

ورشة عمل نظام السوبربيف لتصميم الخلطات الاسفلتية الساخنة

**Workshop on SHRP technology for the design of
asphalt concrete hot mixes (Superpave™)
Superior Performing Asphalt Pavements**

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المركز المتقدم للهندسة
Advanced Engineering Center

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ملاحظات وأسئلة Remarks and Questions



AdEC website موقع المركز

The Advanced Engineering Center (AdEC) is specialized in the SUPERPAVE Technology, for more information visit our website at:

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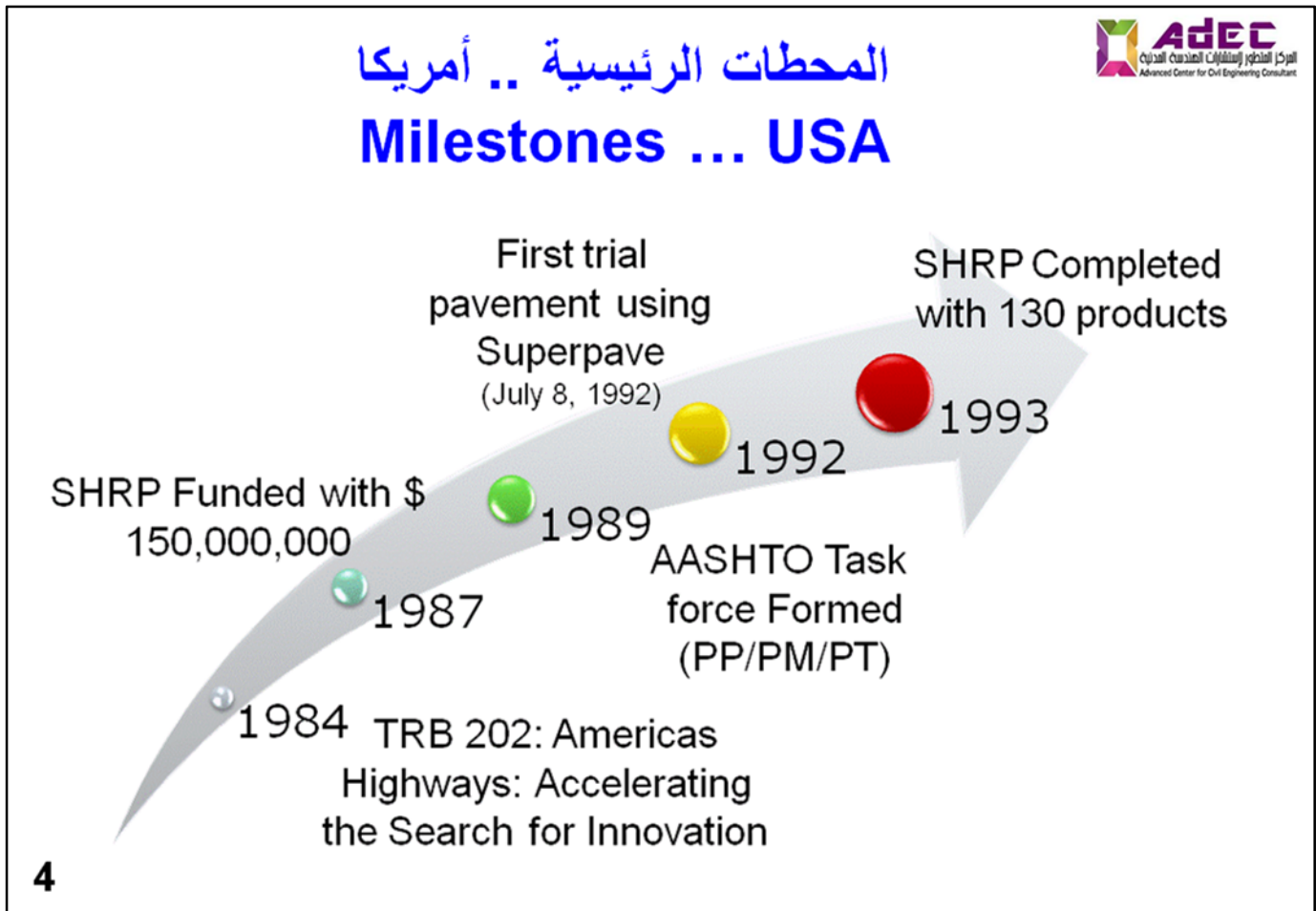
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ملاحظات وأسئلة Remarks and Questions

برنامج الدورة Workshop Program

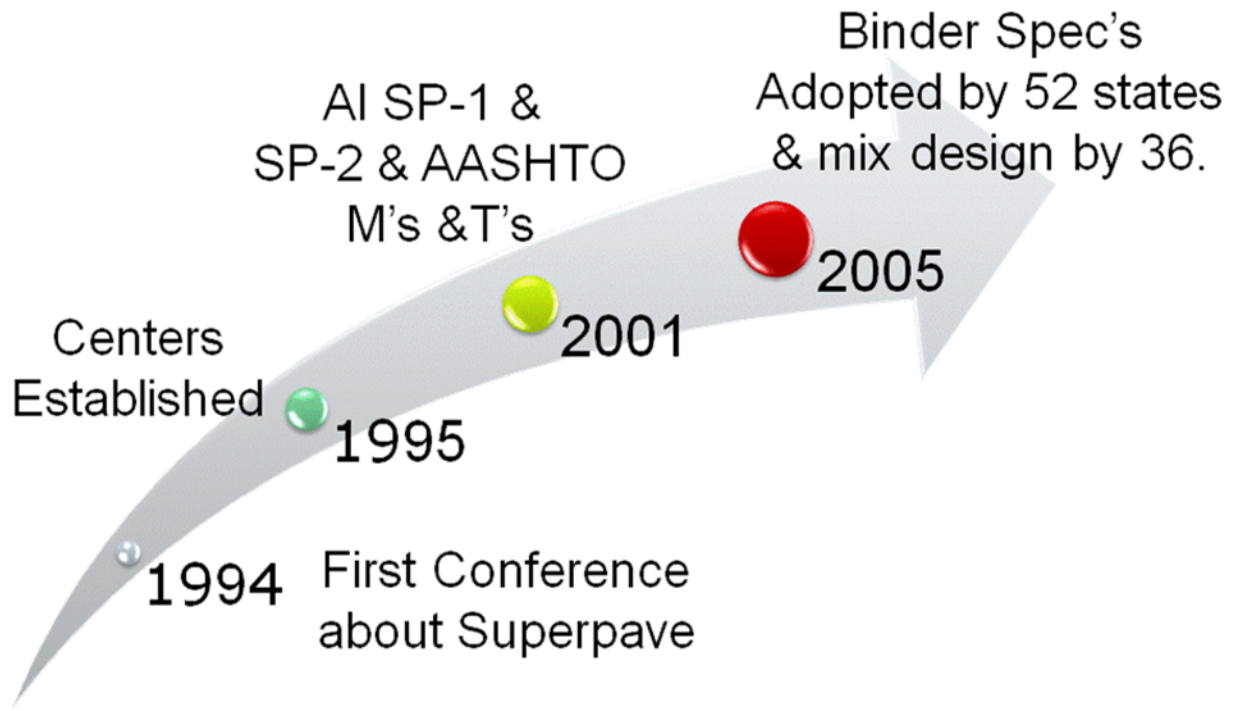
الاحد	الاثنين	الثلاثاء والاربعاء	الخميس
خلفية Background	اختيار هيكل الحصمة DAS	عمل تجارب التصميم واعداد عينات للخلطة في مختبر التدريب التابع للمركز	مراجعة و الاختبار التأهيلي Closing Discus. and Exam.
اختيار المواد Selection of Materials	اختيار محتوى الرابط التصميمي DAC		
تحديد معايير التصميم Design Parameters	التحقق من الدك ومقاومة المياه N_{des} , N_{max} & Water Sensitivity		
	شرح موجز عن برنامج اي-بيف3 ePAVE3		

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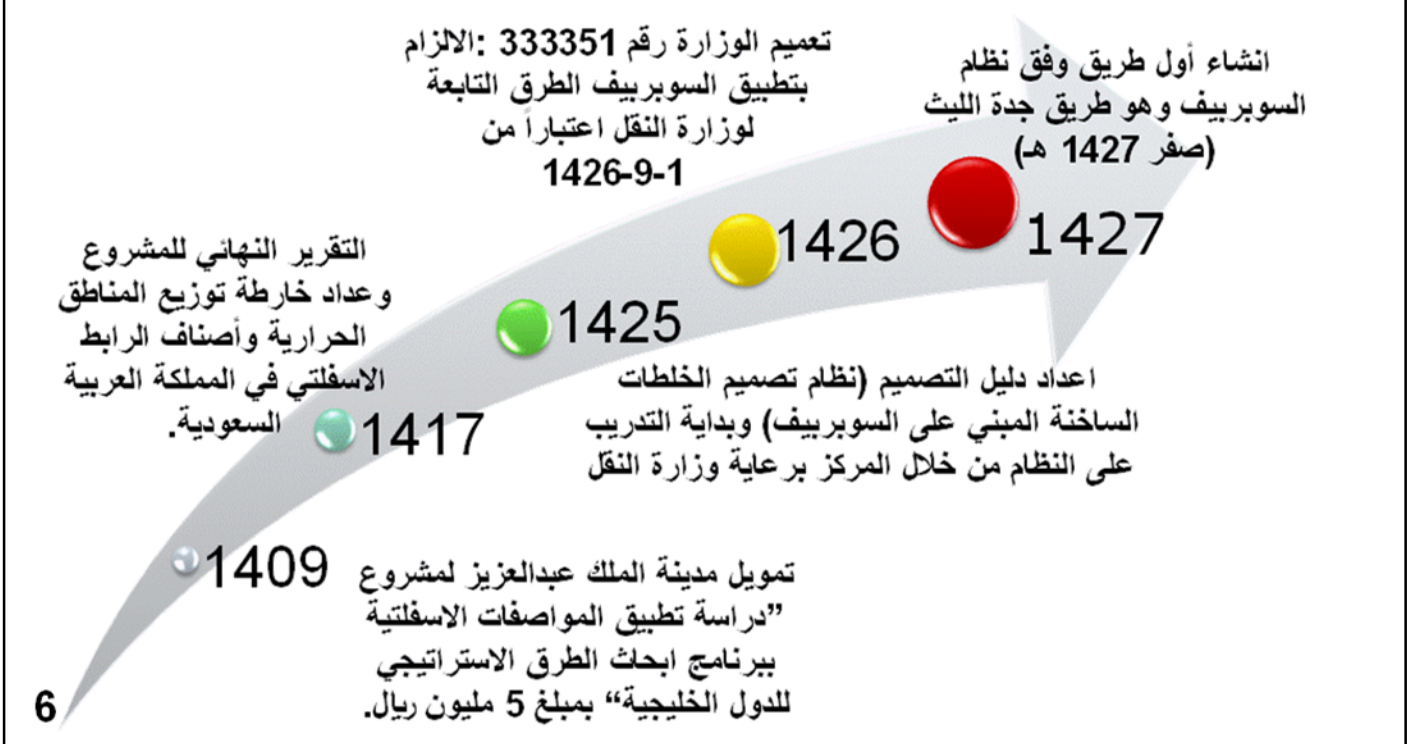
ملاحظات وأسئلة Remarks and Questions

المحطات الرئيسية .. أمريكا Milestones ... USA



ملاحظات وأسئلة Remarks and Questions

المحطات الرئيسية .. المملكة Milestones ... Kingdom



ملاحظات وأسئلة Remarks and Questions

لماذا السوبربيف؟ Why Superpave?

❖ Internationally

- SHRP (1987 to 1993)
- US, Canada, Saudi, Europe, Australia, Jordan, Iran, Pakistan, Japan ...

❖ Locally

- MOT first “Circular No. 2253”
- MOT second “Circular No. 30789”
- MOT third “Circular No. 33335 dated 1-8-1426”

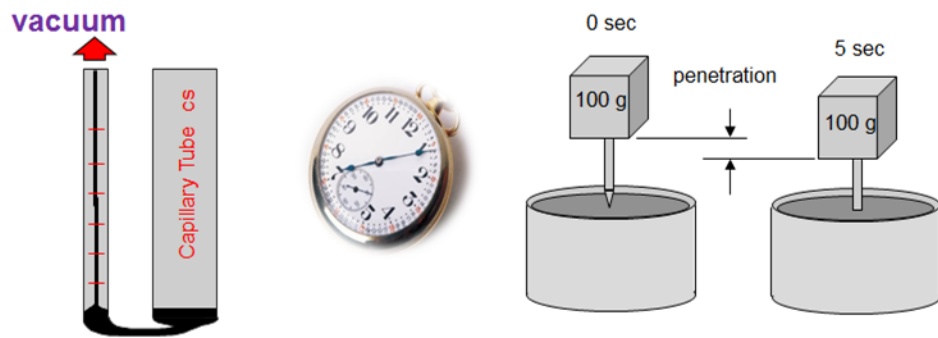
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لماذا السوبربيف؟ Why Superpave?

Pre Superpave Shortcomings:

- Viscosity Grading: Viscous effects only
- Penetration Grading: Empirical measure of viscous & elastic effects
- No low-temperature properties measured
- No consideration of long term aging
- Problems with modified asphalt characterization

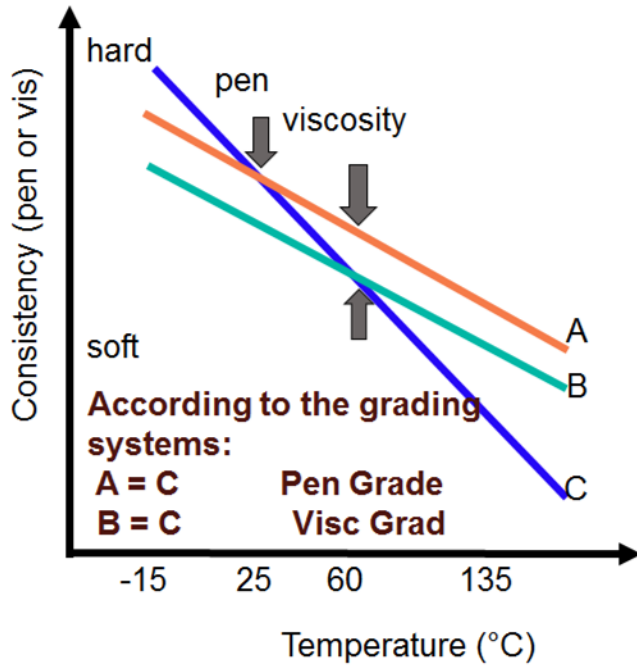


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التصنيف قبل السوبربف

Pre-Superpave Grading



لاحظ الآتي:

- جميع الاسفلتات 1 و 2 و 3 من صنف 60/70
- اسفلت 1 و 2 لهما تأثير متساوي بالحرارة إلا أن قيم التأثير مختلفة.
- اسفلت 1 و 3 لهما نفس القوام عند درجات الحرارة المنخفضة إلا انهما يختلفان عند درجة الحرارة العالية.
- اسفلت 2 يختلف عن 3 على جميع درجات الحرارة بل و ينعكس القوام بين المنخفضة و المرتفعة.

