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Chemical–mineralogical characterisation of coarse recycled concrete aggregate

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Abstract

The construction industry is now putting greater emphasis than ever before on increasing recycling and promoting more sustainable waste management practices. In keeping with this approach, many sectors of the industry have actively sought to encourage the use of recycled concrete aggregate (RCA) as an alternative to primary aggregates in concrete production. The results of a laboratory experimental programme aimed at establishing chemical and mineralogical characteristics of coarse RCA and its likely influence on concrete performance are reported in this paper. Commercially produced coarse RCA and natural aggregates (16–4 mm size fraction) were tested. Results of X-ray fluorescence (XRF) analyses showed that original source of RCA had a negligible effect on the major elements and a comparable chemical composition between recycled and natural aggregates. X-ray diffraction (XRD) analyses results indicated the presence of calcite, portlandite and minor peaks of muscovite/illite in recycled aggregates, although they were directly proportioned to their original composition. The influence of 30%, 50%, and 100% coarse RCA on the chemical composition of equal design strength concrete has been established, and its suitability for use in a concrete application has been assessed. In this work, coarse RCA was used as a direct replacement for natural gravel in concrete production. Test results indicated that up to 30% coarse RCA had no effect on the main three oxides (SiO_2, Al_2O_3 and CaO) of concrete, but thereafter there was a marginal decrease in SiO_2 and increase in Al_2O_3 and CaO contents with increase in RCA content in the mix, reflecting the original constituent's composition.
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1. Introduction

With the introduction of waste legislation in the form of regulations and directives in many parts of world, a significant move towards the sustainable management of construction and demolition (C&D) waste is becoming a legal requirement. In response, different sectors of the construction industry are undertaking various initiatives to minimise waste generation and improve the management of C&D waste to maximise economic and environmental benefits, generally by placing emphasis on increasing recycling for reuse.

Indeed, it is now widely accepted that recycling of C&D wastes for reuse as aggregate in new concrete production offers an environmentally responsible and economically viable route to convert this material into a valuable resource (Dhir et al., 1999; Poon et al., 2002; Sagoe-Crentsil et al., 2001). In fact, suitability of coarse recycled aggregates for use in normal grade concretes meeting requirements for a range of applications has been proven in a number of studies (Limbachiya, 2004; Meinhold et al., 2001). (Recycled concrete aggregate (RCA) is defined as a minimum of 95% crushed concrete, and recycled aggregate (RA) is defined as maximum of 100% crushed masonry (BS 8500, 2002).) As a direct result of these studies, the technical and application aspects of using recycled aggregates in concrete are now reasonably well understood. With a better understanding of the chemical–mineralogical characteristics of RCA and its influence on concrete performance, this material can be used confidently in different value-added concrete outlets.

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Against this background, the study was undertaken to investigate the chemical and mineralogical composition of coarse (16–4 mm size fraction) recycled concrete and natural aggregates (16–4 mm size fraction), and natural sand (<4 mm), which included the examination of the likely influence on engineering properties and durability performance of concrete.

2. Experimental details

To ensure that the study covered a range of potential material supply, C&D debris obtained from three different construction sites, within the Greater London area, were used to produce coarse RCA. The C&D debris selected were clean and free from detrimental levels of chemical impurities and harmful constituents. An existing commercial recycling plant for the production of quality recycled aggregates, comprised of primary jaw and secondary cone crushers, electromagnetic and air separation systems and screens, was used. In essence, large pieces of C&D debris arrived from various sites and they were reduced to 0.4 m maximum size, and the reinforcement was cut by hydraulic shears where required. During this stage, large pieces of wood, steel, plastics etc. (foreign materials) were removed by manually. Thereafter, material was crushed in a primary crusher and the debris was reduced to 75 mm maximum size. The products from the primary crusher were then screened on a deck typically consisting of a 10 mm scalping screen. At this stage, fine materials were discharged by an air blower to eliminate dirt, soil and gypsum and reinforcement and other metals were cleared using an electromagnet belt. The larger material was then passed through a secondary cone crusher in order to reduce the size to 16 mm maximum and screened into 16–8 and 8–4 mm size fractions, to give clean coarse RCAs with grading corresponding to those for crushed rock to BS 882. In general, the RCA used was found to be coarser, porous and rougher but equidimensional to that of natural gravel. Portland cement (PC) of Grade 42.5 N conforming to BS EN 197-1, used for concrete production, was also tested.

