GEOMECHANICAL CHARACTERISATION OF CLASHACH SANDSTONE.

T. Y. Woma, [1] and S.A. Lawal [2]

.1Pure and Applied Physics Department, Federal University Wukari, P.M.B. 1020 Wukari, Taraba State.

2.Mechanical Engineering Department, Federal University of Technology Minna, Niger State, Nigeria

email: timothy.woma@gmail.com

ABSTRACT

Geomechanical rock testing study the relation of rock mass deformation to in-situ stresses prevalent in the earth crust and is applicable in the oil and gas, mining and civil construction industries. This report is concerned with the laboratory geomechanical testing of Clashach sandstone to determine the uniaxial (unconfined) compressive strength, the tensile strength, the modulus of elasticity, poisons ratio and triaxial compressive strength. After thorough analysis of the data from the laboratory tests carried out, it was found that: the uniaxial compressive strength (UCS) of the sandstone ranged from 60.0MPa to 101.4MPa and the triaxial compressive strength is 152.0MPa; the brazilian tensile strength was between 8.2MPa to 8.8MPa, Modulus of Elasticity 23.7GPa, and the Poissons ratio was 0.19. These results are similar to those published earlier by other researchers and the variation indicates that there are discontinuities in rock mechanical properties as a result of geological discontinuity prevalent in in-situ rock masses.

Keywords: Compressive, Elastic modulus, Geomechanical, Sandstone, Strength, Tensile, Testing,

Introduction

Geomechanics involves the geologic study of the mechanical behaviour of soil and rock, thus the two disciplines of geomechanics are soil mechanics and rock mechanics. Rock mechanics is a discipline that uses the principles of mechanics to describe the behaviour of rock of engineering scale, in other words it is the branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment (Brady and Brown, 1999).

Rock mechanics has wide applications including engineering geology, mining, petroleum and civil engineering practice (Jaeger and Cook, 1969). In petroleum geoscience one of the approaches to subsurface study is the identification of suitable exposed rock masses called outcrop whose properties are taken to be the picture of unseen petroleum reservoirs (Richardson, 2013, Haroon, 2007). According to Corbett et al (2013) and Ojala, Ngwenya, and Main, (2004) the Clashach sandstone is one of the outcrops widely used as out crop of some European reservoirs. Laboratory Mechanical testing of rock samples is an aspect of Rock Mechanics which study the relation of rock-mass deformation to in-situ stresses because it is difficult to sample on the scale of the reservoir and it is often both cost prohibitive and impossible to recover core for the purpose of reservoir characterisation Haroon (2007). This paper is a report of the laboratory geomechanical testing and analysis of the Clashach sandstone to determine its mechanical properties.

General Site Description and History

Clashach sandstone is gotten from the Clashach quarry located on the Moray Firth coast as shown in figure. The stone has been quarried since 1846 ceasing in the 1940s because of the Second World War (Building research establishment, 2000). The site is also of special scientific interest with preserved sections of 270 fossilised Permo-Triassic reptilian trackways. The quarry also has exposed Hopeman sandstone which carries the Lossiemouth fault slip plane trending E/W to WSW/ENE and dips to the south which occurred during the Late Jurassic development of the Inner Moray Firth rift (Al-Hinai et al, 2006).

Clashach sandstone is a pale yellow buff, non calcareous, medium grained from the Permean age. There is a progressive colour change from the buff to yellow pink colour across the quarry. Clashach sandstone appears to be very durable and has good resistance to acid rain or air pollution and salt damage because it is extensively used in many U.K. towns and cities as paving stone. Since sandstone properties vary due to geological variation, this research carried out a laboratory geomechanical characterisation of the Clashach sandstone comparing its result with earlier tests.

Materials and Methods

The method used for characterising the sandstone include procurement of a block of Clashach sandstone, coring of the rock, preparation of the cored samples to standard, oven drying the samples, careful mounting of the samples on the test machine, subjection of the samples to uniaxial (unconfined) compressive strength, tensile strength, triaxial compressive strength, modulus of elasticity and poisons ratio tests. The materials and equipment used for this research include a servo-controlled stiff machine, triaxial cell, a computer, strain gauges, steel platens, spherical seating, oven, and a block of Clashach sandstone from which eight samples were prepared for the tests. The general description of the equipments and details of the methodology of the tests carried out are given in the following sub-sections.