ملاحظات وأسئلة Remarks and Questions

لماذا السوبربيف؟

Why Superpave?

❖ Drawbacks of pre-superpave design practices:

- Pre-Superpave procedures do not take Traffic or environmental conditions into considerations
- Marshall
 - Impact compaction.
 - Shear strength of HMA is not adequately estimated.
- Hveem
 - Important volumetric properties are not determined.
 - Expensive and not portable.

❖ pavements Unsatisfactory performance

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أداء الرصفيات

Asphalt Pavement Performance



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ملاحظات وأسئلة Remarks and Questions

تعريف السوبربيف? What is SUPERPAVE?

السوبربيف هو نظام هندسي متكامل يتضمن مواصفات الأداء و طرق الاختبارات و التعليمات الهندسية اللازمة لاختيار وتأهيل المواد وتحديد نسب خلطها كما ويحدد المعلومات الضرورية لإنتاج وفرد الخلطة بما يتواءم مع الظروف المناخية و المرورية لمشاريع التنفيذ والصيانة ، يحتوي النظام على مكونين أساسيين هما: (1) تصنيف الرابط الاسفلتي و (2) تصميم الخلطات الاسفلتية الساخنة.

Superpave™ is one of SHRP products , it is a mix design system for new construction and overlays. This system employs a series of new *performance based specifications, test methods and practices* for *material selection, accelerated performance testing, and mix design* (1994).

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ملاحظات وأسئلة Remarks and Questions

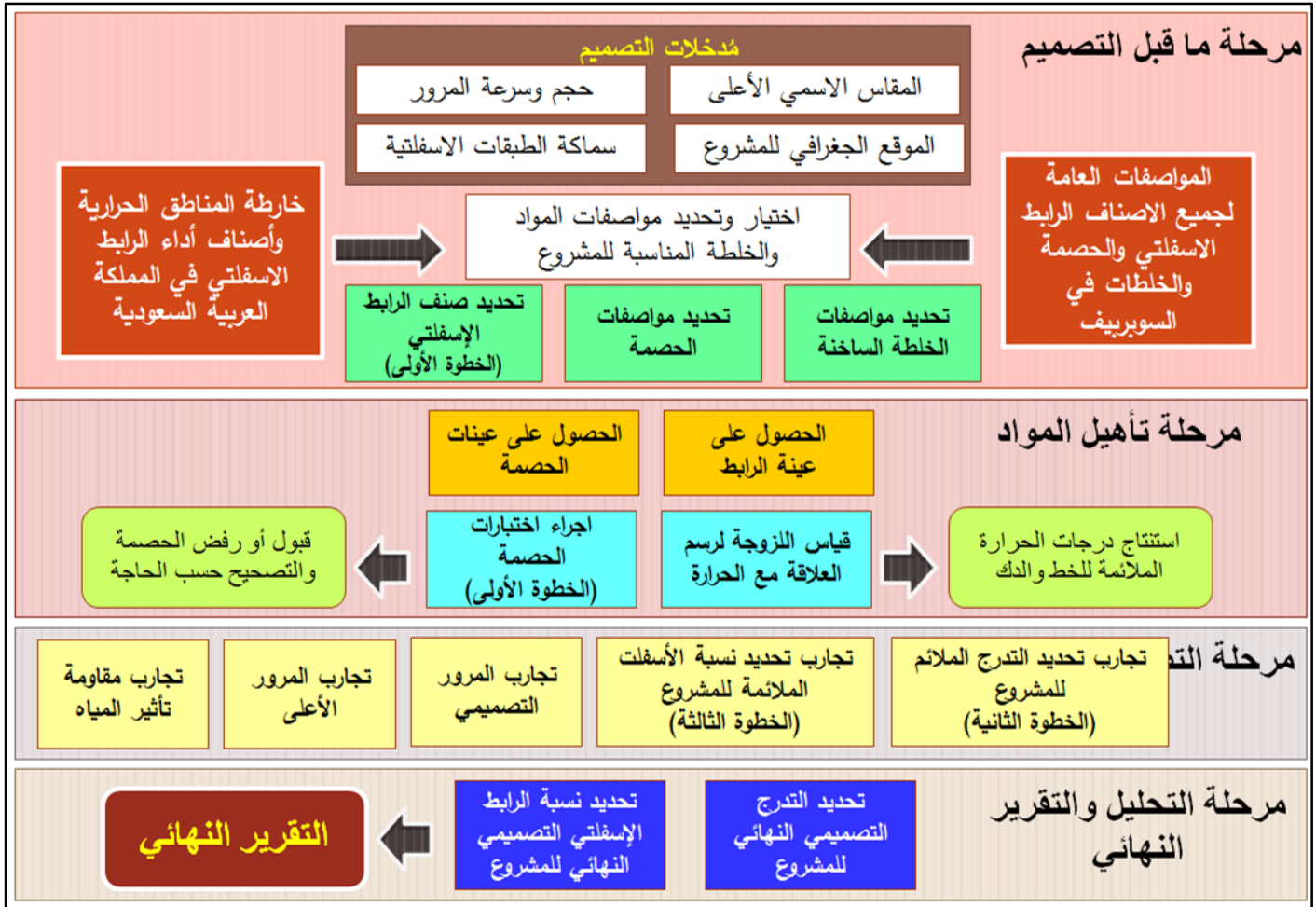
مميزات السوبربيف

Differentiating Aspects of Superpave

- Performance based.
- It is an Integrated approach that includes specifications and mix design method
- The use of formal aggregate evaluation procedures (consensus requirements).
- The use of the PG asphalt binder grading system and its associated asphalt binder selection system.
- The use of the gyratory compactor to simulate field compaction.
- Traffic loading and environmental considerations.
- Its volumetric approach to mix design

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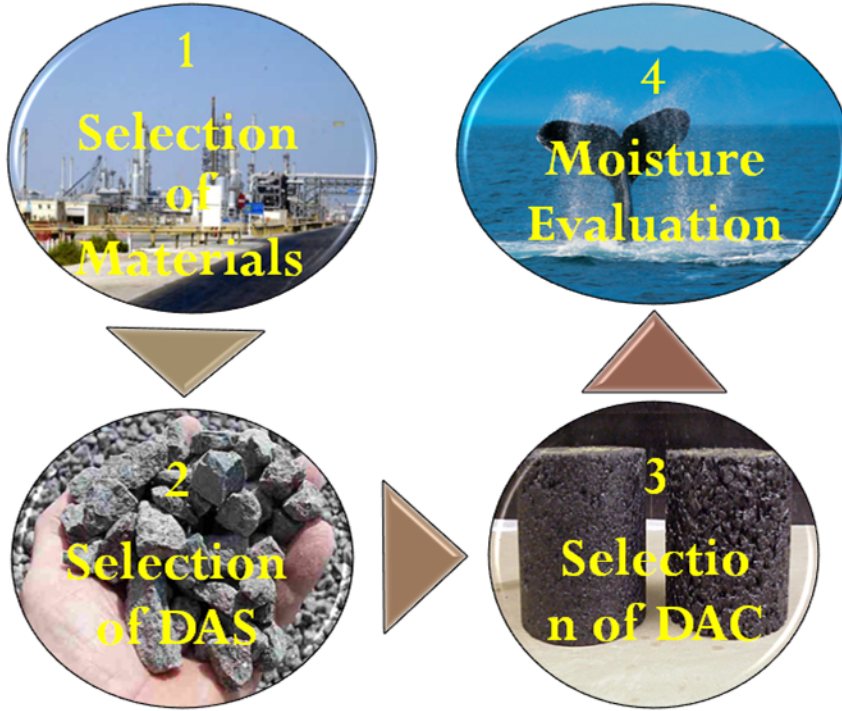
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ملاحظات وأسئلة Remarks and Questions

خطوات تصميم الخلطة

Mix Design Steps

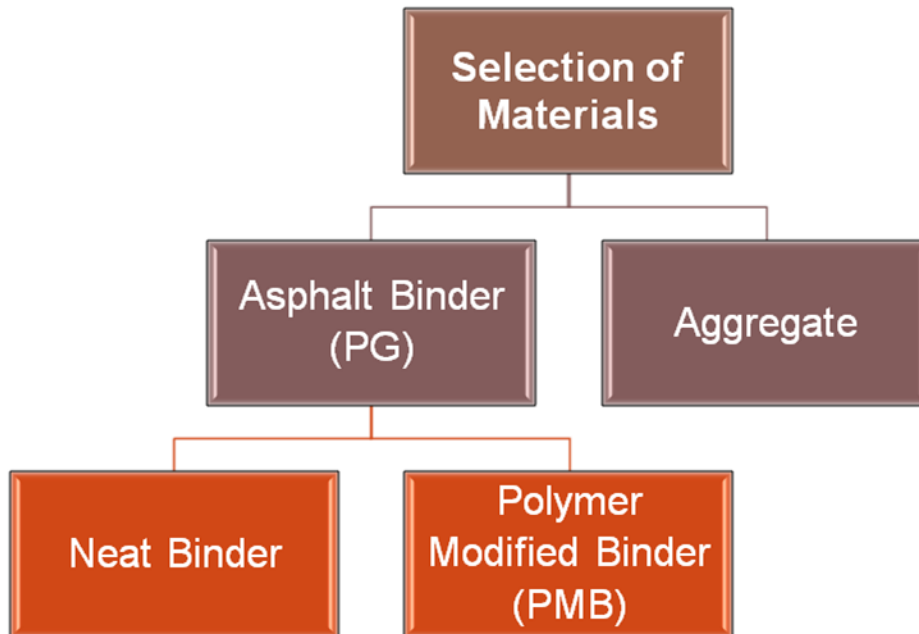


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الخطوة الأولى: اختيار المواد

Step 1: Selection of Materials



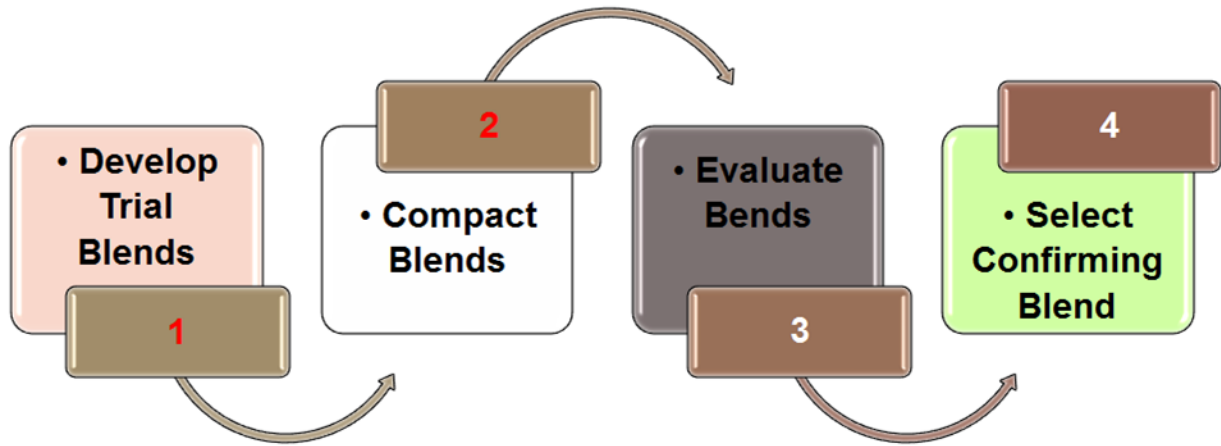
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الخطوة الثانية: اختيار الهيكل التصميمي للحصمة

Step 2: Selection of DAS



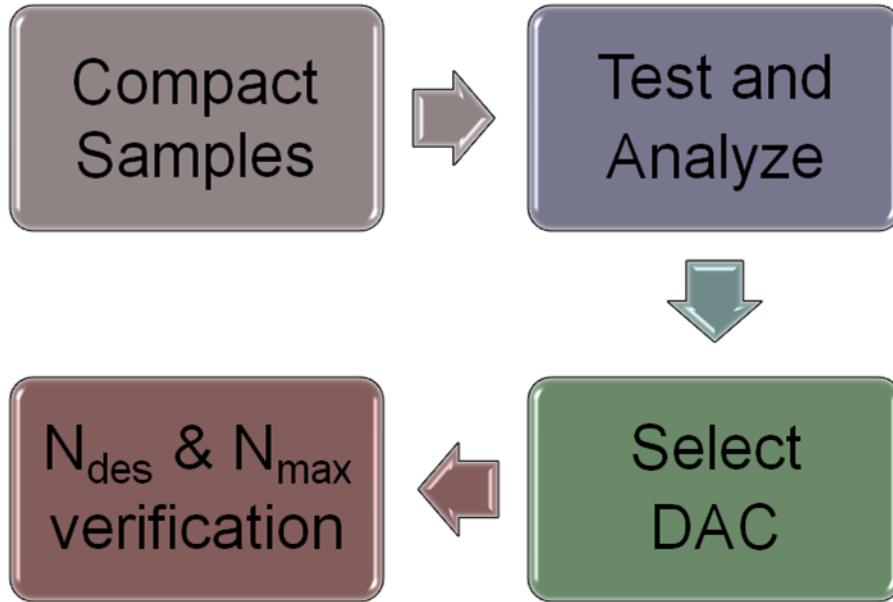
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الخطوة الثالثة: اختيار محتوى الرابط التصميمي

Step 3: Selection of DAC

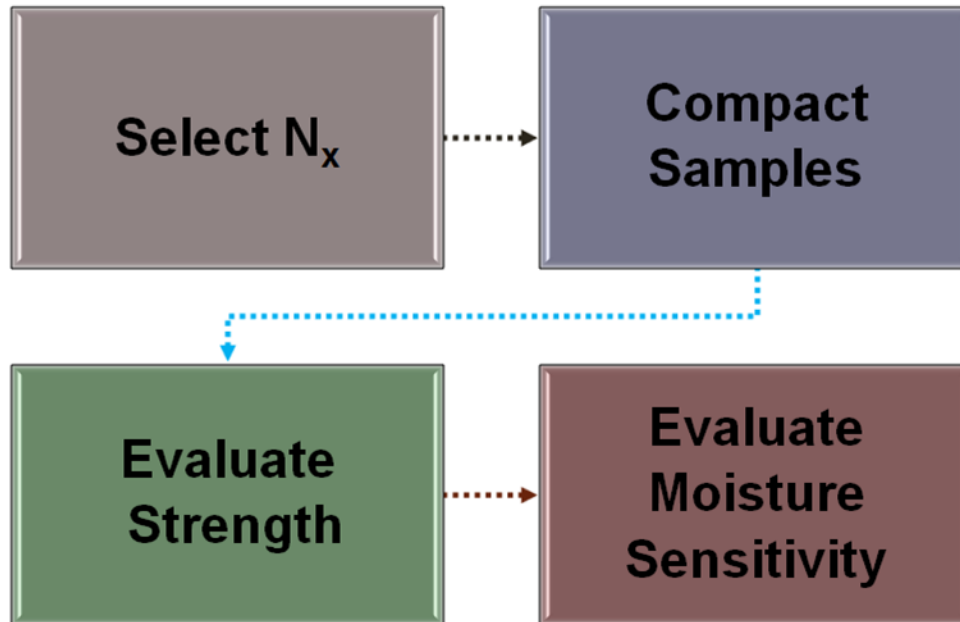


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الخطوة الرابعة: مقاومة المياه

Step 4: Moisture Sensitivity



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معايير التصميم Design Parameters



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معايير التصميم Design Parameters

The Nominal Maximum Size (NMS) is defined as One sieve size larger than the first sieve to retain more than 10%.

