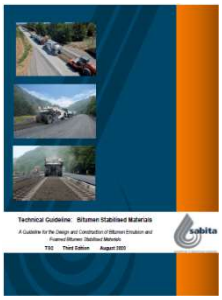
Pavement Rehabilitation by Cold Recycling / Bitumen Stabilisation

CHAPTER 3 (new chapter)

PAVEMENT INVESTIGATION
and
EVALUATION

Pages 16 to34

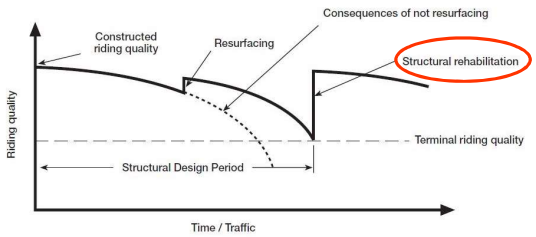


Chapter 3. Pavement Investigation & Evaluation

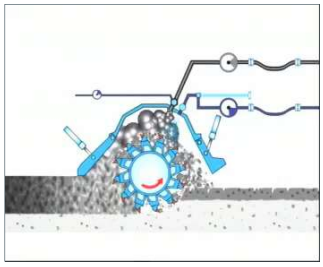
Distressed pavements

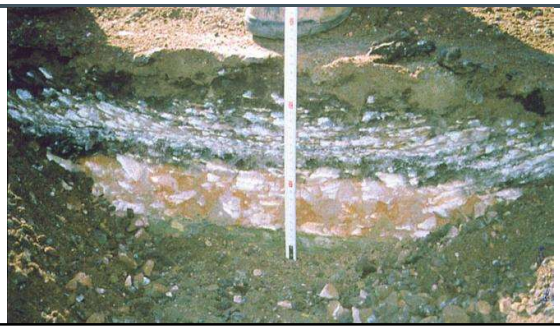
Chapter 3. Pavement Investigation & Evaluation

How is "distress" measured ?

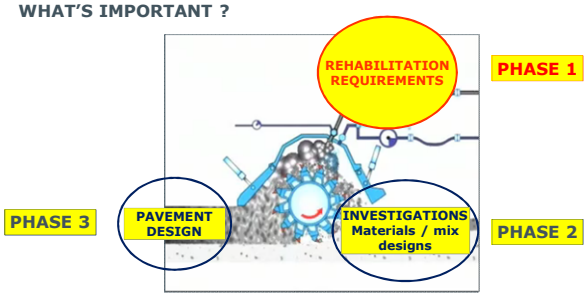


RECYCLING: Recovering / reusing material in the existing pavement





WHAT'S IMPORTANT ?



PHASE 1.

Primary directives	Example
Service life / structural capacity	20 years (n x 10^6 E_{80})
Geometric changes	Changes to horizontal and/or vertical alignment
Geometric capacity	Widening required for additional lanes
Specific requirements	UTFC surfacing layer
Future maintenance	Limited. Side drains to be lined
Budget limitations	National norm available (i.e. $/km)
Timing (urgency)	Construction to start within 24 months

REHABILITATION REQUIREMENTS

When a recycling solution should not be considered

Changes to the existing alignment (in situ)

Politics. e.g. Saudi Arabia

Chapter 3. Pavement Investigation & Evaluation

Projects suitable for recycling

Greece islands (limited infrastructure)

Tourists arrive by air…

Projects suitable for recycling

Runway rehabilitation

PHASE 2.

Pavement Investigations

Obtain all available data

Identify material sources

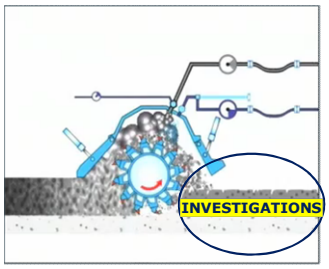
Preliminary assessment

Define Uniform Sections

Detailed investigations

Laboratory testing

Data processing



Recyclers recover pavement material and mix it

Recyclers mix material in the vertical plane
not in the horizontal plane

PRELIMINARY ASSESSMENT

Reconnoitre the route (drive-through)

Study all available data (Pavement Management System (PMS))

Obtain deflection measurements

Initial definition of "Uniform Sections"

