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# The influence of cement fineness on the structural characteristics of normal concrete

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**Abstract.** This research presents the influence of cement fineness on the structural characteristics of normal concrete. The cement was divided into different fineness zones (150  $\mu\text{m}$  – 75  $\mu\text{m}$ , 75  $\mu\text{m}$  – 45  $\mu\text{m}$  and 45  $\mu\text{m}$  – 0  $\mu\text{m}$ ). Thirty (30 Nos.) cement mortar cubes, 54 Nos. of 150 x 150 x 150 mm concrete cubes and 36 Nos. of 150 x 300 mm cylinder specimens were cast, cured by immersion and tested at 3, 7, 14, 21, 28 and 45 days. A concrete mix ratio of 1:2:4 (Cement: Fine aggregate: Coarse aggregate) with water/cement ratio of 0.5 was used. The results reveal that an increase in the fineness of cement particle led to an increase in workability. The setting times (initial and final setting time) reduces progressively as the cement fineness is increased from 175mins (initial setting time) for sizes 150  $\mu\text{m}$  – 75  $\mu\text{m}$  to an initial setting time of 140mins for sizes 45 $\mu\text{m}$  - 0 $\mu\text{m}$ . The final setting time also reduces from 300 mins to 240 mins as the cement fineness is increased. The tensile and compressive strengths recorded an increase due to the increase in cement within the concrete matrix. It was concluded that the finer the cement particle the greater the concrete strength.

**Keywords** Cement fineness; Setting time; Workability; Structural strengths; Concrete.

## 1. Introduction

In Planet Earth, concrete been one of the most preferred choice of construction materials is a produce of the mixture of different constituents, that is fine aggregate, cement, coarse aggregate, water and admixtures. Among the various constituents, cement acts as a binding agent in producing concrete. The property of cement which regulates the level of grinding of cement clinker with gypsum in a milling machine is termed “fineness”. According to some researchers, the change in cement fineness has a direct impact to some key



properties of cement and concrete ranging from setting time, consistency and cement strength for cement while workability, tensile strength, compressive strength and flexural strength for concrete [1].

From the research work on the effect of cement fineness on the fresh state and rheological properties as well as the compressive strength of cementitious systems by [2]. A CEM I 42.5R Portland cement containing 7.92% C<sub>3</sub>A and sulphate resisting cement containing 3.58% C<sub>3</sub>A were used. The cements were ground to 4 different Blaine fineness, ranging from 2800 to 4500 cm<sup>2</sup>/g. In the absence of water-reducing admixture, the water requirement of mixtures increased with an increase in the cement fineness. Thus, a reserve behaviour was observed in the mixtures containing water-reducing admixtures which resulted to the improvement of the properties on concrete both in its fresh and hardened state. From the research work of [3] on the effect of Portland cement fineness and/or mean particle size on the heat of hydration using ASTM C186. The results indicate that for cements of the same mineralogy, increasing cement fineness and/or decreasing its mean particle size increased its heat of hydration. According to [4] finer cement hydrates more quickly and the hydration temperature increases more rapidly. Moreover, according to the same authors, the mixtures with low W/C ratio create a higher hydration heat rate at early hours, which is reduced later on. The maximum hydration heat was reported to be lower in the mixtures including high W/C ratios; however, the total hydration heat within the first 24 hours was found to be roughly the same, regardless of W/C ratio.

In the research carried by [5], the experimental results revealed that cement fineness had slight chemical effects on cement properties such as rapid setting, reduced compressive strength and higher autoclave expansion. The usage of various ultra-fine cement (Blaine fineness: 7800 cm<sup>2</sup>/g) would results to an increased density and their effects are noticeable in concrete produced with low water to cement ratio [6].

The effect of particle size distribution and surface area upon strength development of cement studied by [7]. It was observed that strength is a function of coarse aggregate more than fine aggregate and the fineness of cement has a great effect on the strength of cement. He concluded that some physical parameters like specific surface area and particle size distribution are curial in strength development. According to [8], finer cement consistently produces higher compressive and tensile strengths and this trend was attributed to the combination of its increased reactivity and the smaller interparticle spacing.

