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Study of Single Stage Compressive Test (SST) Laboratory Determination In Soft Formation Rods with Various Compositions Of Silica and Calcite Impurities In High Pressure and Temperature

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Abstract

Single Stage Compressive Test is a compressive test tool to study the nature of reservoir rock strength by modeling the reservoir rock into laboratory conditions. Measurement results on surface conditions generally have different results from actual conditions in reservoir conditions, therefore, the working principle of this tool considers the principal stress that works on reservoir rocks designed with the addition of silica and calcite impurities and models reservoir conditions in more detail such as high temperature conditions, the presence of pore pressure and the influence of the presence of fluid in the reservoir rock. Such a laboratory model will provide an overview of the magnitude of the effect of stress, both the maximum stress or the minimum stress acting on the reservoir rock and the effect of temperature and the presence of fluid on the nature of the reservoir rock strength. SST is designed by considering reservoir conditions in Indonesia, generally described as the maximum axial pressure (overbourden pressure) reaching 4000 psia and radial pressure which can act as confining pressure (pore pressure) reaching 1500 psia and the maximum temperature reaching 400 °F. This paper will explain in detail about the design of the SST tool and report the results of the synthetic core compressive test using this tool.

Keywords : *single stage compressive test, effect of stress, overburden pressure*

Introduction

Triaxial and uniaxial tests are methods that are often used to study the characteristics of reservoir rock strength. The difference between the two methods is the presence of confining pressure acting on the specimen. If the specimen does not have a working pressure confining called uniaxial test, while the triaxial test takes into account the presence of confining pressure acting on the specimen. Specimens that are often used in uniaxial and triaxial tests can be seen in Figure 1. In the picture it can be seen that when the radial stress (σ_3) is not equal to zero is categorized as a triaxial test system, while the uniaxial test system, the radial stress (σ_3) is zero.

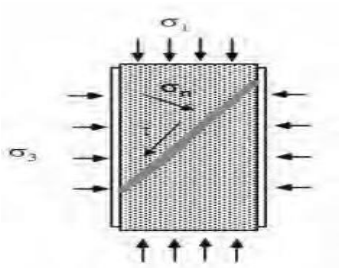

Figure 1. Stress Working at specimen.

Based on the treatment of the specimen during testing, triaxial tests are divided into two types, namely Single Stage Triaxial Compressive Test (SST) and Multistage Triaxial Compressive Test (MST). SST requires quite a lot of specimens, because each specimen is in the testing phase used only for taking one data failure due to axial load (σ_1) at a certain radaial pressure (σ_3), so that at least three specimens are needed, and ideally four or five. In contrast to MST, one specimen can be used to obtain multiple failure data due to axial load (σ_1) at several radial pressure values (σ_3). For more clearly the difference between SST and MST can be seen in Figure 2 to Figure 5.

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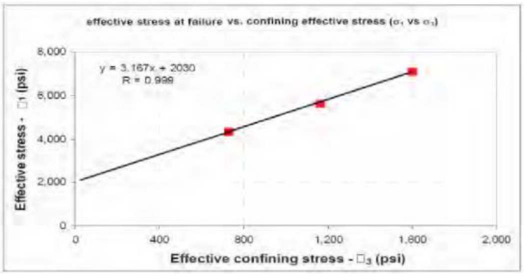

Figure 2. Example of single stage triaxial compressive test (SST) measurement results

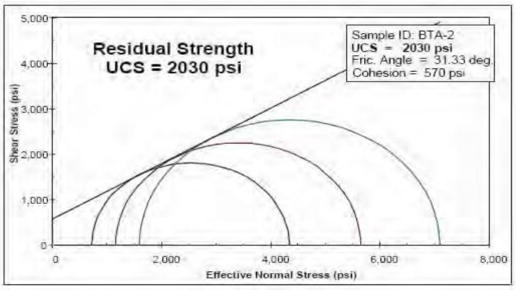

Figure 3. Mohr-coloumb from single stage triaxial compressive test (SST) measurement data

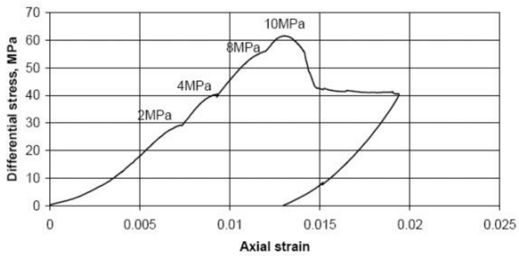

Figure 4. Example of multistage triaxial compressive test (MST) measurement results

