Extraordinary Meeting of the
Transport Advisory Committee
13.30 on the 23rd July 2015
Liberation Room, Secretariat
AGENDA

Part 1	
1.	Apologies for absence
2.	Declarations of interest
3.	Materials used for MPA Road Surface – Paper to be issued
	Date of next meeting

TECHNICAL NOTE

Title:	**MPA Road – Use of crushed aggregates for surfacing on the MPA Road**		
Doc No:	**TN 02**	**Revision:**	**1**
Summary:	Report that reviews the specification of, theoretical and actual, the materials used on the MPA Road for surfacing.		
Author:	Sebastian Reid – Assistant Road Eng.	**Date:**	21/07/15
Checked:	Simon Catton – Head of Highways	**Date:**	22/07/15

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TECHNICAL NOTE

1 Introduction

This report has been written to review the materials used by Public Works Department (PWD) Highways Section for the road surfacing on the MPA Road and presented to the Transport Advisory Committee (TAC) meeting of the 23rd July 2015.

The report will initially define some of the terms used in road engineering. The report will review the specification used for quarried material for highways use and describe in detail the testing process employed by the Falkland Islands Government (FIG) to ensure that the materials used are suitable. These specifications will be compared to testing undertaken at the main FIG quarries used to supply road surfacing aggregate for the MPA Road.

The next section will focus on the production of the aggregate using these material sources reviewing the specification of the aggregate against local and international standards and it will be compared and assessed against the specification, with anecdotal evidence of its performance based on site observations and road trials.

The report will then summarise on the findings of the review, highlighting further risks with the surfacing process and placing the information presented into a larger context of unsealed roads maintenance, linking into international standards where appropriate.

Aggregate for road surfacing in the Falkland Islands is manufactured using the same method across all of the PWD Highways Quarries, to the same specification and using the same equipment.

In all of the quarries currently used (Port Harriet, Canada Ronde, Salinas Beach) the rock is too hard to be excavated using the current PWD plant, and so the rock is drilled and blasted from existing rock faces. At all locations, over-burden material that is not suitable (peat, sub-soil and soft rock not compliant with the specification) is stripped off first during the off-season and disposed of.

Material blast is then fed into a mobile crushing plant operated by PWD. This plant is a 12 year old Tesab 1012T rotary crusher which is set to produce crushed aggregate from 40mm down. The crusher produces some waste materials which are scalped from a side conveyor.

This crusher and this process currently produce 40,000t of road surfacing aggregate per annum. In 2014/15 10,000t was produced at Salinas Beach for the North Arm Road Reconstruction project, and the remaining 30,000t was produced at Port Harriet. The average daily output of the crusher is approximately 600t per day.

2 Definition of Terms

This section seeks to define terms used in this report in a non-technical manner. These definitions are based on the Unified Soil Classification System and the American Association of State highway and Transportation Officials' (AASHTO) Soil Classification System.

2.1 Geological Definitions

- **Sedimentary Rock** – Sedimentary rocks, the principal surface rock type in the Falkland Islands, are types of rocks that are formed by the deposition of material. This rock is formed from sediment that has been deposited through the action of water, wind or ice.
- **Sandstone** – A sandstone is a sedimentary rock that is formed of grains of sand, combined within a matrix of smaller material. The type of sandstone is determined by the predominant type of sand grains within the rock, with clean sandstones being those that have very little silt or clay grains binding together the rock, and wacke sandstones being those that have a significant amount of binding material and a higher proportion of clays and silts.
- **Greywacke** – A variety of sandstone, generally very dark in colour (blue to grey), containing particles of quartz, or other rock fragments in a rich clay-silt matrix which consists of more than 15% of the rock by volume.
- **Tillite** – A sedimentary rock, formed from the deposition of material from glaciation. This rock tends to be very high by volume of silt-clay within its matrix. The rock tends to have embedded within its matrix other pebbles and rocks that are different in colour and classification that have been transported via glaciation.
- **Mudstone / Siltstone / Shale** – Sedimentary rocks that formed predominantly from clays and silts. The definition and naming of each rock depends entirely on the grain sizes within the rock.

