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ملخص

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

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➢ Penetration of Bituminous Material:

* The Penetration Value: The distance in (mm) that a standard needle value vertically penetrates a sample of bitumen under specified conditions of temperature, load & time.

* The Standard Conditions are: 5 seconds, 100g sample weight, 25°C temperature.

* The needle diameter: 1mm.

* Take a read as: 10^{th} of mm.

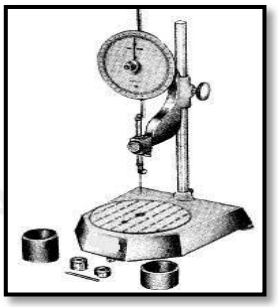
* The distance between needle & sample is: 10mm.

* Lower the needle until it touch the surface at the sample, the needle should be at least (10) mm.

* Sample keep in water bath: (1.5 -2) hrs.

* The Apparatus: Penetrometer.

Penetrometer ⟶



* Take the average read of: three samples.

* Why the penetration test is used?

1- To measure consistency and viscosity.

2- Indicate about material if it hard or soft or in between.

3- Temperature susceptibility & evaluation of damage.

4- The result can be used to describe the softness.

*Time depending duo to: hardening.

* If the penetration > 200: leave the needle inside the sample and place another.

*How presences of plastic on the sample affect the result of penetration? Decrease.

* If the test load is greater than 100g, then the test time must be less than the standard (5sec).

* Cutback Asphalts:

1- Asphalt Cement (AC) + gasoline = Rapid-Curing (RC).

2- AC + Kerosene = Medium-Curing (MC).

3- AC + Road Oil = Slow-Curing (SC).

* What are the meanings of?

MC 30/40: The penetration value (3-4) mm, so its hard bitumen used in hot areas.

MC 80/100: The penetration value (8-10) mm, so its soft bitumen used in cold areas.

* When the test will be repeated?

If the sample or needle comes contact with water

* The Relations:

MC ↑, Soft ↑, Penetrate ↑, Grade ↑, Consistency ↓, Used in COLD regions.

MC ↓, Hard ↑, Penetrate ↓, Grade ↓, Consistency ↑, Used in HOT regions.

Softening Point of Bituminous Material:

* Softening point: Temperature at which a disc of bitumen softness enough to allow a standard ball resting on it to move downward a distance 25mm.

* Rate of heating: 5°C / min.

* Apparatus: Ring & Ball.

* Take the average read of: the two samples.

* Softening of bitumen involves a gradual change in consistency with increasing temp.

* Softening point indicates the: tendency of bitumen to flow.

* If the softening point is in (80 – 160) °C range, you'll use Glycerine Liquid.

* Why softening point test is used? To classify bitumen according to their suitability to use in hot or cold region

* Factors affects on the result of softening point test are:

1- If the rate of heating increases, the softening point decreases under the standard.
2- Performing the test on air instead of the liquid, the softening point increase.
3- If sand present in the sample increase the boiling temp. & increase the softening point.

* I shouldn't use the same sample many times in this test, because the viscosity will change & make error in the test.

* The air voids in the sample should be (3-5) %, because the asphalt wills expansion with time.

* Surface becomes stiff in winter duo to cooling.

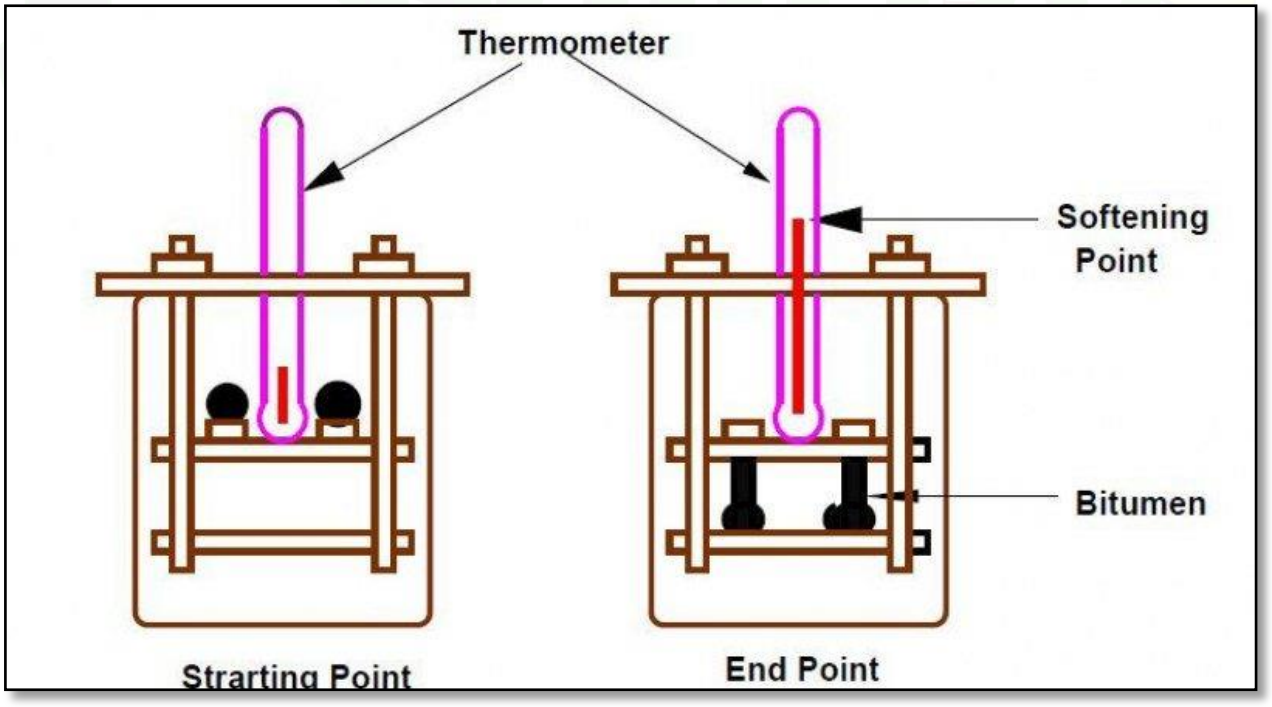
* When the test will be repeated?

If the difference between two samples exceed 1°C.

* The Relations:

Softening Point ↑, Penetration ↓, Viscosity ↑, Temp. ↓, used in hot regions; otherwise used in cold regions

* If asphalt used with low softening point in hot areas, the asphalt will bleeding.



Ductility of Bituminous Material:

* The Ductility of Bitumen Material: The distance it will elongated before breaking, when two ends of the tested sample are pulled apart under specific condition of the experiment.

*The Standard Conditions: Water bath with 25°C temp. ,using briquette moulds.

* Rate of withdrawals: 50mm/min.

*Apparatus: Ductilometer.

* Take the average read of: three successive normal tests.

* If the sample is 1m long, it's within the Jordanian standard.

* If the standard temperature decreases, the ductility also decreases.

* Why ductility test is used?

1- To provide a general idea about the tension properties of the tested bitumen.
2- Used to judge the suitability of the material for different uses.

* The test has two shapes:

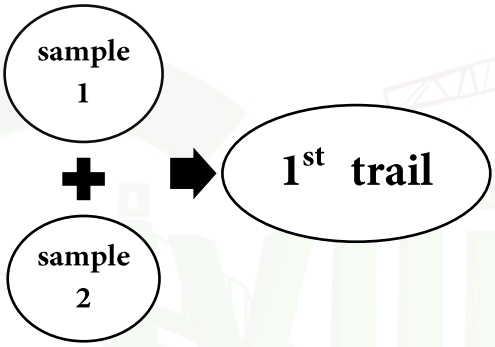
1- Normal: Zero area at ductility point at rupture, and stay at the mid of water bath.
2- Abnormal:
    1- If the sample at the bottom of water bath "that's mean the sample has density higher than the water", the density of water should be increase, so add NACL "Salt".
    2- If the sample at the top of the surface "that's mean the sample has density lower than the water", the density of water should be reduce, so add Alcohol.

* If it non-ductile sample, the cracking will appear.

* When the test will be repeated?

If normal test was not attained after three trails, the test is unobtainable.

