ISAP TC APE
Use of RAP in Pavement Recycling A Global Perspective

Kim Jenkins

ISAP WG2 Meeting Kuala Lumpur, Malaysia

9th October 2010

Stellenbosch

THE SOUTH AFRICAN NATIONAL ROADS AGENCY LTD

Minutes from TRB 2010: ISAP TC Asphalt Pavement and Environment

- WG1 on Recycling (Chantal de la Roche)

WG1

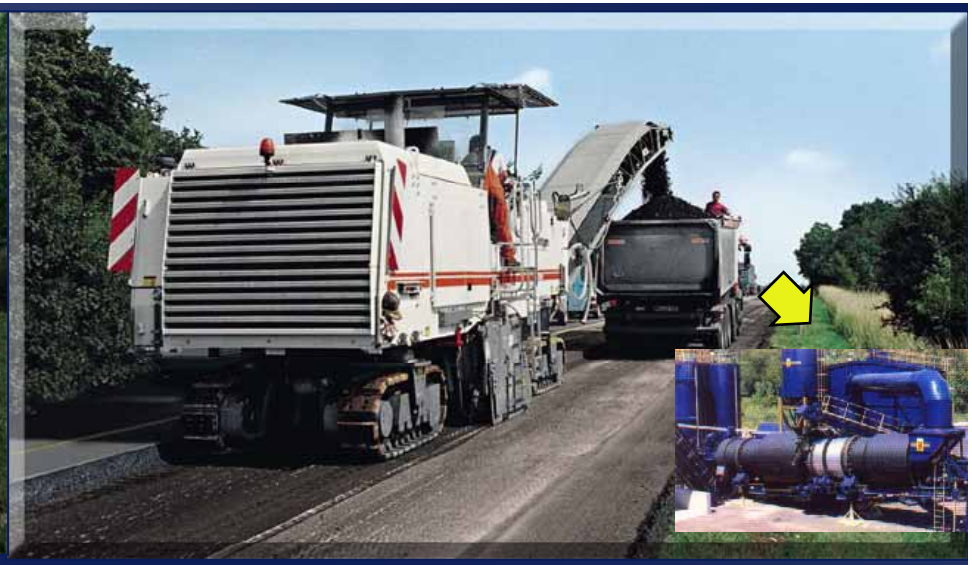
Hot Recycling-RAP

(Peter Sebaaly)

WG2

Cold Recycling-RAP

(Kim Jenkins)



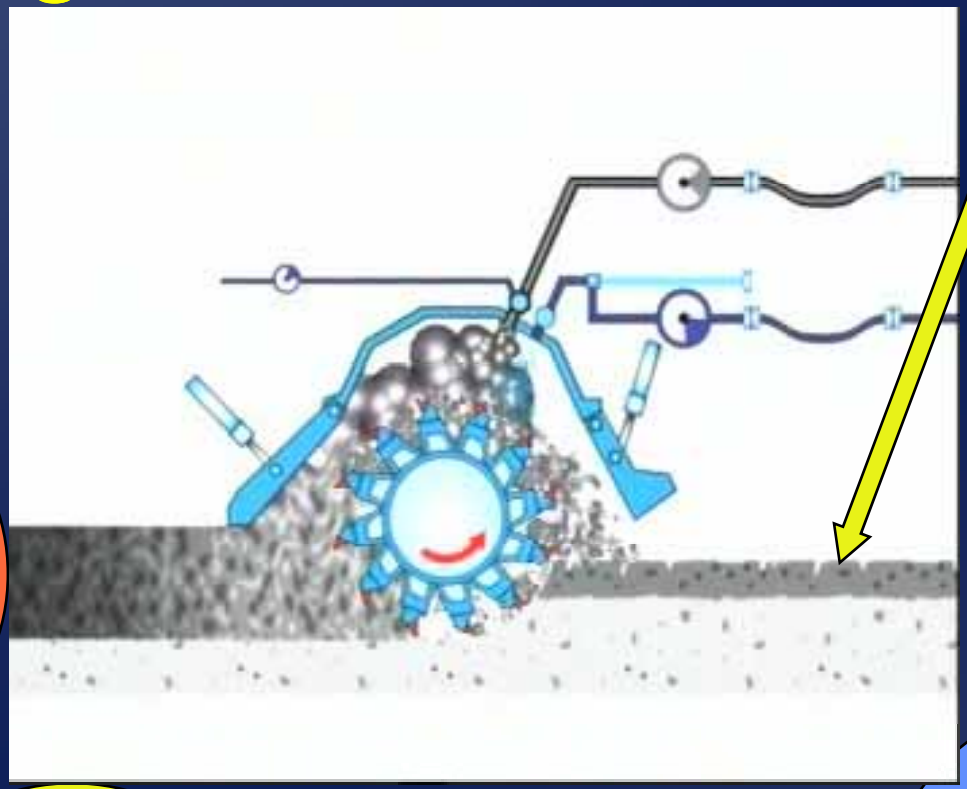
In Place

Hot

Cold

In Plant

Recycling with RAP: How much RAP?



Granular and RAP Materials

Aggregate

Bitumen Emulsion

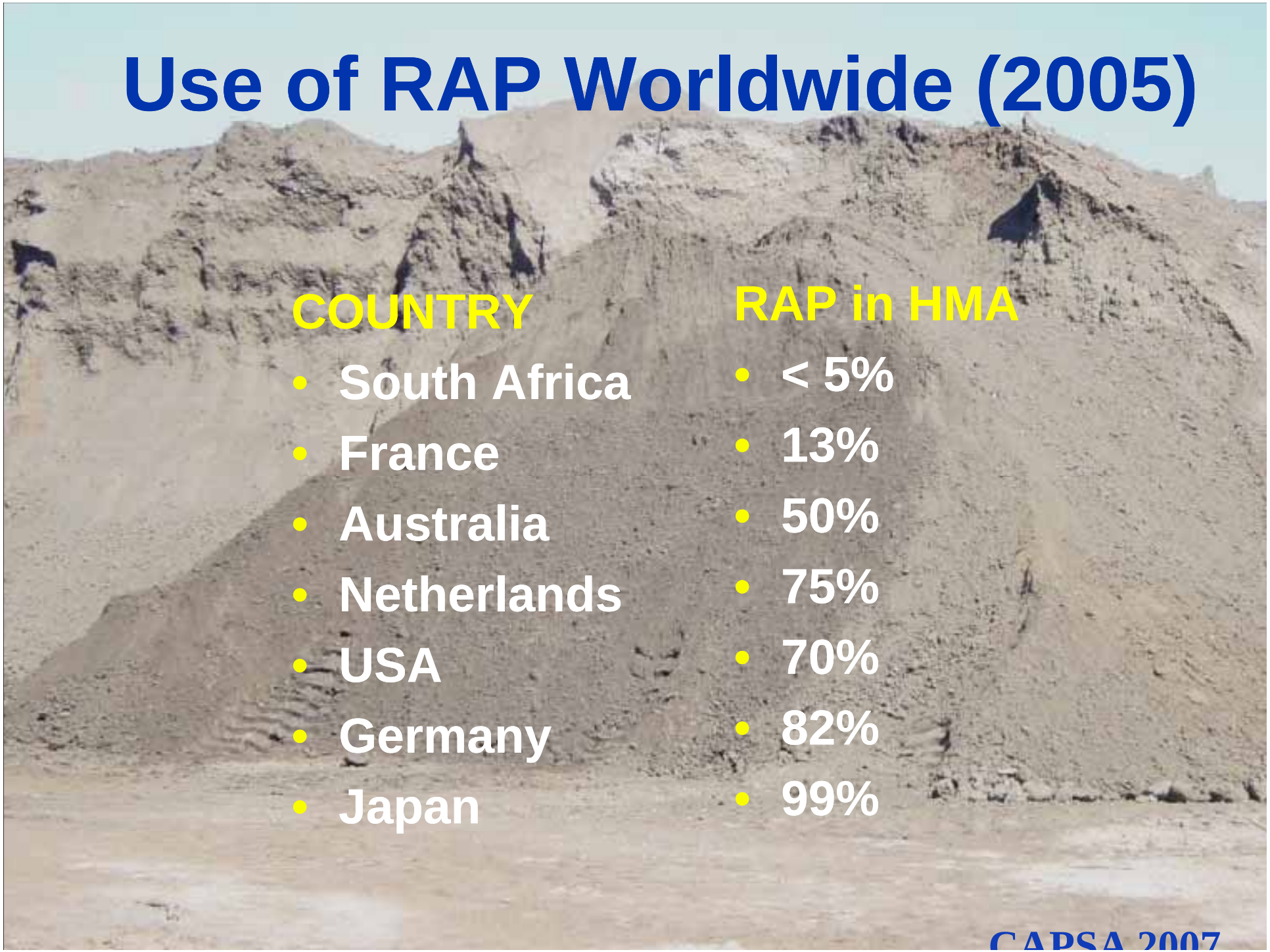
Chemical Additives

Active Filler

Foamed Bitumen

A GLOBAL PERSPECTIVE ON RAP AND RECYCLING

Use of RAP Worldwide (2005)

