Compression Behaviour of Black Shale and Weathered Chert in Pokok Sena, Kedah

by

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Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD BADRULNIZAM BIN KAMALRUZZAMAN

ABSTRACT

Oedometer test and some basic geotechnical test were conducted to understand the compression behaviour of black shale and weathered chert in Pokok Sena, Kedah. The research had been inspired by series of geologist studies on Semanggol Formation which were found expose at North Perak, South Kedah and North Kedah. The study of Semanggol Formation is still lack of information thus it push engineer to study into a new field of study, geotechnical, to understand the relation between geological properties and geotechnical properties of Semanggol Formation. 5 black shale and 5 weathered chert samples were taken from the studied area and undergo into some laboratory tests. The tests were conducted to determine the moisture content, specific gravity, Atterberg limit, particle size distribution, highest dry density and compression behaviour under 1 dimensional vertical stress. The result obtain conclude that black shale and weathered chert are clayey SILT and silty SAND respectively. Range of specific gravity of black shale and weathered chert were 2.29 – 2.52 and 2.34 – 2.57 respectively. Plasticity index of black shale and weathered chert were found in range of 8.91 – 14.31% and 11.61 – 32.94% respectively. Result from oedometer test indicates that black shale had higher overburden pressure (P_c) throughout lifetime compare to weathered chert. Compression index (C_c) of black shale were 0.15 – 0.185 which is higher than weathered chert. This indicates that black shale has high compressibility that weathered chert. The weathered chert swelling index were 0.010 – 0.015 which were higher than black shale. The swelling index were influenced by clay mineral content like montomorillonite and kiolinite in weathered chert. Thus, content of clay mineral allow the soil to absorb water and swell more than black shale.

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Last but not least, great appreciation to my parents and individuals who always cheers and assist me during accomplishing this project. Without their assist, the author may not able to finish this project. May Allah SWT grand their kindness.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

1.1 Background of Study

There were series of investigations were conducted by geologist to study the Semanggol Formation located at North Kedah, South of Kedah and North of Perak. Semanggol Formation is a group of sedimentary rock which believed formed in one deep ocean basin million years ago. This formation had been introduced by Alexander (1969) as Semanggol Formation since it initially found at Semanggol, North of Perak. Later, Burton (1970) found Semanggol Formation located in North of Perak, South of Kedah, and North of Kedah (Figure 1.1). Series of investigation had been conducted among geologist to deeply understand the geological properties of Semanggol Formation.

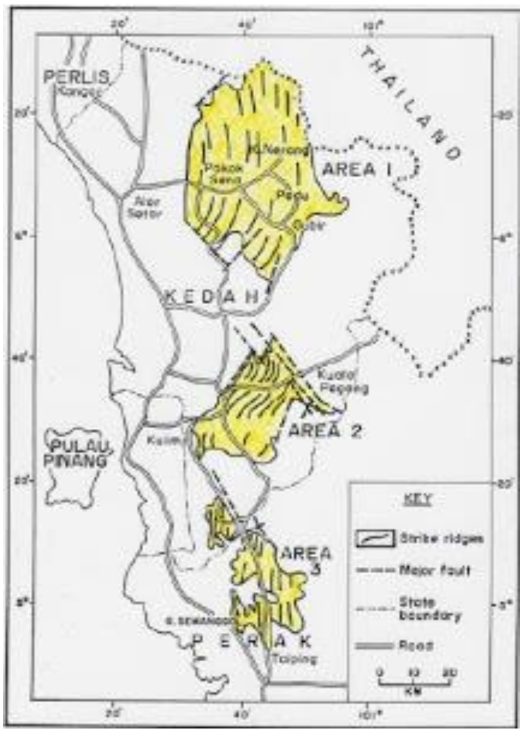


Figure 1-1: Semanggol Formation (Burton, 1970).

Thus, this final year project title was proposed as a step closer to understand the Semanggol Formation. 10 samples consist of 5 black shale and 5 weathered chert had been taken from outcrop 7 of Pokok Sena, Kedah located as shown in figure 1-2.

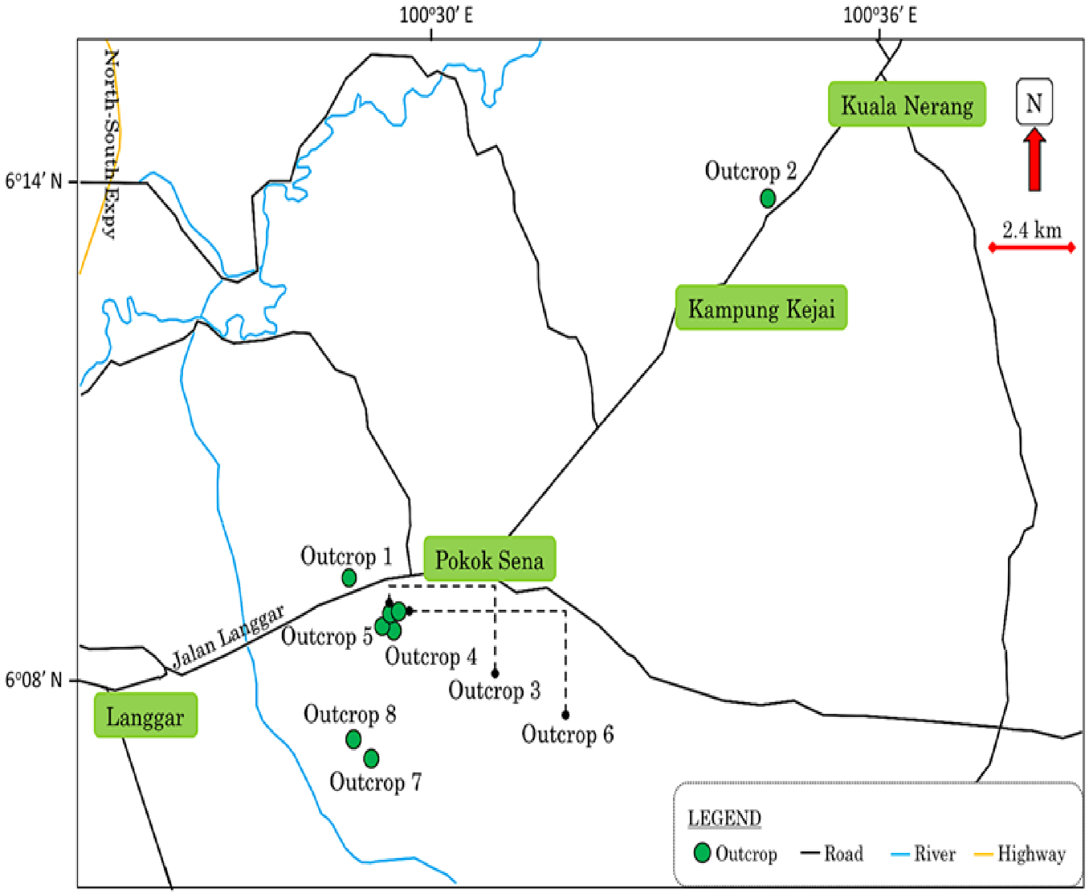


Figure 1-2: location of samples located at Outcrop 7. (Khattab et. al, 2016)

Samples taken was undergo several geotechnical test such as moisture content, Atterberg limit, specific gravity, particle size distribution test and oedometer test to understand the relation between the geotechnical and geological properties of black shale and weathered chert in term of compression behaviour.

1.2 Problem Statement

Malaysia is still lack of soil or rock data. Research and fieldwork is demand to understand more on the Semanggol Formation. Outcrop 7 is only one of hundreds of sections that had been separated by the geologist. To understand the geotechnical properties, it takes lot of research and geotechnical test to be carried at other sections. Formation of weathered chert together with black shale was found at Outcrop 7. There are problems that had been reported in medium of journal or article by engineers regarding shale in term of geotechnical properties. Shale is well known by its swelling behaviour due to presence of water. As reported by Abdullah (1997), expansive shale will lead to destruction to small structure such as residential buildings, sidewalks and pavements in Middle East. Activities like boring and fracturing to get oil and gas either onshore or offshore area also face problems with shale formation. Shale formation may lead to wellbore instability and shale formation collapse (Qiao et al., 2014). The formation chert and shale at outcrop 7 may lead to differential settlement and cause fracture to the light structures. The location will be developed in the future thus precaution has to be taken to treat the soil properly. Thus, this research is required to understand more on Outcrop 7 compression behaviour.

1.3 Objectives

There are several objectives can be expected to achieve for this project. The main objectives of this study are:-

- To investigate the one dimensional compression behaviour of black shale under several vertical stresses.
- To investigate the one dimensional compression behaviour of weathered chert under several vertical stresses.

1.4 Scope of study

Under scope of compressibility of soil, oedometer test is our main discussion to understand the compression behaviour of samples. The discussion will be on the consolidation and swelling behaviour based on the strain: stress graph and void ratio: stress graph. To achieve these graphs, compaction test had been conducted to get the moisture content which gives the highest soil dry density. The highest dry density of sample is taken as initial moisture content to remould the sample before conducting oedometer test. The results of oedometer test will present some of important parameters of compression behaviour such as initial void ratio (e_0), preconsolidation pressure (*Pc*), compression index (*Cc*) and swelling index (*Cs*).

CHAPTER 2

LITERATURE REVIEW

2.0 Literature Review

2.1 Semanggol Formation

Alexander 1959 had introduced the Semanggol Formation exposed initially at Semanggol, range in North Perak. After series of investigation by numerous geologist, the Semanggol Formation is found widely exposed in north of Perak, south of Kedah and north of Kedah. The formation consist of variety of sedimentary rock formations which believed was deposited in the same basin by million years ago. Burton (1973) and Ibrahim Abdullah et al. (1989), separated the three areas by wrench fault exposed. Burton (1973) also divided the formation into three informal members. The majority rock expose at the area is called as 'member'. Semanggol Formation consist of three members namely as the chert member, the rhythmite member and the conglomerate member which were later is called as units rather than members by Teoh (1992). Ahmad Jantan et al., 1989) interpreted the three units to be in lateral and interfingering contact (Figure 2-1).

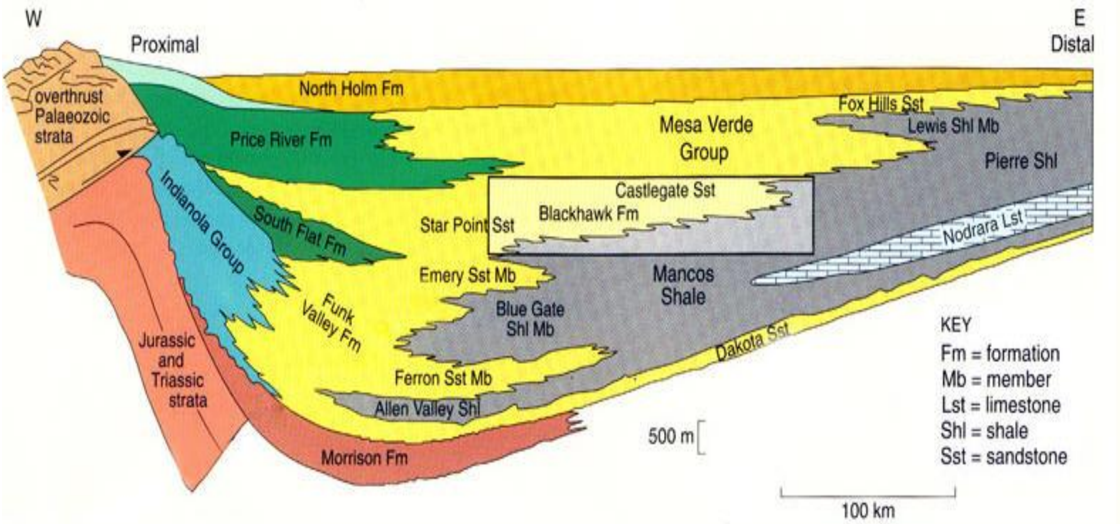


Figure 2-1: Example of interfingering contact of rock layering.

He also conducted survey on the lateral facies variation of rocks rather than in sequential superposition as have previously been reported. Based on sea continental surface (Figure 2-2), he classified the location formation for each units. He reported that the chert unit was deposited in a basin environment, the rhythmite unit was deposited in distal submarine fan and the conglomerate unit was deposited in a proximal submarine fan. The formation was folded and faulted and form them interfingering between each other. The age of the Semanggol Formation was previously assigned as Triassic based on the occurrence Bivalvia (Burton, 1973) and was later changed to Early Permian to Triassic (Basir Jasin, 1996, 1997). Outcrop 7 located at Pokok Sena is under chert unit whereas chert was widely found in this area. Somehow, black shale was exposed within the chert formation at different surface locations (Figure 2-3).

