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THE USE OF QUARRY DUST FOR PARTIAL REPLACEMENT OF CEMENT IN CEMENT-SAND MORTAR

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ABSTRACT
This research was carried out to investigate the effect of partially replacing cement with quarry dust in cement-sand mortar. Tests including setting times, water absorption, compressive strength and density test were carried out on mortar with cement partially replaced with 0%, 5%, 10%, 15%, 20%, 25% and 30% quarry dust and presented. Experimental results show that replacement of quarry dust as partial replacement of cement in cement-sand mortar decrease the initial and final setting times of cement paste and increase the water absorption of the mortar. The partial replacement shows an improvement of compressive strength at 5% quarry dust content after which there is a decrease with increase in quarry dust content at all the ages. The increase in compressive strength at 5% indicates possible pozzalanic activity at that level. Thus quarry dust can be utilized as cement replacement material at 5% dust content. Above this it can be utilized as fine aggregate replacement for use in low-strength mortar applications.

Keywords - Quarry dust, cement-sand mortar, cement partial replacement, setting times, water absorption, compressive strength, density

INTRODUCTION

Cement mortar is a mixture of cement and sand majorly used in bonding blocks/bricks units and in plastering. Usage of high amount of cement increases the consumption of natural resources and increase the construction cost. Acccording to Aliyu et.al (2020), Tavakolia et al. (2013), Meyer (2009) and Mehta (1983), sustainability is another desired reason for using waste products to replace cement in mortar and concrete apart from the factors of high consumption of natural resources and high cost of construction materials. To overcome these problems there is a need to replace cement with some other cheaper materials. There are several alternative materials tested by researchers to replace cement in mortar and concrete (Gingos, 2011; Silva et al., 2008). Fly ash, bottom ash and Ground Granulated Blast-furnace Slag (GGBS) , Rice Husk Ash (RHA) are some of the common waste materials used to replace cement in concrete and mortar (Varma & Gadling, 2017; Suresh & Nagaraju, 2015; Ogork et.al, (2015)). These materials exhibit cement-like characteristics and are classified as pozzolana materials.

Quarry dust is a by-product of the rock quarrying process abundantly available and minimally used in a quarry industry. Quarry dust has a rough surface which aids in bonding with other materials like coarse aggregates and cement (Fatima, 2005). It also has some cementatious materials in its composition such as silicate and aluminium contents (Fatima, 2005). Various researches have shown that quarry dust can be effectively used in concrete as a partial replacement for sand. The suitability of quarry dust as a sand replacement material shows that mechanical properties such as elastic modulus and compressive strength are improved. (Shweta, et - al, 2017; Shyam Prakash & Rao, 2016; Chauhan & Bondre, 2015; Karthick et al., 2014; Balamurugan & Perumal, 2013).

Usage of quarry dust as partial replacement to river sand/natural sand further modified by partial replacement using pozzolanic materials like fly ash revealed excellent performance due to efficient microfilling ability and pozzolanic activity and generally improves the properties of concrete (Rai et al., 2014). On the other hand, (Hoque et al., 2013) concluded that mortars with the replacement of 25% and 50% of fine aggregate and also 5% of cement by quarry dust is quite appropriate to be selected as the substitution of fine aggregate but not as the replacement of cement.

The present research work evaluates the use of quarry dust for partial replacement of cement in cement-sand mortar

MATERIALS AND METHODS

Materials

The quarry dust used in the research was obtained from a local quarry site along Rano Road in Kano Nigeria. It has a specific gravity of 2.6. River sand was also obtained locallyin Rano town in Kano State with a specific gravity of 2.05. Water used for both mixing and curing was ordinary tap water, which is fit for human consumption in accordance with (BS-EN1008, 2002). Cement used in the study was Dangote Portland limestone cement branded as 3X which

conforms with (NIS-44., 2003). It has specific gravity of 3.14.

Methods

Mortar Production

Mortar is a mixture of a cement and sand. The mortar used in this study has a mix ratio of 1:6 as specified in BS EN 196-1 (1995). The absolute volume method was used in determining the quantities of materials required for one cubic metric metre of mortar. The dry mortar was initially prepared by mixing one part of cement with three parts of sand with some part of the cement replaced by quarry dust in the order of 0%, 5%, 10%, 15%, 20%, 25% and 30% by weight of cement. After thoroughly mixing the constituent, water was then added and mixed to produce cement mortar. Each batch of three test specimens were mixed separately and consisted of 450 ± 2g of cement, 1350 ± 5g of sand and 225 ± 1g of water and appropriate quarry dust content. The mortar was used for setting times test, moisture absorption test, density and compressive strength test.

Table 1 shows the quantities of materials per cubic metre of mortar as used.

