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Road Construction with an Environmental Approach

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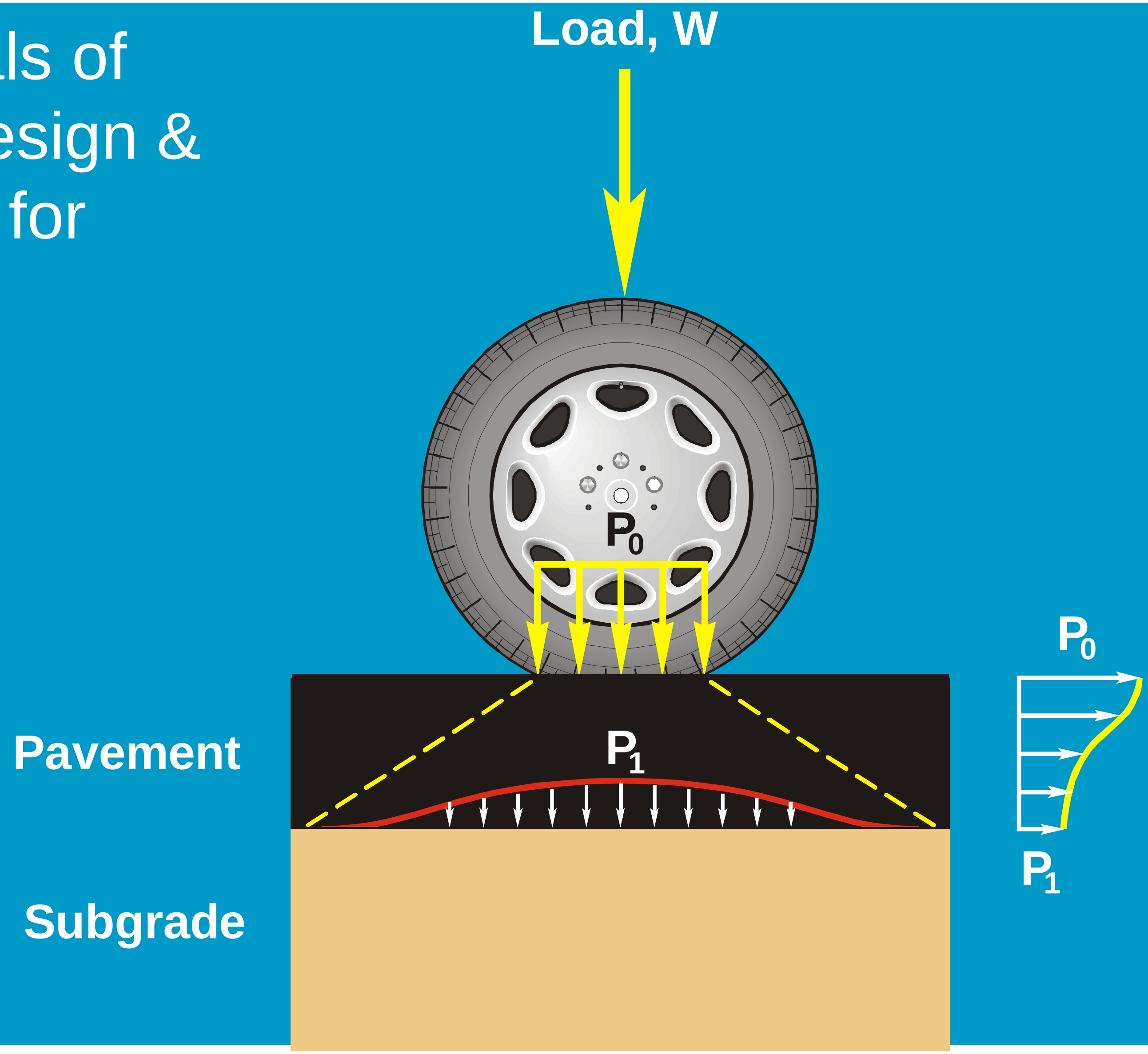
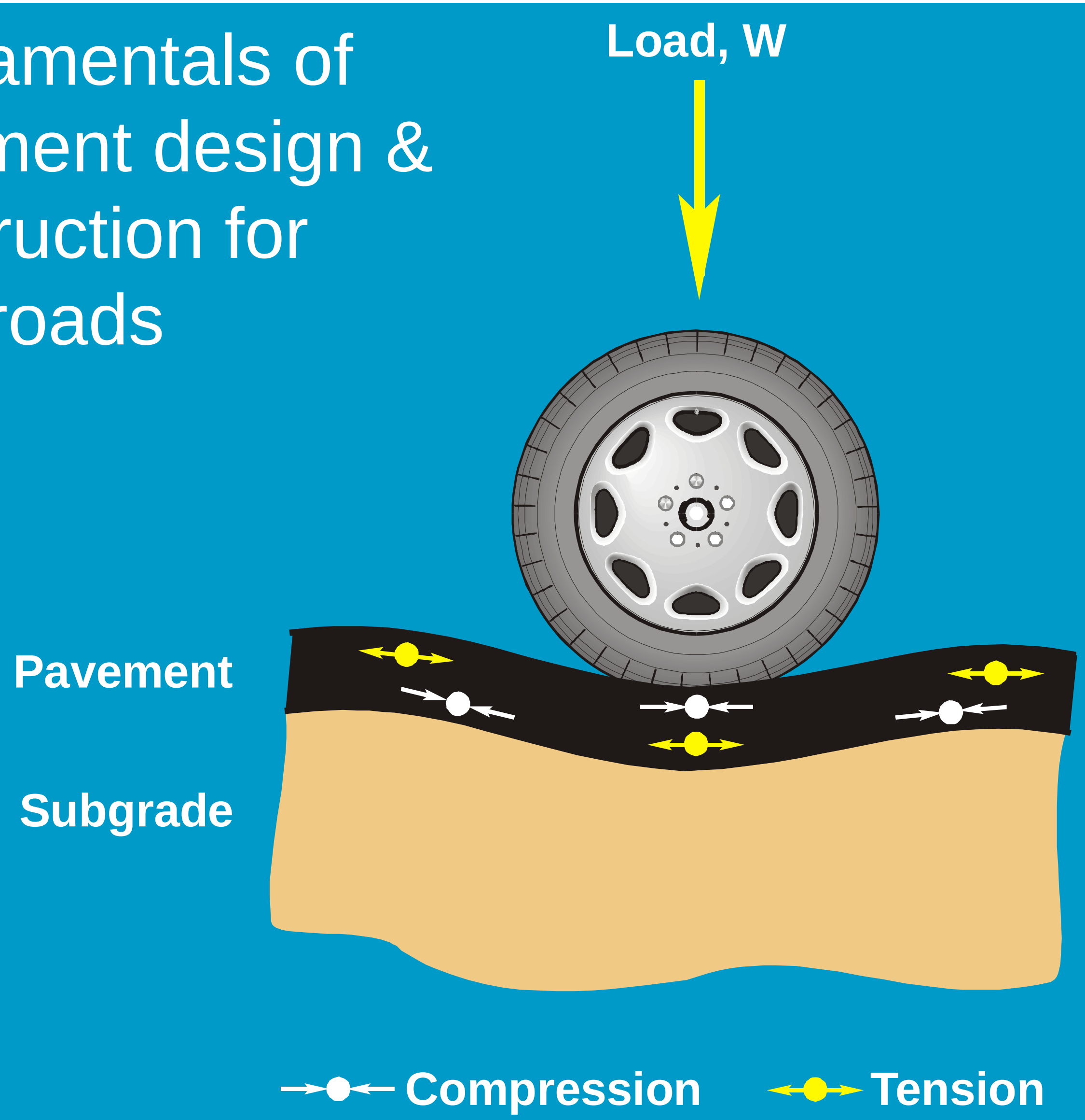
Outline of Presentation

- Fundamentals of pavement design & construction for local roads
- What's important for good quality construction
- Stabilisation
- Sustainability in pavements:
  - reduce total consumption of energy & virgin materials during construction & maintenance eg asphalt production (low energy/low emissions mix), sealing (emulsions), aggregates (recycling); recyclable materials – asphalt, glass, RCC, etc
  - Change attitudes re performance of recycled materials
- Vision for future pavements

Fundamentals of pavement design & construction for local roads



Fundamentals of pavement design & construction for local roads



Pavement Types

- Rigid pavements
  - Unreinforced concrete slabs
  - Reinforced concrete slabs
  - Continuously reinforced concrete slabs
- Flexible pavements
  - Chip seal over granular and/or modified aggregates
  - Asphaltic concrete

Flexible Pavement Types

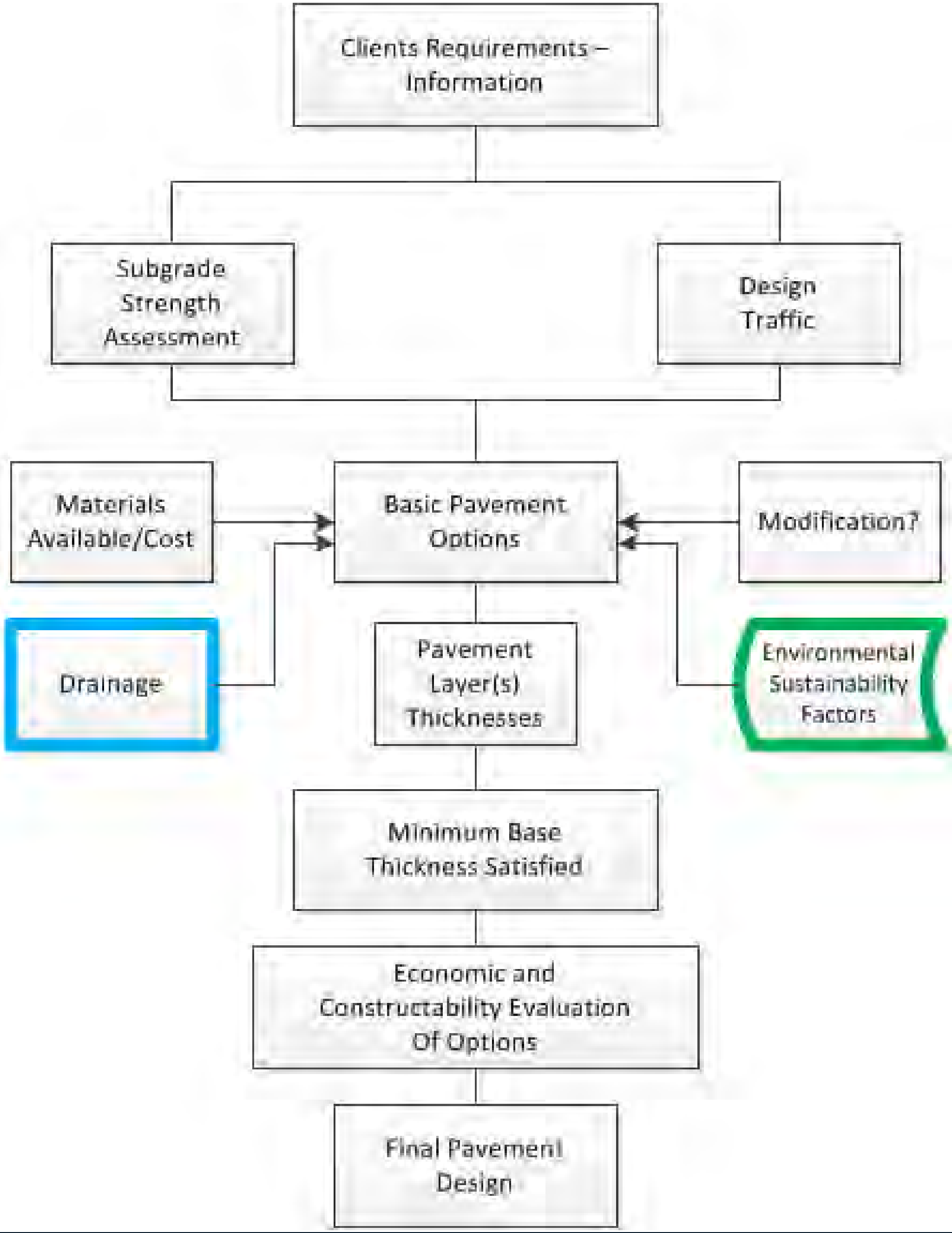
Description
Chip seal over unbound granular
Chip seal over unbound granular on cemented
Chip seal over cemented material
Chip seal over bitumen treated base over unbound
Full depth asphalt
Asphalt on unbound granular
Asphalt on unbound granular on cemented
Asphalt on cemented material
Asphalt on modified material

Equivalent Standard Axle (esa)

Tyre & Axle Configuration	Reference Axle Load (kN)
Single tyre - single axle	53
Dual tyre - single axle	80
Dual tyre - tandem axle	135
Dual tyre - tri-axle	181

- Number of standard axles to cause same damage = $\left(\dfrac{\text{Actual axle load}}{\text{Reference axle load}} \right)^4$

