Performance of Bituminous Mix based on Aggregate Packing

by

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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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Approved by,

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TRONOH, PERAK
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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.

MOHAMMAD NURHAFIZI BIN MOHD HOSNI

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ABSTRACT

Aggregate dominate 90% of mix structure and its interlocking forces is a key to the strength of the bituminous mix. Realizing that aggregate interlocking contribute to the strength, the packing of aggregate would increase the force of intact between aggregate. The packing density represents how well the aggregate can be pack together. Therefore, combination between various aggregate sizes which yield a highest density is the aim. By assimilating both resource and concept, the idea of aggregate packing concept is developed. Further on the report, the well graded aggregate (control) were not necessarily lead to high density. The concept that fully utilizing density and aggregate as main structure of the bituminous mix, results in high performance with low cost of material.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Bituminous mix is produced by a blending of asphalt cement, coarse aggregate, fine aggregate and mineral filler. There are many type of the bituminous mixture which can be described as open-graded, coarse-graded, dense-graded or fine-graded. Each type of mixture comprises of different size or range of aggregates. As a design requirement which reflects on desired characteristics for highway construction, it is mainly depends on the mix design which involved selection of material and its proportions component. Clearly to get a desired mix means to find a favorable balance between a highly stable product and a durable one. Therefore the aim of the mix design is to determine the optimum proportion or blend of different component to meet the desired specification. And the pursuance of finding the best mix is still ongoing, such as altering material of mineral fillers, using different type of aggregate etc. Following that trends, numerous study agreed that the aggregate plays a major role due to its domination almost 90% of the component in bituminous mix.

1.2 PROBLEM STATEMENT

Various researches had been done to produce bituminous mixes which have high performance. The aggregate acts as the structural skeleton of the pavement while the asphalt binder as the glue of the mixture. The properties of the aggregate have direct and significant effect on the performance of asphalt pavements. As the aggregate skeleton play a key role in determining the performance of the mix and it is relates with to the rutting, fatigue, permeability, compactibility and durability, therefore it is possible utilizing aggregate interlocking as part of determinant of mix performance and by mean of a test and experiment, using an aggregate packing in selection of the aggregate gradation.

The result in this report shows that the well graded mix aggregate did not necessarily leads to a high density mix. For that reason the well graded mix aggregate will be the control mix and to be compared to the aggregate packing. Therefore, this project will aim to design bituminous mix with high performance by applying the packing of aggregate concept.

1.3 OBJECTIVE AND SCOPE OF STUDY

The study will be done by optimizing the use of aggregate to boost up the bituminous mix performance and the main objectives of this research are as follow (accordingly):

- To produce the mix design based on aggregate packing
- To analyze the performance of the designed mix and compare with the well graded bituminous mix

Theoretically, a better aggregate packing would reduce the permeability of the paste, asphalt cement and thus bleeding of the asphalt cement. It also would reduce the porosity of the pavement thus improve pavement performance.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Bituminous mix is a combination of aggregate and asphalt binder. From the study, aggregate dominating about 90% of the mix volume, (Denneman, Verhaeghe and Sadzik 2007). It is clearly indicate that the properties of the aggregate have direct and significant effect on the performance of asphalt pavements. Based on the research, numerous studies have related the gradation, shape and texture of aggregate to durability, workability, shear resistance, tensile strength, stiffness, fatigue response, rutting susceptibility and optimum asphalt content in bituminous mix. Therefore in the pursuance of maximising the used of aggregate to improve the bituminous mix performance, this study is conducted to achieved that. In a simple analogy, imagine a mix comprised of a single-sized aggregate, only as in Figure 2.1. There would be a huge amount of void in the mixed. To fill up all the gaps between the aggregate particles so as to drive away the voids, a large amount of asphalt binder will be use. Instead of single-sized aggregate, let maximise the use of aggregate particle size to fill up the gaps within the aggregate skeleton shown in Figure 2.2.

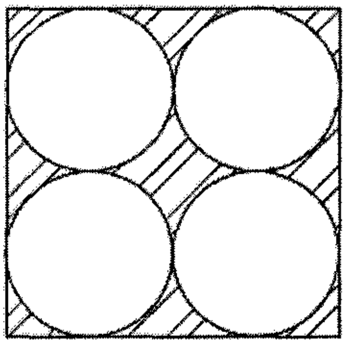


Figure 2.1: Single aggregate sized (After Wong and Kwan, 2007)

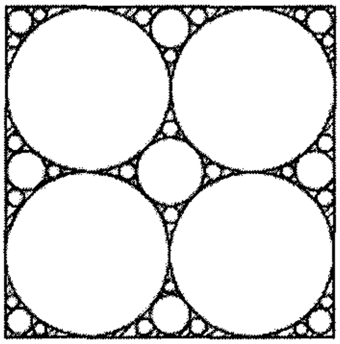


Figure 2.2: Multi-sized aggregate (After Wong and Kwan, 2007)

2.2 AGGREGATE GRADATION

"Aggregates are usually categorized as crushed rock (coarse aggregate), sand and filler. Based on the present standard, the rock material is predominantly coarse aggregate retained in a No. 8 sieve, sand is predominantly fine aggregate passing the No. 8 sieve, and filler is predominantly mineral dust that passes the No. 200 sieve. It is customary for gradations of the combined aggregate and the individual fractions to be specified. The first phase in any mix design is the selection and combination of aggregates to obtain a gradation within the limits prescribed." (Garber and Hoel, 2001).

2.3 AGGREGATE PACKING

In recognition of the importance of aggregate properties on pavement performance, the aggregate directly affects the mixture properties. The aggregate performance is characterized as stone-on-stone skeleton; also known as interlocking. In previous study, the coarse aggregate contact of bituminous mix gradation dominating the interlocking performance of the pavement; therefore, a strong coarse aggregate skeleton is vital in bituminous mix. However, it is impossible for each of the mix design will have the same resistance and performance since there is inconsistency between the aggregate types and its interlocking performances. The aggregate packing gradation comes up front as a way to ensure the consistency of the performance of the mix design. The idea is that it will reduce the inconsistency between aggregate since the gradation of coarse aggregate will be done by selection of percentage of different sizes of coarse aggregate which ranging 5mm and above.

The packing density measured represent how well the aggregate would be packed together and its characteristic is described in Table 2.1. However it is impossible to have a perfectly packed aggregate; firstly, since the finest size of the aggregate cannot be too fine and the largest size particles cannot be too large, and there is a practical limit to the size range of the aggregate. Therefore the void will remain unfilled. Secondly, the shape of the aggregate particles has a limiting effect on the packing of the aggregate. Thirdly, the surface roughness of the aggregate particles would limit the effectiveness of the mixing and compacting process. High surface roughness means large inter-particle frictional forces which affect the mixing and compacting process, as in Figure 2.3. Therefore it will reduce the packing density of the aggregate. The wall effect and loose effect also contribute in reducing the effectiveness of process in approaching maximum packing density as shown in Figure 2.4.

Table 2.1: Description Based on Relative Density, Dr (After Budhu, 2007)

Dr (%)	**Description**
0-20	Very loose
20-40	Loose
40-70	Medium dense or firm
70-85	Dense
85-100	Very dense

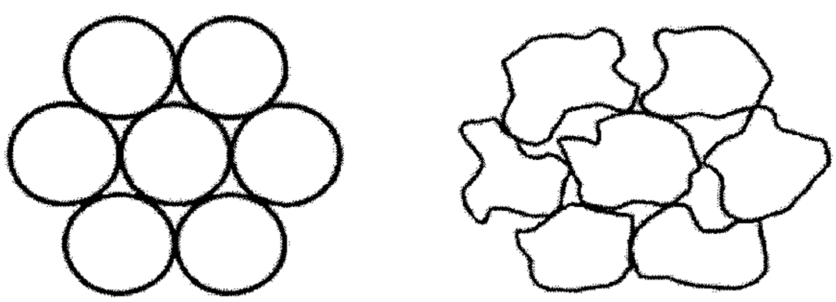


Figure 2.3: Type of aggregate surface roughness (After Wong and Kwan, 2007)

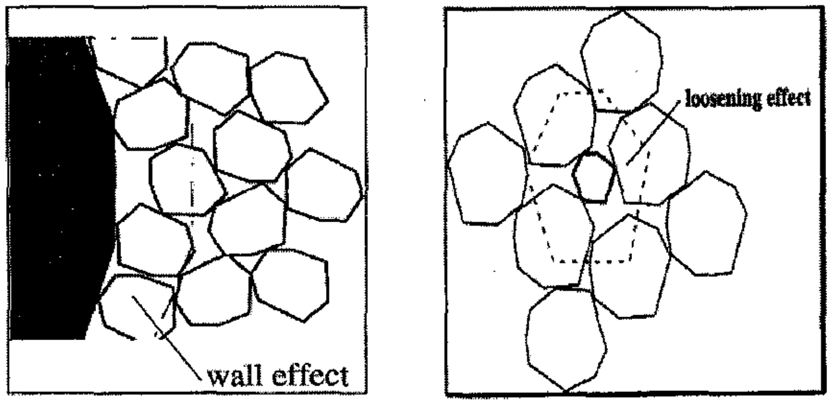


Figure 2.4: Condition which affects compacting and mixing process (After De Larrard, 1999)

2.4 WELL-GRADED MIX

A well-graded mix also known as dense-graded mix and it is relatively impermeable. This type of mix can be use for all purposes. The well-graded mix can further classified as fine-graded or course-graded. The fine-graded mix has more fine and sand sized particle than the coarse-graded one.

The well-graded mix is said to be a dense mix with high density, but further research found that the using well-graded mix aggregates did not lead necessarily to maximum aggregate packing density.

2.5 BITUMINOUS MIX WORK

It is consist of compacting and shaping of bituminous mix works, preparing the aggregates, sieving, washing and drying of aggregates and testing of sample or mix.

2.5.1 Definitions

i. From the Uniform Building By-Laws 1984 [G.N.5178/86], "aggregate" means any material other than cement and water used in the making of concrete which does not contain additions or admixtures.

ii. From the JKR Manual, the aggregate shall be a mixture of course and fine aggregates and if necessary, mineral filler. The coarse aggregate shall be screened crushed hard rock, angular in shape and free from dust, clay, vegetative and organic matter and other deleterious substances. The fine aggregate shall be clean natural sands, screened quarry fines, or mining sand.

iii. From the JKR Manual, the mineral filler shall be finely divided mineral matter such as rock dust, limestone dust, hydrated lime, hydraulic cement or such other suitable material as the S.O shall approve. Not less than 70% by weight shall pass the B.S 75μm sieve act as an adhesion and anti-stripping agent.

Due to short of time, for this project the mineral filler will not included into packing work. Therefore, the packing works involved in combining of course and fine aggregate only. The mineral filler content shall be fixed in bituminous mix process. The mineral filler use in this project is the Ordinary Portland Cement (OPC).

2.5.2 Testing

Marshall Mix

The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute (2 inches/minute). Basically, the load is increased until it reaches a maximum then when the load just begins to decrease, the loading is stopped and the maximum load is recorded.

During the loading, an attached dial gauge measures the specimen's plastic flow as a result of the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time the maximum load is recorded.

The analysis shall conform to the requirements of the appropriate type of mix as given in Table 4.10 in JKR Manual as shown in Table 2.2.

Table 2.2: Test and Analysis Parameters for Asphaltic Concrete

Parameter	Wearing Course
Stability S	> 500 kg
Flow F	> 2.0 mm
Stiffness S/F	> 250 kg/mm
Air Voids in Mix	3.0% - 5.0%
Voids in Aggregate filled with bitumen	75% - 85%

Wheel Tracker

i. Principle

Wheel Tracking Test determine plastic deformation of asphalt based road surface wearing courses under temperature and pressure similar to those experienced under road use.

Such tests are carried out during road construction and also in material design. The use of Wheel Tracking test will prevent road surfaces being laid, which rut in hot weather and which need to be relayed.

The equipment is housed in a insulated heated cabinet. A sample travels horizontally on a reciprocating table under a loaded wheel. Penetration of wheel produces a rut, the depth of which is measured and recorded by a purpose built computer program.

Main Objectives

Main objective of the Wheel Tracking Test is used to assess the resistance to rutting of asphaltic materials under conditions which stimulate the effect of traffic.

ii. Industrial Application

- Determine plastic deformation of asphalt based road surface wearing course under temperature and pressure

- The identification of rut susceptible mixtures, so that experiment remedial works are avoided
- The evaluation of new materials and formulations
- Loaded wheel test can and should be used for verifying designs and for evaluating existing materials.

The wheel load of 520 N is set up for 45 minutes run test and 1953 cycles at temperature of 40° C.

