INTERNATIONAL WORKSHOP, Ghana.

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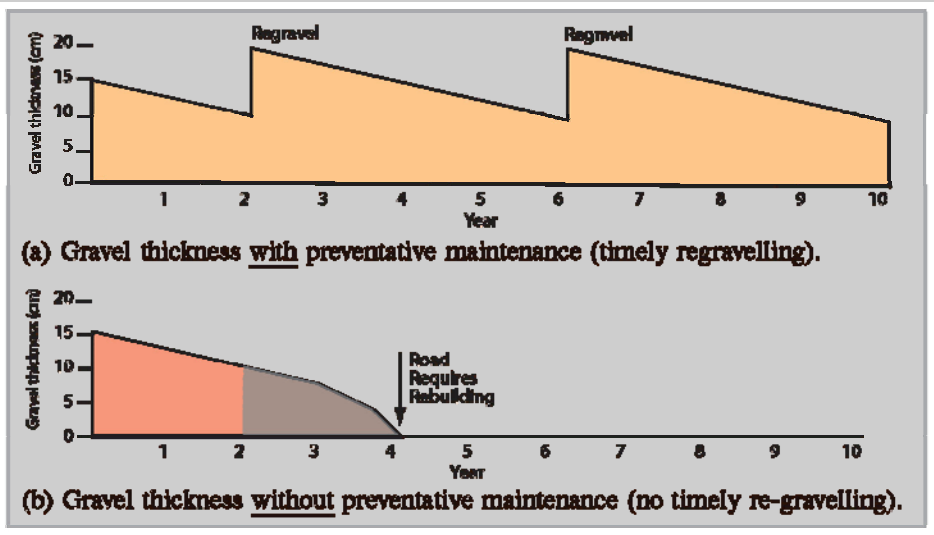
Alternative Surfacing Technologies for Low-Volume Sealed Roads (LVSR) + Case Studies

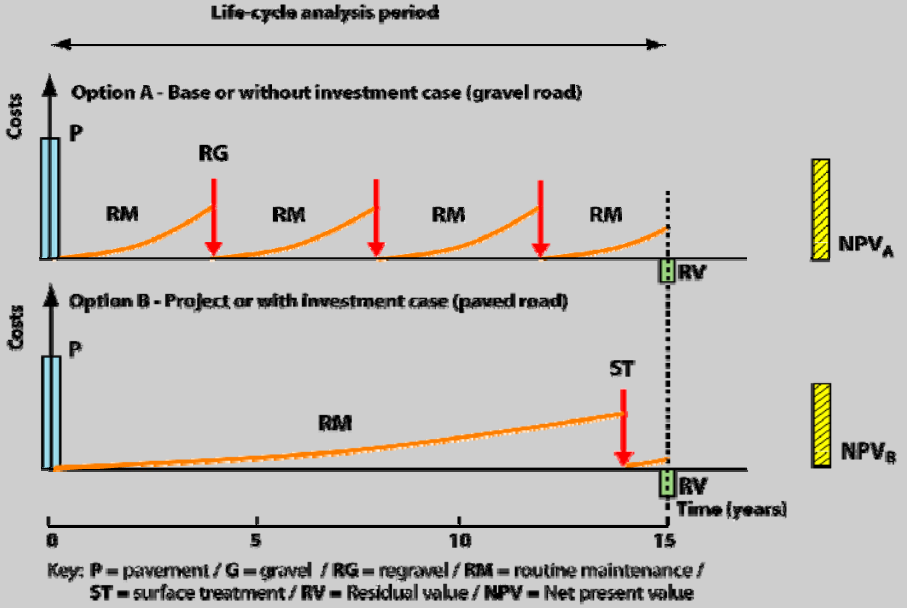
by Charles Overby,
Consultant

Format of the Presentation:

- Introduction
- Types and performance characteristics
- Properties and function of surfacings
- Selection of surfacing type
- Surfacing design and construction
- A brief of the Otta seal
- Case histories

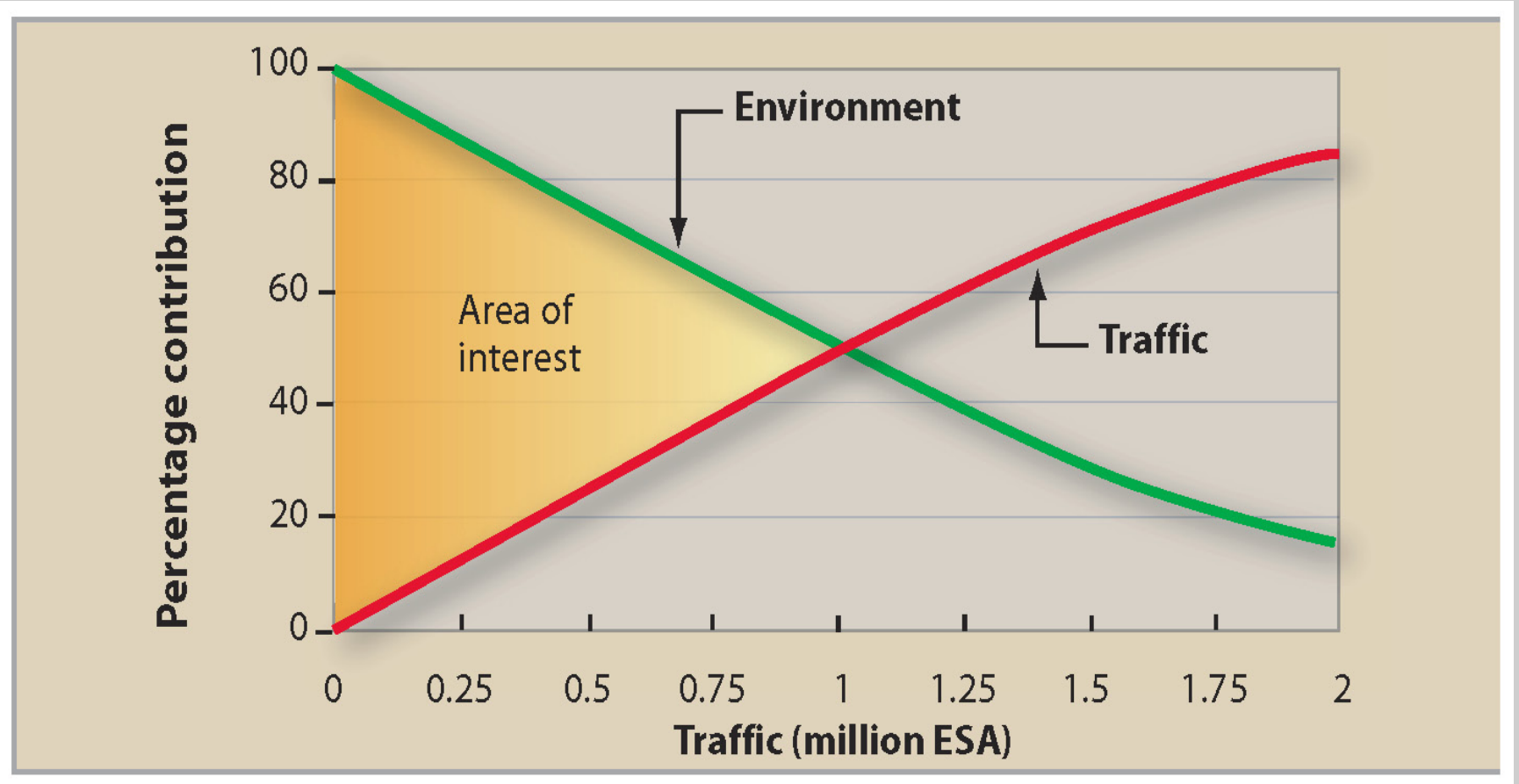

The continous exploitatation of a non-renewable gravel sources is an unsustainable approach.
There is a strong need to move towards a more ecologically sustainable development.





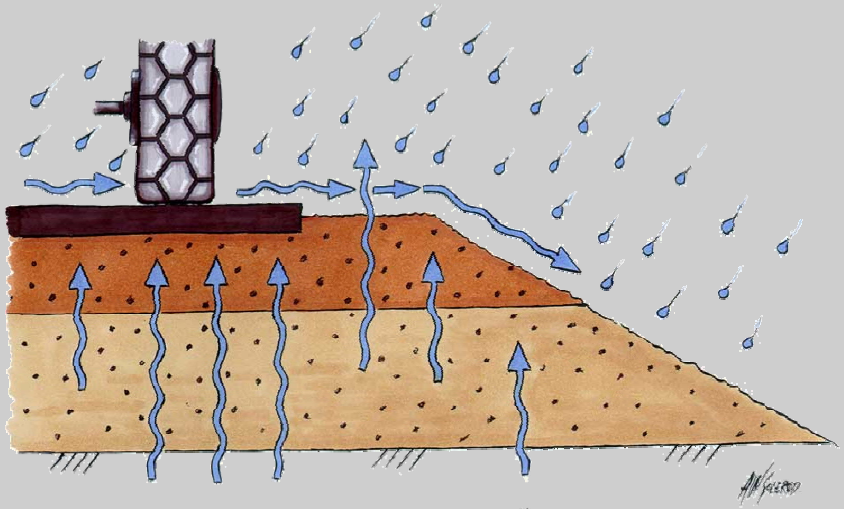
Key: **P** = pavement / **G** = gravel / **RG** = regravel / **RM** = routine maintenance / **ST** = surface treatment / **RV** = Residual value / **NPV** = Net present value

Traffic Loading versus dominant mechanisim of distress



Function of a Bituminous Surfacing

Poor gravel → Good gravel



Even "poor base gravel" may behave well when protected

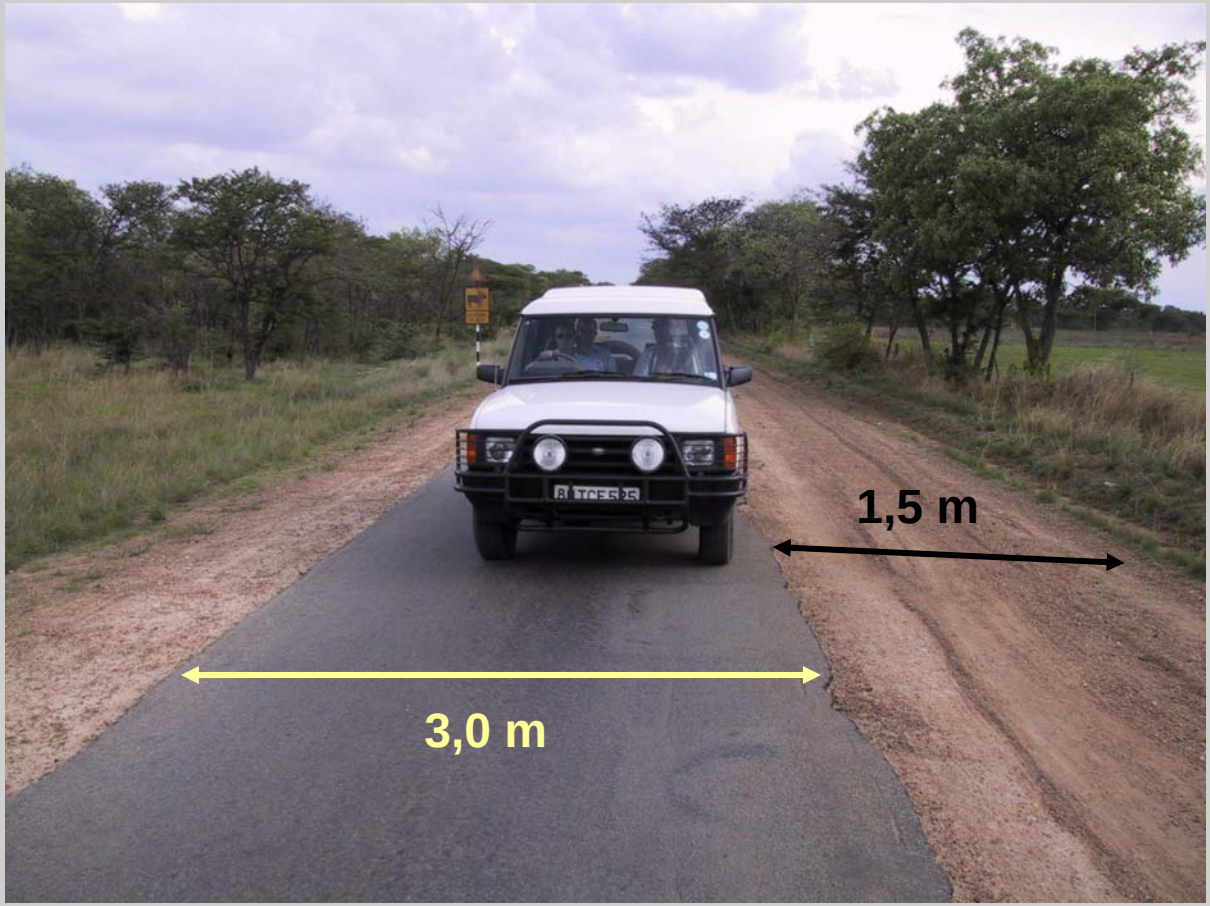
A “surfaced” road from the Roman empire.

Old Strip road, Zimbabwe

Strips 1,0 m wide

Total road width 5,0 m

Mat road, Zimbabwe



Otta Seal, Botswana

6,7 m wide carriageway with 0,75m wide sealed shoulders.

Role and Function of Bituminous Surfacing

- Provision of a durable, impervious surfacing which seals and protects the pavement layers from moisture ingress and consequent loss of pavement strength and degradation;

- Provision of a skid-resistant surface which can resist the abrasive and disruptive forces of traffic and the environment;

- Prevention of the formation of corrugations, dust and mud which generally permits relatively safe travel at higher speeds and lower vehicle operating and maintenance costs.

Economy

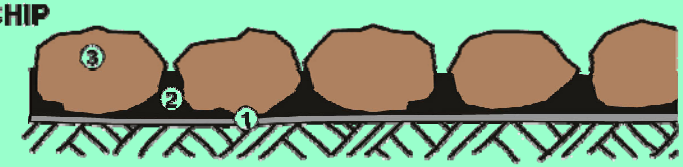
For all type of seals a life-cycle costing should always be carried out.

The assessement of only constrction cost does not give the true picture.

