

# **Influence of Silica Fume on the Workability and Compressive Strength of Dune Sand Concrete**

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**ABSTRACT:** In this study, the influence of silica fume on the workability and compressive strength of dune sand concretes was investigated. Four (4) samples of dune sands randomly collected from Nyiri desert (Kenya) and Two (2) dune sand samples from Sahara Desert (Chad) were used as full replacement of ordinary fine aggregates collected from Meru River (Kenya) and Chari Baguirmi River (Chad). The concrete mix design was done in function of conventional aggregates according to BS Standard. The mix design obtained was 1:2:3 with a 0.5 Water/Cement ratio. The dune sand samples fully replaced with conventional fine aggregates in the concrete mixes and the ordinary cement was replaced at 10% and 15% in each mix. The variation was observed in terms of workability and compressive strength. The assessment of compressive strength was carried out using concrete cubes of 15cm\*15cm\*15cm crushed after 7, 14 and 28.

Results showed that when 10% Silica Fume was replaced by OPC in dune sand concretes from Kenya and Chad, there were 12.18% and 6.58% average gain of compressive strength after 28 days respectively, also, when 15% Silica Fume was replaced by OPC in dune sand concretes from Kenya and Chad, there were 19.87% and 11.85% average gain of compressive strength after 28 days respectively. These gains in compressive strength after treatment showed that there were 1.93% and 28.94% average loss of compressive strength after 28 days of samples from Kenya and Chad respectively.

**KEYWORDS:** Concrete, dune sand, dune sand concrete, Silica fume, compressive strength and workability.

## **I. INTRODUCTION**

Building in desert areas which are generally distant from the main towns where construction materials are available and purchasable at reasonable cost is extremely high due to some supplementary fees included to cover the transport of materials. Finding alternative ways of using non-conventional materials becomes meaningful due to the rarefication of ordinary ones. Dune sands representing about 20% of deserts worldwide would be a good alternative material in concrete. Sand dunes are mounds of windblown sand which vary greatly in size, from less than one meter to tens of meters high. They are ridges of sand created by the wind found in deserts or near lakes and oceans. They are characterized by high fine proportion which would affect workability and compressive strength. It is necessary to use an additive such as silica fume to minimize the weaknesses resulting in dune sand properties.

Silica fume is a highly efficient pozzolanic material and has a considerable potential for use in concrete. It is a by-product resulting from the reduction of high purity quartz with coal in electric arc furnaces in the manufacture of ferro-silicon and silicon metal. Silica fume varies from light- to dark gray in colour and when mixed with water, gives a slurry which is black [1]. Silica fume, like other pozzolanic materials, is generally more efficient in concretes having

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high water-cement ratios. Investigations in Norway and Canada indicate that in concretes with a water-cement ratio of about 0.55 and higher, silica fume, when used in small percentages as cement replacement, has an efficiency factor of 3 to 4 [2].

The purpose of this study was to show the usefulness of dune sands as alternative of fine aggregates in concrete for constructions. Hence would emphasize on the variation in slump and compressive strength in function of various dune sand samples.

## II. MATERIALS AND METHODS

### 2.1 Silica Fume

In this work, the MasterRoc MS 610 was used. It is a high-quality silica fume powder for high performance concrete. It changes the porous structure of the concrete making it denser and more resistant to any type of external influence. It was delivered in powder grey colour, with a density ranging between 0.55 and 0.7kg/l and a chloride content less than 0.1%. MasterRoc MS 610 was added to the concrete during batching and the recommended dosage is 5 to 15% of the cement weight.

### 2.2 Cement

Cement is a hydraulic binder made of raw materials such as; Lime (CaO) from Limestone, Silica (SiO<sub>2</sub>) from clay, and alumina (Al<sub>2</sub>O<sub>3</sub>) from clay, with a very few percentage of magnesia (MgO) and sometimes alkalis, and Iron oxides added to control its composition [3]. In this study, the Optimum Portland Cement 42.5 N was used.

### 2.3 Aggregates

The two aggregates commonly used in construction are fine and coarse. In this work, the ordinary fine aggregates from Kenya were collected from Meru River and the ordinary crushed coarse aggregates from Mombasa Road Quarry Company. In Chad, the fine aggregates were collected from Chari Baguirmi River and the ordinary crushed coarse aggregates purchased from a quarry company. The particle size of conventional fine aggregates ranges from 0-10mm and ordinary coarse aggregates 5-14mm.

### 2.4 Dune sand samples

In this work, dune sand samples were used as full replacement of ordinary fine aggregates. Dune sand samples from Kenya collected from Nyiri Desert. The samples were randomly collected by picking, the minimum distance between each sample collection site was about 50km. In Chad, the samples were collected from Sahara Desert mainly in the region of Hadjer Lamis. The minimum distance between each sample collection site was also about 50km.

The particle size of dune sand samples collected from Kenya ranges from 0-5mm while the one of Chad from 0-1.18mm.

All the dune sand samples classified according to Grading Zone as per IS:383 belonged to ZONE-IV.

### 2.5 Water

Water is a part of the concrete, and it gives the liquid characteristic of the fresh concrete. The cement paste saves the amount of water on the surface of the grains of the cement and the grains of the aggregates to complete the hydration reaction of the cement components inside the concrete [4]. The water used in concrete in this study both from Chad and Kenya was public tap water.

### 2.6 Silica Fume

In this work, the MasterRoc MS 610 was used. It is a high-quality silica fume powder for high performance concrete. It changes the porous structure of the concrete making it denser and more resistant to any type of external influence. It was delivered in powder grey colour, with a density ranging between 0.55 and 0.7kg/l and a chloride content less than 0.1%. MasterRoc MS 610 was added to the concrete during batching and the recommended dosage is 5 to 15% of the cement weight.

