



सत्यमेव जयते

Ministry of Rural Development

Government of India



[Pradhan Mantri Gram Sadak Yojna](#)

# New Technologies and Sustainable Materials in Construction of Rural Roads (LVRs) and Bridges

Professor Kim Jenkins, Stellenbosch University, South Africa

**24<sup>th</sup> to 26<sup>th</sup> May, New Delhi, Indian**

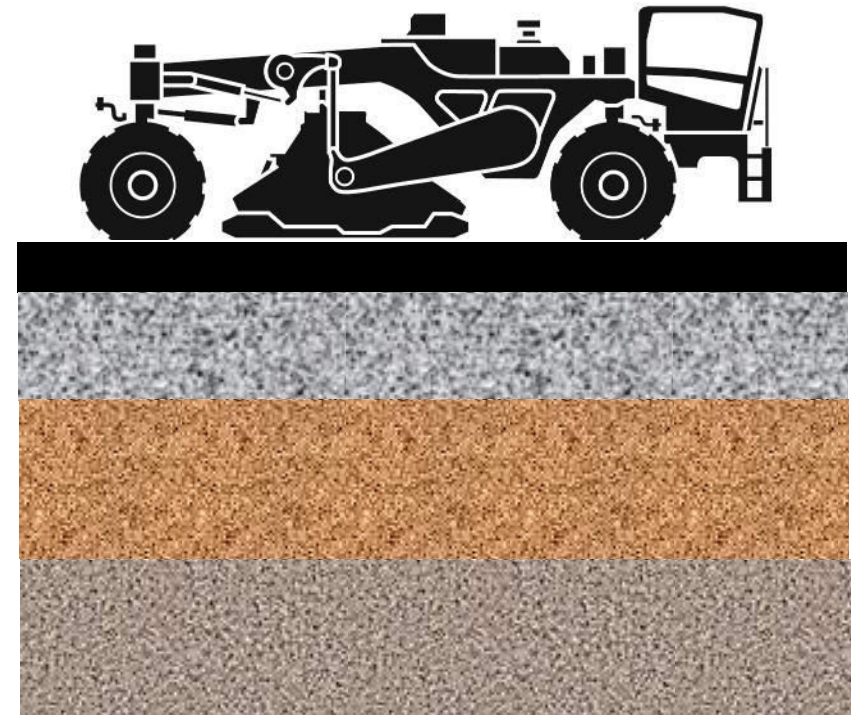


forward together  
sonke siya phambili  
saam vorentoe

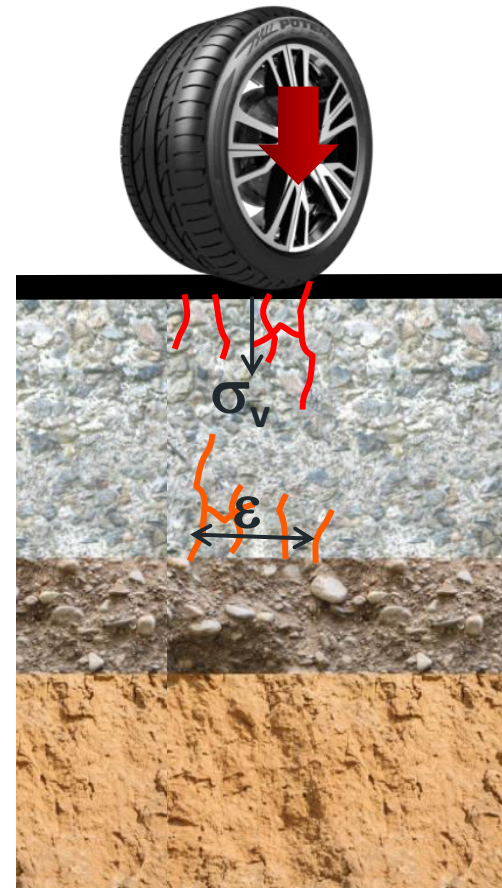


## WHAT CAN YOU EXPECT AS A TAKE AWAY?

- **Why Cold Recycling? Benefits? Challenges?**
- **Technology for Low Volume Roads versus Highways**
- **Classification of Materials Quality from Pavement Evaluation**
- **Mix Design Components**
- **Link to Structural Design**
- **Construction Aspects**



# REMEMBER: FAILURE MECHANISMS!!



**Asphalt surfacing**





**Crushing+Shrinkage**

**Cement stabilised base**

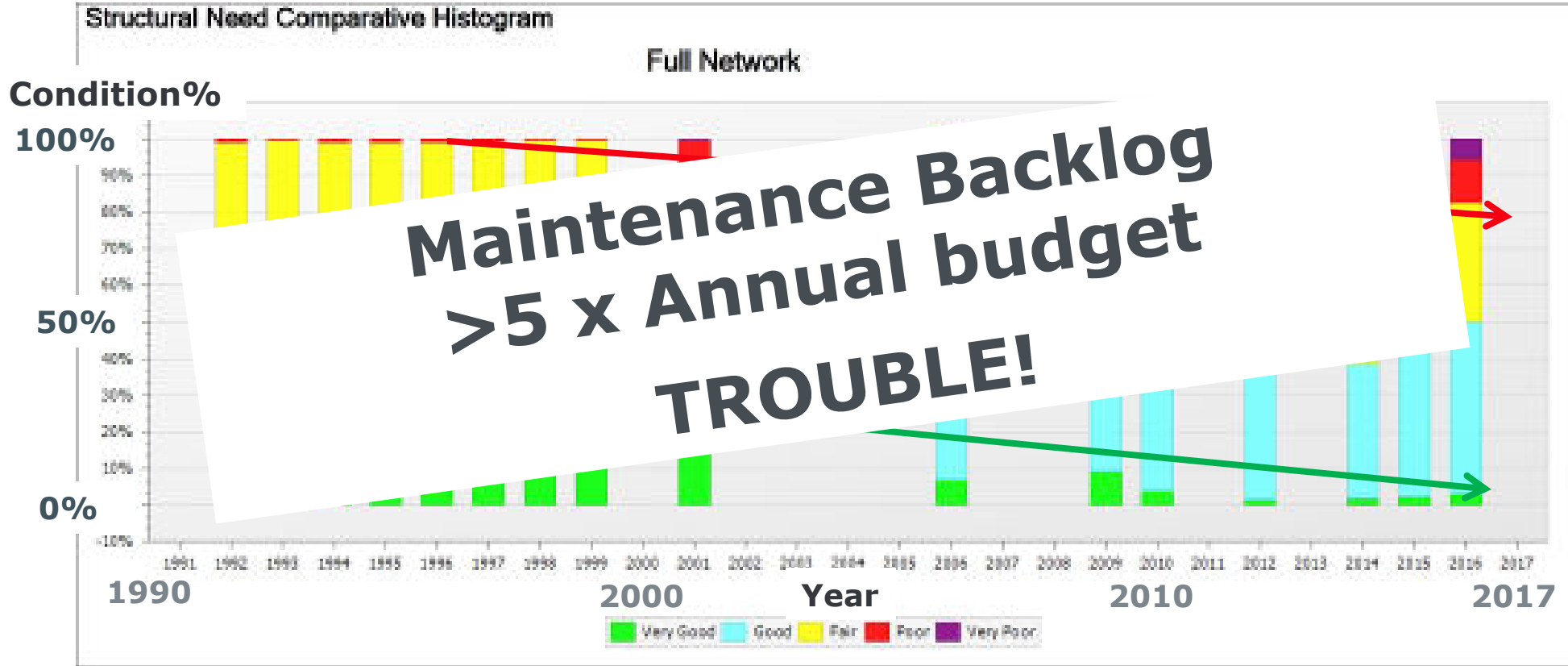
**Fatigue Cracking**

# GLOBAL ROAD INFRASTRUCTURE

- Approximately 65 million km of global roads, with 20 million km surfaced roads
- Structural pavement life: ave. 20 years
  - 1 million kms road need rehab per year
  - No allowance for growth
- Periodic maintenance: 75% asphalt surfacing
  - 15m wide x 50mm thick asphalt
  - Approx.  $500 \times 10^6 \text{m}^3$  RAP generated/yr
  - $>2000 \times 10^6$  tons new HMA is needed/yr
- **IS THIS SUSTAINABLE?? NOOOoo!!**
- **IS THERE A NEED FOR RECYCLING? YES!!**