Simplified pavement design process for local roads



Design Traffic Loading Calculations

Traffic Data
Year of analysis

Current volume, AADT (vpd)	1,000	Annual Average Daily Traffic

Year of treatment

Current volume, AADT (vpd)	1,000	Annual Average Daily Traffic
Direction Factor, DF	0.5	Proportion of 2 way AADT travelling in design lane = 0.5 for a two-lane, two-way road with 50/50 directional split
%HV:	10.0%	Heavy Commercial Vehicle content
HVAG / HCV	2.4	Average number of axle groups per heavy commercial vehicle (HCV). Presumptive value for NZ State Highways = 2.4 (2007 NZ suppl. 7.2.1)
ESA / HVAG	0.60	Average number of ESA per Heavy Axle Group Presumptive value for NZ State Highways = 0.6
Load Factor, ESA / HCV	1.44	Average ESA per Heavy Commercial Vehicle
LDF	1.0	Lane Distribution factor - where there is unequal traffic distributed between the lanes of multilane roads
Design Life (years), y	25	Years
Traffic Growth Rate, i	2.00%	

Cumulative Growth Factor (CGF):

CGF (Geometric)	32.030	Geometric Cumulative Growth Factor = (((1+i)^y)-1)/I
CGF (Arithmetic)	31.000	Arithmetic Cumulative Growth Factor = y + ((y/2) * (y-1) * i)
CGF (Average)	31.515	

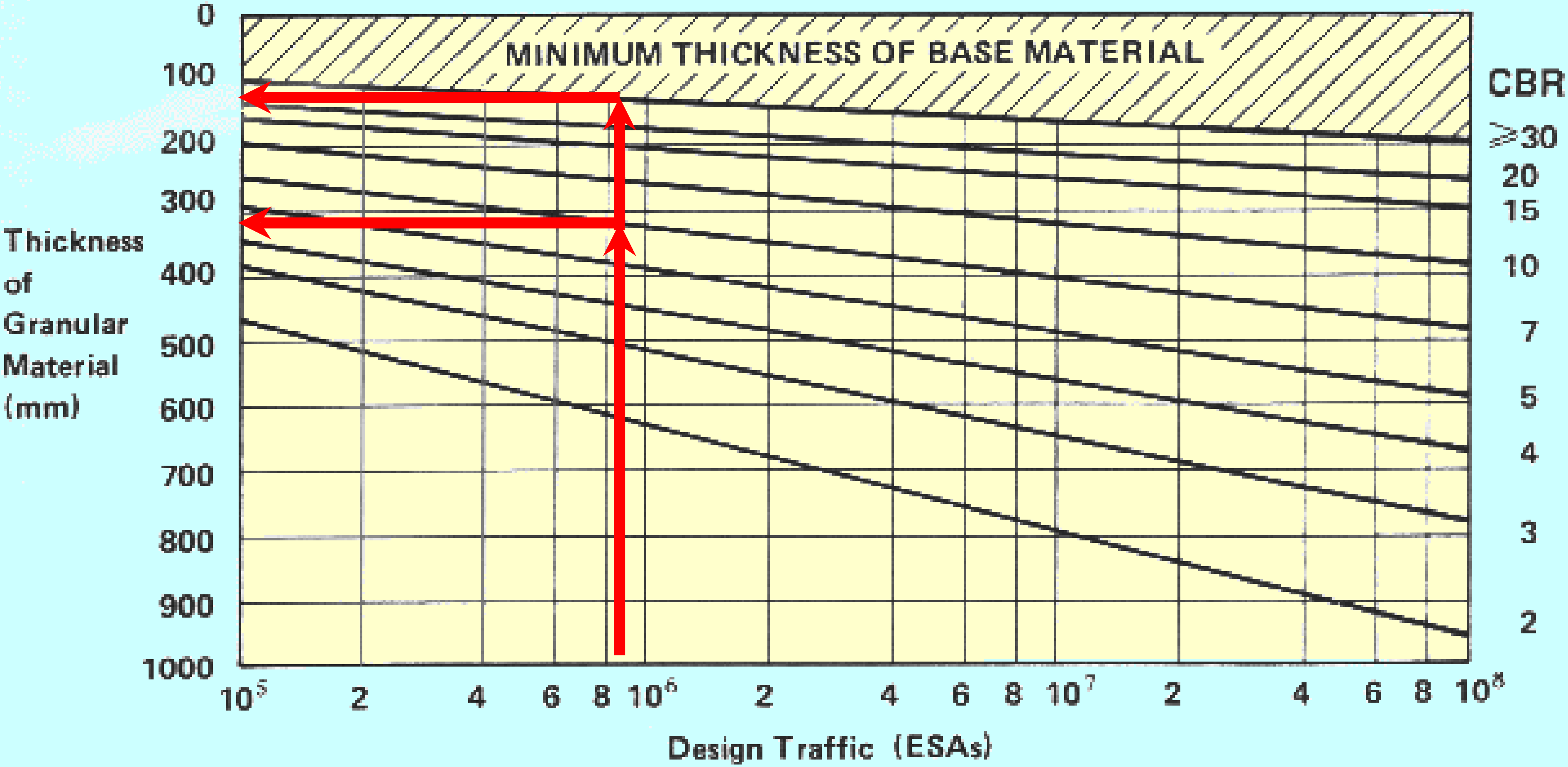
Design Traffic:
Design Traffic, N_{DT} N_{DT} = 365 x AADT x CGF x DF x %HCV x LDF x N_{HVAG} (APDG - Equation 7.1)

N_{DT} **1.4E+06** **HVAG**

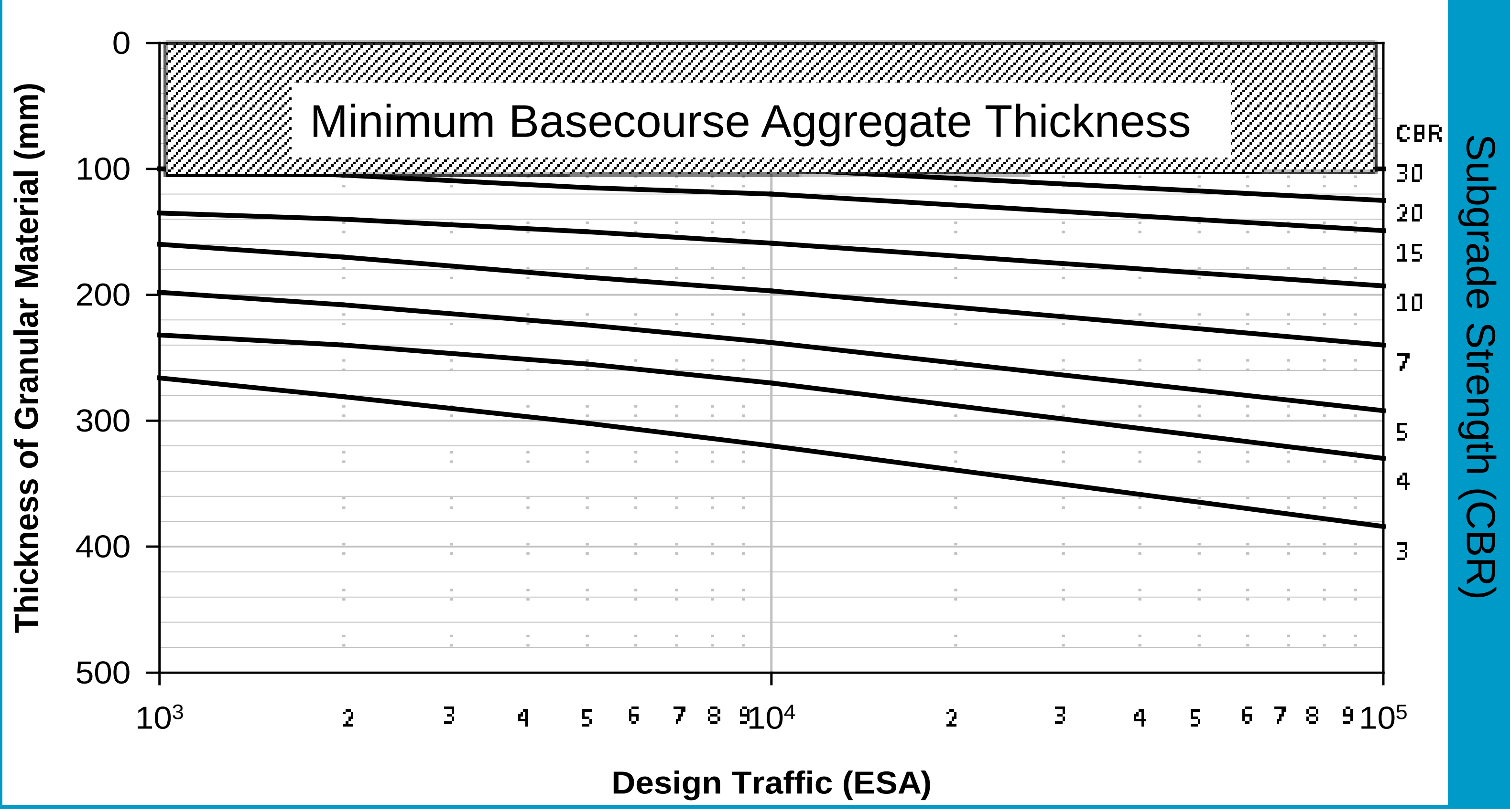
Design Equivalent Standard Axle, DESA = N_{DT} x ESA / HVAG (APDG - Equation 7.4)

DESA **8.4E+05** **ESA** (use in Fig. 8.4)

AUSTROADS Guide Figure 8.4



Design chart for granular pavements with thin bituminous surfacing for lightly trafficked roads



Whole of Life Cycle Costing (WLCC)

Road authority costs:

- Initial capital construction & rehabilitation
- Expected maintenance & re-seal activities
- Residual value of the pavement

Road user costs:

- Traffic delay during construction, maintenance, re-sealing and rehabilitation
- Normal travel time
- User operational costs (vehicle operating costs, accidents & comfort)

<u>Intangibles & Externalities:</u>

- air pollution
- noise
- vibration
- environmental impacts

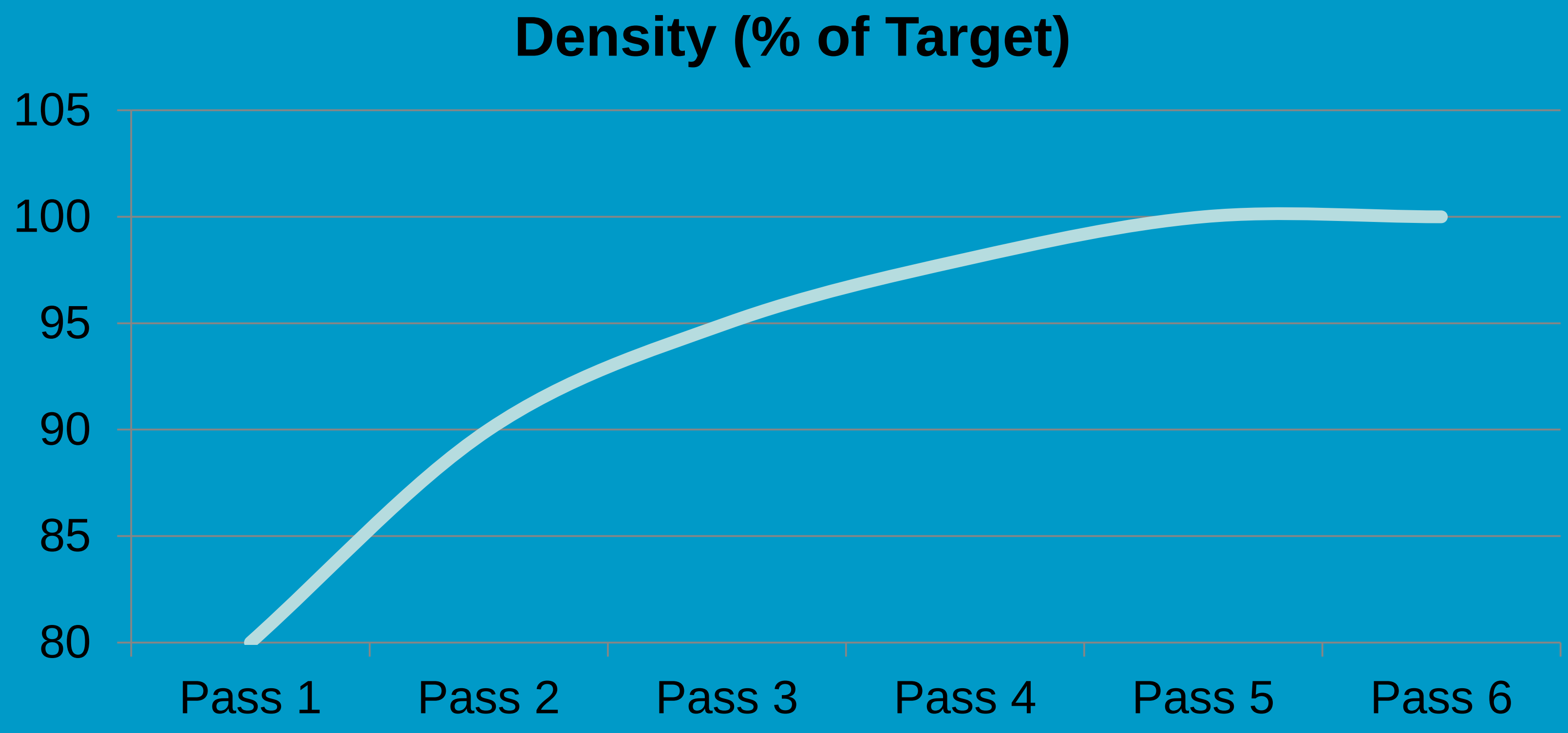
What’s important for good quality construction

