300984 Pavement Materials and Design

Asphalt Mix Design Practical

Student Name:

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1. Asphalt Mix Design Practical Overview

1.1 Objectives

In this practical, students will prepare and undertake Level 1 tests to evaluate the volumetric properties and determine the design bitumen content of a wearing course asphalt mix design for medium and heavy traffic categories.

1.2 Overview of practical

The class is divided into 4 groups. There are also four parts in this practical, each of approximately 30 mins duration. Each group will complete all 4 parts of the practical on a rotational basis.

(a) In Part A, students will prepare the aggregate materials for 3 asphalt specimens corresponding to bitumen content of 4%, 5% and 6% respectively.

(b) In Part B, the asphalt materials (aggregates and bitumen) will be compacted using the gyratory compactor to produce the 3 asphalt specimens of 4%, 5% and 6% bitumen content

(c) In Part C, students will determine the maximum density of the asphalt mixtures corresponding to 4%, 5% and 6% bitumen content based on AS/NZS 2891.7.3 (2014)

(d) Finally in Part D, the bulk density of the compacted asphalt specimens corresponding to 4%, 5% and 6% bitumen content will be determined using a presaturation procedure based on AS/NZS 2891.9.2 (2014).

After completion of the testing, the volumetric properties of the asphalt specimens (see Figure 1.1) will be evaluated for 4%, 5% and 6% bitumen content and the results used to determine the design bitumen content for the asphalt mix design based on the Level 1 tests.

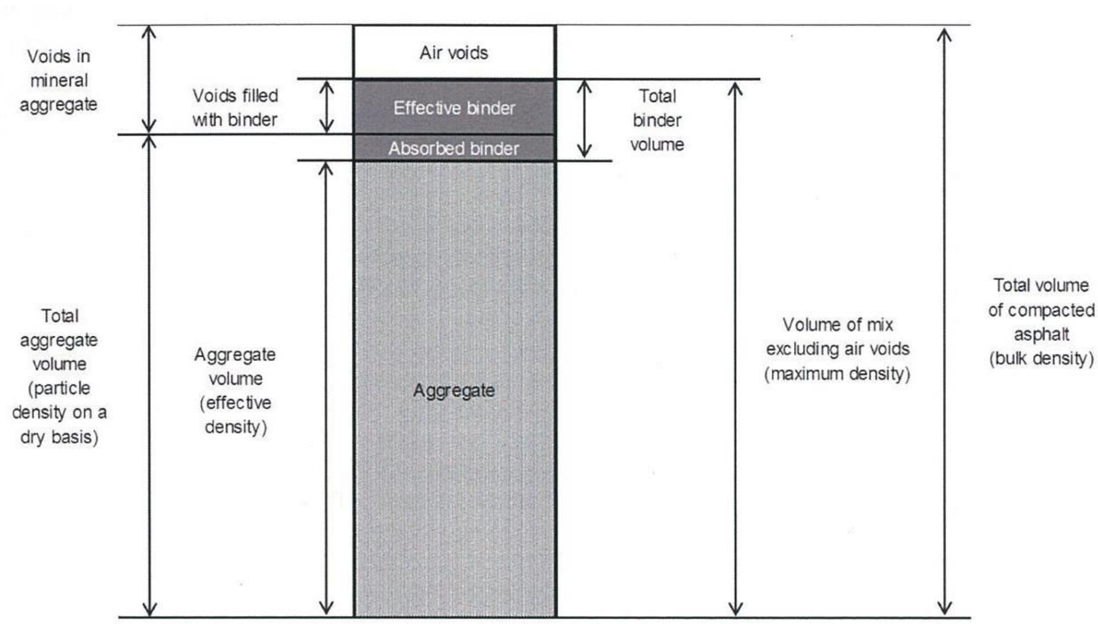


Figure 1.1: Volumetric Constituents of the Asphalt Mixture (AS 2150)

2. Methods and Materials

Part A: Preparation of Aggregates for Asphalt Mix Design Specimens

2.A.1. Introduction

The basic components of asphalt mixture are generally coarse aggregate, fine aggregate, filler and bitumen. The performance of an asphalt mixture is considerably influenced by the proportions of the asphalt components and the properties of the asphalt constituents. The proportion of asphalt components affects different properties of final asphalt mixture, as illustrated in Figure 1.1 Therefore, it is essential to design an asphalt mixture with a right mix of all asphalt components.

