

# Correlation of seismic velocity and density of metasandstone from Kati Formation, Seri Iskandar, Perak, Malaysia

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**Abstract:** In this study, 17 metasandstone core samples from various depths in the CTW-1 Well at Seri Iskandar were used to measure the density and seismic velocity. P-wave and S-wave velocity is measured using Sonic S-X viewer while density is measured from ratio of core samples weight and volume. The density of core samples ranges from 2.43 g/cm<sup>3</sup> to 2.679 g/cm<sup>3</sup>. The P-wave velocity ranges from 2331 ms<sup>-1</sup> to 5133 ms<sup>-1</sup> while the S-wave velocity ranges from 1454 ms<sup>-1</sup> to 3050 ms<sup>-1</sup>. The R<sup>2</sup> value for velocity and density relationship is 0.86 and 0.67 for P-wave and S-wave respectively. Three velocity zones are classified based on the results obtained. The interpretation is supported with petrographic analysis. The results shows a strong correlation between metasandstone rock density when P-wave velocity and fair correlation to S-wave velocity. Since variation will always exist depending on the rock type, the equations only valid for particular test conditions.

**Keywords:** Seismic velocity, density, correlation, Kati Formation

## INTRODUCTION

Density is often estimated from seismic velocity using empirical relationship such as Gardner's equation (Miller & Stewart, 1974) when limited data is available. For the past few decades, a number of researchers have correlated seismic waves with density and found good relationship (Han *et al.*, 1986; Miller & Stewart, 1974; Nafet & Draket, 1957). Since then, numerous laboratory testing conducted to provide a low cost alternative but reliable in predicting density values. However, limited study had been done on sedimentary rocks in Malaysia to evaluate the relationship between their petrophysical properties and seismic velocities. The study conducted in Malaysia mainly focuses to correlate the physical and mechanical properties; uniaxial compressive strength, rock mass quality, of igneous and metamorphic rocks (Goh *et al.*, 2016, 2014).

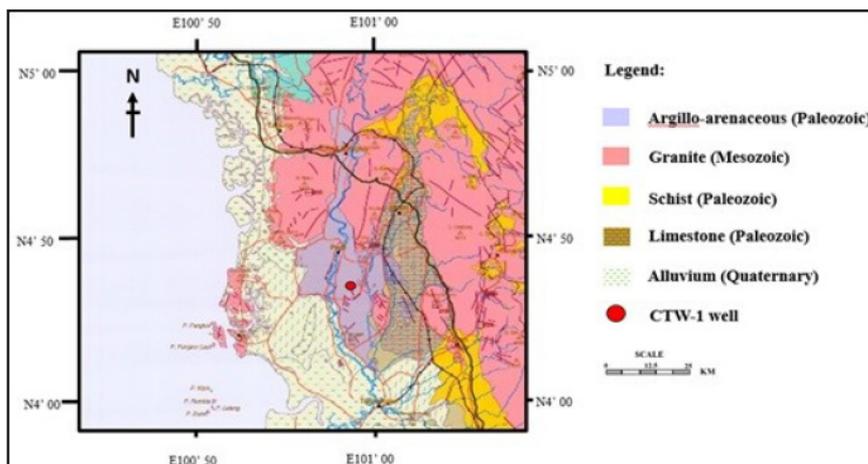
The metasandstone core samples used in this study were obtained from CTW-1 well, a vertical well drilled in UTP campus at Seri Iskandar and the lithology known as

Kati Formation. Located at the Western Belt of Peninsular Malaysia, the distribution of this formation in the western basin extended from the north to south Perak. Kati Formation, previously known as Kati Beds (Alkhali & Chow, 2014), is described as the formation that lies between the granites of Bintang and Kledang ranges (Foo, 1990). When Seri Iskandar area developed, more data became available. The location of this well is shown in Figure 1.

Since density log is absent from CTW-1 well, this study aims to provide a correlation, which derive from laboratory testing as low cost alternative to measure the rock density when P-wave velocity is available. This results will also improve the knowledge and understanding on Malaysian sedimentary rock properties.

## LITERATURE REVIEW

There were several factors that influenced the seismic velocity of rocks; i.e., rock type, texture, density, grain size and shape, porosity, anisotropy, water content, stress and



**Figure 1:** Map of the study area (modified from Mineral and Geosciences Department, 1985).

temperature (Kahraman, 2007). In the field acquisition, weathering/alteration zones, bedding planes and joint properties (roughness, filling material, water, dip and strike etc.) have an important influence on the seismic velocity (Kahraman, 2007).

