Physico–mechanical Properties of Sustainable Building Material Based Gypsum and Recycled Polyethylene Waste

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Abstract

The economic focus in the building sector is on lightweight materials. Recycled polyethylene particles coming from plastic botteles waste can ensure this lightness and can solve not only technical problems, but also produce economic and environmental benefits. Different polyethylene particle proportions of 5,10,15,20 and 25% were introduced in gypsum mortar in order to characterize its physical and mechanical properties. Results proved the positive effect of the introducing of PET particles in the matrix of gypsum mortar, the lightening of this material but a decrease of mechanical properties was recorded comparing in to reference without polyethylene particles. This new material with promising functional properties can be used as a masonry element in a new construction or in the rehabilitation of the old building.

Keywords: Gypsum; Plaster; Waste; Polyethylene; Mechanical strength; Microstructure

1 Introduction

The present day construction industry mainly focuses on the reduction of waste accumulation by effective utilization of wastes and by-products in the production of high value building units (Sophia & Sakthieswaran, 2019). Ouakarrouch et al. (2019) shows that the addition of waste chicken feathers to the plaster leads to a remarkable reduction in apparent density of about 12.3%. The results of Markssuel et al. (2020) proved the feasibility of using the waste in renderings to repair the studied buildings, namely when 25% of sand was replaced with waste. With this composition, flexural strength increased from 0.91 MPa to 1.33 MPa and compressive strength from 1.89 MPa to 3.18 MPa. Jiménez Rivero et al. (2014) and in view of their experimental results, the mechanical strength of plaster decreases with an increase in waste rubber addition. In the present study, taking into account the proportions of recycled polyethylene particles on the physical and mechanical effectiveness of gypsum mortar after hardening. The mechanical and physical properties obtained from the experiments were compared with theoretical evaluations.

2 Materials and Methods

The plaster used in this study is a product of commercial available gypsum. Natural quartz sand 0/2 mm with continuous granulometry and polyethylene terephthalate (PET) particles of plastic recycled bottles waste were used in this study (Fig. 1). Aerial lime is selected in this reasearch as a setting retarder of the plaster because it is liable to decrease its solubility and to increase its time of use.

Fig. 1: Polyethylene terephthalate (PET) particles of plastic recycled bottles

For the formulation of the studied gypsum mortar, the recommendations given by CNERIB (National Centre for Studies and Researches Integrated to Building) have been used:

First, we fixed the Water/Plaster ratio (W/P= 0.60) equal to the saturation mixing ratio. We fix the plaster/sand ratio (P/S = 0.50) by weight (also recommended by the CNERIB (1993) because, according to CNERIB's recommendations (1993), an excess in the sand quantity reduces the mechanical properties of the plaster-based materials.

Regarding the lightweight aggregates, the polyethylene terephthalate (PET) particles were incorporated in a matrix consisting of 'plaster + sand'; the percentages by weight of polyethylene terephthalate (PET) particles varied from 5 to 25% with steps of 5%. The density of the studied composites was determined by measuring the weight and the volumes of samples. The flexural strength was measured on 4x4x16cm^3 prisms and the compressive strength on 4x4x4cm^3 cubes using a universal press of type ‘‘Controls’’ (EN196-1).

3 Results and Discussion

Fig. 2 shows that the density of gypsum mortar decreases with the increase of the quantity of the polyethylene terephthalate (PET) particles. this can be attributed to the low density of the PET aggregates used (257 kg/m^3) hence the beneficial effect of the lightening of the the elaborate material. Our results are concurs with the works of (Laoubi et al., 2018).

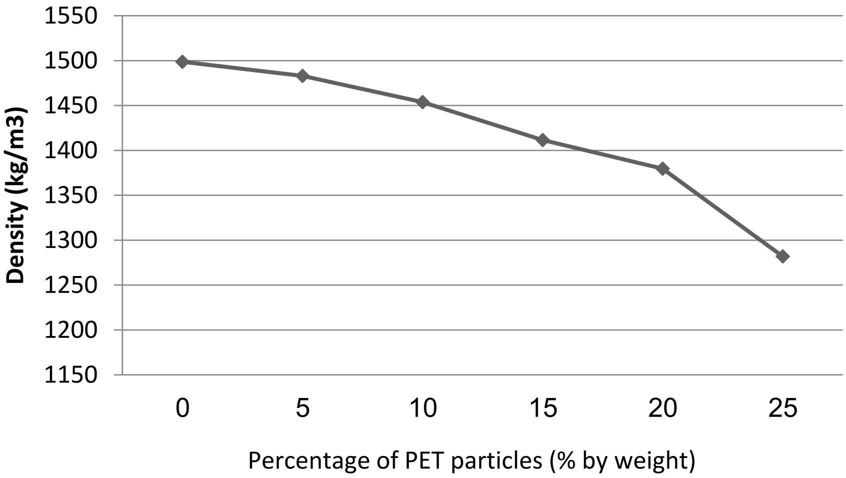

Fig. 2: Variation of the density of gypsum mortar according to the percentage by weight of PET particles