In this test, 3 batches of aggregates will be prepared for the 3 different bitumen contents (4%, 5% and 6%) based on a selected grading target for the aggregates.

2.A.2. Procedure

Record results of this test in **Datasheet No. A. 1** to **A.3** (attached).

1) Calculate the required mass of aggregate for each fraction and the grading percentages based on the grading target and target bitumen content (4%, 5% or 65%) for each sample of total mass 1200 g.
2) Complete **Datasheet No. A.1** for the 3 samples corresponding to bitumen content of 4%, 5%, and 6%.
3) Plot the grading envelopes and grading percentages for the 3 batches in **Datasheet No. A.2** (semi-logarithmic plot) to confirm the position of grading curve relative to gradation limits based on AS 2150 (Note: the 3 grading curves should lie within the grading envelopes).
4) Weigh the required mass of each fraction of the aggregates from the results in **Datasheet No. A.1.**
5) Blend the aggregates by mixing the different fractions obtained in (4) to prepare 3 batches of aggregates corresponding to bitumen content 4%, 5% and 6%
6) Complete **Datasheet No. A.3.** to give the specifications for coarse aggregate (> 4.75 mm), fine aggregate (< 4.75 mm and > 75μm), filler (< 75μm) and bitumen components of the 3 batches.

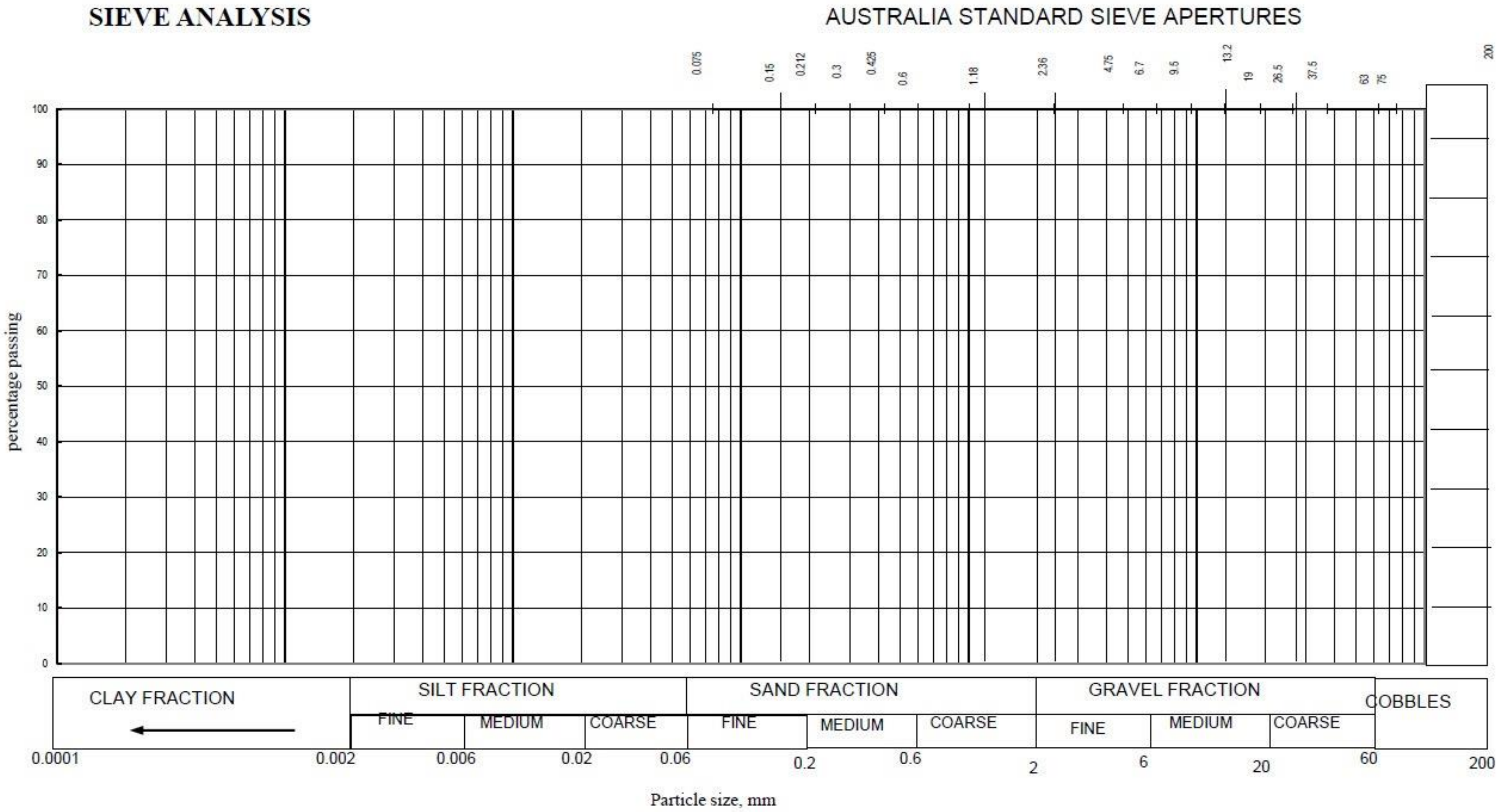
2.A.2. Completion of Tasks in Part A

1) Complete **Datasheet No. A.1 and A.3**
2) Plot the gradation limit and aggregate gradations curves in Datasheet No. A.2 to show that the grading curves lie within the grading envelopes.
3) Blend the aggregates to prepare the three aggregate batches (for 4%, 5% and 6% bitumen content).
4) You MUST complete Tasks 1-3 and present them to the demonstrator before leaving Part A.

DATASHEET NO.A.1: Specification and Grading for Aggregate Selection

Sieve Fractions	Retained Based on Grading Target , % (1)	Sample 1 [4% Bitumen Content]			Sample 2 [5% Bitumen Content]			Sample 3 [6% Bitumen Content]			Grading Envelopes, %	
