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INFLUENCE OF COARSE RECYCLED CONCRETE AGGREGATE ON THE DRYING SHRINKAGE OF OPC CONCRETE

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ABSTRACT

The effects of using crushed waste concrete as coarse aggregates upon deformation due to drying shrinkage of concrete were investigated. Waste concrete cubes which has been tested for compressive strength as a compliance with construction specification were crushed and utilized as coarse recycled concrete aggregates in new concrete. To simulate the real life condition waste concrete with very minimal information about its originality was used in its natural moisture condition. The recycled concrete aggregates were tested for grading, specific gravity, bulk density, impact and crushing value, and water absorption and the results compared with those for natural aggregates. Concrete mix of designed strength 30,35, and 40 N/mm^2 at 28 days were prepared by fully replacing the coarse natural aggregate with coarse recycled concrete aggregate and tested. The ultimate drying shrinkage of OPC concrete containing coarse recycled aggregates shows lower or comparable shrinkage to corresponding OPC concrete.

Keywords: Drying Shrinkage, Recycled Concrete Aggregate

INTRODUCTION

Waste concrete is an unavoidable by product of concrete industry and construction. The most common sources are from demolished concrete structures, fresh batch leftovers, and waste concrete cubes that have been tested as compliance with building specification. This debris is usually thrown away causing environmental pollution. In some area in developed countries such as the United States, Europe and Japan natural aggregates is becoming scarce and bringing aggregates from far away places increases cost of concrete (Frondistou Yannas,1977). Since control of waste materials pollution is increasingly important, hence recycling these waste concrete materials seem inevitable solution. Although in Europe and other developed countries the recycling of buildings material started after the end of World War II (Buck 1977) it utilization was as means of solving an economic problem. Recycling as means of sustainable utilisation of materials did not actually start until fairly recently.

Researchers have tried to relate the quality of recycled aggregate concrete to the properties of the original concrete and paste, deterioration condition of the old concrete, crushing procedure, and the new mix composition; their findings have been extensively reviewed and discussed by Hansen (1992). It is generally accepted that the cement paste from original concrete that is adhered to the recycled aggregate plays an important role in determines the performance of recycled aggregate concrete.. A major problem in using recycled aggregate is the increase in drying shrinkage. Previous investigators have found that drying shrinkage of recycled aggregate concrete shows higher amount of shrinkage to corresponding natural aggregate concrete (Takavoli et al,1996, Ravindrajah et al,1985 and Hansen et al 1985).

Most researcher have taken the absorption of the recycled aggregate into account when designing the concrete mix proportion and this has lead to obtain higher shrinkage. The present study has omitted this and tried to find out the effect it has on the drying shrinkage of the OPC concrete containing the recycled aggregates.

In Malaysia, very little is known about the use of recycled aggregate in manufacture of new concrete. This is probably due to the lack of knowledge about the behaviour of the material under local conditions. Therefore, the main thrust of this investigation, which is part of a compressive study,as reported by Ridzuan at el (2000),Ridzuan et al (2001) and Ridzuan et al (2002), to evaluate recycled aggregate concrete made from waste concrete cubes that has been exposed to local climatic conditions for use as coarse aggregate in new concrete, as such material is likely to provide both environmental and economic advantages. In this study, an investigation has been carried out to quantify properties of concrete made by fully replacing natural coarse aggregate with coarse recycled concrete aggregate. The properties investigated were aggregate characteristic, workability, and drying shrinkage.

MECHANISM OF DRYING SHRINKAGE

The shrinkage or swelling of concrete member may be attributed to a number of factors such as by the settlement of solid, loss-of –free water from the plastic (plastic shrinkage) or by chemical combination of cement with water (autugenous shrinkage), but the primary concern here is drying shrinkage due to moisture loss in hardened concrete. Starting from saturated conditions, the relationship between free drying shrinkage and moisture loss is accompanied by relatively small amount of shrinkage in the second phase, an increased shrinkage rate is observed (Konishi et al, 1988). The early shrinkage is generally attributed to moisture loss from the capillary pore and subsequent shrinkage to moisture loss in cement gel. After an initial rate of drying shrinkage the concrete will continues to shrink for long period of time but at a continuously decreasing rate.

