

PAPER • OPEN ACCESS

## The issue of plastic waste in the environment and its possible uses as a substitute for filler in lightweight concrete

To cite this article: M Ledererová *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **549** 012032

View the [article online](#) for updates and enhancements.



**IOP | ebooks™**

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the **collection** - download the first chapter of every title for free.

# The issue of plastic waste in the environment and its possible uses as a substitute for filler in lightweight concrete

M Ledererová<sup>1</sup>, Z Štefunková<sup>1</sup>, V Gregorová<sup>1</sup>, D.Urbán<sup>1</sup>

<sup>1</sup> Slovak University of Technology, Faculty of Civil Engineering, Radlinského 11, 810 05 Bratislava, Department of Material Engineering, Slovakia

E-mail: miriam.ledererova@stuba.sk

**Abstract.** The specific nature of plastics causes specific problems in waste management. Plastics are relatively inexpensive and versatile with the potential for versatile use in industry, which has led to their rapid development over the past century, which still persists. The aim is to look for the possibility of reusing plastic waste as one of the lightweight filler fillers. It used plastic recycled material recycled from EVA plastic packaging and polystyrene recycled material in various proportions. All are among the medium-recyclable plastics according to their recycling rate. The experimental part of the work is devoted to the verification of the effect of the filler dose on the monitored physical and sound absorption parameters.

## 1. Introduction

Plastics are materials whose essence consists of macromolecular organic compounds, which are produced by organic synthetic reaction or made from natural materials as oil, coal and natural gas. Dating of the plastics industry starts as early as 1907 and can now be found in almost every industry, with worldwide annual production of around 245 million tonnes. The main raw material of plastics is oil, which is a non-renewable resource.

The basic characteristics of plastics include durability, low volume density as well as low production costs, which can be characterized as excellent material for use and application in everyday life as well as in construction practice. However, the greatest negative result of this material is its extremely problematic waste. In addition to the above mentioned statistical annual production of plastics, it is also necessary to mention the amount of 25 million tonnes of annually produced plastic waste in the EU. Of these, 38% are landfilled, 36% are recovered and only 26% are recycled [1,2].

In the environment it can last for hundreds of years, annually 10 million tons of plastic waste ends up in the seas and oceans. Despite the technological difficulty of separation and recycling, it should be our duty to make greater use of this waste, to explore the possibilities for reuse, but above all to perceive it as a feedstock. Plastic waste is generally a major environmental problem, using up to 94% of raw materials, oil and energy can contribute to the use of secondary raw materials.

One way to use plastic recycled material is to incorporate it into lightweight concrete or directly produce lightweight concrete based on polyurethane binders. By choosing suitable filler combinations (expanded polystyrene, expanded polypropylene, recycled cable, recycled electrical cable, etc.) and binder, it is possible to use such building material not only for new construction, but also for the reconstruction and rehabilitation of existing buildings [1,2,3].



## 2. Materials and methods

For experimental testing in research of the recycled waste polystyrene (PS) (C1, L1) and ethylenevinyl acetate (EVA) (C3, L3), was used as shown in figure1. Materials and components of mixtures were mixed in following proportions: fillers 100% EVA (C1), binder Conipur 360, fillers 100% EVA (L1), binder Conipur 360, fillers 50 % PP + 50% EVA (C2) binder Cement 360, fillers 50 % PP + 50% EVA (L2) binder Conipur 360, fillers 100 % PS (C3) binder Cement, 100 % PS (L3) binder Conipur 360.



**Figure 1.** Waste plastic Group Size:

a) ethylene-vinyl acetate 4/8 mm      b) polystyrene - 4/8 mm

Ethylene-vinyl acetate (EVA) is the elastomeric polymer with high elasticity [3]. The recycled material of the polystyrene (PS) has good thermal insulation properties, low volume density and good workability [4].

The PS and EVA were crushed and the fraction 4/8 mm was screened wherein the bulk density of PS 14,27 kg/m<sup>3</sup>, EVA 112,45 kg/m<sup>3</sup>. LC were produced with the use of a filler, or as a combination of two materials according to the percentage share: 100%, 50:50 % (table 1 and table 2).

As a binder was used cement (table 1). The binder dose in all mixtures was also a constant of 0.7 kg per one mixture. The water coefficient was constant at 0.5 for all mixtures.