2.2 Material Constituents Definitions

- **Soil –** A material can be described to have soil like properties when an excess of 5% to 12% of a sample by weight can be passed through a 0.075mm sieve during testing. At this grade, the grain size and the distribution of the soil's grains have a significant impact on the performance of the material by having various plastic and cohesive properties based on the distribution of silty and clayey fractions.
- **Gravel Aggregate** – Material passing the 50mm sieve and retained on the 2mm sieve.
- **Sand** – Material between 2mm and 0.075mm in size.
- **Silt** – Material between 0.075mm and 0.002mm in size. The silt fraction has cohesive and plastic properties in the presence of water.
- **Clay** – Materials less than 0.002mm in size. The clay fraction has cohesive and plastic properties in the presence of water.

2.3 Other Definitions

- **Plasticity** – Soils are not normally used for road construction, but where they are due to local restrictions on available materials soils are used, their properties are determined by the Atterberg Limits. These limits describe the behaviour of the soils, including their compaction, expansion, and shrinkage and shear strength at different water levels. This is because at the minute grain sizes, the presence of water at various concentrations can act as lubrication between the soil particles, and a small change in the water content can radically change the strength of the soils. For roads which are constructed from soils, the presence of water can radically reduce the strength of the road due to these properties. The plastic limit describes the moisture content of a soil where the material can be formed, like playdoh. If the material breaks down at a lower moisture content then this level of moisture is regarded as the plastic limit. The liquid limit is the next determining factor, and this defines the point at which a soil changes from being plastic, into a liquid.

3 Materials used by PWD Highways

This Specification is used as a guideline for the sourcing of material used to surface certain roads. Due to limitations of cost and geology and the issues of sampling and testing, it is not currently possible to undertake these tests on all of the borrow pits used by PWD Highways for the ongoing reconstruction and capping programme.

Where applicable, the specification has been linked to best practice guidelines used in other international countries where unsealed roads are used as a part of a national road network (South Africa, Australia, New Zealand, United States of America, Vietnam etc).

This Specification relates to three specific properties of the rock which impact its performance as a road construction material. Aggregates used in the construction of roads must be durable, abrasion resistant, and not frost susceptible.

We examine these 3 properties using the following tests:

- Material Grading
- Sulfate Soundness (Tests Susceptibility to Frost Action and Weathering)
- The Los Angeles Abrasion Test (tests abrasion resistance and is slowly being replaced with the Micro Deval Abrasion Test)

The Micro Deval and the Los Angeles Abrasion tests both measure similar properties of the material, and are very similar tests however the Micro Deval test measures abrasion loss in the presence of water as many aggregates are more susceptible to abrasion when wet. "ICAR - The Prediction of Coarse Aggregate Performance by Micro-Deval and Other Aggregate Tests". Los Angeles Abrasion tests are reported in this Technical note as there are insufficient comparable results so far for the Micro Deval test on the aggregates we use.

The ideal material that will provide a good quality road surfacing aggregate:

- Grades well after crushing giving a course aggregate (for wind resistance) without too much oversize whilst providing a small amount of fine cohesive material to help bind the materials together,
- Is resistant to frost degradation but is accepted that a reduced resistance does help to breakdown the material over time,
- Resistant to abrasive degradation from trafficking, but not too hard that the aggregate will not self-replenish the loss of cohesive fines removed via erosion.

3.1 Grading of Aggregate

Sieve Analysis and Grading tests the distribution of grain sizes and grading of a material. A sample is passed through a series of sieves of reducing aperture size to capture grains of a particular size. The captured material is then weighed and measured to report the percentage by mass of material being captured by a particular sieve, and the percentage passing. This gives the size gradient of a material.

The grading of road surfacing material varies according to the standards used and the purpose of the material. In general, a road surfacing aggregate needs to:

1. Be cost effective to produce using as little plant and equipment as possible,
2. Be workable using grading and rolling plant at a variety of moisture conditions,
3. Have enough larger aggregate to create a semi-structural layer on the road and resist loads from larger vehicles,
4. Have sufficient cohesive and plastic fines to form a semi-impermeable layer when compacted to provide a smooth running surface,
5. Be able to be graded and maintained so that when weather conditions affect the road surface, defects can be easily remedied by blending and grading the aggregate and filling in the holes.