### 2.5 Methods

The collection of information from literature review available was used to state the importance of treating dune sand properties with silica fume to attenuate its weaknesses due mainly to its fineness and noxious components.

The assessment of the influence of Silica Fume partially replaced at different proportion with OPC was done on Six (6) dune sand concretes.

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The dune sand samples were randomly picked from different places located in Nyiri desert(Kenya) and Sahara Desert(Chad), the dune sand samples were limited to Four (4) and Two (2) respectively. The sieving analysis was carried out according to BS.

Accordingly, the influence of silica fume in concrete was observed through the experiment by comparing the Non-Conventional Aggregate Concrete and the Conventional Aggregate Concrete in terms of constituency, workability, cohesiveness and compressive strength.

The study was executed in Four (4) steps:

- 1- Carrying out normal concrete taken as control group from Kenya and Chad;
- 2- Replacement of 100% of ordinary sand by each sample of Dune Sand;
- 3- Replacement of 10% of Portland cement by silica fume in every Dune Sand Concrete (DSC);
- 4- Replacement of 15% of Portland cement by silica fume in every Dune Sand Concrete (DSC).

Properties of fresh concrete such as workability were assessed through slump test and compared to conventional concretes which were taken as control. In addition, the compressive strength was obtained by using the Universal Testing Machine to crush concrete cubes of 15cm\*15cm\*15cm according to BSI 8110.

The mix design of the control concretes was done according to the BS method. The mix design obtained was 1:2:3 with a 0.5 Water/Cement ratio. All the factors remained the same in the mixes except the full replacement of ordinary fine aggregates by dune sand samples.

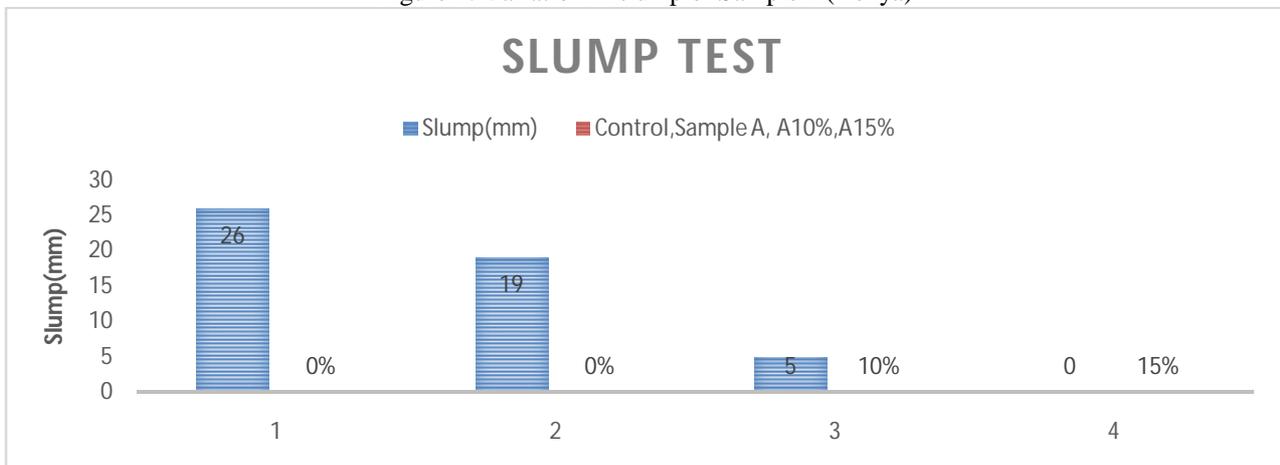
## III. RESULTS AND DISCUSSIONS

### 3.3 Fresh Concrete Testing

#### 3.3.1 Slump Test

The slump test is prescribed by BS1881: Part 102: 1983 [5]. For the control concrete mix design, the specified slump was from 10-30mm. The control concrete mix design was 1:2:3 while the Water/Cement ratio was 0.5 and the cement content 380kg/m<sup>3</sup>. Silica fume was then replaced at 10% and 15% of the weight of cement in all the other mixes. The Figures below give the variation of slump in function of each sample with silica fume replacement.

Figure 1: Variation in slump of Sample A(Kenya)



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Figure 2: Variation in Slump of Sample B(Kenya)

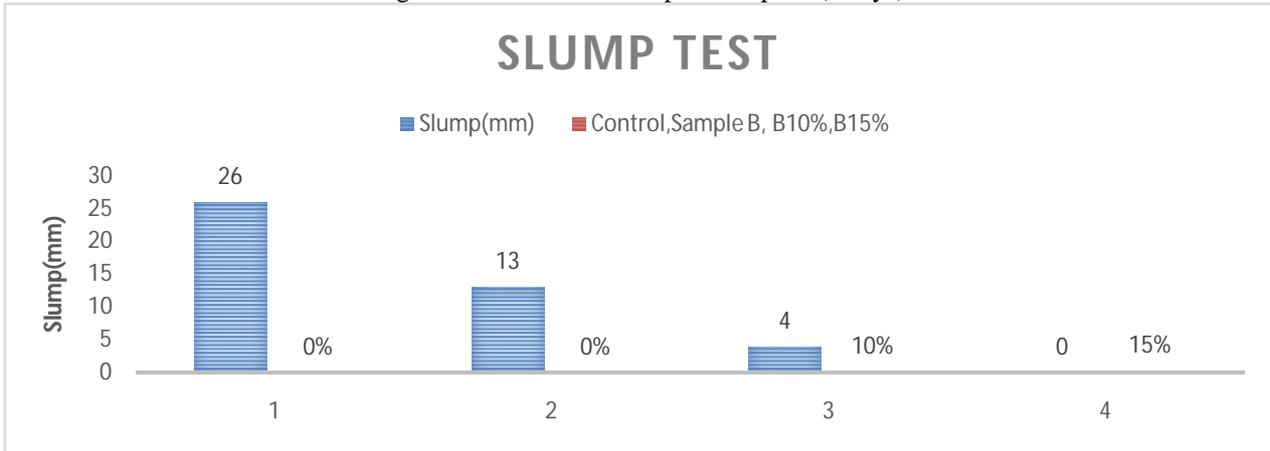


Figure 3: Variation in Slump of Sample C(Kenya)