** Each trail has 2 samples.

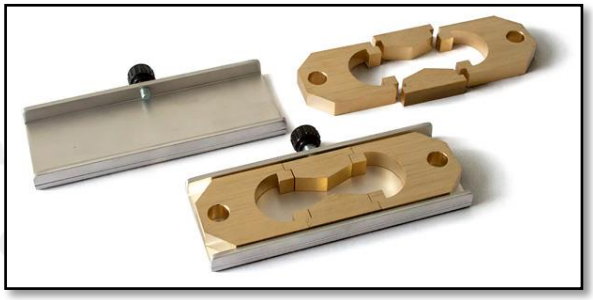


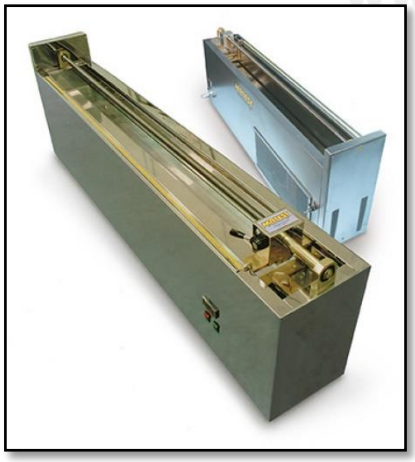
* The Relations:

Temp. ↓, Ductility ↓, Penetration ↓.

High ductility → Cold areas, the opposite used in hot areas.

Briquette moulds →





← Ductilometer

➢ *Flash & Fire Points of Bitumen:*

*Flash Point: The point that has a lowest temperature that the vapours will ignition.

* Fire Point: Lowest temperature that burning the sample for 5 seconds.

* Fire point is higher than flash point.

* Rate of heating: 5°C/min.

* The apparatus: Cleveland open cup →

* The test also called: Safety Test.

* In this method: the asphalt is heated in a metal container suspended in air bath.

* The method is staple for temperature above 80°C.

* Flash point should be larger than mixing & storage temperatures.

* Why flash & fire points are used?

1- Flash point: To access the overall flammability "presence of volatile & flammable substance".

2- Fire point: To measure combustibility.

* Why we must take care of not having air bubbles in the sample?

Because the air bubbles will explode early and give lower temperature than the flash point temperature and make error in reading.

* The difference between two successive test performed by the same operator shouldn't exceed 8°C.

* When the test will be repeated?

If the different between two single & independent results performed shouldn't exceed 17°C for flash point, and 14°C for fire point.

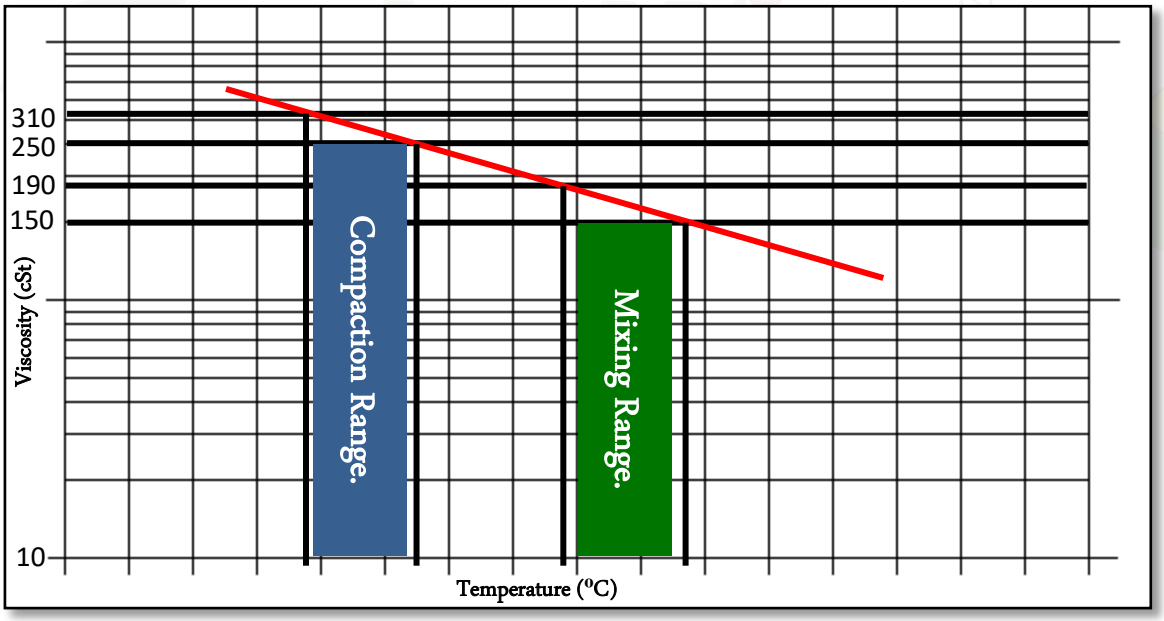
Viscosity of Asphalt:

* Viscosity: Measure of the resistance to flow.

* Apparatus: Brook field rational viscometer, for viscosity at high temp. > 100°C.

* Standard speed: 25 rpm.

* Take the average of: three samples at 135°C & 165°C.



* Mixing viscosity range is: [170 ± 20] cSt

* Compaction viscosity range is: [280 ± 30] cSt

* The scale used in chart: Semi-log scale.

* Unit used in taking readings: cPs.

* Unit used in chart: cSt.

* To convert the units from cPs to cSt: $cSt = {}^{cPs}/_{Gb}$, Gb = specific gravity of asphalt .

* Mixing temperature is higher than compaction temperature, that meaning the viscosity of mixing is lower than the viscosity of compaction.

* Mixing asphalt viscosity should provide proper asphalt coating for aggregate.

* Compaction asphalt viscosity should prevent asphalt bleeding.

* The optimum viscosity should be reached.

* Why paving in Jordan is almost done in the summer?

Since if it done is done in winter, where the temperature is very low then the viscosity will be high, which make the compaction of asphalt is difficult

* If the viscosity is very low, the asphalt will segregation and the rutting action will appear.

* What the meaning of AC 2000 & AC 3000?

AC: Asphalt Concrete.

2000 & 3000: Viscosity at 60°C in cPs. [The higher the number the greater the viscosity].

* The Relations:

If there are some obstacles, the viscosity will increase.

If the test speed is 30 rpm instead of 25 rpm, the viscosity will decrease.

Temperature ↑, Viscosity ↓, Workability ↑.

Brook field rational viscometer →

Specific Gravity of Asphalt Cement:

* Specific Gravity: The ratio of mass of the material "here is the asphalt" at a given temperature to the mass of an equal volume of water at the same temperature.

* Specific gravity is useful in:

1- Making temperature volume correction.

2- Determine the weight per unit volume "density" of asphalt cement.

* The apparatus used: Pycnometer.

* The formula of S.G: $$G_b = \frac{(C-A)}{[(B-A)-(D-C)]}.$$

A: mass of pycnometer.

B: mass of pycnometer filled with water.

C: mass of pycnometer partially filled with asphalt.

D: mass of pycnometer filled with asphalt & water.

* Important formulas you should know:

1- $\rho = S.G \times \rho_w \approx \gamma = S.G \times \gamma_w \dashrightarrow [\rho_w = 997\ kg/m^3]$

2- $V = \frac{wt}{S.G \times \Upsilon_w}$

3- $\gamma = \rho \times S.G$

4- $S.G = \frac{\rho_{sample}}{\rho_{water}}$

* What is the effect of adding petroleum oils in the specific gravity of asphalt?

The density of oil is less than the density of water, so the specific gravity will decrease.

* What is the effect of using glycerine instead of water during the test?

The density of glycerine ($\cong$ 1.26 g/ml) is higher than the density of water (= 1 g/ml), which means the S.G of glycerine, is also higher than the S.G of water, so glycerine will be more massive than water.

The S.G will decrease. $\{S.G \downarrow = \frac{mass\ of\ asphalt\ (constant)}{mass\ of\ the\ fluid\ used \uparrow}\}$.

* Why the pycnometer stopper is concave?

To check there are no air bubbles & to ensure that the pycnometer filled with water.

