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Insulating Block for Elimination of Thermal Bridge

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Abstract

The increasing quantity of waste materials is associated with continuously increasing need for their recycling and reuse. An important subgroup of waste materials is polymers. Selected polymers with suitable thermal and mechanical properties can be used with advantage also in civil engineering. Application of recycled polymers suitably supports decreasing of energy exigency and thus the area of sustainable development. Current trend of energy savings in civil engineering is the proposal and construction of low-energy and passive houses. This new concept is associated with the arisen need to solve originated details both in terms of the design and material. One of the details that is described in the article and solved via the new product made of waste material is a wall footing detail.

Keywords

Waste, Polymers, FEA analysis, Insulation, Thermal bridge

1. Introduction

Using of waste and waste material is a frequent and actual topic, which corresponds to current trends associated with the decreasing of power exigency and sustainable development, i.e. development which satisfies the needs of the present without weakening of the possibilities of future generations to fulfil their own needs (Brundtland, 1991). Sustainability can also be perceived as long-term compatibility. Its basic pillars are environmental, economic and socio-cultural. From the environmental point of view it has three essential protective elements: protection of resources, ecosystems and human health. Solutions that respect only a part of the aspects can have very negative effect on others. This implies the necessity of the widest possible complex approach with regard to all the known influence.

Current capacity of natural resources is limited in the same way as the possibility to store wastes produced by human population. The tool to reduce usage of natural resources and decrease the produced waste consists in an efficient and possibly repeated use of resources - resource recycling. The advantage of recycling is the minimization of originating wastes as well as decrease of power consumption and CO_2 production, which corresponds to the goals of the global politics.

The area of civil engineering produces civil waste that represents an important share of company wastes. In the countries of the European Union there is approximately 700 to 800 kg of civil waste falling on one citizen annually (without excavated earth). The advantage of civil waste consists in its relatively easy recyclability. In some civil areas civil engineering represents an important replacement of primary raw materials. In spite of relatively good utilization the civil waste as the source of raw material has not found application yet in certain areas of civil engineering.

Civil engineering however is not the only producer of waste material. Each branch of the human activities is associated with production of waste of various volume and type. The biggest waste producer is the industry and power engineering producing fly ash, slag etc. This type of waste is for its good properties suitably usable in the civil engineering in production of concrete, concrete products, in brick production, dry stuff, brick walling, grouting and other special mixtures and putties, artificial aggregates and the like. Similarly it is possible to use steel industry slag, which is a considerably hard material with aggregate properties. It can be used in traffic construction industry and other affiliated areas. The industrial waste materials also include waste gravel, aggregates, sands, clays and other materials originating from extraction, which are usually used for backfilling and round filling (Ledererová *et al.*, 2008).

Also the human population is the producer of communal wastes. The statistics show that it can be up to 15% of all the waste production (OECD, 2002). The effort therefore should be to use this communal waste in various areas in civil engineering.

An important subgroup of communal waste is formed by polymers. According to the data of PlasticsEurope, BASF and K2004; approximately 221 mil tons of polymers and caoutchouc (of which 176 mil t. of materials) was manufactured in 2003 (Figure 1) including 19 mil. t. of caoutchouc for technical rubber and tyres. In 15 years the production of plastic materials in global scale doubled. In 2006 it reached the value of 245 million tons (Adámková, 2008) and it grows every year approximately by 5 to 8%. This high production of polymers is associated also the increased production of waste plastic. It is therefore a possible substantial source of material usable for other applications.

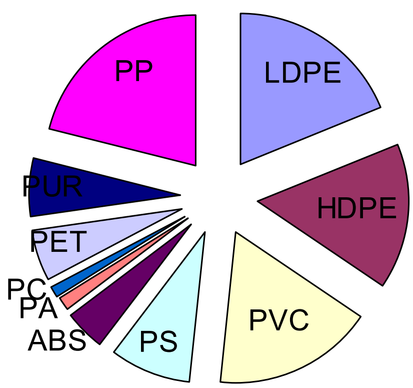

Figure 1: World Production of Polymers (Šinogl, 2008)

2. Polymers in Civil Engineering

Out of a huge quantity of waste polymers (PP, PE, PET, PVC, PUR etc.), which are produced by human population in the form of communal waste it is necessary to select such for the purposes of subsequent reuse (recycling) in civil engineering that have suitable properties for the target field. These properties include especially thermal and mechanical properties. The example of polymers meeting the above requirements is the waste polypropylene PP and waste polyethylene PE in low-density LDPE or high-density HDPE form (Šinogl, 2008). The above polymers represent more than 50% ratio of the total global production of plastics (Figure 1). This high production is associated with high production of wastes, which can be used as a source of material usable for other application.

