AL-BAHA UNIVERSITY
FACULTY OF ENGINEERING
CIVIL ENGINEEING DEPARTMENT

TRAFFIC AND TRANSPORTATION LABORATORY MANUAL

جامعة الباحة
Al-Baha University

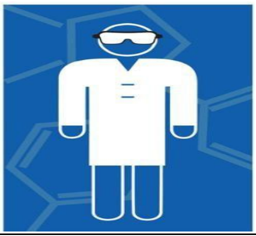
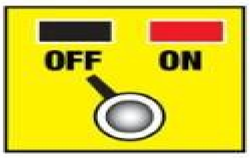
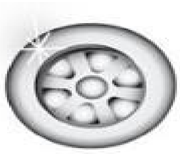
2006

BU

CIVIL ENGINEERING DEPARTMENT
2024

Table of Contents	

General Safety Guidelines:

Rule	Guideline/Prohibition	Rationale
1	No Eating, Drinking, or Chewing Gum	To maintain a sterile and safe environment. 
2	No Smoking in the Laboratory Area	To safeguard the laboratory and its occupants. 
3	Dress Appropriately	Appropriate attire for personal safety and experiment integrity. 
4	Conduct Yourself Responsibly	Maintain a focused and serious atmosphere. 
5	Hazard Symbols Awareness	Identify potential dangers in the laboratory. 
6	Equipment Shutdown	Conserve energy and prevent equipment damage. 
7	Equipment Cleaning	Promote equipment longevity and prevent cross-contamination. 
8	Maintain Cleanliness	Ensure a safe, efficient, and well-maintained laboratory. 

SAFETY FIRST

(General Administration of Safety and Risks)

الإدارة العامة للسلامة والمخاطر

Phone: 0177257700 - 15424

Email: safety@bu.edu.sa

(Important Phone Number)

ارقام مهمة

رقم التلفون	الجهة	رقم التلفون	الجهة
933	طوارئ الكهرباء Electricity Emergency	999	الشرطة Police
939	طوارئ المياه Water Emergency	998	الدفاع المدني Fire Department
937	استشارة طبية Medical advice	997	الاسعاف Red Crescent
911	الدوريات الأمنية Emergency Number	996	امن الطرق Roads Security
980	مكافحة الفساد Corruption (Nazaha)	993	المرور Traffic

Traffic and transportation laboratory

- **Introduction**

The traffic and transportation lab is one of the main labs at the Civil Engineering Department of Al-Baha University. The lab is concerned with the characteristics of highway materials including soil, aggregate, asphalt, and hot asphalt mixes. The main objective of this lab is to enable students to critically evaluate the characteristics of highway materials by running the appropriate experimentation and designing the flexible pavement structure. The laboratory of highway material represents an integral part of the theoretical component of the course of highway material and pavement design. It gives the students the chance to run the experiments by themself and gain self-confidence to work in the field.

- **Objectives**

1. To enable students to critically evaluate the characteristics of highway materials: This is done through a variety of hands-on experiments, such as tests for the basic properties of asphalt, soil, and aggregate, as well as the design of hot mixes asphalt.
2. To provide students with the necessary skills to run the needed tests, interpret results, and extract the basic inputs required for flexible pavement design.
3. To prepare students for careers in civil engineering: The skills and knowledge that students gain in the lab are essential for a career in civil engineering, particularly in the areas of transportation and pavement design.
4. To contribute to the development of the transportation infrastructure in Saudi Arabia: By training the next generation of civil engineers, the lab is helping to ensure that Saudi Arabia has the infrastructure it needs to support its growing population and economy.

- **Report Writing and Grade Distribution**

Use the report template provided in Appendix (A) as a guide. The distribution of lab report grades will be as follow:

Part of the Report	Weight (%)
Summary	5
Introduction and objectives	15
Methodology	15
Test results	15
Analysis, Discussion and Conclusions	40
References	5
Neat Production	5
TOTAL	100

Notes:

1. Absolutely no late reports are accepted.
2. A 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.

- **Lab. Experiments**

The following table presents a list of the experiments needed for the course of Structural Pavement Design along with brief objectives. The detail test procedures can be obtained from standard test methods (either ASTM or AASHTO) mentioned in the last column in the next table. The details of these tests are also presented in the following table:

Name of Experiment	Objectives	Procedures According to:
Standard compaction test or Modified compaction test	To find the optimum water content and max dry density of the compacted soil.	• AASHTO T-99 or ASTM D698 • AASHTO T-180 or ASTM D1557
California Bearing ratio.	CBR is used to evaluate the performance of soil mainly used as a bases, sub-bases, and subgrades beneath of roads and airfields.	AASHTO T-193 or ASTM D1883
Field density by sand cone.	To evaluate the quality of field compaction by finding the field dry density and compare it to Lab max dry density to determine the DOC.	AASHTO T-191 or ASTM D1556
Specific gravity and absorption test for coarse aggregate.	To find the bulk and apparent specific gravity of aggregate along with percent of absorption.	AASHTO T-85 or ASTM C127
Abrasion test for aggregate by Los Angeles machine.	To evaluate the performance of aggregate against toughness and abrasion resistance.	AASHTO T-96 or ASTM C131
Soundness of aggregate.	To determine the aggregate's resistance to disintegration by weathering and, in particular, freeze-thaw cycles.	AASHTO T-104 or ASTM C88
Penetration test for asphalt cement.	Used to measure consistency of bituminous materials under specific conditions of loading, testing time and temperature.	ASHTO T-49 or ASTM D5

