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ANALYSIS OF LONG-TERM BEHAVIOR OF AN INSULATION BLOCK FROM RECYCLED HDPE BY COMRESS LOADING

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Abstract: *Use of waste materials is an actual topic that corresponds to current trends associated with the decreasing of power exigency and sustainable development. The possibility to reduce depletion of natural resources and decrease the produced waste lies in an efficient and possibly repeated use of resources. An important subgroup of waste is formed by materials from petroleum derivatives - polymers (PP, PE, HDPE etc.). Polymers and their composite materials can be used as a base material for most products including products used in civil engineering. One of these products is an insulation block for elimination of thermal bridges in wall footing. During design of this product the MAP method (modelling-analysis-prediction) has been used together with experimental testing. This paper deals with description of long term behaviour of an insulation block made of recycled polymers using full scale testing. Experimental data are compared to different rheological models.*

Keywords: ***Waste materials, recycling, polymer, experimental testing, rheological models.***

1. Introduction

Use of waste materials is an actual topic, which corresponds to current trends of decreasing of power exigency and sustainable development. Current capacity of natural resources is limited. The possibility to reduce depletion of natural resources lies in an efficient and possibly repeated use of resources – resource recycling. The advantage of recycling is the minimization of waste as well as decrease of power consumption and CO_2 production.

An important subgroup of waste is formed by petroleum derivatives – polymers. There exists a huge quantity of waste polymers: PP, PE, HDPE, PET, PVC, PUR etc. (Fig. 1). These materials belong to the group of thermoplastic materials and they can be easily recycled thanks to their basic property – thermal plasticity. Another advantage of using recycled polymers is the possibility to improve their resistance against atmospheric ageing, fire resistance and thermal-technical and mechanical properties (Fig. 2).

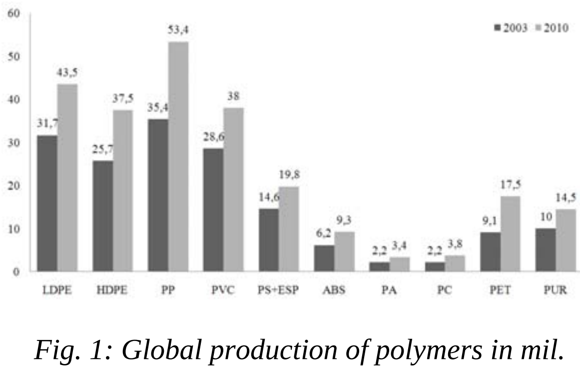

Fig. 1: Global production of polymers in mil. tons in year 2003 and 2010 (OECD 2008).

Properties	HDPE	modified HDPE
Volume mass	952,81 kg/m³	1206,43 kg/m³
Thermal conductivity (ČSN 64 0526)	0,418 Wm⁻¹K⁻¹	0,339 Wm⁻¹K⁻¹
Notch impact resistance (ČSN EN ISO 179-1)	as HDPE	4,8 kJm⁻²
Flexural elasticity modulus (ČSN EN ISO 178)	904 MPa	1001 MPa
Yield stress	23,1 MPa	18,7 MPa

Fig. 2: Example of improvement of mechanical and thermal-technical properties of HDPE.

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2. Solution of wall footing detail using an insulation block

The detail of wall footing i.e. place between the foundation and the masonry and inner floor brings problems (Fig. 3a). In this place thermal bridges originate due to decrease of heat resistance of the structure, if this problem is not solved.

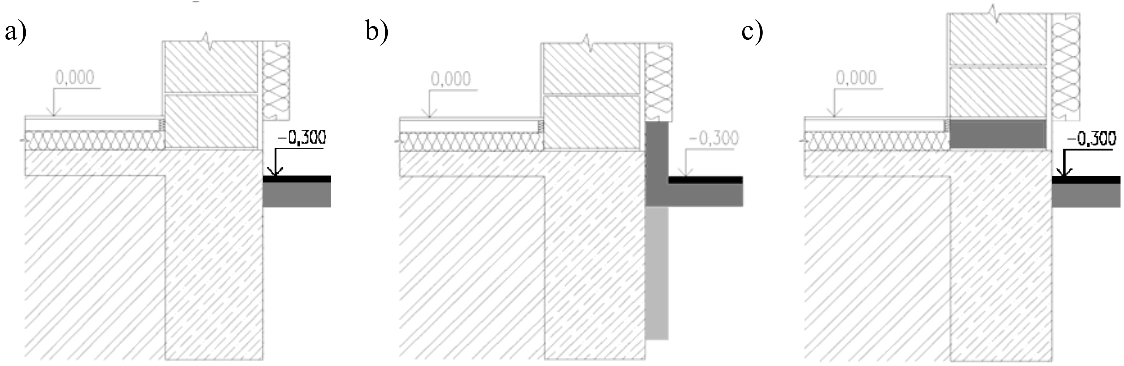

Fig. 3: Wall footing detail - interruption of thermal bridge, methods of solution.

