NZ Guide to Pavement Evaluation and Treatment Design

Rehabilitation guide

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Traffic loading – design values

- Not addressed in either of the Guides
- Austroads Part 2 is due for imminent release
- New Zealand specific design methodology in Part 2 should be used

Loading Calculations in AGPT Part 2 2017

Learning outcomes

- AGPT Part:2 – New loading calculations for ME Design
- Why we are changing
- What are we changing to
- How is that different to old SAR/ESA
- What you will need to do
- Empirical designs keep old ESA approach.

Why - history

- 2012 approach considers relative damage between axle groups to be independent of Pavement Structure
- Current approach developed by Scala (1970a), simply compared axle group loads using surface deflections.
- Scala (1969, 1970b) – Noted that deflection axle group load equivalencies would change with pavement structure

Why - research

Moffet 2015: PhD Thesis

Austroads 2015: The influence of multiple-axle groups loads on flexible pavement design (AP-R481-15)

Table 1. Comparison of maximum surface deflection

Pavement structure	Maximum surface deflection (mm)	
	53 kN SAST	80 kN SADT
Sprayed seal 350 mm (normal standard) crushed rock Subgrade – CBR 5%	1.27	1.21
175 mm Asphalt (E=4000 MPa) 250 mm cemented material (E=5000 MPa) 300 mm select fill (E_{max} = 150 MPa) 300 mm select fill (E_{max} = 80 MPa) Subgrade – CBR 3%	0.37	0.55

Why - summary

Basically – to get better axle group equivalency

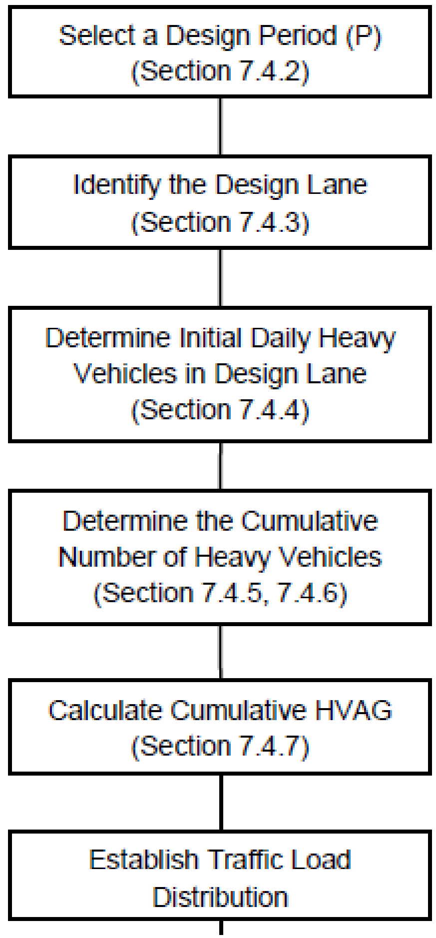
- Old approach: Same Group Deflection = Same Damage
  - i.e. 53 kN SAST = 80 kN SADT = ….. = 226 kN QADT
- New Approach: Same Strain = Same Damage
  - i.e. 53 kN SAST ≠ 80 kN SADT ≠ ….. ≠ 226 kN QADT

The details

The details - outline

- Common Elements to calculations
- The Empirical Approach (Deflection / ESA)
- The new ME Strain Approach
- New limits for AC loading calculations
- Loading Discussion
- Learning Outcomes - check

Common elements to traffic calculations



Common elements – initial daily heavies

$$N_i = AADT \times DF \times \%HV/100 \times LDF$$

where

N_i	=	initial daily heavy vehicles in the design lane
$AADT$	=	Annual Average Daily Traffic[2] in vehicles per day in the first year (Section 7.4.4)
DF	=	direction factor is the proportion of the two-way AADT travelling in the direction of the design lane
$\%HV$	=	average percentage of heavy vehicles (Section 7.4.4)
LDF	=	lane distribution factor, proportion of heavy vehicles in the design lane (Section 7.4.3)