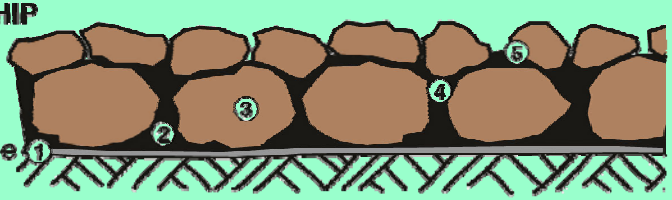
Surfacing types

SAND SEAL
1 Prime
2 Binder
3 Sand

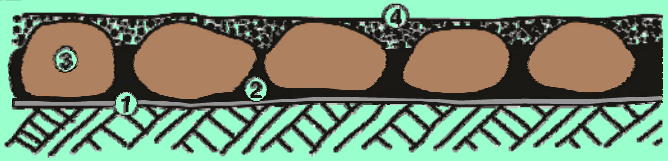
SINGLE CHIP SEAL
1 Prime
2 Binder
3 Stone



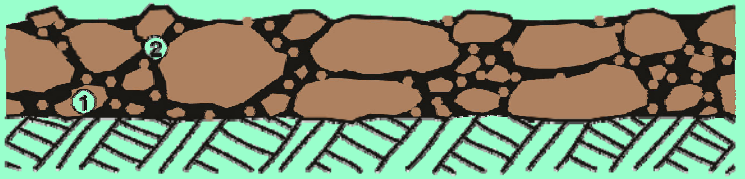
DOUBLE CHIP SEAL
1 Prime
2 Binder
3 Large stone
4 Binder



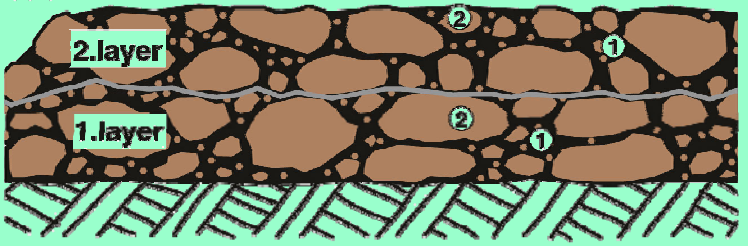
CAPE SEAL
1 Prime
2 Binder
3 Stone
4 Slurry



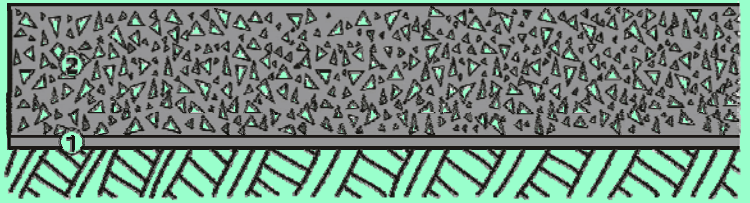
SINGLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate



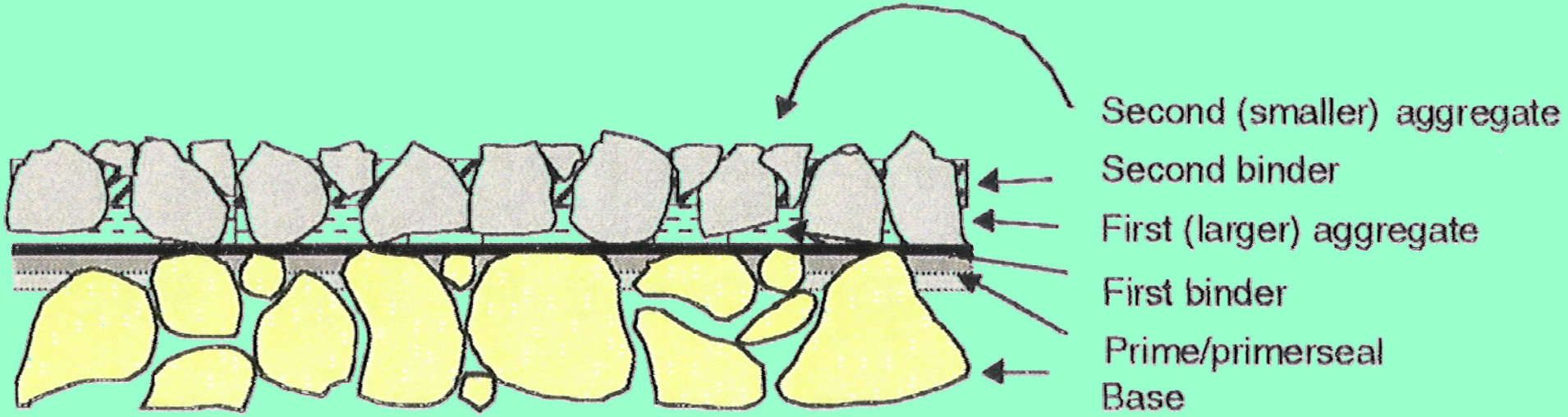
DOUBLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate



ASPHALT CONCRETE
1 Prime
2 Asphalt Premix



Double chip seal, details

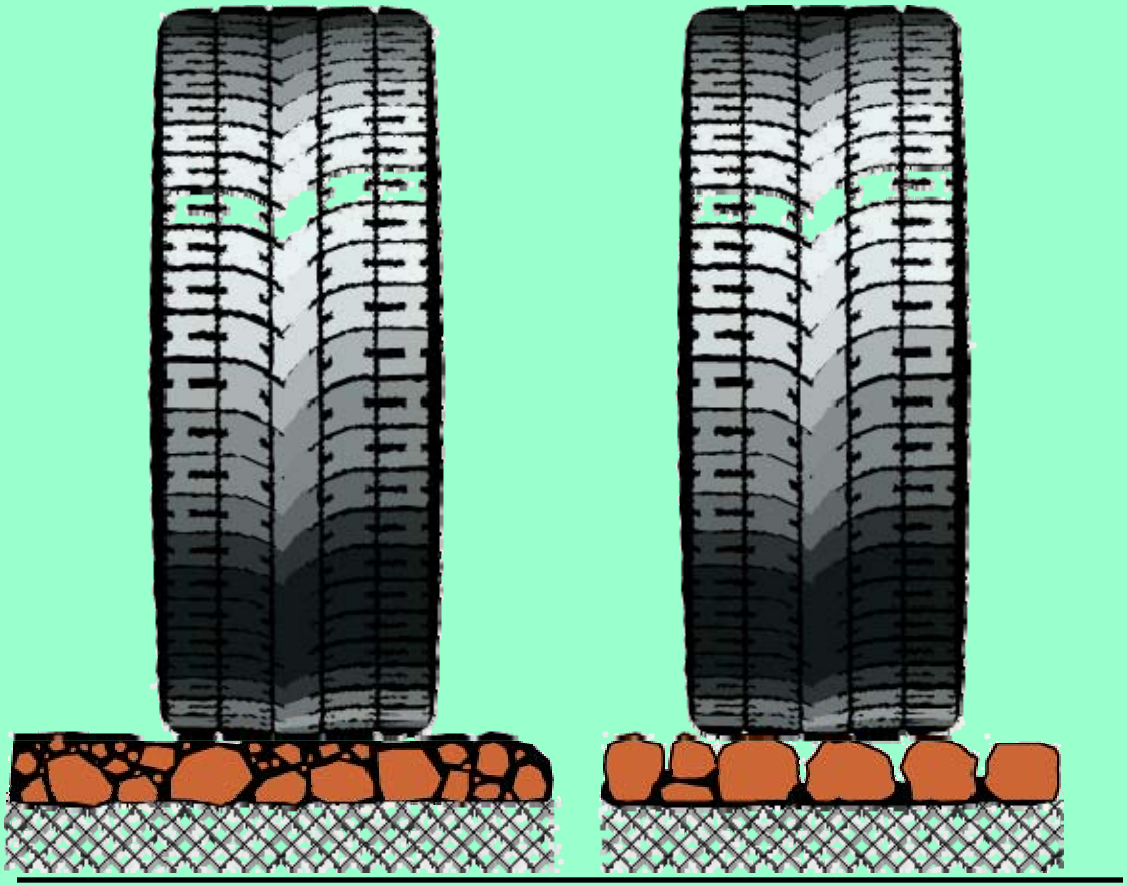


Types of sprayed seals

Other types of sprayed seals – or combinations

- Slurry seal
- Single chip seal + Sand seal
- Penetration Macadam + Sand seal (if key stones are small size aggergate)
- Single Otta Seal + Sand seal
- Brick or Block paving

Mechanisim of performance



Category A type of seal

Category B type of seal

The Cape Seal is a hybrid type of seal falling in between category A and B

Relative difference in required properties between various surface types

Parameter	Category A	Category B
Aggregate quality	Relaxed requirements in terms of strength, grading, particle shape, binder adhesion, dust content, etc. Allows extensive use to be made of natural gravels.	Stringent requirements in terms of strength, grading, particle shape, binder adhesion, dust content, etc. Allows limited use to be made of locally occurring natural gravel.
Binder type	Relatively soft (low viscosity) binders are required.	Relatively hard (high viscosity) binders are normally used.
Design	Empirical approach. Relies on guide-line and trial design on site. Amenable to design changes during construction.	Rational approach. Relies on confirm-atory trial on site. Not easily amenable to design changes during construction.
Construction	Not sensitive to standards of work-manship. Labour-based approaches relatively easy to undertake if desired.	Sensitive to standards of workman-ship. Labour-based approaches relatively easy to undertake if desired.
Durability of seal	Enhanced durability due to use of relatively soft binders and a dense seal matrix.	Reduced durability due to use of relatively hard binders and open seal matrix.

Typical range of Service Lives of Bituminous Surface Treatments

Type of seal	Typical range of service life (years)
Sand Seal	2 - 4
Slurry Seal	2 - 6
Single Chip Seal	4 - 6
Double Sand Seal	6 - 9
Double Chip Seal	7 - 10
Single Otta Seal + Sand Seal	8 - 10
Cape Seal (13mm + single slurry)	8 - 10
Cape Seal (19mm + double slurry)	10 - 14
Double Otta Seal	12 - 16

Some specifications for surfacing aggregates

Test Property	Botswana	South Africa	Zimbabwe (Traffic)	Australia (Traffic)
	-	-	(< $2x10^6$ ESA)	(AADT < 300)
10% FACT (kN) - Dry - Wet/Dry ratio	 > 210 > 0.75	 > 210 > 0.75	 > 120 > 0.65	 > 135 > 0.60
Max. LAA (%)	-	-	35 25	-
Max. FI (%)	30	30	30	35
TBM Value	-	-	-	< 30
Unsound Stone Content (%)	-	-	-	8
Adhesion (R&W)*	< 1	-	-	< 2
Max(%) Sodium or magnesium sulphate soundness	-	-	20	12

* The scales used to describe the degree of stripping vary between countries.

How appropriate are existing aggregate specifications ?

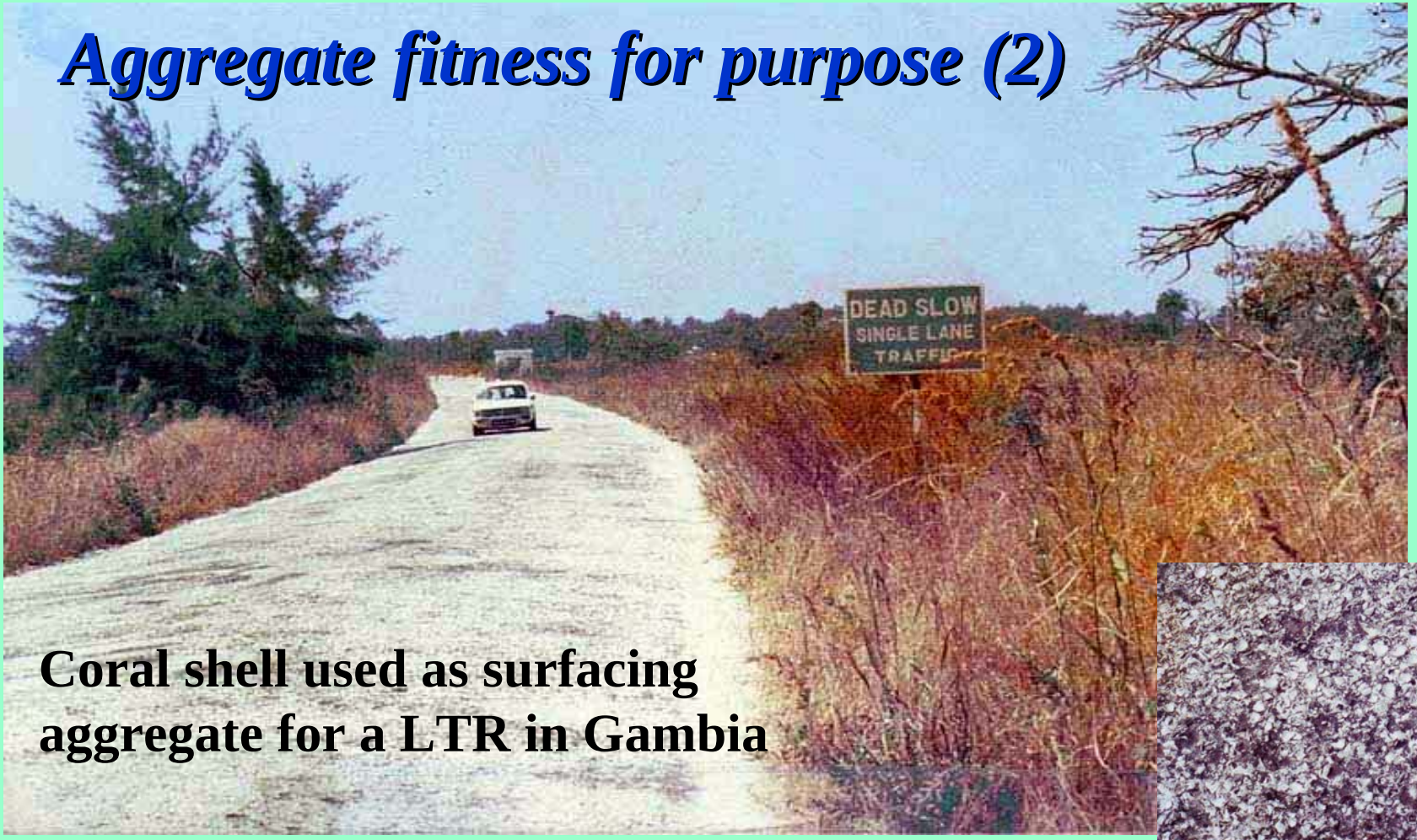
Most of the spec. is “blanket type”spec. and they suffer from a number of shortcomings with regard to LVSRs.

- **They are seldom traffic related and rule out non-standard aggregates**
- **They do not take into account the differing mechanism of performance for the different seal type**
- **The relatively high strength requirement often 210kN**

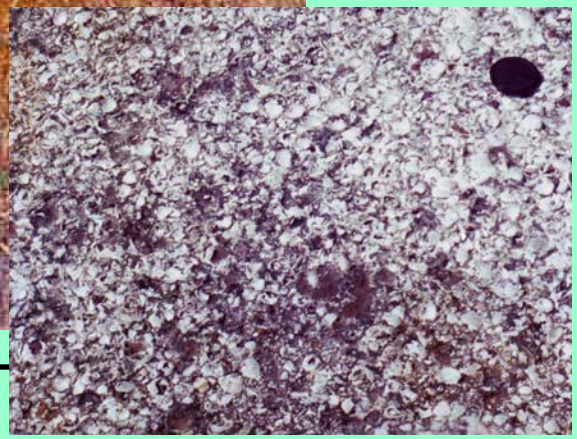
Aggregate fitness for purpose (1)

Lime stone aggregate used in the south east part of Tanzania.