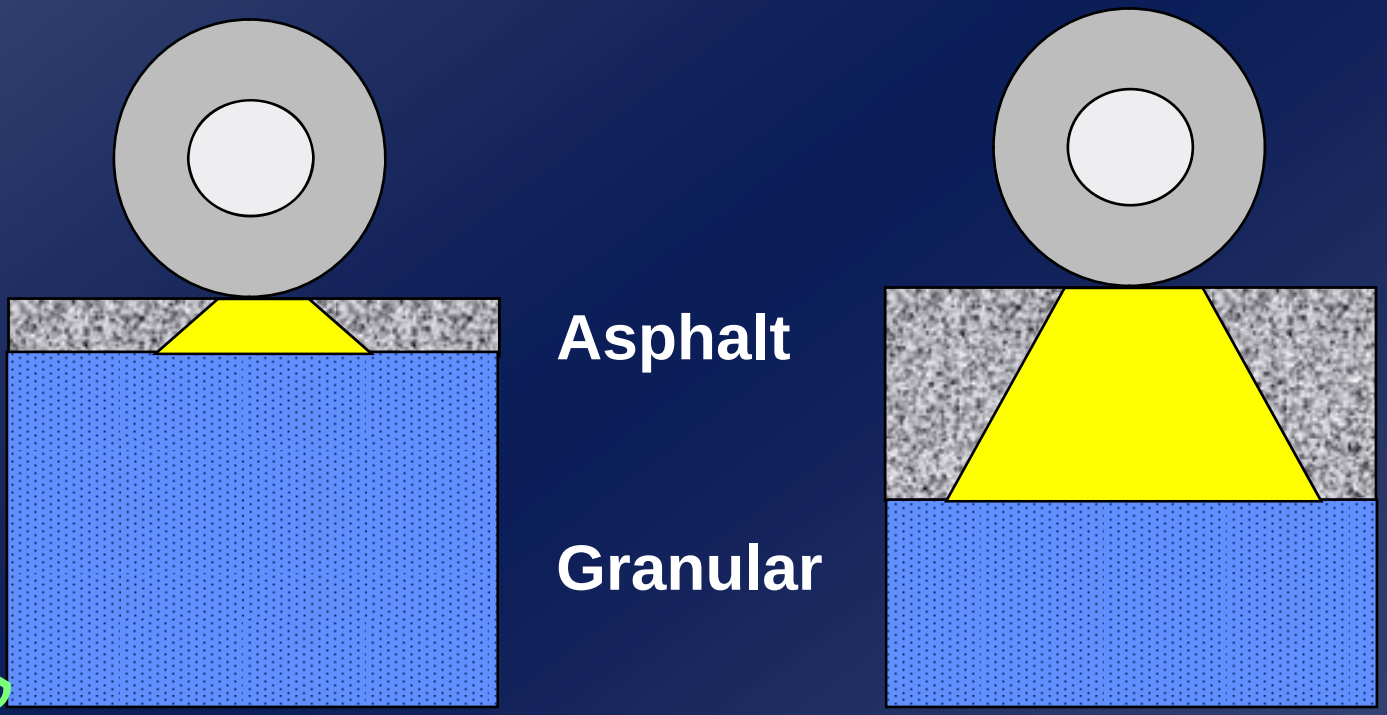


COUNTRY	RAP in HMA
South Africa	< 5%
France	13%
Australia	50%
Netherlands	75%
USA	70%
Germany	82%
Japan	99%

Asphalt layer thickness

Developing world
+ light traffic

EU, USA, China
+ heavy traffic



RECYCLING

Thin asphalt

RAP:Granular blends

Thick asphalt

100% RAP common

EUROPE

Re-use of asphalt in Europe (2009)

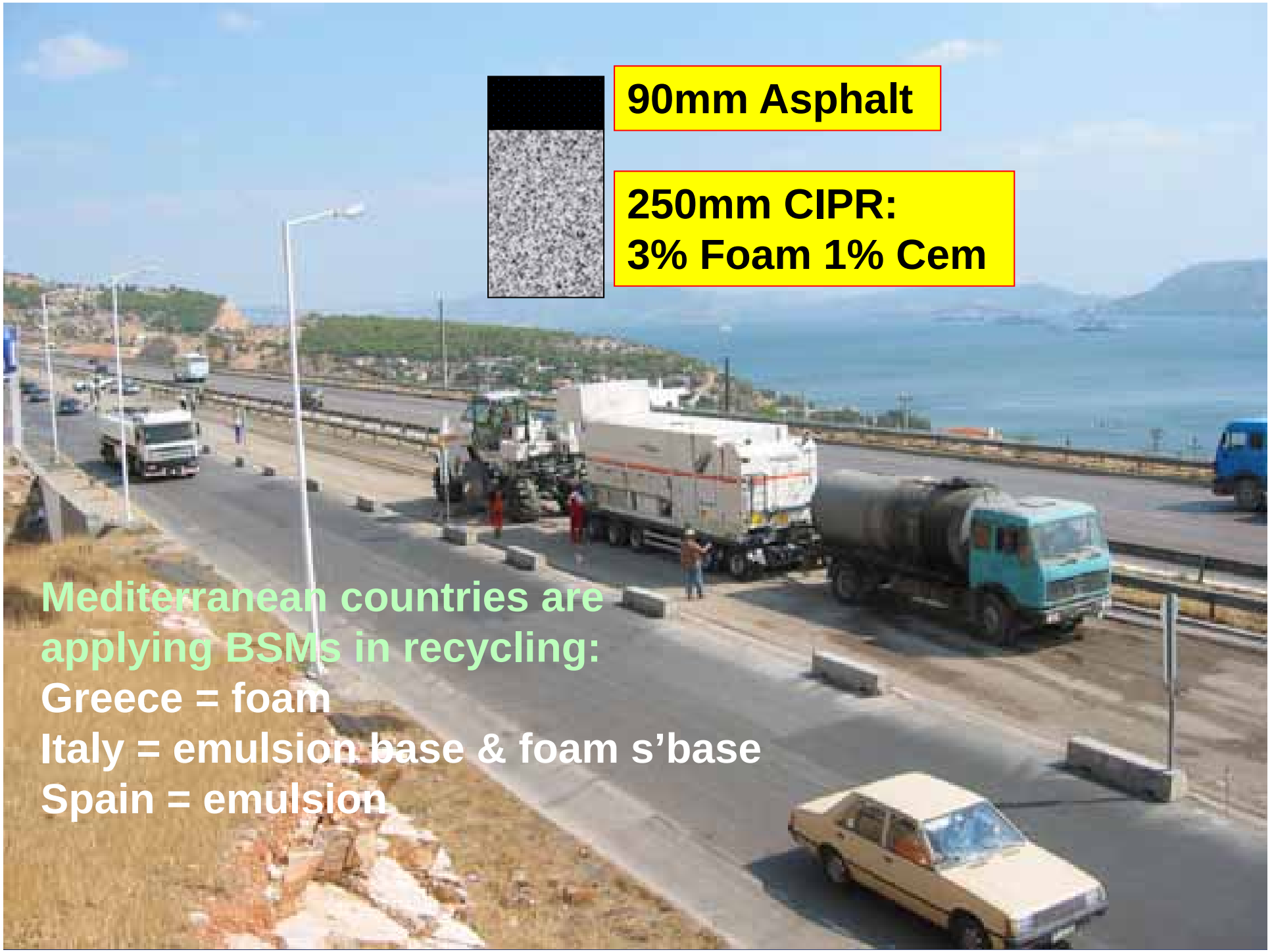
Country	Available RAP (ton)	Re-used HOT (%)	Re-used COLD (%)	%New HMA production
Germany	$14 * 10^6$	82	18	60
Spain	$2.25 * 10^6$	8	4	3.5
Italy	$14 * 10^6$	18	2	
France	$6.5 * 10^6$	13	< 2	< 10
Norway	$0.59 * 10^6$	7	26	8
Netherland	$3 * 10^6$	75		63

(source: Molenaar)

EU Situation

- Re-use of old asphalt is a well developed technique; it is widely applied in a number of countries
- Re-use of old asphalt is not yet a general applied technique
- Re-use and recycling needs firm support and should be enforced by legislation

Molenaar observations


90mm Asphalt
250mm CIPR:
3% Foam 1% Cem
Mediterranean countries are applying BSMs in recycling:
Greece = foam
Italy = emulsion base & foam s'base
Spain = emulsion

Production of Aggregates in Europe (18 countries)

- 2800 million tonnes per year (≈ 50% crushed rock, ≈ 5% recycled aggregate, ≈ 45% gravel and sand)
- 2700 sites
- 1 km of road uses 30 000 tonnes per km