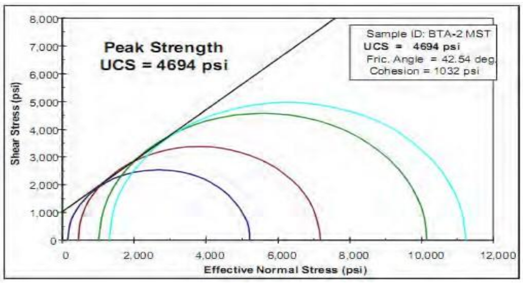

Figure 5. Mohr-coloumb from multistage triaxial compressive test (MST) measurement data

Measurement data from SST and MST both describe the characteristics of the rock both the strength parameters or static elastic properties. Based on the rule of thumb, the accuracy of the data obtained from SST is better compared to MST.

The results of the measurement of rock strength in the laboratory depend on the model used, often the results of measurements under standard surface conditions differ from the actual conditions recommended. Therefore, to approach the actual conditions in the reservoir, consideration of the pressure and temperature aspects of the dilaboartorium is very helpful in achieving these conditions. Based on reservoir data in Indonesia at a depth of several thousand feet, the models designed in the laboratory are recommended to have the following specifications:
- Maximum temperature of 400 °F
- Maximum axial load of 3500 psia and maximum radial pressure radial maksimum of 1500 psia
- Fluid used in the form of formation water, oil or gas.

With the laboratory model, the measurement data obtained can be evaluated on the effect of radial pressure (confining pressure) and certain temperatures on rock strength properties.

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Description of Single Stage Triaxial Compressive Test on Pressure and High Temperature

Purpose

A Triaxial test system has been developed to study the strength properties of reservoir rocks by directly measuring the laboratory of the rock's strength parameters. In a conventional triaxial test system, the specimen gets a load from the axial direction (maximum principal stress) and radial direction (minimum principal stress) while the intermediate principal stress is considered to be the same as the minimum principal stress. The temperature acting on the device is usually adjusted to the surface standard conditions. If you review the reservoir rock specimens that are made that have temperature conditions that are different from surface conditions, causing surface measurement results to differ from the actual reservoir conditions. Therefore, the Single Stage Triaxial Compressive Test tool that we developed takes into account the temperature effect, so that the laboratory model will approach the actual reservoir conditions. Models like this can eliminate at least the assumptions that were previously thought to not affect the nature of the reservoir rock strength due to changes in temperature. Models like this, are not only used to study the rock strength properties affected by each radial stress and temperature changes, but can also study the effects of a combination of radial stress and temperature.

Basic Concepts

Single Stage Triaxial Compressive Test is arranged to simulate the reservoir environment to a laboratory scale, to get a laboratory model like that there are several concepts that are applied in the arrangement, namely:

Reservoir rock specimens taken at a certain depth, become one of the considerations in assembling this SST tool. Based on the origin of the existence of reservoir rocks at a certain depth there are at least two parameters that must be considered, namely pressure and temperature. These two parameters are functions of depth, the deeper the reservoir rock position, the temperature and environmental pressure of the reservoir will increase. This relationship is commonly known as the pressure and temperature gradient. Knowledge of the pressure gradient and temperature is very useful to know the condition of the reservoir environment that will be modeled on a laboratory scale, but the first choice to determine for certain the actual condition of the reservoir environment is to directly measure the reservoir environmental parameters. This gradient concept is used when there are limitations in collecting reservoir environment data directly. The weakness of this gradient concept is to assume the condition of rocks below the surface in normal conditions for each depth, whereas in reality it is possible to meet with abnormal rock layers. Despite these disadvantages, the concept of gradients is very useful for approaching actual environmental conditions rather than just assuming the same conditions on the surface.*Properties Statik Elastisitas Batuan* (Fjaer *et al.*, 1992)

Stress is the magnitude of the force acting on a particular area. When an object is exerted a force or a load, then the object will experience physical changes, the change depends on the elastic modulus of the object. If the load exerted exceeds the elasticity limit, the object will experience failure. Static elastic modulus consists of Young's Modulus and Poisson Ratio. Young's Modulus is a comparison of the amount of load given to changes in the shape of the object (strain). Whereas Poisson Ratio is a comparison of strains that occur laterally to axial strains.

