Introduction to Road Materials Engineering

Part 1: Components, Soils, Aggregates, Road Construction

Presented by SARF

Presenter:
Ron Berkers

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INTRODUCTION TO ROAD MATERIALS ENGINEERING

Main aims of this course:

To achieve a PRACTICAL understanding of WHERE, WHY, and HOW the different types and qualities of materials are used in road construction

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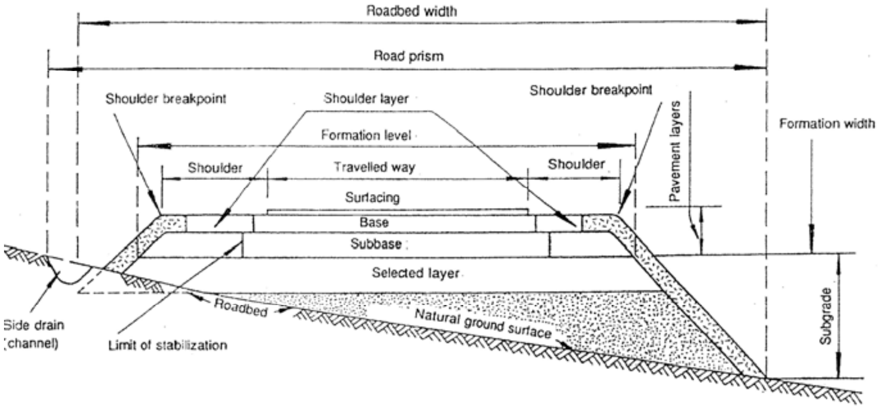
INTRODUCTION TO ROAD PAVEMENTS



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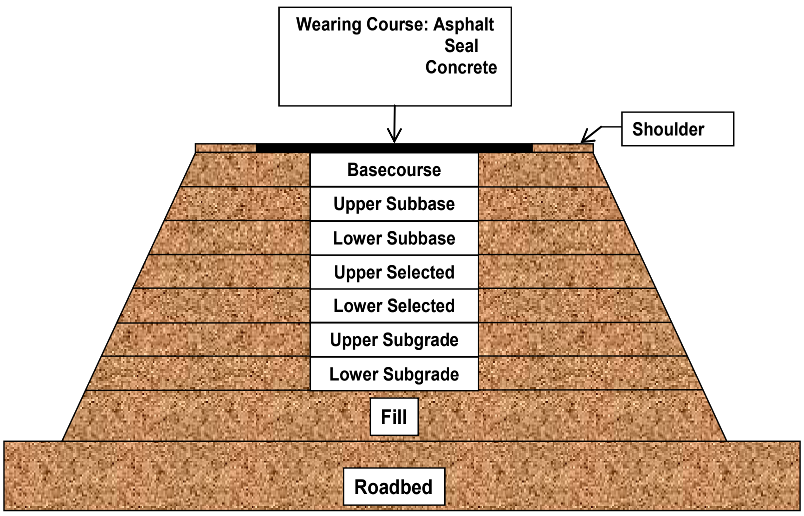
Typical road pavement structure



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Pavement types

Flexible pavements

Well-graded crushed stone base

Water-bound macadam base

Pavement types

Flexible pavements

Hot-mixed asphalt base

Stabilized base

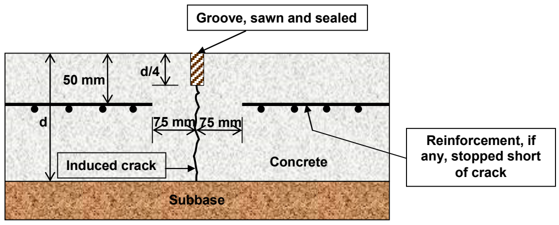
INTRODUCTION TO ROAD PAVEMENTS

Pavement types

Rigid pavements

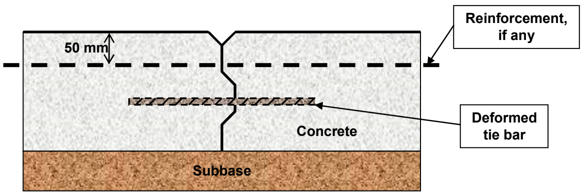
Jointed concrete (JCP)

Continuously reinforced concrete (CRCP)



Contraction Joint

Dowelled jointed concrete (Dowelled JCP)



Construction Joint

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INTRODUCTION TO ROAD PAVEMENTS

Pavement types

Segmented block pavements

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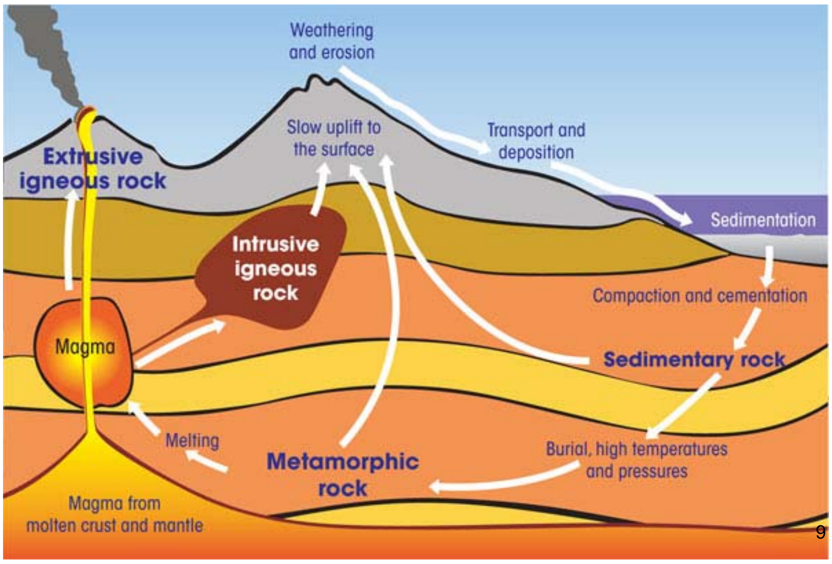
Where does soil come from?

The Rock Cycle:



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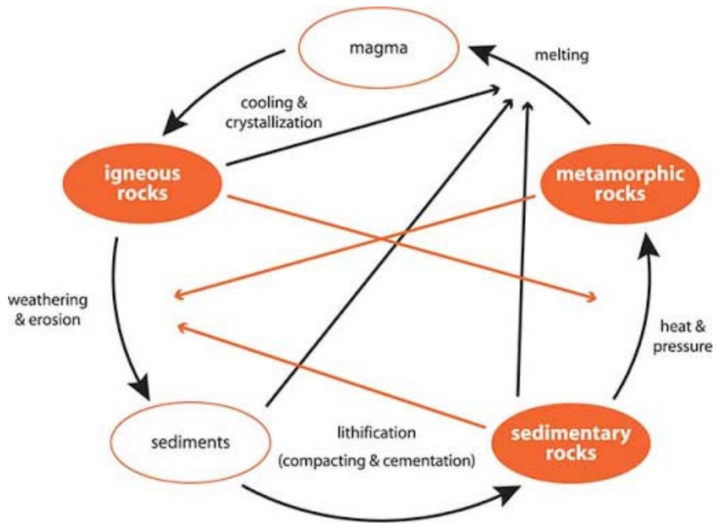
INTRODUCTION TO ROAD PAVEMENTS



Video: https://www.youtube.com/watch?v=EGK1KkLjdQY

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Igneous Rock:

Basalt:

Porphyry:

Granite:

Sedimentary Rock:

Sand Stone:

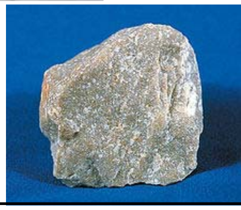
Shale:

Dolomite:

Metamorphic Rock:

Marble:  **From Limestone or Dolomite**

Slate:  **From Shale**

Quartzite:   **From sandstone**

What do we mean by SOILS and AGGREGATES ?

Typical soils profile

Top soil – humus enriched, fertile

Sandy or clayey soil, gravel – transported or residual

Weathered or fresh rock

Quality improves

The most important properties of soils and aggregates

What do we mean by SOILS and AGGREGATES ?

Typical soils profile

Soils

Top soil – humus enriched, fertile

Sandy or clayey soil, gravel – transported or residual

Weathered or fresh rock

Rock – crushed to produce aggregates

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The most important properties f soils and aggregates

What do we mean by SOILS and AGGREGATES ?

Typical soils profile

Top soil – humus enriched, fertile	Remove, stockpile, spread & re-vegetate		
Sandy, clayey or silty soil, gravel – transported or residual	Use in fill and lower layerworks	*Cuts or borrowpits*	
Weathered or fresh rock	Crush into various sized aggregates for use in upper pavement layers, chip seal surfacings, asphalt and concrete	*Quarries*	

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The most important properties of soils and aggregates

Most important properties of soils:

- Grading
- Plasticity
- Strength

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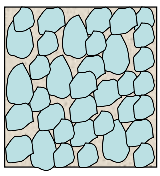
The most important properties of soils and aggregates

Grading

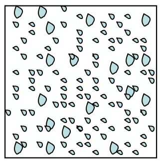
(Particle size distribution)

Poorly graded materials

Coarsely graded –large particle sizes



Finely graded – small particle sizes



But both are poorly graded !

(poor particle distribution)

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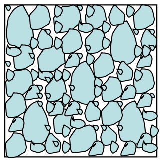
Grading

(Particle size distribution)

Well graded materials

Good particle distribution –

The different sized particles "pack' into the available spaces



Can be described as "continuously graded"

Comparison with poorly graded materials:

- higher degree of compaction possible
- reduced permeability
- usually higher strengths

Coarse well graded – large maximum size

Fine well grade – small maximum size

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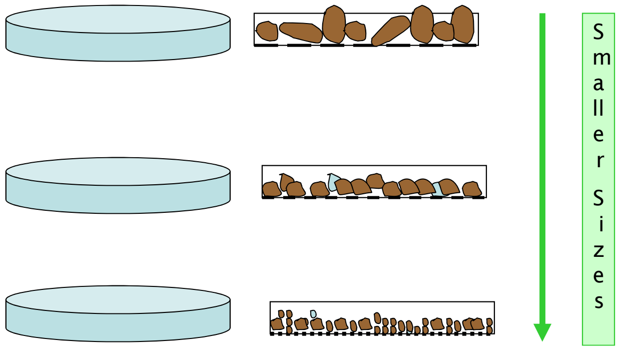
The most important properties of soils and aggregates

Grading



Nest of sieves

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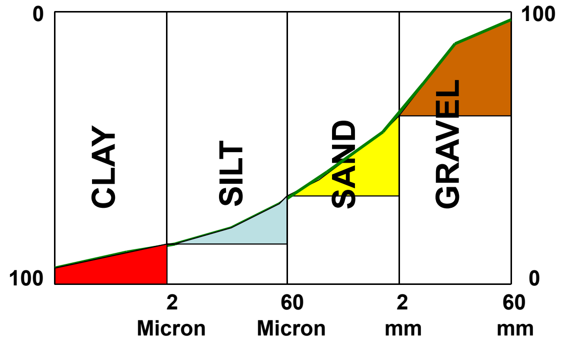
The most important properties of soils and aggregates

INDICATOR TESTS

GRADING ANALYSIS

Classification according to particle size



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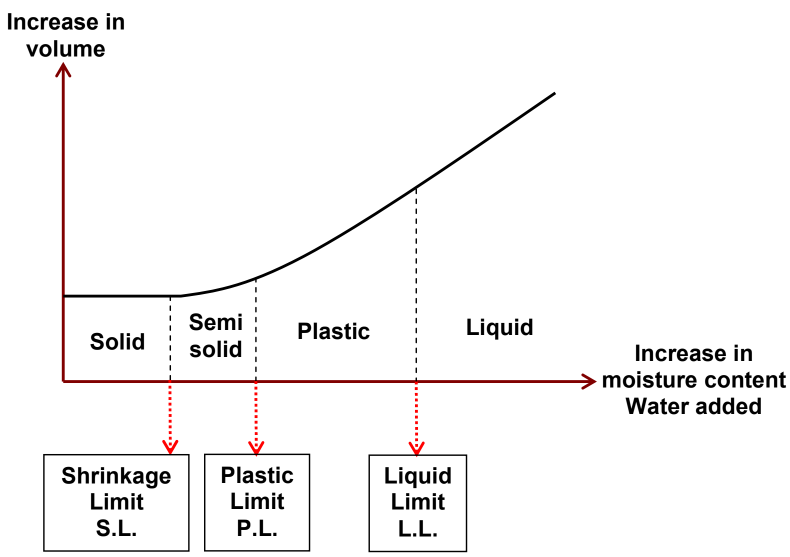
The most important properties of soils and aggregates



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INDICATOR TESTS

ATTERBERG LIMITS

← PI →

SOLID	PLASTIC	LIQUID

Dry — Add Water → Wet

PL = Moisture Content @ the Plastic Limit

LL = Moisture Content @ the Liquid Limit

PI = LL – PL = Plasticity Index

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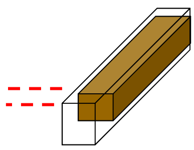
Liquid limit device – used to determine liquid limit



Linear shrinkage trough – used to determine linear shrinkage

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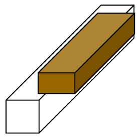
INDICATOR TESTS

LINEAR SHRINKAGE

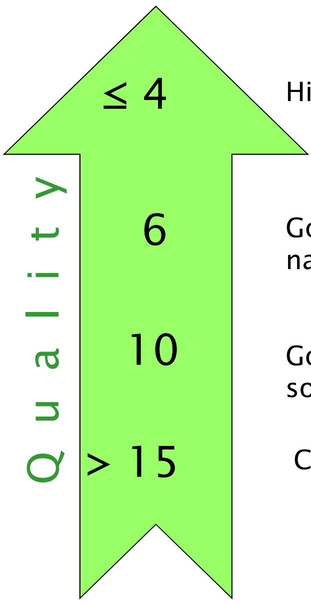
LS = Linear Shrinkage of the soil fines from the Liquid Limit test in a metal trough on drying

Provides a useful check of plasticity and moisture sensitivity
(2 x LS = roughly PI)



GRADING, PI and LS can with experience and knowledge of the soil type provide a very good preliminary guide to the engineering properties of a soil

Indication of quality based on plasticity index (PI)



≤ 4 — High quality crushed stone, sand

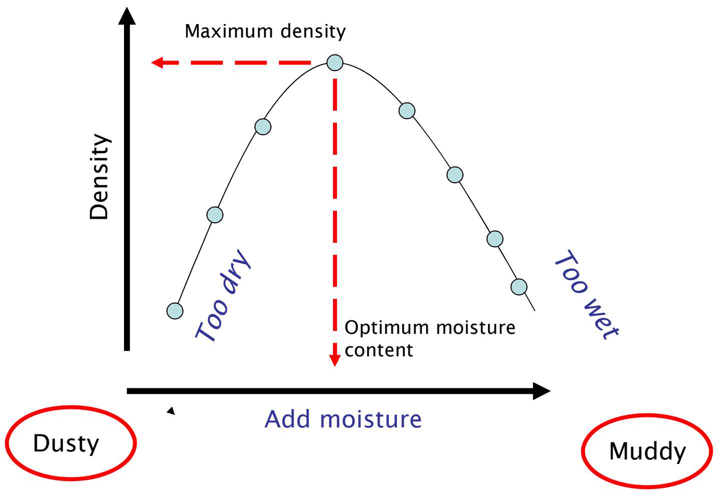
6 — Good quality crushed stone and natural gravel

10 — Good quality natural gravel, sandy soils

> 15 — Clayey soils

The most important properties of soils and aggregates

Moisture/density relationship



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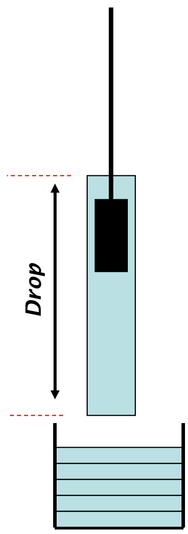
The most important properties of soils and aggregates

Moisture/density relationship



Modified AASHTO Maximum Dry Density Test
[TMH1 – A7] Revised SANS 3001-GR30

Uses standard mould, rammer, drop, number of layers and blows

To provide a STANDARD COMPACTIVE EFFORT

The material is prepared by screening on a 19mm sieve, the oversize material is lightly crushed and added back into the sample

5 samples are compacted at a range of moisture contents

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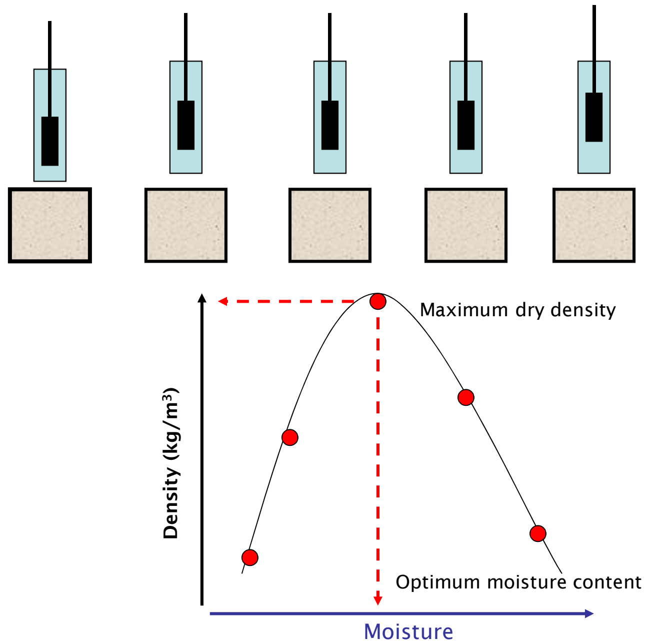
The most important properties of soils and aggregates



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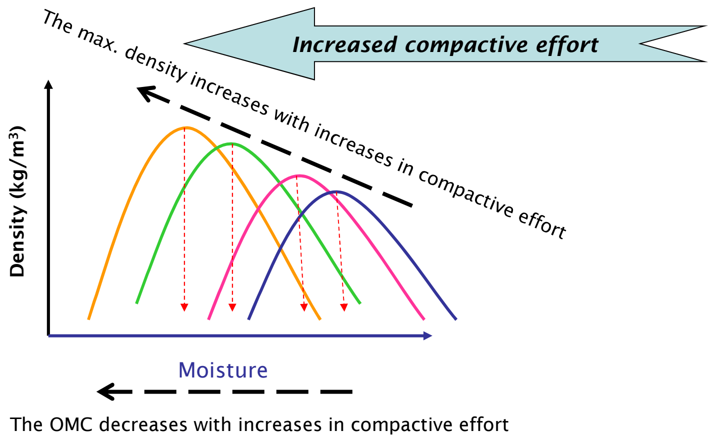
The most important properties of soils and aggregates



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RELATIVE COMPACTION

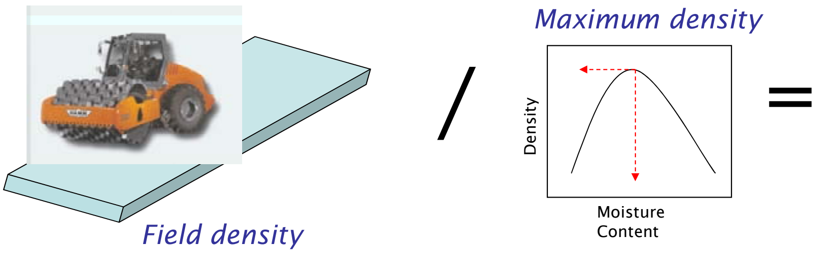
When the actual density obtained is compared to the Standard Density the result, in percent, is termed the Relative Compaction

For Example:-

Field Density = 1985 kg/m³

MDD = 2120 kg/m³

Relative Compaction (MDD) = 1985 ÷ 2120 X 100 = 93.6%



RELATIVE COMPACTION

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CALIFORNIA BEARING RATIO (CBR)

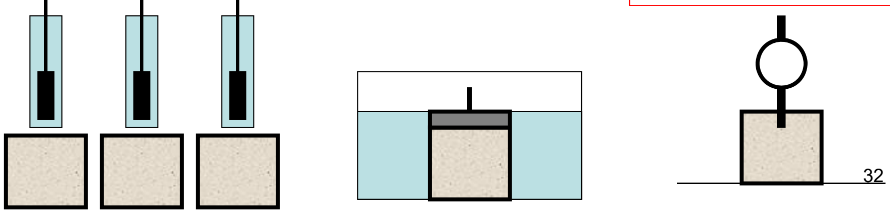
CRUDE TEST OF (BEARING) STENGTH

- **Samples prepared at MDD OMC using three compactive efforts which give: 100%, about 96% and 93% Relative Compaction**
- **After soaking, a standard plunger (2ins Diam) is forced into the sample and the resisting force is measured at 2,5mm, 5mm and 7,5mm penetration**
- **The resisting force is divided by the Standard Force (OJ Porter) to give the CBR**

Prepare 3 moulds at OMC using different compaction efforts

Soak in water bath for 4 days, measure "SWELL"

Penetrate in press, measuring resisting force at depths of 2.5mm, 5mm and 7.5mm



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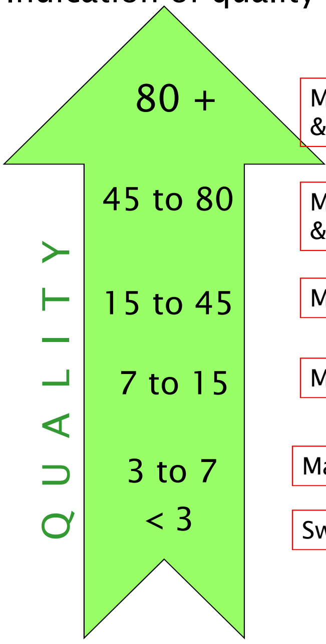
Indication of quality based on CBR value



CBR	Description
80 +	Max swell 0.2 %. High quality crushed stone & gravel
45 to 80	Max swell 0.5 %. Good quality crushed stone & gravel
15 to 45	Max swell 0.5 %. Good quality natural gravels
7 to 15	Max swell 1.5 %. Gravel soils
3 to 7	Max swell 1.5 %. Sandy soils
< 3	Swell > 1.5 %. Unsuitable soils

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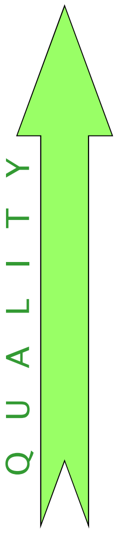
TRH 14 : 1985 Guidelines for road construction materials

Properties of untreated materials



Type	Summary of Requirements	
Graded crushed stone	G1	Crushed from solid good rock. Strict grading requirement. Non-parent fines disallowed. High degree of compaction specified – typically 89% ARD. LL max 25, PI max 4, LS max 4, ACV max 29%, 10% FACT min 110 kN
	G2 & G3	Crushed from rock, boulders, or coarse gravel. Strict grading requirement. May include non-parent fines. LL max 25, PI max 6, LS max 3. CBR ≥ 80, Swell max 0.2%
Natural gravels	G4	Natural gravel that may require crushing. Grading specified. May contain non-parent fines. LL max 25, PI max 6, LS max 3. CBR ≥ 80, Swell max 0.2%
	G5	Natural gravel that may require crushing. LL max 30, PI max 10, LS max 5, CBR ≥ 45, Swell max 0.5%
	G6	PI ≥ 12 or 3GM+10. CBR ≥ 25 at 93% compaction. Swell max 1.0%
Gravel - soils	G7	PI ≥ 12 or 3GM+10. CBR ≥ 15 at 93% compaction. Swell max 1.5%
	G8	CBR ≥ 10 at 90% compaction. Swell max 1.5%
	G9	CBR ≥ 7 at 90% compaction. Swell max 1.5%
	G10	CBR ≥ 3 at 90% compaction. Swell max 1.5%

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Note: Some additional requirements in COLTO

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Problem materials

Type	Situation	Remedy
Soft soils	Vlei and estuarine. Prone to settlement	Investigate extent to decide most practical treatment. Consider: • remove and replace • install subsoil drainage • install geofabrics • treat (stabilize) with lime
Expansive clays	Use PI and clay component with van der Merwe activity chart. Usually: LL > 30, PI >12, LS >8	Investigate extent to decide most practical treatment. Consider: • remove and replace at least 600mm with stable material • stabilize with lime • employ methods to keep moisture content stable
Collapsible soils	Typically low density sandy materials which densify at high moisture contents.	Consider impact rolling or ripping and recompacting to at least 600mm
Dispersive soils	Soils form dongas, gullies and tunnels. Contain sodium or lithium ions	Minimum use of these materials in fills. Consider: • removal to depth of at least 600mm • treat with gypsum

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Aggregates

Typical sieve sizes

Sieve Size (mm)	Class.
37.5	C
28.	O
20.	A
14	R
10	S
7	E
5	
2	F
1	I
0.600	N
0.300	E
0.150	
0.075	Filler

Single sized aggregates for surfacing

Sieve Size (mm)	20 Nominal size	14 Nominal size	10 Nominal size	7 Nominal size
37.5				
28	100			
20	85-100	100		
14	0-30	85-100	100	
10	0-5	0-30	85-100	100
7		0-5	0-30	85-100
5			0-5	0-30
2				0-5
1				
0.600				
0.300				
0.150				
0.075				

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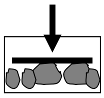
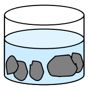
Aggregates

Most important properties:

- Grading 
- Shape 
- Strength 
- Durability 

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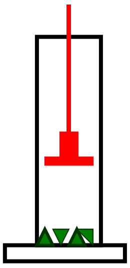
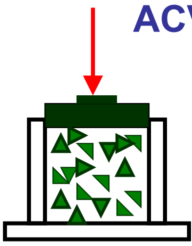
Aggregate Strength Tests

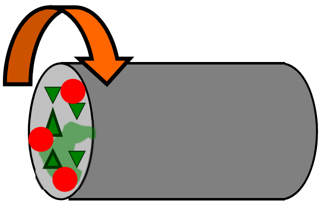
Treton





ACV : % Fines @ 400kN Load

10%FACT : Load to Generate 10% Fines



Modified Ball-Mill
60 rpm for 10mins
B-M I = P0,425 x PI
Using max values

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AGGREGATE STRENGTH

- ✓ **Treton Test - Impact Resistance on -20mm +16mm stone**
- ✓ **Aggregate Crushing Value (ACV) and 10%FACT : (SANS 3001 – AG10), wet and dry on -14mm + 10mm stone – Crushing Resistance**
- ✓ **Modified Ball-Mill Test, (SANS 3001 – AG16) wet and dry, on whole sample - Resistance to degradation during construction and during pavement life**

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Basic compaction technology

STATIC ROLLER

Used mostly for compacting hot-mixed asphalt and in the construction of chip seals . Some road authorities prefer to use it for compacting water-bound macadam

SMOOTH DRUM VIBRATING ROLLER

Extensively used for the compaction of rock-fill and soils in the construction of earthworks as well as the granular pavement layerworks

PADFOOT VIBRATING ROLLER

Used extensively used for compaction in the construction of earthworks and lower pavement layerworks. Breaks down soft rock such as mudstone and shale.

