

26 February 2016



Bam Stone Pty Ltd
P.O. Box 156
Port Fairy VIC 3284

Attention: Mr. Tony Rowe

Bamstone Bluestone

- Evaluation of Bamstone Bluestone

Client reference: Req. T Rowe

Our reference: BAM0315-1A

Investigating officers: James P. Mann, Kate Tonkin, Mark Milevski & Ian Pontifex

Report prepared by: James P. Mann & Mark Milevski

Amended: This report replaces report BAM0315-1 dated 13th of April 2015 due to the correction of a test method used. Please dispose of any previous copies.

James P Mann
Laboratory Manager



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1. INTRODUCTION

Stone Initiatives received a request from the client to evaluate samples of Bam Stone Bluestone. The samples were identified as the following:

- Bam Stone Bluestone (basalt) - our reference B90

2. EVALUATION

The aim of the investigation was to determine the fitness for purpose of the stone type based on an evaluation of the basic physical properties. The tests carried out were:

- Water Absorption / Bulk Specific Gravity
- Flexural Strength
- Unconfined Compressive Strength
- Abrasion Resistance
- Slip Resistance
- Petrographic Examination

Water absorption and bulk specific gravity were determined on sections of the honed samples of each stone type in accordance with ASTM C97-09 "Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone". The specimens had been dried at $60 \pm 2^\circ\text{C}$ for 48 hours followed by soaking at $22 \pm 2^\circ\text{C}$ for a further 48 hours. Specimen size was modified due to sample thickness supplied.

The flexural strength of each specimen was determined in accordance with ASTM C880-09 "Standard Test Method for Flexural Strength of Dimension Stone". The dry specimens had been dried at $60 \pm 2^\circ\text{C}$ for 48 hours prior to testing. The soaked specimens had been immersed in water for 48 hours at $22 \pm 2^\circ\text{C}$.

Unconfined compressive strength was determined on each of the stone types in accordance with ASTM C170-09 "Standard Test Method for Compressive Strength of Dimension Stone". The dry specimens had been dried at $60 \pm 2^\circ\text{C}$ for 48 hours prior to testing. The soaked specimens had been immersed in water for 48 hours at $22 \pm 2^\circ\text{C}$.

Index of Abrasion Resistance was determined in accordance with ASTM C1353-09 "Test Method for Abrasion Resistance of Dimension Stone by the Taber Abraser". Three representative specimens were subjected to 1000 cycles using H-22 wheels with a 1kg load.

As required by the project specification, slip resistance was determined in accordance with AS4586:2013 "Slip resistance classification of new pedestrian surface materials". Testing was carried out at five sites in a wet condition using a British Pendulum fitted with a Slider 96(4S) rubber slider.

A representative portion of the basalt was cut and prepared to be analyzed by petrographic examination to identify the secondary mineral content.

3. RESULTS

Results are summarized in the table below and compared with the City of Melbourne Performance Criteria for Bluestone. Full test data are detailed in Appendix A of this report.

Property	B90 Bamstone Bluestone	City of Melbourne Performance Criteria
Bulk Specific Gravity <ul style="list-style-type: none"> (kg.m⁻³) 	2596 (2588 - 2609)	-
Water Absorption <ul style="list-style-type: none"> (% by weight) 	1.4 (1.4 – 1.5)	1.6% (max)
Flexural Strength <ul style="list-style-type: none"> Dried (MPa) Soaked (MPa) 	15.3 (14.5 – 16.0) 13.8 (13.0 – 14.4)	14 (min) 14 (min)
Compressive Strength <ul style="list-style-type: none"> Dried (MPa) Soaked (MPa) 	126 (119 - 131) 122 (111 - 138)	100 (min) 100 (min)
Abrasion Resistance <ul style="list-style-type: none"> Abrasion Index (Ha) 	26 (24 – 27)	19 (min)
Secondary Mineral Content <ul style="list-style-type: none"> Volume (%) 	None detected	8 (max)
Slip Resistance - Honed <ul style="list-style-type: none"> Classification 	P2 (SRV 25)	P5 (min)
- Sawn <ul style="list-style-type: none"> Classification 	P5 (SRV 67)	P5 (min)

4. SLIP RESISTANCE

Slip resistance was determined in accordance with Appendix A of AS 4586:2013 “Slip resistance classification of new pedestrian surface materials”. Testing was carried out on two surface finishes for each stone type as follows:

- Honed
- Sawn

Testing was carried out at five sites in a wet condition using a British Pendulum fitted with a Slider 96(4S)¹ rubber slider.

