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Effect of Chemical and Physical Properties of Dune Sands On the Compressive Strength of Concrete

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ABSTRACT: The world population is about 7.4 billion but only about 1 billion live in desert areas which occupy 33% of the available land on earth[1]. This poor demography in desert zone is essentially due to difficult living conditions including housing. The tough housing conditions are mainly caused by the cost of construction materials which are very high so there is need to try find a way to use materials which are very available locally such as dune sands for construction[2].

The study focused on Four (4) samples of dune sands randomly collected from Nyiri desert(Kenya) and Two (2) samples from Sahara Desert (Chad). After the assessment of chemical and physical properties of dune sand sampled, the dune sand samples were used as full replacement of ordinary fine aggregates in concrete. The concrete cubes were then crushed after 7, 14 and 28 days to assess the variation of compressive strength in function of dune sand concrete. Finally, the cost estimation of dune sand concretes was done to show the importance of their use for construction industry in desert areas from Kenya and Chad.

KEYWORDS: Concrete, dune sand, dune sand concrete, compressive strength, physical and chemical properties.

I. INTRODUCTION

Concrete is a very common material used in construction sites in the overall world. It is a composite material composed of coarse and fine aggregates bonded together with a fluid cement that hardens over time.

Due to the high cost of construction mainly in desert and semi desert Areas in Africa, the economy is affected. This is justified by the fact that in most Arid zones in Africa, the infrastructure of transport is precarious, and the populations live in the extreme poverty. To build in these areas which are generally distant from the main towns where construction materials are available and purchasable at reasonable cost, contractors generally include some supplementary fees to cover the transport of materials such as aggregates, sand, cement, water, and so on.

Finding an alternative way of using common materials becomes meaningful due to rarefication and over exploitation of ordinary materials in construction industry.

The purpose of this study was to show the usefulness of dune sands as alternative of fine aggregates in concrete for constructions in desert and semi desert Areas. Hence would emphasize on the financial advantages of utilizing dune sands as concrete component in areas where they are available.

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II. MATERIALS AND METHODS

2.1 Cement

Cement is a hydraulic binder made of raw materials such as; Lime (CaO) from Limestone, Silica (SiO₂) from clay, and alumina (Al₂O₃) 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.

2.2 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.

2.3 Dune sand samples

In this study, 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.

2.4 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.

2.5 Methods

The collection of information from literature review available was used to state the usefulness of employing dune sand in concrete and the probable inconvenient of using such a material as concrete component and the potential solutions to mitigate those weaknesses.

Coming out with tangible and exhaustive information about the use of dune sand in concrete focused on the advantages and the disadvantages of using these materials in the concrete instead of the ordinary aggregates. The physical and chemical components of dune sand samples were evaluated to show their influence on the compressive strength of the hardened dune sand concrete.

The data collection was randomly done by picking 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 the dune sand 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- Chemical and physical analysis of properties of the Six (6) samples of dune sand;
- 2- Carrying out normal concrete taken as control group from Kenya and Chad;
- 3- Replacement of 100% of ordinary sand by each sample of Dune Sand;
- 4- Cost analysis of various materials employed in Dune Sand Concrete.

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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

3.1 Chemical properties

3.1.1 Heavy Metal Content

The Table 1 gives the different heavy metals present in the various samples of dune sand collected from Nyiri Desert(Kenya) which are Sample A, Sample B, Sample C, Sample D and those collected from Sahara Desert(Chad) that are Sample 1 and Sample 2.

Table 1: Heavy metal content

Element	Sample A	Sample B	Sample C	Sample D	Sample 1	Sample 2	Unit Conc'n
Potassium (K)	1.55 ± 0.21	1.09 ± 0.20	3.08 ± 0.34	3.11 ± 0.27	ND	ND	%
Calcium (Ca)	4.69 ± 0.24	7.01 ± 0.29	4.54 ± 0.24	3.48 ± 0.20	ND	ND	%
Titanium (Ti)	1.0 ± 0.06	0.907 ± 0.048	1.64 ± 0.09	0.931 ± 0.062	0 ± 0.06	0 ± 0.06	%
Manganese (Mn)	1327 ± 103	1072 ± 97	1244 ± 111	1215 ± 112	0.8 ± 0.06	1 ± 0.06	ppm
Iron (Fe)	6.95 ± 0.27	7.64 ± 0.23	5.28 ± 0.20	6.68 ± 0.29	40.0 ± 0.20	38.0 ± 0.20	ppm
Copper (Cu)	285 ± 24	330 ± 26	343 ± 30	315 ± 34	0.50 ± 20	0.60 ± 20	ppm
Zinc (Zn)	78.225	63.8 ± 6.06	83.2 ± 4.0	95.0 ± 10.2	1.10 ± 0.06	0.80 ± 0.06	ppm
Rubidium (Rb)	35.8 ± 4.0	18.5 ± 1.4	81.6 ± 5.5	89.3 ± 5.1	ND	ND	ppm
Strontium (Sr)	621 ± 17	494 ± 21	536 ± 16	287 ± 11	ND	ND	ppm
Yttrium (Y)	34.8 ± 2.3	25.6 ± 1.9	84.8 ± 6.5	54.6 ± 5.0	ND	ND	ppm
Zirconium (Zr)	689 ± 38	359 ± 21	3867 ± 174	575 ± 36	ND	ND	ppm
Lead (Pb)	25.4 ± 1.3	17.8 ± 1.8	34.5 ± 3.7	28.7 ± 10.0	2.0 ± 0.06	2.50 ± 0.06	ppm
Chromium(Cr)	ND	ND	ND	ND	3.0 ± 0.06	4.0 ± 0.06	ppm

Results showed that samples collected from Kenya contain high proportion of Manganese which were beyond 500mg/L. All the heavy metal of samples collected from Chad remained less than the permissible proportion [5]. Regardless the various proportions of heavy metals contained in different samples collected, the samples are friendly to

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the environment and would not affect the durability of concrete because of the proportions which fit in the allowable rank [6].

