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Effect of Curing Methods on the Compressive Strengths of Palm Kernel Shell Concrete

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Abstract Appropriate curing of concrete is necessary to obtain maximum durability and achieve designed strength for concrete exposed to different environmental conditions. Curing is regarded as the means of regulating the degree and extent of loss of moisture from concrete when the cement in the concrete is undergoing hydration. This study made a comparative study of the consequence of adopting different methods of curing on the compressive strength of concrete modified with Palm Kernel Shell (PKS) aggregate. Concrete cube specimens of mix ratio 1:1:2 were cast with water-cement ratio of 0.55. The specimens were cured using four (4) different procedures: immersion, sprinkling, wet-curing and open-air. The concrete samples were tested for their compressive strengths at ages 7, 14, 21 and 28 days of curing. The results obtained show that immersion method of curing has the highest compressive strength at 28 days with a value of 17.07 N/mm^2. This was followed by the sprinkling method of curing with 15.78 N/mm^2. Wet-curing method has a compressive strength of 14.48 N/mm^2 and open-air curing has compressive strength of 13.11 N/mm^2. It was concluded that immersion and sprinkling methods are suitable methods for curing PKS concrete.

Keywords Concrete, Curing, Compressive Strength, Palm Kernel Shell, Civil Engineering

1. Introduction

Curing of concrete provides sufficient moisture and suitable temperature to aid cement hydration for a period of time. Appropriate concrete curing is critical to obtaining durability and achieving the designed strength for the concrete to fulfil its intended purpose [1]. Curing is defined as the creation of a favourable atmosphere such as a conducive temperature and moisture during the early age of concrete for continuous hydration [2,3]. When concrete is cured at high temperatures, cement hydration is accelerated and the concrete gains strength early. Curing of concrete at temperatures lower than 10 ^{0}C is not desirable for the strength development at the early age and may lead to a halt of the cement hydration [4]. The rate of strength gain of concrete samples depends largely on the environment in which the concrete is placed and measures taken to reduce the loss of heat and moisture from the concrete [3]. Curing strongly influences the strength of hardened concrete; appropriate curing will boost strength, durability, abrasion resistance, water tightness, resistance to freezing, and stability of volume, thawing and dicers [5]. Diverse curing methods are often employed for concrete curing. These methods include sprinkling, wet covering, and open air (no curing) [4]. These methods have their effects on the final strength of the hardened concrete.

Palm Kernel Shells (PKS) are by-products gotten from the production of palm oil and they are in abundant supply in West Africa [6]. PKS are considered as wastes and discarded in the open thereby creating a nuisance with minute commercial benefits. They come in different shapes and sizes. The main palm oil producing states in Nigeria where PKS are mostly found includes, Ogun, Osun, Ondo, Oyo, Edo, Cross River, Anambra, Enugu, Imo, Abia, Ekiti, Akwa-Ibom, Delta and Rivers [7]. Olanipekun *et al.* [8] compared concrete properties using coconut shell and palm kernel shell as coarse aggregates. Two mix ratios (1:1:2 and 1:2:4) were adopted in the study. The study concluded that the compressive strength of the concrete decreased as the percentage of shell substitution increased. However, the coconut shell concrete exhibited a higher compressive strength than palm kernel shell concrete in the two-mix proportion tested. Shafigh *et al.* [9] opined that research over the last two decades shows that oil palm shell can be used as a lightweight aggregate for production of structural lightweight concrete. Alengaram *et al.,* [10] examined the effect of the physical and mechanical properties of different sizes of PKS used as lightweight aggregates (LWA) and their influence on mechanical properties of palm kernel shell concrete (PKSC). It was concluded that PKSC with about 70% of PKS of large size produced the highest modulus of elasticity. Alabi and Mahachi [11] assessed the ternary coarse aggregates for economic production of sustainable and low-cost concrete. The study concluded that the compressive strength of the concrete mixes was less than the strength for lightweight concrete recommended by standards. The construction industry relies largely on cement and crushed aggregates to produce concrete. The astronomic cost of materials used for building in the unindustrialized countries of the world can be reduced by using local materials that are cheap and readily available. The adoption of these materials will minimize environmental pollution and consequently reduce the dead weight of structural elements, thereby leading to sustainable construction. Some other benefits of using lightweight concrete includes improved thermal specifications, better fire resistance, and dead load reduction which result in lower cost of labour. Many agricultural and industrial bye-products with little or no economic benefit could gainfully be used as building materials [6,12–22]. Concrete with inadequate curing shows a lot of distress such as plastic shrinkage and cracking. This could lead to the early failure of the concrete. A lot of problems are associated with concrete with inadequate curing practices on construction site. This research is aimed at determining the influence of methods of curing on the compressive strength of palm kernel shell concrete.