Dynamic Creep Test (beam), Universal Testing Machine (MATTA)

Dynamic Creep Test is a test that applies a repeated pulsed uniaxial stress/load to an asphalt specimen and measures the resulting deformations in the same axis and or radial axis using Linear Variable Displacement Transformers (LVDTs). Test's can also be conducted under confined conditions using a standard triaxial pressure where all or the IPC Global developed Rapid Triaxial Tester (RaTT), The stress/ load applied to the specimen is feed back controlled allowing the operator to select a loading wave shape , the pulse width duration, the rest period before the application of the next pulse, the deviator stress/load to be applied during each loading pulse and the contact stress/load to be applied so that the vertical loading shaft does not lift off the test specimen during the test period. Prior to testing a preload stress/load can also be programmed into the testing sequence. Fr controlled temperature testing, the specimen's skin and core temperatures are estimated by tranducers inserted in a dummy specimen and located near the specimen under test.

i. Main Objective

Gives use the capability to test stiffness modulus, fatigue life and creep, and enables testing of a range of materials from unbound to the stiffest asphalt.

ii. Process and Description

This section refers to IPC supply creep jig with 2 vertical displacement transducers only. For on-specimen measurement, refer to the relevant test methods and procedures. Separate jigs are provided for either 100mm or 150 mm diameter specimens which are mounted vertically in the loading frame. The jigs comprise an upper and lower loading platen which distribute the load evenly to the end of the specimen. The lower jig has a locating slot that mate with a pin fitted to the base of the loading frame to ensure proper registration directly under the loading ram of the actuator.

With the lower platen located on the base of the loading frame, prepare the end of the specimen as required, and then centrally mount the specimen on the lower jig platen. Place the upper platen centrally on the specimen. Now lower the loading shaft and ensure that the bail end seat correctly in the tapered bole of the top platen.

Note: That it may be necessary to adjust the height of the loading frame cross arm to ensure that, not only do the specimen and jig fit, but that sufficient actuator travel remains to allow for specimen deformation during the test.

Vertical axial displacement is measured with LVDT transducers. These are typical calibrated over the range from 0 to 5mm. The transducers are mounted on the support rods attached to the axial loading jig base plate, with the probe ends bearing on the upper loading platen surface. Ensure that the transducers operate over the calibrated operating range using transducers level display.

CHAPTER 3

METHODOLOGY

3.1 PACKING DENSITY

The packing of aggregate can be determined directly by measuring the bulk density of the aggregate. The basic procedure is to mix the aggregate particles thoroughly, place them into a container (mould) of known volume, and then weight the aggregate particles in the container (mould). With the solid density of the aggregate particles known, the packing density of the aggregate (the volumetric ratio of the solid in the bulk volume) may be determine simply as ratio of bulk density of the aggregate to the solid density of the aggregate particles. The packing density so measured represents how well the aggregate would be packed together.

The sample sizes are identified as Sample A (20mm-14mm): retained in sieve size 14mm, Sample B (14mm-12.5mm): retained in sieve size 12.5mm, Sample C (12.5mm-10mm): retained in sieve size 10mm, Sample D (10mm-5mm): retained in sieve size 5mm and E (Below 5mm): Pass 5mm sieve and retained in the pan.

The procedures for the aggregate packing;

1. Prepare the mould and the aggregate which already separated and labeled by Sample A, Sample B, Sample C, Sample D and Sample E. Refer to *Table 3.1: Sample Labeling.*
2. Fill in sample A into the mould approximately until three-quarterly full. Then take the mass of the sample A.
3. Adjust the mass of the sample into a round number (Ex: 1.0 kg). The mass of sample A represent a 100% of sample A.
4. *Diagram 1* shows brie*fly* the sample packaging starting with sample A and B
5. Compact/ shake the aggregate loaded mould by forces until the mix no longer settled.

6. Then, put a leveler on the aggregate and take the height, H_A of the settled mix using Digital Vernier Caliper.
7. Refer the Figure 3.1 and 3.2 and calculate the density of the mix.
8. Find the optimum or maximum density of the combine or packing sample A and B.
9. Take 2kg of optimum or maximum combined sample A plus sample B and mix thoroughly.
10. Use sample A+B combine with the sample C.
11. Proceed with step 5 to 8 with other sample and refer to *Diagram 1* for a work sequence flowchart.
12. Fill in the data in the form provided in *Appendix 1*.
13. Take the optimum density of the packing and prepare the sample of bituminous mix using the aggregate proportion.

Table 3.1: Sample Labeling

Label	Aggregate Sizes(mm)
Sample A	20-14
Sample B	14-12.5
Sample C	12.5-10
Sample D	10-5
Sample E	Sand (<5)

*Note: For Figure 3.1 and Figure 3.2

1. H_1, H_2, H_3 = height from leveler to the top of the mould (as shown in Figure 3.2)
2. H_A = average height $(H_1 + H_2 + H_3)/3$
3. Density (ρ) = Mass (m)/ Volume (V)
4. Volume, $V = (\pi d^2/4)(h)$
5. h = height of settled mix = $H_m - h_A - t_l$
6. H_m = height of mould (Figure 3.2)
7. t_l = thickness of the leveler (Figure 3.2)

8. H_m = 105.00 mm

9. D_o = 117.76 mm

10. D_i = d = 105.13 mm (Figure 1 and Figure 2)

11. t_l = 15.00 mm

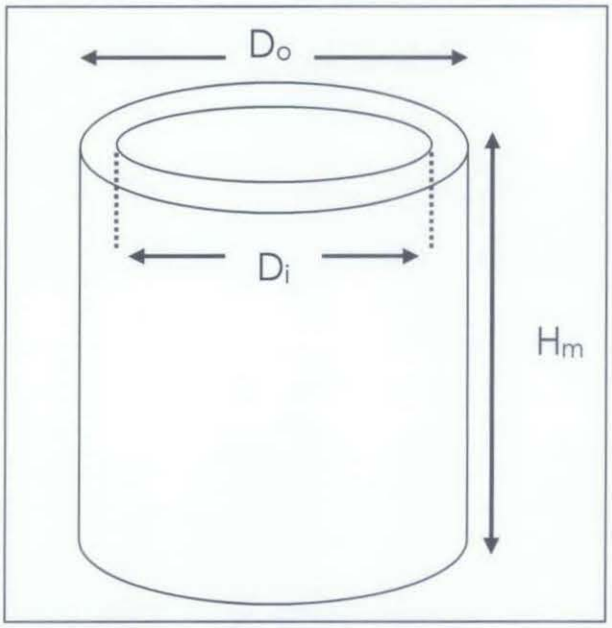


Figure 3.1: Dimension of the mould

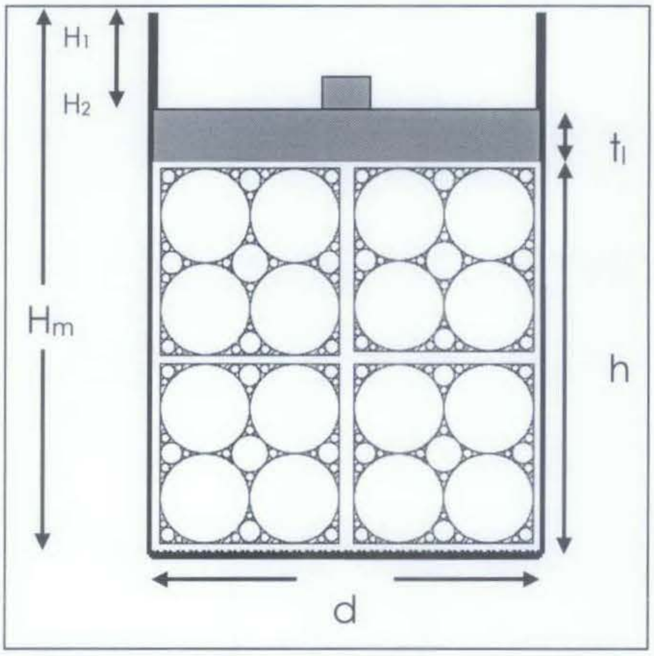
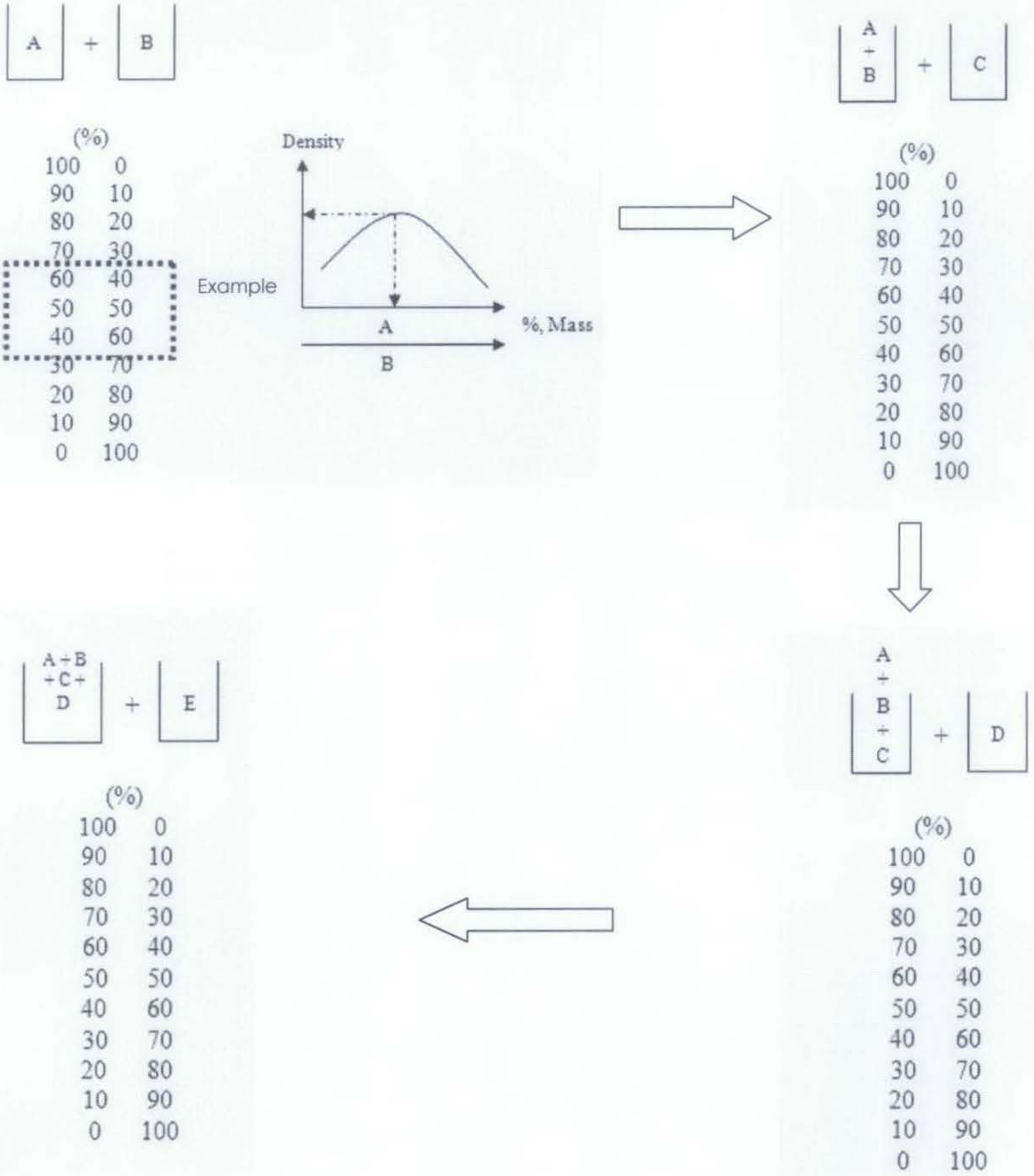


Figure 3.2: Dimension and parameter in calculation



1. For each packing, plot a graph and find the best portion of combined aggregate by identify the maximum packing density. See the example in the first step.
2. Finally, calculate the density and find the portion that lead to maximum density.

Diagram 1: The Flow Chart of the Work Sequence

3.2 BITUMINOUS MIX

The mixing works are based on standard that has been stated in lab manual and additional information from JKR manual on Pavement Design, Arahan Teknik (Jalan) 5/85.

Lab Manual References:

Marshall Mix Design

a. BS598: 1985
b. The Asphalt Institute

   Mix Design Methods for Asphalt Concrete and other hot mix types, 1979

c. Gradation

Table 3.2: Gradation Limits for Asphaltic Concrete (Table 4.8, JKR Manual)

Mix Type	Wearing Coarse
Mix Designation	ACW14
B.S Sieve Size	% Passing By Weight
20.0 mm	100
14.0 mm	80 - 95
10.0 mm	68 - 90
5.0 mm	52 - 72
3.35 mm	45 - 62
1.18 mm	30 - 45
425 um	17 - 30
150 um	716
75 um	410
Pan	0

d. Binder Content

Table 3.3: Design Bitumen Contents (Table 4.9, JKR Manual)

ACW 14 – Wearing Course	5.0 – 7.0%
ACW 14 – Binder Course	4.5 – 6.5%
ACB 28 – Binder Course	4.0 – 6.0%

CHAPTER 4

RESULTS

4.1 PACKING DENSITY

The main concern of this data presentation is to get the highest packing density that can be achieved with combination of sample A, B, C, D and E. From this result, it will leads to the proportions of combination sample A, B, C, D and E. Refer Appendix 1 to see the data and results from the previous works, before it achieving this finalized packing density work stage.

Incorporated with this data presentation also, the method of calculation concern with how to fill-in Table 4.1.