Aggregate fitness for purpose (2)



Coral shell used as surfacing aggregate for a LTR in Gambia



Production of aggregate for bituminous surfacings

Type of seal	Type of aggregate	Winning and processing of materials
Surface dressing	Crushed stone or rock.	Crushing and screening.
Otta seal	Gravel, natural or crushed.	Stockpiling. Normally screening is also required.
Sand seal (used alone)	River sand (crusher dust may be used, but can be expensive).	Stockpiling (while river is dry). Screening out pebbles.
Sand cover seal (over Otta seals)	Any non-plastic sand.	Stockpiling if sand is not available along the roadside.
Slurry	Crusher dust.	Crushing and screening.

Aggregate availability (1)

Sofisticated crushing plant

Aggregate availability (2)

”As dug” (natural gravel) screened through a power screen.

Aggregate availability (3)

LBM to produce surfacing aggregate

Aggregate availability (4)

Labour Based aggregate production

Recommened revised specifications

Rs

Property	Design limits		
	Chip Seals		Otta Seals[1]
	Current	Proposed	
Strength 10% FACT (kN)	≥ 210	≥ 180 (>500 vpd) ≥ 150 (100-500 vpd) ≥ 120 (<100 vpd)	≥ 110 (> 100 vpd) ≥ 90 (<100 vpd)
Grading	As typically specified	As typically specified	Wide grading
Durability Wet/dry 10% FACT	≥ 75%	≥ 65%	≥ 75% (> 100 vpd) ≥ 65% (< 100 vpd)
Flakiness Index (%) 19.0 – 13.2 mm 9.5 – 6.7 mm	 ≤ 25 ≤ 30	 ≤ 35 ≤ 35	If crushed material used, ≤ 35 (weighted on 4.75 to 13.2 mm fractions)
Adhesion	R & W ≥ 3	No relaxation. Precoat if R & W <3	
Water Absorption	-	≤ 5	Spray rate adjusted
Polished Stone Value	-	≤ 50 (> 500 vpd) ≤ 45 (< 500 vpd)	

1 – Otta Seal specifications should comply with the Botswana Roads Department Guideline No. 1.

Factors Affecting Choice

- Type of pavement (strength, flexural properties, etc);
- Economic and financial factors (funds available, life-cycle costs, etc.);
- Riding quality required;
- Operational factors (traffic, surface stresses, geometry, etc.);
- Safety (surface texture, interference with traffic, etc.);
- Environmental considerations (climate, noise, etc.);
- Construction and maintenance strategies;
- Characteristics of available materials (aggregate, binder, etc).

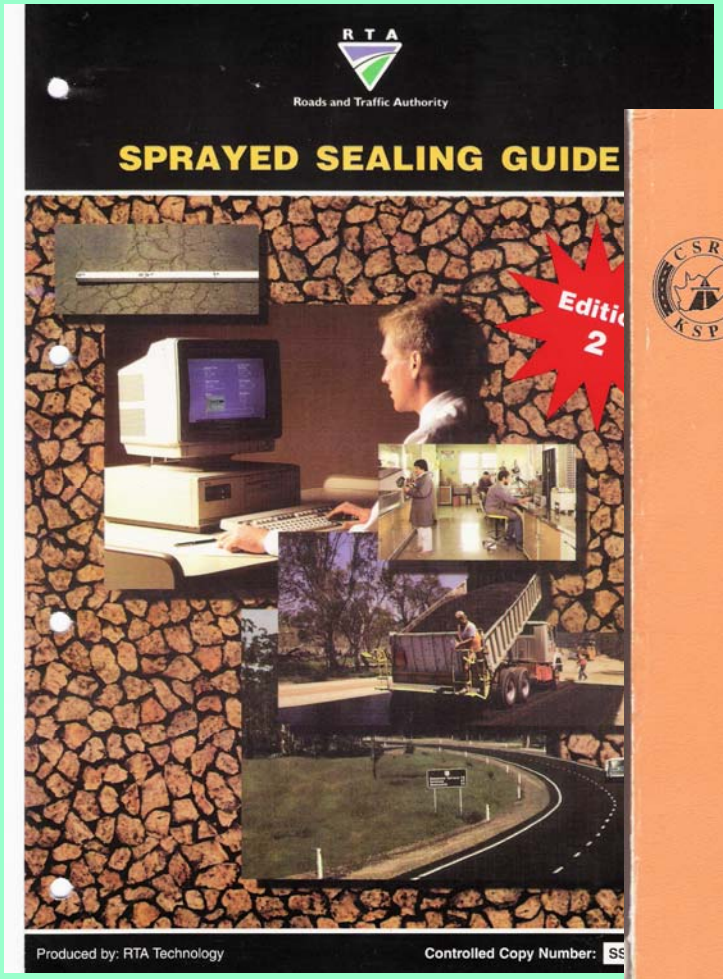
Seal selection based on marginal properties

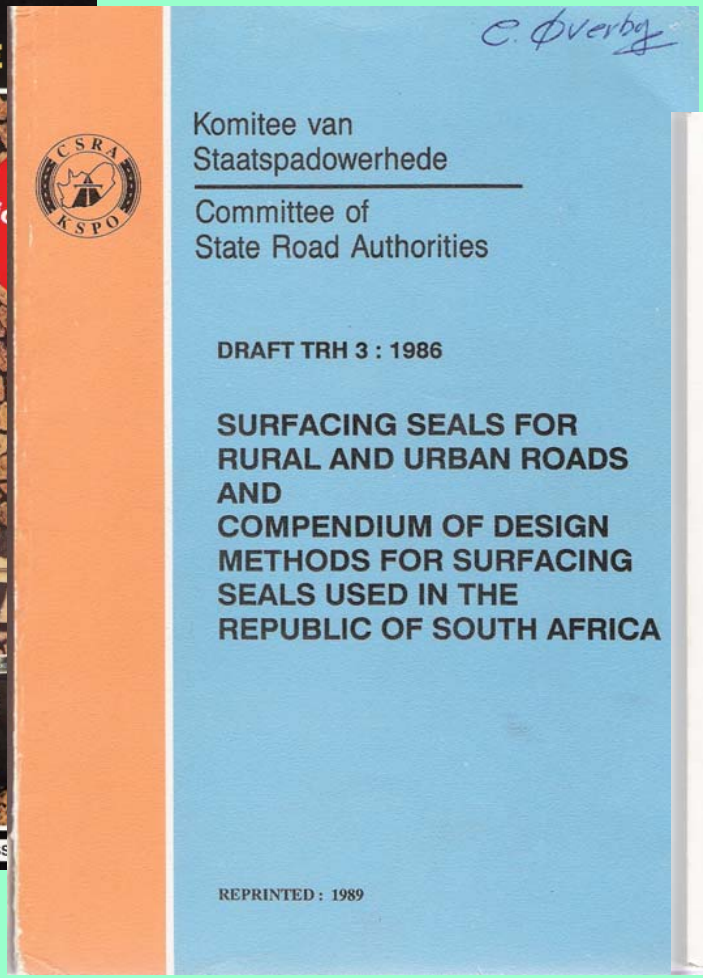
Marginal Property	Recommended seals	Inappropriate seals
Grading	Otta, sand	Slurry, chip, Cape
Strength	Otta, sand, slurry	Chip, Cape
Durability	Otta, sand, slurry, Cape	Chip, slurry
Shape	Otta, sand, slurry	Chip, Cape
Dustiness	Otta, sand	Chip, slurry
Water absorption	Otta, sand	Chip, slurry

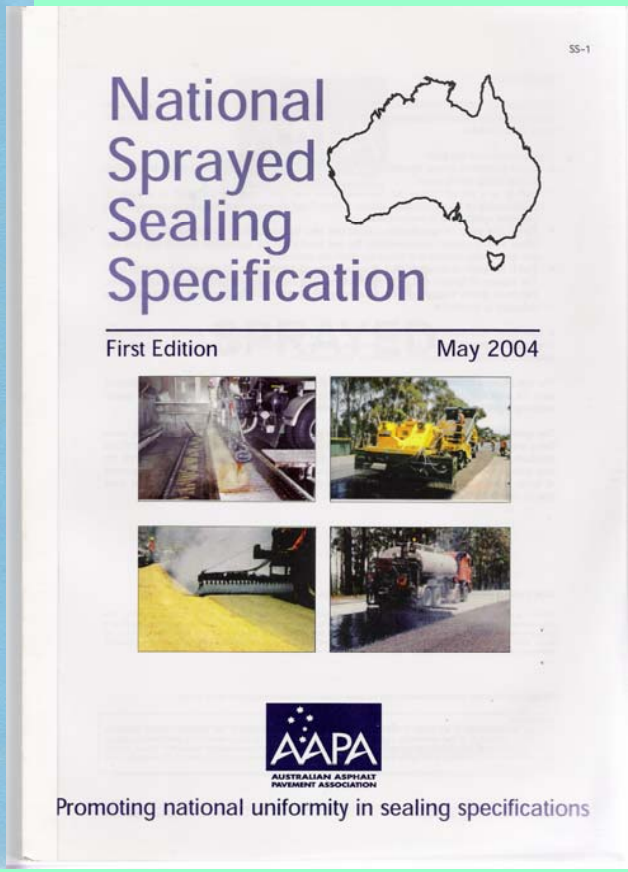
Relative construction costs of LVSR surfacings

Type of seal	Relative cost	
	With prime	Without prime
Sand seal	0.56	N/A
Slurry seal	0.85	N/A
Single chip seal	0.56	0.58
Double sand seal	0.90	0.70
Double chip seal	1.00	N/A
Single Otta seal plus sand seal	1.00	0.75
Cape seal (13mm + single slurry)	1.20	0.60
Cape seal (19mm + double slurry)	1.60	0.90
Double Otta seal	1.00	0.90

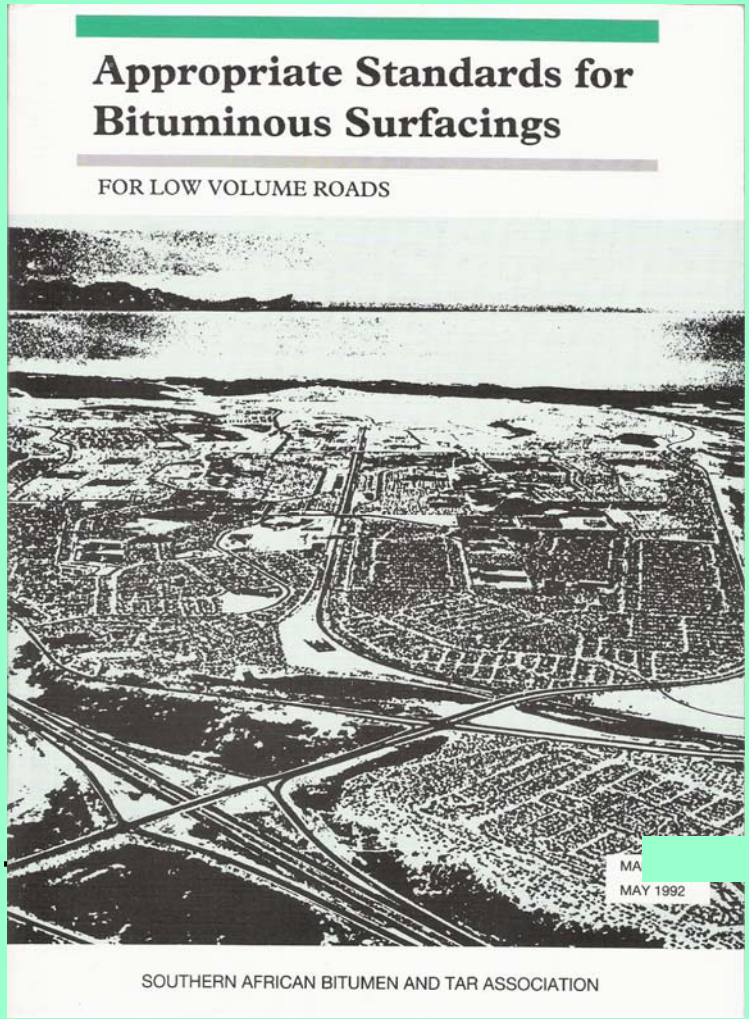
Surfacing Design on LVSRs (1)

