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Effect of cement and admixture on the utilization of recycled aggregates in concrete

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HIGHLIGHTS

- Recycled aggregates concrete (RAC) with recycled concrete sand (RS) and recycled concrete gravel (RG).
- No reduction in slump of recycled aggregates concrete (RAC) up to 30% of recycled aggregates (RA).
- The workability of recycled aggregates concrete (RAC) depend on the combination of cement-concrete.
- Decrease in density and strength of recycled aggregates concrete (RAC).
- Increase in air content of recycled aggregates concrete (RAC).

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ABSTRACT

In this paper, results of an investigation on the effect of type of cement and admixture on fresh and hardened properties of concrete with coarse and fine recycled aggregates (RA) are presented. Natural sand (NS) and natural gravel (NG) were replaced respectively by (15, 30, 70, and 100%) of recycled concrete sand (RS) and recycled concrete gravel (RG). Two types of cement/admixture were used. The fresh (slump, air content and density) and hardened (compressive strength and elastic modulus) properties of recycled aggregates concrete (RAC) are analyzed and compared with those of natural aggregates concrete (NAC). The results indicate that the workability of RAC depends on the combination of cement-admixture and precisely the nature of the admixture and the amount of C_3A. RAC can be used with up to 30% of RS and more than 30% of RG.

1. Introduction

Large quantities of waste materials are produced by the construction and demolition (C&D) each year. The volume of such materials reaches alarming proportions. The issue of use of environmental friendly construction materials is gaining ground as awareness of the need for sustainability in design grows. Therefore, it becomes necessary to find ways to make concrete a more environmentally conscious material.

Utilization of RAC substantially reduces the demand for quarried stone, thereby decreasing transportation costs and emissions related issues, further, the use of RA in the manufacture of concrete and cementitious materials is a way to meet the needs, while preserving the environment in a sustainable approach. With respect to natural aggregates, the recent studies show that fresh concrete behavior depends on the type and dosage of admixture as well as the type and dimensions of aggregates [1–4].

Concretes made with RG have been subjected to numerous studies. Most of them focus on the effect of the quantity of used RA on the concrete strength at early age and long term. The results shown that the compressive strength of RAC was not much significant for 30% replacement of NG by RG but it was lower for 100% replacement [5–10]. For recycled aggregates mortars (RAM), Shi Cong Kou et al. [11] studied properties of cement mortars containing RS, and observed that cement mortars always have better mechanical properties than the corresponding cement–lime mortars, and this could possibly arise from a synergic effect of lime hydraulicity and the filler effect due to the fine fraction of RS within the mix, that lead to better densification of the lime mortars by blocking the capillary pores. In framework of mortar, we can find some authors worked on mortars that contain recycle sand and they showed statistically significant differences for replacement ratios up to 25%. These studies focus on the effect of RG

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Table 1
Chemical analysis and physical properties of cements used.

Cement	C1	C2
Nomination	CEM I 52.5R CE CP2	CEM I 52.5R CE
Finesse Blaine (cm^2/g)	4520	3250
Median diameter (μm)	9.7	16.5
Water demand (%)	27.2	26.0
Initial setting time (min)	120	165
Hydration heat at 41 h (j/g)	328	300
S_iO_2	19.54	20.19
Al_2O_3	5.70	3.81
Fe_2O_3	3.06	2.99
CaO	60.10	61.50
SO_3	3.71	3.31
MgO	1.85	1.96
K_2O	0.86	0.81
Na_2O	0.19	0.17
Cl^-	0.07	0.02
Loss on ignition	0.33	0.68
Clinker (%)	99	98
Alite (C_3S) (%)	53.4	67.0
Belite (C_2S) (%)	15.8	7.4
Aluminate (C_3A) (%)	9.9	5.0
Ferrite (C_4AF) (%)	9.2	9.1

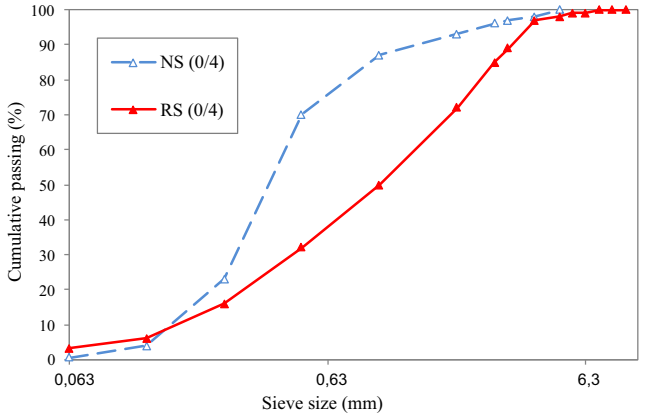

Fig. 1. Grading of natural and recycled sand.