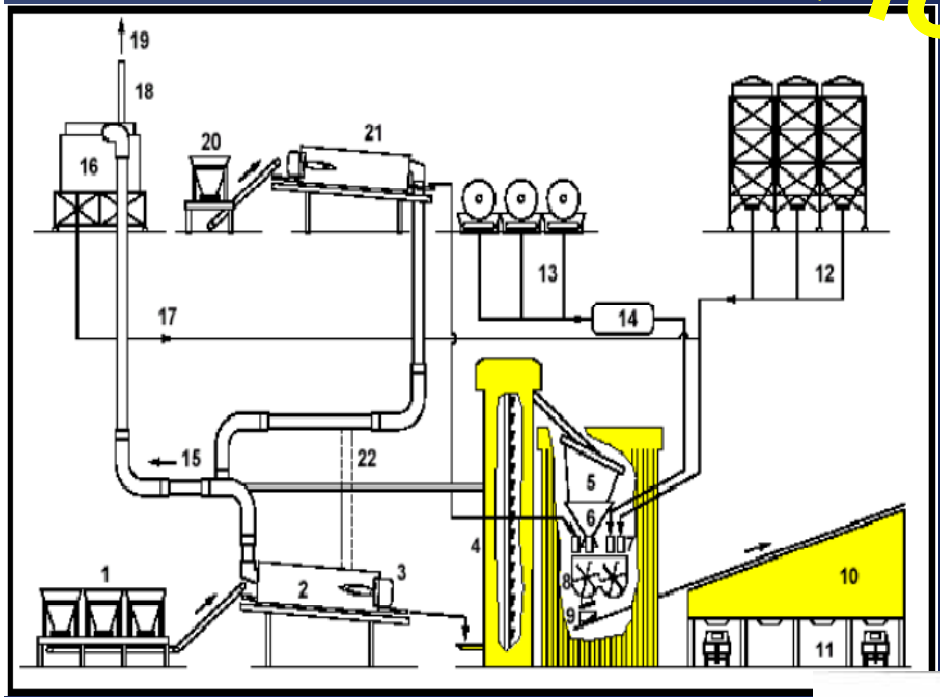
Germany	526	UK	257
Spain	438	Poland	148
France	402	Finland	98
Italy	358	Austria	95

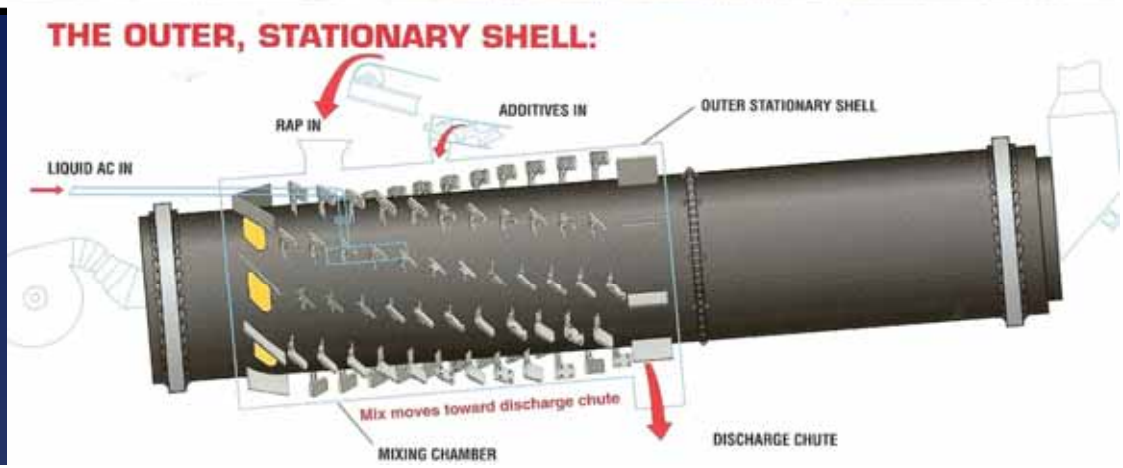
(source: European Aggregate Association)

Concrete and Masonry Recycling

- Re-use and recycling of e.g. concrete and masonry rubble is at embarrassing low level
- Some countries are really front runners; in the Netherlands 90% of the concrete/masonry rubble is recycled as base course for roads
- Much can be gained

