The Influence of Granite Size and Workability on the Compressive Strength of Continuous Flight Auger Pile Concrete

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ORIGINAL RESEARCH

Abstract— Concrete achieving 30N/mm² in Continuous Flight Auger (CFA) concreting is a challenge due to coarse aggregate size and the required workability of the concrete for easy pumping. This study investigated the impact of workability and coarse aggregates on the compressive strength of Continuous Flight Auger concreting. Aggregates sizes of ¾ and ⅜inches were used for the experiments and the slump value for the mix ratios were set in range 145 to 190mm. Three mix ratios; 1:2:4, 1:1.5:3 and 1:1:2 was adopted and mix composition was done by volume method based on what is expected on construction site. Twelve (12) cubes (150x150mm) of each type of coarse aggregate with and without superplasticizers (strength enhancement, and retarder) for the various mixes were cast for 7, 21, 28 and 58 days to determine their compressive strengths. Granite sizes ¾ and ⅜with mix ratio 1:1:2 was found to attain the targeted strength without admixtures, whereas the ¾ inches aggregates for all the mixes with the two admixtures exceeded the targeted strength with at least 13 percent. Hence, concrete of Grade C30 is achievable for CFA pile concrete without using admixture.

Keywords— Compressive strength, concrete, continuous flight auger, superplasticizer, water cement ratio

1 INTRODUCTION

Deep foundations such as piles help to transfer the structural loads of engineering structures into higher competent strata located at deeper depths when shallow foundations become impractical due to weak engineering soils(Harte & Flanagan, 2011; Reul, 2015). The use of Continuous Flight Auger (CFA) piles is expanding in the Nigerian construction industry as it is considered the most appropriate for the different ground conditions with a variety of diameters and depths. CFA piles are constructed by drilling a continuous flush auger into the required depth and pumping concrete down through the hollow center of the auger while it is gradually withdrawn (Zayed, 2009). The speed and efficiency of this type of construction can provide great advantages to engineers for many types of projects (Brown et al., 2007; Hol'ko and Stacho, 2014).

The characteristics strength of concrete continues to be the most crucial aspect of structural concrete from an engineering perspective. The strength of the concrete is determined by the quality of raw materials, water/cement ratio, coarse/fine aggregate ratio, age of concrete, compaction of concrete, temperature, relative humidity and curing of concrete (Viacava, et al., 2012; Hong, et al., 2023). The relation between concrete composition and mechanical properties has long been a matter of research interest. In underwater concrete, hardened concrete is affected by water infiltration during concreting. Concrete strength is found to reduce when there is washout loss of cementitious phase together with relative increases in

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cementitious phase together with relative increases in aggregate concentration (Vanhove and Djelal, 2020).

It is commonly known that aggregates, particularly coarse aggregate, have a significant impact on the strength and caliber of concrete used in building (Corinaldesi, 2010; Kou and Poon, 2009, Tangadagi, et al., 2021, Alqarni, et al., 2020). Coarse aggregate typically occupies over one-third of the volume of concrete, with research showing that changes in the quality of coarse aggregate can affect the strength and fracture properties of concrete produced (Aminulai, et al., 2020). Many types of coarse aggregates have been utilized in concrete production (Etxeberria, et al., 2007; Zega and Di Maio, 2009, Dahunsi, et al.,2022). Concrete made with hundred percent coarse recycled aggregate was found to require high amount of cement to achieve a high compressive strength. Recycled aggregates should be used in concretes with low–medium compression strength (20–45 MPa) (Aminulai, et al., 2020). Aminulai et al., (2020) postulated that a well-graded coarse aggregate mix (size and volume) makes quality concrete with good workability and adequate strength. Conventional concrete with quartzitic coarse aggregate was found to perform better after heat treatment than recycled aggregates obtained from crushed waste concretes. Generally, it was discovered that aggregates play an important role in governing mechanical properties of high strength concrete (Alexander, et al., 1992).

Chemical admixtures are substances that, when applied in small quantities, can drastically change the macroscopic properties of cement and concrete. It ensures quality of concrete during mixing, transporting, placing, curing and overcome certain emergencies during concrete operations (Pereira, et al., 2012). Retarders and strength enhancement admixture were used for this research. Retarding admixture slows down the process of hydration so that concrete remains plastic and workable for a longer time. The mechanisms by which superplasticizers increase the workability of concrete, and the various forces working with the interface of the cement have been fully discussed in literature (Flatt, et al., 2000).

