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COMPARISON OF SANDSTONE MECHANIC PROPERTIES USING ACOUSTIC TEST AND DIRECT UNIAXIAL TEST

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ABSTRACT

Rock mechanic characterization usually can be done through direct test, with uniaxial or triaxial test by equipment of compression unit. The velocity of ultrasonic wave with compressional (P) wave and shear (S) wave can determine the value of rock mechanic characteristic such as Poisson Ratio and Young Modulus. In this study the two test method used for sand stone sample is taken from outcrop. If the result obtained from uniaxial direct test is assumed approximately true value, then the determination of correction factor from acoustic test can be performed to get an equation. By knowing the correction factor of a rock taken from a specific location, one can determine rock mechanic characteristics obtained from the same location without destructing the rock due to testing.

Keywords: Rock Mechanic Characteristics, Ultrasonic Wave Velocity.

1 INTRODUCTION

Rock mechanic is the theoretical and applied science of the mechanical behavior of rock to the force fields of physical environment. Rock mechanic is effect of rock to give physical load in situ condition of formation. The load of rock to effect of stress in rock and strain in rock. The rock mechanic characteristic ,as follow : Poisson Ratio, Modulus of elasticity, Angle of internal friction, Uni axial compressive strength, Tensile strength, Shear strength of the rock, Tri axial compressive strength and Deformation behavior and failure characteristic.

The parameters of rock mechanic properties can be measured by using two methods in laboratory test with direct test (uniaxial and triaxial test) and indirect test from acoustic. In this paper is report the study how to determine mechanical rock properties from acoustic velocity tester. As is well know in this tester is non destructive testing, on the other hand core sample is not leak. Acoustic wave measurement in the laboratory and in the field have been used for various applications ranging from determination of porosity , interpretation and calibration of sonic logs. identification of lithology , determination of classical elastic rock parameter and formation , enhanced seismic interpretation , micro fracture recognition and formation damage evaluation.

Study of rock properties as long time use of oil and gas industry, because oil and gas is stile of reservoir rock in trap stratigraphy and structure of sedimentary rock. Identification of rock properties can be design of optimization drilling program, specially if can drilling exploration is very difficult to determinate this parameter because not any core and logging. If this oil field the stratigraphy and structure any out croup , correlation of stratigraphy and structure can be held with geological map and seismic exploration. This study can be predict physical rock properties several sand stone Malaysia from acoustic velocity of rock. Acoustic tools use sound to measured different characteristics of rock and the sonic tool is used in calculate density, porosity, water saturation and permeability.

Rock mechanic characteristic usually can able from direct test rock sample, in the effect destructive of sample. And than necessary this correlation characteristic with acoustic characteristic is non destructive test. Ultrasonic tester is non destructive testing, and than core sample is not franc (non destructive), whit use correlation rock mechanic characteristic from acoustic test and uniaxial test in laboratories.

The analysis of mechanical rock properties of several samples of Malaysian sandstone we conducted using uniaxial and acoustic test with PUNDIT unit. Frequency transducer 1 MHz longitudinal wave (P wave) and transversal wave (S wave). Young modulus and Poisson ratio as analysis from core with 1 inch diameter and 2.5 inch length. Uniaxial test used compression unit to direct test.

The purpose of the research reported here is first to determine the acoustic velocities to detect young modulus and poison ratio for several sand stone from out croup surface . The anisotropy was determined from measurements of P-wave velocities in the vertical and horizontal directions and of the velocities of S waves with direct test. The second purpose of the research is to determine relationships between the acoustic velocities and the young modulus and poison ratio from two method test.

Tutuncu and Sharma (1992) report of the relating static and ultrasonic laboratory measurements to acoustic log measurement in tight gas sands, comparison of young module and poison ratio obtained from ultrasonic laboratory with static module. The result studied as similar trend is observed with comparing laboratory ultrasonic data (1MHz) with acoustic log data (20 KHz).

Results of the laboratory tests to comparison of graph poison ratio and young modulus versus acoustic velocity P wave and S wave from sand stone Malaysia. Laboratory test is used uniaxial test and acoustic test to determined poison ratio and young modulus.