2. Materials and Methods

The constituents utilized for the casting of the test specimens are Ordinary Portland Cement (OPC) conforming to the strength class specified in BS EN 197-1 [23], sharp sand, PKS and potable water free of deleterious materials and conforming to BS EN 1008 [24]. The sharp sand used are those that passed through 5.6 mm aperture sieve but retained on 4.75 mm aperture sieve, specific gravity of 2.93, water absorption of 2.20 % and fineness modulus of 2.40 %. The palm kernel shell aggregate used was gotten from Ido-Ekiti, Ekiti state, passed through 13.2 mm aperture sieve and was retained on 11.2 mm aperture sieve. It has a specific gravity of 1.27, water absorption of 0.10 % and fineness modulus of 4.71 %. The shells were washed with soap and hot water to remove dust and other impurities that could be detrimental to the concrete and they were dried outdoor until there was no moisture on them. The physical properties of the aggregates were determined in accordance with BS EN 933-1 [25]. The design mix ratio was 1:1:2 with a water/cement ratio of 0.5 for a target (characteristics) strength of 15 N/mm^2. The test specimens, totalling 48 cubes i.e. 12 cubes for each curing method, were cast in steel moulds measuring 150 mm × 150 mm × 150 mm in accordance with BS EN 12390-3 [26]. After casting, the specimens were removed from the mould after 24 hours and subjected to four different curing methods. These are total immersion in water (ponding) (Figure 1), daily sprinkling with water (Figure 2), wet curing with sawdust (Figure 3) and open-air curing methods as shown in Figure 1.

Figure 1. Total Immersion Curing Method

Figure 2. Water Sprinkling Curing

Figure 3. Wet Curing with Sawdust

Figure 4. Open Air Curing

For the total immersion method, the concrete samples were fully immersed in water until the days of testing. For the sprinkling method, daily sprinkling of water on the concrete samples through a rubber pipe connected to a water source was adopted to ensure that the samples were moist. The sawdust wet curing method involved putting soaked sawdust particles on the concrete samples to keep the surface of the concrete constantly moist. Throughout the curing period, the sawdust was kept saturated with water. In the open-air curing method, the cubes were kept in the open air without applying moisture on the surface of the concrete samples.

The samples were cast at Civil Engineering laboratory of the Kwara State Polytechnic, Ilorin. The samples were then tested for their compressive strengths with the aid of a Universal Testing Machine of maximum capacity of 600 kN at the same laboratory. The weight of each test specimen was determined before the crushing test and their density was calculated as the ratio of the weight to the volume of each specimen. The cured test specimens were kept in the open air for about 30 minutes before crushing at 7, 14, 21 and 28 days respectively.

3. Results and Discussion

3.1. Total immersion Curing

The effect of total immersion curing on strength of PKS Concrete is presented in Figure 5. The compressive strength of the immersion curing samples increased with increase in curing age. Meanwhile, the compressive strength at 28 days is above the 17.0 N/mm^2 minimum required strength for lightweight concrete and can be regarded as structural lightweight concrete [27,28].

