NOTES TO THE SPECIFICATION FOR REPEATED LOAD TRIAXIAL (RLT) TESTING FOR PAVEMENT MATERIALS

1. SCOPE

This specification details the 6 stage permanent strain Repeated Load Triaxial (RLT) test. The RLT test results can be used to determine design strain criterion (Arnold and Werkmeister, 2010b) for base and subbase materials (modified and unmodified) as detailed in NZTA Research Report: *Research report 429 Development of a basecourse/sub-base design criterion* http://www.nzta.govt.nz/resources/research/reports/429/index.html.

Modified and bound materials should also be checked to have an appropriate thickness and underlying support to maintain strength and not return to an unbound material as determined using an appropriate tensile strain criterion. This requires the stabilised tensile strength to be measured either by a flexural beam test or approximated from ITS (Indirect Tensile Strength). The tensile strength is used to develop material specific tensile strain criteria at the bottom of the layer for use in CIRCLY Pavement Design.

The Repeated Load Triaxial test and associated analysis provides a method to simulate traffic loading on an aggregate in order to determine the number of wheel loads required to reach a limiting pavement rut depth. See Appendix B for a more detailed description of the Repeated Load Triaxial apparatus and uses.

The intention is three fold:

A. To enable those aggregates that do not meet NZTA M/4 requirements to be used in place of premium aggregates (NZTA M/4) on low volume roads.

B. To reduce the risk of early pavement failure by only using those aggregates on high trafficked roads, which are proven suitable as determined by Repeated Load Triaxial testing and associated pass/fail criteria in NZTA M4 (2012).

C. Allow the use of modified/chemically-stabilised aggregates as a means of utilising good quality aggregates that are moisture sensitive when unmodified in high trafficked areas.

Appendix A details an example of the technical data sheet that must be completed as part of the specification NZTA T/15 for acceptance in NZTA M/4 (2012).

2. GENERAL

The aim of sampling is to ensure a specimen is obtained that is typical of what is produced at the quarry. This sample is used in the RLT test and the aggregate grading and other properties will be used to specify production limits if outside those in NZTA M4 (2012). Therefore, it is important that the sample is in the mid-range of what is typically produced.

Regular grading tests are recommended to establish the grading in the middle of typical production runs. The sample used for RLT testing is then separated into various sieve sizes and re-blended to match the middle grading run determined.

Monitoring gradings from production should be undertaken to enable production limits to be established. If these production limits are outside the range allowed for in NZTA M/4 then two more RLT tests are recommended on samples manufactured to the two extremes of the grading envelope together with the middle of the grading envelope (fine and coarse sides). The RLT result with the highest permanent strain rate will be used for determining the acceptability of the aggregates. Despite the emphasis on grading it has been found that small variations similar to the range of gradings allowed in NZTA M4 (2012) specification has little effect on resulting performance in the Repeated Load Triaxial test.

For modified materials RLT test can be sampled from production runs or manufactured in the laboratory.

2.1 References

If interested, the research behind the development of the RLT test is found in Arnold's thesis and Werkmeister's thesis and the 2007 Land Transport Report Performance Tests for Road Aggregates and Alternative Materials (Arnold, Werkmeister and Alabaster, 2007). Interpretation for pavement design is given in the updated 2010 New Zealand Supplement to the 2004 Austroads Pavement Design Guide and in the recent research reports detailed below:

Arnold et. al. (2007) refers to: Arnold, G., Werkmeister, S., Alabaster, D (2007). *Performance Tests for Road Aggregates and Alternative Materials.* Land Transport New Zealand Research Report.

Arnold, G. and Werkmeister, S. (2010a). Pavement Thickness Design Charts Derived from a Rut Depth Finite Element Model. New Zealand Transport Agency Research Report 427. 2010.

Arnold, G. and Werkmeister, S. (2010b). Development of a Basecourse/Subbase Design Criterion. New Zealand Transport Agency Research Report 429. 2010.

AUSTROADS (2004) refers to the document *Pavement Design - A Guide to the Structural Design of Road Pavements*. Austroads, Melbourne, Australia. 2004.

The New Zealand Supplement (2007) refers to the *New Zealand Supplement to Austroads Pavement Design - A Guide to the Structural Design of Road Pavements (2004)*. New Zealand Transport Agency (NZTA), Wellington, New Zealand. 2007.

3. REPEATED LOAD TRIAXIAL TEST

3.1 Repeated Load Triaxial Apparatus

Repeated Load Triaxial apparatus require calibration of the measuring instruments used (pressure, cell, LVDTs and load cell) every two years being typical calibration period for these types of instruments. The RLT apparatus requires skilled and experienced operators along with experts to interpret the results. Therefore, there is a requirement to check with New Zealand Transport Agency first for the suitability of the Repeated Load Triaxial testing (RLT) equipment and personnel to interpret the results.