From experiment carried by [9], the results reveal that an increase in cement fineness led to an increased workability which caused an increased cohesion and reduced bleeding. He concluded that sticky concrete is a product of very fine cement. Thus, this research addresses the influence of cement fineness on the structural characteristics of normal concrete. A comprehensive experimental finding is presented with results for setting time, workability, compressive strength, cement strength and split tensile strength.

## 2. MATERIALS AND METHODS

### 2.1. Materials

To carry out the investigation, the following materials were used: cement, fine aggregates, coarse aggregates and water. Cement used was Ordinary Portland Cement (Grade 42.5R) produced in accordance with the standards [10, 11]. The water used for the experiment was portable water gotten from University of Lagos Water Corporation [12]. Sharp sand obtained from Ogun river basin located at Ibafo in Ogun State, Nigeria was used as fine aggregate [13]. The cement was sieved into different zones of cement particle sizes (between 150µm to 75µm, between 75µm to 45µm, and between 45µm to 0µm). A mix ratio of 1:2:4 by volume was used, and with a water-cement ratio of 0.50.

## 2.2. Methods

### 2.2.1. Physical Analysis of Materials

Laboratory tests carried out on the aggregates include particle moisture contents, size distribution, bulk densities, specific gravity and dry density.

### 2.2.2. Setting Time Test

The setting times (initial and final) were carried out according to standard [11].

### 2.2.3. Workability Test

The slump test was determined in accordance with the provisions of [14].

### 2.2.4. Compressive Strength Test

Compressive strength test was performed in accordance with [15, 16]. For the tests, 150x150x150mm cube moulds were used. The 54 cubes produced were cured and tested at 3, 7, 14, 21, 28 and 45-days for their compressive strength using Avery Denison Universal Testing Machine at a loading rate of 120kN/min.

### 2.2.5. Tensile Strength Test

The assessment of the tensile characteristics of concrete samples produced with different cement fineness, the split tensile strength test was conducted on 150x300mm concrete cylinder specimens in accordance with the provision of [17]. 36 concrete cylinders were tested at 3, 7, 14, 21, 28 and 45 curing ages. The splitting strengths were determined on 1500kN Avery Denison Universal Testing machine at a loading rate of 120kN/min until failure. The split tensile strength ( $T_s$ ) was then calculated as follows:

$$T_s = \frac{2P}{\pi ld} \quad (1)$$

In equation (1), ' $T_s$ ' is the split tensile strength ( $N/mm^2$ ), ' $P$ ' is the maximum applied load (in Newton) by the testing machine, ' $l$ ' is the length of the specimen (mm) and ' $d$ ' is the diameter of the specimen (mm).