EXPERIMENTAL DETAILS

Materials

The materials used in this study are ordinary Portland cement in compliance with MS 522, river sand, tap water and coarse aggregate, which comply with BS 882: 1992. Waste concrete used in this study were concrete cubes brought from neighboring construction, which send concrete cubes for compressive strength testing at 7 and 28 days as a compliance with construction specification. The range of the design strength of these cubes is between 25 and 30 N/mm^2 and of age more than 2 years. These cubes were first broken into smaller pieces by the help of crushing machine and than into smaller pieces in a jaw crusher to produce recycled concrete aggregate of nominal maximum size of 20mm. The crushed product was than sieve in to 20mm and 10mm fraction. The 20mm and 10mm coarse aggregate for the concrete mix were than combined in the ratio of 2:1 respectively for both natural and recycled aggregate concrete mix. The grading of the aggregates is as shown in Table (1 – 2) in accordance to BS 882 Part 3: 1985.The physical properties of all the aggregates in term of specific gravity, bulk density, aggregates impact and crushing values, and water absorption are presented in Table 3 in accordance to BS 1881.

Mix Design

The design strength chosen for the concrete mixes at 28 days were 30, 35, and 40 N/mm^2. This covered the range of design strength that is commonly used in practice. Two sets of mixes were prepared one for natural aggregates concrete and recycled aggregate concrete. The water cement ratio of the mixes range from 0.55 to 0.64. In this study the absorption of both types of aggregates were not taken into account. Since there is no existing standard method of designing concrete mixes incorporating recycled aggregate the recycled aggregates concrete mixes were derived simply by replacing the natural coarse aggregate proportion in the natural aggregate concrete mix, design using DOE method, with recycled coarse aggregate. All the concretes were mixed in a 0.04 m^3 horizontal pan mixer. The concrete mixing procedures were carried out in accordance with BS 1881: Part 108. The mix design proportion is shown in Table 4. Six concrete mixes were prepared namely NAC 30, NAC 35, NAC 40, RAC 30, RAC 35, and RAC 40,. The denotation indicate that for NAC 30 the concrete mix is of natural aggregate concrete of designed strength $30N/mm^2$, and for RAC 30 this means recycled aggregate concrete of designed strength $30N/mm^2$.

Casting And Curing of Specimens

For each concrete mix 2 nos. of 75 mm x 75mm x 258mm prism were made in standard steel moulds. After 24 hours of moulding, the prism were kept to drying in the laboratory environment of 29°C and 65% RH.

Shrinkage Measurement

The shrinkage strain measurement was made on longitudinal side of a prism over 200mm-gauge length with a demountable mechanical strain gauge. At any time, the average of four reading taken in two identical prism. The shrinkage measurement was continued for a period of 270 days.

RESULTS AND DISCUSSION

Workability

The freshly mixed concrete mixes were tested immediately after mixing for workability using slump tests. The test result showed that the natural aggregates concrete mixes show better workability with slump of 75mm then recycled aggregate concrete mix (RAC) with slump measurement ranging between 40 – 60mm.

Drying Shrinkage

Figure 1 and figure 2 show the results of drying shrinkage development of both OPC concrete without and with coarse recycled concrete aggregate respectively. The OPC concrete results shows that the drying shrinkage increases as strength of the concrete increased but this was not reflected by the OPC concrete containing coarse recycled concrete aggregate. For both type of concrete the concrete shrink with high rate up to 90 days and slow down subsequently after that. After 120 days drying shrinkage seems to be constant. Compared with the OPC concrete, the OPC concrete containing coarse recycled concrete aggregate show lower or comparable shrinkage. This could be attributed to the high absorption of the recycled aggregate which left less water for the cement gel to lose moisture.

CONCLUSION

Within the range of concrete normally used for construction purposes, it may be deduced that OPC concrete made with coarse recycled concrete aggregates and river sand :

- Exhibit lower or comparable drying shrinkage to the corresponding OPC concrete.
- The percentage ultimate drying shrinkage for OPC concrete range between 14-23% while for the OPC concrete containing coarse recycled concrete ranges between 8-14%.

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TABLE 1: Sieve Analysis Of Fine Aggregate (NATURAL SAND)

Sieve Size	Percentage Passing %
5.00mm	96.2
2.36mm	82.5
1.18mm	50.9
600μm	20.9
300μm	3.6
150μm	0.7
pan	0.0

TABLE 2: Sieve Analysis of Coarse Recycled Concrete Aggregate (RA) and Coarse Natural Aggregate (NA).

