Variation of OPC-Saw Dust Ash Composites Strength with Mix Proportion

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ABSTRACT

This work investigated the variation of strength of OPC-SDA cement composites with mix proportion. 168 concrete cubes of 150mm x 150mm x 150mm were produced with OPC and SDA using percentage OPC replacement with SDA of 0%, 10%, 15%, and 20%, and seven water: blended cement: sand: granite mix proportions of 0.6:1:1.5:3, 0.6:1:2:3, 0.6:1:2:4, 0.7:1:2.5:4, 0.7:1:2.5:5, 0.7:1:3:5, and 0.7:1:3:6. 168 sandcrete cubes and 168 soilcrete cubes were also produced using the same percentage replacements and water: blended cement: sand (or laterite for soilcrete) mix proportions 0.6:1:4, 0.6:1:5, 0.6:1:6, 0.7:1:7, 0.7:1:8, 0.7:1:9, and 0.7:1:10. Three concrete, sandcrete, and soilcrete cubes for each percentage OPC replacement with SDA and mix proportion were crushed to obtain their compressive strengths at 28 and 50 days of curing. It was found that irrespective of percentage replacement and curing age, at a given water/cement ratio the compressive strengths increased with leanness of mix up to some level of leanness after which the strength reduced. Concrete compressive strength values for 20% SDA at 50 days of curing rose from 20.10N/mm² for 0.7:1:2.5:4 mix, to 20.70N/mm² for 0.7:1:2.5:5, to 21.60N/mm² for 0.7:1:3:5, and decreased to 21.10N/mm² for 0.7:1:3:6. These results suggest that the leanest mix proportions that would still allow for good compaction should be used in making OPC-SDA cement composites for optimum compressive strength and cost.

Keywords : Blended cement, cement composites, concrete, mix proportion, sandcrete, saw dust ash, soilcrete.

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1 INTRODUCTION

Urgent search for suitable alternatives to Ordinary Portland Cement (OPC) in order to reduce the cost of building projects in Nigeria is necessitated by the critical housing condition in urban and sub-urban districts of the country. The primary focus in this regard is currently on the prospects of commercializing the use of suitable agricultural waste products such as rice husk ash (RHA) and saw dust ash (SDA) as partial replacements for OPC in making cement composites. A number of researchers have already confirmed these otherwise agricultural wastes as pozzolanic materials capable of reacting with the lime produced as by-product of hydration of OPC to produce additional calcium silicate hydrate (C-S-H), thereby enhancing the compressive strength of blended cement composites [1], [2], [3].

Sumaila and Job [4] assessed the properties of OPC-SDA cement concrete at percentage replacement of OPC with SDA of 0 to 30% and reported that all the tested samples developed over 60% of their 28-day strength at 7 days. They recommended the use of SDA to partially replace OPC up to a maximum percentage replacement of 5-10% by volume. Adeagbo [5] investigated the effect of water-cement ratio on the properties of sawdust cement sandcrete and found that 42-57% of sawdust was still adequate in producing sawdust cement sandcrete. Udoeyo and Dashibil [6] found that SDA concrete with SDA used as partial replacement of OPC attained its 28-day design strength at 10% replacement. Their results indicated that SDA concrete could attain the same strength level as conventional concrete at longer curing ages. Elinwa, Ejeh, and Akpabio [7] also found that sawdust ash can be used in combination with metakaolin as a ternary blend with 3% added to act as an admixture in concrete. Elinwa, Ejeh, and Mamuda [8] have also investigated the suitability of sawdust ash as a pozzolanic material and found that it could be used in binary combination with OPC to improve the properties of cement composites. Mageswari and Vidivelli [9] investigated the use of sawdust ash as fine aggregate replacement in concrete by replacing sand with 5 to 30% of SDA in making concrete cubes and cylinders and testing for compressive, tensile, and flexural strengths up to 180 days of curing. Their results indicated the similarity in properties of concrete with 100% sand as fine aggregate and those obtained by replacing sand with SDA at 10-20%.

