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Stabilisation of Western Province Sands

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Abstract—Western Province of Zambia is situated in the western parts of the country, neighbouring Namibia, Angola and Botswana. The geology of the area is predominated by sands. Because of this, there is scarcity of good road building materials. Good quality materials have to be hauled over distances in excess of a 100 km. These long haul distances make road construction more expensive in this region compared to other regions in Zambia. It is against this background that a study was conducted to determine whether the abundant sand in the region could be modified/improved such that it can be used for road base and subbase construction particularly for low volume roads. Sands were sampled from three districts in the province namely; Mongu, Senanga and Sesheke. Classification and strength tests were conducted on the sands. The sands were stabilised with varying percentages of Cement and Bitumen. The results of California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS),Indirect Tensile Strength (ITS)and Marshall stability tests showed marked improvements in the properties of the sands after stabilisation.

Index Terms: California Bearing Ratio (CBR), Indirect Tensile Strength (ITS),Marshall stability, Sand, Stabilization,Unconfined Compressive Strength (UCS),

1 INTRODUCTION

Most of Western Province of Zambia is part of the North-South Kalahari Transect which is essentially a plateau area uplifted following the breakup of Gondwanaland some 65 years ago [1]. The plateau edges were uplifted as the continent moved northwards. Both fluvial and dune sediments are believed to have infilled the uplifted basin with mainly sands interbedded with calcrete and silcrete. Apart from the Barotse Plains with alluvial soils, most of the region is covered with the Kalahari sand with small deposits of calcrete and silcrete. This presents a challenge for road construction as good quality road building materials are scarce in the province. It is against this background that a study was undertaken to establish whether the abundant sand in the region could be modified/improved such that it can be used for road base and subbase construction, particularly for low volume roads. The objectives of the study were;

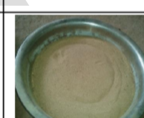
i To determine the engineering properties of Western Province sand through classification and strength tests

ii To determine the characteristic of the sand after stabilisation with cement and bitumen.

2 MATERIALS

Sands were sampled from three districts in the province namely; Mongu, Senanga and Sesheke (Table 1).

TABLE 1
SAND SAMPLES

	Details		
Sand	Mongu	Senanga	Sesheke
Visual Description	Fine whitish sand	Fine brownish white sand	Fine light yellow sand
Pictorial			
Source (Road)	Namushakendi-Nalikwanda	Lui-Simutala	Simungoma-Mulobezi

Classification tests done on the sands included Atterberg Limits, Silt content and grading. The tests were done according to BS 1377: Part 2: 1990. Results of the test are given in Table 2 and shown in Figure 1.

TABLE 2
CLASSIFICATION TEST

Source of Sand	Mongu	Senanga	Sesheke
Plasticity Index	NP	NP	NP
% Passing 2mm Sieve	100	100	100
% Passing 0.425mm Sieve	56	75	77
% Passing 0.075 mm Sieve	2	4	4
Grading modulus	0.5	0.2	0.2
Uniformity coefficient	5	3.4	3.3
Coefficient of gradation	0.7	0.8	0.7
Silt Content	9.7	3	9

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The results of the tests show that 100% of the sands passed through the 2mm sieve. The results also showed that the sands are non-plastic. Therefore, the sands would be broadly classified as poorly graded non-plastic sands.

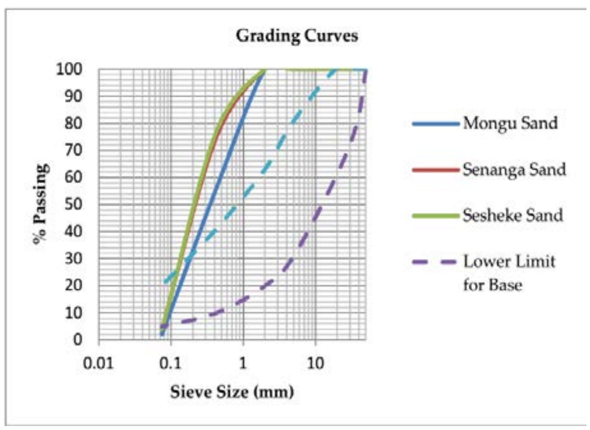

Fig. 1. Grading

3 Experimental Work

Laboratory testing of the experimental work of the study was done at the Road Development Agency Materials Testing Laboratory in Lusaka (Zambia). The sand was initially tested in its neat form to determine grading and strength. The sand was later tested for strength after stabilization. Strength tests conducted are;

- Compaction Tests; Test conducted according to Method A7 of Technical Methods for Highways TMH1:1979. Compaction tests were done to determine the maximum dry density and optimum moisture content of the material.

