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Effect of Pre-treated Oil-based Drill Cuttings on the Compressive Strength of Sandcrete Blocks

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Abstract

This study examines the drill cuttings on the compressive strength of mortar blended with thermally desorbed drill cuttings and Portland-limestone cement grade 42.5R. The thermally desorbed drill cuttings was used as a partial substitute for Portland-limestone cement. Replacement levels of 0, 5, 10, 15, 20 and 25% were used. The chemical oxide composition, initial and final settings times and the compressive strengths of the blended mortar were determined at curing period of 7 days, 28 days and 90 days respectively. The ANOVA analysis showed that the replication means are not significantly different at 5% probability level, while the coefficient of variability obtained is 10.9% which is within the acceptable limit of less than 20%. Also, the results showed that the treatment means are significantly different at 5% probability level and within the acceptable limit of coefficient of variability which is the degree of precision with which the treatments were compared. Hence, this indicates that the 95% probability that the conclusion of the treatment mean being different is correct, keeping other experimental variables constant. Therefore, partial replacement of cement with the pretreated oil based drill cuttings at different replacement levels has a significant effect on the compressive strength of the sandcrete blocks produced.

Keywords: oil-based drill cuttings; compressive strength; sandcrete blocks.

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1. Introduction

The process of drilling oil and gas wells generates two types of wastes – drilling fluids and drill cuttings[1]. Drilling wastes are the second largest volume of waste, behind produced water, generated by exporation and production industry [2]. American production industry (API) estimated that in 1995 about 150 million barrels of drilling waste was generated from Onshore wells in the United State alone [3]. A certain quantity of drilled cuttings cannot be avoided during drilling operations due to several factors such as insufficient setting time, inefficient mechanical separation equipment, the type of formation being drilled and the type of drilling fluid being used. The inability to remove all the drilled solids (cutting) from the fluid system makes them to be considered as a continual contaminant of the fluid system.The quantity of cuttings, or drilled solids removes from the hole during operation is tremendous, and often as much as 100,000ib/day of cuttings must be carried by mud [4]. Also, [5] reported that about 50,000 - 80,000 tonnes of wet weight of oily drill cuttings are produced annually on the UK continental shelf. This drilled cuttings that consists of rock and low-yielding clays incorporated into the mud during drilling is one of the sources of solids in a mud, apart from commercial solids added to the mud and chemically precipated solids. Drill cuttings carried by mud (drilling fluid) are usually retrieved at the surface of the platform where they go through some separations from the drilling fluid, this process allows the circulating fluid to re-enter the drilling process. In this case it would be worthy to find ways and means of processing the drill cuttings (a waste) into a useful product and in that case providing solution to an environmental problem at the same time. The oil-based drill cuttings being used as partial substitute for cement in sandcrete block production was treated by a thermal desorption unit GA 500^0c in 3 hours [6] which is one of the methods of removing oil from the cuttings and to reduce leacheability of other contaminants. This thermally desorbed oil-based drill cuttings can be recycled for use as a major constituent of mixes for making substantially monolithic specialized civil engineering concrete structures of large sizes such as roads and drilling pads [1] Cement can be defined as a hydraulic binder, which hardens when water is added, and is one of the major constituents in the production of sandcrete blocks, which is a major components in the building industry today. Shelter is a scarce necessity and its demand in recent times has been on a steady rise especially among the young corporate class. It therefore behooves on the producers of cement to formulate strategies aimed at meeting up to this ever increasing demand for cements or look for alternatives that can partially substitute for cement in any construction activity in this case pretreated oil based drill cuttings [6]. This high demand for cement has also lead to the high cost of cement, which indirectly has negatively affected the rate of infrastructural development in Nigeria [6]. This study investigated the effect of drill cuttings on the compressive strength of mortar blended with thermally desorbed drill cuttings and Portland-limestone cement grade 42.5R, using analysis of variance for randomized complete block design method. The results showed that the treatment means are significantly different at 5% probability level and within the acceptable limit of coefficient of variability which is the degree of precision with which the treatments were compared.

2. Materials and Methods

The following materials were used in the production of blended sandcrete blocks;

- Portland limestone cement 42.5R grade

- Fine aggregate of natural sand obtained from Choba river of maximum nominal size of 3.18mm
- Thermally treated oil-based drill cuttings of nominal site of < 63µm.
- Water of ordinary portable tap water available in the civil engineering laboratory was used for mixing and cutting the sandcrete blocks.

2.1 Preparation of Drill Cuttings

The oil-based drill cuttings were collected from a waste treatment facility at Onne, Rivers State at a pre-treated temperature and time of 4000C and 90 minutes. In order to prepare the oil-based drill cuttings as a pozzolanic material, it was treated at an optimum temperature and time of 5000C and 3 hours and grinded for 1 hour and then allowed to pass through 63µm sieve [6]. This treated oil-based drill cuttings was used as part substitute of cement at a percentage replacement levels 5,10,15,20 and 25% in the production of sandcrete blocks.

