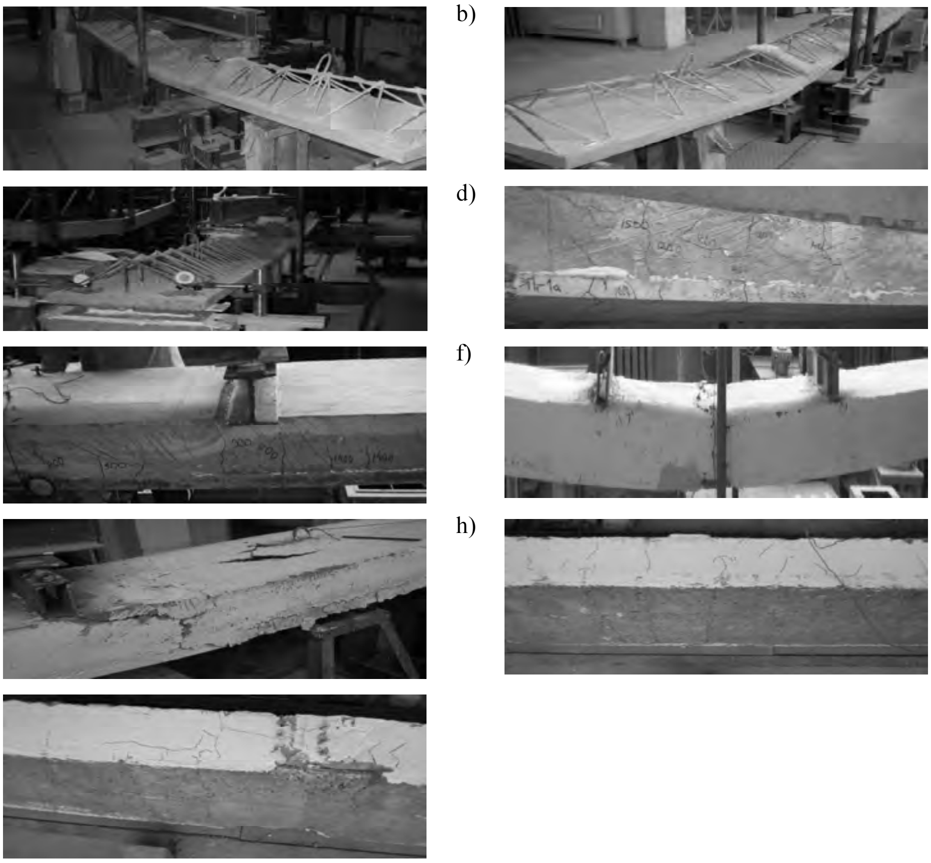

Fig. 4. The appearance of experimental models after destruction:
a) plate of grade P-1; b) plate of grade P-2; c) plate of grade P-3 (series II);
d) plate of grade PP-1 (series III); e) plate of grade PP-3 (series IV);
f) plate of grade PP-5; g) plate of grade PP-6;
h) plate of grade PP-7 (series VI); i) plate of grade PP-9 (series VII)

In all experimental models, at first, the fissures were developed on lower face layer of concrete; afterwards the fissures were expended on face of non-autoclaved foamed concrete.

In Table 1 are presented: experimental values of destroying structural loading for all experimental plates and divergence between values of destroying structural loading reinforced concrete deck form floor slabs and precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete, and also divergence between values of destroying structural loading by improvement extremely admissible flexure [8-10] reinforced concrete deck form floor slabs and precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete. We conducted comparison between experimental models with identical type of transversal reinforcement.

