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Preliminary view of geotechnical properties of soft rocks of Semanggol formation at Pokok Sena, Kedah

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Abstract. The research was inspired by series of geological studies on Semanggol formation found exposed at North Perak, South Kedah and North Kedah. The chert unit comprised interbedded chert-shale rocks are the main lithologies sampled in a small-scale outcrop of Pokok Sena area. Black shale materials were also observed associated with these sedimentary rocks. The well-known characteristics of shale that may swell when absorb water and leave shrinkage when dried make the formation weaker when load is applied on it. The presence of organic materials may worsen the condition apart from the other factors such as the history of geological processes and depositional environment. Thus, this research is important to find the preliminary relations of the geotechnical properties of soft rocks and the geological reasoning behind it. Series of basic soil tests and 1-D compression tests were carried out to obtain the soil parameters. The results obtained gave some preliminary insight to mechanical behaviour of these two samples. The black shale and weathered interbedded chert-shale were classified as sandy-clayey-SILT and clayey-silty-SAND respectively. The range of specific gravity of black shale and interbedded chert/shale 2.3 – 2.6 and fall in the common range of shale and chert specific gravity value. In terms of degree of plasticity, the interbedded chert/shale samples exhibit higher plastic degree compared to the black shale samples. Results from oedometer tests showed that black shale samples had higher overburden pressure (Pc) throughout its lifetime compare to weathered interbedded chert-shale, however the compression index (Cc) of black shale were 0.15 – 0.185 which was higher than that found in interbedded chert-shale. The geotechnical properties of these two samples were explained in correlation with their provenance and their history of geological processes involved which predominantly dictated the mechanical behaviour of these two samples.

1. Introduction

Soft rock geology is a general term to describe the study of sedimentary rocks and the way they were being transported and deposited. Soft rocks basically referring to sandstones, mudstones, shale, greywacke or sedimentary rocks that are generally softer than igneous and metamorphic rocks with classified medium to fine grained size. Many concepts of soft rock were introduced either in geological or engineering soft rocks [1]. In general, soft rocks are critical geomaterials due to their characteristics such as low strength, disaggregation, crumbling, high plasticity, slaking, fast weathering and many others [2]. These characteristics induce some problems in engineering constructions [3], residential buildings [4] as well as wellbore instability and shale formation collapse during drilling activities in oil and gas industry [5].

There are many common geological factors associated with the soft rocks engineering problems such as the presence of the structural geology (fractures) and organic materials, different weathering rates and variability of strength between the fresh and weathered rocks which in some cases they are too soft to be tested in rock mechanics equipment and too hard for soil mechanics equipment [6,7]. In the latest research, the heterogeneity of the soft rocks, the geological processes and the depositional environment history are increasing in concern when interpreting their geotechnical properties. The heterogeneity in the rock physical characteristics such as the fissile and flaky texture in shale, the swelling and shrinkage behaviour associated with water contents [8], cementation in sandstone that tends to weakening when poorly cemented and increasing in hardness when well cemented indicate variability of unconsolidated soils or intact soils produced from these soft rocks. Furthermore, heterogeneity in the sedimentary layers such as the alternating of coarse-grained and fine-grained layers also contributing to the results of wide range of grain size distribution values and different variability in the amount of silts and clays that may be produced. The different history of the geological processes and the depositional environment, mean that they cannot easily be interpreted solely based on the geotechnical properties values that obtained from the laboratory analysis indeed, the correlation between these qualitative and quantitative analysis are important to improved understanding of the behaviours of these soft rocks.

1.1 Objectives

The main objectives of this study are to investigate the geotechnical properties of the weathered soft rock from Semanggol formation, and correlate the geotechnical properties of the soil samples to the geological processes and depositional history.

1.2 Study area and geological settings

The study area for this research is located at the Pokok Sena, Kedah that mainly overlain by series of sedimentary rocks named after Semanggol formation. This outcrop is selected due to the geological history and basin activities that produce variability in soil heterogeneity. There were 10 samples collected consist of five black shale and weathered rock of interbedded chert-shale samples respectively. All the samples were taken from outcrop 7 of Pokok Sena, Kedah as shown in Figure 1. This outcrop represents a preliminary result from a small-scale sampling area of 10 meters^2 compared to the widely distributed Semanggol formation (Figure 2) that lies from the North Perak, South and North of Kedah [9].

