

Hashemite University

College of Engineering Civil Engineering Department

Highway Engineering

Highway Engineering Laboratory Manual

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Hashemite University



College of Engineering Civil Engineering Department

CE401334 Highway Engineering Laboratory

REPORT STRUCTURE

The report should be scientifically prepared, neat, and well organized. It should include the following main parts:

- *Cover Page:* Shows the University name, course name, lab number and title, student name and student I.D. number.
- *Abstract:* Very short statement about the experiment, its final results and your conclusions.
- *Introduction:* General importance of the experiment and particular importance of the findings, location of the study if any and the specific statement of the studied problem.

Objectives: The precise statement of the purposes of the experiment.

Methodology: Describe the methodology of the study and the specific steps (procedure) of your work. Include illustrative maps, sketches, .. etc., if needed.

Data Collection and Analysis:

Present the collected data in an easily interpreted forms (tables, figures, ..) and carry out the needed calculations and analysis so that you are able to draw clear results.

Result: State your final results directly, clearly, and precisely.

Discussion and Conclusions:

Discuss your results and draw clear conclusions.

Recommendations:

List any recommendations about the practical use of the results and how can they be applied.

References: Written in a formal way and in an alphabetical order.



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Following are the weights on the parts of the report:

Part of the Report	Weight (%)
Cover page	5
Abstract	5
Introduction	10
Objectives	10
Methodology	10
Data Collection and Analysis	15
Results	10
Discussion and Conclusions	15
Recommendations	15
References	5
TOTAL	100

Notes: 1. Absolutely no late reports are accepted.

- 2. Bonus is expected for a well prepared report and for any extra put effort.
- 3. Failure to attend the lab meeting implies missing the chance to submit the report required for this session.

Experiment No. 1

California Bearing Ratio Test (CBR)

Objective

To determine the California Bearing Ratio (CBR) of pavement subgrade, subbase, and base/course materials from laboratory compacted specimens. It is a penetration test wherein a standardized piston, having an end diameter of 49.53mm (1.95in), is caused to penetrate the soil at a standard rate of 1.27mm/min (0.05in/min). The CBR value is calculated as the ratio of the unit weight at 2.54mm (0.1in) penetration to a standard unit weight.

Significance of the Test

Although the CBR test is an empirical test, but it's widely used in evaluating the strength of the compacted soil, and is used in pavement design for both roads and airfields. Some design methods use the CBR values directly. Others convert the CBR value to either the modulus of subgrade reaction k_s , or to the resilient modulus M_R using empirical relationships. For example the Asphalt Institute design procedure uses the following formulas to convert CBR to MR:

$$M_R$$
 (MPa) = 10.342 CBR
(1)
 M_R (lb/in²) = 1500 CBR (2)

General Discussion

The basic testing procedure employed in the determination of the CBR was developed by the California Division of Highways before World War II and was used by that agency in the design of flexible pavements. The basic procedures of this test were adopted by the Corps of Engineers of the U.S. Army during the early stages of the war and served as a basis for the development of design curves that were used for determining the required thickness of flexible pavements for airport runways and taxiways. Certain modifications were made in the test procedure, and it became a standardized test procedure (ASTM D 1883).

The selected sample of subgrade soil is compacted in a mold that is 152 mm (6 in) in diameter and 152 to 178 mm (6 to 7 in) high. The moisture content, density, and compactive effort used in molding the sample are selected to correspond to expected field conditions. After the sample has been compacted, a surcharge weight equivalent to the estimated weight of pavement, base, and subbase layers is placed on the sample, and the entire assembly is immersed-in water for 4 days.

At the completion of this soaking period the sample is removed from the water and allowed to drain for a period of 15 min. The sample, with the same surcharge imposed on it, is immediately subjected to penetration by a piston 49.53 mm (1.95 in) in diameter moving at a speed of 1.27 mm/min (0.05 in/min). The total loads corresponding to penetrations of 2.5, 5.0, 7.5, 10.0, and 12.5 mm (0.1, 0.2, 0.3, 0.4, and 0.5 in) are recorded.

A load-penetration curve is then drawn, any necessary corrections made, and the corrected value of the unit load corresponding to 2.5 mm (0.1 in) penetration determined. This value is then compared with a value of 6.9 MPa (1000 lb/in²) required to produce the same penetration in standard crushed rock. The CBR is then calculated by the expressions

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$$CBR(\%) = \frac{\text{unit load at 2.5 mm penetratio n (MPa)}}{6.9 \text{ MPa}} \times 100$$
(3)

$$CBR(\%) = \frac{\text{unit load at 5.0 mm penetratio n (MPa)}}{10.3 \text{MPa}} \times 100$$
(4)

The CBR value is usually based on the load ratio for a penetration of 2.5 mm (equation 3). If however, the CBR value at a penetration of 5.0 mm (equation 4) is higher than the obtained value from equation 3, the test should be repeated. If the repeated test also yields a larger value, then the CBR at 5.0 mm penetration should be used.

It should be noted that this penetration test may also be performed in the field or on "undisturbed" samples.

ASTM D1883 recommends preparing three samples at the optimum moisture content at three compaction efforts to have a unit weight range that will include the field unit weight.

Apparatus and Equipment:

CBR test requires the following equipment:

- 152 mm diam. x 178 mm height (6*7 in) CBR compaction mold with collar and spacer disk (151-mm diam. x 61.4 mm height) (or 51mm height as available).
- Compaction rammer, either 24.4 N (5.5 lb) dropped from 305 mm (12 in) height or 44.5 N (10.0 lb) dropped from 457 mm (18 in) height as designated by instructor. (Figure 4.1)
- Expansion-measuring apparatus consisting of perforated plate with adjustable stem, tripod, and dial gauge reading to 0.01 mm.
- Surcharge weights as required.
- Compression machine equipped with CBR penetration piston (49.53 mm diam. with cross- sectional area of 19.35 cm²) and capable of a penetration rate of 1.3 mm/min (0.05 in/min) (Figure 4.1)
- 150mm diameter course filter paper

Sample Preparation:

- 1- Prepare 36 kg (enough for three samples) of an air dried soil sample that passes the 19mm (3/4") sieve. If the sample contains material larger than 19 mm it has to be replaced by an equivalent quantity passing sieve # 19 mm and retained on sieve number 4.
- 2- Oven dry about 200 g of the soil and determine the natural moisture content.





Figure 4.1: Required equipment for the CBR test

- 3- Add the required amount of water so that the moisture content of the sample is within $\pm 0.5\%$ of the optimum moisture content.
- 4- Weight the empty mold and record its weight in the data sheet.
- 5- Assemble the 150 mm mold, extension collar and perforated base plate by clamping the mold fitted with the extension collar to the base plate.
- 6- Insert the spacer disc over the base plate and position a 150mm diameter course filter paper on top of the spacer disc.
- 7- Compact the sample in 3 or 5 (as specified) equal layers by 10 blows per layer using the specified hammer and height of drop.
- 8- Remove the extension ring and strike off excess soil with a straight edge. Left the mold and remove the base plate and the spacer disk.
- 9- Weight the filled mold, and record it in the data sheet. Calculate the compacted soil density by dividing the soil weight by the mold volume (2305 cm³).

- 10- Place filter paper on the base plate, then invert the mold and place it over the base plate. Place another filter paper on top of the soil in the mold.
- 11- Repeat steps 4 to 11 above but using 25 tamps and 55 tamps.

Test Procedure:

Soaking the Sample and Measurement of Swell

- 1- Place the perforated plate with the adjustable stem attached to it on the filter paper on top of the compacted soil sample.
- 2- Place a surcharge weight on the perforated plate to account for the weight of all the layers that will be placed on top of the subgrade. This surcharge weight should not be less than 4.5 Kg.
- 3- Place the mold in a water bath so that the water level is within 12.5 mm of the top of the mold. Water should be allowed to access the soil from the bottom of the mold. In addition, the water levels inside and outside the mold should be equal.
- 4- Place the tripod with the dial gauge on the mold and take the initial dial readings.
- 5- Allow the specimen to soak for 4 days and maintain the constant water level inside and outside the mold.
- 6- Periodically take the swell readings and record them in the data sheet. At the end of the soaking period, take a final dial reading and calculate the swell as a percentage of the height of the specimen (125 mm).

$$Swell(\%) = \frac{Amount of Swell}{Original Specimen height(125mm)} \times 100$$
(5)

- 7- Remove the expansion apparatus and surcharge weights and lift the mold out of the water bath. Allow the mold to drain for 15minutes.
- 8- Weigh the specimen ($W_{wet filled}$) and determine the soil density after soaking.

Application of Penetration Load

- 9- Place one 2.47Kg annular surcharge disc on the soil surface and place the mold in the loading frame.
- 10- Seat the penetration piston with a 4.54Kg (0.05kN) load and set the dial gauges for load and strain to zero.
- 11- Place further surcharge weights on the sample (if needed) until this surcharge weight equals the soaking surcharge weight.
- 12- Apply the load to the piston at a uniform rate of 1.25mm per minute of penetration. Note the load readings for every 0.25mm of penetration until 7.5mm of penetration.
- 13- On completion of the penetration release the load and remove the mold from the testing machine.
- 14- Remove the specimen from the mold and determine the moisture content for the entire depth of the sample.

Calculation

- 1- Plot the readings of load against the penetration readings and draw a smooth curve through the points.
- 2- The curve is normally concave downward, although the initial portion might concave upward due to surface irregularity. In this case, correction should be done by drawing a tangent to the curve at the point of greatest slope. The corrected curve will be used in all further calculations. Figure 4.2 shows examples of corrected CBR curves.
- 3- From the obtained curve make a computation of the load at the corrected penetration of 2.5mm and 5.0mm. The obtained values (in kg) are expressed as percentages of the standard loads of 3000lb and 4500 lb respectively.
- 4- Calculate CBR as follows:

$$CBR(\%) = \frac{\text{Load at 2.5mm penetratio n (kg)}}{1364 \text{ kg}} \times 100$$
(6)

$$CBR(\%) = \frac{\text{Load at 5.0mm penetratio n (kg)}}{2045 \text{ kg}} \times 100$$
(7)

- 5- Usually the value at 2.5mm is greater than that at 5.0mm penetration and the former is taken as the CBR value.
- 6- If $CBR_{2.5} < CBR_{5.0}$ repeat the test on another soil sample. In the case that the second test still gives $CBR_{2.5} < CBR_{5.0}$, then take the CBR value as the value corresponding to 5.0mm penetration.



Figure 4.2 Corrected CBR curves.

Report

- 1- Draw a curve of molded dry density versus corrected CBR values for the used soil. Figure 4.3 shows an example of the required curve.
- 2- Will equation 3 give different results than the results obtained from equation 6, why?
- 3- Do you think that one sample at each compaction effort is enough, why?



Figure 4.3 Dry density versus corrected CBR values.

References:

- ASTM D1557-91, (2000) "Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³))".
- ASTM D1883-99, (2000) "Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils".
- ASTM D698-91, (2000) "Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³))".

Wright, Paul H., (1996) "Highway Engineering," Sixth Edition, John Wiley, New York.



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California Bearing Ratio Worksheet #1

Operator:	Job Site:			
Date:	Soil Description:			
a) Optimum (or Target) Moisture	-			
Content:				
No. of Layers: Hammer Weigh	nt: Drop Height:			
Determination of Initial Moisture Conte	nt			
b) Container No.				
c) Weight of Can				
d) Weight of Can + Wet Soil				
e) Weight of Can + Dry Soil				
f) Weight of Wet Soil $(d - c)$				
g) Weight of Dry Soil $(e - c)$				
h) Moisture Content $(\frac{f-g}{100} \times 100)$				
h				
Preparation of CBR Samples				
# of Blows per Layer				
i) Total Weight of Used Soil				
j) Required Weight of Water to be Added				
$((a-h)^*(\frac{1}{1+(h/100)}))$				
1 (((, 100))				
k) Mold Number				
l) Empty Mold Weight (without base)				
m) Weight of Mold + Soil				
n) Weight of Soil $(m - l)$				
o) Bulk Density of Soil (n / 2305) (Mg/m ³)				
p) Molded Dry Density				
(100 * o / (100 + a))				
q) Weight of Mold + Soaked Soil				
r) Weight of Soaked Soil $(q - l)$				
s) Bulk Density of Soaked Soil (r / 2305) (1	Mg/m ³)			
Determination of Final Moisture Conten	t			
t) Container No.				
u) Weight of Can				
v) Weight of Can + Wet Soil				
w) Weight of Can + Dry Soil				
x) Weight of Wet Soil (v – u)				
y) Weight of Dry Soil (w – u)				
z) Moisture Content $(\frac{x-y}{y} \times 100)$				

aa) Dry Density of Sample after Soaking		
(100 * s / (100 + z))		



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California Bearing Ratio Worksheet # 2

Swelling Calculation

Operator:		Job Site	Job Site:				
Date:		Soil De	scription:				
Optimum (or Target) Moisture			-				
Content:	U /						
No. of Layers:		Hamme	r Weight:		Drop He	ight:	
Sample Number	r		-				
Number of Bloy	ws per						
Laver	~ F						
Molded Dry De	nsity						
~		Dial	% Strain=	Dial	% Strain=	Dial	% Strain=
Starting Time and Date	Elapsed Time	Reading (*)	$\frac{S}{H} \times 100$	Reading (*)	$\frac{S}{H} \times 100$	Reading (*)	$\frac{S}{H} \times 100$
	0 hr						
	1 hr						
	2 hr						
	4 hr						



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California Bearing Ratio Worksheet # 3

Load – Penetration Data Sheet

Operator:	Job Site:			
Date:	Soil Description:			
1) Optimum (or Target) Moisture				
Content:				
No. of Layers: Hammer Weigh	it:	Drop Hei	ght:	
Sample Number				
Number of Blows per Layer				
Molded Dry Density				
Penetration of Plunger (mm))	Load (kg)	Load (kg)	Load (kg)
0.25				
0.50				
0.75				
1.00				
1.25				
1.50				
1.75				
2.00				
2.25				
2.50				
2.75				
3.00				
3.25				
3.50				
3.75				
4.00				
4.25				
4.50				
4.75				
5.00				
5.25				
5.50				
5.75				
6.00				
6.25				
6.50				
6.75				
7.00				
7.25				
7.50				

Experiment No. 2

Penetration of Bituminous Materials

Definition

Penetration of a bituminous material is defined as the distance in tenths of millimeter that a standard needle vertically penetrates a sample of bitumen under specified conditions of load, time and temperature.

