Performance-Based Specifications
Using Deflection Measurements

Graham Salt & David Stevens
Tonkin & Taylor Ltd
Pavements Group

Contents

• Background
• Comparison of Relationships
• Application
• Case Histories
• Conclusions
Modular ratios of unbound granular layers

- Unbound granular pavement layers show a characteristic increase in moduli from the subgrade to the surface.
- The ratio of moduli between successive layers provides a direct and effective measure of pavement quality that makes due allowance for site conditions and seasonal effects beyond a contractor’s control.

Modular ratios of unbound granular layers

- The modular ratio is an effective indicator for performance-based specifications.
- Modular ratios are readily determined from back-analysis of Falling Weight Deflectometer monitoring.
Limitation of modular ratios

Modular ratios

- Dorman & Metcalf (1965)
- Brown & Pappin (1985)
**Modular ratios**

- Normalised Modular Ratio (NMR)
- $\text{NMR} = \frac{\text{As-built modular ratio}}{\text{Standard modular ratio}}$

**Case histories: Post-construction**

Moduli and NMR for firm subgrade
Case histories: Post-construction

Moduli and NMR for variable subgrade

Cumulative NMR distributions for new, trafficked pavements

Case histories: Post-construction

Cumulative NMR distributions for new, trafficked pavements
Case histories: Construction

Increase in NMR with additional compaction

Case histories: Construction

Low NMR with NO additional compaction

27 mm rut in 18 months!
Case histories: Network condition

Cumulative distribution of subgrade modulus in successive years

Case histories: Network condition

Cumulative distribution of adjusted structural number in successive years
Case histories: Network condition

Cumulative distribution of NMR in successive years

Case histories: Network condition

Trend line of $\Delta$SNP and $\Delta E_{sg}$ (subgrade modulus) for all LTPP Sites
Case histories: Network condition

Independence of NMR for all LTPP Sites

Cumulative distribution of NMR for all LTPP Sites
NMR Zones

Layer 1 Modulus (MPa)

Normalised Modular Ratio

Notes: Data points are the same from Sections 5.0.1.2009 and 2010. Parameters that highlight APM have been removed.
Conclusions

- Unbound granular pavement layers show a characteristic increase in moduli from the subgrade to the surface
- The ratio of moduli between successive layers provides a direct and effective measure for performance-based specifications

Conclusions – New construction I

- FWD measurements allow as-constructed modular ratios to be compared with expected results from known good practice, thereby giving an immediate performance indicator
- Readings should preferably be taken during construction or prior to sealing or application of a bound surface layer
Conclusions – New construction II

- The normalised modular ratio is a quantitative measure of construction uniformity and stiffness of the pavement layers, relative to the subgrade.
- If the 5th percentile is less than 0.75, at time of sealing, substantial early rutting can be expected. Target 5th percentile > 0.95.
- The performance indicator is independent of subgrade weaknesses or non-uniformity.

Conclusions – Network maintenance

- With monitoring of network maintenance contracts of unbound granular pavements, average modular ratios determined in successive years provide direct unbiased performance indicators of the standard of structural maintenance of the pavement layers.
- The measure is irrespective of seasonal variations of subgrade conditions, outside the contractor’s control.
Normalised Modular Ratio NMR