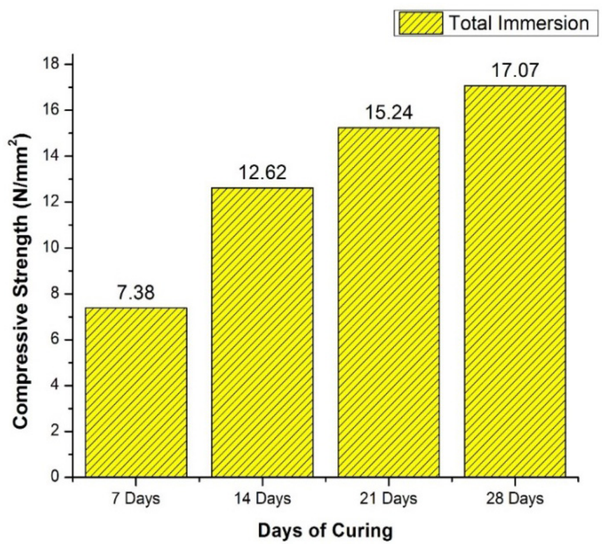

Figure 5. Effect of total immersion curing on Compressive Strength of PKS Concrete

3.2. Sprinkling Curing

The compressive strengths of sprinkling curing method show a similar trend to the immersion curing method as the curing age increased. However, the compressive strength at 28 days (Figure 6) is below 17.0 N/mm^2 minimum required strength for lightweight concrete and thus the concrete can be regarded as non-structural lightweight concrete [28].

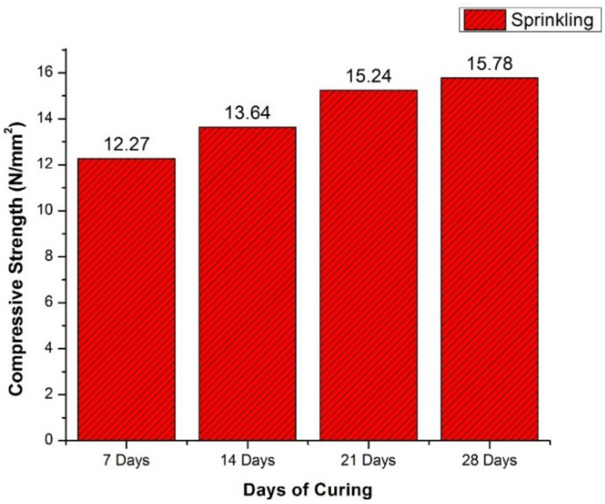

Figure 6. Effect of sprinkling curing on Compressive Strength of PKS Concrete

3.3. Wet Covering Curing

The compressive strengths of wet covering curing method (Figure 7) also show a similar trend to total immersion and sprinkling curing method as the curing age increases. However, the compressive strength at 28 days is below 17.0 N/mm^2 minimum required strength for lightweight concrete, thereby the concrete can equally be regarded as non-structural lightweight concrete [28].

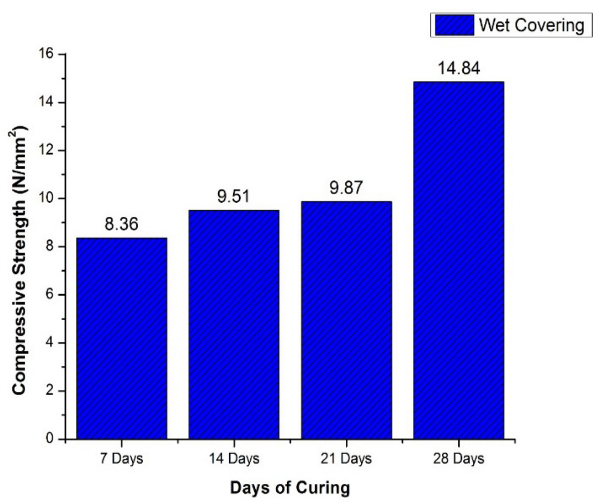

Figure 7. Effect of wet covering curing on Compressive Strength of PKS Concrete

3.4. Open Air Curing

The compressive strengths of the open-air curing method shown in Figure 8 at 28 days are below the minimum recommended strength for structural lightweight concrete as contained in ASTM C-330 [24]. However, the compressive strength at 28 days has the highest strength of 13.11 N/mm^2. The increase in the compressive strength due to increase in curing age can be attributed to the continuous formation of hydration products [29].

