Civil Sciences & Engineering

NRB001 Natural Roadbase Material

Alternative Basecourse Specification

BGC

Prepared for BGC Quarries

16 March 2023

Project Number: CSE22056

Approval for Release		
Name	**Position**	**File Reference**
Colin Leek	Principal Engineer	CSE22056_NRB001_Natural_Roadbase_Material_ Alternative_ Basecourse_Specification_1.6
Signature		

Table of Contents

1 Introduction 1

2 Laboratory testing 2

3 Analysis of Results 4

4 Conclusion 5

List of Tables

Table 2-1: MRWA PSD limits and lab result 2

Table 2-2: MRWA limits and lab results 3

Table 2-3: Resilient modulus test results 3

Table 4-1: Specified grading limits for BGC NRB001 Natural Roadbase 5

Table 4-2: Other limits for BGC NRB001 Natural Roadbase 6

1 Introduction

BGC Quarries have engaged Civil Sciences and Engineering (CSE) to undertake an analysis on crushed granite natural roadbase (NRB001) to be used as an alternative basecourse material.

Recent projects have successfully implemented the use of this material as a basecourse alternative. BGC propose an assessment of this material is carried out using relevant State Road authority specifications to determine its viability.

BGC have recently carried out laboratory testing on the crushed rock material. This data will be used in the assessment of this product.

The material tested is a crushed granite residue from the manufacture of granite aggregates for use as a key material for the manufacture of concrete from the BGC Quarry at the Lakes on Great Southern Highway.

2 Laboratory testing

Over the last 12 months BGC have carried out laboratory testing on the crushed rock material; this data has been provided to CSE to analyse the material.

Laboratory testing includes particle size distribution (PSD), consistency limits (LL) (LS), maximum dry density compaction (MDD), California Bearing Ratio (CBR), maximum dry compressive strength (MDCS), Los Angeles abrasion (LA), Flakiness Index (FI), Wet/Dry strength variation (W/D) and resilient modulus (RLT).

These test results have been evaluated against Main Roads Western Australia (MRWA) limits for crushed rock base basecourse, Specification 501 Pavements – Table 501.09 and Table 501.10. Table 2.1 compares the average PSD against the MRWA limits. Table 2.2 displays the average LL, LS, CBR, FI, MDCS, LA, W/D and RLT obtained from the testing against the MRWA roadbase limits. Appendix A contains the full laboratory testing results.

Table 2-1: MRWA PSD limits and lab result

AS Sieve Size (mm)	% Passing by mass Minimum and Maximum Limits	% Passing by mass
	Crushed Rock Base Basecourse MRWA limits	Average PSD of BGC samples tested
26.5	100	100
19.0	95 – 100	100
13.2	70 – 90	94
9.5	60 – 80	82
4.75	40 – 60	61
2.36	30 – 45	47
1.18	20 – 35	36
0.600	13 – 27	28
0.425	11 – 23	24
0.300	8 – 20	20
0.150	5 – 14	13
0.075	5 – 11	9
Dust ratio	0.35 – 0.60	0.37

Table 2-2: MRWA limits and lab results

Test	Crushed Rock Base Basecourse limits	Average test result
Liquid Limit	25% Max	23%
Linear Shrinkage	2.0% Max 0.4% Min	0.3%
Flakiness Index	30% Max	28%
Los Angeles Abrasion	35% Max	31%
Maximum Dry Compressive Strength	1.7 MPa Min	2.5 MPa
California Bearing Ratio	100% Min	190%
Wet/Dry Strength Variation	35% Max	2%
Resilient Modulus	500 – 700 MPa Min*	628

*The resilient modulus limits are based on Main Roads WA guidelines for a base material with a mean normal stress of 240 kPa and octahedral shear stress of 120 kPa in accordance with Engineering Road Note 9 and Austroads Guide to Pavement Technology Part 2 Pavement Structural Design.

Additional resilient modulus testing was carried out on samples at the lower and upper grading limits presented in Table 4-1. Table 2-3 shows the additional modulus test results.

Table 2-3: Resilient modulus test results

	Lower Grading Limit	Upper Grading Limit
Specimen 1 (MPa)	557	535
Specimen 2 (MPa)	580	514
Specimen 3 (MPa)	608	505
Average (MPa)	582	518

The test results demonstrate the material resilient moduli are acceptable for the specification grading limits in Table 4-1. Main Roads and Austroads specify a minimum resilient modulus range of 500 to 700 MPa for crushed rock basecourse material. It should be noted moduli of unbound granular material are highly stress dependent. If in service stress levels are likely to differ from testing conditions, then modulus values must be extrapolated to ensure minimum requirements are met.

