Hrvatsko asfaltersko društvo Croatian asphalt association

Asfalti visokih modula: francuska iskustva

High Modulus Asphalt: the French Experience

Étienne le Bouteiller – COLAS S.A.

Međunarodni seminar ASFALTNI KOLNICI 2016
International seminar ASPHALT PAVEMENTS 2016
Opatija, 06.–07. 04. 2016.

CONTENT

- Background
- Mix design
- Pavement design: road pavements
- Pavement design: airport pavements
- Manufacturing and placing
- Developments
- Conclusions

BACKGROUND

- 1980
- A COLAS invention
- GBTHP
- Very high performance road base asphalt
- E* = 16000 Mpa (15°C 10 Hz)
- ε_6 = 160 10^{-6} µs (10°C 25 Hz)

BACKGROUND

- 1988
- Technical advice
- GBTHP
- Very high performance road base asphalt
- E* = 16000 Mpa (15°C 10 Hz)
- $\varepsilon_6 = 160\ 10^{-6}\ \mu s$ (10°C 25 Hz)

AVIS TECHNIQUE

CHAUSSEES 22

ENROBES SPECIAUX

G.B.T.H.P.®

Entreprise : COLAS

39, rue du Colisée
75008 Paris
Tél. : (1) 40.75.40.75

La G.B.T.H.P. (Grave-Bitume à Très Haute Performances) est un enrobé pour couche d'assise fortement dosée en bitume très dur (environ 6 %).

Les applications, dont les plus anciennes ont 8 ans d'âge, sont routières, autoroutières et urbaines. Elles ont un bon comportement général (une couche d'assise est normalement calculée pour une durée de service de 15 à 20 ans). Les trafics peuvent atteindre 3 000 poids lourds par jour et par sens.

Le module élevé et la résistance à la fatigue de la G.B.T.H.P. permettent une réduction d'épaisseur par rapport à la grave-bitume type Recommandation 1988 (à paraître). Outre l'aspect économique, ceci est particulièrement intéressant lorsque l'on travaille sous contrainte altimétrique (passage sous ouvrage, réfection de chaussée entre bordure, etc.)

Une couche de roulement en enrobé est nécessaire.

Ce produit, apparu en 1980, a atteint la phase de développement industriel.

Les éléments disponibles permettent, malgré un recul limité pour une couche d'assise, d'envisager son emploi sans grand risque.

Date : Mars 1988

Validité : 3 ans

SOMMAIRE

Présentation du produit par l'entreprise ..... page 2
Essais de caractérisation ..... page 3
Avis ..... page 6

BACKGROUND

- Oct. 1992
- French Standard
- NF P 98140
- Updated in Nov.1999

FA045258 ISSN 0335-3931

norme française

NF P 98-140
Novembre 1999

Indice de classement : P 98-140

ICS : 75.140 ; 93.080.20

Enrobés hydrocarbonés

Couches d'assises :
enrobés à module élevé (EME)

Définition — Classification — Caractéristiques — Fabrication — Mise en œuvre

E : Asphalt — Road base courses : Road base high modulus asphalt concrete — Definition — Classification — Characteristics — Fabrication — Laying
D : Bitumen gebundener Straßenbau — Unterbau : erhöhtes Verformungsmodul — Definition — Klassifikation — Eigenschaften — Einbau

Norme française homologuée

par décision du Directeur Général d'AFNOR le 20 octobre 1999 pour prendre effet le 20 novembre 1999.

Remplace la norme homologuée NF P 98-140, d'octobre 1992.

Correspondance À la date de publication du présent document, il n'existe pas de travaux européens ou internationaux traitant du même sujet.

Analyse Le présent document définit les enrobés à module élevé, fabriqués à chaud en centrale et destinés à la réalisation des couches d'assises des chaussées. Il fixe leurs caractéristiques et les essais appropriés, précise leurs conditions spécifiques de fabrication, de livraison, de mise en œuvre.

Descripteurs **Thésaurus International Technique** : route, chaussée, produit hydrocarboné, produits bitumineux, définition, classification, conditions d'utilisation, constituant, granulat, liant, caractéristique, fabrication, essai, mise en œuvre.

Modifications Par rapport au document remplacé, ce document présente un plan modifié. Des niveaux d'étude de formulation ont été introduits. Les caractéristiques des composants ont été modifiées pour tenir compte de l'évolution de certaines normes. Enfin, certaines informations ont été supprimées et renvoyées dans des normes de portée plus générale.

Corrections

Éditée et diffusée par l'Association Française de Normalisation (AFNOR), Tour Europe 92049 Paris La Défense Cedex
Tél. : 01 42 91 55 55 — Tél. international : + 33 1 42 91 55 55

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BACKGROUND

- Oct. 1992
- French Standard
- NF P 98140
- Updated in Nov.1999
- 2 types of EME
- Focus on EME2:
  - E* > 14000 Mpa (15°C 10 Hz)
  - ε_6 > 130 10^{-6} µs (10°C 25 Hz)

Tableau 6 — Performances mécaniques

Essais sur EME 0/10 — 0/14 ou 0/20	Classe 1	Classe 2
Essai Duriez à 18 °C (NF P 98-251-1) Rapport : r (en MPa) après immersion / R (en MPa) à sec	≥ 0,70	≥ 0,75
Essai d'ornièrage (NF P 98-253-1) Profondeur d'ornière en pourcentage de l'épaisseur de la dalle pour une dalle de 10 cm d'épaisseur à 30 000 cycles et à 60 °C, à un pourcentage de vides compris entre • 7 % et 10 % (classe 1) • 3 % et 6 % (classe 2)	≤ 7,5 % —	— ≤ 5 %
Essai de module complexe (NF P 98-260-2) Module, en mégapascals, à 15 °C, 10 Hz à un pourcentage de vides compris entre • 7 % et 10 % (classe 1) • 3 % et 6 % (classe 2)	≥ 14 000 —	— ≥ 14 000
Essai de traction directe (NF P 98-260-1) Détermination du module et de la perte de linéarité à un pourcentage de vides compris entre • 7 % et 10 % (classe 1) • 3 % et 6 % (classe 2) Module, en mégapascals, à 15 °C, 0,02 s	≥ 14 000 —	— ≥ 14 000
Essai de fatigue (NF P 98-261-1) Déformation relative à 10^6 cycles, 10 °C et 25 Hz et pour un pourcentage de vides compris entre • 7 % et 10 % (classe 1) • 3 % et 6 % (classe 2)	≥ 100 µdef —	— ≥ 130 µdef

BACKGROUND

- A few words about the French asphalt mix design method
- 4 levels of performance based tests
  - Water resistance
  - Resistance to permanent deformation
  - Stiffness modulus E*
  - Fatigue resistance ε_6


LPC Bituminous Mixtures Design Guide

The RST Working Group
"Design of bituminous mixtures "

Under the supervision of

Jean-Luc DELORME,

Chantal de la ROCHE,

Louisette WENDLING

September 2007

LCPC Laboratoire Central des Ponts et Chaussées

Laboratoire Central des Ponts et Chaussées
58, bd Lefebvre, F 75732 Paris Cedex 15

BACKGROUND

- A
  m
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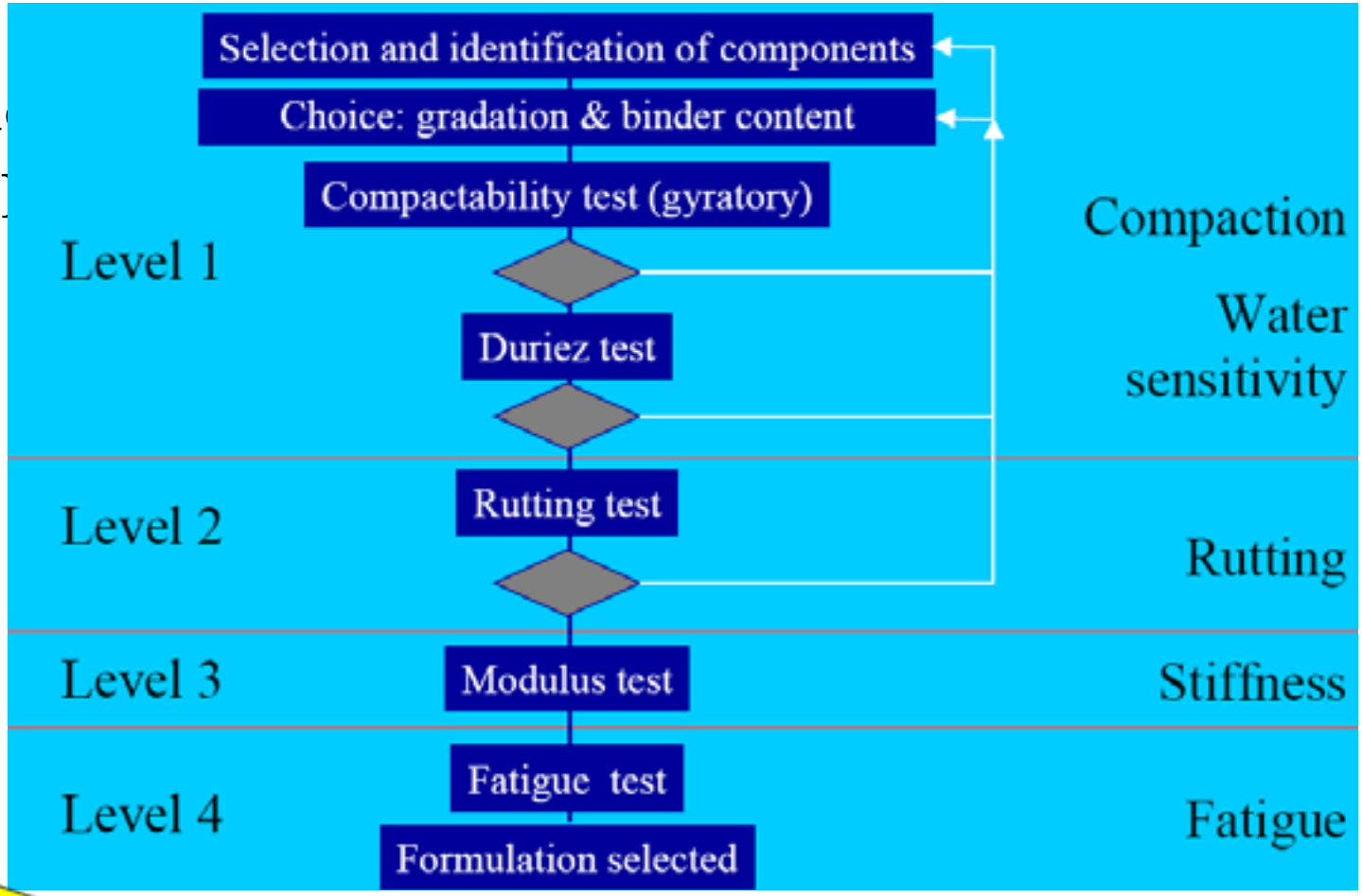