To achieve a specification for grading of the material in the Falkland Islands, reference has been made to a wide variety of best practice guidance from around the world. To suit local geological and climatological conditions, a local specification has been developed taking these examples and suiting them to the material that can be readily produced and has been proven to perform in accordance with the objectives above. The source information for this specification is included in Appendix A, Table 6.1 which is a comparison of the grading of a variety of materials used for the same purposes from across the world. These are then combined to form a grading curve in Appendix A, Figure 1.

The majority of the international standards assessed favour the use of smaller aggregates and sands to create a smooth running surface however due to the Falkland Islands' climate, and the known issue of wind erosion, the use of predominantly small and fine materials is avoided for maintenance and financial reasons. Instead the Falkland Island Specification follows more closely the Type 2 specification from the UK DMRB, allowing a greater quantity of larger rocks which will then break down over time to replenish fine material. Even with these changes, the specification is within the envelope of several other international curves including those used in Vietnam, Australia, New Zealand and South Africa for road surfacing material. In all cases, the specification seeks to reduce the smallest silts and clay content to between 9% and 3% by mass. The Falkland Island Specification is shown in Table 3.1 below.

Table 3-1 - Falkland Island PWD Highways Road Surfacing Specification - Grading Curve

SIEVE (MM)	FIG PWD Highways - Specification Max % Passing	FIG PWD Highways - Specification - Min % Passing
63	100	97
50	100	90
31.5	95	75
16	80	50
8	60	30
4	45	15
1	32	8
0.425	27	5
0.063	9	3

3.2 Frost Susceptibility - Magnesium Sulfate Soundness

All materials used in road construction are to lose **less than 35%** of 10mm – 14mm aggregate by mass – MS 35.

This test is undertaken in accordance with BS EN 1367-2: 2009. An alternative test is available in standard AASHTO T104.

This test demonstrates the aggregate's resistance to disintegration by weathering and freeze thawing cycles. More resistant rocks are less susceptible to breakdown during frosts and this test operates by simulating the growth of ice crystals within the aggregate matrix using sulfate salts.

The 35% loss limits are generally regarded as being the maximum limits for rocks that are within the frost zone on a road and this limit is used by the Australian and New Zealand Unsealed Roads Manual (USRM), the South African Pavement Manual (SAPEM), the AASHTO and the US Department of Transportation and the UK Design Manual for Roads and Bridges (DMRB). Rocks outside of these limits have been successfully used for road surfacing following trafficking trials and empirical testing.

3.3 Abrasion resistance– Los Angeles Co-efficient

All materials used in road construction are to lose **less than 50%** aggregate by mass.

This test is undertaken in accordance with BS EN 1097-2: 2010. An alternative test is available in standard AASHTO T96.

This test demonstrates the durability of an aggregate and its resistance to wear by putting a clean aggregate sample (generally aggregate fractions between 14mm and 10mm in size) into a test chamber with a number of iron balls and then mixing the sample at high speed for a set number of revolutions at a set speed. The resultant loss of aggregate strength is determined by the quantity of fine material (<2mm) found at the end of the test. It is widely regarded that the Los Angeles Test, is a test that breaks aggregates.

4 Review of Testing Results from FIG Quarries, Borrow Pits and Cores

4.1 Ponies Pass Quarry – Sandstone

Ponies Pass Quarry manufactures products based on sandstone that consists of mostly quartzite sands. When tested, the rock sample was crushed and taken from a stockpile.

- MS – 8% - Rock is not frost susceptible, and is highly resistant to weathering.
- LA – 26% - Rock is hard and resistant to fracture.

It was found during previous use of Ponies Pass type 1 as a capping material that the fines were not replaced and the larger aggregates rounded into “marbles” which did not break down due to the strength of the rock. As these wore down, they created an unsafe running surface.

The rock is not acceptable for road surfacing.

4.2 Port Harriet Borrow Pit – Sandstone

Port Harriet has changed substantially as the quarry has developed from a silty clayey sandstone at the top, into a greywacke sandstone through to a sandstone at the bottom of the deepest core.