The possibility of recycling of the above polymers (PP, PE), which belong to the thermoplastic materials, results from their basic property – thermal plasticity. This property guarantees softening of polymers under the influence of heat and their formability. Subsequent cooling and solidifying forms a new product with the same properties as the original material. Recycling can be done according to the technology used physical (direct), chemical (indirect) or energetic (oxidative).

Another advantage of using polymers after the possibility of processing consists in the possibility of improvement of their properties. With regard to the usability of polymers in the area of construction industry it is necessary to deal with the modification of resistance against atmospheric ageing, fire technical resistance, thermal and mechanical properties.

The resistance against atmospheric ageing can be ensured using antioxidants, ultraviolet radiation absorbers, extinguishers, soot or pigments. The adjustment of technical properties can be made using means and procedures for decreasing the combustibility, so-called combustion retarders. Modification of technical properties can be achieved by decreasing the weight using hollow filling material, soluble filling material, evaporation of evaporative filling material, sintering of full or porous granules or foaming. The change of mechanical properties can be done using methods of reticulations by organic peroxides (Šinogl, 2008).

When using polymers for supporting elements it is necessary to deal with the treatment of thermal, technical and mechanical properties. This combined treatment is significantly problematic, because there is an applied indirect proportion of thermal and mechanical properties, i.e. improvement of mechanical properties impairs the thermal properties and vice versa. For these reason composites of macro composites are often created, in which the polymers play a role of filling and the supporting function is assumed by other material.

3. Example Use of Recycled Polymers in Civil Engineering

One of current trends of energy savings in civil engineering is the proposal and construction of low-energy and passive houses. These are houses, in which it is possible to achieve substantial thermal comfort of environment in winter and in summer without any individual active heating or air-conditioning system. The difference between the low-energy and passive house is in the limit of heat consumption per year. In case of the low-energy house the top limit of heat consumption is 50 kWh/m^2 per year and in case of passive house the top limit is 15 kWh/m^2 per year.

This new concept is associated with the arisen need to solve originated details both in terms of the design and material. On the basis of analyses details of critical areas were outlined. These include mainly the details of circumferential casing, which negatively affect the entire thermal-technical function of the passive and low-energy function. The details that can constitute problematic places in designing and construction are especially the following: corner details, wall beams (ceiling link) details, opening fillup embedding detail, wall footing detail, detail of connection of inclined roof to perimeter walling, detail of anchorage of perimeter case and others (Šinogl, 2008).

4. Wall Footing Detail

Of the above details the collective of authors dealt with the issues of the wall footing detail. Especially the detail of footing of perimeter casing in contact with the foundation and composition of inner floor brings about substantial problems. In this place thermal bridges originate due to decrease of heat resistance of the structure, if this problem is not solved.

The effort is to eliminate this heat bridge, because every prevention of the origination of heat bridge contributes to heat savings. Apart from removal of the heat bridge, i.e. improvement of heat insulation properties, also other requirements are imposed on the above detail. They include decreased absorbability, mechanical resistance, steam tightness, shape stability, sanity and resistance against chemical and biological influence.

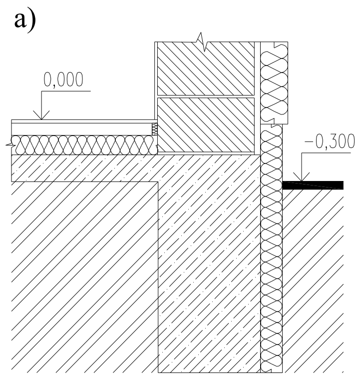

Figure 2: Wall Footing Detail - Interruption of Thermal Bridge, Methods of Solution

There are two methods of solution: Both derive from the principle of interruption of thermal flow. The first method of solution is to insert thermal insulation under adjusted terrain to the necessary depth, which improves the thermal behaviour of the wall footing (Figure 2a). This solution however does not solve the heat bridge in the wall footing directly, but by means of inserted thermal insulation it increases surface temperature at the place of contact of the walling and thermal insulation In case of impossibility to insert thermal insulation under the terrain it is possible in this case to lay the thermal insulation on the terrain to the required distance from the walling (Figure 2b). The second possible way of interruption of the thermal bridge in the wall footing is the interruption using inserted thermal insulation directly to the place of thermal bridge (Figure 2c). This solution solves directly and efficiently the described issues of the detail. The walling is based on insulating block, which transfers the weight of the object to the foundation and foundation base and concurrently forms a protective layer against the rising damp.