2 SPECIMEN PREPARATION AND ASSEMBLY

Specimens of 1 inch diameter and 2.5 inch length cored in the laboratory in directions parallel preserved core. The sand stone Malaysia from out crop from field in core in the laboratory . The ends of each specimen were finally ground flat and parallel with a diamond wheel on a reciprocating grinder to better than the recommendations of the International Society of Rock Mechanics (Brown, 1981) for 'preparing triaxial test specimens: flat to 0.02 mm; not departing from perpendicularity by more than 0.001 radian (0.03mm in a diameter of 1 inch); and straight to within 0.3 mm. The samples this test ultrasonic P & S wave with 1 MHz frequency and than can be test uniaxial with compression unit.

Transducer holders (CNS Electronics, London) for compressional (P) and shear (S) wave velocity measurements are attached to each of the two brass end pieces with a proprietary shear-wave couplant. Specimens with marked bedding planes are oriented with the direction of polarisation of the shear waves parallel to the bedding plane. This procedure permits the measurement of direct measurement velocities for preserved core samples. A CNS Electronics "PUNDIT" pulsing unit is used to pulse the transmitting combined P and S-wave transducers.

3 THE LABORATORY MEASUREMENT

3.1 ACOUSTIC MEASUREMENTS

Analysis condition is a material with ultrasonic wave is Non Destructive Test (NDT) Test. Principal is work as : Electrical wave energy from generator pulse to transfer from transducer (Tx) as mechanical wave, and than can spreading in sample of rock (material). After reaching the receiver transducer (Rx), the wave energy can be retransformed to electrical wave by transducer (Rx) and then it is spread through booster and finally to determined time transit by digital numerical or oscilloscope.

The P and S-wave transducers are each switched sequentially to produce and detect pulses of either type of wave. The pulse train bandwidth, are as used 1 MHz P & S wave. The time-of-flight method is used to determine the P and S wave velocities Vp or Vs, is then recorded for each of the P and S-wave pulses.

From these values have to be subtracted the times, Δtp and Δts, required for the P and S-wave pulses just to traverse the transducer holders and brass end pieces themselves.These values are obtained prior to the tests with rock specimens, by placing. the transducer holders and end pieces in face-to-face contact with a disc. of lead foil between them and. establishing the times of flight, Δtp and Δts, for P and S waves.

The P and S-wave velocities are calculated by dividing the length of the specimen, L, by the appropriate 'pulse time-of-flight, corrected for Δtp and ΔtsΔ:

$$\text{P-wave velocity, } Vp = L/(tp - \Delta tp) \quad (1)$$

$$\text{S-wave velocity, } VS = L/(ts - \Delta ts) \quad (2)$$

Dynamic elastic properties of porous media, including Poison ratio and Young Modulus can be computed from measured compressional (P wave) and shear wave (S wave) velocity using Equation (3) and (4) presented below (Tixier et. al, 1973) :

Young Modulus (E) :

$$E(d) = \rho Vs^2 \frac{[3(\frac{Vp}{Vs})^2 - 4]}{(\frac{Vp}{Vs}\}^2 - 1} \quad (3)$$

Poisson Ratio (V) :

$$V = \frac{0.5(\frac{Vp}{Vs})^2 - 1}{(\frac{Vp}{Vs})^2 = 1} \quad (4)$$

When Vp is Ultrasonic Longitudinal Acoustic velocity, m/sec , Vs is Ultrasonic Transversal Acoustic Velocity, m/sec, and ρ is Density of rock, kg/m^3.

3.2 MEASURED OF POISSON RATIO AND YOUNG MODULUS

3.2.1 Poisson's Ratio

When compressive stress applied to the vertical axis in the cylinder of rock, the ratio horizontal (lateral) strain to vertical (axial) strain is Poisson's ratio (υ)

$$\nu = \frac{\varepsilon_{horizontal}}{\varepsilon_{vertical}} \quad (5)$$

when : $\varepsilon_{horizontaln}$ = The strain parallel to the direction of applied stress, and $\varepsilon_{vertical}$ = The strain to perpendicular to the applied stress, as defined in equation, then :

$$\nu = \frac{\Delta r}{r} * \frac{L}{\Delta L} \quad (6)$$

In general , Poisson's ratio for many rock is in the range of 0.15 to 0.5 and for sand stone often approximately of 0.25 (Allen and Roberts, 1982).

