HIGH MODULUS ASPHALT: Introduction and French Experience

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OUTLINE

Introduction

Purpose
- Pavement design
- Base course (EME)
- Wearing course (BBME)

What is a high modulus HMA?
- Formulation
- Specifications

Good practices with high mod. HMA
- Working temperatures
- Field practices (Compaction…)
- Limitations

Examples of performances
- EME with hard pure binder and PMBs
- BBME with hard pure binder and PMBs

Optimization of pavement design with EME

Examples of job sites

PURPOSE

INTRODUCTION

High modulus HMA in France:

- **EME** (**Enrobé à Module Elevé**) since early 1980's

European standard EN 13108-1

- **BBME** (**Béton Bitumineux à Module Elevé**) since early 1990's

European standard EN 13108-1

Developed by:

- French Administration (LCPC)
- Bitumen producers (Total, Elf,…)
- Roads Contractors (Via France…)

PURPOSE OF HIGH MODULUS HMA

Performance:

- **Reduction of pavement thickness**
- **Resistance to rutting** of subbase / base layers (EME)
- Resistance to superficial rutting (BBME)

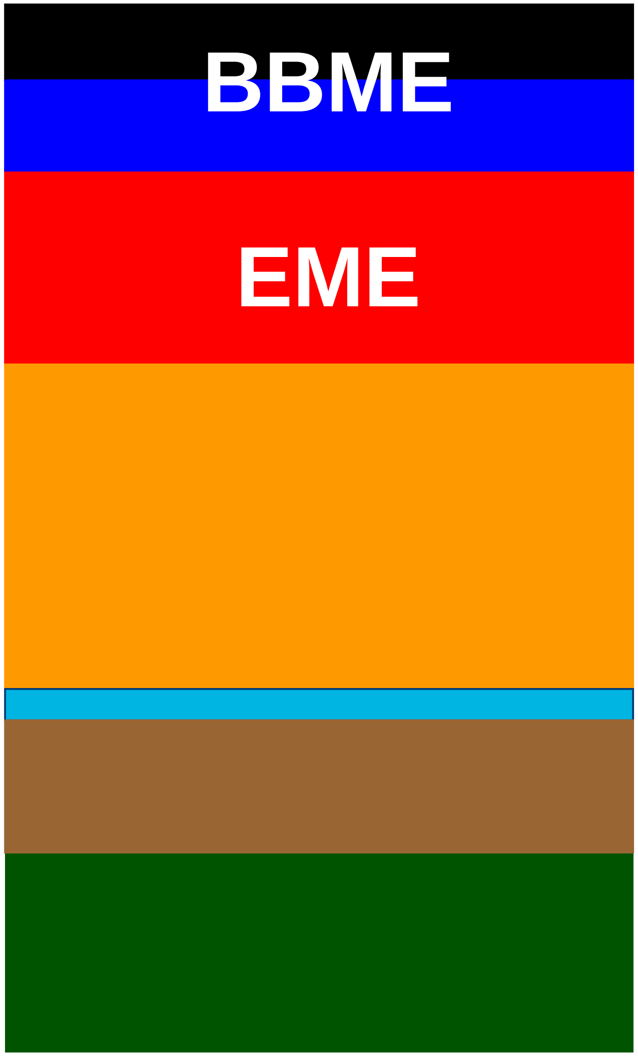
When should High modulus HMA be used?

- Heavy traffic (Highways, slow lanes)
- Super-high loads
- Weak / cracked subbase

How reduce pavement thickness?

- Increase the stiffness of the material
  → reduce deflection (strains) under given load
  → possibility to reduce thicknesses under given traffic

ROAD STRUCTURE



← 1-6 cm : WEARING COURSE

← 6-8 cm : BINDER COURSE

← 10-35 cm : BASE COURSE

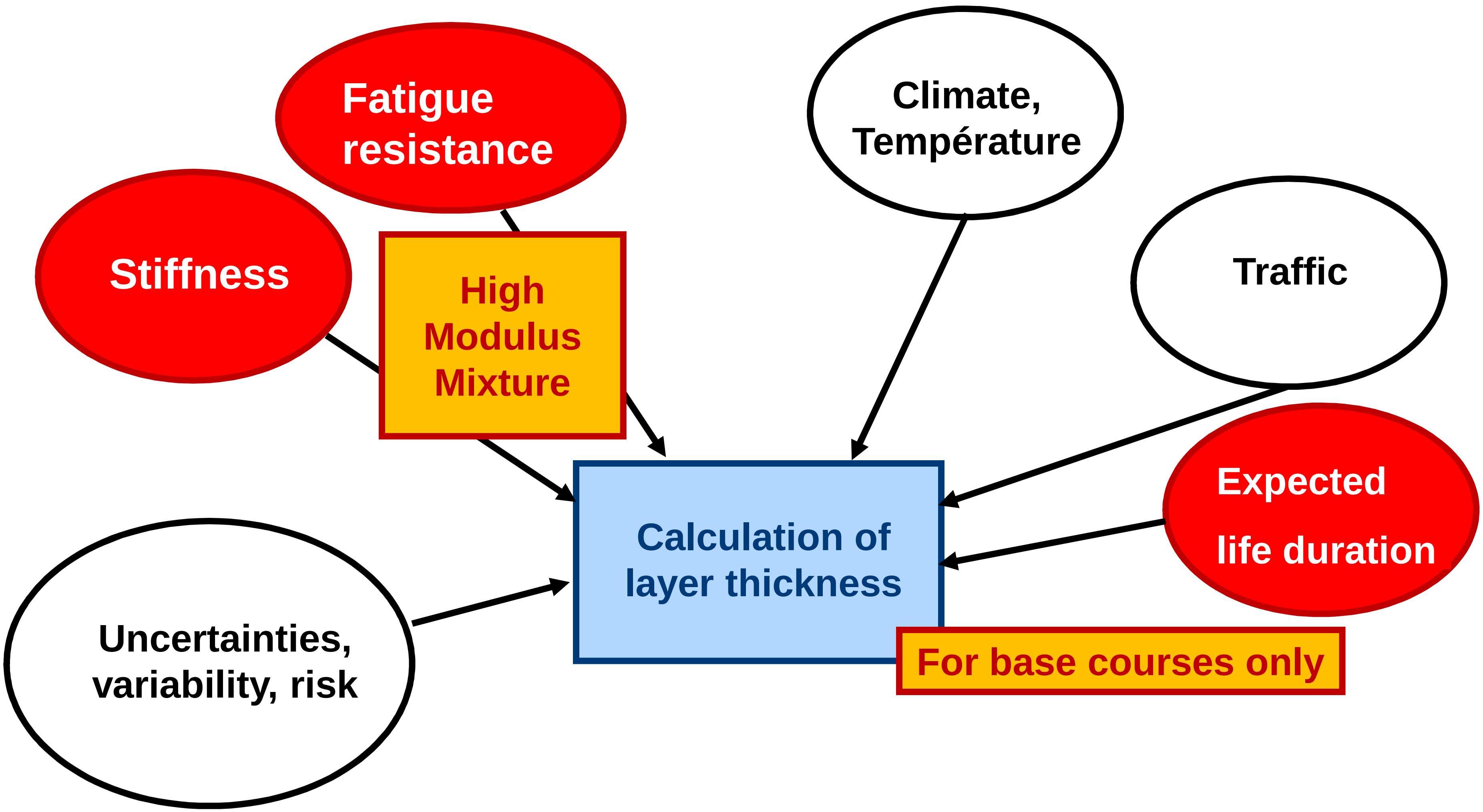
← 15-80 cm : « FOUNDATION COURSE »

