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قسم هندسة البناء والإنشاءات
فرع هندسة الطرق والجسور
مختبر الأسفلت

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مشرف مختبر الاسفلت

2014

University of Technology

Building and Construction

Engineering Department

Highways and Bridges Engineering Branch

Asphalt Laboratory

Asphalt LABORATORY TESTS

MANUAL

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Asphalt Lab. Supervisor

2014

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Requirements for Laboratory Reports:

- ***Purpose:*** *To acquaint the student with technical report preparation, data analysis and interpretation, and presentation of technical information.*

- ***Grading:*** *The following items will be considered:*

  1.Technical accuracy and honesty

  2.Format

  3.Grammar

  4.Spelling

  5.Neatness

  6.Completeness

  7.Timeliness

- ***Report format:*** *The following format is required. The justification for having a fixed format for information presented. The following format includes the most commonly included components in technical reports and papers. All data is to be reported in SI units.*

  1. Title page
  Name of testing , your name, branch name, title, and date of submission

2. *Contents include all information in laboratory testing; why testing was done, etc.*
3. *Description of testing program and methods*
4. *Reference any standard test methods*
5. *Summarize steps in test method*
6. *Materials: Type of material, source (if known).*
7. *Present individual test results as well as any applicable averages, Tables, Graphs*
8. *Sample calculations*
9. *Summarize findings; if materials are substandard, recommend materials be rejected; if you feel more testing is needed, say so.*
10. *Discuss results; reference all tables and figures; compare to acceptable values, ranges, etc.,; if results are unacceptable, say so.*
11. *Discussion for test results.*
12. *References*
13. *Raw data sheet*

Test No. 1

Penetration Test

Prepared by/ Dr. Zaynab Ibrahim

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Test No. 1

Penetration Test

Objectives :

The penetration test is used to measure consistency of bituminous materials expressed as the distance in tenths of millimeter that a standard needle vertically penetrates a sample of the materials under known conditions of loading, loading time and temperature.

Main Principles :

- A needle of specified dimensions is allowed to penetrate vertically into a bituminous material under specified load, loading time and temperature.
- The distance the needle penetrates in units of 1/10 mm is termed the penetration value.
- This method is used for semi – solid and solid bituminous materials having a penetration up to 500.
- Asphalt cements are classified according to their penetration values , such asphalt are called the penetration grade asphalts or grade asphalts namely 40-50, 50-60, 60-70, 85-100 , 120- 150, 200- 300 for example, an asphalt with penetration value of 46, is grade “40 -50”.

Test Condition :

- Load =100gm
- Time =5sec
- Temperature =25 ˚c

References: ASTM D5- 2006 and AASHTO T 49-2010:" *Penetration of Bituminous Materials*".

Figure (1-1) Penetrometer with Accessories

APPARATUS:

1. Standard penetration test assembly
2. Penetration tins.
3. Transfer dish
4. Thermometer
5. Hot plate
6. Water bath
7. Timing device (stop watch)

PROCEDURE:

1. Heat the sample to pouring temperature "about 120 ˚C" then pour it immediately into the sample container to minimum depth of 3 cm, and allow to cool to room temperature.
2. Place the sample in water bath at 25 ˚C for 1-2 hours.
3. Place the sample in transfer dish filled with water from the bath, and then place the transfer dish containing the sample on the stand of penetration device assembly.
4. Immediately adjust the needle to just make contact with the sample surface, Figure (1-1).
5. Bring the dial pointer to zero, and quickly release the needle for 5 sec
6. Adjust the instrument to measure the penetration distance and record the dial reading, Figure (1-2).
7. Return the dish and the sample to the water bath and clean the needle with solvent.
8. Repeat steps 3-7 at least 3times.

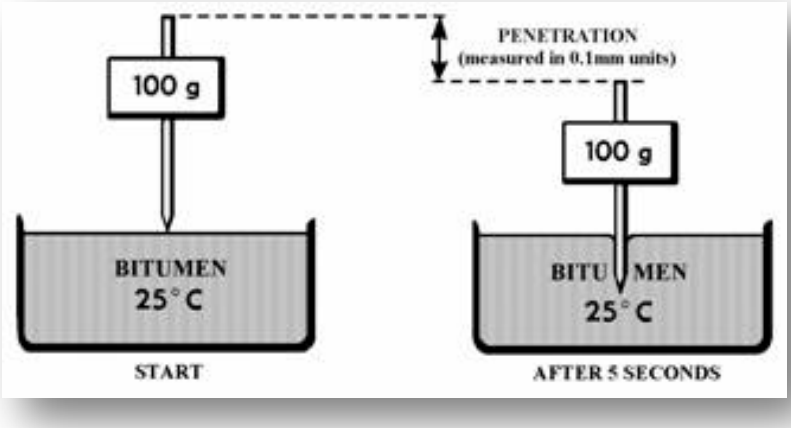

Figure (1-2) distance penetration for asphalt sample

NOTES:

The needle position must be more than 1 cm from the side of the container and any another previous position.

RESULTS:

1. Record the dial reading of step 6 each time and take average, the result from each time should not differ by more than 4%, if not, ignore the readings and repeat the test.
2. Find the grade of asphalt that produced the required penetration.

DISCUSSION:

1. Importance of penetration test.
2. Effect of temperature, load and time on penetration values. State other conditions.
3. The use of different grade in different climates.
4. What is the meaning of “consistency of bituminous materials”?
5. Which value of penetration can be used in construction of roads in Iraq?

Working Sheet

University of Technology **Building and Construction Engineering Department** **Highways and Bridges Engineering Branch** **Asphalt Laboratory**	**Penetration Test** **According to:** **ASTM D 5-10** **AASHTO T 49-06**	**Test No.1**	

Type of material		
Resource		
Reading No.	**Dial Gauge Reading**	**Penetration Value (1/10 mm) 25°C, 100gm, 5sec**
1		
2		
3		
4		
5		
6		
Final Penetration Value (0.1 mm) = Average of the readings:		

Date **Tested by** **Student Name**

Test No. 2

Ductility Test

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University of Technology

Test No. 2

Ductility Test

Objective :

The ductility test is used to describe the ductile and tensile behavior of bituminous binders. The test, which is normally performed at ambient temperature, is believed to reflect the homogeneity of the binder and its ability to flow.

Main Principles :

- It is the distance in centimeters to which bituminous material elongate before braking when the end of a briquette specimen of the material is pulled at a specified speed and specified temperature.
- The specimen is placed in a water bath at 25˚C and allowed to equilibrate before testing.
- If the asphalt sample sage then the test is not normal, add sodium chloride to the water .

Test Condition:

- Temperature =25 ˚C
- Rate of pulling = 5 cm/min

References: ASTM D 113- 99 and AASHTOT 51-2006*:" Standard Test Method for Ductility of Bituminous Materials ".*

Apparatus:

1. Ductility testing machine, (see Fig. 2-1).
2. Ductility mold and plate, (see Fig. 2-2)
3. Water path
4. Thermometer.
5. Hot plate
6. Spatula.

Figure (2-1) Ductility testing machine

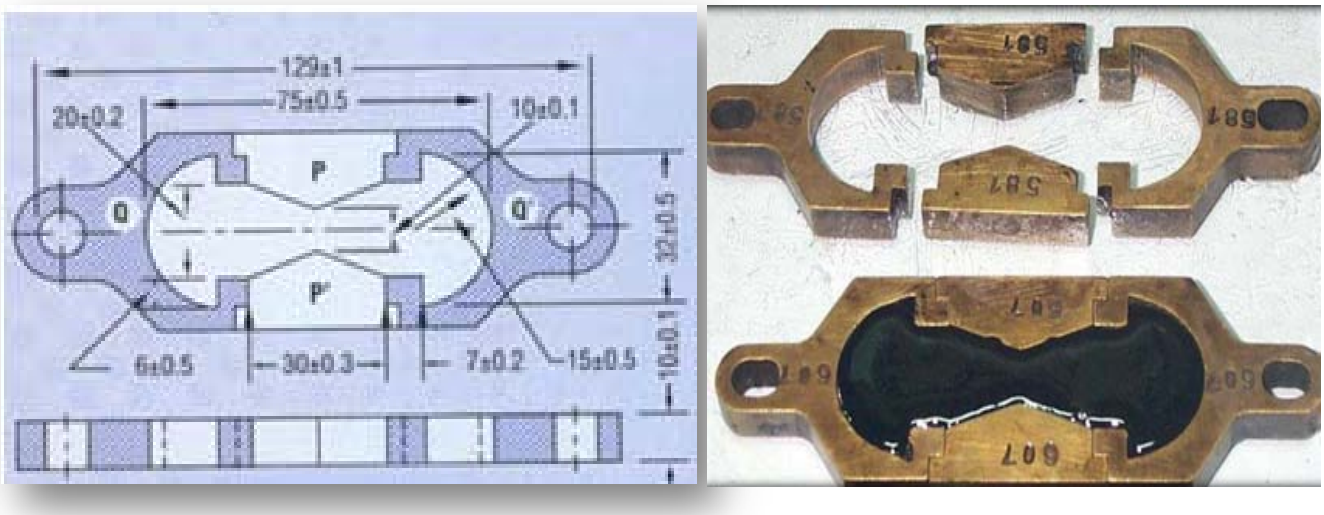

Figure (2-2) Mold for ductility test

Procedures :

1. Molding test specimen:

- arrange the parts of the mold on a flat level plate with mixture of glycerin and dextrin.
- Carefully heat the sample to prevent local overheating until it has become sufficiently fluid to pour.

- Pour the bitumen in a thin stream from end to end of the mold, cool to room temperature from 30-40 min., and then place it in the waterbath maintained at the specified temperature of test for 30 min., and then cut off the excess bitumen by a hot spatula.
- Place the assembly "mold containing the bitumen and the plate in the water bath at 25 ˚C for 90 min.
- Prepare three samples in the same way.

2. Testing:
   - Remove the briquette from the plate, and detach the sidepieces.
   - Immediately, attach the end of the mold to the pins in the testing machine, and run it.
   - The machine will pull apart the specimen at a uniform speed until the briquette rupture.
   - Measure and record the distance in centimeters, which the briquette traveled before rupture. See Fig. (2-1).

Results:

1. Report the distance in centimeters in which the sample elongate before breaking.
2. Report the average of three normal tests.

Discussion:

1. Importance of ductility test for road construction.
2. Iraqi standard for minimum ductility.
3. Effect of "temperature and rate of pulling" on ductility value.
4. Importance of adding "$NaCl_2$" salt .
5. What is the reason of not coating the clips inside surface of ductility mold by a lubricant?
6. Draw the mold of the specimen.

Working Sheet

University of Technology **Building and Construction Engineering Department** **Highways and Bridges Engineering Branch** **Asphalt Laboratory**	**Ductility Test** **According to:** **ASTM D113-1999** **AASHTOT 51-2006**	**Test No.2**	

Grade of Bitumen :

Sample No.	Ductility Reading, cm 25°C, 5cm/min	Average Reading, cm
1		
2		
3		

Date **Tested by** **Student Name**

Test No. 3

Loss on Heating

Prepared by/ Dr. Zaynab Ibrahim

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University of Technology

Test No. 3

Loss on Heating Test

Objectives :

- This method determines the effect of heat and air on a film of bituminous materials under specified conditions.
- It indicates changes in properties during conventional hot mixing and thus yields a residue that approximates the binder condition in a newly constructed pavement.
- To measure the drop in penetration and ductility due to heating and hardening of asphalt.

Main Principles :

- A thin film of bituminous material is heated in an oven at 163°C for 5 hours.
- The effects of heat and air on material properties can be determined by selected tests before and after the oven treatment.

