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Shear Strength Parameters as a Measure of Slope Stability of an Earthfill Dam: A Case Study of Awba Dam University of Ibadan, Nigeria.

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Abstract:- *Failure of earthfill dams can occur as a result of structural instability conditions, seepage conditions and hydraulic conditions. Earlier studies have proved that Awbaearthfill dam located in University of Ibadan, Nigeria is suffering from seepage problem and this prompt to focus on itsslope stability. Soil samples taken were from upstream side as this dictate what would be happening at the downstream side. Nine samples were collected altogether with three samples each at upstream left side, upstream middle and upstream right side and subjected to consolidated undrainedtriaxial test. The test gives the shear strength parameters values viz: cohesion, which ranges betweenbetween 3.3 to 3.8Kpa with an average of 3.4Kpa at the upstream left side, 4.1 to 5.0 Kpa averaging 4.4Kpa at upstream middle and 2.2 to 4.3Kpa with average of 3.5Kpa at the upstream right side. Also, angle of internal friction which varied between 20^0 to 27^0 with average of 22.70^0 for sample upstream left side, 20^0 and 26^0 with average of 23^0 for sample upstream middle and 24^0 to 26^0 with average of 24.70^0 for sample upstream right side. These were used to measure the level of Awbaearthfill dam slope stability. From the results, it was found that the cohesion values were not adequate whereas angle of internal friction was within the acceptable limit for both samples collected.This necessitates prompt attention in order to guide against sudden failure of the dam as result instability of its slope.*

Keywords*: Awbaearthfill dam, Slope stability, Upstream, Consolidated UndrainedTriaxial, Cohesion, Angle of nternal friction*

1. Introduction

Strength of construction materials has great effect on the structure to be constructed, so also the shear strength of soil when dealing with numerous geotechnical problems especially an embankment earthfill dam. For this reason, accurate assessment of shear strength parameters of soil is required for the analysis and design of soil structures involving cohesionless soil types because they are predominantly used for earth embankment dams, highway embankments, earth-retaining structures, foundations, slopes to mention fewOmar and Sadrekarimi (2015).Slope stability problem can be solved by determining the shear strength parameters (cohesion and phi) and stiffness of soil when retaining reservoirs of water. The stability of a slope depends on its ability to sustain the effects of load increases or environmental changes.

Shear strength of unsaturated soil is required in an earthfill dam in order to mitigate one of such challenges encounter like slope stability. A number of shear strength criteria for unsaturated soils have been proposed in the literature during the past three decades or so. Some of them were based on regression analyses of experimental data from either direct shear or triaxial tests, such as Fredlund et al. (1978); Gan et al. (1988); Fredlund et al. (1996); Oberg and Sallfors (1997); Khalili and Khabbaz (1998); Rassam and Williams (1999); Rassam and Cook (2002); Toll and Ong (2003); Tekinsoy et al. (2004); Xu (2004).Advantages over simpler procedures, such as the direct shear test, include the ability to control specimen drainage and take measurements of pore water presures. Primary parameters obtained from the test may include the angle of shearing resistance ϕ, cohesion c, and undrained shear strength*cu*

Triaxial shear test is one of the most reliable methods available for determining shear strength parameters. Three standard types of triaxial tests generally conducted are; unconsolidated-undrained test (UU test), consolidated-drained test (CD test) and consolidated-undrained test (CU test) Braja (2010), which are used to check stability 'at the end of construction', of the 'downstream' and 'upstream slopes' respectively.

However, stability of dams depends on the seepage as it form the basis of earthfill dams structure weakening and is one of the major factors of dams failure. Meanwhile, one of the major problemsassociated with Awbaearthfill dam was seepage as reported by Agbede and Oladejo (2009). An accurate model for evaluating slope stability can provide considerable help for mitigating slope geological hazards (Ducan and Wright, 2005).

2. Dam Location and Geometry

This study was carried out on Awbaearthfill dam located in University of Ibadan, Nigeria (Oladejo, 2011).Figure 1 displays the Conceptual model of AwbaEarthfill Dam.