The complexity of the depositional environment and the geological history of the Semanggol formation are interesting that the Semanggol formation can be divided into three main units which are the chert unit of interbedded chert and shale, the rythmite unit of sandstone and shale and lastly the youngest unit of conglomerate. Based on fossil radiolarians studies, it is first assumed that the chert unit is the oldest unit [10], but new discovery by Basir Jasin [11] determining that the Chert unit is actually interfingering with the rythmite and conglomerate units. During the geological age of Middle to Late Triassic, the Chert unit was suggested to be deposited in a deep marine environment possibly in an anoxic basin and the overlying units on top of Chert unit are possibly in a transition to a shallower water environment [12]. Despite the series of different lithologies that presence in the Pokok Sena area Kedah, the occurrences of organic black material also observed in the shale rock of the chert unit. The organic materials in hypothesis are resulted from the remnants of oceanic crust from the subduction geological event that leading to the formation of foredeep basin in the North-West Peninsula Malaysia [13]. The oceanic crust may contain biogenous and microorganism that becomes the source of the organic compounds that later associated with shale of the chert unit.

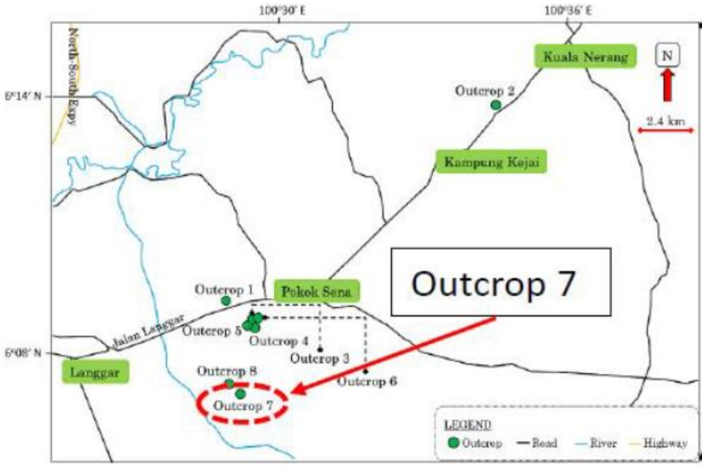

Figure 1: Location of samples located at Outcrop 7. Modified from Khattab et. al, [14].

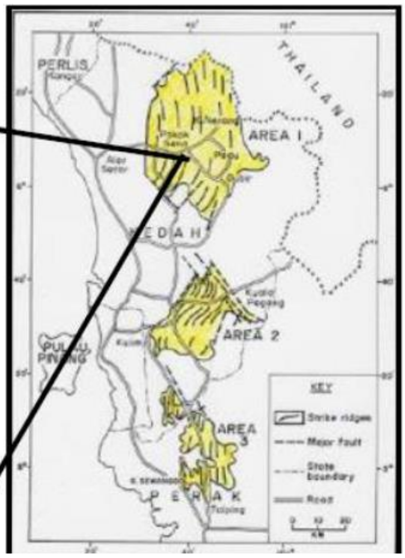

Figure 2: The distribution of Semanggol formation at North Perak, South Kedah and North Kedah modified after Burton [10].

Figure 3: Locations of B1-B5 and W1-W5 samples located at Outcrop 7.

2. Materials used

Basic and engineering soil tests were conducted on the black shale samples according to BS: 1337-2: 1990 to determine the geotechnical properties of the black shale samples.

2.1 Sample material

Five black shale and weathered interbedded chert-shale samples, marked as B1-B5 and W1-W5 respectively, from different locations in Outcrop 7 shown in Figures 1 and 3 were collected and prepared for some basic geotechnical tests. The disturbed outcrop samples were then being broken into small grains by using light weight hammer, and oven dried. For all soil compression tests, the samples were first compacted and the optimum moisture contents corresponded to the highest dry unit density obtained prior to this test were used to reconstitute the samples. The range of water contents for remoulding the black shale and weathered interbedded chert-shale were 18-22% and 20-21%, respectively. The highest dry unit weight for the black shale and weathered interbedded chert-shale were in the range of 1.59 to

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1.67 Mg/m^3 and 1.64 to 1.72 Mg/m^3 respectively. The initial void ratios of the black shale and weathered interbedded chert-shale samples were kept as similar possible.