DOUBLE DRUM VIBRATING ROLLER

Compaction of hot-mixed asphalt

PNEUMATIC (RUBBER) TYRED ROLLER

Compaction of hot-mixed asphalt, as well as in the construction of chip seals

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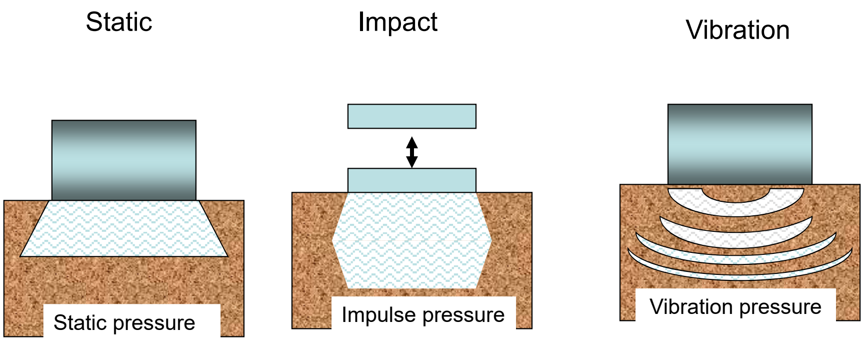
Basic compaction technology

Main forms of compaction



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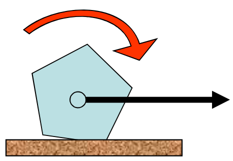
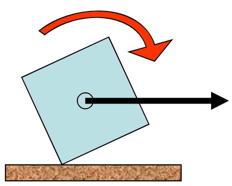
Basic compaction technology

Impact rollers

Used for compaction of earthworks. Useful in dry regions and for compaction of collapsible materials

Impact rollers may be 4 or 5 sided





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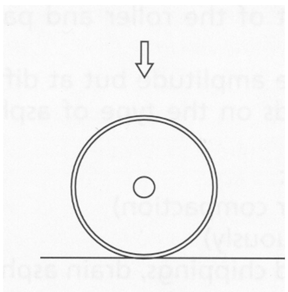
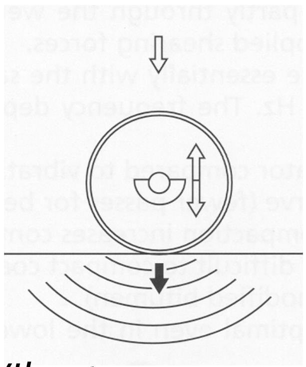
PRINCIPLES OF VIBRATORY COMPACTION

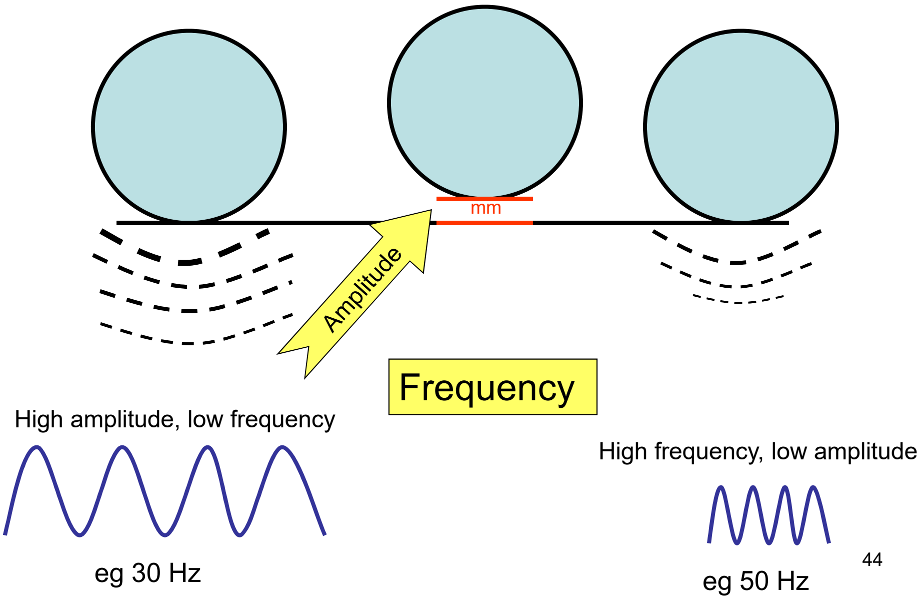


Static compaction



Vibratory compaction

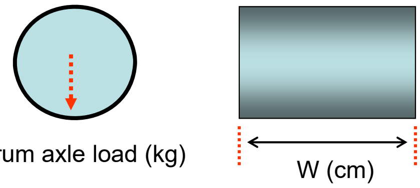
Principles of vibration rollers



Basic compaction technology

Important criteria for vibratory rollers

Static linear load

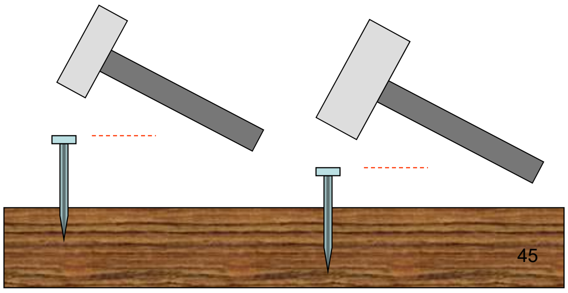


Depth of compaction is proportional to static linear load

Static linear load = drum axle load ÷ drum width

Vibrating mass

Higher vibrating mass = higher compaction performance



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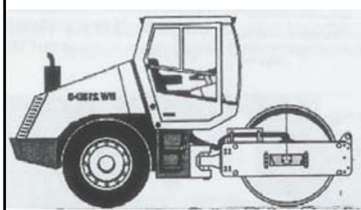
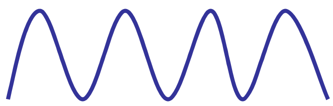
Basic compaction technology

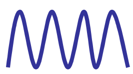
Vibratory roller settings for rockfill, soils and gravels



1. *Start the compaction using HIGH AMPLITUDE / LOW FREQUENCY setting*



2. *Complete the compaction using LOW AMPLITUDE / HIGH FREQUENCY setting*



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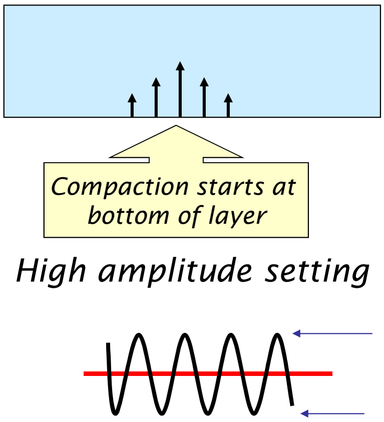
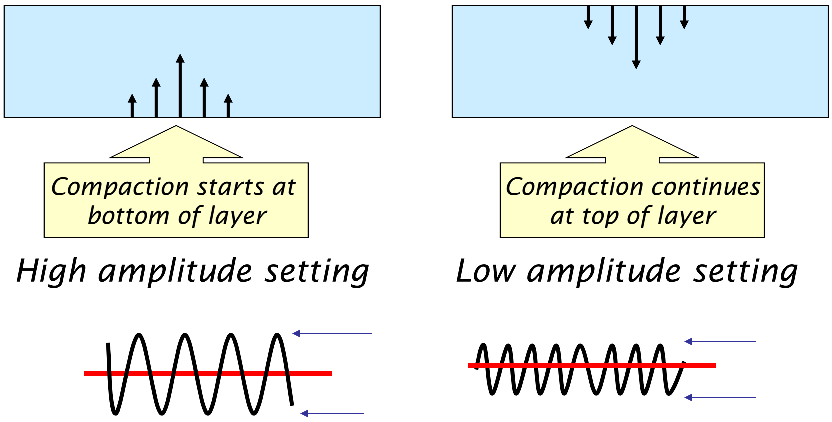
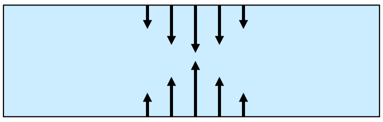
PRINCIPLES OF VIBRATORY COMPACTION



PRINCIPLES OF VIBRATORY COMPACTION



PRINCIPLES OF VIBRATORY COMPACTION



The result:

The full thickness of the layer is properly compacted

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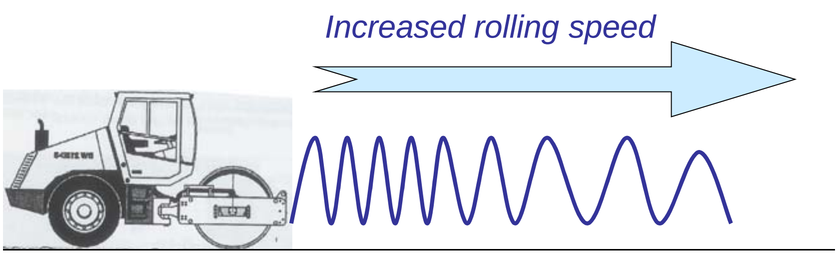
Basic compaction technology

Effect of rolling speed on compaction



The number of vibration impacts decreases as speed increases causing reduction in compaction – required more passes to achieved same level of compaction

TYPICAL OPTIMUM ROLLER SPEEDS	
Rockfill	1 – 2.5 km/h
Gravel, sand	2 – 4 km/h

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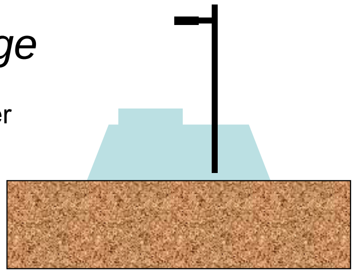
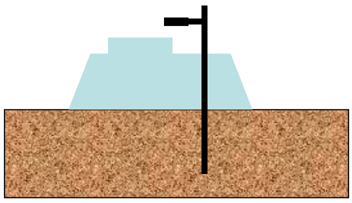
Measurement of compaction

Nuclear gauge

Back scatter



Direct transmission



51

51

Measurement of compaction

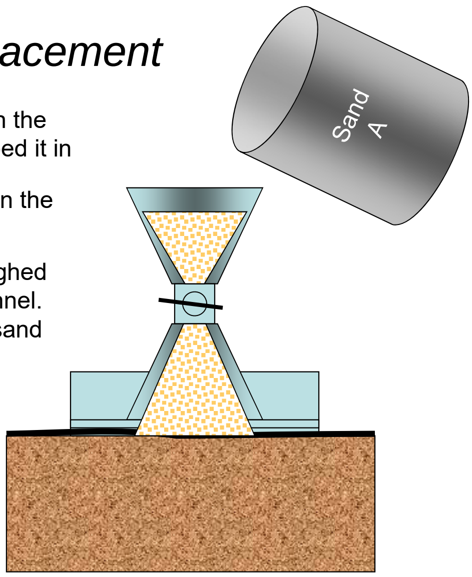
Sand replacement

Place the density ring on the pavement surface and bed it in

Seat the density funnel in the ring

Pour the calibrated, weighed sand into the density funnel. Close the tap once the sand has stopped running in

Pour the sand in the top of the density funnel back into the container



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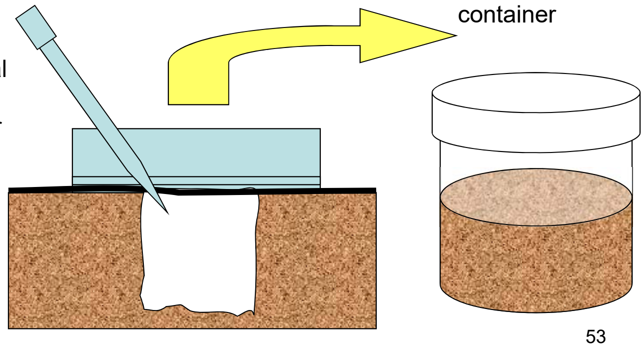
Basic compaction technology

Measurement of compaction

Sand replacement



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53

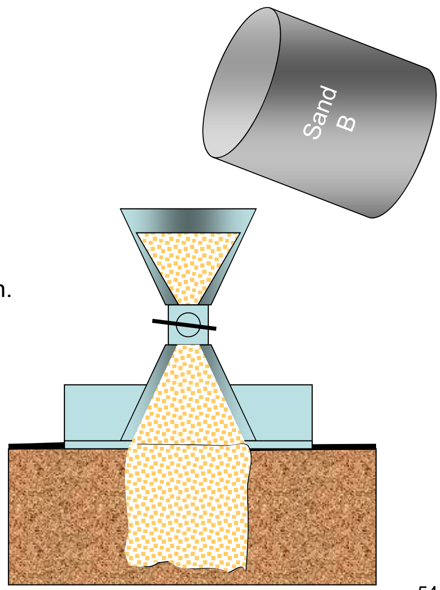
Basic compaction technology

Measurement of compaction

Sand replacement

Once the hole is complete, refit the density funnel to the ring

Pour in the calibrated, weighed sand into the funnel until it stops running in. Close the tap and transfer the sand from the top of the funnel into the container



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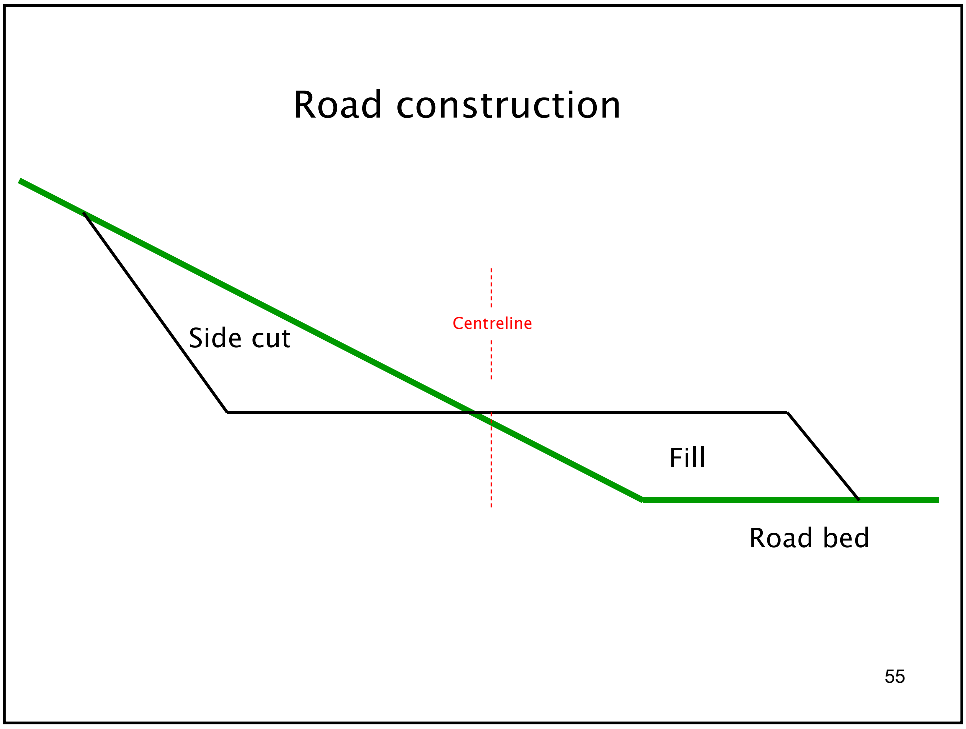
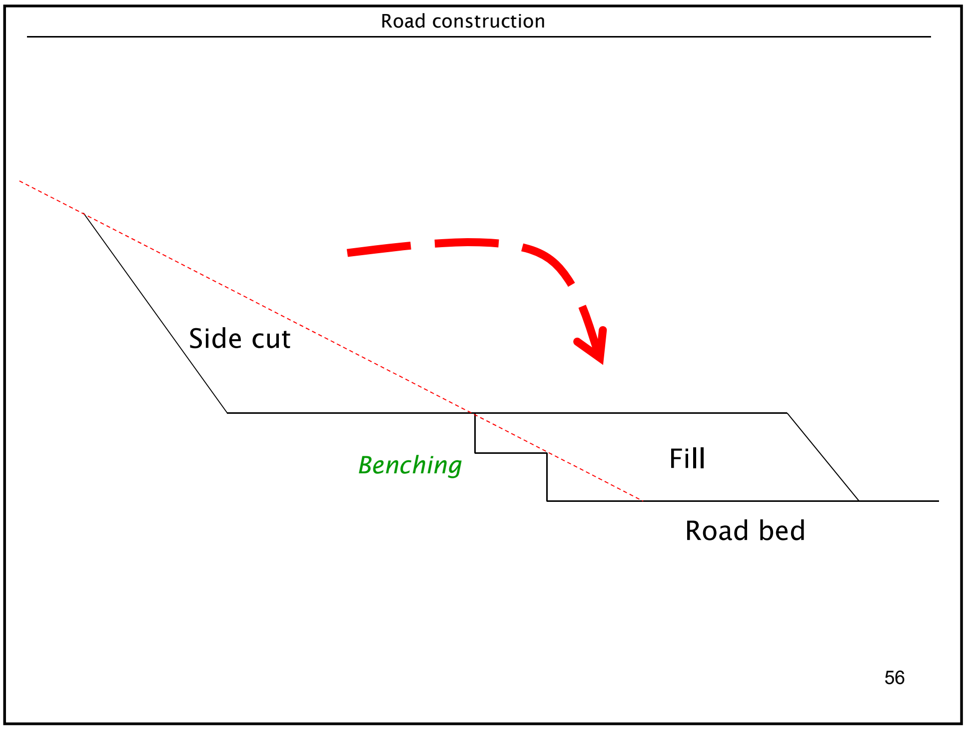
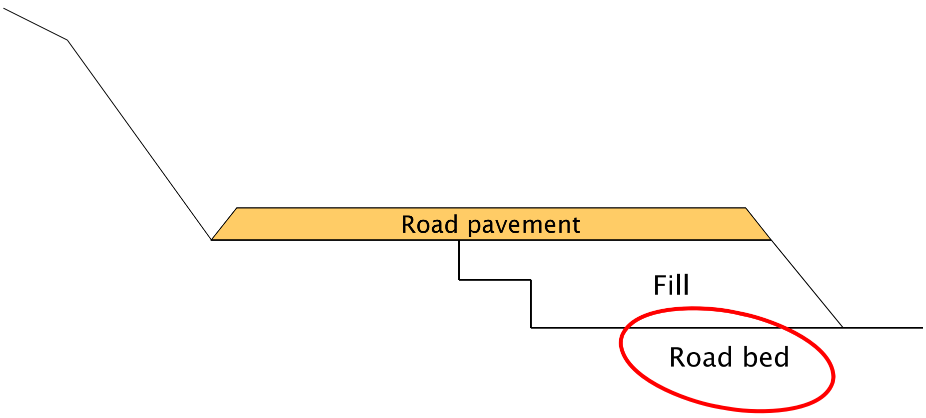

Road construction
Centreline
Side cut
Fill
Road bed
55

55


Road construction
Side cut
Benching
Fill
Road bed
56

56

Road construction



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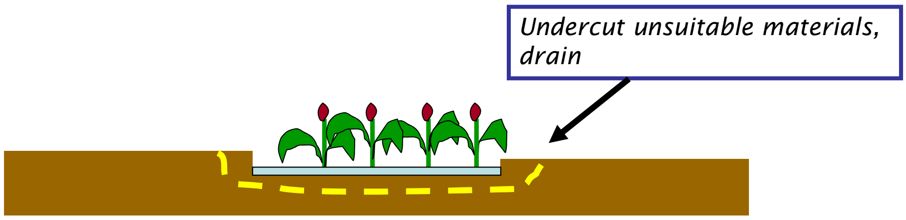
Road construction

Roadbed preparation



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Roadbed preparation

Undercut unsuitable materials, drain

59

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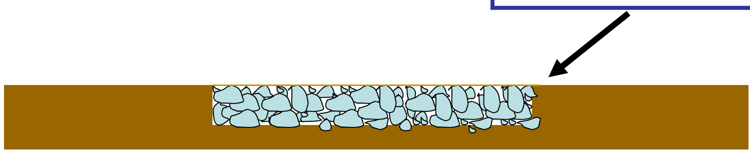
Roadbed preparation

Replace with granular material



Compact the roadbed using a vibrating tamper roller – ensure that the roadbed is stable without signs of "heaving"

Normally minimum 90% Modified AASHTO compaction required

60

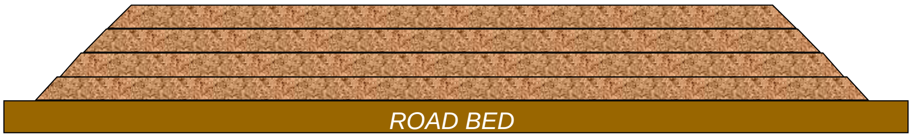
60

Road construction

Fill construction

Compacted layer thickness ≤ 200 mm, except for rockfill

Minimum G10 quality



Normally compaction is minimum 90% Modified AASHTO

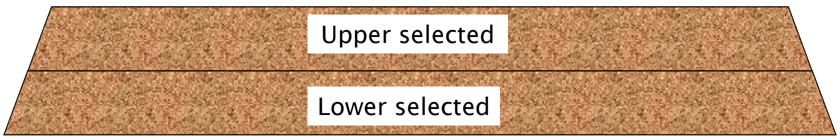
61

61

Road construction

Selected layers

Minimum G7 quality, compacted to min. 93% Mod. AASHTO



Minimum G9 quality, compacted to min. 93% Mod. AASHTO

The thickness of the selected layers are normally 150 mm

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Subbase

Granular pavement types

- G5 or G6 (for lighter pavement designs

Stabilised subbase pavement types

- C3 or C4 (usually heavier pavement designs

The subbase layer is compacted to 95% to 98% Modified AASHTO depending upon the pavement design

Base
Flexible pavements

Well-graded crushed stone base

G1 – very high quality, well-graded crushed stone, compacted to min. 89% ARD

G2 – high quality, well graded crushed stone, compacted to min. 85% BRD

Water-bound macadam base

WB – high quality, large, single sized crushed stone, with finely graded, clean crusher dust vibrated into voids. Usually constructed and compacted in accordance to method specification

Base

Flexible pavements

Hot-mixed asphalt base

Normally continuously graded mix. Usually reserved for heavier pavement designs

Stabilised base

Normally restricted to lighter pavement designs in areas where other pavement designs are not feasible. Prone to block cracking

Introduction to Road Materials Engineering

Part 2: Principles of Stabilisation

Presented by SARF

Presenter:
Ron Berkers

SARF
better roads

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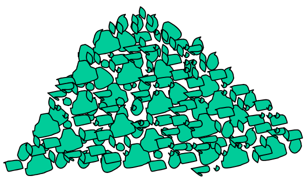
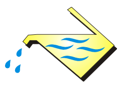
BASIC PRINCIPLES OF STABILISATION



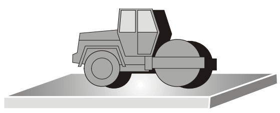
Road building materials

+



Stabilising Agent

=



Improves material's properties, bonds particles, and forms a "beam" in the road

2

2

Most popular stabilizing agents:

cementitious

bituminous

SELECTING THE MOST APPROPRIATE STABILISING AGENT

- *Price*
- *Availability*
- *Materials characteristics*
- *Policy*

Using lime to modify or stabilise soils

Quicklime is made by heating limestone to a high temperature, forming Calcium Oxide

Toxic, burns skin and eyes

Roadlime or “slaked lime” is produced by saturating the quicklime with water, converting the Calcium Oxide to Calcium Hydrocarbonate

Reduced health problem – easier to handle

When roadlime is mixed with clayey materials the PI is reduced. There is usually a long-term gain in strength, depending on the minerals in the material

NOTE

Roadlime may not be effective in improving the strength of low-plasticity materials

Using lime to modify or stabilise soils

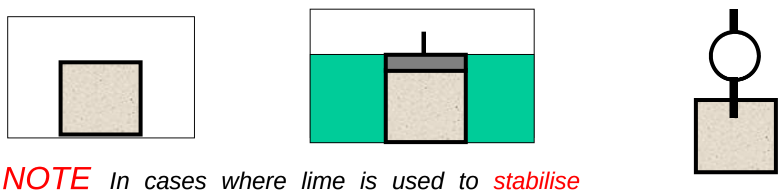
The term “modify” is used to define the process of adding lime mainly as a means of improving the material by reducing its plasticity, which will in turn improve its strength. Where there are strength gains due to cementation, the process is known as “stabilisation”

Besides the Indicator test, the CBR can be used as a means of determining the improvement to the material’s engineering properties after modification with lime. The CBR specimens should be cured for a period of 7 days before soaking

Cure CBR moulds for 7 days

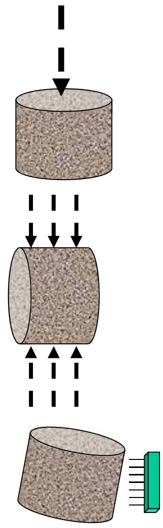
Soak for 4 days

Penetrate



NOTE In cases where lime is used to stabilise materials, it is more appropriate to use UCS or ITS tests to evaluate the material’s properties

Testing of cementitiously stabilised materials



Strength

Unconfined **c**ompressive **s**trength (UCS)

Specimens are compacted at OMC, cured, soaked and then crushed

Indirect **t**ensile **s**trength (ITS)

Specimens are compacted at OMC, cured, and then crushed

Durability

Wet/dry durability (brush test)

Specimens are compacted at OMC and cured. They are then subjected to 12 wet and dry cycles, with brushing using a standard steel brush on each cycle

CBR
California Bearing Ratio

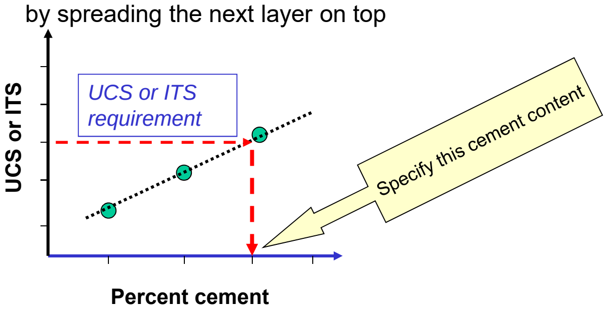
UCS
Unconfined Compressive Strength

Using cement as a stabilizing agent

- different cement types available – use CEM III 32.5 for stabilisation where possible as working time should be slightly longer than other cement types
- consider blending with Ground Granulated Blast Furnace Slag (GGBS)
- reduce processing time – mixing, profiling & compaction – as far as possible
- sample and compact laboratory specimens within 3 hours from the time that the water was added during the mixing process
- use modern soil stabilizer/recycler to carry out the mixing and water addition whenever possible
- carry out the stabilization process at 1.5% below OMC to reduce shrinkage cracking

Properties of cement stabilised materials

- improves the tensile strength of granular materials by bonding the particles together
- the cement stabilised layer is relatively brittle
- the layer is prone to shrinkage cracking – the cement content should be limited to that required to obtain the necessary UCS or ITS, also take the Wet/dry durability into account
- the stabilised layer should be cured by keeping it constantly damp or by spreading the next layer on top



Stabilisation of soil

Click on picture

11

11

Stabilization

The controversy around the curing of stabilized specimens

Curing methods:

Cure specimens in a humidity and temperature controlled curing room at 23.5°C ±1.5°C for various periods, such as 7, 14, 28 and 90 days

Cure specimens sealed in a container submerged in a temperature controlled water bath at 23.5°C ±1.5°C for various periods, such as 7, 14, 28 and 90 days

Accelerated curing of specimens sealed in a container in a temperature controlled oven:

Cement & cement blends	72.5 ± 1.5 °C for 24 ± 0.5 hours
Lime	60.0 ± 2.0 °C for 45 ± 0.5 hours

The jury is still out on which method to use !

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Stabilization

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Stabilization

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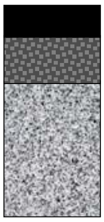
Comparison of equivalent pavement structures

STABILISED WITH CEMENT	STABILISED WITH BITUMEN EMULSION OR FOAMED BITUMEN
	
Brittle cement treated layer requires an asphalt base *Biscuit*	*More flexible bituminously treated layer - thinner recycled layer and no asphalt base required* *Pizza*

15

Stabilization

Reference manuals

GEMS – the design and use of granular emulsion mixes SABITA Manual 14 October 1993

Interim Technical guideline: The design and use of foamed bitumen treated materials Asphalt Academy TG2 September 2002

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Using bitumen emulsion as "modifying" or "stabilizing" agent

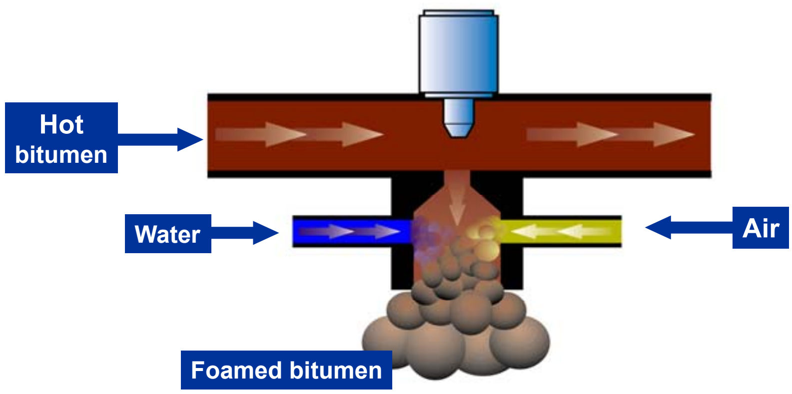
- "Modification" – low percentage of emulsion (residual bitumen content 2% or less.

Acts as compaction aid and improves layer's resistance to ingress of water

- "Stabilisation" – higher percentages of emulsion (residual bitumen contents 2% to 5%).

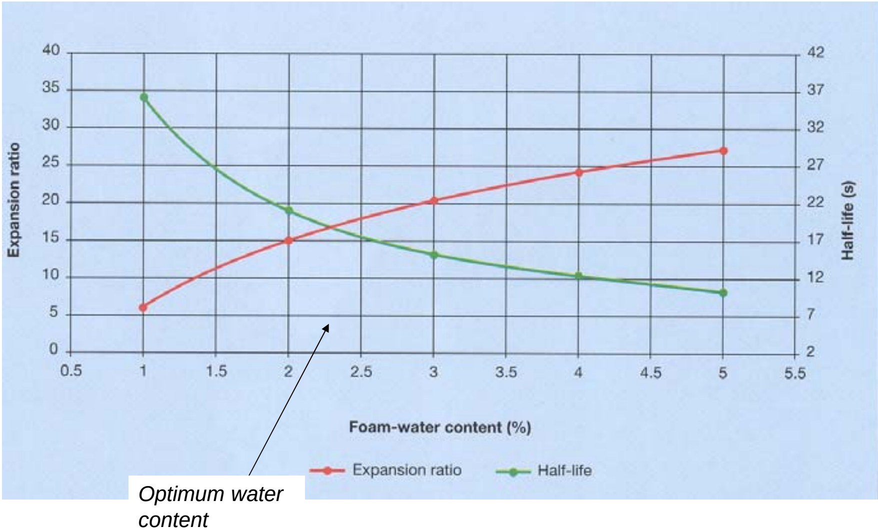
Enhances the material's properties in a similar way to hot-mixed asphalt

Principles of foamed bitumen



Stabilization

Foamed bitumen characteristics “Expansion ratio” and “Half-life”



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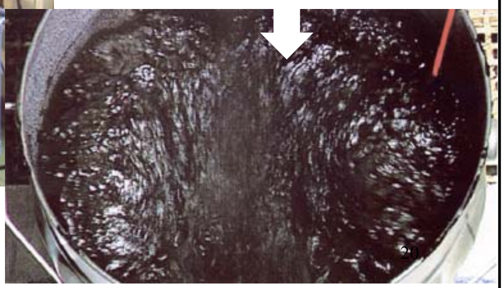
Stabilization

Measure expansion ratio and half life of the foamed bitumen



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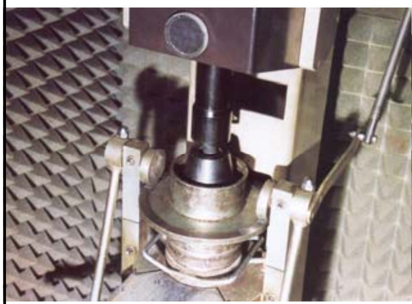
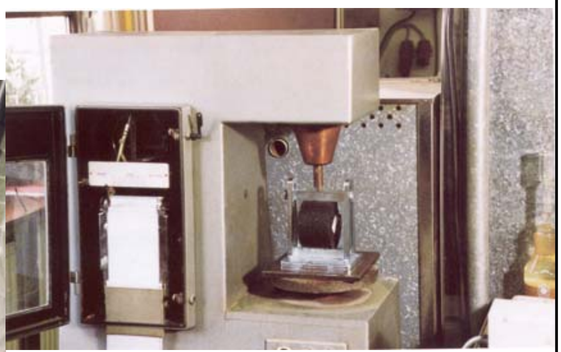
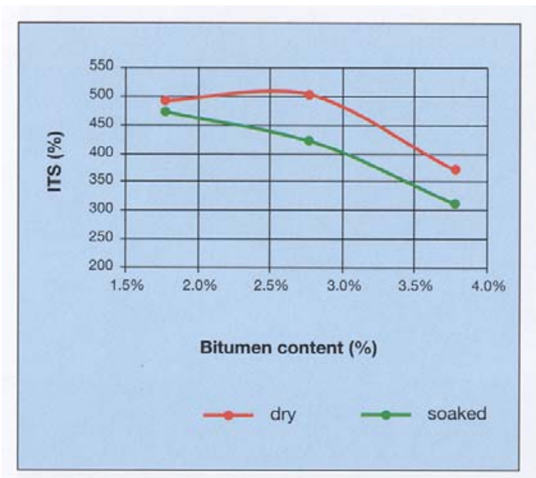




Laboratory testing -

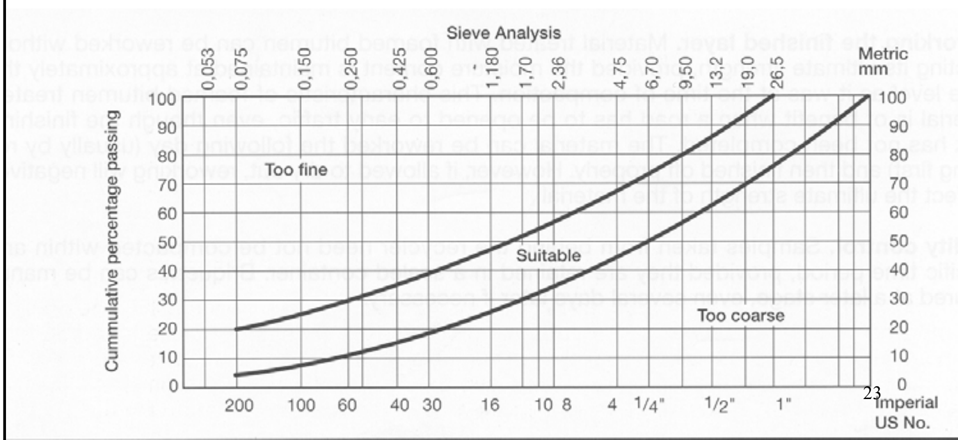
Indirect tensile strength



Plot of ITS results, dry and soaked

Stabilization

Importance of grading on foamed bitumen treated materials



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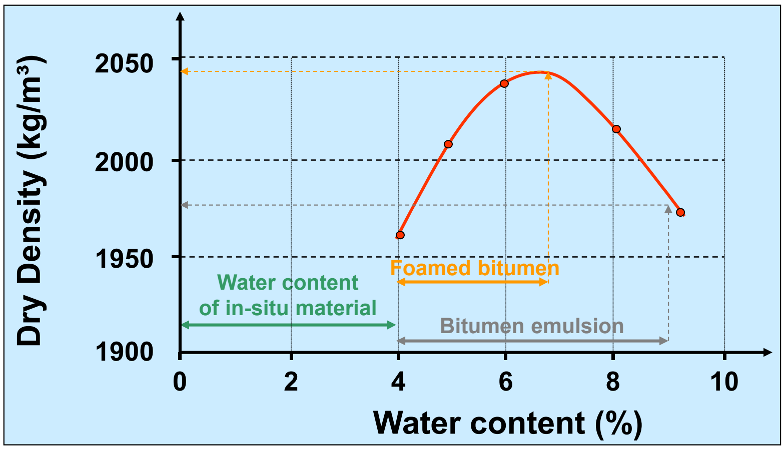
Stabilization