- Subgrade bearing capacity
  - In field, measure with deflection, proof roll or Scala DCP
- Pavement materials
  - Good quality aggregates or mixes
  - Shear resistance & moisture susceptibility
- Compaction
  - Measure with nuclear densometer or deflection or proof roll
  - Check EVERY layer (subgrade, subbase, base)
- All seals & thin bituminous mixes are permeable
  - Reduce water ingress to pavement
  - Primers & surfacing selection/design

Compaction – as per TNZ B/02 – plateau density testing & lab MDD

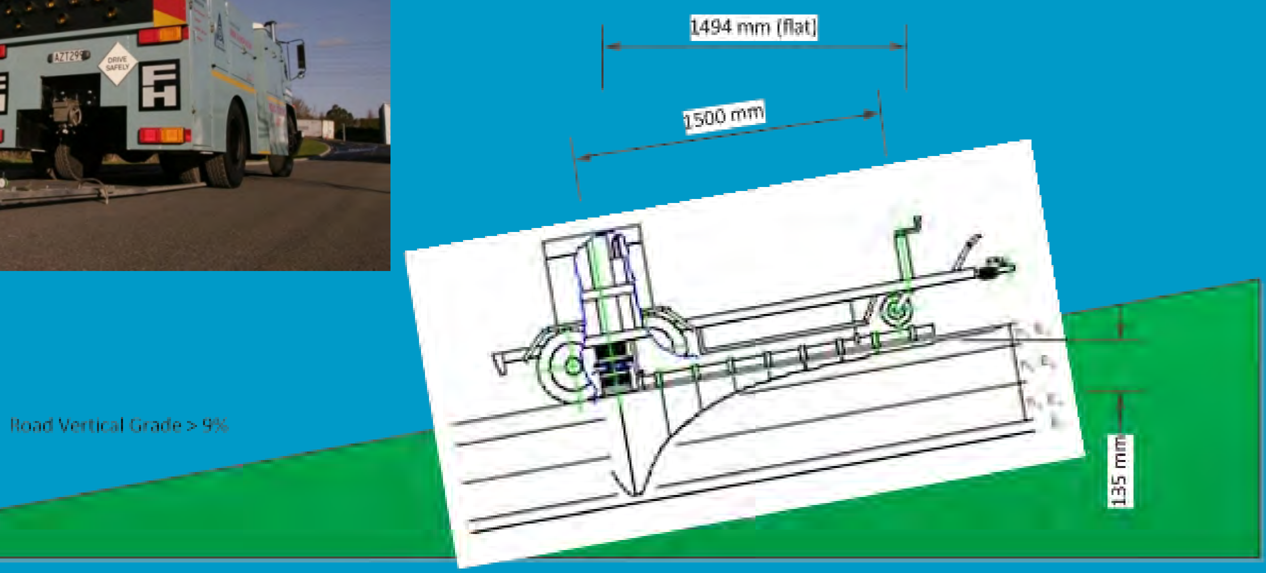
Degree of compaction	Sub-Basecourse Pavement Layer	Basecourse Pavement Layer
Mean Value	≥ 95 %	≥ 98 %
Minimum Value	≥ 92 %	≥ 95 %

Plateau density - compaction



Deflection testing: uphill vs downhill

Benkelman Beam – uphill → higher deflections due to load transfer to rear axle on beam truck



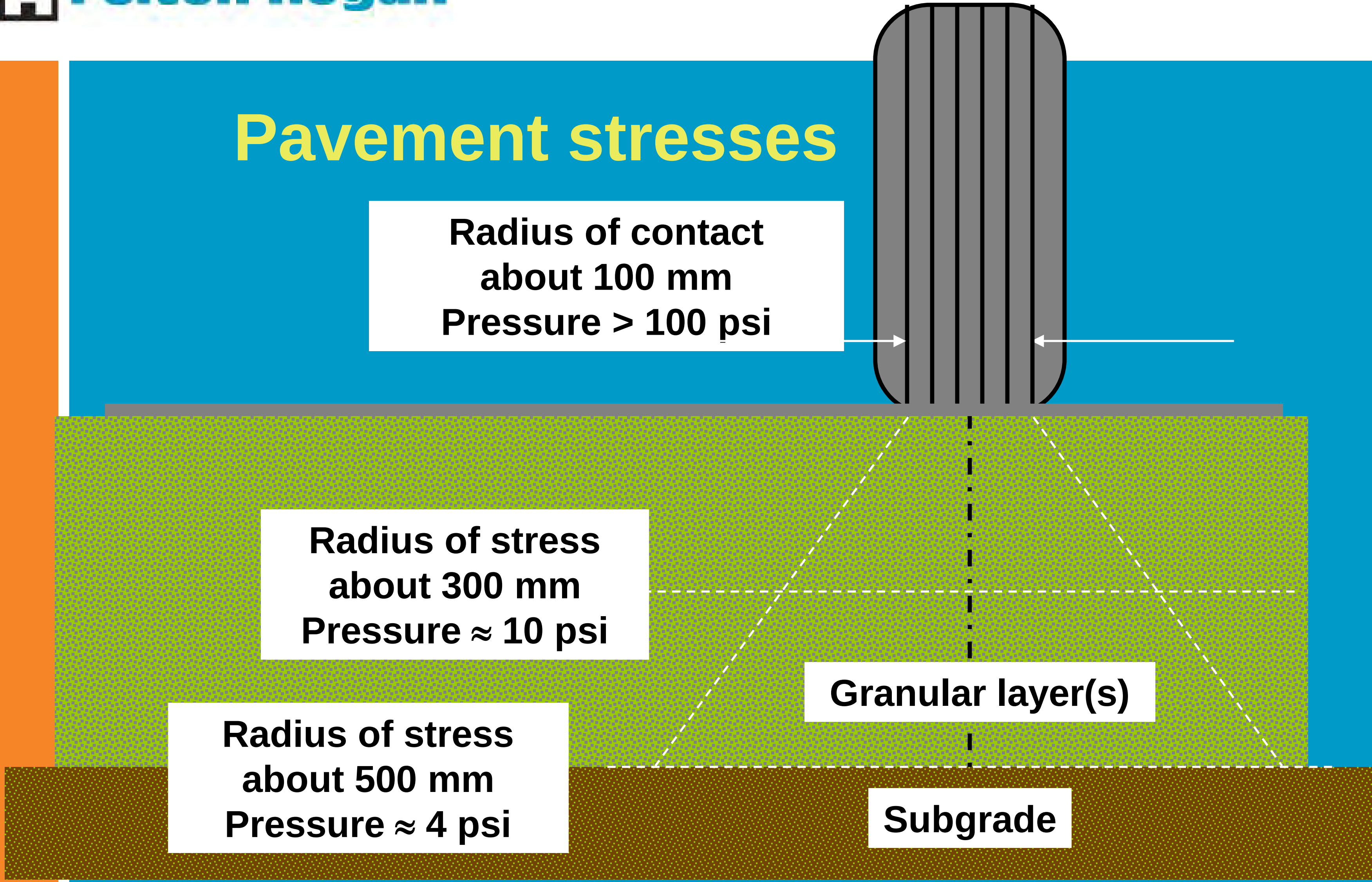
Moisture in the Pavement

A small amount is okay, and is beneficial

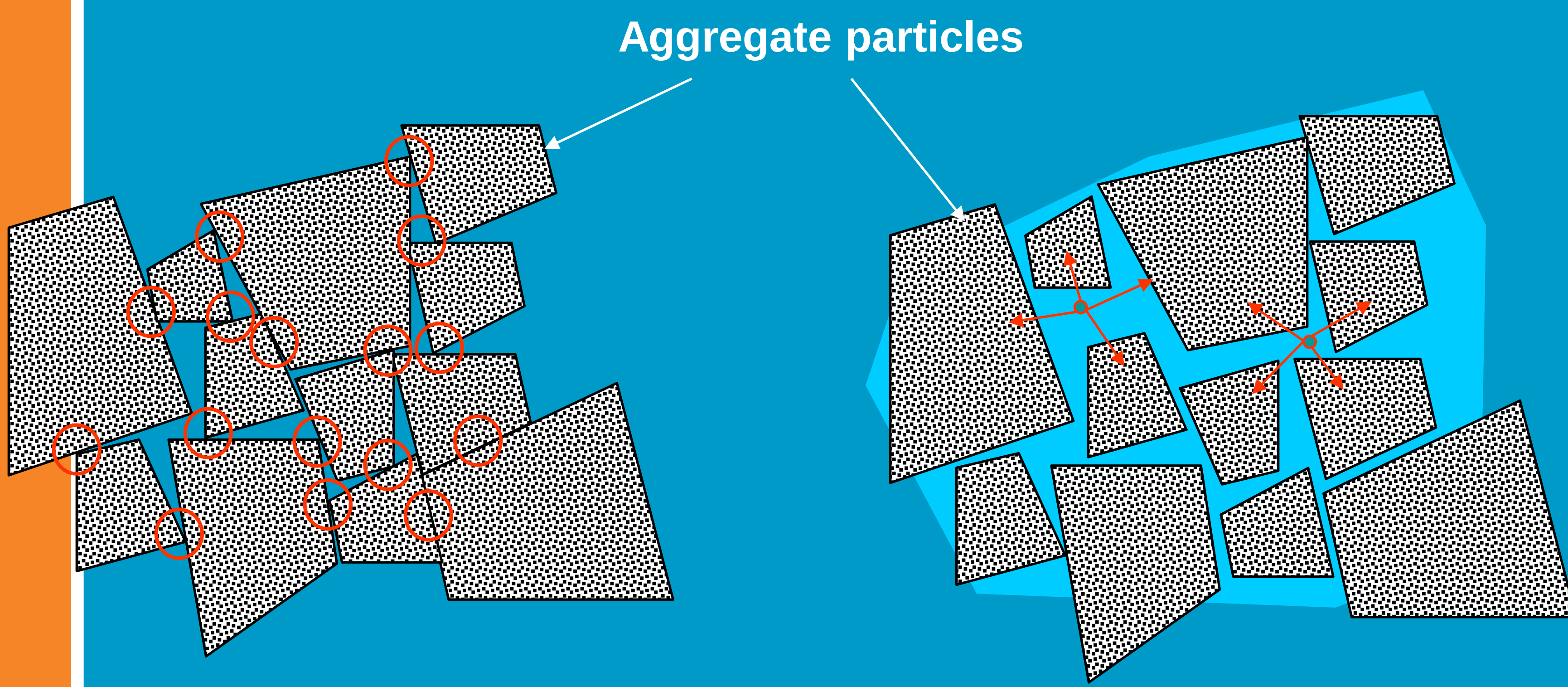
Too much - disastrous!

Everything in Moderation!