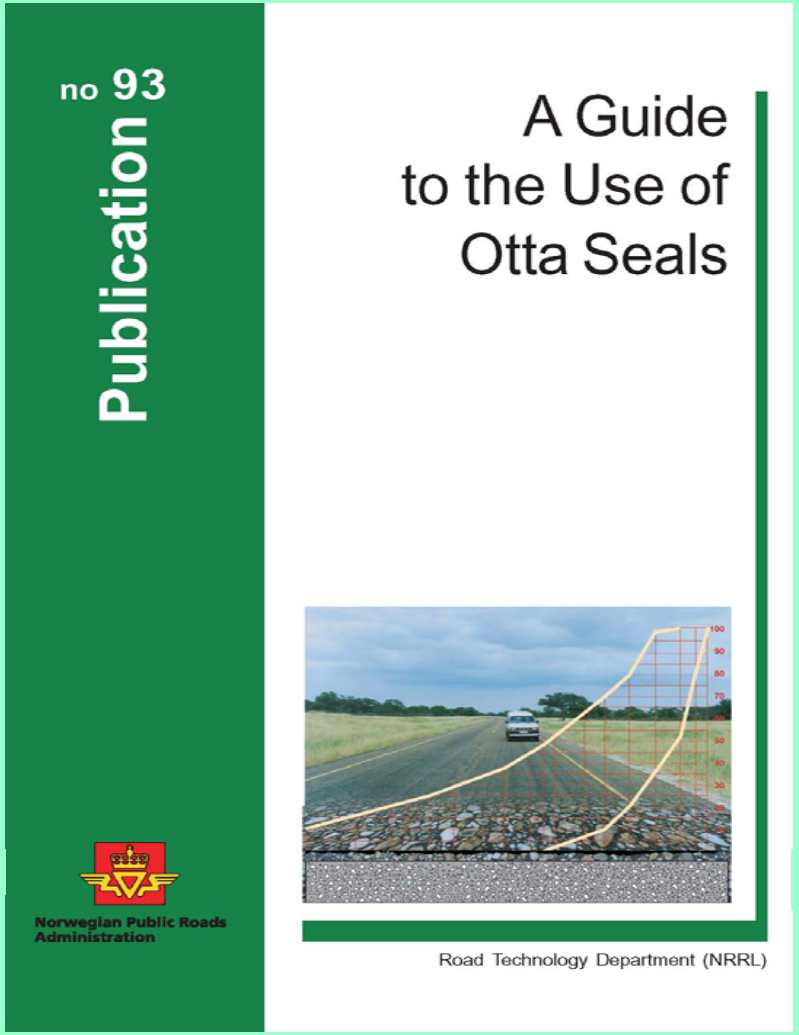




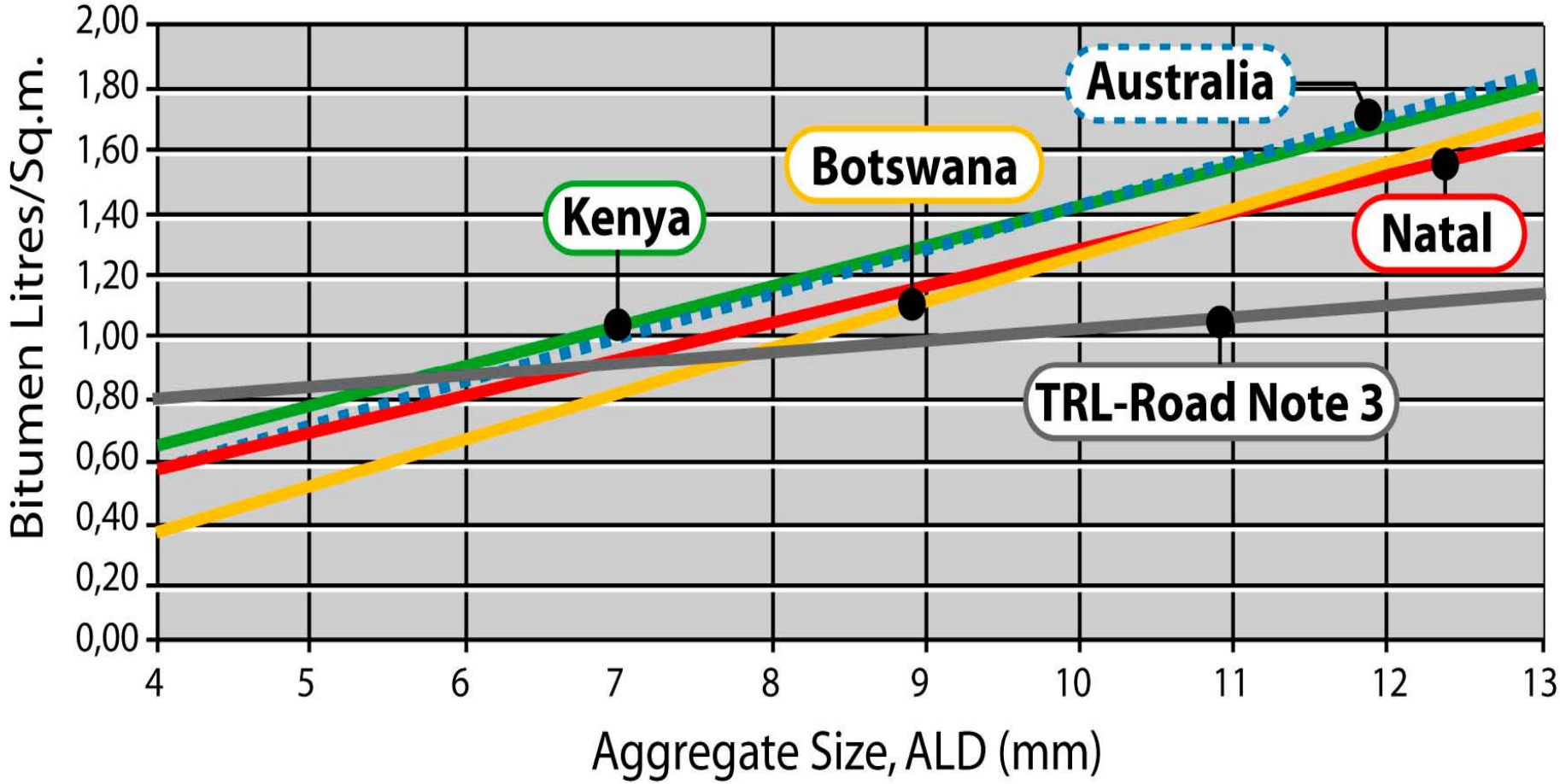


Surfacing Design on LVSRs (2)





Comparison between a few SD designs



Surface seals fat or lean seals

Conventional Surface Dressing

Surface dressing is an area where practitioners often express strong and diverting opinions about how final result should look . The diverting opinions are likely to be caused by a large variety of expectations with regards to service life, aesthetics and skid resistance in wet weather (texture).

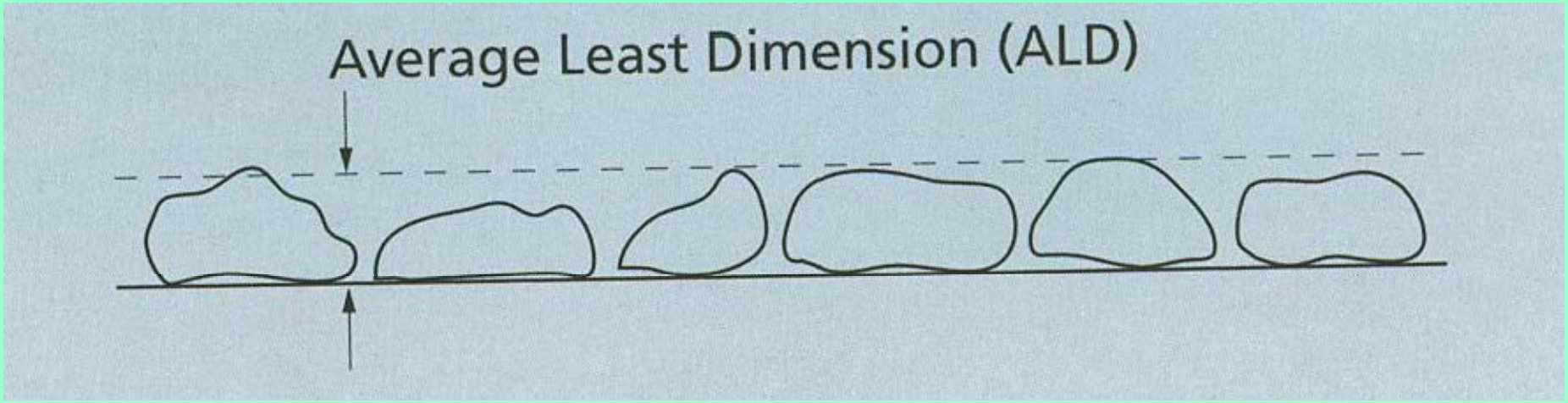
If long service life is important then: FAT seal is “good” (High in bitumen)

If aesthetics is important, then: LEAN seal is “good” (low in bitumen)

If skid resistance (wet) is important, then: LEAN seal is “good” (low in bitumen)

Most manuals Guidelines are based on Hanson’s theories about required proportions of binder filled volume of voids created by the shape and size of the aggregate.

Average least Dimension (ALD)



The ALD is the average vertical projection when the particles are lying on their longest dimension.

Comparison between the terms of bitumen.

Cutback Bitumen grades & Spraying Temperatures

Grade		Allowable viscosity Centistokes @60°C	Equivalent Cutter (%)	Temperature Range (°C)
Grade	ASTM equivalent			
AMC00		8-19	56	10 - 30
AMC0	MC30	20-59	44	35 - 55
AMC1	MC70	69-140	34	60 - 80
AMC2	MC250	150-499	27	75 - 100
AMC3	MC800	500-1499	21	95 - 115
AMC4		1500-4999	16	110 - 135
AMC5	MC3000	5000-11999	11	120 - 150
AMC6		12000-32000	7	135 – 160
AMC7			3	150 - 175

Newly placed sprayed surfacing. Note the gap between the aggregates which allow the 2nd seal to mesh in.

Construction of Bituminous Surface Treatments

Construction of the seal is practical manifestation of the planning, design phases.

The construction may in many circumstances be machine based or LBM based or a combination of these two.

Required input for achievement of a good result

	Required input for achievement of a good result *(Low - Moderate - High)*				
	Surface dressing	**Otta seal**	**Sand seal**	**Slurry**	**AC** 4)
Skills	Moderate	Moderate	Low	Moderate 3)	Un-suitable
Equipment, Spreading	Moderate	Moderate	Low	Low	Un-suitable
Equipment, Bitumen Application 1)	Moderate	Moderate	Low	Low	Un-suitable
Materials quality	High	Moderate	Low 2)	Moderate/ High	Un-suitable

1) A bitumen distributor is required for most sprayed seals. Hand sprayers are an alternative, especially when using emulsions, but spray rates need to be controlled. Mixing slurry in concrete mixers is preferred, even when laying by hand. Self-propelled slurry machines increase efficiency but at much higher cost.

2) Coarse sand, sometimes available by screening, can increase the material quality to "moderate" where sand seals are used alone as permanent seals. Where sand seals are used as cover seals, the material quality requirements can be reduced to "low".

3) The selection and handling of bitumen emulsions, including proportioning and adjustment of consistency, increases the need for handling skills. Training is usually required.

4) Although included for comparison with other seal types, surfacing with AC is usually confined to areas with wet climates and/or steep terrain.

Labour friendliness for LBM

Activity		'Friendliness' for labour-based methods (*Good – Moderate – Poor*)				
		Surface dressing 1)	**Otta seal** 2)	**Sand seal**	**Slurry** 3)	**AC** 4)
Production of aggregate	Quality	Poor	Good	Good	Good	Poor
	Output	Poor	Good	Good	Poor	Poor
Construction of surfacing	Quality	Moderate	Good	Good	Good	Poor
	Output	Good	Good	Good	Moderate	Poor

1) Hand-crushing of aggregate for surface dressing tends to produce flaky chippings with some rock types.

2) Oversize and fines can be removed by hand screening of natural gravel aggregate for use with Otta seals.

3) Output of aggregate production for slurry (crusher dust) depends entirely on availability on the commercial market.

4) Although included for comparison with other seal types, AC would not normally be used on a LVSR.

The use of Mechanized equipment, Chip seal, South Africa

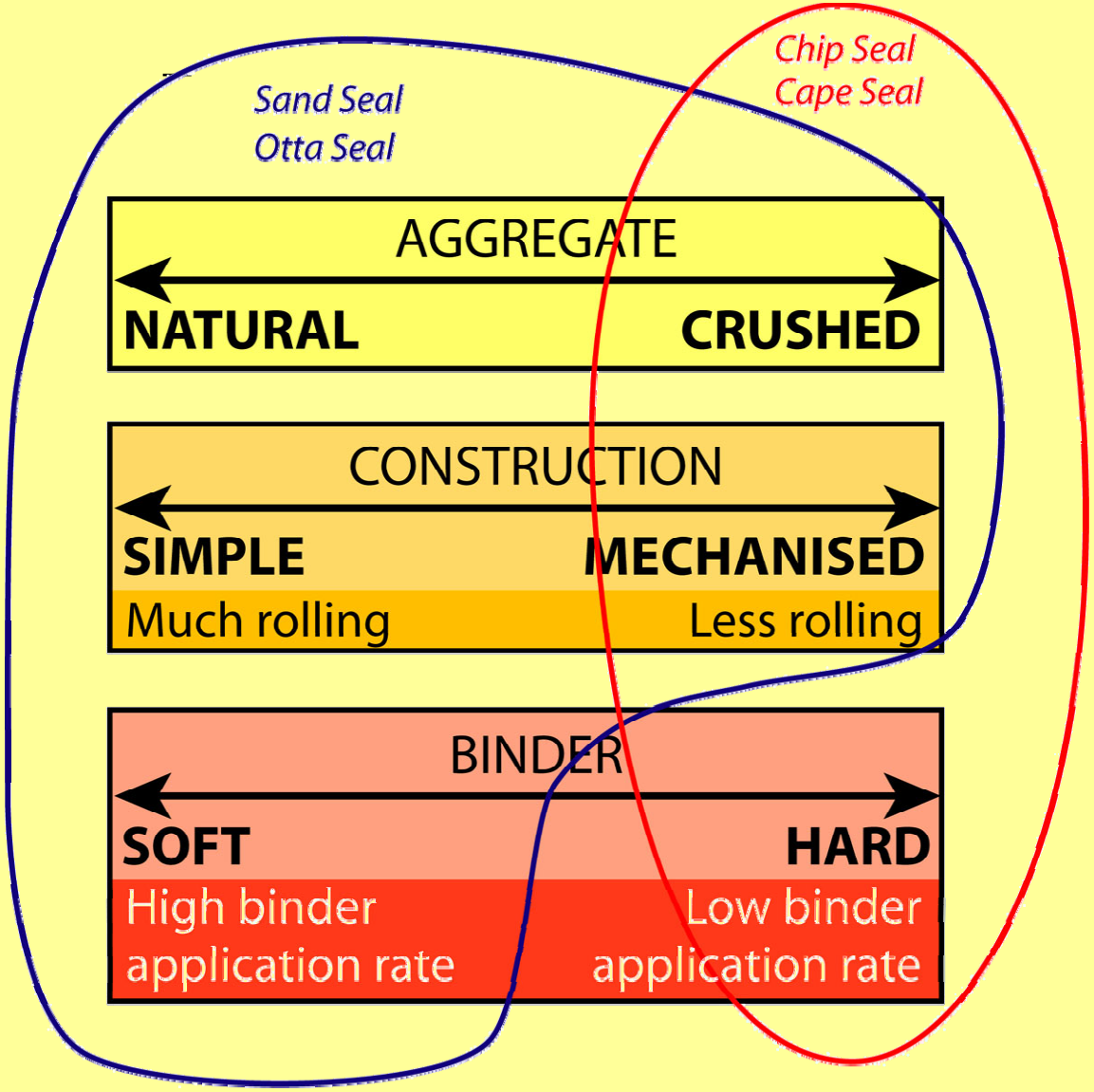
Sand seal by the use of LBM, Botswana

Rolling of a Sand seal

Sand seal on shoulder is often an advantage

- Arrest loss of aggregate
- Provide good surface for pedestrians and bicycles
- Give a desired visual contrast to the carriageway

Difference between Otta/Sand seal and Chip seal



Spreading of Otta Seal aggregate, Kenya and South Africa, two different methods, but in common they do allow a high porportion of fines

The end product.

