THE SOUTH AFRICAN ROAD FEDERATION

ROAD PAVEMENT REHABILITATION COURSE

COURSE OUTLINE

1. Introduction
2. Road construction and maintenance cycle
3. Initial road network level assessment
4. Detailed road project level assessment
5. Road pavement analysis
6. Selection of maintenance or rehabilitation options
7. Drainage improvements
8. Patching and crack sealing
9. Road pavement layer recycling
10. Surfacing and modified binders
11. End of course quiz

SARF ROAD PAVEMENT REHABILITATION COURSE

1. INTRODUCTION

This course covers the theoretical and practical aspects of the REHABILITATION OF SURFACED ROADS.

This is not a pavement design course.

Neither is it a routine road maintenance course.

The Course material comprises this presentation as well as a set of detailed notes which must be studied if you want to get full value from this course.

Also study TRH 3, TRH 4, TRH 6, TRH 14, TMH 1, TMH 5, TMH 9, the SABITA TG 1 and TG 2 manuals and the South African Pavement Engineering Manual (SAPEM)

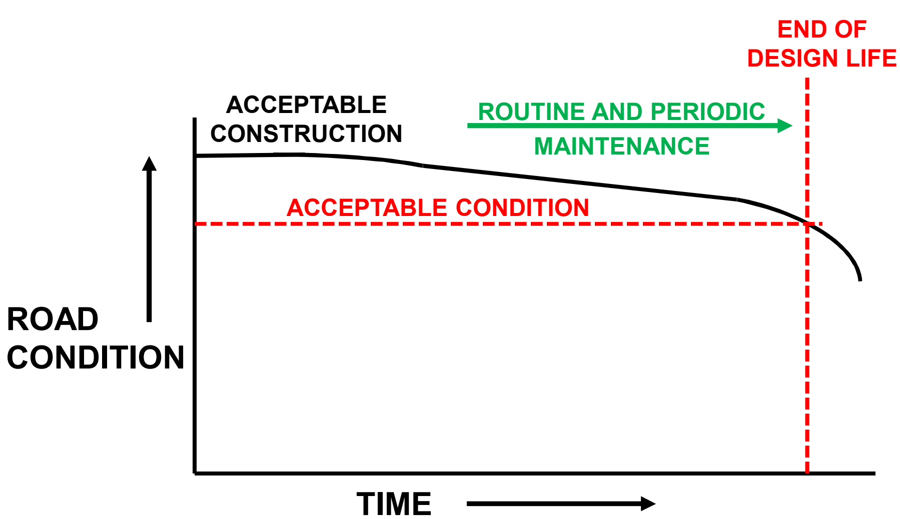
2. THE ROAD CONSTRUCTION AND MAINTENANCE CYCLE

The way in which a road behaves is obviously dependent on how it is initially constructed which is dictated by the initial road pavement design process as well as by the initial construction quality.

Roads are designed to last between twenty and thirty years but they will only carry traffic adequately for the full design life if they are correctly maintained during their life cycle.

This means that the road network must be properly maintained in order to maximise the life of the roads and minimise the rehabilitation and reconstruction costs.

Initial construction quality ?
Routine maintenance ?
Periodic maintenance ?
Maintenance or Rehabilitation required ?



CORRECT ROAD MANAGEMENT

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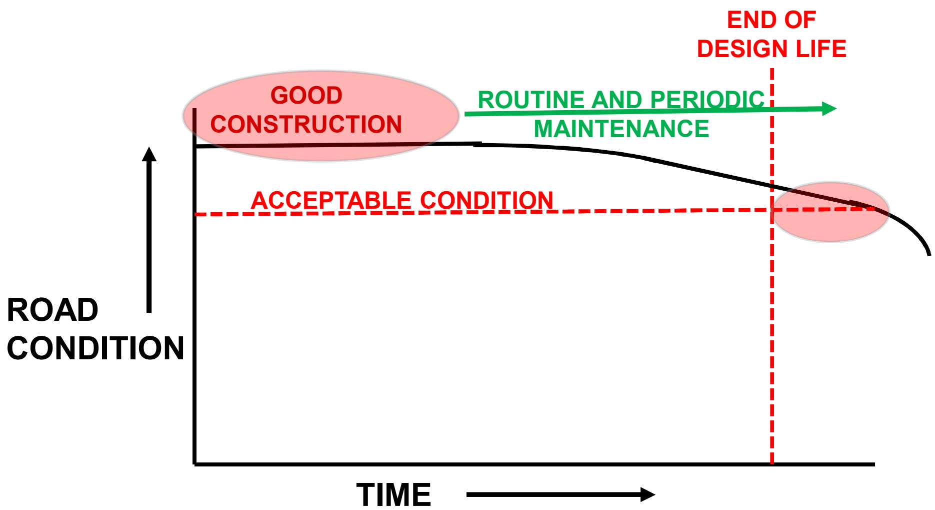

GOOD ROAD MANAGEMENT

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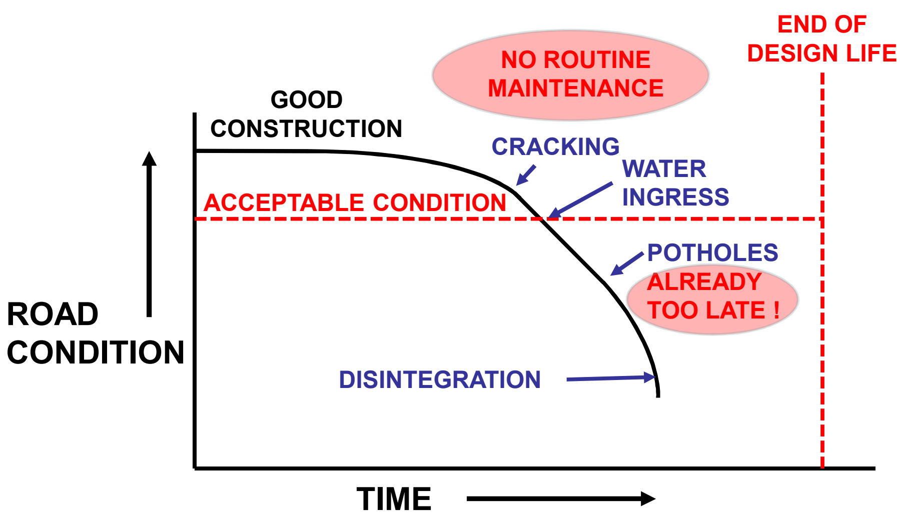
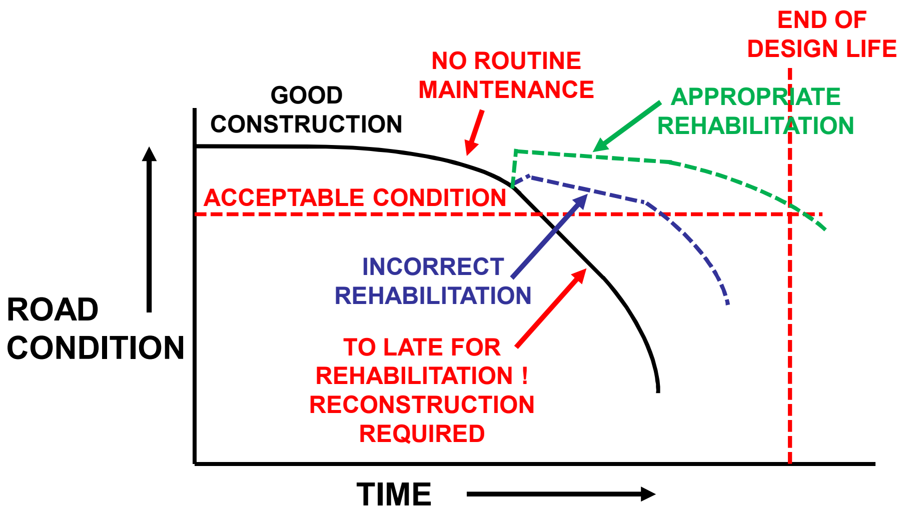


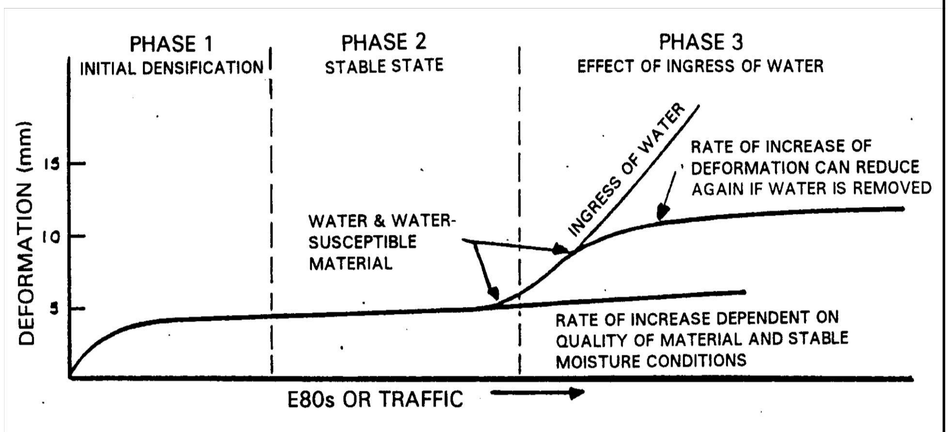
POOR ROAD MANAGEMENT



REHABILITATION INTERVENTIONS

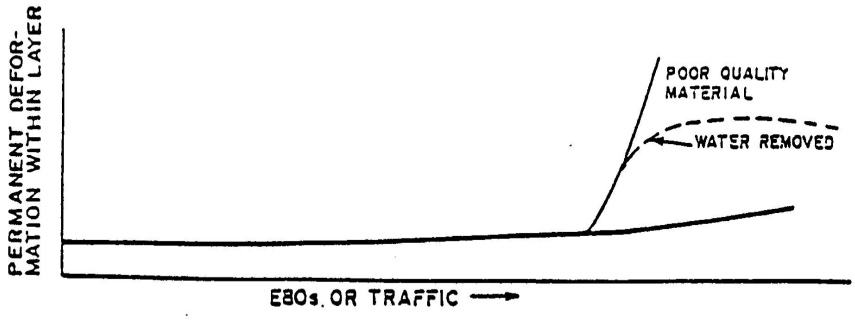
ROADS DETERIORATE WITH TIME DUE TO:

- **INSUFFICIENT MAINTENANCE**
- **CUMULATIVE TRAFFIC LOADING**
- **ENVIRONMENTAL FACTORS –**
  WATER, HEAT, COLD,
  ULTRA-VIOLET LIGHT AND OXYGEN.

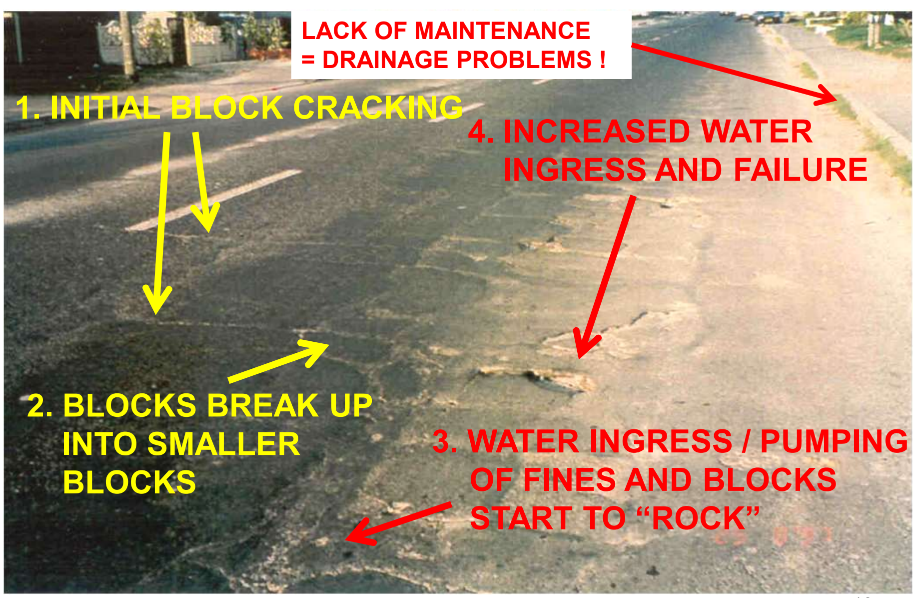


DETERIORATION OF GRANULAR PAVEMENTS

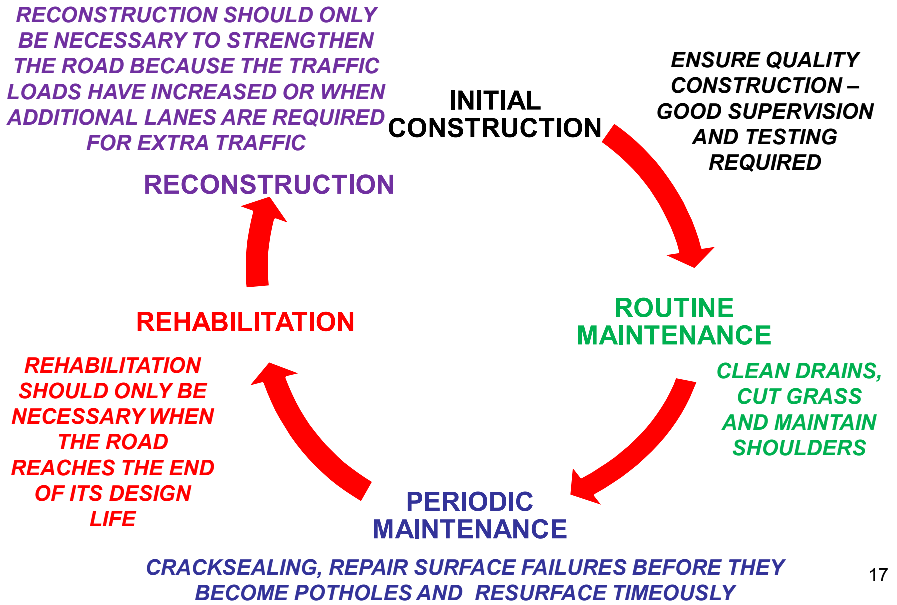
DETERIORATION OF GRANULAR PAVEMENTS



DETERIORATION OF CEMENTED PAVEMENTS



DETERIORATION OF CEMENTED PAVEMENTS



ROUTINE MAINTENANCE SIMPLY MEANS
KEEP THE WATER OUT OF THE ROAD PAVEMENT.

- **CLEAN AND MAINTAIN DRAINS AND CULVERTS**
- **MAINTAIN SHOULDERS**
- **CUT GRASS AND VEGETATION**

EVERY ROAD AUTHORITY SHOULD SEE THIS AS THEIR FIRST PRIORITY AS IT IS AN INEXPENSIVE WAY OF PRESERVING AN EXPENSIVE ASSET !

PERIODIC MAINTENANCE SIMPLY MEANS
KEEP THE WATER OUT OF THE ROAD PAVEMENT.

- **SEAL CRACKS AS SOON AS POSSIBLE**
- **REPAIR SURFACE FAILURES BEFORE THEY DEVELOP INTO POTHOLES**
- **RESEAL THE ROAD SURFACE BEFORE THE EXISTING SURFACE BECOMES PERMEABLE**

PERIODIC MAINTENANCE DOES NOT CONSIST OF PATCHING POTHOLES !

REHABILITATION OR RECONSTRUCTION SHOULD ONLY BE REQUIRED WHEN A ROAD REACHES THE END OF IT'S DESIGN LIFE.

THE DESIGN LIFE WILL NOT BE ACHIEVED UNLESS PROPER ROUTINE AND PERIODIC MAINTENANCE ARE CORRECTLY CARRIED OUT DURING THE LIFE OF THE ROAD.

DESIGN
TRAFFIC / AVAILABLE MATERIALS / DRAINAGE

CONSTRUCTION
QUALITY CONTROL

ROUTINE MAINTENANCE
DRAIN CLEANING / GRASS CUTTING / CRACK SEALING

PERIODIC MAINTENANCE
PATCHING / RESURFACING

REHABILITATION / RECONSTRUCTION
RESTORE ROAD / STRENGTHEN ROAD / WIDEN ROAD

THESE ROAD AUTHORITIES ARE NOT MANAGING THEIR ROADS PROPERLY !

NOT ONLY A SOUTH AFRICAN PROBLEM !

3. INITIAL ROAD NETWORK LEVEL ASSESSMENT

In order to manage a road network correctly you need to have a good Pavement Management System (PMS) that is kept up to date.

The correct use of a PMS will ensure that the current condition of every road is monitored regularly so that :

- **Routine maintenance is carried out properly.**
- **Roads are resurfaced before they allow water into the pavement structural layers.**
- **Road pavements are correctly rehabilitated when they reach the end of their design lives.**
- **The life of roads is maximised and the cost of road rehabilitation or reconstruction is minimised.**

A ROAD MANAGEMENT SYSTEM NEEDS THE FOLLOWING INFORMATION :

- **When was the road constructed ?**
- **What is the road pavement structure ?**
- **What resurfacing / rehabilitation has been done ?**
- **What is the cumulative traffic loading to date ?**
- **What is the estimated future traffic loading ?**
- **What is the current road condition ?**
- **How much is the pavement deflecting under wheel loads ? (This influences the rate of deterioration.)**
- **What environmental factors are influencing the pavement behaviour ? (Particularly poor drainage !)**

After entering the road as-built information the PMS is kept up to date by carrying out regular assessments of the current condition of every road in the road network. These assessments should ideally be done once a year (or every two years for minor roads).

THE ANNUAL ROAD ASSESSMENTS SHOULD INCLUDE MEASUREMENTS AND VISUAL ASSESSMENTS FOR :

(a) Riding quality
(b) Rutting
(c) Skid resistance (ideally)
(d) Pavement deflections
(e) Visual condition of the road
(f) Traffic volumes and loading

(a) RIDING QUALITY

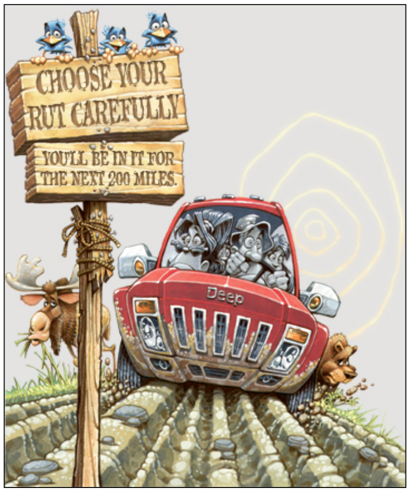
(a) RIDING QUALITY

"The deviation of a pavement surface from the true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and drainage. These dimensions are the longitudinal road profile (undulations), the transverse road profile (rutting) and the road cross slope variations."

RIDING QUALITY is expressed in terms of the International Roughness Index (IRI) which is :

- **calculated using a vehicle mounted laser profilometer to measure the longitudinal road profile in each wheel track.**
- **and is averaged for every 100 metre length of the road.**

(b) RUTTING



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(b) RUTTING

The depth of rutting is also measured across the transverse profile of the road using a vehicle mounted laser profilometer.

Rutting is recorded as the average rut depth measured at 10 m intervals and is usually averaged over a sector length of 1 km.

High speed profilometer used to measure riding quality & rut depths. (Some vehicles also video road signs etc.)

(c) SKID RESISTANCE

No reliable procedure is at present being used in any Southern African countries to measure skid resistance.

(The road authorities do not want to get sued – if they have surface skid resistance measurements these measurements will prove that many of the road surfaces are sub-standard.)

(c) SKID RESISTANCE

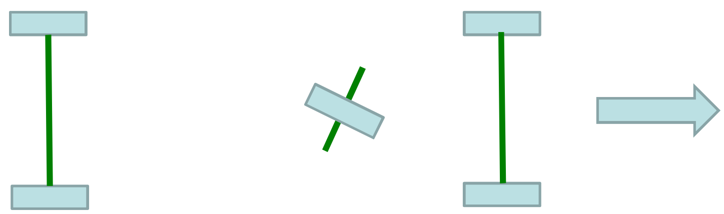
Methods that can be used to measure the skid resistance of a road surface include:

- **Sideways Coefficient Road Investigation Machine (SCRIM)**
- **Grip-tester**
- **Pendulum Tester**

SANRAL currently uses the surface texture depth (as measured by the high-speed laser profilometer) as an indication of the skid resistance.
(The texture depth indicates the ability of the road surface to dissipate surface water from under the tyres – it is not a true measure of skid resistance.)

SCRIM
(Sideways coefficient road investigation machine.)

Truck wheel revolutions
X revs/minute.



5^{th} wheel revolutions on rough and dry surface
0,5X revs/minute.

5^{th} wheel revolutions on smooth and dry surface
0,7X revs/minute.

5^{th} wheel revolutions on smooth and wet surface
0,9X revs/minute.

(d) PAVEMENT DEFLECTION MEASUREMENTS

The deflection of the road pavement under wheel loads is a measure of the strength or load carrying capacity of the road.

These measurements are analysed (together with the other road condition data) by the Pavement Management System to evaluate the structural condition of the road.

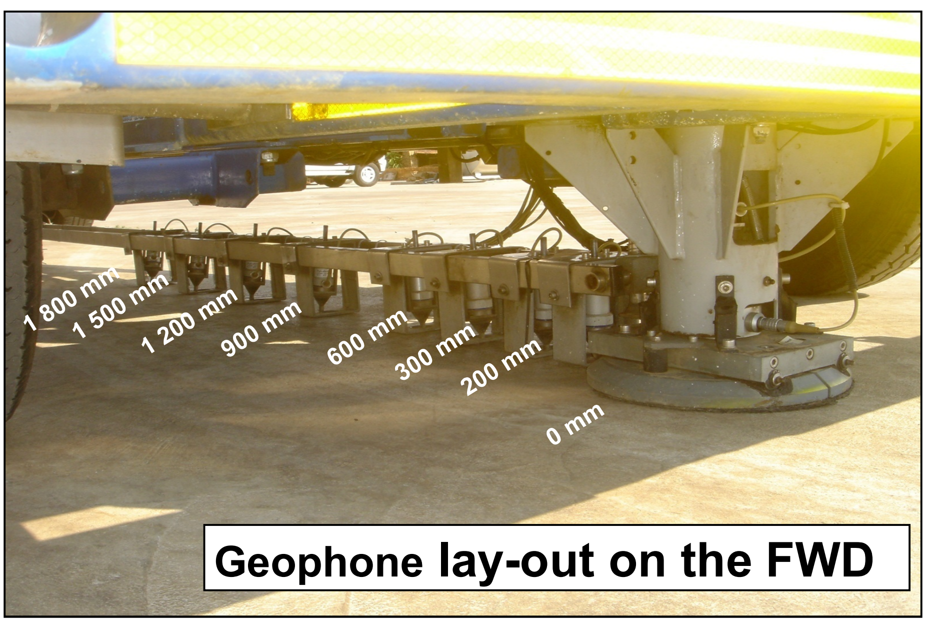
Road pavement deflections under traffic wheel loads can be measured in various ways :

Static or slow moving deflection measurements:
Benkelman beam or LaCroix deflectograph
(too slow for network level measurements)

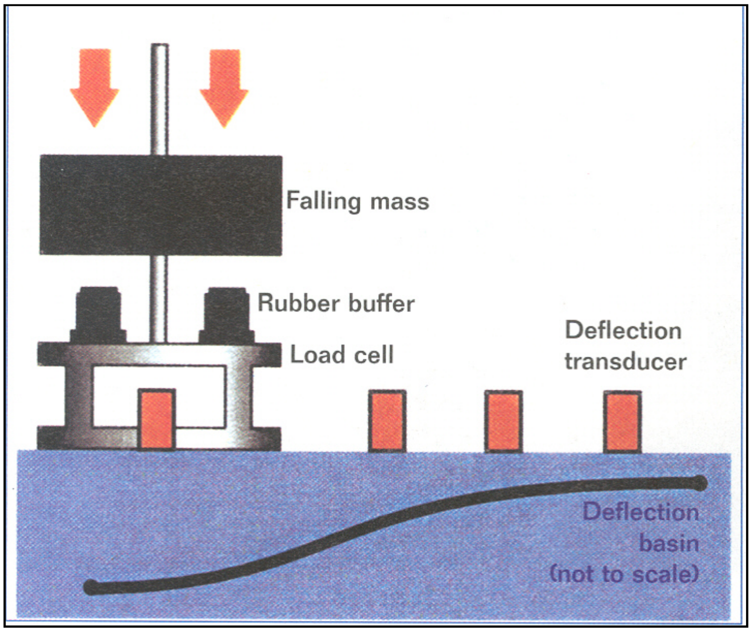
Dynamic impulse load deflection measurements:
Falling weight deflectometer (FWD)
(measures deflections under a falling weight)

Moving vehicle deflection measurements:
Rolling wheel laser deflectometer
(a true measure of pavement deflection under moving wheel loads)

Falling Weight Deflectometer



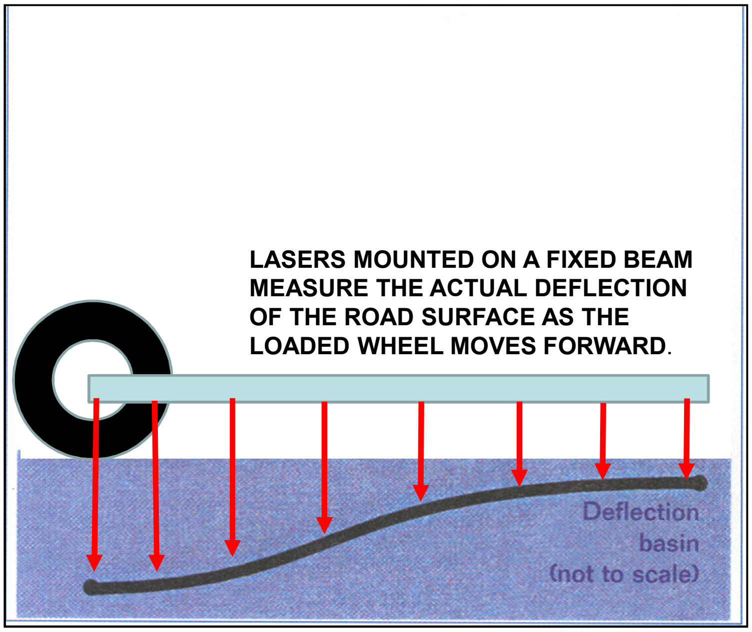
Geophone lay-out on the FWD


Falling mass
Rubber buffer
Load cell
Deflection transducer
Deflection basin (not to scale)

41


Rolling Wheel Deflectometer

42



NOTE :

In addition to using the road pavement deflection measurements to monitor the condition of the road pavements at the road network level these measurements can also be used as a detailed pavement analysis tool during the road project level rehabilitation assessment process.