- CaliforniaBearing Ratio: This test is an indicator of the bearing capacity of a soil and is also used for making comparisons between neat and stabilized materials to show improvements in strength afterstabilisation.Method A8 of TMH 1:1979 was used in carrying out this test.

- Unconfined Compressive Strength: This test is used for design of cement stabilized materials for the selection of the optimum cement content. It is a strength test and will also give an indication of the improvement in strength after cement stabilization. This test was conducted in accordance with Method A14 of TMH 1:1979. The MDD/OMC test was conducted at 6, 8, and 10 % cement contents. Then the UCS specimens were moulded using the OMCs obtained. The specimens were then cured for 7days in plasticbags at room temperature. Before testing, the specimens were submerged in water for 4hrs.

- Indirect Tensile Strength: This test measures the strength of the stabilized material in flexure. The ITS provides an indication of the cracking behaviour of the stabilised material. The test was conducted as per Method A14 of TMH 1:1979.

- Marshal Stability: The Marshal test helps in determining the percentage of the optimum bituminous binder to be used for a particular material. It also provides values for engineering properties of the bituminous material which affect its performance in service. The major parameters measured include stability, flow, air voids and voids in mineral aggregate.The test was conducted in accordance with Method C1 of TMH 1:1979 and Zambia Standard Specifications for Pavement Repairs and Resealing (ZSSPRR). Specimens were prepared at 3, 4, 5, 6, 7% bitumen contents after which the optimum binder content was determined. Samples were then prepared at the obtained optimum binder content and tested for stability and flow. Another set of tests were conducted after addition of 2 and 4% cement to the bitumen stabilised sample.

Figure 2 shows the flow chart used in conducting the tests.

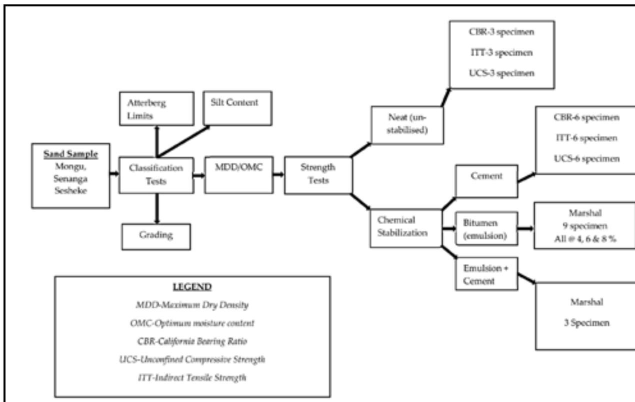

Fig. 2. Experimental Flow Chart

4 Results and Discussion

4.1 Compaction Test Results

Results of density tests are shown in Figure 3. The results show the maximum densities ranged from 1750 kg/m^3 to 1818kg/m^3 with the Mongu sand recording the highest figure. Optimum moisture contents ranged from 8% (Sesheke Sand) to about 13% (Senanga Sand).

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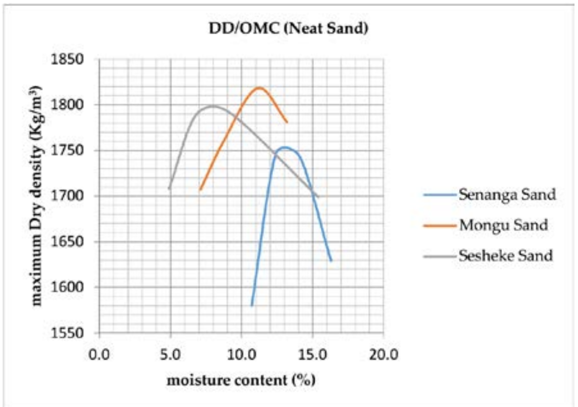

Fig. 3. Relation between Dry Density and Water Content

Cement was added to the samples at dosages of 6, 8 and 10%. The dry densities of all the three sands increased with increasing cement contents to a maximum and then with further increase in cement contents, the densities decreased (Figure 4).

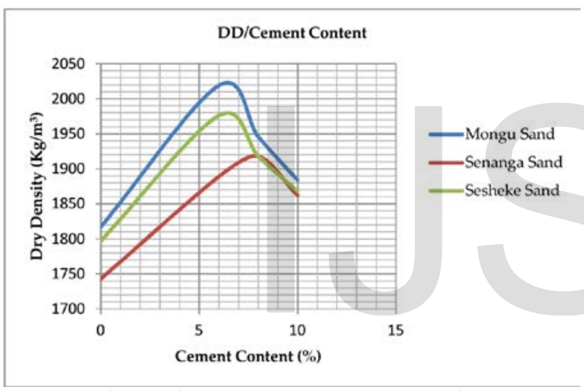

Fig. 4. Relation between Dry Density and Cement Content

The maximum densities were recorded at 6.4%, 6.4% and 8% cement content for Mongu, Sesheke and Senanga sands respectively with the Mongu Sand recording highest. There was no discernible trend in the OMC results as can be seen in Table 3.

