EFFECT OF COARSE GRAIN AGGREGATE ON STRENGTH PARAMETERS OF PREPLACED AGGREGATE CONCRETE

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ABSTRACT. Preplaced aggregate concrete (PAC) is special type of concrete that the method of its construction and implementation is different from conventional concrete. In PAC, coarse aggregate particles are first placed in the formwork and voids between them are subsequently injected with a special cementations mixture. PAC has been successfully used in many applications, such as underwater construction, casting concrete sections congested with reinforcement and concrete repair. PAC has a higher coarse aggregate content than that of conventional concrete. PAC can be considered as a skeleton of coarse aggregate particles resting on each other, leaving only internal voids to be filled with grout. Conversely, in normal concrete the aggregates are rather dispersed. Therefore, PAC has a specific stress distribution mechanism at which the stresses are transferred through contact areas between coarse aggregate particles. Coarse aggregate forms about 60% of the total volume of PAC, while coarse aggregate forms about 40% of the total volume of conventional concrete. In this research coarse aggregate size influence on strength parameters of PAC and comparing it with conventional concrete is done by uniaxial compressive strength test and Brazilian tensile strength test. According to results of tests in this research, the PAC with finest grain of coarse aggregate has higher compressive strength, higher tensile strength, higher modulus of elasticity and less poison ratio from conventional concrete.

Keywords: Preplaced Aggregate Concrete, Conventional Concrete, uniaxial compressive strength, tensile strength

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INTRODUCTION

The preplaced aggregate concrete (PAC) is made by placing the gravel into the mold and then filling the empty spaces between them by the mortar of sand and cement. Usually, emptying spaces between gravel are performed in two ways: weighing and injecting. In the weighting method, the mortar is poured on top of the mold filled with grit and, with the help of a compacting or vibrating, mortar fills the empty spaces. This method can be used in concrete with a maximum height of 300mm. In the injection method, by placing the injection tubes inside the mold, the mortar is injected into the mold by the pump and the injection tubes are gradually increased [1].

PAC differs from conventional concrete (CC) in several aspects. First, all ingredients of conventional concrete are mixed together and then placed in the formwork, while in PAC the grout ingredients are mixed separately and then injected into the pre-placed aggregate mass as mentioned earlier. Second, PAC has a higher coarse aggregate content than that of conventional concrete. PAC can be considered as a skeleton of coarse aggregate particles resting on each other, leaving only internal voids to be filled with grout. Conversely, in normal concrete the aggregates are rather dispersed. Therefore, PAC has a specific stress distribution mechanism at which the stresses are transferred through contact areas between coarse aggregate particles. Coarse aggregate forms about 60% of the total volume of PAC, while coarse aggregate forms about 40% of the total volume of conventional concrete [2,4].

Abdelgader (1999), through some experiments, presented an algorithm for designing PAC. Additionally, he determined the optimal water-cement and sand-cement ratios for manufacturing PAC, and concluded that a water-cement ratio of 0.47 and a cement-sand ratio of 1 produce the highest mortar quality [3]. Compared to conventional concrete, PAC is superior in economic and geomechanical aspects and is less probable to develop cracks [2,10, 11, 12].

Due to the fact that most of the PAC volume is precipitated from the gravel particles, coarse grain aggregate grading can have important effects on the mechanical properties of the concrete. Also, comparing the mechanical properties of PAC and CC can show the advantages and disadvantages of this particular type of concrete in comparison to CC. For this reason, in this study, two types of PAC and a CC were constructed and tested for 28 days of single-axial compressive strength test and Brazilian tensile strength test.

MATERIALS AND METHODS

In this research, to study the effect of coarse-grained particle size on PAC resistance and comparison with CC, two PAC types and one typical type of concrete, which were named PA1, PA2 and CC respectively, were constructed. In total, 75 test specimens were made of 150×300 mm for the various tests required. To determine the elasticity modulus and the Poisson coefficient from the test specimens, the cores were made and test specimens of 50-100mm were tested. Figure 1 shows the coring of a standard cylindrical test.

Figure 1. Coring of a standard cylindrical test.