BACKGROUND

- A
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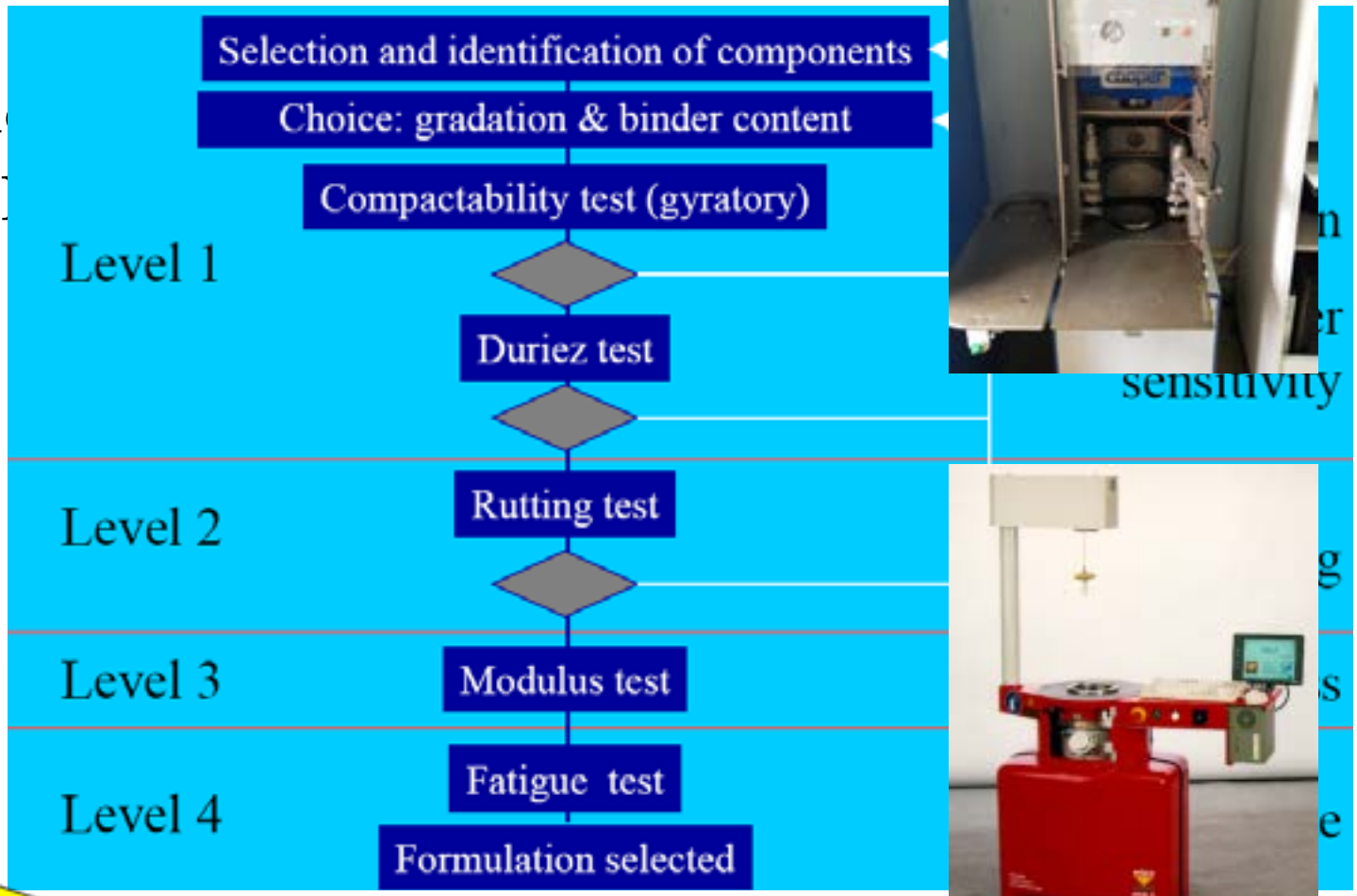

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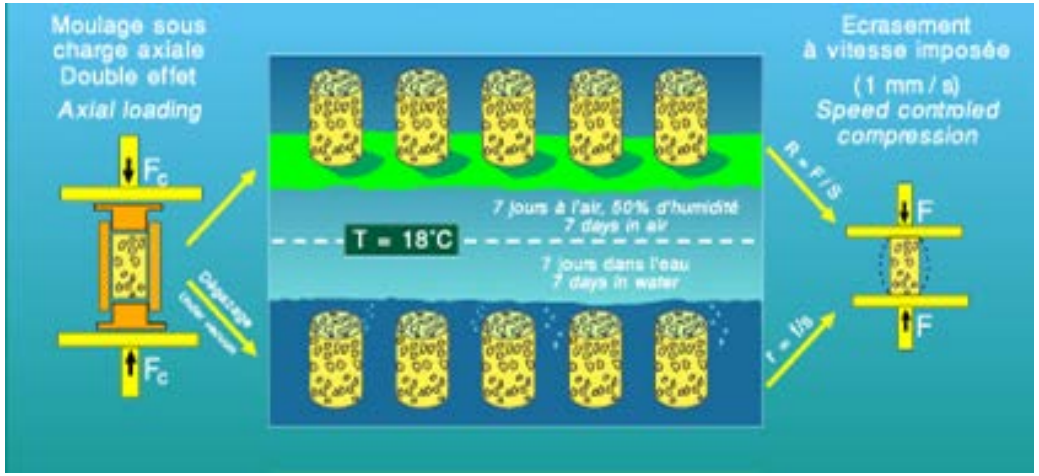
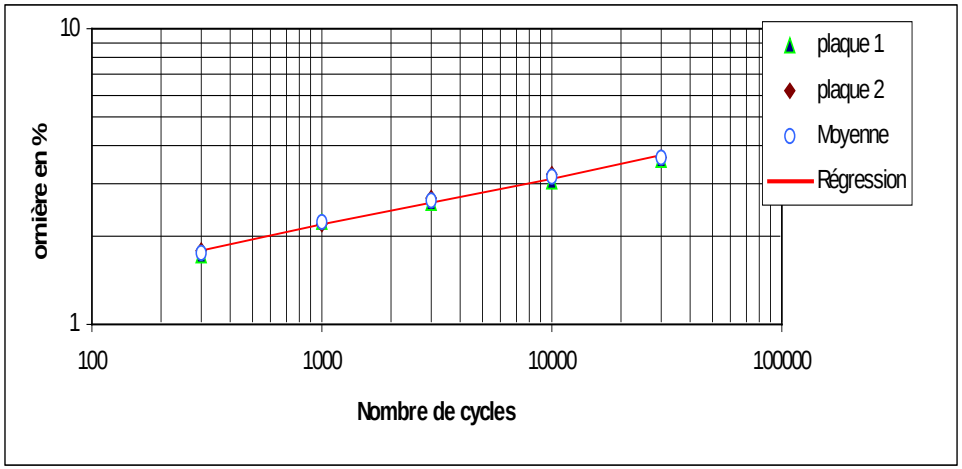
BACKGROUND

- Water resistance EN 12697-12
- Compressive strenght on core after 8 days of immersion