Two methods can be used for elimination of thermal bridge – direct and indirect. Both of them interrupt the thermal flow. The indirect method of solution (see Fig. 3b) inserts a thermal insulation under adjusted terrain to the necessary depth or in case of impossibility to insert thermal insulation under the terrain it is possible to lay the thermal insulation horizontally on the terrain to the required distance from the walling (Fig. 3b). The direct method of solution (see Fig. 3c) inserts a thermal insulation directly to the place of thermal bridge. This solution solves directly and efficiently the described issues of the detail.

A new product for the direct solution is designed – an insulation block (Fig. 4) which can be made from recycled polymer such as recycled HDPE, PP or as a recycled polymer composite (Fig. 5). The design of the insulation block is carried out using FEA analysis by the help of ANSYS system depending on designed material. By mathematical modelling it is assessed in terms of statics and thermal mechanics. The FEA analysis is supplemented by experimental testing.

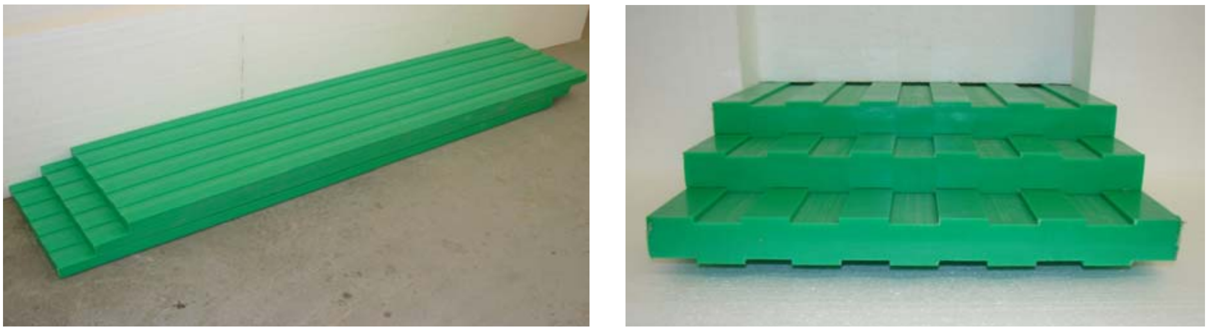

Fig. 4: Insulation block made from recycled HDPE.

Fig. 5: Recycled polymer composite.

3. Experimental testing

The simulation of a long-term state of stress and a verification of a long-term behaviour of the insulation block is done using a stressing frame (Fig. 6) is scale 1:1 i.e. testing in a real cut of masonry. The width of the insulation block boards is 440 mm, the height is 120 mm (3 × 40 mm) and length is 2000 mm. The insulation blocks and masonry is loaded by a contact pressure of intensity 1.2 MPa by means of controlled system of high pressure pneumatic bellows. Vertical and horizontal deformation of the insulation block caused by the load is measured continuously on long-term basis in selected sections using mechanical sensors measuring the track (Fig. 6).

Fig. 6: Stressing frame and detail of mechanical sensors.

The goal of the experimental testing is to ascertain the long term compression of the insulation block in order to enable verification of numerically calculated data with experimental data and to obtain creep curve by means of measuring in 1:1 scale. The experimental data is also used to compare general rheological models for viscoelastic materials (Maxwell model, Kelvin model, Maxwell-Kelvin model and Standard solid model) and for selection of the most appropriate rheological model for modelling of a long term behaviour of recycled polymers, here of recycled HDPE.