BEFORE STARTING…

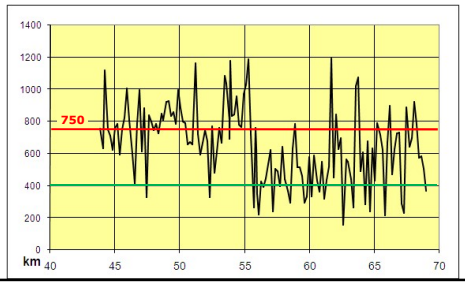
Visible, unambiguous references

DEFLECTION MEASUREMENTS

Falling Weight Deflectometer (FWD)

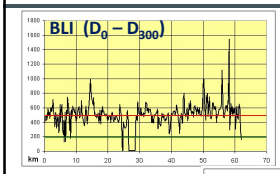
Benkelman Beam

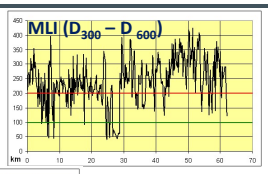
Maximum deflection

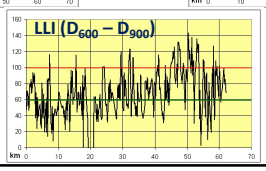


(From Horak)

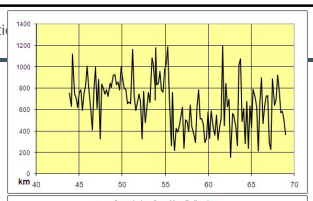
FWD Deflection Indices





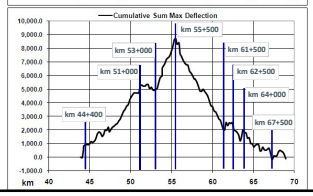


Cumulative-sum analyses



Define "Uniform Sections"

(Uniform STRUCTURAL sections)



DETAILED INVESTIGATIONS

Visual Assessment

Confirm / modify Uniform Sections

Pavement investigations

- Excavate test pits / slots
- Core extraction
- DCP survey

South African publications

SAPEM Chapter 6 Section 5

TRH 6 (1985) – condition surveys

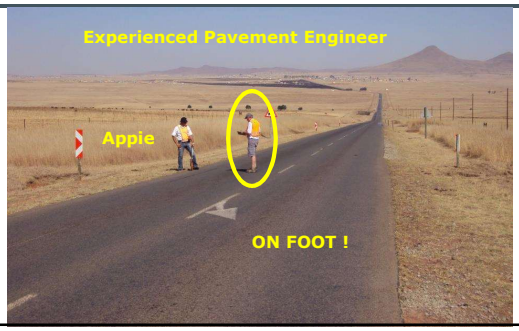
TRH 12 (1997) – pavement rehab

TMH 9 (1992) - visuals

TMH 5 (1981) – sampling

VISUAL ASSESSMENT

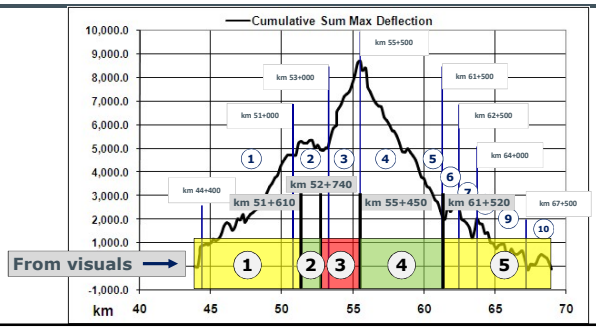
Visual Assessment



See the whole scene.....

The whole scene

Chapter 3. Pavement Investigation & Evaluation



Determine testing requirements

FOR EACH UNIFORM SECTION:

Decide on the location / number of test pits (and/or slots)
(Minimum of 3 per Uniform Section)

Interval / locations for cores to be extracted

Interval / locations for DCP probes

Other investigations (e.g. additional deflection measurements)

Chapter 3. Pavement Investigation & Evaluation

TEST PITS

Determine the pavement composition

- Material quality in each layer
- Condition of the material in each layer
- Thickness of each layer
- Variability within each layer

Obtain bulk samples separately from each layer

TEST PITS

Normally excavated in outer wheel path

750mm x 750mm x 800mm deep

SAMPLING ASPHALT LAYERS

(when the intention is to recycle in situ)

Will a recycler break the asphalt down?