Test Conditions:

- 50 gm of asphalt heating for 5hrs at 163 °C.

References:ASTM D1754-02 and AASHTO T 47-05: *"Standard test method effect of heat and air on asphalt materials (thin- film oven test)"* .

Apparatus:

1. Oven with rotating shelf “ASTM Standard”, see Fig. (3-1).
2. Containers “metal or glass”55 mm in diameter and 35 mm depth, see Fig. (3-2).
3. Thermometer.
4. Balance.

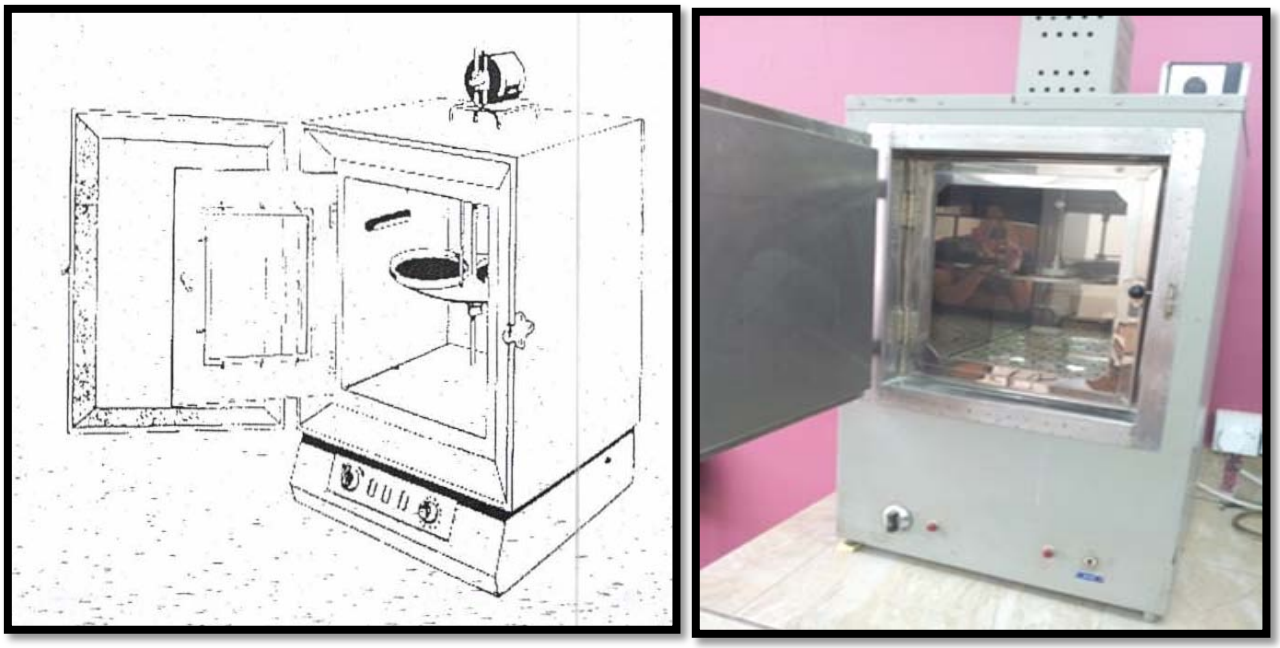


Figure (3-1) Thin - Film Oven device

Figure (3-2) Containers

Procedures :

1. Heat a suitable amount of bitumen to temperature of 150° C, and pour (50 ±0.5) gm of the bitumen in the specified container but avoid the air bubbles in the sample, and weight to the nearest 0.01 gm. This will be W1.
2. Bring the oven to a temperature of 163 ˚C and place the container with the sample, then close the oven and rotate the shelf.

3. Maintain the temperature at (163 ±1) ˚C for 5 hours, after the sample has been introduced. The 5- hrs period shall start when the temperature reach 162 ˚C but the total time in oven shall in no case exceed 5hrs and 15 min. The rate of shelf rotating is of 5 to 6 rpm.
4. Remove the sample container from the oven; cool to room temperature and weight to the nearest 0.01 gm. This is W2.
5. Empty the containers into a larger one stir combined residue thoroughly and prepare it for penetration and ductility test.

Calculations:

1. Find the loss in mass for each sample from:

$$\%loss\ in\ mass = \frac{w1-w2}{w1} * 100$$

Where:

W1=weight of the sample before TFOT (gm)

W2= weight of the sample after TFOT (gm)

Report the average value.

2. Find the penetration and ductility of the residue expressed as percent of the original penetration.

$$\textbf{Retained Penetration (\%)} = \frac{Pen.after\ TFOT}{Pen.before\ TFOT}$$

$$\textbf{Retained Ductility (\%)} = \frac{Duc.\ after\ TFOT}{Duc.before\ TFOT}$$

DISCUSSION:

1. Importance of the test.
2. Is the value of % loss in mass within specification, explain that.
3. What is your expectation about the value of ductility and penetration after heating the asphalt sample at 163˚C for 5 hrs? Explain that.
4. Which of the following condition does this test simulate?
   - Asphalt storage tank.•Mixing process. • Pavement in service.
5. State other asphalt properties which are susceptible to heating.

Working Sheet

University of Technology **Building and Construction Engineering Department** **Highways and Bridges Engineering Branch** **Asphalt Laboratory**	**Loss on HeatingTest** **According to:** **ASTM D 1754-02** **AASHTO T 47-05**	**Test No.3**	

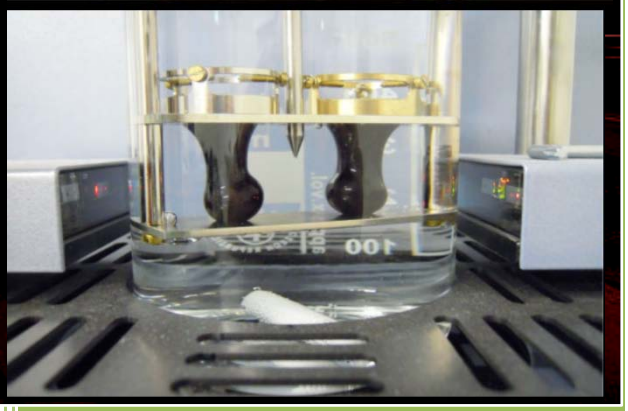
Grade of Bitumen :

Pan No.	Weight of Dish (gm)	Weight of (Sample+ Dish) Before TFOT, (gm)	Weight of (Sample+ Dish) After TFOT, (gm)	% Loss in Mass
A				
B				
Penetration after TFOT				
Ductility after TFOT, cm				

Date **Tested by** **Student Name**

Test No. 4

Softening Point Test



Prepared by/ Dr. Zaynab Ibrahim

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University of Technology

Test No. 4

Softening Point Test

Objectives :

- The softening point test is used to measure and specify the temperature at which bituminous binders begin to show fluidity.
- The softening point is also an indicative of the tendency of the material to flow at elevated temperatures encountered in service.
- For calculating the penetration index (PI) of the grade asphalt.

Main Principles :

- This test is used for determining the softening point of bitumen in the range of (30-157□C) using the ring-ball apparatus immersed in distilled water (30 to 80 □C).
- The temperature of a sample is raised at a constant rate and read when the binder has undergone a specified deformation.
- A steel ball of 3.5 g is placed on a sample of binder contained in a brass ring which is suspended in a water bath. The bath temperature is raised at 5°C per minute, the binder gradually softens and deforms slowly as the ball falls through the ring.
- At the moment the bitumen and steel ball touches a base plate 25 mm below the ring, the temperature of the water is recorded.
- The higher softening point of the two bituminous materials of the same penetration value means a little effect by temperature.

Test Condition:

- Select freshly boiled distilled water for softening point between (30-80) □C, and USPglycerin for softening point (above 80 □C up to 157 □C).
- Use ethylene glycol for softening point between 30 □C and 110 □C.
- The temperature of the liquid must raised 5 □C/ min.
- The maximum variation for any 1-min. after the first 3 minutes shall be 0.5 □C.

References : ASTM D36- 95 and AASHTOT53- 06:" *Standard test method for softening point bitumen (Ring and Ball Apparatus)*".

Apparatus:

1. Standard ring and ball apparatus assembly as Fig. (4-1) and Fig. (4-2)
2. Heat source
3. Pouring plate treated with a mixture of glycerin and dextrin
4. Thermometer
5. Forceps

