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EFFECT OF NANOSILICA AS AD-MIXTURE IN LIGHT WEIGHT CONCRETE

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ABSTRACT

This paper is aimed at assessing the effect of Nano silica on compressive strength and durability properties of lightweight concrete made with waste burnt bricks as coarse aggregate, using a mix ratio of 1:2:4 and water/cement ration of 0.6. Preliminary tests such as sieve analysis, specific gravity, bulk density, water absorption and aggregate impact value were conducted on brick aggregate and the results were compared to that of coarse aggregate. The workability of freshly prepared burnt bricks-concrete and normal concrete were determined, 45 cubes were cast and cured for a period of 3 days, 7 days, and 28 days respectively. The result of compressive strength test obtained show that concrete made with waste burnt bricks as an aggregate has a compressive strength of 10.9 N/mm2 and 17.57 N/mm2at 0 % and 3 % Nano silica addition respectively, this means the compressive strength of the concrete is affected by increasing the percentage of Nano silica. Whereas the compressive strength of the concrete with coarse (granite) aggregate was found to be 26 N/mm2, this indicates that concrete made with waste burnt bricks can be used in structural work where high strength is not of paramount importance such as ground floor slab, ramps, partition wall etc.

Keywords: Light weight concrete, Nano-silica, waste broken, burnt bricks, compressive strength.

INTRODUCTION

Lightweight concrete can be defined as a type of concrete, which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities and lessened the dead weight (Zakaria *et al*., 1978). It is lighter than the conventional concrete with a dry density of 300 kg/m^3 up to 1840 kg/m^3; 87 to 23 % lighter. It was first introduced by the Romans in the second century where 'The Pantheon' has been constructed using pumice, the most common type of aggregate used in that particular year (Samidi *et al*., 1997).

Researchers have indicated that it is now possible to make aggregate from almost anything provided it possesses attributes that will eventually be tailored so that required or desirable property will be realized in concrete (Dennis and Orchard, 1976). Aggregate is occupying three quarters of the volume of concrete indicating a higher proportion than their constituent materials required for concrete works (Neville, 1981). A survey carried out by Nigeria building and road institute (NBRRI), as reported that there are more than twenty existing factories in Nigeria with total production capacity of about 350 million normal size brick annually with an estimate of about 1 % as waste. About 350 million normal size bricks could go into waste annually countrywide.

Nano-materials are very small sized materials with particle size in nanometers. These Materials are very efficient in modifying the properties of concrete by the virtue of their very small size. The small size of the particles also means a greater surface area (Shetty, 2000). Jo *et al.*, (2007) studied on the properties of cement mortar with Nano silica and found that Nano scale silica behaves not only as a filler to improve microstructure, but also as an activator to boost pozzolanic reaction. In the studies reported by (Lin *et al*., 2008) it was shown that Nano silica could aid to produce hydration crystals, that implies that the addition of Nano silica to mortar can improve the influence of sludge fly ash on the development of early strength of the mortar. (Sadrmomtazi *et al.,* 2009) investigated the Influence of Nano silica on different properties of cement mortar in comparison with silica fume, which is a well-known active pozzolan. The addition of nanoparticles had shown to improve various performance of concrete (Sobolev and Gutierez, 2005). For example, nanosilica (silicon dioxide nano particles, nano-SiO2) has been shown to improve workability and strength in high-performance and self-compacting concrete (Collepardi *et al.,* 2002). Improvement in concrete performance has been attributed to several effects of the nanoparticles. Well dispersed nanoparticles can act as crystallization centers for cement hydrates, thereby accelerating the hydration reactions and can act as filler, filling the voids between the cement grains, thus reducing the material porosity.

MATERIALS AND METHODS

Materials

The materials used in this research work are cement, coarse aggregate, broken brick aggregate, water, fine aggregate, and Nano silica (admixture).

Cement

The cement used for this research was ordinary Portland cement (Dangote, grade 42.5). It's a finely powdered, greyish binding material.

Coarse Aggregate

The coarse aggregate is crushed granite of nominal size of 20 mm with a specific gravity of 2.61 and bulk density of 1626.67 kg/m3. The particle size distribution is also shown in Fig 2.

Fine Aggregate

The fine aggregate obtained from the local suppliers in Samaru, Zaria was washed and dried then sieved to remove all the particles that retained on 2.36 mm sieve.