Is the broken-down asphalt likely to be uniform?

How to obtain representative samples ??

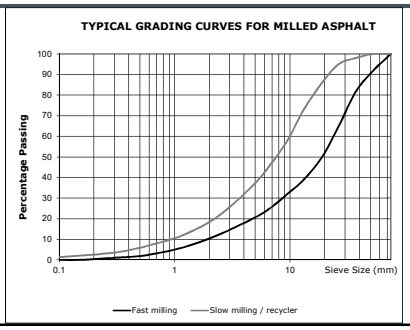
Use a recycler

Normal operating speed of advance (± 8m/min)

Or, a milling machine

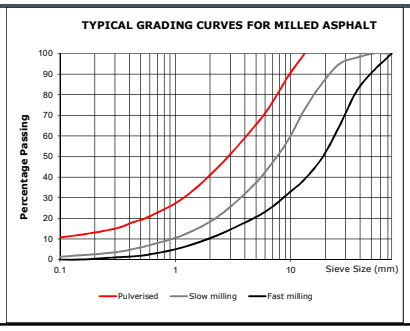
Speed of advance (± 3m/min)

Sampling asphalt layers



Sampling asphalt layers

Sampling asphalt layers



Sampling asphalt layers

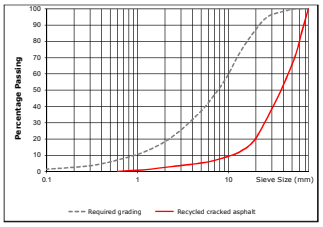
When there is no alternative…

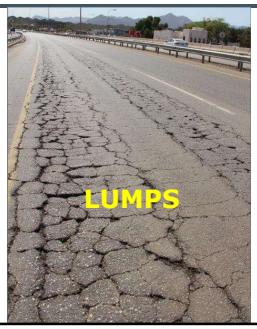
Sample the asphalt as sawn-out slabs

Break the slabs down in a laboratory crusher
(set for max particle size: 19mm)

Dealing with severely cracked asphalt layers

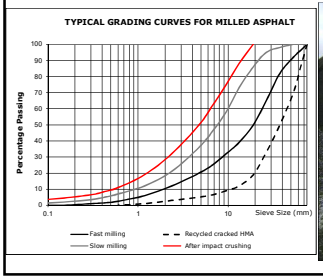
Can this be recycled in situ ??





Dealing with severely cracked asphalt layers

Mill out and pass through an impact crusher (gap setting 20mm)



Layer excavation

Careful hand work

Layer by layer

- Determine in situ density
- Separate sample(s) for moisture content
- Obtain sufficiently large bulk sample
- Drive DCP probe(s) into subbase / subgrade

TEST SLOTS
Full lane width
(750mm wide x 800mm deep)

Determine the damage caused by traffic

LABORATORY TESTS

(Primarily for material classification)

Indicator tests (gradings / Atterberg Limits)

Moisture / density relationship (mod AASHTO)

Material strength tests (CBR)

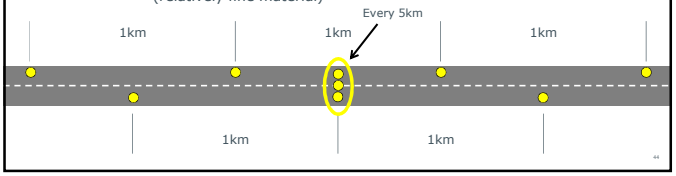
Durability (Los Angeles abrasion)

NB. Retain sufficient material for stabilisation mix designs

Extract cores & DCP probes (outer wheel paths)

Cores: Recovery of bound materials (asphalt and cemented layers)

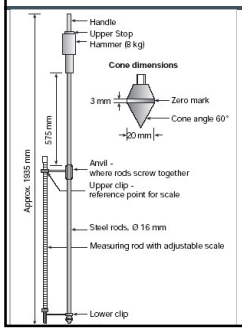
DCP probes: Layer thickness / in situ strength of subbase / subgrade (relatively fine material)