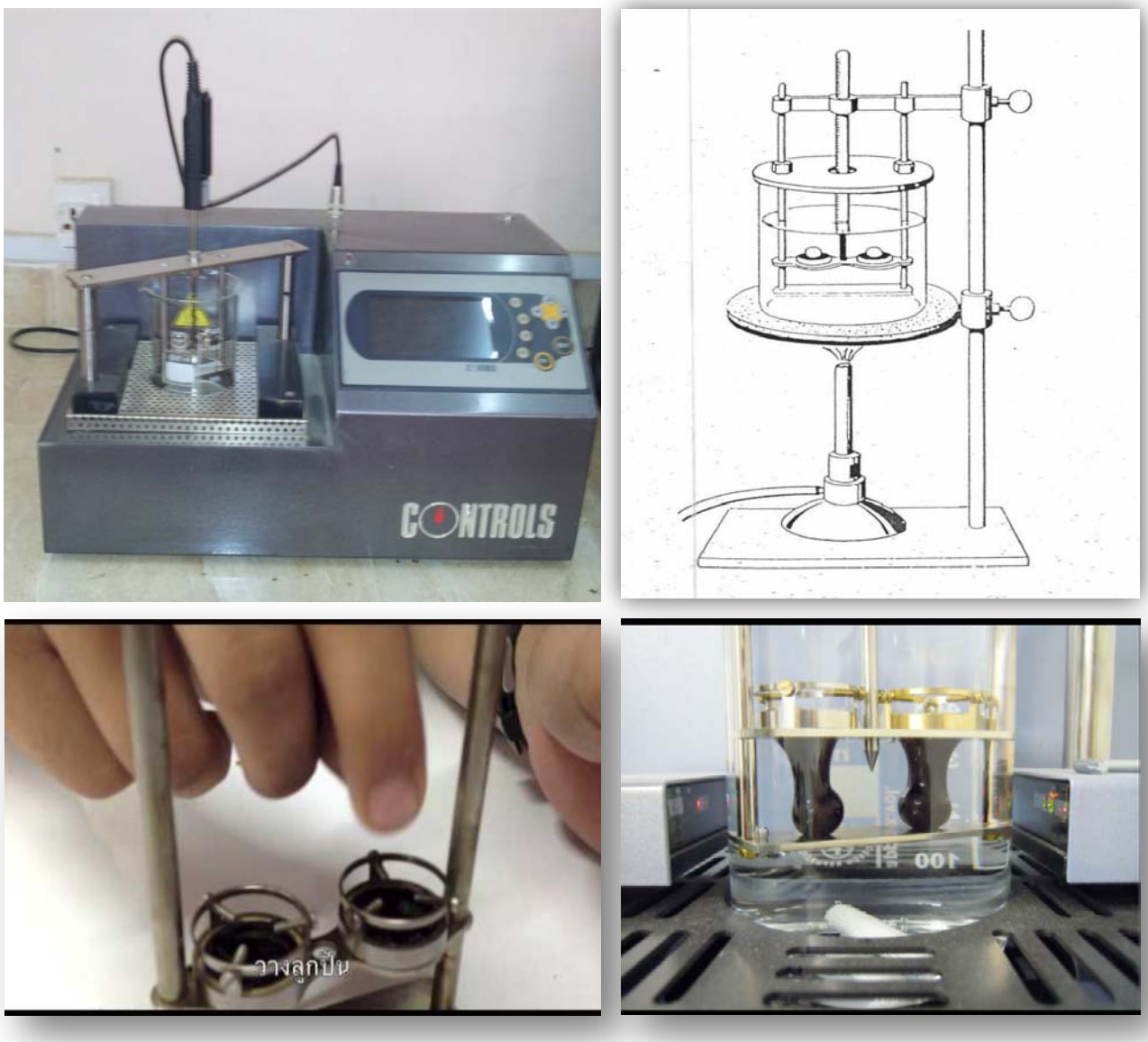

Figure (4-1) Softening point device

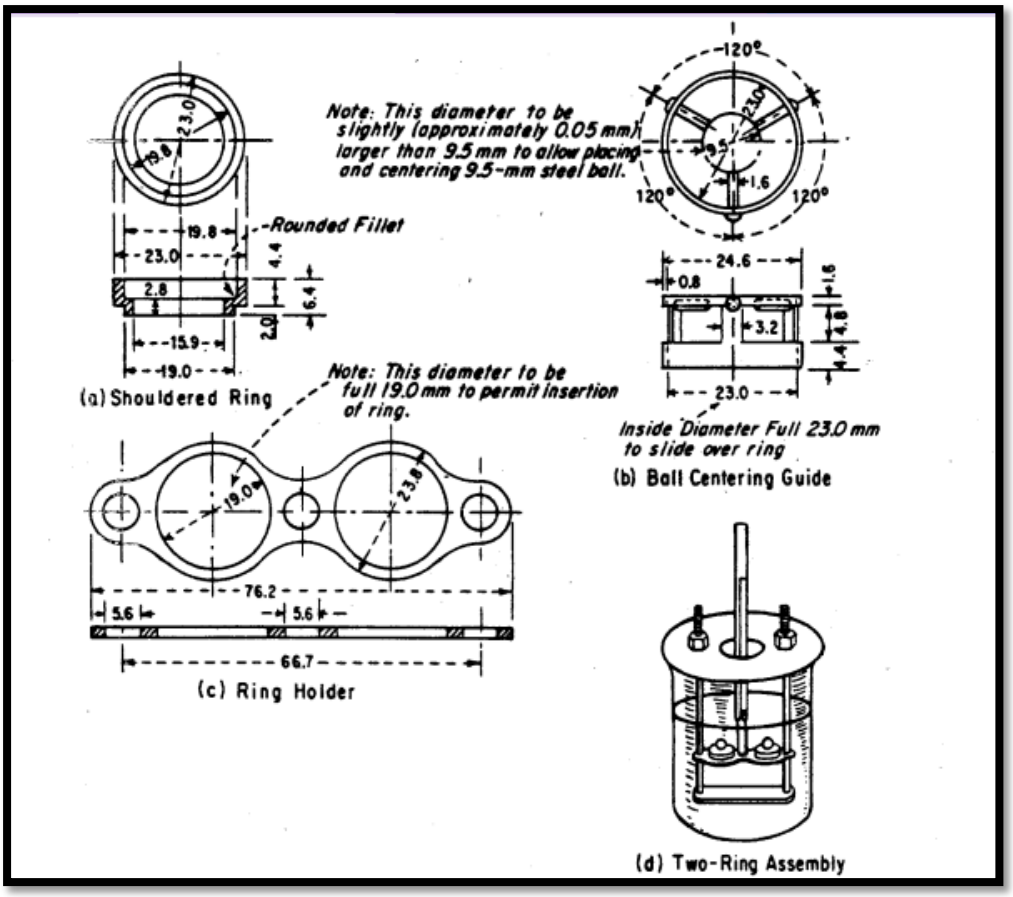

Figure (4-2) Softening point

Procedures:

1. Heat the sample to a temperature that does not exceed the expected softening point by more than 110°C and time must not exceed 2 hours.
2. Pour a heated sample into the preheated ring which is resting on the pouring plate.
3. Cool the specimen for minimum of 30 min., then cut the excess material off by a hot knife of spatula.
4. Assemble the apparatus with the ring and thermometer and fill the container with distilled water to a depth (102-108) mm.
5. Maintain the container temperature at (5 ±1) °C for 15 min. place the test container in ice water if necessary.
6. Using forceps place the balls previously adjusted to 5 °C then apply heat so that the temperature of the liquid is raised 5°C/ min. The maximum variation for any 1 min after the first 3 min. shall be 0.5 °C.
7. Record the temperature shown by the thermometer at the instant the ball touches the bottom.

Results and Calculations:

1. Report the temperature to the nearest 0.5 °C for each ball.
2. The average of the two readings is the softening point.
3. The difference between two tests must not be more than 1.5 °C.
4. Calculate the penetration index (PI) from:-

$$\frac{\mathbf{20 - PI}}{\mathbf{10 + PI}} = \mathbf{50} \times \frac{\mathbf{\log(800) - \log(Pen.)}}{\mathbf{T_{rb} - T}}$$

Where:-

PI = Penetration index
Pen. = Penetration value
T_{rb} = softening point value (°C)
T = Penetration test temperature = 25 °C.

Discussion:

1. Importance of softening point test and penetration index.
2. Find the value of PI, and then compare it with the specifications.
3. Explain the relation between penetration and softening point under the effect of temperature.
4. What is the representation of using the balls in the test?
5. If you have two types of bitumen, which they have softening points of 55°C and 60 °C ; which one is most affected by temperature, why? Explain that.

Working Sheet

University of Technology **Building and Construction Engineering Department** **Highways and Bridges Engineering Branch** **Asphalt Laboratory**	**Softening Point Test** **According to:** **ASTM D36- 95** **AASHTOT53- 06**	**Test No.4**	

Grade of Bitumen :

Ball No.	Softening Point (°C) = the temperature at which the ball touches the bottom	Average Softening point (°C)
1		
2		

Date **Tested by** **Student Name**

Test No. 5

Saybolt Viscosity Test

Prepared by/ Dr. Zaynab Ibrahim

Asphalt Laboratory Supervisor

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Building and Construction Engineering Department
University of Technology

Test No. 5
Saybolt Viscosity Test

Objective :

- Empirical procedure for determining saybolt viscosity of petroleum products at specified temperature (21-99) □C.

References: ASTM D88-99 : *"Standard test method for Saybolt viscosity*".

Main principles :

Saybolt viscosity - Efflux time in seconds of 60 ml. of sample flowing through a calibrated orifice under specified condition.

a. **Saybolt Universal Viscosity "SUV"**
   Determined using an orifice of (1.76 ± 0.015) mm in diameter used for lubricants and distillates with efflux time greater than 32 sec. and less than 1000 sec.
   The viscosity value is reported in Saybolt Universal seconds, abbreviated SUS, at a specified temperature.
b. **Saybolt Furol Viscosity "SFV"**
   Determined using an orifice of (3.15 ± 0.02) mm in diameter used when "SUV" value is greater than 1000 sec.
   The viscosity value is reported in Saybolt Furol seconds, abbreviated SFS, at a specified temperature.
   The "SFV" is approximately one tenth the "SUV".

Apparatus:

1. Saybolt furol viscosity test assembly as Fig. (5-1). The details as Fig. (5-2)
2. Receiving flask, Fig. (5-3)
3. Thermometer
4. Stop watch

Figure (5-1) Saybolt furol viscosity test

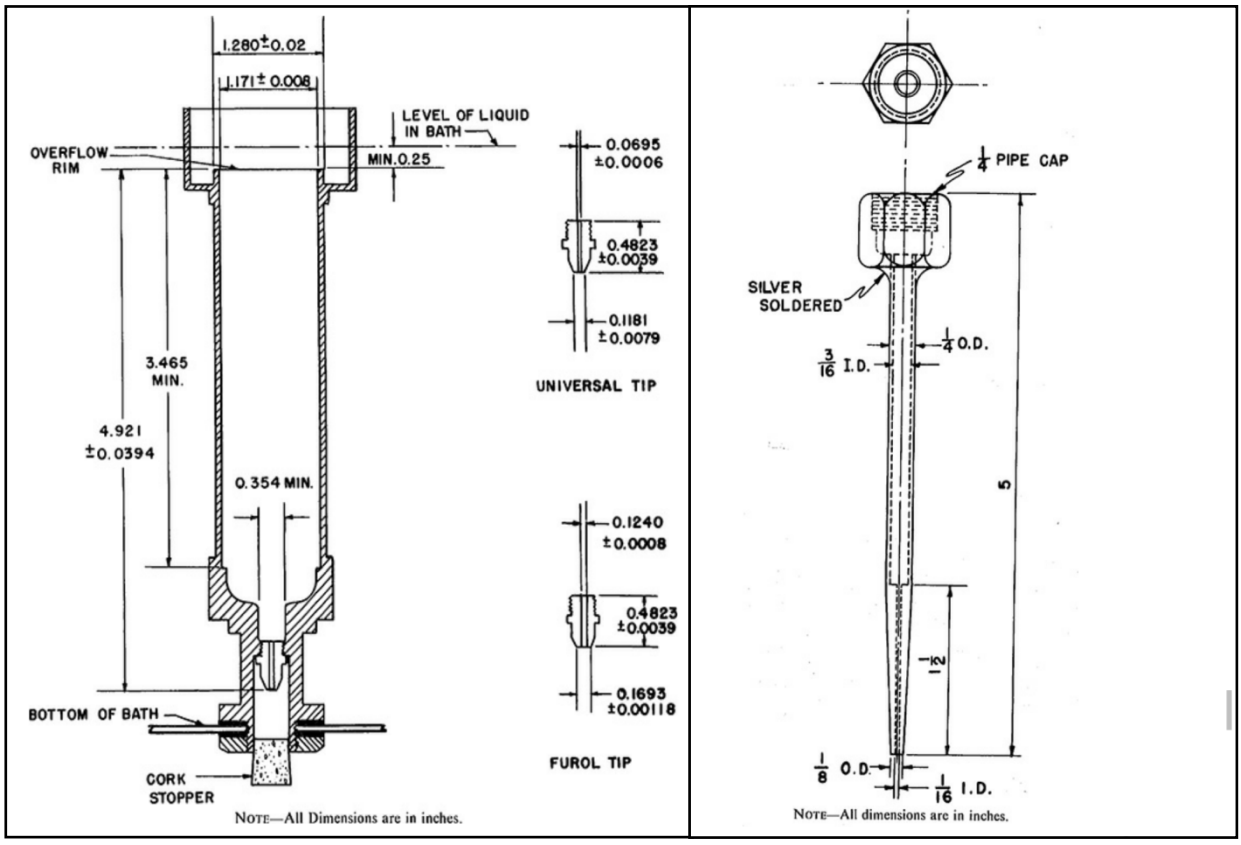


Figure (5-2) Saybolt viscometer with universal and furol orifice

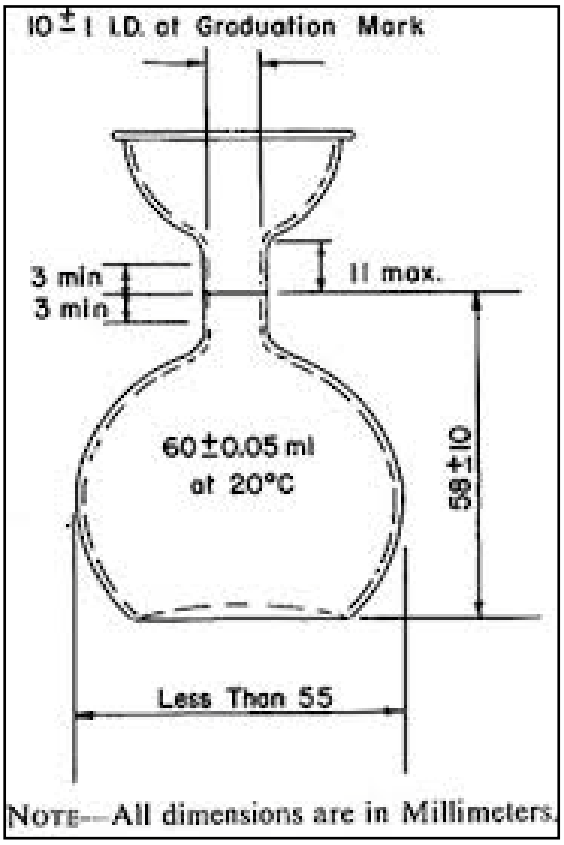


Figure (5-3) Receiving flask

Preparation of Apparatus:

1. Clean viscometer and receiving flask thoroughly with appropriate solvent.
2. Place the receiving flask beneath the viscometer so that the graduation mark on the flask is from (100-130) mm. below the bottom of the viscometer tube.
3. Fill the bath to at least 6 mm. above the over flow rim of the viscometer, the bath media used is water or oil for test temperature less than 98 □C and oil for higher test temperature.

