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Research paper

Experimental Investigation and Computer-Generated Simulation of Reinforced Double-Tee Girders with a Wall of Oriented Standard Board

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Abstract

The problem of sustaining capacity increasing of wooden structures and elements which operate in lateral deflection is always in the researchers' focus of interest, this caused the composite wooden structures creation. One of the ways to improve and increase wooden structures' technical-and-economical efficiency is bar reinforcement, which allows to increase structures' resistibility and rigidness, safety and lasting quality.
The results of experimental investigation of reinforced wooden I-beam with a web of oriented standard wall operation are given in this research paper. The peculiarity of this I-beam is boom fiber-glass reinforcement. The experiment task is to determine the operation characteristics and stress strain behavior of composite beam elements.
In the article, the authors provided a description of the proposed and patented design constructive solution of reinforced double-tee girders with a wall of oriented standard board, which was made of two boards with 38 x 65 mm cross-section and 10 mm x 200 mm wall of oriented standard board (oriented standard board - OSB), which connected with epoxy adhesive, the height of beam is 250 mm.
The experiment results analysis of suggested I-beams with fiber-glass reinforcement was carried out, the operation under the load peculiarities and fracture mode was revealed.

Keywords: *reinforced girder, reinforcement, cross-section, timber frame, oriented standard board, sized structures, computer-generated simulation.*

1. Introduction

The use of reinforced wooden I-beam with a web of oriented strand board became widely spread in native and foreign building practice of low rise building and structures. The problem of sustaining capacity increasing of wooden structures and elements which operate in lateral deflection is always in the researchers' focus of interest. And this caused the composite wooden structures creation, their reinforcement with different materials and methods.
One of the ways to improve and increase wooden structures' technical-and-economical efficiency is bar reinforcement, which allows to increase structures' resistibility and rigidness, safety and lasting quality.
At the same time, previously developed calculation and design provisions of such structures, as a rule, require experimental evidence. A large number of modern publications and works aimed at the construction industry development proves this [1-10].
Wooden I-beams and support pillars of oriented strand boards are widely adopted in low rise buildings; construction and reconstruction as supporting parts of I-beam casing and flooring framework, as supporting parts of side framing, rafter structures. At the same time, previously developed calculation and design provisions of such structures, as a rule, need to be improved.
One of such structures disadvantages is excessive vertical deflection and you have to enlarge the cross-section-element to meet the service ability requirements, therefore the amount of materials and consequently structure cost increase. One of this problem solutions is reinforcement.

2. Main body

2.1. The analysis of recent research sources and publications

The following scholars' works was devoted to the problem outlined in this work: Stoyanov V.V .[1, 2], Bodnarchuk T.B. [3, 4], Demchin B.H., Surmay M.I. [5, 6, 7, 8], Shchuko V.Y. [9, 10], Roshchina S.I. [11], Alfred B. Dorey and J.J. Roger Cheng [17], Nowak, Tomasz [13], Pilarde, R.G., Alfonso, C.E., M.Nieves, G.G. [14], Gugutsidze, G., Draškovič F. [15], Juliano Fiorellia, Antonio Alves Diasb [16], Alfred B. Dorey and J.J. Roger Cheng [17], Kurochkina I.V., Milokhova V.I., Mokshanova R.A., Voronkova G.V. [21] and others.
Problem of constructions computer calculations have being dealed by scientists such as Muhamediev T.A., Shmukler V.S., Zenkevich O. [18-20].

2.2. The selection of previously unsolved parts of the general problem

Wooden I-beam with web of oriented strand boards became widely adopted in construction. At the same time, previously developed calculation and design provisions of such structures, as a rule, need to be improved. One of the disadvantages of such structures is excessive vertical deflection and you have to enlarge the cross-section-element to meet the service ability requirements, therefore the amount of materials and consequently structure cost increase. One of the solutions this problem is reinforcement.
On the basis of latest investigation analysis the possibilities of improving previously mentioned girders were discovered and the construction of a composite reinforced wooden I-beams with a web of oriented strand board with reinforced booms were proposed.
The results of experimental investigation of reinforced wooden I-beam with a web of oriented strand board operation are given in this research paper. The peculiarity of this wooden I-beam is boom fiber-glass reinforcement.