		Mass Retained (g) 1200 × 0.96 × (1)	Mass passing (g)	Grading# (%)	Mass Retained (g) 1200 × 0.950 × (1)	Mass passing (g)	Grading# (%)	Mass Retained (g) 1200 × 0.94 × (1)	Mass passing (g)	Grading# (%)	Min	Max
19	**0**										100	100
13.2	**5**										90	100
9.5	**17**										72	83
6.7	**15**										54	71
4.75	**11**										43	61
2.36	**15**										28	45
1.18	**10**										19	35
0.600	**7**										13	27
0.300	**5**										9	20
0.150	**5**										6	13
0.075	**5**										4	7
Pan	**5**											

SIEVE ANALYSIS



DATASHEET NO.A. 3: Specification for Mix Proportions

Asphalt Components	Percent of Total Mix, %			Proportion of Total Mix, g		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Coarse Aggregate (P_c)						
Fine Aggregate (P_f)						
Filler (P_{fill})						
Bitumen (B)						
Total						

Part B: Compaction of Asphalt Test Specimens Using Gyratory Compactor set for Medium and Heavy Traffic Category

2.B.1. Introduction

An important aim of sample preparation procedures is to ensure that specimens prepared in the laboratory have properties as close as possible to asphalt placed in the road. Sample preparation based on gyratory compaction more closely produce mix characteristics that match those found in the compacted pavement, as this method of compaction is developed to simulate the increasing load and tire pressures of vehicles operating on pavements.

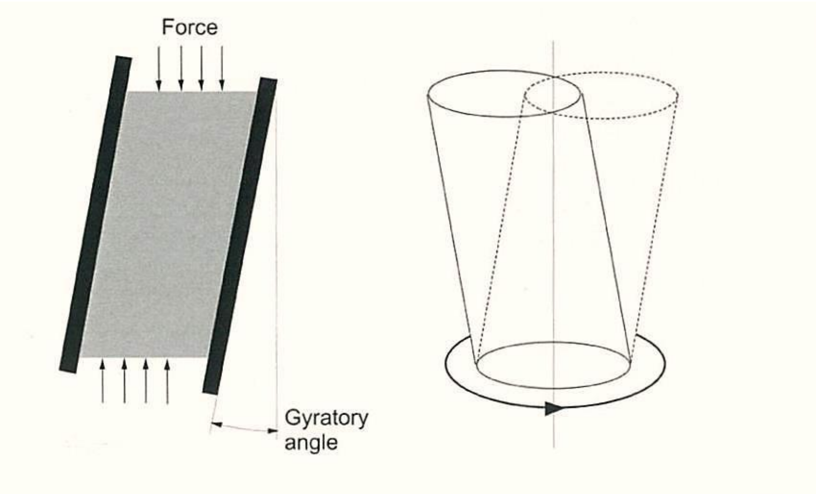


Figure B.1: Principle of Gyratory Compaction

The principle of gyratory compaction is illustrated in Figure B.1. As shown in this figure, during compaction, a vertical compressive pressure is applied to the asphalt sample which is confined in the cylindrical mould. The mould is rotated about its vertical axis through a predetermined angle of gyration. The angle of gyration should remain constant throughout the compaction process.