Name of Experiment	Objectives	Procedures According to:
Softening point (ring and ball) test for asphalt cement.	The main objective is to measure and specify the temperature at which bituminous binders begin to show fluidity. It is also a measure of consistency for air-blown asphalt.	AASHTO T-53 or ASTM D36
Saybolt viscosity for liquid asphalt.	To determining saybolt viscosity of petroleum products at specified temperature.	AASHTO T-72 or ASTM D88
Flash and fire point by Cleveland open cup.	• 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.	AASHTO T-48 or ASTM D92
Marshall mix design:	The objective of Marshall Mix design procedure is to find the optimum binder content in the mix.	
Preparation of asphalt mixture specimens using Marshall apparatus.	As mentioned above	ASTM D 6926 -16
Bulk Specific Gravity Determination Gmb	As mentioned above	ASTM D 2726
Stability and flow test for compacted asphalt mixture.	As mentioned above	AASHTO T-245 or ASTM D5581
Maximum specific gravity test for loss asphalt mixture.	As mentioned above	AASHTO T-209 or ASTM D2041

MORE DETAILS IN APPENDIX (B)

Appendixes

A.Writing lab Report Template

Albaha University

Faculty of Engineering

Civil Engineering Department

Course # (……..)

Course Title: ……………………….

Semester: (…………………)

Instructor: …………………………….

Group ….

Experiment No. …….

Title of Experiment: …………………….

Names	ID.s
1.	

Date of Experiment: …………………

Time of Experiment…………………………….

Table of contents

Team meeting (Optional)

Introduction

Experimental design

Data

Calculations

Figures & Graphs

Results & Discussion

References

(Optional)

Meeting Minutes

Meeting#... of Report#...

Time: ....

Date: ....

Venue: ....

Attendants:

1) ....
2) ....
3) ....
4) ....

Agenda

Writing tasks that are taken before and during the meeting.

Discussion Taken

Writing down all objectives you will discuss in the meeting.

Actions Person Responsible

Writing the distribution of tasks between team members.

Introduction:

Usually, the Introduction is one paragraph that **explains the objectives or purpose of the lab**. In one sentence, state the hypothesis. Sometimes an introduction may contain background information, briefly **summarize how the experiment was performed**, state the findings of the experiment, and list the conclusions of the investigation. Even if you don't write a whole introduction, you need to state the purpose of the experiment, or why you did it. This would be where you state your hypothesis.

Experimental design

a) Materials

List everything needed to complete your experiment.

b) Equipment:

List everything needed to complete your experiment.

c) Methods

Describe the steps you took during your investigation. This is your procedure. Be sufficiently detailed that anyone could read this section and duplicate your experiment. Write it as if you were giving directions for someone else to do the lab. It may be helpful to provide a Figure to diagram your experimental setup.

Data:

Numerical data obtained from your procedure usually is presented as a table. Data encompasses what you recorded when you conducted the experiment. It's just the facts, not any interpretation of what they mean.

Calculations:

The Analysis section contains **any calculations you made based on those numbers**. This is where you interpret the data and determine whether a hypothesis was accepted.

Figures & Graphs

Graphs and figures must both be labeled with a descriptive title. Label the axes on a graph, being sure to include units of measurement.

Results & Discussion

Describe in words what the data means. Sometimes the Results section is combined with the Discussion (Results & Discussion).

Reference:

If your research was based on someone else's work or if you cited facts that require documentation, then you should list these references.

B. Experiments described as per Al-Baha University Curriculum for Traffic and Transportation laboratory.

SOIL TESTS

STANDARD AND MODIFIED PROCTOR COMPACTION TESTS

AASHTO T-99 or ASTM D698 and
AASHTO T-180 or ASTM D1557

Introduction:

Testing procedures for the standard and modified Proctor test procedures are the AASHTO T99 and T180 respectively. The corresponding ASTM testing procedures are D 698 and D 1557 respectively. The differences between AASHTO T99 and T180 are shown in Table 1.

Table 1. Differences Between AASHTO T99 and T180

	AASHTO T99 (Standard Proctor)	AASHTO T180 (Modified Proctor)
Hammer Weight	5.5 lbf	10 lbf
Drop Distance	12 inches	18 inches
Energy	12,400 ft-lbf/ft^3	56,000 ft-lbf/ft^3
Number of Layers	3	5

Objectives:

The general objectives of lab compaction is to determine the proper amount of mixing water to use when compacting the soil in the field and the resulting degree of denseness which can be expected from compaction at this optimum water.

For the same soil, the optimum moisture content (OMC) for a modified Proctor test is usually less than OMC for a standard Proctor test while maximum dry density is higher.

Summary of the methods:

Standard Proctor Testing

For each soil type, water was added to the soil to bring it to a predetermined moisture content percentage. Three layers of the soils then were compacted in a standard four-inch mold using an automatic standard Proctor hammer in accordance with AASHTO T99 (ASHTO D 698). The T99 procedure specifies a hammer weighing 5.5 pounds and a drop distance of 12 inches, which creates 12,400 ft-lbf/ft^3 of force.

Modified Proctor

The modified proctor is similar to the standard proctor; water was added to each soil sample to bring it to the desired moisture content. Five layers of the soil then were compacted in a standard four-inch mold using an automatic modified Proctor hammer in accordance with AASHTO T180 (ASTM D 1557). The T180 procedure specifies a hammer weighing 10 pounds and a drop distance of 18 inches, which creates 56,000 ft-lbf/ft^3 of force. The heavier hammer and lengthened drop distance significantly increase the compactive effort.

