SUCCESSFUL COLD RECYCLING PROJECT EXAMPLES AND A CRITICAL REVIEW OF THE PRACTICAL CHALLENGES DELAYING THE LARGE-SCALE IMPLEMENTATION OF THIS TECHNOLOGY

Andre Greyling
Loudon International Consulting Engineers

AGENDA

AGENDA

Cold Recycling in context

- What are we talking about ?

Cold Recycling success stories over the last 20+ years

- The benefits of Cold Recycling
- This is no longer new and unproven technology…

Practical challenges to implementation

- Why are we not recycling more?

Conclusions and Recommendation

- What should be changed to recycle more ?

COLD RECYCLING IN CONTEXT

What are we talking about ?

WHAT IS COLD RECYCLING ?

- Cold recycling in road construction is
  - a sustainable technique that involves reclaiming existing pavement materials,
  - adding binding agents, and reprocessing them on-site or in-plant
  - thereby creating a new and resilient pavement base course material
    - the technology can be used on a wide range of materials
  - All of this while offering cost savings and environmental benefits.

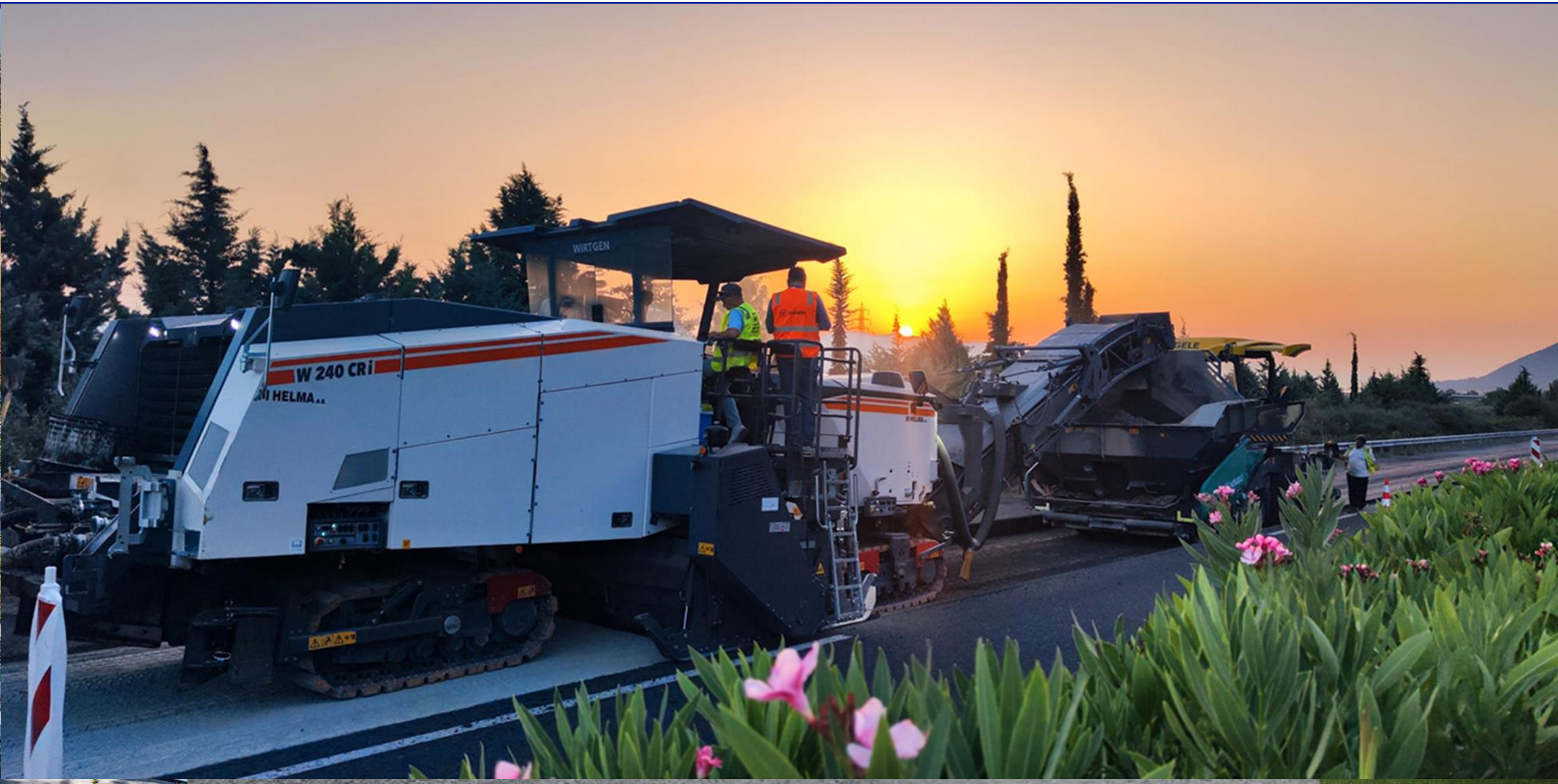
  - No disputing that….

COLD RECYLING IN CONTEXT

Gemsbok fight is a photograph by Johan Swanepoel

How to achieve that is where the dust starts to fly !

EQUIPMENT?



BITUMINOUS STABILISATION AGENT ?

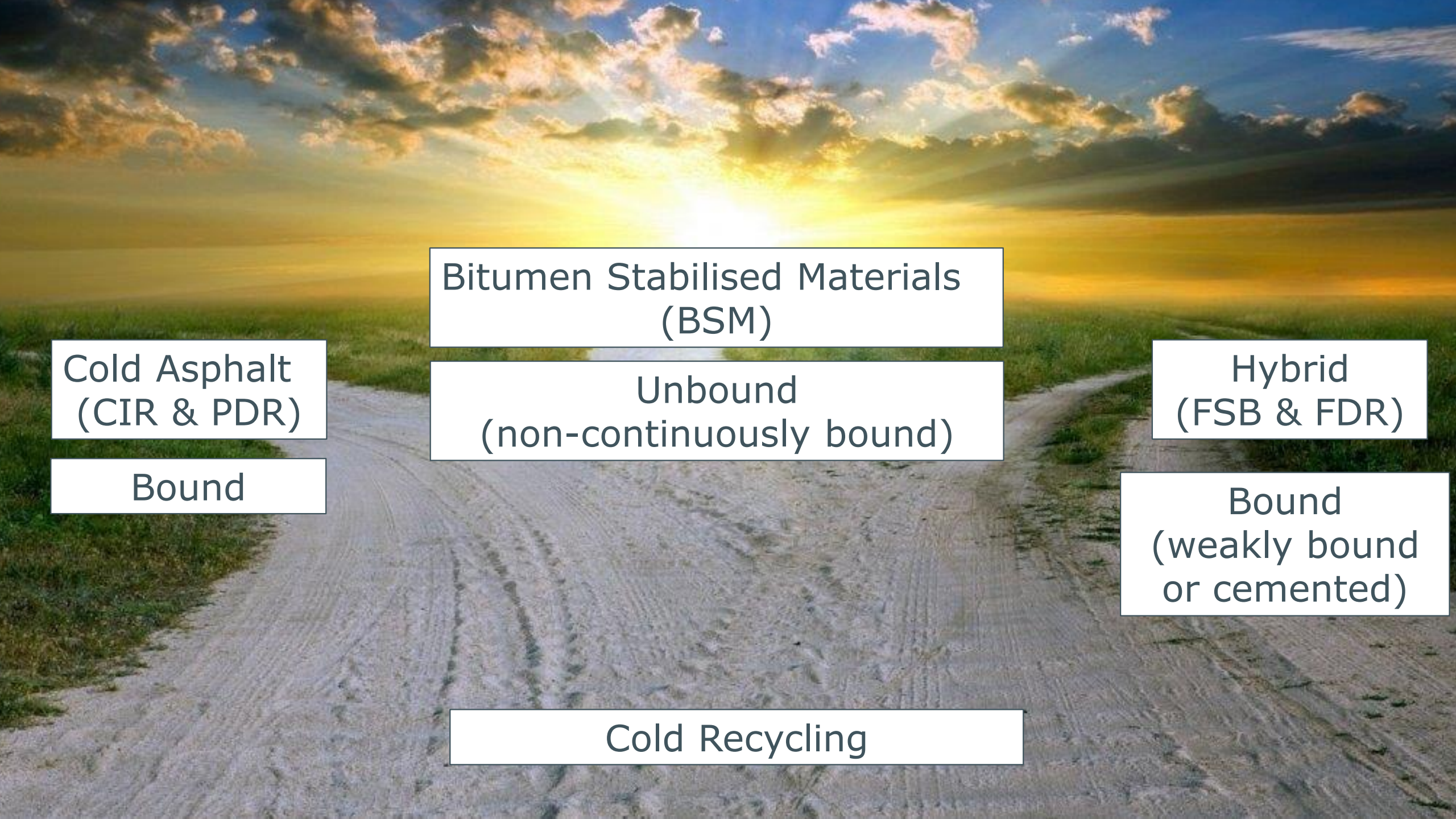
ACTIVE FILLER TYPE AND AMOUNT?

