Pavement Materials & Design

Hot Mix Asphalt (HMA) mix design using Marshall method

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HMA Mix Design

Objective of a mix design

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Objective of a mix design

- The objective of a mix design is to determine the combination of asphalt cement and aggregate that will give long-lasting performance as part of the pavement structure.
- Mix design involves laboratory procedures developed to establish the necessary proportions of materials for use in the asphalt mixture.
- These procedures include
  - *Determining an appropriate blend of aggregate sources to produce proper gradation of mineral aggregate*
  - *Selecting the type and amount of asphalt cement to be used as the binder for that gradation.*

Image source: https://www.floridaridesonus.org/learning-center/asphalt-101/ 3

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Objective of a mix design

- The final goal of mix design is to select a unique design binder content that will achieve a balance among all of the desired properties.
  - *Ultimate pavement performance is related to*
    - durability, impermeability, strength, stability, stiffness, flexibility, fatigue resistance and workability.
- Within this context, there is no single asphalt content that will maximize all of these properties.
    - Instead, an asphalt content is selected on the basis of optimizing the properties necessary for the specific conditions.
    - The optimum binder content (O.B.C) refers to the amount of asphalt binder that balances different desirable mixture properties for each combination of aggregate
- Therefore, the mix design aim to determine the best or Optimum Asphalt (binder) Content (O.A.C) (or O.B.C) that will provide
    - Stability & durability
    - Additional desirable properties such as impermeability, workability, & resistance to bleeding.

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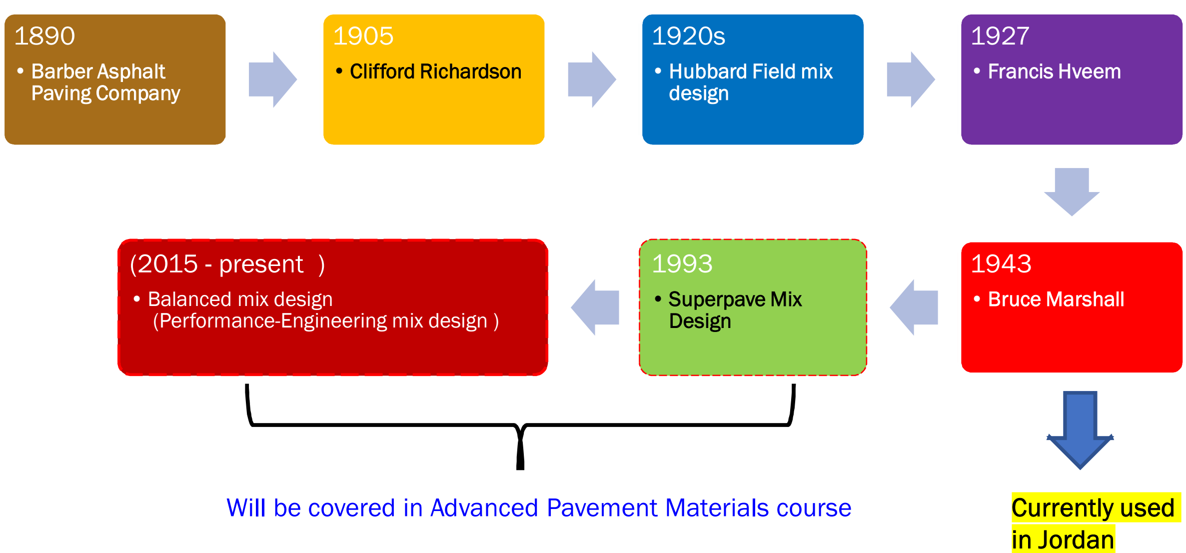
HMA Mix Design

Methods

Asphalt Mix Design Methods



Marshall Mix Design

Steps

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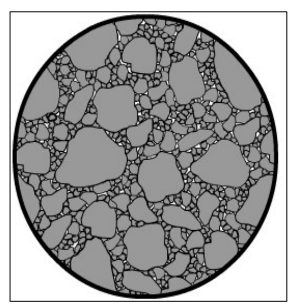
Marshall Mix Design

Overview

- ❑ The Marshall method of mix design is for dense graded HMA mixes.
- ❑ It is used almost everywhere in the world.
- ❑ It is the predominant mix design method for airport pavements
- ❑ General procedures
  - ➢ *Single selected aggregate gradation, five different asphalt contents are tested for various volumetric and strength criteria* ***to select the optimum binder content***



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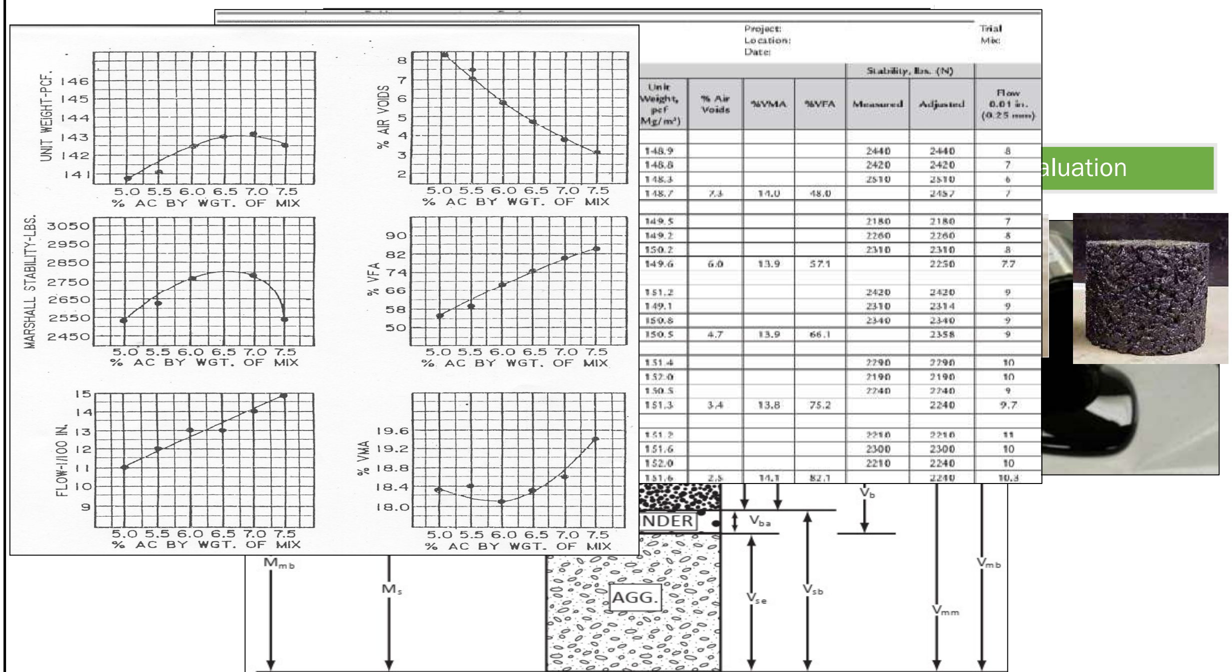

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Marshall Mix Design

Step A : Aggregate Evaluation

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Step A : Aggregate Evaluation

- A-1 : Determine acceptability of aggregate for use in HMA by performing the following aggregate tests:
  - *L.A. Abrasion*
  - *Soundness*
  - *Sand Equivalent*
  - *Flat & Elongated*
  - *% Crushed faces*
  - *Polishing,*
- A-2 : If aggregate pass the requirements in A-1, then perform the following aggregate tests:
  - *Gradation*
  - *Specific gravity (S.G)*
  - *Absorption*

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Step A : Aggregate Evaluation

There are several guidelines to keep in mind :

1. Binder demand increases as the NMAS of the mix decreases
2. Absorptive aggregates have a greater binder demand
3. For a given NMAS,
   - a fine aggregate gradation will require more binder than a coarse aggregate gradation;
4. If higher VMA is anticipated due to hard, angular aggregates, more binder will be required;
5. Mixes with a higher P_{200} tend to require more binder than those with a lower P 200

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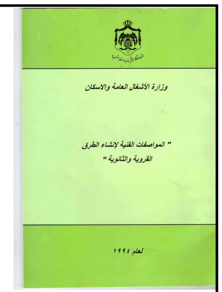
Specifications for secondary and village roads construction



د- الخصائص الطبيعية للحصمة والاختبارات (Physical Properties) جميع أنواع الحصمة المستعملة بالخليط يجب أن تطابق المتطلبات الطبيعية المذكورة في الجدول رقم (٦) المرفق .

١- تدرج خليط الحصمة :

١) يجب أن تكون الحصمة ناتج تكسير حجر جيري أو غرانيتي ولا يسمح باستعمال حصمة الوديان .

٢) باقي الخواص بما فيها تدرج الحصمة المخلوطة ومواد التعبئة (Filler) يجب أن تتطابق مع ملخص المواصفات المرفق .

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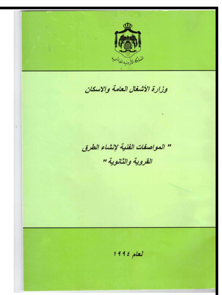

TABLE (6) :

TECHNICAL SPECIFICATION FOR SECONDARY & VILLAGE ROADS :

ASPHALT PAVEMENT , (BINDER AND WEARING)

ITEM OF SPECS.	HOT MIX. LAYER	
	WEARING	BINDER
AGG. SPECS.		
:- ABRASION (%)	35 MAX.	35 MAX.
:- RATIO OF WEAR LOSS 100 REV (--------) 500 REV	0.22 MAX.	0.22 MAX.
:- SAND EQUIVALENT	50 MIN.(HOT BINS)	50 MIN.(HOT BINS)
:- P.I	N.P (HOT BINS)	N.P (HOT BINS)
:-FLAKINESS INDEX(B.S)	20 MAX.	25 MAX.
:ELONGATION INDEX(B.S)	20 MAX.	25 MAX.
:-CLAY LUMPS & FRIABLE PARTICLES (%)	1.0 MAX.	1.0 MAX.

د- الخصائص الطبيعية للحصمة والاختبارات (Physical Properties) جميع أنواع الحصمة المستعملة بالخليط يجب أن تطابق المتطلبات الطبيعية المذكورة في الجدول رقم (٦) المرفق .

