University of salahaddin-Hawler
College of Engineering
Civil Engineering Department
Third Year

Manual of
Highway Engineering Laboratory

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Test No: 1

Proctor Compaction Test

Introduction

Compaction of soil is a process(of densifying) by which the soil particles are packed more closely together by reducing the air voids, thereby increasing the dry density and shear strength and decrease in future settlements.

Increase in dry density of soil depends on:

a) Moisture content in the soil during compacting.

b) Amount of compacting.

For all soils, with increase in moisture content, the dry density first increases and then decreases. This shows that every soil has an Optimum Moisture Content (OMC) at which the soil attains maximum dry density. This fact was first reported by R.R. Proctor in 1933.

Significance of the test

a) The OMC of the soil shows a certain moisture content at which the soil should be compacted to get maximum dry density. If the compacting effort applied is less, the OMC increases, and vice versa.

b) In the field, the compacting moisture content is first controlled at OMC and the adequacy of rolling is controlled by checking the dry density.

Apparatus

1) Cylindrical mould of capacity 1/30 ft^3, with internal diameter of 4'' and height 4.6''.

2) Metal rammer having a 2'' diameter circular face and weighing 5 lbs with a free fall of 12''.

3) Straight edge for trimming the top of the specimen.

4) Moisture containers, balance, oven, mixing bowl …etc.

Test procedure

1) Dry the soil oven, or find the moisture content of the soil and pass it through 19mm sieve.

2) Mix the soil (about 3kg for one sample) thoroughly with a known amount of water measured in a graduated jar (i.e. 7% less than estimated OMC for sandy soil and 10% for clayey soil).

3) Weigh the mould with base plate.

4) The wet soil is compacted into the mould with collar in three equal layers, each layer being given 25 blows of 5 lbs rammer dropped through a height of 12''.

5) Remove the collar and trim the soil to the top of the mould.

6) The mould with base plate and soil is then weighed.

7) A moisture content determination is made on the soil of the mould.

This procedure is repeated four to five times after adding higher water content than the preceding specimen, till the weight of the mould and the soil will decrease in compare with the preceding specimen, then the trial will stopped.

Observations and Calculations

All necessary observations will be recorded in data sheet below and then after completing all required calculations (using formulas given), plot M/C on X-axis and dry density on Y-axis and draw a smooth curve by joining the points(like an example given in data sheet).

Result

From the above curve, the maximum dry density is noted and the corresponding M/C is the OMC of the soil.

Data sheet

Test No: **1**

Title: **Proctor Compaction Test** {From AASHTO designation T99 -86 (method)}

Student Name: **Sec:** **Group:** **Date:** / / 20

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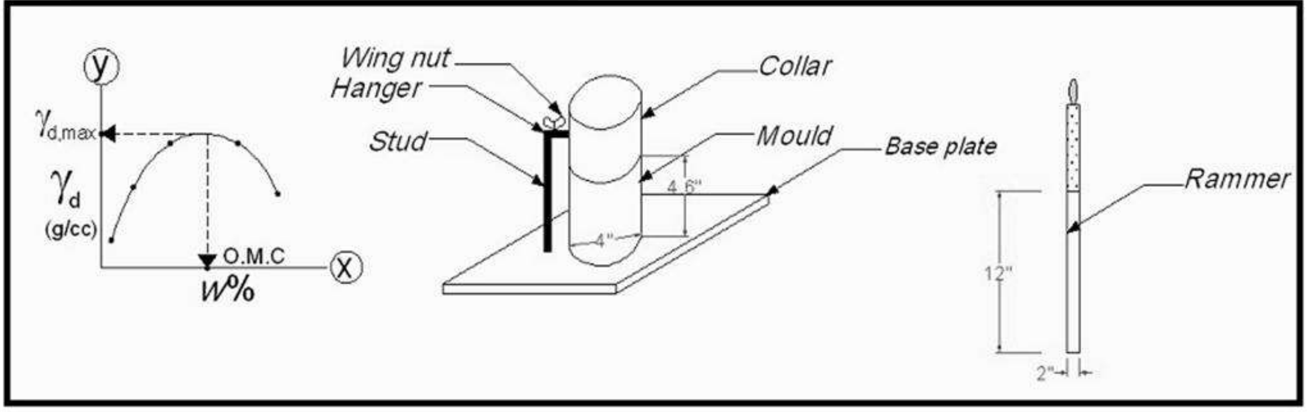
- **Volume** of the mould (V_m) cc {Dia.= cm & Ht. = cm} =
- **Weight** of empty mould with base plate (W_m) gm =

•Rammer of diameter = 2" (5cm), weight = 5.5 lb (2.49kg) & with a free fall of 12'' (30.5cm) (for light compaction).
•Weight of soil taken for each sample is about (**3kg**) of known moisture content and passing sieve (19mm).

Trial number	1	2	3	4	5
Weight of mould + compacted soil (in 3 layers, 25blows each) = (**Ww**)gm					
%Wt. of water in natural soil ……………………………………………… %Wt. of water added (7%< estimated O.M.C. for sandy soil & 10% for clayey soils) or (4%< O.M.C. from AASHTO)…………………………….. Total moisture content (%)…………………………………………………					
Moisture container number Weight of moisture container (W_1) gm …………………………………… Weight of moisture container + wet soil (W_2) gm………………………… Weight of moisture container+ dry soil {oven dried (105ºC -110ºC±5) for 24 hrs & not less than 12 hrs} (W_3)gm …………………………………… **(X)** Moisture content **W(%)** ……………………………..					
Wet density, , g/cc………………………………………… **(Y)** Dry density , g/cc …………….					

Plot graph between **(X)** and **(Y)**.



Results:

From the graph:

- Maximum Dry Density ( ) g/cc =
- Optimum Moisture Content (O.M.C) % =

Signature

Test No: 2

C.B.R.Test

Introduction:

The California Bearing Ratio Test, usually abbreviated to C.B.R. test, is a penetration test developed by the California Division of Highways as a method for evaluating the strength of soil subgrade and base course materials for flexible pavements. The test is arbitrary in that the results cannot be accurately related to any of the fundamental properties of soil like cohesion and angle of internal friction, governing the soil strength.

The C.B.R value is a measure of shearing resistance of the material under controlled density and moisture conditions. For good reproducibility of results, it is necessary that the test procedure is strictly followed. Briefly the test consists of subjecting a cylindrical plunger of 5 cm diameter to penetrate the specimen at 1.25 mm (0.05 inch) per minute. The loads for 2.5 mm and 5mm penetration are recorded. This load is expressed as a percentage of a standard load value at the respective deformation value to obtain C.B.R value. The table below gives the standard load values on standard crushed stone for different penetration values:

penetration (mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

Definition:

C.B.R may be defined as the ratio of the load required to penetrate a standard plunger (5cm dia.) at a standard rate of 1.25 mm/minute (0.05'' / minute) for a standard penetration of 2.5mm (0.1'') or 5mm (0.2'') to that of the standard load for high quality crushed stone materials, thus,

$$\%C.B.R = \frac{Laod\ carried\ by\ specimen\ at\ defined\ penetration}{Load\ carried\ by\ standard\ crushed\ stone\ at\ above\ penetration} * 100$$

Usually the C.B.R. value selected is at 2.5 mm penetration. If the C.B.R. at 5mm is greater than at 2.5 mm, the test should be repeated. If the check test gives similar results, the value for 5mm penetration is adopted for defining the C.B.R. value.

Significance of the test:

a) Based on C.B.R. test data, empirical design charts were developed by the California State Highway Department, correlating the C.B.R. value and flexible pavement thickness requirement. Later on similar design curves were prepared by various other agencies too. The C.B.R. design chart developed by Road Research Laboratory, London is given in the figure.
b) It gives a comparative idea of strength of various locally available materials.

Apparatus:

1) Loading Machine:-
   Any compression machine which can operate at a constant rate of 1.25 mm/minute.
2) Cylindrical mould:-
   A mould of 150mm dia. and 175mm height provided with a collar. A displacer disc of 147mm.dia. and 47.7mm. thickness is used to obtain a specimen of exactly 127.3mm. height.
3) Standard plunger of 5 cm diameter.
4) Dial gauge for recording penetration.

5) Surcharge weights each of 2.5 kg.
6) Sieve, oven, balance etc.
7) compaction hammer:-
The material is usually compacted as specified for the work. The table below gives the details for compaction.

Type of compaction	No. of layers	Wt. of hammer(kg)	Fall (cm)	No. of blows
B.S. compaction	3	2.6 (5 lb)	31(12")	56 (55)
Modified AASHTO Compaction	5	4.89 (10 lb)	45	56 (55)

Precautions:

1) The maximum size of material particles to be tested is limited to 19 mm. Therefore in case of gravels initial sieving is essential.
2) Blows should be applied uniformly over the entire surface of soil in mould.

Test procedure:

1) Sieve the material through 19mm Sieve.
2) To this, add the required amount of water to carry out the test at specified moisture content (usually O.M.C.)
3) Pour the processed soil in to the mould in 3 or 5 equal layers compacting each layer with 56 blows.
4) Remove the collar and using a straight edge struck off the excess soil at the top of the mould.
5) Place the surcharge weights on the surface of soil in the mould. To simulate field conditions a minimum of 5kg. (10 lb) weight of surcharge is placed over the soil. Each 2.5kg (5lbs) surcharge weight is approximately equivalent to 6.5 cm. (2 ") of construction.
6) Bring the plunger in contact with the top surface of the sample.
7) Apply a seating load of 4.5 kg. (10 lb) to the plunger on the surface of the soil.
8) Set the load and penetration gauge to zero.
9) Apply the load at the rate of 1.25 mm/minute (0.05" per minute).
10) Record the load reading at penetration values of 0.0., 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5mm (0.0, 0.025", 0.05", 0.o75", 0.10", 0.15", 0.2", 0.3", 0.4", and 0.5").
11) Release the load and remove the mould from the machine.
12) Collect a sample from the soil immediately under the plunger and another sample from about 3 cms further into the soil.
The average of the two moisture contents obtained from the samples is calculated.

Calculations:

The load-penetration curve for each specimen is plotted on a natural scale and a smooth curve is obtained. The curve is convex upwards although the initial portion of the curve may be concave upwards; the concavity is assumed to be due to the surface irregularity. A correction is applied by drawing a tangent to the curve at the point of greatest slope and the origin is shifted to the intersection of this tangent with the x-axis. .The necessary correction is then applied to the load penetration values.

Results:

Find C.B.R. values at 2.5 mm and 5mm penetration. If C.B.R. value at 5mm is higher, repeat the test. If the C.B.R. value is still higher at 5mm penetration, use this value for design purposes.