IT IS ALL ABOUT THE END PRODUCT…

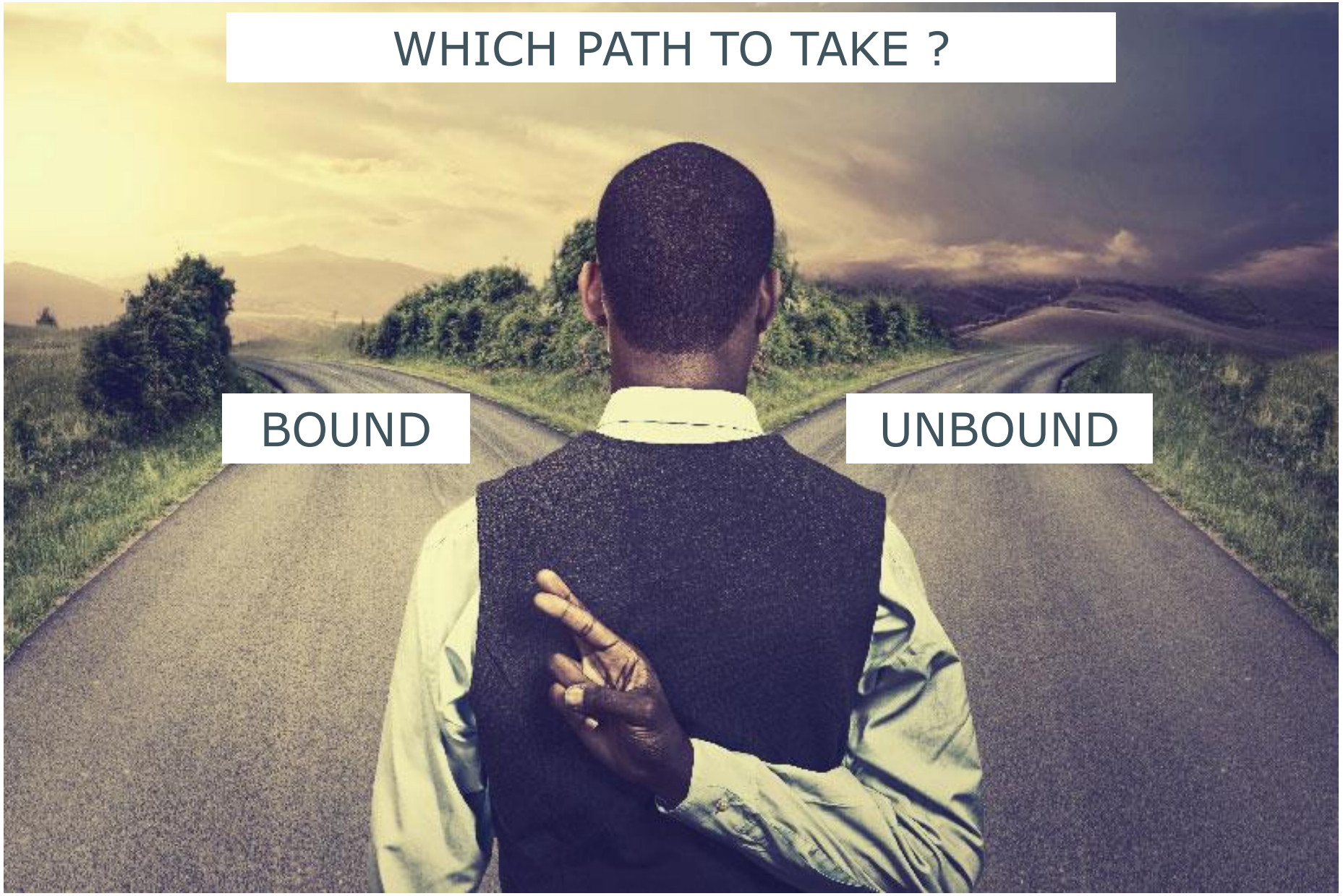
COLD RECYLING IN CONTEXT

Gemsbok fight is a photograph by Johan Swanepoel

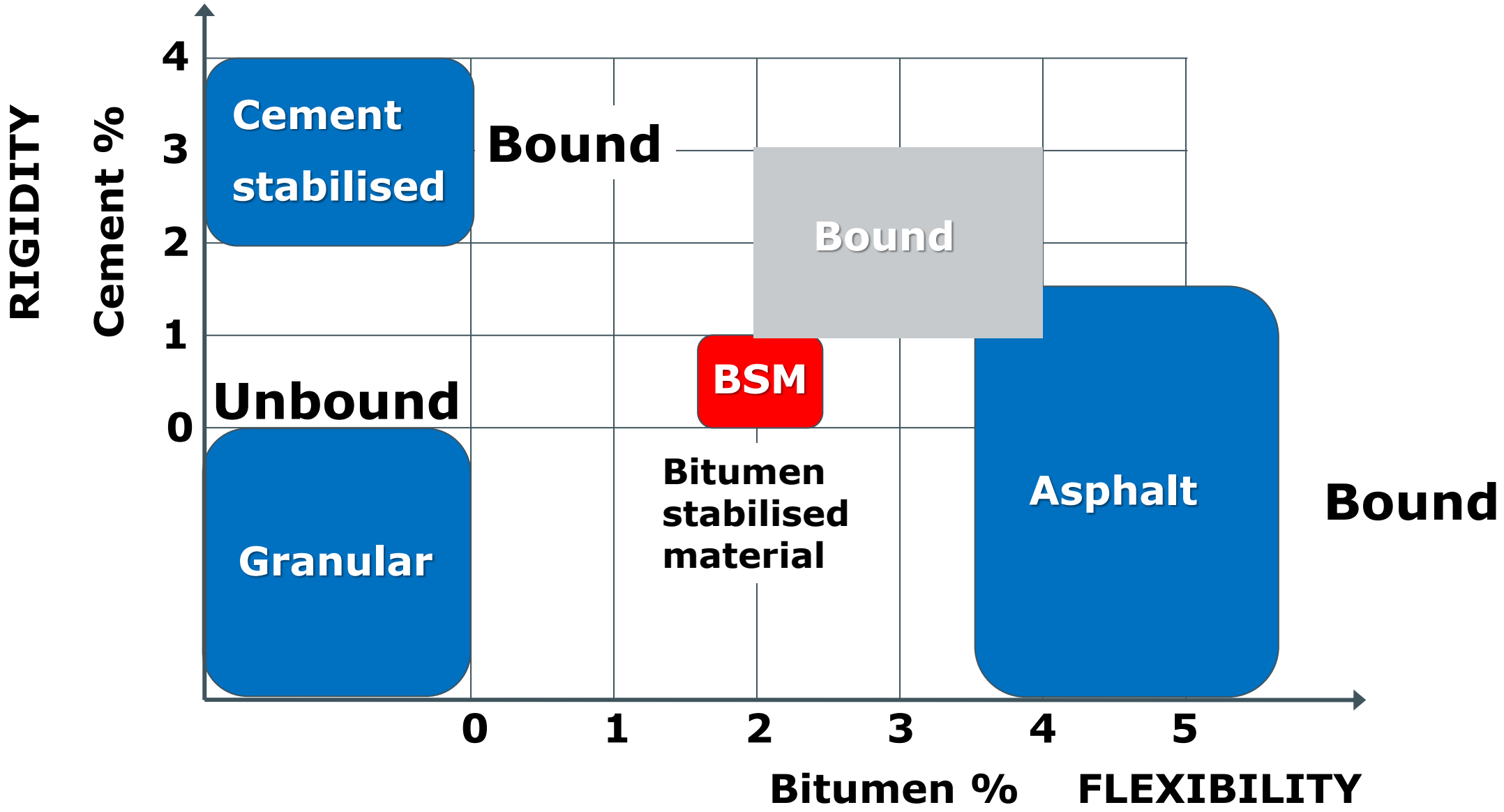
The fight continues…


Bitumen Stabilised Materials (BSM)
Cold Asphalt (CIR & PDR)
Unbound (non-continuously bound)
Hybrid (FSB & FDR)
Bound
Bound (weakly bound or cemented)
Cold Recycling

COLD RECYCLING



BITUMEN STABILISED MATERIALS



COLD RECYCLING

- Can you realistically produce a bound material equivalent to HMA with Cold Recycling?
  - Asphalt and bound material behaviour is very dependent on the grading of the material.
    - In situ recycling changes the grading …
    - With in plant in can be better controlled…
    - Never as perfect a grading as asphalt requires…
    - Therefore, never the same density and fully bound behaviour…

COLD RECYCLING

- Because the material and the process is cold you need to add moisture to aid compaction
  - Once the material has dried back, the water will leave voids
    - Leading to a material with 10% + void content
    - High voids = low density
    - Therefore, never the same density and fully bound behaviour…

COLD RECYCLING

- For bound material, the focus is on modulus and not flexibility
  - To get higher modulus requires the addition of more bitumen and more filler
  - This increases the modulus but decreases the flexibility.
  - Decreased flexibility decreases fatigue resistance …
  - Leading to early life failures…
  - Sometimes everything is just right and then it works....
  - But for this reason, there is significant variation in fatigue behaviour

COLD RECYCLING

- There is worldwide very few (if any) very high-volume road success stories with bound cold recycled materials in the base course
- For the simple reason that it will never be as fatigue resistant as HMA
- But everyone understands HMA and can design HMA and are therefore trying to force Cold Recycling to fit into what they understand
- Should you choose to go the Bound/Cold Asphalt route be assured of an exciting journey!
- Alternatively choose the proven non continuously bound route

COLD RECYLING IN CONTEXT

Whatever path you take should be a peaceful one!

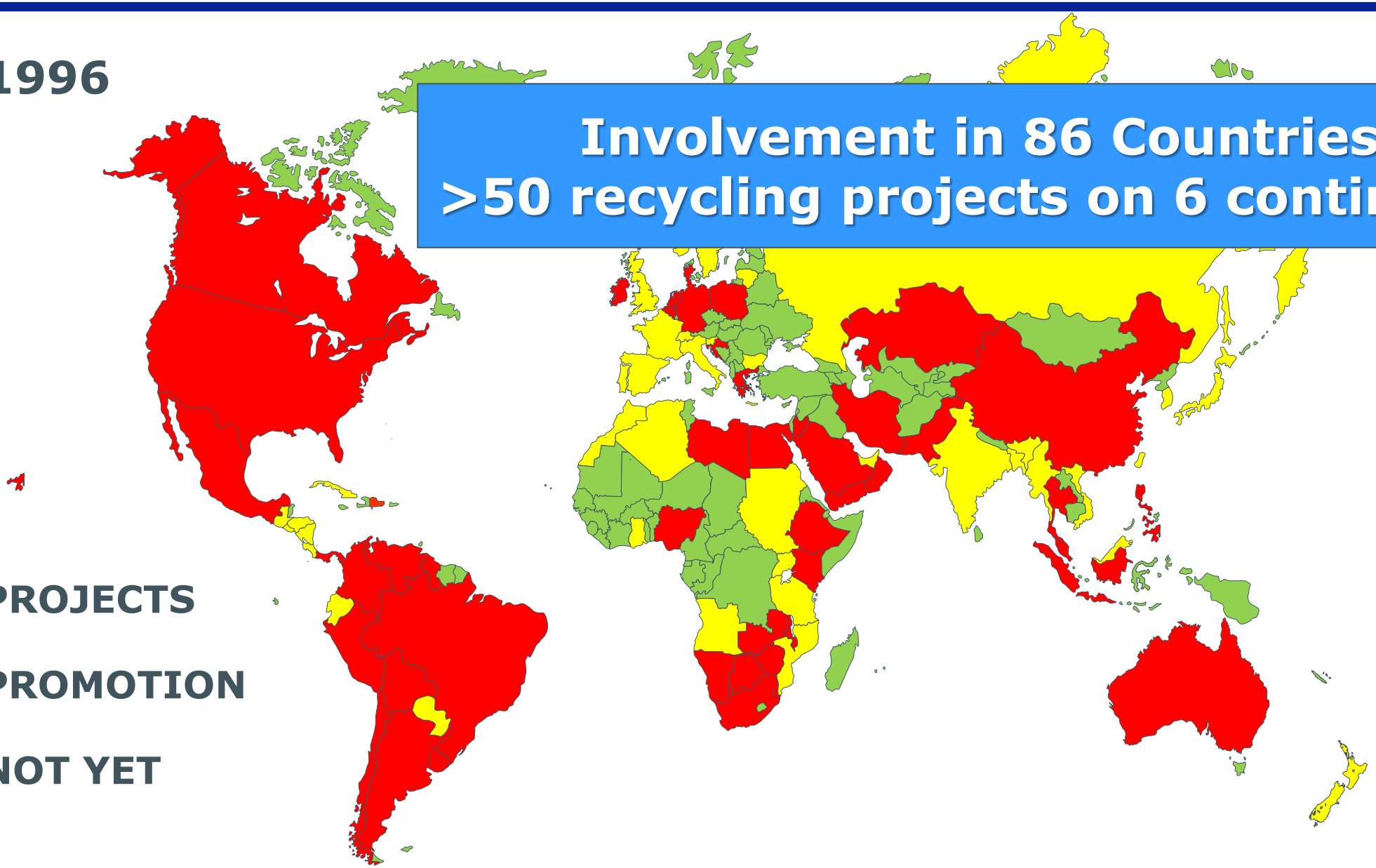
RECYCLING SUCCESS STORIES OVER THE LAST 20+ YEARS

This is no longer new and unproven technology…

INTERNATIONAL INVOLVEMENT

Since 1996

Involvement in 86 Countries
>50 recycling projects on 6 continents



PROJECTS

PROMOTION

NOT YET

SELECTED PROJECT EXAMPLES

- 1996. Libya. Rehabilitation of the Adjedabya – Jelo highway south of Benghazi (MOP)
- 1997. Saudi Arabia. Upgrading the 386km Shaybah Oilfield Access Road (Aramco /Parsons)
- 1998. Colombia. Rehabilitation of major arterials in Bogota City (ICA)
- 1999. Australia. Rehabilitation of the New England Highway (Toowoomba) (QMR / SPA)
- 2000. Canada. Upgrading arterial roads in the City of Edmonton (Municipality / Lafarge)
- **2001 USA (California). Rehabilitation of a 10 mile (16km) section of Highway 20(Caltrans)**
- 2002. Zambia. Rehabilitation of 200km of main road between Livingstone and Sesheke (Gauff)
- 2003. Greece. Rehabilitation 21km of the Athens – Corinth highway (Aktor)
- 2004. Namibia. Rehabilitation of 100km of the Trans-Caprivi Hwy south of Katima Mulilo (Gauff)
- 2005. Malawi. Rehabilitation of 64km of main road between Mangochi and Monkey Bay (Gauff)
- 2006. Kenya. Rehabilitation of 100km of main road between Maai Mahiu and Narok (Gauff)

SELECTED PROJECT EXAMPLES

- 2007. Pakistan. Rehabilitation of 140km of the N5 highway between Lahore and Islamabad (SMEC)
- 2008. China. Rehabilitation of sections of the Tianjin Ring Road (Highway Authority)
- 2009. Peru. Rehabilitation of the Trans-Andes Southern Highway between Nazca and Cuzco (GyM)
- 2010. India. Upgrading the NH-9 Highway between Pune and Solarpur (Tata concession)
- **2011. Brazil. Rehabilitation of sections of the 8-lane Ayrton Senna Highway outside Sao Paulo**
- **(EcoRodovias concession / ANE Group)**
- 2012. Zimbabwe. Rehabilitation of main inter-urban trunk roads (Group Five)
- 2013 Oman. Upgrading rural access roads in the central region north west of Bahja town (PDO)
- 2014 Panama. Rehabilitation of a portion of the Pan-American Highway near San Felix (CUSA)
- 2015 Uruguay. Rehabilitation of 35km of Route 3 south of Trinidad town (HyG)
- 2016 Uruguay. Rehabilitation of 30km of Ruta 23 San Jose Department (CVC)