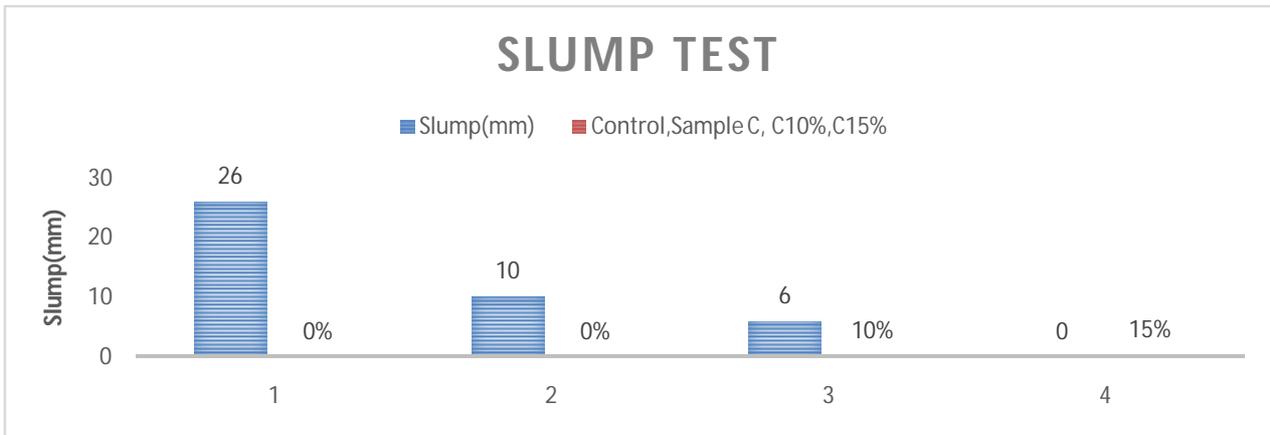
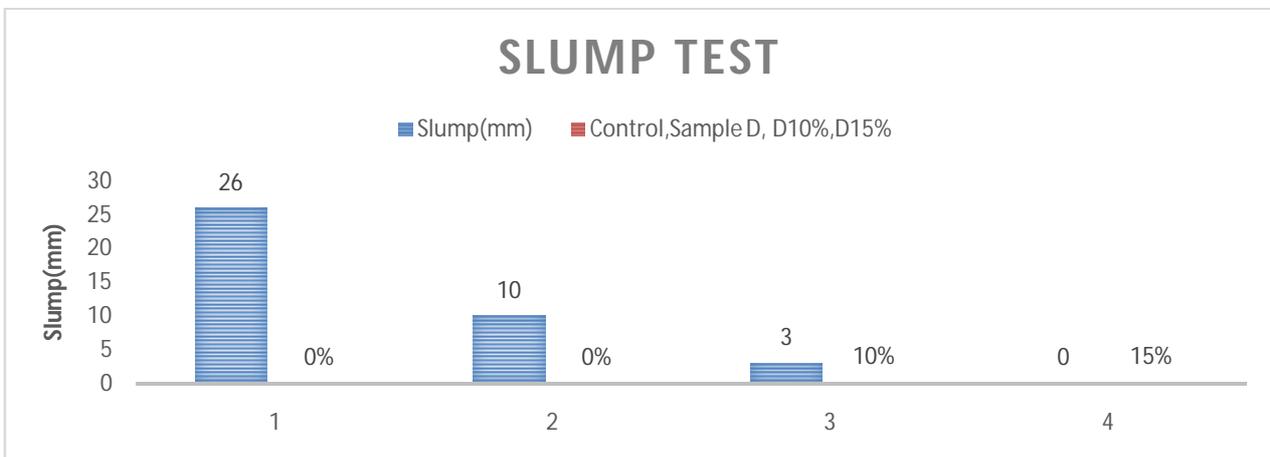


Figure 4: Variation in Slump of Sample D(Kenya)



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Figure 5: Variation in Slump of Sample 1(Chad)