Figure 4.1: Aggregate is filled in the mould

Figure 4.2: The aggregate is compacted and leveled

Figure 4.3: Measuring height, H using Digital Vernier Caliper

4.1.1 Data for Sample (A+B+C+D) +E

A= 20mm-14mm B=14mm-12.5mm C=12.5mm-10.0mm

D=10.0mm-5.0mm E= ≤ 5.0mm

1 kg = 100%

Table 4.1: Sample (A+B+C+D)+E

A+B+C+D (%)	E (%)	Height, H (mm)					V (m^3)	ρ (kg/m^3)
		H_1	H_2	H_3	H_A	h		
100	0	20.09	20.58	20.06	20.24	69.76	605549.55	1651.39
90	10	26.20	24.36	23.14	24.57	65.43	567963.11	1760.68
80	20	32.59	33.17	31.53	32.43	57.57	499734.62	2001.06
70	30	40.38	41.80	39.69	40.62	49.38	428641.58	2332.95
60	40	41.04	41.67	40.34	41.02	48.98	425169.39	2352.00
50	50	38.28	37.95	37.19	37.81	52.19	453033.70	2207.34
40	60	35.63	36.62	35.61	35.95	54.05	469179.37	2131.38
30	70	33.55	32.24	31.56	32.45	57.55	499561.01	2001.76
20	80	26.38	26.84	26.51	26.58	63.42	550515.37	1816.48
10	90	23.41	24.74	24.80	24.32	65.68	570133.23	1753.98
0	100	22.94	23.19	23.07	23.07	66.93	580983.82	1721.22

4.1.2 Calculation

1. Measured (See Figure 3.1 and Figure 3.2);
   H_m = 105.00 mm, D_o = 117.76 mm, D_i = d = 105.13 mm and t_l = 15.00mm
2. H_1, H_2, H_3 = height measured from leveler to the top of the mould (see Figure 2)
3. H_A = average height = $(H_1 + H_2 + H_3)/3$
   For sample (A+B+C+D) 100% and E 0%;

   $H_A = (20.09 + 20.58 + 20.06) / 3 = \underline{20.24 \text{ mm}}$

4. h = height of the settled sample (A+B+C+D) +E = $H_m - H_A - t_l$

For sample (A+B+C+D) 100% and E 0%;

$h = 105.00 - 20.24 - 15.00 = \underline{69.76 \text{ mm}}$

5. Volume, $V = (\pi d^2/4)(h)$

For sample (A+B+C+D) 100% and E 0%

$V = (1/4)(\pi * 105.13^2)(69.76) = \underline{605549.55 \text{ mm}^3}$

6. Density (ρ) = Mass (m)/ Volume (V)

For sample (A+B+C+D) 100% and E 0%

$\rho = 1 \text{ kg}/ (605549.55 \text{ mm}^3)(1 \text{ m}^3/1000000000\text{mm}^3) = \underline{1651.39 \text{ kg/m}^3}$

7. The calculation is valid for all sample proportion.

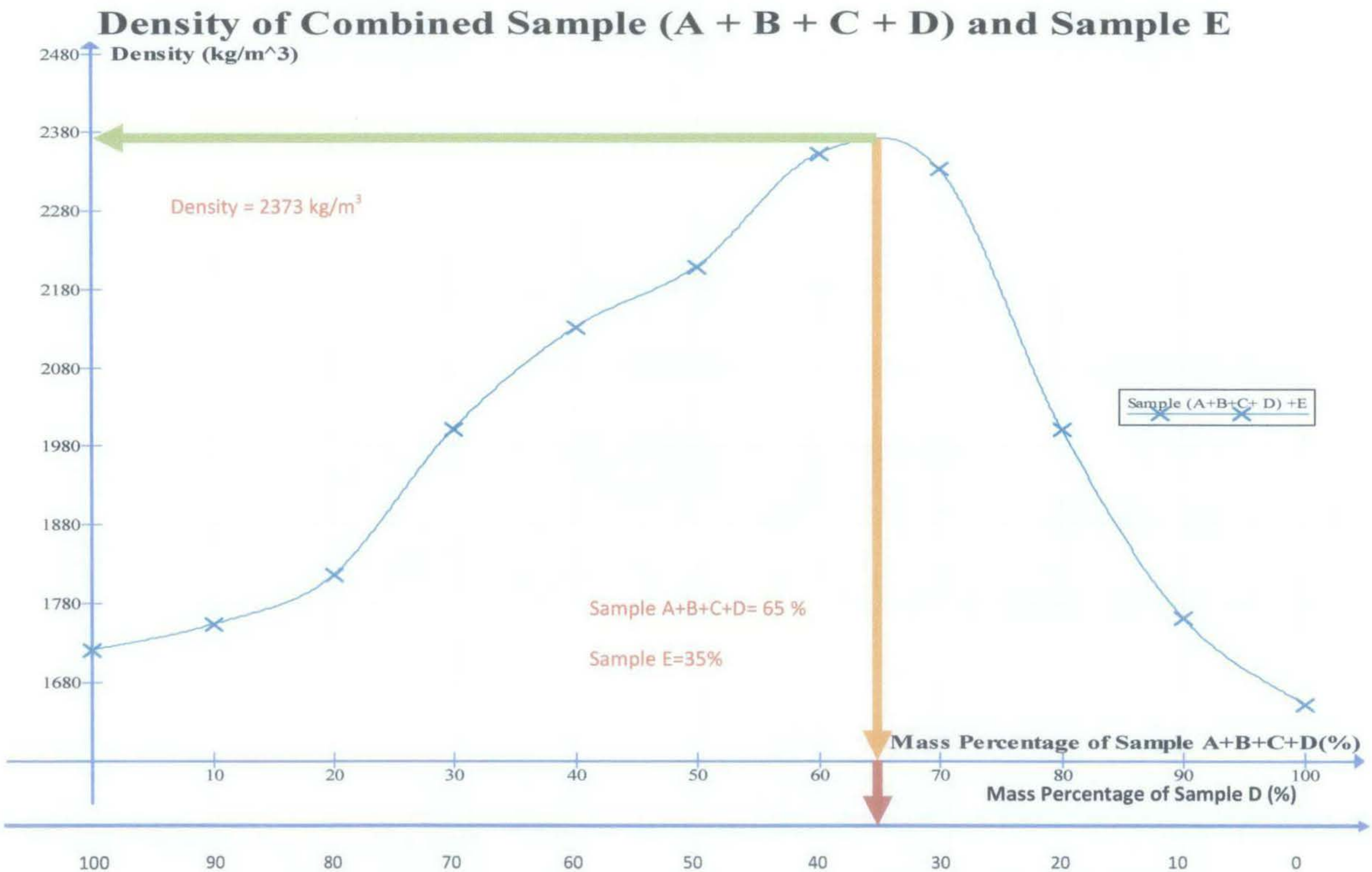


Figure 4.4: Density of Combined (Sample A + Sample B + Sample C+ Sample D) and Sample E

4.1.3 From Figure 4.4: Density of Combined (Sample A + Sample B + Sample C+ Sample D) and Sample E.

The combined Sample A, B, C and D = 59% and sample E (sand) = 41%. Therefore by calculating separately by percentage (%);

i. Sample A = 15.7%
ii. Sample B = 17.6%
iii. Sample C = 6.4%
iv. Sample D = 25.4%
v. Sample E = 35%

With such proportion leads to a 2373 kg/m^3 mix density which are the highest can be achieved. This result will later be used and as a referral in bituminous mix samples preparations.

4.1.4 Aggregate Packing Bituminous Mix

Converting the percentage of each sample to a whole mix weight of 1200 g, gives;

i. Sample A=172.90 g
ii. Sample B=194.50 g
iii. Sample C=70.30 g
iv. Sample D=279.90 g
v. Sample E=386.40 g
vi. Filler (OPC) =96.00 g

4.2 WELL GRADED (Control Sample)

In the literature review and methodology sections mentioned that the well graded mix will be used as a control sample to be compared with aggregate packing sample. Briefly, the well graded is a mix that is on par with the aggregate packing mix because of its high density property. Shown in Table 4.2, the proportion of well graded mix taken based on JKR manual.

Table 4.2: Gradation Limits for Asphalts Concrete and Designed Mix (Table 4.8 in JKR manual)

Mix Type	Wearing Coarse	Designed Mix		
Mix Designation	ACW14	ACW14	ACW14	ACW14
B.S Sieve Size	% Passing By Weight	% Passing By Weight	% Retained By Weight	Mass in Gram (g)
20.0 mm	100	100	0	0
14.0 mm	80 - 95	89	11	145.89
10.0 mm	68 - 90	79	10	132.63
5.0 mm	52 - 72	62	17	225.47
3.35 mm	45 - 62	53.5	8.5	92.73
1.18 mm	30 - 45	37.5	16	174.55
425 um	17 - 30	23.5	14	152.73
150 um	716	11.5	12	130.91
75 um	410	7	4.5	49.09
Pan	0	0	7	

Fairly, compare the well-graded packing density to the aggregate packing density yield that the density of aggregate packing is slightly higher that the well graded by 13%. As shown in Table 4.3.

Table 4.3: Well-Graded mix packing density

Height, H (mm)					V (m^3)	ρ (kg/m^3)
H_1	H_2	H_3	H_A	H		
34.65	35.54	35.36	35.18	54.82	475863.33	2101.44

From Table 4.2, with the whole mix sample is weight of 1200 g and with a 42% of coarse aggregate, 50% of fine aggregate and 8% if mineral filler and the measured samples proportion are;

i. Sample A = 145.89 g
ii. Sample C = 132.63g
iii. Sample D = 225.47g
iv. Sample E = 600.00g
v. Filler (OPC) = 96.00g

*Note that the filler content is fixed to 8% for aggregate packing mix and well graded mix.

4.3 SPECIFIC GRAVITY OF THE MIXTURES

Table 4.4: Bulk Specific Gravity

Material	Specific Gravity
Coarse Aggregate (Granite)	2.56
Fine Aggregate (Sand)	2.66
Mineral Filler (OPC)	3.32
Binder (bitumen 80/100)	1.026

*Details attached in Appendix 3

4.3.1 Specific Gravity of aggregate (Garber and Hoel, 2001)

$$SG_{mixture} = \frac{\%coarse\ aggregate + \%fine\ aggregate + \%mineral\ filler}{\frac{\%coarse\ agg}{SG\ coarse\ agg} + \frac{\%fine\ agg}{SG\ fine\ agg} + \frac{\%mineral\ filler}{SG\ mineral\ filler}}$$

i. Aggregate Packing

$$SG_{AP} = \frac{59.8\% + 32.2\% + 8\%}{\frac{59.8\%}{2.56} + \frac{32.2\%}{2.66} + \frac{8\%}{3.32}}$$

$$= 2.64\ kN/m^3$$

ii. Well-Graded (control)

$$SG_{WG} = \frac{42\% + 50\% + 8\%}{\frac{42\%}{2.56} + \frac{50\%}{2.66} + \frac{8\%}{3.32}}$$

$$= 2.66\ kN/m^3$$

4.3.2 Maximum Specific Gravity (Garber and Hoel, 2001);

$$SG_{maximum} = \frac{100}{\frac{\%\ aggregate}{SG\ aggregate} + \frac{\%bitumen}{SG\ bitumen}}$$

i. Aggregate Packing

$$SG_{AP,\ max} = \frac{100}{\frac{\%\ aggregate}{2.64} + \frac{\%bitumen}{1.026}}$$

Table 4.5: Maximum Specific Gravity (Aggregate Packing)

Bitumen Content (%)	SG Maximum (kN/m^3)
3.0	2.52
3.5	2.50
4.0	2.48
4.5	2.47
5.0	2.45

ii. Well-Graded (control)

$$SG_{WG,\ max} = \frac{100}{\frac{\%\ aggregate}{2.66} + \frac{\%bitumen}{1.026}}$$

Table 4.6: Maximum Specific Gravity (Well graded)

Bitumen Content (%)	SG Maximum (kN/m^3)
5.0	2.46
5.5	2.45
6.0	2.43
6.5	2.41
7.0	2.39

4.4 BITUMEN CONTENT

The design bitumen content is based on Table 4.9 in JKR Manual which for Mix Design ACW14 for Wearing Course is 5.0% to 7% with increment of 0.5%.

