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The Research on Expanded Polystyrene Slabs Bending Strength and Bending Stress

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The results of expanded polystyrene slabs bending strength and bending stress analysis are presented in this article. The influence neither of short- nor of long-term loads was estimated, therefore, the characteristic of bending strength is not circumstantial. Under the influence of short-term load the material slightly deforms but as soon as the load is eliminated, the deformation vanishes. However, permanent deformations causing collapse of macrostructures elements are also possible. It is proposed to use the characteristics of critical bending stress and critical deflection. These characteristics are estimated in the following way: specimens are periodically strained until certain deformations are achieved; if straining continues after having achieved these deformations, the bending stress diminishes and the specimen collapses.

Keywords: expanded polystyrene (EPS) slabs, mechanical properties, bending strength, critical bending stress, critical deflection.

INTRODUCTION

Expanded polystyrene slabs are composed of hard polymer matrix and gaseous phase. The material, due to its composition, maintains good mechanical properties and low density [1]. The macrostructure of the material depends on raw material and technological production parameters. The higher is the density of the material the more value of the materials strength and elasticity characteristics increases [2, 3]. The main mass of the material which is accumulated in the units between the pores and in the places of pore bond determines the materials strength properties [4].

Due to good mechanical properties of expanded polystyrene slabs, it also might be used as a constructive-thermo insulating material. In such constructions the material is under the influence of various short- and long-term loads. The bending strength of expanded polystyrene slabs is estimated according to a standard [5] requirement. When the maximum value of the bending strength is reached, the specimen collapses (Fig. 1). As it can be judged from the bending diagram (Fig.1), which is contrary to compression diagram (Fig. 2) [6 – 9], distinctive turning-points may be hardly noticed. The turning-points are more distinct when the density of foam polymers is 200 kg/m^3, however, when the density descreases, the bending diagram draws near to straight line. After the peak point, the load displacement response follows the plateu where cellular structure collapses by the buckling cell walls and edges [10]. Despite the density of the material, the specimens collapse is suddenly.

Literature sources do not provide data concerning expanded polystyrene slabs maximum deflection, having reached which the strength properties of the material diminish and the structure of the slabs starts collapsing. Usually, the specimens are completely collapsed during the experiment. The specimens of many-layered constructions possessing polyurethane thermo-insulating material inside

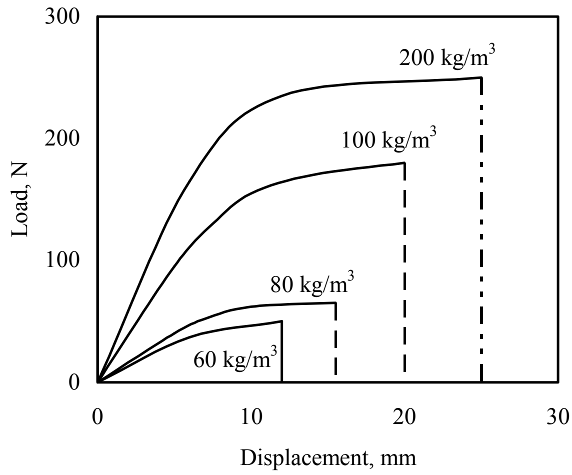

Fig. 1. The diagram of expanded polystyrene slabs bending strength [10]

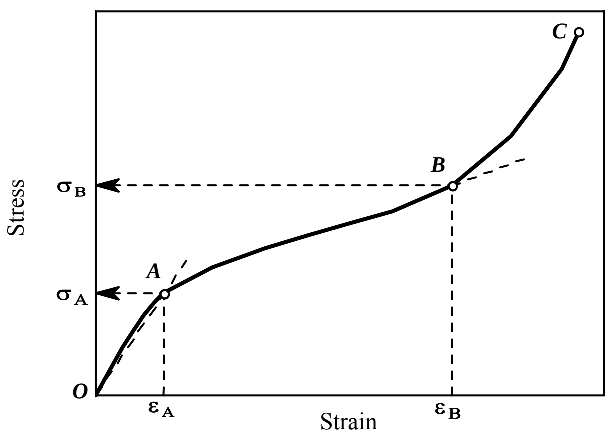

Fig. 2. The diagram of foam polymeric materials compression stress. σ_A indicates the end of segment *OA*, σ_B indicates the end of bending deformation process, which takes place in the walls of pores and causes the walls to lose stability. If σ_B is exceeded, polymeric materials are multiplexed and the elements of macrostructure damaged [6 – 9]

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and protective metal profiles outside may be deformed up to 40 mm [11] during the experiment.