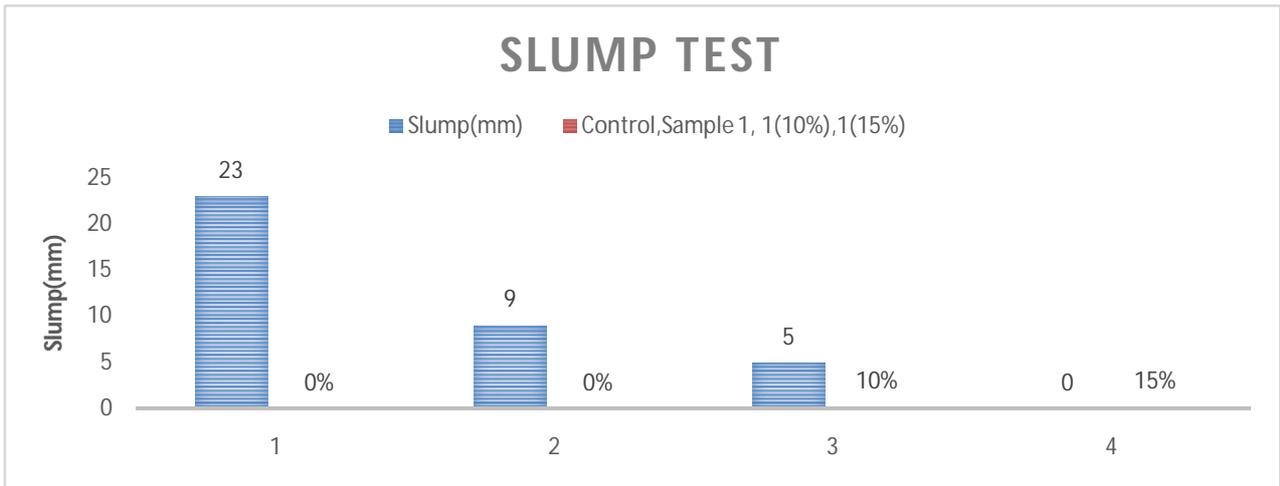
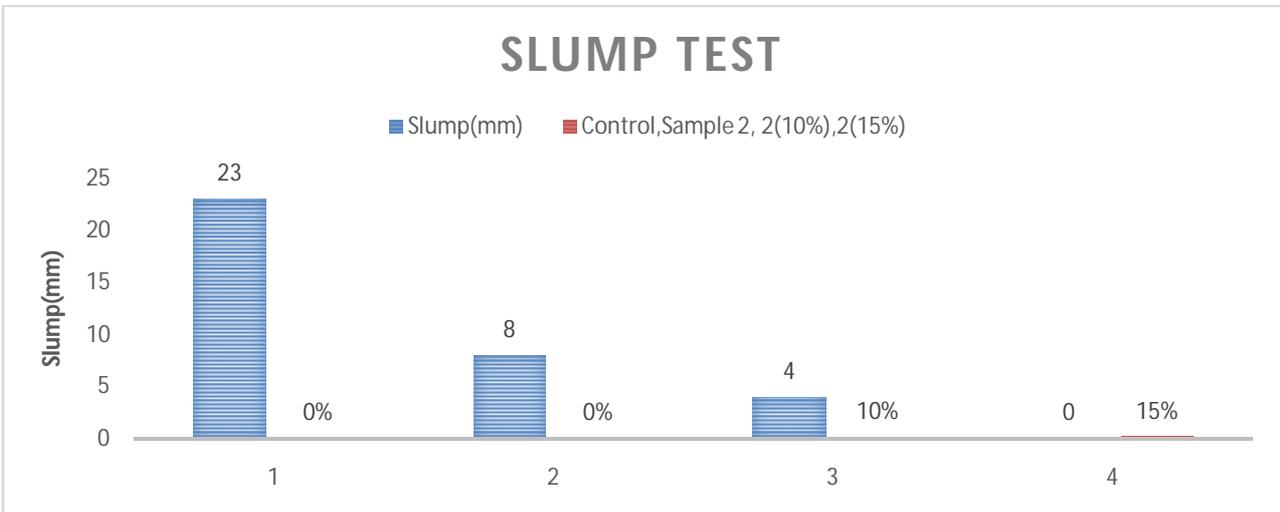


Figure 6: Variation in Slump of Sample 2(Chad)



When silica fume was added as a partial replacement of OPC, the slump started decreasing. At 10% replacement, the slump varied from 2-6mm. When the proportion of silica fume was increased to 15%, the slump was 0mm for all the samples. These results might be justified by the increase of surface area due to the fineness of silica fume and the high-waterabsorption of both dune sand samples and silica fume.

### 3.3.2 Compressive strength

All the compressive strength Tests were carried out with cube specimens of 15cm x 15cm x 15cm. These specimens were tested by compression testing machine after 7, 14 and 28 days curing. Three (3) cubes were crushed using the Universal Testing machine for each sample at the crushing day, the average compressive strength was then adopted for the concerned sample[6].

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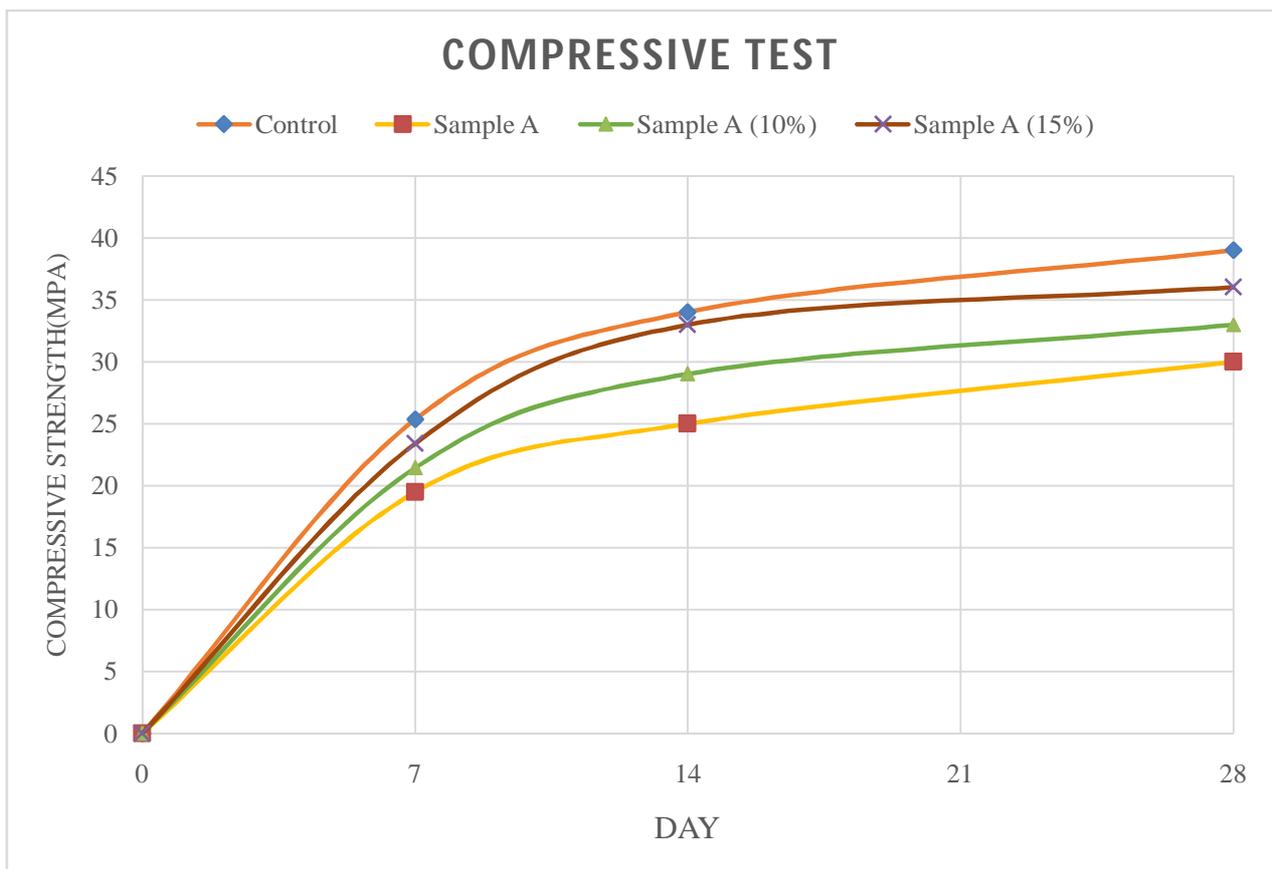
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## ➤ Sample A