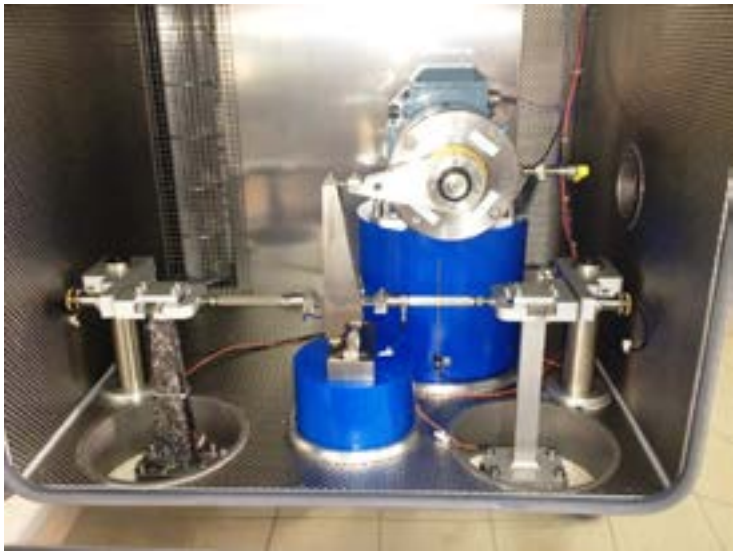
BACKGROUND

- Resistance to permanent deformation : EN 12697-22
- Determination of rut depth



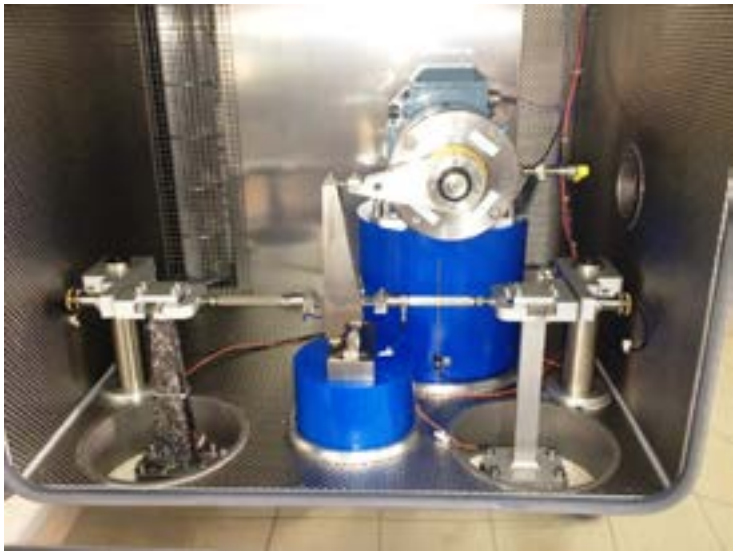
BACKGROUND

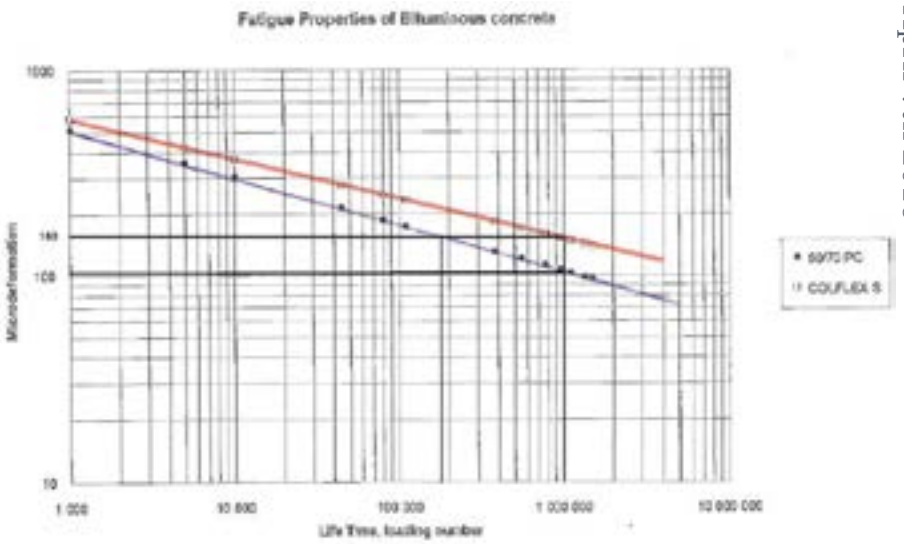
- Stiffness modulus E* EN 12697-26
- Sinusoidal dynamic deflexion15°C 10 Hz
- Direct tension 15°C 0.02 s



BACKGROUND

- Fatigue resistance (EN 12697-24)
- Determination of strain level for 1 million cycles ε_6 (10°C 25 Hz)



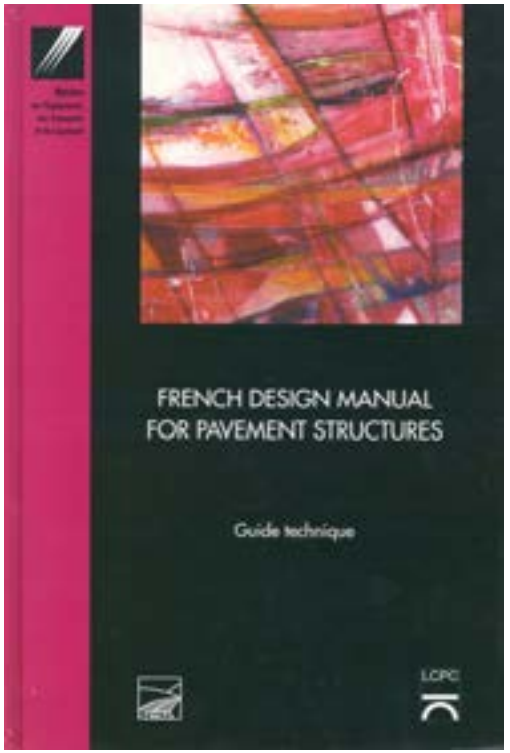


BACKGROUND

- 1994
- The French Design Manual for Pavement Structures

BACKGROUND

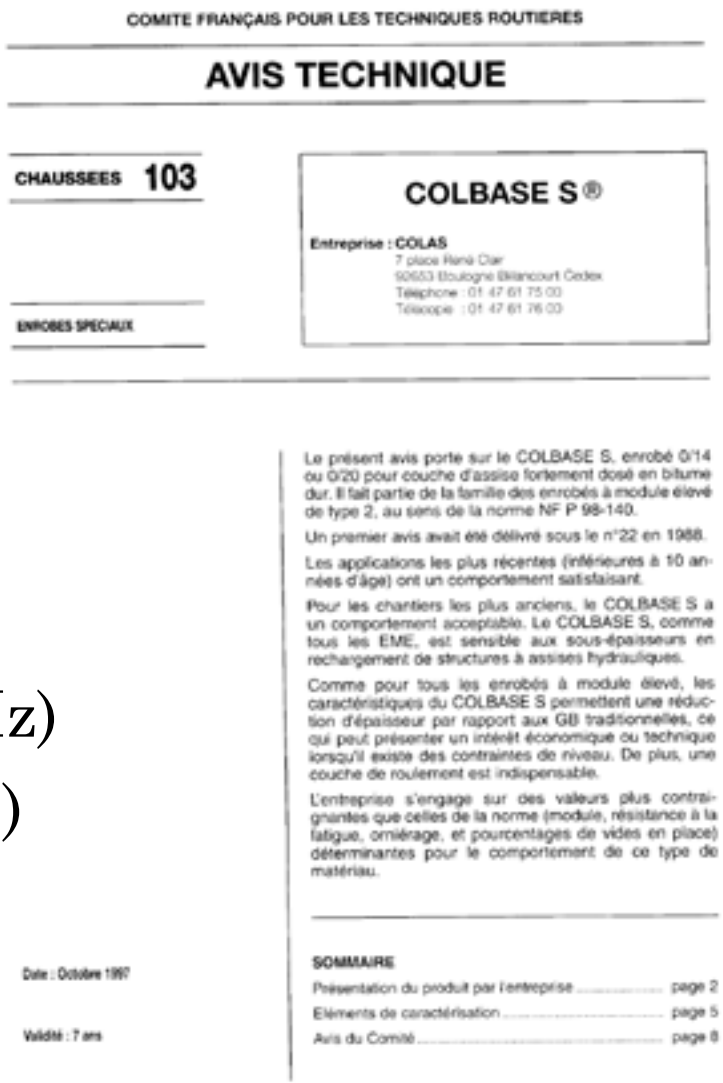
- 1994
- The French Design Manual for Pavement Structures
- English version in 1997



BACKGROUND

- 1997
- An updated Avis Technique
- COLBASE S

- E* = 16000 Mpa (15°C 10 Hz)
- $\varepsilon_6 = 145\ 10^{-6}$ µs (10°C 25 Hz)



COMITE FRANÇAIS POUR LES TECHNIQUES ROUTIERES

AVIS TECHNIQUE

CHAUSSEES 103

ENROBES SPECIAUX

COLBASE S®

Entreprise : COLAS
7 place René Clair
92653 Boulogne Billancourt Cedex
Téléphone : 01 47 61 75 00
Télécopie : 01 47 61 76 00

Le présent avis porte sur le COLBASE S, enrobé 0/14 ou 0/20 pour couche d'assise fortement dosé en bitume dur. Il fait partie de la famille des enrobés à module élevé de type 2, au sens de la norme NF P 98-140.