DATA SHEET

Test No:- **2**

Title:- **California Bearing Ratio (CBR) test**

Name:- Group:- Sec:- Date:- / / 201

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* Type of materials =
* Surcharge weight =
* Rate of loading = 1.25 mm/min.
* 1 division of load gauge =
* 1 division of penetration gauge =

Penetration		**Load**			
		B.S.Compaction		Modified AASHTO compaction	
mm	division	division	Kg	division	Kg
0.00					
0.50					
1.00					
1.50					
2.00					
2.50					
3.00					
4.00					
5.00					
7.50					
10.0					
12.5					

Results:

From the graph

B.S

CBR(2.5) = (/1370)*100= ☐

CBR(5.0) = (/2055) *100= ☐

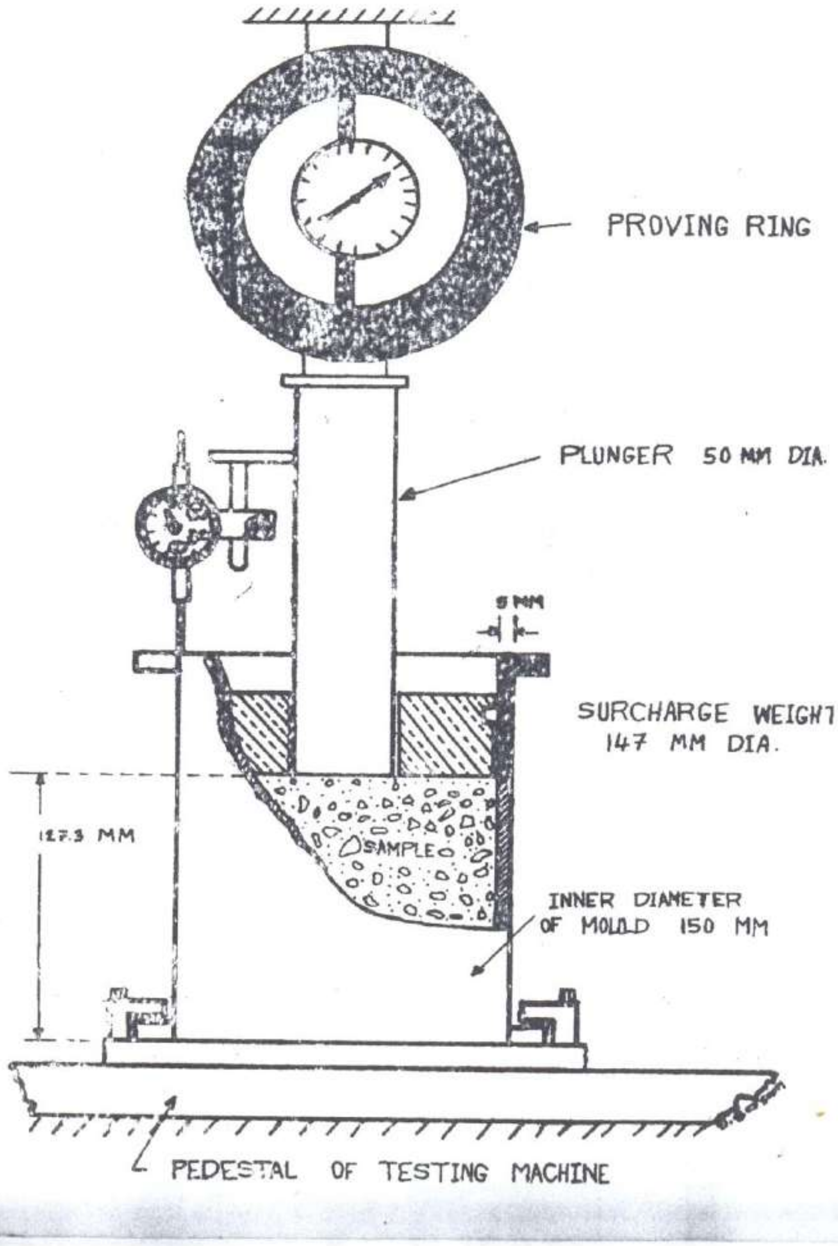
AASHTO

CBR(2.5) = (/1370)*100= ☐

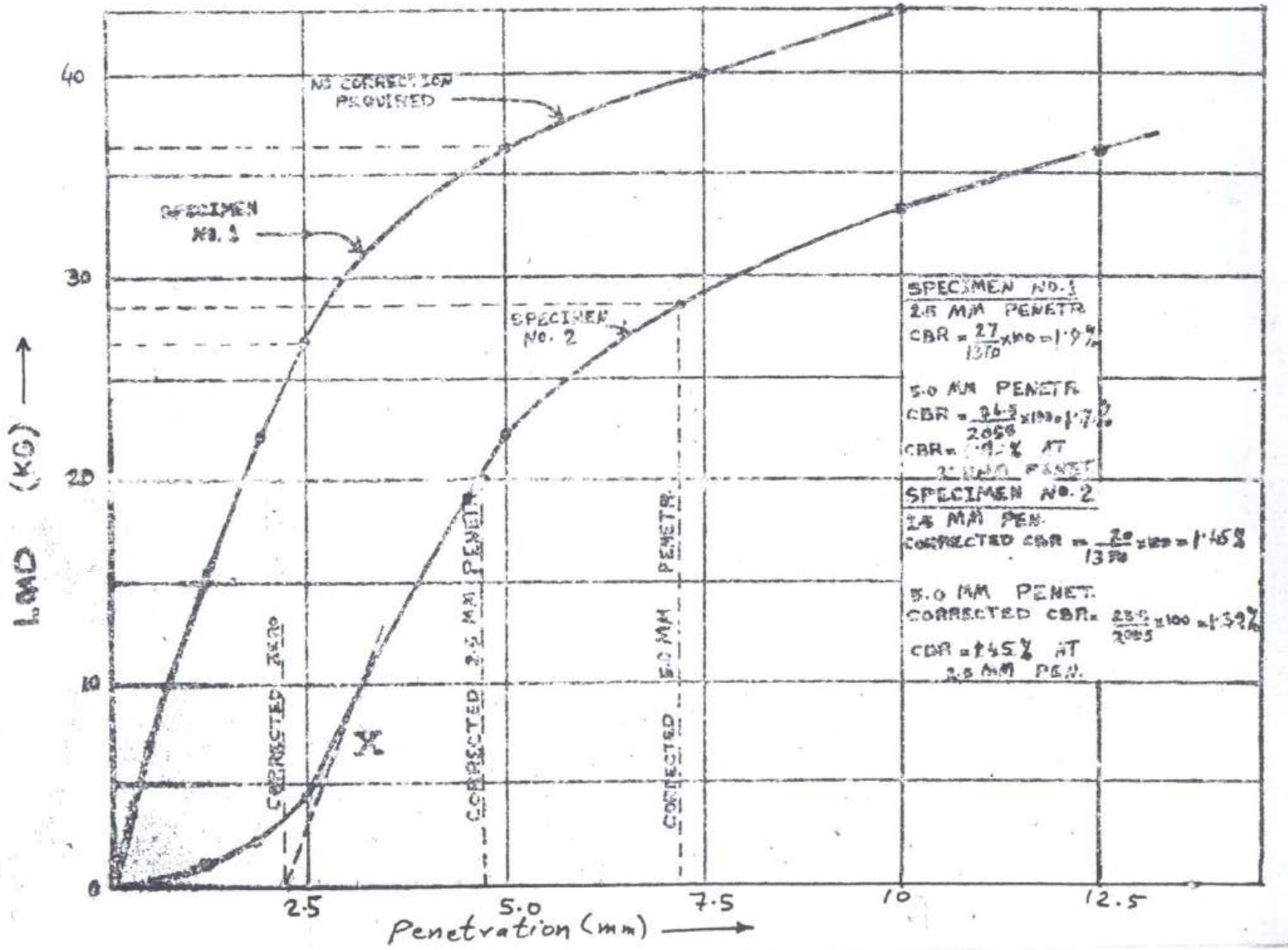
CBR(5.0) = (/2055) *100= ☐

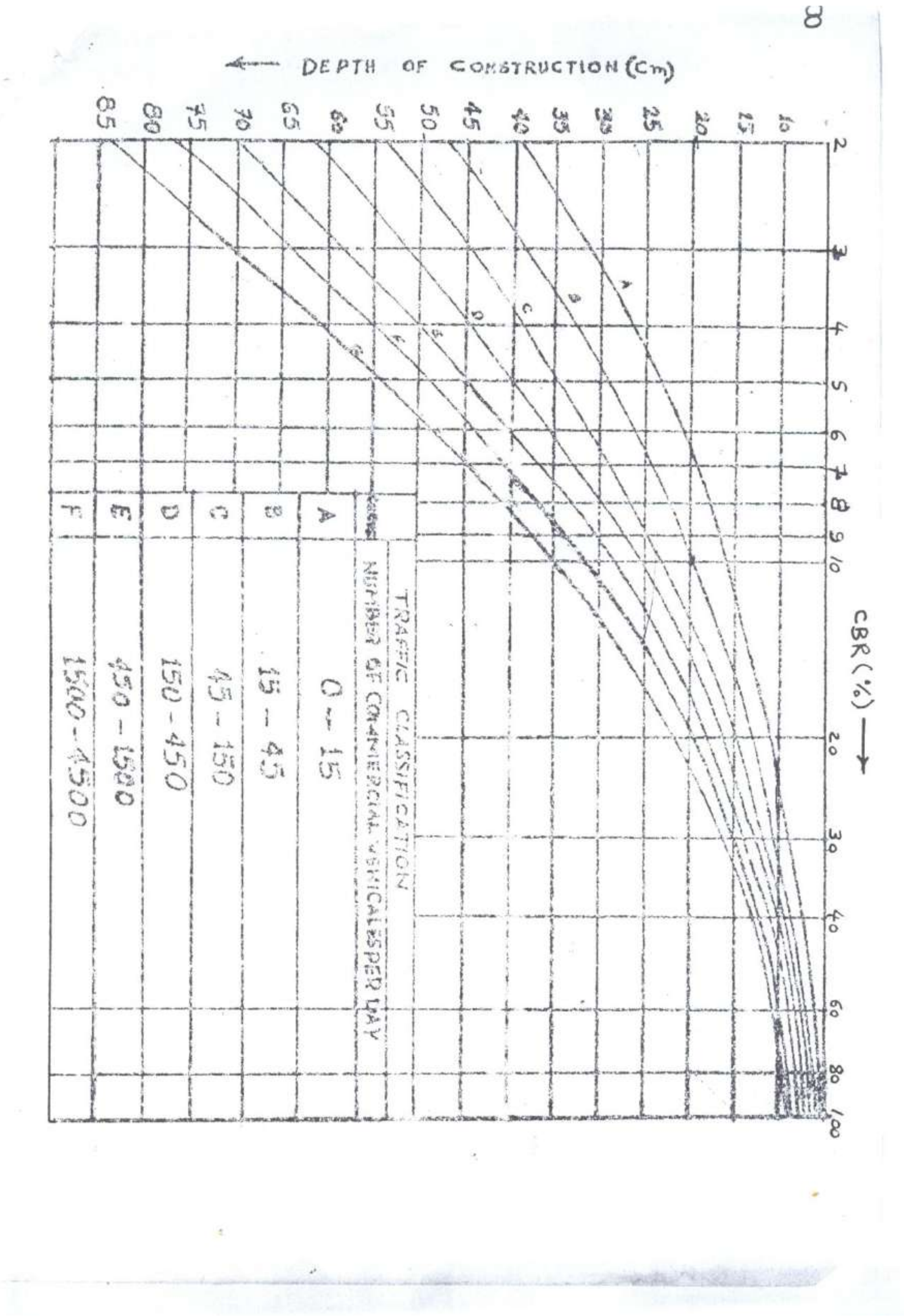
Signature

CBR TEST


PROVING RING
PLUNGER 50 MM DIA.
5 MM
SURCHARGE WEIGHT
147 MM DIA.
127.5 MM
SAMPLE
INNER DIAMETER
OF MOULD 150 MM
PEDESTAL OF TESTING MACHINE

LOAD - PENETRATION CURVE




DEPTH OF CONSTRUCTION (Cm)
CBR (%)
TRAFFIC CLASSIFICATION
NUMBER OF COMMERCIAL VEHICALES PER DAY
A 0 – 15
B 15 – 45
C 45 – 150
D 150 – 450
E 450 – 1500
F 1500 – 4500


VERSA TESTER

Test No: **3**

In-situ Density

Introduction

There are four methods to find the insitu density of the soil and the practical advantages & disadvantages of the different methods may be summarized as follows:

a) **Core cutter method**

Is convenient and quick. The cutting edge is easily damaged and needs frequent resharpening. The method works best on soft, cohesive soils and can not be used on Stony or non-cohesive soils.

b) **Rubber Balloon method**

Is convenient and quick, but the results are not very reproducible owing to the difficulty of controlling the air pressure and ensuring that the balloon conforms to the shape of the hole. This difficulty might be overcome by increasing the size of the apparatus so that the error due to the balloon not conforming to the surface irregularities of the hole would be minimized, with a larger balloon apparatus, the method might be applicable to stony soils

c) **Volumenometer method**

Is lengthy process and it can only be used on cohesive soils. The samples must not be permitted to dry between the time when they are cut from the ground and when their volume is determined.

d) **Sand replacement method**

Is relatively slow, but it can be used on any type of soils.

Significance

1) For measurement of compaction in the field.
2) For determining the field density for various design purposes.

