Pavement Design

Guide to Pavement Technology Parts 2 and 4C

9 March 2018

Austroads

Today's moderator

Eliz Esteban

Communications Officer

Austroads

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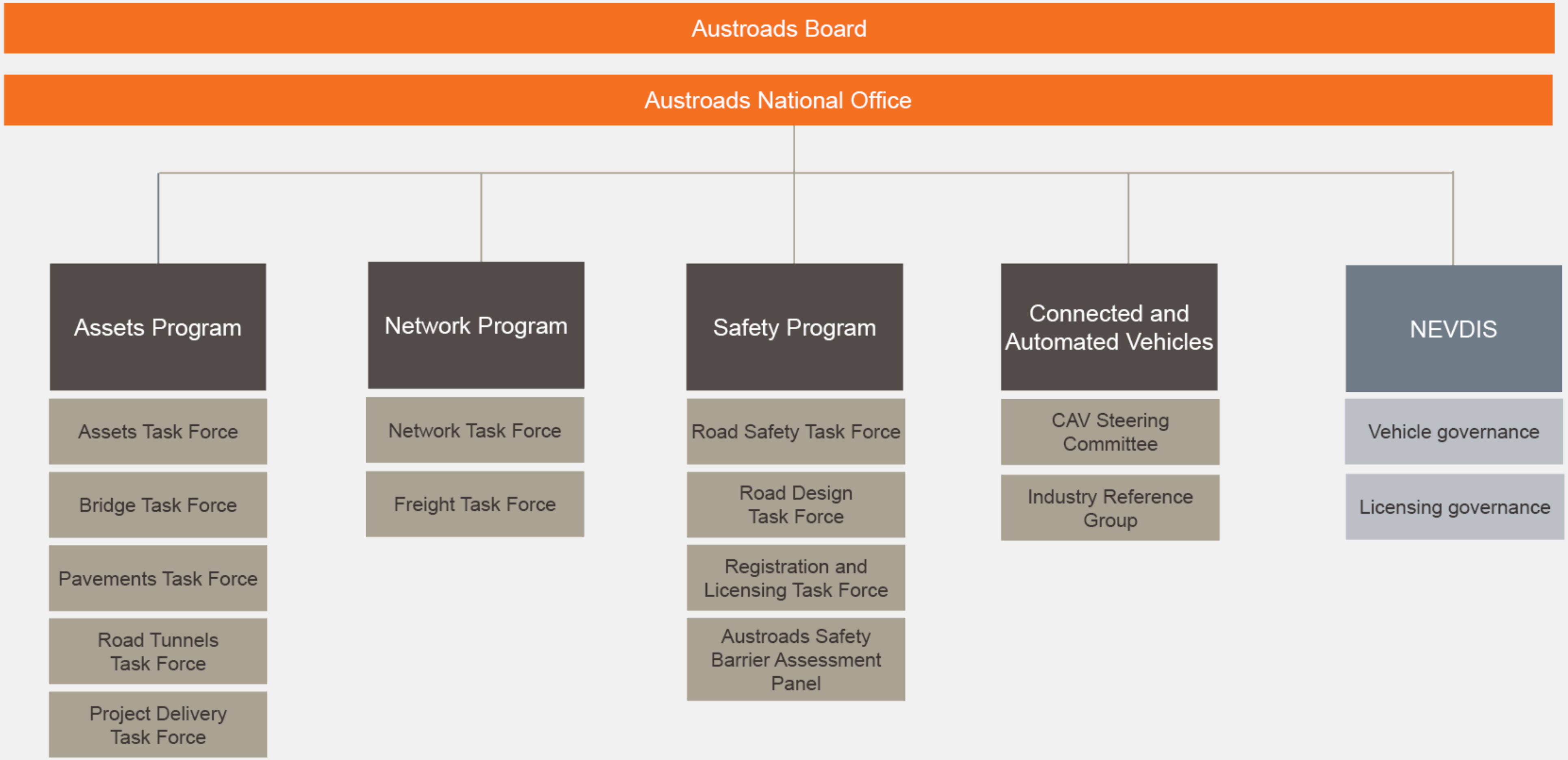
About Austroads

The peak organisation of Australasian road transport and traffic agencies

- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Transport Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- Commonwealth Department of Infrastructure, Regional Development and Cities
- Australian Local Government Association
- New Zealand Transport Agency

Our structure



Housekeeping

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Presentation = 40 mins

Question time = 10 mins

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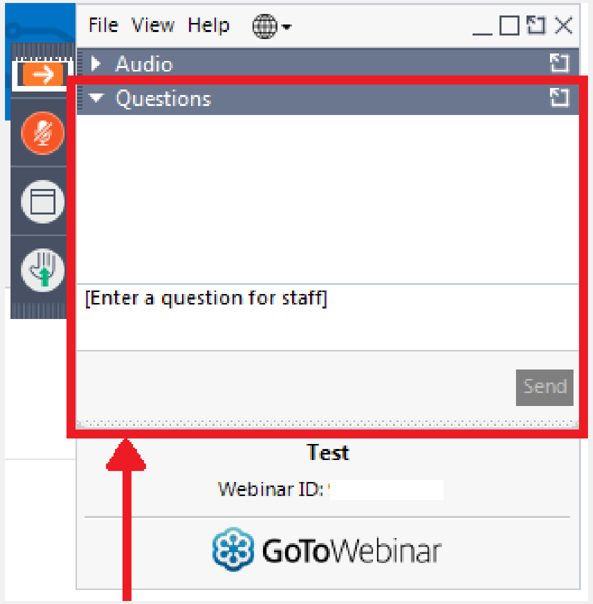

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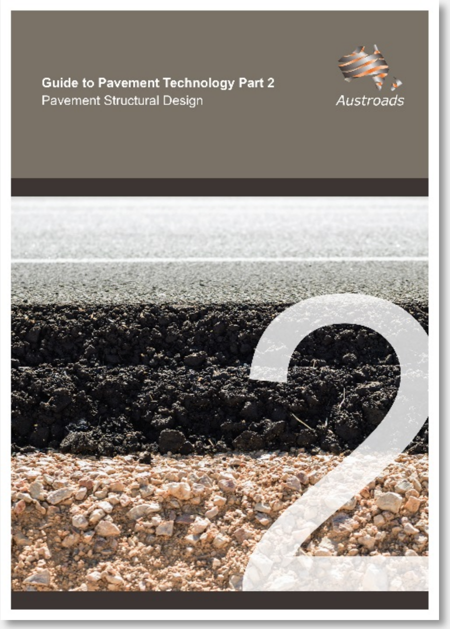

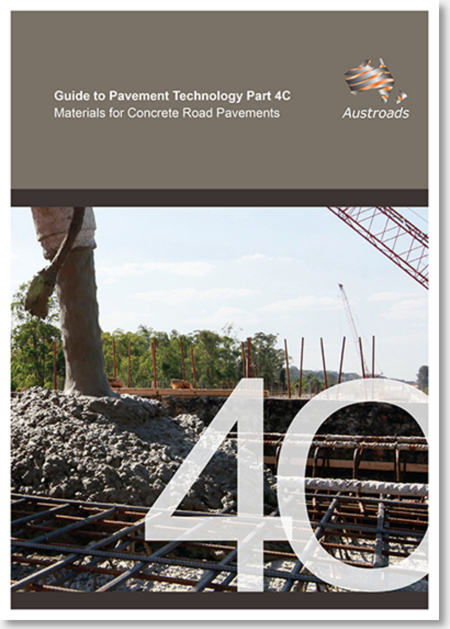

Download from Austroads Website:

- https://www.onlinepublications.austroads.com.au/items/AGPT02-17
- https://www.onlinepublications.austroads.com.au/items/AGPT04C-17

Today’s presenter

Dr Michael Moffatt
National Technical Leader
Pavements and Surfacings
ARRB

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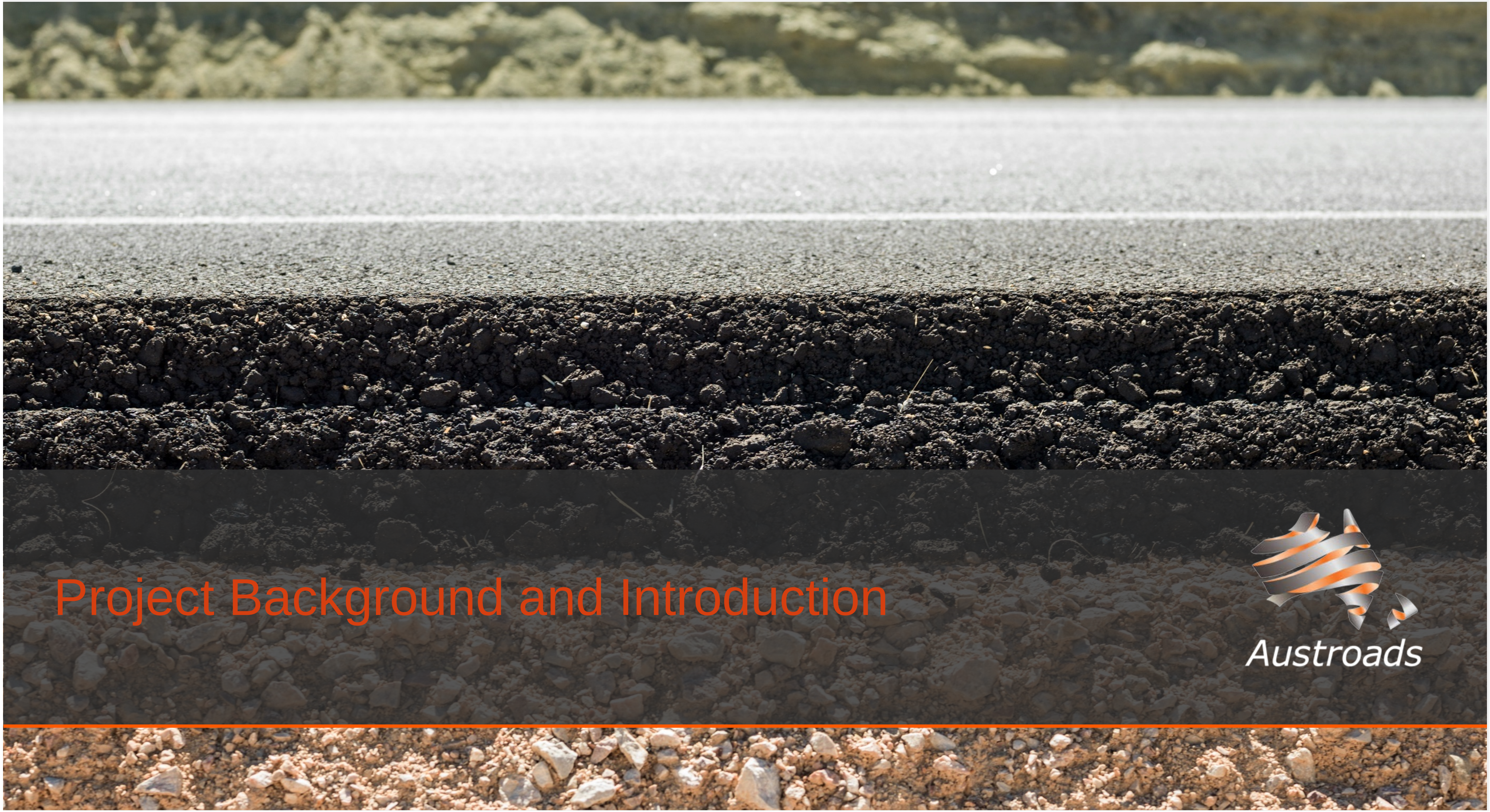
Agenda