Water

BS 3148 (1980) gave the specification of water for use in concrete making.

METHODS

Concrete mix design

The mix proportion of normal and lightweight concrete is shown in table 1. The nano silica suspension was added to the mixing water, taking into account water content of suspension and it was stirred manually; cement and aggregate were mixed and then water containing nano silica was added. Forty-five (45) cubes 100 x 100 x 100 mm were cast in all, nine (9) cubes using coarse aggregate and thirty-six (36) cubes using waste burnt bricks as a full substitute for coarse aggregate with nano silica addition of 0, 1, 2, 3 % with respect to cement mass.
The constituents proportion used are presented in Table 1.

Table 1: Summary of mix proportion for normal weight concrete and light weight concrete.

Concrete Type	Cement (g)	Water (g)	Sand (g)	Coarse Aggregate (g)
Normal weight	340	204	690	1370
Light weight	260	160	530	1050

Consistency, Setting time and Soundness test

Consistency, setting time and soundness test were conducted on the cement sample in order to study the properties of cement.

Standard Consistency Test

This test was done to determine the quantity of water required to produce a cement paste of standard consistency based on BS EN 197-1:2009 standard. When the plunger penetrates the paste to a point 5 to 7 mm above the bottom of the mould, the paste is considered to be at "normal consistency". And the consistency of 6.8 mm was found.

Initial Setting Times Test

This was carried out to determine the initial of cement based on BS EN 196-3:1995 standard. The initial setting time was found to be 133 minutes

Final Setting Times Test

This was carried out to determine the final of cement based on BS EN 196-3:1995 standard. The final setting time (min) is taken when the annular on the final setting time needle does not make an impression on the paste. And the results of final setting time was found to be 193 minutes.

Soundness

This was carried out to determine the soundness of cement based on BS EN 196-3:1995 standard. The result was found to be 3.5 mm.

Compressive Strength

The compressive strength test was performed according to BS EN 206-1 2000 concrete specification. Forty-five (45) cubes 100 x 100 x 100 mm were cast in all, nine (9) cubes using coarse aggregate and thirty-six (36) cubes using waste burnt bricks as a full substitute for coarse aggregate with nano silica addition of 0, 1, 2, 3 % with respect to cement mass.

Water Absorption

This test was done in accordance to BS 812: Part 2, (1995), the results are presented in table 4.

Bulk Density

Bulk density is the actual mass of the sample that would fill a container of unit volume. Bulk density is used to convert quantities of mass quantities by volume. The test is carried out according to BS 812 part 2 (1992), and the results obtained is presented in table 6.

Specific Gravity

The specific gravity test was performed according to BS 812 part 2 (1992), the results obtained are presented in table 2.

Sieve Analysis

Sieve analysis can simply be described as the process of dividing a sample of aggregate into the fraction of same particle size, and the test was carried out in accordance to BS 882, part 2(1992).

Moisture Content

Moisture content is the water in excess of the saturated and surface dry condition of the aggregate i.e. when the pores of aggregate are filled. The test is in accordance to BS 812-109:1990.

Slump Test

This test was used to determine the workability of the fresh concrete in accordance with BS EN 12350, Part 2, 2009. And the result obtained is presented in figure 4.

RESULT AND DISCUSSION

Sieve Analysis Result

The result of sieve analysis for fine, bricks and coarse aggregates are presented in figures 1 and 2 below:

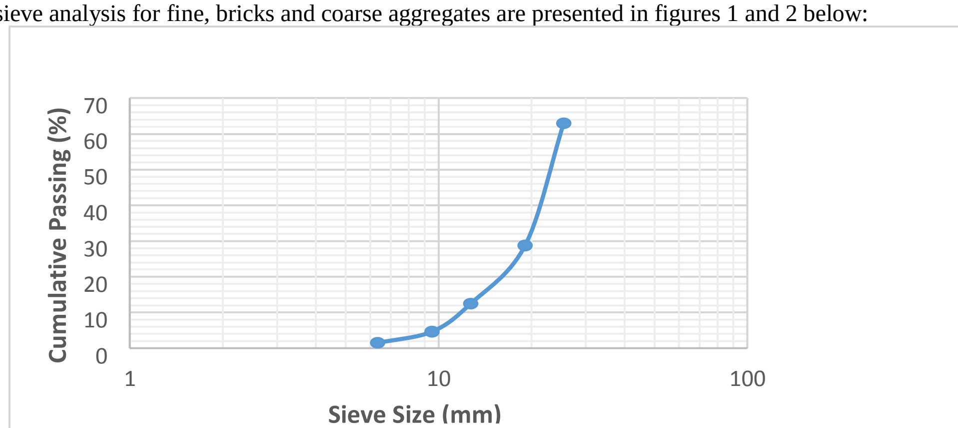

Fig.1: Particle Size Distribution Grading Curve for Waste Broken Bricks Aggregate