As a binder was used undiluted one-component polyurethane adhesive Conipur 360 (table 2). This adhesive is used in the implementation of the polyurethane surfaces. It has a firming effect; it is resistant to abrasion and very easily workable. Dose of glue in all mixtures was also a constant of 0.4 l per one mixture. Considering different surface and material – water content was moistened to 2%, which regulates the surface tension.

**Table 1.** Composition of the individual mixtures with binder cement.

| Test sample | Binder (kg) |     | Graining (l) |           |
|-------------|-------------|-----|--------------|-----------|
|             | Cement      | EVA | PS           | (l) Water |
| <b>C1</b>   | 0.7         | 4   | 0            | 0.35      |
| <b>C2</b>   | 0.7         | 2   | 2            | 0.35      |
| <b>C3</b>   | 0.7         | 0   | 4            | 0.35      |

**Table 2.** Composition of the individual mixtures with binder polyurethane adhesive.

| Test samples | Binder (l)  |     | Graining (l) |  |
|--------------|-------------|-----|--------------|--|
|              | Conipur 360 | EVA | PS           |  |
| <b>L1</b>    | 0.3         | 4   | 0            |  |
| <b>L2</b>    | 0.3         | 2   | 2            |  |
| <b>L3</b>    | 0.3         | 0   | 4            |  |

Samples in the shape of 100×100×100 mm were made from homogeneous mixtures. These samples were treated 48 hours in the laboratory environment. Subsequently, they were removed from the mold

and stored in laboratory environment for adhesive (20 ° C, humidity = 50%) and cement (20 ° C, humidity = 90%) for the binder. Subsequently, the physical properties (bulk density, heat –technical parameter and thermal conductivity) were measured. Samples for sound absorption tests were 100mm and 35mm in diameter, 60mm high. The sound absorption was tested on the EVA sample, the recycled polystyrene and a 50:50% EVA/PS, Conipur 360 binder combination. Measurements of bulk density and heat as technical parameters were carried out in the laboratory conditions of the STU.



**Figure 2.** Samples with binder cement.



**Figure 3.** Samples with binder polyurethane glue.



a) EVA diameter 10/3.5 cm



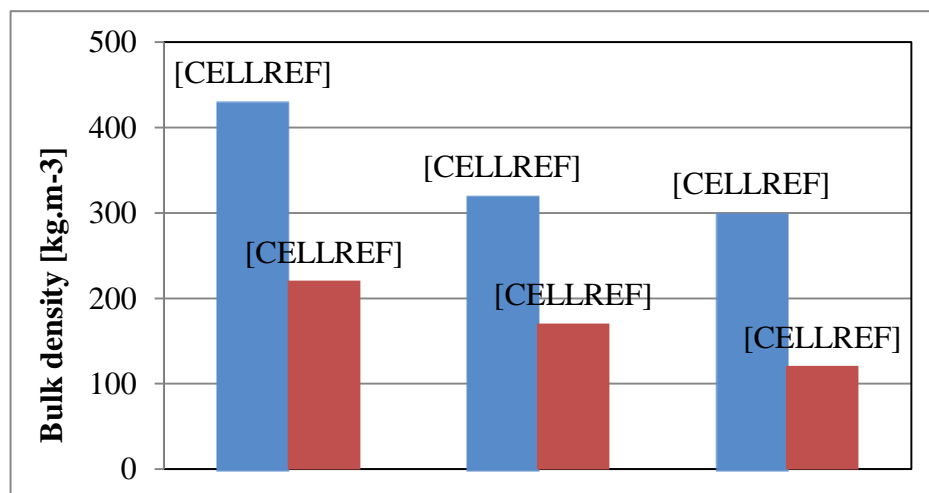
b) PS diameter 10/3.5 cm



**Figure 4.** The reference sample (cylinders with diameter 10 cm /3.5 cm and length 6.5 cm).

### 3. Results

Physical and thermophysical properties are shown in (Figure 5,6,7). While the bulk density of the polyurethane glue samples (L1-L3) ranged from 220 to 120 kg.m<sup>-3</sup>, the bulk density of the samples (C1-C3) increased, by changing the binder used, up to 430 kg.m<sup>-3</sup> (Figure 5). By changing the binder and filler (L1 - L3), the thermal conductivity coefficient of the test samples decreased (Figure 6) and conversely, when using a cement binder and changing the filler, the coefficient of thermal conductivity of the test samples increased (C1-C3) (Figure 7).



