ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV926

The Use of Drill Cuttings as Pozzolan for Concrete Production

[1]Amassoma, C. A.; [1]Eze, C. L.; [1]Abam, T.K. S.; [1]Gobo, A.E
[1] Institute of Geosciences and Environmental Management,
Rivers State University Nkpolu-Oroworukwo, Port Harcourt, Rivers State, Nigeria.

Abstract:- The Increasing need of energy and its high price tempts exploration and production industries to drill more oil wells daily and create more drilling waste. The current trend of waste management in the world is to put the wastes into beneficial use where possible. The waste to wealth approach is the crux of this study which evaluated the pozzolanic properties and potential of using treated drill cuttings as a partial replacement of cement in concrete production. To achieve this objective, chemical tests, physical tests and compressive strength tests were carried out to determine the suitability of the treated drill cuttings for pozzolanicity. All tests were as prescribed by American Society for Testing and Materials (ASTM) Standard and applicable national standard where such exists. The drill cuttings moisture content, loss-on-ignition, pertinent chemical oxides and physical properties were determined. The compressive strength test of the mortar cubes was conducted using a mold of 150 mm x 150 mm x 150 mm, mix proportion of 1:3 (binder: sand) and water-to-cement ratio of 0.4:1. A total of 54 cubes were cast with treated drill cuttings replacement levels of 0% (control), 10%, 20%, 30%, 40% and 50% and each cured for 7days, 14 days and 28 days before testing for the determination of compressive strength of the blended concrete blocks. Results showed that the $SiO_2 + Al_2O_3 + Fe_2O_3$ value of the treated drill cuttings satisfied the requirement of 70% for pozzolans at 69.16% which is less than 1% below the recommended minimum value of 70% specified for a good pozzolan. In previous studies, materials with values of $SiO_2 + Al_2O_3 + Fe_2O_3$ less than 70% but greater than 60% have been used as pozzolans. The other oxides (Na_2O and SO_3) also were within their acceptable limits for pozzolan as stipulated by ASTM C618. The result of the physical properties of the treated drill cuttings complied with the applicable standard limit. The compressive strength of the mortar was higher than that of control mortar (0% treated drill cuttings addition) at 10% and 20% replacements of cement at ages 7, 14, and 28 days with compressive strengths of 18.67 N/mm^2, 19.56 N/mm^2 and 21.03 N/mm^2 respectively, which exceeded the minimum Compressive Strength of 2.5 Nmm^2 to 3.45 Nmm^2 recommended for sandcrete blocks production. Therefore, partial replacement of cement with treated drill cuttings at 10% and 20% replacement levels, has a significant effect on the compressive strength of the produced sandcrete blocks. Hence, treated drill cuttings can serve as a pozzolan for sandcrete blocks production.

I. INTRODUCTION

The process of drilling oil and gas wells generates two types of wastes: drilling fluids and drill cuttings (Onwukwe & Nwakaudu, 2012). According to Boutammine *et al.*, (2020), drill cuttings are mixtures of crushed rock chips, drill muds and some organic and inorganic chemicals. Drill cuttings are produced from the subsurface of rocks when the drilling bit cuts into the formation during drilling activities and it is mixed with drilling fluids as a lubricant and coolant (Chikwue *et al.*, 2020; Nwosu & Ogbonna, 2021).

The creation of a single vertical well bore to an average depth of 1000m brings up about 45m^3 of cuttings, including radioactive substances and heavy metals, mixed with the chemicals in the drilling fluid (Eze *et al.*, 2015). The quantity of cuttings or drilled solids removed from the hole during operation is tremendous, and often as much as 100,000ib/day of cuttings must be carried by mud (Njokuenwu & Nna, 2005). According to NAOC (2013), Ebegoro M well in the Niger Delta area of Nigeria with a projected total drilled depth of 8,933m, was estimated to produce a total of 2,320 tons of drill cuttings. Horizontal wells will produce much more of this material as do vertical wells (Ferrari *et al.*, 2000). According to DPR (2018), Nigeria produced a total of 34,834.07 MT of oil based mud and drill cuttings in 2016. The drill cuttings are composed of the drilling mud and solid particles. Mud consists of soil, loam, silt or clay mixed with water.