Table 1: Quantities of Materials used to Produce One Cubic Metre of Mortar (1:6)

Mix No	Quarry Dust (%)	Constituent Materials (Kg)			
		Cement	Quarry Dust	Sand	Water
0/1	0	9.6	0	57.6	6.72
5/1	5	9.2	0.4	57.6	6.72
10/1	10	8.81	0.70	57.6	6.72
15/1	15	8.41	1.19	57.6	6.72
20/1	20	8.02	1.58	57.6	6.72
25/1	25	7.62	1.98	57.6	6.72
30/1	30	7.22	2.38	56.6	6.72

Setting Time test

Using cement paste with 0%, 5%, 10%, 15%, 20%, 25% and 30% quarry dust replacement, the initial and final setting times of the pastes were determined in accordance with(BS-EN196-3, 2005).

Water Absorption Test

The water absorption test was conducted on three mortar cubes (100x100x100) mm with 0%, 5%, 10%, 15%, 20%, 25% and 30% quarry dust replacement. The cubes were cured in water for 28 days, they were then dried and weighed. They were further cured in water for another 24 hours after which they were further dried and re-weighed. The increase in weight of the sample was used to determine the water absorption rate in percentage using the expression in equation (1).

$$\text{Water absorption (\%)} = \frac{increase\ in\ weight\ of\ cube}{final\ weight\ of\ cube}\ x\ 100 \qquad \text{---------Equation (1)}$$

Compressive strength Test

Compressive strength test on mortar cubes containing 0%, 5%, 10%, 15%, 20%, 25% and 30% quarry dust replacement of size 100 x 100 x 100 millimeter were carried out. Forty Two (42) cubes specimens were prepared, they were weighed to determine the density before being tested for compressive strength at 7and 28 days in accordance with BS EN 196 - 1: 1995.

DISCUSSION OF THE RESULTS

Effect of quarry dust replacement on Setting time of cement paste

The effect of partial replacement of cement with quarry dust is presented in Figure 1. The introduction of the dust decreases the initial and final setting times of the paste. There is a decrease in initial setting time of 5%, 11%, 19%, 21%, 19% and 19% over the 0% control paste for 5, 10, 15, 20, 25 and 30% quarry dust content respectively. Similarly, there is a decrease in final setting time over the 0% control paste of 2%, 4%, 4%, 7%, 7% and 7% for 5, 10, 15, 20, 25 and 30% quarry dust content respectively. However, the decreases are not significant and all the values for the initial and final setting times are within the recommended minimum OPC cement initial setting time of 45 minutes and maximum final cement setting time of 10 hours specified in BS EN 197 (2011). For both the initial and final setting times, the effect of the quarry dust gives the lowest setting times at 20% content of the quarry dust.