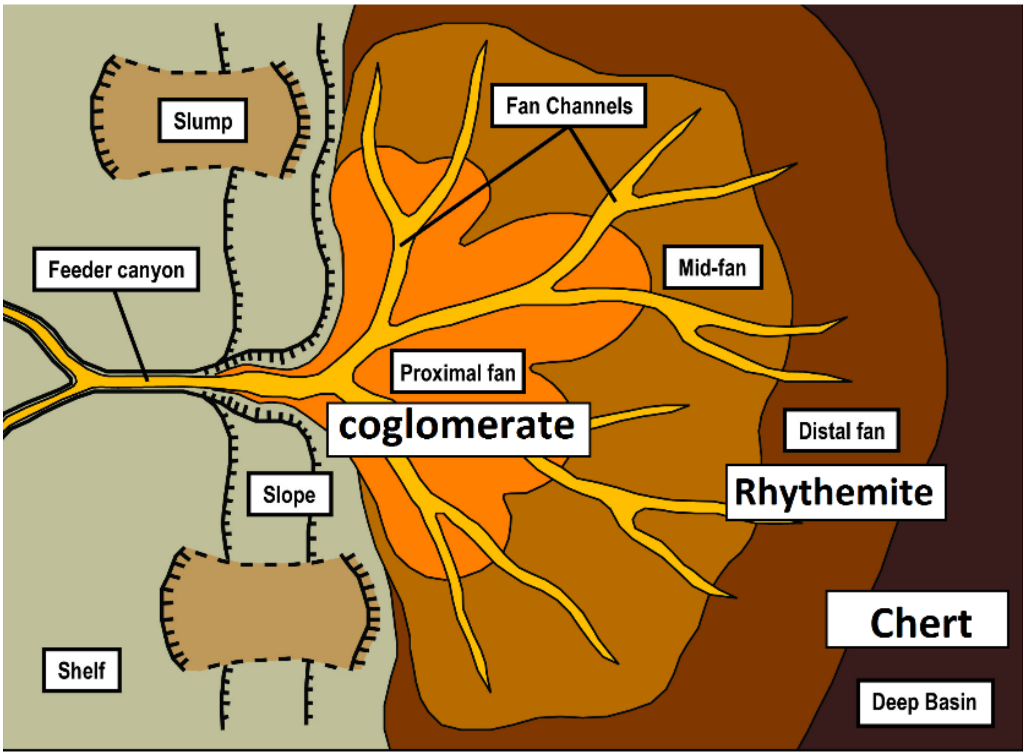


Figure 2-2: location formation of conglomerate, rhythemite and chert.

Figure 2-3: Outcrop 7 location. (Khattab et al., 2016)

2.2 Chert

Chert was made up of microcrystalline or cryptocrystalline and Mudrock. The microcrystalline was contain of silicon dioxide ($SiO2$) and deposition of microorganism like radiolarian (plankton), settle under deep ocean basin. These organisms had a glassy silica skeleton and when these organisms die, their silica skeletons settled to the bottom, dissolved, recrystallized, and might became part of a chert nodule or chert layer. The formation of chert also laminated due to very slow current of water (Figure 2-4). Chert was formed by a well lithification process which allowed a proper cementation and low void ratio when it form into rock. It occurs as nodules, concretionary masses, and as layered deposited. Once weathering process took place on chert rocks, it weathered with a conchoidal fracture, often producing very sharp edges. The radiolarian in chert unit of Semanggol Formation area was studied by numerous geologist. Three biozones were identified by Shashida et al.

(1995) from the chert unit of the Semanggol Formation while five radiolarian zones were identified by Spiller (2002). Moreover, nine biozones were recorded by Basir Jasin et al. (2005a, 2005b) from one locality at Bukit Kukus in the vicinity of Kuala Ketil, south Kedah. The zones were recognized from ten different location in south and north Kedah. Chert formed and consist of microcrystalline is considered as biological sedimentary rock.

Figure 2-4: Chert.

2.3 Shale and Black Shale

Shale is a fine-grained size of sedimentary rock that was formed from the compaction of silt and clay size mineral particles that is commonly call "mud". This contaminant categorized shale as “mudstones”. Shale rock physical characteristic is fissile and laminated (Figure 2.5). Shale rock was laminated when clay was deposited in slow current of bed ocean which allow shale to form in laminated layers. Shale is fissile means the rock is already splits into thin pieces along the lamination. The weathering of shale rock produce sharp and flaky pieces. The product of shale can be found in various colours of black, brown, grey, green, and red. The black colour of shale indicates the presence of organic matter (Harry A. T., 1979). He added, 1 – 2% of carbon may turn the shale colour into black (Figure 2-6). Reported by Dittrick (2013), shale is the most abundant and common sedimentary rock found in worldwide and the organic debris present in black shale makes their appearance in black colour and candidates for oil and gas generation.

Figure 2-5: Shale formation.

Figure 2-6: Black shale.

2.4 Shale Compression Behaviour

Shale is known by its natural characteristic which make it unique among the other sedimentary rock. Typically, the compression behaviour of a natural sedimentary rock results to be significantly different from the behaviour of remoulded samples. The difference is due to the effect of the rock structure developed during their burial history (e.g., Burland, 1990). High pressure and temperature are two factors that contribute to influence the structure developed in samples. Due to high stress of burial depth and proper lithification process, shale were consolidated and strengthened contributes shale structure formation become strong in diagenetic bond. Moreover, mineralogical and chemical processes also impact the geomechanical properties of shales to a considerable degree, causing a significant enhance in strength and brittleness and decreasing their porosity. The phenomena of diagenesis process is suspected influencing the hydro-mechanical behaviour of shale.

William (2005) studied the compression behaviour of remoulded sample of Bringelly shale and compared the results with behaviour of instact samples. The investigation report that there are relatively minor influence of diagenesis when the remoulded samples were compressed to the same density as the intact sample. The difference in compression index between the natural and remoulded specimens was small to indicate that very little cementation due to diagenesis effect was present (William and Airey, 2009). However, Nygård et al. (2004) who investigated the impact of diagenesis on the compaction behaviour of Kimmeridge clay and Kimmeridge Clay shale have different results. The comparison between the hydro-mechanical response of the remoulded material and that of the natural shale, allowed the authors to draw the conclusion that diagenesis process has a significant impact to compression behaviour, since the mechanical compaction alone could not explain how much lower are the porosity, compressibility and permeability of the natural shale with respect to the remoulded sample. Extending the discussion of factors affecting the compaction behaviour, another test carried by Favero F. (2015) on Opalinus shale. The mechanism of porosity reduction can be schematized as shown in Figure 2-7 and 2-8.

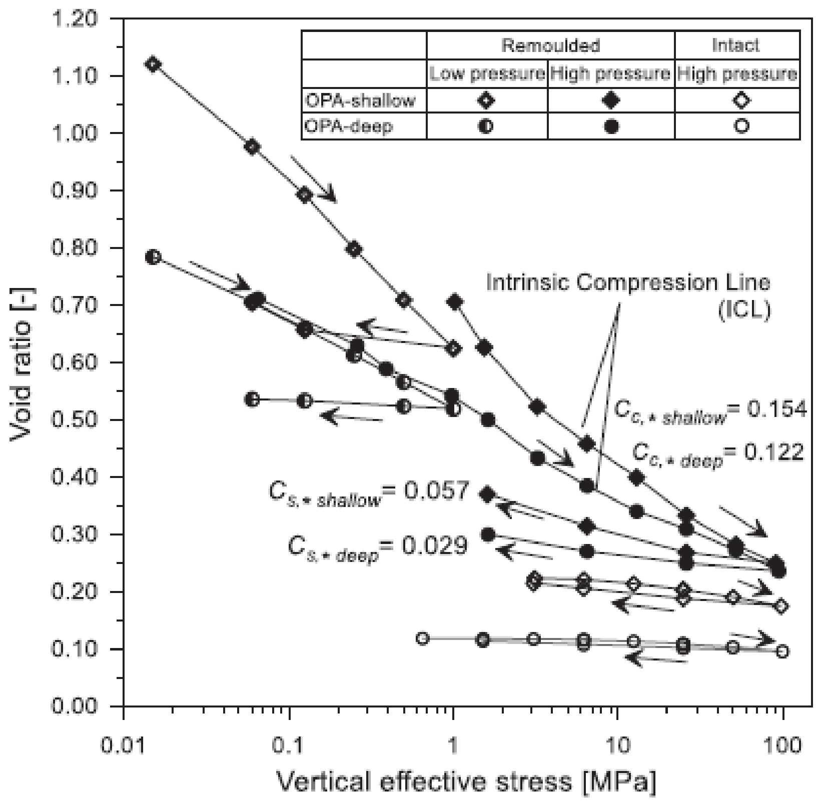


Figure 2-7: Oedometer test result define from opacilus deep (OPA-deep), Opacilus shallow (OPA-shallow) and remoulded Opacilus sample (Favero F, 2015).

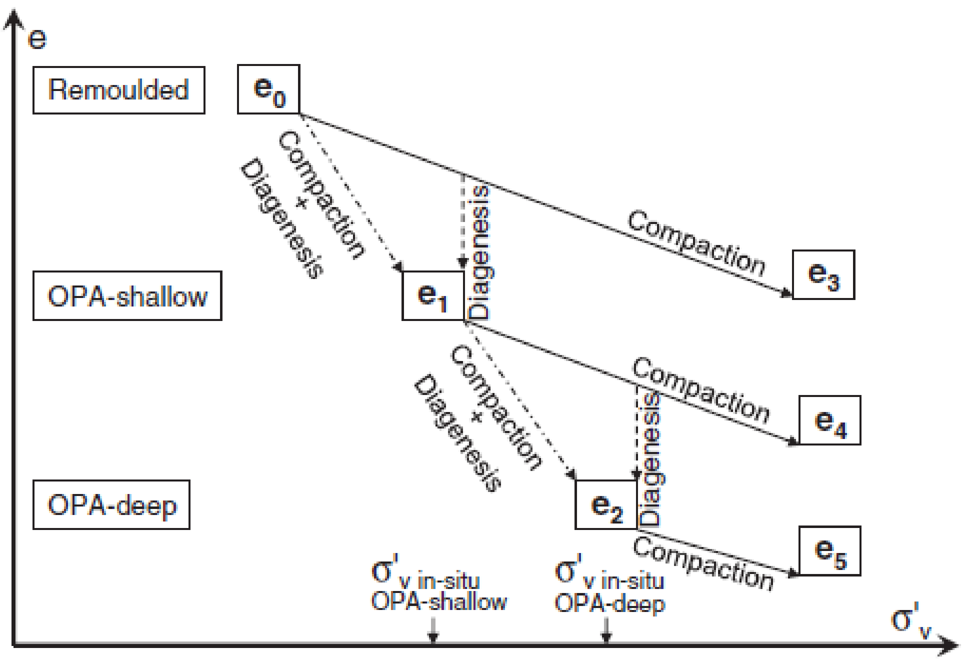


Figure 2-8: Simplified result from Figure 2-7 (Favero F., 2015).

Based on Favero F. (2015), Figure 2.8 is actually representing the Figure 2.7. When remoulded Opalinus Clay is compacted at the in-situ vertical effective stress, its initial void ratio, e_0 reduces to e_3 and give a same pattern and compression index for e_2 to e_5 and e_3 to e_6 for Opalinus Shallow and Opalinus Deep resepectively. The results shows that increment of the vertical effective stresses were responsible for the reduction of porosity and the variation of the void ratio is likely to be related to diagenetic phenomena. The OPA-shallow and OPA-deep manifested the diagenetic process whereas when the OPA-shallow was brought to a vertical stress close to the pressure carried by e_2 observed for the OPA-deep, the void ratio is still considerably bigger. The observed results confirm that mechanical compaction at this high stress is not enough to attain the same void ratio for the three materials. Therefore, the observed lower porosity values of the intact materials with respect to the remoulded one (e_4 and e_5: e_3 in Fig. 2-8) are to be related to the diagenetic effects.

In the other hand, the study of compression behaviour also includes the study on the swelling behaviour. Shale are known by its ability to absorb water. The composite clay mineral in shale are the factor contribute in absorbing water and contain high amount of water. The change in moisture content during swelling is usually accompanied by a change in shale volume which can be as much as several percent. These shales are called "expansive soils." The soil will swell when it contact with water and living shringkage when it dried. Due to this effects, buildings, roads, utility lines, or other structures constructed on this soil can be damaged and fractured due to instable lifting and settling of the soil formation.

During early 90's, widespread rumours regarding problematic expansive shale which lead to destruction to residential buildings, sidewalks and pavements in various parts of the middle region of Saudi Arabia (Abdullah, 1997). According to Muawia A. Dafalla and Mosleh A. Al-Shamrani (2014) who studied on Tayma expansive shale, the swelling of expansive shale is not influence by the moisture content but influence by the dry density of the expansive shale. Result as shown in Figure 2-9 and 2-10 were taken by conducting oedometer test on 4 sample with different moisture content and four samples with different dry density. As conclusion written by author, expensive shale is swell due to high dry density of shale and presence of water, hydrogen peroxide or brine water.

