The influence of binder dilution on the properties of lightweight composites

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Abstract. In the experiment was monitored the influence of thermal-technical properties by binder amount. As binder was used organic based glue 4,4´MDI (Conipur 360). At the same time was verified possible dilution of binder with water. The binder was diluted in amounts of 5, 10, 15, 20, 25 and 30%. However, in the case of 25 and 30% has not been achieved complete dilution. Recycled plastic EVA (ethyl vinyl acetate) was used as filler.

1. Introduction
The biggest global problem in last years is recycling of produced waste. Slovak republic produced in 2015 more than 10 million tons of waste [1]. Paper, clothes, glass, various metal and tires are recycled every day. Plastics also belongs to recycles, which constitute 1/3 from global waste production [1-3]. Plastics are used in all parts of an industry. It is due to their low weight, long life and nontoxicity [4]. Recycling process of plastics is pretty simple because of their workability. But what to do then with recycles? One solution is to use it in civil engineering. Plastic recycles are used as filler of lightweight concrete (e.g. polystyrene concrete). Potential usefulness of plastics as filler of lightweight concrete is explained in next paragraphs.

2. Materials
As filler was used recycled EVA plastic (figure 1.). Plastic was used firstly as the part of sneakers to absorb walking impacts. Plastic was processed to fraction 4/8 after use. Advantage of this plastic is sunlight resistance, aging and water resistance, nontoxicity [4]. It is used also to produce child toys, bags or bottles. In the experiment will be demonstrated good thermal-technical properties of lightweight concrete with EVA plastic used as filler.
Figure 1. Eva plastic.

As binder was used organic based adhesive – 4,4’MDI (methylene – diphenyl – diisocyanate) with the business name Conipur 360 (figure 2.). 4,4’MDI is mostly produced diisocyanate of the industry. In 2016 was made more than 6 million tons of it [5]. It is the main component of polyurethane. 4,4’MDI has good thermal insulation properties. Compared to other organic cyanates, MDI has a relatively low human toxicity, but it is an allergen and sensitizer. Handling MDI requires strict engineering controls and personal protective equipment [6].

In the experiment was monitored the effect of binder dilution with water to selected sample properties – bulk density, thermal conductivity coefficient and tension at defined deformation.

Figure 2. Organic based adhesive 4,4’MDI.

3. Samples preparation
Mixtures components were portioned by the volume. Ideal amount of components were defined in previous experiment as 0,4L of binder and 8L of filler [7]. All of made mixtures were filled to forms 100x100x100mm. There were made 7 different mixtures (table 1.) with constant amount of filler. From every mixture were made 6 samples. Binder amount was changed because of binder dilution with water in ratio 5, 10, 15, 20, 25 and 30% of the binder amount. In 30% water dilution was not achieved homogenous solution (approximately 1/20 of water was not diluted with the binder). One
mixture was made without water dilution (reference mixture – Z1). Samples were removed from the mold after 24 hours and stored in humid environment (humidity is more than 90%).

**Table 1.** Mixture proportions.

| Mixture | Filler [L] | Binder [L] | Water amount | Dilution [%] |
|---------|-----------|------------|--------------|--------------|
| Z1      | 4,00      | 0,20       | 0,00         | 0            |
| Z2      | 4,00      | 0,19       | 0,01         | 5            |
| Z3      | 4,00      | 0,18       | 0,02         | 10           |
| Z4      | 4,00      | 0,17       | 0,03         | 15           |
| Z5      | 4,00      | 0,16       | 0,04         | 20           |
| Z6      | 4,00      | 0,15       | 0,05         | 25           |
| Z7      | 4,00      | 0,14       | 0,06         | 30           |

4. Test methods

4.1. Bulk density

Bulk density was classified as ratio between weight and volume of made samples. Weight was measured by scales accuracy of 0,01g.

4.2. Thermal-technical properties

Thermal-technical properties were monitored by ISOMET 2114 with surface prob. For this experiment was evaluated only thermal conductivity coefficient. However, appliance is capable to monitor thermal temperature coefficient and specific volumetric capacity.

4.3. Tension at defined deformation

The compressive strength was specified as tension at defined deformation, because in lightweight concrete based on foam plastics does not happen fragile fracture. The measurement was performed at samples 100x100x100mm in the hydraulic press. Monitored deformations were defined as 2,5, 5, 7,5 and 10% in previous research.

