Reactions of Hydrated Lime-Saw Dust Ash Blend on the Strength Properties of cement Concrete

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Abstract

- This study was carried out to determine the reaction of Hydrated lime (HL)-Saw dust ash (SDA) blend on the strength properties of cement concrete. Compressive strength and modulus of elasticity with respect to water-cement ratio and percentage replacements of Portland cement (PC) were experimented. Concrete was prepared using a constant mix ratio of 1:2:4 with varying water-cement (w/c) ratios of 0.55, 0.57, 0.58, 0.6, and 0.65respectively. Percentage replacements of port land cement with HL and SDA of 0

***Index terms*—** hydrated lime (HL), saw dust-ash (SDA), water-cement (W/C) ratio, portland cement (PC), compressive strength, modulus of elasticity

1 Reactions of Hydrated Lime-Saw Dust Ash Blend on the Strength Properties of cement Concrete

Awodiji T.G. Chioma , Dimo J. Onyebuchi ? , Nwurumibe Chukwebuke ? , Awodiji O. Olujide ? & Arimanwa I. Joan ¥ Abstract-This study was carried out to determine the reaction of Hydrated lime (HL)-Saw dust ash (SDA) blend on the strength properties of cement concrete. Compressive strength and modulus of elasticity with respect to water-cement ratio and percentage replacements of Portland cement (PC) were experimented. Concrete was prepared using a constant mix ratio of 1:2:4 with varying water-cement (w/c) ratios of 0.55, 0.57, 0.58, 0.6, and 0.65respectively. Percentage replacements of port land cement with HL and SDA of 0%, 10%, 20% and 30% for HL-SDA proportions of 50%:50% and 75%:25% respectively were investigated. Portland cement, river sand, granite chippings, hydrated lime and saw dust ash were the materials used. 150mmx150mmx150mm concrete cube sizes, were adopted as specimen. The concrete were kept damp in open water tanks at room temperature and then tested in compression after 28days and 56days. The values of compressive strength acquired were then used to determine the modulus of elasticity of the concrete. Considering the compressive strength test results, mixes with proportion of HL-SDA of 75%:25% gave higher strength readings than those having 50%:50% ratio. The greatest compressive strengths at 28 days and 56 days, were 27.56N/mm 2 and 30.40N/mm 2 respectively for a w/c ratio of 0.58 at 10% replacement of portland cement. This resulted to an 11.32% and 17.70% strength increase respectively, when compared to the highest values obtained from the control mixes. The mixes having 10% replacement of PC were observed to produce structural concrete. A reduction in strength was generally observed for the 20% and 30% replacement of PC with HL and SDA. At 20% replacement, the highest compressive strengths reached at 28 days and 56 days were 23.11N/mm 2 and 27.11N/mm 2 . For the 30% replacement, it was generally observed that the 56 days, 50%HL: 50%SDA proportion generated slightly higher strength values than the 75%:25% proportions even though, the optimal strengths of 20N/mm 2 and 24N/mm 2 at 28 days and 56 days respectively, were recorded by the 75%HL:25%SDA.It was noted that the addition of 50% HL and 50%SDA, did not improve the modulus of elasticity of the concrete. At 30% replacement, modulus of elasticity for all the mixes considered reduced when compared to the control mixes. For structural purpose, optimum HL-SDA Introduction he use of concrete as a construction material has over the years, gained wide acceptance globally.

This is why the need to come up with concrete with distinct and useful features e.g. improved durability and strength has always been a welcomed idea. According to [1], the current production of cement, which is a major component of concrete is growing by 2.5% annually, and is anticipated to rise from 2.55 billion tons in 2006 to 4.4 billion tons by 2050. Regrettably, cement production is judged to be one of the major giver of the heat wave gas emissions into the atmosphere. It entails the substantial discharge of carbon dioxide from the chemical processes involved. Present-day evaluations are that this process contributes about 5% of total human induced CO 2 emissions excluding land use change [2]. An additional process that could put in a further 60% to the operation is the firing of fossil fuel to bring on the relevant energy requirement for heating up the raw materials at temperature well over 1000 0 C [3].According to [4], total emissions from the cement industry contribute as much as 8% of world-wide CO 2 release. This gas has evolved to the various ruinous climatic conditions wrecking the earth today. So, alternative cement that is more sustainable as well as cost effective are being suggested by sundry researches in the field of concrete technology, in order to minimize the cement industry's contribution to these problems and make cement production more energy efficient.

