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Rheological Study on Strength and Water Absorptivity of Interlocking Block Admixed with Steel Dust and Selected Nano Chemicals

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Abstract
Interlocking blocks are special mix pre-cast piece of concrete commonly used in exterior landscaping pavement application characterized with a deficiency such as low tensile strength. In this study, the strength and water absorptivity properties of Interlocking block admixed with steel dust and selected nano chemicals (Terrasil and Zycobond) was investigated. Steel dusts are chippings from grinding machine produced from local welding company in Ogbomoso. The particle size, bulk density and moisture content of steel dust and sand used were determined. The optimum distribution percentage of nanochemical that produced the maximum compressive strength was determined in a control specimen. Three batches of specimen (Specimen 1, 2 and 3) replicates were prepared at optimum percentage and varying concentration of nanochemicals at 2, 4 and 6% of the water cement ratio using mix ratio 1:3. The Compressive strength and water absorption test were carried out on specimen at 7, 14, 21, 28 and 56 days curing age, respectively using standard method. The sand and steel dust used passed through sieve no 4 (4.75mm) and retained on sieve no 200 (0.0075mm). The bulk density and moisture content of steel dust and sand were 1550kg/m^3 and 2018. The average compressive strength and water absorption for interlocking blocks admixed with steel dust and Terrasil nano chemicals ranged from 14-72 kN/mm^2 and 24.2-31.7 kg. The corresponding values with Zycosil nano chemicals were 10-57 kN/mm^2 and 25.6-32.2 kg. Inclusion of the steel dust and nano chemicals in interlocking blocks enhanced the compressive and water absorption properties. This could be useful where tensile strength is desirable.

Keywords: *Compressive Strength, Water Absorptivity, Nano Chemical, Steel Dust, Interlocking Stone*

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1. Introduction

Most times cracks and damages are experienced in concrete interlocking blocks as a result of weak compressive strength or heavy loads moving on the interlocking blocks. There is a need to improve the strength of interlocking blocks so as to withstand imposed load and avoid unnecessary cracks which might also lead to loss from both the client using the concrete interlocking block and the engineer producing the concreting interlocking block, and other damages as well. The addition of nano particles has shown to improve various performance of concrete, for example Nano-silica has shown to improve the workability and strength in high performance and self-compacting concrete. Dispersed nano-particle can act as crystallization centre for cement hydrates thereby accelerating the hydration reaction and can act as filler between cement grains thus reducing cement porosity. A well dispersed nano-particles have also been shown to promote the formation of smaller sizes crystals thus densifying the microstructure, and to promote crack arrest in interlocking block and improving the material mechanical properties (Hassan, 2010; Birgisson and Taylor, 2010). Steel chips are waste materials from a grinding machine, the grounded steel chip is of dimension 0.02 - 0.04mm in diameter. The steel chips are environmentally disastrous to handle. Its sharp edge and minute size can prevue and injure the hands, nails and other part of the body if improperly handled. The steel chips are mostly discarded into the draws and can block the drainage. The chip will mix up with the soil and that can be compacted to form a blockage to the drain. Blockage of the drain can trigger flooding at peak discharge. Therefore, it's important to find a sink for the waste materials (Olaniyan *et al*., 2016).

Research and technology development at the atomic, molecular, or macromolecular level, at a length scale of approximate 100Nano-meter (a nanometre is one billionth of a meter, too small to be seen with a conventional microscope). Therefore, SEM analysis could be used to view the microstructure of Nano Particles. Creation and use of structure, devices and systems that have noble properties and functions because of their small and intermediate size, at the level of atomic and molecules. It should be dissolved in water before used. The use of materials characteristics in nano scale, offers great advantage in which fundamental evaluation occurs in human life, such as effective use of energy, economy and time. It increases the quality of the product which results in increasing the quality of life, reducing economic dependencies and increasing national income (Ozyidirin and Zegetosky, 2010; Sabolev, 2008).

The addition of nano-particles has been shown to improve various performance of concrete, for example nano-silica (silicon dioxide nanoparticle, Nano-SiO_2) has been shown to improve workability and strength in high performance and self-compacting concrete, (Sanfillipo, 2010). Improvement in concrete performance has been attributed to several effects of nano-particles. Well dispersed nanoparticles can act ascrystallization centre for cement hydrates, thereby accelerating the hydration reaction and can act as filler, filling the void between the cement grain, thus reducing the material porosity and increases compressive strength (Li, 2006; Sabolev, 2008).