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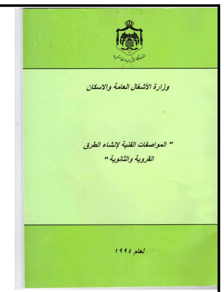
Specifications for secondary and village roads construction



ج- مواد التعبئة (Filler) :

يجب أن تكون مادة التعبئة من مواد مسحوقة سحقا "ناعما" كغبار الحجر الكلسي أو غبار الخامات المعدنية أو الاسمنت أو مسحوق الجير المطفأ وأن تكون خالية من الكتل الهشة أو سهلة التفتت ومن المواد الطينية والمواد العضوية وأن تكون غير لدنة وأن تكون مطابقة للتدرج التالي :

قياس المنخل	النسبة المئوية للمار من المنخل بالوزن
# ٣٠	١٠٠
# ٥٠	١٠٠ - ٩٥
# ٢٠٠	١٠٠ - ٧٠

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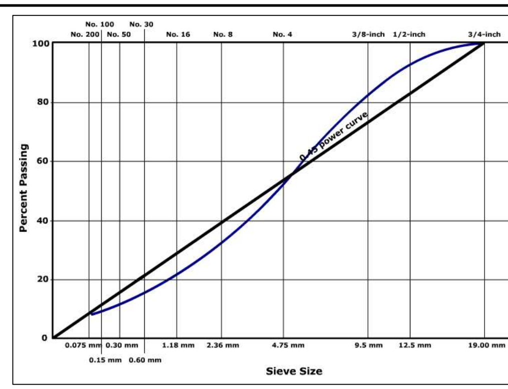
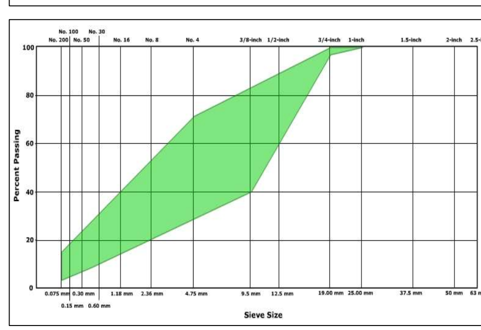
Step A : Aggregate Evaluation

- A-3: Perform aggregate blending to determine the suitable gradation
- Blending Guidelines
  - *Check how close the midband gradation comes to the maximum density line*
    - If it too close, the VMA is likely to be too low
    - VMA is increases as the gradation lines moves away from the maximum density line either up or down

Specification	
Sieve	Limits
25.4 mm (1 in)	100
19.0 mm (3/4 in)	100
12.5 (1/2 in)	90-100
9.51 mm (3/8 in)	0-90
No. 4	------
No. 8	------
No. 16	------
No. 30	------
No. 50	------
No. 100	------
No. 200	2-10





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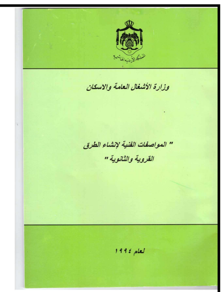
Spe … ction



ITEM OF SPECS.	HOT MIX. LAYER – WEARING	HOT MIX. LAYER – BINDER
- CHERT	5 % MAX.	5 % MAX.
- GYPSUM CONTENT	1 % MAX.	1 % MAX.
- SOUNDNESS (Na)	9 % MAX.	9 % MAX.
(Mg)	12 % MAX.	12 % MAX.
-FRACTURED FACES (PERCENT OF TOTAL WT. RTD. ON #4 CONSISTS OF TWO OR MORE FRACTURED FACES)	90 % MIN.	90 % MIN.
- GRADATION		
1"	100	100
3/4"	90-100	70-100
1/2"	71-90	53-90
3/8"	56-80	40-80
# 4	35-56	30-56
# 8	23-49	23-49
# 10		
# 20	14-43	14-43
# 40		
# 50	5-19	5-19
# 80	4-15	4-15
# 200	2-8	2-8

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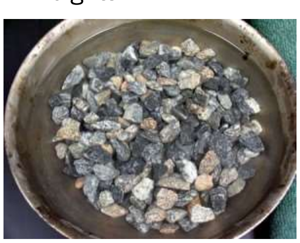
Step A : Aggregate Evaluation

- A-4 :Prepare specimen weigh-out table

by multiplying % aggregate retained between sieves times the required total aggregate weight required to prepare the specimen (usually 1150 g), then determine cumulative weights.



Required Aggregate wt. (g)			1150	
Sieve size	% Passing	Cum. Retained (%)	Cum. Retained (g)	Retained
25.4 mm (1 in)	100.00	0	0.0	0
19.0 mm (3/4 in)	100.00	0	0.0	0
12.5 (1/2 in)	93.00	7	80.5	80.5
9.51 mm (3/8 in)	81.00	19	218.5	138
No. 4	50.00	50	575.0	356.5
No. 8	35.00	65	747.5	172.5
No. 16	25.00	75	862.5	115
No. 30	19.00	81	931.5	69
No. 50	13.00	87	1000.5	69
No. 100	9.00	91	1046.5	46
No. 200	6.60	93.4	1074.1	27.6
Pan	0	100	1150.0	75.9

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Marshall Mix Design

Step B : Asphalt Cement Evaluation

Step B : Asphalt Cement Evaluation

- B-1 : Determine appropriate asphalt cement grade
  - *Based on type geographic location and design speed being designed*
- Asphalt binders with high penetration numbers (called "soft") are used for cold climates
- Asphalt binders with low penetration numbers (called "hard") are used for warm climates

Grade	Penetration min.	Penetration max.
40–50	40	50
60–70	60	70
85–100	85	100
120–150	120	150
200–300	200	300

- JORDAN PETROLEUM REFINERY CO. produces only 60/70 and 85/100 grades only

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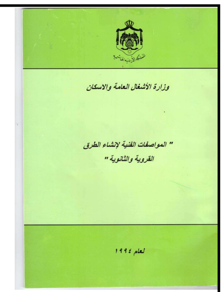
Specifications for secondary and village roads construction



/ب- الخلطة الاسفلتية الساخنة (Hot Mix) :

أ- الخلطة الاسفلتية تكون من نوع (Hot Bituminous Concrete) ويكون الاسفلت المطلوب هو الاسفلت الجامد ٨٠/١٠٠ أو ٦٠/٧٠ وحسب طلب المهندس المشرف .

الرابط

٦- يراعى استعمال :

- الاسفلت ٨٠/١٠٠ للمناطق الباردة .
- الاسفلت ٦٠/٧٠ للمناطق الحارة .

(يتم تحديد نوع الأسفلت المطلوب من قبل المهندس المشرف)

Step B : Asphalt Cement Evaluation

- B-2 : Verify that spec. properties are acceptable

	Penetration Grade									
	40–50		60–70		85–100		120–150		200–300	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 25°C [77°F], 100 g, 5 s	40	50	60	70	85	100	120	150	200	300
Softening Point, °C [°F]	49 [120]		46 [115]		42 [108]		38 [100]		32 [90]	
Flash point, °C [°F], (Cleveland open cup)	230 [450]	...	230 [450]	...	230 [450]	...	220 [425]	...	175 [350]	...
Ductility at 25°C [77°F], 5 cm/min, cm	100	...	100	...	100	...	100	...	100[A]	...
Solubility in trichloroethylene, %	99.0	...	99.0	...	99.0	...	99.0	...	99.0	...
Retained penetration after thin-film oven test, %	55 +	...	52 +	...	47 +	...	42 +	...	37 +	...
Ductility at 25°C [77°F], 5 cm/min, cm after thin-film oven test test	...	...	50	...	75	...	100	...	100[A]	...

[A] If ductility at 25°C [77°F] is less than 100 cm, material will be accepted if ductility at 15°C [60°F] is 100 cm minimum at the pull rate of 5 cm/min.

Step B : Asphalt Cement Evaluation

- B-3 : Determine the specific gravity of asphalt binder.

The pycnometer method is used to determine the specific gravity of asphalt cements.

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Step B : Asphalt Cement Evaluation

Selection of mixing and compaction temperatures

- For years, asphalt mix design procedures have used equiviscous temperature ranges for selecting ***laboratory*** mixing and compaction temperatures
- The purpose of using equiviscous mixing and compaction temperatures in laboratory mix design procedures is to normalize the effect of asphalt binder stiffness on mixture volumetric properties
  - Compaction temperatures
  - Mixing temperatures are
- Laboratory Compaction temperatures
  - Determined where the viscosity-temperature line crosses the compaction viscosity range of 0.28 ± 0.03 Pa-s
- Laboratory Mixing temperatures are
  - Determined where the viscosity-temperature line crosses the mixing *viscosity range of 0.17 ± 0.02 Pa-s*

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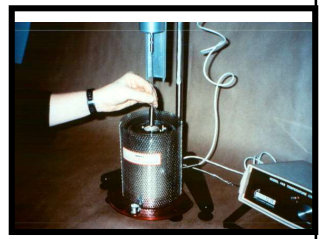
Step B : Asphalt Cement Evaluation

- B-4: Determined the viscosity of asphalt cement



Video source :https://www.youtube.com/watch?v=qhFVc5bw3bc

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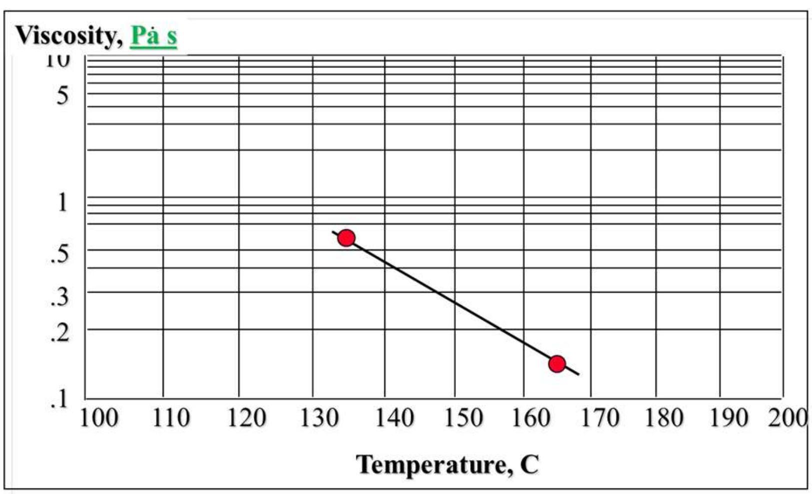
Step B : Asphalt Cement Evaluation

- B-5 : Plot viscosity data on Temperature



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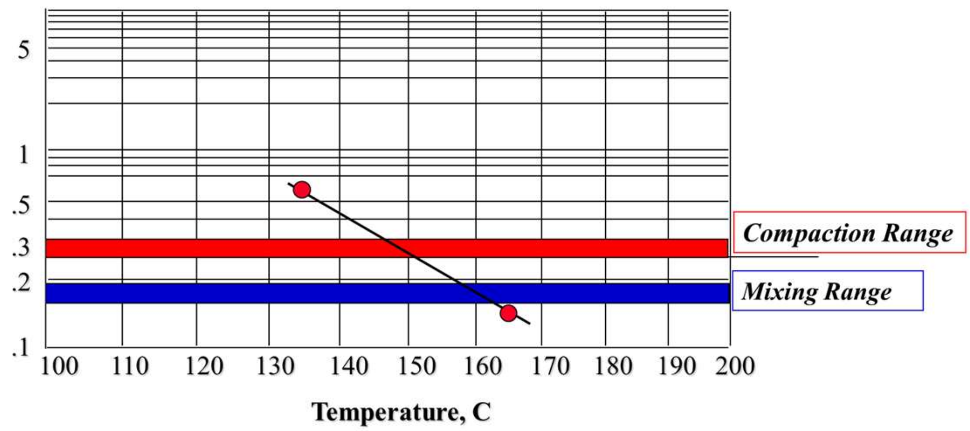
Step B : Asphalt Cement Evaluation