Core extraction

Core extraction

Dynamic Cone Penetrometer (DCP) survey



DCP probes

Through core holes

Or, pre-drill 25mm φ hole through bound layers

DCP probes

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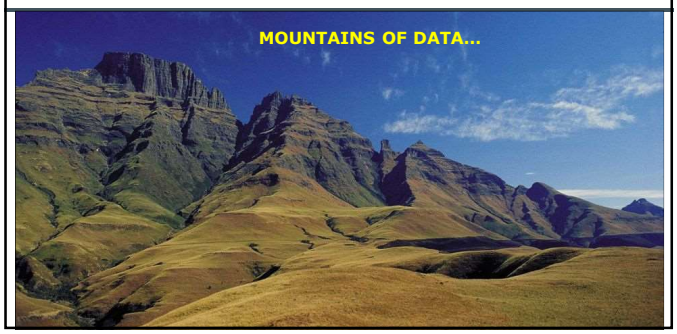
Processing the data



Chapter 3. Pavement Investigation & Evaluation

ANALYSING THE DATA (making sense of the data)

Focus on one Uniform Section at a time

Collate all data for that section

Interrogate to identify misfits / outliers

Obtain additional information where necessary

UNDERSTAND VARIABILITY

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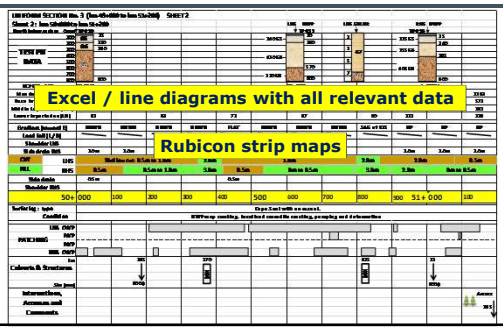
For each Uniform Section:



For each Uniform Section

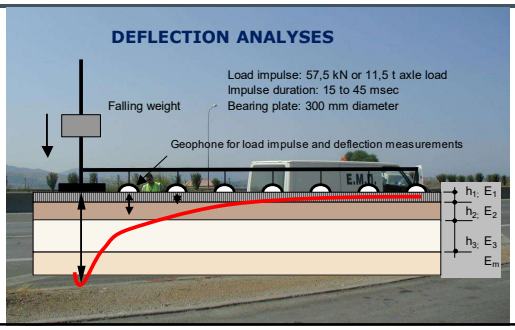
DEFINE REPRESENTATIVE PAVEMENT PROFILE

Example

HMA : 40mm – 60mm	50mm	**DISTRESS MECHANISM**
CBR >80: 130mm – 165mm	150mm	Full-depth cracks Moisture ingress
CBR >45: 280mm – 310mm (previously cement stabilised)	290mm	Pumping Potholes
CBR >15: 125mm – 145mm	130mm	Asphalt aged / dead Base layer damaged
In-situ subgrade (CBR >10)		

Chapter 3. Pavement Investigation & Evaluation

DEFLECTION ANALYSES

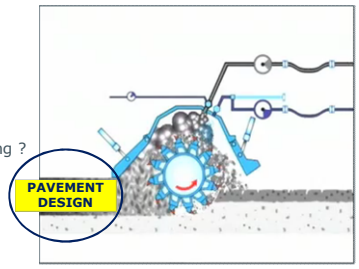


Chapter 3. Pavement Investigation & Evaluation

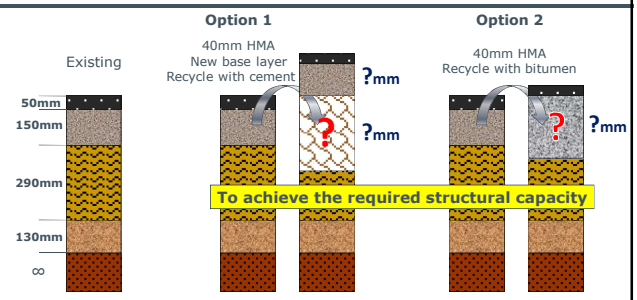
PHASE 3.

Rehabilitation Options

What can be achieved by recycling ?