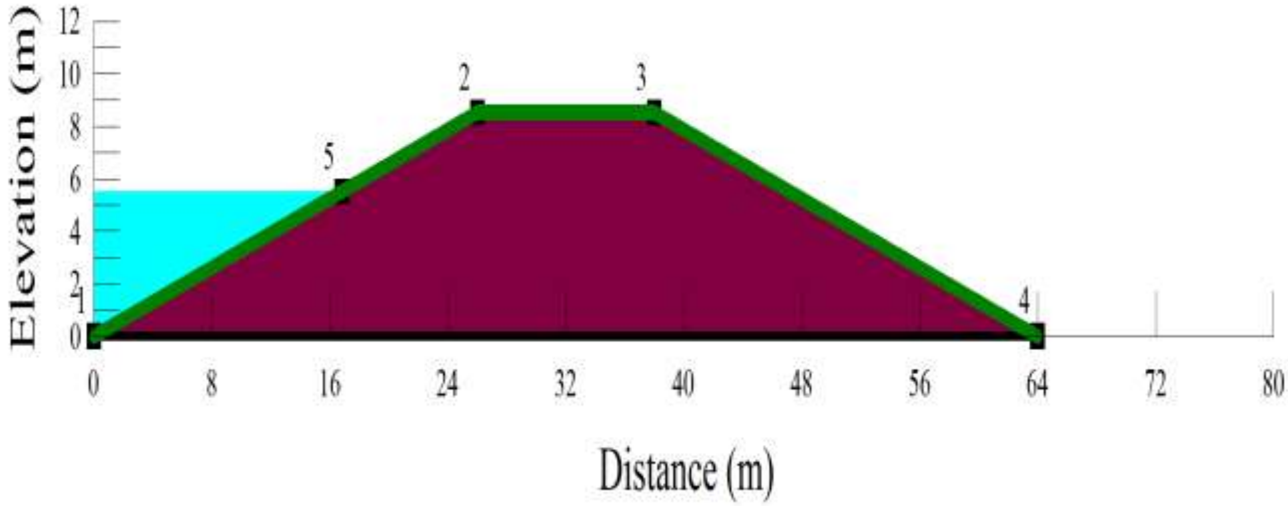


Figure 1: Conceptual model of AwbaEarthfill Dam Embankment, University of Ibadan, Nigeria

3. Materials and Methods

Soil samples were taken from Awba dam at upstream side of the dam which comprises of three samples each from each location: upstream left side (ULS), upstream middle (UM) and upstream right side (URS) giving a total number of nine samples. Thedisturbed soil samples were collectedat depth of 1.2 m and 3 m interval at each location. Triaxial test was carried out as described by geotechnical test standards in accordance withASTM: D4767.

4. Results and Discussion

The Laboratory results obtained from triaxial test was presented in Tables1 to 3. Tables 1, 2 and 3 shows the average results of three samples tested for at upstream left side, upstream middle and upstream right side of Awbaearthfill dam respectively. Generally, it was observed that as the pressure increases, there is corresponding increase in resistance of soil to failure. At a point, when the soil strength reaches its limit, failure set in as indicated by the decrease in the stress dial reading to imposed load on the soil sample (Tables 1, 2 and 3).

Table 1: Mean Triaxial Results of Sample Upstream Left Side

S/N	Strain DR	Stress DR/Load P (kg)1Div=1kg			LOS (cm)	OL (cm)	ΔL	Strain Ɛa=ΔL/OL*100	A0 (cm)	CA(cm^2) A_c=A0-(Ɛa/3)	Deviator stress(kg/cm^2) $\Delta\sigma=P/A_c$		
Normal Stress		5	10	15							5	10	15
1	0	0	0	0	8.5	8.5	0.1	1.18	11.64	11.25	0.00	0.00	0.00
2	100	9	13	19	8.4	8.4	0.1	1.19	11.64	11.24	0.77	1.19	1.66
3	200	15	21	26	8.3	8.3	0.1	1.20	11.64	11.24	1.33	1.87	2.34
4	300	22	30	35	8.2	8.2	0.1	1.22	11.64	11.23	1.96	2.67	3.15
5	400	30	42	45	8.1	8.1	0.1	1.23	11.64	11.23	2.64	3.77	4.04
6	500	35	47	53	8	8	0.1	1.25	11.64	11.22	3.09	4.22	4.72
7	600	39	54	62	7.9	7.9	0.1	1.27	11.64	11.22	3.51	4.81	5.56
8	700	43	61	72	7.8	7.8	0.1	1.28	11.64	11.21	3.86	5.44	6.42
9	800	48	70	81	7.7	7.7	0.1	1.30	11.64	11.21	4.25	6.25	7.20
10	900	51	75	89	7.6	7.6	0.1	1.32	11.64	11.20	4.58	6.67	7.98
11	1000	57	81	99	7.5	7.5	0.1	1.33	11.64	11.20	5.06	7.21	8.81
12	1100	61	84	104	7.4	7.4	0.1	1.35	11.64	11.19	5.45	7.51	9.26
13	1200	62	86	102	7.3	7.3	0.1	1.37	11.64	11.18	5.57	7.66	9.15
14	1300	64	88	103	7.2	7.2	0.1	1.39	11.64	11.18	5.70	7.90	9.19