Table 1. **Description of experimental models of slabs and results of their tests**

Plate of grade	Value of destroying structural loading by physical destroy of experimental model N_u [kN]	Average value of destroying structural loading $\bar{N}_u$ [kN]	$\frac{\bar{N}_u^{rcnafc}}{\bar{N}_u^{rcdff}}$	Value of destroying structural loading by improvement extremely admissible flexure $N_{cr,f}$ [kN]	Average value of destroying structural loading $\bar{N}_{cr,f}$ [kN]	$\frac{\bar{N}_{cr,f}^{rcnafc}}{\bar{N}_{cr,f}^{rcdff}}$
P-1	8	9	-	5	4.5	-
P-2	10			4		
P-3	12	11	-	5.3	5.55	-
P-4	10			5.8		
PP-1	16	17	1.89	7	8.5	1.89
PP-2	18			10		
PP-3	18	17.5	1.94	10.2	10.1	2.25
PP-4	17			10		
PP-5	8	9.5	1.06	5.8	6.75	1.5
PP-6	11			7.7		
PP-7	11	12	1.09	7.2	8	1.44
PP-8	13			8.8		
PP-9	19	20	1.82	10.2	11.1	2
PP-10	21			12		

$\bar{N}_u^{rcdff}$ - average value of destroying structural loading, when physical destroying of reinforced concrete deck form floor slabs were happened;

$\bar{N}_u^{rcnafc}$ - average value of destroying structural loading, when physical destroying of precast-monolithic reinforced concrete floor slabs with usage of non--autoclaved foamed concrete were happened;

$\bar{N}_{cr,f}^{rcdff}$ - average value of destroying structural loading, by improvement extremely admissible flexure of reinforced concrete deck form floor slabs;

$\bar{N}_{cr,f}^{rcnafc}$ - average value of destroying structural loading, by improvement extremely admissible flexure of precast-monolithic reinforced concrete floor slabs with usage of non-autoclaved foamed concrete.

Analyzing facts, which are presented in Table 1, we can come to conclusions, that:

– using as the top layer of precast-monolithic reinforced concrete floor slabs non-autoclaved foamed concrete project grade D1000 is the most economic--efficient, as it gives not only energy-efficient effect, but it increases strength of floor slab in comparison with appropriate reinforced concrete deck form floor slabs;

– we propose to use floor slabs with non autoclaved foamed concrete project grade D700-D800 in covering structures, but floor slabs with non-autoclaved foamed concrete project grade D800 with additional reinforcement polypropylene fibre, project grade D900 and project grade D1000 in floor structures.

CONCLUSIONS

The usage of precast-monolithic reinforced concrete floor slabs with non-autoclaved foamed concrete into construction of floor in housing and public structures is proposed. Their using will permit to guarantee high requirements of energy-saving and ecologic, and also it will decrease cost price of building, because construction form work isn't necessary (reinforced concrete deck form floor slabs perform their duties), hard building equipment isn't necessary in usage, arrangement of sound-proof and heat-insulated layers isn't necessary as well. Simultaneous usage of traditional and new modern materials directly to constructional elements of buildings may give impetus to development ecologically clean, economic reasonable, energy-saving structures with receiving expected operating properties for widespread using.

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KOMBINACJE POŁĄCZENIA TRADYCYJNYCH I ENERGOOSZCZĘDNYCH MATERIAŁÓW W KONSTRUKCJACH NOWOCZESNYCH BUDYNKÓW

Artykuł poświęcony jest szczególnie ważnym problemom współczesności, a mianowicie zastosowaniu energooszczędnych i ekologicznych materiałów budowlanych. Problemy te odnoszą się w prezentowanym artykule do płyt stropowych. Proponuje się połączenie w konstrukcji płyt stropowych materiałów tradycyjnych (beton zwykły i pręty zbrojeniowe) z materiałem energooszczędnym (nieautoklawizowanym pianobetonem). Zakłada się, że zastosowanie stropowych płyt prefabrykowano-monolitycznych z wykorzystaniem nieautoklawizowanego pianobetonu pozwoli zmniejszyć całkowity ciężar stropu i obciążenie fundamentu, zapewnić dobrą izolacyjność cieplną i akustyczną pomiędzy piętrami.

Słowa kluczowe: **prefabrykowano-monolityczne stropy żelbetowe, pianobeton nieautoklawizowany, badanie na zginanie, montaż, eksploatacja, włókna polipropylenowe**