Procedures :

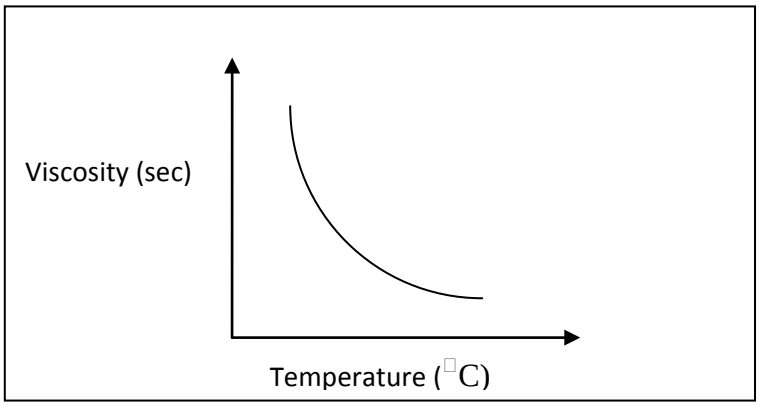
1. Establish and control bath temperature.
2. Insert a cork stopper at the bottom of the viscometer.
3. Preheat the sample to not more than 1.7°C above test temperature, and 28 °C of its flash point.
4. Stir the sample and strain it through sieve No. 100 directly into the viscometer.
5. Stir the sample in the viscometer with the thermometer, use a circular motion at (30to 50) rpm in a horizontal plane. Remove thermometer when the temperature remains constant within 0.03°C of the test temperature during one minute of continuous stirring.
6. Place the tip of the withdrawal tube in the gallery at a point and apply suction to remove oil until its level in the gallery is below the over flow rim.
7. Place the receiving flask in its proper position.
8. Snap the cork and start the timer.
9. Stop the timer the instant the bottom of the oil meniscus reaches graduation mark.
10. Record the efflux timer in seconds to the nearest 0.1 sec. This will be the viscosity.

Results:

1. Report the time in seconds to the nearest 0.1 sec. and the test temperature in °C.
2. To draw the relationship between viscosity and temperature, arrange a table contains (temperature and efflux time) as follows:-

Test number	Temperature °C	Efflux time (viscosity) sec.

3. Draw the curve, it must be as shown below



4. The viscosity, in centistokes can be calculated using this equation:

$$\eta = 0.22\theta - 180 / \theta \qquad \text{when, } 30 < \theta < 500$$

or

$$\eta = 0.216\theta \qquad \text{when, } \theta > 500$$

Where: η = viscosity in centistokes

θ = viscosity in SUS

Discussion:

1. Importance of Saybolt viscosity test.
2. What is the effect of temperature on viscosity?
3. What is used in the bath media of viscosity test? Why?
4. Set another method to determine the viscosity.
5. What is the theoretical meaning of viscosity of material?
6. What is the relation between penetration and viscosity? Explain that.

Working Sheet

University of Technology **Building and Construction Engineering Department** **Highways and Bridges Engineering Branch** **Asphalt Laboratory**	**Saybolt Viscosity Test** **According to:** **ASTM D 88- 99**	**Test No.5**	

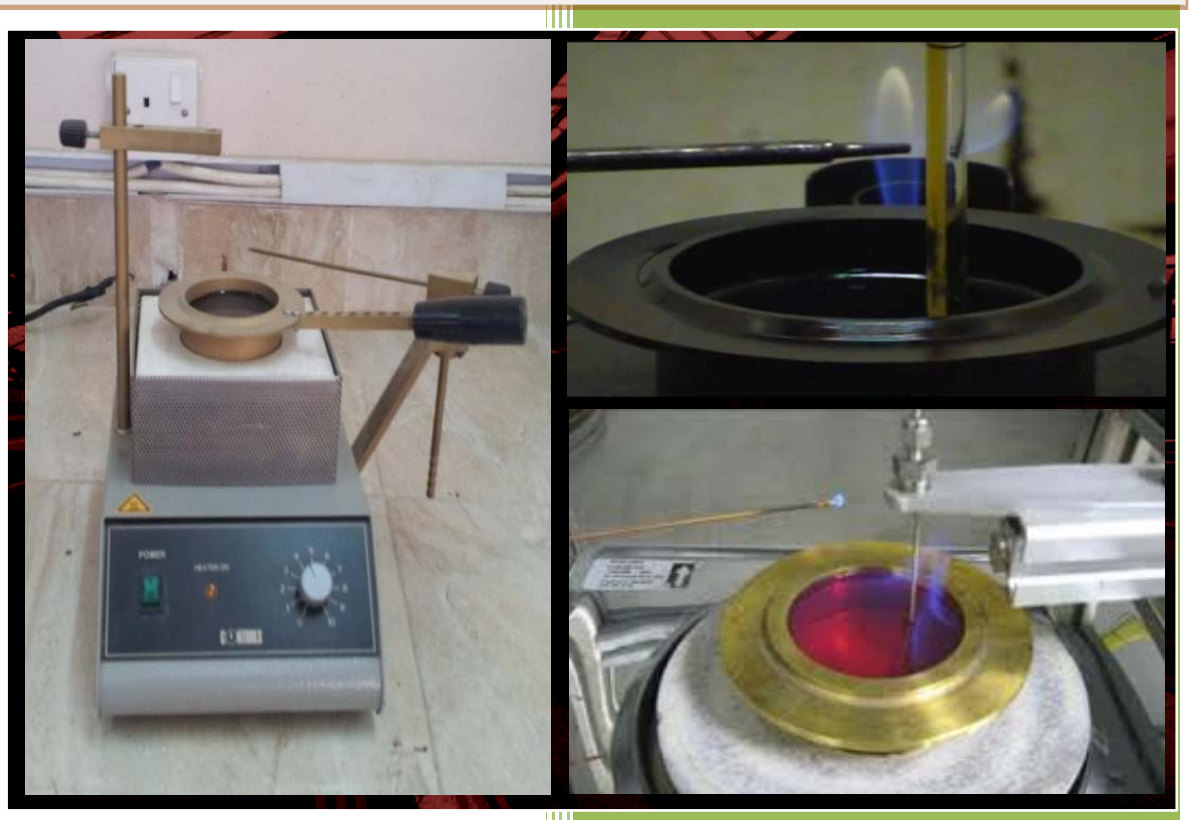
Grade of Bitumen :

Viscometer No.	Testing Temperature	Efflux Time [SUV,SFV]		Kinematic Viscosity "centistokes" (cSt)
		(min)	(sec)	

Date **Tested by** **Student Name**

Test No. 6

Flash and Fire point Test



Prepared by/ Dr. Zaynab Ibrahim

Asphalt Laboratory

Test No. 7

Flash and Fire Point Test

Objectives :

- To determine the flash and fire points of all petroleum products, except fuel oils and materials having an expected flash point below 79 °C.
- The flash and fire points indicate the materials combustibility. The fumes from the material at the flash point temperatures are explosive.

Definitions :

1. Flash point: the lowest temperature corrected to a barometric pressure of 760 mm Hg at which application of the flame causes the vapor of specimen to ignite under specified conditions of test.
2. Fire point: the lowest temperature at which a specimen will sustain burning for 5 sec.

Test Condition:

For petroleum products except fuel oils and materials having an expected flash point below 79 °C.

References : ASTM D92-99 and AASHTO T 48-96 *"Standard test method for flash and fire points using Cleveland open cup".*

Apparatus:

1. Cleveland open cup- apparatus Fig. (6-1)
   A. Test cup
   B. Test flame applicator
   C. Heater
   D. Support
   E. Shield for wind protection
2. Thermometer

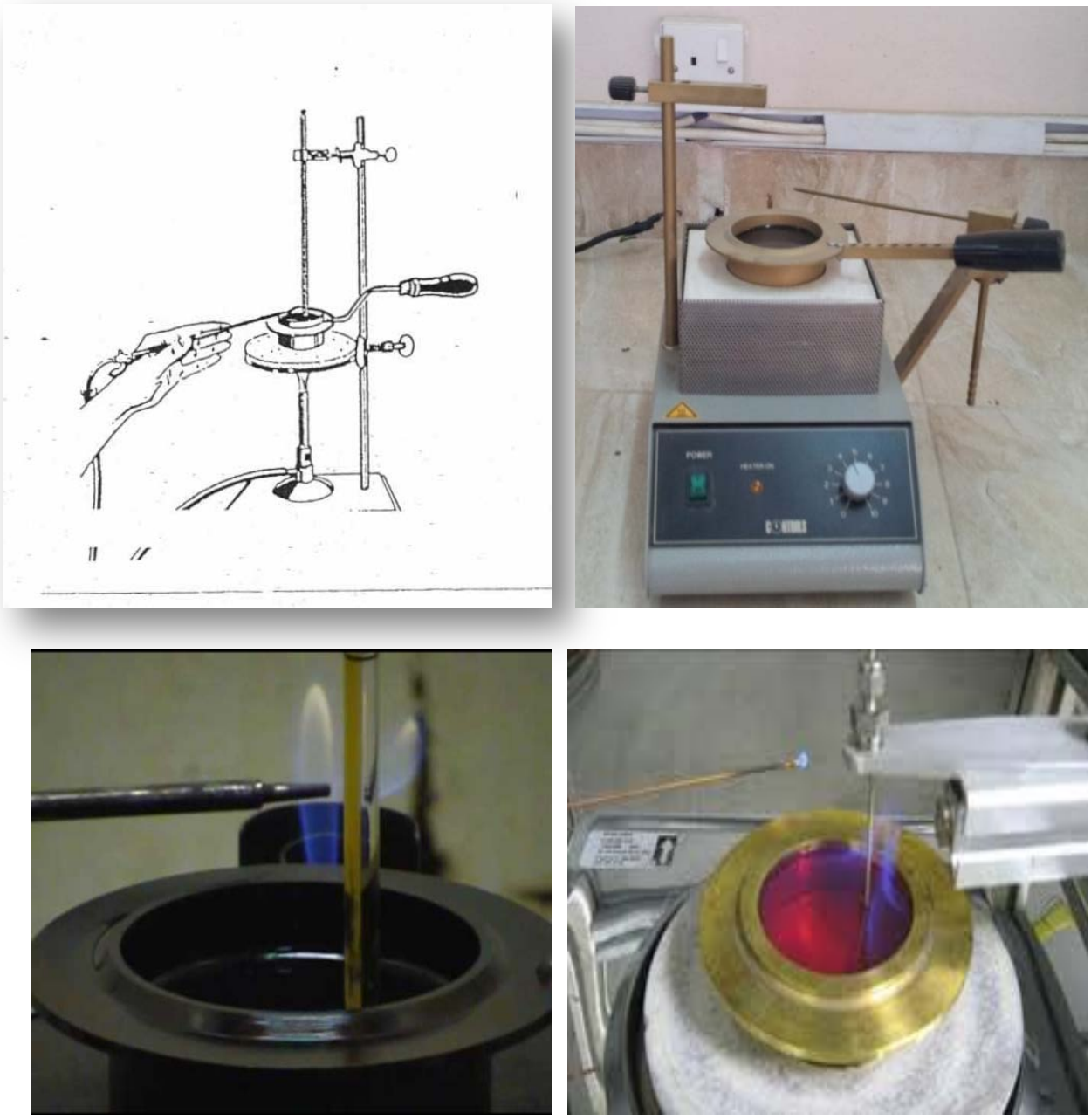


Figure (6-2) Burning the surface of the sample

Procedures :

1. Full the cup by asphalt to the filling line. The temperature of the material should be as low as possible, and the maximum 56 °C below the expected flash point temperature.
2. Apply heat initially so that the rate of temperature rise of the sample is (14 to 17) °C/min. when the sample temperature is approximately 56 °C below the anticipated flash point. Decrease the heat so that the rate of temperature rise of the last 28°C before the flash points is (5-6) °C.
3. Apply the test flame when the temperature becomes at least 28°C below the flash point. Across the center of the cup Fig. (6-1).
4. Record the temperature reading on the thermometer when a flash appears at any point on the surface of the sample.
5. To determine the fire point, continue heating until the surface of the sample burns for at least 5 sec. as shown in Fig. (6-2).