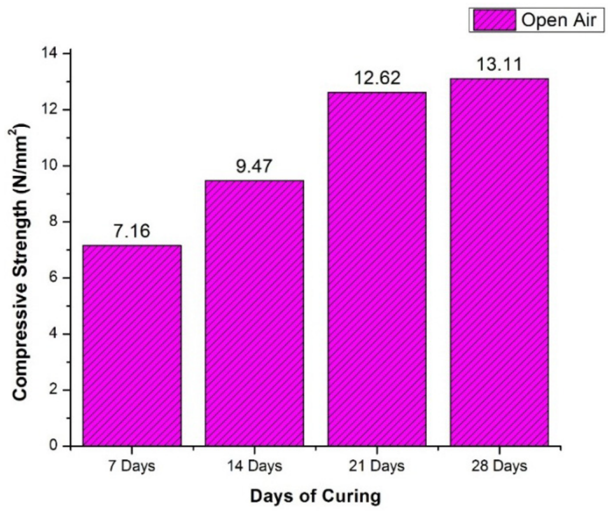

Figure 8. Effect of open-air curing on Compressive Strength of PKS Concrete

3.5. Comparative Study of the Adopted Curing Approach

Figure 9 shows that at seven (7) days of curing, the sprinkling method produced the highest compressive strength of 12.27 N/mm^2. But, as the curing age increased up to 28 days, total immersion method (ponding) of curing produced a compressive strength of 17.07 N/mm^2 and sprinkling method produced a compressive strength of 15.78 N/mm^2. These values are greater than the targeted (characteristics) strength of 15 N/mm^2. The Wet covering method and Open-Air method of curing produced concrete of lesser strengths than the targeted compressive strength. However, the four curing approaches adopted witnessed increase in compressive strengths as curing age increases.

The results obtained followed the same trend for vibrated concrete as obtained by James *et al.* [4].

It is evident from Figure 9 that compressive strength of the total immersion curing method at 28 days met the required minimum strength for lightweight concrete. This is an indication that PKS concrete cured with total immersion method can be used for structural lightweight concrete [27,28]. However, the sprinkling, wet covering and open-air curing method for PKS concrete would only be appropriate for use in non-structural lightweight concrete haven witnessed strengths lower than 17.0 N/mm^2 [28].

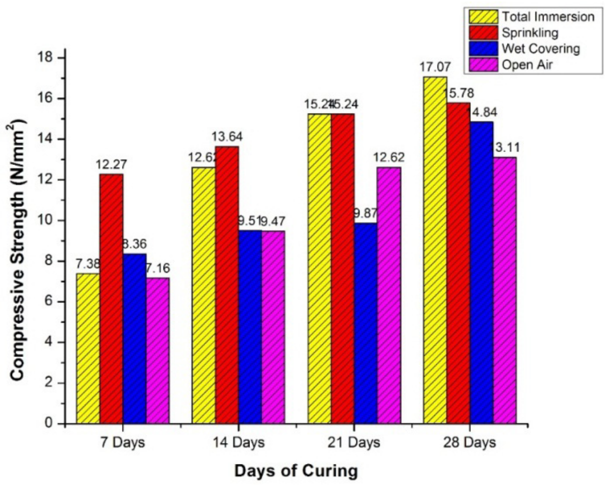

Figure 9. Compressive Strength of PKS Concrete at Different Days of Curing

4. Conclusions

Based on the findings from this study, the following inferences are drawn:

1. The total immersion method (ponding) of curing concrete is the most effective method of curing PKS concrete since it produced the highest compressive strength at twenty-eight (28) days of curing.
2. The sprinkling method can be adopted for curing PKS concrete since it gave a compressive strength greater than the targeted strength of 15 N/mm^2 at twenty-eight (28) days of curing.
3. Increase in compressive strength of PKS concrete is a function of the curing method adopted.
4. Open-Air method of curing concrete should be totally avoided.

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