5. Results

5.1. Bulk density

Measured values of bulk density are shown in table 2.

**Table 2.** Measured values of bulk density.

| Mixture | Dilution [%] | Dimensions [mm] | Mass [g] | Bulk density [kg/m³] |
|---------|--------------|-----------------|----------|----------------------|
|         |              | a₁   a₂  h       |          |                      |
| Z1      | 0            | 98,95 99,81 100,70 | 211,68   | 210                  |
| Z2      | 5            | 99,38 99,67 101,16 | 211,04   | 210                  |
| Z3      | 10           | 99,46 98,65 95,93  | 204,19   | 220                  |
| Z4      | 15           | 99,06 99,38 101,51 | 196,51   | 200                  |
| Z5      | 20           | 99,97 101,44 101,23 | 207,01   | 200                  |
| Z6      | 25           | 99,78 99,49 100,70 | 201,56   | 200                  |
| Z7      | 30           | 99,28 99,81 100,88 | 200,52   | 200                  |
5.2. Thermal-technical properties

Measured values of thermal conductivity coefficient are shown in table 3.

Table 3. Measured values of thermal conductivity coefficient.

| Mixture | Mass [g]  | Dilution [%] | Thermal conductivity coefficient [W/m.K] |
|---------|-----------|--------------|------------------------------------------|
| Z1      | 211,68    | 0            | 0,0706                                   |
| Z2      | 211,04    | 5            | 0,0691                                   |
| Z3      | 204,19    | 10           | 0,0700                                   |
| Z4      | 196,51    | 15           | 0,0691                                   |
| Z5      | 207,01    | 20           | 0,0689                                   |
| Z6      | 201,56    | 25           | 0,0675                                   |
| Z7      | 200,52    | 30           | 0,0690                                   |

5.3. Tension at defined deformation

Measured values of tension at defined deformation are shown in table 4.

Table 4. Measured values of tension at defined deformation.

| Mixture | Dilution [%] | Tension at defined deformation [MPa] |
|---------|--------------|-------------------------------------|
|         |              | Deformation [%]                     |
|         |              | 2,5 | 5 | 7,5 | 10 |
| Z1      | 0            | 2,22 | 2,40 | 2,54 | 2,64 |
| Z2      | 5            | 2,22 | 2,40 | 2,51 | 2,60 |
| Z3      | 10           | 2,15 | 2,36 | 2,49 | 2,59 |
| Z4      | 15           | 2,14 | 2,27 | 2,37 | 2,46 |
| Z5      | 20           | 2,17 | 2,29 | 2,40 | 2,49 |
| Z6      | 25           | 2,14 | 2,27 | 2,35 | 2,46 |
| Z7      | 30           | 2,14 | 2,28 | 2,39 | 2,46 |

6. Conclusion

Binder was not completely diluted in 30% dilution. It was not possible to make a homogenous solution (approximately 1/20 of water was not diluted with the binder). With the decreasing amount of binder, the bulk density of samples was decreasing. Values of bulk density were measured between 200 – 220 kg/m$^3$. The highest bulk density (220 kg/m$^3$) was measured on samples with 10% water dilution. With the decreasing amount of binder, the thermal conductivity coefficient was decreasing. The lowest value (0,0675 W/m.K) reached the mixture with 25% dilution of binder. Amount reduction of binder caused reduction of tension at defined deformation. The lowest values had sample with 25% water dilution, but values were very similar. Therefore the water dilution has no effect on tension at defined deformation. After these measurements is possible to state, that the replacement of binder seems like potential.

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References
[1] Schabjuk T 2018 Did you know how much waste we produced in 2015? (in Czech)
[2] Rousekova I 1985 Plastic Materials (Bratislava: SVST in Bratislava) p 236
[3] Waste separation http://www.triedenieodpadu.sk/plasty.php (online) (in Slovak)
[4] Kovacic L and Bina J 1974 Plastics, Properties, Production, Use (Bratislava: Alfa) p 339
[5] International Agency for Research on Cancer 1999 IARC Monographs on the Evaluation of Carcinogenic Risks to Humans 71 1049-1058
[6] Almaguer D 2006 National Institute for Occupational Safety and Health 42
[7] Dragomirova J 2017 Utilization of recycled EVA plastic for the production of heat insulating polymer concrete (Bratislava: Slovak University of Technology in Bratislava) Diploma thesis