Studies by Elinwa and Abdulkadir [10] confirmed SDA as a pozzolanic material with optimum at 10% replacement and further established the material as reducing porosity as well as being effective in reducing corrosion of reinforcement in concrete. Marthong [11] investigated the strength of mortar cubes, concrete cubes, and beam specimen made with OPC-

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SDA blended cement and found that the inclusion of SDA caused a little expansion due to low calcium content but early strength development was about 50-60% of their 28-day strength. The study suggested the use of SDA as partial replacement of cement up to a maximum of 10% by volume in all grades of cement. Marthong [12] further investigated the size effect phenomenon of OPC-SDA cement concrete with 10% SDA as partial replacement of OPC using cylinders of different sizes. The results showed that OPC-SDA cement concrete had more size effect than 100% OPC concrete, the size effect being more pronounced at 28 days than at 90 days of hydration. Apata and Alhassan [13] evaluated a number of locally available materials as partial replacement for OPC in concrete production, including rice husk ash, calcined clay, and lime, and concluded that partial replacement of these local materials with 10% OPC can be adopted for low cost housing. Onwuka et al. [14] optimized the compressive strength of OPC-SDA cement concrete and obtained 20.44N/mm^2 as the optimum 28-day compressive strength corresponding to 5% replacement of OPC with SDA.

Recent studies by Ettu et al. [15], Ettu et al. [16], Ettu et al. [17], and Ettu et al.[18] have confirmed the suitability of Nigerian SDA as a pozzolanic material for producing concrete, sandcrete, or soilcrete, either in binary combination with OPC or in ternary combination with OPC and one other agricultural by-product pozzolan such as RHA. However, there is still need to examine appropriate mix proportions that would be most beneficial for production of OPC-SDA cement composites. The behavior of purely OPC cement concrete in this regard is reasonable well known. For example, the mechanical interlocking of the coarse aggregate contributes to the strength of concrete in compression and this explains the higher compressive strength of concrete than mortar [19]. In general, the strength of concrete depends on the strength of the mortar (the matrix), the bond between the mortar and the coarse aggregate (the interfacial transition zone), and the strength of the coarse aggregate particles [19]. However, aggregate strength is usually not a factor in normal strength concrete because the aggregate particle is several times stronger than the matrix and the interfacial transition zone, both of which determine concrete failure [20].

It is also known that a change in the aggregate grading without any change in the maximum size of coarse aggregate, and with water-cement ratio held constant, can influence the concrete strength when this change causes a corresponding change in the consistency and bleeding characteristics of the concrete mixture [20]. Moreover, for a given curing age and temperature, water/cement ratio and degree of compaction are the two primary factors that determine the strength of concrete. For a constant water/cement ratio, a leaner mix leads to a higher strength provided good compaction can be achieved. This is so because the cement paste represents a smaller proportion of the volume of concrete in a leaner mix; therefore the total porosity of the cement paste (and hence of the concrete) is lower and the strength higher [21]. This work investigated the variation of strength of OPC-SDA concrete, sandcrete, and soilcrete with mix proportion. The results are expected to facilitate the production of better quality OPC-SDA cement composites for use in building and civil engineering works in South Eastern Nigeria and elsewhere.

2 METHODOLOGY

Saw dust was obtained from wood mills in Owerri, Imo State in South Eastern Nigeria. The material was burnt into ashes in a local furnace at temperatures generally below 650^{o}C. The resultant saw dust ash (SDA) was sieved small particles passing the 600μm sieve were used for this work. No grinding or any special treatment to improve the quality of the ash and enhance its pozzolanicity was applied. The SDA had a bulk density of 810 Kg/m^3, specific gravity of 2.05, and fineness modulus of 1.89. Other materials used for the work are Ordinary Portland Cement (OPC) with specific gravity of 3.13 and bulk density of 1650 Kg/m^3; crushed granite of 20 mm nominal size with a bulk density of 1515 Kg/m^3, specific gravity of 2.96, and fineness modulus of 3.62; river sand with specific gravity of 2.68, bulk density of 1590 Kg/m^3, and fineness modulus of 2.82; laterite with specific gravity of 2.30, bulk density of 1450 Kg/m3, and fineness modulus of 3.30; and potable water. The chemical analysis of the ash showed it satisfied the ASTM requirement that the sum of SiO_2, Al_2O_3, and Fe_2O_3 should be not less than 70% for pozzolans.