Reducing emission from the incinerating exercise means looking for a material other than limestone. Combined cement replaces some of the limestone-based clinker with other materials such as flyash, silica fume and agricultural waste products that are pozollanic in nature. These blends also assist in reducing the energy demand for the calcination process thereby making the procedure more energy friendly. In this innovative examination, a blend of hydrated lime and saw dust ash as incomplete substitutes for cement in making concrete was appraised. Special attention was given to the effects of water cement ratio and percentage replacement of portland cement with HL and SDA on the compressive strength and modulus of elasticity of the concrete. [5] defined hydrated lime as a dry white powder consisting essentially of calcium hydroxide obtained by treating lime with water. It is traditionally called slaked lime. It has many names including builder's lime, pickling lime, cal and slaked lime. It has many uses that comprises: a flocculant, in water and sewage treatment and improvement of acid soil; an ingredient in whitewash, mortar and plaster; an ingredient in baby milk; a home remedy for throat infections as well as sprains and a chemical reagent. In combination of water, sand or cement, it is used to make mortars and plasters.

Saw dust is wood biomass occasioned by the timber industry. It is a notable waste and is usually used as a wood fuel for generating energy. The burning of saw dust reduces its size and gives rise to a product known as saw dust ash (SDA) [6]. Most times, this ash is not capably gotten rid of but is openly left on dump sites. Accordingly, it creates health and environmental challenges. The inhalation of saw dust ash or saw dust into the body can lead to breathing complications like asthma or lung cancer. When in contact with the skin, SDA can result to irritation or ulceration of the skin [7]. One manageable way of doing away with this waste is by integrating it as a part of the materials in the making of concrete.

Works on concrete and mortar incorporated with SDA and HL have been performed by many authors. [8]used SDA having 45% hydrated lime as partial replacement of ordinary portland cement (OPC) for making hollow blocks, in order to solve the issues of environmental and economic consideration. Their results showed at 10% OPC replacement with SDA, a cement to aggregate mix of 1:8at 0.55 w/c ratio, produced the highest compressive strength. They also suggested that the cement-aggregate mix could be reduced to achieve higher strength. [9] studied some properties of concrete made using hydrated lime and pozzolans (silica fume, fly ash and metakaolin) as substitutes for portland cement. Results from this studies revealed that structural concrete could be produced from silica fumelime mixes and silica fume-fly ash-lime mixes. They concluded that metakaolin-lime mix could only be used for making mortar. The pozzolanic-lime mixes showed longer setting time and lower heat of hydration than the PC mix. This is an advantage during hot weather concreting.

[10] worked on the environmental credentials of hydraulic lime-pozzolan concret. They perceivedthat using hydraulic lime (NHL5) alone as a green alternative binder to portland cement (CEM 1) is not practical. But, the use of NHL5 with pozollanic materials, showed a more applicable low-carbon substitute to CEM 1 and CEM 111A in defined conditions. [11] analyzed the partial replacement of cement with SDA in concrete and reported that its advantage can only be derived when PC is replaced with SDA at a level not exceeding 10%. Maximum benefits was seen to occur at 5% substitution. An increase in strength was detected at longer curing age. But, it reduced as the percentage of SDA increased. Further, they perceived that the concrete became more workable as the proportion of SDA increased.

