**Increasing Building Material Efficiency. Mechanical characteristics of polymer concrete with different wastes**

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Abstract

The article analyses the influence of wastes as component of polymer concrete on the mechanical properties. Five types of wastes were used for preparing epoxy resin concrete: fly ash, sun flower, corn, saw dust, polystyrene granules and chopped plastic bottles. Fly ash was used as filler in all mixes. The other wastes were used as aggregate substitution with a percentage of 25% of the weight.

The mechanical properties such as: compressive strength, flexural strength and split tensile strength were experimentally determined and compared with a control mix prepared with epoxy resin and aggregates. Generally the values of compressive strength were smaller than that of the control mix. The flexural strengths presented higher values than the control mix for all types of wastes. The split strength presented higher values than control mix only for concrete with saw dust. The minimum values of mechanical strengths were obtained for concrete with corn cob as aggregate substitution. The density of polymer concrete with wastes generally corresponded to lightweight concrete.

1. **Introduction**

In the entire world the construction industry is rapidly developing and an important objective for the future is that of using sustainable materials and buildings. Wastes, a huge problem for the environment, are of great interest in the manufacture of green construction materials [1-4]. Fly ash, silica fume, ground granulated blast furnace, used tire, plastic bottles, wastes of glass, polystyrene, wood, agro-wastes, sludge, etc. are studied as components of concretes and mortar for ecological reasons but also for improving its properties [5-14]. The use of wastes for obtaining high performance concrete is accepted as usual practice in preparing concrete, but wastes are also used in obtaining geopolymers and polymer concrete. In geopolymers composition wastes such as fly ash, slag, etc. are used for replacing the cement [15]. Polymer concrete has in its composition a resin and aggregates. Wastes can be used as filler or to replace the resin or aggregates [16,17].

The article presents the results of experimental studies on polymer concrete prepared with different types of waste as aggregate substitution. Physical-mechanical characteristics were determined for characterizing these types of polymer concrete and analyzing the effects of different wastes on the mechanical properties of polymer concrete.

1. **Experimental program**
   1. Materials.

In the experimental study a control composition prepared of epoxy resin and two sorts of aggregates was used. The epoxy resin was type ROPOXID, made in Romania by POLICOLOR Bucharest. The resin was used in the same dosage (12.4% from the mix weight) for all types of polymer concrete. The hardener was type ROMANID 407, also made by POLICOLOR Bucharest. The river aggregates were used in two sorts: 0-4 mm (sand) and 4-8 mm (gravel), with continuous granulometry according to Romanian standard [18]. In the control mix both aggregates had a dosage of 43.8% from the mix weight. The control mix was noted **C0.**

The wastes were used as follows:

* *Fly ash* was used as filler in a dosage of 12.8% from the mix weight. Fly ash is from Holboca Power Plant, Romania and was analyzed in previously researches [19]. The fly ash properties are: the color is dark gray, spherical particles of sizes ranging from 0.01 μm to 400 μm, specific area 480-520 m2/kg, density of 2400-2550 kg/m3, chemical components type Si (18.3%), C (17.15%), Al (13.9%), etc. [19]. Fly ash was used in all mixes with wastes substitution in the same dosage.
* *Sun flower* wastes used as substitution of 25% of aggregate weight, sort 0-4 mm, measured in volume. Sun flower aggregate was prepared by cutting the stem of the dried plant in pieces with sizes between 0-4 mm. The density of sun flower waste was experimentally determined and it is 136 kg/m3. The polymer concrete with sun flower was noted **C1.**
* *Corn wastes* used as substitution of 25% of aggregate weight, sort 0-4 mm, measured in volume. Corn cob aggregate was prepared by cutting the dried cob in pieces with sizes between 0-4 mm. The density of corn cob waste was experimentally determined and it is 266 kg/m3.The polymer concrete with corn waste was noted **C2.**
* *Saw dust* used as substitution of 25% of aggregate weight, sort 0-4 mm, measured in volume. Saw dust is a residue from wood industry. The density of saw dust waste was experimentally determined and it is 168 kg/m3. The polymer concrete was noted **C3.**
* *Polystyrene granules* usedas substitution of 25% of aggregate weight, sort 0-4 mm, measured in volume. The polystyrene granules are wastes from construction industry. The density of polystyrene waste was experimentally determined and it is 1.6 kg/m3.The polymer concrete was noted **C4.**
* *Chopped plastic bottles (PET)* as substitution of 25% of aggregate weight, sort 0-4 mm, measured in volume. PET is a sub-product obtained from plastic bottles recycling process. The density of PET waste was experimentally determined and it is 433 kg/m3. The polymer concrete was noted **C5**.
  1. Experimental procedure

For preparing polymer concrete the components were mixed, firstly the dried components after that the epoxy resin combined with hardener was added. The samples were cast into cubes of 7 mm and prisms of 70x70x210 mm. After 24 hours the samples were demolded and kept at a temperature of 200C for 14 days. The density of hardened polymer concrete was determined according to Romanian standards [20]. The cubes were tested in axial compression for determining the compressive strength [21], the prisms were tested in flexure and splitting for determining the flexural strength and split tensile strength according to standards [22,23]. All tested were done on three samples for each type of concrete.

