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Abstract: To sustain the environment, it is crucial to find solutions to deal with waste, pollution, depletion and degradation resources. In construction, large amounts of concrete from buildings' demolitions made up 30-40 % of total wastes. Expensive dumping cost, landfill taxes and limited disposal sites give chance to develop recycled concrete. Recycled aggregates were used for reconstructing damaged infrastructures and roads after World War II. However, recycled concrete consists fly ash, slag and recycled aggregate, is not widely used because of its poor quality compared with ordinary concrete. This research investigates the possibility of using recycled concrete in construction applications as normal concrete. Methods include varying proportion of replacing natural aggregate by recycled aggregate, and the substitute of cement by associated slag cement with fly ash. The study reveals that slag and fly ash are effective supplementary elements in improving the properties of the concrete with cement. But, without cement, these two elements do not play an important role in improving the properties. Also, slag is more useful than fly ash if its amount does not go higher than 50%. Moreover, recycled aggregate contributes positively to the concrete mixture, in terms of compression strength. Finally, concrete strength increases when the amount of the RA augments, related to either the high quality of RA or the method of mixing, or both.

1. Introduction

Nowadays, unfriendly environmentally effects of buildings' demolition, and expensive dumping fees of billion tons of concrete and steel has drawn concerns about sustainable materials, such as recycled concrete. In order to ease the environmental worries, landfill taxes, and policy on minimizing disposal places for construction debris have been applied in United Kingdom, Hong Kong, etc. [1]. A number of researches to transform building-waste-materials into "green", ones have been carried out around the world, which shown that recycled concrete has poorer compressive strength than ordinary concrete [1], so that its use has been limited only for reconstructing infrastructures, roads, sidewalk and flooring [2]. Also, recycled concrete derived from many different types of construction waste, in which old concrete constituted from 30 to 40 per cent, could be used in concrete manufacture to save natural resources, and energy consumption [3]. This study investigates the possibility of recycled concrete in construction applications as normal concrete by improving its properties. The investigation and analysis have been conducted to enhance the performance of reclamation materials by adjusting various proportion of RC, for instance, the replacement of natural aggregate by recycled aggregate, and the substitute of cement by associated slag cement with fly ash.

2. Methodology

2.1. Materials and preparation of the materials

Materials have been used to prepare 12 samples of recycled concrete are Portland cement, fly ash, slag, 10mm and 20mm of natural aggregate, 10mm and 20mm of recycled aggregate, water reducer.

• Portland cement, produced in Cement Australia Company, has been recommended to use for construction concrete such as fiber concrete manufacture, building possesses and all projects of civil engineering. Its components included Portland Cement Clinker less than 97 per cent, Gypsum (CaSO4 2H2O) between 2 and 5 per cent, Limestone (CaCO3) from 0 to 7.5 per cent, Calcium Oxide from 0 to 3 per cent, Crystalline Silica (Quartz) under 1 per cent and Hexavalent Chrome (Cr VI) below 20 ppm [4].

• Fly ash is widely trade in Australia, and is natural as industrial mineral with different advantages. As a raw material, fly ash does not have any effect on the chemical composition of mixture because of its 'pozzolanic' attributes. The components of fly ash consist fly ash 100 percent, Crystalline Silica (Quartz) more than 30 percent, Mullite between 5 and 30 percent and Hexavalent Chromium (Chrome VI) less than 1 ppm [4].

• Slag is the waste material removed from the operation of blast furnaces in the smelting of iron ore during steel manufacturing, namely Granulated Blast Furnace Slag (GBFS) and Ground Granulated Blast Furnace Slag (GGBFS). Slag is characterized by its latent hydraulic properties that play important roles in improving the durability properties of cement as mixing together. The information of components for the slag is Granulated Blast Furnace Slag more than 90 per cent, Gypsum (CaSO4 2H20) between 2 and 5 per cent, Hexavalent Chrome Cr (VI) below 1 per cent, Crystalline Silica (Quartz) under 1 per cent [4].

• Natural aggregate, supplied from St Mary's Recycling Facility, about 350 kg size (10 mm) and about 450 kg size (20 mm).

• Recycled aggregate, supplied from St Mary's Recycling Facility about 300 kg size (10 mm) and about 600 kg size (20 mm).

The initial step of preparing concrete was to keep all materials under the laboratory conditions with the temperature between 20 and 26 Celsius degree. Both natural aggregates and recycled ones have been washed carefully to remove impurities, such as dust and dirt. Then the aggregate have been dried by sunlight for seven full sunny days for ensuring no free water is inside the aggregate [5].