➢ *Pozzolanicity*

Sudarsan (2017) described pozzolans as a different type of refractory materials, naturally available and consist of very fine particles of siliceous and aluminous materials that in presence of water react with calcium hydroxide to create cementitious materials in the form of calcium silicate and calcium silico-aluminate hydrates. According to Farinha *et al.*, (2021), a pozzolan is a material that is not naturally a binder but contains amorphous phases of silica and/or alumina that, under given circumstances, in the presence of water and at room temperature, can be combined with the calcium oxide present in cement or lime, giving rise to stable elements with hydraulic binder properties.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV926

The amount of calcium hydroxide fixed on a pozzolanic material is an indicator of its pozzolanicity activity (Habert *et al.,* 2008). Pozzolanicity can also be evaluated by the mechanical strength of mortars when the hydraulic binder (cement) is replaced with a pozzolanic material (Mostavi *et al.,* 2015). It is possible to obtain pozzolanic materials when clays are thermally heated. Indeed, by heat treatment, the crystal structure of the clay minerals is destroyed and an amorphous or disordered alumino-silicate structure is formed, developing pozzolanic properties (Alp *et al.,* 2013; Sudha *et al.,* 2015).

Thermal desorption is a classical technology to treat organic impacted soil. By heating soil up and above their boiling point, the system evaporates all organic components and produces clean soil, from a pollution standpoint. Soil as such is not suitable for producing concrete because of the swelling properties of its clay particulates. The inner process of thermal desorption, where clay particulates are brought to high temperatures in presence of oxygen, transform the mix sand/clay/gravel that constitutes a traditional soil into a mix sand/gravel/binder (He *et al.,* 2000).

The transformation of the clay particulates into a binder material is the key element for using thermally desorbed soil as base for concrete in substitution for sand, gravel and cement (Mohammed & Cheeseman, 2011; Ghasemi *et al.,* 2017; Adekitan & Popoola, 2020).

II. MATERIALS AND METHODS

Determination of the suitability of a material for pozzolanicity requires a series of tests which are generally classified as chemical tests, physical tests and strength active index tests. All tests were as prescribed by American Society for Testing and Materials (ASTM) Standard and applicable national standard where such exists. The ASTM Standard (ASTM C311-77) is the standard method for testing for Pozzolans.

Experiments were conducted by replacing cement with 10, 20, 30 40, 50 percentages of the pozzolan materials. A compressive strength test was conducted for the ratio of samples to determine if compressive strength meet the target strength. Below is a brief summary of the test methods of the ASTM standard. The Parameters, Standard methods and Target values applied in the Pozzolan Tests are presented in Table 1. Samples were collected from a Thermal Desorption Unit (TDU) at Del Waste Management Company Limited, located in Onne, Rivers State and taken to the laboratory. This Thermal Desorption Unit receives drill cuttings from different parts of the Niger Delta.

Table 1: Testing Parameters, Methods and Target Values of Pozzolans

S/N	Parameter	Standard Method	Target Value
	Chemical Analysis		
1	Moisture content % (max)	ASTM C 618, 2003	3.0
2	Loss on Ignition(Lol) % (max)	ASTM C 618, 2003	6.0
3	Chemical content %	ASTM C 618 2003	
	$SiO_2 + Al_2O_3 + Fe_2O_3$ (min)		70.0
	SO_3 (max)		4.0
	Na_2O (max)		1.5
	Physical Tests		
4	Specific gravity (max)	ASTM 188-14	3.15 g/cc
5	Fineness% Using 45 µm (No. 325) sieve, max. %	ASTM C 430	34.0
6	Soundness % max %	ASTM C 151	0.8
7	Drying Shrinkage % Slab at 28days Project specifications at 28days	ASTM C 157	 0.05 – 0.06 0.035- 0.04
8	Compressive Strength (MPa)/Nmm²/ kg/cm2	ASTM C 109	min for 1:3 and 1:6 mortar cube at age of 28 days is 7.5 MPa and 3 MPa respectively.

III. RESULTS AND DISCUSSION

The chemical and physical properties of the treated drill cuttings are shown in Tables 2 and 3 respectively.