2.3. Problem definition

On the basis of latest investigation analysis the possibilities of reinforced wooden I-beam with a web of oriented strand board improving were discovered. The peculiarity of this wooden I-beam is boom fiber-glass reinforcement.
The investigation aim is to determine the operation characteristics and stress strain behavior of wooden I-beam with a web of oriented strand board, to study the influence of top and bottom surfaces of the I-beam reinforcement and malformed composite reinforced wooden I-beam with web of oriented strand board, the ability to use suggested I-beams in construction.

2.4. Scientific novelty.

The construction of reinforced composite wooden I-beam with web of oriented strand board is presented in this research paper for the first time and taken out a patent for a utility model "Composite reinforced wooden I-beam" [22].
The results of experimental investigation of suggested reinforced wooden I-beam with a web of oriented strand board operation are given analysed.

2.5. The main material and results.

Based on the investigations the utility model of wooden I-beam with web of oriented strand board was developed and patented [22].
The wooden I-beam is the beam, made of two boards with 38 x 65 mm cross-section and 10 mm x 200 mm web of oriented standard board (oriented strand board – OSB), which connected with epoxy adhesive, the height of girders is 250 mm.
The OSB board is installed in 10x20 mm booms' cut groove, ø 4 mm fiber-glass reinforcement is installed in the same groove, the epoxy adhesive joint is used. The beams' length is 3 m.
Table 1 shows the characteristics of the samples.
The test scheme is presented in Fig. 1
Fiber-glass reinforcement takes a special place among composite materials. Composite reinforcement with sand TM "Hard +" was used, it is polymer fiber-glass reinforcement covered with additional sand or gritter layer during production process (Fig.2).

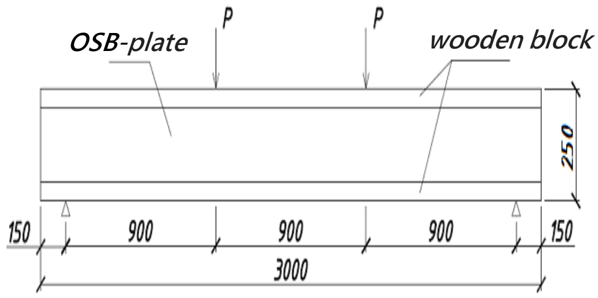

Fig. 1: I-beam design diagram

Table 1: Characteristics of samples

Name	Characteristics
БК	Wooden I-beam without reinforcement
БК-Н1	Wooden I-beam with bottom flange reinforced with ø 4mm steel bar.
БК-В1	Wooden I-beam with top flange reinforced with ø 4mm steel bar.
БК-Н1В1	Wooden I-beam with top and bottom flanges reinforced with ø 4mm steel bar.
БК-Н2	Wooden I-beam with bottom flange reinforced with two ø 4mm steel bars.
БК-В2	Wooden I-beam with top flange reinforced with two ø 4mm steel bars.
БК-Н2В2	Wooden I-beam with top flange reinforced with two bars and bottom flange reinforced with two ø 4mm steel bars.

Fig. 2: General view of fiber-glass reinforcement

These materials are widely used in aircraft engineering, shipbuilding, truck industry, mining and nuclear industry, sandwich laminate is produced and much more.
Physical-mechanical characteristics of oriented strand boards used as webs were determined according to existing standards before wooden I-beams' tests [12]. All received actual characteristics were taken into account in determining the I-beams' sustaining capacity, carrying out experiments and analyzing the results of the experiment.
All I-beans' tests were carried out at the testing laboratory of Department of structures from metal, wood, plastics in Poltava National Technical Yuri Kondratyuk University. The tests were carried out on a universal testing machine UIM-50 in the horizontal in accordance with the scheme of a simple I-beam with socketed piers. The loading was carried out using a distributive cross frame and applied to the I-beam at a distance of 1/3 span of each fig.3. The test method persumed the measurement of deformations and displacements in the central part of the I-beam and its socketed piers. The I-beam's deflection in the middle of the span was measured with a loverarm deflection indicator "6PAO" of graduating mark 0,01 mm. To determine relative deformations, the method of electric strain measuring was used. As primary transducer, resistance strain gauges such as "PKB-20" were used, their signal

level measurement was recorded using the measuring strain gauge system “VNP-8” accuracy class 0.2. The diagram of the tensiometer disposition is shown in Fig. 4.