Pavement stresses



Pavement saturation

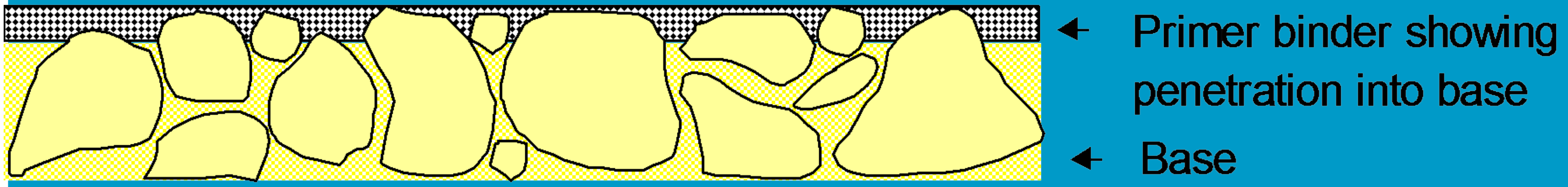


Numerous contact points each, under high stress in a well compacted granular material

In a saturated system the applied load is transmitted equally in all directions, forcing the aggregate particles apart

Primer

- specially formulated bitumen emulsion primer
- is placed without chip
- Should not be trafficked & a more substantial surfacing treatment should be scheduled after the prime has dried.
- Binds & penetrates surface of an unbound granular layer (typically 5 to10 mm)
- Provides a bond onto which a subsequent bituminous surfacing can adhere
- Assists in waterproofing & protecting pavement



First Coats

- On new or rehabilitated pavements
- Construction of a surface to which a first coat will adhere must be a well-bound, relatively dry, smooth hard surface, with clean stones showing & no dust
- Benefits of priming unbound granular pavements

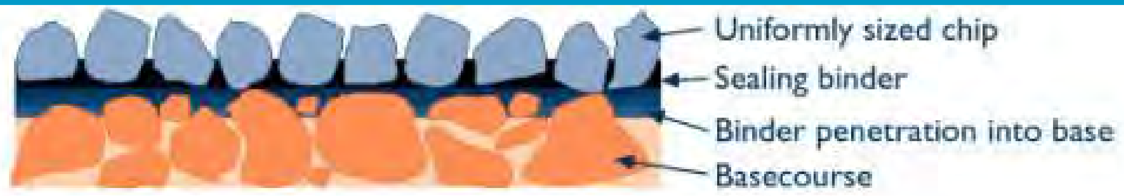


Figure 3-8 A first coat seal. Courtesy of Austroads Sprayed Sealing Guide (2004)

Stabilisation

- when should one go for stabilisation?
- Pros and Cons of cement Stabilisation and Lime stabilisation?
- Testing regime for Subgrade? Sub Base?
- Improving a current CBR to a target CBR through Roller passes, stabilisation, Foam bitumen etc?

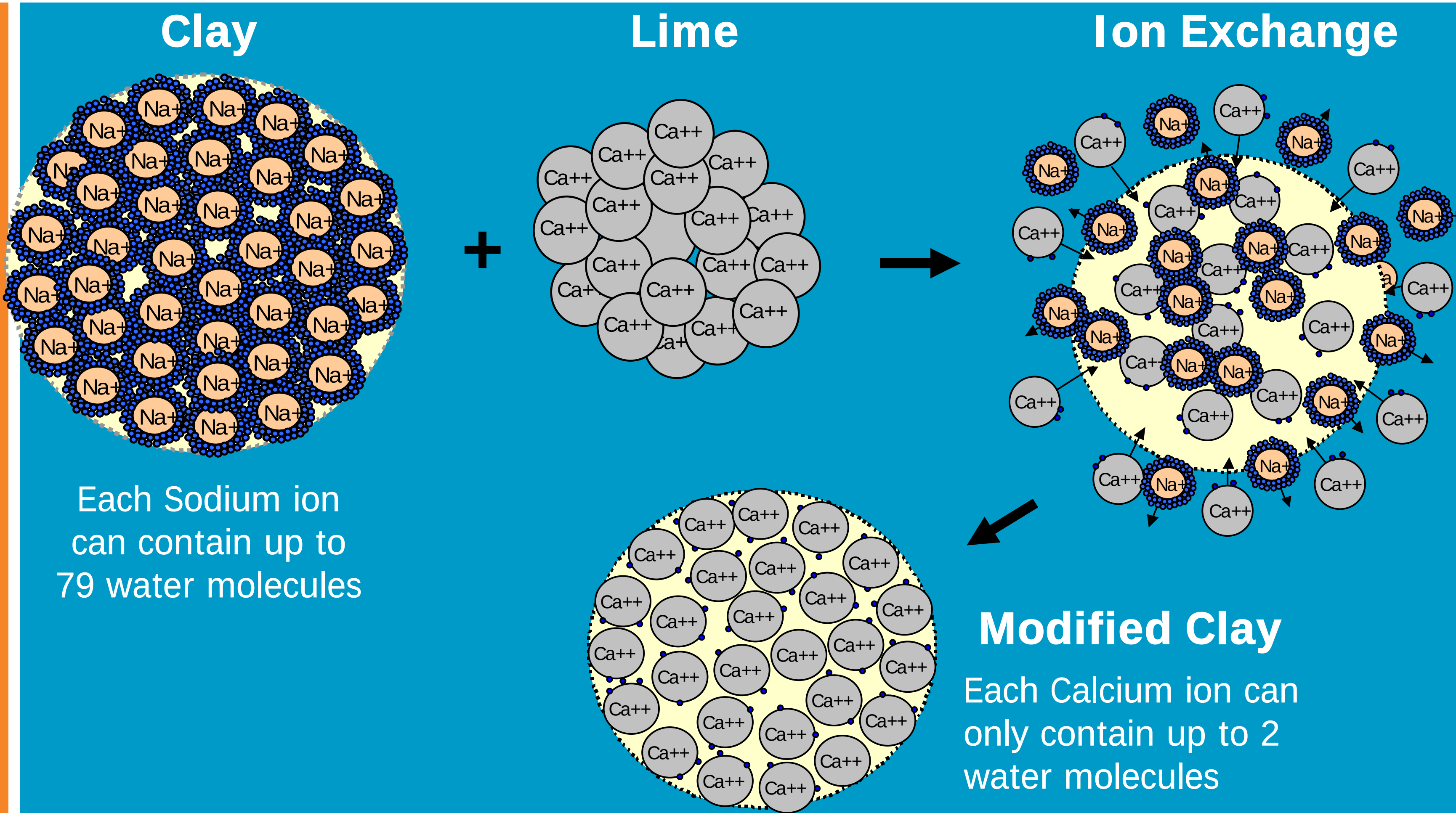
Modification and Stabilisation

- Unable to compact or unstable soil usually due to plasticity
- Insufficient bearing capacity

Soil Modification
and / or
Soil Stabilisation

- Improves long term durability & shear strength of aggregates
- Reduces moisture susceptibility

Base Course Stabilisation
or
Pavement Recycling



Each Sodium ion can contain up to 79 water molecules

Each Calcium ion can only contain up to 2 water molecules

Simplified representation of ion exchange during modification

Quicklime

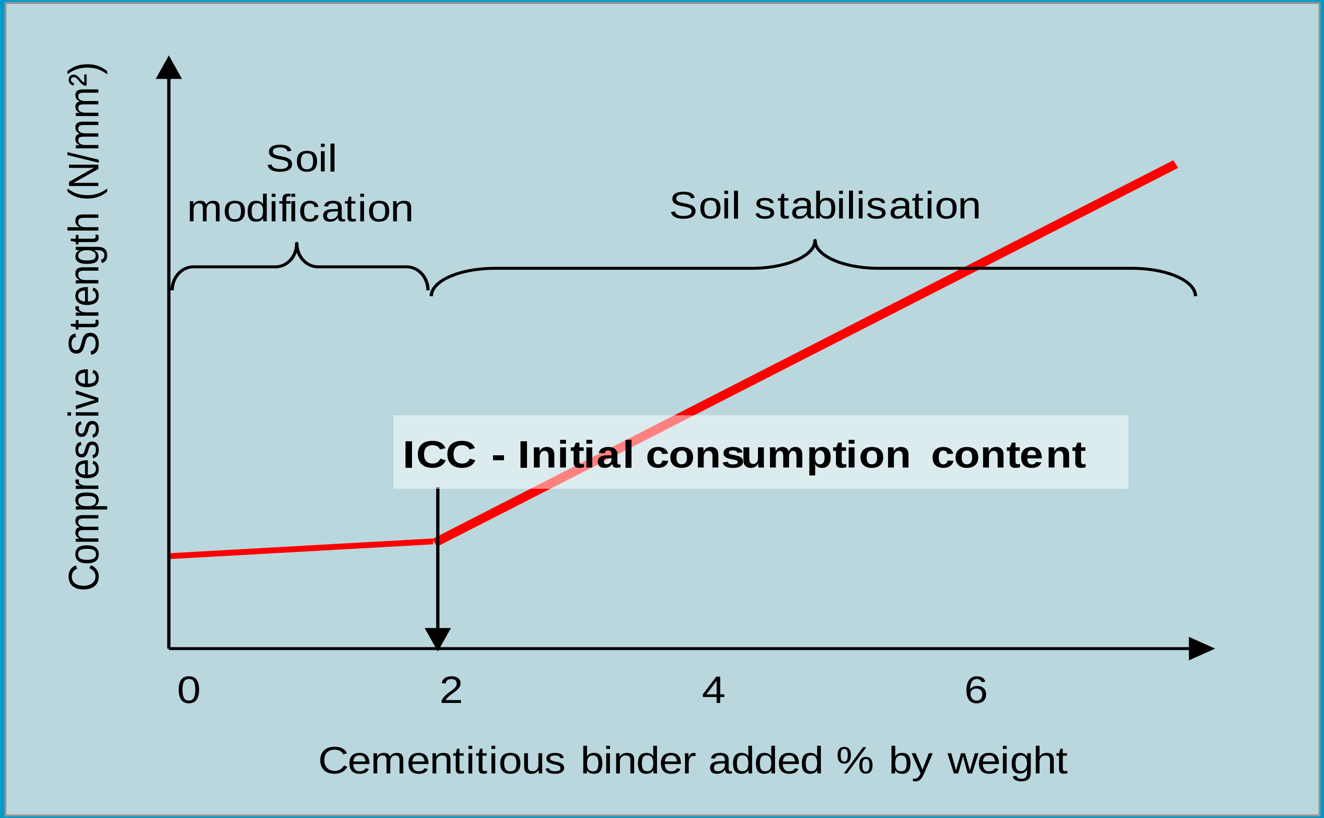
Limestone + Heat → **Quicklime** + Carbon Dioxide

$CaCO_3$ + Heat → **CaO** + CO_2 ↑ (gas)

Hydrated lime or slaked lime

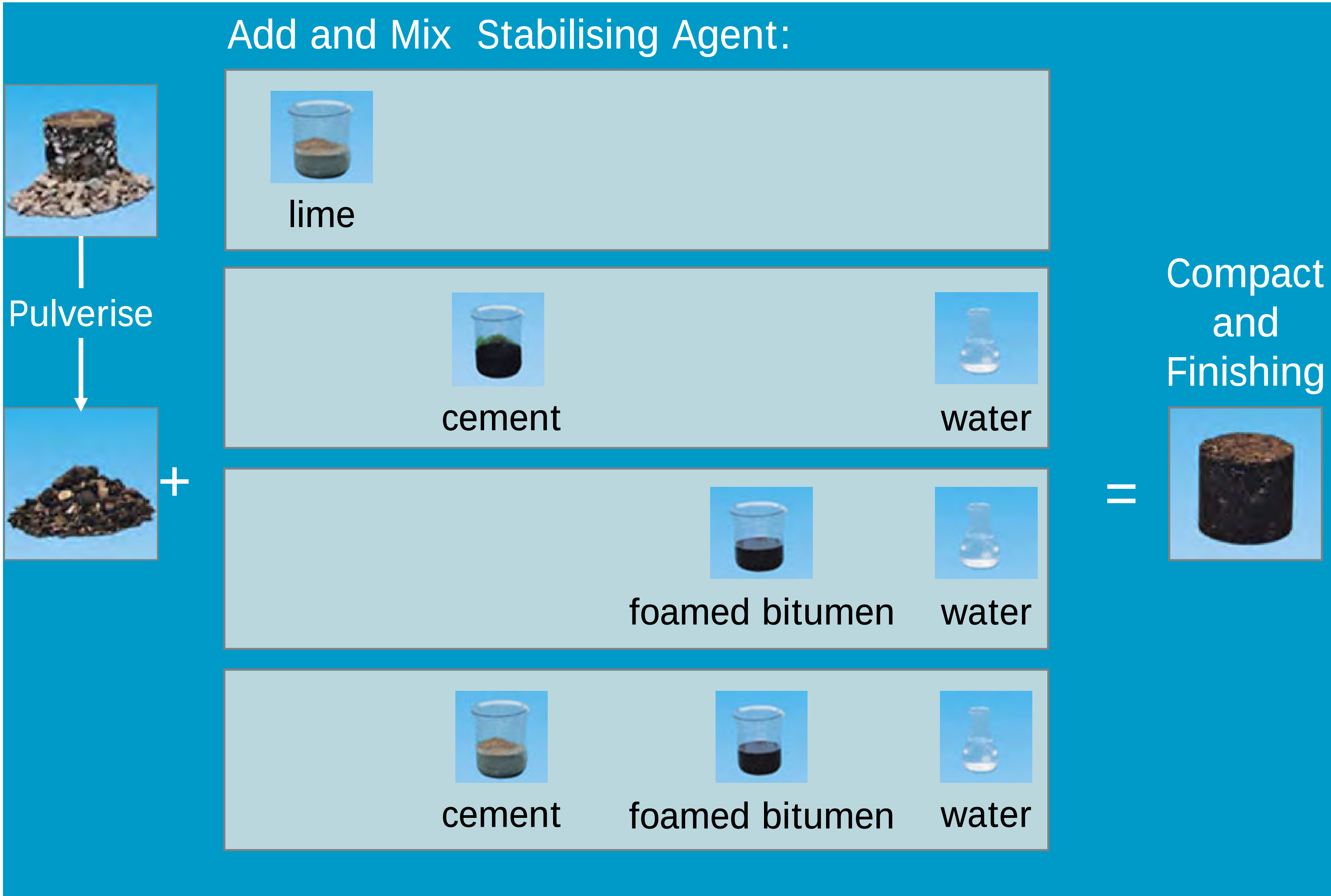
Quicklime + Water → **Hydrated Lime** + Heat

