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Concrete – 2023 (115)

Proficiency Testing Program Report

WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17043

Report

This report is available on the LabSmart Services website. The issue of this proficiency report was authorised by Jeffrey Mulholland, General Manager, LabSmart Services, November 2023.

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Program Coordinator

The program coordinator for this program was Jeffrey Mulholland, with assistance from Shantelle Popple, LabSmart Services.

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Please note that any technical questions regarding this program are to be directed to the program coordinator.

Z-scores Summary

A z-scores summary for this program was issued in June 2023. This technical report supersedes the z-scores summary.

Accredited Proficiency Testing Provider

LabSmart Services is accredited by NATA to **ISO/IEC 17043,** Conformity assessment – General requirements for proficiency testing. Accreditation number 20650. The accreditation provides additional assurance to participants of the quality and importance we place on our proficiency testing programs.

LabSmart Services

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Amendment History

Reports may be downloaded from the LabSmart Services website.
Version 1 – Issued 23 November 2023

Contents

1. Program Aim

This proficiency testing program was conducted in April/May 2023 with 43 participants from around Australia. The program involved the performance of:

- AS 1012.9 – 2014, Compressive strength tests — Concrete, mortar and grout specimens
- AS 1012.12.1 – 1998 (R2014), Determination of mass per unit volume.

The program provides confidence to the construction materials testing industry regarding the competency of participants (and the industry) to perform these tests. Each participant's performance is statistically assessed and used as a measure of competency relative to all those who participated. Other measures of performance are also used.

This report has been prepared using robust statistics. Information regarding the conduct and design of the program can be found in section 5.

Technical comment (section 3) is provided to assist participants to improve the overall performance of these tests. In addition, test data has been reviewed for consistency, and additional feedback regarding aspects of the test are provided.

A Z-score summary was issued on the 6th of June 2023 to facilitate early feedback on performance.

2. Performance

2.1. Identified Outliers

There were 9 outliers across 5 participants identified across the tests performed.

Participant's test results are tabulated in section 4, along with the robust statistics and a z-score. The z-score indicates how far away a participant is from the program's median value. A z-score between –1 and 1 indicates a strong consensus concerning all other participants and represents a very good outcome. The z-score graph gives a quick visual indication of how a result compares to others in the program.

Outliers are where a z-score value is greater than 3 or less than -3. It is recommended that participants with outliers investigate their performance of the test. Participants with outliers are detailed in Table 1.

Those participants with z-scores greater than 2 or less than -2 should review their testing methodology. Only those approaching a z-score of 3 (i.e. outside ± 2.75) have been specifically identified in Table 1 as feedback.

More detail on the robust statistics used can be found in section 5.9.

Technical comment and feedback in section 3 is provided to assist participants to investigate or review their results, as well as for those seeking to improve their testing performance.

Table 1: Statistical Outliers

Test	Investigate (Outliers)		Review (Outside |2.75|)	
	Sample		***Sample***	
	A	**B**	**A**	**B**
Compressive strength	**E2**	**V9, X6, E2**	**-**	**-**
Mass per unit volume	**G9, D2, E2**	**D2, E2**	**-**	**-**

During the reporting process, LabSmart undertakes analysis on all the data supplied by participants and uses the additional information supplied to replicate each participant's final result. If LabSmart identifies a discrepancy during this process the participant in question will be flag as a 'non-statistical' concern, and it is recommended that this participant Review their process. See Table 2 below and section 3 for further detail.

Table 2: Results requiring further investigation or review (non-statistical)

Test	Review (Non-statistical Outliers)	
	Sample	
	A	**B**
Compressive strength	**-**	**A7**
Mass per unit volume	**V2**	**J9 & R6**

2.2. Program Summary

There were 42 participants in the program who returned results on time for the final report.

The overall performance of all the participants was very good. The spread of results (variation) was within industry expectations. Greater care in completing proficiency testing log sheets and better checking by supervisors needs to be undertaken.

The majority of the participants had results (for compressive strength and mass per unit volume) within 1 s.d, which was a good outcome. There were only nine results that had a z-score below -2 or above 2 and it is strongly recommended that these participants review their performance.

Overall, the results are within industry expectations and demonstrated that all participants were competent in performing these tests.

Table 3: Summary of test results statistics.

Statistic	Sample A		Sample B	
	Compressive Strength (MPa)	**Mass per unit volume** (kg/m^3)	**Compressive Strength** (MPa)	**Mass per unit volume** (kg/m^3)
No of participants	42	42	42	42
Median	28.7	2199	49.8	2300
N-IQR	2.24	20.50	1.76	18.35
CV (%)	7.8	0.7	3.5	0.8
Range *	9.2	65	7.3	76

* excludes outlier results.
Some statistics have been rounded

3. Technical Comment

General

A summary of submitted results for all participants may be found in section 6. The reporting requirements under the Australian Standard are 'compressive strength' and 'Mass Per Unit Volume'. Outlier assessment was undertaken based on these results; the robust statistical analysis can be found in section 4 of this report.

Table 4: Summary of CV for current and past programs

Coefficient of Variation (%)			
Program	**Sample**	**Mass per Unit Volume**	**Compressive Strength**
2023(115)	A	0.7	7.8
	B	0.8	3.5
2022 (111)	A	0.7	3.2
	B	0.6	3.7
2022 (108)	A	0.6	5.5
	B	0.7	4.0
2021(102)	A	0.8	2.4
	B	0.6	2.0
2020(95)	A	1.0	6.1
	B	0.6	3.9
2019(88)	A	0.5	3.7
	B	0.6	3.9
2018(80)	A1	1.3	2.8
	B1	1.2	4.9
	A2	0.9	5.0
	B2	1.0	4.0
2017(70)	A1	0.6	5.7
	A2	0.4	2.6
	B1	0.7	5.8
	B2	1.0	8.3

Outcome

Overall, participants had a very good agreement for both the ‘Mass per Unit Volume’ and the ‘Compressive Strength’. The coefficient of variation (CV) shown in Table 4 is one way to **broadly evaluate** that the participant performance is consistent from one program to another. Based on this, participants did well, However, it should be noted that the actual fluctuation in CV values may be attributed to a range of factors. Therefore, further conclusions should not be inferred from the fluctuations observed. See section 5.9 for further details.

Missing Information

Most participants provided all the information requested on the results log sheet. Thank you to all participants, as this makes it far easier to provide informative feedback. However, it was noted that some participants didn’t complete all sections as requested.

3.1. Compressive Strength

Nominated Test Date

At times it is not possible to test a sample on its nominated test date, and this can be the result of a range of factors (for example, staff/equipment availability). In this instance, there were 6 participants that did not test on the nominated date of May 10th. (see Table 5).

