Cold Recycling

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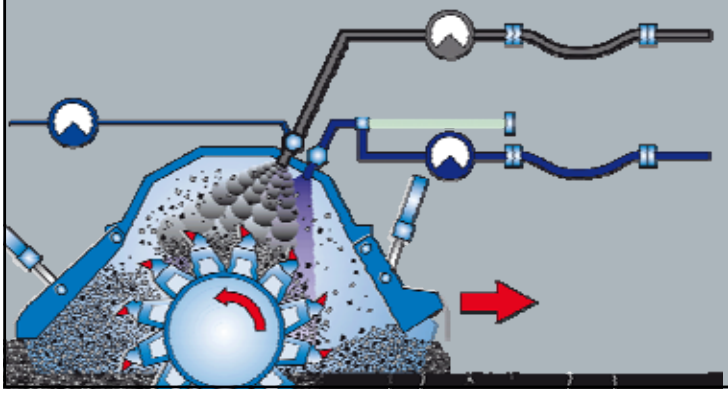
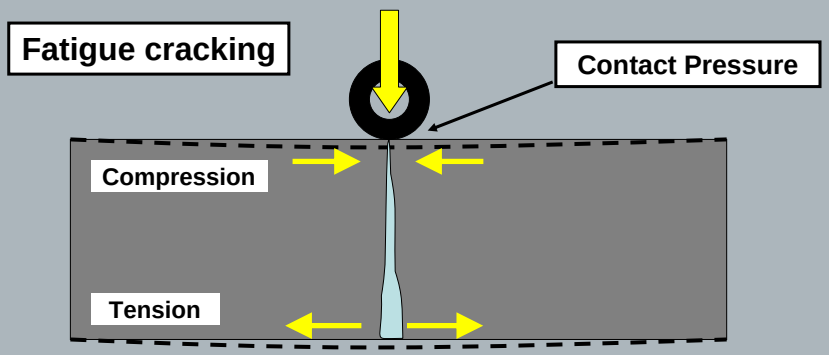
Wirtgen GmbH



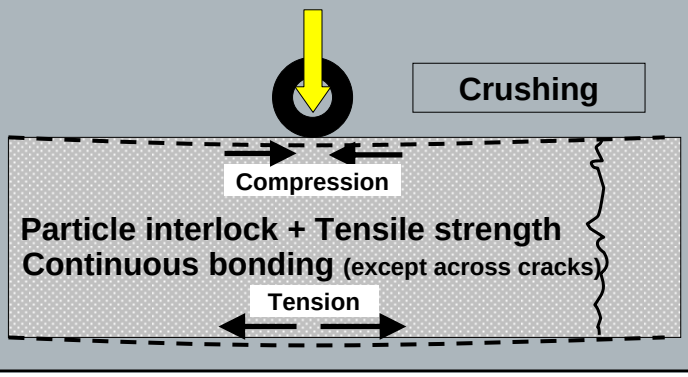
The tip of an iceberg

ASPHALT LAYERS UNDER LOAD

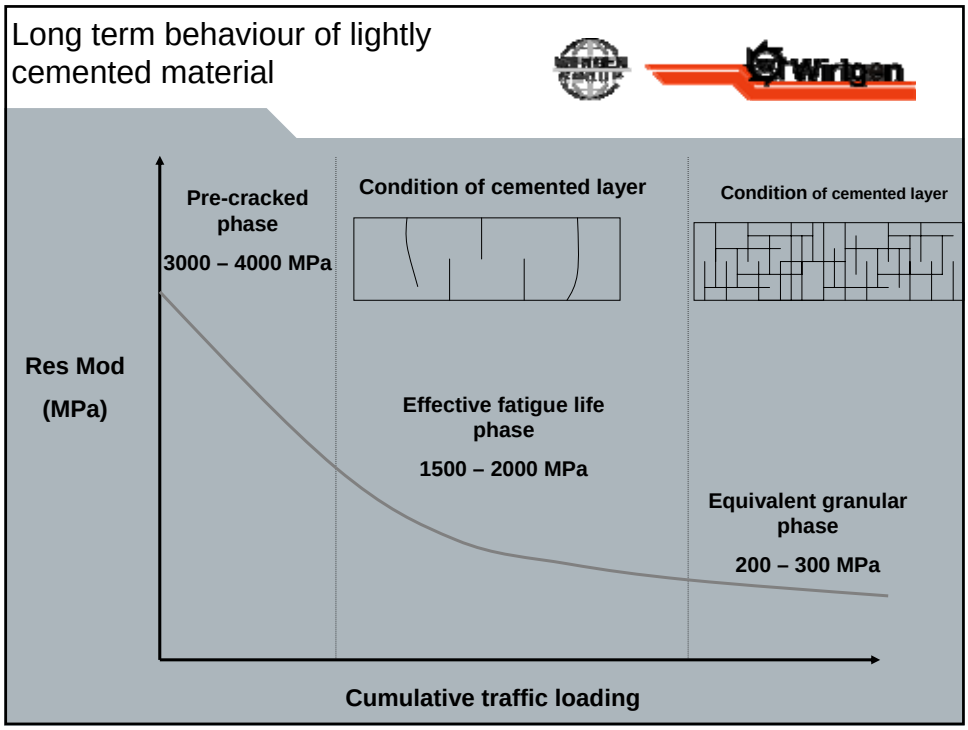


CEMENT STABILISED MATERIAL (NON-TEMPERATURE SENSITIVE)

