Using Triaxial Test for Rock Mechanical Properties Determination (Case Study: Greater Ughelli Depobelt and Costal Swamp Depobelt wells)

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Abstract - *Triaxial tests experiment was carried out under different confining pressures on the cores ranging from 14.5 to 43.5 psi with the Cohesion ranging from 1 to 2 KN/m^2 and the Angle of Frictional Resistance from 36 to 46 Degree. The bulk densities of the Sandstones ranges from 22.9 to 24.82KN/m^2. The samples do show a consistent variation between rock units, with Coastal Swamp Depobelt having the highest density value of 24.82KN/m^{2}giving a more complete picture of the rock's failure envelope as a function of confining stress.*

Keywords — *Triaxial test, failure envelope, cohesion, frictional angle, bulk density, Uniaxial Compressive Strength.*

I. INTRODUCTION

Sand production is predominant in the Niger Delta because almost all the oil and gas reserves are located within the tertiary Agbada sandstones and the upper Akata formation (Adeyanju and Oyekunle 2010). When hydrocarbons are produced from a reservoir, solid particles sometimes follow the reservoir fluid into the well. This unintended by-product of the hydrocarbon production is called sand production. Sand production occurs normally as a result of drilling and reservoir management activities. Sand grains are disengaged from the rock matrix structure under physical (earth stress) and chemical action.

II. TRIAXIAL LABORATORY TEST FOR POINT OF ROCK FAILURE

Triaxial test for point of rock failure experimental setup for geomechanical determination of stress properties in the laboratory for practical simulation which is close to real life conditions was carried out, results gotten from the laboratory experiment will be validated using the developed numerical model.

A. Consolidated-Undrained Triaxial Compression Tests with Pore Pressure Measurements

1) The effective and total strength parameters for sandstone core samples were measured by performing consolidated-undrained triaxial compression tests in a modified triaxial cell that allowed pore pressure measurements. The samples were artificially saturated prior to testing. Multi-stage procedures were used to test the strengths of the samples under increasing confining pressures and sufficient time was allowed for samples to consolidate between stages. The tests were performed in general accordance with ASTM Test Method D-4767 and BS 1377 Part 7: 1990, clause 8.

2) The drill cores were marked where the specimens were taken. The specimens were cut to the specified length according to markings and the cutting surfaces were grinded. The tolerances were checked: parallel and perpendicular end surfaces, smooth and straight circumferential surface. The diameter and height were measured three times each. The respectively mean value determines the dimensions that are reported.

3) Multi-stage, undrained triaxial tests with pore pressure measurements were performed on three specimens per sample. Each sample was tested under three different confining pressures, ranging from 14.5, 29.0 and 58.0psi respectively to define the strength envelope.

Fig. 1. Digital photos were taken on each specimen prior to the mechanical testing.

Fig. 2. The specimen diameter, sample weight, height, drainage (top or bottom) and the membrane thickness stress were all Inserted and the set up data was then confirmed.

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Steps on how to navigate the Triaxial Cell

1. Turn on the Software interface and click on NEW TEST
2. Select Test type
3. Enter the Specimen's details
4. The specimen diameter, sample weight, height, drainage (top or bottom) and the membrane thickness stress were all inserted and the set up data was then confirmed.
5. The Pressure Transducers were vented to the atmosphere before mounting the sample, prior to the Triaxial Cell filling.
6. The lower platen was placed on the base. The bearing faces of the upper and lower platens and of the test specimen were wiped clean, and the test specimen was placed on the lower platen. The upper platen was placed on the specimen and were properly aligned. The flexible membrane (rubber membrane) was fitted over the specimen and platen and the rubber or neoprene O-rings was installed to seal the specimen from the confining fluid (water).
7. The cylinder (Triaxial Cell) was placed over the specimen, while ensuring proper seal with the base, and the hydraulic pressure lines connected. The deformation measuring device (transducers) were all well positioned and the chamber filled with hydraulic fluid (Water).
8. The frame piston was brought down into contact with the specimen with a force