2.2 Mix proportions and Sandcrete Block specimens

The sandcrete block used was a mixture of binder (mixture of cement and drill cuttings), fine aggregate and water. The mix was bathed by weight using mix ratio 1:3 (binder; sand) with a water-binder ratio of 0.45:1 as specified by BS 4550-3.4. cube size of 150mm x 150mm x 150mm were cast and cured in water for 7 28 and 90 days before testing for the determination of compressive strength of the blended sandcrete blocks at different replacement levels of 0%(control) 5%, 10%, 15%, 20% and 25% respectively as shown in plates 1-6.

Plate 1: Moulds for Casting Cubes

Plate 2: Demoulded Cubes Ready for Curing

Plate 3: Blended sandcrete blocks in Curing Tank

Plate 4: Blended Sandcrete blocks at Different Replacement Levels after Curing ready for Crushing

Plate 5: Weighing the Sandcrete blocks before Crushing

Plate 6: Crushing the sandcrete blocks for Compressive Strength Measurement

Table 1: Mix Design for Mix Ratio of 1:3

Constituent Material	0% DC Control	5% DC	10% DC	15% DC	20% DC	25% DC
Cement (kg)	2	1.9	1.8	1.7	1.6	1.5
Drill cuttings (kg)	0.0	0.1	0.2	0.3	0.4	0.5
Sand (kg)	6	6	6	6	6	6
W/B	0.45	0.45	0.45	0.45	0.45	0.45
Total water (kg)	0.9	0.9	0.9	0.9	0.9	0.9

2.3 Experimental Design

A total number of 36 cubes were cast at the different replacement levels and cured for 7, 28 and 90 days. For each mix, 2 cubes were crushed to obtain the average compressive strength. The randomized complete block design (RCBD) method for ANOVA analysis was used in the study with six treatments and two replications per experiment. The least significant difference (LSD) was used to detect the significance of the means differences among treatments. Also, the coefficient of variability (CV) which is the ratio between the standard deviation and the sample means.

$$\text{Coefficient of Variability C.V\%} = \frac{\text{S.D}}{\bar{X}} \times \frac{100}{1} \quad (1)$$

Coefficient of Variablitiy (C.V) % can also be calculated as:

$$\text{C.V \%} = \left(\frac{\sqrt{\text{Error Mean Square}}}{\text{Overall Mean}}\right) \times 100 \quad (2)$$

Where:

$\bar{X}$ = Grand Mean

S.D = Standard deviation

The coefficient of variation C.V % indicates the degree of precision with which the treatments are compared.

$$\text{The least significant difference (LSD)} = t_{(E.df;0.05)}\ x\ S_d \quad (3)$$

Where:

$$S_d = \text{standard error of mean difference } \frac{\sqrt{2EMS}}{t} \quad (4)$$

t= tabular value at 5% probability level at error d_f

3. Results and discussion

3.1 Particle Size Distribution

The particle size distribution analysis and the particle size distribution curve carried out on the fine aggregate (sand) are presented in Table 2 and Figure 1. From the particle size distribution curve of the fine aggregate (sand), more than 95% of the sand passes 4.15mm and less than 1% retained on 0.075mm sieve size. Hence, the fine aggregate is within the specified requirements for fine in mortar/concrete production [7]. Also, the uniformity coefficient CU and coefficient of curvature Cc for the sand are 0.16 and 0.9 which showed that the fine aggregate is well sorted, while the fineness modulus is 4.69 which is within the acceptable value [8].

Table 2: Particle size distribution analysis of the fine aggregate

Sieve Size (mm)	% Passing	% Retained
2.00	99.4	0.6
1.40	98.8	1.2
0.71	91.5	8.5
0.500	74.8	25.2
0.355	43.5	56.5
0.250	13.1	86.9
0.180	5.2	94.8
0.125	2.9	97.1
0.075	1.1	98.9