Special developments needed for production with RAP

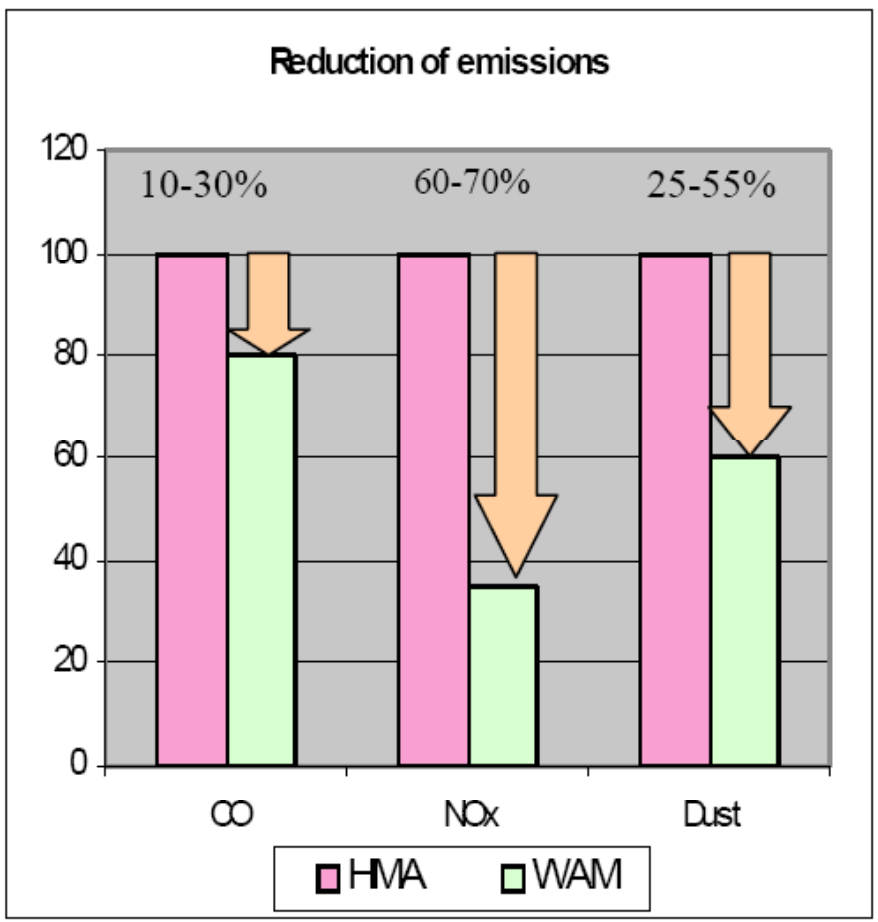


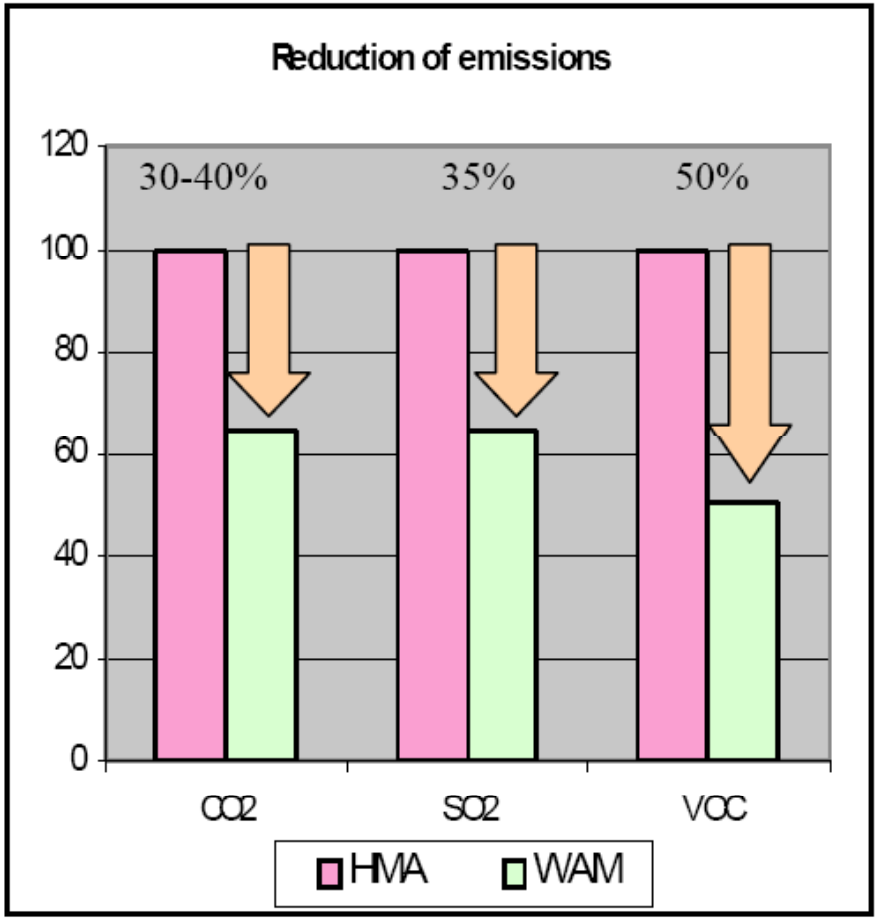


RAP mountains: huge logistical challenges

Changing Technologies helps Environment

Emissions at the Chimney



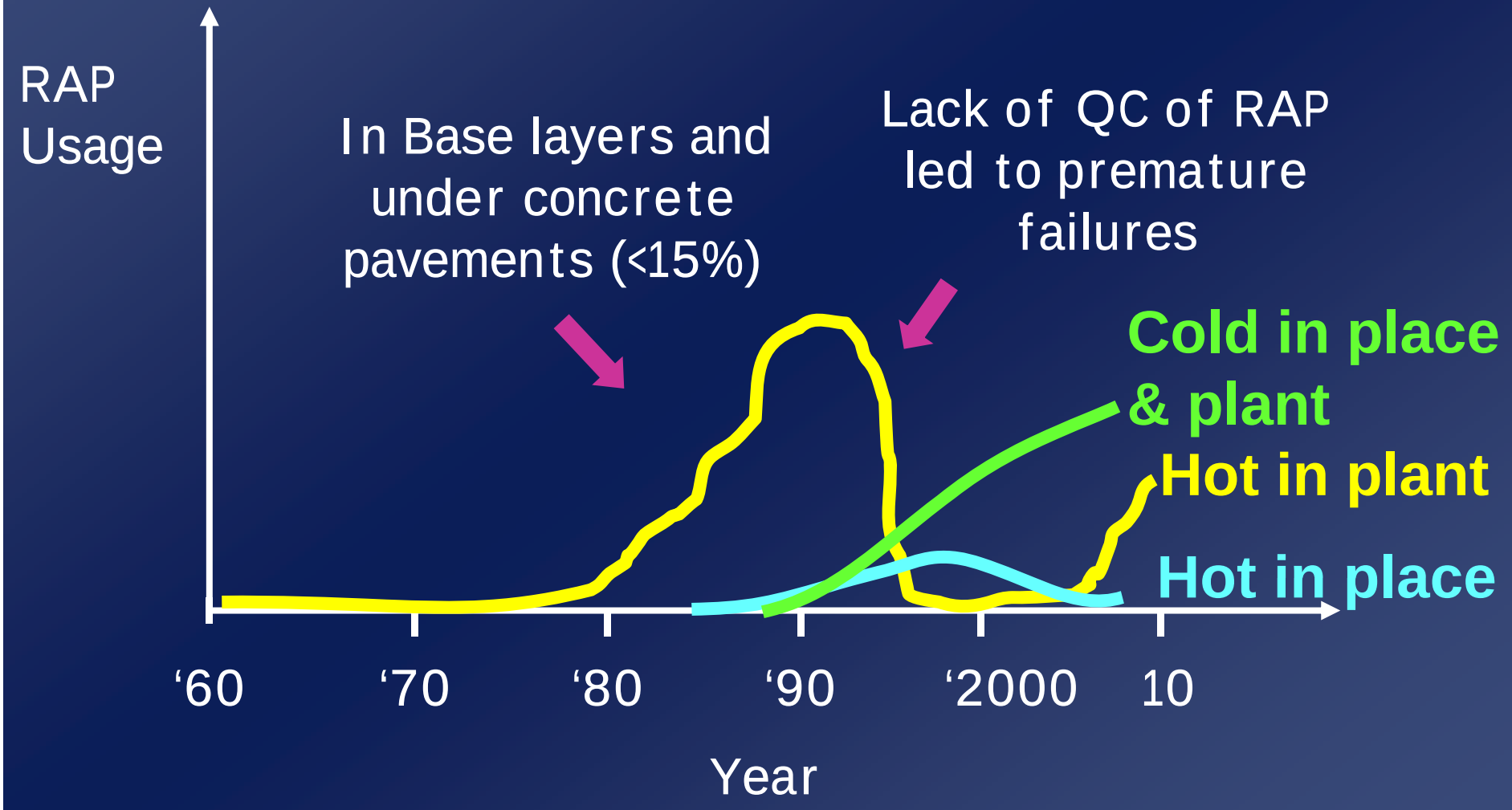


AFRICA

Barriers to recycling of RAP in many developing countries

- Lack of understanding (perceived to be low quality materials)
- Lack of specs/legislation
- Variability of HMA's in situ
- 80% of surfacing in SA = seals
- Economic benefits not realized (need legislation to enforce recycling then contractors will use it for competitive edge)

Evolution of RAP recycling in SA



Availability of RAP in South Africa

- Thick layers seldom used in RSA (only heavily trafficked ones)
- Type of RAP
  - 1960's to 70's = Gap graded RAP
  - 1970's to 90's = Semi-gap graded RAP
  - 1990's + = Continuously graded & PMBs

Mix Design in South Africa

- Recovered Pen, Tr&b and η if >15% RAP in new HMA
- Remember BC in RAP is higher in fines than coarse fraction
- Limits of RAP based on mix type
  - <2% in SMA <12% in PMA
    <18% in unmodified <23% in binder layer
    <27% in base

Manufacture limitations

Mixing Plant Type	Max RAP
• Batch plant	
– Added in pugmill	<15%
– Added before hot elevator	<30%
• Drum plant	
– Parallel heating	10 – 20%
– Contra-flow heating	20 – 30%
• Twin-dryer drum	<50%
• Double drum	<70%
• In plant & in place	<85%

HOT

COLD

TRH21

Some general values

- In South Africa, less than 5% of total RAP used in HMA (see comparative figures in Introduction ppt)
- Only 4 million tons of new HMA every year

BUT….

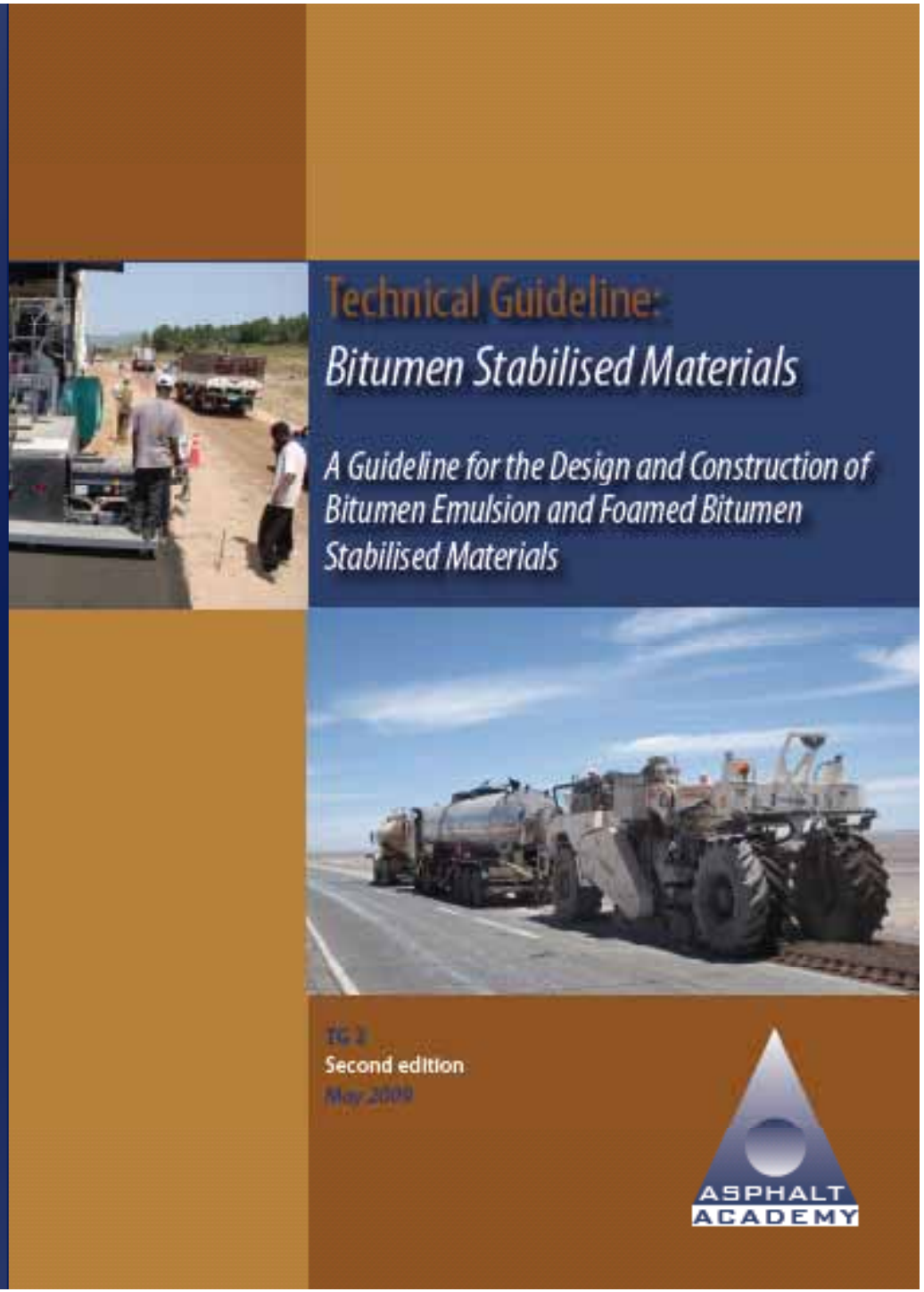
Significant progress has been made with technology guideline manuals in Africa!