Table 4-1 - Port Harriet Testing Results

Test	Port Harriet – Stockpile November 2011	Port Harriet – Top Core Sample – April 2014	Port Harriet – Bottom Core Sample – April 2014
Magnesium Sulfate (MS)	22% Acceptable	35% At Limit	41% Outside Limit
Los Angeles (LA)	25% Acceptable	35% Acceptable	41% Acceptable

Three samples from Port Harriet have been included for comparison purposes. The November 2011 material has been used on the road since 2011 for road surfacing purposes with success. The April 2014 material has been used since September 2013. The bottom core is a sample of future material to be blasted from Port Harriet.

For Magnesium sulfate soundness, the material is acceptable but it is this higher susceptibility to frost that helps break down the material for self-replenishment of the finer cohesive material loss during the summer months.

With the bottom core being outside of the specified limits, further analysis would be required before future use of the deeper material in Port Harriet was confirmed

The rock is acceptable for road surfacing.

4.3 Frying Pan Borrow Pit - Greywacke

The Frying Pan quarry, to the west of Fitzroy, is a well-established pit owned by a private company. The rock is a greywacke, russet grey in colour and was used for road surfacing previously. The rock was found to be very hard with little fines produced during crushing and little fines produced under traffic loading due to its abrasive resistance.

Samples were taken from crushed aggregate stockpile.

- MS – 5% - Rock is not frost susceptible, and is highly resistant to weathering.
- LA – 15% - Rock is very hard and resistant to fracture.

It was found that the rock, when crushed and following substantial road trials, did not produce sufficient fine cohesive material to allow compaction, and thus the aggregate was weak when laid on the road. Additionally, due to the hardness of the material, the larger aggregates rounded into "marbles" which did not break down due to the strength of the rock. As these wore down, they created an unsafe running surface.

The rock is not acceptable for road surfacing.

4.4 Canada Ronde Borrow Pit - Sandstone

Canada Ronde on the Goose Green Road is an FIG quarry which has been used to surface the Goose Green Road and sections of the MPA Road west of Fitzroy Ridge. It has historically produced excellent road surfacing material which has been very hard wearing, while being able to degrade for fines replenishment. Samples were taken and tested from a stockpile on the site.

- MS – 7% - Rock is not frost susceptible, and is highly resistant to weathering.
- LA – 15% - Rock is very hard and resistant to fracture.

The rock is acceptable for road surfacing.

Although the results show the material should perform as Ponies Pass and the Frying Pan, it is not understood why it behaves like Port Harriet and further investigations are needed.

4.5 Fitzroy Development site - Greywacke

This is a potential future development site for a borrow pit. The material was sampled from a deep core from the ridge, approximately 2 miles down the Fitzroy Road. The material found was a Greywacke / cleaner sandstone similar to the bottom levels of Port Harriet.

- MS – 23% - Rock is not frost susceptible, and is highly resistant to weathering.
- LA – 32% - Rock is hard and resistant to fracture.

The rock is acceptable for road surfacing.

This development site will be investigated further.

4.6 Rumford Borrow Pit - Mudstone

The Rumford pit is on the North Camp Road and is regarded as a high quality material which has been successfully used for road base and surfacing material. The material at Rumford is a very hard mudstone which is representative for the geology to the north of East Falkland.

- MS – 16% - Rock is not frost susceptible, and is highly resistant to weathering.
- LA – 28% - Rock is hard and resistant to fracture.

The rock is acceptable for road surfacing.

4.7 March Ridge

The March Ridge Borrow Pit was closed following on site assessment of the degradation of the rock within the borrow pit and on the carriageway and its performance under traffic loading. The rock showed serious signs of frost susceptibility breaking up within only a few years of being open to the elements and formed heavy corrugations under traffic loadings. These corrugations have all but disappeared on the MPA road following discontinued use of this material.

The rock is not acceptable for road surfacing.

4.8 Grading Comparison – PWD Highway Quarries

Appendix B contains tables and figures compare the grading of road surfacing aggregate produced at the PWD Highways quarries at Canada Ronde, Port Harriet and Salinas Beach.

