Protocols for Improving the Proficiency of Material Testing Laboratories in Mozambique

Final Report

Civil Design Solutions

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Cover photo: Sample preparation for the PTS

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Abstract

The pilot Proficiency Testing Scheme (PTS) for Mozambique is developing a baseline for the precision limits for the common tests on road construction materials. The baseline has been used to assess laboratory capacity and identify where constraints lie and where specific training and other interventions may be required. The purpose of this report is to summarise the process for the implementation of the proficiency testing scheme including the results of the third round of the PTS, and final recommendations on a permanent PTS operation for Mozambique.

Ten laboratories participated in the third round of the PTS, including the two laboratories in South Africa. Overall there is a marginal improvement in the results from Rounds 1 to Round 3, but the range of results received from the participating laboratories for most of the tests continues to be large. The results for the soil constants are the most variable along with the grading results for all materials. The most consistent improvements were observed in the aggregate tests for shape and strength as well as the CBR, MDD & OMC determinations. In general, the laboratories have difficulty determining whether a granular material is plastic.

The Standard Deviation of the test results received has been used to provide an initial set of precision limits for the various tests. The 95% Confidence Index (CI) has been calculated for each test method to indicate the range within which the “true” value of the material probably lies in relation to the “average” value. After testing the same materials three times under the project, the “average” value is regarded to be a fair reflection of the actual value of the parameter being measured. With further PTS testing in Mozambique and the adoption of standard test methods, the average values will, over time, be refined to a more accurate reflection of the “true” value.

The results from the two South African laboratories are closer to the average value than the Mozambique laboratories for most of the tests carried out. The priority for Mozambique in building laboratory capacity is therefore to agree on the adoption of an internationally recognised test method series and ensure that the laboratories are properly equipped to carry out these methods. Routine calibration of equipment must be carried out. Training is required for all laboratory technicians on how to carry out the approved methods. The recommended programme for the PTS for 2019 includes staggering of the tests to reduce the management requirements for the scheme.

Key words

Materials, Quality Control, Capacity Development, Proficiency Testing

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Research for Community Access Partnership (ReCAP)

Safe and sustainable transport for rural communities

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Acronyms, Initialisms, 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
CBD	Could not be determined
CBR	California Bearing Ratio
CDS	Civil Design Solutions
CI	Confidence Index
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
g	gram
GM	Grading Modulus
GPS	Global Positioning System
ILC	Intra/Inter Laboratory Comparison
ISO	International Standards Organisation's
INNOQ	Instituto Nacional de Normalização e Qualidade
LEM	Laboratório de Engenharia de Moçambique
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-SA	National Laboratory Association South Africa
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
RRC	Road Research Centre
RTFOT	Rolling Thin Film Oven Test
SA	South Africa
SADCAS	Southern African Development Community Accreditation Service
SANAS	South African National 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)

1 Introduction

1.1 Background to the Project

The Africa Community Access Partnership (AfCAP) is providing a range of support to Mozambique. This includes the development of design guidelines for low volume roads and the monitoring of road experimental sections. The validity of the research on roads 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 delivers test results that can be used with confidence.

The Proficiency Testing Scheme (PTS) has developed a baseline for the precision limits for the common tests on road construction materials. The baseline can be used to assess laboratory capacity and identify where constraints lie and where specific training and other interventions may be required. Participation in the PTS is the first step towards the accreditation of laboratory facilities to the International Standards Organisation's standard ISO/IEC 17025.

Civil Design Solutions (CDS) was appointed under AfCAP to provide technical support to the Mozambique Road Research Centre (RRC), which is implementing the pilot PTS. The RRC members are drawn from the National Road Administration (ANE) and the National Engineering Laboratory (LEM).

1.2 Objectives

The objectives of the assignment are as follows:

- 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.
- 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 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.
- 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 Purpose of this Report

The purpose of this report is to summarise the process for the implementation of the proficiency testing scheme and final recommendations on a permanent PTS operation for Mozambique. The report includes the results of the third round of the PTS and, based on these results, recommends precision limits for the various tests for use in design and for site quality control purposes. The averages for the results for the three rounds of the PTS as well as the statistical data from analysis of the results are summarised in the report and comments provided on each test.

The different test methods e.g. grading, MDD, OMC and CBR have been combined where possible in the report. Where the results are dependent on the material type i.e. sand or granular, they are kept separate.

2 Process for the Implementation of the PTS

2.1 Overview of the PTS process and results

Implementing a PTS results in a new approach to laboratory testing. It encourages participating facilities to rethink their attitude to how a testing facility should operate and how it should evaluate its procedures, methods and the results it produces. The facilities are no longer evaluated only against the results they produce, but rather they are evaluated against a national mean determined by all the participants in the scheme. The more participants that are involved in the PTS, the greater the confidence level in the consensus mean determined for each test method.

The PTS is a continuous process of testing and corrective action, retesting and further corrective action. It is not a once off process that solves all the testing issues simultaneously. Four main issues can influence the results i.e. human error, varying interpretations of the methods in use, calibration of the apparatus and the variability of the material, especially in the sampling and splitting down of the material into the various test samples. The process, as well as the participants, need time to find the correct balance between these various aspects of testing. It is unlikely that all these aspects can be addressed in a single round. As corrections are made to the methods from one round to the next, it is possible to confirm whether the corrective action had the desired effect. The process is iterative by nature. Similarly, new participants that join the PTS will undergo the same transitional process that the initial participants have undergone. They will need a similar time frame to adapt to the system and revise and improve their laboratory procedures in order to produce results to a consistently acceptable standard.

All laboratory facilities will, from time to time, provide results that do not conform to an acceptable level. This is to be expected and is due to human error in the testing process and the high variability of the materials used in the construction industry. What is more important is what action or actions are taken to correct the identified error and monitoring how effective that action was as a continuous quest towards limiting such errors. This is more important than focussing on the error itself.

The results of the pilot PTS in Mozambique are generally favourable and can be used as a basis to continue the PTS programme and progressively improve and refine the overall results. There are two main exceptions:

- Atterberg Limits: The three sets of results for crushed granular material (Form A), plastic material (Form B) and sand (Form C) suggest an inability of most of the laboratories to determine whether the material is plastic. This issue was addressed at the project workshop in Maputo in November 2018 and the requirements to improve this aspect of the testing are now better understood. Improvements can be monitored in subsequent rounds.
- Soil mortar determination: The values applicable to the Mozambican specifications need to be identified, and only those that are relevant should be included in future PTS rounds.

2.2 Selection of participating laboratories

Participation in the PTS included three ANE provincial laboratories, the ANE and LEM central laboratories in Maputo and three commercial laboratories in Maputo. Two accredited laboratories in South Africa participated as control laboratories.

A survey was carried out of all existing facilities in Mozambique, including site laboratories, for the identification and selection process. A questionnaire was sent to the laboratories by ANE. The questionnaire assessed the existing capacity of the laboratories in terms of availability and calibration of equipment, availability of trained personnel, and level of current activity.

Two South African laboratories were proposed by CDS for approval by the RRC, one based in Nelspruit and the other in Pinetown near Durban.

The selection process resulted in the following list of participating facilities:

1. LEM[1] (Maputo)
2. ANE[2] 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, South Africa - private)
10. SoilCo Laboratory (Pinetown, South Africa - private)[3].

2.3 Initial visit to the selected laboratories

A visit was carried out by the CDS Materials Expert to the selected laboratories between the 20th and 31st March 2017. The purpose of the visit was to allow the Materials Expert to familiarise himself with the facilities, meet the laboratory staff, and observe testing in progress. The findings of the initial visit included[4]:

- There are no standard test methods adopted for use in Mozambique;
- Some laboratories were mixing test methods between TMH1 and AASHTO;
- Some test methods were not being followed correctly, including additional steps or apparatus added to methods;
- Very few facilities had calibration certificates for their equipment that were traceable to national or international standards;
- There was very little routine verification carried out on the status of apparatus related to the required tolerances given in the test methods;
- Very few facilities had a master set of sieves to verify the working sieves;
- Suitable thermometers, timing devices, mass pieces and calipers for verification procedures were not available at most facilities;
- Most MDD/CBR hammers were too light in relation to the apparatus mass tolerances as specified in the methods used;
- Most facilities had a small staff complement (less than 5 members), with qualifications ranging from degrees and diplomas to in-house trained staff, but there were no continued competency records for any of the staff; and

[1] Laboratório de Engenharia de Moçambique (National Engineering Laboratory).
[2] Administração Nacional de Estradas (National Road Administration).
[3] Soil-Lab did not return any results for the second round of the PTS due to an internal labour dispute, but Soil-Lab did participate in Round 3.
[4] Pearce, B. and Geddes, R., CDS (2017). Protocols for Improving the Proficiency of Material Testing Laboratories in Mozambique, Report on Initial Laboratory Visits and Protocol for the PTS. MOZ2094A. London: ReCAP for DFID.

- The staff in all facilities were very responsive to comments made by the Materials Expert and were keen to learn and develop their knowledge.

2.4 PTS Protocols

The testing protocols were provided to the laboratories with each round of the PTS. The protocols underwent some revisions over the three rounds to highlight critical aspects requiring attention by the participants and to improve the overall understanding of the documents. The protocols were translated into Portuguese to assist the participants in undertaking the testing to ensure as little variation as possible between the participating facilities. The current versions of the protocols are included in Annex A-D.

2.5 First Round of the PTS

Draft protocols were prepared by CDS for sample preparation and conducting the PTS. A project workshop and practical session were held in Maputo from 13th to 15th June 2017 to:

- discuss the draft protocols with the eight Mozambican laboratories that were participating in the pilot scheme; and
- assist ANE/LEM with the sampling of materials for the first round of the PTS and splitting of the samples before distribution to the participating laboratories.

The material was selected to cover the main types of material found in Mozambique as well as the varying types of material that can be tested i.e. plastic vs non-plastic granular material. The material selected for the PTS were:

- Crushed granular materials from the JJR quarry near Maputo. This is a crushed material used in layer works, which is typically non-plastic or with a low PI.
- "Plastic" material sample brought from Inhambane (passing the 0.425mm sieve) to assess the facilities' ability to undertake Atterberg testing on plastic material.
- Red sand from a borrow pit in Moamba District near Maputo. This is a typical red sand type material found in the southern parts of Mozambique, which is also typically non-plastic.
- Aggregate from the JJR quarry (concrete stone). This is a crushed concrete aggregate which was included to assess ability to test for the basic properties of grading, FI, ACV & 10% FACT.

The testing for the first round of the PTS was carried out between June and September 2017. The results were analysed by CDS and presented in the Baseline Report (November 2017)[5]. The conclusions of the first round of the PTS included:

- 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. The variety of test methods used adds to the variability of the results obtained.
- 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, but the adoption of SANS 3001 would require some laboratories to purchase new equipment[6].
- The results from the first round were variable for all of the test methods, with only 60 – 70 % of the results per test method within a z-score of ±1[7].

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[5] Pearce, B. and Geddes, R., CDS (2017). Protocols for Improving the Proficiency of Material Testing Laboratories in Mozambique, PTS First Round - Baseline Report. MOZ2094A. London: ReCAP for DFID.

[6] Two full subscriptions for SANS were purchased under the project, one for ANE and one for LEM.

[7] The z-score is a normalised value which gives a score to each result relative to the other numbers in the data set. The objective is for all test results to have a z-score in the range of ±1.

- More consistency was required in the way the results are calculated and reported by the laboratories.
- Not all of the information requested for the various test methods and apparatus used, as well as some of the additional testing requirements, was provided by the laboratories.
- The test methods requiring the most attention were:
  - Sample mass used for each test method;
  - PI;
  - CBR and swell; and
  - ACV.

2.6 Second Round of the PTS

The testing for the second round of the PTS was carried out between October 2017 and May 2018. Materials for the crushed granular, aggregate and sand samples were obtained from the same sources as the first round and the splitting was carried out at the LEM laboratory in Maputo. The materials sampling and distribution were carried out independently by the RRC without direct support from CDS. The plastic sample was from a different source from Round 1 due to a misunderstanding by the ANE laboratory in Inhambane that was tasked with preparing the sample, which made it more difficult to determine any improvement in the testing from one round to the next.

During the second round testing period, the CDS Materials Expert visited all the government laboratories that are participating in the PTS to assess their performance and provide hands-on training and advice. The private laboratories were not visited or provided with direct technical support because the intention of the capacity building component of the project was mainly to support the development of the government laboratories. The laboratory visits took place from 20th November to 1st December 2017. The output of the visit was the "Capacity Building and Skills Development Report" dated February 2018. The key findings and recommendations of this report were:

- The priority for Mozambique in building laboratory capacity is to agree on the adoption of an internationally recognised test method series.
- The laboratories need to be properly equipped to carry out the standard test methods and routine calibration of equipment should be carried out. In all laboratories visited the existing equipment was inadequate.
- The staff in the facilities were at an average competency level. Training is required for laboratory technicians on how to carry out the test methods. This training could be carried out by the Southern African Bitumen Association (SABITA), which has experience in laboratory training in the SADC region.
- Following orientation and training courses for all technicians and laboratory managers, the participants would undergo "witnessing for competency" at their worksite conducted by an experienced auditor. Each participant would be rated competent either as a laboratory manager or tester, or they may be required to repeat the initial training. As the competent staff gain experience and benefit from further routine audits, they can attain accreditation by SANAS or a Mozambican authority under ISO 17024 and become capable of conducting their own audit services.
- The goal of each laboratory facility should be the attainment of accreditation under ISO 17025 – "General Requirements for the Competence of Testing and Calibration Laboratories". The main aspects required for this accreditation process are participation in a PTS, proven staff competency, and properly calibrated equipment.

The second project workshop was held in Maputo on 27th and 28th March 2018 to discuss the PTS protocols and process. The intention was to reinforce the information provided by the Materials Expert on his visits to the participating laboratories and at the first project workshop and to ensure that the system was well understood by the participants. This would ensure that they were better prepared for the third round of the pilot project. All the government laboratories in the PTS scheme participated in the workshop, as well as the local private laboratories, apart from SoilCo.

The PTS Report for the second round of testing was prepared by the RRC staff with support from the CDS Materials Expert. A summary of the results of the second round were included in the "Proficiency Report" (September 2018)[8], which included the Second Round PTS Report as an annex. The Proficiency Report found that whilst there had been a general improvement in the consistency of results from most of the methods, there was still much that could be done to improve the overall performance of laboratory testing in Mozambique. The range of results submitted for most of the tests was still unacceptable. However, improvement could be achieved with more time, training, and continued PTS activities being undertaken with as large a group of participants as possible. As had been noted in previous reports, it was of critical importance that the government should agree on the standard test methods for Mozambique, disseminate this information to all laboratories, ensure that the laboratories are properly equipped, and provide training for laboratory staff.

2.7 Third Round of the PTS

The testing for the third round of the PTS was carried out between June and October 2018. The crushed granular, aggregate and sand material samples were obtained from the same sources as the first and second rounds. This was done to evaluate the consistency of the sample splitting, which is critical to obtaining acceptable comparable results. By obtaining most of the material from the same source for all three rounds of the pilot project, the results of the three rounds could be compared with one another to monitor the changes in the results while keeping the material the same. The plastic material for the third round was from the same source as Round 1, so the Round 3 results can be compared with the first round, notwithstanding that the results of the Atterberg tests in all three rounds showed a high degree of variability.

The materials sampling, splitting and distribution for the third round were carried out independently by the RRC without direct support from CDS. The LEM staff who are tasked with the splitting and distribution of the samples now have a very good understanding of this process. There may, however, be constraints in the process of splitting down the samples received from LEM into the various test sub-samples by the individual facilities. Care is required in this process to ensure that each sub-sample is as representative as possible. This is particularly important for the MDD and CBR samples that are split into eight sub-samples after the grading samples has been extracted. Incorrect splitting can result in coarser or finer samples in the sub-samples being compared with one another which can make comparisons very difficult, as well as provide misleading information.

The third project workshop was held in Maputo on 28th and 29th November 2018. All of the participating laboratories participated. Feedback was provided on the Third Round results and the trends emerging from all the three rounds. The workshop was beneficial in helping the participants to better understand the process of the PTS initiative and the benefits it holds for them. This includes improving their overall ability to test accurately in comparison to government facilities and privately-owned commercial laboratories.

The PTS Report for the third round of testing was prepared by the RRC staff with support from the CDS Materials Expert. It is included in Annex E of this report. The results from the three rounds are summarised in Chapter 4.

[8] Pearce, B. and Geddes, R., CDS (2018). Protocols for Improving the Proficiency of Material Testing Laboratories in Mozambique, Proficiency Report. MOZ2094A. London: ReCAP for DFID.

2.8 Using the PTS Results

The Standard Deviation of the test results has been used to provide an initial set of precision limits for the various tests for use in Mozambique (see Section 3.6 and Section 4.6). The 95% Confidence Index (CI) has been calculated for each test method to indicate the range within which the "true value" of the material probably lies in relation to the "average value". In the road sector there are no "reference materials" and one must rely on the consensus mean of test results when undertaking inter-laboratory comparisons. Having tested the same materials three times under the project, the "average" value is regarded to be a fair reflection of the "true" value of the parameter being measured. With further PTS testing in Mozambique and the adoption of standard test methods, the average values will over time be refined to a more accurate reflection of the "true" value.

The position of each laboratory on the ranked results for each round assists the laboratories to gauge their ability to produce results within the national norms. The ranking provides a means of evaluating the ability of the various facilities to produce acceptable results and highlights any need for corrective action when this is not the case. This allows continual improvement in the quality of the results produced within each facility as well as the results provided throughout the country.

The trends in the results across the three rounds provide each facility with an ability to monitor how consistently they are providing results. Since laboratory competency implies all aspects of the testing including the individual's competency, the PTS system can also be used by a laboratory to check the performance of staff members against their peers to ensure that similar results are being obtained from all technicians in the laboratory. If differences are encountered, the laboratory manager can more easily identify where the potential problems lie and take corrective action quickly and effectively. Improvements in the results can be monitored during the following round to determine how effective the interventions were or, if critical, a smaller in-house ILC can be conducted to check the effectiveness of the corrective action. Laboratory competency implies all aspects of the testing, including the suitability of the equipment, equipment calibration, and the training and competency of the individual testers.

3 Method of Analysis

3.1 PTS Reports

The method of analysis of the test results are detailed in PTS Reports which were circulated to all of the participating laboratories. The first of these is incorporated in the Baseline Report (October 2017) and the second in the Proficiency Report (September 2018). The PTS report for Round 3 is included in Chapter 4.

A coding system is used in the PTS Report for the participating facilities. Each facility has been informed of their code, but they were not informed of the codes used for the other laboratories. The PTS Report is in the same format as used by the South Africa National Laboratories Association (NLA-SA) for their ISO 17043 accredited schemes run in South Africa and internationally. The system relies on the integrity of the participating laboratories not to collude, and this would not be to their benefit.

3.2 Round 3 Tests

The following tests were included for Round 3 which replicate the methods used in the previous 2 rounds for comparison purposes:

FORM A[9] – Crushed granular material

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

FORM B – Plastic fines material

- Atterberg Limits

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

3.3 Terms and Abbreviations

The following terms and abbreviations are used in the PTS Report.

a) CV - Coefficient of variance

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

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[9] Form A, B, C and D are based on the testing protocols. See Annex A, B, C and D.

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

d) 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).

e) MC - Moisture content

f) LL - Liquid limit

g) PL - Plastic limit

h) LS - Linear shrinkage limit

i) PI - Plasticity index

j) GM - Grading modulus

k) FM - Fineness modulus

l) MDD - Maximum dry density

m) OMC - Optimum moisture content

n) CBR - California bearing ratio

o) ACV - Aggregate crushing value

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

q) FI - Flakiness index

r) ALD - Average least dimension

3.4 Mean, Standard Deviation, Z-Score Analysis and 95% Confidence Index

Standard deviation is the measure of the spread of results or a set of data from the calculated mean value. It measures the absolute variability of a distribution. The higher the dispersion, variability or range of the results, the greater the standard deviation. The higher the standard deviation relative to the numeric number of the mean, the more variability exists in the data set under analysis.

The standard deviation results reflect reproducibility values analysed from a number of facilities. Should a single facility wish to utilise the standard deviation values for their own quality analysis, they should halve the standard deviation value to obtain a value that is applicable to repeatability values. The repeatability result for a single laboratory is smaller than the reproducibility value for a large number of laboratories due to less variability in the determination of the results. The halved value for the standard deviation is relevant to testing within a single facility using the same operator and sample.

In order to use as many results as possible and not have to make decisions regarding outliers, Robust Indicators were used. 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 wide of the H15 mean to have less 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 of the data set.

A convenient and internationally accepted statistical method for analysing 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); and

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 means that the result agrees well with those from the other laboratories.

The Confidence Index (CI) refers to the percentage confidence one has that the true mean value will lie between the upper and lower limits as determined from the standard deviation and the number of participants. The industry norm for Civil Engineering is that a 95 % confidence level is adequate for the intended applications. The 95 % CI must not be misunderstood as 95 % of the values being found between these calculated upper and lower limits. The 95 % CI values derived from the three rounds of the pilot PTS, and the resulting acceptable upper and lower limits for the test result, are given in Table 4.82, Table 4.83, Table 4.84 and

Table 4.85.

The 95 % CI results reflect reproducibility values analysed from a number of facilities. The calculation of the 95 % CI considers the number of participants. With very low numbers of participants the range could end up being greater than the standard deviation. As the number of participants increases the confidence in the results increases, and the 95 % CI will drop below that of the standard deviation.

Although the analysis is based on the standard deviation, one can also tie the results back to the range specified in local project specifications to evaluate how well the results compare with what is required in the specification. This allows the use of engineering judgement to determine whether the specification range is achievable, based on the range obtained from the analysis of the PTS data.

3.5 Coefficient of Variance

The PTS assessment reports the Coefficient of Variance (CV), which is a measure of the relative variability of the test results. The CV is calculated as the ratio of the standard deviation to the mean and is expressed as a percentage. Accurate and consistent results from the laboratories would give CV values of less than 20 %.

3.6 Acceptable ranges of results

Table 3.1 and

Table 3.2 provide acceptable ranges of results for the various Granular and Aggregate test methods respectively based on inter-laboratory control testing carried out in South Africa. The values provide a broad guideline that may be adapted for use in Mozambique based on results obtained through the PTS. The standard deviation and CI values are expected to lie within the ranges provided under Column A. If the standard deviation and CI values lie in the ranges given in Column B and C, attention must be given to the testing procedures in the form of a detailed root cause analysis, including training of operators, calibration of equipment, etc.

Table 3.1: Acceptable Ranges for Granular Test Results

Test			Range of Results		
			Acceptable	Warning	Unacceptable
Sieve Analysis					
Sieve	**Units**		***A***	***B***	***C***
28 mm	**% passing**		0 - 4	5 - 8	> 8
20 mm			0 - 4	5 - 8	> 8
14 mm			0 - 3	4 - 6	> 6
10 mm			0 - 3	4 - 6	> 6
7 mm			0 - 3	4 - 6	> 6
5 mm			0 - 3	4 - 6	> 6
2 mm			0 - 3	4 - 6	> 6
1 mm			0 - 2	3 - 4	> 4
0.600mm			0 - 2	3 - 4	> 4
0.300mm			0 - 2	3 - 4	> 4
0.150mm			0 - 2	3 - 4	> 4
0.075mm			0 - 1	1 - 2	>2
Atterberg Limits, MDD, OMC, CBR, Swell, Moisture Content					
Test	**Units**	**H15 Mean**	***A***	***B***	***C***
LL	**%**	0 - 20	0 - 2	3 - 4	> 4
		21 - 30	0 - 3	4 - 5	> 5
		> 30	0 - 3	4 - 5	> 5
PI	**%**	0 - 6	0 - 1	2 - 3	> 3
		7 - 13	0 - 2	3 - 4	> 4
		14 - 20	0 - 3	4 - 5	> 5
		> 20	0 - 4	5 - 6	> 6
LS	**%**	0 - 5.0	0 - 1.0	2.0 - 3.0	> 3.0
		5.1 - 10	0 - 1.5	1.6 - 2.0	> 2.1
		10.1 - 16.0	0 - 2.0	2.1 - 2.5	> 2.5
		> 16.0	0 - 3.0	3.1 - 3.5	> 3.5
MDD	**kg/m^3**	All	0 - 30	31 - 50	> 50
OMC	**%**	All	0 - 0.5	0.6 - 1.0	> 1.0
CBR (95 & 90 %)	**%**	0 - 30	0 - 5	6 - 10	> 10
		31 - 50	0 - 8	9 - 15	> 15
		51 - 80	0 - 10	11 - 20	> 20
		81 - 120	0 - 15	16 - 30	> 30
		> 120	0 - 20	21 - 40	> 40
Swell	**%**	0 - 0.2	0 - 0.1	0.11 - 0.25	> 0.25
		0.21 - 1.5	0 - 0.2	0.21 - 0.40	> 0.40
		> 1.5	0 - 0.5	0.50 - 1.00	> 1.00
Moisture content	**%**	0 - 10.0	0 - 1.0	1.1 - 2.0	> 2.0

		10.1 - 20.0	0 - 1.5	1.6 - 2.5	> 2.5
		20.1 - 35.0	0 - 2.5	2.6 - 4.0	> 4.0
		> 35.0	0 - 4.0	4.1 - 6.0	> 6.0

Table 3.2: Acceptable Ranges for Aggregate Test Results

Test			Range of Results		
			Acceptable	Warning	Unacceptable
Sieve Analysis					
Sieve	**Units**		***A***	***B***	***C***
28 mm			0 - 4	5 - 8	> 8
20 mm			0 - 4	5 - 8	> 8
14 mm			0 - 3	4 - 6	> 6
10 mm			0 - 3	4 - 6	> 6
7 mm			0 - 3	4 - 6	> 6
5 mm			0 - 3	4 - 6	> 6
2 mm			0 - 3	4 - 6	> 6
1 mm			0 - 2	3 - 4	> 4
0.600mm			0 - 2	3 - 4	> 4
0.300mm			0 - 2	3 - 4	> 4
0.150mm			0 - 1	2 – 3	> 3
0.075mm	**% passing**		0 - 1	2 - 3	> 3
FI and ALD					
Test	**Units**	**H15 Mean**	***A***	***B***	***C***
FI	**%**		0 - 2	2.1 – 4.0	> 4
ALD	**mm**		0 – 0.04	0.05 – 0.8	> 0.8
ACV and 10% FACT					
ACV	**%**	**0 - 10**	< 1	1.1 - 2	> 2
		11 - 20	< 1.5	1.6 – 2.6	> 2.6
		21 - 30	< 2.0	2.1 – 3.0	> 3
		> 30	0 – 3.0	3.1 – 5.0	> 5
10% FACT	**kN**	**0 – 100**	< 5	6 - 10	> 10
		101 – 250	< 10	11 – 20	> 20
		251 - 400	< 20	21 – 40	> 40
		> 400	< 35	36 - 50	> 50

4 Summary of PTS Results

4.1 Crushed Granular Material – Form A

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

Table 4.1: Atterberg Limits for crushed granular material for the three rounds

	LL (%)			PL (%)			PI (%)			LS (%)		
	Round			Round			Round			Round		
	1	2	3	1	2	3	1	2	3	1	2	3
H15 mean	22.4	15.9	24.9	16.6	6.95	15.7	5.3	6.0	11.5	1.3	0.8	1.4
H15 Std Dev	3.14	15.80	3.6	8.02	11.1	0.32	5.80	9.54	3.13	1.29	1.35	2.06
Range	29.3	3.8	7.3	22	0.0	0.4	9.2	0.0	3.90	4.0	2.8	7.3
CV (%)	14.0%	99.1%	14.6%	48%	160%	2%	110%	160%	27.3%	100%	180%	151%

Table 4.2: Average results for three rounds for Atterberg for crushed granular material

Test Method	H15 mean	H15 Std Dev	Range	CV (%)
LL (%)	21.1	7.52	13.5	42.6%
PL (%)	13.1	6.48	7.5	70.1%
PI (%)	7.6	6.16	4.4	98.9%
LS (%)	1.1	1.57	4.7	143.7%

General comments

There remains a concern regarding the identification of plastic versus non-plastic materials. As only the numerical values were statistically analysed, those reporting the material as NP, SP or CBD were excluded from the analysis. As a result, the statistical analysis does not include all 10 participants as only some provided numerical values while others reported the material to be NP. The LS is the one value that contains the most numerical values in all the rounds and would be considered the most valid result of all the Atterberg results.

This method will require further training and support to enable all the facilities to be able to identify the material as the same type i.e. either plastic or non-plastic.

Trend of Standard Deviation over 3 rounds

Test method	Average trend
LL	Varies
PL	Varies
LS	Varies
PI	Varies

Round 3 has produced lower Std Dev results for LL, PL and PI than Round 2. The standard deviation for all four Atterberg values is considered to be unacceptably high.

Both LL & PL have high 95 % CI due to the low number of facilities providing numerical value for analysis (Table 4.3). The mean value of the LS of 1.1 % points towards a SP type material which confirms that some of the facilities are incorrectly reporting results in a numerical form whereas they should be providing abbreviations in the form of CBD[10] or NP/SP.

Table 4.3: Average 95% Confidence Index for Atterberg Limits for crushed granular material for the 3 rounds[11]

Test Method	95 % CI	Range	
		Upper limit	Lower limit
LL (%)	4.8	25.9	16.2
PL (%)	6.5	19.6	6.6
PI (%)	7.1	14.6	0.5
LS (%)	0.7	1.9	0.4

4.1.2 Optimum Moisture Content test

Table 4.4: OMC results for the three rounds

	OMC Round 1	OMC Round 2	OMC Round 3	Average for three rounds
	%			
H15 mean	8.4	9.2	9.1	8.9
H15 Std Dev	1.8	2.0	3.0	2.3
Range	4.6	6.8	9.0	6.8
CV	21.9%	21.2%	33.3%	25.5%

General comments

These results for the mean, although showing an increase from Round 1 (with Rounds 2 and 3 being similar), are all in an acceptably narrow range. The general increase in both mean and standard deviation might be attributed to changes in the test methods due to the project training interventions.

Trend of Std Dev over 3 rounds

Test method	Average trend
OMC	Increases

The 95 % CI of 0.9 % is considered to have slightly too high a range (Table 4.5) and the standard deviation of 2.3 % (Table 4.5) is considered unacceptably high.

Table 4.5: 95% Confidence Index for OMC

Test Method	95% CI	Range	
		Upper limit	Lower limit
OMC	0.9	9.8	8.0

[10] Could not be determined.

[11] The upper limit value is obtained by adding the 95% CI value to the mean. The lower limit value is obtained by subtracting the 95% CI value from the mean.

4.1.3 Maximum Dry Density test

Table 4.6: MDD results for the three rounds

	MDD Round 1	MDD Round 2	MDD Round 3	Average for three rounds
	kg/m^3			
H15 mean	1917	1919	1956	1930
H15 Std Dev	35	33	37	35
Range	170.	68	116	118
CV	1.8%	1.7%	1.9%	1.8%

General comments

The increase in the mean from Round 1 to 3 could be attributed to improved compaction due to the training interventions provided although it has resulted in an increase in the standard deviation.

Trend of Std Dev over 3 rounds

Test method	**Average trend**
MDD	Varies

The 95 % CI of 13 kg/m^3 is within an acceptable range (Table 4.7) although the standard deviation of 35 kg/m^3 (Table 4.6) is considered to have slightly too high a range.

Table 4.7: 95% Confidence Index for MDD

Test Method	95% CI	Range	
		Upper limit	Lower limit
MDD	13	1944	1917

4.1.4 CBR Hygroscopic Moisture Content test

Table 4.8: Hygroscopic Moisture Content results for the three rounds

	Hygroscopic Round 1	Hygroscopic Round 2	Hygroscopic Round 3	Average for three rounds
	%			
H15 mean	1.6	0.6	0.8	1.0
H15 Std Dev	1.4	0.3	0.3	0.7
Range	53.0	0.6	0.7	18.1
CV	93.5%	47.7%	46.3%	62.5%

General comments

The determination of the hygroscopic moisture content has improved from Round 1 with Rounds 2 and 3 being similar in magnitude.

Trend of Std Dev over 3 rounds

Test method	**Average trend**
Hygroscopic MC	Varies

The 95 % CI of 0.3 % is considered within the borderline of acceptability (Table 4.9),but the standard deviation of 0.7 % (Table 4.8) is considered to be slightly too high…

Table 4.9: 95% Confidence Index for Hygroscopic Moisture Content

Test Method	95% CI	Range	
		Upper limit	Lower limit
Hygro MC	0.3	1.3	0.6

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

Table 4.10: CBR Swell results for the three rounds

	Swell A Round 1	Swell A Round 2	Swell A Round 3	Swell B Round 1	Swell B Round 2	Swell B Round 3	Swell C Round 1	Swell C Round 2	Swell C Round 3
	%								
H15 mean	0.011	0.000	0.106	0.023	0.000	0.152	0.034	0.067	0.413
H15 Std Dev	0.019	0.000	0.159	0.037	0.000	0.211	0.056	0.131	0.188
Range	2.90	0.00	0.30	3.00	0.00	0.40	3.00	0.20	0.50
CV	165.8%	-	149.6%	165.8%	-	138.5%	165.7%	196.0%	131.0%

Table 4.11: Average results for three rounds for CBR % Swell

	CBR mould % Swell			
	H15 mean	H15 Std Dev	Range	CV (%)
A mould	0.04	0.06	1.1	158.7%
B mould	0.06	0.08	1.1	152.2%
C mould	0.17	0.13	1.2	164.2%

General comments

The three moulds used i.e. A, B and C, each receive a different compactive effort through a combination of the number of blows per layer, the number of layer in each mould and/or the mass of the hammer used. This will depend on the method used (TMH1, ASTM, AASHTO or SANS 3001) by the various laboratories. The details of what is to be achieved in each mould is as follows:

- A mould: 100 % of MDD using the same compaction effort and procedure to produce the MDD.
- B mould: Aiming to produce a compaction of approx. 95 % of the A mould (MDD) with a reduced compactive effort.
- C mould: Aiming to produce a further reduction in compaction to between 93 % and 90 % of the A mould (MDD) with a further reduction in the compactive effort.

The determination of the swell is notoriously difficult to replicate especially between facilities. Continued care and attention to detail in this activity by the testers in the repositioning of the swell gauge for the 2nd reading will assist in reducing the variance between facilities over time. The swell is also linked to the compaction effort so as the compaction results decrease, so should the swell's variability.

Trend of Std Dev over 3 rounds

Test method	Average trend
Swell Mould A	Varies
Swell Mould B	Varies
Swell Mould C	Increases

The 95 % CI of 0.02 %, 0.03 % and 0.05 % is within an acceptable range and provides the expected trend of increasing swell as the compaction effort decreases (Table 4.12). The standard deviation of 0.06 % and 0.08 % for the A and B moulds is acceptable although the C mould standard deviation of 0.13 % (Table 4.11) is slightly too high.

Table 4.12: 95% Confidence Index for CBR Swell

Mould	95% CI	Range	
		Upper limit	Lower limit
A mould	0.04	0.07	0.00
B mould	0.05	0.11	0.01
C mould	0.08	0.25	0.09

4.1.6 CBR - Dry Density % (A, B & C moulds)

Table 4.13: Dry Density (%) results for the three rounds

	Mould A Round 1	Mould A Round 2	Mould A Round 3	Mould B Round 1	Mould B Round 2	Mould B Round 3	Mould C Round 1	Mould C Round 2	Mould C Round 3
H15 mean	100.4	100.1	100.2	94.9	94.5	95.0	91.0	90.0	91.1
H15 Std Dev	1.4	2.4	1.0	1.1	1.8	0.8	1.0	1.4	1.3
Range	12.0	7.6	2.3	4.3	6.0	2.3	4.2	7.2	2.9
CV	1.4%	2.4%	1.02%	1.2%	1.9%	0.82%	1.1%	1.6%	1.44%

Table 4.14: Average results for three rounds for CBR mould Dry Density %

CBR mould Dry Density %				
Test Method	H15 mean	H15 Std Dev	Range	CV (%)
A mould	100.3	1.6	7.3	1.60
B mould	94.8	1.3	4.2	1.30
C mould	90.6	1.2	4.8	1.40

General comments:

The determination of the percentage compaction is normally a good indicator of the facilities ability to replicate the compaction effort required in the 3 moulds. The mean results for all 3 moulds are acceptable.

Trend of Std Dev over 3 rounds

Test method	Average trend
%DD Mould A	Consistent
%DD Mould B	Consistent
%DD Mould C	Consistent

The 95 % CI of 0.6 %, 0.5 % and 0.5 % are within an acceptable range and provide the expected results of 100 %, 95 %, and between 93 % and 90 % compaction as stipulated in the methods used (Table 4.15). The standard deviations of 1.6 %, 1.3 % and 1.2 % (Table 4.15) for the A, B and C moulds are acceptable results.

Table 4.15: 95% Confidence Index for Dry Density (%)

CBR mould Dry Density %			
Test Method	95% CI	Range	
		Upper limit	Lower limit
A mould	0.7	100.9	99.6
B mould	0.5	95.3	94.3
C mould	0.5	91.1	90.1

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

Table 4.16: Dry Density (kg/m^3) results for the three rounds

	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
	kg/m^3								
H15 mean	1934	1929	1986	1842	1833	1886	1751	1752	1785
H15 Std Dev	32	30	67	40	52	70	47	67	46
Range	412	101	246	195	168	291	239	257	347
CV	1.7%	1.6%	3.38%	2.2%	2.9%	3.69%	2.7%	3.8%	2.59%

Table 4.17: Average results for three rounds for CBR mould Dry Density kg/m^3

CBR mould Dry Density kg/m^3				
	H15 mean	H15 Std Dev	Range	CV (%)
A mould	1949	43	253	2.20%
B mould	1854	54	218	2.90%
C mould	1763	53	281	3.00%

General comments

The A and B mould density has increased in Round 3 which could be attributed to better compaction processes used by the facilities based on the interventions provided and a better understanding of the method in general.

Trend of Std Dev over 3 rounds

Test method	Average trend
DD Mould A	Varies
DD Mould B	Increases
DD Mould C	Varies

For A and B moulds, the 3rd round has produced higher results than in the 2nd round although the C moulds results have decreased quite considerably.

The 95 % CI of 17 kg/m^3, 22 kg/m^3 and 21 kg/m^3 for the A, B and C moulds respectively are within an acceptable range of approx. 1 % of the MDD (Table 4.18). The A mould should closely replicate the MDD value. This can be seem in the average MDD of 1930 kg/m^3 (Table 4.6) **Error! Reference source not found.**versus 1950 kg/m^3 (Table 4.18) for the CBR A mould due to the same compactive effort used in both cases. One would also expect the B and C moulds 95 % CI values to be higher than the A mould due to the lower compactive effort, which is the case.

The standard deviation for the A mould is slightly too high at 43 kg/m^3 although the B and C moulds are considered unacceptable high at 54 kg/m^3 and 53 kg/m^3 respectively. These values are approximately 3 % of the density of the material tested.

Table 4.18: 95% Confidence Index for Dry Density (kg/m^3)

CBR mould Dry Density kg/m^3			
Test Method	95 % CI	Range	
		Upper limit	Lower limit
A mould	17	1967	1932
B mould	22	1875	1832
C mould	21	1784	1741

4.1.8 CBR (%)

Table 4.19: CBR results for crushed granular material for the three rounds

	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
	%								
H15 mean	110	98	111	61	70	69	32	38	33
H15 Std Dev	43	30	26	26	27	24	18	9	21
Range	109	73	142	97	77	99	46	53	88
CV	39.4%	30.4%	23.3%	42.2%	38.9%	34.4%	56.2%	23.3%	63.4%

Table 4.20: Average results for three rounds for CBR %

CBR %				
	H15 mean	H15 Std Dev	Range	CV (%)
A mould	106	33	108	31.0%
B mould	67	26	91	38.5%
C mould	34	16	62	47.6%

General comments

The CBR results are notoriously difficult to correlate between facilities. The general trend is correct with the A, B and C mould results decreasing in value.

Trend of Std Dev over 3 rounds

Test method	Average trend
CBR% Mould A	Decreases
CBR5 Mould B	Varies
CBR% Mould C	Varies

For A and B moulds, the 3rd round has produced lower results than in the 2nd round with the C mould result having increased quite considerably.

The 95 % CI of 13 % and 10 % for the A and B respectively are considered slightly high although the C mould at 6 % is within an acceptable range (Table 4.21). The standard deviation of 33 %, 26 % and 16 % is considered too high on all three moulds.