Topic	Presenter
Project Background and Introduction	Dr Michael Moffatt
Guide to Pavement Technology Part 2: Pavement Structural Design • Lime Stabilised Subgrades • Cemented Materials • Lean-mix Concrete • Asphalt Characterisation • Design Traffic • Axle Strain Method (ME bound materials)	
Guide to Pavement Technology Part 4C: Materials for Concrete Road Pavements	
Q&A	



Project Background and Introduction

Evolution of Guide to Pavement Technology Part 2

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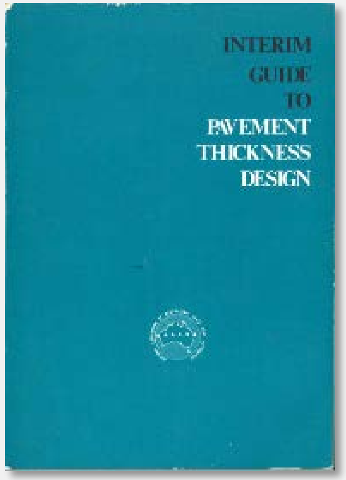

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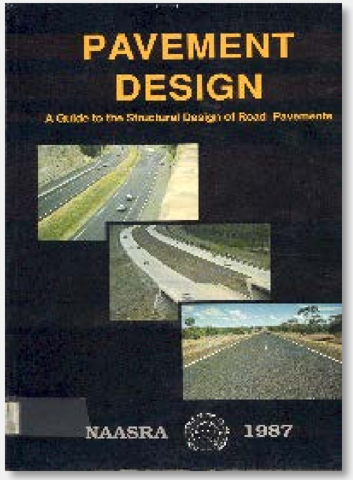

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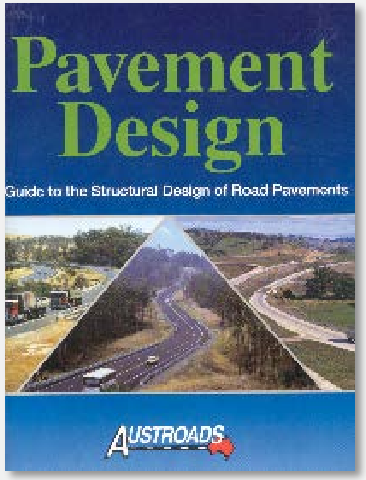

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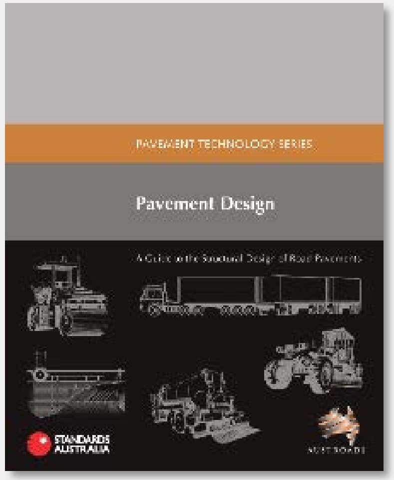

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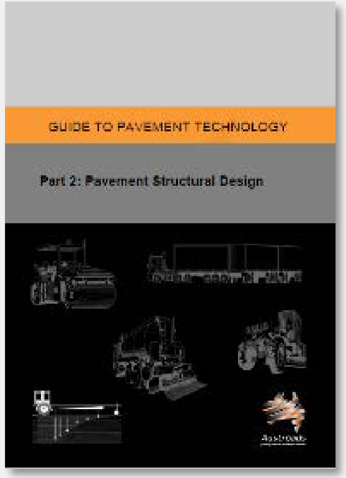
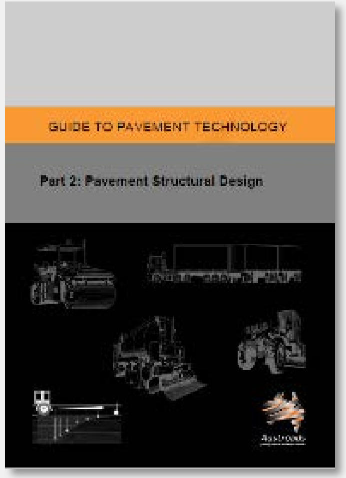
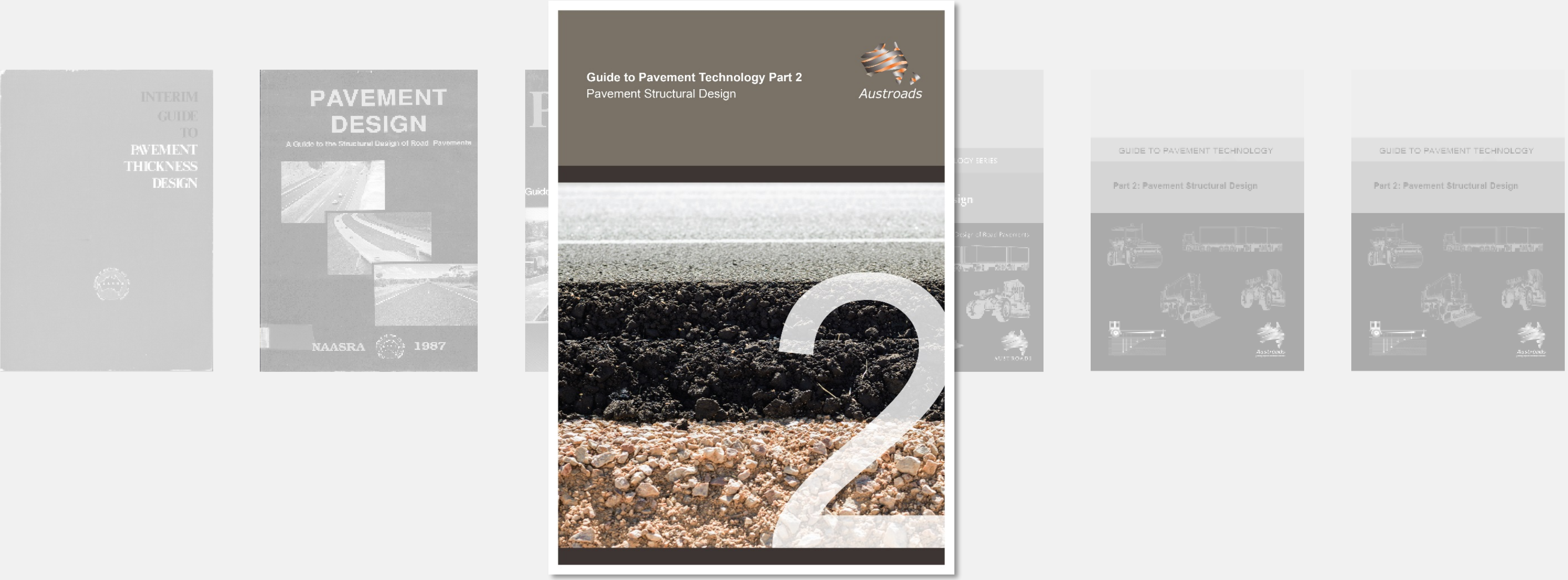


2008
2010



2012

2017 Edition



2017

2002 – 2018 Reports

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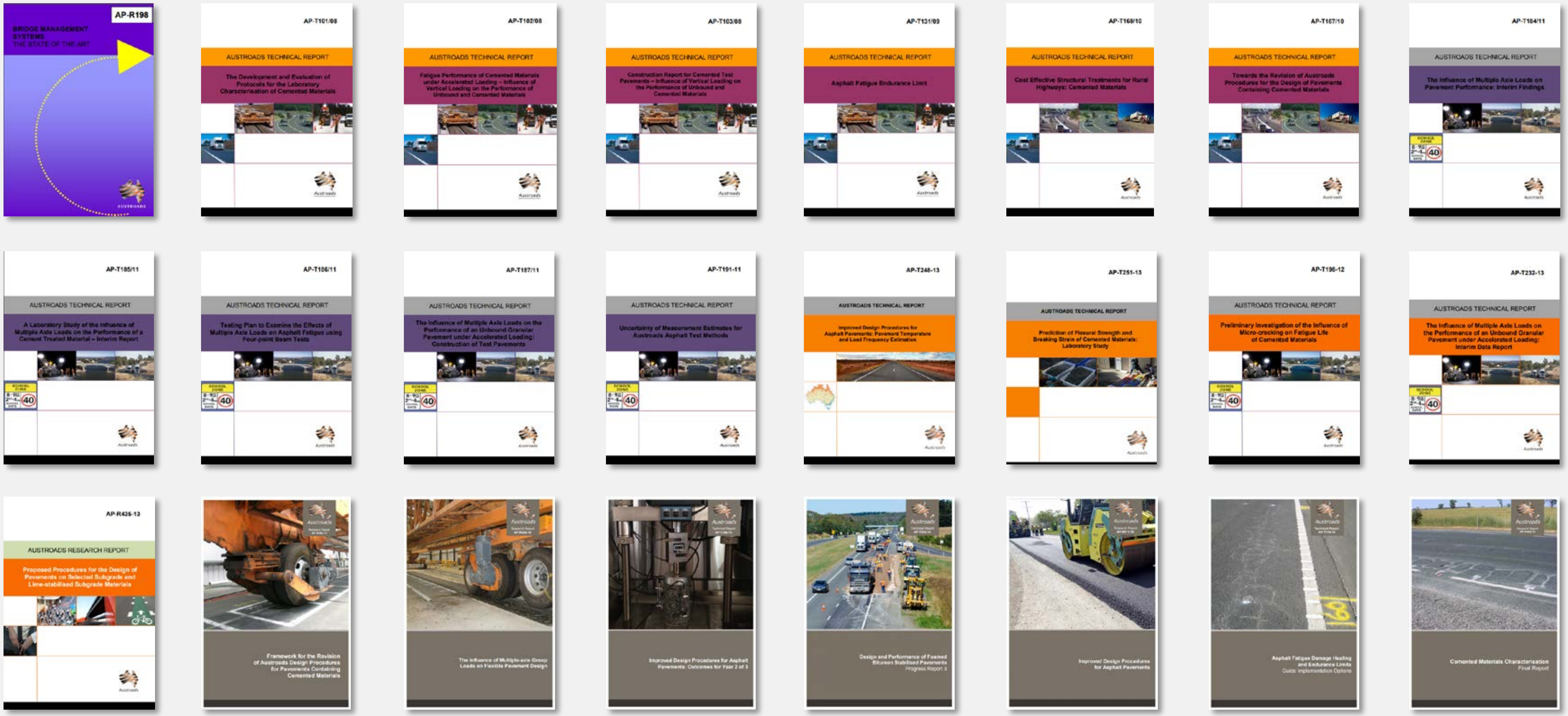

