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METHOD OF TESTING PLASTIC PRODUCTS MANUFACTURED USING 3D PRINTING FOR STRENGTH IN BENDING

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Abstract. The main methods of mechanical testing of composite materials include: determination of material strength under tension, bending, torsion, shock loads, compression, etc. This article presents the preparatory stage of conducting experimental studies on determining the bending strength of structural elements made of ABS plastic, manufactured with the help of 3D printing. As a result 2 series of experimental samples are indicated, which differ in the shape of the cross section (specimens of 1st series have rectangular section, samples of 2nd series have T-shaped section), appropriate dimensions and a test scheme are established in accordance with the requirements of regulatory documents. The percentage of filling of the internal cavity of the experimental elements with polymer material was determined, namely 10%, 50% and 100%. The algorithm of preparation and direct execution of the planned tests under the action of a static short-term load is described. The predicted schemes and criteria for the destruction of the samples, as well as the conditions for stopping the tests, are given.

Keywords: polymers, 3D printing, ABS-plastic, strength, bending, short-term loading, destruction.

Introduction. Polymer materials and plastics used in construction make it possible to save metal, wood, glass, cement and other traditional materials. The main areas of effective use of plastic structures in buildings and structures are to reduce their mass, improve the transportation of light enclosing structures and increase resistance to aggressive external environments. Due to the low modulus of elasticity of polymeric materials, they are effective in structures where their high-strength properties and the small influence of their deformability are used to the maximum. Construction structures using plastics, multi-layer rectilinear or curved enclosing panels, spatial forms of single and double curvature (domes, shells, etc.), as well as transparent enclosing panels are effective.

Also, one of the fairly new, but progressive areas that actively uses polymer materials, including for building structures, is additive manufacturing, which ensures the production of three-dimensional solid products from an automated digital file using 3D printing. Considering the demand and widespread use of products manufactured by 3D printing as structural elements, studying their serviceability under load is an important and relevant scientific task.

Analysis of recent researches and publications. Methods of mechanical testing of polymer composite materials are an important tool for studying their strength, plasticity, stiffness, and other properties [1]. The main methods of mechanical testing of composite materials include in: determining the strength of the material in tension, bending, torsion, compression, under shock loads etc. All these types of tests are carried out before the destruction of the test sample. In addition, there are other methods of mechanical tests, which include in wear tests, studies on the change in shape and size of composite materials, fatigue strength tests, etc.

In addition, in contrast to full-scale experiments, numerical experiments are often carried out with the help of either mathematical [2, 3] or computer modeling with the use of various existing software complexes [4-7].

The accumulated experience of creating structures from polymer composite materials indicates an increased spread of such parameters as stiffness and strength, which is due to the instability of the initial components, deviations in the execution of technological processes, etc. These factors are taken into account by the introduction of an additional safety factor when determining the calculated load, the value of which depends on the coefficient of variation of the mechanical properties of products made of composite materials. Thus, a high-quality selection of methods of mechanical testing of composite materials and improvement of testing methods will allow to predict with high reliability the main mechanisms of destruction and strength of composite materials.

Materials and methods of research. Within the work of the scientific circle of the department of metal, wooden and plastic structures, the solution to the task of developing a methodology for conducting a bending strength test, as well as preparing relevant samples made with the help of 3D printing, was chosen. According to the results of the literature review, 2 series of samples were formed, which differ in the shape of the cross-section: rectangular (series 1) and T-beams (series 2).

According to the requirements [8, 9], the standard sample should have the following dimensions:

– length (l) – not less than 80 mm;
– width (b) – (10.00 ± 0.50) mm;
– thickness (h) – (4.00 ± 0.20) mm.

If it is impossible to produce a sample with the specified dimensions, it is allowed to use samples, the ratio of length and thickness of which should be $l \geq 20h$, the width of the sample should be from 10 to 25 mm, and for materials containing large particles of filler – from 20 to 50 mm. Samples must have a smooth surface without bulges, chips, cracks, shells and other visible defects.

Taking into account the use of additive technologies for the manufacture of test samples, it is possible to adjust the degree of filling of the internal cavity of the beams to save materials and determine the optimal amount of filling to ensure the necessary bending strength. Thus, 3 variations of the filling percentage of the internal cavity of the experimental sample were chosen: 10%, 50%, 100%. The material of all samples is ABS plastic (acrylonitrile butadiene styrene), which is characterized by high strength and impact resistance, therefore it is widely used for the manufacture of structural elements.

The advantages of the material include in an optimal combination of elasticity and strength, and the disadvantages are some nuances during use like odor and shrinkage.

Research results. Taking into account the given recommendations on the size of the samples [8, 9], as well as the technical characteristics of the 3D printer used for their production, a 3D model of the experimental samples of series 1 and series 2 with their dimensions is presented in Fig. 1.

