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INFLUENCE OF COMPOSITION ON THE STRENGTH, DURABILITY AND THERMAL STABILITY OF POLYSTYRENE FOAM

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Key words and phrases: durability; polystyrene foam; strength of working capacity; thermal stability; thermo-fluctuation mechanism of destruction; physical constants.

Abstract: Influence of polystyrene foams composition of different types and makes on the strength, durability and thermal stability has been investigated. Their regularities of destruction in the wide range temperatures, loads and times of exploitation have been determined. It is shown that they are subordinated to general Zhurkov's equation for durability. Parameters of working capacity have been calculated, proceeding from the equation.

Due to new building normative to the thermal insulation of buildings in Russia, the necessity of using thermally efficient insulating materials has appeared. Such materials are plastic foams, among which polystyrene foam is the most widely used [1, 2].

However the influence of material's composition on its durability (such as conservation strength and thermo-physical characteristics of time) has not enough been examined. To solve this problem different types of polystyrene foams have been investigated in the given work.

The determination of durability from the position of thermo-fluctuation mechanism of solid bodies destruction has been carried out [3]. According to kinetic conception of strength supposed forces, and a thermal movement of atoms as a critical factor of mechanical destruction processes act on the body. It was found out that different polymeric materials such as polystyrene foam reveal thermo-time's dependence on strength [6, 7].

The durability tests by cross bending have been carried out [5]. With fixing parameters (stress and temperature) 6 – 12 samples have been tested. The high temperature has been created consecutively by the laboratory electric transformer. The time before destruction has been fixed by stop–watch.

Experimental data have been processed graphically by the diagram $\lg\tau$ - σ (fig. 1, *a*). As the figure shows, the dependencies for polystyrene foam PSB-s (mark 35) have linear character and they form a family of fan–shaped straight lines, coming together in the one point of intersection. To expose analytic dependence, connecting the time before destruction τ, stress σ and temperature T, experimental results have been converted into the diagram $\lg\tau$ - $1/T$ (fig. 1, *b*). As the figure shows, the dependence form a family fan-shaped straight lines in the diagram.

The same dependence of polystyrene foam PS-1, PS-4 and PSB-s M15 has been received for [7].

Equations, describing such dependence's are shown in [5, 6]. They are:

for durability

$$\tau = \tau_m \exp\left[\frac{U_0 - \gamma\sigma}{RT}\left(1 - \frac{T}{T_m}\right)\right]; \quad (1)$$

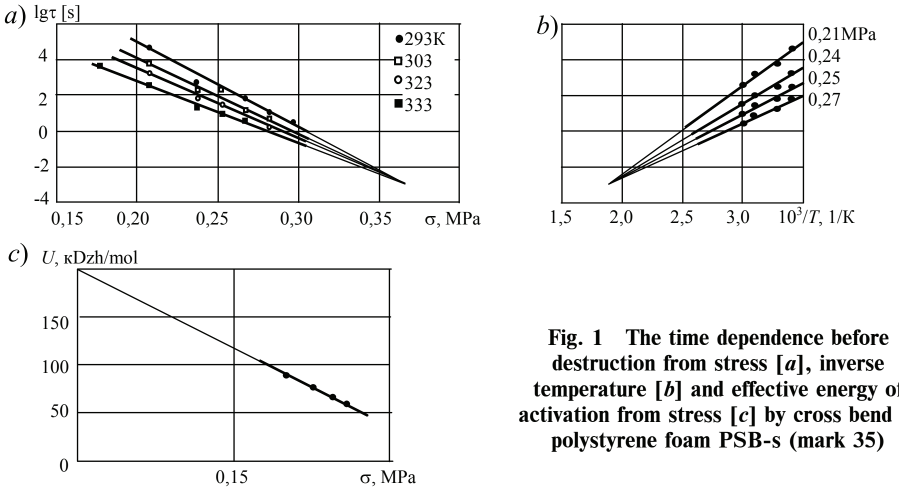

Fig. 1 The time dependence before destruction from stress [*a*], inverse temperature [*b*] and effective energy of activation from stress [*c*] by cross bend of polystyrene foam PSB-s (mark 35)

strength

$$\sigma_{cr} = \frac{1}{\gamma}\left[U_0 - \frac{2,3RT}{1 - T/\ T_m}\lg\frac{\tau}{\tau_m}\right]; \qquad (2)$$

and thermal stability

$$T_{cr} = \left[\frac{1}{T_m} + \frac{2,3R}{U_0 - \gamma\sigma}\lg\frac{\tau}{\tau_m}\right]^{-1}, \qquad (3)$$

where τ_m, U_0, γ, T_m - physical constants of material, R – universal gas – constant, T – temperature, τ - time before destruction (durability).

