The study of selected properties of concrete made on the basis of aggregate recycling

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Abstract

The objective of the project included properties of concretes based on recycled aggregates and definition of their suitability for construction reasons. Verification of parameters was made on basis of laboratory tests. They included preparation and development of formulations of concrete samples from Portland cement CEM I 42,5R basing on three types of recycled aggregates and testing of selected strength, physical and rheological properties.

Keywords: concrete, recycling, laboratory tests, aggregate

1. Introduction

Regulations and environmental policy raise the issue of deliberate waste management more and more frequently. It is simultaneously attempted to persuade consumers to be aware of ecology using promotion programmes, guidelines (sorting out municipal solid waste into coloured containers) and legal orders. Almost all the materials from which resources such as glass, metals, plastic and mineral materials, paper, textiles and others can be recovered are suitable for reusing (recycling). The notion of recycling begin to appear also in construction. Polish Association of Aggregate Producers estimates that approximately 4.5 million tonnes of aggregate are made as a result of recycling. The above mentioned amount is the only equivalent of approximately 2.5 % of all building materials used in Poland. Taking the situation in more developed countries into consideration, you can set forth the thesis that this amount will be taking off [2]. Good recognition of properties and possibilities of applying of such aggregates in building constructions is of great vital in this context.

2. Recipes

The formulation is made based on experimental composition of concrete components using alternative aggregates recovered. It mainly results from ignorance of physical properties of aggregate with a view to gain a small index of water and adhesive. The equation (1) was used in order to estimate necessary amount of cement and silica fume assuming the expected strength similarly to concretes of high strength [1,3].

$$f_c = \frac{188,4}{21,7\left(\frac{W}{C+P_k} - 0,15\frac{P_k}{C}\right)} \tag{1}$$

Properly designed recipes must also satisfy the equation tightness, which has the form:

$$\frac{C}{\rho_c} + \frac{P_k}{\rho_{pk}} + \frac{K}{\rho_k} + \frac{W}{\rho} + \frac{S}{\rho_s} = 1 \tag{2}$$

Where: f_c – compressive strength of concrete [MPa], W – amount of mixing water [kg/m^3], C – amount of cement [kg/m^3], P_k – amount of silica fume [kg/m^3], S – amount of superplasticizer [kg/m^3], K – amount aggregate [kg/m^3], ρ_c, ρ_{pk}, ρ_k, ρ_s, ρ – density [kg/m^3]: cement, silica fume, aggregate, superplasticizer, water.

3. Types of samples and research program

39 concrete samples in total in form of cubes with the dimensions of 10x10x10 cm and 15x15x15 cm and beams with the dimensions of 10x10x46 cm were prepared for tests. Sample markings were defined as follows: CSd – concrete based on fine aggregate made from sanitary ceramic, GB – concrete based on aggregate made from debris, CB – concrete based on aggregate made from construction ceramics.

Figure 1: Damage samples of left: CB, CSd, GB

Testing programme included: marking of strength to compression and strength to tension while bending after 28 days, shrinkage within 30 days from deformation, testing of absorbability, waterproofness and frost resistance.

4. The results of laboratory tests

4.1. *Shrinkage*

The samples in form of beams with the dimensions of 10x10x46 cm were tested for shrinkage after 48 hours from formation. They were earlier placed in the tub with high humidity, which prevented from water loss.

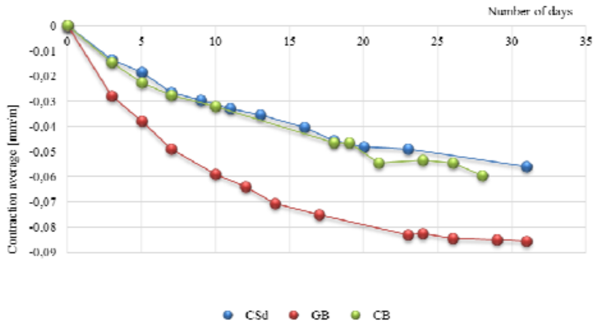

Figure 2: The measurement results of shrinkage

The test took 28 days; at this time changes were measured every 2 days on average, however, in the later stage every 3 days. Amsler apparatuses were used for taking measurements.