The detailed analysis of the road pavement deflection measurements is described later in the next section of this course.

(e) VISUAL CONDITION SURVEY

This is the most important source of data as it provides a detailed picture of the current condition of every road in the road network.

We use TMH 9 to visually assess the following aspects of the road surface and the road pavement structure.

- **Aggregate loss, binder condition, bleeding.**
- **Cracking - block, crocodile, longitudinal & transverse.**
- **Pumping, rutting, patching, failures, pot holes.**
- **Shoulder condition and surface edge breaks.**

Assess the roads in segments of 5 km for rural roads and in street or block length for urban roads.

NOW REPLACED BY UPDATED MAY 2016 VERSION (Parts A & B)

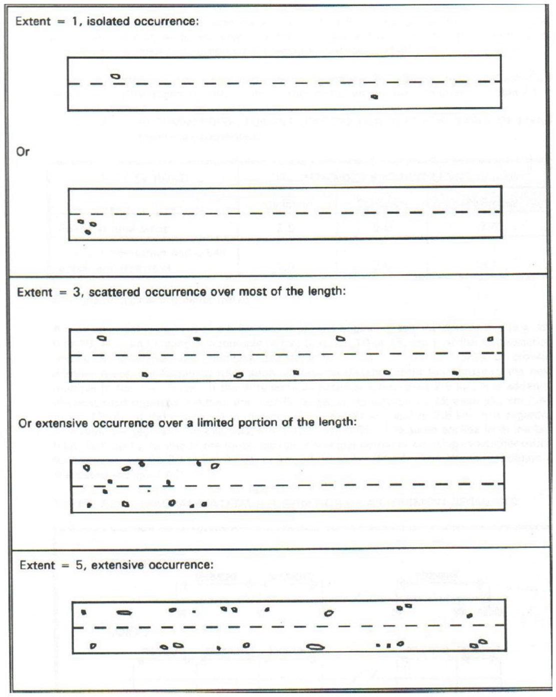
TMH 9 describes how to assess the road condition in a standardized manner.

Surfacing and Pavement Structural Defects are visually assessed by a trained assessor and recorded on a scale of 1-5 for degree of severity and for their extent over the road segment being surveyed.

A functional assessment of other items that affect the structural condition and/or safety of the road is also done at the same time. These items include road drains, culverts, road shoulder condition and surface edge breaking. Riding quality is also subjectively assessed to confirm (or supplement for) the instrument riding quality measurements.

TABLE A2: GENERAL DESCRIPTION OF DEGREE CLASSIFICATION

DEGREE	SEVERITY	DESCRIPTION
0	-	No distress visible.
1	Slight	Distress difficult to discern. Only the first signs of distress are visible.
2	Between Slight and Warning	
3	Warning	Distress is distinct. Start of secondary defects. (Distress notable with respect to possible consequences. Maintenance may be required in near future, e.g. cracks can be sealed.)
4	Between Warning and Severe	
5	Severe	Distress is extreme. Secondary defects are well developed (high degree of secondary defects) and/or extreme severity of primary defect (Urgent attention required).



1. ASSESSMENT OF THE ROAD SURFACE CONDITION

Surface texture / voids in the surfacing

Surface failures

Surfacing cracks ***(as opposed to structural cracks)***

Aggregate loss

Bitumen condition

Bleeding (or flushing) of the bitumen

The condition of the bituminous asphalt or seal surfacing layer affects the rate at which water enters and weakens the road pavement layers underneath.

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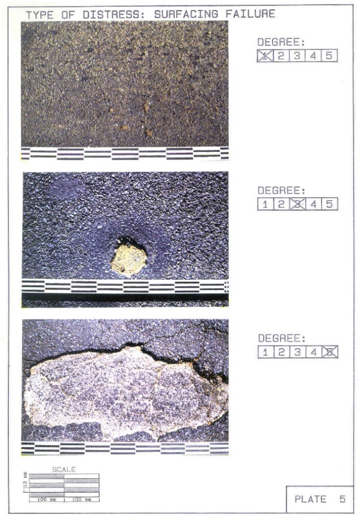
SURFACE TEXTURE / VOIDS

DUE TO AGGREGATE LOSS – DRY BITUMEN

SURFACE FAILURES



DUE TO AGGREGATE LOSS – DRY BITUMEN

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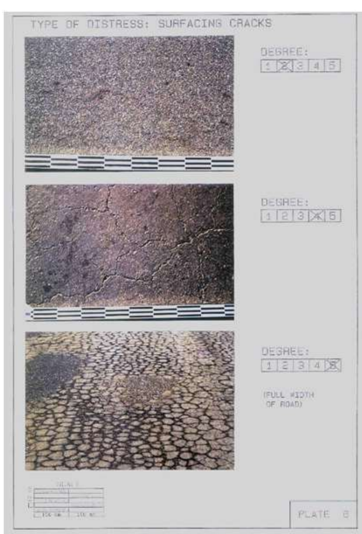
SURFACE CRACKS



DUE TO SHRINKAGE – DRY BITUMEN

BITUMEN BLEEDING

DUE TO SURPLUS BITUMEN / EXCESS TRAFFIC LOADING

2. ASSESSMENT OF THE ROAD PAVEMENT STRUCTURE

Cracks:
- **Block**
- **Crocodile**
- **Longitudinal**
- **Transverse**

Pumping

Rutting

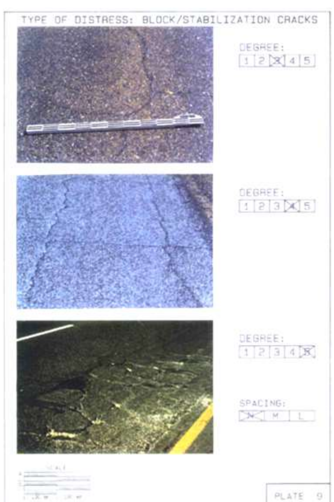
Settlement / undulations

Patching

Failures / potholes

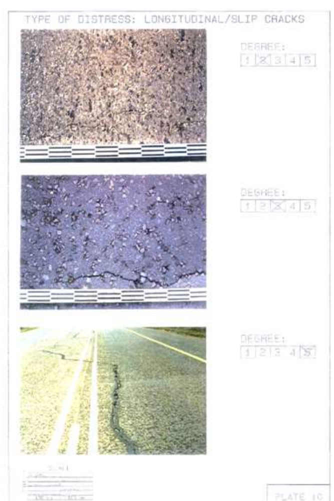
The condition of the road pavement layers affects the load carrying capacity of the road.

BLOCK CRACKING



DUE TO SHRINKAGE OF STIFF LAYERS

LONGITUDINAL CRACKS



DUE TO SETTLEMENT OF LAYERS AND/OR FILL OR ROADBED

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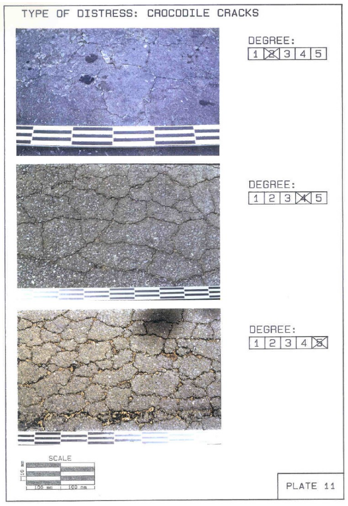
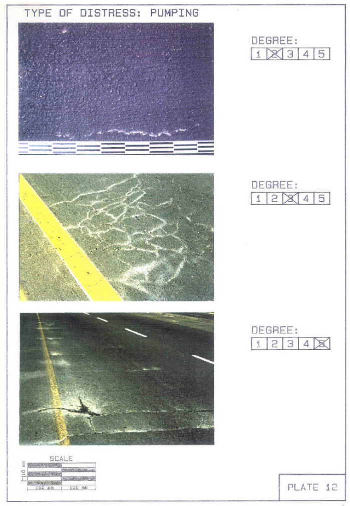
CROCODILE CRACKS



DUE TO WEAK BASE CAUSED BY WATER INGRESS

PUMPING



DUE TO SURPLUS WATER PUMPING UP UNDER WHEEL LOADS

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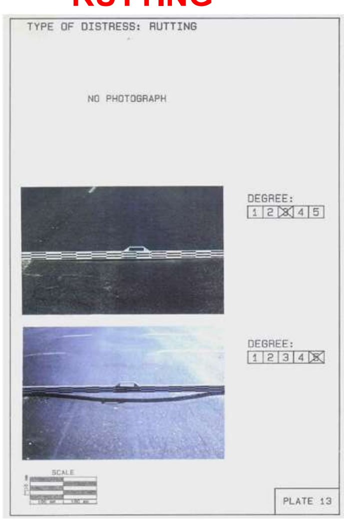
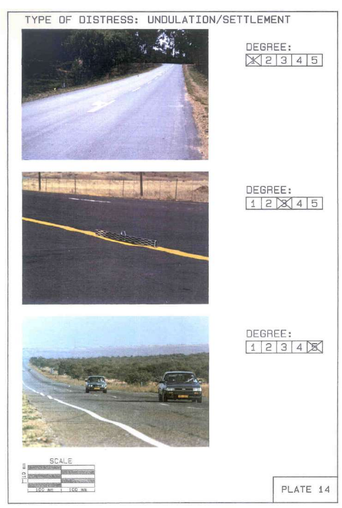
RUTTING



DUE TO DEFLECTION OF WEAK / WET LAYERS

UNDULATIONS



DUE TO MOVEMENT OF SUBGRADE / ROADBED

TABLE III

Various types of distress associated with each mode of distress

MODE OF DISTRESS	TYPE OF DISTRESS	
Pavement Deformation : Caused by weak pavement layers deforming under wheel loads. (Wet or poor quality material / clay or simply too much accumulated loading.)	Depressions Mounds Ruts Ridges Displacements Corrugations Undulations	Minor undulations caused by variable rutting. Major undulations caused by movement in clay subgrade or roadbed.
Structural Cracking : Caused by movement in the pavement layers due to settlement under loading, temperature related shrinkage, breaking up of upper layer under large deflections or cracking of stiff stabilised layers	→ Transverse cracks → Longitudinal cracks → Block cracks Map cracks → Crocodile cracks → Parabolic cracks Star cracks Meandering cracks Multiple cracks	
Surfacing failures : Caused by aging, dry, brittle bitumen and lack of maintenance..	Ravelling Potholes Edge breaks Patches	
Surface smoothening : Caused by excess bitumen or aggregate wear.	Bleeding Polishing	

WHILE CARRYING OUT THE VISUAL CONDITION SURVEY (TMH 9) THE FOLLOWING FUNCTIONAL PARAMETERS SHOULD ALSO BE RECORDED FOR EACH ROAD SEGMENT :

- **Riding quality** *
- **Skid resistance** *
- **Road drainage (side drains, subsoil drains, culverts)**
- **Shoulder conditions**
- **Surfacing edge breaks**

* **Visual confirmation of machine measurements**

District		Assessor					
Road Number		Date					
From (km)		Climate	Very Wet	Wet	Moderate	Dry	
To (km)		Terrain	Mount	Rolling	Flat		
		Width (m)					

SURFACING

		Texture	Varying	Fine	Medium	Coarse
		Voids	Varying	None	Few	Many

Current Surface

		DEGREE (SLIGHT) 1	2	3	4	(SEVERE) 5	EXTENT (ISOLATED) 1	2	3	4	(EXTENSIVE) 5
Failure/Patching	0										
Cracks	0										
Aggregate Loss	0										
Binder Condition	0										
Bleeding/Flushing	0										

STRUCTURE

N | M | L

		DEGREE (SLIGHT) 1	2	3	4	(SEVERE) 5	EXTENT (ISOLATED) 1	2	3	4	(EXTENSIVE) 5
Block/Stab. Cracks	0										
Longitudinal/Slip Cracks	0										
Transverse Cracks	0										
Crocodile/Failure Cracks	0										
Pumping	0										
Rutting	0										
Undulation/Settlement	0										
Patching	0										
Failures/Potholing	0										

FUNCTIONAL

Riding Quality		Very Good	Good	Fair	Poor	Very Poor
	Problems		Undulation	Moles	Corrugation	
Skid Resistance		Very Good	Good	Fair	Poor	Very Poor
	Problems			Bleeding	Polished	
Surfaced Drainage		Adequate	Warning	Inadequate		
	Problems	Rutting	Shoulders	Undulation	Failure	Side Drains
Unpaved Shoulders		Safe	Warning	Unsafe		
	Problems	Eroded	Rutted	Too High	Narrow	Inclined	Overgrown

		1	2	3	4	5	1	2	3	4	5
Edge Breaking	0										

SUMMARY

Type Action Needed	None	Structure			Surface			Routine	
		C	B	A	C	B	A	C	B	A

Overall Pavement Condition	Very Good	Good	Fair	Poor	Very Poor

OTHER EVALUATION

Road Markings	None	Very Good	Good	Fair	Poor	Very Poor

Capt1 Sign & Dt: .... 1 Capt2 Sign & Dt: ....

Western Cape Government
Transport and Public Works

WESTERN CAPE GOVERNMENT
PROVINCIAL ROADS NETWORK MANAGEMENT
PAVED ROAD VISUAL ASSESSMENT 2014

District		Assessor				
Road Number		Date				
From (km)		Climate	Very Wet	Wet	Moderate	Dry
To (km)		Terrain	Mount	Rolling	Flat	
		Width (m)				

SURFACING

Texture	Varying	Fine	Medium	Coarse
Voids	Varying	None	Few	Many

Current Surface

		DEGREE (SLIGHT → SEVERE)					EXTENT (ISOLATED → EXTENSIVE)				
		1	2	3	4	5	1	2	3	4	5
Failure/Patching	0										
Cracks	0										
Aggregate Loss	0										
Binder Condition	0										
Bleeding/Flushing	0										

STRUCTURE

N	M	L

		DEGREE (SLIGHT → SEVERE)					EXTENT (ISOLATED → EXTENSIVE)				
		1	2	3	4	5	1	2	3	4	5
Block/Stab. Cracks	0										
Longitudinal/Slip Cracks	0										
Transverse Cracks	0										
Crocodile/Failure Cracks	0										
Pumping	0										
Rutting	0										
Undulation/Settlement	0										
Patching	0										
Failures/Potholing	0										

Road Assessment Safety Rules :

1. Safety vests must be worn.
2. Safety vehicles must travel on shoulder behind the assessors working on the road.
3. Look left, right and left again before stepping onto the road.
4. Get someone to watch your back.
5. Use your eyes and your ears.

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FUNCTIONAL

Riding Quality		Very Good	Good	Fair	Pocr	Very Poor					
	Problems		Undulation	Moles	Corrugation						
Skid Resistance		Very Good	Good	Fair	Pocr	Very Poor					
	Problems			Bleeding	Polished						
Surfaced Drainage		Adequate	Warning	Inadequate							
	Problems	Rutting	Shoulders	Undulation	Failure	Side Drains					
Unpaved Shoulders		Safe	Warning	Unsafe							
	Problems	Eroded	Rutted	Too High	Narrow	Inclined	Overgrown				
		1	2	3	4	5	1	2	3	4	5
Edge Breaking	0										

SUMMARY

Type Action Needed	None	Structure			Surface			Routine		
		C	B	A	C	B	A	C	B	A
Overall Pavement Condition	Very Good	Good	Fair	Poor	Very Poor					

OTHER EVALUATION

Road Markings	None	Very Good	Good	Fair	Poor	Very Poor

Capt1 Sign & Dt: .... 1 Capt2 Sign & Dt: ....

(f) TRAFFIC LOADING

The number of heavy vehicles using the road obviously affects the rate of deterioration of the road pavement.
The heavy vehicle traffic count information therefore should be one of the inputs for the Pavement Management System.

THE DEGREE AND EXTENT OF EVERY DEFECT FOR EACH ROAD SEGMENT ARE ENTERED INTO THE PAVEMENT MANAGEMENT SYSTEM DATA BASE.

THE PMS THEN USES WEIGHTED ALGORITHMS TO CALCULATE FOR EACH ROAD SEGMENT :

- **THE RESEAL INDEX (RI)**
  (a measure of the condition of the surfacing)
- **THE VISUAL CONDITION INDEX (VCI)**
  (a measure of the condition of the road pavement)

Each Defect Index Value = Degree x Extent x Weighting Factor.

- ***The sum of all the surfacing defect index values = the RI***
- ***The sum of all the structural defect index values = the VCI***

(Both sets of index values expressed as a percentage)

BASIC PAVEMENT MANAGEMENT SYSTEMS

A basic level PMS analyses only the visual assessment data in order to prioritize the road network rehabilitation and resurfacing requirements by ranking each road in order of :

- **the Visual Condition Index which determines the amount of rehabilitation (or reconstruction) required**

and

- **the Reseal Index if only resealing (possibly with some crack sealing and patching) is required.**

The road network rehabilitation and resurfacing projects are then planned according to the ranking provided by the PMS.

HIGH LEVEL PAVEMENT MANAGEMENT SYSTEMS

THERE ARE ALSO HIGH LEVEL PAVEMENT MANAGEMENT SYSTEMS AVAILABLE WHICH ANALYSE ALL THE AVAILABLE DATA USING "Fuzzy Logic" IN ORDER TO SUGGEST SUITABLE RESURFACING AND REHABILITATION MEASURES.

THE PMS CAN THEN ALSO COST THE RECOMMENDED MEASURES USING STANDARD UNIT RATES. THIS ALLOWS THE SYSTEM TO CALCULATE THE COSTS FOR EACH ROAD AND THESE COSTS CAN THEN BE ACCUMULATED AGAINST THE AVAILABLE BUDGET OR USED TO ESTIMATE THE FOLLOWING YEAR'S BUDGET REQUIREMENTS.

IN ADDITION TO THE VISUAL ROAD ASSESSMENT DATA THESE HIGH LEVEL PAVEMENT MANAGEMENT SYSTEMS ALSO ANALYSE THE FOLLOWING DATA :

1. ROAD PAVEMENT CONSTRUCTION INFORMATION

As-built pavement data
(materials used and layer thickness)

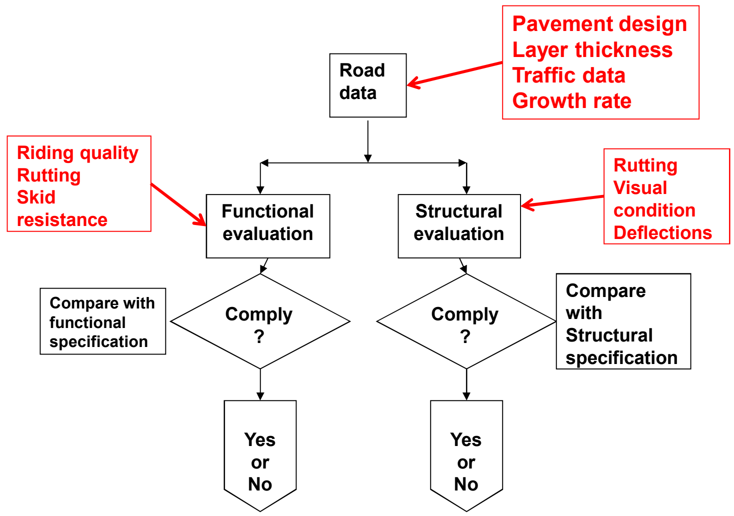
2. CURRENT ROAD ASSESSMENT DATA

Rutting measurements
Visual condition survey data
Deflection measurements

3. TRAFFIC LOADING CALCULATED FROM TRAFFIC COUNT DATA

(E80's per lane/day & traffic growth rate calculated as described in the next part of this course)

PAVEMENT MANAGEMENT SYSTEMS



PAVEMENT MANAGEMENT SYSTEM OUTPUTS :

Option 1: Functional Yes + Structural Yes : **Do nothing**

Option 2: Functional No + Structural Yes : **Resurface**

Option 3: Functional No + Structural ± Yes : **Light Rehab.**

Option 4: Structural No: : **Heavy Rehab.**

OPTION 1 : DO NOTHING

OPTION 2 : RESURFACE THE ROAD

FUNCTIONAL FAILURE MODE	POSSIBLE REHAB. OPTIONS
Riding quality:	- Asphalt overlay. - Slurry pre-treatment to better riding quality plus resurfacing.
Rutting:	- Rut filling by asphalt, coarse slurry or quickset slurry. - Resurface.
Rutting with asphalt deformation:	- Milling of rutted areas and replace. with asphalt.
Skid resistance:	- Resurface.
Visual aspects such as pot-holes etc.:	- Patch and resurface.
Visual aspects indicate asphalt fatigue:	- Resurface or mill and replace asphalt
Visual aspects: Cracking.	- Seal cracks and resurface.

OPTION 3: RESURFACE WITH LIGHT REHAB. ACTIONS

Only fix those areas that have failed or are about to fail before resurfacing the road.

Selective patching and / or mill & replace the failed layers in selected areas.

Be careful of doing relatively expensive patching and resurfacing on a road pavement structure that has already failed or is about to fail just because the funds for the required heavy rehabilitation are not available. You will just be wasting money !

OPTION 4 : REHABILITATION OF ROAD LAYERS

Due to extensive distress the road pavement cannot be economically patched and resurfaced and rehabilitation and / or strengthening of the road pavement structure is required.

When such a road (or section of a road) is identified during the NETWORK level analysis then a more detailed PROJECT level investigation and analysis is carried out in order to select the best rehabilitation measures.

4.
PROJECT LEVEL ASSESSMENT

WHEN THE PAVEMENT MANAGEMENT SYSTEM HAS IDENTIFIED AND PRIORITISED THE ROAD RESURFACING AND REHABILITATION NEEDS OF THE ROADS IN THE WHOLE ROAD NETWORK WE CAN SELECT WHICH ROADS TO WORK ON.

FOR EACH OF THESE ROADS WE NEED TO CARRY OUT A MORE DETAILED PROJECT LEVEL ANALYSIS IN ORDER TO SELECT THE BEST AND MOST COST EFFECTIVE MAINTENANCE OR REHABILITATION MEASURES.

SARF ROAD PAVEMENT REHABILITATION COURSE

THE PROJECT LEVEL ASSESSMENT PROCESS GATHERS ALL THE INFORMATION ABOUT THE ROAD PAVEMENT AND ITS CURRENT CONDITION.
(as described in this section of the course)

WE THEN ANALYSE ALL THIS INFORMATION TO DETERMINE THE CONDITION AND STRENGTH (= load carrying capacity) OF THE ROAD PAVEMENT.

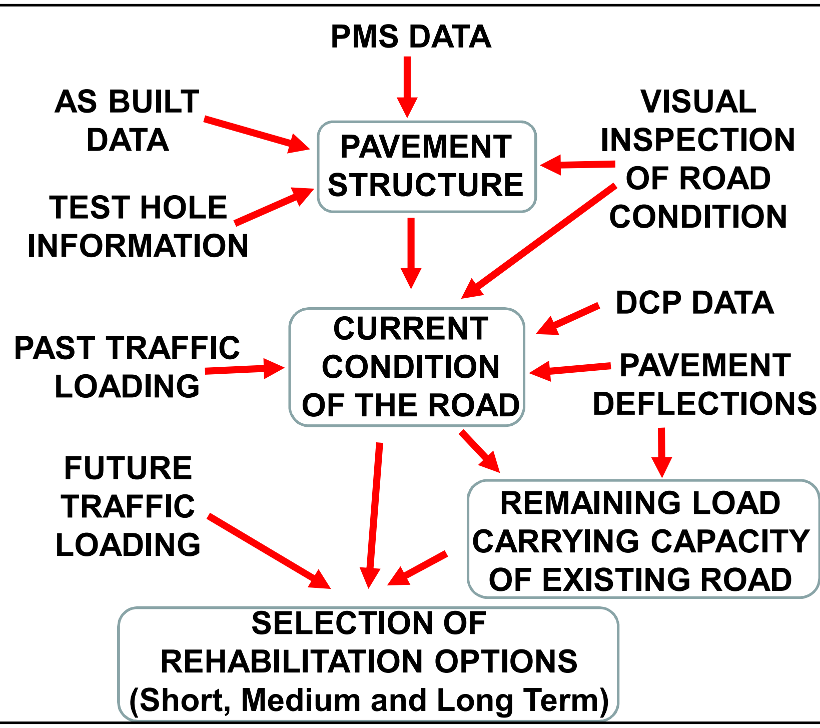
WE THEN COMPARE ITS LOAD CARRYING CAPACITY WITH THE LOAD THAT THE ROAD PAVEMENT STILL NEEDS TO CARRY.

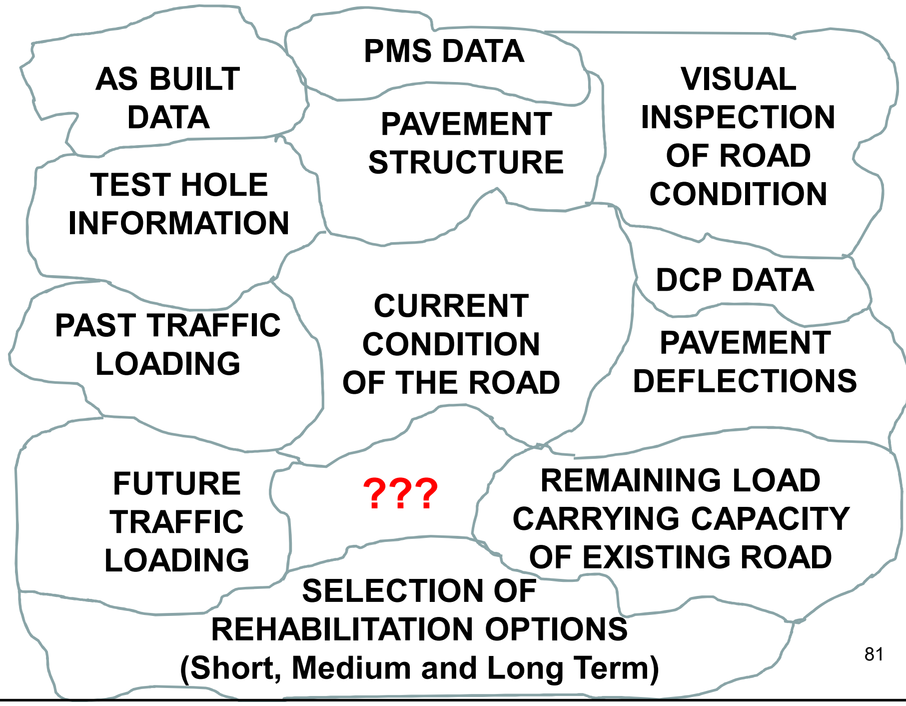
WE WILL THEN BE ABLE TO DECIDE ON THE CORRECT REHABILITATION MEASURES.
(as described later in the course)

Once it has been decided to rehabilitate any particular road (as identified for rehabilitation by the pavement management system) then we first review the network level data (RQ, rut depths and deflections) and the PMS condition indices so that we can get an initial understanding of the condition of the road.

