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EFFECT OF SULPHURIC ACID ON THE COMPRESSIVE STRENGTH OF CONCRETE WITH QUARRY DUST AS PARTIAL REPLACEMENT OF FINE AGGREGATE

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ABSTRACT

This study determines the effect of Sulphuric acid on the compressive strength of concrete with Quarry Dust as partial replacement of fine aggregate at 0 %, 15 %, 25 % and 35 %. A total of seventy-two (72) 100 mm cubes were cast and cured in water up to 28 days. The Compressive strength test was done on the first 36 cubes at 7, 14 and 28 days, while the remaining 36 cubes were exposed to 5 % prepared solution of sulphuric acid after 28 days in water and crushed at 7, 14 and 28 days. The results obtained indicated that the slump decreases as the percentage addition of Quarry Dust increases. However, the result of the compressive strength of Quarry Dust-concrete showed that the compressive strength increased with the curing age and also increased with the addition of Quarry Dust. On the other hand, the resistance of the concrete to acid increases as the percentage addition of Quarry Dust increases. The weight of concrete decreased with an increase in exposure duration and also decreased with an increase in Quarry Dust content. But the water absorption of Quarry Dust-Concrete decreased with an increase in Quarry Dust addition. It can be concluded that Quarry Dust can replace river sand in concrete to improve its resistance to sulphuric acid attack.

Keywords: Concrete, Sulphuric Acid, Quarry Dust, Slump, Concrete and Compressive strength

INTRODUCTION

Concrete is the most widely used material in construction industries globally, it is composed of cementitious material, aggregate (fine and coarse) and water. It is also regarded as the most consumed construction material because of its good durability to cost ratio, ease of placement and can be formed to any desired shape. To meet the global requirement for globalization in building construction and infrastructural development, concrete plays a vital role and a large quantum of it is being used. Hence, the high demand for concrete resulted in high consumption of fine aggregate (river sand), which constitutes about 30 % to 35 % of the concrete mix ratio (Nagpal *et al.*, 2013). The consumption of natural sand by the construction industry has significantly increased resulting in the rapid depletion of the river beds which are the natural sources of sand. The scarcity/or inadequate supply of good quality of sand has resulted in a considerable increase in its price which affects the construction cost (Agrawal *et al.*, 2017). This led experts in academics and construction industries to search for a suitable material that is eco-friendly and can be used effectively in construction practices as an alternative to natural sand and minimise the cost of concrete production (Sivanarayana *et al.*, 2014). However, due to the scarcity and supply of some of these alternative materials, Quarry Dust was discovered as a possible replacement of the fine aggregate. Quarry Dust is a by-product of the extraction of aggregates which is about 20-25 % of the total material crushed in a crusher unit for extraction of aggregates it is considered to be waste (Agrawal *et al.*, 2017; Chauhan and Bondre, 2015). It is referred to as manufactured sand, have been accepted as a building and construction material in the industrially advanced countries for decades, Quarry Dust is used in large scale for the construction of highway projects such as surface finishing material and also used for the production of hollow blocks and lightweight concrete prefabricated elements (Ilangovana *et al.*, 2008). Because of this, a considerable amount of researches have conducted by numerous researchers on the suitability of using Quarry Dust as an alternative to natural sand. Nagpal *et al.*, (2013) reported the use of Quarry Dust as fine aggregate in concrete improves the compressive of the concrete. Meisuh *et al.*, (2018) conducted a study to investigate the effect of Quarry Dust on the flexural strength of concrete. The reported that incorporating Quarry Dust in concrete improves its flexural strength. Agrawal *et al.*, (2017) investigated the use of Quarry Dust as fine aggregate in concrete and concluded that up to 50 % of natural sand in concrete can be replaced with Quarry Dust without affecting the compressive strength of the concrete. Quarry rock dust has been reported to produce concrete with improved strength, mechanical and durability properties when used as fine aggregate (Balamurugan and Perumal, 2013; Kannan *et al.*, 2014; Poonam and Bala, 2015; Shanmugavadivu and Malathy, 2011). Shyam and Rao, (2016) reported that concrete with Quarry Dust of 40-60 % replacement of natural sand gives higher compressive strength than concrete with 100 % natural sand. With the above literature review, it indicates that Quarry Dust improves the properties of concrete.