It has been calculated using formula of;

$$\boldsymbol{Mass\ Bitumen} = \frac{\boldsymbol{\%\ bitumen \times 1200}}{\boldsymbol{(100 - \%\ bitumen)}}$$

For aggregate packing mix, the bitumen content;

i. 3.0% bitumen = 37.11 g
ii. 3.5% bitumen = 43.52 g
iii. 4.0% bitumen = 50.00 g
iv. 4.5% bitumen = 56.54 g
v. 5.0% bitumen = 63.16 g

For well graded (control) mix, the bitumen content;

i. 5.0% bitumen = 63.16 g
ii. 5.5% bitumen = 69.84 g
iii. 6.0% bitumen = 76.60 g
iv. 6.5% bitumen = 83.42 g
v. 7.0% bitumen = 90.32 g

Table 4.7: Summary of sample proportions

Mixture	Aggregate Packing	Well Graded (control)
A	14.4	12.16
B	16.2	0
C	5.9	11.05
D	23.3	18.75
E	32.2	50
Filler (OPC)	8	8

4.5 TESTING RESULTS

4.5.1 Marshall

i) Data (simplified)

Refer Appendix 2 for a complete data

Table 4.8: Data from Marshall Testing of aggregate packing sample

%binder	Porosity	Flow	Density	Stability	VMA
3	4.88	2.44	2.40	19.27	11.92
3.5	3.29	1.94	2.42	17.59	11.62
4	2.47	2.38	2.42	16.02	12.04
4.5	1.44	2.50	2.44	13.13	11.94
5	1.08	2.30	2.42	11.49	12.79

Table 4.9: Data from Marshall Testing of well graded sample

%binder	Porosity	Flow	Density	Stability	VMA
5.0	5.16	2.01	2.34	12.08	16.68
5.5	5.49	1.95	2.32	7.64	17.74
6.0	3.67	2.22	2.34	8.47	17.28
6.5	2.73	2.10	2.35	7.96	17.60
7.0	1.72	2.45	2.35	9.47	17.88