Depending on the ultimate testing of the sample, compaction can be terminated after a set number of cycles or at a set height representing a predetermined volume and density of asphalt. In this experiment the sample will be prepared following a specified number of gyrations. The number of gyrations depends on the design traffic loading for the specimen. In accordance with AS/NZS 2891.2.2, the specimen and testing equipment for gyratory compaction should meet certain requirements. For asphalt mixes with nominal size of 14 mm and **medium and heavy traffic categories**, these requirements are presented in **Table B.1**.

Table B.1: Specimen and Testing Equipment Requirements (Medium/Heavy Traffic Category)

No.	Specimen and equipment Details	Value
1	Diameter of specimen (mm)	100 ± 2
2	Nominal height of specimen (mm)	65
3	Gyratory angle (°)	2 ± 0.1
4	Vertical loading stress (kPa)	240 ± 10
5	Number of gyration	80

2.B.3. Procedure

Record results of this test in **Datasheet No. B.1** (attached).

To save time 3 batches of laboratory asphalt mixtures containing different bitumen content have been pre-prepared through batching the aggregates (as performed in Part A), mixing in the proper amount of binder, and conditioning the prepared mixture of approximately 1200 ± 25 g to provide enough material for a finished specimen of diameter 100 ± 2 mm and height of 65 ± 5 mm.

2.B.3.1. Material Preparation

Laboratory preconditioned mix shall be prepared as follows:

1) Preheat the compaction moulds, and baseplate in an oven at 150 °C for 30–60 minutes to prevent the asphalt mix from sticking to the moulds during the compaction process.
2) Heat the 3 batches of asphalt mixtures in an oven for 60 minutes at 150°C to 160°C.

2.B.3.2. Test Procedure

1) When the asphalt is at the adequate temperature for required time, remove the heated mould and baseplate from the oven and place a circular paper disc in the bottom of the mould.
2) Place the test portion in a compaction mould and spade the asphalt with a heated spoon or spatula 15 times around the perimeter and 10 times over the interior.
3) Place the mould in the oven for sufficient time for the asphalt to reach the specified compaction temperature of 150°C. If it didn't reach the temperature after 60min, discard it.
4) Check the settings of the compactor. Set specimen diameter (100 mm), the required number of revolutions (80 cycles) or specified specimen height (65 mm), the gyratory angle (2°) and the vertical loading stress(240kPa), as presented in Table 1, on the gyratory compactor.
5) Remove the mould from oven. Place a thermometer in the mould and verify that the temperature in the mould is within the tolerance for compaction temperature, as presented in Table B.1. Record the temperature.
6) Place a circular paper disc, and then the upper wearing disc on the top of the mould.

7) Place the filled mould and assembly into the gyratory compactor and centre of the loading ram.
8) Immediately compact the specimen in the gyratory compactor until the nominal height of specimen is 65mm.
9) Record the height of the specimen at every 15 cycles in Datasheet No.1.
10) Remove the specimen from the mould using the specimen extractor. Care should be taken to ensure that the specimen has cooled sufficiently to ensure that it does not deform when removed from the mould. For this purpose, a cooling time of 5 to 10 minutes may be necessary.
11) Allow the specimen to cool.
12) Soon after the compacted bituminous mix specimens have cooled to room temperature, take the sample out of the mould using the sample extractor and measure the weight, average height around the circumference and diameter of the specimen.
13) Remove the paper disks from the top and bottom of the specimen.
14) Repeat steps 1 to 13 for all 3 asphalt specimens, and complete **Datasheet No. B.1**.
15) Based on the test results for the 3 samples, complete **Datasheet No. B.1**.

2.B.4. Calculations

The following parameters shall be calculated:

1) The density of the sample from the following equation:

$$\rho = m/(\pi r^2/4)h$$

where

m= mass of sample, in grams

r = sample diameter, in m

h = sample height, in m

2.B.5 Completion of Tasks in Part B

1) Complete the results of testing in **Datasheet No. B.1**.
2) Using the results obtained from height measurement, estimate the density of sample and complete **Datasheet No. B.1**.
3) You **MUST** complete Tasks 1-2 and present them to the demonstrator before leaving Part B.