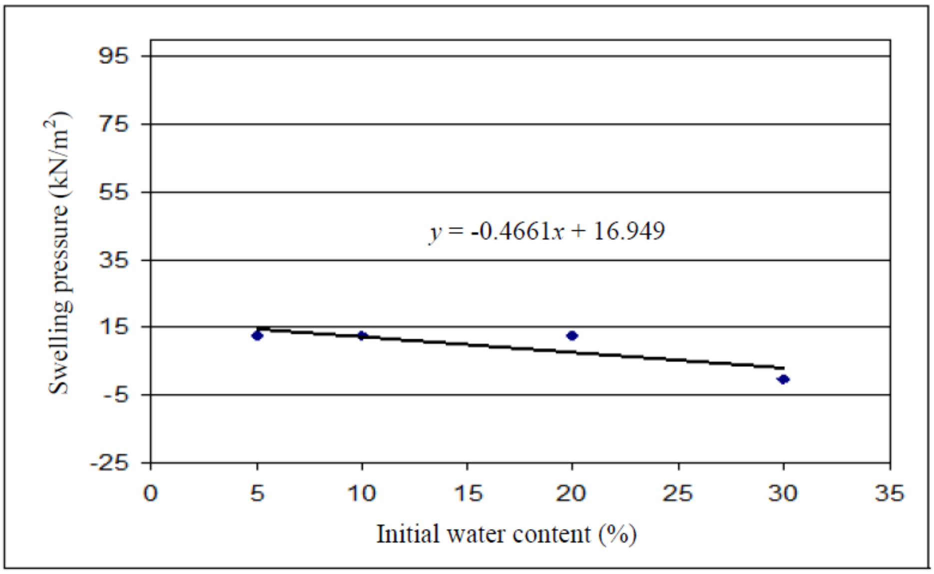


Figure 2-9: Tayma shale swelling pressure against different moisture content (Dafalla and Al-Shamrani, 2014).

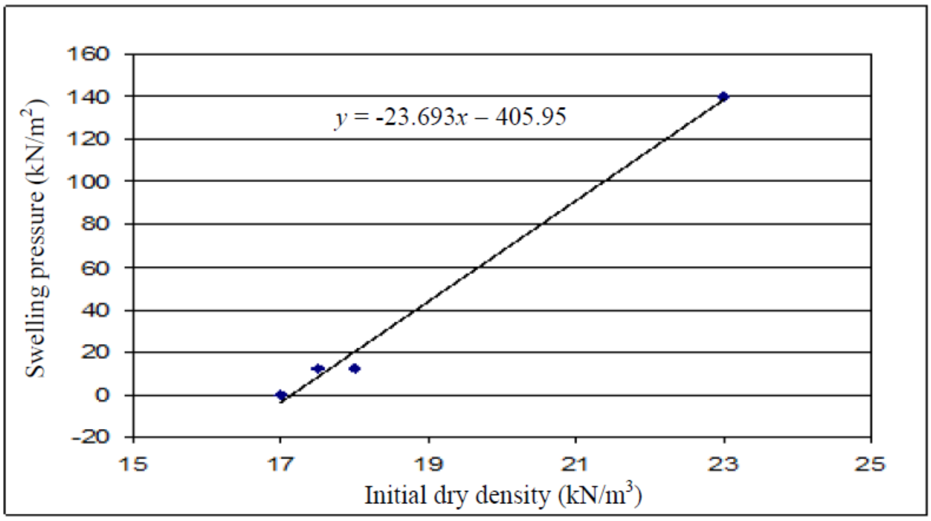


Figure 2-10: Tayma Shale swelling pressure against different dry density (Dafalla and Al-Shamrani, 2014).

CHAPTER 3

METHODOLOGY

3.0 Methodology

3.1 Flow Chart of Project Flow

The samples were taken from the Outcrop 7, excavated quarry area at Pokok Sena, Kedah, Malaysia. It was taken at same area with 10 different locations. For the project purpose, 10 samples were taken to be tested consist of 5 black shale and 5 weathered chert. The samples was kept in container at room temperature to ensure the moisture content is kept.

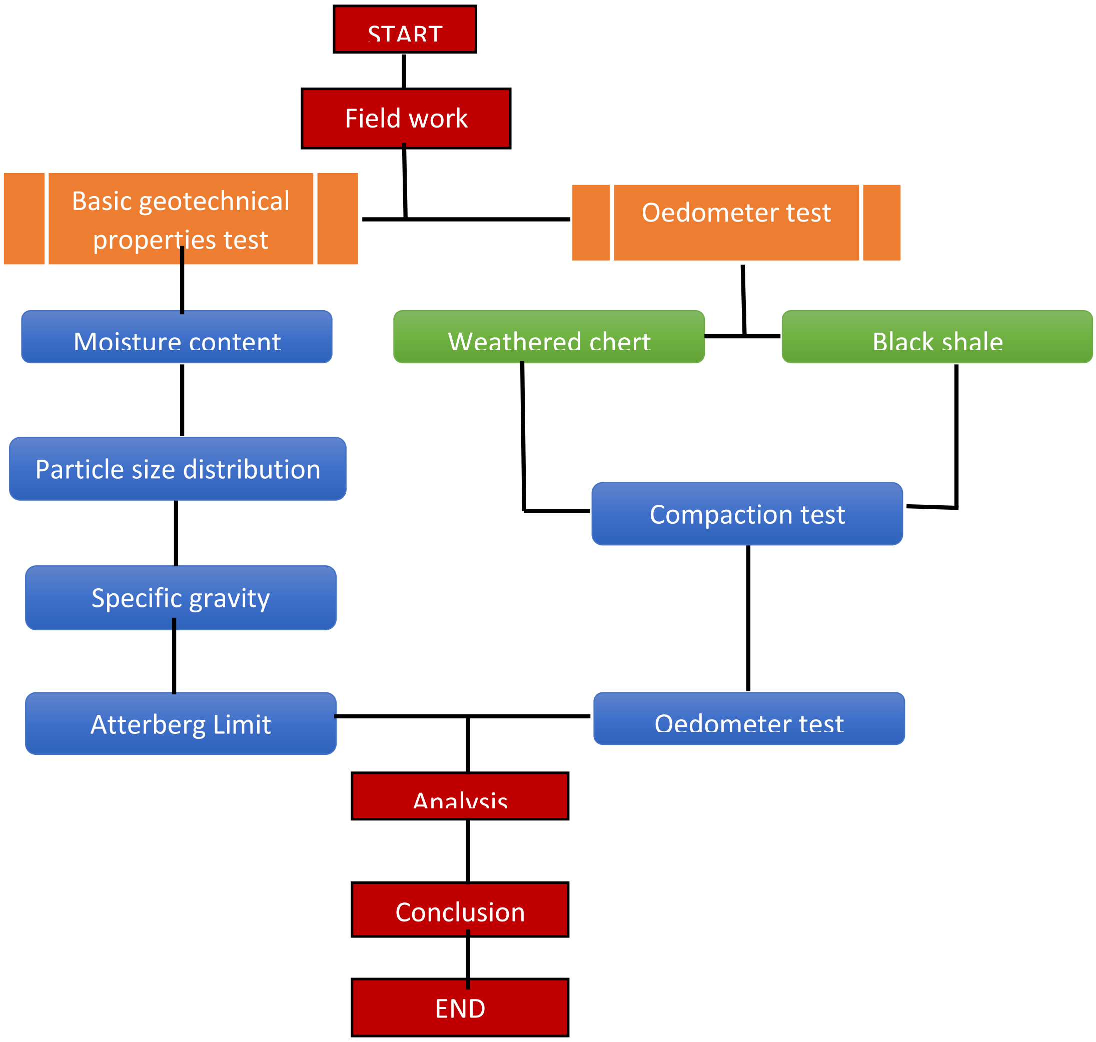


Figure 3-1: Flowchart of laboratory testing conducted.

Generally, the laboratory test can be separated into two part which is the basic geotechnical properties test and oedometer test (Figure 3-1). The basic geotechnical properties test is conducted to determine the soil moisture content, Atterberg Limit (plastic limit and liquid limit), specific gravity and particle size distribution (sieving and hydrometer). All of 10 samples will undergo the test and comparison and analysis between black shale and weathered chert will be discussed. Meanwhile, the oedometer test is conducted to study the compression behaviour of the samples. The graph of strain: stress and void ratio: stress is determined and important parameter from the graph is extracted as for our main discussion.

3.2 Acquiring sample

Sample was taken from Outcrop 7, located in Pokok Sena, Kedah. The formation of black shale and weathered chert were exposed due to quarry excavation activities (Figure 3-5). Five samples of black shale and weathered chert were taken in ten different locations as shown in figure below. The marking on Figures 3-2, 3-3 and 3-4 are the exact location where sample B1, B2, B3, B4, B5, W1, W2, W3, W4 and W5 were acquired.

Figure 3-2: Location of Sample B1, B2 and B3

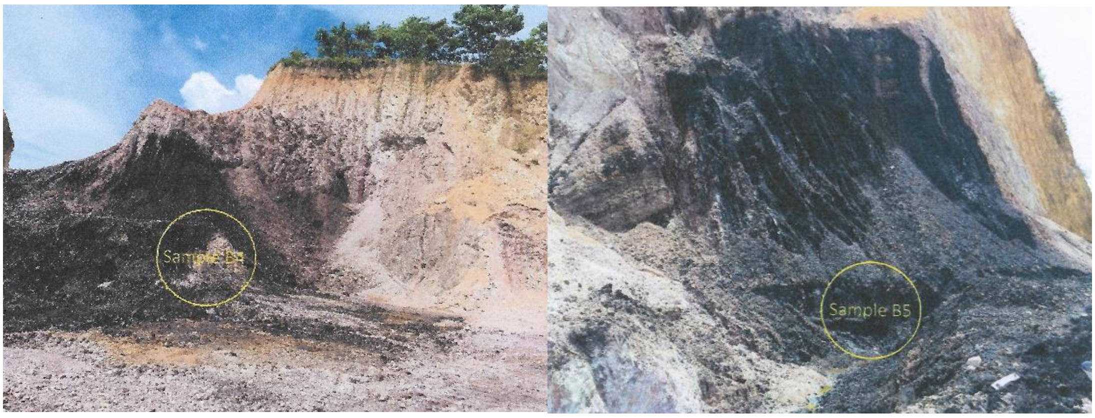


Figure 3-3: Location of Sample B4 and B5.

Figure 3-4: Location of sample W1, W2, W3, W4 and W5.

Figure 3-5: Picture at study area, Pokok Sena, Kedah.

3.3 Sample Preparations

All 10 samples were prepared by crushing and sieving to obtain desired weight and particle sizes for each laboratory tests

Figure 3-6: Samples were crushed using pan and hammer.

Figure 3-7: Samples were sieved and weight for each laboratory test.

3.2 Geotechnical Laboratory Tests

All sample had undergo into laboratory test in accordance to BS 1337 – 2: 1990

3.2.1 Moisture Content (Oven Drying Method)

Moisture content (ω_0) is used for soil classification. 50g of each samples taken from the excavated quarry is weighted and putted into oven. The mass of samples after dried is taken and moisture content is calculated.

$$\text{Moisture content}, \omega o = \frac{M3 - M2}{M2 - M1} X\ 100$$

Equation 3.1

M_1 =Mass of container

M_2 = Mass of container + sample

M_3 = Mass of Container + dried sample

3.2.2 Specific Gravity (Small Pyknometer Method)

Small pyknometer method was used since the samples is fine grained. Specific gravity is used to get the basic soil information such as moist density and initial void ratio. It represents the ratio between dried soil over dried soil plus water. Specific gravity can be determine using the formula below.

$$\text{Specific gravity}, Gs = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)}$$

Equation 3.2

W_1 = weight of bottle

W_2 = weight of bottle + dried soil

W_3 = weight of bottle + dried soil + water

W_4 = weight of bottle + water

Figure 3-8: W3 and W4 were obtained after putted under vacuumed incubator.

3.2.3 Atterberg Limit

Atterberg limit is represent the limit for soil to behave like solid, semisolid, plastic or semi liquid. Soil without moisture content may appear as solid which is very loose. When water is added, the soil start to wet and become semi solid once it pass the shrinkage limit. If more water is added, the soil will behave like plastic once it pass the plastic limit. Moreover, once the moisture content pass the liquid limit, the soil start to behave like liquid and less plastic. Difference between liquid limit and plastic limit represent as plasticity index. High plasticity index shows high content of clay mineral in soil sample.

$$\text{Plasticity index, PI} = \text{LL} - \text{PL}$$

Equation 3.3

LL = Liquid limit

PL = Plastic limit

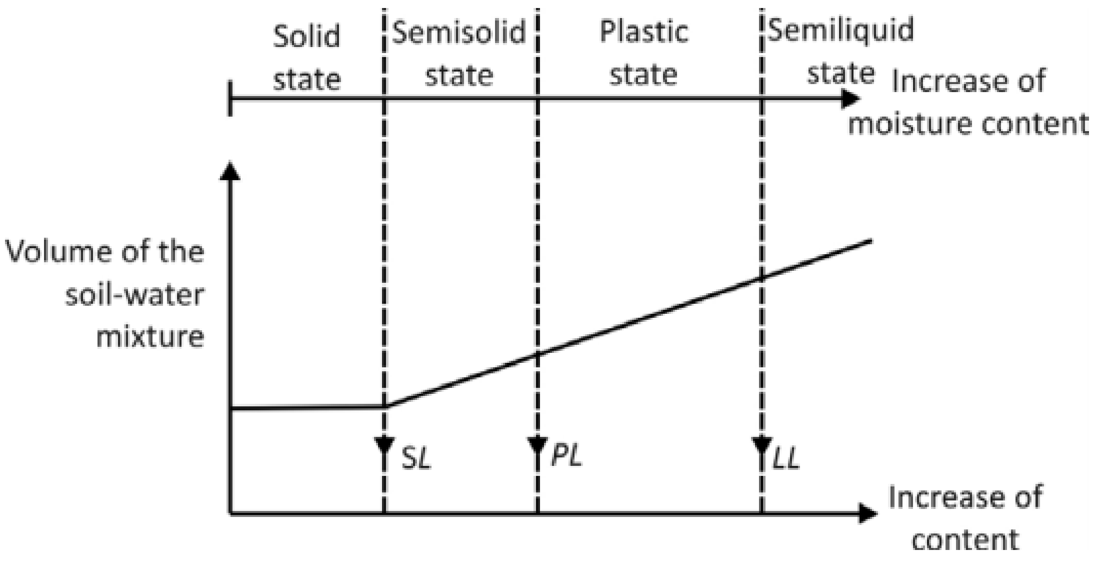


Figure 3-9: Partition of LL, PL and SL.