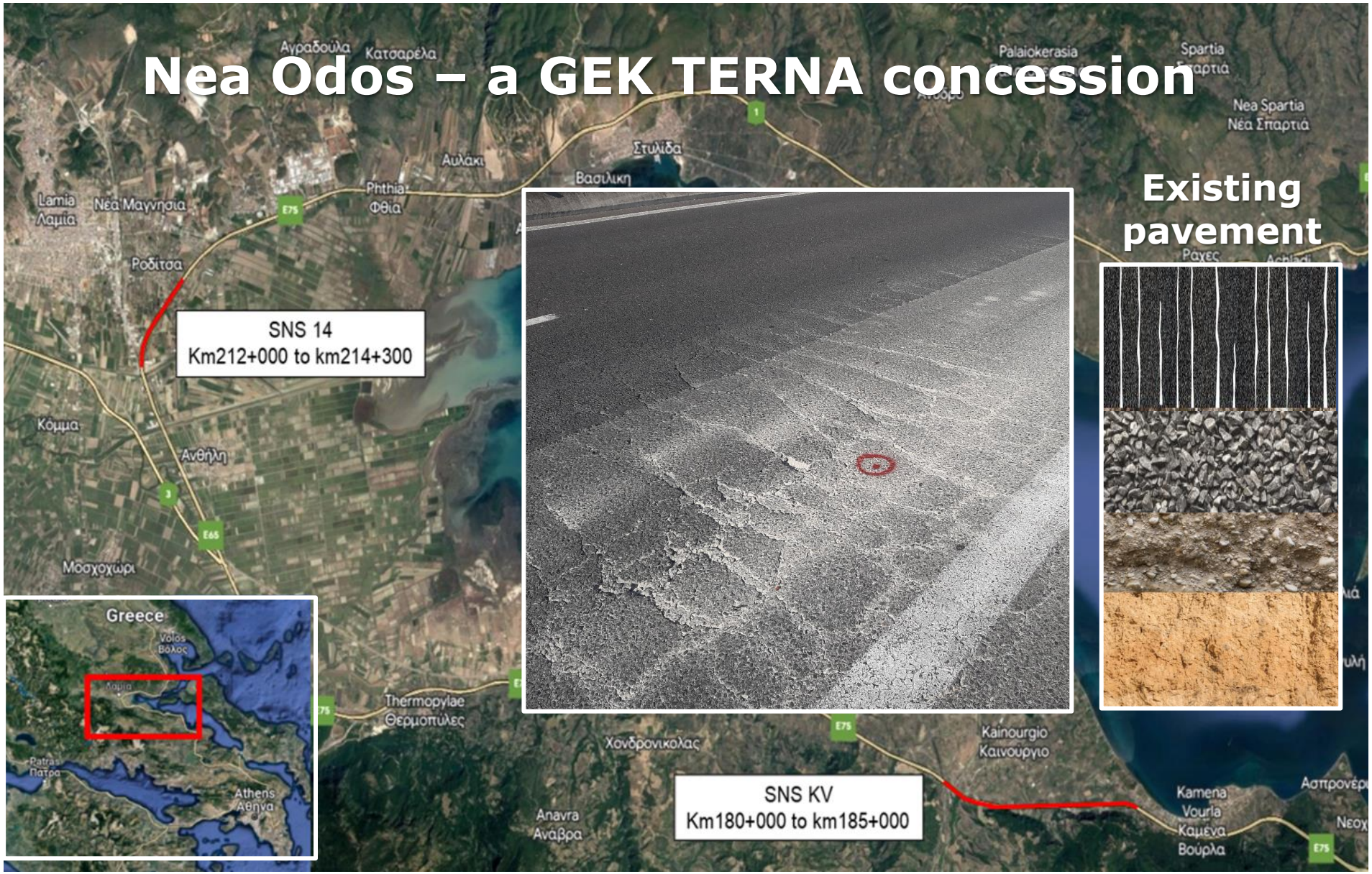
SELECTED PROJECT EXAMPLES

- 2017. Greece. Rehabilitation proposal for Greek Islands runways (Fraport)
- 2018. Uruguay . Rehabilitation of 15km of Ruta 18 Cerro Largo Department (Serviam)
- 2019. Nigeria. Rehabilitation and upgrade of the Abuja-Kano Road – 375.9km (Julius Berger)
- 2020. South Africa. Periodic Maintenance of roads around Uniondale 130km (PGWC)
- 2021. Greece. Pavement Management plan for successful Concession bid for Egnatia Odos (GEK TERNA)
- 2022. Denmark. Lynetteholm Access Road for By&Haven (SR Grupen)
- **2023. Greece. Rehabilitation of a section of the Neo Odos Motorway (Neo Odos Toll Concession)**
- 2024. Morocco, Saudi Arabia, Croatia, Malaysia…

NEO ODOS - 2023

The benefits of cold recycling…

MAJOR GREEK HIGHWAY, 2023



CONVENTIONAL METHOD FOR REHABILITATION

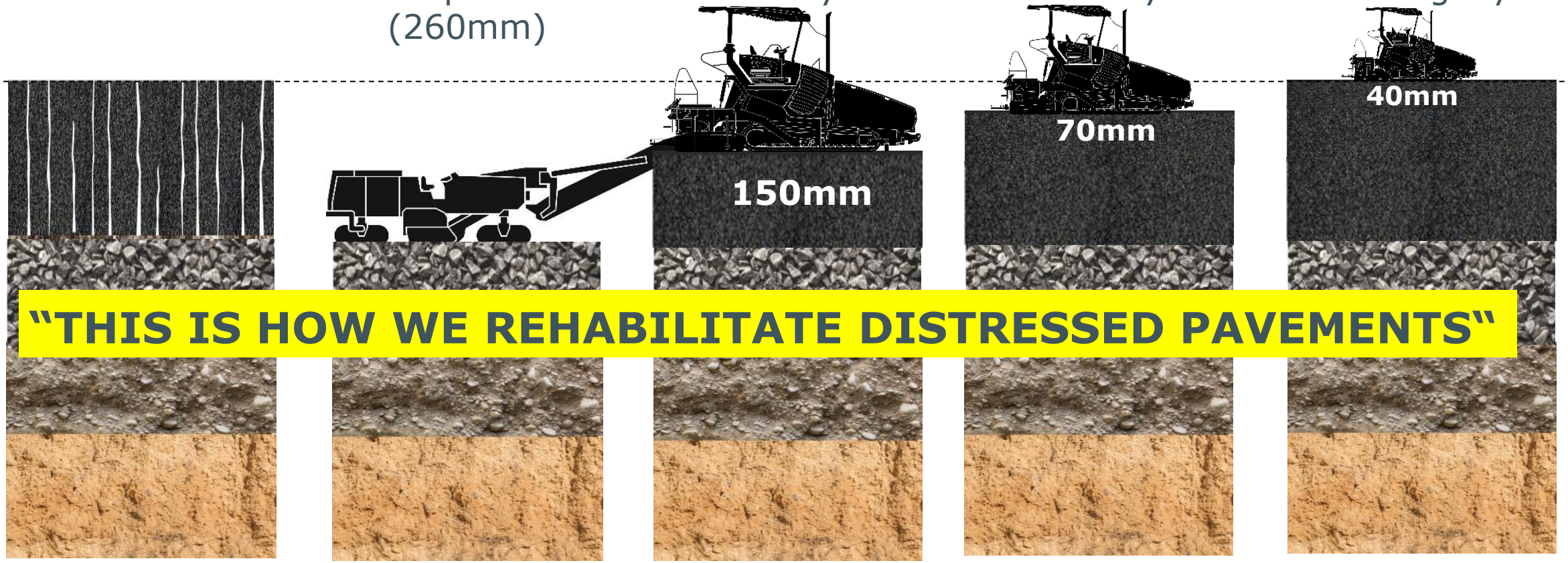
Existing pavement

Mill off all asphalt (260mm)

New asphalt base layer

New asphalt binder layer

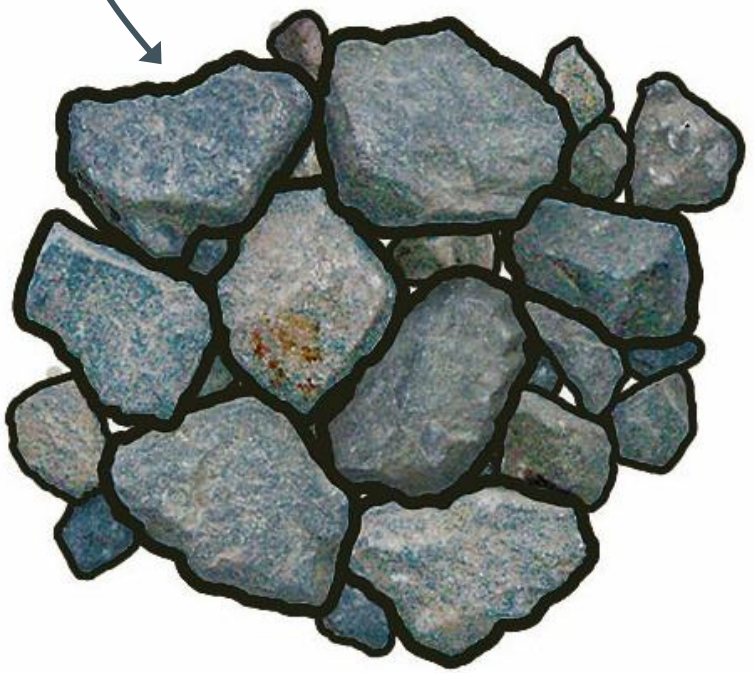
New asphalt surfacing layer



"THIS IS HOW WE REHABILITATE DISTRESSED PAVEMENTS"

ASPHALT. IMPORTANT FEATURES

Film thickness is critical



± 95% Aggregate. Strength / grading / shape / dry

± 5% Bitumen. Rheology / modifiers

Manufactured at 150°C

Paved and compacted at >120°C

CONTINUOUSLY BOUND MATERIAL (contact adhesive)

What would be achieved by milling / replacing?

Problem resolved (eliminate full depth cracking / water ingress)

Original structural capacity restored (± 50 x 10^6 E_{130})

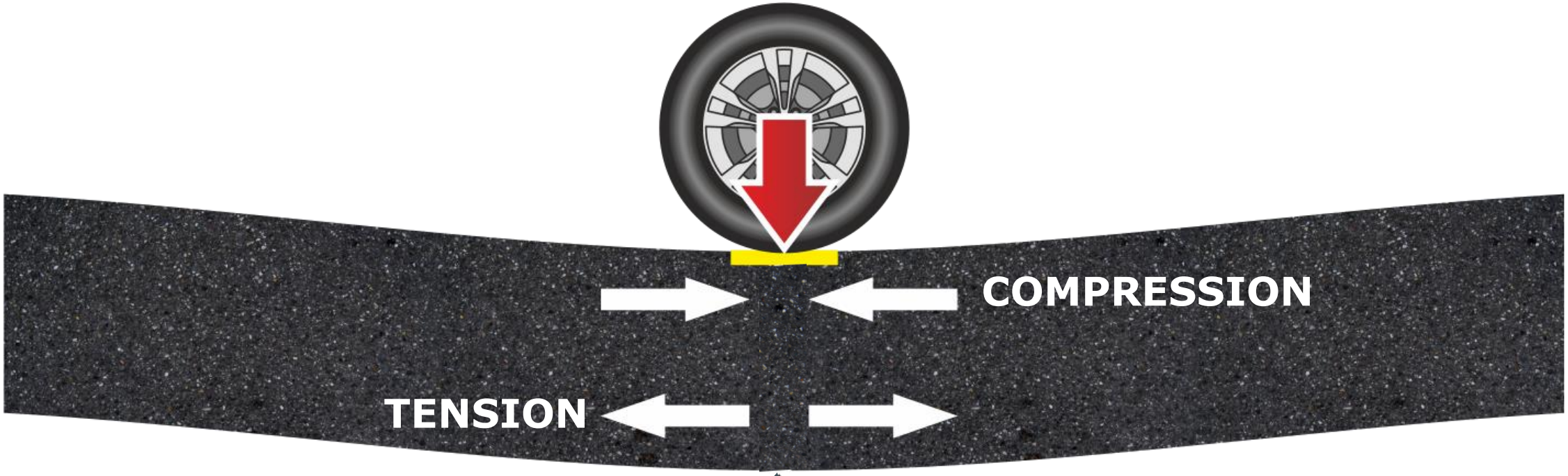
A lot of new best-quality aggregate **consumed**

An enormous amount of energy **burned**

A small fortune **spent** ($)

And then? How would this pavement behave?