- B-6 : Determine mixing & compaction temperature ranges



Mixing viscosity range (0.17 ± 0.02 Pa-s) or (170 +- 20 CSt)
Compaction viscosity range (0.280 ± 0.03 Pa·s) or (280 +- 30 Cst)

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Step B : Asphalt Cement Evaluation

Selection of mixing and compaction temperatures

- **Laboratory** mixing and compaction temperatures are intended for determining design volumetric properties of the asphalt mixture and are ***NOT*** intended to represent field mixing and compaction temperatures at the project level

In an asphalt mix facility:

- The mixing temperature
  - *The temperature at which the aggregate can be sufficiently dried and uniformly coated*
  - *It should not exceed 177 °C*
- The compaction temperature
  - *based solely on the ability of the compaction equipment to achieve adequate in-place density*
  - *for an asphalt mix is usually in the range of 135–155 °C*

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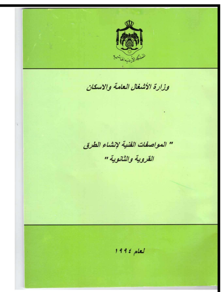
Specifications for secondary and village roads construction



- يجب أن لا تقل درجة الحرارة بعد الفرادة وقبل الدحل مباشرة عن ١٢٠ درجة مئوية كما يجب أن تكون درجة حرارة الخلط كما يلي:

	الاسفلت ٦٠/٧٠	الاسفلت ٨٠/١٠٠
درجة حرارة الخلط	١٥٨ م + ٢	١٥٦ م + ٣
درجة حرارة قوالب مارشال	١٤٨ م +٣	١٤٣ م + ٣

ان درجة الحرارة بعد الفرادة مباشرة هي الدرجة الدنيا التي يجب أن يبدأ عندها الدحل الأولي (Breakdown Rolling) ولا يسمح أن تكون درجة الحرارة أقل من ذلك كما وأنه يجب ملاحظة أن لا تزيد درجة حرارة الخلطة داخل الخلاطة عن ١٦٠ درجة مئوية وأن لا تزيد درجة حرارة الحصمة عن درجة حرارة الاسفلت عند الخلط عن ١٠ درجة مئوية .

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Marshall Mix Design

Step C : Preparation of Marshall Specimen

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Step C : Preparation of Marshall Specimer

❑ C-1 : Prepare a trial specimen

- *It is used to check if the height of the trial specimen (h_1) is within the range of Marshall specimen of*
  - Specimen height = 2.5 ± 0.1 inch [63.5 ±2.5mm]
  - Specimen diameter =4 ± 0.2 inch [101.5 ± 5.1 mm]
- *If the specimen is outside this range,*
  - Make an adjustment of aggregate quantity used in preparing the specimen as follows

for International System of Units (SI),

$$\text{Adjusted mass of aggregate} = \frac{63.5 \times (\text{mass of aggregate used})}{\text{Specimen height (mm) obtained}}$$

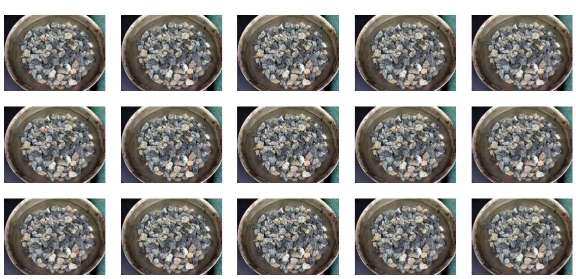
for U.S. Customary Units,

$$\text{Adjusted mass of aggregate} = \frac{2.5 \times (\text{mass of aggregate used})}{\text{Specimen height (in.) obtained}}$$

Step C : Preparation of Marshall Specimen

❑ C-2: Dry, then sieve aggregates into sizes (individual sizes)

- *At least 18 samples with the adjusted aggregate weight*
- *Approximately you will need a total of 25 kg & 4 liters of AC.*



Step C : Preparation of Marshall Specimen

- C-3: Estimate the Optimum binder content (O.B.C)
  - *The optimum binder content (O.B.C) refers to the amount of asphalt binder that balances different desirable mixture properties for each combination of aggregate type, aggregate gradation, additive type, additive dosage and binder type*
- The "expected Optimum binder content (O.B.C) " asphalt content can be based on any or all of these sources:
  - *Experience*
  - *Computational formula*

Step C : Preparation of Marshall Specimen

Example : Computational formula to estimate the *Optimum binder content (O.B.C)*

$$P = 0.035 \times a + 0.045 \times b + K * C + F$$

Where,

- *P = approximate asphalt content of mix, percent by weight of mix*
- a = percent of mineral aggregate retained on 2.36-mm (No. 8) sieve
- b = percent of mineral aggregate passing the 2.36-mm (No. 8) sieve and retained on the 75-µm (No. 200) sieve
- c = percent of mineral aggregate passing 75-µm (No. 200) sieve
- K =
  - 0.15 for 11–15 percent passing 75-µm (No. 200) sieve
  - 0.18 for 6–10 percent passing 75-µm (No. 200) sieve
  - 0.20 for 5 percent or less passing 75-µm(No. 200) sieve
- F =
  - 0 – 2.0 percent. Based on the absorption of light or heavy aggregate,
  - in the absence of other data, a value of 0.7 is suggested

Step C : Preparation of Marshall Specimen

- C-4: Prepare three specimens at five different binder contents

Estimated O.B.C -1.0% 

Estimated O.B.C - 0.5% 

Estimated Optimum binder content (O.B.C) 

Estimated O.B.C + 0.5% 

Estimated O.B.C +1.0% 

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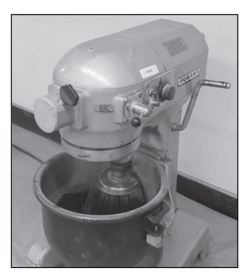
Step C : Preparation of Marshall Specimen

C-5: Mix the aggregate with the specified binder content

- The goal of laboratory mixing operations is to produce uniform batches of properly coated HMA mixtures.
- Mixing is typically done with either
  - *A planetary with wire whips*
  - *Five-gallon bucket mixer*

Five-gallon bucket mixer



A planetary with wire whips

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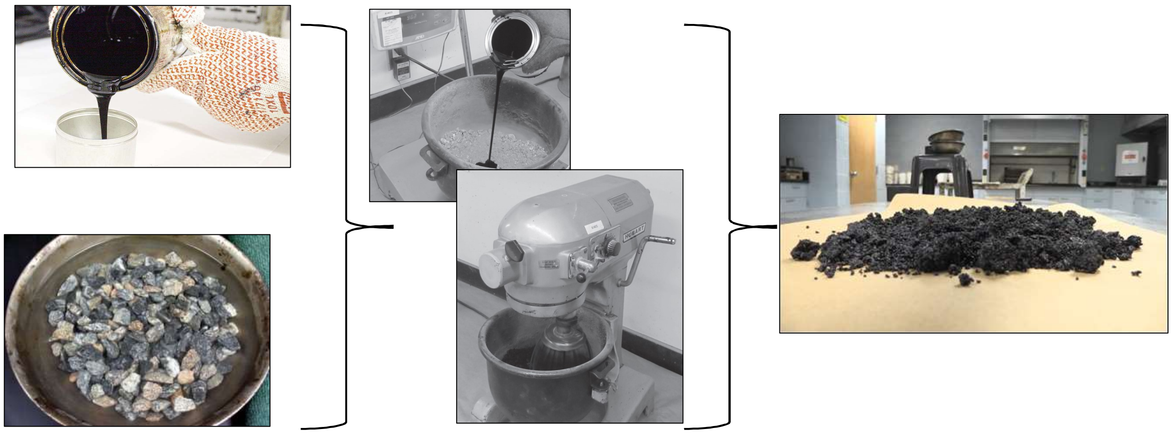
Step C : Preparation of Marshall Specimen

C-5: Mix the aggregate with the specified binder content



Raw materials

Mixing Process

Loose Asphalt Mixture

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Step C : Preparation of Marshall Specimen

C-5: Mix the aggregate with the specified binder content

Video source: https://www.youtube.com/watch?v=BCctip8Rt2Q&t=174s

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Step C : Preparation of Marshall Specimen

C-6: Prepare three loose mixture specimens near optimum AC to measure Rice or Maximum theoretical S.G. (TMD = Theoretical Max density).

Three specimens prepared @ estimated O.B.C

No.1 

No.2 

No.3 

Gmm Specimen No.1

Gmm Specimen No.2

Gmm Specimen No.3

$$Gmm_{mix} = \frac{(GmmS_1 + Gmm_{S2} + Gmm_{S3})}{3}$$

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Step C : Preparation of Marshall Specimen

C-7: Calculate the G_{mm} at the other trial binder contents (

Measured Gmm @ Estimated (O.B.C) (Step C-6)

Find G_{se} for the aggregates

Back-calculate G_{mm} at the other trial binder contents

@ O.B.C - 0.5% | @ O.B.C -1.0% | @ O.B.C + 0.5% | @ O.B.C +1.0%

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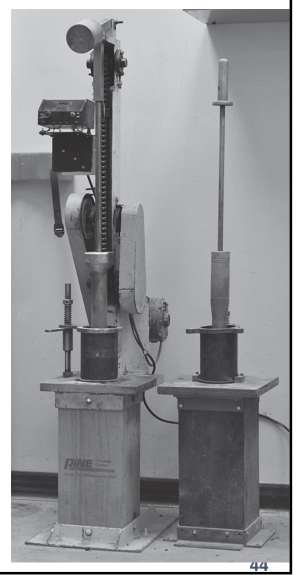
Step C : Preparation of Marshall Specimen

C-8: Compact the specimen at the required Blow/side according to Marshall specifications.

- The laboratory compaction effort is intended to replicate the ultimate or final compacted condition of the pavement after being exposed to several years of traffic loading.
- **Experience** has shown that pavements that maintain an air void level of around 4 percent provide the best long-term performance in the field.
- The Impact compaction is the method for volumetric mix design and quality control testing compaction used in Marshall



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Step C : Preparation of Marshall Specimen

C-8-A : Packing the mold

- Place a filter or nonabsorbent paper disk cut to size in the bottom of the mold.
- Place the entire batch in the mold with collar, and then spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Smooth the surface to a slightly rounded shape.
- The temperature of the mixture immediately prior to compaction shall be within the limits of the compaction temperature established in paragraph otherwise, it shall be discarded. In no case shall the mixture be reheated

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Step C : Preparation of Marshall Specimen

C-8: Compact the specimen at the required Blow/side according to Marshall specifications.