4.1.1. Results

Results are summarised in the table below. Full test data are detailed in Appendix A of this report.

Property	Sawn	Honed
Slip Resistance AS4586:2013		
– Classification	P5	P2
– Slip Resistance Value (BPN)	67	25

4.1.2. Discussion

Bamstone Bluestone with a sawn finish achieved an SRV of 67 attaining a P5 classification (SRV >54). According to Table 3B of the Standards Australia handbook HB198-2014² the surface finish is suitable for the following locations³:

- External ramps and walkways including sloping driveways, footpaths etc., steeper than 1 in 14
- Loading docks undercover and commercial kitchens
- Swimming pool ramps and stairs leading to water

The samples of Bamstone Bluestone with a honed finish tested achieved an SRV of 25, therefore attains a P2 classification (SRV 25 - 34). According to Table 3B of the Standards Australia Handbook HB 198:14 surfaces with this rating are suitable for locations such as:

- Entries and access areas including hotels offices, public buildings, schools kindergartens, common areas of public buildings, internal lift lobbies – TRANSITIONAL areas
- Hotel apartment bathrooms, en-suites and toilets
- Hotel apartment kitchens and laundries
- Wards and corridors in hospital and aged care facilities

¹ Slider Expiry date : 17-OCT-15

² Guide to the specification and testing of slip resistance of pedestrian surfaces

³ 5.2 of HB198 states: “The use of these values should be in the context of design, which also considers abnormal wear, maintenance, abnormal contamination, the presence (or otherwise) of water or other lubricants, the nature of the pedestrian traffic (including age, gait and crowding), the footwear (or lack thereof), slope lighting and handrails.”

5. PETROGRAPHIC EXAMINATION

Petrographically identified as olivine-clinopyroxene and plagioclase basalt, with ~25% evenly scattered vesicles up to 2.5mm diameter and accessory very small crystals of magnetite. Optical microscopy indicates that all component minerals are fresh/unaltered.

Macro

Examined under binocular microscope this rock is seen to incorporate ~25 vol % of evenly and random distributed vesicles, up to about 1.0mm diameter, within a considerably finer crystalline mass of pale and somewhat greenish-grey crystals. (The vesicles are filled by blue impregnating epoxy in the thin section.)

Micro

Mineral Component	Approximate Volume (%)
Plagioclase (labradorite)	50%
Mafic-silicate crystals - Olivine - Clinopyroxene (augite)	50%
Secondary minerals	None detected

The thin section confirms an estimated 20 to 25 volume % of evenly scattered vesicles with shapes variably amoeboidal, spheroidal, and some skeletal, with an overall size of 0.5mm to 2.5mm diameter. These vesicles are completely void, i.e. no minerals specifically within them.

The host rock between these vesicles is a homogeneous microcrystalline basalt, about 50% of which consists of random, loosely interlocking thin lath-form microlites of plagioclase, with a fairly consistent size of 1mm long and up to 0.5mm wide. These are entirely fresh/unaltered, and appear to be the species labradorite.

Areas between and within the random mass of plagioclase laths consist of mafic-silicate crystals, also forming an estimated 50% of this basalt. These include evenly scattered microphenocrysts of olivine rarely up to 1mm, within a subequal groundmass micromosaic of clinopyroxene, probably augite, with a fairly consistent individual crystal size about 0.1mm. All of these mafic-silicate minerals are fresh/unaltered.

Reflected light microscopy indicates very small micro-laths to spicule-like crystals of ilmenite and/or titaniferous magnetite, with an average size of 0.05mm wide x 0.2mm long. These are fresh-unoxidised and otherwise unaltered.

No secondary minerals were detected.



Fig 1 Bamstone Bluestone (B90/34)

Transmitted light, thin section (TS). Relatively low magnification X20 (bar scale 500µm), ordinary light (OL). Random field of view typical of this whole thin section, massive crystalline basalt with abundant random and loosely interlocking thin lath-form microlites of plagioclase (white). Scattered microphenocrysts of olivine, and finer crystalline clinopyroxene interstitial (groundmass).