Apparatus

1) Sand replacement apparatus.
2) Sieves BS No.25 (ASTM = 30) & B.S.No.52 (ASTM 50).
3) Balance.

Test procedure (Sand replacement method)

1) Take oven dry, uniform, medium, loose sand passing ASTM sieve No.30 and retained on No.50 and that has a constant loose density.
2) Fill it in the cylinder of the apparatus.
3) Weigh the cylinder + dry sand (W1).
4) Excavate a hole of about 10 cm diameter in the ground where bulk density is to be determined (the depth of excavation will be nearly as the depth of the layer or at least 10cms).
5) Collect the soil in a bowl & and weigh it (Ws).
6) Allow the sand to run into the hole from the cylinder.
7) Close the valve of the cylinder & weigh it (W2).
8) Determine the weight of sand required to fill the cone(C).
9) Determine the bulk density of sand using a calibrating cylinder of known volume (a) and if the weight of sand filling it is (b).
10) The field moisture content of the soil sample taken from the hole is determined by the same procedure explained in proctor test and the procedure of it is fixed here on data sheet.

Calculations

All necessary formulas for calculating the bulk density are tabulated on the data sheet and after determining the field moisture content of the sample, the corresponding dry density can be determined by the formulas given on the data sheet also.

Result

The maximum dry density which determined by proctor test can be used here to determine the percentage of compaction as below:

% Compaction= Field dry density/ Maximum dry density *100

Hint:

- The % Compaction in most specifications must not be less than 95%.
- In analyzing the results of field compaction tests it may be necessary to make some allowance for the amount of coarse-sized (gravel)particles in the test sample. The laboratory compaction test is usually made with material passing the 19mm sieve size only. If the soil in the field contains a significant amount of gravel particles, the expected density should be revised upwards.

*A corrected maximum dry density can be calculated assuming that the gravel particles in a soil composed mainly of finer grains can be compacted to 90%of the theoretical maximum density. For the gravel of RD(Gs)value of 2.65(often assumed),this would be: 90%of 2.65*1000kg/m^3= 2385kg/m^3(90%of 2.65*62.4lb/ft^3=148.8lb/ft^3).*

- Example: laboratory maximum density of a soil is 1900kg/m^3 (118.6lb/ft^3). Specifications require 95% compaction. In the field dry density of soil is found to be 1800kg/m^3 (112.9lb?ft^3). The soil in the field contains 20% gravel sizes. Check for compaction.

Corrected maximum dry density=0.8*1900+0.2*(90%of 2.65*1000) =1520+477=1997Kg/m^3
(0.8*118.6+0.2*(90%of 2.65*62.4)=94.9+29.8=124.7lb/ft^3)
%Compaction=1810/1997(112.9/124.7)*100=90.6% and is not acceptable, (because it is less than 95%)

References

- Soil mechanics for Road Engineering, page 177, By: Transport and Road Research Lab. (HMSO)
- Highway materials, soils and concretes, By: H.N.Atkins.
- Engineering properties of soils, and their measurements. By: J.E.Bowls.

DATA SHEET

Test No:- **3**

Title:- **IN-SITU DENSITY "Sand Replacement Method"**

Name:- Group:- Sec:- Date:- / / 201

Description	1	2	3
Wt. of cylinder + dry sand before filling …….. (W1) gm Wt. of cylinder + dry sand after filling …….. (W2) gm Wt. of soil from the hole ……………………….. (Ws) gm Wt. of sand in funnel ………………………….. (C) gm			
Vol. of calibrating cylinder……………………(a) c.c. Wt. of sand in calibrating cylinder ……………(b) gm Bulk Density of sand = **b/a**, gm/cc			
Moisture container No……………………………….. Wt. of empty moisture container …………….(W3) gm Wt. of moisture container + wet soil …………(W4) gm Wt. of moisture container + dry soil …………(W5) gm Moisture content (W %) =			
Bulk density of soil ……………………… gm/cc Dry density of soil ………gm/cc			
Degree of compaction ……..%			

• $Insitu(\ bulk\ )density\ of\ soil = \dfrac{Ws}{Vol.of\ soil\ (hole)}$

• $Bulk\ density\ of\ sand = \dfrac{b}{a} = \dfrac{W_1 - W_2 - C}{Volume\ of\ hole}$

• $Vol.of\ hole\ (cm^3) = \dfrac{(W1 - W2 - C) * a}{b}$

• $Insitu\ (bulk)density\ of\ soil\ (\gamma_m) = \dfrac{Ws * b}{a * (W1 - W2 - C)}$

Signature

Test No: 4

Los-Angeles Abrasion Test

Introduction:

Abrasion value is the percentage by weight of aggregate particles passing through a specified sieve (US No.12) after application of specified abrasion by means rotation and dynamic contact with steel spheres over the weight of dry aggregate tested.

Significance:

To select the most suitable aggregate for different kinds of works based on the abrasion value. The test is significant to determine the hardness (and toughness)of the material.

Apparatus:

1) Los angles abrasion testing machine consisting of a steel drum 21" long and 28" diameter attached with a 3 wide projecting shelf inside the drum. It rotates electrically at the rate of 30 – 33 r.p.m.
2) Weighing balance.
3) A set of standard sieves.
4) Steel balls each of 4.8 cm diameter and 390 to 445 gm in weight.
5) Drying oven.

Precautions:

1. The lid of the drums should be tightly closed, so that during rotation of the drum, no particles of the material comes out.
2. Care should be taken to see that no material is left in the drum after the test and nothing spreads out while withdrawing the material from the drum.
3. The material should be properly oven dried before placing in the drum.

Test procedure:

1. Select anyone of the grading from A to G as given in the table hereunder.
2. Wash the aggregates and dry them in an oven between 105 to 110 C^o and cool.
3. Place the required quantity (depending on the grading chosen) of aggregates and the balls in the drum.
4. Fix the lid of the drum tightly.
5. Rotate the machine at 30 to 33 r.p.m for 500 revolutions for grades A, B, C and D and 1000 revolutions for grade F, E and G.
6. Open the drum and take out the materials.
7. Screen this material over 1.7 mm (US No.12) sieve.
8. Wash the portion of material coarser than 1.7 mm size.
9. Dry this coarser material in an oven at 105 to 110 C^o and then find its weight to the nearest one gm.

Result:

Calculate the percentage wear using the formula given below, then compare the result with the permissible limits for different types of works.

(%) wear=(Original weight-Retained weight)/Original weight *100

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Table of gradation

Passing mm	Retaining mm	Weight of aggregate sample in gms.						
		A	B	C	D	E	F	G
80	**63**					2500		
63	**50**					2500		
50	**40**					5000	5000	
40	**25**	1250					5000	5000
25	**20**	1250						5000
20	**12.5**	1250	2500					
12.5	**10**	1250	2500					
10	**6.3**			2500				
6.3	**4.75**			2500				
4.75	**2.36**				5000			
No. of iron balls		***12***	***11***	***8***	***6***	***12***	***12***	***12***
No. of revolutions		***500***	***500***	***500***	***500***	***1000***	***1000***	***1000***

DATA SHEET

Test No: **4**

Title: **Lose-Angles Abrasion Test**

Name:- Group:- Sec:- Date:- / / 201

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- Type of aggregate:
- AASHTO grading:
- Total weight of charge: gm
- No. balls used:
- No. of revolutions:
- Original dry weight of sample (W_1): gm
- Weight after test (retained on 1.7 mm sieve) (W_2): gm
- (%) wear [ ] %

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Allowable Loss

Type of construction	**Allowable loss (%W)**
1- Surface treatment (bituminous)	**40**
2- Surface course W.B.M	**40**
3- Ditto. Bit. Macadam/concrete	**40**
4- Base course W.B.M	**60**
5- Ditto. Bit. Macadam/cons.	**50**
6- Cement concrete pavements	**16**

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Signature

TEST NO.: 5

AGGREGATE GRADATION & BLENDING

Introduction:

Proper gradation of aggregate so as to obtain a dense mix, when compacted, is one of the extreme importance in road construction. Generally, aggregate obtained from natural source may be single size (uniformly graded), gap- graded or well (dense)graded. This is analyzed by passing the aggregate through a set of selected sieves and then plotting the percentages finer in each sieve against the aperture size of the sieves, in a particular manner. The shape of the curve thus obtained will decide the type of gradation.

By the term "**blending"** of aggregate is meant the process by which two or more samples of aggregates are mixed to a determined ratio in order to obtain the desired gradation value.

Significance:

Since the stability of the mixture in which aggregate has been used will normally be affected by the aggregate gradation, this test is very much significant. Moreover, the percentage of voids present in a well compacted aggregate mass will also be affected by its gradation.

Apparatus:

1) A set of sieves.
2) Semi log paper
3) Laboratory oven
4) Riffle box
5) Balance

Test procedure:

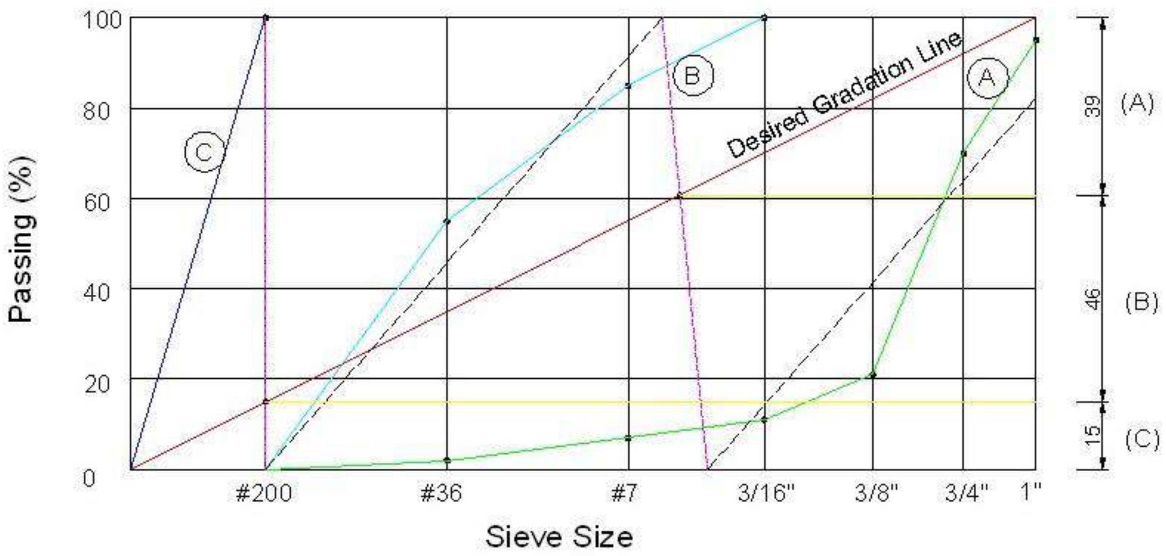
1) Place the aggregate under test in a heap. Divide it into four parts by quartering (passing vertical sections the two being at right angles to each other). This can also be done using a Riffle box. Divide it further into parts so as to obtain finally about 1.5 Kgs of the aggregate sample.
2) Dry the aggregate in the oven at approximately 105 c^o for about 4 hours.
3) Clean and dry the set of sieves as desired. Find the weights of ovary sieves (empty) individually.
4) Place the sieves one above the other in a manner that the max. aperture size will be at the top and the minimum aperture size will be at the bottom which will be just above the pan.
5) Place 1000 gms of the dried aggregate in the top sieves.
6) Shake the sieves (preferably by mechanical source) for a period not less than 2 minutes and not exceeding 7 minutes.
7) Remove the sieves from the shaker and find the weights of every sieve (containing aggregate particles) individually.
8) Enter all the above readings in the observation chart, and calculate the cumulative percentage passing for every sieve separately.
9) Plot a graph in a semi log paper. The aperture size will be plotted in the x axis which will be in logarithmic scale while the corresponding passing percentage will be plotted on the Y axis in ordinary scale. Draw the gradation curve.
10) Repeat the whole above procedure for the second and subsequent aggregate samples and plot the corresponding gradation curves.