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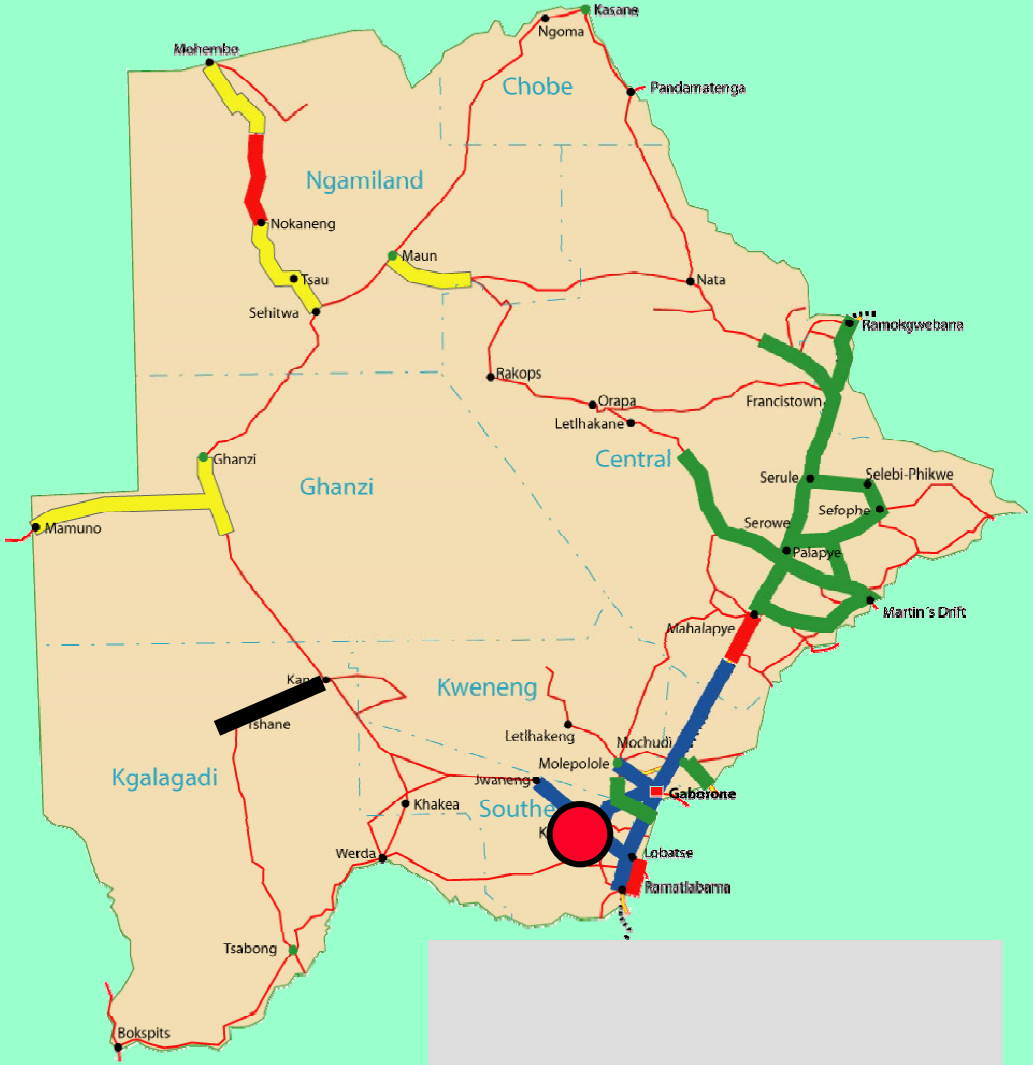
Botswana

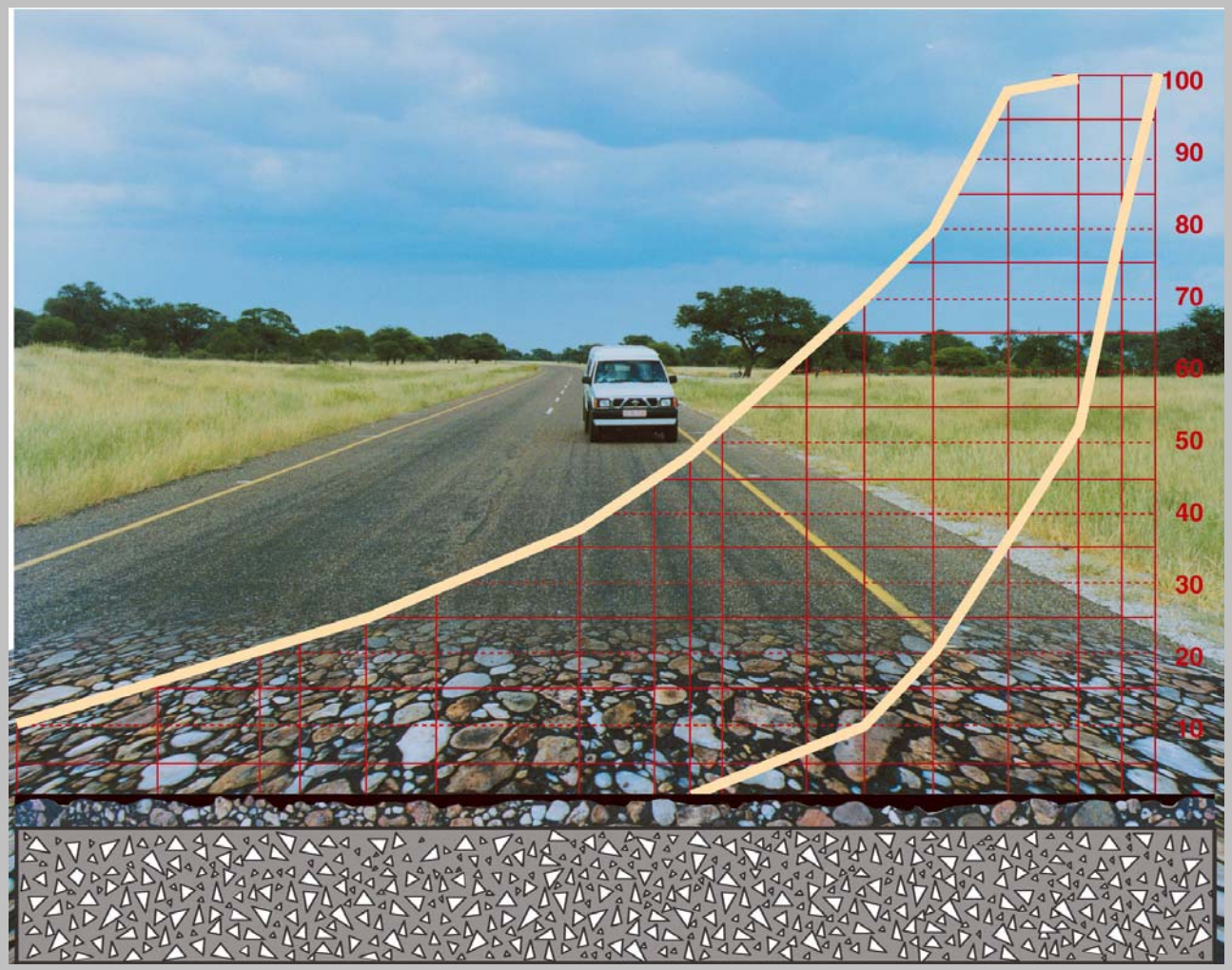

Kasane
Ngoma
Chobe
Pandamatenga
Mohembo
Ngamiland
Okaneng
Maun
Tsau
Nata
Sehitwa
Ramokgwebana
Rakops
Orapa
Letlhakane
Central
Ghanzi
Ghanzi
Serule
Selebi-Phikwe
Sefophe
Serowe
Palapye
Mamuno
Martin's Drift
Mahalapye
Kang
Kweneng
Tshane
Letlhakeng
Mochudi
Molepolole
Kgalagadi
Jwaneng
Gaborone
Khakea
Kanye
Lobatse
Werda
Ramatlabama
Tsabong
Bokspits

Before and after

Botswana


Kasane
Ngoma
Chobe
Pandamatenga
Mohembo
Ngamiland
Nokaneng
Maun
Tsau
Nata
Sehitwa
Ramokgwebana
Rakops
Orapa
Francistown
Letlhakane
Central
Ghanzi
Ghanzi
Serule
Selebi-Phikwe
Sefophe
Mamuno
Serowe
Palapye
Martin's Drift
Mahalapye
Kweneng
Tshane
Letlhakeng
Mochudi
Molepolole
Kgalagadi
Gaborone
Khakea
Lobatse
Werda
Ramatlabama
Tsabong
Bokspits

A brief of the Otta Seal



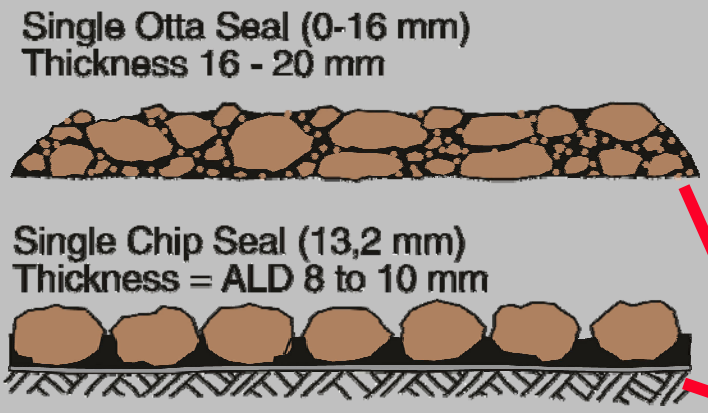
Otta Seals

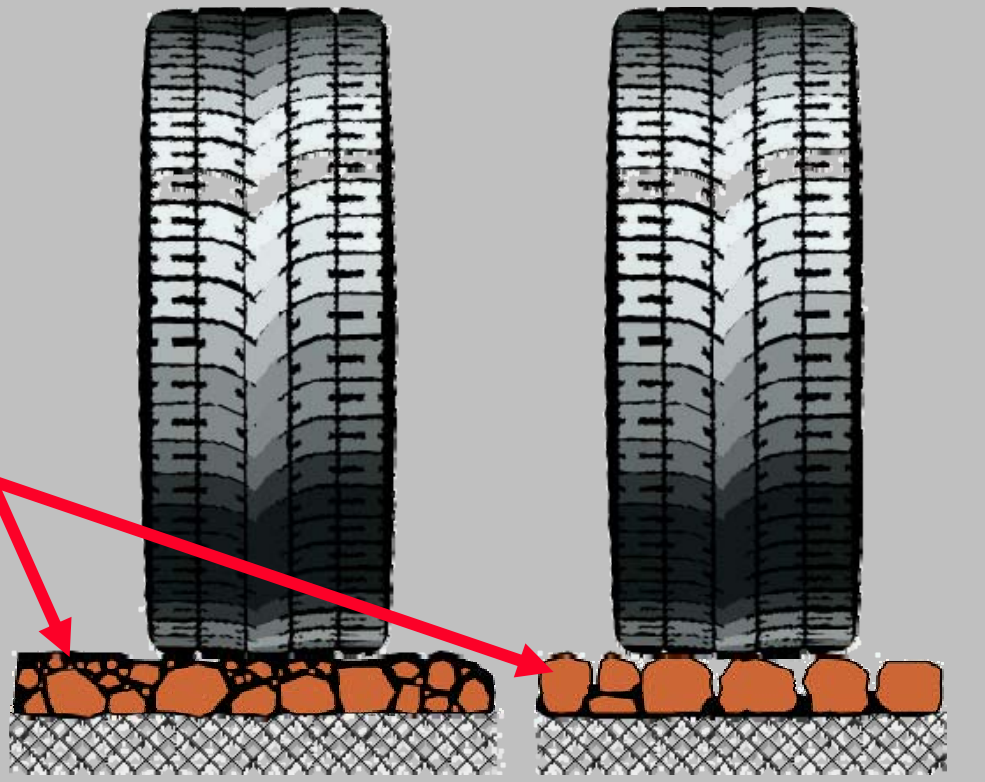
What is it ?

- An Otta Seal is formed by placing graded aggregate on a relatively thick film of comparatively soft binders which, on rolling and trafficking, can work its way upwards through the aggregate interstices.

- In this manner, the graded aggregate relies on both mechanical interlocking and bitumen binding for its strength - a bit like a bituminous premix.

Mechanisim of Performance of Surfacing Types





Under trafficking, the seal acts as a stress-dispersing mat comprised of a bitumen/aggregate admixture – a mechanism of performance which is quite different to that of Category B surfacings.

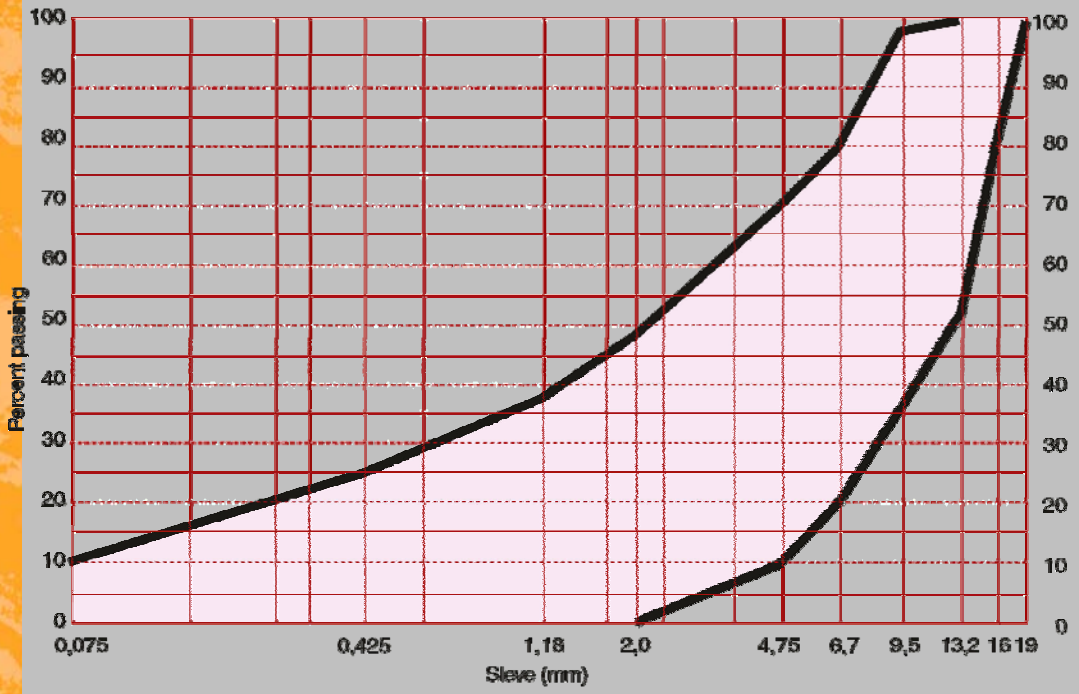
Performance Characteristics (1)

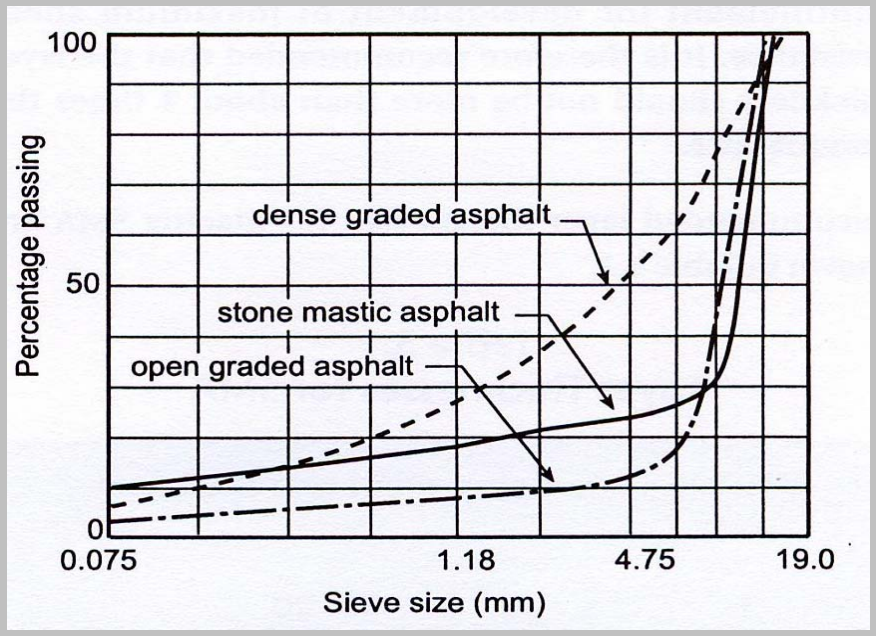
- The texture of an Otta Seal is playing a vital role in it's performance.
- The dense textures as formed by many particles thick layer of aggregates where the interstices are filled with comparatively soft bitumen has been found to be very durable.