Six Mixture Gradation

MS	NMS
50.0 mm	37.5 mm
37.5 mm	25.0 mm
25.0 mm	19.0 mm
19.0 mm	12.5 mm
12.5 mm	9.5 mm
9.5 mm	4.75 mm

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مثال NMS Example

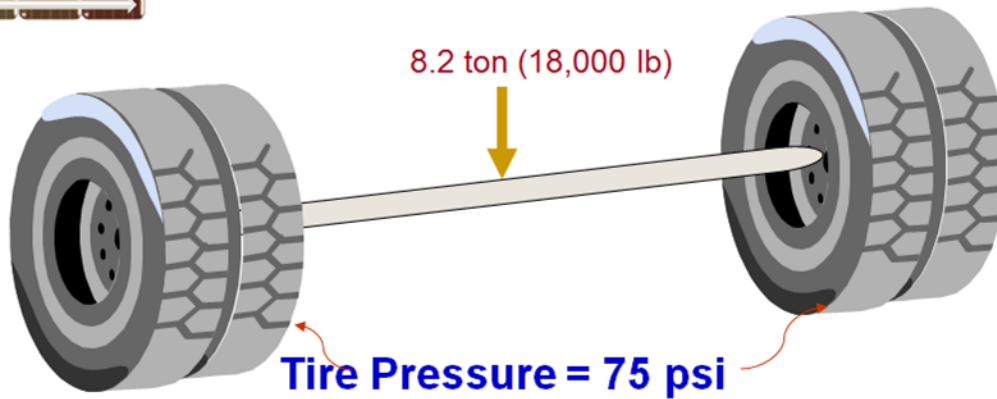
Sieve Size, mm	Sieve Size, in	% Passing
25	1	100.0
19	$\frac{3}{4}$	93
12.5	$\frac{1}{2}$	86
9.5	$\frac{3}{8}$	75
4.75	No 4	61
2.36	No 8	35
1.18	No 16	20.9
0.6	No 30	14.2
0.3	No 50	7.8
0.15	No 100	4.0
0.075	No 200	3.1

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المحور القياسي Standard Axle ...



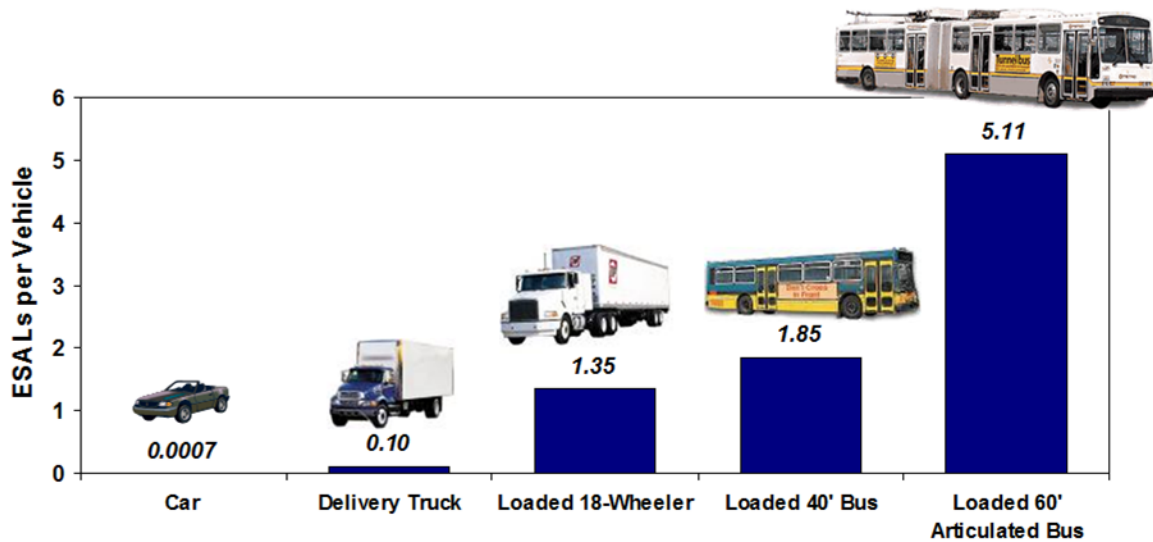
Load Equivalency can be computed from the Generalized fourth power approximation

$$\left(\frac{\text{load}}{8200 \text{ kg}} \right)^4 = \text{relative damage factor}$$

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المحور القياسي المكافئ Equivalent Standard Axle ...



Notice that cars are insignificant and thus usually ignored in pavement design.

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معايير التصميم Design Parameters

**Traffic is the
anticipated project
traffic level in terms of
ESALs expected on the
design lane over a 20-
year period.**

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معايير التصميم Design Parameters

تصنيف المرور الذي أقرته وزارة النقل

MOT has identified the following ESAL classes

<u>Class Designation</u>	<u>ESAL Range</u>	<u>Traffic Description</u>	<u>Typical Applications</u>
VL	Less than 300,000	Very Light	Agricul. roads & local streets
L	300,000 to 3 million	Light	Feeders, collectors
M	3 million to 10 million	Medium	Main Roads, city streets
H	10 million to 30 million	Heavy	Highways & Expressway
VH	More than 30 million	Very Heavy	Heavily trafficked highways

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معايير التصميم Design Parameters

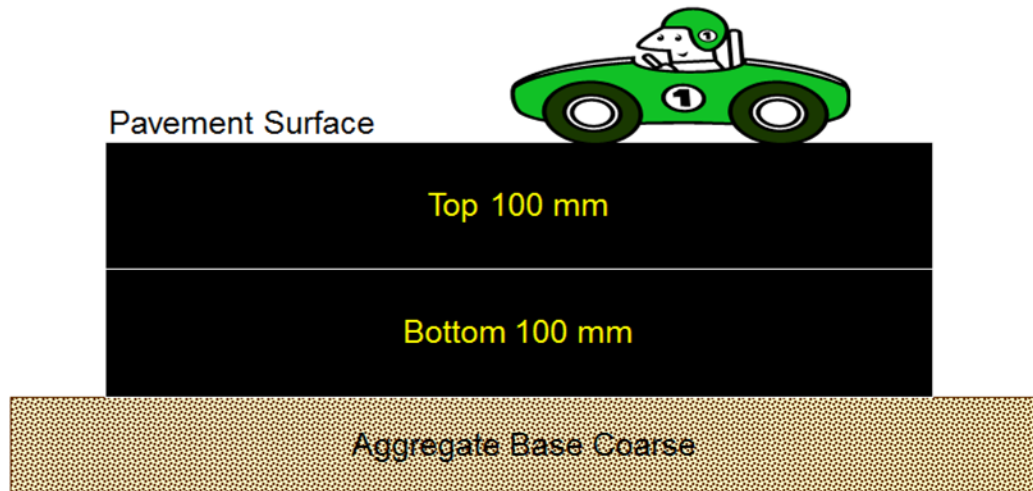
- 1. The geographical location of the project where the Hot Mix Asphalt (**HMA**) will be used.**
- 2. The position of the layer within the pavement**

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ملاحظات وأسئلة Remarks and Questions



قاعدة موقع الطبقات Position Rule



Note: if less than 25% of the layer is within the surface then consider in the bottom.

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ملاحظات وأسئلة Remarks and Questions

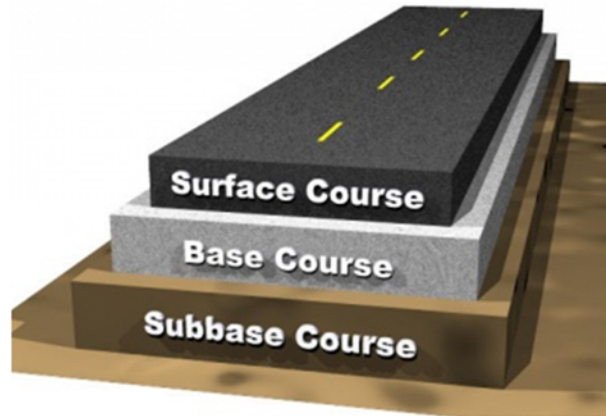


قاعدة موقع الطبقات Position Rule

Example:

Surface Course = 50 mm

Base Course = 80 mm



1. Surface course is 0 mm from the surface, then on the top.
2. % Base Course in the top is $50/80 \times 100 = 62.5 > 25\%$, then on the top.

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ملاحظات وأسئلة Remarks and Questions



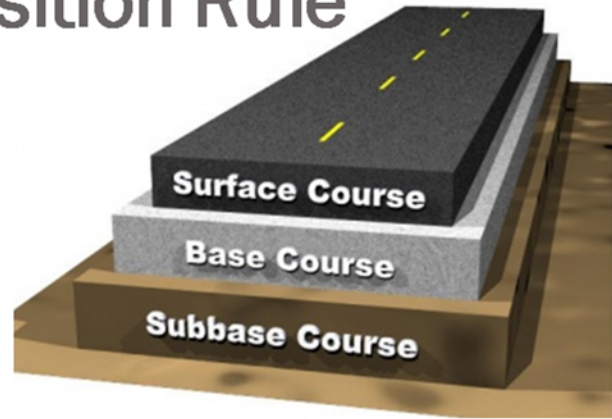
قاعدة موقع الطبقات Position Rule

Example:

B Surface Course = 40 mm

B Binder Course = 50 mm

B Base Course = 80 mm



1. Surface course is 0 mm from the surface, then in the top.
2. Binder course is 40 mm from the surface, then in the top
3. % Base Course in the top is $[(100-(40+50)/80] \times 100 = [10/80] * 100 = 12.5\%$ less than 25%, then in the Bottom.

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ملاحظات وأسئلة Remarks and Questions

متطلبات الخلطة Mixture Requirements



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ملاحظات وأسئلة Remarks and Questions



1. مستويات الدك في المختبر
1. Superpave Gyratory
Compactive Effort (SGCE)

ESAL Class (million)	SGCE		
	عدد الدورات الاولية N_{ini}	عدد دورات التصميمية N_{des}	عدد الدورات القصى N_{max}
VL (<0.3)	6	50	75
L (0.3 to <3)	7	75	115
M and H (3 to <30)	8	100	160
VH (≥ 30)	9	125	205

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ملاحظات وأسئلة Remarks and Questions

عدد الدورات Gyration Numbers

- **عدد الدورات الأولية:** هو مستوى الدك في المختبر المستخدم لقياس قابلية الخلطة الاسفلتية الساخنة للدك اثناء التنفيذ ، حيث ان الخلطات ذات القابلية السريعة للدك (أي تصبح نسبة الفراغات عند هذا المستوى قليلة) يمكن ان تكون خلطات حساسة للتغيرات اثناء التنفيذ وتكون غير ثابتة عندما تتعرض للأحمال المرورية.
- **$N_{initial}$** The number of gyrations used as a measure of mixture compactability during construction. Mixes that compact too quickly (air voids at $N_{initial}$ are too low) may be tender during construction and unstable when subjected to traffic.

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ملاحظات وأسئلة Remarks and Questions

عدد الدورات Gyration Numbers

- **عدد الدورات التصميمية:** هو مستوى الدك في المختبر اللازم لإنتاج عينة تكون لها نفس الكثافة (أي نسبة الدك) المطلوبة للخلطة في الطريق بعد تعرضها للأحمال المرورية المتوقعة (التصميمية) ، ويُحدد السوبربيف نسبة الدك عند هذا المستوى بمقدار 96% أي تكون نسبة الفراغات 4%.
- **N_{design}** This is the design number of gyrations required to produce a sample with the same density (% Compaction) as that expected in the field after the indicated amount of traffic. Superpave requires 96% compaction (i.e. a mix with 4 percent air voids at N_{design} is desired in mix design).

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ملاحظات وأسئلة Remarks and Questions

عدد الدورات Gyration Numbers

- **عدد الدورات القصوى:** هو مستوى الدك في المختبر اللازم لإنتاج عينة ذات كثافة يجب ان لا تتجاوزها كثافة الخلطة في الطريق بعد تعرضها للأحمال المرورية القصوى ، فإذا كانت نسبة الفراغات (أو نسبة الدك) عند هذا المستوى من الدك في المختبر قليلة فمن المتوقع ان تزداد قابلية الخلطة للدك في الطريق مما قد ينتج عنه انخفاض حاد في نسبة الفراغات وظهور التحددات ، وعليه يجب الا تقل نسبة الفراغات عند هذا المستوى عن 2% أي لا تزيد نسبة الدك عن 98%.
- **$N_{maximum}$** The number of gyrations required to produce a laboratory density that should never be exceeded in the field. If the air voids at N_{max} are too low, then the field mixture may compact too much under traffic resulting in excessively low air voids and potential rutting. The air void content at N_{max} should never be below 2 percent air voids.