15	1400	65	89	103	7.1	7.1	0.1	1.41	11.64	11.17	5.82	7.97	9.19
16	1500	64	87	102	7	7	0.1	1.43	11.64	11.16	5.70	7.82	9.11

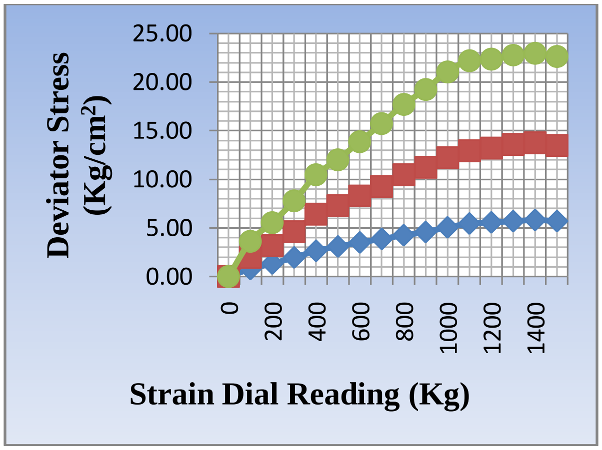
Table 2: Mean Triaxial Results of Sample Upstream Middle

S/N	Strain DR	Stress DR/Load P (kg)1Div=1kg			LOS (cm)	OL (cm)	ΔL	Strain Ɛa=ΔL/OL*100	A0 (cm)	CA(cm^2) A_c=A0-(Ɛa/3)	Deviator stress(kg/cm^2) Δσ=P/A_c		
Normal Stress		5	10	15							5	10	15
1	0	0	0	0	8.5	8.5	0.1	1.18	11.64	11.25	0.00	0.00	0.00
2	100	7	12	18	8.4	8.4	0.1	1.19	11.64	11.24	0.62	1.10	1.60
3	200	14	20	26	8.3	8.3	0.1	1.20	11.64	11.24	1.25	1.78	2.28
4	300	19	25	32	8.2	8.2	0.1	1.22	11.64	11.23	1.66	2.26	2.82
5	400	27	38	42	8.1	8.1	0.1	1.23	11.64	11.23	2.37	3.35	3.74
6	500	31	46	55	8	8	0.1	1.25	11.64	11.22	2.79	4.13	4.90
7	600	37	56	65	7.9	7.9	0.1	1.27	11.64	11.22	3.27	4.96	5.79
8	700	46	63	77	7.8	7.8	0.1	1.28	11.64	11.21	4.10	5.62	6.84
9	800	51	71	85	7.7	7.7	0.1	1.30	11.64	11.21	4.55	6.37	7.61
10	900	55	78	93	7.6	7.6	0.1	1.32	11.64	11.20	4.91	6.93	8.33
11	1000	59	82	99	7.5	7.5	0.1	1.33	11.64	11.20	5.24	7.32	8.87
12	1100	62	85	106	7.4	7.4	0.1	1.35	11.64	11.19	5.57	7.57	9.44
13	1200	64	85	102	7.3	7.3	0.1	1.37	11.64	11.18	5.69	7.57	9.12
14	1300	60	84	101	7.2	7.2	0.1	1.39	11.64	11.18	5.40	7.49	9.07
15	1400	60	83	101	7.1	7.1	0.1	1.41	11.64	11.17	5.34	7.43	9.01
16	1500	59	81	101	7	7	0.1	1.43	11.64	11.16	5.26	7.29	9.08