Performance Characteristics (2)

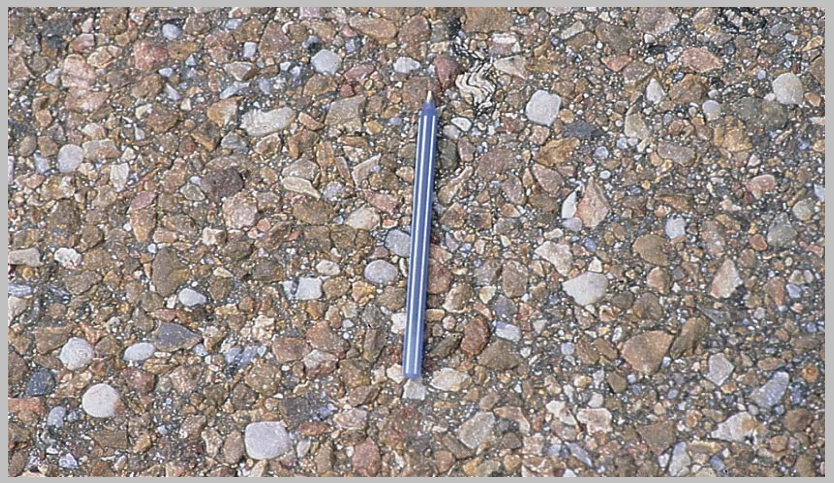
- Often preferred on roads with low bearing capacity due to it's flexible behaviour.
- It seems that the close-texture grading as formed by the Otta Seal concept is less susceptible to binder ageing than a chip seal.

Grading Requirements





Aggregate used in Otta Seals



Thickness of an single Otta seal.

Otta Seals

Why ?

Economy

- Construction cost
- Maintenance life time costs

Construction costs

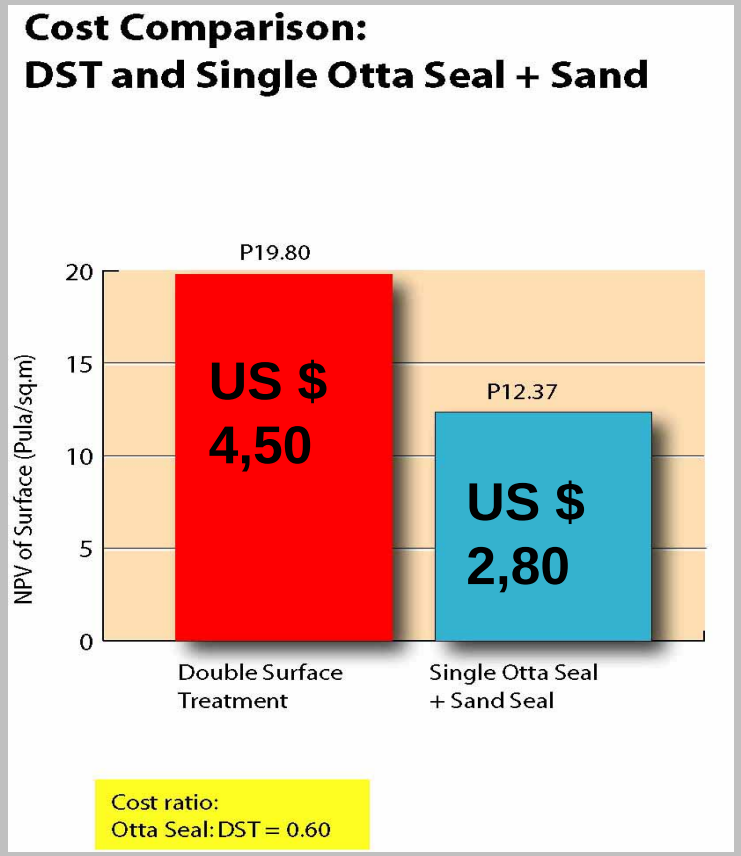
- Reduced cost in aggregate production
- Hauling cost is reduced because of utilization of local materials
- In most cases prime is omitted
- In many cases surfacing operations costs are reduced

In general, this gives a cost saving in the magnitude of 20%. However, savings in the order of 35 - 40% have been reported.

Maintenance Intervention Life - cost comparison (1)

Life expectancy, activities and construction costs	Otta Seals		Double Chip Seal
	Single + sand cover	Double	
Life expectancy (years)	11	15	7
Maintenance activities	Reseal after 10 years. Road marking 3 times.	None	Fog sprays after 4 and 16 years. Reseal after 8 and 12 years. Road marking after each intervention (4 times).
Initial relative cost of construction	1.0	1.2	1.2

Maintenance Intervention Life-cycle cost comparison (2)



For Botswana the cost savings in comparison with:

- **Single Otta Seal with Sand cover Seal**
- **Double Chip seal**

* **COST RATIO 0.60**

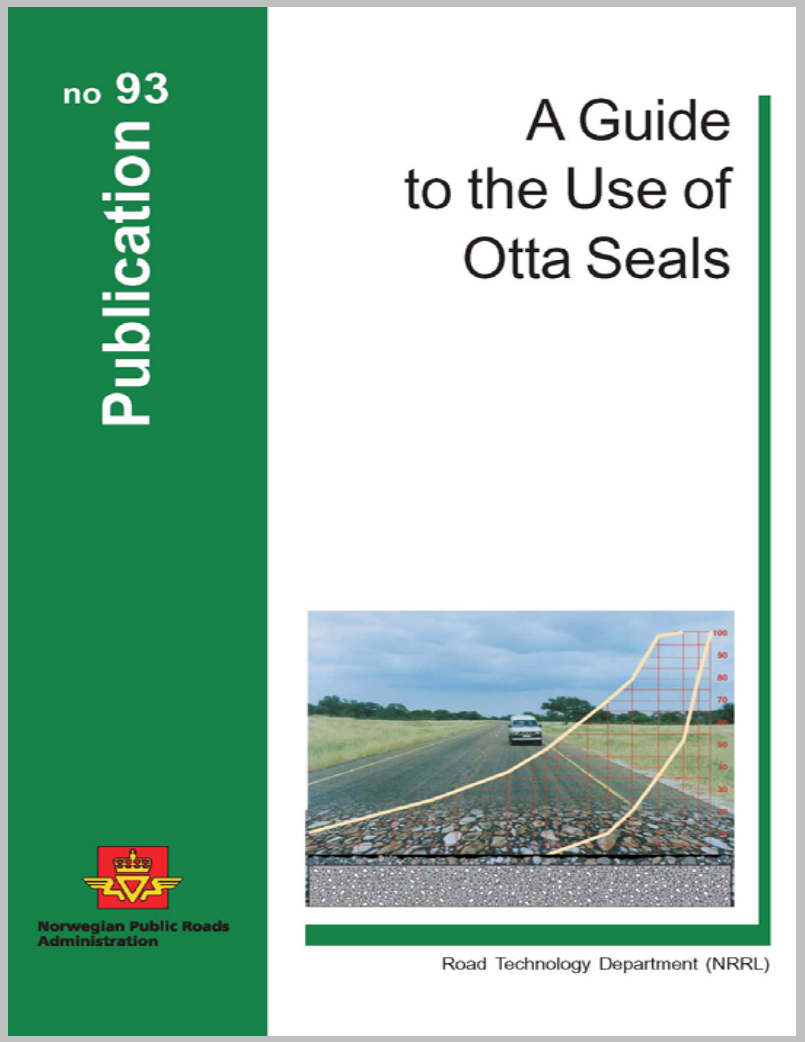
Over a period of 15 years, it has conservatively being estimated a saving of about US$ 124 millions which roughly is estimated to be similar to the cost of a new trunk road standard 600 km long.

Otta Seals

How ?

- Design
- Construction
- The maturation of Otta Seals

Publication no 93 from NPRA

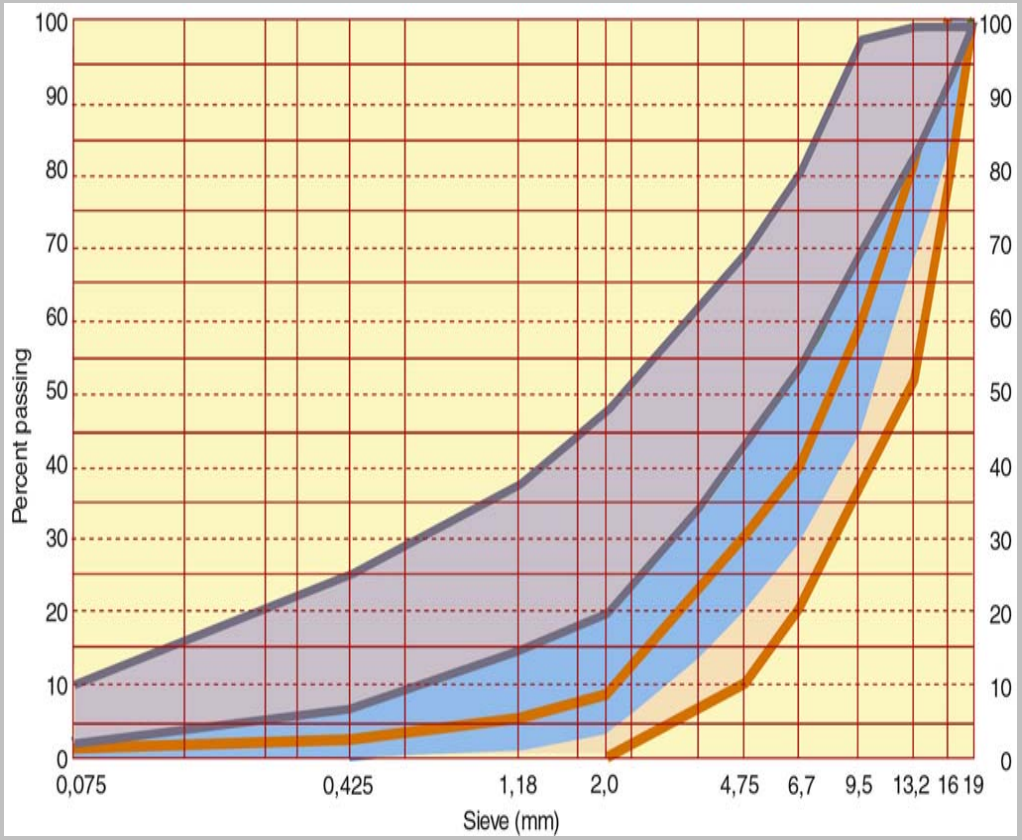


Pavement Strength

Like all other bituminous surface treatments, an Otta Seal will not contribute significantly to the structural strength of the pavement.

The pavement layers and drainage must therefore be adequately designed and constructed to withstand the expected traffic loading through its design life.

General Grading and Strength Requirements



AADT	Best suited grading
Less than 100	"Open"
100 - 1000	"Medium"
More than 1000	"Dense"

Aggregate strength requirements	Vehicles per day at the time of construction		BS Test Designation
	< 100	> 100	
Min. Dry 10% FACT	90 k N	110 k N	BS 812
Min. Wet/Dry strength ratio	0,60	0,75	

Binders

Type of binders of paramount importance.

Correct viscosity range:

Normally MC 3000 or MC 800

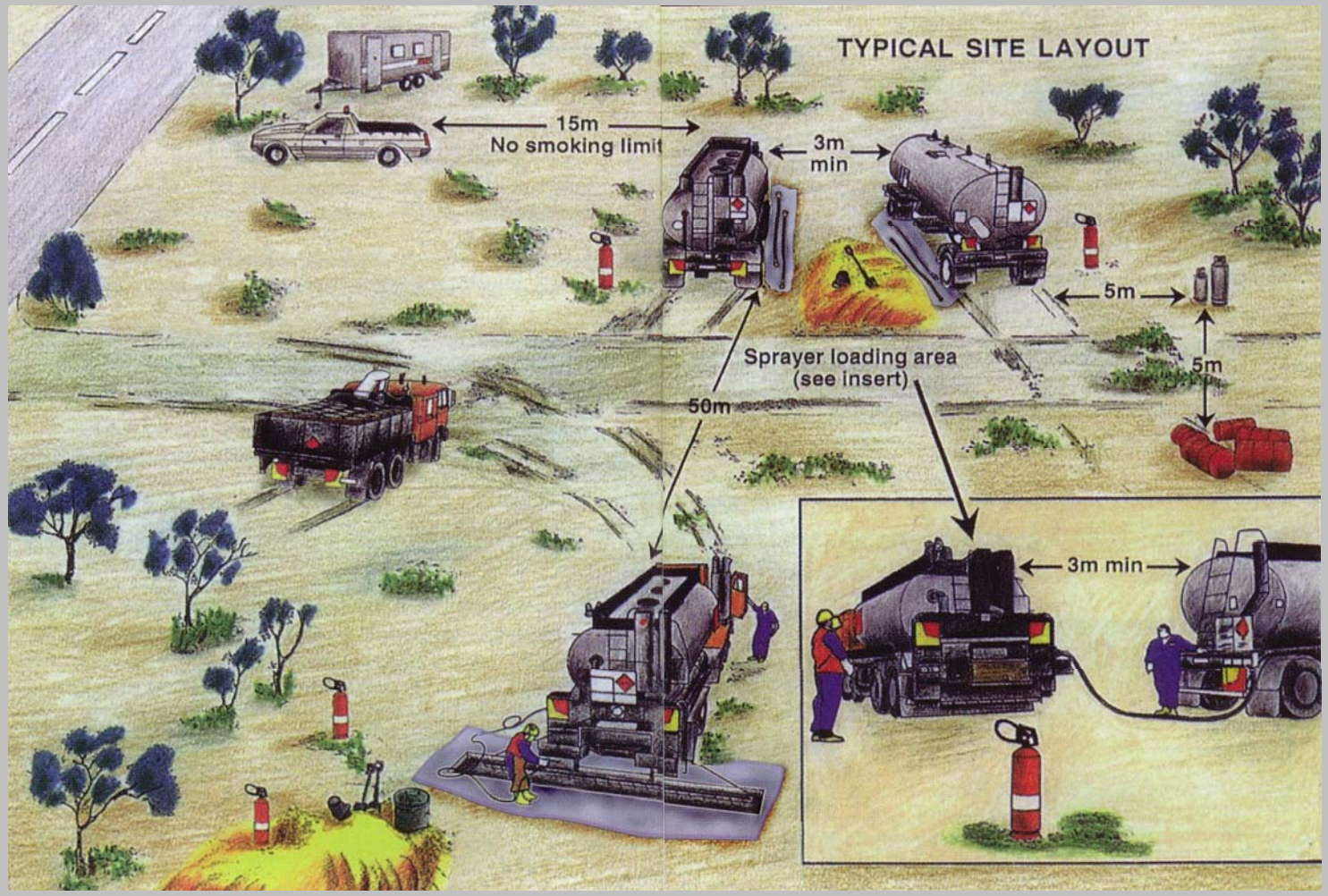
but also pen. bitumen grade 150/200

80/100 pen. bitumen grade *shall NEVER* be used.