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ملاحظات وأسئلة Remarks and Questions



$$2) \% G_{mm} = (100 - \text{Air Voids})$$

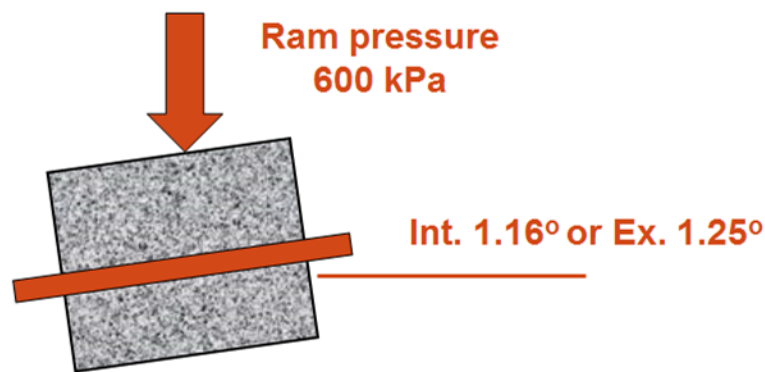
ESAL Class (million)	% G _{mm} @		
	N _{ini}	N _{des}	N _{max}
VL (<0.3)	<u>≤ 91.5</u>	96.0	<u>≤ 98.0</u>
L (0.3 to <3)	<u>≤ 90.5</u>		
M (3 to <10)	<u>≤89.0</u>		
H (10 to <30)			
VH (≥ 30)			

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ملاحظات وأسئلة Remarks and Questions

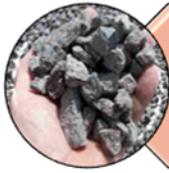
Gyratory Compaction

- ❑ Axial and shearing action ($\text{RPM} = 30 \pm$)
- ❑ 150 mm diameter molds
 - Aggregate size up to 37.5 mm
 - Height measurement during compaction, allows densification during compaction to be evaluated
 - At end of compaction (N_{des}) height must be 115 ± 5 mm



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ملاحظات وأسئلة Remarks and Questions



3) % VMA

NMS, mm	REQUIRED VMA %	
	Min (less reject)	Max (Recommended)
37.5	11.0	13.0
25.0	12.0	14.0
19.0	13.0	15.0
12.5	14.0	16.0
9.50	15.0	17.0
4.75	16.0	18.0

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ملاحظات وأسئلة Remarks and Questions

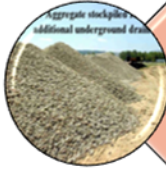


4) % VFA

ESAL Class (million)	VFA %			
	NMS = 19.0 and 12.5 mm	NMS = 9.5 mm	NMS = 25.0 mm	NMS = 37.5 mm
VL (<0.3)	70-80	70-80	67-80	64-80
L (0.3 to <3)	65 – 78		65 – 78	
M (3 to <10)		73 -76		
H (10 to <30)	65 -75		65 -75	
VH (≥ 30)				

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ملاحظات وأسئلة Remarks and Questions



5) DP (Dust to Binder Ratio)

Gradation Type	DP Ratio
Fine, line is above PCS	0.6 – 1.2
Coarse, line is below PCS	0.9 – 1.6

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ملاحظات وأسئلة Remarks and Questions



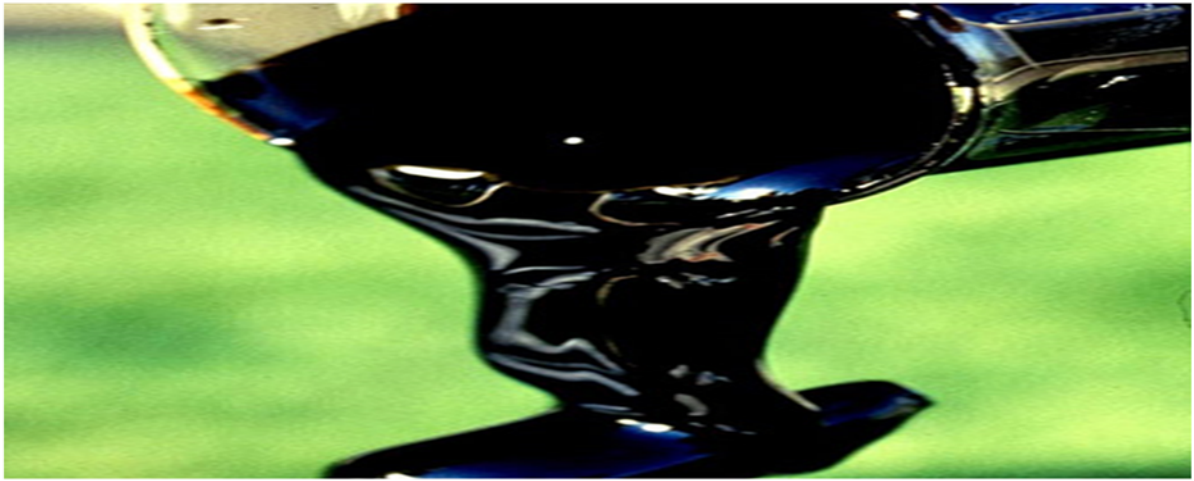
6) Moisture Sensitivity

Property	Requirement
Retained Indirect Tensile Strength	80 % min.

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ملاحظات وأسئلة Remarks and Questions

الخطوة الأولى: اختيار المواد - الرابط
**Step 1.a: Selection of
Materials - Binder**



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ملاحظات وأسئلة Remarks and Questions

Asphalt Binder الرابطة الاسفلتي

الاسفلت هو المكون الاساسي للخرسانة الاسفلتية وهي منسوبة اليه ... يقوم الاسفلت بدور لاصق للحصمة ، مضاد للمياه ، رخيص الثمن. للأغراض الهندسية يلزم اعطاء تعريف دقيق للأسفلت .. لكن ال ASTM-D8 يعرفه بأنه ” مادة لاصقة ذات لون اسود الى بني داكن ، مكونها الاساسي مادة مسحوق الاسفلتين ، يتواجد اما في الطبيعة او يستخرج من تكرير النفط“.

Asphalt is a principal constituents of HMA. Asphalt functions as an inexpensive , waterproof, thermoplastic, viscoelastic adhesive. For engineering purposes, the definition needs to be more unequivocal. ASTM D 8 provides the following definitions: A dark brown to black cementitious material in which the predominating constituents are bitumen, which occur in nature or are obtained in petroleum processing.

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ملاحظات وأسئلة Remarks and Questions

اختيار صنف الأداء للرباط الاسفلتي Asphalt Binder Grade Selection

- Generally one needs to:
 1. Determine project weather data for 30 years in the past.
 2. Select reliability
 3. Determine design temperatures
 4. Drive the performance grade
- In the Kingdom:
 1. Selection of Asphalt Binder Grade is Based on the Kingdom Temperature Zoning Map.
 2. Verify asphalt PG (grade bumping)
 3. Determine temperature-viscosity relationship

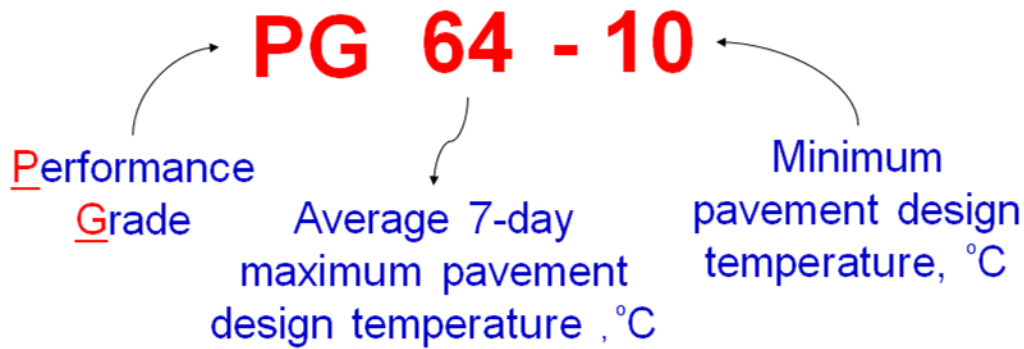
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ملاحظات وأسئلة Remarks and Questions

مواصفات الآشتو

M320 Binder Specification

The grading system is based on Climate .. Example



Note: Property is constant but temperature varies

ملاحظات وأسئلة Remarks and Questions

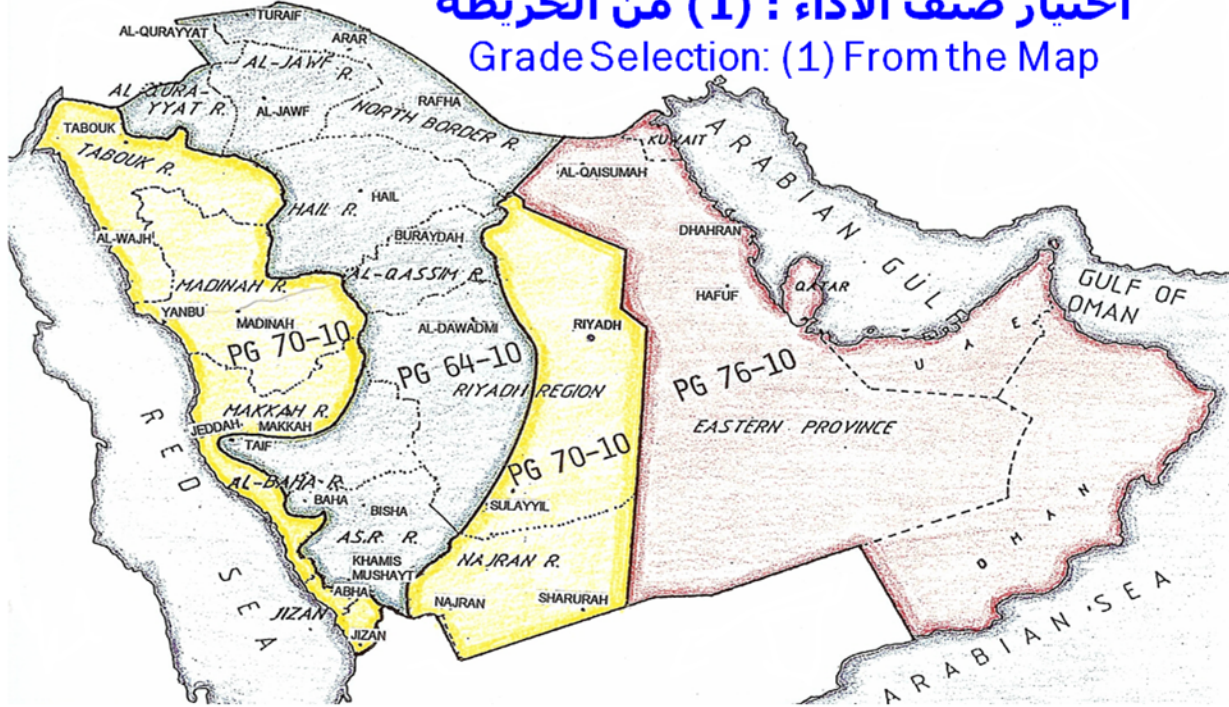
Asphalt Binder . . . Basics

- Performance based binder specifications
 - ❖ AASHTO M320 (*Standard Specifications for Performance—Graded Asphalt Binder*)
 - ❖ For details see Asphalt Institute SP-1
 - ❖ Intended for Modified and unmodified asphalt
- Example PG 64-22
- Every Grade differs by 6 degrees

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ملاحظات وأسئلة Remarks and Questions

اختيار صنف الأداء : (1) من الخريطة Grade Selection: (1) From the Map



Selection of Asphalt Binder Grade is Based on the Kingdom Temperature Zoning Map.

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ملاحظات وأسئلة Remarks and Questions

اختيار صنف الأداء: (2) من الجدول Grade Selection: (2) Bumping

Grade Bumping for speed and loading of traffic; Increase the selected PG based on the map by the grade equivalents as shown below:

الجدول رقم (٦): تعديل صنف الإسفلت بناءً على سرعة و حجم المرور

السرعة Speed	الممرور Traffic Class Designation (or ESAL, million)				
	VL(<0.3)	L(0.3to3)	M(3to<10)	H(10to<30)	VH(>30)
متوقف (متوسط السرعة أقل من ٢٠ كم/س) Standing (average speed < 20 km/h)	يقترح رفع الصنف مرتبة واحدة	2	2	2	2
بطيء (متوسط السرعة بين ٢٠ إلى ٧٠ كم/س) Slow (average speed 20 to 70 km/h)	X	1	1	1	1
سريع (متوسط السرعة أعلى من ٧٠ كم/س) Standard (average speed > 70 km/h)	X	X	X	يقترح رفع الصنف مرتبة واحدة	1

ملاحظات: (١) ارفع الحد الأعلى لصنف الإسفلت الذي تم تحديده من الخارطة مرتبة واحدة (٦ درجات مئوية) دون تعديل للحد الأدنى.
(٢) من النواحي العملية فإنه يجب تلافى التوصية بصنف إسفلتي أعلى من ٨٢ ؛ إلا أنه في حال ضرورة رفع الصنف لموقع ما بناءً على سرعة و حجم المرور أعلى من ٨٢ فإنه يقترح الإبقاء على الصنف ٨٢ و رفع حجم المرور مرتبة واحدة لتلبية متطلبات التصميم (أي من مرتبة ١٠-٣٠ مليون إلى مرتبة أكثر من ٣٠ مليون مثلاً)

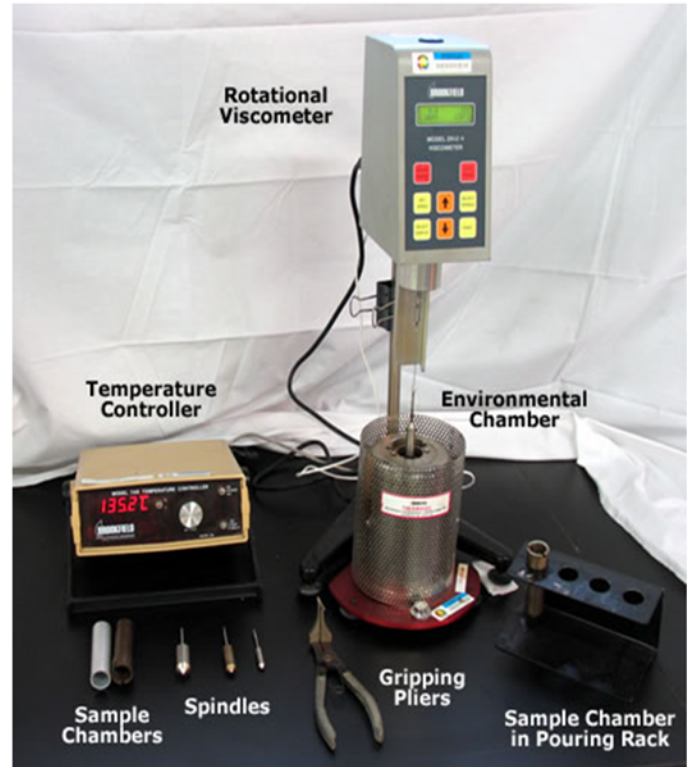
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ملاحظات وأسئلة Remarks and Questions

Asphalt Binder ... Mixing & Compaction

Determine laboratory mixing & compaction temperatures using Rotational Viscometer ASTM D 4402 and AASHTO T 316.

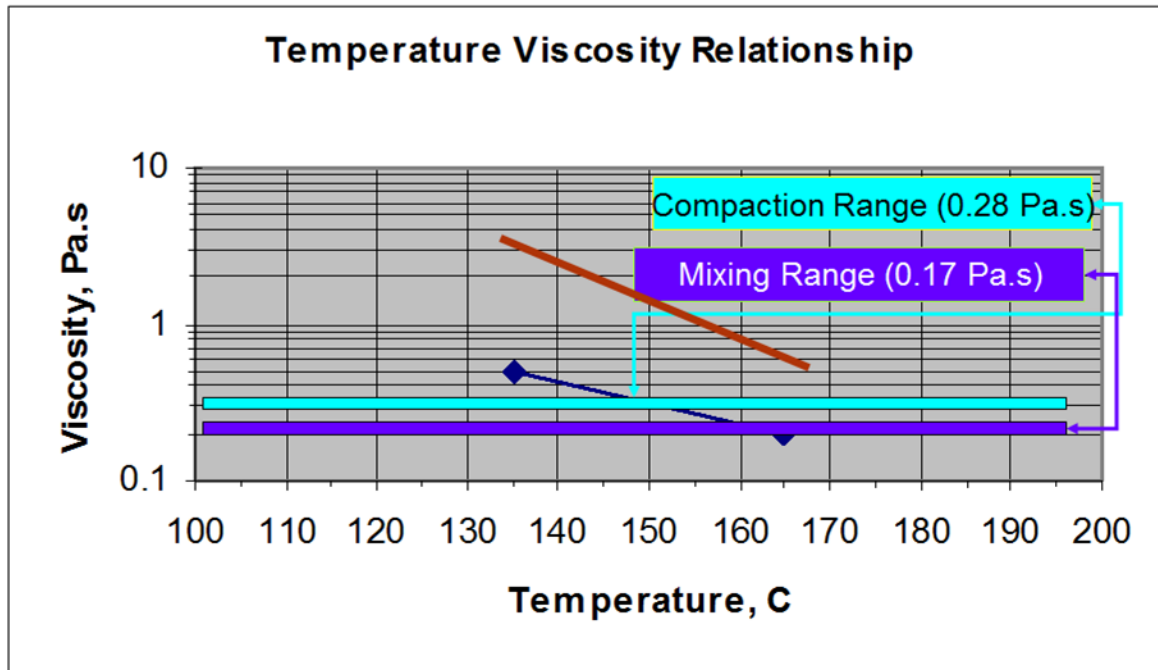
- Mixing Temp @ 0.17 Pa.s ($\pm$)
- Compaction Temp @ 0.28 Pa.s ($\pm$)



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ملاحظات وأسئلة Remarks and Questions

Asphalt Binder Mixing & Compaction Temp.