In this study, coarse-grained aggregates, fine-grained aggregates, cement, and water were used to prepare the samples of PAC and CC. Additionally, expansion additives were used in the PAC mortar. Aggregates of similar origin obtained from the same mine were used in preparation of specimens for both PAC and CC. Moreover, the specific gravity of the aggregates used in the manufacture of PAC was 1.55 ton/m^3 and 1.61 ton/m^3 for PA1 and PA2. However, considering the differences in the grading and manufacture of PAC and CC, the grading of the consumed sand in preparation of specimens was different. Fig. 2 demonstrates the sand grading used in specimens. Moreover, the parameters of the gradation curve for the consumed aggregates in this study are given in Table 1. The aggregate softness module for PAC and CC were 2.21 and 3.47, respectively.

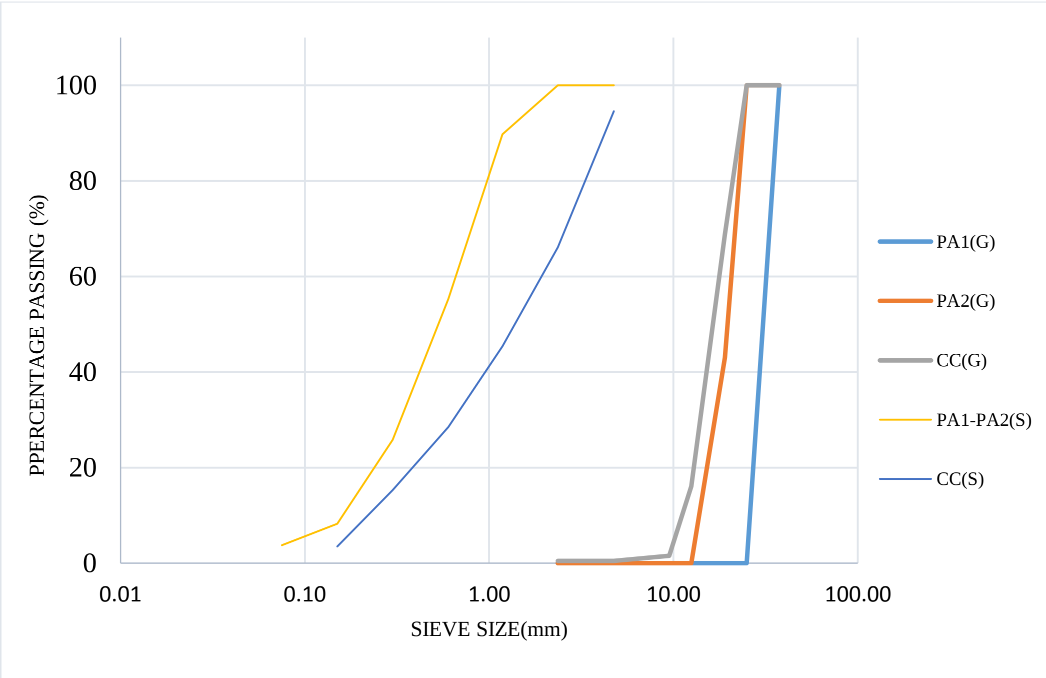

Figure 2. The gradation curve for the aggregates used in this study

Table 1. The parameters of the gradation curve for the consumed materials in this study.

	G*			S		
	PA1	PA2	CC	PA1	PA2	CC
D_{10}(mm)	27	15	12	0.17	0.17	0.22
D_{30}(mm)	29	17	15	0.33	0.33	0.63
D_{50}(mm)	30	20	17	0.53	0.53	1.4
D_{60}(mm)	32	21	18	0.66	0.66	1.9
C_u	1.19	1.4	1.5	3.88	3.88	8.64
C_c	1.03	1.09	0.96	1.03	1.03	1.05

Note: (G) gravel, (S) sand, (PA) preplaced aggregate concrete, (CC) conventional concrete, (D_{10}) the effective size of grain, (C_u) uniformity coefficient, (C_c) curvature coefficient,(G_{max}) the maximum grain size.

Type II cement and drinking water were used for preparation of all specimens. . The mixture ratios for different materials in 1 m^3 of PAC is given in Table 2. In order to prepare the mortar, the materials were mixed in a 30-liter mixer and were mixed for 4 minutes.