- Shrinkage cracking
- 1. Fatigue cracking
- 2. Permanent deformation

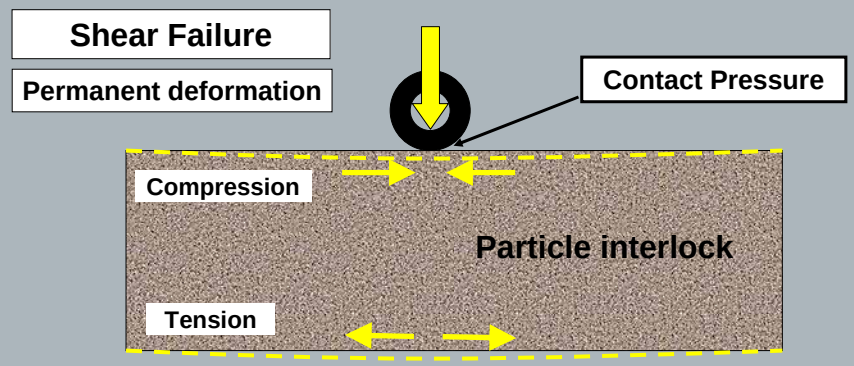


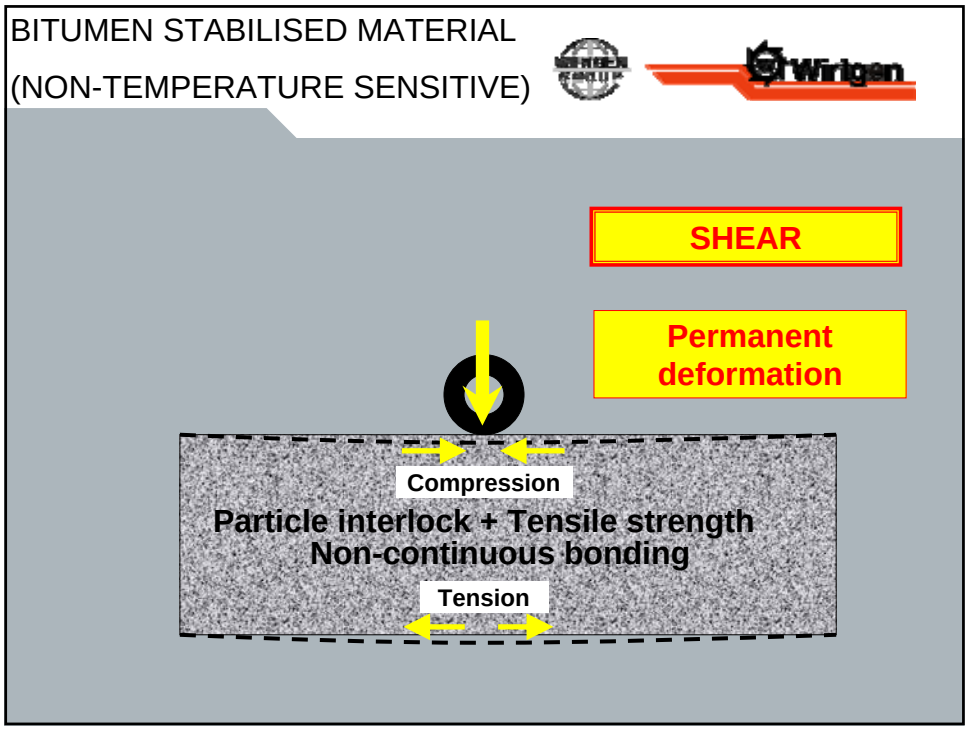
Long term behaviour of lightly cemented material