Un premier avis avait été délivré sous le n°22 en 1988.

Les applications les plus récentes (inférieures à 10 années d'âge) ont un comportement satisfaisant.

Pour les chantiers les plus anciens, le COLBASE S a un comportement acceptable. Le COLBASE S, comme tous les EME, est sensible aux sous-épaisseurs en rechargement de structures à assises hydrauliques.

Comme pour tous les enrobés à module élevé, les caractéristiques du COLBASE S permettent une réduction d'épaisseur par rapport aux GB traditionnelles, ce qui peut présenter un intérêt économique ou technique lorsqu'il existe des contraintes de niveau. De plus, une couche de roulement est indispensable.

L'entreprise s'engage sur des valeurs plus contraignantes que celles de la norme (module, résistance à la fatigue, ornièrage, et pourcentages de vides en place) déterminantes pour le comportement de ce type de matériau.

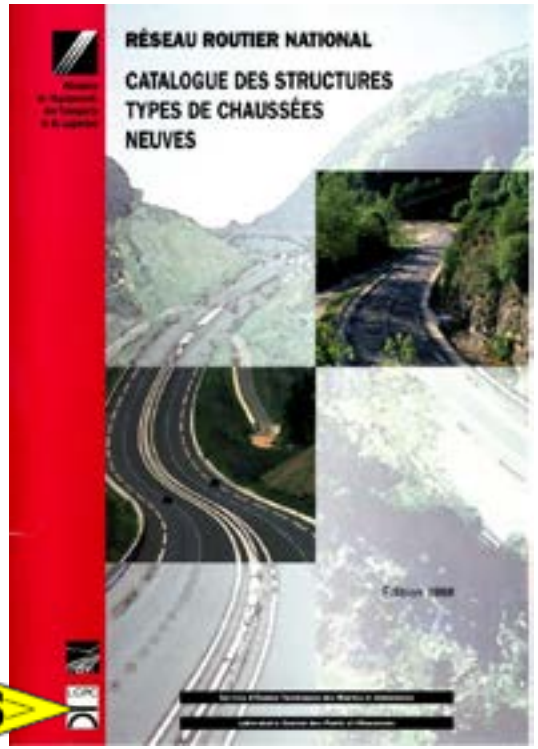
Date : Octobre 1997

Validité : 7 ans

SOMMAIRE

BACKGROUND

- 1998
- The French guide for new pavement structure (SETRA/LCPC)



COLAS

BACKGROUND

- 1998
- The French guide for new pavement structure (SETRA/LCPC)

Road base asphalt : 21 cm

EME: 15 cm

- 29%

BACKGROUND

- 2008
- European Standard EN 13108-1
- EME2

- AC Ø base binder

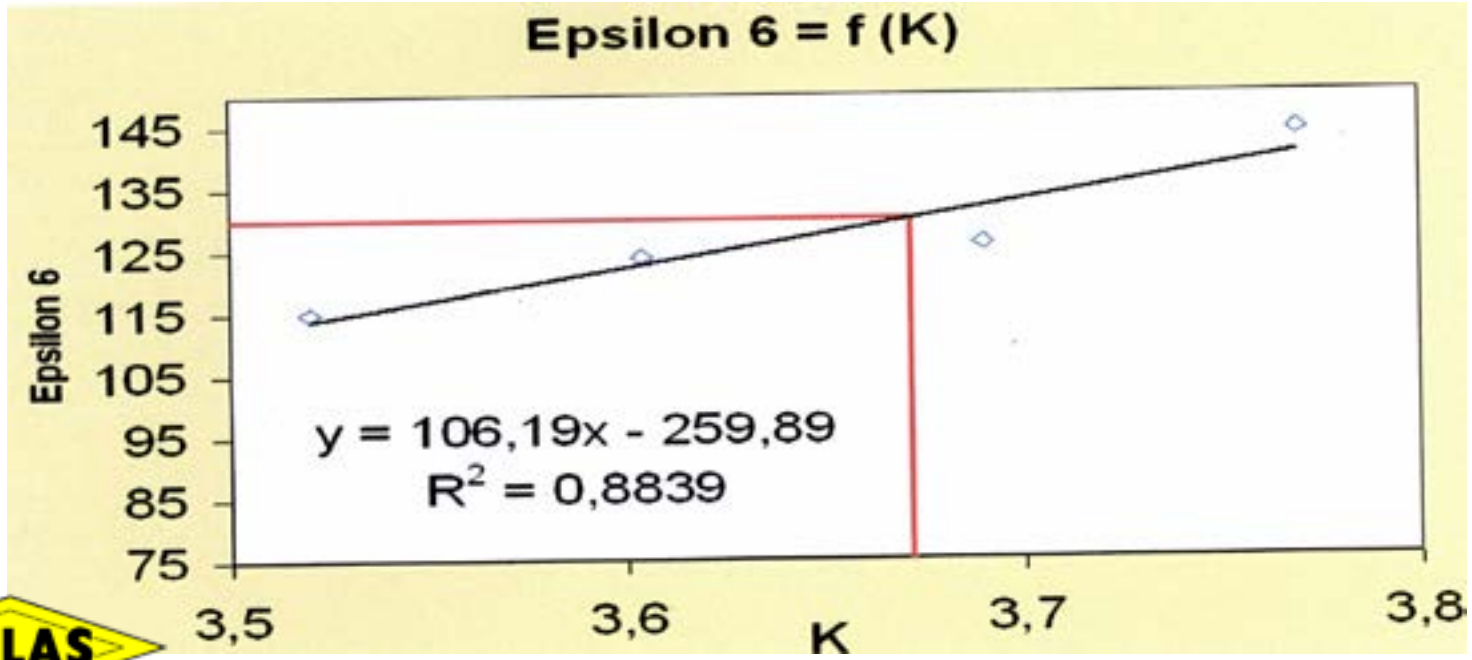
$S_{min\ 14000,}\ \varepsilon_{6\text{-}130}$ Vi =3% and Vs=6%

Mix design

- An appropriate combination of
  - Aggregates
  - Bitumen
- An appropriate gradation
  - The standard does not provide with any specification
  - The main aim is to reach a dense mix: void content between 3 & 6% when tested with the gyratory compactor (80 to 120 revolutions depending on the maximum aggregate size)
- An appropriate bitumen
  - A « hard » bitumen
  - A high bitumen content

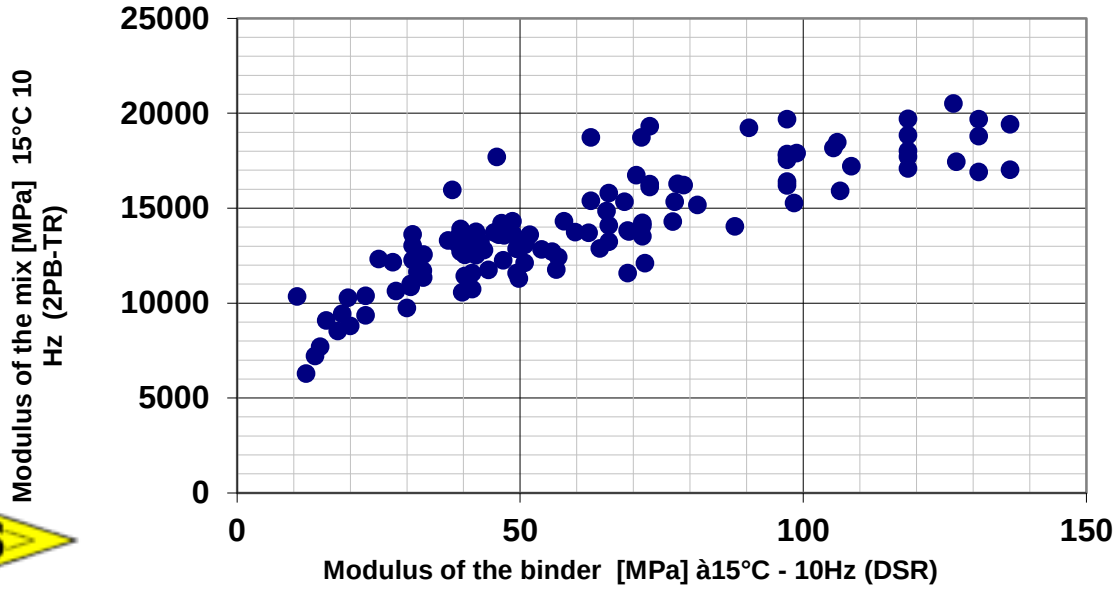
Mix design

- The characteristics of the bitumen will provide the mix with its modulus (and rutting resistance)
- The bitumen content will provide the mix with its fatigue properties (and water resistance)



Mix design

- Basically, the stiffness E* of the mix will depend on the stiffness G* of the binder
- A 10/20 might be suitable (e.g. Netherland)
- A 10/20 might not be suitable (e.g. Cesch Rep.)
- A 20/30 might be suitable (e.g. South Africa)