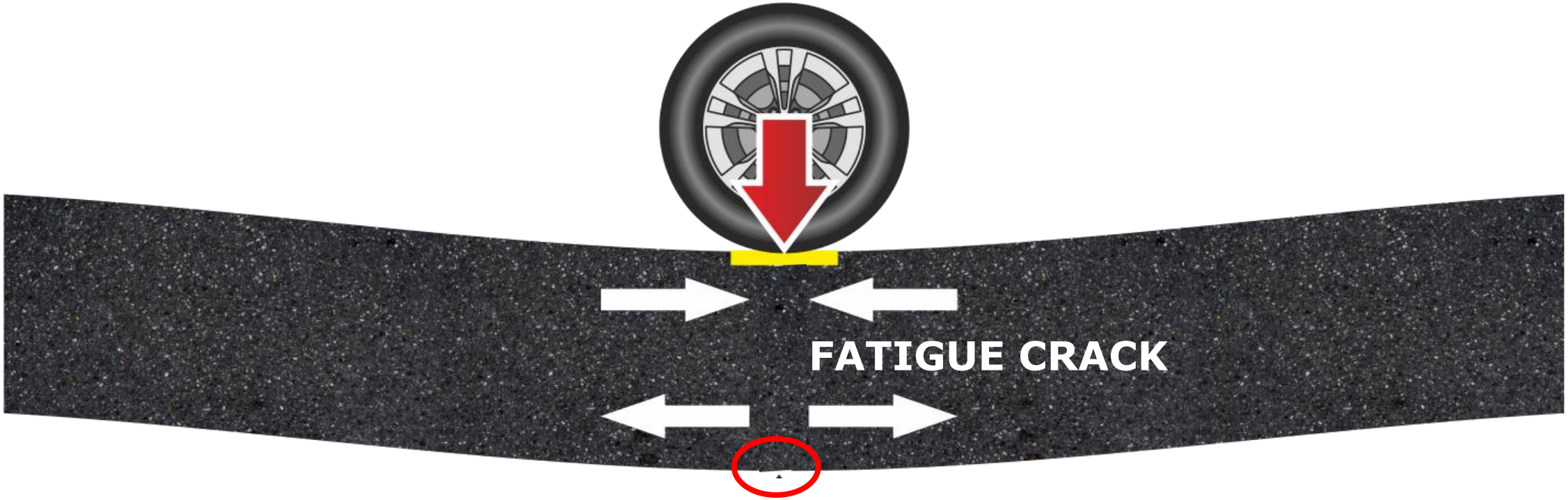
Layers of continuously-bound material bend under load



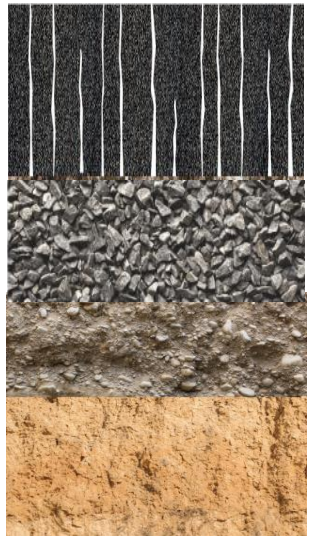
This part of the layer is “stretching” (tensile strain)

Millions of load repetitions cause cracks to develop at the bottom of the layer …

… and then slowly propagate to the top of the layer under more load applications.



The magnitude of tensile strain dictates crack initiation



Failure condition

Full-depth cracking

Moisture ingress

Moisture-activated distress

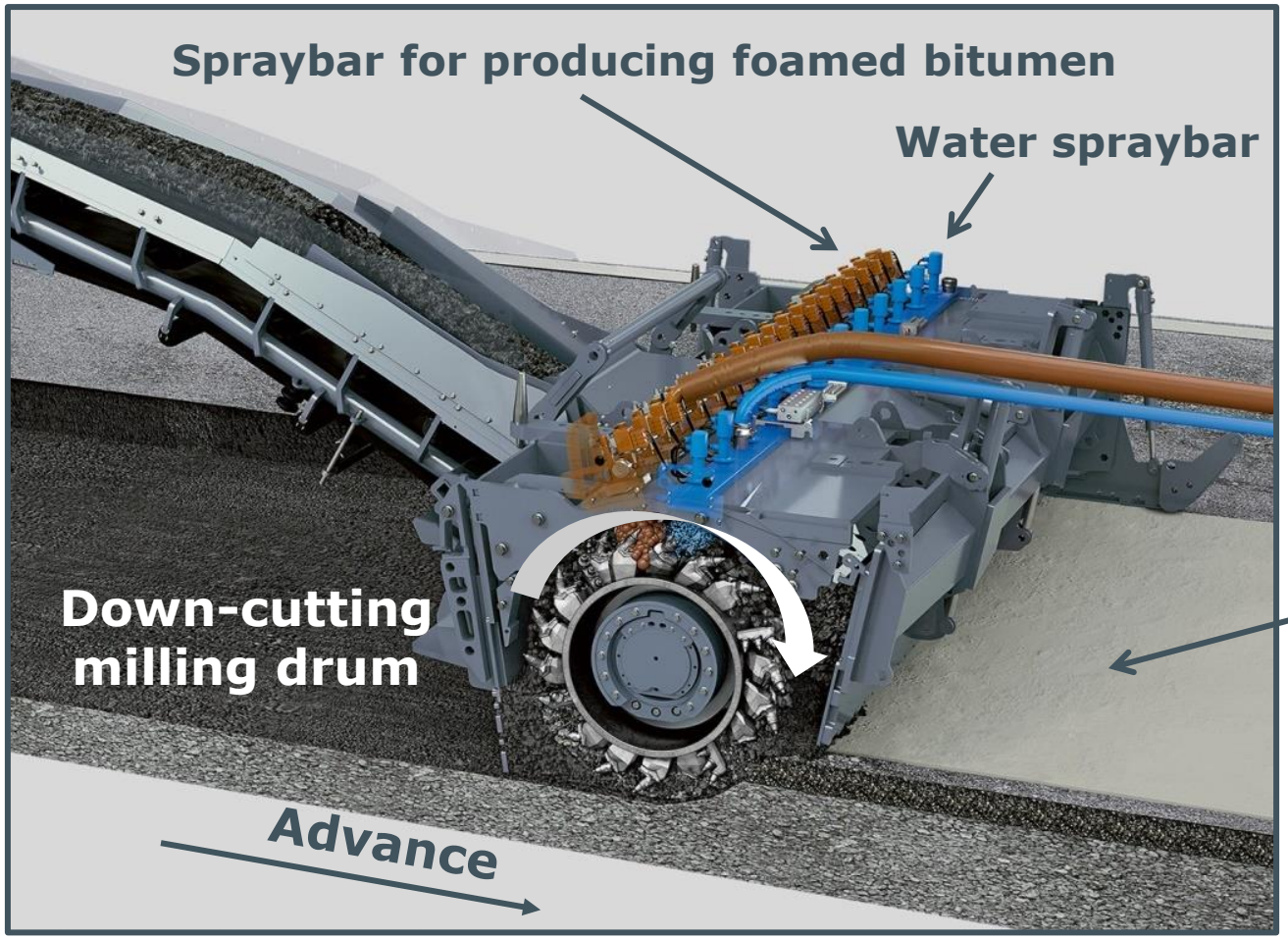
Back to where we started...

when the structural capacity has been consumed

(i.e after 50 x 10^6 E_{130} load repetitions)

IN SITU RECYCLE / STABILISE WITH FOAMED BITUMEN

Treated material passed to paver



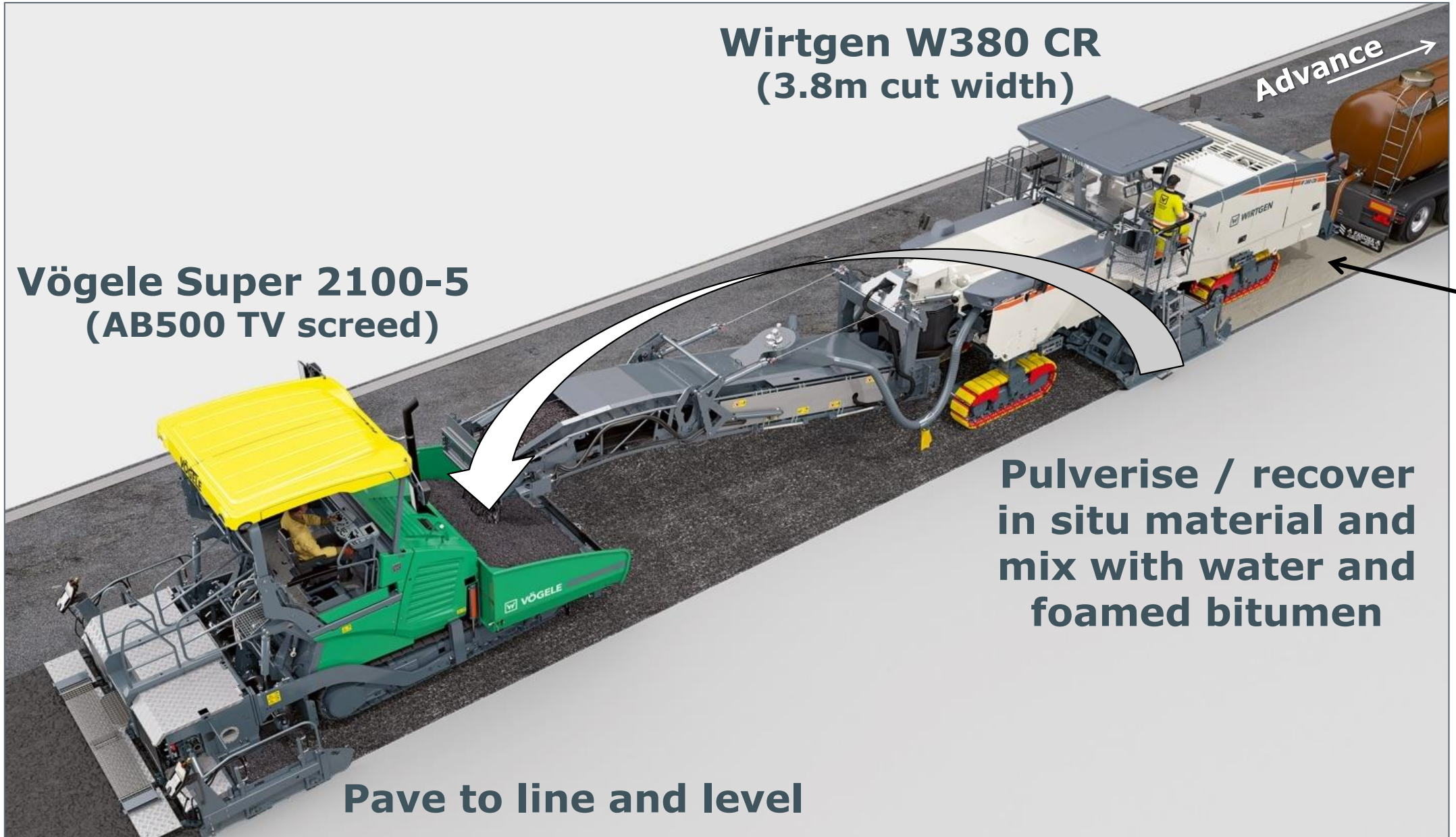
Feed lines for:

Hot bitumen

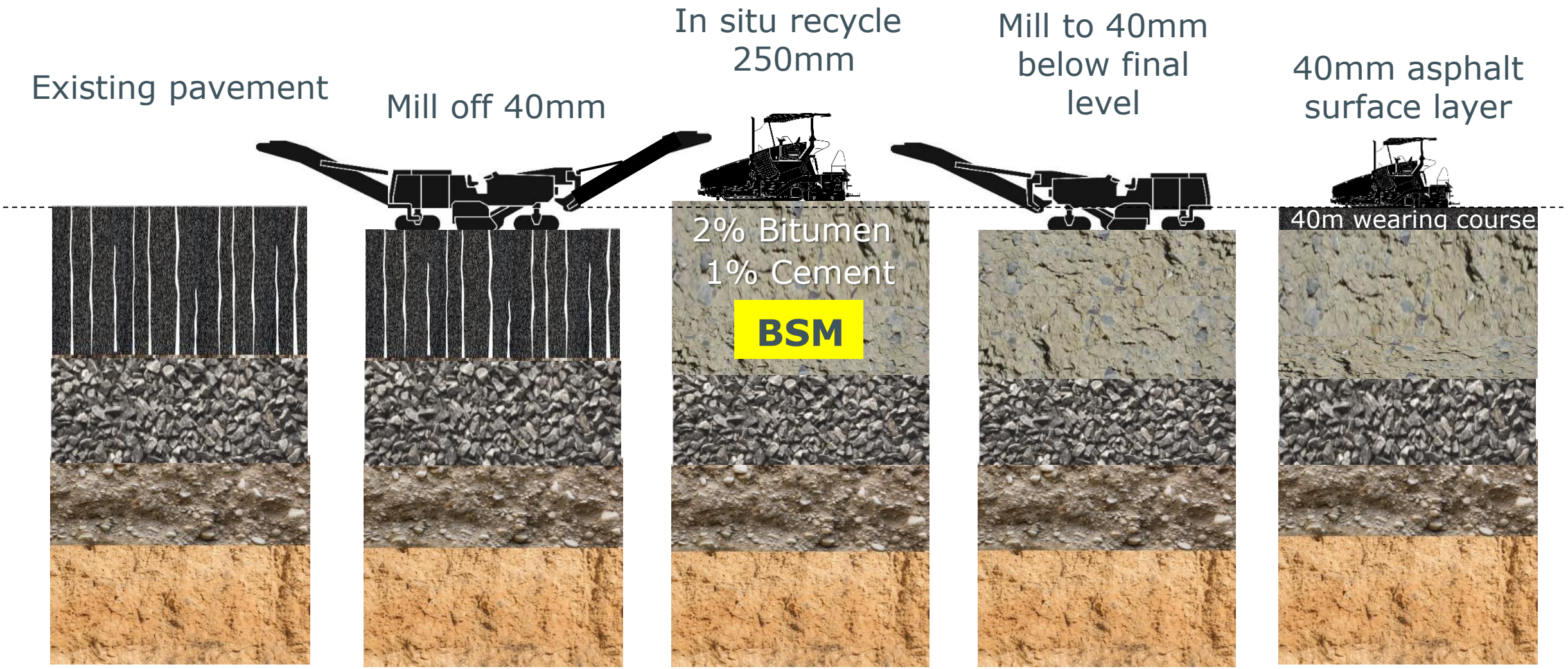
Water

Material spread in front of recycler (e.g. Cement)

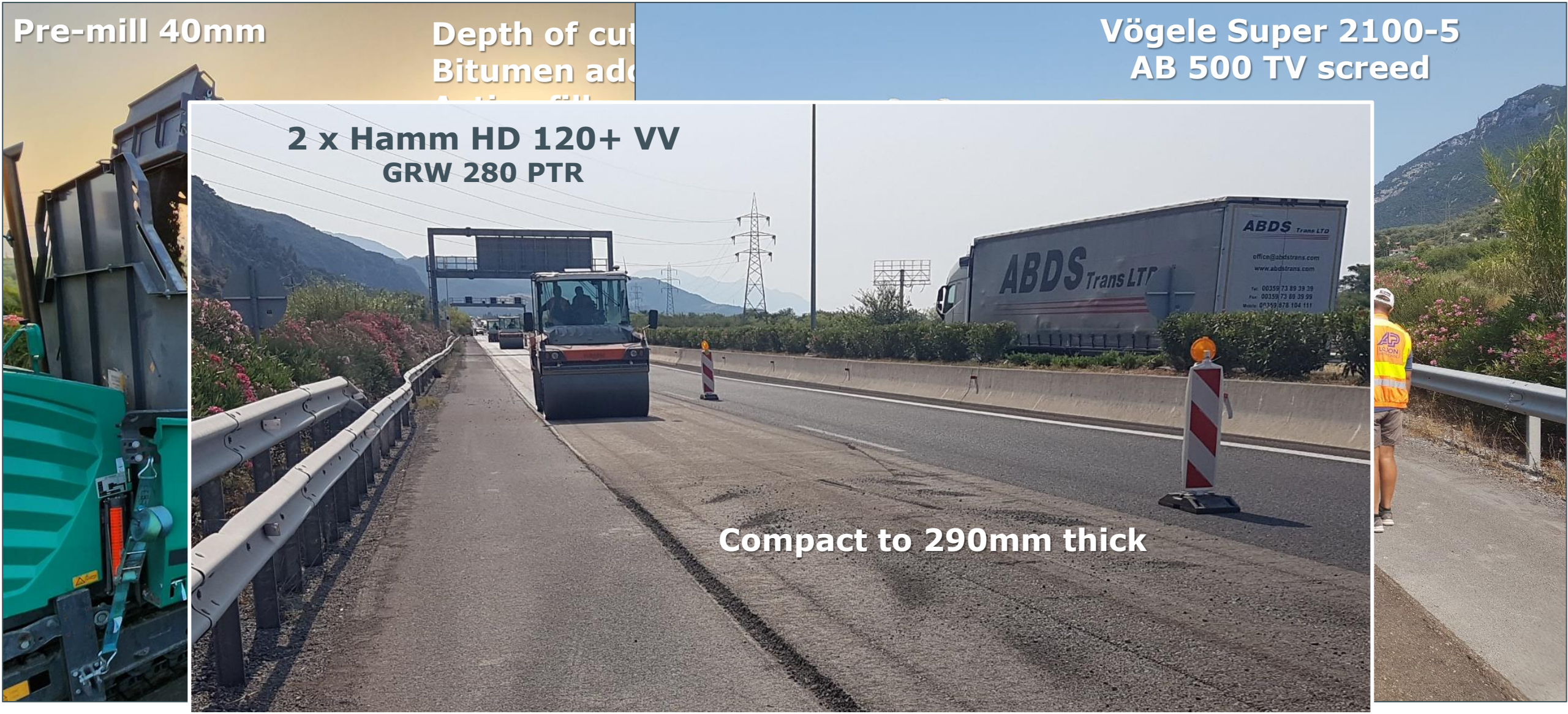
THE RECYCLING PROCESS ADOPTED



THE PROCESS


Existing pavement
Mill off 40mm
In situ recycle 250mm
Mill to 40mm below final level
40mm asphalt surface layer
2% Bitumen
1% Cement
BSM
40m wearing course

HOW WAS THIS DONE?



HOW WAS THIS DONE?

THE FINISHED PRODUCT

BSM. IMPORTANT FEATURES

Aggregate	Most upper pavement materials 100% RAP mixes ideal Moisture content is critical
Bitumen	Straight-run Penetration Grade Bitumen temperature >160°C 1.8% - 2.4% (material dependent)
Active filler	≤ 1% cement or hydrated lime

Manufactured & placed at ambient temperature (>15°C)

Cohesion increases >5 times when compacted

Angle of internal friction remains unchanged

NON-CONTINUOUSLY BOUND MATERIAL

What have we achieved?

Removed the problem (full depth cracking)

Restored the original structural capacity (± 50 x 10^6 E_{130})

Consumed a minimum amount of new aggregate (HMA surfacing)

Burned a small amount of energy (heating the bitumen to >160°C)

Saved a fortune (between 40% and 60% of conventional rehabilitation)

And then? What happens to this pavement?

PERFORMANCE OF BSM LAYERS

BSM is not a continuously bound material

BSM layers therefore do not “bend” under load

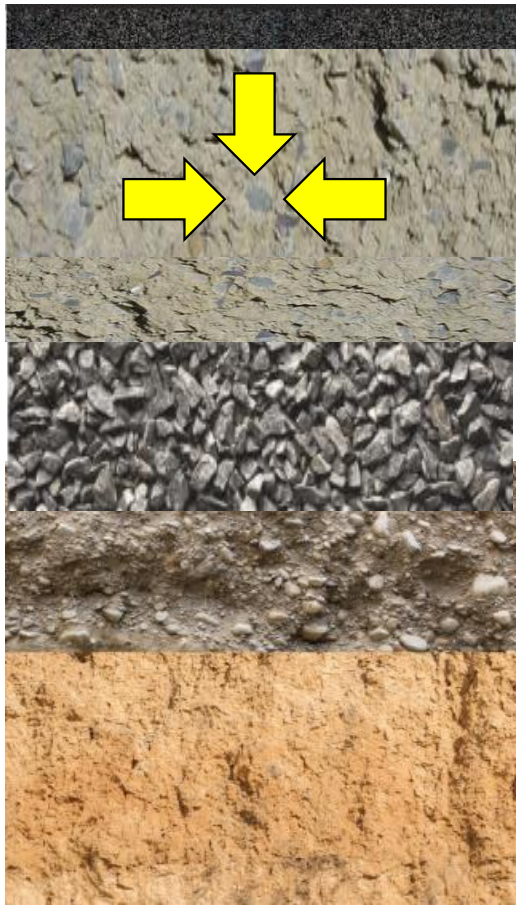
It’s all about the STRESS STATE

(Similar to all granular materials)

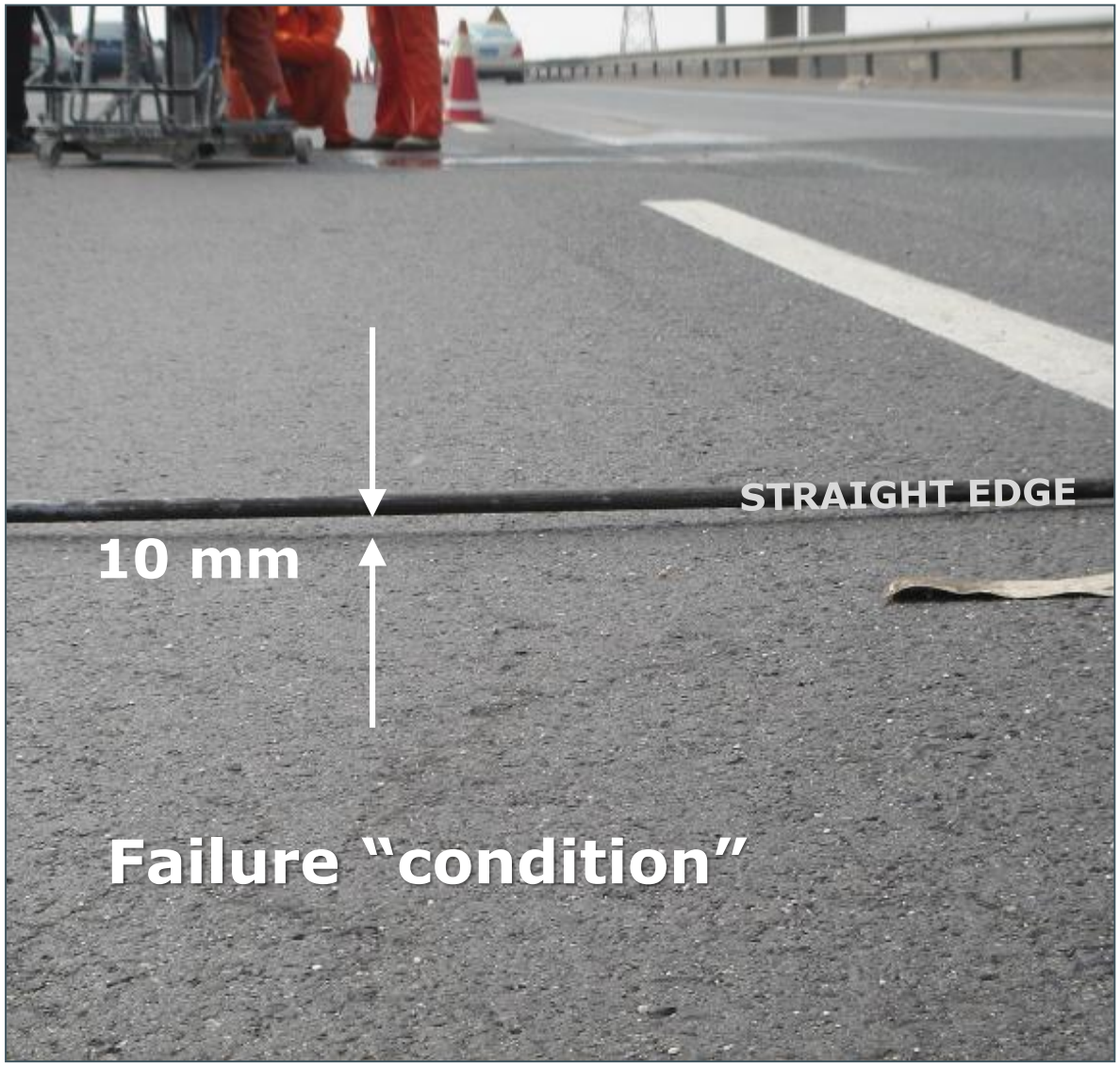
SHEAR PROPERTIES DICTATE PERFORMANCE

(Cohesion and angle of internal friction)