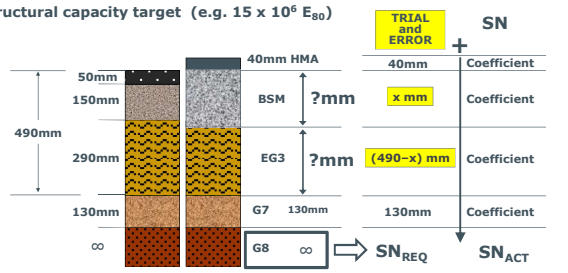


2 recycling options



Estimating recycling depth (Option 2)

Structural capacity target (e.g. 15 x 10^6 E_{80})



AASHTO 1993 (Structural Numbers)

Structural layer coefficients

Typical structural layer coefficients (from AASHTO)		
Material type	Characteristic	Structural layer coeeficient (per inch)
Asphalt surfacing	Elastic modulus 2,500 to > 10,000 MPa	0.20 to 0.44
Asphalt base	Continiously graded (6% voids)	0.20 to 0.38
Bitumen treated base		0.10 to 0.30
Graded crushed stone	CBR > 80%	0.14
Natural gravel, type 1	CBR 65 to 80%	0.12
Natural gravel, type 2	CBR 40 to 65%	0.10
Soil, type 1	CBR 15 to 40%	0.08
Soil, type 2	CBR 7 to 15%	0.06
Cohesionless sand	PI = 0	0.04 to 0.05
Cement-treated crushed stone	1.0 < UCS < 3.0 MPa	0.17
Cement-treated gravel	UCS < 1.0 MPa	0.12

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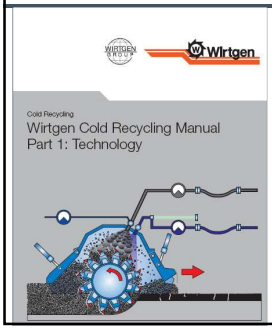
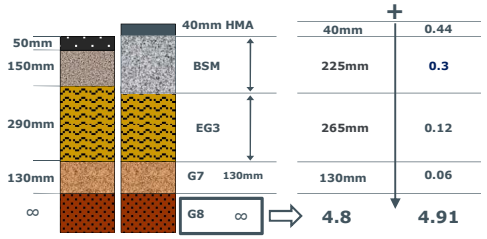


SUGGESTED STRUCTURAL LAYER COEFFICIENTS FOR BITUMEN STABILISED MATERIAL (BSM)

STRUCTURAL LAYER COEFFICIENT (per inch)	0.18	0.23	0.28	max 0.35
INDIRECT TENSILE STRENGTH (ITS) AFTER STABILISATION				
100 / 150mm ϕ specimens				
ITS_{DRY} (kPa)	125	175	225	
ITS_{WET} & ITS_{SOAK} (kPa)	50	75	100	
150mm ϕ specimens				
ITS_{SOAK} (kPa)	95	135	175	
Indicated shear properties				
Cohesion (kPa)	50	100	250	
Angle of Friction (°)	25	30	40	
MATERIAL CBR VALUE BEFORE STABILISATION (at 100% compaction)				
Materials with CBR < 20% not recommended	20	40	80	
ANTICIPATED APPLICATION RATE OF BITUMEN FOR STABILISATION (% by mass)	2.5 - 4.0	2.0 - 3.0	1.8 - 2.3	

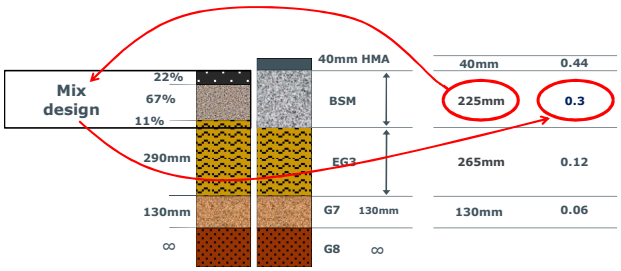
Chapter 3. Pavement Investigation & Evaluation

Structural capacity target (e.g. 15 x 10^6 E_{80})



	SN
40mm	0.44
225mm	0.3
265mm	0.12
130mm	0.06
4.8	4.91

Mix design to confirm the assumed properties



Pavement design to confirm structural capacity

	Thickness (mm)	Poisson's ratio	Resilient modulus (Mpa)
HMA	40	0.4	2500
BSM-1	225	0.35	840
EG3	265	0.35	280
G7	130	0.35	140
G8	∞	0.35	80

Modular ratio rule
(unbound material)

M/E software

START

Check on variability of recycled material

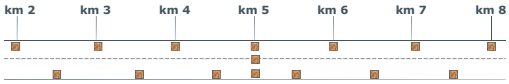
MATERIAL UNIFORMITY

Uniform STRUCTURAL Sections

Uniform MATERIAL Sections

Identifying "Uniform Material Sections"