- Table 6.2 – Grading Results from PWD Highways Quarries
- Figure 2 – Grading Curves - Salinas Beach, Canada Ronde and Port Harriet (2015)
- Figure 3 – Grading Curves – Port Harriet 2011 to 2015 and Washed Trial Product.

From these tables and curves in Appendix B it can be seen that in general, the material produced, except for that produced in Salinas Beach in 2011, is all within the Falkland Island Highways specification for road surfacing, and is all consistent with each other.

- Canada Ronde produces the cleanest material, with a balance of large (20mm+), medium (10 – 20mm) and small (4 – 10mm) aggregate. The majority of the finer material is between 4mm and 1mm with less silty/clayey material. This is consistent from the stone which is the hardest of the three quarries.
- Salinas Beach produces a stone which is medium graded, with the majority of the mass being between 5mm and 20mm in size, and is well graded across the 5mm down fractions. This quarry produces a material that is easily worked and long lasting.
- Port Harriet produces a well graded stone that has a similar curve to Canada Ronde. Port Harriet has more of the silty and clayey fractions than the other pits, but this is well within the limits of the specification and is consistent with a generally softer stone than Salinas Beach and Canada Ronde.

Port Harriet stone has developed over time, and in general, as can be seen by the changing curves in Figure 3, the stone has contained more larger fractions of aggregate as the pit has been developed and made deeper. The fines content has remained consistent over the lifetime of the quarry and in general the curves have been very consistent.

5 Conclusion

PWD produce capping aggregates for use that are comparable to a range of international standards and best practice. The aggregate produced is hard, non-frost susceptible and is within the specification set. The aggregate used much coarser than many countries, using a 40mm down grading curve that contains less fine cohesive material which suits the need for a material that is more resistant to wind erosion.

Port Harriet capping materials consistently meet the grading, abrasion resistance and resistance to frost requirements of the Falkland Islands Specification. Port Harriet material self-replenishes the required fines as it breaks down and is a sustainable and maintainable material.

However, the materials produced and tested at Port Harriet have a high plastic limit due to the percentage of particles passing through the 0.075mm sieve. It is the presence and properties of these materials that when saturated with water causes the capping materials to become soft and plastic. Ponies Pass and the Frying Pan material does not have a high plastic limit but these materials performed poorly under trials because the materials lacked fine cohesive materials.

The performance of the aggregate when laid is heavily dependent on the water content. Water is internationally recognised in all design standards as being the number one cause for road deterioration. When combined with frost and sustained below zero temperatures, which causes the water soaked into an unsealed road surface to freeze and heave, this causes the compacted road surface to loosen up and the road to lose structural integrity producing potholes and loose material, especially in heavily trafficked sections.

From a road engineering perspective, the focus is on mitigating the damage to the road surface from water ingress. This is achieved through the process of providing sufficient crossfall and longfall which is achieved through the application of road surfacing material and maintenance grading. Unfortunately, where sufficient crossfall and longfall isn’t possible (such as at superelevated transitions) potholes will consistently form because the water cannot be shed fast enough to stop it soaking into the road surfacing. In these cases, only regular maintenance will subdue the formation of potholes. Water from below is also an issue in areas where sufficient road base drainage isn’t provided. In these cases, regular maintenance of below surface drainage (culverts, cross drains, drainage channels and ditches) to ensure that the water does not enter the surfacing from below and to shed water that ingresses from the surface, is the best method to mitigate this cause of road surface deterioration.

The damage caused by water ingress is recognised by all countries and states that use unsealed roads as a part of their local and national road networks. It is recognised that the only long term solution to the seasonal deterioration is to seal the roads.