It is noted that all prior tests on aggregates in research projects for developing acceptance criteria have used external transducers (Arnold et al. 2007, 2010a, 2010b)

3.2 Sampling

Sampling is as per NZTA M/4 but it is possible to re-manufacture the grading to align with a typical mid-range grading curve as discussed in Section 2 above.

3.3 Repeated Load Triaxial (RLT) Test

The conditions specified match the current methods used in research to manufacture the specimen. This includes using external LVDTs to measure change in sample length. However, experience has shown that achieving the target density is sometimes difficult. One of the suspected reasons for this is the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are obtained with different conditions from the compaction method being applied to prepare the RLT. These differences are in relation to the vibrating hammer used; grading of the aggregate; scalping of large stones; source stones from a different part of the quarry; and addition of a modifying binder (i.e. there are MDD and OMC values for the source aggregate but not usually for the modified aggregate with binder). To minimise these differences it is recommended that the vibrating hammer compaction test be conducted on the exact same equipment and material that will be used to prepare the RLT sample. This includes any necessary scalping, and curing required if a binder is added.

Another approach to compact a sample is to apply the same compaction effort as is typical to achieve 95% of MDD. If experience/best guess is used to compact the sample then the final achieved dry density needs to be clearly reported against the RLT result, where the dry density achieved becomes the new minimum target density for use in the field.

IPC UTS017 software calculates the information required and the equations in the specification are included in the event of a different system being used.

The soaked/undrained variation of the RLT test is relatively new. The soaked/undrained test may or may not be 100% saturated. The aim is to simulate a case after heavy rain and not be too severe by forcing water in under pressure to achieve 100% saturation. If there is a concern about a material's performance when wet, then repeat tests could be conducted after soaking for 4 days, similar to the soaked CBR test. It has been found that the results of the soaked/undrained test highlights a larger range of performances in aggregates from very poor (fails in the first 4 stages) to very good, where the soaked test gives similar results to the dry RLT test.

The introduction of 6th stage loading in the RLT test (vertical = 550kPa and cell=50kPa) was primarily for modified aggregates. Most unbound aggregates will fail in this 6th stage when soaked due to lack of cell pressure, where like a sand, aggregates need confinement for strength. However, the 6th stage result does give an indication how the aggregate may perform where there is a lack of shoulder support and confinement.

3.4 Reporting

An example of a typical report from the RLT testing is included in Appendix A.

4. AVERAGE PERMANENT STRAIN SLOPE CALCULATION

4.1 General

The interpretation of RLT test results were developed from research that showed that the average permanent strain slope in the RLT test could be correlated with predicted life (traffic loading to achieve a rut depth limit) from rut depth and finite element modelling.

4.2 Average Permanent Strain Slope Determination

The first step is to determine the permanent strain slopes for each of the 6-stages of RLT test as per Table 5 of the specification. The permanent strain slope is calculated from the final 25,000 loading cycles in each stage. Permanent strain values used for calculating permanent strain slopes are shown in Figure 1. If the full 50,000 load cycles in any one stage is not completed then the load cycles where permanent strain values are measured will need to be changed, such that the later slope in the last 25k of each stage is calculated. These 5 or 6 permanent strain slopes are averaged for determining acceptability as per future pass/fail criteria in the principle requirements or the future revision of NZTA M4.

5. COMPLIANCE

The producer's quality plan and completion of the aggregate technical data sheet (example shown in Appendix A) is recommended to accompany all RLT test results.