Beside those factors, Nafe & Draket (1957) proposed velocity-depth relationship which comparing the depth effect on seismic velocity. Through hundreds of sample testing, Gardner *et al.* (1974) proposed velocity ( $V_p$ ) and density ( $\rho$ ) relationship for variety of lithology's which is approximately correct for clastic and carbonates rock which is  $\rho = .23V_p^{2.5}$ . Another empirical relationship correlating acoustic impedance and density proposed by Lindseth (1979) is define by the equation  $V_p = 0.308\rho V_p + 3460$ . Based on these literatures, it is practical that  $V_p$  and  $V_s$  are both dependent on density. Thus, this study will propose another relationship between  $V_p$  and density of metasandstone lithology.

**METHODOLOGY**

A total of 17 core samples were prepared for the velocity test and density measurement. The core were taken at various depth from CTW-1. Since the distribution of the lithology is not uniform throughout the well, the interval of sampling is not fixed as the study only utilized metasandstone core samples. To measure the velocity, high frequency ultrasonic velocity test is conducted using Sonic Viewer S-X equipment. This ultrasonic velocity test used a frequency of 200 kHz to determine the propagation of both P-wave and S-wave at atmospheric pressure (ambient condition). The core dimension for velocity measurement is 6.35cm±0.05cm diameter with 7.62cm±0.05cm height, followed the standard (ASTM D2845-69).

The end of core samples were flattened and polished to have a good acoustic coupling and maximize the propagation of wave from the transducer (Kahraman, 2007). Petroleum gel is rubbed on the flat surface of the core sample to allow wave to propagate through the rock sample. The time taken for the waves to travel from the transmitter to receiver is obtained to determine the wave velocity. The travel time is showed as the first arrival of propagated wave. P-wave and S-wave velocity measured and tabulated in Table 1.

The wave velocity calculated using the following equation:

$$\text{Velocity} = d \times t^{-1} \text{----- (1)}$$

where d is the height of the core sample and t is the first (peak) arrival time of the wave.

Density of the core sample were measured using the following equation:

$$\text{Density} = M \text{ (g)} / V \text{ (cm}^3\text{)} \text{----- (2)}$$

where M is the dry weight measured and V is the volume of the core sample. The volume calculated is average from three times caliper reading.

**RESULTS AND DISCUSSION**

The results of the density and P-wave velocity measured at atmospheric pressure of 17 core samples are tabulated in Table 1.

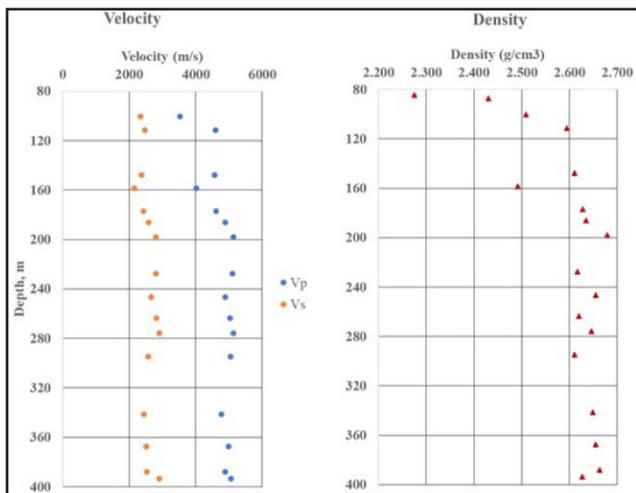
The density range obtained is between 2.43 g/cm<sup>3</sup> to 2.68 g/cm<sup>3</sup>. These density values are affected by many factors such as mineral content, pore space and saturation (Baiyegunhi *et al.*, 2014). In this experiment, the density is mainly affected by the mineralogy of the rock sample itself (Zainal *et al.*, 2012). For example, quartz mineral has density of 2.65 g/cm<sup>3</sup> and calcite is 2.72 g/cm<sup>3</sup>. The metasandstone samples are highly fractured but the fractures are sealed by silica and calcite cement. Hence, the samples has higher density values compare to typical sandstone. Presence of quartz and calcite veins are common and its provenance seems to be derived from the Kledang Granite and Kinta Valley Limestone.

Generally, the velocity values obtained follow the density trend as shown in Figure 2. The P-wave velocity measured have range from 2331 ms<sup>-1</sup> to 5133 ms<sup>-1</sup> while the S-wave velocity range from 1710 ms<sup>-1</sup> to 2906 ms<sup>-1</sup>. The range of velocity obtained is classified into three zonation as described in Table 2. Rafavich *et al.* (1984) indicate that  $V_p$  and  $V_s$  are influenced by rock porosity and rock density. The porosity range for the metasandstone core samples used in this study is 0.41– 1.06 %. The lower the porosity, the higher the density and velocity.

