Experimental Study On Some Hardened Properties Of Air Entrained Recycled Aggregate Concrete

Akinkurolere Olufunke Olanike

Abstract: The use of recycled aggregate as a replacement for natural aggregates has been known for a number of years. The future benefits of using recycled aggregate cannot be overemphasized. This study was an attempt to evaluate some hardened properties if Air Entrained Recycled Aggregate Concrete. In order to minimize the number of samples required per experiment, Taguchi orthogonal optimization technique was adopted for this investigation. In this technique, only a few combination values of control factors required were chosen. The theory behind this technique, which needs to consider both the process of designing the experiment and the way of statistically analyzing the experimental data of response, is based on the usage of the orthogonal arrays, the analysis of variance (ANOVA), and the significance test with F statistics. Also, signal (S) to noise (N) ratio (S/N) were also applied in the analysis. The objective of S/N analysis is to determine the most optimum set of the operating conditions from variations of the influencing factors within the results. The influence of the order of materials used in concrete production (made with recycled aggregates) with respect to compressive and flexural strengths were analyzed and discussed. The results indicate that the higher the air contents the lower the compressive and tensile strengths, respectively.

Keywords: Air-entraining agent, compressive strength, flexural strength, recycled aggregate concrete.

1 INTRODUCTION

Aggregates obtained from recycled concrete are known as recycled concrete aggregates and are produced by the crushing of original concrete; such aggregates can be fine or coarse recycled aggregates. Recycling waste concrete as source for the production of new concrete can help control environmental pollution and the problem of depleted natural aggregates. The physical properties of recycled aggregates depend on both adhered mortar quality and the amount of adhered mortar. The adhered mortar is a porous material; its porosity depends upon the w/c ratio of the recycled concrete employed [1]. The crushing procedure and the dimension of the recycled aggregate have an influence on the amount of adhered mortar [2], [3], [4]. Recycling waste concrete as source for the production of new concrete can help control environmental pollution and the problem of depleted natural aggregates. Also, recycling of waste concrete is beneficial and necessary from the viewpoint of environmental preservation and effective utilization of resources. For effective utilization of waste concrete, it is necessary to use waste concrete as recycled aggregates for new concrete Jianzhuang *et. al*. [5]. Entraining air is the intentional creation of tiny air bubbles in concrete. Air-entraining agents are admixtures used to stabilize the air entrapped during the mixing in the form of very small, discrete bubbles known as entrained air. The use of air entrainment usually is recommended for nearly all concretes, most importantly to improve freeze-thaw resistance when exposed to water and deicing chemicals.

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However, there are other important benefits of entrained air in both freshly mixed and hardened concrete. Besides the increase in freeze-thaw and scaling resistances, air-entrained concrete is more workable than non-entrained concrete. The use of air-entraining agents also reduces bleeding and segregation of fresh concrete [6], [7], [8], [9], [10], [11].

2 METHODS

All concrete mix designs used in this investigation were calculated using absolute volume method. The mix designs with orthogonal arrays are presented in Table 1. All mixing was conducted under laboratory conditions using 100kg capacity concrete mixer in accordance with Chinese code. For each concrete mix, 100 mm cubes, 100 x 100 x 400 mm prisms specimens were cast [12].

TABLE 1
ORTHOGONAL ARRAY L_9 (3^4 SERIES) WITH FACTORS ASSIGNMENT

Test No.	Factors			
	W/C	RA (%)	FA (%)	Air Contents (%)
1	0.45	0	0	2.5
2	0.45	50	20	3.5
3	0.45	100	30	4.5
4	0.50	0	20	4.5
5	0.50	50	30	2.5
6	0.50	100	0	3.5
7	0.55	0	30	3.5
8	0.55	50	0	4.5
9	0.55	100	20	2.5

All specimens were cast into plastic moulds and compacted using a vibrating table. In this study, moist room, also known as Fog room curing was used. For the fog-room cured specimens, the specimens were cured in air in a vibration free environment for a period of 24-48 hours before they were demolded. After demolding, they were then transferred to fog room having a temperature of 20±3 °C and relative humidity (RH) of no less than 95% until test ages were reached. Figures 1 a and b show pictures of some of the samples on the vibrating table and some as arranged in the fog (moist) room respectively.