Blending:

To determine the desired blending percentage, there are several methods, mainly be arithmetic method or by graphic solutions. The most predominant graphical solution is by the Rothfutch method as explained.

1) Take a piece of graph paper.
2) Mark on Y axis percentage passing via 0 to 100 % from bottom to top.
3) Close the rectangle/square and draw the diagonal.
4) This diagonal will be deemed as the gradation line, of the desired aggregate.
5) With respect to this gradation line, mark the corresponding aperture sizes on the X axis.
6) Now using the X axis and Y axis, plot the gradation lines of the given aggregate (which will be 2 or more samples).
7) Adjust these new lines to true straight lines cutting the bottom and top horizontal lines.
8) Draw zigzag lines connecting the junction points between those lines and horizontal lines.
9) Draw horizontal lines from the crossing points between the diagonal line and these zigzag lines to meet the Y axis.
10) The zones now obtained on the Y axis will represent the percentage of various given aggregates at which blending (mixing) should be done to obtain the desired grading.
11) Mix the given aggregate in the obtained percentage and find its gradation to check whether the values obtained are within the tolerable limits to the desired values.

Example of Ruthfutch's method for proportioning mixtures of aggregate



Sieve size	Desired Gradation		A	B	C	Mixture
	Limits	Mean				
1"	100	100	95	–	–	98
3/4"	85-100	92	70	–	–	88
3/8"	65-100	82	21	–	–	69
3/16"	55-85	70	11	100	–	65
#7	40-70	55	7	85	–	57
#36	25-45	35	2	55	–	41
#200	10-25	16	trace	Nill	100	15

DATA SHEET

Test No: 5

Title **Aggregate Gradation & Blending**

Student Name: *Sec:* *Group:* *Date:* / / 20

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Weight of each sample taken = 1000 gm

Sieve Size B.S	Total %passing by weight	Wt. retained (gm)			Wt.ret (gm) cum			Individual % ret			Total % ret			Total %passing		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1"	100															
3/4"	85-100															
3/8"	65-100															
316"	55-85															
No7	40-70															
No36	25-45															
No200	10-25															
pan	0															

Aggregate Gradation and Blending

(Some additional important informations)

Gradation: is particle size distribution.

Uniform or poorly graded or single size ⟶ nearly equal size.

Well graded or dense gradation ⟶ particles vary in amount according to size ⟶ voids filled by smaller particles.

Skip or gap graded ⟶ is poorly graded that it may have particles ranging in size between wide limits but lacking the proper proportions by weight.

Note: In British standard system the various fractions have the following limits of equivalent particle diameters:

Type	Limit (mm)
Gravel	6.0 – 2.0 equivalent particle diameter
Sand	2.0 – 0.06 equivalent particle diameter
Silt	0.06 – 0.002 equivalent particle diameter
Clay	< 0.002 equivalent particle diameter

Or

Type	Limit
Gravel	Retained on No.10 sieve
Sand	Pass No.10 sieve
Filler	Pass No.200 sieve

Gradation is a key property of aggregate. It affects the workability of *Portland cement concrete*, the stability and durability of bituminous concrete and the stability, drainage and frost resistance of base courses.

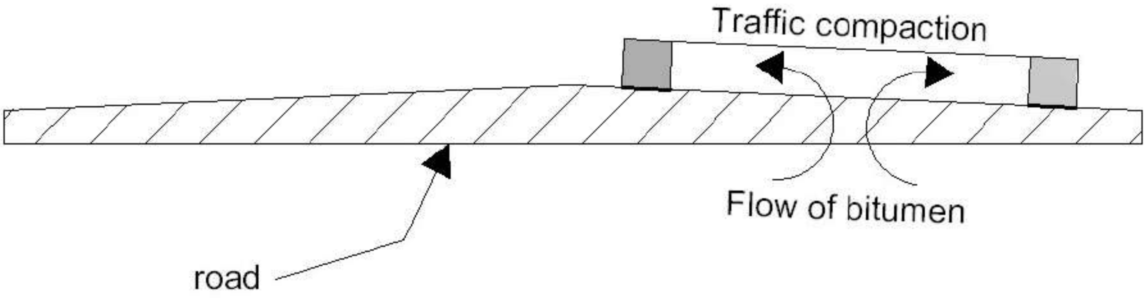
Ideally, aggregate gradation should be tailored to aggregate use.

For example:

In **Portland cement concrete**: more well graded aggregate + less (sand, cement, water) required for given strength.

In **Bituminous materials**: densest aggregate gradation gives greatest durability and minimize air voids.

But sufficient room is not available for traffic compaction ⟶ Bleeding



In **Base courses**: Open gradation ⟶ increased drainage ⟶ decrease stability

Densest gradation ⟶ maximum stability ⟶ poor drainage + increase frost susceptibility.

Blending

(1)By Trial and Error Method

Rule:

When any one aggregate contributes all of a given fraction to the combined grading, the percentage contributed, divided by the total amount of that fraction contained in the aggregate and expressed as a decimal fraction, gives the percentage of that aggregate required to satisfy the combined grading for that particular fraction. The fraction may constitute any one of the following cases:

1) The total percent retained on a given screen.
2) The total percent passing a given screen.
3) The percentage retained on one or more individual screens.

Then:, when A: aggregate sample, T_r: total retained required fraction, a_r: percentage passing contributed.

Example:

Sieve size (US)	%passing													
	Standard limits	Mid-points	**Aggregate A** (Crushed stone)			**Aggregate B** (Coarse sand)			**Aggregate C** (Fine sand)			Combined grading (T1) A+B+C	Combined grading (T2)	Toleran ce
			Total	70% T1	65% T2	Total	20% T1	25% T2	Total	10 % T1	10% T2			
3/4"	100	100	100	70	65	100	20	25	100	10	10	100	100	
1/2"	90-100	95	94	65.8	61.1	100	20	25	100	10	10	95.8	96.1	±5
No.4 (0.187") (4.76mm)	60-75	67.5	54	37.8	35.1	100	20	25	100	10	10	67.8	70.1	±5
No.10 (0.0787") (2mm)	40-55	47.5	31.3	21.9	20.4	66.4	13.3	16.6	100	10	10	45.2	47	±3
No.40 (0.0165") (0.42mm)	20-35	27.5	22.8	16	14.8	26	5.2	6.5	100	10	10	31.2	31.3	±3
No.80 (0.007") (0.177m)	12-22	17	9	6.3	5.8	17.6	3.5	4.4	73.6	7.4	7.4	17.2	17.6	±3
No.200 (0.0029") (0.074m)	5-10	7.5	3.1	2.2	2	5	1	1.3	40.1	4	4	7.2	7.3	±2

Trial (1)

For aggregate (A):

No.4 screen:

$$A = \frac{T_r = (100 - 67.5)/100 = 32.5}{a_r = (100 - 54)/100 = 0.46} = 71\%\ (use\ 70\%)(0\%\ retained\ for\ B\ and\ C)$$

No.200 screen:

The remainder material = 7.5 – 2.2 = 5.3% → come from aggregate C.

For aggregate (C):

No.200 screen:

$$\therefore For\ aggregate\ B: \%required = 100 - (A + C) = 100 - (70 + 10) = 20\%$$

∗Trial (2)

Use aggregate (A) = **65%**, aggregate (B) =**25%**, aggregate (C) = **10%**

***Note**:* No.10 screen falls some what on the coarse side and screen sizes below No.10 produce a still finer graded mixture which is already on the fine side of the specification. Therefore it is better to increase aggregate B at the expense of aggregate A.

∗First look for a screen size which is dependent on one aggregate for furnishing all or most of the material which will be retained upon it.

(2) By Graphical method

Example:

For (C) = 5%

For (A) + (B) = 95% in graph I & in graph II, (A) = 65%, (B) = 35%

$$\therefore (A) = (0.95 * 0.65) * 100 = 62\%\ ,\ \ (B)$$

Step(1): Plot grading of aggregate (A) on scale IV and of aggregate (B) on scale III.

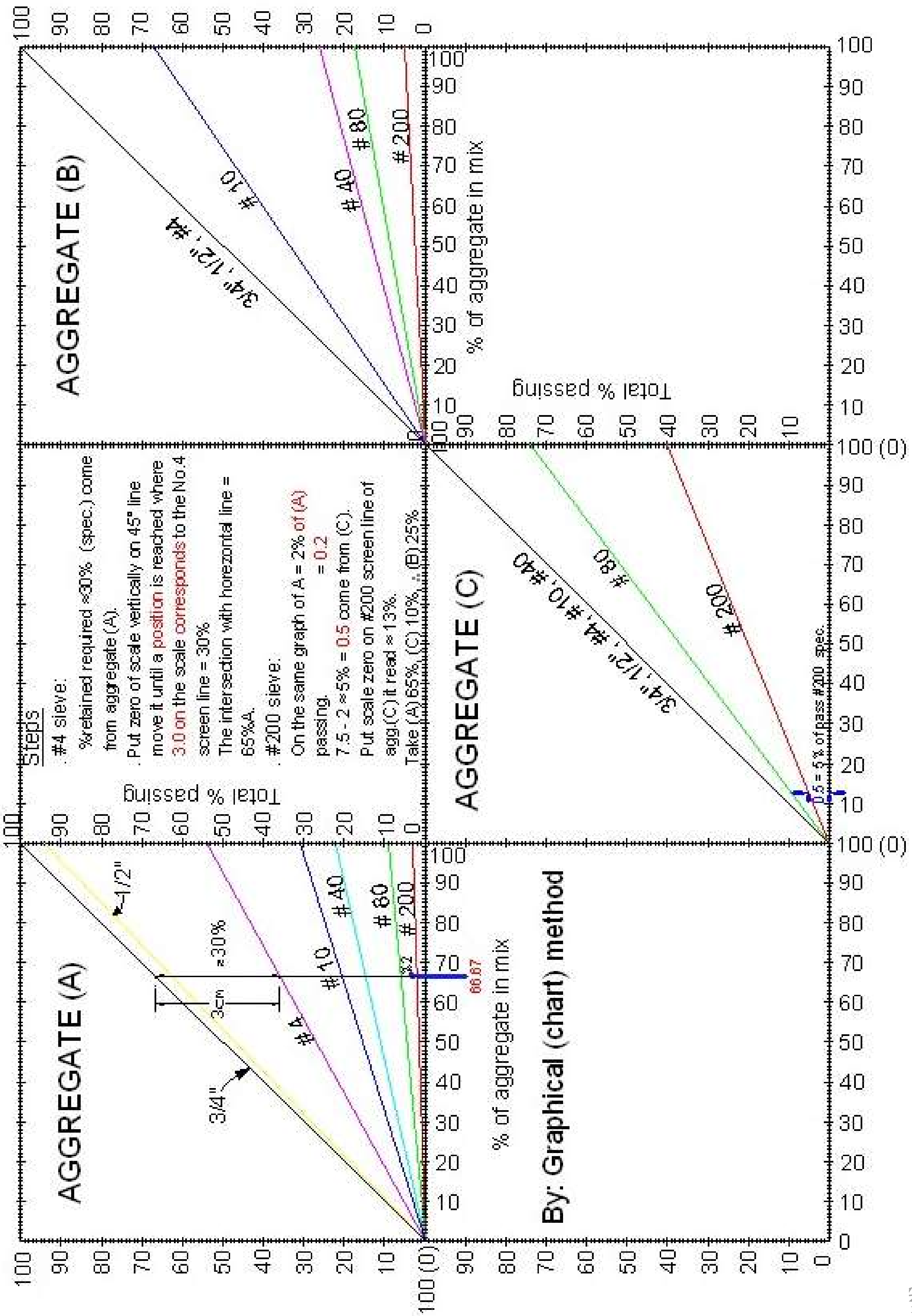
Step(2): Connect by a straight line drawn between scales III & IV, the percentage passing each sieve.

Step(3): In graph II, place the marks on each sieve to indicate the specification limits for each sieve.

Step(4): Choose a vertical line that will strike the test average between specification limits indicated by tie masks on each sieve line.

Step(5): Project horizontally the intersection of each sieve line with the selected vertical line to scale II on graph I.

Step(6): Plot %passing aggregate (C) on scale I and repeat the process todetermine final proportion for blending aggregate (C) with combinations aggregate (A) & (B).