CaO + H_2O → **$Ca(OH)_2$** + Heat

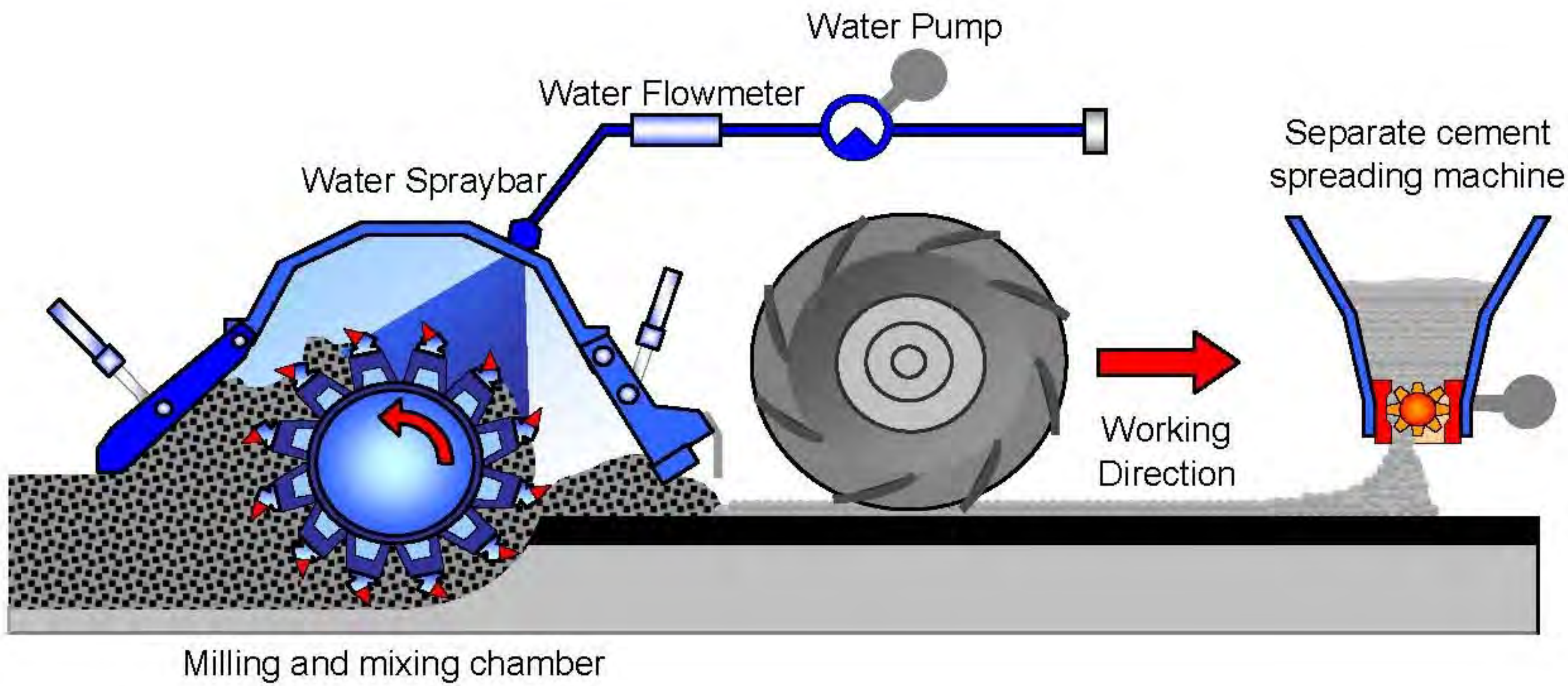


Certain amount of lime is required for modification
Beyond the ICC - free lime for cementation

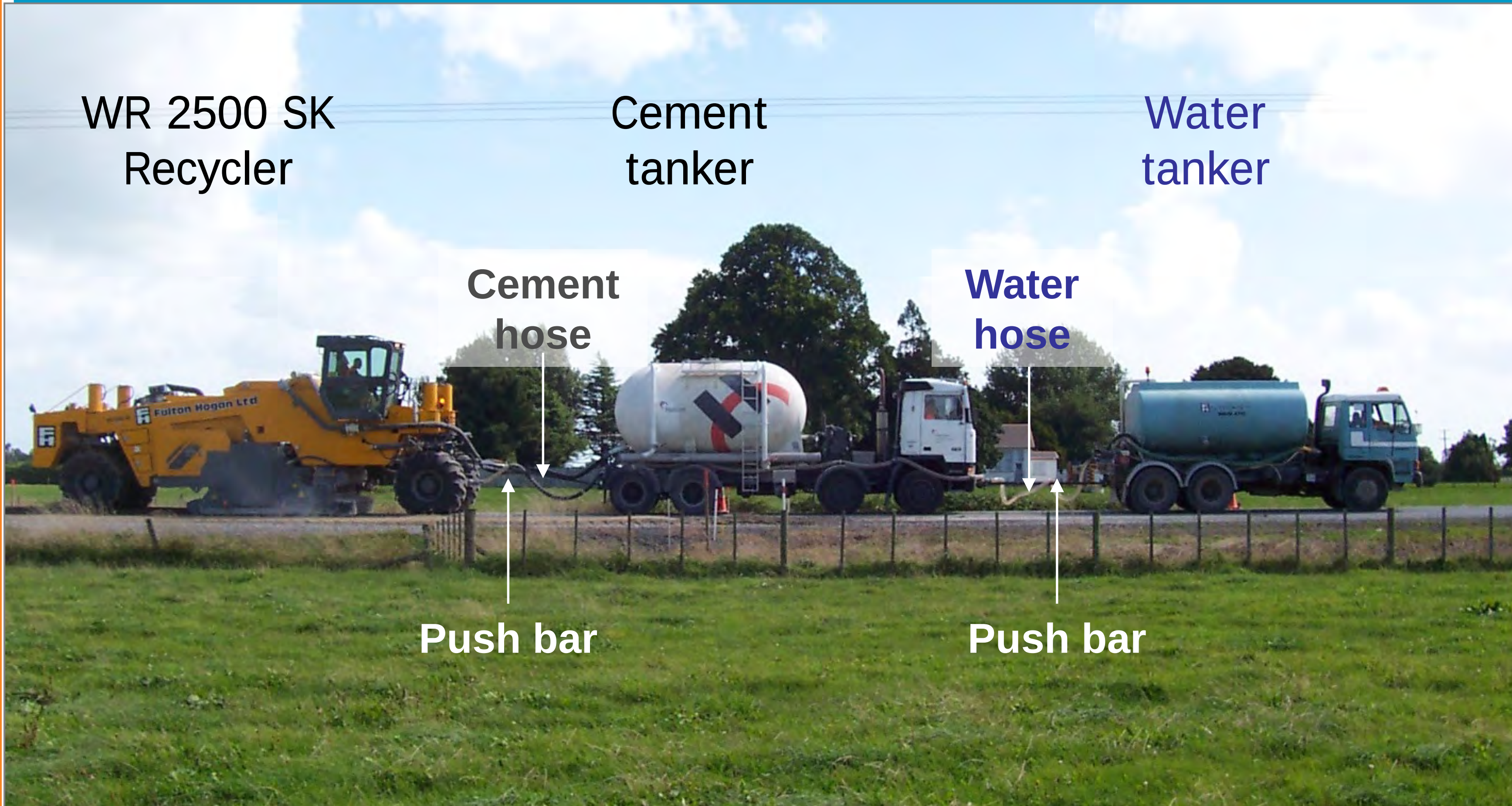
Binding agents for basecourse stabilisation



Cement-only Stabilisation Process

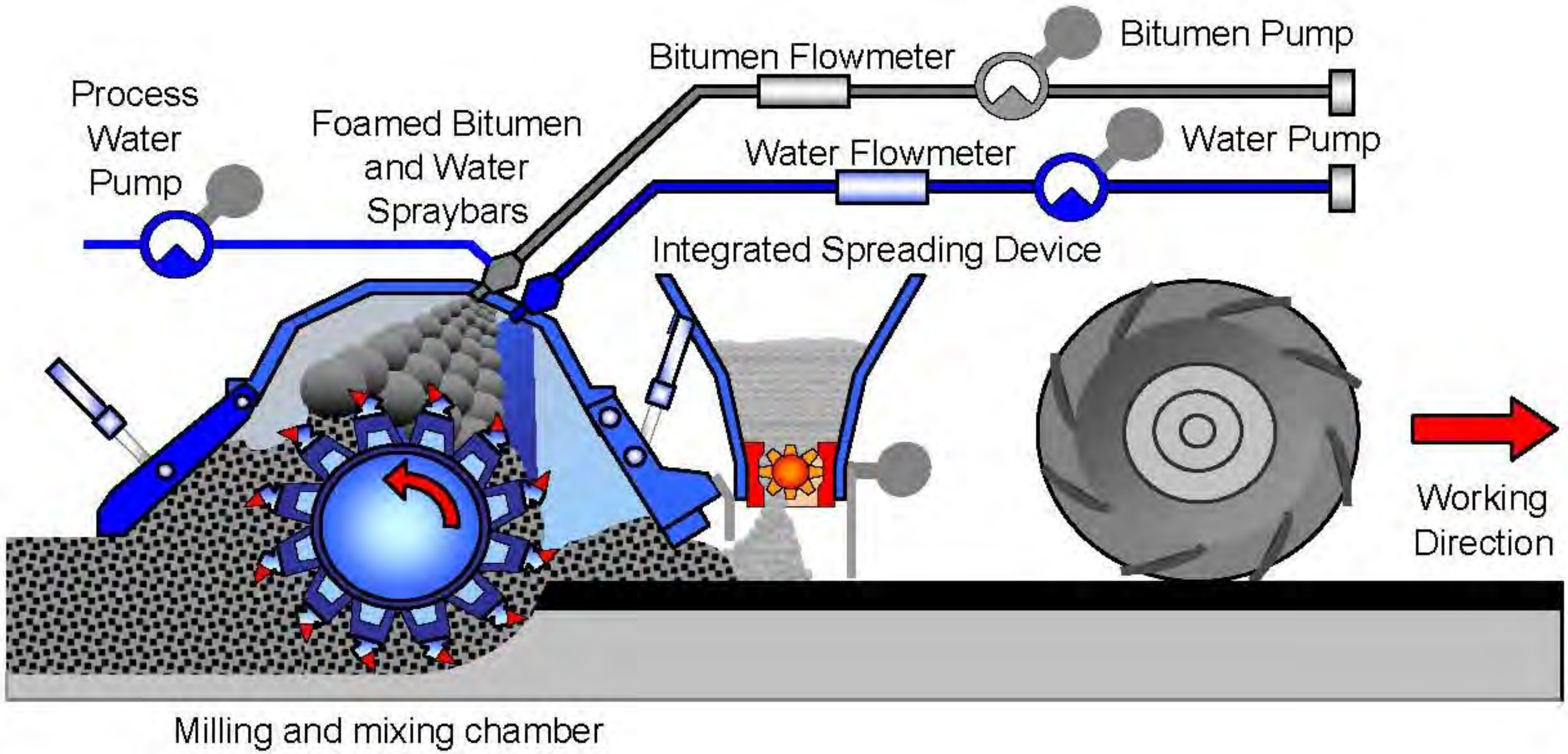


Spreading of binders



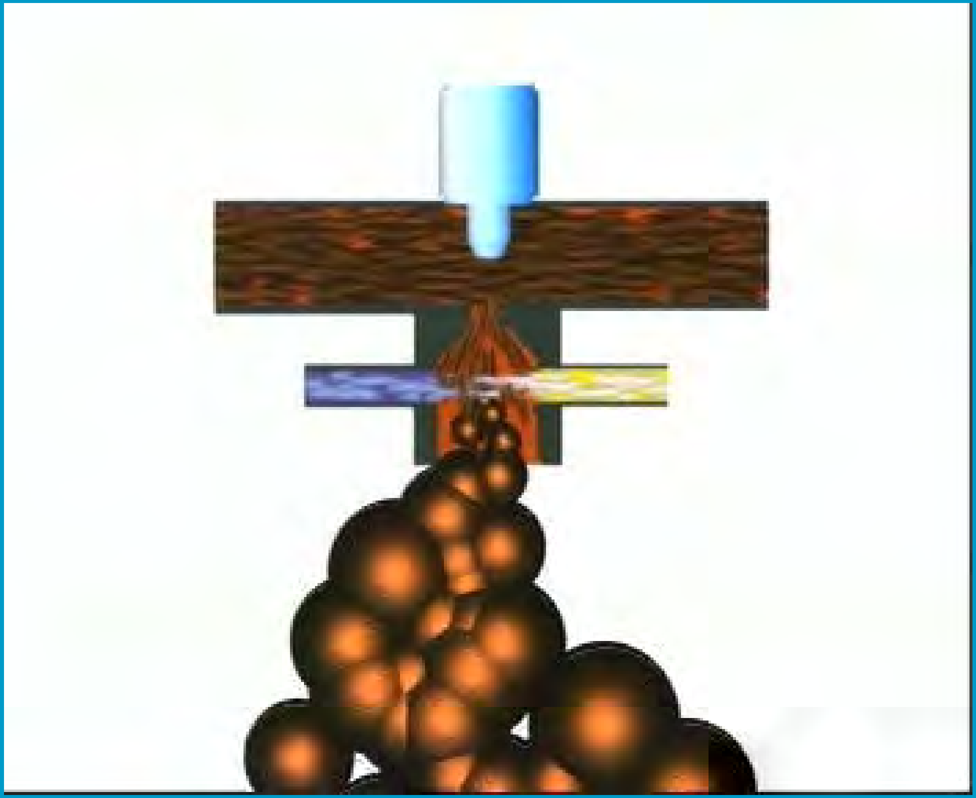
Supply trucks for water and cement are pushed by WR 2500 SK