Table 1: Variation of compressive strength with time of Sample A in function of SF replacement(Kenya)

Day	0	7	14	28
Control	0	25	34	39
Sample A	0	20	25	30
Sample A (10%)	0	21	29	33
Sample A (15%)	0	23	33	36

Figure 7: Variation of compressive strength with time of Sample B in function of SF replacement



The results above showed that when the ordinary sand was replaced by the Sample A, there was a loss of 23.08% compressive strength after 28 days. When 10% and 15% of SF were replaced by OPC, there were gains of compressive strength of 7.69% and 15.38% respectively after 28 days.

From the above, there was a loss of 23.08% after the full replacement of ordinary sand by Sample A. After the replacement of SF by OPC at 15%, there was a gain of 15.38%. Finally, after replacement of Sample A and treatment with SF, there was a loss of 7.7% compressive strength after 28 days. It means that the treatment was efficient but could not recover all the losses due to the influence of properties of Sample A.

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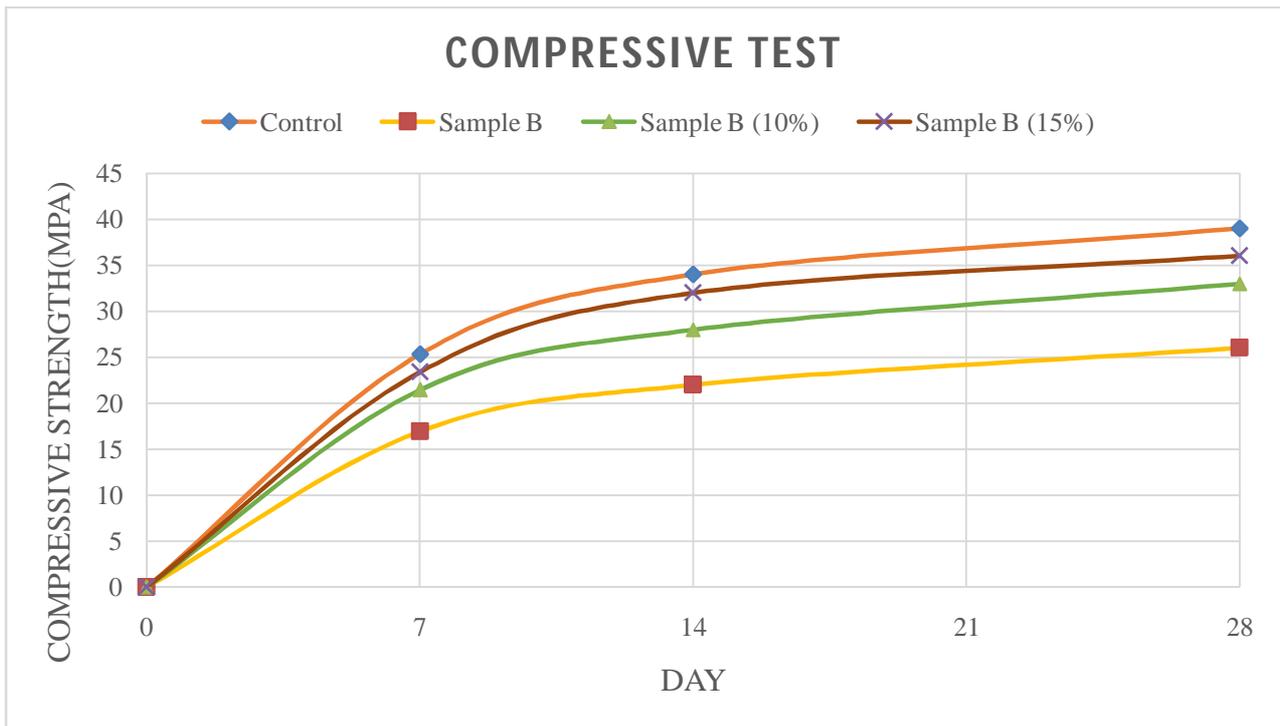
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### ➤ Sample B

Table 2: Variation of compressive strength with time of Sample B in function of SF replacement(Kenya)

Day	0	7	14	28
Control	0	25	34	39
Sample B	0	17	22	26
Sample B (10%)	0	21	28	33
Sample B (15%)	0	23	32	36

Figure 8: Variation of compressive strength of Sample B with time in function SF replacement



The results above showed that when the ordinary sand was replaced by the Sample A, there was a loss of 33.33% compressive strength after 28 days. When 10% and 15% of SF were replaced by OPC, there were gains of compressive strength of 17.95% and 25.64% respectively after 28 days.

