CERTIFICATION OF APPROVAL

Characterization of Local Sand as Proppant in Gravel Packing

By

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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.

MOHD ELIYAS YAAKOB

ABSTRACT

Malaysia's gravel pack wells have been using proppant, manufactured from other countries due to unavailability of gravel pack proppant manufacturer in Malaysia. Using local sand as the material, this project will focus on characterizing local sand as potential material for proppant for gravel pack completion by comparing its characteristic with market proppant which are ceramic proppant Schlumberger and Halliburton.

The project consisted of four main parts. First, the literature review on Malaysia's sand reservoir, gravel pack, proppants, and standard test as recommended by API and other technical report. Second, the acquirement of sand samples at 6 differrent places in Terengganu. Third, analyze particle size distribution of samples using sieve analysis. Finally, analyze characteristic of local samples as compared to industry proppant as mention above.

The findings from this project are as follows:

1. Factor of different points at the same area of study lead to different results can be neglected
2. The samples passed the API recommended specifications are Meraga and Kuala Abang
3. All samples perform better than conventional proppant for size set of 30/50.

The study concluded that Meraga and Kampung Rantau Abang B samples are passing the API requirement and perform better than conventional proppant of size set 30/50.

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CHAPTER 1

INTRODUCTION

This report presents all the works and key milestones done by the author. This introduction describes the study background, problem statement, project objectives and study's scope, relevancy and feasibility of the project.

1.1 Background of study

There are several sand control completions which are gravel pack, fracturing, frac & pack, slotted liner, screen, resin coated gravel pack, and consolidation plastics to tackle the sand issues in production wells (Constien et.al, 2001). Gravel pack completion type is the most popular method to tackle the sand issue (Pineda et.al, 2010).

The method is very expensive (Morgan, 2006) and Malaysia's gravel pack wells have been using proppant, manufactured from other countries due to unavailability of gravel pack proppant manufacturer in Malaysia.

Using local sand as the material, this study will focus on characterizing local sand as potential material for proppant for gravel pack completion by comparing its characteristic with market proppant which are ceramic proppant Schlumberger and ceramic proppant Halliburton.

1.2 Problem statement

Studies of local sand characteristic have been made by Minerals and Geoscience Department Malaysia (JMG) in 1978 to 1989 (P.C.AW, 1989). The report in 1970's and 1980's says that Malaysia has approximately 600 acres unexploited sand reserves in Terengganu. From then, there is no further initiative from government or private sector to characterize local sand for used in gravel pack application.

1.3 Objective and scope of study

The objectives need to be met from this project are;

Characteristic of local sand sample for use in gravel packs application focusing on;

1. Sieve analysis. The fragmented objectives are;
    - 1.1.1. To compare particles distribution at several points along the line adjacent the beach.
    - 1.1.2. To determine sample's particle distribution at all locations.
    - 1.1.3. To obtain different set of sample's size for HPHT experiments (20/40).
    - 1.1.4. To obtain different set of sample's size for HPHT experiments (30/50).
    - 1.1.5. To compare with recommended sieve analysis by API.
2. HPHT test. The fragmented objectives are;
    - 2.1.1. To determine the best amount from variables of 40g, 30g, 20g, 10g sand samples for use in HPHT experiments.
    - 2.1.2. To determine characteristics of particle percentage passing through different sand sample size 30/70.
    - 2.1.3. To determine characteristics of particle percentage passing through different sand sample size 20/40compared with SLB 20/40 ceramic sand.
    - 2.1.4. To determine characteristics of particle percentage passing through different sand sample size 30/50 compared with Halliburton 30/50 ceramic proppant.
    - 2.1.5. To compare local sand samples' characteristic with different set of sample.

As recommended by APIRP, there are six (6) laboratory test should be carried out to characterize the samples to be used as proppant. They are;

1. Sieve distribution
2. Bulk density, apparent density, and absolute density
3. Sphericity and roundness
4. Crush resistance test
5. Acid solubility
6. Loss on ignition of resin-coated proppant

The first four (4) tests have make up the minimum requirement for the characterization of all conventional proppant material (Barmatov, Abbott, et.al. 2008). Other recommended proppant testing methods are; particle passing in near wellbore conditions, turbidity test, optical microscopy, morphology test, RCP pH extraction test, amount of soluble curable resin, and rheology compatibility test.

However, this project will be focusing only on two (2) physical tests which are samples particle distribution and particles passing in near wellbore conditions (laboratory). Both types of tests are compared with market proppant mention earlier.

1.4 Relevancy of the project

As of now, there is no further study has been made to characterize the local sand (Malaysia) as possible proppant used for gravel packing completion method application. This project is very important as a step to make sure our local resources are made known and make used of its potential capacity.

1.5 Feasibility of the project

Based on the scope of study and the time frame set for research; all the objectives will be achieved in providing scientific findings and observations to evaluate our local sand as possible proppant in gravel packing completion method application.

CHAPTER 2

LITERATURE REVIEW

2.1 Sand control

As reservoir rock, particularly sandstone reservoir containing hydrocarbon start to produce, sand formation starts to become poorly cemented together. Well will start to produce sand that will cause damage to equipments, poor performance in injection well, and can lead to lost production. As hydrocarbon reserves will become less as we goes, the industry will face more challenges since most of the reserves left is the hardest to extract from (offshore, deepwater, different pressure reservoir, multilayered, etc). By last year, nearly half of BP's reservoir is suspected to be sand-prone (Morgan, 2006).

There are five (5) major contributors to the sand problem which are inherent rock strength, naturally existing rock stress, additional stresses due to drilling and production, water influx and fluctuation production rate. First option is to tackle the sand problem is to treat the well with 'tender loving care' to reduce the shock to the cemented formation grains by changing drawdown and production rate in small increment. The other one is to perforate the least likely sanding formation. However, both options reduce production (Dulan, 1992). .

To rectify the issue, equipments or application of techniques need to be installed downhole. Four different classes of completion, resin injection, slotted liners and prepacked screens, resin coated gravel without screens, and gravel packing need to be chosen and introduced to the well (Dulan, 1992), but as of 2006, new exploration about sand control technology has been introduced by BP such as expandable sand control completion system (Morgan, 2006).

2.2 Gravel pack/proppant

Gravel packing is said to be the most effective method of stopping sand movement and permitting production although it is expensive, high maintenance, carrier fluid may damage formation, increase drawdown, reduce wellbore diameter, and difficult to adopt in multiple zone (Dulan, 1992).

The gravel pack design must be large enough to minimize pressure drop in perforation tunnel as well as small enough to act as effective filter. The pack size design depends on the size of formation sand, which is usually measured using sieve analysis (Dulan, 1992).

Slurry containing proppants in carrier fuid is injected into either perforated or open-hole completion. Create high permeability granular filter. To maintain long term productivity for gravel pack, proppants need to be clean and depend on the proppant selection, carrier fluid, and placement technique.

According to Schlumberger Oilfield Glossary, 'gravel packing involves the complete placement of selected gravel across the production interval to prevent the production of formation fines or sand. Any gap or interruption in the pack coverage will enable undesirable sand or fines to enter the producing system'

Proppant is divided into three types which are natural sand, lightweight proppant, and sintered ceramics proppant. Natural sand is inexpensive, but low strength and lower flow capacities compared to ceramic proppant type. Ceramic proppant in the other hand, is expensive because of it must be carried out in high temperature, which mean high energy cost. It also has higher bulk density which is greater than 2g/cc and abrasive material that cause equipment wear.

Under the natural sand types, the sand properties are further enhanced by resin coated natural sand where the coating material may comes from organic or inorganic materials.

2.3.1 Kampung Meraga

Report on Kampung Meraga deposit shows that it has 83,000m² equivalent to 20.5 acres potential silica reserves where silica deposit thickness vary from 0.6m to 3.5m with average thickness of 1.5m. An estimated reserve of silica deposit is 115,600m³ with overburden thickness approximately 0.2m. Density to be assumed 1.8g/cc and average particle size are 0.3mm-0.6mm (75%) and the rest are above 0.85mm. Chemical analysis shows that sample has an average 98% silica content. It is recommended to be used in hydraulic fracturing proppant (P.C.AW, 1978).

2.3.2 Batu Tampin

Report on Batu Tampin deposit (refer appendix 1) shows that it has 50,000m² equivalent to 12 acres potential silica reserves where silica deposit thickness vary from 0.3m to 2.6m with average thickness of 1.3m. An estimated reserve of silica deposit is 62,000m³ with overburden thickness approximately 0.2m. Density to be assumed 1.8g/cc and average particle size are 0.177mm-0.6mm (75%) and the rest are above 0.85mm. Chemical analysis shows that sample has an average 98% silica content. It is recommended to be used in hydraulic fracturing proppant (P.C.AW, 1978).

2.3.3 Bukit Senyamok

Report on Bukit Senyamok, Dungun deposit (refer appendix 2) shows that it has 440,000m² equivalent to 109 acres potential silica reserves where silica deposit thickness vary from 0.5m to 2.9m. Density to be assumed is 1.8g/cc and estimated reserve of silica deposit is 440,000m³ with overburden thickness approximately 0.2m. Average particle size is 300μm-600μm (> 60%) and more than 90% are in range of 180μm-750μm. Chemical analysis shows that sample has an average 99.7% silica content. It is recommended to be used in hydraulic fracturing proppant. According to Bukit Senyamok, Dungun geological survey report in 1979, the state of Terengganu possesses the biggest known reserves in Peninsular Malaysia and no silica sand exploitation has been done (P.C.AW, 1979).

2.3.4 Kampung Kuala Abang

Report on Kampung Kuala Abang (refer appendix 2) deposit shows that it has 41 hectares of potential silica reserves where silica deposit thickness varies from 0.5m to 2.7m. Density to be assumed is 1.8g/cc and estimated reserve of silica deposit is 410,000m³ with overburden thickness approximately 0.2m. Average particle size is 300μm-600μm (> 50%) and more than 90% are in range of 150μm-850μm. Chemical analysis shows that sample has an average 99.73% silica content. It is recommended to be used in hydraulic fracturing proppant (P.C.AW, 1978).

2.3.5 Rantau Abang 'B'

Report on Rantau Abang 'B' (refer appendix 2) deposit shows that it has 144 hectares of potential silica reserves where silica deposit thickness varies from 0.5m to 3.6m. Density to be assumed is 1.8g/cc and estimated reserve of silica deposit is 1,440,000m³ with overburden thickness approximately 0.2m. Average particle size is 300μm-600μm (> 50%) and more than 90% are in range of 150μm-850μm. Chemical analysis shows that sample has an average 99.62% silica content. It is recommended to be used in hydraulic fracturing proppant (P.C.AW, 1989).

2.4 Sieve analysis

The objective of sieve analysis is to determine particle size distribution and median particle diameter (MPD) which is relates directly to flow capacity and reservoir productivity (Schechter, 1992, Kaufman et.al, 2006). In gravel packing applications, sieve analysis is one of the core tests where it is essential for determining formation and proppant/sand's particle size distribution.

Sieve analysis on the formation particles is done using the particles acquired from core samples and sand deposited in the surface facilities such as separator and flowlines. Sieve analysis on the proppant or sand sample is done using the samples believed to be suitable for gravel pack. Many researchers have proposed the best formation to proppant size ratio.

One of the earliest literatures on proppant size determination is from Coberly and Wagner. They suggest "*Actual experience in the field has shown that sand entry can virtually be eliminated by the use of gravel approximately 10 times the grain size of the 10 percentile of the finest sand to be screened*" (Saucier, 1974). The claim is supported by winterburn. Karpoff as example had proposed that 50 percentile on cumulative particles size distribution analysis of formation sample multiplied by 6 to 10 gives the range size of gravel pack proppant or sand (Rensvold et.al, 1962).

Clearly, several techniques measuring gravel pack sand size has been published but the most widely used nowadays is Saucier's method. Saucier's suggestion;

D50= (5~6) d50

Where;

D50 = median gravel pack sand diameter
d50 = median formation sand diameter

From the correlation, Saucier suggest that gravel pack sand size should be five to six times the median size of formation sand. Note that Saucier's technique is based solely on the median size of formation sand regardless of the formation sand size range and degree of sorting (Wentao Xiang and Pingshuang Wang, 2003)

2.4.1 Sieve analysis limitation

Dry sieving for sample finer than 100 mesh is significantly less accurate. This is because as particle size decrease, it will increase the attraction effects between the particles making harder to pass the smaller sieve mesh. The solution is using the wet sieving method (wiki, 2011).

Elongated and flat particles are not taken into sieve analysis consideration. Sieve analysis is done assuming all the particles shape are round and sphere will pass through the square shape mesh. The result of samples containing high elongated and flat particles may significantly less reliable (wiki, 2011).

U.S. Sieve sizes / Percent Retained							
8/16		12/20		16/30		20/40	
Sieve	%	Sieve	%	Sieve	%	Sieve	%
6	0.0	6	0.0	6	0.0	6	0.0
8	1.8	8	1.9	8	0.6	8	1.0
10	25.1	10	26.8	10	12.6	10	11.4
12	34.5	12	36.5	12	56.0	12	42.3
14	30.9	14	21.9	14	24.2	14	35.4
16	6.9	16	11.9	16	5.8	16	9.0
Pan	0.8	Pan	1.0	Pan	0.8	Pan	0.9
Total	100%	Total	100%	Total	100%	Total	100%

Figure 2: Typical Sieve Analysis – gravel pack (Carmeuse)

Figure 2 shows the typical sieve analysis results from Brady proppant (Carmeuse) one of the best proppant in the world.

2.4.2 Sieve analysis recommended by API recommended practice 56 and ISO13503-2

According to API recommended practice 56, prior to sieve analysis, the sample must undergo a process of sample reducer and sample splitting (APIRP56, 1995).

A sample reducer is used to reduce large material samples to workable testing size by accomplishing 16 to 1 reduction. A sample splitter is used to divide sieve material into two representative samples by a divider consisting of a number of alternatively arranged partitions (Haver and Boecker, 2011). Figure 3 and figure 4 shows the sample reducer and sample splitter respectively.

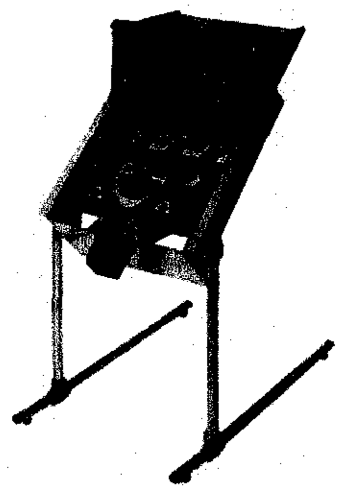

Figure 3: Sample reducer (Haver and Boecker, 2011)

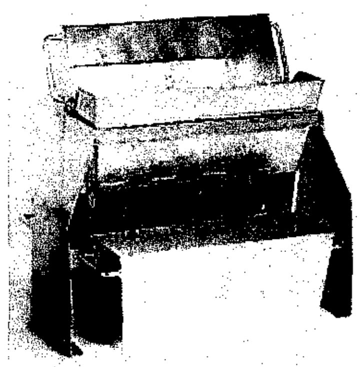

Figure 4: Sample splitter (Haver and Boecker, 2011)

Sieve shaker used according to APIRP56 is a Ro-Tap sieve shaker using tapping sieving method. Tapping sieving is sieve using horizontal circular motion created by tapping actions. This type of sieve can produce higher degree of denser particles. (Wiki, 2011). Figure 5 shows the Ro-Tap sieve shaker as recommended by APIRP56.

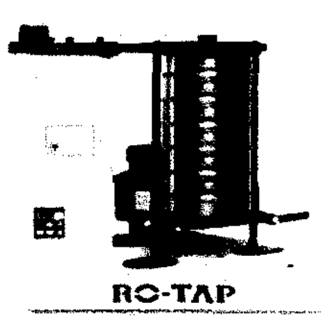

Figure 5: Ro-Tap sieve shaker (Tyler, 2011)

According to APIRP56 and ISO13503-2, a minimum of 90 percent of tested sand sample should fall between the designated sieve sizes as shown in table 1. Not over 0.1% should be larger than first sieve and not over 1.0% should fall in the pan (APIRP56, 1995; Proptester, 2009)

2.5 Sand retention test methods

There are two types of sand retention test methods which are slurry test and sand pack test. For the slurry test, the sand is in slurry state. Pressure is applied through the equipment and the sand passing will be weigh to calculate the weight percentage particle passing versus different pressure. For sand pack test, the same procedure is used but the sand sample is not in slurry condition. Figure 6 and figure 7 shows the equipment diagram for slurry test and sand pack test (William, 2008).