Concrete is generally known as a highly durable structural material, its versatile utilization leads to aggressive environment like sewage and waste water treatment plants where it is its attacked by acid and other chemical actions which can cause its deterioration and total collapses of structures before their design life span elapsed. Often time, Sulphuric acid (H_2SO_4) is one of the most destructive acids to concrete, it causes severe degradation and damage to concrete structures depending on its concentration and formation manner. The acid may be produced in soils and groundwater through the oxidation of iron sulfide minerals in the form of pyrites or marcasite (Richardson, 2002). Singh *et al.,* (2017) conducted a study to investigate the effect of suphuric acid on different grades of Concrete produced with different proportions of materials. they reported that samples with 50 % Quarry Dust replacement of natural sand possess high resistance to the acidic attack. Kawai *et al.,* (2005) conducted a study to assess the deterioration of concrete caused by sulphuric acid. They reported that the rate of concrete deterioration caused by sulfuric acid attack depends on the acid solutions pH value and the erosion depth of the concrete is proportional to the exposure time of the concrete to the flow of acid solution. Reddy *et al.,* (2012) investigate the effect of H_2SO_4 on blended cement concrete (BCC). They reported that the compressive strength of BCC decreases with an increase in the concentration of H_2SO_4 at both 28 and 90 days. The decrease in compressive strengths of BCC was observed to be in the range of 2 to 23 %, with an increase in H_2SO_4 concentration between 28 to 90 days when compared with the control specimens. The study of Madhusudhana *et al.,* (2012) revealed that Sulphate attack can be external or internal on the concrete and has the potential to cause serious damages and structural failures, as such structures in potentially aggressive environments must be designed to recognize the risk of sulphate attack and precautions need to be taken during the design process to manage that risk. They can enter the concrete into solution from the external environment, or they may be mixed into concrete which then reacts with cement compounds to form expansive products. Therefore, large amounts of it in the environment or concrete may have a deleterious effect on concrete and structures because the attack involves a chemical breakdown mechanism where sulphate ions attack components of the cement paste.

Even though, several experimental studies have been made to improve the quality, durability and compressive strength at minimum cost and resistance of concrete to chemical attack.

This study aims to determine the influence of Quarry Dust as a replacement of fine aggregate in concrete strength and to investigate the effect of Sulphuric acid on the concrete.

MATERIALS AND METHODS

Materials

The materials used for this study include; cement (Dangote brand), Coarse aggregate, fine aggregate, Quarry Dust and water.

Cement: The Ordinary Portland Cement used is that of Dangote 3X brand and obtained from Samaru market in Zaria, Kaduna State.

Coarse aggregates: The coarse aggregate used was obtained from Nagarta local quarry along Sokoto Road, Zaria, Kaduna State, Nigeria. The coarse aggregate is a major constituent of concrete, which constitute about 60 % to 75 % by volume of the concrete.

Fine aggregate: The fine aggregate used was river sand obtained from a nearby river Samaru, Zaria, Kaduna State, Nigeria. with a specific gravity of 2.57 and a bulk density of 1632 kg/m^3 was used. The particle size distribution of the sand shown in Fig. 1, indicate that the sand used was classified as zone -1 based on BS 882, Part 2, (1992) grading limits for fine aggregates.

Quarry Dust: The Quarry Dust used in this study was obtained from a construction site at Lower Usuma Dam, Abuja FCT. The Specific gravity and sieve analysis test were carried out on the dust particles in accordance with BS 812-1995.

Water: The water used in this study for making the concrete mixture and curing was clean and complied with the requirements of BS 8148:1980.

METHODS

Test on coarse aggregates

Test conducted on coarse aggregates are; Aggregate impact value test (BS 812 PART 111), Aggregate crushing value (BS 812 PART 112), Aggregate specific gravity BS 812-1995, Size and gradation (BS 812-103.2).

Test on fine aggregates

The tests conducted on the fine aggregates are: specific gravity BS 812-1995, sieve analysis (BS 812-103.2) analysis, and water absorption (BS 812 Part 3)

Test on cement

The tests conducted on cement are; Initial and final setting time (BS EN 196 part 3), Soundness test (BS EN 196 part 3), and specific gravity (ASTM C188).

Concrete mix Proportion

A prescribed concrete mix ratio of 1:2:4 and a water-cement ratio of 0.45 were used to assess the effect of replacing fine aggregate with Quarry Dust in a proportion of 0 %, 15 %, 25 % and 35 % by weight of fine aggregate and the effect of sulphuric acid on concrete. Seventy-two 100 mm cubes specimens were prepared. The tests conducted on the prepared specimens include; Slump test for fresh concrete mix and compressive strength test for hardened concrete.