RCA samples were delivered to Kingston University laboratory in batches of 10 tonnes per delivery. Thereafter, in order to obtain a homogeneous and representative sample of the aggregate population, a quartering method was used as suggested by Goodsall and Mathews (1970). In this study, the samples of 80 kg of each type of aggregate (coarse and fine NA, coarse RCAs) were reduced to 10 kg samples and 42.5 N PC to 5 kg using this method. Aggregate samples were further reduced to 5 kg and PC to 2 kg. Samples were then powdered using an agate mill,

Table 1
XRF chemical composition of the main concrete constituents used in the study

	Main constituents					
	PC	Coarse aggregates				Natural sand
		Natural gravel	RCA 1	RCA 2	RCA 3	
SiO_2	20.60	97.03	65.37	68.43	63.61	88.54
TiO_2	0.22	0.01	0.22	0.39	0.17	0.05
Al_2O_3	5.47	0.34	5.33	5.49	3.57	1.21
Fe_2O_3	3.31	0.10	2.16	2.40	2.03	0.76
MnO	0.06	0.00	0.05	0.05	0.06	0.02
MgO	2.26	0.65	1.91	2.84	2.62	0.42
CaO	62.50	0.26	13.93	11.19	16.86	5.33
Na_2O	0.65	0.16	1.19	0.94	0.87	0.33
K_2O	1.71	0.01	0.61	0.62	0.51	0.31
P_2O_5	0.21	0.02	0.11	0.10	0.49	0.08
LOI	1.64	1.41	9.12	7.56	9.19	2.95
Total	100	100	100	100	100	100
Pb[a]	19	–	50	47	30	6
Zn[a]	53	–	31	29	37	4
Ni	21	–	–	9	10	2
Co	–	418	55	111	–	–
Total Cr	42	8	21	29	52	5
V	134	5	42	62	47	15
Th	–	2	2	1	1	2
S	59,690	–	2879	1698	2964	360

Major oxides expressed in wt%, trace elements expressed in ppm.
[a] Semi-quantitative analysis.

Table 2
Constituent materials of coarse RCAs (sources 1, 2 & 3) used in the study according to BS 8500-2

Constituents present	Proportions % (m/m)			BS 8500 limits
	Test sample (particle fraction 16–4 mm)			
	RCA 1	RCA 2	RCA 3	
Concrete	92.4	92.1	85.5	–
Masonry	1.9	1.6	5.3	5.0
Asphalt	4.9	1.4	3.3	5.0
Lightweight material (ρ <1000 kg/m^3)	0.0	0.6	0.5	0.5
Fines	0.2	3.4	4.4	–
Foreign materials[a]	0.5	0.9	1.0	1.0

[a] Glass, timber, plastic, metal etc.

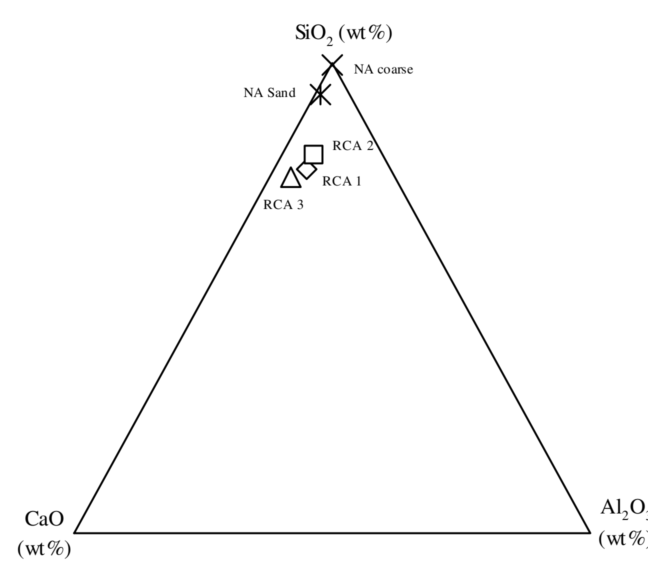

Fig. 1. Position of the NA and RCA on the $CaO–SiO_2–Al_2O_3$ ternary diagram.

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