Significance of the Test

The penetration value is a measure of the consistency of the tested bituminous material. Lower values of penetration indicate harder materials. Therefore, the result can be considered as a property of the material and can be used to describe its softness.

Apparatus and Equipment

The required apparatus for the penetration test is shown in Figure 5.1. It consists of the following:

- 1. Penetrometer consisting of a needle holder which is connected to a scale capable of measurements to the nearest 0.1 mm.
- 2. Weights of 50, 100 and 200 gm.
- 3. Standard penetration needle.
- 4. Sample containers as follows:





	<200	Penetration
		<350
Diameter	55 mm	35 mm
Internal	55 mm	75 mm
Depth		

- 5. A standard water bath capable of maintaining temperature of 25 ± 1 °C.
- 6. Transfer dish of capacity > 350 ml.
- 7. Stop watch accurate to ± 0.1 second.
- 8. Thermometer.
- 9. Gloves.

Figure 5.1: Required

Sample Preparation:

- 1. Heat the sample with care until it is practically fluid. Note not to overheat the sample more than 60°C above the softening point.
- 2. Pour the sample into the container to a sufficient depth. It is a good practice to fill the container 2 to 5 mm below the tip.
- 3. Let the sample cool to room temperature. Cover the sample against dust. Prepare two samples (at least) for every condition of the test.
- 4. Transfer the samples using the transfer dish and place them in a water bath having a controlled temperature. The standard temperature is 25°C.
- 5. Keep the sample in the water bath for about two 1.5 to 2 hours before testing.

Test Conditions:

If the standard temperature could not be met, then special alterations should be made as follows:

Temperature (°C)	0	4	25	45
Load (gm)	200	200	100	50
Time (seconds)	60	60	5	5

Test Procedure:

- 1. Clean the needle and place it in its holder.
- 2. Place the correct weight in position above the needle.
- 3. Transfer the sample to be tested using the transfer dish and place it in position.
- 4. Lower the needle carefully until it touches the surface of the sample. You can watch the reflection of the needle at the surface of the sample. The needle should be at least 10 mm from the sides of the can.
- 5. Bring the pointer of the apparatus to zero position, or take the initial reading.

- 6. Release the needle holder quickly and simultaneously start the stopwatch.
- 7. Once the specified period of time is reached, record the reading of the distance the needle moved and report the value in tenths of millimeter.
- 8. Make at least three readings following steps 1 to 7. Make sure to satisfy the following:
 - A. Each reading should be at least 10 mm far from the previous one.
 - B. During cleaning of the needle, the sample must be kept in the water bath at the specified temperature.
 - C. If penetration is > 200 mm, the needles should be left in the sample until all the three readings have been completed.
- 9. Report the average of at least three readings as the penetration of the tested bituminous material.

Comments:

- 1. If the needle comes in touch with water during testing, discard the reading.
- 2. If water comes in contact with the surface of the sample, discard the whole sample and prepare a new one.

Report:

- 1. Obtain the penetration of the tested material.
- 2. Judge the acceptability of the test results based on the following:
 - a. For single operator, the coefficient of variation for penetrations above 60 should be less than 1.4%; and for penetrations below 50 the coefficient of variation should be less than 0.35%.
 - b. The results of two properly conducted tests by the same operator on the same material of any penetration using the same equipment should not differ from each other by more than 4% or 1 unit whichever is larger.
 - c. For multilaboratory precision, the coefficient of variation for penetrations above 60 should be less

than 3.8%; and for penetrations below 50 the coefficient of variation should be less than 1.4%.

- d. The results of two properly conducted tests on the same material of any penetration, in two different laboratories should not differ from each other by more than 11% or 4 units whichever is larger.
- 3. Based on the penetration value, find the grade of the bitumen and comment on the suitability of the tested bitumen for use in road mixes. Refer to the following table.

Penetration	Uses
40 - 50	Bituminous mixtures known as gap-graded (hot-
	rolled asphalts).
60 - 70	Bituminous mixtures known as gap-graded or
	continuously graded mixes (asphalt concreters).
80 - 100	Continuously graded mixtures or dense bitumen
	macadam base stabilization, and in hot climates
	for surface dressing maintenance with precoated
	clippings in areas where high surface stress
	occurs.
150 - 200	Continuously graded mixtures, bitumen
	macadam, and surface dressing.

- 4. Based on penetration, indicate the types of bitumen that are produced in Jordan, and describe their uses.
- 5. Is the tested bitumen more suitable for use in hot regions or cold regions?

References:

ASTM D5-97, (2000) "Standard Test Method for Penetration of Bituminous Materials".

Experiment No. 3

Softening Point of Bitumen

Definition

The softening point is practically defined as the temperature at which a disc of bitumen softens enough to allow a standard ball resting on it to move downward a distance of 25 mm.

Significance of the Test

As bitumen does not have a distinct melting point, the results of the test can be used to:

- 1. Classify bitumens according to their susceptibility to heat.
- 2. Classify bitumens according to their suitability to use in hot or cold regions.
- 3. Check the uniformity of sources of supplies.
- 4. Indicate the tendency of bitumen to flow at elevated temperatures.

Apparatus and Equipment:

The apparatus used in this experiment is called the "Ring and Ball Apparatus", which is shown in Figure 6.1. Figure 6.2 at the end of this experiment shows the dimensions of the apparatus parts.

The apparatus consists of the following:

1. Two brass rings.

- 2. Two 9.5-mm diameter steel balls, each weighs 3.5 gm.
- 3. Ball centering guides.
- 4. A flat brass plate.
- 5. Water bath in the form of a glass vessel.
- 6. Heating source.
- 7. Stirrer.
- 8. Thermometer capable of measuring temperatures in the range of 2 to 80°C., for low-softening point bitumens, or thermometer capable of measuring temperatures in the range 30 to 200°C., for high-softening point bitumens.
- 9. Any type of silicone oil or grease.
- 10. Liquid as recommended in Table 6.1.



Figure 6.1: Ring & Ball

Test Condition	1	2	3
Expected Softeni ng Point	30 °C to 80 °C	80 °C to 16 0 °C	30 °C to 11 0 °C
Recommended Liquid	Freshly boil ed dist ille d wat er	USP gly cer in	Ethylene gly col
Best Thermo meter	ASTM 15 C or 11 3C	ASTM 16 C or 11 3C	ASTM 11 3C
Starting Temper ature	5 ± 1°C	30 ± 1°C	5 ± 1°C

1. Table 6.1. Recommended Softening Point test conditions

Sample Preparation:

1. Heat the bitumen carefully, with frequent stirring, until it becomes sufficiently fluid to pour. The maximum allowed temperature should not exceed 110°C above its expected softening point. If the sample is a coal-tar pitch, then the maximum allowed temperature should not exceed 55 °C

above its expected softening point.

2. Grease the rings and the pouring plate with a thin layer of grease or silicon oil.

- 3. Heat the two brass rings to the approximate pouring temperature.
- 4. Place the rings on the pouring plate.
- 5. Pour the sample in the rings allowing some excess of the material.
- 6. Let the specimen to cool at room temperature for half an hour. Cut the excess material with a sharp-edged knife.
- 7. Since the softening point is not known in advance, it is quite useful to keep the specimen in a refrigerator in order to obtain low temperature well below the expected softening point.

Test Procedure:

- 1. Select the suitable test condition from Table 6.1:
- 2. Assemble the apparatus into its position.
- 3. Fill the bath with the suitable liquid, as indicated in Table 6.1, making sure that the liquid depth is 105 ± 3 mm.
- 4. Start heating or cooling the sample carefully in order to arrive at the starting temperature. Maintain this temperature for 15 minutes with the apparatus in place.
- 5. Place the ball in the center of the sample using the ballcentering guide.
- 6. Start heating and observing temperature. Make sure that heating is at the rate of 5°C per minute.
- 7. Record the temperature at which the bitumen surrounds each ball touches the support plate (i.e. moved a distance of 25 mm).

Calculations:

- Obtain the softening point as the average of the two samples. Report the value to the nearest 0.2°C when ASTM Thermometer 15C is used. Report the value to the nearest 0.5°C when ASTM Thermometer 15C or 113C is used.
- If water was not the liquid (as in condition 1) and the result was > 80°C, adjust the values as follows:
 - a. If condition 2 was used, then the correction factor should be -4.2°C, if the tested material is asphalt.

- b. If condition 2 was used, then the correction factor should be -1.7° C, if the tested material is coal-tar pitch.
- c. If condition 3 was used, then the results must be adjusted as follows:
 - SP (glycerin) = 1.027 x SP (Ethylene glycol) - 1.35°C, if the material tested is *asphalt*.
 - SP (water) = 0.974 x SP (Ethylene glycol) - 1.44°C, if the tested material is *asphal*t.
 - 3) SP (glycerin) = 1.045 x SP (Ethylene glycol) 5.06°C, if the tested material is *coal-tar pitch*.
 - SP (glycerin) = 1.061 x SP (Ethylene glycol) - 8.41°C, if the tested material is *coal-tar pitch*.
- 3. Obtain the standard deviation of all the tested samples.

Comments:

- 1. If the difference between the two samples in the same test exceeds 1°C, the test must be repeated.
- The difference between the results of two properly conducted tests by the same operator should not exceed 1.2°C (i.e. the standard deviation ≤0.41°C) when conditions 1 or 2 are applied.
- 3. The difference between the results of two properly conducted tests from different laboratories should not exceed 2°C (i.e. the standard deviation ≤0.70°C) when *conditions 1 or 2* are applied.
- The difference between the results of two properly conducted tests by the same operator should not exceed 2°C (i.e. the standard deviation ≤0.72°C) when *condition* 3 is applied.
- 5. The difference between the results of two properly conducted tests from different laboratories should not

exceed 3°C (i.e. the standard deviation \leq 1.08°C) when *condition* 3 is applied.

Discussion:

Discuss the following:

- 1. Comment on the suitability of the tested asphalt for use in Sweden, Jordan and Kuwait.
- 2. Why do results differ when changing the liquid in the bath?
- 3. Why water is not suitable for testing materials having high softening points?
- 4. Explain how the following factors affect the results of the test:
 - a. Increasing rate of heating.
 - b. Presence of sand in the sample.
 - c. Reheating and retesting the same sample.
 - d. Performing the test in air instead of the liquid.

Reference:

ASTM D36-95, (2000), "Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)".



Ductility of Bituminous Materials

Definition

The ductility of a bituminous material is defined as the distance it will elongate before breaking when the two ends of the tested sample, shaped using Briquette moulds, are pulled apart under specific conditions of the experiment.

Significance of the Test

The test provides a general idea about the tensile properties of the tested bitumen, and hence the result can be used to judge the suitability of the material for various uses.

Apparatus and Equipment

The apparatus is called *ductilometer* and is shown in Figure 7.1. It consists of the following:

- 10. Briquette moulds and plates.
- 11. Water bath of a volume not less than 10 liters. A thermostat should be provided in order to control the temperature during testing.
- 12. Testing assembly, which consists of a motor connected to a pulley and a metal thread, which is connected to the test specimen.
- 13. Thermometer capable of measuring temperatures between -8 and 32° C.



Sample Preparation

- 6. Coat the brass plates of Briquette moulds and the moulds with glycerin or any other material in order to prevent sticking.
- 7. Place the plates on a smooth horizontal surface.
- 8. Heat the bituminous sample until it is fluid. Make sure not to overheat the sample.
- 9. Pour the sample carefully in the moulds until they are filled with the material. Do not overfill them.
- 10. Let the material cool at room temperature for 30 to 40 minutes.
- 11. Carry the samples carefully on their plates and immerse them in water of controlled temperature at 25 ± 0.5 °C. The specimens must be kept for a period of not less than 90 minutes in this condition before testing.

