REHABILITATION OF UNBOUND GRANULAR PAVEMENTS

Improved design criteria for each region based on precedent performance throughout each network
One of the more widely recognised examples of a New Zealand region that requires “customised” pavement design rather than using standard Austroads criteria is the central North Island where unweathered volcanic ash subgrades can be designed using deflection or strain criteria that are sometimes a factor of 2 or 3 higher, than those specified by Austroads, for the same lifetime traffic (ESA). The cost savings made by abandoning Austroads criteria in this region are huge.

This study is exploring the degree to which other regions can justify similar variations in design approaches. In such cases a procedure of systematic quantification is being followed, to document the basis for more efficient designs.
IMPROVED DESIGN CRITERIA FOR EACH REGION

Extensive “data mining” of historic pavement structural data (RAMM and FWD analyses).

Pilot study of 5 of the Transport Agency’s regions.

Study has multiple outcomes, some of which are far more substantial than had been anticipated.

(i) Customised design criteria, for each region, rather than Austroads

(ii) Models for Mechanistic Forward Work Programmes

(iii) Load damage exponents for the region.

(iv) Seasonal variation of structural parameters for each region.

(v) Foundation for Traffic Speed Deflectometer (TSD) data interpretation.
Primary structural data is from RAMM, test pit logs, CBR & FWD data, plus an extensive database of the corresponding relevant structural evaluations using multi-layered elastic models.

FWD records include not only peak deflections but also the much more detailed characterisation available from the full time histories for each sensor.
FALLING WEIGHT DEFLECTOMETER: FULL TIME HISTORY

DEFLECTION PLOT

Displacements of each geophone plus plate stress pulse, vs time
FALLING WEIGHT DEFLECTOMETER: FULL TIME HISTORY

VELOCITY PLOT
FALLING WEIGHT DEFLECTOMETER: FULL TIME HISTORY

ACCELERATION PLOT
FALLING WEIGHT DEFLECTOMETER: FULL TIME HISTORY

HYSTERESIS LOOPS
(DISSIPATED ENERGY)

INTEGRATING THE PLATE FORCE OVER THE DURATION OF THE IMPULSE AT EACH GEOPHONE
The study has enabled Austroads design criteria to be modified and customised for optimum use, i.e., developing a “calibrated mechanistic procedure” for each region. Only “mature roads” (in use for some decades) are considered when assessing precedent performance.

The database now holds over a million structural analyses of deflection bowls (collected since 1993). Each analysis outputs several hundred significant fields, and includes the traffic (ESA) at time of testing as well as links to test pitting and high speed data.

Many regions have more than 10,000 structural analyses stored, and some have around 50,000. The two largest databases are Southland and Auckland.
Data mining generates the “customary parameters” that apply in each region, from which parameters relating to “regional precedent performance” (RPP) of local pavements can be established.

Austroads assumes the design life of unbound granular pavement to be a function of subgrade compression (vertical strain) only, but each NZ regional database shows clear trends for other governing variables: material types, stiffnesses, shear, stress-softening behaviour etc.

Rather than use only a single parameter, regional precedent performance modelling can readily include as many other parameters as are identified to be statistically significant from the data mining, and these can be empirical, mechanistic (stress/strain from any preferred layered elastic model) or a combination of both types.
Austroads design method includes use of the full deflection bowl rather than one or two points, but pavement life is related to only one parameter in each layer considered.
REGIONAL PRECEDENT PERFORMANCE

As well as compression, **material type** is also a factor indicated by the RPP model.

**Identical permanent deformation?**

Material type can be discerned approximately from FWD (stress-dependency of moduli).

**CBR 10 Compact Silt**
- Many point contacts, hence low contact stresses
- A given magnitude of cyclic strain would cause relatively small permanent displacements at each contact point

**CBR 10 Loose Gravel**
- Few point contacts, hence high contact stresses
- A given magnitude of cyclic strain would cause relatively large displacements at each contact point
Southland RPP study found 3 or 4 parameters were indicated for each unbound layer and subgrade. While a crude fit could be obtained with just vertical strain, much better interpretations were invariably found by using multiple parameters.
REGIONAL PRECEDENT PERFORMANCE
- CONSIDERS EACH LAYER: MATERIAL TYPE, STIFFNESS, STRESSES & STRAINS

Shear - not in Austroads but intuitively reasonable to contribute additional deformation.

Multiple fatigue criteria for given design ESA

Figure 1 Pavement Response Model [2]
OPTIMISING DESIGN RELIABILITY AND EFFICIENCY

“Customary Practice” parameters for pavement design:

Because the FWD takes measurements in situ, the results reflect the relevant practices of local contractors, designers, subgrade characteristics, aggregate quality, traffic loadings and environment.

- Resulting designs are often similar to standard Austroads designs, but others differ significantly with the more discerning approach.

- Both more and less conservative trends (than Austroads) for any set of rehabilitation sites are typical permitting more reliable and more efficient designs respectively.

- If any design is less conservative than traditional Austroads design, then it is of course important to ensure that all assumptions are verified, or some other independent check is carried out. Regional variants (alternative designs) can be evaluated. Such regional variants are standard practice for NZTA M/4 basecourses.