| Rank | Country   | Road length (km) | Surfaced (%) |
|------|---|------------------|--------------|
|      | <i>World</i>  | 64 285 009       |              |
| 1    |  United States     | 6 586 610        | <b>65</b>    |
| 2    |  India             | 4 689 842        | <b>69</b>    |
| 3    |  China             | 4 237 500        | <b>95</b>    |
| 4    |  Brazil            | 1 751 868        | <b>13</b>    |
| 5    |  Japan             | 1 210 251        |              |
| 6    |  Canada            | 1 042 300        | <b>40</b>    |
| 7    |  Russia            | 982 000          | <b>61</b>    |
| 8    |  France            | 951 200          | <b>100</b>   |
| 9    |  Australia         | 823 217          | <b>17</b>    |
| 10   |  South Africa      | <b>750 000</b>   | <b>32</b>    |
| 11   |  Spain             | 681 298          |              |
| 12   |  Germany           | 644 480          | <b>98</b>    |
| 13   |  Sweden            | 572 900          |              |
| 14   |  Italy             | 487 700          |              |
| 15   |  Indonesia         | 437 759          |              |
| 16   |  Turkey            | 426 906          |              |
| 21   |  Mexico            | 393 473          |              |
| 34   |  Dem Rep of Congo | <b>153 497</b>   |              |
| 45   |  Zimbabwe        | <b>97 267</b>    |              |
| 54   |  Zambia          | <b>91 440</b>    |              |
| 55   |  Tanzania        | <b>91 049</b>    |              |
| 70   |  Madagascar      | <b>65 663</b>    |              |
| 80   |  Angola          | <b>51 429</b>    |              |
| 72   |  Namibia         | <b>64 189</b>    |              |
| 98   |  Mozambique      | <b>30 331</b>    |              |
| 104  |  Botswana        | <b>25 798</b>    |              |

# DETERIORATION TRENDS IN ROAD INFRASTRUCTURE

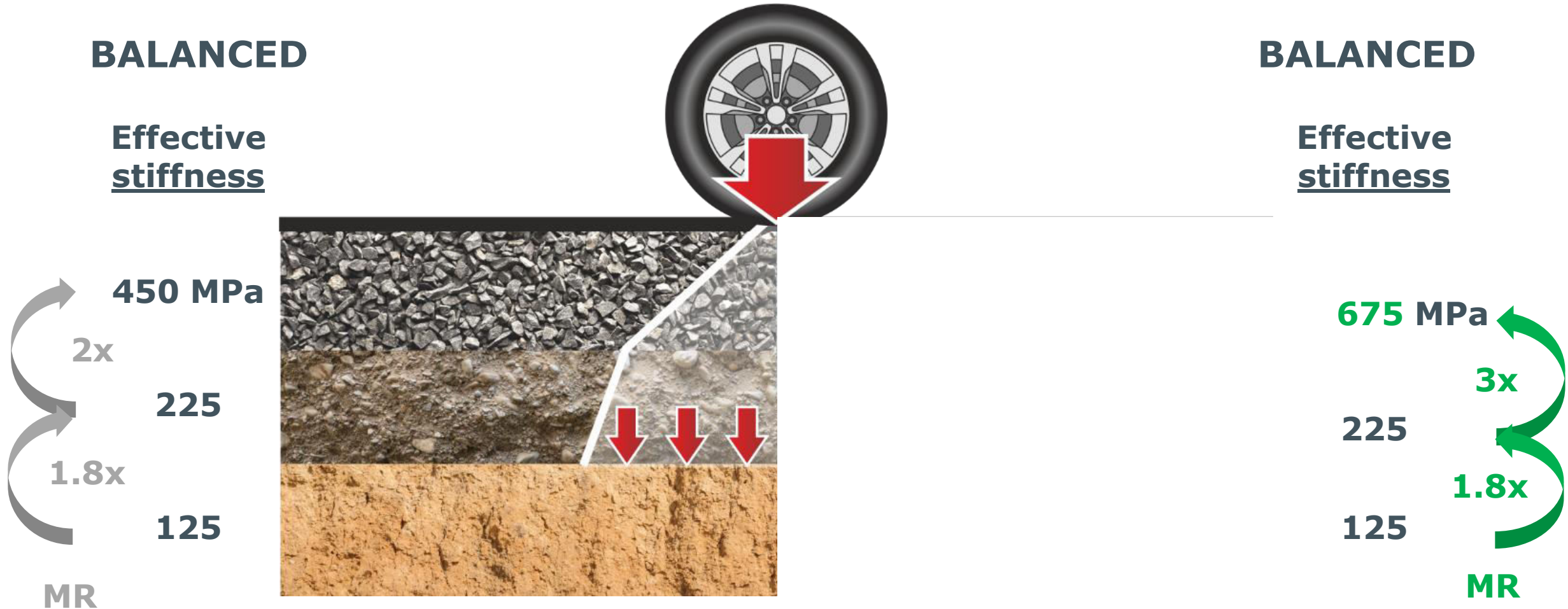


(Southern Africa, 2017)

**Do you know: More than 20% of America's roads are in poor condition?**

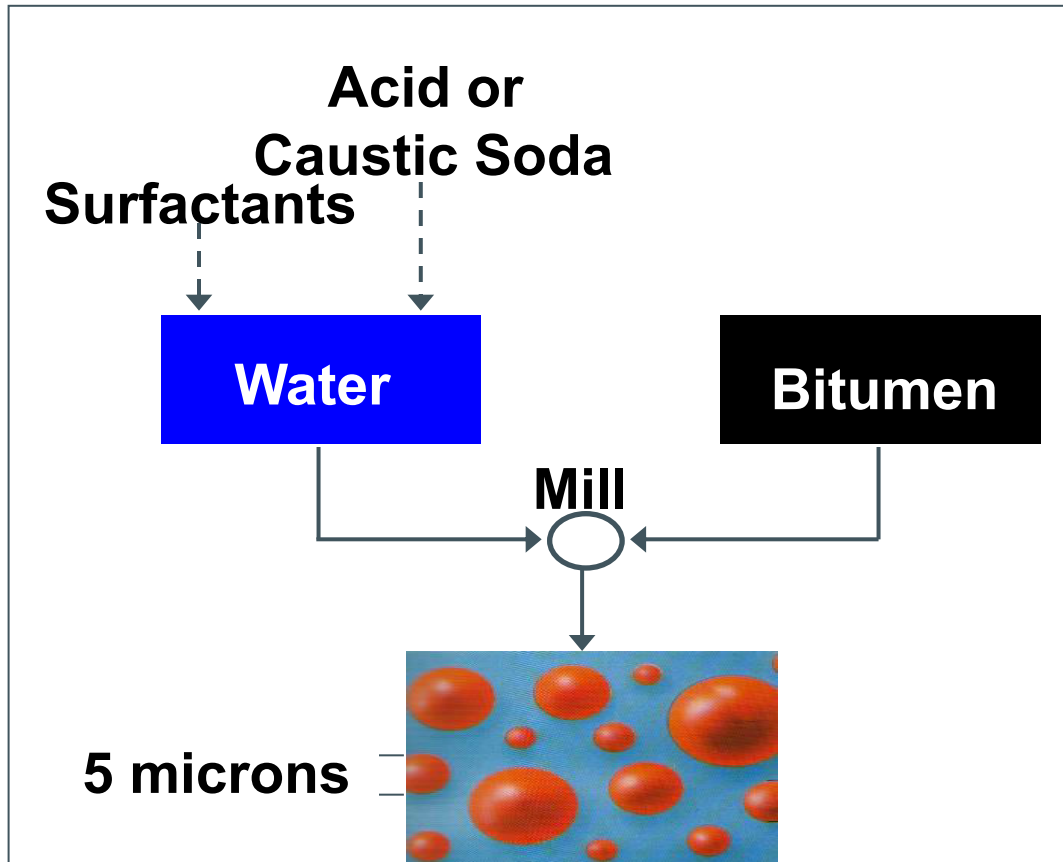
(BBC, 2021)