Test Procedure

- 10. Make sure that at least 10 liters of water are placed in the water bath and that the specimens are immersed for a distance of not less than 10 cm below the surface of water.
- 11. Remove the briquette from the plate.
- 12. Detach the sidepieces of the briquette and place them in the test position.
- 13. Attach the rings at each end of the clips to the pins in the testing machine. Make sure that the specimens are all covered with water.
- 14.Start pulling the specimens with constant speed until rupture happens. Make sure that during the test, the thread of the specimen is covered with water for a depth of not less than 2.5 cm above and below.
- 15. Record the length of the specimen at rupture.

Comments

- 1. A normal test is the one in which the material between the two clips pulls to rupture where the thread has practically no cross-sectional area.
- 2. If the bituminous material comes in contact with the surface of water, then the test is considered abnormal. In this case, the specific gravity of the fluid (water) in the bath should be reduced. Methyl alcohol can be used in this case.
- 3. If the bituminous material comes in contact with the bottom of bath, then the test is considered abnormal. In this case, the

specific gravity of the fluid (water) in the bath should be increased. Sodium Chloride can be used in this case.

- 4. The value of ductility of the tested bitumen is the average of three successive normal tests. If normal test was not attained after three trials, the ductility is reported "unobtainable".
- 5. The test is considered acceptable if the ductility results are within the ASTM precision values given in Figure 7.2.

Report

- 1. Is the test normal?
- 2. Report the ductility of the tested bituminous material.
- 3. Is the precision of the results accepted by ASTM?

References:

ASTM D113-99, (2000), "Standard Test Method for Ductility of Bituminous Materials".



34 Figure 7.2: Precession data chart

Experiment No. 5

Flash and Fire Points of Bitumen

Definitions:

- Flash point is defined as the lowest temperature at which the vapor of the test specimen starts to ignite under the specified conditions of the test.
- *Fire point* is defined as the lowest temperature at which the test specimen will sustain burning for five seconds under the specified conditions of the test.

Significance of the Test

- 1. Flash point can be used to measure the tendency of the material to catch flames. It is one of the properties which can be used to assess the overall flammability of the material.
- 2. Flash point is used to class flammable and combustible materials according to safety regulations.
- 3. Flash point can be used to obtain an idea about the presence of volatile and flammable substances in a, theoretically, non-flammable material.
- 4. Fire point is used to measure combustibility of the material.

Apparatus and Equipment:

The main apparatus is called the Cleveland Open Cup Apparatus, shown in

Figure 8.1.

It consists of the following:

14. Test cup.
15. Heating plate.
16. Test flame.
17. Thermometer capable of measuring high temperatures up to 500°C.



Figure 8.1: Cleveland Open Cup
Sample Preparation:

- 16. Make sure that the sample is fluid. If the sample is not fluid, then heat it carefully making sure that the temperature does not exceed 60°C below the probable flash point.
- 17. Fill the cup with the sample to the specified level. Take care not to overfill the cup.
- 18. Air bubbles or foams should be carefully removed. Make sure that the surface is foam or air bubble-free surface before starting the test.
- 19.If foam could not be removed, then discard the sample completely and prepare a new one.

Test Procedure:

- 1. Let the apparatus stand on a leveled steady place. Protect from strong sunlight.
- 2. Wash the test cup carefully using some solvent in order to remove any traces of oils or residuals.
- 3. Support the thermometer in a vertical position at 6.4 mm from the bottom of the cup. Locate the thermometer halfway between the center and the side of the cup.
- 4. Fill the cup with the sample to the specified level. Take care not to overfill the cup. Air bubbles or foams should be carefully removed as mentioned earlier.
- 5. Light the test flame adjusting the flame to a diameter of 3 to 5 mm.
- 6. Start heating the sample with a relatively high speed (14°C to 17°C per minute). Continue until the temperature is about 60°C below the probable flash point then decrease the heat so that the rate of heating is about 5°C to 6°C per minute.
- 7. When the temperature is about 30°C below the probable flash point, apply the flame to the sample. The flame should be passed along the center of the sample and also about the circumference in a smooth way. The flame must be at a distance of not more than 2 mm above the plane of the edge of the can. Watch for possible ignition. The passing of the flame across the cup should be in about one second.
- 8. Repeat step 7 every increase of 2°C.
- 9. Record the temperature at which flash ignition occurs. Record this value as the flash point.
- 10. Continue heating with the same rate (5°C to 6°C per minute) and repeat steps 7 and 8.

- 11.Record the temperature at which ignition occurs and burning continues for a minimum period of 5 seconds. Record this value as the fire point of the tested material.
- 12. Record the ambient barometric pressure.

Calculations:

Calculate the corrected values of the flash and fire points of the tested samples using the following equations:

$$C_c = C_o + H(A_P - P) \tag{1}$$

where,

 $C_c = Corrected$ flash or fire point.

 C_c = Observed flash or fire point.

 A_p = Barometric pressure at the sea level, which equals 101.3 kPa or 760 Hg.

P = Ambient Barometric pressure.

H = Constant, which equals 0.25 when the pressure is in kPa and

0.033 when the pressure is in Hg.

Comments:

- 6. The final result should be rounded to the nearest 2°C.
- 7. The difference between two successive tests performed by the same operator in the same laboratory should not exceed 8°C.
- 8. The difference between two single and independent results performed at different laboratories should not exceed 17°C for the flash point or 14°C for the fire point.
- 9. If the results obtained do not conform to the conditions 2 and 3, the test must be repeated with new samples.
- 10. The method is suitable for temperatures above 80°C.

Report:

4. Obtain the average value of the tested samples and judge the acceptability of the results.

- 5. Why should the apparatus be sheltered from strong sunlight?
- 6. How is the result affected if air bubbles are present at the surface of the test sample?
- 7. What would you recommend if the flash point of the sample is expected to be 60°C?

References:

ASTM D92-90, (2000), "Standard Test Method for Flash and Fire Points by Cleveland Open Cup".

Experiment No. 6

SPECIFIC GRAVITY OF ASPHALT CEMENT

Definition:

- Specific gravity is defined as the ratio of the mass of the material at a given temperature to the mass of an equal volume of water at the same temperature.
- Since the specific gravity varies with the temperature, test results are expressed in terms of specific gravity (Sp. Gr.) at a given temperature for both the asphalt cement and the water used in the test. For example, Sp. Gr. 1.02 at 60°/60°F (15.6°/15.6°C) means that the asphalt cement specific gravity is 1.02 when both the asphalt cement and the water are at 60°F (15.6°C). Specific gravity at 60°/60°F (15.6°/15.6°C) is normally used for making monetary compensations or transactions concerning asphalt cements.

Significance of the Test

Specific gravity of the asphalt cement changes when the asphalt cement expands on heating. Therefore, Specific gravity determinations are useful in:

- 5. Making temperature-volume corrections.
- 6. Determining the weight per unit volume of asphalt cement heated to its application temperature.

Apparatus and Equipment:

The pycnometer method is used to determine the specific gravity

of asphalt cements. The needed equipment are:

- 18. Glass pycnometer, 25 ml capacity, glass, consisting of a conical vessel with stopper having a h
- 19.600 ml beaker.



20. Water Bath.21. Thermometer.

Figure 9.1: Glass Pycnometer with

Sample Preparation:

- 20. Thoroughly clean, dry, and weigh the pycnometer to the nearest 1 mg. Record this mass as **A**.
- 21. Fill a beaker partially with freshly boiled and cooled distilled water to a level that will allow the top of the pycnometer to be immersed to a depth of not less than 40 mm.
- 22. Fill the pycnometer with freshly boiled distilled water, placing the stopper loosely in the pycnometer. Place the pycnometer in the beaker and press the stopper firmly in place.
- 23. Place the beaker in the water bath to a depth sufficient to allow the bottom of the beaker to be immersed to depth of not less than 100 mm, while the top of the beaker is above the water level of the bath.
- 24. Allow the pycnometer to remain in the water for a period of not less than 30 min at the required test temperature (25°C).
- 25.Remove the pycnometer, immediately dry the top of the stopper with one stroke of a dry towel, then quickly dry the remaining outside area of the pycnometer.
- 26. Weigh the filled pycnometer with water to the nearest 1 mg. Record the weight as **B**.

Test Procedure:

- 13.Heat the asphalt sample with care, stirring to prevent local overheating, until the sample has become sufficiently fluid to pour. In no case should the temperature be raised to more than 110°C above the expected softening point of the asphalt.
- 14. Pour enough sample into the clean, dry, and warmed pycnometer to fill it about three fourths of its capacity. Take precautions to keep the material from touching the sides of the pycnometer above the final level and prevent the inclusion of air bubbles.
- 15. Allow the pycnometer and its contents to cool to ambient temperature for a period of not less than 40 min.
- 16. Weight the partially filled pycnometer with the stopper to the nearest 1 mg. Record this weight as **C**.
- 17.Fill the pycnometer containing the asphalt with freshly boiled distilled water, placing the stopper loosely in the pycnometer.
- 18. Place the pycnometer in the beaker and press the stopper firmly in place. Return the beaker to the water bath.
- 19. Allow the pycnometer to remain in the water bath for a period of not less than 30 min. Remove the pycnometer from the bath and immediately dry it and weigh it. Record this weight as **D**.

Calculations:

Calculate the relative density to the nearest 0.001 as indicated in the following equation:

relative density =
$$(C-A) / [(B-A) - (D-C)]$$
 (1)

where, A = mass of pycnometer (plus stopper),

B = mass of pycnometer filled with water,

C = mass of pycnometer partially filled with asphalt, and

D = mass of pycnometer plus asphalt plus water.

Calculate density to the nearest 0.001 as follows:

Density = specific gravity * γ_w

(2)

where, γ_w = density of water at the test temperature.

At 25°C, $\gamma_{\rm w} = 997.0 \text{ kg/m}^3$

Comments:

- 11. The difference between two successive tests performed by the same operator in the same laboratory should not exceed 2.3 kg/m³.
- 12. The difference between two single and independent results performed at different laboratories should not exceed 5.4 kg/m^3 .

Report:

- 8. Why should the lower surface of the pycnometer stopper be concave?
- 9. Obtain the average value of the tested samples and judge the acceptability of the results.
- 10. How is the result affected if air bubbles are present at the surface or within the test sample?

References:

ASTM D70-97, (2000), "Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method)".



Hashemite University

College of Engineering

Highway Engineering Lab

Specific Gravity of Asphalt Cement

Operator:	Job Site:			
Date: Sample De			:	
1) Weight of empty pycnometer with	stopper, A			
2) Weight of pycnometer + stopper + water, B				
3) Weight of water, = $(B - A)$				
4) Weight of pycnometer + stopper + asphalt, C				
5) Weight of pycnometer + stopper + asphalt +				
water, D				
6) Relative density = $(C-A) / [(B-A) - (D-C)]$				
7) Density of water at 25°C, γ_w , (kg/m ³)			997.0	997.0
7) Density = specific gravity * γ_w				

KINEMATIC VISCOSITY OF BITUMEN

Definitions:

Kinematic viscosity is defined as the ratio of the viscosity to the density of the liquid. It is a measure of the resistance to flow of a liquid under its own weight (gravity force). In SI units, kinematic viscosity is measured in m^2/sec , or mm^2/sec . The common unit for kinematic viscosity is stoke (St). The centistokes (cSt) is 1 mm^2/sec, and 1 cSt = 1/100 St.

Coefficient of viscosity commonly called *viscosity* is defined as the ratio between the applied shear stress and the rate of shear. This coefficient is another representation of the resistance to flow and is often given in poise (P) (= 1 g/cm.sec or 1 dyne.sec/cm²). The SI unit for viscosity is Pa.sec (N.sec/m²); which is equivalent to 10 poise.

Newtonian Liquid is defined as the liquid in which the rate of shear is proportional to the shearing stress, i.e., having a constant viscosity at certain temperature.

Non-Newtonian Liquid is defined, as that liquid in which the rate of shear to the shearing stress is not constant.

Significance of the Test

The test can be used to:

- 7. Characterize the flow behavior of bitumen.
- 8. Obtain an indirect measure of the consistency of bitumen.
- 9. Judge and compare the uniformity of shipments and supplies.

Apparatus and Equipment:

- 22. The main apparatus used is "", and is shown in Figure 10.1.
- 23. Standard kinematic viscosity thermometer.
- 24.Bath of suitable type to allow immersion of the viscometer reservoir.



25. Stop watch capable of reading to 0.1 of a second.26. Stirring tool.

Figure 10.1: Cannon-Fenske Viscometer for Opaque Liquids

Sample Preparation:

A. Liquid Asphalt

- 12. If the specimen is not at room temperature, allow it to stand, while sealed, to reach room temperature.
- 13.Open the sample and mix it thoroughly and gently for 30 seconds.
- 14. If the sample is not fluid, place the sample in a tightly sealed container in a controlled temperature environment at a temperature of $63 \pm 3^{\circ}$ C until it becomes sufficiently fluid to stir.
- 15. Once stirring is complete, charge the viscometer, as will be mentioned later.