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ملاحظات وأسئلة Remarks and Questions

متطلبات السوبريف للحصمة

Superpave Aggregate Requirements

- Consensus Requirements خصائص الإجماع:
 - Gradation
 - Coarse agg. Angularity, (CAA) AASHTO T 335
 - Fine agg. Angularity, (FAA) AASHTO T304
 - Flat and elongated particles (F&E) ASTM D4791
 - Clay content, (SE) AASHTO T176
- Source Requirements خصائص المصدر:
 - Toughness AASHTO T96
 - Soundness AASHTO T104
 - Clay lumps & friable particles AASHTO T112

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ملاحظات وأسئلة Remarks and Questions

Superpave Aggregate Requirements
الجدول رقم (٧): متطلبات السوبربيف لخصائص الإجماع للحصمة

المرور					عمق الطبقة من	الخاصية
Traffic Class Designation (or ESAL, million)					السطح، ملم Layer Depth, mm	Property
VH(>30)	H(10to<30)	M (3 to<10)	L (0.3 to 3)	VL (< 0.3)		
100/100	95/90	85/80	75/-	55/-	≤ 100 mm	زاوية الحصمة الخشنة CAA, % min.
100/100	80/75	60/-	50/-	-/-	> 100 mm	
45	45	45	40	-	≤ 100 mm	زاوية الحصمة الناعمة FAA, % min.
45	40	40	40	-	> 100 mm	
50	45	45	40	40	المكافئ الرملي SE, % min	
10	10	10	10	-	الحبيبات المستطيلة F&E, % max	
١. تمثل القيم المبينة للخاصية الزاوية للحصمة الخشنة (CAA) نسبة الكسر من/ص حيث من وجه واحد مكسور و من وجهين أو أكثر.						

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ملاحظات وأسئلة Remarks and Questions

التدرج Aggregate Gradation

- هو نسبة التوزيع الوزني للمقاسات المختلفة للحبيبات في العينة بالنسبة الى وزنها الكلي.
- يتم تحديد التدرج من خلال التحليل المنخلي للعينة.

- It is the relative distribution of the weight of different sizes to the total weight of the sample.
- It is determined by sieve analysis of the sample.

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ملاحظات وأسئلة Remarks and Questions

انواع التدرجات

Dense graded: التدرج الكثيف

- Refers to a gradation that is near the FHWA's 0.45 power curve for maximum density.

Gap graded: التدرج الناقص

Refers to a gradation that contains only a small percentage of aggregate particles in the mid-size range. The curve is flat in the mid-size range. HMA gap graded mixes can be prone to segregation during placement.

Open graded: التدرج المفتوح

Refers to a gradation that contains only a small percentage of aggregate particles in the small range. This results in more air voids because there are not enough small particles to fill in the voids between the larger particles. The curve is near vertical in the mid-size range, and flat and near-zero in the small-size range.

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ملاحظات وأسئلة Remarks and Questions

انواع التدرجات

- التدرج المنتظم: Uniformly graded:

A gradation that contains most of the particles in a very narrow size range. In essence, all the particles are the same size. The curve is steep and only occupies the narrow size range specified.

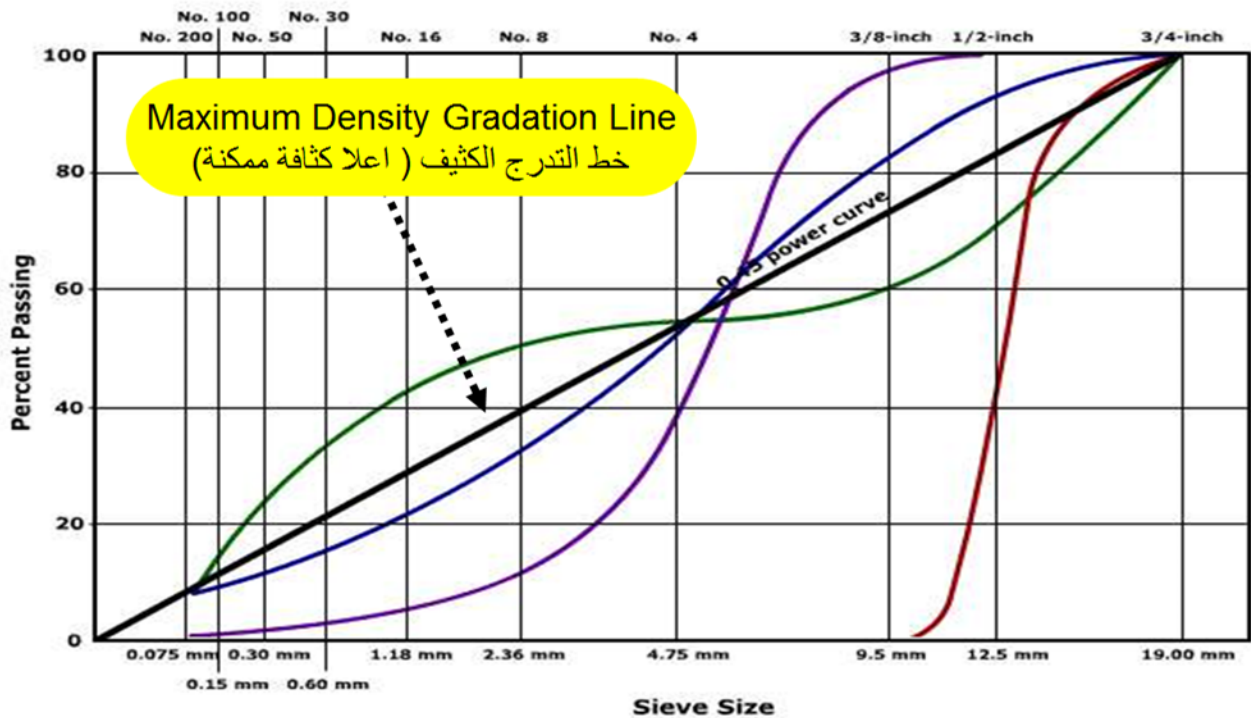
- التدرج الناعم: Fine gradation:

A gradation that, when plotted on the 0.45 power gradation graph, falls mostly above the 0.45 power maximum density line.

- التدرج الخشن: Coarse gradation:

A gradation that, when plotted on the 0.45 power gradation graph, falls mostly below the 0.45 power maximum density line.

ملاحظات وأسئلة Remarks and Questions



Dense Gradation

Uniform Gradation

Open Gradation

Gap Gradation

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ملاحظات وأسئلة Remarks and Questions

فكرة تدرج الحصى Aggregate Gradation Concept

The best gradation is one that produces the maximum density, why:

1. provides particle arrangement where smaller particles are packed between the larger particles.
2. reduces void space between particles.
3. creates more particle-to-particle contact and increase HMA stability and reduce water infiltration.

Therefore, although it may not be the "best" aggregate gradation, a maximum density gradation does provide a common reference. A widely used equation to describe a maximum density gradation was developed by Fuller and Thompson in 1907. Their basic equation is:

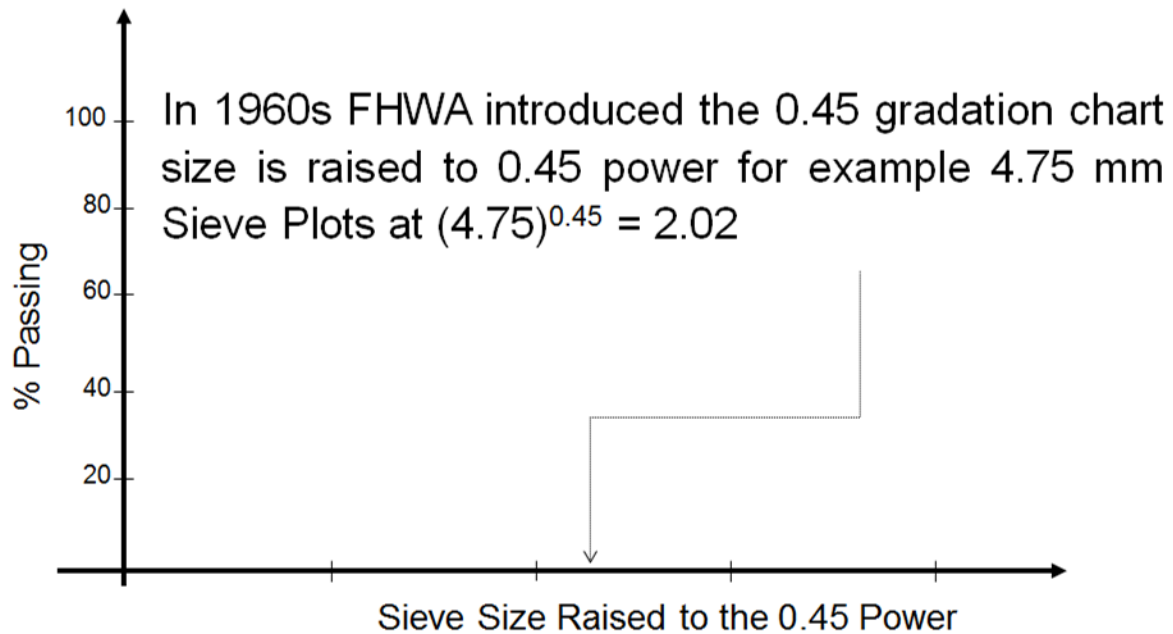
$$P = \left(\frac{d}{D} \right)^n$$

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ملاحظات وأسئلة Remarks and Questions

فكرة تدرج الحصمة

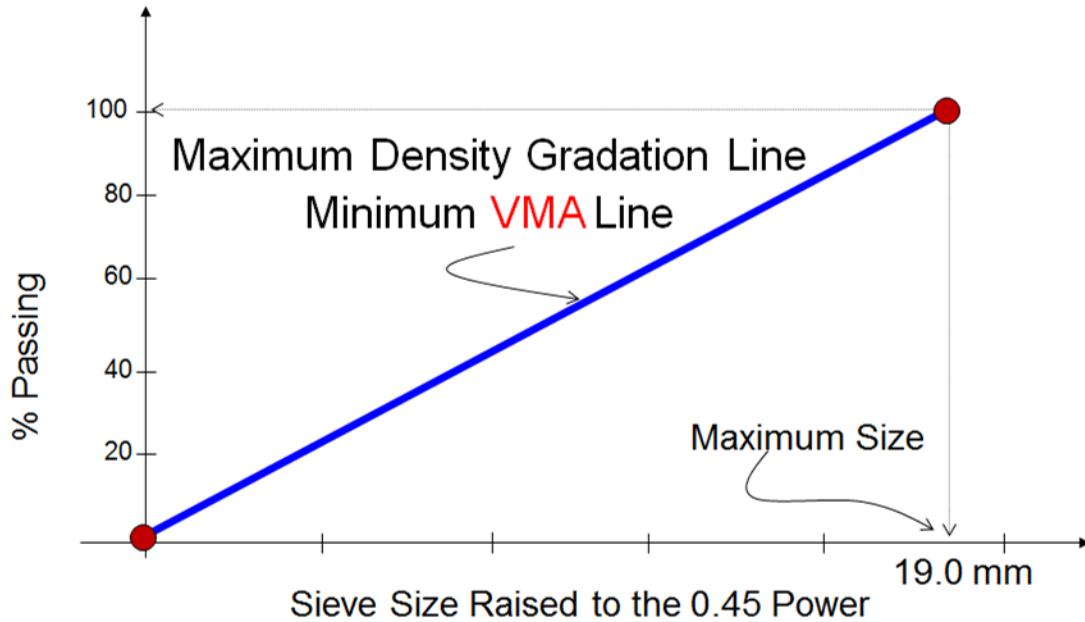
Aggregate Gradation Concept



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ملاحظات وأسئلة Remarks and Questions

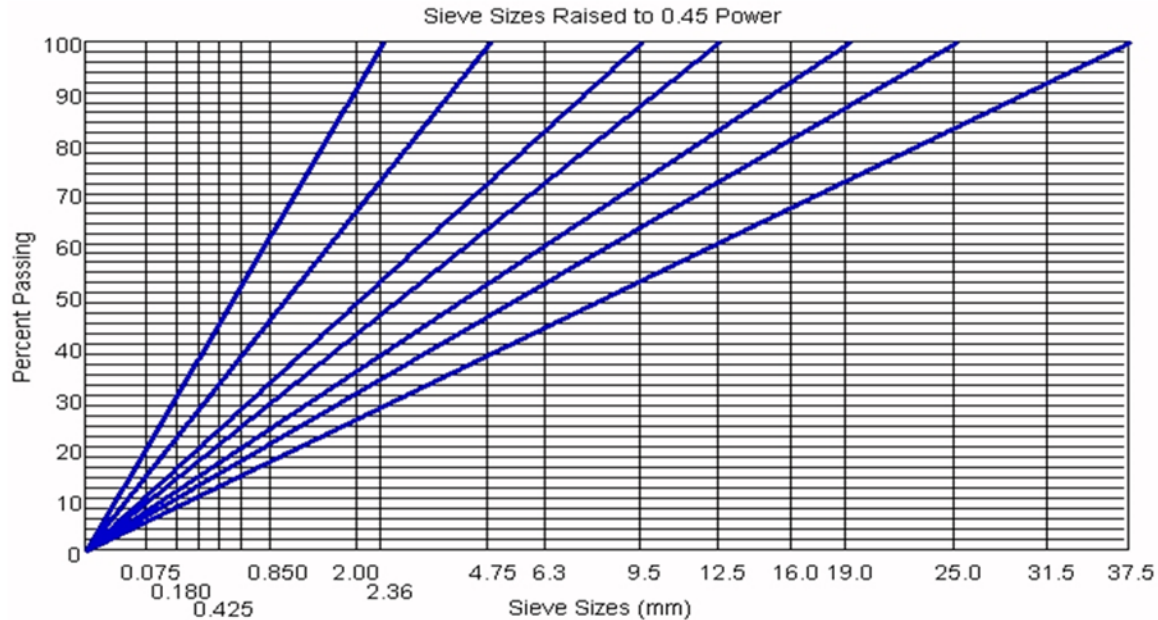
فكرة تدرج الحصى Aggregate Gradation Concept



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ملاحظات وأسئلة Remarks and Questions