2.2 Basic index property testing
Geotechnical basic tests such as moisture content, specific gravity, particle size distribution, Energy-disperse X-ray spectroscopy (EDS) and Liquid and Plastic limits were conducted.

2.3 Compression test
All samples were prepared with saturated cylindrical samples of 76 mm x 38 mm in dimension. The samples were loaded to 400 kPa, and unloaded to 200 kPa, before loaded it back up to 6400 kPa. The samples were tested immediately after the compaction test was carried out to eliminate the effect of aging on the reconstituted samples.

3. Results and discussions

3.1 Basic Index property analysis

3.*1.1 Particle size distribution test (PSD).* The black shales consisted of sand, silt and clay particles ranging from 22 – 36 %, 37 – 55 % and 23 – 29 %, respectively. This indicated that the black shale samples were shale predominant and can be classified as sandy-clayey-SILT. For the weathered interbedded chert-shale samples, the sand, silt and clay particles were ranged from 45 – 56 %, 15-32 % and 18 – 29 %, respectively. The interbedded chert/shale samples are classified as clayey-silty-SAND, where more than 45 % of the samples were predominated by sand. The breakdown of the percentage of the grain particles of each sample is shown in table 1 below.

Table 1. Particle grain classification of black shale and weathered interbedded chert-shale samples.

	Percentage (%)		
Sample	Sand	Silt	Clay
B1	22	54	24
B2	22	55	23
B3	34	37	29
B4	29	42	29
B5	36	39	25
W1	45	32	23
W2	48	31	21
W3	53	29	18
W4	56	15	29
W5	45	31	24

3.1.2 Basic property analysis. Table 2 shows the summary of the black shale and interbedded chert/shale properties. The moisture content of the shale was in the range of 16.45 – 20 %, whereas for interbedded chert/shale samples, the moisture contents range were smaller (10.5 – 14.6 %). The specific gravity for both black shale and interbedded chert/shale samples were in between of 2.3 to 2.6. The values for plastic and liquid limits, plasticity index ranges were also given in the Table 2 below and thus from the plasticity chart using BS 5930:1999, the black shale was categorized in between of CL and CI, as having the degree of plasticity from low to intermediate. As for weathered interbedded chert-shale samples, they can be classified as having intermediate to high degree of plasticity.

Table 2. Black shale and weathered interbedded chert-shale properties.

Sample	Moisture content (%)	Specific Gravity (Gs)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)
B1	20.1	2.52	24.5	35.8	11.3
B2	19.2	2.46	25.7	37.7	11.97
B3	15.3	2.47	24.4	33.3	8.9
B4	17.4	2.39	23.6	37.1	13.5
B5	16.5	2.3	20.5	34.8	14.31
W1	14.62	2.34	24.69	36.3	11.61
W2	14.23	2.38	24.07	36.7	12.63
W3	10.50	2.47	20.81	47.0	26.19
W4	14.66	2.54	19.56	52.5	32.94
W5	15.94	2.57	23.35	35.2	11.85

*3.1.3 Energy-disperse X-ray spectroscopy (EDS).*An example of an EDS results for black shale and interbedded chert/shale samples are shown in Table 3. The elements presented in black shale were mostly Silica, Oxide and Aluminium which were the major elements comprising 60%, whereas for interbedded chert/shale sample, elements like Oxide and Strontium were the major constituents making up of 73.7 %. Strontium element found in the sample supported the provenance of the formation of this deep water geological deposition environment. Although chert was a predominant material in the weathered interbedded chert/shale sample, the Silica element gave small reading of 6.5 %. This result contradicted the amount of sand percentage which found abundant in this sample. This may be due to random picked of element point locations during EDS test.

Table 3. EDS data for Black (B1) and weathered interbedded chert-shale (W2).