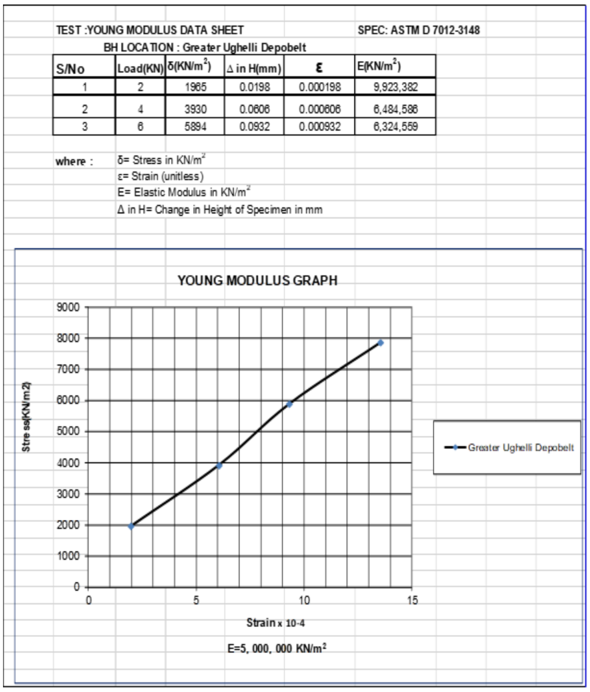
corresponding to a deviator stress of 87.0psi. The cell pressure was then raised to specific level and at the same time keeping the deviator stress constant.
9. The deformation measurement channels were zeroed in the test software.
10. The loading was started and the initial loading rate was set to a radial strain rate of 0.5%/min. The loading rate was increased after reaching the post-failure region. This was done in order to prevent the total time for the test to become too long.
11. Start test countdown button was clicked
12. Saturation stage in progress.
13. Test in progress
14. Selection of Compression/Shearing Stage.
15. The test was stopped automatically after the test had proceeded long enough to reveal the post-failure behaviour/after severe cracking had occurred and it was judged that very little residual axial loading capacity was left in the specimen.
16. The water pressure was brought down to zero and the water was discharged out of the cell. The cell was opened and the specimen removed.
17. Test analysis stage
18. Test analysis completed.
19. Test Report generation stage.

Fig. 4. Sample Preparation Equipment

Fig. 5. The Entire Triaxial Set Up

III. RESULTS / DISCUSSION

Unconfined compression tests were performed on the core samples to help estimate the unconfined compressive strength of the cemented sandstones. The tests were performed in general accordance with ASTM Test Method D-2938.


TEST :YOUNG MODULUS DATA SHEET SPEC: ASTM D 7012-3148

BH LOCATION : Greater Ughelli Depobelt

S/No	Load(KN)	δ(KN/m²)	Δ in H(mm)	ε	E(KN/m²)
1	2	1965	0.0198	0.000198	9,923,382
2	4	3930	0.0606	0.000606	6,484,586
3	6	5894	0.0932	0.000932	6,324,559

where : δ= Stress in KN/m²
ε= Strain (unitless)
E= Elastic Modulus in KN/m²
Δ in H= Change in Height of Specimen in mm

Fig. 6. ***Elastic Modulus plot for Greater Ughelli Depobelt***

Ref: ASTM D-2664

CONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Hauwa's Sand Prediction Experiments

Bore Hole No. 02 Location: Greater Ughelli Depobelt Sample No. 3

Depth of Sample 7444, 7901, 7723 (fts) Description: SANDSTONE Sampling Method: Coring

Test No.	Cell Pressure KN/m²	Deviator Stress KN/m²	Maximum Shear Stress KN/m²
1	100	338.86	438.86
2	200	515.04	715.04
3	300	793.55	1093.55