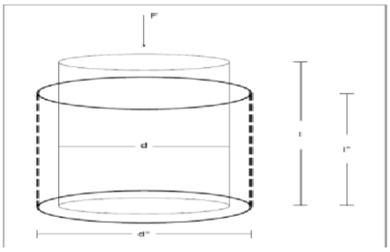

Figure 6. cylindrical objects that are given a certain load in the axial direction.

Figure 6. can help in understanding the relationship between static elastic modulus parameters with one another, mathematically these parameters are:

Volume strains for cylinders:

$$\varepsilon_v = \varepsilon_a + 2\,\varepsilon_r \tag{1}$$

- Young's Modulus

$$Y = \frac{a_a}{\varepsilon_v} \tag{2}$$

- Poisson Ratio

$$v = -\frac{\varepsilon_r}{\varepsilon_a} \tag{3}$$

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Negative sign on poisson ratio, because the price of radial strain is negative (dt <do). *Failure criterion (Mohr-Coloumb)* (Fjaer *et al.*, 1992)

Shear failure can occur when shear stress acting on an area is too large. Shear failure can be defined:

$$\tau = f(\sigma) \tag{4}$$

Where σ, normal stress and τ, shear stress works in all fields. The relationship of normal stress and shear stress from equation (5) above can be described in Mohr's circle. Lingrran Mohr which is formed from these two parameters provides information about the failure area boundaries. Figure 7 explain the relationship τ vs σ. Information obtained from the picture is one of them is the greater the minimum normal stress (σ_3), the maximum normal stress will be even greater, the circle formed from the two stresses is the boundary of the failure area, while the normal stress medium does not affect the limits of failure. This is consistent with Mohr's hypothesis, namely: pure shear failure only depends on maximum normal stress and minimum normal stress and does not depend on normal stress medium (Ahmed. S).

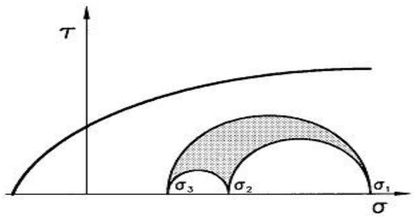

Figure 7. Mohr's diagram as a function of shear stress and normal stress, also illustrates the relationship of principal stress to normal (σ_1, σ_2, and σ_3)

By choosing a simple form of the function f which is assumed to be linear with respect to Mohr Coloumb Criterion, it can be defined that:

$$\tau = S_o + \mu\sigma \tag{5}$$

Where So is the inherent shear strength or cohesion of a material and μ as the coefficient of internal friction. In Figure 8 can be defined internal friction angle Φ as a function of the coefficient of internal friction, namely:

$$\mu = \tan \Phi \tag{6}$$

Whereas 2β is the angle formed from the Mohr circle with a failure line. The magnitude of shear stress and normal stress at that point as the point of failure can be defined by the equation:

$$\tau = \frac{1}{2}(\sigma_1 - \sigma_3 \sin 2\beta) \tag{7}$$

$$\sigma = \frac{1}{2}(\sigma_1 + \sigma_3) + \frac{1}{2}(\sigma_1 - \sigma_3)\cos 2\beta \tag{8}$$

$$\beta = \frac{\Phi}{2} + \frac{\pi}{4} \tag{9}$$

by substituting equation (7) and (8) into equation (5), a relation σ_1 with σ_3 is obtained, namely:

$$\frac{1}{2}(\sigma_1 - \sigma_3 \sin 2\beta) = S_o + \mu\left[\frac{1}{2}(\sigma_1 + \sigma_3) + \frac{1}{2}(\sigma_1 - \sigma_3)\cos 2\beta\right]$$

If the simplified above equation will be obtained:

$$\sigma_1 = 2S_o\frac{\cos \Phi}{1 - \sin \Phi} + \sigma_3\frac{1 + \sin \Phi}{1 - \sin \Phi} \tag{10}$$

The relationship of σ1 with σ3 is shown in Figure 9. in this figure the value of α is not the same as Φ, but α and Φ have the following relationship:

$$\sin \Phi = \frac{\tan \alpha - 1}{\tan \alpha + 1} \tag{11}$$

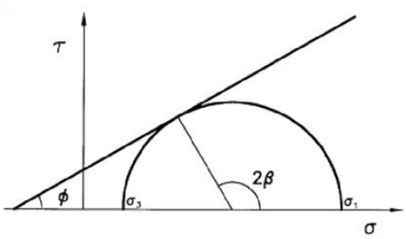

Figure 8. Mohr Coloumb Criterion **τ-σ**.