3.1.2 pH Value and organic impurities

The test procedures are based on British Standard (BS) for testing of soils, aggregates and concrete as prescribed in BS1377: Part 3:1990[7].

The results obtained after testing are shown on the Table 2 below.

Table 2: pH value and organic impurities

Sample	pH	Organic content (% m/m)	Origin
Sample A	8.83 ± 0.06	0.04	Kenya
Sample B	8.97 ± 0.06	0.054	Kenya
Sample C	8.63 ± 0.06	0.094	Kenya
Sample D	8.53 ± 0.06	0.081	Kenya
Sample 1	8.0 ± 0.06	0.242	Chad
Sample 2	7.80 ± 0.06	0.161	Chad

The results showed that the pH value ranges from 7.80 to 8.97 which means that all the samples are basic. Results showed that, the pH value of all the samples remained slightly higher than the neutral state. These results ranging around neutral state might be advantageous to the pH reduction of the future hardened because of the values which were neither too high nor too low[8].

The permissible percentage of organic impurities in aggregates for concrete is 0.5% [9].

All the Six (6) dune sand samples tested indicated lighter colour than the standard solution 24 hours after mixing. This indicates that all the collected were within the organic content limit as set in ASTM C40 [10]. Results showed that organic content ranges from 0.040 to 0.242%. All the samples collected from Kenya showed small proportions of impurities meanwhile dune sand samples collected from Chad showed the highest proportions of organic content. These results must be justified by the rain fall in Nyiri Desert which is greater than in Sahara[11].

Although some samples contained some high proportions of impurities but, regardless permissible organic content, all the samples of dune sand were acceptable to be used as concrete component.

3.2 Physical properties

3.2.1 Particle size distribution

The particle size distribution test was carried out according to BS1377: Part 2:1990[12].The particle size distribution of fine aggregates and normal aggregates are presented in Figures and Tables below.

Table 3: Sieve analysis of ordinary sand

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Ordinary Sand (Kenya)	0	2.1	22.03	44.2	81.1	93.2	96.7	98.2
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

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Figure 1: Sieve analysis graph of Ordinary Sand-Upper Limit-Lower Limit

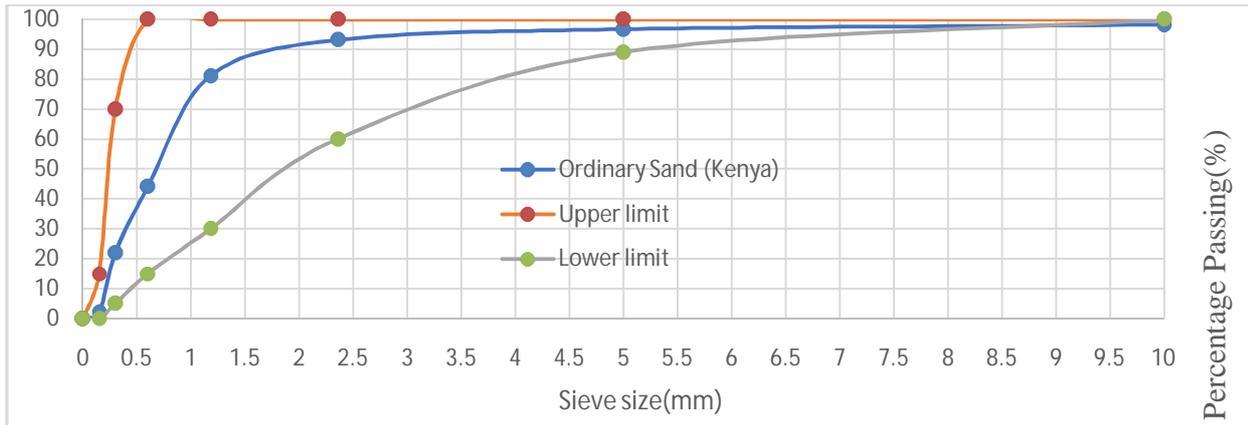
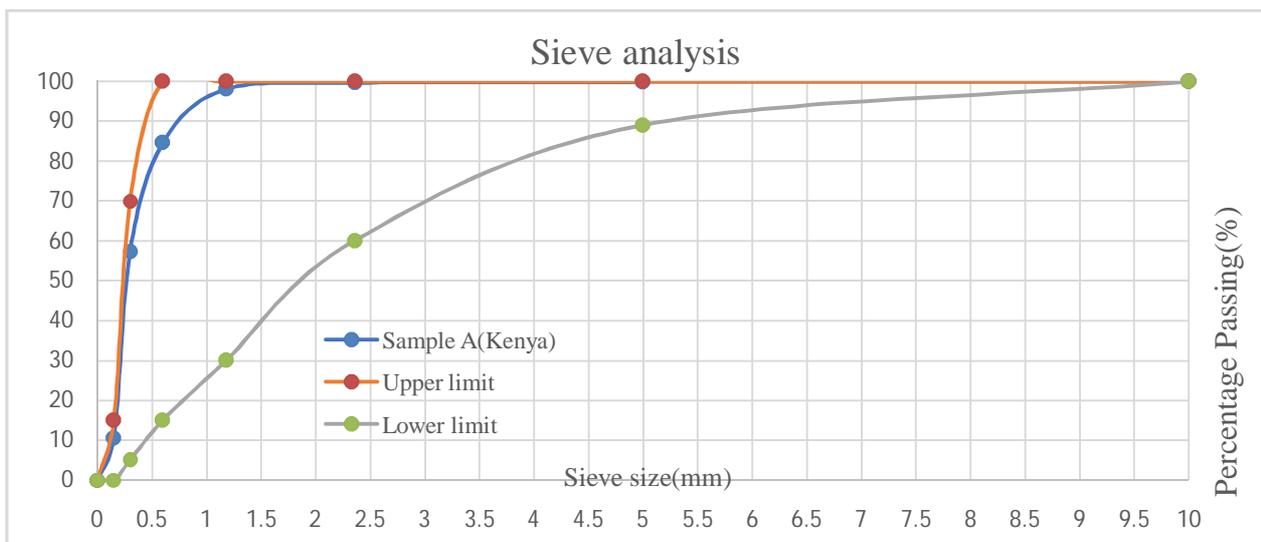