Figure 3-10: Plastic limit can be achieved by rolling 3mm sample on hand palm.

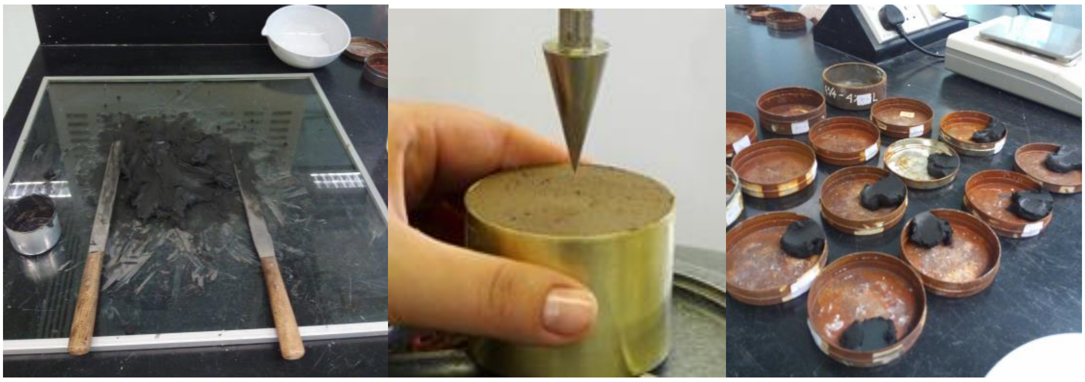


Figure 3-11: Liquid limit test using cone penetrometer.

3.2.4 Particle Size Distribution (Sieve Analysis)

Sieve analysis was conducted to analyse the particle size distribution of samples by allowing the samples to retain and pass throughout different sieve sizes and pan at the bottom. The total amount of soil retain on each sieve is recorded and plotted into semilog of particle size against percentage retain graph. Based on the graph, the soil classification can be determined by identifying the percentage of clay, silt, sand and gravel. Different category of soil represent different behaviour of soil which allow us to understand the geotechnical properties of sample.

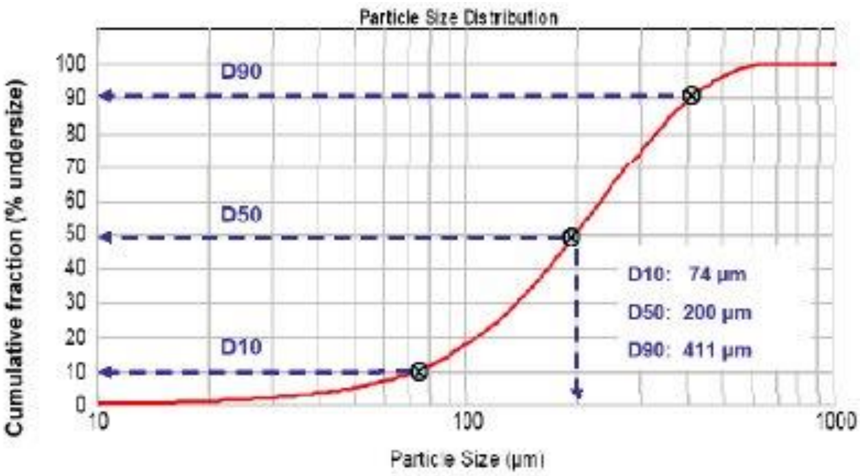


Figure 3-12: Particle size distribution graph.

Two parameter can be determined from the grain-size distribution curves of coarse-grained soils which are coefficient (*Cu*) and the coefficient of gradation or coefficient of curvature (*Cc*)

$$Cu = D_{60}/D_{10}$$

$$Cc = D_{30}^2 / [D_{60} \times D_{10}]$$

Equation 3.4

D_{10} = grain size diameter at 10 percent finer

D_{30} = grain size diameter at 30 percent finer

D_{60} = grain size diameter at 60 percent finer

3.2.5 Particle Size Distribution (Hydrometer Analysis)

Hydrometer analysis is based on the principle of clay size particles sedimentation in water. This test conducting by using 50g of dried and pulverized soil. A deflocculating agent is used by mixing the sample with it. The 125 cc of 4% solution of sodium hexametaphosphate is used as the deflocculating agent in hydrometer analysis. The sample mixtures are shaked by orbital shaker for 24 hours. After the soaking period, Sample is poured onto 63µm sieve. Retaining sample on 63µm sieve will undergo dry sieving while sample which passing 63µm sieve is transferred 1000 mL glass cylinder. Distilled water is added to 1000 mL mark. Hydrometer test is started by shacking the sample until it fully dissolve and place the sample into controlled water temperature for 24 hours. Within 24 hours, hydrometers are calibrated to show the amount of soil that is still in suspension at any given time t. The largest diameter of the soil particles still in suspension at time t can be calculated based on the Stokes' law,

$$D = \sqrt{\frac{18\eta}{(Gs-1)\gamma\omega}\sqrt{\frac{L}{t}}}$$

Equation 3.5

D = Diameter of soil particle

η =Viscosity of water

Gs = Specific gravity of soil solid

Figure 3-13: Samples were mixed with sodium hexametaphosphate and shook for 24 hours before conducting hydrometer test.

3.2.6 Compaction Test

Compaction test is conducted to determine the optimum moisture content that gives the soil highest density. Basically, soil sample with highest density gives higher compression strength. Thus, this allow both sample, Black shale and weathered chert, can be tested at its highest strength before conducting the oedometer test. As shown in the figure, the optimum moisture content can be determine from dry density against moisture content graph.

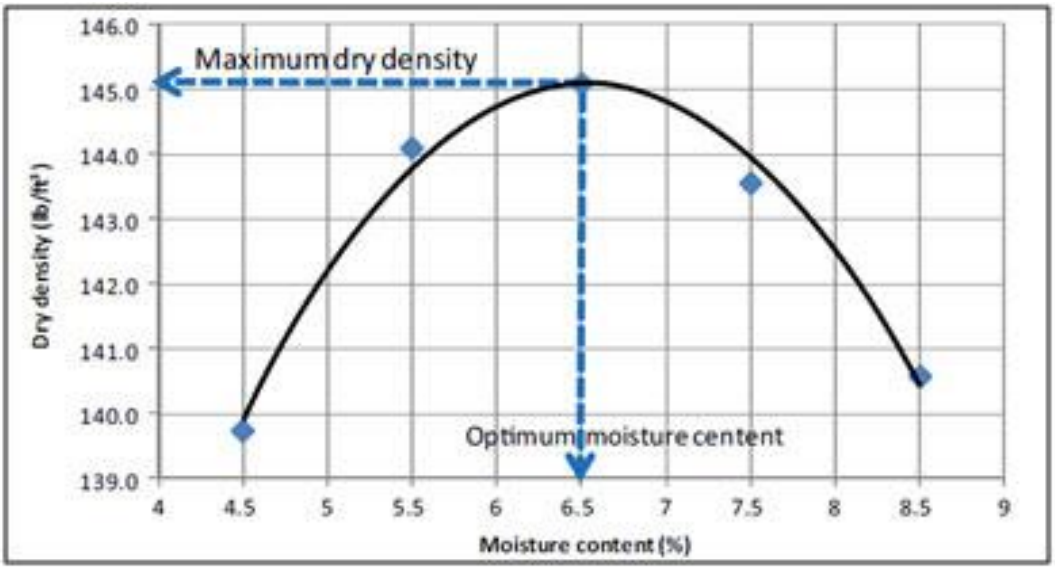


Figure 3-14: Compaction test graph

Figure 3-15: Compactor was used to compact the samples for 27 blow for each layer.

3.2.7 Oedometer Test

To achieve our main objective which is to determine the compression behaviour of black and weathered chert, oedometer test is conducted. The standard oedometer test is carried out on a cylindrical specimen of saturated soil with the dimension of 75 mm diameter and 20 mm thick. The soil sample are placed in oedometer ring and sandwiched between two porous stone at top and bottom of the sample. The porous stones are used to allow water to move in or out of the soil sample. Filter papers are necessary to be added between the soil and the porous stones so that the soil sample can be easily removed from the porous stone when unpacking process after the test had been conducted. Next, the sample is placed in the consolidation cell and the loading unit machine. Water is added into the cell around the sample, so the sample remains saturated during the test.

The test involves applying increments of vertical static load to the sample and recording the corresponding settlement. Increments of vertical static load are usually applied using dead loads and a static loading system. The change in the thickness of the sample against time is recorded during each loading increment. The duration of the application of each load depends on the soil and its consolidation characteristics. Once equilibrium reached for a loading step or reaching 24 hour of loading duration, the next increment is applied. The load is doubled at each increment until reaching the maximum required load. The Table 3-1 shows the load applied on samples.

Table 3-1: Days and loading applied on sample

Days	1	2	3	4	5	6	7	8	9	10	11
Loading (N)	2	5	10	20	50	100	200	400	300	200	300

Days	12	13	14	15	16	17	18	19	20
Loading (N)	400	800	600	400	600	800	1600	3200	6400

Table 3.1 shows the loading phase from 2 kPa until 6400 kPa. Unloading phase is conducted once the load achieve 400 kPa and 800 kPa. Each stage is recorded in log time against strain graph. To ensure the sample are fully settle or swell, the gradient of log time against strains graph is recorded and has to be less than 0.002 before

performing another stage. When all stage are completed the sample is carefully removed and its water content is measured. The consolidation test results is presented in strain: stress graph and void: stress graph in a semi-logarithmic scale. Important parameter can be extracted such as Swelling Index (Cs), Compression Index (Cc) and Preconsolidation (*Pc*) as shown in Figure 3-16 to understand the compression behaviour of the sample.

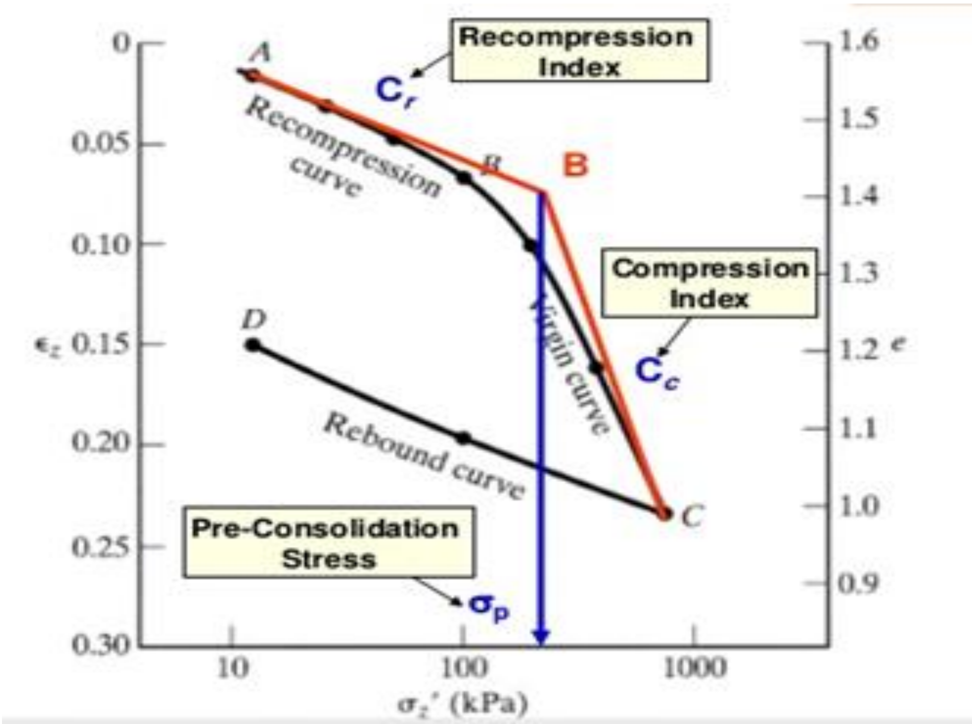


Figure 3-16: *Pc* or σp, *Cc* and *Cs* is determined.

Figure 3-17: sample is remoulded, compacted and putted into ring.

Figure 3-18: Oedometer tests were conducted 4 samples simultaneously. Settlement is observed through DS7 geotechnical software.