Table 5: Variation in test date

Participant	**N2**		**X3**		**J4**	
Sample	**A**	**B**	**A**	**B**	**A**	**B**
Difference in days	+1	+1	+2	+2	+10	+10
Result (MPa)	29.2	49.5	26.6	51.0	31.8	51.8
Median (MPa)	28.7	49.8	28.7	49.8	28.7	49.8
Z-score	**0.25**	**-0.14**	**-0.91**	**0.71**	**1.40**	**1.16**
Participant	**A6**		**K9**		**M3**	
Sample	**A**	**B**	**A**	**B**	**A**	**B**
Difference in days	+10	+10	+10	+10	+10	+10
Result (MPa)	27.5	49.5	26.9	50.8	29.9	48.8
Median (MPa)	28.7	49.8	28.7	49.8	28.7	49.8
Z-score	**-0.51**	**-0.14**	**-0.78**	**0.60**	**0.56**	**-0.54**

Participant **X3**, **N2**, **J4**, **A6**, **K9** & **M3** didn't test on the nominated test date (10/5/2023), for these participants testing ranged from 1-10 days late; analysis of the data showed that it did not significantly affect the final outcome.

Incomplete crushing

It was noted during past programs that some cap failures can caused the compression machine to register that maximum load had been reached, even thou it had not reached its maximum load. For these cases further crushing (retesting) could yield a higher strength. Some participants may have found this, while some may not have been aware that this can occur. This is an area of the test that LabSmart cannot assess, but it is important for laboratories to monitor.

Calculation of compressive strength (Non-Statistical)

From the reported diameter and maximum force, the 'Compressive Strength' results can be determined. This was done for each participant and the calculated result compared to the reported compressive strength. Most participants obtained good agreement. As it is a reporting requirement to round the compressive strength to the closest 0.5MPa; therefore, participants showing a difference greater than 0.3 MPa can be found in Table 6. For these participants, it may be worthwhile reviewing these results.

Table 6: Recalculated 'Compressive Strength' results

Code	Compressive Strength		
	Submitted (MPa)	**Recalculated** (MPa)	**Difference** (MPa)
A7 (Sample B)	52.4	52.0	-0.4

Statistical Outliers

Overall, a satisfactory level of testing was achieved by most participants for compressive strength with only 4 outliers across both Sample A and B.

LabSmart assessed the 'results log' sheets for all 4 outliers for compressive strength. All information supplied by participants supported the outcome for their final results; participants recorded a range of capping methods and failure types (See section 6 for these details), given that all the supplied information matches the final outcome, with the exception of participant **E2** further comment is limited for these participants.

Participant **E2** appears to have mixed up their samples, LabSmart investigated all the data supplied (Supporting data and final results for both strength and MPUV) and had participant **E2** supplied their results for both Sample A and B around the other way, they would have had a more favourable outcome across all testing (only one sample would have been seen as an outlier for compressive strength). Participant **E2** should review their testing process.

Overall, when it comes to outliers for compressive strength, Incomplete crushing (see earlier subsection) may have been an issue for some of samples identified in this program. Additionally, centering the specimens on the platens may have been a factor, but it is hard to check post-testing. Furthermore, checking for transcription errors may be worth considering. However, if no issues can be found with the testing practices, then the outcome would suggest an issue that cannot be checked, e.g. platen centring, grinding etc.

Failure Modes

Out of all the participants who returned the results, ~45% reported 'Cap Failure' for Sample A and ~29% for Sample B. In addition, ~5% reported 'shear failure' for Sample A and ~17% for Sample B. All other participants results reporting either a 'Normal' or 'Conical Failure'. Table 7 shows the 'normal/conical' failure statistics vs abnormal (Both 'Cap' and 'Shear') failures.

The median values are very close to the combined results in section 4 regardless of the failure mode. The variation associated with an abnormal failure was not much different from those showing 'normal' failure.

The comparisons drawn above have been observed in previous programs as well. There is no substantial evidence to suggest that 'Shear failure' or 'Cap failure' values should be discounted or excluded from the data set.

The effect the mode of failure has on the compressive strength result is difficult to determine except in instances where unrealistic results are obtained. Equipment configuration, air voids, variability in compaction and aggregate distribution are only some of the factors that affect the mode of failure. Possible causes of abnormal failures might include capping and crushing practices, the stability of the load frame (i.e. alignment, squareness and rigidity), as well as the correct working/alignment of platens.

Table 7: Normal/Conical and Shear/Cap failure statistics for sample A & B

Compression Statistic MPa	**Sample A**	**Sample B**
	Normal - Conical failure results only.	
Median (MPa)	29.0	49.6
NIQR	1.63	2.34
Number of Participants	21	23
Compression Statistic MPa	**Sample A**	**Sample B**
	Abnormal - Cap or shear failure results only.	
Median (MPa)	27.0	50.0
NIQR	2.22	1.70
Number of Participants	21	19

Capping Methods

Out of the 42 participants who returned the results, 33 participants (79%) used rubber caps, with 8 participants (19%) using grounded ends, and there was 1 participant (2%) who reported using Sulphur capping.

In this program, it was not possible to determine if there was any statistical variation due to the capping method employed, this was due to the small numbers in some groupings. Previous proficiency programs have not encountered any adverse correlation between reported ‘compressive strength’ and the capping method.

For this program, ‘rubber caps’, ‘sulphur capping’ and ‘end-cut’ were considered to yield equivalent results and were analysed as a group.

3.2. Mass Per Unit Volume

Calculation of Mass Per Unit Volume

The 'Mass Per Unit Volume' result can be determined from the reported height, diameter, and weight. For this program, all participants' 'Mass Per Unit Volume' results were recalculated based on the intermediate data supplied. This was done for each result and compared to the reported 'Mass Per Unit Volume'. Generally, good agreement was obtained.

The test method requires the 'Mass Per Unit Volume' result to be rounded to the nearest 20 kg/m^3. However, for this proficiency program, Participants were requested to report to the nearest 1 kg/m^3. Some participants reported results that may have been rounded to the nearest 20 kg/m^3. This reduces the quality of feedback that can be given to participants. For this report, we focused on results that differed by greater than or equal to 10 kg/m^3 (Table 8). These are considered non-statistical outliers.

Table 8: Recalculated 'Mass Per Unit Volume' results

Participant	Submitted (kg/m^3)	Recalculated (kg/m^3)	Difference (kg/m^3)
V2 (Sample A)	2201	2181	-20
J9 (Sample B)	2300	2175	-125
R6 (Sample B)	2300	2224	-76

It is essential that the calculation process is correct and accurate. Instructions on the calculation process can be found in Section 8 of AS 1012.12.1. It states that 'Mass Per Unit Volume' is the mass divided by the cylinder volume. The volume of a cylinder is given by $V=\pi r^2 h$ where 'h' is the cylinder height, and 'r' is the average radius, (i.e. Half the average diameter).