Mix design

- Basically, the stiffness modulus of the mix will depend on the stiffness of the binder
- A 10/20 might be suitable (e.g. Netherland)
  - Pen 19 G* 82 MPa
- A 10/20 might not be suitable (e.g. Cesch Rep.)
  - Pen 18 G* 35 MPa
- A 20/30 might be suitable (e.g. South Africa)
  - Pen 28 G* 80 MPa
- Bitumen used for EME:
  - Straight run bitumen (e.g. Netherland)
  - Propane bitumen (e.g. South Africa)
  - Blown bitumen (e.g. Australia)

Mix design

- Basically, the stiffness modulus of the mix will depend on the stiffness of the binder
- A 10/20 might be suitable (e.g. Netherland)
- A 10/20 might not be suitable (e.g. Cesch Rep.)
- A 20/30 might be suitable (e.g. South Africa)
- A (SBS) modified bitumen will provide the mix with improved fatigue resistance

Mix design

- A summary of this history

	GB2	GB3	GB4	EME1	EME2
E* (Mpa)	9000	9000	11000	11000	14000
ε6 (µs)	80	90	100	100	130

- Binder pen ↓
- Binder content ↑
- Pavement thickness↓

time →

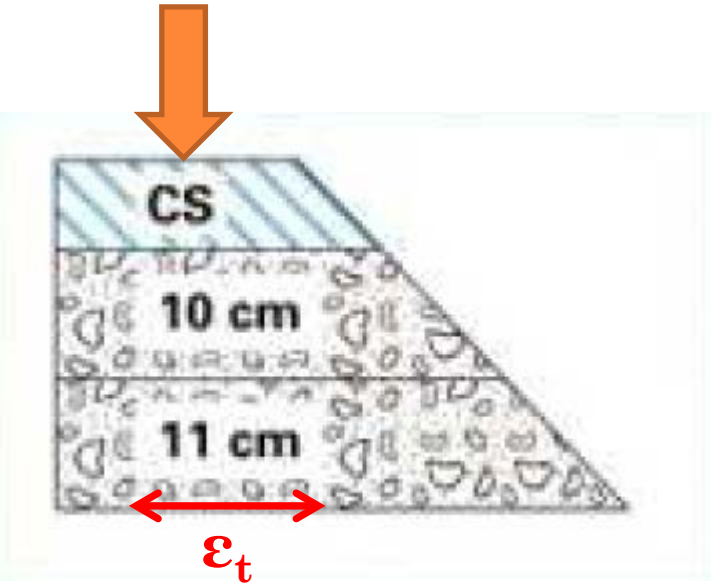
Pavement design: road pavements

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?

?

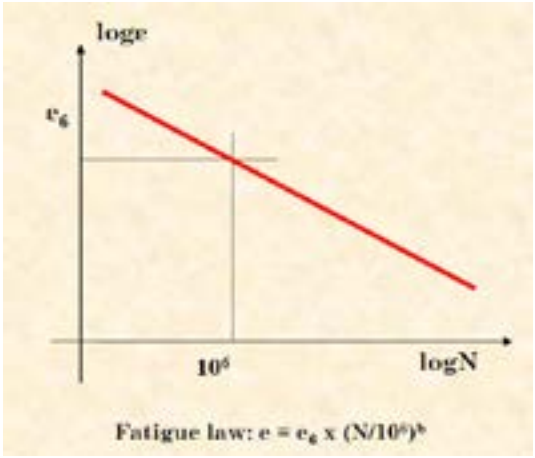
Pavement design: road pavements

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?
- 1st step



Pavement design: road pavements

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?
- 2nd step

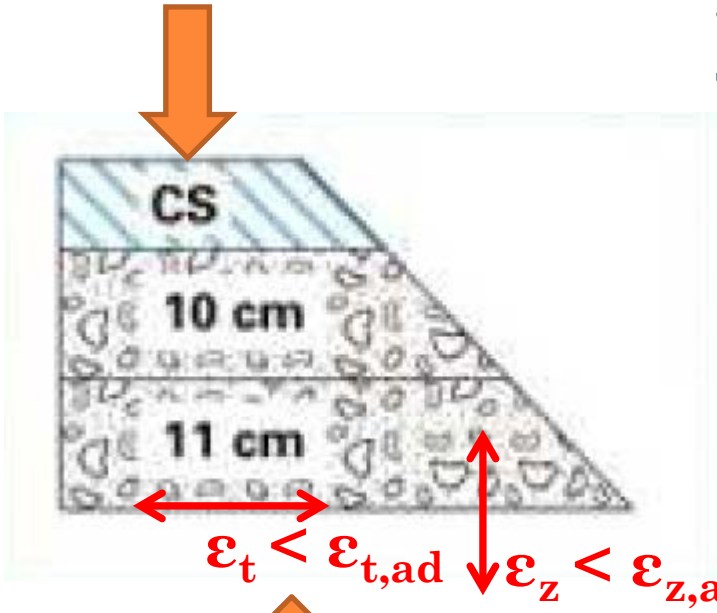


Fatigue law: $\varepsilon = \varepsilon_6 \times (N/10^6)^b$

$$\varepsilon_{t,ad} = \varepsilon\,(NE, \theta_{eq}, f)\, k_r\, k_c\, k_s$$

PAVEMENT DESIGN: ROAD PAVEMENTS

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?
- 2nd step



$$\varepsilon_{t,ad} = \varepsilon\,(NE, \theta_{eq}, f)\; k_r\, k_c\, k_s$$

PAVEMENT DESIGN: ROAD PAVEMENTS

- PF3: 120 Mpa TC6: 6,5 to 17,5 ESAL t°: 15°C

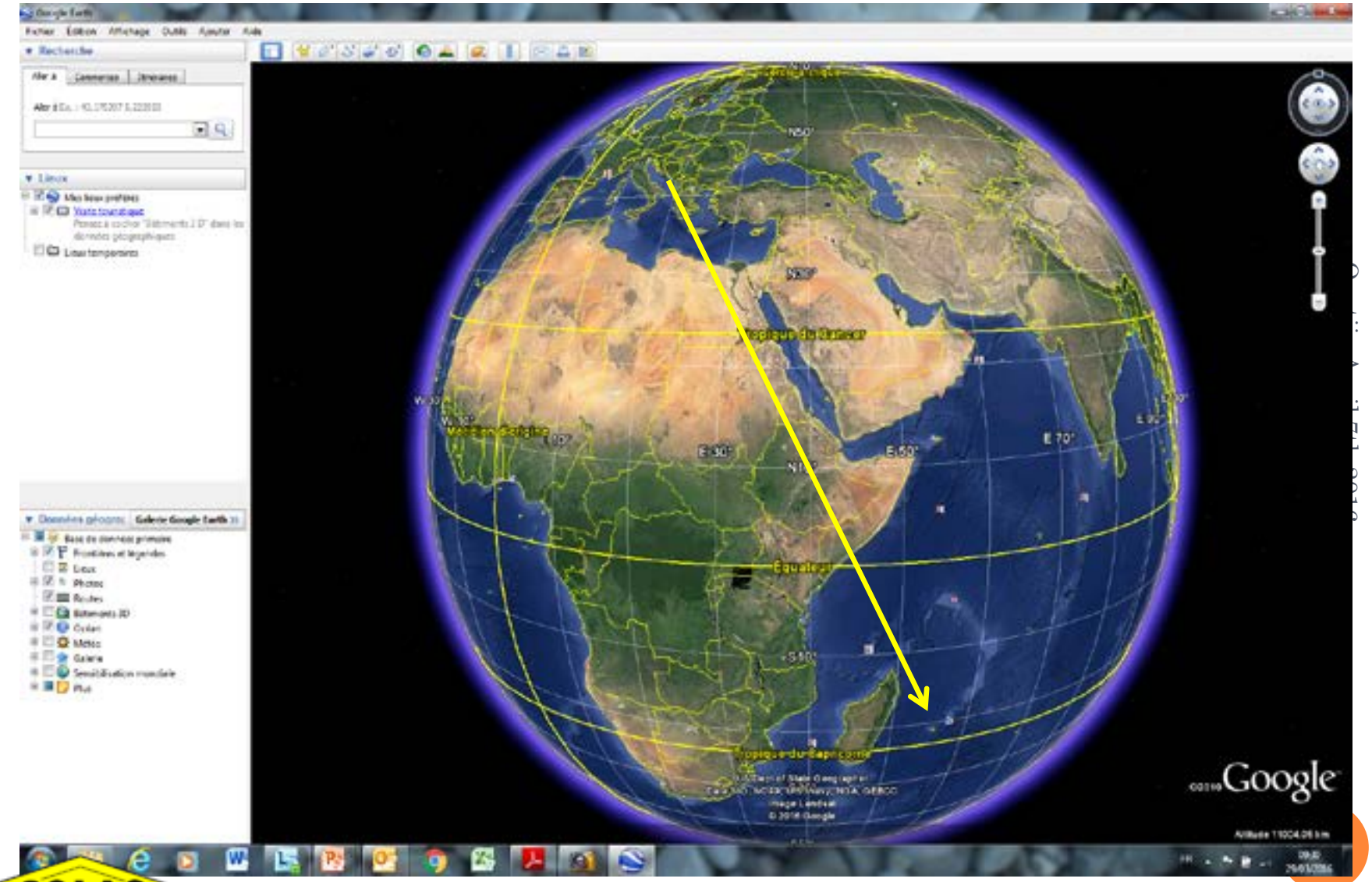
Road base asphalt : 21 cm

EME: 15 cm

- 29%

Pavement design: road pavements

- In France, EME is a commonly used technique
- A technique that is used for both new construction and strengthening works
- The main difficulty is to source appropriate bitumen at an acceptable cost
- A major site: the « tamarin road » in the Réunion Island (Indian Ocean)