Slump of Quarry Dust Concrete

The slump test was conducted on the fresh concrete mixture to ascertain its workability. The test was conducted in accordance with BS EN 12350, Part 2.

Compressive strength test on Quarry Dust-Concrete

The compressive strength test was conducted on hardened concrete specimens produced with and without Quarry Dust in accordance with BS EN 12390, Part 3 specifications. A total of seventy-two (72) 100 mm cube specimens were cast and cured in water. 36 cubes were tested for compressive strength after 7, 14 and 28 days curing. After 28 days of curing, the remaining 36 specimens were transferred to twenty-five (25) litres of water containing 5% sulphuric acid, (H_2SO_4) with a molar concentration of 0.937 M. These specimens were then tested for 7, 14 and 28 days of curing in acidic solution. At the end of every curing regime, twelve samples were crushed using the Avery Denison Compression Machine of 2000 kN load capacity at a constant rate of 15 kN/s. The compressive strength results are as shown in Figures 3 and 4.

Preliminary Tests on Aggregates

The tests carried out on coarse and fine aggregates are as presented in Table 1. The results obtained satisfied with the relevant code recommendations.

RESULTS AND DISCUSSION

Table 1: Test results on the Aggregates Materials

Test Conducted	Code Used	Test Result	Code Limit
Aggregate Crushing Value (%)	BS 812 Part 112	18.5	Max. 25
Aggregate Impact Value (%)	BS 812 Part 111	24.0	Max. 25
Specific Gravity of Coarse Aggregate	BS 812-1995	2.61	2.55 – 2.75
Bulk Density of Coarse Aggregate (Kg/m^3)	ASTM C127	1685.2	>160
Specific Gravity of Fine Aggregates	BS 812-1995	2.57	2.55 – 2.75
Bulk Density of Fine Aggregates (Kg/m^3)	ASTM C127	1632	>160
Water Absorption for Coarse Aggregate (%)	BS 812 Part 2	0.46	< 2
Water Absorption or Fine Aggregate (%)	BS 812 Part 3	8.62	< 15

Chemical Oxide Composition of Cement

The results presented in Table 2 revealed that the chemical composition of the cement is satisfactory and has met the BS EN 197, Part 1, standard. While the oxide composition of Quarry Dust and Natural Sand were presented in Table 3 (Wazumutu and Ogork, (2015)).

Table 2: Oxide Composition of OPC (Dangote Brand)

Oxide (%)	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	Na2O	Tio2	lost of Ignition
Cement	18.0	3.10	4.82	68.37	1.48	0.35	0.32	0.35	1.27

Table 3: Oxide Composition of Quarry Dust and Natural Sand

Oxide (%)	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	Na2O	Tio2	lost of Ignition
Quarry Dust	62.48	18.72	6.54	4.83	2.56	3.18	Nil	1.21	0.48
Natural Sand	80.78	10.52	1.75	3.21	1.37	1.28	0.77	Nil	0.37

Source: (Mir, 2015)

Particles size distribution

The results for the particle size distribution of the coarse and fine aggregate as well as Quarry Dust is shown in the figure 1.