Table 4: Sieve analysis of Sample A

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Sample A(Kenya)	0	10.5	57.3	84.6	98.1	99.7	99.9	100
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

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Figure 2: Sieve analysis graph of sample A-Upper limit-Lower limit



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Table 5: Sieve analysis of Sample B-Upper Limit-Lower limit

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Sample B(Kenya)	0	6.9	57.3	81	96.5	98.8	99.4	100
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

Grading Zone As per IS:383 ZONE-IV

Figure 3: Sieve analysis graph of Sample B-Upper Limit-Lower limit

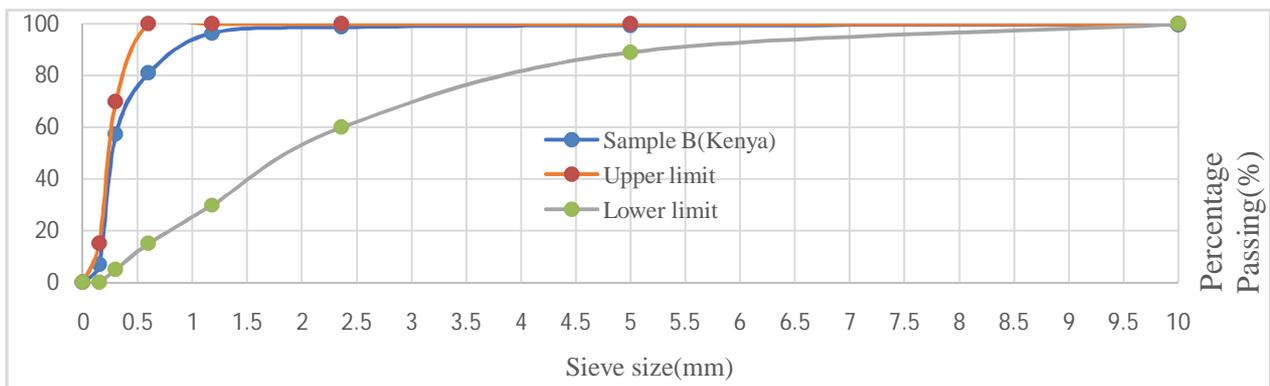
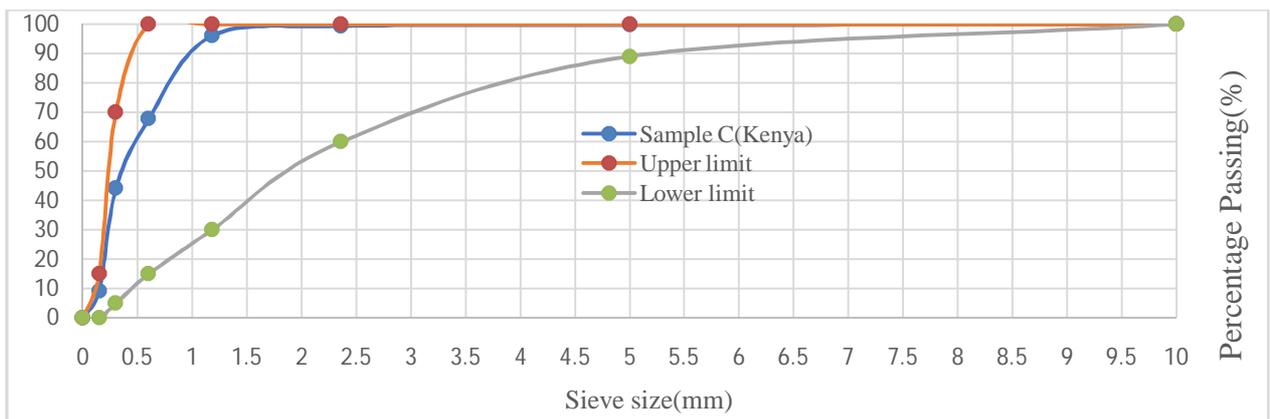