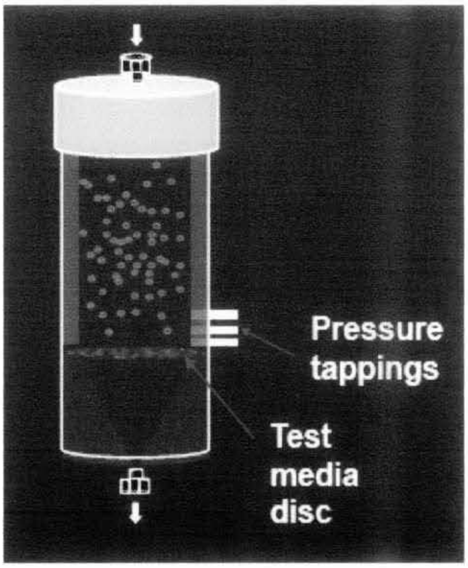

Figure 6: slurry test equipment (William, 2008).

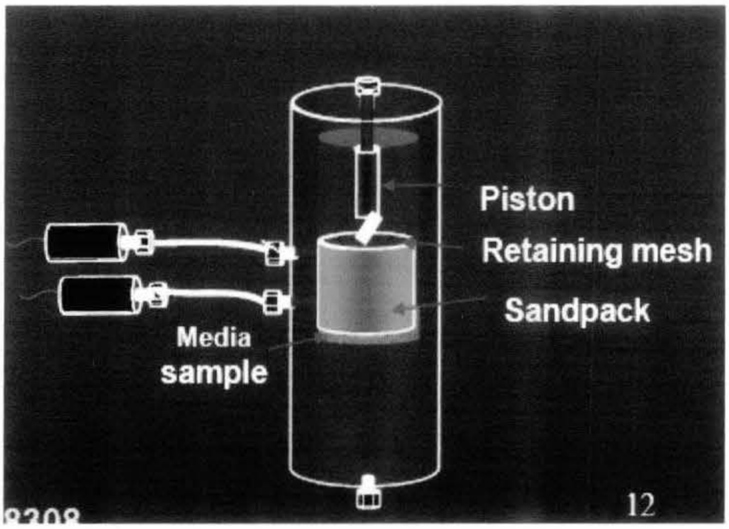

Figure 7: sand pack test equipment (William, 2008).

In 2001, Constien & Associates Inc. has produced a technical report on oil flow method for screen or gravel pack tests. The method actually basically the same with sand retention test method, slurry test.

Formation particles are sluried in oil or water, then flow at 200psi differential pressure. Net confining stressis applied up to 1000psi. The particle passed through sand or proppant is weighted. Figure 8 shows the diagram of C&A oil flow method (Constien and Associates, 2001).

Figure 9 shows test screen used which is metal mesh, twilled dutch weave pattern (William, 2008).

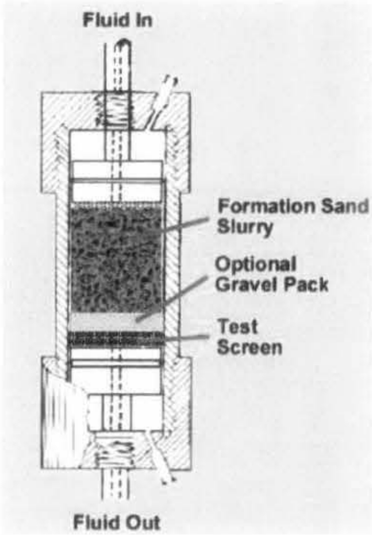

Figure 8: Screen or gravel pack test equipment (Constien and Associates, 2001).

Figure 9: Twilled dutch weave pattern, metal mesh (William, 2008).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Project activities

The FYP2 project activities are mainly consists of six (6) activities which are literature review on local sand sample and gravel pack completion method application, fieldtrip to Terengganu to obtain the sand sample, conduct the lab experiments as stated in FYP1, summarize all findings and analysis, and finally the dissertation. Figure 10 shows the project activities.

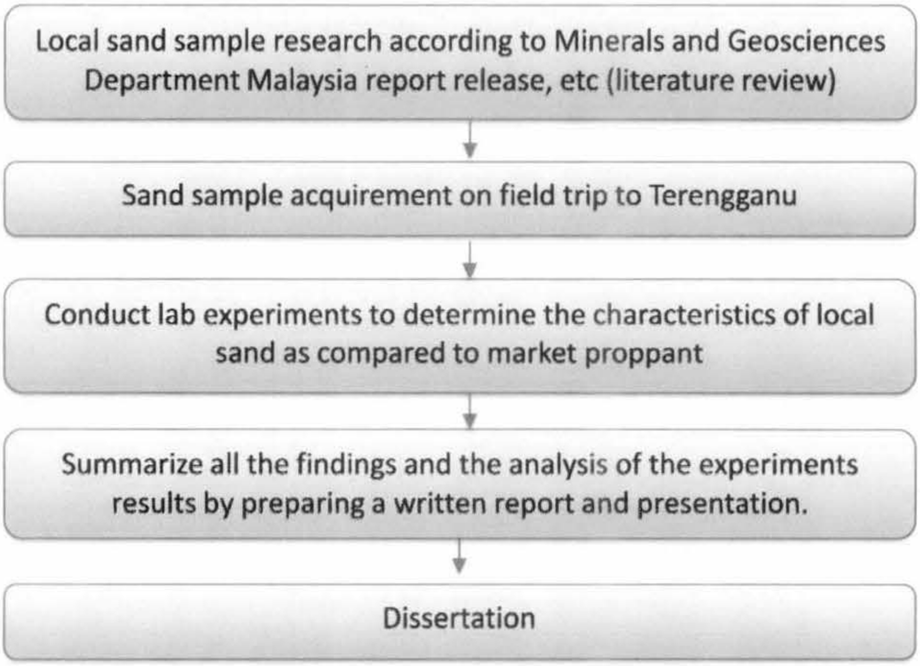

Figure 10: Project activities

During the FYP1, research on local sand reserves has been made and sand sample acquirement has been done and the details of the sand samples will be discussed on chapter 3 and chapter 4.

3.2 Key milestones

Table 1: key milestones

Date	Activity
15th July 2011	Progress Report Submission
Week 11th	PRE-EDX
Week 12th	Submission of draft report
Week 13th	Submission of dissertation (soft bound)
Week 13th	Submission of technical paper
Week 14th	Oral presentation
Week 15th	Submission of dissertation (hard bound)

3.3 Gantt chart

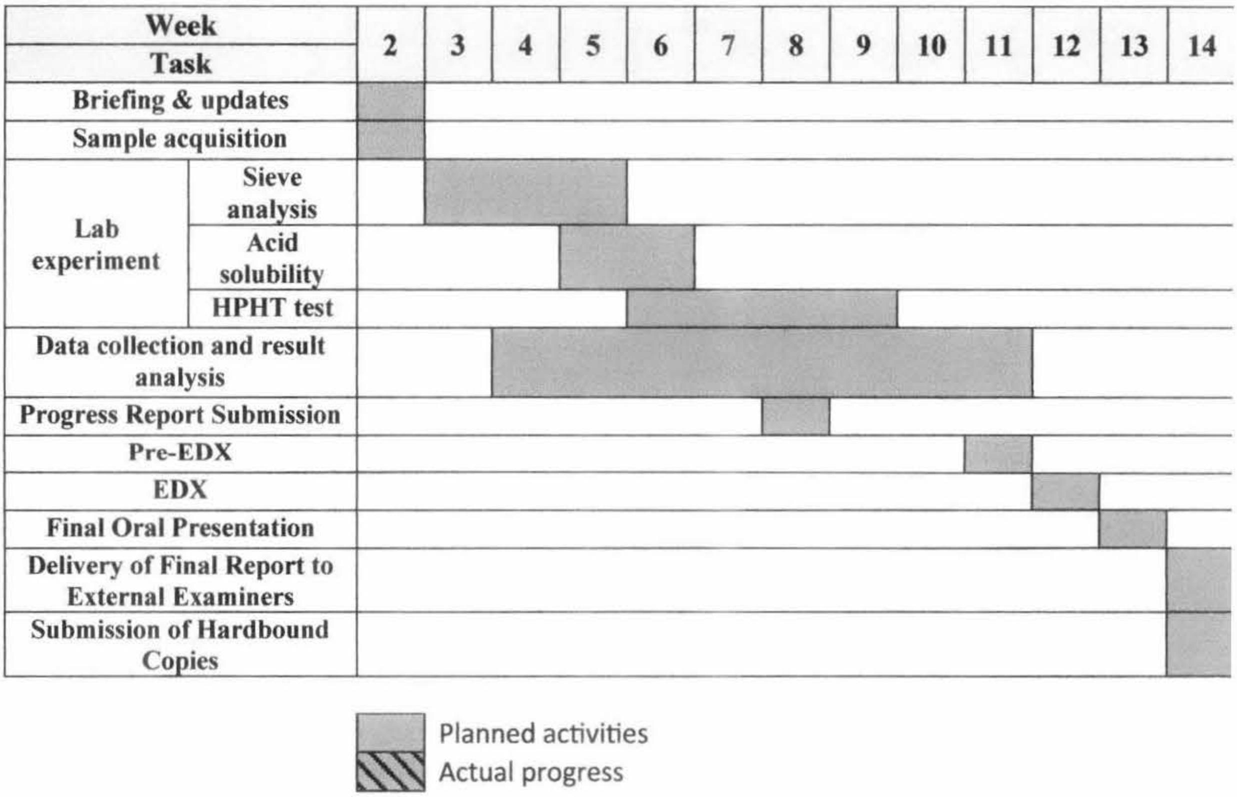

Figure 11: Gantt chart

3.4 Experimental procedure and tools required

3.4.1 Material selection and acquirement

Objectives

1. To compare particles distribution at several points along the line adjacent the beach.
2. To determine sample's particle distribution at all locations.
3. To obtain different set of sample's size for HPHT experiments (20/40).
4. To obtain different set of sample's size for HPHT experiments (30/50).
5. To compare with recommended sieve analysis by API.

Need and Scope

The author was told by Assoc. Prof. Dr. Chow Weng Sum, the sample must be taken at the sand ridges where old sand accumulates despite taking the sand along the beaches. This is because the sand along the beaches are the new sand where contaminations are abundant and further sand exploitation cannot be done along the beaches that may result geographical changes thus changing the environmental ecosystems (P.C.AW, 1978, 1979, 1989)

Due to unavailability of Dormer's hand auger from UTP, some modification on sampling method has been done. About 50cm Perspex has been used to investigate the silica sand depth. Figure 12 shows the cylindrical Perspex used for sand sampling in Terengganu.

Figure 12: Cylindrical Perspex

Another modification is using phone's GPS provided the latitude and longitude coordinates (refer appendix 1 and 2) and car's meter to mark the point for sampling .

Latest geological map and map acquired from literature review (refer appendix 1 and 2) is required to pin down the location of sand sample. A GPS device is also helpful in determining the location.

Apparatus Required

Cylindrical Perspex. Shovel. Measuring tape. Camera. Plastics bag. Cable tie

Procedure

1. Identify location.
2. Push down cylindrical perspex using force from hand or shovel can be used to push down the perspex into the sand formation.
3. Dig out sand around the perspex.
4. Take out the perspex with retained sand.
5. Measure the sand layer and take pictures.
6. Dig the sand to the estimated depth of sand layer.
7. Put sample in the plastic bags and secure with cable tie.

Material selection program (refer appendix 1 and 2)

To determine height of sand bedding required for best silica deposition, parallel and adjacent to the beaches (Meraga sample)

1. Location 1 (Meraga 1)
2. Location 2 (Meraga 2)
3. Location 3 (Meraga 3a, 3b, 3c)
4. Location 4 (Meraga 4a, 4b, 4c)

To determine height of sand bedding required for best silica deposition at other locations.

1. Location 5 (Batu Tampin a)

2. Location 6 (Tampin b)
3. Location 8 (Kampung Rantau Abang B)
4. Location 9 (Kampung Kuala Abang)
5. Location 10 (Bukit Senyamok)
6. Location 11 (Jambu Bongkok)

3.4.2 Sieve distribution analysis

Testing objectives:

The standard grain size analysis test determines the relative proportions of different grain sizes as they are distributed among certain size ranges. Sieve distribution analysis will be used for two different purposes.

1. To compare particles distribution at several points along the line adjacent the beach.
2. To determine sample's particle distribution at all locations.
3. To obtain different set of size for other HPHT experiments 20/40, 30/50, and 30/70.
4. To compare with recommended sieve analysis by API.

Need and Scope

Equations below are needed to calculate;

- Sample Weight, W_{sample} (g) = M_{ti} - M_{si}
- Percentage Retained, R_n (%) = $\left(\frac{M_{ri}}{M_{ts}}\right) \times 100\%$
- Variance = $M_{ts} - M_{ri}$
- Percentage variance, (%) = $(M_{ts} - M_{ri}) \times 100\%$

According to API, for 20/40 sieve set, >90% of sand particles should fall within designated sieve. <0.1% sample on first sieve and <1.0% on last sieve.

Noted that no published data on sand sample size 30/70 for proppant testing and it is not recognized as tested sand size in API recommended practices (APIRP56, 1995) but it still tested according to API standards for reporting purposes. Mesh size of 212 micron is assumed to be mesh size 70.

Apparatus Required

1. Stack of Sieves including pan and cover.
2. Balance (with accuracy to 0.01 g).
3. Rubber pestle and Mortar (for crushing the soil if lumped or conglomerated).
4. Mechanical sieve shaker.
5. Oven.
6. Notice: The balance to be used should be sensitive to the extent of 0.1% of total weight of sample taken.

Test Procedure

1. Take a representative oven dried sample of sample then weighs 1000g of sample using balance. Record the total weight of sand sample (when small amount of sample available).
2. Prepare a stack of sieves. Sieves having larger opening sizes (i.e lower numbers) are placed above the ones having smaller opening sizes (i.e higher numbers). Below are the sieves set for this experiment (lab availability).

Table 2: Sieve set

Sieve Set		
30/70	**20/40**	**30/50**
Pan	Pan	Pan
150	-	-
212	-	-
300	-	300
425	425	425
600	600	600
1180	1180	1180

3. Place pan under last sieve stack to collect the portion of soil passing. Make sure sieves are clean; if many soil particles are stuck in the openings try to poke them out using brush and air compressor.
4. Weigh all sieves and the pan separately.
5. Pour the soil into the stack of sieves from the top and place the cover, put the stack in the sieve shaker and fix the clamps, adjust the time on 10 minutes and get the shaker going.
6. Stop the sieve shaker and measure the mass of each sieve + retained soil.
7. Separate the sample retained at the top sieve and pan with the others.

Experimental program

To compare particles distribution at several points along the line adjacent the beach.

1. Location 2 (Meraga 1)
2. Location 1 (Meraga 2)
3. Location 3 (Meraga 3a, 3b, 3c)
4. Location 4 (Meraga 4a, 4b, 4c)
5. Location 5 (Batu Tampin a)
6. Location 6 (Tampin b)

To determine sample's particle distribution at all locations.

1. Location 7 (Kampung Rantau Abang A)
2. Location 8 (Kampung Rantau Abang B)
3. Location 9 (Kampung Kuala Abang)
4. Location 10 (Bukit Senyamok)
5. Location 11 (Jambu Bongkok)

Note: All experiment program done for three times to ensure accuracy.

To obtain different set of sample's size for HPHT experiments (20/40).

1. 1000g of Meraga sand sample.
2. 1000g of Batu Tampin sand sample.
3. 1000g of Kampung Kuala Abang sand sample.