* The value of S.G of asphalt is very close to the value of S.G of water.

* Approximately range of S.G of asphalt: [1.01 – 1.03].

* The Relations:

Temperature ↑, S.G ↓.

Pycnometer ⟶

California Bearing Ratio (CBR):

* California Bearing Ratio (CBR): Value is calculated as a ratio of load or stress at 2.5mm (0.1 inches) penetration to a standard load or stress.

* Why the CBR test is used?

To evaluate the strength of compacted soil & design pavement.

* The formula of CBR value:

$$CBR_{2.5mm} = \frac{P_1}{6.9}\ [MPa] \approx CBR_{0.1in} = \frac{P_1}{1000}\ [PSi] \approx CBR_{2.5mm} = \frac{P_1}{1364}\ [Kg]$$

$$CBR_{5mm} = \frac{P_2}{10.3}\ [MPa] \approx CBR_{0.2in} = \frac{P_2}{1500}\ [PSi] \approx CBR_{5mm} = \frac{P_2}{2045}\ [Kg]$$

Note: All formulas multiply with 100%.

$CBR_{2.5mm} > CBR_{5mm}$ [*The test is acceptable*].

* Important formulas you should know:

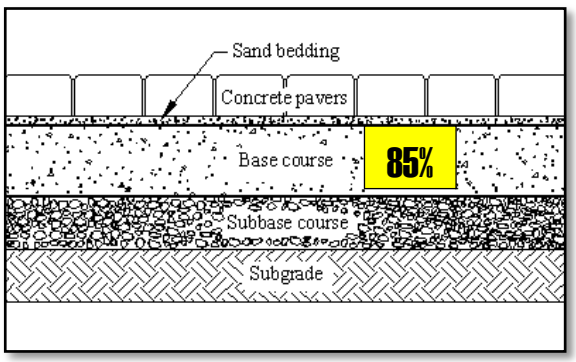
1- Modulus of resilient: MR = 10.34 CBR [MPa] or MR = 1500 CBR [Psi] , just if CBR < 10.

2- Bulk density: $\rho_{bulk} = \frac{wt_{mass+soil} - wt_{mold}}{V_{mold}}$.

3- Dry density: $\rho_{dry} = \frac{\rho_{bulk}}{(1+\%w)}$.

4- Stress: $\sigma = \frac{Load}{Area}\ [MPa]$.

* The CBR test is done for each layer of asphalt, such as: Base, Sub-base, subgrade.



The CBR value will decrease.

* The reading is taken every 0.25mm.

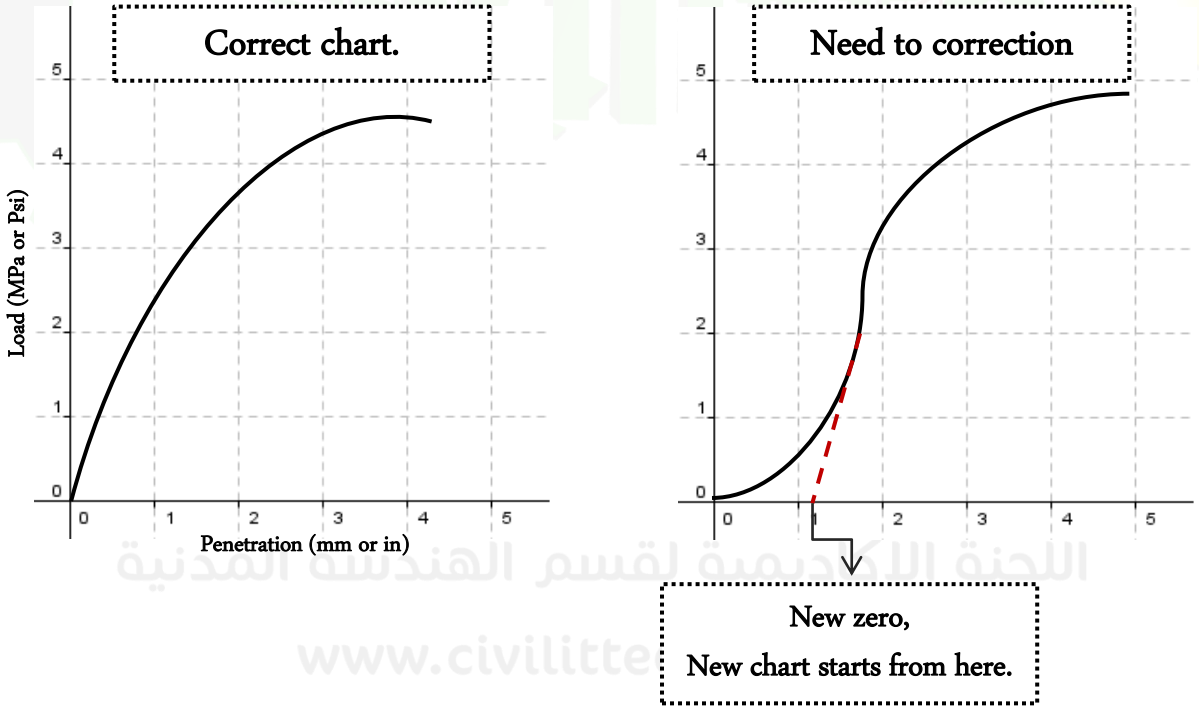
* The sample should be soaked, to be taken on the worst condition when water is present.

* What the meaning of $CBR_{2.5}$ = 85%?

The stress which causes penetration 2.5 equals 85% from the standard crushed stone.

* When the test will be repeated?

If the $CBR_5 > CBR_{2.5}$, the test will repeat and then take the greatest value whether it's for $CBR_{2.5}$ or CBR_5.



The Relations:

Load ↑, CBR ↓, Penetration ↑, Compaction Effort ↑, Density ↑.

➢ A Review of The Midterm Exam :

Summary of Relations:

Penetration ↑, Softening Point ↓, Ductility ↑, Viscosity ↓, Fire Point ↓, used in COLD regions, the opposite used in HOT regions.

Q: - Name the apparatus used in each test?

1- **Viscosity at high temperature > 100°C:** Brook field rational viscometer.
2- **Flash & Fire points:** Cleveland open cup.
3- **Ductility:** Ductilometer.
4- **Softening Point:** Ring & Ball apparatus.
5- **Penetration:** Penetrometer.

Q: -

1- **Define Penetration:** The distance in (mm) that a standard needle value vertically penetrates a sample of bitumen under specified conditions of temperature (25°C), load (100g) & time (5sec).
2- **What is the significance of the penetration test?** Describe the softness of the asphalt and measure viscosity & consistency.
3- **When would you change the liquid of the softening point test and why?** If the softening point is in (80 – 160) °C range, because the softening point will be higher than the boiling point of water and it will evaporate before reaching the softening point.
4- **What type of liquid used?** Glycerine Liquid.

5- What is the difference between AC 3000 & AC 2000 and what do the numbers & letters stand for? The higher the number the greater the viscosity.

AC: Asphalt Concrete.

2000 & 3000: Viscosity at 60°C in cPs.

6- What is the difference between MC 80/100 & MC 40/60 and what do the numbers & letters stand for?

MC: Medium-Curing cutback asphalt.

40/60: The penetration value (4-6) mm, so its hard bitumen used in hot areas.

80/100: The penetration value (8-10) mm, so its soft bitumen used in cold areas.

Q: - Where would use the following types of asphalt?

1- Asphalt with High penetration [Cold areas].

2- Asphalt with High viscosity [Hot areas].

3- Asphalt with High ductility [Cold areas].

4- Asphalt with High softening point [Hot areas].

Q: - When would you report the asphalt ductility test is unobtainable?

If normal test was not attained after three trails, the test is unobtainable.

Q: - What is the reason for the fact that when bituminous material is heated before mixing or application the temperature remains well below the flash point?

At the flash point the vapours of the asphalt will ignite, the material becomes invalid for mixing or application, therefore, the asphalt used should be suitable for the general weather to keep the mixing & application temperatures below the flash point.

Q: - When do you repeat the following experiments?