From the above, there was a loss of 33.33% after the full replacement of ordinary sand by Sample B. After the replacement of SF by OPC at 15%, there was a gain of 25.64%. Finally, after replacement of Sample B and treatment with SF, there was a loss of 7.69% compressive strength after 28 days. The results showed that the treatment was efficient but could not recover all the losses due to the influence of properties of Sample B.

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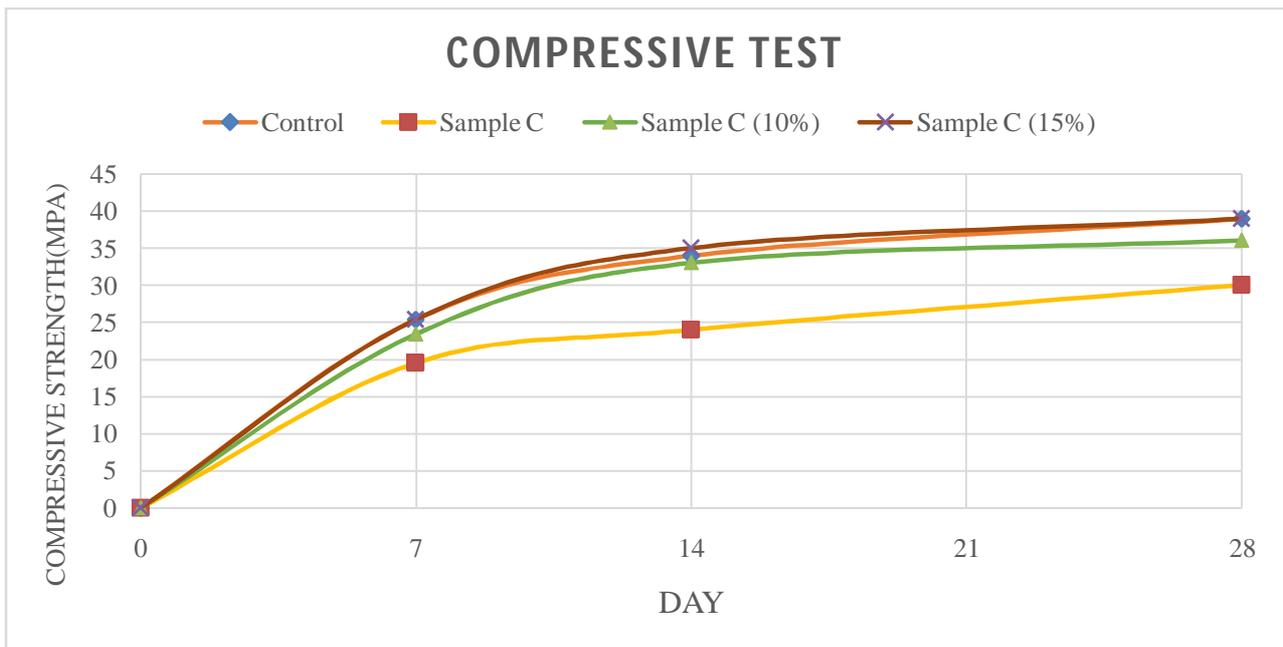
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### ➤ Sample C

Table 3: Variation of compressive strength with time of Sample C in function of SF replacement(Kenya)

Day	0	7	14	28
Control	0	25	34	39
Sample C	0	20	24	30
Sample C (10%)	0	23	33	36
Sample C (15%)	0	25	35	39

Figure 7: Variation of compressive strength with time of Sample C in function of SF replacement



Results obtained after testing showed that when the ordinary sand was replaced by the Sample C, there was a loss of 23.08% compressive strength after 28 days. When 10% and 15% of SF were replaced by OPC, there were gains of compressive strength of 15.38% and 23.08% respectively after 28 days.

From the above, there was a loss of 23.08% after the full replacement of ordinary sand by Sample C. After the replacement of SF by OPC at 15%, there was a gain of 23.08%. Finally, after replacement of Sample C and treatment with SF, there was no loss of compressive strength after 28 days. The results showed that the treatment was efficient and allowed to completely recover losses related to Sample C replacement.

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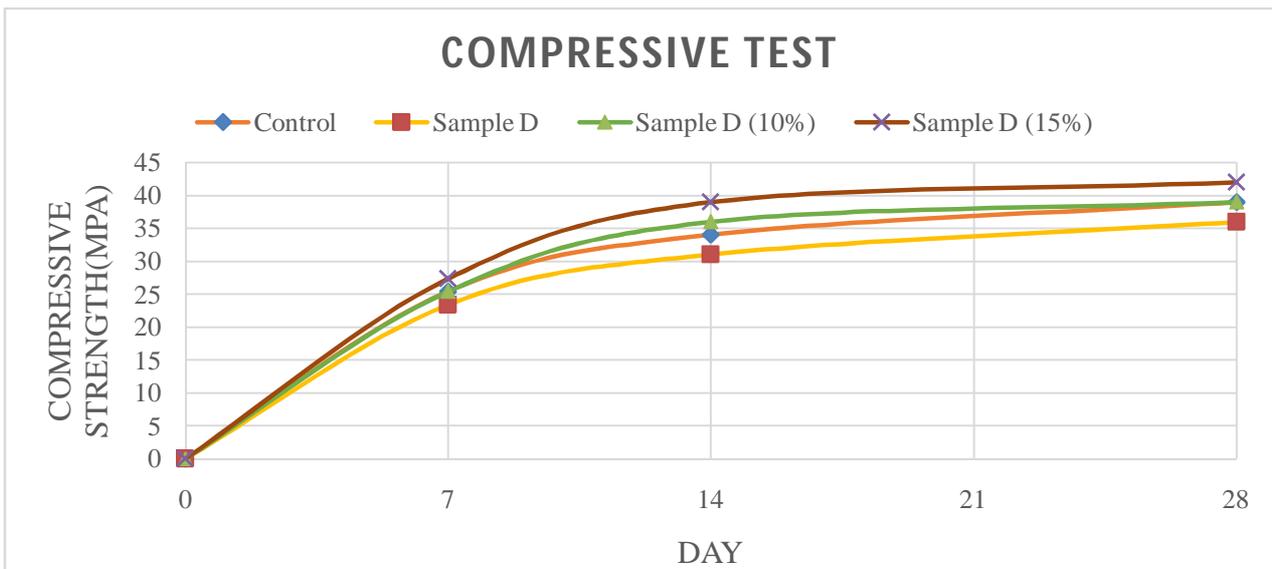
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## ➤ Sample D