4. 1000g of Kampung Rantau Abang sand sample.
5. 1000g of Bukit Senyamuk sand sample.
6. 1000g of Jambu Bongkok sand sample.

To obtain different set of sample's size for HPHT experiments (30/50).

1. 1000g of Meraga sand sample.
2. 1000g of Batu Tampin sand sample.
3. 1000g of Kampung Kuala Abang sand sample.
4. 1000g of Kampung Rantau Abang sand sample.
5. 1000g of Bukit Senyamuk sand sample.
6. 1000g of Jambu Bongkok sand sample.

To compare with recommended sieve analysis by API.

1. Used the data from experimental program.

3.4.3 High pressure high temperature filter press test

Objectives:

1. To determine the best amount from variables of 40g, 30g, 20g, 10g sand samples for use in HPHT experiments.
2. To determine characteristics of particle percentage passing through different sand sample size 30/70.
3. To determine characteristics of particle percentage passing through different sand sample size 20/40compared with SLB 20/40 ceramic sand.
4. To determine characteristics of particle percentage passing through different sand sample size 30/50 compared with Halliburton 30/50 ceramic proppant.
5. To compare local sand samples' characteristic with different set of sample.

Need and scope

Since real formation sample are very hard to acquired, limestone available in the UTP lab has been used for the testing material. Formation's physical and chemical data on the formation sample testing material for this experiment is unknown since there is no proper sampling has been made. Since the objectives of the experiments are mainly to compare the properties between available industrial proppant, the formation particles is to be assumed to be constant along the experimental program. Formation sample is grinded into fine particles.

Apparatus and material required

1. Rocklab mechanical grinder
2. 10g grinded formation particles (Grinded limestone is used as representing the formation particles, the physical properties are unavailable and assumed constant throughout the experiments)
3. 300g Meraga sand sample
4. 40g Batu Tampin, Kampung Kuala Abang, Rantau Abang, Jambu Bongkok, and Bukit Senyamok sand sample.
5. 2,550ml distilled water
6. 150ml graduated cylinder
7. Balance with 0.1 or 0.01 accuracy
8. Syringe
9. Mechanical mixer
10. 150ml or greater cylinder, beaker, container, etc
11. HPHT equipment
12. 150micron industrial metal mesh (Test screen used is metal mesh, twilled dutch weave pattern)
13. Allen key
14. Spanner size 6
15. Spatula
16. Oven

Test procedure

1. 40g of sand sample is balanced with 0.01 accuracy and put into HPHT cylinder above the slotted screen (see figure 13 for HPHT with slotted screen mounting).
2. Cylinder containing sand is shook for evenly bedding.

3. 10g of grinded limestone is balanced with 0.01 accuracy then diluted into 150ml distilled water.
4. The mixtures then mixed using mechanical mixer for 2 minutes and mixtures are stirred continuously using spatula to avoid precipitation.
5. Syringe is used to transfer the mixtures into the HPHT cylinder.
6. Cylinder is shook again for evenly bedding.
7. Top cylinder is locked ensuring the arrow at the top cylinder meet with the arrow at the cylinder body.
8. Lock the top cylinder using allen key. Top and bottom connector are tighten using spanner.
9. Transfer the cylinder into HPHT chamber.
10. Pressure valves are opened from nitrogen tank to the top connector at pressure of 600psi.
11. Temperature is increased and maintain at 185F (85°C).
12. Top connector is opened one and a half rotation counter clockwise slowly to avoid sudden abruption of pressure into the cylinder.
13. Wait for at least 20 seconds until pressure is settle down in the cylinder.
14. Bottom connector is opened counter clockwise, slowly letting the liquid drop into the beaker.
15. Pressure valve is closed when the first abrupt pressure released at the bottom connector.
16. Wait for at least 10 seconds before closing the bottom connector in clockwise direction.
17. Liquid accumulate in beaker then transferred to LPLT equipment.

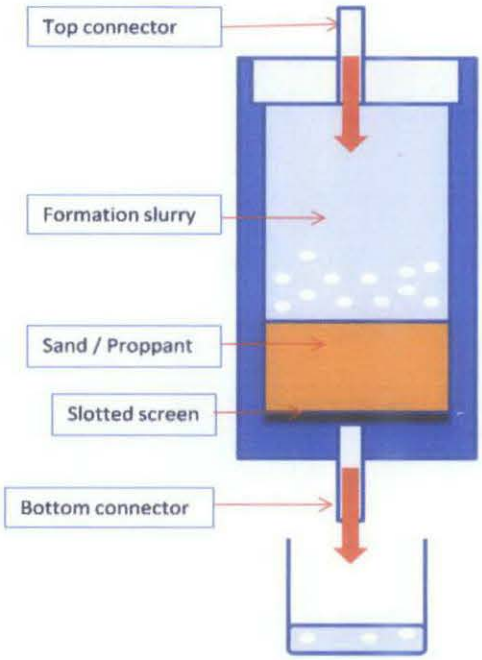

Figure 13: HPHT apparatus

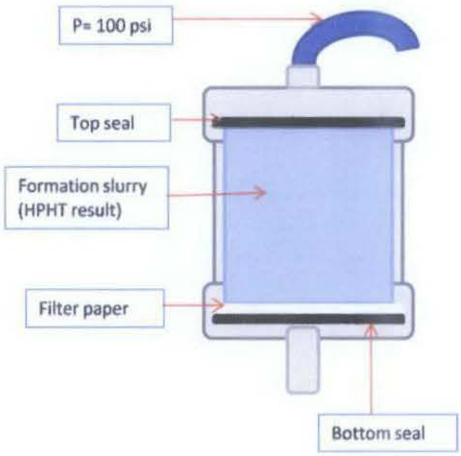

Figure 14: LPLT apparatus

LPLT equipment run at 100psi and ambient temperature used to determine the fluid loss in the drilling mud, or cement. The experiment is adjusted to determine amount of solid particles passing accumulates from HPHT equipment by getting rid of the liquid phase of the mixtures.

1. LPLT equipment is mounted as Figure 14.
2. Filter paper is put above the sieve at the bottom of LPLT cylinder and below the rubber gasket/sealer.

3. Bottom cylinder is locked tightly and mounted on the apparatus.
4. Liquid from HPHT test is poured into the LPLT cylinder then closed tightly by top cylinder. Pressure is run into the cylinder.
5. Wait for 10minutes before dismantle the apparatus.
6. Particles suspended on the filter paper then are put into oven at 105°C for at least 1 hour.
7. Dried filter paper + particles are cooled before weighted.
8. Take three readings for particle weight from a 0.01 accuracy balance.

Experimental program

To determine the best amount from variables of 40g, 30g, 20g, 10g sand samples for use in HPHT experiments.

1. 40g of Meraga sand sample tested for HPHT and LPLT tests.
2. 30g of Meraga sand sample tested for HPHT and LPLT tests.
3. 20g of Meraga sand sample tested for HPHT and LPLT tests.
4. 10g of Meraga sand sample tested for HPHT and LPLT tests.

To compare characteristics of particles passing through different sand 20/40, 30/50, and 30/70

1. 40g or 30g or 20g or 10g of Batu Tampin sand sample.
2. 40g or 30g or 20g or 10g of Kampung Kuala Abang sand sample.
3. 40g or 30g or 20g or 10g of Kampung Rantau Abang sand sample.
4. 40g or 30g or 20g or 10g of Bukit Senyamuk sand sample.
5. 40g or 30g or 20g or 10g of Jambu Bongkok sand sample.

To determine characteristics of particle percentage passing through sand sample size 20/40 compared with SLB 20/40 ceramic sand.

1. 40g or 30g or 20g or 10g of SLB 20/40 ceramic sand.

To determine characteristics of particle percentage passing through sand sample size 30/50 compared with Halliburton 30/50 ceramic proppant.

1. 40g or 30g or 20g or 10g of Halliburton 30/50 ceramic proppant

All experiment program done for three times to ensure accuracy.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Material selection and acquirement

4.1.1 To determine sand bedding parallel and adjacent to the beaches (Meraga sample)

Field trip has been held to acquire the sand sample needed for the project. Total of approximately 180kg of sand sample has been brought back to UTP from the predetermined locations stated in literature review (Chapter 2), which are Kampung Meraga deposit, Bukit Tampin Deposit, Kampung Kuala Abang deposit, Rantau Abang 'B' deposit, Bukit Senyamok Deposit, and Jambu Bongkok deposit. Since Meraga deposit is observed to be the largest reserve of sand, we decided to use it on determination of sand bedding parallel and adjacent to the beach.

Since previous study has shown Kampung Meraga sand sample shows the best sample, delegacy decided to do more sampling at Meraga that explain the number in result section. From author's view, sand sample at all locations are very good based on preliminary judgment on sample's shape, size, and very little eroded shells and contaminant found on the sample but further investigation still need to be done.

During the field trip, the author noticed that Bukit Tampin deposition area has significant development where Mesra Mall and residential houses has been built on top of it. So, further exploitation of the silica sand seems to be impossible in Bukit Tampin.

However, sand sample from Bukit Tampin still be taken for testing purposes. Insignificant development of permanent structure can be seen at the other places so further exploitation still can be done especially Kampung Meraga deposit and Bukit Senyamok deposit.

Table 3 shows result for determination of sand bedding parallel to the beaches. (Refer appendix 1 to see the point of study)

Table 3: Depth of layers parallel to beaches.

Samples	1st Layer depth (cm)	2nd Layer depth (cm)	Length (m)
Meraga A	-1.5	-11.5	25
Meraga B	-2	-15	50
Meraga C	-4	-10.5	75
Meraga D	-3	-11.5	100

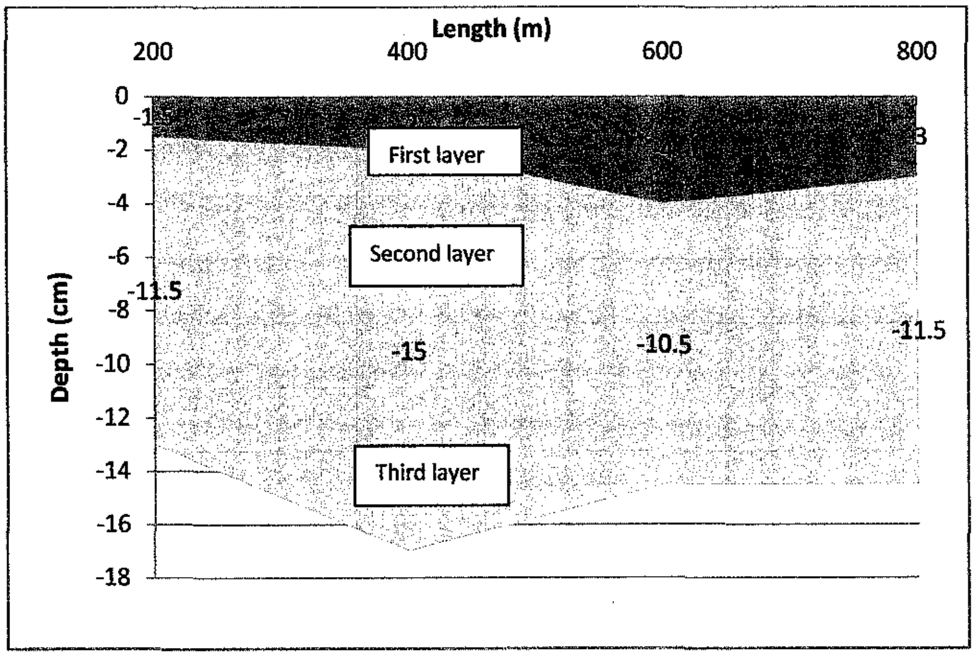

Figure 15: Meraga Sand deposit layer parallel to the beach

Figure 15 shows that layers of sand bedding is quite consistent where the deepest sand layer at first layer of sand is 4cm, shallowest sand layer at second layer where the samples are taken is 10.5cm. Assuming the maximum depth from first layer and minimum depth of second layer is continuous along the line, the height of sand sample should be taken is 6.5cm.

Table 4 shows result for determination of sand bedding adjacent to the beach at point C and D.

Table 4: Depth of layers at point C and D

Samples		1st Layer depth (cm)	2nd Layer depth (cm)	Length (m)
Meraga C	1	-4	-6.5	50
	2	-2.5	-9	100
	3	-3.5	-10	150
Meraga D	1	-3	-8.5	50
	2	-4	-8	100
	3	-3.5	-11.5	150

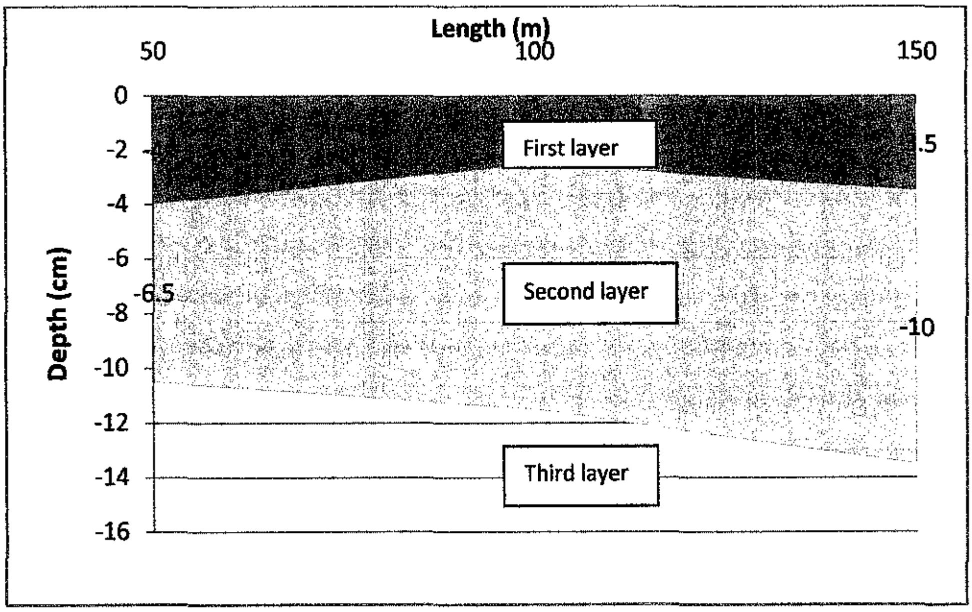

Figure 16: Meraga sand C adjacent to beach

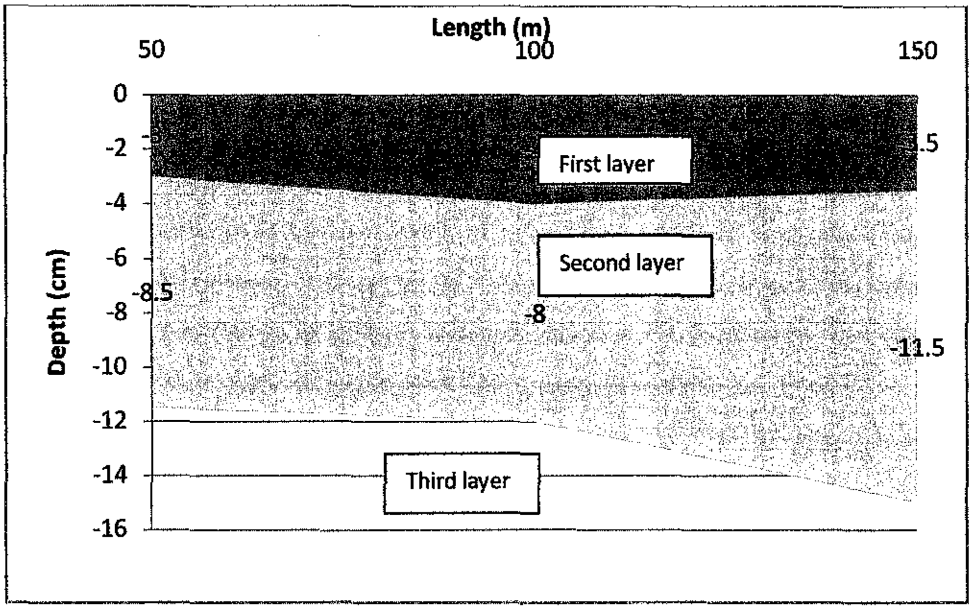

Figure 17: Meraga sand D adjacent to beach

Figure 16 and 17 figure shows the sand bedding for Meraga sample taken at point C and D, three points adjacent to the beach (refer appendix). Both figures shows quite similar result where maximum depth for second layer 4cm and minimum depth for second layer is 8~9cm. Assuming the maximum depth from first layer and minimum depth of second layer is continuous along the line, the height of sand sample should be taken is 4~5cm. Averaging the sample height from parallel points and adjacent points, the average depth the sample should be taken is ±5cm in Kampung Meraga. Given the height of samples taken, we can roughly calculate the volume of the sand reserves given the area of concerns using this equation.

$$V = area \times height$$

Since there is no further investigation about the sample reserves in Terengganu since 1970's and 1980's, it is recommended to do the study. However, this report will not include it as a scope of study. Noted that this report section only presents the determination of sand bedding done on Meraga sample only and the other's sand bedding is taken once and assumed to be same along the area.