Addition of Foamed Bitumen and Cement



Foamed Bitumen and Cement / Lime
can be added to the material in one pass

2 – 3 % water is mixed with 180 °C hot bitumen:
bitumen expands 15 to 20 times its original volume



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

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Specifications for Modified & Bound Layers Produced In-Situ & In-Plant

Layer	Binders	In-Situ	In-Plant
Modified Basecourse & Sub-base	Cement Lime Foamed B. B. Emulsion	**NZTA B/5**	**NZTA B/7**
Bound Sub-Base	Cement Cement / Lime	**NZTA B/6**	**NZTA B/8**
Subgrade	Lime Cement	**NZTA B/9**	N/A

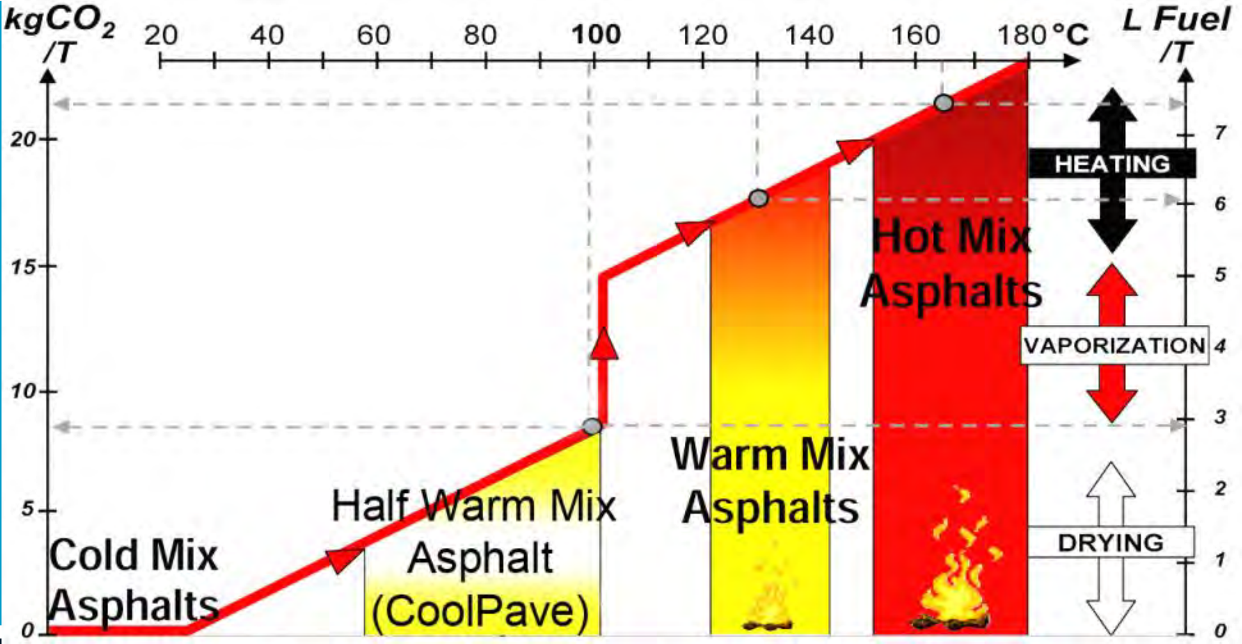
Sustainability in pavements

- Reduce total consumption of energy & virgin materials during construction & maintenance
  - asphalt production (low energy/low emissions mix)
  - sealing (emulsions)
  - aggregates (recycling)
  - recyclable materials – asphalt, glass, RCC, etc

- Main barrier: Attitudes re performance of recycled / sustainable materials

CoolPave with L.E.A (low emissions asphalt)

- Biggest temperature reduction
  - Produced between 95°C to 115°C
  - Before,165°C for HMA and 130°C for other warm mixes
- Lowest fuel usage
- Biggest reduction in greenhouse gases



Coolpave

- Compacts as easily as hotmix, similar roller patterns can be used
- Retains its workability for longer
  - More time for compaction
  - Good for long duration hand work, mix will retain workability
- Can be placed in colder temperatures
- Can be carted further since temperature does not reduce as quickly as hotmix
- Improvement in longitudinal joints

Opportunities for Recycling Materials

- Reclaimed asphalt pavement (RAP)
- Recycled crushed concrete (RCC)
- Crushed Glass
- Melter slag
- KOBM (Klockner Oxygen Blown Maxhutte)
  - by-product of steel production
- Fly ash
- Crushed brick
- Bitumen additives, extenders & replacements

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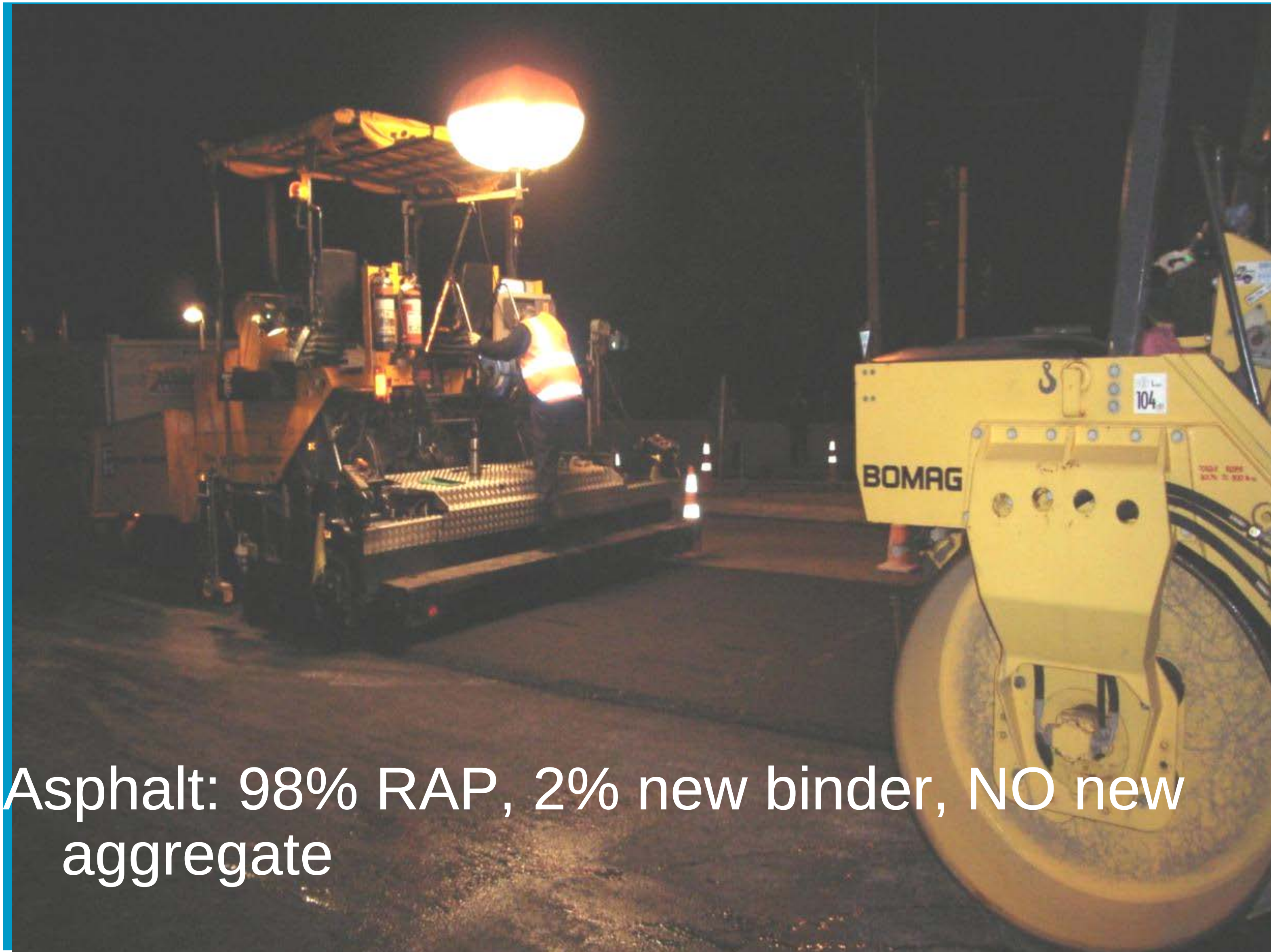
Materials Processing

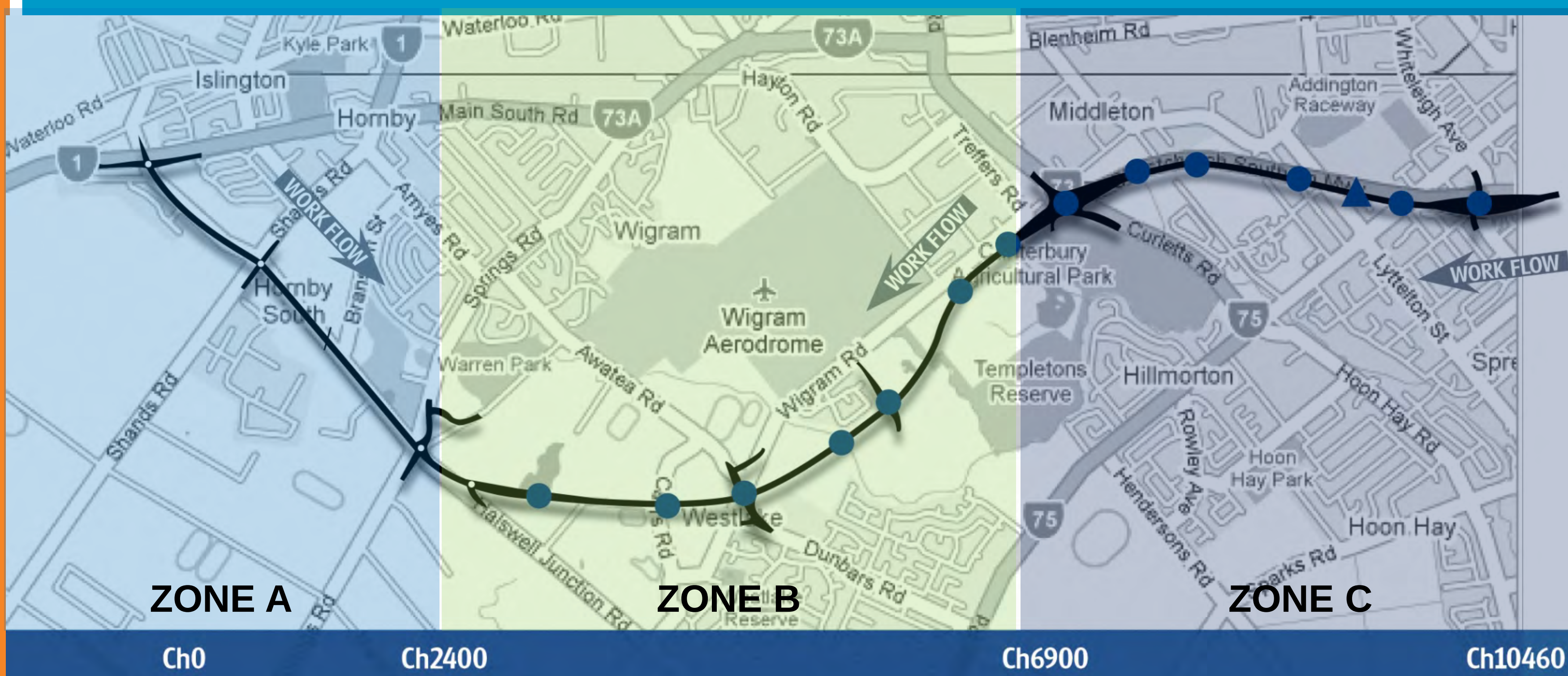


Asphalt: 98% RAP, 2% new binder, NO new aggregate

Project Summary

- Excellent Technical Properties
- Savings obtained when whole of life costs are considered
- Encouraged sustainability of natural resources
- No environmental risks
- Performed well for 7 years until earthquakes!