INSPECTION HOLES (recycling depth)



Indicator tests
(Gradings / Atterberg Limits)

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Chapter 3. Pavement Investigation & Evaluation

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Chapter 3. Pavement Investigation & Evaluation

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Chapter 3. Pavement Investigation & Evaluation

SARF

Chainage	Test pit Number	Depth (mm)	Base layer (mm)	Grading 19.0	13.2	4.75	2.0	0.425	0.075	Grading modulus	Plasticity index	Linear shrinkage		Chainage
160.2	1	200	170	94	84	54	14	2	[illegible]	2.83	NP	0	FINER MATERIAL	160.2
161.2	29	160	135	91	84	44	22	7	4	2.87	3	2		161.2
162.2	2	200	170	99	94	62	43	8	4	2.45	NP	0		162.2
163.2	28	170	150	98	93	56	37	5	4	2.51	NP	0		163.2
164.2	3	200	175	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NP	0		164.2
165.2	27	170	145	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2		165.2
166.2	4	200	185	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NP	0		166.2
167.2	26	180	160	99	94	69	51	11	6	2.32	SP	1.5		167.2
168.2	5	200	175	99	96	63	44	8	4	2.44	NP	0		168.2
169.2	25	160	145	97	91	68	51	11	5	2.33	SP	1.5		169.2
170.2	6	200	175	96	89	54	36	9	4	2.51	NP	0		170.2
171	24	150	125	86	82	56	40	10	5	2.45	5	2.5	Average material	171
172.2	7	180	155	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.5		172.2
173	23	160	140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1		173
174.2	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0		174.2
175	22	150	130	83	72	39	26	6	3	2.65	SP	1		175
176.2	9	130	110	90	83	54	22	14	6	2.58	SP	1.5		176.2
177	21	150	130	85	78	48	35	5	3	2.57	4	2	COARSER MATERIAL	177
178.2	10	150	120	81	65	29	19	3	[illegible]	2.77	SP	1.5		178.2
179.2	20	160	140	80	67	32	22	5	2	2.71	SP	1.5		179.2
180.2	11	150	120	91	85	56	39	10	6	2.45	SO	1		180.2
181.2	19	160	135	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2		181.2
182.2	12	150	125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1		182.2
183.2	18	160	135	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2		183.2
184.2	13	120	[illegible]	71	62	36	25	4	2	2.69	NP	0		184.2
185.2	17	150	130	66	49	25	16	3	2	2.79	NP	0		185.2
186.2	14	180	160	80	67	33	22	4	2	2.72	NP	0		186.2
187.2	16	150	120	68	57	32	23	4	2	2.71	NP	0		187.2
188.2	15	160	135	71	57	31	21	8	4	2.67	SP	1.5		188.2
			Average	86.0	77.4	46.2	30.7	7.3	3.6					
			Std Dev	11.3	14.1	13.6	10.6	2.8	1.4					
				Coarse										
				Fine										

MIX DESIGN # 1

MIX DESIGN # 2

MIX DESIGN # 3

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Some important considerations for in situ recycling

SARF

Contamination with poor underlying material

Understand the capabilities of a recycler

Poor grading of recovered material

Where exactly is the cut horizon?

Be aware of the existing road shape (camber / cross-fall)

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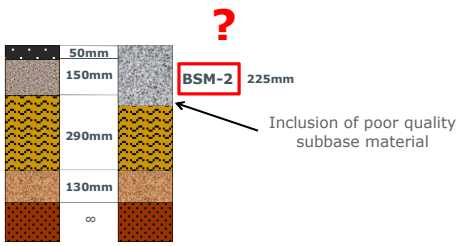
Contamination

SARF



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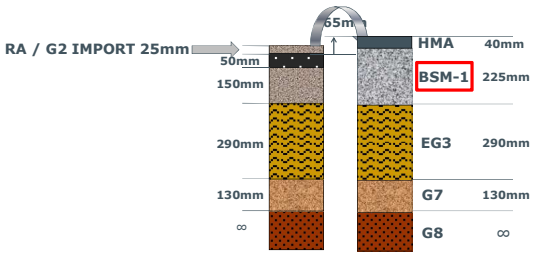
Avoid contamination / import new material