Challenges when using Bitumen Emulsion



Stabilisation with bitumen emulsion often results in the material being wetter than the OMC – the material has to be dried out to enable it to be properly compacted

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Stabilization

Using stabilisation in the rehabilitation of road pavements

In-place recycling

Comparing old and new processes

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Stabilization

The old process using motor graders

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Stabilization

The old process using motor graders

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Stabilization

Modern specialized recyclers

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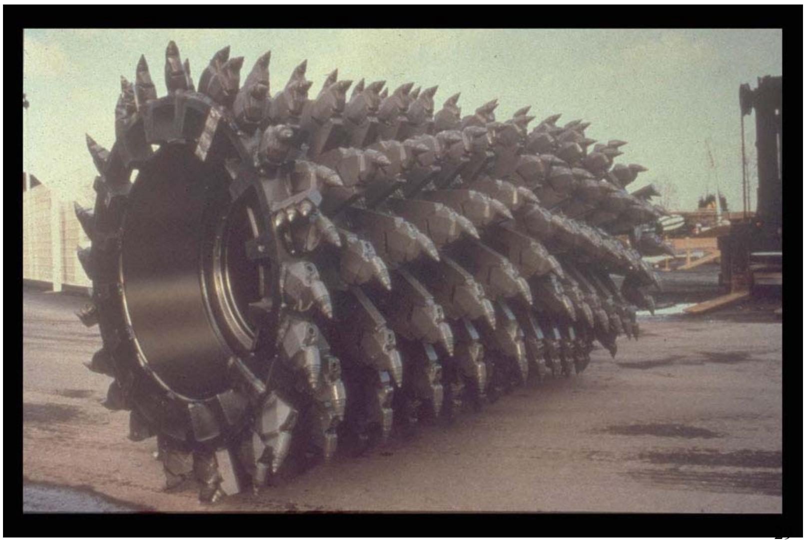
The milling drum



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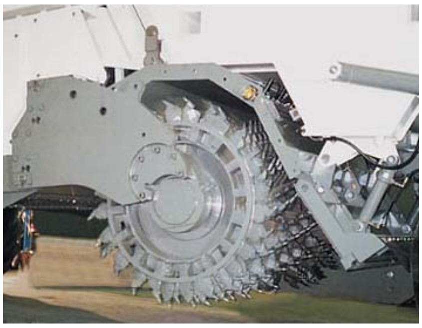
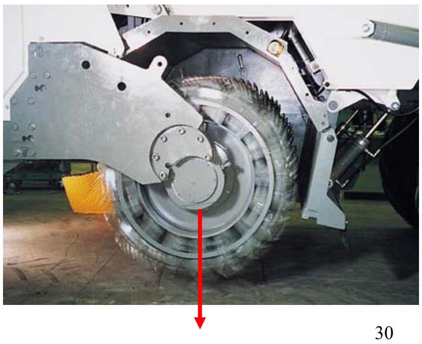
The milling drum is lowered, milling the material in the old pavement





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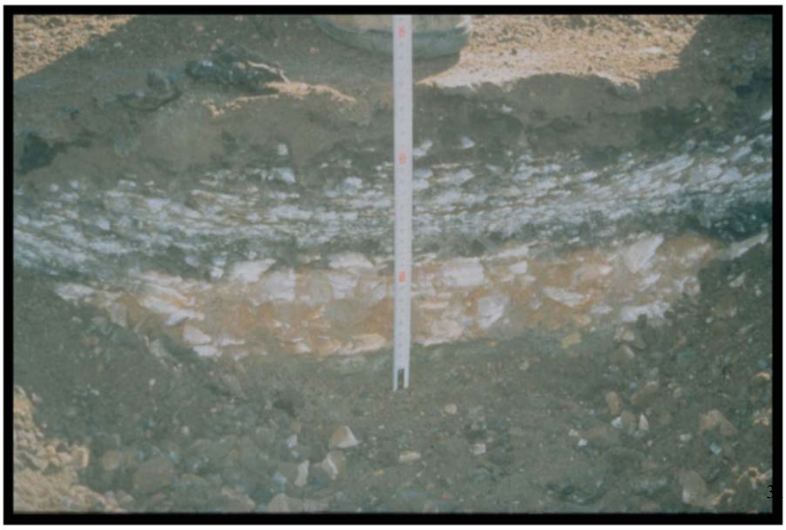
The recycler is capable of milling into tough pavements with thick layers of asphalt



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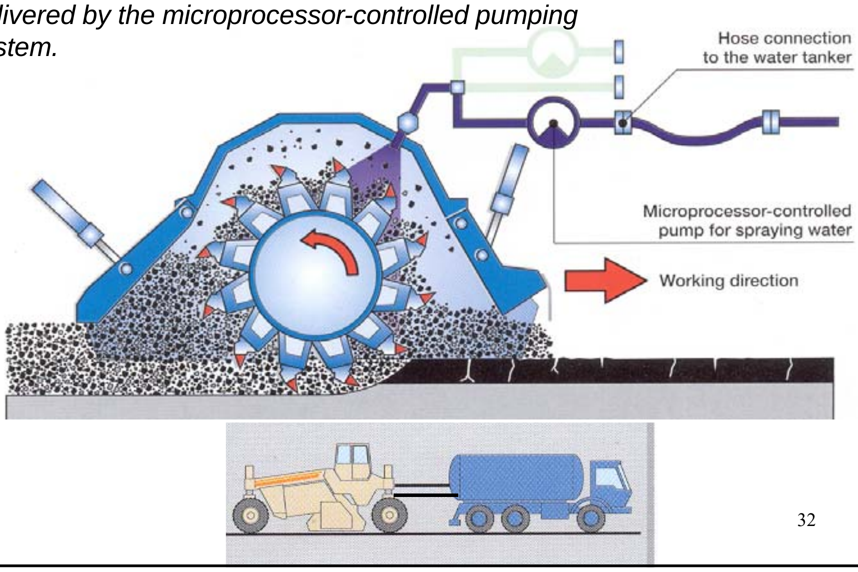
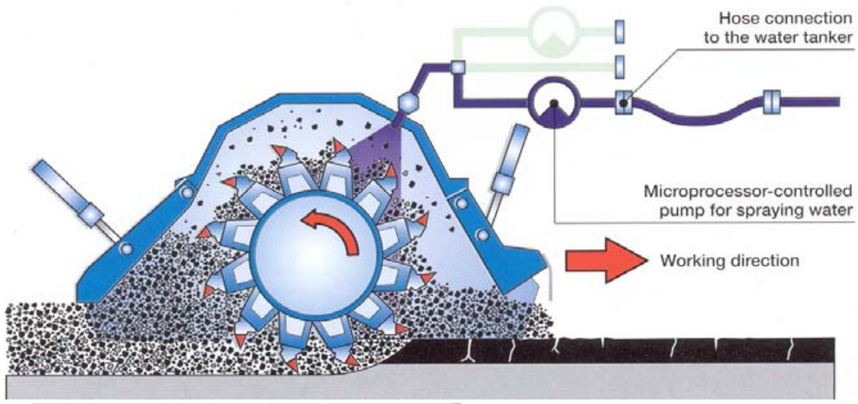
The recycler pushes a tanker filled with water. The water is injected through a spray system into the mixing chamber. A precise quantity of water is delivered by the microprocessor-controlled pumping system.

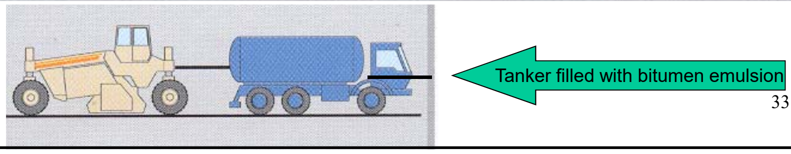


32

32

The recycler pushes a tanker filled with bitumen emulsion. The bitumen emulsion is injected through a spray system into the mixing chamber. A precise quantity of bitumen emulsion is delivered by the microprocessor-controlled pumping system. Usually water is also added during the process – this is delivered from a second tanker which is also pushed by the recycler





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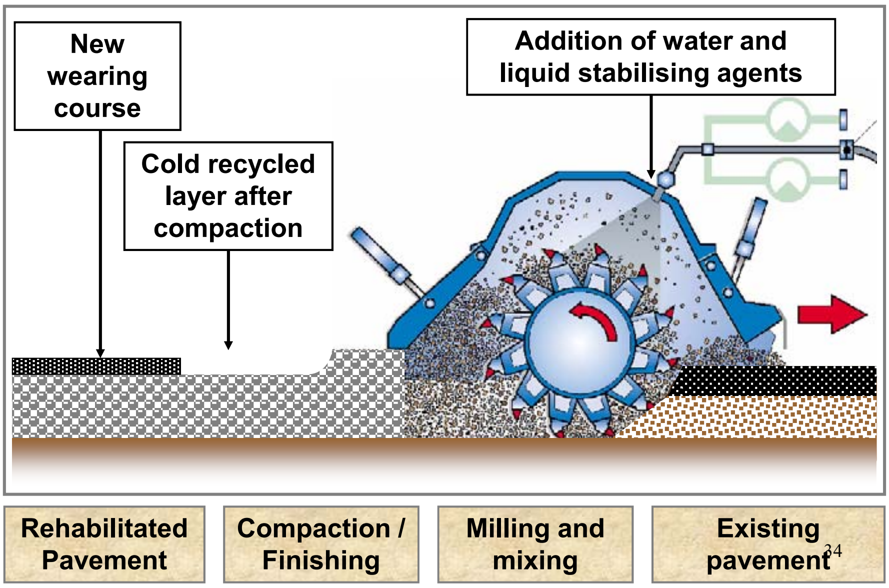
The recycling process using a modern recycler



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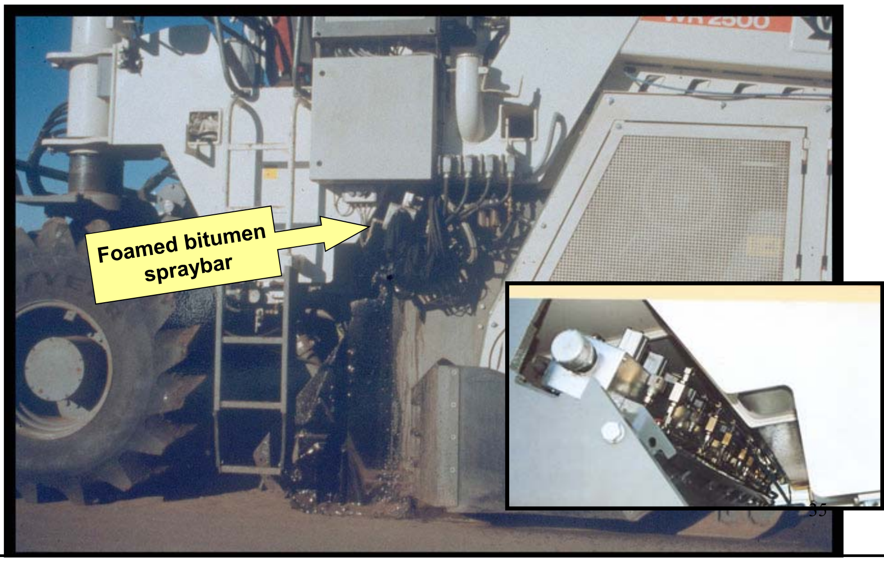
Stabilization

Recycling using foamed bitumen. The foamed bitumen is injected into the recycler's mixing chamber through the spray bar.



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Asphalt Recycling

Click on picture

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Cold in plant recycling

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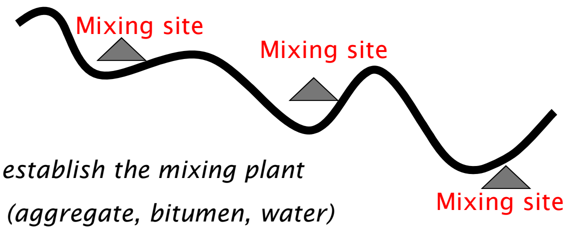

Choose the best locations to establish the mixing plant

in terms of materials supply (aggregate, bitumen, water)

Set up the mixing plant and carry out the mixing, place the foamed bitumen treated material in stockpile

The stockpiled material can be used over a period of several weeks

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Stabilization

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Stabilization

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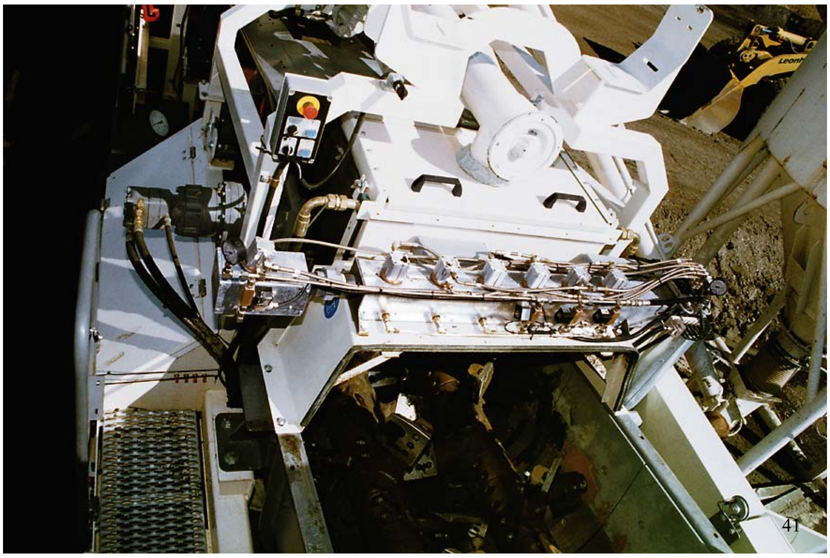
Stabilization



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Stabilization

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Introduction to Road Materials Engineering

Part 3: Basic Bitumen Technology

Presented by SARF

Presenter:
Ron Berkers

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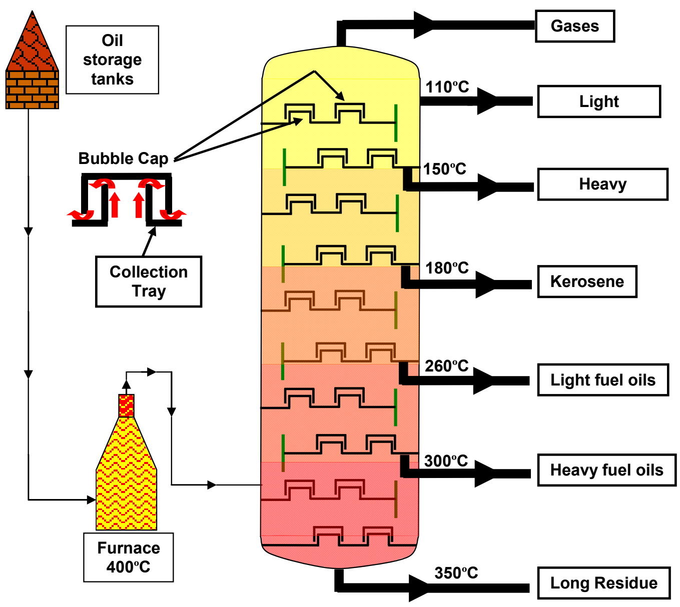
1

Distillation Process



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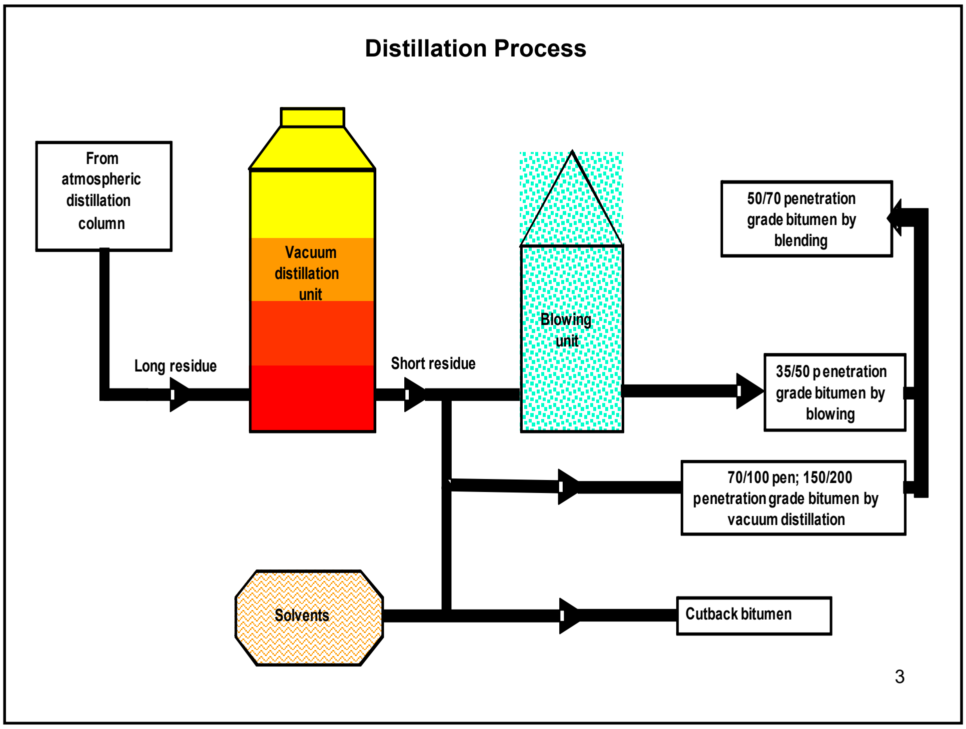
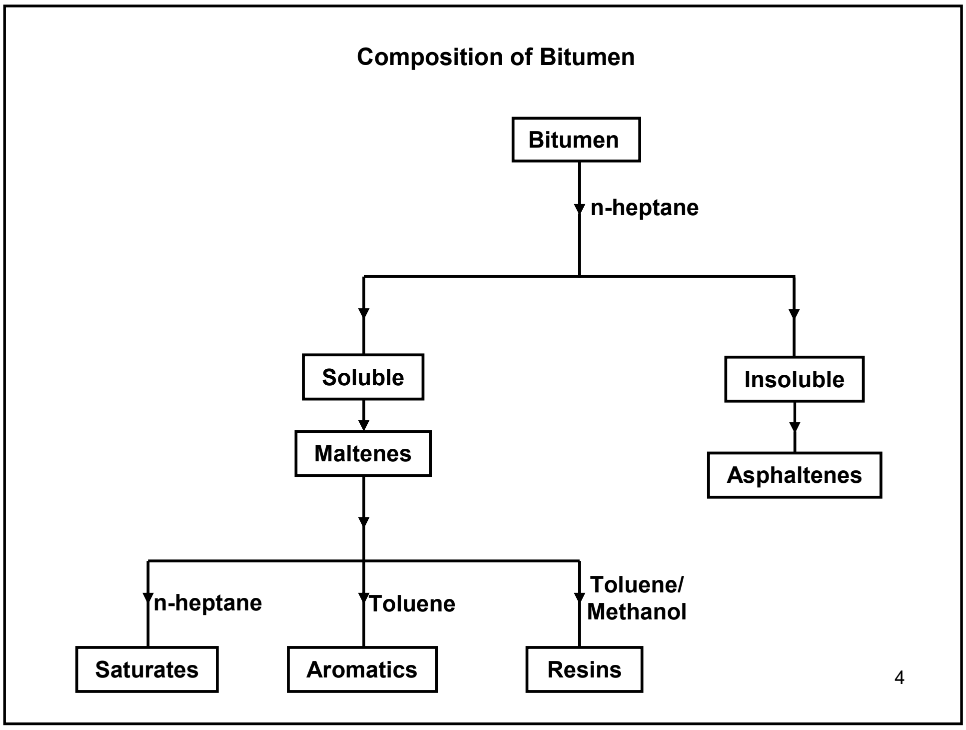

Distillation Process
From atmospheric distillation column
Vacuum distillation unit
Long residue
Short residue
Blowing unit
50/70 penetration grade bitumen by blending
35/50 penetration grade bitumen by blowing
70/100 pen; 150/200 penetration grade bitumen by vacuum distillation
Solvents
Cutback bitumen
3

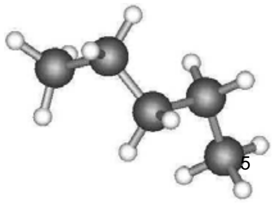
3


Composition of Bitumen
Bitumen
n-heptane
Soluble
Insoluble
Maltenes
Asphaltenes
n-heptane
Toluene
Toluene/ Methanol
Saturates
Aromatics
Resins
4

4

Composition of Bitumen

S – Saturates
A – Aromatics
R – Resins
A - Asphaltenes



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Composition of Bitumen

Saturates:

An increase in saturates tends to soften the bitumen.

Aromatics:

Aromatics are the compounds that give bitumen its fluidity, as they are part of the oils in bitumen. As such they are a major part of the medium in which the asphaltenes are dispersed (peptized)

Resins:

Resins tend to inhibit the oxidation of bitumen, but when oxidation of bitumen occurs it is the resins which, by taking on oxygen, are converted to asphaltenes and in so doing change the thickness, and thus the stiffness, of the bitumen.

Asphaltenes:

Asphaltenes give bitumen its thickness. Increasing the asphaltenes content of bitumen produces a harder bitumen with a lower penetration, a higher softening point and thus a higher viscosity. 6

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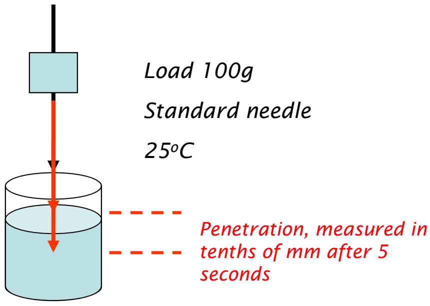
BASIC BITUMEN TECHNOLOGY

Penetration grade bitumen



Commonly used grades:

35/50 pen

50/70 pen

70/100 pen

150/200 pen

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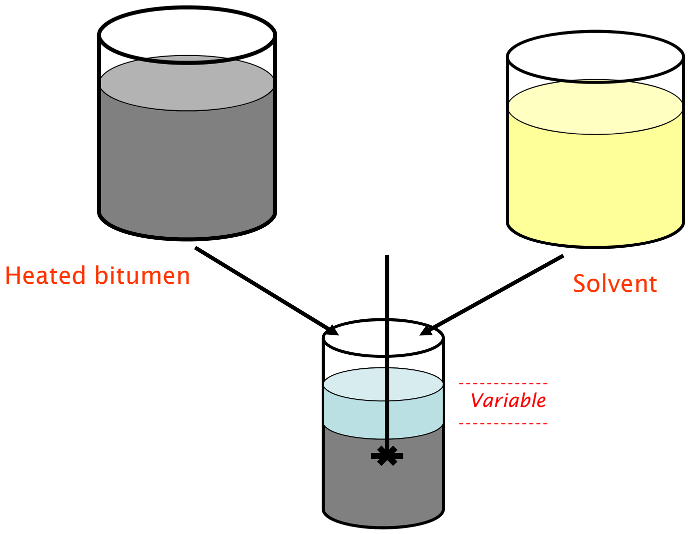
7

BASIC BITUMEN TECHNOLOGY

Bitumen cutbacks



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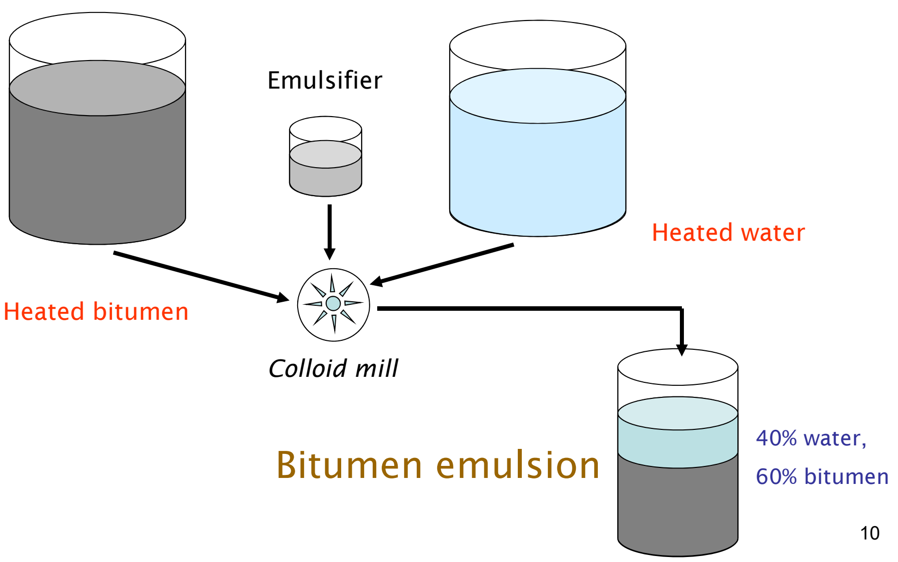
Bitumen cutbacks

Reduced use due to environmental considerations

TYPE	USE
MC10	Prime
MC30	Prime
MC3000	Binder for sand seals
RC250	Prime

Bitumen emulsion



Bitumen emulsion

Main bitumen emulsion types and uses:

ANIONIC Negative charge	Mix grade Stable grade Spray grade	Manufacture of cold mixes for patching Stabilisation Chip seals – tack and fog coats sprays
CATIONIC Positive charge	Stable grade Spray grade	Stabilisation Chip seals – tack and fog coat sprays Asphalt tack coat
INVERTED	Prime	Prime granular bases

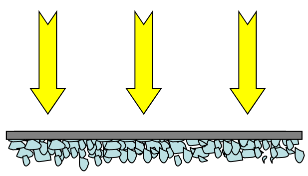
11

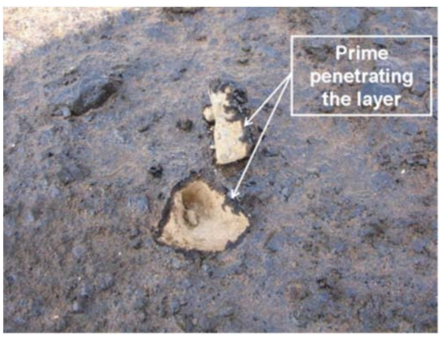
11

BASIC BITUMEN TECHNOLOGY

Primes and Tack Coats

The main purpose of the PRIME is to penetrate into the finished base layer, improving the bond between base and surfacing





Prime types:

MC 30 Bitumen cutback

MSP1 Inverted bitumen emulsion

Typical spray rate 0.7 L/m^2

The use of tar primes is prohibited for health reasons

12

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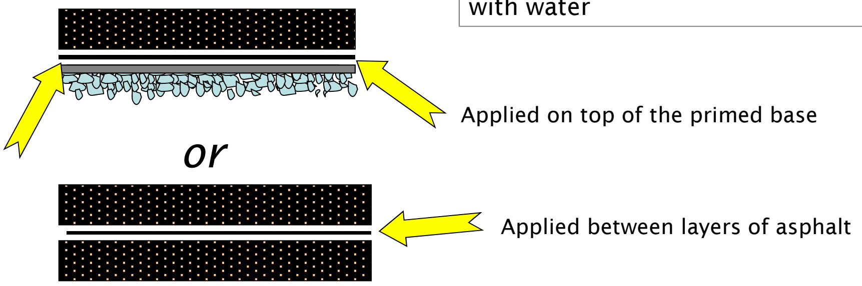
BASIC BITUMEN TECHNOLOGY

Primes and Tack Coats

The main purpose of the TACK COAT is to provide a dust-free bond between the primed base and the asphalt, or between layers of asphalt

Tack coat material: typically anionic stable grade diluted 1:1 with water



Typical spray rate 0.5 L/m²

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Introduction to Road Materials Engineering

Part 4: Introduction to Surfacing Seals

Presented by SARF

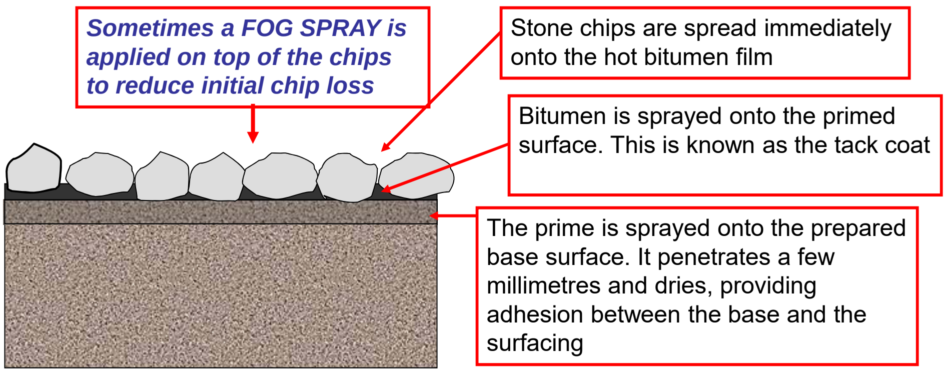
Presenter:
Ron Berkers

1

Introduction to chip seal surface treatments

Basics of chip seals

This is known as a SINGLE SEAL:



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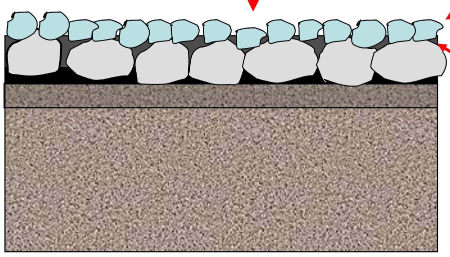
Basics of chip seals

A DOUBLE SEAL consists of two chip applications:

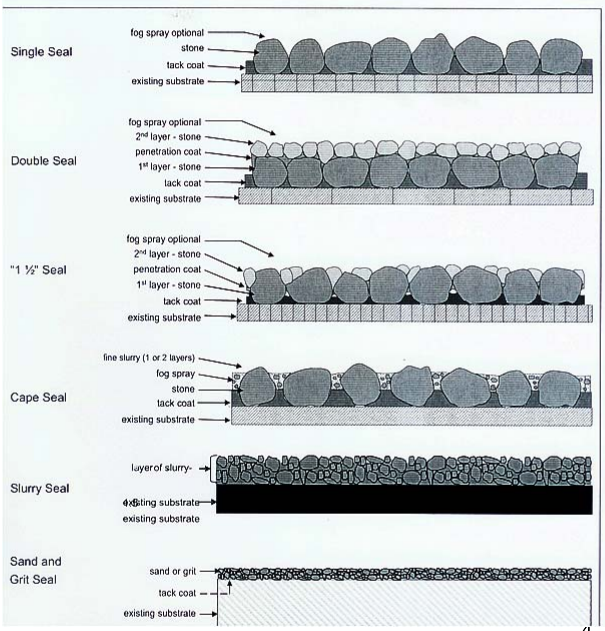
Sometimes a FOG SPRAY is applied on top of the chips

Smaller chips – less than half the size of first chips

Second tack coat – known as penetration coat

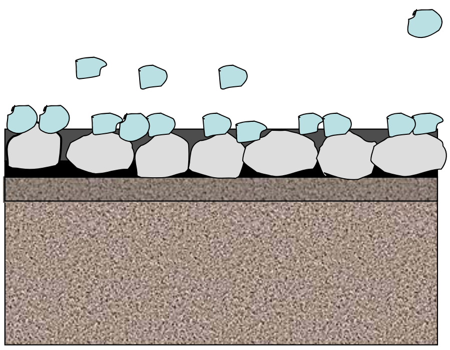


Seal types covered in TRH3



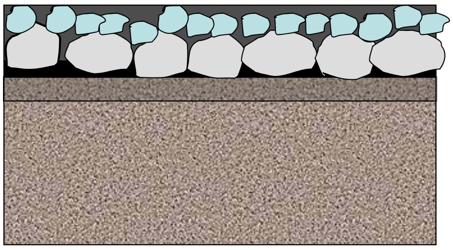
Click Picture

Application rates for the bitumen and chips are of VITAL IMPORTANCE



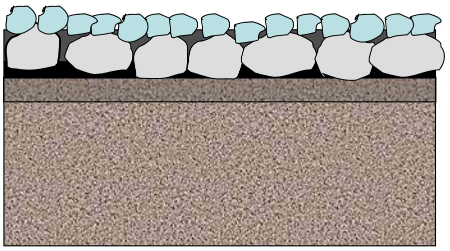
If the bitumen application rate is TOO LOW it will result in the loss of chips – insufficient "glue" to hold the chips

Application rates for the bitumen and chips are of VITAL IMPORTANCE



If the bitumen application rate is TOO HIGH it will result in fattiness, bleeding, and poor skid resistance

Application rates for the bitumen and chips are of VITAL IMPORTANCE



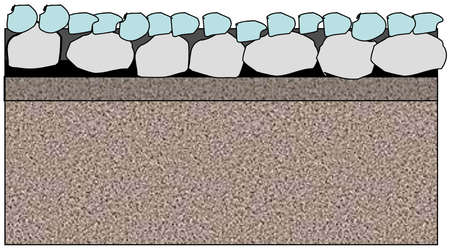
Chip application rates also affect the performance of the seal – too high will result in "whip-off" and too low will result in bleeding

Tack and Penetration Coats

Tack and penetration coats are sprayed onto the prepared road surface using a CALIBRATED distributor, at the specified SPRAY RATE.