3.2.2 Modulus of Elasticity

Modulus of elasticity (Young's modulus) in and elastic constant, which define the linear relationship between the applied stress and strain . If the applied stress is σ and the result of strain is ε , the modulus of elasticity (E) can be defined as the ratio of stress to strain , where the strain is in the direction of the applied stress within the elastic range of the rock. Young Modulus can be show in equitation :

$$E = \frac{\sigma_{vertical}}{\varepsilon_{vertical}} \quad (7)$$

$$E = \frac{F \times L}{A \times \Delta L} \quad (8)$$

where $\sigma = F/A$ and $\varepsilon = \Delta L/L$.

The modulus of elasticity , which is also the tangent modulus at 50% of the uniaxial compressive strength on the stress-strain curve. Base on Equation the modulus of elasticity can be graphically determined from load versus vertical strain by making an axis correction to the chart recording , a tangent to the vertical strain at 50% of compressive strength (50% of failure load). Modulus of elasticity will increase as the density of rock , confining pressure and rate of loading increase. Typical value of the modulus elasticity for sand stone determined in uniaxial compression are in range of 6.2 to 50.3 GN/m^2 (Obert et.al, 1967).

3.2.3 Uniaxial Compressive Strength

Uniaxial compressive strength is defined as the stress at failure under uniaxial compression and it can be determined by Equation (9).

$$Co = \frac{P}{A} \quad (3.9)$$

where Co = Uniaxial compressive strength (Mpa), P = Peak of load at failure (KN), A = cross sectional area (m^2).

The compressive strength is represented by the maximum principal stress in the Mohrs's diagram when the minimum principal stress (confining pressure) is equal to zero. The stress value at failure is defined as compressive strength Co = σ_1. The uniaxial compressive strength of the rock depends on the internal factor such as mineralogy, grain size, porosity and external factor.

4 RESULTS AND DISCUSSION

From examination of 6 samples of Malaysian sand stone cores being tested its acoustic characteristic by using transducer P & S Wave 1 MHZ frequency obtained the smallest value of P wave is 1750 m/sec (T-1A) and biggest is 2066 (sample T-1B), with the value Vp. mean is1895.25 m/sec. Using transducer S wave get the smallest value of 974 m/sec (T-1A) and the biggest one is1169 m/sec (sample T-1B) with value Vs mean is 1081.5 m/sec.

The Modulus Young value measure of test uniaxial obtain the smallest value of 3.7500 Mpa (sample T-2C) and the highest of 11.1111 Mpa (sample T-1A), with the Modulus Young value (E) mean measured of uniaxial test as big as 6.1936 Mpa. The Assess modulus young (E) measured of acoustic test P & S Wave obtaine the smallest value of 2.9236 Mpa (sample T-2C) and the highest of 8.4329 Mpa (sample T-1B), with modulus young (E) mean measured of acoustic test as big as 6.4594 Mpa.

The Poisson ratio value (v) measured of test uniaxial produce the smallest value is 0.8571 (sample T-2C) and the highest is 3.4400 (sample T-1B), with Poison ratio value (v) mean measured of uniaxial test is equal to 1.40 . The Poison ratio value (v) measured of test acoustic P & S Wave give the smallest value of 0.2286 (sample T-2A) and the highest is 0.2755 (sample T-1A) with Poison ratio (v) mean measured of acoustic is equal to 0.2579 .

The results of uniaxial and acoustic tests of the 6 samples sand stone Malaysian for the value of acoustic velocity, poisson ratio and Young modulus can be see at Table 1 and Figure 1 to 4.

TABLE 1. Acoustic Velocity (150 KHz) Vs. Modulus Young (E) and Poisson Ratio (v) Sand Stone MalaysiaFrom Acoustic Test & Uni-Axial Test

Sample Core	Acoustic Velocity (1" – 150 KHz) P wave, m/s	S wave, m/s	Young Modulus (*E*) Uni-Axial Test, MPa	Acoustic Test, MPa	Poisson Ratio (V) Uni-Axial Test	Acoustic Test
T-1A	1750	974	11.1111	6.0990	1.1578	0.2755
T-1B	2066.6	1169	4.5454	8.4329	3.4400	0.2645
T-1C	1925.9	1083	7.2000	7.4685	0.8888	0.2684
T-2A	1885.7	1118	5.5555	7.4944	1.0000	0.2286
T-2B	1787.8	1017	5.0000	6.3385	1.1153	0.2604
T-2C	1955.5	1128	3.7500	2.9236	0.8571	0.2504

Data in table if of cut off, because anomaly data is not possible in graph plotting.