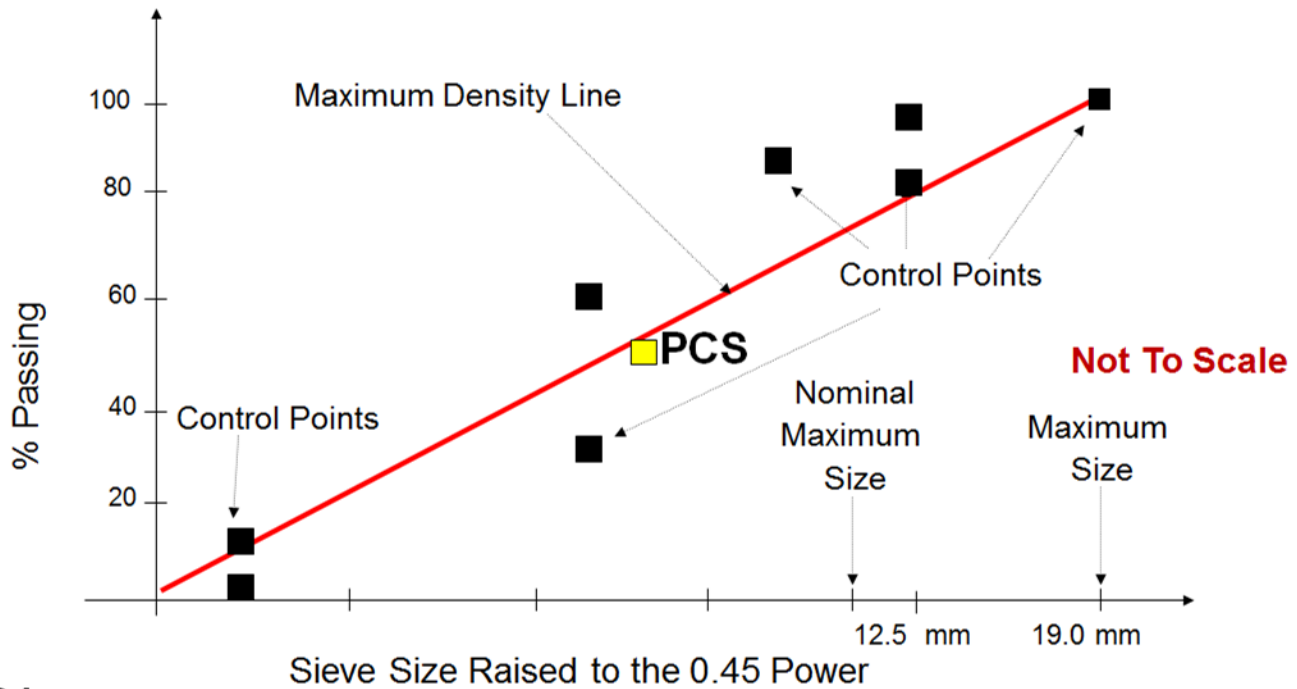
فكرة تدرج الحصى Aggregate Gradation Concept



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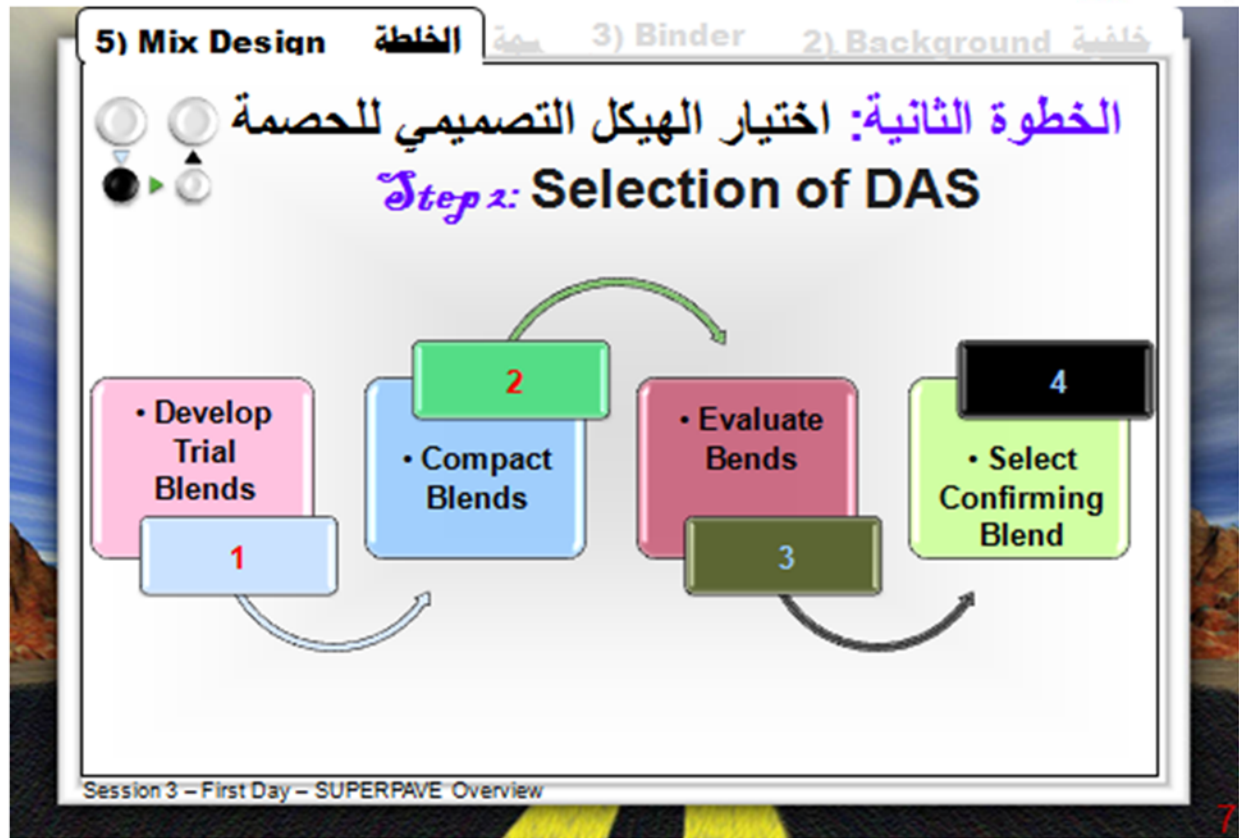
ملاحظات وأسئلة Remarks and Questions

متطلبات السوبربيف للتدرج Superpave Gradation Requirements



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ملاحظات وأسئلة Remarks and Questions



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ملاحظات وأسئلة Remarks and Questions

تحديد الخلطات التجريبية

A) Establish Trial Blends

1. Establish trial blends based on:
 - Minimum of three blends are selected.
 - Based on gradations of samples from hot bins.
 - Vary blending percentages to meet Superpave Criteria
 - Criteria of the design NMS
2. Compute combined aggregate properties
 - Estimate mathematically the combined aggregate properties based on the blending percentages and the individual aggregate properties.
 - For the selected blend verify the combined properties by testing.

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ملاحظات وأسئلة Remarks and Questions

خط و دك الخلطات التجريبية

B) Mix and Compact trial blends

1. **Select % Trial Asphalt Binder (P_{bi}) using one of the following methods:**

- ❖ By computation as outlined in AASHTO R-35, or
- ❖ By experience from previous Superpave designs in the same aggregate sources

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ملاحظات وأسئلة Remarks and Questions

دك الخلطات التجريبية

B) Compact trial blends

a). Estimate effective specific gravity of each blend (G_{se}) using:

$$G_{se} = G_{sb} + C \times (G_{sa} - G_{sb})$$

G_{sb} = Aggregate bulk specific gravity

C = Aggregate absorption factor is assumed 0.8 but for absorptive aggregate use 0.6 or 0.5

G_{sa} = Aggregate apparent specific gravity

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ملاحظات وأسئلة Remarks and Questions

دك الخلطات التجريبية

B) Compact trial blends

b). Estimate the volume of asphalt binder (V_{ba}) absorbed into the aggregate for each blend:

$$V_{ba} = \frac{P_s \times (1 - V_a)}{(P_b)/G_b - (P_s)/G_{se}} \times (1/G_{sb} - 1/G_{se})$$

V_{ba} = volume of absorbed binder

V_a = volume of air voids (assumed 0.04)

P_b = percent of binder (assumed 0.05)

P_s = percent of aggregate (assumed 0.95)

G_b = Sp. Gr. Of binder (assumed 1.02)

ملاحظات وأسئلة Remarks and Questions

دك الخلطات التجريبية B) Compact trial blends

- c). Estimate volume of the effective binder (V_{be}) of the trial blends using:

$$V_{be} = 0.081 - 0.02931 \times \ln (S_n)$$

S_n = the NMS in inches

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ملاحظات وأسئلة Remarks and Questions

دك الخلطات التجريبية

B) Compact trial blends

- d). Finally estimate the initial AB% (P_{bi}) for each trial blend using:

$$P_{bi} = \frac{G_b \times (V_{be} + V_{ba})}{G_b \times (V_{be} + V_{ba}) + W_s}$$

$$W_s = \frac{P_s \times (1 - V_a)}{(P_b / G_b + P_s / G_{se})}$$

W_s = weight of aggregate

P_{bi} = percent binder by weight of mix

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ملاحظات وأسئلة Remarks and Questions

دك الخلطات التجريبية B) Compact trial blends

2. Prepare Hot Mix Asphalt Using:

- The trial blends Design Aggregate Structure
- The estimated initial trial asphalt binder (P_{bi})
- The mixing and compaction temp. determined from the temperature-viscosity relationship.
- Apply the STOA (AASHTO PP2).

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ملاحظات وأسئلة Remarks and Questions

دك الخلطات التجريبية

B) Compact trial blends

3. Compact 2 specimens for each blend to N_{des} ; then for each compacted specimen:

- Measure G_{mb} AASHTO T166.
- Get the specimen height at N_{ini} & N_{des} in mm from the gyratory compactor data.

4. For each blend measure G_{mm} in replicates AASHTO T209.

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ملاحظات وأسئلة Remarks and Questions

تقييم الخلطات التجريبية

C) Evaluate Trial Blends

1. Determine

- $\%G_{mm} @ N_{des}$ by dividing the G_{mb} by $G_{mm} \times 100$
- $\%G_{mm} @ \text{any } N_x$ by multiplying $\%G_{mm} @ N_{des}$ by the ratio of the height at N_{des} to the height at N_x from the gyratory compaction data.
- Air voids & VMA using:

$$\% \text{ Air voids} = 100 - \% G_{mm} @ N_{des}$$

$$\% \text{ VMA} = 100 - (\% G_{mm} @ N_{des} \times G_{mm} \times P_s) / G_{sb}$$

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ملاحظات وأسئلة Remarks and Questions

تقييم الخلطات التجريبية C) Evaluate Trial Blends

$$\%G_{mm} @ N_{ini} = \frac{\%G_{mm} @ N_{des} \times H_{N_{des}}}{H_{N_{ini}}}$$

Where:

$H_{N_{des}}$ = Height of specimen at N_{des}

$H_{N_{ini}}$ = Height of specimen at any N_{ini}

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ملاحظات وأسئلة Remarks and Questions

تقييم الخلطات التجريبية C) Evaluate Trial Blends

2. Recalculate @ 4% air voids (96% G_{mm} @ N_{des}):

- Asphalt content % using:

$$P_{b,estimated} = P_{bi} - (0.4(4 - V_a))$$

- VMA using:

$$\%VMA_{estimated} = \%VMA_{initial} + C(4 - V_a)$$

VFA using:

$$\%VFA_{estimated} = 100 \times (\%VMA_{estimated} - 4.0) / \%$$

$VMA_{estimated}$

- $\% G_{mm}$ @ N_{ini} using:

$$\% G_{mm\ estimated} @ N_{ini} = \% G_{mm} @ N_{ini} - (4.0 - V_a)$$

Note:

C = 0.1 if $V_a < 4.0$

C = 0.2 if $V_a > 4.0$

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ملاحظات وأسئلة Remarks and Questions

تقييم الخلطات التجريبية

C) Evaluate Trial Blends

3. Calculate DP ratio

- Compute P_{be} using:

$$P_{be} = - (P_s \times G_b) \times (G_{se} - G_{sb}) / G_{se} \times G_{sb} + P_{b,estimated}$$

- DP using:

$$DP = P_{0.075} / P_{be}$$

D) Summarize results: Comparing with Superpave criteria and selecting the confirming blend to be used in step 3.

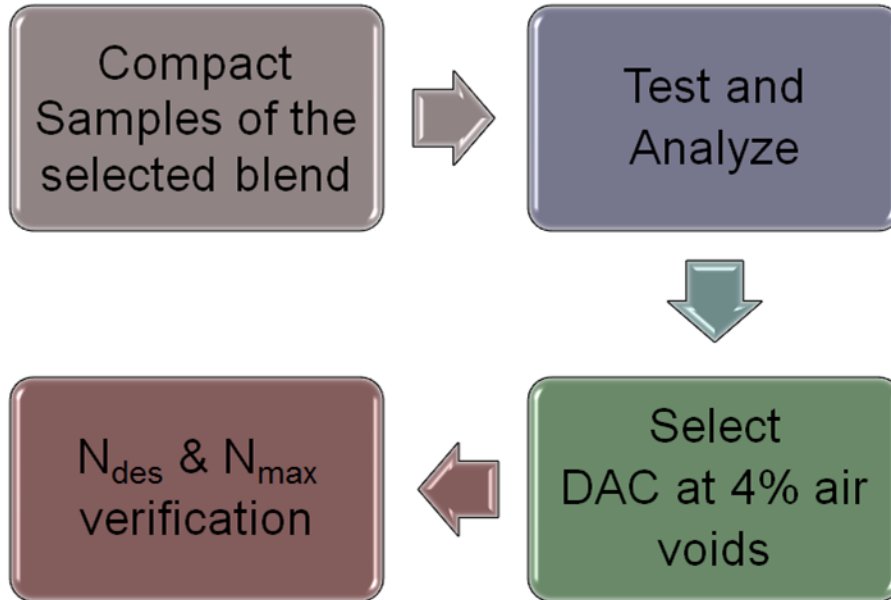
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ملاحظات وأسئلة Remarks and Questions



الخطوة الثالثة: اختيار محتوى الرابط التصميمي

Step 3: Selection of DAC



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ملاحظات وأسئلة Remarks and Questions

تحضير الخلطة ودك العينات

A) Compact Samples

- Prepare HAM using four Asphalt Binder %s:
 - X
 - X - 0.5
 - X + 0.5
 - X + 1.0%

Where: X = Estimated binder content from step 2
at 4.0 air voids for the selected blend

- Compact 2 specimens @ each AB% to N_{des}
- Measure specimen height and G_{mb} @ N_{des}
- Measure two G_{mm} for each mix.