In order to determine the type and extent of the defects and find out how and why the defects have occurred we need to obtain much more detailed data by :

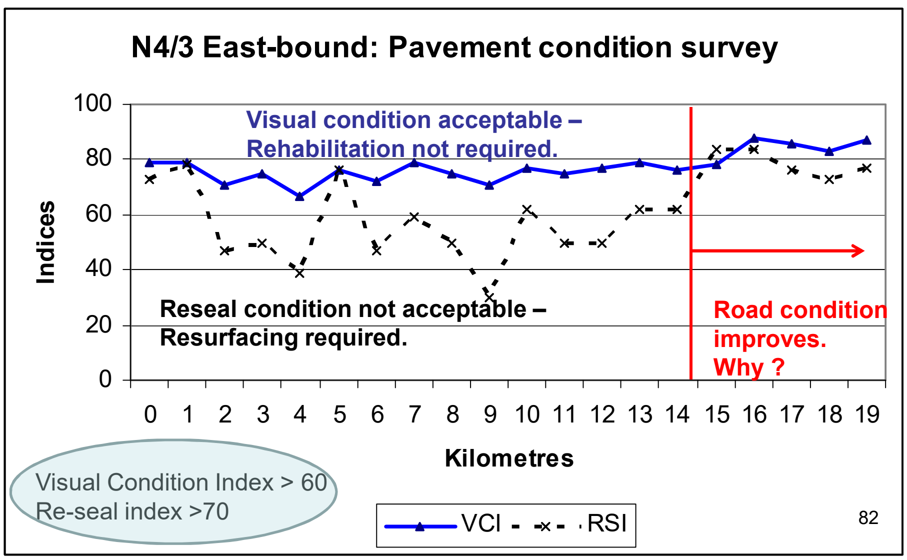
(a) Reviewing the as-built materials data if available.
(b) Carrying out a DETAILED VISUAL INSPECTION.
(c) Doing deflection tests, preferably every 100 m (if not already available from the PMS).
(d) Excavating test pits and testing the road layers.
(e) Carrying out Dynamic Cone Penetrometer (DCP) tests.
(f) Determining the past and future traffic loading.



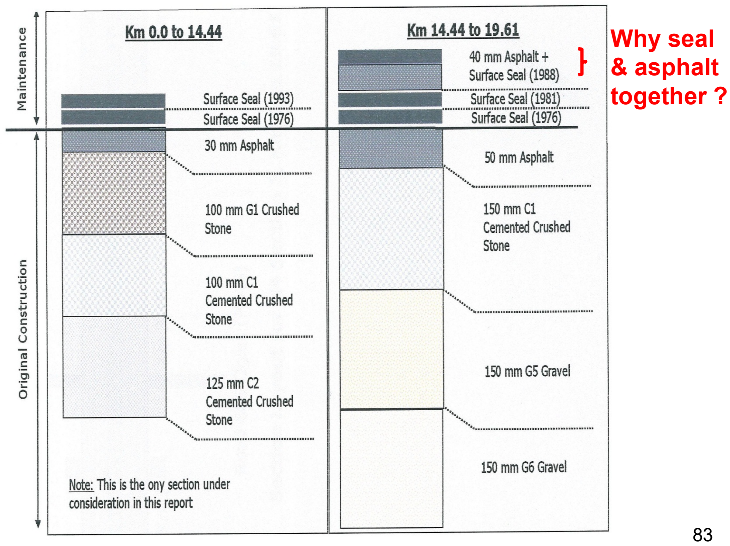


SARF ROAD PAVEMENT REHABILITATION COURSE

General Condition obtained from Network Level PMS Indices.



(a) AS–BUILT DATA INDICATES TWO PAVEMENT TYPES ALONG THE ROAD.



(b) DETAILED VISUAL INSPECTION

A Detailed Visual Inspection is carried out by walking the road and marking the position of each type of defect (TRH 6) accurately on assessment sheets and recording the degree of each defect (TRH 6 / TMH 9).

The pavement assessment includes shoulder condition and edge breaking.

The Drainage and Road Furniture are also assessed :
- **Sub-surface drains**
- **Culverts and pipes with inlet and outlet structures**
- **Corrosion of metal culverts**
- **Side drains and down- chutes**
- **Erosion of cut and fill slopes**
- **Guardrails and road signs**

DATE . 29/4/82   ROAD P12/1   DIRECTION S N   PAGE No 1

NAME: J SMITH   LANE: SLOW   CHAINAGE 16,0 - 16,5

NB: READ INSTRUCTIONS BEFORE USE

CHAINAGE (km)		16,0	16,1	16,2	16,3	16,4	16,5
CRACKING	POSITION (ROAD WIDTH)						
	TYPE	L	C	T			
	DEGREE	3	4	3			
	SPACING (m)			2			
DEFORMATION	POSITION (ROAD WIDTH)						
	TYPE		RU	CO			
	DEGREE		3/3	2			
	SPACING (m)			2			
BREAKING-UP OF SURFACE	POSITION (ROAD WIDTH)						
	TYPE	EB	PH PA			PA	EB
	DEGREE	5	4				5
			5x1			10x1	
SMOOTHING OF SURFACE	POSITION (ROAD WIDTH)						
	TYPE					BL	
	DEGREE					3	
CONSTRUCTION DETAILS AND DEFICIENCIES	POSITION (ROAD)						
			BLOCKED DRAIN				
	CUT / FILL	F1	C1		F4		
TOPOGRAPHY VEGETATION GEOLOGY	POSITION (ROAD)						
	TYPE		GRASS REEDS				

DETAILED VISUAL ASSESSMENT INSPECTION

Road :   Assessor : ____________   Date : ____________

KILOMETRE		0.0	0.5	1.0	1.5	2.0	2.5
DRAINAGE STRUCTURES (State size & No. of openings) B = BLOCKED C = CLEAN E = ERODED OUTLET HD = H/WALL DAMAGE NH = NO HEADWALL S = STRUCT. DEFECT	WEST						
	EAST						
DRAINAGE (OPEN DRAINS) B = BLOCKED C = CLEAN E = ERODED S = SHALLOW L = LINED	WEST						
	EAST						
GUARDRAILS D = DAMAGED G = GOOD COND. P = DAMAGED POSTS R = RUSTED RAILS RP = REPAINT RR = REPLACE REFLECTORS	WEST						
	EAST						
BERMS	W						
	E						
ROAD SIGNS D = DAMAGED F = FADED G = GOOD COND. P = POST DAMAGED M = MISSING	WEET						
	EAST						
FENCING D = DAMAGED G = GOOD COND. MP = MISSING POLES MW = MISSING WIRE RP = RUSTED POLES RW = RUSTED WIRE	WEST						
	EAST						
LAYBYES F= FORMAL IF = INFORMAL	W						
	E						
REMARKS							

EVALUATE VISUAL DATA INTO SOUND, WARNING AND SEVERE CATEGORIES USING THE METHODOLOGY GIVEN IN TRH 6.

The Evaluation Criteria are defined as:

Sound : adequate condition (no action required)

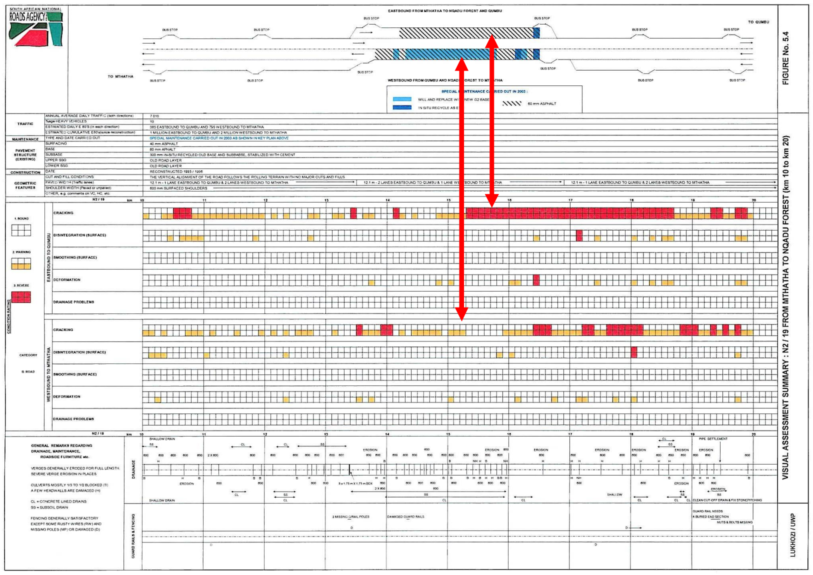
Warning : uncertainty about adequacy of condition (attention required soon)

Severe : inadequate condition (action urgently required)

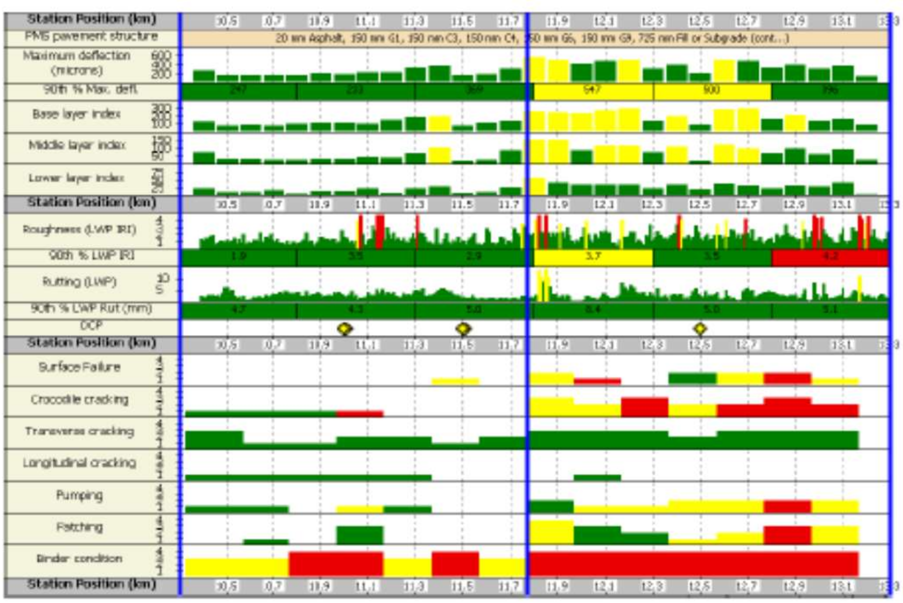
THE DEGREE AND EXTENT OF EACH DEFECT IS ANALYSED (TRH 6) AND THE RESULTS MARKED ON A SUMMARY FORM AS "SOUND", "WARNING" OR "SEVERE" TO CREATE A VISUAL PICTURE OF THE OVERALL ROAD CONDITION.

TRH 6 EVALUATION CRITERIA –
DEFECTS AS A PERCENTAGE OF ROAD LENGTH OR AREA :
SOUND < X
WARNING > X AND < Y
SEVERE > Y.

Distress Parameters	Category of road					
	A		B		C and D	
	X	Y	X	Y	X	Y
Cracking:						
- Crocodile	5	15	10	20	15	25
- Longitudinal	30	60	45	75	60	90
- Other *	10	30	20	40	30	50
Deformation	5	15	10	20	15	25
Disintegration						
- Patching	10	30	20	40	30	50
- Ravelling	20	40	30	50	40	60
Smoothening	20	40	30	50	40	60



FROM THE AS-BUILT ROAD PAVEMENT DATA AND THIS SUMMARY YOU CAN START TO "UNDERSTAND" THE ROAD.



IN ORDER TO "UNDERSTAND" THE CONDITION OF THE ROAD FROM THE DEGREE AND EXTENT OF THE DIFFERENT DEFECTS YOU HAVE IDENTIFIED YOU FIRST NEED TO HAVE A GOOD UNDERSTANDING OF WHY AND HOW A ROAD PAVEMENT FAILS.

SURFACING FAILURES OCCUR BECAUSE :

EITHER

- **THE ROAD PAVEMENT STRUCTURE IS TOO WEAK TO CARRY THE TRAFFIC LOAD AND IT IS NOW DEFLECTING MORE THAN THE BITUMEN IN THE SURFACING CAN DEFORM WITHOUT CRACKING**

AND / OR

- **THE BITUMEN SURFACING HAS BECOME DRY AND BRITTLE DUE TO OXIDATION**

AND / OR

- **THE BITUMEN SURFACING HAS WORN AWAY.**

STRUCTURAL FAILURES IN THE PAVEMENT OCCUR BECAUSE :

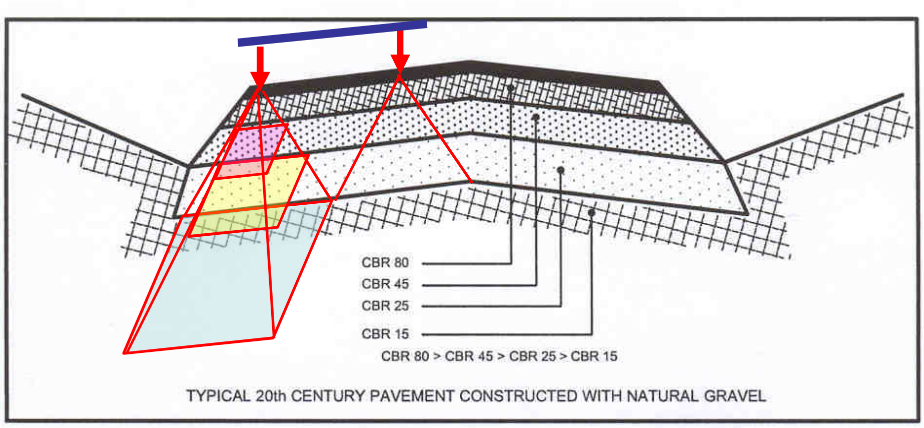
EITHER

- **THE ROAD PAVEMENT STRUCTURE IS NO LONGER CAPABLE OF CARRYING THE INCREASED TRAFFIC LOADS AS IT IS TOO WEAK / NOT THICK ENOUGH.**

OR

- **THE PAVEMENT LAYER MATERIALS HAVE BECOME WET AND LOST STIFFNESS.**

Water ingress occurs through old, brittle, cracked bitumen surfacing and/or from the side or underneath the road pavement layers.



ROAD PAVEMENT LAYERS REDUCE IN STIFFNESS WITH DEPTH AS THE LOAD INDUCED STRESSES ALSO REDUCE:

BASE : CBR > 80

SUB-BASE : CBR > 45 **(Stress = Wheel Load / Area)**

SUBGRADE : CBR > 25

ROADBED / FILL : CBR > 15

PAVEMENT LAYER MATERIALS LOSE STRENGTH QUICKLY WHEN WET BECAUSE :

- **The water acts as a lubricant and reduces the inter-particle friction.**
- **Excess water pushes the particles apart to the point where you lose nearly all the inter-particle friction and the material starts to "pump".**
- **Any clay in the material expands when wet. This reduces the density and therefore the inter-particle friction. The fluid nature of the wet clay also acts as a further lubricant.**

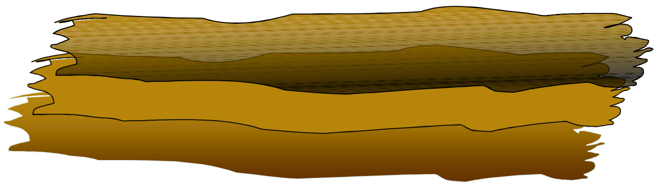
ANY REDUCTION IN INTER-PARTICLE FRICTION REDUCES THE STIFFNESS OF THE ROAD PAVEMENT LAYER AND THE MATERIAL THENS CRACKS, RUTS AND DEFORMS.

THE EFFECT THAT CLAY HAS ON THE STIFFNESS OF A GRANULAR ROAD MATERIAL IS THEREFORE VERY SIGNIFICANT.

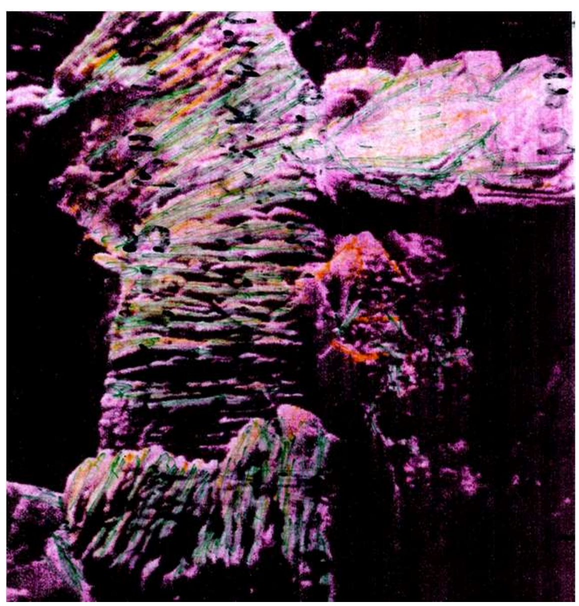
IF THE CLAY IS AN EXPANSIVE TYPE OF CLAY THEN VERY SMALL AMOUNTS OF CLAY CAN WEAKEN THE PAVEMENT LAYER.

IT IS THEREFORE IMPORTANT TO UNDERSTAND THE TYPES OF CLAY AND THEIR BEHAVIOUR.

A CLAY PARTICLE CONSISTS OF A GREAT NUMBER OF VERY SMALL PLATELETS



Adsorbed water is held on the surface of each platelet so water enters and is retained between each platelet. This causes the clay to expand.



A Kaolin particle @ 7 000 magnification

Clay will expand no matter how much fill you place on top of a clay layer.

Clay ADSORBS more water when any is available.

Clays swell, dry out and swell again repeatedly every wet and dry season !

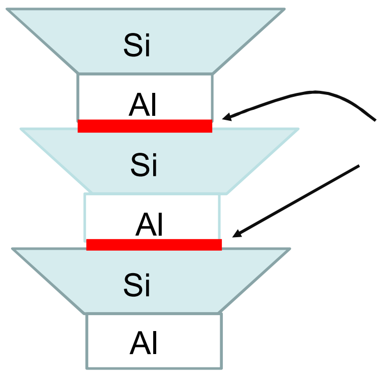
OVER TIME GOOD ROAD MATERIALS USED IN THE ORIGINAL PAVEMENT WEATHER AND IN SOME MATERIALS CLAY FORMS DURING THIS WEATHERING PROCESS.

(FOR EXAMPLE A GOOD G5 SUBBASE MATERIAL COULD DETERORIATE OVER TIME INTO A POOR G9 MATGERIAL)

Note : Refer to new COTO Specification – Chapter 4 for rock types and their weathering characteristics.

Kaolin

Particle Size:
Dia. = 0,3 – 2 μm
Thickness = 0,03 – 0,2 μm

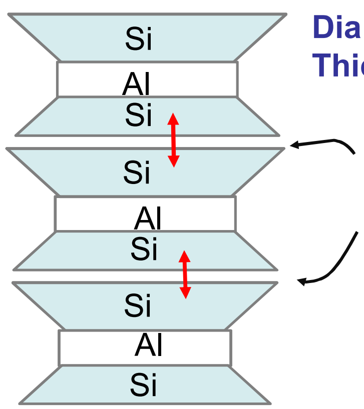


Opposite electrical charges on the aluminlum and silica platelets creates a weak bond so harder for water to penetrate.

Kaolin has a low water adsorption and therefore it has a lower swell potential.

Montmorillonite

Particle Size:
Dia. = 0,01 – 0,1 μm
Thickness = 0,0001 – 0,001 μm



Same electrical charges on the silica platelets repel each other so it is very easy for water to penetrate. Particle size also much smaller as charges keep them separate.

Montmorillonite has a large water adsorption and therefore it has a high swell potential.

The amount of clay in a soil is measured by the ATTERBERG LIMITS.
(Liquid, plastic and shrinkage limits)

These limits can also tell us what type of clay is present.

The type of clay determines the degree of expansiveness of the soil when it gets wet.

LIQUID, PLASTIC & SHRINKAGE LIMITS

LIQUID LIMIT (LL)

The LL of a soil is the moisture content of a soil at the boundary between the liquid and plastic states. (TMH 1 – Method A2)

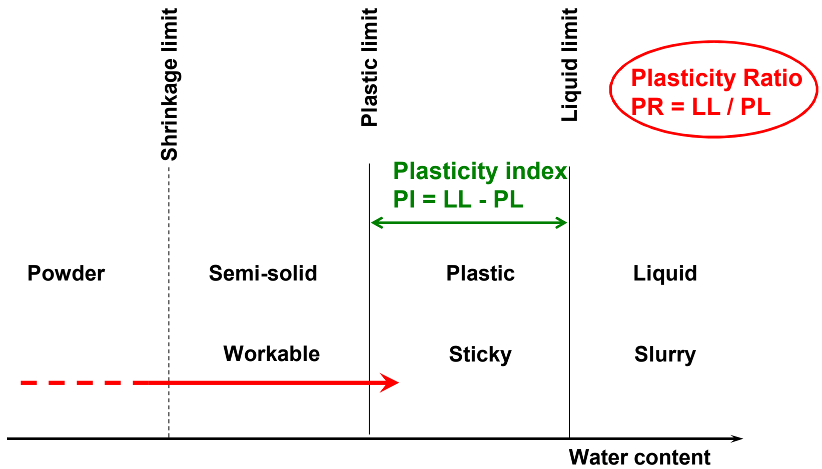
PLASTIC LIMIT (PL)

The PL of a soil is the moisture content of a soil at the boundary between the plastic and semi-solid states. (TMH 1 – Method A3)

SHRINKAGE LIMIT (SL)

The SL of a soil is the moisture content where further loss of moisture will not result in any more volume reduction. (ASTM – Method D4943)

LIQUID, PLASTIC & SHRINKAGE LIMITS



PLASTICITY INDEX, PLASTICITY RATIO AND SHRINKAGE LIMIT

PLASTICITY INDEX : PI
The PI of a soil tells us the quantity of water the clay in the soil can hold
PI = LL – PL

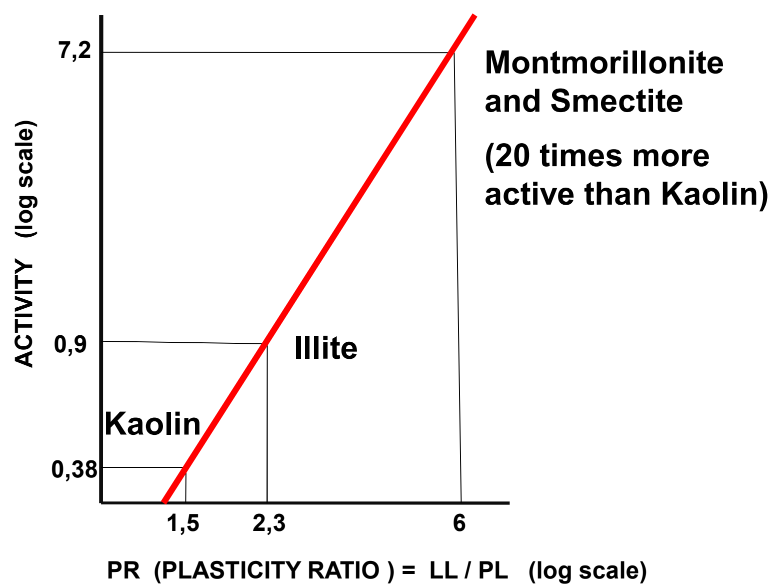
PLASTICITY RATIO : PR
= LL / PL
The PR tells us the TYPE of clay in the soil

SHRINKAGE LIMIT : SL
The SL tells us how much the clay will and shrink and crack when dry and swell again when wet.

Important Clay Types

Clay type	Montmorillonite	Illite	Kaolin
	Very small particles	*Small particles*	
Specific Surface m^2/g	200 – 800	80 – 100	20 – 40
Plasticity Index *	200 – 650	45 – 70	12 - 33
Shrinkage Limit	10 - 15	14 – 18	25 – 30
Plasticity Ratio	> 3.0	2 - 3	< 1,5

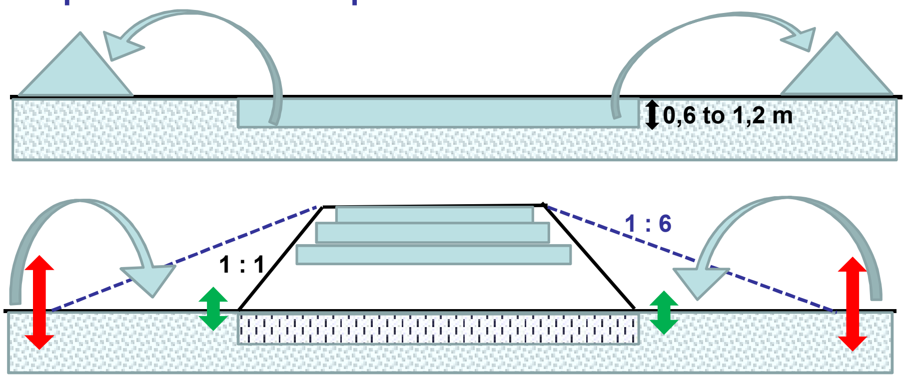
- (PI of the clay, not of the soil containing some clay which is the PI result you get from the laboratory test.)



Clay Activity = $0{,}16 \times PR^{2{,}13}$

UNDULATIONS DUE TO EXPANSION OF CLAY IN THE SUBGRADE LAYERS, FILL OR ROADBED.

Because clay expands when wet and shrinks when dry it must be removed from under the road formation and replaced with non-expansive material.