Under the influence of loads the material more or less deforms. When the material is being deformed, its strength properties change.

The results of experimental research of expanded polystyrene slabs mechanical properties are presented in this article.

The influence of expanded polystyrene slabs density to the bending strength was established experimentally in this work. In order to determine hazardous bending stress and deflections the specimens were loaded down periodically. If the critical bending stress or deflections are exceeded, the bending strength of the material lessens or the specimen collapses.

EXPERIMENTAL

In the experiment the expanded polystyrene slabs made in Lithuanian and Polish factories were used. The density of the slabs was from 11 up to 35 kg/m^3. Rectangular specimens (300×150×150 mm) were made out of the slabs.

In the experiment H10KS press made by Hounsfield was used. The machine used in the experiment was connected to a PC. All parameters (measurements of the specimens, speed of the loads, etc.) were controlled and monitored by the PC. The bending strength and bending stress were calculated by means of a computer program according to the standard [5] requirements. The experiment took place on two carriers, the distance between which is 250 mm. The flat of the specimen was sheer strained by a bending die steadily moving down at speed of 10 mm/min. The force was directed to the center of the specimen held on the two carriers. The diameter of the carriers is 30 mm. The shift of the bending die was measured with 0.01 mm accuracy; and the sensor of the force granted constant measurements of the power with the accuracy of 0.5 % in the whole diapason of the experiment.

The records of maximum power and deflection which equal the collapse of the specimen allowed determining the bending strength.

The specimens loading up to a set deformation provided the establishment of the bending stress.

At the first of all, the specimens of equal density were periodically strained few times in a row until different levels of deformation were achieved. Later, the experiment was repeated with the specimens of different density. The diagrams of the experiment show maximal deformation, which does not cause the bending stress to diminish.

RESULTS AND DISCUSSION

Bending strength test

In order to establish bending strength the specimens of different density were used. It was determined that the bending strength of expanded polystyrene slabs depends on the materials density. The results of the experiment are presented in Fig. 3. The figure shows that the dependence of expanded polystyrene slabs bending strength on the materials density is linear. The dependence may be described by an empirical equation of regression:

$$\sigma_b = 15.1\rho - 81.2 \quad (1)$$

with coefficient of determination $R^2_{\sigma\rho} = 0.955$, where σ_b is the bending strength, kPa, ρ is the density, kg/m^3 [12].

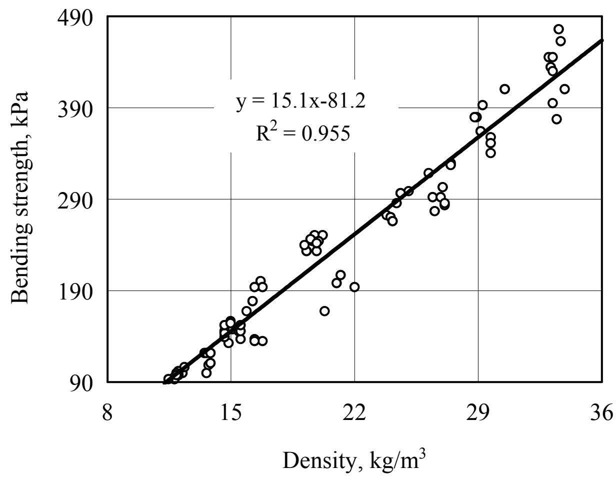

Fig. 3. The dependence of bending strength on density

The analysis of the data shows that if the density increases twice, the bending strength increases approximately 2.6 times. It is very important by manufacturing expanded polystyrene and also at designing sandwiches with thermal insulation of expanded polystyrene slabs.