Table 4: Variation of compressive strength with time of Sample D in function of SF replacement(Kenya)

Day	0	7	14	28
Control	0	25	34	39
Sample D	0	23	31	36
Sample D (10%)	0	25	36	39
Sample D (15%)	0	27	39	42

Figure 10: Variation of compressive strength with time of Sample D in function of SF replacement



Results obtained after testing showed that when the ordinary sand was replaced by the Sample D, there was a loss of 7.69% compressive strength after 28 days. When 10% and 15% of SF were replaced by OPC, there were gains of compressive strength of 7.69% and 15.38% respectively after 28 days.

From the above, there was a loss of 7.69% after the full replacement of ordinary sand by Sample D. After the replacement of SF by OPC at 15%, there was a gain of 15.38%. Finally, after replacement of Sample D and treatment with SF, there were 7.69% gain of compressive strength after 28 days. The results showed that the treatment was efficient and allowed to completely recover losses related to Sample D replacement and to have a compressive strength greater than the one of Control mix.

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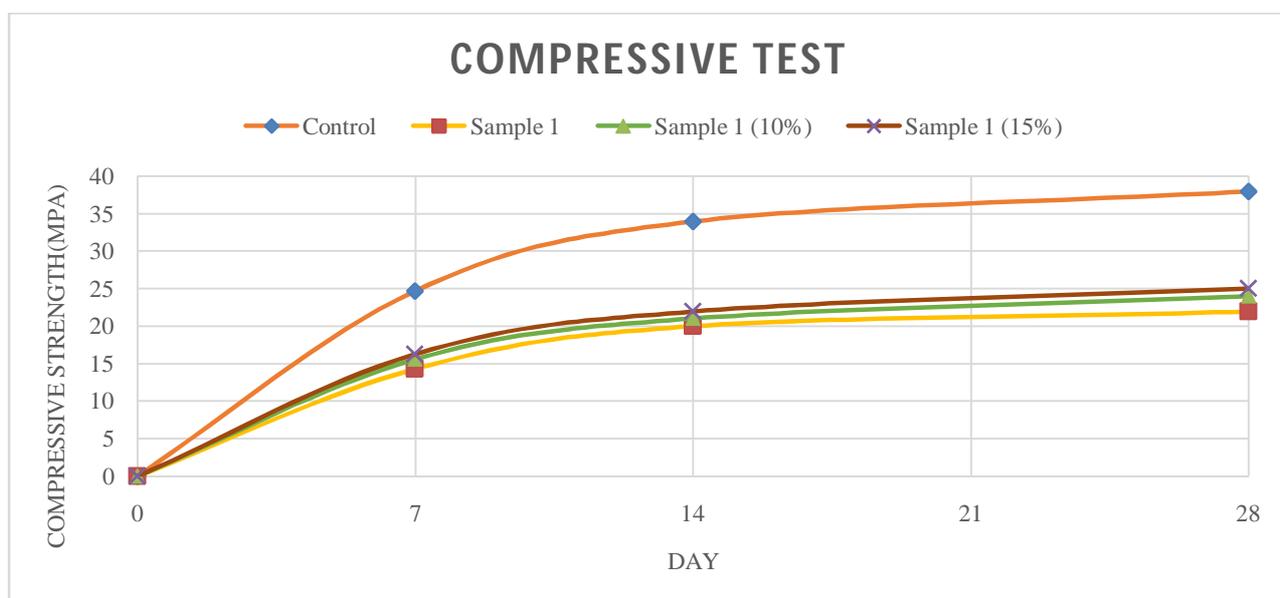
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### ➤ Sample 1

Table 5: Variation of compressive strength with time of Sample 1 in function of SF replacement(Chad)

Day	0	7	14	28
Control	0	25	34	38
Sample 1	0	14	20	22
Sample 1 (10%)	0	16	21	24
Sample 1 (15%)	0	16	22	26

Figure 8: Variation of compressive strength with time of Sample 1 in function of SF replacement



The results above showed that when the ordinary sand was replaced by the Sample 1, there was a loss of 42.10% compressive strength after 28 days. When 10% and 15% of SF were replaced by OPC, there were gains of compressive strength of 5.26% and 10.53% respectively after 28 days.

From the above, there was a loss of 42.10% after the full replacement of ordinary sand by Sample 1. After the replacement of SF by OPC at 15%, there was a gain of 10.53%. Finally, after replacement of Sample 1 and treatment with SF, there was a loss of 31.57% compressive strength after 28 days. The results showed that the treatment was efficient but could not recover all the losses due to the influence of properties of Sample 1.