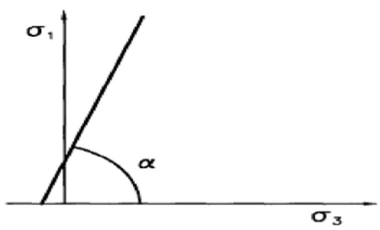

Figure 9. Mohr Coloumb Criterion At σ_1-σ_3

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When the minimum normal stress (σ_3) is zero, the condition is usually called an unconfined compressive strength (UCS), the value can be determined directly on the measurement of the uniaxial test, or indirectly with a triaxial test. The SST tool designed can be used to measure UCS directly or indirectly by setting the minimum normal stress value (σ_3). Indirectly the price of UCS can be obtained using equation (9) derived from equation (11):

$$C_o = 2S_o \frac{\cos \Phi}{1 - \sin \Phi} = 2S_o \tan \beta \tag{12}$$

Whereas when the maximum normal stress value (σ_1) is equal to zero, the price of σ_3 is the Tensile Strength of the material. From equations (10) and (8), the value of Tensile Strength can be defined as follows:

$$T_o = \frac{1 - \sin \Phi}{1 + \sin \Phi} C_o \tag{13}$$

Triaxial Cell Configuration

Triaxial cells in SST are designed using steel material that has resistance due to the large axial and radial loads and the high temperature and the presence of fluids that allow corrosion (especially formation water) in the cell series. SST which works at high pressure and temperature makes consideration of these three parameters highly prioritized to ensure safety during testing. The complete SST configuration can be seen in Figure 10 and Figure 11 The picture shows the specimen testing system by giving axial and radial loads generated by the hydraulic system, as well as simulating reservoir environmental conditions in the presence of formation fluids given high temperatures through heating electric which is mounted on the heat conducting steel inside the cell. While the steel part on the outside (jacket material) plays a role in supporting the cylindrical steel inside to avoid accidents due to the high pressure and temperature acting in the cell. The hydraulic system used in this SST can produce a maximum axial load of 10 tons and a radial pressure of 1500 psia. Whereas heating electric is designed so that it can heat the fluid in the cell to a maximum temperature of 482 °F.

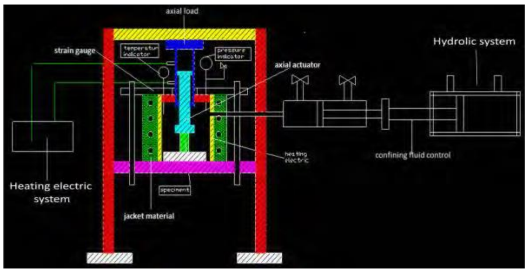

Figure 10. Single stage triaxial compressive test framework.

Figure 11. Configuring single stage triaxial compressive test.

Temperature Control

The temperature in a triaxial cell is controlled by using electric heating, the heat it can produce can reach a maximum temperature of 482 °F. The heat generated from the electric heting is delivered by the heating jacket in order to heat the formation fluid (formation water), this heat in the fluid will then heat the specimen to match the temperature of the reservoir environment. Temperature indicators are installed to measure the temperature of the fluid in the cell and help control the temperature so that the desired temperature is reached during the measurement. The system and the real shape of the temperature controller in SST can be seen in Figure 12 to Figure 14.

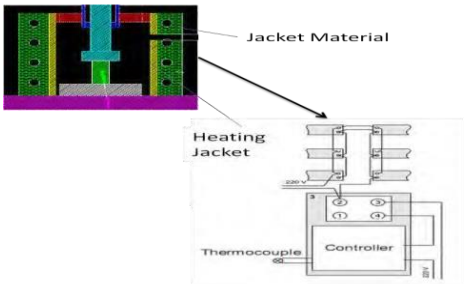

Figure 12 Temperature control model on STT

Figure 13. Electric heating attached to the cell equipped with a gas bull (heat resistance) and electric indicator.

Figure 14. Temperature control system at Single Stage Compressive Test

So that the temperature conditions in the cell are kept constant, between the jacket material and the heating jacket is equipped with a gas bull that can inhibit the heat of the surrounding environment.

Stress Axial Control

The load received by the specimen in the axial direction is controlled by a hydraulic system that can produce a maximum load of 10 tons. The load originating from the hydraulic is carried by the piston actuator (steel material) to the specimen. Figure 15 shows the axial direction loading system for the specimen. During the measurement the piston actuator will always move and the part connects directly with the surface conditions of the fluid in the cell pressure and high temperature, this condition will trigger fluid leakage through the space between the piston actuator with the jacket material, therefore the space is equipped with asbestos-like material (len packing) which is resistant to high pressure and temperature. The presence of the material causes a bottleneck when loading, so before measurements are made it must be calibrated in advance to determine the magnitude of the burden of the obstacle.