Place clay back on fill side slopes to waterproof them.

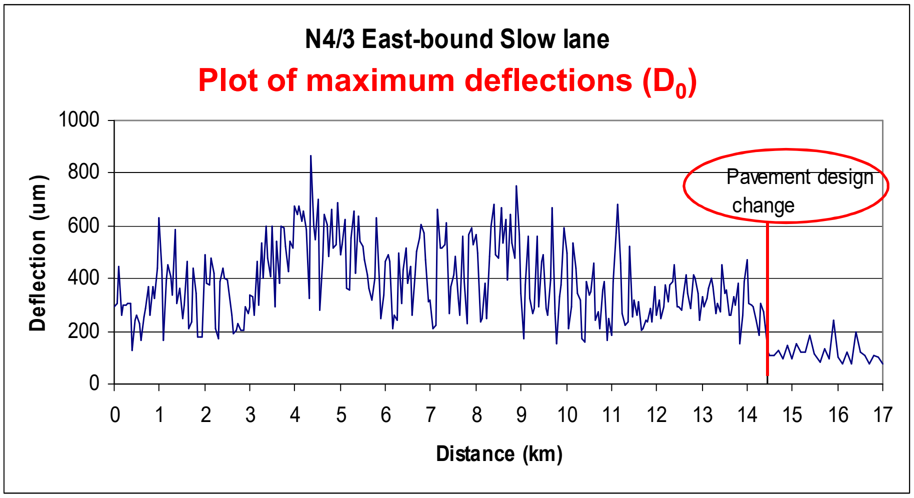
(c) DEFLECTION TESTING

FWD most frequently used in RSA and new rolling wheel laser measurements (SANRAL).

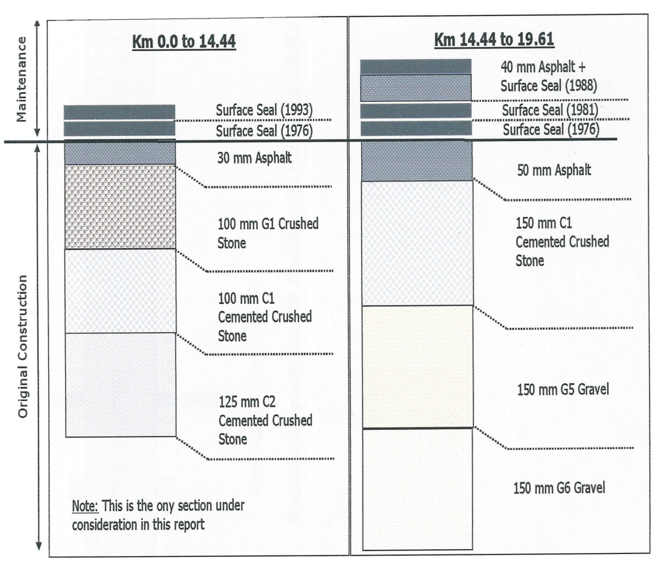
FWD measurements sometimes done every 200m or even 500 m for network level assessments but for project level assessments measurements should be done every 100 m. (Sometimes done every 100 m staggered = every 200 m on each lane to save costs.)

Rolling wheel deflection measurements can be done at very close intervals (every 10 m) without affecting the cost.

Measurements done in slow lane LHS wheel path !



Other deflections (D_{200} D_{300} D_{600} D_{900} $D_{1\ 200}$ and $D_{1\ 800}$ are also measured.

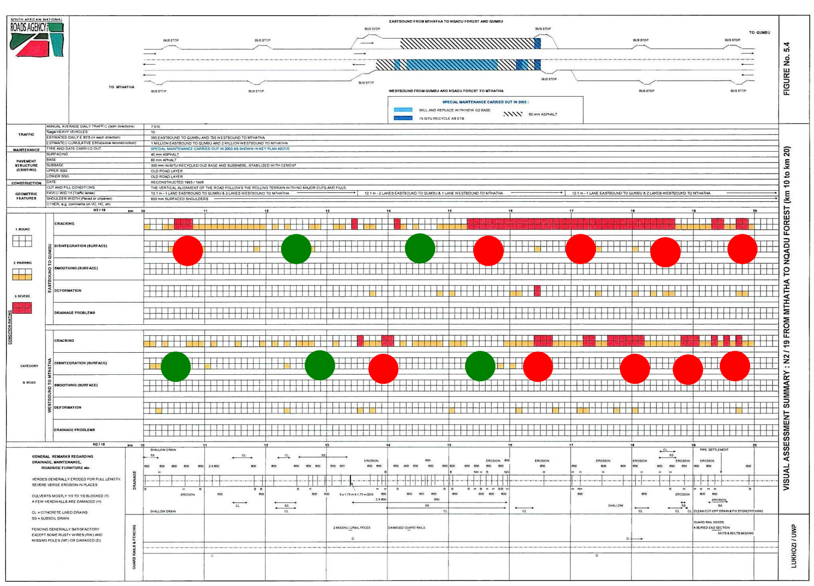


(d) TEST PITS (Field investigation)

The selection of the test pit positions can be done in two ways :

1. Use the differences in road pavement structure as indicated by the as-built data to divide the road into sections and then for each section use the visual assessment summary sheet to select "good" and "bad" spots to investigate with the test pits.

2. Use the D_0 deflection data to calculate Uniform Sections and then excavate test pits at the 90^{th} or 95^{th} percentile maximum deflection position for each Uniform Section.



FROM THE THIS VISUAL ASSESSMENT SUMMARY FORM YOU CAN SELECT "GOOD" (5) AND "BAD" (10) TEST PIT POSITIONS.

IT IS MORE SCIENTIFIC TO DETERMINE UNIFORM SECTIONS OF ROAD PAVEMENT ALONG THE LENGTH OF THE ROAD UNDER INVESTIGATION USING THE MAXIMUM DEFLECTION DATA (D_0).

THE TEST PITS ARE THEN SELECTED WITHIN EACH UNIFORM SECTION AT (or near) THE 90^{TH} / 95^{TH} PERCENTILE D_0 MAXIMUM DEFLECTION DATA POINTS.

THE LAYER THICKNESS AND MATERIAL TYPE INFORMATION AT THE 90^{TH} / 95^{TH} PERCENTILE DESIGN POINTS CAN BE USED WITH THE DEFLECTION DATA TO DETERMINE THE ROAD PAVEMENT LAYER STIFFNESS. THIS INFORMATION THEN ALLOWS US TO ESTIMATE THE REMAINING LOAD CARRYING CAPACITY OF EACH UNIFORM SECTION OF THE ROAD.

DETERMINATION OF UNIFORM PAVEMENT SECTIONS

DO A 'CUMULATIVE SUM' ANALYSIS OF THE MAXIMUM (D_0) DEFLECTION DATA.

Divide the road into uniform section based on cumulative sum method:

$$CumSum\ value = \sum_{i=0}^{i=N} x_i - \overline{x}$$

Carry out a statistical evaluation of the D0 maximum deflection values for each selected uniform section:

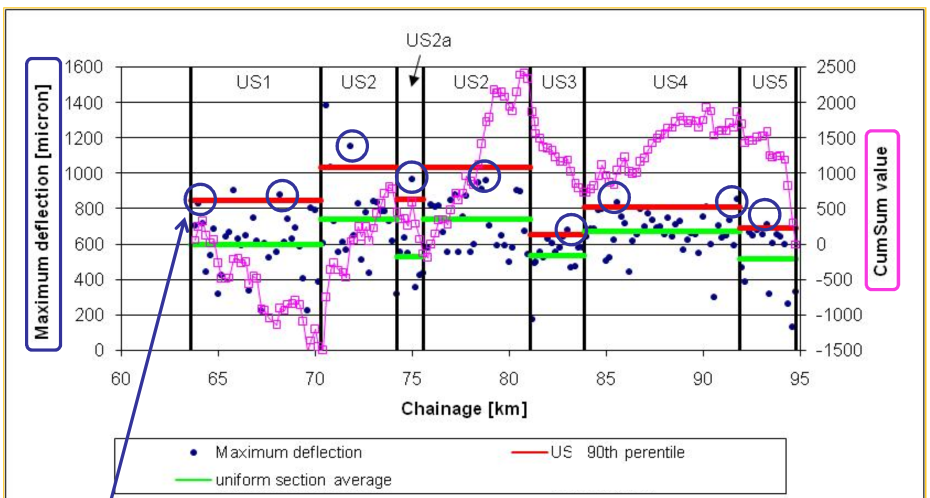
- **Average D_0 Value**
- **Standard deviation of D_0 values within each US.**
- **90^{th} / 95^{th} percentile D_0 value for each US.**
- **Coefficient of variation of D0 values within each US.**

SARF ROAD PAVEMENT REHABILITATION COURSE

$$CumSum\ value = \sum_{i=0}^{i=N} x_i - \bar{x}$$

km	D_0	D_0 - Dave	Cum Sum
0,0	185	- 285	- 285
0,1	378	- 92	- 377
0,2	899	- 429	- 806
0,3	323	- 147	- 953
0,4	176	- 294	- 1 247
0,5	357	- 113	- 1 360
0,6	494	24	- 1 336
0.7	678	208	- 1 128
0.8	796	326	- 802
0.9	234	- 236	- 1 038
1,0	545	75	- 963

SARF ROAD PAVEMENT REHABILITATION COURSE



SELECT ONE (or two) TEST PITS PER UNIFORM SECTION AT THE 90TH / 95TH PERCENTILE D_0 VALUE SO YOU CAN OBTAIN EXACT LAYER DETAILS AT THE DEFLECTION ANALYSIS POINTS.

WHEN SELECTING UNIFORM SECTIONS USE A PRACTICAL APPROACH :

- **KEEP IT AS SIMPLE AS POSSIBLE.**
- **CONSIDER THE MAJOR TYPE/S OF REHABILITATION REQUIRED AND DON'T MIX TOO MANY TYPES OF REHABILITATION OR RECONSTRUCTION.**
- **KEEP SECTION LENGTHS PRACTICAL. RATHER JOIN SECTIONS THAN DOING TOO MANY SHORT SECTIONS WHICH TAKE LONGER TO CONSTRUCT AND THEREFORE INCREASE THE PROJECT COST.**

NOTE :

ONCE THE DEFLECTION DATA HAS BEEN ANALYSED AS SHOWN ON THE PREVIOUS SLIDE TO SELECT UNIFORM SECTIONS AND THE TEST PIT POSITIONS IT IS THEN ALSO USED IN THE PAVEMENT ANALYSIS PROCESS.

THE PAVEMENT ANALYSIS PROCESS AS DISCUSSED IN THE FOLLOWING PART 5 OF THIS COURSE.

FIELD INVESTIGATION : TEST PIT SAMPLING

Check positions of the test pits in field to confirm they are in safe locations with good traffic visibility.

Get a reputable laboratory with proven skills to make test pits correctly. (Otherwise data may be useless !)

Make holes in the slow lane left wheel track 1m x 1,5m

Remove surfacing and do DCP test before taking samples of each layer for indicators, moisture content and CBR. (Also useful to measure layer densities.)

Test cement stabilised layers with hydrochloric acid and phenolphthalein to confirm extend of the stabilisation.

Accurately measure layer thicknesses and take photos.

GOOD PIT PROFILE REQUIRED

0 – 35 mm: Asphalt plus two seals, intact, deformed slightly in wheel track.
35 – 170 mm: Slightly moist, light brown, medium dense crushed granite.
170-266 mm: Slightly moist light brown medium dense granite gravel, stabilised, intact, imported.
266-341 mm: Slightly moist, brown, loose to medium dense felsite gravel.

341-502 mm: Slightly moist, brown, loose to medium dense felsite gravel, intact, imported.

502-598 mm: Slightly moist, brown, loose to medium dense felsite gravel, intact, imported

GOOD PIT IDENTIFICATION REQUIRED

USE A MARKER TAPE IF THERS IS NO CLEAR DISTINCTION BETWEEN LAYERS / MATERIAL TYPES.

FIELD INVESTIGATION : TESTING OF SAMPLES

Large enough samples of each layer are taken to allow a full set of tests to be done.
Tests required on every layer are:

- **Indicator tests = Grading, Atterberg limits and GM.**
- **In situ density, moisture content and CBR.**

When indicator results are available they are analysed to determine where representative CBR tests can be done on material with similar properties so as not to test all samples for CBR. (Also UCS testing if reqd.)
(Surplus samples to be kept in case more tests are needed during pavement analysis phase.)

Test pits must be properly back-filled.

(e) DYNAMIC CONE PENETROMETER ANALYSIS

DCP results from the test pits (and additional DCP tests if required) are analysed to obtain the DCP number.

Use DCP software to obtain limiting stiffness moduli values for each layer to be used, in conjunction with the tests results, for the back-calculation of the deflection results.

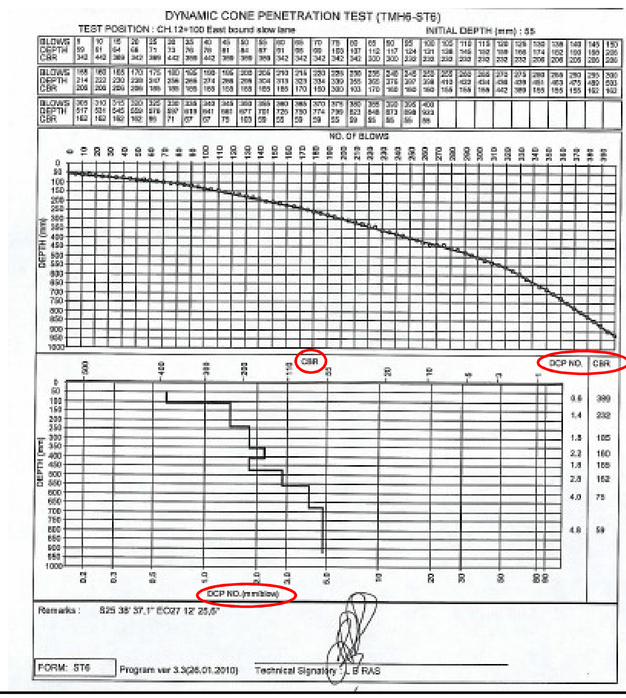
(The DCP results are also used in determination of the Design Equivalent Materials Class determination.)

FIELD INVESTIGATION : DCP ANALYSIS

ANALYSIS OF DCP RESULTS :
REFER TO APPENDIX B (and SAPEM Chap. 10)

A BRIEF EXPLANATION OF HOW TO ANALYSE THE DCP RESULTS IS GIVEN IN THE FOLLOWING SLIDES.

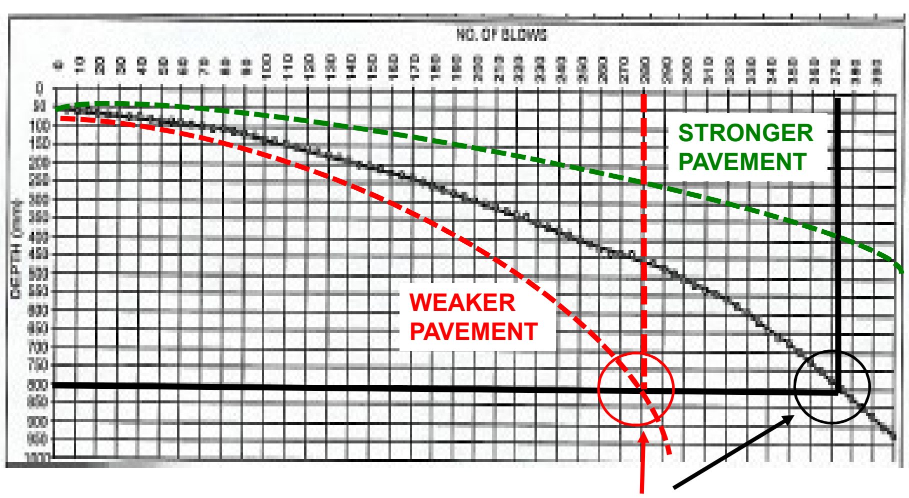
UNDERSTAND WHAT THE DCP ANALYSIS SOFTWARE IS TELLING YOU !



DCP PENETRATION MEASUREMENTS

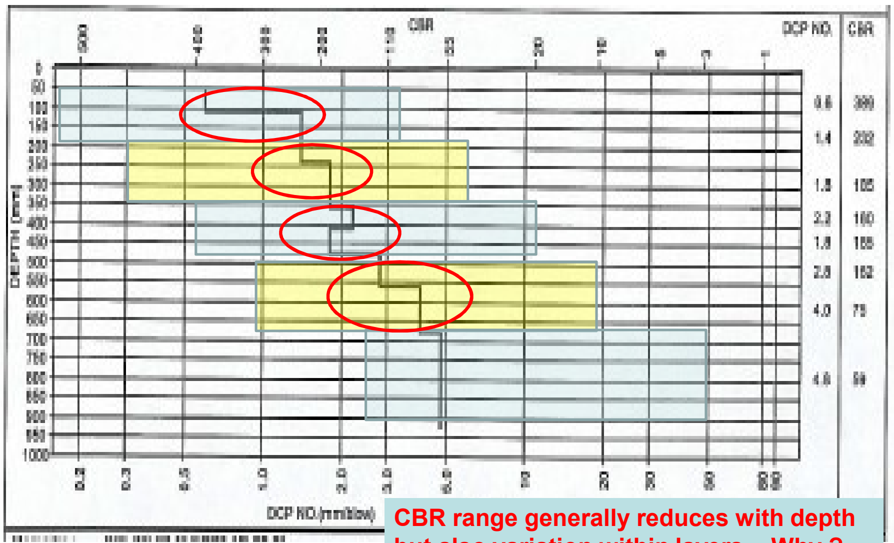
DCP CUMULATIVE PENETRATION MEASUREMENTS (see slide 92)

DCP PENETRATION MEASUREMENTS CONVERTED TO EQUIVALENT IN-SITU CBR VALUES. (see slide 93)



DCP No. = Number of blows to penetrate 800 mm.

- **The higher the DCP number the stronger the pavement.**
- **The smoother the curve the better the "Pavement Balance".**
- **Check for weak layers within the pavement structure !**



mm per blow for each pavement layer converted to estimated in-situ CBR using the relationship developed by EG Kleyn.
(Compare with lab. CBR results and measured layer densities.)

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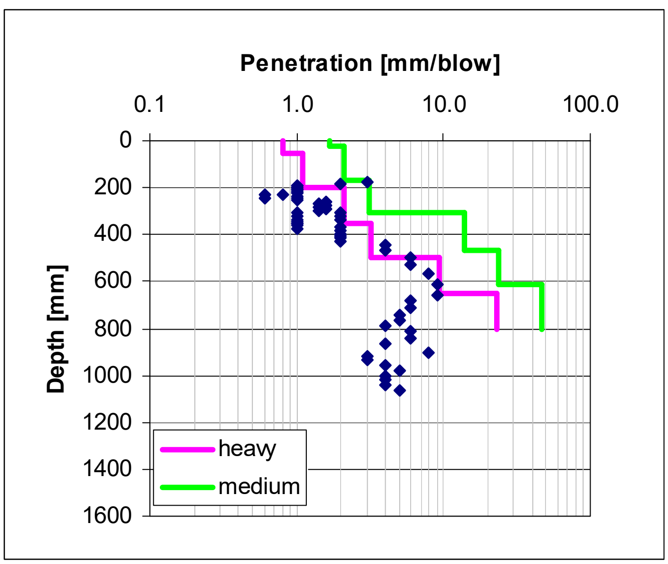

No. of blows can be compared with desired medium or heavy traffic loading requirements using the relationships developed by EG Kleyn. (Refer to SAPEM Chapter 10.)

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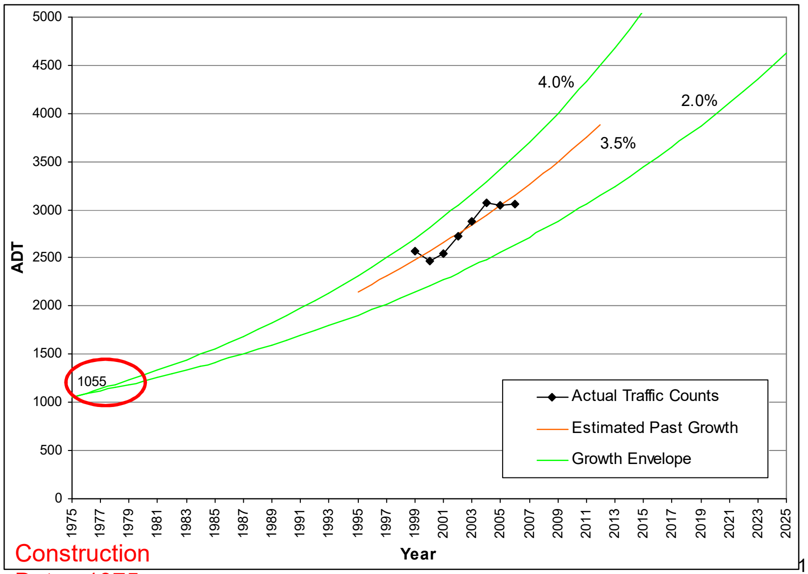
(f) PAST AND FUTURE TRAFFIC LOADING

Determine the past and estimated future cumulative traffic loading using methodology given in TRH 4:

- **Analyse traffic data to obtain number of short, medium and long heavy vehicles using the road.**
- **Convert heavy vehicle numbers to Average Daily Equivalent 80 kN axle loads (E80's).**
- **Calculate cumulative E80's carried by the road pavement since it was built (or last rehabilitated).**
- **Estimate at projected low and high future traffic growth rates the expected future cumulative traffic loading over the next 5, 10, 15, 20 and 25 year design periods.**

	TRAFFIC HIGHLIGHTS OF SITE 185			
1.1	Site Identifier			185
1.2	Site Name			Colesberg South
1.3	Site Description			Between Noupoort and Colesberg
1.4	Road Description			Route : N009 Road : N009 Section : 07 Distance : 82.2km
1.5	GPS Position			25 04 08.5E -30 50 47.4S
1.6	Number of Lanes			2
1.7	Station Type			Permanent Piezo
1.8	Requested Period			2007/01/01 - 2007/12/31
1.9	Length of record requested (hours)			8760
1.10	Actual First & Last Dates			2007/01/01 - 2007/11/16
1.11	Actual available data (hours)			7652
1.12	Percentage data available for requested period			87.4
2.1	Total number of vehicles	237090	213755	450845
2.2	Average daily traffic (ADT)	744	670	1414
2.3	Average daily truck traffic (ADTT)	245	231	476
2.4	Percentage of trucks	33.0	34.4	33.7
2.5	Truck split % (short:medium:long)	20 : 10 : 70	20 : 11 : 69	20 : 11 : 69
2.6	Percentage of night traffic (20:00 - 06:00)	23.8	24.6	24.2

SARF ROAD PAVEMENT REHABILITATION COURSE



Construction
Date : 1975

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SARF ROAD PAVEMENT REHABILITATION COURSE

TABLE 5

*Determination of E80s per heavy vehicle**

Loading of heavy vehicles	E80/heavy vehicle
Mostly unladen	0,6
50 % laden, 50 % unladen	1,2
> 70 % fully laden	2,0

TABLE 6

Average E80s for different heavy vehicle configurations (TRH16, 1991)

Vehicle type	Average E80s per vehicle*	Range in average E80s per vehicle found at different sites
2-axle truck	0,70	0,30 - 1,10
2-axle bus**	0,73	0,41 - 1,52
3-axle truck	1,70	0,80 - 2,60
4-axle truck	1,80	0,80 - 3,00
5-axle truck	2,20	1,00 - 3,00
6-axle truck	3,50	1,60 - 5,20
7-axle truck	4,40	3,80 - 5,00

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Truck Mix	% Long Trucks	Law Enf.	Model	% LT	t/ax	E80/ax	ax/HV	E80/HV
1	Below 35 %	Weak or Strong	KLP nb	29.8	4.845	0.411	4.12	1.69
2	35 – 55 %	Weak	WNKnb	42.2	5.080	0.574	4.54	2.61
3	35 – 55 %	Strong	KMT eb	48.9	5.279	0.415	4.48	1.86
4	Over 55 %	Weak	HDC sb	60.6	5.984	0.583	5.31	3.10
5	Over 55 %	Strong	HDB sb	58.4	5.783	0.453	5.24	2.37

MORE RECENT WORK BY SLAVIK AND BOSMAN
(using traffic count data on number of short, medium & long trucks)

BY MULTIPLYING THE E80/HV FACTOR BY THE NUMBER OF HEAVY VEHICLES PER DAY YOU CAN ESTIMATE THE NUMBER OF E80's / DAY / DIRECTION FOR BOTH THE START DATE WHEN THE ROAD WAS BUILT AS WELL AS FOR THE CURRENT DATE.

USING PAST AND FUTURE ESTIMATED TRAFFIC GROWTH RATES YOU CAN THEN ESTIMATE OF THE TOTAL CUMULATIVE E80 AXLE LOADS THAT THE ROAD HAS CARRIED SINCE IT WAS BUILT AS WELL AS HOW MANY E80 AXLE LOADS THAT IT WILL CARRY IN THE NEXT 5, 10, 15, 20 AND 25 YEARS. (i.e. for the short, medium and long term rehabilitation periods.)