Sieve Size (mm)	RA(20mm) % Passing	NA(20mm) % Passing	RA(10mm) % Passing	NA(10mm) % Passing
37.5	100.0	100.0	100.0	100.0
20.0	100.0	99.92	100.0	100.0
14.0	65.0	97.83	69.35	99.41
10.0	32.5	80.27	30.96	98.47
5.0	2.5	30.36	2.36	28.74
2.8	0.0	18.94	0.09	8.42
pan	0.0	0.0	0.0	0.0

TABLE 3: Physical Properties Of Aggregates

Type of Aggregate	Specific Gravity			Loose Bulk density kg/m^2	Aggregate Impact Value %	Aggregate Crushing Value %	Water absorption %
	SSD	Oven dried	App				
Natural Agg	2.55	2.52	2.60	1390	16.5	16.0	1.35
Recycled Agg.	2.31	2.23	2.41	1255	31.4	31.0	3.3

TABLE 4: Mix Proportions For OPC Concrete With (RAC) and Without Coarse Recycled Concrete Aggregate (NAC)

Mix	Cement Kg/m3	Water Kg/m3	Aggregate kg/m3 20mm NA RA	Aggregate kg/m3 10mm NA RA	Sand	Water Cement
NAC30	320	205	537	268	1065	0.64
NAC35	355	205	550	275	1010	0.58
NAC40	375	205	570	285	960	0.55
RAC30	320	205	537	268	1065	0.64
RAC35	355	205	550	275	1010	0.58
RAC40	375	205	570	285	960	0.55