DATASHEET NO. B.1: Density of Asphalt Mixture

Cycle	Sample 1 (4% Bitumen Content)		Sample 2 (5% Bitumen Content)		Sample 3 (6% Bitumen Content)	
	Sample Height	Sample Density	Sample Height	Sample Density	Sample Height	Sample Density
1						
20						
40						
60						
80						
Sample Mass						
Sample Temperature						

Part C: Determination of Maximum Density of Asphalt

2.C.1. Introduction

Density is one of the most important parameters in construction of asphalt mixtures. A mixture that is properly designed and compacted will contain enough air voids to prevent rutting due to plastic flow but low enough air voids to prevent permeability of air and water. The theoretical maximum density of an asphalt mixture is the density excluding air voids. Thus, theoretically, if all the air voids were eliminated from an HMA sample, the combined density of the remaining aggregate and asphalt binder would be the theoretical maximum density. The maximum density is a critical HMA characteristic because it is used to calculate percent air voids in compacted asphalt.

2.C.2. Procedure

Record results of this test in **Datasheet No. C. 1** (attached).

2.C.2.1. Sample Preparation

1) Weigh 3 test portions of approximately 750 gm of asphalt provided with bitumen content corresponding to 4%, 5% and 6% respectively.
2) Loosen the material by hand, whilst the test portion is warm to a condition where it can be separated into the smallest particles practicable without causing rupture of the binder coating.

2.C.2.3. Determination of the Maximum Density of Asphalt

The procedure shall be carried out for each test portion corresponding to bitumen content 4%, 5% and 6% as follows

1) Weigh a calibrated dry flask and record the mass (m1).
2) Place the test portion of asphalt in the flask, weigh and record the mass (m4).
3) Add sufficient methylated spirits to cover the test portion by about 25 mm. Carefully heat the flask on the hotplate until the methylated spirits is boiling freely but is not distilling out of the flask.
4) Carefully agitate the flask and contents until all occluded air in the sample has been displaced.
5) Remove the flask from the hotplate and allow it to cool in air for a few minutes and then in water.
6) Fill the flask with methylated spirits and immerse it up to the neck in the water bath for 10 mins (reduced from 1h due to time factor) or until a constant temperature of 25°C is obtained. If necessary, weigh down the flask to keep it firmly immersed.
7) Remove the flask to a level bench, carefully seat the capillary tube device on the flask and remove the excess of the methylated spirits by means of the suction pump.

8) Remove the capillary tube device. Then immediately and carefully dry the outside of the flask with paper towels.
9) Weigh the flask and contents and record the mass (m5).

NOTE: During the boiling process there is a tendency for some samples to coagulate, particularly if the bitumen content is high. To extract such samples from the flask at the end of the tests, the bulk of the methylated spirits should be poured out and the residue heated sufficiently to facilitate its removal.

10) Calculate the relevant parameters based on the given formula in section C.3, and complete **Datasheet No. C. 1**.

2.C.3. Calculations

The maximum density ($\boldsymbol{\rho_m}$), in tonnes per cubic metre, for each test portion to the nearest 0.001 t/m^3 from the following equation:

$$\rho_{max} = \frac{(m_4 - m_1)\rho_m}{(m_3 - m_1) - (m_5 - m_4)}$$

where

m_4 = mass of flask and test portion of asphalt, in grams

m_1 = mass of flask, in grams

ρ_m= density of methylated spirits at 25°C, (take as 0.800 t/m^3)

m_3 = mass of flask and methylated spirits, in grams = $\rho_m V + m_1$

V = volume of the flask, in milliliters (take as 1000 mL)

m_5 = mass of flask, test portion and methylated spirits, in grams

C.4. Completion of Tasks in Part C

1) Complete the results of testing in **Datasheet No. C. 1**.
2) Using the results obtained from maximum density test on three samples, estimate the maximum densities of representative test portions of the asphalt (4%, 5% and 6% bitumen content) to the nearest 0.001 t/m^3 and complete **Datasheet No. C.1**.
3) You **MUST** complete Tasks 1-2 and present them to the demonstrator before leaving Part C.