COHESION C_u = 2 KN/m²	ϕ_u = 36°	BULK DENSITY = 22.66KN/m³

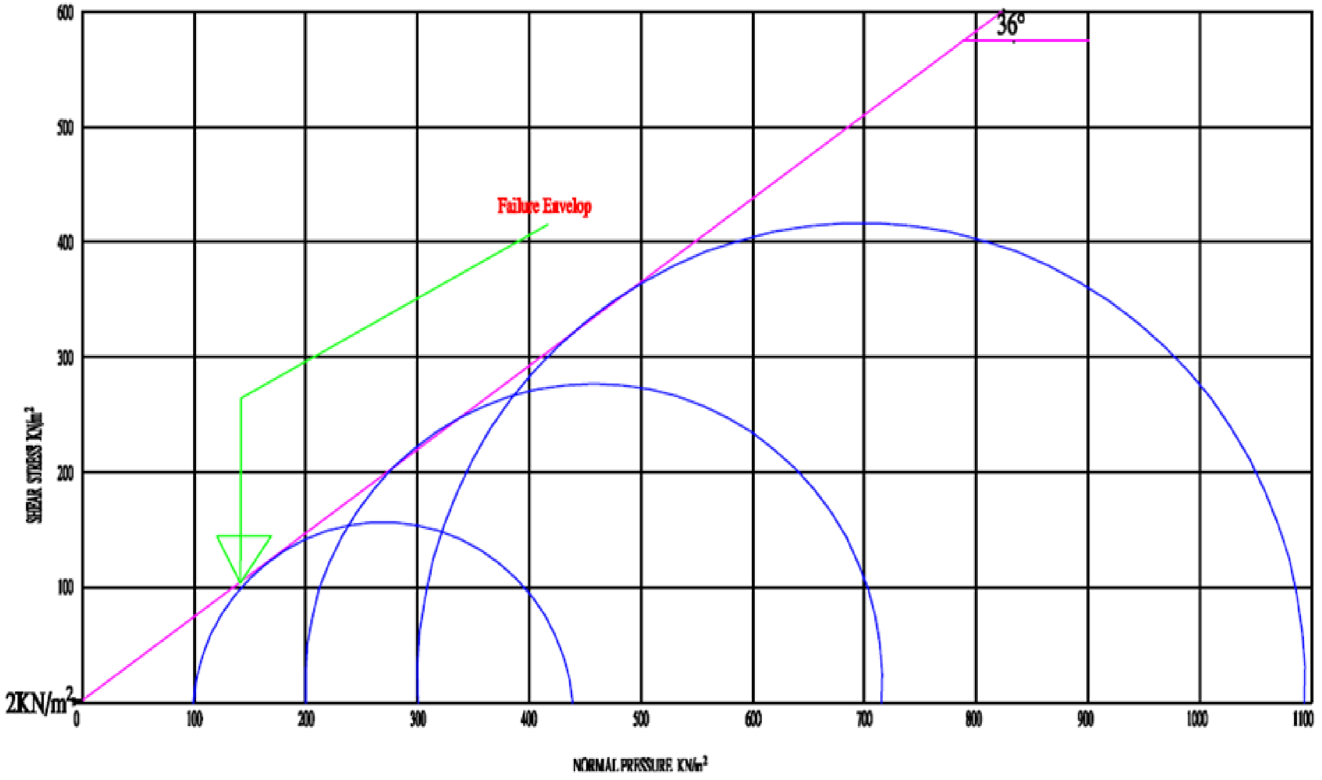


Fig. 7. Failure envelop plot for Greater Ughelli Depobelt

Ref: ASTM D-2664

CONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Hauwa's Sand Prediction Experiments

Bore Hole No. 04 Location: Costal Swamp Depobelt Sample No. 3

Depth of Sample 6910, 6881, 6700(fts) Description: SANDSTONE Sampling Method: Coring

Test No.	Cell Pressure KN/m^2	Deviator Stress KN/m^2	Maximum Shear Stress KN/m^2
1	100	436.90	536.90
2	200	940.25	1140.25
3	300	1291.55	1591.55

