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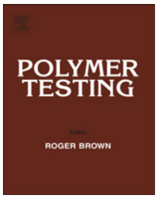

Property Modelling

Analytical description of the creep of expanded polystyrene (EPS) under long-term compressive loading

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ABSTRACT

The results obtained from investigating the compressive creep behaviour of expanded polystyrene (EPS) are presented. It was found that power-law (as in EN 1606) and exponential regression equations used for describing the compressive creep curves agree equally well with experimental results, taking into account the uncertainty.

It has been shown that sufficiently reliable predictions of the creep strains of EPS for lead times of 10, 25 and 50 years can be made based on an empirical exponential equation populated with the data obtained in direct experiments with a duration of 122, 152 and 304 days, respectively.

1. Introduction

Because of the widespread use of expanded polystyrene (EPS) slabs as a construction insulation material that experiences long-term compressive stress σ_c, the analytical description and prediction of EPS creep deformation is of considerable interest.

The data available on the theory of creep of solid materials are based on analysis of structural element deformation. However, these data often give contradictory results [1–3]. Currently, to describe the principles of creep in numerous plastics and polymer compounds, an analytic expression such as the Findley equation is used. This equation was recently applied to metals [4,5]. The formula is as follows:

$$\epsilon(t) = \epsilon_0 + b_0 \cdot t^{b_1} \tag{1}$$

where ϵ_0 and b_0 are parameters depending on the stress, b_1 is a constant for the given material and t is time.

Relation (1) was used to approximate the experimental data of insulation material creep testing under long-term compressive stress [6], and it predicts an impossible deformation increase that does not change as $t \to \infty$; whereas the rate constantly decreases as $\dot{\epsilon}_c \to 0$. Thus, it makes sense to use an exponential temporal dependence [7,8] instead of equation (1):

$$\epsilon(t) = \epsilon_0 + b_0 \left[1 - \exp\left(-b_1 \cdot t^{b_2}\right)\right] \tag{2}$$

where b_0, b_1 and b_2 are experimentally determined parameters.

The starting and ending criteria, which creep curves derived from time-constant stresses of the tested EPS samples comply with, can be written as follows:

$$\begin{array}{cc} \textit{Power – law model } (1) & \textit{Exponential model } (2) \\ t \to 0,\ \epsilon_c(t) \to 0 & t \to 0,\ \epsilon_c(t) \to 0 \\ \dot{\epsilon}_c(t) \to \infty,\ \dot{\epsilon}_c(t) = \dot{\epsilon}_0 & \dot{\epsilon}_c(t) \to \infty,\ \dot{\epsilon}_c(t) = \dot{\epsilon}_0 \\ t \to \infty,\ \epsilon_c(t) \to \infty, & t \to \infty,\ \epsilon_c(t) \to const = b_0, \\ \dot{\epsilon}_c(t) \to 0 & \dot{\epsilon}_c(t) \to 0 \end{array} \tag{3}$$

(where the above-letter dots represent time t derivatives).

In terms of the power-law (1) and exponential (2) models, it should be noted that time $t = 0$ in (3) corresponds to an infinitely high rate of creep. In fact, this is possible under impact loading [9]. Under the final stress σ_c, the speed of the creep cannot infinitely increase. For the exponential model (2), the condition $\dot{\epsilon}_c(t) = 0$ as $t \to \infty$

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shows that the rate of deformation in time can only asymptotically approach zero.

Apart from power-law dependency, EN 1606 [6] allows the use of other mathematic models to describe creep curves, provided that they are supported by direct experimental data from experiments lasting 2 and 5 years.

In Ref. [10], based on the few and relatively short direct experiments, $t_n = 65–608$ days, the possibility of calculating the predicted point-wise values of EPS creep deformation under compressive stress $\sigma_c = 0.35 \cdot \sigma_{10\%}$ was shown for a lead time of 50 years using exponential equation (2) and a direct experiment with a duration of 365 days.