The disadvantage of both specified solutions of interruption of the thermal bridge in the wall footing consists in high price and in some cases problematic realization. Extruded polystyrene is used most frequently for the first method of solution and foam glass for the second one. Foam glass is a progressive material with excellent thermal technical properties, which however has very bad mechanical properties.

To remove the above disadvantages the specialists designed a product – *insulating block*, which actively interrupts the thermal bridge and meets requirements for proper functionality and stability for the entire service life. Thermal insulating block is made of *modified recycled polymer* in MPP, MHDPE version (M = modified).

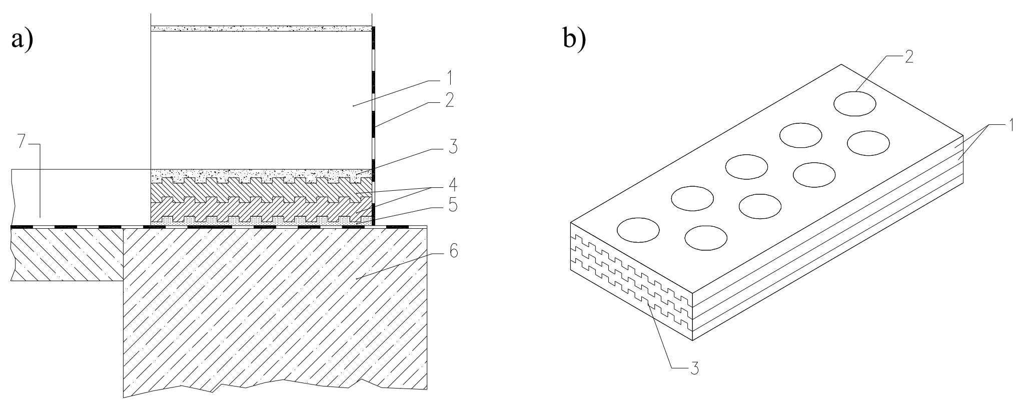

Figure 3: Insulating Block; 1 - Masonry, 2 - Water-proofing, 3 - Cement Mortar or Concrete, 4 - Insulating Block, 5 - Paste, 6 - Foundation, 7 - Floor

The product is formed by boards of constant thicknesses which are laid on one another and the necessary thickness is achieved by increasing the number of these boards (Figure 3). The boards are toothed and the individual toothings fit together and thus prevent mutual shift of the boards. The toothing in the contact with foundation is deposited in glue matter and thus they co-act. The detail is similar to contact of insulating block and cladding and toothing also serve for mutual interconnection of both structures. Total thickness results from the requirements for thickness of the entire thermal insulation in the floor composition. The width of thermal insulating block depends on the width of the cladding and can be arbitrarily adjusted on site. Boards for the entire thickness of the wall with modular dimensions are used for composition of claddings. In case of higher load to increase the static load bearing capacity the boards are equipped with openings that are filled with concrete (Figure 3b).

4.1 FEA Analyses of Insulating Block

The assessment of thermal insulating block was carried out using FEA analysis carried out by ANSYS system. In the mathematic modelling the insulating block is assessed in terms of statics and thermal mechanics.

4.1.1 Thermal technical assessment

In thermal technical assessment of insulating block with regard to internal surface temperature the wall composition suiting the requirements for passive and low-energy houses was considered. The same composition was considered also in modelling of optional arrangement (without interruption of the heat bridge V1, interruption of heat bridge using attached insulation V2 and interruption of thermal bridge with foam glass V3), which was carried out to compare the utilized and proposed solution (V4).