Material consolidates under repeated loads

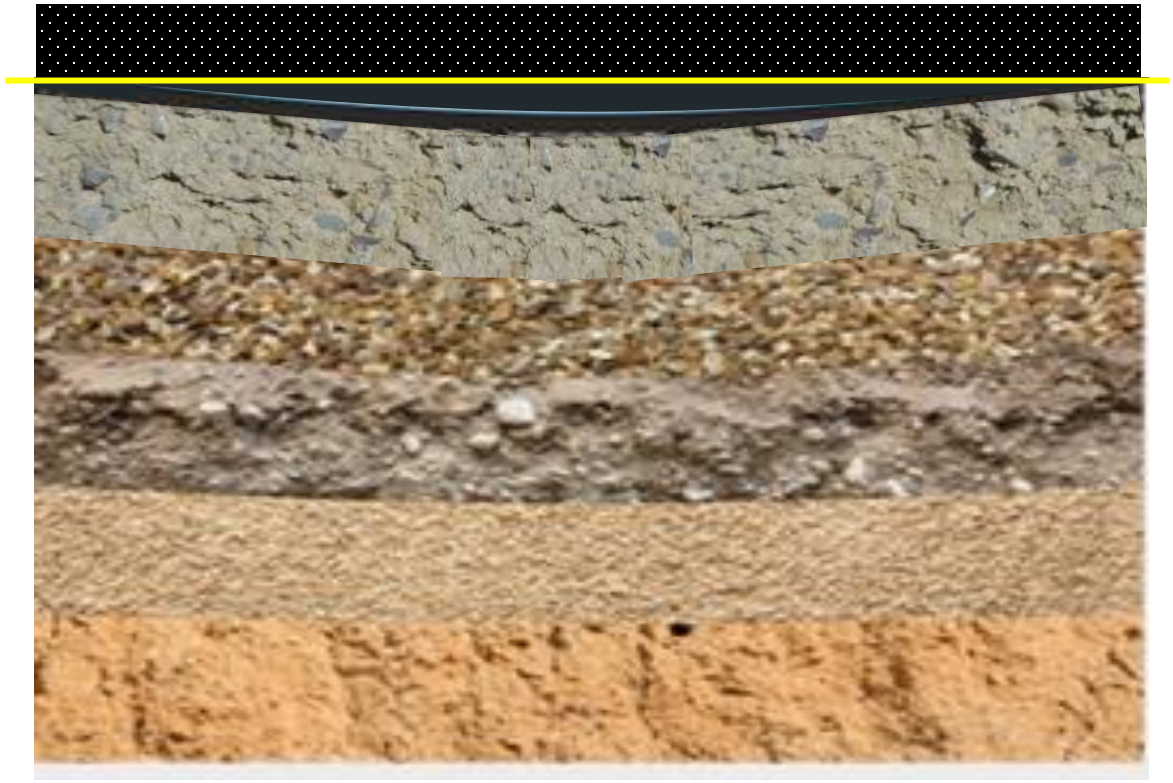


BITUMEN STABILISATION TECHNOLOGY



Pavement "rehabilitation"

Mill and replace the wearing course



Primary technology differences

HMA /Bound		BSM
		
±4% voids	**Density**	±15% voids
M_r >2000MPa (Temperature sensitive)	**Stiffness**	M_r <2000MPa (Modular ratio)
Fatigue	**Failure mechanism**	Deformation
Broken	**Condition at failure**	Intact

IDEAL SURFACING MATERIAL

IDEAL BASE LAYER MATERIAL

STRUCTURAL EQUVALENCY: 1.25 BSM ≈ 1.00 HMA

BENEFITS REALISED ON THE GREEK PROJECT

ITEM	CONVENTIONAL ASPHALT	RECYCLE / BITUMEN STABILISE	BENEFIT
New Crushed aggregate	26,600 tons	4,100 tons	**85% Reduction**
Bitumen	1,276 tons	675 tons	**47% Reduction**
Transport	1,300,000 ton.km	225,000 ton.km	**83% Reduction**
Material Costs	1,819,641.00 €	881,198.00 €	**52% Saving**
CO_2 Emissions	1460 tons	612 tons	**58% Reduction**

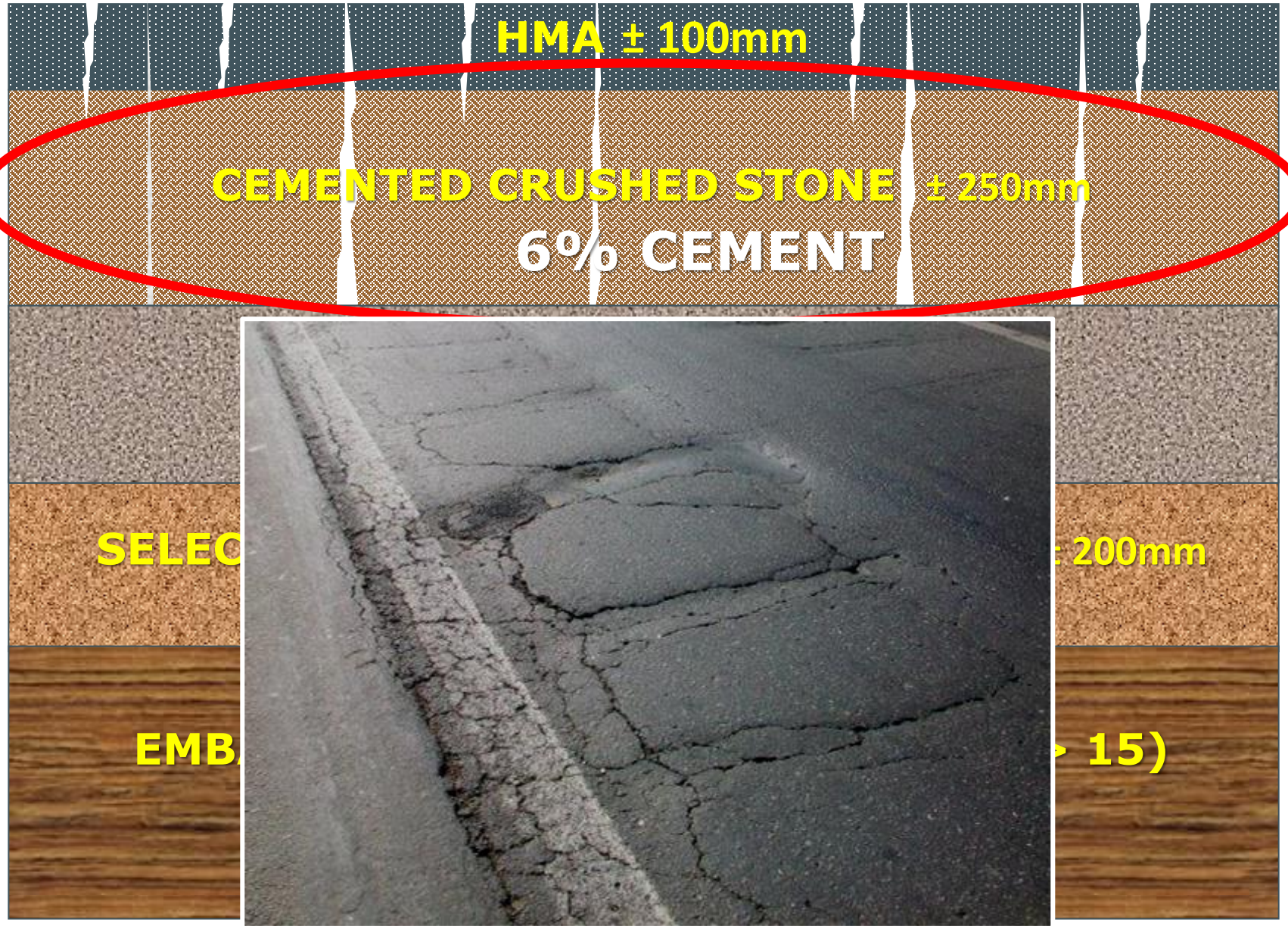
AYRTON SENNA- 2011

This is no longer new and unproven technology…

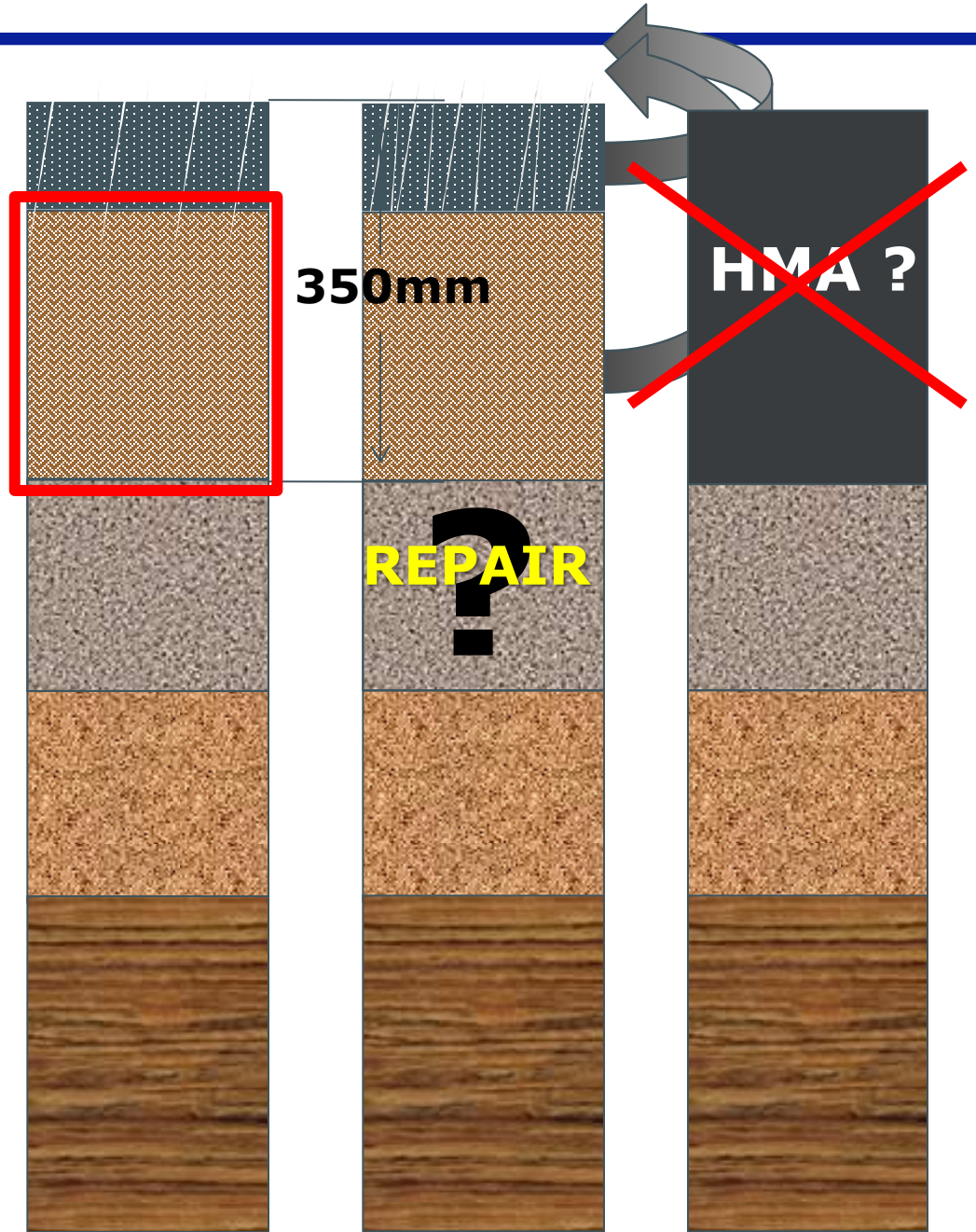

AYRTON SENNA HIGHWAY
SÃO PAULO
Mato Dentro
BR 381
Piracaia
Quiririm
Jarinu
Atibaia
Bom Jesus dos Perdões
Pião
Caçapava
Várzea Paulista
Caetetuba
Nazaré Paulista
Igaratá
Eugênio de Melo
Jundiaí
Francisco Morato
São José dos Campos
Jambeiro
Jacareí
Cristais
Mairiporã
Santa Isabel
BR 116
Cajamar
Franco da Rocha
SERRA DO MAR
Caieiras
Guararema
Santa Branca
Parnaíba
Itaquaquecetuba
Pedras
Osasco
Guarulhos
São Paulo
Grama
São Caetano do Sul
Santo André
Taiaçupeba
Casa Branca
Embu
Diadema
Mauá
São Bernardo do Campo
Itapecerica da Serra
Icatu-Açu
Rio Grande da Serra
Jardim do Sol
Embu-Guaçu
Parelheiros
Cubatão
Santos
São Vicente
Juquitiba
Praia Grande
Guarujá
Porto Velho
Mongaguá
ATLANTIC OCEAN
VENEZUELA
COLOMBIA
AMAZONAS
PERU
BOLIVIA
CHILE
ARGENTINA
SOUTH PACIFIC OCEAN