The dependence of $\lg\tau$ - $1/T$ constants has been determined by graphs–analytic method, where τ_m and T_m - co-ordinates of pole (points of straight lines intersection). The value U under given stress has been calculated on angle's tangent of straight lines pitch, by formula $U = 2,3\ R\ \ \Delta \lg\tau\ /\ \Delta\ 1/T$ and diagram is in the co-ordinates U – σ (fig. 1, *c*). From extrapolation on the $\sigma = 0$ we have determined energy of activation U_0; and on angle's tangent of straight lines pitch diagram U — σ we have determined structure-mechanical factor γ.

The values of calculated constants for examined types of polystyrene foams have been received in the table 1.

It is shown in the table, that composition of reactionary polystyrene foam mixture influences the physical constants and also strength, durability and thermal stability.

Value U_0 corresponds to activation energy of chemical bonds break-up. According to [4, 5] it does not depend on from method of processing and it changes if material contains active chemical additions. As it was stated before [6, 7] for polystyrene foam PS-1 U_0 in value is close to the activation energy of pure polystyrene. For polystyrene foam of types PSB-s the decrease in this value is typical, that is probably connected with introduction of antipyrene additions to composition of reactionary mixture the. As it was stated in [1, 2] this additions have chemical interaction with polystyrene in the process of foaming, that leads to decrease of average molecular weight of polymer and mechanical characteristics of plastic foam. For polystyrene foams PSB-s (mark 15 and mark 35) the value U_0 is approximately equal, because these two materials are not different from their composition. The biggest value of activation energy has been observed in the polystyrene foam PS-4, that is probably connected with the presence of inorganic filler (ammonium carbonate) in the press-composition, which is a chemical stabiliser.

The displacement value of pole temperature $1/T_m$ (where T_m – critical temperature of material's existences), depends on composition, method of processing and active medium [4, 5]. This value is the highest for the polystyrene foam PS-1. The drop of the thermal stability, is probably connected with the nature of fillers. So for polystyrene foam PS-1 organic filler is used, that plastificates the polymer and for PS-4 – mineral filler, that increases thermal stability of polystyrene foam [1, 2].

For polystyrene foams PSB-s (mark's M15 and M35 the displacement value of pole temperature is approximately equal in their significance. The increase of fluctuation value of kinetic units is caused by the modes of processing in accordance to [4, 5].

For all types of polystyrene foams the value τ_m exceeds the classic significance 10^{-12} sec, that is connected with the period of fluctuation kinetic units rather than atoms.

The value of power structural factor γ characterises the effectiveness and the direction of power field and is connected with the structure of material [4, 5]. This value for all examined types of polystyrene foam is the higher than for pure polystyrene. This is explained by the increase of structure's heterogeneity. Besides in the composition of PS-4 and PSB-s water and spirit are added, thus producing a plastificating effect [1, 2]. The materials PSB-s (mark's M15 and M35) differ in density, that affect the value γ. Their significance for mark M15 increases approximately twice, as their density is higher. In addition, the composition of PS-4 has inorganic filler which badly matches the polymer that leads to strong heterogeneity of structure [2] and maximum of value γ.

Therefore it has been found out that composition of polystyrene foam influences the physical constants of material and consequently their strength, thermal stability and durability, which is described by formula (1) – (3). Example of these parameters calculation is represented in the table 1.

Table 1

Influence of composition on the physical constants of polystyrene foams by cross bend and their working capacity parameters

Type of polystyrene foam	Physical constants				Working of capacity		
	τ_m, s	$10^3/T_m$, 1/K	U_0, $\frac{\text{кDzh}}{\text{mol}}$	γ, $\frac{\text{кDzh}}{\text{mol} \cdot \text{MPa}}$	σ, ÌPà*	T, Ê**	τ, s***
PS-1 Ì120	$10^{-0,4}$	2,73	271	64	2,45	244	$10^{1,0}$
PS-4 Ì15	$10^{-3,5}$	2,46	370	2450	0,09	288	$10^{1,9}$
PSB-s Ì15	$10^{-4,5}$	1,80	186	1160	0,076	255	$10^{0,8}$
PSB-s Ì35	$10^{-2,9}$	1,90	200	515,3	0,229	267	$10^{1,5}$

