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The artificial increase of microroughness of various recycled materials used as aggregates in concretes contributes to the increase of the final concrete strength

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Abstract

This study examines different types of recycled materials such as beer green glass and waste tile used in different mixtures in order to prepare concrete specimens and more specifically their effect on concrete strength and how their microroughness influences the mechanical strength of the produced concrete specimens. Concrete, a mixture of cement, aggregates and water, is the most used man-made material and has numerous civil engineering applications (Jackson, 1981, Neville, 2005, Taylor, 1994). Aggregates are the major constituents of concrete, typically occupying between 70% and 80% of its volume. The rapid growth of the construction industry has led to environmental problems caused by excessive mining and usage of natural resources such as aggregate and cements (Mo *et al.*, 2016). Therefore there is a need to improve the reuse value of waste materials. Since the usage of conventional aggregates is not environmental friendly and causes depletion of natural resources (Medina *et al.*, 2012), a variety of waste materials such as clay, waste glass, asphalt, waste tile and plastic wastes have been recycled and used as aggregate in concrete blocks. In concrete, most observed faults either in the case of waste glasses or in the cases of asphalt and tiles are due to their smooth surfaces (Abdallah *et al.*, 2014, Meng *et al.*, 2018) which are responsible for the extended cracks and detachments along the rims of the aggregate particles with the cement paste, limiting the final concrete strength (Petrounias *et al.*, 2018). The surface texture of the recycled materials was studied by using Secondary Electron Images. Since the microroughness of materials used as aggregates in concretes plays severe role on their final strength as it is responsible for the adequate bonding between the cement paste and the aggregate particle, artificial increase of microroughness of the recycled materials specimens was carried out using quartz primer for coating the recycled materials three times, one every 24 hours. Normal concrete cube specimens (150×150 mm) were made from the different mixtures containing recycled materials. The recycled materials were crushed through standard sieves and separated into the size classes of 2.00-4.75, 4.45-9.5 and 9.5-19.1 mm and then washed before their used in concrete specimens. These specimens were tested in a compression testing machine. After the compressive strength test, the quality cohesion between the cement paste and the aggregate particles in concretes were examined. The concrete strength ranged from 14 to 20 MPa. The lowest compressive strength values were observed in concrete specimens made by mixtures containing exclusively glass as aggregates (Fig. 1a). On the other hand, concretes made by mixtures of glass with primer and tile with primer present the highest compressive strength values.

Table 1. Compressive strength of concrete specimens of different mixtures of recycled materials (*glass with primer in the small class and tile with primer in the other two classes, ** tile with primer in the big class and glass with primer in the two small classes).

Sample	Compressive strength of concrete (MPa)
Glass	14
Glass with primer	15
Tile	17
Tile with primer	17.5
Glass with primer and tile with primer*	20
Glass with primer and tile with primer**	18

The results of the compressive strength test of the concrete specimens are in accordance to the artificial given microroughness of the recycled materials used as aggregates in concretes. The artificial increase of microroughness seems to positively contribute to all strength values of the studied concrete specimens. The observations of the surface texture of the recycled aggregates show glassy to smooth surfaces for the studied glass, tile and smooth to almost rough for the studied glass and tile grains which have been coated with quartz primer. In general, the quartz primer, as high adherence material, gave microroughness to the recycled materials used as aggregates in concrete specimens and hence increased their final strength. More specifically, among the various produced concrete specimens, these made by the mixture of glass coated with quartz primer in the smaller class and tile coated with quartz primer in other two classes, attributed to the highest concrete strengths (Fig. 1b).

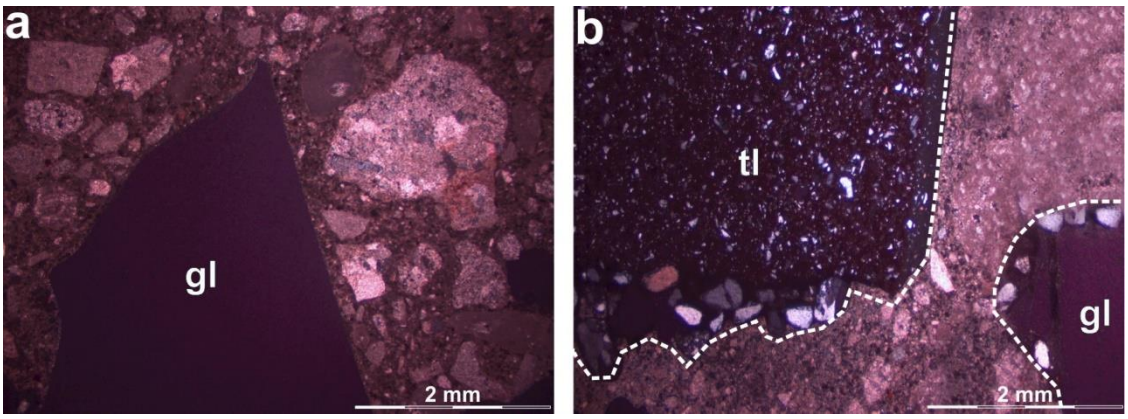

Figure 1. Photomicrograph of concrete specimen in crossed nicols showing a. glass as aggregate, b. mix of beer green glass with quartz primer and tile with quartz primer as aggregates. gl: glass, tl:tile.

This is due both to the artificial increase of and to the optimum interlocking of grains which has been created from the combination of glass coated with quartz primer in the small class tile coated with quartz primer in the bigger classes. Subsequently, concrete specimens made by mixture of tile coated with quartz primer in the bigger class and glass coated with quartz primer in the smaller classes attributed in lower but satisfactory strength. The lower strength is attributed to greater participation of glass coated with quartz primer in concrete specimens. However, its satisfactory strength is due to the artificial increase of microroughness of the aggregate particles as well as due to the good interlocking of grains. The main conclusions of this work are the above:

- The artificial increase of microroughness of the used recycled materials used as aggregates in concretes seems to be determinant factor for the final concrete strength.
- The mixture of glass coated with quartz primer in the small class and tile coated with quartz primer in other two classes due to the optimum cohesion between the cement paste and the aggregate particle as well as due to interlocking of grains lead to the optimum mixture of recycled materials in concretes.

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