1- Flash & Fire points of bituminous test: If the different between two single & independent results performed shouldn't exceed 17°C for flash point, and 14°C for fire point.
2- Penetration of bitumen material test: If the sample or needle comes with contact with water.
3- California Bearing Ratio (CBR test): If the $CBR_5 > CBR_{2.5}$, the test will repeat and then take the greatest value whether it's for $CBR_{2.5}$ or CBR_5.

Q: - What happens in the following cases?

1- Asphalt with high penetration was used in hot regions: The asphalt will bleed and becomes invalid.
2- Asphalt with high softening point was used in hot regions: The asphalt will be suitable for use & acceptable if all other tests are acceptable.
3- Asphalt with low ductility was used in cold regions: The sample will not spreading, and the cracks will appear.
4- Asphalt with low flash & fire points was used in hot asphalt mixture: The asphalt will burn during mixing or casting.
5- In the Asphalt specific gravity experiment there was air bubbles entrapped within the asphalt sample: The presence of air increase in volume and remains the weight as it is, so the pycnometer will be filled with lower weight, and from specific gravity equation the value of the numerator will be reduced, so the S.G will decrease.

Q: - Give reasons to the following?

1- If you were working in hot asphalt mixing plant, you noticed that the asphalt was not coating the aggregates:

Reason: Mixing asphalt viscosity is not enough to coat aggregate.

2- The mix was not homogenous and there was segregation in the asphalt mixture:

Reason: The viscosity is very low.

3- There was difficulties in compaction and spreading the mix on road:

Reason: The asphalt is hard, due to the lack of ductility and increasing in viscosity, or compaction & spreading at low temperature.

4- In the ductility test the sample came in contact with the water surface:

Reason: The density of water is higher than the density of sample.

5- In the softening point test the lab technician changed the water used to a different liquid:

Reason: The softening point is in (80 – 160) ^{o}C range.

Q: - Define the following:

1- Flash Point: The point that has a lowest temperature that the vapours will ignition.

2- Fire Point: Lowest temperature that burning the sample for 5 seconds.

3- CBR: California Bearing Ratio, Value is calculated as a ratio of load or stress at 2.5mm (0.1 inches) penetration to a standard load or stress.

Q: - Write the formula of specific gravity test for asphalt and explain the symbols?

$$G_b = \frac{(C-A)}{[(B-A)-(D-C)]}.$$

A: mass of pycnometer.

B: mass of pycnometer filled with water.

C: mass of pycnometer partially filled with asphalt.

D: mass of pycnometer filled with asphalt & water.

Q: - The following weights are recorded during the determination of the specific gravity of bituminous material by the pycnometer method. Calculate the S.G of this substance.

Weight of pycnometer empty: 34.500g

Weight of pycnometer filled with water: 60.000g

Weight of pycnometer filled with bituminous material: 59.200g

Temperature (all determinations): 25°C.

Answer: $G_b = \frac{59.2-34.5}{60-34.5} = 0.969$

** ممكن يعطيني حجم البيكنوميتر مثلاً 1لتر ومنه بنطلع وزن المي اللي بملأ البيكنوميتر من القانون، ونرى أن الوزن = 1000 جرام "على فرض أن كثافة الماء = 1000 كجم/ م^3".

$$V = \frac{wt}{\rho}$$

Q: - Find CBR & Mr value for a sample of soil given in the following final results.

Penetration (in)	Load on Piston (Lbs)
0.1	60
0.2	200

Hint: The standard unit loads for crushed stone are 1000 & 1500 Psi at 0.1" & 0.2" penetrations respectively and the penetration piston cross section area is 3in².

Answer:

$$CBR_{0.1"} = \frac{60/3}{1000} \times 100\% = 2\%, Mr = 1500 \times 2 = 3000$$

$$CBR_{0.2"} = \frac{200/3}{1500} \times 100\% = 4.44\%, Mr = 1500 \times 4.44 = 6666.67$$

You must repeat the test because CBR@ 0.1" < CBR@0.2".

** ممكن يعطيني 2 تشارتس واحد بقيم الستاندرد وواحد بقيم الاختبار, الفكرة من السؤال اني بستخدم القيم الموجودة في التشارت وبحطها بالمقام (يعني قيم ستاندرد جديدة غير المحفوظة) , وممكن يكون تشارت الاختبار بحتاج لتعديل , فباخد القيم بعد التعديل وهي اللي بتنكتب بالمعادلة.

Q: - An un aged asphalt binder was tested using the Brooks field Rational Viscometer and gave following results;

@ 135°C → 858 cPs

@165°C → 130cPs

Specific gravity of asphalt 1.04

Mixing viscosity range = 170 ± 20 cSt.

Compaction viscosity range = 280 ± 30 cSt.

Find the compaction & mixing temperature ranges fot this binder.

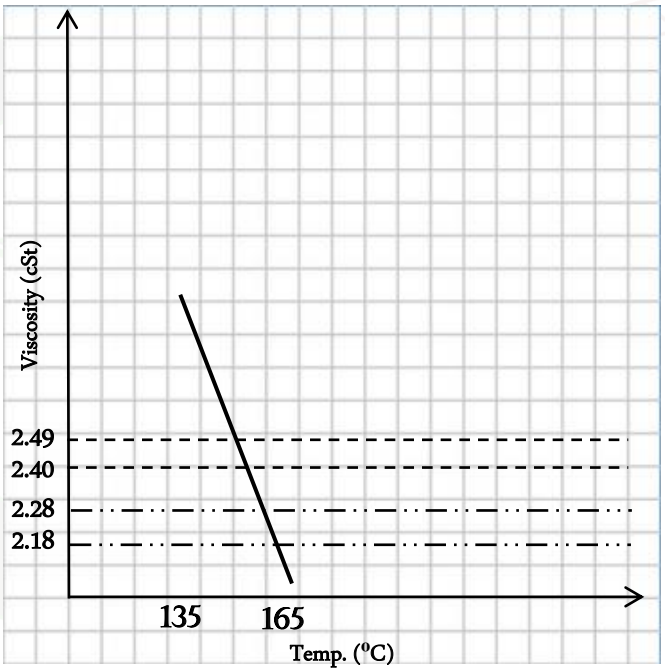
Answer:

@135°C $\longrightarrow \frac{858}{1.04} = 825\ cSt. \longrightarrow$ log (825) = 2.92

@165°C $\longrightarrow \frac{130}{1.04} = 125 cSt. \longrightarrow$ log (125) = 2.10

Mixing viscosity range = [log (150) - log (190)] = [2.18 – 2.28].

Compaction viscosity range = [log (250) – log (310)] = [2.40 – 2.49]



Mixing temp. range ≦ [160 – 163] °C.

Compaction temp. range ≦ [150 – 154] °C.

** الرسم غير دقيق , فالناتج النهائي تقريبي.

➢ *Specific Gravity of Coarse & Fine Aggregate:*

* Specific Gravity: The ratio of mass of material "here is aggregate" at given temperature to the mass of an equal volume of water at the same temperature.

* Types of specific gravity:

1- Bulk specific gravity: Total volume of the aggregate (Volume of aggregate + voids fill with water). {Gsb}

2- Apparent specific gravity: Net volume of the aggregate (No voids, volume of aggregate particles only). {Gsa}

3- Effective specific gravity: Overall volume exclusive of those that absorb asphalt (Total volume + pores that becomes filled with water after 24hrs soaking – volume of the large pores that filled with asphalt). {Gse}

Gsa > Gse > Gsb

** Coarse Aggregate:

* How to make coarse aggregate in SSD condition? Soak in water for 24 hours, and then dry with a towel lightly until the surface becomes pale, taking care to keep the pores filled with water.

$$G_{sa} = \frac{A}{A-C} \, , G_{sb} = \frac{A}{B-C} \, . Absorption = \frac{B-A}{A} \times 100\%$$

A: Weight of oven dry aggregate.

B: Weight of SSD aggregate.

C: Weight of submerged aggregate in water.

** Fine Aggregate:

* How to make fine aggregate in SSD condition? By using cone test (25 free-fall blows at 0.5cm distance to compact it); the sample should partially collapse.

$$G_{sa} = \frac{A}{B+A-C} \, , G_{sb} = \frac{A \text{ or } D}{B+D-C} \, . Absorption = \frac{D-A}{A} \times 100\%$$

A: Weight of oven dry aggregate.