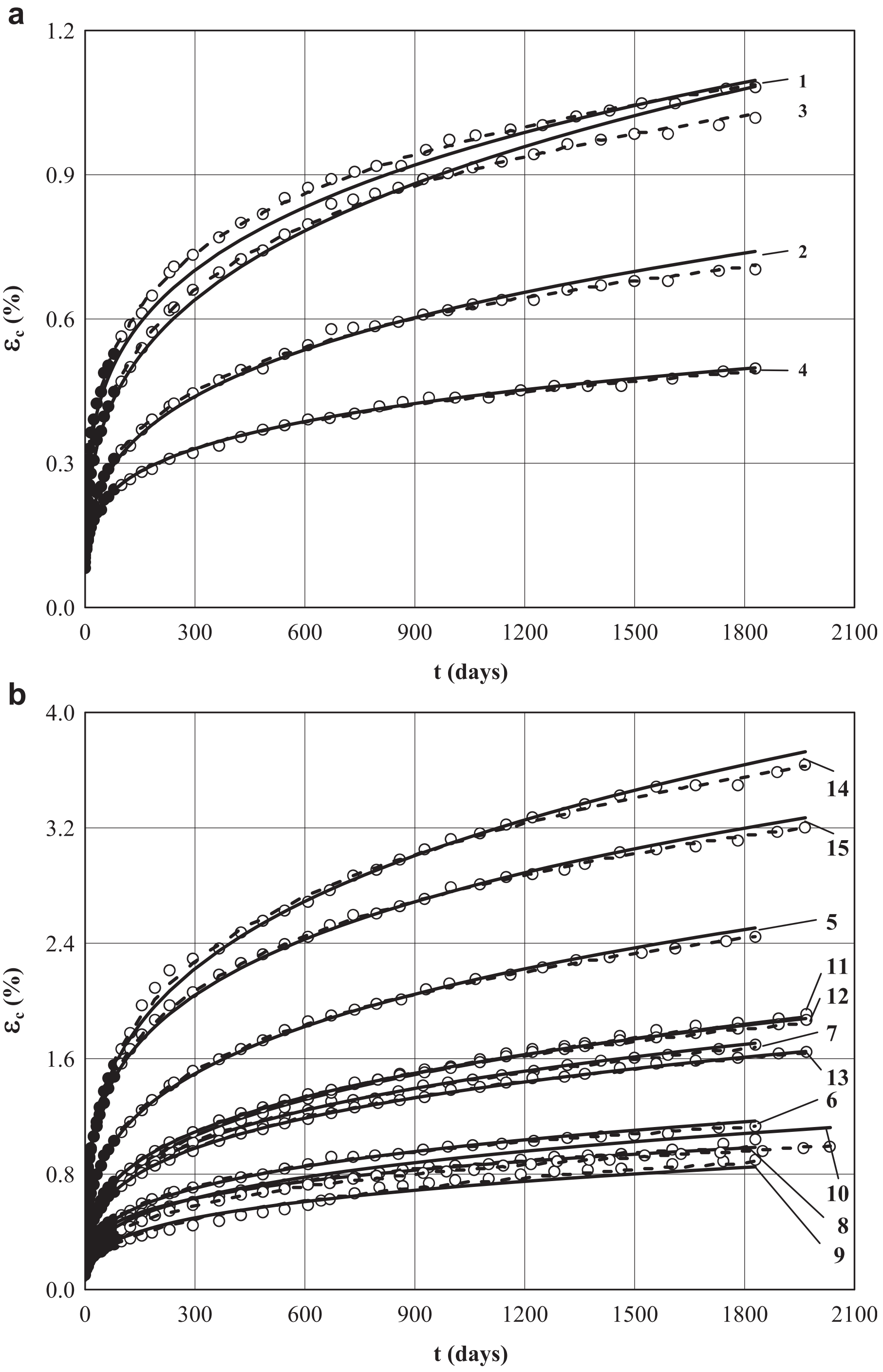

Fig. 1. The development of the creep strain ϵ_c for EPS samples of various density for $\sigma_c = 0.25 \cdot \sigma_{10\%}$ (a) and $\sigma_c = 0.35 \cdot \sigma_{10\%}$ (b) and experiments with a duration of up to 90 days (●) and more than 90 days (○). (—) – approximation by regression equation (1) [12]; (- - -) – same (2). The numbers by the regression lines refer to the number of experimental series (test numbers) given in the Table.