Repeated Load Triaxial Testing of *Your Aggregates* Unmodified and Modified with Cement, Lime or Similiar Additive

PaveSpec Ltd RLT Testing Proposal: PS0001v1

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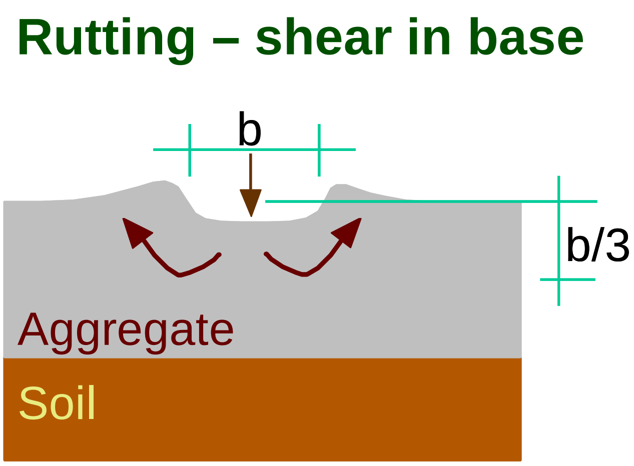
1 SCOPE

To assess the rut resistance/performance (traffic loading limit) under repetitive loading for *your aggregate* for both source and cement, lime or similiar modified aggregate mixes. Each aggregate mix will be tested in the Repeated Load Triaxial apparatus using tests and rut depth modelling procedure developed by Arnold (2004) to predict the amount of rutting expected to occur within a pavement. The method of testing will follow the same method proposed for the revised TNZ M4 Basecourse specification for determining the suitability of aggregates for high trafficked state highways.

2 BACKGROUND

Failure of new pavement construction by early rutting has been a common occurrence in latter years throughout New Zealand. Investigations of these pavement failures generally always show the rutting is within the aggregate layers. Research at Transit New Zealand's test track CAPTIF has shown up to 70% of rutting can be determined to occur in the unbound granular layers (Arnold et al, 2000).



Research at Transit New Zealand's accelerated pavement testing facility CAPTIF (Arnold et al, 2004a; Arnold 2004) found that pavement aggregates all complying with Transit New Zealand (Transit) specification for basecourse aggregate (TNZ M4) resulted in different pavement lives (defined by reaching a certain terminal rut depth). Pavement depths and the subgrade were the same and thus the only differences in performance were attributed to the differences between aggregates. The differences in performance could not be detected with the TNZ M4 specification as all the aggregates passed this specification. However, Arnold (2004) found that permanent strain tests using the Repeated Load Triaxial (RLT[1]) apparatus with appropriate rut depth modelling using finite element analysis could predict the differences in performance found in the CAPTIF tests.

The RLT (Repeated Load Triaxial) apparatus applies repetitive loading on cylindrical materials for a range of specified stress conditions, the output is deformation (shortening of the cylindrical sample) versus number of load cycles (usually 50,000) for a particular set of stress conditions. Multi-stage RLT tests are used to obtain deformation curves for a range of stress conditions to develop models for predicting rutting.

Transit New Zealand plan to revise the TNZ M4 Basecourse aggregate specification to include the Repeated Load Triaxial test developed from research by Arnold to enable materials to be categorised as being suitable as base materials for high, medium or low traffic situations in either dry or saturated conditions. This will ensure the design life can be met; a range of materials including marginal materials (previously discarded) can be used in appropriate locations (ie. low traffic and dry environments); allow other alternative materials, e.g. industrial by-products (e.g. Melter Slag) and waste materials (e.g. glass, recycled crushed concrete) to be assessed and used appropriately according to their level of rut resistance in wet and dry conditions. RLT tests have been undertaken on aggregates in New Zealand where based on experience they are known to provide poor, average and good performance. Results of these tests have resulted in a draft RLT testing procedure that will be discussed and implemented into the specification at a working group meeting to be held in March 2007.

In summary the multi-stage permanent strain RLT test can provide data for rut depth models that in turn can predict the amount of rutting that would occur within a pavement.

3 OBJECTIVES and DELIVERABLES

The objectives of this research project are to:

- To determine through RLT testing using the proposed procedure in the TNZ M4 Basecourse aggregate specification the rut resistance/performance (traffic loading limit) of *your aggregates*;
- To determine through RLT testing using the proposed procedure in the TNZ M4 Basecourse aggregate specification the rut resistance/performance (traffic loading limit) of *your aggregate* mixes.

Deliverables

1. Prediction of rut depth/traffic loading limit for a range of unmodified and cement, lime or similiar modified aggregate mixes;
2. A final report detailing results of all the RLT tests including assessments of ease of compaction learn't through sample preparation;
3. Your aggregate mixes compliance with the proposed RLT test in the new TNZ M4 Basecourse Aggregate specification.