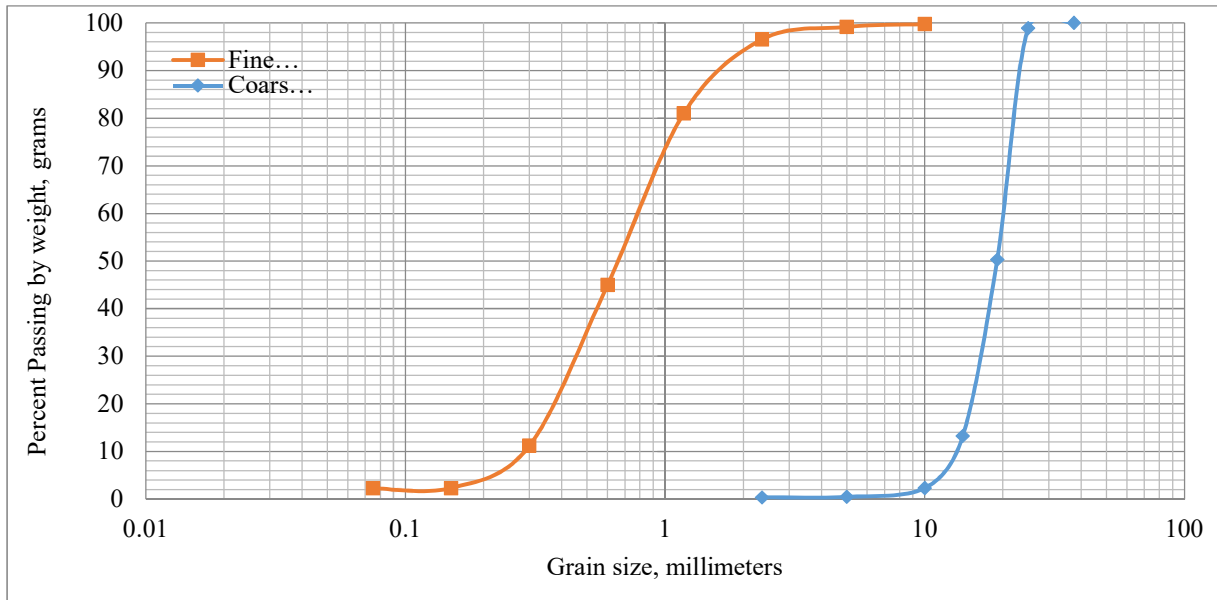
## 3. Results and discussions

### 3.1 Physical Properties and Sieve Analysis

The results of the preliminary investigation on some physical properties of cement and aggregates used, are presented in Table 1. The fine and coarse aggregates had uniformity coefficients ( $C_u$ ) of 2.86 & 1.43 respectively while they had a coefficient of curvature ( $C_c$ ) of 0.90 & 1.03 respectively thus indicating that the aggregates could be classified according to Unified Soil Classification with the fine aggregates as poorly graded medium to coarse sand while the coarse aggregates as well poorly fine to medium granite. Grading curves showed that the sand and granite were gaped graded. The grain size analyses of the materials (fine aggregates and coarse aggregates) used is presented in Figure 1.

**Table 1.** Physical Properties of Aggregates

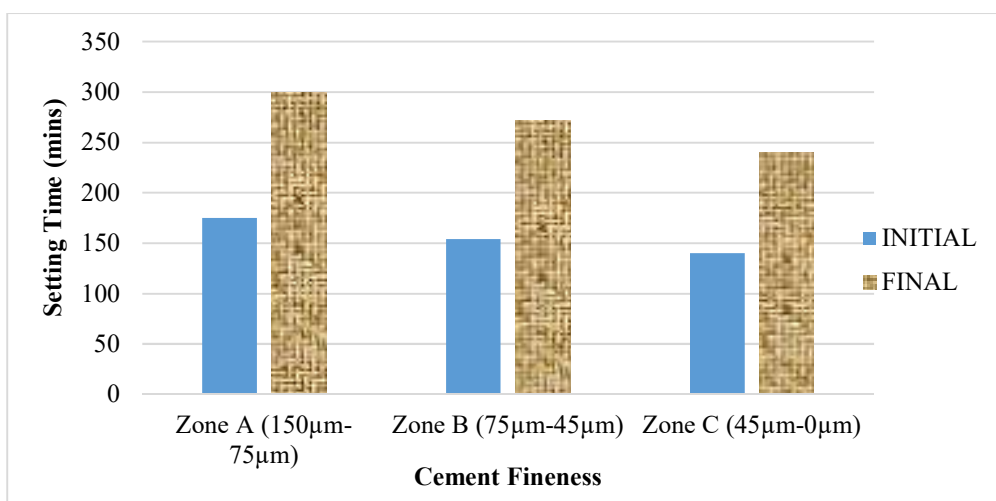
Physical Property	Sand	Granite
Coefficient of Uniformity ( $C_u$ )	2.86	1.43
Coefficient of Curvature ( $C_c$ )	0.90	1.03
Specific Gravity	2.63	2.66
Dry Density ( $Kg/ m^3$ )	153.30	63.45
Bulk Density (( $Kg/m^3$ )	1440.82	1567.06
Moisture Content (%)	8.40	1.42
Aggregate Crushing Value	-	22.12
Aggregate Impact Value	-	9.63



**Figure 1.** Particle Size Distribution Curves for Materials

### 3.2 Effect of Cement Fineness on Setting Time

Cement when mixed with water forms paste which gradually becomes less plastic, and finally a hard mass is obtained. In the process of setting, a stage is reached when the cement paste is sufficiently rigid to withstand a definite amount of pressure. The time to reach this stage is termed as setting time. Division on setting time of cement is based on Initial setting time of cement and Final setting time of cement.