Soundness Test

- Is commonly used to measure the durability (resistance to weathering) of aggregate.
- A sample of aggregate with a specified gradation and weight is saturated in a solution of magnesium sulphate or sodium sulphate, and the removed and dried in an oven.
- This process is repeated for five cycles, each cycle is 16 – 18 hrs.

$$\%loss = \frac{Mass\ of\ particles\ after\ test}{Original\ mass\ of\ sample} \quad (+)$$

(+): Mass of particles which pass a sieve on which the sample was originally retained.

ASTM permits a loss after 5 cycles of **not more** than:

12% when sodium sulphate is used.

Or **18% when magnesium sulphate is used.**

Test No: **6**

Penetration Test

Introduction:

Penetration is a measure of hardness or consistency and is the vertical distance (*expressed in hundred of a centimeter*) that a standard steel needle will vertically penetrate into the sample of asphalt under standard load, temperature and time conditions. Generally these conditions are 100 gm, 25ºC and 5 seconds respectively through test and be conducted under the following conditions too:

S1.No.	Temp. (ºC)	Load (gm)	Time (sec.)
1		200	60
2	**25**	**100**	**5**
3	41.6	50	5

After determining the penetration value, the sample is denoted with standard grades designated by ASTM which is given below:

0 – 20, 20 – 30, 30 – 40, 40 – 60, 60 – 80, 80 –100, 100 – 120, 120 – 160, 160 – 200, 200 – 300

Thus asphalt with a penetration grade of 30 – 40 is harder than the one with a penetration grade of 80 – 100 designate accordingly.

For different types of works and in different temperature zones, materials will be chosen according to their penetration grades. The test is useful to determine the penetrations index which is given as:

$$P_I = \frac{3P}{20} + 1$$

Where P_I: is the penetration index

P: is the penetration value.

Apparatus:

(1) Penetrometer.
(2) Standard needle of 50mm length and 0.1mm diameter at the tip.
(3) Containers: 55mm in diameter and 35mm or 57mm in depth.
The deeper ones will be used for material having penetration of 225mm or more.
4) Transfer dish.
5) Controlled water bath containing not less than 10 litters of water and transfer dish.
6) Stop watch, laboratory heater gloves, tongues, Cleveland and open cup, etc.

Precision:

(1) Allowable error: The difference between the lowest and highest (among minimum 3 observations) values should not exceed by the following limits:

For	0 – 49	50 – 149	150 – 249	Above 249
Permitted limit	2	4	6	8

(2) Repeatability: should not exceed more than 4%.
(3) Reproducibility: should not exceed more than 10%.

Test Procedure:

It consists of two parts:

(a) *Preparation of sample:*

i) Heat the material to fluid consistency for pouring.The temperature may be slightly more than its softening point, i.e 75ºC to 100ºC.

ii) Stir the material thoroughly until it becomes homogeneous and is free from air bubbles and water. Pour it in a container to a depth at least 15mm more than its expected penetration depth.

iii) Cool sample in atmosphere *not lower than 18oC* for one hour.

(b) *Testing the sample:*

i) Place the air cooled sample in the controlled water bath whose temperature is maintained at **25** ± 0.1ºC (or the relevant testing temperature) and allowed to remain for at least one hour.

ii) Check the penetrometer for the followings:

a) Load the needle such that the total load (weight + needle + ferrule) is **100** ± 0.25gm (or the other relevant test load).

b) Clean the needle with benzene to remove all dust and bitumen.

c) Test the clamp and release and see that the penetrometer is working properly.

iii) Place the sample can in a transfer dish containing water at test temperature and keep the assembly on the base of the penetration apparatus under the needle.

iv) Adjust the needle to make contact with the surface. This can be verified by seeing the image of the needle over the top surface of the sample by the help of a suitable light source.

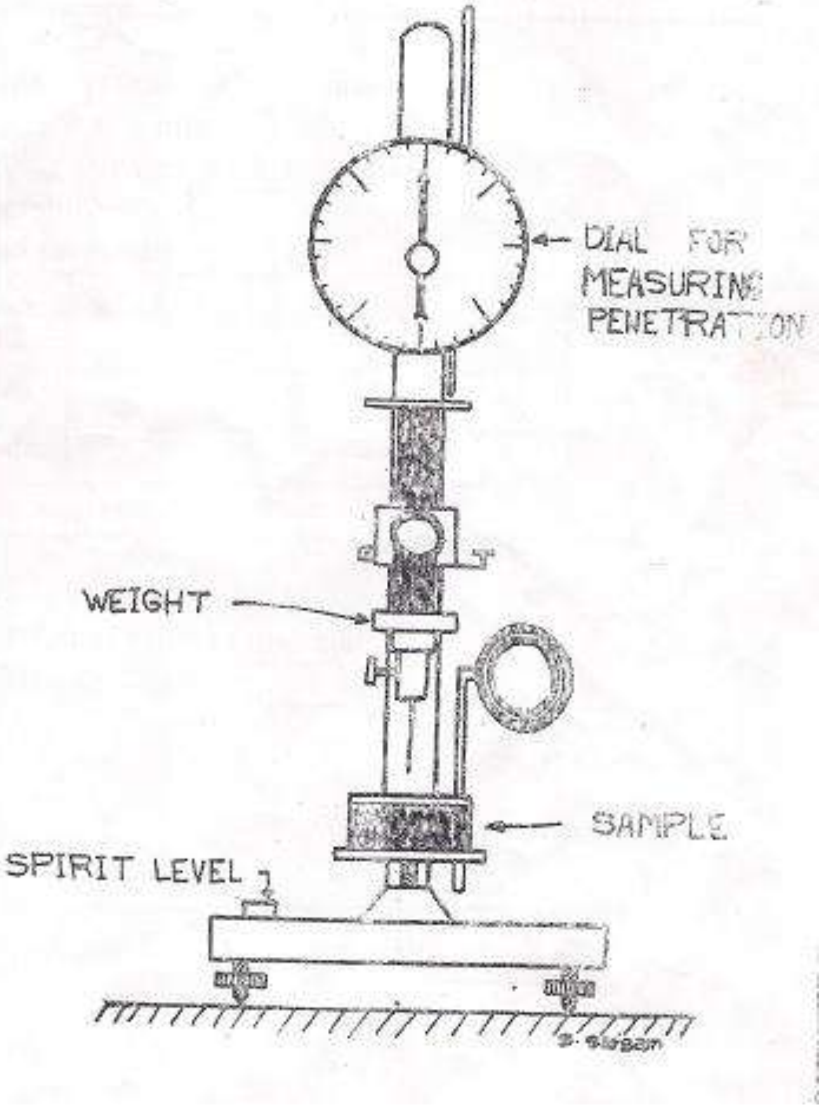
v) Note the initial reading of the dial indicator.

vi) Release the needle for exactly 5 seconds (for the other relevant test time). Then adjust the penetrometer to measure the penetration distance. Record the reading (each division indicates mm). The difference between final and initial reading is the penetration value for this trial.

vii) Raise the needle from the sample and clean it with benzene. Repeat the penetration test for at least three times at different points on the surface of the sample at least 10mm apart. After each test, the sample shall be kept in water bath maintained at test temperature.

viii) Continue to repeat the trials until at least three penetration values are within tolerable limits.

PENETROMETER



DATA SHEET

Test No:- **6**

Title:- **Penetration test**

Name:-   Group:-   Sec:-   Date:-   /   / 201

****

- Pouring temperature =   C°
- Depth of sample in container =   mm
- Air cooling period =   min.
- Period of cooling in water bath =   min.
- Testing temperature =   C°
- Weight of load on needle =   gm

Trial	1	2	3	*Mean value
Final reading				
Initial reading				
Penetration value				

* *Must meet the tolerance required.*

Result:

- Penetration value of material: [ ]
- Grade of material: [ ]

B 40/50   **B 50/60**   **B 60/70**   **B 85/100**

Signature

Bituminous Material

Test	Origin	Grade of bitumen B40/50	B50/60	B60/70	B85/100
1. Penetration at 25º C (100gm, 5 sec) 1/10mm	AASHTO T49 – 74	**40 – 50**	**50 – 60**	**60 – 70**	**85 – 100**
2. Flash point **ºC**(min.)	AASHTO T73 – 74	**240**	**230**	**230**	**230**
3. Loss on heating (5 hrs at 163º C) **%max**	AASHTO T47 – 74	**0.75**	**0.80**	**0.80**	**1.0**
4. penetration after heating Min. % of original	AASHTO T49 – 74	**52**	**50**	**50**	**50**
5. Ductility (at 25º C, 5cm per min.) **Cm** (min).	AASHTO T51 – 74	**100**	**100**	**100**	**100**
6. Ductility after heating (at 25º C, 5cm per min.) **Cm** (min.)	AASTO T51 – 74	**50**	**50**	**50**	**75**
7. Softening point R.B. **ºC**	AASHTO T53 – 74	**54 – 60**	**52 – 57**	**49 – 64**	**45 – 50**
8. Increase of softening point R.B. after heating (5hrs of 163ºC) **ºC** (max.)	AASHTO T53 – 78	**10**	**10**	**10**	**10**
9. Solubility in Organic Solvents. **%** (min.)	AAHTO T44 – 70	**99**	**99**	**99**	**99**
10. Paraffin content **%**(max.)	DIN 52015	**2**	**2**	**2**	**2**
11.Specific Gravity (15.6 ºC)		**1.04**	**1.04**	**1.04**	**1.04**

Reference: **SORB**

Test No.: **7**

Flash and Fire point

Introduction:

The **flash point** of a bituminous material is the temperature at which the substance momentarily takes fire in the form of a flash for **1** second under specified test conditions.

The **fire point** of bituminous material is the lowest temperature at which the material gets ignited and burns on the surface continuously for **5** seconds under specified test conditions.

Significance:

1) This test is intended to determine the temperature to which the material may be heated safely for constructional purpose.
2) The flash point test is sometimes used to determine the existence of impurities like gasoline or kerosene in the material.

Apparatus:

1) Cleveland opened tester complete set.
2) Thermometer :
    - Low range = 7^{o}C to 110 ^{o}C
    - High range = 90^{o}C to 370 ^{o}C
3) Source of flame.
4) Gloves, tongues, … etc.

Precision:

The result shall not differ from the mean value by more than the following:

- 3 ^{o}C in case of flash point.
- 6 ^{o}C in case of fire point.

Precautions:

1) The apparatus should be shielded from air draughts.
2) Continuous stirring is essential to break surface films of slice.
3) The bluish flame that surrounds the test flame should not be confused with true flash.
4) The test flame should not be applied frequently as the surface layer is likely to be superheated.

Test Procedure:

1) All the part of the cup should be thoroughly cleaned and dried before the test is started particular care should be taken to remove all traces of solvent used for cleaning.

2) Fill the cup with the material under tests to the level indicated by the filling mark.
3) Insert the desired thermometer into the sample. The bottom of the thermometer should not touch the bottom of the cup.
4) Switch on the heater. Apply heat at such a rate that the temperature rise is 5^{o}C to 6^{o}C per minute.
5) Light and adjust the test flame so that it is of the size of a bead of 4mm in diameter.
6) Turn the stutter at a rate of approximately 60 revolutions per minute.
7) Apply the test flame at each temperature reading which a multiple of 1oC to 104 oC. For the temperature range above 104 ^{o}C, apply the test flame at each reading which is a multiple of 3 ^{o}C, the first application of the test flame being made at a temperature of 17 ^{o}C below the actual flash point. The flame must be kept in lowered position for one second and then quickly raised to its high position. The material should not be stured while test flame is applied.
8) Report flash point as the thermometer at the time when the flame application causes a distinct bluish flash in the interior of the cup for one second.
9) Continue heating and subsequent application of the flame at interval of 3^{o}C. This will be continued until the material ignites and continuous to burn for 5 seconds, the temperature of the material at this instance as read in the thermometer is recorded as the fire point.