Figure 1 shows the result of sieve analysis for waste broken bricks aggregate carried out in accordance to BS 812-103.1:1985, from the table of result, the maximum percentage is retained on sieve 25.40 mm while 37.00% is retained on 6.35 mm sieve therefore the aggregate contains more particles of 25.4 mm

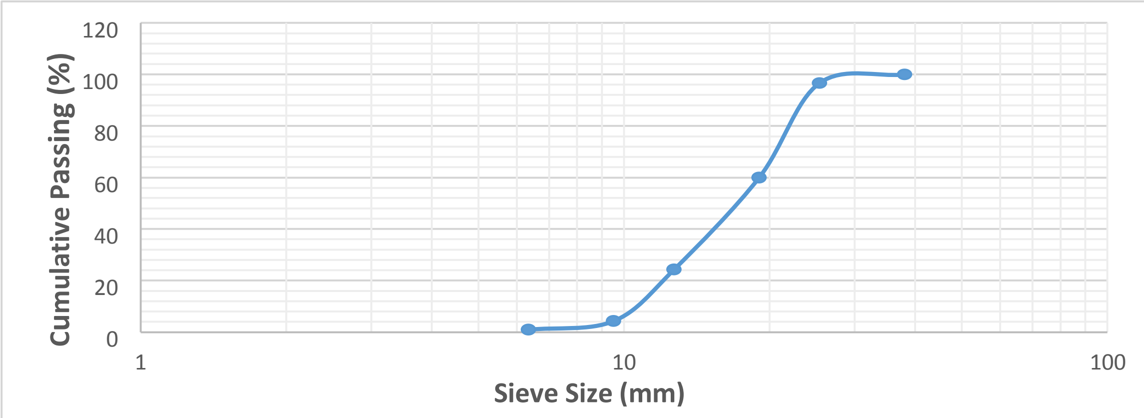

Fig. 2: Particle Size Distribution Grading Curve for coarse Aggregate

Figure 2 shows the result of sieve analysis for coarse aggregate carried out in accordance to BS 812-103.1:1985. This shows that the granite is uniformly graded (Smith and Smith, 1998). It can be concluded that the coarse aggregates is suitable for making good concrete. From the table of result, the maximum percentage is retained on sieve 6.35 mm while smallest percentage is retained on 25.40 mm sieve therefore the aggregate contains fewer particles 25.4 mm.