FUTURE ESTIMATED CUMULATIVE TRAFFIC LOADING

USE ESTIMATED LOW AND HIGH GROWTH RATES & TRH 4 TABLE 12

TABLE 12

Traffic growth factor (f_y) for calculation of cumulative traffic over prediction period from initial (daily) traffic

Prediction period, y (years)	f_y for traffic increase, I (% per annum)									
	2	4	6	8	10	12	14	16	18	20
4	1 534	1 611	1 692	1 776	1 863	1 953	2 047	2 145	2 246	2 351
5	1 937	2 056	2 180	2 312	2 451	2 597	2 750	2 911	3 081	3 259
6	2 348	2 517	2 698	2 891	3 097	3 317	3 551	3 801	4 066	4 349
7	2 767	2 998	3 247	3 517	3 809	4 124	4 464	4 832	5 229	5 657
8	3 195	3 497	3 829	4 192	4 591	5 028	5 506	6 029	6 601	7 226
9	3 631	4 017	4 445	4 922	5 452	6 040	6 693	7 417	8 220	9 109
10	4 076	4 557	5 099	5 710	6 398	7 173	8 046	9 027	10 130	11 369
11	4 530	5 119	5 792	6 561	7 440	8 443	9 588	10 895	12 384	14 081
12	4 993	5 703	6 526	7 480	8 585	9 865	11 347	13 061	15 044	17 336
13	5 465	6 311	7 305	8 473	9 845	11 458	13 352	15 575	18 183	21 241
14	5 947	6 943	8 130	9 545	11 231	13 242	15 637	18 490	21 887	25 927
15	6 438	7 600	9 005	10 703	12 756	15 239	18 242	21 872	26 257	31 551
16	6 939	8 284	9 932	11 953	14 433	17 477	21 212	25 795	31 414	38 299
17	7 450	8 995	10 915	13 304	16 278	19 983	24 598	30 346	37 500	46 397
18	7 971	9 734	11 957	14 762	18 308	22 790	28 458	35 625	44 680	56 115
19	8 503	10 503	13 061	16 338	20 540	25 934	32 859	41 748	53 154	67 776
20	9 045	11 303	14 232	18 039	22 995	29 455	37 875	48 851	63 152	81 769
25	11 924	15 808	21 227	28 818	39 486	54 506	75 676	105 517	147 559	206 727
30	15 103	21 289	30 587	44 656	66 044	98 656	148 459	224 533	340 661	517 664
35	18 612	27 958	43 114	67 927	108 816	176 464	288 595	474 509	782 431	1 291 373
40	22 487	36 071	59 877	102 120	177 700	313 586	558 416	999 544	1 793 095	3 216 609

PAST CUMULATIVE TRAFFIC LOADING

GRAPHICALLY CALCULATE DAILY TRAFFIC LOADING (E80's / day / direction) WHEN ROAD WAS FIRST CONSTRUCTED (or last rehabilitated / reconstructed) AND APPLY THE PAST AVERAGE GROWTH RATE AND THE CUMULATIVE FACTOR f_y GIVEN IN TABLE 12 OF TRH 4 TO CALCULATE CUMULATIVE TRAFFIC LOADING SINCE THE ROAD WAS CONSTRUCTED.

OR

CALCULATE BACKWARDS WHEN ONLY THE CURRENT E80's / day / direction = ADE_{END} IS KNOWN FROM A NEW TRAFFIC COUNT.

$$E80 = \frac{ADE_{end}}{g_x} \times f_y$$

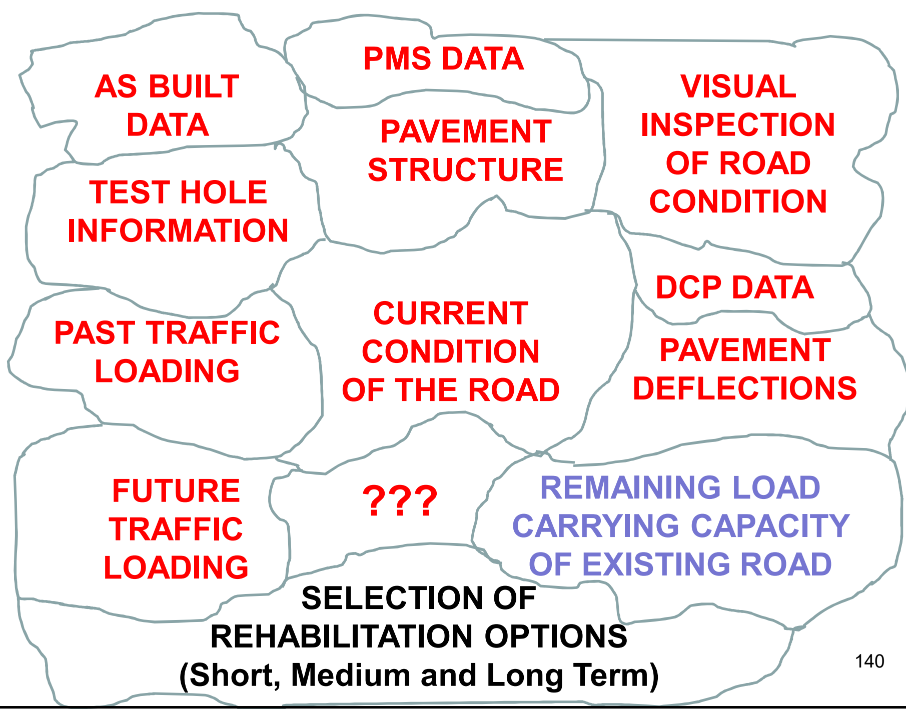
Gx = Growth Factor from Table 11 in TRH 4

Fy = Cumulative Factor from Table 12 in TRH 4

THE CURRENT TRAFFIC VOLUMES AND THE FUTURE GROWTH RATE ARE ALSO VERY IMPORTANT.

WHY ?

5.
ROAD PAVEMENT ANALYSIS



THE PAVEMENT ANALYSIS PROCESS IS AS FOLLOWS :

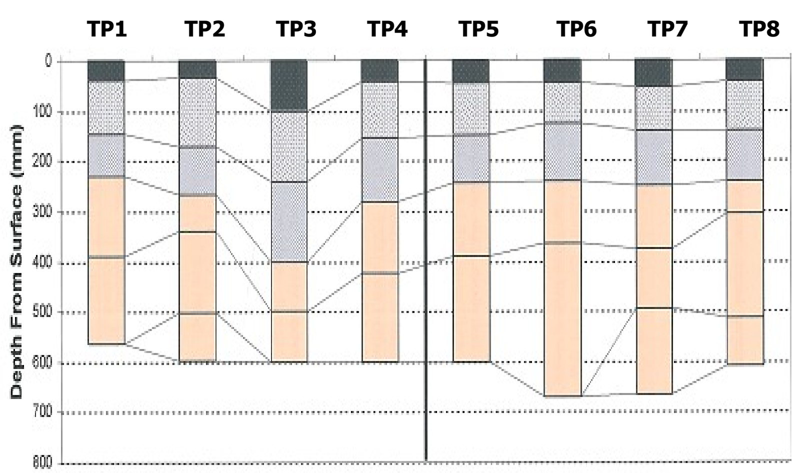
(a) Compile all test pit data to get layer thicknesses.

(b) Use the test hole data to check the material type and quality. Also check density and moisture content !!!

(c) Compare layer thicknesses and material quality against TRH 4 catalogue pavement designs to obtain an initial indication of the road pavement load carrying capacity.

(d) Use the layer thicknesses with the estimated limiting stiffness moduli (E – moduli) to back-calculate the actual layer stiffnesses from the deflection measurements. You can then use the E – moduli to calculate the load carrying capacity of the road pavement and compare with load carrying capacity estimated as per (c).

(a) Compile all test pit data to get layer thicknesses



(b) Use the test pit information to check the material type and quality using one of two methods :

(i) ACCORDING TO NEAREST TRH 14 CLASS

Check lab results carefully as computer generated classifications go strictly by the book and sometimes classify a material into a lower class for some minor deficiency in one test result.

Classification values given in TRH 14 are a guide – use your common sense.

(ii) MATERIALS CLASSIFICATION SYSTEM

Alternatively use the materials classification system as described in Appendix A.

(i) TRH 14 material classification system

Code	PI	LS	GM	CBR	Swell
G1	≤ 5	≤ 2			
G2	≤ 6	≤ 3			
G3	≤ 6	≤3			
G4	≤ 6	≤ 3		≥ 80 @ 98%	≤ 0.2
G5	≤ 10	≤ 5	1.5 ≤ GM ≤ 2.5	≥ 45 @ 95%	≤ 0.5
G6	≤ 12 or 2 x GM +10	≤ 5	1.2 ≤ GM ≤ 2.6	≥ 25 @ 95%	≤ 1.0
G7	≤ 12 or 3 x GM + 10		0.75 ≤ GM ≤ 2.7	≥ 15 @ 93%	≤ 1.5
G8				≥ 10 @ 93%	≤ 1.5
G9				≥ 7 @ 93%	≤ 1.5
G10				≥ 3 @ 93%	

SARF ROAD PAVEMENT REHABILITATION COURSE

(i) SUMMARISE MATERIAL TYPE AND QUALITY FROM THE TEST PIT DATA USING TRH 14 CLASSIFICATION

TEST PIT	BASE				SUBBASE				SELECTED SUBGRADE				SUBGRADE / FILL			
/ US No.'S	Thick (mm)	% mod. / %OMC	CBR @98 %	TRH14 class.	Thick (mm)	% mod. / %OMC	CBR @95%	TRH14 class.	Thick (mm)	% mod. / %OMC	CBR @93%	TRH14 class.	Thick (mm)	% mod. / %OMC	CBR @90%	TRH14 class.
1 / US 1		89.1/46	112	G5	135	101.8/86	14	G8	350	99.2/86	10	G8	+ 330	100.9/84	18	G7
2 / US 1	150	102.9/44	98	G5	150	102.3/83	30	G7	340	97.9/90	8	G9	250	96.6/86	9	G8
3 / US 2	135	98.1/56	75	G5	150	94.3/107	33	G6	150	98.0/103	28	G6	500	93.2/122	16	G6
4 / US 2	130	110.0/54	70	G5	150	98.2/87	26	G7	150	97.1/76	12	G8	+ 540	94.2/102	19	G6
5 / US 2	125	103.5/45	66	G6	130	96.8/99	33	G6	120	95.5/105	30	G6	210	95.5/76	8	G9
6 / US 2	185	106.7/58	80	G6	150	100.9/85	14	G8	150	93.3/186	28	G6	170	95.3/122	14	G7
7 / US 2	140	100.5/78	75	G5	150	94.4/124	23	G7	300	93.0/143	20	G7	210	90.8/175	7	G9
8 / US 3	145	98.6/48	68	G6	200	98.4/84	28	G6	160	95.4/129	20	G7	+ 440	98.3/125	16	G7
9 / US 3	130	104.3/48	47	G6	140	97.8/95	37	G6	240	103.0/64	15	G7	240	99.2/81	8	G9
10 / US 4	140	106.8/47	83	G3	180	94.7/138	42	G6	240	98.5/79	34	G6	190	96.5/81	17	G7
11 / US 4	140	108.1/60	105	G3	140	100.4/88	49	G5	150	101.1/103	34	G6	300	96.1/106	10	G7
12 / US 4	130	101.3/57	160	G5	140	101.4/109	45	G5	300	95.2/113	32	G6	150	91.4/106	6	G9
13 / US 4	120	95.9/34	89	G3	210	96.9/89	45	G5	150	97.5/105	12	G8	160	98.5/133	14	G7
14 / US 5	140	105.5/77	95	G5	145	101.8/102	43	G6	125	99.8/100	16	G7	145	105.4/111	6	G9
15 / US 5	110	103.7/49	105	G3	320	99.4/92	40	G6	190	96.3/116	27	G6	200	93.1/99	11	G6
RANGE	110-185	89.1-110.0/ 34-78	47-160	G3-G6	130-320	94.3-102.3 / 83-138	14-49	G5-G8	120-350	93.0-103.0 / 64-186	8-34	G6-G8	-	91.4-105.4 / 76-175	6-19	G6-G9
AVE.	138	102.3/49	89	G5	166	98.6/98	33	G6	208	97.4/107	22	G7	-	96.3/107	12	G8
Comments	Too thin, some CBR's low, density generally OK				CBR's low, density OK, wet in places.				Density good & in-situ CBR's OK but generally wet.				Density good & in-situ CBR's OK but generally wet.			

***Note :** Figures given in red are considered to be sub-standard.*

Lane and Test Hole Number	km Distance	Pavement Layer	Layer Thickness (mm)	In situ MC (%)	In situ % Mod. Density	PI	GM	CBR @… % Mod. Density	In situ DCP related CBR	TRH 14 Classification
Westbound Slow										
P4	11.2	Base	65	4.5	99.1	NP	1.98	63/98		G5
		Subbase	170	4.8	92.1	SP	1.81	29/95		G6 / not stab.
		USSG	130	7.0	87.5	NP	1.73	25/93		G6
		LSSG	160	8.5	92.3	11	1.78	5/90		G9
		Roadbed	200	5.3	94.0	SP	1.73	23/90		G6
P6	11.9	Base	85	7.4	95.2	NP	2.18	74/98	250	G6
		Subbase	120	6.4	91.8	SP	1.54	17/95	230	G8 / not stab.
		USSG	100	6.3	93.9	NP	1.88	15/93	185	G7
		LSSG	140	20.0	74.4	26	1.46	2/90	70	< G10
		Roadbed	450	14.0	88.2	SP	1.63	4/90	70	G10
P8	12.7	Base	140	3.0	98.3	NP	2.37	89/98		G3
		Subbase	80	7.9	97.6	NP	1.83	21/95		G7 / not stab.
		USSG	110	9.6	99.9	SP	1.92	25/93		G6
		LSSG	160	9.2	90.9	11	2.25	19/90		G7
		Roadbed	470	6.0	92.3	SP	2.12	9/90		G8
P12	14.4	Base	110	2.5	97.9	NP	2.39	70/98		G5
		Subbase	170	7.9	94.9	7	2.47	40/95		G6 / stabilised
		USSG	160	9.0	89.2	SP	2.51	36/93		G6
		LSSG	300	7.8	89.0	12	2.34	18/90		G7
		Roadbed	120	5.9	91.4	SP	2.49	20/90		G6
P14	15.0	Base	140	4.8	83.0	NP	2.52	43/98		G6
		Subbase	250	5.0	97.3	NP	2.59	31/95		G6 / stabilised
		USSG	180	10.5	83.2	9	2.4	34/93		G7
		LSSG	160	10.3	93.9	13	2.17	5/90		G10
		Roadbed	130	6.7	107.3	NP	2.09	32/90		

(ii) Alternatively you can use a MATERIALS CLASSIFICATION SYSTEM (See Appendix A)

This system has been developed to handle vagueness in data and remove human interpretation variables.

The inherent problem is that there are many sources of uncertainty such as:

- **Risk of pavement failure is poorly defined**
- **Small sample sizes over long sections**
- **All tests are only indicators**
- **Interpretation is vague and sometimes subjective.**

To reduce the degree of uncertainty you need relative and methodical interpretation of the materials data.

A fundamental understanding of what is measured by each specific test provides the key to a rational and useful interpretation of test results.

The material is classed in terms of a Design Equivalent Material Class (DEMAC) that does not necessarily meet the TRH14 specification for that class of material but, with a certain degree of certainty, exhibits in situ shear strength, stiffness and flexibility properties similar or better to those of a newly constructed material of the same class.

For example, a material considered to be equivalent to a G2 gravel for design purposes will, based on the available test pit data, be denoted DE - G2.

(Theory - refer to pages 87- 88 in the manual and also SAPEM Chapter 9.)

Step by step Material Classification Process (each US)

Step 1 :

For each test, determine the 90th, median and 10th percentile values.
(If you have only 1 test value – report as median.)

Step 2 :

Determine the certainty factor (CF) for each test.
(refer to Section A3.3 & A4 of Appendix A)

A3.3 Certainty Factor.

Most materials tests provide only partial indication of shear strength and stiffness. A certainty factor (CF) is given for each type of test result as shown in Table A3 (Pg. 94) for granular materials and in Table A11 (Pg. 99) for cemented materials.

Step 3 :

Adjust the CF on each test type depending on the number of samples being analysed in that Uniform Section.
(refer to Section A3.4 of Appendix A)

Table A1: Recommended Adjustment of CF based on Sample size.

SAMPLE SIZE (No of test pit samples)	ADJUSTMENT FACTOR
1	0,2
2	0,3
3	0,6
4 to 6	0,7
6 or greater	1,0

Step 4 : Select likely material class (e.g. DE-G4)
Step 5 : For each test, determine expected ranges of values for each DEMAC.
Step 6: For each test, determine how much the 10th and 90th % ranges overlaps with the expected range of values for the specific material. That gives the relative certainty, C(E). Calculations shown in A3.5.

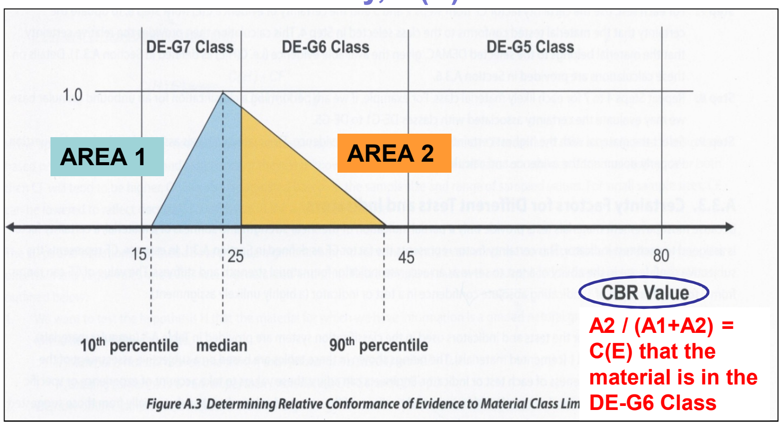


Figure A.3 Determining Relative Conformance of Evidence to Material Class Lim

Step 7 :
For each test type use the certainty factor CF from Steps 2 and 3 and the C(E) from Step 6 to update C(H|E) (as defined in A3.1.)

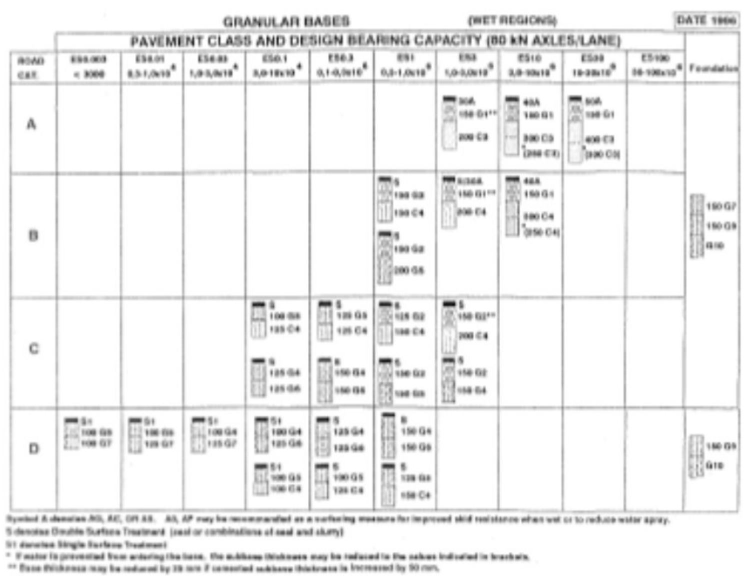
Step 8 :
Repeat Steps 4 to 7 for each material class.
(Two possible classes for each sample)

Step 9 : Select material with the highest certainty and assign to the specific layer in question.

Calculations can be done by entering the test pit data into the programme available on the following website:
www.asphaltacademy.co.za

(c) Compare layer thicknesses and material quality, density and moisture content against the TRH 4 catalogue pavement designs :

AFTER CLASSIFYING AND SUMMARIZING ALL THE TEST PIT INFORMATION FOR EACH UNIFORM SECTIONS YOU CAN THEN COMPARE THE MATERIAL TYPE AND QUALITY AND THE LAYER THICKNESSES FOUND IN THE TEST PITS AGAINST THE TRH 4 CATALOGUE PAVEMENT DESIGNS TO ESTIMATE THE LOAD CARRYING CAPACITY (PAVEMENT CLASS) FOR EACH UNIFORM SECTION.



After summarizing and classifying the material test data you now have a better idea of the pavement structure you need to analyse.

EXAMPLE:

Asphalt surfacing :	**35-52 mm thick, rutted, cracked.**
Base:	**G1 - 135 to 155 mm thick, rutted and moist.**
Subbase:	**C3 to C4 stabilised – 145 to 165 mm thick, dry.**
Selected layers:	**Poor to good (CBR 30 – 90)**
Upper subgrade:	**Good (CBR > 30)**

For this example the TRH 4 catalogue design indicates that the initial design load capacity was approximately 1 million E80 axle loads.
But note that the asphalt is cracked and the base is rutted and moist so actual load carrying capacity is probably less.

THE CALCULATION OF THE REMAINING LOAD CARRYING CAPACITY IS ESTIMATED BY SUBTRACTING THE CUMULATIVE TRAFFIC LOADING CARRIED TO DATE FROM THE THEORETICAL ORIGINAL LOAD CARRYING CAPACITY AS GIVEN IN THE TRH 4 CATALOGUE TABLES.

NOTE THAT THE THEORETICAL LOAD CARRYING CAPACITY IS USUALLY A WIDE RANGE (i.e. 3 – 10 MILLION E80'S) AND AS YOUR EXISTING PAVEMENT CONDITION VARIES THE REMAINING LIFE OF EACH DIFFERENT SECTION OF ROAD WILL ALSO BE VARIABLE.

VARIABLE DESIGN RANGE IN TRH 4 AND A VERY VARYING ROAD CONDITION = A VERY ROUGH ESTIMATE OF REMAINING LIFE !

FURTHER CONFIRMATION CAN BE OBTAINED BY USING THE DEFLECTION MEASUREMENTS TO CARRY OUT A MECHANISTIC ANALYSIS OF THE ROAD PAVEMENT

THIS PROVIDES ANOTHER INDICATION OF THE STRENGTH / REMAINING LOAD CARRYING CAPACITY OF THE ROAD PAVEMENT.

(d) Use the layer thicknesses with the estimated limiting stiffness moduli (E – moduli) to back-calculate the actual layer stiffnesses from the deflection measurements.

Stiffness moduli range limits (MPa) per material type for input into back calculation programmes.

G1: 300-450	C1: 7500
G2: 250-400	C2: 5500
G3: 230-350	C3: 2500
G4: 150-300	C4: 1500
G5: 130-250	AG: 2500
G6: 120-150	AC: 3000
G7: 60-90	AS: 2500
G8: 40-80	AO: 1500
G9: 30-60	AP: 1500
G10: 20-50	**(see Table 4.1 – Pg 26)**

BACK CALCULATION OF DEFLECTION DATA

After analyzing the individual points, decide on stiffness limits and do back calculations until your calculated deflection basin matches the measured deflection basin.

Layer	Layer thickness (mm)	Search range (MPa)		Poisson's ratio
		From	To	
Asphalt surfacing	40	1 500	3 000	0,40
Base and subbase	208	150	2000	0,35
Selected layers	365	70	500	0,35
Upper subgrade	1200	50	200	0,35

BACK CALCULATION OF DEFLECTION DATA

Rubicon Toolbox™ or PADS 2007 or any similar program such as "BISAR" can be used.

Use the layer thicknesses and the possible range of E modulus values determined as just described.

Combine layers to get not more than 4 layers on top of the 5th semi-infinite subgrade layer for analysis. (BISAR can handle 5 layers + semi-infinite subgrade !)

EXAMPLE:
Asphalt stiffness fixed at 2 500 MPa.
Crushed stone base and subbase analysed as one layer.
Selected layers combined as one layer.
Subgrade modelled as two layers with upper layer 1 200 mm thick and lower layer semi-infinite.

Deflection Bowl Report At Station 4

Asphalt plus two surface seals
Layer Thickness = 35 Millimetres
Layer Stiffness = 2500 MPa
Poisson's Ratio = 0.4

Combined Base & Subbase (Crushed Granite)
Layer Thickness = 231 Millimetres
Layer Stiffness = 250 MPa
Poisson's Ratio = 0.35

Selected Layers
Layer Thickness = 332 Millimetres
Layer Stiffness = 70 MPa
Poisson's Ratio = 0.35

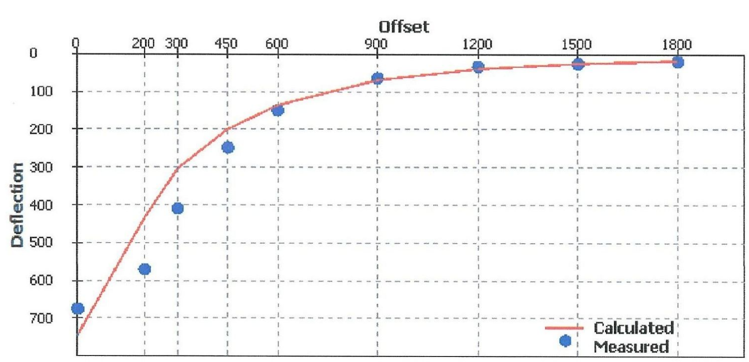
Upper Subgrade: Weathered Felsite/Granite Upper Subgrade
Layer Thickness = 1200 Millimetres
Layer Stiffness = 120 MPa
Poisson's Ratio = 0.35

Substratum is semi-infinite, with stiffness = 350 MPa

Deflections:

Offsets (Millimetres):	0	200	300	450	600	900	1200	1500	1800
Measured (Microns):	675	571	410	248	149	64	34	26	20
Calculated (Microns):	744	434	303	199	136	69.3	39.9	26	18.9
Error at Sensor (%)	9.48	23.1	24.9	17.7	5.37	0	0	0	0

Average Error Per Sensor: 8.95 % **Sum of Errors: 80.6 %**
Note: Errors were adjusted for precision. Errors less than 10 micron are shown as zero.



Km 4.0 Eastbound

Deflection Bowl Analysis

D-2
Rubicon Toolbox: Deflection Bowl Analysis / Ver: 1.7 / (Licenced)

BACK CALCULATION OF ALL DEFLECTION DATA

Use the values below to rate the back-calculated E values in each Uniform Section of the road pavement as "good" or "poor" with respect to layer stiffness. This then provides an indication of the load carrying capacity.