Fig 2 Bamstone Bluestone (B90/34)

Crossed nicols (X nic), same field of view as Fig 1. Plagioclase laths white and some with internal twinning. Colored microphenocrysts apparently mostly olivine with finer crystalline clinopyroxene as interstitial groundmass.

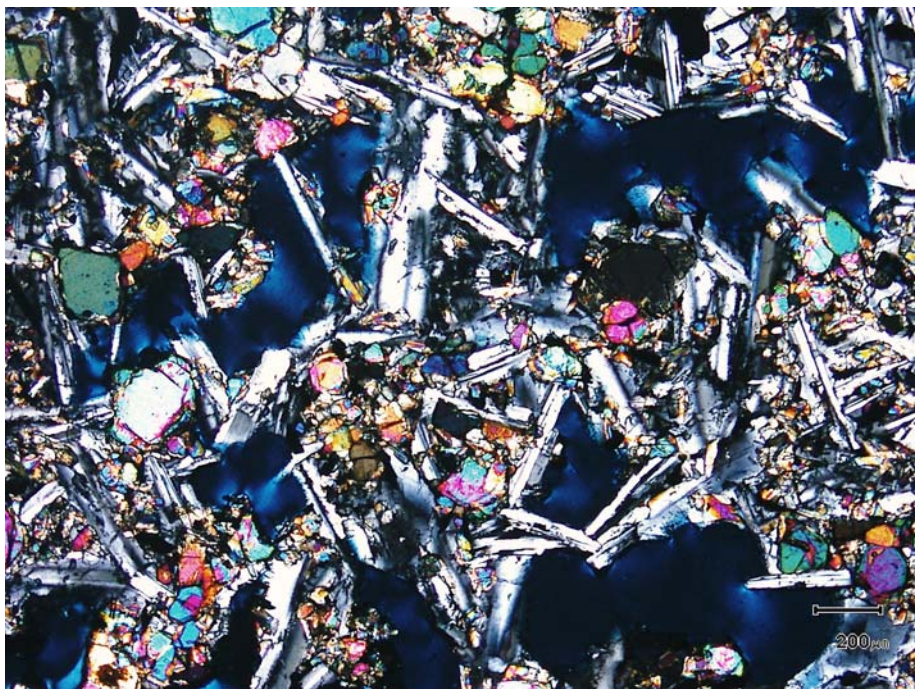
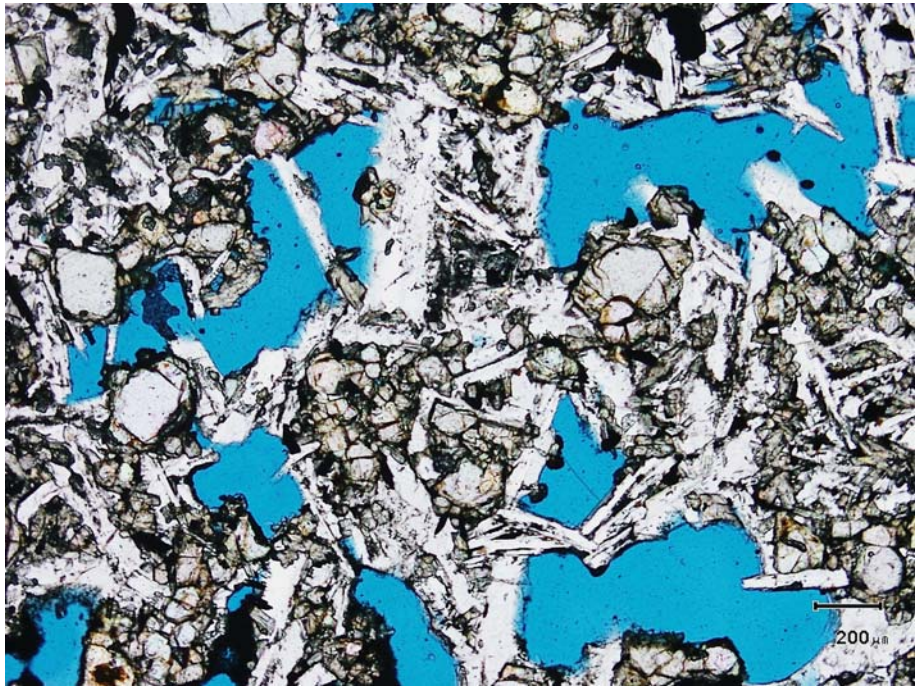


Fig 3 & 4

Bamstone Bluestone (B90/34)

TS, OL and X nic, higher magnification (X50) than figs 1 and 2. Shows detail of random plagioclase microlites, and microphenocrysts of olivine, within darker and finer microcrystalline groundmass of clinopyroxene. Also 'large' blue-epoxy-filled vesicles. No evidence of secondary alteration.