4.1.2 To determine height of sand bedding required for best silica deposition at all locations.

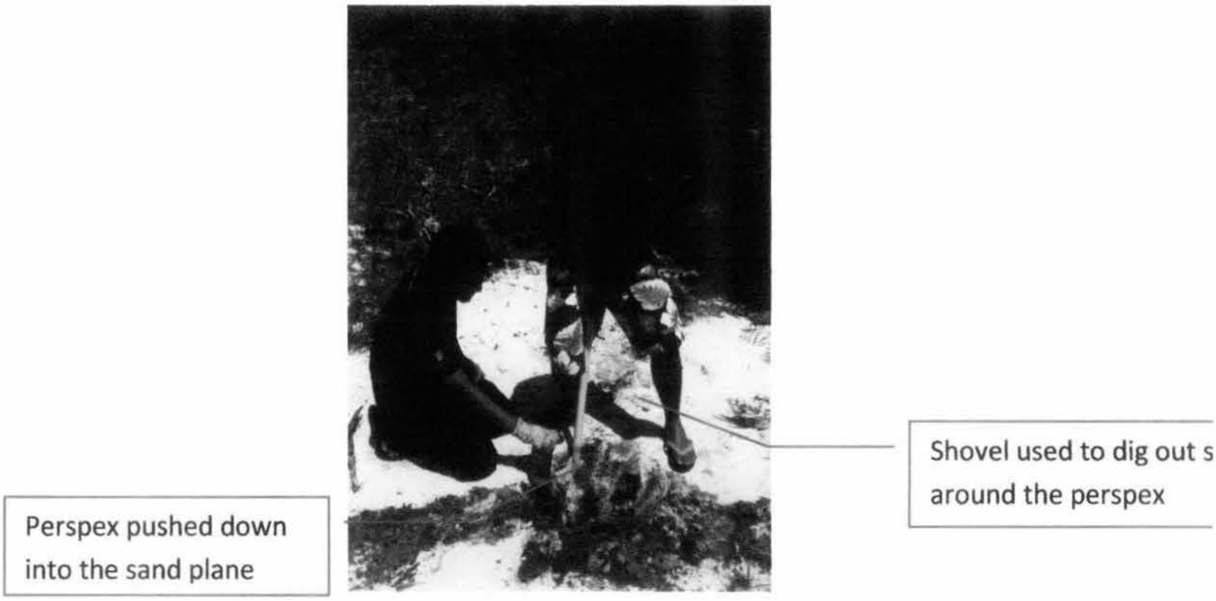

Figure 18: Sampling in the Perspex been digging out.

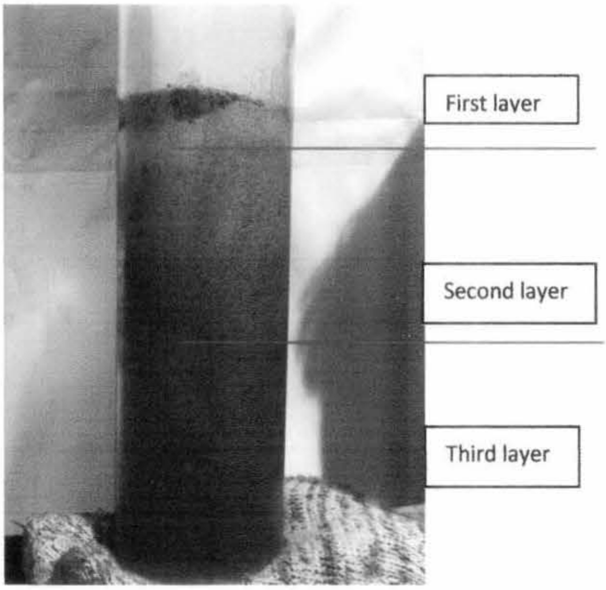

Figure 19: Sampling in Perspex

Figure 18 shows how the sampling using Perspex been done by two persons. Figure 19 shows significance distinctive between sand layers seen through cylindrical Perspex.

Sand layers height is measured and recorded in table 5.Table 5 below shows the sand layers interval and height of sand reserve at all locations.

Table 5: Sand layers at all locations.

Sample	1st Layer (cm)	2nd Layer (cm)	sand reserve's height (cm)
Meraga	4~5	8.5	4~5
Tampin	3.5	7	3.5
Kg. Kuala Abang 'B'	1	2	1
Bukit Senyamok	3	10	7
Rantau Abang 1	2	16	14
Marang	3	13	10
Jambu Bongkok	3.5	14.5	11

From table 5, the highest sand reserve's height is Rantau Abang 1 at 14cm and the lowest is Kampung Kuala Abang 'B' at 1cm only. This is however does not determine the volume of the reserve since the area of study is different for each locations.

As conclusion, there is no significance changes are seen on sand reserve height at different location taken at several points adjacent and parallel to the beaches. Factor of different points at the same area of study can be neglected. All Meraga samples can be used as material for the experiments. All samples then taken while assuming sand reserve height at other points inside the area of study are the same. (Refer appendix 1 and 2 to see the point of study)