General equipment description

The main equipment for this test is an RDP Howden servo-controlled stiff machine with 4900KN/mm deflection of the cross head. The pump runs at 5000Psi to supply hydraulic fluid pressure through servo valves to the main load frame and a pressure intensifier that provide the confining stress to the triaxial cell.

A computer is also attached to log values of triaxial load, axial displacement, confining stress and volume of confining fluid in the triaxial cell (from which an estimate of the radial expansion and contraction can be made).The triaxial cell is the Hoek cell (H o e k and Franklin, 1968), and strain gauges are used to measure vertical and horizontal strains.

Sample preparation

The samples used in this laboratory tests are the Clashach sandstone mostly sourced from the commercial quarry in Elgin Scotland. Eight cylindrical samples were prepared in the laboratory by coring from bulk samples with the aid of thin walled diamond coring bit and water flushed. The ends of each sample was dressed to required length by trimming the core with a water-cooled diamond saw and finally lapped to provide true-flat ends.

To be able to meet tolerance specification of sample geometry according to the American Society for Testing and Materials standard procedures (ASTM, 2001), the following dimension of specimen was used; six samples 38.00mm diameter each were prepaired for the unconfined compressive strength, triaxial strength and elastic constant tests. Two further samples 55.00mm in diameter and 27.50mm thick were prepared for the Brazilian disc tensile strength.

Experimental methodology

For the uniaxial compression test, two standard specimens prepared to required tolerance and diameter as suggested by the international society of rock mechanics (I.S.R.M., 1977), were oven dried until no change in weight could be detected. The specimen were then mounted on centrally on the testing machine between the steel platens of the same diameter as the specimen and a spherical seating of appropriate design was incorporated in the loading system above the specimen. A constant rate of load was then applied until the specimen failed and the load at failure was noted. For Brazilian disc (tensile strength) test, two standard specimens were cushioned by wrapping a masking tape around them and then mounted on the test machine (Fairhurst, 1964). A load at the rate of 6.4mm/min was then applied to the specimen through the machine until failure and the automatic load-lateral displacement record plot was obtained from the computer.

The standard sample for the elastic constants test was oven dried until no change in weight could be detected. The specimen was then mounted centrally on the testing machine between the steel platens of the same diameter as the specimen and a spherical seating of appropriate design was incorporated in the loading system above the specimen. A constant rate of load was then applied while the load, horizontal and vertical strain were measured and recorded continuously.

The core samples for the triaxial strength test were enclosed in the rubber sleeve and inserted into the cell. The end caps of the cell were screwed on firmly and the cell was then bled to remove any trapped pockets of air. Cylindrical end caps were inserted in the upper and lower ends of cell. The protruding ends of these caps are convex shaped to provide spherical seating. The cells were then mounted on the compression machine, the cell was temporarily held in vertical position by jaw clamps. An incremental load was then applied by the compression machine to hold the cell between platens and the jaw clamps were then released and the specimen was finally aligned. A confining pressure was applied to the specimen and maintained constant at selected level, axial load was then applied and increased until failure at peak strength. The onset of failure was indicated by sharp drop in the load registered on the machine to a new level representing the residual strength of the rock.

Results and Discussion

Uniaxial compressive strength

The uniaxial compressive strength (UCS) for the samples are: 60.0MPa for sample 1 (W1) and 101.4MPa for sample 2 (W2) as shown in table 1. The W2 sample gives a UCS that is close to the UCS (105.8MPa) for Clashach sand stone reported by Crawford et al (1995). The lower value of 60.0MPa for W1 may be due to its high porosity and permeability because it is known that the UCS of any sand stone depends on its porosity, permeability, and saturation.

Brazilian disc (tensile strength)

The Clashach sandstone samples W3 and W4 tested indicated tensile strength of 8.2MPa and 8.8MPa respectively represented in table 2, which is very close to 7.6MPa reported by Crawford et al (1995) as tensile strength for the Clashach sand stone.