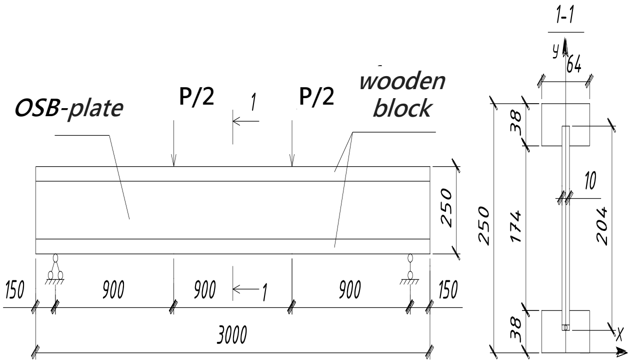

Fig. 3: The calculation I-beam diagram “БК-Н2” series

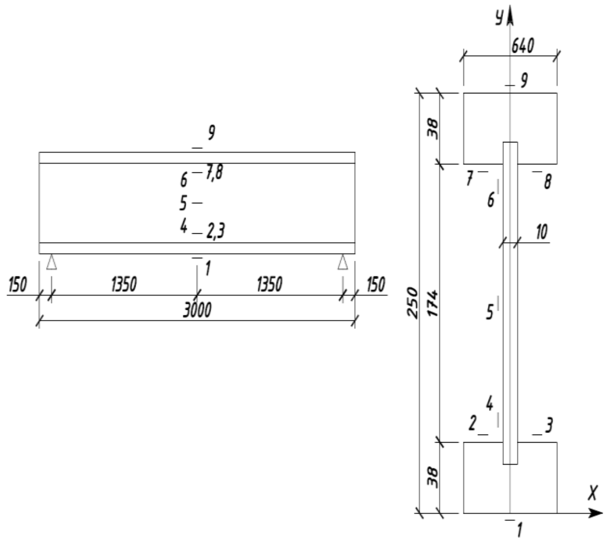

Fig. 4: The diagram of the tensiometer disposition

During I-beam’s testing the load was applied by steps. The number of steps was taken 10 from the expected destructive load, after each load step the instrument reading was made. The interval between loads by steps was 10 min. The general view of the I-beam is shown in Fig. 5, 6.

Fig. 5: General view of the sample in the testing machine

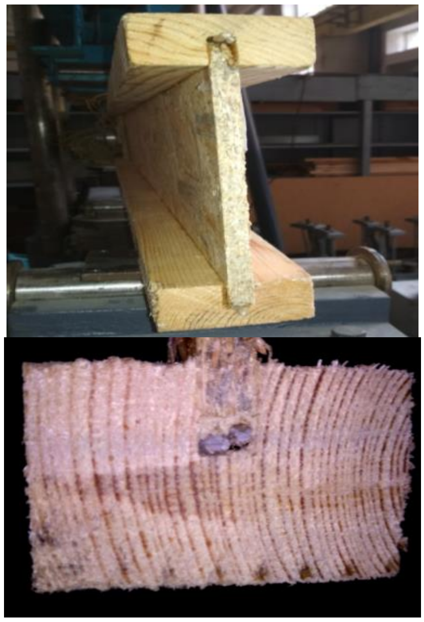

Fig. 6: I-beam “БК-Н2В2” cross-section

Test results analysis.

Features of the I-beam under permanent load are highlighted in this research paper.

I-beam’s sustaining capacity is shown in diagram in Fig. 7.