A. Chemical Composition of the Treated Cuttings Sample

The results of the chemical analysis in Table 2 showed that all parameters analyzed were within their acceptable limits except the moisture content, where the treated drill cuttings failed to meet the chemical requirements recommended in ASTM C618. According to (ASTM C618), a natural pozzolan is required to contain a minimum of 70% $SiO_2 + Al_2O_3 + Fe_2O_3$. The total silica, alumina and iron oxide ($SiO_2 + Al_2O_3 + Fe_2O_3$) obtained was 69.16% which is less than 1% below the recommended minimium value of 70% specified for a good pozzolan. According to previous studies (Alabadan *et al.*, 2005; Technical Bulletin, 2006; Walker & Pavia, 2011), materials with values of $SiO_2 + Al_2O_3 + Fe_2O_3$ less than 70% but greater than 60% have been used as pozzolans.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV926

Table 2: Chemical Analysis Result

S/N	Parameter	Standard Method	Lab Analysis Result	Target Value
1.	**Moisture content % (**maximum**)**	ASTM C 113	6.78	3.0
2.	**Loss on Ignition(Lol) %** (maximum)	ASTM C113	5.24	10.0
3.	**Chemical content %**	ASTM C113		
	Silicon Dioxide (SiO_2)		56.96	-
	Aluminium Oxide (Al_2O_3)		9.33	-
	Iron Oxide (Fe_2O_3)		2.87	-
	$SiO_2 + Al_2O_3 + Fe_2O_3$ (minimum)		69.16	70.0
	Sodium Oxide (Na_20) (maximum)	ASTM C113	0.74	1.5
	Sulphur Trioxide (SO_3) (maximum)	ASTM C113	0.18	4.0

B. Physical Properties and Composition of the Treated Drill Cuttings Sample

The physical properties of the treated drill cuttings are as recorded in Table 3. All the parameters tested are within the standard limit except the fineness test. The treated drill cutting sample was sieved using 75µm sieve to have samples whose fineness compares closely with cement. The result on fineness indicated that the weight of dry samples retained on 75 µm sieve is greater than 10%. Pozzolanic effects have also been reported at larger particle sizes of 75 microns (Alp *et al.*, 2013; Adekitan & Popoola, 2020)

Table 3: Physical Test Result

S/N	Parameter	Standard Method	Lab Analysis Result	Maximum Limits
1	**Drying Shrinkage %**	BS 8500, ASTM C531	2.143	0.05 – 0.06 0.035- 0.04
2	**Specific gravity (maximum)**	BS EN 1097-3, ASTM D894	2.42	3.1 **-** 3.15g/cc
3	**Consistency Test**	BS 8500, ASTM C531	16% (33mm)	33-36mm
4	**Fineness %** Amount retained when sieved on 75 µm sieve, max. %	BS EN 1097-3, ASTM D894, BS EN 197-1:2011	22.7	< 10%
5	**Soundness max.%**	BS 4550: PART 3, ASTM C151	-2.98	<0.8%

C. Compressive Strengths of Mortar of Various Replacement Percentages Compared with Curing Age

Detailed data summarizing the results of the average compressive strength of the treated drill cuttings- cement blended mortar at age 7, 14, and 28 days are shown in Figure 1. It can be seen that the average peek compressive strength of the Treated Drill Cuttings-Cement Blended Mortar increases at 10% from 18.67 N/mm² to 21.03 N/mm² at the ages of 7 to 28 days respectively.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV926