Table 2. The mixture ratios in 1 m^3 of the mortar used for PA1 and PA2.

W/C*	S/C	C (kg)	S (kg)	W	EA/C
0.5	1	800	800	400	0.008

Note: (W) water, (C) cement, (S) sand, (EA) expanding admixture.

To prepare the PAC, 0.0053 m^3 of aggregates (equal to the volume of the mold) were placed in a cylindrical mold, the existing voids between which were filled by mortar with the help of vibrating table. The amount of consumed mortar in the PAC is equal to the void fraction. Consequently, 0.42 m^3 and 0.38 m^3 of mortar was used for PA1 and PA2 specimens. The steps involved in the preparation procedure is illustrated in Fig. 3.

Figure 3. The steps involved in the preparation procedure for PAC.

After their preparation, the PAC and CC specimens were placed and retained in the water in standard conditions. The amount of materials used per 1 m^3 of the PAC is calculated based on void faction and mortar mix plan. The mixture ratios for different materials per 1 m^3 of PAC and CC are given in Table 3.

Table 3. The mix design for the prepared specimens in this study.

Type of concrete	W/C*	G (kg)	C (kg)	S (kg)	W (kg)
PA1	0.5	1510	336	336	168
PA2	0.5	1610	304	304	152
CC	0.57	1225	300	630	170

Note: (W) water, (C) cement, (G) gravel, (S) sand, (EA) expanding admixture.

RESULTS AND DISCUSSION

In this study, to investigate the effect of coarse grain aggregate on PAC resistance and compare it with CC, uniaxial compressive strength tests and Brazilian tensile strength tests were performed on test specimens.

Compressive Strength

Uniaxial compressive strength test was performed on 30 150×300 mm standard cylindrical test specimens, including 10 test specimens of each type of concrete, and uniaxial compressive strength (σ_c) values for test specimens were calculated. Also, by centrifuging the cylindrical specimens, 10 test specimens of 50×100 mm from each test specimen were prepared. Using a strain gauge and performing a single-axial compressive strength test, the compressive strength (q_u), elastic modulus (E) and Poisson coefficient (υ) were also obtained for the test specimens. Figure 4 shows the test apparatus. Figure 5 compares the mean values of the uniaxial compressive strength of concrete specimens. Figure 6 compares the mean values of the modulus of elasticity of concrete specimens. And Figure 7 shows the mean values of Poisson's coefficient for concrete specimens constructed in this study.

Figure 4. Uniaxial compressive strength test on standard cylindrical test piece

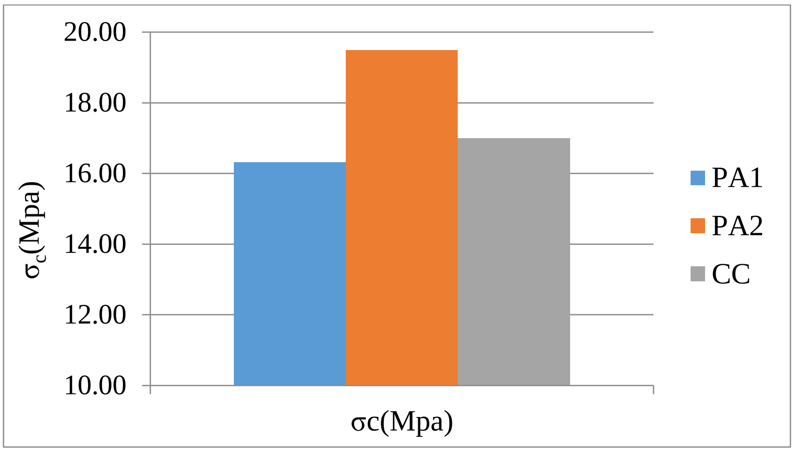

Figure 5. Comparison of the uniaxial compressive strength of standard test specimens