Table 4.21: 95% Confidence Index for CBR for crushed granular material

CBR %			
Test Method	95% CI	Range	
		Upper limit	Lower limit
A mould	13	120	93
B mould	10	77	56
C mould	6	41	28

4.1.9 Washed Grading – Sample Mass

Table 4.22: Sample Mass results for the three rounds

	Sample mass Round 1	Sample mass Round 2	Sample mass Round 3	Average for three rounds
	G			
H15 mean	2894	3848	3902	3548
H15 Std Dev	767	557	2291	1205
Range	1263	695	19293	7084
CV	26.5%	14.5%	58.7%	33.2%

General comments

Although the sample mass is not normally statistically analysed, the objective is to determine whether the sample mass used by the facilities is sufficiently representative to obtain an acceptable result. The increase in the mass used from Round 1 to 3 shows an improvement as the larger the sample size used, the more representative the sample becomes. One laboratory reported a sample mass of over 19 kg.

Trend of Std Dev over 3 rounds

Test method	Average trend
Sample mass	Varies

A sample size of between 3 to 4 kg should provide an acceptable result, although the coarser fraction may be less representative depending on the percentage in the sample.

Table 4.23: 95% Confidence Index for Sample Mass

Test Method	95% CI	Range	
		Upper limit	Lower limit
Sample Mass (g)	711	4260	2836

4.1.10 Washed Grading

Table 4.24: Washed Grading results for the three rounds (Coarse Sieves)

% passing	37.5 mm Round 1	37.5 mm Round 2	37.5 mm Round 3	28/25 mm Round 1	28/25 mm Round 2	28/25 mm Round 3	20/19 mm Round 1	20/19 mm Round 2	20/19 mm Round 3
H15 mean	100.0	100.0	99.6	84.4	88.2	84.8	66.8	77.4	75.6
H15 Std Dev	8.0E-14	0.0	0.8	8.2	12.5	13.3	7.7	20.1	18.4
Range	13.8	0.8	11.8	30.9	44.7	32.4	31.2	86.9	48.0
CV	0.0%	0.0%	0.8%	9.8%	14.2%	15.7%	11.5%	25.9	24.3%

% passing	14/13.2 mm Round 1	14/13.2 mm Round 2	14/13.2 mm Round 3	10/9.5 mm Round 1	10/9.5 mm Round 2	10/9.5 mm Round 3	7.1/6.7 mm Round 1	7.1/6.7 mm Round 2	7.1/6.7 mm Round 3
H15 mean	48.0	72.6	66.2	36.8	61.7	58.7	28.2	55.6	52.2
H15 Std Dev	14.1	15.3	18.7	12.1	15.0	15.9	11.6	14.7	14.2
Range	41.1	44.9	47.2	32.5	37.5	44.3	27.3	36.7	40.5
CV	29.4%	21.0%	28.3%	33.0%	24.4%	27.2%	41.1%	26.4%	27.3%

General comments

With the sample size increasing, there has been a corresponding increase in the percentage passing most of the coarser fractions ≥ 5/4.75 mm. In some instances, the 3rd round has a slightly lower value than the 2nd round but considerably higher than the 1st round.

Table 4.25: Washed Grading results for the three rounds (Fine Sieves)

% passing	5/4.75 mm Round 1	5/4.75 mm Round 2	5/4.75 mm Round 3	2/2.36 mm Round 1	2/2.36 mm Round 2	2/2.36 mm Round 3	1/1.18 mm Round 1	1/1.18 mm Round 2	1/1.18 mm Round 3
H15 mean	26.9	48.7	46.6	18.1	32.8	33.0	18.1	20.5	24.6
H15 Std Dev	8.3	11.5	12.6	7.3	11.0	9.8	7.3	3.0	9.0
Range	35.5	30.6	38.4	24.3	28.0	26.8	12.4	28.0	27.5
CV	30.9%	23.5%	27.0%	40.1%	33.5%	29.6%	44.4%	14.5%	36.9%

% passing	0.600 mm Round 1	0.600 mm Round 2	0.600 mm Round 3	0.425 mm Round 1	0.425 mm Round 2	0.425 mm Round 3	0.300 mm Round 1	0.300 mm Round 2	0.300 mm Round 3
H15 mean	8.9	13.5	16.8	7.4	9.9	13.1	6.1	8.5	10.9
H15 Std Dev	4.2	3.7	5.1	4.0	2.7	3.1	2.8	3.2	2.4
Range	9.0	8.4	29.5	11.0	10.5	3.2	5.9	11.5	33.3
CV	46.8%	27.6%	30.2%	53.6%	26.9%	23.4	46.3%	37.2%	22.4%

% passing	0.150 mm Round 1	0.150 mm Round 2	0.150 mm Round 3	0.0750 mm Round 1	0.075 mm Round 2	0.075 mm Round 3
H15 mean	4.6	6.5	7.1	3.3	5.7	4.8
H15 Std Dev	2.4	2.8	2.9	2.3	1.9	1.2
Range	5.3	12.6	38.0	6.0	17.4	39.9
CV	51.7%	43.2%	40.9%	68.5%	34.3%	25.5%

Table 4.26: Average results for three rounds for Washed Grading (all sieves)

Grading % passing				
Sieve	**H15 mean**	**H15 Std Dev**	**Range**	**CV (%)**
37.5 mm	99.9	0.3	8.8	0.3%
28 / 26.5 mm	85.8	11.4	36.0	13.2%
20 / 19 mm	73.3	15.4	55.4	20.6%
14 /13.2 mm	62.3	16	44.4	26.2%
10 / 9.5 mm	52.4	14.4	38.1	28.2%
7.1 / 6.7 mm	45.3	13.5	34.8	31.6%
5 / 4.75 mm	40.7	10.8	34.8	27.1%
2 / 2.36 mm	28	9.4	26.4	34.9%
1 / 1.18 mm	21.1	6.4	22.6	31.9%
0.600 mm	13.1	4.3	15.6	34.9%
0.425 mm	10.1	3.2	8.2	34.6%
0.300 mm	8.5	2.8	16.9	35.3%
0.150 mm	6.1	2.7	18.6	45.3%
0.075 mm	4.6	1.8	21.1	42.8%

General comments

The results on the finer fraction ≤ 2/2.36 mm are more varied than the coarser fraction. For the coarser fractions it is easier to determine when sieving is completed whereas the finer sieves are more difficult to assess due to the fineness of the particles. This could be influenced by the way that the fines are sieved through, both before and after washing and by rubbing the fines on the wire mesh, versus allowing the particles to pass through the sieve only with force of the wash water.

The comment on the coarse sieves regarding the verification of the sieves is also applicable on the finer sieves, although the method of verification differs for the wire mesh sieves.

Trend of Std Dev over 3 rounds (all sieves)

Test method	**Average trend**
Sieving 37.5 mm	Varies
Sieving 28.26.5 mm	Increases
Sieving 20/19 mm	Varies
Sieving 14/13.2 mm	Increases
Sieving 10/9.5 mm	Increases
Sieving 7.1/6.7 mm	Varies
Sieving 5/4.75 mm	Increases

Test method	Average trend
Sieving 2/2.36 mm	Varies
Sieving 1/1.18 mm	Varies
Sieving 0.600 mm	Varies
Sieving 0.425 mm	Varies
Sieving 0.300 mm	Varies
Sieving 0.150 mm	Increases
Sieving 0.075 mm	Decreases

The 95 % CI for the fractions ≥ 5/4.75 mm is, on average, 5.6 % which gives a result higher than would be considered acceptable (Table 4.27). This could be due to, among other possibilities, the variation in the sieve sizes used by the participating facilities and the lack of verification of the opening sizes. The standard deviation results with an average of 11.5 % are also above acceptable values.

The 95 % CI for the fractions ≤ 2/2.36 is 1.9 % on average, which is far lower than the 95 % Cl for the coarser fractions of 5.6 % (Table 4.27**Error! Reference source not found.**). Although the 95 % CI values for the fine sieves are more acceptable then the coarse sieves, testers need to take care in using the correct sieving operation to obtain comparable results between facilities. The more variation in the techniques used, the more variable the results will be. The standard deviation results, with an average of 4.4 %, are all too high.

Table 4.27: 95% Confidence Index for Grading % passing (all sieves)

Grading % passing				
Sieve size	95% CI		Range	
	Value	Average	Upper limit	Lower limit
37.5 mm	0.1	5.6%	100.0	99.7
28 / 26.5 mm	4.5		90.3	81.3
20 / 19 mm	6.0		79.2	67.3
14 /13.2 mm	6.3		68.5	56.0
10 / 9.5 mm	6.4		58.8	46.0
7.1 / 6.7 mm	6.2		51.5	39.1
5 / 4.75 mm	4.2		44.9	36.6
2 / 2.36 mm	3.7	1.9%	31.6	24.3
1 / 1.18 mm	2.8		23.9	18.2
0.600 mm	1.9		15.0	11.1
0.425 mm	1.4		11.5	8.8
0.300 mm	1.3		9.8	7.2
0.150 mm	1.2		7.3	4.8
0.075 mm	0.7		5.3	3.9

4.1.11 Soil Mortar based on grading analysis

Table 4.28: Soil Mortar results for the three rounds

% passing	GM Round 1	GM Round 2	GM Round 3	Coarse Sand Round 1	Coarse Sand Round 2	Coarse Sand Round 3	Coarse Sand Ratio Round 1	Coarse Sand Ratio Round 2	Coarse Sand Ratio Round 3
H15 mean	2.8	2.3	2.4	55.3	39.8	38.1	2.9	16.2	8.4
H15 Std Dev	0.2	0.2	0.3	45.2	31.8	27.8	2.9	25.1	15.2
Range	0.5	2.4	2.5	86.0	68.7	60.0	8.9	31.4	27.0
CV	6.5%	7.1%	11.8%	81.7%	80.2%	72.9%	99.8%	154.9%	180.1%

% passing	Coarse Fine Round 1	Coarse Fine Round 2	Coarse Fine Round 3	Fine Fine Round 1	Fine Fine Round 2	Fine Fine Round 3	Fine Round 1	Fine Round 2	Fine Round 3
H15 mean	4.2	7.7	8.2	3.6	4.6	6.0	2.7	48	14.0
H15 Std Dev	3.7	4.8	5.2	2.5	3.5	1.6	1.4	3.5	13.0
Range	11.4	9.4	12.9	4.4	18.5	27.0	3.5	7.6	31.3
CV	88.7%	62.7%	62.2%	70.1%	73.2%	27.1%	53.3%	74.3%	92.7%

% passing	Medium Fine Round 1	Medium Fine Round 2	Medium Fine Round 3	Soil mortar Round 1	Soil mortar Round 2	Soil mortar Round 3
H15 mean	3.7	4.3	7.2	16.7	9.9	19.2
H15 Std Dev	36	2.9	3.0	19.9	11.9	18.4
Range	7.2	5.7	6.2	29.2	31.2	39.9
CV	95.5%	66.6	41.4%	119.4%	120.3	96.2%

Table 4.29: Average results for three rounds for Soil Mortar calculations

Soil Mortar calculations				
Parameter	H15 mean	H15 Std Dev	Range	CV (%)
GM	2.5	0.2	1.8	8.5%
Coarse Sand	44.4	34.9	71.6	78.3%
Coarse Sand ratio	9.2	14.4	22.4	144.9%
Coarse Fine	6.7	4.6	11.2	71.2%
Fine Fine	4.7	2.5	16.6	56.8%
Fine	7.1	56.0	14.1	73.4%
Medium Fine	5.1	3.1	6.4	67.8%
Soil Mortar	15.2	16.7	33.4	112.0%

General comments

Although the Soil Mortar calculations are a very simple determination once the grading has been completed, it remains unclear how regularly these determinations are undertaken in the facilities. Therefore, the results are highly variable, and no clear patterns or deductions can be made on the validity of the results.

Trend of Std Dev over 3 rounds

Test method	Average trend
GM	Increases
Coarse sand	Decreases
Coarse sand ratio	Increases
Coarse fine	Varies
Fine fine	Varies
Fine	Increases
Medium fine	Varies
Soil Mortar	Varies

The 95 % CI for the soil mortar calculations varies from 13.7 % down to 0.1 % with an average value of 4.6 % (Table 4.30). As noted above, these values vary too much to make any meaningful determinations. A decision is required by ANE/LEM as to which of these calculations are required in the Mozambique scenario and then to ensure that the formulae for the determinations are correctly implemented. The Soil Mortar calculations are based on the grading results so if there are any errors in the grading, the Soil Mortar results will automatically also be affected.

Table 4.30: 95% Confidence Index for Soil Mortar results

Soil Mortar calculations			
Parameter	95% CI	Range	
		Upper limit	Lower limit
GM	0.1	2.6	2.4
Coarse Sand	15.2	59.6	29.2
Coarse Sand ratio	8.0	17.2	1.2
Coarse Fine	2.5	9.2	4.3
Fine Fine	1.4	6.1	3.4
Fine	2.9	10.0	4.2
Medium Fine	1.8	6.9	3.3
Soil Mortar	8.6	23.9	6.6

4.2 Plastic Material – Form B

4.2.1 Atterberg Limits (Plastic Material)

Table 4.31: Atterberg Limits for plastic material for the three rounds

	LL % Round1	LL % Round 2	LL % Round 3	Average for three rounds	PL % Round 1	PL % Round 2	PL % Round 3	Average for three rounds
H15 mean	33.6	60.1	56.9	50.2	24.8	38.7	37.4	33.6
H15 Std Dev	3.3	24.4	13.4	13.7	6.7	8.0	10.0	8.3
Range	21.9	69.8	36.8	42.8	23.2	49.4	21.0	31.2
CV	9.8%	40.6%	23.5%	24.6	27.2%	20.7%	26.8%	24.9

	LS % Round 1	LS % Round 2	LS % Round 3	Average for three rounds	PI % Round 1	PI % Round 2	PI % Round 3	Average for three rounds
H15 mean	3.0	11.3	8.7	7.7	9.7	27.8	20.5	19.3
H15 Std Dev	1.9	1.5	2.3	1.9	4.9	16.0	9.6	10.2
Range	9.1	12.9	12.7	11.6	20.3	48.0	19.9	29.4
CV	63.1%	13.6%	26.9%	34.5	50.3%	57.6%	47.0%	51.6

General comments

The inclusion of this material was to ascertain the ability of the facilities to determine a PI on plastic material. Unfortunately, the same material was not used in all 3 rounds so the analysis is less consistent than planned. The ANE laboratory in Inhambane that provided the plastic material sample misunderstood the instruction on the sample requirements.

As noted in the Form A comment for the crushed granular material, there remains a concern regarding the identification of plastic versus non-plastic materials. As only the numerical values were statistically analysed, those facilities reporting the material as NP, SP or CBD were excluded from the analysis.

Trend of Std Dev over 3 rounds

Test method	Average trend
LL	Varies
PL	Increases
LS	Varies
PI	Varies

For LL, PL and PI, the 3rd round has produced lower results than round 2.

The LL, PL and PI have a 95 % CI that is on average 1.7 times that of the crushed granular material. The average for the crushed material is 7.6 % (Table 4.3**Error! Reference source not found.**) as against the plastic material which is 12.1 % (Table 4.32**Error! Reference source not found.**). The standard deviations for all four Atterberg results are unacceptably high.

As with the crushed granular material, the mean value of the LS has the lowest 95 % CI which is to be expected, since the LS test is the least affected by operator error. The remaining three values for the LL, PL and PI are all considerably higher than the crushed granular material confirming the concern about the ability of the laboratories to accurately test for plasticity in the material.

Table 4.32: 95% Confidence Index for Atterberg Limits for plastic material

Test Method	95% CI	Range	
		Upper limit	Lower limit
LL %	6.0	56.2	44.2
PL %	3.7	37.3	29.9
PI %	4.6	23.9	14.8
LS %	0.9	8.6	6.8

4.3 Sand Material – Form C

4.3.1 Atterberg Limits (Sand)

Table 4.33: Atterberg Limits for sand material for the three rounds

	LL % Round 1	LL % Round 2	LL % Round 3	Average for three rounds	PL % Round 1	PL % Round 2	PL % Round 3	Average for three rounds
H15 mean	15.9	19.3	15.7	17.0	11.5	-	12.7	12.1
H15 Std Dev	5.4	6.3	12.9	8.2	11.3	-	2.7	7.0
Range	24.9	25.6	10.9	20.5	17.4	-	3.4	10.4
CV	34.3%	32.4%	82.2%	49.6%	98.2%	-	21.2%	59.7%

	LS % Round 1	LS % Round 2	LS % Round 3	Average for three rounds	PI % Round 1	PI % Round 2	PI % Round 3	Average for three rounds
H15 mean	0.5	0.0	3.3	1.3	2.8	-	9.1	6.0
H15 Std Dev	0.7	0.0	4.7	1.8	4.6	-	5.5	5.0
Range	4.0	6.7	8.6	6.4	7.5	-	6.8	7.2
CV	140.1%	298.7%	141.7%	193.5%	162.9%	-	59.9%	111.4%

General comments

The sand is from a borrow pit and assumed to be NP. The concern is again confirmed regarding the ability of some facilities to identify plastic versus non-plastic materials. Some facilities were able to obtain a PI for this material whereas others weren't. Only one value was submitted for the PL and PI in Round 2 and as a result, no analysis was possible.

As stated for the Form A and B material, this method will require ongoing attention to ensure that all the facilities are able to identify the material as the same type i.e. either plastic or non-plastic.

Trend of Std Dev over 3 rounds

Test method	Average trend
LL	Increases
PL	Decreases
LS	Varies
PI	Increases

The mean value of the 95 % CI of 0.9 % for LS is the only value that can be considered acceptable for the Atterberg results. All the other values including the remaining 95 % CI and all standard deviations are considered unacceptably high. The mean LS value of 1.3 % for a sandy type material points towards a material with a very low PI value or a slightly- or non-plastic type material which is what it is assumed to have been.

Table 4.34: 95% Confidence Index for Atterberg Limits for sand material

Test Method	95% CI	Range	
		Upper limit	Lower limit
LL	4.9	21.8	12.1
PL	5.7	17.8	6.4
LS	0.9	2.2	0.4
PI	5.0	11.0	0.9

4.3.2 Optimum Moisture Content test (Sand)

Table 4.35: OMC for sand material for the three rounds

	OMC Round 1	OMC Round 2	OMC Round 3	Average for three rounds
H15 mean	7.8	8.1	8.1	8.0
H15 Std Dev	0.8	0.9	0.7	0.8
Range	2.2	3.8	4.2	3.4
CV	10.5%	11.2%	8.3%	10.0%

General comments

These results, although showing an increase from Round 1 to Round 3, are all within a very narrow and acceptable range.

Trend of Std Dev over 3 rounds

Test method	Average trend
OMC	Consistent

The 95 % CI of 0.3 % (Table 4.36) is well within an acceptable range although the standard deviation of 0.8 % (Table 4.35) would be considered slightly high.

Table 4.36: 95% Confidence Index for OMC for sand material

Test Method	95% CI	Range	
		Upper limit	Lower limit
OMC	0.3	8.3	7.7

4.3.3 Maximum Dry Density test

Table 4.37: MDD for sand material for the three rounds

	MDD Round 1	MDD Round 2	MDD Round 3	Average for three rounds
H15 mean	1983	1975	1960	1973
H15 Std Dev	35	25	48	36
Range	98	61	223	127
CV	1.8%	1.3%	2.5%	1.9%

General comments

The increase in the mean from Round 1 to 3 could be attributed to improved compaction due to the interventions provided, although it has resulted in an increase in the standard deviation.

Trend of Std Dev over 3 rounds

Test method	Average trend
MDD	Varies

The 95 % CI of 14 kg/m^3 (Table 4.38) is within an acceptable range and is also very close to the crushed granular result of 13.7 kg/m^3. The standard deviation at 36 kg/m^3 (Table 4.37) is considered slightly to high.

Table 4.38: 95% Confidence Index for MDD for sand material

Test Method	95% CI	Range	
		Upper limit	Lower limit
MDD	14	1987	1959

4.3.4 CBR Hygroscopic Moisture Content test

Table 4.39: Hygroscopic Moisture Content for sand material for the three rounds

	Hygroscopic MC Round 1	Hygroscopic MC Round 2	Hygroscopic MC Round 3	Average for three rounds
	%			
H15 mean	1.3	0.5	0.8	0.9
H15 Std Dev	1.1	0.1	0.6	0.6
Range	28.4	0.3	1.3	10.0
CV	79.8%	25.8%	77.2%	60.9%

General comments

Although the mean determination of the hygroscopic moisture content has decreased from Round 1, with Rounds 2 and 3 being similar in magnitude, the standard deviation is quite variable.

Trend of Std Dev over 3 rounds

Test method	Average trend
Hygroscopic mc	Varies

The 95 % CI of 0.3 % (Table 4.40) is within the borderline acceptable range and is the same as the 95 % CI for the crushed granular material of 0.3 % (Table 4.9**Error! Reference source not found.**). The standard deviation of 0.6 % (Table 4.39) is considered to have slightly too high a range for the three rounds, but is similar to the standard deviation of 0.7 % for the crushed granular material.

Table 4.40: 95% Confidence Index for Hygroscopic Moisture Content for sand material

Test Method	95% CI	Range	
		Upper limit	Lower limit
Hygroscopic MC	0.3	1.2	0.6

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

Table 4.41: CBR Swell for sand material for the three rounds

	Swell A Round 1	Swell A Round 2	Swell A Round 3	Swell B Round 1	Swell B Round 2	Swell B Round 3	Swell C Round 1	Swell C Round 2	Swell C Round 3
	%								
H15 mean	0.880	0.030	0.014	0.910	0.030	0.049	0.940	0.1481	0.083
H15 Std Dev	1.702	0.054	0.020	1.759	0.054	0.070	1.817	0.235	0.114
Range	10.20	0.50	0.32	11.60	0.70	0.35	11.30	0.90	0.39
CV	193.5%	179.8	149.9%	193.1%	179.8	144.8%	192.8%	158.7%	137.1%

Table 4.42: Average results for three rounds for CBR mould % Swell

CBR mould % Swell				
	H15 mean	H15 Std Dev	Range	CV (%)
A mould	0.3	0.59	3.7	174.4%
B mould	0.3	0.63	4.2	172.6%
C mould	0.4	0.72	4.2	162.9%

General comments

Although the determination of the swell is notoriously difficult to replicate especially between facilities, sand should give a result with minimal swell given the low plasticity found in the material. Continued care and attention to detail is needed in this activity by the testers in the repositioning of the swell gauge for the 2nd reading. This will assist in reducing the variance between facilities over time. The swell is also linked to the compaction effort so as the compaction results decrease, so should the variability of the Swell.

Trend of Std Dev over 3 rounds

Test method	Average trend
Swell Mould A	Decreases
Swell Mould B	Varies
Swell Mould C	Decreases

The 95 % CI of 0.2 %, 0.3 % and 0.3 % (Table 4.43) is within an acceptable range and provides the expected trend of increasing swell as the compaction effort decreases. Although the standard deviation results reflect the same expected trend, the values of 0.6 %, 0.6 % and 0.7 % (Table 4.42) for the A, B and C moulds respectively, are all unacceptably high.

What is surprising is the fact that the sand material has a larger swell result than the crushed granular material by a considerable amount.

Table 4.43: 95% Confidence Index for CBR Swell for sand material

CBR mould % Swell			
Test Method	95% CI	Range	
		Upper limit	Lower limit
A mould	0.3	0.6	0.0
B mould	0.3	0.7	0.0
C mould	0.4	0.8	0.0

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

Table 4.44: Dry Density % (A, B & C moulds) for sand material for the three rounds

	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
	%								
H15 mean	99.0	99.3	99.7	94.9	95.1	95.3	90.9	90.6	91.4
H15 Std Dev	1.5	0.6	0.8	1.2	0.8	1.0	1.1	1.2	1.3
Range	91.0	1.4	2.4	87.4	2.2	2.3	84.5	3.6	3.1
CV	1.5%	0.6%	0.8%	1.2%	0.9%	1.0%	1.2%	1.4%	1.4%

Table 4.45: Average results for three rounds for CBR mould Dry Density %

CBR mould Dry Density %				
Mould	H15 mean	H15 Std Dev	Range	CV (%)
A mould	99.3	1.0	31.6	1.0%
B mould	95.1	1.0	30.6	1.0%
C mould	91.0	1.2	30.4	1.3%

General comments

The determination of the percentage compaction is normally a good indicator of the ability of a facility to replicate the compaction effort required in the 3 moulds. The mean results for all 3 moulds are acceptable.

Trend of Std Dev over 3 rounds

Test method	Average trend
%DD Mould A	Varies
%DD Mould B	Varies
%DD Mould C	Increases

The 95 % CI of 0.4 %, 0.4 % and 0.5 % (Table 4.46) are within an acceptable range and provides the expected results of 100 %, 95 %, and between 93 % and 90 % compaction as stipulated in the test methods used. These values are all lower than obtained for the crushed granular material, which is expected given that the material has a finer grain size. The standard deviation of 1.0 %, 1.0 % and 1.2 % (Table 4.45) for the A, B and C moulds also provide acceptable results.

Table 4.46: 95% Confidence Index for Dry Density % (A, B & C moulds) for Sand

CBR mould Dry Density %			
Mould	95% CI	Range	
		Upper limit	Lower limit
A mould	0.4	99.7	99.0
B mould	0.4	95.5	94.7
C mould	0.5	91.5	90.5

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

Table 4.47: Dry Density kg/m^3 (A, B & C moulds) for sand material for the three rounds

	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
	kg/m^3								
H15 mean	1972	1968	1945	1893	1882	1869	1818	1791	1794
H15 Std Dev	32	26	49	35	31	52	4	37	5
Range	87	62	138	107	75	138	144	81	170
CV	1.6%	1.3%	2.5%	1.8%	1.6%	2.8%	2.2%	2.1%	3.2%

Table 4.48: Average results for three rounds for CBR mould Dry Density kg/m^3

CBR mould Dry Density kg/m^3				
	H15 mean	H15 Std Dev	Range	CV (%)
A mould	1962	36	96	1.80%
B mould	1881	39	107	2.10%
C mould	1801	45	132	2.50%

General comments

The A and B mould density has increased in Round 3 which could be attributed to better compaction processes used by the facilities based on the interventions provided and a better understanding of the method in general.

Trend of Std Dev over 3 rounds

Test method	Average trend
DD Mould A	varies
DD Mould B	varies
DD Mould C	varies

All 3 moulds have produced higher results than in the 2nd round.

The 95 % CI of 14 kg/m³, 15 kg/m³ and 18 kg/m³ for the A, B and C moulds (Table 4.49) are within an acceptable range of approx. 1 % of MDD and follow a similar trend to the crushed granular material results as detailed in Section 4.1.7 of this report. The 95 % CI for the MDD was 14 kg/m³ (Table 4.38) versus 14 kg/m³ for the A mould (Table 4.49), which is expected as the compactive effort is the same. One would also expect the B and C mould values to be higher than the A mould due to the lower compactive effort, which is the case.

The standard deviation for the A, B and C moulds are all slightly too high at 36 kg/m³, 39 kg/m³ and 45 kg/m³ respectively. These values are approximately 2 % of the density of the material tested.

Table 4.49: 95% Confidence Index for Dry Density kg/m³ (A, B & C moulds) for Sand

CBR mould Dry Density kg/m³			
Test Method	95% CI	Range	
		Upper limit	Lower limit
A mould	14	1976	1948
B mould	15	1897	1866
C mould	18	1819	1783

4.3.8 CBR %

Table 4.50: CBR results for sand material for the three rounds

CBR %	Mould 100% Round 1	Mould 100% Round 2	Mould 100% Round 3	Mould 95% Round 1	Mould 95% Round 2	Mould 95% Round 3	Mould 90% Round 1	Mould 90% Round 2	Mould 90% Round 3
H15 mean	40	48	48	26	25	29	16	12	17
H15 Std Dev	32	29	27	21	15	13	14	7	14
Range	68	77	79	50	38	46	47	30	31
CV	78.7%	59.1%	56.5%	81.3%	59.0%	46.7%	90.7%	59.6%	82.8%

Table 4.51: Average results for three rounds for CBR %

CBR %				
	H15 mean	H15 Std Dev	Range	CV (%)
A mould	46	29	75	64.8%
B mould	26	16	45	62.3%
C mould	15	12	36	77.7%

General comments

CBR results are notoriously difficult to correlate between facilities. The general trend is correct, with the A, B and C mould results decreasing in value.

Trend of Std Dev over 3 rounds

Test method	Average trend
CBR% Mould A	Decreases
CBR5 Mould B	Decreases
CBR% Mould C	Varies

For the A and B moulds, the 3rd round has produced lower results than in the 2nd round with the C mould result having increased quite considerably.

The 95 % CI of 11 % and 6 % for the A and B moulds(Table 4.52) are considered slightly high, but the C mould at 5 % considered acceptable. The results for the sand mirror similar trends to the results for the crushed granular material (Table 4.21). The standard deviation of 29 %, 16 % and 12 % is considered too high on all three moulds and follows a similar pattern to the granular material of decreasing variability from the A to the C mould.

Table 4.52: 95% Confidence Index for CBR for sand

CBR %			
Test Method	95% CI	Range	
		Upper limit	Lower limit
A mould	11	57	34
B mould	6	33	20
C mould	5	20	10

4.3.9 Washed Grading Sample Mass

Table 4.53: Washed Grading Sample Mass results for sand material for the three rounds

	Sample mass Round 1	Sample mass Round 2	Sample mass Round 3	Average for three rounds
H15 mean	1030	1393	1206	1210
H15 Std Dev	564	1135	824	841
Range	1300	2617	1960	1959
CV	54.8%	81.5%	68.4%	68.2%

General comments

Although, as noted for the crushed granular material, the sample mass is not normally statistically analysed, but the objective is to determine whether the sample mass used by the facilities is representative. The average mass used is possibly too high and therefore the testing procedure unproductive due to the additional time needed to process the larger quantity of material. The laboratories can obtain an acceptable result with a smaller sample in less time thus being more productive.

Trend of Std Dev over 3 rounds

Test method	Average trend
Sample mass	Varies

A sample size of between 0.9 to 1.5 kg will provide an acceptable result but a smaller sample should be able to provide as good a result in a shorter period. A representative sample of approx. 500+ g would suffice.

Table 4.54: 95% Confidence Index for Sample Mass for Sand

Test Method	95% CI	Range	
		Upper limit	Lower limit
Sample mass (g)	367	1,577	842

4.3.10 Washed Grading

Table 4.55: Washed Grading results for sand material for the three rounds

% passing	2/2.36 mm Round 1	2/2.36 mm Round 2	2/2.36 mm Round 3	1/1.18 mm Round 1	1/1.18 mm Round 2	1/1.18 mm Round 3	0.600 mm Round 1	0.600 mm Round 2	0.600 mm Round 3
H15 mean	100.0	100.0	100.0	99.7	99.8	99.9	96.4	96.6	97.3
H15 Std Dev	0.0	0.1	0.0	0.1	0.2	0.2	1.2	1.0	2.5
Range	0.1	0.1	0.0	0.5	99.3	0.5	4.1	58.7	36.7
CV	0.0%	0.1%	0.0%	0.1%	0.2%	0.2%	1.3%	1.1%	2.6%

% passing	0.425 mm Round 1	0.425 mm Round 2	0.425 mm Round 3	0.300 mm Round 1	0.300 mm Round 2	0.300 mm Round 3	0.250 mm Round 1	0.250 mm Round 2	0.250 mm Round 3
H15 mean	86.6	80.9	86.2	52.7	56.7	52.9	-	-	-
H15 Std Dev	5.2	12.1	3.1	17.5	24.2	27.2	-	-	-
Range	40.4	62.3	59.0	31.4	73.3	81.2	-	-	-
CV	6.1%	15.0%	3.6%	33.1%	42.6%	51.9%	-	-	-

% passing	0.150 mm Round 1	0.150 mm Round 2	0.150 mm Round 3	0.075 mm Round 1	0.075 mm Round 2	0.075 mm Round 3
H15 mean	18.6	23.7	19.0	13.6	15.2	14.4
H15 Std Dev	2.9	13.1	3.0	1.2	3.6	1.9
Range	8.5	78.6	8.3	115.8	26.6	4.4
CV	15.4%	55.3%	15.9%	8.9%	24.0%	13.4%

Table 4.56: Average results for three rounds for Grading % passing (sand)

	Grading % passing			
Sieve size	H15 mean	H15 Std Dev	Range	CV (%)
2 / 2.36 mm	100	0	0.1	0.00%
1 / 1.18 mm	99.8	0.2	33.4	0.20%
0.600 mm	96.8	1.6	33.2	1.70%
0.425 mm	84.5	6.8	53.9	8.20%
0.300 mm	54.1	23	62	42.50%
0.150 mm	20.5	6.3	31.8	28.90%
0.075 mm	14.4	2.3	48.9	15.40%

General comments

The results on the sand fraction ≤ 2/2.36 mm are varied in a similar manner to what was observed in the crushed granular material. This could be influenced by the way the fines are sieved through, both before and after washing and by rubbing the fines on the wire mesh, versus getting the particles to pass through only with the force of the wash water.

Verification of the sieve openings is important on the finer sieves in obtaining acceptable results.

Trend of Std Dev over 3 rounds

Test method	Average trend
Sieving 2/2.36 mm	varies
Sieving 1/1.18 mm	varies
Sieving 0.600 mm	varies
Sieving 0.425 mm	varies
Sieving 0.300 mm	increases
Sieving 0.150 mm	varies
Sieving 0.075 mm	varies

The 95 % CI for the fractions ≤ 2/2.36 is 3.6 % on average (Table 4.57**Error! Reference source not found.**), which is more than half the value for the crushed granular material on the same sieves (Table 4.27**Error! Reference source not found.**). The 95 % CI values are variable, ranging from 0.1 % to 10.5 %. On average the 95 % CI sand grading results are considered slightly high. The testers need to take care in using the correct sieving technique to obtain comparable results between the facilities. The more variation in the techniques used, the more variable the results will be.

The standard deviation results on average of 5.7 % range from 2.3 % to 23 % are also above acceptable values as is the case for the granular materials.

It is expected that the sand should provide a more constant result than the crushed granular material given the reduced number of sieves required for sand sieve analysis as well as the resultant smaller particle size distribution.

Table 4.57: 95% Confidence Index for Washed Grading results for sand material

Grading % passing				
Sieve size	95% CI		Range	
	Value	Average	Upper limit	Lower limit
2 / 2.36 mm	0.0	3.6 %	100.0	100.0
1 / 1.18 mm	0.1		99.9	99.7
0.600 mm	0.7		97.5	96.0
0.425 mm	2.7		87.2	81.9
0.300 mm	10.5		64.6	43.6
0.150 mm	2.9		23.4	17.5
0.075 mm	0.9		15.3	13.5

4.3.11 Soil Mortar based on grading analysis

Table 4.58: Soil Mortar results for sand material for the three rounds

	GM Round 1	GM Round 2	GM Round 3	FM Round 1	FM Round 2	FM Round 3	Soil Mortar Round 1	Soil Mortar Round 2	Soil Mortar Round 3
H15 mean	1.0	1.1	0.9	1.0	-	1.7	71.7	42.3	50.0
H15 Std Dev	0.1	0.2	0.8	0.6	-	0.7	68.4	44.9	47.3
Range	0.5	0.8	1.4	1.2	-	1.6	985.9	86.3	87.3
CV	11.8%	15.6%	92.6%	61.7%	-	41.3%	95.3%	106.0%	94.6%

	Coarse Round 1	Coarse Round 2	Coarse Round 3	Coarse Sand Ratio Round 1	Coarse Sand Ratio Round 2	Coarse Sand Ratio Round 3	Coarse Fine Round 1	Coarse Fine Round 2	Coarse Fine Round 3
H15 mean	4.0	9.7	9.1	3.0	8.5	6.3	27.8	15.3	32.7
H15 Std Dev	5.4	7.1	6.4	2.9	15.67	11.1	26.1	15.3	8.9
Range	11.4	11.4	14.3	4.8	24.4	36.8	52.8	25.7	69.6
CV	136.2%	72.7%	70.5%	96.4%	183.5%	175.5%	93.8%	100.0%	27.3%

	Fine Fine Round 1	Fine Fine Round 2	Fine Fine Round 3	Fine Round 1	Fine Round 2	Fine Round 3	Medium Fine Round 1	Medium Fine Round 2	Medium Fine Round 3
H15 mean	18.2	7.2	12.0	41.5	34.8	43.3	42.5	37.6	36.4
H15 Std Dev	14.8	4.9	3.9	36.3	27.1	35.9	14.1	18.8	12.1
Range	18.4	11.6	54.4	72.3	63.2	86.0	27.4	46.5	50.5
CV	81.0%	67.2%	32.6%	87.5%	78.0%	83.0%	33.1%	50.1%	33.1%

Table 4.59: Average results for three rounds for Soil Mortar calculations

	Soil Mortar			
	H15 mean	H15 Std Dev	Range	CV (%)
GM	1	0.4	0.9	40.0%
FM	1.4	0.7	1.4	51.5%
Soil Mortar	54.7	53.5	386.5	98.6%
Coarse Sand	7.6	6.3	12.4	93.1%
Coarse Sand ratio	5.9	9.9	22.0	151.8%
Coarse Fine	25.3	16.8	49.4	73.7%
Fine Fine	12.5	7.8	28.1	60.3%
Fine	39.9	33.1	73.8	82.8%
Medium Fine	38.8	15.0	41.5	38.8%

General comments

As noted for the crushed granular material, although the Soil Mortar calculations are a very simple determination once the grading has been completed, it remains unclear how regularly these determinations are undertaken in the facilities. Therefore, these results are highly variable, and no clear patterns or deductions can be made on the validity of the results.

Trend of Std Dev over 3 rounds

Test method	Average trend
GM	Increases
FM	Increases
Soil Mortar	varies
Coarse sand	varies
Coarse sand ratio	varies
Coarse fine	decreases
Fine fine	decreases
Fine	varies
Medium fine	varies

The 95 % CI for the soil mortar calculations for the sand vary from 27.6 % down to 0.2 % with an average value of 8.0 % (Table 4.60). These values are considerably higher than observed for the granular material (Table 4.30). A decision is required by ANE/LEM as to which of these calculations are required in the Mozambique scenarios and then to ensure that the formulae for those determinations are correctly implemented by the laboratories. The calculations are all based on the grading results, so if there are any errors in the grading, the results will automatically also be affected.

Table 4.60: 95% Confidence Index for Soil Mortar results for sand material

Soil Mortar			
Test Method	95% CI	Range	
		Upper limit	Lower limit
GM	0.2	1.1	0.8
FM	0.5	1.8	0.9
Soil Mortar	27.6	82.3	27.0
Coarse Sand	2.8	10.4	4.8
Coarse Sand Ratio	6.4	12.3	-0.4
Coarse Fine	9.0	34.2	18.3
Fine Fine	4.8	17.3	7.6
Fine	14.8	54.7	25.0
Medium Fine	7.7	46.6	31.1

4.4 Aggregate Material – Form D

4.4.1 Average Least Dimension (ALD)

Table 4.61: ALD results for aggregate material for the three rounds

	ALD Round 1	ALD Round 2	ALD Round 3	Average for three rounds
H15 mean	9.3	10.5	11.9	10.6
H15 Std Dev	4.7	2.5	5.1	4.1
Range	11.6	9.2	18.7	13.1
CV	50.1%	24.1%	42.7%	39.0%

General comments

The ALD results have increased as expected as the sample size has increased. The increase in the standard deviation for the 3rd round is probably due to revisions undertaken in the test method as discussed in the training interventions. The results should stabilise with time as the facilities implement the methods in a more consistent manner. The standard deviation and range for the 3rd Round were affected by a result of 3.1 mm reported by one facility against the mean of 11.9 mm. Another facility reported a result of 21.8 mm.

Trend of Std Dev over 3 rounds

Test method	Average trend
ALD	Varies

The 95 % CI of 1.9 mm is too high (Table 4.62) but should reduce during the next few rounds with a better understanding of the method and the effects of a more representative sample regime. The standard deviation value of 4.1 mm (Table 4.61) is unacceptably high.

Table 4.62: 95% Confidence Index for ALD for aggregate material

Test Method	95% CI	Range	
		Upper limit	Lower limit
ALD	1.9	12.4	8.7

4.4.2 Sample Mass

Table 4.63: Sample Mass results for aggregate material for the three rounds

	# particle count Round 1	# particle count Round 2	# particle count Round 3	Average for three rounds	Specimen mass Round 1	Specimen mass Round 2	Specimen mass Round 3	Average for three rounds
	Nº				g			
H15 mean	224	318	322	288	832	1159	1183	1057
H15 Std Dev	100	17	121	131	732	566	574	624
Range	505	388	261	385	1831	1207	1508	1515
CV	44.5%	54.8%	37.5%	45.6%	88.0%	48.9%	48.5%	61.8%

General comments

The sample mass has increased with each round providing a more representative sample, resulting in a more acceptable ALD result. The particle count has decreased significantly for both standard deviation and range. The standard deviation for the sample mass has stabilised at around 570 g. The larger average sample size for Round 2 and Round 3 provides a more representative sample, though one laboratory is still using a very small sample size (hence the high range).