TABLE 3
COMPACTION TEST RESULTS

Source of Sand	Mongu		Senanga		Sesheke	
Cement content (%)	MDD (kg/m³)	OMC (%)	MDD (kg/m³)	OMC (%)	MDD (kg/m³)	OMC (%)
0	1817	11.1	1743	14.1	1797	9.1
6	2019	7.9	1889	6.4	1976	11.1
8	1946	11.8	1918	10.3	1918	8.7
10	1884	17.1	1862	10.3	1868	10.7

4.2 UCS Test Results

Figure 5 and Table 4 show the results of UCS testsconducted. There was an increase in strength as the cement content increased to 10%.

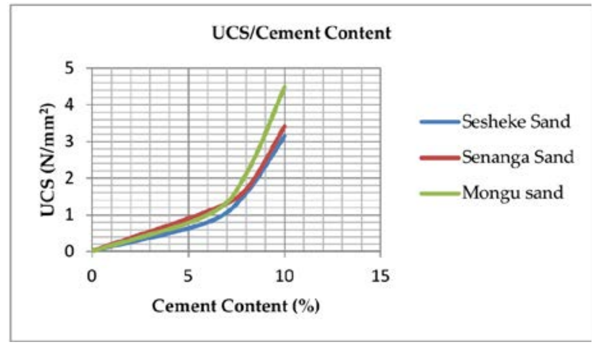

Fig. 5. Relation between Cement Content and UCS

By comparing the UCS results for 0% and 6% cement contents, the results show that for every 1% increase in cement content, the UCS increased by over 15%. The increase in UCS was even much more between 7 and 10% cement content.

TABLE 4
UNCONFINED COMPRESSIVE STRENGTH TEST RESULTS

Source of Sand	Mongu	Senanga	Sesheke
Cement Content (%)	UCS (N/mm²)		
0	0.01	0.02	0.02
6	1	1.1	0.8
8	2.12	1.7	1.6
10	4.49	3.42	3.15
Acceptable UCS value for C4*	0.75-1.5		
Cement Content @ 1.1 N/mm² (Fig 5)	6.5	6	7

C4 materials are cemented natural gravels normally used as subbase material as described in TRH 14: 1985.

4.3 ITS Test Results

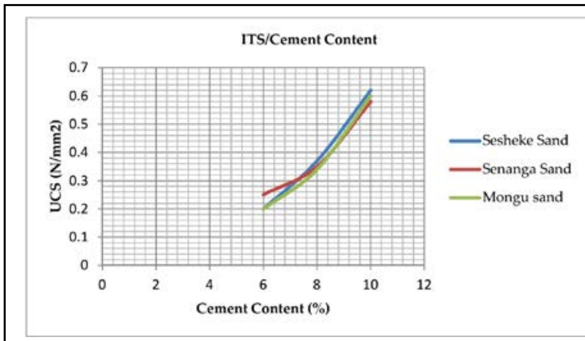

Fig. 6. Relation between Cement Content and ITS

ITS test results are given in Figure 6 and Table 5.

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The ITS values increased with increasing cement content from 6-10%. The average ITS result for all the three sands is 0.22 N/mm². This result is within the recommended values of between 0.20 – 0.25 N/mm²[2].This average is at 6 % cement content. At 8 – 10 % cement contents the ITS values are higher than the specified values.

TABLE 5
INDIRECT TENSILE STRENGTH TEST RESULTS

Source of Sand	Mongu	Senanga	Sesheke
Cement Content (%)	ITS (N/mm²)		
6	0.2	0.25	0.2
8	0.37	0.35	0.34
10	0.62	0.58	0.6
Specification for cement stabilised materials	0.20 – 0.25		

4.4 CBR Test Results

CBR results showed a significant gain in strength for the cement stabilised sand samples as shown in Figure 7 and Table 6. By using the 0% and 8% cement contents, disregarding outliers and using iteration methods, the gain in strength is approximately 5% for every 1% increase in cement content.