Similarly, [12] worked on SDA as partial replacement of cement. He uncovered that the inclusion of SDA in cement promoted the occurrence of little expansion due to low carbon content. In addition, he observed that the early strength gain was about 50% to 60% of the 28 th day strength. Furthermore, he recommended amaximum percentage replacement of PC with SDA of 10% by volume in all grades of cement studied. [13] stated that wood waste, either in the form of saw dust ash or wood aggregate can be included into the concrete mix to form structural concrete. This concrete is seen to have good durability properties as the percentage water absorptions reviewed were less than 10% [14]. They expressed that the replacement level must not be greater than 20%. [15], from their studies observed that the compressive strength of concrete decreased with increase in SDA. They recommended a 5% optimal OPC replacement with SDA. [16] worked on the properties of concrete modified with low density polyethylene (LDPE) and saw dust ash. From their findings, they stated that the workability of the concrete decreased as percentage replacement of LDPE and saw dust ash increased. Also, the strength properties of the modified concrete reduced when compared to the conventional mix. In addition, density of the modified mix was less than that of the conventional mix. Finally, they recommended an optimal combination of LDPE and saw dust of 5% and 3% respectively.

2 II.

3 Experimental Works a) Materials

In this investigation, the material used for making concrete in the laboratory include; portland cement, hydrated lime, saw dust ash, river sand, granite chippings and water. The grade 42.5R portland cement with brand name "Dangote" was used and produced according to [17]. This was bought from Naze market in Owerri-west Local Government Area of Imo state, Nigeria. Hydrated lime was obtained from Eiestening Calcining Company in Okene, Edo State. Its physiochemical properties are presented in Table 1.Saw dust was procured from the Naze wood market. It was air dried for 3 days and then heated (while stirring) in an open pot until it was observed that there was no more release of steam. This was done to reduce to minimum its moisture content. The saw dust was then calcined by open air burning. The ash obtained was further pulverised using a grinding mill and sieved with a 75 micro sieve for efficient mixing with hydrated lime and portland cement. Physio-chemical test result of the saw dust ash is presented on Table 2.

Fine aggregate of nominal size 5mm, obtained from Otamiri River in Owerri-West, was used. This aggregate was washed thoroughly and sun dried for a week, before being used. Also, granite chippings of nominal size 19mm was obtained from the quarry site of Arab contractors Nigeria Limited Owerri, Imo State. The aggregates were properly sieved using a mechanical sieve shakers in accordance with **??**18]. River sand and granite chippings were observed to be poorly graded and had bulk density values of 1657.30kg/m 3 and 1571.65kg/m 3 respectively. The water used for this research work was portable and obtained from the Federal University of Technology, Owerri. A total of 350 mix proportion were investigated. A mix ratio of 1:2:4 (binder: fine aggregate: coarse aggregate) at varying water-cement ratio of 0.55, 0.57, 0.58, 0.60and 0.65 was adopted. Percentage replacement of PC with SDA of 0%, 10%, 20% and 30% were experimented. For each percentage replacement considered, the effect of PC to SDA proportion of 75%: 25% and 50%: 50% were studied. Batching of the material was done by weight using a weighing balance of 50kg capacity. The sand was measured and mixed thoroughly with the cement, hydrated lime, and saw dust ash in a waterproof surface before the granite chippings was added. Water was then included and the whole batch was uniformly mixed using a shovel. Table 3 to Table 6 shows the mix proportioning of materials.

The material was poured into oil coated, metal square molds of cross section 150mm x 150mm. These molds were kept on clean, level and firm surface. The concrete in the mold was compacted in 3 layers with each layer receiving 25 blows of a 25mm steel rod. The surface of the mold was levelled and marked for identification. The specimen were left to set and the molds removed after 24 hours. They were then placed in water tanks at room temperature and left to cure for 28days and 56 days respectively.

4 Plate 3: Concrete cubes

Compressive strength test on hardened hydrated lime-saw dust ash-cement concrete according to [19] was carried out and the equation 1 was used to achieve the compressive strength values.

Compressive Strength (N/mm 2) = F/A

(1) Where F = Applied force by the compression testing machine (KN) and A = Cross sectional area of the cube (m 2). Results obtained from this test are presented on Table 7. In addition, the modulus of elasticity was determine from the values of the compressive strengths of the concrete according to [20] for normal density concrete using the equation 2:???? = 4700?????**(2)**

Where Fc = Compressive strength (N/mm 2). The results obtained are also presented in Table 7 III.