Fig. 3 presents the variation of the porosity of gypsum mortar according to the percentage of PET particles. It is clear that the porosity of the composite decreases compared to plaster alone but it increase slightely with the increase of the quantity of PET particles.

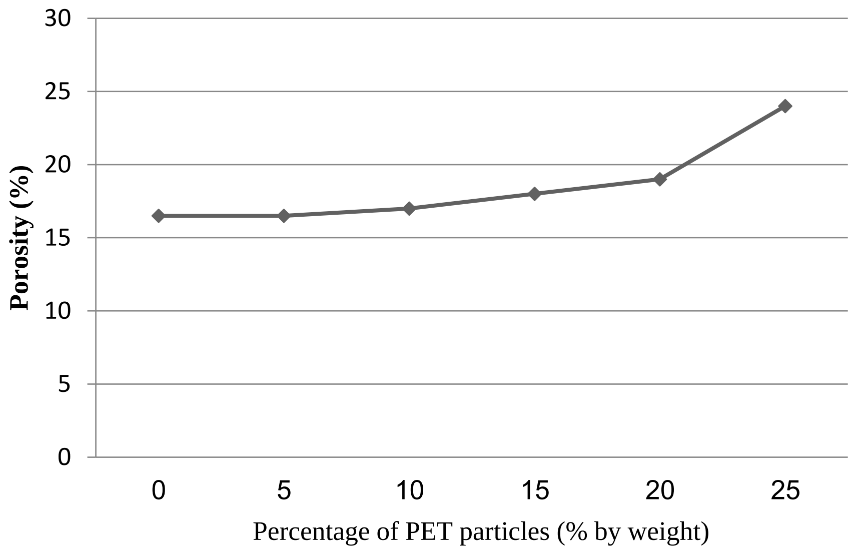

Fig. 3: Variation of the porosity of gypsum mortar according to the percentage by weight of PET particles

Table 1 summarizes the results of the variation of the mechanical properties of gypsum plaster according to the proportions of PET particles.

Table 1: Variation of the mechanical properties of gypsum according to the percentage by weight of PET particles

Compositions	Compressive strength(MPa)	Flexural strength(MPa)
Gypsum mortar (0% of PET particles)	8,13	3,28
Gypsum mortar (5% of PET particles)	6.78	3,02
Gypsum mortar (10% of PET particles)	7,01	2
Gypsum mortar (15% of PET particles)	7,27	3,51
Gypsum mortar (20% of PET particles)	7,49	4
Gypsum mortar (25% of PET particles)	6,88	3,75

According to the Table 1, it is clear that the mechanical strengths decrease with the increase of the content of the PET particles compared to the gypsum mortar (0% by weight of PET particles), this can be attributed to the disturbance of the mineral skeleton of the plaster mortar by the addition of PET particles. An increase is recorded for both properties, compressive and flexural strength, for the content 20% of the PET particles after it falls for the percentage 25% and this is due to a loss of maneuverability.Our results are in agreement with the studies of (Saikia & Brito, 2014; Yazoghli et al., 2006).

Fig. 4 shows the porous microstructure of the gypsum matrix. According to the Fig. 5, it is clear that the grains of sand fill the existing voids in the porous gypsum matrix . The Figs. 6 and 7 give the random distribution of PET particles