Unrounded values for diameter and height should be used when calculating the volume. The value of pi used can also have an effect. Those using Excel can use the pi() function. Those with calculators that do not have a pi function should use 333/106. The use of 22/7 does not have enough accuracy for this test.

Statistical Outliers

Overall, a satisfactory level of testing was achieved by the majority of participants for ‘Mass Per Unit Volume’. There were 5 outliers for ‘Mass Per Unit Volume’ over both samples A and B.

LabSmart assessed the ‘results log’ sheets for all 5 outliers for Mass Per Unit Volume. All information supplied by participants supported the outcome for their final result (See section 6 for these details), given that all the supplied information matches the final outcome, with the exception of participant **E2** further comment is limited for these participants.

Participant **E2** appears to have mixed up their samples, LabSmart investigated all the data supplied (Supporting data and final results for both strength and MPUV) and had participant **E2** supplied their results for both Sample A and B around the other way, they would have had a more favourable outcome across all testing. Participant **E2** should review their testing process.

Reporting of cylinder weights

Some participants cylinder weights were reported in grams instead of kilograms. Converted values are shown in section 6 of the report. Participants need to ensure they follow proficiency program instructions. Conversions were undertaken as these values were used to verify the participants reported MPUV results.

4. Statistics: Z-Score & Graph

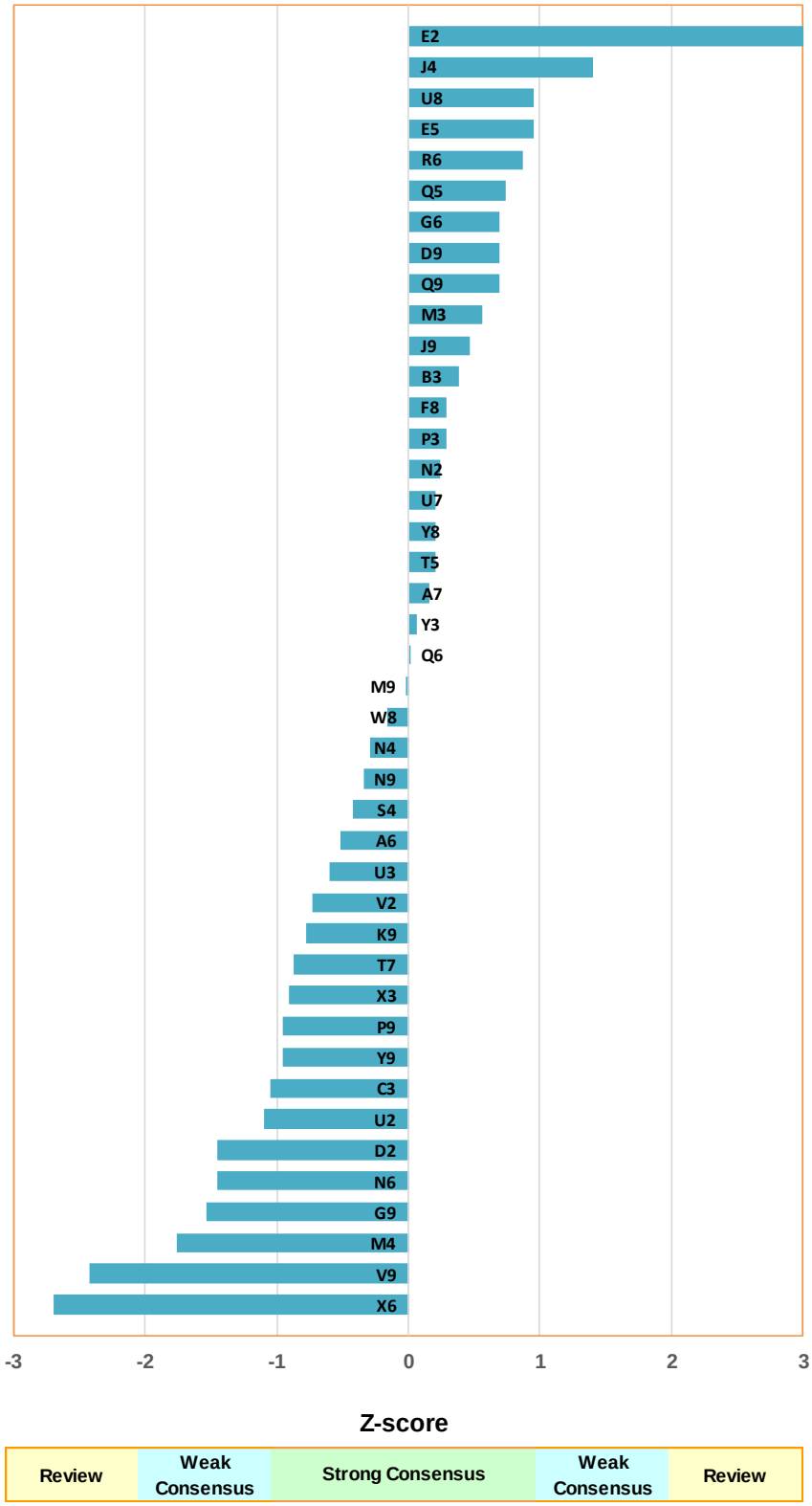
Sample A - Compressive Strength: Z - Scores

Code	Test Result MPa	Z Score	Code	Test Result MPa	Z Score
V9	23.2	-2.43	T5	29.1	0.20
X6	22.6	-2.70	V2	27.0	-0.74
C3	26.3	-1.05	U2	26.2	-1.09
G9	25.2	-1.54	M4	24.7	-1.76
F8	29.3	0.29	Q5	30.3	0.74
D2	25.4	-1.45	N6	25.4	-1.45
W8	28.3	-0.16	S6		
U7	29.1	0.20	J4	31.8	1.40
G6	30.2	0.69	A6	27.5	-0.51
U3	27.3	-0.60	K9	26.9	-0.78
U8	30.8	0.96	M3	29.9	0.56
D9	30.2	0.69	Y9	26.5	-0.96
Y8	29.1	0.20	X3	26.6	-0.91
Y3	28.8	0.07	N2	29.2	0.25
M9	28.6	-0.02	E2	41.0	**5.51** #
P9	26.5	-0.96			
A7	29.0	0.16			
Q6	28.7	0.02			
B3	29.5	0.38			
N9	27.9	-0.33			
T7	26.7	-0.87			
E5	30.8	0.96			
N4	28.0	-0.29			
P3	29.3	0.29			
S4	27.7	-0.42			
J9	29.7	0.47			
R6	30.6	0.87			
Q9	30.2	0.69			

Statistic	*Value*	
Number of results	**42**	
Median	**28.7**	
Median MU	**0.43**	
First Quartile	**26.6**	
Third Quartile	**29.7**	
IQR	**3.03**	
Normalised IQR	**2.24**	
CV (%)	**7.8**	
Minimum	**22.6**	(22.6)
Maximum	**31.8**	(41.0)
Range	**9.2**	(18.4)

Note: A # indicates an outlier where the z-score obtained is either greater then 3 or less than -3. Codes for all participates are shown. The results column shows a blank entry or 'NR' for those participants that did not submit a result for this test. Results in **green** have been calculated by the program coordinator. An R indicates an abnormal result rejected by the program coordinator. Minimum, Maximum and Range are calculated with outliers excluded, those in brackets include outliers.