3.3 Key Project Milestones

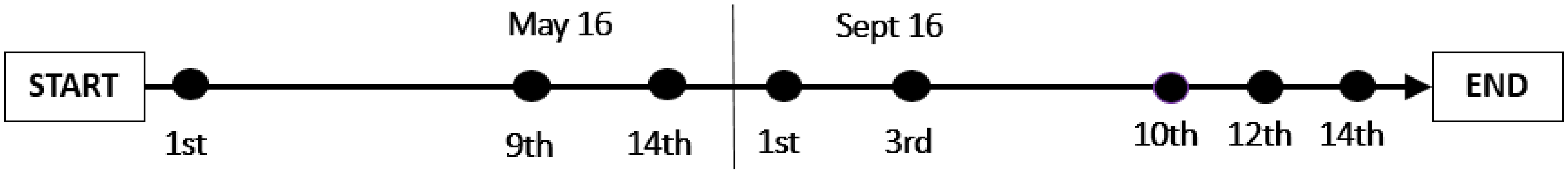


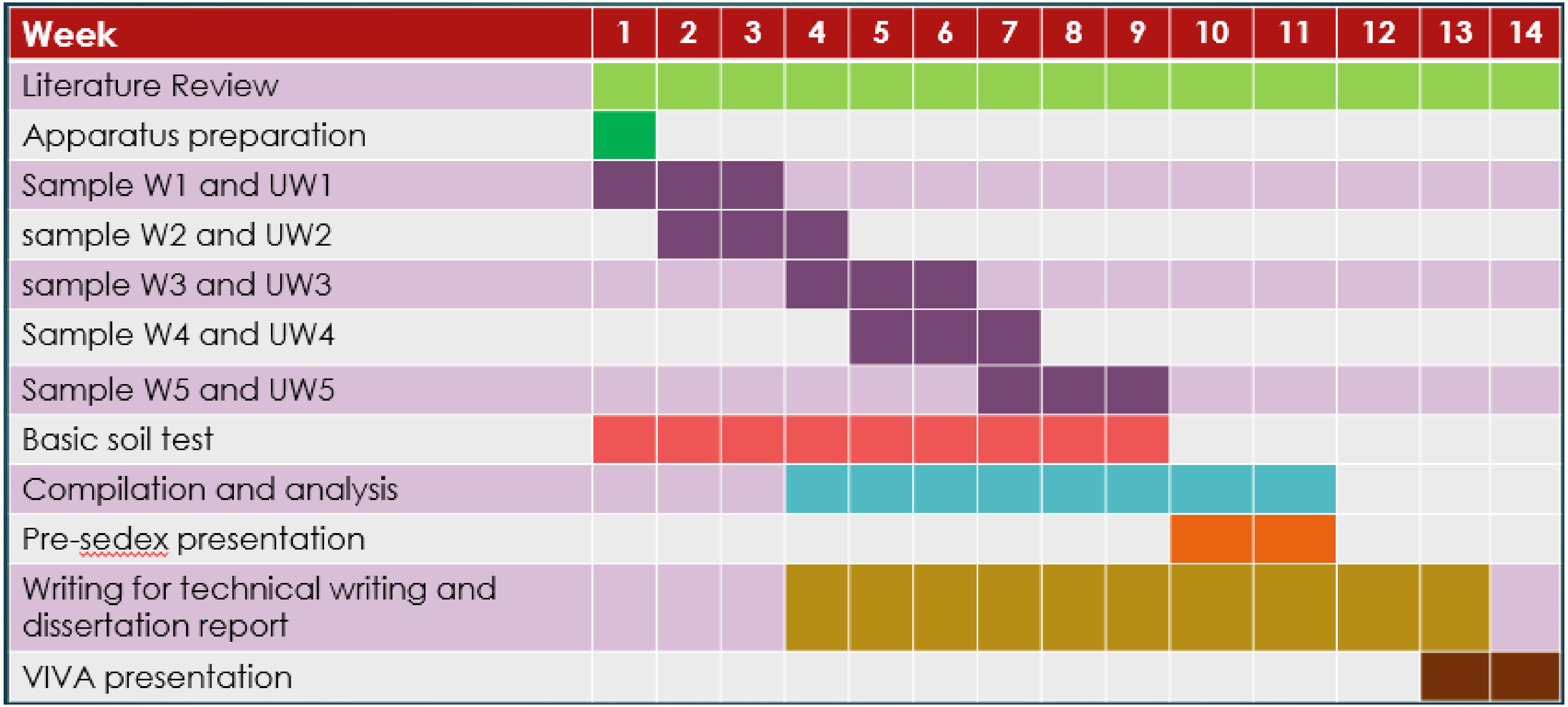
Figure 3-19: Project key milestone.

Based on the figure above, the important date from the project key milestone are:-

- 1st week of May 2016: Propose project title
- 9th week of May 2016: Proposal defend
- 14th week of May 2016: Interim Report submission
- 1st – 9th week of Sept 2016: Basic soil geotechnical test
- 1st – 9th week of Sept 2016: Oedometer test
- 3rd week of Sept 2016: Submission of Progress report
- 10th week of Sept 2016: Presedex presentation
- 12th week of Sept 2016: Submission of dissertation report
- 13th week of Sept 2016: Submission of Technical writing
- 14th week of Sept 2016: VIVA presentation

3.4 Project Timeline (Gantt Chart)

Table 3-2: Gantt chart.



CHAPTER 4

RESULTS AND DISCUSSION

4.0 Results and Discussion

4.1 Basic Geotechnical Test

4.1.1 Moisture Content

Once the sample is taken from the site investigated, each samples were conducted moisture content test. As the result, range of moisture content for black shale and weathered chert is 15.28% – 20.08% and 10.5 – 15.94% respectively. Generally, weathered chert moisture content have lower moisture content than black shale. From the Table 4-1, the sample W3 is 10.5% which is lower than other weathered chert sample.

Table 4-1: Moisture content.

Sample	B1	B2	B3	B4	B5	W1	W2	W3	W4	W5
Moisture content	20.00	19.19	15.28	17.44	16.45	14.62	14.23	10.50	14.66	15.94

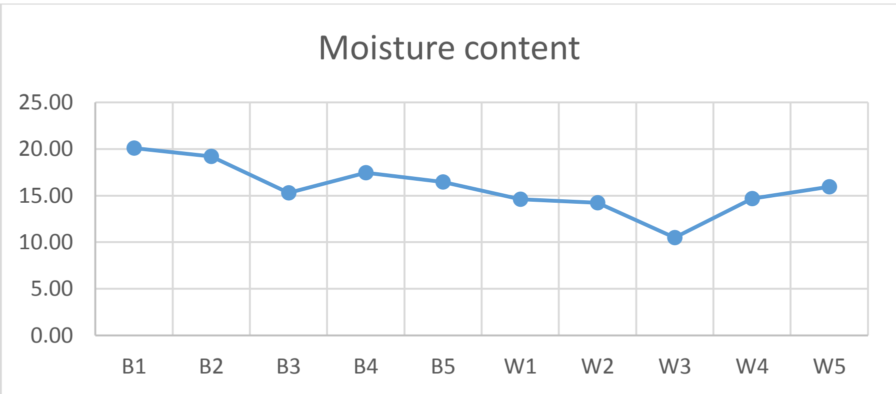


Figure 4-1: Moisture content graph.

4.1.2 Specific Gravity

From table 4-2, specific gravity test was conducted on black shale and weathered chert. As the result, range of specific gravity for black shale and weathered chert are 2.52 – 2.29 and 2.34 – 2.57. Average specific gravity for black shale and weathered chert are range between 2.42 and 2.46 respectively.

Table 4-2: Specific gravity.

Sample	B1	B2	B3	B4	B5	W1	W2	W3	W4	W5
Specific gravity	2.52	2.46	2.47	2.39	2.29	2.34	2.38	2.47	2.54	2.57

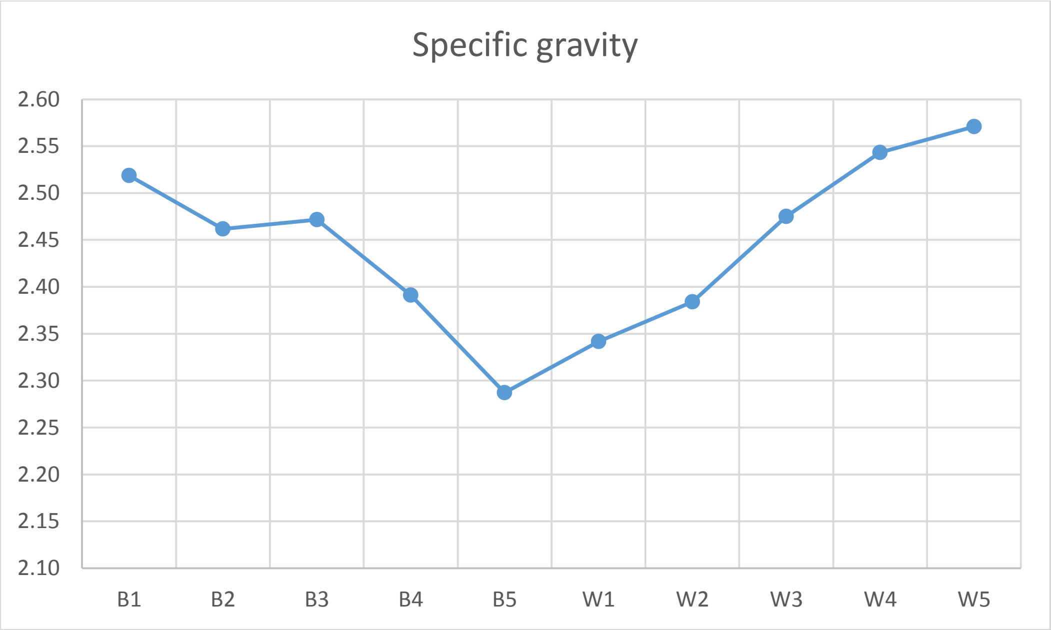


Figure 4-2: Specific gravity graph.

4.1.3 Plastic Limit and Liquid Limit

To identify the plasticity index of samples, plastic limit and liquid limit test were conducted. Range of plastic limit for black shale and weathered chert are 25.73 – 20.49 and 19.56 – 25.69% respectively while the range of liquid limit for black shale and weathered chert are 33.3 – 37.7% and 35.2 – 52.5%. Besides that, the range of plasticity index for black shale and weathered chert are 11.28 – 14.31% and 11.61 – 32.94% respectively. This indicates that the weathered chert has higher plasticity behaviour and may content clay mineral higher than black shale. Mineral content like montmorillonite, kaolinite and illite allow sample to absorb water and behave like plastic. This may contribute the sample to have high swelling index during oedometer test.

Table 4-3: Plastic limit, liquid limit and plasticity index.

Sample	B1	B2	B3	B4	B5	W1	W2	W3	W4	W5
Plastic limit	24.52	25.73	24.39	23.61	20.49	24.69	24.07	20.81	19.56	23.35
Liquid limit	35.80	37.70	33.30	37.10	34.80	36.30	36.70	47.00	52.50	35.20
Plasticity index	11.28	11.97	8.91	13.49	14.31	11.61	12.63	26.19	32.94	11.85

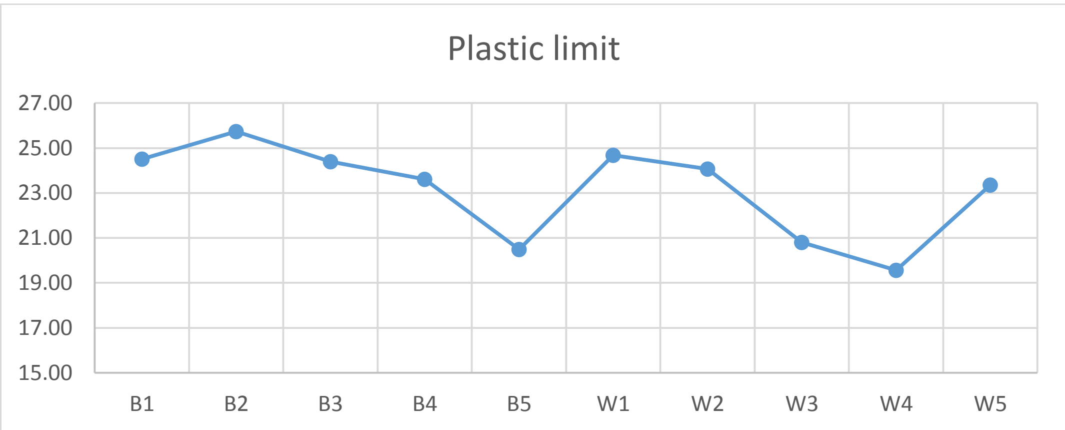


Figure 4-3: Plastic limit graph.