## Granular layers find balance in a pavement structure



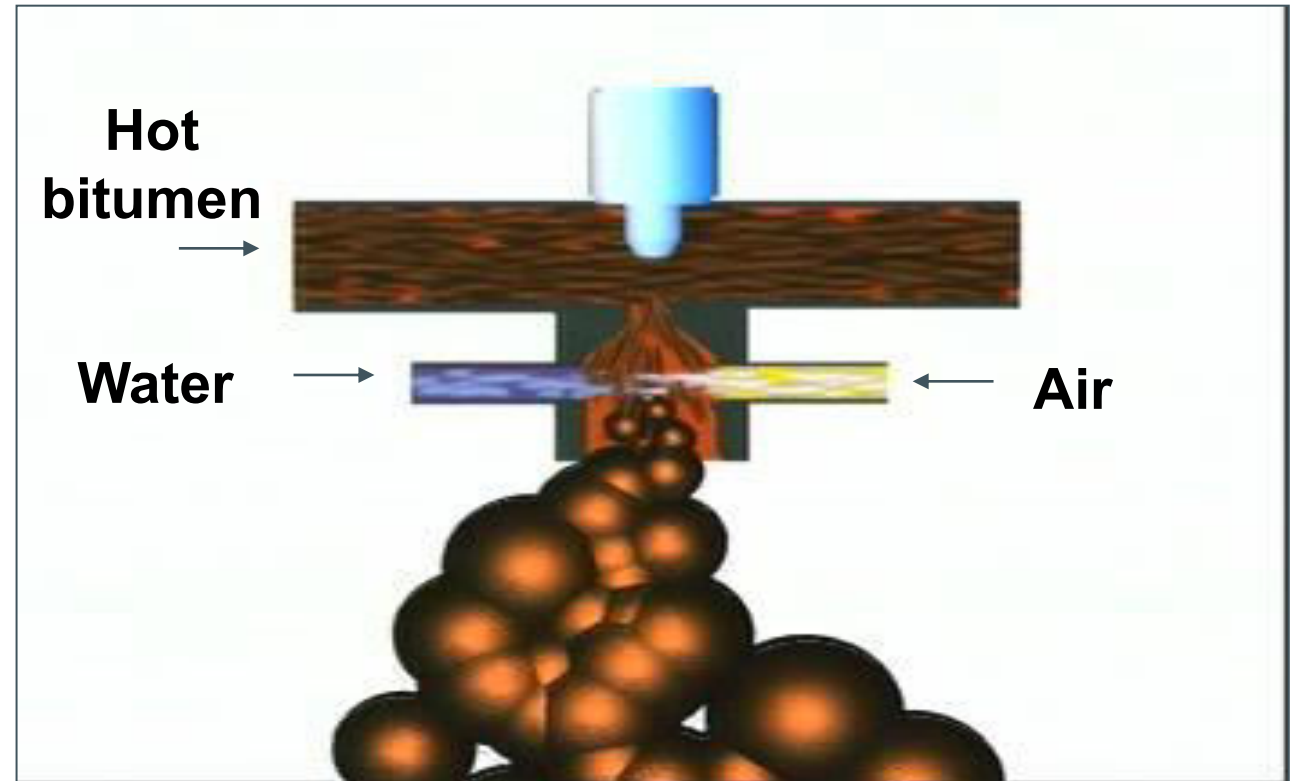
## BITUMEN EMULSION

### Colloidal Mill



## FOAMED BITUMEN

### Expansion chamber



# MICROSTRUCTURE OF MORTAR (SAND + FILLER + BITUMEN)



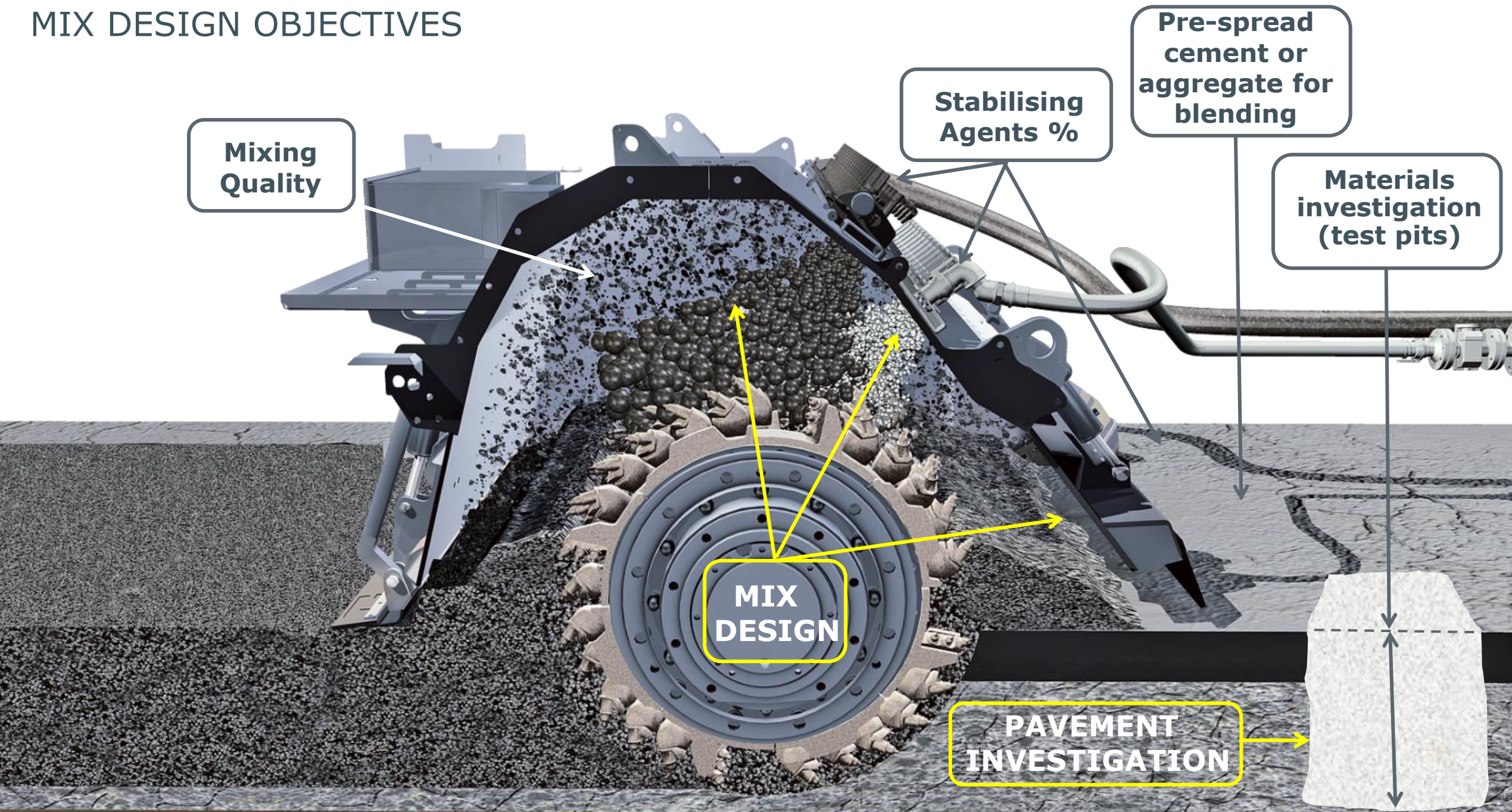