DATASHEET NO.C.1: Maximum Density of Asphalt Mixture

Items	Sample 1 (4% bitumen content)	Sample 2 (5% bitumen content)	Sample 3 (6% bitumen content)
Mass of Flask, m1 (gm)			
Mass of Flask and Methylated Spirit at 25°C, m3 (gm)			
Volume of the Flask, V (mL)	1000	1000	1000
Mass of Flask and Test Portion, m4 (gm)			
Mass of Flask, Test Portion and Methylated Spirit, m5 (gm)			
Density of Methylated Spirit at 25°C, ρ_m (t/m^3)	0.800	0.800	0.800
Maximum Density of each Asphalt Sample, ρ_{max} (t/m^3)			

Part D: Bulk Density Test

2.D.1. Introduction

The bulk density test is used to determine the density of a compacted asphalt mixture sample by determining the ratio of its mass to the mass of an equal volume of water.
The bulk density test measures an asphalt mixture sample's weight under three different conditions:

- Dry (no water in sample).
- Saturated surface dry (SSD) in which water fills some of the asphalt mixture air voids.
- Submerged in water (underwater).

These three masses and their relationships are needed to calculate a sample's apparent density, bulk density and bulk SSD specific gravity as well as to determine mass-volume relationships, various volume-related quantities such as air voids and voids in mineral aggregate (VMA).

2.D.2. Procedure

Record results of this test in Datasheet No. D.1 (attached).

To save time 3 cylindrical samples of compacted asphalt mixtures containing different bitumen content (4%, 5% and 6%) (from Part B) have been pre-prepared and dried using vacuum desiccator based on the procedure described below.

The procedure shall be as follows:

1) Weigh the sample and record its dry mass (m1).
2) Immerse the sample in the water container for at least 5 min.
3) Position the water container directly beneath the balance and attached suspension device, and zero the balance.
4) Transfer the sample to the suspension device so that the sample remains completely immersed. Remove any air bubbles adhering to the sample and weigh. Record the mass (m2).
5) Remove the sample from the suspension device and surface-dry the specimen by blotting quickly with a damp towel.

NOTE: In blotting the surface, a damp cloth towel (not paper) should be used. The towel should be soaked and wrung between samples. The aim of blotting is to remove excess water beaded on the surface and is not meant to draw water from the void spaces of the sample. The desired action is to quickly and lightly blot the excess water from the sample, and determine the saturated surface dry mass as quickly as possible.

6) Weigh the wet sample and record the mass (m3).
7) Record the temperature of the water in the water container to the nearest 1°C.

Table D.1: Variation of Water Density with Temperature (AS/NZS 2891.9.2, 2014)

Temperature, °C	Density, t/m^3	Temperature, °C	Density, t/m^3
0	1.000	21	0.998
1	1.000	22	0.998
2	1.000	23	0.998
3	1.000	24	0.997
4	1.000	25	0.997
5	1.000	26	0.997
6	1.000	27	0.997
7	1.000	28	0.996
8	1.000	29	0.996
9	1.000	30	0.996
10	1.000	31	0.995
11	1.000	32	0.995
12	1.000	33	0.995
13	0.999	34	0.994
14	0.999	35	0.994
15	0.999	36	0.994
16	0.999	37	0.993
17	0.999	38	0.993
18	0.999	39	0.993
19	0.998	40	0.992
20	0.998	—	—

D.3. Calculations

The following parameters shall be calculated:

1) The water absorption by volume, as a percentage, from the following equation:

$$WA = 100\ (m_3 - m_1)/(m_3 - m_2)$$

where,

WA= water absorption by volume of asphalt specimen, as a percentage

m_1= mass in air of the dry sample, in g

m_2 = mass in water of the saturated sample, in g

m_3 = mass in air of the saturated sample, in g

2)The bulk density of sample ($\boldsymbol{\rho_{bulk}}$), in t/m^3, from the following equation:

$$\rho_{bulk} = \frac{m_1 \rho_w}{m_3 - m_2}$$

D.4. Completion on Tasks in Part D

1) Complete the results of testing in **Datasheet No. D. 1**.
2) Using the results obtained from bulk density test, estimate the bulk density of the 3 asphalt samples to the nearest 0.001 t/m^3 and Water absorption by volume to the nearest 0.1%.
3) Complete **Datasheet No. D. 1**.
4) You **MUST** complete Tasks 1-3 and present them to the demonstrator before leaving Part D.