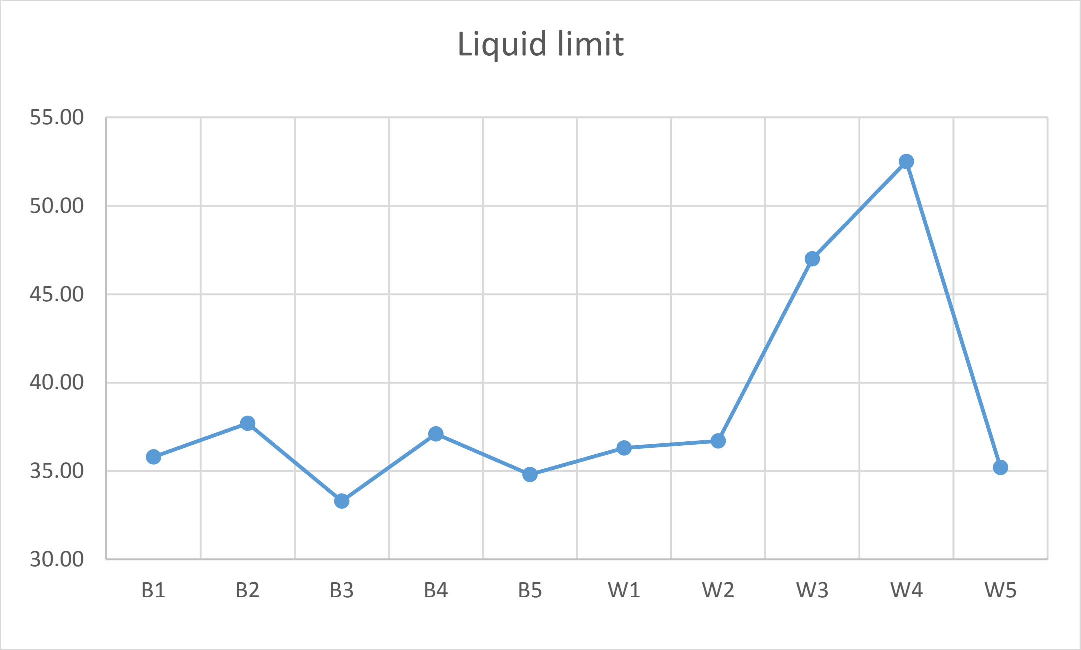


Figure 4-4: Liquid limit graph.

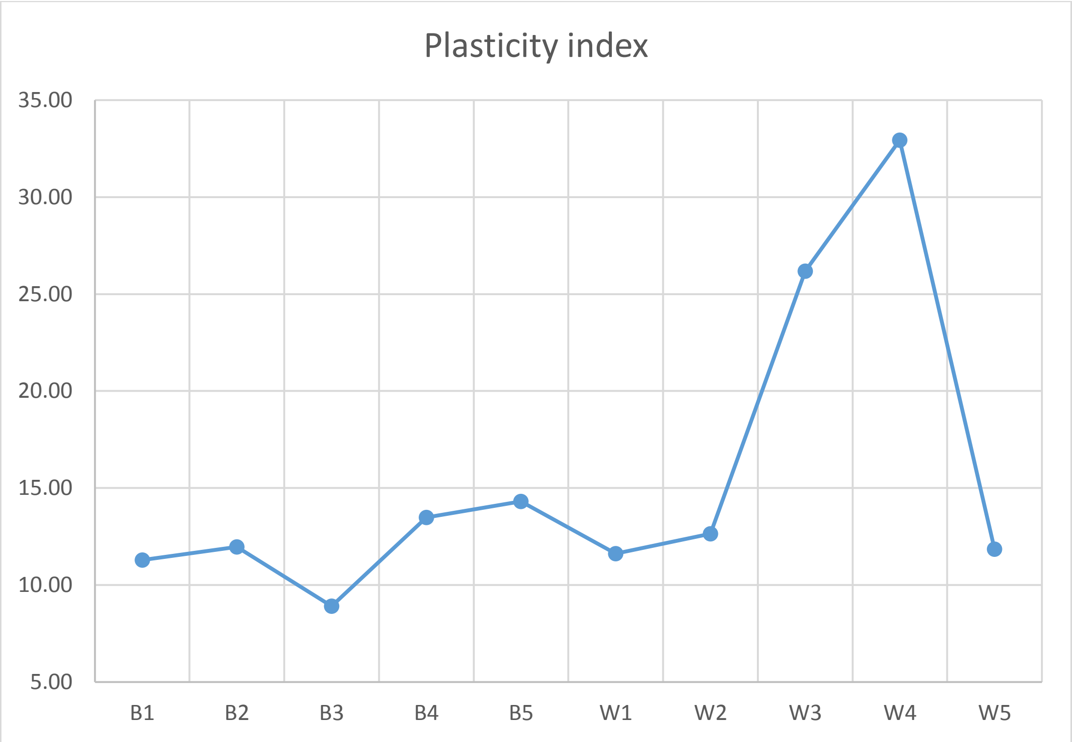


Figure 4-5: Plasticity index graph.

4.1.4 Particle Size Distribution (PSD)

Sieving and hydrometer test had been conducted on all samples to see the particle size distribution. Graph 4-6 shows the percentage of passing against the soil particles. Based on the graph and table below, all samples have pass the 2mm sieve passing diameter. Soil passed 2mm sieve have zero presence of gravel size particle. After undergoing into hydrometer test, the result indicates that shale and weathered chert have well distribution of clay, silt and sand. Black shale consist of high percentage of silt size particle which is 39-55% of silt compare to 22-36% and 23-29% of sand and clay respectively. Meanwhile, weathered chert consist of high percentage of sand size particle which is 45-56% of sand compare to 15-32% and 18-29% of clay respectively.

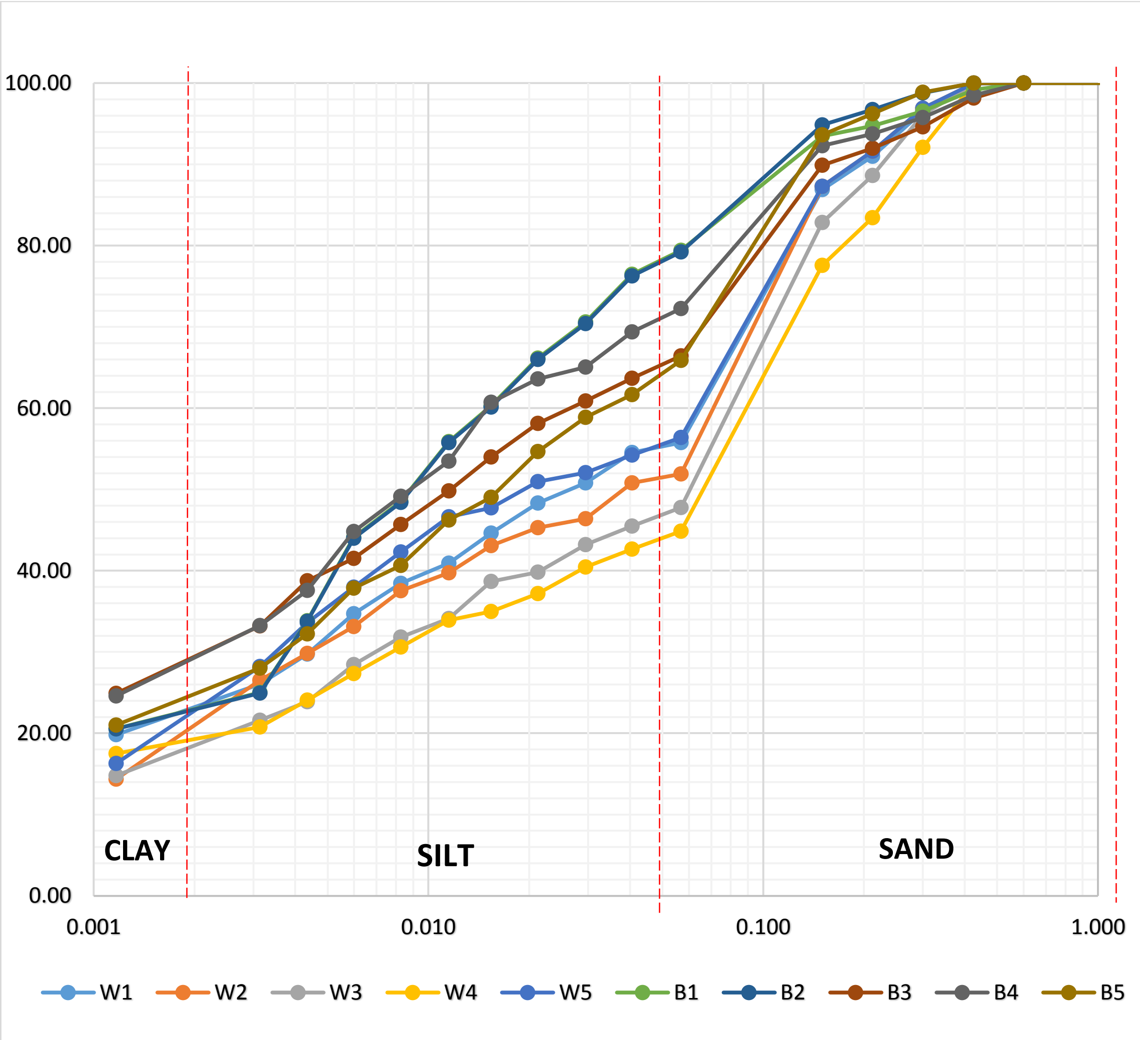


Figure 4-6: Particle size distribution graph

Table 4-4: particle size distribution

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

American Association of State Highway and Transportation Officials (AASHTO) soil classification is used to identify the soil classification. As the result, B1, B2, B4, B5, W1, W2 and W5 is identified as A-6 with silt-clay materials. Besides that, B3 is identified as A-5 while W3 and W4 is identified as A-7-5[a]. To identify the quality of soil, group index is calculated using this formula:-

$$GI = (F200 - 35)[0.2 + 0.005(LL - 40)] + 0.01(F200 - 15)(PI - 10)$$

Equation 4.1

Where F200 = percentage passing through the no 200 sieve.

LL = Liquid limit

PI = Plasticity index

Thus, soil classification is named as shown in the table below. Particle size distribution test shows the soil constituent of black shale and weathered chert are consist of clayey SILT and silty SAND respectively.

Table 4-5: ASHTOO soil classification.

Sample	AASHTO
B1	A-6 (9)
B2	A-6 (10)
B3	A-5 (6)
B4	A-6 (10)
B5	A-6 (9)
W1	A-6 (6)
W2	A-6 (6)
W3	A-7-5a (11)
W4	A-7-5b (13)
W5	A-6 (6)

4.1.5 Compaction Test

Compaction test is conducted to identify moisture content which gives the highest dry density. Basically, soil is expected to have the highest strength when they achieve the highest dry density. Thus, samples have to be compacted before conducting oedometer test so that the soil achieve their highest strength to undergo high compression pressure during oedometer test. The range of water content for remoulding the black shale and weathered chert are 18.32-22.52% and 19.58-21.3% respectively.

Table 4-6: Moisture content which gives highest dry density.

Sample	B1	B2	B3	B4	B5	W1	W2	W3	W4	W5
Moisture content (%)	18.32	20.77	22.52	20.41	18.62	20.60	19.58	20.80	20.30	21.30

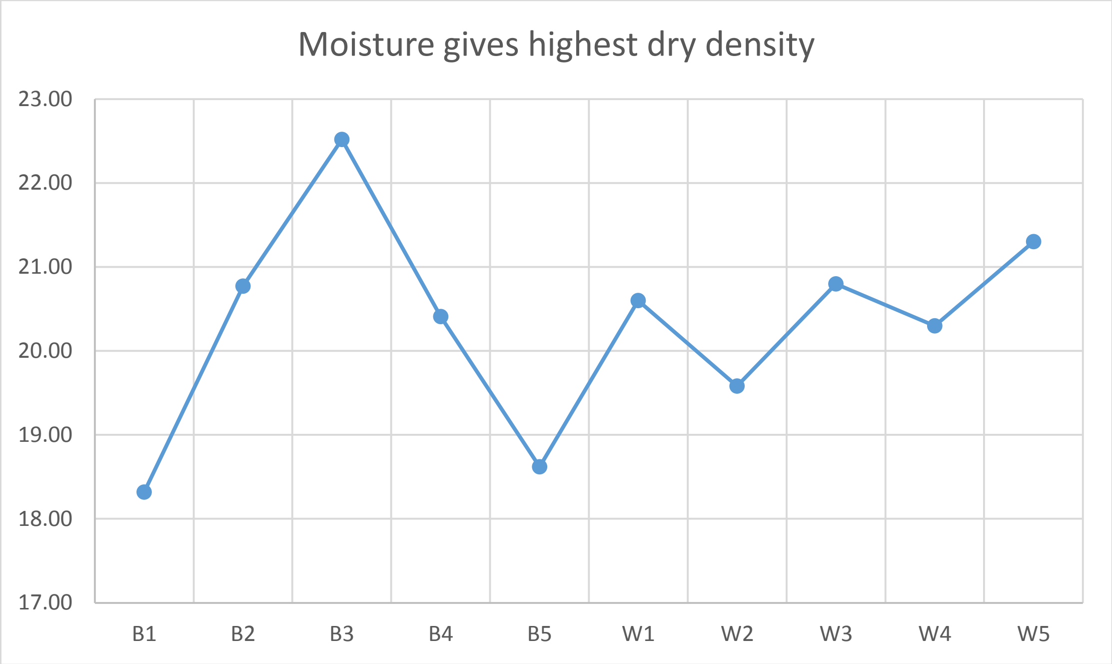


Figure 4-7: Moisture content which gives highest dry density graph.

