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ВЫБОР ОТНОСИТЕЛЬНОЙ ВЫСОТЫ ОБРАЗЦОВ ДЛЯ ИСПЫТАНИЙ НА СЖАТИЕ

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Испытания на осевое сжатие важны при изучении свойств материалов, особенно тех, у которых прочность при сжатии значительно выше, чем прочность при растяжении. Определены оптимальные размеры цилиндрических образцов для испытаний на сжатие. Рассчитаны методом конечного элемента два крайних случая: сжатие образца между жесткими плитами с бесконечно большим трением и без трения. Получены соотношения, позволяющие определить размер образца в зависимости от базы измерения деформации. Приведена экспериментальная кривая, показывающая при каких размерах образца трение на торцах не влияет на точность определения прочностных характеристик.

Ключевые слова: испытания образцов, сжатие, метод конечного элемента, трение, испытания на сжатие.

THE CHOICE OF THE RELATIVE HEIGHT OF SAMPLES FOR TESTS ON COMPRESSION

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Axial compression testing is useful procedure while studying the properties of materials. They are extremely important while studying the properties of materials which compressing strength is substantially higher than tensile strength. The optimal sizes of cylindrical samples for compression testing are suggested theoretically and experimentally. Two extreme cases are calculated by the method of finite elements: compression of the sample between rigid plates with an infinitely large friction and without friction. The relationships allowing to determine the size of the sample depending on the base of measuring strain are got. An experimental curve showing at what sizes of the sample the friction at the ends of it does not affect the accuracy of determination of the strength characteristics.

Keywords: testing of samples, compression, finite element method, friction, compression test.

Compression strength is a key value for design of structures. Compression testing is extremely important while studying the properties of materials which compressing strength is substantially higher than tensile strength. Namely compression testing is main for many building materials. The following materials are typically subjected to a compression test: concrete, metals, plastics, ceramics, composites and others.

The size of the samples for compression test are standardized for many materials [1–5]. But this size choose empirical (by use the results of experiments).

While compression testing the sample is compressed between the bearing surfaces of the testing machine. Thereat the friction between these surfaces and the ends of the sample influence significantly. If this friction would be equal to zero (what is actually not true), then there would be a uniform (homogeneous) deflected mode in the sample for any relative height of the cylindrical sample h/R , where h – half of the height of the sample, and R – its radius. However, due to the influence of friction between the ends of the sample and the bearing surfaces of the testing machine stress state in the sample differs from the homogeneous stress greatly and strength characteristics, determined according to the test results of short samples, are substantially exaggerated compared with the strength of the base material. Strength characteristics determined while testing cubic samples can not be used for calculating the product. So it is important to determine such sizes of the sample for compression that friction at the ends of the sample wouldn't be more than the strength characteristics of the material and did not affect the uniformity of the deflected mode in the strain measurement. This article is devoted to this task.

The character of distribution of deformation in the samples with different relative height was investigated numerically.

The problem of squeezing cylinder between two rigid plates was solved by the finite element method (FEM) [5, 6]. Friction at the ends of the sample was taken: a) infinite; b) zero. The cylinders with the relative height $h/R = 0,5; 1,0; 1,5; 2,0; 3,0$ were calculated. The problem was solved in the elastic formulation. Because of the symmetry only a quarter of the cylinder, which was divided into 200 (with radius 10 and height 20) finite elements, was considered.

Figure 1 shows the variation of axial ε_z , radial ε_r , and tangential ε_θ deformation in the surface layer of elements depending on the height for samples with different relative height. Deformation was calculated relative to the average axial deformation $\Delta h/h$, where Δh was determined by the movement of the bearing surfaces of the testing machine.

Figure 2 shows the dependence of the size of the zone with uniform distribution of axial strain for samples with different relative heights.

It is seen that this dependence is nonlinear. The solid curve corresponds to the size of the zone, where the deviation of an axial deformation from the uniform does not exceed 1%, and the dashed curve – a deviation is not more than 5%. The same dependences for the radial and tangential deformation have the same character. These curves are obtained, when the coefficient of friction between the end of the sample and a reference surface of the testing machine is infinitely large. When the coefficient of friction is equal to zero, then the distribution of deformation will be uniform for any dimensions of the sample. This corresponds to the dashed-dotted line in Figure 2.