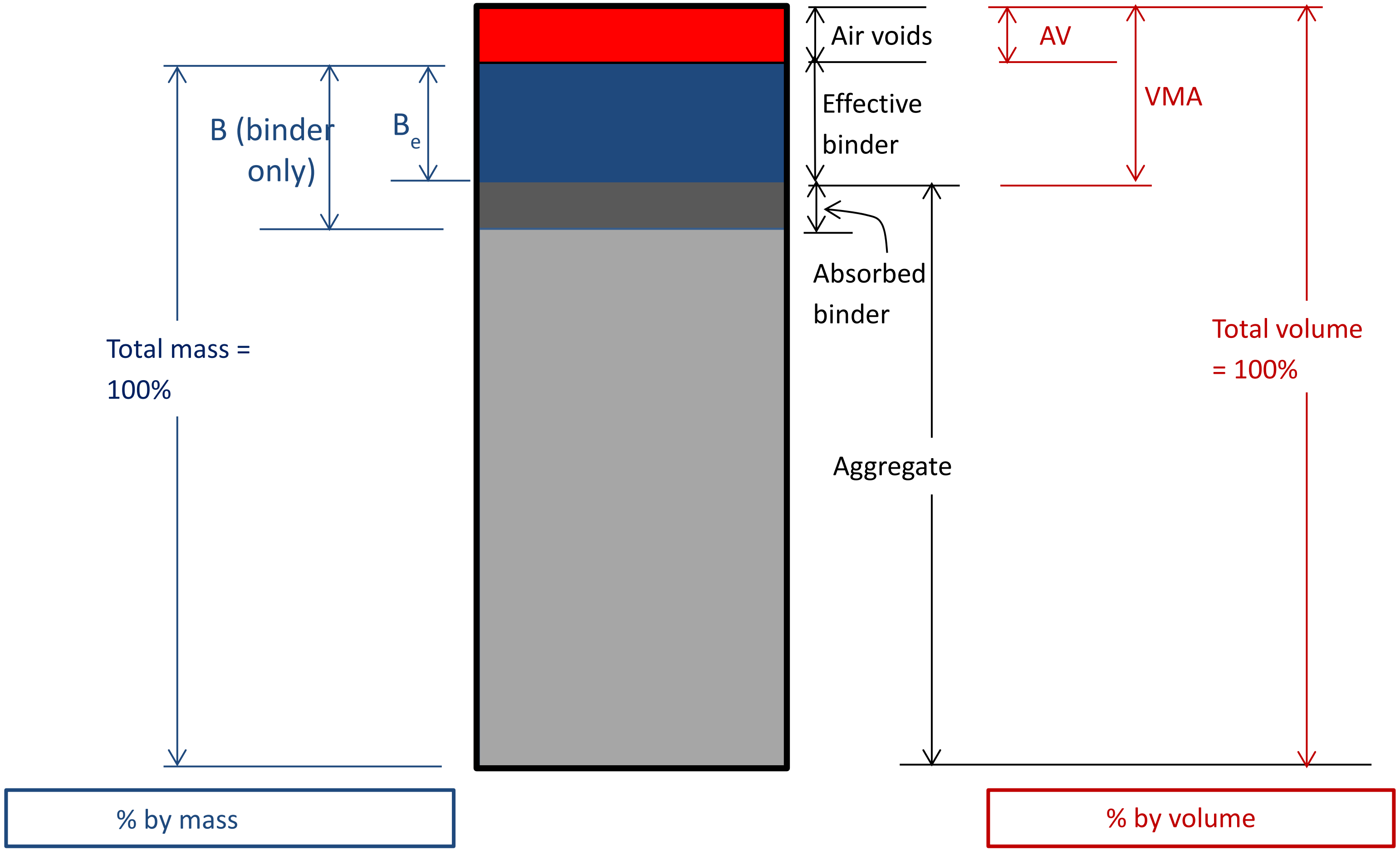
DATASHEET NO.D.1: Bulk Density of Asphalt Mixture

Items	Sample 1 (4% bitumen content)	Sample 2 (5% bitumen content)	Sample 3 (6% bitumen content)
Mass in air of dry sample, m1 (gm)			
Mass in Water of the saturated sample, m2 (gm)			
Mass in air of the saturated sample, m3 (gm)			
Water Absorption by Volume of Asphalt Specimen, WA (%)			
Temperature of Water, T (°C)			
Density of Water at the Test Temperature, ρ_w (t/m^3)			
Bulk Density of Sample, ρ_{bulk} (t/m^3)			