3 Analysis of Results

The particle size distribution is marginally non-compliant with MRWA specified base course limits for granite roadbase. The greatest discrepancy is for the percent passing the 13.2mm sieve where approximately 4% by mass exceeds the allowable percentage passing that sieve. The remaining non-compliant percent passing specified sieve sizes are only outside the limits by 1 or 2 percent. All the non-conforming sizes breach the upper limit of percentage passing which demonstrates the material is slightly fine when compared to crushed rock basecourse limits.

The other testing metrics however demonstrate the material is suitable for basecourse application. The MDCS, CBR and RLT results are performance tests as these tests better indicate the material in-service performance. The average CBR is almost twice as much as the MRWA requirement while the MDCS and resilient modulus are also an acceptable level.

It should be noted, all CBR samples were compacted to 99% of MMDD and soaked for 4 days with 6.75kg surcharge. Basecourse material should be CBR tested with a surcharge of 4.5kg, as surcharge effects CBR the following adjustment has been done.

Razouki and Al-Shefi (2001) undertook research into the effects of surcharge on the CBR value, as CBR increases with surcharge. The relationship developed was:

$$CBR_L/CBR_{45} = 0.00494S + 0.78$$

where: CBR_{45} = CBR at 45 N = 4.5 kg

S = surcharge load in N

CBR_L = CBR at surcharge N

The adjusted average CBR for 4.5kg surcharge is 170%, which is a decrease from the 190% average value when tested with 6.75kg surcharge however it is still above the basecourse minimum limit.

Linear shrinkage does not meet the minimum requirement for base material, and this is the most significant departure from the specification.

The average linear shrinkage is 0.3% which does not meet the 0.4% limit, with the majority of the samples having 0% shrinkage.

Section 501.11 Clause 8 of MRWA Specification 501 states that crushed rock base shall be thoroughly mixed with water using a pugmill to produce a homogeneous product suitable for placement into final position, this would be applicable if the material is to be paver laid, but it does make for very expensive water. It is more economic for grader mixing to add the water on site. BGC confirm they will not be using a pugmill in the manufacture.

VicRoads specification, *812 Crushed Rock for Pavement Base and Subbase*, requires a PI of 2% to 6% for Class 1 crushed rock for use under thin asphalt and spray seals, and for Class 2 under the same traffic conditions but thicker asphalt the PI range is 0% to 6%.

Transport for NSW, *QA Specification 3051*, has similar requirements for Class 1 and Class 2, but the Class 2 material minimum PI limit only applies for use under spray seals.

VicRoads and Transport for NSW use PI as the basis for determining material cohesion, while MRWA use LS, however the objective is the same.

4 Conclusion

Based on the test data supplied, the BGC material achieves high CBR and modulus tests in the RLTT which are typically indicative of a material's structural performance. However, the grading does not conform with MRWA limits and the requirements for linear shrinkage.

Classification testing such as PSD and Atterberg Limits are simple and inexpensive index tests which are used to determine if a particular material is consistent with a material of the same source that has shown to meet performance-based tests such as CBR and RLTT or has shown that the material has performed historically well in the past based on observation or field testing with devices such as the Falling Weight Deflectometer. Classification testing is empirical and therefore does not directly correlate to material performance. Laboratory CBR and RLT testing has been carried out to increase the performance data set which in turn allows the classification testing ranges to be adjusted accordingly. The upper and lower grading limits have had RLT testing done to confirm the resilient modulus conforms to basecourse requirements.

The BGC NRB001 Crushed Rock material is suitable as a granular basecourse for all pavements under asphalt which includes thin surfacing and full depth applications. The crushed rock material however is not suitable for spray seal surfaced pavements due to the zero linear shrinkage. Further testing is currently being carried out to determine its viability under spray sealed pavements.

The PSD limits shown in Table 4-1 have been derived from the MRWA crushed rock subbase limits – *Specification 501, Table 501.05*. Resilient modulus testing on the upper and lower grading limits have confirmed this material is suitable as a basecourse under asphalt surfacing. These grading limits form the specification for this material. Other specification limits for NRB001 Natural Roadbase are shown in Table 4-2.

