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TO THE ISSUE OF STRESS-STRAIN STATE MODELING OF STEEL-CONCRETE COMPOSITE SLIM FLOOR SYSTEMS

Article relevance. Building is one of the key economic sectors, so it's technical and economic indicators, which based on significant scope work value, capital investments, are very important. At the same time forefront is acted the problem of reducing labor, material and energy intensity of construction.

Composite construction has proven popular because it combines structural efficiency with speed of construction to offer an economic solution for a wide range of building types [2].

At the same time it is necessary to refuse the traditional concrete and metal structures and technologies for their manufacturing and construction, which have remained unchanged for several decades.

To improve the efficiency and wider distribution of steel-concrete composite structures is necessary to develop the theory and methods of calculation, in particular taking into account physical and geometrical nonlinearities. Thus, the study of the SCCS bending elements is a practical and scientific interest.

Also, European document Eurocode 4. Design of composite steel and concrete structures [4] and the main document in our country ДБН В.2.6-160:2010 «Конструкції будинків і споруд. Сталезалізобетонні конструкції. Основні положення» [5] did not remove all issues, which are related to the features of design, construction, calculation and technical condition evaluation [6].

So purpose is modeling and determination the stress-strain state and bearing capacity of prefabricated-monolithic SCC beams with finite-element method, as an example the development of the Finnish company Peikko.

Nowadays, much attention is paid to determination of the stress-strained state of structures by modeling it on a computer with real operation materials using different methods of structural mechanics and comparison of theoretical results with experimental tests.

Basic data. A composite floor system has low self-weight, which has a direct impact on the vertical structure and foundation size [3].

The paper describes the design of composite beam Deltabeam company Peikko.

Benefits of structure [1]:

- Even ceilings: allows flexible layouts through the whole life cycle of the building and easy HVAC installations below or inside the floor;
- Composite Action: no additional work at site, achieved by the infill concrete;
- High Fire Resistance: no additional work at site, achieved by the infill concrete;
- Major Savings In Multi-Storey Buildings: due to shallow structure, the total height of the building can be reduced or extra floor can be built: savings in facade material costs and maintenance (air-condition, heating).

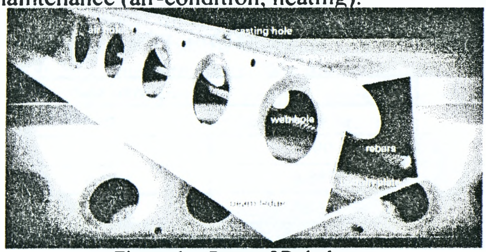

Figure 1 – Parts of Deltabeam

- Easy And Fast Installation: light and easy hoisting, simple to assemble. Hollow core - Deltabeam construction reduces total assembly time compared to traditional methods;
- Free Floor Below: no obstacles to work on floor below, minimum amount of propping if any;
- Flexible Product Range: flexible beam types and details, composite columns, erection work and auxiliary tools for erection groups;
- Common Materials: basic structural steel, reinforcement and concrete used;
- Modern Production Technology: robots weld and paint, modern plasma cutting.

For the calculation will be given the following conditions. Beam span will change from 4.8 to 7.2 m in 1.2 m, between the beams will be taken standard multihollow plates 4.8 - 7.2 m in 1.2 m.

Load will be taken like for residential houses apartments, hostels and hotels, hospitals chambers.

For example there was designed overlap of beams with a nominal length of 6 m and multihollow plates with size 1m x 6m (fig. 2).

Table 1 – Table of load collecting

Load name	Characteristic value of load [kPa]	Safety ratio for load, γ_{wf}	Designed load value [kPa]
1. Beam net weight	0,78*	1,05	0,82*
2. Floor slab	2,84	1,1	3,12
3. Concrete filling	4,84	1,1	5,32
4. Levelcrete 30 мм	1,28	1,2	1,54
5. Equipment, people, animals, stockpiled materials	1,5	1,2	1,8

* – value is given in [kN/m]

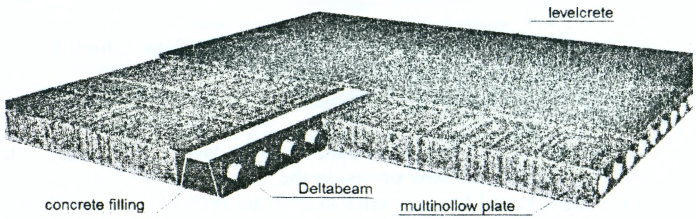

Figure 2 – Overlap of multihollow plates using Deltabeam

Then the load acting on the beam was determined at various spans of beams and multihollow plates.