ii) Porosity vs Binder Content

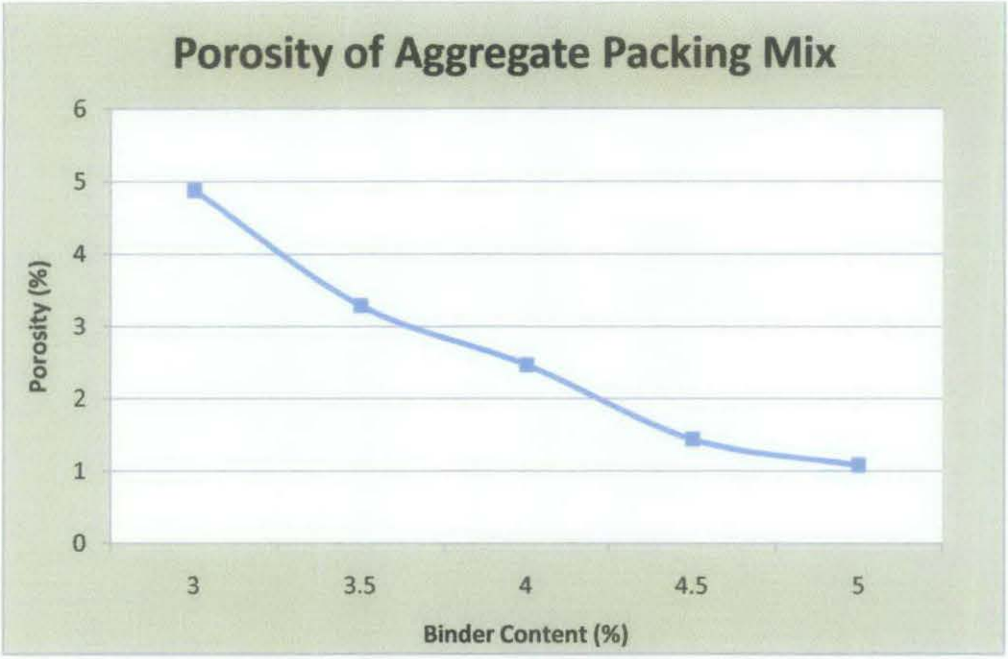


Figure 4.5: Porosity of aggregate packing mix vs binder content

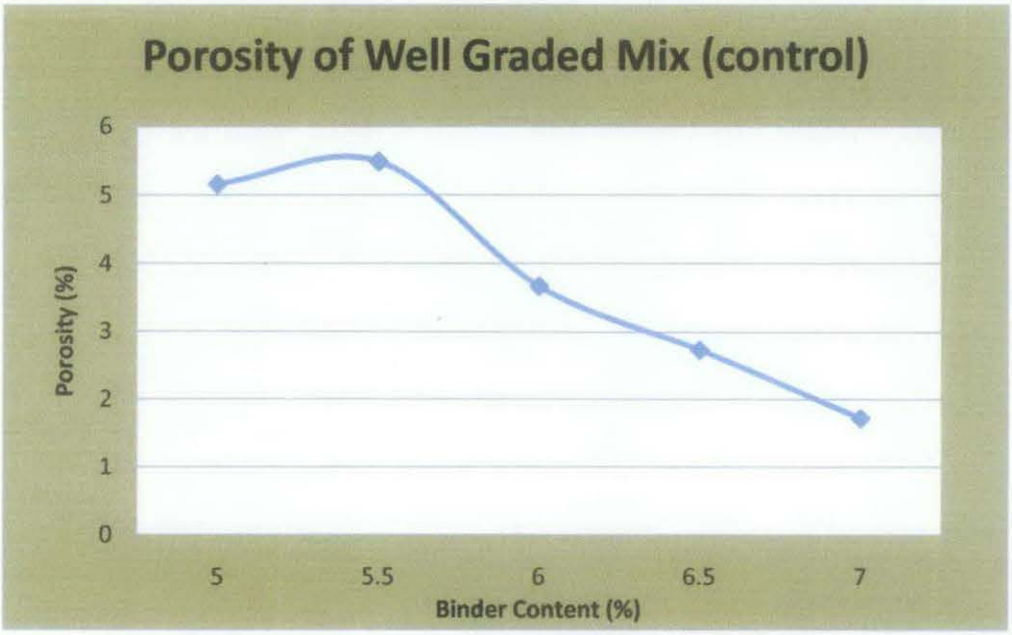


Figure 4.6: Porosity of well graded mix (control) vs binder content

iii) Flow vs Binder Content

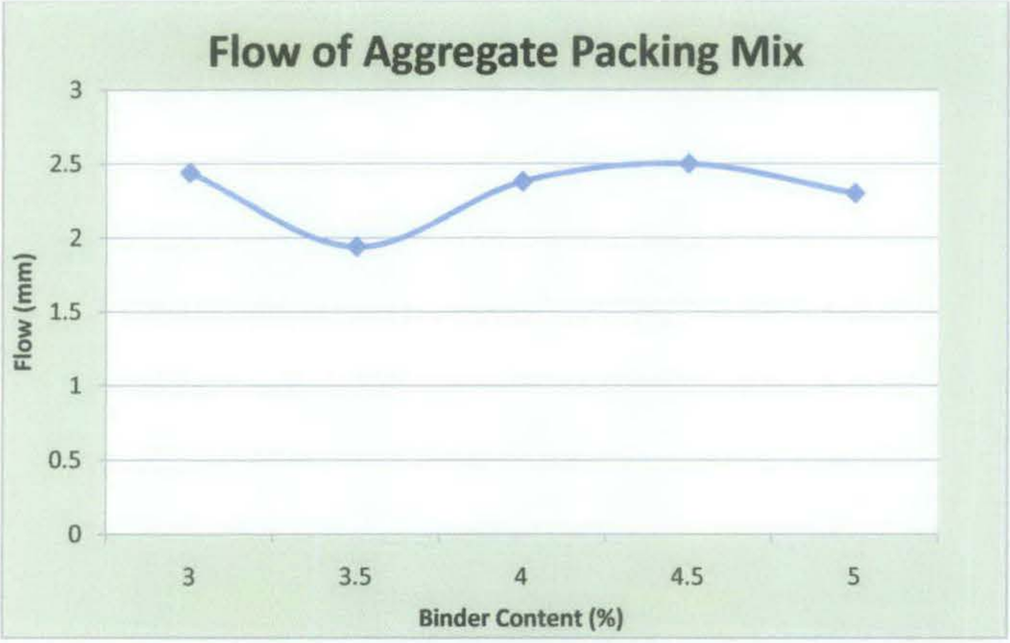


Figure 4.7: Flow of aggregate packing mix vs binder content

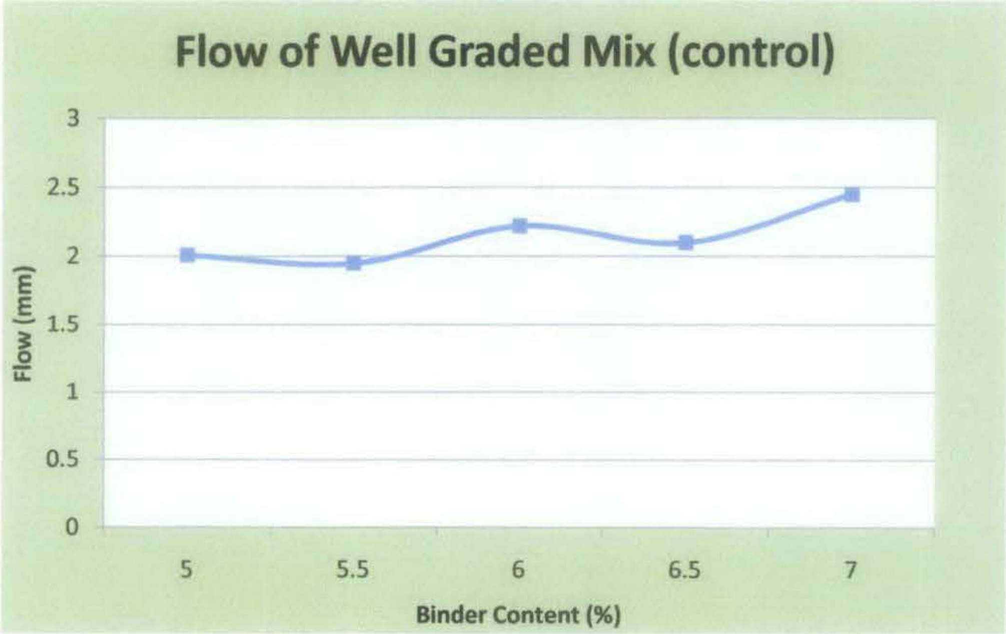


Figure 4.8: Flow of well graded mix (control) vs binder content

iv) Density vs Binder Content

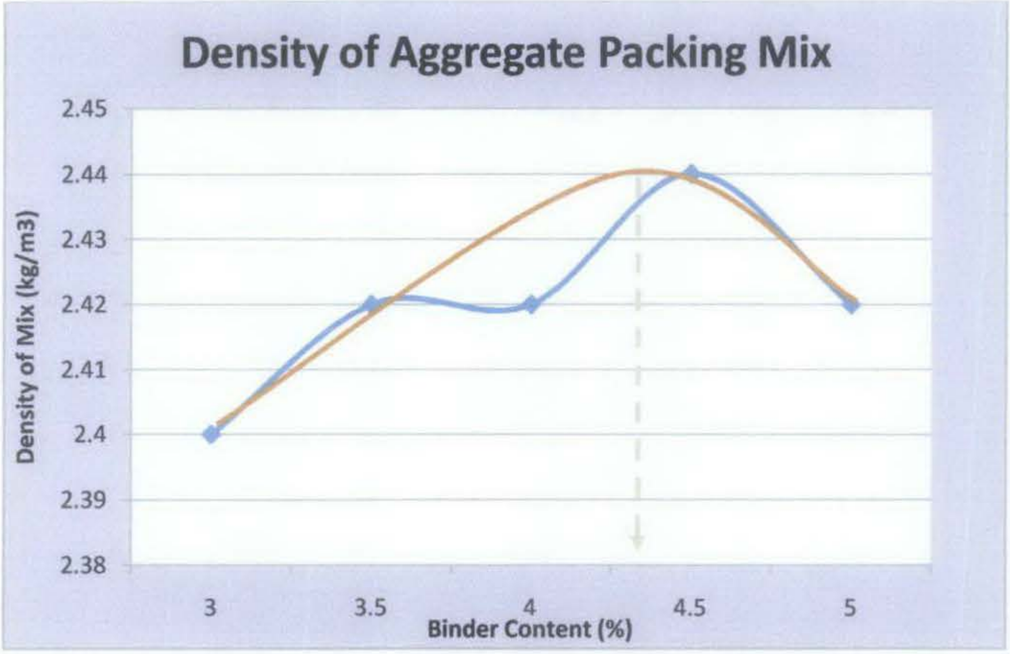


Figure 4.9: Density of aggregate packing mix vs binder content

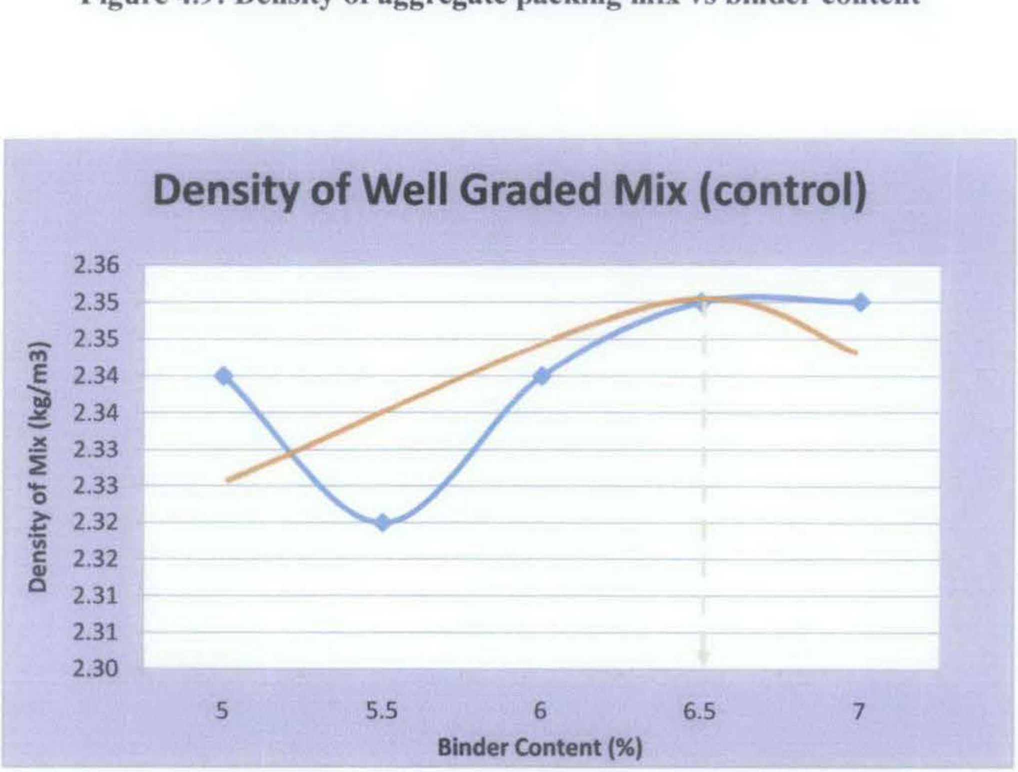


Figure 4.10: Density of well graded mix (control) vs binder content

v) Stability vs Binder Content

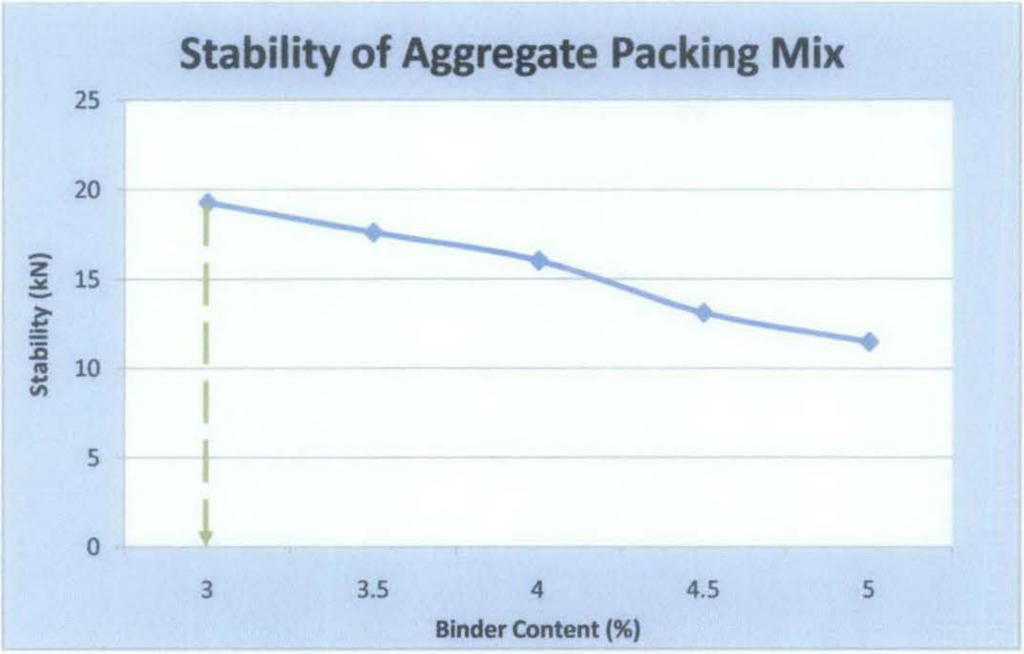


Figure 4.11: Stability of aggregate packing mix vs binder content

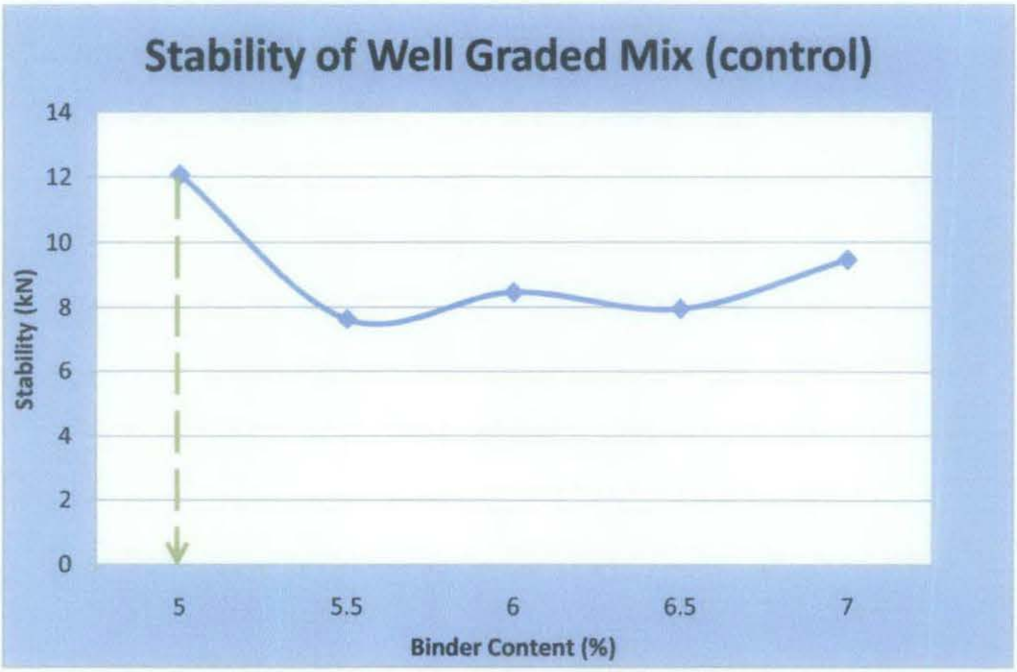


Figure 4.12: Stability of well graded mix (control) vs binder content

vi) VMA vs Binder Content

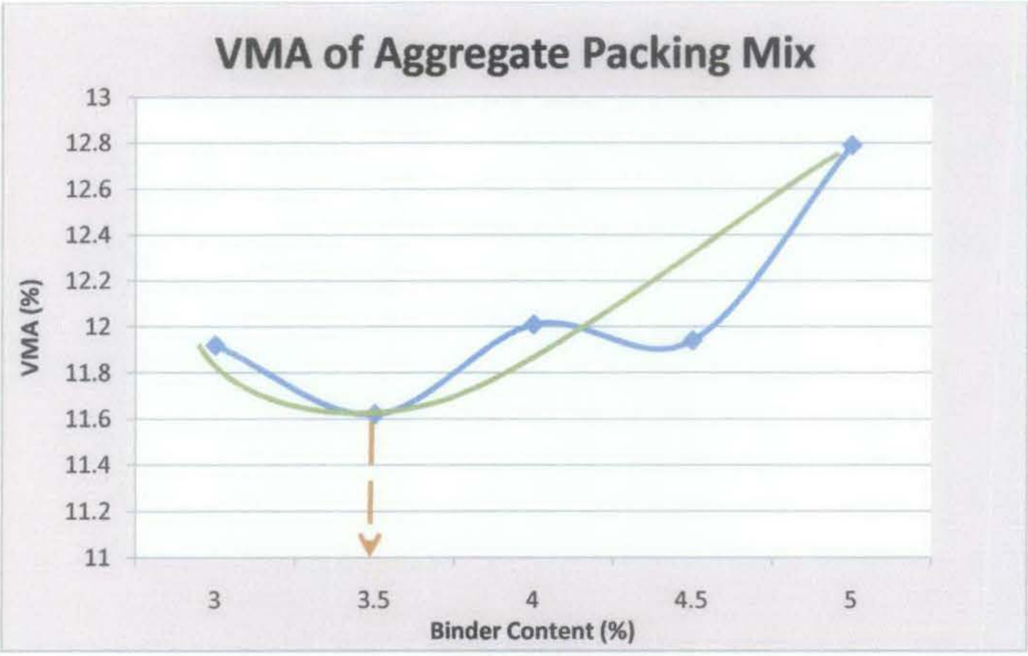


Figure 4.13: VMA of aggregate packing mix vs binder content

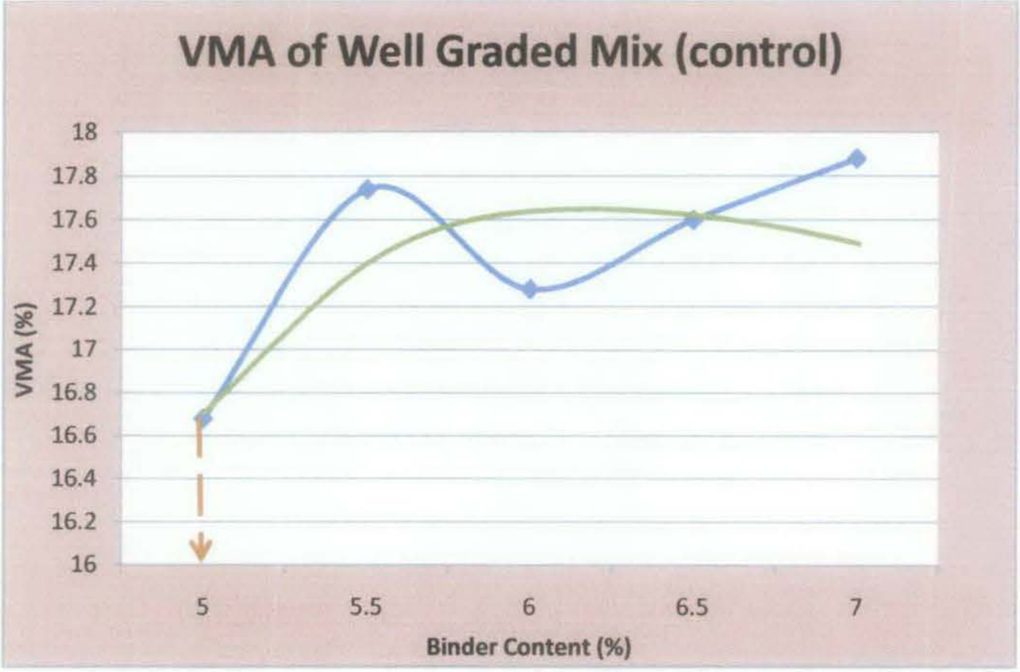


Figure 4.14: VMA of well graded mix (control) vs binder content

vii) Optimum Bitumen Content (OBC), % by Weight

Table 4.10: Optimum Binder Content (%)

Parameter	Aggregate Packing	Well Graded (control)
Density	4.3	6.5
Stability	3.0	5.0
VMA	3.5	5.0
OBC (%)	3.6	5.5

viii) Summary

Table 4.11: Summary of Marshall Testing

Test	Aggregate Packing	Well Graded (control)
Porosity	3.20	5.49
Flow	2.25	1.96
Density	2.43	2.33
Stability	17.30	8.10
VMA	11.62	16.68
Stiffness (S/F)	7.69	4.13

Table 4.12: Summary of sample proportions with binder content

Mixture	Aggregate Packing	Well Graded (control)
A	14.4	12.16
B	16.2	0
C	5.9	11.05
D	23.3	18.75
E	32.2	50
F	8	8
Bitumen Content	3.6	5.5

4.5.2 Wheel Tracking

Figure 4.15: Aggregate Packing Wheel Tracking Sample

Figure 4.16: Well graded (control) Wheel Tracking Sample

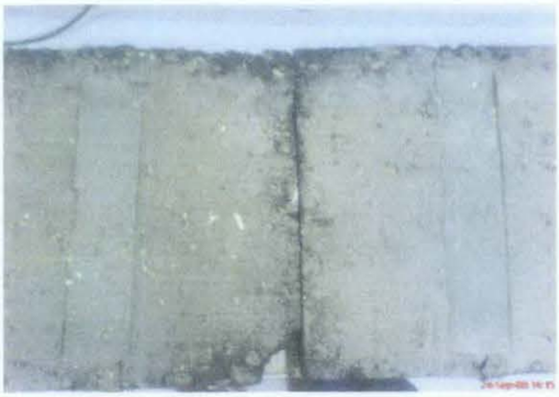


Figure 4.17: Aggregate packing and well graded (control) Wheel Tracking samples

Table 4.13: Maximum depth of rutting from Wheel Tracking Test

Wheel Tracking	Aggregate Packing	Well Graded (control)
Maximum Depth (mm)	1.50	3.03

Due to some problem to the Wheel Tracking Machine, the depth of the rutting by the Wheel Tracker load cannot be visualized and be recorded on the computer. Therefore, the rutting depth manually measured the maximum depth at any point of the sample using digital vernier caliper.