The SPRAY RATE is specified in l/m^2, and can be expressed either as a HOT or COLD spray rate.

The TEMPERATURE of the binder in the distributor must be within the specified limits for the particular type of binder used.



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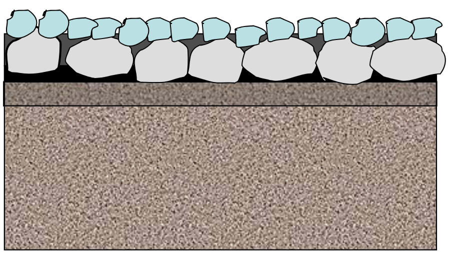
Application of the chips

The chips are applied at the specified APPLICATION RATE on top of the freshly sprayed tack or penetration coat. A motorised CHIP SPREADER is used on most projects.

The APPLICATION RATE (also known as the "spread" rate) is expressed either as m^2/m^3 or m^3/m^2.



It is important that the application of the chips is carried out directly behind the bitumen distributor – there should be no delay between the application of the tack or penetration coat and the application of the chips

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Important design inputs

Quality of the chips:

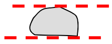
Strength

Durability

Grading

Shape

Flakiness

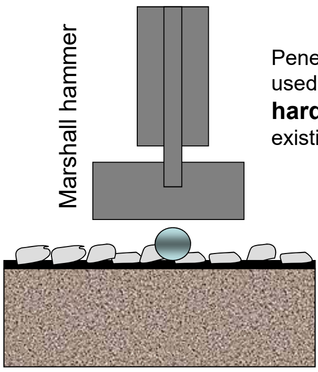


ALD

Traffic volume and type is extremely important

The grade also effects the design – reduce spray rates on steep inclines

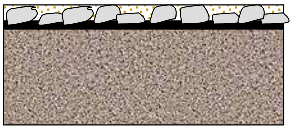
Ball Penetration Test



Penetration test is used to assess **hardness** of existing surface

Sand Patch Test

Sand patch test is used to assess the existing **surface texture**



Pour sand onto surface, level it flush with squeegee

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Introduction to Road Materials Engineering

Part 5: Introduction to Hot Mix Asphalt

Presented by SARF

Presenter:
Ron Berkers

1

What *is* hot-mixed asphalt ?

Mixture of hot bitumen and crushed aggregate that is used in the road pavement as a base or surfacing.

2

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Materials used in hot-mixed asphalt

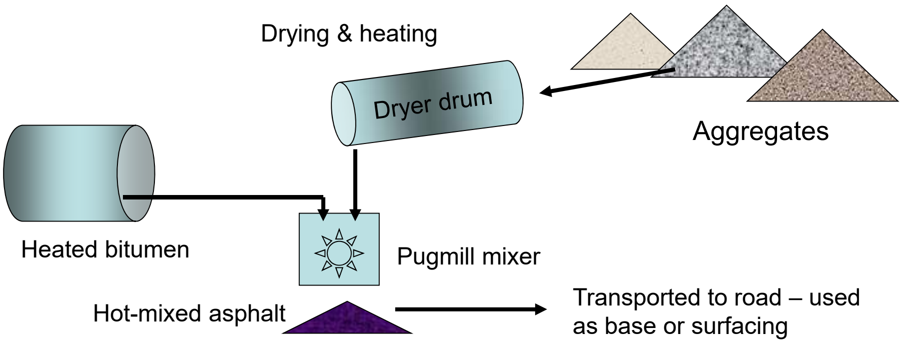
Basic components:

- Stone – quality (strength, shape, grading, absorption, polishing)
- Sand – quality (grading, sand equivalent)
- Filler – choose inert or active filler
- Bitumen – pen grade

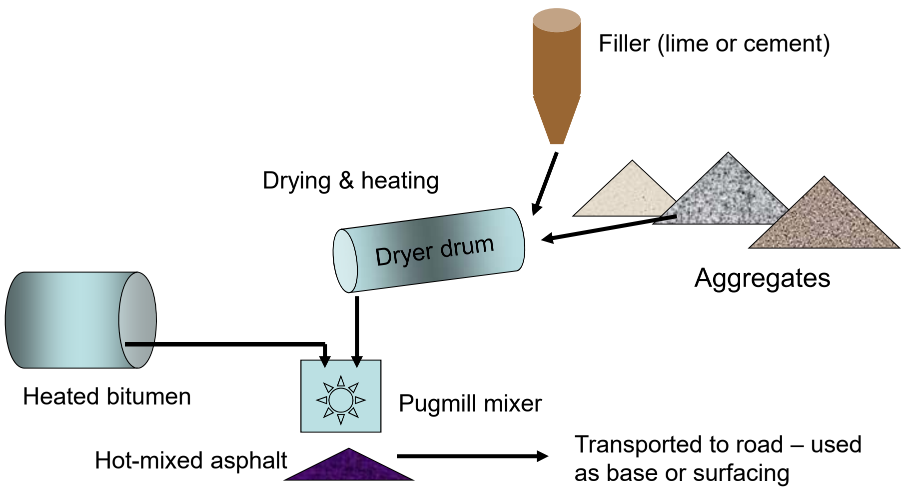
Other materials used in asphalt mixes if needed:

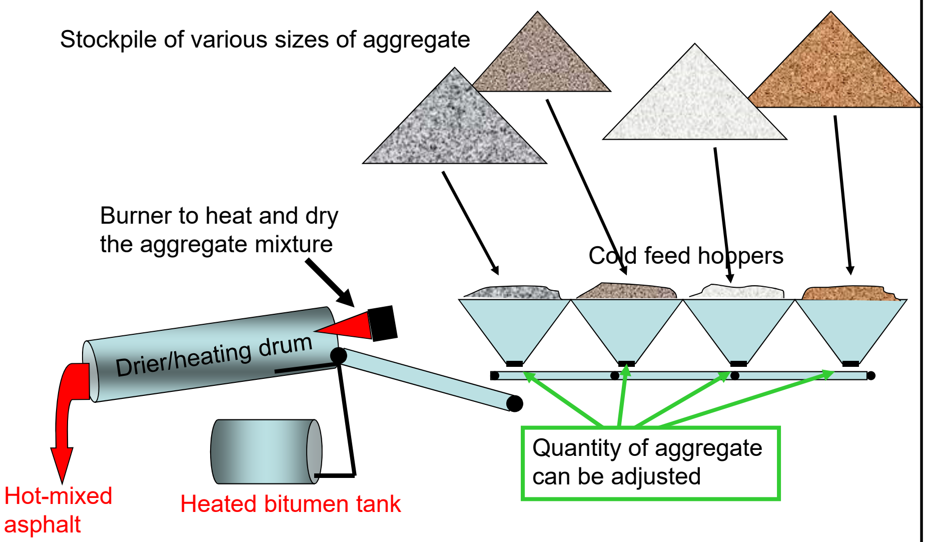
- Polymers – EVA (plastomer), SBS, RB (elastomer)
- Wax
- Gilsonite - resin
- Cellulose wood fibre

What *is* hot-mixed asphalt ?



What *is* hot-mixed asphalt ?





The delivery of aggregate from the cold feed bins must be calibrated to produce the required grading

How asphalt is made

7

Click Picture

7

Introduction to hot-mixed asphalt

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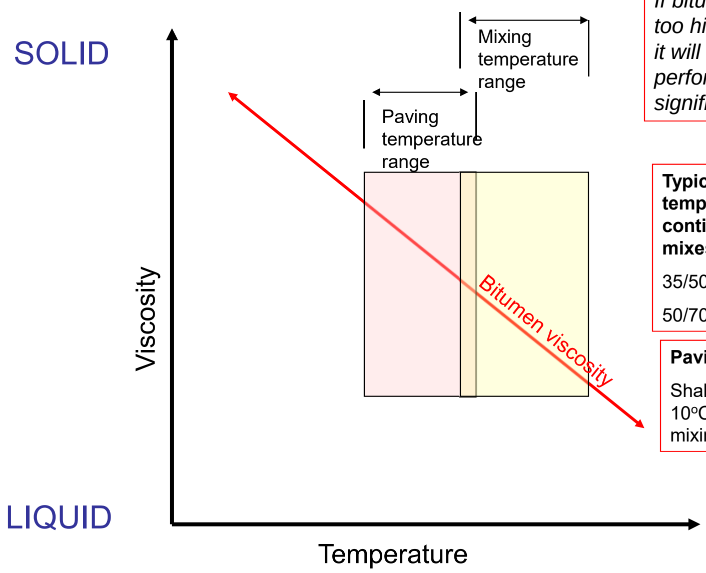
Mill and Overlay

Click Picture



Note

If bitumen is heated to too high a temperature it will degrade and its performance with be significantly reduced

Typical mixing temperatures for continuously graded mixes

35/50pen	140 to 165 °C
50/70pen	135 to 160 °C

Paving temperatures

Shall not be more than 10°C less than min mixing temperature

Summary of some important aspects of asphalt mixes

- Grading
- Bitumen content
- Void content
- Marshall Stability & Flow
- Compaction

Basic asphalt design principles

The Marshall Mix Design Method

Main steps in the Marshall mix design procedure:

1. Combine the various aggregates and filler to make up the required grading
2. Heat the aggregate & filler mixture to the required mixing temperature. Heat the bitumen to the required mixing temperature
3. Mix the aggregates and bitumen together thoroughly, transfer to a Marshall mould and compact using 75 blows of the Marshall hammer on each face.
4. Subject the compacted Marshall briquette to the following tests:
   - bulk relative density
   - Marshall Stability & Flow
   - Maximum theoretical relative density

The Marshall mix design procedure is still widely used although there are moves to use other more sophisticated design methods

Basic asphalt design principles

The Marshall Mix Design Method

Marshall Hammer → **BRD** → **Stability and Flow** → **Bulk Theoretical Relative Density**

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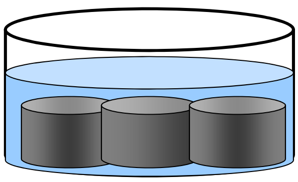
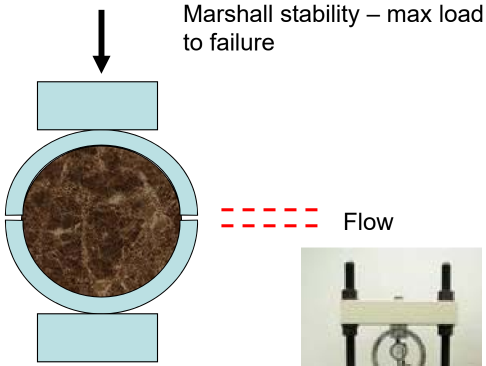
Marshall Stability and Flow Test



Marshall briquettes are soaked in water for 30 minutes at 60°C



6 kN minimum

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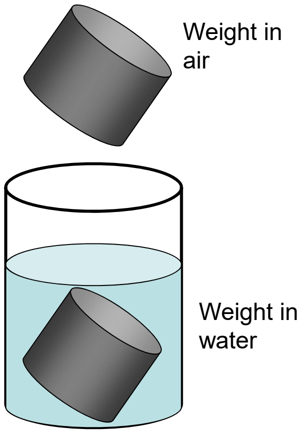
Introduction to hot-mixed asphalt

Bulk Relative Density



Bulk density = weight in air ÷ loss of weight in water

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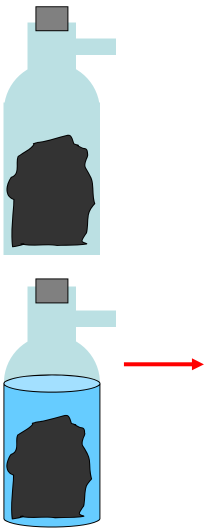
Introduction to hot-mixed asphalt

Max Theoretical Relative Density



Max theoretical relative density = weight of mix in air ÷ volume of voidless mix

Vacuum pump expels the air, filling the voids with water

$$\text{Void Content} = 100 - \left(\frac{BRD}{MTRD} X 100\right)$$

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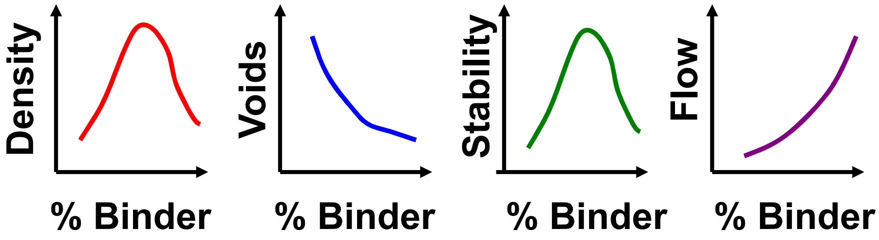
The Marshall Mix Design Method

Marshall briquettes are prepared using the same aggregate mixture at 5 different bitumen contents.

The results of the tests are then plotted.

The optimum binder content is chosen, based on these results.



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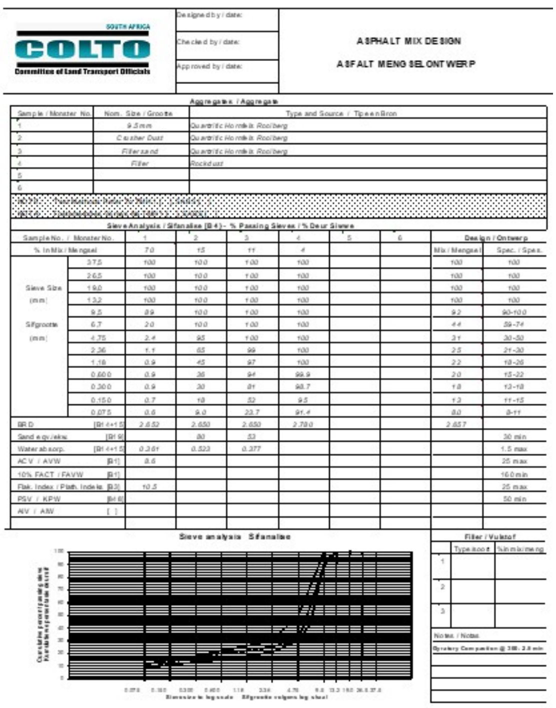


COLTO – Committee of Land Transport Officials – SOUTH AFRICA

Designed by / date:

Checked by / date:

Approved by / date:

ASPHALT MIX DESIGN

ASFALT MENGSELONTWERP

Aggregates / Aggregate

Sample / Monster No.	Nom. Size / Grootte	Type and Source / Tipe en Bron
1	9.5mm	Quartzitic Hornfels Rooiberg
2	Crusher Dust	Quartzitic Hornfels Rooiberg
3	Filler sand	Quartzitic Hornfels Rooiberg
4	Filler	Rockdust
5		
6		

Sieve Analysis / Sifanalise (B4) - % Passing Sieves / % Deur Siwwe

Sample No. / Monster No.		1	2	3	4	5	6	Design / Ontwerp Mix / Mengsel	Spec. / Spes.
% In Mix / Mengsel		70	15	11	4				
Sieve Size (mm) Sifgrootte (mm)	37.5	100	100	100	100			100	100
	26.5	100	100	100	100			100	100
	19.0	100	100	100	100			100	100
	13.2	100	100	100	100			100	100
	9.5	89	100	100	100			92	90-100
	6.7	20	100	100	100			44	59-74
	4.75	2.4	95	100	100			31	30-50
	2.36	1.1	65	99	100			25	21-30
	1.18	0.9	45	97	100			22	18-26
	0.600	0.9	36	94	99.9			20	15-22
	0.300	0.9	30	81	98.7			18	13-18
	0.150	0.7	18	52	95			13	11-15
	0.075	0.6	9.0	23.7	91.4			8.0	8-11
BRD	[B14+15]	2.652	2.650	2.650	2.780			2.657	
Sand eqv./ekw.	[B19]		80	53					30 min
Water absorp.	[B14+15]	0.361	0.523	0.377					1.5 max
ACV / AVW	[B1]	8.6							25 max
10% FACT / FAVW	[B1]								160 min
Flak. Index / Plath. Indeks	[B3]	10.5							25 max
PSV / KPW	[B16]								50 min
AIV / AIW	[ ]								

Sieve analysis Sifanalise

Filler / Vulstof

	Type soort	% in mix/meng
1		
2		
3		

Notes / Notas

18

18

Contract / Kontrak :	
Route / Roete :	
Section / Gedeelte :	
Layer / Laag :	
Mix / Mengsel :	

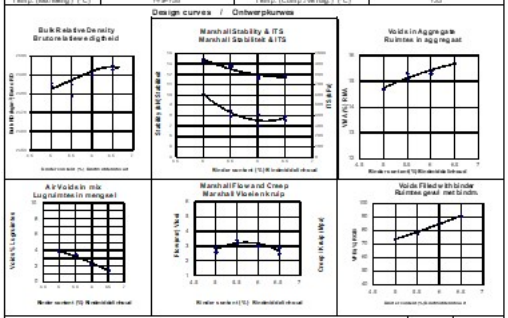
D 3

Sheet no. / Velno. 1 of / van 1

Binder / Bindmiddel

Type / Tipe	60/70	Source / Bron	
Pen @ 25°C (0.1 mm)	62	Visc. @ 60°C (Pa.s)	246
Soft / Sagw. pt (°C)	50.3	Visc. @ 135°C (Pa.s)	0.4275
RD	1.0280	Hot Flow/Warmvloei (mm)	
Temp. (Mix/Meng) (°C)	149-155	Temp. (Comp./Verdig.) (°C)	135

Design curves / Ontwerpkurwes



Design / Ontwerp						Spec.	Proposal
Binder / Bindmiddel (%)	5	5.5	6	6.5			5.8
Max. / Maks. TRD (Rice)	2.480	2.463	2.446	2.429			
BRD (Marshall) (kg/m³)	2385	2382	2391	2394			
Voids in Mix / Ruimtes in Mengsel (%)	3.9	3.3	2.3	1.5		5 - 7	
Stab. (Marshall) (kN)	10.1	8.3	7.6	7.8		6 min	
Flow / Vloei (Marshall) (mm)	2.8	3.3	3.1	2.7		2 - 4	
Stab./Flow Ratio / Stab./Vloei Verh.	3.7	2.5	2.5	2.9			
ITS (kPa)	906	872	772.1	781		700 min	
Creep / Kruip Dynamic / Static (MPa)		6.9 / 53				25 / 100	
Air Perm. [illegible]		2.585					
VMA / RMA (%)	14.7	15.2	15.4	15.7		17 - 21	
VFB / RGB (%)	73.8	78.5	85.4	90.8		69 - 79	
Immersion / Dompel Ind. (%)		97.1				75 min	
Absorp. (Binder/Bindmiddel) (%)	0.323	0.338	0.359	0.374		0.5 max	
Filler / Binder ratio	1.6	1.5	1.3	1.2		1.0 - 1.5	
Film Thickness (µm)	6.4	7.1	7.8	8.5		7.5 - 11.0	
Modified Lottman (%)		98.8				80 min	

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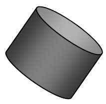
Introduction to hot-mixed asphalt

There are two ways of specifying compaction of hot-mixed asphalt:

- BRD of core sample as a percentage of Marshall density of the same mix



Usually specified as "The compaction of the asphalt shall not be less than 95% of Marshall density"

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There are two ways of specifying compaction of hot-mixed asphalt:

- BRD of core sample as a percentage of Maximum Theoretical Relative Density of the same sample

Usually specified as "The compaction of the asphalt shall not be less than 97% minus the design void content" - if design voids are 5% then min would be 92%

Most commonly used mix types

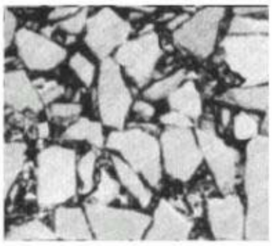
Continuously graded

Good distribution of the various particle sizes. Manufactured using ±3 aggregate fractions and crusher dust

Stone skeleton

Stone-on-stone contact. Voids between the larger aggregate pieces are filled with mastic

Known as SMA – stone mastic asphalt



Ultra thin friction course (UTFC)

- The UTFC is a stone skeleton type mix using modified binder
- An essential part of UTFC is a thick tack coat of modified bitumen emulsion. This provides good adhesion of the thin friction course to the underlying asphalt layer and provides a waterproofing membrane
- A specialised Spray-paver is used to pave UTFC – the tack spray system is incorporated into the paver

UTFC provides good skid resistance and riding quality, and has been found durable under heavy traffic

Introduction to Road Materials Engineering

Part 6: Introduction to Materials Investigations

Presented by SARF

Presenter:
Ron Berkers

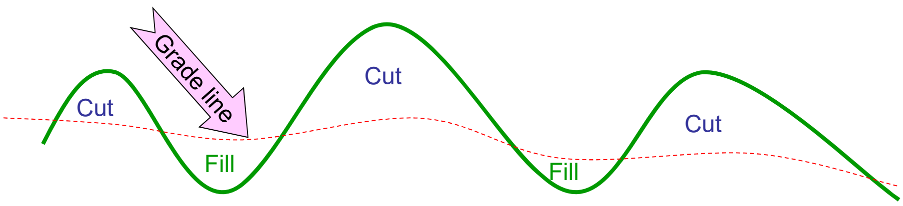
SARF
better roads

1

Overview of materials investigations

Investigations for construction of new roads

Cuts & Fills



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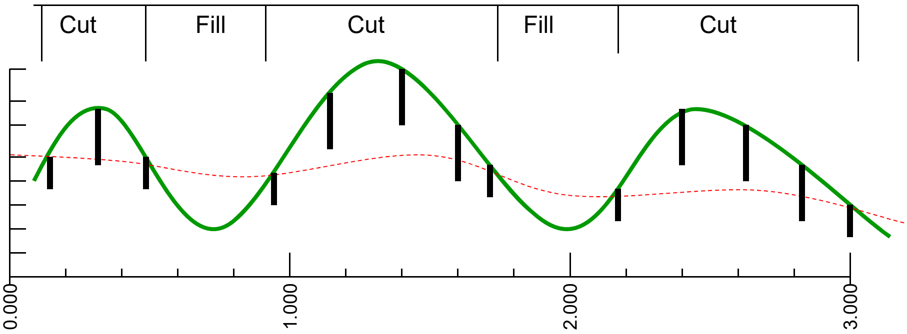
Overview of materials investigations

Investigations for construction of new roads

Trial pits - excavation, profiling & sampling



Position trial pits in the ***CUTS*** at roughly 200m intervals. Include additional trial pits at “prick’ of cut & fill. Aim to investigate to 1m below the gradeline or to max reach of the excavator

3

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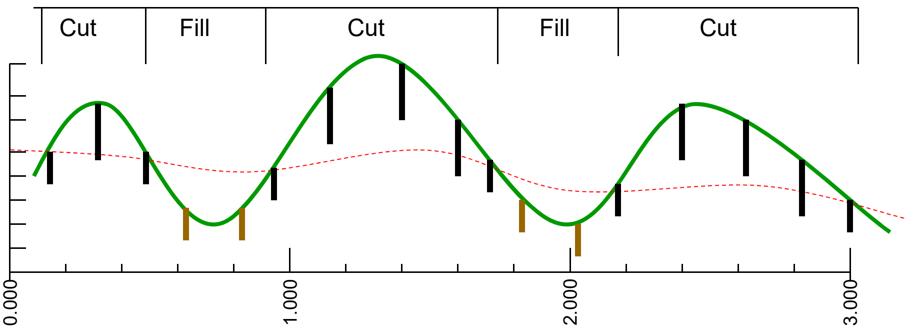
Overview of materials investigations

Investigations for construction of new roads

Trial pits - excavation, profiling & sampling



Position trial pits in the ***FILLS*** at roughly 200m intervals. Investigate to depth of 1m to 2m depending upon materials quality found in the trial pit

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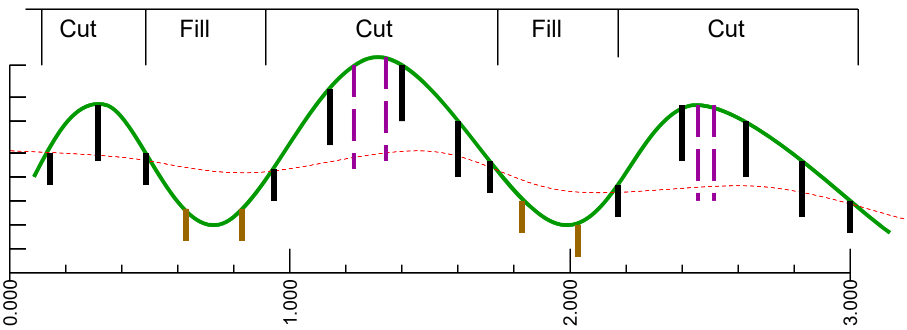
Investigations for construction of new roads

Deep cuts – seismic and core drilling



Consider deeper investigations in deep cuts beyond the reach of large excavators (± 5m) – seismic traverses, core drilling

Trial pits - excavation, profiling & sampling

Using a large, min 20 ton track-mounted excavator to excavate the trial pits

Profiling and sampling

Trial pits - excavation, profiling & sampling

Profiling

- Position a board showing the number and location of the trial pit
- Drop a broad measuring tape down the trial pit
- Take a photograph showing the full length of the profile – preferably use a SLR digital camera with a powerful remote flash

Sampling

- Generally take an Indicator sample from each soil horizon
- Take samples for moisture/density relationship and CBR tests on each different soils type – *USE YOUR DISCRETION*
- Consider whether the cut may be used to provide material for a stabilised layer – in this case take a larger sample so that stabiliser tests can be done in additional to the other tests

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Trial pits - excavation, profiling & sampling

M Moisture content

C Colour

C Consistency

S Structure

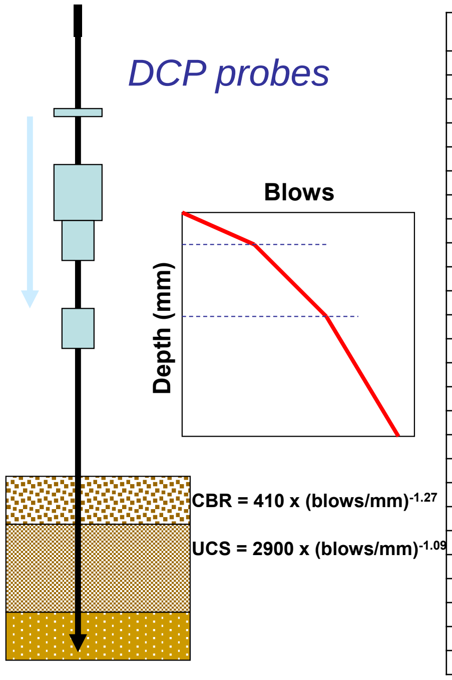
S Soil type

O Origin

8

8

Overview of materials investigations



$CBR = 410 \times (blows/mm)^{-1.27}$

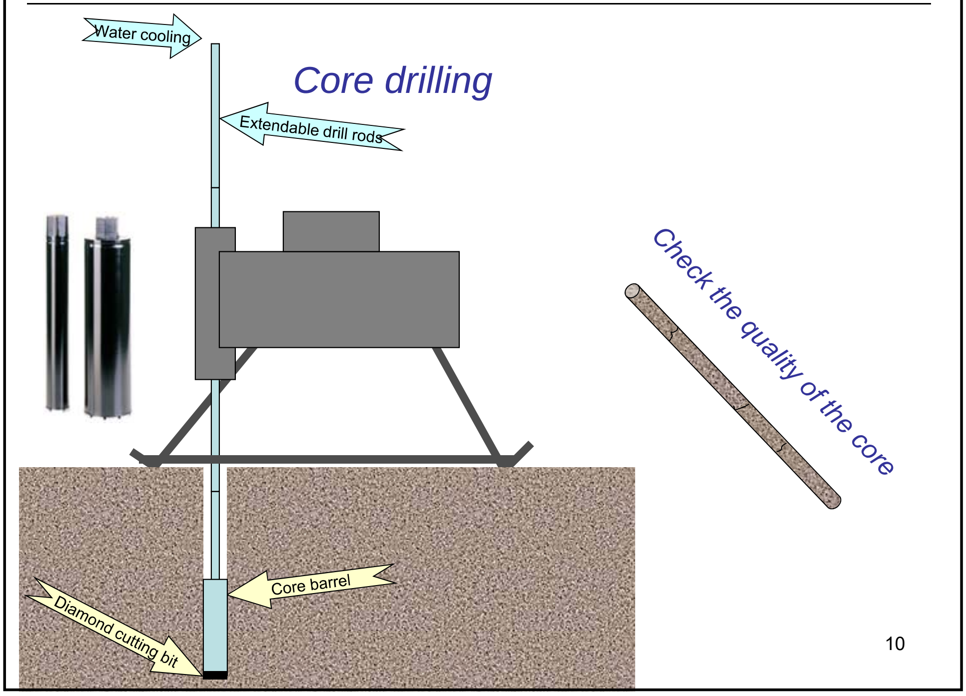
$UCS = 2900 \times (blows/mm)^{-1.09}$

60° Cone mm/blow	CBR (%)	Safe Bearing Pressure (KPa)	Recommended safe bearing pressure (kPa)
3	+50	+350	325
4	50	350	
5	40	300	
6	33	265	230
6	28	240	
7	25	225	
8	22	210	
9	20	200	175
10	18	190	
10	17	185	
11	16	180	
12	15	175	150
12	14	170	
13	13	165	
14	12	160	
15	11	155	
16	10	150	120
18	9	145	
20	8	140	
22	7	135	
26	6	130	100
30	5	125	
36	4	120	
48-56	3	115	
64-72	2	110	
80	1	105	