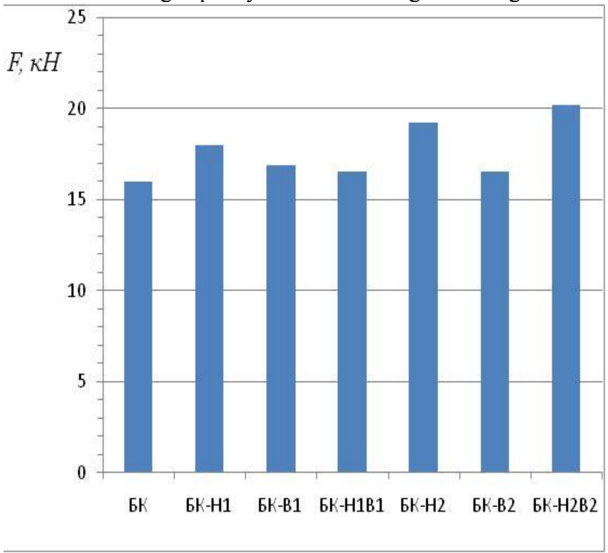

Fig. 7: I-beam’s sustaining capacity

Wooden direct stresses values comparison on the upper and lower beam edges is shown in Fig. 8.

The diagram of I-beam’s deflections-load dependence according to the results of measurements is shown in Fig. 9

An experiment showed that rapture load for built H-beam with complete band is 16 kN. According to the measurement results tensioning-load dependence diagrams (Fig. 8) and load-deflection dependence diagrams (Fig. 9) were made.

As you can see from diagrams above, the biggest tensioning is on the beam flanges, it reaches its maximum value in the investigated section before the sample is destroyed, namely 20 MPa. The maximum tensioning in the middle of beam span is 9,5 MPa. The deflection before destruction was 20mm, the dependence between load and deformations was linear, which indicates the elastic stage of structural behaviour.

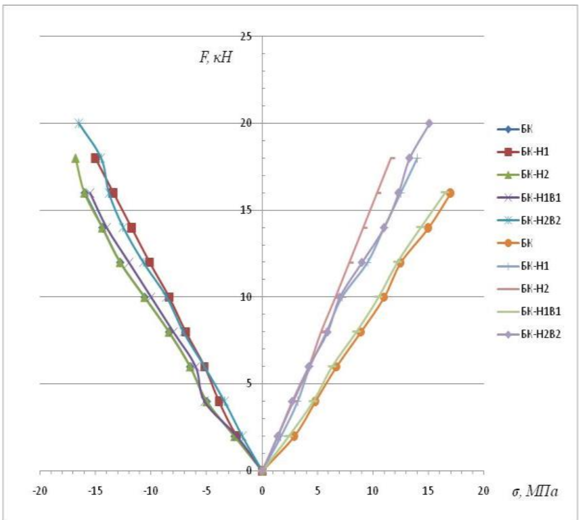

Fig. 8: Wooden direct stresses values comparison on the upper and lower beam edges

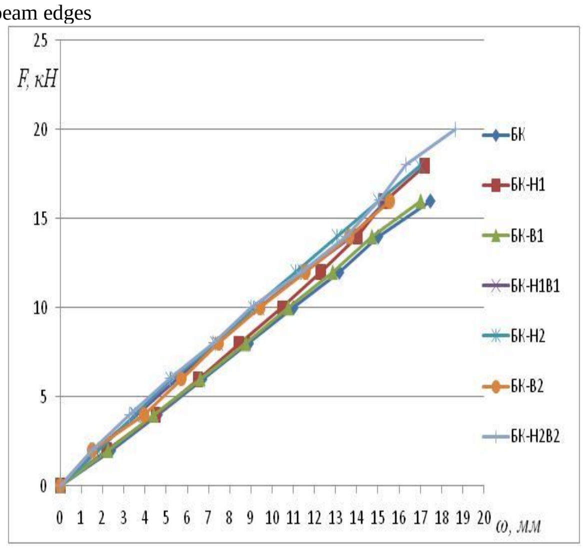

Fig. 9: Load-deflection dependence diagram

The loss of sustaining capacity of the samples occurred as result of OSB web destruction because of share stress Fig.10. Diagonal crack appeared in the share fracture of bay near to the load point with an angle 40°. After the web of some samples has been destroyed there was a fraction of a lower beam band. The destruction is brickly.

While solving the analysis problem of reinforced wooden I-beam with a web of oriented strand board using finite-element method the following steps were carried out:

- system discretization;
- creating the finite element grid of structure;
- addition to the grid of load, initial and adjacent condition;
- solution of the linear system algebraic solving in order to obtain the values of nodal unknowns;
- finding the values of tensioning and deformation according to known nodal displacement.