Table 6: Sieve analysis of Sample C

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Sample C(Kenya)	0	9.3	44.2	67.9	96.1	99.4	99.8	100
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

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Figure 4: Sieve analysis graph of Sample C-Upper Limit-Lower limit



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Table 7: Sieve analysis of Sample D

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Sample D(Kenya)	0	17.3	48.9	77.5	97.7	99.7	99.9	100
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

Grading Zone As per IS:383 ZONE-IV

Figure 5: Sieve analysis graph of Sample D-Upper Limit-Lower limit

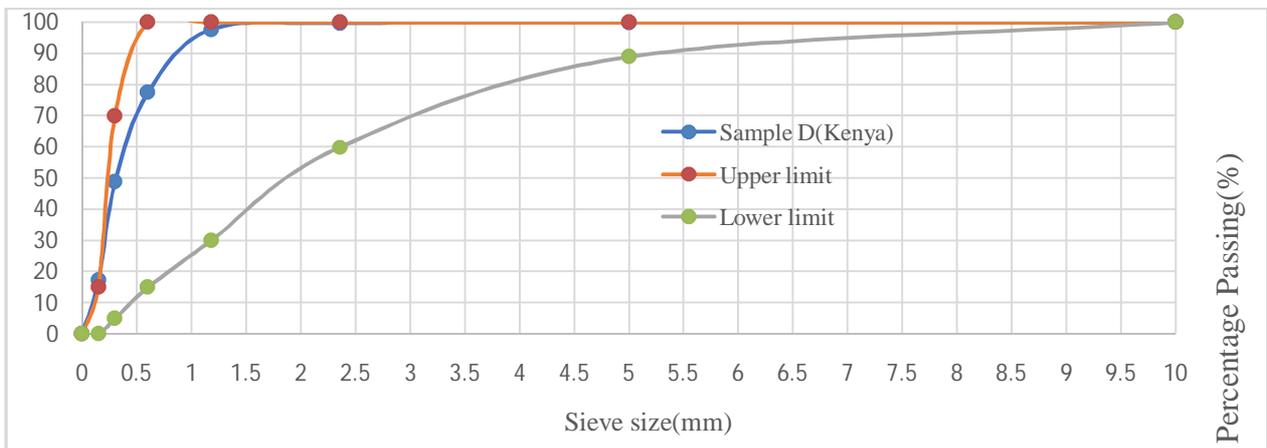
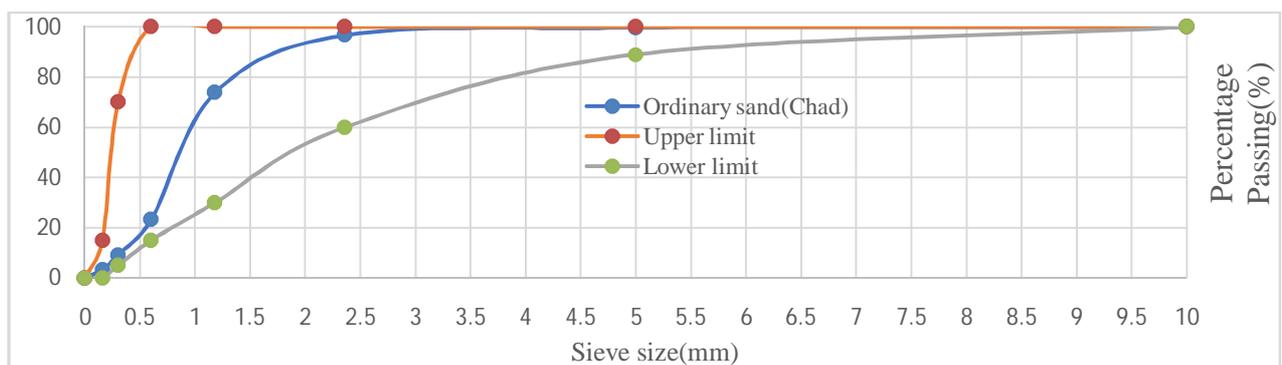


Table 8: Sieve analysis of ordinary sand

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Ordinary sand(Chad)	0	3.3	9.1	23.2	73.8	96.7	99.7	100
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

Grading Zone As per IS:383 ZONE-I

Figure 6: Sieve analysis graph of ordinary sand-Upper Limit-Lower Limit



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Table 9: Sieve analysis of Sample 1

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Sample 1(Chad)	0	14.6	72.71	97	99	100	100	100
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