**Figure 5.** Comparison of the bulk density of mixtures.

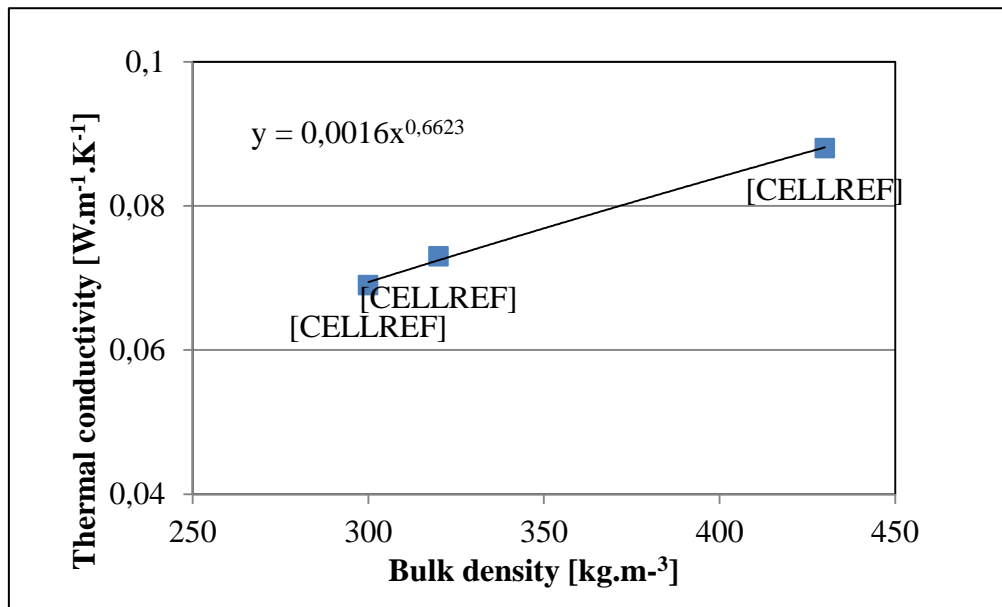


Figure 6. Relationship between thermal conductivity and bulk density of mixtures – cement binder.

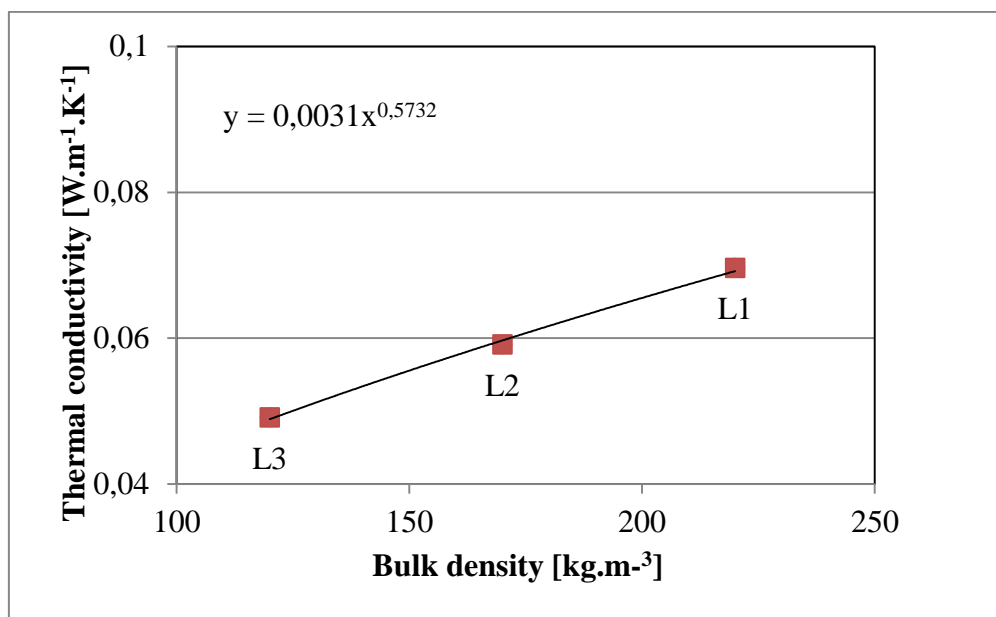


Figure 7. Relationship between thermal conductivity and bulk density of mixtures – binder polyurethane glue.