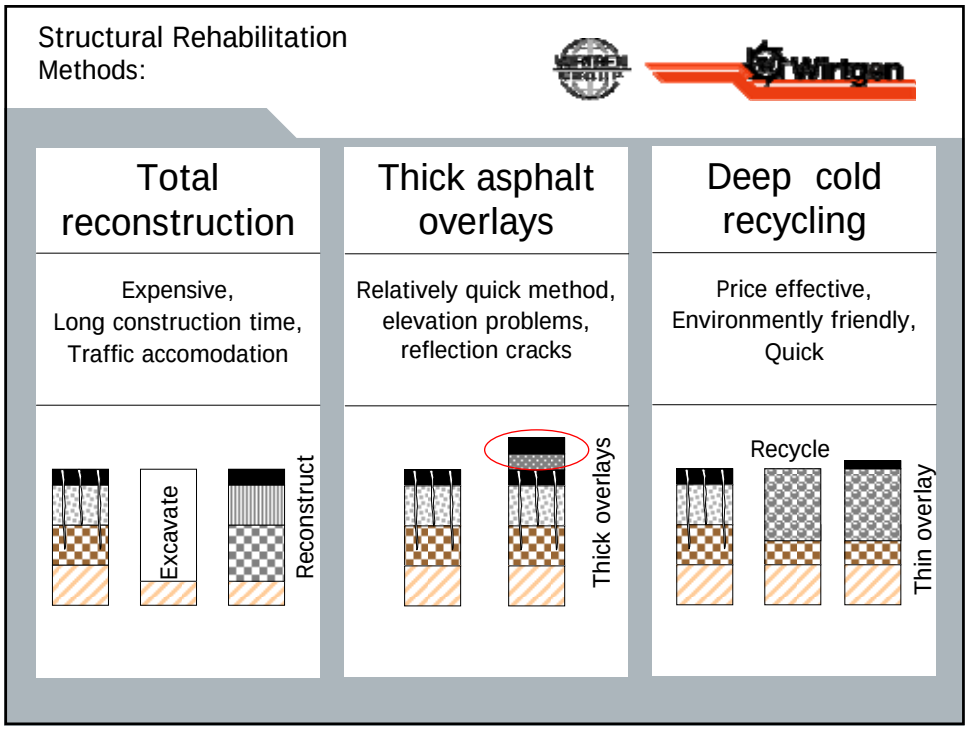


GRANULAR MATERIALS

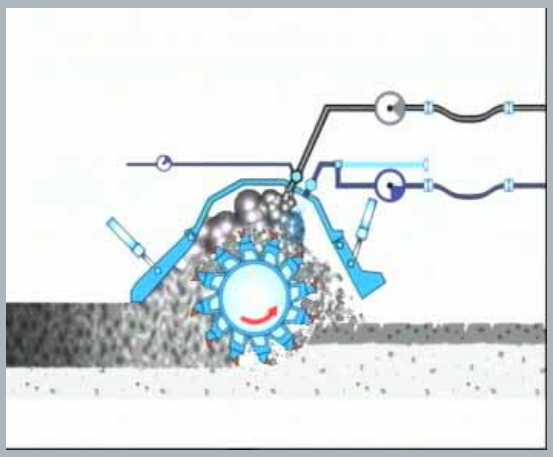
(NON-TEMPERATURE SENSITIVE)




BITUMEN STABILISED MATERIAL
(NON-TEMPERATURE SENSITIVE)
Wirtgen
SHEAR
Permanent deformation
Compression
Particle interlock + Tensile strength
Non-continuous bonding
Tension


Structural Rehabilitation Methods:
Wirtgen
Total reconstruction
Expensive,
Long construction time,
Traffic accomodation
Excavate
Reconstruct
Thick asphalt overlays
Relatively quick method,
elevation problems,
reflection cracks
Thick overlays
Deep cold recycling
Price effective,
Environmently friendly,
Quick
Recycle
Thin overlay

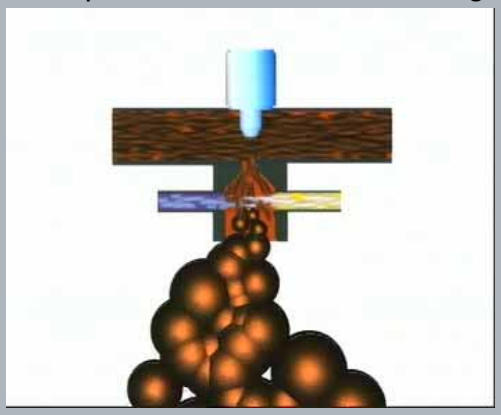
Cold in situ Recycling
The Process



Animation of the cold recycling process

What is Foamed Bitumen ?

2 – 3 % bitumen water in 180 °C hot bitumen:
The bitumen expands 15 to 20 times its original volume.



The increased surface area makes it possible to
mix hot bitumen with cold and damp aggregates

Foamed bitumen

Foamed bitumen treatment is a stabilising process

- Bubbles of foam are thin films of bitumen (low viscosity) surrounding expanded water vapour (steam)
- These bubbles "burst" into small bitumen particles when mixed with aggregate
- Small bitumen particles can only adhere to the fine material
- The moisture content of the material is critical (bitumen particles have only sufficient energy to heat the moisture on the dust)
- The resulting mix is comprised of uncoated coarse granular particles with millions of sticky elastic "spots" in the mortar that hold it together (spot welding)

Foamed bitumen mix

Foamed bitumen mix

Foamed bitumen mix

PERFORMANCE FACTORS

Stress dependent (granular)

Not temperature sensitive

Elastic properties

Not prone to cracking

Highly durable:

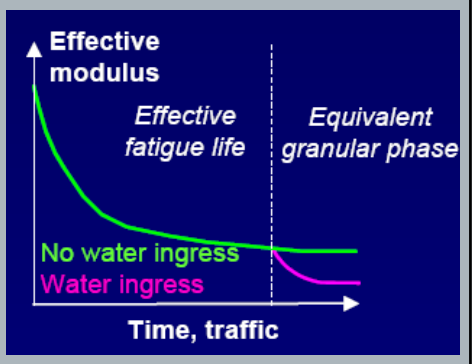
- **no fines loss (pumping)**
- **slow oxidation of bitumen**

MODE OF FAILURE

Permanent deformation

Behaviour of foamed bitumen treated materials

- **High cohesive bonds initially**
  - **Effective fatigue life**
- **Bond destroyed by traffic action leading to reduction in modulus**
- **Equivalent granular phase**
  - **Permanent deformation**



Sensitivity of key variables

BASED ON TG2 PERMANENT DEFORMATION TRANSFER FUNCTION

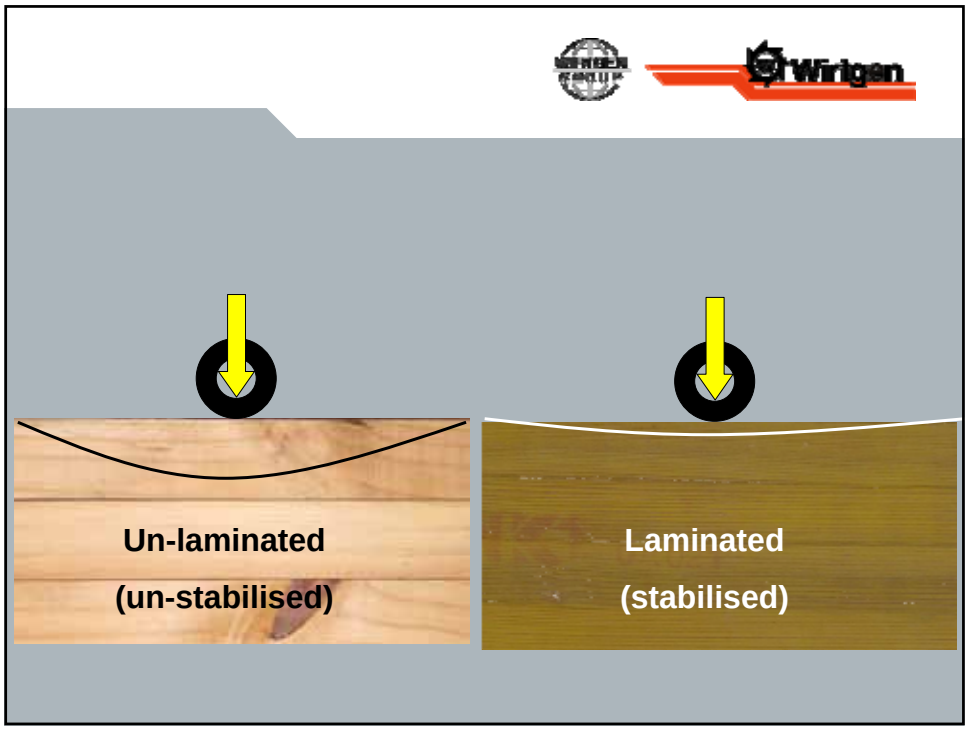
$$N_{PD.FB} = 1/30 \times 10^{[k+11.938RD+0.0726PS-1.628SR+0.68(cem/bit]}$$