Sample A - Compressive Strength: Z - Score Graph



Sample A - MPUV: Z - Scores

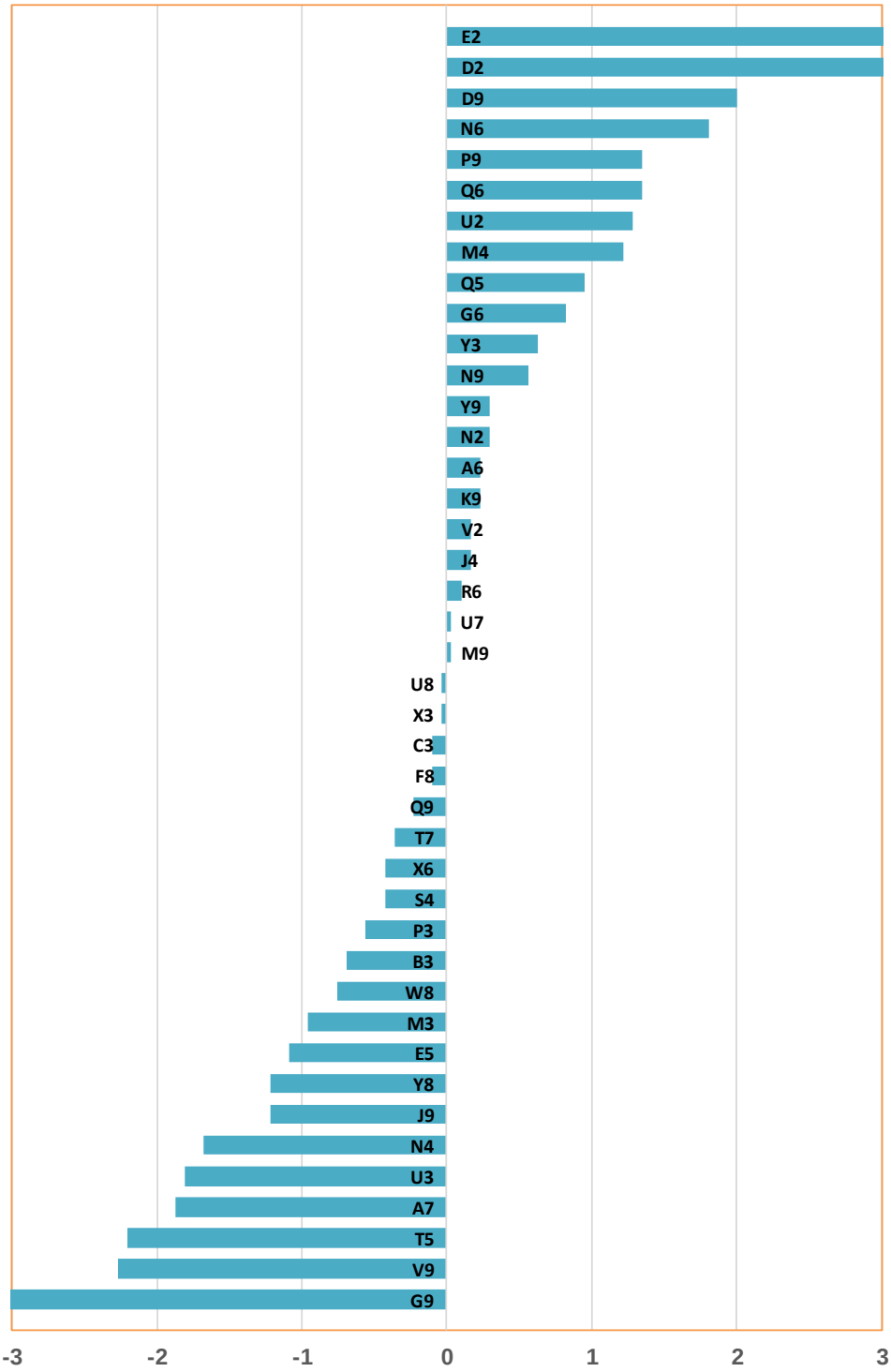
Code	Test Result kg/m³	Z Score
V9	2164	-2.27
X6	2192	-0.43
C3	2197	-0.10
G9	2146	**-3.45** #
F8	2197	-0.10
D2	2307	**7.14** #
W8	2187	-0.76
U7	2199	0.03
G6	2211	0.82
U3	2171	-1.81
U8	2198	-0.03
D9	2229	2.01
Y8	2180	-1.22
Y3	2208	0.63
M9	2199	0.03
P9	2219	1.35
A7	2170	-1.88
Q6	2219	1.35
B3	2188	-0.69
N9	2207	0.56
T7	2193	-0.36
E5	2182	-1.09
N4	2173	-1.68
P3	2190	-0.56
S4	2192	-0.43
J9	2180	-1.22
R6	2200	0.10
Q9	2195	-0.23

Code	Test Result kg/m³	Z Score
T5	2165	-2.20
V2	2201	0.16
U2	2218	1.28
M4	2217	1.22
Q5	2213	0.95
N6	2226	1.81
S6		
J4	2201	0.16
A6	2202	0.23
K9	2202	0.23
M3	2184	-0.95
Y9	2203	0.30
X3	2198	-0.03
N2	2203	0.30
E2	2320	**8.00** #

Statistic	*Value*	
Number of results	**42**	
Median	**2199**	
Median MU	**2.93**	
First Quartile	**2187**	
Third Quartile	**2208**	
IQR	**20.50**	
Normalised IQR	**15.20**	
CV (%)	**0.7**	
Minimum	**2164**	(2146)
Maximum	**2229**	(2320)
Range	**65**	(174)