#### 4. Sound absorption

Knowledge of the sound absorption of building materials, opens up the possibility of their applications also in terms of dampening the sound as in the interior (generally in diffusion audio field), as well as in the outdoors (free sound field) [5,6]. The experiment was aimed at measuring of sound absorption determination. For this purpose, modified measurement set of impedance tube was prepared, process for preparation of this measurement EVA and PS samples were prepared. There have been large differences in the results of two different measurements methods.

For the verification of sound absorption were used samples on the base of ethyl-vinyl acetate (EVA) and polystyrene (PS), in combination with the binder Conipur 360 (polyurethane glue). The

aim was to set up a measurement assembly, to perform a reference measurement of a stable measurement protocol. The samples were EVA and PS. They were 6.5 cm thick. Diameter of cylinder of the sample was 3.5 cm and 10.0 cm. The measurement and the used measuring assembly operates on the principle described in the standard ISO 10534-1, ISO 10534-2 [7,8].



**Figure 8.** The measurement of the reference sample EVA  
a) impedance tube STUBA                      b) impedance tube KU Lueven.

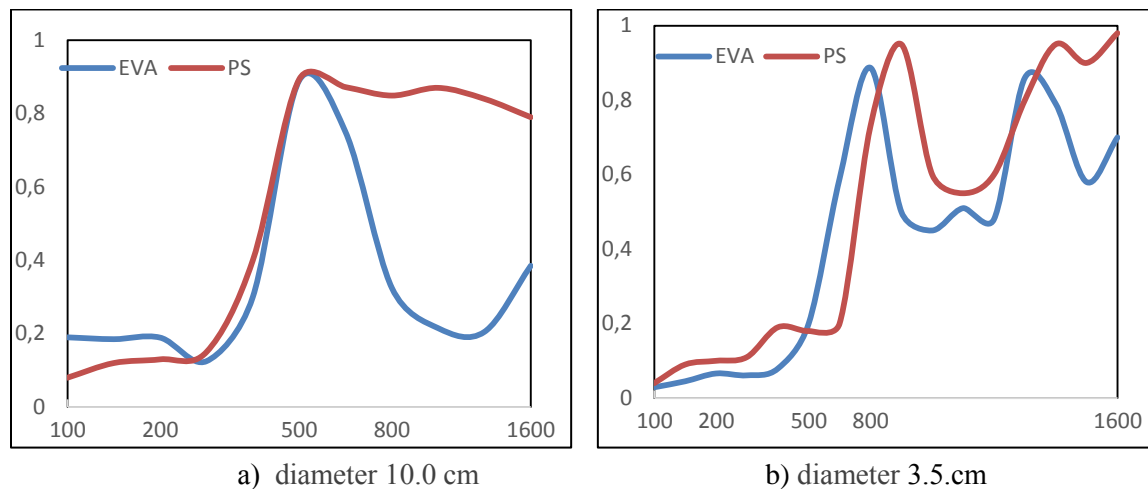
### 5. Description of sound absorption measurement

As was mentioned above for the comparative test was used measurement technique explained in standard ISO 10534 [9]. The big advantage of the impedance tube measurement techniques (also so called the fast measurement techniques) in general is the fact, for sound absorption properties determination just relatively small size measurement sample is needed (the size of specimen can be smaller than wavelength of the sound waves in frequency spectrum of interest). Therefore, impedance tube measurement methods are often used for absorption material development. However, the objective parameter, sound absorption coefficient, is determined just for perpendicular incidence of acoustic plane wave.