Trend of Std Dev over 3 rounds

Test method	Average trend
ALD # particles	Varies
ALD sample mass	Varies

The 95 % CI for both the particle count and sample mass are high (Table 4.64) should reduce over the next few rounds with the better understanding of the test method as discussed during the December 2018 workshop.

Table 4.64: 95% Confidence Index for Sample Mass for aggregate material

Item	95% CI	Range	
		Upper limit	Lower limit
# particle count	59	347	229
Specimen mass (g)	286	1344	771

4.4.3 Flakiness Index (FI)

Table 4.65: Flakiness Index results for aggregate material for the three rounds

	FI Round 1	FI Round 2	FI Round 3	Average for three rounds
	%			
H15 mean	19.1	21.3	21.8	20.7
H15 Std Dev	12.7	12.8	8.9	11.5
Range	32.4	39.6	66.8	46.3
CV	66.8%	60.3%	40.7%	55.9%

General comments

The FI results have remained fairly constant over the 3 rounds.

Trend of Std Dev over 3 rounds

Test method	Average trend
FI	Varies

The 95 % CI of 4.3 % is too high (Table 4.66) but should come down during the next few rounds with a better understanding of the test method. The standard deviation of 11.5 % is also unacceptably high.

Table 4.66: 95% Confidence Index for Flakiness Index for aggregate material

Test Method	95% CI	Range	
		Upper limit	Lower limit
FI	4.3	25.0	16.4

4.4.4 Sample Mass for Flakiness Index

Table 4.67: Results for Sample Mass for Flakiness Index for the three rounds

	FI sample mass Round 1	FI sample mass Round 2	FI sample mass Round 3	Average for three rounds
	g			
H15 mean	2190	1753	2242	2062
H15 Std Dev	1276	69	1091	1002
Range	5742	1721	30 344	3732
CV	58.3%	36.4%	48.7%	47.8%

General comments

Although the sample mass is not ideally something that would be statistically analysed, the objective is to determine whether the sample masses used by the facilities are representative. The increase in the mass used from round 2 to 3 is an improvement as the larger the sample size used the more representative the sample becomes.

Trend of Std Dev over 3 rounds

Test method	Average trend
FI Sample mass	Varies

A larger sample size tending towards the upper limit of the range in Table 4.68 would be preferable. The mass of the sample needs to be in line with the grading sample mass so that the sieving operation is done for the particle size distribution while at the same time preparing the particles into their various sizes for the FI gauging procedure.

Table 4.68: 95% Confidence Index for Sample Mass for the Flakiness Index determination

Item	95% CI	Range	
		Upper limit	Lower limit
FI Sample mass (g)	379	2441	1683

4.4.5 Aggregate Crushing Value (ACV)

Table 4.69: ACV results for aggregate material for the three rounds

	ACV Round 1	ACV Round 2	ACV Round 3	Average for three rounds	Sample mass Round 1	Sample mass Round 2	Sample mass Round 3	Average for three rounds
	%				g			
H15 mean	19	21	20	19.8	2642	2394	2539	2525
H15 Std Dev	4	6	5	4.7	459	210	448	372
Range	8	14	15	12.1	3238	895	3929	2687
CV	21.2%	26.4%	22.8%	23.5%	17.4%	8.8%	17.6%	14.6%

General comments

The 3 rounds provided fairly constant ACV results although there is a slight increase in the standard deviation towards Round 3. The wide range for the third round was due to three laboratories submitting values far from the mean. The sample mass is fairly constant although some facilities provided incorrect values for the sample mass, which has slightly skewed the results.

Trend of Std Dev over 3 rounds

Test method	Average trend
ACV	Varies
ACV Sample mass	Varies

The 95 % CI values for the ACV and the sample mass are considered slightly high (Table 4.70). The standard deviation for the ACV at 4.7 % (Table 4.69) is unacceptably high.

Table 4.70: 95% Confidence Index for Sample Mass for the Flakiness Index determination

Item	95% CI	Range	
		Upper limit	Lower limit
ACV	1.8	21.6	18.0
Sample mass (g)	141	2666	2366

4.4.6 10% Fines Aggregate Crushing Test (10% FACT)

Table 4.71: 10% FACT results for aggregate material for the three rounds

	10% FACT Round 1	10% FACT Round 2	10% FACT Round 3	Average for three rounds	Sample mass (g) Round 1	Sample mass (g) Round 2	Sample mass (g) Round 3	Average for three rounds
	kN				g			
H15 mean	233	183	208	208	2643	2391	2517	2517
H15 Std Dev	48	117	32	65	449	223	459	377
Range	266	147	140	184	3182	875	3948	2668
CV	20.5%	63.7%	15.2%	33.1%	17.0%	9.3%	18.2%	14.8%

General comments

The 10% FACT result is close to the expected 200 kN, which indicates that the facilities have a fairly good understanding of the method. However, the range remains wide, with some laboratories still reporting values far from the mean.

The sample mass is also fairly constant, although some facilities provided incorrect values for the sample mass which has slightly skewed the results. One facility reported a mass of 6 kg whereas all the others ranged from 2.1 to 3 kg.

Trend of Std Dev over 3 rounds

Test method	Average trend
10% FACT	varies
10% FACT Sample mass	varies

The 95 % CI for the 10% FACT determination is too high whereas the 95 % CI for the sample mass is slightly high (Table 4.72). the standard deviation is also considered too high at 65 kN.

Table 4.72: 95% Confidence Index for 10% FACT determination

Item	95% CI	Range	
		Upper limit	Lower limit
10% FACT	26	234	182
Sample mass (g)	151	2668	2366

4.4.7 Sample Mass for Aggregate Grading

Table 4.73: Sample Mass for aggregate grading for the three rounds

	Sample mass (g) Round 1	Sample mass (g) Round 2	Sample mass (g) Round 3	Average for three rounds
H15 mean	2320	2649	2992	2654
H15 Std Dev	719	639	955	771
Range	5549	1678	3567	3598
CV	31.0%	24.1%	31.9%	29.0%

General comments

Although the sample mass is not ideally something that would be statistically analysed, the objective is more to determine if the sample mass used by the facilities is representative. The increase in the mass used from Round 1 to 3 is an improvement as the larger the sample size used the more representative the sample becomes. However, if the sample is too large it takes longer than necessary to obtain an acceptable result.

Trend of Std Dev over 3 rounds

Test method	Average trend
Sample mass	Varies

A sample size of between 2.4 to 3.0 kg should provide a more than acceptable result for the 20/19 mm aggregate sample supplied. The mass should reflect a slightly lower mass than the grading due to the particle sizes discarded that are < 5/4.75 mm.

Table 4.74: 95% Confidence Index for Sample Mass for aggregate grading

Item	95% CI	Range	
		Upper limit	Lower limit
Sample mass (g)	321	2976	2333

4.4.8 Washed Grading

Table 4.75: Washed Grading for aggregate material for the three rounds (coarse sieves)

% passing	20/19 mm Round 1	20/19 mm Round 2	20/19 mm Round 3	14/13.2 mm Round 1	14/13.2 mm Round 2	14/13.2 mm Round 3	10/9.5 mm Round 1	10/9.5 mm Round 2	10/9.5 mm Round 3
H15 mean	99.7	99.6	99.9	37.3	33.5	12.4	7.1	4.6	3.9
H15 Std Dev	0.6	0.7	0.2	8.3	7.8	7.3	2.4	2.0	2.4
Range	29.7	1.5	89.7	28.3	21.0	30.7	6.8	5.1	9.2
CV	0.6%	0.7%	0.2%	22.3%	23.3%	58.6	33.3%	42.5%	62.1%

% passing	7.1/6.7 mm Round 1	7.1/6.7 mm Round 2	7.1/6.7 mm Round 3	5/4.75 mm Round 1	5/4.75 mm Round 2	5/4.75 mm Round 3	2/2.36 mm Round 1	2/2.36 mm Round 2	2/2.36 mm Round 3
H15 mean	2.5	2.1	2.8	2.2	1.5	2.3	1.5	1.3	1.9
H15 Std Dev	0.9	1.9	1.8	1.2	1.6	1.6	0.9	1.0	1.3
Range	6.7	3.9	5.7	8.0	3.1	5.8	8.3	1.7	5.8
CV	36.4%	93.2%	64.9%	52.6%	103.8%	68.9%	61.4%	79.1%	81.6%

Table 4.76: Average results for three rounds for Grading % passing (aggregate)

Grading % passing				
	H15 mean	H15 Std Dev	Range	CV (%)
20 / 19 mm	99.7	0.5	40.3	0.5%
14 /13.2 mm	27.7	7.8	26.7	34.7%
10 / 9.5 mm	5.2	2.3	7.0	46.0%
7.1 / 6.7 mm	2.5	1.5	5.4	64.8%
5 / 4.75 mm	2.0	1.4	5.6	75.1%
2 / 2.36 mm	1.6	1.1	5.3	74.0%
1 / 1.18 mm	1.4	0.9	5.3	63.7%
0.600 mm	1.2	0.8	5.4	68.5%
0.425 mm	1	0.7	2.8	68.2%
0.300 mm	1.1	0.8	5.5	75.1%
0.150 mm	0.9	0.7	5.6	74.4%
0.075 mm	0.7	0.6	5.6	84.8%

General comments

The coarse fractions provide a constant set of results for the mean besides the 14/13.2 mm fraction's 3rd round. The coarser fractions are easier to monitor as to when sieving is completed due to their visual size whereas the finer sieves are more difficult to assess. Variations in the results could be due to, among other possibilities, the variation in the sieve sizes used by the participating facilities and the lack of verification of the opening sizes.

The results on the finer fractions ≤ 2/2.36 mm are more consistent than the coarse fractions. The comment on the coarse sieves regarding the verification of the sieves is applicable on the finer sieves, although the method of verification differs for the smaller wire mesh sieves.

Trend of Std Dev over 3 rounds

Test method	Average trend
Sieving 20/19 mm	Varies
Sieving 14/13.2 mm	Decreases
Sieving 10/9.5 mm	Varies
Sieving 7.1/6.7 mm	Varies
Sieving 5/4.75 mm	Varies
Sieving 2/2.36 mm	Varies
Sieving 1/1.18 mm	Varies
Sieving 0.600 mm	Varies
Sieving 0.425 mm	Increases
Sieving 0.300 mm	Increases
Sieving 0.150 mm	Decreases
Sieving 0.075 mm	Decreases

The average of the 95 % CI for the fractions ≥ 5/4.75 mm is 1.3 % which is acceptable (Table 4.77). The 95% CI for the fractions ≤ 2/2.36 is 0.3 % on average (Table 4.77**Error! Reference source not found.**), far lower than the coarser fractions. Both values are considerably lower than for the crushed granular material (Table 4.27).

Although the 95 % CI values are acceptable, testers need to take care in using the correct sieving operation to obtain comparable results between the facilities. The more variation in the techniques used, the more variable the results will be. The standard deviation for the various grading sieves was also acceptable.

Table 4.77: 95% Confidence Index for Washed Grading for aggregate material (all sieves)

Grading % passing				
Test Method	95% CI		Range	
	Value	Average	Upper limit	Lower limit
20 / 19 mm	0.2	1.3	99.9	99.5
14 /13.2 mm	3.1		30.8	24.7
10 / 9.5 mm	0.9		6.1	4.3
7.1 / 6.7 mm	0.6		3.1	1.8
5 / 4.75 mm	0.6		2.6	1.4
2 / 2.36 mm	0.5	0.3	2.0	1.1
1 / 1.18 mm	0.4		1.8	1.0
0.600 mm	0.4		1.6	0.8
0.425 mm	0.3		1.3	0.6
0.300 mm	0.4		1.4	0.7
0.150 mm	0.3		1.2	0.6
0.075 mm	0.3		1.0	0.5

4.5 Comparison between Results received from Mozambique and South African Laboratories

The absolute average z-scores for the third-round results submitted by the South African laboratories were compared with the results from the Mozambican facilities. This provides an indication of performance of the facilities based on the magnitude of the average z-score. In the majority of cases, the Mozambican facilities have a much higher average z-score than the SA facilities, which indicates that the SA facilities are more accurate in their testing. The results are summarised in Table 4.78, Table 4.79, Table 4.80 and Table 4.81.

Table 4.78: Comparison of average z-scores for SA & Mozambican facilities - Form A Crushed Granular Material

Test method	Mean	Actual value		z-score	
		SA	Mozambique	SA	Mozambique
LL %	24.9	CBD	24.9	CBD	0.9
PL %	15.7	CBD	15.7	CBD	0.6
PI %	1.4	0.0	2.5	0.7	**1.1**
LS %	11.5	NP	11.5	NP	0.6
OMC %	9.1	5.6	9.6	**1.2**	0.6
MDD kg/m^3	1956	1948	1960	0.5	**0.8**
Hygroscopic MC %	0.7	1.1	0.6	**1.0**	0.5
CBR Swell % A mould	0.1	0.0	0.2	0.6	**0.8**
CBR Swell % B mould	0.2	0.0	0.2	0.6	**0.9**

Test method	Mean	Actual value		z-score	
		SA	Mozambique	SA	Mozambique
CBR Swell % C mould	0.1	0.1	0.2	0.5	**1.0**
CBR Dry Density % A mould	100.2	100.7	100.0	0.6	**0.8**
CBR Dry Density % B mould	95.0	95.1	95.0	0.3	**0.7**
CBR Dry Density % C mould	91.1	91.4	91.0	0.7	**0.8**
CBR Dry Density kg/m³ A mould	1986	1961	2004	0.5	**1.0**
CBR Dry Density kg/m³ B mould	1886	1860	1916	0.4	**1.1**
CBR Dry Density kg/m³ C mould	1785	1790	1809	0.2	**0.6**
CBR % A mould	118.5	143.5	112.2	**1.0**	0.7
CBR % B mould	71.5	68.0	70.9	0.4	**1.0**
CBR % C mould	36.0	35.0	39.8	0.2	**0.9**
Washed Grading % passing					
37.5 mm	99.6	100.0	97.9	0.5	**2.7**
28 / 26.5 mm	84.8	95.0	82.2	**0.8**	0.7
20 / 19 mm	75.6	88.0	72.5	0.7	**0.7**
14 /13.2 mm	66.2	80.0	62.7	0.7	0.7
10 / 9.5 mm	58.7	NULL	59.1	NULL	0.7
7.1 / 6.7 mm	52.2	NULL	52.7	NULL	0.7
5 / 4.75 mm	46.6	NULL	45.0	NULL	0.7
2 / 2.36 mm	33.0	35.5	32.6	0.3	**0.8**
1 / 1.18 mm	24.6	NULL	25.4	NULL	0.8
0.600 mm	16.8	NULL	19.3	NULL	1.2
0.425 mm	13.1	15.5	15.5	0.8	**1.7**
0.300 mm	10.9	NULL	14.8	NULL	2.3
0.150 mm	7.1	NULL	11.4	NULL	2.1
0.075 mm	4.8	4.5	9.3	0.4	**4.8**
Soil Mortar Calculations					
GM	2.4	2.4	2.1	0.1	**1.9**
Coarse Sand	38.1	54.1	32.8	0.6	**0.8**
Coarse Sand ratio	8.4	0.5	11.6	0.5	**0.8**
Coarse Fine	8.2	13.0	7.1	**0.9**	0.7
Fine Fine	6.0	19.1	5.2	**8.1**	0.5
Fine	14.0	NULL	14.0	NULL	0.7
Medium Fine	7.2	9.0	6.7	0.6	**0.7**
Soil Mortar	19.2	12.6	21.8	0.4	**0.9**

Table 4.79: Comparison of average z-scores for SA & Mozambican facilities - Form B Plastic Material

Test method	Mean	Actual value		z-score	
		SA	Mozambique	SA	Mozambique
LL %	56.9	60.0	54.6	0.23	**0.96**
PL %	37.4	43.5	35.0	0.61	**0.84**
LS %	8.7	8.4	7.9	0.40	**1.43**
PI %	20.5	16.5	19.5	0.42	**0.73**

Table 4.80: Comparison of average z-scores for SA & Mozambican facilities - Form C Sand Material

Test method	Mean	Actual value		z-score	
		SA	Mozambique	SA	Mozambique
LL %	15.7	CBD	21.0	CBD	**0.4**
PL %	12.7	CBD	12.7	CBD	**0.5**
LS %	3.3	0.0	6.7	0.7	0.7
PI %	9.1	NP	9.1	NP	0.6
OMC %	8.1	7.3	8.4	**1.5**	0.8
MDD kg/m^3	1960	1918.5	1964.6	0.6	**1.0**
Hygroscopic MC %	0.76	1.3	0.6	**0.9**	0.4
CBR Swell % A mould	0.0	0.0	0.1	0.7	**4.1**
CBR Swell % B mould	0.0	0.0	0.1	0.6	**1.8**
CBR Swell % C mould	0.1	0.1	0.1	0.6	**1.2**
CBR Dry Density % A mould	99.7	100.0	99.6	0.3	**1.0**
CBR Dry Density % B mould	95.3	95.6	95.2	0.6	**0.7**
CBR Dry Density % C mould	91.4	90.7	91.7	0.6	**0.6**
CBR Dry Density kg/m^3 A mould	1945	1948.5	1942.3	0.7	**0.7**
CBR Dry Density kg/m^3 B mould	1869	1864.5	1868.4	**0.9**	0.7
CBR Dry Density kg/m^3 C mould	1794	1769.5	1802.9	0.7	**0.8**
CBR % A mould	47.9	60.5	43.3	**0.8**	0.7
CBR % B mould	28.7	22.5	29.4	0.5	**0.9**
CBR % C mould	17.2	10.5	19.1	0.5	**0.9**
Washed Grading % passing					
2 / 2.36 mm					
1 / 1.18 mm	99.86	NULL	99.8	NULL	0.9
0.600 mm	97.32	NULL	93.5	NULL	2.23
0.425 mm	86.16	88.0	81.0	0.6	**2.7**
0.300 mm	52.92	NULL	44.4	NULL	0.7
0.150 mm	18.98	NULL	18.8	NULL	0.8
0.075 mm	14.40	16.5	13.8	**1.1**	0.5
Soil Mortar Calculations					
GM	0.9	NULL	0.9	NULL	0.6
FM	1.7	NULL	1.7	NULL	0.7
Soil Mortar	50.0	16.0	56.8	0.7	**0.7**
Coarse Sand	9.1	12.2	7.8	0.5	**0.8**
Coarse Sand Ratio	6.3	0.1	13.2	0.6	**1.2**
Coarse Fine	32.7	30.0	35.9	0.3	**1.8**
Fine Fine	12.0	9.0	0.2	21.6	**3.0**
Fine	43.3	68.6	39.7	0.7	**0.7**
Medium Fine	36.4	36.0	0.0	39.2	**1.0**

Table 4.81: Comparison of average z-scores for SA & Mozambican facilities - Form D Aggregate Material

Test method	Mean	Actual value		z-score	
		SA	Mozambique	SA	Mozambique
ALD	11.9	11.0	12.5	0.2	**1.0**
Sample mass # particle count	321.6	373	301	0.5	**0.8**
FI	21.8	21.3	26.2	0.1	**1.4**
ACV	20.3	24.2	19.4	**0.8**	0.6
10% FACT	207.8	185.0	220.0	0.7	**0.9**
Aggregate Grading % passing					
28 / 25 mm	100.0	100.0	93.6	0.5	**>100**
20 / 19 mm	99.9	100.0	88.6	0.5	**56.8**
14 /13.2 mm	12.4	19.0	12.3	0.9	**0.9**
10 / 9.5 mm	3.9	2.5	4.6	0.6	**0.8**
7.1 / 6.7 mm	2.8	2.0	3.0	0.4	**0.8**
5 / 4.75 mm	2.3	2.0	2.5	0.2	**0.9**
2 / 2.36 mm	1.9	1.0	2.4	0.7	**1.0**
1 / 1.18 mm	1.5	1.0	2.1	0.7	**1.5**
0.600 mm	1.3	0.7	2.0	0.6	**1.2**
0.425 mm	1.1	0.3	1.9	1.0	**1.3**
0.300 mm	1.2	0.6	1.9	0.7	**1.3**
0.150 mm	0.9	0.6	1.6	0.7	**1.9**
0.075 mm	0.8	0.4	1.8	1.1	**2.6**

4.6 Summary of 95% Confidence Limits and Standard Deviation for all Test Methods

The 95% Confidence Limits determined from the three rounds of the pilot PTS are summarised in Table 4.82, Table 4.83, Table 4.84 and

Table 4.85. These represent the rounds average "true value". The Standard Deviation can be use as initial precision limits for the various tests for use in design and for site quality control purposes in Mozambique. National specifications should give the range allowed[12], whereas the results from the PTS indicate what is achievable by the facilities. For individual facilities the standard deviation needs to be halved to be applicable to the repeatability scenario due to the reduced variability of one tester as against the reproducibility between facilities which was used to determine these values. The range of results produced by the laboratories is expected to narrow as they become more proficient and standard test methods are adopted throughout the country.

Table 4.82: Summary of 95% Confidence Index Results: Form A Crushed Granular Material

Test method	Mean	95% CI	StDev	Reliability of results
LL %	21.1	4.8	7.5	Poor
PL %	13.1	6.5	6.5	Poor
PI %	7.6	7.1	6.2	Poor
LS %	1.1	0.7	1.6	Warning
OMC %	8.9	0.9	2.3	Poor
MDD kg/m^3	1930	13	35	Warning
Hygroscopic MC %	1.0	0.3	0.7	Warning
CBR Swell % A mould	0.04	0.04	0.06	Acceptable
CBR Swell % B mould	0.06	0.05	0.08	Acceptable
CBR Swell % C mould	0.17	0.08	0.13	Warning
CBR Dry Density % A mould	100.3	0.7	1.6	Acceptable
CBR Dry Density % B mould	94.8	0.5	1.3	Acceptable
CBR Dry Density % C mould	90.6	0.5	1.2	Acceptable
CBR Dry Density kg/m^3 A mould	1949	17	43	Warning
CBR Dry Density kg/m^3 B mould	1854	22	54	Poor
CBR Dry Density kg/m^3 C mould	1763	21	53	Poor
CBR % A mould	106	13	33	Poor
CBR % B mould	67	10	26	Poor
CBR % C mould	34	6	16	Poor
Washed Grading % passing				
37.5 mm	99.9	0.1	0.3	Acceptable
28 / 26.5 mm	85.8	4.5	11.4	Poor
20 / 19 mm	73.3	6.0	15.4	Poor
14 /13.2 mm	62.3	6.3	16.0	Poor
10 / 9.5 mm	52.4	6.4	14.4	Poor
7.1 / 6.7 mm	45.3	6.2	13.5	Poor
5 / 4.75 mm	40.7	4.2	10.8	Poor
2 / 2.36 mm	28	3.7	9.4	Poor
1 / 1.18 mm	21.1	2.8	6.4	Poor
0.600 mm	13.1	1.9	4.3	Poor
0.425 mm	10.1	1.4	3.2	Warning
0.300 mm	8.5	1.3	2.8	Warning
0.150 mm	6.1	1.2	2.7	Warning
0.075 mm	4.6	0.7	1.8	Warning
Soil Mortar Calculations				
GM	2.5	0.1	0.2	Acceptable[13]

[12] National specifications for road building materials with precision limits for testing do not currently exist in Mozambique.
[13] Although the value is acceptable, the method used and formula to calculate GM needs to be confirmed in each facility.

Test method	Mean	95% CI	StDev	Reliability of results
Coarse Sand	44.4	15.2	34.9	Poor
Coarse Sand ratio	9.2	8	14.4	Poor
Coarse Fine	6.7	2.5	4.6	Poor
Fine Fine	4.7	1.4	2.5	Poor
Fine	7.1	2.9	56	Poor
Medium Fine	5.1	1.8	3.1	Poor
Soil Mortar	15.2	8.6	16.7	Poor

Table 4.83: Summary of 95% Confidence Index Results: Form B Plastic Material

Test method	Mean	95% CI	StDev	Reliability of results
LL %	50.2	6.0	13.7	Poor
PL %	33.6	3.7	8.3	Poor
PI %	19.3	4.6	10.2	Poor
LS %	7.7	0.9	1.9	Warning

Table 4.84: Summary of 95% Confidence Index Results: Form C Sand Material

Test method	Mean	95% CI	StDev	Reliability of results
LL %	17	4.9	8.2	Poor
PL %	12.1	5.7	7.0	Poor
PI %	6	5.0	5.0	Poor
LS %	1.3	0.9	1.8	Warning
OMC %	8.0	0.3	0.8	Warning
MDD kg/m^3	1973	14	36	Warning
Hygroscopic MC %	0.9	0.3	0.6	Warning
CBR Swell % A mould	0.3	0.3	0.6	Poor
CBR Swell % B mould	0.3	0.3	0.6	Poor
CBR Swell % C mould	0.4	0.4	0.7	Poor
CBR Dry Density % A mould	99.3	0.4	1.0	Acceptable
CBR Dry Density % B mould	95.1	0.4	1.0	Acceptable
CBR Dry Density % C mould	91.0	0.5	1.2	Acceptable
CBR Dry Density kg/m^3 A mould	1962	14	36	Warning
CBR Dry Density kg/m^3 B mould	1881	15	39	Warning
CBR Dry Density kg/m^3 C mould	1801	18	45	Warning
CBR % A mould	46	11	29	Poor
CBR % B mould	26	6	16	Poor
CBR % C mould	15	5	12	Poor
Washed Grading % passing				
2 / 2.36 mm	100	0	0	N/A
1 / 1.18 mm	99.8	0.1	0.2	Acceptable
0.600 mm	96.8	0.7	1.6	Acceptable
0.425 mm	84.5	2.7	6.8	Poor
0.300 mm	54.1	10.5	23	Poor
0.150 mm	20.5	2.9	6.3	Poor
0.075 mm	14.4	0.9	2.3	Warning
Soil Mortar Calculations				

Test method	Mean	95% CI	StDev	Reliability of results
GM	1.0	0.2	0.4	Acceptable
FM	1.4	0.5	0.7	Warning
Soil Mortar	54.7	27.6	53.5	Poor
Coarse Sand	7.6	2.8	6.3	Poor
Coarse Sand Ratio	5.9	6.4	9.9	Poor
Coarse Fine	25.3	9	16.8	Poor
Fine Fine	12.5	4.8	7.8	Poor
Fine	39.9	14.8	33.1	Poor
Medium Fine	38.8	7.7	15.0	Poor

Table 4.85: Summary of 95% Confidence Index Results: Form D Aggregate Material

Test method	Mean	95% CI	StDev	Reliability of results
ALD	10.6	1.9	4.1	Poor
# particle count	288	59	131	Poor
Sample mass	1057	286	624	Acceptable
FI	20.7	4.3	11.5	Poor
Sample mass	2062	379	1002	Poor
ACV	19.8	1.8	4.7	Poor
10% FACT	208	26	65	Poor
Aggregate Grading % passing				
20 / 19 mm	99.7	0.2	0.5	Acceptable
14 /13.2 mm	27.7	3.1	7.8	Poor
10 / 9.5 mm	5.2	0.9	2.3	Acceptable
7.1 / 6.7 mm	2.5	0.6	1.5	Acceptable
5 / 4.75 mm	2.0	0.6	1.4	Acceptable
2 / 2.36 mm	1.6	0.5	1.1	Acceptable
1 / 1.18 mm	1.4	0.4	0.9	Acceptable
0.600 mm	1.2	0.4	0.8	Acceptable
0.425 mm	1.0	0.3	0.7	Acceptable
0.300 mm	1.1	0.4	0.8	Acceptable
0.150 mm	0.9	0.3	0.7	Acceptable
0.075 mm	0.7	0.3	0.6	Acceptable

5 Lessons Learned from the Pilot Project

The lessons learned from the pilot PTS project in Mozambique are summarised below.

1. Because the PTS process is a major shift from the norm of how testing is undertaken and checked for accuracy, the pilot project took longer than anticipated. This included the testing within the laboratories as well as the development of the skills and understanding to prepare, split and package the samples, capture the data after each round, analyse the results and compile the reports.
2. A strict program for sample preparation and dissemination, result submission, data capture, analysis and report dissemination must be maintained to ensure the laboratories keep to the requirements of the programme. This assists all parties in understanding the process and obtaining the full benefit of participation in a professionally run scheme. Sufficient time and personnel must be allocated to the logistical aspects of the programme including sample collection, preparation, splitting and packaging, data capture, analysis and the compilation of the reports. It takes time to develop the system and ensure it is working quickly and efficiently.
3. The PTS project manager and project team are critical to the success of the PTS process. There is a lot of additional work at the beginning of the process while the organisers get used to the process and modify it to achieve the maximum benefits from the scheme. The project manager requires patience and commitment to the objective of improving the performance of all the laboratories partaking in the PTS. The success of the pilot project is largely attributable to the passion and drive of the LEM/ANE project team and the manner in which they applied themselves to the process.
4. The PTS organisers need to spend time witnessing test methods and staff at the participating facilities to ensure that the laboratories obtain maximum benefit from the process, especially in the early phase. This involvement of the organisers also provides a training intervention for the laboratory personnel and ensures consistency in interpretation of the methods used. It is recommended that at least three days should be spent in each facility, though this may depend on the number of tests being witnessed.
5. The participating laboratories need to understand their responsibilities and the PTS process from the start. They should be included in the initial planning of the scheme and setting up of test methods specified in the protocols. They should also be involved in any changes to the standard protocols to get more buy-in and better participation through greater appreciation of the goals, benefits and outcomes of the PTS.
6. The PTS process has highlighted various issues that need to be addressed for Mozambique laboratories to achieve ISO 17025 accreditation including:
    - the need for continued training of personnel and keeping updated training records (see recommendations for training and capacity development in the "Protocols for Improving the Proficiency of Material Testing Laboratories in Mozambique - Capacity Building and Skills Development Report" of February 2018);
    - the need for calibration facilities in Mozambique and issuing calibration certificates for equipment; and
    - keeping accurate control sheets in the laboratories and records of apparatus and its calibration where applicable.
7. Converting to ISO 17025 certification is not a major step once the PTS process is in place. This particularly applies to LEM and the commercial facilities operating in Mozambique, which are already relatively well established.
8. On future pilot projects the initial rounds should be limited to fewer tests, as proposed for the 2019 programme in

9. Table 6.1. Although there are benefits in addressing as many issues as possible, there are logistical constraints to achieving reasonable turnaround times per round. The final analysed information needs to be made available to the participating facilities as soon as possible after each round of testing is completed, while the work completed is still fresh in the minds of the laboratory staff. This also allows for effective corrective action to be implemented and practiced before the next round is underway. The possible disadvantage of this approach is that it may take longer to get through a full cycle of all of the test methods that are being covered by the PTS.
10. Test methods must be standardised before start-up of the process with enough time for the testers to become confident in the method proposed. Training should be provided to the testers where necessary.

6 The Way Forward

6.1 Programme for 2019

A typical annual programme for the PTS should consider the following:

- Each round to contain only 1 material type - too many tests per round results in delayed reporting and the effectiveness of the process is reduced.
- Each material type should be repeated two to three times per year – ANE/LEM could start with two rounds per material type per year and increase this to three rounds if necessary or once the system is well entrenched and running smoothly.
- Rotate granular material between the crushed material and sand annually to ensure that the facilities are able to identify and test both types of material.
- PI should be conducted on both plastic and non-plastic material to ensure that the facilities can identify and test both types of material.
- The programme must stipulate fixed dates for the following and be strictly adhered to:
  - Sample preparation and distribution;
  - Results submission;
  - Confirmation of results; and
  - Draft and final report.
- The annual PTS Programme should be circulated before the end of the year for the following year to allow facilities sufficient time to plan for their participation. The protocols for each round must include specific methods to be used, with possible revisions required to ensure that the requirements are consistent with Mozambique specifications. The same materials sources should be used each year to assist in analysis of the results.
- The PTS programme must allow sufficient time for LEM to split and package the samples. If this process is rushed the samples may not be representative. Sufficient staff are required to assist in the splitting process. The programme must allow enough time to transport the samples to the various facilities around the country.
- The dates for report submission should be strictly enforced. If a facility misses the deadline date they should be excluded from the analysis for that round.
- After capturing the data, it should be circulated to all participants, so they can check the correctness of data capture. Enough time should be allowed in the programme for preparation of the PTS Report. Consideration should be given to making this report available on the ANE website with password protection.

A recommended programme for the PTS for 2019 to continue the process that has been started under the pilot project is given in

Table 6.1. The programme staggers the testing of plastic samples, aggregates and the crushed granular material to reduce the work load on ANE and LEM for the splitting and distribution of samples.

Table 6.1: Programme for PTS Testing for 2019

Month (2019)	Material type	Methods
February	Plastic soil	Atterberg Limits - LL, PL, LS, PI
March	Aggregates	Grading, ALD, FI, ACV & 10% FACT
May	Granular	Grading, MDD, OMC, CBR, Atterberg
July	Plastic soil	Atterberg Limits - LL, PL, LS, PI
August	Aggregates	Grading, ALD, FI, ACV & 10% FACT
October	Granular	Grading, MDD, OMC, CBR, Atterberg

6.2 Increasing the number of facilities participating in the PTS

In considering expansion of the PTS to include additional participants, it is recommended that initially the other ANE provincial laboratories should be brought into the scheme to get them all to the same quality platform. Once a stable set of results are being obtained from the expanded ANE participants, the scheme could be expanded to include other commercial facilities.

It is recommended that the commercial facilities should participate on a paid for service basis, the cost of which would be determined by LEM and ANE. ANE could also establish a contractual requirement that any laboratory facility providing testing for any ANE contract must partake in the PTS. This would ensure that the results the facility was reporting compared favourably with the norms obtained by other facilities and provide confidence in the results produced.

As new facilities join the scheme, they will go through a learning curve which may affect the average results of the PTS, depending on how many new facilities join for each round. Once all of the ANE facilities are participating with acceptable results, there will be confidence to compare results from other facilities and provide them with guidance on any identified corrective action.

6.3 Test methods

It is imperative for ANE with the assistance of LEM to motivate for a standard testing regime to be implemented throughout Mozambique to better manage and utilise the PTS results. The decision on standard test methods should be done in consultation with other SADC member states through the Association of Southern Africa National Road Agencies (ASANRA), which has a responsibility to promote regional integration and harmonisation of standards.

6.4 Continued assistance from ReCAP

It would be beneficial to have limited offsite assistance for ANE/LEM during 2019 to support the process of bringing the PTS completely under their control. This assistance would include general guidance as required in the management of the PTS process and assistance with queries on the analysis and compilation of the reports. Thereafter ANE/LEM should be able to continue running the scheme independently without further assistance.

6.5 Expansion of the PTS initiative

The Mozambique PTS pilot project has provided an example for replication in other countries in the region. For a new PTS scheme supported through technical assistance it is recommended that a first round should be implemented to benchmark the abilities of the participating laboratories and kick-start the process, followed by at least 3 but preferably 4 rounds. This would ensure that the system is well entrenched and there is enough confidence in the project team to continue the process unassisted after the technical assistance is withdrawn. A project period of at least two years is required to effectively entrench the process and ensure its continuation after external funding is removed.

The PTS programme in Mozambique (and the region) could be linked to the SADC drive to establish National Laboratory Associations in each country. The United Nations Industrial Development Organization (UNIDO) is supporting this process in cooperation with the Southern African Development Community's (SADC) Regional Laboratory Association (SRLA). The UNIDO project was launched in May 2017 and training has been provided for 11 Southern African National Laboratory Associations (NLA). Funding was provided by the Ministry of Foreign Affairs of Finland. The training aims to support the NLAs to sustainably serve the needs of their member laboratories and clients. This will ultimately improve national conformity assessment capacity, which is a key requirement for the facilitation of trade and regional integration. A PTS scheme in each country, if provided on a "charged for service" basis, could provide funding for the establishment of these associations.

Annex 1 PTS Round 3 Results Report

Road Construction Materials Proficiency Test Scheme Report

Form A - Gravel Samples
(Grading, PI, OMC, MDD and CBR)

Form B - Plastic fines Sample
(PI)

Form C - Aggregate Sample
(Grading, FI, ALD, ACV & 10 % FACT)

Form D - Sand Sample
(Grading, PI, OMC, MDD and CBR)

Pilot round 3 / 2018

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1. INTRODUCTION

This report contains the results for Pilot PTS Round 3 of 2018 and tabulated statistical results of all 3 rounds. The following tests were included for this round:

FORM A – crushed granular material
- Wet preparation and sieve analysis
- Atterberg Limits
- MDD/OMC
- CBR

FORM B – Plastic fines material
- Atterberg Limits

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

JJR Construction, ANE Maputo & ANE Inhambane, provided the samples for all rounds of the Road Construction Materials Proficiency Testing Scheme (PTS) and the splitting was undertaken at LEM in Maputo. The ANE would like to acknowledge these contributions.

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

The following, a) – t), is a reference for the whole of this report and has been reproduced here to enable specific comments on each test to be accommodated on the pages in question.

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
   - due to the not being undertaken either due to the equipment not being available
f) CBD - Could not be determined
   - when a test is undertaken but a result is not determinable like 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 % Fines Aggregate Crushing Test
s) FI - Flakiness index
t) ALD - Average least dimension

2. EVALUATION OF RESULTS

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 laboratories in the same field.

Whilst it is not possible to guarantee a single ‘target’ value for evaluation purposes, the organizers are confident that the H15 robust mean and H15 standard deviation is sufficiently representative of each sample. In the case where the result submitted is considered to be an obvious error (OE), the result was excluded from the analysis.

Stability and Homogeneity testing

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

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 method.

3. 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.

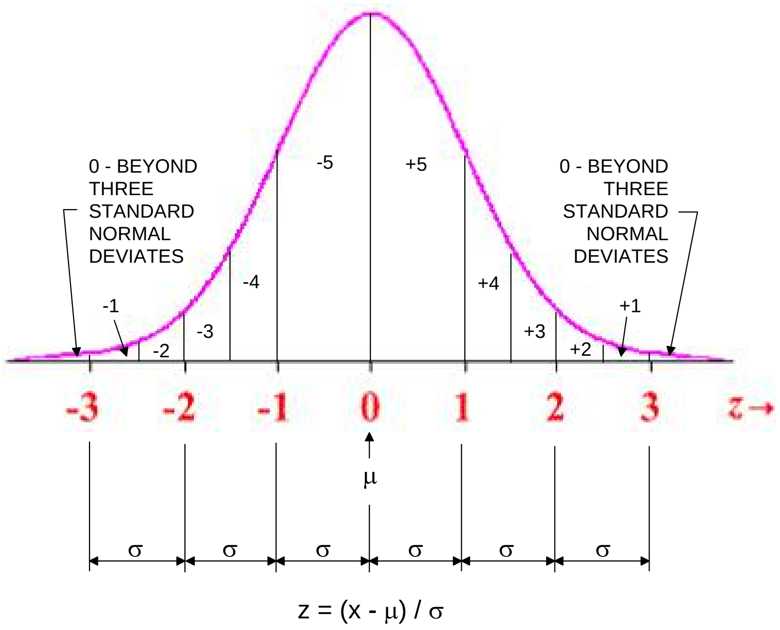
A negative sign on a Z-Score or Rating indicates that the laboratory's result was below the average, while a positive Z-Score or Rating indicates that the laboratory's result was above the average.

Reference:

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

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). 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 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:



<u>Sample Calculation</u>

- Assume mean, μ = 20,73 and standard deviation, σ = 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.

4. GENERAL COMMENTS

After the first round results came out, visits and workshops were carried out in ANE with all participating facilities so that some relevant considerations and discussions could be done around the results. Relevant aspects on the protocols were discussed and participants were assisted in identifying where some of the methods are being undertaken incorrectly.

On the first and third rounds all 10 participants partook in the PTS while in the second round a total of nine facilities partook.

The expectation was that the results would be more consistent, and less errors would be committed on reporting the results by the third round.

After all three round had been completed, the resolution of the answers reported by the various facilities have improved to a degree. Although some facilities that are still reporting answer of 0, instead of CBD or NP for the Atterberg values, some of the results were removed from the analysis and noted as obvious errors (OE).

The main tests that require attention are as follows

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

These areas are briefly discussed below with additional comments under the relevant sections that follow in this report.

The variability in the sample mass used per method needs to be addressed so as to ensure each result is as representative as possible. Some facilities are using too small a sample size to obtain a result that can be considered representative. The large sample sizes used would provide better representivity, but it'll take far longer to conduct the test which will adversely affect the laboratories production. It is proposed that an acceptable mass be determined as to what is an acceptable range in sample size per methods.

At the beginning of the PTS project, determining the PI was a problem particularly in the identification of material with or without plasticity. The split between the two methods used in Mozambique as well as the variations in the interpretations on how the test is undertaken adds to the variability in the results. By the third round, the PI determinations had improved. Improvement is however still required in how the information is reported for the various PI components e.g. a LL percentage cannot be reported if there is no PL and values of 0 cannot be reported for the LL or LS. At the workshop in late November 2018 the concepts behind how to correctly undertake the test methods and present the results was discussed at length and it is now assumed that the test will be undertaken in a more consistent manner between the facilities as well as further improvements in the reporting in the next Atterberg round.

After all three rounds, the conclusion regarding the CBR is that there is still need to improve the variability especially on sand materials. Since the beginning of the programme 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 has not been the case. The results of sand materials are more variable than the crushed granular material.

The swell measurements can be difficult in so much as 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 which is expected to be a more consistent material, is concerning.

There where improvements in the ACV results in terms of variability and mean determinations. The reproducibility was good which is expected on this particular method. Calibration of the apparatus is necessary and it was assumed that the method is largely being followed correctly.

In summary the results for the third round have highlight the need to provide feedback to the participants in the areas of concern so that the reproducibility can be reduced to within acceptable limits as detailed in the standard methods used. It is imperative that the variability in the results produced by the individual facilities be reduced. From this point on, it is expected that improvements can be monitored, and persistent issues noted and addressed with the various facilities. It was expected that the variability in this round would have reduced. This was however not the case in all methods.

There was again an improvement in some tests, but more still need to be done on others.

5. TEST RESULTS

A. CRUSHED GRANULAR MATERIAL

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

Lab Code	LL %	z-score
DG3DK	22	0.739
WQ3LN	**23.2**	0.787
AO7VU	**25**	0.859
DF6CP	**29.3**	1.032
AB4WQ	**CBD**	
EN2QS	CBD	
TF5SK	CBD	
DK9WF	NP	
EN2QS	**NP**	
CV6ZX	0	OB

Lab Code	PL %	z-score
AO7VU	**15.5**	-0.624
DF6CP	**15.9**	0.624
AB4WQ	**CBD**	
EN2QS	CBD	
TF5SK	CBD	
WQ3LN	**CBD**	
DG3DK	NP	
DK9WF	**NP**	
EN2QS	NP	
CV6ZX	0	OB

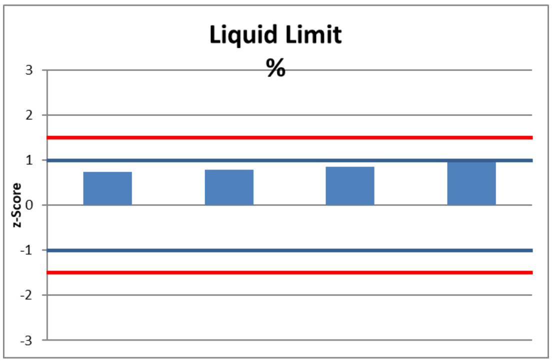
Lab Code	LS %	z-score
DK9WF	0	-0.661
AB4WQ	**0**	-0.661
CV6ZX	0	-0.661
EN2QS	0	-0.661
WQ3LN	**2**	0.312
AO7VU	**3.3**	0.944
DF6CP	**7.3**	2.890
TF5SK	CBD	
EN2QS	NP	
DG3DK	NULL	

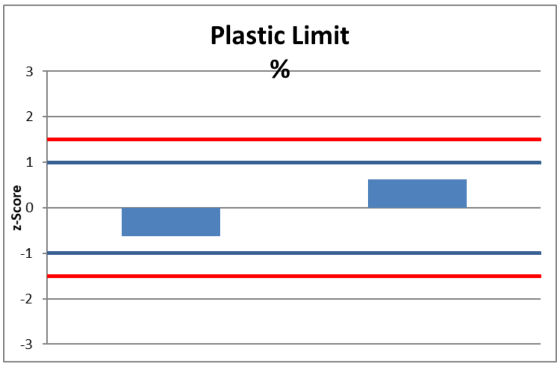
Lab Code	PI %	z-score
AO7VU	**9.5**	-0.624
DF6CP	**13.4**	0.624
AB4WQ	CBD	
TF5SK	CBD	
WQ3LN	CBD	
CV6ZX	NP	
DK9WF	NP	
EN2QS	NP	
EN2QS	**NP**	
DG3DK	**NULL**	

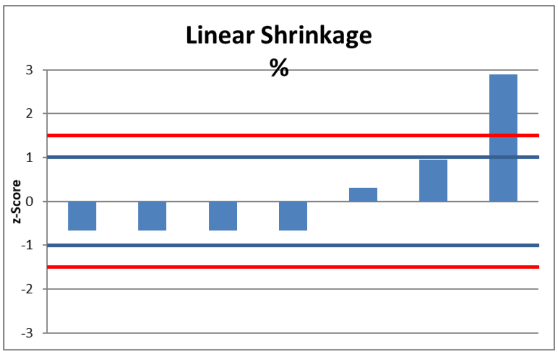
	LL Round			PL Round			LS Round			PI Round		
	1	2	3	1	2	3	1	2	3	1	2	3
H15 mean	22.4	15.9	24.9	16.6	6.95	15.7	1.29	0.75	1.4	0.3	6.0	11.5
H15 Std Dev	3.14	15.8	3.6	8.02	11.1	0.3	1.29	1.35	2.1	5.8	9.5	3.1
Range	29.3	3.8	7.3	22	0	0.4	4	2.8	7.3	9.2	0	7.3
CV (%)	14	99.1	14.6	48.3	160	2.0	100	180	151.2	110	160	27.3

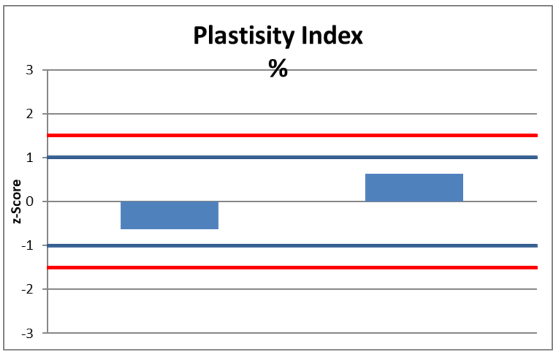
Method information

Method	AASHTO T180/89	SANS 3001 GR10/11/12	TMH1 A1 & A5
# participants	3 (30%)	2 (20.0%)	5 (50.0 %)









	LL-1	LL-2	LL-3	PL-1	PL-2	PL-3	LS-1	LS-2	LS-3	PI-1	PI-2	PI-3
Additional participant statistics												
Number of participants	10	8	10	10	8	10	10	8	10	10	8	10
CBD	3	4	3	4	4	4	1	1	1	2	2	-
NP	1	-	2	1	-	3	-	-	1	2	1	
SP	-	-	-	-	-	-	-	-	-	1	1	
NULL	-	-	-	1	1	-	1	1	1	2	2	
Non-participants	-	-	-	-	-	-	-	-	-	-	-	
OB	-	1	1	-	1	1	-	2	-	-	1	
Statistics for Z-scores < ±1												
Range	3.2	3.8	1.2	3.3	-	0	1.9	-	2	0.7	-	0
Percentage of participants	67%	100%	20%	75%	-	80%	63%	-	80%	67%	-	80%
Reporting format												
Participants reported correctly to 1 %	2	1	1	2	-	1	2	2	5	1	1	2
Participants reported to 0.1 %	4	1	2	2	1	2	6	2	2	2	1	-

Comments – Atterberg limits

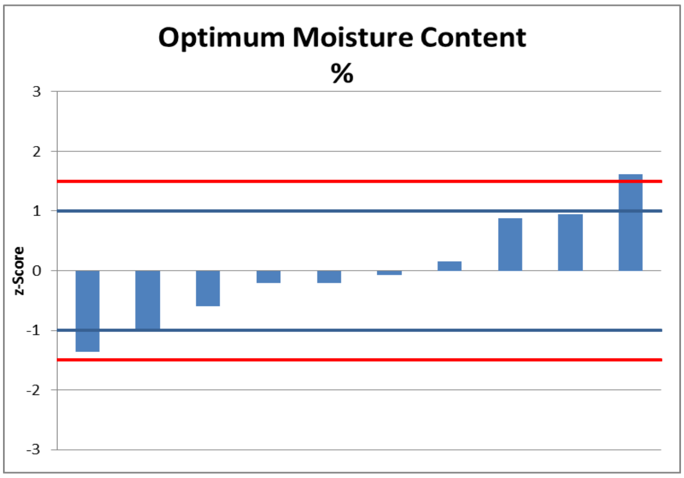
- It can be assumed from the results as submitted that the material is either NP or at most SP, although there are two facilities that report a PI. Of the other facilities reported LL & PL which should have been reported as CBD.
- In general, the variability in the results produced on the third round by the individual facilities has improved.
- The split between the two methods used in Mozambique as well as the variations in the interpretations on how the test is undertaken adds to the variability in the results.
- At the workshop in late November the concepts behind how to correctly undertake the test methods and present the results was discussed at length and it is now assumed that the test will be undertaken in a more consistent manner between the facilities as well as further improvements in the reporting in the next Atterberg round.

NOTE: *The last two points are applicable to all Atterberg testing done in this round which includes Form B and C's results.*

Optimum Moisture Content test

#	Lab code	OMC %	OMC z-score
1	CV6ZX	5	-1.356
2	EN2QS	6.1	-0.993
3	TF5SK	7.3	-0.598
4	AO7VU	8.5	-0.202
5	DF6CP	8.5	-0.202
6	YY3QP	8.9	-0.070
7	AB4WQ	9.6	0.161
8	DG3DK	11.8	0.886
9	WQ3LN	12	0.952
10	DK9WF	14	1.611

	OMC Round 1	OMC Round 2	OMC Round 3
H15 mean	8.40	9.41	9.11
H15 Std Dev	1.836	2.202	3.034
Range	4.6	6.8	9.0
CV	21.9%	21.2%	33.3%



Apparatus information

Automatic	Manual	Auto	Non-responsive
1	7 (70.0%)	1 (10%)	2 (NULL)

Additional participant statistics

	OMC Round 1	OMC Round 2	OMC Round 3
Number of participants	10	8	10
Non-participants	-	2	-
OB	-	-	-

Statistics for Z-scores < ±1

Range	3.20	3.5	5.9
Percentage of participants	80.0%	75%	80.0%

Reporting format

Participants reported correctly to 0,1 %	10	8	7

Comments - Optimum Moisture Content (OMC) test

- There is scope to further reducing the range of the overall result.

- 2 SA laboratories have the lowest OMC (6.1 %) while Mozambique laboratories range is higher (7 – 14 %)
- There has been a general increase of the Mean, StDev, Range & CV though the rounds which is a concern.

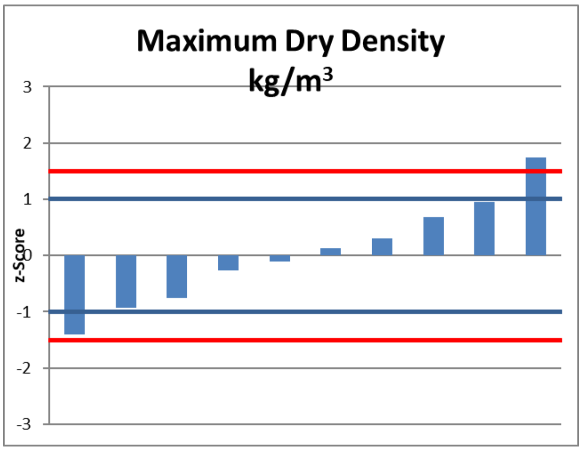
Maximum Dry Density test

Lab code	MDD kg/m³	MDD z-score
YY3QP	1904	-1.413
WQ3LN	1922	-0.924
CV6ZX	1928	-0.761
AB4WQ	1946	-0.273
DG3DK	1952	-0.110
DK9WF	1961	0.134
EN2QS	1967	0.297
AO7VU	1981	0.677
TF5SK	1991	0.948
DF6CP	2020	1.735

	MDD Round 1	MDD Round 2	MDD Round 3
H15 mean	1916.5	1918.7	1956.1
H15 Std Dev	34.76	29.41	36.85
Range	170.0	67.5	116.0
CV	1.8%	1.7%	1.9%

Method information

Method	AASHTO T180	SANS 3001 GR30	TMH1 A7	Non-responsive
# participants	(30%)	3 (30 %)	4 (40 %)	0 (NULL)



Additional participant statistics

	Round 1	Round 2	Round 3
Number of participants	10	10	10
Non-participants	-	-	-
OB	-	-	-

Statistics for Z-scores < ±1

Range	68	63	69
Percentage of participants	80.0%	75.0%	80.0%

Reporting format

Participants reported to 1 kg/m³	4	7	10
Participants reported to 0.1 kg/m³	1	1	-
Participants reported to 0.001	5	-	-

Comments -Maximum Dry Density (MDD)

- The 2 SA Labs have a lower mean than the Mozambican facilities with a Range 39 kg/m^3 versus 116 kg/m^3 respectively.
- Two (2) different methods (AASHTO & TMH1) were used by the Mozambican facilities which can add to the variability in their results.
- There is a slight increase of the Range, Mean and StDev in this round

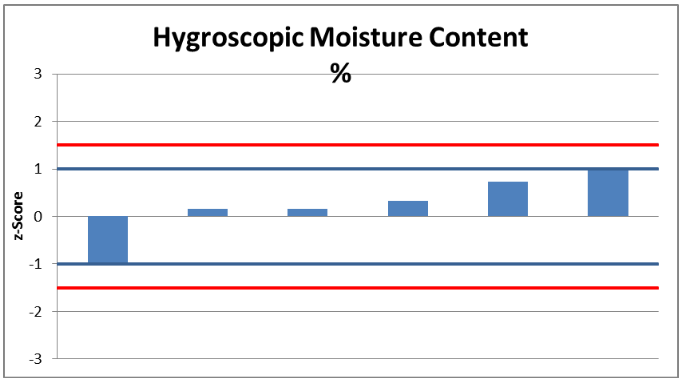
CBR Hygroscopic Moisture Content test

#	Lab code	Hygroscopic MC (%)	z-score
1	WQ3LN	0.4	-1.004
2	DG3DK	0.8	0.154
3	AB4WQ	0.8	0.154
4	TF5SK	0.86	0.328
5	AO7VU	1	0.733
6	EN2QS	1.1	1.023
7	EN2QS	0	-2.162
8	DK9WF	NULL	
9	DF6CP	NULL	
10	CV6ZX	NULL	

	Hygroscopic Round 1	Hygroscopic Round 2	Hygroscopic Round 3
H15 mean	1.55	0.59	0.747
H15 Std Dev	1.447	0.275	0.345
Range	53.00	0.00	0.70
CV	93.5%	47.7%	46.3

Method information

Method	AASHTO T193	SANS 3001 GR40	TMH1 A8
# participants	3 (30 %)	2 (20 %)	4 (40 %)



Apparatus information

Automatic	Manual	Non-responsive
3	5	1 (NULL)

Proving Ring	Load Cell	Non-responsive
4	3	3 (NULL)

Additional participant statistics

	Round 1	Round 2	Round 3
Number of participants	9	8	10
Non-participants	1	2	-
NULL	2	2	-
OB	-	-	1

Statistics for Z-scores < ±1

Range	1.88	0.36	0.2
Percentage of participants	71.4%	37.5%	40.0%

Reporting format			
Participants reported to 1 %	1	-	2
Participants reported correctly to 0.1 %	5	3	4
Participants reported to 0.01 %	1	2	1

Comments - Hygroscopic Moisture Contents test

- Most of the results provided were reasonably close to one another.
- In general, the variability in the results produced on the third round by the individual facilities have reduced considerably.
- One facility report zero (0 %) as their Hygroscopic Moisture content. It is assumed that this sample was over dried and does not represent hygroscopic MC as per the definition.

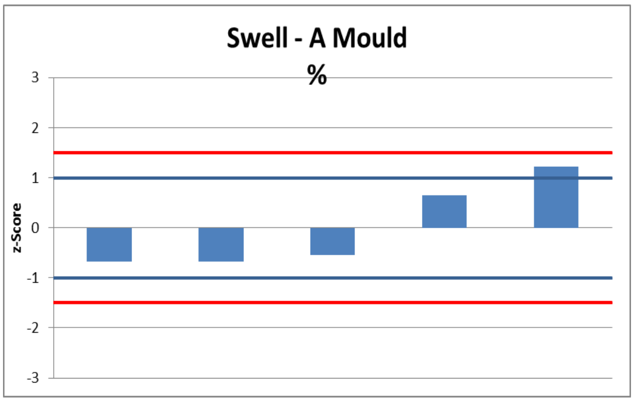
CBR - % Swell (A, B & C moulds)

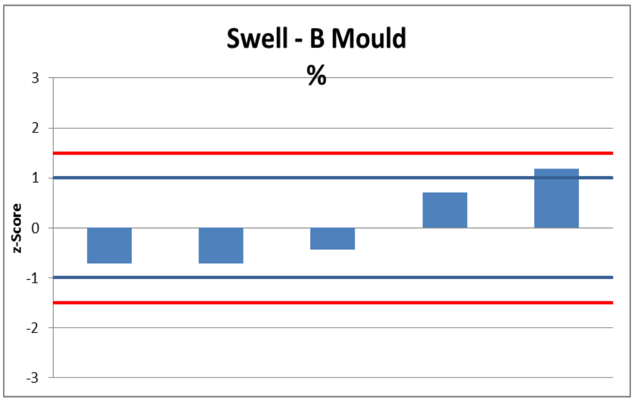
Lab Code	A	Z-score
EN2QS	0	-0.668
YY3QP	0	-0.668
CV6ZX	0.02	-0.542
WQ3LN	0.21	0.656
DG3DK	0.3	1.223
DF6CP	CBD	
AO7VU	Null	
DK9WF	NULL	
AB4WQ	Null	
TF5SK	Null	

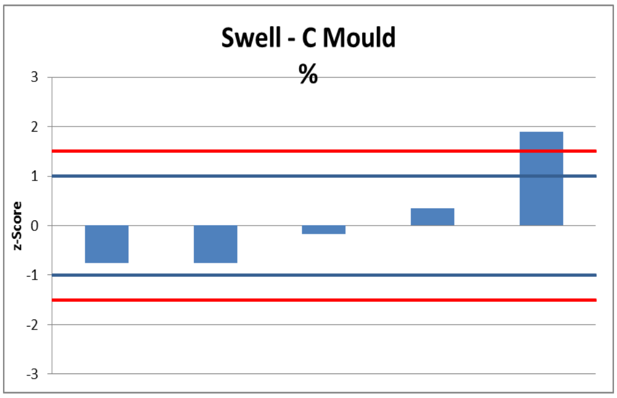
Lab Code	B	Z-score
EN2QS	0	-0.722
YY3QP	0	-0.722
CV6ZX	0.06	-0.437
WQ3LN	0.3	0.703
DG3DK	0.4	1.178
DF6CP	CBD	
AO7VU	Null	
DK9WF	NULL	
AB4WQ	Null	
TF5SK	Null	

Lab Code	C	Z-score
EN2QS	0	-0.761
YY3QP	0	-0.761
CV6ZX	0.11	-0.175
WQ3LN	0.21	0.358
DG3DK	0.5	1.903
DF6CP	CBD	
AO7VU	NULL	
DK9WF	NULL	
AB4WQ	NULL	
TF5SK	NULL	

	Swell A (%) Round 1	Swell A (%) Round 2	Swell A (%) Round 3	Swell B (%) Round 1	Swell B (%) Round 2	Swell B (%) Round 3	Swell C (%) Round 1	Swell C (%) Round 2	Swell C (%) Round 3
H15 mean	0.011	0.000	0.106	0.023	0.000	0.152	0.034	0.067	0.413
H15 Std Dev	0.019	0.000	0.159	0.037	0.000	0.211	0.056	0.131	0.188
Range	2.900	0.0	0.30	3.0	0.0	0.40	3.00	0.0	0.5
CV	165.8%	0.0%	149.6%	165.8%	0.0%	138.5%	165.7%	196.0%	131.0%







	A mould 1	A mould 2	A mould 3	B mould 1	B mould 2	B mould 3	C mould 1	C mould 2	C mould 3
Additional participant statistic									
Number of participants	5	8	10	5	8	10	5	8	10
Non-participants	-	2	-	-	2	-	-	2	-
CBD	2	-	1	2	-	1	2	-	1
NULL	3	4	4	3	5	4	3	5	4
OB	-	-	-	-	-		-	-	-
Statistics for Z-scores < ±1									
Range	0.2	0	0.21	0.04	0	0.3	0.06	0	0.21
Percentage of participants	71.4	0%	40.0%	80.0%	0%	40.0%	80.0	25%	40.0%
Reporting format									
Participants reported correctly to 1 %	2	4	2	2	3	2	2	2	2
Participants reported to 0,1 %	1	-	1	1	-	2	1	1	1
Participants reported to 0,01 %	2	-	2	2	-	1	2	-	2

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

- The two SA facilities reported minimal swell.
- The five Mozambican facilities reported as Null or CBD which is not clear if CBD was zero (0) or they didn’t physically measure the swell.
- All results reported are very small in value.
- It is known to be a very difficult measurement to make accurately.
- Great care is required in measuring from the same point before and after the four day soak.

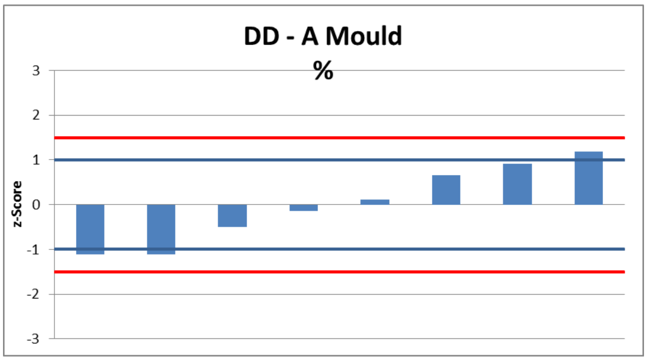
Dry Density % (A, B & C moulds)

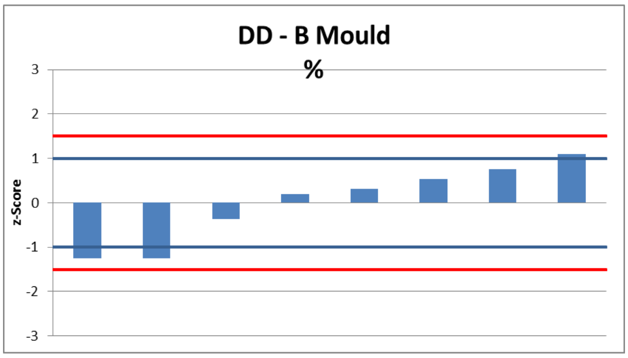
Lab Code	A	Z-score
DK9WF	99.0	-1.164
TF5SK	99	-1.164
AB4WQ	99.7	-0.478
CV6ZX	100.1	-0.086
DF6CP	100.4	0.208
DG3DK	101.0	0.797
EN2QS	101	0.797
EN2QS	101.3	1.091
WQ3LN	*2090.0*	OE
AO7VU	NULL	

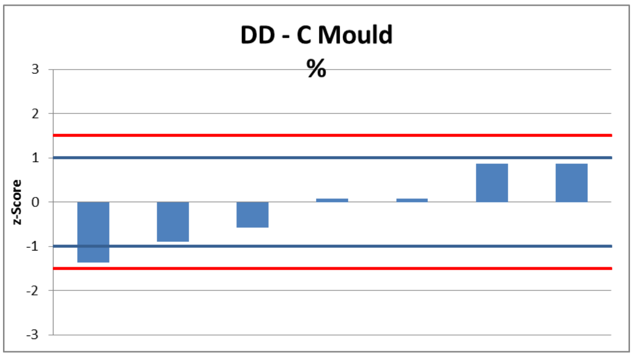
Lab Code	B	Z-score
DK9WF	94	-1.271
TF5SK	94	-1.271
EN2QS	94.8	-0.241
EN2QS	95	0.016
CV6ZX	95.3	0.402
DG3DK	95.4	0.531
AB4WQ	95.6	0.788
DF6CP	95.8	1.046
WQ3LN	2237	OE
AO7VU	NULL	

Lab Code	C	Z-score
DK9WF	89.4	-1.273
TF5SK	90	-0.816
EN2QS	90.4	-0.511
DF6CP	91.2	0.098
EN2QS	92	0.707
DG3DK	92.2	0.859
CV6ZX	92.3	0.936
AB4WQ	1776	OE
WQ3LN	1866	OE
AO7VU	NULL	

	Mould A (%) Round 1	Mould A (%) Round 2	Mould A (%) Round 3	Mould B (%) Round 1	Mould B (%) Round 2	Mould B (%) Round 3	Mould C (%) Round 1	Mould C (%) Round 2	Mould C (%) Round 3
H15 mean	100.440	100.130	100.188	94.940	94.470	94.988	90.950	89.760	91.071
H15 Std Dev	1.418	2.388	1.020	1.141	1.837	0.777	0.966	1.437	1.313
Range	12.00	7.60	2.30	4.30	6.00	2.32	4.20	7.20	2.90
CV	1.4%	2.4%	1.0%	1.2%	1.9%	0.2%	1.1%	1.6%	1.4%







	A mould Rd 1	A mould Rd 2	A mould Rd 3	B mould Rd 1	B mould Rd 2	B mould Rd 3	C mould Rd 1	C mould Rd 2	C mould Rd 3
Additional participant statistics									
Number of participants	9	8	10	9	8	10	9	8	10
Non-participants	-	2	-	-	2	-	-	2	-
NULL	1	1	1	1	1	1	1	1	1
OB	-	-	1	-	-	1	-	-	1
Statistics for Z-scores < ±1									
Range	1.50	3.7	1.6	1.60	2.5	1	1.70	1.6	2.3
Percentage of participants	66.7%	62.5%	50.0%	77.8%	62.5%	50.0%	77.8%	62.5%	70.0%
Reporting format									
Participants reported to 1 %	1	0	2	1	1	3	1	1	2
Participants reported to 0,1 %	8	7	7	8	6	6	8	6	7

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

- The Range of the two SA facilities averages 0.9 % versus 2.2 % for the Mozambique facilities
- The StDev reduced slightly on all 3 moulds in this round as well as the Mean which has remained fairly constant on all 3 moulds of all 3 rounds.
- One facilities report density instead of %DD, which was considered OE and was removed from the analysis while another facility reported NULL for all three determinations.

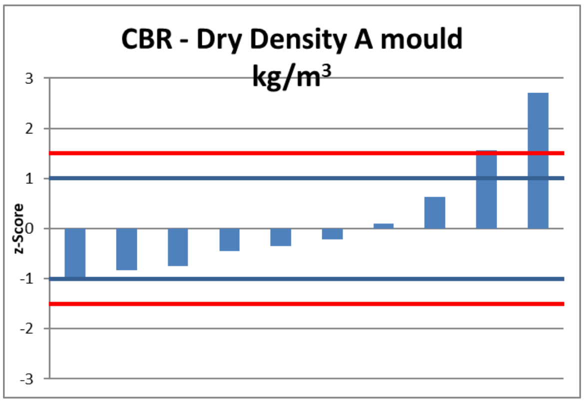
CBR - Dry Density kg/m³ (A, B & C moulds)

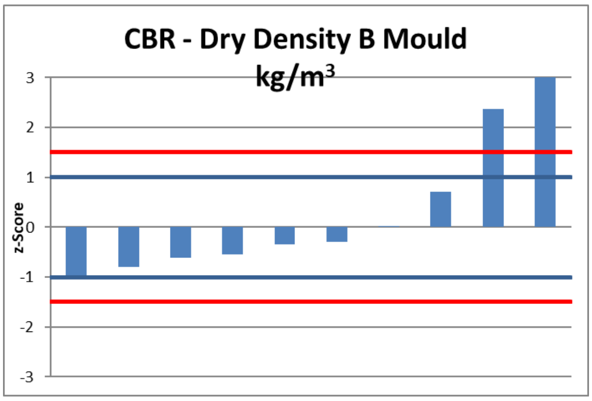
Lab Code	A	Z-score
YY3QP	1921	-0.965
CV6ZX	1930	-0.831
AB4WQ	1936	-0.741
DK9WF	1955	-0.458
TF5SK	1962	-0.354
DG3DK	1971	-0.219
EN2QS	1992	0.094
DF6CP	2028	0.631
WQ3LN	2090	**1.556**
AO7VU	2167	**2.704**

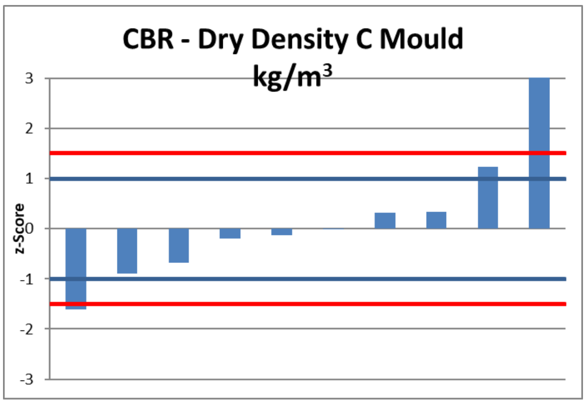
Lab Code	B	Z-score
YY3QP	1818	-0.976
CV6ZX	1831	-0.789
AB4WQ	1843	-0.617
DK9WF	1848	-0.545
DG3DK	1861.8	-0.347
TF5SK	1865	-0.301
EN2QS	1888	0.029
DF6CP	1935	0.704
WQ3LN	2051	**2.369**
AO7VU	2109	**3.202**

Lab Code	C	Z-score
WQ3LN	1711	**-1.602**
YY3QP	1744	-0.889
DK9WF	1754	-0.672
AB4WQ	1776	-0.197
CV6ZX	1779	-0.132
TF5SK	1785	-0.003
DG3DK	1800	0.321
EN2QS	1801	0.343
DF6CP	1842	**1.229**
AO7VU	2058	**5.896**

	A mould round 1	A mould round 2	A mould round 3	B mould round 1	B mould round 2	B mould round 3	C mould round 1	C mould round 2	C mould round 3
H15 mean	1933.7	1928.7	1986.1	1842	1833.3	1886.3	1751	1752.1	1786.2
H15 Std Dev	32.085	30.236	63.208	40.000	52.279	66.21	46.800	66.767	43.28
Range	412.0	101.0	237.0	195.0	168.0	279.0	239.0	257.0	347.0
CV	1.7%	1.6%	3.2%	2.2%	2.9%	3.5%	2.7%	3.8%	2.4%







	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
Additional participant statistics									
Number of participants	9	8	10	9	8	10	9	8	10
Non-participants	-	2	-	-	2	-	-	2	-
NULL	1	1	-	1	1	-	1	1	-
OB	-	-	-	-	-	-	-	-	-
Statistics for Z-scores < ±1									
Range (kg/m^3)	34.1	37.0	93	76.0	78.0	105	63.0	121.0	47.0
Percentage of participants	66.7%	62.5%	80.0%	77.8%	62.5%	70.0%	66.7%	75%	70.0%
Reporting format									
Participants reported correctly to 1 kg/m^3	5	7	10	5	7	9	5	7	10
Participants reported correctly to 0.001	5	0	-	5	0	-	5	0	-

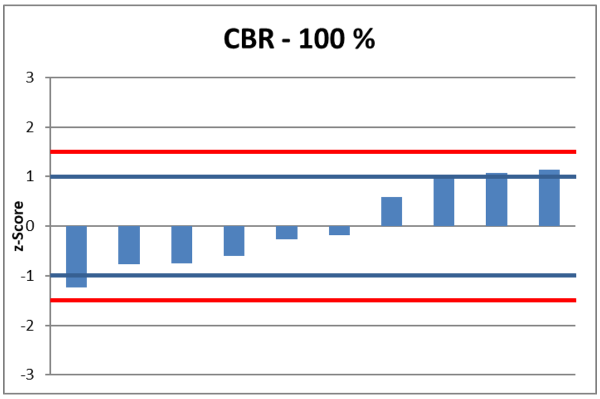
Comments - Dry Density kg/m^3 (A, B & C moulds)

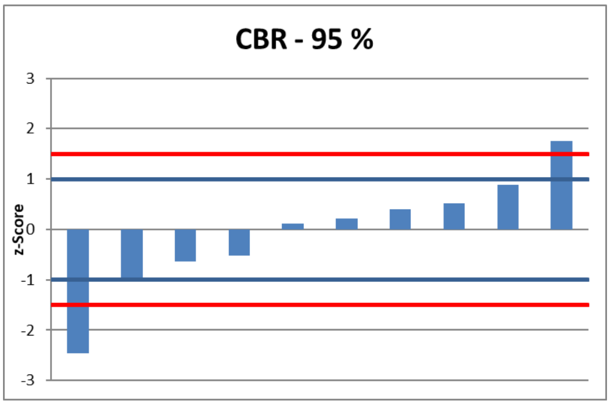
- The Range of the two SA facilities averages 47 kg/m^3 versus 295 kg/m^3 for the Mozambique facilities. The Mozambican range definitely needs to be reduces as this represents a 16 % variation in the results which is far too high.
- The Mean, StDev, CV and Range all increased on average for round 3.

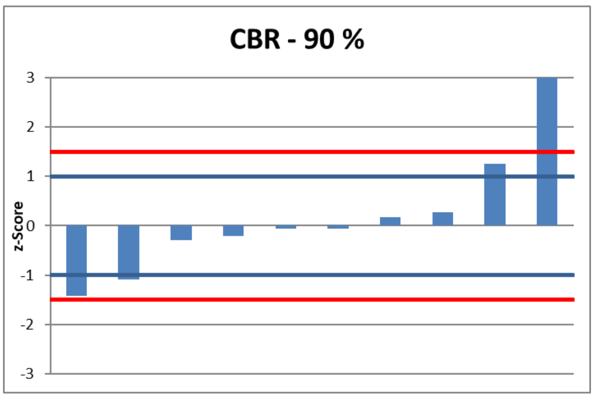
CBR (%)

Lab Code	100%	Z-score	Lab Code	95%	Z-score	Lab Code	90%	Z-score
WQ3LN	88.7	**-1.240**	WQ3LN	31.4	**-2.462**	AO7VU	12	**-1.429**
DK9WF	100	-0.769	YY3QP	55.6	-0.976	WQ3LN	17.6	**-1.095**
DF6CP	100.3	-0.757	CV6ZX	61	-0.645	CV6ZX	31	-0.296
AB4WQ	104	-0.602	AO7VU	63	-0.522	YY3QP	32.5	-0.206
AO7VU	112	-0.269	DG3DK	73.4	0.117	AB4WQ	35	-0.057
TF5SK	114	-0.186	EN2QS	75	0.215	TF5SK	35	-0.057
DG3DK	132.7	0.594	DK9WF	78	0.399	EN2QS	39	0.181
CV6ZX	143	**1.023**	TF5SK	80	0.522	DG3DK	40.6	0.277
EN2QS	144	**1.065**	AB4WQ	86	0.890	DK9WF	57	**1.255**
YY3QP	145.8	**1.140**	DF6CP	100	**1.750**	DF6CP	89	**3.163**

	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
H15 mean	109.7	97.9	118.5	61.4	70.0	71.5	31.7	37.9	36.0
H15 Std Dev	43.23	29.72	23.99	25.88	27.21	16.29	17.83	8.82	16.77
Range	109.17	73.05	57.10	97.300	77.00	68.60	45.89	53.00	77.00
CV	39.4%	30.4%	20.25%	42.2%	38.9%	22.78%	56.2%	23.3%	46.62%







	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
Additional participant statistics									
Number of participants	9	8	10	9	8	10	9	8	10
Non-participants	-	2	-	-	2	-	-	2	-
NULL	1	1		1	1	-	1	1	-
OB	-	-	1	-	-	1	-		1
Statistics for Z-scores < ±1									
Range (%)	34.1	24	43.0	76.0	44.29	68.60	63.0	9	9.6
Percentage of participants	66.7%	50%	70.0%	77.8%	62.5%	22.78%	66.7%	62.5%	6
Reporting format									
Participants reported correctly to 1 %	5	4	6	5	5	7	5	6	3
Participants reported correctly to 0.1	5	2	4	5	1	3	5		2
Participants reported correctly to 0.01		1	-		1	-		1	-

Comments –CBR %

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- The Range of the two SA facilities averages 8 % versus 68 % for the Mozambique facilities. As with the densities, the Mozambican range is again far too high.
- The StDev and Range improved on the A and B specimens but increased on significantly for the C specimen.
- Two different methods (AASHTO & TMH1) were used by the Mozambican facilities which can add to the variability in their results.

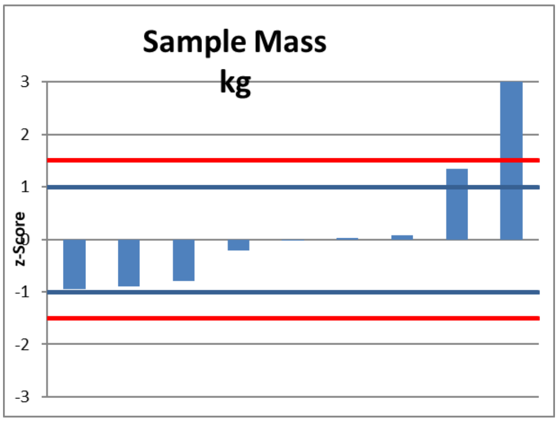
Washed Grading

	Lab Code	Sample mass	z-score
1	EN2QS	1725.6	-0.950
2	DK9WF	1853	-0.895
3	DF6CP	2067.8	-0.801
4	YY3QP	3414	-0.213
5	TF5SK	3890	-0.005
6	AO7VU	3960	0.025
7	DG3DK	4066.93	0.072
8	AB4WQ	7000	**1.352**
9	CV6ZX	21019	**7.472**
10	WQ3LN	NULL	

	Sample mass Round 1	Sample mass Round 2	Sample mass Round 2
H15 mean	2894.1	3847.5	3902.4
H15 Std Dev	766.8	557.0	2290.7
Range	1262.6	695	19293
CV (%)	26.5	14.5	58.7

Method information

Method	AASHTO T27	SANS 3001 GR1	TMH1 A1 (a)	Non-responsive
# participants	3 (30 %)	2 (20 %)	4 (40 %)	0 (NULL)



Comments - Washed grading sample mass

- This information is more to confirm an acceptable sample size was used for the grading analysis.
- Too big a sample size takes too long to complete operation and impedes production in the facility.
- Too small a sample means its less representative and if too small non-representative.
- Two different methods (AASHTO & TMH1) were used by the Mozambican facilities which can add to the variability in the results.

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
WQ3LN	88.2	-14.083
DF6CP	96.4	-3.920
YY3QP	98.8	-0.945
AO7VU	100	0.542
DK9WF	100	0.542
DG3DK	100	0.542
AB4WQ	100	0.542
TF5SK	100	0.542
CV6ZX	100	0.542
EN2QS	100	0.542

Lab Code	28/25 mm	Z-Score
AB4WQ	67.6	-1.285
YY3QP	69.8	-1.121
WQ3LN	74.9	-0.738
DF6CP	76.5	-0.619
DK9WF	86.5	0.131
DG3DK	87.24	0.186
CV6ZX	93	0.618
TF5SK	95	0.768
EN2QS	97	0.918
AO7VU	100	1.142

Lab Code	20/19 mm	Z-Score
AB4WQ	51.4	-1.318
YY3QP	52.00	-1.285
DF6CP	*63.1*	-0.681
WQ3LN	72.7	-0.157
DK9WF	76.6	0.055
DG3DK	79.7	0.224
CV6ZX	82	0.349
TF5SK	85	0.513
EN2QS	94	1.003
AO7VU	99.40	1.297

% passing	37,5 mm Round 1	37,5 mm Round 2	37,5 mm Round 3	28/25 mm Round 1	28/25 mm Round 2	28/25 mm Round 3	20/19 mm Round 1	20/19 mm Round 2	20/19 mm Round 3
H15 mean	100.0	100.0	99.56	84.4	88.2	84.78	66.8	77.4	75.59
H15 Std Dev	7.9E-14	0.0	0.807	8.240	12.522	13.345	7.685	20.077	18.351
Range	13.80	0.8	11.8	30.90	44.7	32.4	31.20	86.9	48
CV	0.0%	0.0%	0.8%	9.8%	14.2%	15.7%	11.5%	25.9%	24.3%

Lab Code	14/13.2 mm	Z-Score
YY3QP	43.72	-1.199
AB4WQ	45.2	-1.120
DF6CP	51.2	-0.799
WQ3LN	54.9	-0.602
DK9WF	69.3	0.168
DG3DK	71.38	0.279
TF5SK	75	0.472
CV6ZX	75	0.472
EN2QS	85	1.007
AO7VU	90.9	1.322

Lab Code	10/9.5 mm	Z-Score
YY3QP	39.07	-1.232
DF6CP	45.6	-0.823
WQ3LN	53.1	-0.352
DK9WF	60.7	0.125
DG3DK	64.68	0.374
TF5SK	67	0.520
AO7VU	83.4	1.549
AB4WQ	Null	
CV6ZX	Null	-
EN2QS	Null	-

Lab Code	7.1/6.7 mm	Z-Score
YY3QP	34.87	-1.216
DF6CP	38.2	-0.982
WQ3LN	51.2	-0.068
DK9WF	54.1	0.136
DG3DK	56.87	0.331
TF5SK	58	0.411
AO7VU	75.4	1.635
AB4WQ	Null	
CV6ZX	Null	-
EN2QS	Null	-

% passing	14/13.2 mm round 1	14/13.2 mm round 2	14/13.2 mm round 3	10/9.5 mm round 1	10/9.5 mm round 2	10/9.5 mm round 3	7.1/6.7 mm round 1	7.1/6.7 mm round 2	7.1/6.7 mm round 3
H15 mean	48.0	72.6	66.16	36.8	61.7	58.71	28.2	55.6	52.16
H15 Std Dev	14.114	15.255	18.715	12.140	15.080	15.941	11.588	14.650	14.215
Range	41.10	44.9	47.18	32.50	37.5	44.33	27.30	36.7	40.53
CV	29.4%	21.0%	28.3%	33.0%	24.4%	27.2%	41.1%	26.4%	27.3%

Lab code	5/4.75 mm	Z-Score
YY3QP	29.96	**-1.322**
DF6CP	32.3	**-1.136**
AB4WQ	34.7	-0.945
DK9WF	48	0.111
DG3DK	48.35	0.139
TF5SK	49	0.191
WQ3LN	49.2	0.207
CV6ZX	53	0.508
EN2QS	57	0.826
AO7VU	68.4	**1.732**

Lab Code	2/2.36 mm	Z-Score
YY3QP	21.83	**-1.143**
DF6CP	23	**-1.024**
AB4WQ	23.8	-0.942
TF5SK	31	-0.206
DK9WF	33	-0.001
DG3DK	34.4	0.142
CV6ZX	35	0.203
EN2QS	36	0.306
WQ3LN	45.1	**1.236**
AO7VU	48.6	**1.594**

Lab Code	1/1.18 mm	Z-Score
YY3QP	15.7	-0.978
DF6CP	17.2	-0.812
DK9WF	22	-0.282
TF5SK	23	-0.172
DG3DK	23.26	-0.143
AO7VU	33.6	1.000
WQ3LN	43.2	**2.061**
AB4XQ	Null	
CV6ZX	Null	-
EN2QS	Null	-

% passing	5/4.75 mm Round 1	5/4.75 mm Round 2	5/4.75 mm Round 3	2/2.36 mm Round 1	2/2.36 mm Round 2	2/2.36 mm Round 3	1/1.18 mm Round 1	1/1.18 mm Round 2	1/1.18 mm Round 3
H15 mean	26.9	48.7	46.60	18.1	32.8	33.01	18.1	32.8	24.55
H15 Std Dev	8.296	11.468	12.587	7.281	11.010	9.781	7.281	11.010	9.049
Range	35.50	30.6	38.44	24.30	28.03	26.77	24.30	28.03	27.5
CV	30.9%	23.5%	27.0%	40.1%	33.5%	29.6%	40.1%	33.5%	36.9%

Lab Code	0.600 mm	Z-Score
YY3QP	11.79	-0.994
DF6CP	12.3	-0.893
DK9WF	14.7	-0.422
DG3DK	15.62	-0.241
TF5SK	19	0.424
AO7VU	20.6	0.738
WQ3LN	41.3	**4.807**
AB4XQ	NULL	
CV6ZX	NULL	
EN2QS	NULL	

Lab Code	0.425 mm	Z-Score
DF6CP	9.7	**-1.117**
YY3QP	9.88	**-1.059**
AB4XQ	10.5	-0.857
DK9WF	11.7	-0.468
DG3DK	12.5	-0.208
AO7VU	13.6	0.149
TF5SK	15	0.604
CV6ZX	15	0.604
EN2QS	16	0.929
WQ3LN	41.3	**9.144**

Lab Code	0.300 mm	Z-Score
DF6CP	8.0	**-1.186**
DK9WF	9.7	-0.490
YY3QP	9.75	-0.469
DG3DK	10.14	-0.310
AO7VU	11.4	0.206
TF5SK	13	0.861
WQ3LN	41.3	**12.444**
AB4XQ	Null	
CV6ZX	Null	
EN2QS	NULL	

% passing	0.600 mm Round 1	0.600 mm Round 2	0.600 mm Round 3	0.425 mm Round 1	0.425 mm Round 2	0.425 mm Round 3	0.300 mm Round 1	0.300 mm Round 2	0.300 mm Round 3
H15 mean	8.9	13.5	16.84	7.4	9.9	13.14	6.1	8.5	10.90
H15 Std Dev	4.150	3.727	5.087	3.970	2.655	3.080	2.805	3.155	2.443
Range	9.00	8.4	29.51	11.00	10.5	3.16	5.90	11.50	33.3
CV	46.8%	27.6%	30.2%	53.6%	26.9%	23.4	46.3%	37.2%	22.4%

Lab Code	0.150 mm	Z-Score
AO7VU	3.2	**-1.342**
DF6CP	5.8	-0.448
DK9WF	6.5	-0.208
DG3DK	6.5	-0.208
TF5SK	7	-0.036
YY3QP	9.72	0.900
WQ3LN	41.2	**11.723**
AB4XQ	Null	
CV6ZX	Null	-
EN2QS	Null	-

Lab Code	0.075 mm	Z-Score
AO7VU	1.2	**-2.930**
CV6ZX	4	-0.622
DF6CP	4.2	-0.457
AB4XQ	4.2	-0.457
DG3DK	4.46	-0.243
DK9WF	4.7	-0.045
TF5SK	5	0.202
EN2QS	5	0.202
YY3QP	9.7	**4.076**
WQ3LN	41.1	**29.958**

% passing	0.150 mm Round 1	0.150 mm Round 2	0.150 mm Round 3	0.0750 mm Round 1	0.075 mm Round 2	0.075 mm Round 3
H15 mean	4.6	6.5	7.10	3.3	5.7	4.75
H15 Std Dev	2.363	2.785	2.908	2.294	1.943	1.213
Range	5.30	12.60	38.00	6.00	17.35	39.90
CV	51.7%	43.2%	40.9%	68.5%	34.3%	25.5%

	37,5 mm Rd 1	37,5 mm Rd 2	37,5 mm Rd 3	28/25 mm Rd 1	28/25 mm Rd 2	28/25 mm Rd 3	20/19 mm Rd 1	20/19 mm Rd 2	20/19 mm Rd 3
Additional participant statistics									
Number of participants	7	8	10	9	8	10	10	8	10
Non-participants	3	2	-	1	2	-	-	2	-
OB	-	-	-	-	-	-	-	-	-
Statistics for Z-scores < ±1									
Range	0.00	0.00	1.2	10	13.00	22	14.50	28.22	21.9
Percentage of participants	85.7	85.0	80.0	66.7	75.0	70.0	80.%	62.5	60.0
Reporting format									
Participants reported to 1 %	3	6	7	3	2	4	2	1	3
Participants reported to 0,1 %	3	1	3	4	4	5	6	3	5
Participants reported to 0,01 %	1	-	-	2	-	1	2	3	2

	14/13.2 mm Rd 1	14/13.2 mm Rd 1	14/13.2 mm Rd 1	10/9.5 mm Rd 2	10/9.5 mm Rd 2	10/9.5 mm Rd 2	7.1/6.7 mm Rd 3	7.1/6.7 mm Rd 3	7.1/6.7 mm Rd 3
Additional participant statistics									
Number of participants	9	8	10	7	7	7	6	7	7
Non-participants	1	2	-	3	3	3	4	3	3
OB	-	-	-	-	-		-	-	*

Statistics for Z-scores < ±1

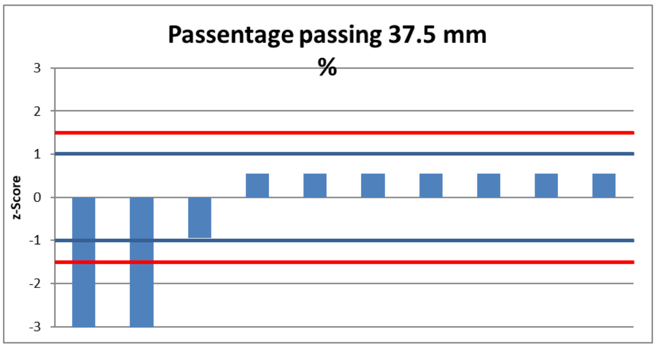
Range	15.8	22.8	23.8	7.6	18.5	21	19.7	19.8	20
Percentage of participants	80.0	75	60	71.4	71.4	50	83.3	71.5	5

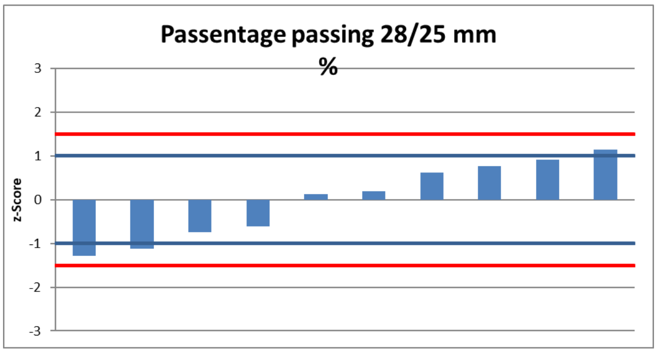
Reporting format

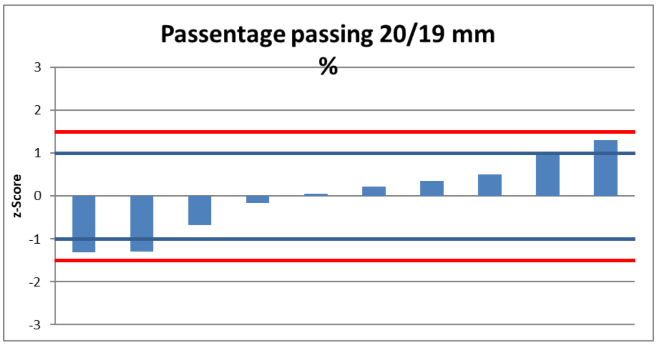
Participants reported to 1 %	2	2	4	-	2	1	-	2	1
Participants reported to 0,1 %	6	5	4	5	5	4	5	4	4
Participants reported to 0,01 %	2	1	2	2	-	2	1	-	2

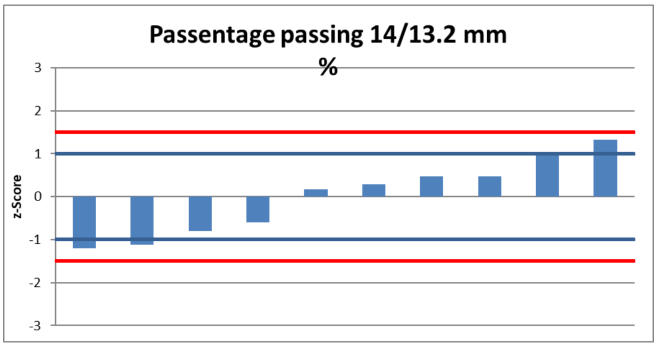
	2/2.36 mm Rd 1	2/2.36 mm Rd 1	2/2.36 mm Rd 1	1/1.18 mm Rd 1	1/1.18 mm Rd 1	1/1.18 mm Rd 1	0.600 mm Rd 1	0.600 mm Rd 1	0.600 mm Rd 1
Additional participant statistics									
Number of participants		10	10		7	7		7	7
Non-participants		-	-		3	3		3	3
OB		-	-		-	-		-	-
Statistics for Z-scores < ±1									
Range		10.29	12.2		5.05	18		2.70	8.8
Percentage of participants		70.0	60.0		71.4	60.0		71.4	60.0
Reporting format									
Participants reported to 1 %		1	5		1	2		1	1
Participants reported to 0,1 %		7	4		4	4		4	4
Participants reported to 0,01 %		2	1		2	1		2	2

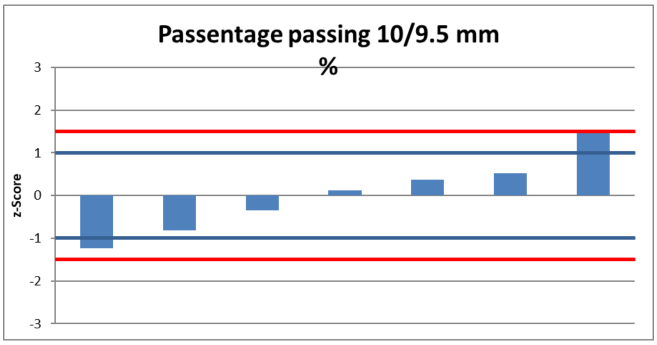
	0.425 mm Rd 1	0.425 mm Rd 1	0.425 mm Rd 1	0.300 mm Rd 2	0.300 mm Rd 2	0.300 mm Rd 2	0,150 mm Rd 3	0.150 mm Rd 3	0.150 mm Rd 3
Additional participant statistics									
Number of participants	9	8	10	7	7	/	7	7	7
Non-participants	2	2	-	3	3	3	3	3	3
OB	-	-	-	-		-	-	-	*
Statistics for Z-scores < ±1									
Range	5.5	5.5	5.5	1.70	1.70	3.3	1.9	1.9	3.92
Percentage of participants	62.5	62.5	70.0	71.4	71.4	71.4	71.4	71.4	71.4
Reporting format									
Participants reported to 1 %	1	1	4	-	-	1	-	-	1
Participants reported to 0,1 %	7	7	4	5	5	2	5	5	4
Participants reported to 0,01 %	-		1	2	2	3	2	2	2

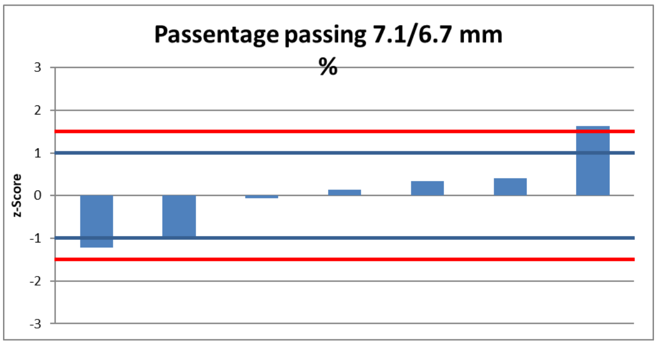

Passentage passing 37.5 mm
%
z-Score
3
2
1
0
-1
-2
-3

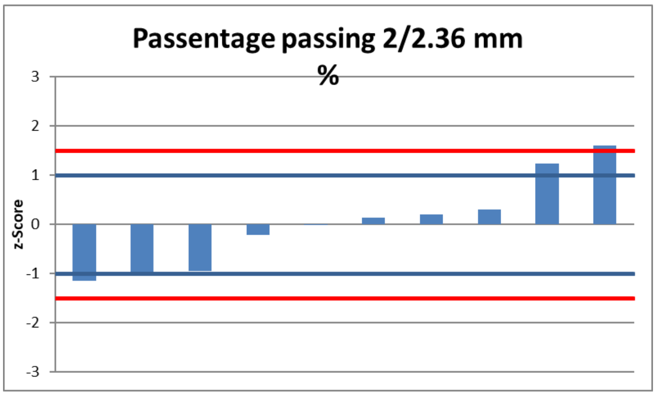

Passentage passing 28/25 mm
%
z-Score
3
2
1
0
-1
-2
-3

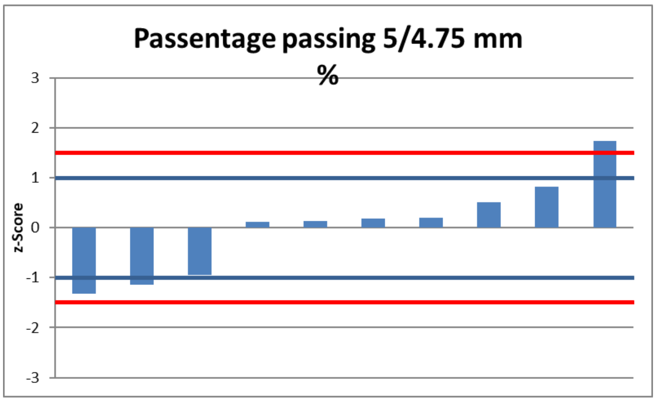

Passentage passing 20/19 mm
%
z-Score
3
2
1
0
-1
-2
-3

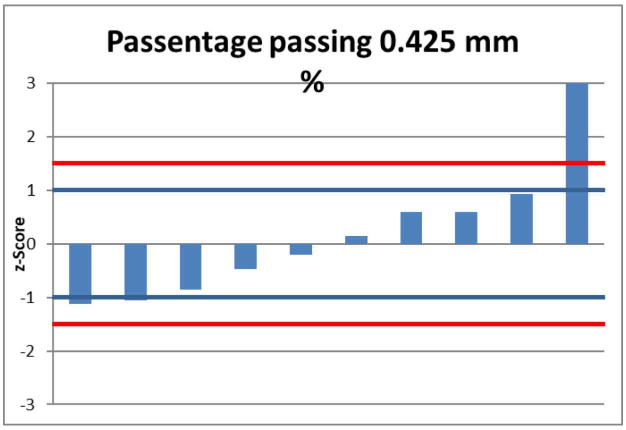

Passentage passing 14/13.2 mm
%
z-Score
3
2
1
0
-1
-2
-3

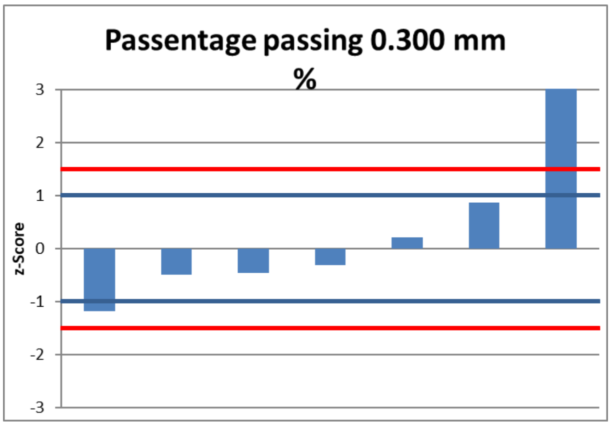

Passentage passing 10/9.5 mm
%
z-Score
3
2
1
0
-1
-2
-3

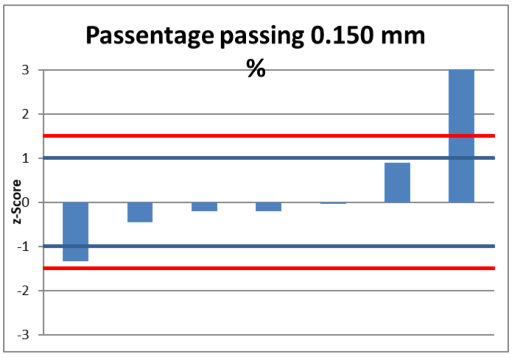

Passentage passing 7.1/6.7 mm
%
z-Score
3
2
1
0
-1
-2
-3

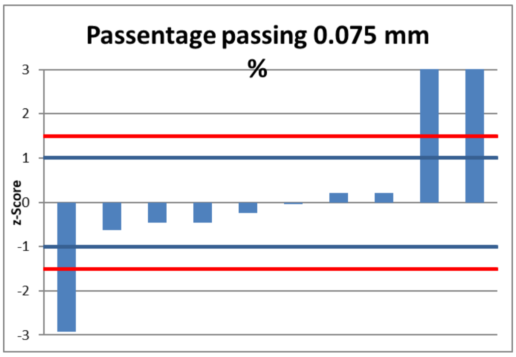

Passentage passing 2/2.36 mm
%
z-Score
3
2
1
0
-1
-2
-3


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


Passentage passing 0.425 mm
%
z-Score
3
2
1
0
-1
-2
-3


Passentage passing 0.300 mm
%
z-Score
3
2
1
0
-1
-2
-3





Comments – Washed Grading

- The Range of the two SA facilities averages 4 % & 1 % for coarse & fine material respectively versus 34 % & 35 % for the Mozambique facilities. As with the densities and CBR results, the Mozambican range is far too high.
- In general, for fine materials (0.425 to 0.075), the Mean and STDV, is fairly constant.
- For coarse materials although the Mean is slightly different the StDev, is fairly constant
- Two different methods (AASHTO & TMH1) were used by the Mozambican facilities which can add to the variability in their results. In some instances, the sieve sizes differ and the some of the facilities do not conduct the sieving on all the sieves.

Soil Mortar based on grading analysis

GM

Lab Code		Z-score
TF5SK	0.24	-7.635
WQ3LN	1.73	-2.401
AO7VU	2.37	-0.153
EN2QS	2.43	0.057
CV6ZX	2.45	0.128
DG3DK	2.5	0.303
DK9WF	2.62	0.725
AB4XQ	2.64	0.795
DF6CP	2.69	0.971
YY3QP	0	OB

Coarse sand

Lab Code	%	Z-score
WQ3LN	3.7	-1.239
DF6CP	4.8	-1.199
DK9WF	20	-0.652
CV6ZX	51.1	0.467
AO7VU	51.4	0.478
AB4XQ	53.2	0.543
EN2QS	57	0.680
DG3DK	63.7	0.921
YY3QP	0	OB
TF5SK	NULL	

Coarse sands ratio

Lab Code		Z-score
TF5SK	0.5	-0.522
CV6ZX	0.51	-0.522
EN2QS	0.556	-0.519
DG3DK	0.637	-0.513
DF6CP	0.74	-0.507
AO7VU	28	1.285
AB4XQ	28.2	1.298
WQ3LN	NULL	
DK9WF	NULL	
YY3QP	NULL	

	GM Round 1	GM Round 2	GM Round 3	Coarse Sand Round 1	Coarse Sand Round 2	Coarse Sand Round 3	Coarse Sand Ratio Round 1	Coarse Sand Ratio Round 2	Coarse Sand Ratio Round 3
H15 mean	2.77	2.25	2.414	55.26	39.84	38.113	2.94	16.23	8.449
H15 Std Dev	0.179	0.18	0.285	45.158	31.84	27.783	2.938	25.12	15.215
Range	0.51	0.34	2.45	86.00	63.50	60.0	8.87	0	27.70
CV	6.5%	7.1%	11.8%	81.7%	80.2%	72.9%	99.8%	154.9%	180.1%

Coarse fine sand

Lab Code	%	Z-score
WQ3LN	0.1	-1.588
AB4XQ	6	-0.436
DG3DK	7	-0.241
AO7VU	9.2	0.188
TF5SK	13	0.930
EN2QS	13	0.930
DF6CP	CBD	
DK9WF	NULL	
CV6ZX	NULL	
YY3QP	NULL	

Fine fine sand

Lab Code		Z-score
DF6CP	4.2	-1.091
TF5SK	5	-0.596
AB4XQ	5.6	-0.224
DG3DK	5.8	-0.100
EN2QS	7	0.643
CV6ZX	31.2	15.636
YY3QP	99.9	OB
AO7VU	NULL	
WQ3LN	NULL	
DK9WF	NULL	

Fine sand

Lab Code		Z-score
WQ3LN	0.1	-0.917
AB4XQ	6.2	-0.436
AO7VU	10.2	-0.121
TF5SK	13	0.099
DG3DK	23.3	0.910
DF6CP	31.4	1.548
YY3QP	0	OB
CV6ZX	NULL	-
DK9WF	NULL	
EN2QS	NULL	-

% passing	Coarse Fine Round 1	Coarse Fine Round 2	Coarse Fine Round 3	Fine Fine Round 1	Fine Fine Round 2	Fine Fine Round 3	Fine Round 1	Fine Round 2	Fine Round 3
H15 mean	4.20	7.7	8.236	3.60	4.6	5.962	2.65	4.75	14.033
H15 Std Dev	3.723	4.83	5.23	2.524	3.48	1.614	1.410	3.53	13.009
Range	11.40	3	12.90	4.40	16.55	27.00	3.50	6.79	31.30
CV	88.7%	62.7%	62.2%	70.1%	73.2%	27.1%	53.3%	74.3%	92.7%

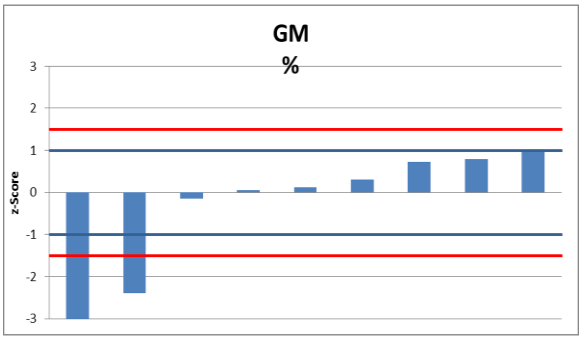
Medium fine sand		
Lab Code	%	Z-score
DF6CP	4.3	-0.964
AB4XQ	5	-0.728
TF5SK	7	-0.054
EN2QS	9	0.620
DG3DK	10.5	1.126
AO7VU	NULL	
WQ3LN	NULL	
DK9WF	NULL	
CV6ZX	NULL	
YY3QP	NULL	

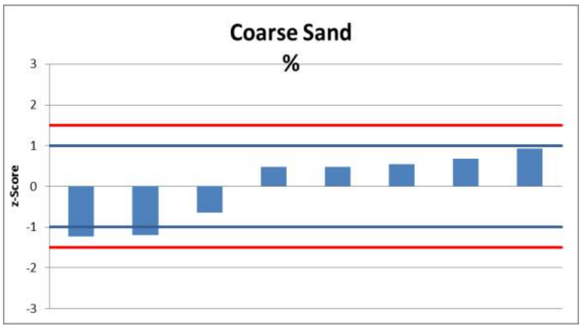
Soil mortar		
Lab Code	%	Z-score
AO7VU	1.2	-0.974
AB4XQ	1.3	-0.969
CV6ZX	11.1	-0.437
EN2QS	14	-0.280
TF5SK	31	0.642
DG3DK	34.4	0.827
WQ3LN	41.1	1.190
DF6CP	83.9	OB
DK9WF	NULL	
YY3QP	NULL	

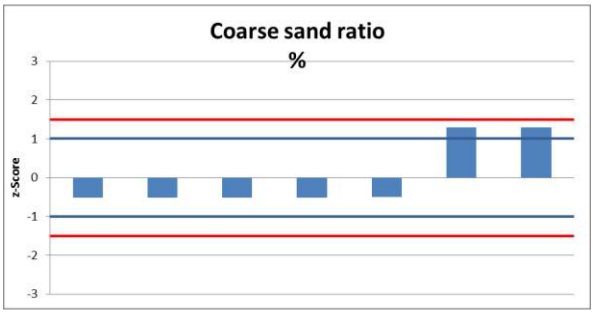
% passing	Medium Fine sand Round 1	Medium Fine sand Round 2	Medium Fine sand Round 3	Soil mortar Round 1	Soil mortar Round 2	Soil mortar Round 3
H15 mean	3.73	4.3	7.160	16.67	9.87	19.157
H15 Std Dev	3.557	2.87	2.967	19.909	11.87	18.433
Range	7.20	4.7	6.20	6999.20	27	39.90
CV	95.5%	66.6%	41.4%	119.4%	120.3%	96.2%

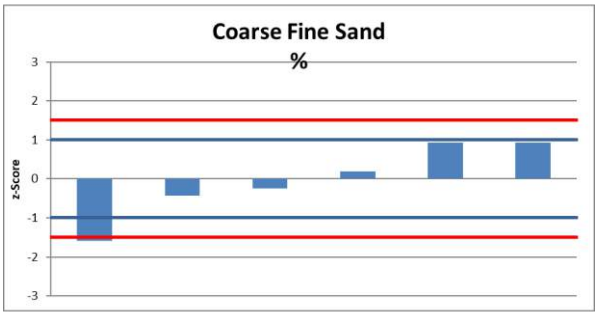
Method information

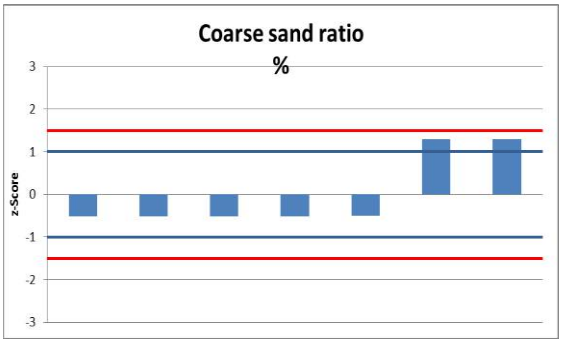
Method	AASHTO T27	SANS 3001 PR5	TMH1 A1 (a)	AASHTO T27	Non-responsive
# participants	2 (20 %)	3 (30 %)	3 (30 %)	1 (10%))	1 (NULL)

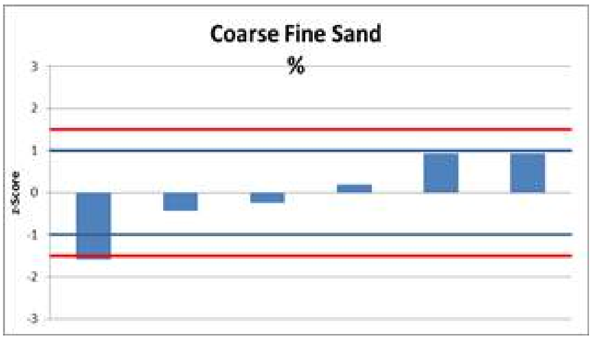


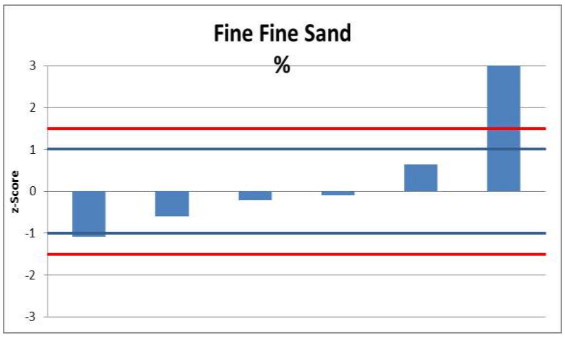


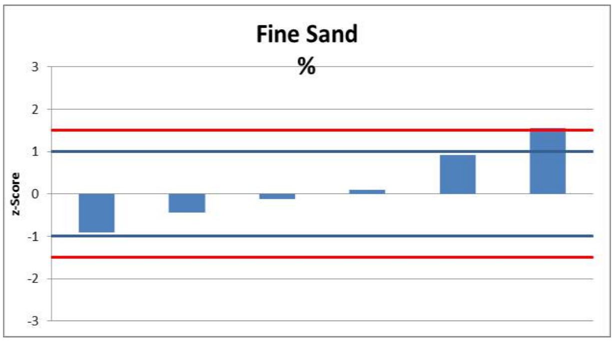


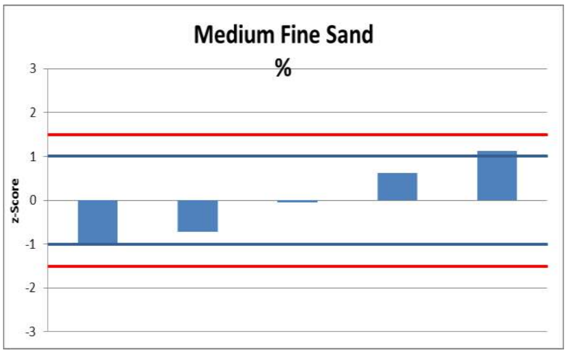


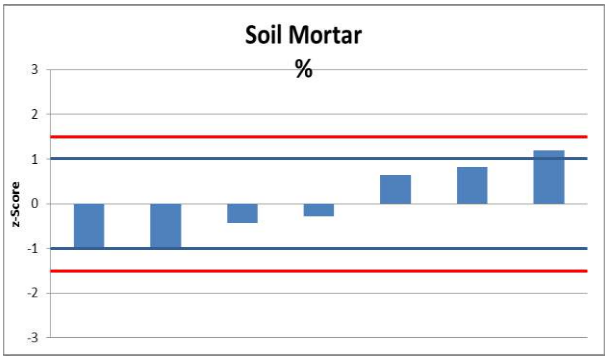












Comments – Soil mortars

- The calculations for the Soil Mortar constants are still not well understood by the various facilities and improvements need to be done so as to resolve the uncertainties into the future rounds.
- Between 2 and 5 participants did not report values for some of the Soil Mortar constants which has further influenced the accuracy of the results
- Should these calculations not form part of the Mozambican specifications it is proposed to have them removed from the PTS.
- Five of the eight Soil Mortar calculations reflected an increase in the StDev and CV this increase could be attributed to
    - the uncertainties in the inputs for the calculations
    - errors in the grading results
    - less participants in some of the data as supplied.

B. PLASTIC MATERIAL

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

Lab code	LL %	z-score
AB4WQ	33.2	-1.771
DK9WF	43	-1.038
EN2QS	58	0.083
TF5SK	61	0.307
CV6ZX	61.9	0.375
DG3DK	66	0.681
EN2QS	70	0.980
DF6CP	CBD	
AO7VU	NULL	
WQ3LN	NULL	

Lab code	PL %	z-score
AB4WQ	26	-1.140
DK9WF	27	-1.040
TF5SK	32	-0.541
EN2QS	42	0.458
EN2QS	42.9	0.548
CV6ZX	45	0.757
DG3DK	47	0.957
DF6CP	CBD	
AO7VU	NULL	
WQ3LN	NULL	

Lab code	LS %	z-score
AB4WQ	0.3	-3.589
EN2QS	7.4	-0.565
DG3DK	9	0.117
DK9WF	9.2	0.202
CV6ZX	9.3	0.245
EN2QS	13	1.821
DF6CP	CBD	
AO7VU	NULL	
TF5SK	NULL	
WQ3LN	NULL	

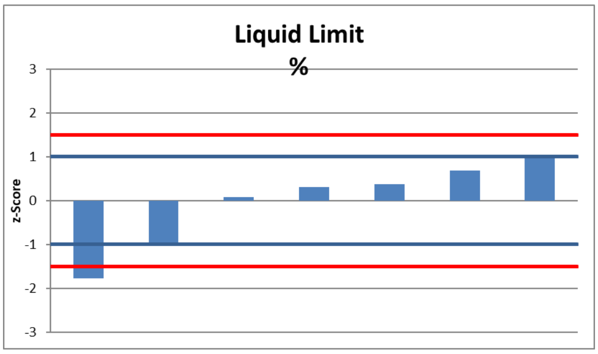
Lab code	PI %	z-score
AB4WQ	7.2	-1.380
DK9WF	15.2	-0.550
EN2QS	16	-0.467
CV6ZX	17	-0.363
DG3DK	19	-0.156
EN2QS	27.1	0.685
TF5SK	29	0.882
DF6CP	CBD	
AO7VU	NULL	
WQ3LN	NULL	

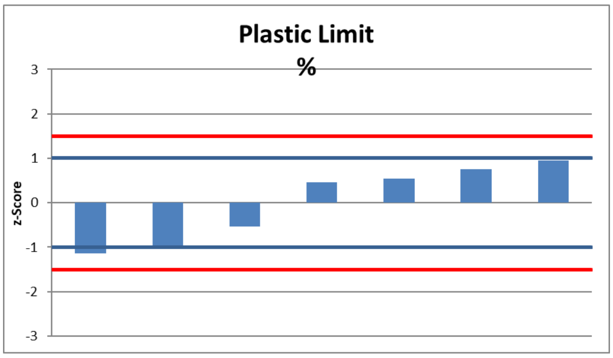
	LL Round 1	LL Round 2	LL Round 3	PL Round 1	PL Round 2	PL Round 3
H15 mean	33.57	60.07	56.889	24.75	38.65	37.414
H15 Std Dev	3.300	24.40	13.376	6.736	8.010	10.016
Range	21.90	69.8	36.80	23.20	49.40	21.00
CV	9.8%	41%	23.50%	27.2%	20.7%	26.8%

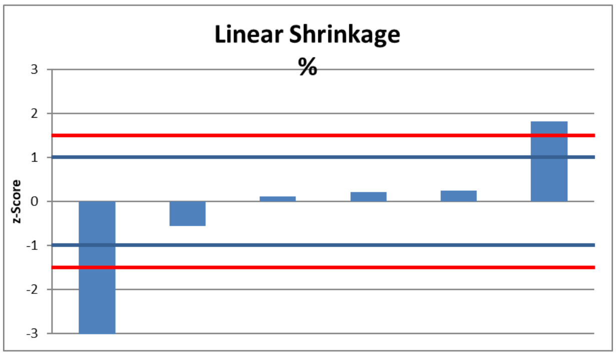
	LS Round 1	LS Round 2	LS Round 3	PI Round 1	PI Round 2	PI Round 3
H15 mean	3.03	11.31	8.725	9.67	27.8	20.500
H15 Std Dev	1.915	1.535	2.347	4.862	16.013	9.634
Range	9.10	12.90	12.70	20.30	48.00	19.90
CV	63.1%	13.6%	26.9%	50.3%	57.6%	47.0%

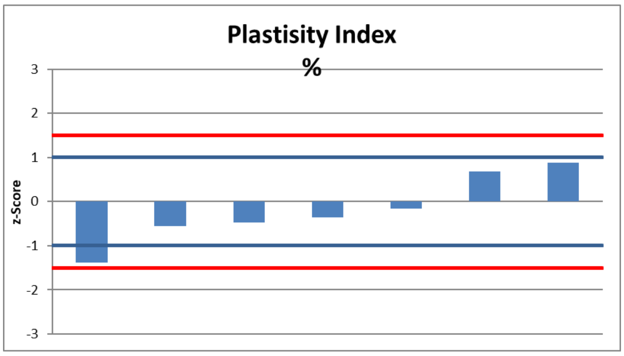
Method information

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









Comments – Atterberg limits

- The Range has decreased for all 4 results which is a positive sign however the StDev and the CV increased for the PL & LS and while it decreased for the LL & PI.
- The Sample material used for this set of results varied between the three rounds making the analysis somewhat more difficult to compare the results across all three rounds.
- As with the granular material from Form A, there is still concern in the laboratories ability to differentiate between plastic and non-plastic material. Three of the facilities determined the material to be non-plastic.

C. SAND MATERIAL

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

Lab code	LL %	z-score
DG3DK	16	0.021
DF6CP	20	0.331
WQ3LN	26.9	0.864
AB4XQ	CBD	
TF5SK	CBD	
EN2QS	CBD	
DK9WF	NP	
YY3QP	NP	
CV6ZX	0	OE
AO7VU		

Lab code	PL %	z-score
DF6CP	11.04	0.300
WQ3LN	14.4	0.693
AB4XQ	CBD	
TF5SK	CBD	
EN2QS	CBD	
AO7VU	NP	
DK9WF	NP	
DG3DK	NP	
YY3QP	NP	
CV6ZX	0	OE

Lab code	LS %	z-score
CV6ZX	0	-0.706
EN2QS	0	-0.706
WQ3LN	4.7	0.292
DF6CP	8.6	1.120
AB4XQ	CBD	
AO7VU	NP	
DK9WF	NP	
YY3QP	NP	
DG3DK	NULL	
TF5SK	NULL	

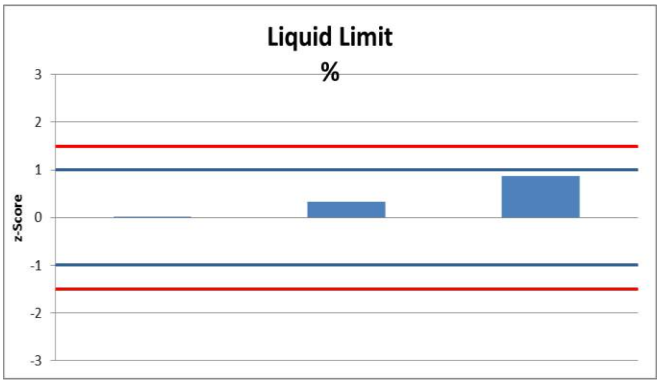
Lab code	PI %	z-score
DF6CP	5.7	-0.624
WQ3LN	12.5	0.624
TF5SK	CBD	
AO7VU	NP	
DK9WF	NP	
CV6ZX	NP	
EN2QS	NP	
YY3QP	NP	
DG3DK	NULL	
AB4XQ	SP	

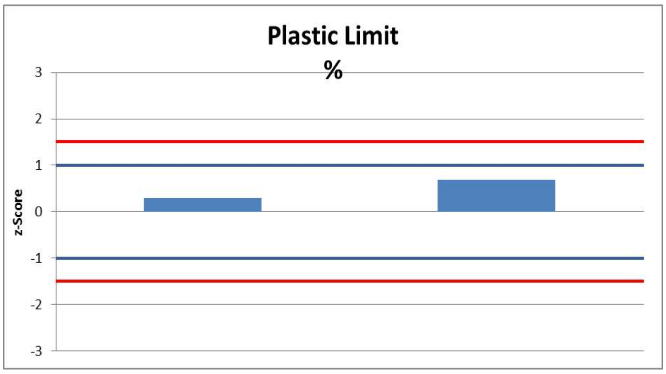
Method information

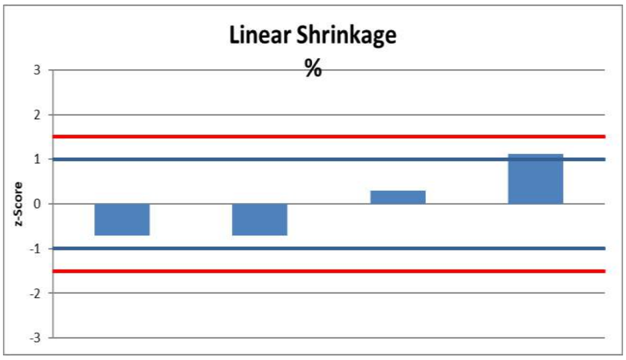
Method	AASHTO T89	SANS 3001 GR10/11/12	TMH1 A2, A3 & A4	Non-responsive
# participants	3(30 %)	2 (20 %)	3 (3 %)	1 (NULL)

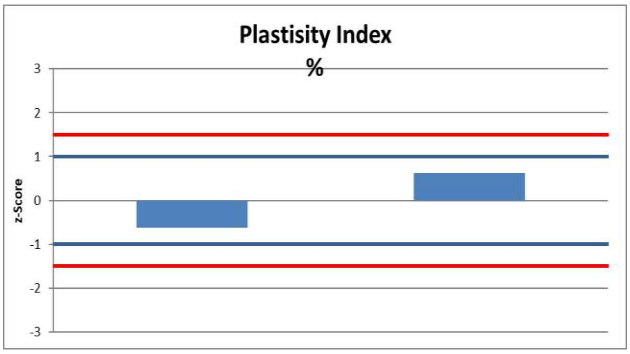
	LL Round 1	LL Round 2	LL Round 3	PL Round 1	PL Round 2	PL Round 3
H15 mean	15.90	5.8	15.725	11.47	0.00	12.72
H15 Std Dev	5.446	9.932	12.931	11.257	0.000	2.693
Range	24.90	25.60	10.90	17.40	13.60	3.36
CV	34.3%	171.5%	82.2%	98.2%	0.0%	21.2%

	LS round 1	LS round 2	LS round 3	PI Round 1	PI Round 2	PI Round 3
H15 mean	0.52	0.00	3.33	2.83	0.00	9.10
H15 Std Dev	0.725	0.000	4.711	4.615	0.000	5.450
Range	4.00	6.70	8.60	7.50	12.00	6.80
CV	140.1%	0.0%	141.7%	162.9%	0.0%	59.9%









	LL round 1	LL round 2	LL round 3	PL round 1	PL round 2	PL round 3
Number of participants	10	9	10	10	9	10
CBD	2	3	2	4	3	3
NP	2	2	3	2	2	4
SP	-	-	-	-	-	-
NULL	-	1	-	1	1	-
Non-participants	-	-	-	-	-	-
OB	-	1	1	-	-	1

Statistics for Z-scores < ±1

Range	5.0	1.7	10.9	0.4	0	3.36
Percentage of participants	66.7%	22.2%	30.0%	66.7%	100%	20%

Reporting format

Participants reported correctly to 1 %	2	2	3	1	2	-
Participants reported to 0,1 %	4	2	-	2	1	1

	LS round 1	LS round 2	LS round 3	PI round 1	PI round 2	PI round 3
Number of participants	10	9	10	10	9	10
CBD	1	-	1	2	1	1
NP	1		3	3	-	6
SP	-	3	-	-	-	1
NULL	1	1	2	2	1	1
Non-participants	-	-	-	-	-	
OB	-	-	-	-	-	-

Statistics for Z-scores < ±1

Range	0.4	0	4.7	1.0	0	6.8
Percentage of participants	71.4%	100%	30%	66.%	100%	20.0%

Reporting format

Participants reported correctly to 1 %		4	2	2	8	2
Participants reported to 0,1 %		1	2	1	-	-

COMMENTS – ATTERBERG LIMITS

- As noted in the comments for the results of Form A & B, again the identification of material that is plastic or non-plastic is again noted for the sand type material in Form C. Again, the reporting of the results in the correct manner e.g. LS given as an actual % shrinkage with the LL & PL both reported as CBD would correctly reflect a SP or NP material.

- Eight of the facilities have reported the material to be either NP or SP whereas two facilities did report obtaining a PI value. As a result of the majority reporting this material to be NP it is assumed that the two facilities that obtained a PI need to look carefully at their practice to determine what was done differently to the other facilities.
- The variety of methods ad apparatus used in by the various facilities also assist in adding to the variability of the Atterberg results in all three of the materials tested in this round and during the previous rounds.

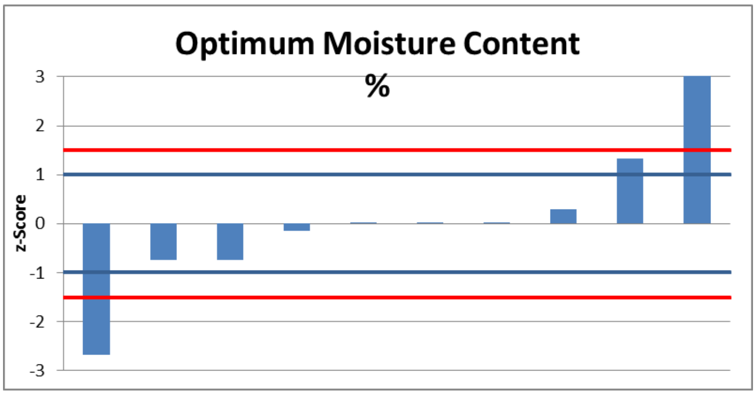
Optimum Moisture Content test

Lab code	OMC %	OMC z-score
CV6ZX	6.3	-2.674
WQ3LN	7.6	-0.743
TF5SK	7.6	-0.743
DF6CP	8.0	-0.149
DG3DK	8.1	0.000
AB4XQ	8.1	0.000
YY3QP	8.1	0.000
EN2QS	8.3	0.297
AO7VU	9.0	1.337
DK9WF	10.5	3.566

	OMC round 1	OMC round 2	OMC round 2
H15 mean	7.80	8.07	8.1
H15 Std Dev	0.819	0.907	0.673
Range	2.20	3.80	4.20
CV	10.5%	11.2%	8.3%

Method information

Method	AASHTO T180	SANS 3001 GR30	TMH1 A7	Non-responsive
# participants	4 (40 %)	2 (20 %)	4 (40 %)	-



Apparatus information

Apparatus	Automatic	Manual	Non-responsive
Hammer	1	8	1 (NULL)

Additional participant statistics

	Round 1	Round 2	Round 3
Number of participants	10	9	10
Non-participants	-	1	-
OB	-	-	-

Statistics for Z-scores < ±1

Range	1.1	1.2	0.7
Percentage of participants	70.0%	66.7%	

Reporting format

Participants reported correctly to 0,1 %	10	8	10
Participants reported to 1 %	-	1	-

COMMENTS - OPTIMUM MOISTURE CONTENT (OMC) TEST

- The mean OMC has remained fairly consistent during the three rounds.
- The StDev & CV have both decreased to the lowest value in the three rounds which is encouraging although the range did increase in this round.

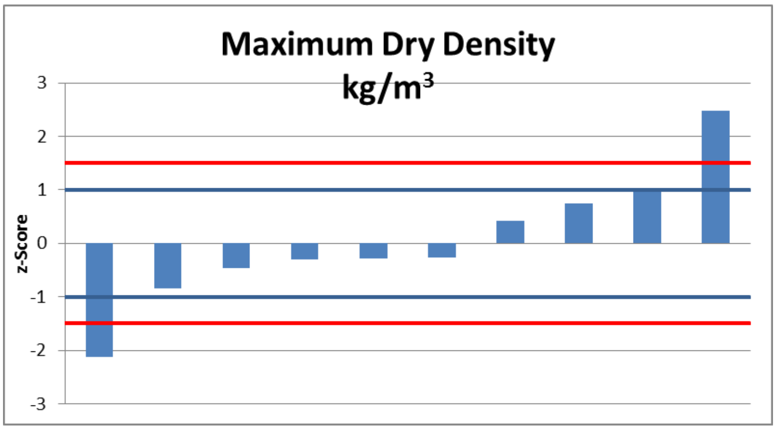
Maximum Dry Density test

Lab code	MDD kg/m³	MDD z-score
DK9WF	1857	**-2.128**
CV6ZX	1919	-0.846
WQ3LN	1937	-0.473
DF6CP	1945	-0.308
TF5SK	1946	-0.287
YY3QP	1947	-0.266
EN2QS	1980	0.416
DG3DK	1996	0.747
AB4XQ	2009	**1.016**
AO7VU	2080	**2.485**

	MDD Round 1	MDD Round 2	MDD Round 3
H15 mean	1983.4	1975.4	1959.9
H15 Std Dev	35.18	25.4	48.337
Range	98.00	61.00	223.00
CV	1.8%	1.3%	2.5%

Method information

Method	AASHTO T189	AASHTO T93	AASHTO T 180	SANS 3001 GR30	TMH1 A7	Non-responsive
# participants Round 1	3 (30 %)	1(10 %)	1(10%)	2 (20 %)	4 (40 %)	(NULL)



Additional participant statistics

	Round-1	Round-2	Round-3
Number of participants	10	9	10
Non-participants	-	-	-
OB	-	-	-

Statistics for Z-scores < ±1

Range	62.0	49.0	77.0
Percentage of participants	80.0%	77.8%	70.0%

Reporting format

Participants reported to 1 kg/m³	4	9	10
Participants reported to 0.1 kg/m³	1	-	-
Participants reported to 0.001	5	-	-

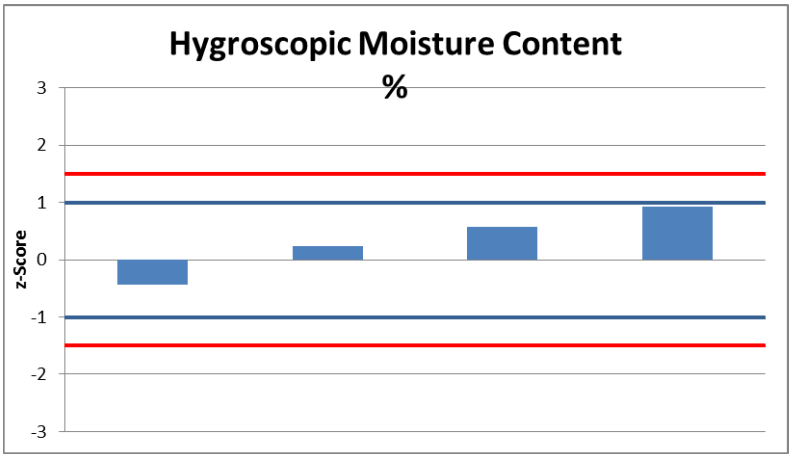
Comments -Maximum Dry Density (MDD) test

- The third rounds results for both StDev & CV have increased quite substantially.
- The SA labs have produced arrange on 61 kg/m^3, whereas the Mozambican labs have range of 223 kg/m^3. This range far too high (> 10 % of MDD) although its largely due to the two facilities on the extremities of the analysis.

CBR Hygroscopic Moisture Contents test

Lab ID	Hygroscopic Moisture content (%)	Z-score
WQ3LN	0.5	-0.443
AB4XQ	0.9	0.239
DG3DK	1.1	0.579
EN2QS	1.3	0.920
YY3QP	0	**-1.295**
AO7VU	NULL	
DK9WF	NULL	
DF6CP	NULL	
TF5SK	NULL	
CV6ZX	NULL	-

	Hygroscopic MC (%) Round 1	Hygroscopic MC (%) Round 2	Hygroscopic MC (%) Round 3
H15 mean	1.34	0.51	0.76
H15 Std Dev	1.07	0.13	0.587
Range	28.40	0.3	1.30
CV	79.8%	25.8%	77.2%



Additional participant statistics

	Round 1	Round 2	Round 3
Number of participants	9	6	10
Non-participants	1	1	-
NULL	2	3	5
OB	-	-	-

Statistics for Z-scores < ±1

Range	1.6	0.2	0.8
Percentage of participants	83.3%	83.3%	40.0%

Reporting format

Participants reported to 1 %	1	-	1
Participants reported correctly to 0,1 %	4	5	4
Participants reported to 0,01 %	1	1	-

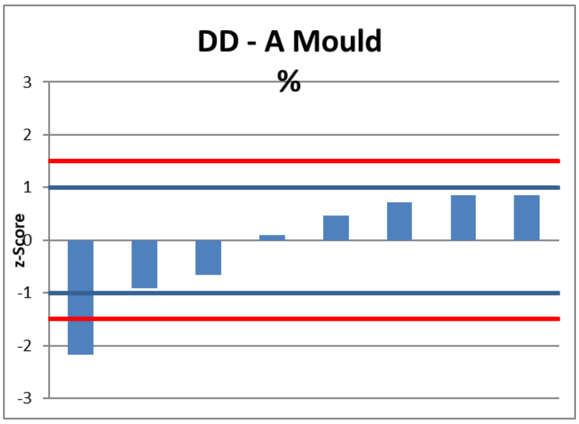
Comments - Hygroscopic Moisture Contents test

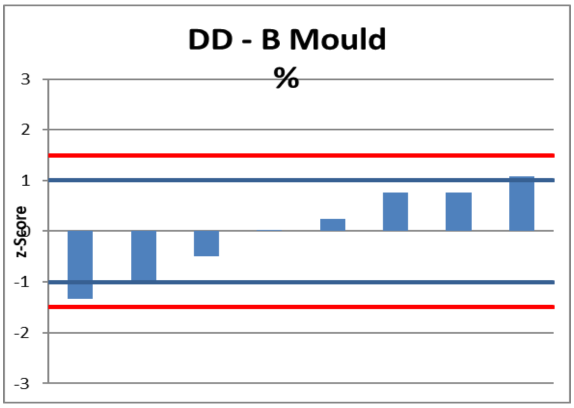
- The variability of the results is still quite high given that half the facilities did not report a value.
- All of the statistical values have increased in this round which is a concern.
- The concept of hygroscopic moisture is an important one in determining ho much water is to be added to obtain the OMC. This terminology needs to be well understood so the correct value is reported for analysis purpose.

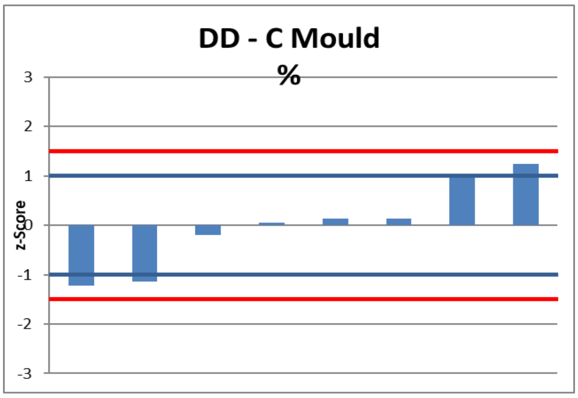
CBR - % Swell (A, B & C moulds)

Lab code	% Swell									
	A	Z-score		Lab Code	B	Z-score		Lab Code	C	Z-score
TF5SK	0	-0.667		EN2QS	0	-0.691		EN2QS	0	-0.730
EN2QS	0	-0.667		YY3QP	0	-0.691		YY3QP	0	-0.730
YY3QP	0	-0.667		DG3DK	0.02	-0.406		DG3DK	0.05	-0.291
DG3DK	0.01	-0.175		CV6ZX	0.08	0.447		CV6ZX	0.13	0.410
CV6ZX	0.03	0.809		WQ3LN	0.35	**4.287**		WQ3LN	0.39	**2.689**
WQ3LN	0.32	**15.080**		DF6CP	CBD			DF6CP	CBD	
DF6CP	CBD			AO7VU	NULL			AO7VU	NULL	
AO7VU	NULL			DK9WF	NULL			DK9WF	NULL	
DK9WF	NULL			AB4XQ	Null			AB4XQ	NULL	
AB4XQ	NULL			TF5SK	Null			TF5SK	NULL	

	Swell A (%) round 1	Swell A (%) round 2	Swell A (%) round 3	Swell B (%) round 1	Swell B (%) round 2	Swell B (%) round 3	Swell C (%) round 1	Swell C (%) round 2	Swell C (%) round 3
H15 mean	0.88	0.030	0.014	0.91	0.030	0.049	0.94	0.1481	0.083
H15 Std Dev	1.702	0.0538	0.020	1.759	0.0538	0.070	1.817	0.2346	0.114
Range	10.20	0.5	0.32	11.60	0.70	0.35	11.30	0.90	0.39
CV	193.5%	179.8	149.9%	193.1%	179.8	144.8%	192.8%	158.7%	137.1%







	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3

Additional participant statistics

Number of participants	10	5	10	10	5	10	10	5	10
Non-participants	-		-	-	-	-	-	-	-
CBD	2	1	1	2	1	1	2	1	1
NULL	1	5	2	1	5	4	1	5	4
OB	-	-	-	-	-	-	-	-	-

Statistics for Z-scores < ±1

Range	0.01	0.02	0.03	0.02	0.02	0.08	0.03	0.1	0.13
Percentage of participants	71.4%	33.3%	40%	71.4%	33.3%	40.0%	71.4%	33.3%	40.0%

Reporting format

Participants reported to 1 %	2	2	3	2	2	2	2	1	2
Participants reported correctly to 0,1 %	3	1	3	3	1	-	3	2	-
Participants reported to 0,01 %	2	1	-	2	1	3	2	1	3

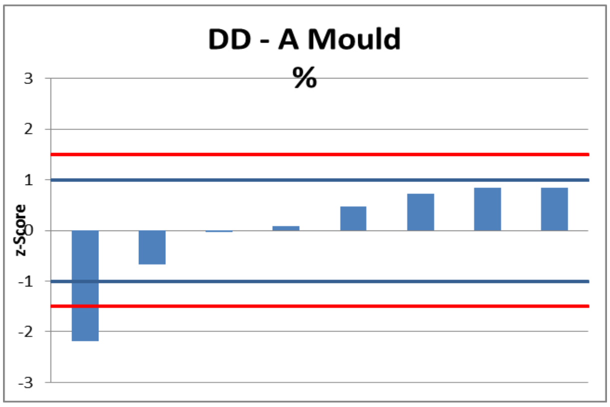
COMMENTS - % SWELL (A, B & C MOULDS)

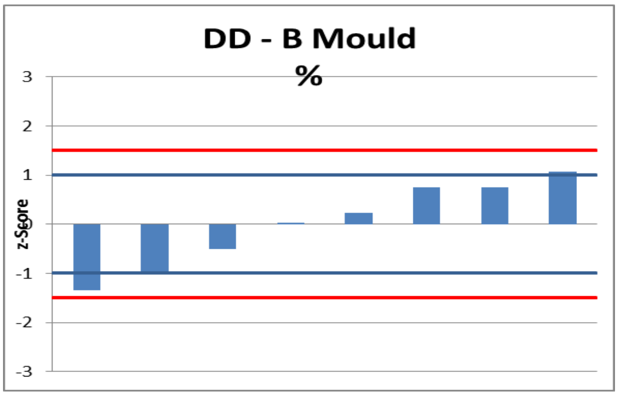
- Only three of the Mozambican facilities reported the swell.
- In general, there has been an improvement on swell determinations although five of the facilities did not provide a result.
- One of SA labs are lower side and other on higher side with a range of 0.08 % whereas the Mozambican facilities range was 0.41 %.

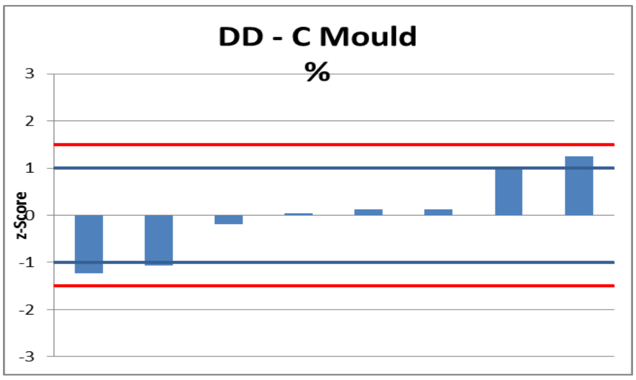
Dry Density % (A, B & C moulds)

Lab Code	% DD									
	A	Z-score		Lab Code	B	Z-score		Lab Code	C	Z-score
TF5SK	98	-2.181		YY3QP	94	-1.337		CV6ZX	89.9	-1.225
AB4XQ	99.2	-0.666		AB4XQ	94.3	-1.022		YY3QP	90.1	-1.066
YY3QP	99.7	-0.034		CV6ZX	94.8	-0.498		AB4XQ	91.2	-0.189
CV6ZX	99.8	0.092		DG3DK	95.3	0.026		EN2QS	91.5	0.050
EN2QS	100.1	0.471		DF6CP	95.5	0.236		DF6CP	91.6	0.130
DF6CP	100.3	0.723		DK9WF	96	0.760		DG3DK	91.6	0.130
DK9WF	100.4	0.850		TF5SK	96	0.760		DK9WF	92.7	1.006
DG3DK	100.4	0.850		EN2QS	96.3	1.075		TF5SK	93	1.245
WQ3LN	2085	OB		WQ3LN	2072	OB		WQ3LN	2040	OB
AO7VU	NULL			AO7VU	NULL			AO7VU	NULL	

	A mould (%) Round 1	A mould (%) Round 2	A mould (%) Round 3	B mould (%) Round 1	B mould (%) Round 2	B mould (%) Round 3	C mould (%) Round 1	C mould (%) Round 2	C mould (%) Round 3
H15 mean	99.0	99.3	99.727	94.9	95.1	95.28	90.9	90.6	91.44
H15 Std Dev	1.504	0.58	0.792	1.185	0.83	0.954	1.054	1.23	1.255
Range	91.00	1.4	2.40	87.40	2.2	2.30	84.50	3.6	3.10
CV	1.5%	0.6%	0.8%	1.2%	0.9%	10%	1.2%	1.4%	1.4%







	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
Additional participant statistics									
Number of participants	10	9	10	10	9	10	10	9	10
Non-participants	-	-	-	-	-	-	-	-	-
NULL	-	1	1	-	1	-	-	1	2
OB	-	-	1	-	-	1	-	-	1
Statistics for Z-scores < ±1									
Range	2.2	0.9	1.2.	3.1	1.3	1.2	0.7	1.4	0.4
Percentage of participants	80.0%	62.5%	70.0%	70.0%	75.0%	50.0%	80.0%	75.0%	40.0%
Reporting format									
Participants reported to 1 %	2	2	2	1	1	3	1	2	2
Participants reported to 0,1 %	8	6	6	9	7	5	9	6	6

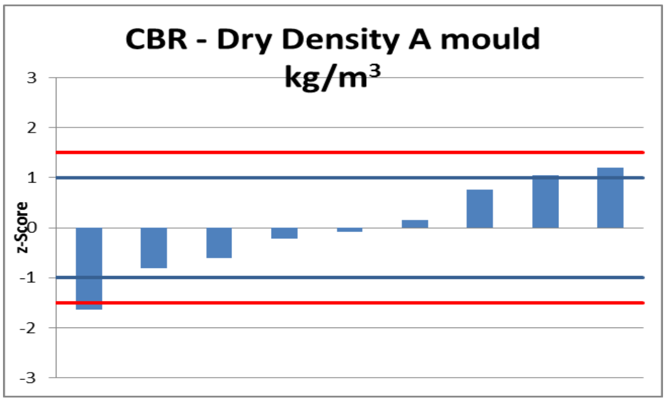
COMMENTS - MAXIMUM DRY DENSITY % (A, B & C MOULDS)

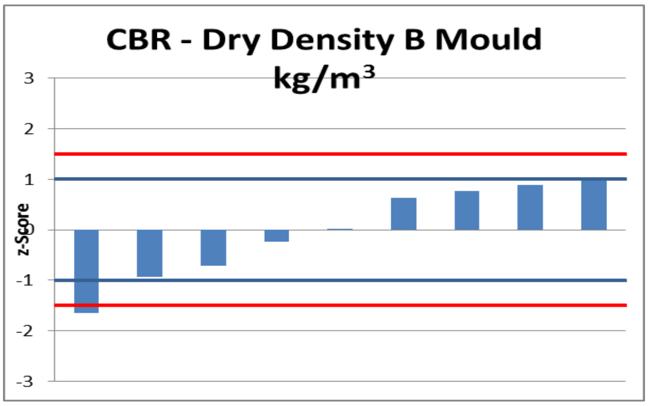
- The mean reflects the expected results of close to 100 %, 95 % and 90 % of MDD, with an acceptably low range.
- One of the Mozambican facilities again reported the density instead of the % of DD in this round.
- The difference of SA labs results is 0.3% on A mould, 1.5% on B and 1.6% on C mould, and of Mozambican labs are 2.4% on A mould, 2.0% on B, and 1.9% on C mould.

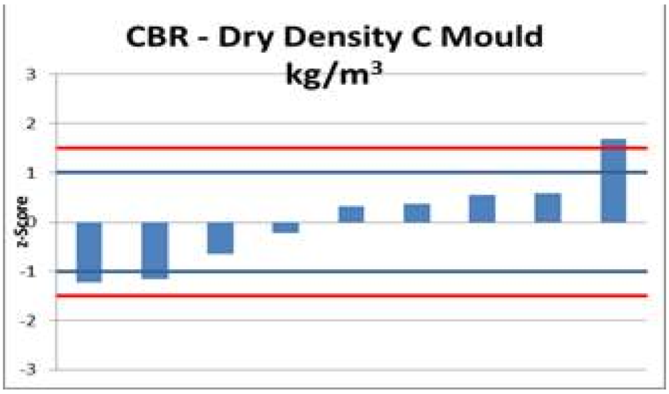
CBR - Dry Density kg/m³ (A, B & C moulds)

Lab Code	Dry Density (kg/m³)									
	A	Z-score		Lab Code	B	Z-score		Lab Code	C	Z-score
DK9WF	1865	-1.637		DK9WF	1783	-1.652		DK9WF	1722	-1.231
TF5SK	1905	-0.817		CV6ZX	1820	-0.941		CV6ZX	1726	-1.162
CV6ZX	1915	-0.613		YY3QP	1832	-0.710		YY3QP	1756	-0.647
WQ3LN	1934	-0.223		DF6CP	1857	-0.229		DF6CP	1781	-0.218
YY3QP	1941	-0.080		TF5SK	1869	0.002		EN2QS	1813	0.330
DF6CP	1952	0.145		DG3DK	1901.6	0.630		TF5SK	1816	0.382
EN2QS	1982	0.760		EN2QS	1909	0.772		AB4XQ	1826	0.553
AB4XQ	1996	1.047		AB4XQ	1915	0.887		DG3DK	1827.4	0.577
DG3DK	2003.3	1.196		WQ3LN	1921	1.003		WQ3LN	1892	1.686
AO7VU	NULL			AO7VU	NULL			AO7VU	NULL	

	A mould round 1	A mould round 2	A mould round 3	B mould round 1	B mould round 2	B mould round 3	C mould round 1	C mould round 2	C mould round 3
H15 mean	1972	1968	1944.9	1893	1882	1868.9	1818	1791	1793.7
H15 Std Dev	32.37	25.62	48.815	34.57	30.91	51.973	40.46	37.25	58.296
Range	87.10	62.40	138.30	107.00	75.0	138.0	144.00	81.0	170.0
CV	1.6%	1.3%	2.5%	1.8%	1.6%	2.8%	2.2%	2.1%	3.2%







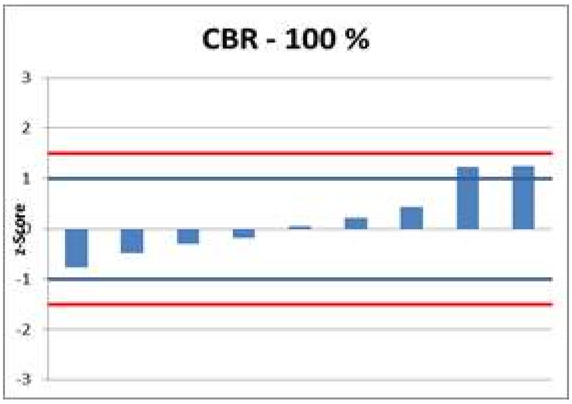
Comments - Dry Density kg/m^3 (A, B & C moulds)

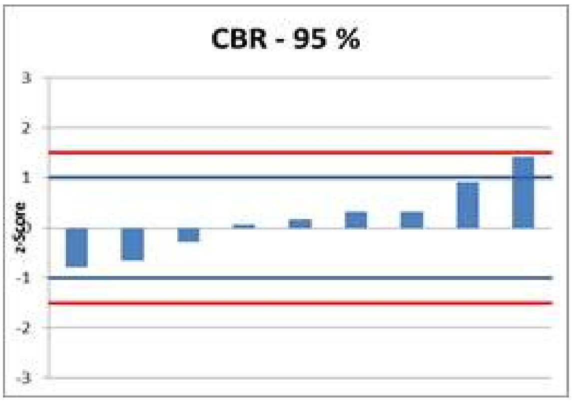
- In this round all the statistical values have increased which is a concern.
- The major variability was in the Mozambican facilities especially on the C mould. The range was as follow: Mozambican labs range was 138, 138 & 170 and the SA facilities 67, 89 & 87 on A, B, and C moulds respectively. The Mozambican range is more than double that of the SA facilities.

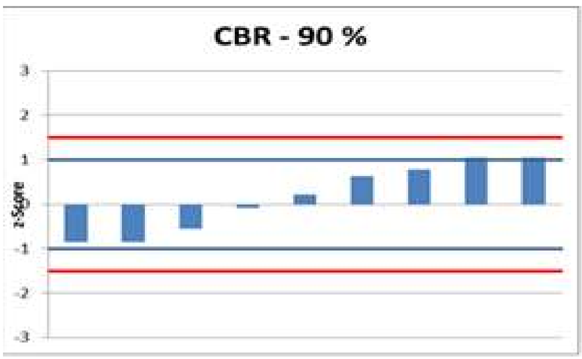
CBR %

CBR %										
Lab Code	100%	Z-score		Lab Code	95%	Z-score		Lab Code	90%	Z-score
WQ3LN	27.1	-0.770		WQ3LN	18.1	-0.792		TF5SK	5	-0.856
DF6CP	35	-0.478		CV6ZX	20	-0.650		CV6ZX	5	-0.856
EN2QS	40	-0.293		EN2QS	25	-0.278		WQ3LN	9.4	-0.547
DK9WF	43	-0.182		YY3QP	29.7	0.072		EN2QS	16	-0.082
YY3QP	49.3	0.051		DF6CP	31	0.169		YY3QP	20.4	0.228
AB4XQ	54	0.224		DK9WF	33	0.318		DF6CP	26	0.622
TF5SK	60	0.446		TF5SK	33	0.318		DG3DK	28.1	0.770
CV6ZX	81	**1.222**		AB4XQ	41	0.914		DK9WF	32	**1.044**
DG3DK	81.6	**1.244**		DG3DK	47.9	**1.428**		AB4XQ	32	**1.044**
AO7VU	NULL			AO7VU	NULL			AO7VU	NULL	

CBR %	Mould 100 % Round 1	Mould 100 % Round 2	Mould 100 % Round 3	Mould 95 % Round 1	Mould 95 % Round 2	Mould 95 % Round 3	Mould 90 % Round 1	Mould 90 % Round 2	Mould 90 % Round 3
H15 mean	40.29	48.28	47.93	25.53	24.59	28.73	15.71	11.67	17.17
H15 Std Dev	31.714	28.54	27.063	20.767	14.51	13.426	14.241	6.96	14.205
Range	67.50	77.10	54.50	49.99	37.50	29.80	46.52	29.7	27.00
CV	78.7%	59.1%	50.2%	81.3%	59.0%	46.7%	90.7%	59.6%	82.8%







	A mould Round 1	A mould Round 2	A mould Round 3	B mould Round 1	B mould Round 2	B mould Round 3	C mould Round 1	C mould Round 2	C mould Round 3
Additional participant statistics									
Number of participants	10	9	10	10	9	10	10	9	10
Non-participants	-	1	-	-	1	-	-	1	-
NULL	-	1	1	-	1	1	-	1	1
OB	-	-	-	-	-	-	-		-
Statistics for Z-scores < ±1									
Range (kg/m^3)	44.0	49.2	32.9	40.0	15.1	22.9	23.8	9.0	23.1
Percentage of participants	50.0%	75.0%	70.0%	80.0%	75.0%	80.0%	70.0%	62.5%	70.0%
Reporting format									
Participants reported correctly to 1 %	4	5	6	4	4	6	4	5	6
Participants reported to 0,1 %	5	2	3	5	3	3	5	2	3
Participants reported to 0,01 %	1	1	-	1	1	-	1	1	-

Comments –CBR %

- The variability of CBR results is considered unacceptably high taking into account the Mean of CBR.
- All the statistical values have increased in this round quite considerably.
- For both the SA and Mozambican facilities, especially on the A mould where for mould A, SA facilities had a range of 83.5 % and a corresponding value of 113.7 % for the Mozambican facilities.
- The variability on B&C mould were as follows SA facilities: 17.40 % and 64.1 % respectively and Mozambican facilities: 103.7 % and 157 % respectively.

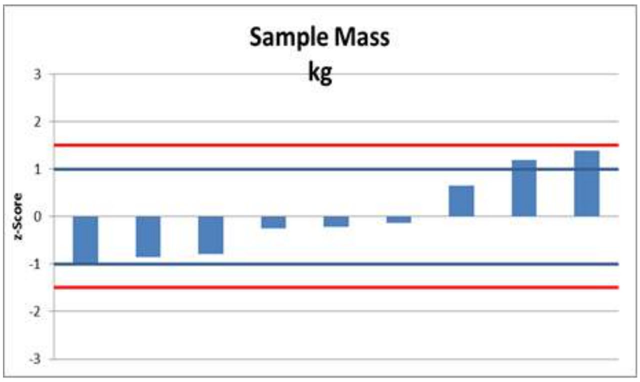
Washed Grading

#	Lab code	Sample mass (g)	z-score
1	AB4XQ	385.7	-0.995
2	TF5SK	503	-0.853
3	EN2QS	555.9	-0.788
4	DG3DK	1000.24	-0.249
5	DK9WF	1035.5	-0.206
6	DF6CP	1090.7	-0.139
7	AO7VU	1745.0	0.654
8	CV6ZX	2189	**1.193**
9	WQ3LN	2346	**1.384**
10	YY3QP	Null	

	Sample mass Round 1	Sample mass Round 2	Sample mass Round 3
H15 mean	1029.8	1393.0	1205.67
H15 Std Dev	564.36	1135.1	824.23
Range	1300.00	2617.10	1960.30
CV	54.8%	81.5%	68.4%

Method information

Method	AASHTO T27	SANS 3001 GR1	TMH1 A1 (a)	Non-responsive
# participants-round 2	2 (20 %)	2 (20 %)	5 (50 %)	-



	Sample Mass round 1	Sample Mass round 2	Sample Mass round 3
Additional participant statistics			
Number of participants	6	9	10
Non-participants	4	2	-
OB	-	-	-
Statistics for Z-scores < ±1			
Range	872.0	1681.1	1359.3
Percentage of participants	83.3%	85.7%	70.0%
Reporting format			
Participants reported to 1 g	2	2	3
Participants reported to 0,1 g	4	5	4
Participants reported to 0,01 g	-	-	1

COMMENTS - WASHED GRADING SAMPLE MASS

- Three methods were used by the 9, participants in the grading analysis.
- There still large range in the mass used that needs to be resolved to ensure more consistent results

Washed Grading

NOTE: Fraction 5 mm, 3.35 & 2.35 mm were not analyzed as they all had 100 % passing

Lab Code	2 / 2.36 mm	Z-Score
AO7VU	100	
WQ3LN	100	
DK9WF	100	
DF6CP	100	
DG3DK	100	
TF5SK	100	
CV6ZX	100	
EN2QS	100	
YY3QP	100	
AB4XQ	Null	

Lab Code	1 / 1.18 / 0.810 mm	Z-Score
AO7VU	99.5	-2.393
WQ3LN	99.8	-0.400
DK9WF	99.8	-0.400
DF6CP	99.80	-0.400
DG3DK	99.97	0.730
TF5SK	100	0.929
YY3QP	100	0.929
AB4XQ	NULL	
CV6ZX	NULL	_
EN2QS	NULL	_

Lab Code	0.600 mm	Z-Score
AO7VU	63.3	-13.513
WQ3LN	95.6	-0.684
DK9WF	96.3	-0.406
DG3DK	96.4	-0.367
DF6CP	97.5	0.070
TF5SK	99	0.666
AB4XQ	100	1.063
YY3QP	100	1.063
CV6ZX	NULL	_
EN2QS	NULL	_

% passing	2 / 2.36 mm Round 1	2 / 2.36 mm Round 2	2 / 2.36 mm Round 3	1 / 1.18 mm Round 1	1 / 1.18 mm Round 2	1 / 1.18 mm Round 3	0.600 mm Round 1	0.600 mm Round 2	0.600 mm Round 3
H15 mean	100.00	99.97	100.0	99.72	99.8	99.86	96.37	96.6	97.32
H15 Std Dev	0.000	0.065	0.00	0.144	0.216	0.150	1.217	1.036	2.518
Range	0.10	*99.33*	0.00	0.51	*99.3*	0.50	4.10	*58.7*	*36.70*
CV	0.0%	*0.1%*	0.0%	0.1%	*0.2%*	0.2%	1.3%	*1.1%*	*2.6%*

Lab Code	0.420 / 0.425 mm	Z-Score
AO7VU	38	-15.549
DK9WF	83.5	-0.859
WQ3LN	84	-0.698
AB4XQ	85.4	-0.246
CV6ZX	86	-0.052
DG3DK	86.12	-0.013
YY3QP	87.07	0.293
DF6CP	87.2	0.335
EN2QS	90	1.239
TF5SK	97	3.499

Lab Code	0.300 mm	Z-Score
AB4XQ	8.8	-1.605
AO7VU	26.5	-0.961
YY3QP	50.9	-0.074
DG3DK	51.03	-0.069
DK9WF	53.5	0.021
WQ3LN	58.2	0.192
DF6CP	77.7	0.901
TF5SK	90	1.349
CV6ZX	NULL	_
EN2QS	NULL	_

Lab Code	0.250 mm	Z-Score
TF5SK	66	
AO7VU	NULL	
DF6CP	NULL	
DG3DK	NULL	
CV6ZX	NULL	
EN2QS	NULL	
YY3QP	Null	
WQ3LN	66	
DK9WF	NULL	
AB4XQ	NULL	

% passing	0.425 mm Round 1	0.425 mm Round 2	0.425 mm Round 3	0.300 mm Round 1	0.300 mm Round 2	0.300 mm Round 3	0.250 mm Round 1	0.250 mm Round 2	0.250 mm Round 2
H15 mean	86.60	80.85	86.16	52.72	56.70	52.92	-	-	-
H15 Std Dev	5.239	12.143	3.097	17.474	24.164	27.249	-	-	-
Range	40.36	62.30	59.00	31.40	73.30	81.20	-	-	-
CV	6.1%	15.0%	3.6%	33.1%	42.6%	51.9%	-	-	-

Lab Code	0.105 / 0.150 mm	Z-Score
AO7VU	13.7	-1.747
DK9WF	17	-0.656
TF5SK	18	-0.325
YY3QP	18.6	-0.127
DG3DK	20.7	0.568
WQ3LN	21.8	0.932
DF6CP	22	0.998
AB4XQ	0	OB
CV6ZX	NULL	_
EN2QS	NULL	_

Lab Code	0.075 mm	Z-Score
YY3QP	12.63	-0.645
AO7VU	12.7	-0.613
DG3DK	12.79	-0.573
DK9WF	13.3	-0.342
TF5SK	14	-0.024
DF6CP	14.9	0.384
EN2QS	16	0.882
WQ3LN	16.3	1.018
CV6ZX	17	1.335
AB4XQ	0	OB

% passing	0.150 mm Round 1	0.150 mm Round 2	0.150 mm Round 3	0.075 mm Round 1	0.075 mm Round 2	0.075 mm Round 3
H15 mean	18.64	23.73	18.98	13.60	15.20	14.40
H15 Std Dev	2.879	13.115	3.024	1.203	3.643	1.929
Range	8.48	78.60	8.30	115.80	26.60	4.37
CV	15.4%	55.3%	15.9%	8.9%	24.0%	13.4%

	2/2.36 mm Round 1	2/2.36 mm Round 2	2/2.36 mm Round 3	1/1.18 mm Round 1	1/1.18 mm Round 2	1/1.18 mm Round 3	0.600 mm Round 1	0.600 mm Round 2	0.600 mm Round 3
Additional participant statistics									
Number of participants	8	9	10	6	9	10	5	9	10
Non-participants	2	7	-	4	3	-	5	3	-
OB	-	-	-	-	-	-	-	-	-
Statistics for Z-scores < ±1									
Range	0.0	0.0	0	0.2	0.2	0.2	1.4	1.3	3.4
Percentage of participants	85.7%	66.7%	100%	83.3%	74.1%	60.0%	66.7%	71.4%	50.0%
Reporting format									
Participants reported to 1 %	3	2	8	-	2	2	-	2	3
Participants reported to 0,1 %	2	1	-	4	5	3	4	5	5
Participants reported to 0,01 %	3	-	-	1	-	2	1	-	-

	0.425 mm Round 1	0.425 mm Round 2	0.425 mm Round 3	0.300 mm Round 1	0.300 mm Round 2	0.300 mm Round 3	0.150 mm Round 1	0.150 mm Round 2	0.150 mm Round 3
Additional participant statistics									
Number of participants	8	9	10	5	9	10	6	9	10

Non-participants	2	3	-	5	3	-	4	3	-
OB	-	-	-	-	-	-	-	-	1

Statistics for Z-scores < ±1

Range	2.9	13.0	3.7	31.4	31.1	51.2	3.3	3.6	5
Percentage of participants	66.7%	77.8%	70.0%	100.0%	71.4%	60.0%	66.7%	57.1%	60.0%

Reporting format

Participants reported to 1 %	1	4	5	1	4	1	-	2	4
Participants reported to 0,1 %	5	5	3	3	3	5	4	5	3
Participants reported to 0,01 %	2	-	2	1	-	1	2	-	-

Additional participant statistics

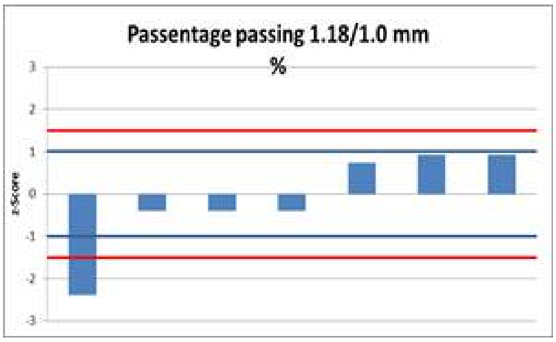
	0.075 mm Round 1	0.075 mm Round 2	0.075 mm Round 3
Number of participants	9	9	10
Non-participants	1	1	-
OB		-	1

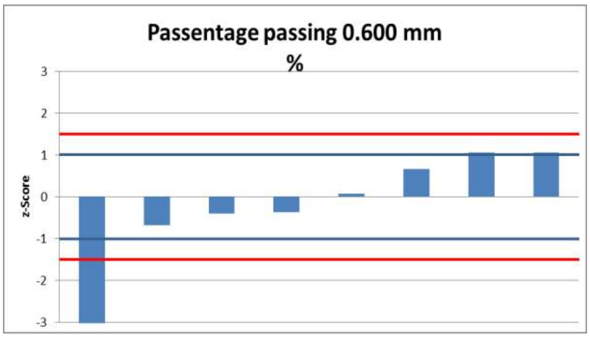
Statistics for Z-scores < ±1

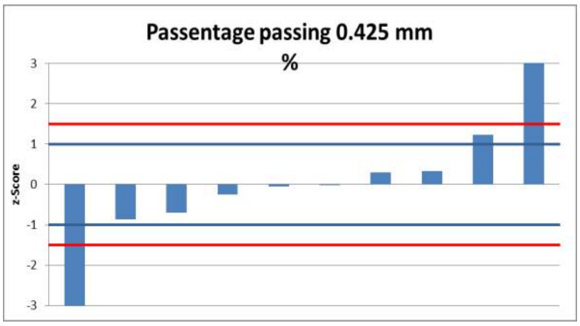
Range	1.9	2.1	3.37
Percentage of participants	77.8%	66.7%	70.0%

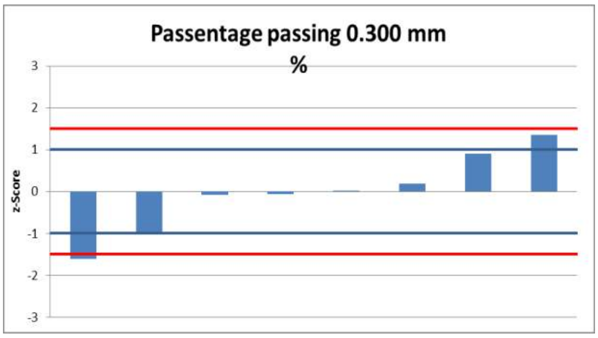
Reporting format

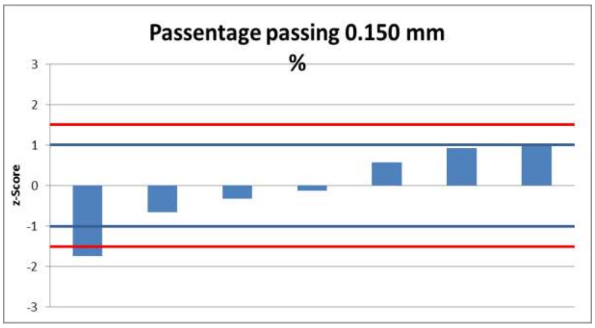
Participants reported to 1 %	2	5	3
Participants reported to 0,1 %	5	4	4
Participants reported to 0,01 %	2	-	1

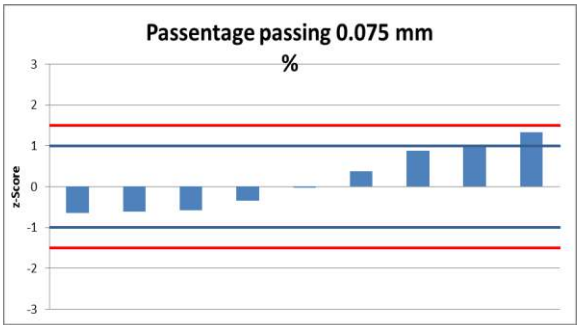












COMMENTS - WASHED GRADING

- Due to the various methods used some of the sieve sizes do not have a full set of results making it more difficult to determine the trends.
- On the third round in general the variability is less than others round with the exception of the 0.600 and 0.300 mm sieves.

Soil Mortar based on grading analysis

Lab ID	GM	
	%	Z-score
TF5SK		Z-score
WQ3LN	0.1	-0.955
AO7VU	1	0.171
DK9WF	1.49	0.784
DF6CP	NULL	
DG3DK	NULL	
AB4XQ	NULL	
CV6ZX	NULL	
EN2QS	NULL	_
YY3QP	NULL	_

Lab ID	FM	
	%	Z-score
DF6CP	1.03	-0.972
YY3QP	1.43	-0.410
WQ3LN	1.5	-0.312
AO7VU	1.98	0.362
DG3DK	2.67	1.331
DK9WF	NULL	
AB4XQ	null	
TF5SK	NULL	
CV6ZX	NULL	
EN2QS	NULL	

Lab ID	Soil mortar	
	%	Z-score
AO7VU	12.7	-0.789
EN2QS	16	-0.719
WQ3LN	16.3	-0.712
AB4XQ	55	0.106
DG3DK	100	1.057
TF5SK	100	1.057
DF6CP	CBD	
DK9WF	NULL	
YY3QP	Null	
CV6ZX	_	_

% passing	GM Round 1	GM Round 2	GM Round 3	FM Round 1	FM Round 2	FM Round 3	Soil Mortar Round 1	Soil Mortar Round 2	Soil Mortar Round 3
H15 mean	1.020	1.054	0.863	0.980	-	1.722	71.71	42.33	50.00
H15 Std Dev	0.120	0.164	0.799	0.604	-	0.712	68.35	44.872	47.299
Range	0.49	0.76	1.39	1.24	-	1.64	985.90	86.30	87.30
CV	11.8%	15.6%	92.6%	61.7%	-	41.3%	95.3%	106.0%	94.6%

Method information

Method	AASHTO T27	SANS 3001 PR5	TMH1 A1 (a)	Non-responsive
# participants round 2	2 (20%)	3 (30%)	4(40%)	1 (10%)

Lab ID	Coarse sand	
	%	Z-score
AO7VU	0.0	-1.418
DF6CP	2.3	-1.059
AB4XQ	10	0.143
EN2QS	10	0.143
YY3QP	12.9	0.596
DG3DK	13.9	0.752
CV6ZX	14.30	0.814
WQ3LN	NULL	
DK9WF	NULL	
AB4XQ		

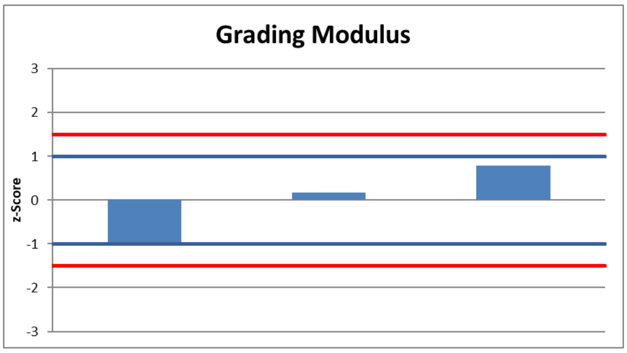
Lab ID	Coarse sands ratio	
	%	Z-score
TF5SK	0.03	-0.567
EN2QS	0.1	-0.561
DG3DK	0.139	-0.557
CV6ZX	0.14	-0.557
AB4XQ	16	0.874
AO7VU	36.8	2.750
DF6CP	CBD	
WQ3LN	NULL	
DK9WF	NULL	
YY3QP	Null	

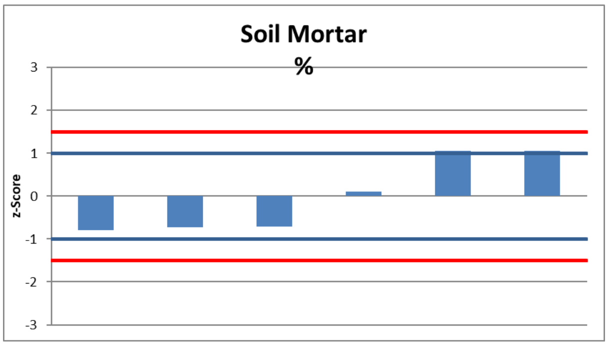
Lab ID	Coarse fine sand	
	%	Z-score
WQ3LN	4.4	-3.171
AB4XQ	29	-0.417
EN2QS	30	-0.305
DG3DK	35.1	0.266
AO7VU	36.8	0.456
TF5SK	74	4.621
DF6CP	CBD	
DK9WF	NULL	
CV6ZX	NULL	_
YY3QP	Null	

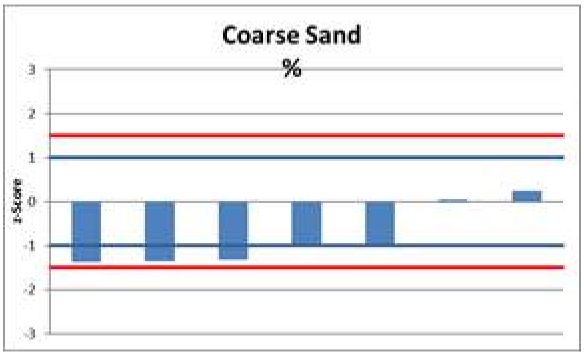
% passing	Coarse Sand round 1	Coarse Sand round 2	Coarse Sand round 3	Coarse Sand Ratio round 1	Coarse Sand Ratio round 2	Coarse Sand Ratio round 3	Coarse Fine Sand round 1	Coarse Fine Sand round 2	Coarse Fine Sand round 3
H15 mean	4.0	**9.7**	9.085	3.0	**8.5**	6.314	27.8	15.3	32.724
H15 Std Dev	5.41	**7.06**	6.406	2.89	**15.67**	11.084	26.09	15.26	8.932
Range	11.40	11.40	14.30	4.80	24.38	36.77	52.80	25.70	69.60
CV	136.2%	72.7%	70.5%	96.4%	183.5%	175.5%	93.8%	100.0%	27.3%

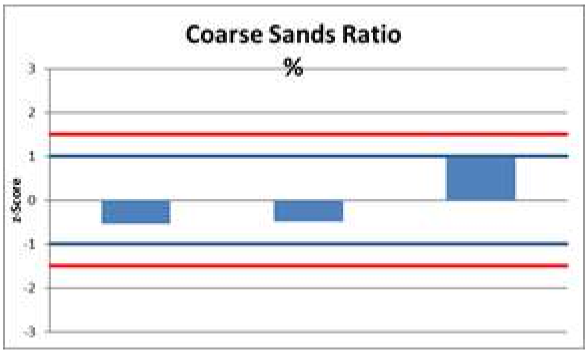
Lab ID	Fine fine sand		Lab ID	Fine sand		Lab ID	Medium fine sand	
	%	Z-score		%	Z-score		%	Z-score
DG3DK	7.9	**-1.042**	YY3QP	6	**-1.038**	TF5SK	18	**-1.526**
EN2QS	9	-0.760	AO7VU	13.8	-0.821	DG3DK	30.3	-0.507
AB4XQ	11	-0.248	DF6CP	14.9	-0.791	EN2QS	36	-0.035
YY3QP	12.6	0.162	AB4XQ	36	-0.204	WQ3LN	37.4	0.081
TF5SK	14	0.520	WQ3LN	41.9	-0.039	AB4XQ	42	0.462
DF6CP	62.3	**12.885**	CV6ZX	68.6	0.704	YY3QP	68.5	**2.657**
AO7VU	NULL		DG3DK	73.3	0.835	DF6CP	CBD	
WQ3LN	NULL		TF5SK	92	**1.355**	AO7VU	NULL	
DK9WF	NULL		DK9WF	NULL		DK9WF	NULL	
CV6ZX	NULL	_	EN2QS	NULL	_	CV6ZX		

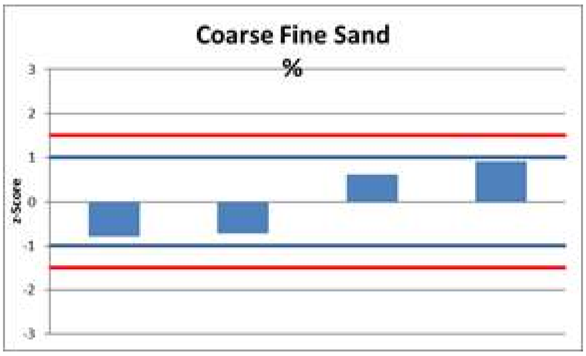
% passing	Fine Fine Sand round 1	Fine Fine Sand round 2	Fine Fine Sand round 3	Fine Sand round 1	Fine Sand round 2	Fine Sand round 3	Medium Fine Sand round 1	Medium Fine Sand round 2	Medium Fine Sand round 3
H15 mean	18.2	7.23	11.969	41.5	34.75	43.31	42.5	37.58	36.43
H15 Std Dev	14.75	4.85	3.906	36.29	27.11	35.931	14.07	18.82	12.074
Range	18.40	11.60	54.40	72.30	63.20	86.00	27.40	46.50	50.50
CV	81.0%	67.2%	32.6%	87.5%	78.0%	83.0%	33.1%	50.1%	33.1%

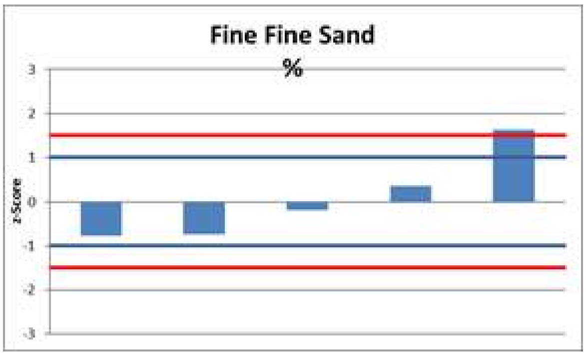


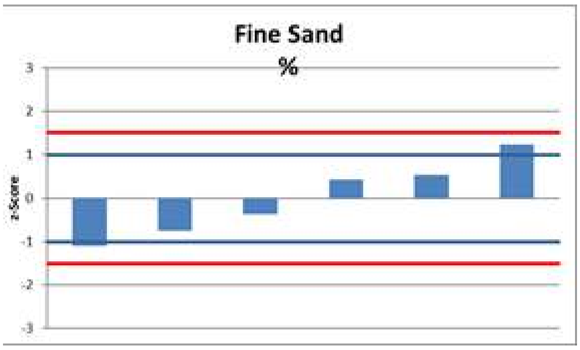


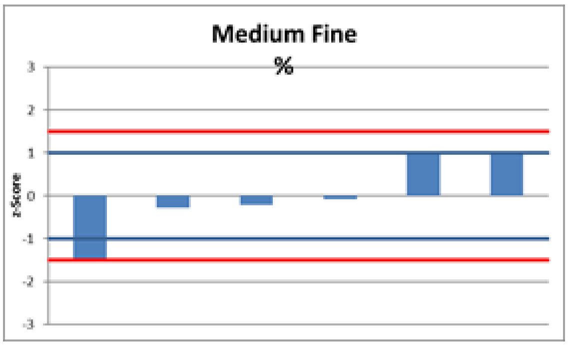












Comments – Soil mortars

- The comments from the granular section are relevant here where a decision is required as to what information is relevant to the Mozambican specifications and only these values are to be included in the analysis in future rounds.
- In general, the statistical results varied equally between increasing and decreasing in value.

D. AGGREGATE MATERIAL

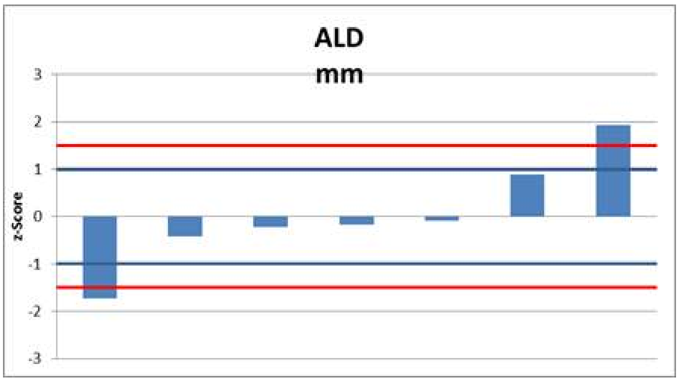
AVERAGE LEAST DIMENSION (ALD)

#	Lab code	ALD (mm)	z-score
1	AB4WQ	3.1	**-1.735**
2	DK9WF	9.77	-0.424
3	EN2QS	10.8	-0.222
4	CV6ZX	11.1	-0.163
5	DG3DK	11.48	-0.089
6	DF6CP	16.51	0.899
7	AO7VU	21.77	**1.932**
8	EN2QS	NULL	
9	TF5SK	NULL	
10	WQ3LN	NULL	

	ALD Round 1	ALD Round 2	ALD Round 2
H15 mean	9.280	10.47	11.93
H15 Std Dev	4.653	2.52	5.092
Range	11.55	9.22	18.6
CV	50.1%	24.1%	42.7%

Method information

Method	TMH 1 B18(a)	SANS 3001 AG2	Non-responsive
# participants	5 (50 %)	2 (20 %)	3 (NULL)



	ALD Round 1	ALD Round 2	ALD Round 3
Additional participant statistics			
Number of participants	7	7	7
Non-participants	3	3	-
OB	-	1	-
Statistics for Z-scores < ±1			
Range	6.1	3.1	6.74
Percentage of participants	71.4%	83.3%	71.4$
Reporting format			
Participants reported to 0.1 mm	3	3	2
Participants reported to 0,01 mm	4	3	3
Participants reported to 0,001 mm	-	1	1

COMMENTS – ALD DIRECT MEASURMENT

- The two SA facilities produced an ALD range of 0.3 mm and particle count range of 121.
- The Mozambique labs produce an ALD range of 18.6 mm and Particle count range 261.
- The range for the ALD is unacceptably high for the aggregates StDev, Range & CV.

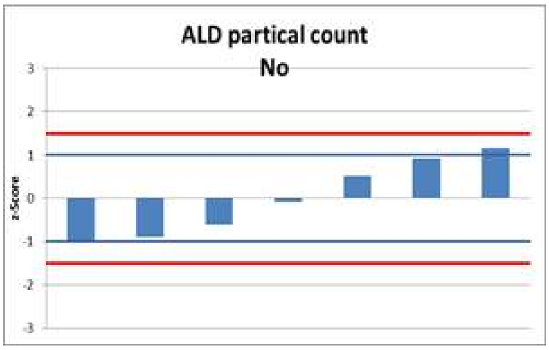
ADDITIONAL INFORMATION ON ALD

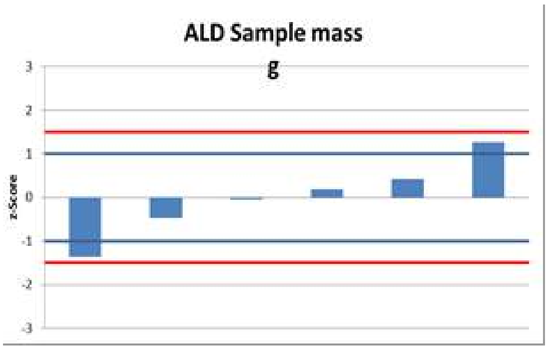
Lab Code	# particles	Z-Score
AB4WQ	200	**-1.009**
AO7VU	213	-0.901
DF6CP	248	-0.611
CV6ZX	312	-0.079
DG3DK	384	0.518
EN2QS	433	0.925
DK9WF	461	**1.157**
EN2QS	NULL	
TF5SK	NULL	
WQ3LN	NULL	

Lab Code	Specimen mass	Z-Score
AO7VU	400	**-1.364**
AB4WQ	913.6	-0.469
DF6CP	1157	-0.045
DG3DK	1294.58	0.195
CV6ZX	1423.8	0.420
EN2QS	1908	**1.263**
DK9WF	NULL	
EN2QS	NULL	
TF5SK	NULL	
WQ3LN	NULL	

	# particle count round 1	# particle count round 2	# particle count round 3	Specimen mass round 1	Specimen mass round 2	Specimen mass round 3
H15 mean	224.191	317.62	321.57	831.838	1158.54	1182.8
H15 Std Dev	99.804	174.17	120.50	732.409	566.18	574.0
Range	505.00	388.00	261.00	1830.70	1207.00	1508.00
CV	44.5%	54.8%	37.5%	88.0%	48.9%	48.5%

	# Particle Count 1	# Particle Count 2	# Particle Count 3	Sample Mass 1	Sample Mass 2	Sample Mass 3
Additional participant statistics						
Number of participants	7	7	7	7	7	5
Non-participants	3	3	3	3	3	4
OB	-	-	-	-	-	-
Statistics for Z-scores < ±1						
Range	117	94	220	831.6	515.0	510.4
Percentage of participants	71.4%	71.4%	71.4%	71.4%	71.4%	80.0%
Reporting format						
Participants reported to 1	7	7	7	2	5	3
Participants reported to 0,1	-	-	-	4	1	2
Participants reported to 0,01	-	-	-	1	1	1





COMMENTS – ALD

- This table is more to detail the importance of correct sample sizes for obtaining a representative sample.
- Too big a sample would take too long to complete the test whereas too small a sample could lead to an inaccurate results.

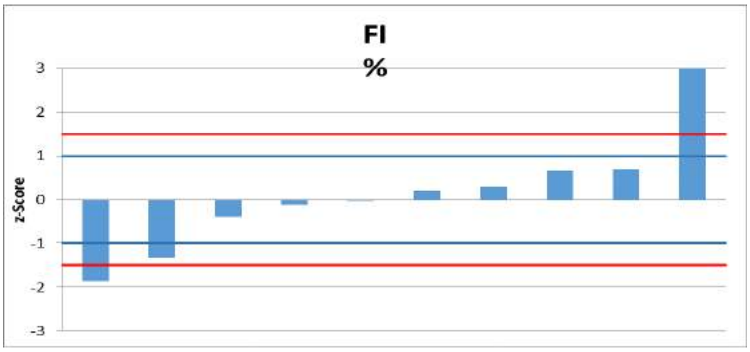
FLAKINESS INDEX (FI)

#	Lab code	FI	z-score
1	AB4WQ	5.3	**-1.860**
2	AO7VU	10.0	**-1.331**
3	EN2QS	18.25	-0.401
4	EN2QS	20.7	-0.125
5	CV6ZX	21.8	-0.001
6	WQ3LN	23.6	0.202
7	TF5SK	24.4	0.292
8	DK9WF	27.7	0.664
9	DG3DK	28	0.698
10	DF6CP	72.1	**5.669**

	FI Round 1	FI Round 2	FI Round 3
H15 mean	19.054	21.26	21.81
H15 Std Dev	12.732	12.82	8.872
Range	32.39	39.58	66.80
CV	66.8%	60.3%	40.7%

Method information

Method	ASTM D4791	TMH 1 B3	SANS 3001 AG4	Non-responsive
# participants	2 (20 %)	6 (60 %)	2 (20 %)	2 (NULL)



	FI Round 1	FI Round 2	FI Round 3
Additional participant statistics			
Number of participants	10	9	10
Non-participants	-	1	-
OB	-	-	-
Statistics for Z-scores < ±1			
Range	14.1	12.6	9.8
Percentage of participants	71.4%	66.7%	70.0%
Reporting format			
Participants reported to 0.1 mm	7	6	8
Participants reported to 0.01 mm	3	3	1

COMMENT – FI

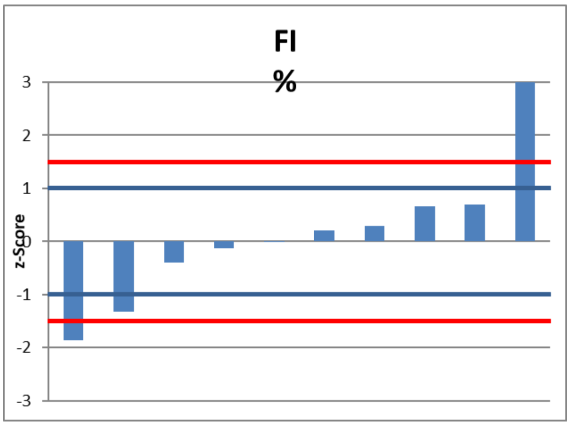
- The two SA facilities produce a FI range of 1.1 %, while the Mozambique facilities produced a FI range 67 % (23 %).

- One facility reported the 72.1 % passing which is more likely to be % retained which skewed the range and statistical values obtained in this round.
- The Mean remains stable whereas the StDev & CV both have decreased while the Range increased due to the one value of 72.1 %.

ADDITIONAL INFORMATION ON FI

Lab Code	FI sample mass	Z-Score
WQ3LN	823.7	-1.381
DF6CP	1066.8	-1.134
CV6ZX	1782.1	-0.405
AO7VU	1789	-0.398
AB4WQ	2096	-0.085
EN2QS	2299.3	0.1220
DK9WF	2334.2	0.158
DG3DK	2914.5	0.749
EN2QS	3167.5	1.007
TF5SK	3521.9	1.368

	sample mass Round 1	sample mass Round 2	sample mass Round 3
H15 mean	2190.3	1753.19	2179.5
H15 Std Dev	1276.2	638.70	981.574
Range	5742.0	1721.00	2698.2
CV	58.3%	36.4%	45.0%



	FI sample mass Round 1	FI sample mass Round 2	FI sample mass Round 3
Additional participant statistics			
Number of participants	10	9	10
Non-participants	-	1	-
OB	-	-	-
Statistics for Z-scores < ±1			
Range	185.0	570.0	1132.6
Percentage of participants	71.4%	66.7%	60.0%
Reporting format			
Participants reported to 1 g	3	5	2
Participants reported to 0,1 g	6	2	8
Participants reported to 0,01 g	1	2	-

COMMENTS – FLAKINESS INDEX

- The same comments related to the ALD sample mass is applicable here.
- Some of the sample sizes used are too small for a representative sample. This sample size should relate to the sample size used for the grading so as to save time in doing the FI & grading from the same sample.

AGREGATE CRUSHING VALUE (ACV)

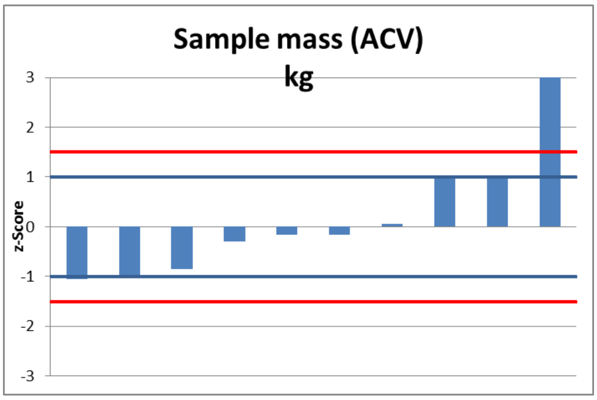
Lab Code	ACV %	Z-Score
WQ3LN	13.4	**-1.488**
DK9WF	13.9	**-1.380**
TF5SK	18.31	-0.425
CV6ZX	20.3	0.006
DG3DK	20.3	0.006
EN2QS	21.7	0.309
AB4WQ	22	0.374
DF6CP	22.06	0.387
AO7VU	23.61	0.722
EN2QS	28	**1.673**

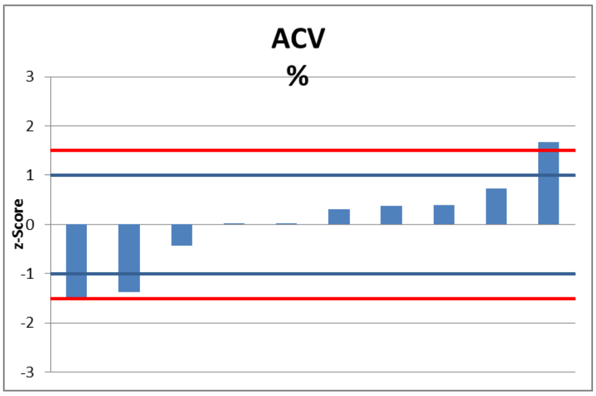
Lab Code	Specimen mass	Z-Score
TF5SK	2069	**-1.050**
DK9WF	2104	-0.971
DF6CP	2154.7	-0.858
CV6ZX	2402.4	-0.305
EN2QS	2463.3	-0.17
DG3DK	2469.02	-0.156
WQ3LN	2567	0.062
AB4WQ	2984	0.994
EN2QS	3000	**1.029**
AO7VU	5998	**7.724**

	ACV % Round 1	ACV % Round 2	ACV % Round 3	Specimen mass Round 1	Sample mass Round 2	Sample mass Round 3
H15 mean	18.45	20.789	20.27	2641.60	2393.779	2539.0
H15 Std Dev	3.90	5.483	4.619	459.08	209.919	447.8
Range	8.25	13.50	14.60	3237.67	894.67	3929.0
CV	21.2%	26.4%	22.8%	17.4%	8.8%	17.6%

Method information (ACV)

Method	ASTM D5821	TMH 1 B1	SANS 3001 AG10	Non-responsive
# participants	2 (20 %)	(60 %)	2 (20 %)	1 (NULL)





Additional participant statistics

	ACV Round 1	ACV Round 2	ACV Round 3	Specimen mass Round 1	Specimen mass Round 2	Specimen mass Round 3
Number of participants	10	8	10	10	8	10
Non-participants	-	1	-	-	1	-
OB	-	1	-	-	1	-

Statistics for Z-scores < ±1

Range	7.4	6.7	5.3	822.2	210.7	880
Percentage of participants	90.0%	75.0%	70.0%	8.0%	66.7%	70.0%

Reporting format

Participants reported to 1 %	1	1	1	4	6	6
Participants reported to 0,1 %	6	5	5	5	2	3
Participants reported to 0,01 %	3	1	3	1	1	1

COMMENTS – ACV

- The two 2 SA facilities produced an ACV range of 7.7 % whereas the Mozambique facilities range is 10.2 %
- The StDev & CV decreased in this round whereas the range increased slightly.

10% FINES AGGREGATE CRUSHING TEST (10% FACT)

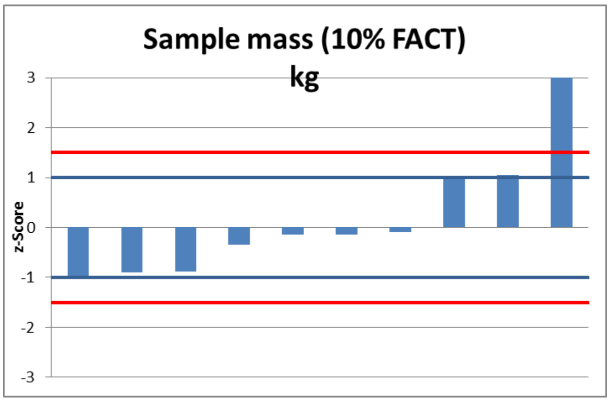
Lab Code	10 % FACT kN	Z-Score
DF6CP	170	-1.198
EN2QS	176	-1.008
CV6ZX	195	-0.405
WQ3LN	200	-0.246
TF5SK	202.55	-0.165
AB4WQ	210	0.071
EN2QS	219	0.357
DG3DK	245	1.182
DK9WF	310.2	3.250
AO7VU	10.33	OB

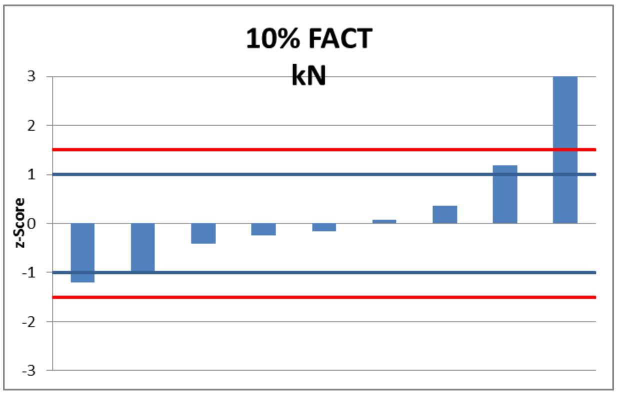
Lab Code	Specimen mass	Z-Score
DK9WF	2052	-1.013
TF5SK	2105.5	-0.896
DF6CP	2109.8	-0.887
WQ3LN	2358	-0.347
EN2QS	2452.9	-0.14
CV6ZX	2453.1	-0.140
DG3DK	2476.22	-0.089
AB4WQ	2984	1.016
EN2QS	3000	1.051
AO7VU	6000	7.583

	10 % FACT (kN) Round 1	10 % FACT (kN) Round 2	10 % FACT (kN) Round 3	Specimen mass Round 1	Specimen mass Round 2	Specimen mass Round 3
H15 mean	232.76	183.14	207.761	2643.15	2390.71	2517.19
H15 Std Dev	47.71	116.698	31.518	448.81	222.59	459.28
Range	265.50	147.00	140.20	3182.33	875.00	3948.0
CV	20.5%	63.7%	15.2%	17.0%	9.3%	18.2%

Method information (10% FACT)

Method	ASTM D5821	TMH 1 B2	SANS 3001 AG10	Non-responsive
# participants	2 (20 %)	6 (60 %)	2 (20 %)	1 (NULL)





Additional participant statistics

	10 % FACT kN Round 1	10 % FACT kN Round 2	10 % FACT kN Round 3	Specimen mass Round 1	Specimen mass Round 2	Specimen mass Round 3
Number of participants	9	9	10	8	9	10
Non-participants	1	1	-	2	1	-
OB	0	2	1	-	0	-

Statistics for Z-scores < ±1

Range	77.7	120.2	24	798.0	249.0	370.62
Percentage of participants	66.7%	85.7%	55%.56	87.5%	66.7%	60.0%

Reporting format

Participants reported to 1	6	4	7	3	6	5
Participants reported to 0,1	2	2	1	3	2	3
Participants reported to 0,01	1	3	2	2	1	1

COMMENTS – 10 % FACT

- The two SA facilities produced a range 19 kN whereas the Mozambique facilities produced a range of range 140 kN. This value is far too high.
- The StDev, range and CV have all decreased in this round which is encouraging.

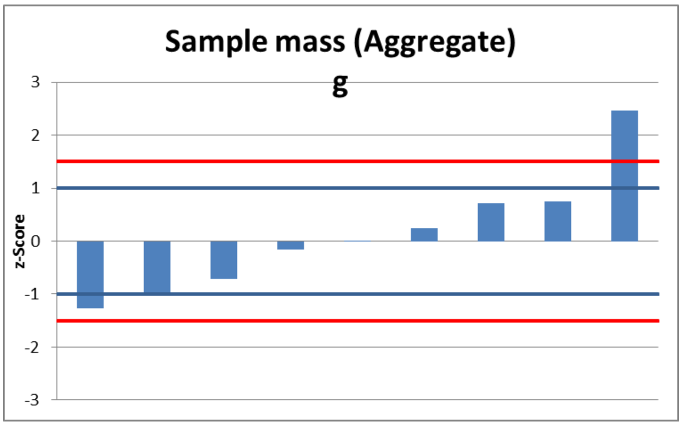
Aggregate grading

#	Lab code	Sample mass (g)	z-score
1	CV6ZX	1782.7	-1.267
2	DF6CP	2057.9	-0.979
3	EN2QS	2307.5	-0.717
4	DK9WF	2838	-0.162
5	DG3DK	2998.3	0.006
6	EN2QS	3230	0.249
7	TF5SK	3670	0.710
8	WQ3LN	3703	0.745
9	AO7VU	5350	2.470
10	AB4WQ	Null	

	Sample mass Round 1	Sample mass Round 2	Sample mass Round 3
H15 mean	2320.47	2649.38	2992.29
H15 Std Dev	719.26	638.81	954.579
Range	5549.20	1677.60	3567.3
CV	31.0%	24.1%	31.9%

Method information

Method	AASHTO T27	SANS 3001 AG1	TMH1 B4	AASTHO T88	TMH1 A1(a)&A5	Non-responsive
# participants	2(20 %)	2 (20 %)	3 (30 %)	1(10.0%)	1 (10.0%)	1 (NULL)



	Sample Mass Round 2	Sample Mass Round 2	Sample Mass Round 3
Additional participant statistics			
Number of participants	9	9	9
Non-participants	1	4	--
OB	-	-	-
Statistics for Z-scores < ±1			
Range	74.8	526.0	1645.1
Percentage of participants	66.7%	66.7%	7000%
Reporting format			
Participants reported to 1 g	3	4	5
Participants reported to 0,1 g	5	2	4
Participants reported to 0,01 g	1	-	-

Comments – Aggregate grading sample mass

- Three methods were used by the 9 participants
- The sample mass gives a indication of the comparative sizes used by the various facilities. As with the other sample mass comments it more related to identifying whether a facility has used a representative sample or not for the grading analysis.
- The variability of the mass used in the third round has increased across all statistical values.

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
DG3DK	98.5	**-1.617**
DF6CP	98.8	**-1.190**
WQ3LN	100	0.516
DK9WF	100	0.516
TF5SK	100	0.516
CV6ZX	100	0.516
EN2QS	100	0.516
YY3QP	Null	
AB4XQ	Null	
AO7VU	6.2	**OB**

Lab Code	14/13.2 mm	Z-Score
DF6CP	4.3	**-1.115**
WQ3LN	6.8	-0.771
AO7VU	7.6	-0.660
EN2QS	7.61	-0.659
TF5SK	10	-0.330
DG3DK	10.1	-0.316
DK9WF	16.8	0.607
CV6ZX	18	0.773
EN2QS	20	**1.048**
AB4WQ	35	**3.116**

Lab Code	10/9.5 mm	Z-Score
DF6CP	0.9	**-1.241**
EN2QS	1	**-1.201**
WQ3LN	2.6	-0.546
EN2QS	2.92	-0.415
CV6ZX	4	0.027
DG3DK	4.2	0.109
DK9WF	4.2	0.109
TF5SK	6	0.846
AO7VU	6.1	0.887
AB4WQ	10.1	**2.524**

% passing	20/19 mm Round 1	20/19 mm Round 2	20/19 mm Round 3	14/13.2 mm Round 1	14/13.2 mm Round 2	14/13.2 mm Round 3	10/9.5 mm Round 1	10/9.5 mm Round 2	10/9.5 mm Round 3
H15 mean	99.66	99.6	100	37.26	33.5	12.39	7.08	4.6	3.93
H15 Std Dev	0.63	0.7	3.31E-13	8.30	7.8	7.256	2.36	2.0	2.43
Range	29.70	1.50	89.7	28.30	21.00	30.70	6.76	5.10	9.20
CV	0.6%	0.7%	0	22.3%	23.3%	58.6	33.3%	42.5%	62.1%

Lab Code	7.1/6.7 mm	Z-Score
DF6CP	0.4	**-1.318**
WQ3LN	1.5	-0.707
CV6ZX	2	-0.429
AB4WQ	2.2	-0.318
EN2QS	2.24	-0.296
DG3DK	3.1	0.182
DK9WF	3.2	0.237
TF5SK	5	**1.237**
AO7VU	6.1	**1.848**
EN2QS	0	**OB**

Lab Code	5/4.75 mm	Z-Score
DF6CP	0.3	**-1.259**
WQ3LN	0.9	-0.875
AB4WQ	1.3	-0.619
EN2QS	1.93	-0.216
CV6ZX	2	-0.171
DK9WF	2.7	0.277
DG3DK	2.8	0.341
TF5SK	4	**1.109**
AO7VU	6.1	**2.452**
EN2QS	0	**OB**

Lab Code	2/2.36 mm	Z-Score
DF6CP	0.3	**-1.261**
CV6ZX	1	-0.704
AB4WQ	1.1	-0.625
EN2QS	1.63	-0.203
DK9WF	2	0.092
DG3DK	2.4	0.410
TF5SK	3	0.888
AO7VU	6.1	**3.356**
EN2QS	0	**OB**
WQ3LN	NULL	

% passing	7.1/6.7 mm Round 1	7.1/6.7 mm Round 2	7.1/6.7 mm Round 3	5/4.75 mm Round 1	5/4.75 mm Round 2	5/4.75 mm Round 3	2/2.36 mm Round 1	2/2.36 mm Round 2	2/2.36 mm Round 3
H15 mean	2.53	2.1	2.77	2.20	1.5	2.267	1.50	1.3	1.884
H15 Std Dev	0.92	1.9	1.800	1.16	1.6	1.563	0.92	1.0	1.256
Range	6.70	3.90	5.70	7.97	3.10	5.80	8.32	1.70	5.80
CV	36.4%	93.2%	64.9%	52.6%	103.8%	68.9%	61.4%	79.1%	81.6%

Lab Code	1/1.18 mm	Z-Score
DF6CP	0.2	-1.795
CV6ZX	1	-0.669
EN2QS	1	-0.669
AB4WQ	1.3	-0.247
EN2QS	1.43	-0.064
DK9WF	1.5	0.034
TF5SK	2	0.738
DG3DK	2.1	0.879
AO7VU	6.1	6.508
WQ3LN	NULL	

Lab Code	0.600 mm	Z-Score
DF6CP	0.1	-1.327
EN2QS	0.3	-1.101
AB4WQ	1.1	-0.198
CV6ZX	1.1	-0.198
DK9WF	1.2	-0.085
EN2QS	1.25	-0.029
DG3DK	1.9	0.705
TF5SK	2	0.818
AO7VU	6.1	5.446
WQ3LN	NULL	

Lab Code	0.425 mm	Z-Score
DF6CP	0.1	-1.182
EN2QS	0.3	-0.952
DK9WF	1.1	-0.032
EN2QS	1.16	0.037
AB4WQ	1.2	0.083
DG3DK	1.7	0.658
AO7VU	6.1	5.717
CV6ZX	NULL	-
TF5SK	NULL	
WQ3LN	NULL	

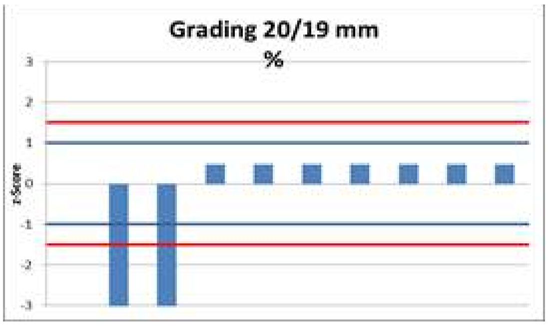
% passing	1/1.18 mm Round 1	1/1.18 mm Round 2	1/1.18 mm Round 3	0.600 mm Round 1	0.600 mm Round 2	0.600 mm Round 3	0.425 mm Round 1	0.425 mm Round 2	0.425 mm Round 3
H15 mean	1.44	1.2	1.48	1.23	1.1	1.275	0.99	0.8	1.1
H15 Std Dev	0.83	1.0	0.711	0.69	0.9	0.886	0.46	0.6	0.9
Range	8.40	1.50	5.90	8.49	1.80	6.0	1.40	1.10	6.0
CV	58.1%	84.8%	48.2%	56.2%	79.7%	69.5%	46.3%	81.3%	77.1%

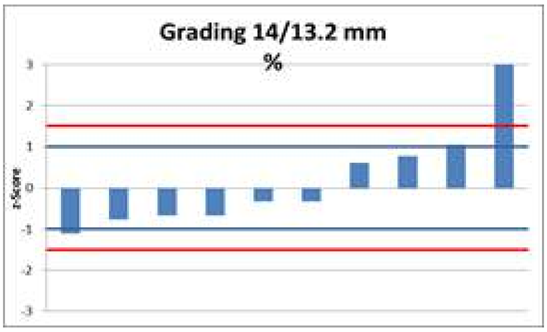
Lab Code	0.300 mm	Z-Score
DF6CP	0.1	-1.283
EN2QS	0.3	-1.040
CV6ZX	0.9	-0.309
DK9WF	1	-0.187
EN2QS	1.07	-0.102
AB4WQ	1.1	-0.065
DG3DK	1.6	0.543
TF5SK	2	1.031
AO7VU	6.1	6.024
WQ3LN	NULL	

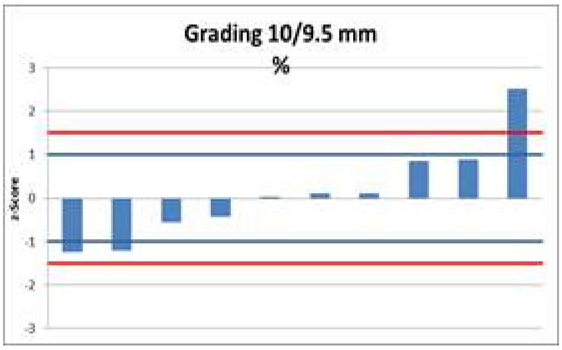
Lab Code	0.150 mm	Z-Score
DF6CP	0.1	-1.561
EN2QS	0.3	-1.163
CV6ZX	0.8	-0.168
DK9WF	0.8	-0.168
EN2QS	0.89	0.011
TF5SK	1	0.230
AB4WQ	1.1	0.429
DG3DK	1.3	0.827
AO7VU	6.1	10.382
WQ3LN	NULL	

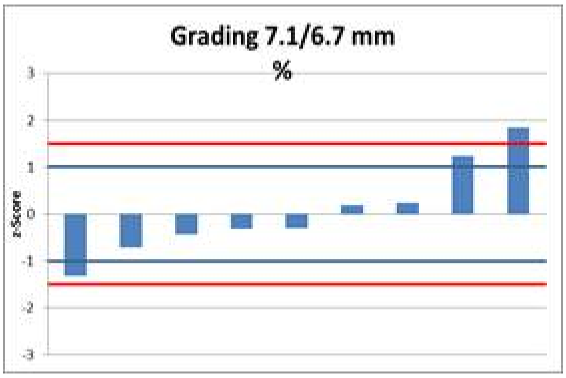
Lab Code	0.075 mm	Z-Score
EN2QS	0.2	-1.586
CV6ZX	0.6	-0.587
DK9WF	0.6	-0.587
EN2QS	0.71	-0.312
AB4WQ	1	0.412
TF5SK	1	0.412
DG3DK	1.1	0.662
AO7VU	6.1	13.147
DF6CP	0	OB
WQ3LN	NULL	

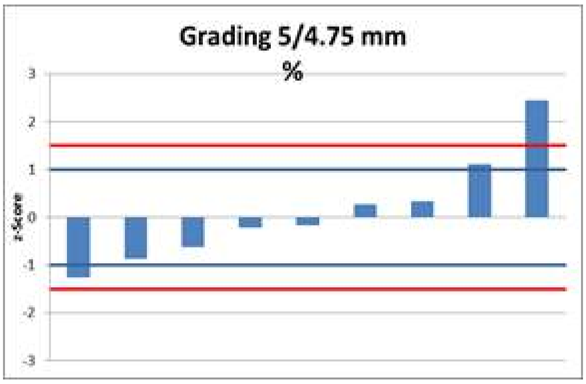
% passing	0.300 mm Round 1	0.300 mm Round 2	0.300 mm Round 3	0.150 mm Round 1	0.150 mm Round 2	0.150 mm Round 3	0.075 mm Round 1	0.075 mm Round 2	0.075 mm Round 3
H15 mean	1.07	1.0	1.15	0.97	0.8	0.88	0.78	0.6	0.84
H15 Std Dev	0.76	0.8	0.821	0.82	0.7	0.502	0.76	0.6	0.400
Range	8.58	1.80	6.0	8.88	1.80	6.0	8.87	1.80	6.10
CV	71.3%	82.8%	71.2%	84.4%	82.0%	56.8%	97.1%	109.3%	48.0%

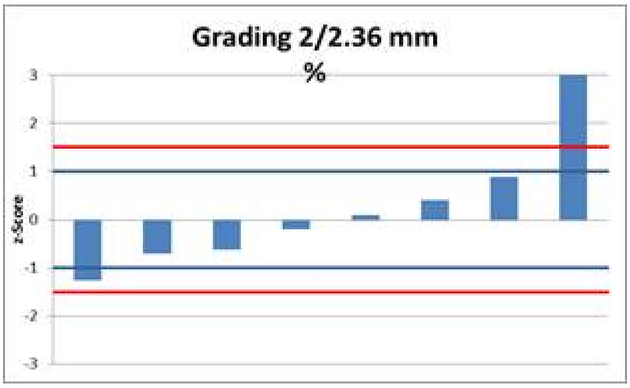

Grading 20/19 mm
%
z-Score

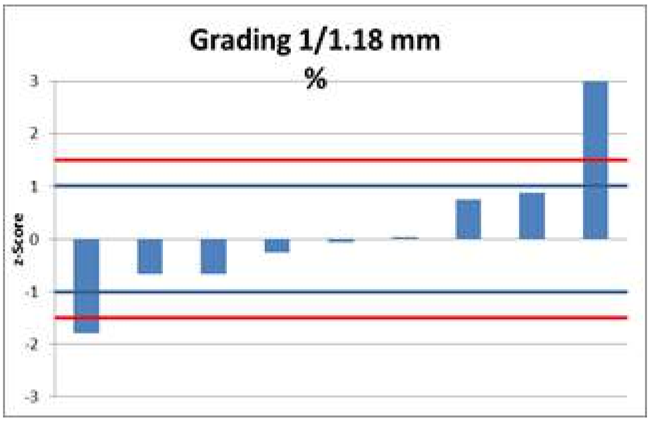

Grading 14/13.2 mm
%
z-Score

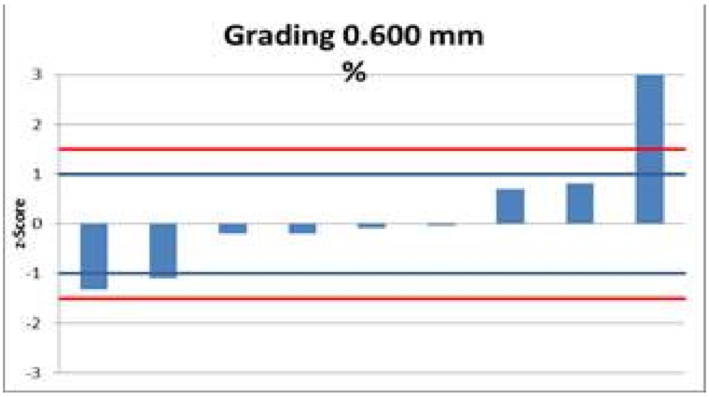

Grading 10/9.5 mm
%
z-Score

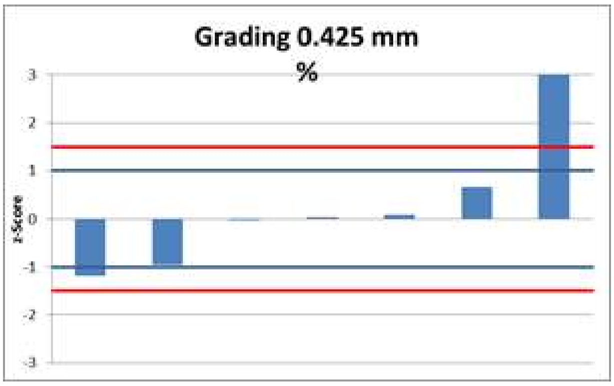

Grading 7.1/6.7 mm
%
z-Score

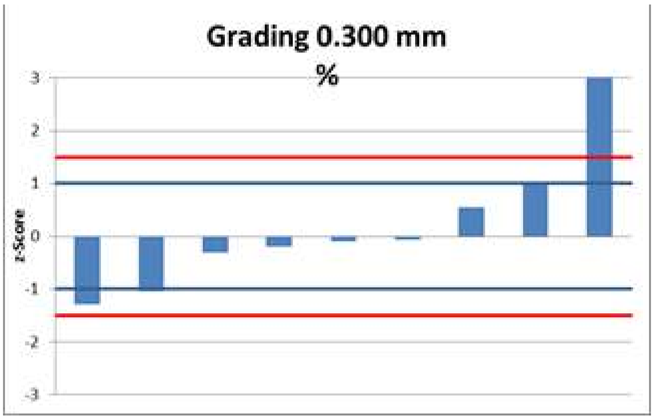

Grading 5/4.75 mm
%
z-Score

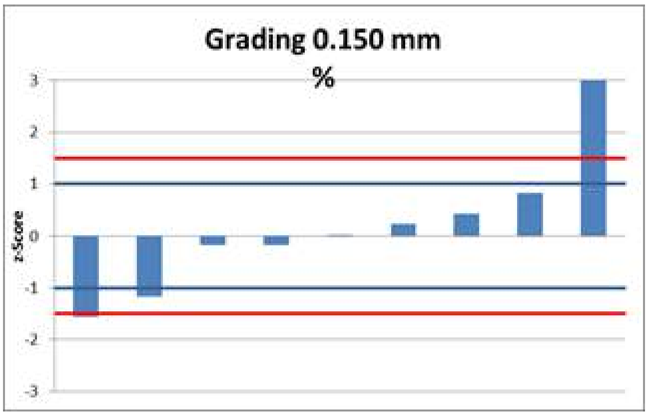

Grading 2/2.36 mm
%
z-Score

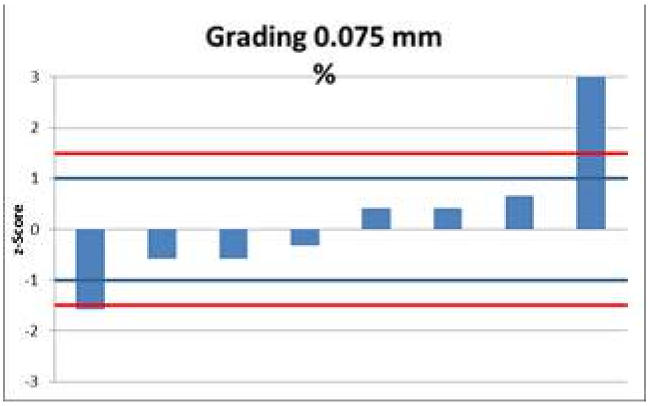

Grading 1/1.18 mm
%
z-Score


Grading 0.600 mm
%
z-Score









COMMENTS – AGGREGATE GRADING

- The different sieve sizes used in the various methods does make the analysis and deductions more difficult to make with any certainty.
- The results of course material a less variable than the fine fractions which is a normal trend.

--- END OF REPORT --

Annex 2 PTS Protocol for Material Sampling and Splitting - Crushed Material & Borrow Pit Sand

Crushed material & borrow pit sand testing round: Instructions to the Preparation Participant.

Please read all instructions carefully prior to commencing

1 These instructions describe the preparation of participants secondary or laboratory samples for the crushed granular tests –.

1.1 Grading, Atterberg, MDD & CBR Minimum of 100 kg.

1.1.1 **NB!** This is provided in 3 separate bags that need to be combined into 1 sample & then split for the grading & MDD/CBR testing

2 The samples are prepared for:

2.1 The participating laboratories from which the results will be used for the inter-laboratory comparison analysis.

2.2 Results from the participating laboratories will be accepted and analysed using the consensus mean and robust statistics to evaluate the results.

2.3 LEM is appointed to undertake homogeneity and stability testing on 6 of the prepared samples

2.3.1 Homogeneity testing to be undertaken on 3 samples at the same time as their sample is tested to determine the consistency of the samples as distributed to the participating laboratories.

2.3.2 Stability testing will be undertaken on the remaining 3 samples at one month intervals (i.e. July, August & September of 2017) to determine how stable the material over a period of 4 months.

3 Obtain one (1) *representative sample* of crushed primary or field sample gravel or sand of about 1 600 kg + 5 %

3.1 *This sample mass is for a split for up to a maximum of 16 participants. Should more participants be partaking, the bulk field sample mass will need to be revised accordingly.*

3.2 The material will need to be selected based on the type of material that has one of the following characteristics

3.2.1 A determinable PI or

3.2.2 A non-plastic (NP) or slightly-plastic (SP) characteristic.

3.2.3 The material type required will be indicated for each round.

4 Splitting the sample into representative samples

4.1 **Ensuring that the samples are as representative as possible is critical for comparative results to be meaningfully analysed.**

4.2 Ensure the sample complies to the correct mass required to obtain 100 kg samples for the amount of participants in the round plus the additional samples.

4.2.1 If the sample size is too small, discard the sample and collect a new sample

4.2.2 If the sample size is too large, reduce the sample size to an acceptable size through coning and quartering.

4.3 Spread the primary sample on a non-absorbent, smooth surface. Rake it in order to obtain an even air dry moisture content over 24 hrs.

4.4 If there is a course aggregate fraction > 20 mm, sieve the entire sample thru a 20 mm sieve to separate the coarse fraction from the finer fractions.

4.4.1 For sand fractions this operation should not be necessary due to the fineness of sand samples.

4.5 Broom the coarse and fine samples into separate heaps.

4.6 Divide each of the 2 heaps in half using a suitably sized riffler.

4.6.1 The riffler sizes will differ for the 2 heaps.

4.6.2 Ensure the riffle openings allow the largest size to fall through without causing any blockages to facilitate easy of riffling.

4.6.3 Alternate the split material into the 2 piles to ensure representativeness is maintained due to differences in the pans content

4.7 Continue riffling down the material until the correct number of sub-samples are obtained from each half to ensure representative secondary or laboratory samples of approx. 50 kg each.

4.8 Recombine 2 samples (1 from each half) to obtain 1 representative sample per participant of a minimum of 100 kg.

4.8.1 As the sample is heavy, the sample can be split into 3 bags of approx. 35 kg each.

4.8.2 2 of the bags can be made up of the 2 halves of the fine material with coarse aggregate placed on top of the fines to prevent them from tearing the bags,

4.8.3 The 3rd bag can be filled with the last fines fraction of approx. 35 kg.

4.8.4 **Ensure the participants are aware that the 3 bags are to be combined into a single sample before commencing their internal laboratory splitting and testing.**

5 Packaging

5.1 Split the gravel sample into 3 approximately equal portions.

5.2 Place each portion of the sample in a plastic bag of dims approx. 540 mm x 910 mm with a minimum thickness of 200 µm

5.3 Flatten the sample portion into the bottom of each bag and secure with a cable tie of at least 4.8 mm width.

5.4 Place each sample bag inside a second bag & secure with a second cable tie.

5.5 Place the sample that is now inside 2 plastic bags into a plastic woven sample bag of dims approx. 540 mm x 910 mm with a minimum thickness of 200 µm to ensure maximum protection during transportation.

5.6 *Each participant will receive 3 bags which will need to be recombined to undertake the testing.*

6 Label each secondary sample with the following information:

6.1 Preparation date

6.2 “ANE / LEM PTS Scheme”

6.3 “Round 1-1 / 2017”

6.4 Sample number, which is a combination of the scheme, date and type: e.g. ANE/LEM 15/1-1/2017 provided by Carlos

7 Labelling

7.1 Place a label **inside** the 1st sample bag with the sample portion.

7.2 Ensure all 3 bags have labels in them.

7.3 Place a 2nd label on the outside of each of the plastic woven bag for identification purposes.

7.3.1 This information can also be written on the bag itself as against using a label.

8 If you are also participating in the PTS as a testing facility, select one (1) secondary samples for your own use.

9 At random, select six (6) secondary samples for homogeneity and stability testing.

9.1 The homogeneity and stability testing need not be conducted with every round if the same source is used regularly.

10 The couriers, arranged by the ANE/LEM office, will collect the samples at your laboratory for shipping to the participating laboratories.

10.1 A weigh bill will be supplied by the ANE/LEM from the courier company that will need to be attached to the outer side of the sample bag with the delivery address.

10.2 A representative from the ANE/LEM will be present on the collection day to assist in the dispatching of the samples and attaching of the weigh bills to the samples.

11 Keep any remaining prepared laboratory samples in storage for at least 6 months.

Annex 3 PTS Protocol for Material Sampling and Splitting – Aggregate Material

Aggregate testing:
Instructions to the Preparation Participant.

Please read all instructions carefully prior to commencing

1 These instructions describe the preparation of the participants secondary or laboratory samples for the aggregate tests –.

1.1 Grading, FI & ALD, ACV & 10% FACT minimum of 25 kg

1.1.1 Fraction to be used for the ACV & 10% FACT will be communicated to all participants by ANE / LEM

2 The samples are prepared for:

2.1 The participating laboratories from which the results will be used for the inter-laboratory comparison analysis.

2.2 Results from the participating laboratories will be accepted and analysed using the consensus mean and robust statistics to evaluate the results.

2.3 LEM is appointed to undertake homogeneity and stability testing on 6 of the prepared samples

2.3.1 Homogeneity testing to be undertaken on 3 samples at the same time as their sample is tested to determine the consistency of the samples as distributed to the participating laboratories.

2.3.2 Stability testing will be undertaken on the remaining 3 samples at one month intervals (i.e. July, August & September of 2017) to determine how stable the material over a period of 4 months.

3 Obtain one (1) separate *representative sample* for the material:

3.1 A single sized 14 mm – 20 mm aggregate with a minimum mass of 400 kg + 5 %

3.1.1 *This sample mass is for a split for up to a maximum of 16 participants. Should more participants be partaking, the bulk field sample mass will need to be revised accordingly.*

4 Splitting the samples into representative samples

4.1 **Ensuring that the samples are as representative as possible is critical for comparative results to be meaningfully analysed.**

4.2 Ensure the sample complies to the correct mass required to obtain 25 kg samples for the amount of participants in the round plus the additional samples.

4.2.1 If the sample size is too small, discard the sample and collect a new sample

4.2.2 If the sample size is too large, reduce the sample size to an acceptable size through coning and quartering.

4.3 Single sized aggregate sample

4.3.1 Broom the samples into a heap.

4.3.2 Divide the material in half using a suitably sized riffler.

4.3.2.1 Ensure the riffle openings allow the largest size to fall through without causing any blockages to facilitate easy of riffling.

4.3.2.2 Alternate the split material into the 2 piles to ensure representativeness is maintained due to differences in the pans content.

4.3.3 Continue riffling down the material until the correct amount of sub-samples are obtained from each half to ensure representative secondary or laboratory samples of a approx. 12.5 kg each.

4.3.4 Recombine 2 samples (1 from each half) to obtain 1 representative sample per participant of a minimum of 25 kg.

5 Packaging

5.1 Single sized sample to be placed in a black plastic bag of dims approx. 540 mm x 910 mm with a minimum thickness of 200 µm

5.2 Place the sample bag inside a second bag & secure with a second cable tie.

5.3 Place the sample that is now inside 2 plastic bags into a plastic woven sample bag of approx. 540 mm x 910 mm with a minimum thickness of 200 µm to ensure maximum protection during transportation.

6 Label each secondary sample with the following information:

6.1 Preparation date

6.2 “ANE/LEM PTS scheme”

6.3 “Round 1-4 / 2017”

6.4 Sample number, which is a combination of the scheme, date and type: e.g. ANE/LEM 15/1-4/2017 provided by Carlos

7 Labelling

7.1 Place a label **<u>inside</u>** the 1st sample bag with the sample.

7.2 Place a 2nd label on the outside for the plastic woven bag for identification purposes.

7.2.1 This information can also be written on the bag itself as against using a label.

8 If you are also participating in the testing, select one (1) secondary samples for your own use.

9 At random, select six (6) secondary samples for homogeneity and stability testing.

10 The couriers, arranged by the ANE/LEM office, will collect the samples at your laboratory for shipping to the participating laboratories.

10.1 A weigh bill will be supplied by the ANE/LEM from the courier company that will need to be attached to the outer side of the sample bag with the delivery address.

10.2 A representative from the ANE/LEM will be present on the collection day to assist in the dispatching of the samples and attaching of the weigh bills to the samples.

11 Keep any remaining prepared laboratory samples in storage for at least 6 months.

Annex 4 PTS Testing Protocol: Form A, B, C and D

Protocol for Testing Gravel Samples
(Indicator, OMC/MDD & CBR)

Round _/20__

Compiled by:	Approved By:
Barry Pearce	Hilario Tayob

1. Sample Description

1.1. The samples are distributed to the participating laboratories via courier packed in plastic bags and are referenced as follows:

1.1.1. ANE Crushed Granular Sample   Round _- A/20__

1.1.1.1. *consists of 3 bags of approx. 30 kg each*

1.1.1.2. All 3 bags must be combined together to make up the total sample

1.1.2. ANE PI Sample   Round _- B/20__

1.1.2.1. *consists of 1 small bag of approx. 0.5 - 1 kg*

1.1.3. ANE Borrow Pit Sand Sample   Round _- C/20__

1.1.3.1. *consists of 3 bags of approx. 30 kg each*

1.1.3.2. All 3 bags must be combined together to make up the total sample

1.1.4. ANE Aggregate Sample   Round _- D1/20__

1.1.4.1. Consists of 1 bag of approx. 25 kg

2. Instructions

2.1. Treat all samples as you would treat any routine sample received in your laboratory

2.2. The samples provided do not present a safety hazard other than being extremely heavy and should be handled with care to prevent injury.

2.3. Split down the individual field samples to representative laboratory samples, ensuring that the samples are as representative as possible.

2.4. Please make use of the following abbreviations in the submission of your results

2.4.1. CBD - where the soil is NP or SP for the LL and PL determinations

2.4.2. NP - non-plastic for the PI value

2.4.3. SP - slightly-plastic for the PI value

2.4.4. NULL - where no value is submitted should you not be able to undertake the test method

2.4.4.1. Do not fill in a zero (0) as it'll be taken as a determined value and included in the statistical analysis.

2.5. Carry out the following testing on the 4 samples as detailed below;

SAMPLE A

2.5.1. Crushed granular sample approx. 100 kg. Ref: Round _- A/20 (*3 bags*)

2.5.1.1. Tests to be conducted on this sample include

2.5.1.1.1. Grading

2.5.1.1.2. LiquidLimit (LL)

2.5.1.1.3. PlasticLimit (PL)

2.5.1.1.4. Linear Shrinkage (LS)

2.5.1.1.5. Maximum Dry Density (MDD) & Optimum Moisture Content (OMC)

2.5.1.1.6. California Bearing Ratio (CBR) - (CBR)

2.5.1.2. Remove the grading sample first and use the remaining samples material to undertake the OMC/MDD and CBR

2.5.1.3. Conduct the Liquid Limit, Plastic Limit, Linear Shrinkage and Plasticity Index determination from the **-0.425 mm material only** obtained from the grading analysis.

2.5.1.4. Results must be entered on Form A.

2.5.1.4.1. Please select (✓) the test method from those provided on the forms. ***ONLY MAKE USE OF ONE OF THE METHODS LISTED.***

2.5.1.4.2. Fill in the sieve opening sizes used for the grading analysis along with the percentage passing each sieve.

SAMPLE B

2.5.2. **PI <u>(-0.425 mm only)</u>** **approx. 500 g** **Ref: Round _-B/20__**

2.5.2.1. Tests to be conducted on this sample include

2.5.2.1.1. LiquidLimit (LL)

2.5.2.1.2. PlasticLimit (PL)

2.5.2.1.3. Linear Shrinkage (LS)

Conduct the Liquid Limit, Plastic Limit, Linear Shrinkage and Plasticity Index determination from the **<u>-0.425 mm material only</u>** as supplied.

Results must be entered on Form B

2.5.2.1.4. *Please select (✓) the test method from those provided on the forms.* ***ONLY MAKE USE OF ONE OF THE METHODS LISTED.***

SAMPLE C

2.5.3. **Borrow pit sand** **approx. 100 kg** **Ref: Round _- C/20__** *(3 bags)*

2.5.3.1. Tests to be conducted on this sample include

2.5.3.1.1. Grading

2.5.3.1.2. Liquid Limit (LL)

2.5.3.1.3. PlasticLimit (PL)

2.5.3.1.4. Linear Shrinkage (LS)

2.5.3.1.5. Maximum Dry Density (MDD) & Optimum Moisture Content (OMC)

2.5.3.1.6. California Bearing Ratio (CBR) - CBR

2.5.3.2. Remove the grading sample first and use the remaining sample to undertake the OMC/MDD and CBR

2.5.3.3. Conduct the Liquid Limit, Plastic Limit, Linear Shrinkage and Plasticity Index determination from the **-0.425 mm material only** obtained from the grading analysis.

2.5.3.4. Results must be entered on Form C

2.5.3.4.1. *Please select (✓) the test method from those provided on the forms.* ***ONLY MAKE USE OF ONE OF THE METHODS LISTED.***

SAMPLE D

2.5.4. Aggregate sample approx.25 kg Ref: Round 3-4/2018 (1 bag)

2.5.4.1. Tests on the single sized Aggregate sample are to include

2.5.4.1.1. Aggregate grading

2.5.4.1.2. ALD by direct measurement

2.5.4.1.3. Flakiness Index (FI)

2.5.4.1.4. ACV

2.5.4.1.5. 10 % FACT

2.5.4.2. The participating laboratory must first remove a single representative sample from the aggregate sample for the aggregate grading, FI & ALD and then use the remainder of the single sized aggregate sample to undertake the ACV & 10% FACT methods (dry process only).

2.5.4.3. Results must be entered on Form D

2.5.4.3.1. Please select (✓) the test method from those provided on the forms. ***ONLY MAKE USE OF ONE OF THE METHODS LISTED.***

3. Results submission

3.1. Only **one (1) full set of results** is required on each report sheet obtained from the 4 samples supplied.

3.2. The results should reach Eng. Tayob at ANE via e-mail *by Day / Month / Year*

3.3. Should you have any queries with regards to what is required, please contact Eng. Tayob at ANE, email address: tayobh1@gmail.com

Form A

Measurement Result Form

Crushed granular sample   Round _- A/20__

Laboratory code		Analyst	

IMPORTANT:

1. **Report individual results for each test undertaken.**
2. **Report the results to the correct decimal place as detailed in the method used.**
3. **Ensure your units correspond to those as given on this test result form.**
4. **Please indicate whether the apparatus you make use of is fully automatic or manual where applicable.**
5. **If NO result is submitted please report as NULL, do not leave space blank.**

1. Sieve analysis Test Results

Sieve analysis							**% passing**
Select (✓)Test method used:	AASHTO T27		TMH1 A1(a) & A5		SANS 3001-GR1		
Please select the sieves sizes as used for the grading analysis							
Percentage Passing (%)	Sieve size (mm)						
	Mass of dry sample used for grading						**g**
	63	63					**%**
	53	50					**%**
	37.5	37.5					**%**
	26.5	28					**%**
	19	20					**%**
	13.2	14					**%**
	4.75	5					**%**
	2.36	2					**%**
	0.425	0.425					**%**
	0.250	0.250					**%**
	0.150	0.150					**%**
	0.075	0.075					**%**

Form A (continued)

Sieve analysis – Soil mortar calculations						
Select (✓) Test method used:	AASHTO T27		TMH1 A1(a) & A5		SANS 3001-PR5	
GM						
Coarse sand						%
Coarse sand ratio						
Coarse fine sand						%
Fine fine sand						%
Fine sand						%
Medium fine sand						%
Soil mortar						%

2. AtterbergResults using only -0.425 mm material

Select (✓) Test method used:	AASHTO T89 & 90		TMH1 A2 – A5		SANS 3001-GR10 - 12	
LiquidLimit						%
PlasticLimit						%
Linear Shrinkage						%
PlasticityIndex						%

3. OMC & MDD

Select (✓) Test method used:	*AASHTO T180*		*TMH1 A7*		*SANS 3001-GR30*	
Compaction hammer (*circle the correct apparatus as used*)						*Automatic / manual*
OMC						**%**
MDD						kg/m^3

Form A (continued)

4. CBR Test Results

<table>
<tr><td colspan="2">Select (✓) Test method used:</td><td>AASHTO T193</td><td></td><td>TMH1 A8</td><td></td><td>SANS 3001-GR40</td><td></td></tr>
<tr><td colspan="5">CBR press (circle the correct apparatus as used)</td><td colspan="3">Automatic / manual</td></tr>
<tr><td colspan="5">CBR measurement device (circle the correct apparatus as used)</td><td colspan="3">Loadcell / Proving Ring</td></tr>
<tr><td>Mould</td><td colspan="2">A</td><td colspan="2">B</td><td colspan="3">C</td></tr>
<tr><td>% Swell</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="3">%</td></tr>
<tr><td>% of MDD</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="3">%</td></tr>
<tr><td>Dry Density</td><td colspan="2">kg/m³</td><td colspan="2">kg/m³</td><td colspan="3">kg/m³</td></tr>
<tr><td>Moulding moisture</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="3">%</td></tr>
<tr><td colspan="5">CBR value @ 100 %</td><td colspan="3"></td></tr>
<tr><td colspan="5">CBR value@ 95 %</td><td colspan="3"></td></tr>
<tr><td colspan="5">CBR value@ 90 %</td><td colspan="3"></td></tr>
</table>

Laboratory Supervisor :……………………………………………….

Date: ……………………………………………………………….

Form B

Measurement Result Form

PI (-0.425 mm only) Round _-B/20__

Laboratory code		Analyst	

IMPORTANT:

1. **Report individual results for each test undertaken.**
2. **Report the results to the correct decimal place as detailed in the method used.**
3. **Ensure your units correspond to those as given on this test result form.**
4. **Please indicate whether the apparatus you make use of is fully automatic or manual where applicable.**
5. **If NO result is submitted please report as NULL, do not leave space blank.**

1. AtterbergResults using only -0.425 mm material

Select (✓) Test method used:	AASHTO T89 & 90		TMH1 A2 – A5		SANS 3001-GR10 - 12	
Liquid Limit						**%**
Plastic Limit						%
Linear Shrinkage						%
PlasticityIndex						%

Laboratory Supervisor: ……………………………………………

Date: ……………………………………………………………

Form C

Measurement Result Form

Borrow pit sand Round _-C/20__

Laboratory code		Analyst	

IMPORTANT:

1. **Report individual results for each test undertaken.**
2. **Report the results to the correct decimal place as detailed in the method used.**
3. **Ensure your units correspond to those as given on this test result form.**
4. **Please indicate whether the apparatus you make use of is fully automatic or manual where applicable.**
5. **If NO result is submitted please report as NULL, do not leave space blank.**

2. Sieve Analysis Test Results

Sieve analysis						
Select (✓) Test method used:	AASHTO T27		TMH1 A1(a) & A5		SANS 3001-AG1	
Mass of dry sample used for Grading					g	
Please fill in sieves sizes as used for the grading analysis					% passing	
9.5	10				%	
6.7	7.1				%	
4.75	5				%	
2.36	2				%	
1.18	1				%	
0.600	0.600				%	
0.300	0.300				%	
0.150	0.150				%	
0.075	0.075				%	

Sieve analysis – FM calculations						
Select (✓) Test method used:	AASHTO T27		TMH1 A1(a) & A5		SANS 3001-PR5	
FM						

Form C (continued)

3. Atterberg Results using <u>only</u> <u>-0.425 mm material</u>

Select (✓) Test method used:	AASHTO T89 & 90		TMH1 A2 – A5		SANS 3001 GR10 - 12	
LiquidLimit					%	
PlasticLimit					%	
Linear Shrinkage					%	
PlasticityIndex					%	

4. OMC & MDD

Select (✓) Test method used:	*AASHTO T180*		*TMH1 A7*		*SANS 3001-GR30*	
Compaction hammer (*circle the correct apparatus as used*)					*Automatic / manual*	
OMC					**%**	
MDD					kg/m³	

5. CBR Test Results

Select (✓) Test method used:	*AASHTO T193*		*TMH1 A8*		*SANS 3001-GR40*	
CBR press (*circle the correct apparatus as used*)					*Automatic / manual*	
CBR measurement device (*circle the correct apparatus as used*)					*Load cell / Proving Ring*	

Mould	A	B	C
% Swell	%	%	%
% of MDD	%	%	%
Dry Density	kg/m³	kg/m³	kg/m³
Moulding moisture	%	%	%
CBR value @ 100 %			
CBR value@ 95 %			
CBR value@ 90 %			

Laboratory Supervisor: …………………………………………………………

Date: ………………………………………………………………………

Form D

Measurement Result Form
Aggregate sample Round _-D/20__

Laboratory code		Analyst	

IMPORTANT:

1. **Report individual results for each test undertaken.**
2. **Report the results to the correct decimal place as detailed in the method used.**
3. **Ensure your units correspond to those as given on this test result form.**
4. **If NO result is submitted please report as NULL, do not leave space blank.**

Singlesized aggregate sample results

Sieve analysis						
Select (✓) Test method used:	AASHTO T27		TMH1 B4		SANS 3001-AG1	
Mass of dry sample used for Grading					g	
Please fill in sieves sizes as used for the grading analysis					% passing	
37.5	37.5				%	
26.5	28				%	
19	20				%	
13.2	14				%	
9.5	10				%	
6.7	7.1				%	
4.75	5				%	
2.36	2				%	
1.18	1				%	
0.600	0.600				%	
0.300	0.300				%	
0.150	0.150				%	
0.075	0.075				%	

Form D (continued)

Single sized aggregate sample results (continued)

Select (✓) Test method used:	TMH1 B18(a)T		SANS 3001-AG2	
Average Least Dimension (ALD) (direct measurement)			mm	
Mass of sample used			g	
Number of particles counted			Nº	

Select (✓) Test method used:	*ASTM D4791*		*TMH1 B3*		*SANS 3001-AG4*	
Flakiness Index (FI)					%	
Mass of sample used					g	

Select (✓) Test method used:	*ASTM D5821*		*TMH1 B1*		*SANS 3001 -AG10*	
Aggregate Crushing Value (ACV)					%	
Mass of single specimen used					g	

Select (✓) Test method used:	*ASTM D5821*		*TMH1 B2*		*SANS 3001-AG10*	
10% Fines Aggregate Crushing Test (10% FACT) (*dry method only*)					kN	
Mass of single specimen used					g	

Laboratory Supervisor: ……………………………………………………

Date: ………………………………………………………………