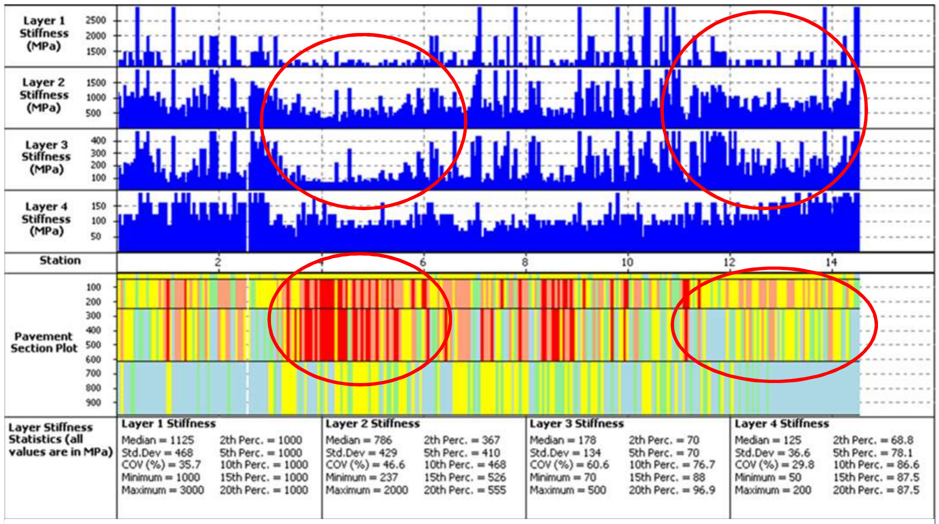
Material	Interpretation ranges used (MPa)				
	Very good	Good	Fair	Poor	Very poor
Asphalt	3000-5000	1800-3000	1200-1800	800-1200	0-800
Crushed stone	500-2000	250-500	160-250	120-160	0-120
Selected layer	180-500	140-180	90-140	70-90	0-70
Subgrade	150-500	90-150	60-90	50-60	0-50

You first do the back analysis for each Uniform Section by using the deflection data at the 90th / 95th percentile maximum deflection (D_0) point which is used for the design of the pavement strengthening / rehabilitation measures.

You can also carry out a sensitivity analysis by analysing the deflection data at
good (high stiffness) points where D_0 is low and at
poor (low stiffness) points where D_0 is high.

Computer programs such as "Rubicon" can analyse every deflection data point (100 m intervals) but remember you only have accurate layer thickness values at your test pit positions so analysis elsewhere is not necessarily very accurate. *(Is all this info. relevant ?)*

SARF ROAD PAVEMENT REHABILITATION COURSE



VARIABILITY IN MATERIALS, DENSITY, LAYER THICKNESS & MOISTURE CONTENT = VERY VARIABLE DATA ! DO NOT GET CONFUSED BY TOO MUCH DATA OR READ MORE INTO THE DATA THAN WHAT IS THERE.

SARF ROAD PAVEMENT REHABILITATION COURSE

SENSITIVITY ANALYSIS OF BACK CALCULATION DATA

Parameter	High deflection		Low deflection	
Station (km)	**3.35**	**8.4**	**12.15**	**1.5**
Max deflection (micron)	**775**	**808**	**222**	**251**
Base and subbase stiffness (MPa)	**266**	**258**	**1191**	**959**
Selected layer stiffness (MPa)	**70**	**70**	**392**	**231**
Subgrade stiffness (MPa)	**69**	**106**	**162**	**88**

SENSITIVITY ANALYSIS OF BACK CALCULATION DATA
(Refer to paragraph 4.5 on pg. 32)

Asphalt poor to fair.

Combined base and subbase:
- Where deflections are high = low stiffness
- Where deflections are low = higher stiffness

Where deflections are high the asphalt is more deteriorated. (Why ?)
•Base failure due to water ingress ?
•Cracking up of stiff cemented subbase layer ?

Selected layers are generally OK

Upper subgrade is generally OK

AFTER CARRYING OUT THE BACK CALCULATION OF THE DEFLECTION DATA FOR EACH UNIFORM SECTION OF THE ROAD YOU SHOULD NOW HAVE AN IDEA OF :

- **The 90th / 95th pavement stiffness values that you can use for calculating the remaining load carrying capacity / pavement life for rehabilitation design purposes.**
- **The "low" & "high" stiffness values which tell you how much the pavement within each uniform section varies. This may affect your selection of suitable rehabilitation measures.**
- **A good idea of where the pavement weaknesses are which will determine which rehabilitation measures you must use.**

CALCULATION OF PAVEMENT STRUCTURAL CAPACITY

Modulus values for each layer are used with transfer functions to estimate the "Remaining Life" or load carrying capacity of the pavement structure.
(Refer to APPENDIX C & D)
(Empirical analysis: Refer to Appendix C)

Use a computer program such as Rubicon Toolbox™. (Appendix C pages 8-17 and 8-18.)

ALTERNATIVE METHODS TO CALCULATE THE STRUCTURAL CAPACITY OF A ROAD PAVEMENT

There are two other methods based on the measured deflection parameters.

The Pavement Number (PN) Method - (Pg. 35)

Structural Number (SN) – (Appendix C Pg. 8-26)

ALSO REFER TO SAPEM CHAPTER 10

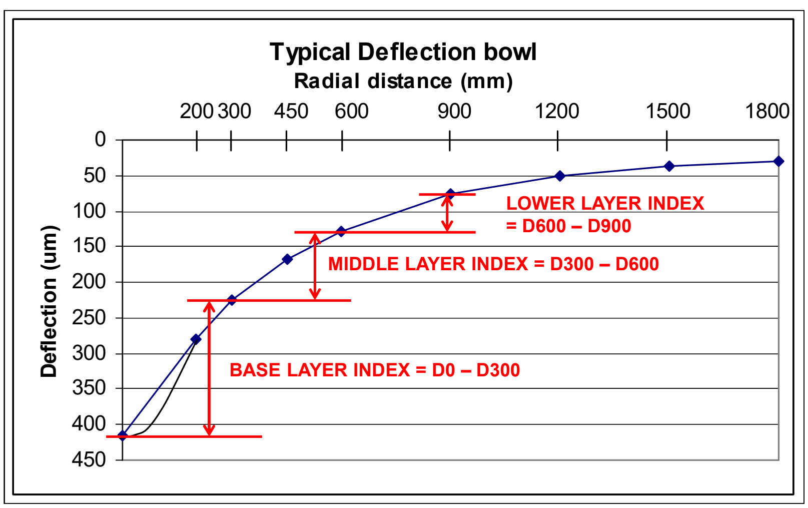
TRH 12 PROVIDES ANOTHER METHOD OF ESTIMATING REMAINING STRUCTURAL CAPACITY USING LAYER INDICES

Basin Parameter	Calculation
Ymax = maximum deflection (µm)	D_0
BLI = Base Layer Index (µm)	$D_0 - D_{300}$
MLI = Middle Layer Index (µm)	$D_{300} - D_{600}$
RC = Radius of curvature	$\frac{(D_0-D_a)^2 + r^2}{2(D_0-D_a)}$

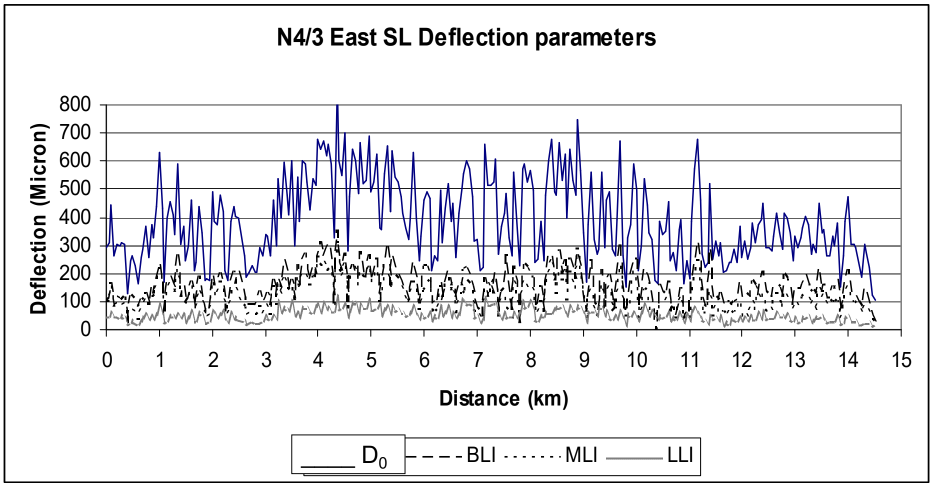
D_x = FWD Deflection measured at an offset of x mm from the centre of the loading plate.
D_a = FWD deflection at the edge of the loading plate. As there is no sensor to measure the deflection at the edge of the plate, the deflection is calculated as follows:
$D_a = 0{,}125D_0 + 1{,}125D_{200} - 0{,}25D_{300}$ (a=150mm for the FWD)

REFER APPENDIX C

CALCULATION OF LAYER INDICES



SARF ROAD PAVEMENT REHABILITATION COURSE



NOTE :

VARIATION IN MAX. DEFLECTION D_0

AND EVEN MORE VARIATION IN THE THREE INDICES

SARF ROAD PAVEMENT REHABILITATION COURSE

TRH 12 LAYER INDICIES LIMITS FOR TRAFFIC LOADING CATEGORIES (90th or 95th percentile values)

GRANULAR BASE PAVEMENT					
E80 CLASS	ALLOWED TRAFFIC ($E80 \times 10^6$)	LIMITS (μm)			
		YMAX.	SCI	BDI	BCI
E0L	0,05 - 0,1	1 050 - 1 300	700 - 900	410 - 560	230 - 310
E0H	0,1 - 0,2	870 - 1 050	540 - 700	310 - 410	170 - 230
E1L	0,2 - 0,4	700 - 870	420 - 540	230 - 310	125 - 170
E1H	0,4 - 0,8	580 - 700	320 - 420	170 - 230	94 - 125
E2L	0,8 - 1,6	470 - 580	250 - 320	130 - 170	70 - 94
E2H	1,6 - 3,0	390 - 470	200 - 250	100 - 130	54 - 70
E3L	3,0 - 6,0	320 - 390	160 - 200	75 - 100	40 - 54
E3H	6,0 - 12,0	260 - 320	120 - 160	55 - 75	29 - 40
E4L	12,0 - 24,0	210 - 260	90 - 120	40 - 55	21 - 29
E4H	24,0 - 50,0	170 - 210	70 - 90	30 - 40	16 - 21
E5	50,0 - 100,0	0 - 170	0 - 70	0 - 30	0 - 16
		D_0	**BLI**	**MLI**	**LLI**

Note : These traffic loading categories were derived from Benkelman Beam deflection measurements. If using a FWD then the deflection measurements must be converted. Moving wheel deflection measurements are probably not the same as Benkelman Beam measurements either.

SARF ROAD PAVEMENT REHABILITATION COURSE

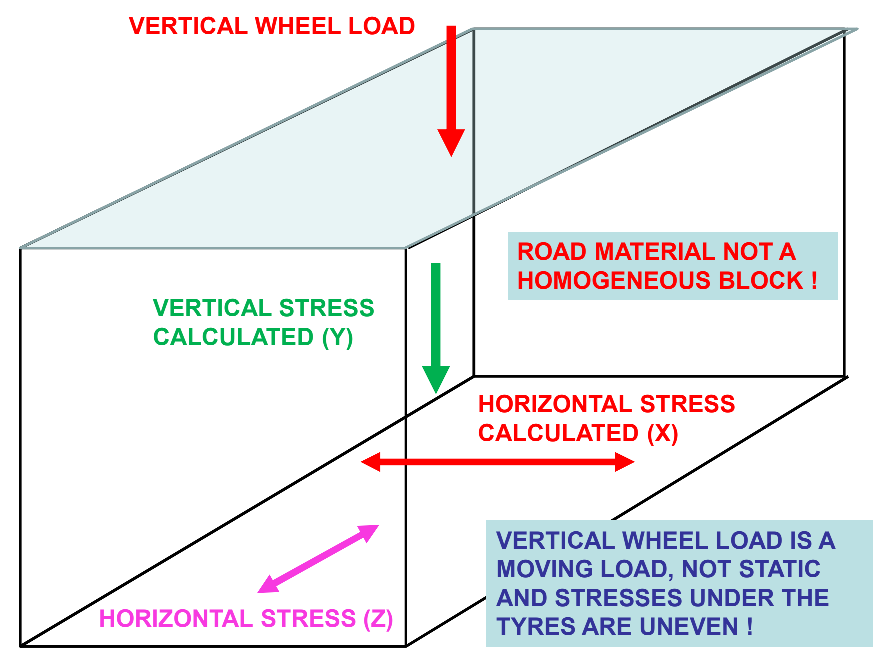
CALCULATION OF PAVEMENT STRUCTURAL CAPACITY

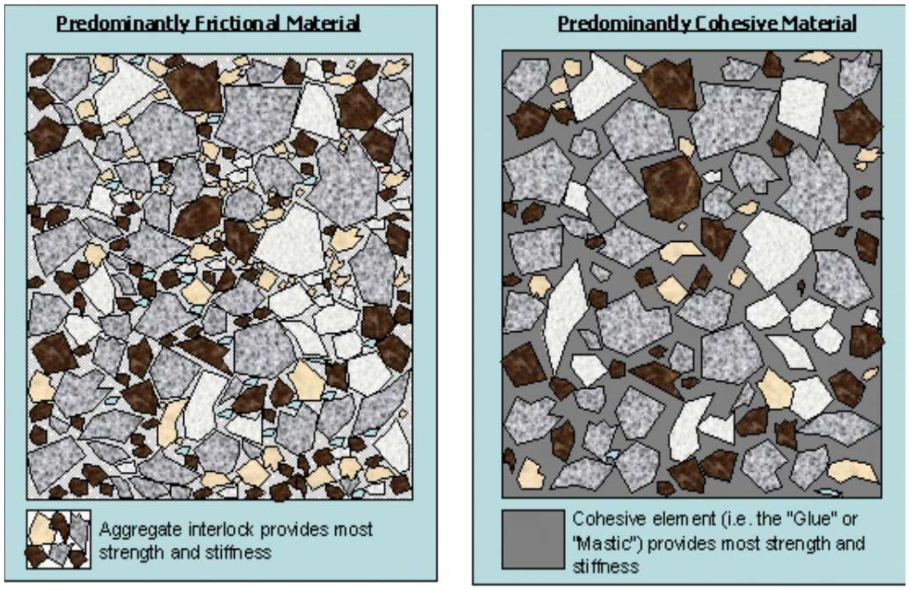
However, you must keep in mind the limitations of your calculations. The main limitations are :

Deflection analysis are done at a few points where you have test pits and there are a lot of variations in between (as indicated by the variations in deflection measurements.)

The mechanistic analysis calculations calculate stresses and strains in two dimensions (vertical and horizontal) assuming a uniform material but the compacted material particles are not one homogeneous layer but a lot of individual irregular shaped particles that interact in three dimensions.

The "Transfer" functions were developed on a few material types tested during Heavy Vehicle Simulator experiments. They do not necessarily apply accurately to all material types, material grading variations and material interlock mechanisms.





NOTE : FURTHER VARIATION ALSO IN DEPTH (Z direction)

THE ESTIMATED REMAINING LOAD CARRYING CAPACITY IS CONVERTED INTO REMAINING YEARS OF USEFUL PAVEMENT LIFE BY COMPARING THE ESTIMATED REMAINING LOAD CARRYING CAPACITY FOR THE ROAD PAVEMENT STRUCTURE (at the 90^{th} / 95^{th} percentile point) AGAINST BY THE CUMULATIVE TRAFFIC LOADING ESTIMATED FROM THE TRAFFIC COUNT DATA FOR THE 5, 10, 15, 20 & 25 YEAR REHABILITATION DESIGN PERIODS.

NOTE :
ALL METHODS CURRENTLY USED ARE INACCURATE AND GIVE VERY VARIABLE RESULTS WHICH ARE OFTEN NOT BELIEVABLE.
(If you see a report saying the remaining life is say 1 236 458 E80's taken from the output from some analysis programme then you know the pavement engineer does not understand what he is doing !)

THE GOOD NEWS

A NEW WEB BASED SYSTEM FOR PROCESSING THE ROAD DATA SHOULD BE RELEASED SOON AND IT SHOULD PROVIDE A MORE RELIABLE METHOD OF ESTIMATING THE REMAINING LOAD CARRYING CAPACITY OF A ROAD PAVEMENT.

THE BAD NEWS

THE LIMITS OF THE MODELLING TOOLS AND TRANSFER FUNCTIONS AS WELL AS THE VARIABLE MATERIAL PROPERTIES AND THE CONDITION OF THE EXISTING ROAD PAVEMENT STILL NEED TO BE TAKEN INTO CONSIDERATION.

TO DO THIS YOU STILL NEED TO USE YOUR BRAIN AND YOUR EXPERIENCE AS WELL AS A GOOD DOSE OF COMMON SENSE.
(Relying on some computer programme is not a good substitute for ensuring that you use all the available information to understand why, and how quickly, the road pavement is deteriorating.)

6. SELECTION OF MAINTENANCE OR REHABILITATION OPTIONS

Once the Uniform Sections have been selected, inspected, tested and analysed then, based on :

- **an understanding of how and why the pavement is failing**
- **the degree, extent and variability of the pavement distress**
- **the estimated future traffic loading compared with the remaining structural capacity of the pavement**
- **the available funds and network requirements**

you can select a suitable option from one of the following :

- **Do nothing now (understand what is going to happen !)**
- **Short term maintenance action: 2 - 10 years life**
- **Medium term rehabilitation option: 10 - 15 years life**
- **Long term rehabilitation option: > 15 years life**

DO NOTHING NOW OPTION

If both the functional and structural requirements are met then no further action is required. However, consider the risk of postponing any action.

If only functional parameters are the problem the Road Authority may reduce his standards for riding quality and rut depth temporarily and adopt a Do Nothing strategy.

The degree or extent of the failures may be too small to warrant any rehabilitation immediately. Consider a temporary holding action to keep it going.

Structural evaluation indicates failure but road is visually acceptable then understand why road is performing better than it should and wait for physical failure to occur.
(Put the road on a monitoring list.)

SHORT TERM MAINTENANCE ACTIONS

When full scale rehabilitation is not warranted or funds are limited but something must be done to prevent on-going deterioration then choose this option.

A good maintenance action may extend the pavement life by many years and is often good value for money.

Consider the risk and the long term economy.
Not economical to spend a lot of money on something that won't last very long. It may be better to put the money towards a medium or long term action on the worst part of the road.

SARF ROAD PAVEMENT REHABILITATION COURSE

SHORT TERM MAINTENANCE ACTIONS (2 - 5 years)

Mark out sections showing signs of failure.

DCP investigation or visually determine extent of failure.

Do required base patching.

Seal cracks.

Fill or patch excessive rutting.

Replace subsoil drains that are not working.

Clean / deepen the road side drains.

After repairing the failures and improving the drainage you can then resurface the road.

MEDIUM TERM REHABILITATION OPTIONS (5 – 10 years)

Used when funds are available to reconstruct or to partly reconstruct sections of the road pavement so it will last a while longer.

Do a proper pavement analysis as described in Chapter 5.

Decide on the design life of the rehab sections compared to remaining life of the rest of the pavement.

Determine uniform sections and design the new rehabilitated pavement structure for each uniform section.

Select the best Rehabilitation Options to meet the design requirements for each uniform section.

MEDIUM TERM REHABILITATION OPTIONS (5 – 10 years)

Select one or more of the following medium term rehabilitation measures :

- **Base patching and crack sealing if not recycling.**
- **Fill or patch excessive rutting if not recycling.**
- **In situ recycle the base layer (and surfacing).**
- **Replace subsoil drains that are not working.**
- **Clean / deepen the road side drains.**

After patching and/or recycling the base and improving the drainage you can then resurface the road.

LONG TERM REHABILITATION OPTIONS (> 15 years)

When the road is in a poor condition and funds are available to fix it properly then a long term rehabilitation option is used.

Do proper pavement analysis as described in Chapter 5.

Decide on the design life of rehab sections compared to remaining life of the rest of the pavement.

Determine uniform sections and design the new rehabilitated pavement structure for each uniform section.

Select the best Rehabilitation Options to meet the design requirements for each uniform section.

LONG TERM REHABILITATION OPTIONS (> 15 years)

Select one or more of the following long term rehabilitation measures :

- **In situ recycle the base layer, possibly with bitumen stabilisation if necessary.**
- **In situ recycle and stabilise the base with cement to create a stabilised subbase layer and then add a new base layer on top.**
- **Replace subsoil drains that are not working.**
- **Clean / deepen the road side drains.**

After recycling the base and / or strengthening the pavement with additional layers (and improving the drainage) you can then resurface the road.

LONG TERM REHABILITATION OPTIONS (> 15 years)

What long term rehabilitation measures would you choose for this road ?

ECONOMIC COMPARISON OF REHAB. OPTIONS

1. BASE and/or SUBASE OPTIONS :

Asphalt overlay of existing pavement.

Recycle existing layers and stabilize with cement or lime.

Recycle existing layers and stabilize with bitumen and possibly a small quantity of cement.

Mill and replace base with asphalt base.

Mill and replace asphalt surfacing.

ECONOMIC COMPARISON OF REHAB. OPTIONS

2. SURFACING OPTIONS :

Asphalt – various thicknesses using straight or modified bitumen and the most suitable type of asphalt :
Continuously or gap graded asphalt, stone mastic asphalt, HiMA and/or ultra-thin friction course.

Pre-treatment with slurry.

Single seal - straight or modified bitumen.

Double seal – straight or modified bitumen.

Cape seal.

ECONOMIC COMPARISON OF REHAB. OPTIONS

3. ANCILLARY WORKS :

Sub-soil drains.

Side drains.

New guardrails, fencing and road signs.

If layers are added you may also have to

- **Rebuild shoulders**
- **Replace guardrails**
- **Replace or raise concrete lined side drains**
- **Extend culverts / widen bridges.**
- **Raise kerbs, channels and sidewalks.**

LIFE CYCLE ANALYSIS

Select all suitable options considering:

Construction cost
Maintenance cost
Salvage cost
and
the probability of failure due to :

- **Pavement rehabilitation option/s chosen**
- **Local environmental factors**
- **Traffic loading**
- **Design variables, etc.**
- **Implications of deferred maintenance.**

CALCULATE <u>ACCURATE</u> COST FOR EACH OPTION.

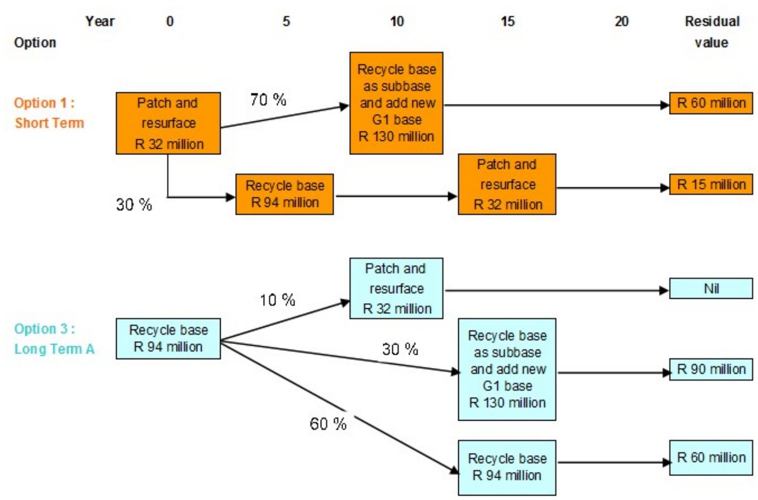
LIFE CYCLE ANALYSIS

Carry out a Present Worth of Costs (PWOC) analysis based on accurate cost estimates derived from a fully priced schedule of quantities for each option.

A PWOC analysis allows you to consider the various rehabilitation options and the possible consequences of each of the various choices that can be made.

This means you can make a considered choice.

Present Worth of Costs (PWOC) analysis (over 25 years)



Present Worth of Costs (PWOC) analysis.

Select discount rate / use the Road Authority rate and apply it to the costs of the various options multiplied by the percentage chance of the option being used.

OPTION 1 (Short Term) using an annual discount rate of 8 % :

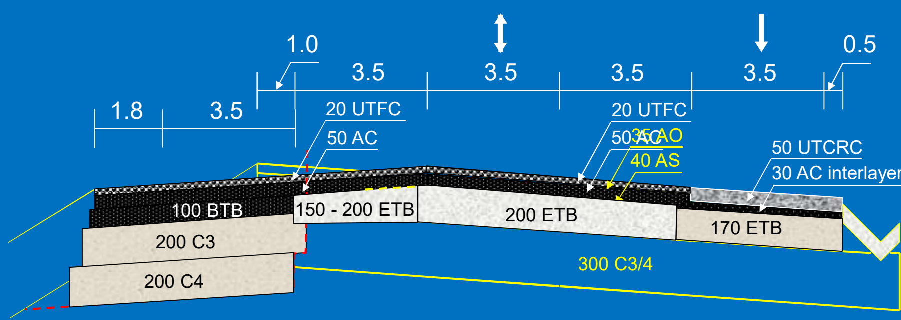
PWOC = [R 32 m] + [R 130 m x 0.7 x 1.08^{-10}] + [R 94 m x 0.3 x 1.08^{-5}] + [R 32 m x 0.3 x 1.08^{-15}] - [R 60 m x 0.7 x 1.08^{-25}] - [R 15 m x 0.3 x 1.08^{-25}]
= R 32 m + R 42.15 m + R 19.19 m + R 3.03 m – R 6.13 m – R 0.66 m
= R 91.6 million.

OPTION 3 (Long Term A) using an annual discount rate of 8 % :

PWOC = [R 94 m] + [R 32 m x 0.1 x 1.08^{-10}] + [R 130 m x 0.3 x 1.08^{-15}] + [R 94 m x 0.6 x 1.08^{-15}] - [R 90 m x 0.3 x 1.08^{-25}] - [R 60 m x 0.6 x 1.08^{-25}]
= R 94 m + R 1.48 m + R 12.29 m + R 17.78 m – R 3.94 m – R 5.26 m
= R 116.3 million.

PWOC IS SIMILAR. IF SHORT OF FUNDS NOW THEN PICK SHORT TERM OPTION. IF ROAD IS HEAVILY TRAFFICKED / POOR RIDING QUALITY THEN IT WOULD BE BETTER TO PICK LONG TERM OPTION AS RISKS OF FAILURE ARE GREATER.

EXAMPLE : SELECTION OF REHABILITATION OPTIONS



CONSTRUCTION ASPECTS

7.
DRAINAGE IMPROVEMENTS

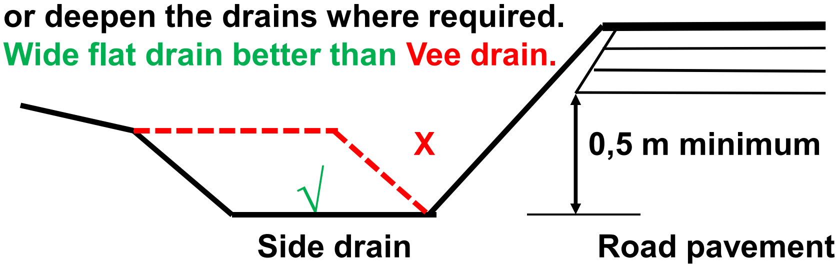
GOOD DRAINAGE IS ESSENTIAL IN ORDER TO ENSURE THAT WATER DOES NOT ENTER THE ROAD PAVEMENT LAYERS.