4 METHODOLOGY

The RLT test simply tests materials chosen by the quarry owner to predict their performance. It is unknown the most appropriate aggregate type, stabilising agent and associated grading that will prevent early rutting failure. Further, compaction level, moisture content, curing time, stabilising method (ie. mix and stockpile for 7 days at the quarry or mix insitu) and temperature all affect the materials performance/resistance to rutting. Any one of these different mixes and associated method of preparation requires a new RLT test. For efficiency and expedience of this research project it is proposed to aim as closely as possible to the best aggregate mixes and change mixes/tests on the go as new results come to hand. This will also enable various different mixes of *your aggregates* to be developed and trialled quickly.

The standard number of RLT tests for each source aggregate/quarry and stabilising agent (*example shows cement only*) is shown in the Table below:

Table 1: Matrix of RLT Tests per Aggregate/Quarry with Cement as a Stabilising Agent

RLT Mixtures to test (in order of priority)	**TNZ M4 Aggregate**	**Reason**	**[1]GAP 40 or fine side of TNZ M4 grading aggre-gate**	**Reason**
Source at 70% of OMC (dry)	1	Current basecourse used to assess typically field performance and check compliance of new TNZ M4	8	Results used to determine traffic loading limit as may be suitable for use on low volume roads
Source at 100% of OMC (wet)	2	Current basecourse used to assess sensitivity to water and check compliance of new TNZ M4	3	Results are used to compare performance when adding cement
2% Cement mixed insitu (compacted and mixed at same time) – 7 day curing – (wet – 120%OMC)	9	May wish to know the effect of cement on premium M4 aggregate	4	Determine if cement reacts well with the GAP product (ie. before proceeding to 7 day hydration in stockpile mixes) and provides design information for insitu stabilisation.
2% Cement mixed with water (120%OMC) left in stockpile for 7 days, 1% water added for compaction, 1 day cured in compacted sample	10	May wish to know the effect of cement using 7 day hydration on premium M4 aggregate. Product may be requested by some consultants for high trafficked roads	5	This process follows the same as used in Perth and is a practical way of stockpiling cement modified material at the quarry. Aim is to check if this process works with 2% cement.
1% or 3% Cement *(depends on result with 2%)* mixed with water (120%OMC) left in stockpile for 7 days, 1% water added for compaction, 1 day cured in compacted sample	11		6	This process follows the same as used in Perth and is a practical way of stockpiling cement modified material at the quarry. Aim is to check if this process works with 2% cement.
1% Cement mixed insitu (compacted and mixed at same time) – 7 day curing – (wet – 120%OMC)	12		7	Determine if 1% cement is sufficient to achieve the necessary cementation for insitu stabilisation as this is more economic

1: Note: This GAP product or fine side of TNZ M4 could be the same as the TNZ M4 Aggregate, the reason a suggested different product is used, is because those “dirtier” aggregates with more fines react better with cement, also if cement is added you may as well add it to a lower cost product.

Recommended Initial Repeated Load Triaxial Tests

Tests in Table 1 are ordered in priority and it is recommended the initial tests conducted are those numbered 1 to 6 in Table 1.

Vibrating Hammer Compaction Tests

Ideally vibrating hammer compaction tests to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are required for each aggregate mix tested in the RLT apparatus. This ensures that the RLT samples are compacted to the correct density being 95%MDD which is specified in TNZ B/2 as the minimum. However, vibrating hammer compaction tests are costly and timely exercise therefore it is usual to just test the source aggregates (ie. M4 and GAP 40) where a test result may already be available. Compactive effort to achieve 95%MDD is determined for the source aggregates, so that the same compactive effort can be applied to the cement modified mixes. When the best modified mix is determined a compaction test is recommended to obtain the target density and moisture content for compaction

Therefore for 1 source aggregate = **1(source) + 1(cement modified) = 2 vibrating hammer compact tests.**

References

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5 MILESTONE SCHEDULE AND COSTS

Each Repeated Load Triaxial test, including: sample preparation, rut depth modelling, reporting and meeting costs = $1500 + GST each.

Each vibrating hammer compaction test costs $450+GST each.

6 LOCATION OF LABORATORY EQUIPMENT

PaveSpec Ltd's Repeated Load Triaxial Testing equipment is located in the upper North Island located at a reputable Quarry owners laboratory. Tests will be run by PaveSpec Ltds staff and conducted anonymously. For 5 or more RLT tests PaveSpec Ltd will visit your site to collect samples and prepare samples on site for RLT testing.