### ➤ Sample 2

Table 6: Variation of compressive strength with time of sample 2 in function of SF replacement(Chad)

Day	0	7	14	28
Control	0	25	34	38
Sample 2	0	15	21	23
Sample 2 (10%)	0	17	22	26
Sample 2 (15%)	0	18	25	28

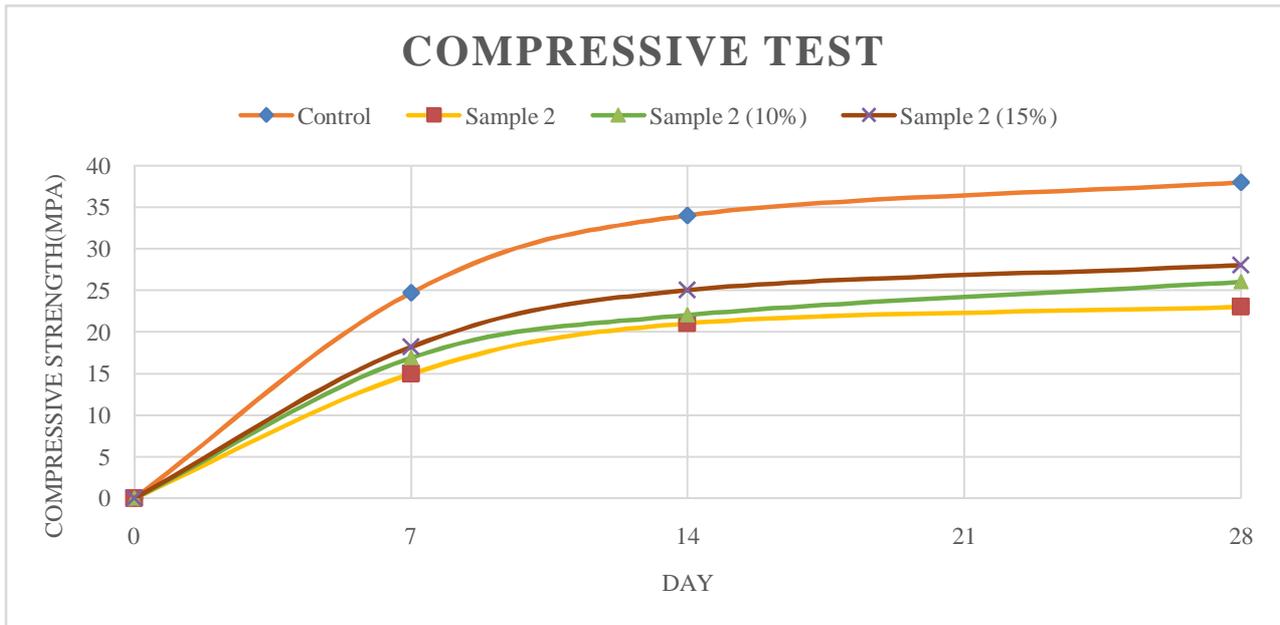
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Figure 9: Variation of compressive strength with time of Sample 2 in function of SF replacement(Chad)



Results above showed that when the ordinary sand was replaced by the Sample 2, there was a loss of 39.47% compressive strength after 28 days. When 10% and 15% of SF were replaced by OPC, there were gains of compressive strength of 7.89% and 13.16% respectively after 28 days.

From the above, there was a loss of 39.47% after the full replacement of ordinary sand by Sample 2. After the replacement of SF by OPC at 15%, there was a gain of 13.16%. Finally, after replacement of Sample 1 and treatment with SF, there was a loss of 26.31% compressive strength after 28 days. The results showed that the treatment was efficient but could not recover all the losses due to the influence of properties of Sample 2.

## IV. CONCLUSIONS AND RECOMMENDATIONS

### 4.1 Conclusions

The general objective of this study was to assess the effect of chemical and physical properties of dune sands on the compressive strength of concrete, the following conclusions can be made:

1. When 10% Silica Fume was replaced by OPC in dune sand concrete, there was 81.63% average reduction in slump;
2. When 15% Silica Fume was replaced by OPC in dune sand concrete, there was 100% reduction in slump;
3. The smaller the proportion of Silica fume, the higher the slump and inversely;
4. The finer the aggregates, the smaller the slump;
5. When the ordinary sand was fully replaced by dune sand samples from Kenya and Chad, there were 22% and 41% average loss of compressive strength after 28 days respectively;
6. When 10% Silica Fume was replaced by OPC in dune sand concretes from Kenya and Chad, there were 12.18% and 6.58% average gain of compressive strength after 28 days respectively;

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7. When 15% Silica Fume was replaced by OPC in dune sand concretes from Kenya and Chad, there were 19.87% and 11.85% average gain of compressive strength after 28 days respectively;
8. After treatment of dune sand concretes from Kenya and Chad at 15% Silica Fume, there was 1.93% and 28.94% average loss of compressive strength after 28 days respectively;
9. When the choice of dune sand is well made, it can be used without any treatment for concrete of classes 15/20, 20/25 and 25/30;

## 4.2 Recommendations

From this work and its findings, the following recommendations will be suggested for eventual future study to ascertain the use of dune sand concrete in construction industry:

10. To extend compressive strength test after 90 days and 1 year to follow the strength development with time;
11. To carry out compressive strength test on dune sands from Nyiri Desert and Sahara Desert with the same grading;
12. To carry out splitting tensile strength and flexural strength tests on dune sand concrete as compared to ordinary concrete;
13. To assess the influence of density of dune sand concrete treated with Silica Fume on the compressive strength and durability;
14. To extend compressive strength test after 90 days and 1 year to follow the strength development with time;
15. To study the influence of pH of dune sands on the pH of dune sand concrete treated with Silica Fume;
16. To evaluate the effect of superplasticizer on the compressive strength and durability of dune sand concrete treated with Silica Fume;

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