Grading Zone As per IS:383 ZONE-IV

Figure 3: Sieve analysis graph of Sample 1-Upper Limit-Lower Limit

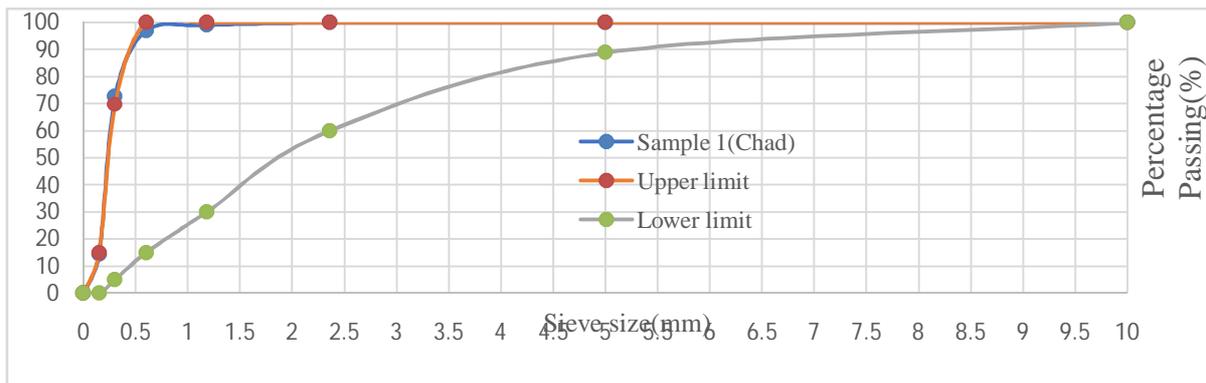
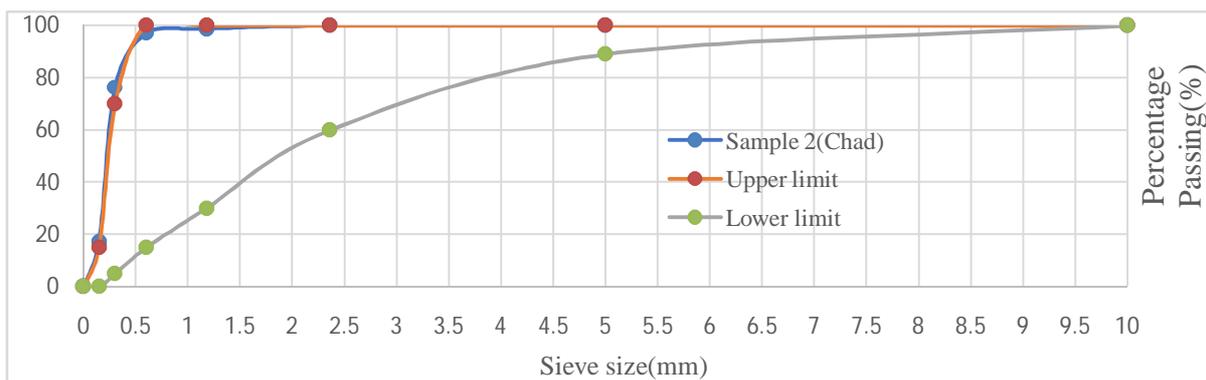


Table 10: Sieve analysis of Sample 2

Sieve size(mm)	Pan	0.15	0.3	0.6	1.18	2.36	5	10
Sample 2(Chad)	0	17.3	76.5	97	98.7	100	100	100
Upper limit	0	15	70	100	100	100	100	100
Lower limit	0	0	5	15	30	60	89	100

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Figure 8: Sieve analysis graph of Sample 2-Upper Limit-Lower Limit



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Particle size distribution of fine and micro-aggregate is known to strongly influence the microstructure of concrete. Sieve testing is one of the very fast methods of checking the quality of construction sand. Even though, the result of sieve test cannot be considered as the result to ensure the quality of sand.

The maximum ordinary fine aggregates size was 10mm for the ordinary sand from Kenya and 5mm for the ordinary sand from Chad. While the maximum dune sand size was 5mm for the dune sand from Kenya and 1.18mm for the dune sand samples from Chad.

The average proportion of passing through the sieve size 0.600mm was 97% for the dune sand samples collected from Sahara Desert while the one of samples from Nyiri desert was an average of 77.75%. The difference in fine proportion might be to the fact that Sahara Desert is originated from the various transgressions of Paleo-Chadian Sea and Nyiri Desert is caused by the rain shadow of the Mount Kilimanjaro. The fineness of fine aggregates would necessitate more bonding elements resulting in supplementary cost.

The particle size distribution tests of all the samples as well as ordinary sand dune sands collected from Chad and Kenya were shown on the Figures and Tables above. After classification as per IS-383, the ordinary sand from Chad belonged to Zone-I meaning that the sand was coarse. Meanwhile the ordinary sand from Kenya belonging to Zone-II was normal sand. All the dune sand samples collected from Chad and Kenya after classification belonged to Zone-IV representing the finer sand in all the four zones.

From the particle size distribution curves shown in Tables above, the gradings of only ordinary fine aggregates were observed to be within the upper and lower limit requirements of BS EN 12620:2002+A1:2008[13], indicating a uniformly graded particle size distribution of all the two types of aggregates. Meanwhile the ones of all the dune sand samples reached the upper limit grading due to their fineness.

3.2.2 Specific gravity and Water absorption

The 24-hour water absorption obtained for all the aggregates are shown on the Table 12 below.