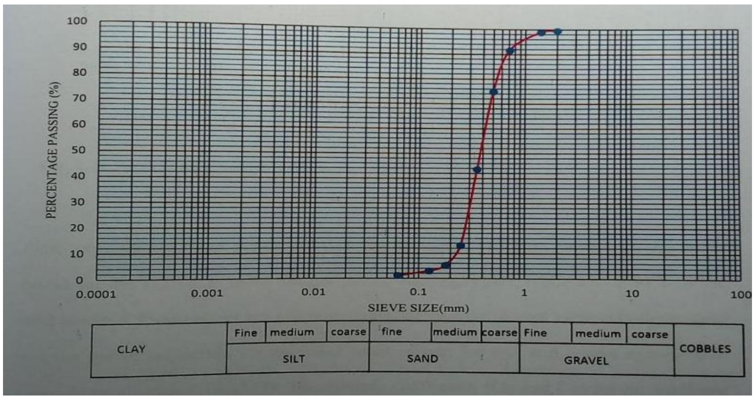

Figure 1: Particle size distribution curve

3.2 Effect of percentage replacement levels on the compressive strength of the blended sandcrete blocks

The randomized complete block design (RCBD) method for ANOVA analysis as shown in Table 3 was used in the study with six treatments and two replications per treatment at 28 days curing period. As shown in Table 3, the average compressive strength of the mortar decreased as the percentage of added drill cuttings increased, this is in agreement with the works of the authors [9, 10, 11]. In all, the average compressive strength of drill cutting–cement blended mortar ranged from 15.19 – 22.00N/mm^2 at replacement levels of 5, 10, 15, 20, and 25% respectively, while that of normal mortar (0% drill cuttings addition) is 24.44N/mm^2. Meanwhile, Nigerian Industrial Standard (NIS) specified a minimum of 2.5N/mm^2 for sandcrete blocks [12]. Thus, the compressive strength of the drill cutting-cement blended mortar is adequate for sandcrete production and usage in construction, using 1:3 mix ratios with a water/binder ratio of 0.45:1.

Table 3: Compressive strength of cement-drill cuttings blended sandcrete blocks (n/mm2) at 28 days curing period

Treatment Levels (%)	Replication		Total	Mean
	1	2		
0	24.44	24.44	48.88	24.44
5	23.11	20.89	44.00	22.00
10	22.22	19.29	41.51	20.76
15	16.62	20.27	36.89	18.45
20	16.04	16.98	33.07	16.54
25	17.69	12.89	30.58	15.29
Total	120.17	114.76	234.93	19.58

Table 4: Analysis of variance for the data in table 3 using RCBD method

Sources of Variation	d/f	SS	MS	Fc	Ft 1%	Ft 5%
Replication	1	2.4390	2.4390	0.5327	16.26	6.61
Treatment	5	119.64185	23.92837	5.2257	10.97	5.05
Error	5	22.89495	4.57899			
Total	11					

The coefficient of variability C.V = (√EMS)/(Overall Mean)×100

i.e (√4.57899)/19.58×100=10.9%

The result from Table 4 showed that there was no significant difference among the replication means since the F_c value are less than both the $F_{\mathbf{c}}$ 1% and F_t 5%. This indicates that whatever differences observed among the replication means may not be attributed to the effect of the treatment alone but may also be due to unknown factors, during the crushing. Also, the results from Table 4 showed that there are significant differences among the treatment means since the F_c value is higher than the F_t at 5% but lower than the F_t at 1% probability level. The coefficient of variability is within the acceptable limit of less than 20%, an indication that the conclusions drawn from the data are reliable. Since the ANOVA declared that mean differences are significant at 5% but not at 1% level, the least significant difference at 5% level is chosen. Any mean difference greater than the computed LSD value indicates significant difference from the control. Using the results from Table5 where error mean square is 4.57899 and using the 5% t-table value for error df of 5 gives 5.05, the LSD at 5% level is 6.2390. The absolute mean difference from the control treatment (0%) is shown in Table 5.

Table 5: Compressive Strength Mean Differences from the Control Treatment

Treatment levels %	Mean	Absolute D/F from Control
0	24.44	
5	20.00	2.44
10	20.76	3.68
15	18.45	5.99
20	16.54	7.9
25	15.29	9.15

The results from Table 5 shows that only treatments 20 and 25% replacements levels are significantly different from the control since their differences are greater than the LSD value (7.9>6.2390, 9.15>6.2390). All the other treatments (5, 10 and 15%) are not significantly different from the control.

4. Conclusion

Drill cuttings was burnt to 5000C for 3 hours using electric furnace. The thermally desorbed drill cuttings was grounded and sieved through 63 microns sieve. The chemical oxide composition of the drill cuttings gave a favourable result for use as pozzolana. The thermally desrobed drill cuttings was partially used to substitute Portland-limestone cement of 42.5R grade in the production of sandcrete blocks. The replacement levels of 0, 5,10,15,20 and 25% were used. The mix proportion for the control sandcrete block was 1:3(ratio of binder to sand). The ANOVA analysis shows that the differences observed among the replication means may not be attributed to the effect of the treatment alone. Also, there are significant differences among the treatment means, since the F-calculated is higher than the F-tabulated at 5% but lower than the F-tabulated at 1% probability level. This indicates a 95% probability that the conclusion of the treatment means being different is correct i.e 5% probability that the conclusion is not correct. The coefficient of variability is 10.9% which is the acceptable limit of less than 20%. Finally, only the 20 and 25% replacement levels are significantly different from the control, since their differences are greater than the least significant difference calculated.

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