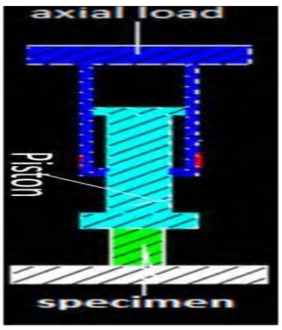

Figure 15. specimen loading system in the axial direction.

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Because the unit of axial load is still in metric-ton units, converting it into pressure units requires data on the area of the circle of the weighted specimen. Because the specimen holder in SST is available for three diameters, the following equation can be used to determine the pressure:
Specimen diameter: 1 in

$$A = \pi r^2 = \pi \left(\frac{2.54\ cm}{2}\right)^2 = 5.067\ cm^2$$

$$P = \frac{m.\ g}{A} \frac{m\ (9.8)}{5.067\ cm^2} = 1.934\ m\ \left(\frac{N}{cm^2}\right)$$

Where m is in Kg. because,

$$\frac{N}{cm^2} = 1.4504\ psi$$

Then

$$P = 2.80115\ m\ (psi)$$

Or if m is in tons,

$$P = 2801.15\ m\ (psi) \quad (15)$$

Specimen diameter: 1.5 in
In the same way as for a 1 in specimen, we get:

$$P = 1246.73\ m\ (psi) \quad (16)$$

Specimen diameter: 2 in

$$P = 701.288\ m\ (psi) \quad (17)$$

Radial Stress Control

The radial stress control system uses the same hydraulic system as the hydraulic axial stress, the difference is that the media is used to carry the load generated by the hydraulic to the specimen. In the hydraulic axial stress which acts as the medium is the piston actuator (steel material) while the radial stress uses the formation fluid media (formation water). Hydraulic radial stress can produce a maximum pressure of 1500 psia. Aside from being a pressure giver in the radial direction, the pressure generated by this hydraulic can act simultaneously as a pore pressure, because this SST assumes the specimen is undrained. Radial stress generating hydraulic system can be seen in Figure 16

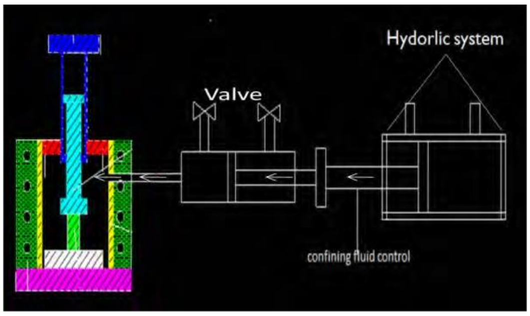

Figure 16. Radial stress produced by a hydraulic system

Complementary Components

One of the complementary components of the Single Stage Compressive Test is where the specimens are located inside the cell. If there is no such component, the specimen position in the cell is unstable, it is feared that its position is not in the middle or not in a standing position as the effect of fluid input into the cell to provide radial stress. The specimen storage area is designed with a specific profile shape so that it can be mounted to pull out to make it easier to install the specimen. The profile form can be seen in Figure 17 and Figure 18

Figure 17. The specimen holder is mounted in a cell.

Figure 18. Shape of specimen holder profile. Left: upper part. Right: bottom.

Measurement Procedure

Preparation of Specimens

The sample core or specimen to measure rock strength is measured in length and diameter (H / D: 5/5) and in accordance with the specimen holder available. The measured specimen is then heated (deoven) so that the dry weight is obtained. This is done so that during saturation with the desired fluid is actually 100% saturated by the fluid. After obtaining a specimen that has been saturated the next step is the preparation of SST tools.

Preparation of SST Tools

At this stage, precision and caution are required, because the measurement of rock strength with SST works at high pressure and temperature, therefore every component in the SST tool must be installed in the right position, if not careful of each component, it is possible to leak, and The measurement must be repeated from the beginning. SST components that must be checked before measuring are:

1. Hydraulic: axial hydraulic and radial stress hydraulic must be locked
2. Electric heating: all sets of heating electrics must be installed and use a 220 volt electric voltage.
3. Check the cell components starting from the cell cover, specimen holder, and valve and make sure they are in their respective positions.