9

9

Overview of materials investigations



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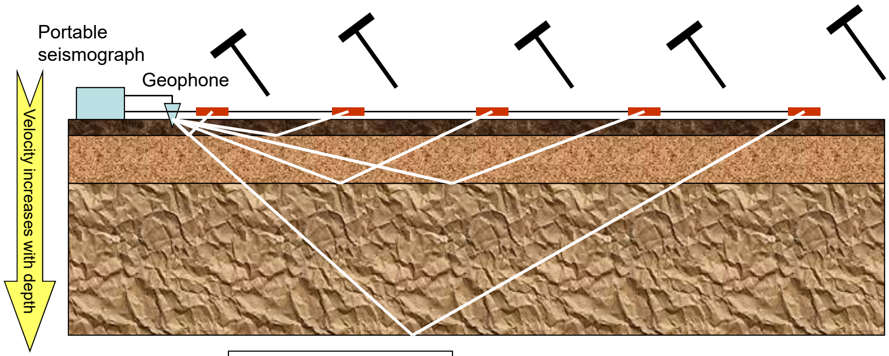
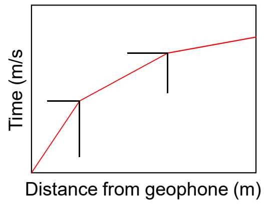
Overview of materials investigations

Seismic Traversing



Measures time taken for first arrival of the seismic wave



Calculate VELOCITY and LAYER THICKNESS

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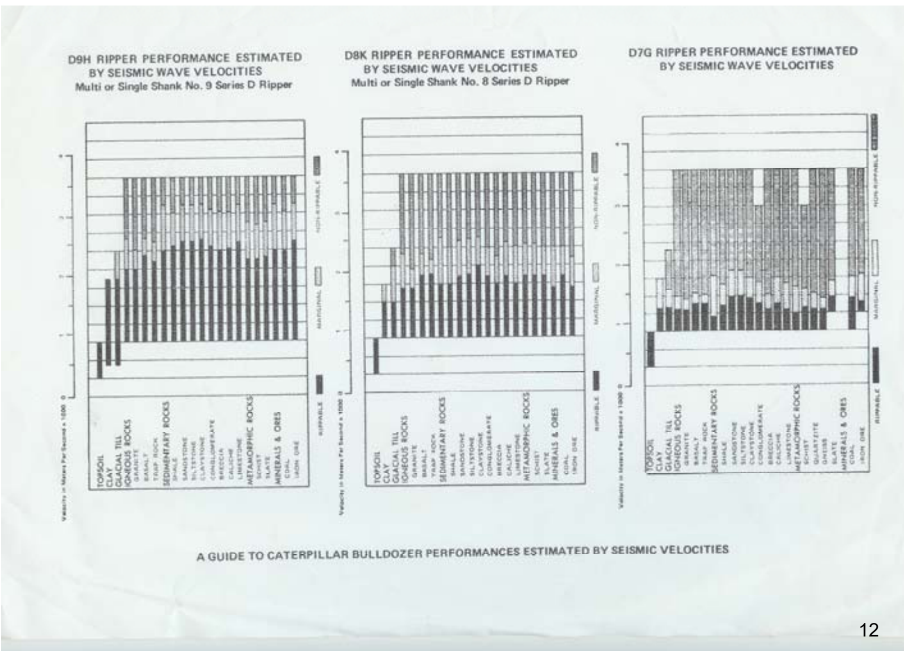
Overview of materials investigations



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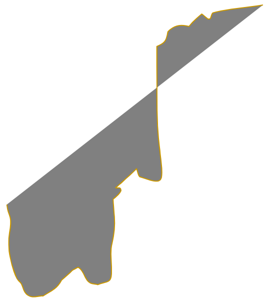
Borrowpit & Quarry Investigations

Borrowpits

Softer materials, limited blasting required. Remove material using excavators and dozers

Quarries



Hard material, rock. Usually required drilling and blasting before material can be removed

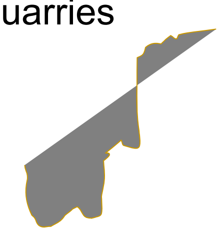
Borrowpit & Quarry Investigations

Borrowpits

Investigation tools

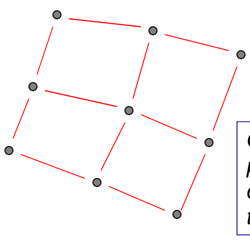
- trial pits
- seismic
- core drilling
- bulldozer slots

Quarries



Investigation tools

- seismic
- core drilling



Carry out the investigations in a grid pattern - the grid dimensions depend on quantity of material required and topography

Investigations for road rehabilitation

Investigation tools

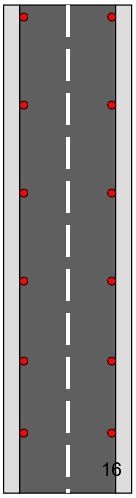
- *Visual inspection*
- *Trial pits*
- *Core samples*
- *DCP probes*
- *Field density measurements*
- *Deflection measurements*
- *Rut measurements*
- *Riding quality measurements*

Visual assessments

Valuable tool for assessing the type, severity and cause of pavement distress !

Take adequate traffic safety precautions – flags, cones, safety vests, flagmen

Use a measuring wheel to mark the road at 20m intervals on both sides



Visual assessments (TMH9)

MODE	TYPE	SEVERITY
Cracking	Crocodile Map Transverse Longitudinal	1 Least severe 2 3 4 5 Most severe
Deformation	Rutting Mounding	1 Least severe 2 3 4 5 Most severe
Surface disintegration	Potholing	1 Least severe 2 3 4 5 Most severe
Surface smoothing	Bleeding	1 Least severe 2 3 4 5 Most severe

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Crocodile Cracking

Map Cracking

Transverse Cracking

Longitudinal Cracking

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Overview of materials investigations

Rutting

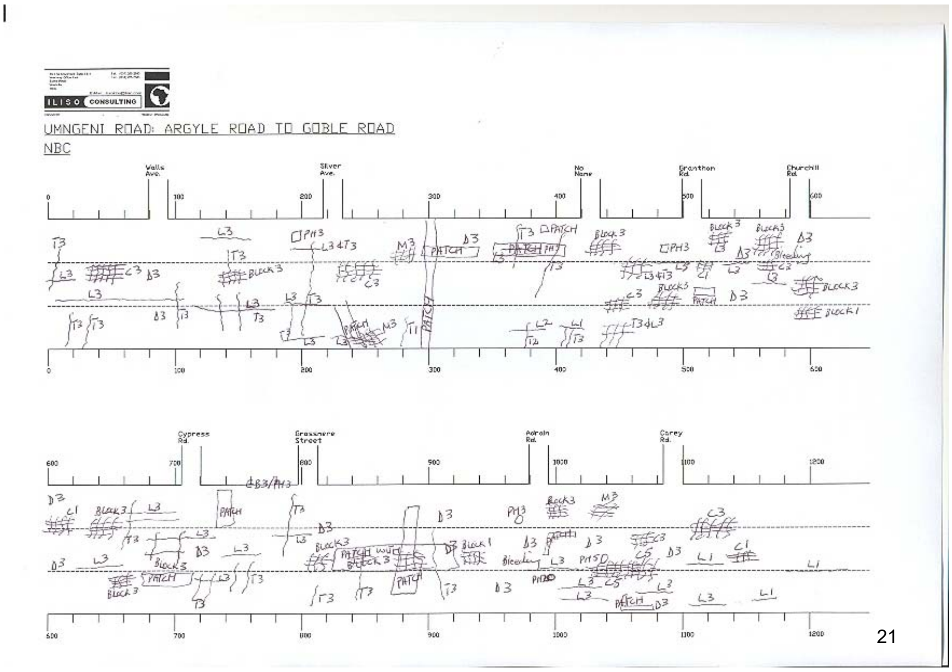
Mounding

Overview of materials investigations

Pot holing

Bleeding

Overview of materials investigations



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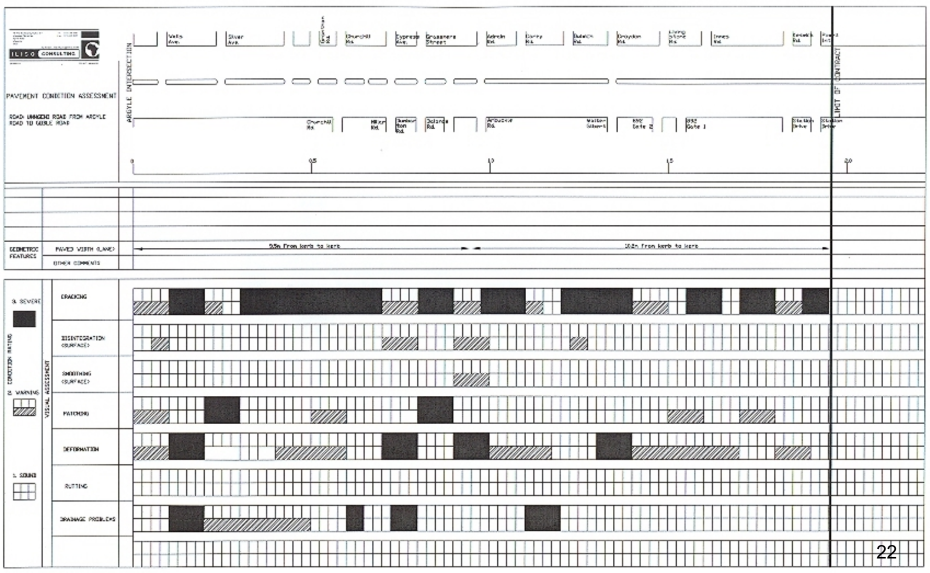
Overview of materials investigations



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Trial Pits

Trial pits provide accurate information on the thicknesses of the pavement layers, the moisture content and compaction of the layers

Trial pits should be excavated by hand using power tools so that the materials in the various layers, as well as layer thicknesses can be properly distinguished. The use of a TLB to excavate trial pits is NOT RECOMMENDED

Trial Pits

Trial pits are normally excavated to a depth of 1m. The detailed profile of the trial pit is then recorded, the various layers are demarcated using string, and a photograph is taken to show the full length of the profile

Trial Pits

Samples for Indicator and CBR tests are taken from material from each of the pavement layers.

The trial pit is then backfilled in layers not exceeding 150mm, with thorough compaction of each layer. Cold-mix asphalt is then laid as a surfacing.

Core samples

Coring machine and newly extracted core

Overview of materials investigations

Core samples

Cores provide an accurate means of checking layer thickness, and laboratory testing can be carried out to determine void content, bitumen content and grading

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Overview of materials investigations

Core samples

Thorough investigation using cores !

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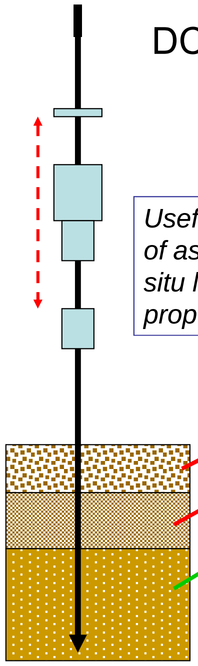
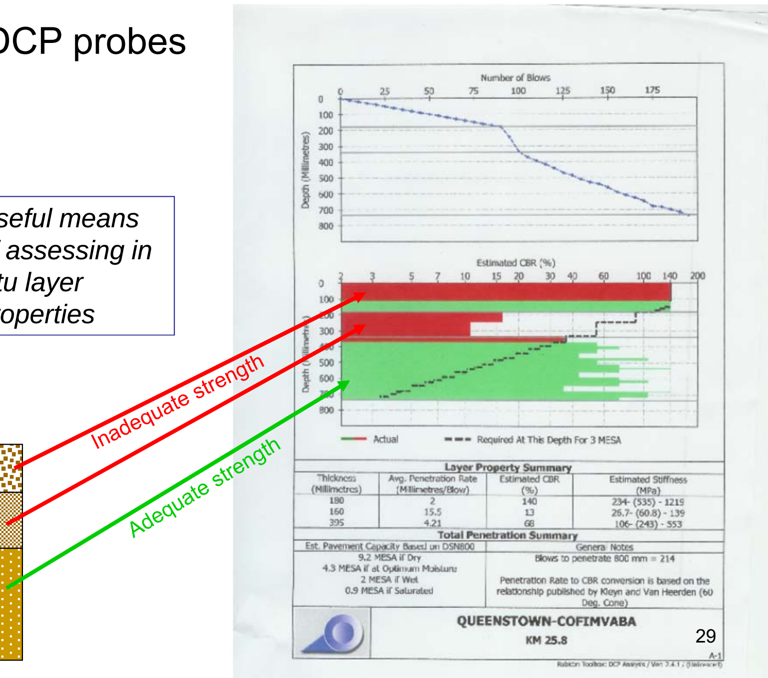
DCP probes



Useful means of assessing in situ layer properties



Layer Property Summary

Thickness (Millimetres)	Avg. Penetration Rate (Millimetres/Blow)	Estimated CBR (%)	Estimated Stiffness (MPa)
180	2	140	234- (535) - 1219
160	15.5	13	26.7- (60.8) - 139
395	4.21	68	106- (243) - 553

Total Penetration Summary

Est. Pavement Capacity Based on DSN800	General Notes
9.2 MESA if Dry 4.3 MESA if at Optimum Moisture 2 MESA if Wet 0.9 MESA if Saturated	Blows to penetrate 800 mm = 214 Penetration Rate to CBR conversion is based on the relationship published by Kleyn and Van Heerden (60 Deg. Cone)

QUEENSTOWN-COFIMVABA

KM 25.8

A-1

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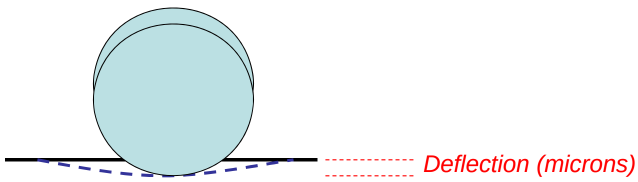
Deflection measurements

Methods:

- Benkelman Beam – maximum deflection
- La Croix Deflectograph – maximum deflection and deflection bowl
- Falling Weight Deflectometer (FWD) – max deflection and deflection bowl



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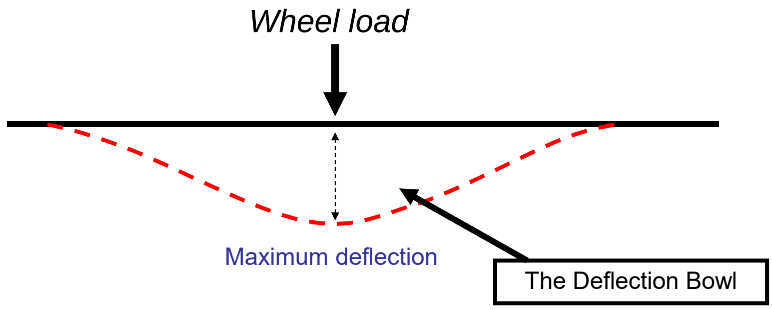
Overview of materials investigations

Deflection measurements



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Overview of materials investigations

Benkelman Beam

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Click Picture

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Overview of materials investigations

La Croix Deflectograph

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Click Picture

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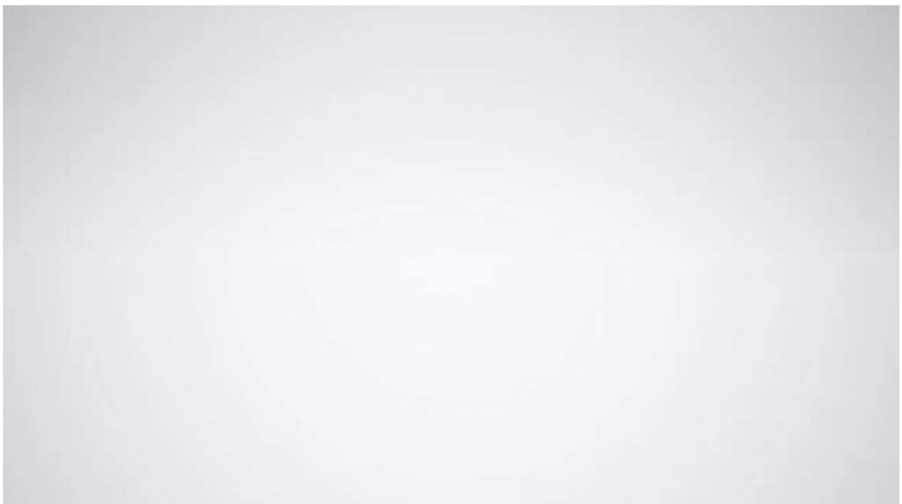
Overview of materials investigations

Falling Weight Deflectometer



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Click Picture

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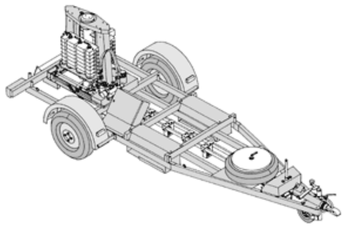
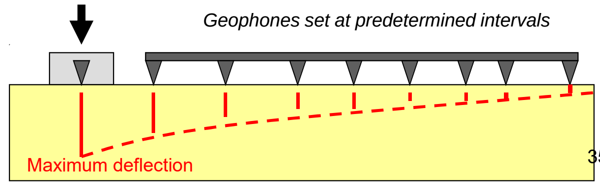
Deflection measurements

Falling weight deflectograph





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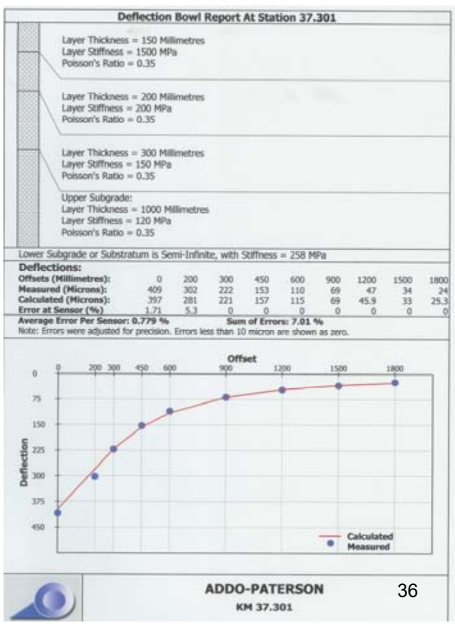
Deflection measurements

Deflection bowl analysis

The results of the deflection measurements can be processed to obtain the stiffness of the various layers in the pavement. This process is known as BACK CALCULATION

These results can then be used in a FORWARD CALCULATION process to estimate the structural design life of the pavement


Deflection Bowl Report At Station 37.301

Layer Thickness = 150 Millimetres
Layer Stiffness = 1500 MPa
Poisson's Ratio = 0.35

Layer Thickness = 200 Millimetres
Layer Stiffness = 200 MPa
Poisson's Ratio = 0.35

Layer Thickness = 300 Millimetres
Layer Stiffness = 150 MPa
Poisson's Ratio = 0.35

Upper Subgrade:
Layer Thickness = 1000 Millimetres
Layer Stiffness = 120 MPa
Poisson's Ratio = 0.35

Lower Subgrade or Substratum is Semi-Infinite, with Stiffness = 258 MPa

Deflections:

Offsets (Millimetres):	0	200	300	450	600	900	1200	1500	1800
Measured (Microns):	409	302	222	153	110	69	47	34	24
Calculated (Microns):	397	281	221	157	115	69	45.9	33	25.3
Error at Sensor (%)	1.71	5.3	0	0	0	0	0	0	0

Average Error Per Sensor: 0.779 % **Sum of Errors: 7.01 %**
Note: Errors were adjusted for precision. Errors less than 10 micron are shown as zero.

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Modern technology makes the job easy!

Laser bar takes rut depth measurements at frequent intervals

The road surface profiler enables rut depth and riding quality measurements to be taken along the project

A camera takes photos of the road in both directions at 10m intervals – the pavement condition can be reviewed in the office

Introduction to Road Materials Engineering

Part 7: Introduction to Rehabilitation

Presented by SARF

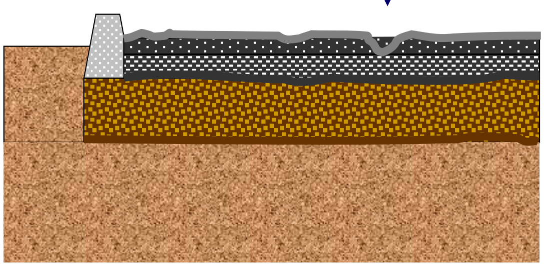
Presenter:
Ron Berkers

1

Overview of pavement rehabilitation methods

TYPICAL SEVERELY DISTRESSED PAVEMENT

Cracks, ruts and potholes



Two layers of asphalt – original and overlay

G5/G6 quality gravel base & subbase

G8 to G10 quality selected and subgrade

A variety of rehabilitation methods is available, the trick is to choose the most effective ! 2

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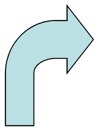
Full pavement reconstruction



Remove existing asphalt and base layers to spoil

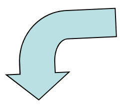
Compact and re-profile the selected/subgrade. Check for "heave", undercut and replace problem areas

Hope it doesn't rain !

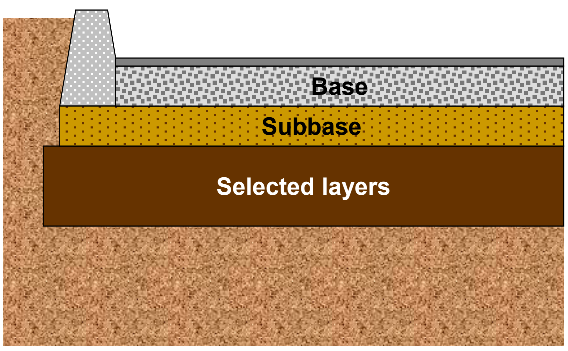
3

3

Full pavement reconstruction



Import new layerworks – tip, spread, profile, compact



Hope it doesn't rain !

4

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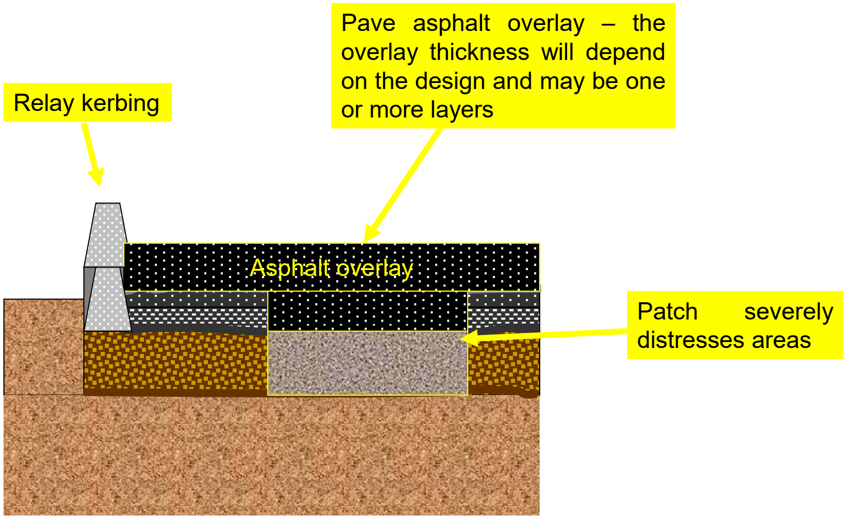
Mill-patch-overlay

Often it is necessary to mill out and patch badly cracked and rutted areas before paving the asphalt overlay



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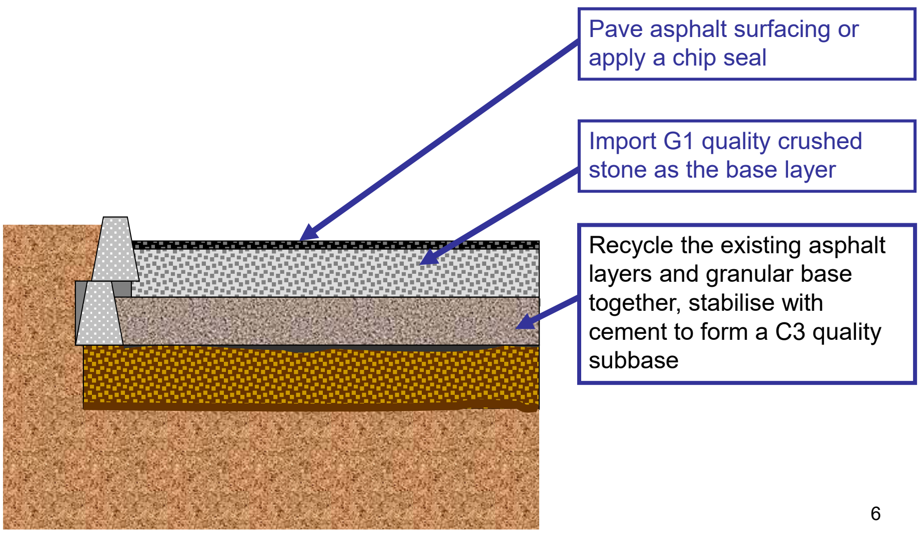
Crushed stone base overlay



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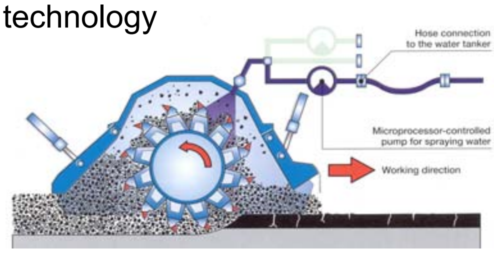
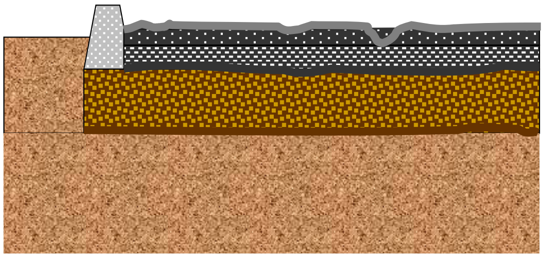
Cold in-place recycling technology

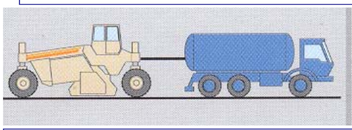
To recap:

Cold in-place recycling is carried out by specialised equipment that is capable of milling into strong road pavements





Water and liquid stabilising agents from the tanker pushed ahead of the recycler are injected into the recycler' s mixing chamber and are mixed together with the recycled material

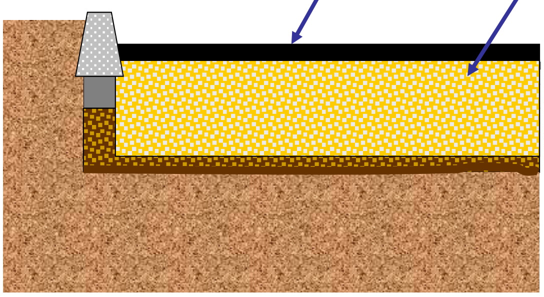


Stabilising agents include cement, bitumen emulsion or foamed bitumen

Cold in-place recycling technology

Apply chip seal for lightly trafficked roads and one or two layers of asphalt on more heavily trafficked roads.

Recycle the existing pavement using foamed bitumen or bitumen emulsion together with small percentage of cement (1% to 1.5%)



The maximum practical recycling depth is usually around 250 mm – difficult to achieve good compaction if recycled deeper

Cold in-place recycling technology

Click Picture

Choice of rehabilitation method

The cold in place recycling method is often the most effective in terms of price, speed of construction, and reducing traffic disruption.

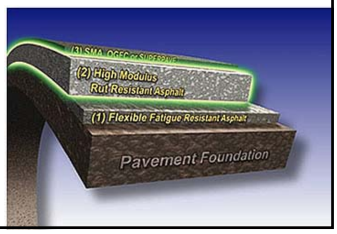
However it is not always the most suitable means of rehabilitation and the various other methods should also be carefully considered.

Introduction to Road Materials Engineering

Part 8: Introduction to Pavement Design

Presented by SARF

Presenter:
Ron Berkers



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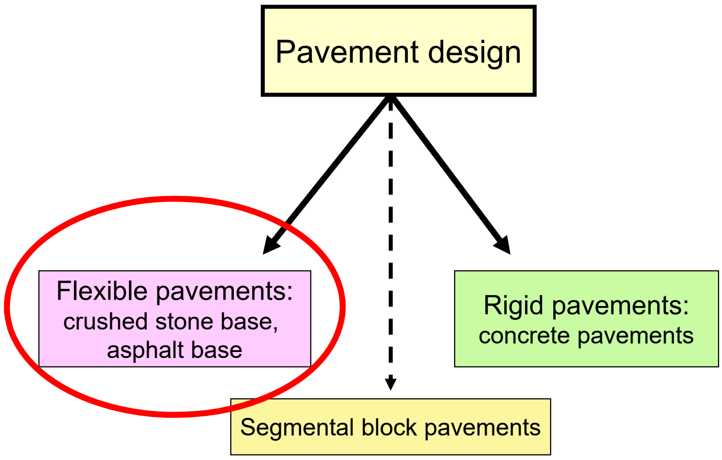
Basics of pavement design



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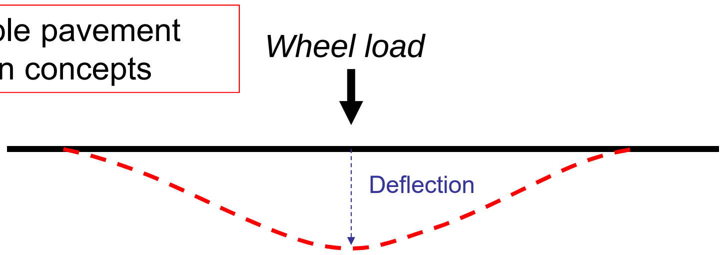
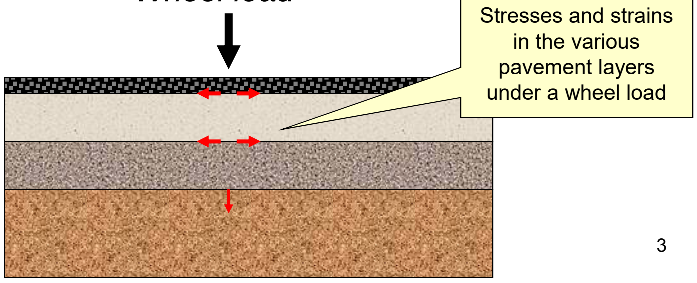
Basics of pavement design

Flexible pavement design concepts



Damage is caused by repetitive loading rather than a single load



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Basics of pavement design

What is the basis for the design of flexible road pavements ?

"The pavement must be capable of carrying the traffic in an acceptable condition for the required number of years without major strengthening being necessary"

Structural Design Period (SDP)

Structural design periods vary, depending upon the importance of the road:

Typically:

Major roads 25 years

Minor roads 15 years

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What is the basis for the design of flexible road pavements ?