**BSM-emulsion**



**BSM-foam**



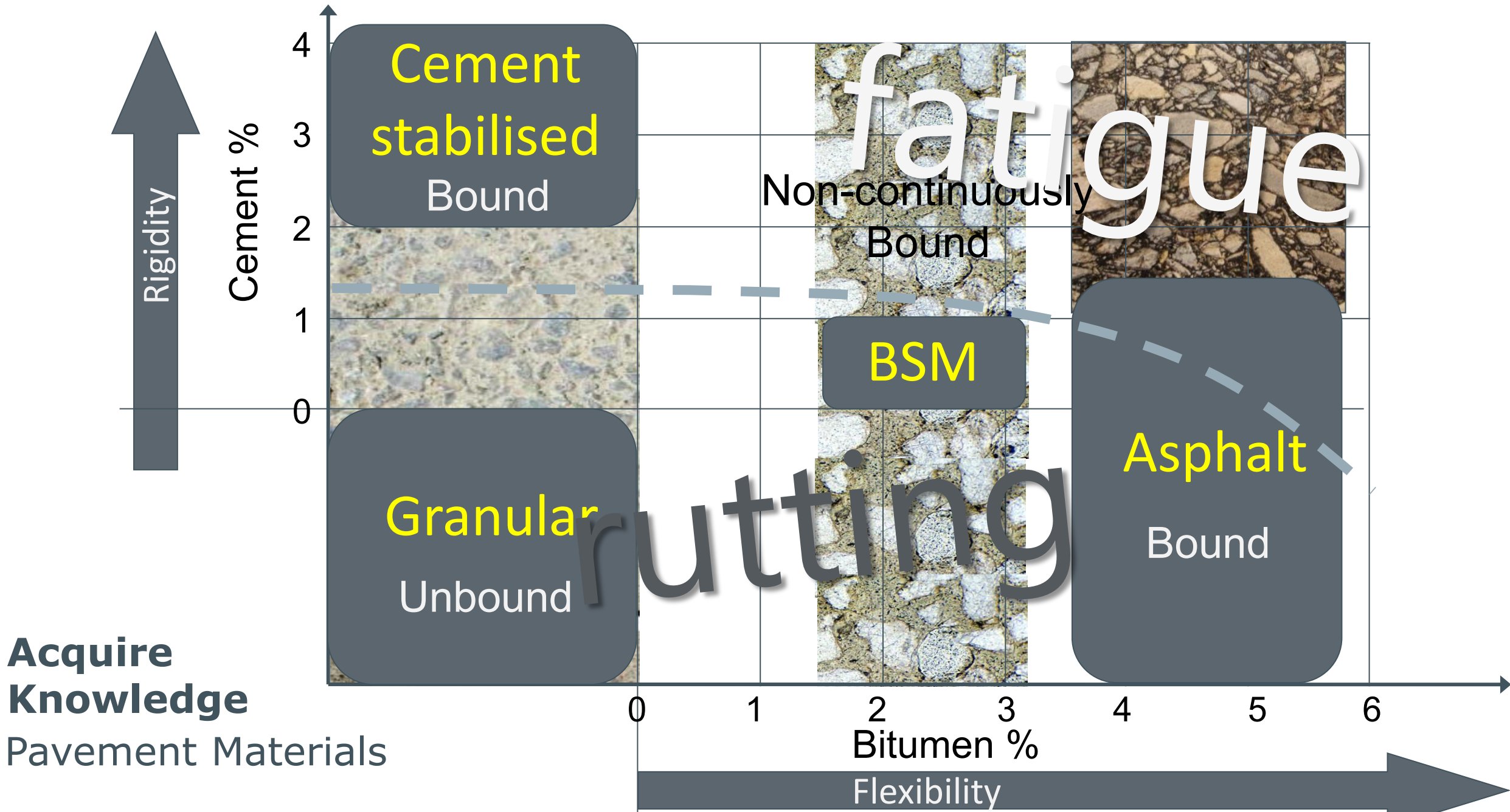
# MIX DESIGN OBJECTIVES





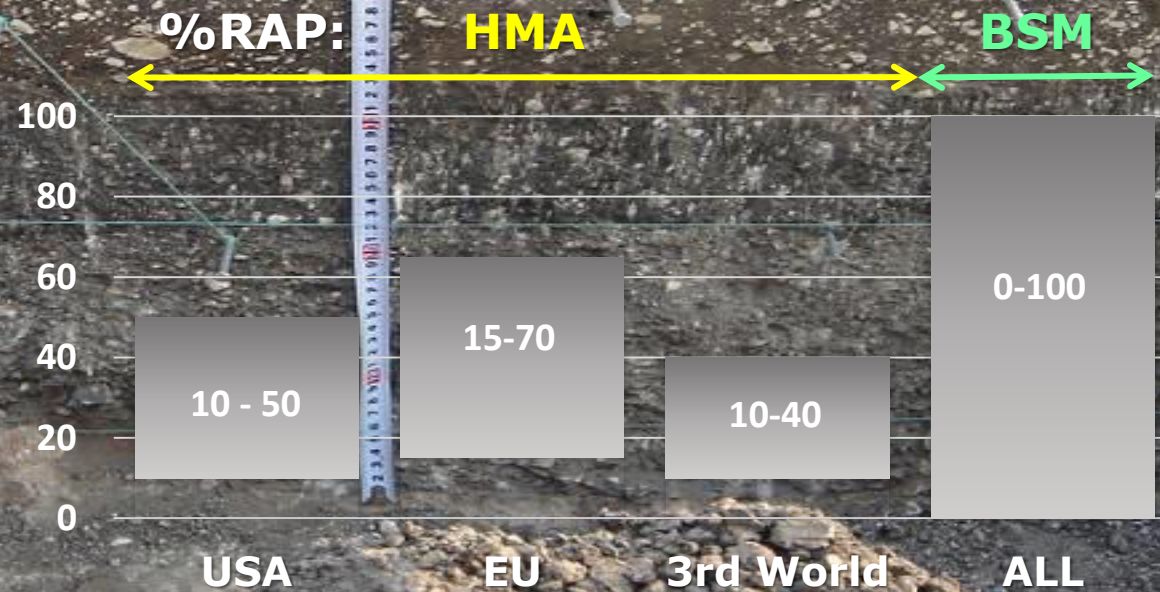
**Upgrading Low Volume Gravel Roads to LVR Surfaced Roads**