Testing specimens

If the SST specimens and instruments are ready for use, then the rock strength testing of the specimens can begin. The steps that must be considered during testing the specimen include:

1. Place the specimen exactly on the specimen holder in the cell
2. Fill the cell with the desired fluid (for example fresh water), if the cell is almost full, the next fluid is filled through a hydraulic radial stress tube after it is ensured that the cell cover is securely attached.
3. Give radial stress as expected by using hydraulic radial stress, if it reaches a certain radial stress, heat the fluid in the cell by regulating the heating electric at a certain temperature, after reaching a certain temperature, let stand for 2 hours.
4. Give the axial load at the same time make a reading on the gauge when the specimen begins to fail and stop the measurement.
5. For other specimen measurements, perform the steps above repeatedly.

Triaxial with Core Syntetic

The core sample (specimen) used in the trial of this SST tool uses synthetic cores. The weight composition of a synthetic core consists of 80% bentonite, 10% sand and 10% cement and the addition of silica and calcite impurities. Because SST requires quite a number of core samples (at least three), it is expected that with these compositions the core samples can be considered to represent rocks taken at the same place and environment, so that in the analysis of changes in radial stress and temperature are not influenced by differences in rock types (assuming: the core sample is sourced from the same rock). The size of the core sample has a ratio of 5: 5 in length and diameter (ISRM standard). With such a size, the sample core is expected to accommodate shear penetration in all parts of the sample core. Therefore, the synthetic core that will be used in this test uses a length of 5 cm and a diameter of 5 cm. prior to the test, the core sample is saturated with reservoir fluid (formation water) for 24 hours. The magnitude of the axial pressure that is charged throughout the test can be directly read on the pressure indicator until the sample core occurs failure under certain radial stress and temperature conditions. The data obtained can be used to analyze the effects of radial stress, temperature and a combination of the two.

Measurement Results Data

Rock strength testing of the specimens was carried out by uniaxial and triaxial testing. For triaxial specimens treated with varying radial stress at a certain temperature. The test results can be seen in Tables 1, 2 and 3.

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Table 1. Synthetic Core Compositions

Samples	Water	Bentonite	Sand	Cement	Silicate
1	200	240	30	30	5
2	200	216	27	27	10
3	200	192	24	24	15

Table 2. Measurement of Rock Strength from Specimens by The Uniaxial Method

uniaxial			
No. samples	σ_3 (psi)	σ_1 (Ton)	σ_1 (psi)
1	0	1.2	3366
2	0	1.3	3647
3	0	1.2	3366

Table 3. Measurement of Rock Strength from Specimens Using The Triaxial (SST) Method

Triaxial Temperature 30 °C			
No samples	σ3 (psi)	σ1 (Ton)	σ1 (psi)
8	70	2	5610
18	140	2.5	7013
19	210	2.8	7854
Temperature 90 °C			
No sample	σ_3 (psi)	σ_1 (Ton)	σ_1 (psi)
21	70	1.6	4488
13	140	1.75	4909
3	210	2	5610

Failure Criterion (Mohr-Coloumb)

To make a failure criterion from MohrColoumb you can use equations (5) to (14) that have been discussed previously.

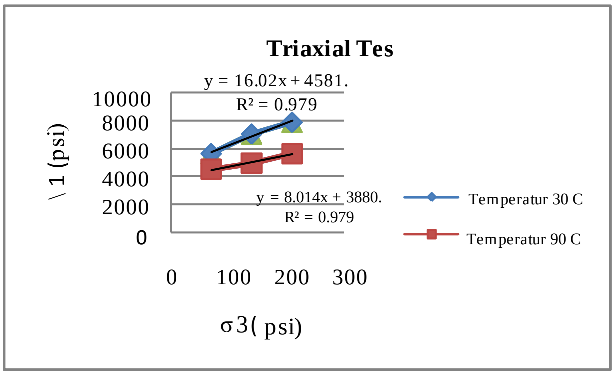

Figure 19. Correlation stress axial with stress radial.