Appendix A

Test Certificates



WATER ABSORPTION, BULK SPECIFIC GRAVITY Test Certificate

TEST METHOD	ASTM C97M-09
TEST DATE	24-Mar-15 to 30-Mar-15
CLIENT	BAM Stone
OUR REFERENCE	BAM0315-1
SAMPLE	Bamstone Bluestone (Basalt)
SURFACE FINISH	Honed
SAMPLE ORIGIN	Port Fairy, Victoria
SAMPLING DATE	01-Mar-15
SAMPLE LOCATION	Not Known
NOMINAL SIZE	50x50x50 mm

Conditioning: Dried min 48 hrs @ 60deg C / Soaked for 48 hours @ 22 deg C

Test Number	Specimen Identification	Dried Mass (g)	Soaked mass (g)	Suspended mass (g)	Bulk SG (kg.m-3)	% Absorption by Volume	% Absorption by Weight
W5260	B90/21	324.59	329.17	204.20	2,597	3.66	1.41
W5261	B90/22	330.76	335.35	207.91	2,595	3.60	1.39
W5262	B90/23	331.42	336.11	208.06	2,588	3.66	1.42
W5263	B90/24	330.51	335.42	207.89	2,592	3.85	1.49
W5264	B90/25	334.63	339.48	211.24	2,609	3.78	1.45

MEAN BULK SPECIFIC GRAVITY (Kg.m-3)	2,596 ± 2 (U95)
MEAN ABSORPTION BY Volume (%)	3.71% ± 0.08 (U95)
MEAN ABSORPTION BY Weight (%)	1.43% ± 0.03 (U95)

NOTE: The expanded measurement uncertainty values (u95) quoted in this report are at a confidence level of 95 % with a nominal coverage factor of 2. These values do not include any estimate of the effects associated with sampling.

COMMENTS/VARIATIONS

TESTED BY: J. Mann & M. Milevski

APPROVED SIGNATORY:

NAME: James P Mann



ISSUE DATE: 30-Mar-15



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FLEXURAL STRENGTH Test Certificate

TEST METHOD	ASTM C880M-09		
TEST DATE	24-Mar-15	to	26-Mar-15
CLIENT	BAM Stone		
OUR REFERENCE	BAM0315-1		
SAMPLE	Bamstone Bluestone (Basalt)		
FINISH IN TENSION	Sawn		
SAMPLE ORIGIN	Prt Fairy, Victoria		
SAMPLING DATE	1/03/2015	SAMPLE LOCATION	Not Known
NOMINAL SIZE	100x450x40 mm		
LOADING ORIENTATION	Unknown		

Conditioning: Dried for minimum 48 hours @ 60 deg C

Test Number	Specimen Identification	Span (mm)	Test Condition	Width (mm)	Thickness (mm)	Max. Load (Newtons)	Dried Strength (MPa)
F4213	B90/1	400	Dried	100.5	39.2	7741	15.0
F4214	B90/2	400	Dried	100.1	39.2	8225	16.0
F4215	B90/3	400	Dried	100.1	39.2	8110	15.8
F4216	B90/4	400	Dried	100.5	39.1	7639	14.9
F4217	B90/5	400	Dried	100.7	38.5	7190	14.5

MEAN DRIED FLEXURAL STRENGTH (MPa): **15.3 ± 0.3 (u95)**
Standard Deviation: **0.6**

Conditioning: Soaked for 48 hours @ 22 deg C

Test Number	Specimen Identification	Span (mm)	Test Condition	Width (mm)	Thickness (mm)	Max. Load (Newtons)	Soaked Strength (MPa)
F4218	B90/6	400	Soaked	100.3	38.8	7224	14.4
F4219	B90/7	400	Soaked	100.3	39.1	6934	13.6
F4220	B90/8	400	Soaked	100.4	38.5	6969	14.1
F4221	B90/9	400	Soaked	100.1	38.5	6992	14.2
F4222	B90/10	400	Soaked	100.9	39.1	6682	13.0

MEAN SOAKED FLEXURAL STRENGTH (MPa): **13.8 ± 0.3 (u95)**
Standard Deviation: **0.6**

NOTE: The expanded measurement uncertainty values (u95) quoted in this report are at a confidence level of 95 % with a nominal coverage factor of 2. These values do not include any estimate of the effects associated with sampling.