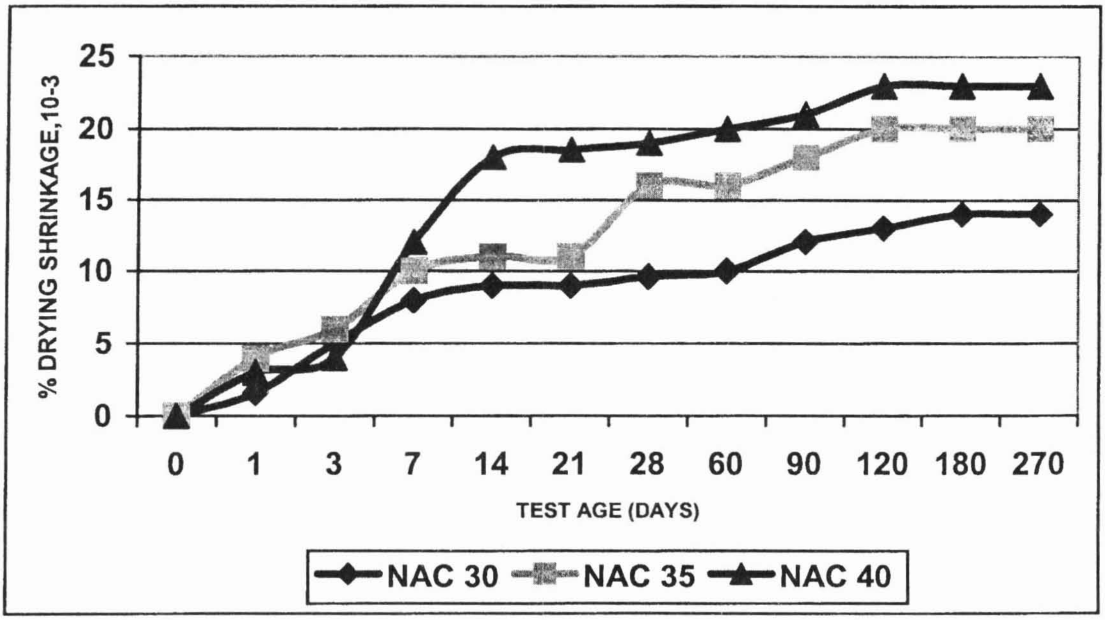

Figure 1 : Drying Shrinkage of OPC Concrete

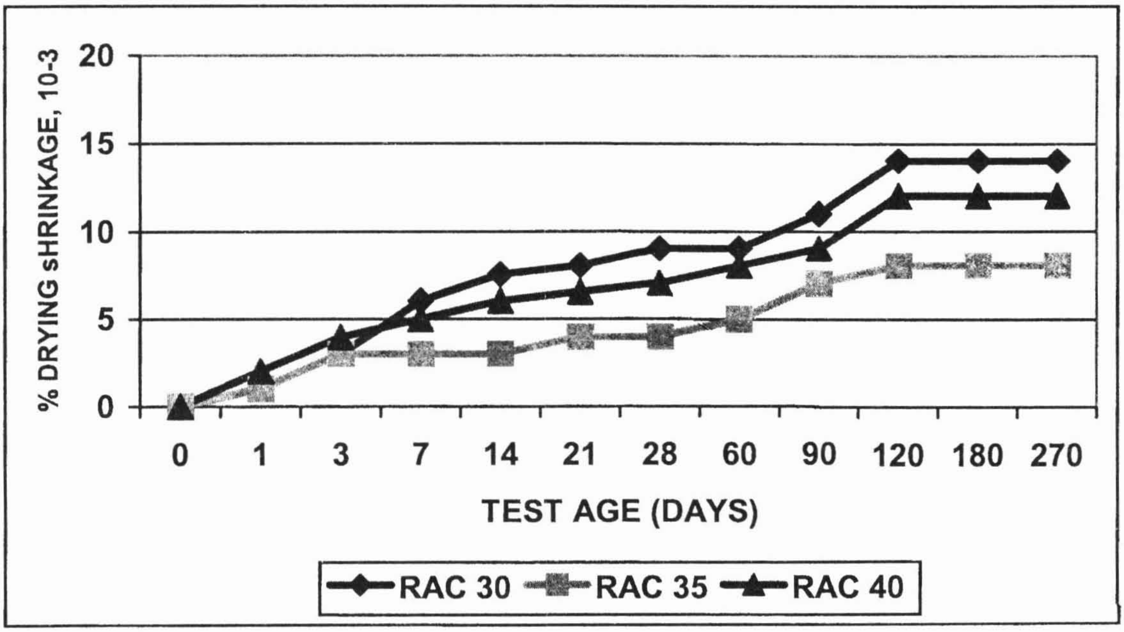

Figure 2: Drying Shrinkage of OPC Concrete Containing Coarse Recycled Concrete Aggregate

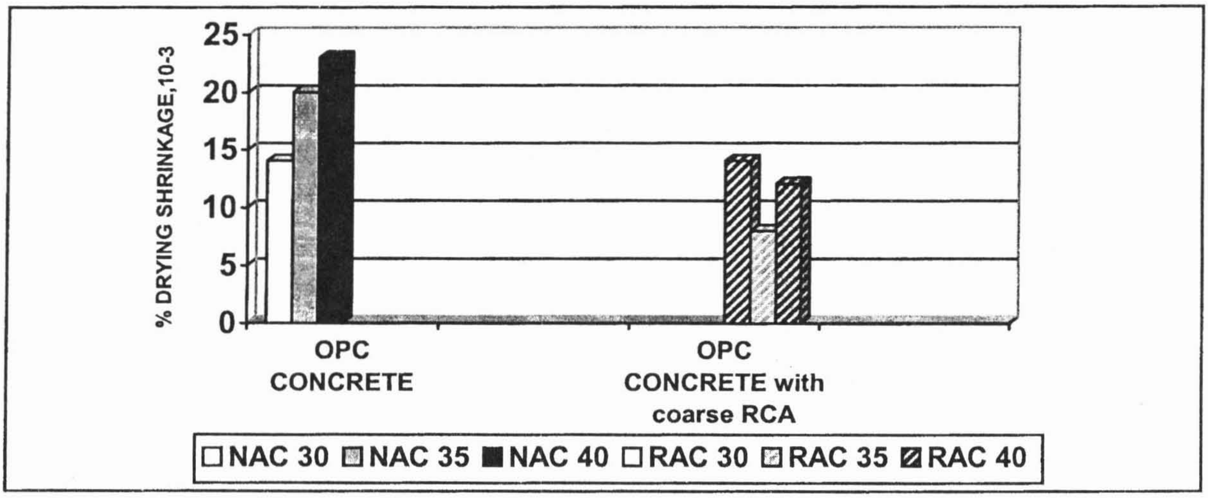

Figure 3: Ultimate Drying Shrinkage of OPC Concrete and OPC Concrete with coarse RCA.