COHESION C_u = 1 KN/m ^{2}	ϕ= 46°	BULK DENSITY = 25.43KN/m^3

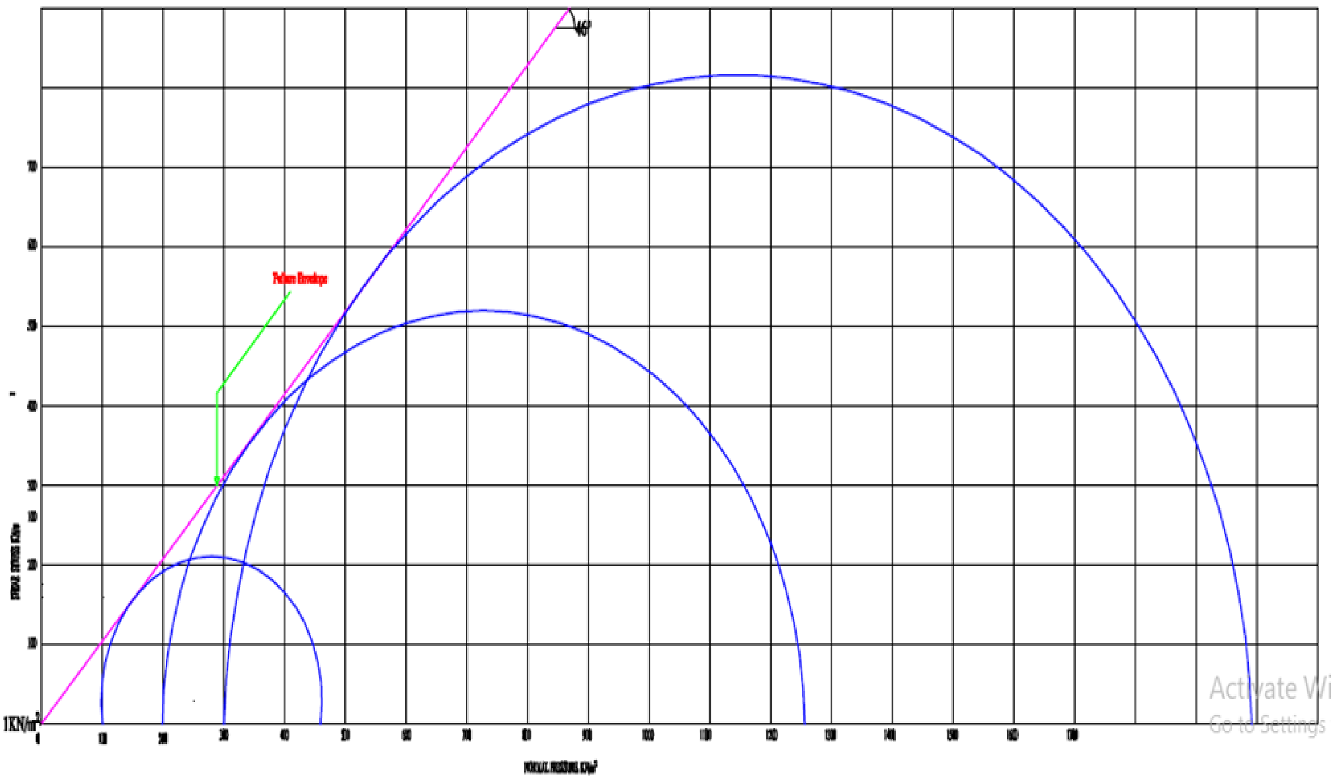


Fig. 8. Failure envelop plot for Central Swamp Depobelt

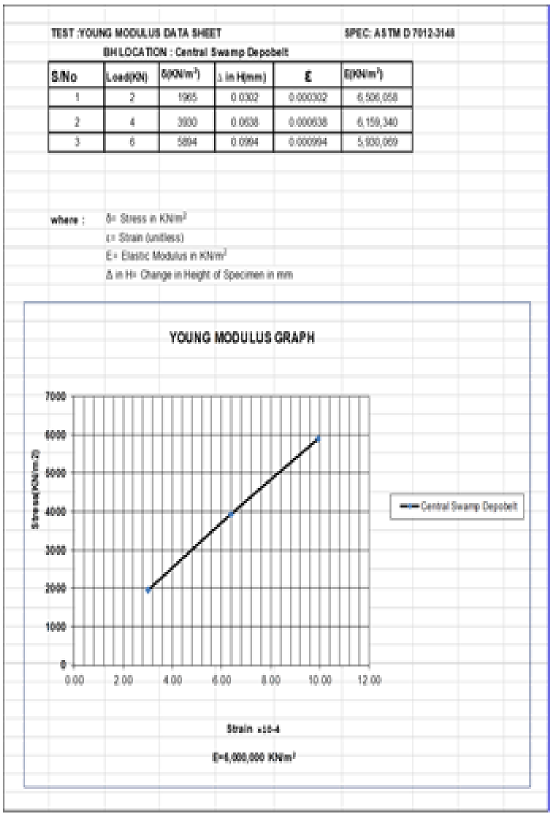


Fig. 9. Elastic Modulus plot for Central Swamp Depobelt

Results are summarized in Table 1 and 2 below shows the tests failure in shear along existing joints or discontinuities as indicated on the laboratory test data sheets, and these results do not represent the strength of intact rock mass. Tests on weakly cemented sandstone indicated that the cementation is so weak that material becomes friable upon test loading. Test results on these samples ranges from 7712.2 to 8000.13 KN/m^2 unconfined compressive strengths. Unconfined compression test results thus measured do not reflect the in-place strength of this type of material whose strength will be dependent on confining pressures. This type of rock was subsequently tested using triaxial test procedures.

The elastic properties were measured without applying the confining stresses on samples. Axial strains were measured with local strain measurement devices clamped to the middle third of the samples. The strains at which these elastic properties were measured are generally between 0.05% to 0.1%. Test results are summarized in Table 1 and 2.

Table 1: Unconfined Compression and Young Modulus Test with Poisson's Ratio.

Core Sample Location	**Ucs test (KN/m2)**	**Young Modulus x 106 (KN/m2)**	**Bulk Density (KN/m3)**	**Poisson's Ratio**	**Mode of Failure**
Greater Ughelli Depobelt	8000.13	5	22.9	0.15	Axial splitting