4.5.3 Beam Fatigue

Table 4.14: Beam Fatigue Results

	Aggregate Packing	Well Graded (control)
Initial Flexural Stiffness (MPa)	9197	4652
Termination Stiffness (MPa)	4599	2326
Loading Time	3:55:42	1:16:22
Cycle Count	70710	22910

Figure 4.18: Beam Sample

4.6 COST ASSESSMENT

Table 4.15: Cost Assessment

Type	Aggregate		Cement	Total
	Course	Fine(sand)		
Aggregate Packing	108.8 x (172.90+194.50+70.30+279.90)	119.4 x (386.40)	same rate	124211.04
Well-Graded	108.8 x (145.89+132.63+225.47)	119.4 x (600)	same rate	126474.11

*note that the calculation based on index shown in Table 4.16

Table 4.16: Building Material Works Section Index by Building Material & Region

JADUAL 3: INDEKS KOS BAHAN BINAAN MENGIKUT BAHAN BINAAN DAN KAWASAN
Table 3: Building Material Works Section Index By Building Material and Region

(Jul.2002=100)

Perkara Item	Tempoh Period	Kawasan/Region					
Bahan Binaan Building Material		A Pulau Pinang, Kedah, Perlis	B Perak	C Kuala Lumpur, Selangor, Negeri Sembilan, Melaka	D Johor	E Pahang	F Kelantan, Terengganu
(1) Simen Cement	Jan 2008	108.0	108.9	109.1	109.2	108.5	110.0
	Feb 2008	108.0	108.9	109.1	109.2	108.5	110.0
	Mar 2008	108.0	108.9	109.1	109.2	108.5	110.0
	Apr 2008	108.0	108.9	109.1	109.2	108.5	110.0
(2) Agregat Aggregates	Jan 2008	112.4	107.8	114.8	111.2	103.5	110.0
	Feb 2008	112.4	107.6	119.8	111.2	103.5	110.0
	Mar 2008	113.9	107.6	128.1	111.2	104.4	110.0
	Apr 2008	113.9	108.8	120.0	111.2	104.4	110.0
(3) Pasir Sand	Jan 2008	130.9	123.0	128.1	112.4	105.4	118.6
	Feb 2008	130.9	123.0	134.2	113.2	105.4	118.6
	Mar 2008	131.3	123.0	140.5	113.2	105.9	118.6
	Apr 2008	131.6	119.4	140.7	113.2	111.9	118.6

Even though the bitumen cost didn't included, but due to the optimum bitumen content of aggregate packing mix is much lower than the well graded mix (control), it can be deducted and conclude that the overall material cost for aggregate packing is lower and better than the well graded mix (control)

CHAPTER 5

DISCUSSIONS & RECOMMENDATION

5.1 PACKING DENSITY

a. Shown in Figure 4.4 and data on Table 4.1, the combined Sample A, B, C, D and E gives larger density rather than Sample E alone or Sample A, B, C and D alone. This similar pattern has been shown by previous packing works where for example sample A alone and sample B alone cannot achieved higher density than combination of sample A and B. Refer Appendix for previous data of aggregate packing works.

b. The density of the mix is influenced by the volume, as amount of mass is fixed. As the volume increases, the density increases and it's proven in equation of density

   Density (ρ) = Mass (m)/ Volume (V)

c. From the graph in Figure 4.4, at the right hand side of the graph, the density is increasing abruptly when smaller aggregate, Sample E is filled in the mould together with Sample A,B,C and D.

d. When the voids already filled, adding more the smaller aggregate, Sample E may increase the volume of the mix and that is occurred on the left hand side of the graph in Figure 4.4.

e. As the density increasing, the void will be decreasing as it will be filled with the smaller aggregate sizes and therefore the volume of the mix is lowered.

f. Observed Table 4.3, fairly, compare the well-graded packing density to the aggregate packing density yield that the density of aggregate packing is slightly higher that the well graded by 13%. This occurrence verified the problem statement where the well graded aggregate gradation didn't necessarily lead to a high density.

5.2 BITUMEN CONTENT SELECTION

a. In reference to the JKR manual, it is stated that, for wearing course, the optimum bitumen content design selection should be vary from 5.0% to 7.0% with 0.5 % increment.
b. The bitumen content shows an excellence output for the well graded mix sample. However for aggregate packing, when preparing sample for 5.5% bitumen content, the mixture show binder bleeding result.
c. Therefore, the bitumen content selection for aggregate packing is set to vary from 3.0% to 5.0% with 0.5 % increment.
d. At the very beginning of the project, it shows that aggregate packing uses less binder than the well graded. This satisfied the condition discussed in chapter 1 and 2 of the report.

5.3 RESULTS ANALYSIS

As the first phase completed, the project proceed with the bituminous mix work using the identified aggregate packing distribution. The second phase is to evaluate and analyze the effect of aggregate packing to the performance of the bituminous mix.

In this phase, the crucial part is the result of the performance of the bituminous mix. The mix with aggregate packing is then will be compared to the control mix with well graded aggregate grading mix samples (control).

a. *Marshall*
   i. Porosity of aggregate packing sample is lower than the control sample where it indicates the aggregate packing sample is less permeability and it would lead to high strength and durability. Low porosity induced by a filled void with aggregate and binder. However, the porosity is still in the range of 3%-5% (as shown in Table 2.2) where the mixture will not suffer bleeding.

ii. However the flow of the aggregate packing slightly higher than the well graded sample. This result is not been expected since the high density mixture is expected to be stiff and less flexible. High flow indicates that the ability of the sample to deform. Therefore higher flow means high flexibility. Checking with Marshall Quotient which equal to stability by flow (S/F), the aggregate packing result in higher stiffness than the well graded sample.

iii. As been expected, the density of aggregate packing samples way much higher than the well graded samples. This explained by the previous work in the early stage of the project; finding high packing density. With high density mixture indicates the mixture has less volume and therefore less voids. High density also signifies lower porosity, less binder use and therefore reduces in material cost.

iv. The stability of the aggregate packing recorded as highest. Due to filled voids, therefore more intact between aggregate particles that lead to higher interlocking force that identical to high stability.

v. VMA of aggregate packing is lower than the well graded sample relates with porosity and density as discussed earlier.

vi. Overall, all the result is begin with density characteristic which mainly reflects other tested parameters.

b. Wheel Tracking

i. From the results in Table 4.13, the maximum depth on aggregate packing sample imposed with 520 N loads in 40°C temperature for 45 minutes; which stimulate the effect of traffic, is 1.50 mm. 50% way better than the well graded sample which maximum depth of 3.03 mm.

ii. Due to less voids, more intact between particles made aggregate packing sample highly resistance to rutting.

c. Beam Fatigue

i. From the results in Table 4.14, with same applied load imposed to the sample, clearly the aggregate packing mix shows an excellent performance against fatigue.

ii. Based on data presented in Table 4.14, for aggregate packing beam sample to failed, it needs 70710 cycles load which consumed almost 4 hours time. Compared to well graded beam sample, it failed at an hour with 22910 cycles load. The indicator of failure shows that at 4599 MPa, the aggregate packing beam will failed (test terminated) while the well graded sample failed at 2326 MPa. It shows the well graded beam will failed at lower stiffness than the aggregate packing.

iii. From the data also shows that the aggregate packing beam can sustained a maximum tensile micro-strain with 9197 MPa resistance to bending, twice as good as well graded beam sample (4652 MPa).

iv. Overall, beam fatigue test shows a positive result of aggregate packing mix performance over well graded mix.

d. Texture

i. With high performance from test results, the aggregate packing sample has it flaws. The texture. The aggregate packing mixture is brittle in the edge, clearly can be seen in Figure 4.17. The left hand side sample has a missing fraction on its edge.

ii. The aggregate tends to strip away and it similarly conveys a same problem that usually happened to the pavement, the stripping problem.

iii. As the granite as an aggregate when it's coated with bitumen it has a problem of stripping when in contact with water. The OPC as an anti-stripping agent may effectively improve the adhesion between bitumen binder and aggregate, thus reducing the stripping problem.

iv. Since aggregate packing sample utilized aggregate as major component, the 8% filler (OPC) may not sufficient. As a recommendation, filler should be included in optimizing packing density process to improve adhesion.

e. *Other Concerns*

i. The results shows an excellent outcome, but be aware that the method used for aggregate packing is primitive, and it can be improve by using mechanical or automated machine to compact that would gives a constant rate of force and amplitude. Thus it will reduce variation in results and gives better and reliable results.

ii. The recommendation on methodology can be improve by using mechanical compactor available in geology and geotechnical laboratory.

f. *Cost Assessment*

i. Already presented in chapter 4 and discussed in chapter 1 and 2, the aggregate packing sample is expected to be cost saving. Referring to Table 4.15 and 4.16, the material cost for aggregate and sand only, shows that the aggregate packing costing less than the well graded sample.

ii. With the optimum binder content of aggregate packing is much lower than the well graded, it can be concluded that the aggregate packing propose much more appealing offer. Less cost high performance.

CHAPTER 6

CONCLUSION

As a conclusion, the aggregate packing mix formed a high density mix and a well-graded mix did not necessarily achieve the high density in the mix. From the results and discussion, the aggregate packing mix potentially going ahead of the well-graded mix in term of performance as well as cost assessment and it can further be improve. It can be deduce that high density mix or high packing density mix contribute to a higher performance bituminous mix with lower cost of material. All project objectives have been achieved.

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1. **Sample A+B**

A= 20mm-14mm B=14mm-12.5mm

Mass, m = 1 kg = 100%

Table 4.0: Data for Sample A and Sample B

A (%)	B (%)	Height, H (mm)					V (mm^3)	ρ (kg/m^3)
		H_1	H_2	H_3	H_A	h		
100	0	15.72	16.11	16.79	16.21	73.79	640531.88	1561.20
90	10	16.47	16.23	16.85	16.52	73.48	637840.64	1567.79
80	20	18.41	18.17	17.77	18.12	71.88	623952.18	1602.69
70	30	17.86	18.33	18.66	18.28	71.72	622563.31	1606.26
60	40	18.49	18.44	18.92	18.62	71.38	619611.95	1613.91
50	50	20.14	19.56	19.95	19.88	70.12	608674.56	1642.91
40	60	19.74	19.32	19.67	19.58	70.42	611278.70	1635.92
30	70	17.03	17.34	17.46	17.28	72.72	631243.78	1584.17
20	80	16.60	17.27	17.34	17.07	72.93	633066.68	1579.61
10	90	17.02	17.20	16.80	17.01	72.99	633587.51	1578.31
0	100	16.94	16.36	17.04	16.78	73.22	635584.01	1573.36

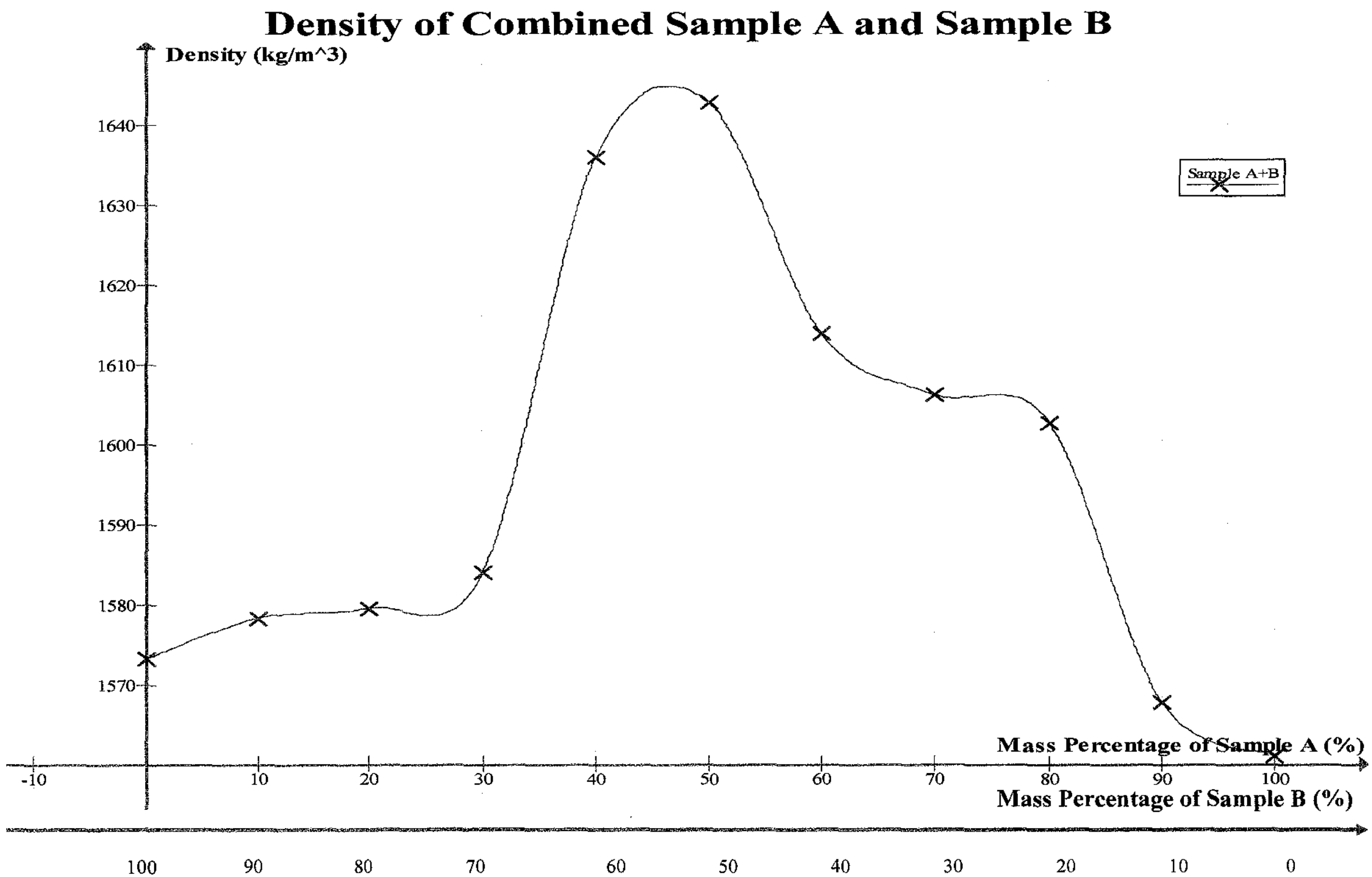


Figure A: Density of Combined Sample A and Sample B

2. **Sample A+B+C**

A= 20mm-14mm B=14mm-12.5mm C=12.5mm-10.0mm

1 kg = 100%

A+B (%)	C (%)	Height,H (mm)					V (m^3)	ρ (kg/m^3)
		H_1	H_2	H_3	H_A	h		
100	0	19.46	20.08	19.07	19.84	70.46	611625.87	1634.99
90	10	18.88	18.57	18.76	18.74	71.26	618570.25	1616.63
80	20	19.86	19.67	19.54	19.69	70.31	610323.80	1638.47
70	30	17.58	19.50	18.88	18.54	71.36	619438.30	1614.37
60	40	18.24	18.37	18.13	18.25	71.75	622823.68	1605.59
50	50	17.43	17.60	18.42	17.81	72.19	626643.09	1595.80
40	60	16.91	17.76	17.66	17.44	72.56	629854.86	1587.67
30	70	17.65	16.40	17.17	17.07	72.93	633066.63	1579.61
20	80	16.38	17.29	17.14	16.94	73.06	634195.09	1576.80
10	90	17.15	16.53	16.25	16.64	73.36	636799.23	1570.35
0	100	15.30	15.78	15.92	15.67	74.33	645219.29	1549.86