← PROTECTION / WATERPROOFING

← SHAPE LAYER

← GROUND

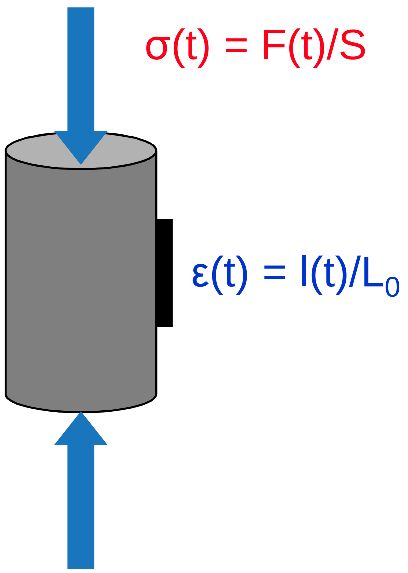
PRINCIPLES OF FRENCH PAVEMENT DESIGN METHOD

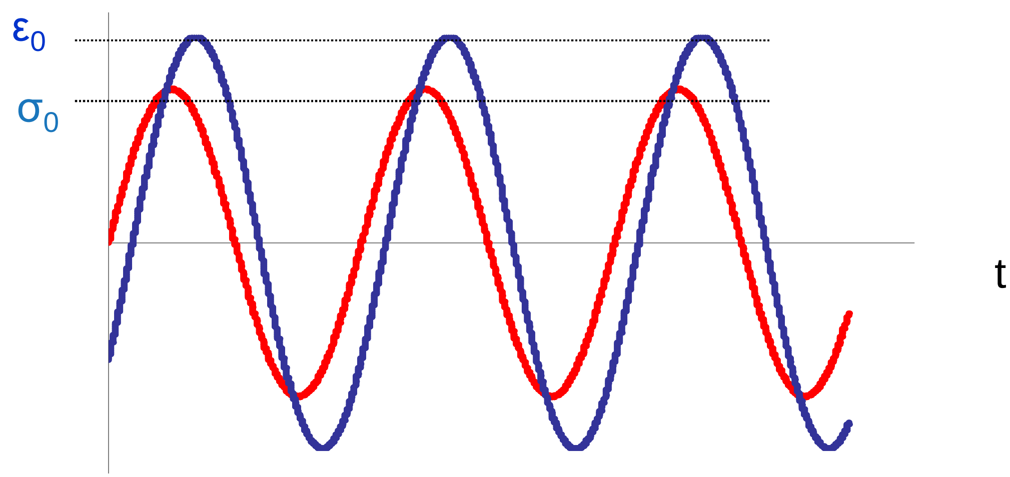


COMPLEX MODULUS (EN12697-26) TRACTION/COMPRESSION TEST

Traction/Compression at 15°C-10Hz

- Oscillation motion on cylindrical specimens (cut in asphalt mix slabs)
- Displacement (ε) registered depending on solicitation (σ)