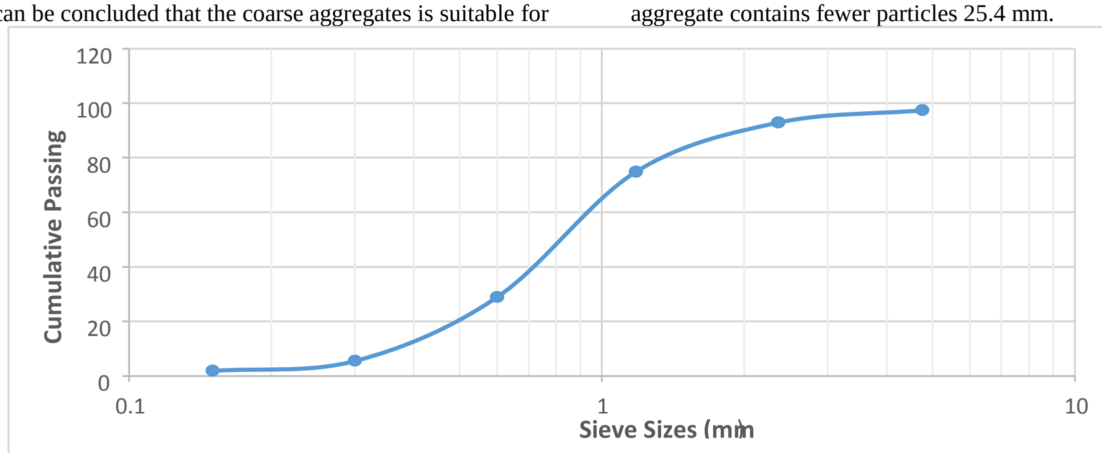

Fig. 3: Particle Size Distribution Grading Curve for fine Aggregate

Figure 3 shows the result of sieve analysis for fine aggregate carried out in accordance to BS 812-103.1:1985, and the sand is classified as zone-1 based on BS 882 (1992) grading limits for fine aggregates From the table of result, the maximum percentage is retained on sieve 0.6 mm while low percentage is retained on 4.76 mm sieve therefore the aggregate contains fewer particles of 4.76 mm, thus finer. This shows that the fine aggregate is uniformly graded (Smith and Smith, 1998). It can be concluded that the fine aggregates is suitable for making good concrete.

Specific Gravity

The result of the specific gravity test of coarse aggregate and waste broken bricks is shown in table 2 below:

Table 2: SPECIFIC GRAVITY TEST

Materials	Specific Gravity
Coarse (Granite) Aggregate	2.61
Waste Broken Brick Aggregate	2.19

The table indicates that waste broken brick aggregate has a specific gravity value of 2.19 which is less than 2.5 while the coarse aggregate has a specific gravity value of 2.61 which is within the range of 2.5 to 3.0 as provided by the BS 812 recommendation for normal weight aggregate.

Moisture Content
The results of moisture content are presented in table 3 below:

Table 3: Moisture Content of CA, FA and WBBA

Materials	Moisture Content
Coarse (Granite) Aggregate	0.59
Fine (Sand) Aggregate	16.69
Waste Broken Brick Aggregate	8.40

The result shows that waste broken brick aggregate has higher moisture content of 8.40 %, which is greater than that of coarse aggregate 0.59 % but less than that of fine aggregate. This indicates that waste broken brick aggregate will absorb water more than coarse aggregate.

Water Absorption

Table 4: Water Absorption

Materials	Water Absorption (%)
Coarse (Granite) Aggregate	0.92
Waste Broken Brick Aggregate	8.98

The table indicates that coarse aggregate absorbed less water at the end of 24 hours (i.e. 0.92 %) than waste broken brick aggregate (i.e. 8.98 %). These values are however within the range specified for coarse aggregate by BS 812-109 1990.

Aggregate Impact Value (AIV)

Table 5: Aggregate Impact Value

Materials	Aggregate Impact Value (%)
Coarse (Granite) Aggregate	37.8
Waste Broken Brick Aggregate	57.40

The result of the AIV test indicates that waste broken brick aggregate has higher impact value (57.40%) than coarse aggregate (37.80%). This simply means that waste broken brick aggregate has a lower resistance to failure by impact than coarse aggregate. This is an indication that a concrete with coarse aggregate will have a higher compressive strength than a concrete produced with waste broken brick aggregate (light concrete).

Bulk Density

Table 6: Bulk Density Test

Materials	Bulk Density (kg/m3)
Coarse (Granite) Aggregate	1626.67
Waste Broken Brick Aggregate	1190

The table shows the bulk density result determined in compliance with BS 812 indicates that waste broken brick aggregate has a lower bulk density compared to coarse aggregate. This indicates that the waste broken brick aggregate can be used to produce lightweight concrete.

Slump Test
Figure 4 shows the variation in slump for different nano silica dosages in light weight concrete with waste broken bricks as coarse aggregate.