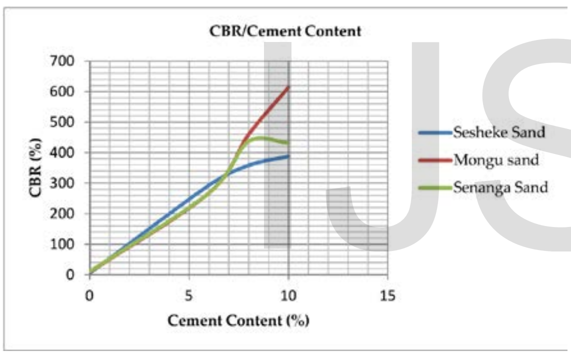

Fig. 7. Relation between Cement Content and CBR

TABLE 6
CARLIFORNIA BEARING RATIO TEST RESULTS

Source of Sand	Mongu	Senanga	Sesheke
Cement content (%)	CBR (%) @ 98% Mod		
0	5	9	10
6	293	268	268
8	388	460	437
10	683	614	432

4.5 Marshal Stability Test Results for Bitumen Stabilised sand

Marshal Stability test results are given in Table 7. There was reasonable gain in strength after bitumen stabilisation for all the three sands. The neat sand had zero stability as it were not possible to do the Marshal test since the briquettes would not be able to withstand soaking. At an average optimum binder content of 6.3% the average increase in strength was 300%. However, the 3.0 kN average stability obtained, was far below the specification for base Asphalt which is between 6-12 kN[3].

TABLE 7
BITUMEN STABILISED SAND TEST RESULT

Sand Origin	Mongu	Senanga	Sesheke	SATCC Spec
Parameter	Average Result			
Binder Content (%)	6.5	6.5	6	5.5-6.0
Stability (kN)	3	2.4	2.8	6.0-12.0
Flow (mm)	4	2.4	2.8	02-4
Air Voids (%)	12	12.2	11.2	3.0-6.0
Density (Kg/m³)	1870	1990	1880	-

The average air voids result of 12% was above the 3.0-6.0 specification while the average flow of 3.1mm is within the specified range of 2-4mm.

Compared to the unstabilised sand compaction test results (Figure 3), the 2% bitumen stabilised sand showed an almost 7% increase in density.

4.6 Marshal Stability Test Results for Bitumen-CementStabilised sand

Marshal Stability test were also conducted for a combination of the two stabilisers with cement content at 2 and 4%. Results of the tests are shown in Table 8.

TABLE 8
BITUMEN-CEMENT STABILISED SAND TEST RESULT

Sand Origin	Mongu	Senanga	Sesheke
Parameter	Average Result @ 2% Cement Content		
Binder Content (%)	6.5	6.5	6
Stability (kN)	4.1	4.2	3.8
Flow (mm)	2.3	2.7	2.9
Air Voids (%)	13.2	12.6	13.1
Density (Kg/m³)	2050	2110	2030
Parameter	Average Result @ 4% Cement Content		
Binder Content (%)	6.5	6.5	6
Stability (kN)	5.1	4.3	5.7
Flow (mm)	3.3	3.5	4.3
Air Voids (%)	12.9	13.2	12.6
Density (Kg/m³)	2010	2230	2000

There was an average 0.5 kN gain in strength for every 1% cement added to the bitumen stabilised sand. However, the 5.0 kN average stability obtained with the addition of 4% cement was still below thespecification for base Asphalt which is between 6-12 kN. Equally there was a 1% increase in the air voids when cement was added to the bitumen stabilised sand. However, there was no significant change in the average air voids between the 2% and 4% cement bitumen stabilised sand. The air voids content still remained higher than the specification of 3-6%.

There was a 0.5mm decrease in the flow when 2% cement was added. With the addition of a further 2% cement content the flow increased by 0.7mm. The flow values were still within the specified range of 2-4mm.

Compared to the un-stabilized sand compaction test results, the 2% bitumen stabilised sand showed an increase in density of about 7%. The average density continued increasing with cement content increase.

5 Conclusions

This study was limited to three sand sources in the region and stabilisation only by bitumen and cement. However, the results of the study show that there is potential of improving the sand in the region for use in road construction. Results of particularly cement stabilisation showed marked improvement in strength properties (UCS and ITS) while marginal improvements were noted with bitumen stabilisation. The study also showed that stability results of bitumen stabilised sands could be improved with the addition of cement.

Bitumen stabilised specimens had significantly higher air voids content (average 12%) against the specified 3 - 6% range. The higher air voids content has the effect of reducing the durability and strength of the bitumen stabilised layers by interconnecting and allowing the ingress of air and moisture. Therefore, this (air voids content) needs further investigation to establish whether it's a result of experimental error or otherwise. Further investigations are also required to determine the optimal content of stabiliser to use for this sand and the economic comparison of hauling material against stabilisation.

Acknowledgment

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References

[1] L., Wang, P.D. Odorico, S. Ringrose, S. Coetzee, S.A. Macko, Biochemistry of Kalahari Sands. Available at: http://www.sciencedirect.com/science/article/pii/S0140196307000997, 2007 (Accessed: 13th Oct. 2015)

[2] COLTO, Standard Specifications for Road and Bridge Works for State Authorities.1998. South African Institution of Civil Engineering.

[3] SATCC, Standard Specifications for Road and Bridge works. 1998.Division of Roads and Transport Technology, Council for Scientific and Industrial Research.