Results:

1. Report the flash point °C.
2. Report the fire point °C.
3. Correct the flash and fire point according to barometric pressure at the time of test as following:

$$\text{Corrected flash or fire point} = C + 0.033\,(760-P)$$

where:
C = observed flash or fire point, °C,
P = ambient barometric pressure, mm Hg

Discussion:

1. Importance of “Flash and fire points test” and uses?
2. Define the “Flash and fire points”, which one appears first?
3. Is the value of flash and fire points within the specifications? Explain that.

Working Sheet

University of Technology **Building and Construction Engineering Department** **Highways and Bridges Engineering Branch** **Asphalt Laboratory**	**Flash and Fire Point Test** **According to:** **ASTM D92- 99** **AASHTOT48- 96**	**Test No.6**	

Grade of Bitumen :	
Flash Point (°C)	
Fire Point (°C)	
Barometric Pressure, mm Hg	
Corrected Flash and Fire Point	

Date **Tested by** **Student Name**

Test No. 7

California Bearing Ratio CBR Test

Prepared by/ Dr. Zaynab Ibrahim

Asphalt Laboratory

Test No. 7

California Bearing Ratio CBR Test

Objective :

- CBR number is used to rate the performance of soil primarily used as a bases, subbases and subgrades beneath of roads and airfields.

Definition:

It is determining the bearing ratio of a soil by penetrating a piston with a fixed diameter at a specified speed in the soil sample.

Main Principles:

- This method covers the laboratory determination of the California Bearing Ratio (CBR) of a compacted sample of soil.
- The CBR value is the resistance to a penetration of 2.5 mm of a standard cylindrical plunger of 50 mm diameter, expressed as a percentage of the known resistance of the plunger to 2.5 mm in penetration in crushed aggregate.

References : ASTM D1883-99 *:"Standard test method for California bearing ratio of laboratory compacted soil, CBR test ".*

Theory of the Test:

The CBR number is obtained as the ratio of unit load required to cause a certain depth of penetration of the penetration piston into a compacted specimen of soil at a certain water content and density to the standard unit load required to obtain the same depth of penetration on a standard sample of crushed stone.

In equation form CBR is given as:-

California Bearing Ratio (CBR) %

$$= \frac{Stress\,for\,0.1"(2.54\,mm)\,or\,0.2"(5.08mm)\,penetration\,for\,soil}{Stress\,for\,0.1"(2.54\,mm)\,or\,0.2"(5.08mm)\,penetration\,for\,standard\,crushed\,stone} \times 100$$

The stresses for standard crushed stone corresponding to the penetration values are given in Table (7-1).

Penetration (mm)	Standard unit load	
	Mpa	Kg / cm^2
2.5	6.9	69
5.0	10.3	103
7.5	13.0	130
10.0	16.0	160
12.7	18.0	180

Note: The CBR number is usually based on the load ratio for penetration 2.54 mm. If CBR value for penetration of 5.08 mm value is larger; the test is entirely repeated on fresh specimens, if the new percentage value at 5.08mm penetration is still greater, then the CBR number at 5.08mm penetration value is used for design purposes.

Apparatus:

1. Loading machine – capacity 44.5 KN, with
   a. Movable head which rotate at a uniform rate of 1.27 mm/ min.
   b. Penetration piston with across sectional area of 1935 mm^2.
   c. Two dial gauges reading to 0.025 mm or 0.001" one for the load and the other for the penetration.
2. Mold 152 mm diameter, 178 mm height with extension collar of 51 mm height, Fig. (7-1).
3. Spacer disk having 151 mm diameter and 61.4 mm height.
4. Hammer 24.5 N or 44.5 N weights.
5. Two surcharge weight of 4.54 kg for each one, and 149.23 to 150.81 mm diameter with a center hole of 53.98 mm.
6. Miscellaneous apparatus. See Fig. (7-2).

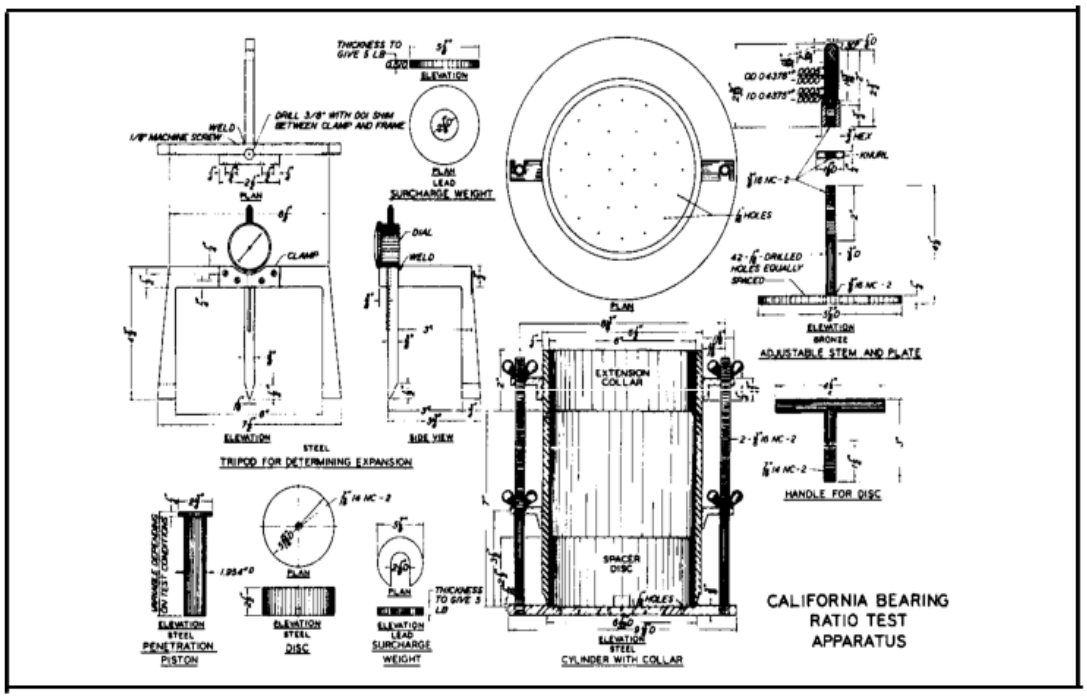
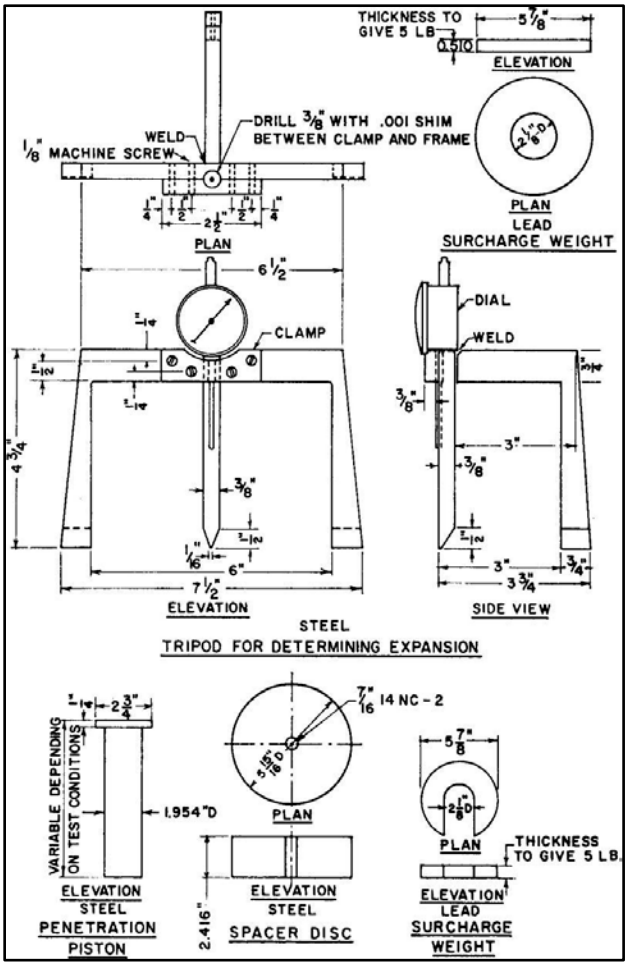


Figure (7-1) Molds of California Bearing Ratio Test apparatus



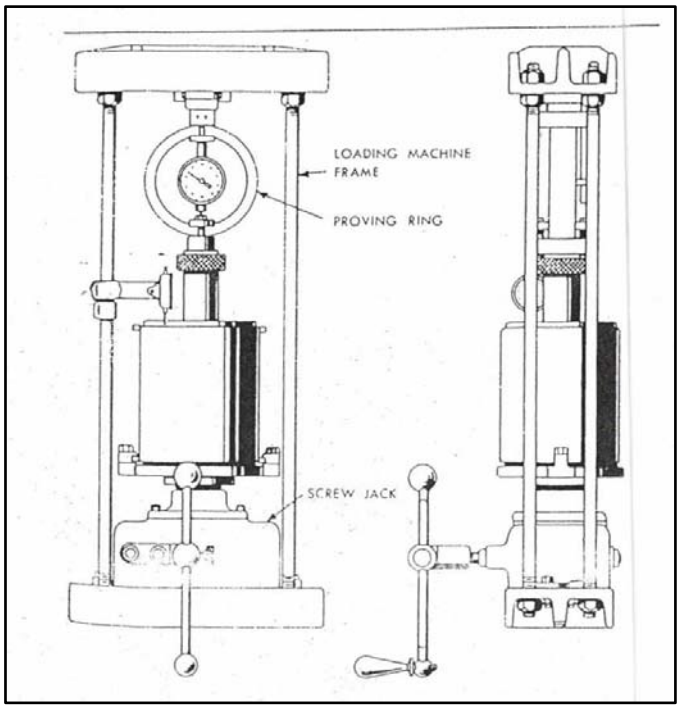


Figure (7-2) California Bearing Ratio Test apparatus

Procedures:

A. Molding test specimen

1. Record the weight of the empty mold = W_1
2. After drying the soil, weight about 5.25 kg from it, then sift it from sieve No.4.
3. Mix the soil with an amount of water needed to bring it to the design moisture content.
4. Apply the amount of wet soil in the steel CBR mold with attached collar in five equal layers, each layer being compacted 56 blows using compacted hammer.
5. Detach the extension collar, and then remove the exceeding part of soil using spatula.
6. Record the weight of the mold containing compacted soil as W_2.