Unless cut back to 150/200 v.grade using engine oil, used or new.

All cutting back can easily be carried out on site providing certain safety measures are applied.

Typical site lay-out for bituminous work.



Binders, cutting back on site to required viscosity

The appropriate type of binder and viscosity may be obtained by cutting back with engine oil and power paraffin on site.

Bitumen Hot Spray Rates

Traffic level at time of construction (AADT)	Hot spray rates (l/m2)
< 100	1,8 – 2,2
100 - 500	1,8 – 2,0
> 500	1,6 – 1,8

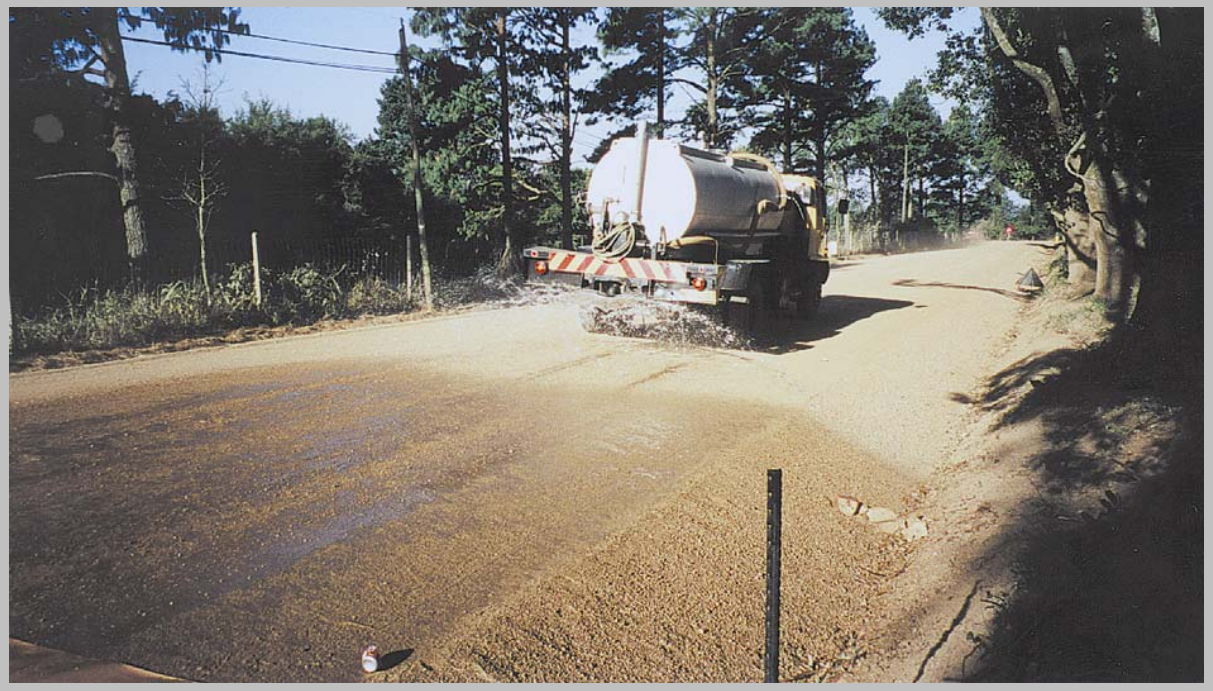
Prime

On a calcareous type of base and on stabilised bases (cement/lime) prime is required.

Construction (1)

Preparatory work prior to sealing operations.

Construction (2)

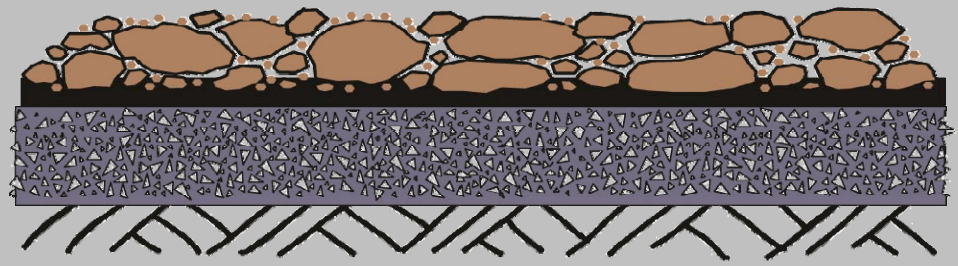


Light watering of the broomed base before spraying, the binder will enhance the bond between the surfacing and the base layer.

Fines and dust are allowed in an Otta Seal

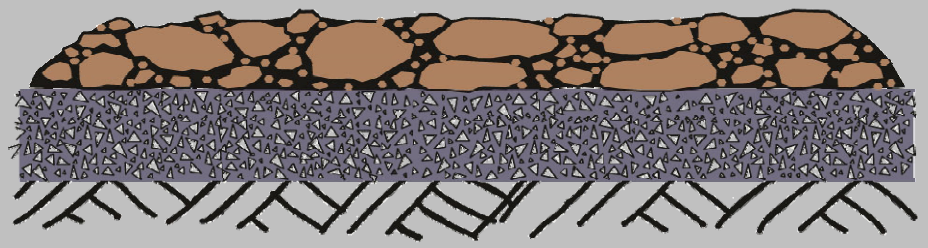
Spreading of Aggregate

Aggregate application



A wide range of aggregates can be used, fines included. Both mechanical chip-spreaders and Labour Based Methods can be used in the spreading of aggregate.

Rolling of Aggregate



Excessive rolling with pneumatic tyre rollers is essential to achieve a good result. Sufficient rolling in the construction of Otta Seals can not be over-emphasised.

The Situation Immediately after Construction

The Situation After 1 - 2 weeks

3 - 4 weeks after Construction, some Excessive Aggregate has been Dislodged by Traffic

Sweeping back Dislodged Aggregate is a part of the ”After Care Work”.

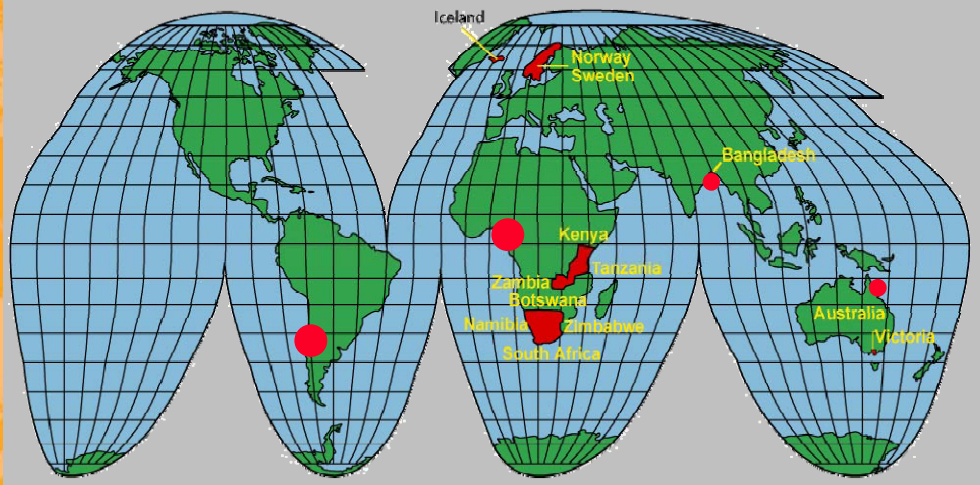
Some Fatty up in the Wheel paths form a Normal part of the Curing process

The Situation Immediately after Construction, but after 8 – 10 weeks the situation changes.

8 - 10 week after Construction

The Otta Seal Matrix

Where have the Otta Seal been used ?



Country	Length	Comments
Norway	4000 km	In 1985 the figure was 12000 km
Sweden	4000 km	
Iceland	2000 km	
Kenya	500 km	
Botswana	3000 km	
Zimbabwe	80 km	Inclusive several trials
South Africa	One trial, 2 km	About 100 km to be Otta Sealed in1999-2000
Bangladesh	20 km +	Only labour based methods used
Australia (Victoria)	Two trials ~2,2 km	
Namibia	Trial	
Tanzania	100 km	
Zambia	15 km	

For Tanzania and Zambia a number of road projects are planned with Otta Seal in 2003/04.

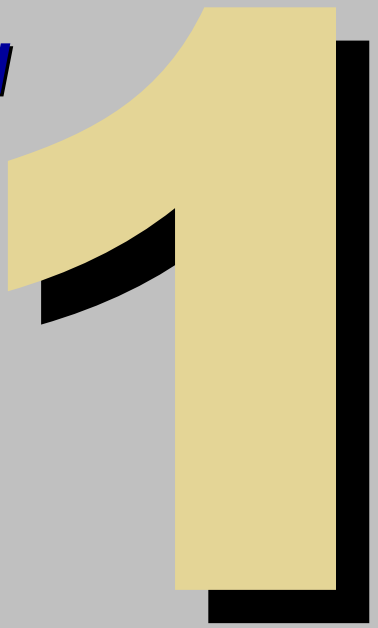
Mali ??????????

Chile about 10 -15 km …

and Ghana 6 km

Conclusions

Has developed from being an economical "maintenance seal" to a fully fledged bituminous surfacing with no other limitations regarding traffic than one would apply to other sprayed bituminous surfacings.



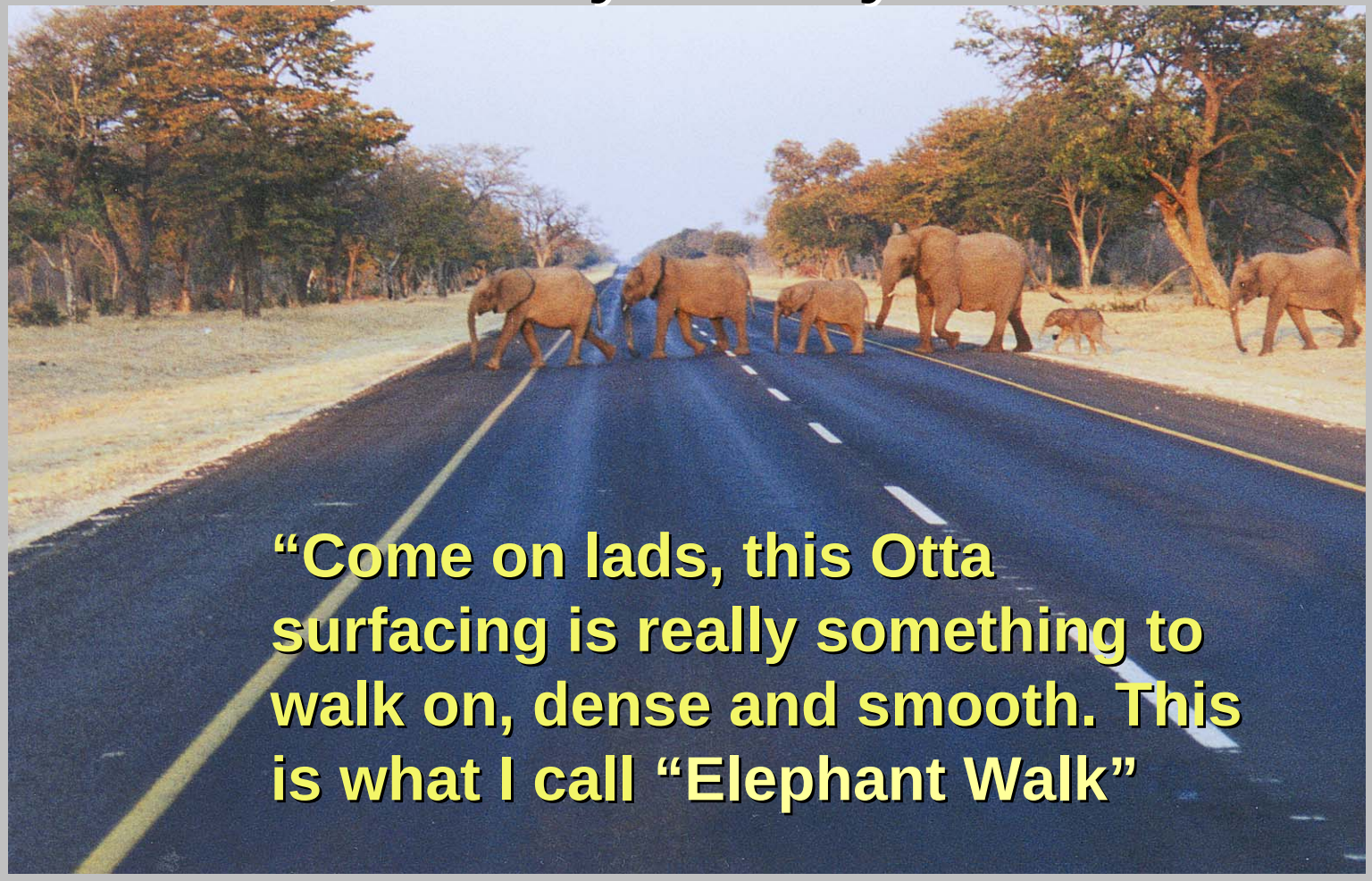
Conclusions

The Otta seal method is an example of the innovative use of local, often marginal quality materials, in combination with appropriate bituminous binders to produce a durable surfacing.

Conclusions

The Otta Seal has proved to be a very cost-effective surfacing and its use has under many circumstances allowed construction of roads under very unfavourable conditions, where conventional bituminous sprayed surfacings would have been too expensive or not possible at all.