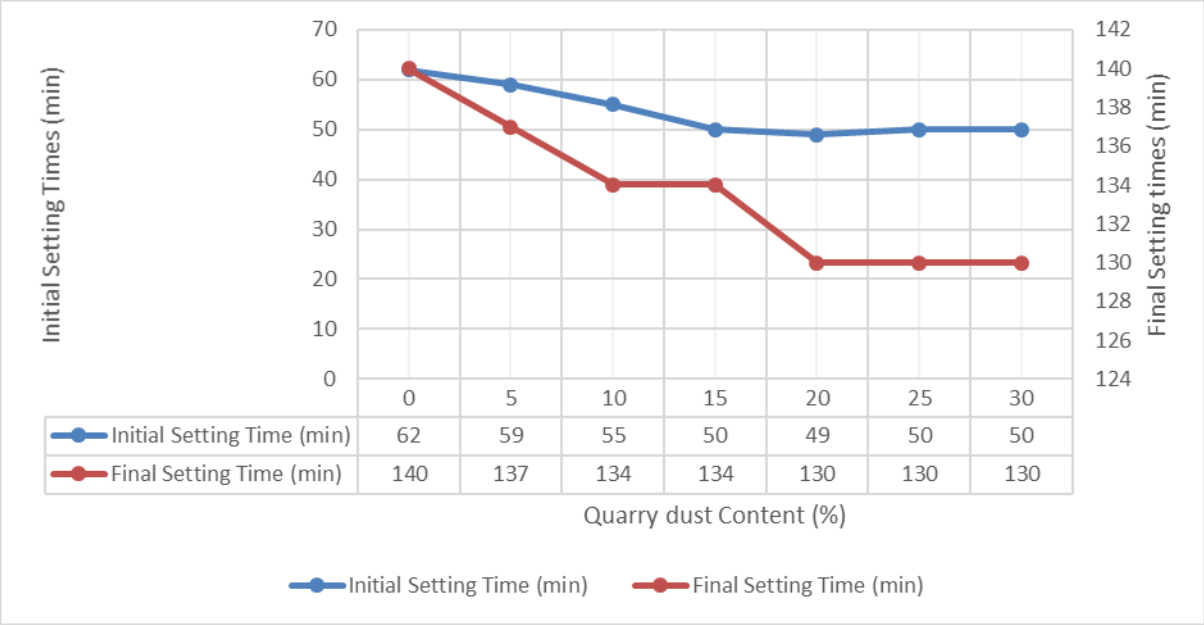

Figure 1: Effect of Quarry dust replacement on setting times of cement paste

Effect of quarry dust on water absorption of mortar

The effect of cement replacement with quarry dust on water absorption of mortar is presented in Figure 2. The result shows an increase in water absorption with increase in the quarry dust replacement. This shows that quarry dust caused more water absorption by the mortar. There is increase over the 0% control paste of 2%, 5%, 23%, 25%, 30% and 30% for 5, 10, 15, 20, 25 and 30% quarry dust content respectively. Durability of mortar is directly related to its water absorption. The higher water is absorbed by mortar, the less durable it becomes (Gingos, 2011).

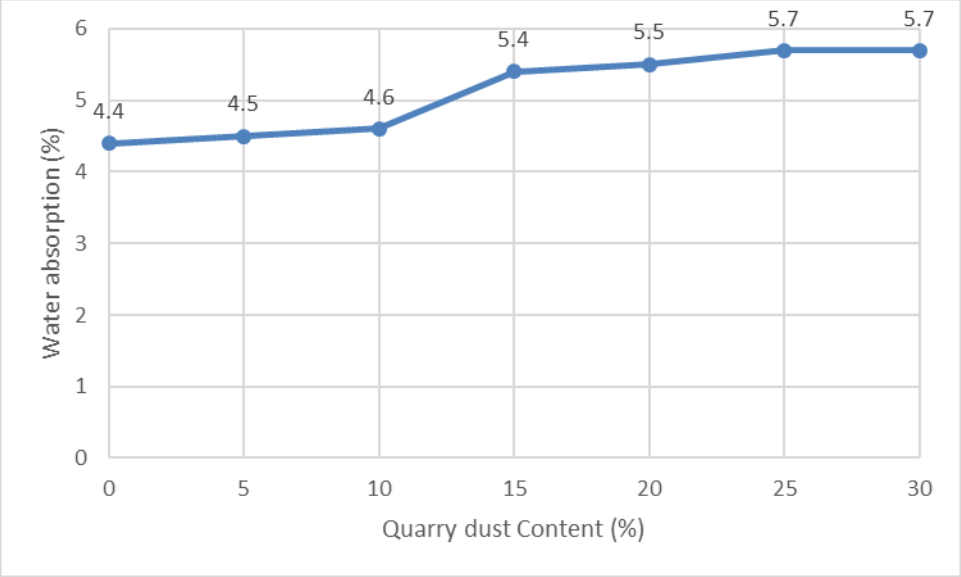

Figure 2: Effect of quarry dust replacement level on Water absorption

Effect of quarry dust on compressive strength of mortar

Figure 3 shows the effect of cement replacement with quarry dust on compressive strength of mortar at 7 and 28 days, respectively. From the Figure, at 5% quarry dust content there is an initial increase of 5 percent of the compressive strength over the control mortar with (0% quarry dust) at 7 days and 2 percent at 28 days, respectively. Thereafter, the strength decreases with increase in quarry dust content for both ages. The decrease in strength with increase in quarry dust content may be due to the reduction of the quantity of cement in the mix. The increase in compressive strength at 5% indicates possible pozzalanic activity, however as the quarry dust content increases, it acts as fine aggregate rather than the cement replacement material. This indicates that quarry dust can be utilized as cement replacement material only in smaller content (5% content).