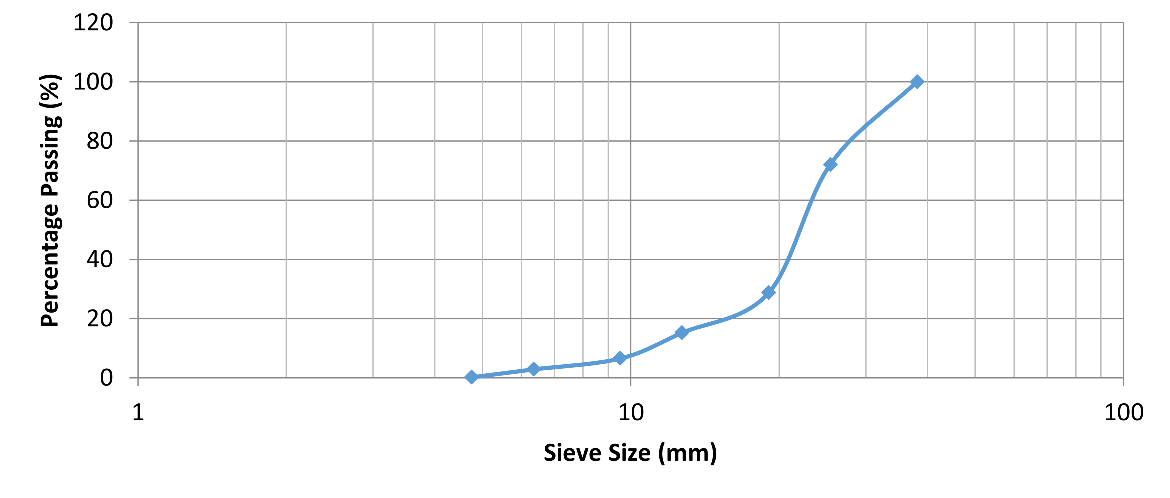

Fig. 1: Particles Size Distribution

Slump

The slump of concrete decreased with an increase in the addition of Quarry Dust content as shown in Figure 2. This may be due to the high specific surface of Quarry Dust for a constant water content.

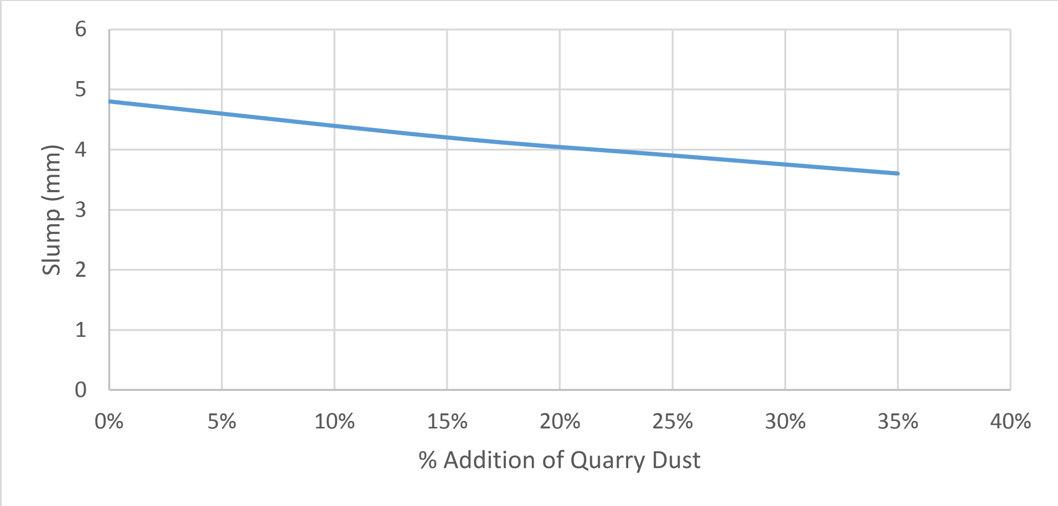

Fig. 2: Slump versus % Addition of Quarry Dust Content

Compressive Strength of Quarry Dust-Concrete

The results of the compressive strength of Quarry Dust-concrete showed that the compressive strength increased with curing age and also increased with the addition of Quarry Dust, this finding is in par with Meisuh *et al.*, (2018). A further increase in the addition of Quarry Dust of 35 %, 7 days showed a slight decrease in compressive strength of the concrete as shown in Figure 3. The increase in compression strength with curing age is due to hydration of cement, while an increase in compressive strength with the addition of Quarry Dust may be due to filling of the voids within the concrete matrix by the Quarry-Dust producing a stronger product. The reduction in compressive strength with the addition of Quarry Dust at 35 %, 7 days and 28 days may be due excess Quarry Dust left within the mix after voids saturation, hindering inter-particle bond between cement particles and between aggreagtes and cement.