B. Testing

1. After compaction the sample is subjected to a surcharge weight equivalent to the estimated weight of flexible pavement expected. Annular weights each equivalent to 63.5 mm of flexible pavement height are used for this purpose.
2. Place the specimen in compression machine and seat the piston using seating load and penetration dials to zero.
3. Arrange a table containing the applied loads for each 0.025 mm penetration.
4. Penetration test is accomplished in a compression machine using a strain rate of 1.27 mm / min. Record readings of load vs. penetration in the data sheet.
5. Extrude the sample and take a representative water content sample.

Note: In practice an initial seating load is applied to the plunger before the loading and penetration gauges are set to zero and this seating load is then neglected in subsequent calculations.

- Cross sectional area of the piston = 1935.5 mm^2
- Weight of the soil = 5250 gm
- Weight of the empty mold W_1 = (gm)
- Weight of the mold with the wet compacted soil W_2 = (gm)
- Volume of the mold = volume of compacted soil V = (cm^3)

$$V\ (cm^3) = \left(\frac{15.2}{2}\right)^2 \times \pi \times (17.8 - 6.14)$$

Penetration		Load		Stress
Inches	**mm**	**kg**	**N**	**N/mm^2**
0	0			
0.025	0.64			
0.05	1.27			
0.075	1.9			
0.1	2.54			
0.125	3.18			
0.15	3.81			
0.175	4.45			
0.2	5.08			
0.225	5.71			
0.25	6.35			
0.3	7.62			
0.35	8.89			
0.4	10.16			
0.45	11.48			
0.5	12.79			
0.55	13.97			
0.6	15.00			

Weight of empty tin W_3 = (gm)

Weight of (tin + wet soil) W_4 = (gm)

Weight of (tin + dry soil) W_5 = (gm)

Results and Calculations:

1. Plot a stress – penetration curve for the data just obtained as in example No.1 of Fig. (7-3).
2. If the curve is not essentially linear through the origin, extend a line from the straight – line portion to intersect the abscissa. The difference between this value and zero penetration is a correction to apply to compute the CBR value as in example No.2 of Fig. (7-3).
3. Determine the value of moisture content (m.c)

$$\text{m.c (\%)} = \frac{w_w}{w_S} = \frac{w_4 - w_5}{w_5 - w_3}$$

Where:

W_w: weight of water (gm)

W_s: weight of dry soil (gm)

$$\gamma = \frac{W}{V} = \frac{W_2 - W_1}{V}$$

Where:

W: weight of the wet compacted soil (gm)

γ: density of soil (gm/cm^3)

The CBR ratio of the soil is then obtained by reading off from the curve the load (stress) which causes penetration of 2.54 mm and dividing this value by the load (stress) required to produce the same penetration in the standard crushed stone mixture. At the same time the load causing a penetration of 5.08 mm is determined and divided by stress causing the same penetration in crushed stress stone.

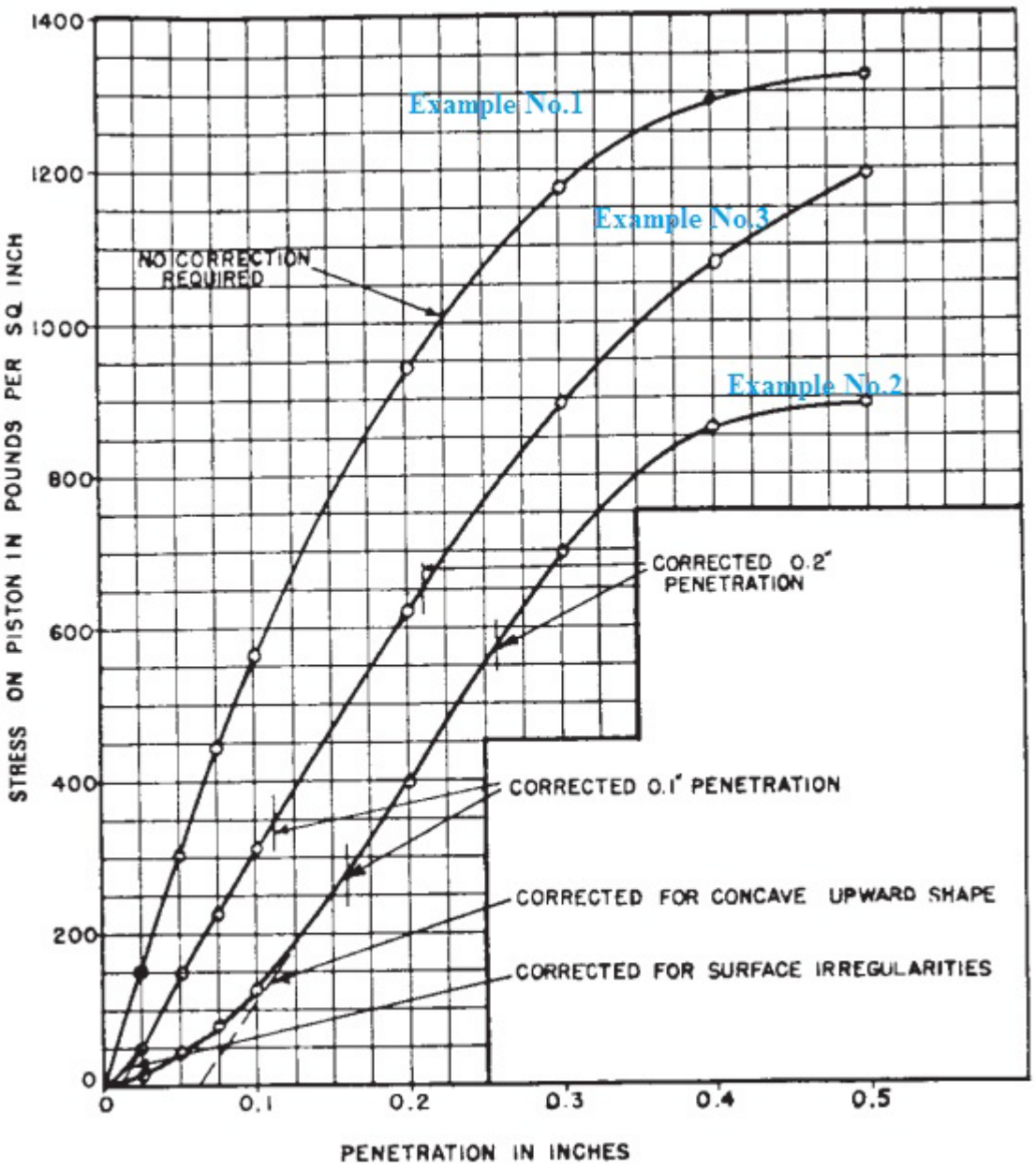


Figure (7-3) Correction of load - penetration curve

Discussion:

1. Importance of the test.
2. Which of basic properties of soil is represented by CBR test?
3. How could the CBR value be used in pavement design? Explain with an example.
4. Does this test simulate the field conditions? If not, what are the points of dissimilarity? List them.
5. The reason of applying surcharge weights above the sample of the soil before testing?
6. The reason of mixing the dry soil with water before testing? and How can that affect the value of CBR?
7. What is the reason of compacting the soil before testing?
8. Why, in normal the value of CBR at penetration of 2.54 mm is greater than the value of CBR at a penetration of 5.08 mm.
9. How can we get a relative compaction RC > 100?
10. How can we improve the soil?

Working Sheet

University of Technology **Building and Construction Engineering Department** **Asphalt Laboratory**	**CALIFORNIA BEARING RATIO (CBR) TEST** **According to:** **ASTM D 1883- 99**	**Test No.7**	

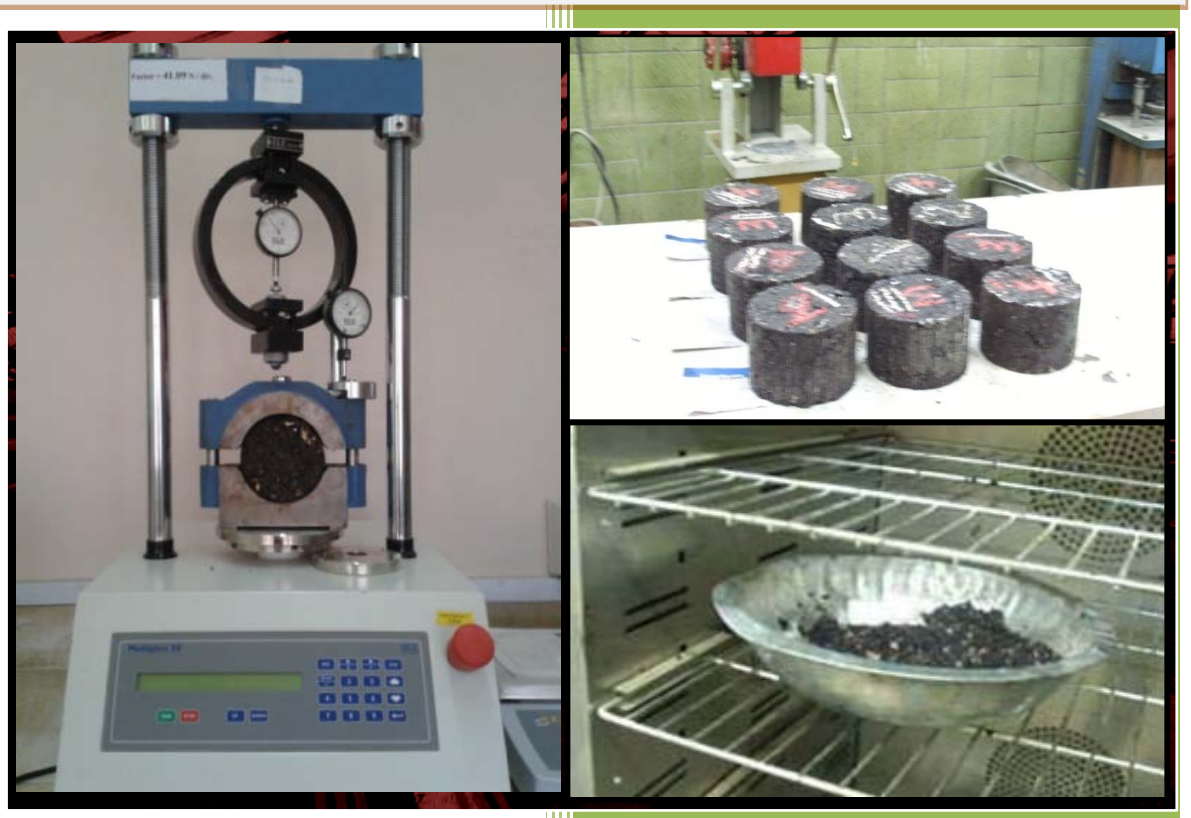
Penetration of plunger mm	Force gauge reading div		Force on plunger kN			Penetration of plunger mm	Force gauge reading div		Force on plunger kN	
	Top	Bottom	Top	Bottom			Top	Bottom	Top	Bottom
0						4.00				
0.25						4.25				
0.50						4.50				
0.75						4.75				
1.00						5.00				
1.25						5.25				
1.50						5.50				
1.75						5.75				
2.00						6.00				
2.25						6.25				
2.50						6.50				
2.75						6.75				
3.00						7.00				
3.25						7.25				
3.50						7.50				
3.75						7.75				

Container No.					**CBR Value at penetration of 2.5mm 5.0mm**	
M2 =Mass of wet soil+ container (gm)					**Top**	**%**
m_3 = Mass of dry soil + container (gm)						
m_1 = Mass of container (g)					**Bottom**	**%**
m_2-m_3 = Mass of moisture (g)						
m_3-m_1 = Mass of dry soil (g)						
Moisture content % $\text{m.c}' = \left(\frac{m_2 - m_3}{m_3 - m_1}\right)100$					**Accepted CBR %**	
Average moisture content (%)						

Date **Tested by** **Student Name**

Test No. 8

Marshall Test



Prepared by/ Dr. Zaynab Ibrahim

Asphalt Laboratory Supervisor

ASPHALT LABORATORY
Building and Construction Engineering Department
University of Technology

Test No. 8

Marshall Test

Objective :

- The objective of Marshall Mix design procedure is to find the optimum binder content in the mix .