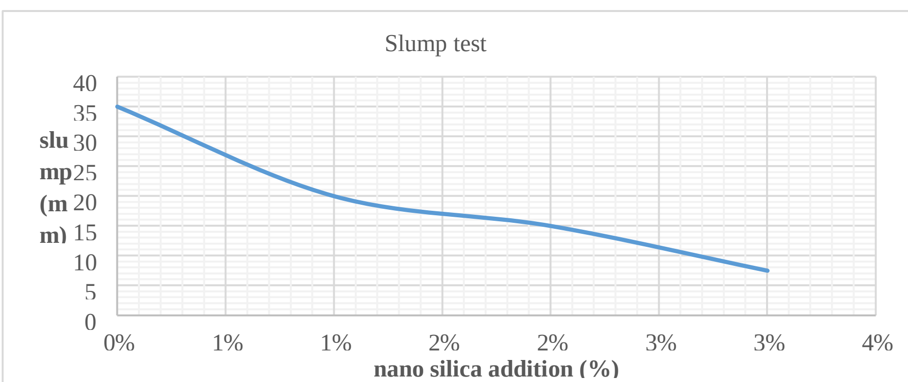

Fig 4: Variation in slump with increase in percentage of Nano silica

The results of the slump test carried out are shown in Table 3, indicating the workability of light concrete. The table indicates that the slump value decreases as the percentage of Nano silica increases. From the result, it was observed that concrete became less workable as the percentage of Nano silica increases, meaning that more water is required to make the mixes more workable.

Compressive Strength and Density of Concrete

Figures 5 – 8 shows the result of compressive strength and density of normal concrete and light weight concrete made with waste broken burnt bricks in histogram form.

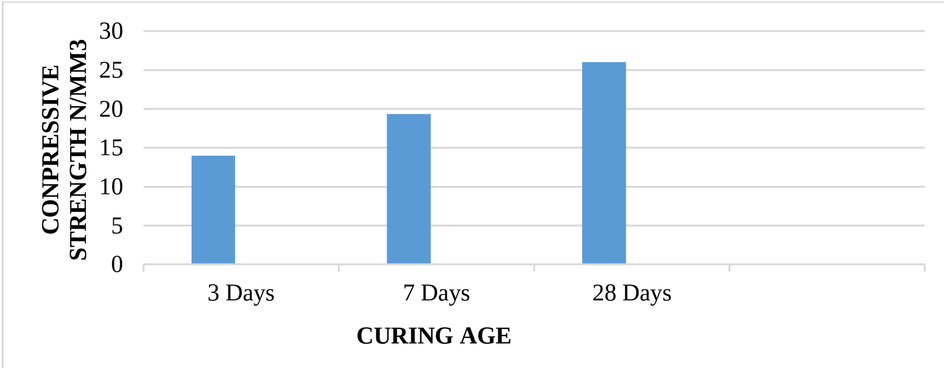

Fig. 5: Compressive Strength of Hardened Concrete with full Coarse Aggregate

The compressive strength of the normal concrete cubes for 3days, 7 days and 28 days are presented in the figure.
The results obtained showed that the compressive strength of hardened concrete with coarse aggregate increases as curing age increases. And also the highest value of 26 N/mm^2 was obtained at 28 days of curing which is greater that of light concrete with the addition of Nano silicon of 28 days.

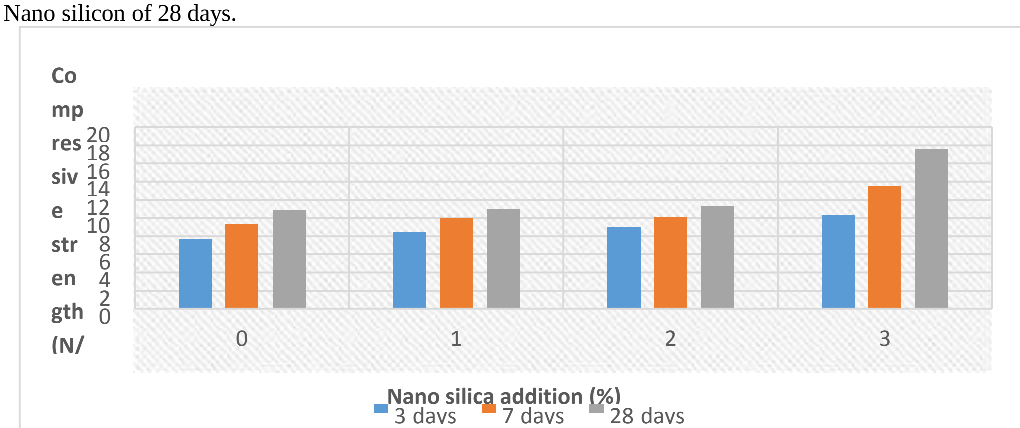

Fig. 6: Compressive Strength of Hardened Concrete with Waste Broken Bricks Aggregate and Nano Silica as Admixture

The compressive strength of light concrete cubes with the addition of Nano silica are shown in figure 6. The figure shows that the compressive strength of concrete increases with curing age and also increases as the percentage of Nano silica increases. The highest value of compressive strength of 17.57 N/mm^2 was obtained at 3% addition of Nano silicon for 28 days. All the results obtained satisfy the recommendation of BS EN 206-1 2000 concrete specification.