Table 2 – The acting load on the beam [kNm], which depended on plates span and beams span

Span of beam, m	Span of slab, m		
	4.8	6	7.2
4.8	99.6	122.0	144.4
6	155.6	190.6	225.6
7.2	224.0	274.4	324.8

Based on the calculated metal expenses to the appropriate beam were offered recommended beam mark for different spans of beams and plates.

Nowadays, finite element method serves as a versatile tool for structure analyzing and, diversity among CAD / CAM / CAE-software, finite element analysis packages played most responsible role. Analysis of structures using the finite element method is actually a global standard for strength and other calculations. The basis of this is the universality of the finite element method, which allows analyzing different types of structures with different material properties by single method.

To investigate the stress strain state of this structure type beam mark 22-400-6-12-4 was chosen like optimal structure for beam span 6 m and 6 m slab's span.

Analysis of the stress-strain state was maiden for several cases:

1. Under installation load (installation plates on one side along the entire beam), which shown on figure 3. This analysis was carried out to understand the structure deformation during multihollow plates installation on one side of the beam span without concrete filled condition. There were investigated beam ledge stress-strain state of the metal part and the beam deformation at all, because in this case (before monolithic) beam is worse withstand torsion in such plates allocation because of its box-like thin-walled design.

2. Under design load (with concrete filling), which shown on figure 4. Modeling and solving this problem was carried out only for the quarter of structure because of its symmetry about the two planes (Fig. 9 a). This reduce the time to create the model and to calculate it, as for this calculation amount need less computing resource consumption.

According to the software analysis were generated tables to estimate stress-strain state of different beam marks and conclusions.

After completing the analysis, we obtain the following results.

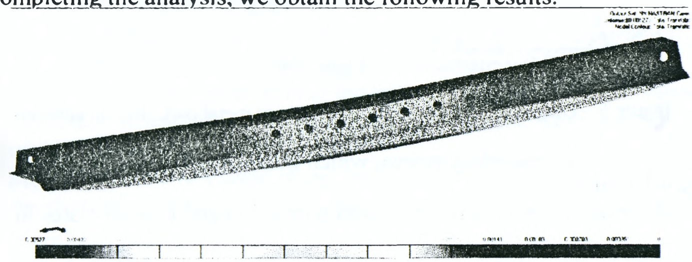

Figure 3 – Deformed finite element model with total translation contour

Examining the results, the following tables were obtained, which provide a quantitative assessment of the stress-strain state. Counting were recorded at the bottom plate at place were of lateral plate is jointed near support and at span center.

After completing the calculation under design load, we get the following results. There were obtained deformed schemes in different directions, the normal stress in the cross section in metal and concrete parts. We also obtain the value of tension at characteristic points of section, diagram of normal stresses in steel top and bottom plates, in concrete filling inside and outside the metal beams.

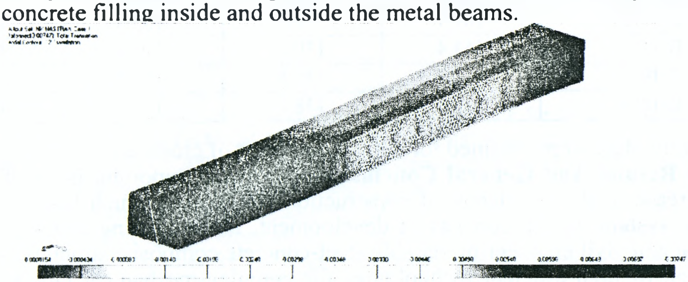

Figure 4 – Deformed finite element model with total translation contour

To get information about stress-strain state in cross-section of structure, there were investigated the possible diagrams of normal stresses in metal (fig. 5 a) and concrete parts (fig. 5 b). Result data were obtained from the characteristic points, which marked σ_i.