Table 4-1: Specified grading limits for BGC NRB001 Natural Roadbase

AS Sieve Size (mm)	Percentage Passing (%)
26.5	100
19.0	95 – 100
9.5	60 – 85
4.75	40 – 70
2.36	30 – 55
1.18	20 – 42
0.600	13 – 32
0.425	11 – 28
0.300	8 – 25
0.150	5 – 20
0.075	5 – 15

Table 4-2: Other limits for BGC NRB001 Natural Roadbase

Test	Limits
Liquid Limit	25% Max
Linear Shrinkage	2.0% Max 0.0% Min
Flakiness Index	30% Max
Los Angeles Abrasion	35% Max
Maximum Dry Compressive Strength	1.7 MPa Min
California Bearing Ratio	100% Min
Wet/Dry Strength Variation	35% Max
Resilient Modulus	500 – 700 MPa Min

Conformance testing shall be carried out in accordance with *Main Roads WA Specification 201 – Quality Management, Table 201A-4* for basecourse material.

Appendix A – Test Results

A1 - Stockpile Lot 89 lab results relative to MRWA Specification 501 limits

AS Sieve Size (mm)	% Passing by mass Minimum and Maximum Limits		Percentage Passing (%)				
	Crushed Rock Base Subbase	Crushed Rock Base Basecourse	21 BGC Q 2711	21 BGC Q 2722	21 BGC Q 2804	21 BGC Q 2810	21 BGC Q 2891
26.5	100	100	100	100	100	100	100
19.0	95 – 100	95 – 100	99	100	100	100	99
13.2		70 – 90	95	95	95	93	92
9.5	60 – 85	60 – 80	85	83	83	78	79
4.75	40 – 70	40 – 60	66	57	62	53	56
2.36	30 – 55	30 – 45	53	42	48	40	43
1.18	20 – 42	20 – 35	41	33	36	31	34
0.600	13 – 32	13 – 27	32	26	29	24	26
0.425	11 – 28	11 – 23	28	23	25	21	22
0.300	8 – 25	8 – 20	24	19	21	18	18
0.150	5 – 20	5 – 14	15	12	14	12	11
0.075	5 – 15	5 – 11	10	8	10	8	7

Test	Crushed Rock Base Basecourse limits	21 BGC Q 2711	21 BGC Q 2722	21 BGC Q 2804	21 BGC Q 2810	21 BGC Q 2891
Liquid Limit	25% Max	23%	24%	22%	22%	23%
Linear Shrinkage	2.0% Max 0.4% Min	1.0%	1.0%	0.0%	0.0%	0.2%
Flakiness Index	30% max	-	-	-	-	-
Los Angeles Abrasion	35% Max	-	-	-	-	31%
Maximum Dry Compressive Strength	1.7 MPa Min	-	-	-	-	1.74 MPa
California Bearing Ratio	100% Min	-	-	-	-	230%
Wet/Dry Strength Variation	35% Max	-	-	-	-	-
Resilient Modulus	600 MPa*	-	-	-	-	-

A2 - Stockpile Lot 90 lab results relative to MRWA Specification 501 limits

AS Sieve Size (mm)	% Passing by mass Minimum and Maximum Limits		Percentage Passing (%)				
	Crushed Rock Base Subbase	Crushed Rock Base Basecourse	21 BGC Q 2922	21 BGC Q 2947	21 BGC Q 2951	22 BGC Q 53	22 BGC Q 73
26.5	100	100	100	100	100	100	100
19.0	95 – 100	95 – 100	100	100	100	100	99
13.2		70 – 90	94	93	94	94	94
9.5	60 – 85	60 – 80	85	80	82	83	83
4.75	40 – 70	40 – 60	65	56	59	62	61
2.36	30 – 55	30 – 45	50	41	46	49	46
1.18	20 – 42	20 – 35	37	31	35	38	35
0.600	13 – 32	13 – 27	27	24	26	30	27
0.425	11 – 28	11 – 23	23	21	22	26	24
0.300	8 – 25	8 – 20	20	17	19	22	20
0.150	5 – 20	5 – 14	13	12	12	14	13
0.075	5 – 15	5 – 11	9	8	8	9	8