Furthermore, well dispersed nano-particles have also been shown to promote the formation of smaller sized crystals (e.g. CA $(OH)_2$ and AFm), thus densifying the microstructure, promoting crack arrest and interlocking thus invariably improves the material mechanical properties (Olaniyan *et al.*, 2016). Most of the research on the addition of nano-particle to cementations systems has been performed using nano-SiO_2. Nano-SiO_2, has been found to accelerate the hydration reaction of C_3S improving concrete workability at early age strength, efficient in enhancing strength than silica fume, and improving the bond between the aggregate and the cement paste (Hassan, 2010). As an alternative to nanoparticle addition, the idea of nano-binder was recently proposed to improve concrete performance. In nano binder, the mineral addictive acts as the primary component and nano sized cement are used to fill the gap between the particles. The nano sized cement thus acts as a glue to bind the less reactive mineral additives together (Sanfillipo, 2010; Wille and Loh, 2010). In this paper, a rheological study is carried out on strength and water absorptivity of interlocking block admixed with steel dust and selected nano chemicals. It is believed that the results obtained from the study could be useful where tensile strength is desirable.

2. Materials and methods

2.1 Materials

The materials used in this study are cements, aggregate, water, steel chips and XL-Terrasil Nano-chemicals. The sand was graded in conformity to BS 882 (1983). The cement used is ordinary Portland cement from West African Cement Company, Ewekoro in Ogun State of Nigeria with properties conforming to BS 12 (1978). The water used conformed to specification by BS 3148(1980). Steel dust used in this study was obtained from the grinding operation of crankshaft. It was collected, sieved and mixed with the cement in varying proportion at 2, 4, 6, 8 and 10% of weight of interlocking blocks. Three replicates of specimens were prepared to represent different percentages. The specimen were cured and crushed after 7, 14 and 28 days. The percentage that produced the maximum compressive strength represented the optimum value that was used to produce other interlock block at varying nano chemicals (20, 40 and 60%) of the water content of the mix. The concentration of Nano chemical used was 2.5g/L, procured from Zydex Company in Lagos.

The sieve analysis was carried out in accordance with the provision of Section 103 of BS 812(1985). The measured aggregate was mixed with steel dusts and thoroughly mixed with the cement. The varying percentage of nano chemicals (in Litres) was measured and added to the water used for mixing. After thorough mixing, the material was put in oiled manual mould and compacted using a tamping rod. The concrete was de-moulded and cured in curing tank after 24 hours of demoulding the interlocking blocks. Compressive strength and water absorption test were carried out on the hardened concrete. The constituent of the mix used in the control and specimen (1, 2 and 3) is presented in Table 1.

Table 1: Batching proportion of interlocking paving stones admixed with nano particles

Mix	Sand(kg)	Cement	Steel dust (Kg)	T/Z(L)	Water (L)
Control mix	37.5	12.5	0	0	0
Specimen 1	34.5	12.5	3	2.0	8.0
Specimen 2	34.5	12.5	3	4.0	6.0
Specimen 3	34.5	12.5	3	6.0	4.0

2.2 Compressive strength test

The test was carried out on the interlocking block at different curing ages of 7, 14, 21 and 28days. The surface of the sample was placed on the bearing surface, another plate was placed on the block to ensure equal distribution of the applied load. The gauge of the machine was adjusted to be zero reading. While the machine was on, the applied load was gradual and gauge reading increased as the load increased until failure was noticed. This reading was carried out to compute the compressive strength of the specimen.

2.3 Water absorption test

This is a measurement to test the dimensional stability of the interlocking block. This is a popular method of determining the water tightness of interlocking. It measures the amount of water that penetrates into interlocking sample when submerged. A water absorption test was carried out in accordance with BS 1881-122: 2011. Test specimens were soaked in water for 7, 14, 28 and 56days, respectively. The specimen weight was measured at each age of curing using semi-automatic balance. Water absorption was expressed as the changed distortion of the interlocking block on drying. Indeed, a water content of about 25% of the weight of cement will be needed to combine the mix chemically. The difference in the weight was recorded as the water absorption value.