Zone 1 had the lowest velocity and density values as it is obtained from shallow section. Zone 2 shows a significant rise in velocity of the rocks. This indicate the lithological properties had changed. The velocity at this particular zone shows decrease in reading up to 4000 m/s at 158 m before rises to 4700 m/s at 177 m. This anomaly is caused by the presences of shear zone. This might be related to the tectonic event or compressional effect probably due to compressional event or tectonic activity in the late Triassic

**Table 1:** Density and velocity measurement.

No	Depth (m)	Density (g/cm <sup>3</sup> )	Average Vp (m/s)	Average Vs (m/s)
1	87.42	2.43	2968	1845
2	100.3	2.51	3526	2337
3	111.4	2.59	4597	2466
4	147.9	2.61	4572	2364
5	158.43	2.49	4022	2148
6	177	2.63	4617	2432
7	186	2.64	4887	2587
8	197.94	2.68	5133	2808
9	227.77	2.62	5106	2804
10	246.5	2.65	4880	2664
11	263.6	2.62	5034	2818
12	275.95	2.65	5136	2906
13	294.7	2.61	5046	2566
14	341.5	2.65	4770	2442
15	367.5	2.66	4987	2515
16	387.95	2.66	4893	2528
17	393.63	2.63	5066	2901



**Figure 2:** Seismic velocity and density values in respond to depth at different depth.

**Table 2:** Classification of velocity zone.

Zone	Range of depth, m	Range of velocity, m/s	Lithology
1	80 – 100	2000 – 4000	Sandstone
2	100 – 180	4000 – 4700	Metasandstone
3	180 – 400	4700 – 5200	Metasandstone

when Sibumasu collided with East Malaysia (Alkhali & Chow, 2014).

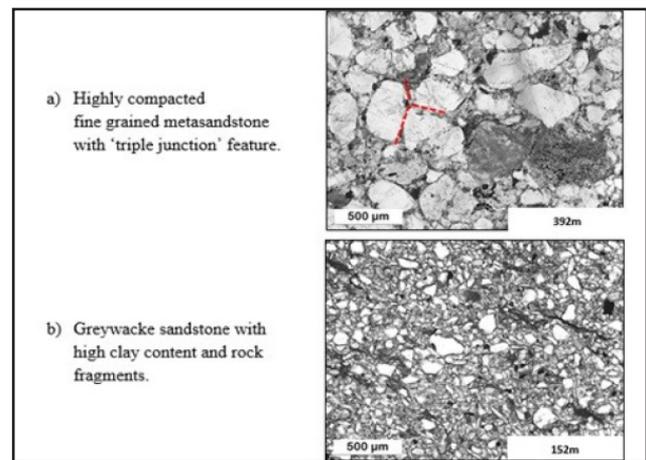
Thin section image obtained at zone 2 presented at Figure 3b shows the rock had high clay content and rock fragments. Han *et al.* (1986) stated that clay content will cause reduction in velocity. Hence, the lower reading of velocity might cause by the higher percentage of lithic of the rock samples. This also reduced the pore spaces between the grains and resulted in very low porosity values.

Zone 3 shows more consistent velocity and density values. A low porosity values indicate a tight sandstone which has been compacted and metamorphosed. Figure 3a shows 'triple junction' features or known as *granoblastic* which a common micro-texture in low grade metamorphism (Nockolds *et al.*, 1978). This confirm that the metamorphism had taken place and the effect on Kati Formation reach up until 100m from the surface.

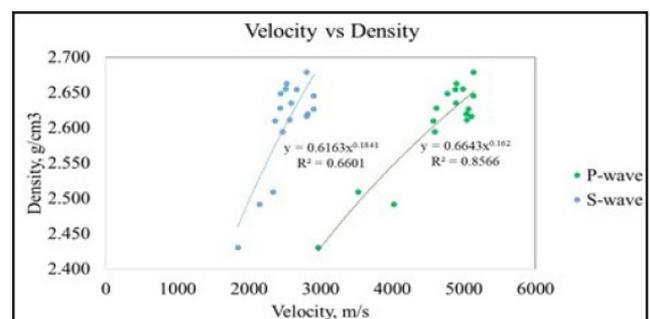
Figure 4 shows the empirical relationship between density and seismic velocity for the Kati Formation core samples. P-wave shows good correlation with density as the regression value is higher compare to S-wave. The results shows a strong correlation only between density and P-wave velocity, which can be used as an alternative to measure the metasandstone rock density when seismic well data is available.

## CONCLUSION

In conclusion, the study successfully achieved the objective to establish a new correlation between P-wave velocity and density using sedimentary rock samples. There



**Figure 3:** Thin section at two different zone.



**Figure 4:** Seismic velocity and density relationship.

are three different velocity zones identified in this study. Zone 1 had lowest density and velocity reading while Zone 2 shows higher values and interpreted as shear zone. Zone 3 show more consistent measurement for both properties. The velocity measured from all samples is higher compared to typical sedimentary rock due as the rock had undergone low grade metamorphism. The samples are highly compacted and had very low porosity values. Empirical relationship between density and seismic velocity shows  $R^2$  values 0.86 and 0.67 respectively for P-wave and S-wave.

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