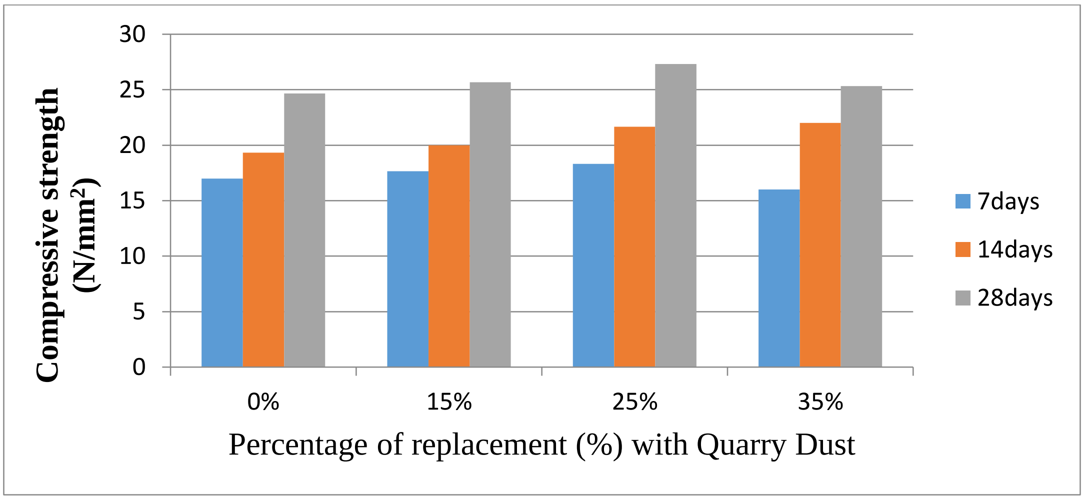

Fig. 3: Compressive strength versus % Addition of Quarry Dust Content

Effect of Sulphuric Acid on Quarry Dust-Concrete.

For specimens exposed to Sulphuric acid, the compressive strength of the concrete decreases significantly from 7 days up to 28 days (Figure 4). Also, the resistance of the concrete to acid increases with an increase in % replacement with Quarry Dust; this showed that the effect of the Sulphuric Acid on Quarry Dust is less compared with river sand. the result showed that at 7 days, 35 % has a strength of 18.00 N/mm^2 compared to 13.33 N/mm^2 obtained for 0 % replacement. At 28 days of exposure to Sulphuric acid, 35 % have a strength of 14.47 N/mm^2 compared to 9.33 N/mm^2 for 0 % replacement. Generally, exposing the specimen to sulphuric acid for 28 days, 0% replacement losses 62.2 % compressive strength and 35 % replacement losses 42.10 % strength.

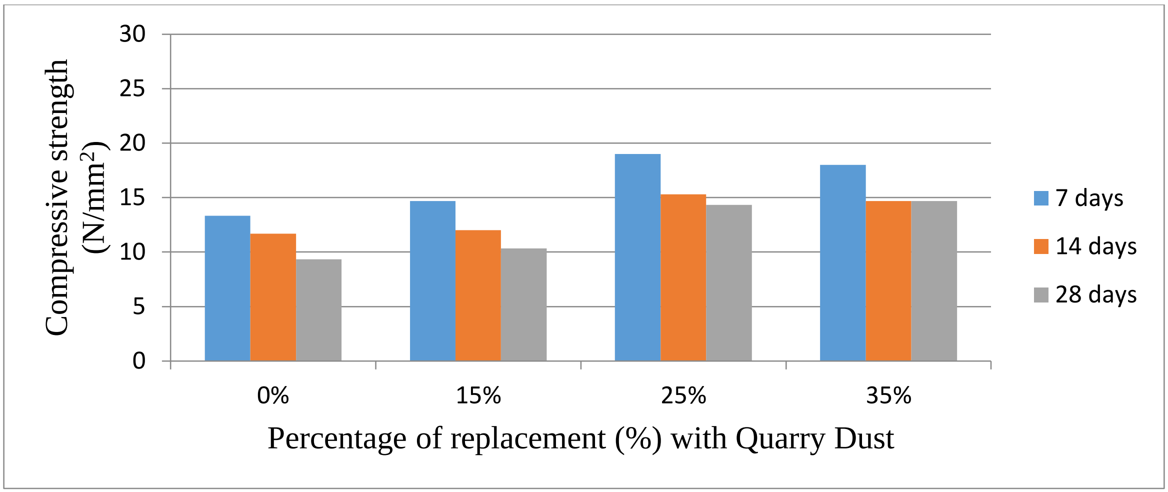

Fig. 4: Compressive strength result in concrete after exposure to H_2SO_4

Figure 5 shows the weight retained of Quarry Dust-Concrete specimens exposed to the sulphuric acid environment. The weight of concrete retained decreased with an increase in exposure duration and also decreased with an increase in Quarry Dust content. This decrease is generally due to aggressive nature of the acid which leads to the deterioration of the concrete constituents with time.