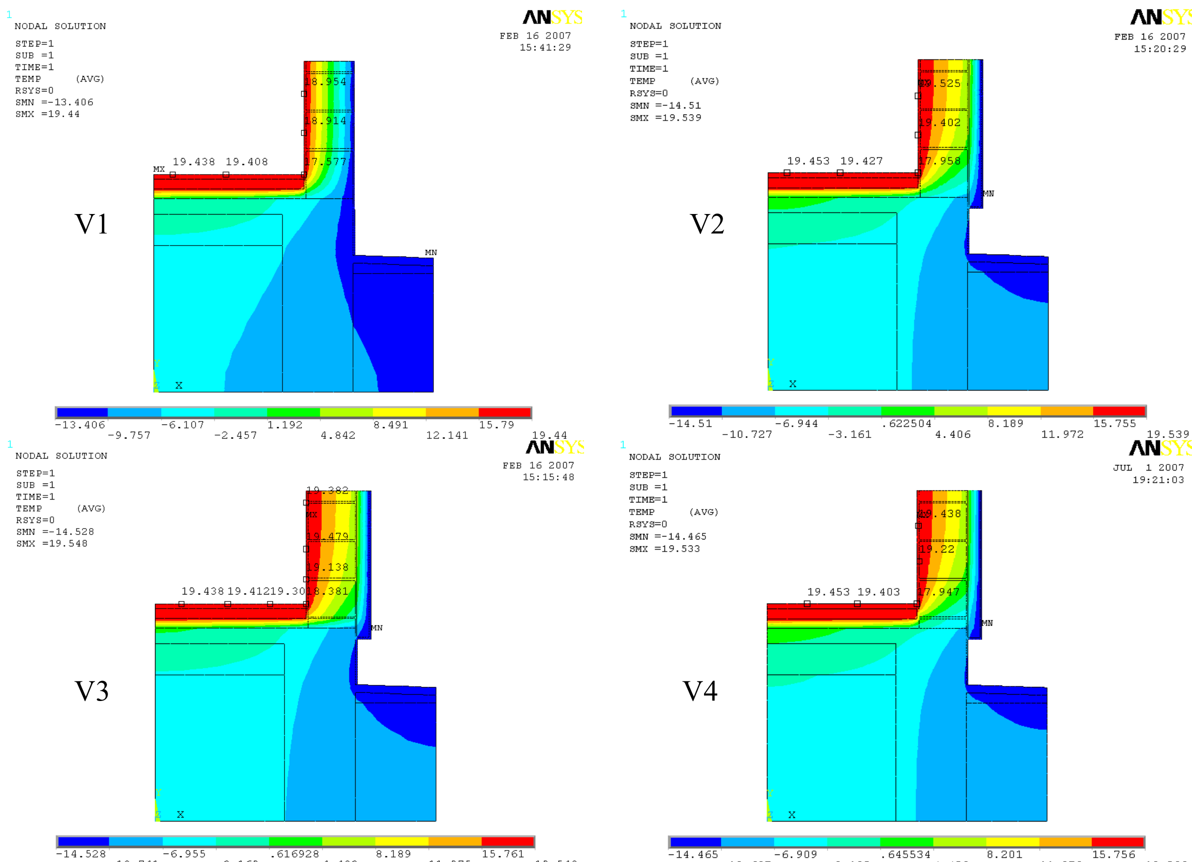

Figure 4: FEA Results - Distribution of Thermal Field for Solution V1 to V4

The wall is designed as airtight, with the thermal transmission coefficient corresponding to the objects, for which this product will be used. Boundary conditions are the following: interior (surface temperature 20°C, humidity 50%, bulk coefficient 23 $Wm^{-2}K^{-1}$) and exterior (-15°C, 84%, 8 $Wm^{-2}K^{-1}$).

The results in the Table 1 and Figure 4 imply that by interrupting the heat bridge with insulating block made of modified polymer (V4) the same surface temperature is achieved as in case of use of the option with foam glass (V3). The best option from the comparison is the option with thermal insulation (V2), which however in some cases can not be used.

Table 1: Minimal Surface Temperature

Optional arrangement	Temperature [°C]
V1	17.577
V2	18.381
V3	17.958
V4	17.947

Apart from the thermal technical assessment focused on the assessment of surface temperature in the interior studies to discover the influence of the placement of openings fill by concrete in the insulating blocks for increasing the static load bearing capacity on distribution of the thermal field. The study consisted in modification of the size of opening, number of rows and method of their location (Figure 5). By evaluation of the results it was discovered that sizes of the openings, numbers of rows and their positioning do not have strong influence on the distribution of temperature field. In comparison of surface temperatures differences ranging up to 1.5% were discovered.