BITUMEN STABILISED MATERIALS

TG2 : 2nd EDITION

Published in
South Africa
by
Asphalt Academy
(CSIR / SABITA)

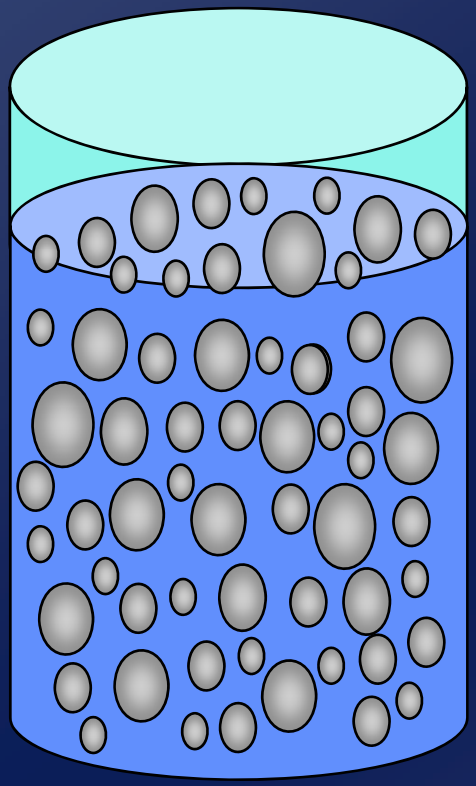
May 2009



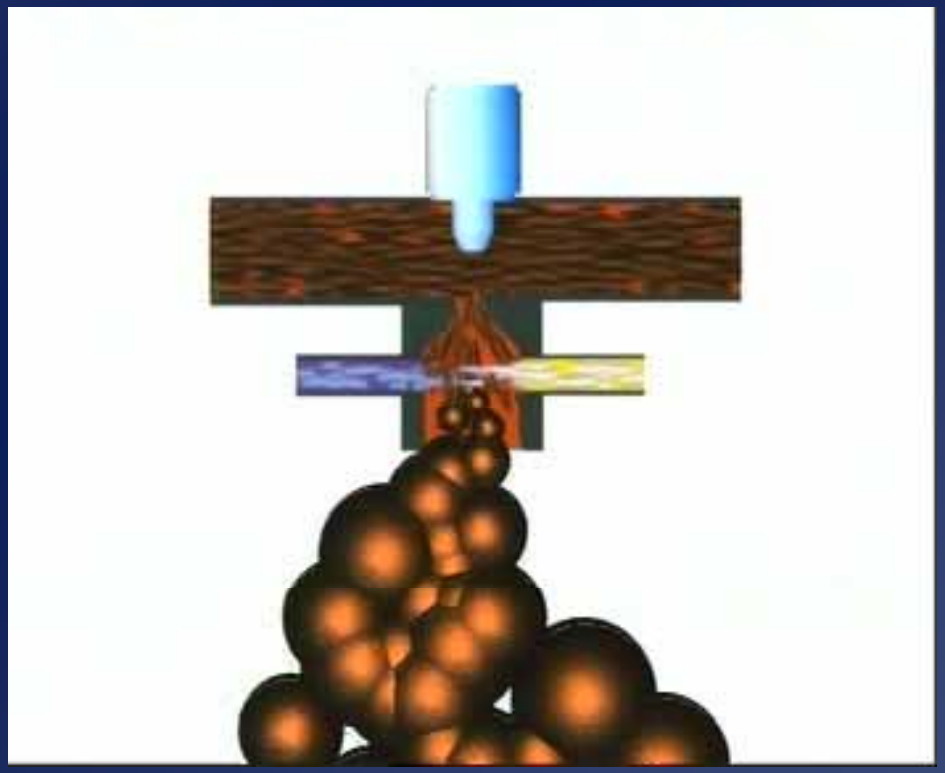
BSM BINDERS

EQUAL FOOTING

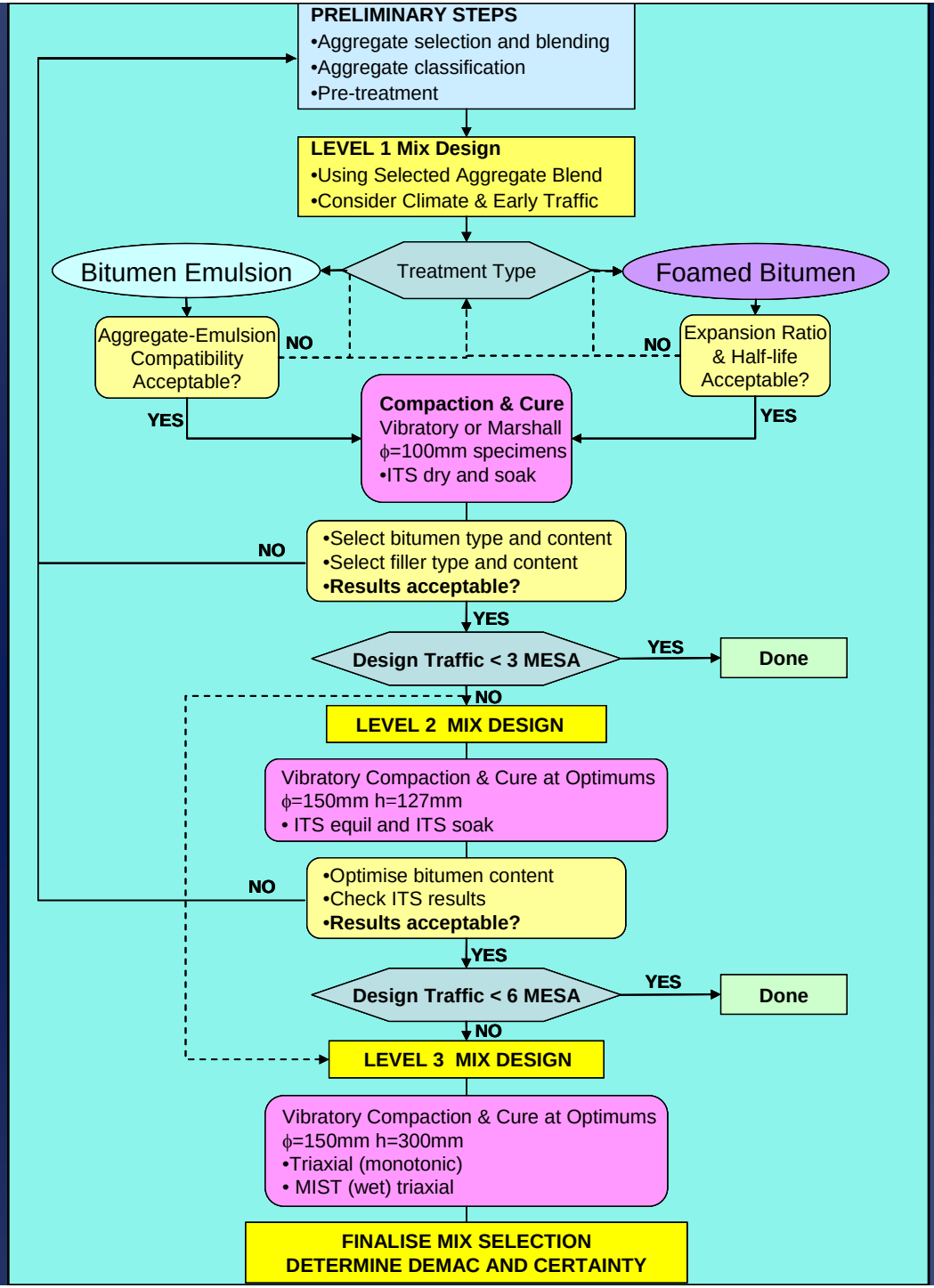
Emulsion



Foamed Bitumen

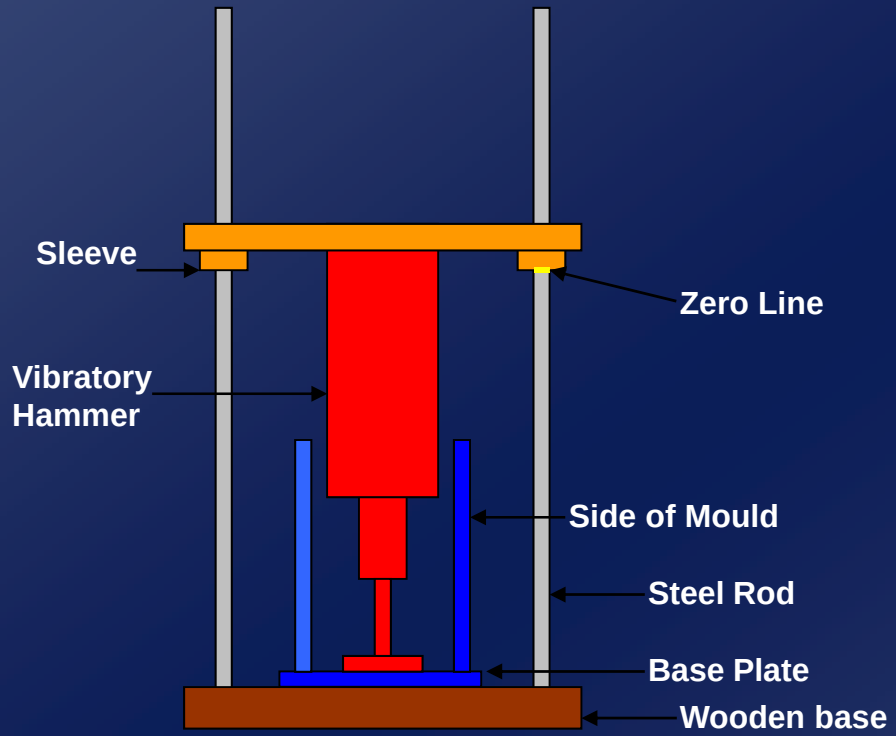


Mix Design


PRELIMINARY STEPS
•Aggregate selection and blending
•Aggregate classification
•Pre-treatment
LEVEL 1 Mix Design
•Using Selected Aggregate Blend
•Consider Climate & Early Traffic
Bitumen Emulsion
Treatment Type
Foamed Bitumen
Aggregate-Emulsion Compatibility Acceptable?
NO
NO
Expansion Ratio & Half-life Acceptable?
YES
YES
Compaction & Cure
Vibratory or Marshall
ϕ=100mm specimens
•ITS dry and soak
NO
•Select bitumen type and content
•Select filler type and content
•Results acceptable?
YES
Design Traffic < 3 MESA
YES
Done
NO
LEVEL 2 MIX DESIGN