References : ASTM D 6926 -10 : *"Standard test method for resistance to plastic flow of bituminous mixture using Marshall Apparatus ".*

Definitions:

It is essentially an unconfined compression test in which a cylindrical specimen is compressed in a special cylindrical test – head, with a constant rate of 50.8 mm/min.

This test is used for with mixtures containing asphalt cement; asphalt cut – back or tar and aggregate up to 25.4 mm maximum.

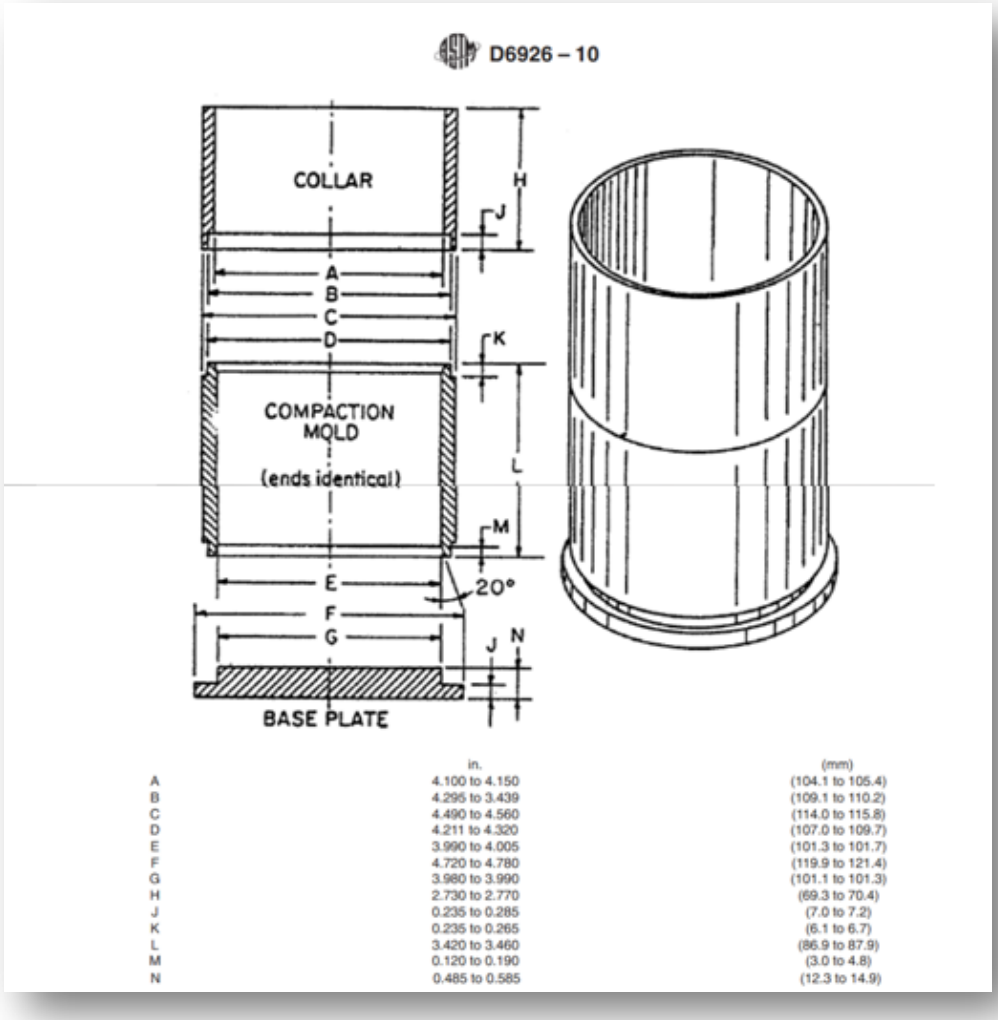
Main principles :

- The binder content is varied in steps of typically 0.5% around an assumed optimum binder content.
- The binder content is determined which best complies with Marshall stability, flow, void content, voids filled with binder and density requirements for the mix being investigated.

Apparatus:

1. Specimen mold 101.6 mm diameter and 76.2 mm height with extension collar and base plate, see Fig. (8-1)
2. Specimen extractor
3. Compaction hammer 4.536 kg weight, 457.2 mm drop, see Fig. (8-3)
4. Specimen mold holder
5. Breaking head

6. Ring dynamometer assembly
7. Flow meter
8. Oven or hot plate
9. Mixing bowls
10. Water bath
11. Water tank balance, see Fig. (8-2)
12. Thermometers
13. Miscellaneous apparatus, see Fig. (8-3)



	in.	(mm)
A	4.100 to 4.150	(104.1 to 105.4)
B	4.295 to 3.439	(109.1 to 110.2)
C	4.490 to 4.560	(114.0 to 115.8)
D	4.211 to 4.320	(107.0 to 109.7)
E	3.990 to 4.005	(101.3 to 101.7)
F	4.720 to 4.780	(119.9 to 121.4)
G	3.980 to 3.990	(101.1 to 101.3)
H	2.730 to 2.770	(69.3 to 70.4)
J	0.235 to 0.285	(7.0 to 7.2)
K	0.235 to 0.265	(6.1 to 6.7)
L	3.420 to 3.460	(86.9 to 87.9)
M	0.120 to 0.190	(3.0 to 4.8)
N	0.485 to 0.585	(12.3 to 14.9)

Figure (8-1) Marshall Compact mold

Figure (8-1) Water tank balance

Figure (8-3) Compaction hammer &Marshall apparatus

Procedures:

1- Preparation of Materials :

1. Prepare at least three specimens for each combination of aggregate and bitumen content. Each specimen at least requires 1200 g of mixtures.
2. Preparation of aggregate:
   Dry aggregate to constant temperature of (105 - 110) □C and separate the aggregate by dry sieving into the desired size fractions, as shown in Table (8-1) and Fig. (8-4).
3. Preparation of liquid asphalt:
   Specify the required temperature for asphalt heating that makes asphalt viscosity 170 ± 20 centistokes for mixing and 280 ±30centistokes for compacting , as shown in Fig. (8-5).

Table (8-1) Bituminous Mixture Grading for Wearing Course (Type III A) (Maximum Aggregate Size 19.0 mm).

According to Iraqi Specification for Roads & Bridges (2003)

Sieve size		SORB Specification % passing	Blending % our choice	Retaining %	Weight of aggregate (gm)					
					Asphalt cement (% by total weight of mix)					
in.	mm				4	4.5	5	5.5	6	6.5
"3/4	19	100	100	0	0	0	0	0	0	0
"1/2	12.5	90-100	95	5	57.6	57.3	57	56.7	56.4	56.1
"3/8	9.5	76-90	83	12	138.24	137.52	136.8	136.0	135.3	134.6
#4	4.75	44-74	59	24	276.48	275.04	273.6	272.1	270.7	269.2
#8	2.36	28-58	43	16	184.32	183.36	182.4	181.4	180.4	179.5
#50	0.3	5-21	13	30	345.6	343.8	342	340.2	338.4	336.6
#200	0.075	4-10	7	6	69.12	68.76	68.4	68.04	67.68	67.32
Pan				7	80.64	80.22	79.8	79.38	78.96	78.54
Weight of total mix (gm)					1200	1200	1200	1200	1200	1200
Weight of aggregate (gm)					1152	1146	1140	1134	1128	1122
Weight of asphalt (gm)					48	54	60	66	72	78

Figure (8-4) Separated aggregate by dry sieving into the desired size fractions

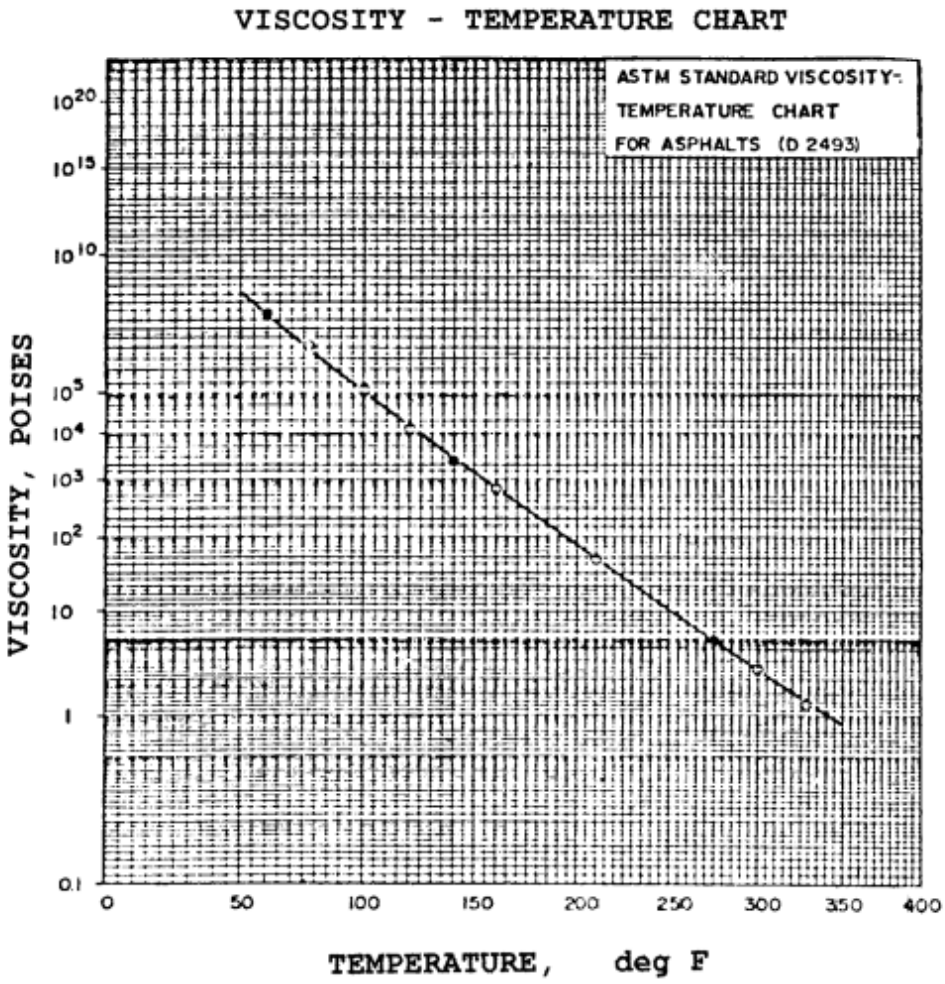


Figure (8-5) viscosity- temperature chart

2- Preparation of specimens:

1. Weight into separate pans for each test specimen the amount of each size fraction required to produce with result in compacted (63.5±1.27) mm in height and 101 mm in diameter (about 1200 gm).
2. Place the pans on the hot plate or in the oven and heat to a temperature not exceeding the mixing temperature by more than approximately 28 □C for asphalt cement and tar mixes, and 14□C for cutback asphalt mixes.
3. Charge the mixing bowl with the heated aggregate and dry mix thoroughly.
4. Form a crater in the dry blended aggregate and weight the preheated required amount of bituminous material into the mixture. At this point the

temperature for the aggregate and bituminous material shall be within the limits of the mixing temperature.