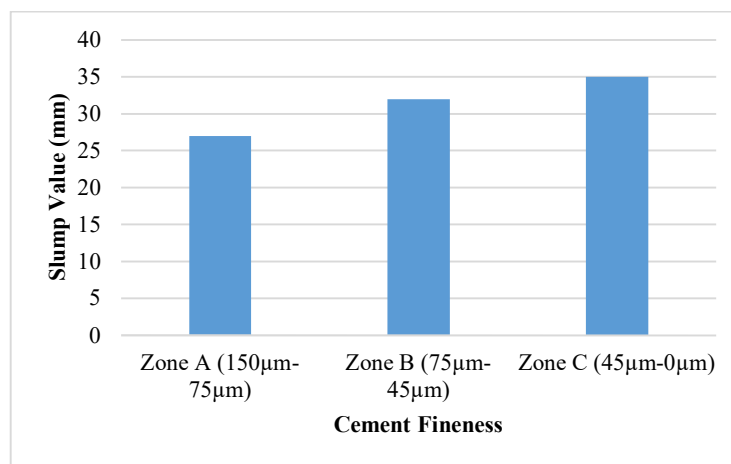


**Figure 2.** Relationship between Cement Fineness and Initial and Final Setting Times

From the Figure 2, the finest cement (Zone C) was found to have the shortest initial and final set times. However, similar trends of initial and final set times were not observed from mixes with the two coarser cements used in this study (Zones A and B). The phenomenon might be due to the fact that although the coarser cement particles reduce the rate of hydration, it requires slightly less hydration to achieve equivalent set than a finer cement due to the higher degree of structure build-up from the bigger size of particles.

### 3.3 Effect of Cement Fineness on Workability

Slump is a measure of concrete's workability or fluidity. Results of the slump test on the ceramic waste concrete are presented in Figure 3.

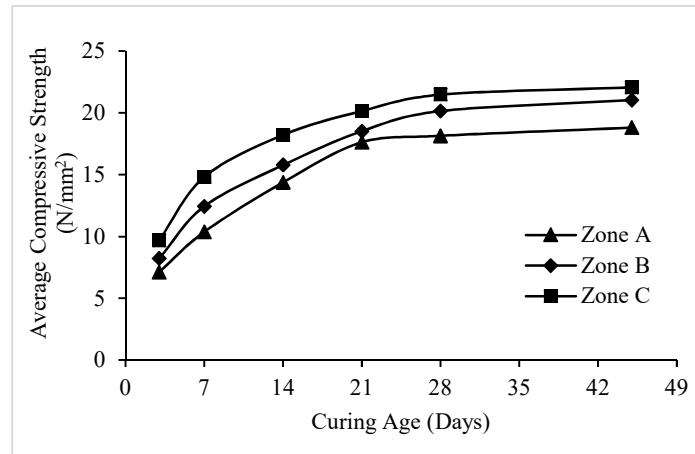


**Figure 3.** Relationship between Cement Fineness and Slump Value (mm)

It was observed that the workability of the concrete mixture for a water/cement ratio of 0.5 increases with an increase in the fineness of the cement particles. An increase in workability means an increase in flow ability at the same water/cement ratio, this means a decrease in water demand to get the same degree flowable concrete. When water is added to concrete mixture, it wets the surface of particles and reduces the interparticle frictional resistance. When fineness of cement increases beyond a certain particle size, the particles of cement itself starts acting as lubricants in the concrete. Therefore, the particles flow and less effort/work are required for compaction of concrete i.e. the water demand decreases to obtain the same degree of workability.

### 3.4 Effects of Cement Fineness on Compressive Strength of Concrete

The compressive strength of concrete cube specimens for different zones of cement fineness are shown in Figure 4.