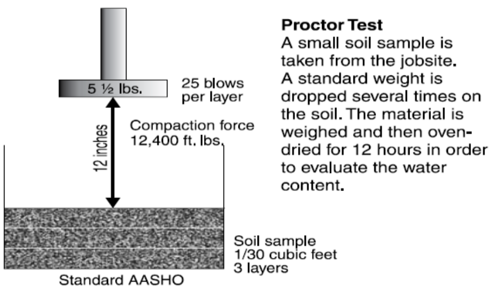
Specific Gravity

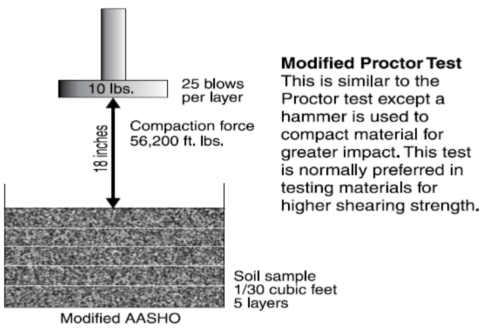
A small sample for each of the soils was taken to perform AASHTO T84 (ASTM C 128) procedures. Once the specific gravity was determined, it was used to plot a zero air voids (ZAV) curve as a reference for each soil's two compaction curves.

Equipment (see next figure)

1. Proctor mold with a detachable collar assembly and base plate.
2. Manual/automatic rammer.
3. Sample Extruder.
4. A sensitive balance.
5. Straight edge.
6. Squeeze bottle.
7. Mixing tools such as mixing pan, spoon, trowel, spatula etc.
8. Moisture cans.
9. Drying Oven.







Test procedure:

1. Obtain approximately 10 lb (4.5 kg) of air-dried soil in the mixing pan, break all the lumps so that it passes No. 4 sieve.
2. Add an approximate amount of water to increase the moisture content by about **5**%.
3. Determine the weight of empty proctor mould without the base plate and the collar. W1, (lb). (Row #1 of the table)
4. Fix the collar and base plate.
5. Place the first portion of the soil in the Proctor mould as explained in the class and compact the layer applying 25 blows.
6. Scratch the layer with a spatula forming a grid to ensure uniformity in distribution of compaction energy to the subsequent layer. Place the second layer, apply 25 blows, place the last portion and apply 25 blows.
7. The final layer should ensure that the compacted soil is just above the rim of the compaction mould when the collar is still attached.
8. Detach the collar carefully without disturbing the compacted soil inside the mould and using a straight edge trim the excess soil leveling to the mould.
9. Determine the weight of the mould with the moist soil W2, (lb). Extrude the sample and break it to collect the sample for water content determination preferably from the middle of the specimen.
10. Weigh an empty moisture can, W3, (g) and weigh again with the moist soil obtained from the extruded sample in step9, W4, (g). Keep this can in the oven for water content determination.
11. Break the rest of the compacted soil with hand (visually ensure that it passes US Sieve No.4). Add more water to increase the moisture content by 2%.
12. Repeat steps 4 to 11. During this process the weight W2 increases for some time with the increase in moisture and drops suddenly. Take two moisture increments after the weights starts reducing. Obtain at least 4 points to plot the dry unit weight, moisture content variation.
13. After 24 hrs recover the sample in the oven and determine the weight W5, (g).
14. Fill out the following table completely; Calculate rows 9 and 10, these two will give one point of the plot.

Notice that: The modified compaction procedure is similar to the above with a change in the compactive effort. The rammer used in the modified compaction is a **10 lb** with a height of drop of **18"**.

Calculations and Reporting the Results:

See Table 2

Table 2: The form for compaction test					
Test No.	1	2	3	4	5
1. Weight of the mold without the base and collar, W1, (lb)					
2. Weight of the mold + moist soil, W2 (lb)					
3. Weight of the moist soil, W2-W1, (lb)					
4. Moist unit weight, $\gamma = [(W2-W1)/(1/30)]$, (lb/ft3)					
5. Moisture can number					
6. Weight of moisture can, W3, (g)					
7. Mass of can + moist soil, W4, (g)					
8. Mass of can + dry soil, W5, (g)					
9. Moisture content: $w(\%)= [(W4-W5)/(W5-W3)] \times 100$					
10. Dry unit weight of compaction: γd (lb/ft3) $= \gamma t /[1+(w/100)]$					

CALIFORNIA BEARING RATIO TEST (CBR)

(AASHTO T-193 or ASTM D1883).

Objective:

The California Bearing Ratio (CBR) test is used to evaluate the quality of pavement subgrade, subbase, and base/course materials from laboratory compacted specimens.

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 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 cm^2) and capable of a penetration rate of 1.3 mm/min (0.05 in/min) (Figure 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.

3- Add the required amount of water so that the moisture content of the sample is within ±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 cm^3).

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 65 tamps.

Figure 1: Required equipment for the CBR test

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).

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

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 1.27mm 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- Convert loads applied to stress by dividing the load by the area of the piston. Then plot the stress 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 2 shows examples of corrected CBR curves.

3- From the obtained curve make a computation of the stress at the corrected penetration of 2.5mm and 5.0mm. The obtained values (in kg/cm2) are expressed as percentages of the standard stress of 1000 psi and 1500 psi respectively.

4- Calculate CBR as follows:

$$CBR\,(\%) = \frac{\text{Stress on soil at penertation of } 0.1\text{ inch } (2.5\text{ mm}) \text{ in specific units}}{\text{Standard stress in the same units}} \times 100$$

The standard stress at different units are shown in the next table.

	PSI	MPa	Kg/cm^2
Standard stress at 0.1 inch (2.5 mm) penetration	1000	6.9	69
Standard stress at 0.2 inch (5 mm) penetration	1500	10.5	105

Applying standard stresses shown in the table in case of using PSI unit, the expression well be as follow:

$$CBR\,(\%) = \frac{\text{Stress on soil at penertation of } 0.1\text{ inch}}{1000} \times 100$$

If stress used was in kg/cm^2 the expression will be as follow:

$$CBR\,(\%) = \frac{\text{Stress at } 2.5\text{mm penetration } (\text{kg/cm}^2)}{69} \times 100$$

$$CBR\,(\%) = \frac{\text{Stress at } 5.0\text{mm penetration } (\text{kg/cm}^2)}{105} \times 100$$

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.