2.2. Mixing design

There are 12 different types of concrete has been made in the project experiment, which was divided into 4 groups. Some of them include natural aggregate, while others were made of recycled aggregate, also recycled and natural aggregate were used together in some mixtures. Generally, all the 12 mixtures differed from each other either by the volume of each ingredient, or by using some elements in a few of them, while it is not used in others, for example, recycled aggregate. The processes started with weighting the amount of materials involved in the formation for each type of concrete and placed in a concrete mixer.

In order to comply with the Australian standards [5], at the beginning, the mixer was in charged with approximately half of coarse aggregate was put over the cement or the powdered materials. After that, an appropriate quantity of water was added into the mixer to operate for 30 seconds. Then cement was the next adding to the mixture after the mixing operation was stopped for a while. Before restarting the mixing operation, cement was covered by another half of coarse aggregate to not lose powdered materials. As for admixtures, they were used in two different ways, either before or after adding cement. It has been suggested that admixtures should be distributed separately and uniformly to assure their distribution and to grant their effects [5]. A part of the balanced water should be used to dissolve the soluble admixtures before being added to the mixer. If the powder materials are over 10 percent of the amount of cement, they should be balanced then added to the mixing operation in the same way as cement. Water was added at the end to make a homogeneous mixture. The ingredients were worked out in the mixer until well-mixed. In some cases, the volume of water content of the mixture was not enough, what required the addition of the water reducer to improve the water content and ensure the workability of concrete.

The molds have been prepared and cleaned, and special oil has been sprayed in order to resist the stickiness with the moulds. After filling with concrete, the moulds were put in a covered place in the factory away from rainwater. After 24 hours or may be more (depends on the type of the concrete), the samples were taken and wrapped in plastic cover in order to save the water from evaporation. Table 1 and table 2 shows the quantities of elements that were used in each mixing.

Table 1. Mixing design details.

Group	Group 1			Group 2		
Mix design	NC	S50	FA50	S50+FA50	FA100	S100
Water (kg)	10.50	10.50	10.50	10.50	10.50	10.50
Cement (kg)	23.33	11.67	11.67	-	-	-
Fly ash (kg)	-	-	11.67	11.67	23.33	-
Slag (kg)	-	11.67	-	11.67	-	23.33
Sand (kg)	24.99	24.99	24.99	24.99	24.99	24.99
10mm natural aggregate (kg)	20.39	20.39	20.39	20.39	20.39	20.39
10mm recycled aggregate (kg)	-	-	-	-	-	-
20mm natural aggregate (kg)	40.79	40.79	40.79	40.79	40.79	40.79
20mm recycled aggregate (kg)	-	-	-	-	-	-

Table 2. Mixing design details (continued)

Group	Group 3			Group 4		
Mix design	RAC50	RAC50+S50	RAC50+FA50	RAC50+FA50+S50	RAC50+FA100	RAC50+S100
Water (kg)	10.50	10.50	10.50	10.50	10.50	10.50
Cement (kg)	23.33	11.67	11.67	-	-	-
Fly ash (kg)	-	-	11.67	11.67	23.33	-
Slag (kg)	-	11.67	-	11.67	-	23.33
Sand (kg)	24.99	24.99	24.99	24.99	24.99	24.99
10mm natural aggregate (kg)	10.20	10.20	10.20	10.20	10.20	10.20
10mm recycled aggregate (kg)	10.20	10.20	10.20	10.20	10.20	10.20
20mm natural aggregate (kg)	20.40	20.40	20.40	20.40	20.40	20.40
20mm recycled aggregate (kg)	20.40	20.40	20.40	20.40	20.40	20.40

2.3. Compression test

Compression test is for cylinders which has standard size (height = 2002 mm and diameter = 1002 mm). The samples were tested after 7, 14 and 28 days. Three cylinders were used in each time after the dimensions (high and diameter) have been measured by an electronic ruler. Then caps have been made to the rough poles to make them more regular and straight. Then the cylinders have been tested in the compression device. According to the Australian standards [6], capping is necessary for any rough surface of the cylinder. In addition to that thin, the maximum thickness of each cap can be no more than 6 mm.

3. Results and Discussion

The results of compression test have shown in the table 3 and also it is been shown in figure 1. 100% of slag or fly ash or together 50% slag and 50% fly ash without cement gave a weak concrete as seen in the samples (S50+FA50), (FA100) and (S100). The sample (FA100) which is contained 100% fly ash was so soft and it was broken before testing, therefore, there were no results about compressive strength and the main reason behind that could be the quantity of CaO, since the cement includes about 60% while the volume of this element in the fly ash is less than 3-6% [7] and [8]. The characteristics of these mixtures (S50+FA50, S100) were unsatisfying since compressive strength test was reduced more than 60% and 65% respectively compared to the ideal concrete. According to Cement Australia Company who supplied the fly ash and slag, it was recommended that these materials should be mixed with cement as supplementary elements to improve the concrete properties [4]. As a result, recycled concrete with 100% slag or fly ash are not strong enough in order to be used in structure applications. This result can be also proved by [7] who noticed that, increasing the replacement of fly ash in concrete declined the modulus of rupture and the strength as well.