Note: A # indicates an outlier where the z-score obtained is either greater then 3 or less than -3. Codes for all participates are shown. The results column shows a blank entry or 'NR' for those participants that did not submit a result for this test. Results in **green** have been calculated by the program coordinator. An R indicates an abnormal result rejected by the program coordinator. Minimum, Maximum and Range are calculated with outliers excluded, those in brackets include outliers. Results in **orange** have had the units of measurement changed e.g Grams to Kilograms

Sample A - MPUV: Z - Score Graph



Sample B - Compressive Strength: Z - Scores

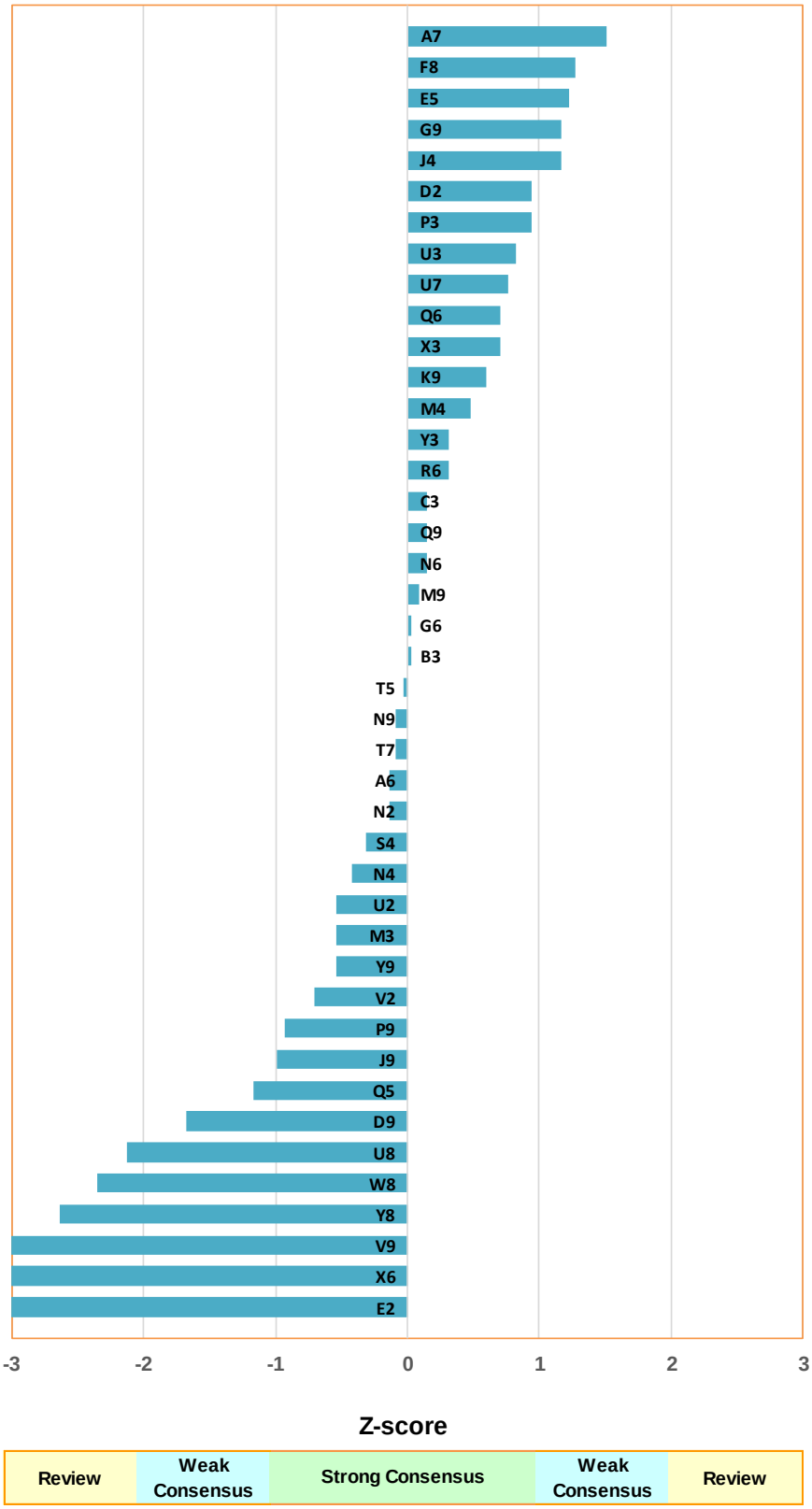
Code	Test Result MPa	Z Score
V9	41.9	**-4.46** #
X6	37.7	**-6.84** #
C3	50.0	0.14
G9	51.8	1.16
F8	52	1.28
D2	51.4	0.94
W8	45.6	-2.36
U7	51.1	0.77
G6	49.8	0.03
U3	51.2	0.82
U8	46.0	-2.13
D9	46.8	-1.68
Y8	45.1	-2.64
Y3	50.3	0.31
M9	49.9	0.09
P9	48.1	-0.94
A7	52.4	1.51
Q6	51.0	0.71
B3	49.8	0.03
N9	49.6	-0.09
T7	49.6	-0.09
E5	51.9	1.22
N4	49.0	-0.43
P3	51.4	0.94
S4	49.2	-0.31
J9	48.0	-0.99
R6	50.3	0.31
Q9	50.0	0.14

Code	Test Result MPa	Z Score
T5	49.7	-0.03
V2	48.5	-0.71
U2	48.8	-0.54
M4	50.6	0.48
Q5	47.7	-1.16
N6	50.0	0.14
S6		
J4	51.8	1.16
A6	49.5	-0.14
K9	50.8	0.60
M3	48.8	-0.54
Y9	48.8	-0.54
X3	51.0	0.71
N2	49.5	-0.14
E2	28.3	**-12.18** #

Statistic	*Value*	
Number of results	**42**	
Median	**49.8**	
Median MU	**0.34**	
First Quartile	**48.6**	
Third Quartile	**51.0**	
IQR	**2.38**	
Normalised IQR	**1.76**	
CV (%)	**3.5**	
Minimum	**45.1**	(28.3)
Maximum	**52.4**	(52.4)
Range	**7.3**	(24.1)

Note: A # indicates an outlier where the z-score obtained is either greater then 3 or less than -3. Codes for all participates are shown. The results column shows a blank entry or 'NR' for those participants that did not submit a result for this test. Results in **green** have been calculated by the program coordinator. An R indicates an abnormal result rejected by the program coordinator. Minimum, Maximum and Range are calculated with outliers excluded, those in brackets include outliers.