AYRTON SENNA HIGHWAY KEY DATA

RESULTS OF PAVEMENT INVESTIGATIONS

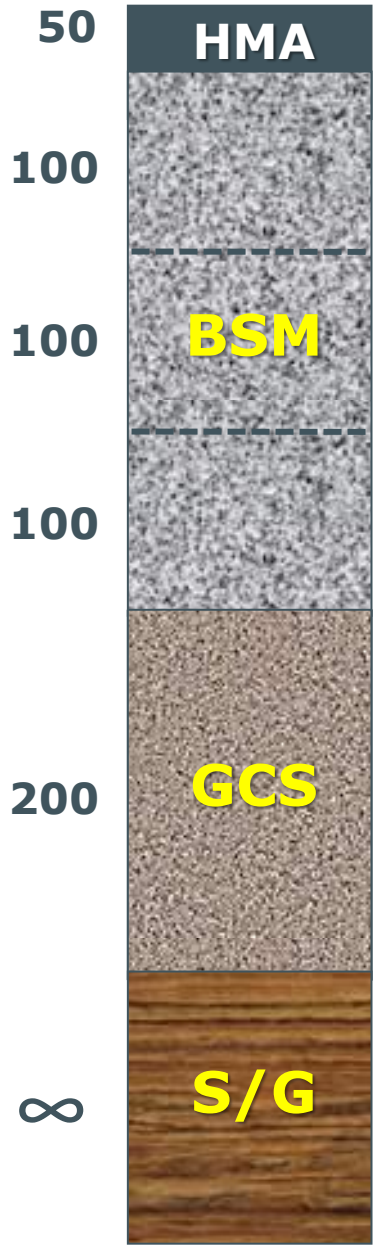


REHABILITATION OPTIONS ?? (6-HOURS)



20mm (temp HMA)
50mm
100mm
200mm

MODELLING (RUBICON LET)



"BALANCED PAVEMENT"

Thickness = 100 Millimetres;
Bitumen Stabilised Material
Stiffness = 1200 MPa; Poisson = 0.35;
Criterion: BSM Deformation (Loudon)
Coh: 280 kPa; Phi: 41; RD: 86; Satur: 70; PS: 13.5;

Shear Stress Ratio: 0.149
Position: Between Loads/25% Of Layer Thickness
Axle Capacity: >100 million (Effective: > 100 million)
Cum. Damage, Phase Start to End: < 0.01 to 0.34

85 : 15 RAP : Dust blend

Thickness = 100 Millimetres;
Bitumen Stabilised Material
Stiffness = 1000 MPa; Poisson = 0.35;
Criterion: BSM Deformation (Loudon)
Coh: 300 kPa; Phi: 38; RD: 84; Satur: 70; PS: 13.5;

Shear Stress Ratio: 0.244
Position: Load Centreline/25% Of Layer Thickness
Axle Capacity: >100 million (Effective: > 100 million)
Cum. Damage, Phase Start to End: < 0.01 to 0.34

100% RAP

Thickness = 100 Millimetres;
Bitumen Stabilised Material
Stiffness = 600 MPa; Poisson = 0.35;
Criterion: BSM Deformation (Loudon)
Coh: 300 kPa; Phi: 38; RD: 82; Satur: 70; PS: 13.5;

Shear Stress Ratio: 0.129
Position: Load Centreline/25% Of Layer Thickness
Axle Capacity: >100 million (Effective: > 100 million)
Cum. Damage, Phase Start to End: < 0.01 to 0.34

100% RAP

Thickness = 200 Millimetres;
G4 material in moderate condition
Stiffness = 200 MPa; Poisson = 0.35;
Criterion: Granular Materials Cat A
Cohesion = 34.4 kPa; Angle of Friction = 43.4

Shear Safety Factor: 2.96
Position: Between Loads/Middle of Layer
Axle Capacity: >100 million (Effective: > 100 million)
Cum. Damage, Phase Start to End: < 0.01 to 0.34

Thickness = Semi-Infinite;
G7 Subgrade Material
Stiffness = 100 MPa; Poisson = 0.35;
Criterion: RSA Subgrade 10mm Rut, Cat A
No special material properties needed

Vertical Compressive Strain: 300 Microstrain
Position: Between Loads/Top of Layer
Axle Capacity: >100 million (Effective: > 100 million)
Cum. Damage, Phase Start to End: < 0.01 to > 1.0

Modular Ratio Rule


To local stockpile
UNIFREZA
REMOVE 100mm HMA

DAYTIME OPERATIONS

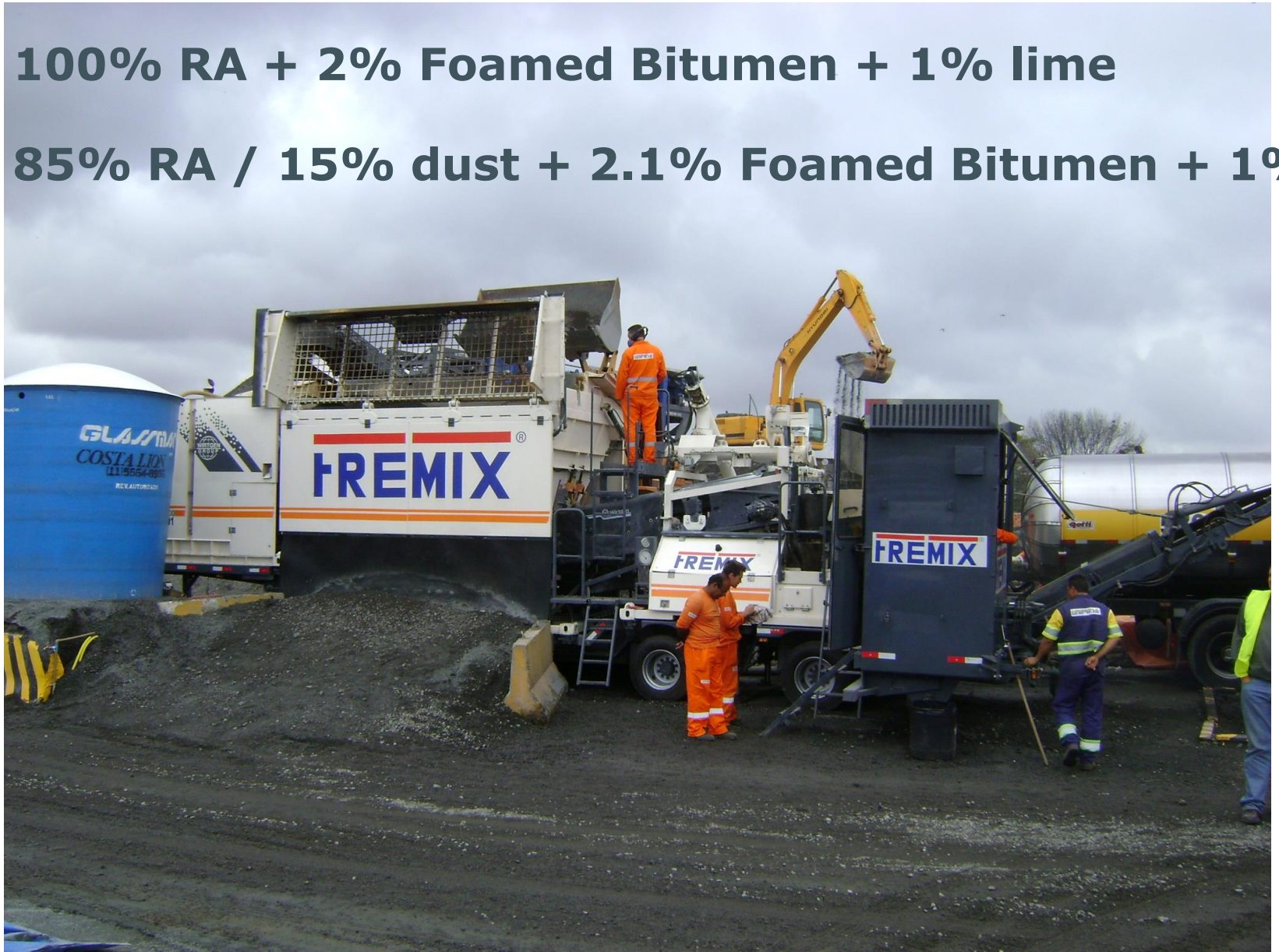
RAP processing

Impact crusher (20mm gap)