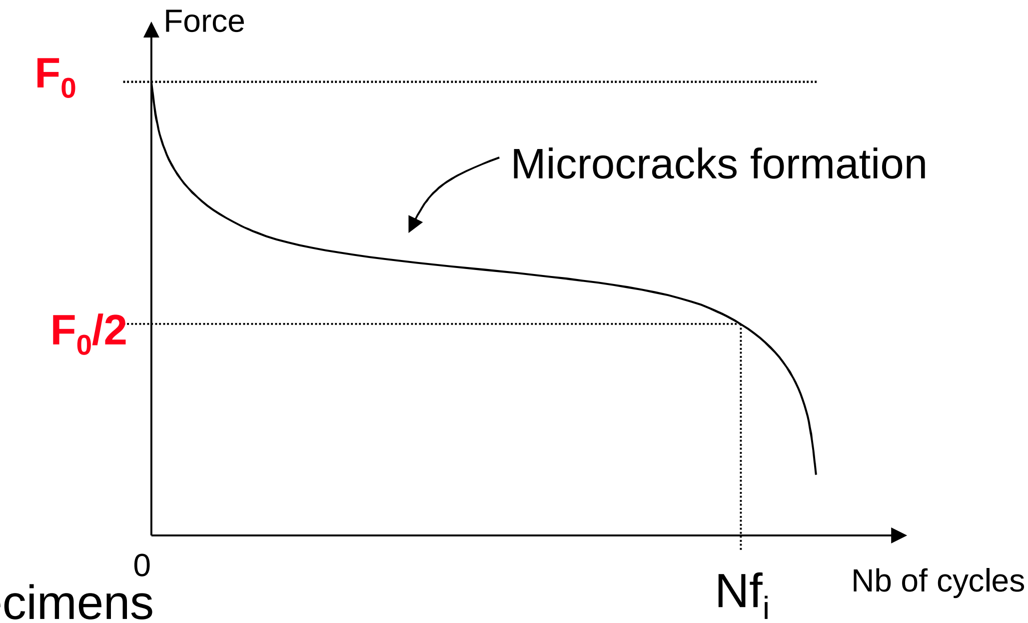




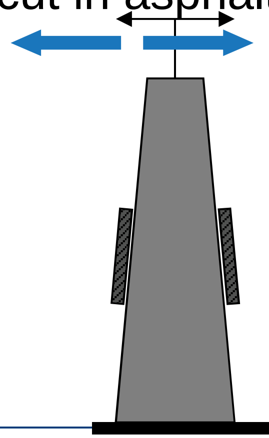
- **Calculation on complex modulus (stiffness):** $E = \sigma_0/\varepsilon_0$

FATIGUE TEST (EN12697-24)
2 POINT BENDING ON TRAPEZOIDAL SPECIMEN

Lifetime quantification:



Trapezoidal specimens cut in asphalt mix slabs



Max strain → ε_i constant

10°C, 25 Hz

Calculation of deformation to obtain a <u>force /2</u> within 1 million cycles:

→ ε_6

WHAT IS A HIGH MODULUS ASPHALT ?

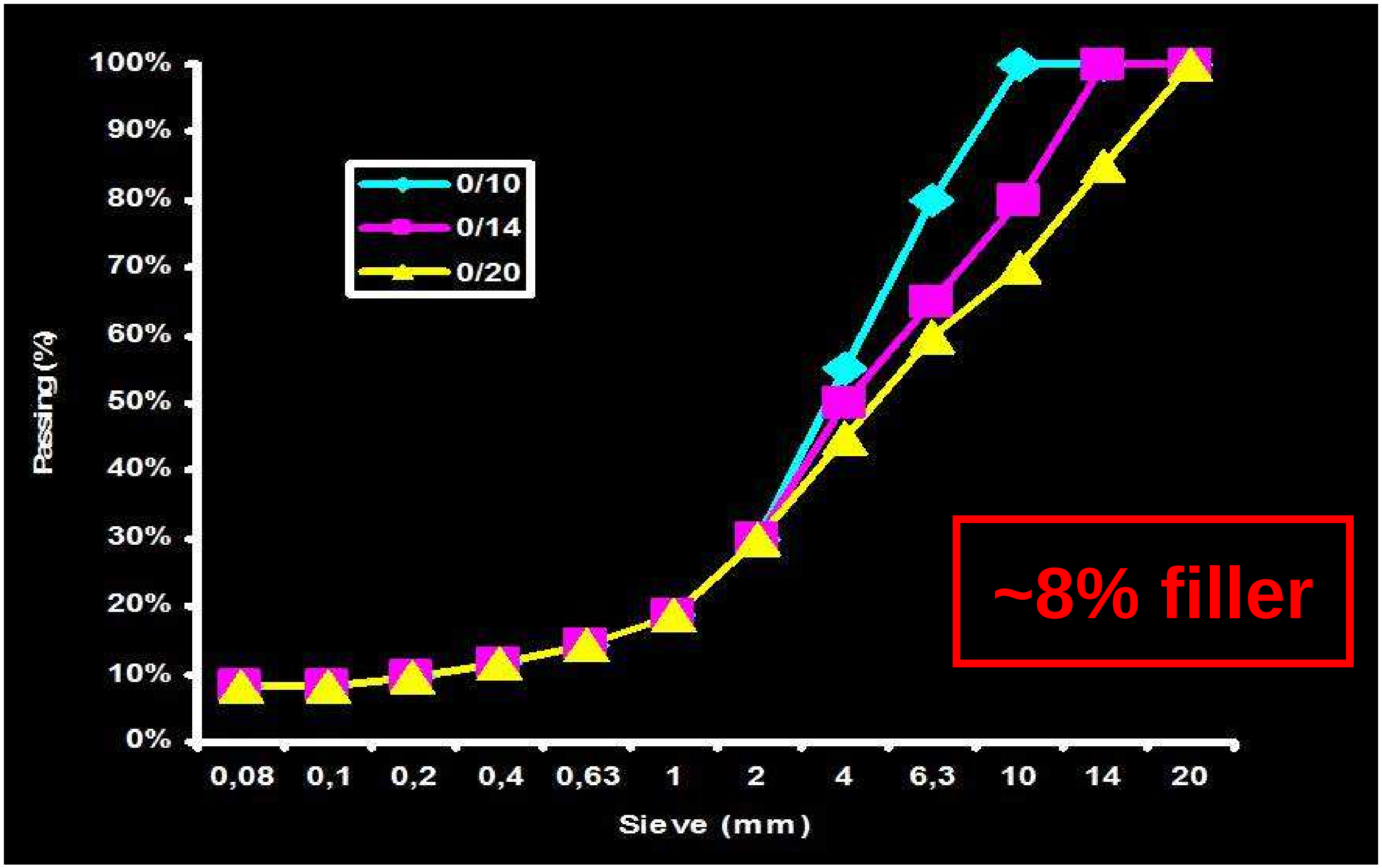
EME

Formulation:

- **Very hard binder: 10-25 pen**
  - Use of PmB is even better but still rarely used
- Aggregates:
  - **Crushed aggregates**
  - No particular requirements
- Gradation
  - **Continuous**
  - 0/10, 0/14 or 0/20
  - 0/20 (rarely used because risk of heterogeneity)

EME

Gradation curve:



EME

Volumetrics:

EME Class1:

- **Low binder content:**

  4 ppc (3.85%)

- Average void content:

  Up to 10%

EME Class2:

- **High binder content:**

  6 ppc (5.66%)

- Low void content:

  < 6%

EME - SPECIFICATIONS 2007 (EN 13108-1)

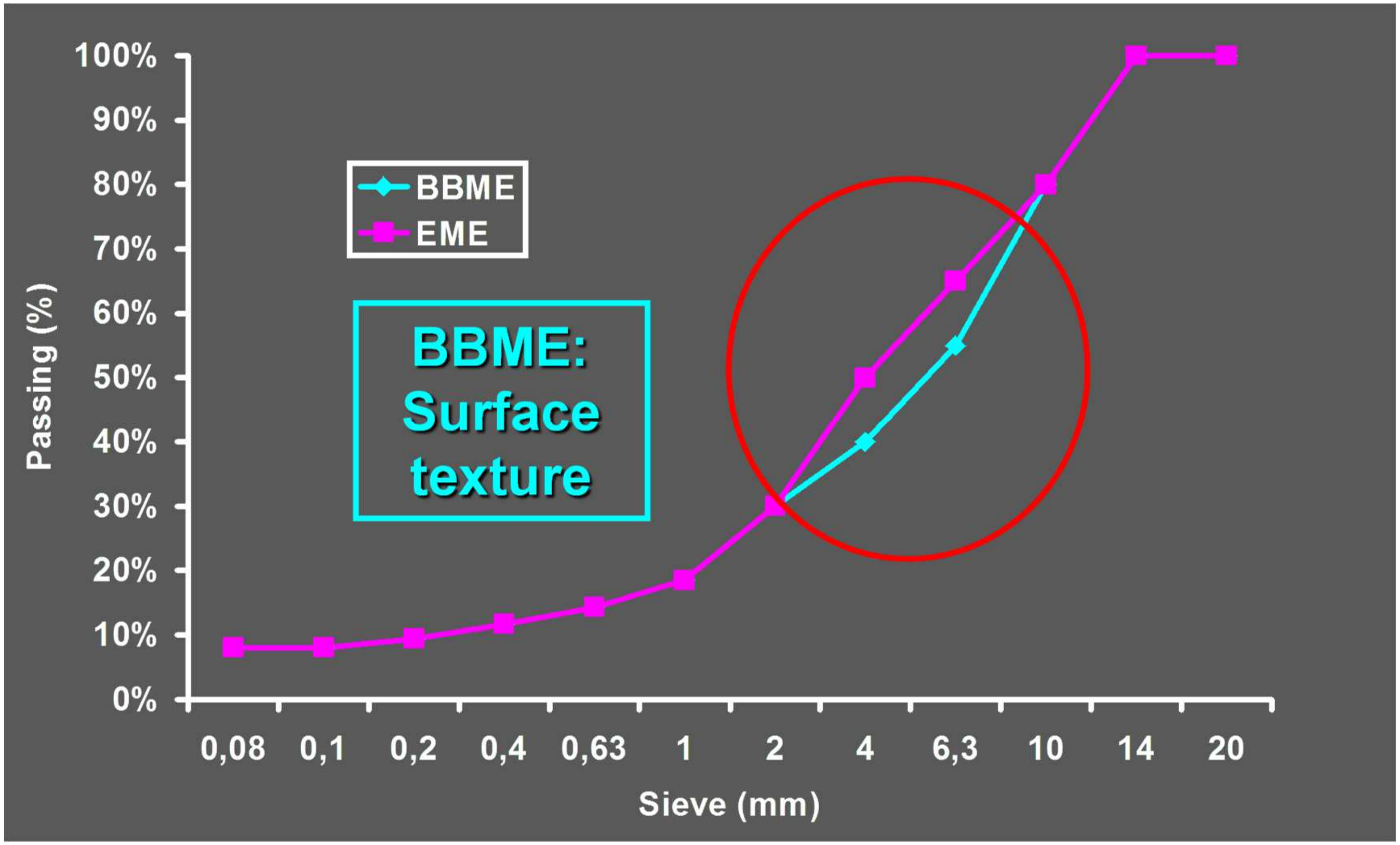
	Standard Mix.	EME Cl. 1	EME Cl. 2
Void content	5% to 10%	< 10%	< 6%
Duriez ratio (moisture damage)	> 0.70	> 0.7	> 0.70
Rutting @ 30 000 cycles	< 10%	< 7.5%	< 7.5%
Stiffness (15°C, 10Hz)	> 7000 MPa	> 14000 MPa	> 14000 MPa
Fatigue resistance (ε_6)	> 100µdef.	> 100µdef.	> 130µdef.

BBME
Formulation:

- **Hard binder: 20-30 pen** (esp. for Cl2 and Cl3)
  - **Use of PmB is even better**
- Same as regular HMA except for stiffness
- Aggregates:
  - **Crushed aggregates**
  - No particular requirements
  - **Resistance to polishing** is important
- Gradation
  - **Continuous**
  - 0/10, 0/14
- Volumetrics
  - Identical to regular HMA
  - **Typical binder content: 5.8 ppc**

BBME

Gradation curve:



BBME – SPECIFICATIONS 2007 (EN13108-1)

	Standard Mix.	BBME Cl.2	BBME Cl.3
Void content	5% to 10%	5% to 10%	5% to 10%
Duriez ratio (moisture damage)	~~> 0.70~~	> 0.8	> 0.8
Rutting @ 30 000 cycles	< 5% to 7.5%	< 7.5%	< 5%
Stiffness (15°C, 10Hz)	~~> 7000 MPa~~	> 11000 MPa	> 11000 MPa
Fatigue resistance (ε_6)	> 100µdef.	> 100µdef.	> 100µdef.

