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EXPERIMENTAL ANALYSIS OF MESH ELEMENTS GLULAM DOME

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Abstract. To study the stress-strain state of the mesh dome model with the diameter 4 m, the series of glulam rods were prepared for the central compression test. The tests were carried out in the laboratory of the Department of Metal, Wooden and Plastic Structures. The stresses at the distinguished points of the elements were determined through the deformations using the resistance strain sensors. The feature of prismatic samples was the presence of stress concentrators in the support zones in the form of the holes for the location of universal connectors [3]. The significant sizes of the model made it possible to minimize the influence of the scaling factor on the obtained results. The general conclusion of the study should be considered high bearing capacity of the tested samples. The destruction of the samples took place in the support zone due to the crushing of the wood. The next tasks of the research will be the optimization of the elements sizes and testing of the dome model. The cross-section of the elements, in addition to providing the load-bearing capacity, is affected by the need to obtain certain thermotechnical characteristics of the enclosure, i.e. the elements of the dome must have the dimensions that allow placing a layer of effective insulation in their plane. A separate task is the selection of the roof, which can be considered exclusively as a part of the permanent load on the supporting system, or as a continuous shell that unfastens the frame.

Key words: the test of the rods of a mesh glulam dome, the test of wooden elements for central compression.

Introduction. The assessment of the bearing capacity and reliability of the structure under the load is possible only as a result of a comprehensive analysis of the deformation and strength properties of its elements and the observations of their behavior up to the point of failure. The important requirement for the tests is keeping the scheme of load applying and measuring the deformations unchanged, which makes it possible to obtain the graph of their dependence on the load increasing. The tests were preceded by the following works: planning the test program, determining the limit load, designing and manufacturing the installation and equipment for testing, the schemes and means of loading, drawing up the layout of the deformation measurement points, placing the measuring equipment, preparing the test log. The most important element of the mesh dome is the nodal connection of the elements. The structural solution of the connector requires the execution of two holes in close proximity to the elements ends. This is the weakest point of the structure – the stress concentrator. Therefore, the immediate task of the tests is to determine the nature of the destruction and the stress-strain state of the support zones of the elements. And if it is necessary to carry out the optimization of the design solution of the connector and the cross-section of the element.

Analysis of publications on the methodology of testing wooden elements. The testing of wooden structures and elements is carried out according to the generally known methodology for building structures, considering the wood characteristics. The innovations refer to the use of either new devices or design features of the structure that needs to be investigated. The most complete issue of testing is reflected in the research work by V. Klymenko and I. Belov “Testing of the structures, inspection and monitoring of buildings and structures”, Kyiv, 2015 [4]. The principle test positions are as follows. Testing is an experimental determination of parameter values and quality indicators of the research object during its operation or under the influence of artificially performed loads simulating real operating conditions. Compliance requirements of the first and second groups of limit states apply to any design. Any test has an objective disadvantage, which is in differences from the actual operation of the structure. This difference consists of the convention of the calculation scheme, the calculation characteristics of the material, the additional external influences that cannot be predicted and other factors of a specific situation. The researcher should create the experimental conditions as close as possible to the real operating conditions in order to be able to obtain reliable results for further conclusions regarding the reliability of behavior and the optimization of design decisions. When calculating the forces, the stresses, and the deformations, they proceed from probable values of the loads and the mechanical characteristics of materials established experimentally.

Based on the classification, our work concerns the scientific research tests for the study of new structural forms. According to the type, it is a test on models that reproduce the researched object on a different scale to improve the calculation theory and to optimize the constructions of nodes and cross-sections of the elements. After drawing up the work plan, it is necessary to design a test bench with the provision of the appropriate calculation scheme and the general stability of the compressed elements. Next, the degrees and means of loading are determined, similar to the operational ones, which should provide the occurrence of the necessary stresses and deformations in the structures. The devices are required to be simple, small in size, easy to read and accurate. When modeling, special attention should be paid to the geometric similarity and the loads similarity of the model and the original and the subjection of the model material to Hooke’s law. Modeling of wooden structures from solid wood meets an additional requirement to take into account its natural defects, which makes it impossible to manufacture the elements of small cross-sections. The problem is partially solved by using glued wood. The transfer of the test results of the model to the original, of any material, must be carried out considering the scale factor. Modeling of the structures is a complex process that requires vigilance to the smallest detail in order to obtain reliable results. Preliminary results of the stress-strain state were obtained during the tests of a segment of a mesh dome [2]. After making the appropriate changes, it was decided to conduct a series of tests on the dome rods. The first series is three samples for central compression.

The aim of the research is to determine the stressed-deformed state of the elements of a mesh glulam dome under the static load effect.

Research methodology. The samples were made from glued timber strip of mesh dome elements with the diameter 4 m and the cross-section 40x150 mm for the test. The material for the samples is the 2nd grade glued pine wood. Three samples were produced. In accordance with the research tasks, the program of the experimental tests of the experimental samples was developed (Table 1).