Costal Swamp Depobelt	7712.2	6.8	24.82	0.11	Axial splitting and bending

Table 2: Consolidated-Undrained Triaxial Compression Tests with Pore Pressure Measurements

Core Sample Location	**Confined Pressure (KN/m2)**	**Cohesion (KN/m2)**	**Angle of Internal Friction (ϕ)**	**Poisson's Ratio**	**Elastic Modeulus (KN/m2)**
Greater Ughelli Depobelt	100, 200, 300	2	36	0.15	6,000,000
Costal Swamp Depobelt	100, 200, 300	1	46	0.11	6,800,000

IV. CONCLUSIONS

The stratigraphy of the Tertiary Niger Delta is complicated by syndepositional collapse of clastic wedges as shales of the underlying Akata Formation are mobilized under loads of the prograding overlying deposits of the deltaic Agbada and fluvial Benin Formations. This situation makes correlation of reservoirs of same genetic units difficult (Samuel Okechukwu Onyekuru et al 2011). Hence, the importance of analyzing the reservoir strength for sand predication considering the various depobelts cannot be over emphasis as analyzing single sample from a particular region will not give the true failure analysis for the entire Niger Delta Basin.

Multi-stage triaxial tests have been successfully performed on drill cores from Greater Ughelli Depobelt and Costal Swamp Depobelt wells. The results have been used to determine the strength and failure properties of different lithofacies observed in the cores.

ACKNOWLEDGMENT

My profound gratitude goes to the Federal Government of Nigeria who, through the Petroleum Technology Development Fund (PTDF) scholarship scheme, offered me the opportunity to realize this dream. I'm very grateful.

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