# Managing RAP

- HMA
- BSM Foam
- Rubbelized RAP

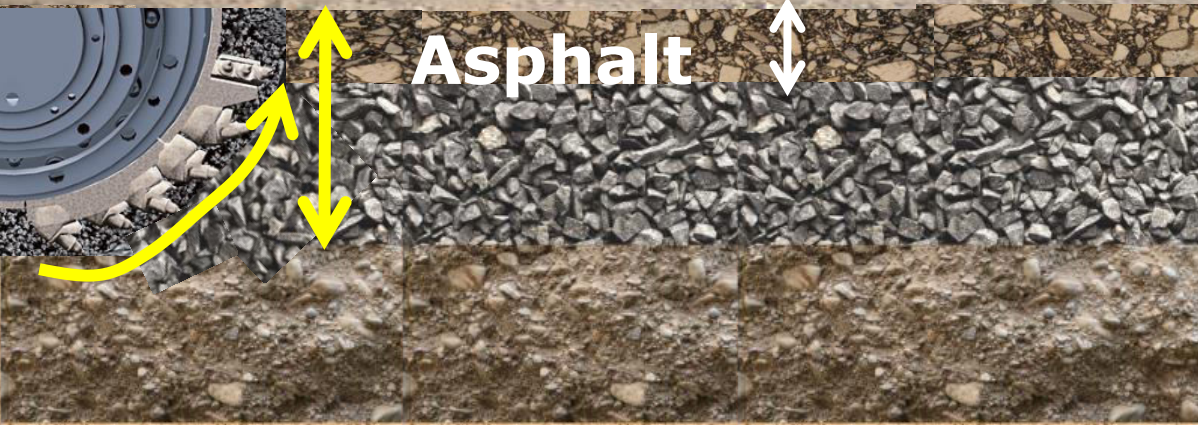


**Material Costs = 70% of Pavements Costs**

**BSM Costs are 20% to 45% < Asphalt Costs**

# TRACTION FOR COLD RECYCLING

**In situ Recycling  
< 50% RAP**



**In Situ Recycling 1990 onwards**

# AGGREGATES FOR COLD RECYCLING

**In situ Recycling  
< 50% RAP**



**Asphalt**



**In Situ Recycling 1990 onwards**

**In situ Recycling  
> 50% RAP**



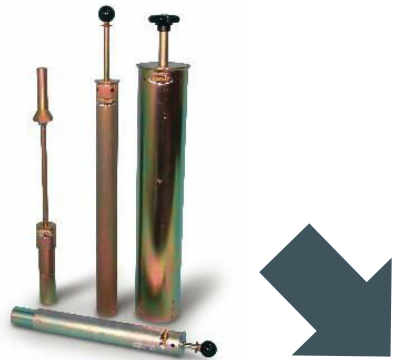
**Asphalt**

**In Situ + In Plant Recycling 2000+**

# EVOLUTION OF BSM TEST METHODS

## Compaction

1990



2010+



## Testing



ITS



Triaxial





# COLD RECYCLING

## In Place



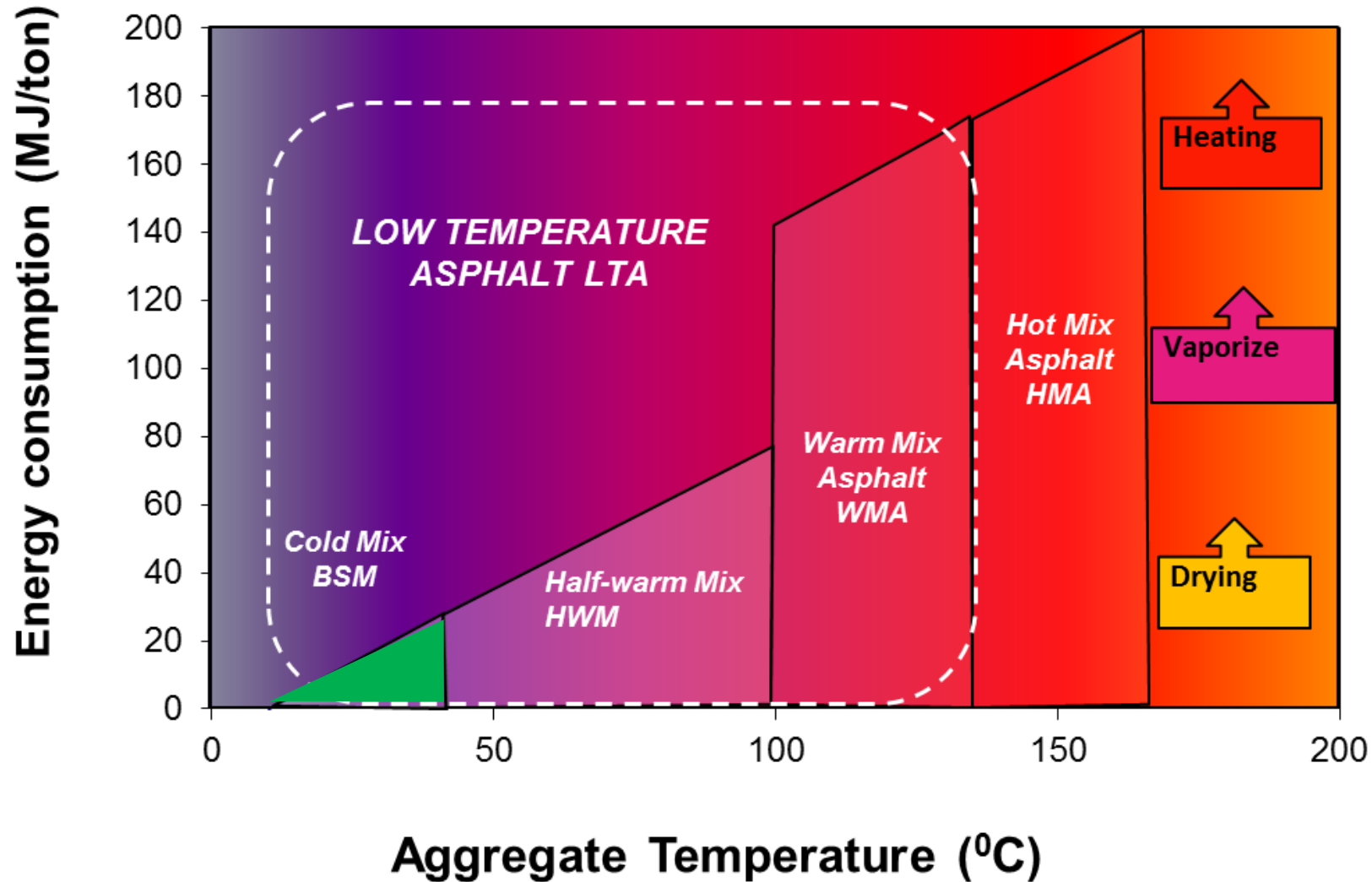
## How to select?