Sample	Element Symbol	Element Name	Percentage (%)
B1	Si	Silica	30.8
	O	Oxide	52.4
	Al	Aluminium	8.6
	K	Potassium	2.5
	C	Carbon	5.7
W2	O	Oxide	40.3
	Sr	Strontium	33.4
	F	Fluoride	11.8
	Si	Silica	6.5
	Al	Aluminium	4.6
	C	Carbon	2.5
	K	Kalium	0.9

3.2 Oedometer analysis

3.2.1 Compression curves. The compression curves for both black shale and interbedded chert/shale samples were plotted in figure 4. The preconsolidation pressure, Pc, as tabulated in table 4 for black shale samples were in between of 270-300 kPa while weathered interbedded chert-shale samples were 200-220 kPa. This indicated that the black shale samples had undergone higher overburden pressures throughout its formation lifetime in comparison with interbedded chert/shale. The compression index, Cc for black shale and interbedded chert-shale samples were found to be ranging from 0.15-0.19 and 0.12-0.15, respectively. Although interbedded chert-shale samples were having slightly lower Cc than black shale, this low compressibility behaviour is probably owing to the silica materials composing the chert fabric, whereas the black shale was composed mainly by shale and clayey materials. As for the swelling index property, Cs for both materials, the Cs values were of similar range. This perhaps of the presence of sands in both samples were not consistent, hence the pattern of Cs could not be concluded.

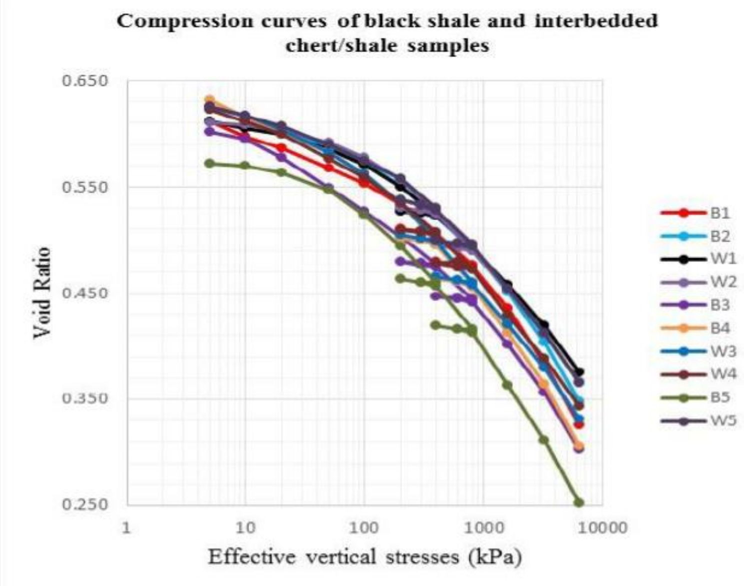

Figure 4. Compression curves for black shale and weathered interbedded chert-shale samples.

Table 4. Compression properties of black shale and weathered interbedded chert-shale samples.

Sample	Initial void ratio (e_o)	Preconsolidation Pressure (Pc) kPa	Compression index (Cc)	Swelling index (Cs)
B1	0.59	270	0.175	0.011
B2	0.60	300	0.15	0.013
B3	0.61	300	0.16	0.009
B4	0.63	290	0.185	0.014
B5	0.58	270	0.175	0.01
W1	0.61	220	0.12	0.01
W2	0.61	200	0.13	0.012
W3	0.63	200	0.135	0.015
W4	0.62	220	0.15	0.013
W5	0.63	210	0.13	0.012

4. Conclusion

The preliminary insight of geotechnical properties of both black shale and interbedded chert/shale samples were obtained and although these two samples were found close to each other, they have slightly different geotechnical properties. This may be due to owing to their provenance and depositional processes involved during the formation of these layers, where the chert unit predominantly deep-water environment whereas the black shale may belong to the different sedimentation processes environment of transitional zone between deep water to shallow marine environment. Although the chert unit was reported the oldest unit in the Semanggol formation area, however Basir Jasin [7], reported that the chert unit was interfingering with the rythmite and conglomerate units (black shale). Therefore, the formation of chert and black shale at this area probably happened at the same time, thus the geotechnical properties of these materials were not consistent. Therefore, it shows that the understanding of the depositional processes involved during the formation of these layers would help in evaluating the preliminary geotechnical properties of these layers at Outcrop 7.

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