B: Weight of pycnometer filled with water.

C: Weight of pycnometer + water + specimen.

D: Weight of SSD aggregate (500g "constant value").

G_{sb}: (use A: If it in dry basis, D: If it in SSD basis)

* Specific gravity of combined aggregate:

$$G_{s,comb} = \frac{\sum_{i=1}^{n} P_{Wt_i}}{\sum_{i=1}^{n} \frac{P_{Wt_i}}{G_{s,i}}} \, , P_{Wt_i} = \% \, by \, wt \, of material.$$

* Absorption of combined aggregate:

$$A_{comb} = \frac{\sum_{i=1}^{n} P_{Wt_i} \times A_i}{100}$$

* When aggregate absorption equal (Zero), that meaning there is no air voids in aggregate particles {theoretical case}, so all types of specific gravity are equal.

Tools to determine S.G for fine aggregate →

← Tools to determine S.G for coarse aggregate.

Aggregate Blending to Meet Specification:

* Blending of Aggregates: Aggregates that are used in AC mixture must have a certain gradation to achieve the desired interlocking of different aggregate sizes.

* Process used: Trail & error.

* In asphalt concrete mixes two or more aggregate of different gradations are typically blended to meet specifications limits for the following reasons:

1- Aggregates are separated into size to improve handling characteristics.

2- Mixing coarse aggregates & fine aggregates in one stockpile results in segregation.

3- It's unlikely that a single natural or quarried material will meet the specification.

4- It's often more economical to combine naturally occurring & processed materials to meet specifications than to use all processed material.

* Advantage of gradation limits: To achieve maximum density & desired voids.

* Aggregate Blending Formula: P= aA + bB + cC [a,b&c : percentage of each aggregate].

* Critical Sieve:

هو اصغر منخل بتكون فيه قيمة العبور للحصمة 100% لمنخلين (المنخل الحرج 1) , واصغر منخل بتكون فيه قيمة العبور 100% لمنخل (المنخل الحرج 2), "في حال كنا نملك 3 انواع للحصمة"؛ بالمثال التالي ستوضح الأمور.

* a= $\frac{specification\ median\ (retain)}{\%\ of\ retatin}$

* b = specification median (retain) – (a * % retain in A).

* c = 1 - a - b

* النسب اللي بتطلع عندي بضربها بالتدرج الخاص فيها , وبجمع الأنواع كلها فبطلع عندي خليط من الحصمة , وبعدها بشيّك على الخليط إن كان ضمن المواصفة إو لا , أو بحتاج إلى تحسين .

** Example:

	Sieve No.	Cumulative Passing %			Specification Range	Specification Median
		A	B	C		
	1"	100	100	100	100	100
	1/2"	63	100	100	70-85	78
Critical	#4	19	100	100	40-55	48
	#8	8	93	100	30-42	36
Critical	#30	5	55	100	20-30	25
	#100	3	36	97	12-22	17
	#200	2	3	88	5-11	8

** INITIAL GUESS:

The critical sieve for A: #4 and the critical sieve for B: #30

* a: - (from sieve #4)

Specification median (retain): 100 – 48 = 52

% of retain in A gradation: 100 – 19 = 81

$a = \frac{52}{81} = \underline{0.64}$

* b: - (from sieve #30)

Specification median (retain): 100 – 25 = 75

% of retain in A gradation: 100 – 5 = 95

b = 75 – (0.64 * 95) = 0.14

* c = 1 – 0.64 - .14 = 0.22

Sieve No.	Cumulative Passing %			Blend	Remark
	aA	bB	cC		
1”	64	14	22	100	Ok
1/2”	40.32	14	22	76.32	Ok
#4	12.16	14	22	48.16	Ok
#8	5.12	13.02	22	40.14	Improve
#30	3.20	7.70	22	32.90	Rejected
#100	1.92	5.04	21.34	28.30	Rejected
#200	1.28	0.42	19.36	21.06	Rejected

Decrease the percentage of C.

**FINAL GUESS:

Trail & Error.

a = 0.66, b = 0.28, c = 0.06

Sieve No.	Cumulative Passing %			Blend	Remark
	aA	bB	cC		
1”	66	28	6	100	Ok
1/2”	41.58	28	6	75.58	Ok
#4	12.54	28	6	46.54	Ok
#8	5.28	26.04	6	37.32	Ok
#30	3.30	15.40	6	24.70	Ok
#100	1.98	10.08	5.82	17.88	Ok
#200	1.32	0.84	5.28	7.44	Ok

Marshall Mix Design:

* Marshall Mix design method is the most popular method; because it's simple & the equipment used are inexpensive.

* Components of Asphalt Concrete are:

1- Asphalt as a binder.

2- Aggregate as filler. [Coarse Aggregate, Fine Aggregate, Mineral Filler].

3- Air voids that fill the spaces in the asphalt mixture.

* Properties should be in Asphalt mixture:

1- Stability.

2- Durability.

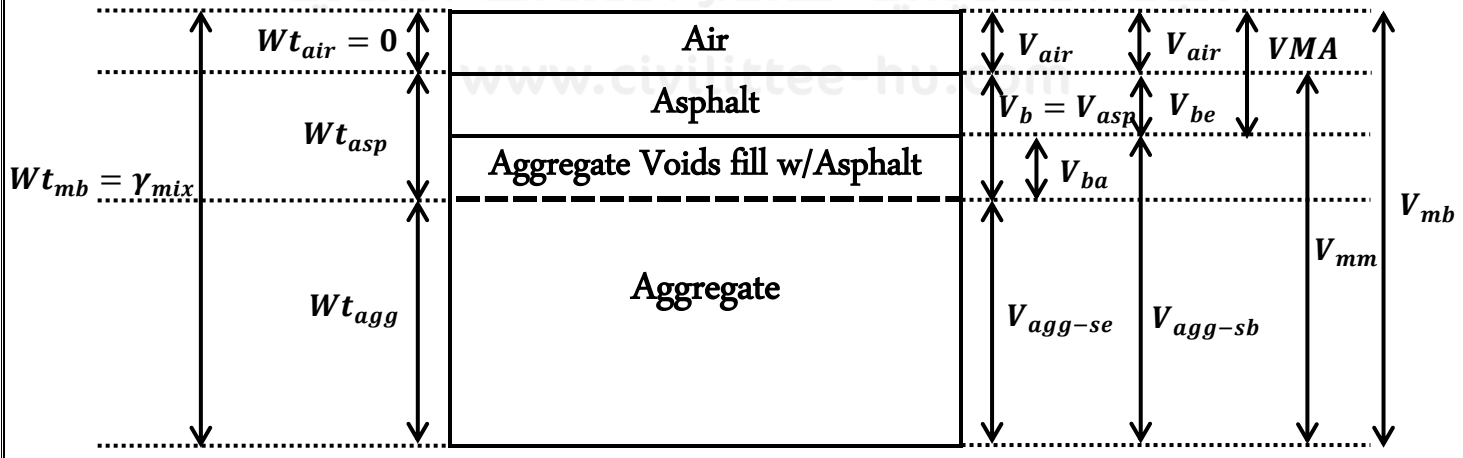
3- Being the most economical mix.

4- Safety {Skid resistance}.

* Stability: Maximum load carried by a compacted specimen tested at 60°C at loading rate of (2 in / min).

* Flow: (Reduction in height) Vertical deformation of the sample in hundreds of an inch (0.01 inch) or (0.25 mm).

* Phase diagram of bituminous mixture:



* Mould used: 4" diameter, 2.5" height, 1" maximum size of aggregate.

* Quantity of aggregate = (2.5 / h1) * 1150, 1150: weight of aggregate in mould.

* List of abbreviations:

Gse	Effective specific gravity of aggregated coated with asphalt.
Gmm,exp	Theoretical maximum specific gravity.
Gb	Specific gravity of the asphalt binder.
Gsb	Bulk specific gravity of aggregate.
Gmb	Bulk specific gravity of the compacted specimen.
Gmm,cal	Theoretical maximum specific gravity of asphalt concrete.
AV% or VTM	Percent of air voids in the compacted bitumen paving mixture.
VMA%	Voids in mineral aggregate (AV + volume of effective asphalt).
VFA%	Voids filled with asphalt.
Ps	Percent weight of aggregate.
Pb	Precent weight of the asphalt cement.