4.2 Oedometer Test

Oedometer tests were conducted to study the compression behaviour of black shale and weathered chert. As a constant variable, all samples were remoulded and compacted to achieve its highest dry density before conducting oedometer test. Samples were allow to achieve saturated condition under controlled swelling effect for 24 hours. Then, oedometer test is conducted with series of loading and unloading stage from 5kPa to 6400 kPa vertical pressure applied on soil sample. Each stage period is 24 hours and to reassure loading or unloading stage is constant with time, the gradient of log-time against dial gauge graph should achieve less than 0.002.

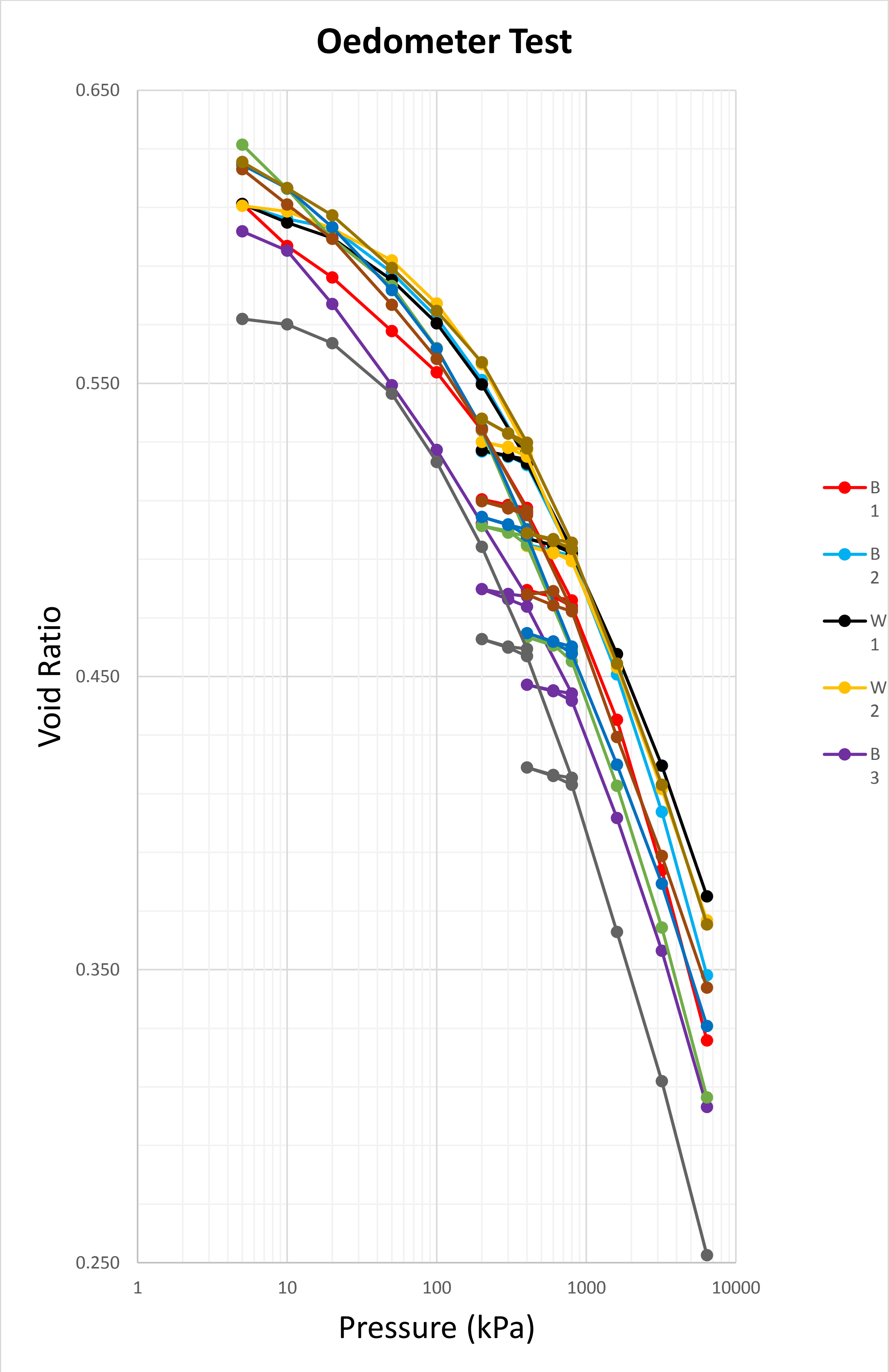


Figure 4-8: e: log-pressure curve graph.

Typical void ratio: log- pressure graph was plotted as shown in the graph above. Initial void ratio for black shale and weathered chert are 0.580 – 0.630 and 0.606-0.630. Black shale was found contain lower water quantity required for compaction than weathered chert makes the black shale form smaller initial void ratio. The preconsolidation, P_c, for black shale samples are between 270-300kPa while weathered chert samples are 200-220kPa. This indicates that black shale has higher overburden pressure throughout lifetime compare to weathered chert.

The compression index for black shale and weathered chert are 0.11-0.15 and 0.12-0.13 which means the black shale have higher compressibility compare to weathered chert. Black shale may have higher compressibility by its soil texture with flocculated pattern. This allow black shale to compress its volume and removed its water content when load is applied. Weathered chert has low compressibility due to its geological properties. Chert was undergo a proper lithification process which increase its rock form strength. Although weathering process has took place, chert sample may still has low compressibility then black shale.

The swelling index was obtained when load was removed from the samples. Swelling index measures the ability of samples to swelling by absorbing water. Swelling index for black shale and weathered chert are 0.015-0.018 and 0.018 – 0.019. Weathered chert has higher swelling index than black shale because the weathered chert has high plasticity index compare to black shale. Plasticity index was obtained from Atterberg limit test conducted. Plasticity index plays important role of having high clay mineral which allow soil to absorb water and content more water than other soil. In term of geological properties, contaminant of chert is made from microcrystalline and mudrock. Microcrystalline is made from microorganism (plankton or radiolarian) and small particle which allow microorganism undergo a proper cementation to form rock while mudrock is made from clay. Soil is classified as chert once it contain more microcrystalline. Otherwise, if mudrock content is higher than mircrocrystalline, the soil is classified as chalk (limestone). Sort of clay mineral content in microcrystalline is expected to contribute to this higher swelling in weathered chert than black shale.

Table 4-7: initial void ratio, preconsolidation, compression index and swelling index.

Sample	Initial void ratio, e_o	Preconsolidation, *Pc*	Compression index, *Cc*	Swelling index, *Cs*
B1	0.589	270	0.175	0.011
B2	0.600	300	0.150	0.013
B3	0.610	300	0.160	0.009
B4	0.630	290	0.185	0.014
B5	0.580	270	0.175	0.010
$B_{average}$	0.602	286	0.169	0.0114
W1	0.612	220	0.120	0.010
W2	0.606	200	0.130	0.012
W3	0.630	200	0.135	0.015
W4	0.620	220	0.150	0.013
W5	0.630	210	0.13	0.012
$W_{average}$	0.619	210	0.133	0.0124

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Section outcrop 7 was identified located in chert unit area which chert was expected as major soil exposed in that area. However, the studied area was found black shale in formation of weathered chert. 5 samples of black shale and weathered chert were undergo into geotechnical tests. As the result, moisture content for black shale and weathered chert were 15.28% – 20.08% and 10.5 – 15.94% respectively. This indicate that chert may retain lower water content than black shale. Besides that, range of plastic limit for black shale and weathered chert were 25.73 – 20.49 and 19.56 – 25.69% respectively while the range of liquid limit for black shale and weathered chert were 33.3 – 37.7% and 35.2 – 52.5%. Plasticity index for black shale and weathered chert were 11.28 – 14.31% and 11.61 – 32.94% respectively. This shows that weathered chert may behave like plastic more than black shale. High plasticity index of weathered chert were also expected to have higher clay mineral such as montmorillonite and kaolinite and higher swelling index compare to black shale. The water content at highest dry density during compaction test for black shale and weathered chert were found to be in range of 18.3 – 22.5% and 19.6 – 21.3%. This water content were used to remould sample before conducting oedometer test. The preconsolidation pressure of black shale and weathered chert were 270 – 300 kPa and 200 – 220 kPa respectively. This indicates that black shale has higher overburden pressure throughout lifetime compare to weathered chert. The compression index of black shale and weathered chert were 0.15 – 0.185 and 0.12 – 0.15. In term of geological explanation, the weathered chert was undergo a proper lithification process with lower void ratio to form rock. Although weathering process had took place, chert may still have high compressive strength. The swelling index of black shale and weathered chert were 0.011 – 0.014 and 0.010 – 0.015 respectively. This indicates that chert content higher clay mineral than black shale. The plasticity index of weathered chert also higher than black shale. It prove that weathered chert contain high of clay mineral which allow it to absorb water and swell more than black shale. In geological explanation, weathered chert may has high content of clay mineral in microcrystalline during the rock formation. Results of compression behaviour of Semanggol Formation at Outcrop 7 indicate that black shale and weathered chert are stable although there are small differences in their value of compression and swelling index. Future construction at site investigated are safe and precaution action for soil stability can be mitigated to reduce cost and construction time.

5.2 Recommendations

The relation between geological properties and geotechnical properties of Semanggol Formation is still lack of information. Although tests had been conducted on samples at Outcrop 7, there are still hundreds of section which available for geotechnical test to understand more on Semanggol Formation. Thus, more research has to be conducted into a new field area to get more understanding of it.

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Appendices

Table1: compilation results of basic geotechnical tests

			Atterberg limits			
Sample	Moisture content	Specific gravity	Plastic limit	Liquid limit	Plasticity index	moisture give highest dry density
B1	20.08	2.52	24.52	35.80	11.28	18.32
B2	19.19	2.46	25.73	37.70	11.97	20.77
B3	15.28	2.47	24.39	33.30	8.91	22.52
B4	17.44	2.39	23.61	37.10	13.49	20.41
B5	16.45	2.29	20.49	34.80	14.31	18.62
W1	14.62	2.34	24.69	36.30	11.61	20.60
W2	14.23	2.38	24.07	36.70	12.63	19.58
W3	10.50	2.47	20.81	47.00	26.19	20.80
W4	14.66	2.54	19.56	52.50	32.94	20.30
W5	15.94	2.57	23.35	35.20	11.85	21.30

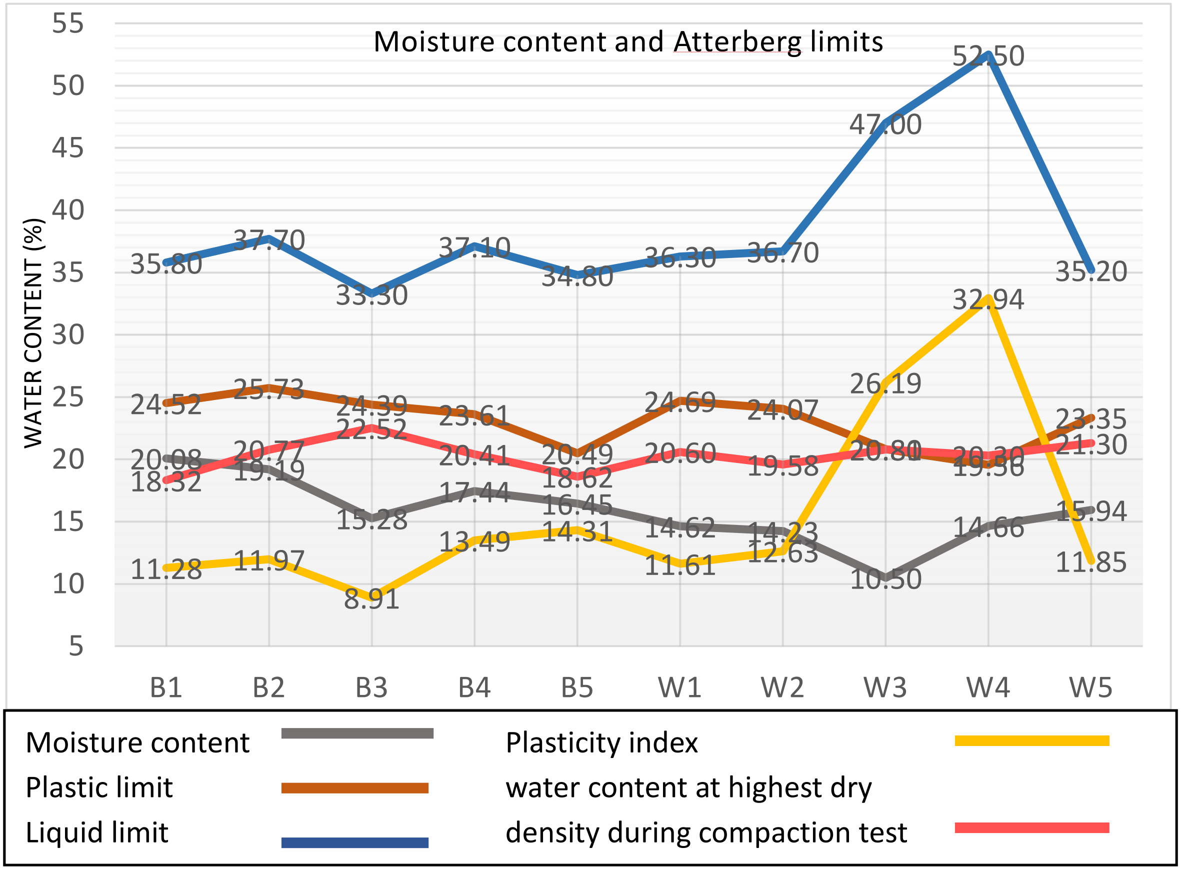

Figure 1: Moisture content, plastic limit, liquid limit, plasticity index and water at highest dry density