Introduction to Team

Project Team

Austroads Project Manager
Andrew Papacostas
VicRoads

Project Leader
Michael Moffatt
ARRB

Team Member
Geoff Jameson
ARRB

Review Team

Austroads Pavements Structures Working Group

Austroads Pavements Task Force

Stakeholders - Road & Traffic Authorities & Industry

Austroads Board

Guide to Pavement Technology Part 2

Pavement Structural Design

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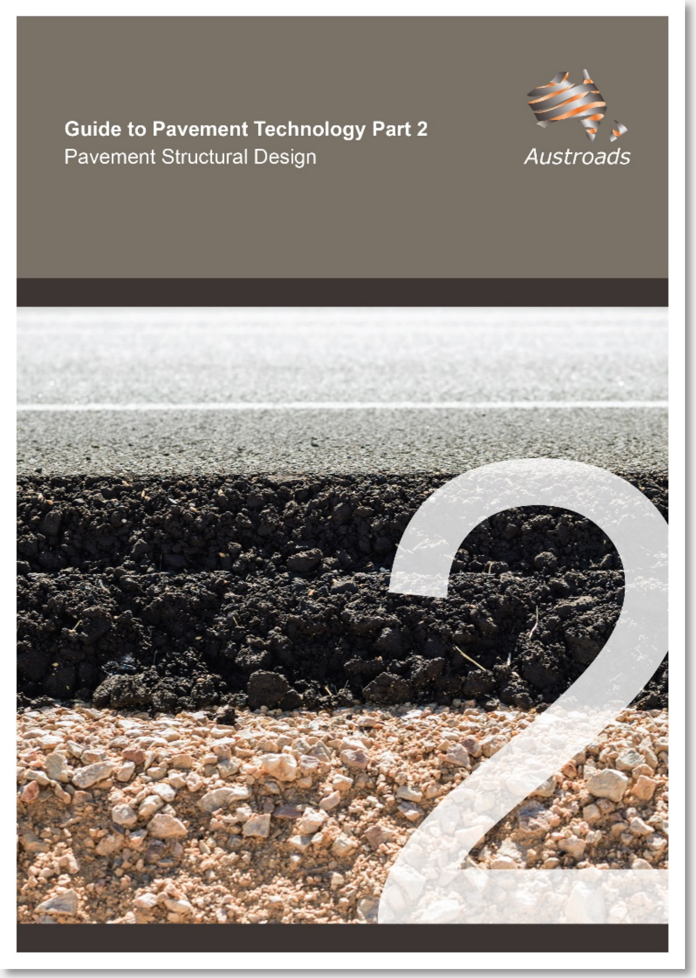
Overview of Part 2 changes



Flexible pavements

- Lime stabilised subgrades
- Cemented materials
- Lean-mix concrete
- Asphalt
- Design traffic
- Removal of Standard Axle Repetitions (SARs)
- Axle-strain method

Rigid pavements

- Joint detailing diagrams

Lime Stabilised Subgrades

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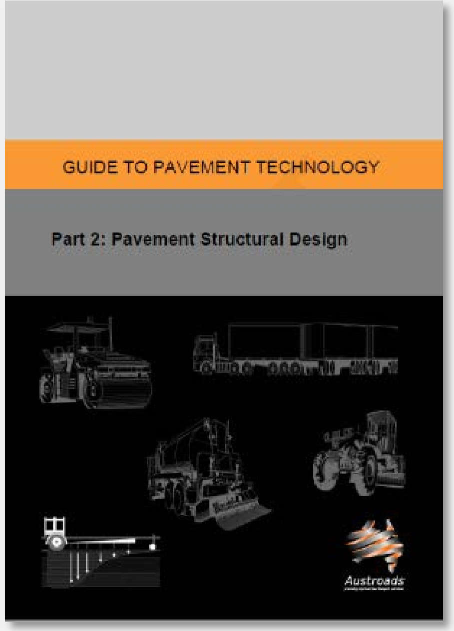
Lime Stabilised Subgrades



2012

- Lime stabilised subgrades not structural

2013

- Researched methods
- Lime stabilised subgrades

  = selected subgrades

  ≠ subbase layers
- ME procedure
- Empirical procedure

Adoption in 2017

Only applicable if:

- Lime provides long term strength
- Lime content meets lime demand test (lime content when pH = 12.4)
- Minimum CBR of 60%

Allows maximum E = 150 MPa

Lime stabilised subgrade considered in same way as selected materials

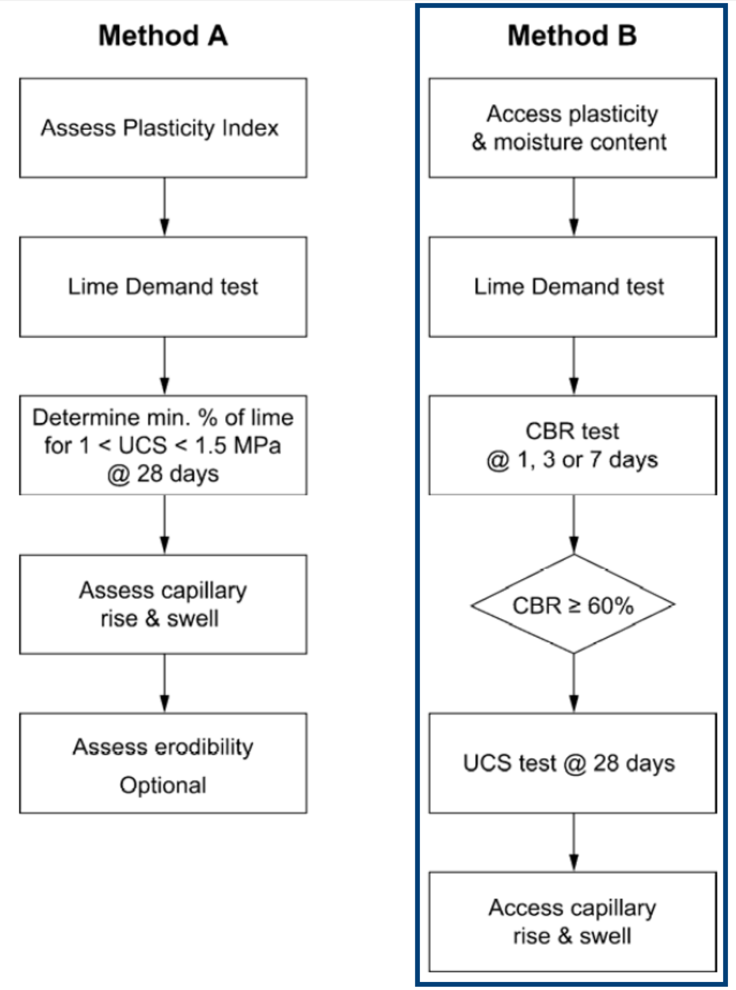


Figure 5.4: Selection of lime content

Cemented Materials

2012 Design Modulus

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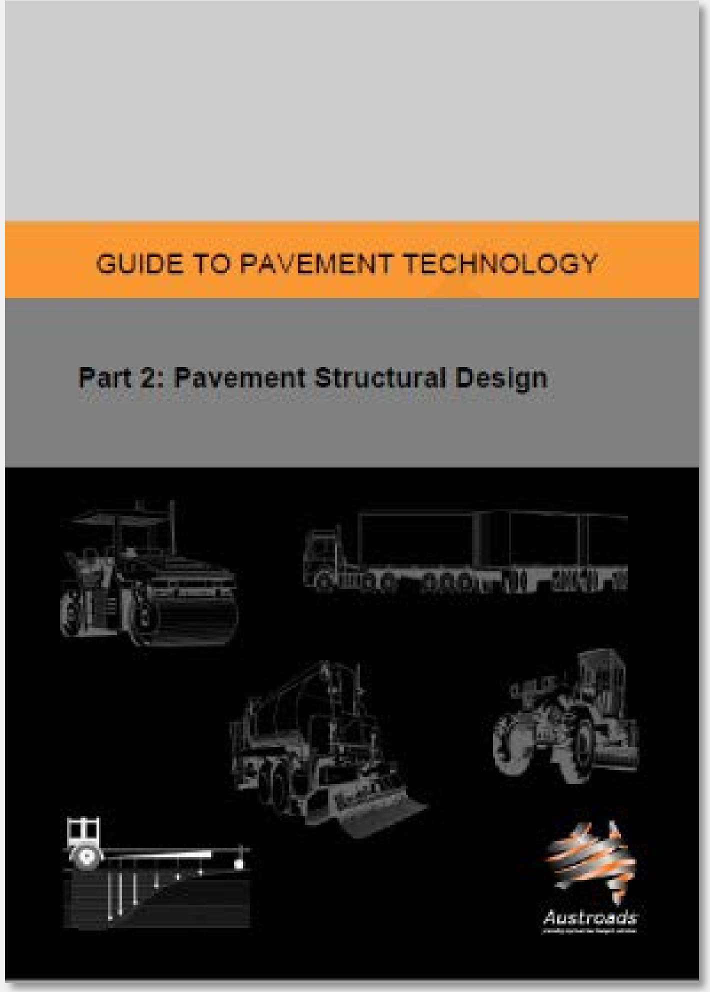
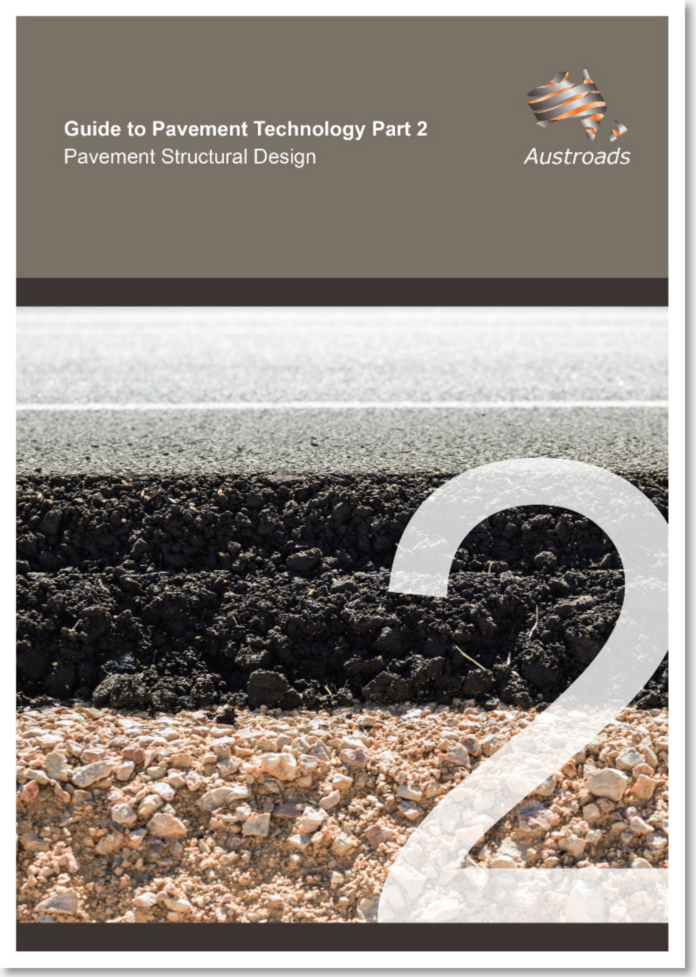