The End, thank you for your attention



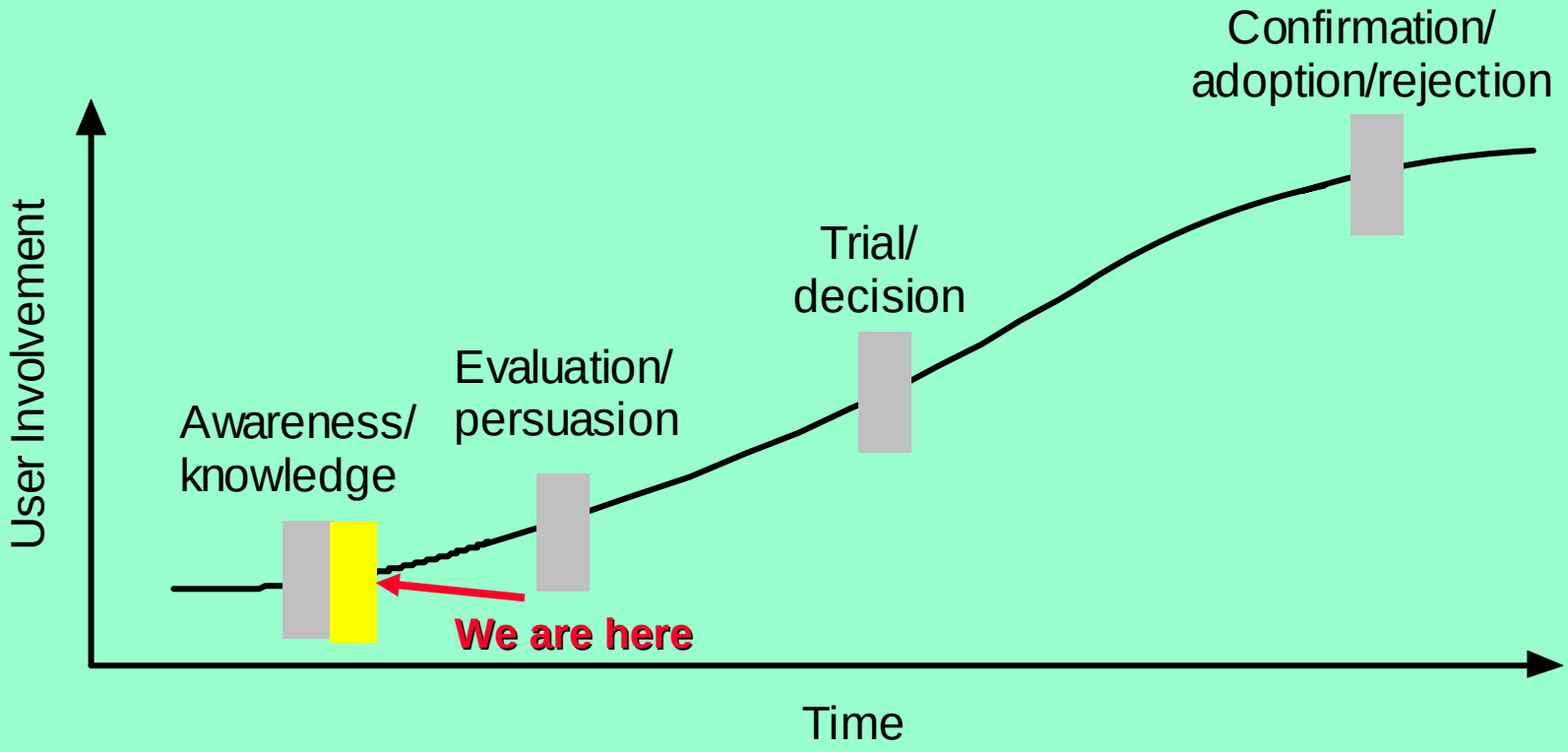
Format of the Presentation:

- Introduction
- Types and performance characteristics
- Properties and function of surfacings
- Selection of surfacing type
- Surfacing design and construction
- A brief of the Otta seal
- Case histories

Otta seal in Kenya more than 20 years old


the challenges

Phases in Uptake of New Technology

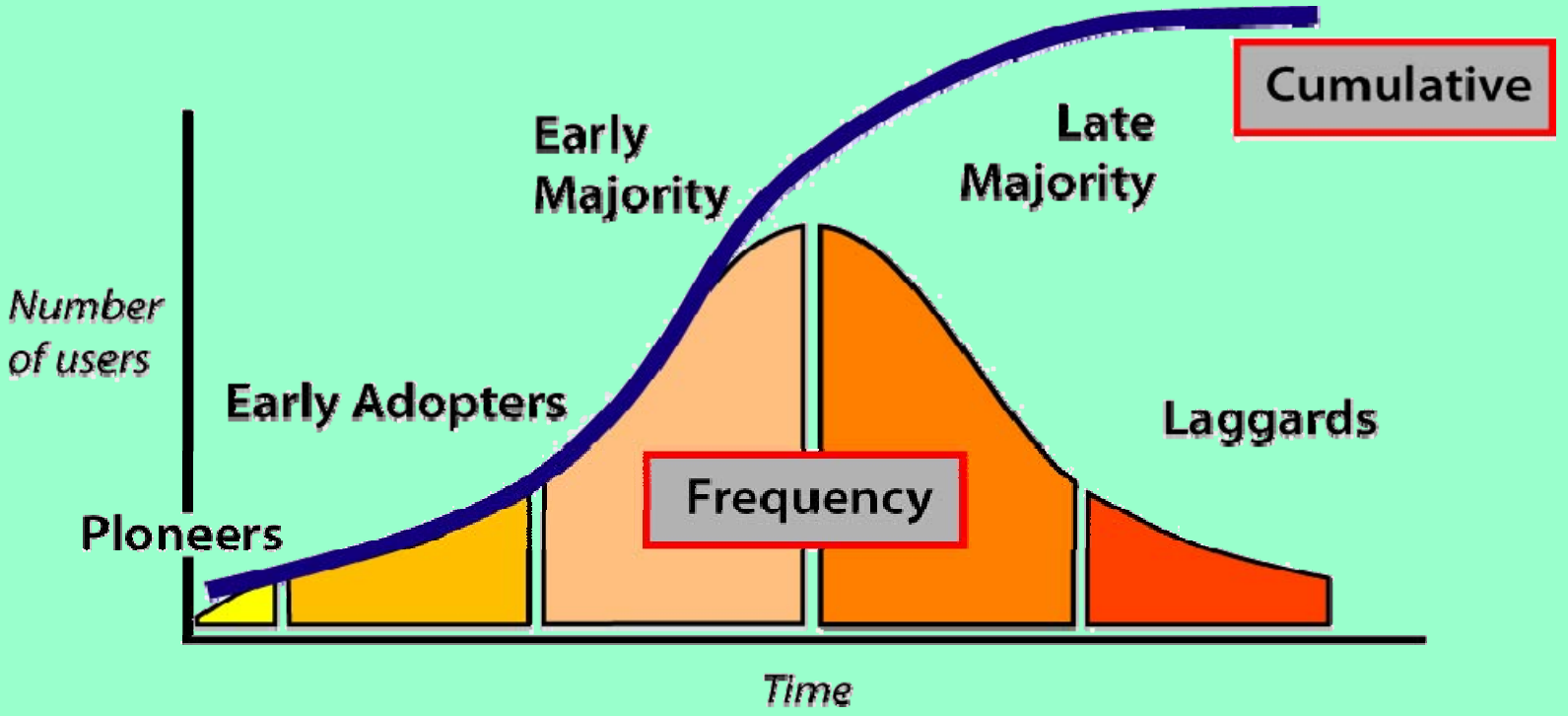


Technology in Practice

Typical Constraints and Barriers

- **Political-** government policy
  - promotion and incentives
- **Social** - culture
  - attitudes
- **Institutional**- Resistance to change
  - interest group resistance
  - institutional incentives
  - limited agency capacity
  - risk taking
  - regulations

The Otta seal – Quo vadis?

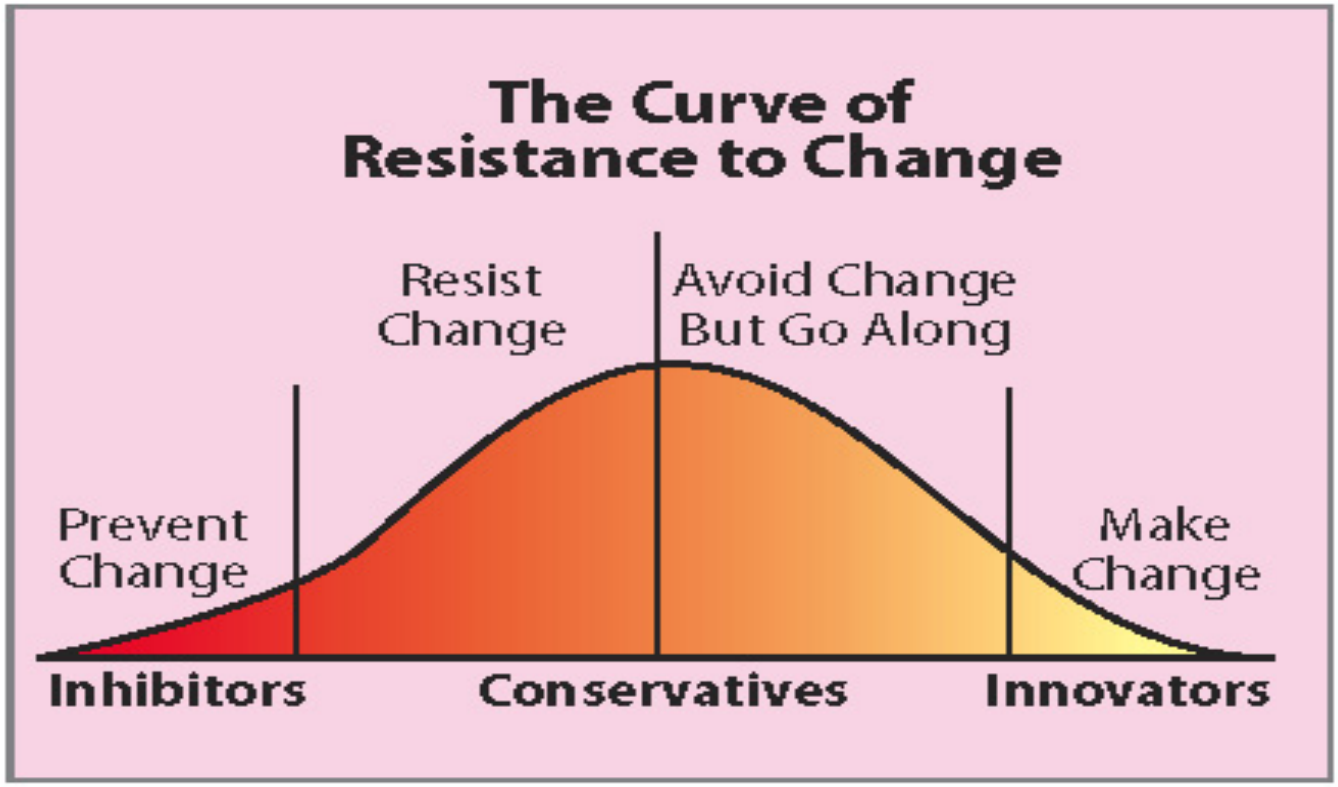


Research shows that when 20 – 25% of a target population has adopted an innovation, the whole process becomes self-sustaining.

Stakeholder Attitudes

- Politicians & road users
- Roads agency
- Consultants
- Contractors

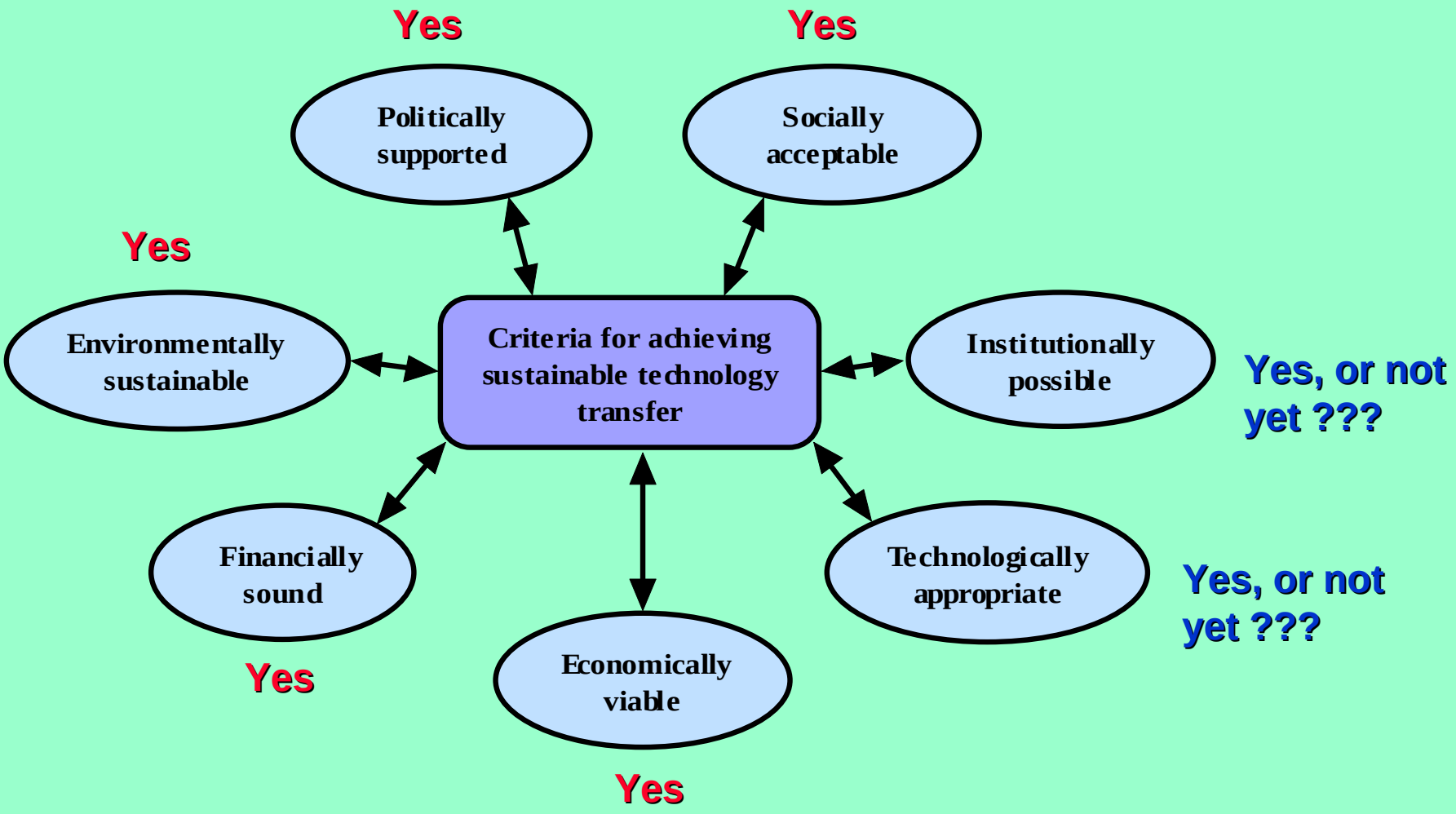
THE RESISTENCE TO CHANGE



Machiavelli, The Prince (1513)

There is nothing more difficult to take in hand, more perilous to conduct or more uncertain in its success, than to take the introduction of a new order of things, because the innovator makes enemies of all those who prospered under the old order, and only lukewarm support from those who would prosper under the new.

The seven dimensions ?????



Adoption of New Technology (I) will need:

Prepare a Guideline for Mali's prevailing conditions with regard to the Design, Construction and Maintenance of Otta Seals.

- **Training of Feeder Roads staff**
- **Training of Consultants**
- **Training of the Contractors** ***…….*** ***and possibly***

conduct information meetings with people living along the road to be constructed and surfaced.

Adoption of New Technology (II)

…….. or we adopt the following statement

“ The operation was very successful, but unfortunately the patient died”

Adoption of New Technology (III)

The new idea either finds a champion or dies...No ordinary involvement with a new idea provides the energy required to cope with the indifference and resistance that major technological change provokes... Champions of new inventions must display persistence and courage of heroic quality.

Edward Schon, MIT.

WHICH WAY DO WE GO?

Thank You