B. Asphalt Cement

- 1. Heat the sample carefully, while stirring occasionally until it becomes pourable.
- 2. Transfer a minimum of 20 ml into a suitable container and heat to $135 \pm 5.5^{\circ}$ C, stirring occasionally to prevent local overheating and taking care to avoid the entrapment of air.

Test Procedure:

- 27. Maintain the bath temperature at the required test temperature, i.e. $60 \pm 0.01^{\circ}$ C for liquid asphalt, and $135 \pm 0.03^{\circ}$ C for asphalt cement.
- 28. Select a clean, dry viscometer which will give an efflux time greater than 60 sec and preheat to test temperature.
- 29. Once the sample is ready, charge the sample as follows:
 - A. Invert the viscometer.
 - B. Immerse tube N in the liquid sample (Figure 10.2).
 - C. Apply suction to tube L.
 - D. Draw liquid through tube N, filling bulb D to fill mark G.
- 30. Place stopper in tube L.
- 31. Wipe the excess material off tube N, place stopper in it, and revert the viscometer to its normal position.
- 32. Mount the viscometer in the constant-temperature bath, keeping tube L vertical.

- 33. Allow the viscometer to stand in the constant temperature bath in order to reach a constant temperature. The time required should be between 10 and 30 minutes.
- 34. Remove the stopper in tube N.
- 35.Remove the stopper in tube L.
- 36. Allow the sample to flow in the viscometer by gravity.



Figure 0.2 Cannon-Foncke

- 37. Observe the sample and record the time, to the nearest 0.1 sec, required for the material to pass from timing mark E to timing mark F.
- 38. Report the temperature.
- 39. Once test is finished, clean the viscometer using solvents and water. Usually Chromic acid cleaning solution is used. It may be prepared by adding 800 ml of concentrated sulfuric acid to a solution of 92 g of sodium dichromate in 458 ml of water.
- 14. Dry the tube by passing a slow stream of filtered dried air through the capillary for 2 min, or until the last trace of solvent is removed.

Calculations:

1. Calculate the kinematic viscosity at the specified temperature as follows:

KV at test temperature =
$$C * t$$
 (1)

where:

KV = kinematic viscosity, cSt.

t = efflux time in seconds.

- C = viscometer calibration constant, cSt/sec. The constant can be obtained using Table 10.1
- 2. Obtain the mean value of all the tested samples.
- 3. Calculate the standard deviation and the coefficient of variation and then comment on the acceptance of the results according to Table 10.2.

Size	Kinematic Viscosity	Approximate Constant
No.	Range (cSt)	(cSt/sec)
50	0.8 to 4	
75	1.6 to 8	
200	6 to 100	0.10
300A	15 to 200	0.25
300B	50 to 250	0.246
350	30 to 500	0.50
400	72 to 1200	1.20
450	150 to 2500	2.50
500	340 to 8000	8.00
600	1200 to 20000	20.0

Table 10.1 Constants of the Different Sizes of Cannon-Fenske Viscometers

Table 10.2 Acceptability of Test Results for Kinematic Viscosity

Material	Operator	Coefficient of	Acceptable	
Tested		Variation (%	Range of two	

		of the mean)	results (% of the
			mean)
Asphalt cements at 135°C	Single Operator	0.64	± 1.8
Liquid asphalts at 60 °C a. <3000 cSt b. 3000 - 6000 cSt c. >6000 cSt	Single Operator	0.53 0.72 3.2	$\pm 1.5 \\ \pm 2.0 \\ \pm 8.9$
Asphalt cements at 135 °C	Multi- laboratories	3.1	± 8.8
Liquid asphalts at 60 °C a. <3000 cSt b. 3000 - 6000 cSt c. > 6000 cSt	Multi- laboratories	1.06 3.11 3.6	± 3.0 ± 9.0 ± 10.0

Viscosity-Temperature Chart for Asphalts:

The viscosity of asphalt can be estimated at other temperatures else than the temperatures it is performed at using the viscosity chart. The chart coordinates are logarithm of the logarithm of the viscosity in mPa.s as the ordinate, and logarithm of the absolute temperature in degrees Kelvin (degrees C + 273.2) as the abscissa. However, for simplicity, viscosity in centistokes (on log scale), and the temperature in degrees Celsius (on arithmetic scale) are shown in the chart (Figure 10.3).

For temperatures above 60°C plot two viscosity-temperature points and carefully draw a straight line through the points. Plot at least three viscosity-temperature points if the included temperature range is below 60°C.



Figure 10 3. Viscosity-Temperature Chart for

Carefully draw a straight line or curve through the points. A point on this line, within the temperature range of the points plotted, shows the viscosity at the corresponding desired temperature.

To establish mixing and compaction temperatures, it is necessary to develop a Temperature-Viscosity chart for the asphalt to be used. This can be done by determining the viscosity at two temperatures, usually at 135° and 165°C. These two viscosities are then plotted on the Temperature-Viscosity chart. Then Mixing temperature should be selected to provide a viscosity of 170 \pm 20 centistokes. The Compaction temperature should be selected to provide a viscosity of 280 \pm 30 centistokes (Figure 10.3).

Comments:

- 13. Why are there different sizes of viscosity tubes?
- 14. Is the tested material considered a *Newtonian or non-Newtonian* liquid? Why?
- 15. Grade the tested asphalt according to viscosity.
- 16. Draw the obtained viscosities at the viscosity-temperature chart and obtain the required mixing and compaction temperatures for this asphalt according to the recommended temperatures in the Marshall mix design procedure. The recommended temperatures are:
 - a. Mixing temperature should be selected to provide a viscosity of 170 ± 20 centistokes.
 - b. Compaction temperature should be selected

to provide a viscosity of 280 ± 30 centistokes.

References:

ASTM D 2170-95, (2000), "Standard Test Method for Kinematic Viscosity of Asphalts (Bitumens)".

ASTM D 2493-95a, (2000), "Standard Viscosity-Temperature Chart for Asphalts".

Experiment No. 8

VISCOSITY OF ASPHALTS BY VACUUM CAPILLARY VISCOMETER

Definitions:

Coefficient of viscosity commonly called *viscosity* is defined as the ratio between the applied shear stress and the rate of shear. This coefficient is another representation of the resistance to flow and is often given in poise (P) (= 1 g/cm.sec or 1 dyne.sec/cm²). The SI unit for viscosity is Pa.sec (N.sec/m²); which is equivalent to 10 poise.

Absolute Viscosity is related to the measured time for a fixed volume of the asphalt to be drawn up through a capillary tube by means of vacuum, under closely controlled conditions of vacuum and temperature. The viscosity in poises is calculated by multiplying the flow time in seconds by the viscometer calibration factor. The test is usually performed at 60°C.

Newtonian Liquid is defined as the liquid in which the rate of shear is proportional to the shearing stress, i.e., having a constant viscosity at certain temperature.

Non-Newtonian Liquid is defined, as that liquid in which the rate of shear to the shearing stress is not constant.

Significance of the Test

The test can be used to:

- 1. Characterize the flow behavior of bitumen.
- 2. Obtain an indirect measure of the consistency of bitumen.
- 3. Judge and compare the uniformity of shipments and supplies.
- 4. The result can be used for specification requirements of cutbacks and asphalt cements.

Apparatus and Equipment:

- 1. The main required apparatus is "AIVV", and is shown in Figure 11.1.
- 2. Standard thermometers of accuracy of 0.02°C.
- 3. Bath of suitable type to allow immersion of the viscometer reservoir (Figure 11.2).



- 4. Vacuum system capable of maintaining a vacuum to within ± 0.5 mm of the desired Figure 11.1: Asphalt Institute Vacuum Viscometer up to and including 300 mm Hg.
- 5. Stop watch capable of reading to 0.1 of a second.
- 6. Stirring tool.

Sample Preparation:

- 1. Heat the sample carefully, while stirring occasionally until it becomes pourable.
- 2. Transfer a minimum of 20 ml into a suitable container and heat to $135 \pm 5.5^{\circ}$ C, stirring occasionally to prevent local overheating and taking care to avoid the entrapment of air.



Figure 11.2: Immersion Bath and Vacuum Control

Test Procedure:

- 1. Maintain the bath temperature at the required test temperature, i.e. $60 \pm 0.02^{\circ}$ C.
- 2. Select a clean, dry viscometer which will give an efflux time greater than 60 sec and preheat to test temperature.
- 3. Preheat the viscometer to $135 \pm 5.5^{\circ}$ C.
- 4. Pour the sample to within ± 2 mm of the fill line E shown in Figure 11.3.
- 5. Place the viscometer in a controlled temperature environment (bath or oven). The temperature must be $135 \pm 5.5^{\circ}$ C. A minimum period of 10 minutes is necessary.
- 6. Quickly, remove the viscometer from the controlledtemperature environment, and position it vertically in the bath making sure that the sample level is at least 20 mm above the farthest timing mark.
- 7. Apply a 300 \pm 0.5-mm Hg vacuum below atmospheric pressure to the viscometer tube.
- 8. Wait for 30 minutes and then open the toggle valve to allow vacuum to reach the tube.
- 9. Start the timer once vacuum is allowed.
- 10. Measure the time required for the leading edge of the meniscus to pass between successive pairs of timing marks. Report the time to the nearest 0.10 of a second.
- 11.Report the first flow time that exceeds 60 seconds between a pair of timing marks, noting the pair of timing marks.

12. Clean and dry the viscometer carefully using the appropriate solvents and methods before starting a new experiment. See Experiment No. 9 for cleaning procedure.



Figure 11.3 Asphalt Institute Vacuum

Calculations:

1. Calculate the viscosity at the specified temperature to three significant figures as follows:

V at test temperature and pressure =
$$k * t$$
 (1)

where, V = viscosity in poises.

t = flow time in seconds.

- k = viscometer calibration constant that corresponds to the pair of timing marks used for time determination, in poise/s, Table 11.1.
- 2. Obtain the mean value of all the tested samples.
- 3. Calculate the standard deviation and the coefficient of variation and then comment on the acceptance of the results according to Table 11.2.
- 4. Absolute viscosity of bitumen can be calculated from kinematic viscosity by multiplying the kinematic viscosity by the specific gravity of the bitumen.

Absolute viscosity in poises = Kinematic viscosity in stokes * specific gravity (2)

Comments:

- 17. Why are there different sizes of viscosity tubes?
- 18.Is the tested material considered a *Newtonian or non-Newtonian* liquid? Why?
- 19. Grade the tested asphalt according to viscosity.

|--|

Size	Capillary Badius	Approximat	Viscosity		
No.	mm	Bulb B	Bulb C	Bulb D	Range, P
25	0.125	2	1	0.7	42 to 800
50	0.25	8	4	3	180 to 3 200
100	0.50	32	16	10	600 to 12 800
200	1.0	128	64	40	2 400 to 52 000
400	2.0	500	250	160	9 600 to 200 000
400R	2.0	500	250	160	9 600 to 1 400 000
800R	4.0	2000	1000	640	38 000 to 5 800 000

Table 11.2 Acceptability of Test Results for Kinematic Viscosity

Operator	Acceptable Range of two results (% between the means)
Single Operator (Same viscometer)	± 7
Multi-laboratories	± 10

References:

ASTM D 2171-94, (2000), "Standard Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer".

Experiment No. 9

SAYBOLT VISCOSITY OF LIQUID ASPHALT (UNIVERSAL and FUROL)

Definitions:

- Saybolt Universal viscosity is defined as the efflux time, in seconds, for a standard sample, 60 ml, to pass through a standard, Universal, orifice under specified conditions.
- Saybolt Furol viscosity is defined as the efflux time, in seconds, for a standard sample, 60 ml, to pass through a standard, Furol, orifice under specified conditions. The relationship between Saybolt and Universal viscosities is as follows:

Saybolt Universal viscosity = 10 x Saybolt Furol viscosity (1)

Furol (according to ASTM) is an acronym of "Fuel and road oils"

Significance of the Test

The test can be used to:

- 1. Characterize certain petroleum products and compare their uniformity.
- 2. Obtain an indirect measure of the consistency of petroleum product.
- 3. Judge and compare the uniformity of shipments and supplies.
- 4. The results can be used to obtain an estimate of the kinematic viscosity using special tables.

Apparatus and Equipment:

- 1. Thermometers capable of measuring temperatures up to 0.2 °C.
- 2. Filter funnel with interchangeable 150μm and 75-μm wire-cloth inserts.



- 3. Receiving flask having a volume greater than 60 ml with a calibration mark at the 60 ml volume.
- 4. Timer with accuracy of 0.1 of a second.

Figure 12.1: Saybolt viscometer and bath

Sample Preparation:

Heat the sample with care stirring occasionally. Make sure that the sample temperature does not exceed the flash point minus 28°C.