Test	Crushed Rock Base Basecourse limits	21 BGC Q 2922	21 BGC Q 2947	21 BGC Q 2951	22 BGC Q 53	22 BGC Q 73
Liquid Limit	25% Max	22%	22%	23%	23%	22%
Linear Shrinkage	2.0% Max 0.4% Min	0.0%	0.0%	1.0%	0.0%	0.0%
Flakiness Index	30% Max	-	-	-	-	-
Los Angeles Abrasion	35% Max	-	-	-	32%	-
Maximum Dry Compressive Strength	1.7 MPa Min	-	-	-	2.82 MPa	-
California Bearing Ratio	100% Min	-	-	-	210%	-
Wet/Dry Strength Variation	35% Max	-	-	-	-	-
Resilient Modulus	600 MPa*	-	-	-	-	-

A3 - Stockpile Lot 91 lab results relative to MRWA Specification 501 limits

AS Sieve Size (mm)	% Passing by mass Minimum and Maximum Limits		Percentage Passing (%)				
	Crushed Rock Base Subbase	Crushed Rock Base Basecourse	22 BGC Q 363	22 BGC Q 285	22 BGC Q 184	22 BGC Q 175	22 BGC Q 123
26.5	100	100	100	100	100	100	100
19.0	95 – 100	95 – 100	100	100	100	100	100
13.2		70 – 90	93	95	96	93	93
9.5	60 – 85	60 – 80	84	85	85	83	81
4.75	40 – 70	40 – 60	61	67	62	63	58
2.36	30 – 55	30 – 45	46	52	47	49	44
1.18	20 – 42	20 – 35	35	41	36	37	33
0.600	13 – 32	13 – 27	27	31	27	28	25
0.425	11 – 28	11 – 23	23	26	23	24	21
0.300	8 – 25	8 – 20	20	21	19	21	18
0.150	5 – 20	5 – 14	13	14	13	13	12
0.075	5 – 15	5 – 11	9	9	8	9	8

Test	Crushed Rock Base Basecourse limits	22 BGC Q 363	22 BGC Q 285	22 BGC Q 184	22 BGC Q 175	22 BGC Q 123		
Liquid Limit	25% Max	21%	21%	21%	23%	23%		
Linear Shrinkage	2.0% Max 0.4% Min	0.0%	0.0%	0.0%	0.5%	1.0%		
Flakiness Index	30% Max	-	-	-	-	-		
Los Angeles Abrasion	35% Max	-	31%	-	-	-		
Maximum Dry Compressive Strength	1.7 MPa Min	2.51 MPa	-	-	-	-		
California Bearing Ratio	100% Min	190%	-	-	-	-		
Wet/Dry Strength Variation	35% Max	-	-	-	-	-		
Resilient Modulus	600 MPa*	-	-	-	-	623	645	617

A4 - Stockpile Lot 92 lab results relative to MRWA Specification 501 limits

AS Sieve Size (mm)	% Passing by mass Minimum and Maximum Limits		Percentage Passing (%)				
	Crushed Rock Base Subbase	Crushed Rock Base Basecourse	22 BGC Q 545	22 BGC Q 544	22 BGC Q 518	22 BGC Q 418	22 BGC Q 406
26.5	100	100	100	100	100	100	100
19.0	95 – 100	95 – 100	100	100	100	99	100
13.2		70 – 90	93	95	95	93	96
9.5	60 – 85	60 – 80	82	84	83	81	83
4.75	40 – 70	40 – 60	63	64	60	58	58
2.36	30 – 55	30 – 45	50	51	46	42	43
1.18	20 – 42	20 – 35	39	40	35	30	34
0.600	13 – 32	13 – 27	30	31	26	22	26
0.425	11 – 28	11 – 23	25	26	22	19	22
0.300	8 – 25	8 – 20	21	22	19	15	19
0.150	5 – 20	5 – 14	14	15	12	10	12
0.075	5 – 15	5 – 11	10	10	8	7	8

Test	Crushed Rock Base Basecourse limits	22 BGC Q 545	22 BGC Q 544	22 BGC Q 518	22 BGC Q 418	22 BGC Q 406
Liquid Limit	25% Max	22%	23%	23%	22%	22%
Linear Shrinkage	2.0% Max 0.4% Min	0.0%	0.0%	0.0%	0.0%	0.0%
Flakiness Index	30% Max	-	-	-	-	27%
Los Angeles Abrasion	35% Max	33%	-	-	-	-
Maximum Dry Compressive Strength	1.7 MPa Min	-	-	-	-	-
California Bearing Ratio	100% Min	-	-	-	-	-
Wet/Dry Strength Variation	35% Max	-	-	-	-	2%
Resilient Modulus	600 MPa*	-	-	-	-	-