3. Results and discussion

3.1 Optimum steel dust

The percentage replacement of sand with steel dust that produced the maximum compressive strength of 33.1N/mm^2 was 8%. Therefore, 8% of steel dust was used in all the specimens but at varying content of nano chemicals. The mix ratio of the specimen1, 2 and 3 is shown in Table 1.

3.2 Compressive strength of interlocking blocks

The result of the compressive test on interlocking block mixed with steel dust and nano chemicals (Terassil and Zycobond) at 7, 14, 28 and 56 days is presented in Table 2 and Figure 1 respectively. For control mix, the compressive strength increased as the curing age increased. The compressive strength increased from 14 to 40 and 10 to 30 kN/mm^2 for Terrasil and Zycobond nano chemicals, respectively. Specimen with Terrasil nano chemicals produced higher compressive strength than those with Zycobond Chemicals. Compressive strength increased for specimen 1, 2 and 3 admixed with Terrasil and steel dust as follows: 32 - 55, 30 - 70, and 30 - 70 N/mm^2, respectively. The corresponding values for Zycobond admixed specimen were 15 - 55, 20 - 57 and 20 - 56 N/mm^2, respectively. Specimen 1 produced the highest compressive strength of 72 N/mm^2 at 56 days. This value is higher than average compressive strength of corresponding interlocking block (of around 19.15N/mm^2).

In most structural application, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the members takes place in a vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the members, will take place on application of axial compression load and propagates further due to the lateral tensile strains.

Nanotechnology in concrete is still in its explanatory phase and full-scale applications in the field of construction are till date very limited. Nevertheless, the potential of nanotechnology helps improve the performance and durability of concrete. The strength and durability were assessed in this work by partially replacing sand with steel chips admixed with Nano- particles.

Table 2: Average compressive strength of interlocking block admixed with steel dusts and nano chemicals

Nano Chemicals	7 days		14 days		28 days		56 days	
	Terassil	Zycobond	Terassil	Zycobond	Terassil	Zycobond	Terassil	Zycobond
Control mix	14	10	25	15	33	24	40	30
Specimen 1	32	15	40	27	55	45	72	55
Specimen 2	30	20	42	28	56	40	70	57
Specimen 3	30	20	40	30	55	42	70	56
Average compressive strength	31	17	40	27	55	43	70	55