Table 3: Mean Triaxial Results of Sample Upstream Right Side

S/N	Strain DR.	Stress DR/Load P (kg)1Div=1kg			LOS (cm)	OL (cm)	ΔL	Strain Ɛa=ΔL/OL*100	AO (cm)	CA(cm^2) A_c=AO-(Ɛa/3)	Deviator stress(kg/cm^2) Δσ=P/A_c		
Normal Stress		5	10	15							5	10	15
1	0	0	0	0	8.5	8.5	0.1	1.18	11.64	11.25	0.00	0.00	0.00
2	100	5	9	11	8.4	8.4	0.1	1.19	11.64	11.24	0.47	0.80	0.95
3	200	10	14	18	8.3	8.3	0.1	1.20	11.64	11.24	0.89	1.22	1.60
4	300	14	24	25	8.2	8.2	0.1	1.22	11.64	11.23	1.25	2.17	2.23
5	400	20	32	33	8.1	8.1	0.1	1.23	11.64	11.23	1.81	2.82	2.97
6	500	27	40	45	8	8	0.1	1.25	11.64	11.22	2.38	3.53	4.01
7	600	34	50	58	7.9	7.9	0.1	1.27	11.64	11.22	3.00	4.46	5.14
8	700	40	58	67	7.8	7.8	0.1	1.28	11.64	11.21	3.54	5.14	5.95
9	800	43	65	77	7.7	7.7	0.1	1.30	11.64	11.21	3.84	5.77	6.90
10	900	46	70	84	7.6	7.6	0.1	1.32	11.64	11.20	4.14	6.22	7.47
11	1000	51	77	90	7.5	7.5	0.1	1.33	11.64	11.20	4.53	6.85	8.01
12	1100	54	80	91	7.4	7.4	0.1	1.35	11.64	11.19	4.80	7.12	8.13
13	1200	55	82	92	7.3	7.3	0.1	1.37	11.64	11.18	4.95	7.30	8.20
14	1300	56	83	95	7.2	7.2	0.1	1.39	11.64	11.18	5.01	7.43	8.47
15	1400	57	84	100	7.1	7.1	0.1	1.41	11.64	11.17	5.13	7.55	8.95
16	1500	59	86	97	7	7	0.1	1.43	11.64	11.16	5.26	7.67	8.72

Figures 2 to 4 present graphs of strain dial reading against deviator stress. These graphs display respond of soil samples at upstream left side, upstream middle and upstream right side to normal stresses of 5kg, 10kg and 15kg. The point at which the graph begins to decline shows the point of failure. Any additional load beyond is not required as the soil sample as reached its maximum limit.
Furthermore, figures 5 to 13 show the graphs of normal stress (5kg, 10kg and 15kg) against maximum deviator stress. From these graphs, the soil cohesion value and it's correspond angle of internal friction are obtained for the nine samples. Results of the shear strength parameters (cohesion and phi) of the nine samples are given in table 4.



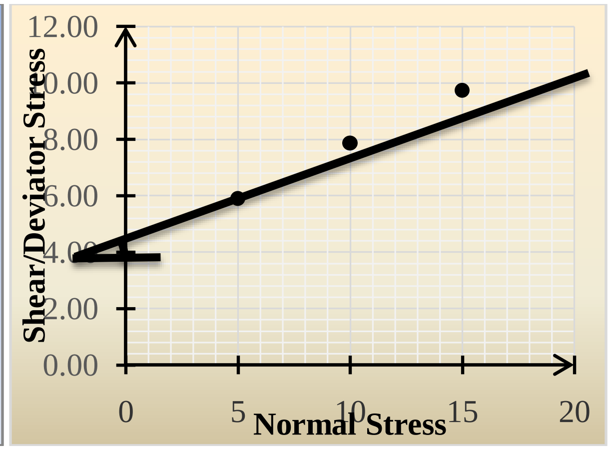
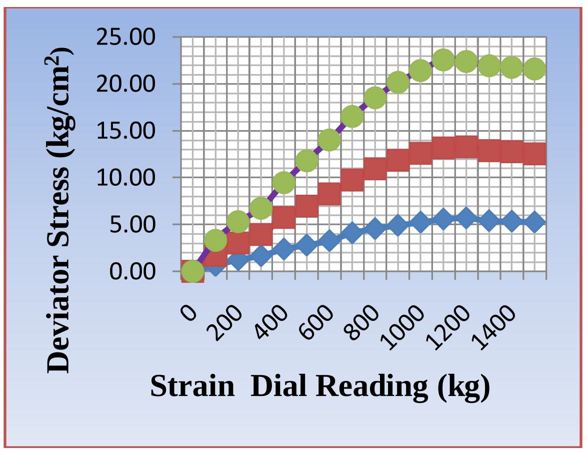