Table 11: Specific gravity and Water absorption of aggregates

Sample	Specific gravity	Water Absorption (%)	Origin
Ordinary Sand	2.45	6.53	Kenya
Coarse Aggregates	2.58	2.92	Kenya
Sample A	2.39	8.24	Kenya
Sample B	2.29	12.31	Kenya
Sample C	2.4	5.45	Kenya
Sample D	2.04	13.61	Kenya
Ordinary Sand	2.52	4.35	Chad
Coarse Aggregates	2.6	3.16	Chad
Sample 1	1.85	13.52	Chad
Sample 2	1.78	13.83	Chad

As shown above, the proportion of water absorption of all the samples were between 2.92 and 13.93%. The finer the aggregates, the higher the water absorption and inversely.

In general, most lightweight aggregates have higher water absorption values than normal weight aggregates. The high-water absorption properties of dune sands might be attributed to high porosity and large interconnecting pore structure

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of the aggregates. Since the water absorption of the dune sands is high, it is reasonable to conclude that the dune sand absorbs a greater amount of mixing water during concrete production.

The values of the specific gravities of the ordinary aggregates were from 2.45 to 2.60 meanwhile the one of dune sand samples were from 1.78 to 2.40 which fall below the permissible values[4].

The high porosity of dune sands is likely to have contributed to the low specific gravity value compared to that of the ordinary sands. Generally, aggregates with specific gravity less than about 2.4 are classified as light weight while normal weight concrete aggregates have specific gravity around 2.6[14]. The specific gravities obtained from the study were considered representative of lightweight and normal weight aggregate respectively.

3.2.3 Fineness modulus, Silt and clay content

The permissible Silt and clay content in sand percentage is only 6%, IS:2686-1977 allows up to 8%[15]. Fineness modulus of sands is determined in accordance with 7.2.1 of BS 812-103.1:1985, the amount of material passing the 75µm sieve shall not exceed the quantities of 2%, [16].

Table 12: Fineness modulus, Silt and clay content

Sample	Fineness Modulus	Silt content/clay (%)	Origin
Ordinary Sand	2.68	3.6	Kenya
Sample A	1.53	5.01	Kenya
Sample B	1.74	5.12	Kenya
Sample C	1.83	5.2	Kenya
Sample D	1.59	4.96	Kenya
Ordinary Sand	2.89	3.26	Chad
Sample 1	1.2	20.43	Chad
Sample 2	1.1	19.68	Chad

ASTM C33 suggests that the fineness modulus be kept between 2.3 and 3.1. Very fine sand will increase the water demand of the mix, while very coarse sand could compromise its workability[17]. All the ordinary sands are within the allowable limit. The FM of the sand dune samples ranges from 1.10 to 1.83. All these values are below the permissible limit in terms of fineness of fine aggregates.

The proportion of silt and clay content of ordinary sands from Chad and Kenya were from 3.26 to 3.60 which are below the permissible value.

The silt and clay content of dune sand samples collected from Kenya ranged from 4.96 to 5.20% which are below the permissible silt content while the silt and clay content of the two samples collected from Sahara Desert were from 19.68 to 20.43% which are highly beyond the permissible value.

3.3 Fresh Concrete Testing

3.3.1 Slump Test

The slump test is prescribed by BS1881: Part 102: 1983 [17]. 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/m³. These factors above remained constant for all the mixes, control mixes as well as dune sand concrete.

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Table 13: Slump Test of concrete

Sample	Slump(mm)	Origin
Control	26	Kenya
Sample A	19	Kenya
Sample B	13	Kenya
Sample C	10	Kenya
Sample D	10	Kenya
Control	23	Chad
Sample 1	9	Chad
Sample 2	8	Chad

The slump was measured in terms of millimetre unit. Table 27 shows the results of the slump test. It shows that the slump value ranges from 0–26 mm.

All the control mixes fell within the expected rank. When the sand dune was fully replaced by ordinary sand, Samples A, B, C and D had slumps which remained within the specified slump interval while the slumps of Samples 1 and 2 were below the specified slump. This variation in slump was due to the increase of surface area and high-water absorption of dune sands.

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.

Table 14: Variation of compressive strength in function of various Samples(Kenya)

Day	0	7	14	28
Control	0	25	34	39
Sample A	0	20	25	30
Sample B	0	17	22	26
Sample C	0	20	24	30
Sample D	0	23	31	36