COMMENTS/VARIATIONS

TESTED BY: K. Tonkin & M. Milevski

APPROVED SIGNATORY:

NAME: James P Mann



ISSUE DATE: 26-Mar-15



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UNCONFINED COMPRESSIVE STRENGTH Test Certificate

TEST METHOD	ASTM C170M-09		
TEST DATE	24-Mar-15	to	26-Mar-15
CLIENT	BAM Stone		
OUR REFERENCE	BAM0315-1		
SAMPLE	Bamstone Bluestone (Basalt)		
SURFACE FINISH	Sawn		
SAMPLE ORIGIN	Port Fairy, Victoria		
SAMPLING DATE	01-Mar-15	SAMPLE LOCATION	Not Known
SHAPE and NOMINAL SIZE	PRISM: 50x50x50 mm		
LOADING ORIENTATION	Unknown		

Conditioning: Dried for minimum 48 hours @ 60 deg C

Test Number	Specimen Identification	Test Condition	Length (mm)	Width 1 (mm)	Width 2 (mm)	Max. Load (Newtons)	Compressive Strength(MPa)
C4266	B90/11	Dried	49.2	49.4	51.8	329750	129
C4267	B90/12	Dried	49.3	51.4	52.0	331520	124
C4268	B90/13	Dried	49.3	52.0	49.2	320670	125
C4269	B90/14	Dried	49.4	49.1	50.7	326050	131
C4270	B90/15	Dried	49.4	52.2	51.3	317850	119

MEAN DRIED COMPRESSIVE STRENGTH (MPa): 126 ± 1.5 (U₉₅)

Standard Deviation: 4.8

Conditioning: Soaked for 48 hours @ 22 deg C

Test Number	Specimen Identification	Test Condition	Length (mm)	Width 1 (mm)	Width 2 (mm)	Max. Load (Newtons)	Compressive Strength(MPa)
C4271	B90/16	Soaked	49.2	51.6	52.0	296520	111
C4272	B90/17	Soaked	49.2	51.0	51.6	313220	119
C4273	B90/18	Soaked	50.9	49.4	49.2	334960	138
C4274	B90/19	Soaked	49.2	49.6	52.1	291100	113
C4275	B90/20	Soaked	49.2	49.5	51.6	335680	131

MEAN SOAKED COMPRESSIVE STRENGTH (MPa): 122 ± 1.5 (U₉₅)

Standard Deviation: 11.9

NOTE: The expanded measurement uncertainty values (u95) quoted in this report are at a confidence level of 95 % with a nominal coverage factor of 2. These values do not include any estimate of the effects associated with sampling.

COMMENTS/VARIATIONS

TESTED BY: Mark Milevski

APPROVED SIGNATORY:

NAME: James P Mann



ISSUE DATE: 30-Mar-15



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WET SLIP RESISTANCE (AS 4586:2013 APP A) Test Certificate

TEST METHOD	AS 4586:2013 Appendix A (Wet Pendulum)		
TEST DATE	24-Mar-15		
CLIENT	BAM Stone		
OUR REFERENCE	BAM0315-1		
SAMPLE	Bamstone Bluestone (Basalt)		
SURFACE FINISH	Sawn		
SAMPLE ORIGIN	Prt Fairy, Victoria		
SAMPLING DATE	1/03/2015	SAMPLE LOCATION	Not Known
NOMINAL SIZE	300x300x50 mm		
AIR TEMPERATURE	21.1 °C	TEST SITE	SI Laboratory
WEATHER	Not Applicable		
TEST TYPE	Unfixed		
ANGLE OF TEST	Horizontal		
SLIDER TYPE	Slider 96	SLIDER EXPIRY	17-Oct-15
SLIDER PREPARATION	Slider passed 3x over 400 grit paper, 10x over 3mic lapping film.		
SURFACE PREPARATION	Washed with potable water and cloth		

Test Number	Orientation	BPN Readings	Mean
S8164	B91/1	66, 66, 66, 66, 66	66
S8165	B91/2	69, 68, 67, 67, 66	67
S8166	B91/3	69, 68, 68, 67, 67	67
S8167	B91/4	68, 67, 67, 67, 66	67
S8168	B91/5	70, 69, 69, 69, 69	69

MEAN Wet SLIP RESISTANCE VALUE (SRV): 67 ±2 (U95)
SLIP RESISTANCE CLASSIFICATION: P5

NOTE: The expanded measurement uncertainty values (u95) quoted in this report are at a confidence level of 95 % with a nominal coverage factor of 2. These values do not include any estimate of the effects associated with sampling.

