TECHNICAL NOTE:

APPLICATIONS OF MECHANISTIC PAVEMENT DESIGN IN NEW ZEALAND (I)

CASE HISTORIES COMPARING OVERLAY DESIGN METHODS INCLUDING THE TRANSIT NEW ZEALAND SUPPLEMENT TO THE AUSTROADS PAVEMENT DESIGN GUIDE

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Graham Salt
Tonkin & Taylor Ltd

1. INTRODUCTION

Overlay design for pavement rehabilitation in New Zealand is based on mechanistic procedures given in the AUSTROADS Pavement Design Guide. In July 1997, Transit New Zealand issued a Supplement to the AUSTROADS Guide, promoting some variation to the existing methods to give due regard to the past performance of any road section programmed for rehabilitation.

The New Zealand Supplement overlay design methods have now been applied to many projects on state highways and local authority roads. This article presents the results from a number of case histories for unbound pavements where overlay requirements have been calculated using both the original AUSTROADS design methods and the procedures set out in the New Zealand Supplement. Comparisons show the strengths and limitations of the various methods, providing a guide to the most useful conditions under which each method should be applied to five both cost effective design and assurance of long term performance.

2. OVERLAY DESIGN METHODS

Details of the various overlay design procedures are provided in the Pavement Design Guide (AUSTROADS, 1992) and the Transit New Zealand Supplement (TNZ, 1997). Further background is given in the Transit New Zealand State Highway Pavement Design and Rehabilitation Manual (TNZ, 1989). All methods require input of the proposed design traffic (ESA), but otherwise the bases of the various approaches are summarised below.

Table 1. Basis of Overlay Design Methods for Unbound Granular Pavements

	OVERLAY DESIGN METHOD	BASIS
1	AUSTROADS Chapter 10	Surface central deflection.
2	General Mechanistic Procedure (GMP)	Subgrade strain, irrespective of soil type.
3	TNZ Supplement, Eqn 10.3 SHPDRM (equivalent to TNZ State Highway Pavement Design and Rehabilitation Manual method)	Past performance of the subgrade. *Allowable design strain differs for each test point.*
4	TNZ Supplement, Precedent Strain Uses Eqn. 10.3 and 10.4.	Past performance of the subgrade. *A specific allowable design strain is derived for the soil type.*

The Transit New Zealand Supplement methods continue to apply the concept of past performance, which has been the basis of unbound pavement design in New Zealand for several decades, and is well summarised by Major (1980):

> **"The pavement that is a candidate for repair, rehabilitation or reconstruction in fact provides a full scale calibrated-for-location performance research section. Design.....depends only on identifying the true performance of that section."**

There is an important difference between the two TNZ Supplement methods, as italicised in the above table. Method 3, the "TNZ SHPDRM" method is essentially the same as proposed by Major and assumes that for the existing pavement, every test point where the subgrade CBR (or modulus from deflection analysis) is measured, would experience a strain under a 1 ESA loading which is the maximum allowable for the past traffic. In practice, subgrade variations in stiffness will be such that there may well be significant intervals of the road which are under-stressed.

Method 4, labelled "TNZ Precedent Strain" addresses the deficiency of the former method, by examining the variation in strain along the full length of the section to be rehabilitated. This allows an appropriate subgrade strain criterion to be derived for the specific soil type in that location and environment.

The following figures give case histories examined recently showing overlay results for all four methods. The GMP results use the AUSTROADS subgrade strain criterion. However because poor quality basecourses (high in silt content from original construction or degradation) are often found in New Zealand unbound pavements due for rehabilitation, the same vertical strain criterion has also been applied to all unbound layers (Danish method - Ullidtz, 1987). This allows early recognition of pavements susceptible to shoving. (Alternatively, as discussed above, CBR may be inferred from the basecourse modulus, then the shear strength checked as described in the Transit Supplement.)

Fig. 1 is a case examining Trial Section CO, a section of SH 6 which includes sidling and box cuts through hard unweathered greywacke rock. Incipient shoving was apparent locally with very pronounced shoving failure at the 1.0 km station. The AUSTROADS Chapter 10 method could not be expected to determine the problem from surface deflection alone as the subgrade is essentially unyielding, thus masking the problem of highly yielding basecourse. Ullidtz (1987) gives other examples showing the incompatibility of deflection and strain citeria, and points out that use of deflection criteria alone are not adviseable. The GMP (after including checks for strain in all layers) shows a good representation of the situation. The TNZ Supplement methods are not applicable because subgrade strain is not the cause of distress. (Basecourse degradation may have been a factor, as drainage was good.)

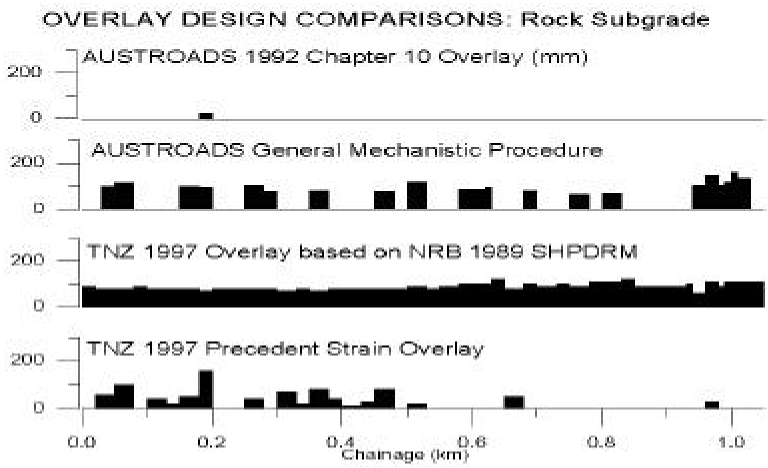

Figure 1

The second case study (Fig. 2) was obtained from a severely rutted pavement underlain by deep volcanic soil on SH 1 in the central North Island. The AUSTROADS Chapter 10 method shows extremely high overlay requirements (about 400 mm), but locally experienced practitioners advise that such overlays are quite unrealistic. The GMP indicates overlays which are also excessive. Both the TNZ methods provide results which are in good accord with local expectation. Volcanic soils appear to be much more resistant to high strain levels than other soil types, possibly because of their highly angular particles and cementation effects from ferric weathering products when located in an oxidising environment. The TNZ past performance methods appear to provide for highly cost effective rehabilitation solutions in anomalously behaving soils such as recent volcanic ash and pumice.

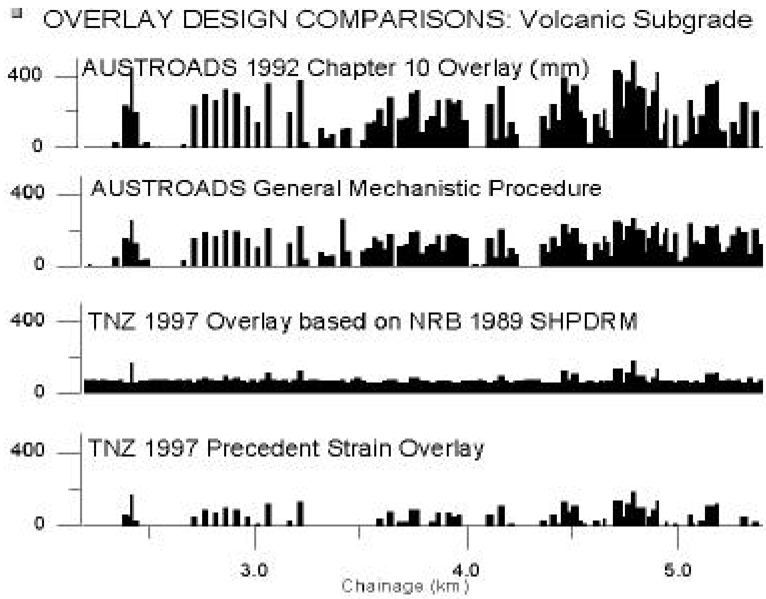

Figure 2

The former 2 cases show extreme (but not unusual) conditions to emphasise the differences in the overlay requirements. The final example (Fig. 3) is more representative of a typical rehabilitation project in New Zealand. This comes from a highway on an alluvial plain of variable sediments (not volcanic) but with subgrade conditions ranging from soft clay to gravel. One side of the road had been widened and there was significant rutting and incipient shoving with loss of shape. There were multiple seal layers over a silty basecourse (commonly encountered in pavements constructed in pre-M/4 days). An additional graph at the base of this set shows the layer in which the greatest vertical strains occur. (Layer 1 represents the basecourse, layer 2 is the subbase, layer 3 a lower subbase while the 4th layer is the subgrade.)

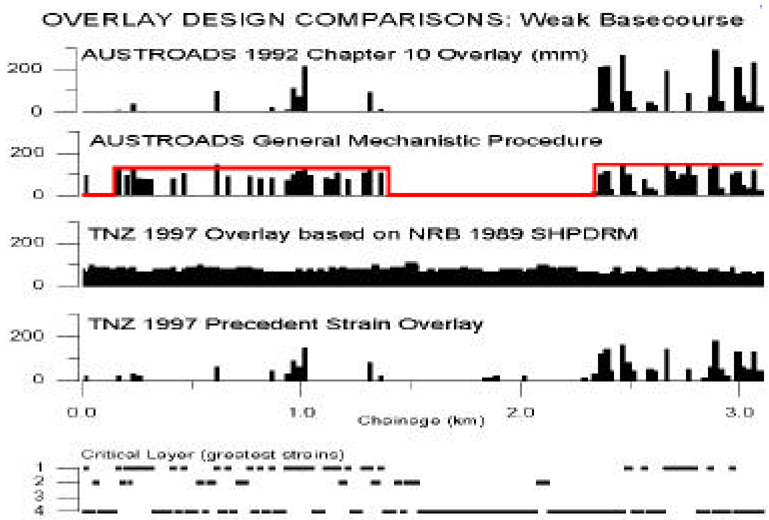

Figure 3

The AUSTROADS Chapter 10 method did not recognise sections where incipient shoving was occurring over gravel subgrade but provided otherwise conservative design for the rutting. GMP results were consistent with evidence of surface distress.

The TNZ SHPDRM method provided realistic overlay thicknesses but failed to identify that there is a section about 1 km long near the centre of the test interval that required minimal overlay - a common finding inherent in the method. It should be noted that SHPDRM does not readily identify any locally weaker or stronger intervals within the test section- all overlay requirements are similar throughout and structurally adequate portions are "tarred with the same brush". The big advantage (but also the reason for its limitation) is that very little subsurface information is required as input. The overlay thickness is governed principally by the ratio of future to past traffic.

The TNZ Precedent Strain method gave reasonable results along the second half of the road where the subgrade was soft but failed to recognise much of a problem in areas of incipient basecourse shoving, particularly along the first half of the road - again an inherent feature of the technique but this deficiency would normally be picked up from the visual survey and subsequent basecourse CBR testing in accordance with the TNZ Supplement. The points to target for CBR testing are those where the critical layer graph shows high strains to be occurring in the basecourse. It is particularly important that the visual survey is suitably detailed and sectionalised when using either of the precedent methods.

The horizontal line above the GMP overlay results shows the approximate construction sectioning and overlay requirements that might be adopted from this data. There are two intervals that require about 130-150 mm overlay. There is a long central section that requires no structural improvement and a minimum thickness overlay could be applied for shape correction or probably deferred for many years depending on local roughness and maintenance costs.

3. SELECTION OF OVERLAY DESIGN METHOD

Each overlay design method has different conditions for application. Design assurance may be obtained by examining the sensitivity of overlay thicknesses, comparing several of the methods. Table 2 summarises the conditions under which each should or should not be applied. The limitations of each method can be readily deduced from the principles on which each design method is based, and have been verified from case studies.

Table 2. Criteria for Design Method Selection

AUSTROADS (1992) Chapter 10, Central Deflection Method. Note: Transit NZ specific approval is required before using this method on a NZ state highway.	
Use where	**Avoid where**
Short rehab. section (say 500 m or less)	Rock or very hard subgrade is present (under design)
"Conventional" pavement	Distress mechanism is unknown (under design)
Needed overlay for structural improvement is small or similar to shape correction requirements	Volcanic soils are present (over design), or where experience has shown that high deflection pavements perform adequately.

AUSTROADS General Mechanistic Procedure	
Use where	**Avoid where**
Failure mechanism is uncertain	Volcanic soils are present (over design)
Long lengths are to be rehabilitated	
Variable subgrade conditions exist	
Pavement profile is unconventional (or conventional)	
Past traffic (ESA) is uncertain	
Maintenance history is uncertain	
Needed overlay for structural improvement is larger than shape correction requirements	

TNZ (1997) SHPDRM Based Method	
Use where	**Avoid where**
Volcanic soils are present	Shoving is evident (under design)
Pavement test data is limited in quantity or quality	Fill embankments overlie soft ground (over design)
Rehabilitation lengths are short	Failure mechanism is uncertain
	Subgrade conditions are variable
	Past traffic is uncertain
	Maintenance history is uncertain

TNZ (1997), Precedent Strain Method	
Use where	**Avoid where**
Volcanic (or any other) soils are present	Shoving is evident (under design)
Subgrade conditions are variable (in space)	Basecourse is susceptible to degradation (under design)
Long lengths are to be rehabilitated	Fill embankments overlie soft ground (over design)
Needed overlay for structural improvement is larger than shape correction requirements	Seal permeability has failed
	Failure mechanism is uncertain
	Past traffic is uncertain
	Maintenance history is uncertain
	Subgrade conditions may have changed with time

4. CONCLUSIONS

Overlay design using GMP has now been applied in New Zealand for at least 5 years over lengths totalling several thousand kilometres, with several hundred kilometres now overlain and in service. Good performance appears to result where GMP principles and the basic requirements of TNZ B/2 and M/3 Notes have been followed.

Several kilometres of highway have recently been overlain where design has adopted the TNZ Precedent Strain method. Most if not all of these cases are on volcanic ash or pumice subgrades and substantially reduced overlay thicknesses (compared to the original AUSTROADS requirements) have been used. Provided that the future/past traffic ratios have been correctly assessed, the long term performance of these sections should be assured.

Comparison of results from all methods allows the designer to appreciate the sensitivity of overlay requirements. Making a final selection of the most appropriate method that gives due regard to the specific conditions applicable at each site will provide the most cost effective design.

5. ACKNOWLEDGEMENT

This is one of a series of articles prepared from Transfund Research Project PR3-0171. Further details on these case histories are contained in the project reports.

6. REFERENCES

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