It was established by the experiment that the collapse of the specimens, which occurs when the material is bent, does not depend on the density of specimens. The collapse of the specimens is different and ranges from 7 to 15 mm in the range of all specimens density.

Bending stress and deflection

The specific characteristic is observed (in the diagram stress-deflection) when expanded polystyrene deforms and its macrostructure collapses due to the bending stress, which is caused by periodical loading of the material. When the load straining the material is not hazardous to its structure (the structure does not collapses) and the deflection does not exceed critical deformation, the diagram shows that the bending stress increases in each cycle (see Fig. 4). However, when the strain and deflection reaches critical point, the diagram of stress-deflection (Fig. 5) shows that the bending stress in every cycle decreases or remains the same. In such cases the specimen collapses in 5 – 6 cycles.

The dependence of the critical bending stress on the density was established by the experiment. The results are provided in Fig. 6.

The dependence is linear and can be described by an empirical equation of regression:

$$\sigma_{cr} = 12.9\rho - 103 \quad (2)$$

with coefficient of determination $R^2_{\sigma\rho} = 0.976$, where σ_{cr} is the critical bending stress, kPa.

However, it is not enough to determine critical bending stress, critical deflection also has to be taken into consideration because the loads and deformations may be different in various layered constructions. The estimations of critical deflection are provided in Fig. 7. The

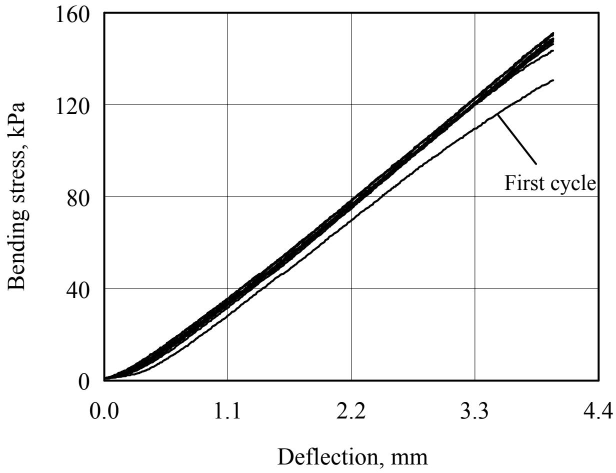

Fig. 4. The dependence of bending stress on deflection, when the specimen is under the influence of periodic load, which is not damaging

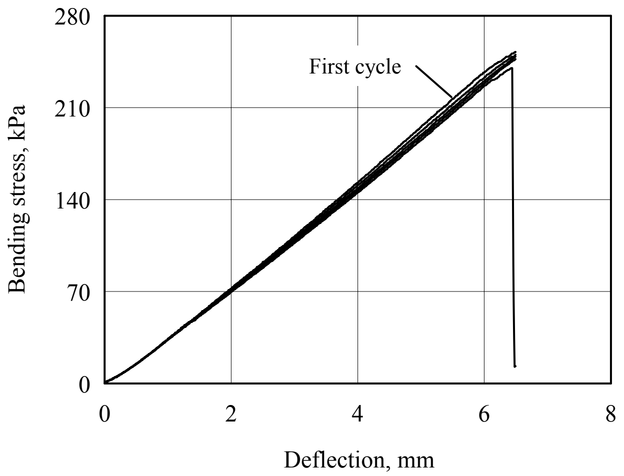

Fig. 5. The dependence of bending stress on deflection, when the specimen is under the influence of periodic damaging load