Figure 2: Strain dial Reading againstmeanFigure 5: Failure envelope for sample
Deviator stress on sample ULS upstream left side 1 (ULS 1)



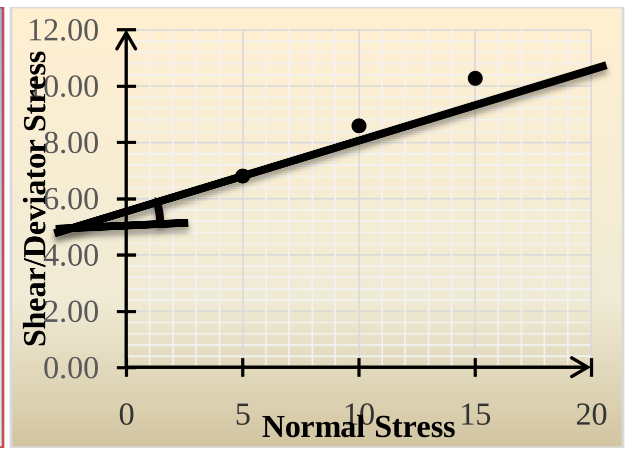
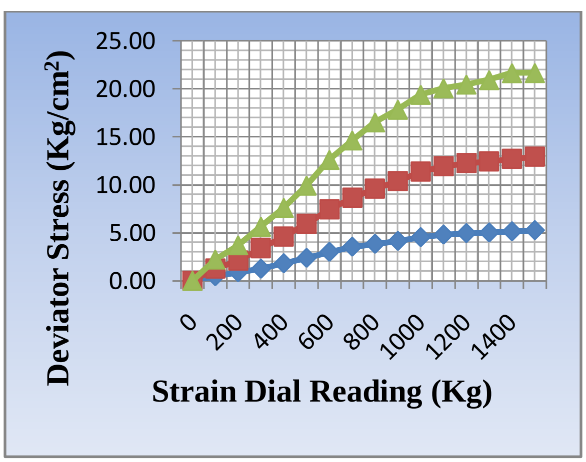


Figure 3: Strain dial Reading against mean Figure 6: Failure envelope for sample
Deviator stress on sample UM upstream left side 2 (ULS 2)



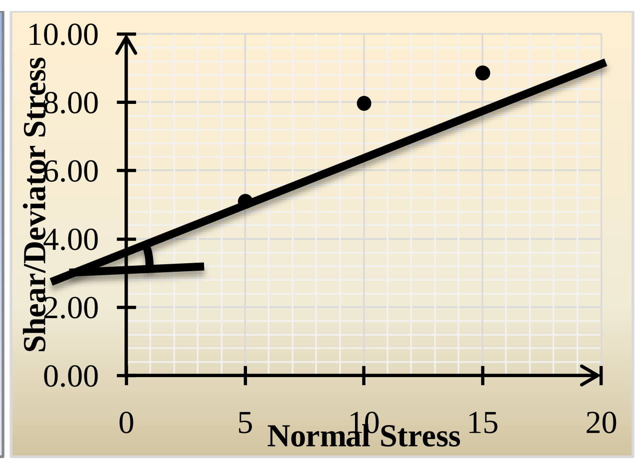


Figure 4: Strain dial Reading againstmeanFigure 7: Failure envelope for sample
Deviator Stress onsample ULS upstream left side 3 (ULS 3)

Legends:5Kg 10Kg 15 Kg

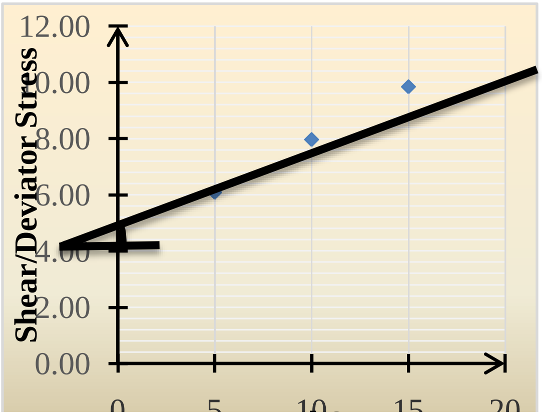


Figure 8: Failure envelope forsample upstreammiddle 1 (UM 1)