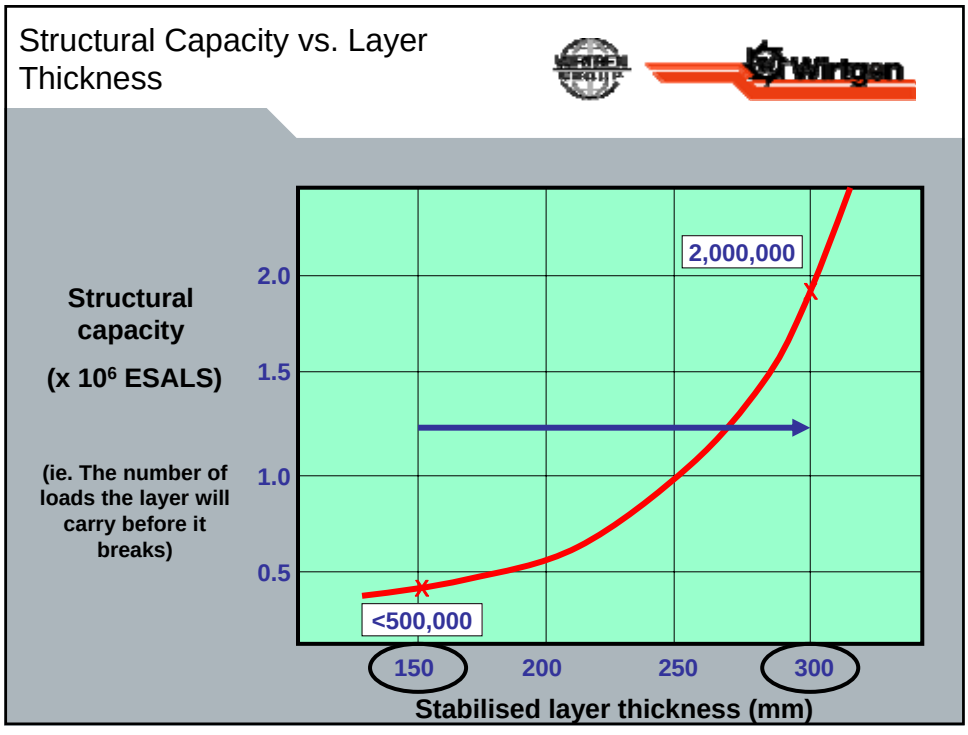
Road category	Relative density	Plastic strain	Stress ratio	
A = - 2.047	0.78 to 0.88	5 to 20	0.1 to 1.0	Max cement 1.5%
B = - 1.950			MODEL	
C = - 1.816	0.86	10	0.25	0.4
D = - 1.625				

$N_{PD.FB}$ = 20,000,000 ESALS(8t)

0.84

$N_{PD.FB}$ = 12 x 10^6 ESALS(8t)


Un-laminated
(un-stabilised)
Laminated
(stabilised)


Structural Capacity vs. Layer Thickness
Structural capacity
(x 10⁶ ESALS)
(ie. The number of loads the layer will carry before it breaks)
2.0
1.5
1.0
0.5
2,000,000
<500,000
150
200
250
300
Stabilised layer thickness (mm)

Distress mode

Permanent deformation, but …….

Shear failure – consolidation – reconstitutes

(provided bitumen remains active)

NO FATIGUE CRACKING

		Konventionell			Recycling		
Structural Layers	Structural number range	Thickness (cm)	Structural number used	Product of structural numbers	Thickness (cm)	Structural Layer	Product of structural numbers
Asphalt wearing course	0,16	4	0,16	0,64	4	0,16	0,64
Asphalt binder course	0,15	6	0,15	0,9		0,15	0
Asphalt base course	0,13		0,13	0		0,13	0
Foamed bitumen	0,08 - 0,15		0,12	0	22	0,12	2,64
CTB	0,06 - 0,12		0,08	0		0,08	0
Gr. Layers (CBR>100)	0,06		0,06	0		0,06	0
Gr. Layers (CBR>50)	0,04		0,04	0		0,04	0
Gr. Layers (CBR>20)	0,02	40	0,02	0,8	24	0,02	0,48
		50		2,34	50		3,76

It is not necessary to reinvent the wheel ?