COMMENTS/VARIATIONS Sawn Surface

TESTED BY: Mark Milevski

APPROVED SIGNATORY:

NAME: James P Mann



ISSUE DATE: 24-Mar-15



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WET SLIP RESISTANCE (AS 4586:2013 APP A) Test Certificate

TEST METHOD	AS 4586:2013 Appendix A (Wet Pendulum)		
TEST DATE	24-Mar-15		
CLIENT	BAM Stone		
OUR REFERENCE	BAM0315-1		
SAMPLE	Bamstone Bluestone (Basalt)		
SURFACE FINISH	Honed		
SAMPLE ORIGIN	Prt Fairy, Victoria		
SAMPLING DATE	1/03/2015	SAMPLE LOCATION	Not Known
NOMINAL SIZE	300x300x30 mm		
AIR TEMPERATURE	21.4 °C	TEST SITE	SI Laboratory
WEATHER	Not Applicable		
TEST TYPE	Unfixed		
ANGLE OF TEST	Horizontal		
SLIDER TYPE	Slider 96	SLIDER EXPIRY	17-Oct-15
SLIDER PREPARATION	Slider passed 3x over 400 grit paper, 10x over 3mic lapping film.		
SURFACE PREPARATION	Washed with potable water and cloth		

Test Number	Orientation	BPN Readings	Mean
S8149	B90/26 Random	30, 28, 27, 27, 27	27
S8150	B90/27 Random	29, 27, 25, 25, 25	25
S8151	B90/28 Random	27, 25, 25, 25, 24	25
S8152	B90/29 Random	26, 25, 25, 24, 24	24
S8153	B90/30 Random	29, 28, 27, 26, 26	26

MEAN Wet SLIP RESISTANCE VALUE (SRV): 25 ±2 (U₉₅)
SLIP RESISTANCE CLASSIFICATION: P2

NOTE: The expanded measurement uncertainty values (u₉₅) quoted in this report are at a confidence level of 95 % with a nominal coverage factor of 2. These values do not include any estimate of the effects associated with sampling.

COMMENTS/VARIATIONS Honed Surface

TESTED BY: Mark Milevski

APPROVED SIGNATORY:

NAME: James P Mann



ISSUE DATE: 24-Mar-15



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ABRASION RESISTANCE Test Certificate

TEST METHOD	ASTM C1353-09		
TEST DATE	24-Mar-15	to	31-Mar-15
CLIENT	BAM Stone		
OUR REFERENCE	BAM0315-1		
SAMPLE	Bamstone Bluestone (Basalt)		
SURFACE FINISH	Sawn		
SAMPLE ORIGIN	Port Fairy, Victoria		
SAMPLING DATE	1/03/2015	SAMPLE LOCATION	Not Known
NOMINAL SIZE	100x100x10 mm		

Conditioning: Dried @ 60 deg C for 48 hours
Relative Humidity: 50%
Bulk SG: 2.60

Test Number	Specimen Identification	Total Cycles	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Index of Abrasion Resistance
A841	B90/31	1000	481.33	477.37	3.96	24.1
A842	B90/32	1000	408.80	405.28	3.52	27.2
A843	B90/33	1000	420.23	416.76	3.47	27.5

MEAN INDEX OF ABRASION RESISTANCE: **26.3 ±0.8 (U95)**
Standard Deviation: **1.9**

NOTE: The expanded measurement uncertainty values (u95) quoted in this report are at a confidence level of 95 % with a nominal coverage factor of 2. These values do not include any estimate of the effects associated with sampling.

COMMENTS/VARIATIONS

TESTED BY: Mark Milevski
APPROVED SIGNATORY:
NAME: James P Mann



ISSUE DATE: 31-Mar-15



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