Marking	Marking / sample size (mm)	Number	Test method	Research aim
SERIES 1	1.C1 [800x150x40]	1	Compression is central	Ultimate bearing capacity
	2.C1 [800x150x40]	1	Compression is central	Ultimate bearing capacity
	31.C1 [800x150x40]	1	Compression is central	Ultimate bearing capacity

Compression testing of the samples was carried out in the laboratory of the Department of Metal, Wood and Plastic Structures of Odesa State Academy of Civil Engineering and Architecture.

Fig. 1. Test bench for compression testing of glued wood samples

The tests were performed on a test bench using the hydraulic jack with a maximum possible load 20 tons. The test bench is a steel frame fixed in the power floor. The calculation scheme of the rod was taken as freely supported. The amount of the load was controlled by the dynamometer using the divisions of the built-in indicator. The strain sensors made of constantan wire on a film base with the base 30 mm were used to study the stress-strain state. To write the data, the strain sensor was used, designed to measure the output tension of tensor resistors with the information transfer to the external control computer. The layout of tensor resistors is presented in Fig. 2.

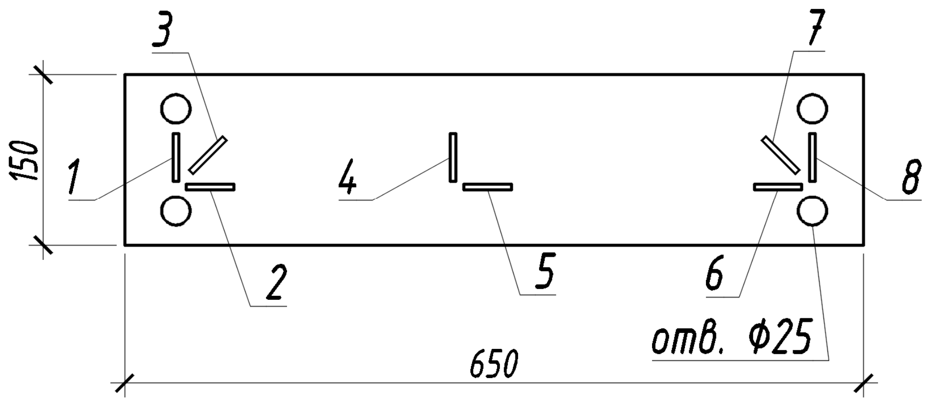

Fig. 2. Configuration plan of resistive strain sensors

The load was carried out in the stages 3.4 t with the duration 10–15 minutes at each stage. During the tests, the photographic evidence and visual observation were carried out. The moisture content of the wood was determined using a hygrometer for each studied sample. Before the test, the structure of the segment was carefully inspected visually. The actual wood defects were compared with those allowed by the standards. During the tests, the continuous monitoring of the structure condition was carried out in order to fix possible damages.

Research results. Based on the test results, the experimental dependency graphs of compressive, tensile and shear stresses on the load at the maximum level of 17 t were drawn (Fig. 3). After analyzing the test results, the following features of the samples were established. The destruction occurs, as predicted, in the weakest point of the rod – near the holes for the connector, by crushing the wood. First, at the first stages of loading, the first small crack is formed, starting in one of the holes. Then it expands, there are new ones and the sample collapses after the attempt to increase the load by more than 17 tons. The compression and stretching deformations corresponded to shear deformations. Up to the load 8 tons, the deformation nature of the samples and the results of stress analysis according to strain sensor data corresponded to the elastic work. Further loading led to stress increasing, getting the critical deformations up to the complete loss of bearing capacity.