A5 - Stockpile Lot 93 lab results relative to MRWA Specification 501 limits

AS Sieve Size (mm)	% Passing by mass Minimum and Maximum Limits		Percentage Passing (%)				
	Crushed Rock Base Subbase	Crushed Rock Base Basecourse	22 BGC Q 546	22 BGC Q 564	22 BGC Q 565	22 BGC Q 575	22 BGC Q 576
26.5	100	100	100	100	100	100	100
19.0	95 – 100	95 – 100	100	100	100	100	100
13.2		70 – 90	94	94	94	92	92
9.5	60 – 85	60 – 80	83	83	83	82	82
4.75	40 – 70	40 – 60	65	65	65	62	62
2.36	30 – 55	30 – 45	52	52	52	49	49
1.18	20 – 42	20 – 35	40	40	40	39	39
0.600	13 – 32	13 – 27	31	31	31	30	29
0.425	11 – 28	11 – 23	27	26	26	26	25
0.300	8 – 25	8 – 20	23	22	22	22	21
0.150	5 – 20	5 – 14	15	14	14	15	14
0.075	5 – 15	5 – 11	10	10	10	10	9

Test	Crushed Rock Base Basecourse limits	22 BGC Q 546	22 BGC Q 564	22 BGC Q 565	22 BGC Q 575	22 BGC Q 576
Liquid Limit	25% Max	22%	23%	23%	23%	23%
Linear Shrinkage	2.0% Max 0.4% Min	0.0%	0.0%	0.5%	1.0%	1.0%
Flakiness Index	30% Max	-	-	-	-	-
Los Angeles Abrasion	35% Max	-	31%	-	-	-
Maximum Dry Compressive Strength	1.7 MPa Min	2.87 MPa	-	-	-	1.59 MPa
California Bearing Ratio	100% Min	220%	-	-	-	210%
Wet/Dry Strength Variation	35% Max	-	-	-	-	-
Resilient Modulus	600 MPa*	-	-	-	-	-

A6 - Stockpile Lot 94 lab results relative to MRWA Specification 501 limits

AS Sieve Size (mm)	% Passing by mass Minimum and Maximum Limits		Percentage Passing (%)				
	Crushed Rock Base Subbase	Crushed Rock Base Basecourse	22 BGC Q 620	22 BGC Q 624	22 BGC Q 626	22 BGC Q 668	22 BGC Q 576
26.5	100	100	100	100	100	100	100
19.0	95 – 100	95 – 100	99	99	100	99	100
13.2		70 – 90	89	94	93	90	93
9.5	60 – 85	60 – 80	74	85	81	77	82
4.75	40 – 70	40 – 60	55	65	62	53	59
2.36	30 – 55	30 – 45	43	53	48	39	45
1.18	20 – 42	20 – 35	34	40	36	30	33
0.600	13 – 32	13 – 27	27	31	27	25	25
0.425	11 – 28	11 – 23	23	26	23	22	22
0.300	8 – 25	8 – 20	20	22	19	19	18
0.150	5 – 20	5 – 14	13	15	13	12	12
0.075	5 – 15	5 – 11	8	10	9	8	8

Test	Crushed Rock Base Basecourse limits	22 BGC Q 620	22 BGC Q 624	22 BGC Q 626	22 BGC Q 668	22 BGC Q 576
Liquid Limit	25% Max	23%	24%	23%	23%	22%
Linear Shrinkage	2.0% Max 0.4% Min	0.0%	1.0%	0.0%	0.0%	0.0%
Flakiness Index	30% Max	-	-	29%	-	-
Los Angeles Abrasion	35% Max	-	-	31%	-	-
Maximum Dry Compressive Strength	1.7 MPa Min	-	-	3.2 MPa	-	-
California Bearing Ratio	100% Min	-	-	100%	-	-
Wet/Dry Strength Variation	35% Max	-	-	-	-	-
Resilient Modulus	600 MPa*	-	-	-	-	-

62-64 Wittenberg Drive

Canning Vale, 6155 WA

admin@civilse.com.au