"The pavement must be capable of carrying the traffic in an acceptable condition for the required number of years without major strengthening being necessary"

Design Traffic

Obtain traffic data which should include:

Average daily traffic counts

Percentage of heavies (estimate E80s per heavy)

Growth rate

Design traffic = ADT x 365 x %heavies x E80s per heavy x growth rate x SDP

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The standard axle load in South Africa is 80kN

Pavement bearing capacity is expressed in standard (80kN) axle repetitions – known as E80s

The pavement's design bearing capacity is expressed as the number of E80s it is capable of carrying

TRH4(1996) pavement classification

Pavement class*	Pavement design bearing capacity (million 80 kN axles/lane)	Volume and type of traffic**	
		Approximate v.p.d. per lane***	Description
ES0.003	< 0,003	< 3	Very lightly trafficked roads; very few heavy vehicles. These roads could include the transition from gravel to paved roads and may incorporate semi-permanent and / or all weather surfacings.
ES0.01	0,003 - 0,01	3 - 10	
ES0.03	0,01 - 0,03	10 - 20	
ES0.1	0,03 - 0,10	20 - 75	
ES0.3	0,10 - 0,30	75 - 220	
ES1	0,3 - 1	220 - 700	Lightly trafficked roads, mainly cars, light delivery and agriculture vehicles; very few heavy vehicles.
ES3	1 - 3	> 700	Medium volume of traffic; few heavy vehicles.
ES10	3 - 10	> 700****	High volume of traffic and / or many heavy vehicles.
ES30	10 - 30	> 2200****	Very high volume of traffic and / or a high proportion of fully laden heavy vehicles.
ES100	30 - 100	> 6500****	

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TABLE 1

Definition of the road categories

ROAD CATEGORY				
	A	B	C	D
Description	Major interurban freeways and major rural roads	Interurban collectors and rural roads	Lightly trafficked rural roads, strategic roads	Rural access roads
Importance Service level	Very important Very high level of service	Important High level of service	Less important Moderate level of service	Less important Moderate to low level of service
TYPICAL PAVEMENT CHARACTERISTICS				
RISK	**Very low**	**Low**	**Medium**	**High**
Approximate Design Reliability (%) *	95	90	80	50
Total Equivalent Traffic Loading (E80/lane) **	$3 - 100 \times 10^6$ over 20 years	$0,3 - 10 \times 10^6$ Depending on design strategy	$< 3 \times 10^6$ Depending on design strategy	$< 1 \times 10^6$ Depending on design strategy
Typical Pavement Class ***	ES10 - ES100	ES1 - ES10	ES0.003 - ES3	ES0.003 - ES1
Daily Traffic: (e.v.u) ****	> 4000	600 - 10 000	< 600	< 500

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Basics of pavement design

Typical TRH4 catalogue design sheet

GRANULAR BASES (WET REGIONS) DATE 1996

ROAD CAT.	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE) ES1 < 3000	ES2 $0,3\text{-}1,0 \times 10^4$	ES3 $1,0\text{-}3,0 \times 10^4$	ES4 $3,0\text{-}10 \times 10^4$	ES5 $0,1\text{-}0,3 \times 10^6$	ES6 $0,3\text{-}1,0 \times 10^6$	ES7 $1,0\text{-}3,0 \times 10^6$	ES8 $3,0\text{-}10 \times 10^6$	ES9 $10\text{-}30 \times 10^6$	ES10 $30\text{-}100 \times 10^6$	Foundation
A							30A 150 G1** 200 C3	40A 150 G1 300 C3 *(250 C3)	50A 150 G1 400 C3 *(300 C3)		
B						S 150 G2 150 C4 S 150 G2 200 G5	S/30A 150 G1** 200 C4	40A 150 G1 300 C4 *(250 C4)			150 G7 150 G9 G10
C				S 100 G5 125 C4 S 125 G4 125 G6	S 125 G5 125 C4 S 150 G4 150 G6	S 125 G2 150 C4 S 150 G2 150 G5	S 150 G2** 200 C4 S 150 G2 150 G4				
D	S1 100 G5 100 G7	S1 100 G5 125 G7	S1 100 G4 125 G7	S1 100 G4 125 G6 S1 100 G5 100 C4	S 125 G4 125 G6 S 100 G5 125 C4	S 150 G4 150 G6 S 125 G5 150 C4					150 G9 G10

8

8

What about non-standard pavement design, such as when designing pavements for rehabilitation?

Resort to using the South African Mechanistic Pavement Design Method

Use software such as Rubicon to carry out the various options to achieve the required structural capacity of the pavement

In any case, pavement design, whether using the TRH4 catalogues of other methods, requires consideration of a number of factors, some of which are:

- *local climatic conditions*
- *availability of materials in the vicinity of the project – crushed stone, asphalt*
- *local contractor's experience and capabilities*
- *Client's preferences*

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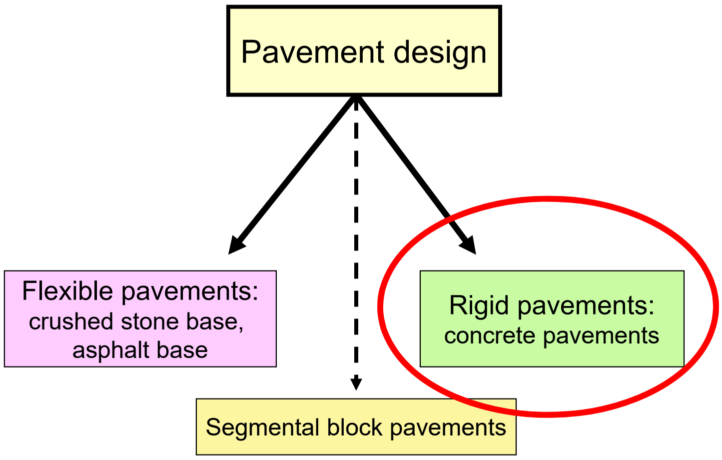
Basics of pavement design



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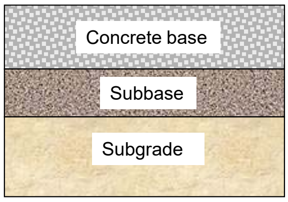
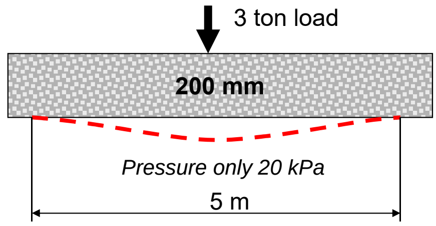
Concrete pavement design concepts



The concrete base can be un-reinforced, dowelled or reinforced



*Concrete pavements do **not require strong subgrades**, but the support should be **uniform***

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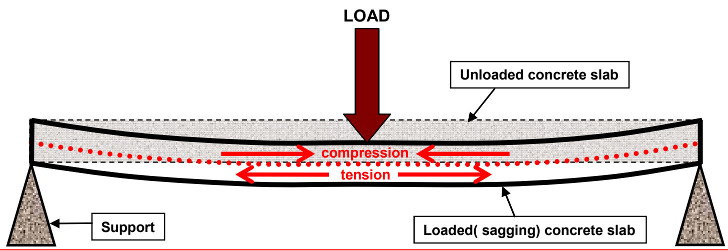
Concrete pavement design concepts



The flexural strength of the concrete becomes important in the design of a concrete pavement

cncPave is a useful pavement design program for concrete pavements

Typically a minimum 4.5 MPa flexural strength is required, while other requirements, such as minimum water/cement ratio and minimum cement content may be specified to ensure good durability as well as satisfactory strength

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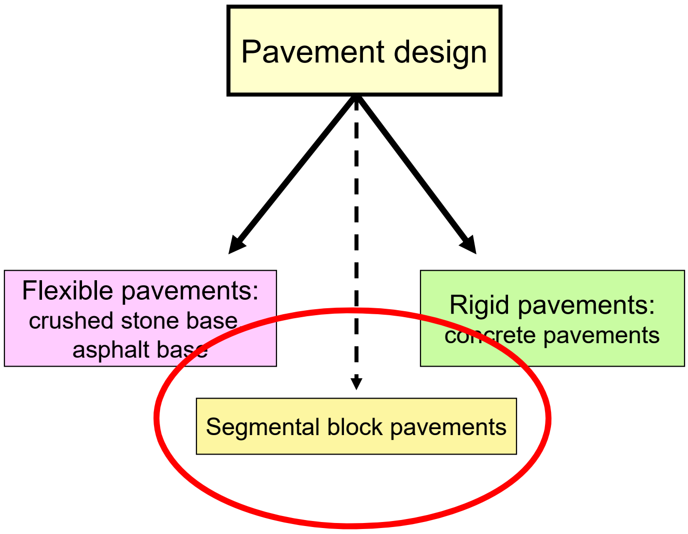
Basics of pavement design



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Basics of pavement design

Segmental block pavement design concepts

May be divided into 3 categories:

← **Architectural**

Industrial →

← **Roads**

14

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Segmental block pavement design concepts

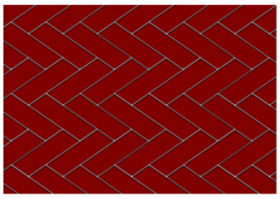
The easy way:

Segmental block pavement design concepts

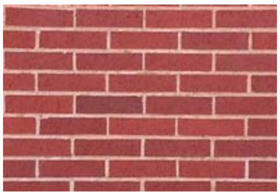
The design procedure is fairly similar to that for flexible pavements:

- *select structural design period*
- *estimate Design Traffic*
- *consider in situ material quality*
- *consider climatic region*
- *consider laying pattern – herringbone, stretcher bond*

Herringbone



Stretcher Bond



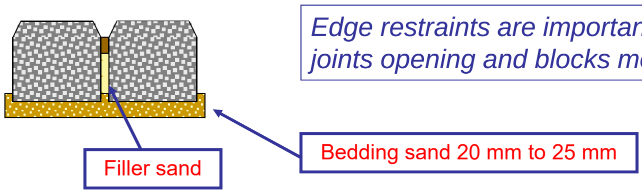
Segmental block pavement design concepts

Use guidelines in Draft UTG 2 1987 – somewhat dated but still useful

Lockpave is a user-friendly software program

Important practical aspects:

- block thickness – 60 mm or 80 mm
- block strength
- thickness and grading & quality of bedding sand
- grading and quality of filler sand



Edge restraints are important to prevent joints opening and blocks moving apart

Introduction to Road Materials Engineering

Part 9: Introduction to Concrete Technology

Presented by SARF

Presenter:
Ron Berkers

SARF
better roads

1

Basics of concrete technology

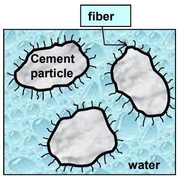
What is concrete ?

- Concrete has two main components – aggregates and paste.
- The aggregates consist of stone and sand – the paste consists of cement, water and some air.
- After mixing the concrete hardens to the required strength and durability.

2

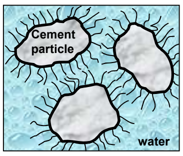
2

The Hydration Reaction



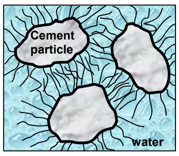
Stage 1

Stage 1:
Fibers start forming, but are still very short. The mix is still workable, i.e. it can be poured and formed very easily. This stage takes between 0 and 45 minutes after pouring has started.



Stage 2

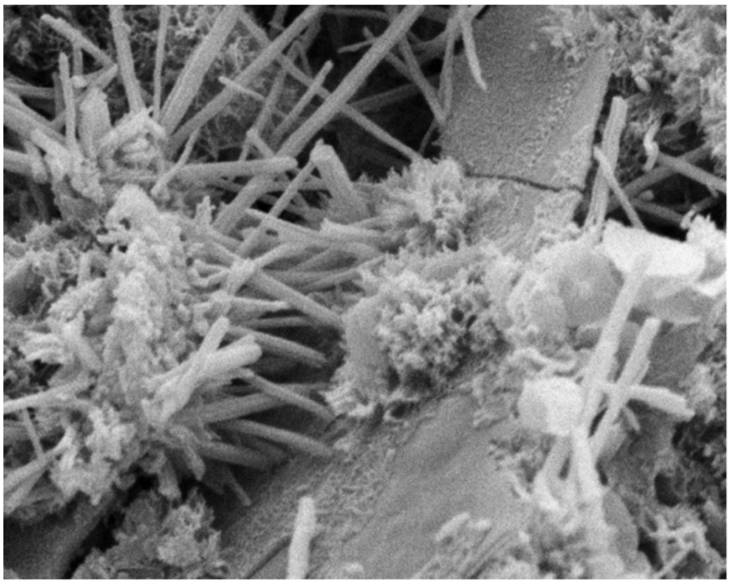
Stage 2:
The fibers are growing and are almost interlocking. The mix gets less workable. The duration of this stage is between 45 minutes and 2 hours after pouring of the concrete has started.



Stage 3

Stage 3:
The fibers are interlocking. Because of this the mix is not workable anymore and is setting. To reach this stage takes between 2 and 4 hours after the pouring of the concrete has started.

The Hydration Reaction



Cement in the mix – forms a "glue" which hardens to give strength

The strength of concrete depends primarily on the water/cement ratio.

If additional water is added to a concrete mix, the "glue" is diluted thus reducing the strength

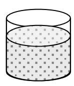
The water/cement ratio also determines the durability, impermeability and abrasion resistance of concrete

After setting the concrete hardens and continues to gain in strength due to a process know as hydration

If the concrete is allowed to dry out it will not continue to gain in strength – therefore proper curing is very important

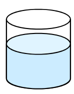
NOTE: Some authorities use CEMENT/WATER RATIO while others use WATER/CEMENT RATIO

CEMENT/WATER RATIO (C/W)



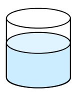
170kg cement

C/W = 170/100 = 1.7



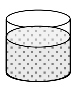
100kg water

WATER/CEMENT RATIO (W/C)



100kg water

W/C = 100/170 = 0.59



170kg cement

Typical W:C Ratio's

Type of concrete	Water:cement ratio
High performance concrete	0,25 – 0,40
Conventional concrete	0,45 – 0,80
Sand-cement floor screeds	0,55 – 0,60
Bedding mortar for masonry; cement plaster	1,00 – 1,15

Stone in the mix – provides bulk and stability to the mix

The most economical mix is one that has the highest proportions of aggregate to paste and yet has the required workability .

High stone content = reduced workability

The quantity of stone that can be used in a mix depends on the average particle size of the sand. The finer the sand the more stone can be accommodated in the mix.

Large stone is more economical than small stone in a concrete mix

Sand in the mix – used as a void filler, also reduces friction (harshness) between the stone particles

Round or cubical sand particles produces smooth flowing mixes with good workability. Flat, flaky particles produce a harsh mix with poor workability.

The grading of the sand is important to the concrete's workability, particularly the smaller sieve sizes.

Main components of Portland Cement

Portland Cement is the basis for all our commonly used cements and consists of limestone and shale which is blended in specific proportions and fired at high temperatures to form clinker. A small amount of gypsum is added to the cooled clinker, it is then ground to a fine powder

Cement extenders and fillers

These materials are added to Portland Cement to effect cost savings and improve some properties such as durability and impermeability

- *Ground granulated blast furnace slag (GGBS)*
- *Fly ash (FA)*
- *Condensed silica fume (CSF)*
- *Limestone filler*

	Effect	
Extender	**Fresh Concrete**	**Hardened Concrete**
GGBS	• Improves workability slightly • Retards setting slightly	• Slows development of strength • Increases later age strength • Reduced permeability • Increases rate of carbonization • Reduced generation of heat during cementing reaction
FA	• Improves workability • Reduces water requirements for given slump • Retards setting slightly	• Slightly reduces rate of strength development • Increases later age strength • Reduces permeability • Improves sulphate resistance • Reduced generation of heat during cementing reaction
CSF	• Reduces workability • Increases cohesiveness • Reduces bleeding significantly	• Increases strength • Reduces permeability

Admixtures are commonly used to enhance the properties of concrete

Air-entrainers

Improve workability of harsh mixes, reduce bleeding. Must be carefully controlled as overdosing will reduce concrete strength

Plasticizers & Superplasticizers

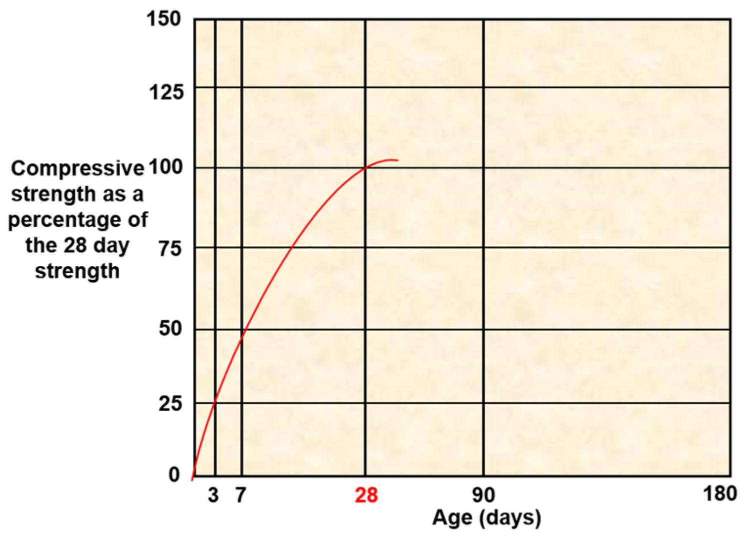
Improve workability of harsh mixes, better flowability, pumping qualities

Retarders

Retard reaction of the cement – stiffens slowly. Useful in hot weather, readymix. Careful dosage rates necessary

Accelerators

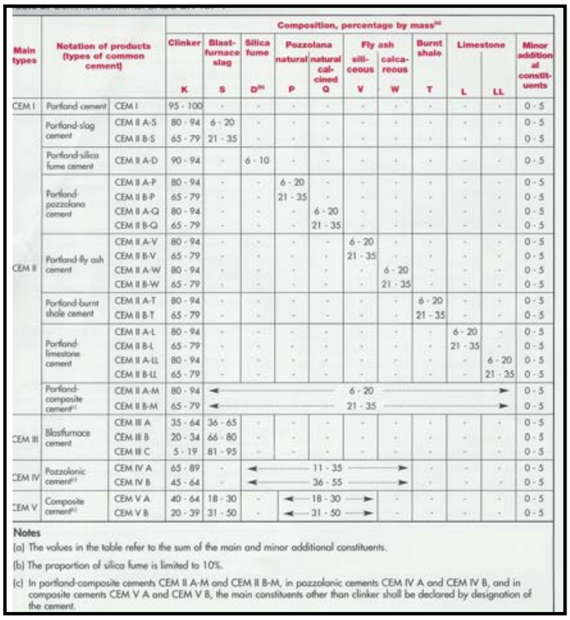
Cause rapid reaction with cement and reduce setting time and accelerated early strength. Used in cold weather. Beware increased drying shrinkage



Compressive strength requirements of SABS EN 197-1

Strength class	Compressive strength, MPa			
	Early strength		Standard strength	
	2 days	7 days	28 days	
32,5N	-	≥ 16,0	≥ 32,5	≤ 52,5
32,5R	≥ 10,0	-		
42,5N	≥ 10,0	-	≥ 42,5	≤ 62,5
42,5R	≥ 20,0	-		
52,5N	≥ 20,0	-	≥ 52,5	-
52,5R	≥ 30,0	-		

Composition of cement types



Main types	Notation of products (types of common cement)		Clinker K	Blast-furnace slag S	Silica fume D[b]	Pozzolana natural P	Pozzolana natural calcined Q	Fly ash siliceous V	Fly ash calcareous W	Burnt shale T	Limestone L	Limestone LL	Minor additional constituents
CEM I	Portland cement	CEM I	95 - 100	-	-	-	-	-	-	-	-	-	0 - 5
CEM II	Portland-slag cement	CEM II A-S	80 - 94	6 - 20	-	-	-	-	-	-	-	-	0 - 5
		CEM II B-S	65 - 79	21 - 35	-	-	-	-	-	-	-	-	0 - 5
	Portland-silica fume cement	CEM II A-D	90 - 94	-	6 - 10	-	-	-	-	-	-	-	0 - 5
	Portland-pozzolana cement	CEM II A-P	80 - 94	-	-	6 - 20	-	-	-	-	-	-	0 - 5
		CEM II B-P	65 - 79	-	-	21 - 35	-	-	-	-	-	-	0 - 5
		CEM II A-Q	80 - 94	-	-	-	6 - 20	-	-	-	-	-	0 - 5
		CEM II B-Q	65 - 79	-	-	-	21 - 35	-	-	-	-	-	0 - 5
	Portland-fly ash cement	CEM II A-V	80 - 94	-	-	-	-	6 - 20	-	-	-	-	0 - 5
		CEM II B-V	65 - 79	-	-	-	-	21 - 35	-	-	-	-	0 - 5
		CEM II A-W	80 - 94	-	-	-	-	-	6 - 20	-	-	-	0 - 5
		CEM II B-W	65 - 79	-	-	-	-	-	21 - 35	-	-	-	0 - 5
	Portland-burnt shale cement	CEM II A-T	80 - 94	-	-	-	-	-	-	6 - 20	-	-	0 - 5
		CEM II B-T	65 - 79	-	-	-	-	-	-	21 - 35	-	-	0 - 5
	Portland-limestone cement	CEM II A-L	80 - 94	-	-	-	-	-	-	-	6 - 20	-	0 - 5
		CEM II B-L	65 - 79	-	-	-	-	-	-	-	21 - 35	-	0 - 5
		CEM II A-LL	80 - 94	-	-	-	-	-	-	-	-	6 - 20	0 - 5
		CEM II B-LL	65 - 79	-	-	-	-	-	-	-	-	21 - 35	0 - 5
	Portland-composite cement[c]	CEM II A-M	80 - 94	← 6 - 20 →									0 - 5
		CEM II B-M	65 - 79	← 21 - 35 →									0 - 5
CEM III	Blastfurnace cement	CEM III A	35 - 64	36 - 65	-	-	-	-	-	-	-	-	0 - 5
		CEM III B	20 - 34	66 - 80	-	-	-	-	-	-	-	-	0 - 5
		CEM III C	5 - 19	81 - 95	-	-	-	-	-	-	-	-	0 - 5
CEM IV	Pozzolanic cement[c]	CEM IV A	65 - 89	-	← 11 - 35 →					-	-	-	0 - 5
		CEM IV B	45 - 64	-	← 36 - 55 →					-	-	-	0 - 5
CEM V	Composite cement[c]	CEM V A	40 - 64	18 - 30	-	← 18 - 30 →			-	-	-	-	0 - 5
		CEM V B	20 - 39	31 - 50	-	← 31 - 50 →			-	-	-	-	0 - 5

Notes

(a) The values in the table refer to the sum of the main and minor additional constituents.

(b) The proportion of silica fume is limited to 10%.

(c) In portland-composite cements CEM II A-M and CEM II B-M, in pozzolanic cements CEM IV A and CEM IV B, and in composite cements CEM V A and CEM V B, the main constituents other than clinker shall be declared by designation of the cement.

15

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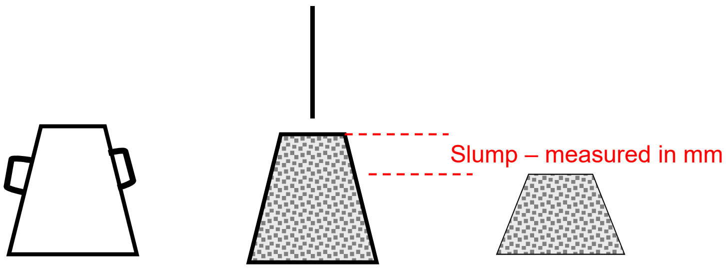
Slump Test



Slump cone

Filled with fresh concrete in layers.

Each layer is compacted using a steel rod

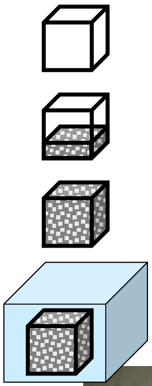
Slump measured as difference in height from top of cone to top of concrete

16

16

Compressive strength of concrete

Basic steps in making, curing & compressive strength testing of concrete cubes

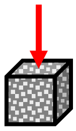


Make cubes immediately after the concrete has been mixed

Fill the mould in 50mm layers, compacting each layer with the standard tamping bar or on a vibrating table

Finish off the top surface using a trowel

Store the cube, in the mould, in moist, humid air at 22 to 25°C for 24 hours, remove the mould, cure in water at a temperature of 22 to 25°C Compressive strength is usually specified at 28 days, but cubes may be tested at 7 or 14 days



The cube is placed in the press and the load at which it fails is recorded

17

17

18

Click Picture

18

Introduction to Road Materials Engineering

Part 10: Introduction to Rehab Methods

Presented by SARF

Presenter:
Ron Berkers

1

Jobsite reports – rehabilitation using in place recycling

Typical urban pavement rehabilitation project

2

2

Jobsite reports – rehabilitation using in place recycling

Cement is spread on top of the existing pavement. The recycler pushes a tanker filled with hot bitumen.

During the recycling process the traffic is accommodated on one side of the street.

3

3

Jobsite reports – rehabilitation using in place recycling

Once compaction of the recycled layer is complete, the street can be opened to traffic

4

4

Jobsite reports – rehabilitation using in place recycling

The surface of the recycled layer is tacked using dilute bitumen emulsion and an asphalt wearing course is then paved on top.

5

5

Jobsite reports – rehabilitation using in place recycling

The strengthened pavement is reopened to traffic

6

6

Improvement of lightly trafficked rural roads

The existing gravel road is recycled to a depth of 120 mm using foamed bitumen or bitumen emulsion. A sand seal is applied as a surface treatment.

7

The upgrading of 386 km of gravel track to a new oil field in the Arabian desert using foamed bitumen and cement. A slurry seal was used as a surfacing. The design team and site staff included several South Africans.

The project was completed in the required 6 months!

8

Recycling with bitumen emulsion in China

The recycler pushes two tankers, the first filled with bitumen emulsion and the second with water.

Crushed stone is spread onto the surface of the existing pavement to improve the grading of the recycled layer

9

9

Jobsite reports – rehabilitation using in place recycling

The completed recycled layer. This will be surfaced with hot-mixed asphalt

10

10

Jobsite reports – rehabilitation using in place recycling

The recycling on this project in China is carried out using a track-mounted recycler

11

11

Jobsite reports – rehabilitation using in place recycling

Recycling with foamed bitumen in Malaysia

The track-mounted recycler pushes a tanker filled with hot bitumen

12

12

Jobsite reports – rehabilitation using in place recycling

The recycled layer is compacted using a large vibratory roller as well as a rubber tyred roller

13

13

Jobsite reports – rehabilitation using in place recycling

Completed recycled layer – it will be surfaced with hot-mixed asphalt

14

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Recycling sections of Old South Coast Road, Durban

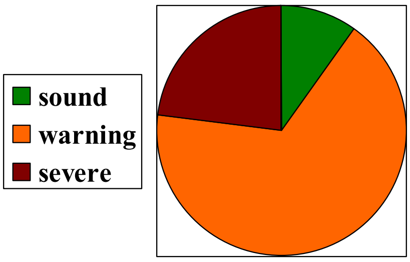
Length 2.3km

Width 2 to 4 traffic lanes

Traffic 6 000 AADT

10% heavies

Pavement condition



Extent of surface cracking

- sound 10%
- warning 67%
- severe 23%

Jobsite reports – rehabilitation using in place recycling

Condition of the existing pavement showing extensive cracking

17

17

Jobsite reports – rehabilitation using in place recycling

Information obtained from the trial pits

SOILCO MATERIALS INVESTIGATIONS (PTY) LTD
CIVIL ENGINEERING MATERIALS TESTING LABORATORY

Client Iliso Consulting Engineers
Project Old Main Road - Isipingo

PHOTOGRAPHS

Test Pit 6 - Km. 0.595

Test Pit 6 - Km. 0.595

SOILCO MATERIALS INVESTIGATIONS (PTY) LTD
CIVIL ENGINEERING MATERIALS TESTING LABORATORY

Client	Iliso Consulting Engineers
Project	Old Main Road Isipingo
Job Card No.	110846
Date of Test	2005-12-05
Field Technician	J.Venter / M.Ndevu
Position	Km 0.595
Test Pit Number	6
Chainage	
Diameter of TP	1000 x 800

FIELD SOIL SURVEY TEST REPORT

Water Table	Soil Legend	Depth (mm)	DESCRIPTION Moisture; Colour; Consistency; Structure; Soil Type; Origin; Sampling; Laboratory Testing abbreviations (I = Ind; M = MOD; C = CBR);
		110	Asphalt (Dry, brittle and cracked) 2 to 3 layers
		240	Slightly moist, dusky blue and light brown, dense, crushed TILLITE and shale gravel Lab No. 3196
		310	Slightly moist, dark olive and dark yellowish orange, dense, weathered SHALE gravel Lab No. 3197
		600	Slightly moist, dusky blue and dark olive, dense, weathered SHALE gravel Lab No. 3198
		1000	Moist to very moist, dark brown, medium dense, silty and clayey SAND Lab No. 3199

The above test report is pertinent only to the area tested. This report shall not be reproduced, except in full, without the prior consent of SOILCO MATERIALS INVESTIGATIONS (PTY) LTD.

Remarks :

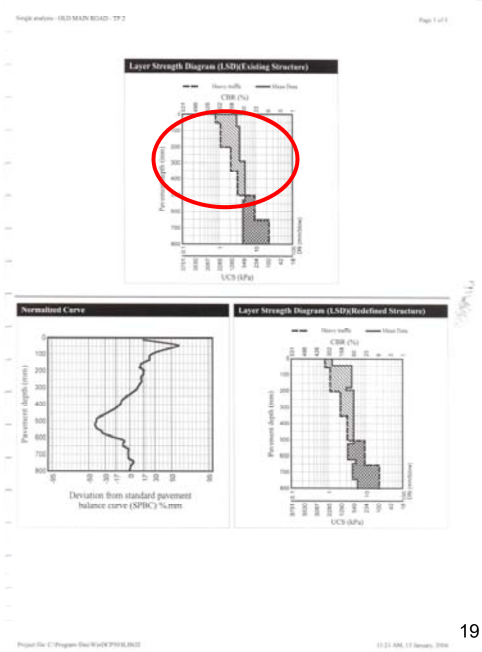
For Soilco :

18

18

Jobsite reports – rehabilitation using in place recycling

The DCP probes showed inadequate strength in the upper pavement layers



19

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Jobsite reports – rehabilitation using in place recycling

Asphalt test results

TESTPIT No.	4	5	7
BITUMEN CONTENT (%)	4.6	4.2	4.8
PENETRATION (1/10mm)	4	2	7

- *Low penetration values*
- *Brittle asphalt prone to cracking*

20

20

REHABILITATION OPTIONS

- ~~RECONSTRUCT PAVEMENT LAYERS~~

  Traffic disruption problems!

- ~~MILL & PATCH, OVERLAY~~

  Cracking too extensive

- RECYCLE PAVEMENT

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21

Jobsite reports – rehabilitation using in place recycling

Pavement design

Existing pavement

80 to 140mm asphalt

120 to 180mm crushed stone

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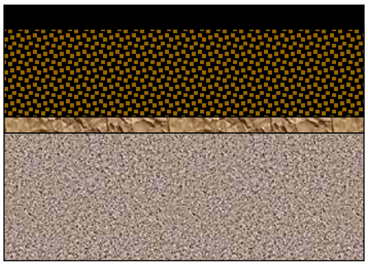
Pavement design

Recycled pavement

50mm modified AC



Recycle 225mm with 2.5% to 3% foamed bitumen and 1.5% cement

The asphalt and base in the existing pavement is recycled to a depth of 225 mm

Cement is spread onto the surface of the existing pavement. The recycler pushes two tanker, one with hot bitumen and the other with water

The recycled layer is compacted using a large vibrating roller

Jobsite reports – rehabilitation using in place recycling

The partially compacted recycled layer is profiled using a motor grader and is then finally compacted

The recycled layer is opened to traffic once it has been fully compacted

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Jobsite reports – rehabilitation using in place recycling

A diluted bitumen emulsion tack coat is applied and is surfaced using hot-mixed asphalt

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Jobsite reports – rehabilitation using in place recycling

Before and after photos….