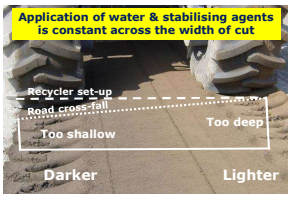


In situ recyclers

Understand the machine – what does it do / can it do

Chapter 3. Pavement Investigation & Evaluation

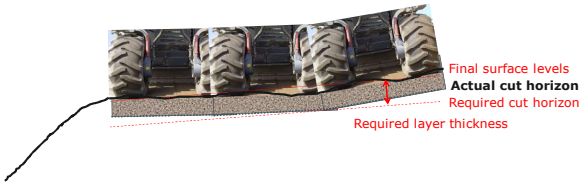
The cut horizon is dictated by the slope of the machine



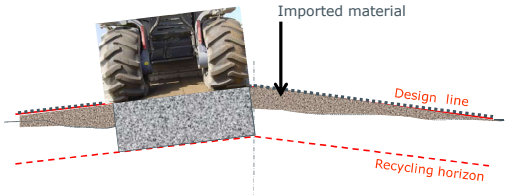
Consequence of not "zero-ing" the machine

The recycler will follow the existing surface shape

Pre-shape the upper material in the layer to be recycled

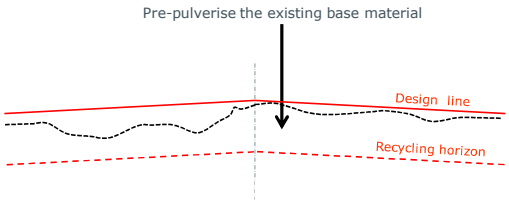


Or, import new material to achieve the correct cross-fall ?

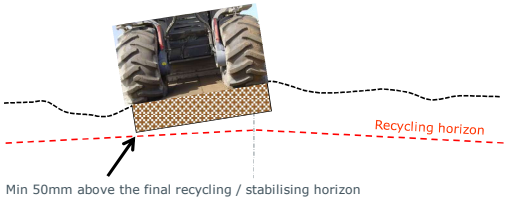


Beware of introducing non-uniformity !

Pre-pulverising and spreading prior to importing the new material may be required

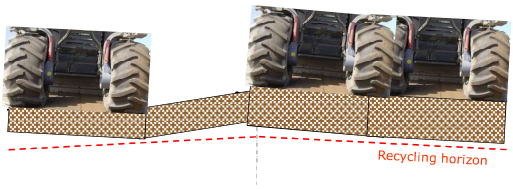


Pre-pulverise the existing upper horizon



Pre-pulverising

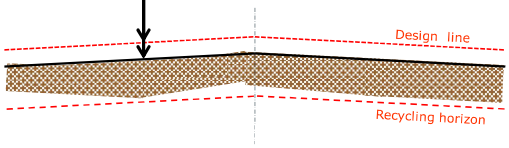
Pre-pulverise across the full recycling width



Pre-shape to follow the design line / pre-compact

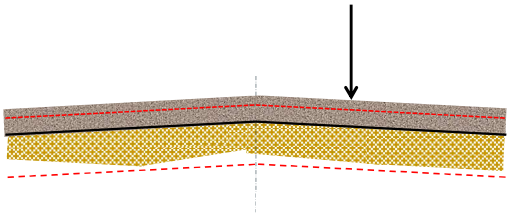
WIRTGEN

Pre-shape to match final levels / compact



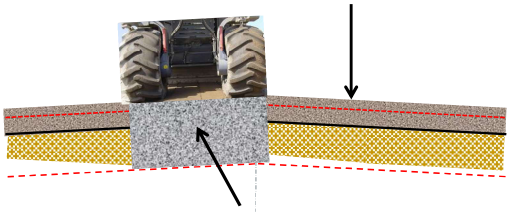
WIRTGEN

Import / spread and compact fresh material



WIRTGEN

Import / spread and compact fresh material



Uniform blend of treated material

SUMMARY (pavement rehabilitation by recycling)

Understand the rehabilitation requirements

Carry out a comprehensive investigation

Recognise variability and deal with it

Investigate / evaluate several rehabilitation options

Evaluate each option (whole-of-life costing)

Understand what recyclers can do / can't do