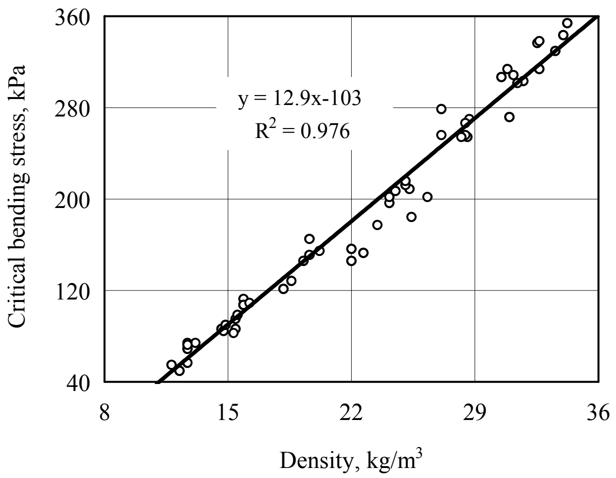

Fig. 6. The dependence of critical bending stress on density

dependence of critical deflection on density may be described by equation of regression:

$$I_{cr} = 0.0492\rho + 3.\,96 \tag{3}$$

with coefficient of determination $R^2_{\sigma p} = 0.870$, where I_{cr} is the critical deflection, mm.

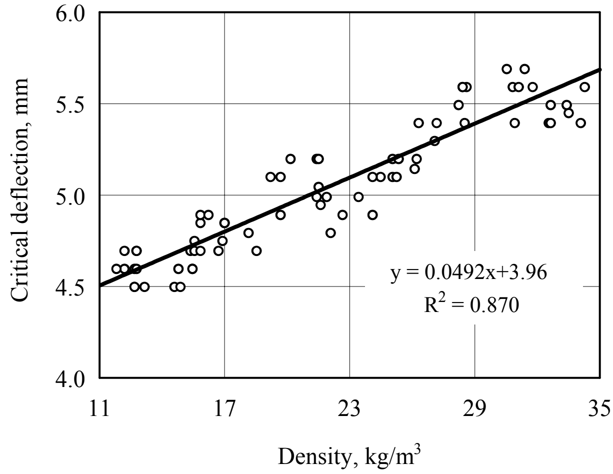

Fig. 7. The dependence of critical deflection on density

It was established by the experiment that critical deflection does not depend on the thickness of the specimen therefore the deflection has to be expressed in millimeters instead of percents as it is common to express compression strength.

The dependence of critical bending stress on critical deflection is presented in Fig. 8.

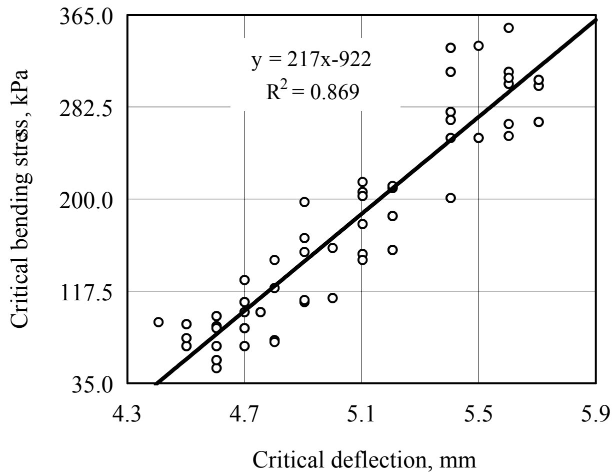

Fig. 8. The dependence of critical bending stress on critical deflection

It may be described by equation of regression:

$$\sigma_{cr} = 217\, I_{cr} - 922 \tag{4}$$

with coefficient of determination $R^2_{\sigma p} = 0.869$.

The analysis of the data indicate that higher critical deflection is possible when critical bending stress increases, e.g., if the specimens bending stress increases 200 kPa, it is possible that critical deflection would increase approximately 0.9 mm.

CONCLUSIONS

1. Experimentally it was established that the dependence of expanded polystyrene slabs bending strength on the density is linear. Knowing density of plates it is possible to predict bending strength, and also by

manufacture to pick up the necessary bending strength selecting density.
2. There is a possibility of expanded polystyrene slabs collapse prior to the time established by the experiment with bending strength. To obtain more precise estimations the characteristics of critical bending stress and critical deflection are offered. These characteristics show when irrevocable a process of collapse in a material begins.
3. Dependences between critical bending stress, critical deflection and density are determined. Knowing density of plates it is possible to predict critical stress and deformation values.

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