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ملاحظات وأسئلة Remarks and Questions

تحليل النتائج

B) Analyze the results

Use the same formulas in the selection of DAS to compute:

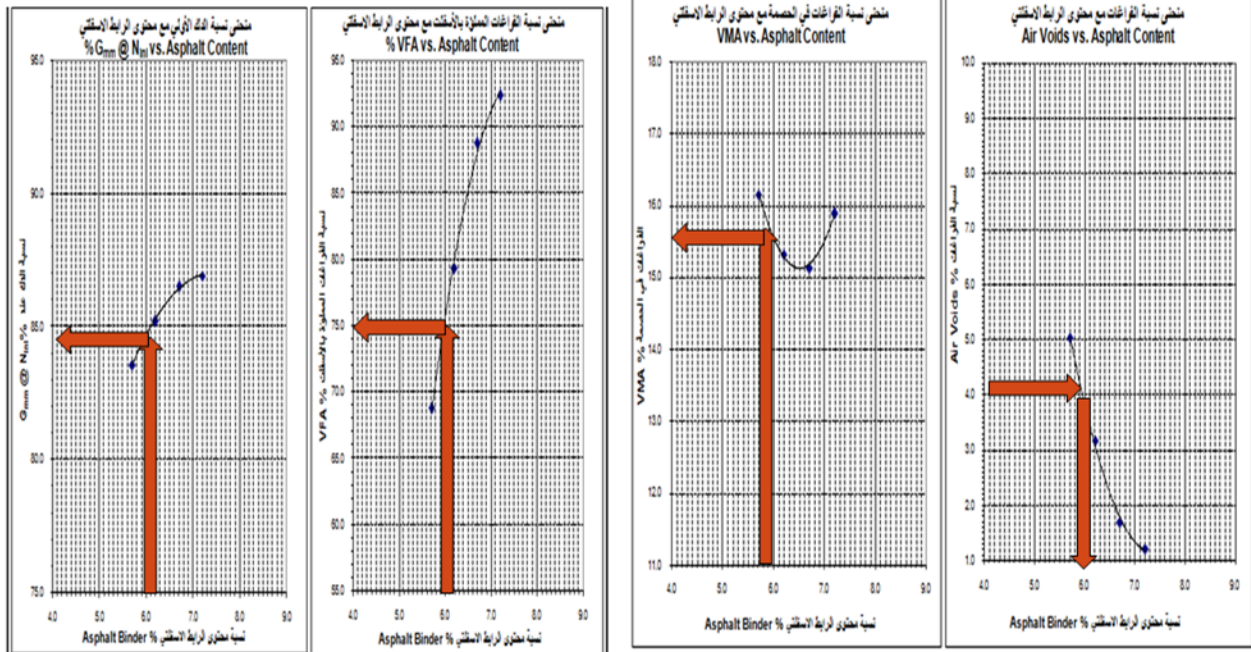
- % G_{mm} @ N_{ini} and N_{des}
- Volumetric properties (Air voids, VMA, VFA)
- DP ratio
- Generate graphs for each property vs. AB%

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ملاحظات وأسئلة Remarks and Questions

تحليل النتائج

B) Analyze the results



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ملاحظات وأسئلة Remarks and Questions

اختيار محتوى الرابط التصميمي

C) Select DAC

- From the graphs @ 4.0 % air voids determine DAC and check:
 - ❖ VMA and VFA and % G_{mm} @ N_{ini}
 - ❖ Compute DP at the effective DAC
- Compare with Superpave criteria and adjust your design as needed.

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ملاحظات وأسئلة Remarks and Questions

التحقق من خصائص الخلطة عند الدك التصميمي والأعلى

D) N_{des} and N_{max} Verification

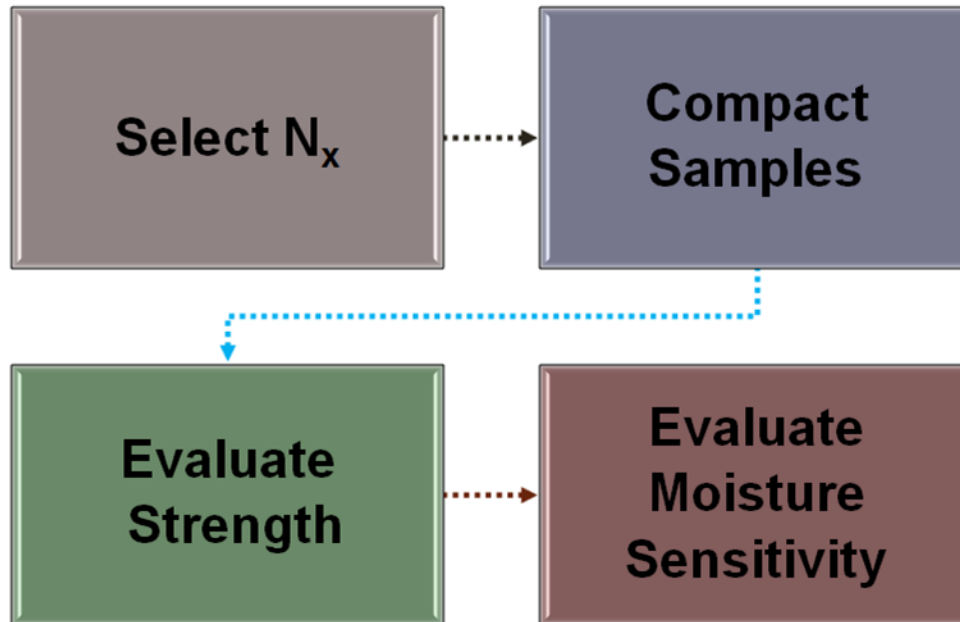
- Prepare hot mix at selected DAC and DAS
- Gyratory compact 2 specimens to N_{des} and another 2 specimens to N_{max}
- Compute all mixture properties @ N_{des} and % G_{mm} @ N_{max}
- Compare the results with Superpave criteria and adjust your design as needed.

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ملاحظات وأسئلة Remarks and Questions



الخطوة الرابعة: التحقق من مقاومة المياه Step 4: Moisture Sensitivity



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ملاحظات وأسئلة Remarks and Questions

الخطوة الرابعة: التحقق من مقاومة المياه

Step 4: Moisture Sensitivity

- Select N_x
 - ❖ 7 % air voids
- Compact specimens
 - ❖ 6 specimens
 - ❖ Compact to N_x
- Evaluate
 - ❖ Follow AASHTO T283 with MOT modification.
 - ❖ The retained ITS must be 80% minimum.
 - ❖ Compare with the criteria and adjust your design as needed.

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ملاحظات وأسئلة Remarks and Questions

A) Select N_x أختيار مستوى الدك

- Trial and error
- Use the densification data of the N_{max} verification step to determine the number of gyrations to achieve 7% air voids i.e. **% G_{mm} of 93.0**

$$\%G_{mm} @ N_x = \frac{\%G_{mm} @ N \quad H_N}{H_{N_x}}$$

Where:

H_N = Height of specimen at N

H_{N_x} = Height of specimen at any N_x

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ملاحظات وأسئلة Remarks and Questions

مثال Example

Determination of N_x to Achieve 7% voids

N	H, mm	% G _{mm}
5	129.0	85.1
$N_{ini} = 8$	127.0	86.5
10	125.7	87.7
30	120.1	91.5
40	119.0	92.4
50	118.0	93.1
60	117.2	93.8
100	116.0	94.7
160	115.2	95.4
G_{mb}	2.445	
G_{mm}	2.563	

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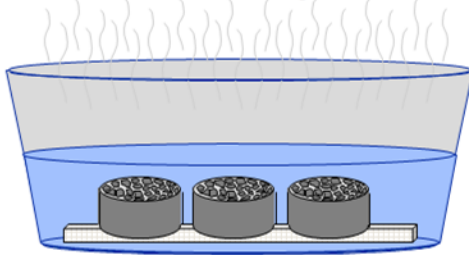
ملاحظات وأسئلة Remarks and Questions

تحضير الخلطة ودك العينات

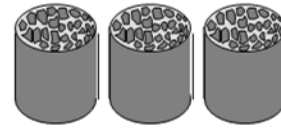
B) Compact Samples

- Prepare HAM using DAS and DAC
- Gyrotory compact 6 specimens to N_x
- Three specimens are control (no conditioning).
- The other three is conditioned for 24 h at 60 °C
- Test all specimens to determine maximum indirect tensile load at failure.

3 Conditioned Specimens



3 Dry Specimens

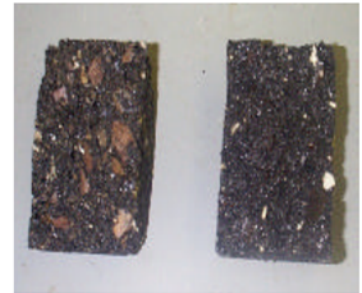
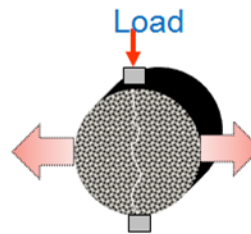
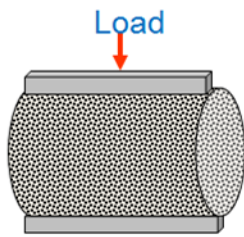


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ملاحظات وأسئلة Remarks and Questions

C) Evaluate التقييم

- Compute ITS (Indirect Tensile Strength)
- Maximum allowable ITS loss is 20%
- Compare with Superpave criteria and adjust your design as needed.
- In case ITS is failing use cement dust, lime, Portland cement or anti-stripping agents as per MOT Specs.



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ملاحظات وأسئلة Remarks and Questions



ملاحظات وأسئلة Remarks and Questions

Good pavement

- **Acceptable performance for 20 years:**

- ☐ No fatigue cracking
- ☐ No rutting
- ☐ No low (thermal) temperature cracking

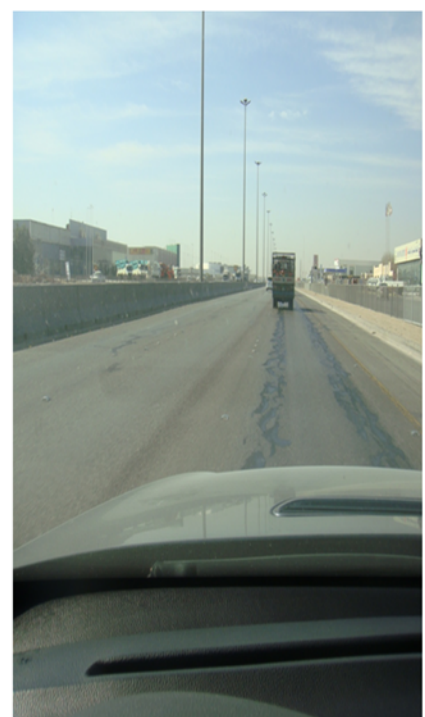
- **No major maintenance:**

- ☐ Minimize LCC
- ☐ Minimize Traffic interruption

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Remarks and Questions ملاحظات وأسئلة

Fatigue Cracking



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ملاحظات وأسئلة Remarks and Questions

Temperature Cracking



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ملاحظات وأسئلة Remarks and Questions

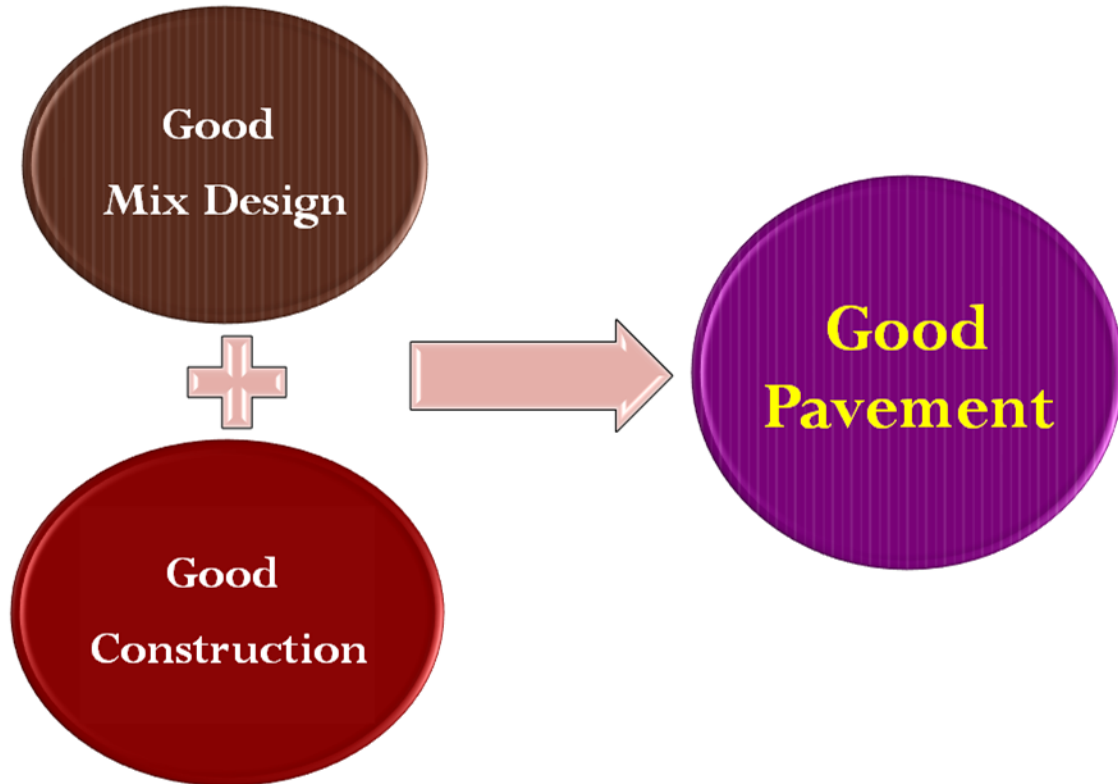
Rutting



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ملاحظات وأسئلة Remarks and Questions

How can we avoid this??



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ملاحظات وأسئلة Remarks and Questions

إذاً .. الرصفيات الناجحة الجيدة لا تحدث بمحض
الصدفة ولكنها نتيجة للتخطيط والتصميم
والتنفيذ الصحيح.