One hundred and sixty eight (168) concrete cubes of 150mm x 150mm x 150mm were produced with OPC and SDA using percentage OPC replacement with SDA of 0%, 10%, 15%, and 20%, and seven water: blended cement: sand: granite mix proportions of 0.6:1:1.5:3, 0.6:1:2:3, 0.6:1:2:4, 0.7:1:2.5:4, 0.7:1:2.5:5, 0.7:1:3:5, and 0.7:1:3:6. One hundred and sixty eight (168) sandcrete cubes and one hundred and sixty eight (168) soilcrete cubes were also produced using the same percentage OPC replacements with SDA and water: blended cement: sand (or laterite for soilcrete) mix proportions 0.6:1:4, 0.6:1:5, 0.6:1:6, 0.7:1:7, 0.7:1:8, 0.7:1:9, and 0.7:1:10. Batching was by weight and mixing was done manually on a smooth concrete pavement. The ash was first thoroughly blended with OPC at the required proportion and the homogenous blend was then mixed with the fine aggregate-coarse aggregate mix (or fine aggregate only for sandcrete and soilcrete), also at the required proportions. Water was then added gradually and the entire concrete, sandcrete, or soilcrete heap was mixed thoroughly to ensure homogeneity. All the concrete cubes were cured by immersion while the sandcrete and soilcrete cubes were cured by water sprinkling twice a day in a shed. Three concrete, sandcrete, and soilcrete cubes for each percentage OPC replacement with SDA and mix proportion were crushed to obtain their compressive strengths at 28 and 50 days of curing.

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3 RESULTS AND DISCUSSION

The variation of the compressive strengths of the OPC-SDA cement composites with mix proportion is shown in Tables 1, 2, and 3 for concrete, sandcrete, and soilcrete respectively.

TABLE 1
COMPRESSIVE STRENGTH OF OPC-SDA CEMENT CONCRETE WITH DIFFERENT MIX RATIOS

W/C Ratio	Mix Ratio	28-Day Compressive Strength (N/mm^2)			
		0% SDA	10% SDA	15% SDA	20% SDA
0.6	**1:1.5:3**	23.00	19.80	18.50	18.00
	1:2:3	23.60	20.50	19.90	18.60
	1:2:4	24.00	21.50	20.70	19.50
0.7	**1:2.5:4**	20.00	18.30	17.80	17.30
	1:2.5:5	20.30	19.40	18.50	18.00
	1:3:5	21.00	19.90	19.20	18.70
	1:3:6	20.60	19.60	19.00	18.30
W/C Ratio	**Mix Ratio**	**50-Day Compressive Strength (N/mm^2)**			
		0% SDA	**10% SDA**	**15% SDA**	**20% SDA**
0.6	**1:1.5:3**	24.50	22.80	21.50	20.00
	1:2:3	25.10	23.50	22.70	21.60
	1:2:4	25.80	24.00	23.20	22.40
0.7	**1:2.5:4**	21.70	21.50	20.80	20.10
	1:2.5:5	22.30	21.80	21.20	20.70
	1:3:5	23.00	23.30	22.10	21.60
	1:3:6	22.70	22.50	21.80	21.10
Mix ratio refers to Blended Cement: Sand: Granite					

It can be seen in the Tables 1, 2, and 3 that the strength values of OPC-SDA composites vary with mix proportion in a similar way as those of normal OPC composites (with 0% SDA). For all percentage replacements of OPC with SDA at 28 and 50 days of curing, at a given water/cement ratio, the compressive strengths increased with leanness of mix up to some level of leanness after which the strength reduced. This result agrees with previous findings by researchers for normal OPC concrete (with 0% SDA). Concrete compressive strength values for 20% SDA at 50 days of curing rose from 20.10N/mm^2 for 0.7:1:2.5:4 mix, to 20.70N/mm^2 for 0.7:1:2.5:5, to 21.60N/mm^2 for 0.7:1:3:5, and decreased to 21.10N/mm^2 for 0.7:1:3:6.

TABLE 2
COMPRESSIVE STRENGTH OF OPC-SDA CEMENT SANDRETE WITH DIFFERENT MIX RATIOS

W/C Ratio	Mix Ratio	28-Day Compressive Strength (N/mm^2)			
		0% SDA	10% SDA	15% SDA	20% SDA
0.6	**1:4**	10.50	8.40	7.80	7.50
	1:5	10.80	8.80	8.60	8.30
	1:6	11.00	9.30	8.90	8.60
0.7	**1:7**	9.00	8.20	7.40	7.10
	1:8	9.20	8.70	7.90	7.50
	1:9	9.50	9.00	8.20	7.80
	1:10	9.30	8.80	8.00	7.60
W/C Ratio	**Mix Ratio**	**50-Day Compressive Strength (N/mm^2)**			
		0% SDA	**10% SDA**	**15% SDA**	**20% SDA**
0.6	**1:4**	11.30	9.90	9.30	8.50
	1:5	11.60	10.10	9.80	9.50
	1:6	11.90	10.50	10.10	10.80
0.7	**1:7**	9.90	9.30	8.90	8.50
	1:8	10.20	9.50	9.20	8.80
	1:9	10.50	10.30	9.70	9.30
	1:10	10.40	9.90	9.40	9.00
Mix ratio refers to Blended Cement: Sand					

