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Investigation of 30% recycled coarse aggregate content in sustainable concrete mixes

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HIGHLIGHTS

- The research mainly focuses on 30% RCA content effects.
- There are 2 concrete groups to investigate and compare the effects of 30% RCA.
- Group A is applied on different types of cement materials with natural coarse aggregate.
- Group B is applied on different types of cement materials with 30% recycled coarse aggregate (replaced 30% Natural aggregate).
- This research provides to maximize the usage of RCA content in sustainable concrete construction for future.
- The research aim helps to use 30% RCA content in buildings for controlling CO_2 emissions.

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ABSTRACT

The improvement of sustainable concrete, by applying recycled coarse aggregates has an important role to ensure the minimization of damages towards environment. The amount of construction waste increases annually. Also modern technology is given a chance to improve recycling usage in sustainable concrete industry. In modern technology world, recycling plays a vital role to protect the natural resources in our planet. This research carries out a thorough investigation of fresh & hardened RCA concrete, the thermal performance (thermal properties & thermal dynamic properties) with 30% recycled coarse aggregate content. It provides a clearer understanding on how it can be applied to improve the usage of 30% RCA content in concrete for sustainable development.

1. Introduction

In recent times, the ubiquity of sustainable concrete construction has been expanding annually; and the purpose of the construction industry is to insure the wellbeing of the inhabitants by lowering CO_2 emissions and to encourage the utilization of natural resources. The most important constituent in a concrete when volume is concerned is aggregates, therefore aggregates have substantial impact on engineering properties as well as having major effect on the eventual cost of concrete mixtures. Besides, the increase in demand of the construction industry has brought about a decrease in accessible natural resources to be utilized in construction of structures. For instance, the amount of natural resources used in the construction industry is more than 165 million tonnes every year. Then again, around 109 million tonnes of demolition waste is created every year in the UK, out of this figure 60 million tonnes are generated from concrete. This value also shows that the principle material utilized in the construction of buildings is still concrete and furthermore, the property of the concrete to absorb natural mineral resources has increased the significance of recycling rubble concrete. Using recycling rubble concrete to maintain natural resources and replacing proportion of the aggregate by using the destroyed concrete thereby negates the requirement of disposal. The greater the proportion of aggregates replaced by recycled materials, the more sustainable the concrete is. Also, such usage can also minimize the discharge of the amount of carbon-dioxide and reduces the energy consumption in the production of concrete. In conclusion, the extraction of virgin aggregates can cause enormous damage to the environment while on the other hand vast amount of energy is required during the extraction and crushing process, due to the awareness towards using recycled aggregates which is generated from demolished constructions works is on the increase as opposed to natural aggregates [1].

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2. Experimental details

2.1. Mix proportions

Throughout the research experiments, the CEMI concrete mixes were designed following steps described in BRE mix design procedure. Concrete mixes were proportioned using different proportion of PFA, GGBS, SF and RCA, as replacement of PC and coarse aggregate respectively. In total, 28 concrete mixes were cast in two different groups namely; Group A and B. The 28-day characteristic strength concrete mixes in Group A and B were designed as class C40. These concrete strength were selected as they commonly adopted in the practice for commercial, residential and multi-storey buildings concrete structure (floors, walls and columns) constructions. All of the concrete mixes in Group A were designed by containing only 100% natural course aggregate content with CEMI cement. On the other hand, all Group B concrete mixes were proportioned using 30% Recycled Coarse Aggregate as direct replacement of natural coarse aggregate.

2.2. Methodology

2.2.1. Aggregate characterisation

The physical properties of aggregates tests were done. Such as particle size distribution, particle density, water absorption, and moisture content (BS 812: Part 109) tests were determined.

2.2.2. Fresh properties of sustainable concrete mixes

The main aim was to measure the workability for the concrete mixes using Slump and compacting factor (BS 1881: Part 103) tests were done.