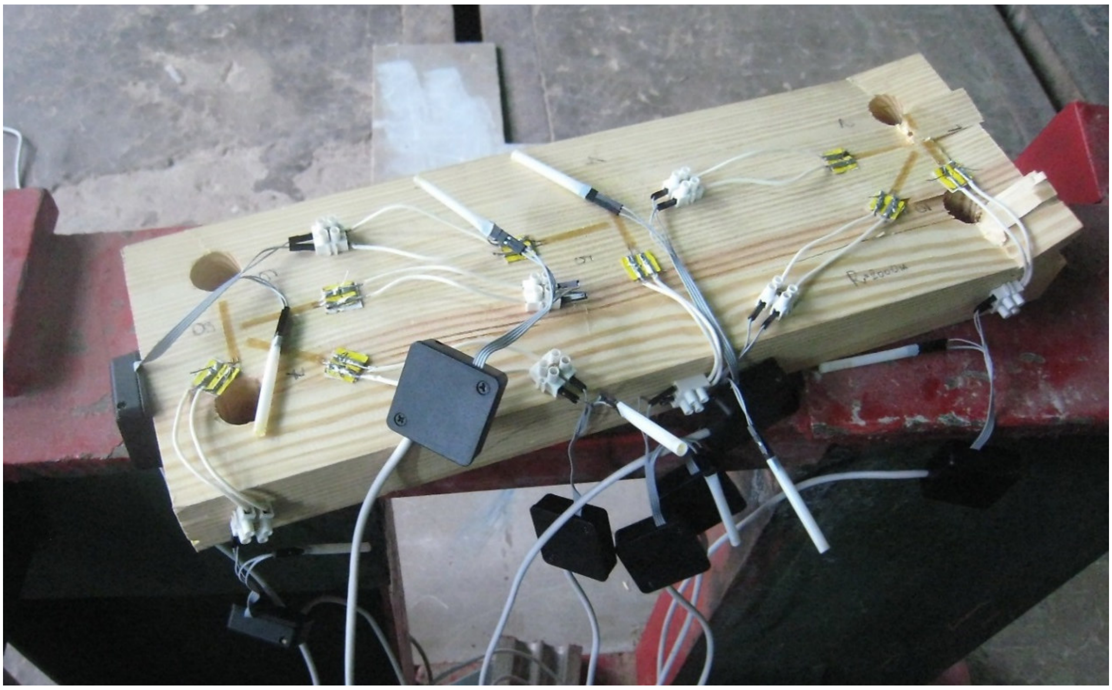

Fig. 3. Sample after testing

To analyze the stress-strain state of the element, a spatial computer model was developed in the "LIRA-SAPR" software complex. The stiffness characteristics of volumetric finite elements were set taking into account the anisotropic wood properties in accordance with the requirements [1].

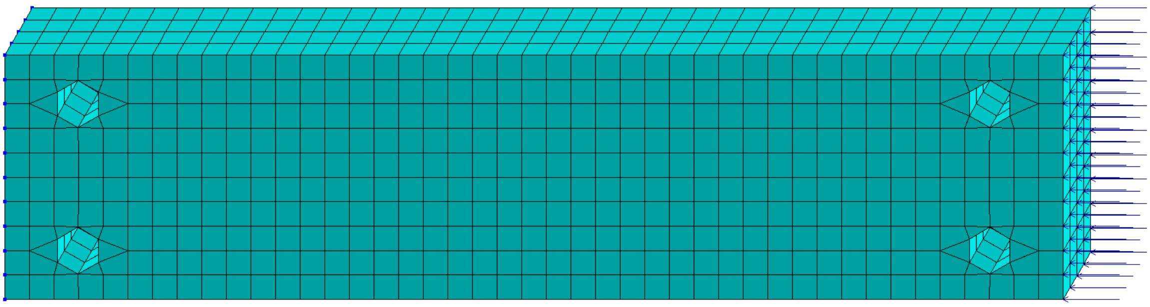

Fig. 4. Calculation model of the element

The element is modeled by the universal spatial eight-node isoparametric finite elements (CE № 36). The load was applied to the end nodes of the element.