* List of equations:

Gmb	A/(B –C)
Gmm,exp	A/(D+A – E)
Gse	$\frac{Pmm-Pb}{\frac{Pmm}{Gmm,exp}-\frac{Pb}{Gb}}$
Gmm,cal	$\frac{100}{(\frac{Ps}{Gse}+\frac{Pb}{Gb})}$
AV%	$\left[1-\frac{Gmb}{Gmm}\right]*100$
VMA	$\left[1-\frac{Gmb\,(1-Pb)}{Gsb}\right]*100$
VFA	$\left[\frac{VMA-AV}{VMA}\right]*100$
Ps	100% - Pb%
Pba	$[\frac{Gse-Gsb}{Gse*Gsb}]*Gb*100\%$

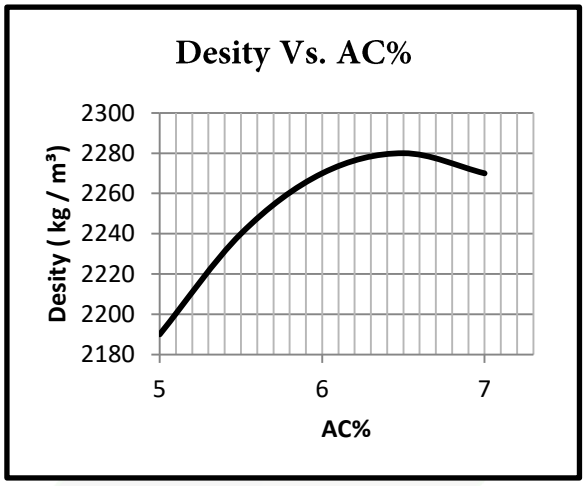
Pbe	$[Pb - \frac{Pba}{100}] * Ps$

* Marshall's Procedure:

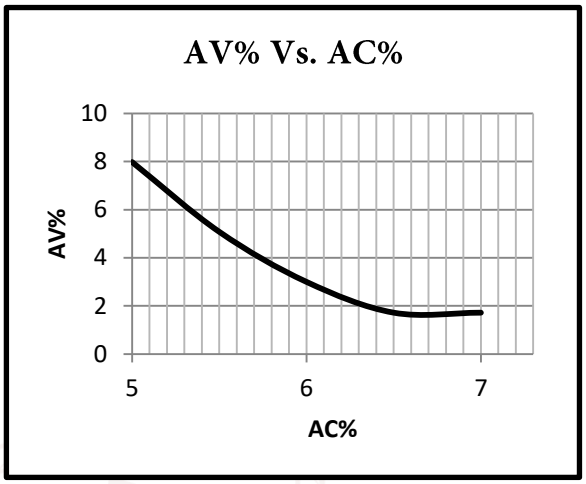
- Prepare 15 compacted samples, 3 samples for each percentage (5 percentages), two percentages above the optimum & two below the optimum and between each percentage and other (0.5), and also prepare 3 loose samples at optimum.
- Apply an increasing load (kN) until the failure occurs then this is the value of stability.
- After finding the stability, observe the reduction in height (flow).
- Calculate bulk S.G for compacted sample.
- Calculate Gmm,exp from loose sample at optimum asphalt content.
- Calculate Gse at optimum asphalt content.
- Calculate Gmb for each AC%.
- Calculate Gmm,cal for each AC%.
- Calculate AV% for each AC%, it should be in [3-5] % range, if the percentage greater than the range will cause the permeability of the mixture, and if it less than the range it will cause the bleeding of the mixture.
- Calculate VMA% for each AC%.
- Calculate VFA% for each AC%.
- Plot AC Content Vs. Density, AV, VMA, VFA, Stability and Flow.
- Finding optimum AC content (Institute or NAPA).
- Checking with specification if it accepted or not.

* Charts &its relations:

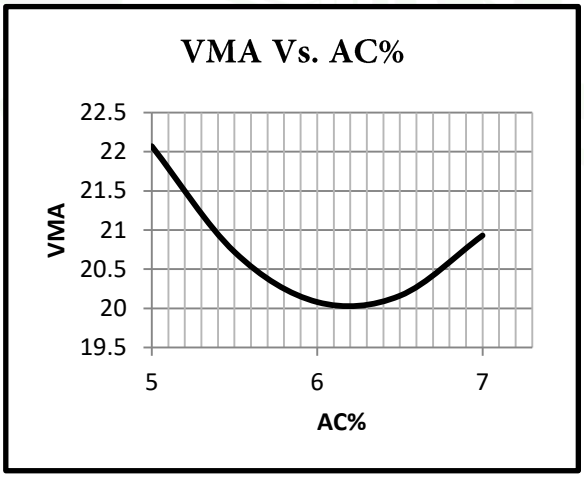
* القيم اللي بالرسم فقط للتوضيح ..



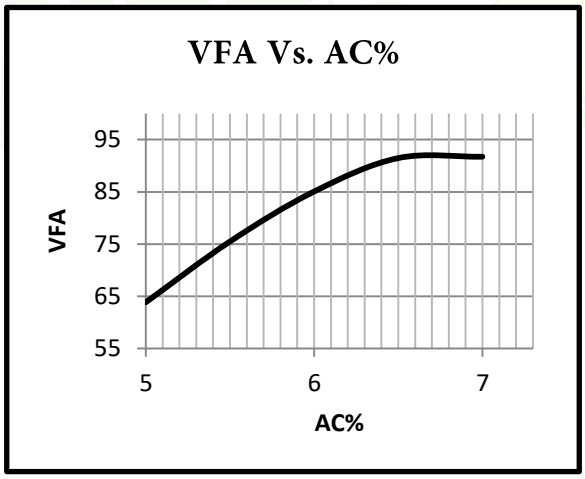
Inverse Parabola



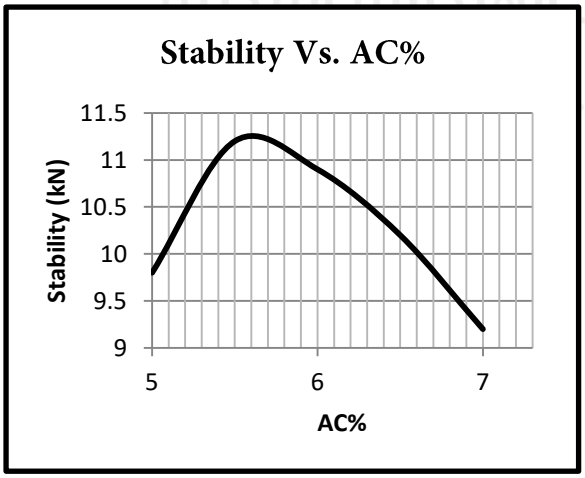
Inverse Non-Linear



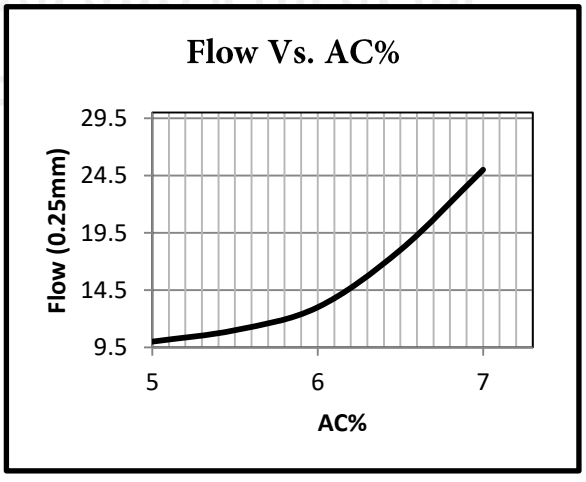
Positive Parabola



Directly Non-Linear



Inverse Parabola

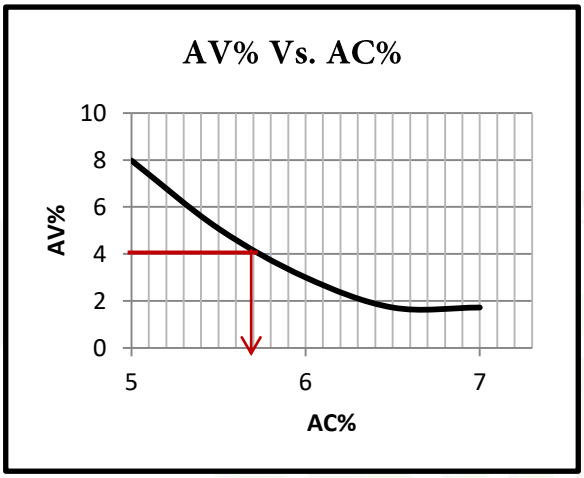


Directly Non-Linear

* Determination of optimum AC content:

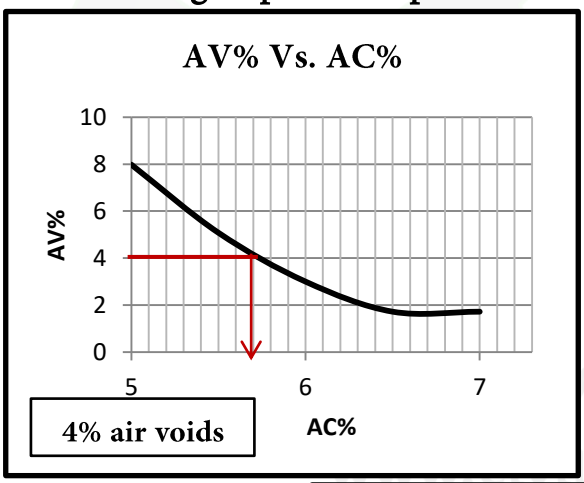
1- National Asphalt Pavement Association (NAPA) Procedure:

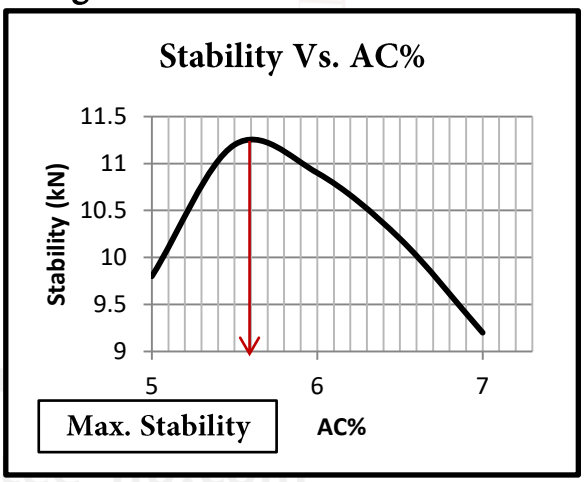
- Target optimum asphalt content = the asphalt content at 4% air voids.

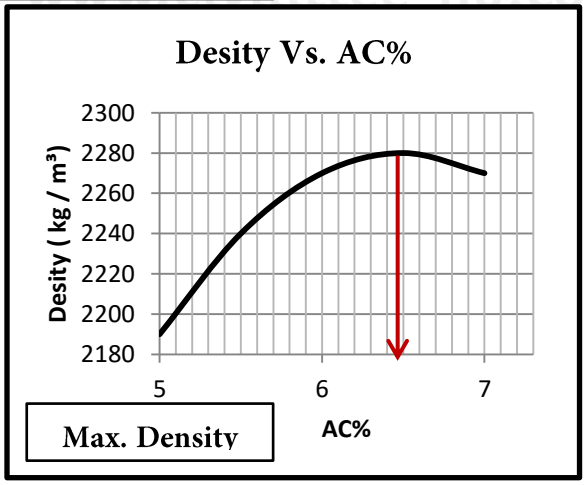


2- Asphalt Institute Procedure.

- Target optimum asphalt content = average.







** بعد ما نطلع نسبة الأسفلت المُثلى, برجع للرسمات البيانية ال6, وبسقط عليهم نسبة الأسفلت المُثلى, فبطلع عندي قيم , وبعدها بقارن قيمي بالواصفة إن كانت ضمنها أو لا..

* The specification depends on: 1- Traffic. 2- Nominal maximum size of aggregate.

* What happened in these cases?

1- Using round aggregates in AC mix? High density & low stability, I should to break it.
2- Only using mineral filler in AC mix? High stability & low air voids (bleeding).

* What should you do in these cases?

1- If the AC has low stability & low air voids? Add more coarse aggregate, or reduce AC content (only if the asphalt is more than what is normally used, and if the excess is not required as replacement for amount absorb) but you should care since this might reduce durability & increase permeability.
2- If the AC has satisfactory stability & low air voids? Add coarse aggregate to increase air voids & stability.
3- If the AC has satisfactory stability & high air voids? Add mineral filler, to reduce permeability.
4- If the AC has satisfactory air voids & low stability? This condition suggests low quality aggregates, the aggregates quality should be improve.
5- If the AC has high air voids & low stability? Adjust the voids (increase mineral filler) if stability is not improved; and consider improvement of the aggregate quality.

Skid Resistance:

* Skid Resistance: A measure of the resistance of pavement surface to sliding or skidding of the vehicle.

* Apparatus: British Pendulum Tester, used to evaluate the highway surface frictional properties.

* The type of the test above: Dynamic pendulum impact tester.

* The values measured referred to: British Pendulum Number (BPN).

* Take the average read of: Three tests.

* The surface should be wet before make the test to represent worse case.

* The highway surface should have some sort of roughness to facilitate friction between the car wheels and pavement surface.

* It's a relationship between the vertical & horizontal force developed as a tire slides along the pavement surface.

* Factors providing skid resistance:

1- The texture of the pavement surface.
2- It's ability to resist the polishing effect of traffic.

* Polishing: The reduction in micro-texture resulting in the smoothing and rounding of exposed aggregates.

* The Relations:

1- BPN hot weather is less than BPN at cold weather.
2- Skid resistance at rainy weather is less than skid resistance at non-rainy weather.
3- Skidding on wet areas is greater than skidding on dry areas.
4- ↑BPN, ↑Friction.

➢ Asphalt Extraction:

* Asphalt extraction test is used to: Check the asphalt percentage in the mixture.

* The quantity of asphalt is directly effects in mixture properties, like: (film thickness, air voids, stability and flow).

* Mixture with low asphalt is not durable.

* Mixture with high asphalt is not stable.

* Obtained aggregates from this test can be used for gradation analysis (sieve analysis) to check the quality of the produced mixes.

* The methods used in this test:

1- National Center for Asphalt Technology (NCAT) Method.

2- Centrifuge Extraction Method.

* In this lecture NCAT Ignition method studied, because it's widely used.

* In NCAT method the sample of HMA is subjected to an elevated temperature of (538°C = 1000°F).

* The apparatus used: NCAT oven.

* Equation used in NCAT method:

$$\%AC = \left(\frac{w_1 - w_2}{w_1}\right) \times 100\%$$

, w_1: Weight of test sample (g). w_2: Weight of ignited sample(g)

* Comparison between the two methods:

	NCAT	Centrifuge
More Accurate	√	
More Hazardous		√
Used to find aggregate gradation	√	√

NCAT Oven →

➢ A Review of The Final Exam:

**Note: the review only includes experiments taken after the mid-term exam.

Q: - What are the types of Specific gravity and what is the difference between them?

1- Bulk specific gravity: Total volume of the aggregate (Volume of aggregate + voids fill with water). {Gsb}
2- Apparent specific gravity: Net volume of the aggregate (No voids, volume of aggregate particles only). {Gsa}
3- Effective specific gravity: Overall volume exclusive of those that absorb asphalt (Total volume + pores that becomes filled with water after 24hrs soaking – volume of the large pores that filled with asphalt). {Gse}

Gsa > Gse > Gsb

Q: - When working in a hot mix asphalt plant. What are the most important things which need to be taken care of?

1- Mixing temperature.
2- Jmf which include:
   - Optimum asphalt.
   - Gradation of agg that meet specification limits.
3- Weight of agg + asphalt.