Each series includes 6 samples with the following filling percentages of the internal cavity: 10%, 50% and 100%. For each filling percentage, 2 identical twin specimens were made to establish the average bending strength between them.

The tests will be carried out on a PROFLINE hydraulic press with load capacity 10 tons. A device with a loading tip and supports will be placed on the test machine. Their convergence will take place at a constant speed.

The radius of the tip (r_1) and the edges of the supports (r_2) (Fig. 2) have the following dimensions in mm:

– $r_1 = (5 \pm 0.1)$;
– $r_2 = (2.0 \pm 0.2)$.

Before testing, in the middle third of the length of the sample, measure the width of the sample with an error of ±0.1 mm and the thickness – with an error of ±0.02 mm.

Before the test, the samples are conditioned according to the requirements [10] for at least 16 hours at a temperature of (23±2)°C and a relative humidity of (50±5)%. The tests will be conducted under the same conditions.

The distance between the supports is taken as (15...17)h. For samples reinforced with unidirectional fiber and having a very large thickness, the distance between the supports is chosen based on the largest value of l_V / h to avoid failure by shear.

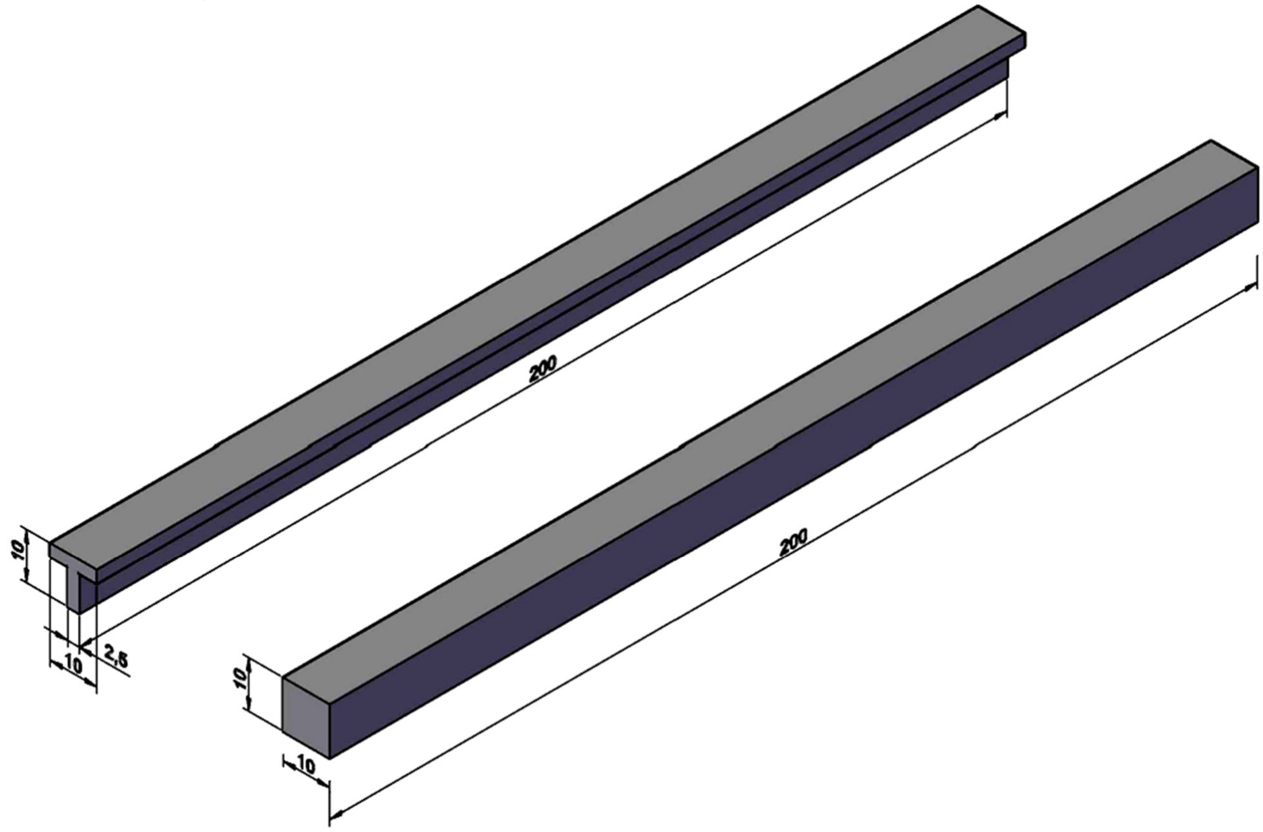

Figure 1. 3D model of the specimens

The sample is placed on supports with the wide side. If the sample was subjected to mechanical processing on one side, then it is placed on the supports with the side that was not subjected to mechanical processing. The loading of the sample will be carried out in the middle of the span between the supports smoothly, without jolts.