COMPARISON EME / BBME

	EME cl 2	BBME cl 3
Characteristics		
Granular curve	**0/10 – 0/14 – 0/20**	**0/10 – 0/14**
Binder content (typical)	**5,6 %**	**5,8 %**
Void content	**< 6 %**	**5 – 10 %**
Performances		
Moisture resistance	**+**	**++**
Rutting resistance	**+**	**++**
Stiffness	**+++**	**++**
Fatigue resistance	**+++**	**+**

EXAMPLES OF PERFORMANCES

PURE HARD GRADES IN EME (1/2)

Importance of hard grade nature in EME

- Comparison of 10/20 bitumen bases, of **different suppliers,** in the **same EME formula:**
  - **same aggregates nature**
  - **same granular curve**
  - **same binder content**

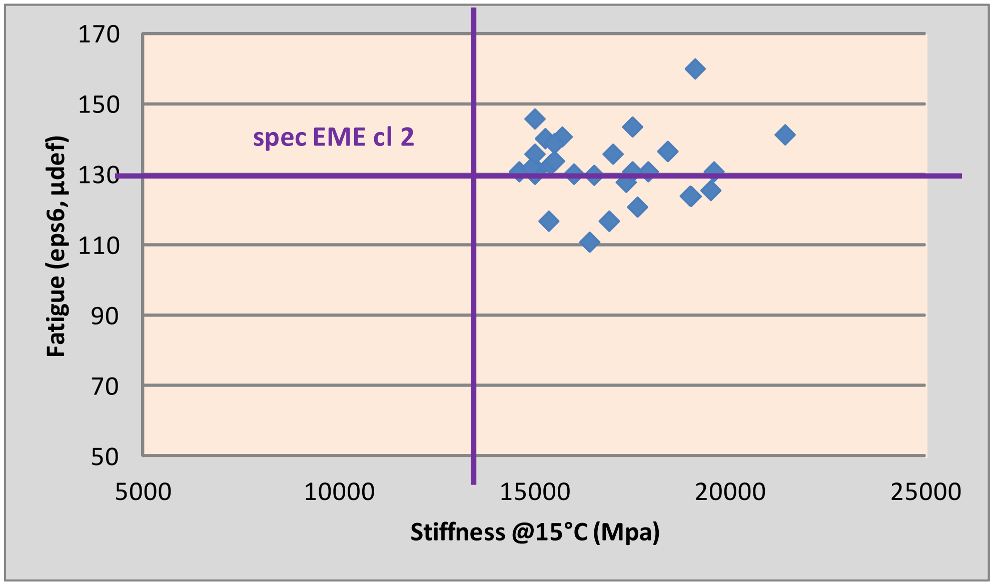
	Commercial 10/20 #1	Commercial 10/20 #2	Commercial 10/20 #3	Commercial 10/20 #4	Commercial 10/20 #5
Stiffness @ 15°C, 10 Hz (Mpa)	**14500**	**16000**	**16300**	**17100**	**18100**
Fatigue @ 10°C (ε6, µdef)	**140**	**115**	**133**	**140**	**133**

➡ **All hard grades are not equivalent**

PURE HARD GRADES IN EME (2/2)

Statistical results

- Comparison of 10/20 bitumen bases, of different suppliers, in **different asphalt mix formulas**