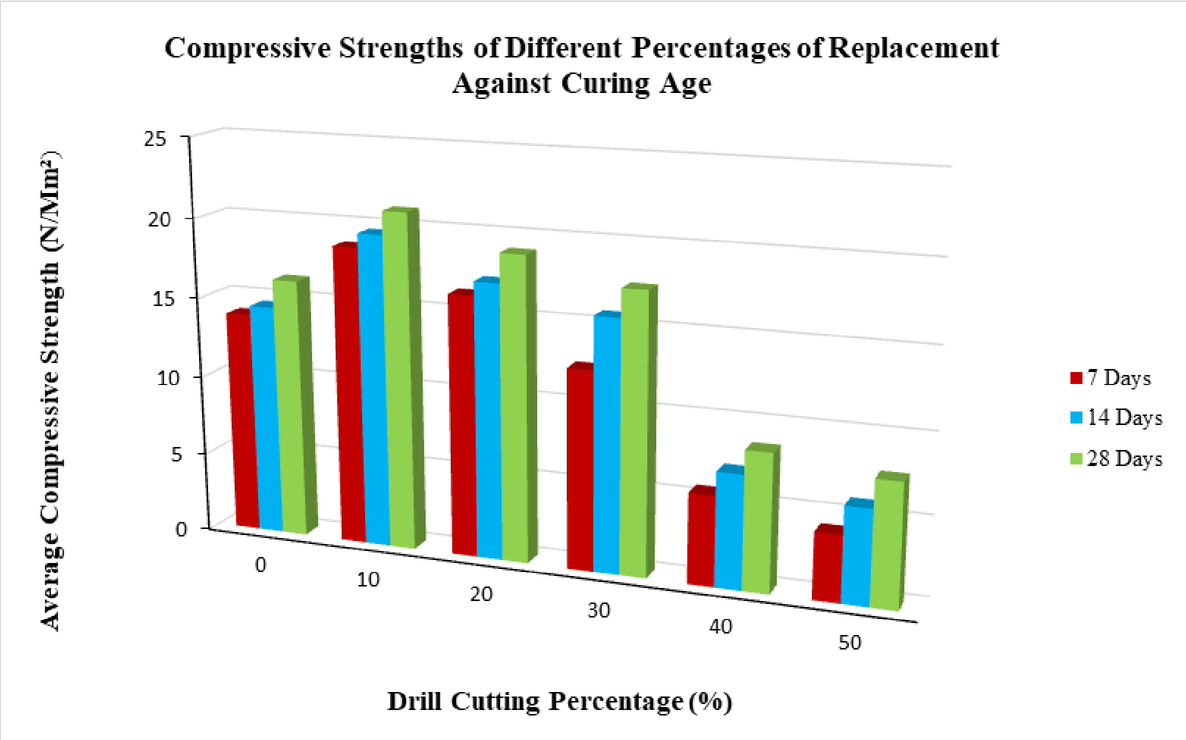

Fig 1: Compressive Strengths of Mortar of Various Replacement Percentages Against Curing Age

Figure1 shows a plot of the compressive strengths of the different replacement percentages against curing age. The figure illustrates that the treated drill cuttings induced a significant compressive strength increments in mortar at 10% and 20% levels of replacement at 7, 14, and 28 days then decreases from 30% to 50% treated drill cuttings replacement of cement. Figure 1 also indicates that the 30% treated drill cuttings replacement did improve strength later at 14 and 28 days of curing age higher than that of the control mortar. However, the 10% treated drill cuttings replacement samples produced the highest 7 day, 14 day and 28-day strengths of 18.67 N/mm², 19.56 N/mm² and 21.03 N/mm² respectively. Thus, the 10% replacement of cement with treated drill cuttings is considered as the optimal limit.

Meanwhile, Nigerian Industrial Standard (NIS 87:2000) specified a minimum Compressive Strength of 2.5 Nmm² for sandcrete blocks.

IV. CONCLUSION

This study was carried out to determine the pozzolanic potential of treated drill cuttings in the production of mortar and the effect of incorporating pozzolanic materials (treated drill cuttings) with ordinary portland cement on the properties of cement, mortar and concrete with the following conclusions drawn:

The physical and chemical oxide tests on the samples indicated that the treated drill cuttings meet the requirements for a pozzolan for use in the production of blended cements.

The combined chemical oxide mix composition (i.e. $SiO_2+Al_2O_3+Fe_2O_3$) of the treated drill cuttings demonstrated that the treated drill cuttings satisfied the criteria for pozzolans as stipulated by ASTM C618 (ASTM 2003), which requires a minimum sum of 70% for the three main oxides (SiO_2, Al_2O_3, Fe_2O_3).

The results of the compressive strength confirmed that the strength enhancements of mortar are achievable with partial replacement of cement with treated drill cuttings. The strength of pozzolanic cement is higher than that of control mortar (0% treated drill cuttings addition) at 10% and 20% replacements of cement at ages 7, 14, and 28 days.

This study therefore concludes that, the compressive strength of the treated drill cuttings-cement blended mortar is adequate for sandcrete block production with improved properties and usage in construction, using 1:3 mix ratios with a water/binder ratio of 0.40:1. Thus demonstrating the potential for the beneficial reuse of oil drill cuttings treated by thermal desorption, as partial replacement of cement for the production of sandcrete blocks.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV926

REFERENCES

[1]. Adekitan, O. A., & Popoola, M. O. (2020). Potentials of calcined clay as a pozzolan építőanyag. *Journal of Silicate Based and Composite Materials, 72(2),* 70–71

[2]. Alabadan, B.A., Olutoye, M.A., Abolarin, M.S., & Zakariya, M. (2005). Partial replacement of Ordinary Portland Cement (OPC) with Bambara Groundnut Shell Ash (BGSA) in concrete. *Leonardo Electronic Journal of Practices and Technologies, 6,* 43–48.