Tropique du Cancer
Équateur
Tropique du Capricorne
Méridien de Greenwich
E 30°
E 50°
E 70°
©2016 Google

Pavement design: road pavements

- A major (and exotic) reference: the « tamarin road » in the Réunion Island (Indian Ocean)
  - 200,000 T of EME
  - Basaltic local aggregates (high specific gravity)
  - Impact of the porosity: part of the bitumen is not « active »
  - B 20/30 from Engen (South Africa)
  - Impact of the binder content
    - 5.8%: 128 µs
    - 6.2%: 132 µs

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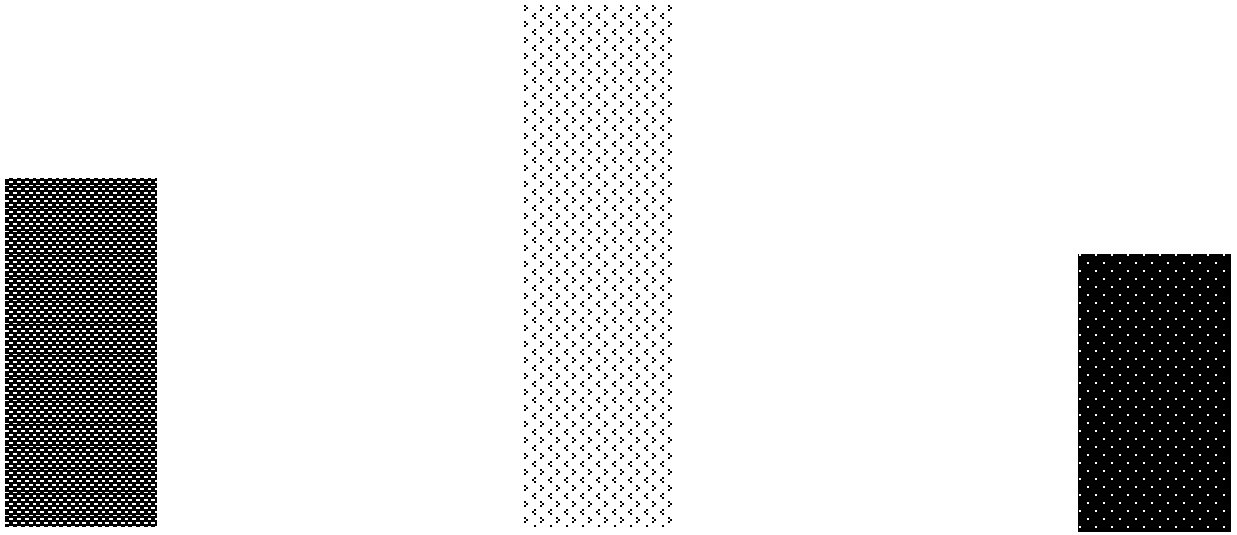
Pavement design: airports

- In France, airport pavement design has been based on the use of structural numbers
- Structural numbers:
  - Bituminous concrete 2.0
  - Road base asphalt (GB) 1.5
  - Crushed graded material 1.0 (reference)
- Structural numbers for « new » materials
  - EME 1.9
  - BBME 2.5

Pavement design: airports

- Road base asphalt (GB) 1.5
- EME 1.9

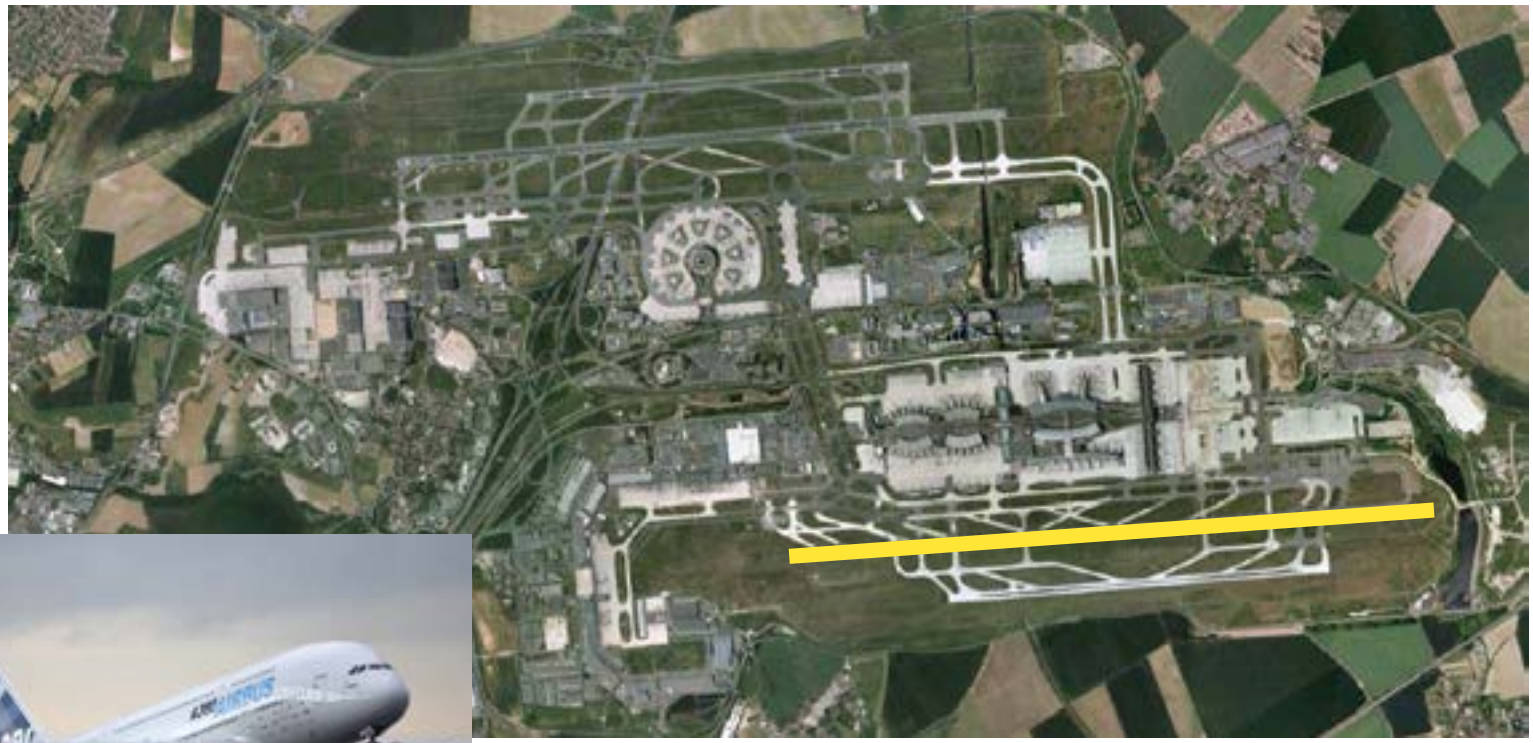
GB Crushed graded material EME



10 cm x 1.5 = 15 cm : 1.9 = 7.9 cm

Pavement design: airports

- Use on CDG (Paris) airport in 2002: runway 2



Pavement design: airports

- An existing concrete pavement
- Pavement design:
  - Linking concrete slabs
  - 2 cm SAMI: PMB sand asphalt
  - 7 cm EME (B20/30)
  - 6 cm BBME (PMB) high modulus asphalt concrete

Manufacturing and placing

- Nothing very specific compared to conventional asphalt mixes
- Manufacturing temperature: 160 to 190°C
- Placing and compaction:
  - High bitumen content may lead to fating up
  - Specific care to the joints
  - The use of RAP eases compaction
  - Aim a low void content (spec: < 6%)


Manufacturing and placing

- First warm EME has been used in Dec. 2007 (city of Meaux)
- Morning temperature: -1°C
- Manufacturing temperature: 140°C

Manufacturing and placing

- A (warm) thin overlay was placed on the EME base course

Developments (outside France)

- Preliminary remark:
- Pavement design methods vary (empirical, rationnal, combination)
- Testing methods vary
- Local conditions vary
  - Temperature, axle load, traffic

Developments (outside France)

- Example: modulus assessment

Sinusoidal dynamic deflection

Impulsion

Direct Tension

Appendix A
15°C 10 Hz
2 PB-TR

Appendix B
20°C 8Hz
3-4 PB-PR

Appendix C
20°C 124ms
IT-CY

Appendix D
15°C 0.02s
DTC-CY

Correlation between value

Developments (outside France)

- Local assessment needs to be made:
  - Testing methods
  - Performances
- Example in South Africa: testing methods