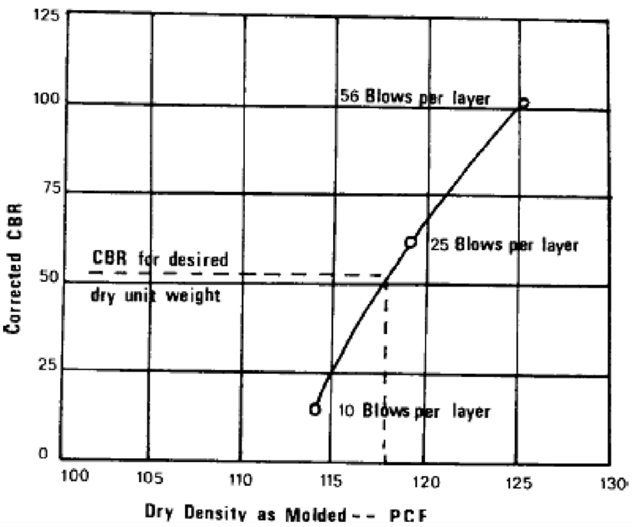
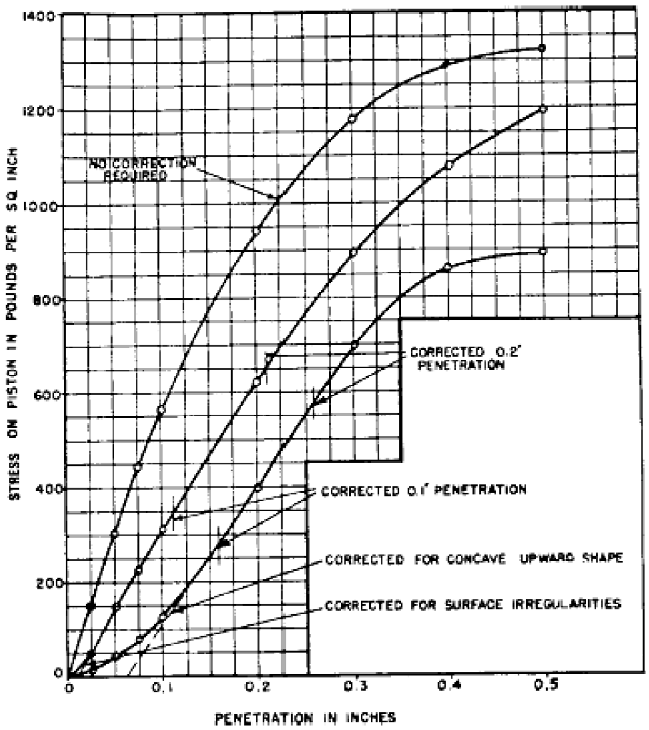


Figure 3 Dry density versus corrected CBR values.



example

Figure 2 Corrected CBR curves.

AGGREGATE TESTS

SPECIFIC GRAVITY OF COARSE AGGREGATE

AASHTO T 85 and ASTM C 127

Objective:

The objective of the test is to find the bulk and apparent specific gravity of aggregate along with percent of absorption.

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

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

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

Significance of the Test:

Specific gravity of aggregate is useful in:

1. Making weight-volume conversions.
2. Calculating the void content in a compacted HMA.

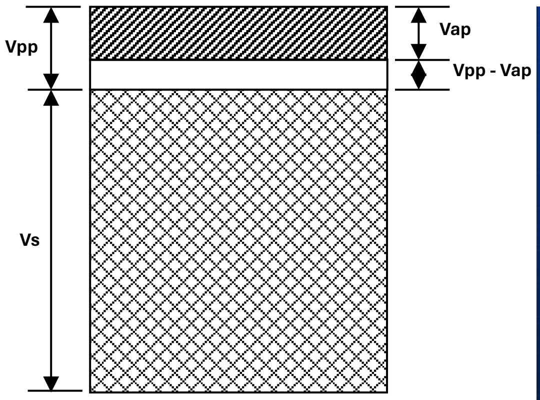
Scope:

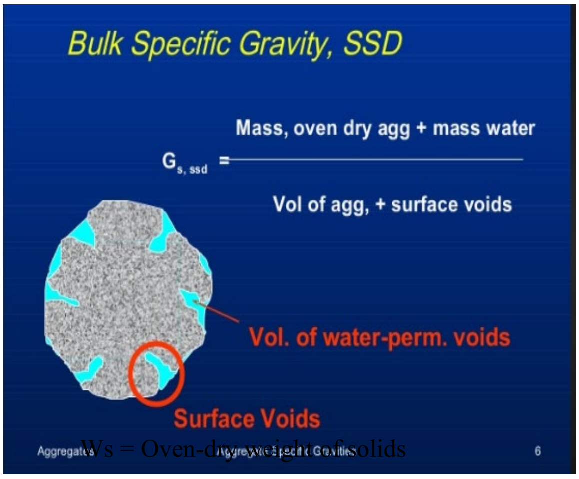
Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Water, at a temperature of 73.4°F (23°C) has a specific gravity of 1. Specific Gravity is important for several reasons. Some deleterious particles are lighter than the good aggregates. Tracking specific gravity can sometimes indicate a change of material or possible contamination. Differences in specific gravity may be used during production to separate the deleterious particles from the good using a heavy media liquid.

Specific gravity is critical information for the Hot Mix Asphalt Design Engineer. The value is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt (VFA). All are critical to a well performing and durable asphalt mix. Water absorption can also be an indicator of asphalt absorption. A highly absorptive aggregate may lead to a low durability asphalt mix.

A summary of the test procedure:

- 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**.
- Use the pervious equations to calculate the different specific gravity of aggregate.