Sample B - Compressive Strength: Z - Score Graph



Sample B - MPUV: Z - Scores

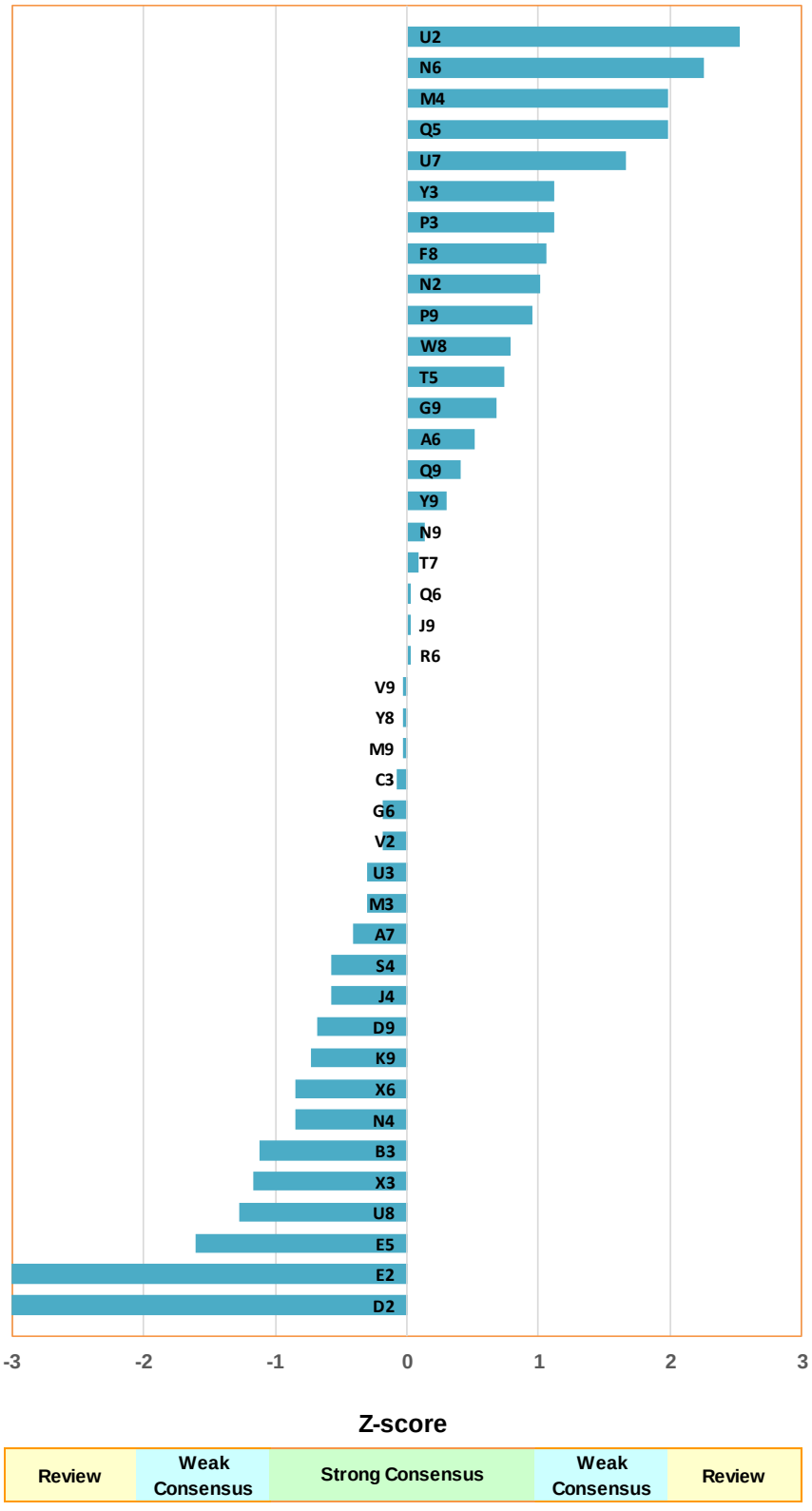
Code	Test Result kg/m³	Z Score
V9	2299	-0.03
X6	2284	-0.84
C3	2298	-0.08
G9	2312	0.68
F8	2319	1.06
D2	2147	**-8.31** #
W8	2314	0.79
U7	2330	1.66
G6	2296	-0.19
U3	2294	-0.30
U8	2276	-1.28
D9	2287	-0.68
Y8	2299	-0.03
Y3	2320	1.12
M9	2299	-0.03
P9	2317	0.95
A7	2292	-0.41
Q6	2300	0.03
B3	2279	-1.12
N9	2302	0.14
T7	2301	0.08
E5	2270	-1.61
N4	2284	-0.84
P3	2320	1.12
S4	2289	-0.57
J9	2300	0.03
R6	2300	0.03
Q9	2307	0.41

Code	Test Result kg/m³	Z Score
T5	2313	0.74
V2	2296	-0.19
U2	2346	2.53
M4	2336	1.99
Q5	2336	1.99
N6	2341	2.26
S6		
J4	2289	-0.57
A6	2309	0.52
K9	2286	-0.74
M3	2294	-0.30
Y9	2305	0.30
X3	2278	-1.17
N2	2318	1.01
E2	2220	**-4.33** #

Statistic	*Value*	
Number of results	**42**	
Median	**2300**	
Median MU	**3.54**	
First Quartile	**2289**	
Third Quartile	**2314**	
IQR	**24.75**	
Normalised IQR	**18.35**	
CV (%)	**0.8**	
Minimum	**2270**	(2147)
Maximum	**2346**	(2346)
Range	**76**	(199)

Note: A # indicates an outlier where the z-score obtained is either greater then 3 or less than -3. Codes for all participates are shown. The results column shows a blank entry or 'NR' for those participants that did not submit a result for this test. Results in **green** have been calculated by the program coordinator. An R indicates an abnormal result rejected by the program coordinator. Minimum, Maximum and Range are calculated with outliers excluded, those in brackets include outliers. Results in **orange** have had the units of measurement changed e.g Grams to Kilograms.

Sample B - MPUV: Z - Score Graph



5. Program Information

5.1. Z-score Summary

This proficiency program was conducted in April/May of 2023. A 'Z-score Summary' was issued on the 6th of June 2023. The summary is intended as an early indicator of participant performance; all results were accepted as they were submitted, except for adjusting units of measurements (i.e. grams to Kilograms).

Since the release of the 'Z-score Summary' a correction was made to Sample A's Mass Per Unit Volume Z-score. The original z-score did not show all results in their correct manner, this has been corrected for this report. This report supersedes the original z–score summary.

Further information can be found in section 5.9, 'Statistics'.

5.2. Program Design

5.2.1. Design

This program is held one to two times a year. Participants are required to test two concrete cylinders. The cylinders may be matched (same strength) or unmatched in strength (different strengths). The compressive strength also changes from program to program.