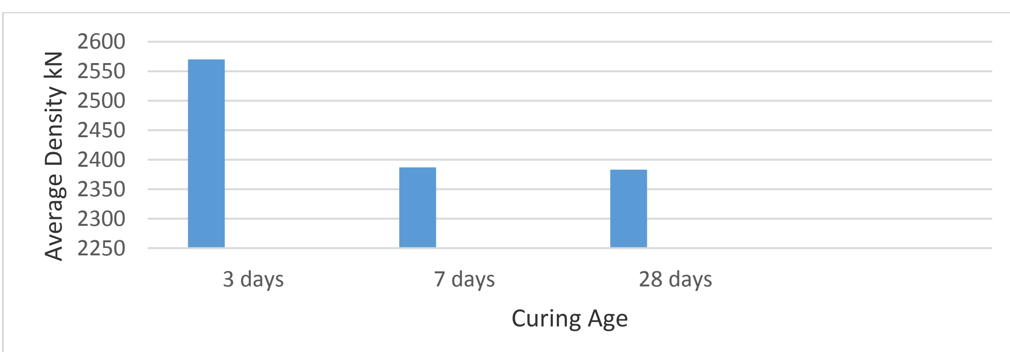

Fig. 7: Average Density of Hardened Concrete with Coarse Aggregate

The results obtained indicated that the average density of normal concrete increases with curing age. It also showed that the highest value was obtained at 3 days, which is even greater than that of light concrete at 28 days. This indicates that normal concrete is heavier that light concrete produced with waste broken brick aggregate.

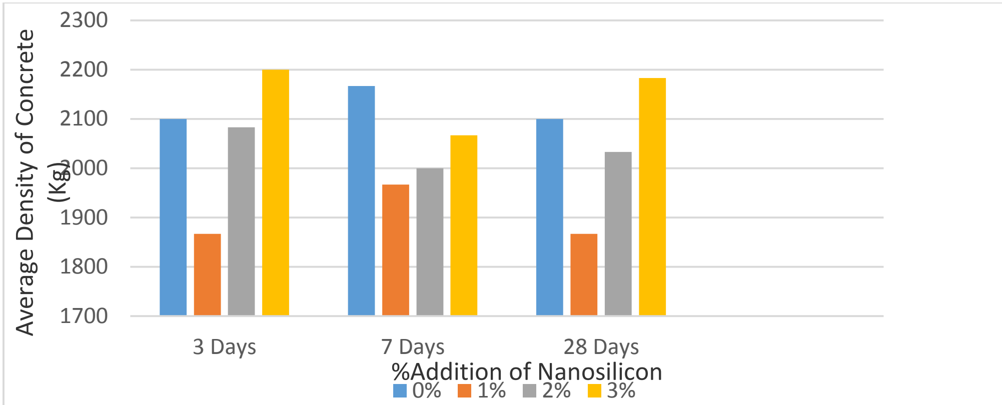

Fig. 8: Average Density of Hardened Concrete Made with Full Replacement of Coarse Aggregate with Broken Bricks and Nano Silica as Admixture.

The results presented in the figure shows that the highest density obtained was 2200 kg/m3 for 3% at 3 days.

CONCLUSIONS

Based on the research conducted, the following conclusions can be drawn;

1) From all the result obtained, the physical properties of cement consistency, setting times and soundness of cement conducted on the research conform to BS 4550 part3.
2) It can be concluded that waste broken brick aggregate possesses all properties of light weight aggregate, which has a specific gravity of 2.19 less than the specific gravity of dense aggregate, it has an average bulk density of 1090 kg/m^3 lower than the density of universal aggregate (1600 kg/m^3), this satisfies BS recommendation and can be used as a full replacement of coarse aggregate in light concrete production.
3) It has been concluded that, Nano silica improves the strength of light concrete with maximum strength of 10.30 N/mm^2 obtained at 3 % addition.
4) The maximum strength of 17.57 N/mm^2 was obtained at 3 % addition of Nano silica at 28 days for light concrete this range of strength is adequate for structural works where high strength is not paramount.
5) Increase in percentage of Nano silica increases compressive strength, it increases the workability of concrete, and it minimizes segregation compared to 0% addition.

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