Ws = Oven-dry weight of solids

γ_w= Unit weight of water = 1gm/cm^3

Vs = Volume of solids

Vpp = Volume of water permeable pores

Vap = Volume of pores absorbing asphalt

V pp - Vap = Volume of water permeable pores not absorbing asphalt

Apparent specific gravity = Gsa = Ws / (Vs * γ_w)

Relationship between the Different Specific Gravities of an Aggregate Particle

Apparatus (See Figure 1):

- Balance, conforming with class G5 (AASHTO M231)
- **The Specific** Gravity **Bench with 2**in (51mm) diameter holes in the top balance platform
- Sample container, wire basket of No. 6 (3.35 mm) or less mesh wire cloth, with a capacity of 1 to 1 3/4 gal. (4 to 7 L) to contain aggregate with a nominal maximum size of 1 1/2 in. (37.5 mm) or smaller; larger basket for larger aggregates.
- Water tank, watertight and large enough to completely immerse aggregate and basket, equipped with an overflow valve to keep water at a constant level.
- Suspended Apparatus, wire used to suspend apparatus with the smallest practical diameter. A hitest fishing leader or other thin wire with utility hook can be used with a small hook attached to the handle of the basket or sample container.
- Sieves, No. 4 (4.75 mm) or other size as needed, conforming to AASHTO M 92.

Procedure:

1. Thoroughly mix the sample and reduce the sample to the required size (Figure 2) in accordance with AASHTO T248 (Reducing Field Samples of Aggregate to Test Size). Use sample sizes as indicated in Table 1.

Table 1	
Nominal Maximum size	Min. sample weight
1/2 in. (12.5 mm)	4.4 lb (2 kg)
3/4 in. (19 mm)	6.6 lb (3 kg)
1 in. (25 mm)	8.8 lb (4 kg)
1 1/2 in. (37.5 mm)	11 lb (5 kg)
2 in. (50 mm)	18 lb (8 kg)
2 1/2 in. (63 mm)	26 lb (12 kg)
3 in. (75 mm)	40 lb (18 kg)
1/2 in. (12.5 mm)	4.4 lb (2 kg)

2. Dry sieve the sample through a No. 4 (4.75 mm) sieve and discard any material that passes the sieve (if a substantial amount of material passes the No. 4 (4.75mm) sieve, you may need to use a No. 8 (1.18 mm) sieve instead of the No. 4 (4.75 mm), or you may need to perform a specific gravity on the minus No. 4 (4.75 mm) material). Wash the aggregate retained on the No. 4 (4.75 mm) sieve.
3. Dry test sample to constant weight in an oven regulated at 230 ± 9°F (110 ± 5°C). Cool sample at room temperature for 1 to 3 hr. After the cooling period, immerse the aggregate in water at room temperature for a period of 15 hr.

4. Place entire sample in a container and weigh in water maintained at 73.4 ± 3°F (23 ± 1.7°C). Shake container to release any entrapped air and weigh on minimum diameter wire suspended below scale apparatus. Ensure that the water overflow outlet is working properly to compensate for the water displaced by the sample. Record to the nearest 1.0 g or 0.1% of total weight, whichever is greater, as the weight in Water (C).
5. Remove the sample from the container and drain any excess water from the aggregate. Using an absorbent cloth (an absorbent towel usually works best), roll the aggregate until the surface water has been removed (Figure 3). Rolling up the aggregate into the towel and then shaking and rolling the aggregate from side to side is also an effective procedure in reducing the sample to an SSD (saturated, surface-dry) condition.

   An SSD condition is one in which the aggregate has no FREE water on the surface of the aggregate. If the test sample dries past the SSD condition, immerse the sample in water for 30 minutes and resume the process of surface-drying.

6. Weigh SSD sample to nearest 1.0 g or 0.1% of the total weight, whichever is greater and record this as SSD weight.
7. Dry the sample in a pan to a constant weight in an oven set at 230 ± 9°F (110 ± 5°C). Cool in air at room temperature for 1 to 3 hr, or until the aggregate can be comfortably handled. Record weight to nearest 1.0 g or 0.1%, whichever is greater, as oven dry weight.

Calculations:

Determine calculations based on appropriate formula.

A = Oven dry weight, B = SSD weight, C = Weight in water

Bulk Specific Gravity (Gsb) = A / (B-C)

Bulk SSD Specific Gravity (Gsb SSD) = B / (B-C)

Apparent Specific Gravity (Gsa) = A / (A-C)

Absorption (% Abs) = [(B-A) / A] x 100

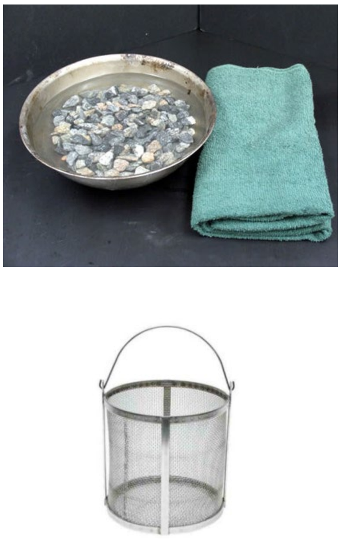


Figure 1: The Equipment used in the test

Figure 3: Water overflow outlet

Figure 2: Reducing sample to test size

ABRASION OF AGGREGATE BY USE OF THE LOS ANGELES ABRASION TESTING MACHINE

(ASTM C131 for fine agg. & **ASTM C535** for coarse agg.)

Objective:

To evaluate the performance of aggregate against toughness and abrasion resistance.

Scope:

This test method describes the procedure used to determine the resistance of coarse aggregate to impact in a rotating cylinder containing metallic spheres. This test is also known as the Los Angeles Rattler Test.