Table 1: French performance tests and selected South African equivalents

Parameter	French test method	Selected South African equivalent
Workability	EN 12697 - 31: Gyratory compactor	ASTM D6926: SUPERPAVE gyratory compacor
Durability	EN 12697 - 12: Duriez test	ASTM D4867: Modified Lottmann test
Permanent deformation	EN 12697 - 22: Wheel tracker	AASHTO 320-03 SUPERPAVE shear test
Dynamic modulus	EN 12697 - 26: Flexural beam	AASHTO TP 62 dynamic modulus

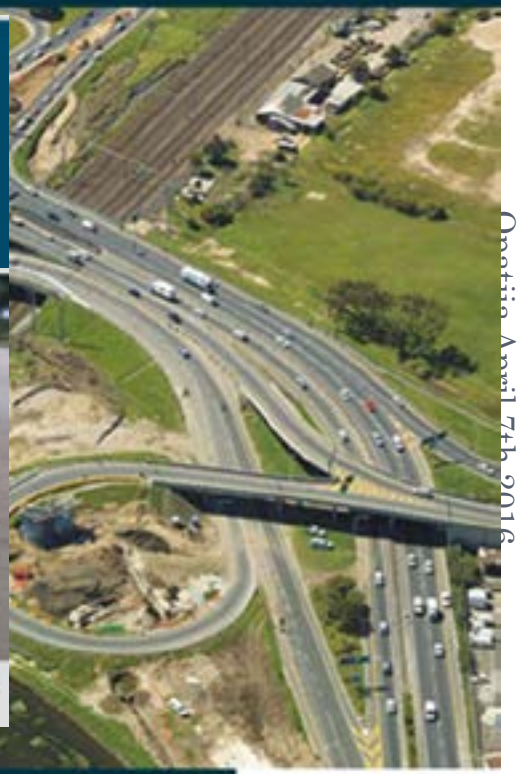
Developments (ou

asphaltNEWS

Latest tests confirm outstanding durability characteristics of high modulus asphalt

Figure 1(a). Severe rutting caused by heavy vehicles

Figure 1(b). Current condition of the trial section



August 2013

Workability	after 45 gyrations			
Moisture sensitivity	Modified Lottman			
Permanent deformation	RSST-CH, 55C, 5á000 repititions			
ic modulus	Dynamic modulus test at 10Hz 15°C			
Fatigue	Beam fatigue test at 10 Hz, 10C, to 70% stiffness reduction		repetitions	repetitions

COLAS

sabita

excellence in bituminous products

Quattro, April 7th, 2016

Developments (outside France)

- Local assessment needs to be made:
  - Pavement design
- Example in the United Kingdom

DESIGN MANUAL FOR ROADS AND BRIDGES HD 26/06

THE HIGHWAYS AGENCY

SCOTTISH EXECUTIVE

WELSH ASSEMBLY GOVERNMENT
LLYWODRAETH CYNULLIAD CYMRU

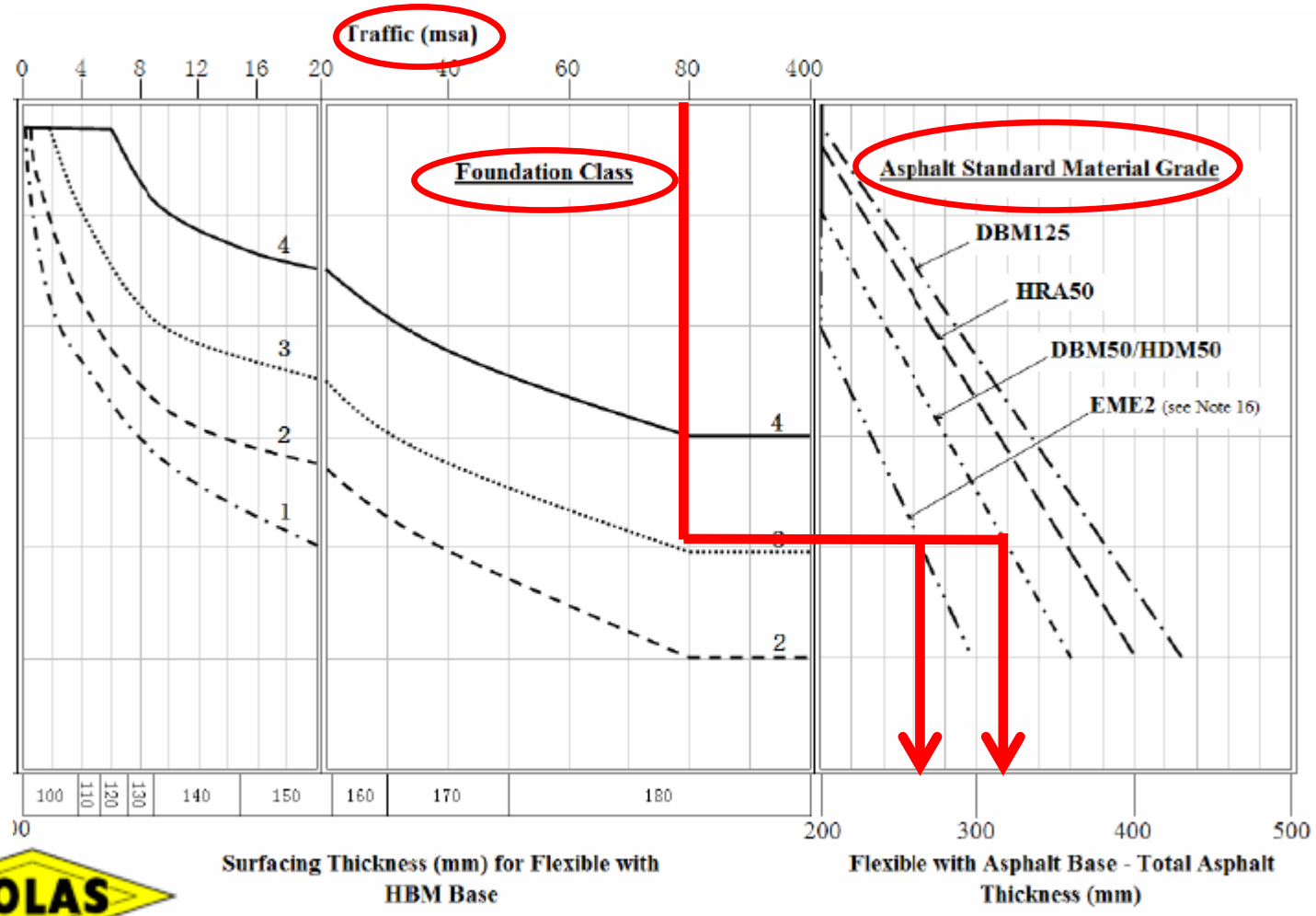
Llywodraeth Cynulliad Cymru
Welsh Assembly Government

DRD
Department for Regional Development
www.drdni.gov.uk

THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

Pavement Design

Developments (outside France)



Same Traffic and subgrade

DBM50 : 320 mm

EME 2 : 260 mm

- 60 mm

Developments (outside France)

- Poland
- Morocco
  - First worksite in 2000
  - Often used on highways
  - Mix design includes RAP 25%
- Australia
- Mauritius