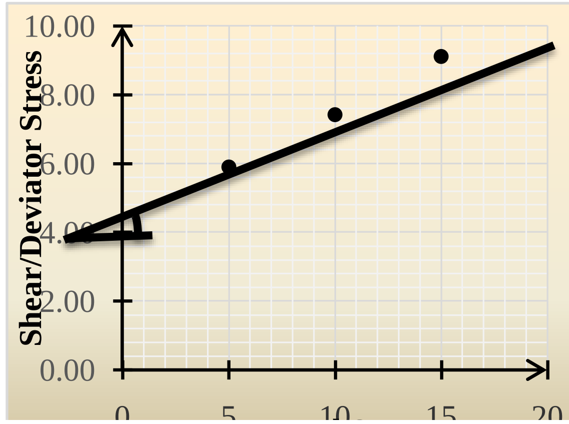


Figure 11: Failure envelope forsample upstream right side 1 (URS 1)

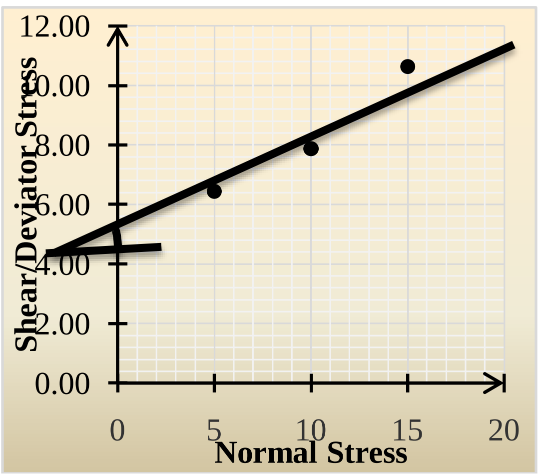


Figure 9: Failure envelope forsample upstream middle 2 (UM 2)

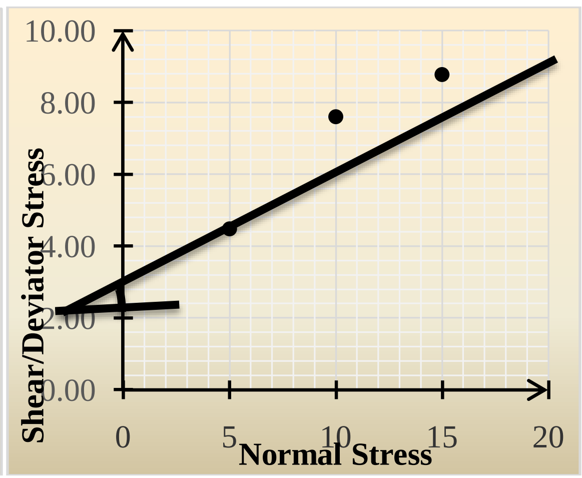


Figure 12: Failure envelope forsample upstream right side 2 (URS 2)

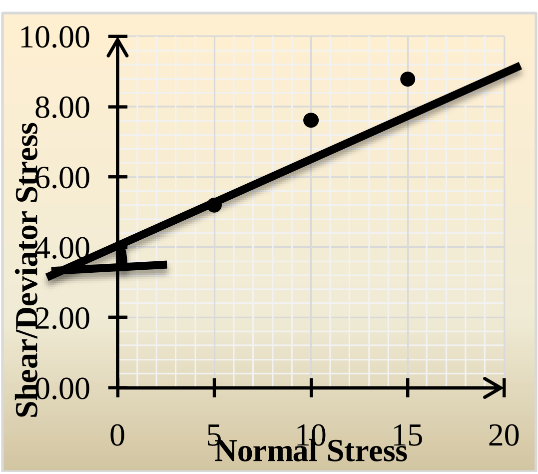


Figure 10: Failure envelope forsample upstream middle 3 (UM 3)