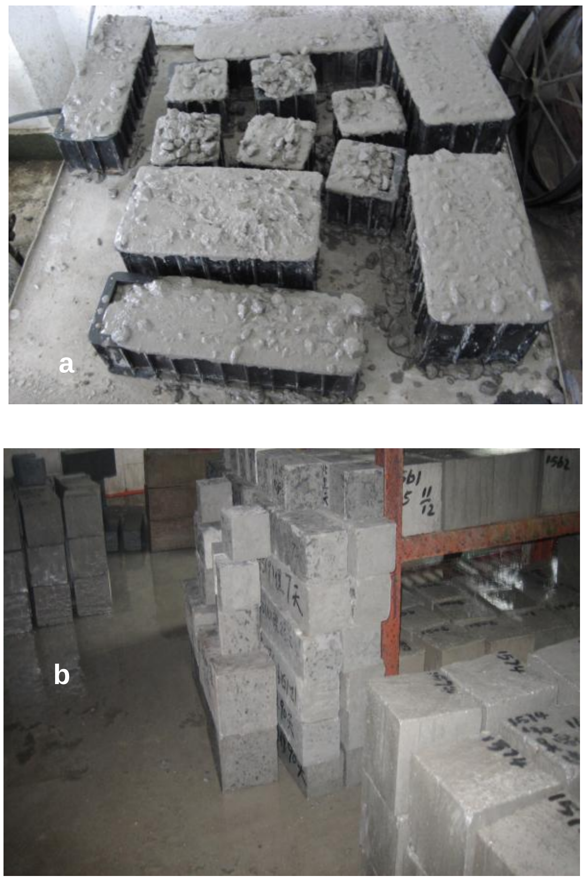

Fig. 1 (a) some concrete samples on the vibrating table **(b)** some concrete samples in the fog (moist) room.

Compressive strength flexural strength tests were carried on standard 100mm concrete cubes and 100 x 100 x 400 prisms twenty-eight days after initial curing respectively. Orthogonal arrays can be traced back to Euler's Graeco-Latin squares, but in Euler's time they were known as a type of mathematical game. The idea of using orthogonal arrays for the design of experiments was studied independently in the United States and Japan during World War II [13]**.** Dr. Taguchi started to develop new methods to optimize the process of engineering experimentation in Japan after World War II. He developed techniques which are known as the Taguchi method. With this method, which can be applied easily by the researcher, the results obtained are able to be standardized. Standard tables known as orthogonal arrays (OA) are used for the design of the experiments in the Taguchi method. Dr. Genichi Taguchi's approach to finding which factors affect a product in a Design of Experiments can dramatically reduce the number of trials required to gather necessary data. OA are a special set of Latin squares, constructed by Taguchi to lay out the product design experiments. By using this table, an orthogonal array of standard procedure can be used for a number of experimental situations. Taguchi Orthogonal Array table with three levels and three factors was used to prepare the mixing proportions, and Analysis of Variance and significance test with F statistic were used to check the existence of interaction and level of significance. The influence of the order of materials used in concrete production (i.e. concrete made with recycled aggregates) with respect to compressive and flexural strengths were analyzed and discussed. Figures 2 a-c show the experimental set-ups.

3 DISCUSSION OF RESULTS

The strengths and the ratios of compressive strength development of the recycled concrete for the nine sets of tests are presented in table 2, from the table, water-cement ratios and percentage volume of recycled aggregates contributed greatly to the strength development of the sample, with the highest S/N ratio for both strengths test corresponding to the lowest water cement- ratio of 0.45 and also zero percent recycled aggregates replacement. The orthogonal analysis in table 3 also confirms the above assertion. However, percentage of air contents also had an effect on the strength developments, with the strength reducing with increase in air content.

Fig. 2 (a) Test set up for compressive strength of concrete cube specimens **(b)** Three-point loading flexural testing device and set-up **(c)** Air content test by pressure method

TABLE 2
L9 (3^4 SERIES) ORTHOGONAL ARRAYS RESULTS FOR THE FREEZE-THAW SAMPLES

Test No.	**Average 28-day compressive strength f_c(Mpa)**	**S/N ratio of average compressive strength**	**Average 28-day flexural strength f_f(Mpa)**	**S/N ratio of average 28-day flexural strength**
1	47.53	33.52	5.11	14.17
2	43.84	32.84	4.11	12.25
3	39.7	31.97	3.76	11.5
4	38.91	31.8	3.56	11
5	38.29	31.66	3.45	10.75
6	37.02	31.37	3.21	10.13
7	34.12	30.66	3.15	9.94
8	33.28	30.44	3.1	9.82
9	32.52	30.24	3.03	9.52

TABLE 3
L9 (3^4 SERIES) ORTHOGONAL ANALYSIS FOR COMPRESSIVE AND FLEXURAL STRENGTHS OF FREEZE-THAW SAMPLES

	Factors	**E1**	**E2**	**E3**	**R**
28- Day Compressive Strength f_c(Mpa)	W/C	43.69	38.07	33.31	10.65
	RA	40.19	38.47	36.41	3.78
	FA	39.28	38.42	37.37	1.91
	AC	39.45	38.33	37.30	2.15
28- Day flexural strength f_f(Mpa)	W/C	4.33	3.41	3.09	1.24
	RA	3.94	3.55	3.33	0.61
	FA	3.81	3.57	3.45	0.36
	AC	3.86	3.49	3.47	0.39

*E1, E2, E3, E4 – Average effect of three factors at levels 1, 2 and 3.
*R –Rank of significance among the factors.

4 CONCLUSION

At a given water-cement ratio, increasing the air content usually cause the porosity to increase, thereby decreasing the strength of concrete. However, there are other important benefits of entrained air in both freshly mixed and hardened concretes. Besides the increase in freeze-thaw and scaling resistances, air-entrained concrete is more workable than non-entrained concrete. The use of air-entraining agents also reduces bleeding and segregation of fresh concrete.

5 END SECTIONS

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