The test requires a minimum skill level. Adherence to the test method is essential for consistent test results. Participant results are checked where possible.

It is expected that the level of experience/skill needed to perform these tests will present a reasonable assessment of the overall competency of the tester and industry performance.

The program was designed to provide technical feedback regarding performance as well as possible improvements. Other considerations involving the design of the program are detailed below.

5.2.2. Selection of material used in the program

Materials used in the preparation of concrete cylinders are selected to ensure that the desired characteristics, such as finish, compressive strength, etc., are obtained.

The concrete cylinders used for this program are made specifically for the program under controlled conditions to ensure uniformity in the strength of the cylinders provided.

5.2.3. Role of proficiency testing

The determination of outliers is an important task of this proficiency program. A secondary function is to provide feedback that can help those with outliers identify possible areas to investigate and assist all participants to improve.

In addition to the statistics, proficiency programs often obtain other information that is not normally made available. It allows for a better understanding of the testing and can provide information that can lead to improvements in the testing process or test method.

Proficiency testing enables participants to measure competency against others. It is also a measure of staff performance and the equipment used. Apart from ‘measurement uncertainty’, it is the most useful tool a laboratory has in better understanding the performance of a test.

5.2.4. Participant assessment

Assessment of each participant is based on a z-score related to the program consensus value (median); this is used to determine any statistical outliers. Compliance with proficiency program requirements, including the correct calculation of results, adherence to program and test method requirements, may also be used as part of the assessment process. Participants may also be asked to investigate any discrepancies detected with the paperwork submitted. See section 5.10 for further details.

5.2.5. Confidentiality

All information, including test results are treated confidentially. The proficiency testing report does not identify either companies or individuals. Each participant is issued a unique identifying code during enrolment that is used in the report to ensure confidentiality of performance.

5.2.6. Reporting of results - Significant figures

The number of decimal places (significant figures) reported for a test has a bearing on the statistical analysis and, therefore, the interpretation of the results. There is a need to strike a balance between what is desirable from a statistical viewpoint while recognising how the results are used in practice.

Too few decimal places (e.g. due to rounding) can cause an increase in the observed spread of results. Increasing the number of decimal places (with respect to normal reporting) can distort the observed spread of results compared to that encountered in actual practice. Large numbers of similar, rounded results can also cause a distortion in the analysis.

For example, rounding to 0.5 % means that any number between 10.75 and 11.25 will be 11.0%. If the largest value is 10.75 in a set of results, it is pushed out to 11.0 through rounding. Rounded results are beneficial from “an end-user” perspective but are not as useful when considering laboratory performance. The test method acknowledges that additional decimal places may be used for statistical purposes.

For this program, it was decided that the benefits of using additional decimal places would complement the aim of the proficiency program.

Participants results were analysed as received regardless of whether there were ‘more or less’ significant figures than the number requested by the program.

5.2.7. Additional information requested

This program requested additional information as detailed in section 6 that may not usually be reported. However, the additional information is consistent with the test's performance and the records that the test method requires laboratories to maintain. The additional information is used to interpret participants' performance and provide technical comments, including feedback on outliers and possible participant improvement.

5.2.8. Data checks

As often observed, ‘operator errors’ can occur in the result calculation process. Every participant’s results were recalculated. Both strength and unit mass results were recalculated based on the data provided. Such checks, however, are only as accurate as the raw data supplied by each participant. These checks help ensure that the data is

comparable. Any inconsistencies identified during this process are identified as possible feedback for participant improvement. In some cases, inconsistencies identified may need to be investigated by participants.

5.3. Sample Preparation

Two batches of concrete were prepared using two different mix designs. For each mix, there were around 80 cylinders cast. Each cylinder was individually numbered. Cylinders were then cured in water baths after casting.

After curing, each cylinder was removed from the tank and was wrapped in paper and double sealed in two plastic bags. One batch was marked as ‘Sample A’ and the other ‘Sample B’. After removing homogeneity samples (at evenly distributed intervals). Samples were drawn at random from each batch to make a pair. Each pair of cylinders was assigned a unique participant code.

5.4. Packaging and Instructions

Each pair of cylinders was placed into a sturdy box with bubble wrap. The boxed samples weighed approximately 6 kg. Participants were instructed to test according to the nominated test method and report to the accuracy indicated on the ‘Results log’ sheet. See ‘Appendix A’ for a copy of the instructions issued to participants and ‘Appendix B’ for the log sheet used. A set of instructions and Result log sheets were placed in the box prior to sealing and dispatch.

5.5. Quarantine

For all participants, Quarantine requirements were assessed and met. There were no steps taken that would have affected individual participants.

5.6. Sample Dispatch

Samples were dispatched to participants on the 20th of April 2023 using Pack and Send. Dispatched samples are tracked from dispatch to delivery for each participant by LabSmart Services.

5.7. Homogeneity Testing

Samples for homogeneity testing were treated in the same manner as those used for all participants. The homogeneity samples were tested by a NATA accredited laboratory. The laboratory was issued the same instructions as the participants to approximate the same conditions.

Testing was undertaken prior to releasing samples to participants. This allows for early assessments, however, due to how concrete cures homogeneity data will be different from participant results. The homogeneity data was reviewed and found to be satisfactory. A summary of the homogeneity data is provided in Table *9*.

Table 9: Homogeneity Results

	Sample A			Sample B	
	Compressive Strength MPA	Mass per Unit Volume kg/m^3		Compressive Strength MPA	Mass per Unit Volume kg/m^3
H1	27.7	2196	H11	45.9	2299
H2	24.5	2197	H12	45.6	2303
H3	25.5	2217	H13	46.4	2319
H4	23.8	2194	H14	47.3	2317
H5	26.6	2175	H15	47.4	2300
H6	27.5	2185	H16	48.2	2301
H7	25.5	2207	H17	47.6	2286
H8	27.2	2189	H18	45.3	2311
H9	27.2	2196	H19	46	2299
H10	23.8	2200	H20	44.1	2301
Average	25.9	2196	Average	46.38	2303.6
Standard Deviation	1.5	11.5	Standard Deviation	1.2	9.7
Range	3.9	42	Range	4.1	33
Coefficient of Variation (%)	5.9	0.52	Coefficient of Variation (%)	2.7	0.42

5.8. Participation

Out of the 43 participants who entered the program, all except 1 participant did not return their results in time to be included in the report due to machinery breakdown.

5.9. Statistics

Z-Scores were calculated for each test and used to assess the variability of each participant relative to the consensus median. A corresponding z-score graph was produced for each test.

The use of median and quartiles reduces the effect that outliers have on the statistics and other influences. As a consequence, z-scores provide a more realistic or robust method of assessment.