6 Appendices

6.1 Appendix A – International Standards for Comparison

Table 6-1 - International Grading Tables for Road Surfacing Aggregates

SIEVE (MM)	USRM Australia - Unsealed Surfacing		USRM New Zealand - Unsealed Surfacing		AASHTO M147 Surface Course - Grade E		South African Pavement Manual - Grade G2 / 3		Vietnam Rural Road Standards - Type 1		UK - Design Manual for Roads & Bridges - Type 2 Sub-base	
	Max % Passing	Min % Passing	Max % Passing	Min % Passing	Max % Passing	Min % Passing	Max % Passing	Min % Passing	Max % Passing	Min % Passing	Max % Passing	Min % Passing
63											100	100
55	100	100										
50									100	100		
37.5	100	95							100	90		
31.5											99	75
26.5	100	90	100	100			100	100				
25					100	100			95	75		
19	100	80	80	60			95	85				
16											90	50
14							84	71				
9.5									85	50		
8											75	30
4.75					100	55	60	42	75	35		
4											60	15
2.36	65	35	60	40								
2					100	40	45	27	60	25		
1											35	0
0.425	50	15	35	25	50	20	27	13	40	15		
0.075	40	10	20	10	20	6	12	5	30	5		
0.063											9	0

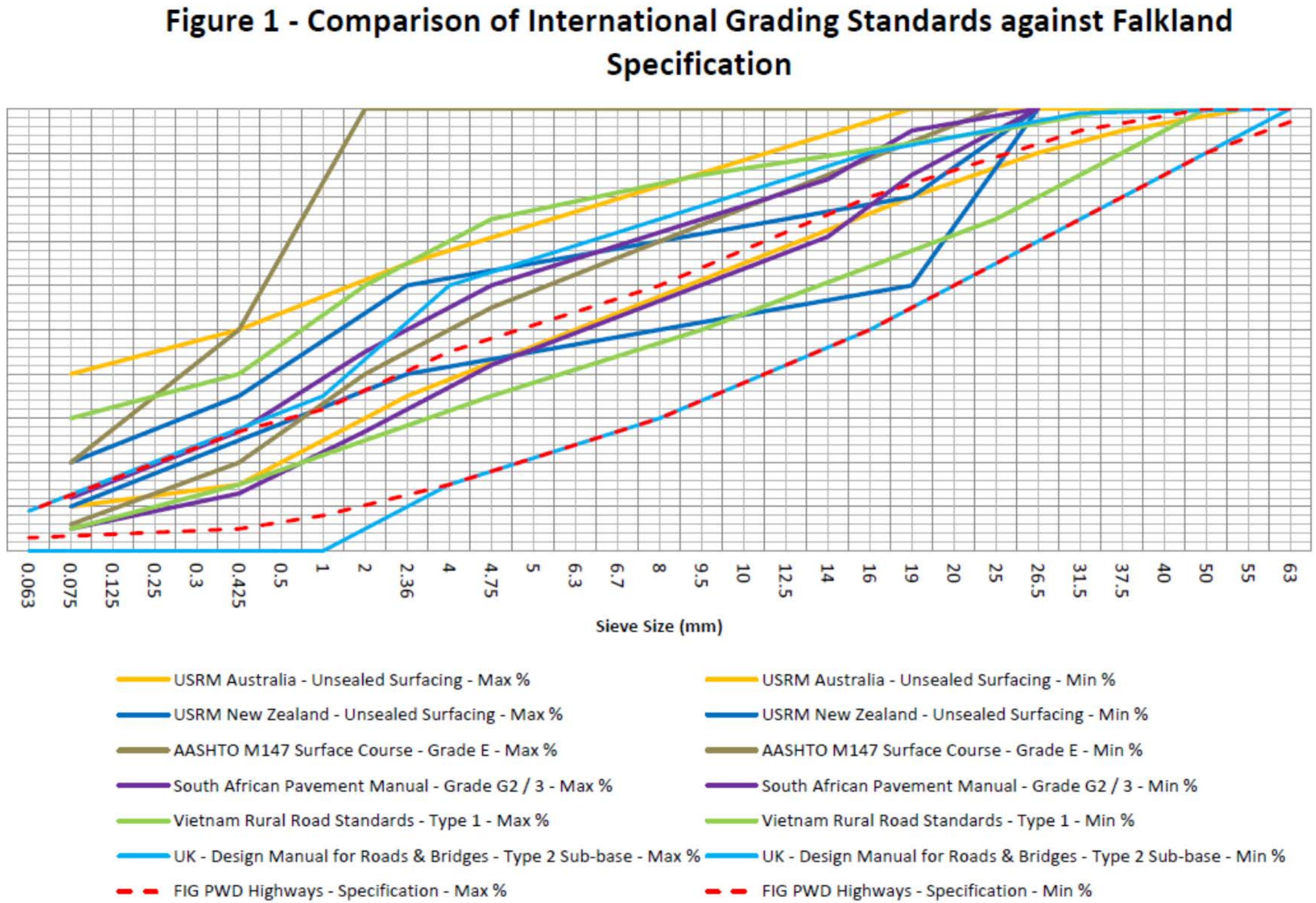
Figure 1 - Comparison of International Grading Standards against Falkland Specification
Percentage Mass Passed
Sieve Size (mm)
0.063
0.075
0.125
0.25
0.3
0.425
0.5
1
2
2.36
4
4.75
5
6.3
6.7
8
9.5
10
12.5
14
16
19
20
25
26.5
31.5
37.5
40
50
55
63
USRM Australia - Unsealed Surfacing - Max %
USRM Australia - Unsealed Surfacing - Min %
USRM New Zealand - Unsealed Surfacing - Max %
USRM New Zealand - Unsealed Surfacing - Min %
AASHTO M147 Surface Course - Grade E - Max %
AASHTO M147 Surface Course - Grade E - Min %
South African Pavement Manual - Grade G2 / 3 - Max %
South African Pavement Manual - Grade G2 / 3 - Min %
Vietnam Rural Road Standards - Type 1 - Max %
Vietnam Rural Road Standards - Type 1 - Min %
UK - Design Manual for Roads & Bridges - Type 2 Sub-base - Max %
UK - Design Manual for Roads & Bridges - Type 2 Sub-base - Min %
FIG PWD Highways - Specification - Max %
FIG PWD Highways - Specification - Min %