Determining the angle of rupture (internal friction) from Figure 19 obtained a gradient value (tanα) for each temperature, namely:
Temperature 30°C

$$\alpha = 86°$$

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Then the angle of rupture is:

$$\sin \Phi = \frac{\tan \alpha - 1}{\tan \alpha + 1} = \frac{16.02 - 1}{16.02 + 1} = 0.882$$

$$\Phi = 62°$$

Internal friction = tan 62 = 1.87

$$2\beta = 62 + 90 = 152$$

Temperature of 90°C

$$\tan \alpha = 8.041$$

$$\alpha = 83°$$

Then the angle of rupture is:

$$\sin \Phi = \frac{\tan \alpha - 1}{\tan \alpha + 1} = \frac{8.041 - 1}{8.041 + 1} = 0.778$$

$$\Phi = 51°$$

Internal friction= tan = 1.23

$$2\beta = 51 + 90 = 141$$

Determine cohesive strength

Cohesive strength can be determined by equation (11) which is rearranged into:

$$S_o = \frac{\sigma_1 - \sigma_3 \frac{1 + \sin \Phi}{1 - \sin \Phi}}{2 \frac{\cos \Phi}{1 - \sin \Phi}}$$

- Temperature 30 °C
  $\sigma_1 = 7013\ psi$
  $\sigma_3 = 140\ psi$
  $S_o = 593\ psi$
- Temperature 90 °C
  $\sigma_1 = 4909\ psi$
  $\sigma_3 = 140\ psi$
  $S_o = 671\ psi$

Determination of Unconfined Compressive Strength

Unconfined Compressive Strength (UCS) UCS (Co) can be determined directly by the uniaxial method, the results of this method the price of UCS is the same as the value of σ_1 in Table 1, whereas with the SST method, UCS can be determined by drawing the equation of the line, and the UCS price is taken when the value of σ_3 is equal to zero, and the last UCS can also be determined through equation (12). Full results can be seen in the Table 4 below.

Table 4. Determination of The Price of UCS

Temperature	UCS		
	Room	**30 ° C**	**90 °C**
Uniaxial on average (psi)	3460		
Triaxial Average (psi)		4581	3880

Of the three UCS prices the results through Triaxial are greater than with Uniaxial, this is because there is an influence of water that is during the measurement period, so the load that comes from axial load is partially held by water

Radial Stress Effects

From the measurement data it can be clearly seen that the greater the radial stress given to the specimen, the greater the failure pressure of the specimen. Figure 20 and Figure 21 show the relationship of radial stress to axial.

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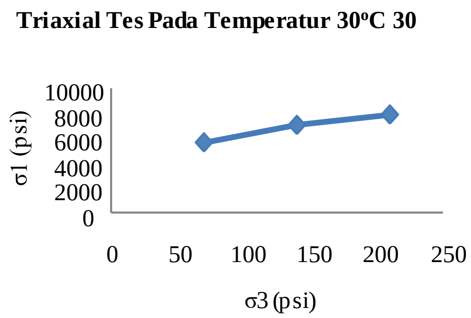

Figure 20. Correlation stress axial with stress radial pada temperatur 30°C

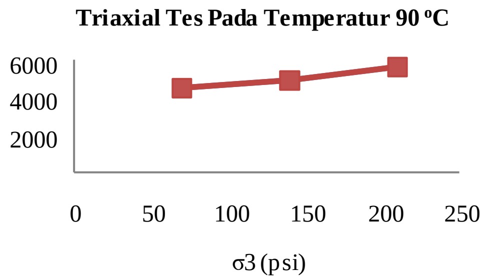

Figure 21. Correlation stress axial with stress radial at temperatur 90°C

Analysis of changes in radial stress (confining stress) can be done using the triaxial method, while Uniaxial can not do this. The greater confining pressure will provide support for specimen, so that the failure pressure of the specimen will increase. Such behavior is called strain hardening.

Temperature Effects

Effect of temperature on rock strength can be identified through the magnitude of the failure pressure at different temperature conditions. The results of testing of rock specimens at temperatures of 30 °C and 90 °C can be seen in Figure 22 From the picture it can be seen that the higher the temperature, the pressure of rock failure will decrease, this is possible because of damage to the rock cementation system due to heating. This is one of the benefits of SST, it can analyze changes in rock strength due to temperature changes. So that the actual model recommended can be approached with a laboratory model.

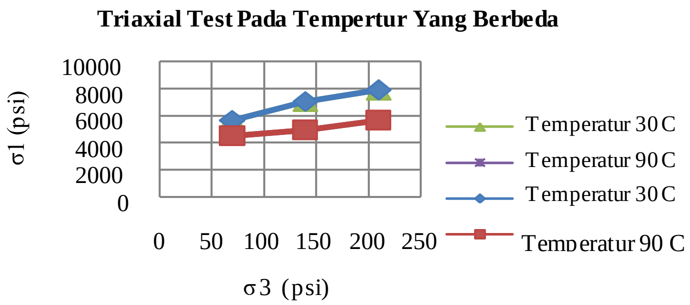

Figure 22. Correlation Failure Pressure with temperature.