Q: - In a Marshall mix design what is the quantity of asphalt that should be added to 1300g aggregate to a mix having asphalt content of 5.5%?

Answer: 1300g = 94.5% of mix, then 5.5% of asphalt in mix = 75.66g

* الفكرة نسبة وتناسب.

Q: - The table below shows the particle size distribution of two aggregates A & B. these are blended to produce an acceptable aggregate for use in manufacturing an asphalt concrete for highway pavement construction. The required limits of particles size distribution fot the mix are shown in the table below.

Sieve Size	Percentage Passing by Weights.		Required Mix
	A	B	
1”	100	100	100
¾ “	95	100	95-100
3/8 “	72	75	60-75
#4	54	52	40-55
#10	43	35	30-40
#40	27	17	12-22
#200	8	4	3-6

A. Determine maximum & minimum proportion of A & B to satisfy the specification?

Final Answer: Maximum of A = 50%, Minimum of B = 50%.

Minimum of A =0%, Maximum of B= 100%.

The procedure used to find maximum A is same the procedure in the example page 24.

If we try any percentage above 50% for A it will be out of the specification.

Sieve Size	Max. of A	Min. of B	Blend	Remark
1”	50	50	100	Ok
¾”	47.5	50	97.5	Ok
3/8”	36	37.5	73.5	Ok
#4	27	26	53	Ok
#10	21.5	17.5	39	Ok
#40	13.5	8.5	22	Ok
#200	4	2	6	Ok

Sieve Size	Min. of A	Max. of B	Blend	Remark
1”	0	100	100	Ok
¾”	0	100	100	Ok
3/8”	0	75	75	Ok
#4	0	52	52	Ok
#10	0	35	35	Ok
#40	0	17	17	Ok
#200	0	4	4	Ok

B. Regardless to your answer if the proportion of aggregate A is 60% and its specific gravity is 2.55 and the proportion of aggregate B is 40% with specific gravity 2.75. Find the combined specific gravity of the blend.

Answer: $G_{s,comb} = \frac{\sum_{i=1}^{n} P_{Wt_i}}{\sum_{i=1}^{n} \frac{P_{Wt_i}}{G_{s,i}}} = \frac{0.60+0.40}{\frac{0.60}{2.55}+\frac{0.40}{2.75}} = 2.626$

Q: - The dry mass of a sample of aggregate is 1206.1g. The mass in a saturated surface dry condition is 1226.8g. The volume of the aggregates, excluding the volume of absorbed water is 440.6 cm^3.

Calculate the bulk Gs, the apparent Gs and the percentage of absorption.

Answer: Absorption = $\frac{1226.8-1206.1}{1206.1} \times 100\% = 1.716\%$

$$Gsa = \frac{Wt_s}{V_s \times \gamma_s} = \frac{1206.1}{440 \times 1} = 2.741$$

$$Gsa = \frac{Wt_s}{Wt_s - W_{sub}} = 2.741 = \frac{1206.1}{1206.1 - W_{Sub}} \rightarrow W_{sub} \cong 766g$$

$$Gsb = \frac{Wt_s}{Wt_{ssd} - W_{sub}} = \frac{1206.1}{1226.8 - 766} = 2.617$$

Q: - Specific gravity test was conducted for a fine aggregate. If the following data was obtained during the test:

Weight of pycnometer fill of water = 750g

Weight of pycnometer and sample and water= 1050g

Oven dry weight of sample is 475g. For this aggregate, find the apparent specific gravity, the bulk specific gravity on SSD basis and the percentage of absorption.

Answer: SSD weight of the sample = 500g "constant value".

$$Gsa = \frac{475}{750 + 475 - 1050} = 2.71$$

$$Gsb = \frac{500}{750 + 500 - 1050} = 2.50$$

$$\%A = \left(\frac{500 - 475}{475}\right) \times 100\% = 5.26\%$$

Q: - A sample of hot mix asphalt: Diameter 10cm, Height 7cm, and it's Gmb= 2.182 the % of Asphalt = 6% and its S.G = 1.01 and the S.G of Aggregate is 2.5. Find the following:

1) Density : $G_{mb} \times \rho_w = 2.182 \times 1000 = 2182\ Kg/m^3$.
2) Volume of sample : $\frac{\pi}{4} \times (10)^2 \times 7 = 549.78 cm^3$.
3) Weight of aggregate: $Wt_{sample} = V \times G_{mb} \times \rho_w = 549.78 \times 2.182 \times 1 \cong 1200\ g$.
   $Wt_{agg} = Wt_{sample} \times \%\ agg\ in\ the\ sample = 1200 \times 0.94 = 1128 g$.
4) Volume of aggregate:

$$V = \frac{wt}{S.G \times \Upsilon_w} = \frac{1128}{2.5 \times 1} = 451.2 cm^3.$$

5) Weight of A.C:

$Wt_{A.C} = Wt_{sample} \times \%\ agg\ in\ the\ sample = 1200 \times 0.06 = 72g$.

6) Volume of A.C:

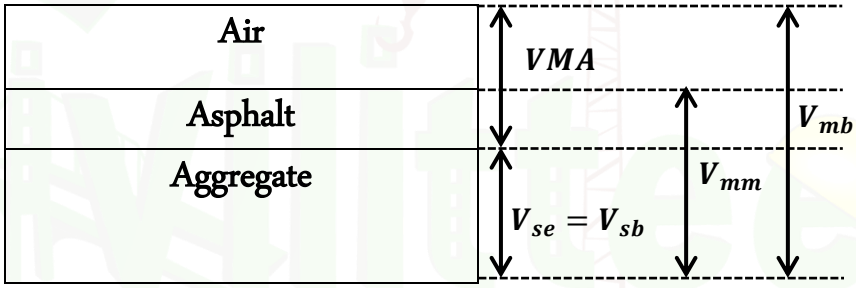
$$V = \frac{wt}{S.G \times \Upsilon_w} = \frac{72}{1.01 \times 1} = 71.29\ cm^3.$$

7) Volume of air voids: 549.78 – (451.2 + 71.29) = 27.29 cm^3.
8) % of air voids: $\frac{26.58}{549.78} \times 100\% = 4.83\%$
9) VMA: $\left[1 - \frac{2.182\ (1-0.06)}{2.5}\right] * 100 = 17.96\%$
10) VFA: $\frac{VMA - VTM}{VMA} = \frac{17.96 - 4.83}{17.96} \times 100\% = 73.11\%$

Q: - The weight and volume of a sample of Marshall hot mix. Asphalt was found to be 1100g and 475 cm³ respectively and the maximum S.G. of the sample is 2.406, the asphalt content and specific gravity is 4% and 1.05 respectively. Assume the absorption of asphalt in the aggregates zero, find the following:

1) Draw a sketch for this sample showing VMA, Vse, Vsb, Vmb & Vmm:

No absorption



2) Volume of air voids (I.e. the %): $G_{mb} = \frac{1100}{475 \times 1} = 2.316$

$$Va = 1 - \frac{G_{mb}}{G_{mm}} = \left[1 - \frac{2.316}{2.406}\right] \times 100 = 3.74\%$$

3) Volume of asphalt: $V_b = \frac{1100 \times 0.04}{1.05 \times 1} = 41.90 cm^3.$

4) Volume of aggregate: $G_{mm} = 2.406 = \frac{100}{\frac{96}{G_{se}} + \frac{4}{1.05}}$

$$G_{se} = 2.543 = G_{sb} = G_{sa}$$

$$V_{agg} = \frac{1100 \times (1 - 0.04)}{2.543 \times 1} = 415.26 cm^3.$$

5) VMA: $\left[100 - \frac{2.316 \times 96}{2.543}\right] = 12.57\%$

6) VFA: $\left[\frac{12.57 - 3.74}{12.57}\right] \times 100\% = 70.25\%$

7) In addition, find the maximum S.G. of the sample if the asphalt content is 5%: $G_{mm} = \frac{100}{\frac{95}{2.543} + \frac{5}{1.05}} = 2.374$

Done..

Good luck with your exam. Stay calm and it'll be a breeze.