Elastic constants (modulus of elasticity and poissons ratio)

The result for elastic constants test this test is given in table 3 produced directly from the testing machine and associated equipment (strain gauges). The modulus of elasticity for the sandstone is 23.7GPa and the poison ratio is 0.19, the elastic constant is twice that reported by earlier research while the poison ratio is lower. This large difference indicates that there is a geologic structural difference between the block of rock mass used for this research and that used by Crawford et al (1995), this geologic difference might be a local fault similar to that reported by other researchers like Al-Hinai et al (2006).

Triaxial strength

The result of the triaxial strength test is shown in table 4 produced directly from the testing machine and associated equipment (strain gauges) while the principal stress plot is shown in figure 2. The triaxial stress factor is 6 and the triaxial compressive strength of the sandstone is 152MPa, this result is very similar to earlier published work by Crawford et al (1995).

CONCLUSSION

The laboratory mechanical test of the strength and elastic constant of the Clashach sandstone has been successfully carried out. The sand stone has uniaxial compressive strength (UCS) ranging from 60.0MPa to 101.4MPa and the triaxial compressive strength is 152.0MPa; the brazilian tensile strength was between 8.2MPa to 8.8MPa, Modulus of Elasticity 23.7GPa, and the Poissons ratio was 0.19. These results are similar to those published earlier by other researchers and the variation indicates that there are discontinuities in rock mechanical properties as a result of geological discontinuity such as fault, porosity and permeability prevalent in in-situ rock masses. The sandstone will be very good and durable construction material for houses and roads due to its high strength.

This test result can also be applied to petroleum studies of reservoirs where clashach sandstone is believed to be the appropriate outcrop, such as well stability (sands and shales), Hydraulic fracture orientation and height, propped conductivities, sand production and produced water injection, reserve calculations, reservoir description, enhanced reservoir simulation with stress state sensitivity, compaction, subsidence and fault activation studies.

Table 1: Ultimate compressive strength (UCS) test

Core diameter = 38mm

Sample	Peak axial load (KN)	UCS (MPa)
W1	68.0	60.0
W2	115.0	101.4

Table 2: Brazilian disc (tensile strength) test

Diameter	55.0mm,	Thickness	27.5mm

Sample	Peak load (KN)	Tensile strength (MPa)
W3	19.6	8.2
W4	20.8	8.8

Table 3: Elastic constants (modulus of elasticity and poissons ratio)

Modulus of Elasticity	Clashach (White) sandstone	
Load 1KN	Stress	0.9MPa
Load 10.9KN	Stress	9.6MPa
Delta stress		8.7MPa

Strain 1 (4.2cm*54*e-6 strain/cm)	0.0002268
Strain 2 (11cm*54*e-6 strain/cm)	0.000594
Delta strain	0.0003672

Modulus of Elasticity 23.7GPa

Poissons Ratio Clashach (White sandstone)

	Vertical strain	Horizontal strain
Load 1 (11KN)	0.0005724	0.0000918
Load 2 (1KN)	0.0001836	0.0000162
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Delta strain	0.0003888	0.0000756

Poissons ratio 0.19

Table 4: triaxial strength tests (discrete failure mode)

triaxial strength test Clashach (white) sandstone

Core diameter 38.00mm

Samples	Axial load KN	Axial stress MPa	Confining stress Psi	Confining stress MPa
W6	215	189.6	1000	6.89
W7	319	281.3	3000	20.67
W8	400	352.7	5000	34.45

Principal stress plot

Sigma 3 MPa	Sigma1 MPa	Triaxial stress factor	Extrapolated UCS MPa	Measured UCS MPa
6.89	189.6	6	152	60
20.67	281.3			
34.45	352.7			