Data sheet

Test No: 7

Title: Flash and Fire Point

Student Name: *Sec:* *Group:* *Date:* / / 20

****
*

- Type of the Material:
- Grade of the Material:

Time (min)	Temp (ºC)	Temp. Rise ºC/min	Remarks

Results:

Flash Point ☐ **ºC**

Fire Point ☐ **ºC**

Signature

Test No: 8

Specific Gravity of Bituminous Materials

Introduction:

Specific gravity is the ratio of the mass of a given volume of the substance to the mass of an equal volume of water, the temperature of both being specified.

The specific gravity can be determined either by Pycnometer method or by Balance method.

Significance:

The test is done for the following purposes:

1) For billing purpose while being transshipped from one place to another.
2) For incorporation in the mix design method (calculations).
3) To identify the various kinds of bituminous material with reference to the specific gravity values.
4) To detect the presence of impurities in the material.

Apparatus:

a. Pycnometer method: Specific gravity bottles of 50 ml capacity.
b. Balance method : Analytical balance, 12mm diameter brass mold, beaker.

Cleveland open cup, laboratory heater, tongues, gloves, …etc, will be required in both methods.

Precision:

Test results will not differ from the mean by more than **±0.005**.

I:Pycnometer method:

Precautions:

1) Only refresh boiled distilled water shall be used.
2) During weighing, the temperature of apparatus should exceed the specified value.
3) While filling the apparatus and inserting the stopper, no air bubbles should be present in the pycnometer.
4) Weight should be determined just after filling the apparatus and shall be accurate to 0.10 gm.
5) In order to avoid breakage of the bottle while cleaning in case of very viscous materials, it is advisable to warm it at a temperature less than 100^{o}C, until most of the material is poured out and then to swab it with cotton waste. When cooled, it may finally be rinsed with benzene and wiped clean.

Test Procedure:

1) Clean, dry and weigh the specific bottle together with the stopper.
2) Fill it with freshly boiled distilled water and insert the stopper firmly.
3) Keep the bottle for about half an hour in a beaker containing distilled water maintained at 25 ± 0.1^{o}C? Wipe the surface with clean cotton and weigh again.

4) In case of solids and semisolid material, gently heat a small amount of the material to a fluid condition, care being taken to prevent loss by evaporation.
5) Pour the material into the specific gravity bottle to fill to approximately half of it. Slightly warm the bottle before filling.
   Note: In case of liquids, fill the bottle up to the brim and insert the stopper quickly.
6) To prevent escape of entrained air bubbles, allow the bottle to remain for half an hour at the room temperature.
7) Cool the bottle to the specified temperature (25^{o}C) and weigh it with the stopper.
8) Fill the bottle with distilled water and insert the stopper firmly.
9) Keep the bottle in a beaker containing distilled water at 25 ±0.1^{o}C for half an hour.
10) Remove the bottle from the bath and wipe the surface with clean dry cloth and weigh again.

Observations:

1) Grade of the material =
2) Room temperature =
3) Weight of bottle (empty) = (a)
4) Weight of bottle filled with water = (b)
5) Weight of bottle + half filled with material = (c)
6) Wight of bottle + half filled with material + Remaining filled with water = (d)

In case of liquid materials only:

Weight of bottle + completely filled with liquid material = (e)

Calculations:

a) Specific gravity of solid & semisolid materials = (c-a)/((b-a)-(d-c))
b) Specific gravity of liquid materials = (e-a)/(b-a)

II: Balance method:

Precautions:

1) No parts of the support for beaker should touch the balance.
2) No parts of the specimen should touch the beaker.
3) Care should be taken to avoid inclusion of air bubbles while pouring the material into the mold.

Test procedure:

1) Melt a small quantity of material by gentle application of heat, care being taken to avoid loss by evaporation.
2) Pour the hot material into the brass mold placed on a brass plate. The plate and the bottom edge of the mold should be amalgamated before this.
3) After cooling the sample in room temperature, cut the excess material by means of a hot spatula.
4) Remove the specimen from the mold.
5) Tare the balance with a piece of fine waxed silk thread.

6) Attach the test specimen to the thread so as to be suspended about 25mm above the straddle from the hook on the pan support and weigh it to the nearest 0.10 gm.
7) Weigh the specimen, still suspended by the thread and completely immersed in freshly boiled distilled water at 25±0.1°C to the nearest 0.1 mg. there should not be any air bubbles in the water.

Observations:

Weight of dry specimen in air = a
Weight of the specimen when immersed in distilled water 25°C = b

Calculations:

$$Specific\ gravity\ of\ the\ material = \frac{a}{a-b}$$

DATA SHEET

Test No:- **8**

Title:- **Specific Gravity of Bituminous Materials**

Name:- Group:- Sec:- Date:- / / 201

****

- Grade of Bitumen:
- Weight of bottle empty (a) =
- Weight of bottle filled with water (b) =
- Weight of bottle half filled with bitumen (c) =
- Weight of bottle + half filled with bitumen + remaining filled with water (d) =
- **In case of liquid materials only**:
- Weight of bottle + completely filled with liquid material (e) =

$$Specific\ gravity\ of\ solid\ and\ semisolid\ materials = \frac{c-a}{(b-a)-(d-c)}$$

$$Specific\ gravity\ of\ liquid\ materials = \frac{e-a}{b-a}$$

Result:

Specific gravity =

Signature

Test No: 9

Softening Point

Introduction

Softening point of a bitumen material is the temperature at which the substance attains a particular degree of softening under specified test conditions. In other words, it is the temperature at which the material just changes from semisolid to liquid state under controlled heating.

Significance

1) It gives an idea of temperature susceptibility. Higher the softening point, lower the temperature susceptibility.
2) It is used in specifications for asphalts for crack filling, joint sealing, roofing, …etc where the materials are used in thick films. Usually any value between **45ºC to 65ºC** is desired.

Apparatus

1) Ring and ball apparatus which consist of steel ball (3/8" dia. and 3.5 gms in weight), ball guide supports, brass ring, glass container, …etc.
2) Thermometer of relevant range.
3) Stirrer.
4) Laboratory heater, Cleveland open cup, laboratory tongues, stop watch, …etc.

Precision

Test result shall not differ from the mean by more than the followings:

Softening point	Repeatability	Reproducibility
Below 30ºC	2 ºC	4 ºC
30ºC to 80ºC	1 ºC	2 ºC
Above 80ºC	2 ºC	4 ºC

Precautions

1) Only freshly boiled distilled water shall be used in the test to avoid bubble formation on the specimen.
2) The specified rate of heating should be strictly observed to ensure accurate results.
3) The rate of temperature rise shall not be distributed over the period of test and any test in which the rate of temperature rise does not fall within specified limits after the first three minutes shall be rejected.

Test Procedure

It consists of:

(a) Preparation of sample.
(b) Testing of sample.

(a)Preparation of sample

1) Heat the material to 75ºC – 100ºC above its approximate softening point, stir until it is completely fluid and free from air bubbles and water.
2) Heat the rings to the temperature of the molten material and place on brass plate previously amalgamated.
3) Pour the hot material into the rings sufficiently in order to give excess above the top level of the ring when cooled.

4) Cool the ring containing the material in air for a period of 30 minutes and level the material by removing the excess material by a hot spatula.

(b)Testing of sample

1) Assemble the apparatus with rings, thermometer and ball guides in position. Fill the glass container with water to a height of 100 mm.
2) The bath temperature is to be maintained at 5^oC for 15 minutes.
3) Place the ball (already cooled to 5^oC) over the surface of the material in the ring using forceps.
4) Heat the water at the rate of $5^o \pm 0.5^oC$ per minute until the material softens and allows the ball to fall down (through a distance of 25mm) and touch the bottom of the beaker. Read the temperature in the thermometer at this instance which is recorded as the softening point.
5) Repeat the test for the second time and find the mean value.

Deviation

For material whose softening point is above 80^oC, the following deviations will be made in the test specifications:

1) Glycerin should be used as heat media in place of water.
2) Initial temperature should be kept as 32^oC in lieu of 5^oC

DATA SHEET

Test No:- **9**

Title:- **Softening Point**

Name:- *Group:-* *Sec:-* *Date:- / / 201*

****

Grade of the material =

Room temperature =

Cooling time in room temperature =

Time for which the specimen was kept in 5^{o}C water bath =

Time readings (minute)	Temperature (^{o}C)	Temperature rise (^{o}C /min)	Remarks

Result:

Softening Point = ☐ ^{o}C

Signature

Test No: 10

Ductility

Introduction

Ductility is the property which permits asphalts to undergo deformation without breaking. The ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before rupture when two ends of a standard briquette specimen of the material are pulled at a speed of 50 ± 2.5 mm per minute at a temperature of 25^o ± 0.5^oC or other relevant test conditions (speed of 10 ± 0.5mm per minute at a temperature of 4^o ± 0.5^oC).

Significance

High ductility is associated with high temperature susceptibility. Also, materials with high ductility have generally good binding power and ability to resist shocks and vibrations. However, the ductility value of a good material should be within the desired/permitted range which has been specified to be **50 t0 110 cm by AASHTO(>100cm by SORB)**.

Apparatus

(1) **Ductility Testing Machine:** It consists of a rectangular water bath fitted with a moving device at a constant speed of 5 cm/minute (also could be alternated to 1 cm/minute). The test piece is so fitted that one of its ends is clamped while the other is pulled.

(2) **Mould:** It is made of brass and is used to prepare briquettes. It gives a test briquette such that its cross section at the center is 1 cm^2.

(3) Laboratory heater.

(4) Cleveland open cup, thermometer, laboratory tongues, …etc.

Precision

The test result shall not differ from the mean by more than the followings:

Repeatability	**5%**
Reproducibility	**10%**

Precautions

1) The bitumen should be poured in thin layers and evenly throughout so that no air pockets are left in the molded sample.
2) In filling the mould, care should be taken not to disarrange the parts and thus distort the briquette.
3) The plates on which the moulds are placed shall be perfectly flat and level so that the bottom surface of the mould touches it throughout.

Test Procedure

1) Soften the material to fluid consistency under a temperature of 75^oC to 100^oC approximately above the softening point of the material.
2) Assemble the mould on a brass plate previously amalgamated with HCI and mercury or soap solution. The interior surfaces of the sides of the mould should also be thoroughly amalgamated.
3) Pour the material in a stream back and forth from end to end of the mould until it is more than level full.
4) Allow it to cool at room temperature for 30 to 40 minutes and then place it in a water bath maintained at a temperature 25^oC ± 0.5^oC for 30 minutes.
5) Take out the moulds from the water bath and cut off the excess bitumen by means of a hot spatula so that the mould is just level full.

6) Place the mould with specimen and plate in water bath **25ºC** ± 0.5ºC for a period of 85 to 95 minutes.
7) Remove the briquette from the plate, detach the side pieces and attach the rings at each end of the clips to the ends for hooks in the testing machines.
8) Start the machine to the specimen horizontally at a rate of **50 mm per minute** until the sample is ruptured.
9) Measure the distance in centimeters through which the clips have been pulled to produce ruptured. During the test, be sure that the water in the tank of the testing machine covers the specimen both above and below by at least 10mm and is maintained within ±0.5ºC of the specified temperature.
10) Three test should be conducted on a sample and mean value should be reported.
11) *If the sample thread sags down in the water from its horizontal line, the specific gravity of water can be increased by addition of salt (Nacl), and in case the sample floats up above the water level, the specific gravity of water can be decreased by addition of methyl alcohol.*

DATA SHEET

Test No:- **10**

Title:- **Ductility**

Name:- Group:- Sec:- Date:- / / 201

****

Grade of material:
Pouring temperature (ºC):
Test temperature (ºC):
Period of cooling (min.) in air:
Period of cooling (min.) in water bath before trimming:
Period of cooling (min.) in water bath after trimming:

Result:

Ductility value (cm)= ºC

Signature

Test No: 11

Say-bolt Furol Viscosity of Cutback

Introduction

Viscosity is the property of a fluid by which it resists flow due to internal friction. One of the methods by which it is measured, is by determining the time taken by 50 cc of the material to flow from a cup (container) through a specified orifice under standard test conditions and at specified temperature.

Significance

The test is quite useful to designate the material according to its viscosity and to choose the most ideal material for different works.