THIS IS A PRIORITY REQUIREMENT AND MUST BE ATTENDED TO BEFORE ANY MAINTENANCE AND / OR REHABILITATION WORK IS CARRIED OUT.

REPAIRING THE DEFECTS IN THE ROAD WITHOUT ENSURING THAT THE ROAD IS WELL DRAINED IS OBVIOUSLY A WASTE OF MONEY.

SIDE DRAINS

Check the existing side drains and clean or deepen the drains where required.
Wide flat drain better than Vee drain.



On flat gradients (= poor flow which allows water to soak into the subgrade under the road) or on very steep gradients (= erosion) it is best to construct stone pitched or concrete lined side drains.

SARF ROAD PAVEMENT REHABILITATION COURSE

WATER STANDING IN
FLAT SIDE DRAIN

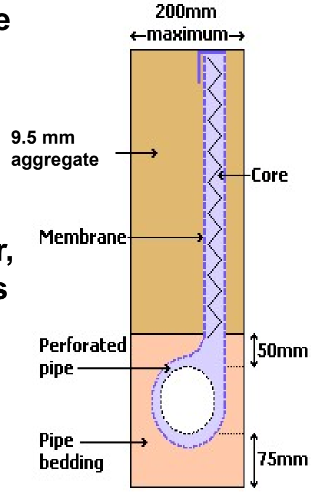
WATER STANDING IN
SILTED UP CULVERT

SUB-SOIL DRAINS

Investigate existing sub-soil drainage and clean or replace if required.

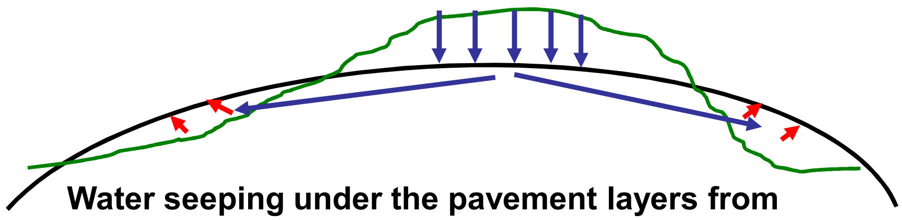
Determine where new sub-soil drains are needed.

Place outside concrete side drains or, if not possible, use thinner fin drains inside the side drain or sidewalk.



DRAINAGE IN CUTTINGS

Check for failures due to sub-surface water and determine where new sub-soil drains are needed or where the drain in the cutting should be deepened.



Water seeping under the pavement layers from blocked / shallow side drains, or through the road layers if the surfacing is old and cracked, runs down the hard rock layer under the road until it pops out again in the approach fills.

Should have a drainage layer under the pavement !

MAJOR BOX CULVERTS AND BRIDGES

Check the flood capacity of major culverts and bridges if you are carrying out a major road upgrade.

Previous flood capacity check calculations may be available – if not they may need to be re-done.

Check for erosion around the abutments and piers as well as for any structural damage.

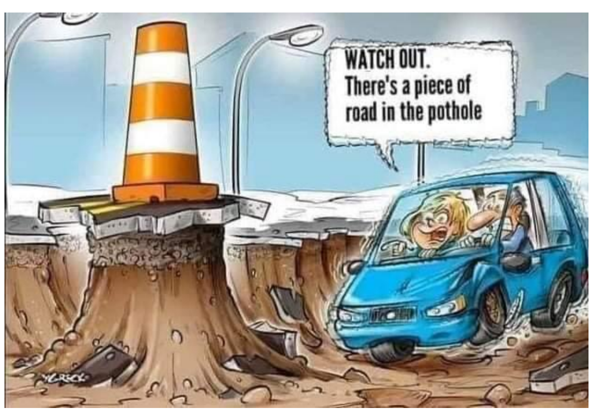
PIPE CULVERTS

Check for cracking in concrete pipe culverts (usually longitudinal crack in top of the pipe) and rusting at the bottom of metal (ARMCO) pipe culverts.

Culverts may still be functioning under the existing traffic loading but when you use a heavy vibratory roller to re-compact the rehabilitated pavement layers these culverts fail.

You then have unbudgeted additional costs to replace the culverts and extend the contract period as well as a standing time / delay cost claim from the Contractor.

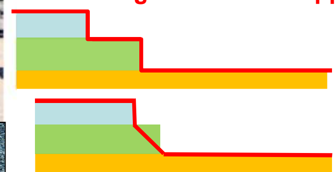
8. PATCHING AND CRACKSEALING



SARF ROAD PAVEMENT REHABILITATION COURSE

PATCH AREAS TO BE CUT SQUARE AND PROPERLY CLEANED OUT . THE FLOOR AREA MUST THEN BE RECOMPACTED BEFORE THE BACKFILL MATERIAL IS PLACED AND PROPERLY COMPACTED.

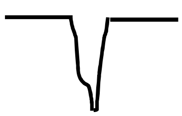
Vertical edges must be stepped :



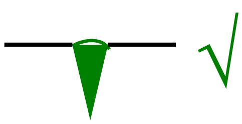
PATCHES MUST BE RESURFACED WITH A THICK, WELL COMPACTED LAYER OF ASPHALT (or with a good double seal.)

A THIN LAYER OF UNCOMPACTED ASPHALT IS USELESS !

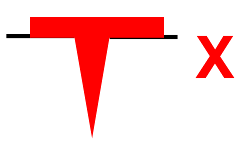
SARF ROAD PAVEMENT REHABILITATION COURSE



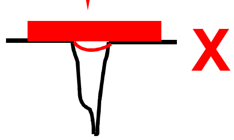
CLEAN OUT THE CRACK WITH COMPRESSED AIR AND PRIME SIDES OF CRACK WITH DILUTE (30%) BITUMEN EMULSION IF CRACK IS WIDE.



FILL THE CRACK WITH CRACK SEALANT.
3 – 6 mm wide : Use a modified bitumen emulsion.
> 6 mm wide : Use a bitumen-rubber crack sealant.



DO NOT OVERFILL THE CRACK AND SMEAR THE EXCESS SEALANT ALL OVER THE ROAD.



DO NOT JUST SMEAR SEALANT OVER THE CRACK.

IN SOME INSTANCES YOU CAN COVER THE CRACKS WITH A STICK ON PATCH WHICH CONSISTS OF A SINGLE MODIFIED SEAL PLACED ONTO A BACKING SHEET. THE BACKING SHEET IS THEN STUCK ONTO THE ROAD USING A LAYER OF BITUMEN EMULSION. STRONG BUT COSTLY.

A GEOFABRIC SUCH AS "Bidim" CAN ALSO BE STUCK OVER THE CRACKED AREA WITH BITUMEN EMULSION AND THEN MORE EMULSION AND CRUSHER DUST IS APPLIED ON TOP. THIS IS ONLY SUITABLE FOR LIGHTLY CRACKED / LOW TRAFFIC ROADS.
WEAK BUT RELATIVELY INEXPENSIVE. (Cannot recycle later !)

9. ROAD PAVEMENT LAYER RECYCLING

RECYCLING CHOICES

When recycling sections of an existing pavement

- **Decide what has to be done on areas not being recycled.**
- **Decide how the new and old surfaces should blend in.**

Recycled area constructed level with existing road level and then resurface the full width.

Recycled area constructed lower than the existing surface and infill with asphalt up to existing road level and then resurface full width.

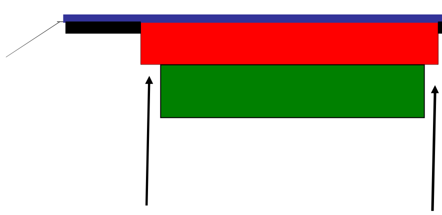
Note the stepped joints.

RECYCLING CHOICES

When recycling sections of an existing pavement

- **Decide what layers need to be recycled.**
- **Decide on how material is to be used.**

Recycle existing surfacing & base (& possibly some or all of the subbase) into a new layer and then resurface the full width.



Remove existing base & surfacing to spoil or windrow/stockpile for reuse before recycling the subbase (& possibly some of the subgrade) and then reconstruct base layer and resurface the full width.

Note the stepped joints.

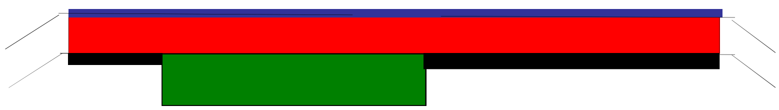
RECYCLING CHOICES

When recycling sections of an existing pavement

•Decide if additional structural / load carrying capacity is required.

•Decide which existing layers need to be recycled and stabilised.

•Decide on how many new layers are required and what material is required for any new layers (new material / recycled material ?)



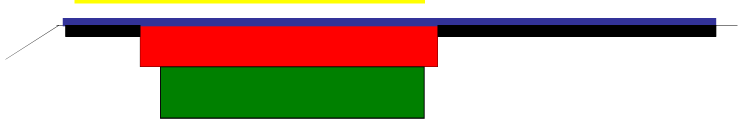
Recycle existing surfacing & base (& possibly some or all of the subbase) into a new layer and then add a new granular or asphalt base layer on top for the full width before resurfacing,

RECYCLING – STABILISATION CHOICES

When recycling sections of an existing pavement

- **Decide what layers need to be stabilised.**
- **Decide on cement or bitumen stabilisation.**

Recycling of upper layer can be done without stabilization or with bitumen stabilization. Cement stabilization not usually used in upper layer due to shrinkage cracks but light cement stabilization can sometimes be considered.



Recycled or new base can be done without stabilization or with bitumen stabilization. The recycled subbase is usually strengthened by stabilizing it with cement.

ADDITION OF LAYERS

- Raising road level will require replacing guard rails, side drains, possible verge and fill widening , lengthening of culverts / raising headwalls etc.
- Shoulders to be reconstructed to new road level.
- Traffic accommodation difficult – must have a plan !
- Rip existing bituminous surface to prevent a moisture barrier.
- If done in two lanes, bench on the centre line.
- Prevent water from accumulating against edge.

WIDENING OF SHOULDERS

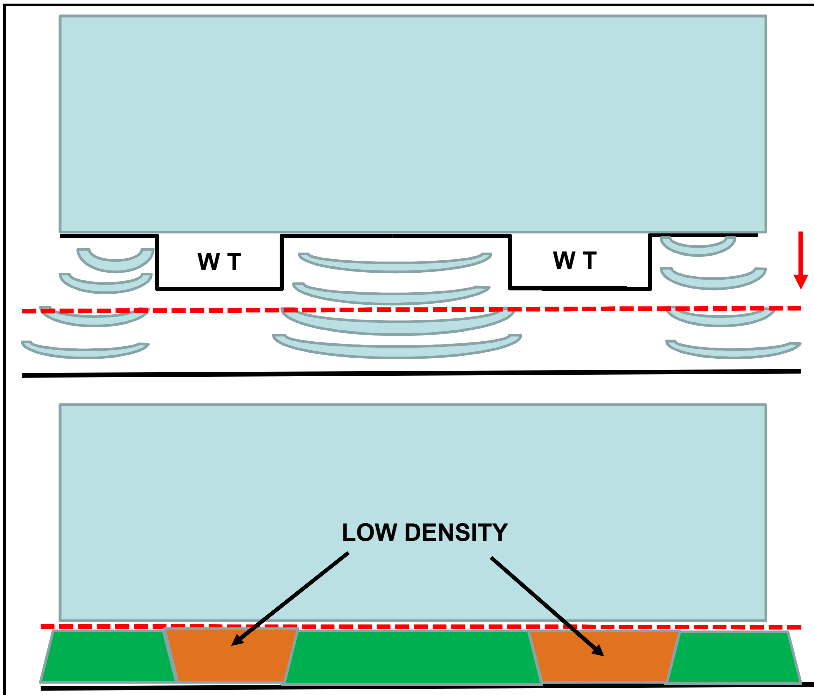
- Benching of layers so that construction joints staggered.
- Remove part of the old surfacing to create a staggered joint on the surfacing as well.
- Design layers such that a water trap is not formed.

RECYCLING CONSIDERATIONS

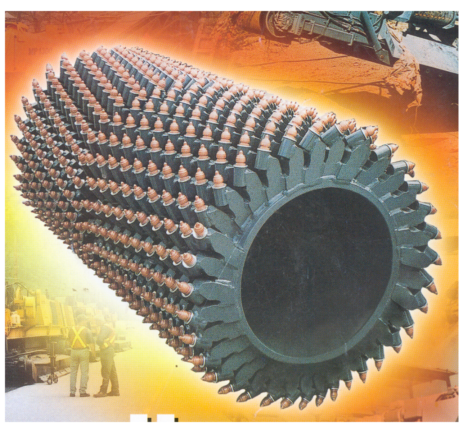
- Construction joints not to be in wheel track.
- Crushed stone base to be protected when surface milled off.
- When using a recycler and more than one pass of the machine is used, loosen material in wheel track by ripping after second pass.
- Recycler should be heavy enough to handle the mass of milled material without lifting.
- Carefully regulate water quantity - Wet spots must be prevented.
- Carefully choose compaction equipment to suit the thickness of the recycled layer that is being compacted.
- CHECK TEETH WEAR ON THE CUTTING DRUM !

MATERIAL IN OVERLAP WILL GET ADDITIONAL MOISTURE UNLESS OUTER SPRAY NOZZLES CLOSED !

MATERIAL IN WHEEL PATHS IS PRE-COMPACTED !



RECYCLING DEPTH MUST NOT EXCEEED THE MACHINE'S CAPABILITY !



CHECK THE TYPE OF CUTTING DRUM. (IS IT FOR REMOVING MATERIAL OR FOR RECYCLING MATERIAL.

THIS IS A MILLING DRUM WITH CLOSELY SPACED TEETH FOR REMOVING ASPHALT OR OTHER PAVEMENT LAYERS TO SPOIL OR STOCKPILE.

NOTE THE TEETH PATTERN TO MOVE MATERIAL TO THE CENTRE SO IT CAN BE PICKED UP ON A CONVEYOR BELT.

MILLING MACHINE REMOVING BASE LAYER TO WINDROW FOR LATER RE-USE AFTER THE SUBBASE LAYER HAS BEEN IN-SITU RECYCLED AND STABILISED WITH CEMENT. (Asphalt already milled to stockpile.) 223

A DRUM USED FOR RECYCLING GRANULAR LAYERS HAS FEWER TEETH SPACED FURTHER APART AND THEY ARE LONGER.
THE TEETH ARE ALSO STRAIGHT SO THE MILLED MATERIAL IS CIRCULATED AROUND THE DRUM AND NOT MOVED SIDEWAYS. 224

WORKING IN URBAN AREAS

Some issues to be considered are :

- **Traffic accommodation / peak traffic hours**
- **Overlays instead of layer works and seals**
- **Services (depth of recycling, vibratory compaction)**
- **Accesses (can you accommodate level changes and maintain access to properties during construction)**
- **Kerbs, channels and sidewalks**
- **Traffic signal induction loops**
- **Compaction – use of vibratory rollers with regard to damage to underground pipes & adjacent buildings.**
- **Noise, dust and working hours**

STABILISATION

STABILISERS ARE OFTEN ADDED TO RECYCLED MATERIAL TO ENHANCE THE PROPERTIES OF A MATERIAL WHICH IS NOT STRONG ENOUGH BECAUSE :

IT HAS DEGRADED OVER TIME DUE TO WEATHERING AND/OR REPEATED TRAFFIC LOADING.

THE RECYCLING PROCESS CHANGES ITS GRADING, THEREBY REDUCING ITS STIFFNESS / STRENGTH.

THE STRENGTH OF THE PAVEMENT MUST BE INCREASED TO CARRY THE NOW HIGHER TRAFFIC LOADING.

THE PAVEMENT LAYERS NEED TO BE WATERPROOFED.

STABILISATION

THE STABILISING AGENTS WHICH ARE MOST OFTEN USED ARE :

- **Lime to neutralise any clay in the material. (TRH 13)**
- **Cement to increase the stiffness of the compacted layer (and to waterproof it). (TRH 13 / Gautrans manual)**
- **Bitumen to increase the flexibility of the compacted layer (and to waterproof it).
(1% cement is usually added as a stiffening agent.)
(SABITA publications, especially TG2 – 2020 edition)**

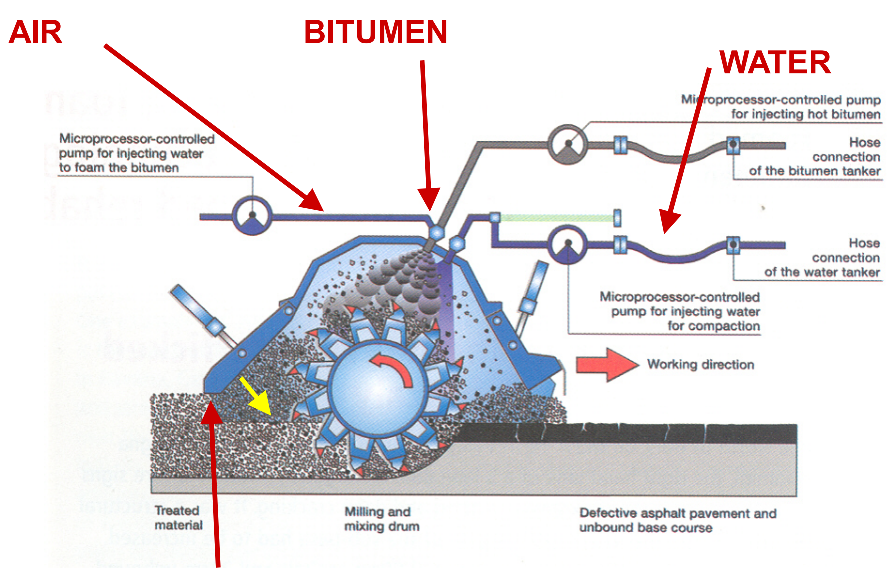
CEMENT OR LIME STABILISER MUST BE PRE-SPREAD ACCURATELY BEFORE THE RECYCLING MACHINE BREAKS UP THE PAVEMENT LAYER AND MIXES IN THE STABILISER.

BITUMEN STABILISER CAN BE ADDED

EITHER
AS AN EMULSION WHICH CAN BE EASILY MIXED IN WITH THE RECYCLED MATERIAL

OR
AS A FOAMED BITUMEN. THE FOAM INCREASES THE VOLUME OF THE NEAT BITUMEN AND THIS MAKES IT EASIER TO MIX IN.

NOTE :
It is not possible to mix in a small percentage of hot bitumen with cold aggregate with a recycler. That is why asphalt is made by mixing the bitumen with heated aggregate inside a mixing drum - the hot aggregate keeps the bitumen fluid until all the aggregate has been coated with bitumen.



GRADING CONTROL GATE – close gate to reduce particle size and / or to reduce segregation and improve mixing.

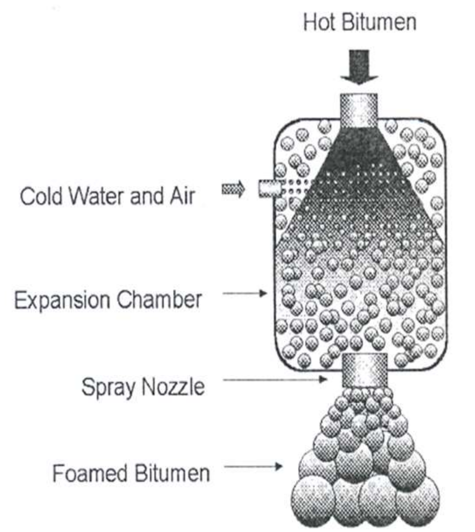


Figure 1.1 Foamed Bitumen Production in Expansion Chamber

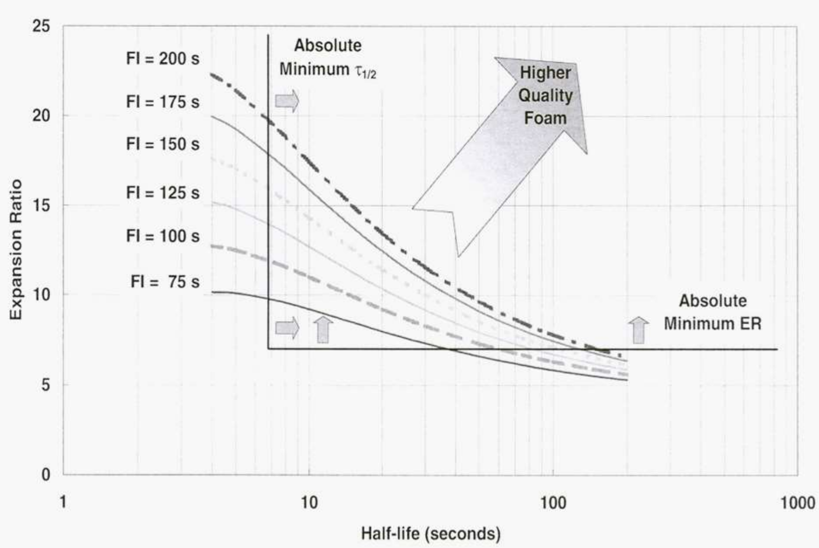


Figure 3.4 Ranking of Foamed Bitumen Suitability on the Basis of the Foaming Characteristics

DESIGN OF BITUMEN STABILISED PAVEMENTS :

- SABITA MANUAL TG 2 (2020 EDITION)

- SARF TRAINING COURSE –

PAVEMENT REHABILITATION BY COLD RECYCLING / BITUMEN STABILISATION

10.
RESURFACING

Read
- **TRH 3 – SEAL DESIGN**
- **TG 1 – MODIFIED BINDERS**

RESURFACING DESIGN CONSIDERATIONS

SEALS, OVERLAYS AND SURFACE TREATMENTS ARE USED TO ENHANCE FUNCTIONAL PROPERTIES.

WITH HIGHER AVERAGE DEFLECTIONS YOU SHOULD USE A POLYMER MODIFIED SEAL OR ASPHALT.

IF TEXTURE DEPTH OF EXISTING SURFACE > 1 mm USE A TEXTURE SLURRY BEFORE RESEALING.

CONSIDER COMBINED OVERALL COST OF PRE-TREATMENT AND SEAL AND THEN COMPARE COST WITH UTFC OR OTHER ASPHALT OVERLAYS.

RESURFACING

In deciding on the type of surfacing to use consider:

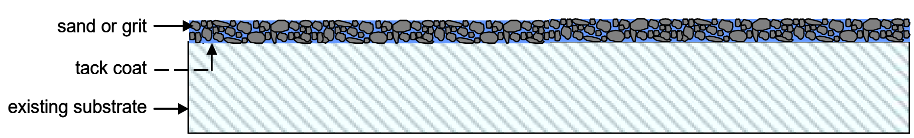
1. Pavement structure and traffic loading:
Low : Use a normal bituminous seal.
Med. to High : Use a polymer modified seal.
High: Use asphalt, possibly polymer modified.

2. Environmental conditions:
Temperature, rainfall, number of sunny days

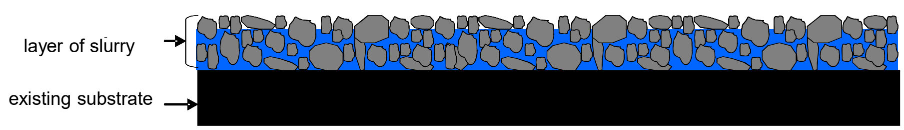
3. Existing and required surface texture:
Texture depth / skid resistance.

SURFACING TYPES

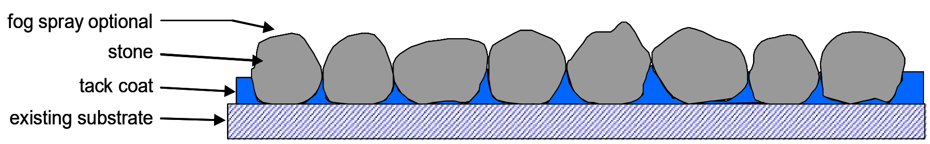
TREATMENT TYPE	EXPECTED SERVICE LIFE
Bituminous enrichment sprays	**1 to 3 years**
Reinforced crack filling (For active cracks >6mm)	**Up to 3 years**
Crack sealing (for cracks 3-6mm)	**Up to 3 years**
Single seal	**5 to 10 years**
Double seal	**10 to 15 years**
Cape seal	**10 to 15 years**
Slurry seal (if deflections are low)	**3 to 5 years**
Ultra thin friction course (check cost)	**5 to 10 years**
Asphalt overlay (35 - 40 mm) (if deflections are low)	**15 to 25 years**
Consider using a modified bitumen if deflections are high, the road surface is cracked or an extended surfacing life is desired.	