Summary of the method:

The Los Angeles Rattler test is a measure of degradation of mineral aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres (dependent upon the test sample's grading). As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, causing an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate impacts and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

Apparatus (Figure 1):

- Los Angeles Abrasion Machine - See AASHTO T 96 specifications.
- Sieves - Standard, 300mm (12") dia., 4.75mm (#4) and 1.70mm(#12) sieves conforming to the requirements of AASHTO M 92.
- Balance - Conforming to the requirements of AASHTO Designation M231 (Class G5 or better) with a readability and sensitivity of 1 gram and an accuracy of 1 gram or 0.1%.
- Oven - For drying samples capable of maintaining a temperature of110 ± 5 °C (230 ± 9 °F).
- Charge - Shall consist of steel spheres averaging approx. 46.8mm (127/32") in diameter and each weighing between 390 and 445g.
- The abrasive charge, depending upon the grading of the test specimen and as shown in next table.

Grading	No of spheres
A	12
B	11
C	8
D	6
E	12
F	12
G	12

Note:

Steel ball bearings 46.0mm (1 13/16") and 47.6mm (1 7/8") in diameter, weighing approximately 400 and 440geach, respectively, are readily available. The charge may consist of a mixture of these three sizes provided that the individual spheres conform to the 395 - 445g limits and that the total charge conforms to the requirements in Section1210.4.

Preparation of test specimen:

1. Wash dirty or coated aggregate and dry to constant weight. Cool the aggregate to room temperature before preparing the test specimen.
2. Select the grading from Table 1 or Table 2 most nearly representative of the aggregate furnished for the work. Separate the aggregate on the required sieve sizes.

   Prepare the test specimen using the weight of each sieve size fraction specified for the grading selected. Determine and record the weight of the prepared test specimen to the nearest 1 g.

Table 1: Fine aggregate grading ASTM C131					
Sieve size (inch)		Weight in g for each grading			
Passing	Retained on	A	B	C	D
1½	1	1250 ± 25			
1	3/4	1250 ± 25			
3/4	1/2	1250 ± 25	2500 ± 10		
1/2	3/8	1250 ± 25	2500 ± 10		
3/8	1/4			2500 ± 10	
1/4	No. 4			2500 ± 10	
No. 4	No. 8				5000 ± 10
Total Weight		5000 ± 10	5000 ± 10	5000 ± 10	5000 ± 10

Table 2: Coarse aggregate grading ASTM C 535				
Sieve size (inch)		Weight in g for each grading		
Passing	Retained on	E	F	G
3	2.5	2500 ± 50		
2.5	2	2500 ± 50		
2	1.5	5000 ± 50	5000 ± 50	
1.5	1		5000 ± 50	5000 ± 50
1	3/4			5000 ± 50
Total Weight		10000 ± 50	10000 ± 50	10000 ± 50

Basic Procedure:

1. Obtain the aggregate sample to be tested and reduce the sample to adequate size (Sampling).
2. Wash the sample and oven dry to a constant mass at 230ºF (110ºC).
3. After drying, sieve the material into individual size fractions, and recombine to one of four specified gradings that most nearly represents the aggregate gradation as received. Record the total sample mass (W1). The total sample mass W1 should be about 5000 g for fine aggregate and 10000 g for coarse aggregate.

4. Place the sample and the specified number of steel spheres into the drum and rotate for 500 or 1000 revolutions for fine or coarse gradation of aggregate respectively.
5. The charge required is dependent upon the grading used.
6. Discharge the material and sieve the aggregate over a sieve coarser than a 1.70-mm (No. 12) sieve.
7. Sieve the finer material on a No. 12 (1.70 mm) sieve.
8. Wash the aggregate coarser than the No. 12 (1.70 mm) sieve and oven-dry to a constant mass at 230ºF (110ºC). After cooling, determine the mass W2.
9. Calculate the percentage of loss as follow:

$$\% \text{ Loss} = [(W1-W2)/ W1]*100$$

Where:
W1 = Weight of original test specimen to the nearest 1 g
W2 = Weight retained on the No. 12 sieve after the specified number of revolutions to the nearest 1 g

Notes:

- There is no standard L.A. abrasion specification for Superpave mix design; specifications are typically established by state or local agencies.
- Typically U.S. state specifications limit the abrasion of coarse aggregate for **HMA** use to a maximum ranging from 25 to 55 percent, with most states using a specification of 40 or 45 percent.
- Requirements for Portland Cement Concrete (PCC) tend to be similar, while requirements for specialized mixes such as Stone Matrix Asphalt (SMA) tend to be lower;
- AASHTO specifies a maximum L.A. abrasion loss of 30 percent for SMA.

Figure 1: Los Angeles Abrasion Machine

BITUMINOUS MATERIALS TESTS

PENETRATION OF BITUMINOUS MATERIALS

ASTM D5-97

Objective:

Used to measure consistency of bituminous materials under specific conditions of loading, testing time and temperature.

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 isshown in Figure 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:

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

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

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.

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.

Figure 1: Asphalt penetration apparatus

SOFTENING POINT OF BITUMEN

(Ring-and-Ball Apparatus)

ASTM D36-95

Objective:

The main objective is to measure and specify the temperature at which bituminous binders begin to show fluidity. It is also a measure of consistency for air-blown asphalt.

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:

- Bitumens are viscoelastic materials without sharply defined melting points; they gradually become softer and less viscous as the temperature rises. For this reason, softening points must be determined by an arbitrary and closely defined method if results are to be reproducible.
- The softening point is useful in the classification of bitumens, as one element in establishing the uniformity of shipments or sources of supply and is indicative of the tendency of the material to flow at elevated temperatures encountered in service.

The results of the test might 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 1. Figure 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 1.

Table 1. Recommended Softening Point test conditions.