- In situ flexural modulus
  - after 28 days curing in roadbed
- Estimated
  - Unconfined Compressive Strength (UCS) tests
  - Presumptive values

2017 Design Modulus



- In situ flexural modulus
  - after 90 days curing in roadbed
- Measured
  - 4-point flexural beam
  - Lab-field adjustment factor
- Estimated
  - Unconfined Compressive Strength (UCS) tests
  - Presumptive values

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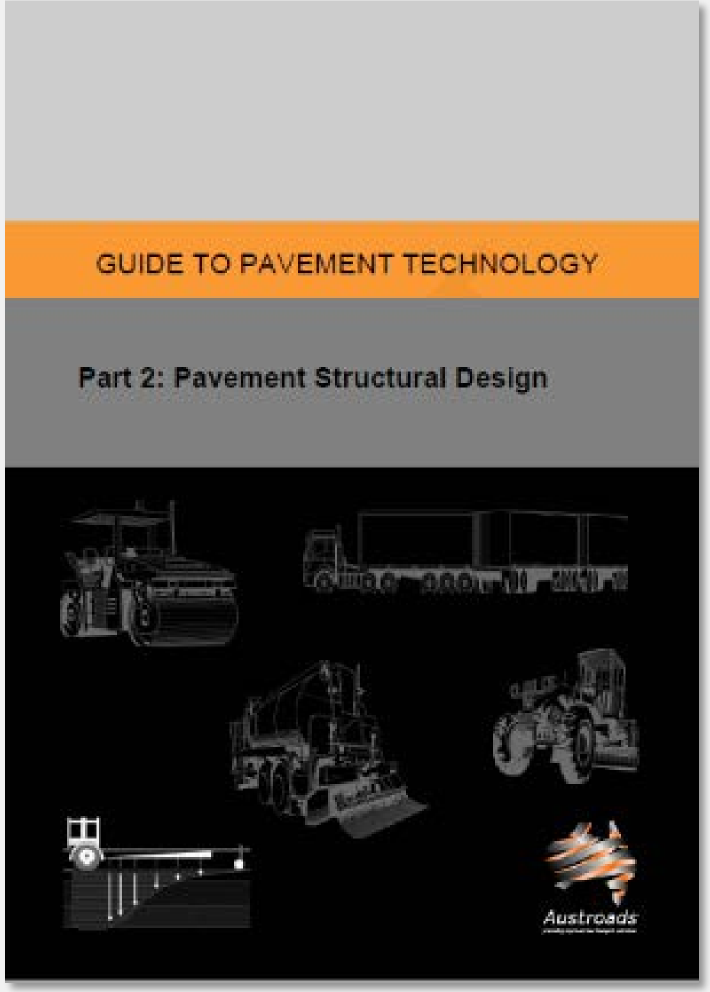
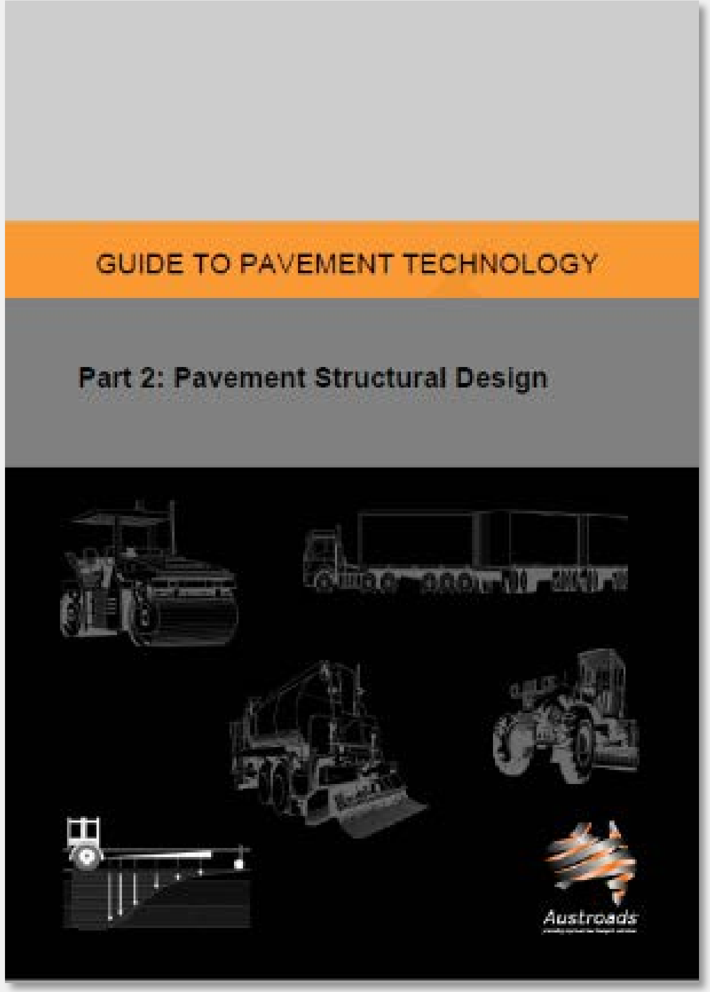
2012 Fatigue Performance

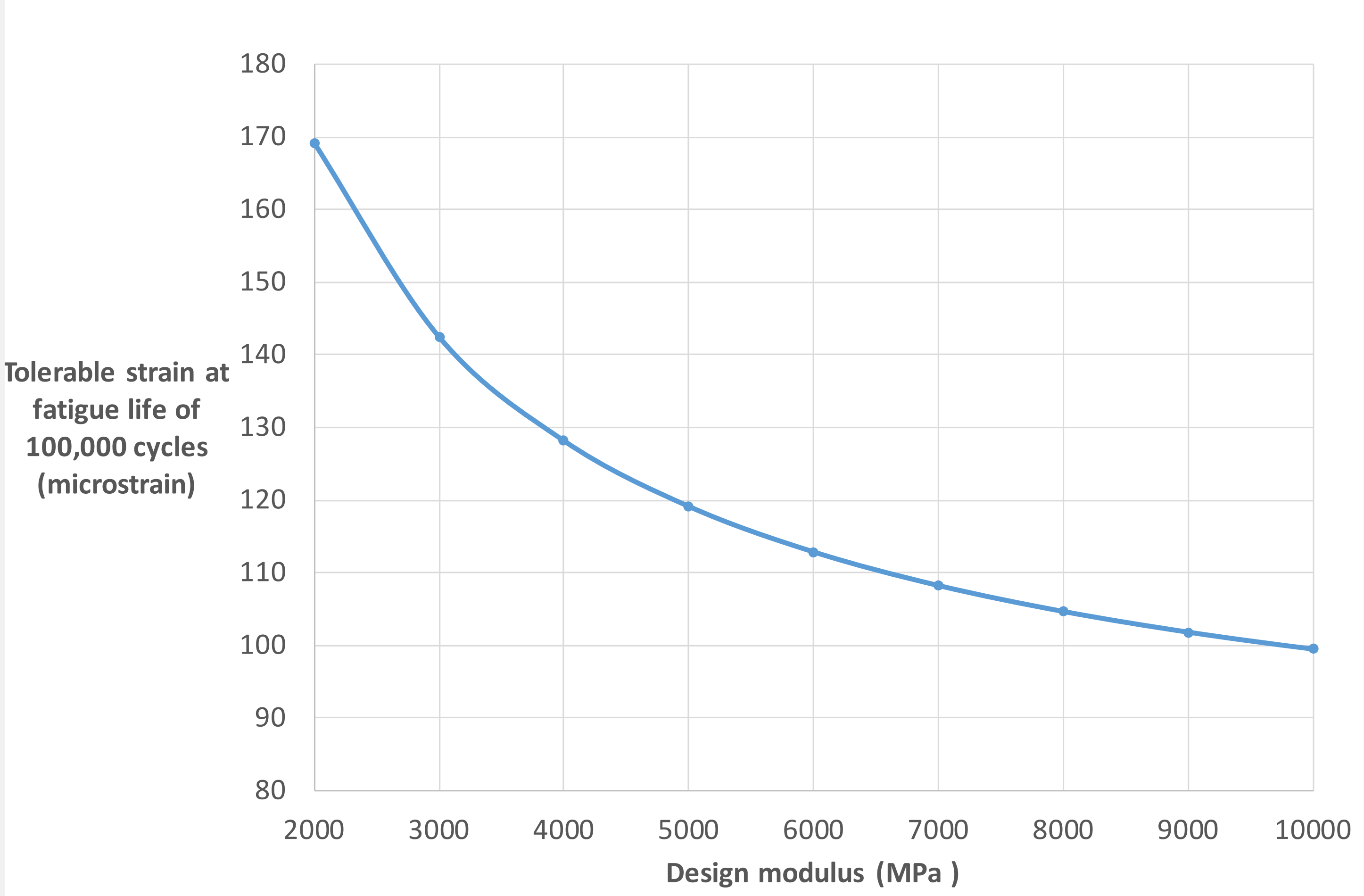


- Applied tensile strain
- Modulus
- Project reliability

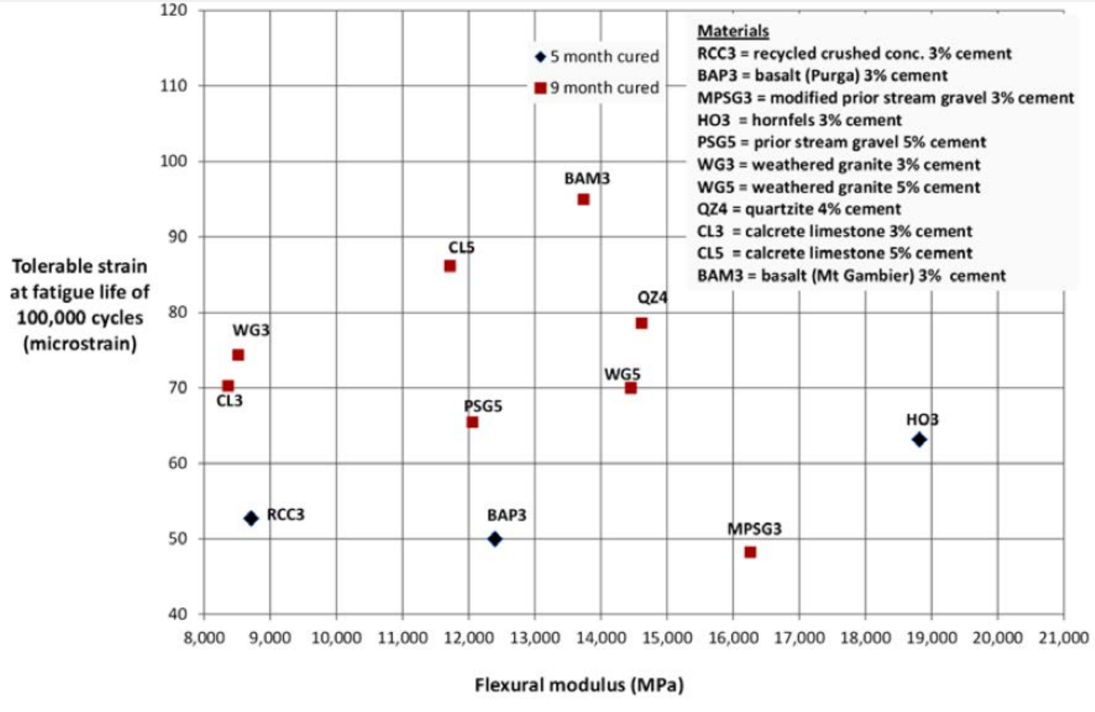
$$N = RF\left[\frac{\frac{113000}{E^{0.804}} + 191}{\varepsilon}\right]^{12}$$