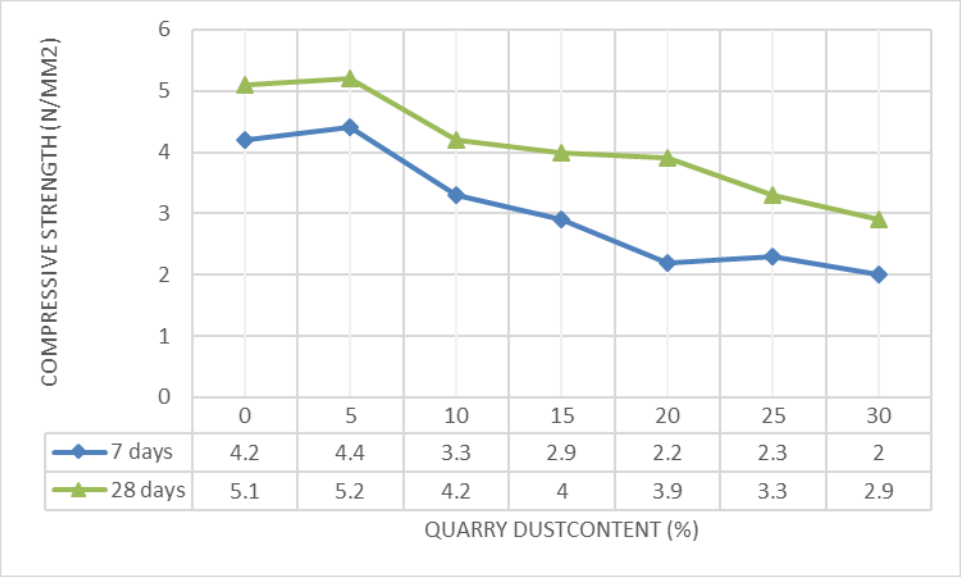

Figure 3: Effect of Quarry Dust replacement level on Compressive Strength of Mortar

ASTM C 270 (ASTM, 2006) classify mortars into four Types: M, S, N and O. Type M mortar mix has the highest amount of Portland cement and is recommended primarily for walls bearing heavy loads. It is a high compressive-quality mortar, however not exceptionally workable and has compressive strength of 17.2MPa (17.2N/mm^2). Type S mortar is the ideal product to be used in masonry at or below grade. It is a mortar with higher flexural bond quality, it has compressive strength of 12.4MPa (12.4 N/mm^2). Type N mortar is usually recommended on exterior and above-grade walls that are exposed to severe weather and high heat. It has compressive strength of 5.2MPa (5.2 N/mm^2). Type O mortar is a Low-strength mortar, utilized generally for inside applications and reclamation with compressive strength of 2.4MPa (2.4 N/mm^2).It is therefore obvious that mortar with quarry dust replacement fall more in Type O category and are more suitable for low-strength mortar applications.

Density

The effect of cement replacement with quarry dust on mortar density is presented in Figure 4. It can be seen that density of the mortar decreases as the percentage of replacement increase. This could be attributed to the difference in the weight of the materials (the specific gravity of quarry dust is less than that of the cement it replaces).

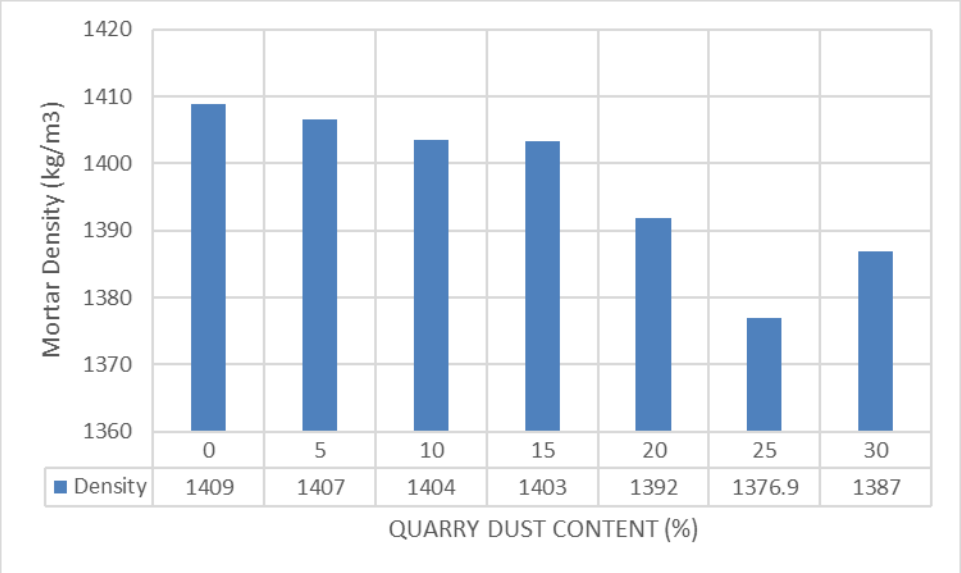

Figure 4: Effect of quarry dust replacement level on Density of Mortar

CONCLUSION

The use of quarry dust as partial replacement of cement in cement-sand mortar decrease the initial and final setting times of cement paste, however, the decreases are not significant and all the values for the initial and final setting times are within the range recommended by the standard. Also, quarry dust caused more water absorption by the mortar. It can also be concluded that the replacement of cement with quarry dust shows an improvement of compressive strength at 5% quarry dust content after which there is a decrease with increase in quarry dust content at all the ages. The increase in compressive strength at 5% indicates possible pozzalanic activity at that level. The partial replacement made the density of the mortar to decrease as the quarry dust content increases.

Thus quarry dust can be utilized as cement replacement material at 5% dust content. Above this it can be utilized as fine aggregate replacement for use in low-strength mortar applications.

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