5. Thoroughly clean the specimen mold assembly and the face of compaction hammer and heat them on the hot plate to a temperature of (93.3 - 148.9) °C. Place a paper toweling cut to size in the bottom of the mold before the mixture introduced.
6. Place the entire batch in mold.
7. Place the mold assembly on the compaction pedestal in mold holder; apply 75 blows with the compaction hammer falling 457.2 mm distance, perpendicularly to the base of the mold.
8. Remove the base plate and collar. Reverse and reassemble the mold.
9. Apply the same number of compaction blows to the face of the reversed specimen.
10. After compaction, remove the base plate and let the sample be free by using the specimen extractor.

3- Testing of specimens:

1- Carefully transfer the specimen to a smooth, flat surface and allow it to stand overnight at a room temperature. Weight, measure and test the specimen.
2- Bring the specimen to the specified temperature by immersing them in the water bath (30-40) min. at (60±1) °C.
3- After drying the specimen put it in the testing machine. Apply the load to the specimen by means of constant rate of movement of the testing machine head of 50.8 mm/min until the maximum load is reached, and the load decreases as indicated by the dial gauge. Fig. (8-6).
4- Record the maximum load noted on the testing machine.
5- Record the flow value at the maximum load reading.
6- The elapsed time for the test from removal of the specimen from water bath to the maximum load deformation shall not exceed 30 sec.

Figure (8-6) Marshall test

Data obtained:

Arrange a table containing the following data:-

Group No.	Binder (%)	Average height of specimen (mm)	Weight of specimen in air (gm)	Weight of basket in water (gm)	Weight of basket + sample in water (gm)	Stability KN	Flow (mm)

Where:

- Stability: maximum load sustained by the specimen at 60 °C.

$$Measured\ stability\ (KN) = stability\ reading \times F$$

Where:

F : the instrument constant

$$Corrected\ stability\ (KN) = measured\ stability \times correction\ ratio$$

To get correction ratio use Table (8-2).

- Flow: deformation corresponding to maximum load resistance of the standard specimen at 60 °C.

$$Measured\ flow = flow\ reading \times 0.001 \times 25.4$$

Flow reading = No. of division

Each division = 0.001"

1" = 25.4 mm.

Notes:

- Measured stability of a specimen multiplied by the ratio of the specimen thickness equals the corrected stability for 63.5 mm (2 ½ in) specimen.
- Volume – thickness relationship is based on a specimen diameter of 101.6 mm (4 in).

Table (8-2) Stability Correction Ratios

Volume of Specimen (ml)	Approximate Thickness of specimen		Correction Ratio
	mm	inch	
200 - 213	25.4	1	5.56
214 - 225	27.0	1 1/16	5.00
226 - 237	28.6	1 1/8	4.55
238 - 250	30.2	1 3/16	4.17
251 - 264	31.8	1 ¼	3.85
265 - 276	33.3	1 5/16	3.57
277 - 289	34.9	1 3/8	3.33
290 - 301	36.5	1 7/16	3.03
302 - 316	38.1	1 ½	2.78
317 - 328	39.7	1 9/16	2.50
329 - 340	41.3	1 5/8	2.27
341 - 353	42.9	1 11/16	2.08
354 - 367	44.4	1 ¾	1.92
368 - 379	46.0	1 13/16	1.79
380 - 392	47.6	1 7/8	1.67
393 - 405	49.2	1 15/16	1.56
406 - 420	50.8	2	1.47
421 - 431	52.4	2 1/16	1.39
432 - 443	54.0	2 1/8	1.32
444 - 456	55.6	2 3/16	1.25
457 - 470	57.2	2 ¼	1.19
471 - 482	58.7	2 5/16	1.14
483 - 495	60.3	2 3/8	1.09
496 - 508	61.9	2 7/16	1.04
509 - 522	63.5	2 ½	1.00
523 - 535	64.0	2 9/16	0.96
536 - 546	65.1	2 5/8	0.93
547 - 559	66.7	2 11/16	0.89
560 - 573	68.3	2 ¾	0.86
574 - 585	71.4	2 13/16	0.83
586 - 598	73.0	2 7/8	0.81
599 - 610	74.6	2 15/16	0.78
611 - 625	76.2	3	0.76

Calculations:

1. Find bulk unit weight (γ) from:

   γ (gm / cm^3) = $\frac{W_a}{V} = \frac{W_a}{W_a - W_w}$

   Where:

   W_a: weight of specimen in air (gm)

   W_w: weight of specimen in water (gm)

   V: volume of specimen = volume of displaced water (cm^3).

2. Determine % of air void by determining maximum theoretical unit weight (ψ) :

   Ψ (gm / cm^3) = $\frac{W_a}{V_b + V_c + V_f + V_{mf}}$

   $$= \frac{W_a}{W_b \times G_b + W_c \times G_c + W_f \times G_f + W_{mf} \times G_{mf}}$$

   then determine % void in total mix (i.e. in specimen)

   % V.T.M = $\frac{\Psi - \gamma}{\Psi} \times 100$

   Where:

   V_b, W_b, G_b = Volume (cm^3), Weight (gm) and specific gravity (gm/cm^3) of binder

   V_c, W_c, G_c = Volume (cm^3), Weight (gm) and specific gravity (gm/cm^3) of course aggregate

   V_f, W_f, G_f = Volume (cm^3), Weight (gm) and specific gravity (gm/cm^3) of fine aggregate

   V_{mf}, W_{mf}, G_{mf} = Volume (cm^3), Weight (gm) and specific gravity (gm/cm^3) of mineral filler

   V.T.M = Voids in total mix.

   Taking:

   G_b = 1.02 gm/cm^3

   G_c = 2.64 gm/cm^3

   G_f = 2.66 gm/cm^3

   G_{mf} = 2.85 gm/cm^3

Note: specific gravity values of the aggregate (G_c, G_f, G_{mf}) are the apparent and not bulk specific gravity, i.e. volumes of permeable void in aggregate are excluded from calculation, i.e. it is assumed that voids are filled with binder material.

3. For every specimen, determine % voids filled with binder

$$V.M.A = V - V_c - V_f - V_{mf}$$

$$= \frac{W}{\gamma} - \frac{W_c}{G_c} - \frac{W_f}{G_f} - \frac{W_{mf}}{G_{mf}}$$

Where:

V.M.A = void in mineral aggregate (cm^3)

$$\% \text{ V.M.A} = \frac{V.M.A}{V} \times 100$$

Where:

$$V = \frac{W_a}{\gamma}$$

$$\% \text{ V.F.B} = \frac{V_b}{V.M.A} \times 100$$

Where:

$$V_b = \frac{W_b}{G_b}$$

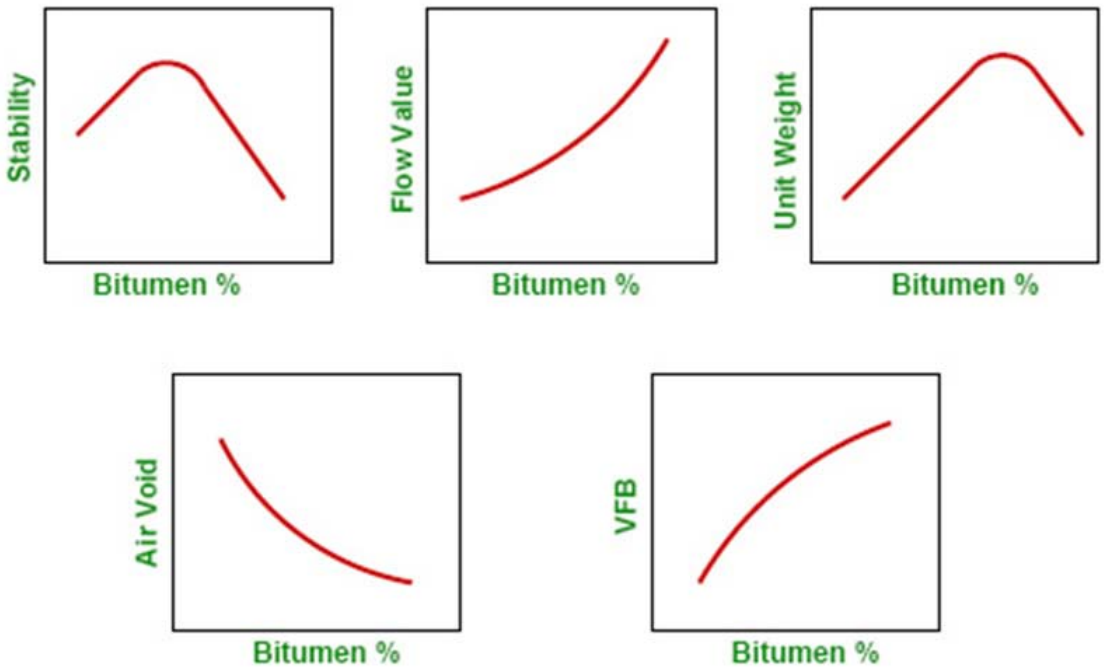
or

$$\% \text{ V.F.B} = \frac{\%V.M.A - \%V.T.M.}{\%V.M.A} \times 100$$

4. Arrange a table containing the following data:-

Group No.	Binder (%)	γ (kg/m^3)	(V.T.M.) %	(V.F.B.) %	Corrected stability (KN)	Flow (mm)

5. From the previous data draw curves between (binder content) and the following:
    a. Corrected stability (KN)
    b. Marshall Flow (mm)
    c. % of voids in total mix V.T.M. (%)
    d. % of voids filled with binder V.F.B. (%)
    e. Unit weight γ (gm / cm^3).



6. Find the optimum binder content from the drown curves to get mixture containing 4% voids in total mix as follow:

$$\text{O.B.C} = \frac{{}^{b}/_{c}(max.stability) + {}^{b}/_{c}(max.\gamma) + {}^{b}/_{c}(V.T.M.\%)}{3}$$

Where:-

O.B.C. = optimum binder content.

${}^{b}/_{c}\,(max.stability)$ = binder content at maximum stability.

7. Determine the max. characteristics at the optimum binder content (stability, flow, %V.T.M. & % V.F.B.).
8. Compare the value you get with SORB specifications shown in Table (8-3)

Table (8-3) SORB specifications

Property	Wearing Course	Binder Course	Base Course
Stability	> 8 KN	> 7 KN	> 5 KN
Flow	(2 - 4) mm	(2 - 4) mm	(2 - 5) mm
% V.T.M.	(3 - 5) %	(3 - 7) %	(3 - 7) %
% V.F.B.	(70 - 85) %	(60 - 80) %	----------

Discussion:

1. What is the importance of the test?
2. What is the meaning of (stability, flow, % V.T.M.,Ψ)?
3. What are the specifications of the aggregate used?
4. What is the reason of preheating of the aggregate before mixing it with asphalt?
5. Explain the relation between stability, flow and %Ac.
6. What are the elements that affect the value of flow and stability?
7. How can we obtain the best ratio of asphalt?

Working Sheet

University of Technology **Building and Construction Engineering Department** **Highways and Bridges Engineering Branch** **Asphalt Laboratory**	**Marshall Test** **According to:** **ASTM D 6926 -10**	**Test No.8**	

Group No.	Binder %	Average height of specimen (mm)	Weight of specimen in air (gm)	Weight of basket in water (gm)	Weight of basket + sample in water (gm)	Stability (KN)	Flow (mm)

Group No.	Binder %	γ (kg/m3)	(V.T.M.) %	(V.F.B.) %	Corrected stability (KN)	Flow (mm)

Date **Tested by** **Student Name**