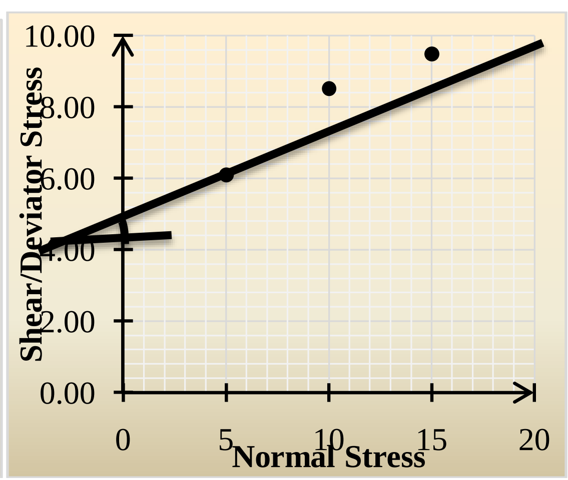


Figure 13: Failure envelope forsample upstream right side 3 (URS 3)

Table 4: Results Summary of Cohesion (C) and Phi (Ø)

S/N	Sample location	Sample numbering	Cohesion C (Kpa)	Average	Phi Ø (^{0})	Average
1	Upstream left side (ULS)	ULS 1	3.8	3.9	20	22
2		ULS 2	5.0		20	
3		ULS 3	3.0		27	
4	Upstream middle (UM)	UM 1	4.1	3.9	23	24
5		UM 2	4.2		26	
6		UM 3	3.3		24	
7	Upstream right side (URS)	URS 1	3.9	3.5	24	25
8		URS 2	2.2		26	
9		URS 3	4.3		24	

Cohesion values of soil samples ranges between 3.3 to 3.8Kpa with an average of 3.4 at the upstream left side, 4.1 to 5.0Kpa averaging 4.4 at upstream middle and 2.2 to 4.3Kpa with average of 3.5Kpa at the upstream right side (Table 4). Also, the correspond angle of internal friction varied between 20 to 27^0 with average of 22.70^0 for sample upstream left side, 20 and 26^0 with average of 23^0 for sample upstream middle and 24 to 26^0 with average of 24.70^0 for sample upstream right side.

The results of cohesion obtained averagely are below the limits for the samples to be used as impermeable core of an earth dam (Table 4 and 5). This indicates high degree of looseness and high content of silty materials and very low bearing capacity of the soil samples. Also, the low value of cohesion may be due to effect of seepage on the dam. However, internal friction angle results averagely show that the soil samples are impermeable core. The range of 19 to 70KN/m^2 and 3 to 21^0 for cohesion and internal friction angle reported by Umoren (2016) as compared to 3.5 to 3.9Kpa and 22 to 25^0 of cohesion and internal friction angle respectively was similar because it shows that as cohesion increaseswhile there is corresponding decreases in the value of internal friction and vice versa (Table 4).

Table 5: Acceptable ranges of properties for materials used in the zones of composite dam
(Brink, Partridge and Williams 1984)

S/N	Solid parameter	Impermeable core	Semi permeable intermediate zone	Permeable shell zone
1	Angle shearing resistance (^{0})	20 - 30	30 - 35	>35
2	Cohesion (Kpa)	25 - 50	25	>25

5. Conclusions and Recommendations

The evaluation of slope stability of Awbaearthfill dam, University of Ibadan, Nigeria has been carried out via consolidated undrainedtriaxial test according to ASTM: D4767. The study investigates shear strength parameters and compared with the acceptable standard. Soil samples at upstream right side, upstream middle and upstream right side behave almost the same way and this could be attributed to homogeneity of the dam. From the results, cohesion values for both samples are below the requirement and this point to higher rate of looseness of soil and high level of instability of Awbaearthfill dam. Meanwhile, angle of internal friction values for both samples fall within the acceptable ranges, this implies that the angle of friction resistance existing between soil particles are adequate for Awbaearthfill dam.However, prompt attention is needed in order to guide against sudden failure of the dam as result of slope instability.

The following recommendations were suggested:

1. increasing shear strength parameters especially the soil cohesion to give a more stable slope
2. Seepage problem within the dam body should be checked and corrected
3. Further study should be embarked upon using finite element software like GeoStudio, Abaqus, Modflow and Plaxis to determine slope stability of Awbaearthfill dam.
4. The clay quantity of Awba dam soil samples should be increased in order to improve its plasticity index thereby enhancing strong bond between soil particles.

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