Vibratory Compaction & Cure at Optimums
ϕ=150mm h=127mm
• ITS equil and ITS soak
NO
•Optimise bitumen content
•Check ITS results
•Results acceptable?
YES
Design Traffic < 6 MESA
YES
Done
NO
LEVEL 3 MIX DESIGN
Vibratory Compaction & Cure at Optimums
ϕ=150mm h=300mm
•Triaxial (monotonic)
• MIST (wet) triaxial
FINALISE MIX SELECTION
DETERMINE DEMAC AND CERTAINTY

Vibratory Compaction Hammer

To prepare specimens



Rear View of Frame

Kelfkens

(Simple) Triaxial Testing

τ

Shear stress

BSM_{equil}

ϕ Friction angle

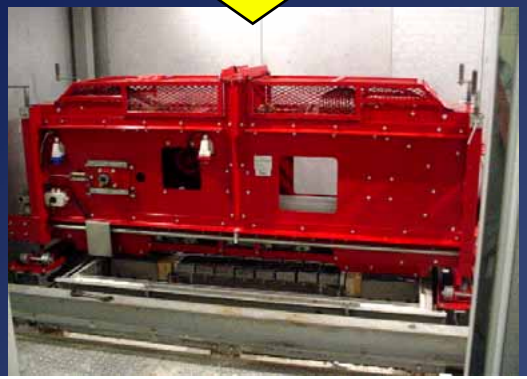
$BSM_{wet\ MIST}$

Effect of Moisture

C

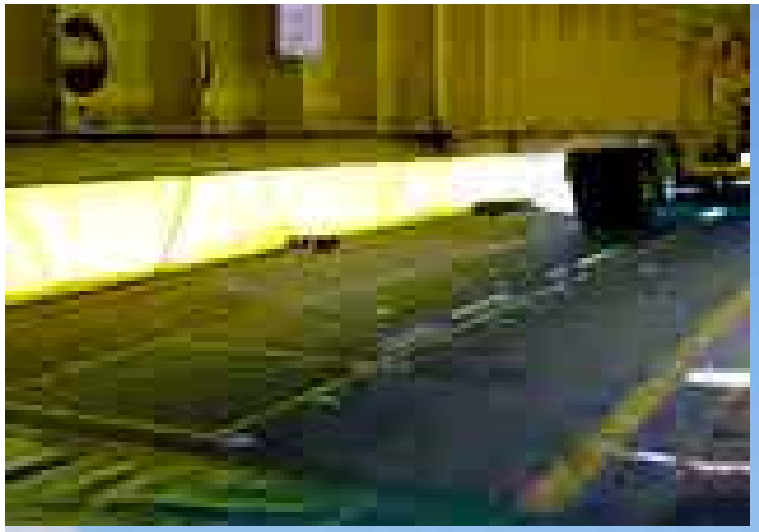
Cohesion

Lower Cohesion



σ

Normal stress



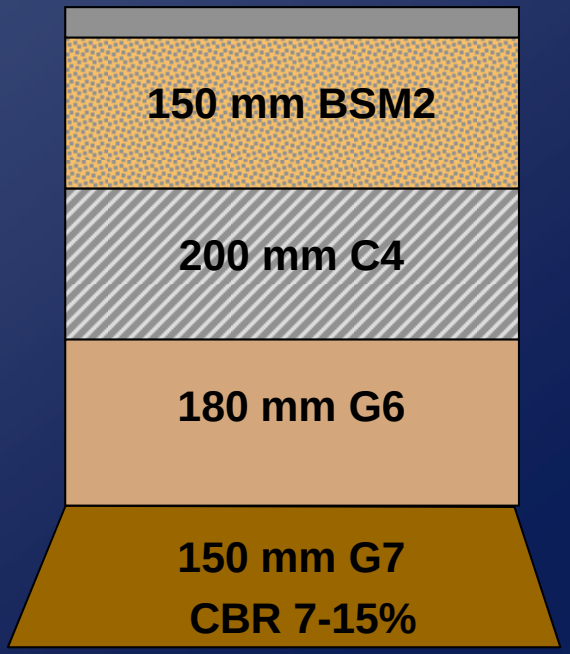
APT Tests: CIPR with Foamed Bitumen in Cape Town with HVS

PERMEABILITY

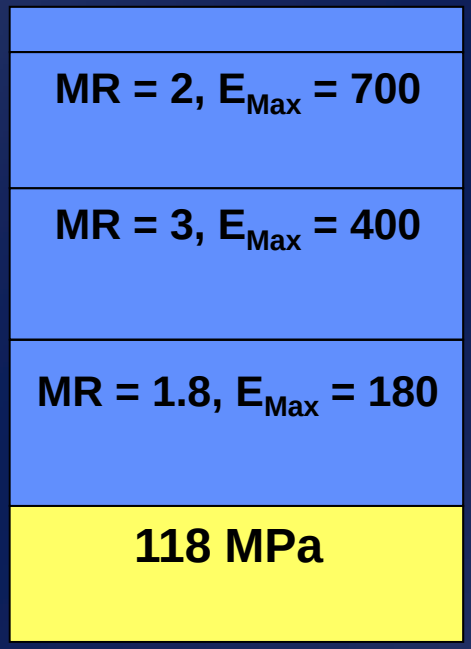
Water induction into 2.3% foamed bitumen stabilised base