During pile-driving operation using CFA (Fig 1), the rheological characteristics of the concrete have a significant impact on how low the reinforcing cage enters the concrete. The workability of the concrete is expected to be high so as to allow grout/concrete to be pumped under pressure through a hose to the top of the rig and delivered to the base of the auger via the hollow center of the auger stem. The need to place reinforcement within the pile after placement of the grout also influences the high workability expected. In addition, the size of the granite used for the mix is small, most times ¾ and ⅜ inches of granite to allow for easy pumping and reduced risk of clogging (Brown et al., 2007; Vanhove and Djelal, 2020, Akinyele et al., 2018). These two constraints; workability and granite sizes will have effect on the characteristic's strength of the concrete. Consequently, the aim of this work is to investigate the influence of granite sizes and workability on compressive strength of continuous flight auger concrete.

Fig. 1. Continuous Flight Auger machine.

2 Materials and Method

2.1 Materials

For these investigations, cement, fine aggregates, coarse aggregates, and admixtures were utilized as materials.

2.1.1 Cement

Ordinary Portland cement of grade 42.5 was used in this work to satisfy the requirements in BS 12 (1996) and NIS 444 (2003).

2.1.2 Coarse aggregates

A locally procured nominal size aggregate of a ⅜inches and ¾ inches was used as coarse aggregate in this experimental program as shown in Fig 2(a) and Fig 2(b). The sieve analysis and specific gravity were evaluated by the procedures given in Standard Specifications BS EN 1097-6:2013. Aggregates were sieved through a set of sieves to obtain sieve analysis as per the procedure given in BS EN 933-1:2012.

2.1.3 Fine aggregates

Fine aggregate was locally sourced from Ogun River Basin, Nigeria (Fig. 2(c)). Following BS 882 (1992), the sand was dried, sieved through a 2.36 mm sieve, and treated.

Fig. 2. Aggregates used for the experiment (a) sample ¾ of coarse aggregates (b) sample of ⅜coarse aggregates (c) fine aggregates

2.1.4 Water

The water used for mixing and curing the concrete was portable tap water, free from impurities such as organic matter, acid, silt, alkaline, salt, etc.

2.1.5 Admixtures

The admixtures used are COSTAMIX200MH and Master Rhebuild561M.The Costamix200 is a retarding superplasticizer admixture (delays setting time of concrete) and the MasterRhebuild561M is an admixture to increase strength of concrete.

2.1.6 Batching method

The method of batching applied in this research work is batching by volume. This was applied based on construction methodology that are normally used during CFA piling concreting operation in Nigeria.

2.2 Mixture Proportions

For this research work, the mix proportions used were; 1:2:4, 1:1.5:3, and 1:1:2 with various cement water ratio to meet the workability requirement of the CFA concreting works. For each mix, we have 4 sets of data; the control mix (concrete without admixture), mix with delay setting admixture (AD1), mix with strengthening admixture (AD2), and mixing the delay setting and enhanced strength admixture (AD3).

2.3 Experimental Investigations

2.3.1 Workability test

The slump test was carried out in accordance with the provisions of (BS EN 12350-2, 2019). The replacement of the superplasticizer was done at different rate depending on the admixture applied. For AD1, 0.65kg was applied per 50kg of cement, 0.7kg of AD2 per 50kg and AD1+AD2, half of each earlier mentioned was added simultaneously. The slump values were recorded for each mix as shown in Fig 3a.

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2.3.2 DENSITY AND COMPRESSIVE STRENGTH TEST

In accordance with BS EN 12350 Part 6 (British Standards Institution, 2000; BS EN 12390-3, 2009), tests on the density and compressive strength of 150x150x150 cube specimens were performed, respectively. Two hundred specimens, each measuring 150 by 150 by 150 cubes, were made. They were cured by submerging them in water from the time they were taken out of the molds, which was 24 hours after they were cast, until the testing period, when they were taken out of the curing water tank and allowed to air dry before their strength was evaluated. The cube specimens were subjected to density and compressive strength testing at 7, 21, 28 and 56 days of curing age. On a 600 kN Avery Denison Universal Testing Machine, each cube's compressive strength properties were measured at a loading rate of 120 kN/min (Fig 3b). Crushing three (3) specimens to failure was used to test each curing age, and the failure load was noted. The compressive strength was then calculated by dividing the average failure load of the three specimens by their area. The weight of every cube specimen was recorded at the time of the compressive strength test, and this information was subsequently utilized to compute the density.