Test Procedure:

- 3. Choose the suitable orifice. Use the Universal orifice with liquids and cutbacks having low viscosity. Use the Furol orifice with liquids and cutbacks having high viscosity.
- 4. Clean the viscometer and all other equipment with a solvent and then dry them completely.
- 5. Place the receiving flask in position, centered beneath the orifice.
- 6. Fill the bath with the suitable liquid to a level 6 mm above the overflow of the rim of the viscometer.
- 7. Stir the sample during heating so that the sample temperature is as close as possible to the temperature of the bath.
- 8. Calibrate the Saybolt viscometer using standard oil at temperature of 37.8°C following the same steps as for testing the sample.
- 9. Calibrate the Furol viscometer using standard oil at temperature of 50°C following the same steps as for testing the sample.
- 10. Choose the test temperature using the following table:

Viscosity	Standard Test Temperature: °C (°F)
Universal	21.1 (70), 37.8 (100), 54.4 (130), 60 (140),
	82.2 (180), 98.9 (210)
Furol	25 (77), 37.8 (100), 50 (122), 60 (140), 82.2
	(180), 98.9 (210)

- 11. After choosing the test temperature, control the temperature of the bath to the required one.
- 12. Close the sample outlet tightly using the cork stopper.
- 13.Stir the sample and then strain it through the 150-µm-wire cloth in the filter funnel directly into the viscometer until the levels are above the flowing rim.

- 14.Immerse the thermometer in the sample in its position in the viscometer and stir well. Withdraw the thermometer.
- 15. Check the sample temperature while stirring. The temperature must be within 0.03°C of the test temperature. Stirring in a circular motion should continue until the required temperature is reached.
- 16.Snap the cork stopper from the outlet and start the timer simultaneously.
- 17. Stop the timer once the level of the oil reaches the calibration mark.

Calculations:

Calculate the Saybolt viscosity at the specified temperature as follows:

Saybolt viscosity (Universal or Furol) at temperature (T)

= Time x Correction Factor(2)

Correction factor = Standard time / Measured time during calibration (3)

Comments:

- 20. Why are there different types of the Saybolt viscosity (Universal and Furol)?
- 21. Use the results to obtain an estimate of the kinematic viscosity.
- 22. The ASTM states that viscosity measurements should not be made at temperatures below the dew point of the room's atmosphere. Discuss this recommendation.

References:

ASTM D 88 - 81, "Standard Test Method for Saybolt Viscosity".

Experiment No. 10

AGGREGATE BLENDING TO MEET

SPECIFICATIONS

Definition:

- Aggregates that are used in asphalt concrete mixes have to have a certain gradation to achieve the desired interlocking of the different aggregate sizes. Gradation limits are usually selected to achieve maximum density and desired void properties. Two or more aggregates of different gradations are typically blended to meet the specifications limits for the following reasons:
- It is unlikely that a single natural or quarried material will meet these specifications.
- Aggregates are separated into sizes to improve handling characteristics.
- Mixing of coarse and fine aggregate in one stockpile results in segregation.
- It is often more economical to combine naturally occurring and processed materials to meet specifications than to use all processed materials.
 - Therefore, aggregates are separated into sizes, for example, 3/4 inch-3/8 inch (19 mm-9.5 mm), 3/8 inch-No. 4 (9.5 mm - 4.75 mm), and minus 4 (4.75 mm) prior to hauling and stockpiling.
 - The nature of particle size distribution can be examined by graphically representing the gradation by (a) a cumulative percent passing on a semi-log scale, or (b) the cumulative percent passing versus the sieve sizes raised

to the 0.45 power. Both methods are commonly used by engineers to help select the best aggregate blend.

A large number of blending methods (techniques of determining relative proportions of various aggregates to obtain a desired gradation) have been developed since the suggestion of the maximum density curves by Fuller and Thompson (15). The suitability of these methods depends on the types of specification and number of aggregates involved, the experience of the individual, and the major emphasis of the blending (closeness to the desired gradation or economics).

Regardless of the number of aggregates or blending techniques selected, the basic formula expressing the combination is

where, p = the percent of material passing a given sieve for the combined aggregates A, B, C,....

A, B, C,... = the percent of material passing a given sieve for each aggregate A, B, C,...

a, b, c,... = proportions (decimal fractions) of aggregates A, B, C,... to be used in the blend, a+ b + c... = 1.00

- It is desirable, no matter which method is used, to first plot the gradations of the aggregates to be blended and the specification limits on a gradation chart before actual blending is attempted. From these plots, decisions can be made prior to any calculation depending on:
- (a) whether a blend can be found using the available aggregates to meet the specification limits,
- (b) where the critical sieve sizes are, and
- (c) the approximate trial proportions to be selected.

These decisions can be made based on the following simple facts and the gradations shown in Figure 13-1:

- 1. The gradation curves for all possible combinations of aggregates A and B fall between curves A and B. It is impossible to blend aggregates C and B to meet the specification regardless of the method used.
- 2. If two curves cross at any point (B and D), the grading curves for all possible combinations pass through that point.
- 3. The curve for a blend containing more of aggregate A than B is closer to curve A than B and vice versa.



Figure 13.1. Example of blending different aggregates to

The most common method of determining the proportions of aggregate to meet specification requirements is the **trial-and-error method**. As the name implies, a trial blend is selected (aided by experience and plots of individual gradation curves and specification limits) and calculations made using Equation 1 to determine the percent passing each sieve size for the blend. The grading that is calculated from this trial is compared with the specification requirements. Adjustments are made for the second trial blend and the calculations repeated for the critical sieves until a satisfactory or optimum blend is obtained.

The trial-and-error method involves the following steps:

- 1. Selecting critical sieves for the aggregates in the blend;
- 2. Determining an initial set of proportions a, b, c, etc., which will meet the specification requirements for the critical sieves;
- 3. Checking the calculated blend using the proportions determined for all sieves in the specification requirements; and
- 4. Adjusting the proportions, as necessary, to ensure that the percentages for all sieves are within specification limits.
- **Example 13-1.** Determine a blend of the two aggregates shown in Table 13.1 which will meet the included specification limits using trial-and-error method.

Sieve Aggregate Specification Median of	Sieve Ag
---	----------

Table 13.1.	Blending of	Two Aggregates
-------------	-------------	----------------

				Specif
				ication
				S
	А	В		
3/4"	100	100	100	100
1/2"	90	100	100 - 80	90
3/8"	59	100	90 - 70	80
# 4	16	96	70 - 50	60
# 8	3	82	50 - 35	43
# 30	0	51	29 - 18	24
# 50	0	36	23 - 13	18
# 100	0	21	16 - 8	12
# 200	0	9	10 - 4	7

Examination of the grading indicates that it is possible to find a blend that falls within the specification limits, possibly a 50-50 blend because of the relative distance of the curves to the center of the band (desired gradation). The first trial blend can be determined more intelligently if certain critical sieve sizes are selected. By inspecting the gradations, it is seen that all material retained on the 3/8inch or 9.5 mm sieve (100 - 80 = 20 percent desired) has to come from aggregate A, and all material finer than the No.30 (0.6 mm) sieve must be furnished by aggregate B. With regard to aggregate A, because 100 - 59 = 41percent is retained on the 3/8-inch (9.5 mm) sieve from A, the percentage needed from A to retain 20 percent on this sieve (specification median) is A = 20/41 = 0.49; the percentage of aggregate B will be 1 - 0.49 = 0.51. With regard to aggregate B, because there is 51 percent passing the No.30 (0.6 mm), the percentage of aggregate B required to arrive at the desired 24 percent passing this sieve is B = 24/51 = 0.47; the percent of aggregate A for this blend will be 1 - 0.47 = 0.53. Hence, analysis of the two critical sieves produces very similar results.

- Evaluation of one of the critical sieves shows that the percent of aggregate A should be 49 percent and the other critical sieve shows that A should be 53 percent. For the first trial use 50 percent of aggregate A and 50 percent of aggregate B.
- A form that is easy to use is shown in Table 13.2. Multiply 0.50 times the percent passing each sieve size for aggregate A and aggregate B. Add the two results to get the gradation of the blend. The resulting gradation is compared to the desired one and it appears that the use of 50 percent A and 50 percent B results in a gradation very close to the desired gradation.
- Hence, for this example, the proportions should be 50 percent A and 50 percent B. The percentage of these two aggregates could be changed slightly, if desired, without having an adverse effect on the blend. For instance, if aggregate A costs more than aggregate B, the percentages could be changed to slightly increase the amount of aggregate B and decrease the amount of aggregate A, thus reducing the overall cost of the mix. The project specification will still be met but with a less expensive mix.

	Percent					Sieve Si	ze		
	U								
	s e							#	
	d	3/4"	1/2"	3/8"	# 4	# 8	# 30		
	Original	100	90	59	16	3	0	0	
	Original	100	100	100	96	82	51	36	
			100		70			23	
				90 -		50 -	29 -		
		400							
n		100							
		100	90	80	60	43	24	18	
	50	50	45	29.5	8	1.5	0	0	
	50	50	50	50	48	41	25.5	18	
		100	95	79.5	56	42.5	25.5	18	
		ОК	ОК	OK	OK	OK	OK	OK	

 Table 13.2. Calculation for Blending Two Aggregates
Example 13.2. Given in Table 13.3 the gradation of aggregates A, B, and C, determine the required percent of each to result in a blend meeting the required specification requirements.

Sieve	A	Aggrega B	ate C	Specification	Median of Specif ication s
1"	100	100	100	100 - 94	97
1/2"	63	100	100	85 - 70	78
# 4	19	100	100	55 - 40	48
# 8	8	93	100	42 - 30	36
# 30	5	55	100	30 - 20	25
# 100	3	36	97	22 - 12	17
# 200	2	3	88	11 - 5	8

Table 13.3. Blending of Three Aggregates

The critical sieves in this case would be the No.4 (4.75 mm) and No. 30 (0.6 mm). The No. 200 (75 μ m) sieve is also critical since aggregate C has 88 percent passing the No. 200 (75 μ m) sieve and the specifications only allow up to 11 percent. The desired 52 percent of material larger than the No. 4 (4.75 mm) sieve must come from aggregate A. Hence, the percent of aggregate A to use for the first trial should be:

Now looking at the No.30 (0.6 mm) sieve it is apparent that 75 percent of the material larger than a No. 30 (0.6 mm) sieve must come from materials A and B. Since 75 percent is the total desired to be retained on the No. 30 (0.6 mm) and 0.64(95) is that portion provided by aggregate A.

% of B = 75 - 0.64 (95) = 75 - 61 = 14

Based on these calculations, it appears that the best first estimate would be 64 percent of aggregate A, 14 percent of aggregate B, and 22 percent of aggregate C. It is obvious, however, that using 22 percent of aggregate C would produce too much material passing the No.200 (75 μ m) sieve. The percent of aggregate C should probably be no more than 8 percent, since that aggregate alone will produce approximately 7 percent passing the No. 200 (75 μ m) sieve. Based on this analysis, the first estimate should be 71 percent of aggregate A, 21 percent of aggregate B, and 8 percent of aggregate C. The calculations are shown in Table 13-4.

	Percent				Sieve Size		
aoto	U						
gate	e s						
	d	1"	1/2"	# 4	# 8	# 30	# 10
	Original	100	63	19	8	5	3
	Original	100	100	100	93	55	36
	Original	100	100	100	100	100	97
		100					
							22 -
nation			85 - 70	55 - 40	12 - 30	30 - 20	
ion		07	70				17
Iall		97	70	40	30	25	17
	71	71	44.72	12.40	E 69	2.55	0.47
	71	71	44.73	13.49	5.08	3.55	2.13
	21	21	21	21	19.53	11.55	7.56
	8	8	8	8	8	8	7.76
nd		100	73.7	42.5	33.2	23.1	17.5
ark		ОК	Improve	Improve	Improve	Improve	ОК
	66	66	41.58	12.54	5.28	3.3	1.98
	28	28	28	28	26.04	15.4	10.0
	6	6	6	6	6	6	5.82
nd		100	75.6	46.5	37.3	24.7	17.9

Table 13.4. Calculation for Blending Three Aggregates

	ark		ОК	OK	ОК	OK	ОК	OI
--	-----	--	----	----	----	----	----	----

The estimated percentages of 71 percent A, 21 percent B, and 8 percent C produce a blend that meets the specification requirements.

- However, the blend can be improved slightly to get it closer to the desired gradation. To improve the blend, use 2 percent less of aggregate C and 5 percent less of aggregate A and, hence, 7 percent more of aggregate B. For each 1 percent that two aggregates are changed the resulting blend will change by the difference between the percent passing for any given sieve size for the two aggregates times 1 percent. For instance, increasing aggregate B by 5 percent and decreasing aggregate A by 5 percent will result in a change of (.81) 5 or 4.0 on the No.4 sieve.
- After making the calculations (Table 13-4) it can be seen that the amount of each aggregate to use is 66 percent A, 28 percent B, and 6 percent C.
- The computations required by the trial-and-error method shown in the example were carried out manually to show the steps. However, successive trials can be done easily and quickly by using personal computers and electronic spreadsheet software. If desired, the gradations of the blends as well as the specification band can be plotted and examined using the graphic capabilities of a typical

personal computer.

There are several graphical methods that have been used to determine the percent of each aggregate to use in a blend. These methods are generally not used since the trial-and-error method is quicker and easier in most cases.