Apparatus

a) Viscometer: the various parts of a viscometer are:
- Cup- having standard dimensions.
- Valve- it serves to close the orifice.
- Sleeves- to receive the cup and to hold it in position.
- Stirrer- to maintain the uniform temperature of the material.
- Curved shield- it carries an insulated handle for rotating the stirrer, a support for thermometer and a support for the valve.

b) Receiver- 100 ml graduated cylinder (beaker) for receiving the material flowing out from the orifice.
c) Thermometer- 2 standard thermometers are required one for the bath and the other for the cup.
d) Laboratory heater, Cleveland open cup, stop watch,… etc.

Precision

In case of	**Redwood No.1** Viscosity (seconds)		**Redwood No.2** Viscosity (seconds)
	100 or less	more than 100	100 or more
Repeatability	1 sec.	1% of mean	1% of mean
Reproducibility	2 sec.	2% of mean	4% of mean

Precautions

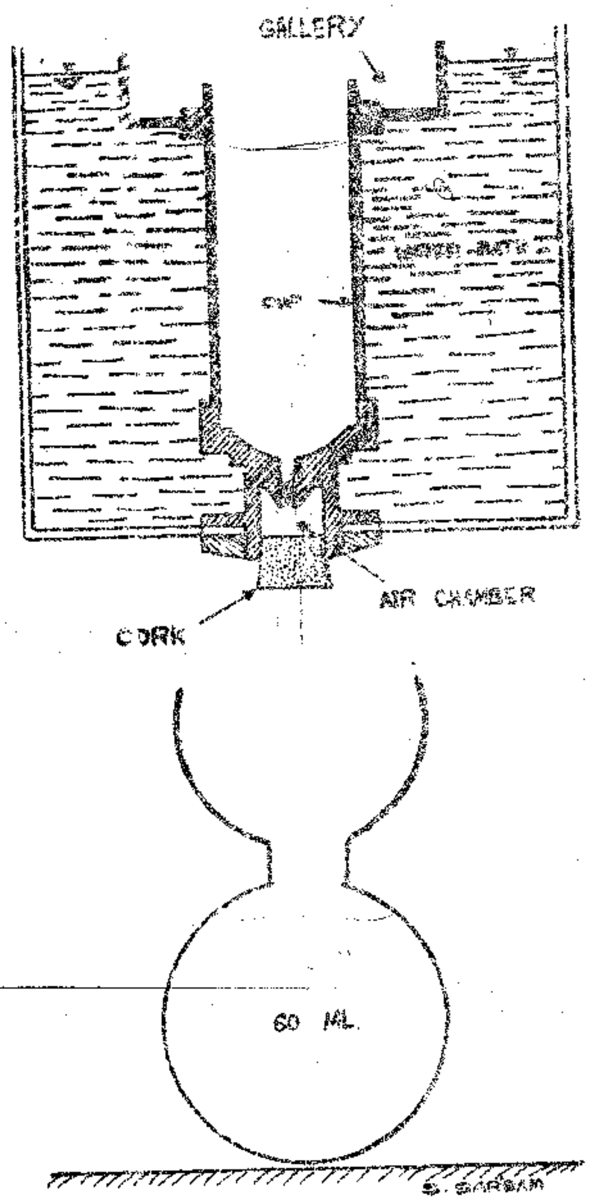
1) The temperature of test shall be a multiple of 50 and shall not be lewer than 200.
2) The cup is a critical part of the viscometer and care should be taken in its handling.
3) The orifice of the cup shall be tested at frequent intervals with a suitable gauge.
4) The working range of the instrument (with 4 mm orifice for cut-back) is such that the time of efflux shall be between 20 and 200 seconds.
   Note: - In case of tar materials, the orifice shall be 10 mm diameter and the time of efflux shall be between 10 and 140 seconds.
5) No stirring should be done just after the valve is suspended.

Procedure

1) Adjust the viscometer so that its top is level.
2) Heat the water in the bath to the temperature specified for the test. (Say **50ºC**) and maintain it within ±0.1C throughout the test. At this time, the stirrer should be continuously rotated.

3) Clean the cup orifice of the viscometer with a suitable solvent (say Benzene) and dry it thoroughly.
4) Warm and stir the material to 20 ^{o}C above the specified temperature of the test and cool it.
5) When the temperature has fallen to slightly above the specified value, pour the material under test into the cup until the leveling pins on the valve rod is just immersed when the later is vertical.
6) Pour into the graduated receiver 20 ml of mineral oil or soap solution and place it under the orifice of the cup.
7) Place the other thermometer in the material and stir it until the temperature is within ±0.1 ^{o}C of the specified value.
8) Allow the assembled apparatus to stand for 5 minutes during which period, the thermometer reading shall remain within 0.05°C of the specified temperature.
9) Remove the thermometer and quickly remove any excess material so that the final level is on the centre line of the leveling pins when the value is in its vertical position.
10) Immediately suspend the value by means of the hemisphere at the upper end in the value support which shall be brought immediately previously to its inner position.
11) Start the stop watch when the reading in the receiver is 25 ml and stop it when it is 75 ml. Note the time lapse in second which will be reported as the viscosity of the material at the test temperature.

SAYBOLT-FUROL VISCOMETER



DATA SHEET

Test No:- **11**

Title:- **Saybolt-Furol Viscosity**

Name:- Group:- Sec:- Date:- / / 201

****

Saybolt-Furol Viscosity Grades

Saybolt-Furol, Seconds	Grade⊗	Using
15 – 30	0	•Used as a tack, a thin adhesive bonding coat for hard dense surface, and as a prime or penetrating coat for very open surface.
40 – 80	1	
100 – 200	2	•Higher viscosity. •Used in surface treatments and penetration macadam applications. •More heat must be used with the higher grades, but less diluents is used.
250 – 500	3	
600 – 1200	4	
1500 – 3000	5	

⊗For 60 ml of liquid asphalts at 60 C^o.

RC (Rapid Curing Cutback) = Asphalt of Penetration (70 – 110) + Naphtha or Gasoline
MC (Medium Curing Cutback) = Asphalt of Penetration (70 – 250) + Kerosene
SC (Slow Curing Cutback) = Manufactured by straight run distillation or road oils

R.C: 1) Hard-base asphalt.
2) Solvent evaporates at low temperature.
3) Used in a northern region.

M.C: 1) Softer-base asphalt.
2) Less volatile solvent and cure at slower rate.
3) Used in the deep south.

Also these are differences depending on curing rate.

S.C:

Principal uses are in road – mixing and dust laying applications, also used in stockpile patching mixes, plant mixes with graded aggregates, and occasionally for priming. They are useful in the type of work where construction involves seasonal tearing and relaying of the existing of SC oil material. The SC materials do not have the fire or toxicity hazards that are inherent in the cutback liquid asphalts.

Result:

Time: ☐ seconds, **Grade:** ☐

Signature

Test No: **12**

Marshal Stability Test

Introduction

The **stability** of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature i.e 140º F (60º C).

Equipment

1) mould Assembly: Cylindrical moulds of 4 inch (10.16 cm) diameter and 3 inch(7.5 cm) height with base plate and collar extension.
2) Compaction hammers, weight 10 lbs (4.55 Kg.) for a drop of 18 inch (45.7 cm).
3) Specimen extractor.
4) Compaction pedestal and specimen mould holder.
5) Breaking head assembly with 4" dia; gauge for flow measurements.
6) Loading unit.
7) Oven or hot plate.
8) Balance, sieve shaker, mixing pan, spatula.
9) Water bath.
10) Thermometers of range up to 400°F (203°C).

Significance

The test aim at an economical blend of aggregates and binder so as to fulfill the designed properties of the mix.

Precautions

1) Heating of bitumen for more than one hour should be avoided.
2) The time elapsed for the test after the removal of specimen from water bath to the maximum load determination should not exceed 30 seconds.

Test Procedure

It consists of the following steps:

1) Preparation of batch mixes.
2) Compaction.
3) Weighing the samples.
4) Stability and flow values.

1) Preparation of batch mixes

i. Select the grading of aggregate as given in Table (2).
ii. Weigh the different sizes of aggregates in different pans to from 1150 gms of the mix, and then place in a mixing container.
iii. All the constituents are mixed, and then placed either in hot oven or on hot plate to heat them to the required mixing temperature (154 °0).
iv. Heat the bitumen binder of the specified grade to the required mixing temperature (154°0).
v. Place the container having all sizes of aggregate on the balance and to this add the required quantity of hot bitumen.
vi. Mix the aggregates and bitumen manually or with a mechanical mixer as quickly and thoroughly as possible. At the start of the compaction, the mix should attain the desired compacting temperature (138ºC).

- For mixing and compacting operations, the following temperatures are recommended:

Bitumen Grade	Temperature	
	Mixing	compacting
180/200 80/100 60/70	290º F (138º C) 310 º F (154º C) 320 º F (160º C)	270º F (132º C) 290 º F (138º C) 300º F (149º C)

2) Compaction

i. In advance to preparing batch mix, the face of compaction hammer and compaction moulds (3 Nos.) are thoroughly cleaned, heated to 200 to 300º F (100 to 150°C).
ii. Pour the hot batch mix into the hot mould.
iii. Place the compaction mould along with batch mix on the compaction pedestal.
iv. Place the hammer face over the batch top and the mix is compacted by giving 50 blows of hammer.
v. Reverse the mold and apply 50 blows to the mix again.

Note: *If the mix is designed for an expected tyre pressure of 7 Kg/cm² (100 P.s.i) or medium traffic, specimen is compacted by giving 50 blows of the hammer on each side of the specimen. For a tyre pressure of 14 Kg/cm² (200 P.s.i) or for heavy traffic, 75 blows on each side are given. However for a light traffic 35 blows on each side are sufficient.*

vi. Remove the collar and base plate and allow the specimen along with mould to cool in water for at least 2 minutes.
vii. Remove the specimen from the mould with the help of extrusion device.
viii. Number each specimen.
ix. Allow the specimen to cool at room temperature for 24 hours.

3) Weighing the samples

The samples should be weighted in air, in water and saturated surface dry , so that to determine the total voids in the mix, aggregate voids filled with bitumen and the unit weight of the sample.

4) Stability and flow values

i. Immerse the test specimen in hot water bath at 140 ± 1.8ºF (60 ± 1°C) for 30 to 40 minutes before the test.
ii. Place the flow dial gauge over the guide rod and adjust the dial gauges of proving ring and flow value to read zero.
iii. Clean and lubricate the testing head and quickly place the specimen on the base plate of the compression testing machine.
iv. Apply the testing load to the specimen at a constant rate of deformation of 5 cm/minute, until the maximum value is reached.
v. Record the values of maximum load and the flow dial gauges.
vi. Reverse the machine.

Report

Record all the above data in the prepared data sheet and draw the following graphs:

i. Corrected stability Vs %bitumen content {make use of Correction Table(3)}.
ii. Flow values Vs %bitumen content.
iii. % voids Vs %bitumen content.
iv. % voids filled with bitumen Vs %bitumen content.
v. Unit weight Vs %bitumen content.

And by making use of the limiting criteria in Table(1), determine the Optimum Asphalt Content.

Criteria For Design

This determination is made by the application of the following limiting criteria to test data for the mix at its binder content.