Field Test Results

Lith	Depth (ft)	TLS (sec)	THS (sec)	RLS (ft/s)	RHS (ft/s)
Sand	0.984252	200	175	0.005	0.006
Clay	0.984252	250	225	0.004	0.005
Cbn	0.984252	330	282	0.003	0.004

Description :

Lith : lithologi
Cbn : Carbonate
TLS : Time Low Speed (sec)
THS : Time High Speed (sec)
RLS : Rop Low Speed (ft/s)
RHS : Rop High Speed (ft/s)

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Conclusion

1. Temperature and pressure parameters are very important in simulating reservoir conditions on a laboratory scale.
2. Single Stage Triaxial Compressive Test can be used to analyze the effect of temperature and confining pressure on the rock's marine properties.
3. Increased temperature causes rock strength to decrease, whereas with increasing confining pressure causes rock strength to increase.

Recommendations

1. Single Stage Compressive Strength tools can be equipped with strain gauges and computer sensors to be able to analyze strain changes, both radially and axially.
2. The hydraulic system currently installed in the future can be replaced with an electric motor system so that the measurement process is simpler.
3. A more in-depth study of changes in the nature of the fluid is inside the cell so that the measurement results are more accurate.
4. A more in-depth study of the effect of fluid changes used in cells (such as gas and oil) on the strength of rock properties.

List of symbols

Σ : stress
σ1 : maximum normal stress principal
σ2 : principal stress normal medium
σ3 : minimum normal principal stress
σr : radial stress
τ : shear stress
So : cohesive strength
μ : coefficient of internal friction.
Φ : broken angle
Co : unconfined compressive strength
To : tensile strength
A : surface area
P : pressure
F : style
UCS : unconfined compressive strength
SST : Single Stage Compressive Test
MST : Multi Stage Compressive Test

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Lembar Tanya Jawab

Moderator : Putri Restu Dewati (UPN "Veteran" Yogyakarta)
Notulen : Indriana Lestari (UPN "Veteran" Yogyakarta)

1. Penanya : Putri Restu Dewati (UPN "Veteran" Yogyakarta)
   Pertanyaan : Apakah benar bahwa SST dapat digunakan untuk menentukan kekuatan dari batuan?
   Apa nama alat yang digunakan dalam metode SST ini?
   Apa yang menjadi dasar penentuan variasi komposisi sampel?
   Jawaban : Benar, tetapi pengukurannya masih satu arah saja, yaitu *axial load*.
   Manual hydraulic pressure test
   Pada dasarnya, di alam tidak ditemui batuan dalam kondisi yang murni, karena terbentuk secara alami dari proses sedimentasi, sehingga ada proses interaksi antar material selama perjalanannya. Material-material kuat akan berbentuk *rounded* atau butiran yang bagus. Jika dilautan, plankton yang mati dan tertimpa batuan menjadi *source rock* atau batuan induk reservoir, apabila ada gerakan bumi atau terjadi patahan, maka batuan yang melewati patahan tersebut menjadi perangkap hidrokarbon (HC), dimana di dalam perangkap HC ada bahan yang *traprock* yaitu *clay impermeable porous* sehingga mampu menyimpan fluida tetapi tidak mampu mengeluarkannya.

2. Penanya : Rudi Firyanto (UPN "Veteran" Yogyakarta)
   Pertanyaan : Berapakah rentang suhu dan tekanan operasional yang dibutuhkan agar diperoleh kondisi yang optimal?
   Berapakah suhu dan tekanan yang digunakan pada penelitian ini?
   Jawaban : Rentang suhu dan tekanan yang optimal dapat diperoleh dengan cara membaca kurva hubungan antara *strain* dan *stress*, yaitu melihat kemampuan suatu material bagaimana elastisitasnya yaitu jika diberi beban akan kembali kebentuk semula atau tidak ada deformasi setelah beban tersebut dihilangkan, dan setelah melewati batas elastisitas maksimal akan terjadi batas plastisitas, dimana material masih mampu menahan beban namun tidak kembali apabila gaya yang diberikan dihilangkan, serta jika beban ditambah hingga ke batas *brittle* yaitu maksimum *stress* untuk mendapatkan regangan, sehingga dapat kita gunakan untuk mendesain alat pengeboran, contohnya menentukan jenis material untuk mata bor.
   Pada rentang suhu antara 30 – 90 °C dan tekanan 3.000 – 5.000 Psia.