**Successful good pavements do
not happen by accident; They
are the result of careful
planning, design and
implementation**

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ملاحظات وأسئلة Remarks and Questions



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ملاحظات وأسئلة Remarks and Questions



Jeddah-Alleath
2006/03/01

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ملاحظات وأسئلة Remarks and Questions



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ملاحظات وأسئلة Remarks and Questions

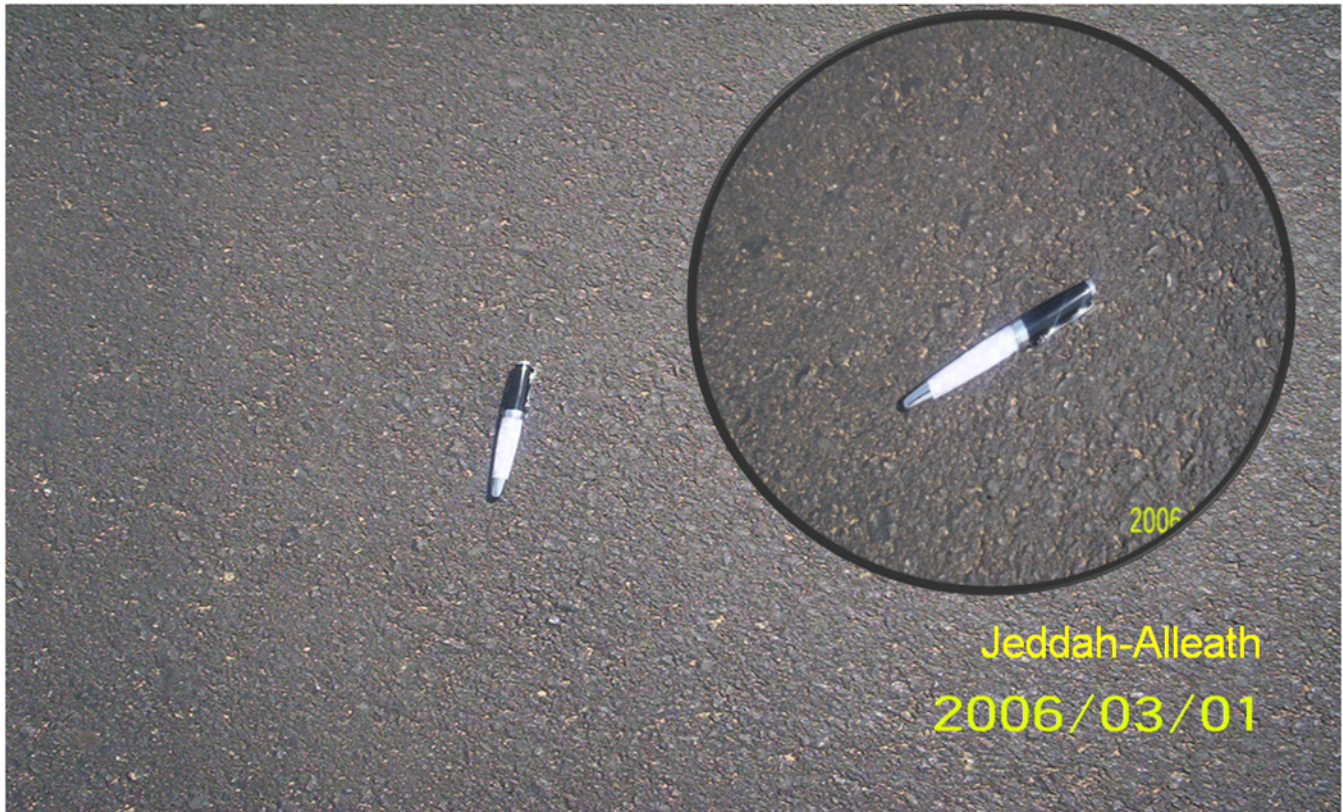


Jeddah-Alleath
2006/03/01

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Dr Ibrahim Aldubabe د. إبراهيم الضبيبي

ملاحظات وأسئلة Remarks and Questions



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Dr Ibrahim Aldubabe د. إبراهيم الضبيبي

ملاحظات وأسئلة Remarks and Questions

How can we get good Mix Design ??

Superpave target is good pavement, so requirements for the design of the mix are:

- ❖ PG matching the project site environment.
- ❖ Project level ESAL for 20 years .. !!
- ❖ Critical Speed on the road !!
- ❖ Pavement thickness design .. !!
- ❖ Volumetric properties (initial, design and max.)

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ملاحظات وأسئلة Remarks and Questions

Is Good Mix Design Enough ?

NO .. WHY?

Analogy ... Doctor and Patient !!

- Doctor
 - Diagnosing
 - Selecting suitable medicine
 - Providing Instructions
- Patient
 - Implementing the treatment plan to produce a health body

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ملاحظات وأسئلة Remarks and Questions

In our Case .. Who is the Doctor and who is the patient?



- Doctor is mix designer.

- Diagnosing → Defining the mix parameters
- Selecting → Selection of materials & %s
- Instructions → JMF, temperatures, % G_{mm} , ...

- Patient is mix construct, objective is to produce and place a mixture meeting the specified design requirements

- Quality
- Volumetric
- Mechanical

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ملاحظات وأسئلة Remarks and Questions

Mix Production .. What is wrong?

- Failure to maintain aggregate quality at the whole course of production.
 - At the beginning everything is ok until the "good" material is all consumed and in the later part of production, "not so good" or even sometime "bad" material is being fed to the production line.
- Hot bin aggregates are randomly checked only for gradation just to meet the JMF requirements.
 - Often, contractors "ignore" the aggregate quality tests (such as fine aggregate angularity), the mentality is that FAA is not being checked in the handing over

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ملاحظات وأسئلة Remarks and Questions

Mix Production .. What is wrong?

- Same mix design although new source of aggregate is being used
 - Although the old aggregate and the new have the same color and texture and comes from the same location, checking all the properties of the new aggregate must be done. Aggregates changes its properties as you go deeper in the quarry site.
- Asphalt binder is "under modified" or less than the PG required
 - homogeneity is questionable due to inadequate agitators (specially crumb rubber modified binder)
 - improper storage which causes unnecessary alteration of asphalt "freshness"
- Less frequency of tests in the daily production of mix
 - Test is done mostly on a one time /batch basis.
 - Neither the contractor (QC) nor consultant (QA) do sufficient checking

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ملاحظات وأسئلة Remarks and Questions

Mix Handling and Placement

- Truck drivers often neglect the importance of covering the asphalt, Exposure of the mix to the atmosphere for long travel / hauling time (even on summer days) effect the mix
 - Loss of temperature
 - lumps of cooled HMA will develop
 - Specified density and smoothness of the finished pavement can only be achieved when the mix temperature is uniform.
- load truck properly
 - Paver pulls up to meet the truck
 - DON'T BUMP THE PAVER!
 - Break the load before opening tailgate
 - Charge the hopper before it's empty

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ملاحظات وأسئلة Remarks and Questions

Temperature

- ❑ Regardless of the type and capacity of the haul vehicles, the delivery of HMA from the plant to the paving project requires consistency and regularity so that the mix being placed is of uniform temperature.
- ❑ Temperature segregation tends to occur in a cyclic manner with each truckload and is the result of:
 - Loss of heat from the sides, top and bottom of the load during transport.
 - Transfer of that cool material to the sides of the paver hopper.
 - Uneven feeding of the cool material from the sides of the hopper, mainly when emptying the hopper after each load.

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ملاحظات وأسئلة Remarks and Questions

Temperature

Use Shuttle Buggy to have a consistent mat temperature, there are three main things the Shuttle Buggy gives us:

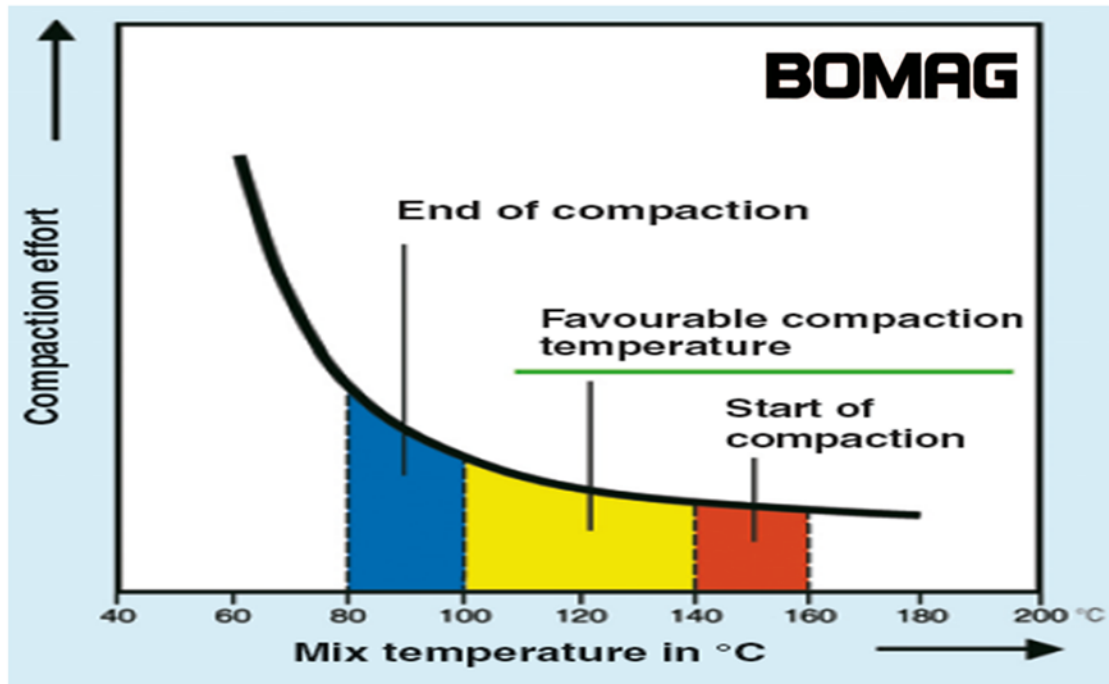
- First, it helps us meet smoothness specifications.
- Second, it cures our segregation problems.
- And third, it gives us good compaction numbers



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Remarks and Questions ملاحظات وأسئلة

Effect of Compaction temperature on compaction effort



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ملاحظات وأسئلة Remarks and Questions

Mix Handling and Placement

- Avoid segregation : Segregation is a lack of homogeneity in the hot mix asphalt constituents of the in-place mat of such a magnitude that there is a reasonable expectation of accelerated pavement distress(es).”
- Sources of Segregation
 - Large size asphalt mixes (coarse)
 - Poor operation, poor storage and truck loading systems (use shuttle buggy)
 - Start and end of truck loads
 - Paver mechanical and operation through uneven flow of material
 - Poor handwork
 - Asphalt binder drain-off in open graded and stone mastic asphalt mixes

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ملاحظات وأسئلة Remarks and Questions

تجنب حدوث الانفصال الحبيبي .. Avoid Segregation

the commonly accepted qualitative definition of aggregate segregation is “the non-uniform distribution of coarse and fine aggregate components within the asphalt mixture.” There are two basic types of aggregate segregation:

- Coarse segregation. Occurs when gradation is shifted to include too much coarse aggregate and not enough fine aggregate. Coarse segregation is characterized by low asphalt content, low density, high air voids, rough surface texture, and accelerated rutting and fatigue failure (Williams et. al., 1996b[5]). Typically, coarse segregation is considered the most prevalent and damaging type of segregation; thus segregation research has typically focused on coarse segregation. The term “segregation” by itself is usually taken to mean “coarse segregation.
- Fine segregation. Occurs when gradation is shifted to include too much fine aggregate and not enough coarse aggregate. High asphalt content, low density, smooth surface texture, accelerated rutting, and better fatigue performance characterize fine segregation (Williams, Duncan and White, 1996[8]).

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ملاحظات وأسئلة Remarks and Questions

تجنب حدوث الانفصال الحبيبي .. Avoid Segregation

A quantitative aggregate segregation definition is less certain. Since coarse segregation is generally accepted as most destructive, a general quantitative definition is a sample ³ 10% coarser than the JMF on the 2.36-mm or the 4.75-mm sieve. AASHTO) and NAPA identified five major segregation sources:

- ☐ **Mix design.** The key mix design parameters in determining segregation susceptibility are gradation and asphalt content (AASHTO, 1997[7]). Specifically, open-graded mixes and low asphalt binder content mixes are particularly prone to segregation.
- ☐ **Stockpiling.** If aggregate is loaded on top of a conical stockpile then larger aggregate sizes are more likely to roll to the outside and bottom.

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ملاحظات وأسئلة Remarks and Questions

تجنب حدوث الانفصال الحبيبي .. Avoid Segregation

- ❑ **Asphalt plants.** Key portions of the plant generally concerned are :
 - ❖ Cold feed bins. Bins may not feed uniformly.
 - ❖ Batch plant hot bins. Dust may collect on the wall and discharge in large concentrated slugs.
 - ❖ Drum mixers. Large particles will generally flow through a drum mixer more quickly than smaller particles.
 - ❖ Surge and storage bins. Situations such as an off-set discharge chute, angled material flow from the discharge chute, and excessively large bin openings can lead to segregation.
- ❑ **Truck loading and unloading.** Loading trucks in one large dump may cause the larger aggregate sizes to roll to the outside and bottom.
- ❑ **The asphalt paver.** Segregation occurs as a result of hopper operation, auger speed, and disruptions in paver movement. The chief detrimental effects of segregation on HMA performance are: reduced fatigue life, rutting, raveling, and moisture damage. These effects can cause a severe reduction in pavement life.

More information on segregation causes and cures can be found in
AdEC web site at www.adeceng.com

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ملاحظات وأسئلة Remarks and Questions

Compaction.. Be careful !!

- Test Strip is often neglected:
 - Establish rolling pattern for compaction Speed and lap pattern for each roller
 - No. of passes for each roller, there is no "counting of number of passes" to reach the desired compaction being done
 - Minimum temperature by which each roller must complete pattern
- Equipment versus the area
 - Adequacy of compaction equipment specially on winter days must be observed.
 - TAC (Time available for compaction) 10 to 20 min.
 - Compaction must end before the temperature goes down below 90°C for NAB and 115 C for PMB or when you see signs or appearance of broken aggregates.

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ملاحظات وأسئلة Remarks and Questions

Compaction.. Be careful !!

- Equipment control
 - operators must know and be trained on how to treat the pavement "nicely".
 - Swerving, over vibration and sudden stops must be avoided
 - Right setting of frequency and amplitude.
 - Equipment condition (efficiency)
 - There is segregation after the paver. The vibration is not enough to deliver the initial compaction
 - Cycle time
 - One of the most neglected method of construction.
 - The supply of mix must be continuous to avoid cold joints
 - Coordinate mixture delivery, paver speed and compaction operations
- IMPORTANT:** Paver speed must not exceed that of the compaction operation!!!

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ملاحظات وأسئلة Remarks and Questions

Compaction.. Be careful !!

- Stability of the underlying structure (aggregate base course)
- Strength of the adhesive material used
 - MC1 and RC2 must be correctly, evenly and properly sprayed
 - Always check its cleanliness and freshness (recommended curing time and expiration)

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ملاحظات وأسئلة Remarks and Questions

Compaction.. Be careful !!

- Weather factor
 - Weather limitations must always be observed.
 - In case of saturated aggregate base course surface, ensure that it is totally dried up and the MC1 must be removed and re-sprayed.
- Construction Joints (side and longitudinal)
 - should be totally watertight to avoid water seepage. Joint treatment by saw-cutting joints after completion before next day's production
 - stagger transverse joints
- Equipment Parking
 - Avoid parking of compaction equipment on the fresh asphalt pavement during delay of supply or while spreading, because it creates "depression" on the area.
 - Overnight parking on the newly finished pavement also must be avoided

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ملاحظات وأسئلة Remarks and Questions

Balance

- It is the key to effective placement of HMA
- Balance between placement & production and between mix delivery & production yield the best results.
- Careful control of the paving speed enables efficient laydown and compaction of the mix at consistent temperatures.
- The best paving projects find balance between each of these elements.

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ملاحظات وأسئلة Remarks and Questions

Concluding Remarks

- Good Superpave mix design needs good input.
- Good mix design is not enough.
- Good construction practice of HMA accounts for a major part in achieving an acceptable pavement performance.
- Successful good pavements do not happen by accident; they are the result of careful planning and implementation.

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ملاحظات وأسئلة Remarks and Questions

تم بحمد الله
مع تمنياتي لكم بالتوفيق والسداد



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ملاحظات وأسئلة Remarks and Questions