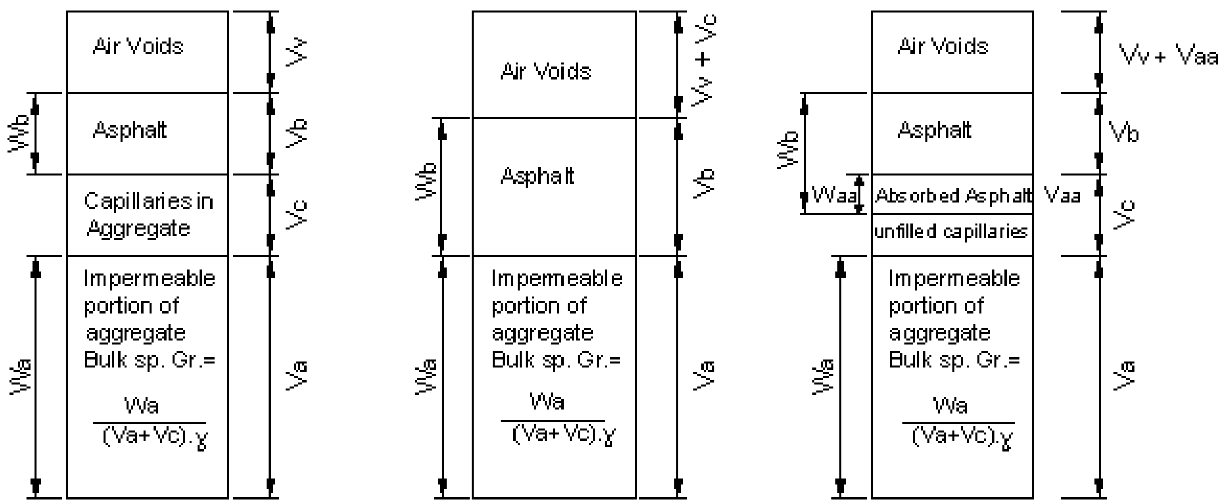
Table (1): Properties of Bituminous Materials	Property	
	Binder course	Surface course
Stability Marshal (75 blows on each face)	Min. 7 kN	Min. 8 kN
Flow Marshal	(2 – 4) mm	(2 – 4) mm
Percentage voids in Mix	(3 – 7)%	(3 – 5)%
Swelling after 28 days (%Vol.)	Min. (1.0)%	Min. (1.0)%
Voids filled with bitumen (%)	(60 – 80)%	(70 – 85)%
Index of Retained strength (AASHTO T165)	Min. 80%	Min. 80%

From "Standard Specifications for roads & Bridges", Iraqi specification

Table(2) BITUMINOUS MIXTURE GRADINGS

U.S Sieve size		Percentage Passing by Weight of Total Aggregate	
mm	Imperial	Binder Course	Surface Course
25.0	1"	100	
19.0	$\frac{3}{4}$"	90-100	100
12.5	$\frac{1}{2}$"	70-90	80-100
9.5	$\frac{3}{8}$"	60-80	70-85
4.75	No.4	42-60	60-80
2.0	No.10	27-47	40-60
1.0	No.18	20-37	28-48
0.6	No.30	15-30	22-40
0.25	No.60	8-20	10-30
0.125	No.120	6-15	8-20
0.075	No.200	5-10	6-12
Asphaltic Cement (%weight of total mix)		**4-6**	**4.5-6.5**

Effect of Absorption



Three Methods of Correction:

1) Design of bulk Sp. Gr. then adding asphalt absorbed into the stone to the design quantity to obtain corrected optimum asphalt content.

2) To employ the average of the Bulk Sp. Gr. and the Apparent Sp. Gr. in making the calculations.
3) Using effective Sp. Gr.

****

In actual practice

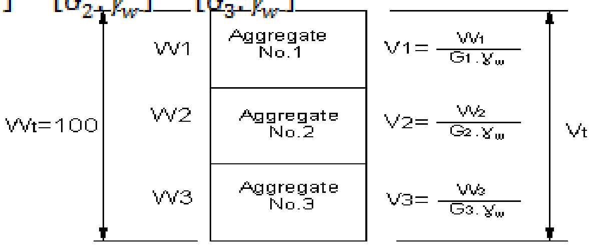
$$effective\ Sp.Gr. = \left\{\frac{Apparent\ Sp.Gr. + Bulk\ Sp.Gr.}{2}\right\}$$

****

Specific Gravity of Combined Aggregates

$$Average\ density = G.\gamma_w = \frac{W_t}{V_t} = \frac{100}{\left[\frac{W_1}{G_1.\gamma_w}\right] + \left[\frac{W_2}{G_2.\gamma_w}\right] + \left[\frac{W_3}{G_3.\gamma_w}\right]}$$

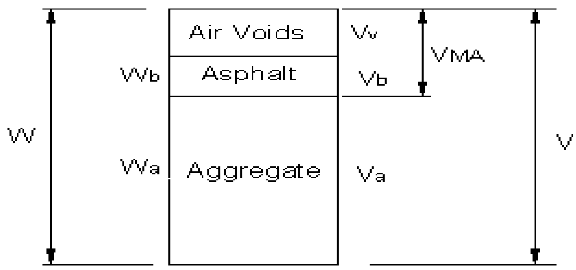
$$G = \frac{100}{\left[\frac{W_1}{G_1}\right] + \left[\frac{W_2}{G_2}\right] + \left[\frac{W_3}{G_3}\right]}$$

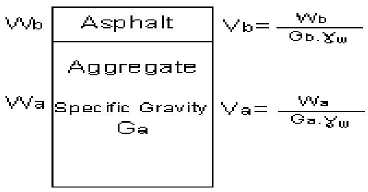


Where:
W_1, W_2 & W_3: Weight of each Aggregate (Wts%)
G_1, G_2 & G_3: Sp. Gr. of Aggregates.
Ref.: "Asphalt pavement Engineering" by Wallace & Martin

Marshal Stability Test

(Volume Relation of Asphaltic Concrete)





(G) – Actual

(G_o) – Theoretical

<u>(Total volume of specimen)</u>

$$Bulk\ volume = \left\{\begin{matrix} Wt.of\ spec. \\ saturated\ surface \\ dry\ in\ air \end{matrix}\right\} - \left\{\begin{matrix} weight\ of \\ spec.in \\ water \end{matrix}\right\}$$

$$Bulk\ density\ of\ spec.G = \left[\frac{Wt.in\ air}{Bulk\ Volume}\right]$$

<u>(Volume of solids in specimen)</u>

$$G_o = \left[\frac{W}{V_b + V_a}\right] = \frac{W}{\left[\frac{W_b}{G_b.\gamma_w}\right] + \left[\frac{W_a}{G_a.\gamma_w}\right]}$$

$$G_o = \left[\frac{W}{\frac{W_b}{G_b} + \frac{W_a}{G_a}}\right] = \frac{100}{\left[\frac{W_b}{G_b}\right] + \left[\frac{100 - W_b}{G_a}\right]}$$

$$G_o = \frac{100}{\left[\frac{W_b}{G_b}\right] + \left[\frac{W_a}{G_a}\right]}$$

When W=100, W_b & W_a in Wt.%

****

$$Total\ volume\ of\ solid\ (\%) = \left[\frac{V_b + V_a}{V}\right] * 100$$

$$V_b + V_a = \frac{W}{G_o.\gamma_w} \quad , \qquad V = \frac{W}{G.\gamma_w}$$

$$R = \left[\frac{W/(G_o.\gamma_w)}{W/(G.\gamma_w)}\right] * 100 = \left[\frac{G}{G_o}\right] * 100 = \%theoretical\ density.(\%solids\ by\ volume).$$

$$100 - R = percentage\ volume\ of\ air\ voids.$$

$$VMA\% = \left[\frac{V - V_a}{V}\right] * 100 = \left(1 - \frac{V_a}{V}\right) + \left\{1 - \frac{W_a/(G_a.\gamma_w)}{W/(G.\gamma_w)}\right\} * 100 = 100 - W_a\left[\frac{G}{G_a}\right]$$

Put W=100

VMA%= %Volume of voids in mineral aggregate. { – for on sized or poorly graded Agg. ≥ 35%
W_a=Aggregate content percent by weight. + for well graded Agg. <20% }

$$\%voids\ filled\ by\ Asphalt = \left[\frac{VMA - (100 - R)}{VMA}\right]$$

Ref.: "Asphalt pavement Engineering" by Wallace & Martin

Table (3): Stability Correction Ratios

Volume of specimen (cc)	Correction ratio	Volume of specimen (cc)	Correction ratio	Volume of specimen (cc)	Correction ratio	Volume of specimen (cc)	Correction ratio
200-213	5.56	302-316	2.78	406-420	1.47	509-522	1.00
214-225	5.00	317-328	2.50	421-431	1.39	523-535	0.96
226-237	4.55	329-340	2.27	432-443	1.32	536-546	0.93
238-250	4.17	341-353	2.08	444-456	1.25	547-559	0.89
251-264	3.85	354-367	1.92	457-470	1.19	560-573	0.86
265-276	3.57	368-379	1.79	471-482	1.14	574-585	0.83
277-289	3.33	380-392	1.67	483-495	1.09	586-598	0.81
290-301	3.03	393-405	1.56	496-508	1.04	599-610	0.78
						611-625	0.76

Test No:

Marshall Stability Test

Hot-mix design data by the Marshall Method

Name:

class: sec: class No:

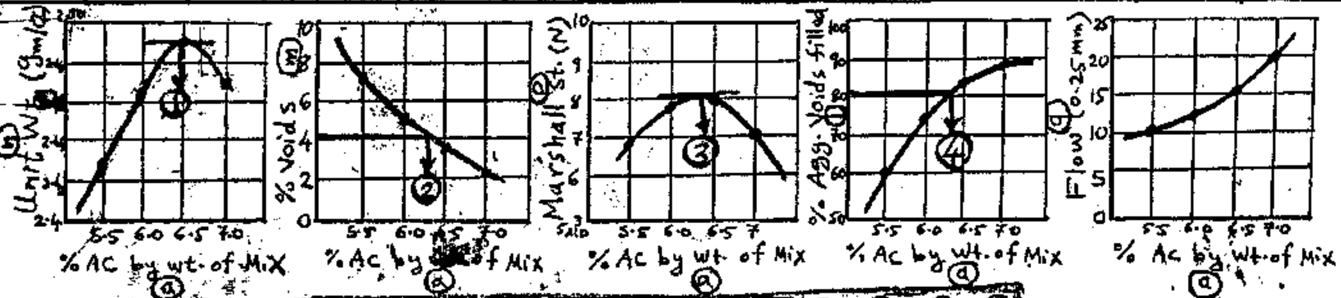
Date:

Sp. gr. of AC = 1.0 (0.95 - 1.05) ; Av. sp. gr. Agg. Blend = 2.8 (2.6-3.0) ; Pen. Grade AC: 80-100

% AC spec.	Weight (gm)			Bulk Volume	Spec. Gravity		Volume (% Total)			Voids (%)			Unit Weight	Stability (N)		Flow 1/100"
NO.	in air	in Water	S.S.D. in air	cc.	Bulk «G»	Max. Theo. «Go»	Ac.	Agg.	Voids	Agg. (VMA)	Filled (Agg.)	Total Mix	(gm/cc)	Meas.	Adjust	(0.25 mm)
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
% AC. by wt. of Mix				(d-c)	$\frac{b}{e}$	*	$\frac{a \cdot f}{G_{AC}}$	$\frac{(100-a)f}{G_{Agg}}$	100-h-i	100-i	$\frac{h}{K}\times 100$	$100-\frac{100f}{g}$	1.0×f		**	

$$* \; G_o = \frac{100}{\frac{\%AC}{G_{AC}} + \frac{\%Agg}{G_{Agg}}}$$

** See Conversion Table.



• Result: Optimum Asphalt Content = $\frac{①+②+③+④}{4}$

Cover of Report

Typical Report

University of Salahaddin-Hawler
College of Engineering
Civil Eng.Department
Highway Engineering Lab.
3rdYear

Test No.	
Test Name	
Date of Test	
Date of Report	
Student Name	
Section	
Group	

Test No.

Test Name:

Object:

Introduction:

All important data i.e: definitions, formulas...etc related to the test are recorded here

Apparatus:

Hand Sketch of most important instrument used in proper scale

Procedure:

Mention all the deviations with standard procedure

Observations & Calculations:

All observations & calculations recorded in table as data sheet& details in appendix

Results:

The final result of table-or graph- should be recorded here briefly

Discussion:

This will be in 3 paragraphs:
1.Compare the final result with standard limits and decide,
2.Mension the sources of deviations (errors), and
3.Explain the practical application of the Test, make use to the references here.

•Put the data sheet at the end of the report after completing it by pen and signed by the supervisor, and any report without the data sheet will be neglected

•Try to prepare the report by yourself, and any two or more similar reports will neglected

•Finally the report submitted after 1 week of the test excecution