Requirement:

The Ministry of Public Works & Housing (MPW's&H) has specified certain gradation limits for both the Wearing and Binder Courses of the asphalt concrete mixes in Jordan. Two gradation limits are specified for the Wearing course for heavy traffic and medium and light traffic. In addition, two extra gradation limits are specified for the Binder course for heavy traffic and medium and light traffic. Table 13.5 shows the specified gradation limits. A local company has four stock piles that they blend together to achieve the required mixes. You are required to do the following:

- Grade the supplied materials from the four stockpiles..
- Draw the required gradation envelope for the Heavy Traffic Wearing Course mix.
- On the same figure, draw the gradation of the four stock piles.
- From the drawn figure, do you think that it is possible to achieve the required gradation from blending the material from the four stock piles, why?
- Find the required percentage from each stock to get a gradation in the middle of the gradation envelope.
- Calculate the allowable tolerance on each sieve size.
- Discuss the obtained gradation and allowable tolerance.

Table 13.5 Recommended Gradations by MPW's&H

	Sieve		Не	avy Traffic	Mediun	A	
ieve	O p e n	Sieve	Binder C	Wearing C	Binder C	Wearing C	
	i n q		o u r	o u r	o u r	o u r	
	(mm)		e e	e s	e	e	
1"	25.4	1"	100	100	100	100	:
3/4"	19.05	3/4"	70 – 1 0 0	90 – 100	70 – 1 0 0	90 – 100	
1/2"	12.7	1/2"	53 – 90	71 – 90	53 – 90	71 – 90	:
3/8"	9.525	3/8"	40 – 80	56 – 80	40 - 80	56 – 80	
# 4	4.75	# 4	30 – 56	35 – 56	30 – 56	35 – 65	
# 8	2.36	# 8	23 – 38	23 – 38	23 – 49	23 – 49	:
ŧ 20	0.850	# 20	13 – 27	13 – 27	14 – 43	14 – 43	:
ŧ 50	0.300	# 50	5 – 17	5 – 17	5 – 19	5 – 19	
ŧ 80	0.180	# 80	4 – 14	4 – 14	4 – 15	4 – 15	
200	0.075	# 200	2 - 8	2 – 8	2 - 8	2 – 8	

References:

National Center for Asphalt Technology, (1996), "Hot Mix Asphalt Materials, Mixture Design and Construction", NAPA research and Education Foundation, Maryland.



Hashemite University

College of Engineering

Highway Engineering Lab

Blending of Aggregates

Sieve Analysis Worksheet

Oper	ator:				Job Site:					
Date	:				Soil Description:					
Samp	ple									
Num	ber									
Sieve	Sieve	Weight	%	Cum.	%	Weight	%	Cum.	%	
No.	Size	Retained	Retained	Retained	Passing	Retained	Retnd.	Retnd	Passg.	
	(mm)	(gm)		%	U	(gm)		(%)		
1"										
3/4"										
1/2"										
3/8"										
#4										
#8										
#16										
#50										
#100										
#200										
To	tal									

Samp	ple								
Num	ber								
Sieve No.	Sieve Size (mm)	Weight Retained (gm)	% Retained	Cum. Retained %	% Passing	Weight Retained (gm)	% Retnd.	Cum. Retnd (%)	% Passg.
1"									
³ / ₄ "									
1/2"									
3/8"									
#4									
#8									
#16									
#50									
#100									
#200									
To	otal	al line line line line line line line lin							



Hashemite University

College of Engineering

Highway Engineering Lab

Aggregate Blending Worksheet

Percent		Sieve Size									
U											
e											
d	1"	3/4"	1/2"	3/8"	# 4	# 8	# 16	# 5			
Original											
Original											
Original											
Original											
		90 -	71 -	56	25	22	16	5			
	100		71-	50-		23 -	10-	5-			
	100	95.0	80.5	68.0	45.5	30.5	23.0	11.0			

SPECIFIC GRAVITY OF COARSE AND FINE AGGREGATE

Definition:

Specific gravity of an aggregate is the ratio of the weight of a unit volume of the material to the weight of an equal volume of water at approximately 23°C (73.4°F). The commonly used equation for specific gravity is:

Specific gravity = (weight / volume) / unit weight of water (1)

When working in the metric system the unit weight of water is 1.0 gram/ml. Hence the equation for specific gravity becomes:

Specific gravity = weight/volume (2)

when the weight is in grams and the volume is in ml.

Significance of the Test

Specific gravity of aggregate is useful in:

- 5. Making weight-volume conversions.
- 6. Calculating the void content in a compacted HMA.

Types of Specific Gravity

There are four different aggregate specific gravities used for HMA based on the method used to define the volume of the aggregate particles:

- 1. Apparent specific gravity;
- 2. Bulk specific gravity;
- 3. Effective specific gravity; and 4. Bulk impregnated specific gravity.

Referring to Figure 14.1, **the apparent specific gravity** includes only the volume of the aggregate particle; it does not include the volume of any pores or capillaries that become filled with water after a 24-hour soaking.

The **bulk specific gravity** includes the overall volume of the aggregate particle, as well as the volume of the pores that become filled with water after a 24-hour soaking. The **effective specific gravity** includes the overall volume of the aggregate, plus the pores that become filled with water after a 24-hour soaking, minus the volume of the larger pores that absorb asphalt. The effective specific gravity can be calculated from the theoretical maximum specific gravity (Rice specific gravity) using ASTM D2041.



Figure 14.1: Relationship between the Different Specific

When the aggregate absorption is zero, all three types of aggregate specific gravity are theoretically equal. The bulk and apparent specific gravities of coarse and fine aggregates can be determined by ASTM C127 and C128, respectively.

Specific Gravity and Absorption of Coarse Aggregate

A summary of the test procedure is:

- Approximately 5 kg of thoroughly washed aggregate retained on a No.4 (4.75 mm) sieve is oven dried to a constant weight.
- The dried sample is then immersed in water for 24 hours.
- The aggregate is removed from the water, drained, and surface dried until all visible films of water are removed. The surfaces will still appear damp.
- The weight of the sample in the surface dry condition is then obtained and recorded as **B**.
- The saturated surface dry sample is placed in a wire basket, submerged in water, and the submerged weight determined and recorded as **C**.
- The sample is then removed from the Water, drained and placed in an Oven and dried to a constant weight.
- The oven dried weight is recorded as **A**.

The specific gravity and absorption are calculated as follows:

Apparent specific gravity =
$$Gsa = A / (A-C)$$
 (3)

Bulk specific gravity,
$$= Gsb = A / (B-C)$$
 (4)

Absorption,
$$\% = (B-A) * 100 / A$$
 (5)

where, A= oven dried weight of aggregate, g;

B= saturated surface dry (SSD) weight of aggregate, g; and

C= submerged weight of aggregate in water, g.

Specific Gravity and Absorption of Fine Aggregate

The procedure is briefly outlined as:

- The flask (pycnometer) to be used to measure specific gravity is filled with water and the weight recorded as **B**.
- Approximately 1,000 g of fine aggregate is oven dried to a constant weight.
- The dried sample is then immersed in water for 24 hours.
- The fine aggregate is spread on a clean flat surface and exposed to a gently moving current of warm air until a saturated surface dry condition is achieved. A saturated surface-dry condition is reached at the moisture content at which the

lightly compacted material (by 25 light drops of the tamper) in a cone first slumps

when the cone is removed.

- Approximately a 500 g sample of the saturated surface dry material is placed in the flask and the actual weight of the sample recorded as **D**.
- The flask is then filled with water, using a specified procedure, and the weight recorded as C.
- The fine aggregate is removed from the flask, oven-dried to a constant weight, and the weight recorded as **A**.

The specific gravity and absorption are calculated as follows:

Apparent specific gravity =
$$Gsa = A / (B+A-C)$$
 (6)

Bulk specific gravity, =
$$Gsb = A / (B+D-C)$$
 (7)

Absorption,
$$\% = (D-A) * 100 / A$$
 (8)

where, A= oven dried weight of sample, g;

B= weight of flask (pycnometer) filled with water, g;

- C= weight of flask (pycnometer) with specimen and water to calibration mark, g; and
- D = saturated surface dry weight of sample (500 \pm 10 grams).

To get the specific gravity of an aggregate mix consisting from a number of aggregate fractions with different specific gravities, use the following equation:

$$G = \frac{P_1 + P_2 + \dots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \dots + \frac{P_n}{G_n}}$$
(9)

where, G = average specific gravity;

 G_1, G_2, \dots, G_n = specific gravity values for fraction 1, 2,, n; and P_1, P_2, \dots, P_n = weight percentages of fraction 1, 2,, n.

Requirement:

- 1. Find the Apparent, and the Bulk specific gravities, and Absorption of both coarse and fine aggregates.
- Following the recommended gradation by Ministry of Public Works
 & Housing (MPW's&H) for wearing course for heavy traffic, find the following:
 - a. Required weights from the different aggregate sizes to make five kilograms coarse aggregate (Retained on sieve # 4).
 - Required weights from the different aggregate sizes to make one kilograms fine aggregate (Passing sieve # 4).
 - c. Combined Apparent, and the Bulk specific gravities of the aggregate.

References:

- ASTM C127-88, (2000), "Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate".
- ASTM C128-97, (2000), "Standard Test Method for Specific Gravity and Absorption of Fine Aggregate".
- National Center for Asphalt Technology, (1996), "Hot Mix Asphalt Materials, Mixture Design and Construction", NAPA research and Education Foundation, Maryland.



MARSHALL MIX DESIGN PROCEDURE

Introduction

- Asphalt pavements are composed of aggregates as a filler, asphalt cement as a binder, and air voids that fill the spaces in the asphalt mixture. Three groups of aggregates are usually used in asphalt concrete mix design. These are coarse aggregate, fine aggregate, and mineral filler.
- A successful flexible pavement must have several desirable properties. These are stability, durability, safety (skid-resistance) and being the most economical mix. Because of the binding property of the asphalt cement, it is the most important constituent in the asphalt concrete mix. Quality control of asphalt cement is always required and essential for a successful mix. Some of these quality control tests are penetration, softening point, ductility, flash point, thin-film oven test, solubility, viscosity and others. Asphalt content is a very important factor in the mix design and has an effect on all the characteristics of a successful pavement. That is why all various mix design procedures are intended to provide a means for selecting the "optimum" asphalt content.
- Among the various mix design procedures, Marshall Mix design method is the most popular one because the equipment needed for the method is relatively simple and inexpensive.

Part I - SAMPLE PREPARATION

Introduction

In this experiment, students will prepare different asphalt concrete mixes by varying the asphalt content in each mix in accordance with the Marshall method of mix design. These specimens will be tested to obtain the optimum asphalt content by performing the Marshall test for stability and flow, bulk specific gravity and unit weight, theoretical maximum specific gravity and air voids percentage in total mix.

Material and Equipment

- 1. Asphalt, course aggregate, fine aggregate, and mineral filler.
- 2. Sieve analysis equipment.
- 3. Pans and mixing molds.
- 4. Spatula; balance; oven & hot plate.
- 5. Mixing bowel and mixer (Figure 15.1).





Figure 15.1: Compaction pedestal and compaction hammer

Preparation Procedure

- a) The aggregates to be used are dried to constant weight and sieved into the following size fractions: 1" (passing), 3/4", 1/2", 3/8", #4, #8, #30, #50, #100, #200.
- b) Blend sufficient aggregate to produce three, 2.5" height, specimens at each asphalt content. Usually five different asphalt contents are used in the mix design. Around 1150 gm of aggregate are sufficient to produce one Marshall Sample. Additional three samples are required for the determination of theoretical maximum specific gravity. A minimum of 2000 gm per sample are required for theoretical maximum specific gravity samples.

Blending of the aggregate should be according to the road type and layer position (either wearing or binder course). In this experiment we will make the mix design for a heavy trafficked wearing course layer. Therefore, the blending of the aggregates should be according to the following proportions:



- c) Determine the ranges of mixing and compaction temperatures from the temperature-viscosity plot:
 - Mixing temperature should be selected to provide a viscosity of 170 ± 20 centistokes.

- Compaction temperature should be selected to provide a viscosity of 280 ± 30 centistokes.
- d) Heat enough asphalt, at the obtained mixing temperature, to prepare a total of 18 specimens. Three specimens should be prepared at each of the selected five different asphalt contents. Asphalt contents should be selected at 0.5 percent increments with at least two asphalt contents above "optimum" and at least two below "optimum". Additional three loose mixture specimens should be prepared near the optimum asphalt content for determining theoretical maximum specific gravity.
- e) Heat the aggregate to a temperature 10°C above the mixing temperature (from c above).
- f) Place the aggregate in the mixing bowl and add the required amount of the asphalt cement and mix the aggregate and asphalt quickly and thoroughly.
 As stated above, five different asphalt cement percentages by weight of the mix are proposed:

Asphalt Cement <u>Percent by</u> <u>weight of</u> <u>mix</u>	No. of Spe cim ens	Weight of Asphalt to be Added per Sample
4.0	3	48.0
4.5	3	54.3
5.0	3	60.6
6.0	3	67.0
6.5	3	73.5

g) Clean and heat the molds and hammer to be between 100 and 150°C. Place a piece of filter paper in the bottom of the mold.