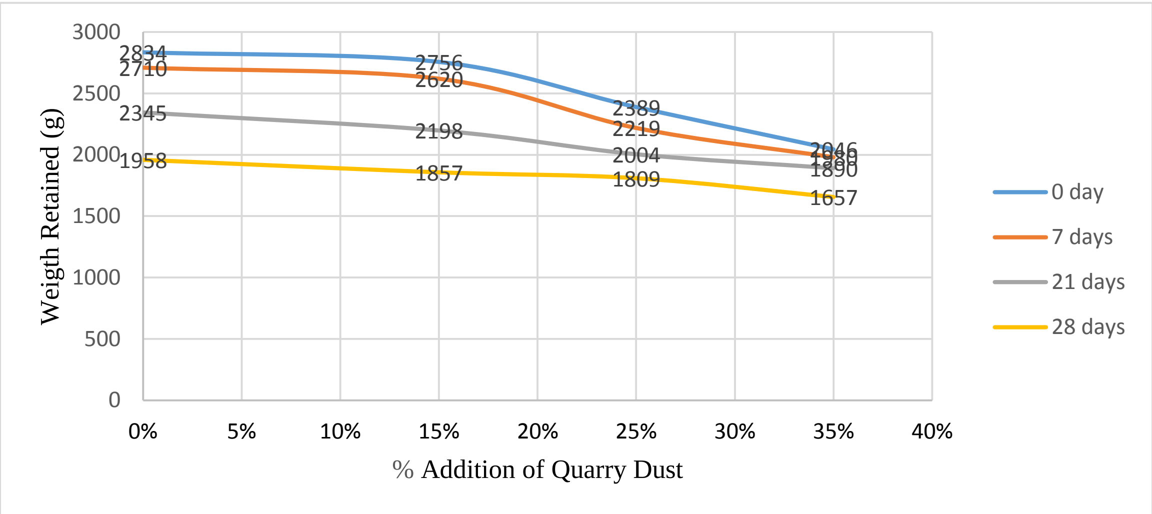

Fig. 5: Weight of concrete retained after exposure to Sulphuric Acid

Water Absorption of Quarry Dust-Concrete

The water absorption of Quarry Dust-Concrete decreased with an increase in Quarry Dust addition as shown in Figure 6. This may be because, the more the percentage of Quarry Dust increases, the more the concrete voids are filled up, hence the less the concrete absorps water; it may also be due to the presence of phosphorous (v) oxide in Quarry Dust, which is known to be an effective drying and dehydrating agent (Ababio, 2006).

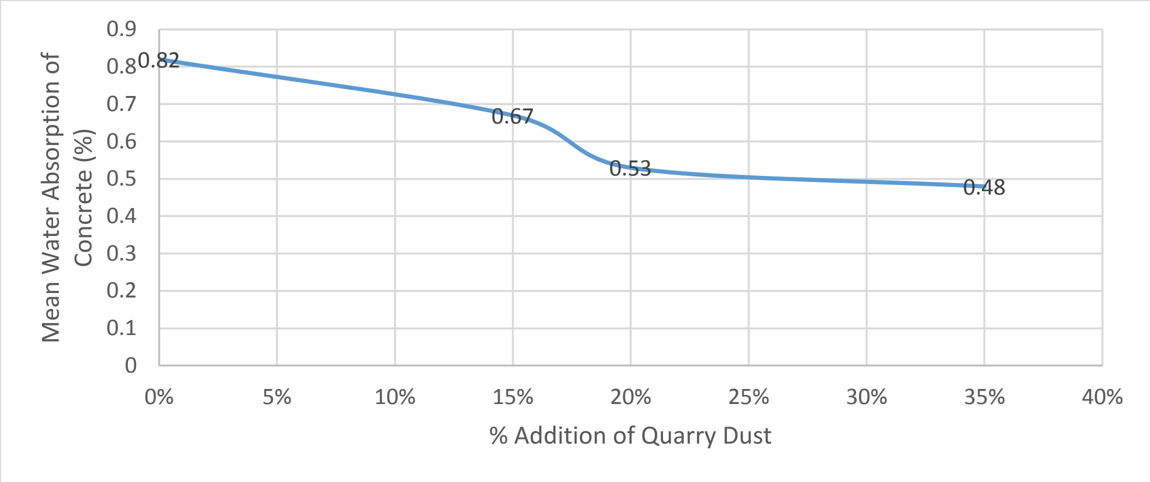

Fig. 6: Mean Water Absorption of Concrete versus % Addition of Quarry Dust

CONCLUSION

From the results of this research, it was concluded that the addition of Quarry Dust decreases the workability (slump) of fresh concrete mix and increases the resistance of the hardended concrete to the exposed acidic environment. Also addition of up to 25 % Quarry Dust increased the compressive strength of the hardended concrete and hence the optimum Quarry Dust content should be less than or equal to than 25 % replacement.

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