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Project Level Methodology for Flexible Pavement Design

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GENERAL OBJECTIVE

- Examine developments made to the Austroads methodology for flexible pavement design.
- Provide a comparison against that of previous guides.
- Illustrate the incorporation of overseas research into a modified design procedure aimed at enhancing the design process.

First Guide Published in 1987 by the National Association of Australian State Road Authorities (NAASRA)

Re-issued in 1992 by Austroads

Significant revisions made to the Guide in 2004 and 2008

Flexible Pavement Design Guide considers a Mechanistic-Empirical Procedure

Fundamental material characteristics

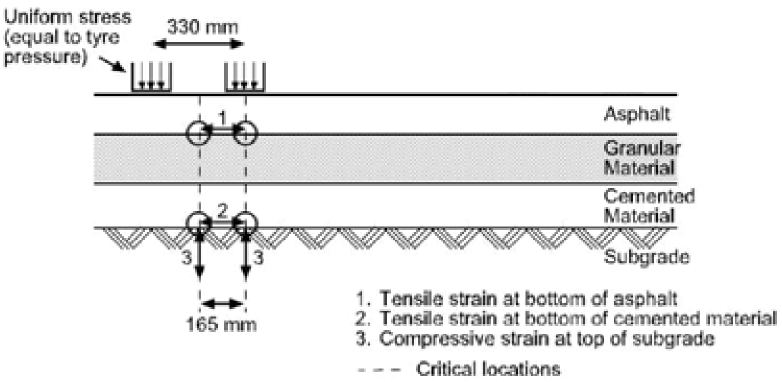
- Relationship between stress & strain (linear, non-linear)
- Time dependancy of strain (viscous, non viscous)
- Recovery of strain (elastic, plastic)

Failure mechanisms

- Empirical observations describing the axle repetitions to failure
- Fatigue of bound materials
- Permanent deformation of subgrade material

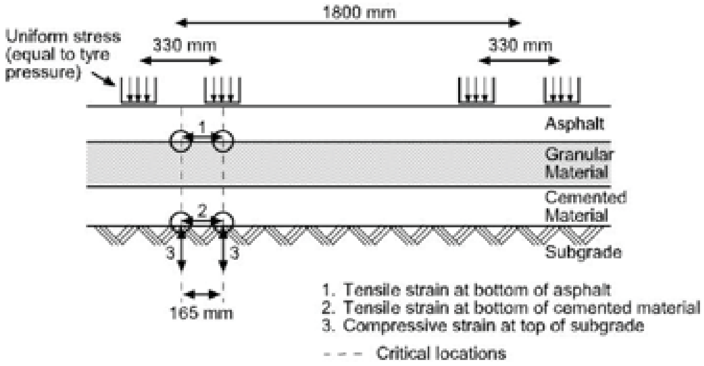
Pavement Response Model

1992



- Half a Standard Axle
- 550 kPa tyre pressure

2004



- Increased pavement thickness & stiffness – influence of opposite tyre set on strains deeper in the pavement
- Full Standard Axle
- Radial tyres 750 kPa (1997)

Design Traffic (Standard Axle Repetitions – SARs)

1992

- Limited load axle data with which to determine Traffic Load Distributions (TLDs)
- SARs estimated as;
  - Ø 1.1 x ESA (asphalt & subgrade)
  - Ø 18 x ESA (cemented)
- Exponent of strain dependency
  - Ø Asphalt – 5
  - Ø Subgrade – 7.14
  - Ø Cemented – 18

2004

- WIM data used to determine TLDs for Urban & Rural roads
- Incorporation of the number of HVAGs
- SARs determined for each failure mechanism based on damage exponent
- Damage Exponent
  - Ø Asphalt – 5
  - Ø Subgrade – 7
  - Ø Cemented – 12
- Consistent with exponent of strain dependency

Limiting Strain Criterion for Design Traffic & Reliability Factors

- Fatigue of Asphalt

$$N = RF \left\{ \frac{6918 \times (0.856 \times V_b + 1.08)}{S_{mix}^{0.36} \times \mu\varepsilon} \right\}^5$$

Reliability Factors ranging from 2.5 – 80% to 0.67 – 97.5%

- Subgrade Permanent Deformation

$$N = \left(\frac{8511}{\mu\varepsilon} \right)^{7.14} \qquad N = \left(\frac{9{,}300}{\mu\varepsilon} \right)^{7}$$

Relationship considered reliable up to $1x10^8$ SARs therefore no reliability factors

- Fatigue of Cemented Materials

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

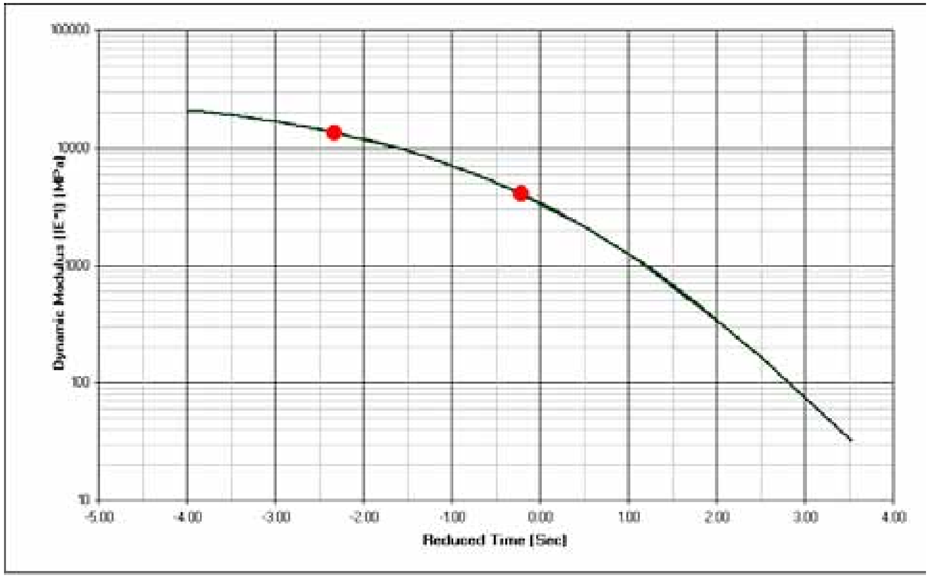
Reliability Factors ranging from 4.7 – 80% to 0.5 – 97.5%

Modified Mechanistic-Empirical Pavement Design Procedure

- Environmental factors
  - Ø wet / dry seasons (tropics)
  - Ø hot summer / cold winter (inland / southern regions)
- Coincidence with variable traffic loads/volumes
- Minimum six seasons
- Overseas research

Modified Mechanistic-Empirical Pavement Design Procedure

- Temperature and rainfall
  - Ø Min & max air temperature
  - Ø Mean monthly rainfall
  - Ø Surface temperature (US Asphalt Institute)
  - Ø Asphalt temperature at depth within the pavement (BELLS)
- Distribution of SARs
- Asphalt modulus
  - Ø Master curves
  - Ø Bitumen properties, mix volumetrics
  - Ø Temperatures
  - Ø Time of Loading



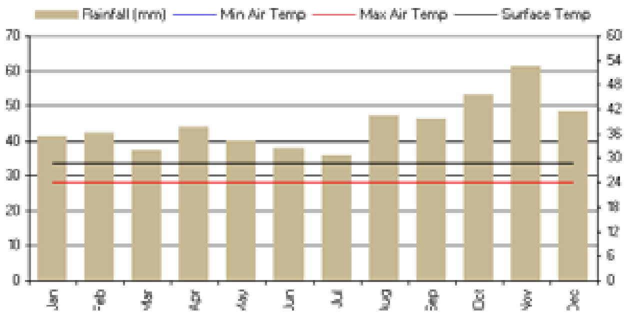
Design Comparison

- Environmental and Traffic Inputs
  - Ø Traffic volumes fluctuate throughout the year with lower volumes in winter and the end of the year
  - Ø Stiffness of granular material reduced in winter months despite no clear wet season to reflect lower evaporation rates in winter
- Project Reliability of 90%
- Standard approach considered only the distribution of traffic, with the asphalt modulus based on a WMAPT and granular materials based on soaked wet season state
- Modified approach considered both the distribution of traffic and affect of rainfall and temperature on the stiffness of granular materials and asphalt across the six seasons

Standard Approach

Seasonal Traffic / Environmental Details

Site: Melbourne Airport 086282
Latitude: 37.67 °South



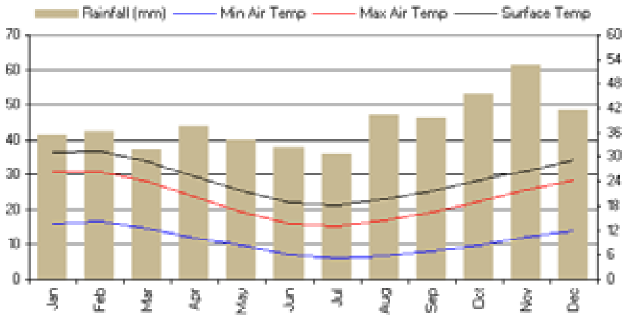
Traffic (SARs)	Jan	Mar	May	Jul	Sep	Nov
Distribution	20.0%	20.0%	15.0%	15.0%	20.0%	10.0%
Fatigue of Asphalt	5.52E+05	5.52E+05	4.14E+05	4.14E+05	5.52E+05	2.76E+05
Rutting & Shape Loss	8.28E+05	8.28E+05	6.21E+05	6.21E+05	8.28E+05	4.14E+05
Fatigue of Cemented Materials	7.08E+06	7.08E+06	5.31E+06	5.31E+06	7.08E+06	3.54E+06

Environment	Jan	Mar	May	Jul	Sep	Nov
Rainfall (mm)	41.7	40.6	38.9	41.4	49.7	54.8
Min. Air Temp (°C)	24.0	24.0	24.0	24.0	24.0	24.0
Max. Air Temp (°C)	24.0	24.0	24.0	24.0	24.0	24.0
Surface Temperature (°C)	24.0	24.0	24.0	24.0	24.0	24.0
Granular Reduction Factor	1.00	1.00	1.00	1.00	1.00	1.00

Modified Approach

Seasonal Traffic / Environmental Details

Site: Melbourne Airport 086282
Latitude: 37.67 °South



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Fatigue of Cemented Materials	7.08E+06	7.08E+06	5.31E+06	5.31E+06	7.08E+06	3.54E+06

Environment	Jan	Mar	May	Jul	Sep	Nov
Rainfall (mm)	41.7	40.6	38.9	41.4	49.7	54.8
Min. Air Temp (°C)	13.9	11.4	7.3	5.6	7.7	11.2
Max. Air Temp (°C)	26.4	22.2	15.1	13.7	17.9	23.2
Surface Temperature (°C)	31.1	27.1	20.3	19.0	23.0	28.0
Granular Reduction Factor	0.99	0.95	0.85	0.81	0.92	0.95

Standard Approach

Pavement Structure

	AC	Cement	Deform	Degree of Anisotropy	Poisson's Ratio	Jan	Mar	May	Jul	Sep	Nov
						Modulus (MPa)					
Layer 1	☑	☐		1	0.40	2611	2611	2611	2611	2611	2611
Layer 2	☑	☐	☐	1	0.40	3270	3270	3270	3270	3270	3270
Layer 3	☐	☐	☐	2	0.35	390	390	390	390	390	390
Layer 4	☐	☐	☐	2	0.35	170	170	170	170	170	170
Layer 5	☐	☐	☐	2	0.35	95	95	95	95	95	95
Layer 6	☐	☐	☐	2	0.35	53	53	53	53	53	53
Layer 7	☐	☐	☑	2	0.45	30	30	30	30	30	30

Season columns: Jan, Mar, May, Jul, Sep, Nov

Modified Approach

Pavement Structure

	AC	Cement	Deform	Degree of Anisotropy	Poisson's Ratio	Jan	Mar	May	Jul	Sep	Nov
						Modulus (MPa)					
Layer 1	☑	☐		1	0.40	1737	2600	4585	5075	3740	2384
Layer 2	☑	☐	☐	1	0.40	2566	3751	6378	7071	5340	3492
Layer 3	☐	☐	☐	2	0.35	476	457	409	389	442	457
Layer 4	☐	☐	☐	2	0.35	207	199	178	170	193	199
Layer 5	☐	☐	☐	2	0.35	116	112	100	95	108	112
Layer 6	☐	☐	☐	2	0.35	65	63	56	53	61	63
Layer 7	☐	☐	☑	2	0.45	37	35	31	30	34	35

Standard Approach

Pavement Materials

	Material	Description	Thickness (mm)	Modulus Calculation Method		Constants			
Layer 1	Asphalt	DG14	40	PMS-QF4-003					
Layer 2	Asphalt	DG20	63	PMS-QF4-003					
Layer 3	Granular(Sub Layered)	Crushed Gravel	150	Power	Austroads Gravel	k1	2.2973967	k2	1
Layer 4	Granular(Sub Layered)	Subbase Select	125	Power	Austroads Select	k1	1.7817974	k2	1
Layer 5	Granular(Sub Layered)	Subbase Select	125	Power	Austroads Select	k1	1.7817974	k2	1
Layer 6	Granular(Sub Layered)	Subbase Select	125	Power	Austroads Select	k1	1.7817974	k2	1
Layer 7	Subgrade	Silty Clay	0	Rainfall Adjustment		Dry Mod.*	30		

Modified Approach

Pavement Materials

	Material	Description	Thickness (mm)	Modulus Calculation Method		Constants			
Layer 1	Asphalt	DG14	40	PMS-QF4-003					
Layer 2	Asphalt	DG20	50	PMS-QF4-003					
Layer 3	Granular(Sub Layered)	Crushed Gravel	150	Power	Austroads Gravel	k1	2.2973967	k2	1
Layer 4	Granular(Sub Layered)	Subbase Select	125	Power	Austroads Select	k1	1.7817974	k2	1
Layer 5	Granular(Sub Layered)	Subbase Select	125	Power	Austroads Select	k1	1.7817974	k2	1
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Layer 7	Subgrade	Silty Clay	0	Rainfall Adjustment		Dry Mod.*	37		

Standard Approach

Damage Permanent Deformation		Reliability Factor	Damage Factor (%)						
	Layer 7	1	0%	0%	0%	0%	0%	0%	5.8
								0%	Accepted
								1.20.E+09	SAR's
								20	Years
Damage Asphalt Fatigue		**Reliability Factor**	**Damage Factor (%)**						
	Layer 1	1.5	0%	0%	0%	0%	0%	0%	6.5.6
	Layer 2	1.5	19%	19%	14%	14%	19%	9%	6.5.6
								95%	Accepted
								2.91.E+06	SAR's
								20	Years
Damage Cemented Materials Fatigue		**Reliability Factor**	**Damage Factor (%)**						
									N/A
								N/A	SAR's
								N/A	Years

Modified Approach

Damage Permanent Deformation		Reliability Factor	Damage Factor (%)						
	Layer 7	1	0%	0%	0%	0%	0%	0%	5.8
								0%	Accepted
								1.88.E+09	SAR's
								20	Years
Damage Asphalt Fatigue		**Reliability Factor**	**Damage Factor (%)**						
	Layer 1	1.5	0%	0%	0%	0%	0%	0%	6.5.6
	Layer 2	1.5	13%	17%	17%	19%	19%	8%	6.5.6
								94%	Accepted
								2.93.E+06	SAR's
								20	Years
Damage Cemented Materials Fatigue		**Reliability Factor**	**Damage Factor (%)**						
									N/A
								N/A	SAR's
								N/A	Years

Conclusion and Future Developments

The most recent Austroads Pavement Design Guide incorporates;

- More detailed traffic load distributions for urban and rural roads based on the collection of substantial WIM data.
- Pavement response model
- Design confidence

Modified Approach

- Material characterisation according to temperature and rainfall variation
- Asphalt Modulus – Master Curve, Volumetrics, Temperature, Load Frequency

Future Developments

- Asphalt Modulus - Daily temperature vs hourly traffic spectrum