3 RESULTS AND DISCUSSIONS

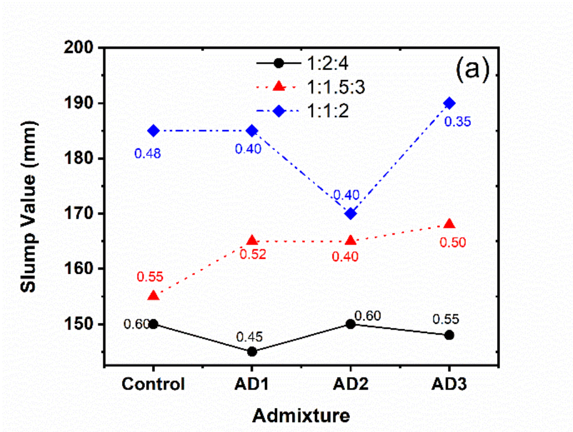
3.1. PRELIMINARY INVESTIGATIONS

The results for the sieve analysis for the aggregates shows that ¾ coarse aggregate has the uniformity coefficient (Cu) and curvature coefficient (Cc) of 1.83, and 1.52, respectively. ⅜granite has Cu and Cc of 1.80 and 1.09, respectively. The coarse aggregates can be classified as poorly graded. The sand has Cu and Cc of 6.67 and 3.10, respectively, hence can be classified as well graded.

Fig. 3. Experimental studies (a) Slump test (b) Compressive strength test

3.2. SLUMP

The workability of concrete, expressed in terms of slump, varied within the range from 140 mm to 190 mm due to the usage of admixtures dosages between 0.8-2.0 litre/ 100kg total cementitious material. These slump values were within the slump value range that was intended for this work, which is required if this investigation's findings are to be accepted as suitable for CFA piling concreting work. The slump values of all concrete mixes are shown in Fig. 4. The value of water cement ratio is indicated on the plot. It can be seen that slump value for 1:1:2 mix gave higher values than the other two mixes. This was noticed for both ¾ and ⅜inches granite sizes. The aggregates with higher volume required more water-cement ratio to make it workable. For example, the mix ratio 1:2:4 requires water-cement ratio of 0.9 to get the expected workability as compared to 1:1:2, whose water-cement ratio is 0.4. Water-cement ratio for ⅜aggregate was higher compared to the ¾ aggregates. The retarding admixtures lowered the water-cement ratio as compared to the increase in strength and an obvious variation in strength was noticed in comparison to other mixture. Generally, mixes with admixtures have higher slump values than the control mix.



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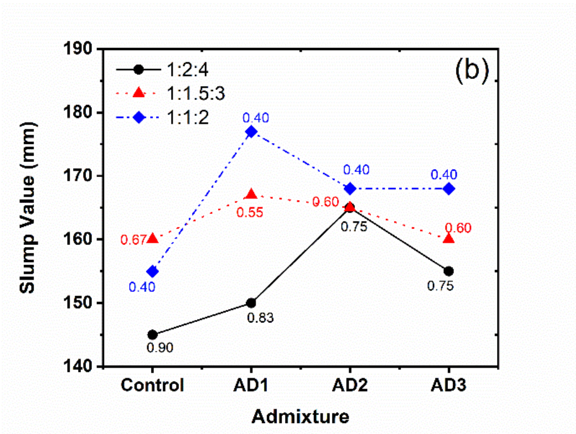

Fig. 4. Slump value for the three mixes (a) ¾ inches granite (b) ⅜ inches granite

3.3. Compressive Strength

The results of the compressive strength tests on the cube specimens are shown in Figs. 5–7. The average of three measurements is shown for each value. These figures show the relationships between the measured compressive strengths and the two aggregate sizes and the three mixes considered. The compressive strengths of all specimens, with and without superplasticizer, increased with curing age, as shown in Figs. 5 –7. It is expected that the strength-forming products of hydration will increase with the curing ages, as previously established (Dahunsi, et al.,2022). It can also be observed that the compressive strength of mixes without admixture tend to gain strength slowly as compared to mixes with admixture. For illustration, in 1:1.5:3 mix with ¾ inches granite, the 7-day strength for control mix, AD1, AD2 and AD3 are 9.7 N/mm², 22 N/mm², 20 N/mm², and 20.5 N/mm², respectively. However, at the 56-day strength, the difference between the concrete with and without superplasticizer has reduced (Pereira, et al., 2012). For the expected strength of 30 N/mm² at 28 days, 1:1:2 mix with ¾ and ⅜granites mixes achieved the expected compressive strength without admixtures. The values of 34.04 N/mm² and 30.66 N/mm² are obtained at control for the two granites sizes. However, from Figs 6 and 7, it can be noted that the targeted compressive strength was achieved at control for 56 days test for the 1:1.5:3 and 1:1:2 mixes for the two aggregates sizes.