With the help of figure 2 you can determine the dimensions of the sample, which has homogeneous (uniform) deflected mode in the area of measuring deformation. For example, for a sample of 20 mm in diameter at the base of

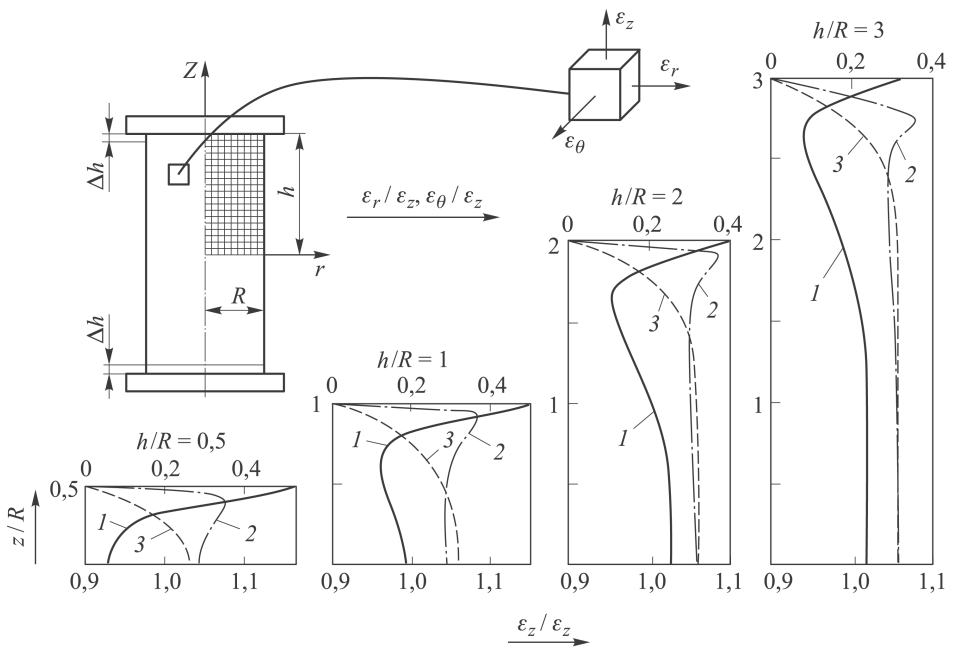


Fig. 1. Design model MFE and graphics of changes of axial ε_z (1), radial ε_r (2) and tangential ε_θ (3) deformation relative to the average deformation (or strain) $\hat{\varepsilon}_z = \Delta h/h$ for samples with different relative height h/R

measuring deformation 20 mm the height should be more than 40 mm. Thereat the deviation of the distribution of deformation in the zone of measuring does not exceed 1% from uniform one.

Solving the problems taking into account the plastic properties of material graphs (figure 1) will have more smooth character and curves (figure 2) will be raised a bit. This solution is inconvenient to use as the size of the zone with the uniform distribution of deformation depends on the load due to the nonlinear dependence between the tension and deformation. The elastic solution gives the smallest size of this zone.

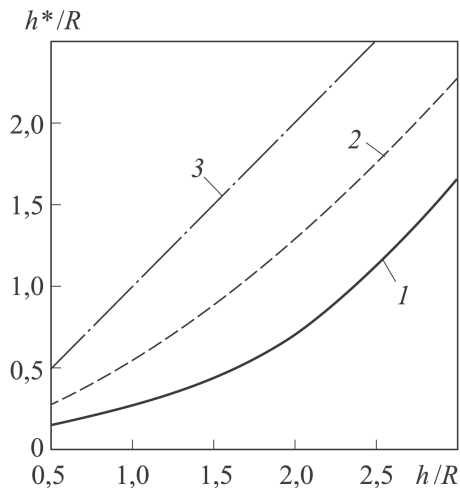


Fig. 2. The size of the zone with the uniform distribution of deformation h^*/R depending on the relative sizes of the sample h/R :