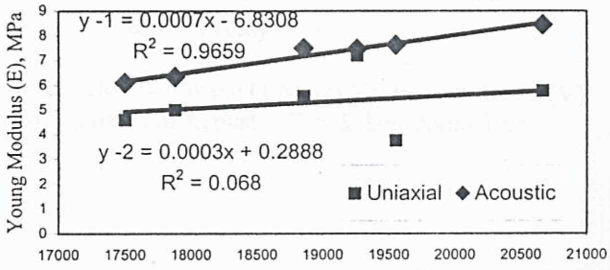

FIGURE 1. Acoustic Velocity P wave (150 KHz) Vs Modulus Young (E)

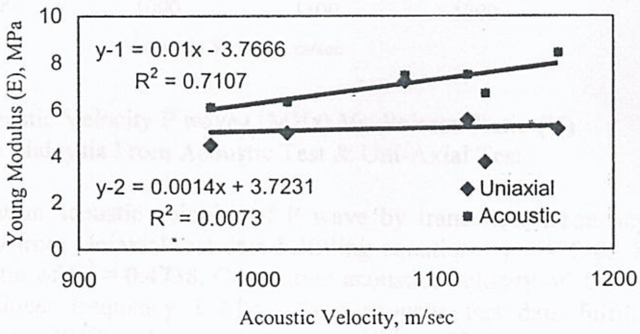

FIGURE 2. Acoustic Velocity S wave (1MHz) Vs Modulus Young (E)

The acoustic velocity of P wave correlation to Young modulus by transducer frequency 1 MHz, from Uniaxial test data fulfilling equation : y = 0.0007 X –6.8308, and corrective factor of R^2 = 0.9659. Correlation acoustics velocity of P waves to Young modulus by transducer frequency 1 MHz from Acoustic test data fulfilling equation of; y = 0.0003 X + 0.2888, and corrective factor of R^2 = 0.068.

The graph from Figure 2 as acoustic velocity (S wave) by transducer frequency 1 MHz correlation to Young modulus from Uniaxial test data fulfilling equation : y = 0.01 X-3.7666, and corrective factor of R^2 = 0.7107. Correlation acoustics velocity of S waves to Young modulus by transducer frequency 1 Mhz from acoustic test data fulfilling equation of; y = 0.0014 X +3.7231 , and corrective factor of R^2 = 0.0073. Figures 3 and 4 is illustration correlation Acoustic velocity P & S wave versus Poisson ratio from Uniaxial and Acoustic test.

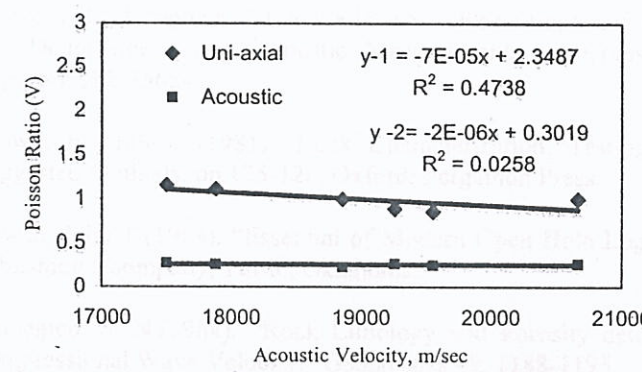

FIGURE 3. Acoustic Velocity P wave (1 MHz) Vs. Poisson Ratio (V) Sand Stone Malaysia from Acoustic Test & Uni-Axial Test

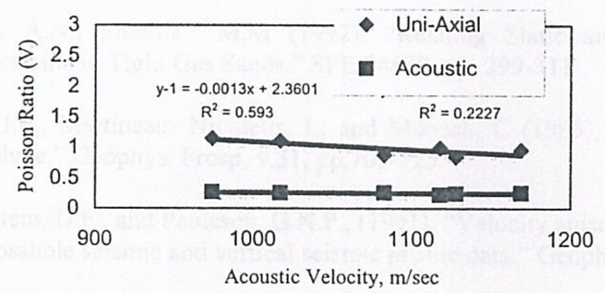

FIGURE 4. Acoustic Velocity P wave (1MHz) Vs. Poisson Ratio (V) Sand Stone Malaysia From Acoustic Test & Uni-Axial Test