Cold Recycling Manual

November 2004 release

100% rewrite

Embodies all the latest technology

Appendix 2: Mix design

Appendix 3: Pavement design

REHABILITATION DESIGN PROCEDURES

Testpit excavation

Record Layer thicknesses

DCP testing

Plate bearing test

REHABILITATION DESIGN PROCEDURES

Foaming

Laboratory unit - WLB

Marshall Samples

ITS-testing

REHABILITATION DESIGN PROCEDURES

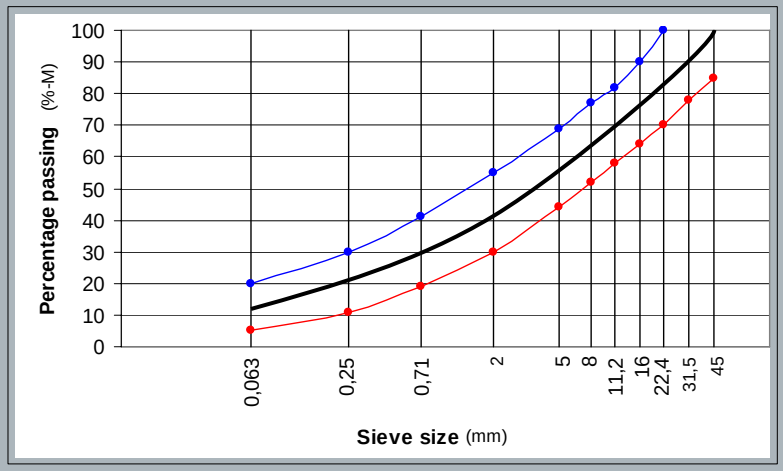
Tests done on the milled sample:

- Grading analysis
- Water content
- Bitumen content
- Modified Proctor to determine the optimum water content (OMC) and maximum dry density (MDD)

Tests done on the bitumen sample:

- Optimisation of foaming properties – variation of bitumen temperature and bitumen water quantity

REHABILITATION DESIGN PROCEDURES



Aggregate up to 2,0 mm are usually coated in a Foamed Bitumen Mixture

REHABILITATION DESIGN PROCEDURES

Mix design and manufacturing briquettes:

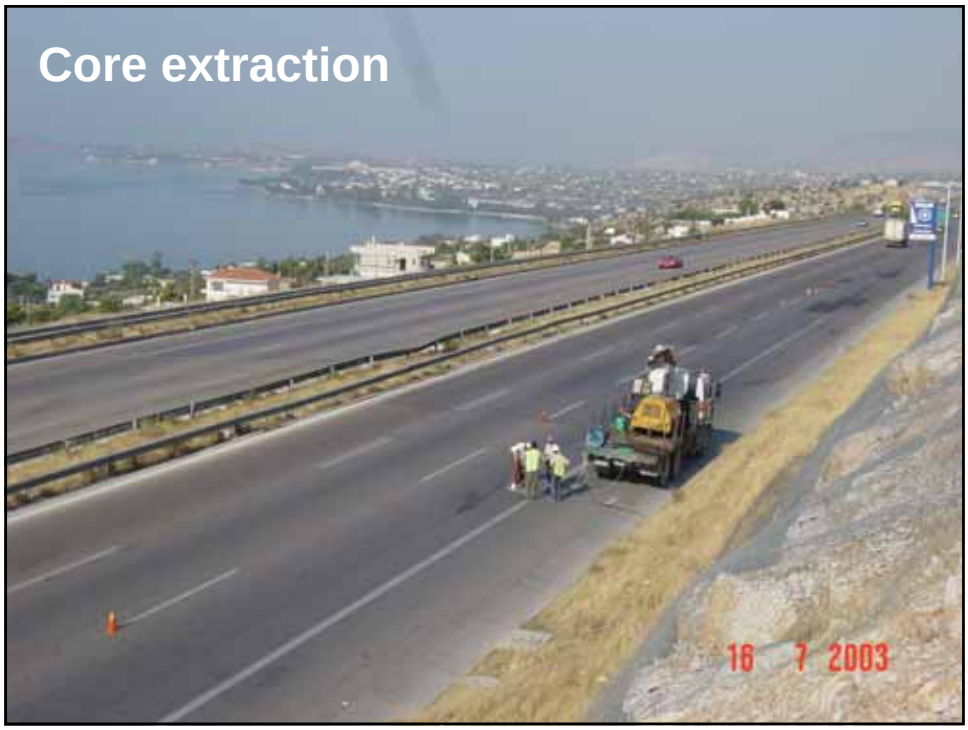
- Addition of cement (1.5 M.-%)
- Addition of water (80 - 90% of OMC)
- Addition of Foamed Bitumen (2; 3; 4; 5 M.-%): with WLB 10 directly into the laboratory mixer
- Production of briquettes by Marshall compaction – modified to 75 blows / briquette-side
- Storing for 72 hours at 40 °C (simulating 28 days)
- Indirect tensile strength on dry and soaked briquettes at 25 °C (5 °C)

The Iliki – Athens – Corinth Project

Project Review

1. Pavement investigation
2. Summary / distress mechanism
3. Preliminary design
4. Mix designs
5. Final pavement design
6. Construction planning
7. Project execution