5 Results and Discussion

The results obtained after the investigation on compressive strength and modulus of elasticity of the HL-SDA cement concrete are as shown in Table 7. Comparing this value with that of the control mix, a rise in strength of 17.70% was achieved. Highest 28 days strength obtained was 27.56N/mm 2 . Therefore, an increase in strength of about 10.31% was observed from 28 days to 56 days of curing. The mixes having 10% replacement of PC were observed to produce structural concrete. Except for mix A 5 which had a 50% HL: 50%SDA proportion at water-cement ratio of 0.65. This may be due to the fact that the water content in the concrete was too high and so, strength dropped. The strength of concrete with 75%HL: 25%SDA at 56 days, were higher than those of the control values.

A reduction in strength was generally observed for the 20% and 30% replacement of PC with HL and SDA. But, at 20% replacement, 56 days of curing and 50%HL: 50%SDA, an increase in strength of 15.66%, 1.62% and 4.555% were observed at water-cement ratios of 0.58, 0.6 and 0.65 respectively, when compared to the 10% replacement. The highest compressive strengths reached at 28 days and 56 days were 23.11N/mm 2 and 27.11N/mm 2 at mix nos. B 7 and B 9 respectively. 20% replacement of PC with HL and SDA still resulted to the production of structural concrete except for mix nos. B 1 , B 2 and B 5 at 28 days.

At 30% replacement, it was generally observed that the 56 days, 50%HL: 50%SDA proportion generated slightly higher strength values than the 75%:25% proportions. Although, the optimal strengths of 20N/mm 2 and 24N/mm 2 at 28 days and 56 days respectively, were recorded by the 75%HL:25%SDA. Since hydrated lime is known to improve workability in fresh concrete, a 50% content of SDA in the mixture will absorb more water than a 25% SDA content. This resulted to less water in the 50%HL:50%SDA and more in the 75%HL:25%SDA. With lesser water content in the concrete, strength increased slightly.

At 10% replacement of PC with 75%HL: 25%SDA, optimum values of modulus of elasticity were recorded at 0.58 w/c ratio. These highest values were 24,673.88N/mm 2 at 28 days and 25,914.01N/mm 2 at 56 days. These were higher than the control values, showing that the inclusion of HL and SDA in the proportion of 75%:25% resulted to a stiffer concrete. This concrete will experience a reduction in deflection when compared to the conventional one. On the other hand, highest values of modulus of elasticity for the 50%HL:50%SDA inclusion occurred at a w/c of 0.57. These values were 23,235.31N/mm 2 and 23,612.53N/mm 2 for the 28 days and 56 days respectively. It was generally observed that the addition of 50%HL: 50%SDA, did not improve the modulus of elasticity of concrete.

20% inclusion of HL and SDA generally reduced the values of the modulus of elasticity of the concrete when compared to the 10% inclusion. Highest value of 24, 471.61N/mm 2 was achieved at 0.6 w/c ratio for the 56 days having 75%HL: 25%SDA mixture. Overview, the control readings were higher than those obtained from the 28 days specimen. Only the concrete produced from the 75% HL and 25%SDA at w/c between 0.6 and 0.65, experienced an improvement of modulus of elasticity.

The results of modulus of elasticity from the 30% inclusion of HL and SDA gave values that were lower than those obtained from the control mixes. This means that a 30% replacement of PC with HL and SDA will reduce the stiffness of the concrete.

6 b) Effect of water cement ratio on the strength

properties of HL-SDA cement concrete. In general, it can be seen that the compressive strengths of the concrete increased to optimum watercement ratios, before they began to drop. At 10% replacement of PC with HL and SDA, compressive strength for the 50%HL: 50%SDA increased until an optimum water-cement ratio of 0.57 was achieved. Thereafter, strength reduced. For 75%HL: 25%SDA, optimum water cement ratio happened at 0.58. These were observed for the two curing ages. At a watercement ratio of 0.55, the concrete mix having 50%HL: 50%SDAat 56 days, experienced the highest strength value.