- h) Place half of the required amount of the mix in the mold and spade the mixture vigorously with a heated spatula 15 times around the perimeter and 10 times over the interior. Place the second half of the batch in the mold and repeat the foregoing procedure. Remove the collar and smooth the surface of the mix with a trowel to a slightly rounded shape. Place a piece of filter paper.
- Replace the collar and place the mold assembly on the compaction pedestal. Apply 75 blows of the 10 lb hammer, falling freely a distance of 18". Remove the mold and turn it over and apply the same number of blows to the other side.
- j) Remove the two filter papers and leave the sample to cool down then extrude the sample.

Part II - SAMPLE TESTING

Introduction

In this experiment, the students will carry out the following tests and analysis on the samples prepared in Part I of this experiment:

- A. Bulk specific gravity determination (ASTM D 2726).
- B. Stability and flow test.
- C. Theoretical maximum specific gravity determination (ASTM D 2041).
- D. Density & voids analysis.

Apparatus and Equipment

- a) Marshall testing machine with holding mould (Figure 15.2).
- b) Water bath for heating the Marshal
- c) Balance with specific gravity frame
- d) Large size pycnometer with vibrate
- e) Vacuum pump.

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).
//arshal
y fram
vibratc
Figure 1
Marshall testing machin
und

A. Bulk Specific Gravity Determination:

This test is performed according to ASTM D 2726 test procedure as follows:

- (a) Measure the height or thickness of the specimen and take its weight in air. Designate this as A.
- (b) Immerse the specimen in a water bath at 25°C for 3 min to 5 min and then weigh in water. Designate this weight as C.
- (c) Surface dry the specimen by blotting quickly with a towel and then weigh in air.Designate this weight as **B**.
- (d) Record the weights A, B & C for each sample in Worksheet # 1. Calculate the Bulk specific gravity of the compacted specimens as follows:

Bulk specific gravity = A/(B - C) (1)

where, A = mass of the dry specimen in air, g,

B = mass of the saturated surface-dry specimen in air, g, and

C = mass of the specimen in water, g.

B. Stability & Flow Test:

- (a) Immerse the specimen in the water bath at $60^{\circ}C \pm 1^{\circ}C$ for 30-40 minutes before test.
- (b) Thoroughly clean the inside surfaces of the testing ring. Ensure that the dial indicator in the proving ring is securely fixed and is zeroed for the no-load position.
- (c) Remove the specimen from the water bath, dry the surfaces and place the sample in the lower half of the testing ring. Fit the upper testing head into position and center the complete assembly in the loading device.
- (d) Place the flow meter over one of the guide rods and initialize it.
- (e) Apply load to the specimen, at a constant rate of deformation, 1 in. per min, until failure occurs. The *maximum* load required to produce failure, in kN at 60°C is recorded as the Marshall Stability value.
- (f) The reading on the flow meter at the point of maximum load is recorded as the flow value of the specimen, expressed in mm.

Note: The entire procedure from removal from the water bath to failure of the specimen should not take longer than 30 secs.

(g) Data obtained should be recorded in Worksheet # 1.

C. Theoretical Maximum Specific Gravity:

Determine the theoretical maximum specific gravity by ASTM method D2041. The test is performed on the loose mixed sample prepared in Part I of this experiment.

- a- Separate the particles of the sample, taking care not to fracture the mineral particles, cool the sample to room temperature, place in a container and get the net weight of the sample. Designate the net weight of the sample as **A**.
- b- Fill the large-size pycnometer (*Type E*) with water. Put the transparent cover in place and fill the pycnometer with water till it gets completely full upto the brim. Care should be taken to release any air bubbles entrapped by jarring the side of pycnometer. The outside of the pycnometer is then wiped dry. The filled pycnometer is then weighed. Designate this weight as **D**.
- c- Put the asphalt concrete mix sample in the pycnometer and add sufficient water at room temperature (25°C) to cover the sample.
- d- Remove entrapped air by subjecting the contents to an increasing vacuum until the residual pressure manometer reads 30 mm Hg or less. Maintain this residual pressure for 5 to 15 min. While vacuuming, agitate the container and contents either continuously by mechanical device or manually by vigorous shaking at intervals of about 2 min. At the end of the interval, gradually release the vacuum.
- e- For any given mix, optimum time of vacuum application or agitation may be established by trials or by experience. Lean mixes required less and rich mixes may require more time or agitation. In general, the minimum time required to dispel all the free air is 10 min.
- f- Immediately after removal of entrapped air, fill the pycnometer with water and dry the outside using towel. Determine the mass of the container (and contents) and designate this weight **E**.

g- Calculate the theoretical maximum specific gravity of the sample (@ 5% AC) as follows:

Theo. Max. Sp. Gravity (Gmm) =
$$A / (A + D - E)$$
 (2)

where, A = mass of oven dry sample in air, g,

- D = mass of container filled with water at 25°C (77°F), g, and
- E = mass of container filled with sample and water at 25°C, g.

D. Density & Voids analysis:

Definitions

Air voids: the pockets of air between the bitumen-coated aggregate particles in a compacted bituminous paving mixture.

Dense bituminous paving mixtures: bituminous paving mixtures in which the air voids are less than 10% after compaction.

After the completion of the stability and flow tests, bulk specific gravity, and theoretical maximum specific gravity, determine the average unit weight or density for each asphalt content by multiplying the average bulk specific gravity value by 62.4 Ib/ft³ or 1000 kg/m³. Then determine the % Air voids for each mix using the following formulas:

 Based on the maximum specific gravity, Gmm, value at optimum asphalt content determined by the experiment, calculate the effective specific gravity (Gse) of aggregate. Then using Gse, find out Gmm values at the different asphalt contents with the help of the following formulas:

$$Gse = \frac{Pmm - Pb}{\frac{Pmm}{Gmm} - \frac{Pb}{Gb}}$$

$$Gmm = \frac{Pmm}{\frac{Ps}{Gse} + \frac{Pb}{Gb}}$$
(4)

where, Gse = effective sp. gravity of aggregate,

Gmm⁼ maximum theoretical sp. gravity at a particular asphalt content,

Pmm = 100% (Total loose mixture),

Ps = % aggregate by total weight of mixture,

Pb = % asphalt by total weight of mixture, and

Gb = sp. gravity of asphalt.

2)

The percent air voids in a compacted bituminous paving mixture is calculated as follows:

Percent air voids (AV)

$$= [1 - \frac{Bulk \, Sp.Gravity}{Theoritical \, Max. Sp.Gravity}] * 100$$
(5)

3) Calculate Volume of asphalt and Voids Filled with asphalt at each asphalt content as follows:

Volume of asphalt (Vb) =
$$\frac{\% AC \times Gmb}{Gb}$$
 (6)

Voids Filled with Asphalt (VFA) = [Vb / (Vb + AV)] * 100 (7)

 Calculate Voids in Mineral Aggregate (VMA) at each asphalt content and check your calculated values of VFA from the following equations:

Voids in Mineral Aggregate (VMA) = 100 $[1 - \frac{Gmb(1-Pb)}{Gsb}]$ (8)

Voids Filled with Asphalt (VFA) = $\left[\frac{VMA - AV}{VMA}\right] * 100$ (9)

Part III. REPORT AND DISCUSSION

- a) Determine unit weight (density), stability & flow and % air voids for each asphalt percentage.
- b) Plot unit weight versus asphalt content.
- c) Plot Marshall Stability versus asphalt content.
- d) Plot flow versus asphalt content.
- e) Plot air voids (AV) versus asphalt content.
- f) Plot voids-filled with asphalt (VFA) versus asphalt content.
- g) Plot voids in mineral aggregate (VMA) versus asphalt content.

- h) Determine the optimum asphalt content from air void curve, which yield 4% AV.At the corresponding asphalt content check the following:
 - i. Marshal Stability;
 - ii. Flow;
 - iii. Voids in Mineral Aggregate (VMA); and
 - iv. Voids Filled with Asphalt (VFA).
- i) Compare the corresponding values with the recommended limits from Ministry of Public Works & Housing. If corresponding values outside recommended limits, reselect optimum asphalt content and check corresponding values.
- j) Determine the optimum asphalt content from curves, which yield the following:
 - (1) Maximum stability.
 - (2) Maximum unit weight.
 - (3) Median of limits for percent air voids.
- k) Compare the recommended optimum asphalt content from i & j above.

Basic Data for Sample Preparation of Paving Mixture

Worksheet # 1. Aggregate Gradation for Wearing Course Mix

Sieve Size	% Passing	% Retained	Wt. Retained,	Cumulative Retained Wt.,
			am	am
1"	100	-	-	0
3/4"	95	5	58	58
1/2"	80.5	14.5	167	225
3/8"	68	12.5	144	369
#4	45.5	22.5	259	628
# 8	30.5	15	173	801
# 16	23	7.5	86	887
#50	11	12	138	1025
#100	8.5	2.5	29	1054
#200	5	3.5	40	1094
Pan	-	5	58	1152
		Total	1152 gm	

Worksheet # 2. Weight of Added Asphalt for each Asphalt Percentage:

Wt. Of added Asphalt (based on wt. Of total mix) = $\frac{AC\%}{1-AC\%} \times 1152$

%AC	Wt. Of Asphalt (gm)
4.0	48.0
4.5	54.3
5.0	60.6
5.5	67.0
6.0	73.5

Specific Gravity of Asphalt (Gb) == 1.022

AC, percent	Weight in air (A)	Weight in water (C)	SSD Weight (B)	Specimen Height (mm)	Bulk SP. GR. (Gmb) $\frac{A}{B-C}$	Density (Unit Wt.) Kg/mt ³	Flow (mm)	Stability (kg)
4.0								
4.5								
5.0								
5.5								
6.0								

Worksheet # 3 Marshall Stability Testing Sheet

Worksheet # 4 Theoretical Maximum Specific Gravity Testing Sheet

	Wt. of	Wt. Of	Wt. of	Theo. Max.	Air Voids in Total Mix,
A.C.	Mix in	Pycnometer	Pycnometer +	Specific Gravity	(%)
Percent	Air	Plus Water	Water + Sample	A	$Gmb_{1\times 100}$
(%)	(A)	(D)	(E)	A + D - E	$Gmm^{J\times 100}$
4,0					
4.5					
5.0					
5.5					
6.0					

MPW's & H Mix Design Specifications

Property		Heavy Traffic		Medium & Light Traffic		Approved To ler an ce fro m JM
	Sieve	Binder C o u r s	Wearing C o u r s	Binder C o u r s	Wearing C o u r s	
	<u> </u> 1"	100	100	100	100	± 5.0%
	3/4"	70 –	90 - 1 0 0	70 – 100	90 –	± 5.0%
	1/2"	53 –	90 (53 – 90	71 –	± 5.0%
	3/8"	40 –	8 56 - 80	40 – 80	56 –	± 5.0%
	# 4	30 –	5 - 56	30 – 56	35 –	± 4.0%
	# 8	23 –	23 – 38	23 – 49	23 –	± 4.0%
	# 20	13 –	2 13 – 27	14 – 43	14 –	± 4.0%

# 50	5 – 17	5 – 17	5 – 19	5 – 19	± 4.0%
# 80	4 – 14	4 – 14	4 – 15	4 – 15	± 4.0%
# 200	2 - 8	2 - 8	2 - 8	2 – 8	± 1.5%
Bitumen Con tent					± 0.3%
Marshal Sta bilit y (kg)	900 (i i)	1000 (m i n)	800 (m in)	900	
Flow (mm)	2 – 3.5	2 – 3.5	2 - 4	2 – 4	
VMA	13 (; ; ; ; ; ; ; ; ; ; ; ;	14 (m i n)	13 (min)	14	
Air Voids (%)	4 - 7	4 - 6	3 - 5	3 - 5	
Stiffness (kg/ mm)	500 (i i)	500 (m i n)	500 (m in)	500	
Loss of Sta bilit y (%)	25 (; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;	25 (m a x)	25 (max)	25	

References:

ASTM D70-97, (2000), "Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method)".

ASTM D2726-96, (2000) "Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures".

ASTM D1559-89, (Discontinued 1998), "Test Method for Resistance of Plastic Flow of Bituminous Mixtures Using Marshall Apparatus".

ASTM D2041-95, (2000), "Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures".

ASPHALT EXTRACTION

Introduction

- Asphalt Content is mixture property that must be evaluated in asphalt concrete mixtures. The asphalt content of a mixture is very important to ensure satisfactory performance. A mixture with low asphalt content is not durable, and one with high asphalt content is not stable. The actual asphalt content directly affects mixture properties, such as asphalt film thickness, voids, stability, and Marshall Flow. Therefore, It is important to monitor asphalt content, because it really affects mixture properties that need to be controlled.
- Asphalt extraction test is used to quantify the quantity of used asphalt in the asphalt concrete mixtures. Obtained aggregates from this test can be used for gradation analysis to check quality of the produced mixes.