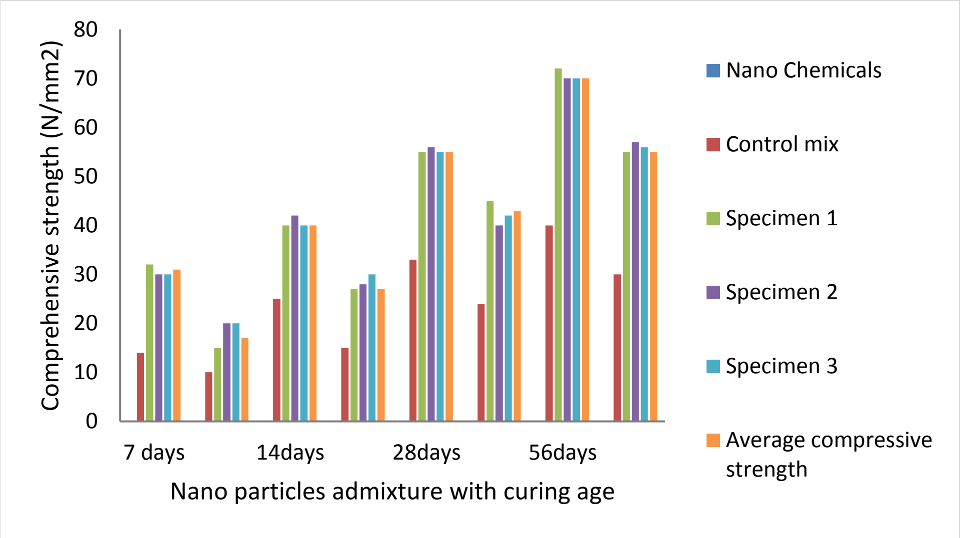

Fig. 1: Effect of curing age on the compressive strength of interlocking blocks

3.3 Water absorption test

Water absorption test was carried out at curing age of 7, 14, 28 and 56 days. The result of water absorptivity test is presented in Table 3 and Figure 2 respectively. Water absorption for control, specimens 1, 2 and 3 varied from 24.2 - 27, 30-31 and 30 - 31.7 kg from 7 - 56days. Interlocking block Specimens mixed with Terrasil increased in weight which varied from 2.6 - 3.7 kg. Corresponding values for interlocking specimens admixed with Zycobond varied in weight from 0.1 - 2.3 kg. This inferred that Zycobond nano chemicals reduce permeability of specimen. For specimen 1, the percentage of absorbed water was 0.6% as compared to control specimen that absorbed 8.9% of water. It is clear that steel dusts reduce the void in the mix by filling the void. This void was drastically reduced at the inclusion of Zycobond nano chemicals. Although, the inclusion of Zycobond and Terrasil chemicals reduces the permeability of the specimen, the optimum mix in terms of compressive strength and water absorption properties was specimen 1.

Table 3: Water absorption for interlocking blocks at different ages

Curing Age	7 days		14days		28days		56days	
Nano particle	Terassil (kg)	Zycobond (kg)	Terassil (kg)	Zycobond (kg)	Terassil (kg)	Zycobond (kg)	Terassil (kg)	Zycobond (kg)
Control mix	24.2	25.6	24.8	26	25.3	26.4	27	27.9
Specimen 1	30	31.5	30.3	31.7	31.2	31.78	31.7	32.1

Specimen 2	30	31.6	30.2	31.6	31.3	31.8	31.7	32.2
Specimen 3	29.6	31.6	30.4	31.6	31.3	31.9	31.7	32.2

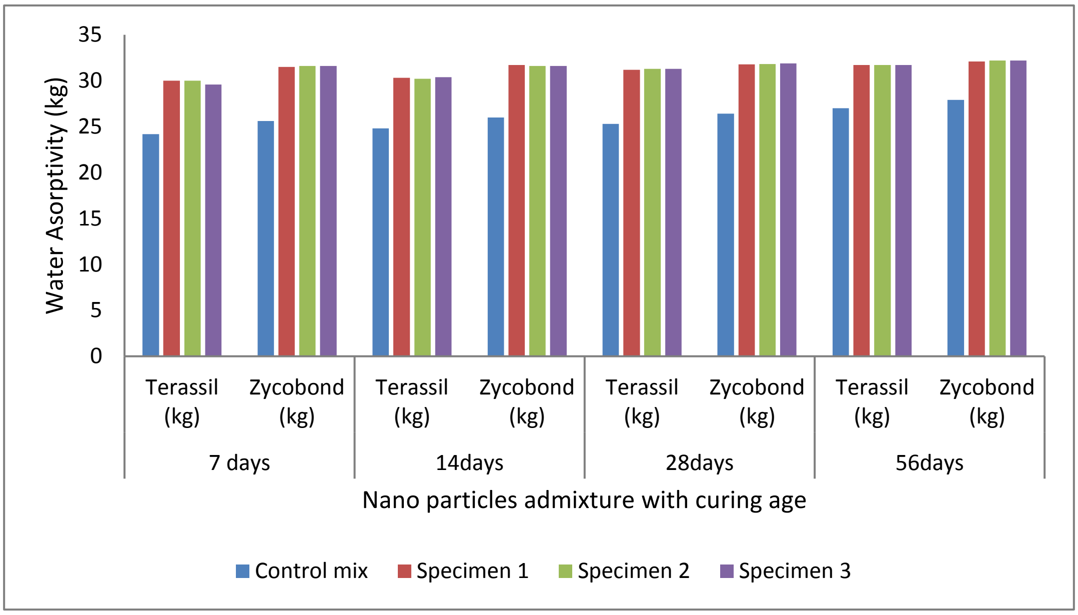

Fig. 2: Effect of different percentage combination of nano particles on water absorptivity of interlocking paving stones

According to Neville (2002), the rate of water absorption of aggregate influences the bond between aggregate and the cement paste, the resistance of concrete of freezing and thawing, chemically stability, resistance to abreaction and specific gravity.

4. Conclusions

The following conclusions were drawn from this study:

a. The composite (steel dust and nano chemicals) enhanced the compressive strength and water absorption properties of interlocking blocks.
b. Interlock blocks admixed with steel dust and Terrassil nano chemicals produced the highest compressive strength above the standards.
c. Interlock blocks admixed with steel dust and Zycobond nano chemicals reduced the permeability of water into the bricks.
d. Terassil and Zycobond at 4% water ratio in interlocking should be allowed to enjoy the benefit of strength.

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