- The number of blow/side is function with design traffic level

Marshall Method Criteria[1]	Light Traffic[3] Surface & Base		Medium Traffic[3] Surface & Base		Heavy Traffic[3] Surface & Base	
	Min	Max	Min	Max	Min	Max
Compaction, number of blows each end of specimen	35		50		75	

- Traffic classifications
  - *Light Traffic conditions resulting in a 20-year Design ESAL < 10^4*
  - *Medium Traffic conditions resulting in a 20-year Design ESAL between 10^4 and 10^6*
  - *Heavy Traffic conditions resulting in a 20-year Design ESAL > 10^6*

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Step C : Preparation of Marshall Specimen

C-8: Compact the specimen at the required Blow/side according to Marshall specifications.

Video source: https://www.youtube.com/watch?v=SuJMH5RDFcQ

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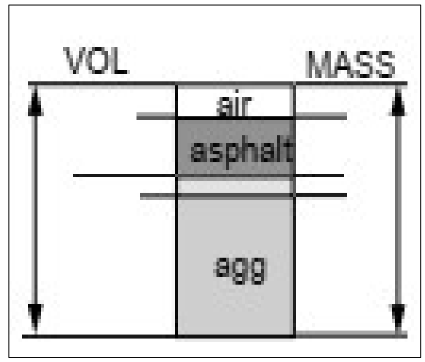
Step C : Preparation of Marshall Specimen

- C-9 Determine the Bulk Specific Gravity, G_{mb}



https://www.youtube.com/watch?v=U6-8C1hRdDk

Marshall Mix Design

Step D : Density and voids analysis

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Marshall Mix Design Method Procedures

Step D : Density and voids analysis

- D-1: Use the G_{mb} from step C-9 and G_{mm} to calculate the percent air void
  - $V_a = 100 \times \frac{G_{mm} - Gmb}{G_{mm}}$
- D-2: Determine the unit weight of Marshall specimen
  - $Unit\ weight\ = G_{mb} \times \delta_{water}$
  - δ_{water} = 1000 kg/ m^3 (62.4 lb/ft^3)
- D-3: Determine VMA
  - VMA= $100 - \frac{G_{mb} - Ps}{G_{sb}}$
- D-4 : Determine VFA
  - $VFA = 100 \times \frac{VMA - Va}{VMA}$

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Step C : Preparation of Marshall Specimen

- C-4: Prepare three specimens at five different binder contents

Estimated O.B.C -1.0%

Estimated O.B.C - 0.5%

Estimated Optimum binder content (O.B.C)

Estimated O.B.C + 0.5%

Estimated O.B.C +1.0%

Step C : Preparation of Marshall Specimen

- C-4: Prepare three specimens at five different binder contents

Estimated O.B.C -1.0%

Estimated O.B.C - 0.5%

Estimated Optimum binder content (O.B.C)

Estimated O.B.C + 0.5%

Estimated O.B.C +1.0%

Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial
Mix:

		Mass, grams										Stability, lbs. (N)		
% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	In Air	In Water	Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m³)	% Air Voids	%VMA	%VFA	Measured	Adjusted	Flow 0.01 in. (0.25 mm)
3.5 - A		1240.6	726.4	1246.3	519.9	2.386		148.9				2440	2440	8
3.5 - B		1238.7	723.3	1242.6	519.3	2.385		148.8				2420	2420	7
3.5 - C		1240.1	724.1	1245.9	521.8	2.377		148.3				2510	2510	6
Average						2.383	2.570	148.7	7.3	14.0	48.0		2457	7
4.0 - A		1244.3	727.2	1246.6	519.4	2.396		149.5				2180	2180	7
4.0 - B		1244.6	727.0	1247.6	520.6	2.391		149.2				2260	2260	8
4.0 - C		1242.6	727.9	1244.0	516.1	2.408		150.2				2310	2310	8
Average						2.398	2.550	149.6	6.0	13.9	57.1		2250	7.7
4.5 - A		1249.3	735.8	1250.2	514.4	2.429		151.2				2420	2420	9
4.5 - B		1250.8	728.1	1251.6	523.5	2.389		149.1				2310	2314	9
4.5 - C		1251.6	735.3	1253.1	517.8	2.417		150.8				2340	2340	9
Average						2.412	2.531	150.5	4.7	13.9	66.1		2358	9
5.0 - A		1256.7	739.8	1257.6	517.8	2.427		151.4				2290	2290	10
5.0 - B		1258.7	742.7	1259.3	516.6	2.437		152.0				2190	2190	10
5.0 - C		1258.4	737.5	1259.1	521.6	2.418		150.5				2240	2240	9
Average						2.425	2.511	151.3	3.4	13.8	75.2		2240	9.7
5.5 - A		1263.8	742.6	1264.3	521.7	2.422		151.2				2210	2210	11
5.5 - B		1258.8	741.4	1259.4	518.0	2.430		151.6				2300	2300	10
5.5 - C			742.5	1259.5	517.0	2.435		152.0				2210	2240	10
Average						2.429	2.493	151.6	2.5	14.1	82.1		2240	10.3

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Marshall Mix Design

Step E : Marshall stability and flow test

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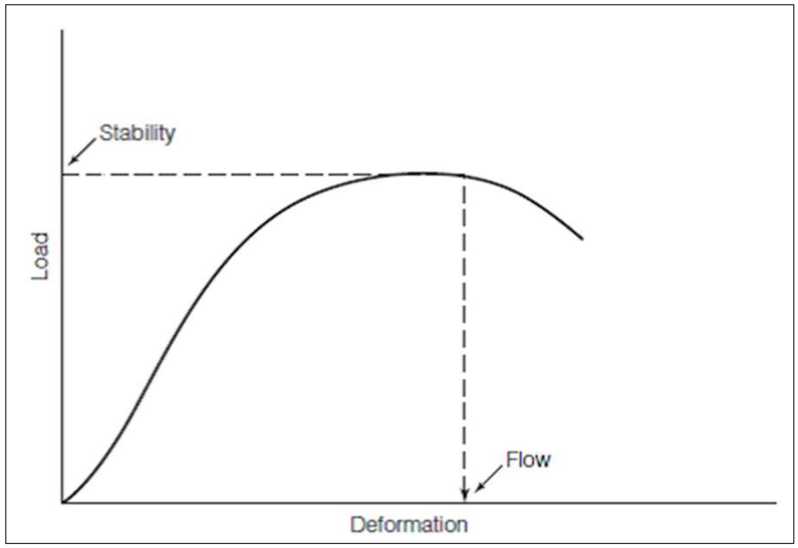

https://www.youtube.com/shorts/LmvBokJwsr0

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Marshall Mix Design

Step F : Tabulating and plotting test results

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Marshall Mix Design Method Procedures

Step F : Tabulating and plotting test results

- F-1: Tabulate the results from testing
  - *Volumetric analysis*
  - *Correct stability values for specimen height*
  - *Flow*

82

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Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial Mix:

		Mass, grams										Stability, lbs. (N)		
% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	In Air	In Water	Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m³)	% Air Voids	%VMA	%VFA	Measured	Adjusted	Flow 0.01 in. (0.25 mm)
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3.5 - B		1238.7	723.3	1242.6	519.3	2.385		148.8				2420	2420	7
3.5 - C		1240.1	724.1	1245.9	521.8	2.377		148.3				2510	2510	6
Average						2.383	2.570	148.7	7.3	14.0	48.0		2457	7
4.0 - A		1244.3	727.2	1246.6	519.4	2.396		149.5				2180	2180	7
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4.0 - C		1242.6	727.9	1244.0	516.1	2.408		150.2				2310	2310	8
Average						2.398	2.550	149.6	6.0	13.9	57.1		2250	7.7
4.5 - A		1249.3	735.8	1250.2	514.4	2.429		151.2				2420	2420	9
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4.5 - C		1251.6	735.3	1253.1	517.8	2.417		150.8				2340	2340	9
Average						2.412	2.531	150.5	4.7	13.9	66.1		2358	9
5.0 - A		1256.7	739.8	1257.6	517.8	2.427		151.4				2290	2290	10
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5.0 - C		1258.4	737.5	1259.1	521.6	2.418		150.5				2240	2240	9
Average						2.425	2.511	151.3	3.4	13.8	75.2		2240	9.7
5.5 - A		1263.8	742.6	1264.3	521.7	2.422		151.2				2210	2210	11
5.5 - B		1258.8	741.4	1259.4	518.0	2.430		151.6				2300	2300	10
5.5 - C			742.5	1259.5	517.0	2.435		152.0				2210	2240	10
Average						2.429	2.493	151.6	2.5	14.1	82.1		2240	10.3

83

83

Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial
Mix:

% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	Mass, grams In Air	In Water	Sat. Surface Dry In Air	Bulk S.G. Specimen
3.5 – A		1240.6	726.4	1246.3	2.386
3.5 – B		1238.7	723.3	1242.6	2.385
3.5 – C		1240.1	724.1	1245.9	2.377
Average					2.383

$$Gmb = \frac{Dry\ mass}{Bulk\ volume}$$

Find Gmb

$$G_{mb} = \frac{W_{dry}}{W_{ssd} - W_{sub}}$$

$Gmb\ @\ 3.5 - A = \frac{1240}{1246.3 - 726.3}$ =2.386

$Gmb\ @\ 3.5 - B = \frac{1238.7}{1242.6 - 723.3}$ =2.385

$Gmb\ @\ 3.5 - C = \frac{1240.1}{1245.9 - 7\quad .1}$ =2.377

$$Average\ Gmb\ @\ 3.5 = \frac{2.386 + 2.385 + 2.377}{3} = 2.383$$

84

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Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial
Mix:

% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	Max. S.G. (Loose Mix)
4.5 – A		
4.5 – B		
4.5 – C		
Average		2.531

Measure the Gmm at the O.B.C

85

85

Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial
Mix:

% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	Max. S.G. (Loose Mix)
4.5 – A		
4.5 – B		
4.5 – C		
Average		2.531

Find the G_{se}

$$G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$

$$G_{se} = \frac{100-4.5}{\frac{100}{2.531} - \frac{4.5}{1.030}} = 2.717$$

86

86

Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial
Mix:

% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	Max. S.G. (Loose Mix)
3.5 – A		
3.5 – B		
3.5 – C		
Average		2.570
4.0 – A		
4.0 – B		
4.0 – C		
Average		2.550
4.5 – A		
4.5 – B		
4.5 – C		
Average		2.531
5.0 – A		
5.0 – B		
5.0 – C		
Average		2.511
5.5 – A		
5.5 – B		
5.5 – C		
Average		2.493