Structural Design Methods

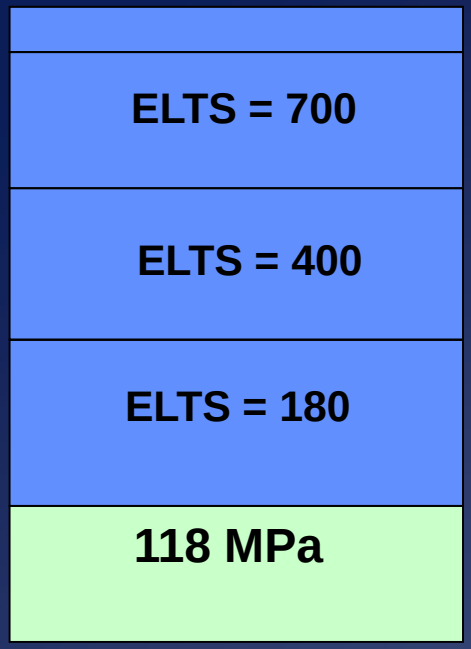
1. Material Classes



5. Assign modular ratio's and Maximum Emods



6. Calculate Layer ELTS Values



2. Determine subgrade stiffness (140 MPa)

3. Adjust for climate (126 MPa)

4. Adjust for cover (118 MPa)

6. ELTS = min ($E_{support}$*MR , Emax)

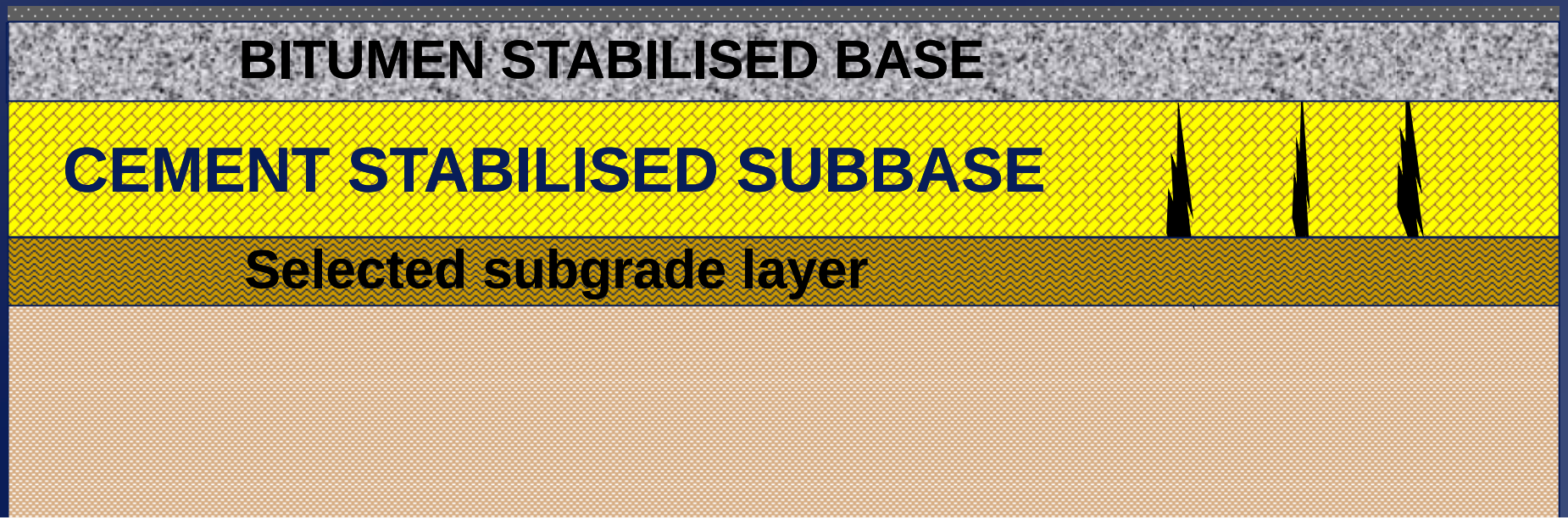
7. Layer PN = thickness * ELTS

8. PN = Σ layer PN

www.bitstab.roadrehab.com

The South African “upside-down” pavement

Applying the Recycled Layer



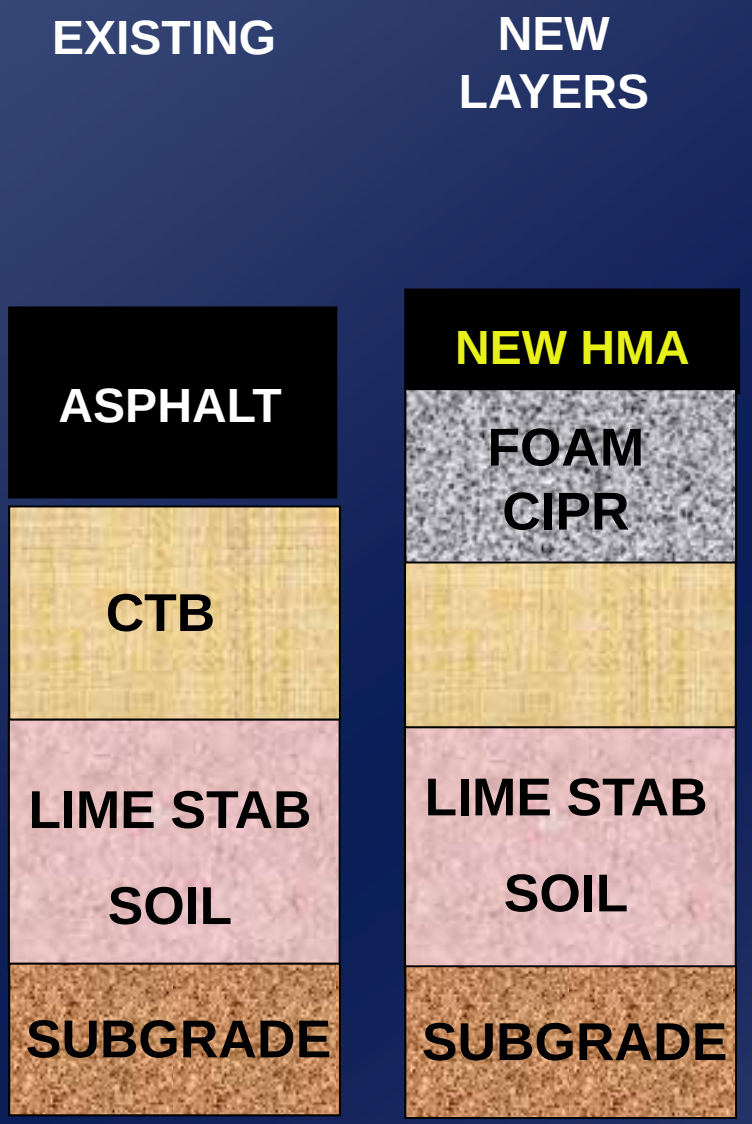
ASIA

Cold Recycled RAP
Xi’an, China

Top of Recycled Base

Surfacing

Expressway and Highway Rehab

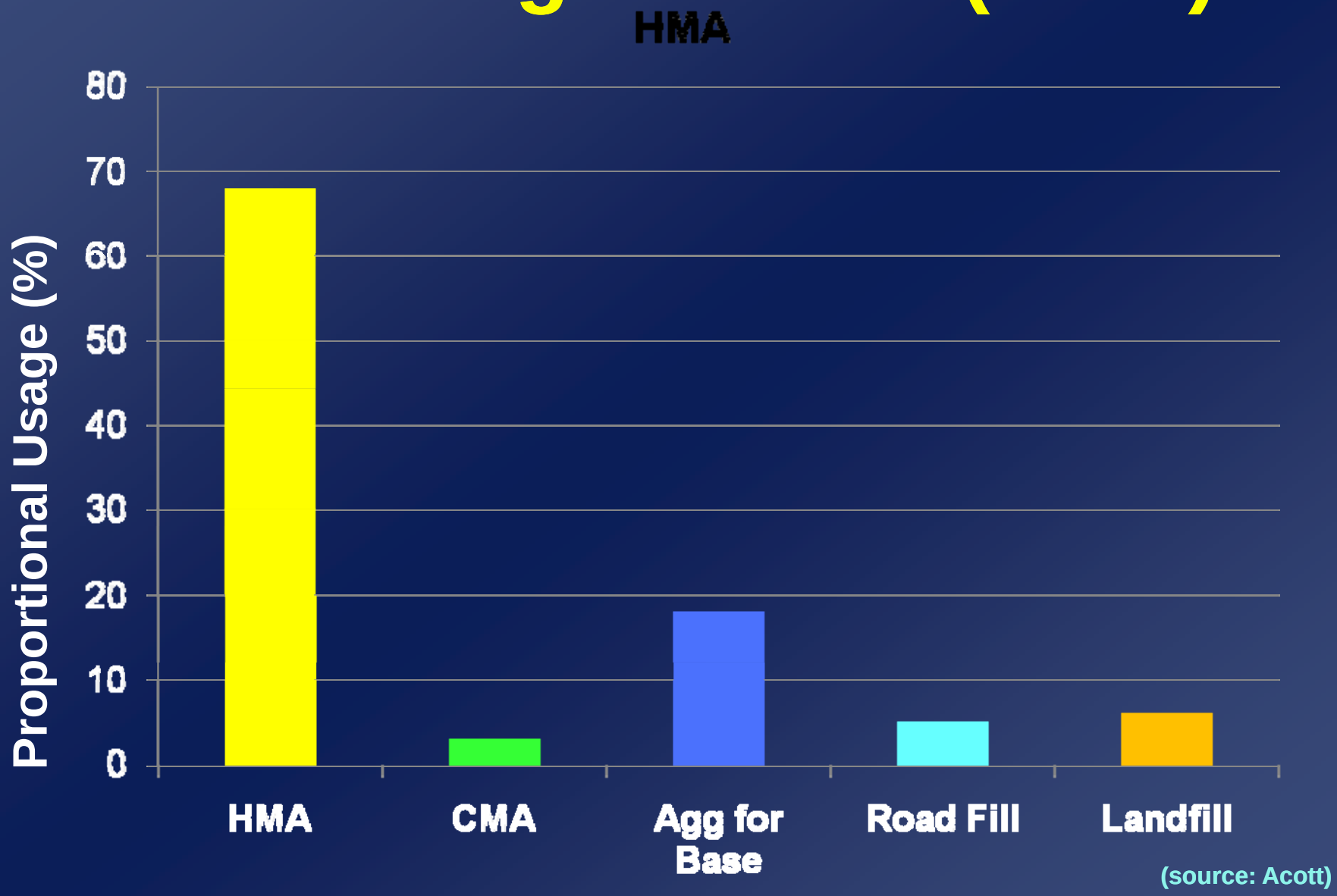


DISTRESS SOLVED?