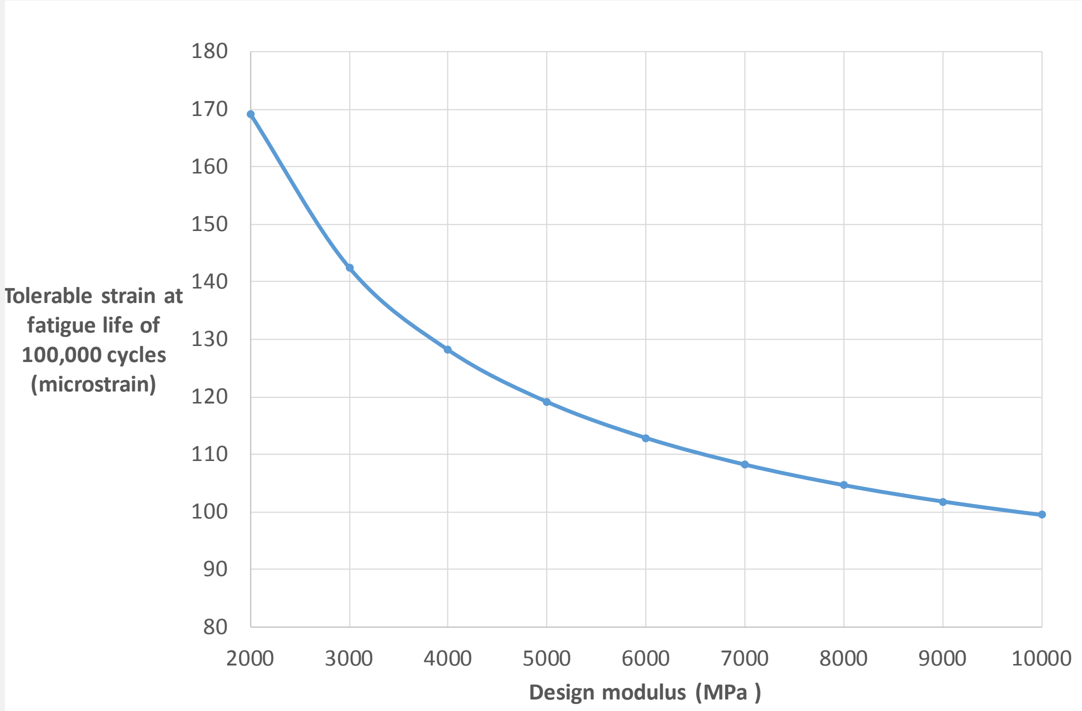
2012 Fatigue Performance



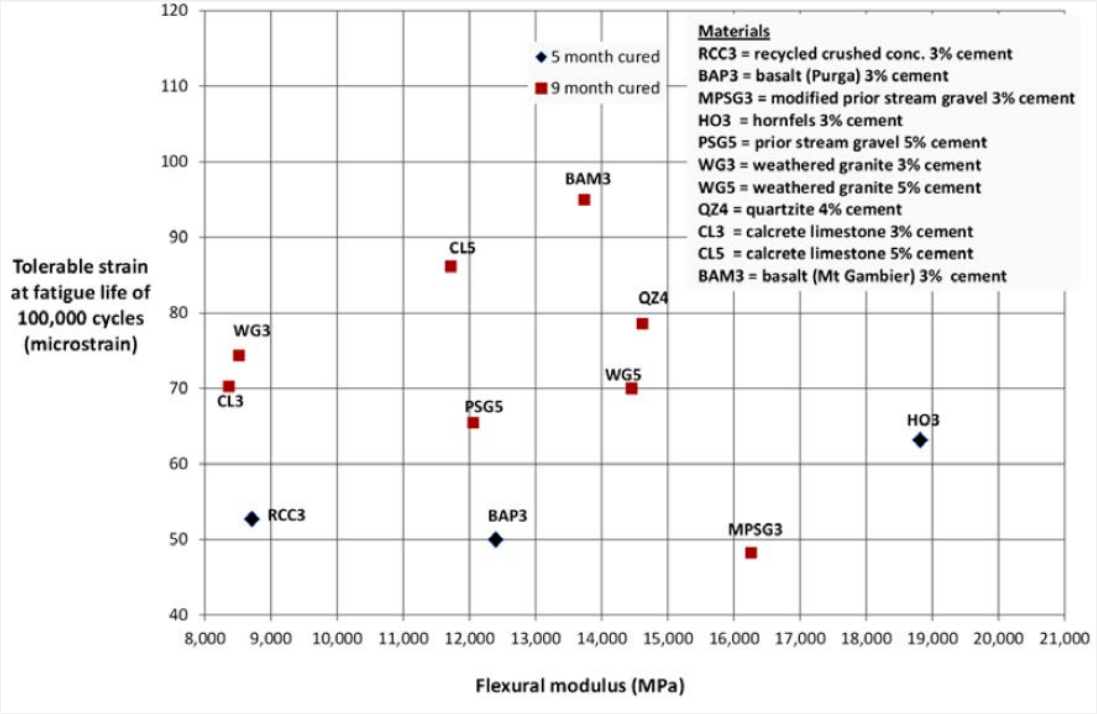


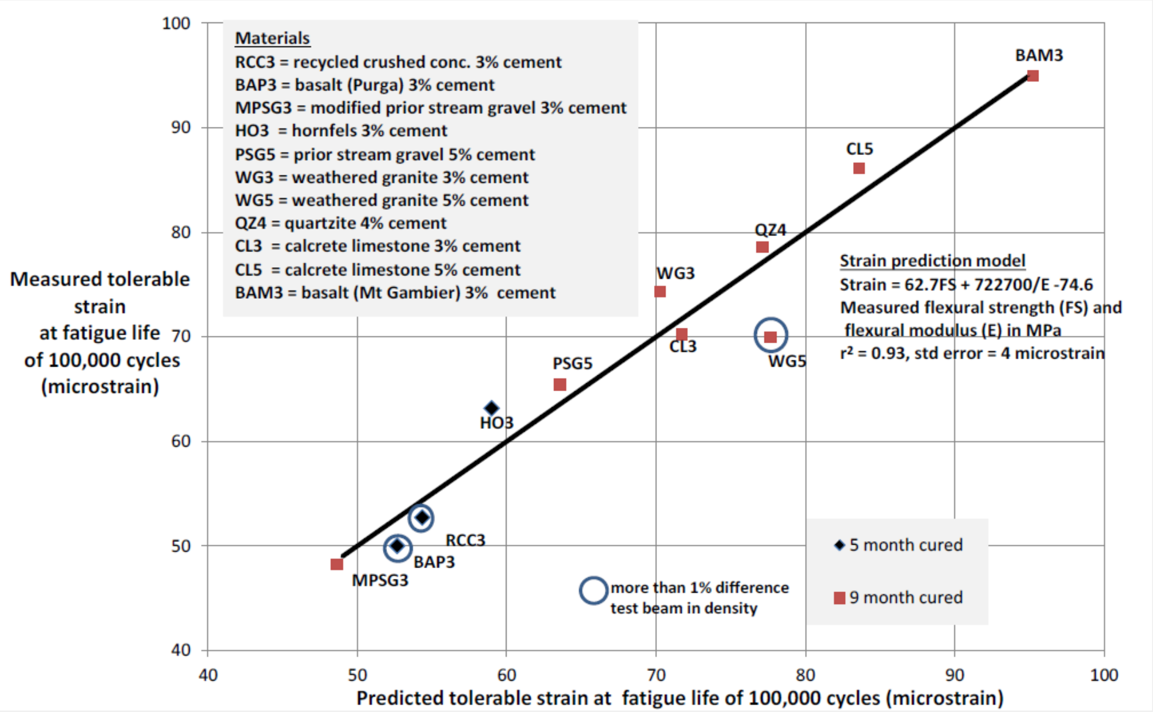
4-point Beam Testing: Modulus





4-point Beam Testing: Modulus + Strength





2017 Fatigue Performance

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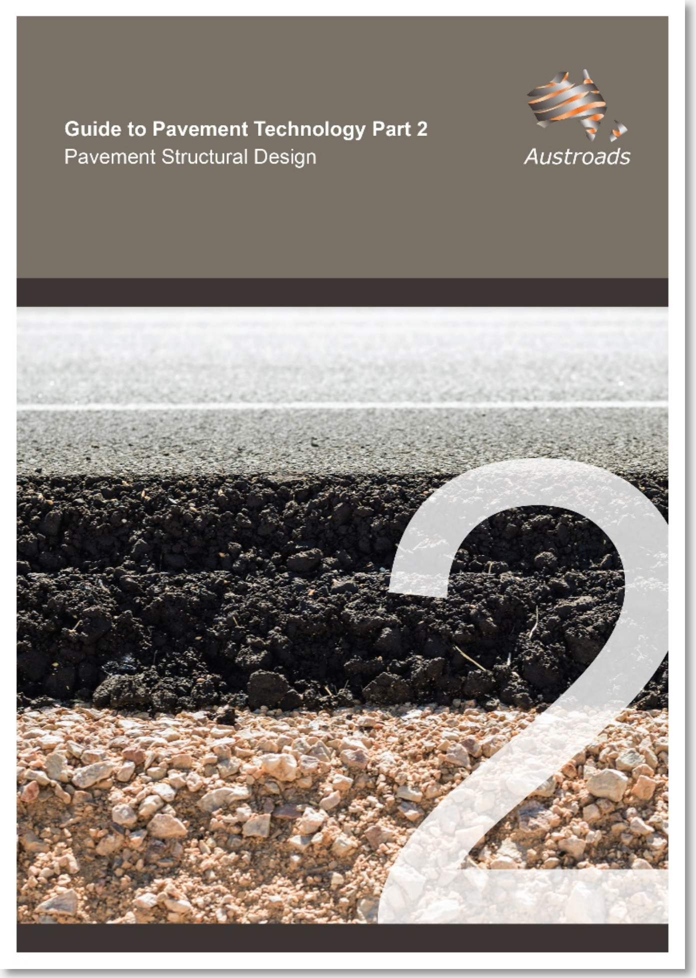

3 methods

Same as 2012

$$N = RF\left(\frac{K}{\varepsilon}\right)^{12}$$

1. Fatigue measurements (inc. lab-field factor)
2. Estimated from measurements of flexural strength & modulus (inc. lab-field factor)
3. Presumptive values (No RF)