Estimate Gmm at other binder contents

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

$$G_{mm@\,3.5} = \frac{100}{\frac{96.5}{2.717} + \frac{3.5}{1.030}} = 2.570$$

$$G_{mm@\,4.0} = \frac{100}{\frac{96}{2.717} + \frac{4}{1.030}} = 2.550$$

$$G_{mm@\,5} = \frac{100}{\frac{95.5}{2.717} + \frac{5}{1.030}} = 2.511$$

$$G_{mm@\,5.5} = \frac{100}{\frac{95}{2.717} + \frac{5.5}{1.030}} = 2.493$$

where:
G_{mm} = maximum specific gravity of asphalt mixture
P_s = percentage of aggregate by total mix weight
P_b = percentage of binder by total mix weight
$P_s + P_b = 100$
G_{se} = effective specific gravity of aggregate
G_b = specific gravity of binder
M_{mb} = bulk mass of paving mixture (which would be the same as M_{mm}, since the air has no mass), typically in g
V_{mm} = volume of aggregate and binder, typically in cm^3
ρ = density of water, 1.000 g/cm^3

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Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial
Mix:

		Mass, grams						
% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	In Air	In Water	Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m³)
3.5 – A		1240.6	726.4	1246.3	519.9	2.386		148.9
3.5 – B		1238.7	723.3	1242.6	519.3	2.385		148.8
3.5 – C		1240.1	724.1	1245.9	521.8	2.377		148.3
Average						2.383	2.570	148.7

δ_{water}= 1000 kg/ m^3 (62.4 lb/ft^3)

Find unit weight $Unit\ weight\ = G_{mb} \times \delta_{water}$

$Unit\ weight$ @ 3.5- A = 2.386 *62.4 = 148.9 pcf

$Unit\ weight$ @ 3.5- B = 2.385 *62.4 = 148.8 pcf

$Unit\ weight$ @ 3.5- C = 2.377 *62.4 = 148.3 pcf

Average $Unit\ weight$ @ 3.5 = (148.9+148.8+148.8)/3 = 148.7

Average $Unit\ weight$ @ 3.5 = (2.386*62.4 + 2.385*62.4 + 2.377 *62.4)/3 =- 148.7

Average $Unit\ weight$ @ 3.5 = 62.4(2.386 + 2.385* + 2.377)/3 =- 148.7

Average $Unit\ weight$ @ 3.5 = 62.4 * (2.383)=148.7

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Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial
Mix:

		Mass, grams							
% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	In Air	In Water	Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m³)	% Air Voids
3.5 – A		1240.6	726.4	1246.3	519.9	2.386		148.9	
3.5 – B		1238.7	723.3	1242.6	519.3	2.385		148.8	
3.5 – C		1240.1	724.1	1245.9	521.8	2.377		148.3	
Average						2.383	2.570	148.7	7.3

Find air void

$$V_a = 100 \times \frac{G_{mm} - G_{mb}}{G_{mm}}$$

$$Va\ @\ 3.5\ Pb\ = 100 - \frac{2.570-2.383}{2.570}=7.3$$

89

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Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial Mix:

		Mass, grams								
% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	In Air	In Water	Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m^3)	% Air Voids	%VMA
3.5 – A		1240.6	726.4	1246.3	519.9	2.386		148.9		
3.5 – B		1238.7	723.3	1242.6	519.3	2.385		148.8		
3.5 – C		1240.1	724.1	1245.9	521.8	2.377		148.3		
Average						2.383	2.570	148.7	7.3	14.0

Find VMA

$$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$

$$\text{VMA} = 100 - \frac{2.383*(100-3.5)}{2.674} = 14.0$$

90

Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial Mix:

		Mass, grams									
% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	In Air	In Water	Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m^3)	% Air Voids	%VMA	%VFA
3.5 – A		1240.6	726.4	1246.3	519.9	2.386		148.9			
3.5 – B		1238.7	723.3	1242.6	519.3	2.385		148.8			
3.5 – C		1240.1	724.1	1245.9	521.8	2.377		148.3			
Average						2.383	2.570	148.7	7.3	14.0	48.0

Find VFA

$$VFA = 100 \times \frac{VMA - V_a}{VMA}$$

$$\text{VFA} = 100 - \frac{14-7.3}{14} = 48.0$$

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Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial Mix:

% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	Mass, grams: In Air	Mass, grams: In Water	Mass, grams: Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m³)	% Air Voids	%VMA	%VFA	Stability, lbs. (N): Measured	Stability, lbs. (N): Adjusted	Flow 0.01 in. (0.25 mm)
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3.5 – C		1240.1	724.1	1245.9	521.8	2.377		148.3				2510	2510	6
Average						2.383	2.570	148.7	7.3	14.0	48.0		2457	7

Perform Marshall Stability test

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Compaction: 75 Blows
Specific Gravity of AC: 1.030
Bulk S.G. Aggregate: 2.674

Grade AC: AC-20
Absorbed AC of Aggregate: 0.6%
Effective S.G. Aggregate: 2.717

Project:
Location:
Date:

Trial Mix:

% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	Mass, grams: In Air	Mass, grams: In Water	Mass, grams: Sat. Surface Dry In Air	Bulk Volume, cc	Bulk S.G. Specimen	Max. S.G. (Loose Mix)	Unit Weight, pcf (Mg/m³)	% Air Voids	%VMA	%VFA	Stability, lbs. (N): Measured	Stability, lbs. (N): Adjusted	Flow 0.01 in. (0.25 mm)
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5.0 – A		1256.7	739.8	1257.6	517.8	2.427		151.4				2290	2290	10
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Average						2.425	2.511	151.3	3.4	13.8	75.2		2240	9.7
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5.5 – C			742.5	1259.5	517.0	2.435		152.0				2210	2240	10
Average						2.429	2.493	151.6	2.5	14.1	82.1		2240	10.3

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Marshall Mix Design Method Prc

Step F : Tabulating and plotting test results

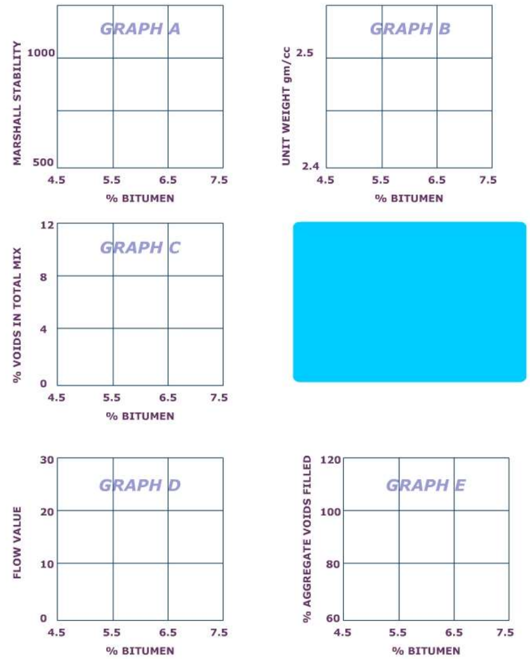

Image source: https://www.civil.iitb.ac.in/~vmtom/1100_LnTse/407_InTse/plain/

PLAY

5

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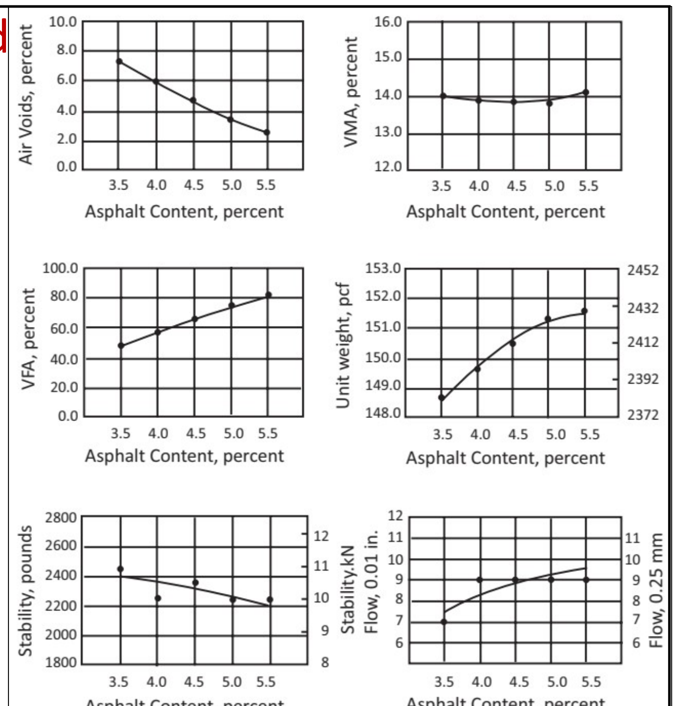
Marshall Mix Design Method

Step F : Tabulating and plotting test results



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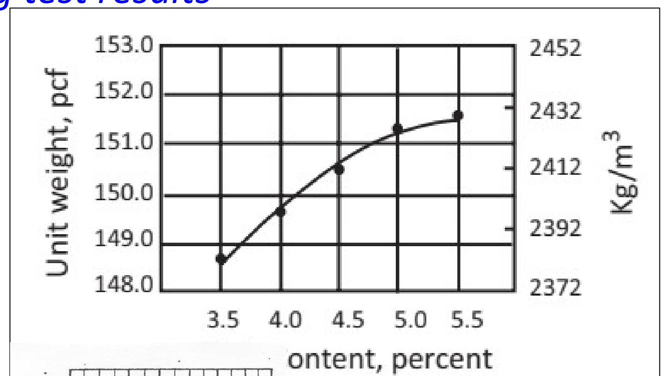
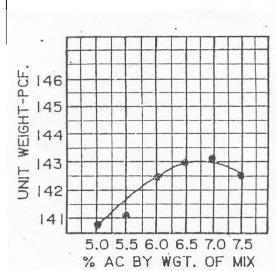
Marshall Mix Design Method Procedures

Step F : Tabulating and plotting test results

F-2 : Plot %AC vs. Unit wt. (Density)

- Density increases with increasing asphalt content, reaches a peak and then decreases
- Peak density usually occurs at a higher asphalt content than peak stability





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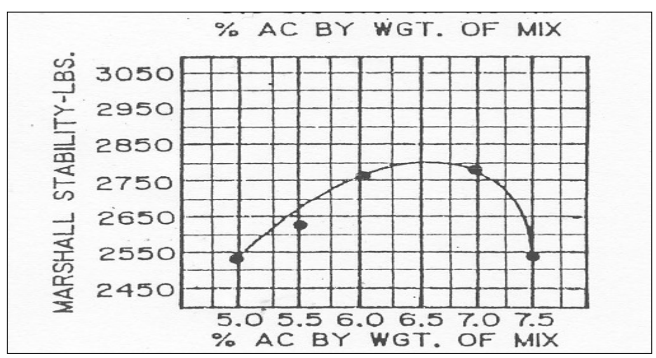
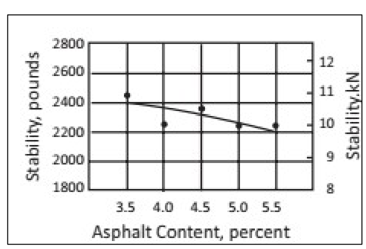
Marshall Mix Design Method Procedures