LETTRE INTERNE D'INFORMATIONS TECHNIQUES

TECH-NEWS

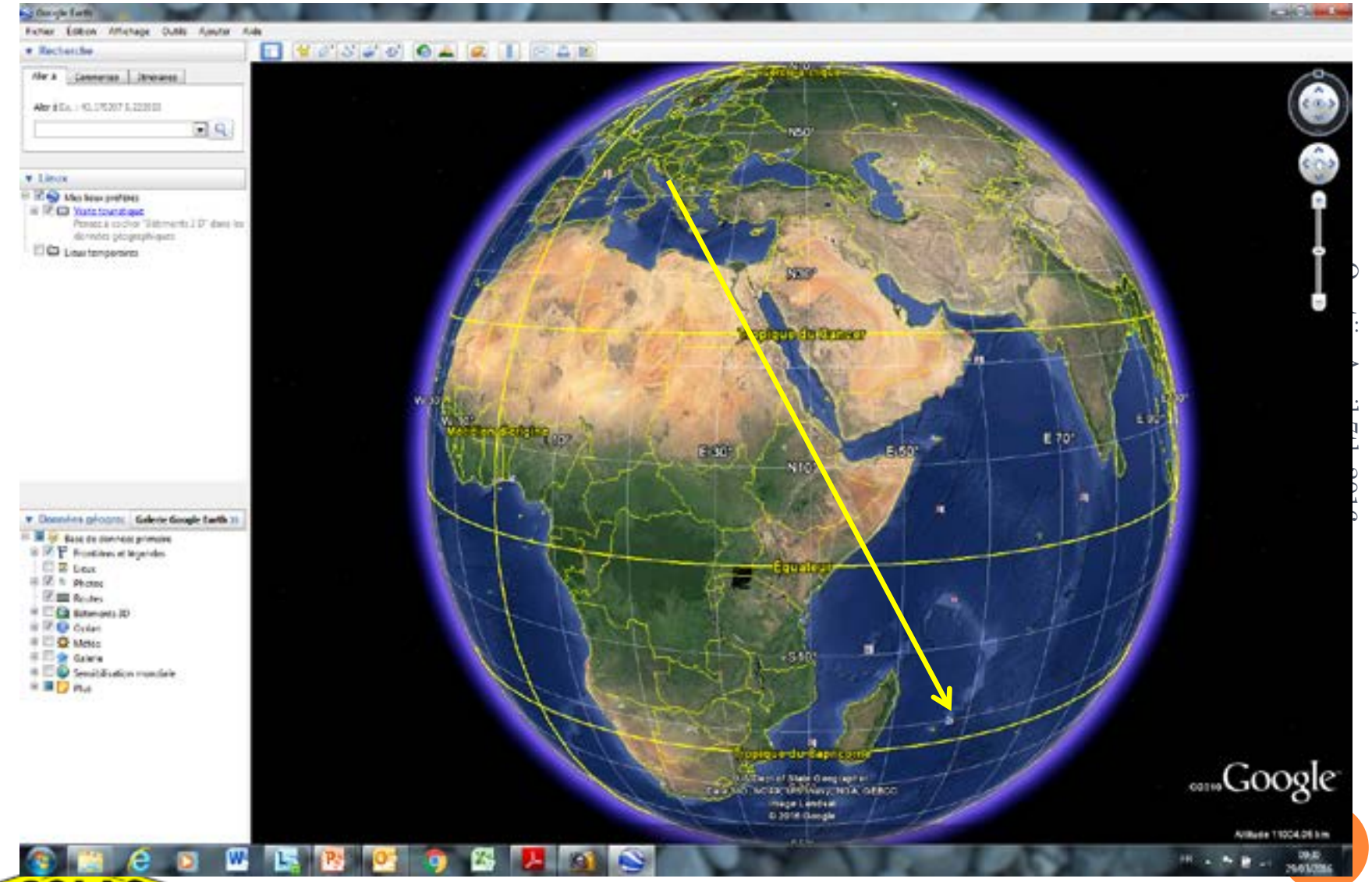
FRENCH PAVEMENT STRENGTHENING IN POLAND

In order to straighten the National Road n° 2 on a 9 km long stretch (expressway from Berlin to Warsaw, section Swiecko-Strzyzewo), Strada, a Polish subsidiary of Colas, obtained the approval of the General Direction of Roads and Motorways to implement an alternative pavement structure composed of COLBASE 0/16 and RUFLEX 0/11.

The works (20,000 tons of hot mix asphalt) were executed in November 2002, weather permitting.

This jobsite stands as a significant reference in view of the future improvement of the Polish national road network requested to comply with european standards.
It follows the important development of the group technologies (including COLBASE, RUFLEX, COLSOFT) performed for the city of Poznan since 1999.

In the single year 2002, 0-1,000 tons of patented Colas hot mixes have been laid by STRADA in the vicinity of Poznan.


Google
COLAS

Developments (outside France)

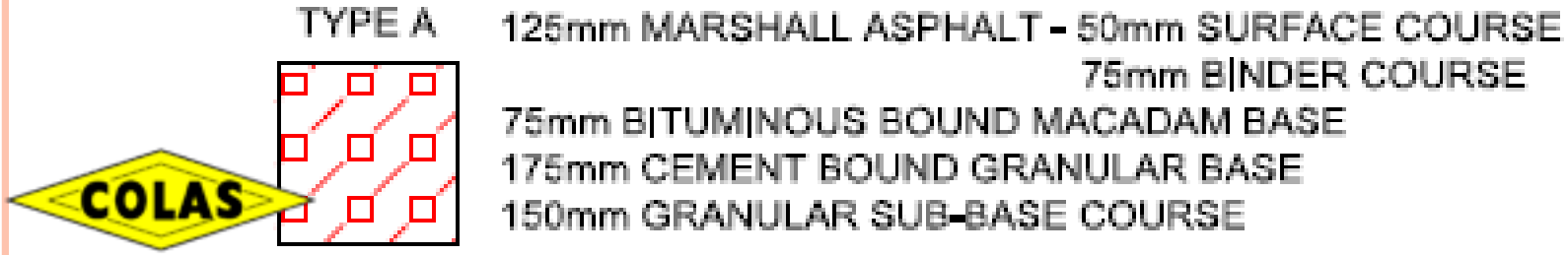
- Mauritius
  - Several road projects since 2010
    - Triolet bypass

Developments (outside France)

- Mauritius
  - SSR international airport

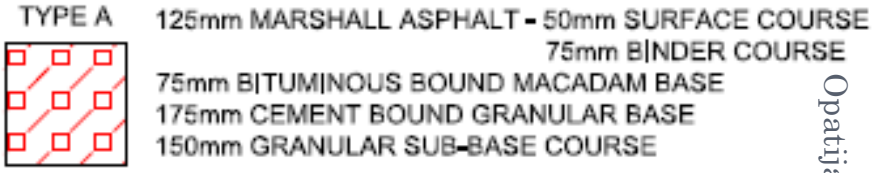
Developments (outside France)

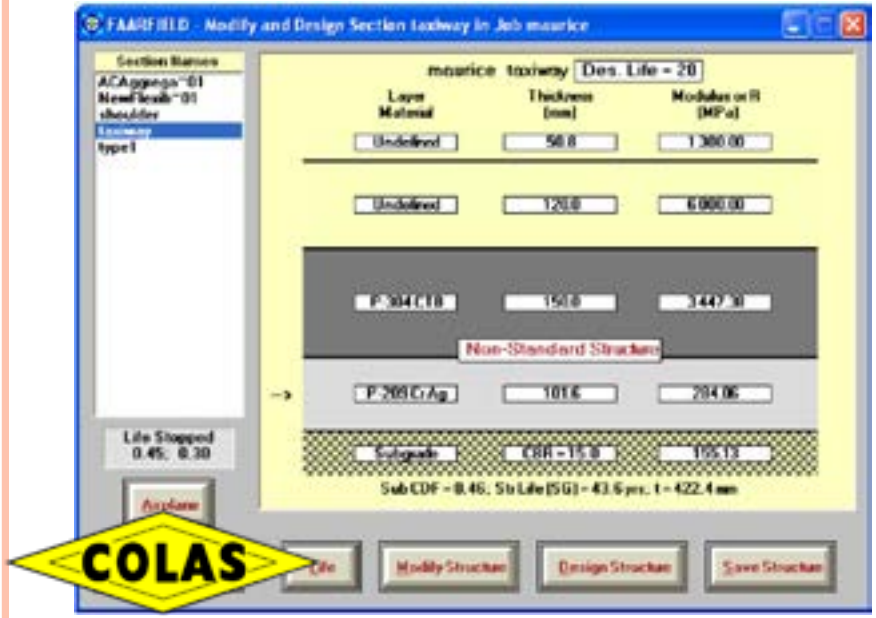
- Mauritius
  - SSR international airport
- Runway overlay and parallel taxiway works
  - Owner: Airports of Mauritius
  - Engineer: Jacobs (UUK) and Gibb (Mauritius)
- Design system: FAARFIELD
- Alternatives main goal: to save materials
- Basic design (new taxiway)

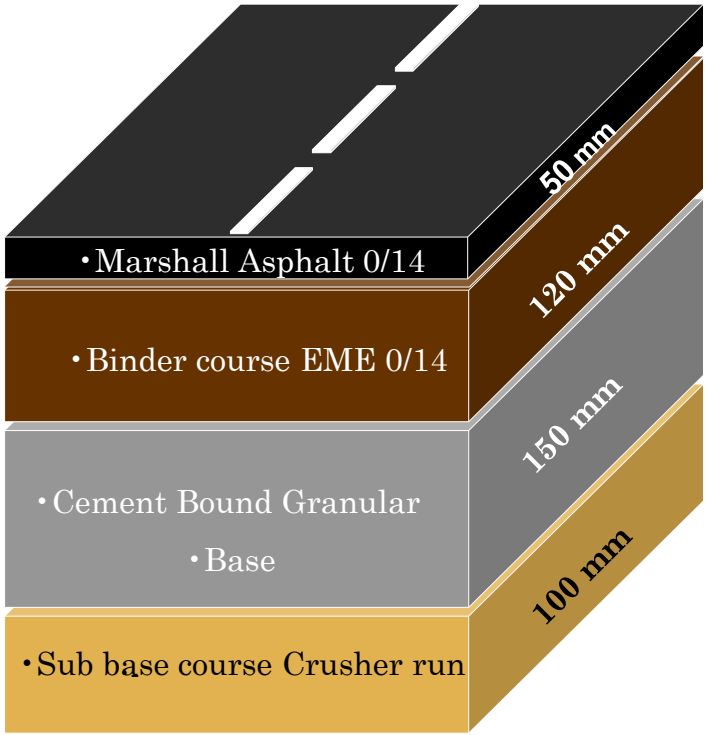


Developments (outside France)

- Basic design (new taxiway)
- Alternative design
  - 105 mm thickness saving







Conclusions

- EME is a fully reliable technique that has been used for more than 20 years
- Developments outside France have confirmed its efficiency
- The selection of the right binder is a crucial issue
- Development should include a careful study of its mechanical characteristics, to be used in the pavement design model
- All of you are more than welcome to visit our main lab facilities and worksites in progress