7 BIO/CV

Dr Greg Arnold – Pavement Engineer PaveSpec Ltd

Greg Arnold has been working within the roading Industry for the past 12 years. Upon graduating from the University of Canterbury as a Civil Engineer with honours in November 1991, he accepted a position as a roading engineer for T.H. Jenkins & Associates in Christchurch. His work at T.H. Jenkins & Associates consisted primarily of: geometric road design; pavement design; RAMM (Road Assessment Maintenance Management); and development of a bridge inspection and maintenance management database. Based on his experience of forest roads, Greg obtained a position with LIRO (Logging Industry Research Organisation) in Rotorua as a Forest Road Researcher. At LIRO his responsibilities were to determine forest road research needs and then to accurately plan, undertake, manage, complete and communicate the results of forest road research projects to ensure the benefits of research are realised. Some of the research projects undertaken at LIRO were: chip seal trials on a private forest road; development of a pavement thickness design method for corduroy roads; training Foresters in forest road engineering; and development of a costing program for end-haul road construction. Several research projects undertaken at LIRO required use of the Benkelman Beam and Falling Weight Deflectometer to determine the material properties for pavement design of locally available materials used in forest roads.

In November 1996, Greg Arnold accepted a position with Transit New Zealand in the Engineering Policy Section as a Roading Engineer in Wellington. Greg was responsible for development/revision of road construction specifications and the New Zealand Supplement to the AUSTROADS Pavement Design Guide (NZ Supp.) based on industry consultation, research results and technological advances in road construction. An achievement at Transit New Zealand was the development of a pavement design procedure for rehabilitation treatments and implementation by revising the NZ Supp. and assisting in courses held throughout New Zealand to train pavement designers in the new procedure. In addition Greg has developed performance based specifications for pavement construction and materials.

Greg Arnold holds a Bachelor of Engineering (honours) degree from the University of Canterbury and a APSARC (Australasian Pavement Studies And Research Centre) Masters of Technology in Pavements. Greg has also completed his PhD in Engineering in 2004 at the University of Nottingham on a research project developing pavement design methodologies based on the shakedown theory. The pavement modelling work investigating the shakedown theory will be relevant for this research project.

In 2003/2004 Dr Arnold was the director of Pavespec Ltd whom had analysed and reported the results for the Transfund Mass Limits project at CAPTIF for Transit New Zealand.

Dr Arnold was the Engineering Policy Manager, Transit New Zealand whom has managed and been the researcher in various Land Transport Research projects for Transit New Zealand, including:

Project #	Project Title
1/05/30	Performance Tests for Road Aggregates and Alternative Materials
1/05/32	OECD Project Phase II: Design and Testing of Long Life Wearing Courses
1/05/29	The design of stabilised pavements in New Zealand
	Fatigue Design Criteria for Low Noise Surfacings

	FRST funded: High Performance Roading : Effect of Shoulder Support
	Austroads funded: Optimum use of granular bases. ($1.2M over 4 years)
1/05/15	Construction of waterproof pavement surfacings
1/05/18	Compaction of thick granular layers
1/05/19	Prediction of pavement remaining life
1/05/20	Selection of aggregates for skid resistance
4/05/03	Assessing the environmental impact of new and recycled materials in road construction
4/05/17	Environmental Impact of Industrial By-products in Road Construction - A literature review.
1/05/39	Flexural Modulus of Typical New Zealand Asphalt Mixes
1/05/11	Benchmarking Pavement Performance Between Transit's LTPP and CAPTIF Programs

Earlier Transfund research projects that Greg Arnold has been involved via project management and as a technical advisor in include:

- **PR3 – 0404 - *Relationships between Laboratory Predicted Performance and In-Service Performance of Unbound Granular Pavements Based on Measured Stresses and Strains* combined with *Increase in Mass Limits Effect on Pavement Wear***
- **PR3 – 0312 – ALF/CAPTIF Cross Trials**
- **PR3-0032 - Subgrade for use at CAPTIF**
- **PR3-0094 - Dynamic Wheel Loads and Pavement Wear (CAPTIF project)**
- **PR3 - 0171 - Pavement Asset Evaluation and Depreciation**
- **Performance Based Specifications Using The FWD - Stage 1 – Comparison of Computed to Measured Strains and CIRCLY Analysis of FWD/ELMOD Derived Moduli**
- **PR3 - 0188 - Application of Austroad's Pavement Design Guide for Wanganui Materials**
- **PR3 - 0150 - Moisture in Pavements and its Influence on Strength**
- **PR3 - 0165 - Literature Review for the Design of Pavements Incorporating a Stabilised Subgrade Layer**
- **Pavement Density**
- **Characterisation of New Zealand Subgrades**
- **Dynamic Load Properties of New Zealand Basecourses**
- **Loadman Portable Falling Weight Deflectometer – *Transfund Research Reports No.s 124 and 125***
- **Mechanistic Design of Pavements Incorporating a Stabilised Subgrade - *Transfund Research Reports No. 127***
- **Survey of New Zealand Roading Authorities**
- **Fibre Reinforcement of Stabilised Basecourse**

Greg Arnold was an active member in the following Austroads Reference Groups: stabilised and unbound materials; Austroads Pavement Design Guide.

Major publications

Arnold, G., Alabaster, D.A., Steven, B.D. 2006 (in press). Effect on Pavement Wear of an Increase in Mass Limits for Heavy Vehicles – Concluding Report. Land Transport New Zealand Research Report.

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