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Jobsite reports – rehabilitation using in place recycling

Before and after photos….

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Rehabilitation of Main Street, Maclear, Eastern Cape

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After investigating the existing pavement it was decided to recycle the existing pavement to a depth 200 mm using 3% foamed bitumen and 1,5% hydrated lime

30

30

Jobsite reports – rehabilitation using in place recycling

Bags of hydrated lime being placed at the required spacing to achieve a stabiliser content of 1.5%

31

31

Jobsite reports – rehabilitation using in place recycling

The recycler pushes two tankers, the first containing hot bitumen and the second with water

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Jobsite reports – rehabilitation using in place recycling

A large vibrating roller compacted the newly recycled layer

33

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Jobsite reports – rehabilitation using in place recycling

A motor grader shapes the partially compacted recycled layer

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Jobsite reports – rehabilitation using in place recycling

Once the road has been profiled using the motor grader the compaction of the recycled layer is completed. A tack coat of dilute emulsion is then sprayed onto the surface

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Jobsite reports – rehabilitation using in place recycling

The 40 mm asphalt surfacing is then paved

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Jobsite reports – rehabilitation using in plant recycling

Rehabilitation of Newland East Access Road, Durban

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Jobsite reports – rehabilitation using in plant recycling

Details of the mixing plant, showing milled asphalt (RAP) being tipped into the feed bin. A bitumen tanker supplies hot bitumen while the storage silo provides cement. The mixed material is transferred via a conveyor onto the tip truck

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Jobsite reports – rehabilitation using in plant recycling

The cold bituminous mix is paved using a conventional asphalt paver and is compacted using vibratory and rubber tyred rollers

39

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Jobsite reports – rehabilitation using in plant recycling

Once compaction is complete the surface looks very similar to hot-mix

40

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Jobsite reports – rehabilitation using in plant recycling

An asphalt surfacing is paved over the cold in plant recycled asphalt layer

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Jobsite reports – rehabilitation using asphalt inlay

The rehabilitation of a portion of Umgeni Road, Durban

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Jobsite reports – rehabilitation using asphalt inlay

Cracks, but very little rutting

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Jobsite reports – rehabilitation using asphalt inlay

Centre island, channel, and sidewalks in poor condition

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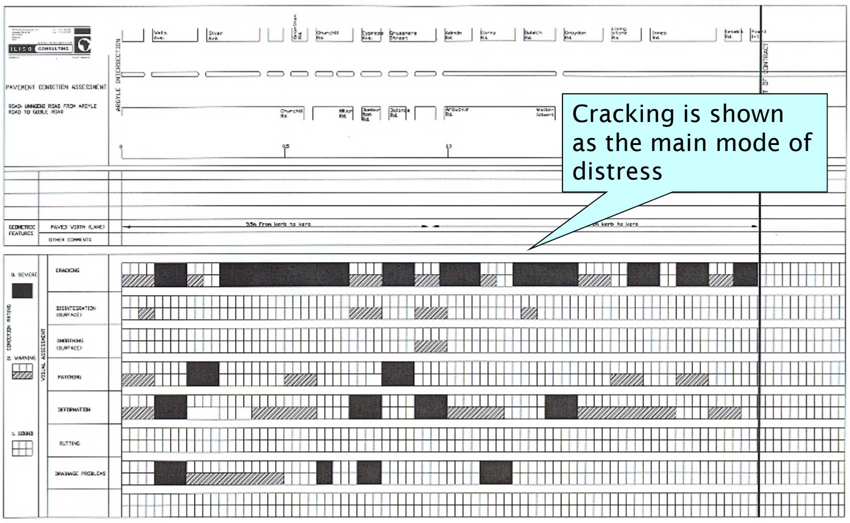
The detailed visual inspection is carried out by first marking the road at 20m intervals. The type, frequency and severity of different types of distress are recorded in each 20m segment

Note marks on edge of pavement at 20m intervals on each carriageway

45

45

Summary of detailed visual inspection



Cracking is shown as the main mode of distress

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Jobsite reports – rehabilitation using asphalt inlay

Sites for trial pits are selected, and the crack pattern is marked with chalk and photographed before the trial pits are excavated

47

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Jobsite reports – rehabilitation using asphalt inlay

As the trial pit is excavated, the materials from the various layers found in the trial pit are stockpiled separately next to the pit. Once the excavation is complete the trial pit is carefully profiled

Note how the materials from the different layers are stockpiled separately

48

48

The various pavement layers are demarcated with string and their thickness is measured and recorded

Note the base consists of large pieces of hand-placed rock

This method of construction was popular many years ago, and is known as Telford base

49

Core samples are taken at frequent intervals to assess the thickness and condition of the existing asphalt layers

50

Jobsite reports – rehabilitation using asphalt inlay

The thickness of the asphalt layers along as well as across the carriageways is measured

A concrete pavement was found under the asphalt over a short section of the road

Note the large differences in asphalt mixes and thicknesses

51

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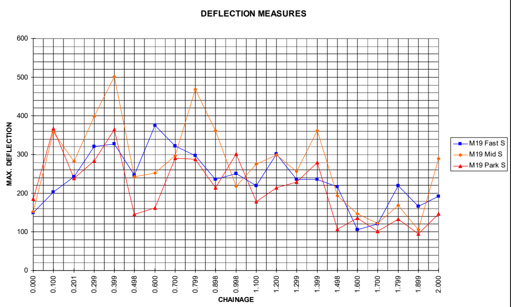
Jobsite reports – rehabilitation using asphalt inlay

Deflection measurements are taken using a falling weight deflectometer



52

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ESTIMATION OF DESIGN TRAFFIC

Position	10 year structural design life E80s x 10^6	20 year structural design life E80s x 10^6
Churchill Road Intersection	8.8	23.2
Arbuckle Road Intersection	8.2	21.5
Walter Gilbert Intersection	8.4	22.2
Innes Road Intersection	8.5	22.4
Goble Road Intersection	7.2	18.8

PAVEMENT CLASS

ES10 for 10 YEAR SDP

ES30 for 20 year SDP

REHABILITATION OPTIONS

1. RECONSTRUCT PAVEMENT LAYERS

2. OVERLAY EXISTING PAVEMENT

3. RECYCLE MATERIAL IN EXISTING PAVEMENT

1. RECONSTRUCT PAVEMENT LAYERS

Huge implications with accommodating heavy traffic and entry into business premises

55

55

2. OVERLAY EXISTING PAVEMENT

Requires extensive reconstruction of drainage, sidewalks and entrances

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Large hand-placed Telford base makes recycling impractical

57

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Most practical solution:

- *Partially mill off existing asphalt*

Existing asphalt layers

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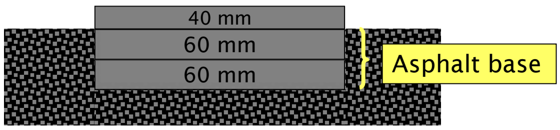
Most practical solution:

- *Partially mill off existing asphalt*
- *Replace with modified asphalt base and surfacing*



Existing asphalt layers

Modified asphalt mixes have to be considered in this case, as the asphalt thickness has to be minimized as far as possible, due to level constraints

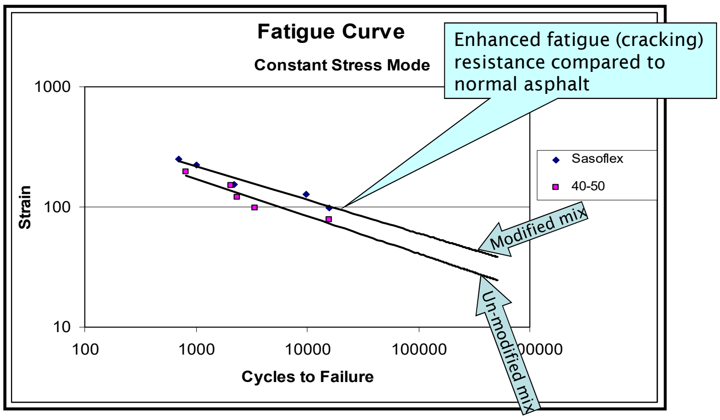
MODIFIED ASPHALT MIXES

Modified asphalt mixes are made using polymer or wax additives. These mixes have better rut and cracking resistance properties compared to normal asphalt. This enables layer thickness to be reduced in relation to unmodified asphalt – a significant benefit where the surface levels are constrained, as on this project

Specialised testing is carried out to assess the enhanced engineering properties of the modified asphalt mixes

Jobsite reports – rehabilitation using asphalt inlay

ASPHALT BASE



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Jobsite reports – rehabilitation using asphalt inlay

Milling out 120 mm of the existing asphalt

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Mostly night work…….

63

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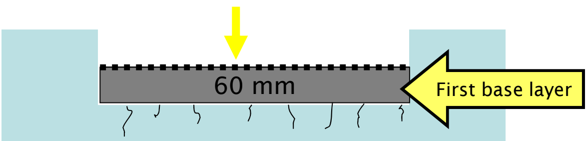
Where severe cracking was found after milling out the 120 mm of asphalt, the areas were carefully demarcated, and a geogrid was installed between the two asphalt base layers



The geogrid is installed to retard the reflection of cracks through the new base and surfacing layers

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64

Once the asphalt work has been completed the centre island is reconstructed and repairs are carried out to the sidewalks and channels

The completed project….

Introduction to Road Materials Engineering

Part 11: Introduction to Polymer Modifiers

Presented by SARF

Presenter:
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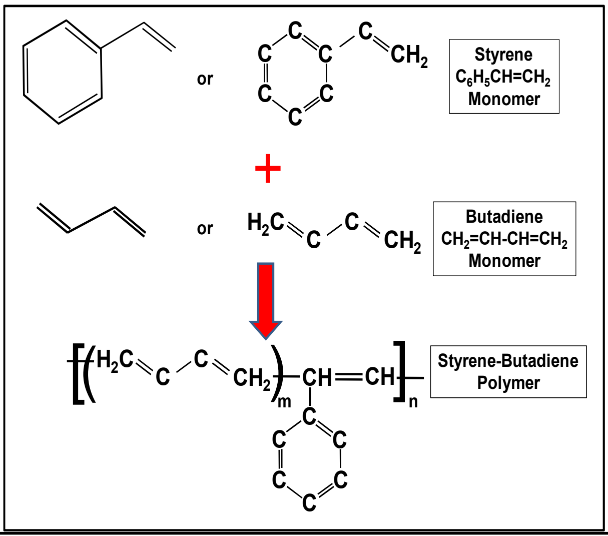
What are polymer modifiers?

A copolymer or polymer is a long chain molecule that is formed from a single or various monomers that repeat themselves.

A monomer is a single simple, usually small, low-weight molecule.



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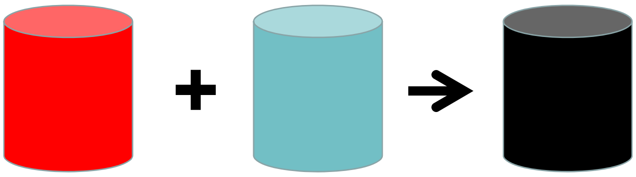
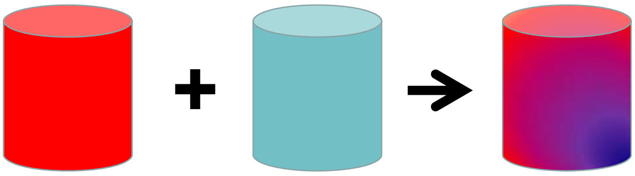
Homogeneous v/s non-homogeneous

Homogeneous mixture:



Non-Homogeneous mixture:



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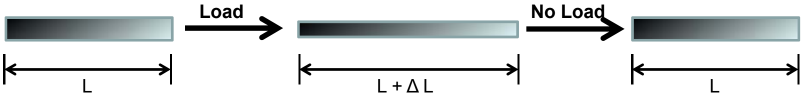
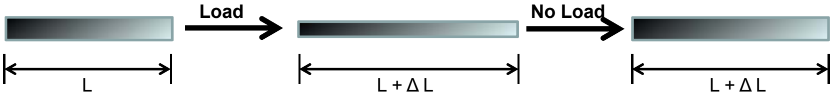
Elastomer v/s plastomer

Elastomer:



Plastomer:



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Elastomer:

Elastomers are polymer modifiers that have a “rubber” back bone that gives flexibility to the binder when it is deformed.
When a load (i.e. the load on account of tyres) is applied to a binder in which an elastomer is mixed, and the binder shape is deformed, the shape of the binder will tend to move back to its original shape after the load has been removed.

Plastomer:

Plastomers are polymer modifiers that will deform in a plastic or viscous manner at high temperatures and will become stiff and hard at low temperatures.
As such, after a load has been applied to the plastomer which results in a change in dimensions of the plastomer, a permanent deformation will be visible after the load has been removed.

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Why are polymer modifiers used?

- **Binder-Aggregate Adhesion**
- **Durability**
- **Elasticity**
- **Deformation resistance**
- **Flexibility at low temperatures**
- **High viscosity at high temperatures**
- **Improved consistency**
- **Improved stiffness and cohesion**
- **Improved flexibility, resilience and toughness**
- **Improved resistance to in-service ageing**

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Classification of polymer modified binders (according to TG1):

- Polymer modification can be done in various ways.
- A lot of polymer modifiers as well as end products are available on the market but at the end they all can be grouped into various groups according to their characteristics and end uses.
- With this in mind a classification system for modifiers has been devised which does not prescribe the type and amount of modifier to be introduced to the end product but rather concentrates on the end use of the product and the temperature at which it has to be used.
- The following abbreviation codes are used in conjunction with the modified binder classification system:

- The type of application in which the modifiers are going to be used:

  - S = Seal
  - A = Asphalt
  - C = Crack Sealant

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Classification of polymer modified binders (according to TG1):

- The type of binder system:
  - C = applied at colder temperatures, which indicates that an emulsion is used in conjunction with the modifier.
  - “No letter” = applied at hot temperatures
- The predominant type of binder to be used:
  - E = Elastomer
  - P = Plastomer
  - R = Rubber
  - H = Hydrocarbon
- The number (1 or 2) indicates the softening point of the binder. This means that according to the classification system, a binder that has a “1” at the end has a lower softening point than a binder that has a “2” at the end. This is not necessarily an indication of the performance of the modifier.
- Cutters (solvents) can be introduced to the binder to change the properties of a binder. If the end use application does not permit the introduction of a cutter, the letter “t” will be added at the end of the classification.

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Classification of polymer modified binders (according to TG1-2019):

Modified binder class	Type of modifier	Type of application	Type of binder system
S-E1	elastomer	seal	hot applied
S-E2	elastomer	seal	hot applied
S-R1	rubber	seal	hot applied
S-R2	rubber	seal	hot applied
SC-E1[(1)]	elastomer	seal	emulsion
SC-E2[(1)]	elastomer	seal	emulsion
A-E1	elastomer	hot mix asphalt	hot applied
A-E2	elastomer	hot mix asphalt	hot applied
A-P1[(2)]	plastomer	hot mix asphalt	hot applied
A-H1	hydrocarbon	hot mix asphalt	hot applied
A-H2[(2)]	hydrocarbon	hot mix asphalt	hot applied
A-R1	rubber	hot mix asphalt	hot applied
A-R2	rubber	hot mix asphalt	hot applied
AC-E1	elastomer	microsurfacing	emulsion
AC-E2	elastomer	microsurfacing	emulsion
C-E1	elastomer	crack sealant	hot applied
CC-E1	elastomer	crack sealant	emulsion
C-R1	rubber	crack sealant	hot applied
C-R2	rubber	crack sealant	hot applied

Notes:

(1) These emulsions have the option of being made with or without cutters depending on their application

(2) Some of the modifiers in these generic classification classes are also capable of imparting fuel resistant properties

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Example:

The binder classification is **AC-E1(t)**:

A = the binder is going to be used in an asphalt mix, in this case as microsurfacing

C = the microsurfacing is going to be applied cold, i.e. an emulsion is used in the mix

E = the predominant modifier is an elastomer

1 = the binder has a lower viscosity than AC-E2 (if available)

(t) = it is not allowed to use a cutter

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Types of polymer modifiers

Styrene-Butadiene-Styrene (SBS)

Advantages:

- Reduced permanent deformation (rutting) of the asphalt layer because of higher stiffness of the asphalt mix.
- A reduction in fatigue cracking of the asphalt layer.
- A reduction in thermal cracking of the asphalt layer.
- At higher temperatures the binder used in the asphalt will exhibit higher viscosity properties. This will result in higher stiffness, increased resistance to flow, reduced bleeding and reduced flushing of the binder.
- At lower temperatures the SBS modifier will provide improved flexibility to the asphalt mix.
- The addition of SBS will result in lower application temperatures of the asphalt mix than the addition of Styrene-Butadiene-Rubber or Bitumen Rubber.
- A possible advantage of using SBS as a modifier in an asphalt wearing course is that, as a result of higher stiffness of the asphalt wearing course, either the thickness of the asphalt layer or the thickness of the base course can be reduced which will result in a potential savings on total pavement costs, energy and natural resources.

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Types of polymer modifiers

Styrene-Butadiene-Styrene (SBS)

Disadvantages:

- The asphalt mix is more difficult to produce and become less workable on site on account of an increase in stiffness (because of higher viscosity) as more SBS is added to the binder .
- Modification is restrained as there is a tendency of highly modified hard binders to segregate in unstirred storage, making the binder unusable.
- Aggregate must be precoated to ensure adhesion with the modified binder.
- The addition of SBS restricts the evaporation of entrapped moisture in the asphalt mix.
- Adding of SBS modifier will result in an increase in binder costs.

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Types of polymer modifiers

Styrene-Butadiene-Rubber (SBR)

Advantages:

- SBR modified bitumen exhibits elastic properties ideal for treating lightly cracked surfaces.
- SBR modified bitumen has been used extensively in southern Africa both as cold applied bitumen emulsion and hot applied binder.
- SBR modified bitumen is useful where the pavement is structurally weak. In some areas, good natural gravel is scarce and crushed stone is very expensive. Asphalts where SBR is used as the modifier in the bitumen used for the asphalt have been successfully used with sub-standard natural gravel base courses for new roads in residential and township areas.
- The spray temperature of SBR modified bitumen is lower than rubber bitumen and it can be sprayed with normal spray equipment.
- Modification with SBR results in a reduction of the risk of bleeding of road surfaces in regions where the pavement temperature is high.
- SBR modified product have a lower application temperature than SBS and BR modified products.
- The addition of SBR to the binder improves the adhesion between the binder and the aggregate in seal applications, which results in reduced stone loss

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Types of polymer modifiers

Styrene-Butadiene-Rubber (SBR)

Disadvantages:

- The addition of SBR will increase the binder costs.
- SBR modifier has a limited storage life at application temperature.
- The addition of SBR can restrict the evaporation of entrapped moisture in a mix.
- SBR modified products are difficult to hand spray.

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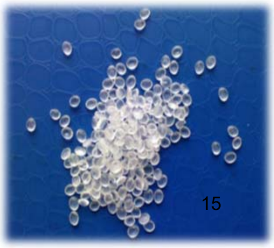
Types of polymer modifiers

Ethylene-Vinyl-Acetate (EVA)

Advantages:

- EVA copolymers are easily dispersed in bitumen and have a good compatibility with the bitumen.
- EVA is thermally stable at normal mixing and handling temperatures. As EVA is more heat stable EVA modified binders have better storage stability than SBS and SBR modified binders.
- EVA provides high shear resistance against aggregate loss when used in bitumen for seal work.
- The addition of EVA to a binder used for tack coat will increase the "tack" of the binder.
- EVA will exhibit minimal viscosity changes compared to SBS and SBR.



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Types of polymer modifiers

Ethylene-Vinyl-Acetate (EVA)

Disadvantages:

- When EVA modified binder is stored statically, separation of the bitumen and copolymer may occur. The product should be stirred before use.
- Because of the rise in temperature of EVA when added to heated bitumen, the binder will initially have a reduced stiffness and, when used for seals, the loss of aggregate (stripping) can occur if the binder is not cooled down enough when the road is opened up for traffic.
- The addition of EVA to a binder will not improve the elastic recovery of the binder.

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Types of polymer modifiers

Rubber Crumb modified binder

Advantages:

- The increased viscosity at higher temperatures reduces the risk of bleeding.
- Maintenance costs of the pavement are reduces on account of a reduction in cracking of the pavement.
- Bitumen rubber is ideal for sealing cracks which are wider than 3 mm.
- The addition of rubber crumbs improves the resistance of the binder to age hardening.
- Hot mix asphalt produced with bitumen rubber modified binder exhibits an improved skid resistance of the surface.
- The use of bitumen rubber modified binder in an asphalt mix can reduce the noise levels of the asphalt mix surface with as much as 5 dB.

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Types of polymer modifiers

Rubber Crumb modified binder

Disadvantages:

- High initial surfacing costs.
- The application of bitumen rubber modified products need specialised equipment .
- Bitumen rubber modified binder is difficult to hand spray.
- Bitumen rubber modified binder has a limited storage life when kept at application temperature.
- Bitumen rubber modified binder does restrict the evaporation of entrapped moisture from the modified product.
- Problems are experienced with early adhesion between the binder and aggregate as a result of cold temperatures and/or moisture.
- When using bitumen rubber modified binder aggregate must be precoated.

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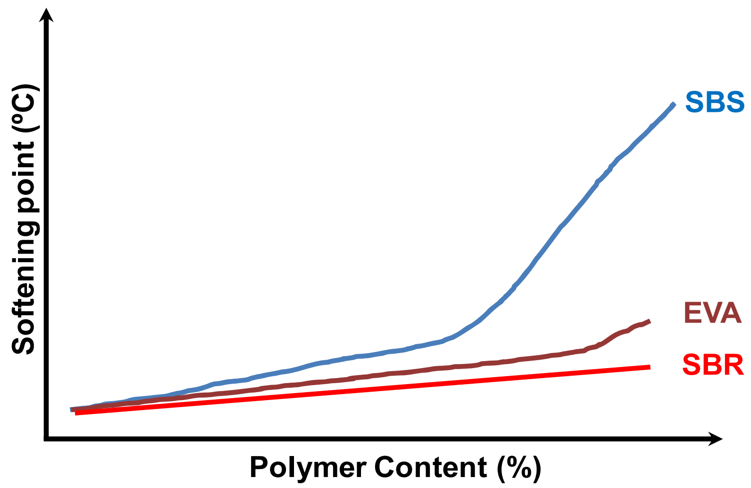
Characteristics of polymer modifiers



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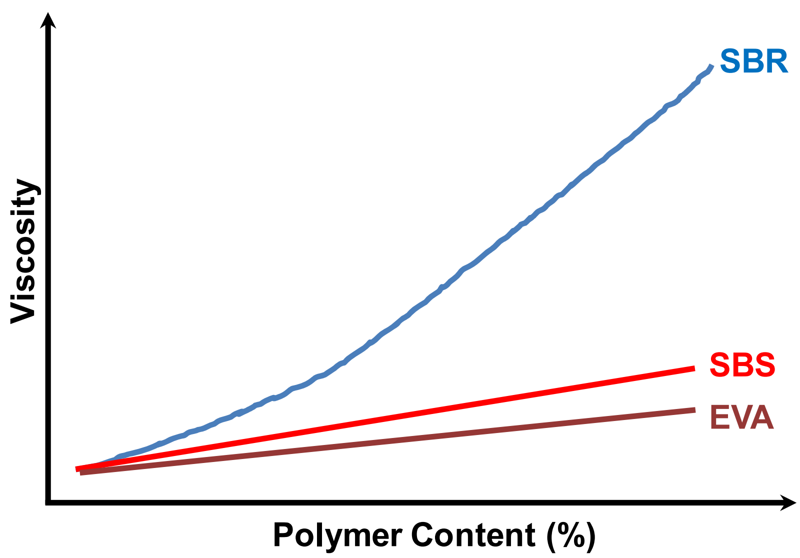
Characteristics of polymer modifiers



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Introduction to Road Materials Engineering

Part 12: PG Grading and Asphalt

Presented by SARF

Presenter:
Ron Berkers

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Asphalt

PG binder classification system

- South Africa went from an industrial grade type bitumen specification to a performance grade (PG) specification.
- This is contained in the SABITA Manual 35: Design and use of asphalt in Road Pavements.
- The South African design methods for asphalt mixes were updated because:
  - The design of asphalt mixes and the mechanistic-empirical design of the pavement structure need to be linked.
  - To incorporate international and local advances in asphalt technology.
  - The increase in volume of heavy vehicles on South Africa's roads.
  - A demand for higher performance mixes, often leading to more sensitive mix designs.
- The purpose of asphalt mix design is to find a cost-effective combination of binder and aggregate, that is workable in the field, with sufficient binder to ensure satisfactory durability, fatigue performance and suitable aggregate configuration providing structure and space between particles to accommodate the binder and prevent bleeding and permanent deformation.
- If the material is used as a wearing course, the aim is to provide a surfacing that is waterproof (with the exception of porous asphalt) and meets functional requirements such as friction, noise attenuation and comfort.

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Asphalt

PG binder classification system

- Performance grade specifications for binders focus on the evaluation of binder properties based on the traffic loading and environmental conditions (mainly temperature) which the binder will be subjected to in the field.
- The temperature of the asphalt layer (as determined by the climate), in conjunction with the grade (initial stiffness) and age of the binder, plays a pivotal role in determining the stiffness or dynamic modulus of the asphalt layer.
- Four levels of designs are used in relation to traffic volume and risk profile. A volumetric design approach is used to select optimum binder content for design situations with low to medium traffic levels (Levels IA and IB).
- The binder content obtained at this level serves as the starting point to select the optimum mix for design situations with moderately high to very high traffic volume with high level risk of structural damage (Level II and Level III).
- Ultimately the traditional penetration grade binder selection will be replaced by performance grade binder selection methodology in which the binder is selected based on the loading and environmental conditions which the binder will be subjected to in service.
- There is also a move away from grading bands to control points for aggregate design.

Asphalt

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PG binder classification system

- The Bailey method, which has been used with success in South Africa, can be used to optimize aggregate grading and mix design criteria.
- The Bailey method of gradation evaluation focuses on the aggregate properties that affect the way aggregates fit together (or pack) in a confined space or volume.
- The Bailey method gives the practitioner tools to develop and adjust aggregate blends.
- The bailey method determines which fraction of the aggregate is in control of the overall structure, the course fraction or the fine fraction.
- The method than looks at how the two fractions pack into each other and if segregation will take place.
- Mixes designed with help of the Bailey method to determine the aggregate packing show a lesser rutting potential, lesser temperature sensitivity and yield a higher stiffness.

Asphalt

PG Classification System

- The South African maps depicting the 7-day average maximum asphalt temperatures at 20 mm depth and the 1-day minimum asphalt temperatures at the surface are presented in the following two figures.
- The maximum pavement design temperatures adopted for South Africa are 58˚ C, 64˚ C and 70˚ C.
- While the minimum temperature in SA rarely falls below -10˚ C, the minimum temperatures adopted for grading purposes are considerably lower, to align the specification to the US standard and to determine the temperatures at which other tests are carried out i.e.:
  - intermediate temperatures for fatigue (durability) and
  - low temperatures for thermal fracture
- The three low temperatures associated with 58˚ C, 64˚ C and 70˚ C are -22˚ C, -16˚ C and -10˚ C, respectively i.e. an 80˚ C difference in all cases.
- The maximum asphalt temperature zones are major determinants in the definition of a PG classification system.

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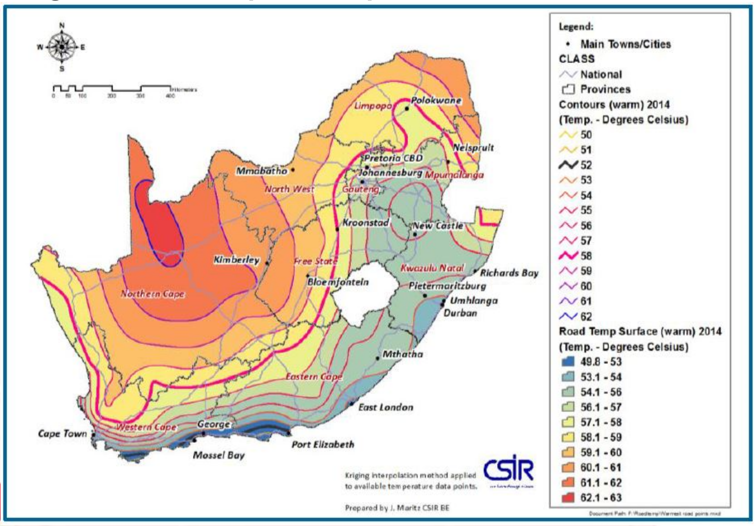
Asphalt

PG Classification System

7-Day average maximum asphalt temperatures:



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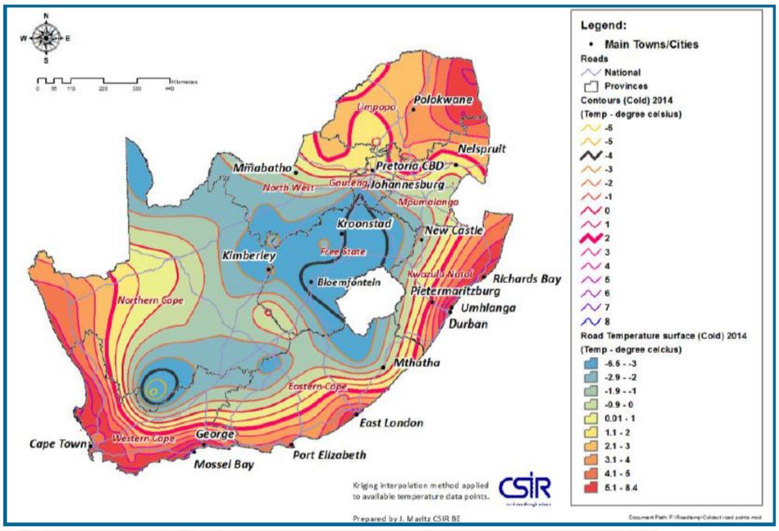
Asphalt

PG Classification System

Minimum asphalt temperatures:



Asphalt

PG Classification System

Based on these maps, South Africa is divided into two maximum temperature zones for performance grading of binders based on the 7-day average maximum asphalt temperatures:

- **PG 58 Zone** which would include the Western Cape (except for the northern inland regions), Eastern Cape, most of KwaZulu-Natal, eastern half of the Free State, Gauteng, South Eastern part of Limpopo, and Mpumalanga (except for the eastern region bordering Mozambique).
- **PG 64 Zone** which covers the rest of the country, including the Northern Cape (except for the mountainous southern region), North West, the extreme northern coastal region of KwaZulu- Natal and rest of Limpopo.

The maximum asphalt temperature zones are major determinants in the definition of a PG classification system.