## In Plant

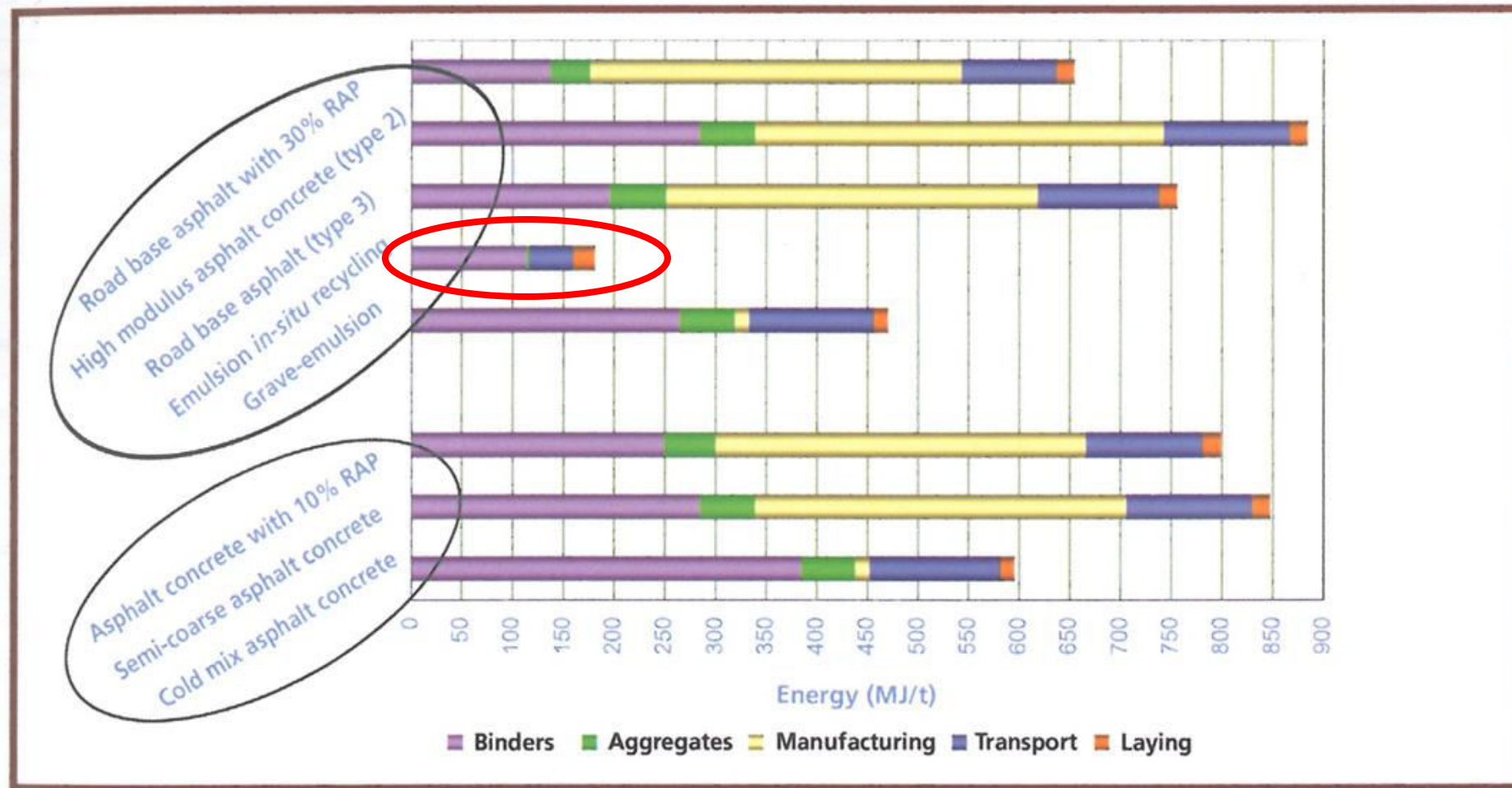


Emissions (%) **40-50** **60-70** **80-90** **100**  $\text{CO}_x$   $\text{NO}_x$   $\text{SO}_x$



(Jenkins, 2000)

# SUSTAINABILITY = SOCIAL, ENVIRO & ECONOMIC



# SAMPLING ASPHALT LAYERS

**Use a recycler**

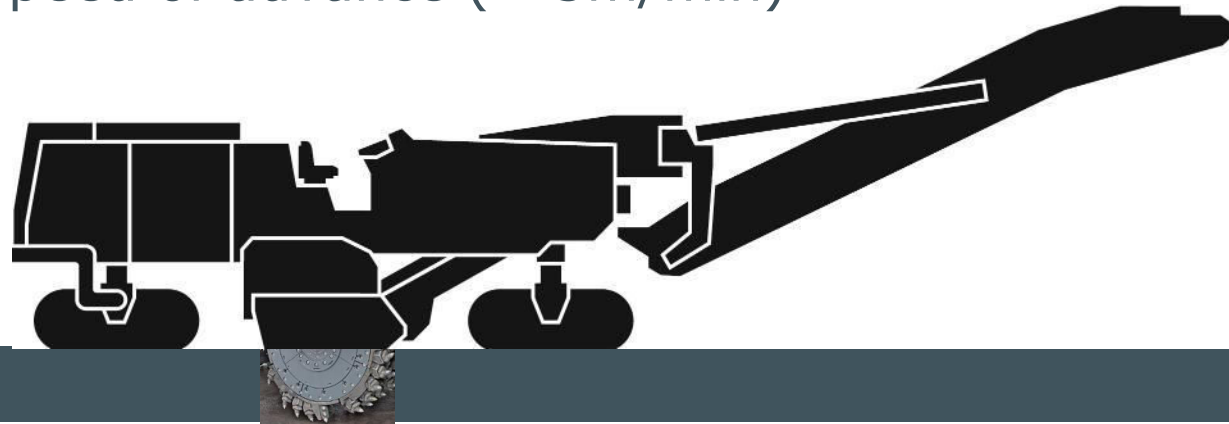
Normal operating speed of advance ( $\pm 8\text{m/min}$ )



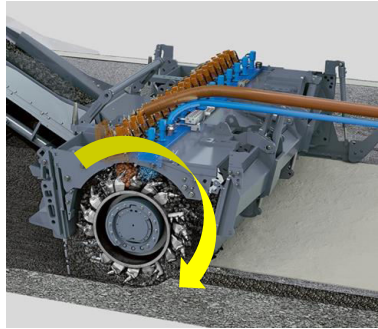
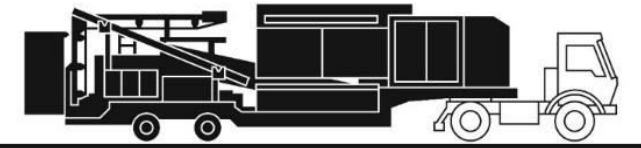
Obtain bulk sample  
(full depth)

**Or, a milling machine**

Speed of advance ( $\pm 3\text{m/min}$ )



# SAMPLING AND PROCESSING OLD ASPHALT LAYERS

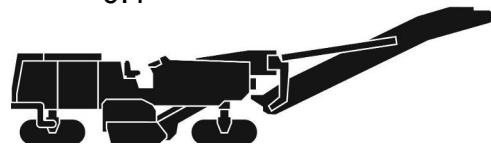
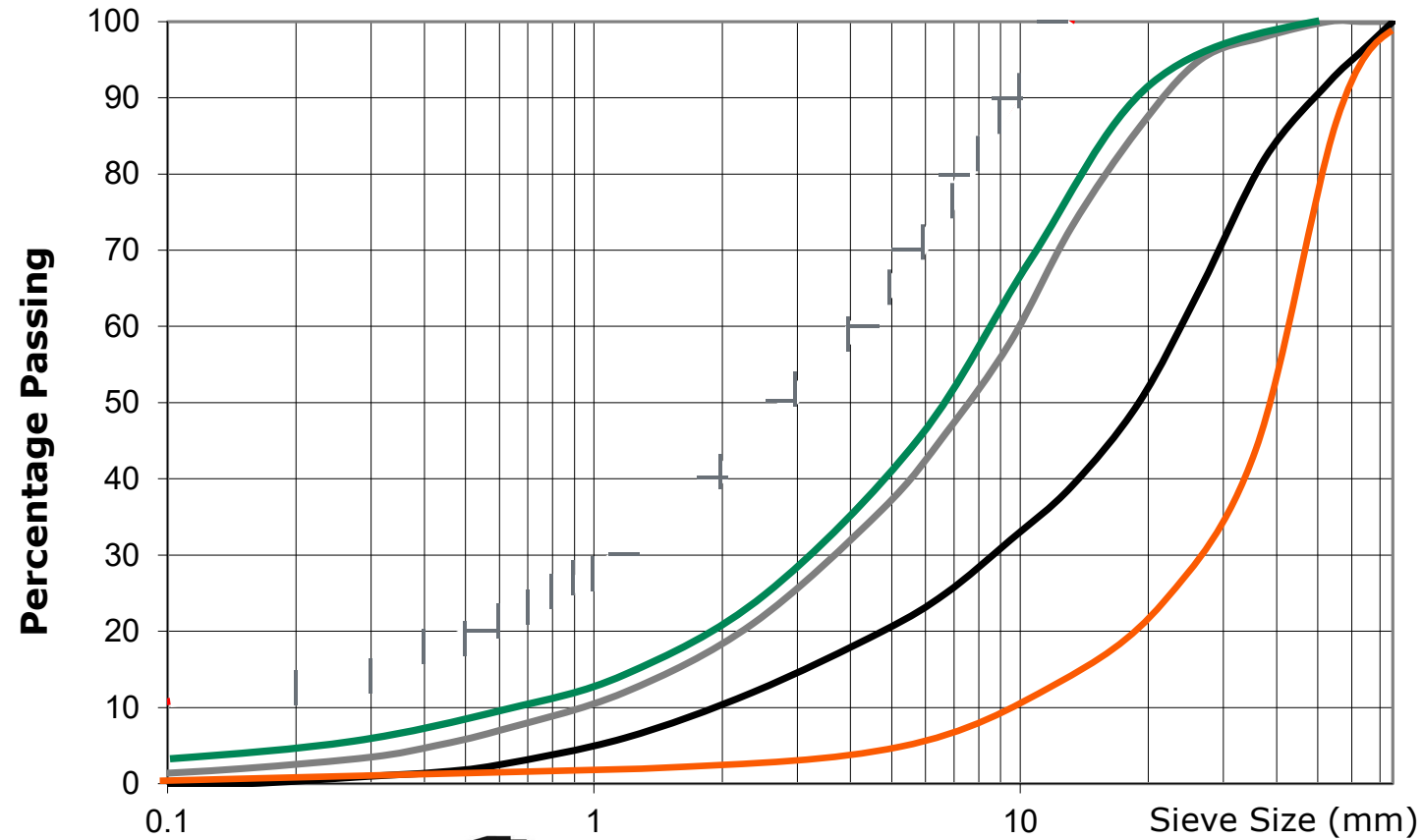