Detailed visual inspection


Core extraction
16 7 2003


16 7 2003

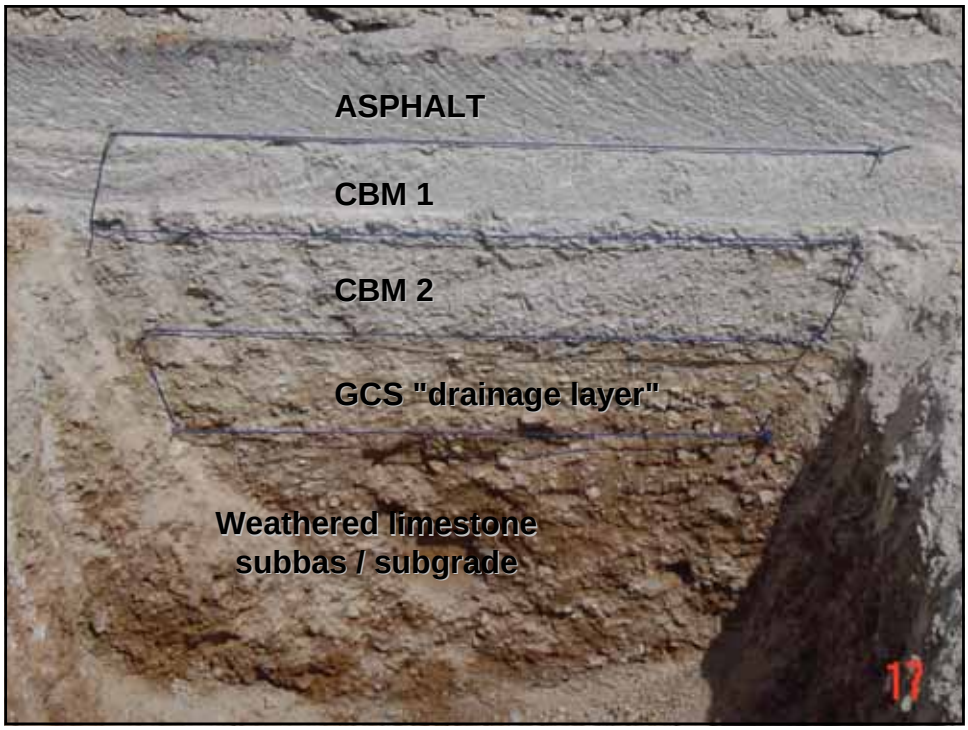

① 67+800


DCP probes


TEST PIT EXCAVATION
Wirtgen

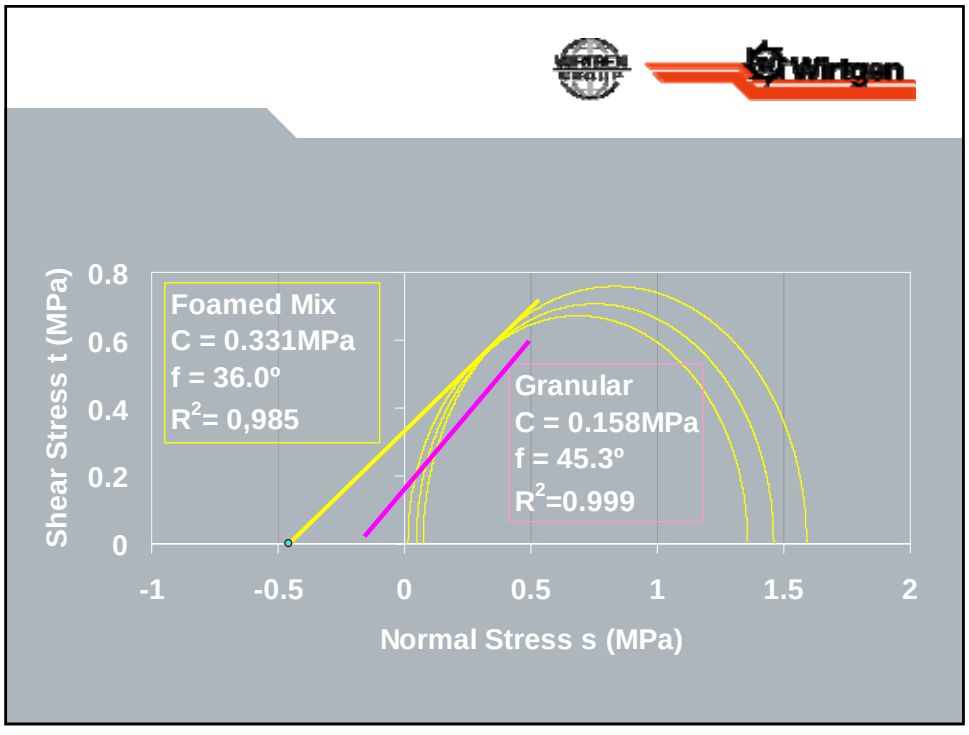

17 7 2003

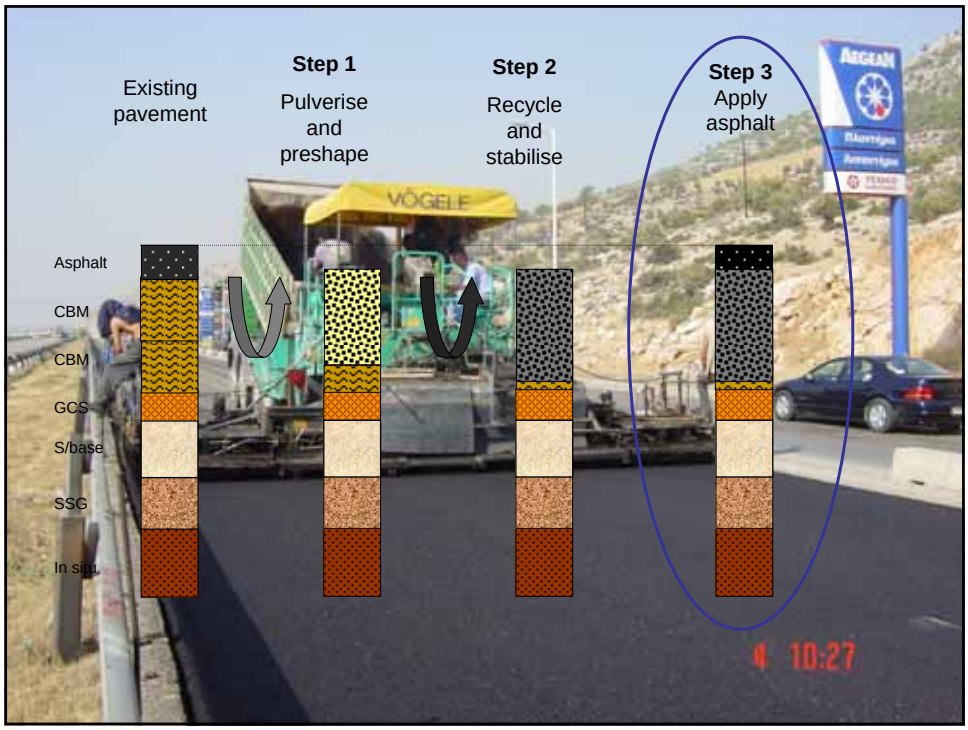

17 7 2003


ASPHALT
CBM 1
CBM 2
GCS "drainage layer"
Weathered limestone
subbas / subgrade
17

Dynamic tri-axial tests

Determination of resilient modulus M_r




Existing pavement
Step 1
Pulverise and preshape
Step 2
Recycle and stabilise
Step 3
Apply asphalt
Asphalt
CBM
CBM
GCS
S/base
SSG
In situ
VÖGELE
10:27