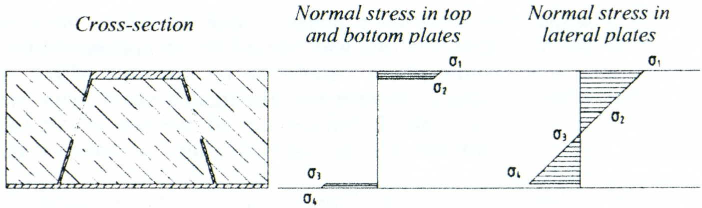

Figure 5 a

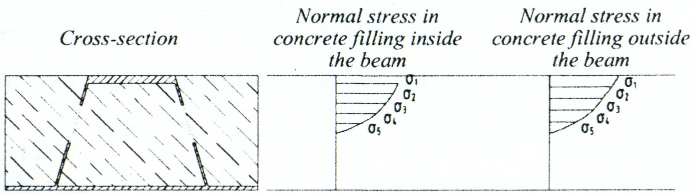

Figure 5 b

Figure 5 – Diagrams of Z normal stress: (a) – in metal part, (b) – in concrete part

Therefore, for corresponding points, which indicated on Fig. 5, readings there were withdrawn for analysis.

Below there are the results for the metal part at top and bottom plates in the section center.

Table 3 – Normal stress in the metal part at the section center [MPa]

Beam mark	Stress value, [MPa]			
	σ_1	σ_2	σ_3	σ_4
D-12-4	181.1	161.1	-171.4	-181.6
D-12-6	176.6	154.9	-167.1	-177.1
D-12-8	173.1	151.7	-163.8	-173.6
D-14-4	171.5	150.5	-165.2	-174.7
D-14-6	168.9	148.2	-162.7	-171.9
D-14-8	167.7	147	-160.5	-169.7
D-16-4	163.4	139.4	-162.8	-171.9
D-16-6	162.3	138.5	-160.8	-169.8
D-16-8	161.7	138.1	-158.9	-167.9

Similarly, data were obtained for the concrete part of cross-section.

Basic Results And General Conclusions. To solve important issue of a significant increase in the efficiency of construction established which basis on a single technical system, which consists of development, is researching and application to industrial and civil engineering reliable steel-concrete composite structures and a new generation of high-efficient technologies for complex-mechanical labors related to production and elevation of structures.

1. Constructive solutions which promote to use more effective material properties:

– increasing the strength properties of concrete in the compressed area due to volumetric stress state, centrifugation, fiber reinforcing;

– metal reduction of compressed steel elements of steel-concrete composite structures;

– metal reduction of steel-concrete structures through high-strength steels using, including prestressed elements;

– metal reduction through using non-metallic elements;

– optimization of joints and elements in steel-concrete composite structure.

Steel-concrete composite structures have a number of benefits of an overall plan, which relating to buildings and structures in general.

2. Stress-strain state features of structure for simulation results

Under installation load deformation of beam ledge has been researched, then there were formed the following conclusions:

- Distribution of stress in the beam ledge at the span center is somewhat different from the distribution near the support;

- Normal stress through the ledge thickness at utmost fibers is different; the ratio of normal stress in the top fiber to the bottom is approximately 0.94;

- The most stressed area appeared near the bottom fiber of ledge near support;

During structure researching with concrete filling there were maiden following conclusions.

- Strength of materials in elastic stage, as evidenced by the magnitude of stresses obtained by theoretic calculation and calculation using FEM. That tension is not reach the design resistance for metal about 19% and for concrete - 5%;

- Materials are effective jointed, as evidenced by the distribution of normal stresses in the concrete-filled (Fig. 19). Compressed concrete has higher compressed area, if it compared with theoretical calculations, because the theoretical calculation does not account the joint and compression;

- The structure is quite tough and has a very low hogging ratio (for example):

$$\frac{f}{l}=\frac{15.2\text{мм}}{6000\text{мм}}=\frac{1}{395}.$$

3. With a large load variation of patterns, you can refuse to expensive experiments, referring to the results, which obtained with software packages.

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