Test Condition	**1**	**2**	**3**
Expected Softening Point	30 °C to 80 °C	80 °C to 160 °C	30 °C to 110 °C
Recommended Liquid	Freshly boiled distilled water	USP glycerin	Ethylene glycol
Best Thermometer	ASTM 15C or 113C	ASTM 16C or 113C	ASTM 113C
Starting Temperature	5 ± 1°C	30 ± 1°C	5 ± 1°C

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 1:
2. Assemble the apparatus into its position.
3. Fill the bath with the suitable liquid, as indicated in Table 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 ball-centering 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:

1. 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.
2. 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:
        1) SP (glycerin) = 1.027 x SP (Ethylene glycol) – 1.35°C, if the material tested is *asphalt*.
        2) 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*.
        4) 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.
2. 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.
4. 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 ≤1.08°C) when *condition 3* is applied.

Figure 1: Ring & Ball Apparatus

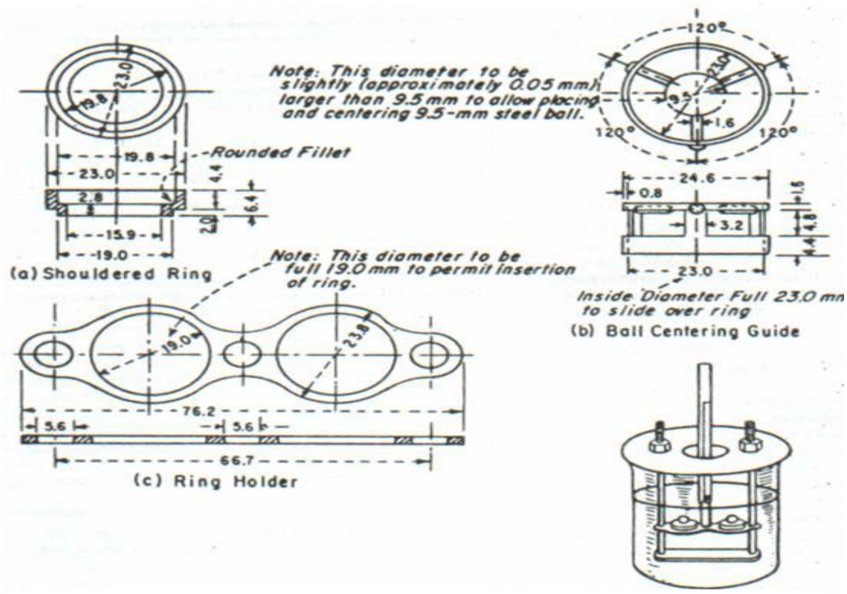


Figure 1: Compaction pedestal and compaction hammer

SAYBOLT VISCOSITY OF LIQUID ASPHALT

(UNIVERSAL and FUROL)

AASHTO T-72 or ASTM D88-81

Objective:

To determining saybolt viscosity of petroleum products at specified temperature.

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 "**F**uel and **r**oad **oil**s."

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: (See Figure 1):

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

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:

1. 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.
2. Clean the viscometer and all other equipment with a solvent and then dry them completely.
3. Place the receiving flask in position, centered beneath the orifice.
4. Fill the bath with the suitable liquid to a level 6 mm above the overflow of the rim of the viscometer.
5. Stir the sample during heating so that the sample temperature is as close as possible to the temperature of the bath.
6. Calibrate the Saybolt viscometer using standard oil at temperature of 37.8°C following the same steps as for testing the sample.
7. Calibrate the Furol viscometer using standard oil at temperature of 50°C following the same steps as for testing the sample.
8. 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)

9. After choosing the test temperature, control the temperature of the bath to the required one.
10. Close the sample outlet tightly using the cork stopper.
11. 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.
12. Immerse the thermometer in the sample in its position in the viscometer and stir well. Withdraw the thermometer.
13. 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.
14. Snap the cork stopper from the outlet and start the timer simultaneously.
15. 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)

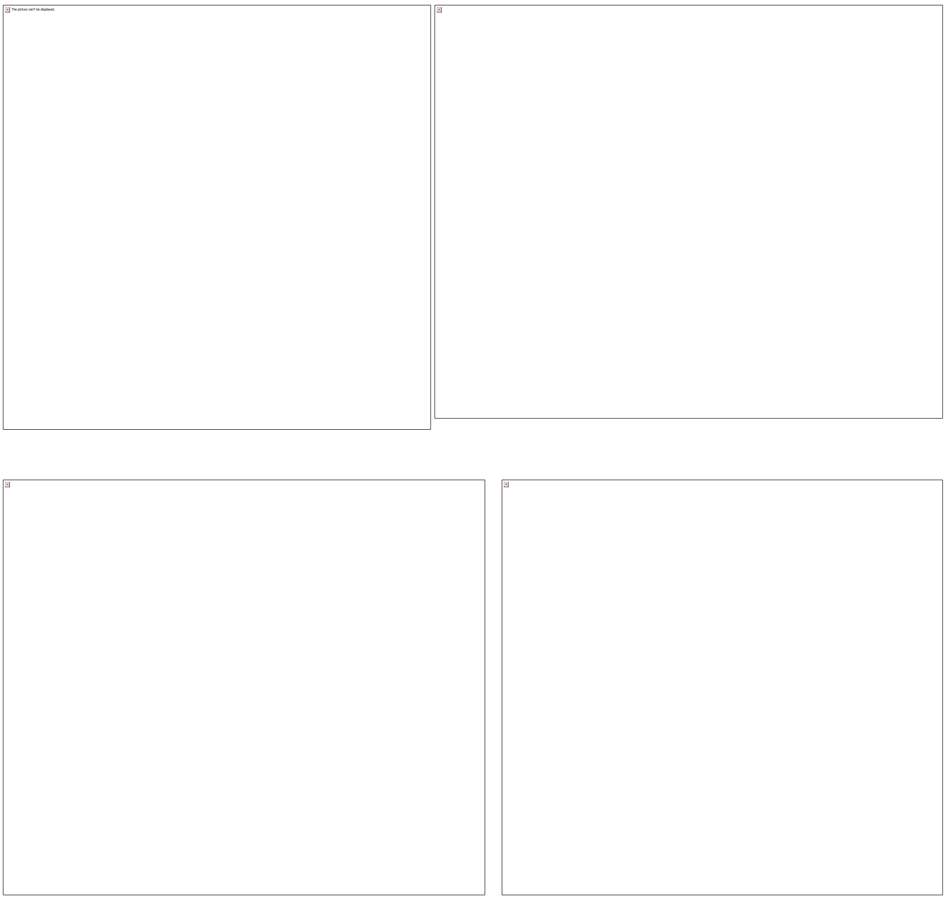


Figure1: Saybolt viscometer and bath

ASPHALT MIXES TESTS
(Marshall method)

