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Experimental Determination of Viscoelastic Behavior of Core for Composite Sandwich Beam

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Abstract. The experimental assessment of viscoelastic properties of the core for sandwich beams is given. Theoretical results are compared with experimental values.

Introduction

Foam-core sandwich panels and beams offer a high stiffness per unit weight, but creep even at room temperature, what is limiting their use in structural applications [1],[2]. In this paper, the experimental determination of viscoelastic behavior of the core for sandwich beams will be given. Theoretical results even for sandwich beam are compared with data from tests [3].

Experiment

For the mechanical long-time tests was supplied the plate is a sandwich structure, which is part of the sandwich of the wagon-body for means of transport, produced by the Czech company VARIEL s.r.o. Test specimen with the shape of a cube with dimensions 50x50x50 mm was inserted into the set-up, manufactured in the Klokner Institute, enabling the long-time loading by a constant force. The longitudinal deformation of the test body were measured by inductive sensors (LVDTs) and resistive strain gauges. Test specimens were 24 h loaded and then 24 h unloaded. (Fig.1 and 2 show a loading of the sandwich beam [3]).


Fig.1 Testing set-up

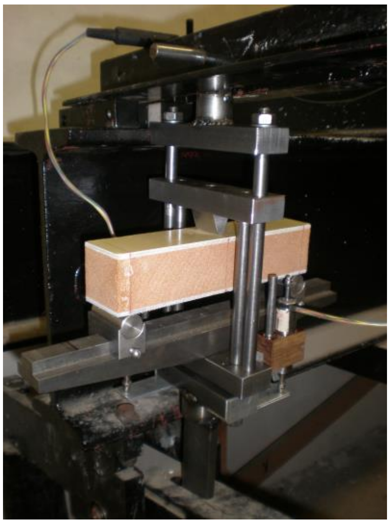


Fig.2 Sandwich beam

Mathematical Approximation of Viscoelastic Behavior

In viscoelastic problems for the evaluation of the time effect on stress and deformation are usually used the rheological models containing elastic and viscous elements operating in parallel or in series, in order to capture the characteristics of rheological models.

Basic of viscoelastic models are two-element models Kelvin-Voigt and Maxwell. Kelvin-Voigt model consists of parallel springs (E) and dampers (K). Maxwell's model consists of serial connection of the springs and dampers. Differential relations for two-element Voigt models and Maxwell can be written directly by a superposition of deformation speeds.

The three-element models containing three material characteristics are often used, in particular Poynting - Thomson model representing the serial connection of spring and Kelvin-Voigt element. The used model is also called a standard visco-elastic material.

$$\frac{1}{E_1}\sigma(x,t) = \varepsilon(x,t) - \frac{E_1}{K}\int_0^t e^{-\frac{E_1+E_2}{K}(t-\tau)}\,\varepsilon(x,\tau)\,d\tau$$

In the inverted physical equation we get thus

$$\varepsilon = E_1^{-1}\left(\sigma + \frac{E_1}{K}\int_0^t e^{-\frac{E_2}{K}(t-\tau)}\,\sigma(\tau)\,d\tau\right)$$

For the constant stress we get for the Poynting-Thomson model the relationship

$$\varepsilon = E_1^{-1}\left(1 + \frac{E_1}{K}\int_0^t e^{-\frac{E_2}{K}(t-\tau)}\,d\tau\right)\sigma_0$$

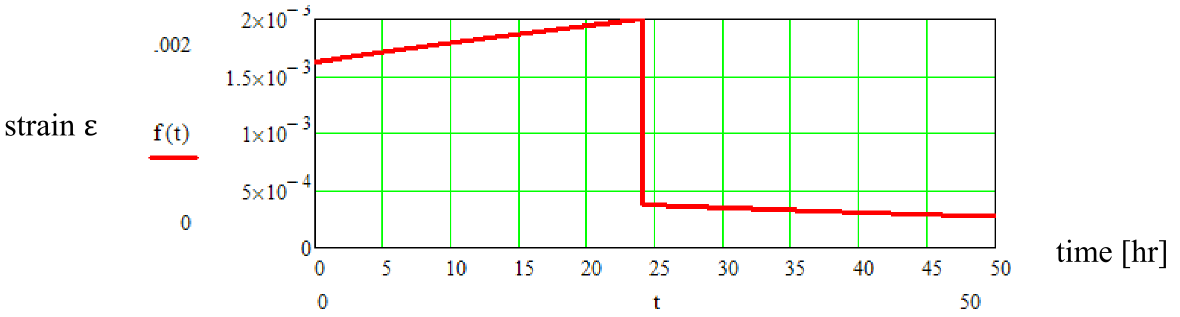
and after integration

$$\varepsilon = \frac{\sigma_0}{E_1} + \frac{\sigma_0}{E_2}\left(1 - e^{-\frac{E_2}{K}t}\right)$$

Results from experiment

An element subjected to the load constant in time was after 24 hrs load removed and the results of the experiment were compared with viscoelastic behaviour according to the Poynting-Thomson model. An arrangement of the experiment has been similar to Fig.1.

The theoretical course of the strain is dependent from the three material constants E_1, E_2, K.



For the estimated standard linear material can be the values of the respective coefficients determined on the basis of carried out experiments. The size of the module E_1 follows from the values $\varepsilon = \varepsilon_0$ at the immediate load at the time $t = 0$ still didn't Kelvin model with the structural formula E / K and the Poynting-Thomson model is then reduced to an elastic model Hooke. Out of here is $E_1 = \dfrac{\sigma_0}{\varepsilon_0}$. On the other hand, the value of E_2 can be approximated using the estimated values of the deformation in time $t \to \infty$, when the limit deformation of the coming term $\varepsilon_\infty \approx \dfrac{\sigma_0}{E_1} + \dfrac{\sigma_0}{E_2}$. What concerns the value of K, it is necessary to know the value of the deformation for the next time indication, e.g. for $t = t_1$. We obtain the relation $K = K(E_2)$. For the estimated standard linear material can be the values of the respective coefficients determined on the basis of carried out experiments.

The proposed procedures illustrate their use on a numerical example. Let
$\varepsilon_0 = 1{,}625.10^{-3},\ \ \varepsilon_1 = 2{,}0.10^{-3},\ \ t_1 = 24h,\ \ \sigma_0 = 0{,}04\,MPa,\ \ \ t_1 = 24h$.

Then comes the E_1 = 24,6 MPa, E_2 in the range of 27 to 45 MPa , which correspond to values of K in the range 1970 to 2220 MPa.h.

Conclusion

The experimental determination of viscoelastic behavior of the core for sandwich beams has been given and Poynting- Thomson model used.

If the theoretical curve for creep under mechanical model for the measured values, we have the possibility of changes of parameters or switch to another mathematical model. Formally we can also carry out replacement base e in exponential function by another suitably elected number, for example a. According to whether a <e, or a>e , the new curve is upper or under of the original creep curve, respectively.

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