Lean-mix Concrete

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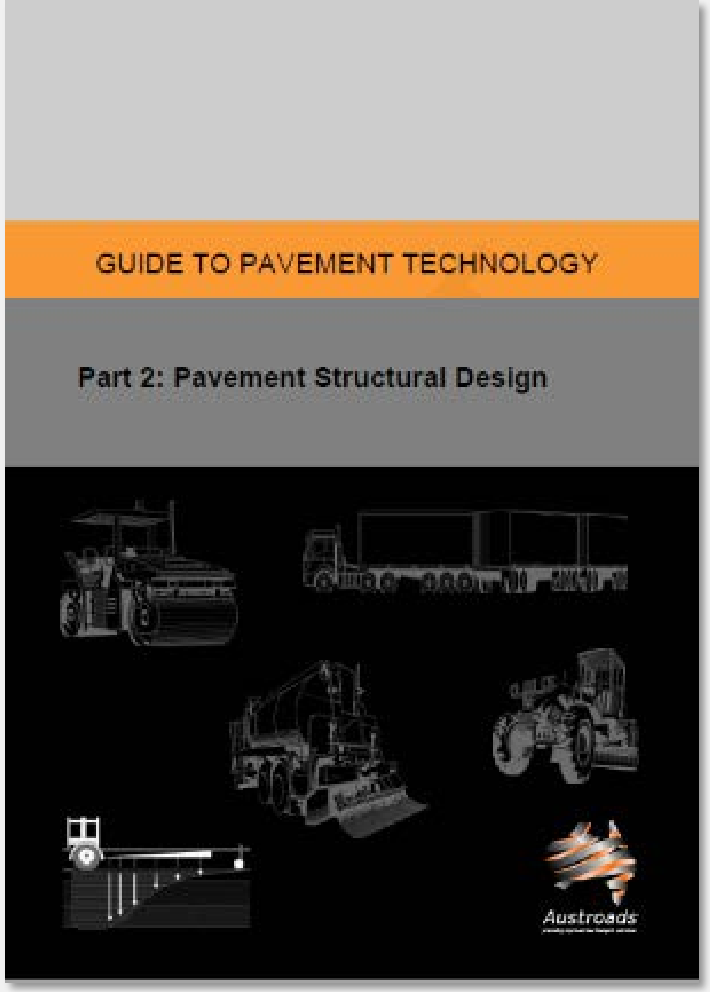
2012 Cemented materials



Cemented materials type included lean-mix concrete

$$N = RF\left[\frac{\frac{113000}{E^{0.804}} + 191}{\varepsilon}\right]^{12}$$

2017 Cemented materials

- Lean-mix concrete a separate material type
- Presumptive values

Asphalt Characterisation

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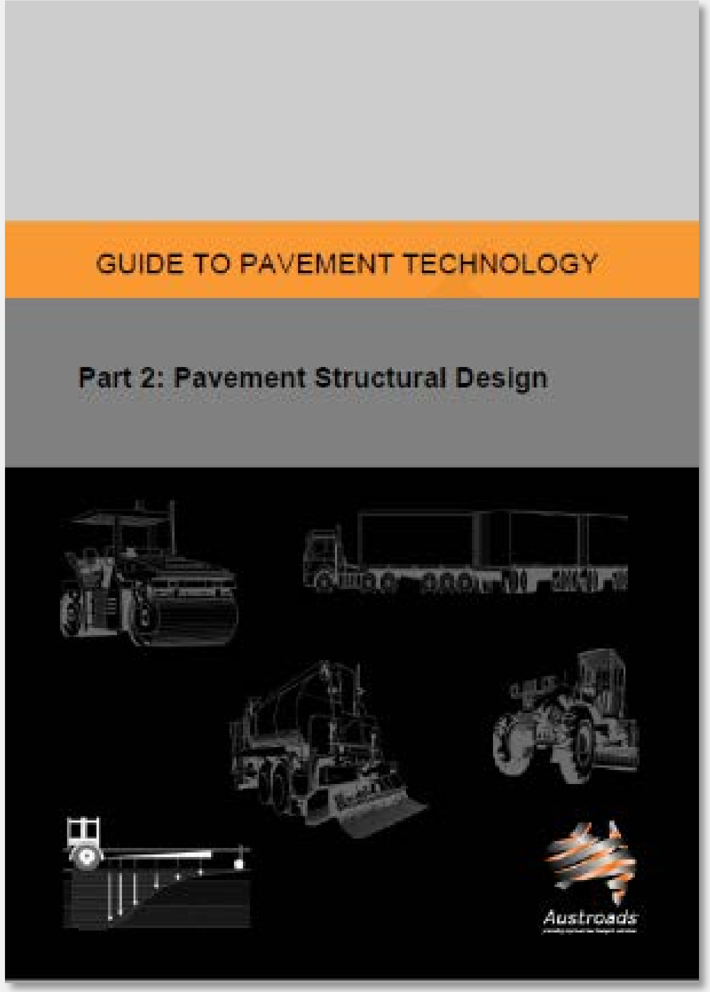
2012 Design Modulus



Estimate of the value obtained from either:

- Resilient modulus measured using the standard indirect tensile test (ITT) adjusted to in-service temperature and rate of loading
- Estimation from bitumen properties using Shell nomographs and in-service temperature and rate of loading

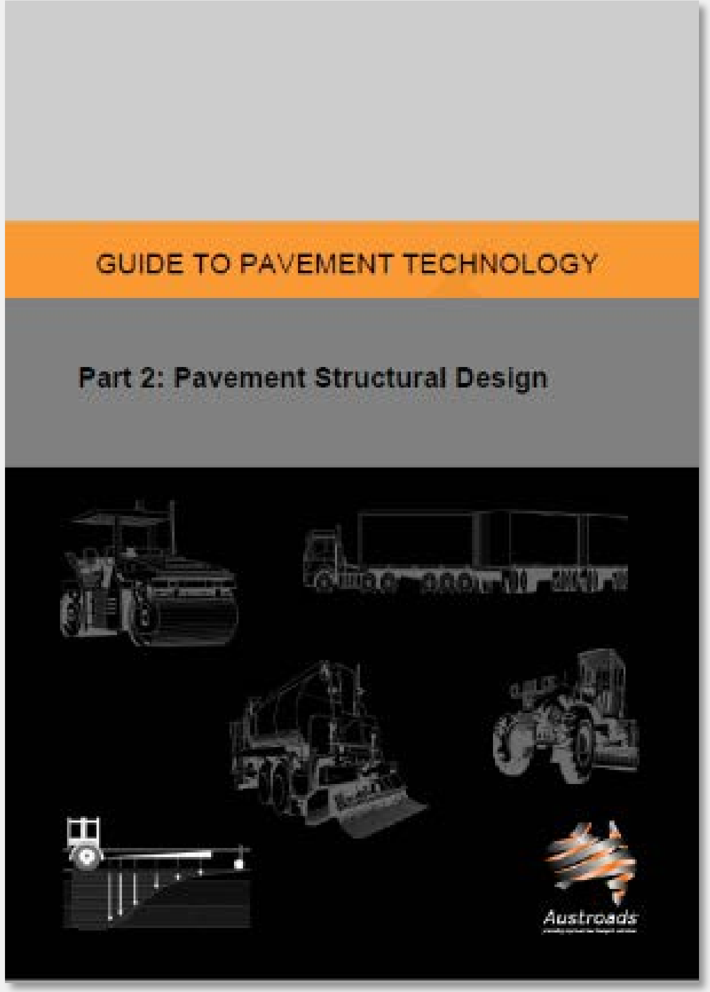
2017 Design Modulus

- Retains both methods
- Clarifies that both yield a flexural modulus (built into rate of loading adjustment)
- Adds direct measurement of flexural modulus

2017 Design Modulus

1. Flexural modulus measurement at in-service speed and temperature (WMAPT)
2. Interpolation from measured flexural modulus over a wide range of speed and temperatures
3. Measure ITT as in 2012 Guide
4. Estimation from Shell nomographs as in 2012 Guide

2012 Fatigue Performance



$$N = RF\left[\frac{6918(0.856V_b + 1.08)}{E^{0.36}\varepsilon}\right]^5$$

Desired project reliability				
80%	**85%**	**90%**	**95%**	**97.5%**
2.5	2.0	1.5	1.0	0.67

2017 Fatigue Performance

$$N = \frac{SF}{RF}\left[\frac{6918(0.856V_b + 1.08)}{E^{0.36}\varepsilon}\right]^5$$

Presumptive $SF = 6$

Desired project reliability					
50%	80%	85%	90%	95%	97.5%
1.0	2.4	3.0	3.9	6.0	9.0

2017 Fatigue Performance

- Guidance on using laboratory measured fatigue performance in design
- Requires understanding relationship between lab and field performance

WMAPT (°C)	≤ 25	26 - 34	≥ 35
Design traffic limit (ESA)	4×10^8	2×10^8	10^8

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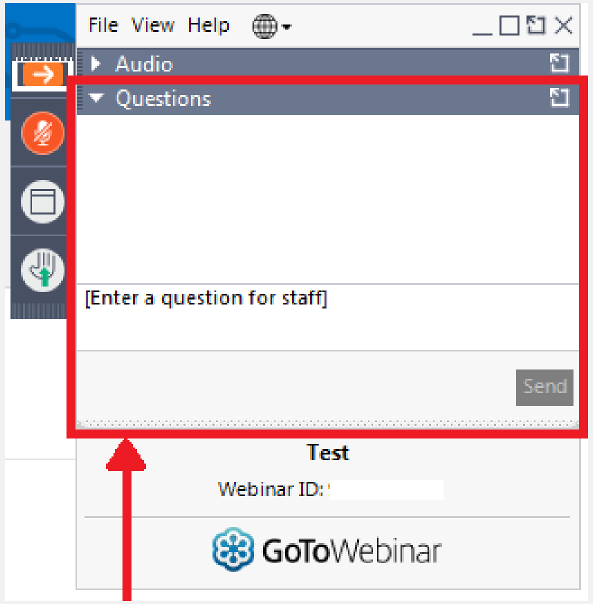

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Let us know the slide number your question relates to