Modeling the strain-stress distribution of reinforced I-beams with a web of oriented strand board was carried out using finite-element method. The contimum discretization as elements connected with finite number of nodal constraints allows to save environment qualities while determining the strain-stress distribution of each element.

The finite number of nodal constraints allows to enter the relation between forces applied to nodal places and displacements caused by them. This relation is shown as element stiffness matrix [18, 19, 20].

Fig. 10: Beam "БК-Н2В2" after destruction

To compare experimental and virtual samples of reinforced wooden I-beam with a web of oriented strand board computer program package was used, which allowed to decrease the amount of full-scale experiments. Uncommercial version "LIRA-SAPR 2013 R4" was used.

The calculation of the stress-strain distribution of reinforced wooden I-beam with a web of oriented strand board was used when comparing the results of numerical and experimental investigations. In this work the models of reinforced wooden I-beam with a web of oriented strand board were created and calculated using finite-element method (Fig.11).

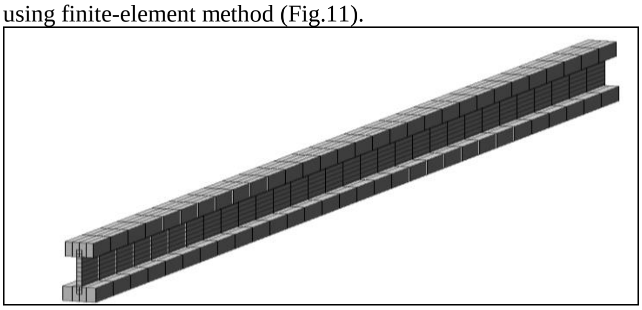

Fig. 11: Computer dimensional model of I-beam БК-Н2В2

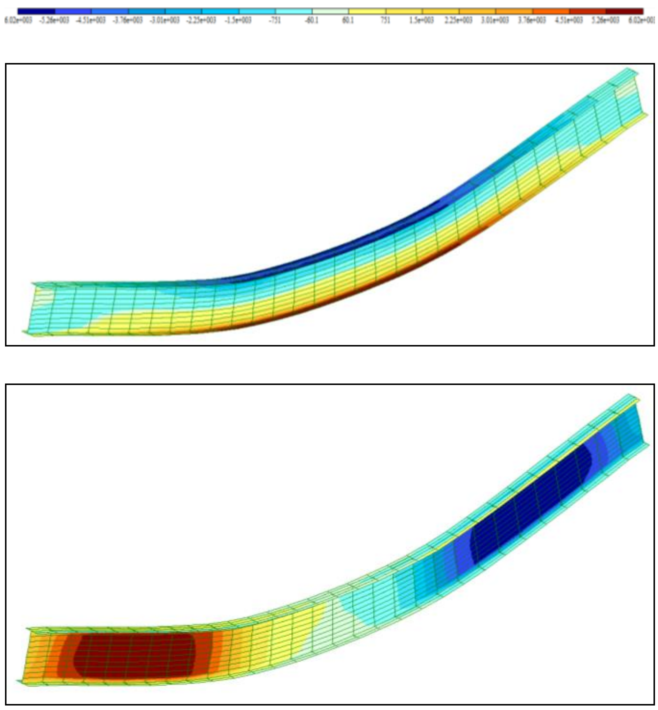

Fig. 12: Isofields of direct and shear stress in model beam's elements

3. Conclusioni

The experiments showed the satisfactory performance of fiberglass reinforced wooden I-beam with a web of oriented strand board.

The destruction of I-beams of this type occurs as a result of the web fraction under shear stress. When constructing structures, special attention should be paid to the quality of the adhesive bonding of the web with the bands of the beam. If safe adhesion is provided, displacements between webs and flanges are absent.

The most positive effect is the reinforcement of the extended zone. If the reinforcement is 2,5%, the sustaining capacity increases in 11%, if the reinforcement is 5%, the sustaining capacity increases in 25%.

The reinforcement decreases I-beam deflection from 2 to 14,4%, and decreases direct stress in wooden bands to 20%.

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