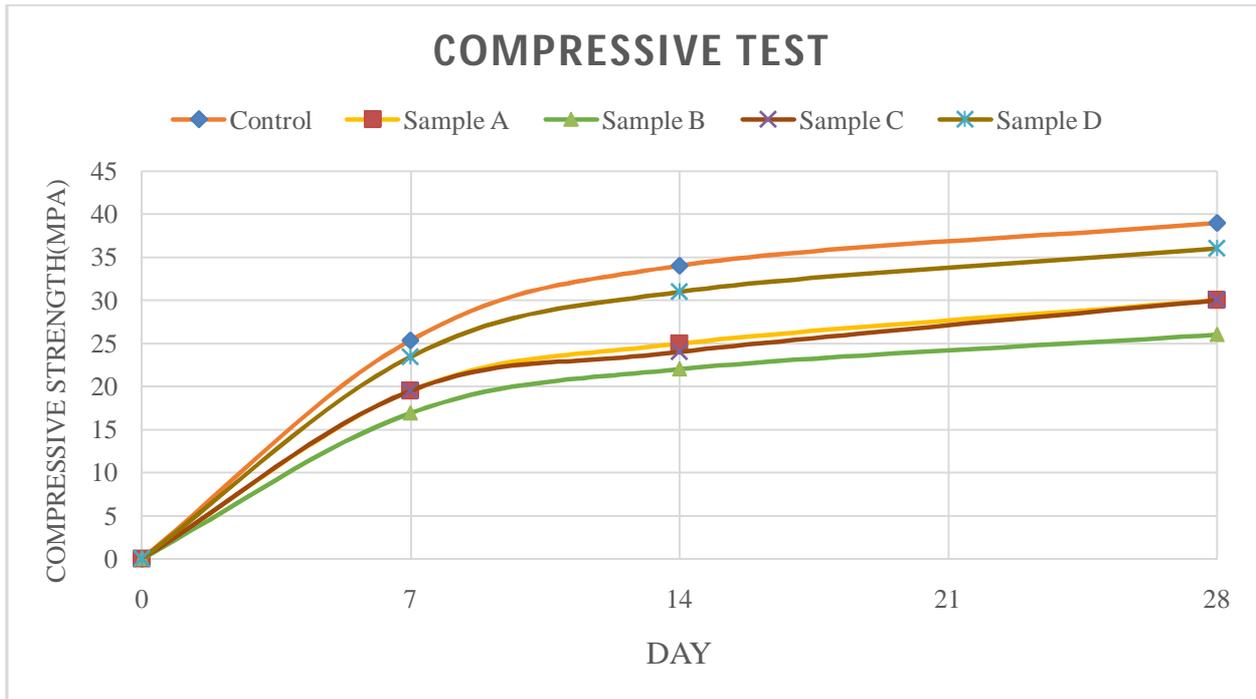
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Figure 9: Variation of compressive strength in function of various Samples(Kenya)



The results above obtained from various samples collected from Kenya showed the average compressive strength obtained after 7, 14 and 28 days. The control mix gave the compressive strength of 25, 34 and 39 MPa after 7, 14 and 28 days respectively. The ordinary sand was then replaced fully by each sample of dune sand. All the factors remained the same except the dune sand replacement. The Sample A mix gave the minimum compressive strength which was much smaller as compared to the control mix while the one of Sample D was close to the control mix.

Regardless these results, the Sample D had the smallest proportion of silt and clay content as compared to those of Samples A, B and C as showed on Table 12. The high compressive strength of Sample D might be related to the silt and clay content, as the silt and clay content is one of the factors influencing the compressive strength of concrete.

Table 15: Variation of compressive strength in function of various samples(Chad)

Day	0	7	14	28
Control	0	25	34	38
Sample 1	0	14	20	22
Sample 2	0	15	21	23

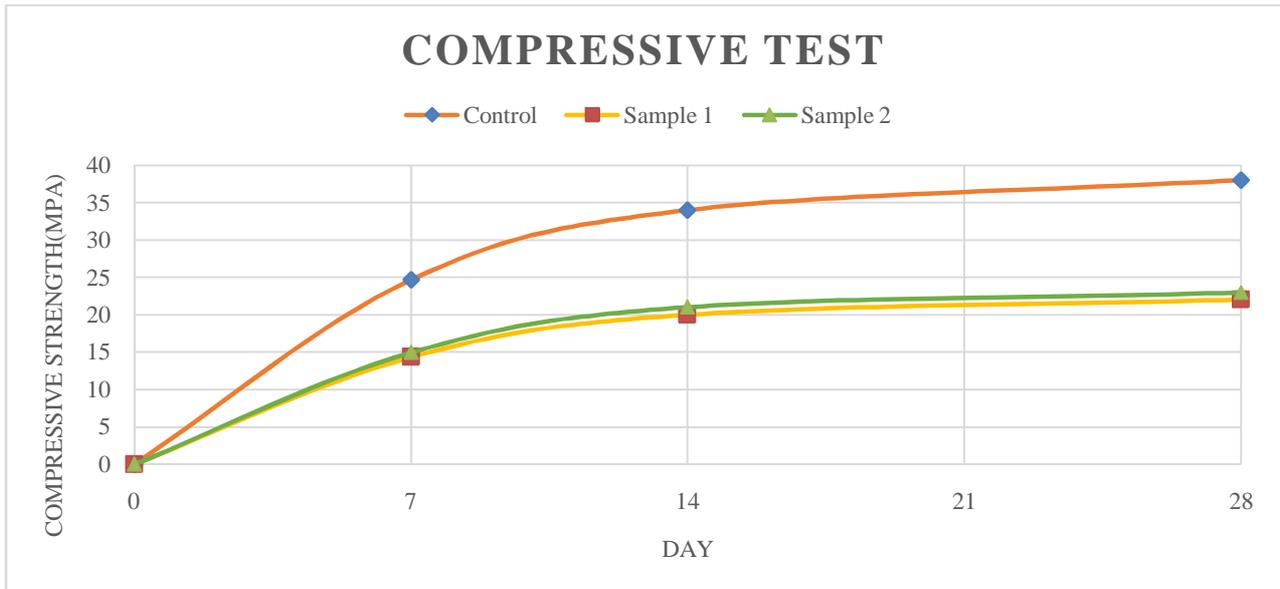
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Figure 10: Variation of compressive strength in function of various samples(Chad)



The results above obtained from various samples collected from Chad showed the average compressive strength obtained after 7, 14 and 28 days. The control mix gave the compressive strength of 25, 34 and 38 MPa after 7, 14 and 28 days respectively. The ordinary sand was then replaced fully by the two (2) samples of dune sand for the two batches. All the factors remained the same except the dune sand fully replaced by the ordinary sand. The dune sand mixes gave compressive strength which were much smaller as compared to the control mix. The Sample 2 mix gave results which were better than the one of Sample 1. The high compressive strength of Sample 2 might be due to its less proportion in silt and clay as compared to that of Sample 1 as showed on Table 12.