Design Traffic

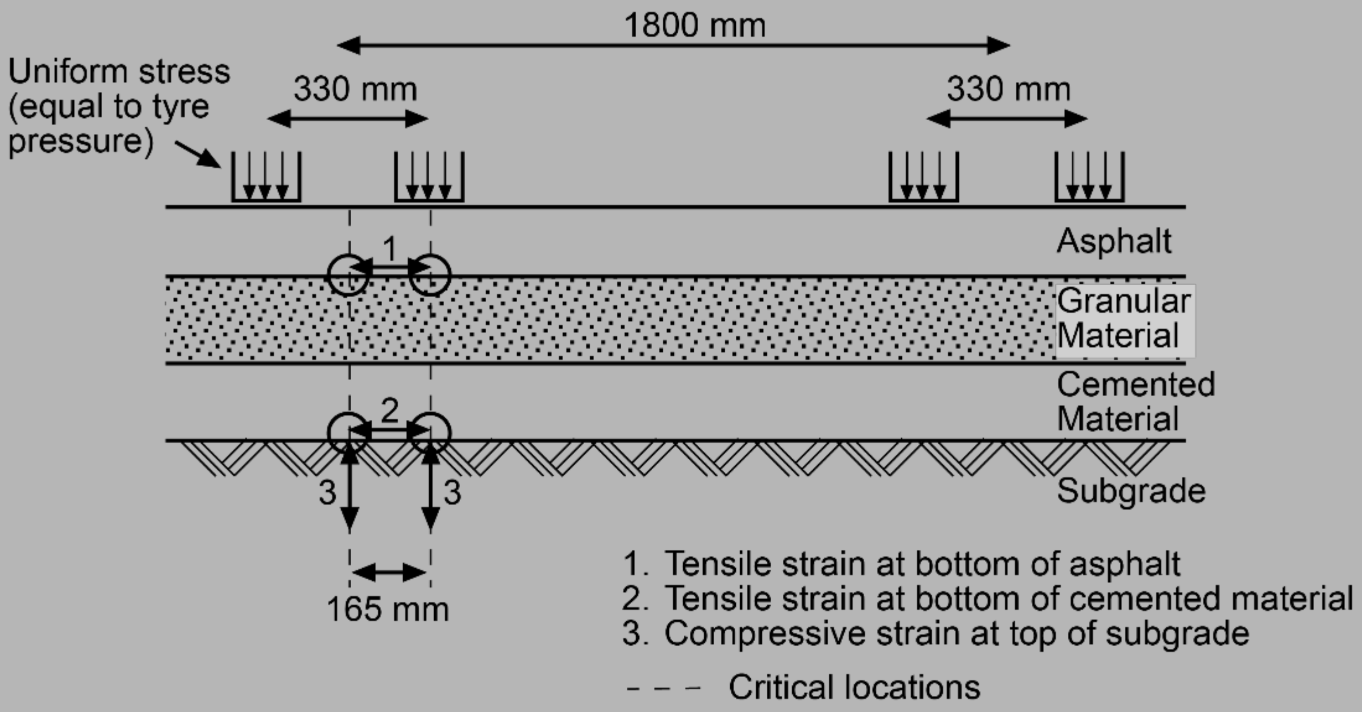
2017 Capacity Check

Check that:

Annual number of Heavy Vehicles ≤ lane capacity

Simple approach adopted:

Capacity is when flows mean that road is saturated 24 h/day



Axle Strain Method
Mechanistic Empirical (ME) Bound Materials

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2012 Axle Strain Method (ME Bound Materials)

- Calculate strain only under a 80 kN Standard Axle load
- Calculate allowable traffic loading under 80 kN Standard Axle load
- Design traffic needed to be expressed in terms of repetitions of a Standard Axle
- Cumulative traffic over design period includes various axle group types and loads

2012 Axle Strain Method (ME Bound Materials)

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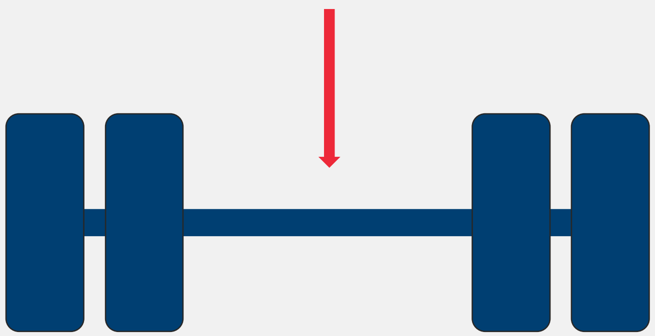
- From strains calculate the <u>allowable loading</u> in terms Standard Axle Repetitions
- Hence, express the <u>design traffic</u> in Standard Axles Repetitions of damage



Standard Axle

Axle group load [kN]	Proportion of load levels by axle group type [%] Single single-tyres	Single dual-tyres	Tandem single-tyres	Tandem dual-tyres	Triaxle dual-tyres	Quad-axle dual-tyres
10	0.0101	1.0001		0.0900		
20	1.2666	1.5502		0.2100	0.0200	
30	12.5342	13.5614		0.4600	0.0300	
40	13.9123	14.6415	0.0414	1.7100	0.1100	
50	13.8717	14.8615	0.1448	2.5000	0.6000	
60	18.4011	13.5814	1.5517	4.1100	2.0900	0.5539
70	20.6708	10.5511	5.6481	5.7500	3.6800	0.5539
80	14.8445	9.1009	9.0824	7.0100	5.2800	0.3728
90	4.4888	7.1007	8.7825	6.8800	5.6500	2.2262
100		5.3405	10.6031	6.2500	5.2800	5.9438
110		3.7704	13.1271	5.6300	4.8400	9.8530
120		2.3202	13.5306	4.7000	4.3200	18.4065
130		1.4901	14.1202	4.7600	4.3300	12.6438
140		0.7801	10.9341	4.7000	3.8800	5.3899
150		0.3500	6.6205	4.9700	3.8900	2.7908
160			3.7550	5.5600	4.1600	2.5991
170			2.0585	5.4800	3.9000	2.0452
180				5.7200	4.3000	0.7456
190				5.1800	4.3000	1.6723
200				4.8500	4.6000	1.2995
210				4.4200	5.2400	0.5539
220				3.2700	5.1800	1.1184

equivalent *Standard Axle Repetitions*

2012 Axle Strain Method (ME Bound Materials)

$$SAR = \sum_{i=1}^{m} \left(\frac{L_i}{SL_i} \right)^{LDE}$$

Axle type	Standard group load [kN]
single axle – single tyres	53
single axle – dual tyres	80
tandem – dual tyres	135
triaxle – dual tyres	181
quad-axle – dual tyres	221

Distress type	LDE
asphalt fatigue	5
cemented material /LMC fatigue	12
rutting and shape loss	7

Shortcomings of 2012 Method

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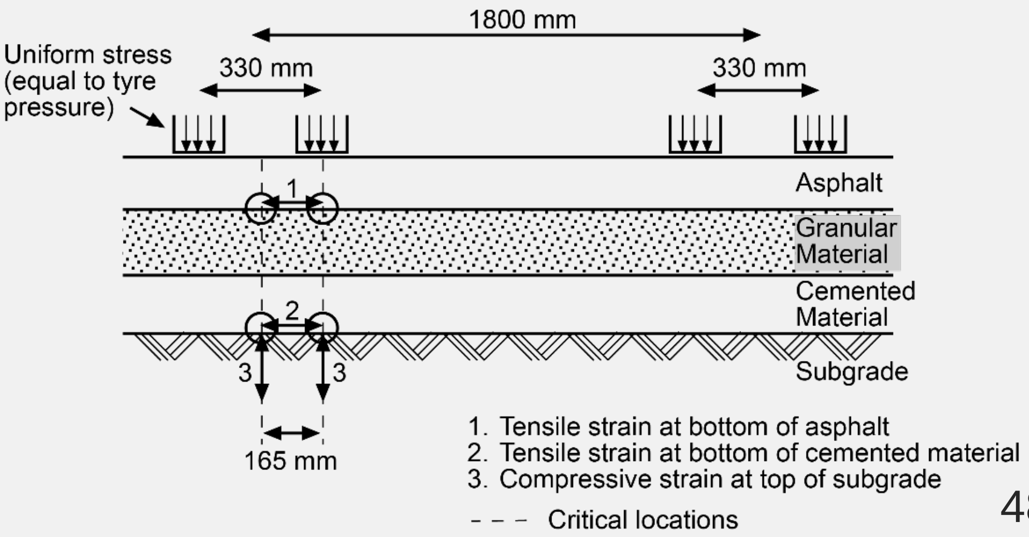
- Standard loads used to determine SAR independent based on equal deflection
- Standard loads assumed equal maximum deflection equals equal damage
  - Regardless of number of occurrences of that deflection (i.e. Axles with group)
- Design method equates damage to strains not deflections
- Standard loads independent of structure
  - Strains vary with pavement structure



2017 Method

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- **Design traffic** - expressed as the expected number of repetition for each axle load on each axle group type
- **Allowable loading in terms of fatigue damage** - calculated for each axle load on each axle group type
- **Fatigue damage** - calculated by dividing the expected repetitions by the allowable repetitions

Table L 11: Calculation of asphalt damage – single axle/dual tyres (SADT) – full depth asphalt pavement

Axle group load (kN)	Expected group repetitions	Axles in group	Critical strain (microstrain)	Allowable group repetitions	Damage
10	66 334	1	21.9	2.06E+11	1.14E-09
20	166 094	1	43.8	6.42E+09	1.45E-07
30	448 086	1	65.6	8.46E+08	1.19E-06
40	418 863	1	87.5	2.01E+08	1.59E-05
50	320 880	1	109.4	6.58E+07	1.60E-04
60	183 475	1	131.3	2.64E+07	5.82E-04
70	124 150	1	153.1	1.22E+07	1.45E-03
80	88 299	1	175.0	6.27E+06	2.52E-03
90	56 708	1	196.9	3.48E+06	3.54E-03
100	26 606	1	218.8	2.06E+06	5.70E-03
110	7 827	1	240.6	1.28E+06	7.95E-03
120	2 212	1	262.5	8.26E+05	1.17E-02
130	466	1	284.4	5.54E+05	1.72E-02
				Total SADT damage	0.271

2017 Method

- Consistent with method used for concrete pavements

SINGLE AXLES / SINGLE WHEELS (SAST)

Equivalent Stress 0.726

Stress Ratio Factor 0.171

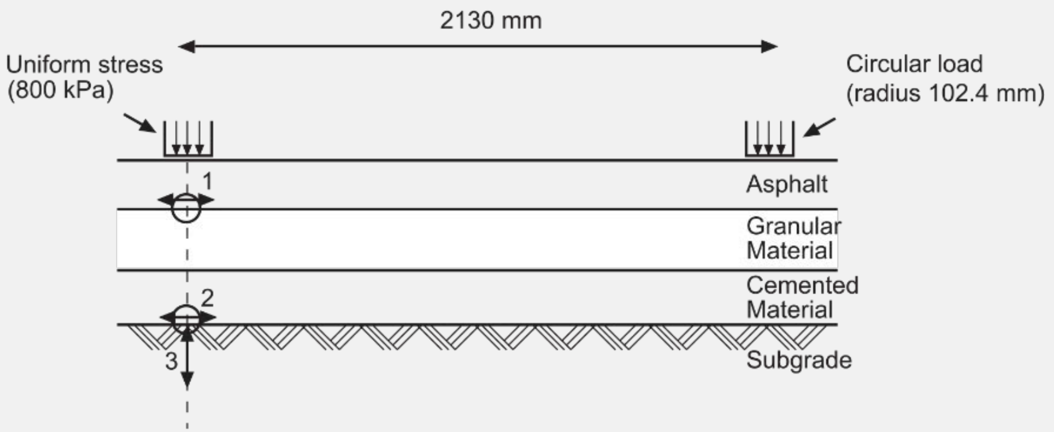
Erosion Factor 1.837

Axle Load (kN)	Design Load (kN)	Expected Repetitions	Fatigue Analysis		Erosion Analysis	
			Allowable Repetitions	Fatigue (%)	Allowable Repetitions	Damage (%)
130	169.0	2,361	5,668	41.66	197,614	1.19
120	156.0	4,990	21,487	23.23	331,752	1.50
110	143.0	7,673	81,994	9.36	605,940	1.27
100	130.0	9,069	371,291	2.44	1,261,027	0.72
90	117.0	20,606	6,279,485	0.33	3,320,332	0.62
80	104.0	92,189	UNLIMITED	0.00	15,721,676	0.59
70	91.0	1,018,852	UNLIMITED	0.00	UNLIMITED	0.00