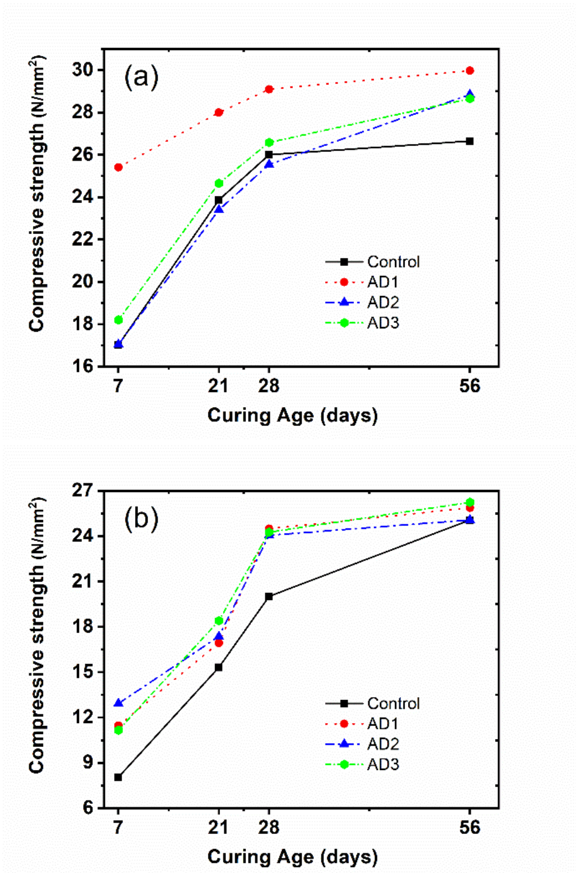

Fig. 5. Effect of admixtures on the Compressive Strength for 1:2:4 mix on (a) ¾ inches granite (b) ⅜inches granite

The addition of strength enhancement, delayed setting and the combination of the admixtures to the concrete revealed that 1:1.5:3 and 1:1:2 mixes can attain more than the targeted strength at 28 days. For example, addition of delay setting admixture (AD1) to 1:1:2 mix with ¾ size aggregate gave the maximum compressive strength of 42 N/mm² at 28-day test. The delay setting admixture gave the highest compressive strength for all the mixes and the two aggregates sizes. The performance of the two admixtures is noticeable in the enhancement of the compressive strength of the concrete for all the mixes. However, it effects is significantly noticed for 1:1:2 mix with ⅜aggregates sizes. The mix with admixtures (AD1, AD2, and AD3) has compressive strength of 39 N/mm², 38 N/mm² and 36 N/mm² respectively, whereas the control has compressive strength of 31 N/mm². The difference in compressive strength values for the concrete with admixtures are about 16 percent more than the control mix.

Test results revealed that the compressive strength gained for AD1, AD2 and AD3 at 56-day test is almost the same for all the mixes. Though, it was observed that admixture for AD 1 performed better than admixture for AD2. Combining two admixtures; retarding and strength enhancement superplasticizers to the concrete mixtures did not yield higher compressive strength as using only the retarding admixture.