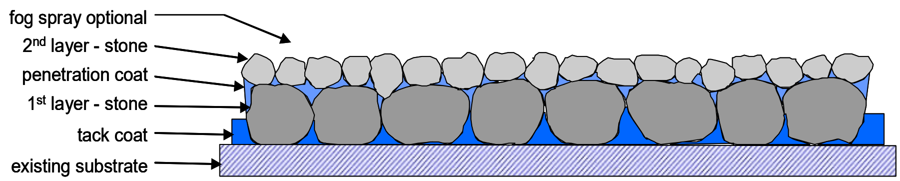
SAND SEAL



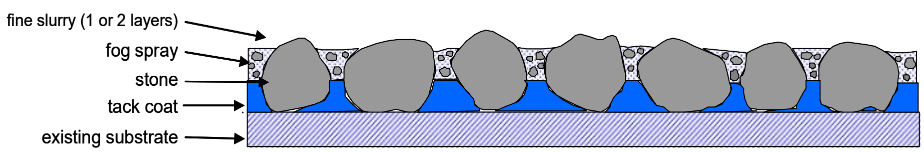
SLURRY SEAL



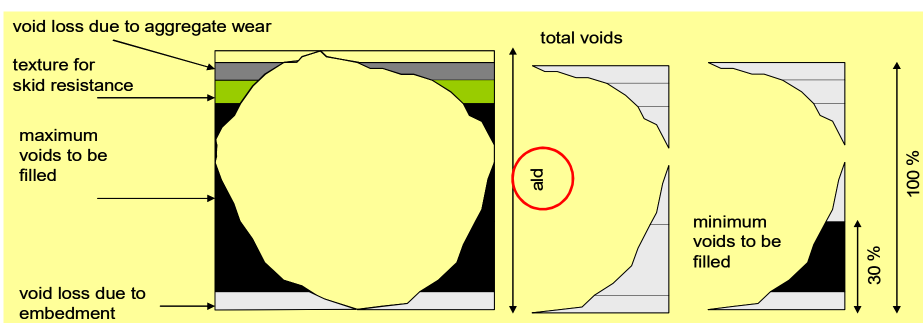
SINGLE SEAL



DOUBLE SEAL



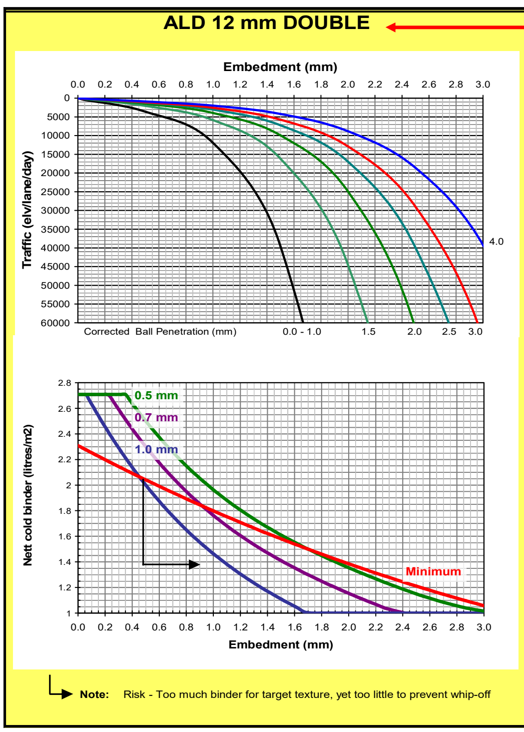
“CAPE” SEAL



AMOUNT OF BITUMEN EQUALS THE VOLUME REQUIRED TO FILL THE REMAINING VOIDS
(between minimum & maximum levels)

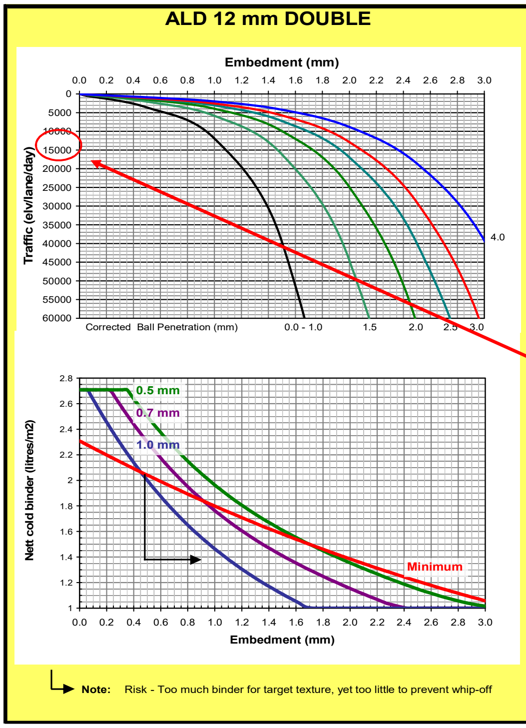
Three important design input parameters :

- **Average Least Dimension (ALD) of the aggregate.**
- **Traffic = Equivalent Light Vehicles / lane / day;**
  1 heavy vehicle = 40 ELV
- **Corrected Ball Penetration value which measures the hardness of the road surface.**
  (TMH 6 – ST 4)



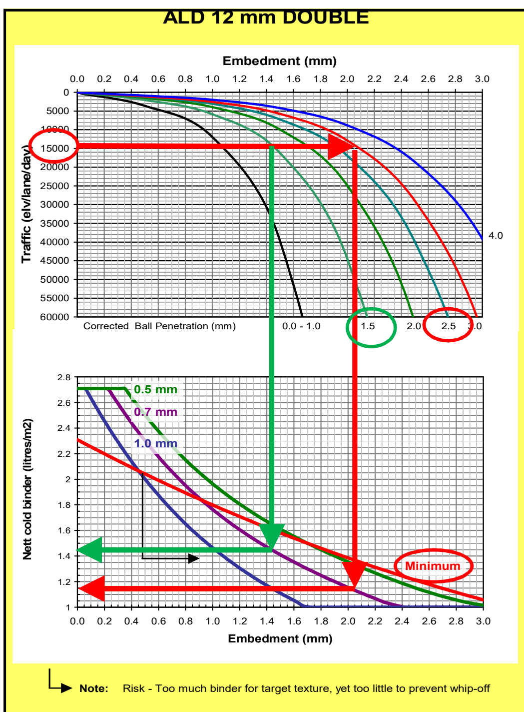
Use the ALD of the aggregate to select the required Design Chart.

Double Seal : use combined total ALD of both aggregates



Use the ELV's
To get the Design
Start Point

For example :
ELV's =
15 000
per direction
per day



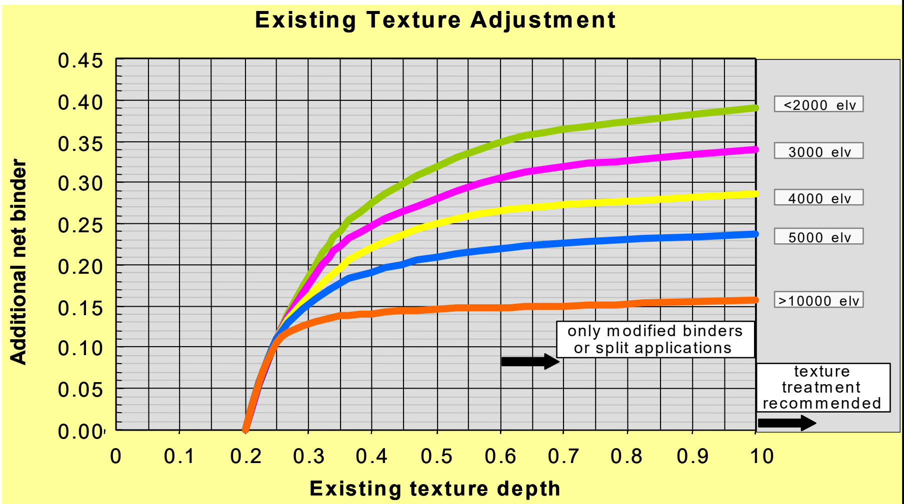
Use the Corrected Ball Penetration Rate to select the seal binder application rate.

15 000 ELV's
Ball pen = 2.5 mm
Ball pen = 1.5 mm

Corrections still need to be applied for the following parameters :

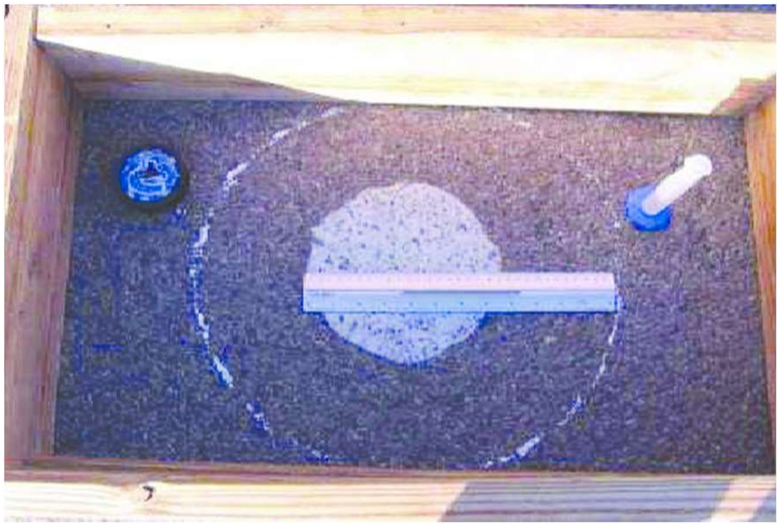
- Existing surface texture.
- Climate zone.
- Steep grades.
- Aggregate spread rate.

1. CORRECTION FOR SURFACE TEXTURE



Note : With a modified binder you can seal on a texture depth of up to 1.0 mm without using a texture treatment.

Sand patch test : (ASTM E965, 2006).



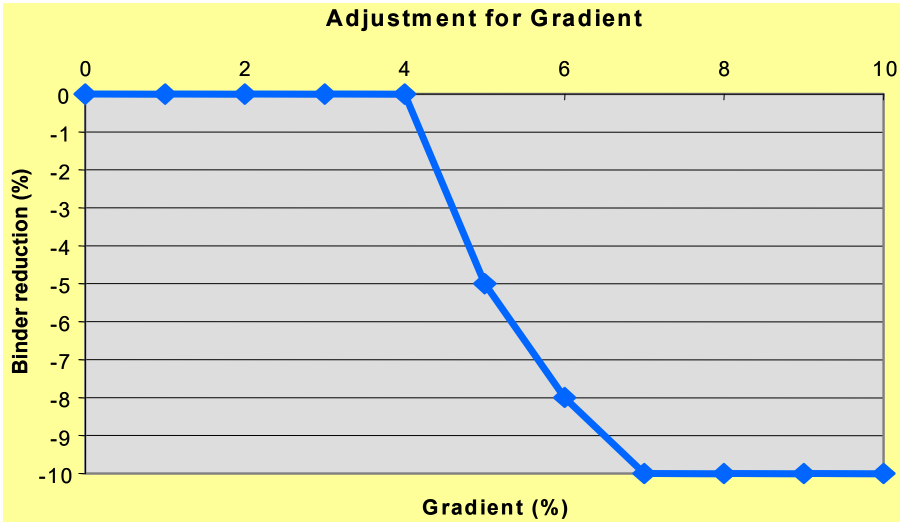
2. ADJUSTMENT FOR CLIMATE

Increase binder by up to 10 % where N > 5

Reduce by up to 10% where N < 2

No adjustment required if using a modified binder as it is less sensitive to temperature and does not oxidize (age) as easily.

3. ADJUSTMENT FOR GRADIENTS



Length of grade and No. of heavy vehicles to be considered.

Usually need binder reduction if vehicle speed < 30 km/hr.

4. ADJUSTMENT FOR AGGREGATE SPREAD RATE

Add more binder as the matrix opens up :

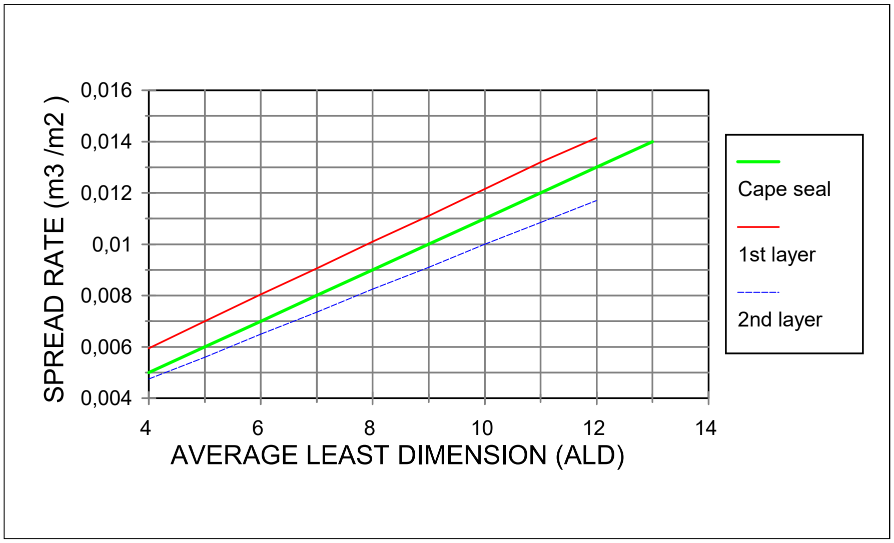
- **add 10% for medium dense packing**
- **add 20% for open mosaic**

Note : <u>Very subjective.</u>

This aspect is not well related to the theoretical determination of the aggregate application rate which is based on a Flakiness Index of 15%.

Better to get aggregate application correct and not make any adjustments !

DESIGN AGGREGATE SPREAD RATE



SARF ROAD PAVEMENT REHABILITATION COURSE

1. ENSURE CORRECT APPLICATION RATE AND EVEN SPRAY ACROSS WIDTH

SARF ROAD PAVEMENT REHABILITATION COURSE

2. DO NOT LET THE BITUMEN DISTRIBUTOR GET TOO FAR AHEAD OF THE AGGREGATE SPREADER.

253

Spray bar height correct = even triple overlap.

(Application rate = average of 3 nozzles, not just one !)

254

3. CHECK THAT THE AGGREGATE IS SPREAD EVENLY.

Always pre-check the chip spreader

Too open !

Satisfactory – slightly too little

Satisfactory (slightly too much)

259

Over application !

260

261

SARF ROAD PAVEMENT REHABILITATION COURSE

4. ROLL THE AGGREGATE INTOTHE BITUMEN BEFORE IT GETS COLD (or before the bitumen emulsion breaks).

262

SARF ROAD PAVEMENT REHABILITATION COURSE

5. BROOM THE AGGREGATE INTO ANY GAPS BEFORE THE FINAL ROLLING HAS BEEN COMPLETED.

SARF ROAD PAVEMENT REHABILITATION COURSE

6. A PERFECT SEAL REQUIRES CORRECT DESIGN (as per TRH 3) AS WELL AS GOOD QUALITY CONTROL DURING CONSTRUCTION.

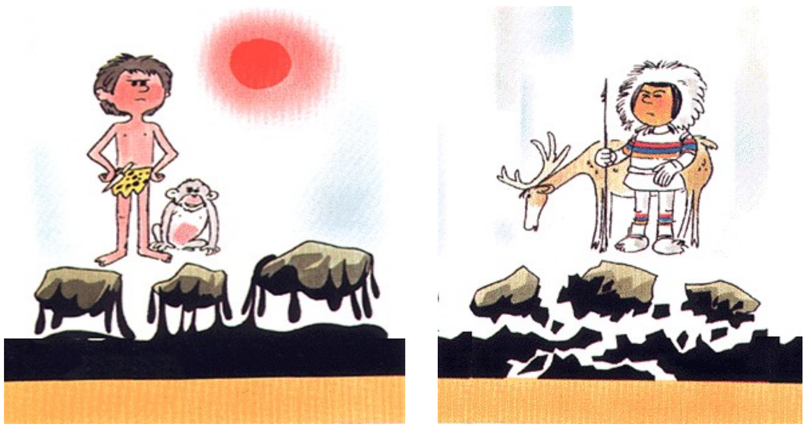
7. INSUFFICIENT BITUMEN TO RETAIN AGGREGATE.
(Consider weather conditions and traffic speed before opening a new section.)

8. TOO MUCH BITUMEN
(Almost impossible to correct this !)

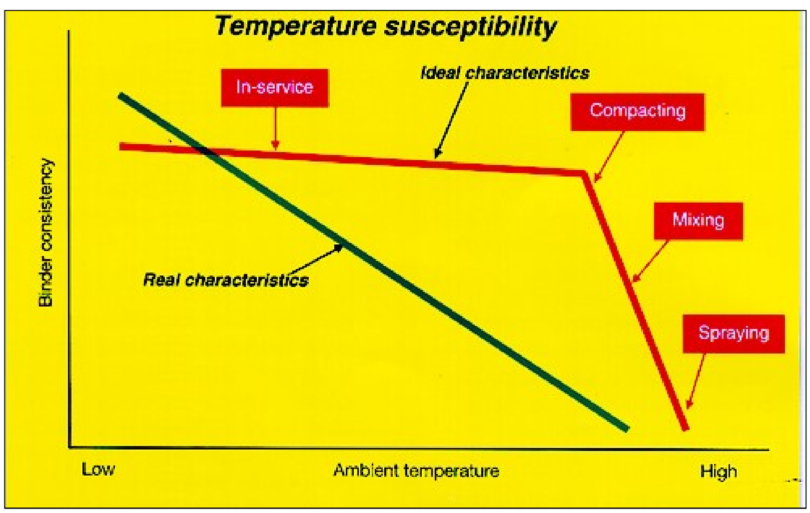
8. TRAMLINING DUE TO UNEVEN DISTRIBUTION OF BITUMEN
(Impossible to correct this !)

VARIABLE SURFACE TEXTURE – WHY ?
WHAT SHOULD THE SEAL DESIGNER HAVE DONE ?

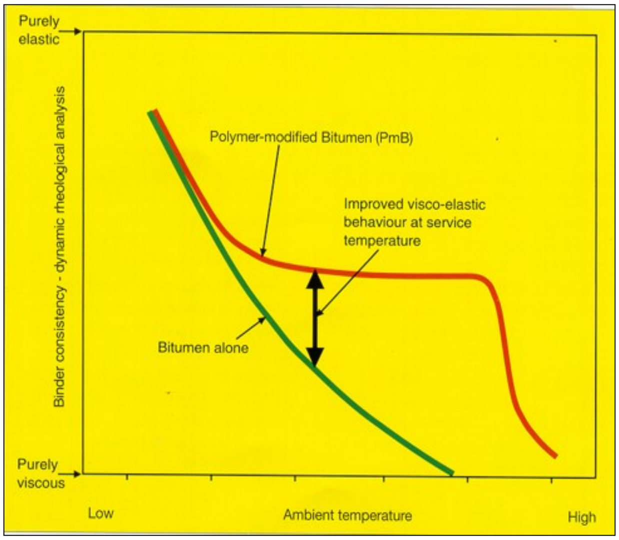
USE OF MODIFIED BITUMEN



USE OF MODIFIED BITUMEN



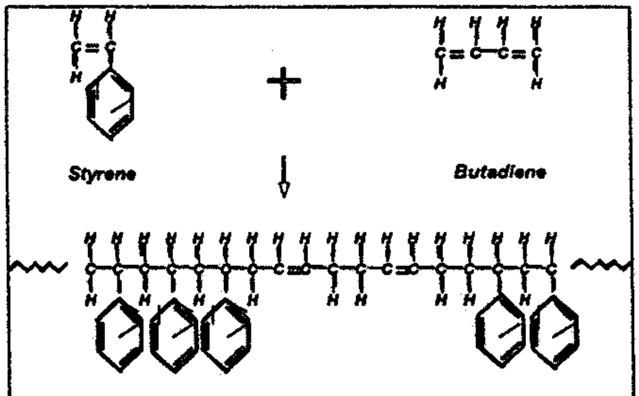
USE OF MODIFIED BITUMEN



SARF ROAD PAVEMENT REHABILITATION COURSE

USE OF MODIFIED BITUMEN

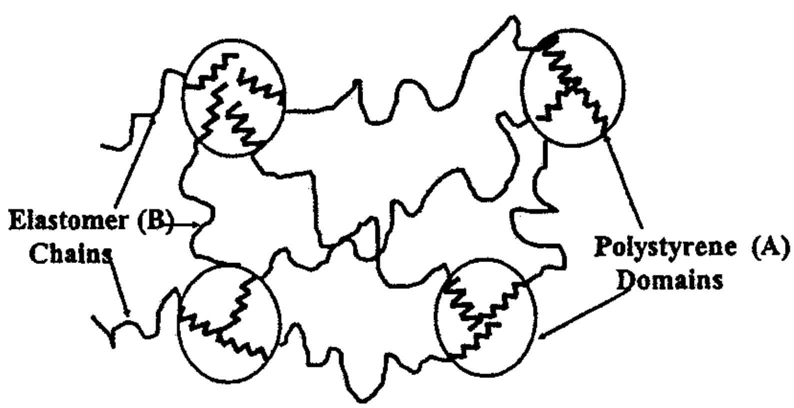
Formation of SBS



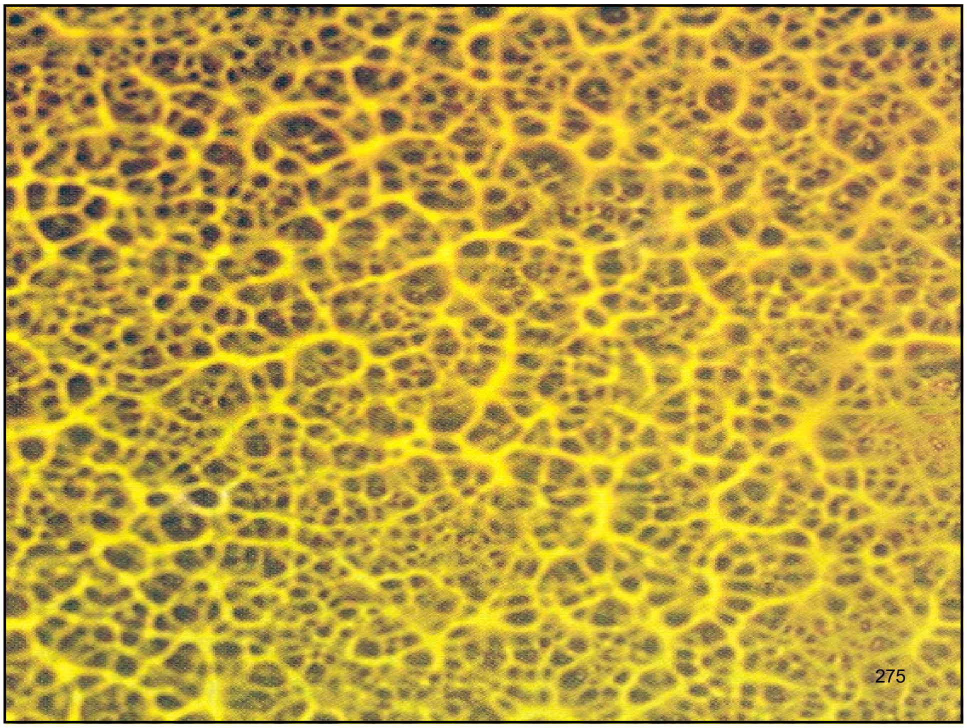
SBS Block Copolymer with Unsaturated Butadiene Chain

H. Bahia 21

Polymers Advantage: Phase Arrangement in A-B-A Block Copolymers .. (Physical Cross-linking)

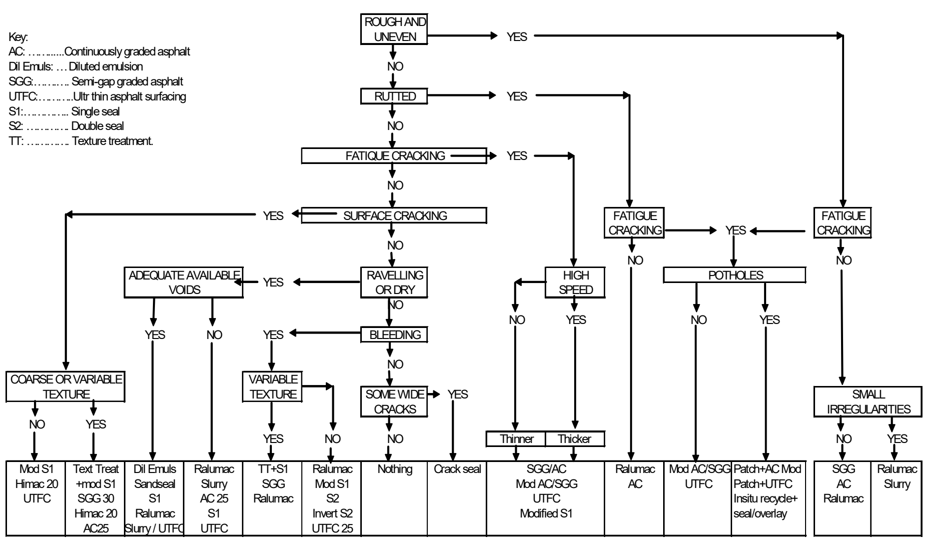


H. Bahia 20



SARF ROAD PAVEMENT REHABILITATION COURSE

RESURFACING SELECTION GUIDE



After Dr Steve Emery and friends

FURTHER MATERIALS INFORMATION

Refer to the additional information given in the course notes :

- **Crack sealing : Appendix E.**
- **Surface enrichment sprays : Appendix F**
- **Cement stabilised materials: Appendix G**
- **Asphalt : References 12, 13 &14.**

Other essential information is given in the following documents which can be downloaded from the SANRAL website :

- **Seal work – TRH 3**
- **Pavement design – TRH 4**
- **Granular materials - TRH 14**
- **Bituminous stabilised materials: SABITA Manual TG2.**

11.
END OF COURSE QUIZ

Study the following pictures and write down :

1. **What type of defect (or defects) you can see ?**
2. **Why have the defect / defects occurred ?**
3. **How you think the section of road pavement should be rehabilitated ?**
4. **What type of surfacing would you recommend for the rehabilitated road pavement ?**

SARF ROAD PAVEMENT REHABILITATION COURSE

WHAT : ____

WHY : ____

REHAB : ____

SURFACING : ____ 279

SARF ROAD PAVEMENT REHABILITATION COURSE

WHAT : ____

WHY : ____

REHAB : ____ 280

SURFACING : ____

SARF ROAD PAVEMENT REHABILITATION COURSE

WHAT : ______________________________
WHY : ______________________________
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SARF ROAD PAVEMENT REHABILITATION COURSE

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SARF ROAD PAVEMENT REHABILITATION COURSE

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SARF ROAD PAVEMENT REHABILITATION COURSE

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SARF ROAD PAVEMENT REHABILITATION COURSE

WHAT : ______________________________

WHY : ______________________________

REHAB : ______________________________ 287

SURFACING : ______________________________

SARF ROAD PAVEMENT REHABILITATION COURSE

WHAT : ______________________________

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SARF ROAD PAVEMENT REHABILITATION COURSE

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SARF ROAD PAVEMENT REHABILITATION COURSE

WHAT : ____________________

WHY : ____________________

REHAB : ____________________

SURFACING : ____________________ 290

WHAT : ____

WHY : ____

REHAB : ____

SURFACING : ____

SARF ROAD PAVEMENT REHABILITATION COURSE

PRIORITY READING LIST :

1. **COURSE NOTES**
2. **SAPEM**
3. **TMH 9 AND TRH 6**
4. **TRH 4**
5. **TRH 3**
6. **TRH 17**
7. **TG 1 & TG 2**
8. **ALL OTHER TRH AND TG DOCUMENTS**

THANK YOU FOR YOUR ATTENDANCE AT THIS COURSE.

IF YOU HAVE ANY QUESTIONS PLEASE CONTACT MIKE WHITE.

e-mail: mikewhite4535@gmail.com