4.2 Sieve analysis

4.2.1 To compare particles distribution at several points along the line adjacent the beach (Meraga and Tampin).

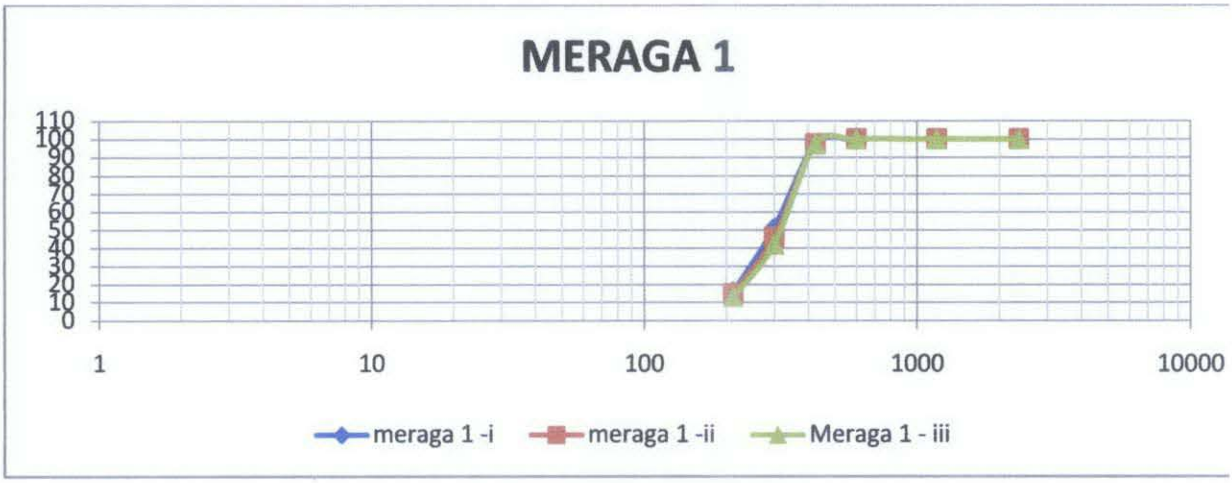

Figure 20: Meraga 1 particle size distribution

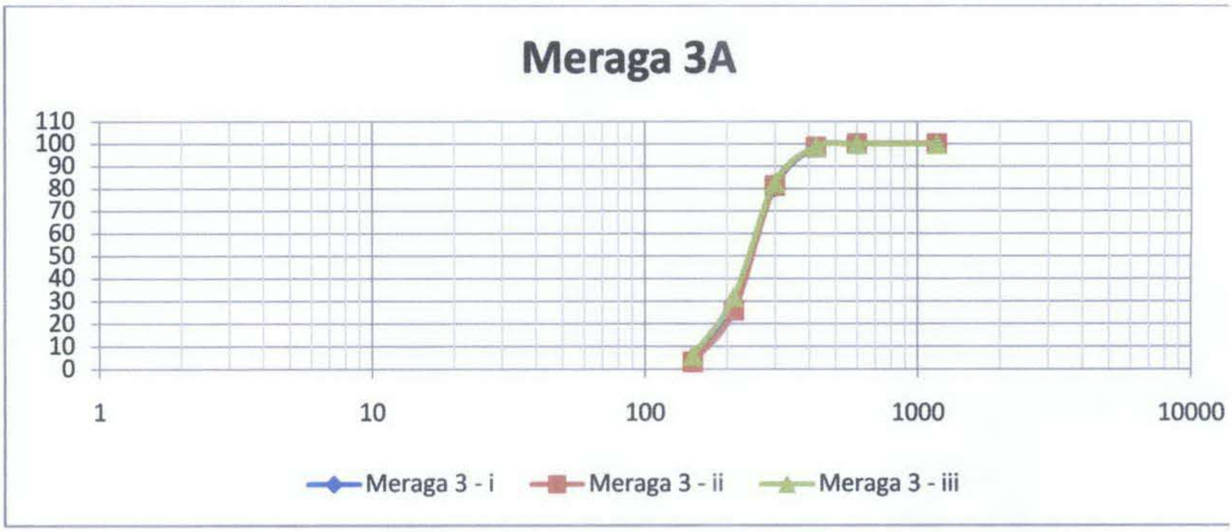

Figure 21: Meraga 3A particle size distribution

Figure 22: Meraga 3B particle size distribution

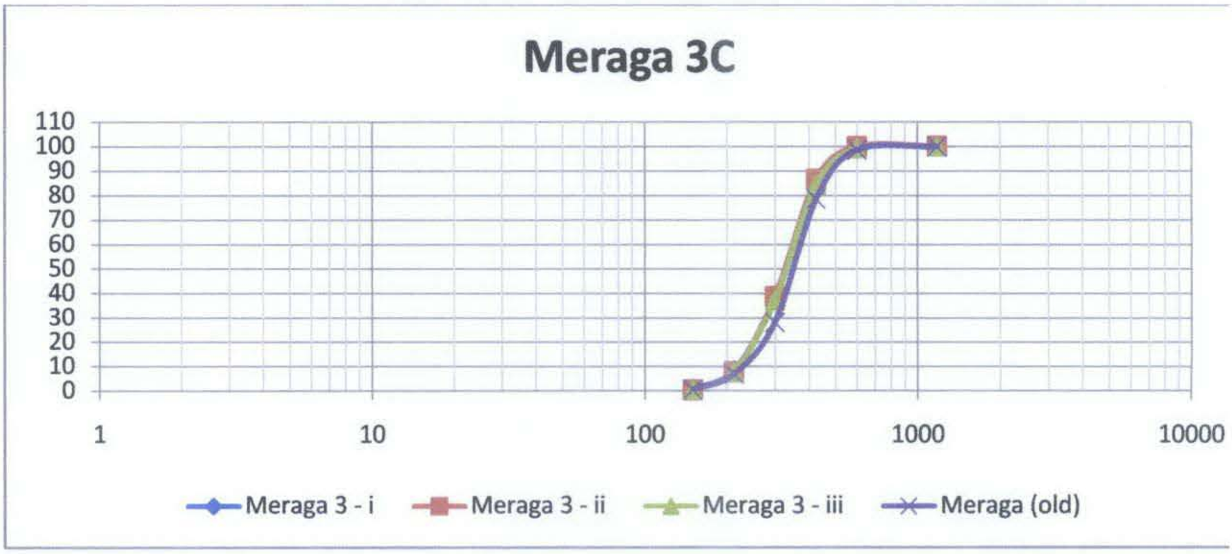

Figure 23: Meraga 3C particle size distribution

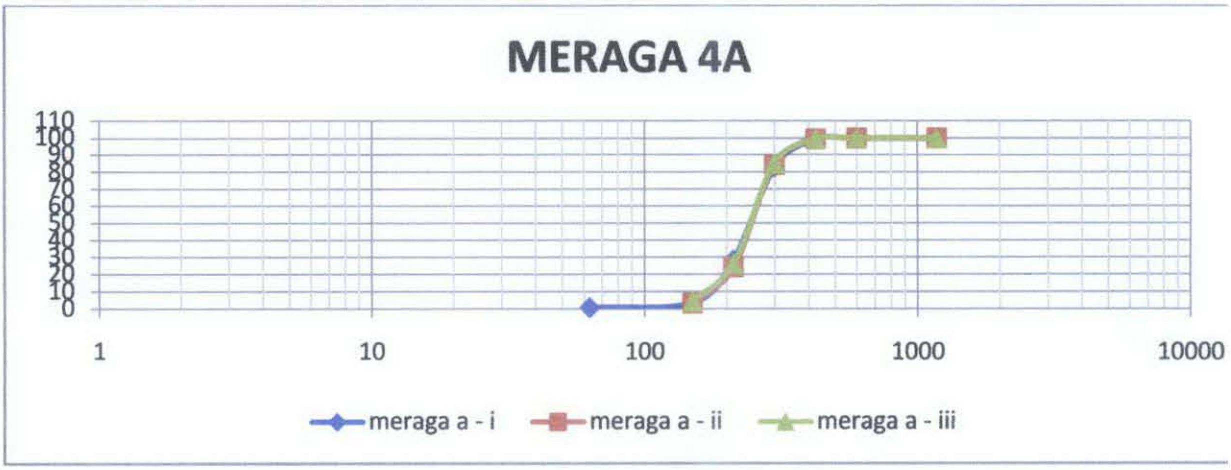

Figure 24: Meraga 4A particle size distribution

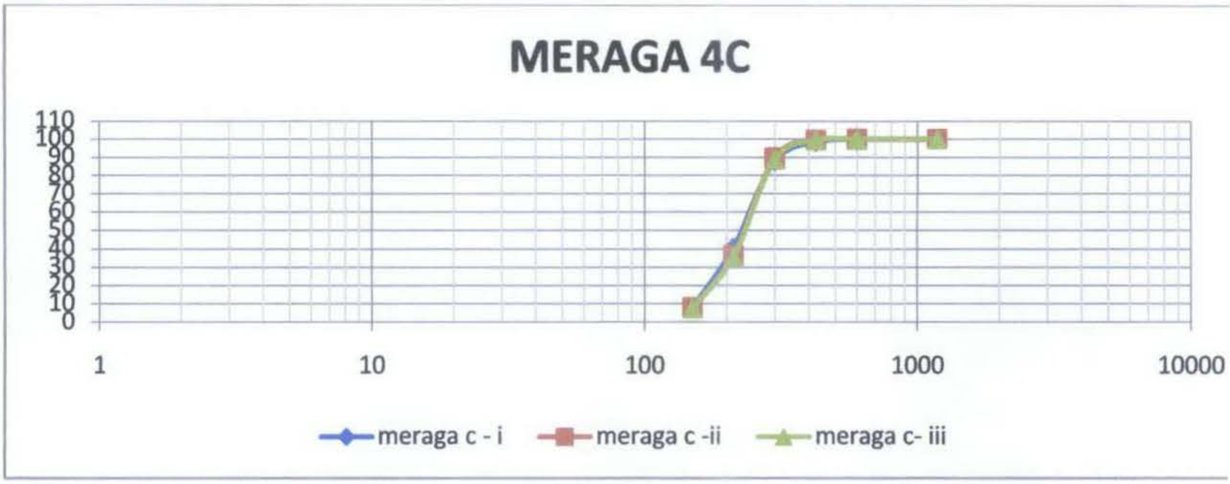

Figure 25: Meraga 4C particle size distribution

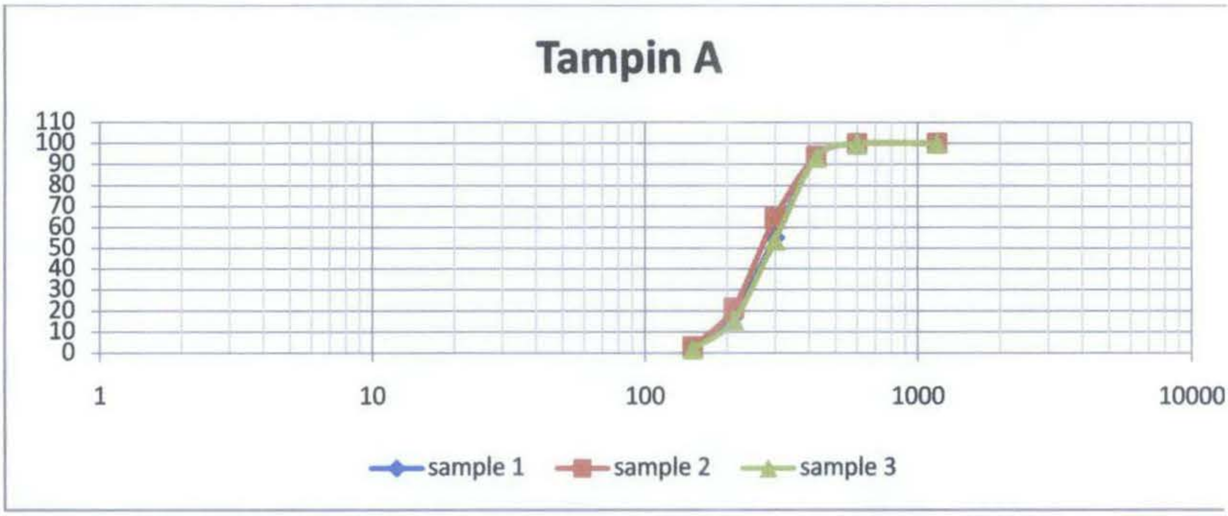

Figure 26: Tampin A particle size distribution

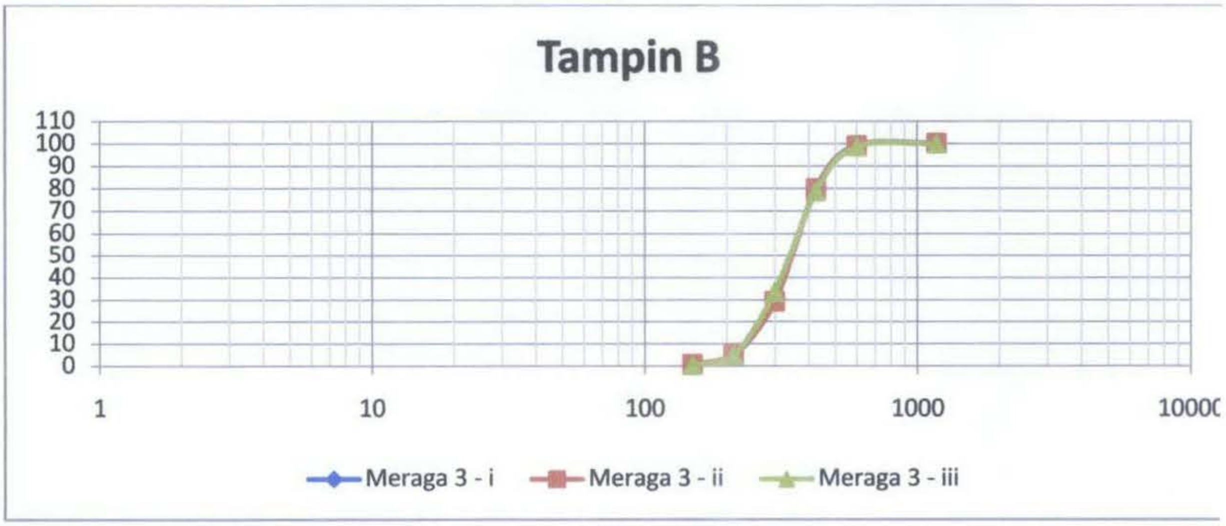

Figure 27: Tampin B particle size distribution

(See appendix 3 to 10 for sieve analysis data for Meraga and Tampin samples.)

Table 6: Median and uniformity coefficient at points parallel and adjacent to the beach

Samples	D90 (micron)	Median size, D50 (micron)	D40 (micron)	Uniformity coefficient, C=d40/d90	Sort
Meraga 1	400	320	300	0.75	Uniform
Meraga 3A	350	250	230	0.66	Uniform
Meraga 3B	390	320	250	0.64	Uniform
Meraga 3C	450	320	300	0.64	Uniform
Meraga 4A	300	250	230	0.77	Uniform
Meraga 4C	300	250	230	0.77	Uniform
Tampin A	300	280	260	0.87	Uniform
Tampin B	500	350	320	0.64	Uniform

Figure 20 to 27 shows the sieve analysis of all points in Kampung Meraga parallel and adjacent to the beaches. The graphs show almost the same steepness pattern. Uniformity coefficient that can be used to determine the degree of sorting ranges from 0.64 to 0.77 which are highly sorted. There are two median sizes of Meraga sample which are 250micron and 320micron which is quite consistent.

As for Tampin sand sample, there are two median sizes which are 280micron and 350micron. The uniformity coefficient is ranging from 0.64 to 0.87. The sand samples are uniformly sorted.

As conclusion, previous claim that all Meraga sample at different points can be used as a whole sample can be justified by sieve analysis of the sample. The size of the samples are consistent as well as it is all uniformly sorted. Different point parallel and adjacent to the beach factor can be neglected. All Kampung Meraga sample can be used as one package of sample.

As for Tampin sand sample, the median sizes for two locations parallel to the beach are different but can be neglected since there is only small in difference. Furthermore, the two samples are uniformly sorted. This proves that the same cases in Meraga can be used in Tampin and other locations.

4.2.2 To determine sample's particle distribution at all locations.

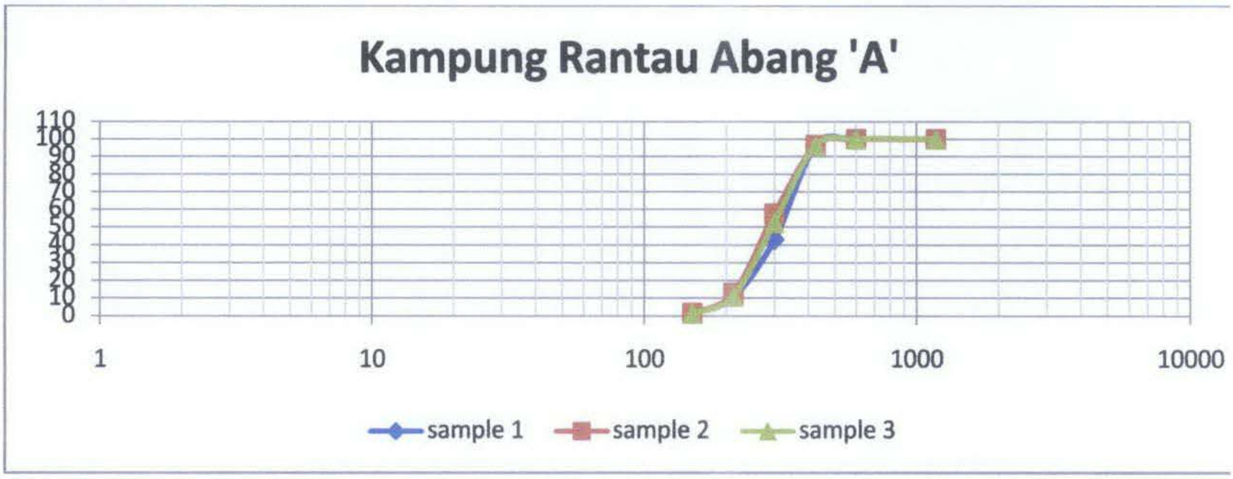

Figure 28: Kampung Rantau Abang A particle size distribution

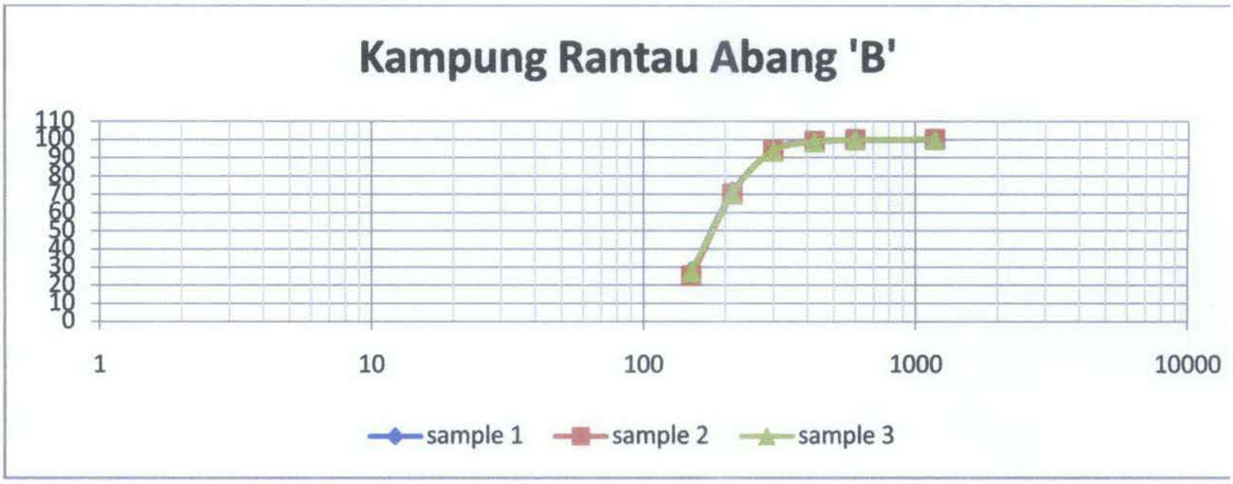

Figure 29: Kampung Rantau Abang B particle size distribution

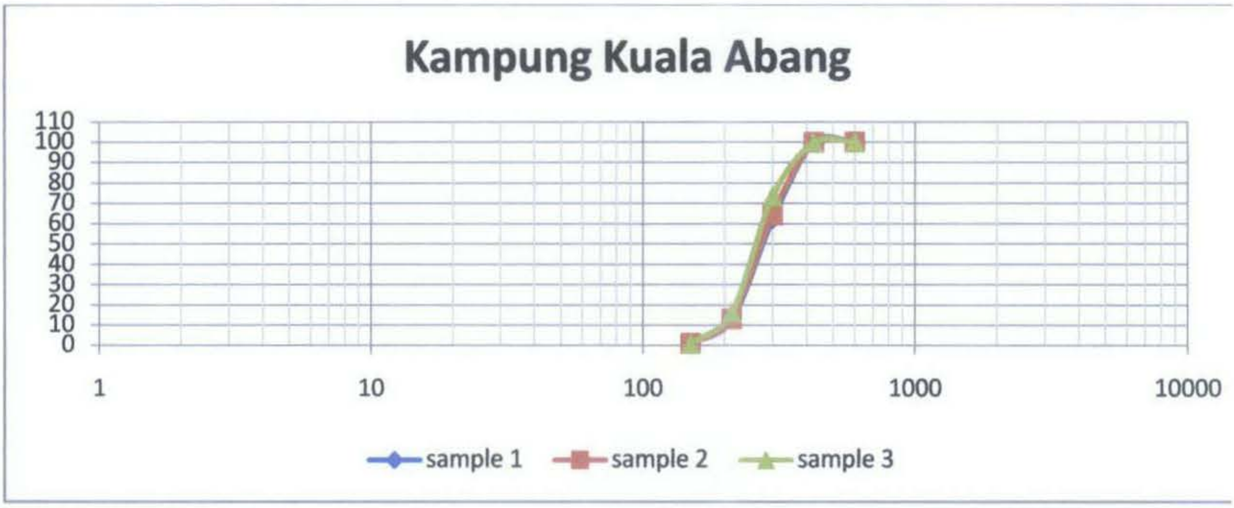

Figure 30: Kampung Kuala Abang particle size distribution

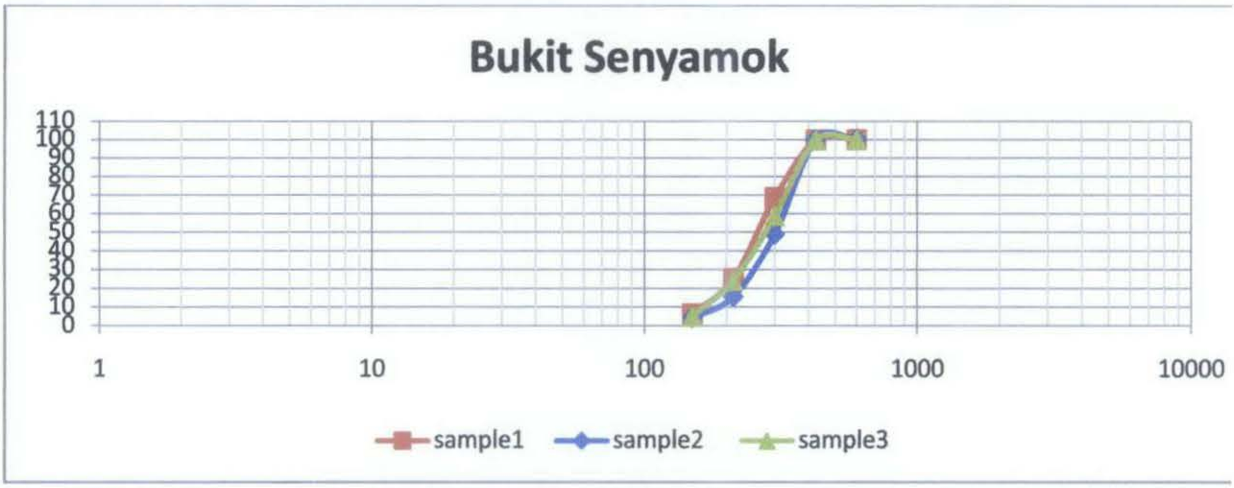

Figure 31: Bukit Senyamok particle size distribution

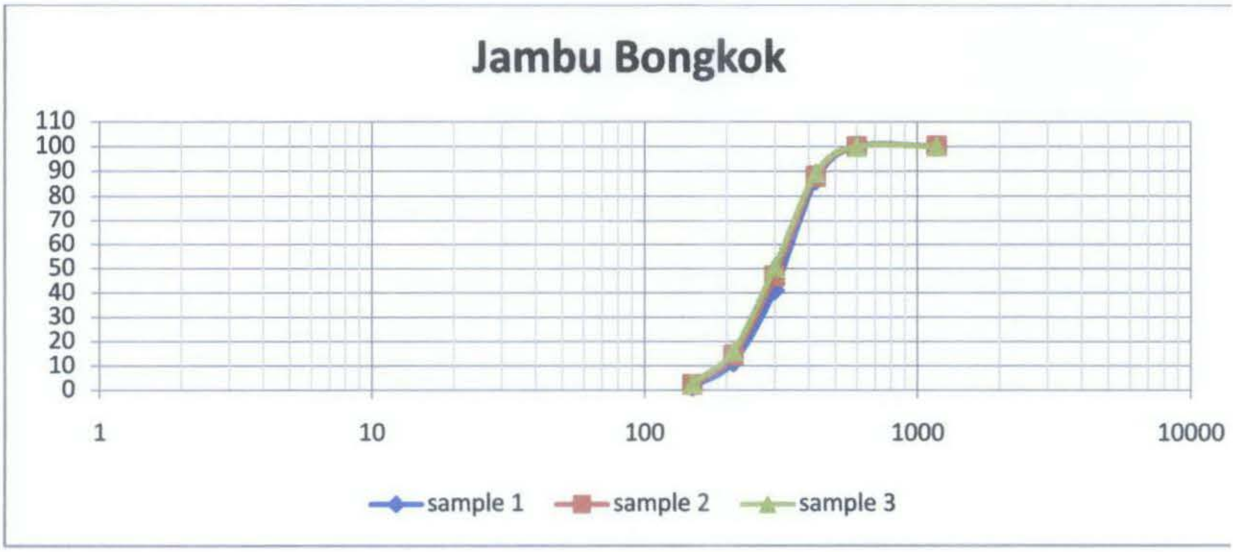

Figure 32: Jambu Bongkok particle size distribution

(See appendix 11 to 15 for sieve analysis data for Kg. Rantau Abang, Kuala Abang, Bukit Senyamok, and Jambu Bongkok.)