4.2. *Strength*

Strength to compression and tension while bending was tested by means of samples respectively: cubic ones the side of which was 10 cm and rectangular ones with the dimensions of 10x10x46 cm after 28 days of maturation.

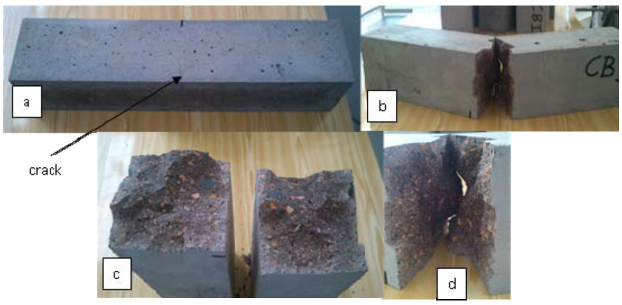

Figure 3: Damage beam CB II; a- beam after damage, b- beam after crack, c, d- surface crack

Load speed during the test was 0,1 kN/s.

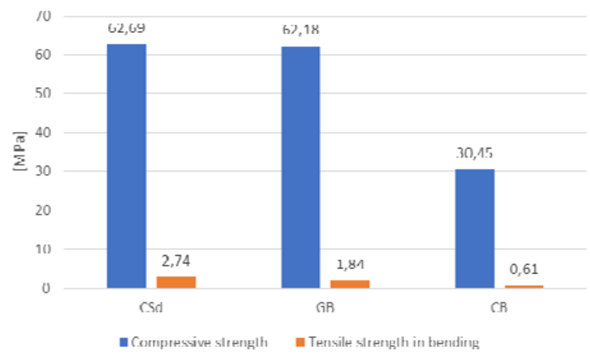

Figure 4: Compressive strength and tensile strength in bending.

4.3. *Waterproofness*

Waterproofness was tested by means of cubes with the dimensions of 15x15x15, however, each series was represented by three maturing units for 28 days. The samples were dried to permanent weight before testing.

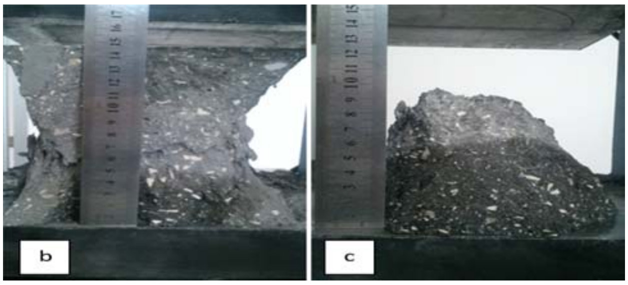

Figure 5: Measuring waterproofness CSd; b – measuring at the edge, c – measurement in the middle

4.4. *Frost resistance*

Concrete resistance to frost action or ability to preserve proper structure while using a certain number of cycles of freezing and defrosting was measured in compliance with PN 88 B-06250 standard.

5. Conclusions

Concrete designed based on debris and sanitary ceramic was characterized by high and approximate strength parameters. Properties of concrete composed based on aggregate from construction ceramic appeared relatively poor. Lower strength was stated by approximately 40% in relation to two remaining materials. The reason for that is mainly high porosity of aggregate, thus absorbability leading to a remarkable increase of water demand, thus coefficient of water and adhesive. As a result, this material is not recommended to be used as a component of construction concretes.

The tests also showed lack of suitability of greater fractions of sanitary ceramic (8-16 mm) as they are characterized by worse adhesion to cement matrix due to flat and very smooth grains.

Debris gained through recycling and sanitary ceramic (finer fractions) are suitable for application in construction concretes alike natural aggregate and a proper way of grinding guarantees obtainment of required grinding curves.

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