[3]. Alp, I., Deveci, H., Sungun, Y. H., Yilmaz, A.O., Kesimal, A., & Yilmaz, E. (2013). Pozzolanic characteristics of a natural raw material for use in blended cements. *Iranian Journal of Science & Technology, 33(B4),* 291-300

[4]. Boutammine, H., Salem, Z., & Khodja, M. (2020). Petroleum drill cuttings treatment using stabilization/solidification and biological process combination. *Soil and Sediment Contamination, 29(4),* 369-383.

[5]. Chikwue, I. M., Okparanma, R. N., Ayotamuno, J. M., & Asinyetogha, H. I. (2020). Effect of pre-treated oil-based drill cuttings on the compressive strength of sandcrete blocks. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS), 73(1),* 20-29

[6]. Department of Petroleum Resources (2018). Nigerian oil and gas industry annual report.

[7]. Eze, C.L., Iheonu, C.A., & Godwin, A.C. (2015). The level of base oil recovery from Niger Delta drill cuttings using thermal desorption unit. *International Journal of Engineering Research and Applications, 5(7),* 1–5

[8]. Farinha, C., De Brito, J., & Do Veiga, M. (2021). Eco-efficient rendering mortars: *Use of Recycled Materials*. Woodhead Publishing Series in Civil and Structural Engineering, 492pp

[9]. Ferrari, G., Ceccini F., & Xiao, L. (2000). Drilling wastes treatment and management practices for reducing impact on HSE: ENI/AGIP experiences. *In the proceedings of the SPE International Oil and Gas Conference and Exhibition,* China, Beijing, 1-11

[10]. Ghasemi, S., Gitipour, S., Ghazban, F., & Hedayati, H. (2017). Treatment of petroleum drill cuttings using stabilization/solidification method by cement and modified clay mixes. *Iranian Journal of Health, Safety and Environment, 4(3),* 781–787.

[11]. Habert, G., Choupay, N., Montel, J. M., Guillaume, D., & Escadeillas, G. (2008). Effects of the secondary minerals of the natural pozzolans on their pozzolanic activity. *Cement and Concrete Research, 38(7),* 963–975.

[12]. He, C., Makovicky E., & Osbaeck B. (2000). Thermal stability and pozzolanic activity of raw and calcined mixed-layer mica/ smectite. *Applied Clay Science, 17(3-4),* 141-161.

[13]. Mohammed, B., & Cheeseman, C. R. (2011). Use of oil drill cuttings as an alternative raw material in sandcrete blocks. *Journal of Waste and Biomass Valorization, 2(4),* 373-380

[14]. Mostavi, E., Asadi, S., & Ugochukwu, E. (2015). Feasibility study of the potential use of drill cuttings in concrete. *In: International Conference on Sustainable Design, Engineering and Construction, Procedia Engineering, 118,* 1015 – 1023

[15]. Nigerian Agip Oil Company, (2013). Final environmental impact assessment report for the drilling of additional well in Ebegoro field.

[16]. Njokuenwu, D.O., & Nna, E. (2005). The effect of critical wetting agent concentration on drilling fluids performance. *Journal of Science Technology Research, 4,* 65-71.

[17]. Nwosu, B. E., & Ogbonna, F. J. (2021). Treatment efficiency of drill cuttings using thermal desorption technology. *Journal of Engineering Research and Reports, 21(3),* 1-12

[18]. Onwukwe, S. I., & Nwakaudu, M. S. (2012). Drilling wastes generation and management approach. *International Journal of Environmental Sciences and Development, 3(3),* 252-257.

[19]. Sudarsan, V. (2017). Materials for hostile chemical environments. *Materials Under Extreme Conditions, 1,* 129-158.

[20]. Sudha, P., Selvaraj, R., & Palanisamy, T. (2015). Intensification of calcined clay as a pozzolanic material in cement mortar. *International Journal of Applied Engineering Research* 10 *(15),* 35640-35644.

[21]. Technical Bulletin (2006). Ground Granulated Blast Furnace Slag: Its Chemistry and Use with Chemical Admixtures. No.: TB-0102. Grace Construction Products, USA. pp. 1-3.

[22]. Walker R, Pavia S (2011). Physical properties and reactivity of pozzolans, and their influence on the properties of lime-pozzolan pastes. *Materials and Structures 44*, 1139–1150.