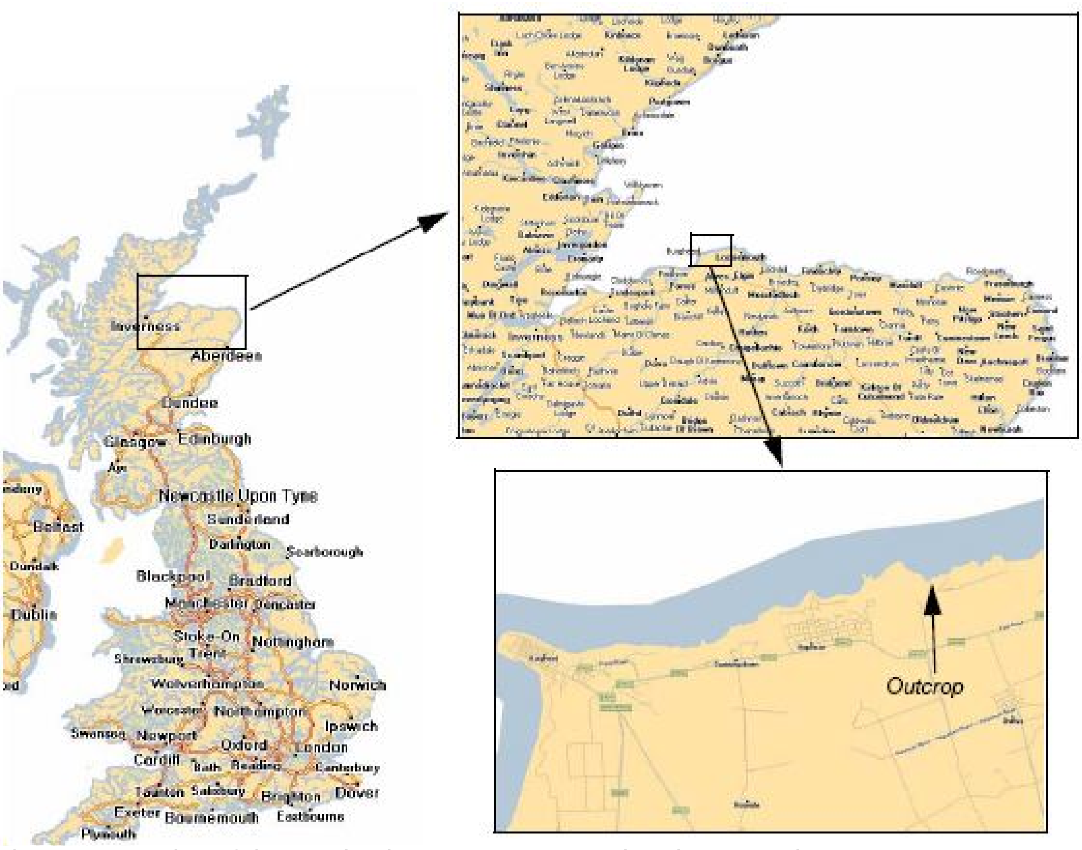

Figure 1: Location of the Clashach Quarry, near Burghead, Scotland.

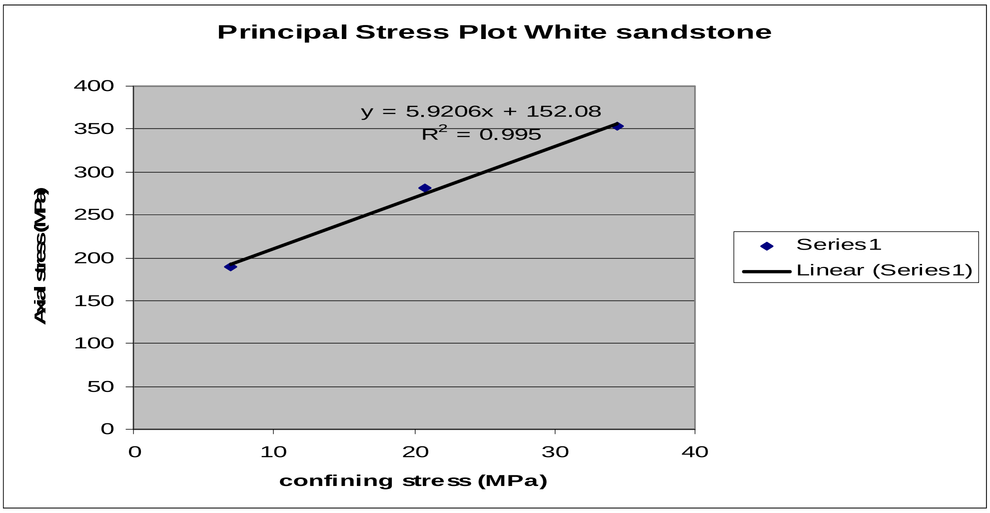

Figure 2: Principal stress plot for Clashach (white) sandstone discrete failure mode

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