6.2 Appendix B – PWD Highways Quarry Comparisons

Table 6-2 - Grading Results from PWD Highways Quarries

SIEVE (MM)	FIG PWD Highways – Spec Max %	FIG PWD Highways - Spec Min %	Salinas Beach - 11/10/09 - % Passing	Canada Ronde - 09/11/11 - % Passing	Port Harriet - 14/04/11 - % Passing	Port Harriet - 16/08/11 - % Passing	Port Harriet - 17/05/12 - % Passing	Port Harriet - 01/04/13 - % Passing	Port Harriet - North Stockpile - 13/07/15 - % Passing	Port Harriet - South Stockpile - 13/07/15 - % Passing	Port Harriet & PPQ Blended mix - 13/07/15 - % Passing
63	100	97	100	97	100	100	100	100	100	96	98
50	100	90									
31.5	95	75	90	83	95	95	87	93	91	84	89
25			75	76	89	89	75	85	82	75	84
20			66	69	82	83	67	78	76	66	76
16	80	50	54	62	75	76	59	71	67	58	67
14			48	58	70	72	55	68	63	54	62
12.5			43	54	66	69	52	65	60	51	59
10			34	49	59	62	46	59	54	46	52
8	60	30	27	43	53	56	41	54	48	41	46
6.3			21	38	46	51	36	48	44	36	39
5			17	33	41	46	32	44	39	32	33
4	45	15	15	31	38	43	30	41	37	30	29
2			10	20	27	33	23	31	27	22	21
1	32	8	8	14	21	27	18	25	21	18	18
0.5			7	10	17	21	15	19	17	14	14
0.25			6	7	13	15	11	14	12	10	10
0.125			6	5	9	10	7	9	8	7	5
0.063	9	3	4.9	3	6.4	7.5	5.2	5.7	5.4	5.1	3