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TABLE 3
COMPRESSIVE STRENGTH OF OPC-SDA CEMENT SOILCRETE WITH DIFFERENT MIX RATIOS

W/C Ratio	Mix Ratio	28-Day Compressive Strength (N/mm^2)			
		0% SDA	10% SDA	15% SDA	20% SDA
0.6	**1:4**	9.50	7.40	6.80	6.40
	1:5	9.70	7.70	7.40	7.20
	1:6	10.00	8.20	7.90	7.50
0.7	**1:7**	8.10	7.30	6.50	6.10
	1:8	8.30	7.50	6.80	6.50
	1:9	8.60	7.90	7.30	6.90
	1:10	8.40	7.70	7.00	6.70
W/C Ratio	**Mix Ratio**	**50-Day Compressive Strength (N/mm^2)**			
		0% SDA	**10% SDA**	**15% SDA**	**20% SDA**
0.6	**1:4**	10.20	8.80	8.30	7.50
	1:5	10.60	9.20	8.90	8.40
	1:6	10.90	9.60	9.20	9.00
0.7	**1:7**	8.80	8.30	7.90	7.40
	1:8	9.10	8.60	8.30	7.90
	1:9	9.50	9.20	8.80	8.30
	1:10	9.30	8.90	8.50	8.00
Mix ratio refers to Blended Cement: Laterite					

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Sandcrete strength values for 20% SDA at 50 days of curing rose from 8.50N/mm² for 0.7:1:7 mix, to 8.80N/mm² for 0.7:1:8, to 9.30N/mm² for 0.7:1:9, and decreased to 9.00N/mm² for 0.7:1:10. Soilcrete strength values for 20% SDA at 50 days of curing similarly rose from 7.40N/mm² for 0.7:1:7 mix, to 7.90N/mm² for 0.7:1:8, to 8.30N/mm² for 0.7:1:9, and decreased to 8.00N/mm² for 0.7:1:10. Reduced voids within the composite as much of the water is used up by the composite could account for the increase in strength with leanness of mix at constant water/cement ratio. The composite strength begins to decrease when the mix becomes so lean that the degree of compaction gets too low.

In terms of aggregates proportion, the results show that for a constant water/cement ratio at 0% to 20% replacement of OPC with SDA, the higher the ratio of total aggregate to OPC-SDA blended cement the greater the composite compressive strength, provided a high degree of compaction is still achievable. It also appears from the results that the variation of OPC-SDA cement concrete strength with mix proportion does not depend so much on the ratio of fine aggregate to coarse aggregate as on the proportion of total aggregate.

On the basis of compressive strength and obvious cost effectiveness, these results suggest that the leanest mix proportions that would still allow for good compaction should be used in making OPC-SDA cement composites. Thus, water: blended cement: sand: granite mix proportion of 0.7:1:3:5 would be ideal for OPC-SDA binary blended cement concrete from the stand point of both cost and compressive strength. Similarly, water: blended cement: sand (or laterite for soilcrete) mix proportion of 0.7:1:9 would be ideal for OPC-SDA binary blended cement sandcrete and soilcrete since these mix proportions give strength values suitable for general works in cement composites.

It is also interesting for engineering purposes to note that at 10-20% OPC replacements with SDA the 50-day strength values of OPC-SDA blended concrete, sandcrete, and soilcrete are respectively 82-99%, 75-95%, and 74-96% of those for 100% OPC composites. This result is striking for all the mix proportions considered and further confirms the suitability of OPC-SDA blended cement for making concrete, sandcrete, and soilcrete.

4 CONCLUSIONS

(i) OPC-SDA composites vary with mix proportion in a similar way as those of normal OPC composites (with 0% SDA).

(ii) The compressive strengths of OPC-SDA cement composites increased with leanness of mix up to some level of leanness after which the strength reduced.

(iii) On the basis of compressive strength and obvious cost effectiveness, mix proportion of 0.7:1:3:5 would be ideal for OPC-SDA binary blended cement concrete. Similarly, mix proportion of 0.7:1:9 would be ideal for OPC-SDA binary blended cement sandcrete and soilcrete.

(iv) The 50-day strength values of OPC-SDA blended concrete, sandcrete, and soilcrete are respectively 82-99%, 75-95%, and 74-96% of those for 100% OPC composites.

(v) The results seem to suggest that the variation of OPC-SDA cement concrete strength with mix proportion does not depend so much on the ratio of fine aggregate to coarse aggregate as on the proportion of total aggregate. Further studies would be required to determine the most suitable fine to coarse aggregate ratio for OPC-SDA blended cement concrete.

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