2.2.3. Hardened properties of sustainable concrete mixes

The hardened properties included compressive strength such as cube (100 × 100 × 100 mm), cylinder (150 × 300 mm) and flexural strength such as beam (100 × 100 × 500 mm) were tested at 7 and 28 days.

2.2.4. Thermal performance of sustainable concrete mixes

The thermal properties were main research applications which included thermal conductivity (BS EN ISO 8990:1996 and BS EN 1934: 1998) such as slab (75 × 300 × 300 mm) a testing method called "hot-box" is developed by Dundee University. Specific heat capacity is tested by performing an experimental procedure in an insulated box such as cube (70 × 70 × 70 mm) and density, and a cube (100 × 100 × 100 mm) accurately determined using a Buoyancy Balance. Concrete samples were tested at 28 day [6–9]. After that an excel spreadsheet is set up to calculate the thermal dynamic properties of concrete mixes by applying the thermal properties data (thermal conductivity, density and specific heat capacity) of the concrete mixes. Factors which affect the thermal storage are taken under consideration that include R-value and decrement factor. The main aim is to understand the effects of 30% recycled coarse aggregate content of the concrete mixes on the thermal dynamic properties with theoretical calculations. That's why BS EN ISO 13786:2007 standard is used to calculate those parameters.

2.3. Materials

2.3.1. Cement

Portland cement (PC) used in this research is selected based on CEM-I. The quantity of the cement is bought in the amount that is required for the tests, so that long term storage is prevented. In this way, the possible contact of cement with humidity is minimized. Beside of this, bought cement is stored in a laboratory environment for the same reason.

2.3.2. Pulverised Fly Ash (PFA)

PFA is used according to [3]. PFA is used as the second component in the concrete production in addition to cement. PFA used in this research that is the most common type of PFA used in the UK and is classified as CEM IV according to [2].

2.3.3. Ground Granulated Blast furnace Slag (GGBS)

GGBS used in the research was based on [4]. GGBS can be easily found in the UK and classified as CEM III according to [2]. Hanson is the supplier of GGBS material.

2.3.4. Silica fume (SF)

In this research, silica fume is used based on EN 13263-1 in a slurry format. Slurry form of silica fume is liquid containing 50% water and 50% silica fume powder. This slurry is stored in close-fitting containers, so that the contamination among slurry ad air is prevented. In this way, worsening of silica fume over time is minimized [5]. The supplier of the silica fume is Elkem Materials Process Service B.V. from Netherlands.

2.3.5. Types of aggregates

Generally, the type of aggregate as defined by BS EN 12620:2002 +A1:2008 comes in the form of natural, manufactured or re-cycled.

2.3.5.1. Fine Aggregates (FA). In this research, fine aggregate used in the concrete mixes which consist of graded natural sand with maximum particle sizes of 5 mm according to BS 882:1992.

2.3.5.2. Natural coarse aggregate (NCA). Throughout the research experiments, Thames valley natural aggregate was used in concrete mixes with the maximum size of 20 mm according to BS 882:1992.

2.3.5.3. Recycled coarse aggregate (RCA). RCA is obtained from managing the remained, unwanted concretes and from the concretes that will be destroyed. The proportional size of RCA was used in 20–5 mm. The Day Company is the producer. RCA included crushed concrete, hydrated cement paste and also is dirtied with minor quantities of masonry, lightweight materials, gypsum, metals, plastics, glasses and other substances obtained from various sites within Greater London, according to Annex B of BS 8500 Part 2 [2006] (See Table 1).

3. Aggregate characterization

3.1. Particle size distribution

The test sieves applied in this research conformed to the requirements and also the grading was identified as the cumulative percentage passing by weight through the sieves as following British Standards. The results of fine aggregate with a maximum particle size of 5 mm was applied to make concrete mixes in this research. The requirement is conformed in Table 2.

Also the results of the natural and recycled coarse aggregates are shown in Table 3. The requirement is conformed by grading of the natural and recycled coarse aggregates.

3.2. Aggregate particle density and water absorption

Density of the particles and water absorption of the aggregates are controlled based on pyknometer method. The excellence of