Figure 28 to 32 shows the sieve analysis for all location except for Meraga and Tampin. The graphs are observed to have same pattern of steepness which mean high degree of sorting.

Table 7: Median and uniformity coefficient at all locations.

Samples	D90 (micron)	Median size, D50 (micron)	D40 (micron)	Uniformity coefficient, C=d40/d90	Sort
Meraga (average)	365	285	257	0.71	Uniform
Tampin (average)	400	315	290	0.76	Uniform
Kg.Rantau Abang A	400	300	360	0.9	Uniform
Kg.Rantau Abang B	300	180	170	0.57	Uniform
Kampung Kuala Abang	360	270	250	0.69	Uniform
Bukit Senyamok	380	270	250	0.66	Uniform
Jambu Bongkok	420	300	290	0.69	Uniform

From table 7, it shows that the lowest median size is at Kampung Rantau Abang which is 180micron while the highest median size is at Tampin which is 315micron. The best sand sample sorting is at at Tampin with 0.76 and the least sorting is Kampung Rantau Abang B with 0.57

Although all samples shows different median size and uniformity coefficient, it is to be noted that all samples have high degree of sorting which is very good for gravel pack's proppant material.

Higher degree of sorting means better load distribution the proppant handles. In conclusion, all samples are very good and can be used for further sampling in other experiments.

4.2.3 To compare with recommended sieve analysis by API.

Table 8: Comparison between local samples' sieve analysis with recommended API

Percentage Retained (wt %)							
Sieve Size (mm)	**Meraga**	**Tampin**	**Rantau Abang B**	**Kuala Abang**	**Senyamok**	**Jambu Bongkok**	**Recommended API**
1.180	0.02	0.21	0.04	0.14	0.13	-	<0.1
0.850	-	-	-	-	-	-	>90
0.600	1.47	5.92	1.86	1.14	9.05	0.15	
0.425	10.45	29.37	13.63	5.15	26.89	36.13	
0.355	-	-	-	-	-	-	
0.300	47.66	43.11	41.89	23.25	38.06	39.00	
0.250	-	-	-	-	-	-	
0.212	32.44	18.54	34.53	42.90	19.65	19.03	
0.150	7.78	2.35	7.40	19.97	4.67	5.05	
Pan	0.18	0.49	0.65	7.36	1.54	0.62	<1.0
Results	√	x	√	x	x	x	

Table shows the data of sieve analysis for all locations. According to the table, only two (2) samples are passed with accordance to recommended API which are Meraga sample and Kampung Rantau Abang B.

The samples are failed according to API recommended specification is because the sieve analysis done on the raw sand samples without prior cleaning to get rid of impurities of larger and fines particles. Due to unavailability of cleaning apparatus as recommended in API in UTP, we are unable to produce good results. Samples cleaning apparatus need to be purchased and used for better results for the future study.

In conclusion, taking the cleaning process into consideration, all samples show very good result where the differences as compared to API specification for proppant are very small. All samples assumed to be accepted for HPHT tests.

4.3 HPHT filter press test

4.3.1 To determine the best amount from variables of 40g, 30g, 20g, 10g sand samples for use in HPHT experiments.

Theoretically, increasing the amount of sand sample will result decreasing solid passing from HPHT equipment test. Figure 1 shows the results from varying Meraga sample weight of 10g, 20g, 30g, and 40g.

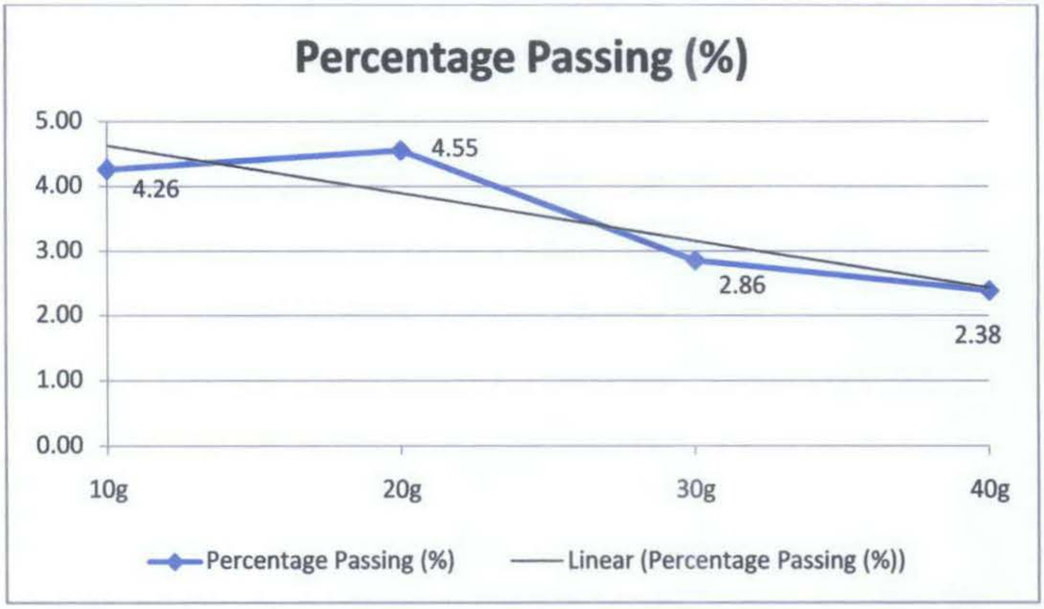

Figure 33: Percentage passing vs. sample weight

From the figure 33, 40g of sample has the lowest formation particles passing as compared with others with 2.38% or 0.238g passing from 10g of formation particles. The highest formation particles passing is at 10g of sand sample with 4.26%.

Figure 34: (From left to right) Meraga sand sample of 10g, 20g.

Figure 35: (From left to right) Meraga sand sample of 30g, 40g.

There is significant concentrated particles mark (sand bridging into the sample) on the surface of 150mmicron slotted screen from 10g sand sample from figure 34 while none on 20g, 30g, and 40g sand sample (see figure 34 and 35). Amount of 10g sand sample is decided below adequate for this experiment.

Particle percentage passing is higher at 20g sand sample which is 4.26% (10g) compared to 4.55% (20g). This maybe because of several factors observed from the experiments;

1. Particles slurry not stirred well before put into the HPHT equipment leaving the solid settled on the bottom of the container.
2. Liquid drop at 1/8 lower valve opening is crystal clear or contain no particles. Varying time taken for 1 opening may affect the total amount of particle passing.
3. Liquid containing particles, loss to environment due to sudden burst of pressure from lower valve.

It is to be concerned that there is no documentation on how much amount of sand sample needed for one set of HPHT experiment. The amount of sand must be adequate enough to sustain the formation particles without unduly reduce the permeability of passing fluids. Further testing should be done to determine the optimum amount of sand sample needed according to several factors like sand sample size, formation particles size, slotted screen size, etc.

From the result, amount of 40g sand sample is the best amount compared to 30g, 20g, and 10g of sand sample while other factors mention above are made constant to make comparison between available variables possible.

4.3.2 To compare characteristics of particles passing through different sand 20/40, 30/50, and 30/70

Table 9: All samples proppant range 20/40, 30/50, and 30/70

	Proppant Range		
Sample	**20/40**	**30/50**	**30/70**
Meraga	6.93	6.08	2.38
Kg Kuala Abang	3.49	6.00	1.55
Bukit Senyamok	7.59	5.89	4.24
Jambu Bongkok	4.68	5.03	3.76
Kg Rantau Abg B	9.29	9.36	4.94
Kg Bt Tampin	4.54	2.04	13.35

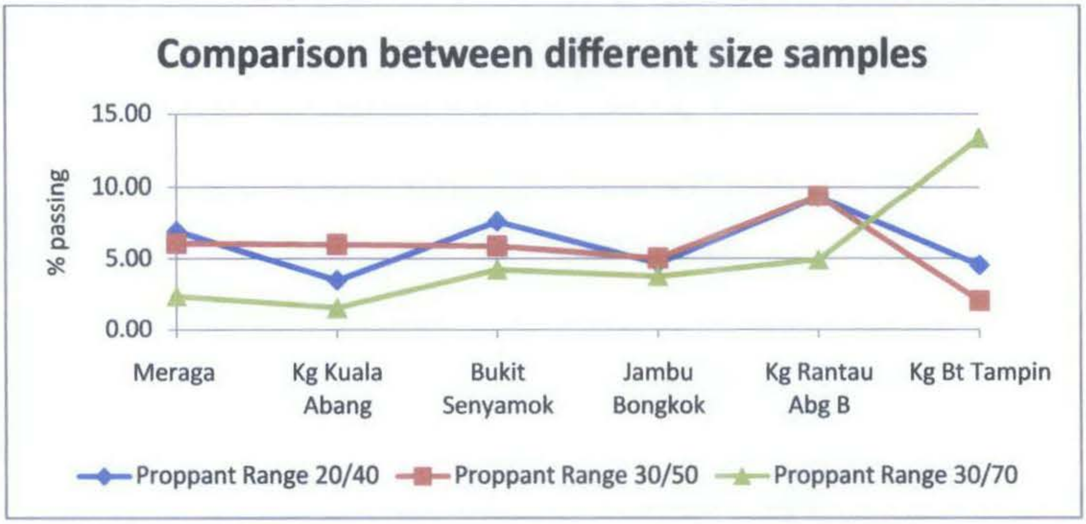

Figure 36: comparison between different size samples

Table 9 shows the percentage particles passing; representing the efficiency percentage by assuming from a total of formation particles, a portion or a percentage of them will be able to pass through the gravel pack (local sand samples).

Figure 36 shows the comparison of percentage particles in slurry passing through samples and metal mesh size 150micron. Through the graph, proppant range of 30/70 is the best proppant size for Meraga given the least percentage passing at 2.38% followed by 30/50 and 20/40 size range both at 6.08 and 6.93 respectively. Bukit Senyamok result followed the same pattern of Meraga sample with the least sample passing at proppant range 30/70 at 4.24%.

30/70 is the best size for Kg Kuala Abang at 1.55% but followed by proppant range 20/40, and 30/50. The result is different from Meraga sample. This may because of different characteristic of its roundness and sphericity and other unknown causes. Jambu Bongkok and Kg Rantau Abang B followed the same pattern with least passing at proppant range 30/70 at 3.76% and 4.94% respectively.

At Kg Batu Tampin however, different pattern can be seen where proppant range of 30/50 comes the best proppant range with percentage passing at only 2.04% followed by proppant range 20/40 and unexpectedly proppant range 30/70 with the highest percentage passing of all samples at 13.35%. It is to be point out that the experiments are done for three times for each samples proppant range. So, the result should be reliable enough and experiment's ralat should be negligible. This result maybe because of the sand's characteristic itself as example the roundness and sphericity, samples properties under high temperature and high pressure, etc.

From the results, we can say that proppant range of 30/70 is the best proppant range for local samples aside for Batu Tampin samples which its best at proppant range of 30/50. From the proppant range 30/70, the best sand sample is Kg. Kuala Abang with percentage passing at only 1.55% of particles passing. Further analysis on other physical and chemical properties must be carried out to compare the results.

4.3.3 To determine characteristics of particle percentage passing through sand sample size 20/40 compared with SLB 20/40 ceramic proppant.

Table 10: All samples proppant range 20/40

20/40	
Sample	**avg % passing**
Meraga	6.93
Kg Kuala Abang	3.49
Bukit Senyamok	7.59
Jambu Bongkok	4.68
Kg Rantau Abg B	9.29
Kg Bt Tampin	4.54
20/40 Slb	6.0933

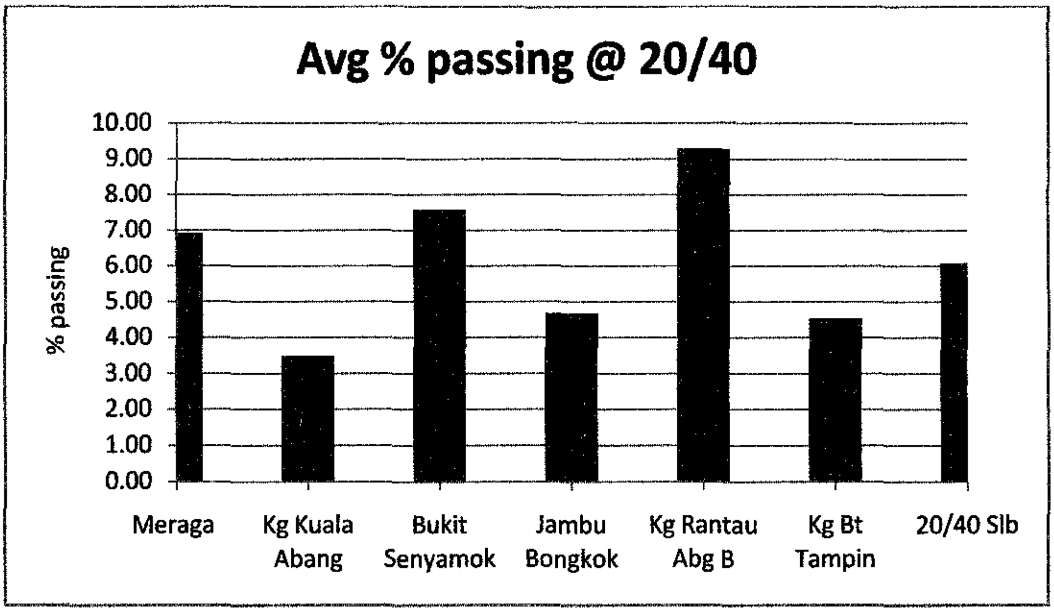

Figure 37: Average percentage passing at 20/40 proppant range

(Note: Refer appendix 16 for HPHT filter press percentage passing data at all locations.)

Table 9 and figure 37 shows the comparison between average percentage particles passing through sand samples 20/40 and Schlumberger ceramic proppant 20/40. From the figure, we can say that, there are three (3) local sand samples that perform better than conventional proppant (SLB 20/40).

Average percentage passing for 20/40 SLB is 6.09% while Kg Kuala Abang, Jambu Bongkok, and Kg Batu Tampin are 3.49%, 4.68%, and 4.54% respectively. This shows that our local sand has very good characteristic for proppant in gravel pack application.

The other three (3) samples which are Meraga, Bukit Senyamok, and Kg Rantau Abang record higher average passing through them. The highest percentage passing is at Kg Rantau Abang B with 9.29%.

All samples are able to filter out more than 90% of formation particles for proppant range 20/40.

4.3.4 To determine characteristics of particle percentage passing through sand sample size 30/50 compared with Halliburton 30/50 ceramic proppant.