Step F : Tabulating and plotting test results

F-3 : Plot %AC vs. Corrected Marshall stability

- Two trends may be provided
  - *Stability increases with increasing asphalt content, reaches a peak, then decreases*
  - *Stability decreases with increasing asphalt content and does not show a peak*
    - This curve is common for recycled HMA mixtures





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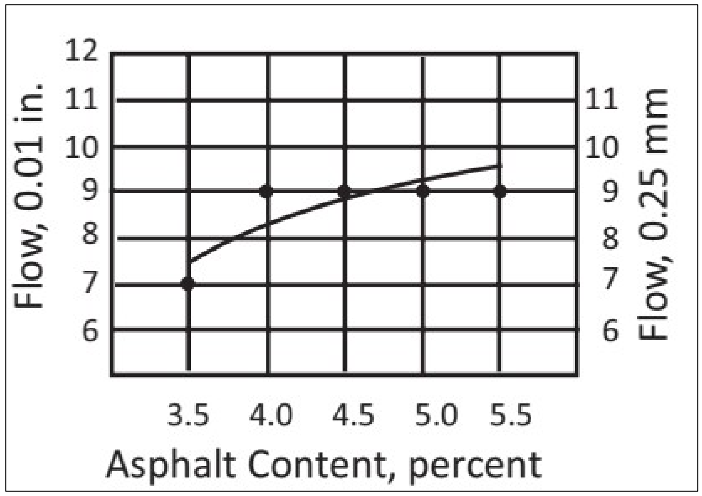
Marshall Mix Design Method Procedures

Step F : Tabulating and plotting test results

F-4 : Plot %AC vs. Flow

- Flow should increase with increasing asphalt content



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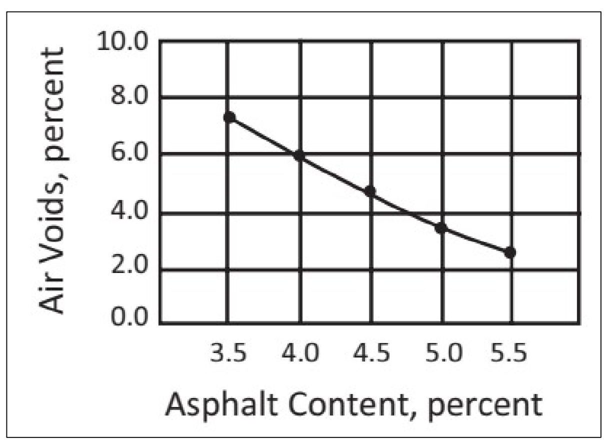
Marshall Mix Design Method Procedures

Step F : Tabulating and plotting test results

F-5 : Plot %AC vs. air void

- Air void should decrease with increasing asphalt content



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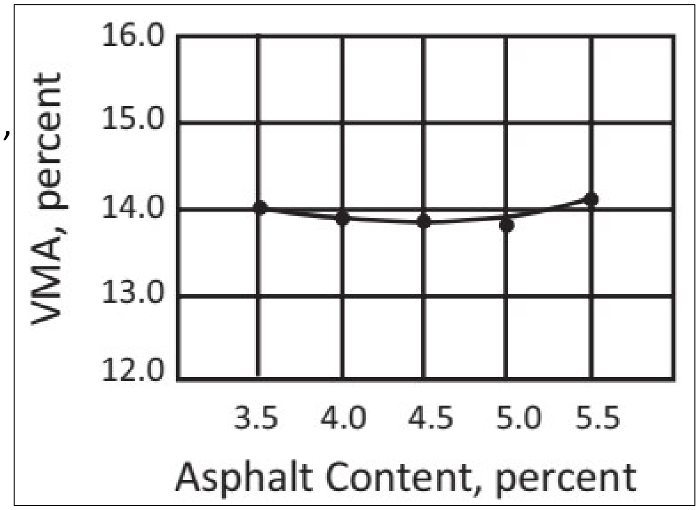
Marshall Mix Design Method Procedures

Step F : Tabulating and plotting test results

F-6 : Plot %AC vs. VMA

- Percent VMA should decrease with increasing asphalt content , reaches a minimum, and then increases

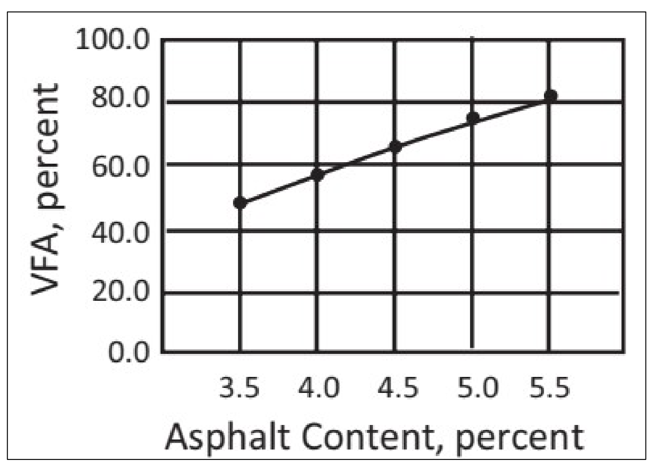


Marshall Mix Design Method Procedures

Step F : Tabulating and plotting test results

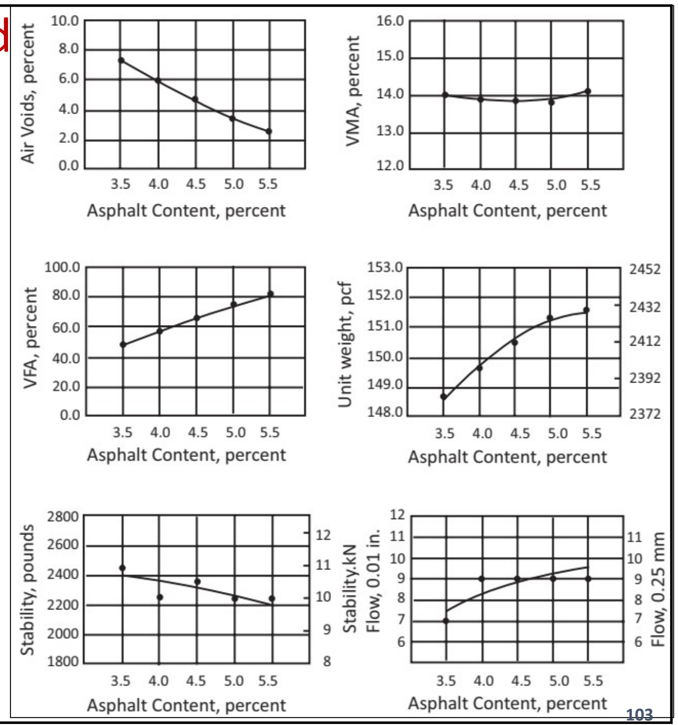
F-6 : Plot %AC vs. VFA

- Percent VFA should increase with increasing asphalt content



Marshall Mix Design Method

Step F :
Tabulating and plotting test results



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Marshall Mix Design

Step G : Determination of optimum asphalt content

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Marshall Mix Design Method Procedures

Step G : Determination of optimum asphalt content

Two methods are used to determine optimum asphalt content :

- *Method 1: National Asphalt Pavement Association (NAPA) Procedure*
- *Method 2: Asphalt Institute Procedure*

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Marshall Mix Design

Step G : Determination of optimum asphalt content

Step G-1 : NAPA method procedures

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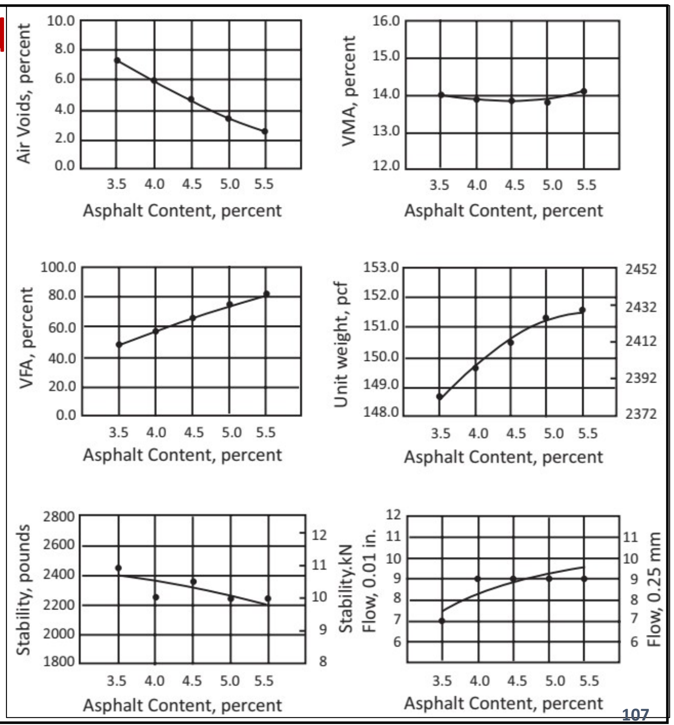
Marshall Mix Design Method

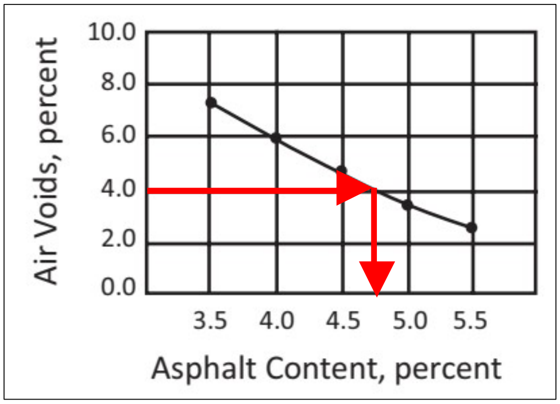
Step F : Tabulating and plotting test results



Marshall Mix Design Method Procedures

Step G-1 : NAPA method procedures

- ❑ G-1-1: Determine the optimum asphalt content (O.B.C) which corresponds to the specification air void content (4 %)