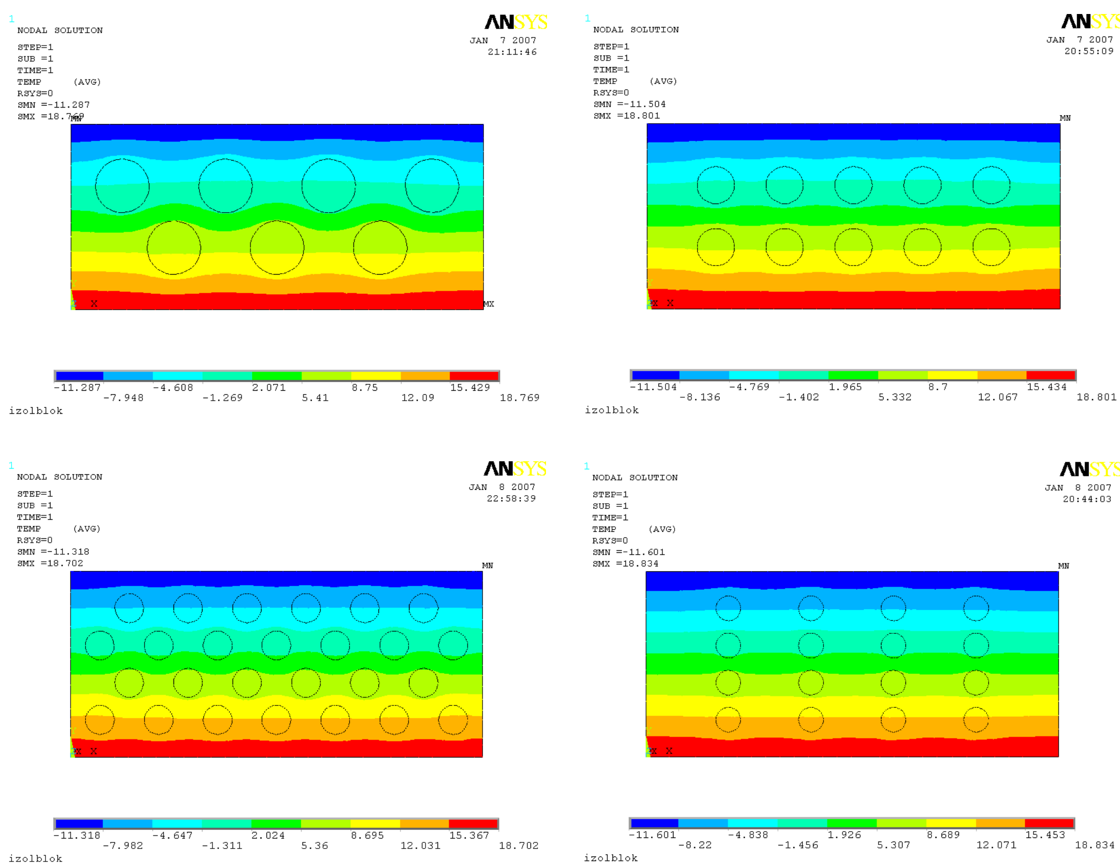

Figure 5: FEA Results-Distribution of Thermal Field for Different Size and Placement of Openings

4.1.2 Static assessment

Static assessment of the insulating block considered it primary use for passive and low-energy family houses. The load in these houses in the wall footing ranges depending on the type of utilized structure approximately from 23,0 kN/m in single-storey houses of bungalow type up to 90,0 kN/m for two-storey houses with habitable attic. Higher value of load including possible eccentricity of the acting load was considered for the purpose of assessment.

The behaviour of polymers is time-dependent and is also influenced by the way of their straining. As the insulating block must fulfil the function for its entire service life, it was necessary to consider material values decreased by the creep influence. These values were defined on the basis of experimental measurements on the device developed by the authors.

The assessment of behaviour and possibilities of use was carried out using 2D parametric calculation model of insulating block formed by final number of the boards of arbitrary thickness and parts of the wall with foundation (Figure 6). Non-fixed connection of the parts was modelled using standard contacts.