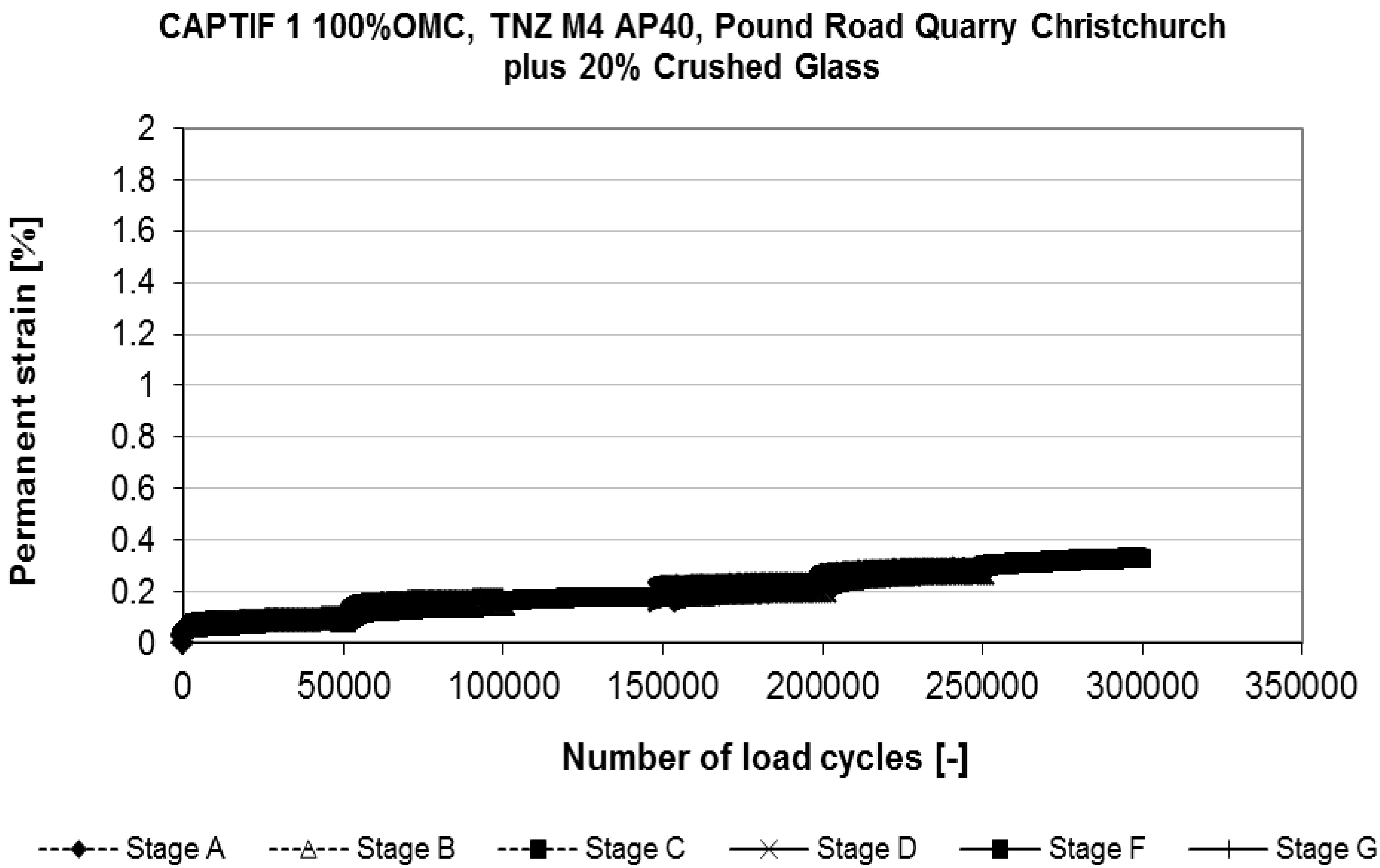
APPENDIX A

EXAMPLE TECHNICAL DATA SHEET FOR AGGREGATE TESTED IN THE REPEATED LOAD TRIAXIAL APPARATUS

Repeated Load Triaxial as per NZTA T/15 Test Report # (Rut Depth prediction report # PRD00xx_070308v1) – note this report is partially fictitious so cannot be used for compliance with NZTA M/4			
TEST	**TEST NO**	**DESCRIPTION**	**LAB TEST REF#/ REPORT**
QUARRY NAME, LOCATION AND OWNER	Clause 3.0 NZTA T/15	Pound Road Quarry, Christchurch Fulton Hogan PO Box xxx Christchurch Contact Person: Jo Blogs Ph: Email:	PRD00xx_070308v1
MATERIAL NAME IDENTIFIER	Clause 3.0 NZTA T/15	Pound Road Quarry, AP40 plus 20% crushed glass (< 4.75 mm)	PRD00xx_070308v1
AGGREGATE DESCRIPTION AND SOURCE LOCATION IN QUARRY	Clause 3.0 NZTA T/15	Standard production run NZTA M/4 AP40 Greywacke with the addition of up to 20% by mass of crushed glass (< 4.75 mm) with no adjustments to grading of the source aggregate	
SAMPLE LOCATION AND DATE	Clause 3.0 NZTA T/15	Routine sample collect on 1/02/07	
REPEATED LOAD TRIAXIAL TEST LABORATORY USED	Clause 3.0 and 4.0 NZTA T/15	Dr Sabine Werkmeister Civil Engineering University of Canterbury Christchurch Email: sabine.werkmeister@canterbury.ac.nz	Lab Report #: CIVENG_00132_061207
LABORATORY USED FOR OTHER TESTS	NZTA M/4 and NZS 4402 Test 4.1.3	Fulton Hogan Laboratory Pound Road Christchurch	
DATE OF REPEATED LOAD TRIAXIAL TEST	Clause 3.0 NZTA T/15	6/11/2006	
WEATHERING QUALITY INDEX	NZS 4407 Test 3.11	AA	
CRUSHING RESISTANCE	NZS 4407 Test 3.10	160kN	
CALIFORNIA BEARING RATIO	NZS 4407 Test 3.15	130%	
BROKEN FACE CONTENT	NZS 4407 Test 3.14	80%	
QUALITY OF FINES			
SAND EQUIVALENT (SE) OR	NZS 4407 Test 3.6	50	
CLAY INDEX (CI) ON FRACTION PASSING 75 μm SIEVE	NZS 4407 Test 3.6	NA *(Non Plastic)*	
PLASTICITY INDEX (PI) ON FRACTION PASSING 425 μm SIEVE	NZS 4407 Test 3.4	NA *(Non Plastic)*	
WET SIEVING TEST	NZS 4407 Test 3.8.1	Record the PSD of the basecourse or modified basecourse material	
TEST SIEVE APERTURE		AP40 PSD Before Glass Added	