Table 11: All samples proppant range 30/50

30/50	
Sample	**avg % passing**
Meraga	6.08
Kg Kuala Abang	6.00
Bukit Senyamok	5.89
Jambu Bongkok	5.03
Kg Rantau Abg B	9.36
Kg Bt Tampin	2.04
30/50 hbn	17.1433

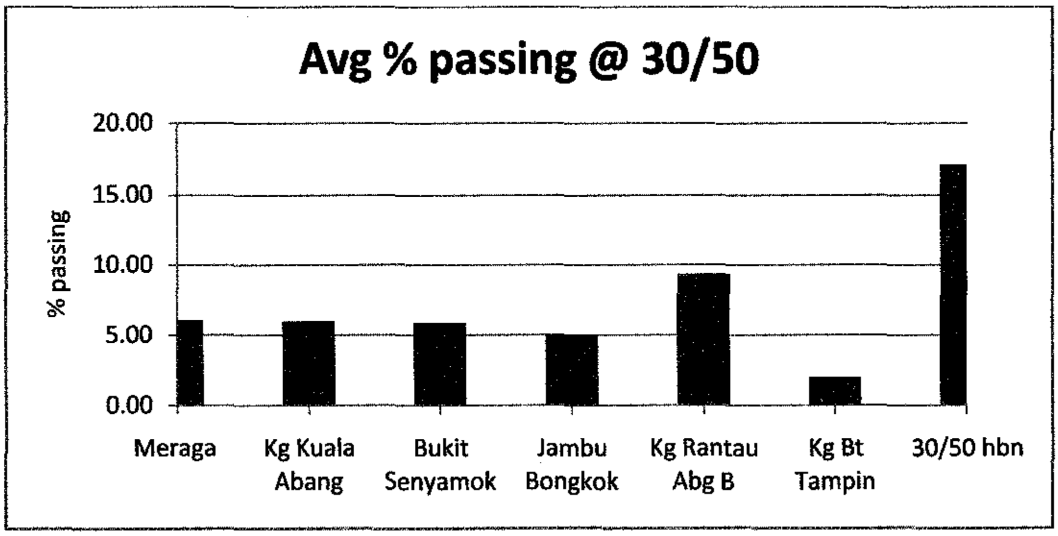

Figure 37: Average percentage passing at 30/50 proppant range

(Refer appendix 16 for HPHT filter press percentage passing data at all locations.)

Table 10 and figure 37 shows the comparison between average percentage particles passing through sand samples 20/40 and Halliburton ceramic proppant 30/50. From the figure, we can say that all local sand samples perform much better than conventional proppant (HBN 30/50).

All samples also are able to filter out more than 90% of formation particles for proppant range 30/50.

All in all, proppant range of 30/70 is the best size range for gravel pack given the same size range of formation particles used in this experiment. Kg Kuala Abang, Jambu Bongkok, and Kg Batu Tampin shows better performance for 20/40 size range while all samples are performing better for proppant range of 30/50. All samples are able to filter out more than 90% of formation particles with constant formation particles been used.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Table 12 below shows the summary of all activities done for this project.

Table 12: Material acquisition, sieve analysis, and HPHT filter press results summary.

Samples	Average thickness (cm)	Sieve analysis	HPHT filter press performance	
			20/40	30/50
Meraga	4~5	Pass	Lower	Higher
Kg Kuala Abang	1	Fail	Higher	Higher
Bukit Senyamok	7	Fail	Lower	Higher
Jambu Bongkok	11	Fail	Higher	Higher
Kg Rantau Abg B	14	Pass	Lower	Higher
Kg Bt Tampin	3.5	Fail	Higher	Higher

(Note: higher means higher performance as compared to industry proppant and vice versa for lower.)

There is no significance changes are seen on sand reserve height at different location taken at several points adjacent and parallel to the beaches. Factor of different points at the same area of study lead to different results can be neglected.

Sieve analysis of the samples indicated that our local sand samples are very good. The samples passed the API recommended specifications are Meraga and Kuala Abang. The result from particle size distribution shows that all samples are uniformly sorted ranging from 0.57 to 0.9 which are very high degree of sorting. If the sand samples are cleaned with proper sampling method (reducing and splitting) before the sieve analysis is done, the probability of samples passing the specification by API is very high.

In the HPHT filter press experiment, comparison between different mesh size set of different samples shows that size set of 30/70 is superior for the formation particles used in this experiment. Since there are no industry proppant of 30/70, 20/40 and 30/50 size mesh is compared and resulting 30/50 size mesh is better for proppant in gravel pack for this type of formation. From table 12, all samples perform better than conventional proppant for size set of 30/50.

Considering all experiments, Meraga and Kampung Rantau Abang B samples are passing the API requirement and perform better than conventional proppant of size set 30/50.

5.2. Recommendation

For material acquirement, longer reach hand auger should be used instead of cylindrical Perspex to investigate deeper buried sand layers. For sieve analysis, sand splitter, sand reducer and Ro-tap sieve shaker should be used as recommended by APIRP to ensure the level of work can be compared and standardized. For particle passing test, using different particles slurries is recommended since different size of formation particles will end with different results towards different sand samples. Equipment with higher pressure and higher temperature should be used for simulates different wellbore conditions.

Further analysis like crush resistance test, acid solubility, and roundness and sphericity characterization, and other experiment should be carried out to further prove our local sand can be used as proppant in gravel pack application.

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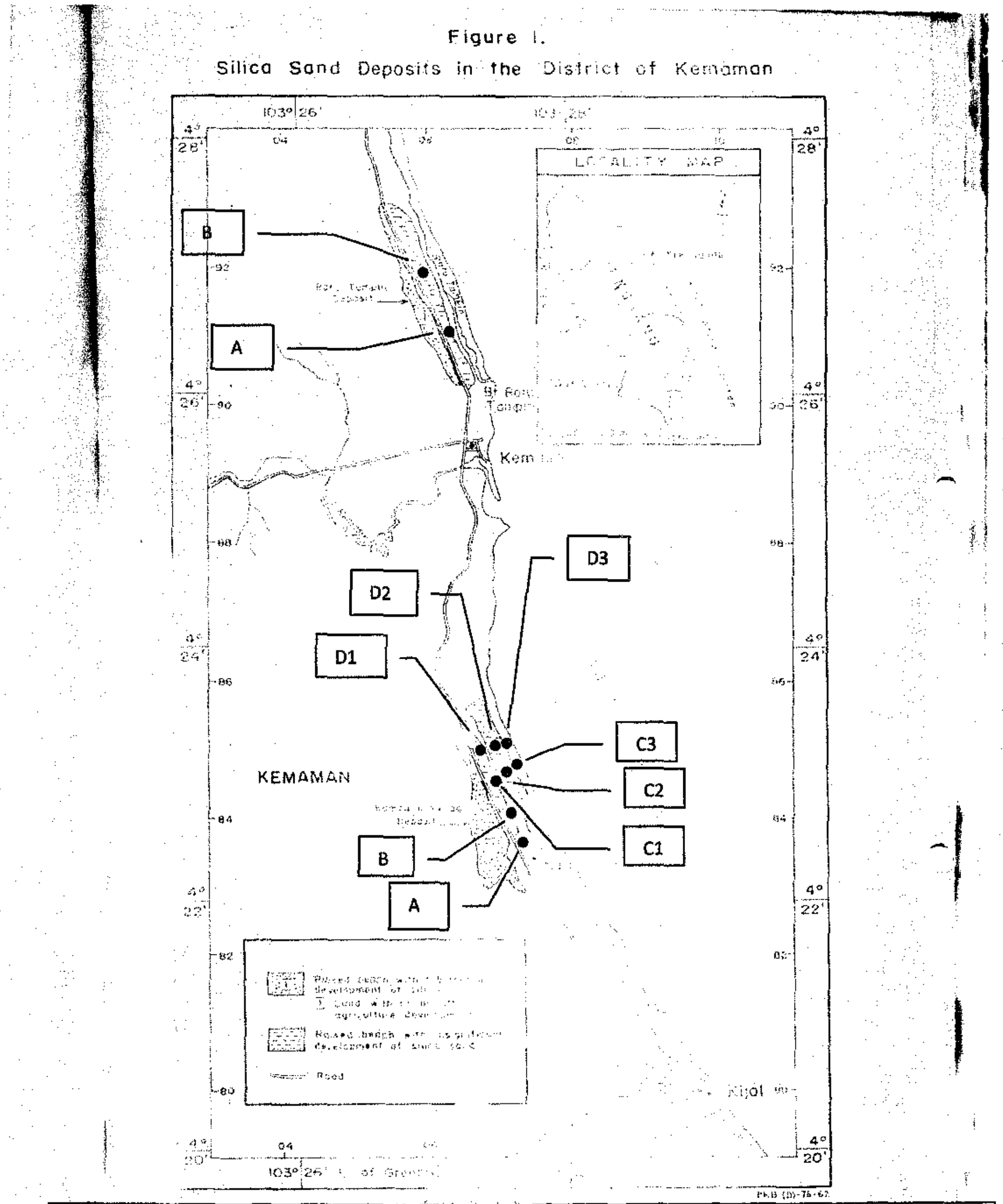
Appendix

Appendix 1 – Map showing Kampung Meraga and Bukit Tampin deposit locations (P.C.AW, 1978).

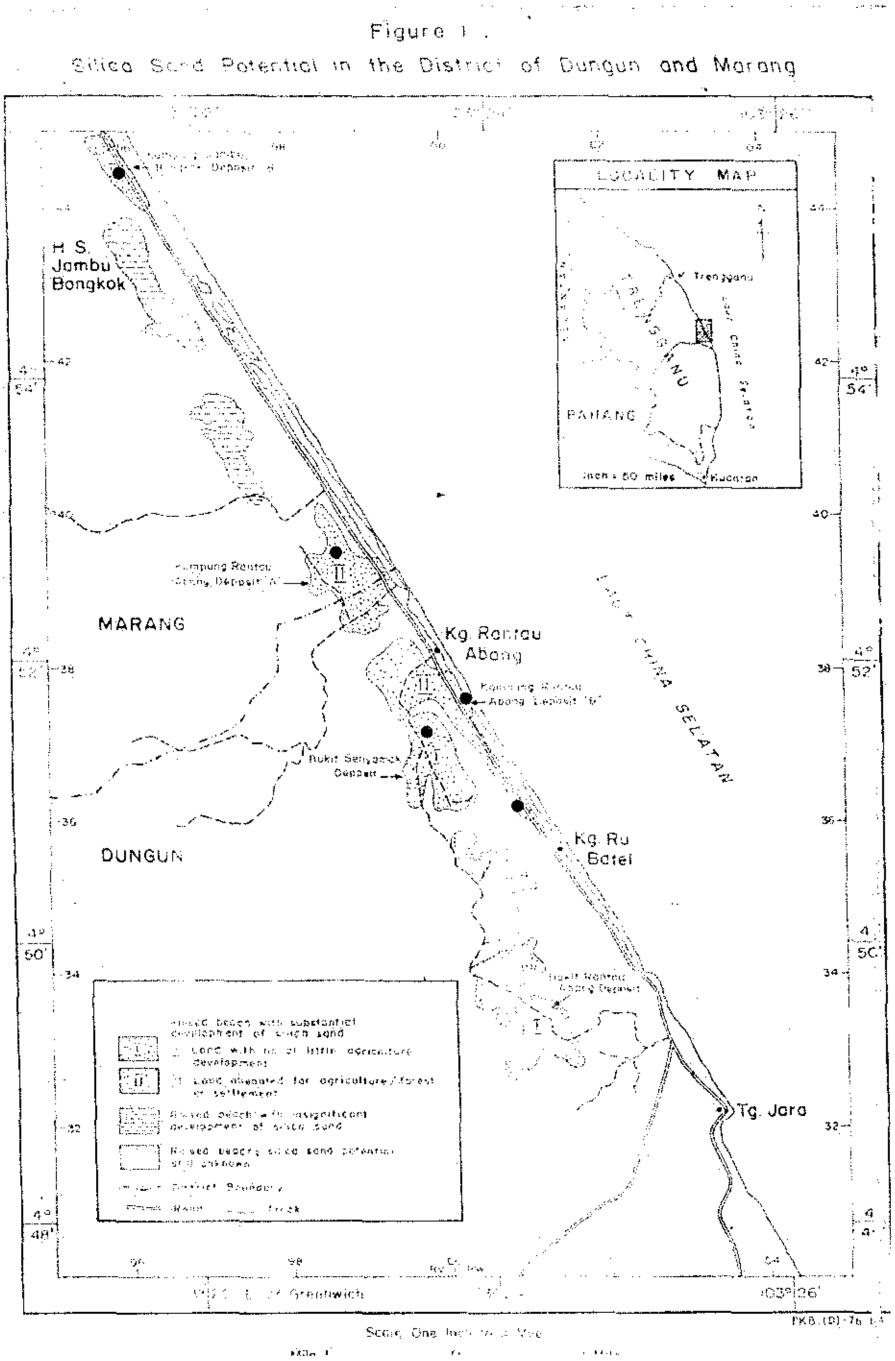


Meraga samples parallel to the beach
A : Meraga A
B : Meraga B
C1 : Meraga C1
D1 : Meraga D1

Meraga samples adjacent to the beach
C2: Meraga C2
C3: Meraga C3
D2: Meraga D2
D3: Meraga D3

Batu Tampin samples parallel to the beach
A: Tampin A
B: Tampin B

Appendix 2 – Map showing Kuala Abang 1, Bukit Senyamuk, Rantau Abang 'B' and Jambu Bongkok deposit locations (P.C.AW, 1978, 1979, 1989).



Appendix 3 - Meraga 1 sieve analysis data

Meraga 1						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	PAN	244	300	56	2.8	2.8
	212	344	603	259	12.95	15.75
	300	280	984	704	35.2	50.95
	425	296	1216	920	46	96.95
	600	339	400	61	3.05	100
	1180	354	354	0	0	100
	2360	399	399	0	0	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	PAN	244	301	57	2.85	2.85
	212	344	588	244	12.2	15.05
	300	280	899	619	30.95	46
	425	296	1323	1027	51.35	97.35
	600	339	392	53	2.65	100
	1180	354	354	0	0	100
	2360	399	399	0	0	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	PAN	244	303	59	2.95	2.95
	212	344	551	207	10.35	13.3
	300	280	860	580	29	42.3
	425	296	1393	1097	54.85	97.15
	600	339	396	57	2.85	100
	1180	354	354	0	0	100
	2360	399	399	0	0	100

Appendix 4 - Meraga 3A sieve analysis data

Meraga 3A						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	0	387.73	393.75	6.02	0.602	0.602
	150	275.82	318.13	42.31	4.231	4.833
	212	344.63	590.21	245.58	24.558	29.391
	300	281.06	795.96	514.9	51.49	80.881
	425	388.15	562.63	174.48	17.448	98.329
	600	331.36	347.79	16.43	1.643	99.972
	1180	350.66	350.94	0.28	0.028	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	0	244.03	249.83	5.8	0.58	0.58
	150	397.48	422.53	25.05	2.505	3.085
	212	275.88	505.01	229.13	22.913	25.998
	300	356.41	910.15	553.74	55.374	81.372
	425	297.96	470.1	172.14	17.214	98.586
	600	340.27	354.1	13.83	1.383	99.969
	1180	354.31	354.62	0.31	0.031	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	0	387.72	396.31	8.59	0.859	0.859
	150	275.84	326.71	50.87	5.087	5.946
	212	344.49	603.99	259.5	25.95	31.896
	300	281.12	788.94	507.82	50.782	82.678
	425	388.21	547.01	159.16	15.916	98.594
	600	331.31	345.12	13.81	1.381	99.975
	1180	350.65	350.9	0.25	0.025	100

Appendix 5 - Meraga 3B sieve analysis data

Meraga 3B						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	0	387.75	390.34	2.59	0.259	0.259
	150	275.87	298.49	22.62	2.262	2.521
	212	345.63	492.78	147.15	14.715	17.236
	300	281.55	680.52	398.97	39.897	57.133
	425	388.65	788.45	399.8	39.98	97.113
	600	331.8	360.25	28.45	2.845	99.958
	1180	350.73	351.15	0.42	0.042	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	0	244.03	248.24	4.21	0.421	0.421
	150	379.45	406.82	27.37	2.737	3.158
	212	275.85	473.23	197.38	19.738	22.896
	300	356.67	844.72	488.05	48.805	71.701
	425	298.31	549.93	251.62	25.162	96.863
	600	339.78	370.93	31.15	3.115	99.978
	1180	354.78	355	0.22	0.022	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	0	387.76	391.09	3.33	0.333	0.333
	150	275.82	305.73	29.91	2.991	3.324
	212	344.79	553.57	208.78	20.878	24.202
	300	280.98	766.27	485.29	48.529	72.731
	425	388.33	633.02	244.69	24.469	97.2
	600	331.35	358.93	27.58	2.758	99.958
	1180	350.67	351.09	0.42	0.042	100