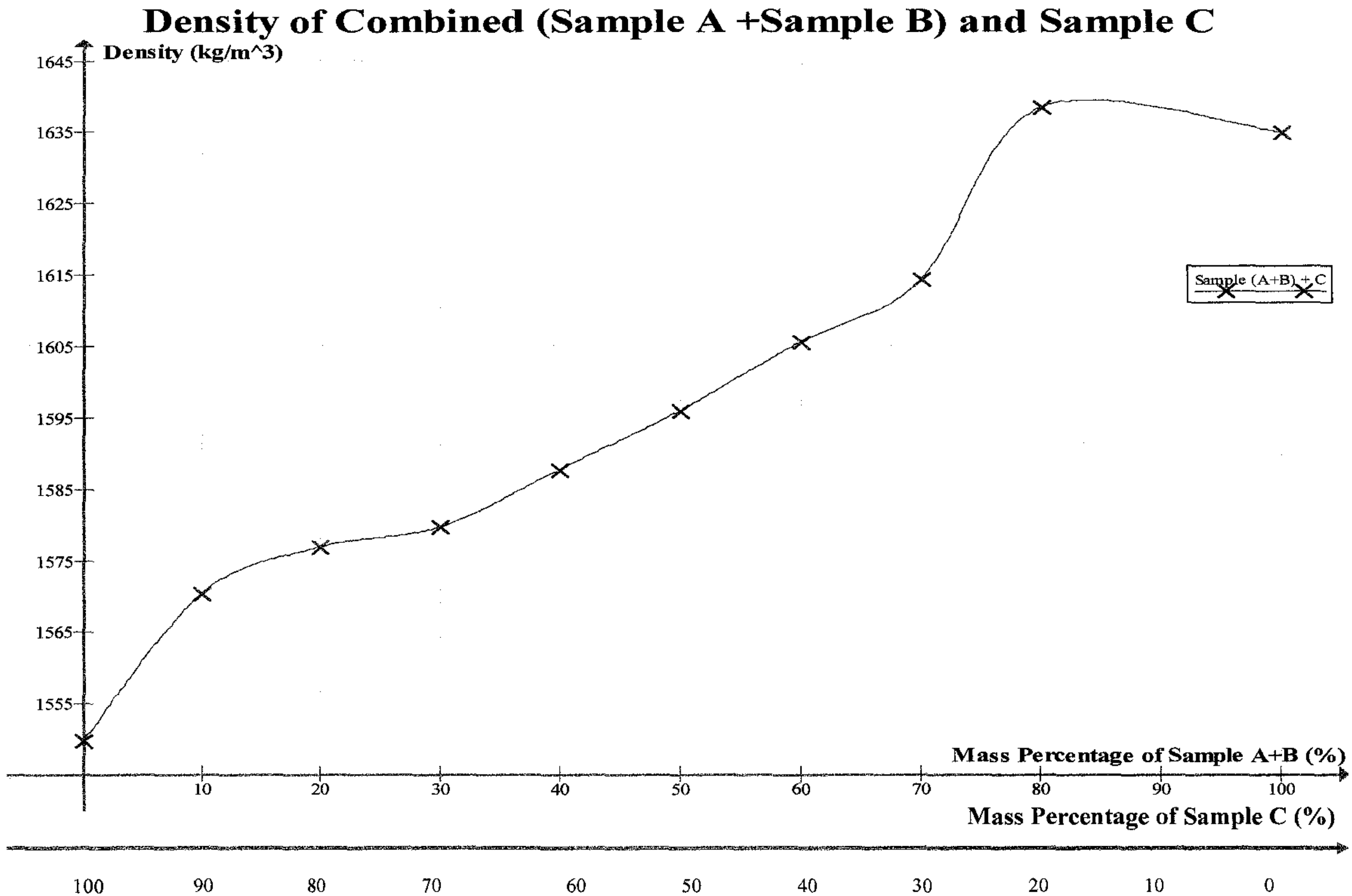


Figure B: Density of Combined (Sample A + Sample B) and Sample C

3. **Sample A+B+C+D**

A= 20mm-14mm B=14mm-12.5mm
C=12.5mm-10.0mm D=10.0mm-5.0mm

1 kg = 100%

A+B+C (%)	D (%)	Height, H (mm)					V (m^3)	ρ (kg/m^3)
		H_1	H_2	H_3	H_A	h		
100	0	18.13	18.79	18.43	18.45	71.55	621087.59	1610.08
90	10	20.18	19.43	19.04	19.55	70.45	611539.07	1635.22
80	20	19.30	18.48	18.85	19.74	70.26	609889.78	1639.64
70	30	18.86	18.55	19.26	18.89	71.11	617268.18	1620.04
60	40	20.60	20.26	20.82	20.56	69.44	602771.79	1659.00
50	50	19.19	18.55	19.58	19.11	70.89	615358.48	1625.07
40	60	18.34	18.31	19.00	18.55	71.45	620219.54	1612.33
30	70	16.90	18.23	17.43	17.52	72.48	629160.42	1589.42
20	80	18.40	17.77	18.18	18.12	71.88	623152.14	1602.69
10	90	19.30	18.48	18.85	18.88	71.12	617354.98	1619.81
0	100	19.63	18.43	18.86	18.97	71.03	616573.74	1621.87

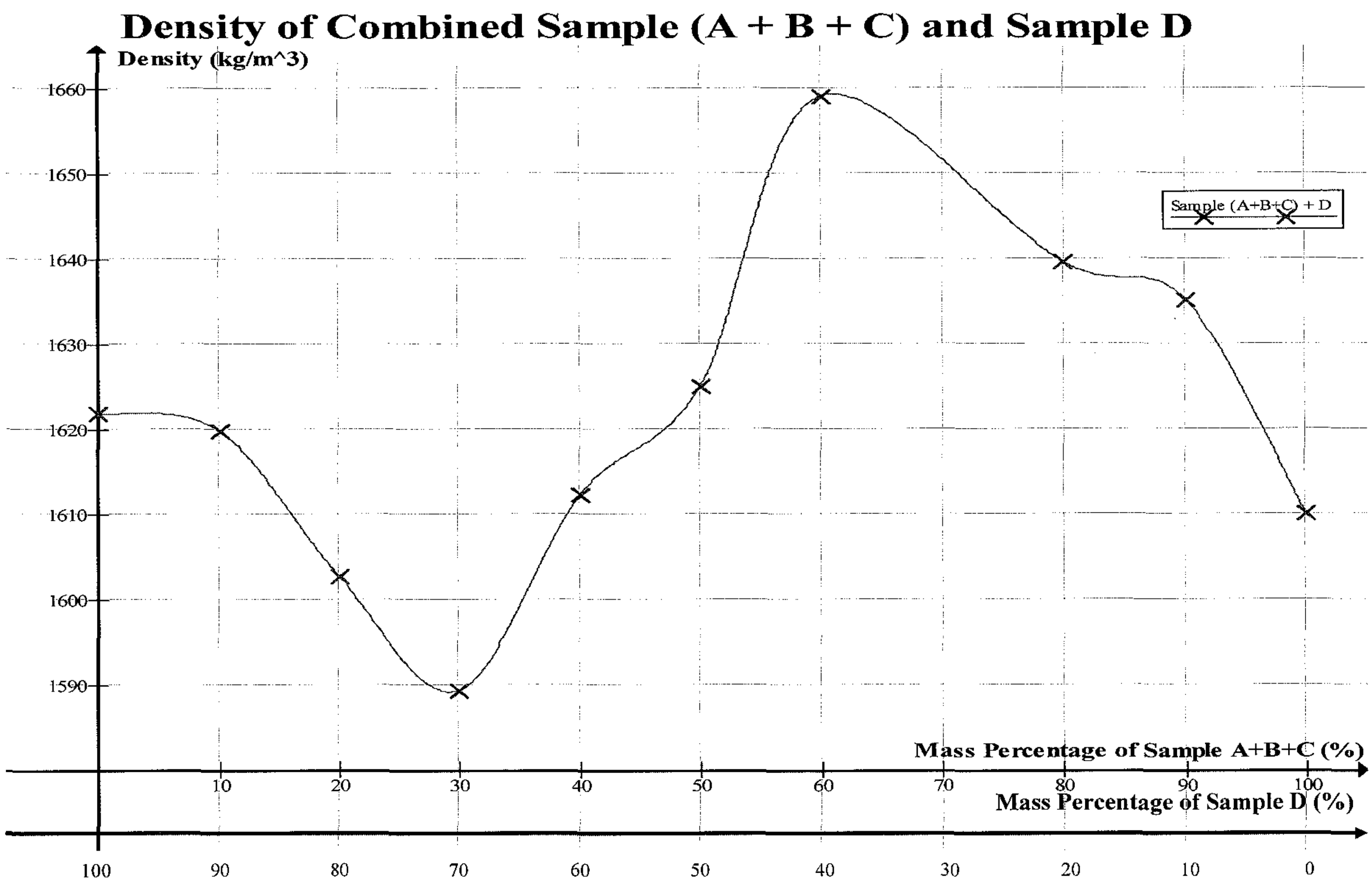


Figure 5: Density of Combined (Sample A + Sample B + Sample C) and Sample D

FYP 2 MARSHALL MIX DESIGN & TEST

AGGREGATE PACKING MIXTURES

Sample No	Binder content by Mass of Mix (%)	Height (mm)	Mass of Specimen		Volume (cm3)	Specific Gravity of mix		Air Voids (%)		Flow (mm)	Stability (kN)		
			In Air (g)	In Water (g)		Bulk	Max	Porosity	VMA		Measured	C.F	Corrected
	A	B	C	D	E	F	G	H	I	J	K	L	M
16	3.0	67.34	1224.5	712.0	512.50	2.39		5.19	12.21	2.29	16.45	0.93	15.30
17	3.0	66.84	1231.5	716.0	515.50	2.39	2.52	5.20	12.22	2.55	20.71	0.93	19.26
18	3.0	66.31	1229.5	720.0	509.50	2.41		4.24	11.34	2.49	25.00	0.93	23.25
19	3.5	67.58	1235.5	721.0	514.50	2.40		3.95	12.22	2.06	15.19	0.89	13.52
20	3.5	66.19	1237.0	727.0	510.00	2.43	2.50	2.98	11.34	1.99	23.02	0.93	21.41
21	3.5	66.02	1237.5	727.5	510.00	2.43		2.94	11.31	1.76	19.17	0.93	17.83
22	4.0	66.15	1239.0	728.5	510.50	2.43		2.14	11.74	2.54	19.49	0.93	18.13
23	4.0	67.21	1242.0	729.0	513.00	2.42	2.48	2.38	11.96	2.30	16.00	0.93	14.88
24	4.0	67.19	1241.5	726.0	515.50	2.41		2.89	12.42	2.30	16.17	0.93	15.04
25	4.5	67.59	1248.0	731.5	516.50	2.42		2.18	12.59	3.01	13.20	0.93	12.28
26	4.5	66.34	1249.0	737.5	511.50	2.44	2.47	1.14	11.67	2.46	14.74	0.93	13.71
27	4.5	66.27	1247.0	737.0	510.00	2.45		1.01	11.55	2.03	14.40	0.93	13.39
28	5.0	65.54	1247.5	737.0	510.50	2.43		0.82	12.56	2.46	14.87	0.96	14.28
29	5.0	66.75	1253.5	738.0	515.50	2.43	2.45	0.75	12.50	2.36	11.32	0.93	10.53
30	5.0	66.66	1240.5	725.5	515.00	2.41		1.68	13.32	2.08	10.85	0.89	9.66

FYP 2 MARSHALL MIX DESIGN & TEST

WELL-GRADED MIXTURE (CONTROL SAMPLE)