Repeated Load Triaxial as per NZTA T/15 Test Report # (Rut Depth prediction report # PRD00xx_070308v1) – note this report is partially fictitious so cannot be used for compliance with NZTA M/4			
TEST	**TEST NO**	**DESCRIPTION**	**LAB TEST REF#/ REPORT**
37.5 mm 26.5 mm 19 mm 9.5 mm 4.75 mm 2.36 mm 1.18 mm 600 µm 300 µm 150 µm 75 µm		100 83 69 47 32 22 15 10 7 5 3	FH_Lab_Test_No.XXXXX
TEST SIEVE APERTURE		AP40 PSD After 20% by Mass Glass Added	
37.5 mm 26.5 mm 19 mm 9.5 mm 4.75 mm 2.36 mm 1.18 mm 600 µm 300 µm 150 µm 75 µm		100 86 74 56 41 25 16 10 7 4 3	FH_Lab_Test_No.XXXXX
CRUSHED GLASS		Crushed glass complies with NZTA M/4:2006 Regional Variant for AGGREGATE/RECLAIMED GLASS BLENDED BASECOURSE 20% Crushed Glass by Mass of Aggregate was added to the source AP40 aggregate	
CRUSHED GLASS PSD TEST SIEVE APERTURE		PSD of Crushed Glass Cullet	
9.5 mm 4.75 mm 2.36 mm 1.18 mm 600 µm 300 µm 150 µm 75 µm		100 85 43 22 10 6 2 1	FH_Lab_Test_No.XXXXX
STABILISED/MODIFIED MATERIALS			
BINDER TYPE AND CONTENT	NZTA T/15 Clause 3.0 (Table 1)	NA	
BINDER MIXING METHOD	NZTA T/15 Clause 3.0 (Table 1)	NA	
CURING METHOD	NZTA T/15 Clause 3.0 (Table 1)	NA	
OTHER REQUIREMENTS			

Repeated Load Triaxial as per NZTA T/15 Test Report # (Rut Depth prediction report # PRD00xx_070308v1) – note this report is partially fictitious so cannot be used for compliance with NZTA M/4			
TEST	**TEST NO**	**DESCRIPTION**	**LAB TEST REF#/ REPORT**
OPTIMUM MOISTURE CONTENT (OMC)	NZS 4402 Test 4.1.3	4.7%	
MAXIMUM DRY DENSITY (MDD)	NZS 4402 Test 4.1.3	2.05 t/m^3	
MOISTURE CONTENT IN RLT TEST	NZS 4407 Test 3.1	4.7% (100%OMC)	
DRY DENSITY (DD) IN RLT TEST	NZTA T/15 Clause 3.0	1.95 t/m^3 (95%MDD)	
Average Slope – 1st 5 stages	NZTA T/15 2012 Clause 4.0	Average slope 0.29 %/1Million Date of RLT test: 6/11/2006	PRD00xx_070308v1
Average Slope – all 6 stages	NZTA T/15 2012 Clause 4.0	Average slope 0.55 %/1Million Date of RLT test: 6/11/2006	PRD00xx_070308v1


CAPTIF 1 100%OMC, TNZ M4 AP40, Pound Road Quarry Christchurch
plus 20% Crushed Glass
Permanent strain [%]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50000
100000
150000
200000
250000
300000
350000
Number of load cycles [-]
Stage A
Stage B
Stage C
Stage D
Stage F
Stage G

APPENDIX B

LIST OF Available LABORATORIES TO undertake NZTA T15

To date (2014) there are only three RLT testing apparatuses in New Zealand suitable for the testing specified in NZTA T/15:2014, these are:

Fulton Hogan (email: chris.wright@fultonhogan.com)

Opus Research (email: rosslyn.mclachlan@opus.co.nz),

Road Science (email: greg.arnold@roadscience.co.nz).

Once every 2 years round robin testing is required for all Repeated Load Triaxial apparatuses. These apparatuses shall test the same aggregate as per T15:2014 and results submitted to NZTA's Principal Pavement Engineer (david.alabaster@nzta.govt.nz) for approval to test.