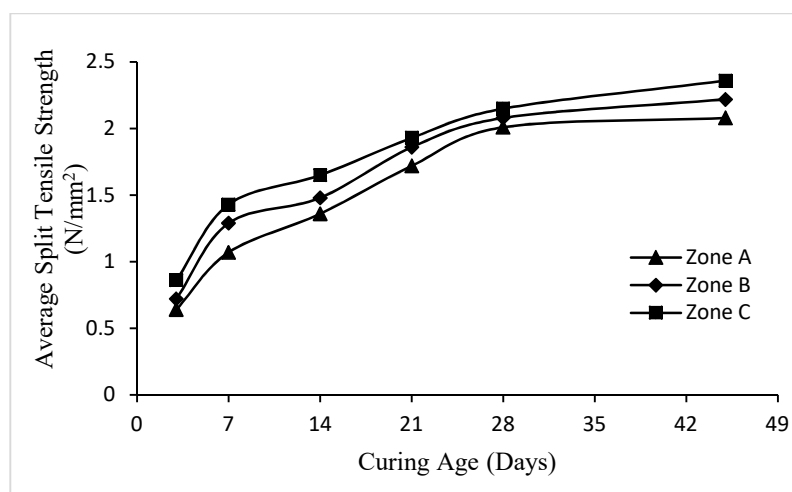


**Figure 4.** Variations of Compressive Strength with change in Cement Fineness

It was observed that the compressive strength of the concrete cubes was 18.15N/mm<sup>2</sup>, 20.15N/mm<sup>2</sup> and 21.48N/mm<sup>2</sup> at 28 days curing age for Zone A, Zone B and Zone C respectively. The increase of the fineness of the cement clearly improved the compressive strength of the concrete. This confirms the role of the granulometry (mechanical activation or advanced grinding) in the fast and complete hydration of the cement (pozzolanic activity) by the formation of the Ca(OH)<sub>2</sub> released during the hydration of the cement. This pozzolanic reaction gives the second C-S-H supplementary, main responsible for the hardening of the concrete [18,19]. Therefore, the weakness of the strengths to the short-term can be compensated by mechanical activation of cement (increase of the fineness). The strength values increased progressively as the curing age increased; an indication of the effect of curing age on concrete strength development.

### 3.5 Effects of Cement Fineness on Tensile Strength of Concrete Cylinders

The effect of cement fineness on the tensile strength of concrete is presented in Figure 5.

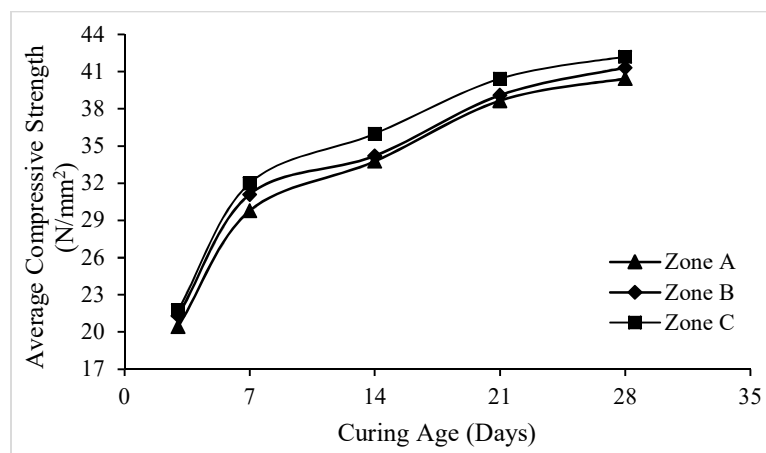


**Figure 5.** Variations of Tensile Strength with change in Cement Fineness

Trends observed are similar to that of compressive strength. As the cement fineness is increased, tensile strengths of all the specimens also increased. As the curing age increased from 0 to 45 days, a gradual increase in tensile strength was observed. The increase in tensile strength due to increase in cement fineness can be associated with respect to the surface area available for hydration.

### 3.6 Effects of Cement Fineness on Compressive Strength of Cement

The strength of cement is the most important of all the cement properties. The compressive strength of cement cube specimens for different zones of cement fineness are shown in Figure 6. It can be observed that an increase in cement fineness results in an increase in the compressive strength of the cement mortar. This can be explained by the increase of the fast kinetics of hydration of the mineral C3S (tricalcium silicate) and C2S (dicalcium silicate). These two phases are the two principal minerals which ensure the development of the strength. Thus, it can be concluded that the fineness of cement is a significant characteristic during the hydration of the mix, more the particles are fine, more the cement surface in contact with water is large and more the hydration is fast and complete (shortening of set times).



**Figure 6:** Variations of Compressive Strength of Cement with change in Cement Fineness

## 4. Conclusion

The setting times are shortened as the cement particle fineness increases. This is due to the fact that the coarse cement particles require less hydration to achieve equivalent set than a finer cement particle. The workability of concrete increases with an increase in cement fineness. The compressive and split tensile strengths of concrete increases as cement particles increase in fineness from Zone A to C. Also, the finer the cement, the high the reactivity of its particle. The compressive strength of the cement mortar is also increased with an increase in the fineness of the cement particle sizes.

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