While a mixture of 50% of slag and 100% of natural aggregate showed more developed results, but it still not as effective as that of the ideal concrete mixture since the strength of concrete was reduced about 15% - 20%, [8] argued that 50% of slag is not only very beneficial but also it gives the best results concerning the strength. The author maintained that the strength showed by the mentioned mixture was 45.7 and 49.8MPa after 28 and 84 days respectively. The difference between Berndt results and the ones concluded from the current study could be based on the quality and the proprieties of the slag.

Moving to the recycled aggregates, the study showed that 50% of recycled aggregate with 100% of cement increased the strength more than 6% compared to that of normal concrete although it has been proved that the RA may be beneficial only in the case when the quantity is less than 30% [9]. So that increase in strength could be due to the methods of mixing and the quality of the RA as it was maintained by [3]. However, 50% of recycled concrete aggregate with 50% of slag give result better than that given by the NA with 50 % of slag, while the results were similar to those of the control one. Therefore, the RA may prove a satisfied result with the slag as long as the quantity of latter does not go more than 50%. In a mixture of 50% of recycled aggregate with 50% of fly ash, the compressive strength declined about 15%.

Table 3. Compressive strength results.

Groups	Label	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
Group 1	NC	20.6	25.9	31.9
	S50	16.2	21.5	25.7
	FA50	18.7	21.2	31.9
Group 2	S50+FA50	3.2	4	6.9
	FA100	0	0	0
	S100	6.6	8.6	12.7
Group 3	RAC50	25	27.3	34.8
	RAC50+S50	19.8	25.2	29.8
	RAC50+FA50	17.6	20.6	27.3
Group 4	RAC50+S50+FA50	1.9	3.6	6.1
	RAC50+FA100	0	0	0
	RAC50+S100	4.6	9.3	11.1

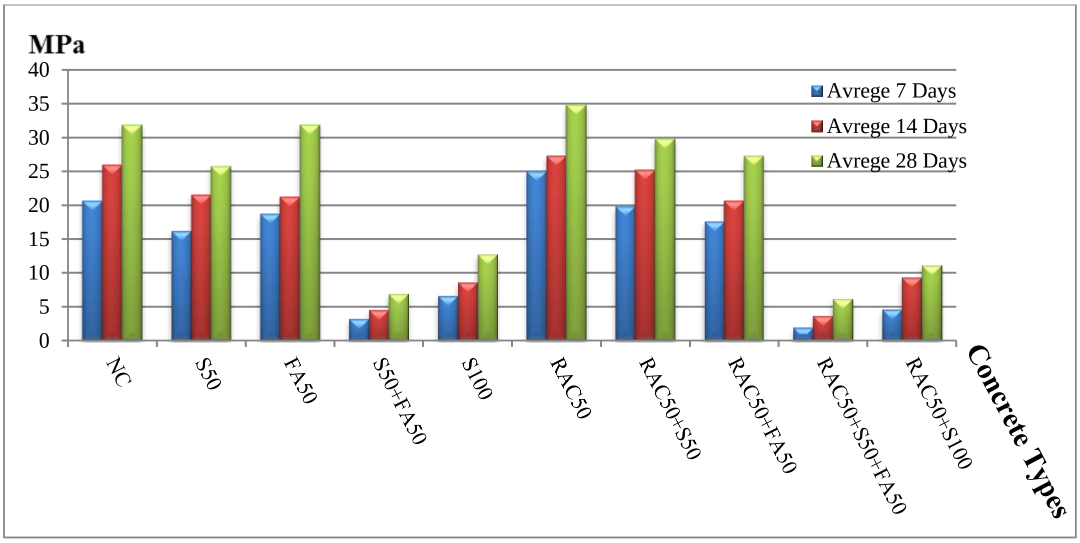

Figure 1. Compression test results.

4. Conclusions

The study reveals that slag and fly ash are effective supplementary elements in improving the properties of the concrete with cement. However, without cement, slag and fly ash together, or slag alone gave weak concrete and unsatisfying compressive strength test, while fly ash alone yielded broken concrete before testing. It was recommended that these materials should be mixed with cement as supplementary elements to improve the concrete properties. This result agreed with previous research that increasing the replacement of fly ash in concrete declined the strength as well [7]. Moreover, the recycled aggregate was slightly beneficial to improve a mixture with fly ash, but not a mixture with slag in terms of compressive strength. Also, fly ash is more useful than slag if its amount does not go higher than 50 per cent. Finally, concrete strength increases when the amount of the RA augments, related to either the high quality of RA or the method of mixing, or both.

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