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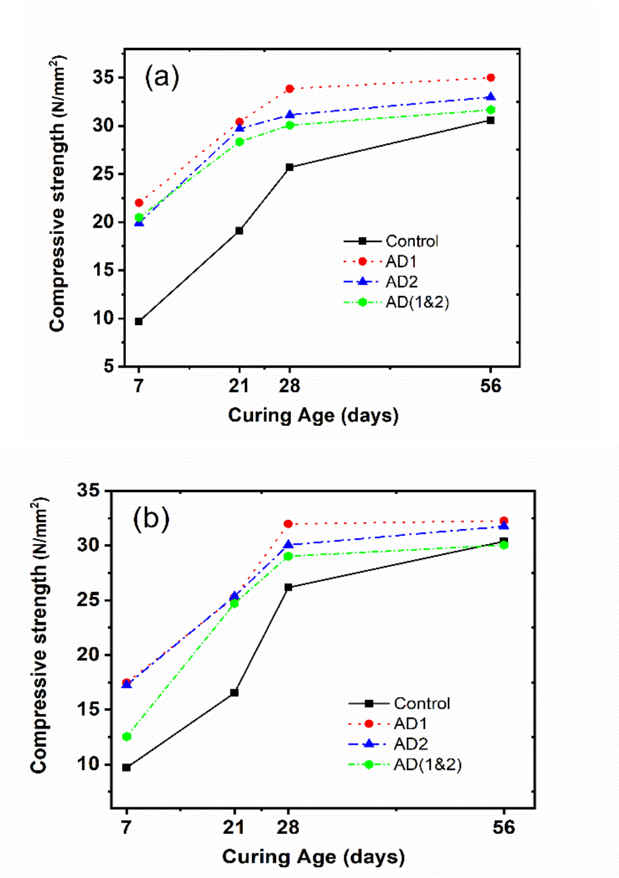

Fig. 6. Effect of admixtures on the Compressive Strength for 1:1.5: 3 mix on (a) ¾ inches granite (b) ⅜inches granite

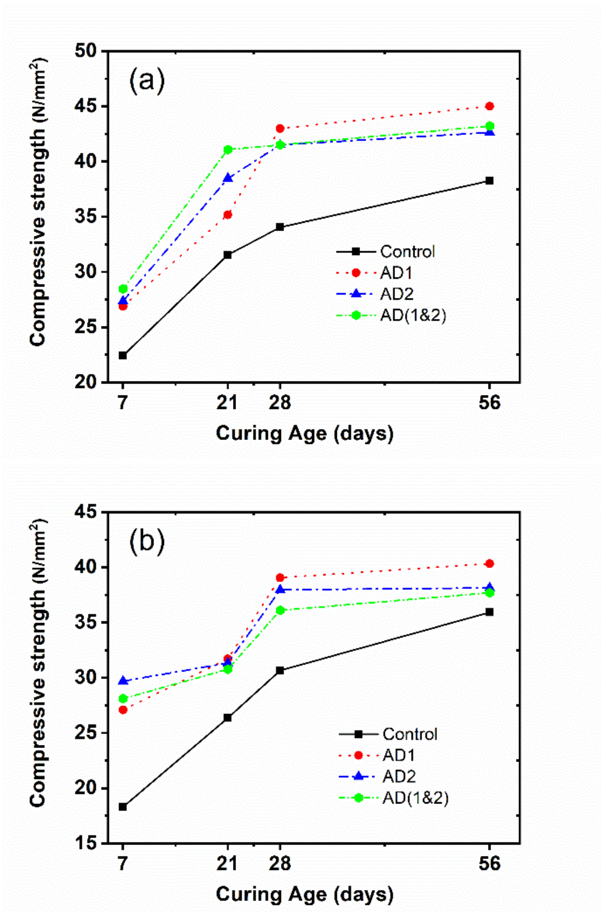

Fig. 7. Effect of admixtures on the Compressive Strength for 1:1:2 mix on (a) ¾ inches granite (b) ⅜inches granite

4.0 Conclusion And Recommendations

In this study, compressive strength of concrete made with two different sizes of aggregate with specified slump values has been investigated. The conclusions derived from this study are summarized as follows:

1. The slump value range (140 mm to 190 mm) expected to be obtained during CFA concreting works was achieved with the use and without superplasticizer for three different mix ratios.
2. Concrete mix of 1:1:2 made with ¾ and ⅜ coarse aggregates yielded 13% and 2% more than the targeted compression strength at 28-day. However, for the 56 -day strength, concrete mix 1:1.5:3 achieved the targeted strength without admixture.
3. The targeted strength for all mixes with the application of admixture was only achieved at 1:1.5:3 and 1:1:2 mixes.
4. Applying delay setting time admixture on the concrete improved the compressive strength more than the combination of strength improvement and delay setting time superplasticizer admixtures.

The slump value of the mix can also be increased to more than 190mm to ease the pumping of the concrete. Hence, there is need to try other mixes to ascertain the possibility of gaining 30N/mm². This is therefore recommended for future investigations.

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