Christchurch Southern Motorway
Sustainability



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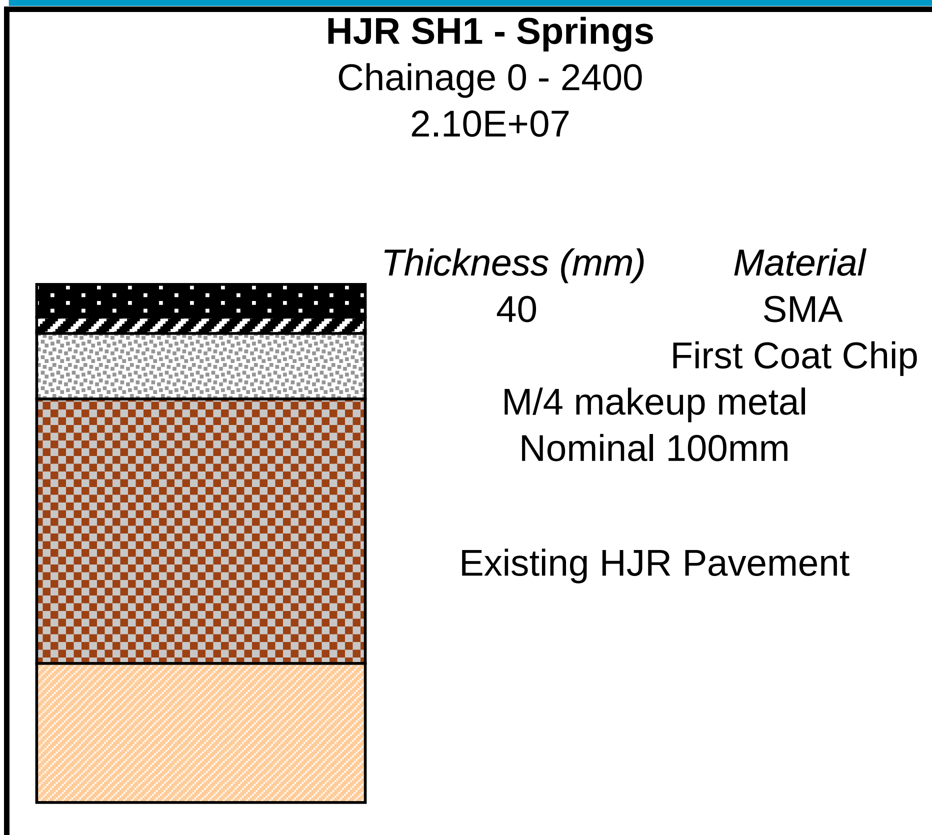
RCC Stockpile

Prince of Wales & Duchess of Cornwall on CSM Nov 2012

Materials & Design

- Maximised use of RCC
  - Trials to confirm optimum maximum size for stabilising
  - Tests confirmed optimum cement content to add for cemented subbase
- Maximised use of recycled asphalt (RAP)
  - RAP sorting & storage methodology
  - 30% RAP in asphalt mix
- Maximised sustainable use of virgin aggregates
  - Maximised use of existing aggregate in Halswell Junction Rd
  - Broken faces as per B/5 spec in Zone B
- Trials of aggregate from 3 different quarries - Zone B
  - PSD vs moisture susceptibility

Halswell Junction Road – Zone A



- Existing pavement well compacted & low deflections but low % broken faces
- Removed upper 100 mm
- Placed 100 mm AP40
- Stabilised 150 mm deep with 1.5% cement
- Applied seal & SMA

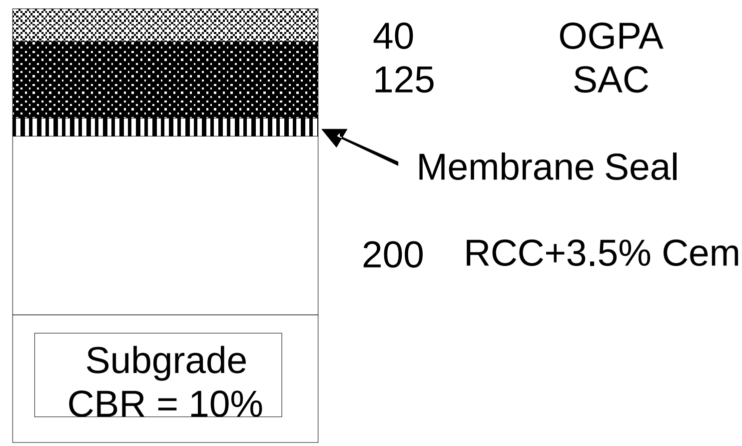
Shands Road intersection – Bitumen Treated Basecourse

Structural Asphalt – Zone C

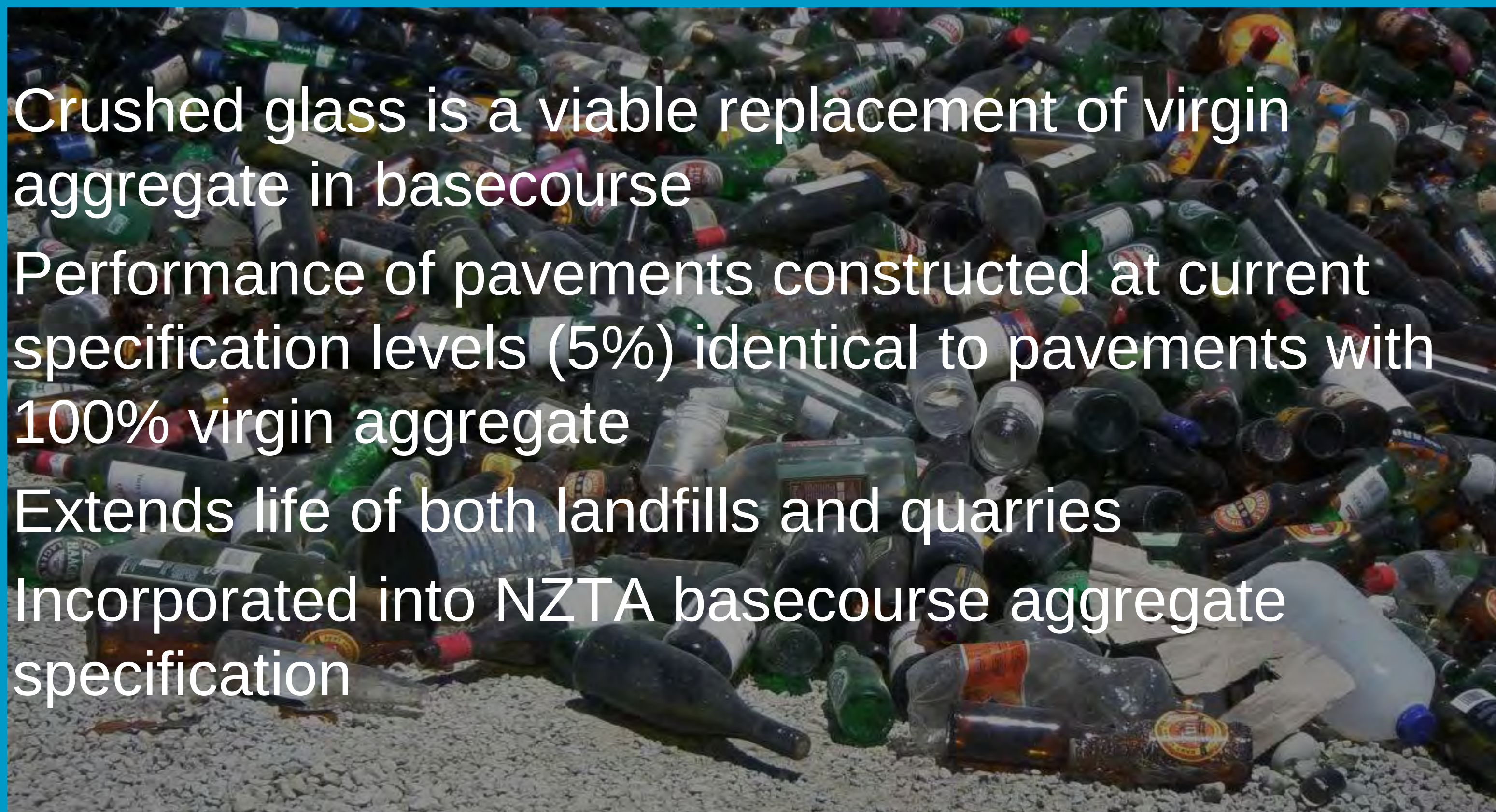
Traffic: 4 x 10^7 ESA
Design CBR: 10
Pavement: Structural Asphalt

Typical Design

Curletts - Collins
Chainage 7700 - 10300
4.00E+07



Recycling Crushed Glass



- Crushed glass is a viable replacement of virgin aggregate in basecourse
- Performance of pavements constructed at current specification levels (5%) identical to pavements with 100% virgin aggregate
- Extends life of both landfills and quarries
- Incorporated into NZTA basecourse aggregate specification

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Crushing Process

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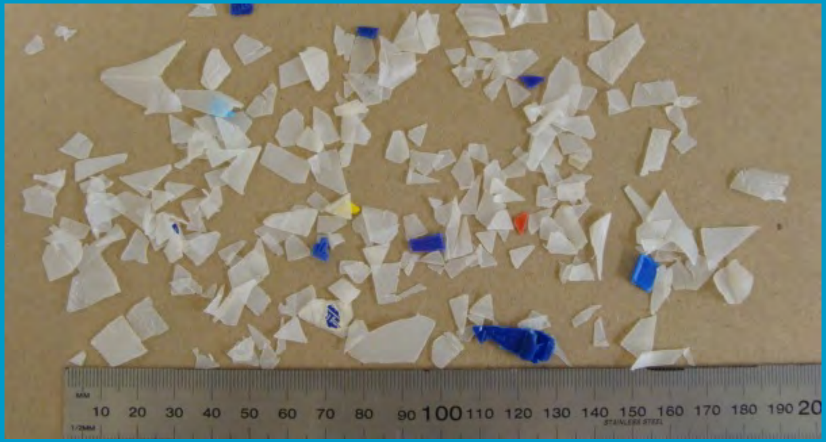
Bitumen Additives, Extenders & Replacements

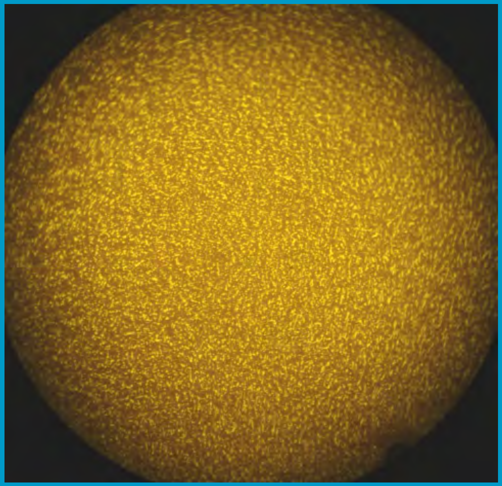
- Bitumen was a heavy residue “by-product” of petroleum refining
- Now, heavy residue can be cost-effectively refined to produce fuels & products with higher margins so no one wants to refine bitumen
- Australian refineries closing; those that continue, won’t produce bitumen
- NZRC Marsden Point – New Route bitumen
- AUSTROADS project investigating common Aust/NZ bitumen performance graded spec

Recycling & Alternative Bitumen sources

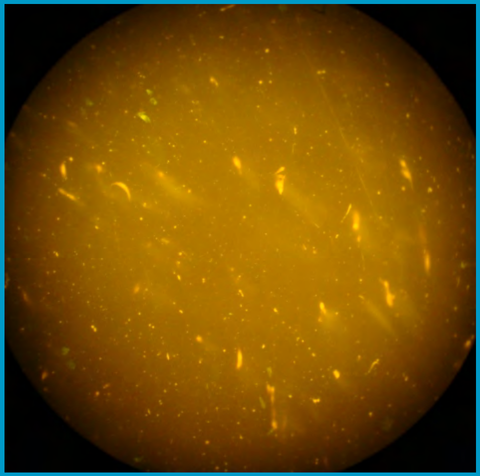
- Crumb tyre rubber
- Toner (from photocopiers)
- Plastic milk bottles
- Bio-binders