Table 2: Particle size distribution

particle size (mm)	Percentage (%)									
	B1	B2	B3	B4	B5	W1	W2	W3	W4	W5
5.000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
3.350	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1.180	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0.600	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0.425	99.17	100.00	98.16	98.52	100.00	99.96	99.98	99.94	99.98	99.98
0.300	96.55	98.79	94.63	95.75	98.85	96.51	96.89	96.12	92.10	96.89
0.212	94.73	96.73	91.98	93.75	96.22	91.01	91.62	88.65	83.43	91.62
0.150	93.47	94.85	89.90	92.31	93.64	86.89	87.31	82.83	77.56	87.31
0.057	79.41	79.21	66.43	72.27	65.87	55.78	51.91	47.76	44.84	56.39
0.041	76.47	76.28	63.66	69.37	61.66	54.54	50.81	45.49	42.65	54.22
0.029	70.59	70.41	60.90	65.04	58.86	50.82	46.39	43.22	40.46	52.05
0.021	66.17	66.01	58.13	63.59	54.65	48.34	45.28	39.80	37.18	50.97
0.015	60.29	60.14	53.98	60.70	49.05	44.62	43.07	38.67	35.00	47.72
0.012	55.88	55.74	49.82	53.48	46.25	40.90	39.76	34.12	33.90	46.63
0.008	48.53	48.41	45.67	49.14	40.64	38.42	37.55	31.84	30.62	42.29
0.006	44.12	44.01	41.52	44.80	37.84	34.71	33.13	28.43	27.34	37.96
0.004	33.82	33.74	38.75	37.58	32.23	29.75	29.82	23.88	24.06	33.62
0.003	25.00	24.94	33.22	33.24	28.03	26.03	26.51	21.61	20.78	28.20
0.001	20.59	20.54	24.91	24.57	21.02	19.83	14.36	14.78	17.50	16.27

Table 3: percentage of sand silt and clay

	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

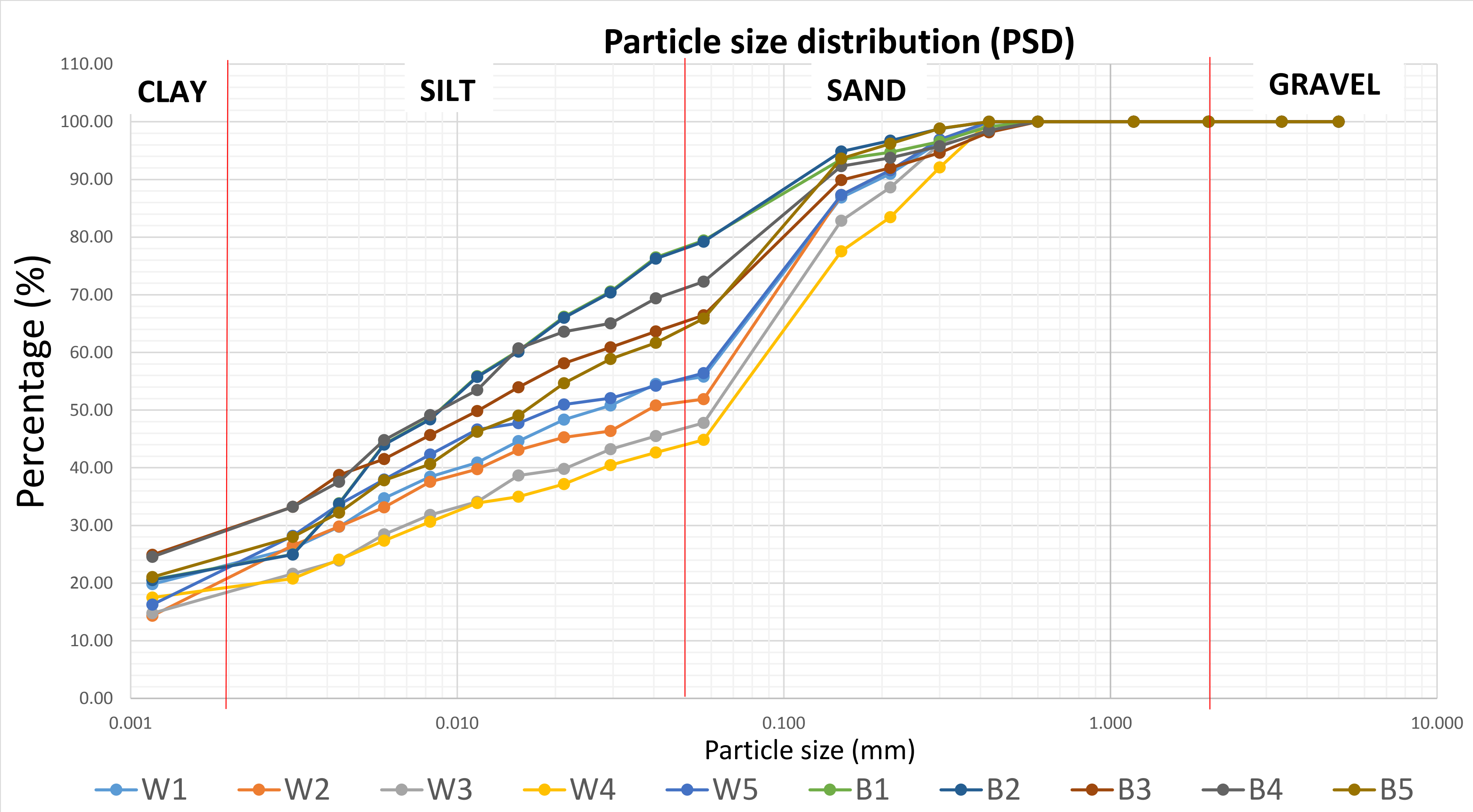

Figure 2: Particle size distribution graph

Table 4: Soil group index based on ASSHTO

AASHTO group index				
sample	F200	LL	PI	group index
B1	83.00	35.80	11.28	9
B2	83.00	37.70	11.97	10
B3	72.00	33.30	8.91	6
B4	77.00	37.10	13.49	10
B5	72.00	34.80	14.31	9
W1	63.00	36.30	11.61	6
W2	60.00	36.70	12.63	6
W3	55.00	47.00	26.19	11
W4	52.00	52.50	32.94	13
W5	63.00	35.20	11.85	6

Table 5: Soil group classification based on ASSHTO

sample	AASHTO
B1	A-6 (9)
B2	A-6 (10)
B3	A-5 (6)
B4	A-6 (10)
B5	A-6 (9)
W1	A-6 (6)
W2	A-6 (6)
W3	A-7-5a (11)
W4	A-7-5b (13)
W5	A-6 (6)

Table 6: Pressure and void ratio

Pressure (kPa)	Void ratio, e									
	B1	B2	B3	B4	B5	W1	W2	W3	W4	W5
0	0.590	0.600	0.610	0.630	0.580	0.610	0.610	0.630	0.620	0.619
5	0.611	0.611	0.602	0.631	0.572	0.611	0.611	0.625	0.623	0.626
10	0.597	0.606	0.595	0.616	0.570	0.605	0.609	0.617	0.611	0.617
20	0.586	0.603	0.577	0.599	0.564	0.600	0.603	0.603	0.599	0.607
50	0.568	0.588	0.549	0.583	0.547	0.585	0.592	0.582	0.577	0.589
100	0.554	0.572	0.527	0.562	0.523	0.570	0.577	0.562	0.558	0.575
200	0.534	0.551	0.502	0.534	0.494	0.550	0.557	0.535	0.534	0.557
400	0.507	0.524	0.477	0.498	0.459	0.524	0.527	0.500	0.507	0.530
300	0.508	0.525	0.478	0.499	0.460	0.525	0.528	0.502	0.508	0.533
200	0.510	0.527	0.480	0.501	0.463	0.527	0.530	0.504	0.510	0.538
300	0.508	0.525	0.476	0.500	0.460	0.525	0.528	0.502	0.507	0.533
400	0.506	0.522	0.474	0.495	0.457	0.523	0.525	0.498	0.505	0.528
800	0.476	0.491	0.444	0.459	0.415	0.493	0.490	0.460	0.473	0.496
600	0.477	0.493	0.445	0.461	0.416	0.495	0.492	0.462	0.479	0.497
400	0.479	0.495	0.447	0.463	0.419	0.497	0.495	0.465	0.478	0.499
600	0.477	0.493	0.445	0.461	0.416	0.495	0.492	0.462	0.474	0.496
800	0.474	0.490	0.442	0.455	0.413	0.492	0.489	0.458	0.472	0.494
1600	0.435	0.451	0.402	0.413	0.363	0.458	0.453	0.420	0.429	0.454
3200	0.384	0.404	0.356	0.364	0.312	0.420	0.412	0.379	0.389	0.413
6400	0.326	0.348	0.303	0.306	0.253	0.375	0.367	0.331	0.344	0.365

Table 7: Parameters extracted from pressure: void ratio graph

sample	Initial void ratio, eo	Preconsolidation, Po	Compression index, Cc	Swelling index, C
B1	0.59	270	0.175	0.011
B2	0.6	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
B avg	0.602	286	0.169	0.0114
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
W avg	0.619	210	0.133	0.0124

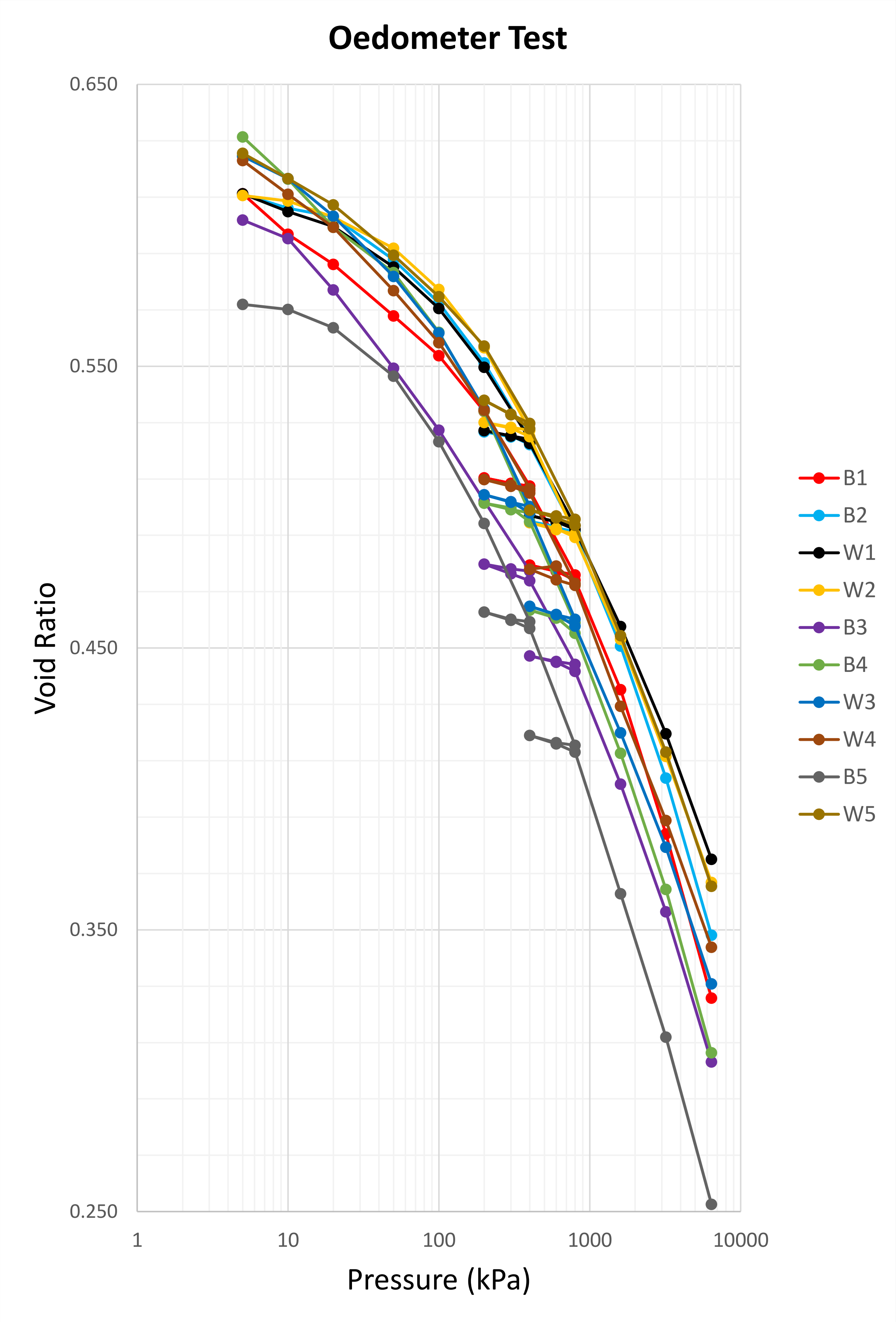

Figure 3: Pressure: void ratio, e graph