3.4 Advantages of using dune sand concrete as alternative to ordinary concrete in desert area

The construction project can vary from tremendously profitable or to loss depending on the management. The focus of a project contractor is to make profit by executing constructions according standards and within time while remaining in the budget. Time and cost management are of main concern of any contractor.

Constructing in desert areas is challenged by the availability of materials such as fine aggregates meanwhile, dune sands are very available in those zones. Purchasing normal fine aggregates which might be distant from the construction site demands more time and resources.

The estimation of this study was done on the average transport distance of ordinary fine aggregates of about 300km and 800 km from Kenya and Chad respectively. The choice was made based on the nearest place where ordinary fine aggregates can be found and transported to desert areas. The places where ordinary fine aggregates can be found are Meru (Kenya) and Ndjamaena (Chad).

The Table 16 and 17 below give an estimation in cost reduction when dune sand concrete is used for construction in desert environment.

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Table 16: Cost estimate, first case study (Nyiri Desert, Kenya)

S/No.	Items	Unit	Price per Unit(Ksh)	Price per Unit(USD)
1	Concrete of class 25/30	m ³	21,500	215
2	Dune sand concrete 25/30	m ³	14,500	145
3	Average Cost benefit of using dune sand concrete in desert area	m ³	7,000	70

Table 17: Cost estimate, second case study (Sahara Desert, Chad)

S/No.	Items	Unit	Price per Unit(XOF)	Price per Unit(USD)
1	Concrete of class 25/30	m ³	262,500	471
2	Dune sand concrete 25/30	m ³	197,500	355
3	Average Cost benefit of using dune sand concrete in desert area	m ³	65,000	117

After the investigation of the few dune sand samples randomly collected from Nyiri and Sahara Deserts, results showed that when the choice of dune sand samples is fairly made, they can be used for an ordinary concrete without any treatment resulting then in time and cost reduction of projects in desert environment. The use of these materials can be extended to non-arid zones due to the unavailability of aggregates also, the over exploitation of ordinary fine aggregates which threaten the environment.

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. Dune sands contained noxious heavy metal but remains within the permissible proportions;
2. Dune sands had pH value slightly basic non-affecting the compressive strength of the hardened concrete;
3. Dune sands from Sahara Desert had more impurities than those of Nyiri Desert but remained the allowable limit;
4. Dune sands from Nyiri Desert contained 77.75% average particle size of less than 0.600mm while those of Sahara Desert had 97%;
5. Ordinary sands from Chad and Kenya contained 33.7% average particle size of less than 0.600mm;
6. Dune sands from Nyiri Desert contained 5.07% average silt and clay content while those of Sahara Desert had 20.06%;

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7. Dune sands from Nyiri Desert had an average Fineness Modulus of 1.67 while the ones from Sahara had an average of 1.15;
8. When the ordinary sands were fully replaced by dune sand samples, the slump reduced of an average of 53.06%;
9. The compressive strength of all the concrete samples increase with increasing curing days;
10. The compressive strength of normal concretes is greater than the one of dune sand concretes;
11. The finer the aggregates, the smaller the slump and inversely;
12. 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;
13. 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;
14. When dune sand concrete is used for construction industry in desert environment from Kenya, that would result in cost and time reduction estimated at USD 70 per cubic meter;
15. When dune sand concrete is used for construction industry in desert environment from Chad, that would result in cost and time reduction estimated at USD 117 per cubic meter.

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:

1. To extend compressive strength test after 90 days and 1 year to follow the strength development with time;
2. To carry out compressive strength test on dune sands from Nyiri Desert and Sahara Desert with the same grading;
3. To carry out splitting tensile strength and flexural strength tests on dune sand concrete as compared to ordinary concrete;
4. To execute durability tests such as chemical resistance, freeze/thaw resistance, stain resistance, deep abrasion resistance, crazing resistance, thermal shock resistance, Warpage, wedging, bond strength, breaking strength, thermal expansion, and moisture expansion;
5. To assess the influence of dune sand concrete density on the compressive strength and durability;
6. To study the influence of pH of dune sands on the pH of dune sand concrete;
7. To evaluate the effect of superplasticizer on the compressive strength and durability of dune sand concrete;
8. To estimate the cost reduction of using dune sand concrete as compared to ordinary concrete at wide scale;
9. To assess the environmental benefit of using dune sand concrete compared with ordinary concrete;
10. To estimate the cost reduction of using dune sand concrete treated with silica fume compared with ordinary concrete at wide scale;

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11. To evaluate the reduction of desertification resulting from the use of a certain quantity of dune sand in concrete over a defined period.

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