Figure 3 show correlation acoustic velocity of P wave by transducer frequency 1 MHz versus poison ratio from Uniaxial test data fulfilling equation : y = -7E-05 X + 2.3487, and corrective factor of R^2 = 0.4738. Correlation acoustics velocity of P waves to Poison ratio by transducer frequency 1 MHz, from acoustic test data fulfilling equation of; y = -2E-06 X + 0.3019, and corrective factor of R^2 = 0.0258 . The graph from Figure 4 as acoustic velocity of S wave correlation to Poison ratio by transducer frequency 1 MHz, from Uniaxial test data fulfilling equation : y = -0.0013 X + 2.3601, and corrective factor of R^2 = 0.593. Correlation acoustics velocity of S waves to Poison ratio by transducer frequency 1 MHz, from acoustic test data fulfilling equation of; y = -0.0001 X + 0.3738 , and corrective factor of R^2 = 0.2227.

5 CONCLUSION

Generally it was observed that correlation in the comparison data uniaxial test and acoustic test for Young modulus and Poisson ratio values , is follow from curve young modulus (E) of rock versus acoustic velocity to get increasing Young modulus (E) to effect increasing of acoustic velocity.From curve Malaysia sand stone is Poisson ratio (v) of rock versus Acoustic Velocity to get increasing is Poisson ratio (v) to effect decreasing of acoustic velocity.

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REFERENCES

Ajuro, A. O., Chapman D.J. and Kier J.S.(1996). "Improved Reservoir Characterization and Delineation Using Acoustic Measurements on Cores." Society of Petroleum Engineer SPE 35654.

Brown, E.T(Editor).(1981) "Rock Characterization, Testing and Monitoring." ISRM Suggested Methods, pp.125-126, Oxford: Pergamon Press.

Dewan, John T.(1983). "Essential of Modern Open Hole Log interpretation." Pennwell Publishing Coompany, Tulsa , Oklahoma.

Domenico. S. N.(1984). "Rock Lithology and Porosity determination from Shear and Compressional Wave Velocity." Geophysics 49, 1188-1195.

Jituboh, C-.K., Sams, M.S., King, M.S. and Worthington, M.H., (1991). "Field studies of the anisotropic properties of sedimentary rocks." Abstracts Eur. Assoc. Exploration Geophysicists '54th Annual Meeting, Florence, pp.284-285.

Tixier M.P., Loveles G.W., and Anderson R.W. (1973). "Estimation of Formation Strength from The Mechanical Properties Log." Society of Petroleum Engineers 4532.

Tutuncu A.N., Sharma M.M (1992). "Relating Static and Ultrasonic Laboratory Measurements in Tight Gas Sands." SPE 24689, pp. 299-311

White, J.E., Martineau- Nicoletis, L. and Monash, C (1983), "Measured anisotropy in Pierre Shale." Geophys. Prosp, v.31, pp.709-725.

Winterstein, D.F., and Paulsson, G.N.P., (1991), "Velocity anisotropy in shale determined from crosshole seismic and vertical seismic profile data." Geophysics,v.55,pp.470-479

Raymer L.L., Hunt, E.R., and Gardner.J.S. (July 1980). "An Improved Sonic Transite Time-To Porosity Transform." SPWLA Twenty-Fist Annual Conference, 8-11

King M.S. , Khanshir M.S., and Worthington M.H.(Dec 1991). "Petrophysical Studies Of Core From A Cross-Hole Seismic Test Site." Royal School of Mines Imperial College of Science, Technology and Medicine, London SW 7 2BP, Presented of The Socienty Professional Well Log Analysts (SPWLA)"THAMES 1991", London 9-11.

Halmshaw, R(1987). "Non Destructive Well Testing." Edward Arnold London, England.

Marion Dominique P. and Pallerin Francois, M.(June 1994). "Acoustic Measurements on Cores as a Tool for Calibration and Quantitative Interpretation of Sonic Logs." SPE Formation Evaluation ,100-104.

Nation J.F. (June 1974). "Lithology and Porosity from Acoustic Shear and Compressional Wave Transite Time Relationship." SPWLA Fifteenth Annual Logging Symposium.