1 — the deviation from the uniform distribution of the deformation in the zone h^*/R does not exceed 1%, 2 — the deviation does not exceed 5%, the two curves for solutions with infinite friction at the ends of the sample, 3 — the solution without friction

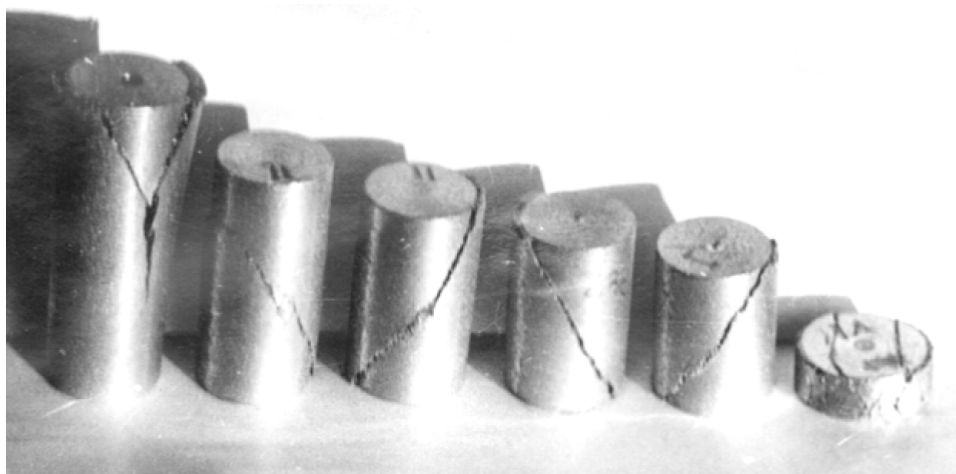


Fig. 3. The fracture mode of cylindrical samples under compression (from right to left $h/R = 0,50; 1,00; 1,75; 2,00$ and $3,00$)

The effect of the relative height of the sample on the maximum compression σ^* (the compression at which the sample is destroyed) as investigated experimentally in this paper.

When the velocity of the active gripping of testing machine was 0.5 mm/min, the samples of 20 mm in diameter with the relative height $h/R = 0.50; 1.00; 1.50; 1.75; 2.00; 2.25; 2.50$ and 3.00 were tested. Each series with the same relative height consisted of eight samples. The samples were prepared by mechanical processing from highly filled polymeric material.

Maximum tension was determined with the instrumental error not exceeding 0.2 MPa.

The fracture mode of almost all samples with different relative height was similar (Fig. 3). There was a shift of one part of a sample toward another along a plane inclined to the axis of the sample at an angle of approximately 45°.

Dependence of compressive strength σ^* defined as the average according to the results of testing eight samples for each relative height of the sample h/R is shown in figure 4.

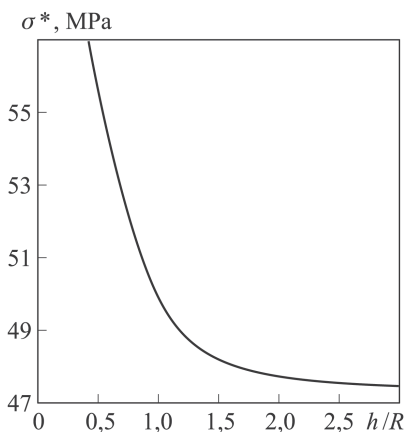


Fig. 4. The dependence of compressive strength σ^* from the relative height of the samples

Figure 4 shows that short samples have a great effect of friction at the ends of the sample and they give excessive values of tensile strength. When the relative height of the sample is more than 1.5 the effect of friction decreases and samples with the relative height $h/R = 2.0; 2.5$ can be used for determining (finding) the compressive strength characteristics. As the height of the samples increases their destruction can occur in consequence of losing stability and such samples can not be also used to determine the compressive strength.

Conclusion. Numerical and experimental investigation of the deflected mode of the samples on compression, on base of which it is concluded that the optimal relative height of the cylindrical samples on compression should be $h/R = 2.5$.

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