Summary of Test Method

- The extraction test involves adding a solvent to the asphalt mixture to dissolve the asphalt cement. Then the asphalt concrete and solvent are centrifuged to assure that all the asphalt is dissolved leaving a clean aggregate. This test is not a highly accurate test but it is widely used for measuring asphalt content. One advantage of the extraction test is that it allows determination of the aggregate gradation of the mixture. A disadvantage of the extraction test is that the solvent used is hazardous and is difficult to dispose.
- The National Center for Asphalt Technology (NCAT) has developed a test method to determine the asphalt content of the HMA mixtures by ignition. In the NCAT ignition method, a sample of HMA mixture is subjected to an elevated temperature of 538°C (1000°F) in a furnace to ignite and burn the asphalt content from the aggregate. NCAT's work has resulted in a test procedure and equipment: that automatically measures the asphalt content in 30-40 minutes. The

grading of the aggregate can then be determined using standard sieve analysis. Accuracy and precision of the NCAT ignition test were found to be better than those of the solvent extraction method. Therefore, this test: method is increasingly replacing solvent extraction methods. NCAT oven has to be calibrated to find if there will be a loss in the weight of the aggregate due to the ignition temperature, and to find percentage of weight loss if any.

Apparatus and Equipment:

- 1- Oven, capable of maintaining the temperature at 110°C.
- 2- Pan
- 3- Balance.t
- 4- Hot Plate, electric, 700-W.
- 5- Small-Mouth Graduate, 1000 or 2000-mL capacity.
- 6- Optional small-mouth graduate, 100-mL capacity.
- 7- Ignition Dish, 125-mL capacity.
- 8- Desiccator.
- 9- Analytical Balance.
- 10-
- 11- Container for catching the solvent.
- 12- Filter Rings.

).

13- Solvent.





Figure 16.1: NCAT ignition oven

Figure 16.2: Centrifuge Extraction Apparatus

Test Procedure

The extraction test will be performed using centrifuge and NCAT extraction methods.

a) Centrifuge Extraction Procedure:

The recommended test procedure for the centrifuge extraction test is as follows:

- 1- If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan and warm to 110°C, only until it can be handled or mixed.
- 2- Dry the empty centrifuge bowl with the filter paper to a constant weight, and record this weight in the data sheet.
- 3- Dry the test sample at 110°C to remove the moisture from it.
- 4- Place a sample (650-2500 g) of the asphalt concrete mixture into the bowl of the centrifuge apparatus. Record this weight as *W1*.
- 5- Cover the test sample with trichloroethylene, trichloroethane, methylene chloride, or diesel and allow sufficient time for the solvent to disintegrate the test portion (not over 1 h).
- 6- Fit the filter paper on the bowl, clamp the cover on the bowl tightly and place a beaker under the drain to collect the extract.
- 7- Start the centrifuge revolving slowly and gradually increase the speed to a maximum of 3600 rpm or until solvent ceases to flow from the drain pipe.
- 8- Stop the machine, add 200 ml of the solvent, and repeat the centrifuge procedure.
- 9- Repeat Step # 8 sufficient times (not less than three) so that the extract has a light color.
- 10- Collect the extract and the washings in a suitable graduated cylinder.
- 11- Dry the bowl with the filter paper to a constant weight in an oven at $110 + 5^{\circ}$ C.
- 12- Weight the dried aggregate and the filter paper. Designate the weight of the aggregate with the increase in the weight of the filter paper as *W*2.
- 13- Determine the amount of mineral matter in the extract using the following procedure:
 - a. Record the volume of the total extract (from Step 8) in the graduated cylinder. Designate this volume as V1.
 - b. Agitate the extract thoroughly and immediately take a representative sample (between 300-500ml) from the extract. Designate this volume as *V*2.
 - c. Place the selected extract into a previously tared and calibrated flask.
 - d. Place the flask in a controlled-temperature bath controlled to ±0.1°C, and allow to come to the temperature at which the flask was calibrated.
- e. Fill the flask with solvent which has been kept at the same temperature. Bring the level of the liquid in the flask up to the neck, insert the stopper, making sure the liquid overflows the capillary, and remove from the bath.
- f. Wipe the flask dry, determine the mass to the nearest 0.1 g, and record this mass as the mass of flask plus extract.

Calculations:

Calculate the volume of asphalt and fines in the extract as follows:

$$V4 = (V3 - \frac{(M1 - M2)}{G1}) * \frac{V1}{V2}$$
(1)

where, V1 = Total volume of the extract, ml,

V2 = volume of the selected sample from the extract,

V3 = volume of the flask,

- V4 = volume of asphalt and fines in the extract,
- M1 = mass of the contents of the flask,
- M2 = mass of the asphalt and fines in the extract = mass of the total sample minus the mass of the extracted aggregate = W1-W2, and
- G1 = specific gravity of the solvent determined to the nearest 0.001.

Calculate the mass of fines in the extract as follows:

$$W3 = K(M2 - G3 * V4)$$
 (2)

where, W3 = mass of fines in the extract,

- G2 = specific gravity of fines as determined in accordance with Experiment 12,
- G3 = specific gravity of asphalt as determined in accordance

with Experiment 11, and

$$K = G2 / (G2 - G3),$$

Calculate the percent bitumen in the test portion as follows:

Bitumen Content, AC% =
$$(\frac{W1 - W2 - W3}{W1})*100$$
 (3)

where, W1 = original mass of test sample,

W2 = mass of the extracted aggregate, and

W3 = mass of fines in the extract,

Calculate the standard deviation and the coefficient of variation and then comment on the acceptance of the results according to the following stated allowable variability:

Precision	Standard Deviat ion	Acceptable Range of Two Test Results
Single-operator precision	0.21	0.59
Multilaboratory precision	0.22	0.62

b) NCAT Extraction Procedure:

- 1- If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan and warm to 110°C) only until it can be handled or mixed.
- 2- Split or quarter the material until the mass of material (around 3 kg) required for test is obtained.
- 3- Dry the test sample at 110°C to remove the moisture from it.
- 4- Weight the sample and record this weight as, W4.
- 5- Spread the sample on the ignition tray.
- 6- Leave the sample inside the oven for 30-40 min.
- 7- At the end of the ignition time, take the sample out of the oven and leave it to cool down.
- 8- Take the weight of the ignited sample and record it as W5.
- 9- Calculate the bitumen content as:

Bitumen Content, AC% =
$$\left(\frac{W4 - W5}{W5}\right)^*100$$
 (4)

9- Sieve analysis can be performed on the obtained sample.

Comments:

- 23. Determine the bitumen content of the asphalt concrete mixture.
- 24. Determine the gradation of the aggregate.
- 25. Compare the results of Centrifuge and NCAT extraction methods.

References:

ASTM D2172-95, (2000), "Standard Test Method for Quantitative Extraction of Bitumen

From Bituminous Paving Mixtures".



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Asphalt Extraction by Centrifuge method

Operator:	Job Site:	
Date:	Sample Description:	
1) Weight of the empty bowl with the	e filter	
paper		
2) Weight of bowl + filter paper + test sample		
3) Weight of test sample, $W1 = (2 - 1)$		
4) Weight of bowl + filter paper + test sample		
after centrifuging and drying		
5) Weight of dry aggregate, $W2 = (4 - 1)$		
6) Total volume of extract, <i>V1</i>		
7) Volume of the selected sample fro	m the	
extract, V2		
Calculation of the solvent density		
8) Weight of empty flask with stopper		
9) Weight of flask + stopper + solvent		
10) Weight of solvent, $= (9 - 8)$		
11) Volume of flask, <i>V3</i>		
12) Specific gravity of solvent, <i>G1</i> , =	= 10/11	
13) Weight of flask + stopper + solvent +		
extract		
14) Weight of solvent + extract, $M1$, = (13 – 8)		

15) Volume of asphalt and fines in the extract,		
V4,		
$V4 = (11 - \frac{(14 - (3 + 5))}{12}) * \frac{6}{7}$		
16) Specific gravity of fines, G2		
17) Specific gravity of asphalt, G3		
18) K = 16 / (16 – 17)		
19) Weight of fines in the extract, <i>W3</i> ,		
W3 = 18 (3 – 5- (17 *15)		
20) Bitumen Content, AC%, $(\frac{3-5-19}{3} \times 100)$		



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Asphalt Extraction by NCAT Ignition Oven method

Operator:	Job Site:	
Date:	Sample Description:	
1) Weight of empty container		
2) Weight of container + test sample		
3) Weight of test sample, $W4 = (2 - 1)^{-1}$	1)	
4) Weight of container + test sample after		
ignition		
5) Weight of dry aggregate, $W5 = (4 - 1)$		
6) Bitumen Content, AC%, $(\frac{3-5}{5} \times 100)$		

SKID RESISTANCE

Definition:

- The highway surface should have some sort of roughness to facilitate friction between the car wheel and pavement surface. Skid resistance is a measure of the resistance of the pavement surface to sliding or skidding of the vehicle. It is a relationship between the vertical force and the horizontal force developed as a tire slides along the pavement surface. Therefore, the texture of the pavement surface and its ability to resist the polishing effect of traffic is of prime importance in providing skidding resistance.
- Polishing of the aggregate is the reduction in micro texture, resulting in the smoothing and rounding of exposed aggregates. This process is caused by particle wear on a microscopic scale and is difficult to quantify. Low-speed friction measurements, such as the British Portable Friction Tester, have been used in an attempt to quantify polishing.

Significance of the Test

In this experiment the will be used to evaluate the skid resistance of a pavement surface. This test method is used to evaluate the highway surface frictional properties. Such measurements are, of course, made with the surface wetted, but the rubber shoe of the pendulum tester displaces enough water so that the hydrodynamic effects (which influence friction at higher speeds and which are controlled by the coarser features of the surface) are practically absent. The rubber responds essentially only to microtexture.



The tester is a dynamic pendulum impact type tester which is based on the energy loss occurring when a rubber slider edge is propelled across a test surface. The apparatus may be used for both laboratory and field tests on flat surfaces, and also for polished stone value measurements on curved laboratory specimens from accelerated polishing wheel tests. The values measured are referred to as British Pendulum (tester) numbers (BPN) for flat surfaces, and polished stone values (PSV) for specimens subjected to accelerated polishing.

Apparatus and Equipment:

- 1. British Pendulum tester (Figure 17.1).
- 2. Slider bonded with a 6mm by 25m by 75mm rubber strip for testing flat surfaces.
- 3. Contact path gauge (thin ruler).
- 4. Water container.
- 5. Brush.
- 6. Thermometer.

Test Preparation:

- 1. Field test surfaces shall be brushed and flushed with clean water.
- 2. Level the instrument accurately by turning leveling screws until the bubble is centered in the spirit level.
- 3. Raise pendulum mechanism by loosening locking knob (directly behind pendulum pivot) and turn either of pair of head movement knobs at center of tester to allow slider to swing free of test surface. Tighten locking knob firmly.
- 4. Place pendulum in release position and rotate the drag pointer counter clockwise until it comes to rest against adjustment screw on pendulum arm.
- 5. Release pendulum and note pointer reading. If reading is not zero, loosen locking ring and rotate friction ring on bearing spindle slightly and lock again.
- 6. Repeat test and adjust friction ring until the pendulum swing carries pointer to zero.
- 7. Place spacer under adjusting screw of lifting handle.
- 8. Lower pendulum so edge of slider just touches surface.
- 9. Lock pendulum head firmly, raise lifting handle, and remove spacer.
- 10. Raise slider by lifting handle, move pendulum to the right of the lower slider, and allow pendulum to move slowly to left until edge of slider touches surface.
- 11. Place the contact path gauge beside slider and parallel to direction of swing to verify length of contact path.

- 12. Raise slider, using lifting handle, and move pendulum to left, then slowly lower until slider edge again comes to rest on surface. If the length of the contact path is not between 124 and 127 mm on flat test specimens measured from trailing edge to trailing edge of the rubber slide, adjust by raising or lowering instrument with the front leveling screws. Readjust level of instrument if necessary.
- 13.Place pendulum in release position and rotate the drag pointer counterclockwise until it comes to rest against adjustment screw on pendulum arm.

Test Procedure:

- 1. Apply sufficient water to cover the test area thoroughly.
- 2. Execute one swing, but do not record reading.
- 3. Always catch the pendulum during the early portion of its return swing. While returning the pendulum to its starting position, raise the slider with its lifting handle to prevent contact between the slider and the test surface and return the pendulum and the pointer to their starting position.
- 4. Immediately, make four more swings, rewetting the test area each time and record the results. After each drop repeat Step 4.
- 5. Recheck the slide contact length on completion of the test.

Report:

- 1. Record the British Pendulum tester Number (BPN) as the average of the four test values.
- 2. Type, age, condition, texture and location of test surface.
- 3. Temperature of test surface.
- 4. Comment on the texture of the test surface.

References:

ASTM E 303 – 93 (Reapproved 1998), (2000), "Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester".



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British Pendulum Test Worksheet

Operator:	Job Site:	
Date:	Surface Condition:	
Surface Age	Surface Temperature	
British Pendulum Number (BPN) 1st	Reading	
British Pendulum Number (BPN) 2 nd	Reading	
British Pendulum Number (BPN) 3 rd Reading		
British Pendulum Number (BPN) 4 th	Reading	
Average British Pendulum Numbe	r (BPN)	

Comments: