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Protocols for Improving the Proficiency of Material Testing Laboratories in Mozambique – ANE/LEM PTS

PTS First Round - Baseline Report (final)

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Project No. MOZ2094A

22 November 2017

CIVIL DESIGN SOLUTIONS

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Cover Image: PTS sample preparation and testing

Quality assurance and review table			
Version	**Author(s)**	**Reviewer(s)**	**Date**
Draft	Barry Pearce	Robert Geddes	27 October 2017
		Henry Nkwanga	29th October 2017
		Nkululeko Leta	31st October 2017
Draft Final	Barry Pearce Robert Geddes	Henry Nkwanga	2nd November 2017
Final	Barry Pearce Robert Geddes		18 November 2017

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ReCAP Completion Report Template

ReCAP Database Details: Economic Growth through Effective Road Asset Management			
Reference No:	MOZ2094A	**Location**	Mozambique
Source of Proposal	Tender	**Procurement Method**	Open Competitive Tendering
Theme		**Sub-Theme**	
Lead Implementation Organisation	Civil Design Solutions	**Partner Organisation**	Learning Matters etc
Total Approved Budget		**Total Used Budget**	
Start Date	13 December 2016	**End Date**	31 July 2018
Report Due Date	31 October 2017	**Date Received**	2 November 2017 (V2)

Key Words

Materials, Quality Control, Capacity Development, Proficiency Testing

Acronyms, Units and Currencies

10% FACT	10 % Fines Aggregate Crushing Test
$	United States Dollars
AASHTO	American Association of State Highway and Transport Officials
ACV	Aggregate Crushing Value
AFCAP	Africa Community Access Partnership
AIV	Aggregate Impact Value
ALD	Average Least Dimension
AMRL	AASHTO Materials Reference Laboratory
ANE	Administração Nacional de Estradas; National Road Administration
ARMFA	African Road Maintenance Fund Association
ASCAP	Asia Community Access Partnership
BS	British Standard
CBR	California Bearing Ratio
CDS	Civil Design Solutions
CSIR	Council for Scientific and Industrial Research
DCP	Dynamic Cone Penetrometer
DFID	Department for Further International Development
DIMAN	Directorate of Maintenance
DIPLAN	Directorate of Planning
DIPRO	Directorate of Projects
DN	Number of mm penetration per blow of a DCP
EU	European Union
FACT	Fines Aggregate Crushing Test
FI	Fineness Index
FM	Fineness Modulus
FWD	Falling Weight Deflectometer
GM	Grading Modulus
GPS	Global Positioning System
ISO	International Standards Organisation's
INNOQ	Instituto Nacional de Normalização e Qualidade
LL	Liquid Limit
LMetc	Learning Matters etc
LNEC	Laboratório Nacional de Engenharia Civil (Portugal)
LS	Linear Shrinkage
LVR	Low Volume Road
MCA	Millennium Challenge Account
MDD	Maximum Dry Density
NLA	National Laboratory Association
NP	Non Plastic
OMC	Optimal Moisture Content
PMU	Project Management Unit
PI	Plasticity Index
PL	Plastic Limit
PT	Proficiency Testing
PTS	Proficiency Testing Scheme
ReCAP	Research for Community Access Partnership
RL	Reference Laboratory
RTFOT	Rolling Thin Film Oven Test
SA	South Africa
SADCAS	Southern African Development Community Accreditation Service
SANAS	South African Accreditation Service
SANS	South African National Standards

SE	Sand Equivalent
SC	Steering Committee
SP	Slightly Plastic
TMH	Technical Methods for Highways
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)

Contents

1 Introduction

1.1 Background to the Project

The Africa Community Access Partnership (AfCAP) is providing a range of support to Mozambique. This support includes the development of design guidelines for low volume roads and the evaluation of existing road experimental sections constructed previously in Mozambique.

The validity of research on roads in Mozambique and the region depends on the reliability of laboratory test results. As a result, AfCAP is supporting the implementation of a pilot project for Proficiency Testing in selected laboratories. The overall objective is to establish laboratory testing in Mozambique that is in line with international practices and standards and test results that can be used with confidence.

The Proficiency Testing Scheme (PTS) is developing a baseline for the precision limits for the common tests on road building materials. The baseline will be used to assess laboratory capacity and identify where constraints lie and where specific training and other interventions may be required. It is expected that participating laboratories will ultimately become accredited to the International Standards Organisation's standard ISO/IEC 17025.

The Mozambique PTS project is a pilot project for Mozambique and for a possible AfCAP regional initiative to support capacity development in materials laboratory testing through a PTS process. This will improve the confidence level in test results being used for research, design and quality control purposes during construction and maintenance operations.

1.2 Objectives

The objectives of the assignment are as follows:

- To identify the repeatability and reproducibility (precision limits) of the principal test methods currently being carried out in Mozambican laboratories; evaluate the existing testing competence of laboratories in Mozambique.
- Determine how the test results of the Mozambican laboratories compare with those of internationally accredited (ISO/IEC 17025) laboratories. Two SANAS accredited laboratories were selected from South Africa and used as independent controls in the baseline survey and PTS pilot.
- Identify where interventions are needed for improving test results and the type of intervention required.
- Design and manage a pilot PTS and transfer knowledge and expertise to Mozambican laboratory personnel on how to implement a PTS and to evaluate the test results obtained.
- Keep ANE and sector stakeholders fully informed on project implementation and outcomes in order for precision limits of tests to be included in relevant National Standards for Roads in Mozambique.

1.3 Approach

The approach to the project implementation focuses on the following key objectives:

1. To ensure that ANE and LEM are the leaders of the research process.
2. To ensure effective linkages with parallel and associated project initiatives.
3. Establish linkages between the participating laboratories.

The purpose of establishing linkages between the participating laboratories is to promote the concept of a self-supporting network of laboratories, with a joint commitment to quality and reliability of results.

1.4 Participating laboratories

The laboratories that are participating in the first round of the pilot PTS are as follows:

1. LEM
2. ANE Maputo
3. ANE Nampula
4. ANE Manica
5. ANE Inhambane
6. JJR (Maputo - private)
7. Soil-Lab (Maputo - private)
8. Geoma (Maputo – private)
9. Letaba Laboratory (Nelspruit - private)
10. SoilCo Laboratory (Pinetown - private).

1.5 Purpose of this Report

This report presents the analysis of test results received from the participating laboratories in the first round of the pilot PTS of 2017.

The following tests were included for this round:

FORM A[1] – Crushed granular material

- Wet preparation and sieve analysis
- Atterberg Limits
- MDD/OMC
- CBR

FORM B – Plastic fines material

- Atterberg Limits

[1] Form A, B, C and D included in the "Protocols for Testing Gravel Samples (Indicator, OMC/MDD & CBR) & Aggregates Samples (Grading, FI, ALD, ACV & 10% FACT). May 2017.

FORM C – Aggregate material

- Sieve analysis
- Flakiness Index
- Average Least Dimension
- ACV & 10 % FACT

FORM D – Sand material

- Wet preparation and sieve analysis
- Atterberg Limits
- MDD/OMC
- CBR

The samples for the first round of the PTS were provided by JJR Construction, ANE Maputo & ANE Inhambane. The splitting was undertaken at LEM in Maputo. ANE would like to acknowledge these contributions.

The results are presented in a form that laboratories should find useful, but the participating laboratories are encouraged to submit comments on the format to the organizers of the PTS should they have suggestions as to how this format could be improved.

In the report on the test results (Chapter 3) a unique code was used to identify each participating laboratory. The laboratories have been informed of their own code but not the codes used of the other laboratories.

The following terms and abbreviations are used in Chapter 3.

a) OE - Obvious error (listed but excluded from analysis of results)

b) CV - Coefficient of variance

c) NP - Non-plastic (Used to define the PI classification for a zero (0) % shrinkage only)

d) SP - Slightly-plastic (Used to define the PI classification for shrinkage less than 1.5 % only)

e) Null - No value submitted (test not undertaken either due to the equipment not being available or when the PL is not being undertaken due to the LL not being determinable).

f) CBD - Could not be determined (When a test is undertaken but a result is not determinable, for example LL when the material is NP or SP).

g) MC - Moisture content

h) LL - Liquid limit

i) PL - Plastic limit

j) LS - Linear shrinkage limit

k) PI - Plasticity index

l) GM - Grading modulus

m) FM - Fineness modulus

n) MDD - Maximum dry density

o) OMC - Optimum moisture content

p) CBR - California bearing ratio

q) ACV - Aggregate crushing value

r) 10% FACT - 10 % Fine Aggregate Crushing Test

s) FI - Flakiness index

t) ALD - Average least dimension

2 Methodology

2.1 System Design

The objective of the ANE/LEM PTS is to provide laboratories with an external mechanism for having their results compared with a relatively large sample of other materials laboratories.

Whilst it is not possible to guarantee a single 'target' value for evaluation purposes given the inherent variability of civil roads materials, the organizers are confident that the H15 robust mean and H15 standard deviation is representative of each sample. In the case where the result submitted is an obvious error (OE), the result was excluded from the analysis.

2.2 Stability and Homogeneity testing

Based on the results received, the samples provided to the participating laboratories are considered to be sufficiently stable and homogenous.

2.3 Statistics Employed

A convenient and internationally accepted statistical method for analyzing test results is to calculate a z-score for each laboratory's result. A z-score is a normalised value which gives a "score" to each result, relative to the other numbers in the data set.

A standard formula for the calculation of z-scores is:

$$z_i = \frac{x_i - \bar{x}}{s}$$

Where:

(x_i) is the ith result

($\bar{x}$) is the assigned value (e.g. mean or median)

s is an estimate of the spread of all results e.g. robust standard deviation or fitness for purpose criteria.

A z-score value close to zero therefore means that the result agrees well with those from the other laboratories.

In order to use as many results as possible and not have to make decisions with regard to outliers, Robust Indicators were used. The Robust Indicators include both a Robust Mean and Robust Standard Deviation.

The H15 Robust Mean and H15 Robust Standard Deviation are used to analyse the data due to their ability to include outliers in the data set as analysed while applying a weighting to each value. This weighting allows the data values wider of the H15 mean to have less of an effect on the results, both for the mean and the standard deviation. This results in a more accurate mean and standard

deviation determination that better identifies the consensus mean and z-score analysis of the data set.

Results were evaluated using the standard z-score as detailed in the AMRL[2] method.

2.4 AMRL Method of Evaluation

A more stringent rating is used by AMRL as laid out below, which may be a more acceptable rating scale than the standard z-score rating.

The laboratory rating calculation is based on the absolute value of the Z-Score (or number of standard deviations from the average). The following describes the laboratory rating system:

- **If Z-Score ≤ 1** **Then Rating = 5**
- **If Z-Score > 1 and ≤ 1.5** **Then Rating = 4**
- **If Z-Score > 1.5 and ≤ 2** **Then Rating = 3 – needs investigation**
- **If Z-Score > 2 and ≤ 2.5** **Then Rating = 2 - problematic**
- **If Z-Score > 2.5 and ≤ 3** **Then Rating = 1 – needs in-depth investigation**
- **If Z-Score > 3** **Then Rating = 0 – unacceptable**

In this report the results are given as a calculated z-score accurate to three decimal places and colour coded according to the above rating for easier identification of where each facility lies in relation to the mean and the other rating groups.

A negative sign on a Z-Score or Rating indicates that the laboratory's result was below the average, while a positive Z-Score or Rating indicates that the laboratory's result was above the average.

Reference:

- AMRL: AASHTO Materials Reference Laboratory
- AASHTO: American Association of State Highway and Transportation Officials

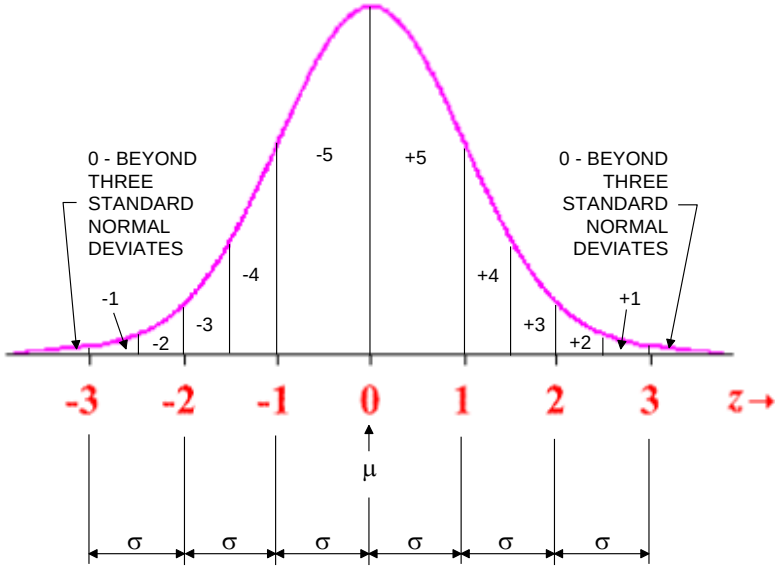
2.5 Scoring of Proficiency Samples by AMRL

Scoring of proficiency test samples is determined by fitting a standard normal distribution to the data from all laboratories (with outliers eliminated[3]). Laboratories whose results fall within one standard normal deviation from the mean are assigned a numerical score of "5." Laboratories whose results fall between 1 and 1½ standard normal deviations from the mean are assigned a score of "4," and the ratings are further decreased one point for each half standard normal deviate thereafter. A

[2] AASHTO Materials Reference Laboratory.

[3] No results have been excluded in this report as it is a base line of the current situation. Outliers are identified as those with exceptionally high z-score values i.e.> 3.

positive sign (+) indicates the lab result is above the mean, and a negative sign (-) indicates the lab result is below the mean. This system can be depicted graphically, as follows:



$z = (x - \mu) / \sigma$

Sample Calculation

- Assume mean, $\mu = 20.73$ and standard deviation, $\sigma = 0.65$ with lab result, $x = 19.8$
- Standard normal deviations from mean = (lab result – mean)/(standard deviation) = (19.8 – 20.7)/0.65 = -1.38
- Note that negative sign here indicates the lab result is below the mean.
- The lab result is between 1 and 1½ standard normal deviations below the mean, so that the lab rating for this particular result, according to the figure shown above, would be -4.

3 Test Results

3.1 Crushed Granular Material

Liquid Limit (LL), Plastic Limit (PL), Linear Shrinkage (LS) and Plasticity Index (PI) tests

Lab code	LL %	z-score
CV6ZX	0	**-7.120**
WQ3LN	20.8	-0.501
YY3QP	22.2	-0.056
AB4XQ	22.5	0.040
DG3DK	24	0.517
AO7VU	29.9	**2.395**
DF6CP	CBD	
EN2QS	CBD	
TF5SK	CBD	
DK9WF	NP	

Lab code	PL %	z-score
CV6ZX	0	**-2.069**
AO7VU	18.7	0.262
YY3QP	19.5	0.362
DG3DK	22	0.673
DF6CP	CBD	
EN2QS	CBD	
TF5SK	CBD	
WQ3LN	CBD	
DK9WF	NP	
AB4XQ	NULL	

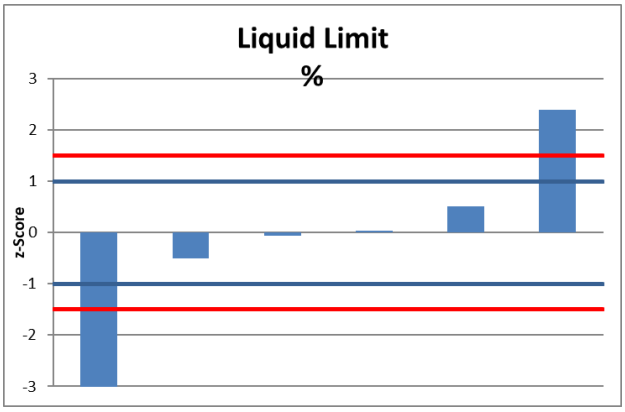
Lab code	LS %	z-score
AB4XQ	0	**-1.000**
CV6ZX	0	**-1.000**
DG3DK	0.4	-0.689
YY3QP	1.0	-0.223
EN2QS	1.5	0.166
WQ3LN	2.0	0.554
DK9WF	2.3	0.787
AO7VU	4.0	**2.108**
DF6CP	CBD	
TF5SK	NULL	

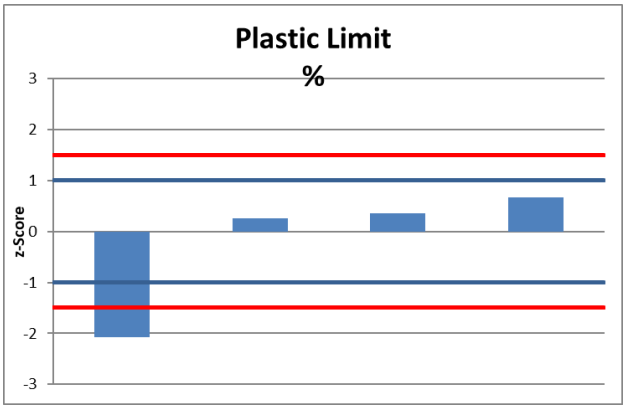
Lab code	PI %	z-score
DG3DK	2	-0.569
YY3QP	2.7	-0.448
AO7VU	11.2	**1.016**
DF6CP	CBD	
TF5SK	CBD	
CV6ZX	NP	
DK9WF	NP	
AB4XQ	NULL	
WQ3LN	NULL	
EN2QS	SP	

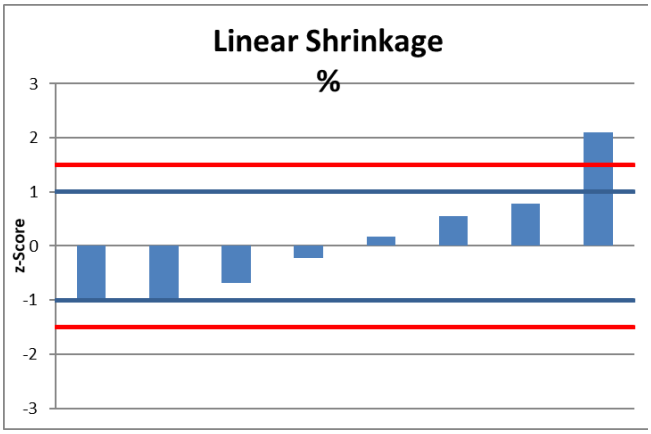
Test method information

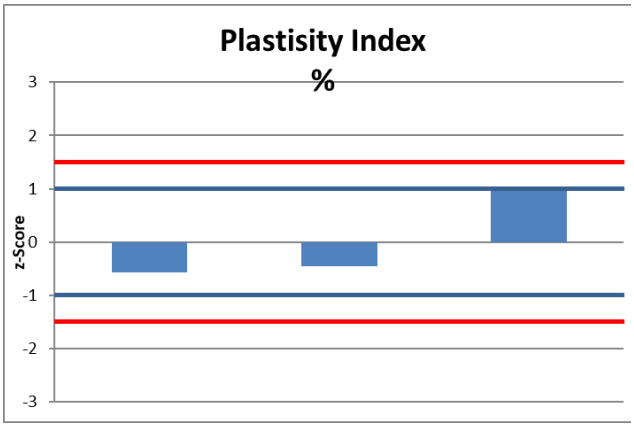
Test method	AASHTO T88/89	SANS 3001 GR10/11/12	TMH1 A2, A3 & A4	Non-responsive
# participants	3 (30 %)	2 (20 %)	4 (40 %)	1 (NULL)

	LL	PL	LS	PI
H15 mean	22.37	16.60	1.29	5.30
H15 Std Dev	3.14	8.02	1.29	5.80
Range	29.90	22.00	4.00	9.20
CV	14.0%	48.3%	100.0%	109.5%









	LL	PL	LS	PI
Additional participant statistics				
Number of participants	10	10	10	10
CBD	3	4	1	2
NP	1	1	-	2
SP	-	-	-	1
NULL	-	1	1	2
Non-participants	-	-	-	-
OB	-	-	-	-

Statistics for Z-scores < ±1				
Range	3.2	3.3	1.9	0.7
Percentage of participants	67 %	75 %	63 %	67 %

Reporting format				
Participants reported correctly to 1 %	2	2	2	1
Participants reported to 0.1 %	4	2	6	2

Comments – Atterberg limits

- Three test methods were used by the 10 participants in the PI determination.
- Only three facilities of the ten obtained a PI value.
- Much needs to be done to get the results reported correctly of this range of test methods.
- In general, the results are too variable for the PL, LS and PI.
- The LL, although it has a low CV, is still not constant enough to identify the material as either having plasticity or not

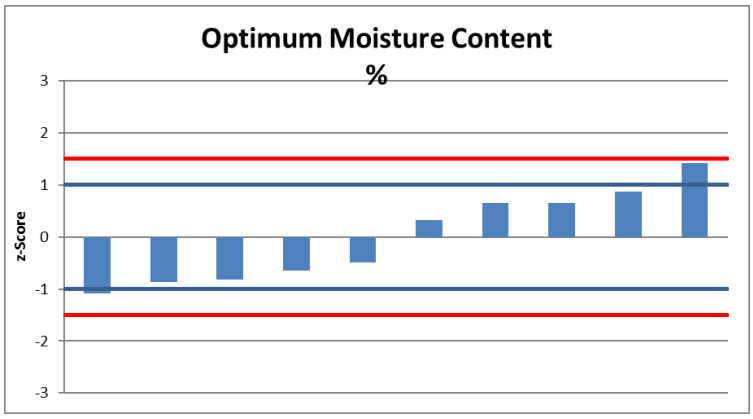
Optimum Moisture Content test

#	Lab code	OMC %	OMC z-score
1	WQ3LN	6.4	**-1.089**
2	AO7VU	6.8	-0.871
3	EN2QS	6.9	-0.817
4	CV6ZX	7.2	-0.654
5	TF5SK	7.5	-0.490
6	YY3QP	9.0	0.327
7	DF6CP	9.6	0.654
8	DG3DK	9.6	0.654
9	AB4XQ	10.0	0.871
10	DK9WF	11.0	**1.416**

	OMC
H15 mean	8.40
H15 Std Dev	1.836
Range	4.60
CV	21.9%

Test method information

Test method	AASHTO T180	AASHTO T99	SANS 3001 GR30	TMH1 A7	Non-responsive
# participants	3 (30 %)	1 (10 %)	2 (20 %)	4 (40 %)	0 (NULL)



Apparatus information

Automatic	Manual	Non-responsive
2	7	1 (NULL)

Additional participant statistics

Number of participants	10
Non-participants	-
OB	-

Statistics for Z-scores < ±1

Range	3.20
Percentage of participants	80.0%

Reporting format

Participants reported correctly to 0.1 %	10

Comments - Optimum Moisture Content (OMC) test

- Four test methods were used by the 10 participants in the OMC determination
- These results were reasonable given the low StDev, although there is still scope for improvement by reducing the range of the overall results.

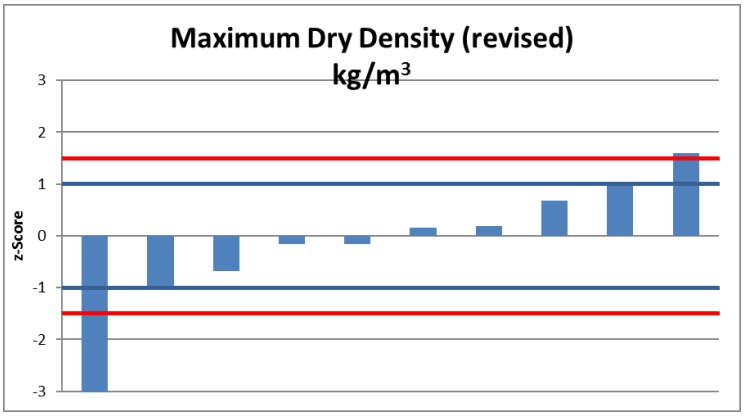
Maximum Dry Density test

#	Lab code	MDD kg/m³	MDD z-score
1	AO7VU	1802	**-3.294**
2	EN2QS	*1882*	-0.992
3	WQ3LN	*1893*	-0.676
4	DG3DK	1911.0	-0.158
5	YY3QP	1911	-0.158
6	CV6ZX	*1922*	0.158
7	TF5SK	1923	0.187
8	AB4XQ	1940	0.676
9	DF6CP	1950	0.964
10	DK9WF	1972	**1.597**

	MDD
H15 mean	1916.5
H15 Std Dev	34.762
Range	170.00
CV	1.8%

Test method information

Test method	AASHTO T180	AASHTO T99	SANS 3001 GR30	TMH1 A7	Non-responsive
# participants	3 (30 %)	1 (10 %)	2 (20 %)	4 (40 %)	0 (NULL)



Additional participant statistics

Number of participants	10
Non-participants	-
OB	-

Statistics for Z-scores < ±1

Range	68.0
Percentage of participants	80.0%

Reporting format

Participants reported to 1 kg/m³	4
Participants reported to 0.1 kg/m³	1
Participants reported to 0.001	5

Comments -Maximum Dry Density (MDD) test

- Four test methods were reportedly used by the 10 participants in the MDD determination.
- The results for the MDD were all converted to kg/m^3 for ease of analysis. This is as a result of the different test methods making use of various reporting formats.
- The range of 170 kg/m^3 looks high and represents a variation of just under 9 %. This value drops to 68 kg/m^3 for the z-scores less ± 1.
- The use of manual versus the automatic hammer would influence the results. Half the participants made use of automatic hammers. This value may increase as two participants didn't provide the information as requested. This point is also applicable to the CBR determinations.

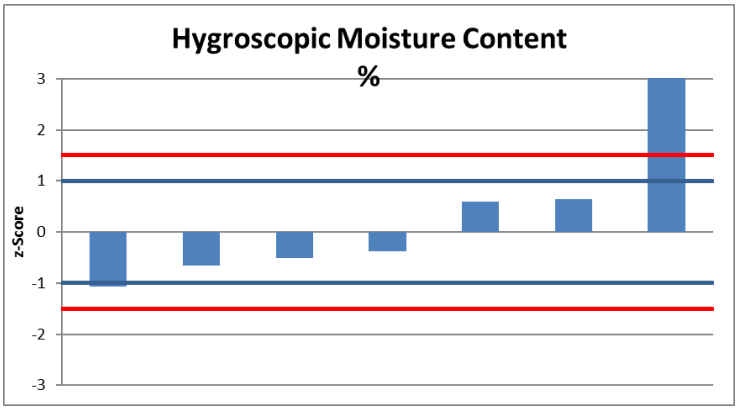
CBR Hygroscopic Moisture Contents test

#	Lab code	Hygroscopic MC (%)	z-score
1	DK9WF	0.0	**-1.070**
2	AB4XQ	0.6	-0.655
3	DG3DK	0.8	-0.517
4	EN2QS	1.0	-0.379
5	CV6ZX	2.4	0.589
6	TF5SK	2.48	0.644
7	WQ3LN	53	**35.561**
8	AO7VU	NULL	
9	DF6CP	NULL	
10	YY3QP		

	Hygroscopic MC (%)
H15 mean	1.55
H15 Std Dev	1.447
Range	53.00
CV	93.5%

Test method information

Test method	AASHTO T193	SANS 3001 GR40	TMH1 A8	Non-responsive
# participants	4 (40 %)	2 (20 %)	4 (40 %)	0 (NULL)



Apparatus information

Automatic	Manual	Non-responsive
5	3	2 (NULL)

Proving Ring	Load Cell	Non-responsive
-	4	6 (NULL)

Additional participant statistics

Number of participants	9
Non-participants	1
NULL	2
OB	-

Statistics for Z-scores < ±1

Range	1.88
Percentage of participants	71.4%

Reporting format

Participants reported to 1 %	1
Participants reported correctly to 0.1 %	5
Participants reported to 0.01 %	1

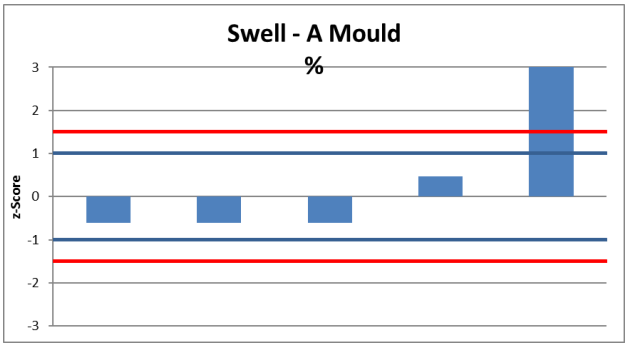
Comments - Hygroscopic Moisture Contents test

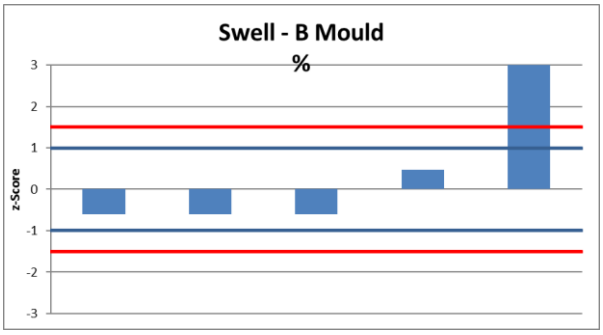
- Four test methods were used by the 10 participants in the CBR determination
- The values vary vastly. This value should represent the moisture in the material after air drying. It should not be zero (0) percent nor should it be as high as 53 %.
- Most of the results provided were reasonably close to one another.

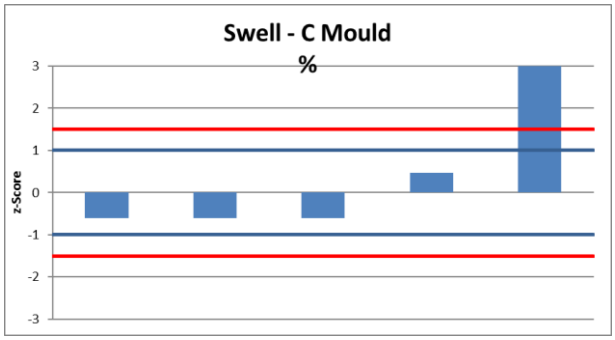
CBR - % Swell (A, B & C moulds)

Lab code	% Swell							
	A	Z-score	Lab Code	B	Z-score	Lab Code	C	Z-score
AB4XQ	0	-0.603	AB4XQ	0	-0.603	AB4XQ	0	-0.603
EN2QS	0	-0.603	EN2QS	0	-0.603	EN2QS	0	-0.603
YY3QP	0.00	-0.603	YY3QP	0.00	-0.603	YY3QP	0.00	-0.603
CV6ZX	0.02	0.467	CV6ZX	0.04	0.467	CV6ZX	0.06	0.467
DG3DK	2.9	**154.537**	DG3DK	3.0	**79.653**	DG3DK	3.0	**52.908**
DF6CP	CBD		DF6CP	CBD		DF6CP	CBD	
TF5SK	CBD		TF5SK	CBD		TF5SK	CBD	
AO7VU	NULL		AO7VU	NULL		AO7VU	NULL	
DK9WF	NULL		DK9WF	NULL		DK9WF	NULL	
WQ3LN	NULL		WQ3LN	NULL		WQ3LN	NULL	

	Swell A %	Swell B %	Swell C %
H15 mean	0.011	0.023	0.034
H15 Std Dev	0.019	0.037	0.056
Range	2.90	3.00	3.00
CV	165.8%	165.8%	165.7%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	5	5	5
Non-participants	-	-	-
CBD	2	2	2
NULL	3	3	3
OB	-	-	-
Statistics for Z-scores < ±1			
Range	0.02	0.04	0.06
Percentage of participants	71.4%	80.0%	80.0%
Reporting format			
Participants reported correctly to 1 %	2	2	2
Participants reported to 0.1 %	1	1	1
Participants reported to 0.01 %	2	2	2

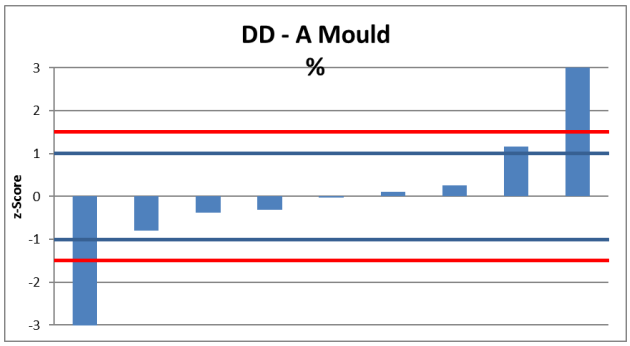
Comments - % Swell (A, B & C moulds)

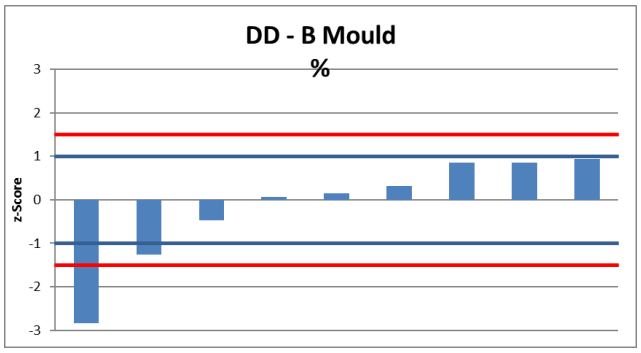
- The swell values are far too variable reporting from 0 % up to 3 %.
- Reporting the swell to a single decimal point should result in an improvement in the variability especially when there are very low swell values.
- Special care is required to ensure that the swell gauge is not reset once the initial reading is taken and placed in exactly the same place when taking the readings at end of the four-day soaking process. This is necessary to obtain an acceptable swell reading.

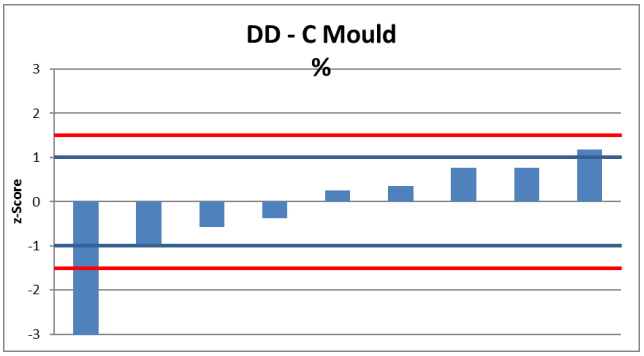
Maximum Dry Density % (A, B & C moulds)

Lab Code	% DD								
	A	Z-score		Lab Code	B	Z-score		Lab Code	C	Z-score
TF5SK	93.4	**-4.965**		TF5SK	91.7	**-2.837**		TF5SK	87.9	**-3.161**
DK9WF	*99.3*	-0.806		WQ3LN	93.5	**-1.259**		DF6CP	90	-0.988
AB4XQ	99.9	-0.383		DK9WF	94.4	-0.470		DG3DK	90.4	-0.574
DF6CP	100	-0.312		DF6CP	95	0.056		YY3QP	90.6	-0.367
CV6ZX	100.4	-0.030		AB4XQ	95.1	0.144		EN2QS	91.2	0.254
DG3DK	100.6	0.111		DG3DK	95.3	0.319		DK9WF	*91.3*	0.358
EN2QS	100.8	0.252		CV6ZX	*95.9*	0.845		AB4XQ	91.7	0.772
YY3QP	102.1	**1.168**		EN2QS	95.9	0.845		CV6ZX	91.7	0.772
WQ3LN	105.4	**3.495**		YY3QP	96.0	0.933		WQ3LN	92.1	**1.186**
AO7VU	NULL			AO7VU	NULL			AO7VU	NULL	

	A %	B %	C %
H15 mean	100.44	94.94	90.95
H15 Std Dev	1.418	1.141	0.966
Range	12.00	4.30	4.20
CV	1.4%	1.2%	1.1%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	9	9	9
Non-participants	-	-	-
NULL	1	1	1
OB	-	-	-
Statistics for Z-scores < ±1			
Range	1.50	1.60	1.70
Percentage of participants	66.7%	77.8%	77.8%
Reporting format			
Participants reported to 1 %	1	1	1
Participants reported to 0.1 %	8	8	8

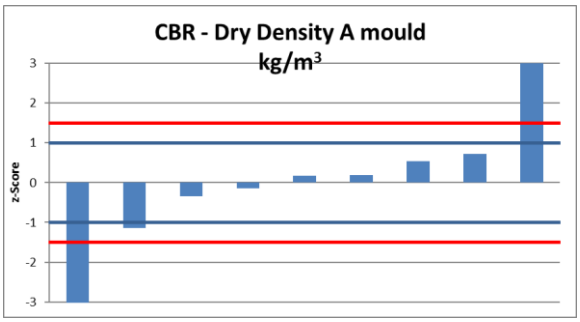
Comments - Maximum Dry Density % (A, B & C moulds)

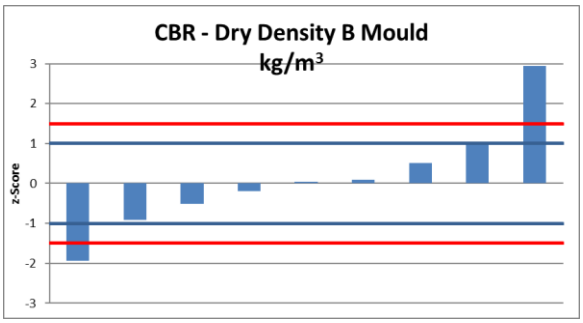
- Although the mean reflects the expected results of close to 100 %, 95 % and 90 % of MDD, the range of the results are too high especially for mould A.
- This points to a possible problem with the laboratories ability to divide the bulk sample as supplied into representative portions for use in the 5 MDD and 3 CBR points.

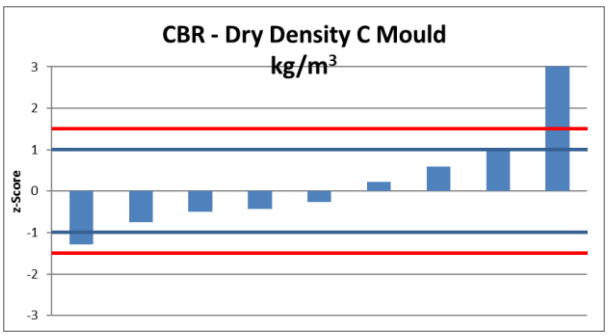
CBR - Dry Density kg/m³ (A, B & C moulds)

Dry Density (kg/m³)									
Lab Code	A	Z-score		Lab Code	B	Z-score		Lab Code	C	Z-score
TF5SK	***1797***	**-4.261**		TF5SK	**1764**	**-1.940**		TF5SK	***1691***	**-1.292**
EN2QS	1897	**-1.144**		EN2QS	1805	-0.915		EN2QS	1716	-0.758
DG3DK	1922.9	-0.337		DG3DK	1821.0	-0.515		DG3DK	1727.8	-0.506
CV6ZX	1929	-0.147		YY3QP	1834	-0.189		YY3QP	1731	-0.438
AB4XQ	*1939*	0.165		CV6ZX	1843	0.036		DF6CP	***1739***	-0.267
DF6CP	***1940***	0.196		AB4XQ	*1845*	0.086		CV6ZX	1762	0.224
YY3QP	1951	0.539		DK9WF	**1862**	0.511		AB4XQ	*1779*	0.587
DK9WF	**1957**	0.726		DF6CP	***1881***	0.986		DK9WF	**1800**	**1.036**
WQ3LN	**2209**	**8.580**		WQ3LN	**1959**	**2.937**		WQ3LN	**1930**	**3.812**
AO7VU	NULL			AO7VU	NULL			AO7VU	NULL	

	A	B	C
H15 mean	1933.70	1842	1751
H15 Std Dev	32.085	40.0	46.8
Range	412.00	195.00	239.00
CV	1.7%	2.2%	2.7%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	9	9	9
Non-participants	-	-	-
NULL	1	1	1
OB	-	-	-
Statistics for Z-scores < ±1			
Range (kg/m^3)	34.1	76.0	63.0
Percentage of participants	66.7%	77.8%	66.7%
Reporting format			
Participants reported correctly to 1 kg/m^3	5	5	5
Participants reported correctly to 0.001	5	5	5

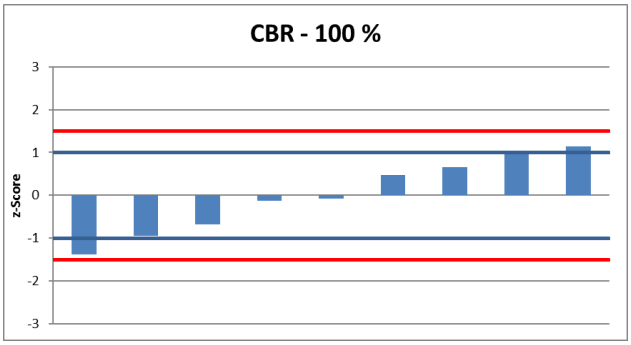
Comments - Dry Density kg/m^3 (A, B & C moulds)

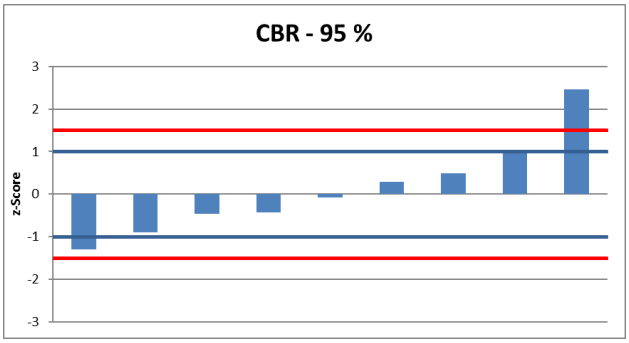
- Most of the results are within an acceptable range.
- Although the CV is acceptably low, the range is far too high. The range for the value with z-score of ±1 is far more acceptable.
- Laboratories should check that their A mould density is as close as possible to the MDD

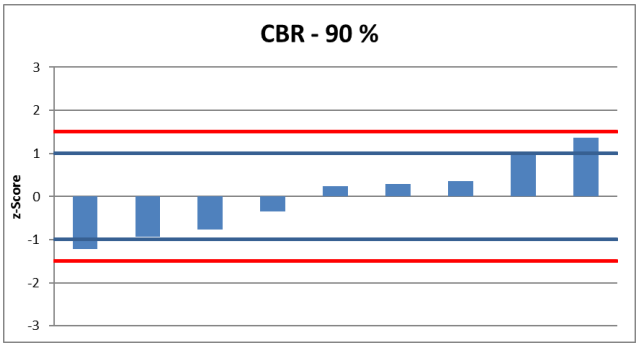
CBR %

CBR %								
Lab Code	100%	Z-score	Lab Code	95%	Z-score	Lab Code	90%	Z-score
WQ3LN	**49.83**	**-1.386**	YY3QP	27.7	**-1.300**	WQ3LN	**10.11**	**-1.214**
YY3QP	68.7	-0.950	CV6ZX	38	-0.902	YY3QP	15.1	-0.934
DF6CP	**80**	-0.688	WQ3LN	**49.25**	-0.468	CV6ZX	18	-0.771
CV6ZX	104	-0.133	DF6CP	**50**	-0.439	DG3DK	25.5	-0.350
AB4XQ	106	-0.087	DG3DK	59.3	-0.079	EN2QS	36	0.239
TF5SK	**130**	0.468	TF5SK	**69**	0.295	AB4XQ	37	0.295
DG3DK	138.2	0.658	EN2QS	74	0.489	DK9WF	**38.0**	0.351
EN2QS	*152*	0.977	AB4XQ	87	0.991	DF6CP	**50**	**1.024**
DK9WF	**159.0**	**1.139**	DK9WF	**125.0**	**2.459**	TF5SK	**56**	**1.360**
AO7VU	NULL		AO7VU	NULL		AO7VU	NULL	

CBR %	**100%**	**95%**	**90%**
H15 mean	109.7	61.4	31.7
H15 Std Dev	43.23	25.88	17.83
Range	109.17	97.30	45.89
CV	39.4%	42.2%	56.2%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	9	9	9
Non-participants	-	-	-
NULL	1	1	1
OB	-	-	-
Statistics for Z-scores < ±1			
Range (%)	83.3	49.0	22.9
Percentage of participants	77.8%	77.8%	66.7%
Reporting format			
Participants reported correctly to 1 %	5	5	5
Participants reported to 0.1 %	3	3	3
Participants reported to 0.01 %	1	1	1

Comments – CBR %

- The CBR results are highly variable but this is to be expected given the nature of the material in this sample, which contains larger crushed particles.
    - If a large stone particle lies directly below the CBR piston head, the results will be skewed to the high side especially if there is another stone below
    - The result is expected to be more consistent with finer grained material.
- The z-score between ±1 are also still too high.

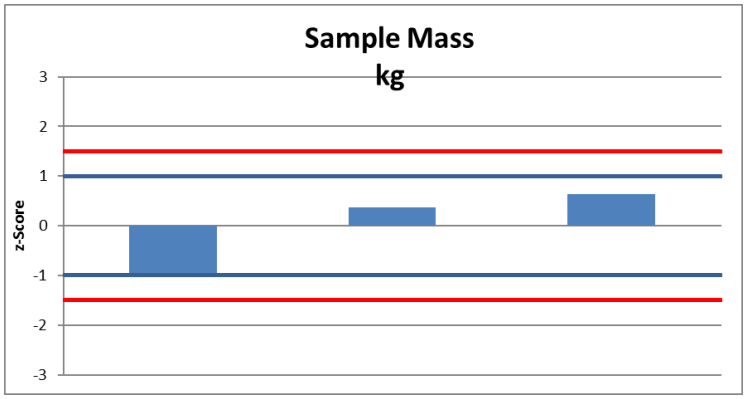
Washed Grading Sample Mass

#	Lab code	Sample mass (g)	z-score
1	WQ3LN	**2122.4**	**-1.006**
2	AO7VU	***3175***	0.366
3	YY3QP	**3385.0**	0.640
4	AB4XQ		
5	CV6ZX		
6	DF6CP		
7	DG3DK		
8	DK9WF		
9	EN2QS		
10	TF5SK		

	Reduction Factor
H15 mean	2894.1
H15 Std Dev	766.8
Range	1262.6
CV	26.5%

Test method information

Test method	AASHTO T27	AASHTO T88	ASTM C136	SANS 3001 GR1	TMH1 A1 (a)	TMH1 A1	Non-responsive
# participants	2 (20 %)	1 (10 %)	1 (10 %)	2 (20 %)	2 (20 %)	2 (20 %)	0 (NULL)



	Sample Mass
Number of participants	3
Non-participants	7
OB	-
Range	210.0
Percentage of participants	66.7%
Participants reported to 1 g	1
Participants reported to 0.1 g	2

Comments - Washed grading sample mass

- Too few results were reported to make any meaningful deductions regarding the sample mass used.

Washed Grading

NOTE: *Fraction 100 mm, 75 mm, 63 mm and 50 mm were not analyzed as they all had 100 % passing*

Lab Code	37.5 mm	Z-Score
AB4XQ	86.2	**-1.74E+14**
AO7VU	100	0.357
CV6ZX	100	0.357
DK9WF	100.0	0.357
EN2QS	*100*	0.357
TF5SK	*100.00*	0.357
YY3QP	100	0.357
DF6CP		
DG3DK		
WQ3LN		

Lab Code	28/25 mm	Z-Score
WQ3LN	*69.1*	**-1.855**
AB4XQ	75.1	**-1.127**
AO7VU	80.0	-0.533
DK9WF	84.7	0.038
TF5SK	86.42	0.247
EN2QS	*87*	0.317
DG3DK	87.50	0.378
CV6ZX	*90*	0.681
DF6CP	100	**1.895**
YY3QP		

Lab Code	20/19 mm	Z-Score
WQ3LN	47.8	**-2.474**
AB4XQ	*59.7*	-0.925
AO7VU	59.7	-0.925
YY3QP	65.92	-0.116
DK9WF	67.6	0.103
CV6ZX	*68*	0.155
TF5SK	68.76	0.254
DG3DK	70.6	0.493
DF6CP	74.2	0.962
EN2QS	*79*	**1.586**

% passing	37,5 mm	28/25 mm	20/19 mm
H15 mean	100.0	84.4	66.8
H15 Std Dev	7.953E-14	8.240	7.685
Range	13.80	30.90	31.20
CV	0.0%	9.8%	11.5%

Lab Code	14/13.2 mm	Z-Score
AO7VU	*27.9*	**-1.425**
WQ3LN	31.5	**-1.170**
AB4XQ	*40.2*	-0.554
CV6ZX	*51*	0.211
TF5SK	51.11	0.219
DF6CP	52.6	0.325
DK9WF	53.7	0.403
DG3DK	56.0	0.566
EN2QS	*69*	**1.487**
YY3QP		

Lab Code	10/9.5 mm	Z-Score
AO7VU	*14.5*	**-1.837**
WQ3LN	23.2	**-1.120**
DF6CP	39.4	0.214
DK9WF	41.7	0.404
TF5SK	41.81	0.413
YY3QP	44.54	0.637
DG3DK	47.0	0.840
AB4XQ		
CV6ZX		
EN2QS		

Lab Code	7.1/6.7 mm	Z-Score
AO7VU	*11.1*	**-1.476**
WQ3LN	18.7	-0.820
DF6CP	32.8	0.397
TF5SK	33.15	0.427
DK9WF	33.8	0.483
DG3DK	38.4	0.880
AB4XQ		
CV6ZX		
EN2QS		
YY3QP		

% passing	14/13.2 mm	10/9.5 mm	7.1/6.7 mm
H15 mean	48.0	36.8	28.2
H15 Std Dev	14.114	12.140	11.588
Range	41.10	32.50	27.30
CV	29.4%	33.0%	41.1%

Lab Code	5/4.75 mm	Z-Score
AO7VU	***9.5***	**-2.095**
WQ3LN	**15.2**	**-1.408**
AB4XQ	24.7	-0.263
DF6CP	25.2	-0.203
CV6ZX	*28*	0.135
DK9WF	**29.1**	0.268
TF5SK	29.28	0.289
YY3QP	**31.26**	0.528
DG3DK	32.3	0.653
EN2QS	*45*	**2.184**

Lab Code	3.35 mm	Z-Score
TF5SK	24.32	
AB4XQ		
AO7VU		
CV6ZX		
DF6CP		
DG3DK		
DK9WF		
EN2QS		
WQ3LN		
YY3QP		

Lab Code	2/2.360 mm	Z-Score
AO7VU	***5.7***	**-1.709**
WQ3LN	**9.5**	**-1.188**
AB4XQ	11.8	-0.872
CV6ZX	*18.7*	0.076
DK9WF	**19.7**	0.213
TF5SK	20.28	0.293
DF6CP	*21.4*	0.447
DG3DK	21.7	0.488
YY3QP	**22.09**	0.542
EN2QS	*30*	**1.628**

% passing	5/4.75 mm	3.35 mm	2/2.36 mm
H15 mean	26.9	24.3	18.1
H15 Std Dev	8.296	0.000	7.281
Range	35.50	0.00	24.30
CV	30.9%	0.0%	40.1%

Lab Code	1/1.18 mm	Z-Score
AO7VU	*4.4*	**-1.404**
WQ3LN	6.3	**-1.037**
YY3QP	11.75	0.016
DK9WF	13.7	0.393
DF6CP	*14*	0.451
TF5SK	14.62	0.571
DG3DK	16.8	0.992
AB4XQ		
CV6ZX		
EN2QS		

Lab Code	0.600 mm	Z-Score
AO7VU	*3.3*	**-1.340**
WQ3LN	4.0	**-1.172**
DK9WF	9.6	0.178
TF5SK	10.44	0.380
DF6CP	11	0.515
YY3QP	11.40	0.611
DG3DK	12.3	0.828
AB4XQ		
CV6ZX		
EN2QS		

Lab Code	0.425 mm	Z-Score
AO7VU	*3.0*	**-1.111**
WQ3LN	3.2	**-1.061**
AB4XQ	5.0	-0.607
DK9WF	7.8	0.098
DF6CP	8.1	0.174
CV6ZX	*8.7*	0.325
DG3DK	10.5	0.778
EN2QS	*14*	**1.660**
TF5SK		
YY3QP		

% passing	1/1.18 mm	0.600 mm	0.425 mm
H15 mean	11.7	8.9	7.4
H15 Std Dev	5.174	4.150	3.970
Range	12.40	9.00	11.00
CV	44.4%	46.8%	53.6%

Lab Code	0.300 mm	Z-Score
WQ3LN	**2.4**	**-1.303**
AO7VU	***2.7***	**-1.196**
DF6CP	6.6	0.195
DK9WF	**6.8**	0.266
TF5SK	7.46	0.501
YY3QP	8.12	0.736
DG3DK	8.3	0.801
AB4XQ		
CV6ZX		
EN2QS		

Lab Code	0.150 mm	Z-Score
WQ3LN	**1.4**	**-1.341**
AO7VU	***1.9***	**-1.130**
DK9WF	**4.8**	0.098
TF5SK	5.29	0.305
DF6CP	5.9	0.564
YY3QP	**5.99**	0.602
DG3DK	6.7	0.902
AB4XQ		
CV6ZX		
EN2QS		

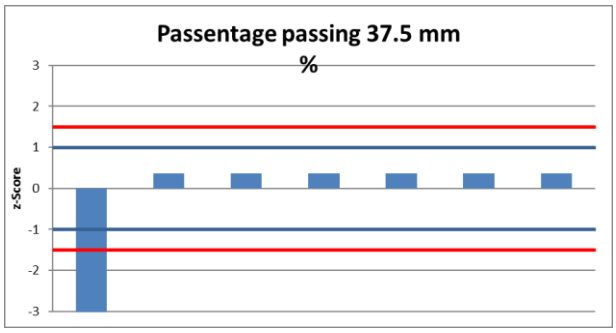
Lab Code	0.075 mm	Z-Score
AB4XQ	0	**-1.461**
WQ3LN	**0.8**	**-1.112**
AO7VU	***1.1***	-0.981
CV6ZX	*3.6*	0.109
DK9WF	**3.6**	0.109
TF5SK	3.90	0.240
DF6CP	4.2	0.371
YY3QP	**4.71**	0.593
DG3DK	*5.5*	0.938
EN2QS	*6*	**1.156**

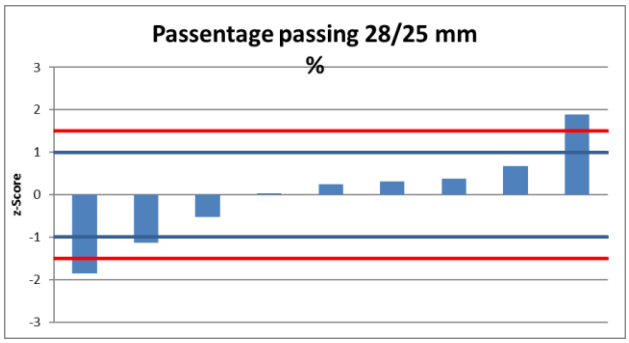
% passing	0.300 mm	0.150 mm	0.075 mm
H15 mean	6.1	4.6	3.3
H15 Std Dev	2.805	2.363	2.294
Range	5.90	5.30	6.00
CV	46.3%	51.7%	68.5%

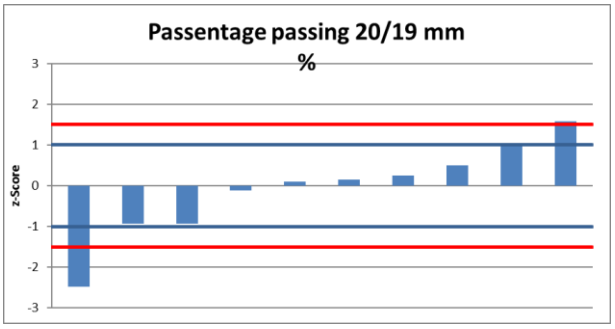
	37,5 mm	28/25 mm	20/19 mm	14/13.2 mm	10/9.5 mm	7.1/6.7 mm	5/4.75 mm	3.35 mm
Additional participant statistics								
Number of participants	7	9	10	9	7	6	10	1
Non-participants	3	1	-	1	3	4	-	9
OB	-	-	-	-	-	-	-	-
Statistics for Z-scores < ±1								
Range	0.00	10.00	14.50	15.80	7.60	19.70	7.60	-
Percentage of participants	85.7%	66.7%	80.0%	66.7%	71.4%	83.3%	70.0%	-
Reporting format								
Participants reported to 1 %	3	3	2	2	-	-	2	-
Participants reported to 0.1 %	3	4	6	6	5	5	6	-
Participants reported to 0.01 %	1	2	2	1	2	1	2	2

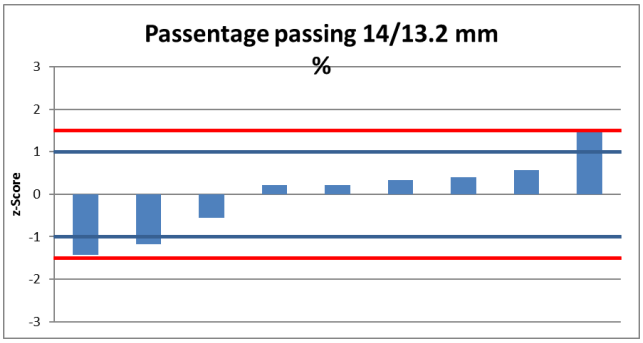
	2/2.36 mm	1/1.18 mm	0.600 mm	0.425 mm	0.300 mm	0.150 mm	0,075 mm
Additional participant statistics							
Number of participants	10	7	7	8	7	7	10
Non-participants	-	3	3	2	3	3	-
OB	-	-	-	-	-	-	-
Statistics for Z-scores < ±1							
Range	10.29	5.05	2.70	5.50	1.70	1.90	4.40
Percentage of participants	70.0%	71.4%	71.4%	62.5%	71.4%	71.4%	70.0%
Reporting format							

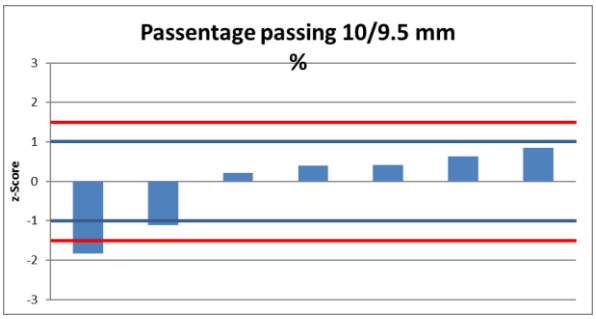
Participants reported to 1 %	1	1	1	1	-	-	2
Participants reported to 0.1 %	7	4	4	7	5	5	6
Participants reported to 0.01 %	2	2	2	-	2	2	2

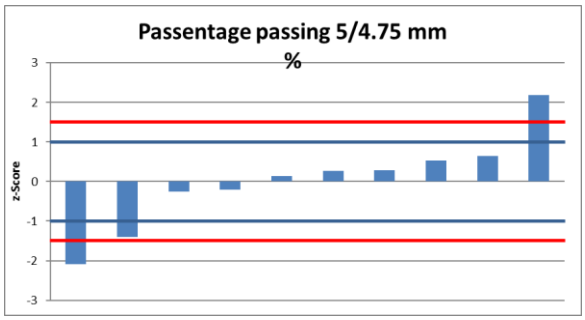


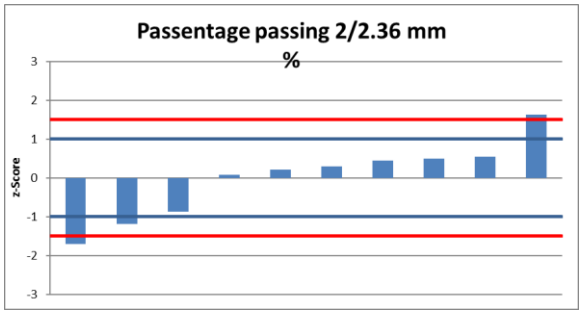


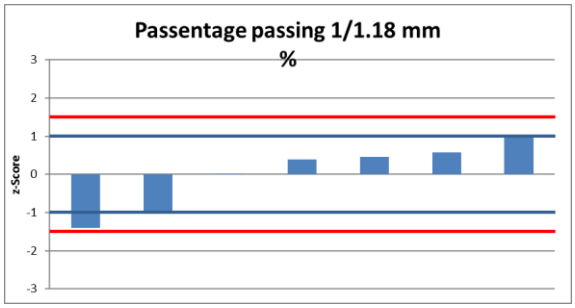


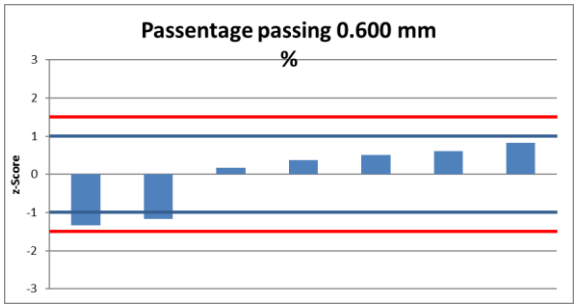


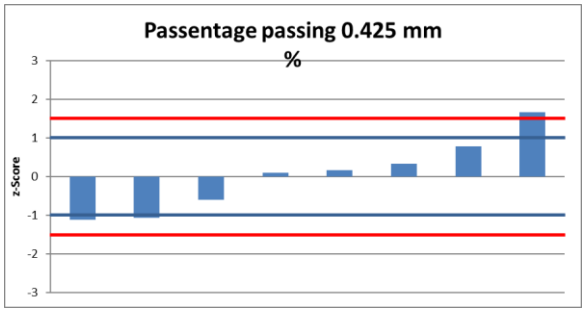


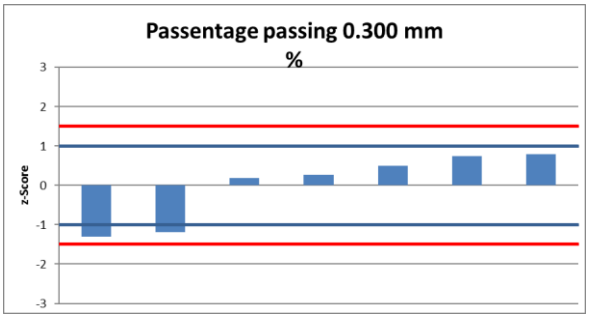


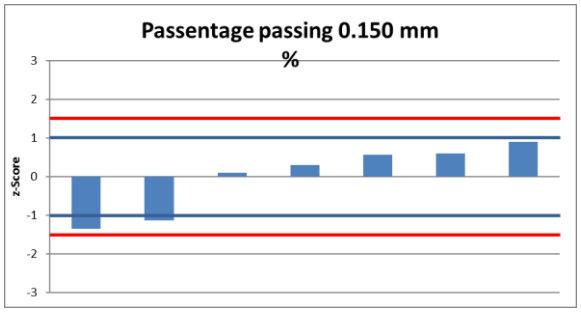


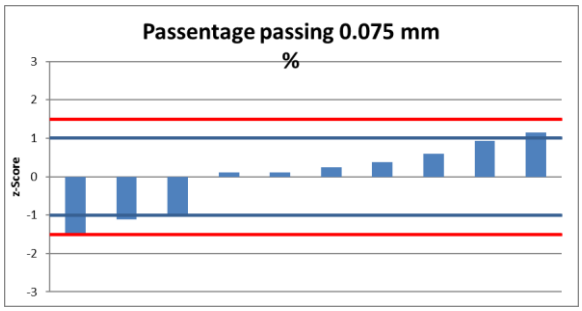












Comments – Washed Grading

- Six test methods were used by the 10 participants in the grading analysis.
- Some of the test methods used are for aggregates, whereas this material is a crushed material with both coarse and fine material which more represents a graded soil than an aggregate sample.
    - These types of discrepancies in the test method used need to be resolved to obtain more consistent results.

Soil Mortar based on grading analysis

Lab Code	GM	Z-Score
EN2QS	*2.49*	**-1.542**
DG3DK	2.62	-0.815
CV6ZX	*2.69*	-0.423
DK9WF	2.75	-0.087
DF6CP	2.78	0.080
WQ3LN	2.87	0.584
AO7VU	*2.9*	0.752
AB4XQ	3	**1.311**
TF5SK		
YY3QP		

Lab Code	Coarse Sand	Z-Score
DG3DK	8.3	**-1.040**
CV6ZX	*10*	**-1.002**
YY3QP	10.7	-0.987
EN2QS	*53*	-0.050
DK9WF	86.3	0.687
DF6CP	89	0.747
WQ3LN	90.5	0.780
AO7VU	*94.3*	0.864
TF5SK	NULL	
AB4XQ		

Lab Code	Coarse Sand ratio	Z-Score
EN2QS	*0.53*	-0.822
WQ3LN	**0.91**	-0.692
AO7VU	***2.4***	-0.185
DK9WF	**4.0**	0.359
DG3DK	9.4	**2.197**
DF6CP	CBD	
AB4XQ		
CV6ZX		
TF5SK		
YY3QP		

% passing	GM	Coarse Sand	Coarse Sand Ratio
H15 mean	2.77	55.26	2.94
H15 Std Dev	0.179	45.158	2.938
Range	0.51	86.00	8.87
CV	6.5%	81.7%	99.8%

Test method information

Test method	AASHTO T27	AASHTO T88	ASTM C136	SANS 3001 PR5	TMH1 A1 (a)	TMH1 B4	Non-responsive
# participants	2 (20 %)	1 (10 %)	1 (10 %)	2 (20 %)	2 (20 %)	1 (10 %)	1 (NULL)

Lab Code	Coarse Fine Sand	Z-Score
AO7VU	***0.6***	-0.966
DK9WF	**2.8**	-0.375
DF6CP	2.9	-0.348
WQ3LN	**5.5**	0.350
EN2QS	*12*	**2.096**
TF5SK	NULL	
AB4XQ		
CV6ZX		
DG3DK		
YY3QP		

Lab Code	Fine Fine Sand	Z-Score
WQ3LN	**1.6**	-0.792
DK9WF	**3.2**	-0.158
EN2QS	*6*	0.951
AO7VU	***NULL***	
TF5SK	NULL	
AB4XQ		
CV6ZX		
DF6CP		
DG3DK		
YY3QP		

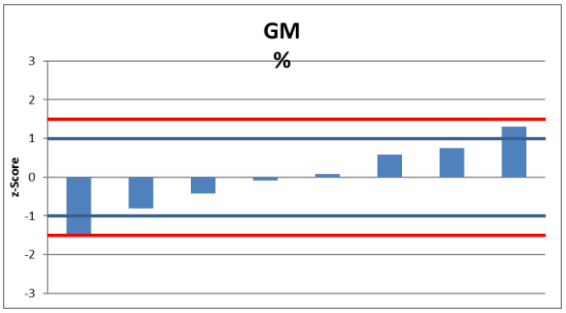
Lab Code	Fine Sand	Z-Score
AO7VU	***1.6***	-0.742
WQ3LN	**1.6**	-0.742
DF6CP	1.7	-0.671
DG3DK	2.8	0.109
DK9WF	**3.6**	0.677
CV6ZX	*5.1*	**1.741**
YY3QP	**5.4/1.3**	
EN2QS	*NULL*	
TF5SK	NULL	
AB4XQ		

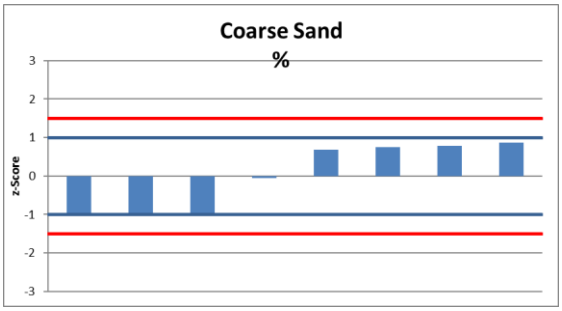
% passing	Coarse Fine Sand	Fine Fine Sand	Fine Sand
H15 mean	4.20	3.60	2.65
H15 Std Dev	3.723	2.524	1.410
Range	11.40	4.40	3.50
CV	88.7%	70.1%	53.3%

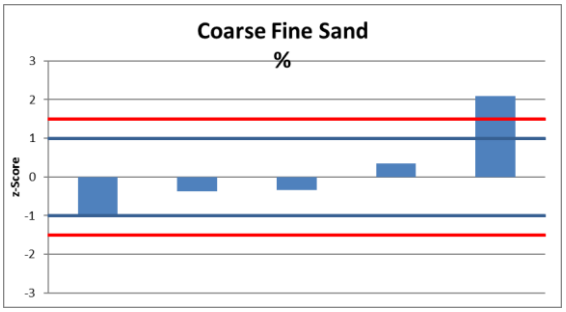
Lab Code	Medium Fine Sand	Z-Score
WQ3LN	**0.8**	-0.822
DF6CP	2.1	-0.457
DG3DK	4.0	0.077
EN2QS	*8*	**1.202**
AO7VU	***NULL***	
TF5SK	NULL	
AB4XQ		
CV6ZX		
DK9WF		
YY3QP		

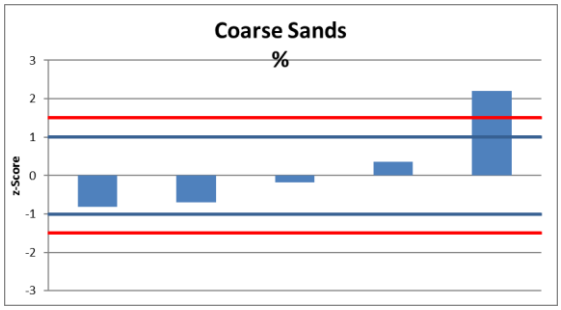
Lab Code	Soil Mortar	Z-Score
WQ3LN	**0.8**	-0.797
AO7VU	***1.1***	-0.782
DG3DK	5.5	-0.561
CV6ZX	*18.7*	0.102
EN2QS	*30*	0.670
DF6CP	**7000**	**350.771**
TF5SK	NULL	
AB4XQ		
DK9WF		
YY3QP		

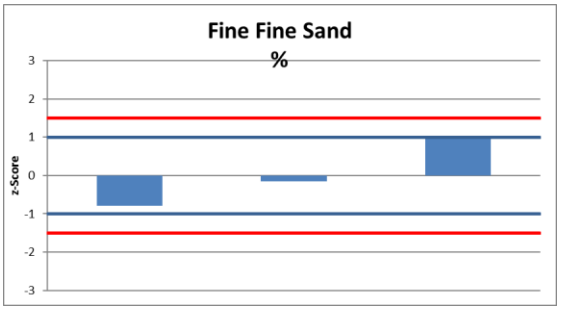
% passing	Coarse Fine Sand	Fine Fine Sand
H15 mean	3.73	16.67
H15 Std Dev	3.557	19.909
Range	7.20	6999.20
CV	95.5%	119.4%

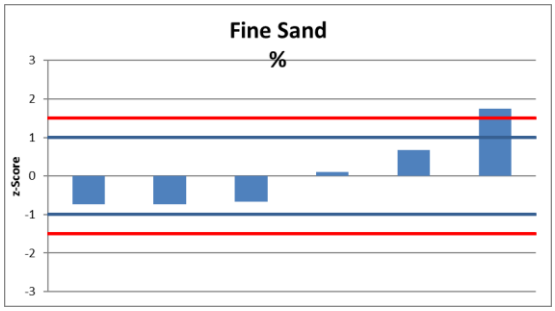


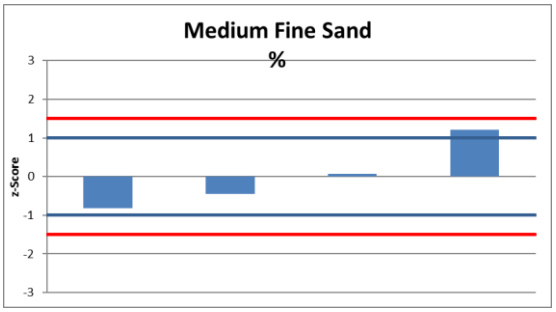


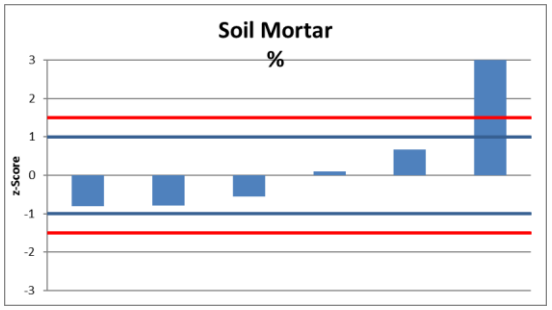












Comments – Soil mortars

- This portion of the report was the worst in the reported results.
    - It seems as if what was required was not well understood by the various facilities and these uncertainties need to be resolved before the next round, or this section on Soil Mortars analysis needs to be removed.
- The GM had an acceptable result with a low CV and range.

3.2 Plastic Material

Liquid Limit (LL), Plastic Limit (PL), Linear Shrinkage (LS) and Plasticity Index (PI) tests

Lab code	LL %	z-score
WQ3LN	**20.8**	**-3.870**
DK9WF	**29.6**	**-1.203**
EN2QS	*32*	-0.476
CV6ZX	*34.1*	0.160
AO7VU	**34.3**	0.221
AB4XQ	35	0.433
DG3DK	35	0.433
TF5SK	**35**	0.433
YY3QP	42.7	**2.766**
DF6CP	CBD	

Lab code	PL %	z-score
AO7VU	**9.1**	**-2.323**
DK9WF	**19.0**	-0.854
TF5SK	**20**	-0.705
EN2QS	*26*	0.185
AB4XQ	27.2	0.364
DG3DK	29	0.631
CV6ZX	*29.2*	0.661
YY3QP	32.3	**1.121**
DF6CP	CBD	
WQ3LN	**CBD**	

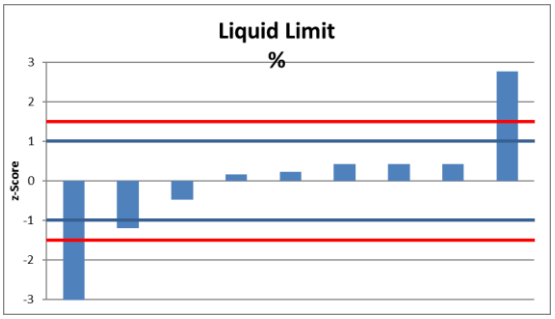
Lab code	LS %	z-score
AB4XQ	0.2	**-1.480**
WQ3LN	**2.0**	-0.540
CV6ZX	*2.2*	-0.435
DG3DK	2.5	-0.278
EN2QS	*3*	-0.017
DK9WF	**3.5**	0.244
YY3QP	5	**1.027**
AO7VU	**9.3**	**3.273**
DF6CP	CBD	
TF5SK	**NULL**	

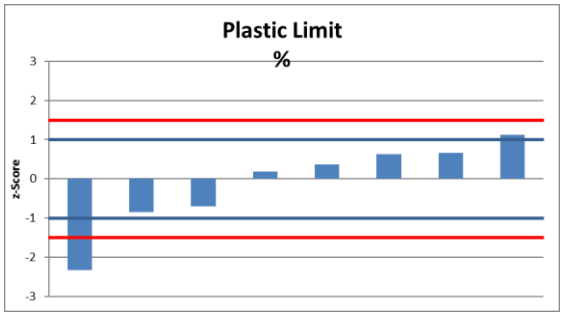
Lab code	PI %	z-score
CV6ZX	*4.9*	-0.982
DG3DK	6	-0.756
EN2QS	*6*	-0.756
AB4XQ	8	-0.344
YY3QP	10.4	0.149
DK9WF	**10.6**	0.190
TF5SK	**15**	**1.095**
AO7VU	**25.2**	**3.193**
DF6CP	CBD	
WQ3LN	**NULL**	

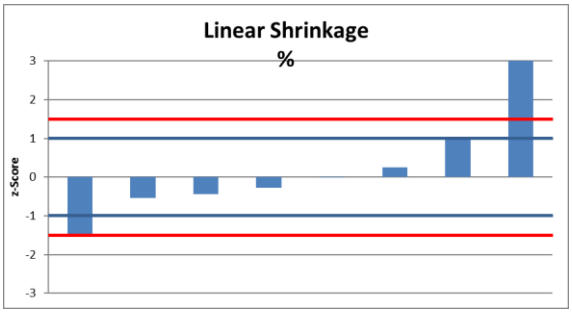
Test method information

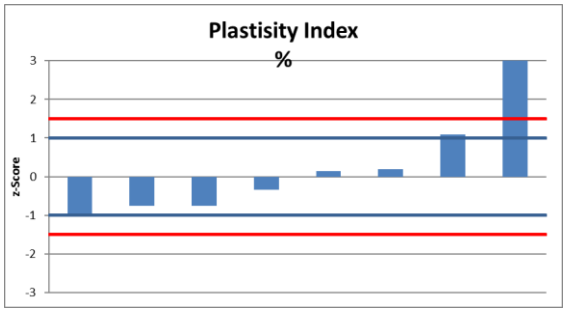
Test method	AASHTO T89	SANS 3001 GR10/11/12	TMH1 A2, A3 & A4	Non-responsive
# participants	4 (30 %)	2 (20 %)	4 (40 %)	0 (NULL)

	LL	PL	LS	PI
H15 mean	33.57	24.75	3.03	9.67
H15 Std Dev	3.300	6.736	1.915	4.862
Range	21.90	23.20	9.10	20.30
CV	9.8%	27.2%	63.1%	50.3%









	LL	PL	LS	PI
Additional participant statistics				
Number of participants	10	10	10	10
Non-participants	-	-	-	-
CBD	1	2	1	1
NULL	-	-	1	1
OB	-	-	-	-
Statistics for Z-scores < ±1				
Range	3.00	10.20	1.50	5.70
Percentage of participants	66.7%	75.0%	62.5%	75.0%
Reporting format				
Participants reported correctly to 1 %	4	3	2	4
Participants reported to 0.1 %	5	5	6	4

Comments – Atterberg limits

- It was expected that this material would be more difficult to obtain a result, but the fine plastic material provided better results than the crushed granular material although there is still much to be done to reduce the range and variability of the results.
- The difference in how the material is prepared needs to be limited to provide more consistent results.
    - This relates back to the variety in test methods used between the facilities with some doing the test from dry to wet and others doing from wet to dry.
- Three test methods were used by the 10 participants in the PI determination.
- Eight facilities of the ten obtained a PI value although two reported that the material was not plastic.
- Much needs to be done to get the results reported correctly of this test method.
- In general, the results are too variable for the PL, LS and PI.

3.3 Aggregate Material

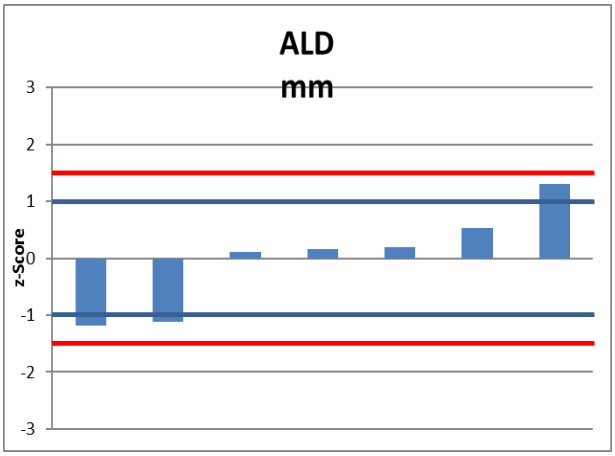
Average Least Dimension (ALD)

#	Lab code	ALD (mm)	z-score
1	AB4XQ	3.8	**-1.178**
2	DF6CP	4.11	-1.111
3	CV6ZX	*9.8*	0.112
4	EN2QS	*10.0*	0.155
5	DK9WF	10.19	0.196
6	DG3DK	11.71	0.522
7	AO7VU	15.35	**1.305**
8	TF5SK		
9	WQ3LN		
10	YY3QP		

	Reduction Factor
H15 mean	9.280
H15 Std Dev	4.653
Range	11.55
CV	50.1%

Test method information

Test method	AASHTO	TMH 1 B1 & B2	TMH 1 B18(a)	SANS 3001 AG2	Non-responsive
# participants	1 (10 %)	1 (10 %)	3 (10 %)	2 (20 %)	3 (NULL)



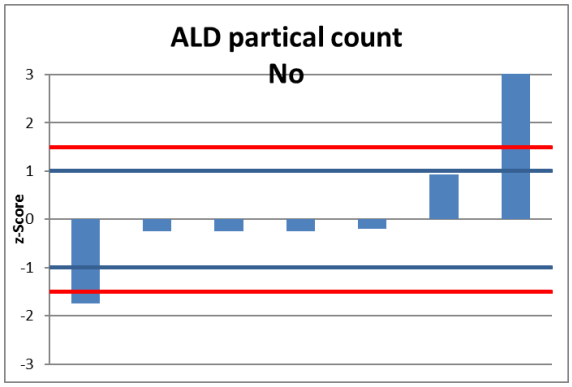
	ALD
Number of participants	7
Non-participants	3
OB	-
Range	6.1
Percentage of participants	71.4%
Participants reported to 0.1 mm	3
Participants reported to 0,01	4

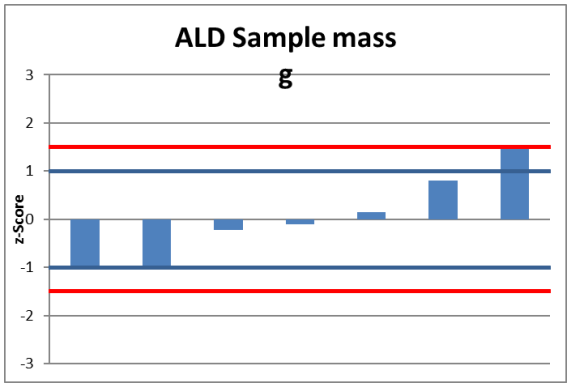
Additional Information on ALD

Lab Code	# particles	Z-Score
AO7VU	50	**-1.745**
AB4XQ	200	-0.242
DF6CP	200	-0.242
DG3DK	200	-0.242
CV6ZX	*204*	-0.202
DK9WF	317	0.930
EN2QS	*555*	**3.315**
TF5SK		
WQ3LN		
YY3QP		

Lab Code	Specimen mass	Z-Score
AO7VU	80	**-1.027**
DF6CP	111.9	-0.983
CV6ZX	*669.1*	-0.222
AB4XQ	753	-0.108
DG3DK	943.50	0.152
DK9WF	1415.8	0.797
EN2QS	*1910.7*	**1.473**
TF5SK		
WQ3LN		
YY3QP		

% passing	# particles counted	Specimen mass
H15 mean	224.191	831.838
H15 Std Dev	99.804	732.409
Range	505.00	1830.70
CV	44.5%	88.0%





	# Particle Count	Sample Mass
Number of participants	7	7
Non-participants	3	3
OB	-	-
Range	4.0	831.6
Percentage of participants	71.4%	71.4%
Participants reported to 1	7	2
Participants reported to 0.1	-	4
Participants reported to 0.01	-	1

Comments – ALD Direct Measurement

- Four test methods were used by the seven participants in the ALD determination.
- Three participants did not provide a result.
- The variability can be attributed to the difference in mass used by the various facilities which varied from 80 g to 2 000 g as well as the corresponding particle counts varying from 50 to 555.

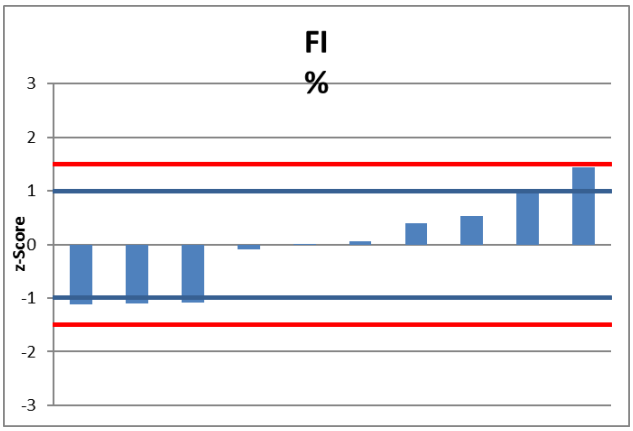
Flakiness Index (FI)

#	Lab code	FI	z-score
1	DK9WF	4.9	**-1.112**
2	AB4XQ	5.1	-1.096
3	DG3DK	5.3	-1.080
4	CV6ZX	*17.9*	-0.091
5	YY3QP	19.16	0.008
6	EN2QS	*19.8*	0.059
7	AO7VU	24.1	0.396
8	TF5SK	25.79	0.529
9	WQ3LN	31.3	0.962
10	DF6CP	37.29	**1.432**

	Reduction Factor
H15 mean	19.054
H15 Std Dev	12.732
Range	32.39
CV	66.8%

Test method information

Test method	AASHTO	ASTM D4791	TMH 1 847	TMH 1 B3	SANS 3001 AG4	Non-responsive
# participants	1 (10 %)	1 (10 %)	1 (10 %)	4 (40 %)	2 (20 %)	1 (NULL)

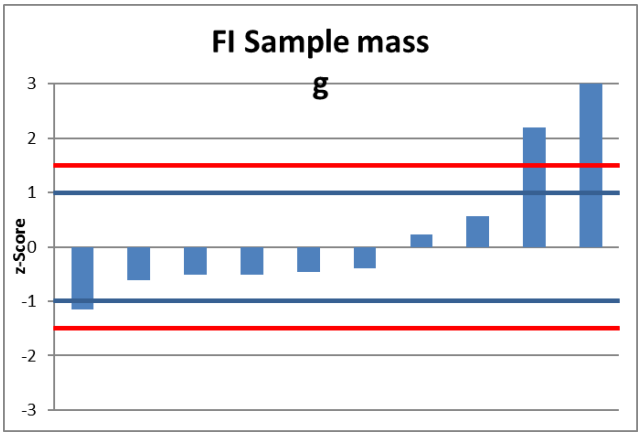


	FI
Number of participants	10
Non-participants	-
OB	-
Range	14.1
Percentage of participants	71.4%
Participants reported to 0.1 mm	7
Participants reported to 0,01	3

Additional Information on FI

Lab Code	FI sample mass	Z-Score
AB4XQ	725	**-1.148**
DK9WF	1415.8	-0.607
AO7VU	1535	-0.513
DG3DK	1537.7	-0.511
EN2QS	*1600.8*	-0.462
CV6ZX	*1678.1*	-0.401
YY3QP	2486.4	0.232
WQ3LN	2914.1	0.567
DF6CP	5000	**2.202**
TF5SK	6467.00	**3.351**

% passing	# particles counted
H15 mean	2190.3
H15 Std Dev	1276.2
Range	5742.0
CV	58.3%



	FI sample mass
Number of participants	10
Non-participants	-
OB	-
Range	185.0
Percentage of participants	71.4%
Participants reported to 1	3
Participants reported to 0.1	6
Participants reported to 0.01	1

Comments – Flakiness Index

- Five test methods were used by the 10 participants in the FI determination.
- As with the ALD the mass of the sample varied vastly from 725 g to 6 467 g contributing to the variability of the results.

- The interpretation of the test methods could further add to the differences e.g. are fractions weighing less than 10 % excluded from the analysis.

Aggregate Crushing Value (ACV)

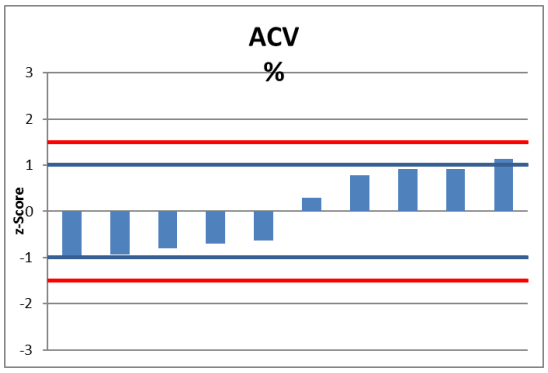
Lab Code	ACV %	Z-Score
TF5SK	14.65	-0.973
EN2QS	14.8	-0.935
DF6CP	15.33	-0.799
CV6ZX	15.7	-0.704
DK9WF	16.0	-0.627
YY3QP	19.6	0.295
AO7VU	21.50	0.782
AB4XQ	22	0.910
WQ3LN	22.0	0.910
DG3DK	22.9	**1.141**

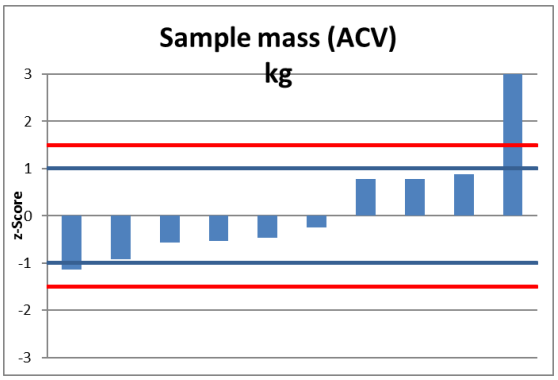
Lab Code	Specimen mass	Z-Score
DK9WF	2122.0	**-1.132**
DG3DK	2220	-0.918
AB4XQ	2383	-0.563
EN2QS	2396.0	-0.535
CV6ZX	2428	-0.465
DF6CP	2530.3	-0.242
AO7VU	3000	0.781
YY3QP	3000.0	0.781
WQ3LN	3042.2	0.873
TF5SK	5359.67	**5.921**

% passing	ACV %	Specimen mass
H15 mean	18.45	2641.60
H15 Std Dev	3.90	459.08
Range	8.25	3237.67
CV	21.2%	17.4%

Test method information (ACV & 10% FACT)

Test method	AASHTO	ASTM D5821	TMH 1 841	TMH 1 B1/B2	SANS 3001 AG10	Non-responsive
# participants	1 (10 %)	1 (10 %)	1 (10 %)	4 (40 %)	2 (20 %)	1 (NULL)





	ACV	Specimen mass
Number of participants	10	10
Non-participants	-	-
OB	-	-
Range	7.4	822.2
Percentage of participants	90.0%	80.0%
Participants reported to 1	1	4
Participants reported to 0.1	6	5
Participants reported to 0.01	3	1

Comments – ACV

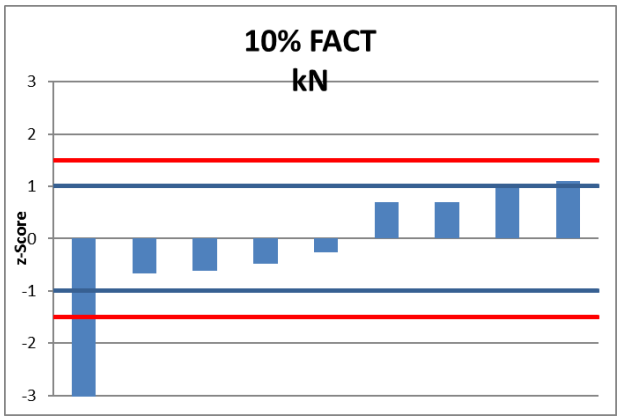
- Five test methods were used by the 10 participants in the ACV determination.
- The mass used per sample is possibly a reason for the variability, but this particular test should provide a better correlation with a lower CV and range than obtained in the round.
- Calibration of the apparatus may also add to the variability of the results.

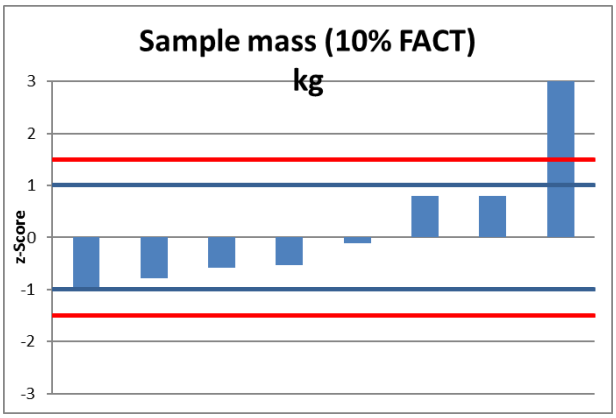
10% Fines Aggregate Crushing Test (10% FACT)

Lab Code	10 % FACT kN	Z-Score
AO7VU	19.50	**-4.470**
WQ3LN	201	-0.666
DG3DK	203	-0.624
AB4XQ	210	-0.477
YY3QP	220	-0.267
DF6CP	265.9	0.695
EN2QS	266	0.697
DK9WF	278.7	0.963
TF5SK	285	**1.095**
CV6ZX		

Lab Code	Specimen mass	Z-Score
WQ3LN	2202.0	-0.983
DG3DK	2291	-0.785
AB4XQ	2383	-0.580
EN2QS	2401.4	-0.539
DF6CP	2595.4	-0.106
AO7VU	3000.00	0.795
YY3QP	3000	0.795
TF5SK	5384.33	**6.108**
CV6ZX		
DK9WF		

% passing	10 % FACT kN	Specimen mass
H15 mean	232.76	2643.15
H15 Std Dev	47.71	448.81
Range	265.50	3182.33
CV	20.5%	17.0%





	10 % FACT kN	Specimen mass
Number of participants	9	8
Non-participants	1	2
OB	-	-
Range	77.7	798.0
Percentage of participants	66.7%	87.5%
Participants reported to 1	6	3
Participants reported to 0.1	2	3
Participants reported to 0.01	1	2

Comments – 10 % FACT

- Five test methods were used by the 10 participants in the 10 % FACT determination.
- One facility did not provide a result.
- The range and the CV are higher than would be acceptable.

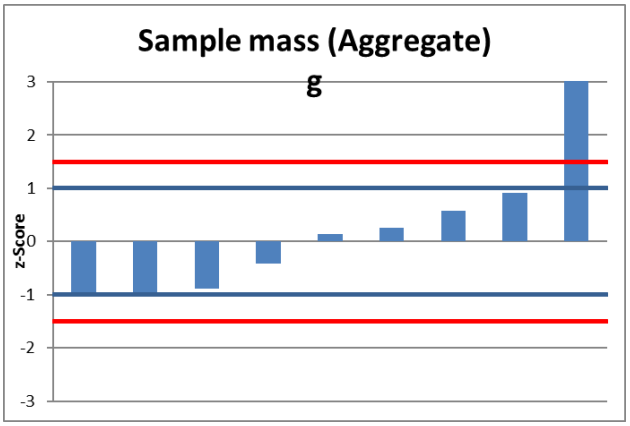
Aggregate Grading Sample Mass

#	Lab code	Sample mass (g)	z-score
1	EN2QS	*1600.8*	**-1.001**
2	TF5SK	1603.32	-0.997
3	CV6ZX	*1678.1*	-0.893
4	AO7VU	2022	-0.415
5	DK9WF	2425.0	0.145
6	DF6CP	2500	0.250
7	YY3QP	2735.5	0.577
8	WQ3LN	2981.4	0.919
9	AB4XQ	7150	**6.715**
10	DG3DK		

	Sample mass
H15 mean	2320.47
H15 Std Dev	719.26
Range	5549.20
CV	31.0%

Test method information

Test method	AASHTO T27	AASHTO T88	ASTM C136	SANS 3001 GR1	SANS 3001 AG1	TMH1 A1 (a)	TMH1 B4	Non-responsive
# participants	2 (20 %)	1 (10 %)	1 (10 %)	1 (10 %)	1 (10 %)	2 (20 %)	2 (20 %)	0 (NULL)



	Sample Mass
Number of participants	9
Non-participants	1
OB	-
Range	74.8
Percentage of participants	66.7%
Participants reported to 1 g	3
Participants reported to 0.1 g	5
Participants reported to 0.01 g	1

Comments – Aggregate grading sample mass

- The sample mass, as with the other aggregate test methods, varies too much.

Washed Grading

NOTE: Fraction 100 mm, 75 mm, 63 mm, 50 mm, 37,5 mm & 28/25 mm were not analyzed as they all had 100 % passing

Lab Code	20/19 mm	Z-Score
AO7VU	**70.3**	**-46.605**
DK9WF	**98.5**	**-1.834**
DF6CP	99.7	0.071
AB4XQ	*100*	0.548
CV6ZX	*100*	0.548
EN2QS	*100*	0.548
TF5SK	100.00	0.548
YY3QP	**100.00**	0.548
DG3DK		
WQ3LN		

Lab Code	14/13.2 mm	Z-Score
AO7VU	**23.7**	**-1.634**
DF6CP	31.7	-0.670
WQ3LN	**32.7**	-0.549
AB4XQ	*33*	-0.513
TF5SK	36.51	-0.090
DK9WF	**40.5**	0.391
DG3DK	41.40	0.499
CV6ZX	*45*	0.933
EN2QS	*52*	**1.777**
YY3QP		

Lab Code	10/9.5 mm	Z-Score
DF6CP	5.1	-0.838
WQ3LN	**5.1**	-0.838
TF5SK	5.44	-0.694
DK9WF	**5.6**	-0.626
CV6ZX	*5.7*	-0.584
EN2QS	*7*	-0.033
DG3DK	7.4	0.137
AB4XQ	*8.7*	0.688
AO7VU	**10.3**	**1.367**
YY3QP	**11.86**	**2.028**

% passing	20/19 mm	14/13.2 mm	10/9.5 mm
H15 mean	99.66	37.26	7.08
H15 Std Dev	0.63	8.30	2.36
Range	29.70	28.30	6.76
CV	0.6%	22.3%	33.3%

Lab Code	7.1/6.7 mm	Z-Score
DF6CP	1.1	**-1.552**
TF5SK	2	-0.900
AB4XQ	*2.1*	-0.466
WQ3LN	**2.3**	-0.248
CV6ZX	*2.4*	-0.140
DK9WF	**2.9**	0.404
EN2QS	*3*	0.512
DG3DK	3.3	0.838
AO7VU	**7.8**	**5.727**
YY3QP		

Lab Code	5/4.75 mm	Z-Score
TF5SK	1.14	-0.914
AB4XQ	1.4	-0.689
WQ3LN	**1**	-0.689
CV6ZX	*1.5*	-0.603
EN2QS	*2*	-0.170
DK9WF	**2.1**	-0.084
DG3DK	2.6	0.349
AO7VU	**3.8**	**1.387**
YY3QP	**9.11**	**5.980**
DF6CP	NULL	

Lab Code	2/2.36 mm	Z-Score
TF5SK	0.67	-0.899
CV6ZX	*1*	-0.758
WQ3LN	**0.8**	-0.758
EN2QS	*1*	-0.540
AB4XQ	1.2	-0.322
DK9WF	**1.5**	0.004
DG3DK	2.1	0.658
AO7VU	**2.6**	**1.202**
YY3QP	**8.99**	**8.159**
DF6CP		

% passing	7.1/6.37 mm	5/4.75 mm	2/2.36 mm
H15 mean	2.53	2.20	1.50
H15 Std Dev	0.92	1.16	0.92
Range	6.70	7.97	8.32
CV	36.4%	52.6%	61.4%

Lab Code	1/1.18 mm	Z-Score
TF5SK	0.59	**-1.015**
WQ3LN	**0.6**	**-1.003**
EN2QS	*1*	-0.524
AB4XQ	1.2	-0.284
DK9WF	**1.4**	-0.045
DG3DK	2.0	0.674
AO7VU	**2.1**	0.794
YY3QP	**8.99**	**9.047**
CV6ZX		
DF6CP		

Lab Code	0.600 mm	Z-Score
WQ3LN	**0.5**	**-1.057**
TF5SK	0.55	-0.985
EN2QS	*0.8*	-0.624
AB4XQ	1.2	-0.046
DK9WF	**1.3**	0.099
AO7VU	**1.4**	0.243
DG3DK	1.9	0.965
YY3QP	**8.99**	**11.205**
CV6ZX		
DF6CP		

Lab Code	0.425 mm	Z-Score
WQ3LN	**0.5**	**-1.068**
CV6ZX	*0.6*	-0.850
EN2QS	*0.8*	-0.413
AO7VU	**0.9**	-0.195
AB4XQ	1.2	0.460
DK9WF	**1.3**	0.679
DG3DK	1.9	**1.989**
DF6CP		
TF5SK		
YY3QP		

% passing	1/1.18 mm	0.600 mm	0.425 mm
H15 mean	1.44	1.23	0.99
H15 Std Dev	0.83	0.69	0.46
Range	8.40	8.49	1.40
CV	58.1%	56.2%	46.3%

Lab Code	0.300 mm	Z-Score
AO7VU	**0.4**	-0.877
WQ3LN	**0.4**	-0.877
DK9WF	0.51	-0.733
DF6CP	*0.8*	-0.352
DG3DK	1.1	0.042
AB4XQ	**1.3**	0.304
TF5SK	1.9	**1.091**
CV6ZX	**8.98**	**10.381**
EN2QS		
YY3QP		

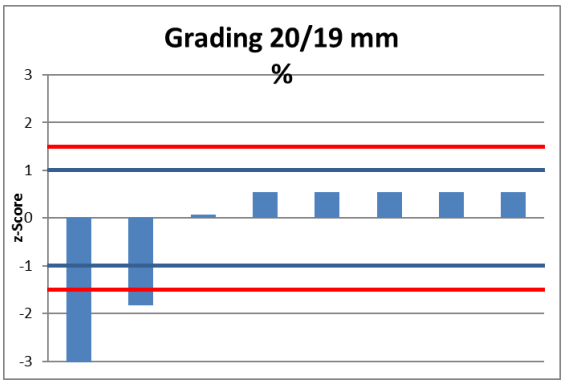
Lab Code	0.150 mm	Z-Score
AO7VU	**0.1**	**-1.062**
WQ3LN	**0.3**	-0.818
TF5SK	0.43	-0.658
EN2QS	*0.7*	-0.3
AB4XQ	1.1	0.2
DK9WF	**1.2**	0.284
DG3DK	1.8	**1.018**
YY3QP	**8.98**	**9.807**
CV6ZX		
DF6CP		

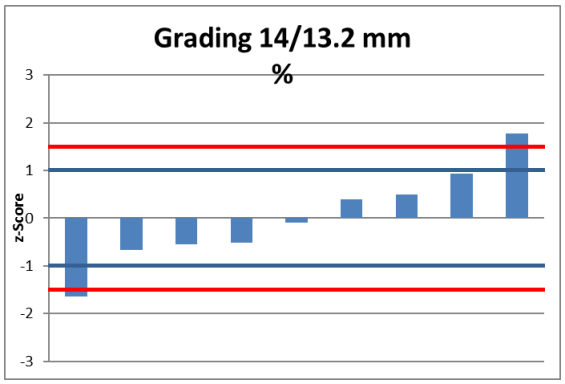
Lab Code	0.075 mm	Z-Score
AO7VU	**0.1**	-0.898
WQ3LN	**0.1**	-0.898
TF5SK	0.3	-0.661
CV6ZX	*0.3*	-0.634
EN2QS	*0.6*	-0.239
AB4XQ	1.0	0.288
DK9WF	**1.1**	0.419
DG3DK	*1.7*	**1.210**
YY3QP	**8.97**	**10.785**
DF6CP		

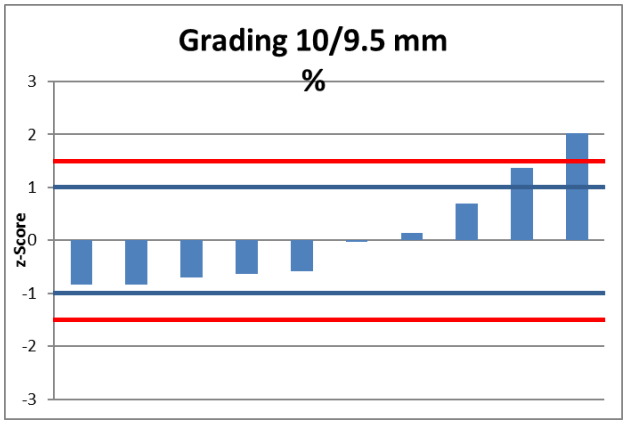
% passing	0.300 mm	0.150 mm	0.075 mm
H15 mean	1.07	0.97	0.78
H15 Std Dev	0.76	0.82	0.76
Range	8.58	8.88	8.87
CV	71.3%	84.4%	97.1%

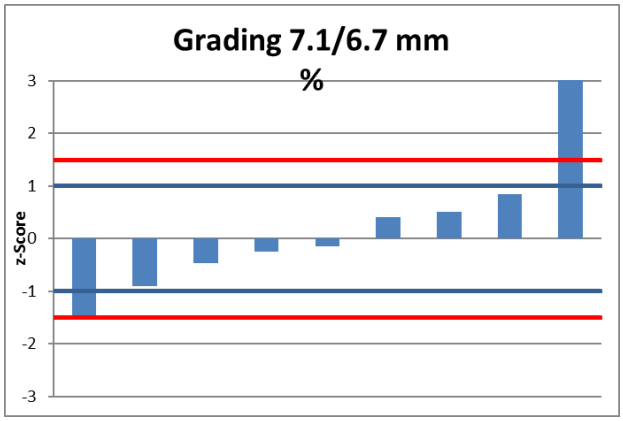
	20/19 mm	14/13.2 mm	10/9.5 mm	7.1/6.7 mm	5/4.75 mm	2/2.36 mm	1/1.18 mm	0.600 mm
Additional participant statistics								
Number of participants	8	9	10	9	9	9	8	8
Non-participants	2	1	-	1	1	1	2	2
OB	-	-	-	-	-	-	-	-
Statistics for Z-scores < ±1								
Range	1.2	1.0	0.3	0.4	0.0	0.0	0.4	0.3
Percentage of participants	66.7%	66.7%	66.7%	66.7%	66.7%	66.7%	66.7%	66.7%
Reporting format								
Participants reported to 1 %	3	3	1	2	2	2	1	-
Participants reported to 0.1 %	3	4	7	7	5	5	5	6
Participants reported to 0.01 %	2	2	2	-	2	2	2	2

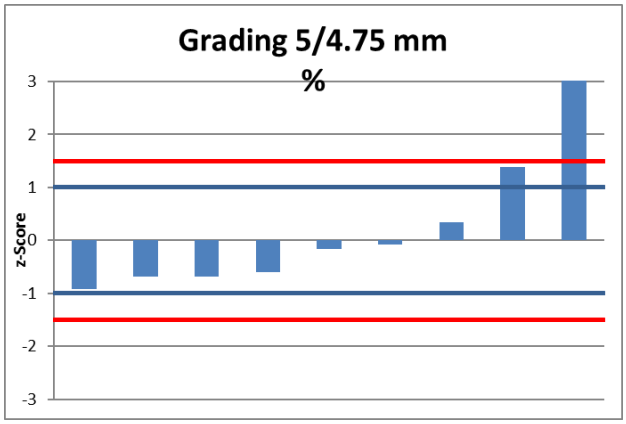
	0.425 mm	0.300 mm	0.150 mm	0,075 mm
Additional participant statistics				
Number of participants	7	8	8	9
Non-participants	3	2	2	1
OB	-	-	-	-
Statistics for Z-scores < ±1				
Range	0.2	0.1	0.1	0.2
Percentage of participants	66.7%	66.7%	66.7%	66.7%
Reporting format				
Participants reported to 1 %	-	-	-	-
Participants reported to 0.1 %	7	7	6	8
Participants reported to 0.01 %	-	2	2	1

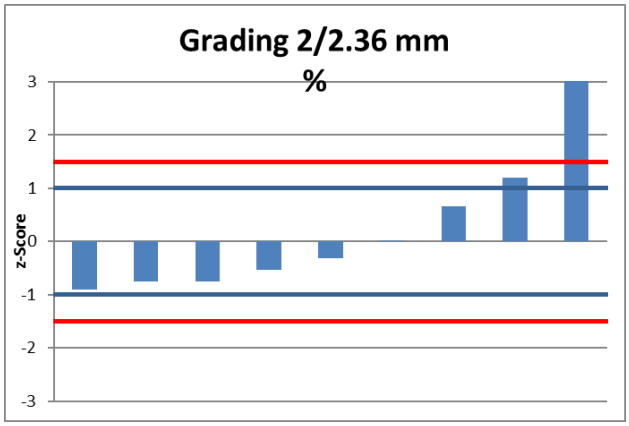


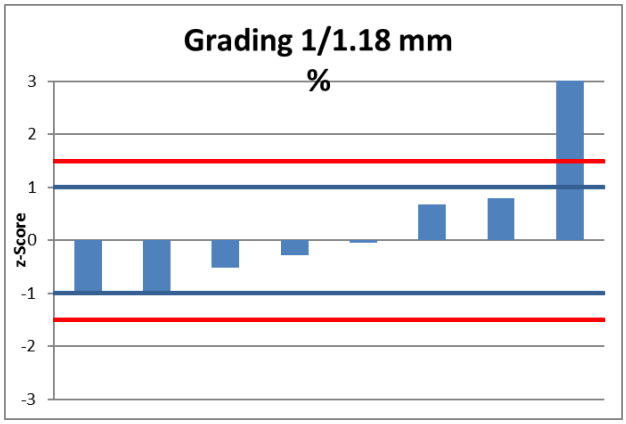


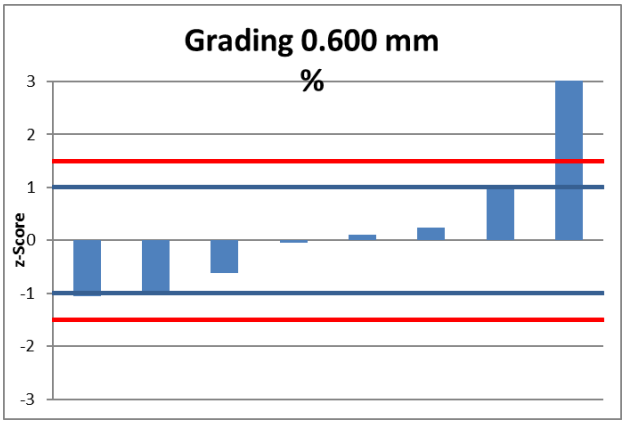

Grading 10/9.5 mm
%
z-Score
3
2
1
0
-1
-2
-3

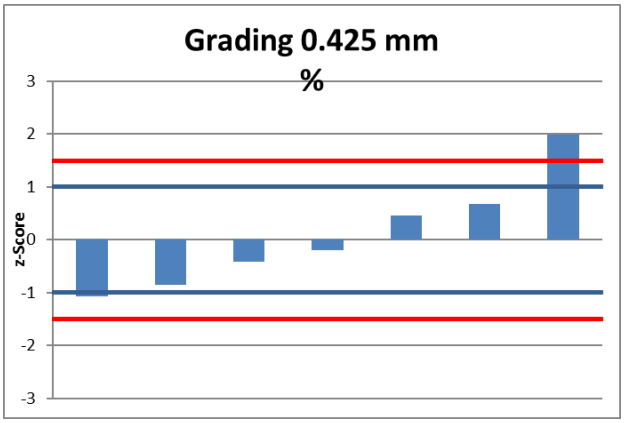

Grading 7.1/6.7 mm
%
z-Score
3
2
1
0
-1
-2
-3

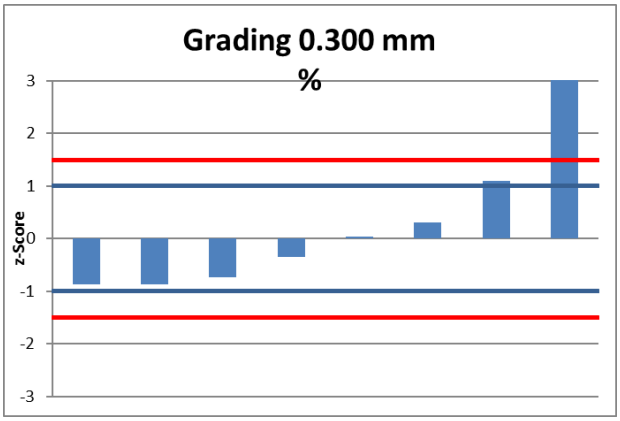

Grading 5/4.75 mm
%
z-Score
3
2
1
0
-1
-2
-3

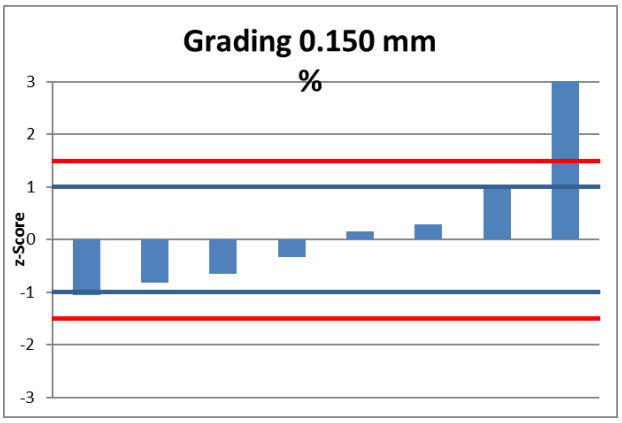

Grading 2/2.36 mm
%
z-Score
3
2
1
0
-1
-2
-3

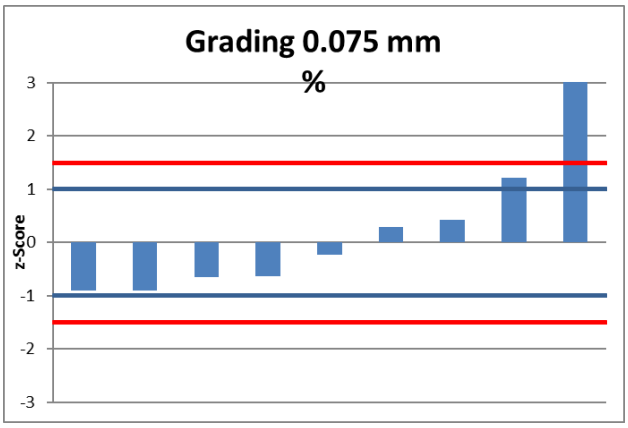

Grading 1/1.18 mm
%
z-Score
3
2
1
0
-1
-2
-3


Grading 0.600 mm
%
z-Score
3
2
1
0
-1
-2
-3









Comments – Aggregate Grading

- Seven test methods were used by the 10 participants in the aggregate grading determination.
- Most of the results are acceptable with only one or two facilities with values vastly different from the mean as calculated.
- The different sieve sizes used in the various test methods does make the analysis and deductions more difficult to make with any certainty.

3.4 Sand Material

Liquid Limit (LL), Plastic Limit (PL), Linear Shrinkage (LS) and Plasticity Index (PI) tests

Lab code	LL %	z-score
CV6ZX	0	**-2.920**
TF5SK	13	-0.533
WQ3LN	16.2	0.055
AB4XQ	16.4	0.092
DG3DK	18.0	0.385
AO7VU	24.9	**1.652**
DF6CP	**CBD**	
EN2QS	**CBD**	
DK9WF	***NP***	
YY3QP	***NP***	

Lab code	PL %	z-score
CV6ZX	0	**-1.019**
DG3DK	17.0	0.492
AO7VU	17.4	0.527
DF6CP	**CBD**	
EN2QS	**CBD**	
TF5SK	**CBD**	
WQ3LN	**CBD**	
DK9WF	***NP***	
YY3QP	***NP***	
AB4XQ	***NULL***	

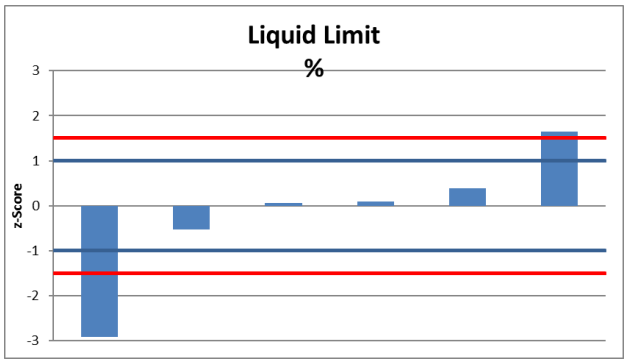
Lab code	LS %	z-score
CV6ZX	0	-0.714
DK9WF	0.0	-0.714
EN2QS	0	-0.714
AB4XQ	0.4	-0.162
DG3DK	0.4	-0.162
WQ3LN	1.3	**1.079**
AO7VU	4.0	**4.801**
DF6CP	**CBD**	
YY3QP	***NP***	
TF5SK	***NULL***	

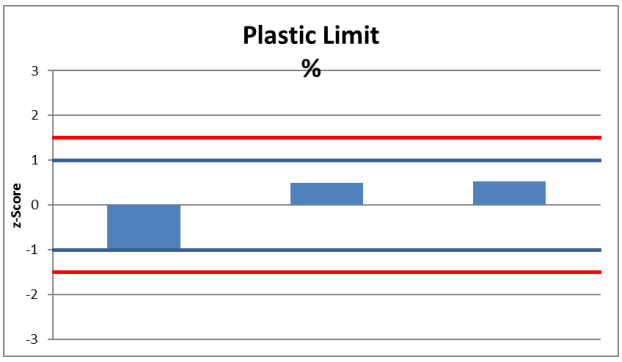
Lab code	PI %	z-score
YY3QP	0	-0.614
DG3DK	1	-0.397
AO7VU	7.5	**1.011**
DF6CP	**CBD**	
TF5SK	**CBD**	
CV6ZX	***NP***	
DK9WF	***NP***	
EN2QS	***NP***	
AB4XQ	***NULL***	
WQ3LN	***NULL***	

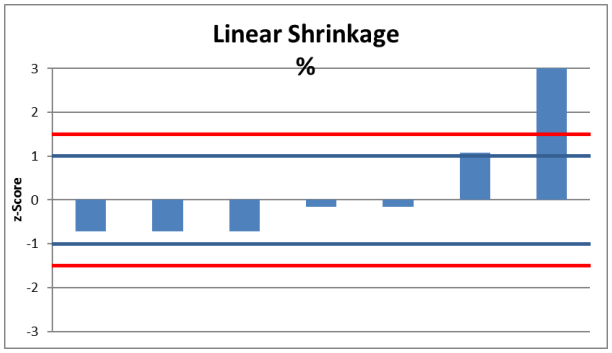
Test method information

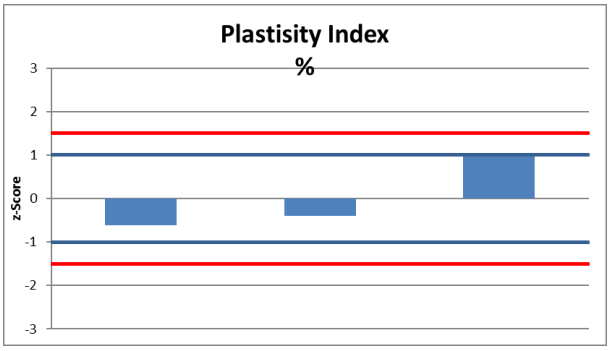
Test method	AASHTO T27	AASHTO T89	SANS 3001 GR10/11/12	TMH1 A2, A3 & A4	Non-responsive
# participants	1 (10 %)	3 (30 %)	2 (20 %)	4 (40 %)	0 (NULL)

	LL	PL	LS	PI
H15 mean	15.90	11.47	0.52	2.83
H15 Std Dev	5.446	11.257	0.725	4.615
Range	24.90	17.40	4.00	7.50
CV	34.3%	98.2%	140.1%	162.9%









	LL	PL	LS	PI
Additional participant statistics				
Number of participants	10	10	10	10
CBD	2	4	1	2
NP	2	2	1	3
SP	-	-	-	-
NULL	-	1	1	2
Non-participants	-	-	-	-
OB	-	-	-	-
Statistics for Z-scores < ±1				
Range	5.0	0.4	0.4	1.0
Percentage of participants	66.7%	66.7%	71.4%	66.7%
Reporting format				
Participants reported correctly to 1 %	2	1	2	2
Participants reported to 0.1 %	4	2	5	1

Comments – Atterberg Limits

- This material was used as a basis to check for consistencies in the more variable test methods such as Atterberg and CBR.
    - It is assumed that the material is NP.
- Four test methods were used by the 10 participants in the PI determination.
- Eight facilities of the ten concluded the material was NP.
- Much needs to be done to get the results reported correctly of this test method.

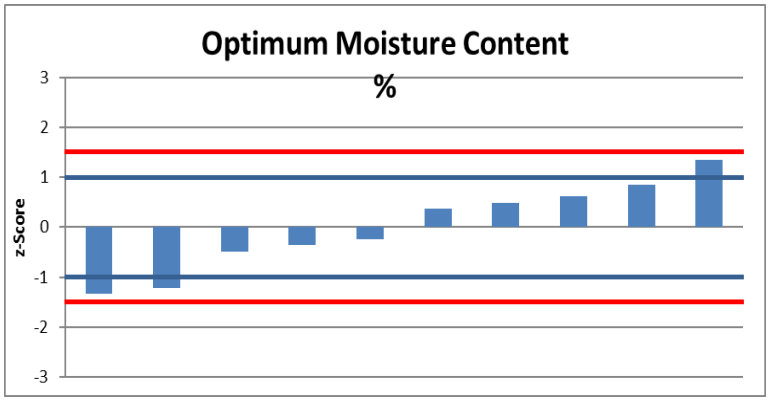
Optimum Moisture Content test

#	Lab code	OMC %	OMC z-score
1	CV6ZX	6.7	**-1.343**
2	DK9WF	6.8	**-1.221**
3	WQ3LN	*7.4*	-0.488
4	EN2QS	7.5	-0.366
5	DG3DK	7.6	-0.244
6	YY3QP	8.1	0.366
7	AB4XQ	8.2	0.488
8	TF5SK	8.3	0.610
9	DF6CP	8.5	0.855
10	AO7VU	8.9	**1.343**

	OMC
H15 mean	7.80
H15 Std Dev	0.819
Range	2.20
CV	10.5%

Test method information

Test method	AASHTO T180	AASHTO T99	SANS 3001 GR30	TMH1 A7	Non-responsive
# participants	2 (20 %)	1 (10 %)	1 (20 %)	4 (40 %)	2 (NULL)



Apparatus information

Automatic	Manual	Non-responsive
2	7	1 (NULL)

Additional participant statistics

Number of participants	10
Non-participants	-
OB	-

Statistics for Z-scores < ±1

Range	1.1
Percentage of participants	70.0%

Reporting format

Participants reported correctly to 0.1 %	10

Comments - Optimum Moisture Content (OMC) Test

- Four test methods were used by the 10 participants in the OMC determination.
- These results are considered good given the low StDev and CV.

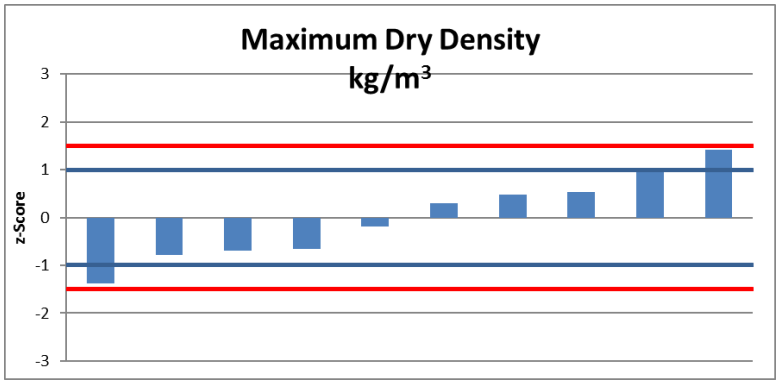
Maximum Dry Density test

#	Lab code	MDD kg/m³	MDD z-score
1	DF6CP	*1935*	**-1.376**
2	CV6ZX	1956	-0.779
3	TF5SK	1959	-0.694
4	YY3QP	*1960*	-0.665
5	WQ3LN	*1977*	-0.182
6	EN2QS	1994	0.301
7	AB4XQ	*2000*	0.472
8	DG3DK	2002.1	0.531
9	DK9WF	*2018*	0.983
10	AO7VU	2033	**1.410**

	MDD
H15 mean	1983.4
H15 Std Dev	35.18
Range	98.00
CV	1.8%

Test method information

Test method	AASHTO T180	AASHTO T99	SANS 3001 GR30	TMH1 A7	Non-responsive
# participants	2 (20 %)	1 (10 %)	1 (20 %)	4 (40 %)	2 (NULL)



Additional participant statistics

Number of participants	10
Non-participants	-
OB	-

Statistics for Z-scores < ±1

Range	62.0
Percentage of participants	80.0%

Reporting format

Participants reported to 1 kg/m³	4
Participants reported to 0.1 kg/m³	1
Participants reported to 0.001	5

Comments -Maximum Dry Density (MDD) test

- It is somewhat surprising that the borrow pit sand had a slightly higher MDD to the crushed granular material.
- Four test methods were used by the 10 participants in the MDD determination.
- The results for the MDD were all converted to kg/m^3 for ease of analysis.
    - This is as a result of the different test methods making use of various reporting formats.
- The use of a rubber mat by some of the facilities to contain the sand during the compaction process could influence the densities obtained.

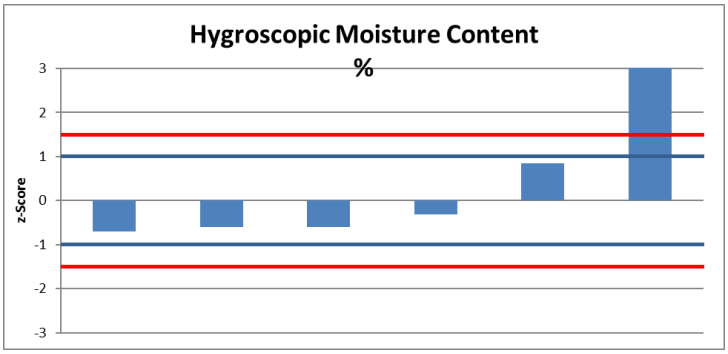
CBR Hygroscopic Moisture Contents test

#	Lab code	Hygroscopic %	z-score
1	DG3DK	0.6	-0.694
2	AB4XQ	0.7	-0.600
3	EN2QS	0.7	-0.600
4	CV6ZX	1.0	-0.320
5	TF5SK	2.25	0.847
6	WQ3LN	29	**25.821**
7	DF6CP	NULL	
8	AO7VU		
9	DK9WF		
10	YY3QP		

	Hygroscopic MC %
H15 mean	1.34
H15 Std Dev	1.07
Range	28.40
CV	79.8%

Test method information

Test method	AASHTO T193	SANS 3001 GR40	TMH1 A8	Non-responsive
# participants	4 (40 %)	1 (20 %)	4 (40 %)	1 (NULL)



Apparatus information

Automatic	Manual	Non-responsive
5	4	1 (NULL)

Proving Ring	Load Cell	Non-responsive
1	4	5 (NULL)

Additional participant statistics

Number of participants	9
Non-participants	1
NULL	2
OB	-

Statistics for Z-scores < ±1

Range	1.6

Percentage of participants	83.3%

Reporting format

Participants reported to 1 %	1
Participants reported correctly to 0.1 %	4
Participants reported to 0.01 %	1

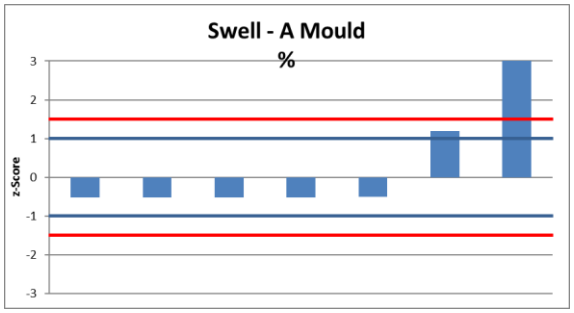
Comments - Hygroscopic Moisture Contents test

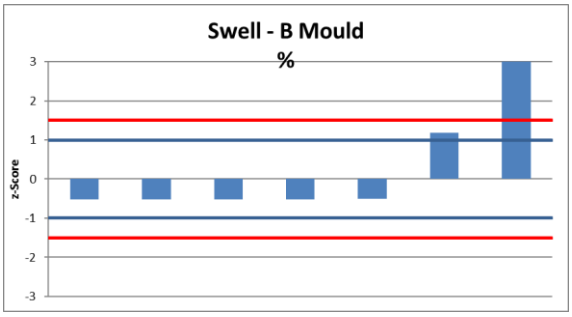
- Two of the results varied drastically from the mean.
  - This value should represent the moisture in the material after air drying.
  - It should not be anywhere near as high as 29 %.
- Most of the results provided were reasonably close to one another.

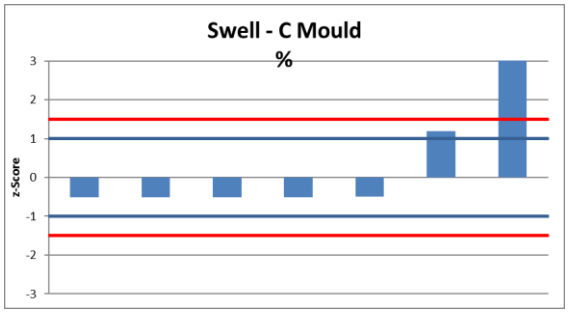
CBR - % Swell (A, B & C moulds)

Lab code	% Swell								
	A	Z-score		Lab Code	B	Z-score		Lab Code	C	Z-score
AB4XQ	0	-0.517		AB4XQ	0	-0.518		AB4XQ	0	-0.519
DK9WF	0.0	-0.517		DK9WF	0.0	-0.518		DK9WF	0.0	-0.519
EN2QS	0	-0.517		EN2QS	0	-0.518		EN2QS	0	-0.519
YY3QP	0.00	-0.517		YY3QP	0.00	-0.518		YY3QP	0.00	-0.519
CV6ZX	0.01	-0.511		CV6ZX	0.02	-0.506		CV6ZX	0.03	-0.502
DG3DK	2.9	**1.188**		DG3DK	3.0	**1.188**		DG3DK	3.1	**1.187**
AO7VU	10.2	**5.478**		AO7VU	11.6	**6.077**		AO7VU	11.3	**5.700**
DF6CP	CBD			DF6CP	CBD			DF6CP	CBD	
TF5SK	CBD			TF5SK	CBD			TF5SK	CBD	
WQ3LN	NULL			WQ3LN	NULL			WQ3LN	NULL	

	Swell A %	**Swell B %**	**Swell C %**
H15 mean	0.88	0.91	0.94
H15 Std Dev	1.702	1.759	1.817
Range	10.20	11.60	11.30
CV	193.5%	193.1%	192.8%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	10	10	10
Non-participants	-	-	-
CBD	2	2	2
NULL	1	1	1
OB	-	-	-
Statistics for Z-scores < ±1			
Range	0.01	0.02	0.03
Percentage of participants	71.4%	71.4%	71.4%
Reporting format			
Participants reported correctly to 1 %	2	2	2
Participants reported to 0.1 %	3	3	3
Participants reported to 0.01 %	2	2	2

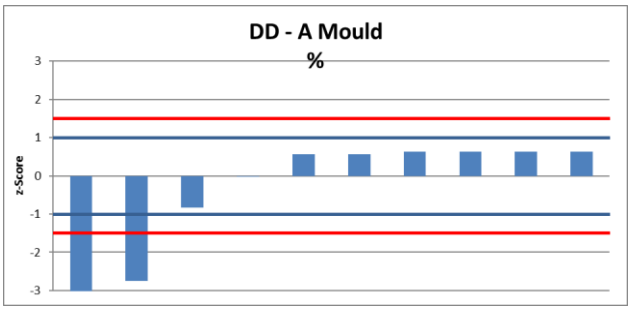
Comments - % Swell (A, B & C Moulds)

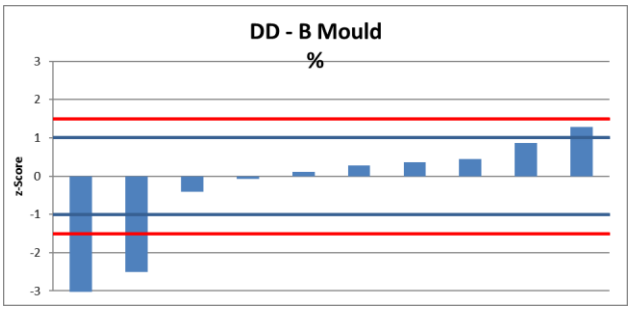
- The swell values are far too variable reporting from 0 % up to 11.3 %.
- Setting up the swell gauge and taking the readings before and after soaking could well be the result of the variability in the results.

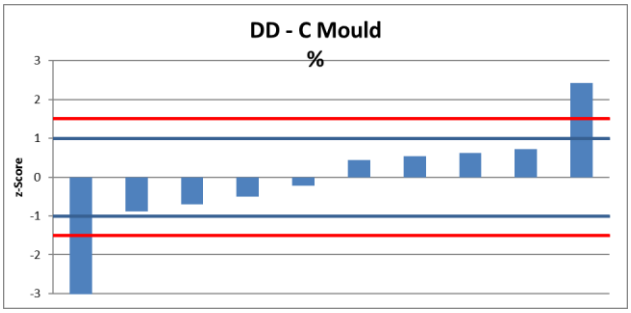
Dry Density % (A, B & C moulds)

Lab Code	% DD								
	A	Z-score		Lab Code	B	Z-score		Lab Code	C	Z-score
AO7VU	9.0	**-59.867**		AO7VU	9.0	**-72.473**		AO7VU	9.0	**-77.707**
WQ3LN	94.9	**-2.753**		WQ3LN	91.9	**-2.514**		DF6CP	90	-0.889
TF5SK	97.8	-0.825		DK9WF	94.4	-0.404		DG3DK	90.2	-0.699
DK9WF	*99.0*	-0.027		CV6ZX	*94.8*	-0.066		CV6ZX	90.4	-0.510
AB4XQ	99.9	0.572		DF6CP	95	0.102		WQ3LN	90.7	-0.225
YY3QP	99.9	0.572		DG3DK	95.2	0.271		AB4XQ	91.4	0.439
CV6ZX	100	0.638		TF5SK	95.3	0.355		YY3QP	91.5	0.533
DF6CP	100	0.638		YY3QP	95.4	0.440		EN2QS	91.6	0.628
DG3DK	100.0	0.638		AB4XQ	95.9	0.862		DK9WF	*91.7*	0.723
EN2QS	100.0	0.638		EN2QS	96.4	**1.284**		TF5SK	93.5	**2.430**

	A %	B %	C %
H15 mean	99.0	94.9	90.9
H15 Std Dev	1.504	1.185	1.054
Range	91.00	87.40	84.50
CV	1.5%	1.2%	1.2%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	10	10	10
Non-participants	-	-	-
NULL	-	-	-
OB	-	-	-
Statistics for Z-scores < ±1			
Range	2.2	3.1	0.7
Percentage of participants	80.0%	70.0%	80.0%
Reporting format			
Participants reported to 1 %	2	1	1
Participants reported to 0.1 %	8	9	9

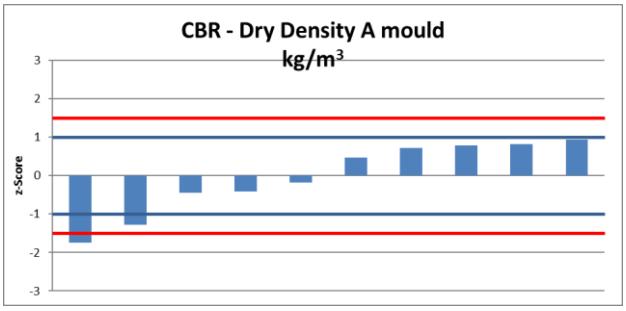
Comments - Maximum Dry Density % (A, B & C Moulds)

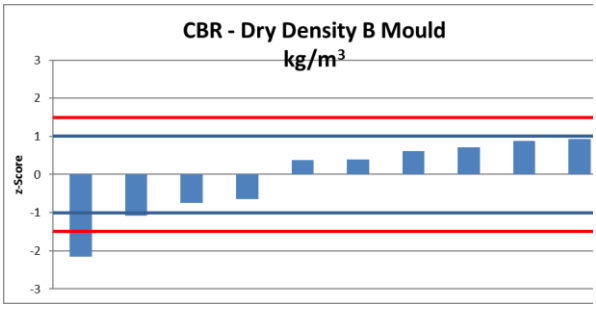
- Although the mean reflects the expected results of close to 100 %, 95 % and 90 % of MDD the range of the results are too high.
- This material was not expected to have such high variability.

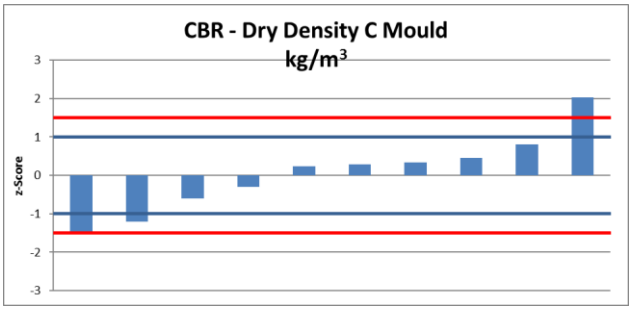
CBR - Dry Density kg/m³ (A, B & C moulds)

Dry Density (kg/m³)								
Lab Code	A	Z-score	Lab Code	B	Z-score	Lab Code	C	Z-score
TF5SK	*1915*	**-1.748**	DF6CP	*1818*	**-2.158**	DF6CP	*1756*	**-1.520**
DF6CP	*1930*	**-1.284**	CV6ZX	1855	**-1.087**	CV6ZX	1769	**-1.199**
CV6ZX	1957	-0.450	TF5SK	1867	-0.740	YY3QP	*1793*	-0.606
YY3QP	*1958*	-0.419	YY3QP	*1870*	-0.654	DG3DK	1805.1	-0.307
AO7VU	1966	-0.172	DG3DK	1905.5	0.373	EN2QS	1827	0.234
WQ3LN	1987	0.477	DK9WF	1906	0.388	AB4XQ	*1829*	0.284
EN2QS	1995	0.724	AO7VU	1914	0.619	TF5SK	*1831*	0.333
AB4XQ	*1997*	0.786	AB4XQ	*1917*	0.706	AO7VU	1836	0.457
DK9WF	1998	0.817	EN2QS	1923	0.880	DK9WF	1850	0.803
DG3DK	2002.1	0.943	WQ3LN	1925	0.938	WQ3LN	1900	**2.039**

	A	B	C
H15 mean	1972	1893	1818
H15 Std Dev	32.37	34.57	40.46
Range	87.10	107.00	144.00
CV	1.6%	1.8%	2.2%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	10	10	10
Non-participants	-	-	-
NULL	-	-	-
OB	-	-	-
Statistics for Z-scores < ±1			
Range (kg/m^3)	45.1	58.0	57.0
Percentage of participants	80.0%	80.0%	70.0%
Reporting format			
Participants reported correctly to 1 kg/m^3	4	4	4
Participants reported correctly to 0.1 kg/m^3	1	1	1
Participants reported correctly to 0.001	5	5	5

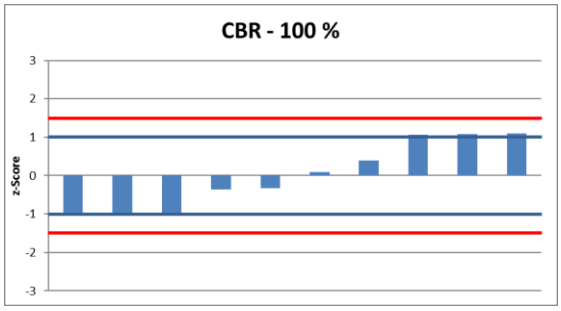
Comments - Dry Density kg/m^3 (A, B & C moulds)

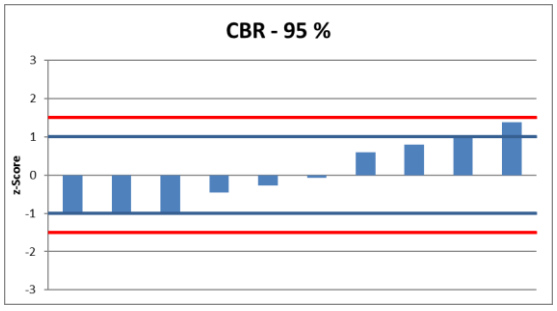
- Most of the results are within an acceptable range with a low CV.

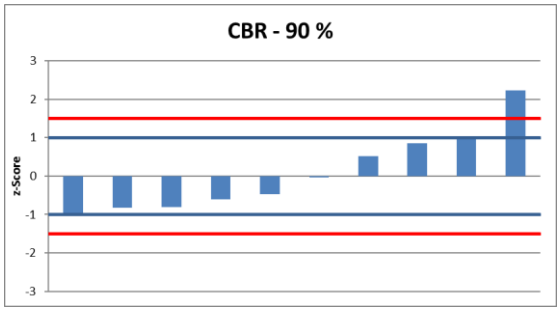
CBR %

CBR %									
Lab Code	100%	Z-score		Lab Code	95%	Z-score		Lab Code	90%	Z-score
YY3QP	7.5	**-1.034**		YY3QP	4.3	**-1.022**		WQ3LN	1.0	**-1.033**
WQ3LN	7.8	**-1.024**		DF6CP	5.5	-0.964		DF6CP	4.0	-0.822
DF6CP	9.0	-0.987		WQ3LN	5.7	-0.955		YY3QP	4.2	-0.808
AO7VU	28.8	-0.362		CV6ZX	16	-0.459		CV6ZX	7	-0.611
CV6ZX	30	-0.324		EN2QS	20	-0.266		EN2QS	9	-0.471
EN2QS	*43*	0.086		AO7VU	24.0	-0.074		AO7VU	15.1	-0.043
AB4XQ	53	0.401		TF5SK	38	0.601		TF5SK	23	0.512
DK9WF	74.17	**1.068**		AB4XQ	42	0.793		DG3DK	27.8	0.849
DG3DK	74.6	**1.082**		DG3DK	45.5	0.962		AB4XQ	30	**1.004**
TF5SK	75	**1.095**		DK9WF	54.29	**1.385**		DK9WF	47.52	**2.234**

CBR %	100%	95%	90%
H15 mean	40.29	25.53	15.71
H15 Std Dev	31.714	20.767	14.241
Range	67.50	49.99	46.52
CV	78.7%	81.3%	90.7%







	A mould	B mould	C mould
Additional participant statistics			
Number of participants	10	10	10
Non-participants	-	-	-
NULL	-	-	-
OB	-	-	-
Statistics for Z-scores < ±1			
Range (kg/m^3)	44.0	40.0	23.8
Percentage of participants	50.0%	80.0%	70.0%
Reporting format			
Participants reported correctly to 1 %	4	4	4
Participants reported to 0.1 %	5	5	5
Participants reported to 0.01 %	1	1	1

Comments –CBR %

- The CBR results are highly variable.
- The CV is almost double that of the crushed material which is expected to provide a more variable set of results due to the coarser aggregate present in the crushed material.
- Given the nature of the finer graded borrow pit sand in this sample, the CBR results were expected to be more constant than the crushed granular materials results.

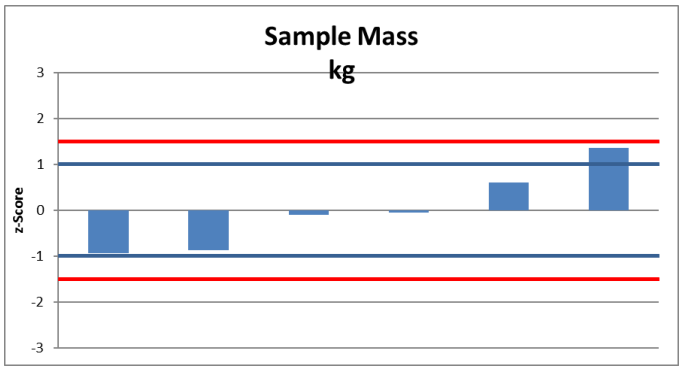
Washed Grading Sample Mass

#	Lab code	Sample mass (g)	z-score
1	YY3QP	500.0	-0.939
2	EN2QS	535.4	-0.876
3	AB4XQ	971.5	-0.103
4	DF6CP	1000	-0.053
5	DK9WF	1372.0	0.606
6	WQ3LN	1800	**1.365**
7	AO7VU		
8	CV6ZX		
9	DG3DK		
10	TF5SK		

	Reduction Factor
H15 mean	1029.8
H15 Std Dev	564.36
Range	1300.00
CV	54.8%

Test method information

Test method	AASHTO T27	E-239 1970	SANS 3001 GR1	TMH1 A1 (a)	TMH1 A8	Non-responsive
# participants	2 (20 %)	1 (10 %)	1 (10 %)	3 (30 %)	1 (20 %)	2 (NULL)



	Sample Mass
Number of participants	6
Non-participants	4
OB	-
Range	872.0
Percentage of participants	83.3%
Participants reported to 1 g	2
Participants reported to 0.1 g	4

Comments - Washed Grading Sample Mass

- Five test methods were used by the 10 participants in the grading analysis.
- The large range in the mass used needs to be resolved to ensure more consistent results

Washed Grading

NOTE: *Fraction 5 mm and 3.35 mm were not analyzed as they all had 100 % passing*

Lab Code	2/2.36 mm	Z-Score
DF6CP	*99.9*	**-1.3E+12**
AB4XQ	100	0.360
CV6ZX	100	0.360
DK9WF	100.0	0.360
EN2QS	100	0.360
TF5SK	100.00	0.360
WQ3LN	100.00	0.360
YY3QP	100.00	0.360
AO7VU		
DG3DK		

Lab Code	1/1.18 mm	Z-Score
TF5SK	99.31	**-2.890**
DF6CP	*99.6*	-0.869
DG3DK	99.8	0.524
DK9WF	99.8	0.524
WQ3LN	99.8	0.524
YY3QP	99.82	0.664
AB4XQ		
AO7VU		
CV6ZX		
EN2QS		

Lab Code	0.600 mm	Z-Score
DF6CP	93.1	**-2.684**
DK9WF	95.8	-0.466
DG3DK	97.0	0.520
WQ3LN	97.1	0.602
YY3QP	97.20	0.684
AB4XQ		
AO7VU		
CV6ZX		
EN2QS		
TF5SK		

% passing	2/2.36 mm	1/1.18 mm	0.600 mm
H15 mean	100.00	99.72	96.37
H15 Std Dev	0.000	0.144	1.217
Range	0.10	0.51	4.10
CV	0.0%	0.1%	1.3%

Lab Code	0.425 mm	Z-Score
DF6CP	50.30	**-6.928**
DK9WF	70.7	**-3.034**
DG3DK	87.8	0.230
AB4XQ	88.4	0.344
CV6ZX	88.6	0.383
WQ3LN	88.8	0.421
EN2QS	90	0.650
TF5SK	90.66	0.776
AO7VU		
YY3QP		

Lab Code	0.300 mm	Z-Score
DF6CP	38	-0.842
DK9WF	40.1	-0.722
DG3DK	47.1	-0.322
YY3QP	69.00	0.932
WQ3LN	69.4	0.955
AB4XQ		
AO7VU		
CV6ZX		
EN2QS		
TF5SK		

Lab Code	0.250 mm	Z-Score
TF5SK	61.63	-
AB4XQ		
AO7VU		
CV6ZX		
DF6CP		
DG3DK		
DK9WF		
EN2QS		
WQ3LN		
YY3QP		

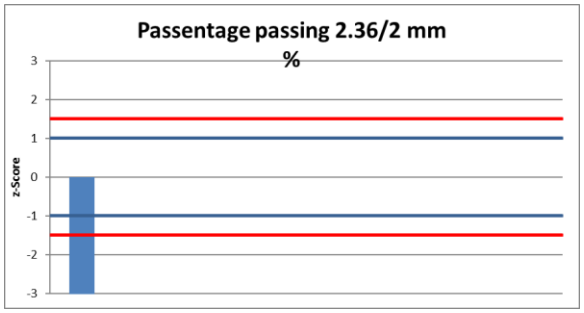
% passing	0.425 mm	0.300 mm	0.250 mm
H15 mean	86.60	52.72	-
H15 Std Dev	5.239	17.474	-
Range	40.36	31.40	-
CV	6.1%	33.1%	-

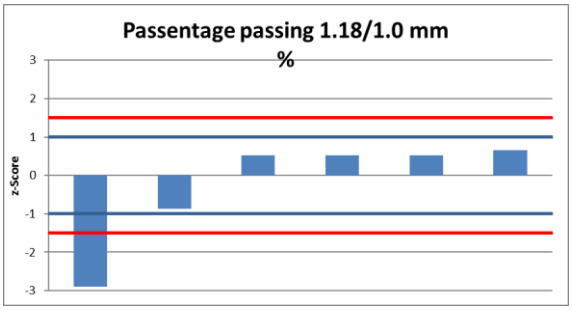
Lab Code	0.150 mm	Z-Score
DF6CP	15.4	**-1.124**
DK9WF	16.5	-0.742
DG3DK	18.4	-0.082
WQ3LN	19.1	0.161
YY3QP	19.84	0.418
TF5SK	23.88	**1.822**
AB4XQ		
AO7VU		
CV6ZX		
EN2QS		

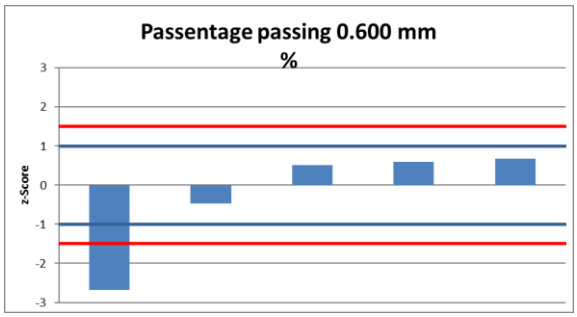
Lab Code	0.075 mm	Z-Score
CV6ZX	10.3	**-2.739**
DK9WF	12.6	-0.828
AB4XQ	13	-0.495
YY3QP	13.00	-0.495
TF5SK	13.97	0.311
EN2QS	14	0.336
DG3DK	*14.1*	0.419
WQ3LN	14.5	0.751
DF6CP	126.1	**93.494**
AO7VU		

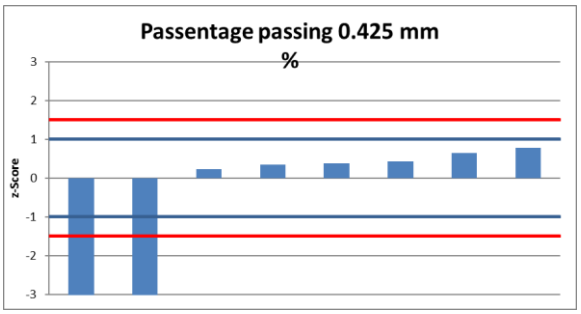
% passing	0.150 mm	0.075 mm
H15 mean	18.64	13.60
H15 Std Dev	2.879	1.203
Range	8.48	115.80
CV	15.4%	8.9%

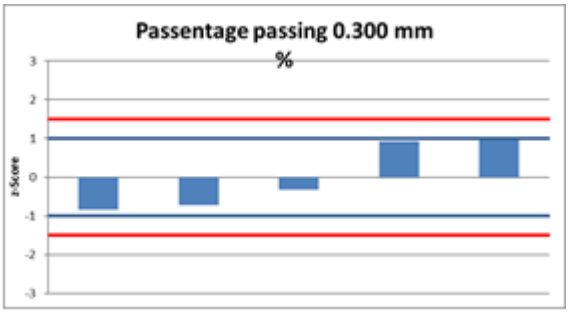
	2/2.36 mm	1/1.18 mm	0.600 mm	0.425 mm	0.300 mm	0.250 mm	0.150 mm	0,075 mm
Additional participant statistics								
Number of participants	8	6	5	8	5	1	6	9
Non-participants	2	4	5	2	5	9	4	1
OB	-	-	-	-	-	-	-	-
Statistics for Z-scores < ±1								
Range	0.0	0.2	1.4	2.9	31.4	-	3.3	1.9
Percentage of participants	85.7%	83.3%	66.7%	66.7%	100.0%	-	66.7%	77.8%
Reporting format								
Participants reported to 1 %	3	-	-	1	1	-	-	2
Participants reported to 0.1 %	2	4	4	5	3	-	4	5
Participants reported to 0.01 %	3	2	1	2	1	1	2	2

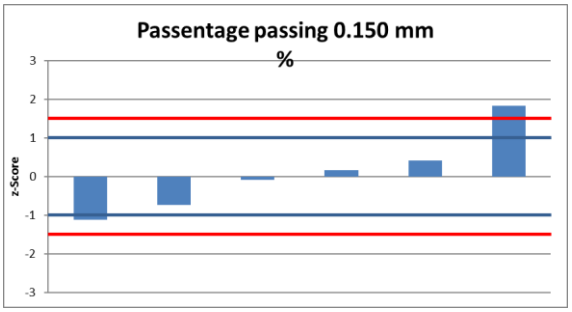


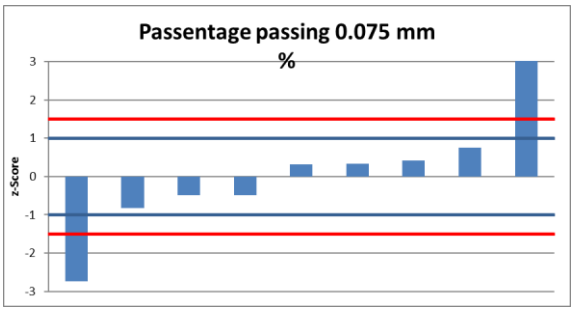












Comments - Washed Grading

- Due to the various test methods used some of the sieve sizes do not have a full set of results making it more difficult to determine the trends.

Soil Mortar based on grading analysis

Lab Code	GM	Z-Score
AO7VU	0.88	**-1.164**
EN2QS	0.96	-0.498
WQ3LN	0.97	-0.414
DG3DK	0.98	-0.331
AB4XQ	1	-0.165
CV6ZX	1.01	-0.081
DK9WF	1.17	**1.251**
DF6CP	1.37	**2.916**
TF5SK		
YY3QP		

Lab Code	FM	Z-Score
AO7VU	0.300	**-1.125**
WQ3LN	0.55	-0.711
YY3QP	1.14	0.265
DG3DK	1.37	0.646
DF6CP	1.539	0.925
EN2QS	NULL	
AB4XQ		
CV6ZX		
DK9WF		
TF5SK		

Lab Code	*Soil Mortar*	Z-Score
DG3DK	14.1	-0.843
WQ3LN	14.5	-0.837
AO7VU	36.4	-0.517
CV6ZX	100	0.414
EN2QS	100	0.414
DF6CP	1000	**13.581**
TF5SK	NULL	
AB4XQ		
DK9WF		
YY3QP		

% passing	GM	FM	Soil Mortar
H15 mean	1.020	0.980	71.71
H15 Std Dev	0.120	0.604	68.35
Range	0.49	1.24	985.90
CV	11.8%	61.7%	95.3%

Test method information

Test method	AASHTO T27	AASHTO T88	ASTM C136	SANS 3001 PR5	TMH1 A1 (a)	TMH1 B4	Non-responsive
# participants	2 (20 %)	1 (10 %)	1 (10 %)	2 (20 %)	2 (20 %)	1 (10 %)	1 (NULL)

Lab Code	Coarse Sand	Z-Score
AO7VU	0.0	-0.734
DK9WF	0.2	-0.697
DF6CP	0.4	-0.660
YY3QP	2.8	-0.217
DG3DK	3.0	-0.180
EN2QS	10	**1.115**
CV6ZX	11.4	**1.374**
TF5SK	NULL	
WQ3LN	NULL	
AB4XQ		

Lab Code	Coarse Sand Ratio	Z-Score
EN2QS	0.10	**-1.003**
DK9WF	4.0	0.346
AO7VU	4.9	0.657
WQ3LN	NULL	
AB4XQ		
CV6ZX		
DF6CP		
DG3DK		
TF5SK		
YY3QP		

Lab Code	Coarse Fine Sand	Z-Score
WQ3LN	2.9	-0.955
DF6CP	6.5	-0.817
EN2QS	30	0.084
AO7VU	44.0	0.620
DK9WF	55.7	**1.069**
TF5SK	NULL	
AB4XQ		
CV6ZX		
DG3DK		
YY3QP		

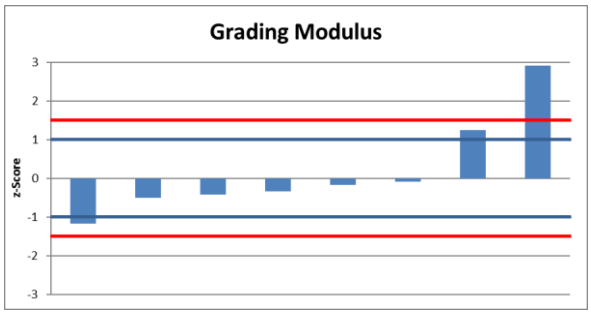
% passing	Coarse Sand	Coarse Sand Ratio	Coarse Fine Sand
H15 mean	4.0	3.0	27.8
H15 Std Dev	5.41	2.89	26.09
Range	11.40	4.80	52.80
CV	136.2%	96.4%	93.8%

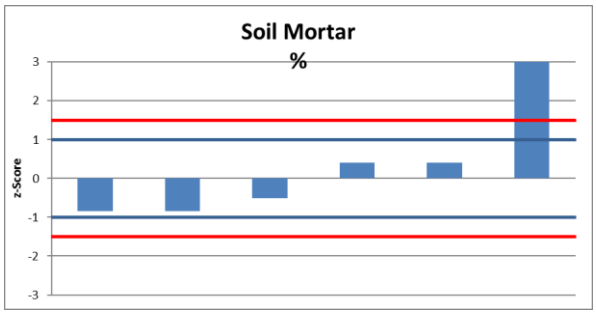
Lab Code	Fine Fine Sand	Z-Score
EN2QS	9	-0.624
DK9WF	27.4	0.624
DF6CP	CBD	
AO7VU	NULL	
TF5SK	NULL	
WQ3LN	NULL	
AB4XQ		
CV6ZX		
DG3DK		
YY3QP		

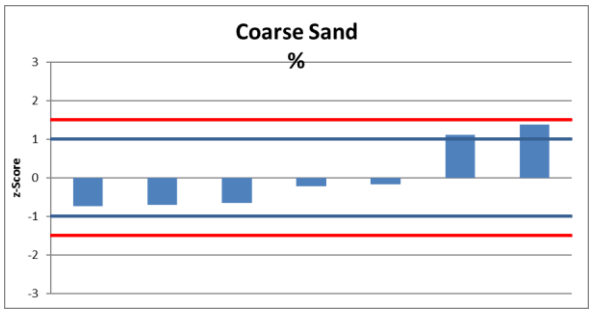
Lab Code	Fine Sand	Z-Score
DK9WF	12.6	-0.795
AO7VU	14.7	-0.738
DF6CP	25.3	-0.445
DG3DK	33.0	-0.233
CV6ZX	78.3	**1.015**
WQ3LN	84.9	**1.197**
YY3QP	77.4/6.8	
EN2QS	NULL	
TF5SK	NULL	
AB4XQ		

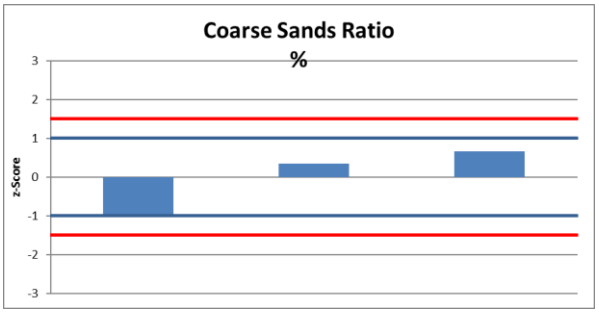
Lab Code	Medium Fine Sand	Z-Score
WQ3LN	27.8	**-1.043**
EN2QS	37	-0.389
DG3DK	49.9	0.528
DF6CP	55.2	0.904
AO7VU	NULL	
TF5SK	NULL	
AB4XQ		
CV6ZX		
DK9WF		
YY3QP		

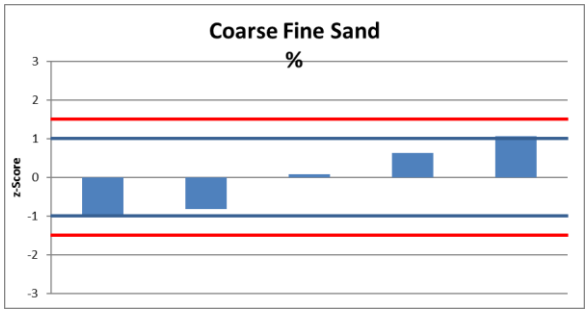
% passing	Fine Fine Sand	Fine Sand	Medium Fine Sand
H15 mean	18.2	41.5	42.5
H15 Std Dev	14.75	36.29	14.07
Range	18.40	72.30	27.40
CV	81.0%	87.5%	33.1%

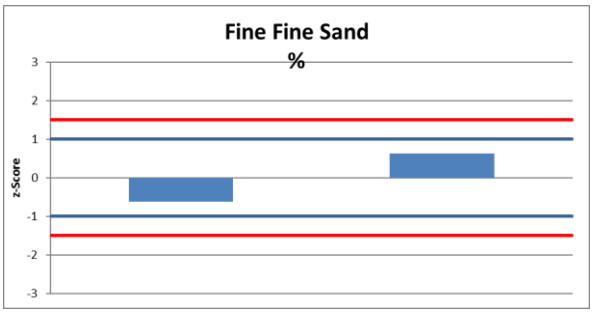


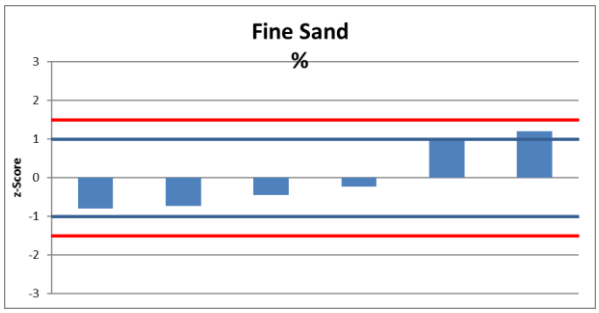


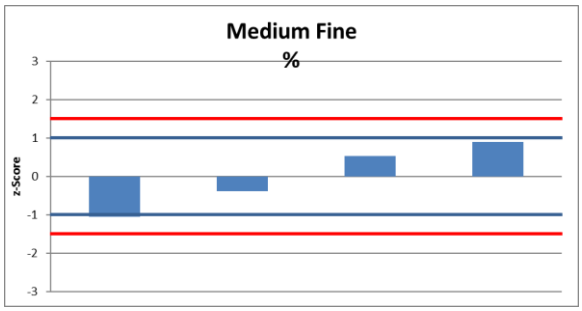












Comments on Soil Mortars

- This portion of the report was poorly reported. Evidently what was required was not well understood and the uncertainties need to be resolved before the next round.

4 Summary of Findings, Recommendations and Next Steps

4.1 Findings

Facilities Participating

A total of ten facilities took part in the first pilot PTS.

Test Methods

There needs to be consistency in the test methods used throughout Mozambique to be able to identify with greater clarity the issues in the various facilities. At present the variety of test methods adds to the variability of the results obtained. It is unlikely that this matter will be resolved before the next two rounds of the PTS have been completed, and these differences will need to be considered in the evaluation of the results.

The SANS 3001 test methods are recommended for Mozambique because they have been developed with years of experience on local materials found in the Southern African environment. The SANS methods are precise in the way they are specified whereas the AASHTO methods are less clearly set out.

The adoption of SANS 3001 would require some laboratories to purchase new equipment:

- The laboratories that are currently testing on TMH1 would need to purchase of a new set of sieves for aggregates and granular testing and a new flakiness gauge due to the sieve size change. The ACV & 10% FACT press would not need to be changed although the CBR press may need to be recalibrated. There is an option to leave the CBR press calibrated to the imperial requirements as it is in TMH1.
- It is not expected that the laboratories that are currently testing on AASHTO or ASTM methods will need to replace equipment, but they will need to confirm this by checking compliance to the apparatus requirements as stipulated in the applicable methods.

Analysis of Results

In this first pilot round no results were removed from the analysis and noted as obvious errors (OE). All results as provided where included in the statistical analysis.

All the results from the first round are variable. This is not unusual as the process of PTS is a new concept and it will take some time to get the participants to be familiar with how to present the results and how to follow the test methods more consistently. It is also expected that as additional facilities join the PTS over time they will need to undergo the same process of getting used to what is required in a formal PTS. A better correlation of results is expected as the PTS gains momentum.

On average 60 – 70 % of the results per test method are within a z-score of ±1. All facilities need to aim towards obtaining results in the range of ±1. It is expected that the proportion of results within a z-score of ± 1 could be increased to around 75 % per test method.

Information Provided by Laboratories

The resolution of the answers reported by the various facilities needs to be more closely followed to ensure results can be compared effectively with one another. An answer of 0 is seen very differently in statistical analysis to an answer of 0.4 due to rounding off. More consistency in the way the results are calculated and reported by the laboratories will assist greatly in this regard.

The information requested for the various test methods and apparatus used, as well as some of the additional testing requirements, is necessary to assist in identifying where some of the test methods are being undertaken incorrectly. All the facilities are urged to provide all the information as requested on the forms to ensure greater accuracy in the analysis of the results and easier identification of where facilities need to pay further attention in their testing procedures.

Areas Requiring Attention

As this is the first round undertaken in Mozambique, it is difficult to identify clearly where some of the difficulties lie. This will become clearer as further rounds of the PTS are undertaken and specific trends are identified over time. However, there are some obvious issues that need to be resolved in some of the facilities before the second round is undertaken, to ensure a more representative set of results and lower the variability in the results as reported in the first round.

From the results, the test methods that require most attention are as follows

- Sample mass used per test method
- PI
- CBR and swell
- ACV

These areas are briefly discussed below with additional comments under the relevant sections in Chapter 3.

- The variability in the sample mass used per test method needs to be addressed to ensure each result is as representative as possible. Some facilities are using too small a sample to obtain a representative result.

- The PI seems to be a problem in the identification of material with or without plasticity. Also, how the information is reported for the various PI components requires improvement. For example, a LL cannot be reported if there is no PL.

- The CBR test method will require additional training input as this test method is notoriously variable. It was expected that the borrow pit sample with the finer sandy type material would present a more uniform and constant set of results, but this was not the case. Both samples i.e. crushed granular and borrow pit sand, were however equally variable.

- Swell measurements can be variable due to the difficulty in fixing the initial reading point and using the exact same place for the last reading to determine the actual swell. The variability in the results, especially for the borrow pit material, is concerning.

- The ACV was more variable than would be expected. This is a result that normally provides a good reproducibility result. It is possible that there are problems with the calibration of the apparatus assuming the test method is being followed correctly.

Summary of Findings

The results of the first round of the PTS have provided a starting point which indicates the variability of the results currently being produced in Mozambique. Given the importance of the decisions that are made based on such results, it is imperative that the variability in the results produced by the individual facilities be reduced. From this baseline it is expected that improvements can be achieved through continuous monitoring

whilst persistent issues are noted and addressed with the various facilities. The high variability in the first round was expected and this variability should reduce over the next two rounds. If the PTS becomes a regular activity in the monitoring of laboratory consistency in Mozambique, the variability should over time be reduced even further. The results of such a PTS can be used to assist client bodies and laboratories to evaluate their results and aim towards a process of continual improvement hence providing quality results that are reliable and valid.

4.2 Recommendations

The main recommendation is that it is imperative for Mozambique to agree a standard series of test methods for use in Mozambique e.g. SANS 3001 or AASHTO. This would ensure that PTS results can be evaluated without built-in variations due to a variety of the testing methods in use across the country.

4.3 Next Steps

The next step in the project is a visit to the participating ANE and LEM laboratories by the Materials Testing Expert in November 2017. Feedback will be provided at each facility during the site visit on how to read the report and action the comments applicable to each facility. The revisions to the test methods will be witnessed during the visits to assist in making additional corrections where required to assist in reducing the variability in the results for the following two rounds of the PTS. It is noted that the visit of the expert will not include the private laboratories in Mozambique and South Africa.

After the November laboratory visits a recommendation will be made on whether the participating laboratory personnel should gather for another workshop to discuss the PTS process.

Following the analysis of the results obtained from the laboratories from the second round of the PTS, a third round will be launched. The third round will be the final round under the current project.