Recycling Plastic Milk Bottles





4% SBS



3% HDPE Blend

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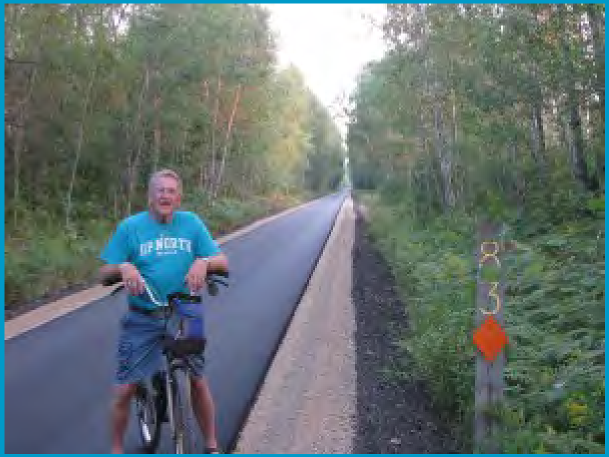
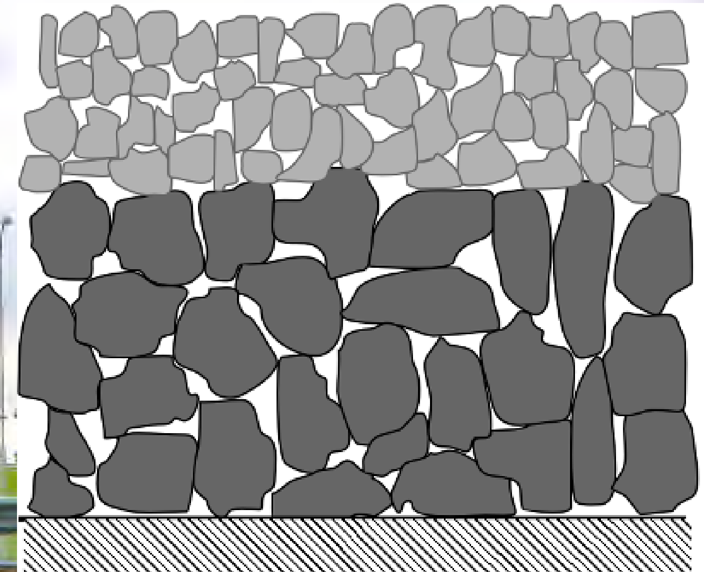
Bio-binders

- Superheat biomass (corn stalks, wood waste, etc) without oxygen
- Creates bio-binder, can be used with bitumen
- Trial of binder containing 5% bio-binder



Noise reduction



Double layer porous asphalt

Top: 25mm thick, 8mm max. aggregate, >20% air voids

Bottom: 45mm thick, 16mm max. aggregate, 25% air voids, mod. binder

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Truck noise measurements

Surface	Noise Levels from Trucks (dBA)			
	2005	2006	2007	2008
OGPA	**88.8**	**89.9**	**91.8**	**90.4**
Δ 2005		**+1.1**	**+3.0**	**+1.8**
WhispA™	**86.2**	**86.8**	**88.0**	**86.8**
Δ 2005		**+0.6**	**+1.8**	**+0.6**
WhispA™ - OGPA	**-2.6**	**-3.1**	**-3.8**	**-3.6**

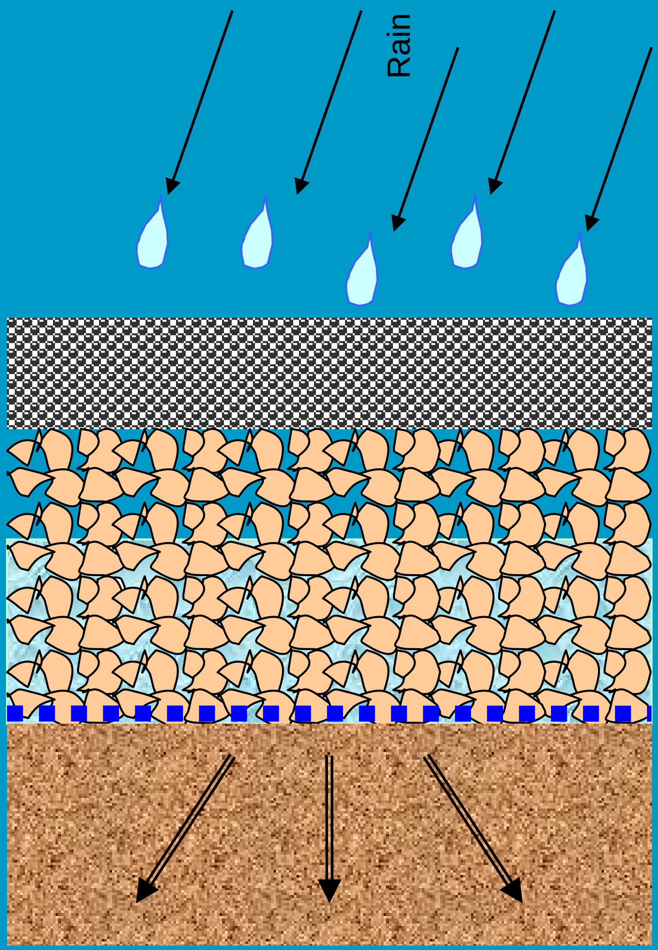
Data from NZ Transport Agency & Opus Research

Porous Pavements – Stormwater retention

Water passes through surfacing

Water temporarily retained

Water infiltrates into subgrade



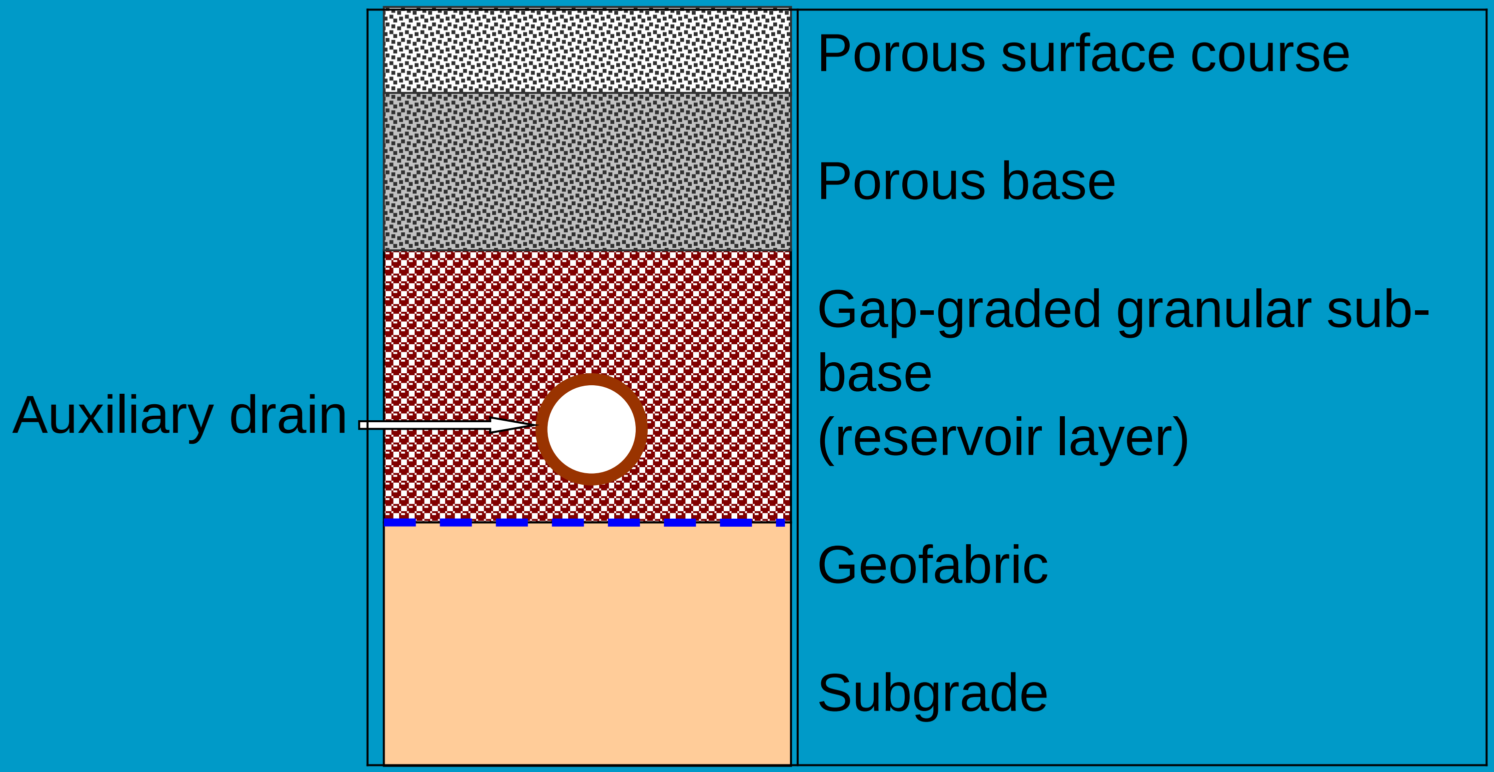
Porous surfacing

Porous granular material

Optional geotextile, woven filter fabric or sand blanket

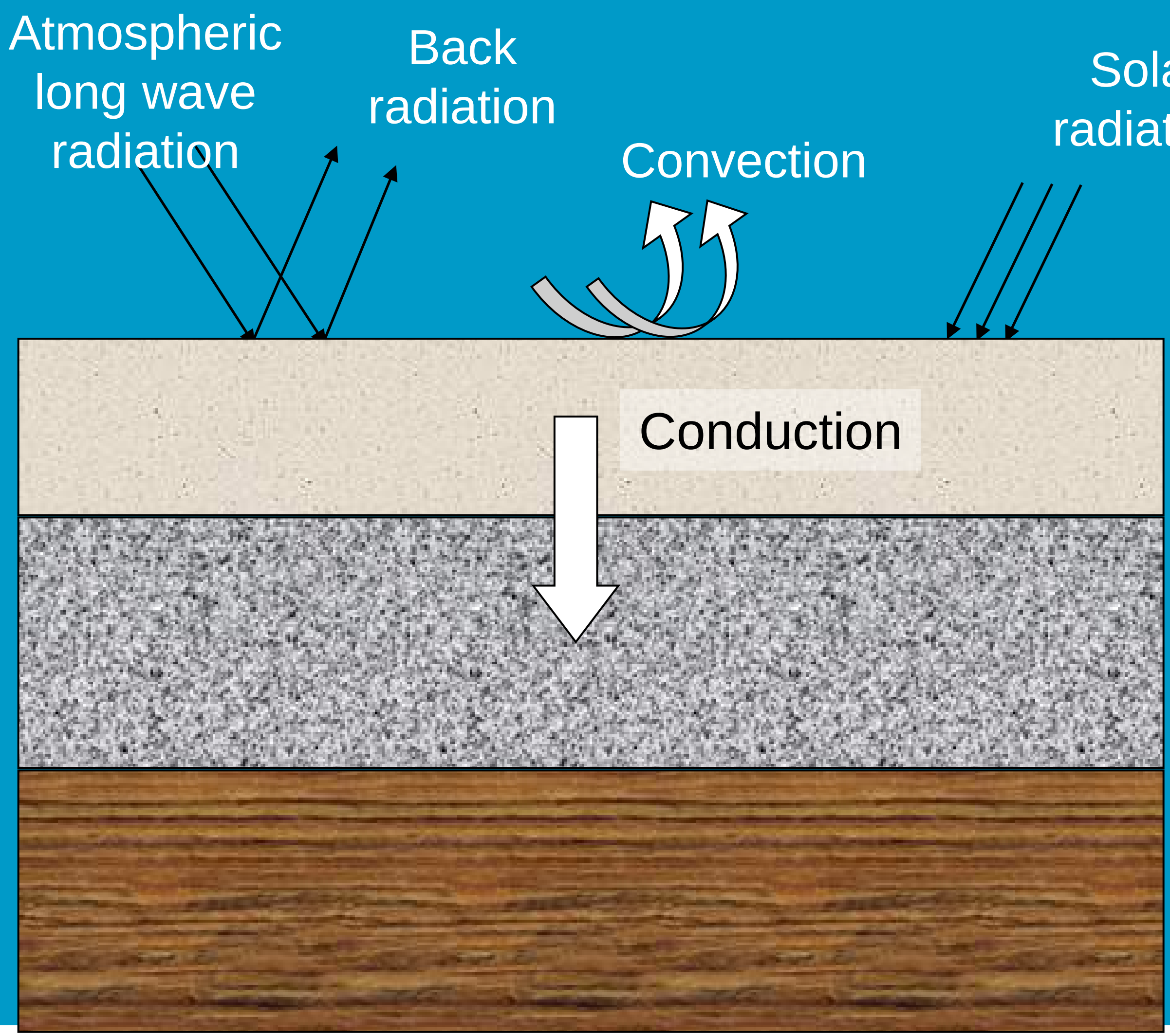
Natural subgrade

Porous Pavements




Vision

Pavements as solar heat collectors



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Flexible pavements generate electricity

- Variety of systems:
  - rubber discs or judder bars that compress, & kinetic energy converted to electricity
  - Piezoelectric generators embedded in pavement