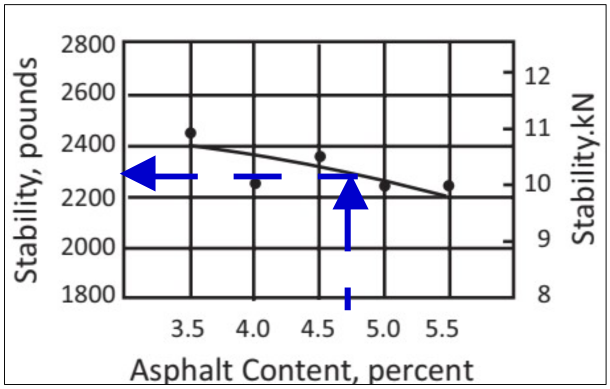


O.B.C = 4.75

Marshall Mix Design Method Procedures

Step G-1 : NAPA method procedures

- ❑ G-1-2: Determine Marshall stability which corresponds at selected O.B.C

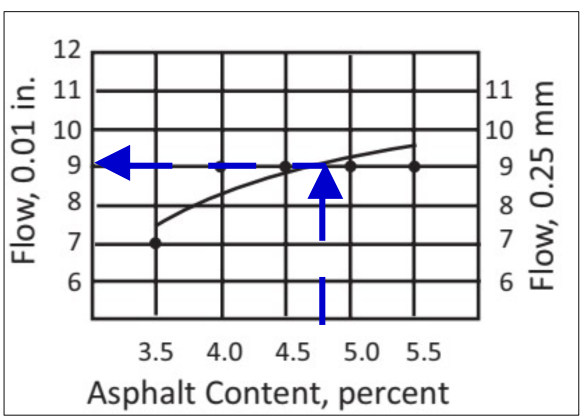


Stability = 2300 ib (10.5 KN) at O.B.C of 4.75%

Marshall Mix Design Method Procedures

Step G-1 : NAPA method procedures

- ❑ G-1-3: Determine Marshall Flow which corresponds at selected O.B.C

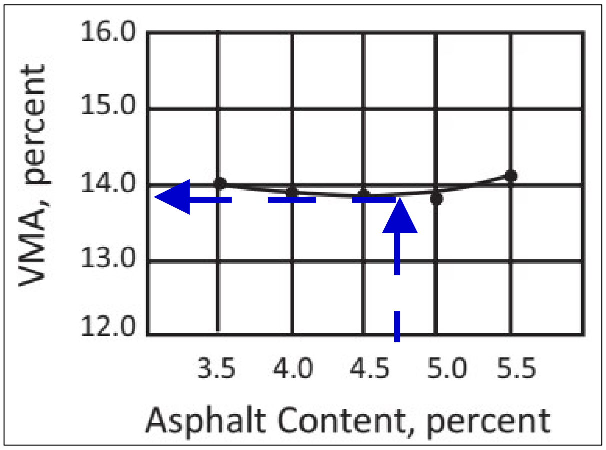


Flow = 9 at O.B.C of 4.75 %

Marshall Mix Design Method Procedures

Step G-1 : NAPA method procedures

- G-1-4: Determine VMA which corresponds at selected O.B.C



% VMA = 13.8 at O.B.C of 4.75 %

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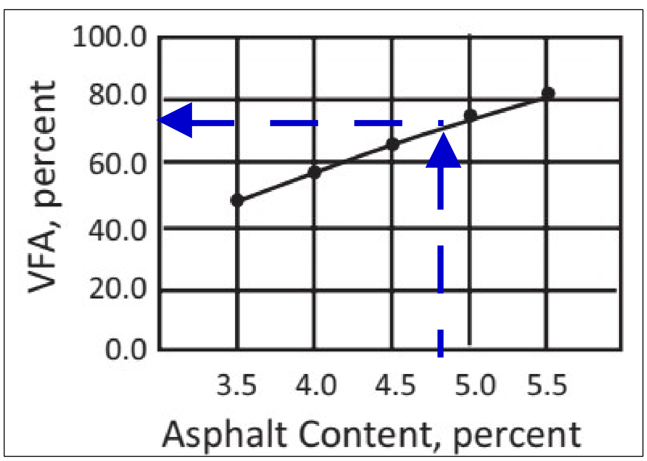
Marshall Mix Design Method Procedures

Step G-1 : NAPA method procedures

- G-1-5: Determine VFA which corresponds at selected O.B.C



% VFA = 78 at O.B.C of 4.75 %

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Marshall Mix Design Method Procedures

Step G-1 : NAPA method procedures

- G-1-6: Compare the obtained stability, flow, %VMA, VFA with against the specification values

  - *If it pass the requirement then preceding O.B.C is satisfaction*
  - *If any of these properties is outside the specifications range, the mixture should be redesigned*

- Traffic classifications
  - *Light Traffic conditions resulting in a 20-year Design ESAL < 10^4*
  - *Medium Traffic conditions resulting in a 20-year Design ESAL between 10^4 and 10^6*
  - *Heavy Traffic conditions resulting in a 20-year Design ESAL > 10^6*

Marshall Method Criteria[1]	Light Traffic[3] Surface & Base		Medium Traffic[3] Surface & Base		Heavy Traffic[3] Surface & Base	
	Min	Max	Min	Max	Min	Max
Compaction, number of blows each end of specimen	35		50		75	
Stability[2], N (lb.)	3336 (750)	-	5338 (1200)	-	8006 (1800)	-
Flow[2,4,5], 0.25 mm (0.01 in.)	8	18	8	16	8	14
Percent Air Voids[7]	3	5	3	5	3	5
Percent Voids in Mineral Aggregate (VMA)[6]	See Table 7.3					
Percent Voids Filled With Asphalt (VFA)	70	80	65	78	65	75

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Marshall Mix Design Method Prc

Step G-1 : NAPA method procedures

Nominal Maximum Particle Size[1,2]		Minimum VMA, percent		
		Design Air Voids, Percent[3]		
mm	in.	3.0	4.0	5.0
1.18	No. 16	21.5	22.5	23.5
2.36	No. 8	19.0	20.0	21.0
4.75	No. 4	16.0	17.0	18.0
9.5	⅜	14.0	15.0	16.0
12.5	½	13.0	14.0	15.0
19.0	¾	12.0	13.0	14.0
25.0	1.0	11.0	12.0	13.0
37.5	1.5	10.0	11.0	12.0
50	2.0	9.5	10.5	11.5
63	2.5	9.0	10.0	11.0

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Marshall Mix Design Method Procedures

Step G-1 : NAPA method procedures

Nominal Maximum Particle Size[1,2]		Minimum VMA, percent		
		Design Air Voids, Percent[3]		
mm	in.	3.0	4.0	5.0
1.18	No. 16	21.5	22.5	23.5
2.36	No. 8	19.0	20.0	21.0
4.75	No. 4	16.0	17.0	18.0
9.5	⅜	14.0	15.0	16.0
12.5	½	13.0	14.0	15.0
19.0	¾	12.0	13.0	14.0
25.0	1.0	11.0	12.0	13.0
37.5	1.5	10.0	11.0	12.0
50	2.0	9.5	10.5	11.5
63	2.5	9.0	10.0	11.0

Marshall Method Criteria[1]	Light Traffic[3] Surface & Base	
	Min	Max
Compaction, number of blows each end of specimen	35	
Stability[2], N (lb.)	3336 (750)	-
Flow[2,4,5], 0.25 mm (0.01 in.)	8	18
Percent Air Voids[7]	3	5
Percent Voids in Mineral Aggregate (VMA)[6]		
Percent Voids Filled With Asphalt (VFA)	70	80

Light traffic, O.B.C =4.75%, NMAS =19.0 mm

Stability = 2300 ib

Flow = 9

% VMA =13.8

% VFA = 78

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Marshall Mix Design

Step G : Determination of optimum asphalt content

Step G-2 : Asphalt Institute Procedure

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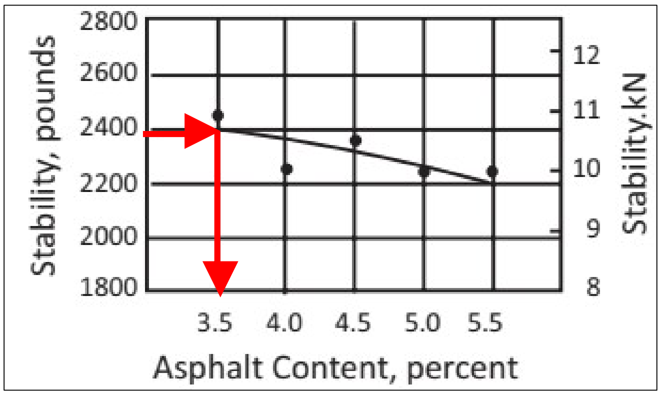
Marshall Mix Design Method Procedures

Step G-2 : Asphalt Institute Procedure

- G-2-1: Asphalt content at maximum stability



B.C. @ Max. Stability = 3.5 %

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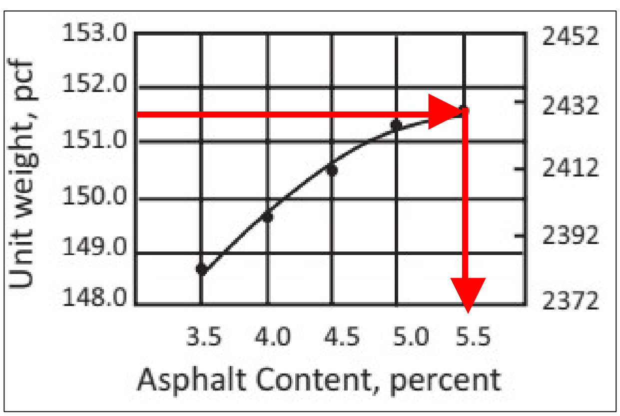
Marshall Mix Design Method Procedures

Step G-2 : Asphalt Institute Procedure

- G-2-2: Asphalt content at maximum density



B.C. @ Max. density = 5.5 %

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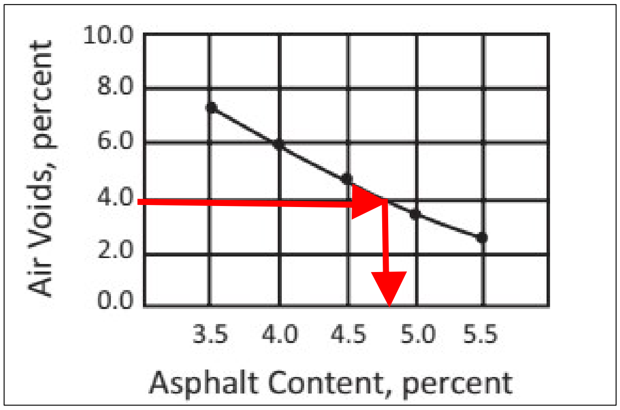
Marshall Mix Design Method Procedures

Step G-2 : Asphalt Institute Procedure

- *G-2-3: Asphalt content at mid point of specified air void range(Typically 4 %*



B.C. @ Design air void content = 4.75 %

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Marshall Mix Design Method Procedures