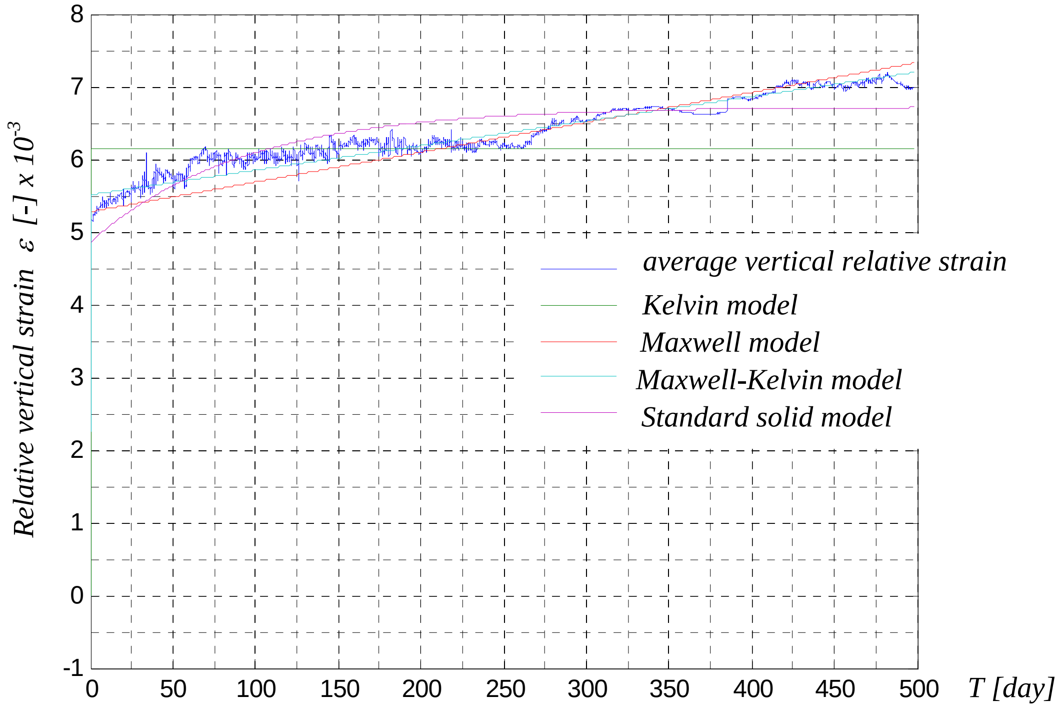

Fig. 7: Long time measuring.

Long time measurement is shown in graph in Fig. 7 where average vertical relative strain from all measuring sensors is drawn together with compensation of temperature influence (blue line) and results obtained using general rheological models for viscoelastic materials mentioned in Barbero (2008). The graph represents a time interval of 500 days. Using measured data the ratio of strain to applied stress, which is a compliance $D(t) = \varepsilon(t)/\sigma_0$, is found.

Maxwell model:

$$D(t) = 1/E_0 + 1/\tau E_0 \tag{1}$$

$$E_0 = 227.135;\ \tau = 1284.492$$

Kelvin model:

$$D(t) = 1/E_0[1\text{-}exp(t\text{-}\tau)] \tag{2}$$

$$E_0 = 194.533;\ \tau = 0.025$$

Maxwell-Kelvin model:

$$D(t) = 1/E_0 + 1/\tau_1 E_0 + (1/E_2)[1\text{-}exp(t\text{-}\tau_2)] \tag{3}$$

$$E_0 = 534.012;\ E_2 = 366.676;\ \tau_1 = 664.565;\ \tau_2 = 0.036$$

Standard solid model:

$$D(t) = 1/E_0 + (1/E_2)[1\text{-}exp(-t/\tau_2)] \tag{4}$$

$$E_0 = 247.215;\ E_2 = 639.075;\ \tau_2 = 92.166$$

4. Conclusions

Waste polymers in general may play an important role in selection of building materials in the future. Resistance against atmospheric ageing, fire resistance, and thermal-technical and mechanical properties can be improved.

The mentioned materials can be used for example for elimination of thermal bridges in wall footing detail in a form of an insulation block. Because of the nature of polymers it is necessary to test, verify and predict their long term behaviour. This can be achieved through experimental testing and modelling based on general rheological models for viscoelastic materials.

By comparing results for recycled HDPE insulation block (Fig. 7) for different rheological models for viscoelastic materials can be concluded that Maxwell-Kelvin rheological model represents the most accurate approximation of behaviour of the insulation block under long term constant pressure. The suitability of this model is confirmed by comparing the results of the evaluation criteria, which was the smallest sum of squares.

Acknowledgement

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