Down-milling



Pulverised

## RAP TYPICAL GRADING CURVES FOR MILLED ASPHALT



Slow milling Fast milling



Impact crusher



Cracked asphalt

# DETAILED PAVEMENT INVESTIGATIONS



Visuals



FWD



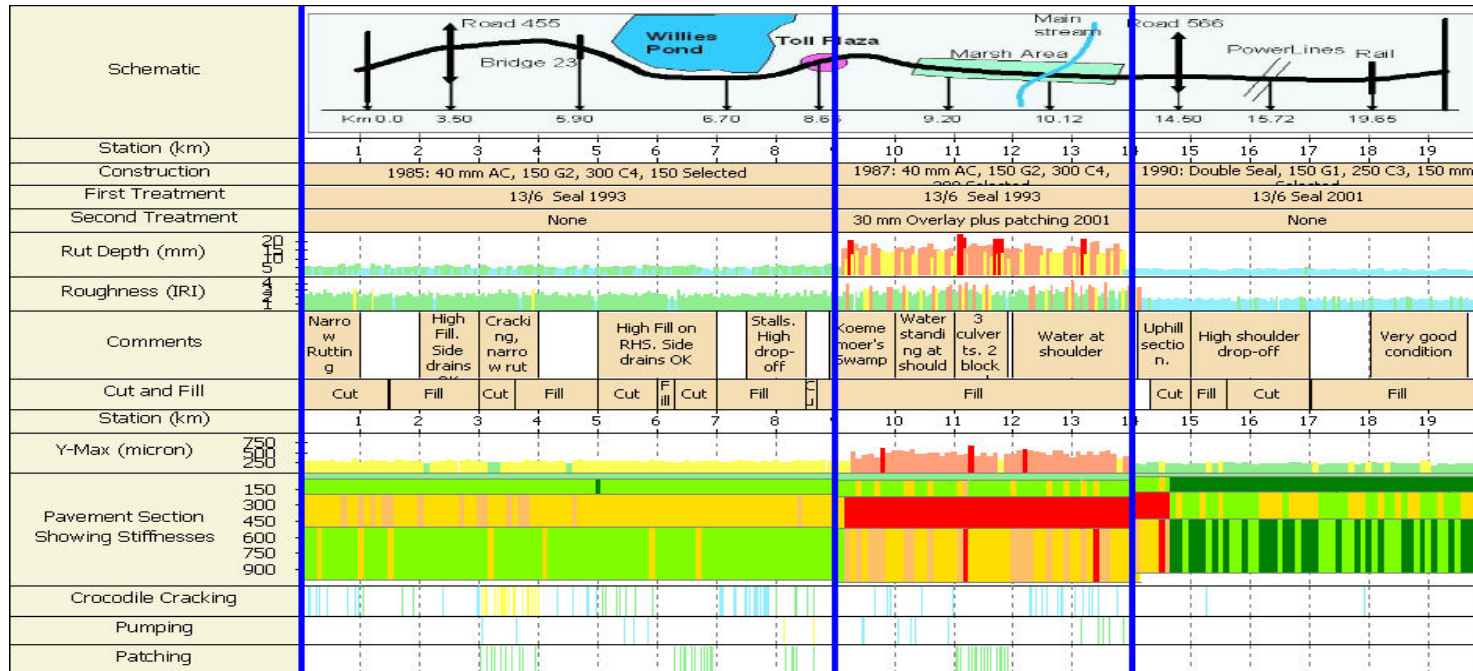
DCP



Coring



Test Pits



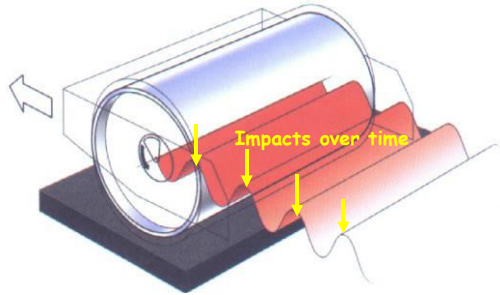
- Uniform Sections
- Layer thickness
- Material Class
- Distress Mechanisms
- Etc

# MIX DESIGN: SPECIMEN IMPROVEMENTS

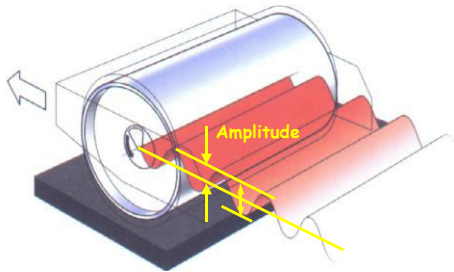
## Padfoot Dynamic Roller

## Drop Weight Hammer

Frequency - vpm (hz)