Considering the 20% replacement (50%HL: 50%SDA), the water-cement ratio that generated the greatest strength was 0.6 at 28 days and 0.58 at 56 days. For 75%HL: 25%SDA, highest strength occurred at water-cement ratio of 0.60. At 30% PC substitution with HL and SDA, highest strength also occurred at 0.58 water-cement ratio. The effects of w/c ratio on the modulus of elasticity of the concrete is illustrated in Fig 5 to Similar to the compressive strength, modulus of elasticity of the various concrete mixes increased up to their optimum w/c ratios before declining. Highest values of modulus of elasticity at 10% and 20% replacement of PC with HL and SDA occurred at the w/c ratios of 0.58 and 0.6 respectively. These were obtained from the 56 days specimen of 75%HL: 25%SDA. An optimum w/c ratio of 0.57 was recorded from the 56 days control mix. At w/c of 0.55, the modulus of elasticity of the 28 days concrete produced from 50%HL: 50%SDA was far less than those of the other mixes at 30% inclusion of HL and SDA. At 20% replacement, improvement of the modulus of elasticity of the concrete was observed only for w/c ratios of 0.59, 0.6 and 0.65 for the 75% Hl: 25%SDA at 56 days.

7 IV.

8 Conclusions

From this experimental studies, the following conclusions were made: a. The best percentage replacement of PC with HL and SDA is 10%. b. The concrete with proportion 75%HL: 25%SDA generally gave better strength results than those with 50%HL: 50%SDA. c. The strengths of concrete with 75%HL: 25%SDA at 56 days, were higher than those of the control values. d. Highest compressive strength values obtained at 28 days and 56 days were 27.56N/mm 2 and 30.40N/mm 2 respectively. This occurred at watercement ratios of 0.57 and 0.58 for 10% replacement of PC with 75% HL and 25% SDA. e. For 20% replacement of PC with HL and SDA, the 75%HL: 25%SDA is recommended for structural use. 50%HL: 50%SDA can still be used for structural works. But, the concrete must be allowed to cure for up to 56 days in other to generate the required strength needed before loading. [1]

1 

Figure 1: Fig 1 to

1 

Figure 2: Fig. 1 :

4

Figure 3: Fig. 4 :

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Component	Percentage (%) composition
CaO	82
MgO	5.3
H 2 0	0.87
Ca(OH) 2	86.47
SiO 2	2.54
PH	9.03
Al 2 O 3	4.85
Others	3.52
Loss of ignition	0.23
Property	Description
Colour	White
Solubility	Partially soluble in H 2 O and HCl
Texture	Smooth
	Plate 1: Hydrated lime

Figure 4: Table 1 :

2

		( ) Volume XIx X Issue III V ersion I E of Researches in Engineering
Component K 2 O Na 2 O Fe 2 O 3	Percentage (%) composition 1.77 2.76 2.41	Global Journal
SiO 2	65.3	
Al 2 O 3	4.25	
MgO	5.32	
CaO	9.98	
Loss of ignition	3.95	
Specific gravity	2.33	
Mean particle size	179 µm	
Bulk density	760kg/m 3	

Figure 5: Table 2 :

3

			Mix Ratio					Mix proportion in weight for 1 cube (kg)				
MIX NO	W/C	PC	HL	SDA	Sand	Granite	Water	PC	HL	SDA	Sand	Grani
A 1	0.55	0.90	0.05	0.05	2	4	0.707	1.157	0.064	0.064	2.571	5.143
A 2	0.57	0.90	0.05	0.05	2	4	0.733	1.157	0.064	0.064	2.571	5.143
A 3	0.58	0.90	0.05	0.05	2	4	0.746	1.157	0.064	0.064	2.571	5.143
A 4	0.60	0.90	0.05	0.05	2	4	0.772	1.157	0.064	0.064	2.571	5.143
A 5	0.65	0.90	0.05	0.05	2	4	0.836	1.157	0.064	0.064	2.571	5.143
A 6	0.55	0.90	0.75	0.25	2	4	0.707	1.157	0.096	0.032	2.571	5.143
A 7	0.57	0.90	0.75	0.25	2	4	0.733	1.157	0.096	0.032	2.571	5.143
A 8	0.58	0.90	0.75	0.25	2	4	0.746	1.157	0.096	0.032	2.571	5.143
A 9	0.60	0.90	0.75	0.25	2	4	0.772	1.157	0.096	0.032	2.571	5.143
A 10	0.65	0.90	0.75	0.25	2	4	0.836	1.157	0.096	0.032	2.571	5.143