9:57


9:56


2.25% foamed bitumen
1% cement


REFUSAL DENSITY
Compactometer
0
20
40
60
80
100
120
140
HMV
HRMM

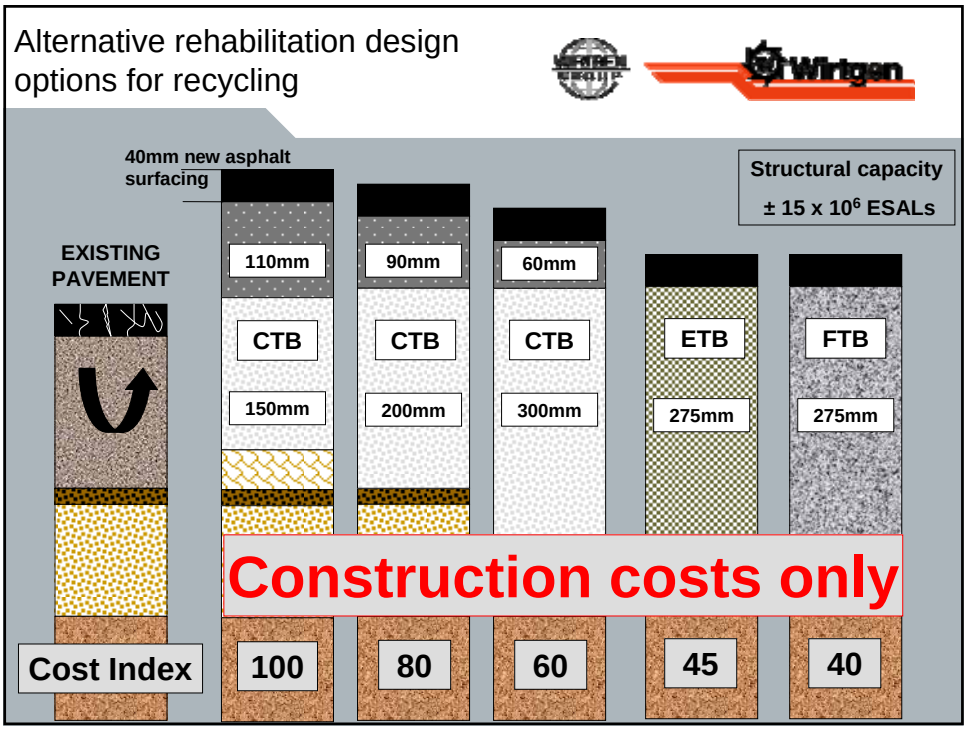

10:55

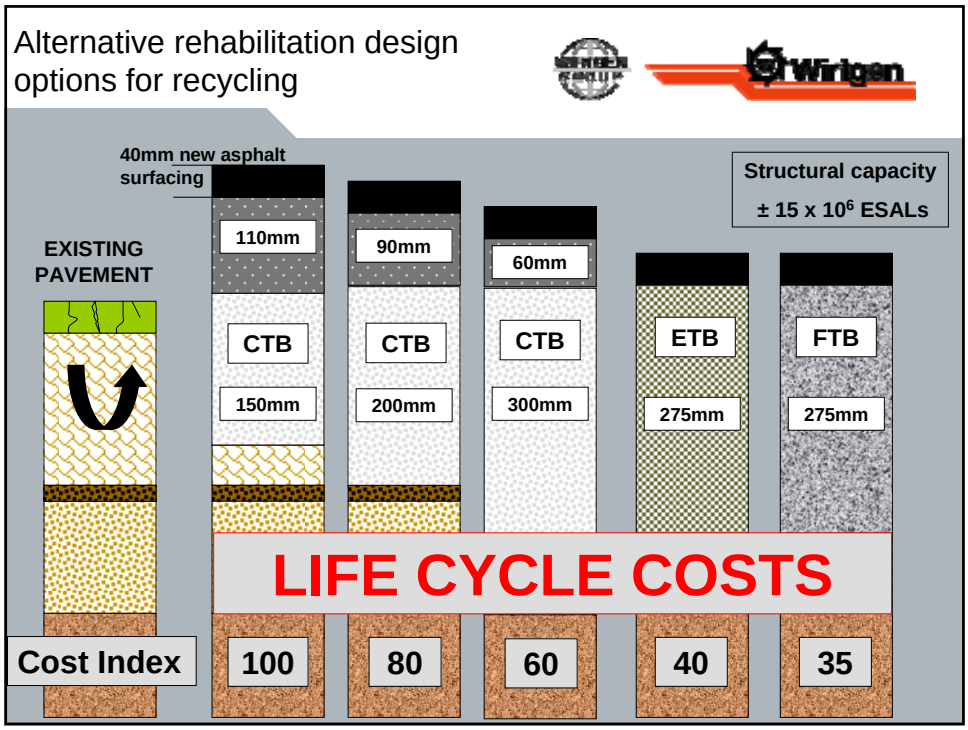

ΠΑΠΑΗΛΙΑΣ

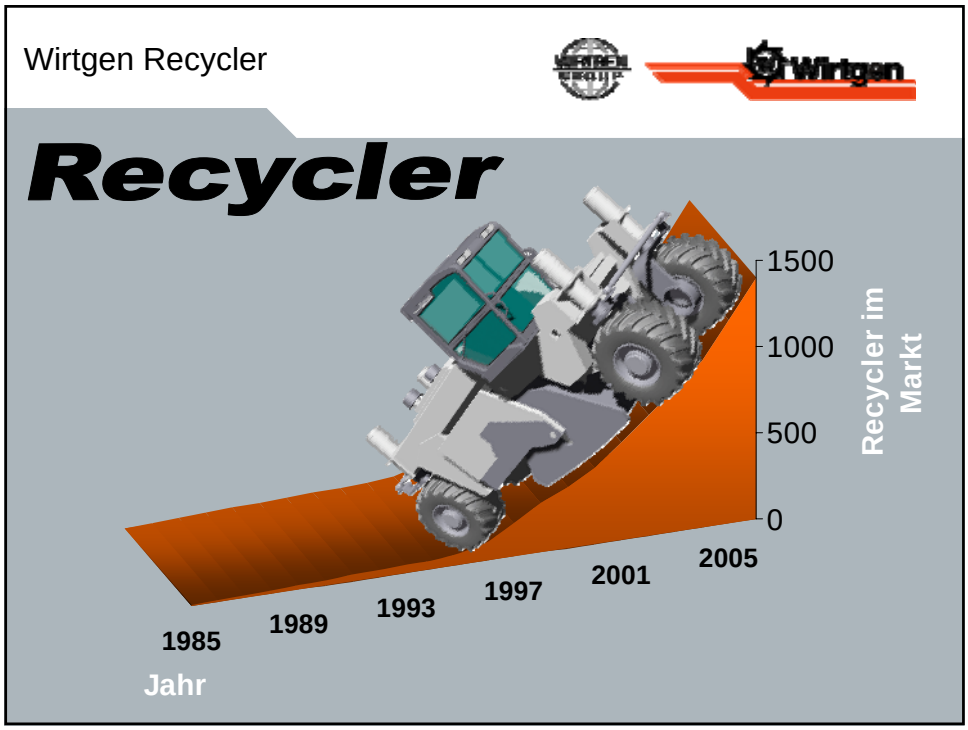
Construction costs

Life cycle costs

Alternative rehabilitation design options for recycling




Alternative rehabilitation design options for recycling
40mm new asphalt surfacing
EXISTING PAVEMENT
Structural capacity
± 15 x 10⁶ ESALs
110mm
CTB
150mm
90mm
CTB
200mm
60mm
CTB
300mm
ETB
275mm
FTB
275mm
LIFE CYCLE COSTS
Cost Index
100
80
60
40
35


Wirtgen Recycler
Recycler
1500
1000
500
0
Recycler im Markt
1985
1989
1993
1997
2001
2005
Jahr

Cold Recycling in situ in Italy

In situ Cold Recycling with cement and foamed bitumen on a Highway with the WR 2000

WR 2000 Cold Recycling in Japan

Cold Recycling of the asphalt layer with the Schotterunterbau Working depth 200 mm

WR 2000 Cold Recycling in Germany

Recycling of tarry asphalt granulate by adding bitumen emulsion and water

Cold Recycling in situ in Norway

Cold Recycling with bitumen emulsion; (pre-spread aggregate)

Cold Recycling in situ in Malaysia

Cold Recycling the asphalt and granular base layers by adding pre-spread cement and bitumen emulsion

Cold Recycling in situ in Russia

Cold Recycling with bitumen emulsion and cement slurry (WR 2500 + WM 400)