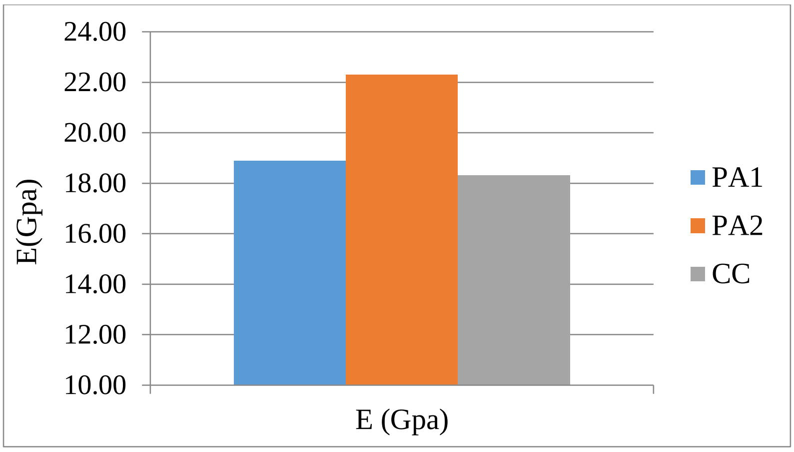

Figure 6. Comparison of modulus of elasticity of test specimens

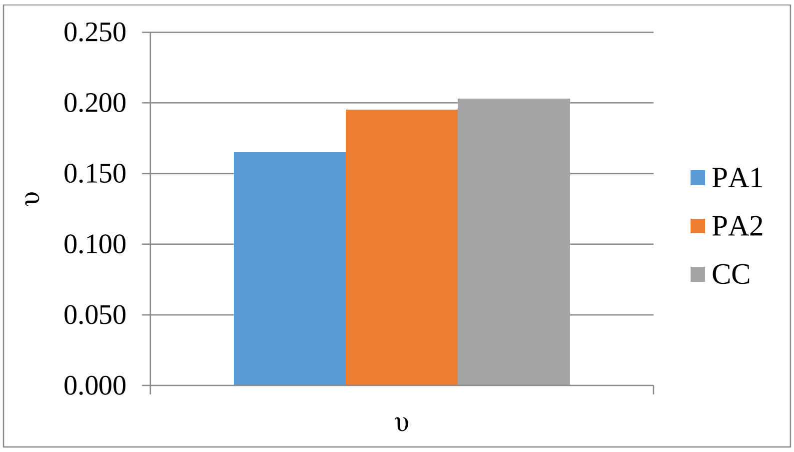

Figure 7. Comparison of the values of Poisson's ratio of test specimens

Tensile strength

The Brazilian tensile strength test was performed on 10 standard 150×300 mm cylindrical specimens of each type of concrete and the tensile strengths of the test specimens were calculated. Figure 8 shows the device used in this test. Figure 9 also shows the comparison of tensile strength values for different test specimens.

Figure 8. Brazilian test on standard cylindrical specimens

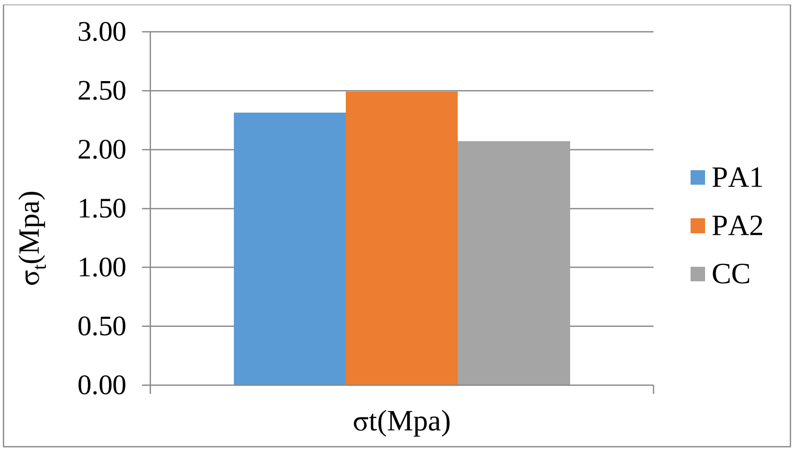

Figure 9. Comparison of tensile strength values of test pieces

The relationship between compressive strength and tensile strength

Based on the results obtained from the experiments and the drawing of the tensile strength curve based on the compressive strength, the equation (1) to (3) were obtained for PA1, PA2 and CC specimens, respectively. Figure 10 also shows the relationship between tensile strength and compressive strength in this study.