Figure 6: Table 3 :

4

			Mix Ratio					Mix proportion in weight for 1 cube (kg)				
MIX NO.	W/C	PC	HL	SDA	Sand	Granite.	Water	PC	HL	SDA	Sand	Gran
B 1	0.55	0.80	0.10	0.10	2	4	0.707	1.029	0.129	0.129	2.571	5.143
B 2	0.57	0.80	0.10	0.10	2	4	0.733	1.029	0.129	0.129	2.571	5.143
B 3	0.58	0.80	0.10	0.10	2	4	0.746	1.029	0.129	0.129	2.571	5.143
B 4	0.60	0.80	0.10	0.10	2	4	0.772	1.029	0.129	0.129	2.571	5.143

Figure 7: Table 4 :

5

						and saw -	dust ash					
			Mix Ratio				Mix proportion in weight for 1 cube (kg)					
C 1	0.55	0.70	0.15	0.15	2	4	0.707	0.90	0.193	0.193	2.571	5.143
C 2	0.57	0.70	0.15	0.15	2	4	0.733	0.90	0.193	0.193	2.571	5.143
C 3	0.58	0.70	0.15	0.15	2	4	0.746	0.90	0.193	0.193	2.571	5.143
C 4	0.60	0.70	0.15	0.15	2	4	0.772	0.90	0.193	0.193	2.571	5.143
C 5	0.65	0.70	0.15	0.15	2	4	0.836	0.90	0.193	0.193	2.571	5.143
C 6	0.55	0.70	0.225	0.075	2	4	0.707	0.90	0.289	0.032	2.571	5.143
C 7	0.57	0.70	0.225	0.075	2	4	0.733	0.90	0.289	0.096	2.571	5.143
C 8	0.58	0.70	0.225	0.075	2	4	0.746	0.90	0.289	0.096	2.571	5.143
C 9	0.60	0.70	0.225	0.075	2	4	0.772	0.90	0.289	0.096	2.571	5.143
C 10	0.65	0.70	0.225	0.075	2	4	0.836	0.90	0.289	0.096	2.571	5.143

Figure 8: Table 5 :

6

		Mix Ratio			Mix proportion in weight for 1 cube (kg)			
D 1	0.55	1	2	4	0.707	1.286	2.571	5.143
D 2	0.57	1	2	4	0.733	1.286	2.571	5.143
D 3	0.58	1	2	4	0.746	1.286	2.571	5.143
D 4	0.60	1	2	4	0.772	1.286	2.571	5.143
D 5	0.65	1	2	4	0.836	1.286	2.571	5.143

Figure 9: Table 6 :

B 5	0.65	0.80	0.10	0.10	2	4	0.836	1.029	0.129	0.129	2.571	5.143
B 6	0.55	0.80	0.15	0.05	2	4	0.707	1.029	0.193	0.064	2.571	5.143
MIX NO	W/C	PC	HL	SDA	Sand Sand	Granite Granite	Water	PC Water	HL	SDA	Sand	Granite

MIX NO	W/C	PC	Sand	Granite	Sand	Water	Cement	Sand	Granite

Figure 10:

7

MIX PLAN	HL:SDA	Mix no.	28 DAYS COMPRESSIVE STRENGTH (N/mm 2)	56 DAYS COMPRESSIVE STRENGTH (N/mm 2)	28 MODULUS OF ELASTICITY (N/mm 2)	56 DAYS MODULU OF E TICITY (N/mm 2
		A 1	21.33	24.44	21706.67	23235.31
		A 2	24.44	25.24	23235.31	23612.53
	50%:50%	A 3	22.67	22.67	22378.12	22378.12
		A 4	21.42	22.22	21752.42	22154.90
		A 5	18.67	19.77	20308.13	20897.83
		A 6	23.02	24.00	22550.21	23025.20
	75%:25%	A 7	24.44	25.69	23235.31	23822.09
HL-SDA		A 8	27.56	30.40 27.64 25.78	24673.88	25914.01
10%		A 9	27.11		24471.61	24709.67
		A 10	23.56		22813.16	23863.78
		B 1	16.89	23.11	19315.80	22594.24
		B 2	17.96	24.00	19918.24	23025.20
	50%:50%	B 3	21.33	26.22	21706.67	24066.57
		B 4	22.49	22.58	22289.10	22333.66
		B 5	17.78	20.67	19818.18	21368.21
		B 6	22.58	21.78	22333.66	21934.45
HL-SDA	75%:25%	B 7 B	23.11	25.33 25.44 27.11	22594.24	23654.59
20%		8 B 9	22.67		22378.12	23705.90
			21.33		21706.67	24471.61
		B 10	21.33	26.44	21706.67	24167.33
		C 1	19.11	21.33	20546.04	21706.67
		C 2	18.67	22.67	20308.13	22378.12
	50%:50%	C 3	18.72	21.89	20335.31	21989.77
		C 4	18.89	21.78	20427.43	21934.45
		C 5	17.86	19.91	19862.71	20971.69
HL-SDA	75%:25%	C 6 C	17.78	21.33 21.78 24.00	19818.18	21706.67
30%		7 C 8	18.67		20308.18	21934.45
			20.00		21019.04	23025.20
		C 9	17.78	18.67	19818.18	20308.13
		C 10	16.71	18.13	19212.60	20012.29
		D 1	23.11	23.11	22594.24	22594.24
		D 2	24.44	25.02	23235.30	23509.40
HL-SDA 0%		D 3	23.56	24.44 23.56	22813.16	23235.30
		D 4	22.22		22154.90	22813.16
		D 5	18.13	19.11	20012.29	20546.04

a) Effect of percentage replacement of PC with HL and SDA on the concrete
A close review of the results shown in Table 7 revealed that in general, mix ratios having a proportion of 75%HL:25%SDA gave higher strength values than those with 50%HL:50%SDA. As the curing age increased, compressive strength of the concrete increased as well. Highest compressive strength wa obtained at 10% replacement of PC with HL and value of 30.40N/mm 2 at 56 days was reached at a

Figure 11: Table 7 :

) Compressive strength (N/mm 2 30 0 5 10 15 20 25 23.11 0.5 26.22 0.58 water-cement ratio 25.33 0.57 27.11 0.6

30 Fig. 2: Fig. 3: Relationship between the compressive strength of HL-SDA cement concrete with 30% PC water-cement ratio.

strength (N/mm 2) 15 20 25 30 35 Compressive 0 5 10 24.44 25.69 30.4 27.64 0.55 0.57 0.58 0.6 Water-cement ratio

Figure 12:

Fig. 7:

Modulus of) elasticity (N/mm 2 55 0.57 0.58 W/C ratio 0.6 0.65 28 days 50% :50% 28 days 75% :25% 28 days 0% 56 days 50% : 50% 56 days 75% :25%

Modulus of elasticity (N/mm2) 0 5000 10000 15000 20000 25000 30000 0.55 0.57 0.58 W/C ratio 0.6 24470.65 56 days control 28 days (50%HL:50%SDA) 56 days (50%HL:50%SDA) 28 days (75%HL:25%SDA) 56 days (75%HL:25%SDA) 28 days(control)

Fig. 6: Effect of water-cement ratio on the modulus of elasticity of HL-SDA cement concrete with 20% and replacement.

Figure 13:

) of elasticity (N/mm 2 10000 23509.4 28 days
15000 (50%HL:50%SDA)
20000 56 days
25000 (50%HL:50%SDA)
28 days
(75%HL:25%SDA)
56 days
(75%HL:25%SDA)
28 days(control)
Modulus 0 56 days control
5000
0.55 0.570.58 0.60.65
W/C
ra-
tio

f. For safety purposes, 30% replacement of PC with HL and SDA should be avoided for structural purposes.

Figure 14:

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