Step G-2 : Asphalt Institute Procedure

- G-2-4: Average the three asphalt contents selected in steps (Step G-2-A to C)
  - *Step G-2-1 …. B.C. = 3.5 %*
  - *Step G-2-1 …. B.C. = 5.5 %*
  - *Step G-2-1 …. B.C. = 4.75 %*
  - *Average Binder content …. (3.5%+5.5%+ 4.75%)/ 3 = 4.60%*
  - *Avg.B.C = 4.60 %*

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Marshall Mix Design

Jordanian Specifications for secondary and village roads construction

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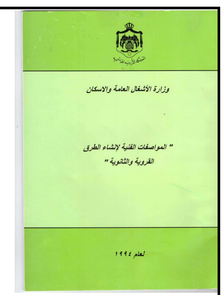
Ministry of Public Works and Housing

Specifications for secondary and village roads construction



هـ- خصائص الخلطة التصميمية (Marshall Trial Mix.) :

تكون خصائص الخلطة التصميمية حسب المتطلبات التالية :

١- درجة الثبات (كغم)

Stabilility AASHTO T245 ٧٥٠ الحد الأدنى

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Ministry of Public Works and Housing

Specifications for secondary and village roads construction

٢- (الزحف)

Flow Test I245   (٠٠/١٠٠-١٦/١٠٠)من الانش

٣- نسبة الفراغات الهوائية في الخليط الاجمالي   ٪ (٣ - ٥)

٤- النقص في درجة فقدان الثبات حسب فحص مارشال للعينات المنقوعة في ماء حرارته ٦٠م لمدة ٢٤ساعةبالمقارنة مع درجة الثبات التي تقاس بعـد الغمر في ماء حرارته ٦٠م لمدة ٣٠ دقيقـة(Loss Of Stability)   ٢٥٪ الحد الأعلـــى

٥- نسبة الفراغات المعدنية VMA محسوبـــة بطريقة معهد الاسفلت الأمريكي (MS-2) :   ١٣٪ حد أدنى الطبقة السطحيـــــة

١٢٪ حد أدنى الطبقة الرابطــــــة

٦- يراعي استعمال :

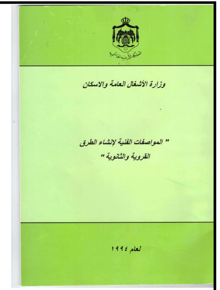

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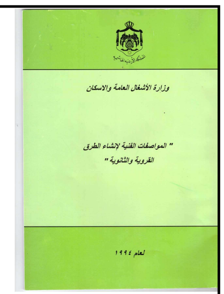
TABLE (6) :

TECHNICAL SPECIFICATION FOR SECONDARY & VILLAGE ROADS :

ASPHALT PAVEMENT , (BINDER AND WEARING)

tion

ITEM OF SPECS.	HOT MIX. LAYER	
	WEARING	BINDER
:- TYPE OF MATERIAL	LIME STONE/OR GRANITE	LIME STONE/OR GRANITE
:- TYPE OF BITUMEN	A.C 60/70 80/100	A.C 60/70 80/100
:- STABILITY (KG)	750 MIN.	750 MIN.
:- FLOW (1/100)"	8 - 16	8 - 16
:- STIFFNESS	-	-
:- L. OF STABILITY	25 MAX.	25 MAX.
:- V.M.A (%)	13 MIN.	12 MIN.
:- ASPHALT CONTENT (TOTAL MIX.)	AS DESIGNED	AS DESIGNED
AIR VOID (%)	3-5	3-5
:- STRIPPING *		
-STATIC TEST	95 MIN. COATING	95 MIN. COATING
-DYNAMIC TEST SCAND	60 MIN. COATING	60 MIN. COATING
:- COMPACTION	98%	97%
:- THICKNESS (CM)	5 OR AS SPECIFIED ON THE DRAWINGS	



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Jordanian National Building council

Specifications for highway and bridge construction

Table 4.15: JOB MIX REQURIEMENTS TO BITUMINOUS BINDER AND WEARING COURSES

Property	Heavy Traffic		Medium-Light Traffic	
	Binder	Wearing	Binder	Wearing
Marshall Stability at 60°C (kg)	900	1000 = 9806 N	800	900
Flow (mms)	2 - 3.5	2 - 3.5	2 - 4	2 - 4
Voids in Mineral Aggregate (VMA)	13 (-1)	14 (-1)	13 (-1)	14 (-1)
Air Voids (%)	4 - 7	4 - 6	3 - 5	3 - 5
Stiffness (Kg/mm)	500 (Min)	500 (Min)	400 (Min)	400 (Min)
* Loss of stability (%)	25 (max)	25 (max)	25 (max)	25 (max)

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Loss of Stability Test (AASHTO T 165-86)

Effect of Water on Cohesion of Compacted Bituminous Mixtures

1. Scope

1.1 This test method covers measurement of the loss of compressive strength resulting from the action of water on compacted bituminous mixtures containing asphalt cement. A numerical index of reduced compressive strength is obtained by comparing the compressive strength of freshly molded and cured specimens with the compressive strength of duplicate specimens that have been immersed in water under prescribed conditions.

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Loss of Stability Test (AASHTO T 165-86)

Effect of Water on Cohesion of Compacted Bituminous Mixtures

3. Significance and Use

3.1 This test method is useful as an indicator of the susceptibility to moisture of compacted bitumen-aggregate mixtures.

Index of retained strength, % = $(S_2/S_1) \times 100$

where:

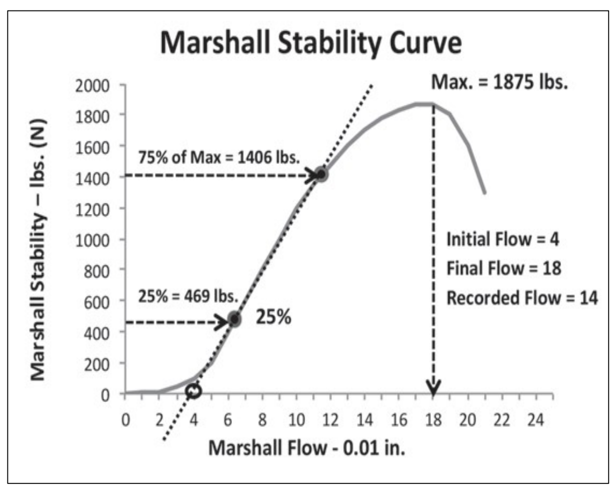
S_1 = compressive strength of dry specimens (Group 1), and
S_2 = compressive strength of immersed specimens (Group 2).

Jordanian National Building council

Stiffness

$$Marshall\ Stiffness = \frac{stability}{flow}$$

$$Marshall\ Stiffness = \frac{850\ kg}{4.5\ mm} = 188\ kg/mm$$



Stability = 1875 ibs =8340 N = 850. Kg

flow = 18 0.01in = 18 0.25mm =4.5 mm

Marshall Mix Design

Guidelines for Adjustments

Marshall Mix Design Method Procedures

Guidelines for Adjustments

- When mix design for optimum asphalt content does not satisfy all the requirements
  - *it is necessary to adjust the original blend of aggregates.*
- Trial mixes can be adjusted using the following general guidelines
  - *Low Voids & Low Stability*
  - *Low Voids & Satisfactory Stability*
  - *High Voids & Satisfactory Stability*
  - *Satisfactory Voids & Low Stability*
  - *High Voids & Low Stability*

Guidelines for Adjustments

Low Voids & Low Stability

- VMA can be increase
  - *Adding more coarse aggregates*
  - *Reducing asphalt content*
    - Only if the asphalt is more than what is normally used, and if the excess is not required as replacement for the amount absorbed).
    - Reducing asphalt should be done in care since this might reduce durability and increase permeability.

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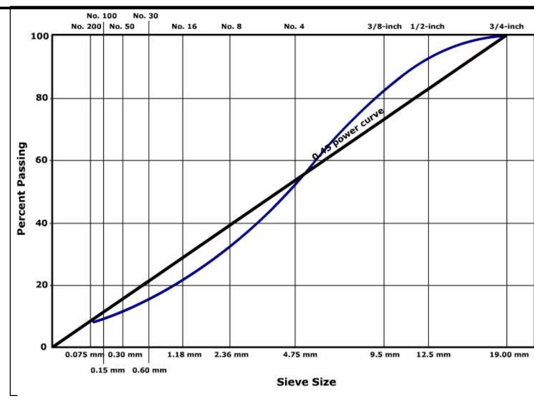
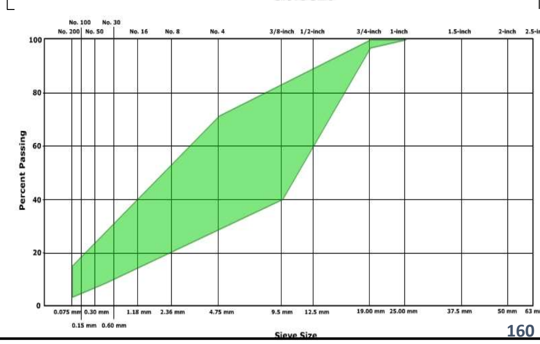
- Blending Guidelines
  - *Check how close the midband gradation comes to the maximum density line*
    - If it too close, the VMA is likely to be too low
    - VMA is increases as the gradation lines moves away from the maximum density line either up or down





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Guidelines for Adjustments

Low Voids & Satisfactory Stability

- This mix can lead to
  - *Reorientation of the particles*
  - *Additional compaction due to traffic can lead to bleeding of asphalt.*
- This cam be solved by
  - *Adding more aggregates*

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Guidelines for Adjustments

High Voids & Satisfactory Stability

- High voids lead to
  - *Increase permeability.*
  - *Air and water can circulate through the pavement causing hardening of the asphalt.*
- This can be solved by
  - *increasing the amount of mineral filler in the mix.*

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Guidelines for Adjustments

Satisfactory Voids & Low Stability

- This condition suggest low quality aggregates
  - *The aggregate quality should be improved.*

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Guidelines for Adjustments

High Voids & Low Stability

- Adjust the voids (increase mineral filler).
  - *If stability is not improved*
    - Consider improvement of the aggregate quality.

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Marshall Design Method

- Advantages
  - *Attention on voids (volumetric), strength, durability*
  - *Inexpensive equipment*
  - *Easy to use in process control/acceptance*
- Disadvantages
  - *Impact method of compaction*
  - *Does not directly consider shear strength*
  - *Load perpendicular to compaction axis*
  - *Developed for dense grad, ≤ 1" max size*
  - *Viscosity or pen graded AC*

New Advances in Asphalt Mix design

Asphalt mix design methods

Methods objective : To design an economical blend that would provide adequate level of field performance during pavement surface life

1943
- Bruce Marshall

1993
- Superpave

Rutting

[6,7]

Cracking

[8]

Balanced Mix Design Method (BMD)

[9,10]

What is next ?