Ring Road in Moscow

Cold Recycling in situ in Germany

Cold Recycling with bitumen emulsion and cement with the WR 2500 S

Cold Recycling in situ in South Africa

Upgrading an unbound gravel road by Cold Recycling with foamed bitumen

Cold Recycling in situ in Bosnia

Cold Recycling the asphalt and granular base layers by adding pre-spread cement, water and foamed bitumen

Cold Recycling in situ in Kazakhstan

Cold in situ Recycling of a mayor road cement slurry and foamed bitumen:
WR 2500 + WM 1000

Cold Recycling in situ Highway in Italy

A 14 Milan – Rimini: Rehabilitation of a highway lane
- Cold Rrecycling with foamed bitumen and cement slurry -

Cold Recycling in situ Highway in Italy

In situ Cold Recycling with cement slurry and foamed bitumen

Cold Recycling in situ in California

Highway 20 recycling with foamed bitumen

Cold Recycling in situ in Alaska

Foam recycling project, Red Dog Zinc Mine

Cold Recycling in situ in China

Cold in place recycling with bitumen emulsion and cement
Yingkou/Liaoning Province

Cold recycling in situ in Malysia

Recycling with cement + emulsion

Cold Recycling Highway I 80 in California

Recycling of the right shoulder with the WR 4200

Cold recycling in plant in Durban, South Africa

Recycling production of 200 t/h with cement and foam

Cold recycling in plant in Durban, South Africa

Paving 125 mm thick layer with Vögele Paver