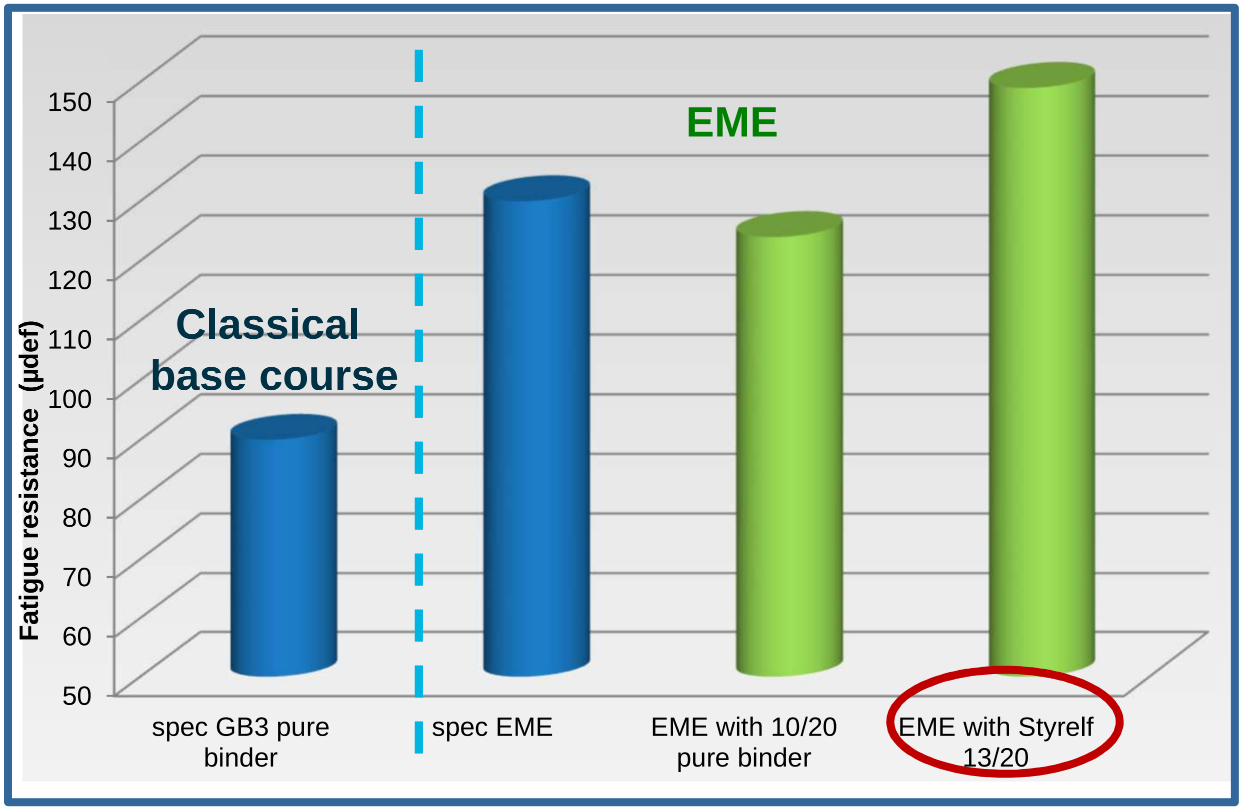


- **It can be sometimes difficult to meet EME 2 specifications, depending on:**
  - **Binder type**
  - **Aggregates nature, especially for stiffness**

ADVANTAGES OF STYRELF IN EME (1/2)

Fatigue in base course (EME = high modulus asphalt)

- **Same asphalt mix formula**



Styrelf 13/20 in base course
Higher fatigue resistance / pure hard grade

ADVANTAGES OF STYRELF IN EME (2/2)

Fatigue in base course compared to stiffness

- **Different asphalt mix formulas**

Type	Aggregate size (mm)	Binder	Grade EN 14023	PEN grade (dmm)	**Stiffness @15°C, 10 Hz (Mpa)**	**Fatigue @10°C (ε6, µdef)**
EME 2	0/20	**Styrelf® 11/20**	**10/40-60**	20	**17000**	**131**
EME 2	0/14	**Styrelf® 13/20**	**10/40-65**	20	**14572**	**149**
EME 2	0/20	**Styrelf® 11/20**	**10/40-60**	20	**14405**	**147**

- **Styrelf® 13/20 in base course**
  - **Higher fatigue resistance**
  - **High stiffness**

➡ **enables <u>thickness decrease</u> and <u>resistance to higher loads</u>**

ADVANTAGES OF STYRELF IN BBME (1/2)

Statistical results

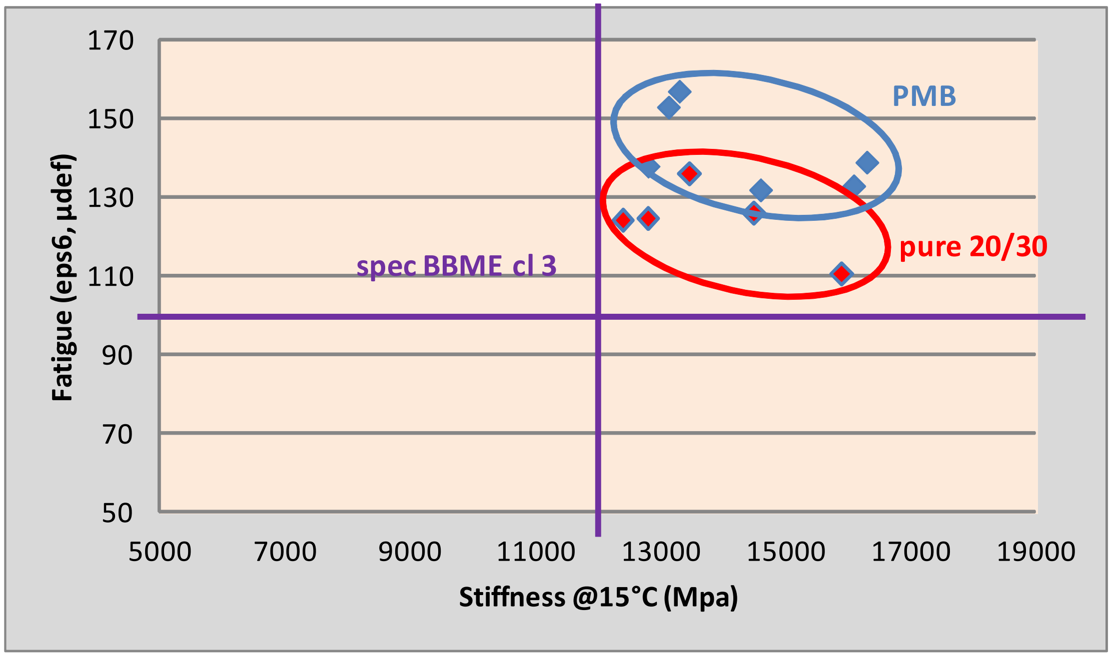
- Comparison **different asphalt mix formulas** with
  - **pure binder 20/30**
  - **hard Styrelf → same stiffness, higher fatigue resistance**

Type	Aggregate size (mm)	Binder	Grade EN 14023	PEN grade (dmm)	Stiffness @15°C, 10 Hz (Mpa)	Fatigue @10°C (ε6, µdef)
BBME 3	0/10	Azalt® 20/30	-	25	12800	124,5
BBME 3	0/10	Azalt® 20/30	-	25	13800	
BBME 3	0/10	Azalt® 20/30	-	25	16800	
BBME 3	0/14	Azalt® 20/30	-	25	12400	124
BBME 3	0/10	Azalt® 20/30	-	25	14500	126
BBME 3	0/10	Azalt® 20/30	-	25	15900	110,4
BBME 3	0/10	Azalt® 20/30	-	25	16900	
BBME 3	0/10	Azalt® 20/30	-	25	13477	136
BBME 3	0/10	Styrelf® 11/20	10/40-60	20	13126	153
BBME 3	0/14	Styrelf® 13/20	10/40-65	20	12600	
BBME 3	0/14	Styrelf® 11/20	10/40-60	20	13300	157
BBME 3	0/14	Styrelf® 11/20	10/40-60	20	16090	133
BBME 3	0/10	Styrelf® 13/20	10/40-65	20	14600	132
BBME 3	0/14	Styrelf® 13/20	10/40-65	20	12800	138
BBME 3	0/14	Styrelf® 11/20	10/40-60	20	16300	139