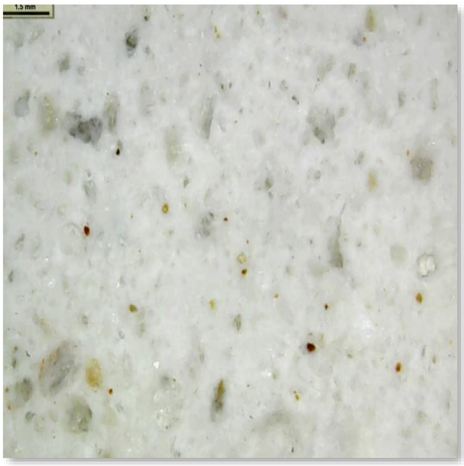

Fig. 4: Gypsum matrix

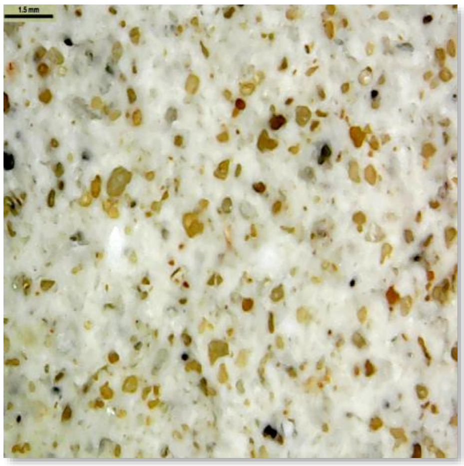

Fig. 5: Mortar based gypsm Matrix

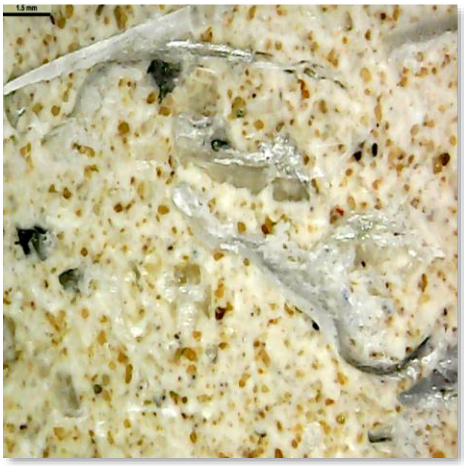

Fig. 6: Mortar based gypsm + 5% of PET particles

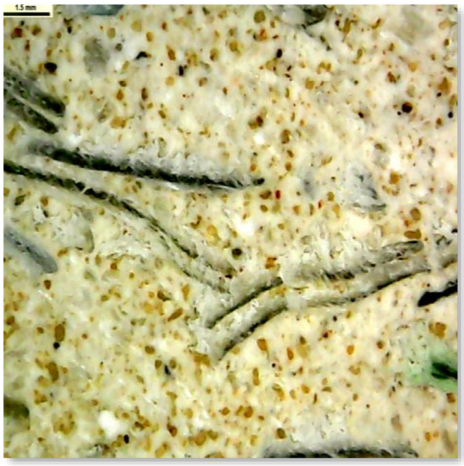

Fig. 7: Mortar based gypsm + 10% of PET particles

According to the Figs. 8 and 9 , We notice the different dispositions of PET particles in the mortar based gypsum matrix. Finally Fig 10 shows the good adhesion between the matrix and the PET particles.

Different dispositions of PET particles

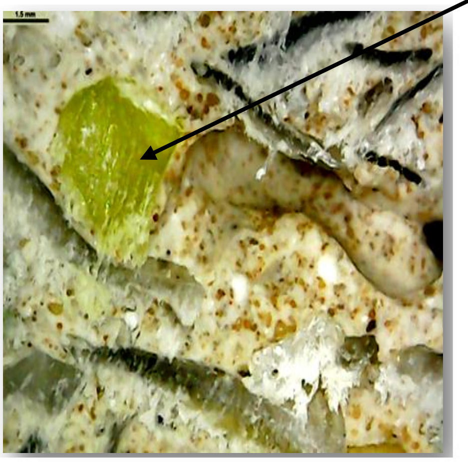

Fig. 8: Mortar based gypsm + 15% of PET particles

Fig. 9: Mortar based gypsm + 20% of PET particles

Fig. 10: Mortar based gypsm + 25% of PET particles

4 Conclusion

The present study has shown the possibility of using mortar based gypsum with the PET particles in several construction areas, given their satisfactory mechanical properties. The incorporation of PET plastic waste in mortar based gypsum is beneficial from the point of view of lightweighting. It was possible to reduce the density from 1498.67 to 1281.87 Kg / m^3 for The mortar based gypsum. An increase in the porosity was recorded of about 31.25%.Depending on the proportion of the PET particles introduced, a clear improvement of the flexural strength was obtained for the gypsum mortar with 20% of the PET particles (4 MPa) and this is due to the good adhesion between gypsum mortar and the PET particles. The addition of PET plastic waste has reduced compressive strength from 8,13 to 6,78 MPa for the mortar based gypsum with 5% of the PET particles. According to the ACI21-213R-87 Guide, the best compressive strength for this new composite is included in the range of 7 to 17 MPa with densitiy included in the range of 800 to 1350 Kg/m3, which allows us to classify it in the class of concrete of medium strength. Moreover, a microscopy study has shown a good interaction between the mortar based gypsum matrix and the the PET particles.

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