WIRTGEN KMA 220 MIXING PLANT

Mix 1: **100% RA + 2% Foamed Bitumen + 1% lime**

Mix 2: **85% RA / 15% dust + 2.1% Foamed Bitumen + 1% lime**



MIXED MATERIALS PLACED IN STOCKPILES

INSPECTION OF EXCAVATION FLOOR

PROOF ROLLING

LOWER BSM LAYER

COMPACTION OF LOWER BSM LAYERS

DENSITY TESTING

TOP BSM LAYER

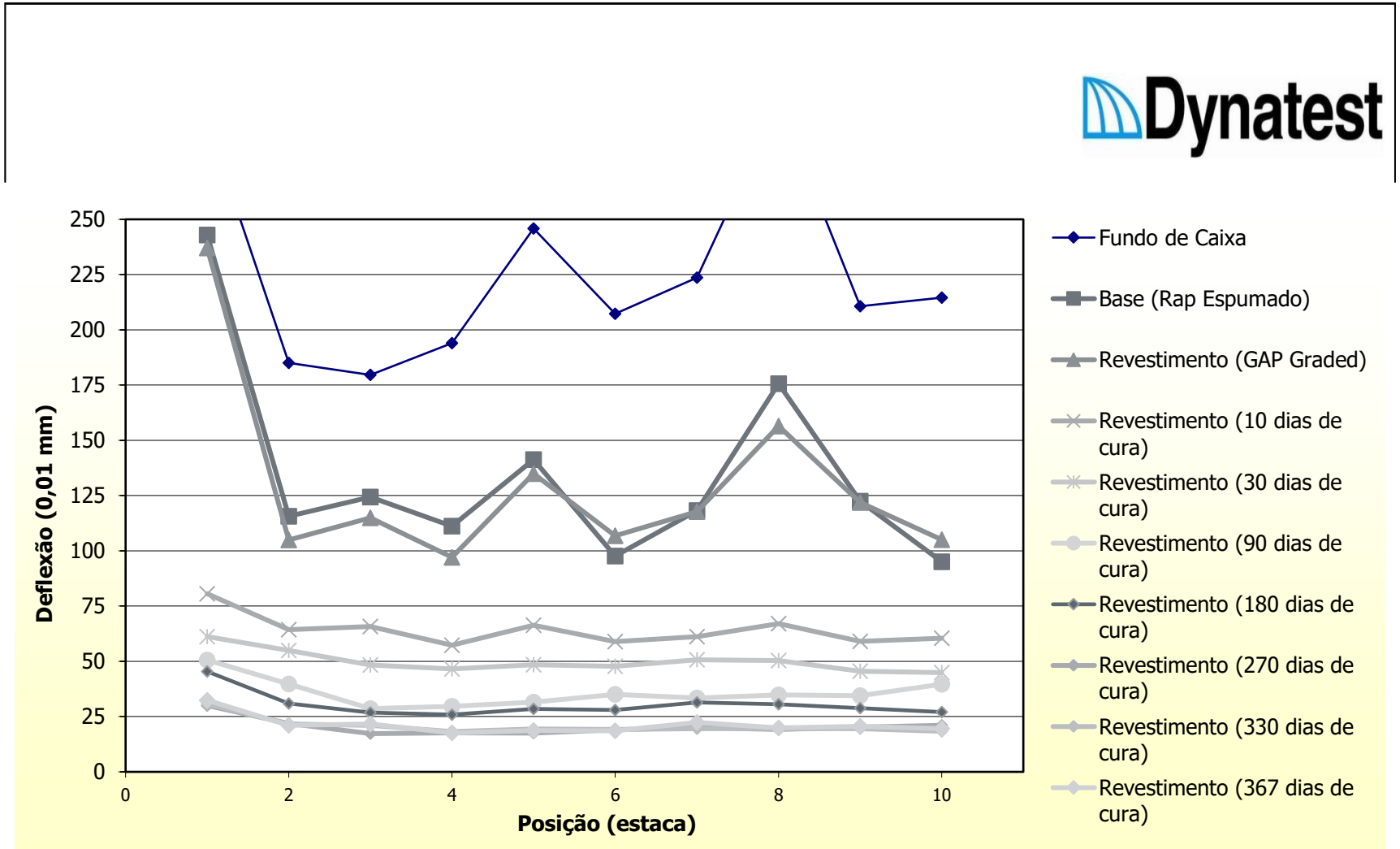
COMPACTION OF TOP BSM LAYER

FINAL ASPHALT LAYERS

2CM GAP GRADED

FINAL PROJECT

STIFFNESS DEVELOPMENT WITH TIME



ANALYSIS OF FWD SURVEY – OCTOBER 2014

FWD Analysis: From km 15+650 to km 16+250						
SLOW LANE Applied Load:		8 ton axle load, 541 to 607 kPa applied pressure				
Pavement Layers		Thickness (mm)	Poisson's ratio	**Derived resilient modulus (M_R) (MPa)**		
				Average	80th %ile (high)	80th %ile (low)
	Asphalt surfacing	50	0.4	3000	3000	3000
	BSM base	100	0.35	**1633**	**1954**	**1312**
	BSM upper subbase	200	0.35	**1192**	**1527**	**857**
	Natural lower subbase	250	0.35	346	459	253
	Subgrade support	Inf	0.35	275	309	204

3 months later…

CURRENT CONDITION (2024)

PRACTICAL CHALLENGES TO IMPLEMENTATION

Why are we not recycling more?

WHY ARE WE NOT RECYCLING MORE?

WHY ARE WE NOT RECYCLING MORE?

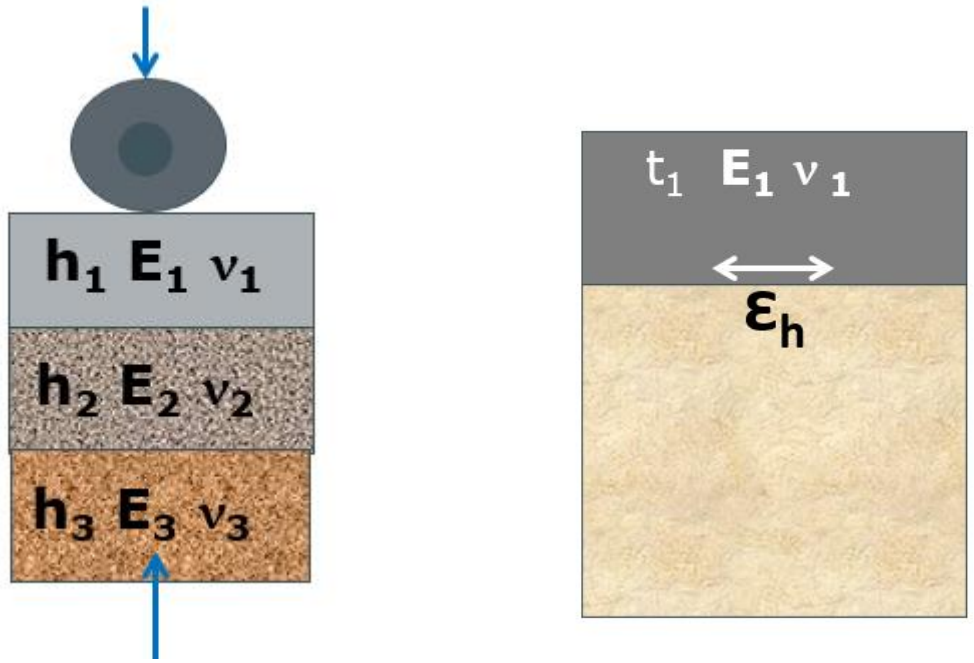
- Humans have a general resistance to change…
  - Asphalt is a great material so why change?

WHY ARE WE NOT RECYCLING MORE?

- There is not one uniformly accepted definition for the method or materials produced during cold recycling
  - This leads to confusion and creates caution.

WHY ARE WE NOT RECYCLING MORE?

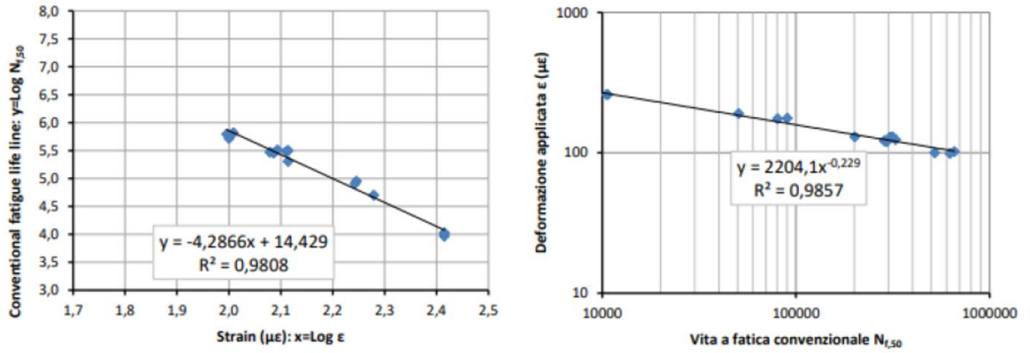
- The international road industry design capabilities is asphalt orientated
  - Modulus and fatigue parameters

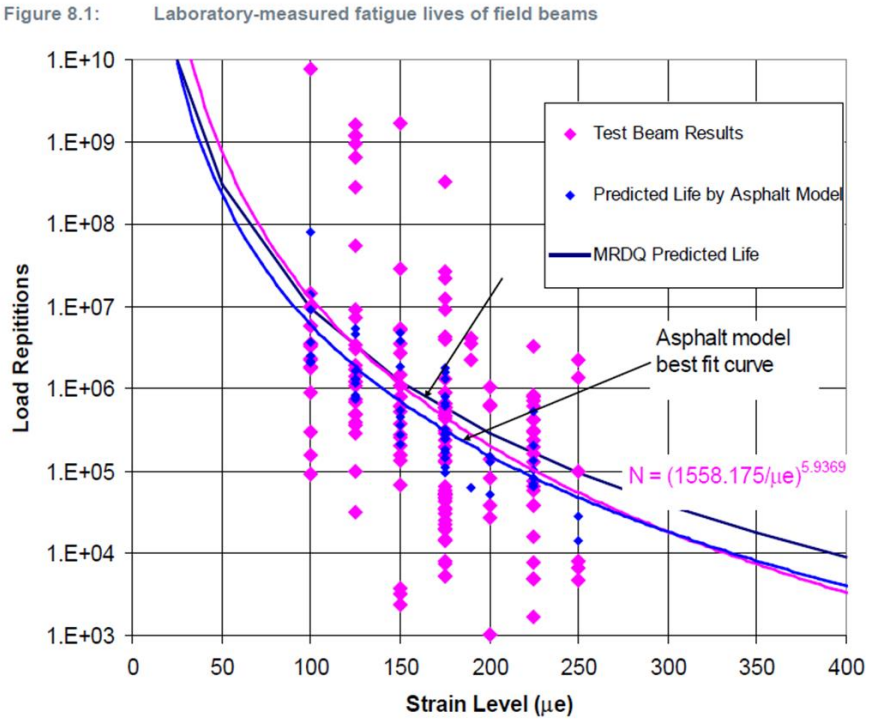


WHY ARE WE NOT RECYCLING MORE?

- The international road industry design capabilities is asphalt orientated
  - Modulus and fatigue parameter

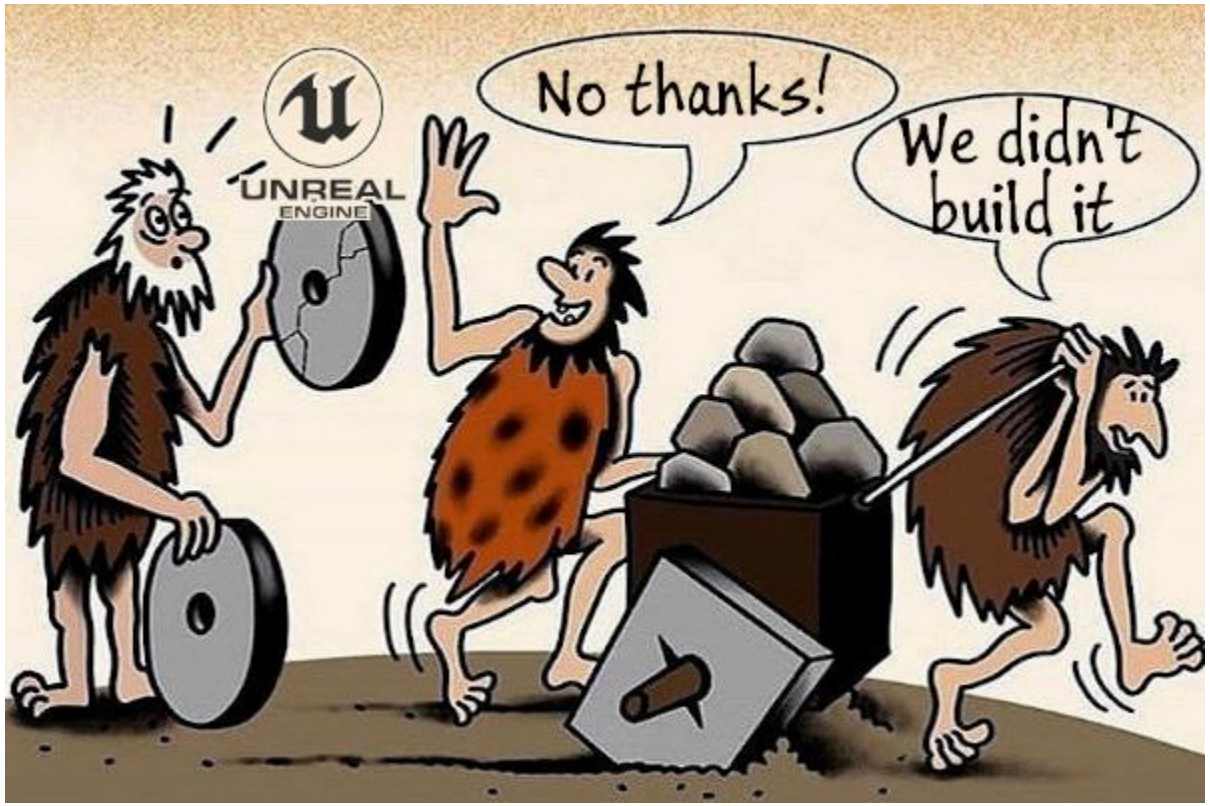
Παραμόρφωση που αντιστοιχούν σε 10^6 κύκλους ϵ_6 (με) Deformation *corresponding to 10^6 cycles, ϵ_6*	Συντελεστής συσχέτισης *Correlation coefficient* R2	Κλίση καμπύλης 1/b *Curve*	Τυπική απόκλιση υπολειπόμενη *standard deviation residual* SN
93	0,9808	-4,2866	0,06





WHY ARE WE NOT RECYCLING MORE?

- Road Design Nationalism
  - Every country wants to reinvent the wheel



CONCLUSIONS AND RECOMMENDATION

What should be changed to recycle more?

WHAT SHOULD BE CHANGED?

- The focus should shift from the equipment , stabilising agents and fillers to final material…
- We need to promote acceptance and understanding of this unique material…
- We need to learn from each other experiences…
- We need to standardise terminology and testing…
- We need to identify the drivers for change!
- We need a united voice to promote this at the highest levels!

WHAT SHOULD BE CHANGED?

- My wish is that ART2024 will be start of the change we require for more implementation of all asphalt recycling technology !
- I look forward to seeing you all again at ART2025!

THANK YOU FOR YOUR TIME…