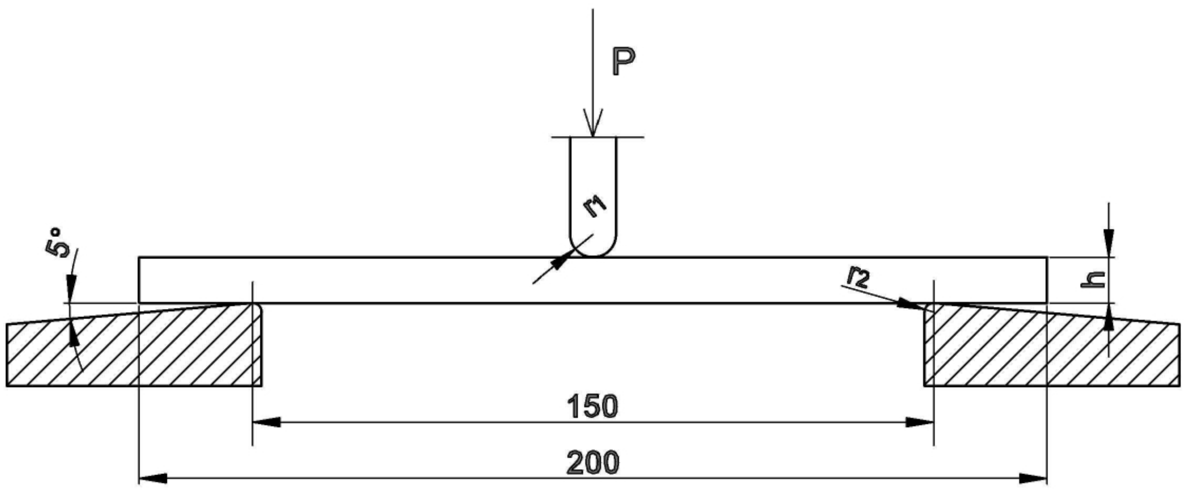

Figure 2. Scheme of loaded sample

Two cases of sample deformation and destruction are assumed [11]:

1. The sample will destruct at the specified deflection value or before reaching this value. At the same time, we will determine the load and deflection at failure.

2. The sample does not collapse at the specified deflection value or until this value is reached. We determine the load at the moment of reaching the given deflection.

The tests will be continued until the destruction of the sample or until the specified maximum load is reached. In any of these cases, we determine the load and deflection.

If, during the test of the sample, the maximum value of the load is observed before reaching the specified amount of deflection, then we determine the maximum load and the corresponding value of the deflection.

If the sample collapses beyond the middle third of the distance between the supports, the result obtained will not be counted and the test will be repeated on a new sample.

Conclusions. Based on the results of the given data, the following conclusions can be presented:

1. In order to carry out indicated research, a 3D model of the experimental samples was made and 2 series of experimental samples with 6 prototypes each, made of ABS plastic using 3D printing, were prepared for testing.

2. Each series contains 2 twin samples with different percentages of filling the internal cavity with plastic: 10%, 50% and 100%.

3. A sample loading scheme was prepared, and an algorithm for conducting experimental studies of the strength of plastic structures in bending under the action of short-term loads was drawn up.

Among the prospects for further research are the analysis and comparison of the obtained results, as well as the manufacture and testing of 3 series of samples under the action of repeated loads of different levels.

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МЕТОДИКА ВИПРОБУВАННЯ ВИРОБІВ З ПЛАСТИКУ, ВИГОТОВЛЕНИХ ЗА ДОПОМОГОЮ 3D ДРУКУ, НА МІЦНІСТЬ ПРИ ЗГИНІ

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Анотація. До основних методів механічних випробувань композиційних матеріалів належать: визначення міцності матеріалу при розтягу, згині, крученні, ударних навантаженнях, стиску та ін. В даній статті представлено підготовчий етап проведення експериментальних досліджень щодо визначення міцності при згині конструкційних елементів з пластику ABS, виготовлених за допомогою 3D друку, зазначено 2 серії дослідних зразків, що відрізняються за формою поперечного перерізу (1 серія – прямокутний переріз, 2 серія – тавровий переріз), встановлено відповідні розміри та схему випробування згідно вимог нормативних документів. Означено варіювання відсотка заповнення внутрішньої порожнини дослідних елементів полімерним матеріалом, а саме 10%, 50% та 100%. Описано алгоритм підготовки та безпосередньо виконання запланованих випробувань за дії статичного короткочасного навантаження. Наведені прогнозовані схеми й критерії руйнування зразків, а також умови припинення виконання випробувань.

Ключові слова: полімери, 3D друк, ABS-пластик, міцність, згин, короткочасне навантаження, руйнування.