Common elements – design heavies

$$N_{HV} = 365 \times CGF \times N_i$$

where

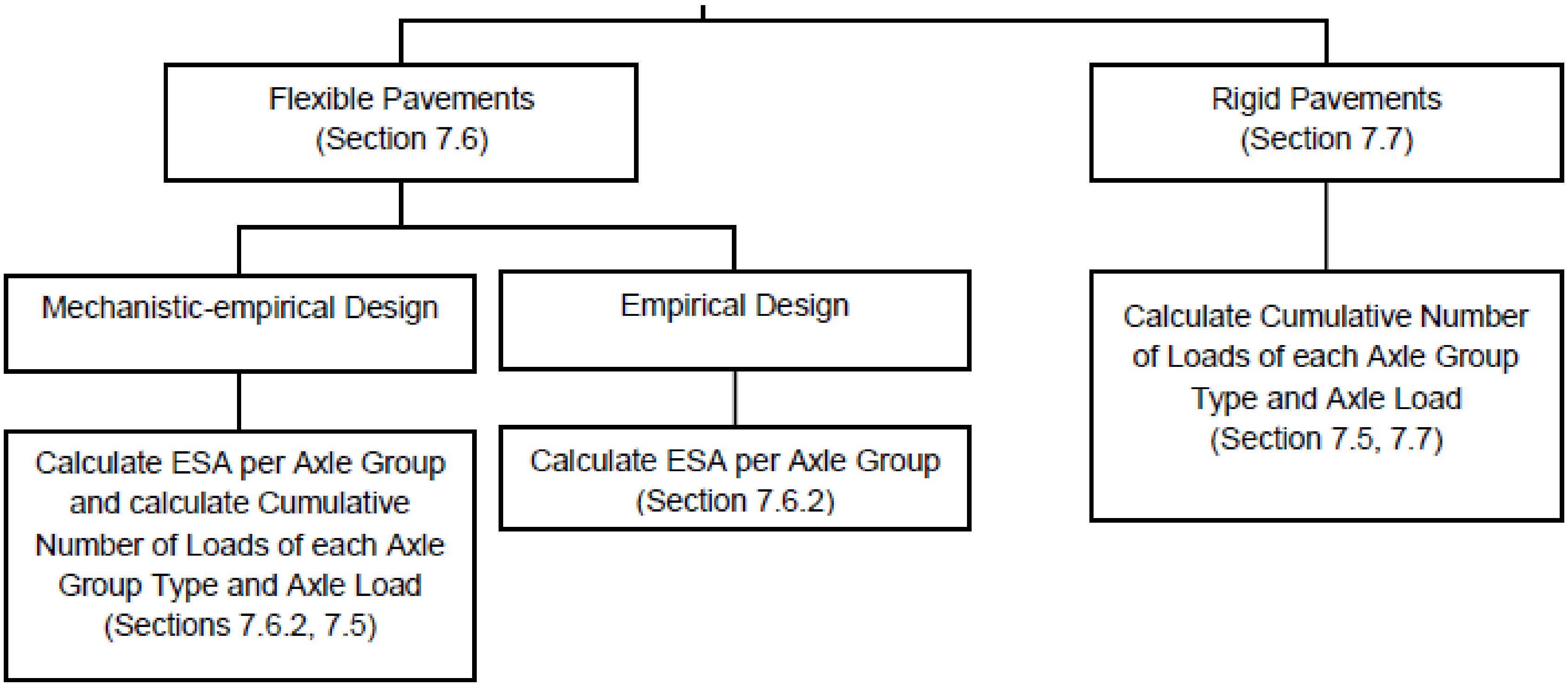
N_{HV}	=	Design traffic in cumulative heavy vehicles
CGF	=	cumulative growth factor (Section 7.4.5 and Section 7.4.6)
N_i	=	average daily number of heavy vehicles in the first year of opening to traffic (Section 7.4.4)

$$N_{DT} = N_{HV} \times N_{HVAG}$$

where

N_{DT}	=	the cumulative heavy vehicle axle groups in the design lane over the design period
N_{HV}	=	cumulative number of heavy vehicles (Section 7.4.5, Section 7.4.6)
N_{HVAG}	=	average number of axle groups per heavy vehicle

Specific elements to traffic calculations



Empirical ESA approach

$$ESA_{ij} = \left(\frac{L_{ij}}{SL_i}\right)^4$$

where

ESA_{ij}	=	Number of repetitions of a Standard Axle which causes the same amount of damage as a single passage of axle group type i with load L_{ij}
SL_i	=	Standard Load for axle group type i (from Table 7.7 and Table 7.8)
L_{ij}	=	j^{th} load magnitude on the axle group type i

Empirical standard on axle groups

- Austroads Reference Load - Single axle with two sets of dual wheels that carries a load of 80 kN.
- The loads on other axle groups that cause the same damage as a Standard Axle are:

Axle Configuration	Load (kN)
Single Axle Single Wheels	53
Single axle Dual Wheels	80
Tandem Axle Single Wheels	90
Tandem Axle Dual Wheels	135
Triaxle	181
Quad axle	221

Empirical ESA approach

The design number of Equivalent Standard Axles of traffic loading (DESA) is calculated as follows (Equation 37):

$$DESA = ESA/HVAG \times N_{DT} \qquad 37$$

where

$ESA/HVAG$ = average number of Equivalent Standard Axles per Heavy Vehicle Axle Group

N_{DT} = cumulative number of Heavy Vehicle Axle Groups over design period (from Equation 35)

Empirical Approach is easy

Axles Loads = $26kN$ $\quad 45kN$

Equivalent Standard Axles = $\left(\frac{26}{53}\right)^4 + \left(\frac{45}{90}\right)^4$

Empirical design loading

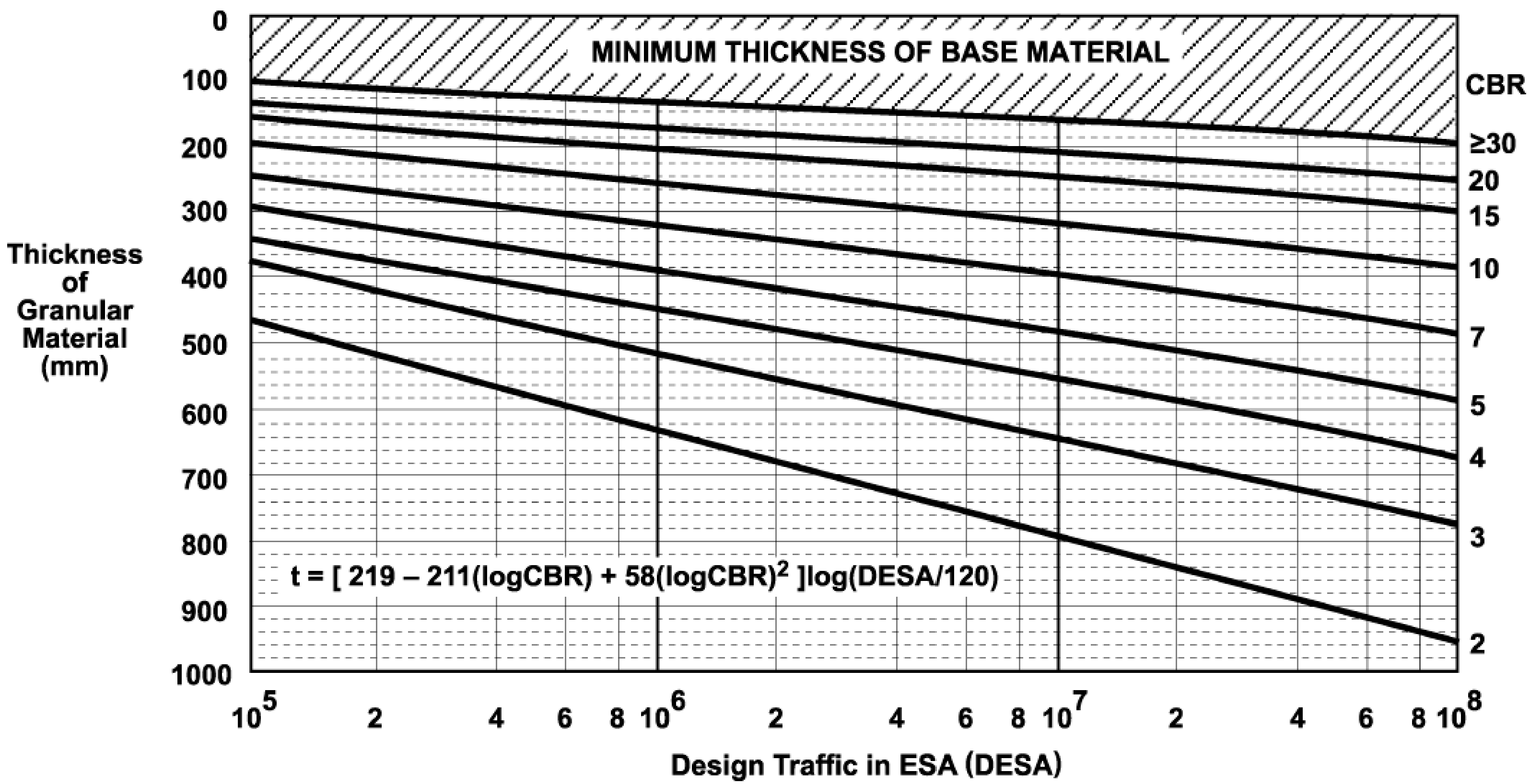


Figure 8.4: Design chart for granular pavements with thin bituminous surfacing

Empirical design loading

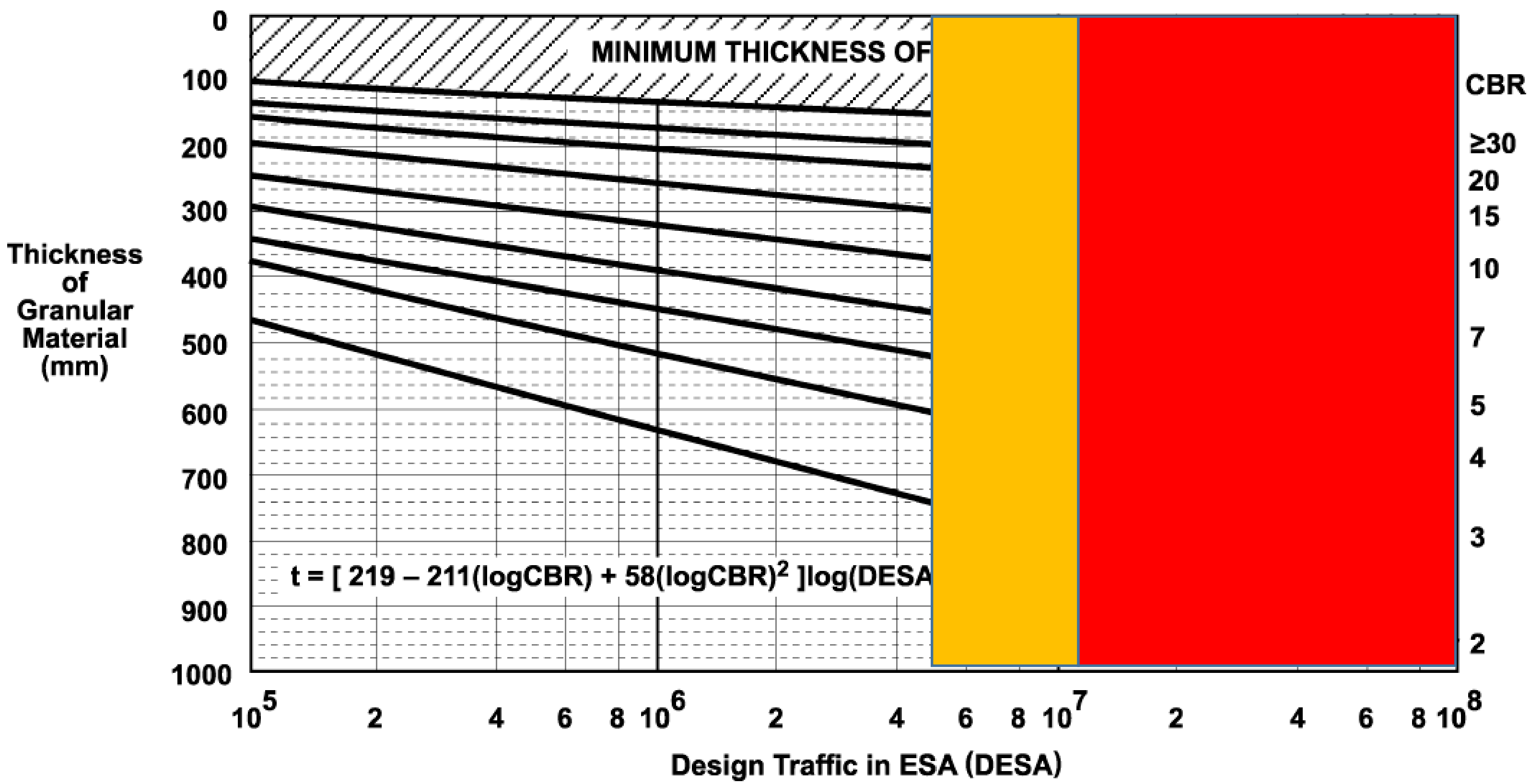


Figure 8.4: Design chart for granular pavements with thin bituminous surfacing

ME approach – 2017 AC fatigue equation

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

where

N	=	allowable number of repetitions of the load-induced tensile strain
$\mu\varepsilon$	=	load-induced tensile strain at the base of the asphalt (microstrain)
V_b	=	percentage by volume of bitumen in the asphalt (%)
E	=	asphalt modulus (MPa)
SF	=	shift factor between laboratory and in-service fatigue lives (presumptive value = 6)
RF	=	reliability factor for asphalt fatigue (Table 6.16)

2017 AC fatigue equation in practice

Asphalt

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

where

N_{ij} = allowable number of repetitions of axle group type i with total load equal to the j^{th} load magnitude

n = number of individual axles within axle group type i (e.g. $n = 2$ for a tandem axle group)

$\mu\varepsilon_{ij}$ = load-induced tensile strain at the base of the asphalt (microstrain) caused by a single axle, with the same number of tyres as those used by the individual axles within axle group i, applying a load equal to the j^{th} load magnitude divided by n (microstrain)

ME approach – calculate strains for all cases

$$\mu\varepsilon_{ij} = \frac{L_{ij}}{n} \times \frac{\mu\varepsilon_{SAST,53}}{53}$$ for single axle with single tyres (a)

$$\mu\varepsilon_{ij} = \frac{L_{ij}}{n} \times \frac{\mu\varepsilon_{SADT,80}}{80}$$ for single axle with dual tyres (b)

where

$\mu\varepsilon_{ij}$ = load-induced strain caused by a single axle, with the same number of tyres as those used by the individual axles within axle group i, applying a load equal to the j^{th} load magnitude divided by n (microstrain)

L_{ij} = magnitude of the j^{th} load applied to axle group i (kN)

n = number of individual axles within axle group type i (e.g. $n = 2$ for a tandem axle group)

$\mu\varepsilon_{SAST,53}$ = strain induced by a single axle with single tyres applying a load of 53 kN (microstrain)

$\mu\varepsilon_{SADT,80}$ = strain induced by a single axle with dual tyres applying a load of 80 kN – i.e. the Standard Axle (microstrain)

ME approach – all case calculations

- Requires response to load calculation for each load and axle type
- Using layered linear-elastic modelling
- Can linearly scale response from model
- Demonstrated not to significantly affect outcome

2017 AC fatigue equation – in use

Asphalt

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

where

N_{ij} = allowable number of repetitions of axle group type i with total load equal to the j^{th} load magnitude

n = number of individual axles within axle group type i (e.g. $n = 2$ for a tandem axle group)

$\mu\varepsilon_{ij}$ = load-induced tensile strain at the base of the asphalt (microstrain) caused by a single axle, with the same number of tyres as those used by the individual axles within axle group i, applying a load equal to the j^{th} load magnitude divided by n (microstrain)

ME damage caused by an axle group

$$d_{ij} = \frac{e_{ij}}{N_{ij}}$$

where

d_{ij} = damage caused by axle group i with total load equal to the j^{th}magnitude

e_{ij} = expected number of repetitions of axle group i with total load equal to the j^{th} magnitude

N_{ij} = allowable number of repetitions of axle group type i with total load equal to the j^{th} load magnitude

ME Summing up the TLD damage

$$D = \sum_{all\ i,j} d_{ij}$$

where

D = total damage of the asphalt, cemented material or lean-mix concrete layer resulting from the design traffic

d_{ij} = damage caused by axle group i with total load equal to the j^{th} magnitude

ME allowable HV axle groups

$$A_{HVAG} = \frac{N_{DT}}{D}$$

where

A_{HVAG} = allowable HVAG repetitions for the asphalt, cemented material or lean-mix concrete layer

N_{DT} = cumulative heavy vehicle axle groups traversing the design lane during the design period

D = total damage of the asphalt, cemented material or lean-mix concrete layer resulting from the design traffic (Equation 49)

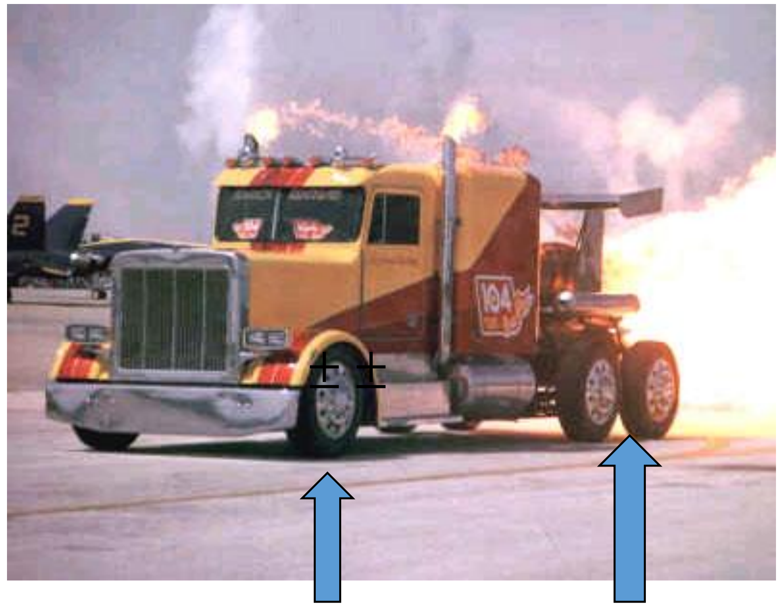
Converted back to allowable ESA

$$A_{ESA} = \frac{N_{DT} \times ESA/HVAG}{D}$$

where

A_{ESA}	=	allowable ESA repetitions for the asphalt, cemented material or lean-mix concrete layer
N_{DT}	=	cumulative heavy vehicle axle groups traversing the design lane during the design period
D	=	total damage of the asphalt, cemented material or lean-mix concrete layer resulting from the design traffic (Equation 49)
$ESA/HVAG$	=	average ESA/HVAG for the design traffic load distribution (Section 7.6.2)

Mechanistic Empirical approach not that hard



Critical Strains $\left(\frac{26}{1}\ \frac{\mu\varepsilon_{SAST,53}}{53}\right)$, $\left(\frac{45}{2}\ \frac{\mu\varepsilon_{SAST,53}}{53}\right)$

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

Thickness limits for AC – using DESA

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

$$N_{DT\ limit} = \frac{DESA_{limit}}{(ESA/HVAG)}$$

where

$N_{DT\ limit}$ = Upper limit of cumulative number of Heavy Vehicle Axle Groups over design period for use in the asphalt fatigue damage calculations

$DESA_{limit}$ = upper limit of the design traffic expressed as Equivalent Standard Axles (ESA) for use in the asphalt fatigue damage calculations (Table 7.9)

$ESA/HVAG$ = average number of ESA per HVAG from the project traffic load distribution

Traffic loading - discussion

NZ Transport Agency has

- 1600 Traffic Counting site – 1 site per 7 km
- 390 Continuously – 1site per 28 km
- 6 Weigh in Motion Site – 1 site per 1800 km
- Data averaged across sites
- Can estimate loading from AADT and %HCV
- Best estimates in RAMM

Australia has 200 Weigh in Motion Sites

- ESA/HCV ranges from 1 - 7

Questions also around "power laws", reference loads/width and axle group equivalency.

Learning outcomes - check

- Austroads Guide to Pavement Technology Part:2 –New loading calculations for ME Design
- Why we are changing?
- What are we changing to?
- How is that different to old SAR/ESA?
- What you will need to do?
- Empirical designs keep old ESA approach.