ADVANTAGES OF STYRELF IN BBME (2/2)

Statistical results

- Comparison **different asphalt mix formulas** with
  - **pure binder 20/30**
  - **hard Styrelf → same stiffness, higher fatigue resistance**



GOOD PRACTICES WITH HMA

GOOD PRACTICES

EME (1/2) :

- **Should not be used as surface or binder layer**
  - Thermal cracking
  - Too smooth surface texture

- Thickness range:
  - 6 to 8 cm for 0/10 graded EME
  - 7 to 13 cm for 0/14 graded EME
  - 9 to 15 cm for 0/20 graded EME
  - **Possibility to make multiple layers of EME (CAUTION: good bonding is CRUCIAL!!)**
  - **Sensitive to “under-design”**

GOOD PRACTICES

EME (2/2) :

- **Usually topped with thin to very thin wearing course**
  - Risk of cracking if wearing course brings insufficient thermal protection
- **Mixing temperature: 180°C**
- Compaction:
  - Temperature > 140°C
  - Watch for weather conditions and temperatures
  - **Use tire compactors and optionally vibrating cylinders** (watch for longitudinal cracking)
- Targeted void content
  - Class 1: 10% or less
  - Class 2: 6% or less

GOOD PRACTICES

BBME (1/2):

- **Used as surface or binder layer**
  - E.g. maintenance of cracked pavement
  - Watch for thermal cracking in case of high amplitude daily or yearly temperature variations

- Thickness range
  - 5 to 7 cm for 0/10 graded BBME
  - 6 to 9 cm for 0/14 graded BBME

- **Surface texture IS important**

GOOD PRACTICES

BBME (2/2):

- **Mixing temperature: 180°C**

- Compaction:
  - Temperature > 140°C
  - **Use tire compactors and optionally vibrating cylinders** (watch for longitudinal cracking)
  - Watch for weather conditions and temperatures

- Targeted void content: 4 to 8%

OPTIMISATION OF PAVEMENT DESIGN WITH EME

EXAMPLE 1

HYPOTHESES

Design for: <u>30 years</u>

Traffic:

- **<u>600 Trucks / day</u>**
- Geometric increase: 5% / yr
- No “super high” loads

No frost

Subbase stiffness: 120 to 200 MPa

EME ALLOW SIGNIFICANT REDUCTION OF LAYER THICKNESSES – EXAMPLE 1

Two alternative designs:

Classical

Wearing course: 2.5cm

Binder course: 6cm

Base course: 11cm

Base course: 12cm

Total: 31.5cm

With EME

Wearing course: 2.5cm

EME: 9cm

EME: 10cm

Total: 21.5cm

EXAMPLE 2

HYPOTHESES:

Design for: <u>20 years</u>

Traffic:

- **<u>600 Trucks / day</u>**
- Arithmetic increase: 2% / yr
- No "super high" loads

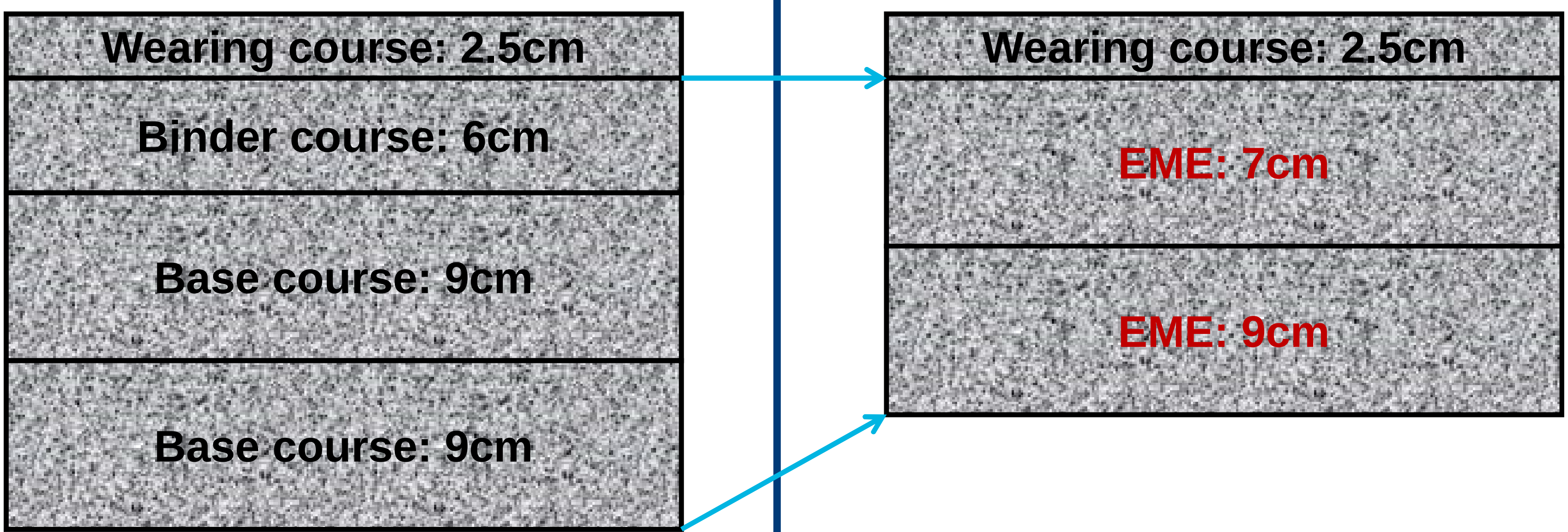
No frost

Subbase stiffness: 120 to 200 MPa

EME ALLOW SIGNIFICANT REDUCTION OF LAYER THICKNESSES – EXAMPLE 2

Two alternative designs:

Classical | **With EME**



Total: 26.5cm | **Total: 18.5cm**

EXAMPLES OF JOB SITES

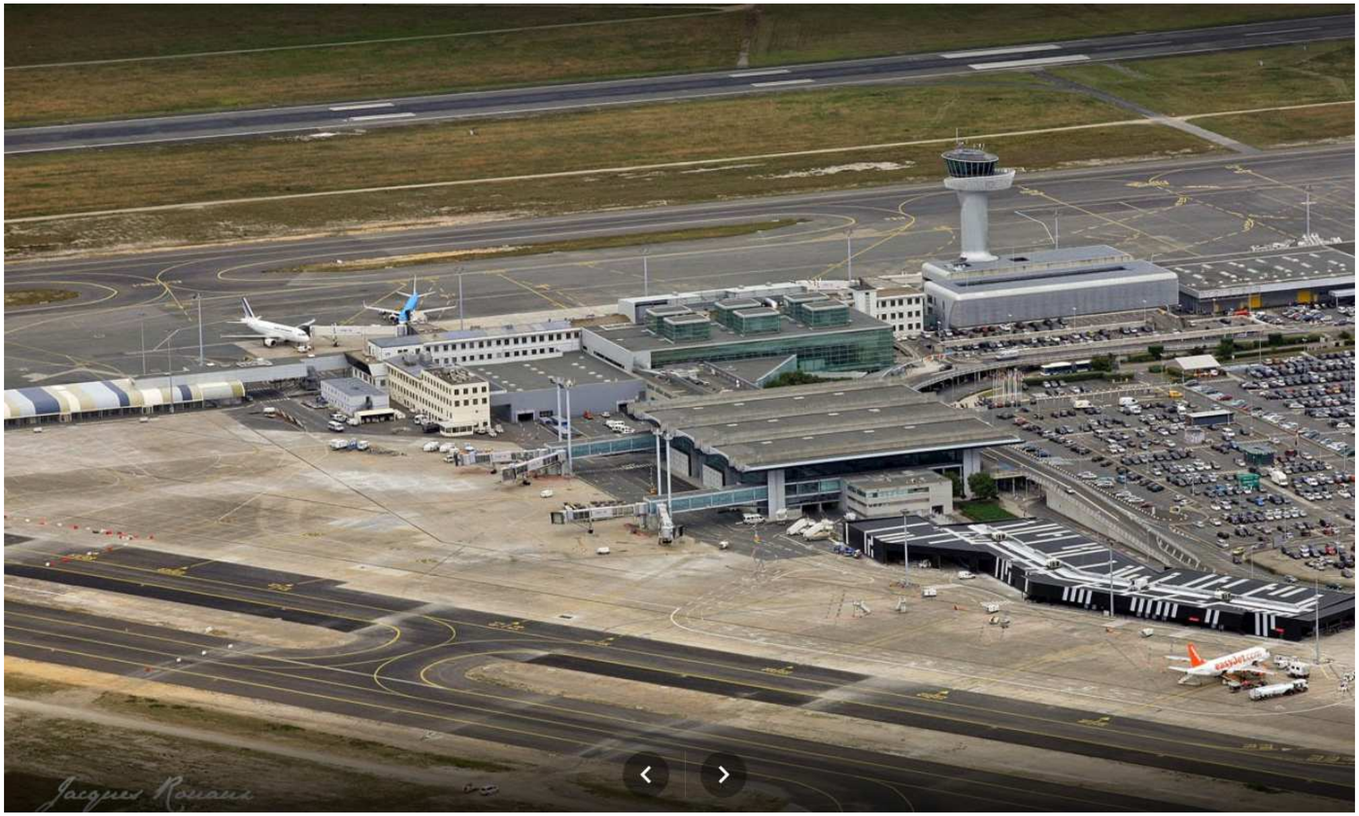
REFERENCE JOB SITE

Marseille (France) harbour : **plateforme exposed to high static load** (presence of containers)

- 2 layers of 11 cm of EME 0/14 - Modulotal® 10/20

REFERENCE JOB SITE

Bordeaux-Mérignac airport (France) – Modulotal ® 10/20



REFERENCE JOB SITE

SAINT MEDARD EN JALLES - RD1215 between Bordeaux and Lacanau (France)

- EME 0/10 classe 2 with 20 % RAP - Styrelf® 11/20
- 2 layers of 8 cm of EME with Styrelf 11-20 covered by 6 cm BBSG

TOTAL

CONCLUSION

CONCLUSIONS (1)

There are different types of high-stiffness HMAs

- EME Cl1, EME Cl2
- BBME Cl1, 2 & 3

EME should NEVER be used as a surface layer

- Cracking
- Superficial rutting

EME Cl1 is VERY different from EME Cl2

- EME Cl1 is like a regular base layer, except stiffer
  - Good resistance to rutting of base course
- EME Cl2:
  - Dense (waterproofing)
  - Stiff
  - Extra resistant to fatigue

Ideal to reduce layer thicknesses / on weak subbase

CONCLUSIONS (2)

BBME is a stiffer version of regular HMA for binder and wearing courses

- **Less stiff than EME to avoid cracking**
- Fatigue resistance is not as important
- **Surface texture** (skid resistance) and resistance to moisture damage are important

BBME Cl 1, 2 & 3 only differ by:

- Rutting resistance
- Fatigue resistance

THANK YOU FOR YOUR ATTENTION