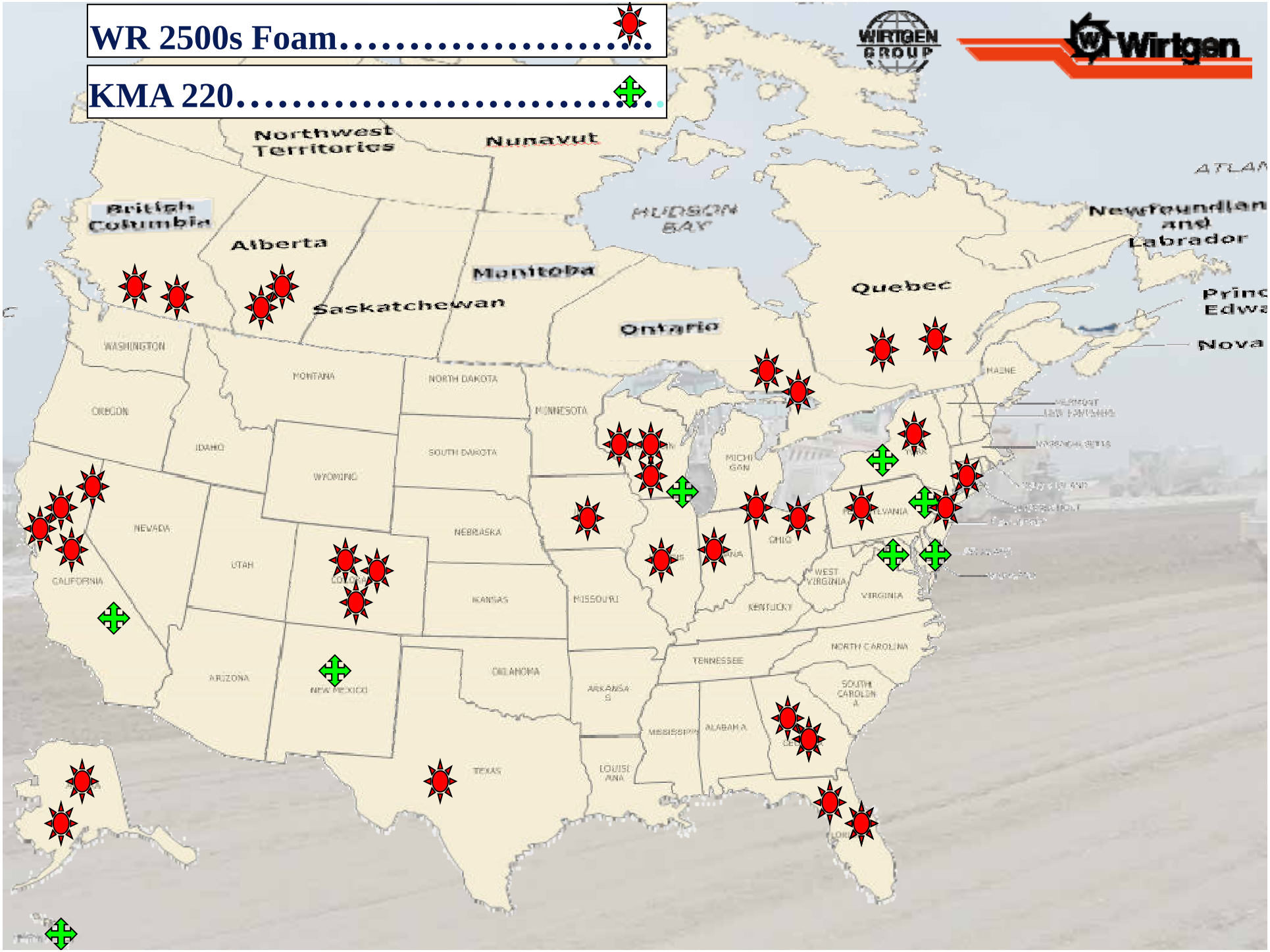
- Shoving ✓
- Rutting ✓
- Block cracking ✓

AMERICA

RAP usage in USA (2007)



(source: Acott)

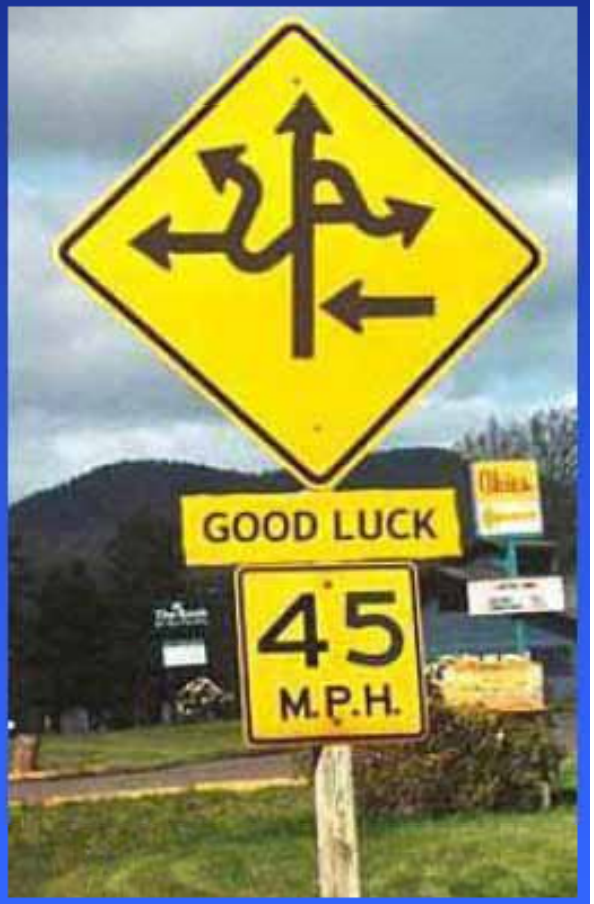

WR 2500s Foam……
KMA 220……
Northwest Territories
Nunavut
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Quebec
Newfoundland and Labrador
HUDSON BAY
WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
MAINE
WIRTGEN GROUP
Wirtgen


Cold Recycled RAP
I80, California, USA

Alternatives

UCPRC Research Focus

- Recycling/sustainability strategic initiative
- FDR and FDR-FA study
  - Literature review
  - Mechanistic sensitivity analysis
  - Pilot project assessment
  - Laboratory study
  - Guidelines
- Next phases
  - FDR with cement
  - FDR with emulsion + active filler
  - PDR (CIR) with emulsion
    - High air voids
    - Weak base / reflection crack concerns



Observations

- State dependent (recycling versus none)
- Foam versus emulsion (experience)
- Legislation and Incentives
- Growth in WMA
- Highest level of reuse

Focus of presentations

- Research focus areas (Global)
  - Laboratory
  - Field (APT and LTPP)
- Key findings and developments
  - Mix design
  - Structural design
  - Specifications
- Publications, documents and manuals

Continental issues to be highlighted

- 100% RAP versus Granular-RAP blends
- Emulsion vs Foam Bitumen Selection
- In Place versus In Plant mixing
- Active filler: Type and application

Research internationally in RAP is huge

- Healing of mixtures with RAP
- How to recycle with PMB
- Properties at higher percentages RAP
- Use of logPen rule: must be proven
- Re-use of Porous Asphalt RAP (NL)
- More general: re-use of RAP in top layers

Issues for discussion

- Barriers to Cold Recycling of RAP?
- Is current research addressing needs?
- Distress mechanisms (rut, fatigue, dur)?
- Key areas for future research?
- Harmonisation of mix & structural design?
- Global research cooperation?
- Future activities of WG2?

Conclusions

- Understanding of material behaviour of BSMs has increased significantly
- Active filler versus bitumen content in BSM is very important
- Cemented layer is best in subbase
- More advanced test methods (triaxial)
- Mix Design is linked to Structural Design method for BSMs


Thank you
I hope your head is not spinning?