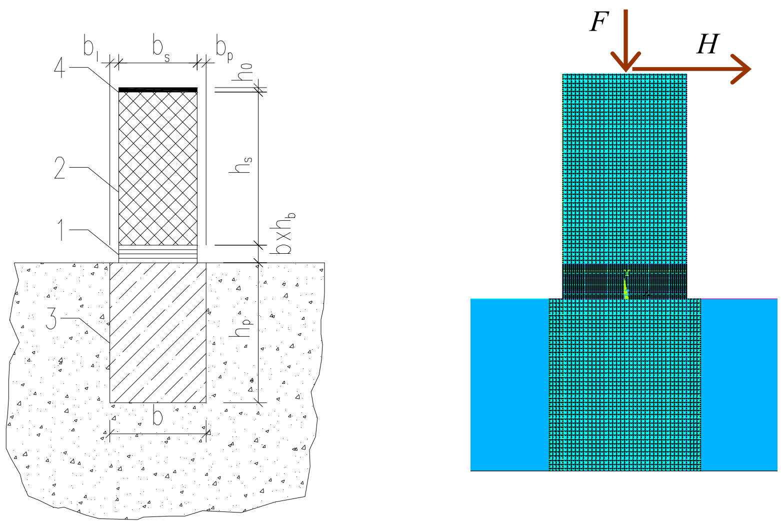

Figure 6: FEA 2D Parametric Model, Results of Stress Field

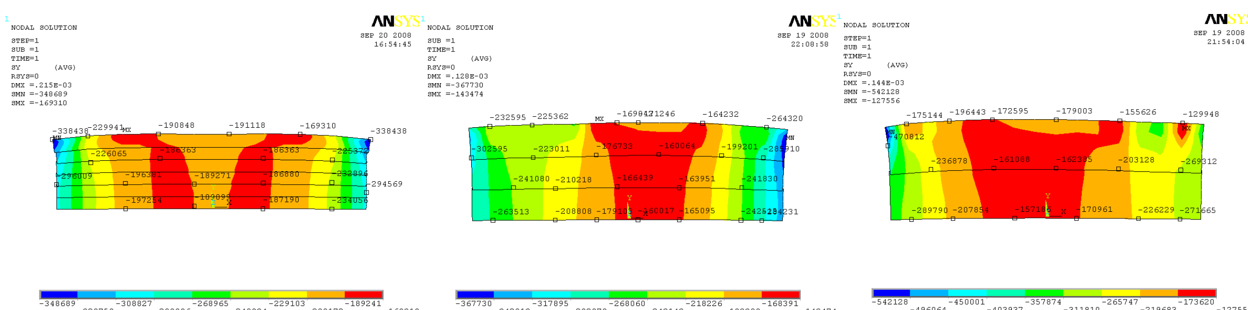

Figure 7: FEA Results of Vertical Normal Stress Field SY [Pa] for 6, 3 and 2 Layers (Height is 120 mm)

After the evaluation of the results of analyses it was discovered that in terms of the distribution of tension on the insulating block the more massive profiles and their lower number is more suitable (Figure 7). Economically the most advantageous and concurrently the best resisting the imposed load are the insulating blocks of boards with a thickness of 20, 25 mm. The stresses that originate in the insulating blocks differ significantly; they range from 167 kPa to 944 kPa. With the above load the vertical deformations of the insulating block were reaching to 0.3 mm.

4.2 Price Comparison of the Optional Arrangement

The FEA analysis discovered that designed insulating block made of modified recycle polymer can be used for solving the detail in wall footing. The analyzed options were also compared in terms of price (Table 2). The price comparison implies that the insulating block can compete with concurrently used products intended for interruption of the heat bridge.

Table 2: Price Comparison for Arrangement V2, V3 and V4 (Figure 4)

Optional arrangement	Insulator	Thermal conductivity of insulator [$Wm^{-1}K^{-1}$]	Price [EUR/m´]
V2	Polystyren (Perimetr)	0.033	12.92
V3	Foam glass (Perinsul)	0.049	85.62
V4	Insulating block (modified recycle polymer)	0.390	17.31

5. Concluding Remarks

The use of wastes and waste material is the most frequent and actual topic, which corresponds to current trends associated with decreasing of energetic demandingness and sustainable development. An important subgroup of communal waste is formed by polymers. It is a material that can be easily recycled and therefore returned for reuse in the form of other products in various areas, for example in civil engineering. In civil engineering for example it is possible to use modified polymer in polypropylene or polyethylene form. One of the products that can be made from this material for the purposes of civil practice is the presented insulating block. The performed mathematic modelling proved the ability of the above component to act reliably in the structure and for the purpose, for which it was proposed.

6. Acknowledgements

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7. References

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