Appendix 6 - Meraga 3C sieve analysis data

MERAGA 3C						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	PAN	244.06	245.11	1.05	0.105	0.105
	150	275.77	282.37	6.6	0.66	0.765
	212	275.99	352.44	76.45	7.645	8.41
	300	355.99	652.2	296.21	29.621	38.031
	425	297.43	772.85	475.42	47.542	85.573
	600	330.93	469.24	138.31	13.831	99.404
	1180	353.84	359.8	5.96	0.596	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	0	244.06	245.18	1.12	0.112	0.112
	150	275.77	278.94	3.17	0.317	0.429
	212	275.59	348.89	73.3	7.33	7.759
	300	355.99	665.72	309.73	30.973	38.732
	425	297.43	775.65	478.22	47.822	86.554
	600	330.93	464.03	133.1	13.31	99.864
	1180	353.84	355.2	1.36	0.136	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	0	244.06	245.1	1.04	0.104	0.104
	150	275.77	282.57	6.8	0.68	0.784
	212	275.59	346.33	70.74	7.074	7.858
	300	355.99	652.19	296.2	29.62	37.478
	425	297.43	766.39	468.96	46.896	84.374
	600	330.93	480.02	149.09	14.909	99.283
	1180	353.84	361.01	7.17	0.717	100

Appendix 7 - Meraga 4A sieve analysis data

MERAGA 4A						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	0	244.06	245.06	1	0.1	0.1
	63	261.19	265.08	3.89	0.389	0.489
	150	275.77	304.74	28.97	2.897	3.386
	212	275.59	522.83	247.24	24.724	28.11
	300	355.99	900.98	544.99	54.499	82.609
	425	297.43	465.4	167.97	16.797	99.406
	600	330.93	336.71	5.78	0.578	99.984
	1180	353.84	354	0.16	0.016	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	0	244.06	245.89	1.83	0.183	0.183
	150	275.77	306.34	30.57	3.057	3.24
	212	275.59	485.14	209.55	20.955	24.195
	300	355.99	955.94	600.56	60.056	84.251
	425	297.43	450.06	152.63	15.263	99.514
	600	330.93	335.33	4.4	0.44	99.954
	1180	353.84	354.3	0.46	0.046	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	0	244.06	251.96	7.9	0.79	0.79
	150	275.77	310.91	35.14	3.514	4.304
	212	275.59	491.18	215.59	21.559	25.863
	300	355.99	947.95	591.96	59.196	85.059
	425	297.43	442.29	144.86	14.486	99.545
	600	330.93	335.12	4.19	0.419	99.964
	1180	353.84	354.2	0.36	0.036	100

Appendix 8 - Meraga 4C sieve analysis data

	MERAGA 4C					
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	PAN	244.06	245.81	1.75	0.175	0.175
	150	275.77	353.6	77.83	7.783	7.958
	212	275.99	600.37	324.38	32.438	40.396
	300	355.99	832.61	476.62	47.662	88.058
	425	297.43	401.96	104.53	10.453	98.511
	600	330.93	345.66	14.73	1.473	99.984
	1180	353.84	354	0.16	0.016	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	PAN	244.06	254.4	10.34	1.034	1.034
	150	275.77	343.64	67.87	6.787	7.821
	212	275.59	563.6	288.01	28.801	36.622
	300	355.99	885.08	529.09	52.909	89.531
	425	297.43	397.37	99.94	9.994	99.525
	600	330.93	335.5	4.57	0.457	99.982
	1180	353.84	354.02	0.18	0.018	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	PAN	244.06	254.79	10.73	1.073	1.073
	150	275.77	341.63	65.86	6.586	7.659
	212	275.59	558.97	283.38	28.338	35.997
	300	355.99	884.85	528.86	52.886	88.883
	425	297.43	403.18	105.75	10.575	99.458
	600	330.93	336.11	5.18	0.518	99.976
	1180	353.84	354.08	0.24	0.024	100

Appendix 9 – Tampin A sieve analysis data

Tampin A						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	PAN	387.73	391.18	3.45	0.345	0.345
	150	275.83	294.5	18.67	1.867	2.212
	212	344.48	494.09	149.61	14.961	17.173
	300	281.32	660.37	379.05	37.905	55.078
	425	388.78	768.73	379.95	37.995	93.073
	600	330.8	397.78	66.98	6.698	99.771
	1180	354.09	356.38	2.29	0.229	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	PAN	244.04	249.03	4.99	0.499	0.499
	150	379.5	403.02	23.52	2.352	2.851
	212	275.68	461.05	185.37	18.537	21.388
	300	355.94	787.07	431.13	43.113	64.501
	425	297.22	590.89	293.67	29.367	93.868
	600	340.13	399.35	59.22	5.922	99.79
	1180	350.59	352.69	2.1	0.21	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	PAN	387.71	389.76	2.05	0.205	0.205
	150	275.84	292.84	17	1.7	1.905
	212	344.33	482.68	138.35	13.835	15.74
	300	281.43	661.99	380.56	38.056	53.796
	425	389.18	783.18	394	39.4	93.196
	600	331.38	397.18	65.8	6.58	99.776
	1180	354.17	356.41	2.24	0.224	100

Appendix 10 – Tampin B sieve analysis data

Tampin B						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	PAN	387.73	389	1.27	0.127	0.127
	150	275.84	279.36	3.52	0.352	0.479
	212	344.54	389.85	45.31	4.531	5.01
	300	280.7	524.93	244.23	24.423	29.433
	425	387.13	891.6	504.47	50.447	79.88
	600	331.22	522.42	191.2	19.12	99
	1180	354.29	364.29	10	1	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	PAN	387.73	389.48	1.75	0.175	0.175
	150	275.84	279.53	3.69	0.369	0.544
	212	344.54	393.5	48.96	4.896	5.44
	300	280.7	518.59	237.89	23.789	29.229
	425	387.13	893.43	506.3	50.63	79.859
	600	331.22	522.27	191.05	19.105	98.964
	1180	354.29	364.65	10.36	1.036	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	PAN	244.05	245.26	1.21	0.121	0.121
	150	379.48	382.41	2.93	0.293	0.414
	212	275.81	322.12	46.31	4.631	5.045
	300	356.36	640.59	284.23	28.423	33.468
	425	296.86	749.48	452.62	45.262	78.73
	600	339.45	539.79	200.34	20.034	98.764
	1180	350.65	363.01	12.36	1.236	100

Appendix 11 – Kuala Abang 1 sieve analysis data

Kuala Abang 1						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	0	387.7	390.53	2.75	0.275	0.275
	150	275.8	283.1	7.3	0.73	1.005
	212	345.36	441.76	96.4	9.64	10.645
	300	280.54	603.75	323.21	32.321	42.966
	425	388.3	923.81	535.51	53.551	96.517
	600	331.88	366.56	34.53	3.453	99.97
	1180	350.89	351.19	0.3	0.03	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	0	387.7	391.14	3.44	0.344	0.344
	150	275.8	284.43	8.63	0.863	1.207
	212	345.36	459.45	114.09	11.409	12.616
	300	280.54	728.68	448.14	44.814	57.43
	425	388.3	778.99	390.69	39.069	96.499
	600	331.88	366.63	34.75	3.475	99.974
	1180	350.89	351.15	0.26	0.026	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	0	244.04	248.7	4.66	0.466	0.466
	150	379.38	386.65	7.27	0.727	1.193
	212	275.95	373.54	97.59	9.759	10.952
	300	357.37	774.32	416.95	41.695	52.647
	425	299.83	734.72	434.89	43.489	96.136
	600	339.87	378	38.13	3.813	99.949
	1180	354.73	355.24	0.51	0.051	100

Appendix 12 – Kampung Rantau Abang 'B'sieve analysis data

Kampung Rantau Abang 'B'						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	PAN	244.06	253.65	9.59	0.959	0.959
	150	379.72	454.15	74.43	7.443	8.402
	212	275.18	619.94	344.76	34.476	42.878
	300	354.52	768.96	414.44	41.444	84.322
	425	295.85	431.98	136.13	13.613	97.935
	600	338.72	358.81	20.09	2.009	99.944
	1180	350.59	351.15	0.56	0.056	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	PAN	244.06	256.36	12.3	1.23	1.23
	150	379.72	458.62	78.9	7.89	9.12
	212	275.18	615.3	340.12	34.012	43.132
	300	354.52	760.21	405.69	40.569	83.701
	425	295.85	436.49	140.64	14.064	97.765
	600	338.72	360.37	21.65	2.165	99.93
	1180	350.59	351.29	0.7	0.07	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passin
3	PAN	244.06	250.62	6.56	0.656	0.656
	150	379.72	453.98	74.26	7.426	8.082
	212	275.18	620.21	345.03	34.503	42.585
	300	354.52	773.43	418.91	41.891	84.476
	425	295.85	431.63	135.78	13.578	98.054
	600	338.72	357.78	19.06	1.906	99.96
	1180	350.59	350.99	0.4	0.04	100

Appendix 13 – Kg. Kuala Abang sieve analysis data

Kg. Kuala Abang						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	pan	387.65	388.47	0.82	0.082	0.082
	150	275.73	285.47	9.74	0.974	1.056
	212	343.77	462.08	118.31	11.831	12.887
	300	280.17	777.77	497.6	49.76	62.647
	425	385.86	758.46	372.6	37.26	99.907
	600	330.18	331.11	0.93	0.093	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	pan	387.65	388.44	0.79	0.079	0.079
	150	275.73	284.7	8.97	0.897	0.976
	212	343.77	465.16	121.39	12.139	13.115
	300	280.17	793.64	513.47	51.347	64.462
	425	385.86	739.6	353.74	35.374	99.836
	600	330.18	331.82	1.64	0.164	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	pan	244.21	245.91	1.7	0.17	0.17
	150	379.63	386.58	6.95	0.695	0.865
	212	275.56	428.28	152.72	15.272	16.137
	300	354.97	928.75	573.78	57.378	73.515
	425	296.36	559.38	263.02	26.302	99.817
	600	339.53	341.36	1.83	0.183	100

Appendix 14 – Bukit Senyamok sieve analysis data

Bukit Senyamok						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	pan	387.65	394.9	7.25	0.725	0.725
	150	275.73	332.12	56.39	5.639	6.364
	212	343.77	531.43	187.66	18.766	25.13
	300	280.17	714.89	434.72	43.472	68.602
	425	385.86	698.33	312.47	31.247	99.849
	600	330.18	331.69	1.51	0.151	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	pan	387.65	393.9	6.25	0.625	0.625
	150	275.73	313.25	37.52	3.752	4.377
	212	343.77	455.99	112.22	11.222	15.599
	300	280.17	613.83	333.66	33.366	48.965
	425	385.86	899.27	513.41	51.341	100.306
	600	330.18	327.12	-3.06	-0.306	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	pan	387.65	392.89	5.24	0.524	0.524
	150	275.73	320.43	44.7	4.47	4.994
	212	343.77	536.78	193.01	19.301	24.295
	300	280.17	625.6	345.43	34.543	58.838
	425	385.86	795.89	410.03	41.003	99.841
	600	330.18	331.77	1.59	0.159	100

Appendix 15 – Jambu Bongkok sieve analysis data

Jambu Bongkok						
Sample	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
1	PAN	387.67	390.02	2.35	0.235	0.235
	150	275.78	288.97	13.19	1.319	1.554
	212	343.58	443.26	99.68	9.968	11.522
	300	279.49	575.57	296.08	29.608	41.13
	425	385.53	838.19	452.66	45.266	86.396
	600	329.78	464.47	134.69	13.469	99.865
	1180	354.08	355.43	1.35	0.135	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
2	PAN	387.67	393.27	5.6	0.56	0.56
	150	275.78	294.44	18.66	1.866	2.426
	212	343.58	462.4	118.82	11.882	14.308
	300	279.49	604.96	325.47	32.547	46.855
	425	385.53	795.97	410.44	41.044	87.899
	600	329.78	449.72	119.94	11.994	99.893
	1180	354.08	355.15	1.07	0.107	100
	Mesh	Weight sieve (g)	Sample+sieve (g)	Weight sample (g)	% passing	cumulative % passing
3	PAN	387.67	395.13	7.46	0.746	0.746
	150	275.78	295.84	20.06	2.006	2.752
	212	343.58	477.9	134.32	13.432	16.184
	300	279.49	623.17	343.68	34.368	50.552
	425	385.53	772.79	387.26	38.726	89.278
	600	329.78	436.02	106.24	10.624	99.902
	1180	354.08	355.06	0.98	0.098	100

Appendix 16 – HPHT filter press percentage passing at all locations.

<table>
<tr><th rowspan="2"></th><th rowspan="2"></th><th colspan="2">Result(Total Dried Weight in gram)</th><th rowspan="2">Picture</th></tr>
<tr><th>% passing</th><th>average % passing</th></tr>
<tr><td rowspan="2">Ceramic Proppant</td><td>20/40 Slb</td><td colspan="2">6.0933</td><td></td></tr>
<tr><td>30/50 hbn</td><td colspan="2">17.1433</td><td>missing</td></tr>
<tr><td rowspan="8">Meraga</td><td rowspan="3">20/40</td><td>6.7380</td><td rowspan="3">6.93</td><td rowspan="3"></td></tr>
<tr><td>7.0423</td></tr>
<tr><td>7.0030</td></tr>
<tr><td rowspan="3">30/50</td><td>7.6120</td><td rowspan="3">6.08</td><td rowspan="3"></td></tr>
<tr><td>6.5753</td></tr>
<tr><td>4.0573</td></tr>
<tr><td rowspan="2">30/70</td><td>2.0133</td><td rowspan="2">2.38</td><td rowspan="2"></td></tr>
<tr><td>2.7543</td></tr>
<tr><td rowspan="9">Kg Kuala Abang</td><td rowspan="3">20/40</td><td>3.1633</td><td rowspan="3">3.49</td><td rowspan="3"></td></tr>
<tr><td>4.1467</td></tr>
<tr><td>3.1733</td></tr>
<tr><td rowspan="3">30/50</td><td>6.9533</td><td rowspan="3">6.00</td><td rowspan="3"></td></tr>
<tr><td>2.9300</td></tr>
<tr><td>8.1167</td></tr>
<tr><td rowspan="3">30/70</td><td>1.3167</td><td rowspan="3">1.55</td><td rowspan="3">missing</td></tr>
<tr><td>1.6633</td></tr>
<tr><td>1.6800</td></tr>
<tr><td rowspan="9">Bukit Senyamok</td><td>20/40</td><td>11.5167</td><td rowspan="3">7.59</td><td rowspan="3"></td></tr>
<tr><td></td><td>6.8600</td></tr>
<tr><td></td><td>4.3867</td></tr>
<tr><td>30/50</td><td>4.2300</td><td rowspan="3">5.89</td><td rowspan="3"></td></tr>
<tr><td></td><td>4.9033</td></tr>
<tr><td></td><td>8.5433</td></tr>
<tr><td>30/70</td><td>3.2767</td><td rowspan="3">4.24</td><td rowspan="3"></td></tr>
<tr><td></td><td>4.3133</td></tr>
<tr><td></td><td>5.1267</td></tr>
</table>

		Result(Total Dried Weight in gram)		Picture
		% passing	average % passing	
Jambu Bongkok	20/40	3.7433	4.68	
		5.1100		
		5.1733		
	30/50	5.9000	5.03	
		5.0100		
		4.1767		
	30/70	3.5500	3.76	
		5.8200		
		1.9200		
Kg Rantau Abg B	20/40	10.0267	9.29	
		7.6000		
		10.2500		
	30/50	9.9100	9.36	
		12.9700		
		5.2067		
	30/70	4.7833	4.94	missing
		3.9567		
		6.0700		
Kg Bt Tampin	20/40	5.2110	4.54	
		5.3297		
		3.0713		
	30/50	4.4450	2.04	
		0.8606		
		0.8028		
	30/70	19.7533	13.35	missing
		13.5900		
		6.7167		