1) $$\sigma_t = 0.4945\sigma_c^{0.5529}$$

2) $$\sigma_t = 0.5463\sigma_c^{0.5112}$$

3) $$\sigma_t = 0.5251\sigma_c^{0.4847}$$

σ_t and σ_c respectively tensile strength and compressive strength of the concrete.

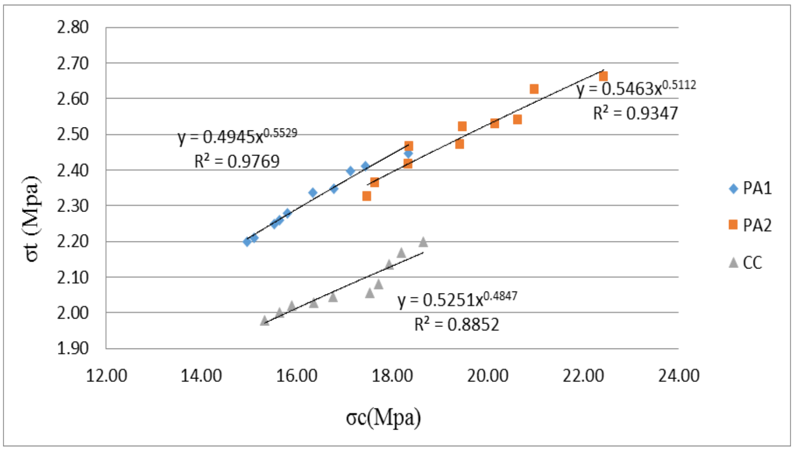

Figure 10. The relationship between compressive strength and tensile strength

By combining the results of PA1 and PA2 test specimens and drawing the tensile strength and compressive strength curve, the relationship between compressive strength and tensile strength in PAC was obtained in accordance with equation (4). Figure 11 shows the relationship between the compressive strength and tensile strength in PAC.

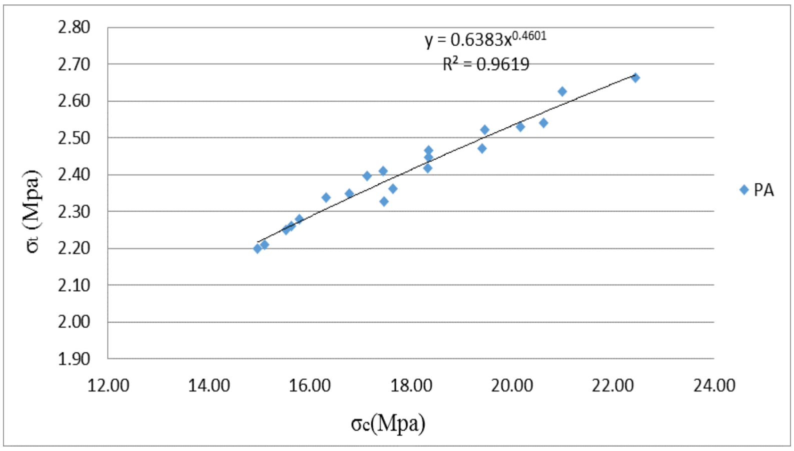

Figure 11. The relationship between compressive strength and tensile strength for PAC

4) $$\sigma_t = 0.6383\sigma_c^{0.4601}$$

CONCLUSION

According to the experiments carried out in this study, it can be concluded that coarse grain aggregates play a very important role in the preplaced aggregate concrete resistance parameters. The fine grained gravel increases the compressive strength, increases the tensile strength, increases the elastic modulus, and reduces the PAC Poisson's coefficient. Using finer gravel, the PAC compressive strength was 1.15 times higher than that of conventional concrete. The modulus of elasticity of PA2, 1.22 times the CC. The tensile strength of the PAC with finer aggregate was also 1.2 times higher than that of CC. The Poisson ratio of PAC of the second type was 0.96 times the CC. According to the results, PAC with suitable mix selection has higher resistance properties than CC and can withstand higher compressive and tensile strengths than CC.

Due to the increasing use of concrete and the fact that preplaced aggregate concrete can be technically and economically better than conventional concrete, it is recommended to apply applied research in this subject.

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