$$^{*}\left\{\begin{matrix} T = 303\ \text{K} \\ \tau = 10^3\ \ \text{s} \end{matrix}\right\};$$

$$^{**}\left\{\begin{matrix} \tau = 10^3\ \text{s} \\ \sigma = 0,10\ \text{MPa (for PS-4 and PSB-s M15)} \\ \sigma = 0,267\ \text{MPa (for PSB-s M35)} \\ \sigma = 3,5\ \text{MPa (for PS-1)} \end{matrix}\right\};$$

$$^{***}\left\{\begin{matrix} T = 303\ \text{K} \\ \sigma = 0,10\ \text{MPa (for PS-4 and PSB-s M15)} \\ \sigma = 0,267\ \text{MPa (for PSB-s M35)} \\ \sigma = 3,5\ \text{MPa (for PS-1)} \end{matrix}\right\};$$

Conclusions:

1. The regularities of polystyrene foam destruction, which are described by formula (1) – (3) have been determined and the influence of composition on the physical constants of material has been shown.

2. Formula (1) – (3) can be used for prediction of polystyrene foam working capacity in the wide range of strength, temperature and exploitation time.

References

1. Pavlov V. P. Polystyrene foam. - M.: Chemistry, 1973. - 240 p. *(in Russian).*
2. Romanenkov I. G. Physico–mechanical properties of plastic foams. - M.: Gosstandart, 1970. - 170 p. *(in Russian).*
3. Regel V. R., Slutsker A. I., Tomashevsky Ed. E. Kinetic nature of strength of solid bodies. M.: Science, 1974. - 560 p. *(in Russian).*
4. Yartsev V. P. Physico-technical bases of organic materials working capacity in parts and constructions: Synopsis of thesis… doct. of techn. science. - Voronezh, 1998. - 42 p. *(in Russian).*
5. Ratner S. B., Yartsev V. P. Physical mechanics of plastics. How to predict working capacity? - M.: Chemistry, 1992. - 32 p. *(in Russian).*
6. Andrianov K. A., Yartsev V. P. The determination of durability of polystyrene foam under tension // The modern problems of building material observing. The materials of fifth academic reading: Col. scien. art.- Voronezh, 1999.- P. 22 - 24. *(in Russian).*
7. Andrianov K. A., Yartsev V. P. Strength, durability and thermal stability of polystyrene foam of the enclosing structures // Col. of materials a Russian scien. – practical conferences of young scientists «Building constructions - 2000». Part 3. «Constructions from wood and plastics. Building mechanics» / MSTU, 2000. P. 48 - 53. *(in Russian).*

Влияние состава на прочность, долговечность и термостойкость пенополистирола

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Ключевые слова и фразы: долговечность; пенополистирол; прочностная работоспособность; термостойкость; термофлуктуационный механизм разрушения; физические константы.

Аннотация: Исследовано влияние состава пенополистиролов различных типов и марок на прочность, долговечность и термостойкость. Установлены закономерности их разрушения в широком диапазоне температур, нагрузок и времен эксплуатации. Показано, что они подчиняются обобщенному уравнению долговечности Журкова. Исходя из этого уравнения, рассчитаны параметры их прочностной работоспособности.

Einwirkung der Zusammensetzung auf die Festigkeit, Nutzungsdauer und Thermobeständigkeit von Schaumpolisterol

Zusammenfassung: Es ist die Einwirkung der Zusammensetzung von Schaumpolisterol der verschiedenen Arten auf die Festigkeit, Nutzungsdauer und Thermobeständigkeit untersucht. Es sind die Gesetzmäßigkeiten ihres Bruches im breiten

Bereich von Themperaturen, Belastungen und Gebrauchsdauer festgestellt. Es ist gezeigt, daß sie der gesamten Zhurkov-Gleichung der Nutzungsdauer entsprechen. Auf Grund dieser Gleichung sind die Parameter ihrer festigkeitbaren Arbeitsfähigkeit berechnet.

Influence de la composition sur la densité, la durabilité et la stabilité thermique

Résumé: On a étudié l'influence de la composition du polystirène de diffétents types et marques sur la densité, la durabilité et la stabilité thermique. On a établi les régularités de leur destruction dans la haute gamme des températures, des charges et du temps de l'exploitation. On a montré qu'elles sont subordonnées à l'équation générale de Jourkov. A partir de cette équation sont calculés les paramètres de la densité de leur capacité de fonctionnement.