MARSHALL MIX DESIGN PROCEDUR

ASTM D6926 -16 +
ASTM D 2726 +
AASHTO T-245 or ASTM D5581 +
AASHTO T-209 or ASTM D2041

Objective:

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

The Marshall mix design procedure consist of three parts as follow:

Part 1: Sample preparation ASTM D6926 -16

Part 2: Sample testing which includes:

A. Bulk Specific Gravity Determination Gmb. ASTM D 2726
B. Stability and flow test for compacted asphalt mixture. AASHTO T-245 or ASTM D5581
C. Maximum specific gravity test for loss asphalt mixture. AASHTO T-209 or ASTM D2041
D. Density & voids analysis.

Part 3: Report and discussion

Part 1: 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, coarse aggregate, fine aggregate, and mineral filler.
2. Sieve analysis equipment.
3. Pans and mixing molds.
4. Spatula; balance; oven & hot plate.
5. Mixing bowl and mixer.

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:

Sieve Size	% Passing
1”	100
3/4"	95
1/2"	80.5
3/8"	68
#4	45.5
#8	30.5
#16	23
#50	11
#100	8.5
#200	5

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 Percent by weight of mix	No. of Specimens	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.

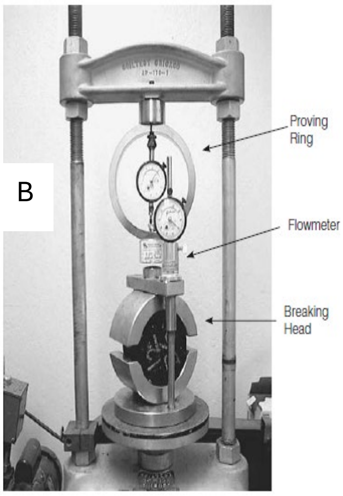
h) Place half of the required amount of the mix in the mold and spade the mixture vigorously with a heated spatula 15 times around the perimeter and 10 times over the interior. Place the second half of the batch in the mold and repeat the foregoing procedure. Remove the collar and smooth the surface of the mix with a trowel to a slightly rounded shape. Place a piece of filter paper.

i) Replace the collar and place the mold assembly on the compaction pedestal. (Figure 1 photo A) Apply 75 blows of the 10 Ib 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.

A

B



C

Figure 1: Marshall Mix Design:

Samples and equipment

Part 2 – Sample testing

Introduction:

In this part, the following tests and analysis will be carried out (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 sample holding mould (Figure 1- photo B).
b) Water bath for heating the Marshall samples.
c) Balance with specific gravity frame.
d) Large size pycnometer with vibrator.
e) Vacuum pump.

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:

$$\text{Bulk specific gravity} = A/(B - C) \qquad (1)$$

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°C ± 1°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:

$$\text{Theo. Max. Sp. Gravity (Gmm)} = A / (A + D - E) \quad (2)$$

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 lb/ft^3 or 1000 kg/m^3. Then determine the % Air voids for each mix using the following formulas:

1) 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:

$$Gse = \frac{Pmm - Pb}{\frac{Pmm}{Gmm} - \frac{Pb}{Gb}} \quad (3)$$

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

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)

$$\text{\% air voids (AV)} = [1 - \frac{Bulk\ Sp.Gravity}{Theoritical\ Max.Sp.Gravity}] * 100 \quad (5)$$

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

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

$$\text{Voids Filled with Asphalt (VFA)} = [Vb / (Vb + AV)] * 100 \quad (7)$$

4) 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) = [$\frac{VMA-AV}{VMA}$] * 100 (9)

Part 3. 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).
   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
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

Worksheet # 3 Marshall Stability Testing Sheet

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 # 4 Theoretical Maximum Specific Gravity Testing Sheet

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

Example of Hot Mix Design Specifications (as per some agencies)

Property	Heavy Traffic		Medium & Light Traffic		Accepted Tolerance
Sieve Size	**Binder Course**	**Wearing Course**	**Binder Course**	**Wearing Course**	
1"	100	**100**	100	100	± 5.0%
3/4"	70 – 100	**90 – 100**	70 – 100	90 – 100	± 5.0%
1/2"	53 – 90	**71 – 90**	53 – 90	71 – 90	± 5.0%
3/8"	40 – 80	**56 – 80**	40 – 80	56 – 80	± 5.0%
# 4	30 – 56	**35 – 56**	30 – 56	35 – 65	± 4.0%
# 8	23 – 38	**23 – 38**	23 – 49	23 – 49	± 4.0%
# 20	13 – 27	**13 – 27**	14 – 43	14 – 43	± 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 Content					± 0.3%
Marshal Stability (kg)	900 (min)	**1000 (min)**	800 (min)	900 (min)	
Flow (mm)	2 – 3.5	2 – 3.5	2 - 4	2 – 4	
VMA	13 (min)	14 (min)	13 (min)	14 (min)	
Air Voids (%)	4 - 7	4 - 6	3 - 5	3 - 5	
Stiffness (kg/mm)	500 (min)	500 (min)	500 (min)	500 (min)	
Loss of Stability (%)	25 (max)	25 (max)	25 (max)	25 (max)	