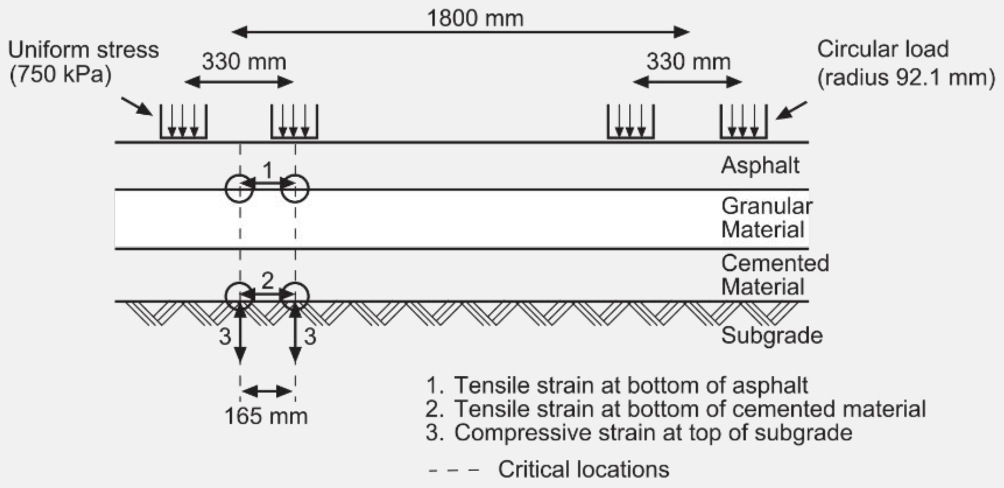
2017 Calculation of Allowable Repetitions to Fatigue

- Simplifications
  - Assume axles act in isolation to each other
  - Assume strains linearly proportional to load
- Requires two response-to-load calculations

53 kN single axle/single tyres



80 kN single axle/dual tyres



2017 Calculation of Allowable Repetitions to Fatigue

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For each axle group type and load level

- Predict strain under each isolated axle
- Use fatigue relationship to predict the allowable repetitions considering number of axles in the group

$$N_{ij} = \frac{1}{n} \times \frac{SF}{RF}\left[\frac{6918(0.856V_b + 1.08)}{E^{0.36}\mu\varepsilon_{ij}}\right]^5$$

Axle group load (kN)	Expected group repetitions	Axles in group	Critical strain (microstrain)	Allowable group repetitions
10	3 740	2	10.9	3.29E+12
20	14 905	2	21.9	1.03E+11
30	16 167	2	32.8	1.35E+10
40	51 204	2	43.8	3.21E+09
50	168 246	2	54.7	1.05E+09
60	246 335	2	65.6	4.23E+08
70	283 346	2	76.6	1.96E+08
80	253 017	2	87.5	1.00E+08
90	197 125	2	98.4	5.57E+07
100	187 568	2	109.4	3.29E+07
110	162 315	2	120.3	2.04E+07
120	154 157	2	131.3	1.32E+07
130	152 240	2	142.2	8.86E+06

Concept of Standard Axle Repititions (SARs) Removed

Empirical design chart

– Permanent deformation	ESA (as per 2012)

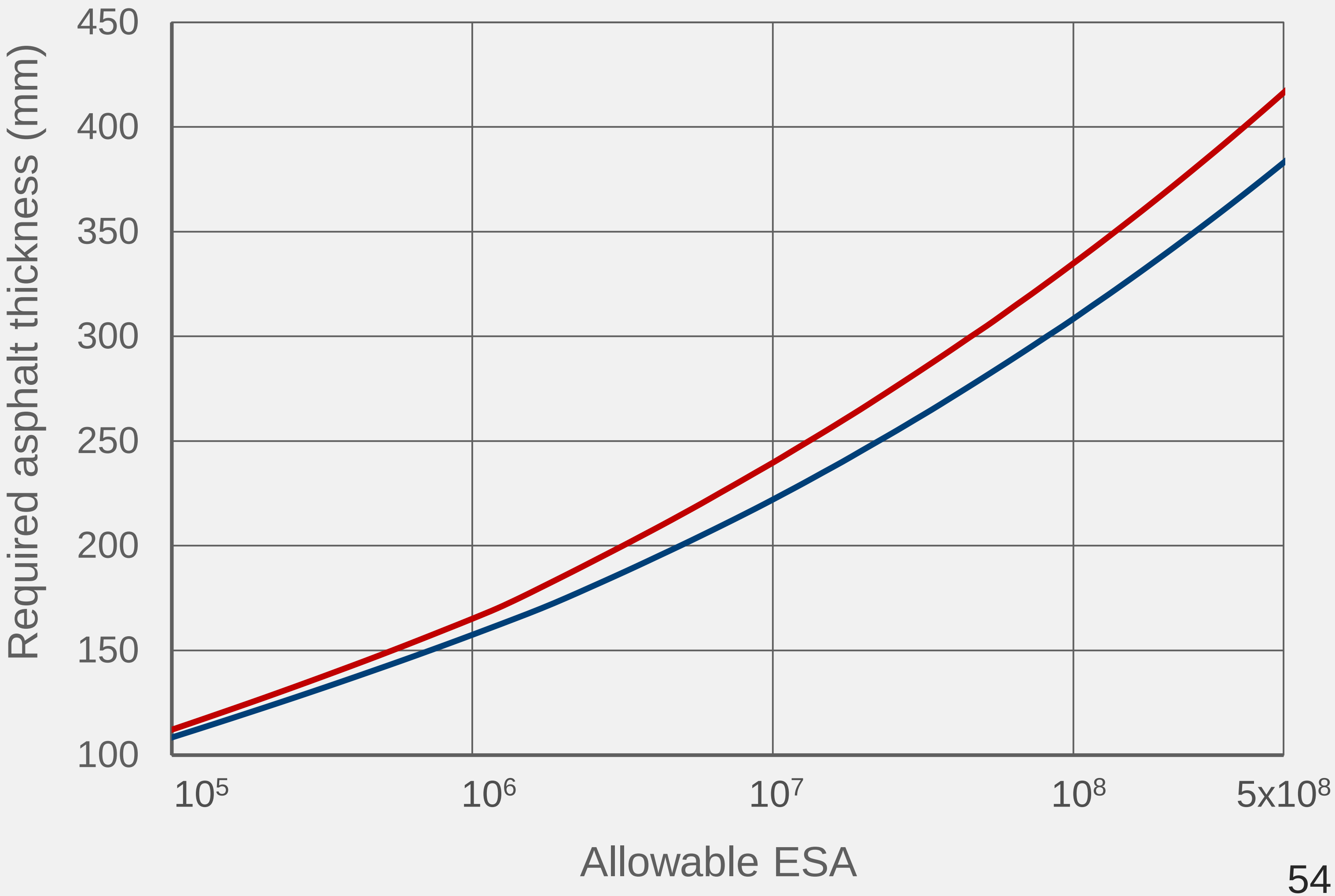
Mechanistic-empirical method

– Asphalt	HVAGs & traffic load distribution
– Cemented materials	HVAGs & traffic load distribution
– Lean-mix concrete	HVAGs & traffic load distribution
– Permanent deformation	ESA

$$N_{Standard\ Axle} = \left(\frac{9300}{\mu\varepsilon}\right)^7 \longrightarrow N_{ESA} = \left(\frac{9150}{\mu\varepsilon}\right)^7$$

Example of Asphalt Thickness Changes

TLD: Kwinana Fwy (Mandurah) South



Cemented Materials Thickness Changes

Including lean-mix concrete

- Similar to asphalt, the use of the axle-strain method would have resulted in a general decrease in cemented materials thicknesses
- The thickness decrease varies with the traffic load distribution, being greater for distribution in which tandem axles and triaxles caused greater fatigue damage
- Experienced road agency practitioners advised:
  - they agreed the axle-strain method provided an improved method of assessing fatigue damage
  - but there was no evidence in support of a general reduction in cemented materials thickness

Overview of Part 2 changes

Flexible pavements

- Lime stabilised subgrades
- Cemented materials
- Lean-mix concrete
- Asphalt
- Design traffic
- Removal of Standard Axle Repetitions (SARs)
- Axle-strain method

Rigid pavements

- Joint detailing diagrams

Guide to Pavement Technology Part 4C

Materials for Concrete Road Pavements

Austroads

Introduction to team

Austroads

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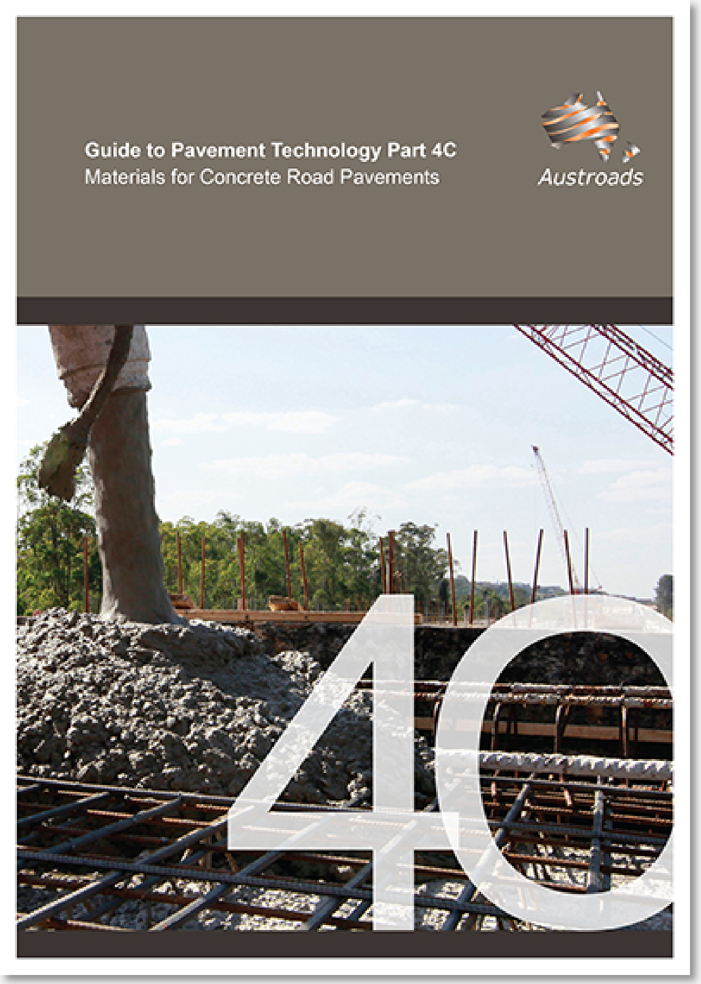
Stakeholders - Road & Traffic Authorities & Industry

Austroads Board

Key changes



- Diagrams updated and made consistent with Roads and Maritime Services (RMS) practice
- Reference made to geopolymer cements
- References updated
- Minor editorial changes

Questions?

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Upcoming Austroads webinar

Austroads

Topic	Date
Local Road Access for High Productivity Freight Vehicles	27 March
Geopolymer Concrete and its Applications	1 May

Register at http://www.austroads.com.au/event

Thank you for participating