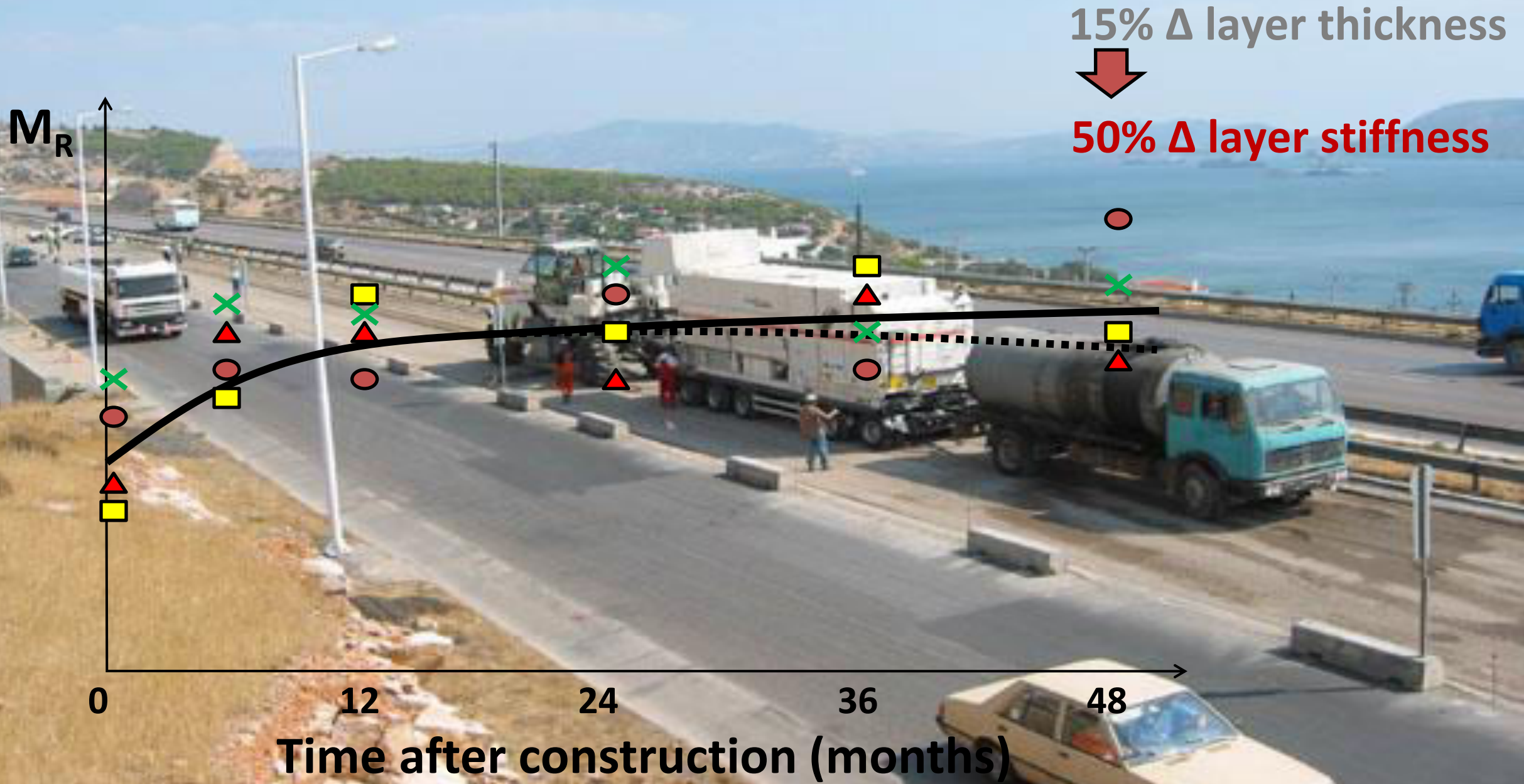
Amplitude - mm



|                       | Field<br>(Vibro) |
|-----------------------|------------------|
| <b>Frequency (Hz)</b> | <b>50 – 65</b>   |
| <b>Amplitude (mm)</b> | <b>0.4 – 1</b>   |

| Lab<br>(Mod.Proc) |
|-------------------|
| <b>1</b>          |
| <b>457.2</b>      |

# FWD Deflection Survey Data - NTUA





# MIX DESIGN IMPROVEMENTS - TRIAXIAL TEST

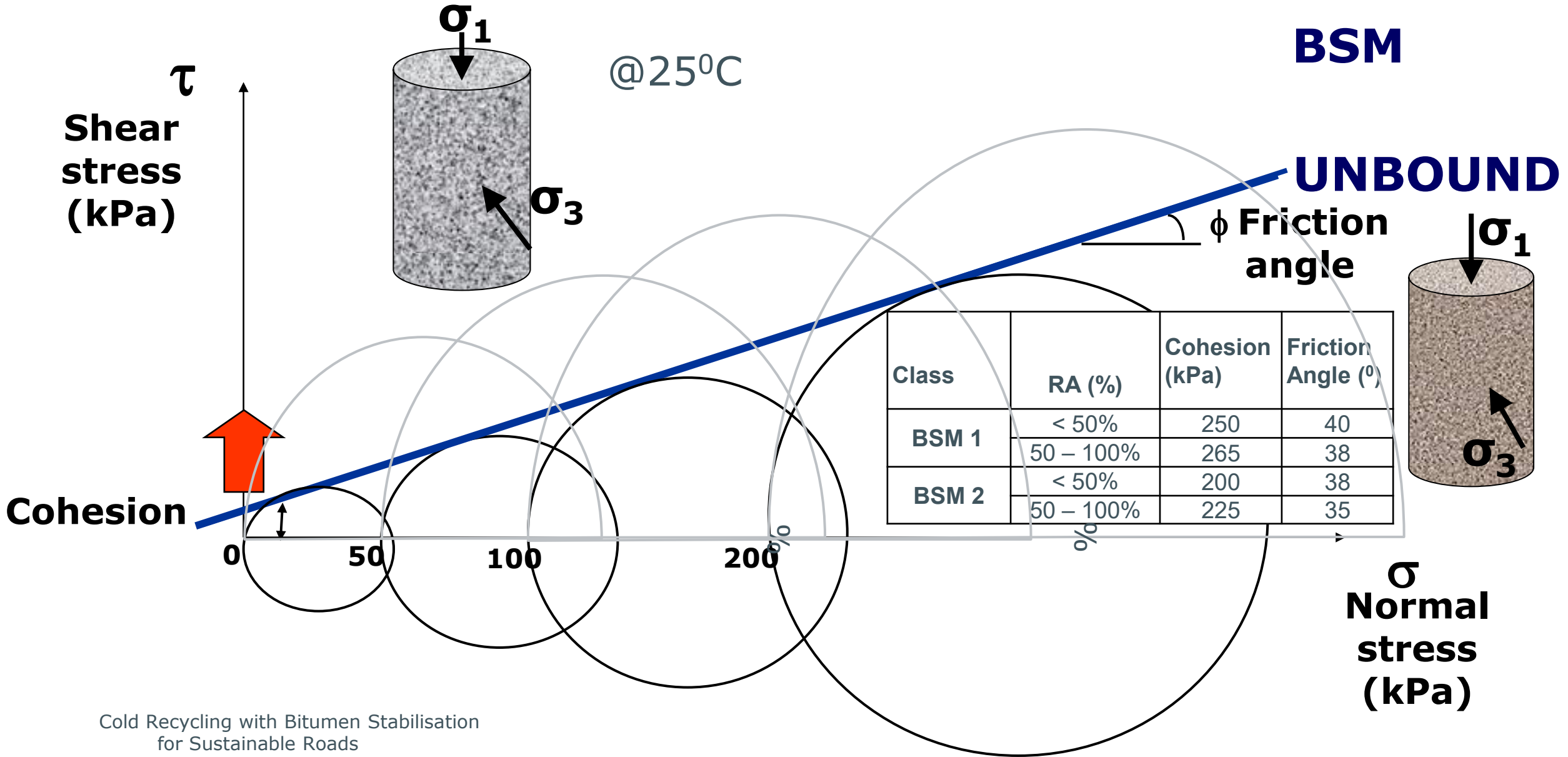


Cold Recycling with Bitumen Stabilisation  
for Sustainable Roads

**Test at 25°C**

**Confining Pressure**  
**0 kPa 50 kPa**  
**100 kPa 200kPa**

# TRIAXIAL TEST @ EQUILIBRIUM MC – MOHR COULOMB PLOTS



# MIX DESIGN FEEDS INTO PAVEMENT DESIGN

$$DSR = \frac{\text{Actual}}{\text{Max}}$$



$$\sigma_d / \sigma_{d,f} = 60\%$$

**Plastic Strain  $\epsilon_{P,V}$  (Rutting)**

$$\epsilon_p = aN^b$$

**Contours from Research**

$$\sigma_d / \sigma_{d,f} = 50\%$$

**Design Life for 10mm rut**

$$\sigma_d / \sigma_{d,f} = 40\%$$

$$\sigma_d / \sigma_{d,f} = 30\%$$

**Load (Axle) Reps N**



with Bitumen Stabilisation for Sustainable Roads



# SUMMARY

(BASED ON > 350 MIX DESIGNS)



## **BSM 1**

**Traffic:** High to Medium

**Aggregate:** CBR > 80% Bearing Capacity

**GCS & RAP** Source

**BSM mix:** High C,  $\phi$  and Ret.C



## **BSM 2**

**Medium to Low**

**CBR > 40%**

**Crushed Gravel & some RAP**

**Moderate**

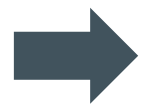
Cold Recycling with Bitumen Stabilisation for Sustainable Roads **Links to Structural Design**

# SUITABLE PROJECTS

# PAVEMENT LIFE



# FINAL OVERVIEW



**PERFORMANCE**

**ECONOMY**

**QUALITY**

**FLEXIBILITY**

**DURABILITY**

**RELIABILITY**

**THE MIX**

**STRUCTURAL DESIGN**

**CLASSIFICATION**



**THANK YOU!**

PHEW, THAT WAS TRICKY!

**QUESTIONS?**