- The most beneficial application of customary practice parameters is as a reality check for any proposed design as that provides practical verification that the design is, (or is not), consistent with expected performance.
A crude “one size fits all” parameter was required when the “structural number” concept originated in the late 1950’s, when data accuracy was poor and collection slow. NZ introduction 1999.

Now the data can be refined and collection is becoming increasingly rapid.

In the common range of SNP 3 to 4 this coarse parameter has very weak correlation with pavement life by any state-of-the-art method: result may be a factor of several orders of magnitude (corresponding to a predicted pavement life (for a given SNP) range of less than 1 year to over 50. The average of a large number of SNP values cannot even crudely compare one network with another, or usefully discern or predict performance of any individual road or treatment length. Relativity.

“One size fits all” ? 2014:SNP
CUSTOMARY PARAMETERS: SUBGRADE STRAIN

- All state highway LTPP sites

- Austroads subgrade strain criterion, implies nothing else about the subgrade matters.

- Realistic? Not according to in situ test results.
CUSTOMARY PARAMETERS: SUBGRADE STRAIN

Alternative 3D Model for Allowable Subgrade Strain as a Function of Modulus and Design Traffic (25 year MESA).
Inconsistent with Austroads SSC.
Consistent with:

1. Scala Deflection-CBR design
2. European practice
3. AASHTO M-EPDG
4. Caltrans
5. Figure 8.4 design chart:
   CBR-thickness-traffic.

Not just strain-traffic
CUSTOMARY PARAMETERS: SUBGRADE STRAIN

- Changing x axis from moduli to design traffic gives allowable vertical microstrain at the top of the subgrade for given values of subgrade modulus.
- Austroads is an approximate average if second variable must continue to be ignored, but much less discerning.
- 40-100 MPa change in modulus gives factor of 2 change in allowable strain. Reliability and efficiency are obvious issues.
- How to address this in a traditional mechanistic design.
- (i) Use M-E PDG, Caltrans. ELMOD
- (ii) Determine appropriate subgrade modulus for the site, and construct fatigue equation for CIRCLY (anisotropic).
- (iii) Spreadsheet (now being tested).
APPLICATION TO NETWORKS

• The study allows all existing roads in the network to be ranked in terms of their future structural performance, and at the same time establishes the effectiveness of any recent rehabilitation relative to an ideal design (calculate 25 year life, or CDF)
• This provides straightforward, definitive identification of those roads which will deteriorate most rapidly, allowing informed decisions on
  (i) where to prioritise structural strengthening, and
  (ii) clearly identifying roads where resurfacing only, will be all that is needed
  (iii) roads which require basecourse stabilisation (where critical layer is basecourse)
  (iii) the degree of under or over-design of recent rehabilitation
LOAD DAMAGE EXPONENTS

- Implications of multiple parameters for rutting.
- Implicit set of load damage exponents for incremental ranges, increasing with number of governing variables.
- Literature indicates exponents from “1.6 to over 10”
- Implications: can easily be a factor of 10 error in calculated pavement life (e.g., an axle load increased by a factor of 1.3 on a CBR 4 subgrade)
- (First application) Now 5Dx2

Pavement Wear = (Axle Load) ^ 4

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<thead>
<tr>
<th>Subgrade CBR</th>
<th>LDE Table</th>
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<tr>
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<td>Allowable Traffic (ESA)</td>
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<tr>
<td></td>
<td>Austroads</td>
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<td>8</td>
<td>6</td>
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- Implications: can easily be a factor of 10 error in calculated pavement life (e.g., an axle load increased by a factor of 1.3 on a CBR 4 subgrade)
SURFACINGS CHIPSEALS, THIN AC, OGPA

What relevant criteria can be identified from precedent study of existing networks

1. Empirical (curvature) – governed by thickness
2. Mechanistic – tensile strain at top and bottom of surfacing
TOP-DOWN VERSUS BOTTOM UP CRACKING
Change in profile with speed: upward curvature decreases, downward curvature decreases behind, but increases in front of dynamic wheel due to viso-elastic and inertia effects.
Preliminary study of customary parameters for determining flexure life of surfacings (to be designed to exceed the life for other distress modes, eg ravelling in OGPA).

Note traffic figures are 25 year MESA (for subgrade), not the intended design traffic for the surfacing life which will be much less. Similar results for chip-seals.

Curvature alone, did not discern well. Two parameters give much better fit, with best match so far as shown, using horizontal strains at both top and bottom of surfacing.

(Horizontal Strain at Bottom of Surfacing approximates to 1000 x Curvature)
SUMMARY: REGIONAL PRECEDENT PERFORMANCE

Extensive “data mining” of historic pavement structural data

Deliverables for each region

(i) Customised design criteria, for each region, rather than Austroads
(ii) Subsectioning to Structural Treatment Lengths (STL)
(iii) Structural life for each STL
(iv) Models for Mechanistic Forward Work Programmes
(v) Identification of Terminal Distress Modes for each STL
(vi) Identification of Critical Layer for each STL
(vii) Quantified Load Damage Exponents for the relevant critical layer in each TL
(viii) Susceptibility of each STL to HPMV loading increases.
(ix) Seasonal variation of structural parameters for each region.
(x) Graphical outputs, and for site inspection, smartphone app showing distress/life/moduli with GIS locations for site inspection
PAVESTATE APP

Smartphone or Desktop