Asphalt

PG Classification System

- Traffic in the PG specification is classified both in terms of volume or severity and speed.
- This is done to take account of the fact that, for a given loading intensity, slow moving traffic would exert more severe loading conditions.
- The combined effect of traffic loading and speed will be categorized as follows:

S – 'S' refers to standard conditions;
H – 'H' refers to Heavy conditions;
V – 'V' refers to Very heavy conditions, and
E – 'E' refers to Extreme conditions

Design traffic (million E80)	<20 km/h	20-80 km/h	>80 km/h	Asphalt mix design level
<0.3	S	S	S	IA
0.3 - 3	H	S	S	IB
>3 - 10	V	H	S	II
>10 - 30	E	V	H	
>30 - 100	E	E	V	III
>100	E	E	E	

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Asphalt

PG Classification System

PG binder selection:

1. Locate the position of the asphalt layer on the map indicating the 7-day average maximum asphalt temperatures at 20 mm depth.
   - If the asphalt layer is to be located wholly or partially within the > 58˚C Zone, a PG 64 binder is selected; or
   - If the asphalt layer is to be located wholly within the ≤ 58˚C Zone, a PG 58 is selected (a PG 64 will also conform to minimum requirements)
2. Determine the traffic level and average speed and choose the correct grade of binder according to the table on the previous page (i.e. 58H-22, 64E-16).
3. Until such time when a performance grade specification is fully implemented, binder selection would be based on the current specification - SANS 4001-BT1 - and guidelines in SABITA TG1.
4. For specific mix types (like EME, "Enrobé à Module Élevé", sand asphalt, warm mix asphalt etc.) refer to SABITA Manual 35, chapter 3.3.

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Asphalt

PG Classification System

Major advantages of the proposed PG grading include:

1. Improved prediction of asphalt mix performance is possible, thereby promoting more cost- effective design of mixes;
2. The effects of long-term ageing on performance of the binder, and hence the mix, can now be evaluated;
3. The specification is binder-blind and will promote cost effective use of costly modified binders, and
4. The specification is aligned to international practice.

Asphalt

The primary objective of asphalt mix design is to achieve a durable mix meeting certain specification criteria using an economical blending of aggregates and with binder.
To achieve this objective, the following are important performance factors to consider:

- Sufficient workability;
- Durability by having sufficient binder;
- Sufficient stability under traffic loads (stiffness);
- Resistance to moisture damage;
- Resistance to permanent deformation (Rutting);
- Resistance to fatigue cracking.

Asphalt

Workability:

- Workability is the ease of handling, placing and compacting the mix under the prevailing conditions. A number of factors that affect workability are:
  - Mixes containing high percentage of coarse aggregates have the tendency to segregate and could present difficulties to attain a uniformly well compacted layer;
  - Too high or too low filler in the mix;
  - Too low or too high temperature will make the mix unworkable or tender, respectively;
  - Excessive proportion of large sized aggregate in relation to the layer thickness.
- For a given aggregate grading, workability can be improved by:
  - Increase in binder content;
  - Decrease in binder viscosity;
  - Less angular aggregate;
  - Limiting the maximum particle size to less than a third of the layer thickness;
  - Construction controls that ensure the mix is compacted at the proper temperatures.

Asphalt

Durability:

- Durability of asphalt mix is its ability to resist:
  - Hardening of the binder due to:
    - Oxidation;
    - Loss of volatiles;
    - Physical (steric) hardening;
    - Loss of oily substances due to absorption into porous aggregates (exudative hardening).
  - Disintegration of the aggregate;
  - Stripping of the bituminous binder from the aggregate;
  - Action of traffic.
- Durability of mixes can be improved by using:
  - An appropriate binder in relatively thick films;
  - Dense aggregate packing, i.e. low air voids;
  - Sound, durable and strip resistant aggregates;
  - Use of adhesion-promoting or anti-stripping additives or hydrated lime.

Asphalt

Stiffness:

- The stiffness of asphalt determines its ability to carry and spread traffic loads to underlying layers.
- Relatively stiff asphalt is generally required for asphalt bases.
- Less well supported surfacing layers e.g. pavement structures with a lower radius of curvature associated with higher vertical deflection, may be better served by a lower stiffness asphalt, to avoid traffic induced cracking, provided the underlying support is still adequate to carry the traffic loads.
- The stiffness of asphalt is mostly influenced by:
  - ➢ Transient traffic loading time;
  - ➢ Temperature;
  - ➢ Binder content and binder rheology;
  - ➢ Aggregate packing;
  - ➢ Degree of compaction achieved during construction.

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Asphalt

Permeability:

- Permeability of asphalt is a measure of the penetration of the mix by air, water and water vapor.
- Low permeability of a dense asphalt surfacing promotes long term durability and protects underlying layers from the ingress of water, which may lead to failure.
- Factors that reduce permeability are:
  - ➢ High binder contents with adequate film thickness;
  - ➢ Dense aggregate packing;
  - ➢ Dispersed rather than inter-connected air voids within the mix;
  - ➢ Well compacted asphalt layers.

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Asphalt

Resistance to permanent deformation (Rutting):

•Rutting can typically occur during the summer pavement temperatures in excess of 40° C which frequently occur in South Africa in summer.
•Under such conditions deformation is resisted by the frictional resistance in the aggregate and binder stiffness.
•The predominant factor would be dependent on the mix type, e.g. stone or sand skeleton.
•The ability of an asphalt mix to resist permanent or plastic deformation under the influence of traffic and elevated temperatures depends primarily on:

➢Internal frictional resistance of the aggregates in the mix;
➢Cohesion (tensile strength) resulting from the bonding ability of the binder in the mix;
➢Cohesive strength, i.e. resistance to viscous flow of the binder at elevated temperatures.

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Asphalt

Resistance to fatigue cracking:

- Resistance to fatigue cracking is the ability of the mix to withstand repeated tensile strains without fracture.
- Fatigue failure in asphalt layers occurs when the number of repetitions of applied loads exceeds the capacity of the asphalt to withstand the associated tensile strains.
- The situation may be worsened by stresses induced by thermal fluctuations.
- High voids, which may accelerate binder ageing, or low binder content could lead to low fatigue life.
- Generally thin asphalt layers are more prone to fatigue as a result of high deflections or bending when compared with thick asphalt layers.

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Asphalt

Asphalt Mix Types:

In manual 35, asphalt mixes are primarily classified into two main categories based on aggregate packing i.e. sand-skeleton or stone-skeleton types.

Sand skeleton mixes

- In sand-skeleton mixes, the loads on the layer are mainly carried by the finer aggregate fraction, with the larger fractions providing bulk and replacing a proportion of the finer fraction.
- There is no meaningful contact between the individual larger aggregate particles.
- Examples include semi-gap graded asphalt, gap-graded asphalt, and medium / fine continuously graded asphalt.

Stone skeleton mixes

- The spaces between the coarser aggregate fractions are filled by the finer aggregate fractions, but do not push the coarser aggregates apart.
- Contact between the coarser aggregate fractions is thus assured.
- This situation results in the loads on the layer being carried predominantly by a matrix (or skeleton) of the coarser aggregate fraction.
- Examples include coarse continuously graded asphalt, stone mastic asphalt, ultra-thin friction courses, and open graded asphalt (porous) asphalt.

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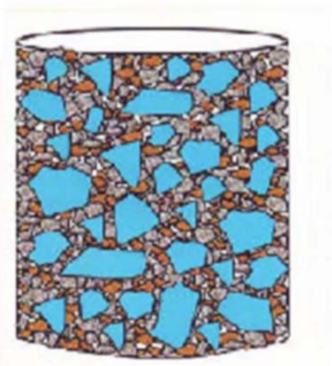
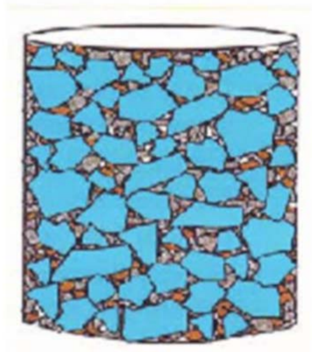
Asphalt



Sand skeleton mix



Stone skeleton mix

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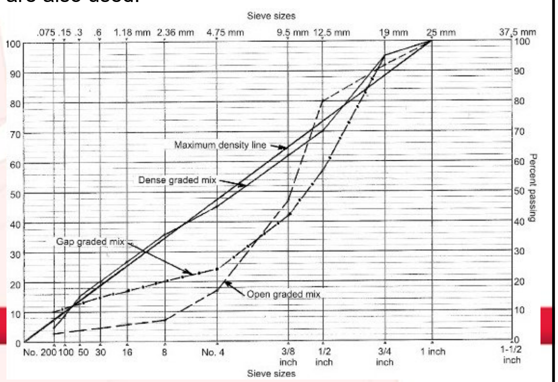
Asphalt

Asphalt Mix Types:

- Five basic asphalt types are used in South Africa, namely:
  - Continuously graded;
  - Gap-graded;
  - Semi-gap-graded;
  - Open graded (porous asphalt), and
  - Stone Mastic Asphalt.
- For special applications the following are also used:
  - Large aggregate mixes;
  - Sand asphalt, and
  - Modified binder mixes



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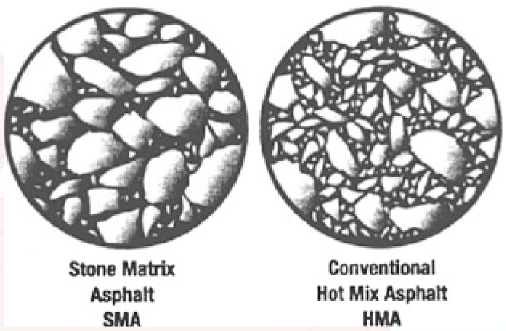
Asphalt

Asphalt Mix Types:

Continuously graded asphalt:

- In continuously graded mixes, maximum density is obtained by the so-called telescopic effect where the smaller particles fit into the voids of the larger particles to obtain a condition approaching zero voids.



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Asphalt

Continuously graded asphalt:

- Because of the fact that very close aggregate-to-aggregate contact is achieved in continuously graded asphalt, the load bearing capacity, or resistance to plastic deformation, is given by the stone skeleton.
- At low temperatures, because of higher shear resistance of the binder, the mix will become very stiff and resistant to deformation.
- At high temperatures the interlocking action of the aggregate will determine the deformation resistance of the asphalt.
- Because of the fact that the voids in the aggregate are designed to be at a minimum, air trapped in the mix and voids formed by poor aggregate distribution will increase the possibility of the mix being permeable to air and water, with associated effects.

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Asphalt

Asphalt Mix Types:

Gap-graded asphalt:

- Gap-graded asphalt consists of coarse aggregate of a fairly uniform size blended with fine aggregate and filler
- The load bearing capacity of this type of mix is not as dependent on the aggregate interlock principle, but to a much larger extent depends on the stiffness of the binder.
- It can therefore be argued that the resistance to deformation of gap-graded mixes is expected to be much lower than that of continuously graded mixes, unless a very hard binder is used.

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Asphalt

Gap-graded asphalt:

- The main advantage of gap-graded mixes lies in the fact that due to the use of high percentages natural sand, which is not supposed to be continuously graded in itself, a much higher percentage of voids is formed in the mineral aggregate.
- This enables the mix to contain more binder than continuously graded mixes, which makes it more durable and less permeable.
- The relatively low stone content and associated lower internal stiffness also allows the rolling in of chips to provide a better non-slip surface than can be obtained with continuously graded mixes.
- When choosing the sand for gap graded mixes one should, however, be careful not to use a sand with too much fine material or clay size fractions as this will make the mix too stiff and could lead to cracking and accelerated aging.

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Asphalt

Asphalt Mix Types:

Semi-gap-graded asphalt:

- Semi-gap-graded asphalt consists of a more graded coarse aggregate blended with fine aggregate and filler.
- This type of mix has been used successfully for the construction of asphalt bases and overlays.
- In some instances where this mix was used in overlays, rolled-in pre-coated chips were used successfully to provide a better skid resistance.
- Semi-gap-graded asphalt will show some of the positive properties of continuously graded mixes such as high stability and low deformation, but will not have negative properties such as high permeability and lower durability.

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Asphalt

Asphalt Mix Types:

Porous asphalt:

- Porous asphalt was specifically designed as a surface drainage layer to drain surface water away and thus limit spray and splash behind vehicles in wet weather.
- It also reduces tyre rolling noise due to its sound absorbing properties.
- Due to the structure of this type of asphalt, shear resistance is attained by having a coarse stone skeleton held together by the binder.
- The choice of binder is therefore critical to ensure long term performance. The use of a modified binder such as bitumen rubber, is recommended.
- The aggregate should also have a high rugosity and should, preferably, not have adhesion problems.
- It is important that a dense asphalt mix is constructed directly underneath the porous asphalt to ensure that water does not penetrate the pavement but is removed to the edge of the road.

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Asphalt

Asphalt Mix Types:

Stone mastic asphalt:

- Stone Mastic Asphalt (SMA) is an excellent mix type to use as a surfacing under heavy traffic conditions.
- SMA is characterised by a good resistance to permanent deformation and high durability.
- It has better wet weather skid resistance and noise reduction than densely graded mixes.
- SMA is a gap-graded asphalt.

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Asphalt

Stone mastic asphalt:

- It contains an increased amount of coarse aggregate, mineral dust, bituminous binders and cellulose fibre.
- One of the basic concepts of SMA is that coarse aggregate (plus 2 mm) forms a self-supporting stone skeleton. This self supporting skeleton is achieved when there is contact between the particles larger than 2 mm throughout the whole SMA layer and that this contact is firm enough to carry the traffic load. The supporting particles skeleton is kept in place due to adhesion / cohesion of the mastic (binder and aggregate finer than 2 mm).
- It is important to compose the skeleton as well as the mastic in such a way that the stone-to-stone contact is intact as possible. Particles finer than 2 mm should partially fill the air voids in the skeleton.

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Introduction to Road Materials Engineering

Part 13: Geosynthetics

Presented by SARF

Presenter:
Ron Berkers

1

Geosynthetics

- Geosynthetics are polymeric materials, either natural or synthetic, that are used together with soil, rock and asphalt and other geotechnical materials to perform one or more of the following functions:
    1) Filtration
    2) Drainage
    3) Separation
    4) Reinforcement
    5) Barrier
    6) Erosion control

2

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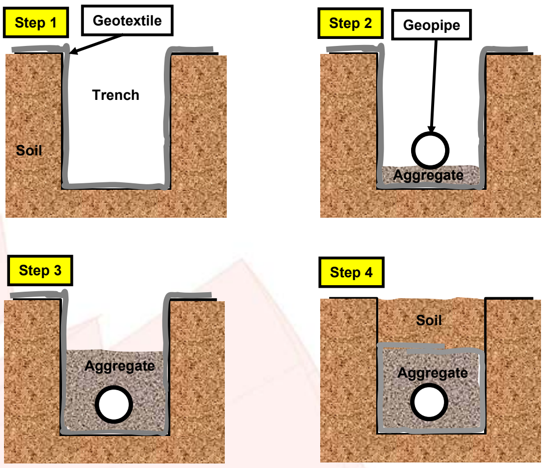
Filtration

Subsurface Drain:

1) A trench is dug alongside the road.
2) The trench is lined with a geotextile after which the bottom of the trench is filled with single size aggregate, usually 13,2mm stone. On this bed of aggregate a geopipe, which is a plastic pipe with holes on the side and on top but which is solid on the bottom, is placed.
3) The trench is than filled with more stone after which the geotextile is wrapped around the stone.
4) The rest of the trench is than filled with soil and compacted until the level of the road is reached



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Drainage

Gabions:

Gabions are basically big square or rectangular cages made from strong chicken wire which are filled with rocks.

Geotextiles are normally placed behind the gabions where it is in contact with the soil. The geotextile acts as a filter through which water can flow but soil particles will stay behind, thus preventing the soil eroding away.

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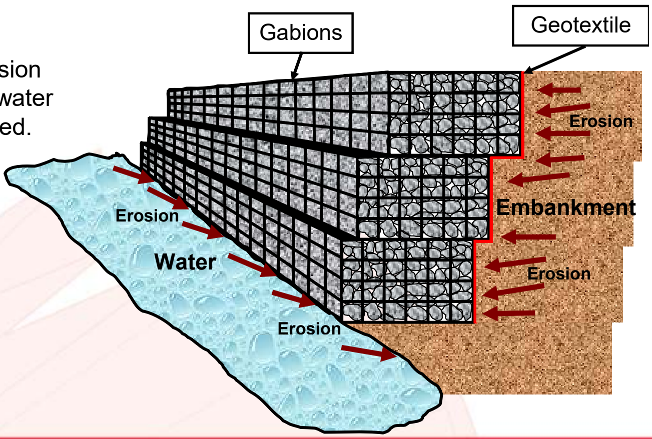
Drainage

Gabions:

Gabions are usually needed for the following:

1) as retaining walls
2) to prevent soil erosion
3) where the flow of water needs to be reduced.



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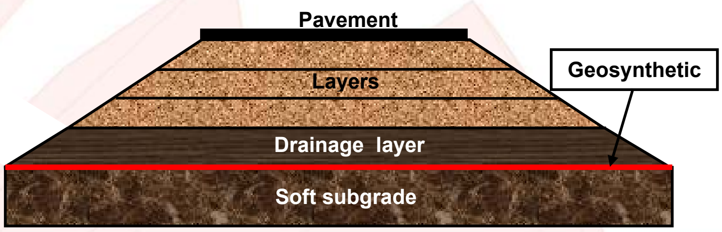
Separation

- The geosynthetic acts to separate two layers of soil that have different particle size distributions.
- Separators help to prevent fine-grained subgrade soils from being pumped into permeable granular road bases.
- Geotextiles are used to prevent road base materials from penetrating into soft underlying soft subgrade soils, thus maintaining design thickness and roadway integrity.
- Usually the soft underlaying layer is covered with a geosynthetic material which is very strong and pervious.
- On top of the geosynthetic material a drainage layer is build. This drainage layer acts as a base on which further layers are constructed on which the construction project is built.



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Reinforcement

- The geosynthetic acts as a reinforcement element within a soil mass or in combination with the soil to produce a composite that has improved strength and deformation properties over the unreinforced soil.
- For example, geotextiles and geogrids are used to add tensile strength to a soil mass in order to create vertical or near-vertical changes in grade (reinforced soil walls).
- Soil, especially granular soil, is relatively strong in compression. If geotextiles are used to carry the tensile stresses induced in a soil because of loads the overall tensile strength properties of the soil improve drastically. This concept is used when building soil walls where compacted soil is wrapped in geotextile cloth, thus producing a stable structure.

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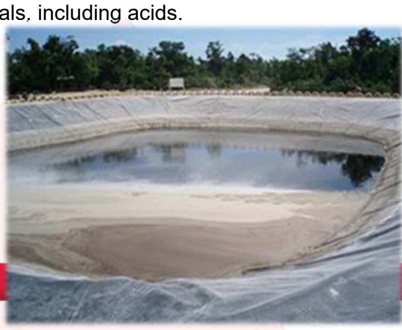
Barrier

Geosynthetic liners:

- Containment of fluids is one of the major functions provided by geosynthetics.
- Geosynthetic Barriers (GBR) guard against seepage loss, prevent infiltration, improve the flow of fluids, protect groundwater, isolate contaminated soils, etc.
- A geomembrane is basically a impermeable plastic sheet which is used as a liner for dams in which hazardous leech-off products, usually from mines, are stored and processed.
- Geomembranes used as liners must have the following properties:

  1) Impervious to punching, usually not a problem as the liner is lying on top of clay.
  2) Very strong, resistant to tearing.
  3) Chemically resistant to hazardous materials, including acids.



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Erosion Control

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- Uncontrolled erosion results in a host of environmental problems.
- Many of these problems can be prevented by employing relatively simple erosion control techniques.
- Among these solutions may be found those that are offered by the use of geosynthetic products.
- The geosynthetic acts to reduce soil erosion caused by rainfall impact and surface water runoff.

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Erosion Control

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Erection of geotextile fences:

- Poles are inserted in the slope in a straight line along the side of the slope.
- A geotextile is fastened to these poles, effectively creating a barrier in the path of any water that is streaming down the slope.
- This water is known as hill wash.
- The geotextile barriers will catch any soil particles that are being washed down the slope by the water.
- The water itself is allowed to filter through the geotextile on account of the holes that were punctured in the geotextile by needles during the manufacturing process of the geotextile cloth.

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Erosion Control

Lining the slope with a geotextile:

- Another method to prevent soil being washed away by water down a slope is lining the whole slope with a geotextile.
- The geotextile is than sprayed with a grass seed mixture.
- The grass starts to grow through the geotextile, thus anchoring the geotextile to the slope.
- As the soil is under the geotextile, water will wash down the slope on top of the geotextile, consequently preventing soil erosion down the slope.

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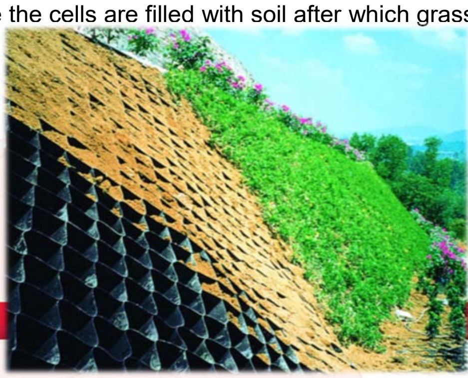
Erosion Control

Geocells:

- Geocells are plastic divisions that can be placed on a slope or on the bottom or sides of a riverbed.
- Geocells are placed on the spots where soil erosion takes or can take place after which the divisions are filled with soil.
- In the case of a riverbed the divisions can be filled up with soil-cement or low strength concrete which will prevent any erosion of the bottom or sides of the riverbed.
- If geocells are used against a slope the cells are filled with soil after which grass is seeded on the geocells.



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Introduction to Road Materials Engineering

Part 14: Introduction to nanotechnology

Presented by SARF

Presenter:
Ron Berkers

SARF
better roads

1

Nanotechnology

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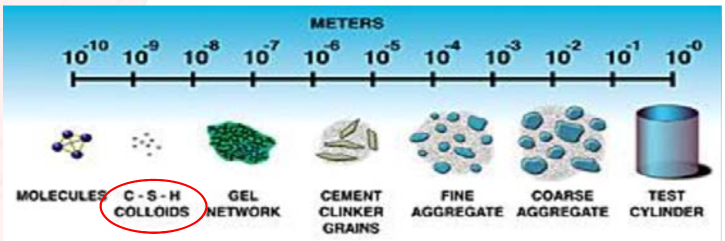
- Nanotechnology is not a new science and it is not a new technology.
- Nanotechnology is the use of very small particles of material.
- Nanotechnology is an enabling technology that allows us to develop materials with improved or totally new properties.
- A nanometer is a billionth of a meter, 10^{-9}m or 0.000000001 m.



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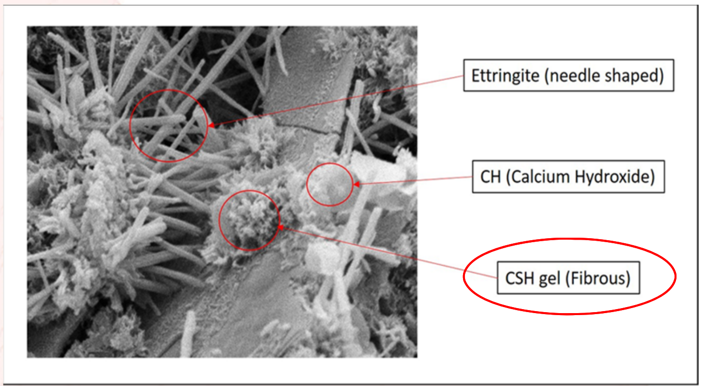
Nanotechnology

- Calcium silicate hydrate, $C_3S_2H_3$ (abbreviated to CSH), which grows outwards from the surfaces of the particles of unhydrated cement, is in the form of a gel, which is a rigid structure made up of extremely small rods and platelets joined at point of contact.
- This gel (CSH) provides most of the strength of hardened concrete.



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Nanotechnology

Scale:

- The thickness of a sheet of paper is 100 000 nm, which is 0.1 mm.
- Human hair 80 000 to 100 000 nm
- A single gold atom is 0.3 nm in diameter.
- A fingernail grows 1 nm in 1 second

4

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Nanotechnology

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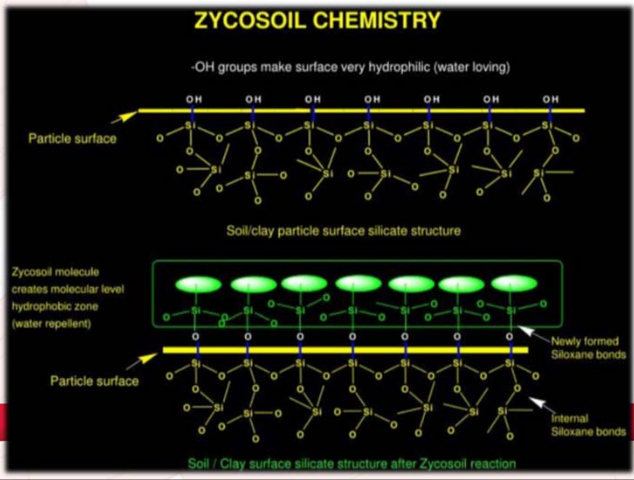
Zycosoil/Zycotherm:

- Zycosoil reacts with the soil particles and waterproofs the surfaces permanently.
- It improves the load bearing properties of different types of expansive and silty soils.
- The CBR value of 2-10 under four day soak conditions increased to 10-70 with Zycosoil treatment. (20% (diluted Zycosoil solution (1:100)) on weight of soil)



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Nanotechnology

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Zycosoil/Zycotherm:

- Zycosoil also can be used in asphalt.
- Zycosoil chemically bonds with the surface of the aggregate which eliminates debonding of the asphalt binder.
- Zycosoil increases the tensile strength of an asphalt mix by some 15 to 20% which has the potential to increase its fatigue life.
- Zycosoil also increases the Marshall stability of asphalt mixes to provide the increased resistance to rutting while keeping it flexible.
- Zycosoil also improves the asphalt binder properties in terms of lowered mixing viscosity, higher resistance to rutting and increased elasticity.
- A Zycosoil modified asphalt mix is easier to compact both in the laboratory and in the field. Field compaction is improved by 1 to 1.5% with the same compactive effort, resulting in construction cost savings and increased durability of asphalt pavement with reduced air voids.

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Nanotechnology

Graphene nanotubes:

- Trials of the world's first experimental section of road pavement with graphene nanotubes have demonstrated a 67% improvement in rutting resistance and a 67.5% boost in fatigue cracking resistance.
- Graphene nanotubes form a reinforcing network in asphalt concrete, which improves its physical and mechanical properties: rutting resistance, ring-and-ball softening point, ultimate compressive strength, and fatigue life.
- Nanotubes are introduced into bitumen using adhesive agents, and the modified bitumen is then added to asphalt concrete.
- Nanotubes improve the properties of road bitumen even at very low concentrations, from 0.025% to 0.035% in the total weight of bitumen, while the content of bitumen itself in asphalt does not exceed 6%.
- The tests showed an increase in the softening point by 10ºC and a more than twofold increase in the viscosity of the binding agent.

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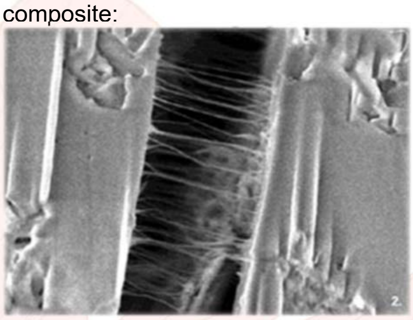
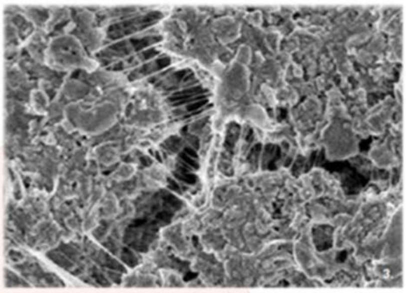
Nanotechnology

Graphene nanotubes:

- The below pictures show carbon nanotubes bridging cracks in a cement composite:





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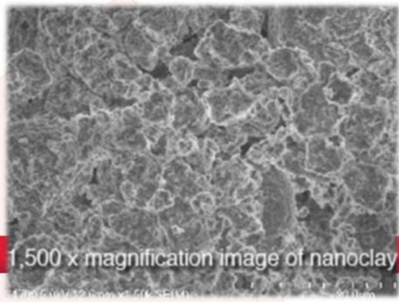
Nanotechnology

Nano Clay:

- Nanoclays are tiny particles of layered mineral silicates.
- Clays can be organized into several classes, including montmorillonite, bentonite, kaolinite, and a few others.
- Nanoclays are known to enhance the properties of many polymers.
- Bitumen can be enhanced when it is modified with small amounts of nano-clay, on the condition that the clay is dispersed at the nano-scopic level.
- Nanoclays are used to improve elasticity, rutting resistance, low temperature rheological properties and resistance to cracking of asphalt.
- Montmorillonite is the most common type of nanoclay used in materials applications.
- When nano clay is used with SBS it will enhance to performance properties of the SBS copolymer modified binder.
- The nano clay will also make the bitumen and polymer more compatible and lead to better dispersion of the polymer in the bitumen.



1,500 x magnification image of nanoclay

Nanotechnology

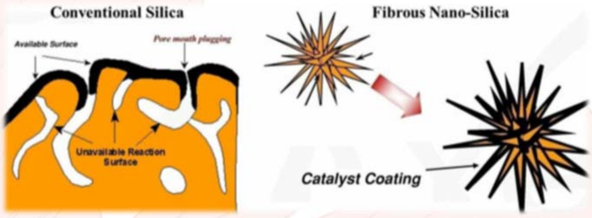
Nano Silica:

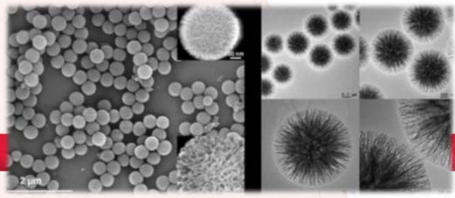
- Cold In-place Recycled (CIR) pavement properties are not as effective as HMA.
- Nano particles like nano silica (in place of active filler) can improve the mechanical properties of CIR and can improve the maximum theoretical density of the asphalt mixture by 3 to 4%.
- The advantage of these nanomaterials resides in the low cost of production and in the high performance features.
- When Nano Silica is added to bitumen it slightly reduces the viscosity of the binder (WMA potential), improved rutting resistance, improved resistance to thermal cracking, reduced susceptibility to oxidative aging, improved fatigue resistance and improved aggregate binder adhesion.
- Nano Silica synthesized from silica fume tends to decrease the penetration value and increase the softening point temperature of a modified binder.
- In one study the addition of 5% nano silica to mortar containing 70% of fly ash replacement of cement improved the compressive strength with 94%.

Nanotechnology

Nano Silica:

- The chemist's first choice for heterogeneous catalysts is often porous silica because of its high surface area. However, these surface areas are mostly due to the pores and are thus not always accessible.
- Another option now available is fibrous silica nanosphere.
- Its high surface area is due to these fibers and not pores.





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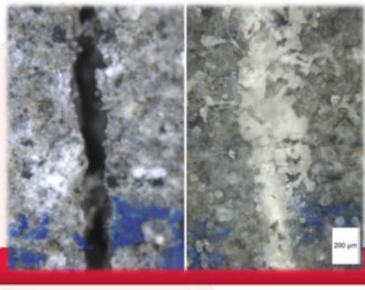
Nanotechnology

Self healing concrete:

- Researchers have developed a polymer material that has the ability to automatically heal cracks.
- Autonomic (spontaneous) healing is accomplished by incorporating a microencapsulated healing agent and a catalytic chemical trigger within an epoxy matrix.
- An approaching crack ruptures embedded microcapsules, releasing the healing agent into the crack plane through capillary action.
- The microcapsules were dispersed in fresh cement mortar along with carbon nano fibers and silica fumes.
- Another method to enhance the healing mechanism of concrete, microfibres are added to the mixture. By mixing microfibres in the concrete, multiple cracking occurs. So, not one wide crack, but several small cracks are formed, which close more easily due to autogenous healing (self-healing of concrete as a result of water contained in the concrete).



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