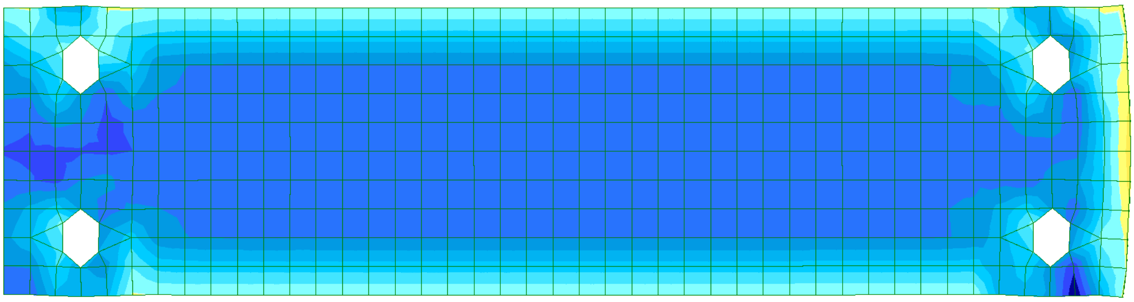

Fig. 5. The nature of compressive stress distribution

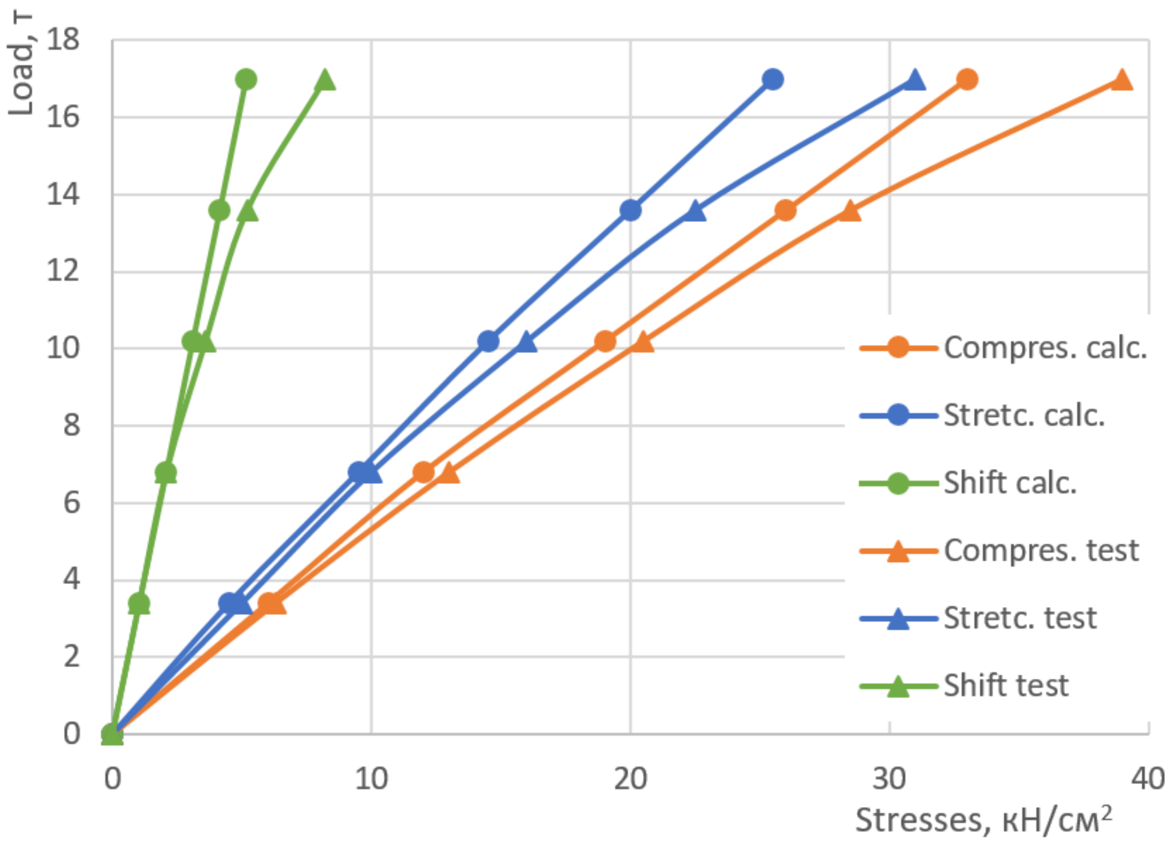

Fig. 6. Comparative graph of stresses

Conclusions:

1. The destruction of the samples occurs as a result of the wood crushing under the influence of the concentration of normal stresses near the holes for the nodal connector.
2. The nature of stress development in the area of the holes indicates that the determining force, which led to the loss of bearing capacity, is the compressive force.
3. The destructive load significantly exceeded the calculated resistance of glued wood, which makes it possible to optimize the cross-section of the dome rods, determined from the requirements of manufacturing technology and thermal insulation.
4. For a comprehensive analysis of the behaviour of the dome rods, it is necessary to test them for off-center compression and as a part of a nodal connection.

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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ ЕЛЕМЕНТІВ СІТЧАСТОГО КУПОЛА З КЛЕЄНОЇ ДЕРЕВИНИ

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Анотація. Для дослідження напружено-деформованого стану моделі сітчастого купола діаметром 4 м була підготовлена серія стрижнів з клеєної деревини для випробування на центральний стиск. Випробування виконували в лабораторії кафедри Металевих дерев'яних та пластмасових конструкцій. Напруження в характерних точках елементів визначали через деформації за допомогою тензорезисторів. Особливістю призматичних зразків була наявність в приопорних зонах концентраторів напружень у вигляді отворів для розташування універсальних конекторів [3]. Значні розміри моделі дозволили мінімізувати вплив масштабного фактору на отримані результати. Загальним висновком дослідження слід вважати високу несучу здатність зразків, що були випробувані. Руйнування зразків проходило в приопорній зоні внаслідок зминання деревини. Наступними задачами досліджень будуть оптимізація розмірів елементів і випробування моделі купола. На переріз елементів крім забезпечення несучої здатності, впливає необхідність отримання певних теполотехнічних характеристик огородження, тобто елементи купола повинні мати розміри, що дозволяють розмістити в їхній площині шар ефективного утеплювача. Окремим завданням залишається вибір покриття, яке може розглядатись виключно, як частина постійного навантаження на несучу систему, або як суцільна оболонка, що розкріплює каркас.

Ключові слова: випробування стрижнів сітчастого купола з клеєної деревини, випробування дерев'яних елементів на центральний стиск.