Sample No	Binder content by Mass of Mix (%)	Height (mm)	Mass of Specimen		Volume (cm3)	Specific Gravity of mix		Air Voids (%)		Flow (mm)	Stability (kN)		
			In Air (g)	In Water (g)		Bulk	Max	Porosity	VMA		Measured	C.F	Corrected
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	5.0	68.09	1240.5	708.0	532.5	2.33		5.30	16.80		Failed Sample		
2	5.0	68.87	1240.5	707.0	533.5	2.33	2.46	5.48	16.96	2.12	13.1	0.89	11.66
3	5.0	68.76	1242.0	711.5	530.5	2.34		4.83	16.39	1.89	14.03	0.89	12.49
4	5.5	68.94	1249.0	718.0	531.0	2.35		3.99	16.44	2.62	Failed Sample		
5	5.5	70.51	1253.5	711.5	542.0	2.31	2.45	5.60	17.84	1.92	8.44	0.86	7.26
6	5.5	69.70	1248.5	710.0	538.5	2.32		5.37	17.63	1.98	9.31	0.86	8.01
7	6.0	69.86	1254.0	714.5	539.5	2.32		4.35	17.86	2.67	Failed Sample		
8	6.0	70.03	1264.0	724.0	540.0	2.34	2.43	3.67	17.28	2.25	9.62	0.86	8.27
9	6.0	69.59	1259.5	721.5	538.0	2.34		3.66	17.27	2.18	10.07	0.86	8.66
10	6.5	69.31	1256.0	721.5	534.5	2.35		2.50	17.40	2.91	Failed Sample		
11	6.5	69.85	1270.0	730.0	540.0	2.35	2.41	2.41	17.33	2.17	10.28	0.86	8.84
12	6.5	70.56	1271.0	727.0	544.0	2.34		3.05	17.87	2.02	8.22	0.86	7.07
13	7.0	67.64	1229.0	706.0	523.0	2.35		1.68	17.84	2.37	Failed Sample		
14	7.0	69.41	1272.0	731.5	540.5	2.35	2.39	1.53	17.72	2.89	10.58	0.86	9.10
15	7.0	69.89	1279.0	733.5	545.5	2.34		1.90	18.03	2.01	11.43	0.86	9.83

Table 1: Result on Characteristic Tests for Coarse Aggregate

Test	Result
Specific Gravity	2.56
Water Absorption Rate Test	1.10%
LA Abrasion	18%
Aggregate Impact Value	23.9%

Table 2: Result on Characteristic Tests for Fine Aggregate

Test	Result
Specific Gravity	2.66
Water Absorption Rate Test	0.51%

Table 3: Result on Characteristic Tests on Bitumen

Test	Result
Specific Gravity	1.026
Softening Point	48.3°C
Ductility	116.9cm
Penetration grade	80/100

Table 4: Standard Penetration Test

Standard Penetration Test				
Temperature : *25°C*		Load : *100 g*		Time : *5 seconds*
Sample No.	Determination 1	Determination 2	Determination 3	Mean
A	88	88	85	87
B	86	86	84	85.333

Table 5 : Result on Specific Gravity Test for Filler

Type of Filler	Average Density (g/cc)
Ordinary Portland Cement	3.32

Table 6: Result for Aggregate Impact Value Test for granite.

		Test No.	
		1	2
Nett weight of the aggregate in the measure (A)	(g)	796.00	798.00
Weight of sample coarser than 2.36 mm (no.8) sieve. (B)	(g)	606.00	607.00
Weight of sample retained in the pan. (C)	(g)	190.00	191.00
Aggregate Impact Value (AIV)	(%)	23.87	23.93

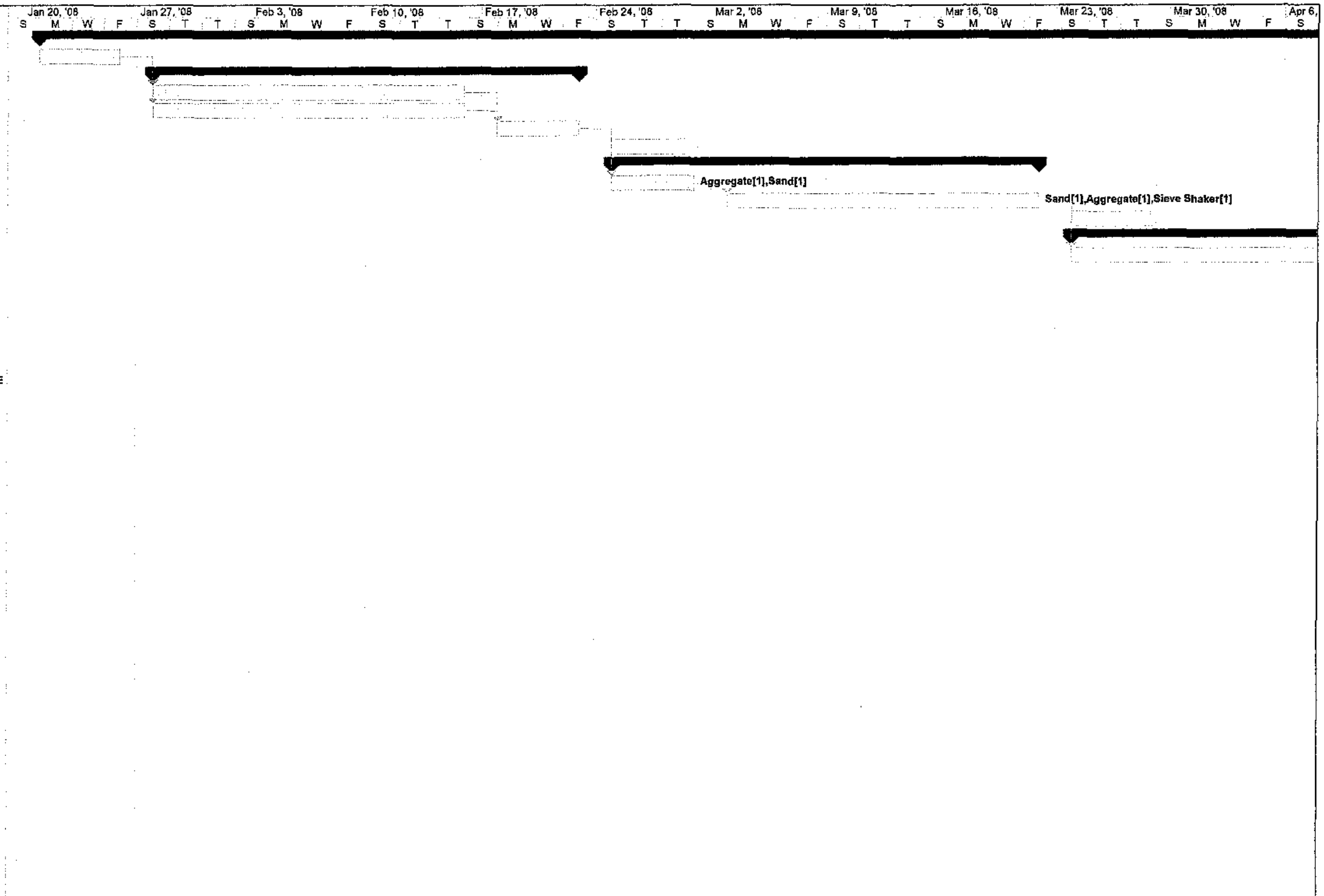
Properties of Materials

- Aggregate – Granite:
  - Specific gravity = 2.56
  - Water absorption = 1.10%
  - AIV for granite = 23.90%

Table 7: Result for Aggregate Abrasion Value Test for granite.

		Test1
Mass of aggregate retained on No. 4 ASTM sieve, M_1	kg	5.0
Mass of material passing No. 12 ASTM sieve, M_2	kg	0.9
Los Angeles abrasion value $\frac{M_2}{M_1} \times 100\%$	%	18

ID	Task Name
1	**FINAL YEAR PROJECT 1**
2	Submission of FYP Topic
3	**STUDY OF LITERATURE REVIEW & RESEARCH**
4	Internet Research
5	Journal Studies
6	Hazard Studies
7	**Preliminary Report Submission**
8	**LABORATORY WORK 1**
9	Gathering Material (aggregate,sand and cement)
10	Sieving, Washing and Labeling Aggregate
11	**Progress Report Submission**
12	**LABORATORY WORK 2**
13	Sieving, Washing & Labeling Aggregate
14	Packing Density
15	**Final Draft Report Submission**
16	**Final Report Submission**
17	**Oral Presentation 1**
18	**FINAL YEAR PROJECT 2**
19	Submission of FYP Revised Topic
20	**SUPPLEMENTARY STUDY OF LITERATURE REVIEW & RESE**
21	Internet Research
22	Journal Studies
23	Laboratory Manual Studies
24	**LABORATORY WORK 3**
25	**Bituminous Mix Performance 1**
26	**Marshall Method**
27	Prepare Materials
28	Prepare Marshall Samples
29	Samples Testing (Marshall Testing)
30	Analysis of Marshall Testing Data
31	**Submission of Progress Report 1&2**
32	**LABORATORY WORK 4**
33	**Bituminous Mix Performance 2**
34	**Wheel Tracking**
35	Prepare Materials
36	Prepare Wheel Tracking Samples
37	Samples Testing (Wheel Tracking Testing Run)
38	Analysis of Wheel Tracking Data
39	**Beam**
40	Prepare Materials
41	Prepare Beam Samples
42	Cutting the Beam Samples
43	Samples Testing (Beam Fatigue Testing)
44	Analysis of Beam Fatigue Data
45	**Poster Presentation**
46	**Desertation Submission**
47	**Oral Presentation 2**
48	**Final Desertation Submission**



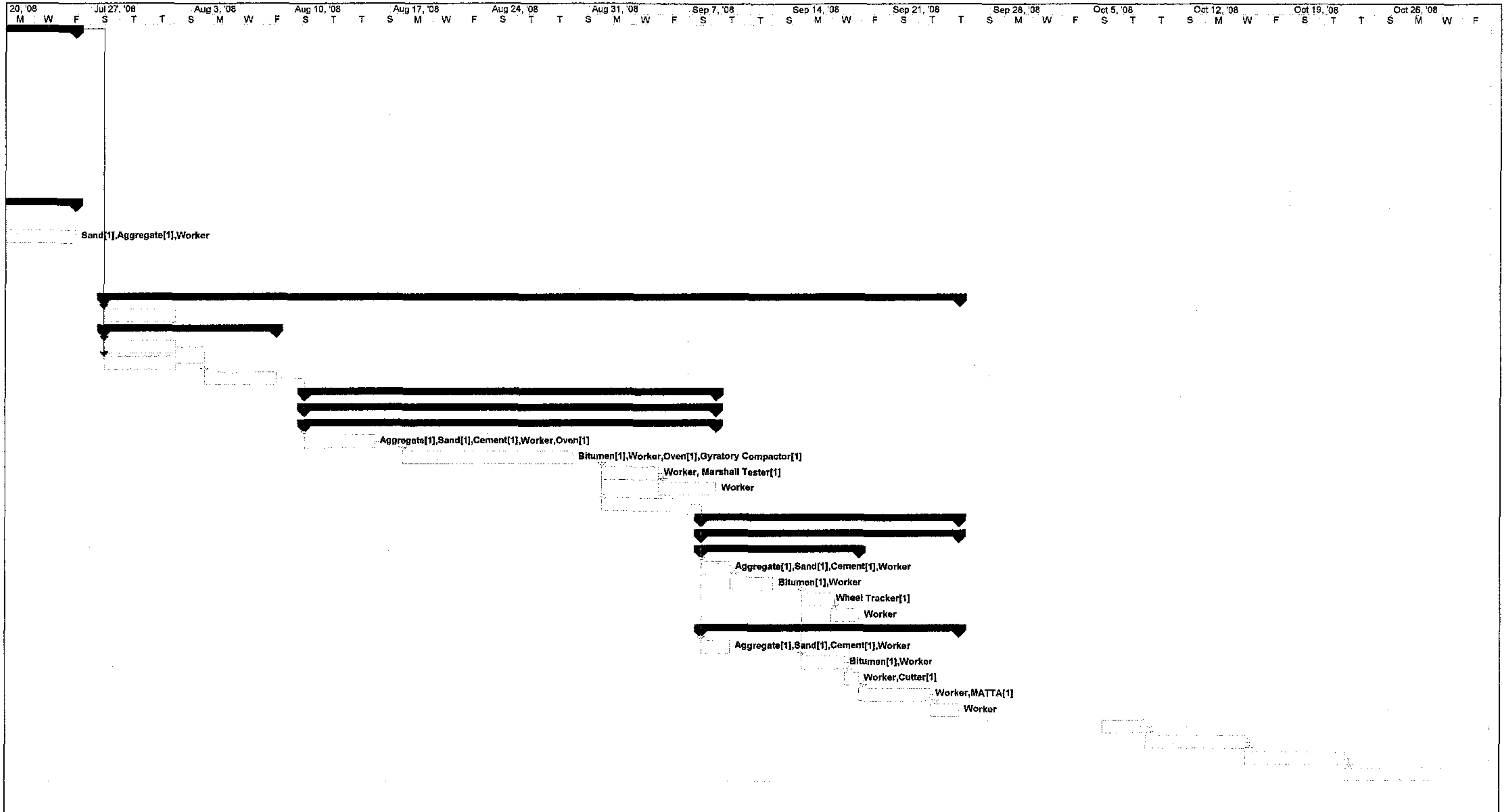
Project: Project3
Date: Tue 11/25/08

Task	Progress	Summary	External Tasks	Deadline
Split	Milestone	Project Summary	External Milestone	

'08	Apr 13, '08	Apr 20, '08	Apr 27, '08	May 4, '08	May 11, '08	May 18, '08	May 25, '08	Jun 1, '08	Jun 8, '08	Jun 15, '08	Jun 22, '08	Jun 29, '08	Jul 6, '08	Jul 13, '08	Ju
T T	S M W F	S T T	S M W F	S T T	S M W	F S T T	S M W F	S T T	S M W F	S T T	S M W F	S T T	S M W F	S T T	S

Aggregate[1],Sand[1],Worker,Sieve Shaker[1]

Project: Project3 Date: Tue 11/25/08	Task		Progress		Summary		External Tasks		Deadline
	Split		Milestone	◆	Project Summary		External Milestone		



Project: Project3
Date: Tue 11/25/08

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone