BASECOURSE/SUBBASE DESIGN STRAIN CRITERION

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Austroads Pavement Design

The Austroads Pavement Design Guide is currently used in New Zealand for pavement design. This design guide includes a design criterion for the subgrade limiting the subgrade strain value. In the last few years significant concerns have been raised by industry in New Zealand about the uncertainty in the validity of the Austroads subgrade strain criterion.

Within the Austroads design procedure, a strain criterion limiting the vertical elastic subgrade strain is used to limit the risk of rutting within the basecourse/subbase as well. Equation 1 shows the correlation between the pavement life (number of Standard Axles Repetitions (SAR) to pavement failure) and the compressive elastic strain at the top of the subgrade.

$$N_f = \left(\frac{9\,300}{e}\right)^7 \qquad (1)$$

where:

N_f [-] number of Standard Axles Repetitions (SAR) to failure

ε [10^{-6} m/m] compressive elastic strain at the top of the subgrade produced by the load (Austroads Design Guide 2004).

In the relationship it is assumed:

- the pavement materials are homogeneous and linearly elastic,
- the E-Moduli can be obtained from RLT (Repeated Load Triaxial) testing or from the backcalculation of pavement deflection bowls,
- a single design moisture condition exists in the pavement (Vuong 1994).

In addition, the basecourse/subbase materials must comply with material specifications such as grading limits. However, these methods do not consider the plastic deformation performance of the basecourse/subbase layers. Hence, the predicted life in terms of ESAs using the Austroads approach can sometimes indicate a long pavement life. To assess the validity of the Austroads approach, linear elastic back-calculations were conducted by ARNOLD (*2004*) and Werkmeister (*2006*) using CAPTIF test results. The Austroads approach was applied to FWD measurements taken immediately after compaction. The analysis was undertaken for selected pavement segments in the PR3-0805 and PR3-0610 CAPTIF tests. These FWD measurements were back-analysed using the computer program EFROMD2 to determine the stiffness of the pavement layer. Two different materials (basecourse and subgrade) were assumed in the pavement and each material was divided into three sub-layers to account for material non-linearity. It was found in the analysis that limits were occasionally needed on the maximum and minimum aggregate moduli to ensure the top layer had the highest stiffness. After the pavement layer moduli were determined, linear elastic analysis with an applied load of 50kN was undertaken to compute the vertical compressive strain at the top of the subgrade. The calculated subgrade strain using FWD results was plotted against the pavement life as shown in Figure 1. The dotted line shown in Figure 1 presents the Austroads approach.

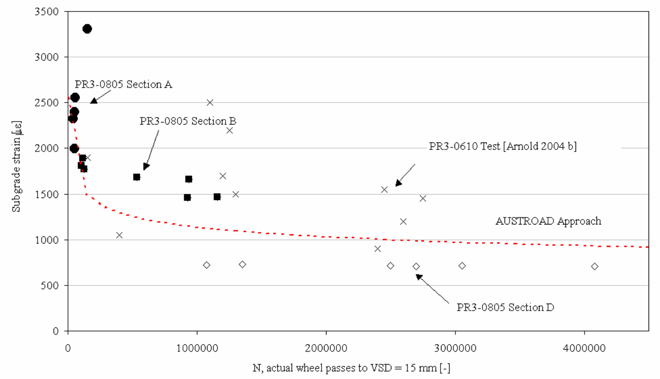

Figure 1. Subgrade strain at each section plotted against pavement life from Vertical Surface Deformation (VSD) data (Werkmeister et al. 2006)

Basecourse/Subbase Strain Criterion

It can be concluded, that the subgrade strain criterion cannot be used to limit the risk of rutting within the basecourse/subbase. Hence, within the current Austroads design procedure no basecourse/subbase deformation criterion exists. However, rutting within the basecourse/subbase is one of the main causes of damage on New Zealand's roads and latest studies dealing with the improvement of design methods for flexible pavements have pointed out the key role played by plastic deformations in the basecourse/subbase. For instance, the basecourse in the CAPTIF pavements contributed up to 70% of the total amount of the surface rutting (Steven 2005). In spite of this, adequate methods for predicting plastic basecourse/subbase deformations are lacking.

Recent research conducted by the applicants was focused to investigate the stress-strain relationship of various New Zealand basecourse materials using the Repeated Load Triaxial (RLT1) test. These test data are included in the Transit New Zealand's RLT test data-base. As a result of this research, a relationship between the elastic strains and the plastic strain rates for the basecourse aggregates used at CAPTIF (Figure 2) was developed and compared with the field performance.

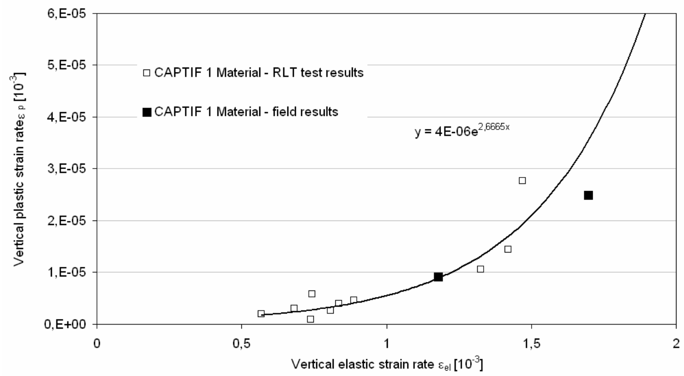

Figure 2. Axial elastic strain versus plastic strain rate for CAPTIF 1 material (Greywacke from Pounds Rd Quarry), RLT test results and CAPTIF results

Figure 2 shows on one hand that there is a relationship between the elastic and plastic (long term) deformation behaviour and on the other hand that the plastic strains measured during the RLT tests were close to those that actually occurred at CAPTIF. Thus, the new approach developed shows potential for use in pavement design and hence this the aim is to use this strain approach to derive a pavement design criterion for the basecourse/subbase. The criterion will take into account the number of ESAs applied and lead to different pavement designs.

From the RLT test results on basecourse materials, a N-ε_{el} relationship will be developed relating the elastic properties, described by the elastic strains ε_{el} and the number of ESAs. The material parameters of the basecourse materials required for this approach is determined from multi-stage permanent strain RLT tests.

A generic relationship for all basecourses is not possible as these vary in quality and resulting performance as shown in RLT testing. Material specific strain criterion from Repeated Load Triaxial testing are required. Relationships found for typical weak, medium and high quality basecourses where RLT testing has been conducted can be used to give a range of designs.

Finally, the new approach can be validated using CAPTIF results (Transit New Zealand's accelerated pavement testing facility).

References

ARNOLD, G. (2004) Rutting of Granular Pavements. PhD. University of Nottingham, England, UK. *(If interested email: greg.arnold@pavespec.co.nz for a copy)*.

ARNOLD, G., ALABASTER, D.A., STEVEN, B.D. 2006. Effect on Pavement Wear of an Increase in Mass Limits for Heavy Vehicles – Concluding Report. Land Transport New Zealand Research Report.

STEVEN, B. D., 2005. Development and Verification of A Pavement Performance Model Suitable for Use with New Zealand Materials and Pavements, PhD Thesis, University of Canterbury, Christchurch, NZ.

VUONG, B. 1994. Evaluation of Back-Calculation and performance Models using full scale granular Pavement tested with the accelerated loading facility (ALF), Proceedings of the 4th International Symposium on the Bearing Capacity of Roads and Airfields (BCRA), Mineapolis, 17.-21. June 1994.

WERKMEISTER S, STEVEN, B D and ALABASTER D 2006. A mechanistic-empirical approach using accelerated pavement test results to determine remaining life of Low Volume Roads, Road & Transport Research Journal, Vol 1, March 2006, Australia.