3. Reporting of Results

A type-written report is to be submitted within one week of the lab class. The report should be **concise** and include addressing the following:

a) Objectives of the practical (50 words).
b) A brief outline of the experimental procedures (in bullet form, 300 words).
c) Completed Datasheets (you need to scan the Datasheet and place it in the report).
d) The maximum densities of the asphalt mixture corresponding to 4%, 5% and 6% bitumen content
e) The bulk densities of the asphalt mix specimens corresponding to 4%, 5% and 6% bitumen content
f) Determine the air voids of the asphalt mix specimens corresponding to 4%, 5% and 6% bitumen content
g) Determine the Voids in Mineral Aggregates (VMA) of the asphalt mix specimens corresponding to 4%, 5% and 6% bitumen content
h) Tabulate the volumetric properties: air voids, VMA and bulk density against the bitumen content (Use schematic relationships in Figure 3.1 and the equations in Section 4 to obtain the volumetric properties).
i) Plot the volumetric properties: air voids, VMA and bulk density against the bitumen content
j) What is the design bitumen content for this asphalt design mix based on design air voids of 4%?
k) Has the asphalt design mix for the wearing course met the minimum VMA threshold of 16?
l) Does the asphalt design mix (with recommended design bitumen content) meet the asphalt mix requirements for the wearing course of medium/heavy traffic category based on Level 1 tests?



Note: Ignore weight/mass of air voids

Figure 3.1: Schematic relationships between volumetric properties

4. Equations of volumetric properties

Air Void content $AV = \frac{(\rho_{max} - \rho_{bulk})}{\rho_{max}}$

Voids in Mineral Aggregate $VMA = 100 - \frac{\rho_{bulk}}{\rho_a}(100 - B)$

Or $VMA = AV + \left(\frac{\rho_{bulk} B_e}{\rho_b}\right)$

Voids Filled with Binder $VFB = \frac{100 B_e}{VMA} \times \frac{\rho_{bulk}}{\rho_b}$

Or $VFB = \frac{VMA - AV}{VMA} \times 100$

where,

ρ_{max}= maximum density of asphalt (t/m^3) as per AS2891.7.1, AS2891.7.2 or AS2891.7.3

ρ_{bulk}= bulk density of asphalt (t/m^3) as per AS2891.9.1, AS2891.9.2 or AS2891.9.3

B= proportion by mass of binder in total mix, as a percentage from DATASHEET NO.A.3

ρ_b= density of binder (t/m^3), assumed as 1.037 t/m^3

ρ_a= bulk density of combined mineral aggregates (t/m3) as per AS2891.8 can be obtained from the following equation:

$$\rho_a = \frac{100}{\frac{P_c}{\rho_c} + \frac{P_f}{\rho_f} + \frac{P_{fill}}{\rho_{fill}}}$$

In the above equation,

P_c= proportion of combined coarse aggregate, as a percentage from DATASHEET NO.A.3

P_f= proportion of combined fine aggregate, as a percentage from DATASHEET NO.A.3

P_{fill}= proportion of filler, as a percentage from DATASHEET NO.A.3

ρ_c= particle density of the combined coarse aggregate, assumed as 2.64 t/m^3

P_f= particle density of the combined fine aggregate, assumed as 2.88 t/m^3

P_{fill}= apparent particle density of the filler, (t/m3), assumed as 1.51 t/m^3

B_e= proportion by mass of the effective binder, as percentage which can be obtained from the following equation based on AS2891.8:

$$B_e = B - b$$

in which,

b= proportion by mass of the binder absorbed, as percentage which can be calculated from the following equation based on AS2891.8:

$$b = B - \rho_b\left(\frac{100}{\rho_{max}} - \frac{(100 - B)}{\rho_a}\right)$$

5. Performance Criteria and Assessment Standards

The following criteria will be used in assessing the submitted lab report:

- Active participation and satisfactory completion of the required lab tasks during the lab class. It will include punctuality, dress code and compliance with OH&S requirements.

[20 %]

- Adequate elaboration of objectives of the experiment, and accurate but concise description of experimental procedures (in bullet or dot-point form).

[10%]

- Clear and concise reporting and presentation of experimental results (including clarity, neatness and correctness). Keep in mind that this is to be a type-written report although the recorded data sheets can be hand-written, scanned and placed with the report. I expect to see the use MS Excel spreadsheet and the equation editor in MS Word in preparing the report, if this is required.

[30%]

- Addressing the objectives of the experiment adequately. If there were unexpected errors in the experimental results, clear and rational explanations should be provided.

[30%]

- Reporting the conclusions of the experiment clearly and accurately.

[10%]