Table 2
Water absorption and density of aggregates used.

Type of aggregate	Water absorption (%)	Density (%)
NS (0/4 mm)	0.9	2.59
RS (0/4 mm)	10.0	2.71
NG (4/10 mm)	0.5	2.71
RG (4/10 mm)	5.1	2.17
NG (10/20 mm)	0.4	2.31
RG (10/20 mm)	5.7	2.29

but there have been few studies on the effect brought by RS on the mechanical properties of concrete. And in previous studies, the analysis on properties of concretes in fresh state was not given importance. To complete this lack, a recent study [12] showed that the rheology and strength of RAC are negatively influenced by the substitution in coarse and fine recycled aggregates.

Use of RAC in high performance concrete is not a common practice, yet simply due to the reductions in mechanical properties as well as durability properties. Further, it has been found that cement paste in RAC contributes to a lowered relative density and higher water absorption than virgin aggregates, while higher shrinkage and creep strains were also observed. There is reduction in the mechanical properties and significant reduction in the porosity of the concrete when natural aggregate is replaced by recycled aggregate concrete [5]. Unit weight, workability, and durability of concrete containing 30–100% of waste aggregate decrease when subjected to freezing and thawing cycles [13].

In reality, a large number of experiments are required as to decide a suitable mixture for obtaining the desired requirements for concrete made with recycled concrete coarse/fine aggregate. Some authors as Lin et al. [7] used Taguchi's approach to reduce the numbers of experiment. Ryou et al. [8] studied the durability of recycled aggregate concrete incorporating pozzolanic materials pulverized fuel ash and ground granulated blast furnace slag. Based on the results, It was concluded that (i) 30% PFA and 65% GGBS concretes increased the compressive strength to the level of control specimens made with natural granite gravel, but the tensile strength was still lowered at 28 days; (ii) improved the chloride ion permeability; (iii) kept corrosion rate of 30% PFA and 65% GGBS concretes at a lower level after corrosion initiation, compared to the control specimens, presumably due to the restriction of oxygen and water access. Juan [9] indicated that attached mortar content has an impact on recycled aggregate concrete properties, and it aversely influences the resulting concretes main properties in different applications. Debieb et al. [10] reported that contaminated recycled aggregate are much sensitive to chlorides than sulfates and are rapidly leached when soaked into water. Significant differences were observed between the properties of original and new concrete and the results clearly show the necessity of taking these contaminations into account. Chakradhara Rao et al. [14] introduced a new term called "coarse aggregate replacement ratio " and defined as the ratio of weight of recycled coarse aggregate to the total weight of coarse aggregate in a concrete mix. Fonseca et al. [15] concluded that mechanical performance of RAC is affected by curing conditions roughly in the same way as conventional concrete (CC). Tegguer [16] developed a new approach of water absorption measurement using hydrostatic weighing in order to observe the kinetic absorption of aggregates, and concluded that the model of capillarity processes of aggregates can be obtained using Hall's model. Silva et al. [17] advocated the use of recycled aggregates from construction and demolition waste in concrete production if proper procedure of ensuring the quality of recycled aggregates is maintained. Kou et al. [11] reported that at higher temperatures, concretes made with recycled aggregates suffered less deterioration in mechanical and durability properties than the concrete made with natural aggregates. Zhao et al. [18] investigated the influence of fine recycled aggregates concrete (FRAC) on the properties of mortars and concluded that (i) slump of mortars containing dried FRCA is always larger than that of mortars containing saturated FRAC; (ii) the compressive strength of mortars containing dried FRAC is always larger than that of mortars made with saturated FRAC, which is attributed to a thinner interfacial transition zone improving its mechanical properties. Raeis Samiei et al. [19] reported deterioration in mechanical properties with increased recycled aggregates in the cement mortars, whereas cement–lime mortars exhibited improvement in mechanical properties were up to 60% when increasing the amount of recycled aggregates. To explain this improvement, the same explication as that of Shi Cong Kou et al. [11] has been given by Raeis Samiei et al. [19]. In this context, the objective of this research is to study the effect of the cement-admixture combination on the behavior of RAC with different substitution percentages (15, 30, 70, and 100%) of coarse and/or fine NA by RA. Since they are dependent on time in order to interpret concrete rheological properties, four different time – T0, T30, T60, T90 corresponding to the output of mixer and 30 min, 60 min, 90 min afterwards – were tested.