The measurement principle by means of impedance tube and standing wave method based on sound pressure level measurement inside of the tube is based on seeking for nodes, or superposition, of standing wave in tube (maximal, and minimal value of pressure in impedance tube, also so – called the Kundt's tube). The standing waves are generated by acoustic plane wave source (loudspeaker) mounted on the one end of the tube, on the other side of the tube is mounted the specimen under investigation [10]. This measurement technique is used in practice since 40ties of 20<sup>th</sup> century. Measurement performed can be divided to two laboratories, the comparative test between 2 labs STUBA (STU CI Bratislava, Slovakia), KU Lueven (The Katholieke Universiteit Leuven, Belgium). Measurement were performed in frequency range from 100- 1800Hz. The excitation signal was time stationary sine signal tuned in of 1/3<sup>rd</sup> frequency generated by external sine generator.

The results achieved by interlaboratory tests of sound absorption measurement were compared. Three EVA and PS based composite materials were distributed between two laboratories. In both cases, the excitation measurement signal was sine signal generated by sine tone generator, the tone was gradually tuned 1/3<sup>rd</sup> octave step. The average values of sound absorption coefficient spectra in frequency range from 100 to 1800Hz are compared in Figure 9. one can see the similar trend of absorption spectra shape. Measurement from both laboratories verified the significant sound absorption in spectrum from 400 to 700Hz. However, there is deviation in results in low and high frequency range. The deviation is usually caused by background noise, tightness of specimen mounting in the device but also by used filter. It is not unusual to have deviation in low frequency spectra. Difference in interlaboratory results comparison was up to  $\Delta\alpha = 0.2$ .





**Figure 9.** The interlaboratory results comparison of sound absorption (average results for EVA/PS cylinders with length 6.5 cm in range 100 Hz to 1600 Hz).

## 6. Conclusion

Based on the results obtained, we can conclude that samples of lightweight plastic-based concrete have favourable properties with different fillers. The best heat transfer properties were achieved with samples equipped with 100% polystyrene (P3, L3), which also had the lowest bulk density depending on the type of binder. Its density was increased by the addition of EVA, which also increased the conductivity of lightweight concrete. Most of the differences in sound absorption were in the combination of EVA and polystyrene and 100% EVA.

From the results comparison of sound absorption is clear, that the differences occurred between laboratories measurements. Generally, most sensitive are low frequencies. There was also shown, if the same measurement device and specimen is used, and the same data are processed in the different ways, the results can differ. The measurement presented here were performed on samples with same of size diameter 10 cm and 3.5 cm, but their material properties were not comparable.

For unambiguous conclusions, it would be necessary to perform a larger number of measurements on the samples in order to say more clearly which method is more accurate and comparable with the measurement in the reverberation chamber [10].

The right choice of recycled plastic waste, in combination with particular binder, can have significant influence in decreasing the bulk density as well as improving thermal conductivity. Results of measurements of sound absorption suggest that this material mixtures can be used in floor insulation, noise walls (barriers) and other components where sound absorption is crucially important.

## Acknowledgements

This article was created with the support of the Ministry of Education, Science, Research and Sport of the Slovak Republic within the Research and Development Operational Program for the project "University Science Park of STU Bratislava", ITMS 26240220084, co-funded by the European Regional Development Fund and by the Slovak Research and Development Agency under the contractNo. APVV-15-0681.

## References

- [1] Kuraš M, Dimera V, Slivka V and Březina M 2008 *Odpadové hospodářství Vodní zdroje spol.s.r.o (Chrudim)* p 143
- [2] Gregorova V 2015 *Proc. Int. Conf. on for PH.D Students and Yong Researchers (Vilnius)* pp 2484–2489
- [3] Chandra S and Berntsson L 2002 *Lightweight aggregate concrete Science Technology and Applications Noyes Publications* p 450

- [4] Sicakova A and Sad J 2009 Build. Mater. **5** 36-40
- [5] Beranek L L, Tichý J, Břeský M, Kaplan J and Wanke J 1965 *Snižování hluku (Praha)*
- [6] Hopkins C 2012 *Sound insulation. Routledge (London)* p 648
- [7] ISO 10534-1:1996 *Determination of sound absorption coefficient and impedance in impedance tubes - Part 1: Method using standing wave ratio*
- [8] ISO 10534-2:1998 *Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Part 2: Transfer-function method*
- [9] ISO 354:2003 *Acoustics – Determination of sound absorption in a reverberation room*
- [10] Vigran T E 2008 *Building Acoustics CRC Press* p 364