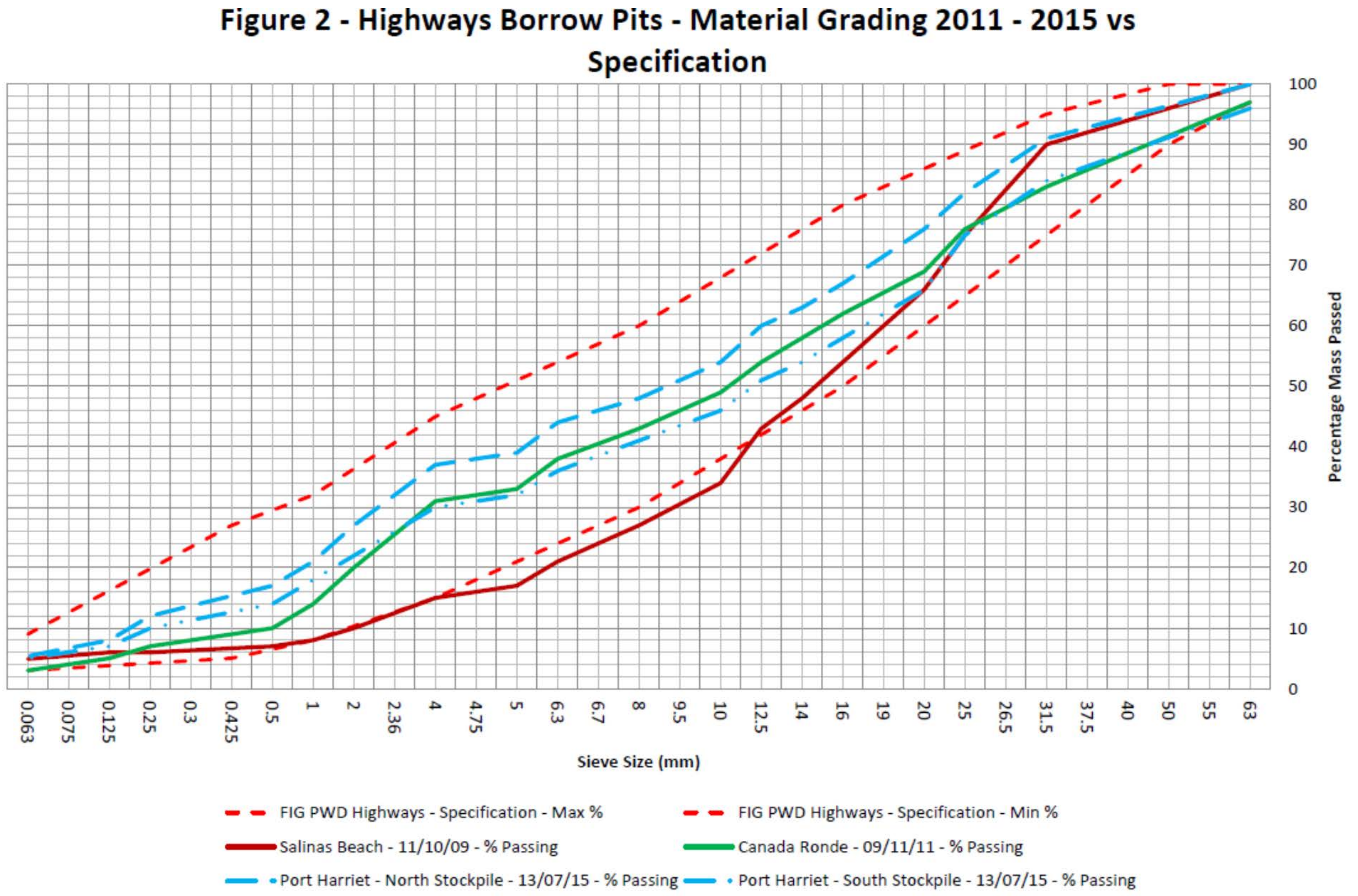
Figure 2 - Highways Borrow Pits - Material Grading 2011 - 2015 vs Specification
Percentage Mass Passed
0
10
20
30
40
50
60
70
80
90
100
Sieve Size (mm)
0.063
0.075
0.125
0.25
0.3
0.425
0.5
1
2
2.36
4
4.75
5
6.3
6.7
8
9.5
10
12.5
14
16
19
20
25
26.5
31.5
37.5
40
50
55
63
FIG PWD Highways - Specification - Max %
FIG PWD Highways - Specification - Min %
Salinas Beach - 11/10/09 - % Passing
Canada Ronde - 09/11/11 - % Passing
Port Harriet - North Stockpile - 13/07/15 - % Passing
Port Harriet - South Stockpile - 13/07/15 - % Passing

Figure 3 - Port Harriet - Material Grading 2011 - 2015 vs Specification