1. **Results and discussions**

The experimental results obtained for polymer concrete with various types of waste are given in Table 1.

Table 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sample | fc, MPa | fti, MPa | ftd, MPa | Density, kg/m3 |
| C0 | 69.93 | 12.26 | 6.82 | 2116 |
| C1 | 39.30 | 16.30 | 6.63 | 2027 |
| C2 | 28.96 | 13.61 | 5.15 | 1973 |
| C3 | 56.60 | 16.59 | 6.98 | 1919 |
| C4 | 44.59 | 14.84 | 5.28 | 1861 |
| C5 | 47.21 | 16.94 | 6.14 | 1946 |

* 1. Compressive strength

From Table 1 the values of compressive strength varied from 56.6 MPa for polymer concrete with corn as aggregate substitution to 28.96 MPa for concrete with saw dust as aggregate substitution. All values of fc were smaller than that of control mix with percentages between 19.1% for C3 and 58.6% for C2. For the same aggregate substitution, the wastes influenced differently the compressive strength. All values of fc indicate that polymer concrete with studied wastes can be used for structural applications.

* 1. Flexural strength

From experimental results the values of flexural strengths for all mixes with wastes were higher than that of the control mix, with percentages ranging from 38.2% to 11.1%. The maximum flexural strength was obtained for concrete C5 and the minimum value for C2.

* 1. Split tensile strength

From Table 1, the values of split tensile strength for mixes with wastes were lower than that of the control mix, except for the C3 mix, for which a small increase of the strength was obtained. The values of fti varied between 6.98 MPa for C3 and 5.15 MPa for mix C2, which means an increase of 2.3% for C3 and a maximum decrease of 24.5% for C2.

* 1. Density

The values of density for hardened concrete are given in Table 1. The type of waste influences differently the density. All densities of polymer concrete with waste were lower than that of the control mix. For mixes C2, C3, C4 and C5 the densities were smaller than 2000 kg/m3, this fact indicates that these concretes are lightweight concretes. The minimum value of density was obtained for mix C4, for which mechanical strengths presented relatively higher values. C4 can be considered as a lightweight concrete that can be used for structural applications.

Generally, the polymer concrete with aggregate substitution of agro-wastes present smaller values of mechanical strengths in comparison with that for the other types of wastes, for the same dosage of substitution. The densities of concretes with agro-wastes content were higher than those with other types of wastes.

For each mechanical strength, the maximum value was obtained for different mix. The type of waste influenced differently each mechanical property. Only in the case of mix C3 the maximum value was obtained for fc and ftd.

In the case of minimum value of mechanical strengths, these were obtained for the same mix prepared with corn cob.

1. **Conclusions**

Five types of wastes were used for preparing epoxy resin concrete: fly ash, sun flower, corn, saw dust, polystyrene granules and chopped plastic bottles. Fly ash was used as filler in all mixes. The other wastes were used as aggregate substitution with a percentage of 25% of the weight. A control mix prepared with epoxy resin and aggregates was used for control.

For the same aggregate substitution, the wastes influenced differently the mechanical strengths. For all types of wastes the values of compressive strength were smaller than that of control mix. The higher value of compressive strength was obtained for mix with saw dust aggregate substitution. The flexural strengths were for all mixes bigger than that of control mix. The higher value of flexural strength was obtained for mix with chopped PET aggregate substitution. The split tensile strengths were generally smaller than that of control mix, only the mix with saw dust presented a higher value than that of control mix.

The density was for all types of wastes smaller than that of control mix. The concretes with corn waste, saw dust, polystyrene granules and chopped PET are lightweight polymer concrete.

The mechanical strengths of polymer concrete with different types of wastes as aggregate substitution are not very much diminished in comparison with that of polymer concrete without wastes, especially in the case of tensile strengths, case in which the wastes improved the behavior in flexure.

In conclusion, in the case of studied wastes as aggregate substitution the polymer concrete presented some special characteristics:

* mechanical properties are comparable with that of structural concretes;
* higher flexural strength than control polymer concrete;
* the densities were closed to lightweight concrete.

In the mix of polymer concrete different types of wastes can be used contributing to the consuming of wastes that polluted the environment. Studying the properties of polymer concrete with wastes is a possibility of application in construction industry of new eco-materials.

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