Some results were reported by participants to more decimal places than requested as part of the proficiency program and by others to fewer decimal places. In all instances, test results have been used as submitted by participants.

A z-score is one way of measuring the degree of consensus with respect to the grouped test results. The z-scores in this report approximate standard deviations. For each test, a z-score graph is shown. Use the graph to visually check statistically how you compare to other participants.

The following bar is shown at the bottom of each graph. This helps to visualize where each participant's result falls quickly.

Review	Weak Consensus	Strong Consensus	Weak Consensus	Review

Figure 1: Z-score interpretation bar

For example:

- A **strong consensus** (i.e. agreement) means that your test result is close, i.e. within 1 standard deviation of the median.

- A **weak consensus** means that your test result is satisfactory and is within 2 standard deviations of the median.

- If you have obtained a test result that is outside 2 standard deviations, then it may be worth **reviewing** your testing processes to ensure that all aspects are satisfactory. Only those obtaining a z-score approaching 3 (I.e. outside 2.75 range) have been highlighted in the report for review.

If you have obtained a test result that is outside 3 standard deviations, then you will need to investigate your testing processes to ensure that all aspects are satisfactory.

Further details on the statistics used in this proficiency program can be obtained from LabSmart Services or download the 'Participant Guide' from the LabSmart Services website.

5.9.1. Z-score summary

A “Z-Scores Summary” is issued soon after most results are received. It gives participants early feedback as to any program outliers as needed. The summary is usually available on the LabSmart Services website up until the final report is issued. The final report supersedes the z-score summary.

The final report contains detailed technical feedback regarding the performance of tests and revised z-scores. The inclusion of late results or corrections is at the discretion of the program coordinator. In some instances, this may change some of the z-scores slightly, but generally, the performance outcome remains the same. If there is any impact, it will be discussed in section 5.1 of the report.

5.9.2. Comparing statistics from one program to another

The statistics generated from one proficiency program are not usually comparable to those from another proficiency testing program. Only very general comparisons may be possible. The reason statistics from one program may not be compared to another is due to the range of variables that differ from one proficiency program to another.

These variables include:

- Type of material selected
- The number of participants
- Experience of participants
- Test methodology variations
- Equipment used
- Test methods used
- Experience of supervisors
- Range of organisations involved
- Program design and the statistics employed

The program outcome represents a ‘snapshot’ of the competency within the industry and hence provides an overview of the industry. The more participants involved in the program than the more representative the overview.

5.9.3. Measurement uncertainty

The statistics detailed in this program (for each test) do not replace the need for laboratories to calculate measurement uncertainty when required by the client or NATA. However, the proficiency program does give information useful for calculating the MU and benchmarking the MU calculated.

5.9.4. Metrological traceability

The assigned median value used in this proficiency testing program is derived from participant performance and is not metrologically traceable.

5.10. Non-statistical Outliers

One of the issues faced by proficiency testing providers is what to do with an incorrect result even if its z-score is satisfactory. In many cases, they cannot be detected but still can have a significant impact on the statistics calculated. This can cause biased (or unfair) outcomes for other participants.

To limit the effect that erroneous results have on a program, additional information is requested to allow the main results to be recalculated. In some cases, results shown to be erroneous may be rejected for inclusion in the program. If the result does not add any statistical bias, it is left in the program. In the case of this program, if there was a Non-Statistical Outlier detected, it was taken as received and mention within this report.

The result, however, is incorrect even though it may have a satisfactory z-score. To highlight that the participant needs to investigate erroneous results, it is considered a ‘non-statistical outlier’.

This may also be applied to non-compliance to program requirements, e.g., incorrect reporting of results etc. or incorrect partial calculations/data.

6. Summary of Participants Results

Summary of Participant Results Sample A

Code	Damage	Surface	Conditioning	Capping	Height mm	Diameter mm		Weight kg	Mass per unit volume kg/m^3	Maximum Force kN	Compressive Strength MPa	Failure	Date Tested
V9	na	SS WET	Tropical	Rubber	199	100.1	101.2	3.426	2164	183	23.2	Cap Failure	10/05/2023
X6	na	SS WET	Tropical	Rubber	199	100.2	100.5	3.450	2192	179	22.6	Cap Failure	10/05/2023
C3	4 air voids	wet	Temperate	Rubber	199.5	99.50	99.64	3.412	2197	204.4	26.3	Cap Failure	10/05/2023
G9		wet	Temperate	Rubber	199	99.7	99.8	3.338	2146	196.9	25.2	Cap Failure	10/05/2023
F8	some surface bubbles	SS WET	Temperate	End Grind	198	100.4	99.9	3.427	2197	231	29.3	Conical F	10/05/2023
D2		SS WET	Tropical	End Grind	196	100.2	100.4	3.572	2307	201	25.4	Conical F	10/05/2023
W8		SS WET	Tropical	End Grind	197	100.2	100.0	3.390	2187	223	28.3	Conical F	10/05/2023
U7	na	SS WET	Tropical	Rubber	196	100.0	100.2	3.390	2199	228	29.1	Cap Failure	10/05/2023
G6	none	SS WET	Temperate	Rubber	198	100.0	100.0	3.439	2211	237	30.2	Cap Failure	10/05/2023
U3	na	SS WET	Tropical	Rubber	199	99.8	100.0	3.387	2171	214	27.3	Shear F	10/05/2023
U8	none	SS WET	Tropical	Rubber	200	100.0	100.2	3.460	2198	242	30.8	Normal	10/05/2023
D9	none	SS WET	Tropical	Rubber	200	99.8	99.8	3.487	2229	236	30.2	Normal	10/05/2023
Y8	nil	SS WET	Tropical	Rubber	198	100.4	100.6	3.424	2180	231	29.1	Normal	10/05/2023
Y3	NA	SS WET	Temperate	End Grind	197	99.6	99.8	3.396	2208	225	28.8	Normal	10/05/2023
M9	no defects	wet	Tropical	Rubber	198	100.4	100.2	3.440	2199	226	28.6	Normal	10/05/2023
P9	nil	SS WET	Tropical	Rubber	198	100.0	99.8	3.444	2219	208	26.5	Cap Failure	10/05/2023
A7	none	wet	Temperate	End Grind	197	100.0	100.0	3.358	2170	228	29.0	Normal	10/05/2023
Q6	good	SS WET	Temperate	End Grind	197	100.2	100.2	3.447	2219	226	28.7	Normal	10/05/2023
B3		SS WET	Tropical	Rubber	197	99.9	100.2	3.389	2188	232	29.5	Cap Failure	10/05/2023
N9	none	SS WET	Temperate	Rubber	199	99.6	99.8	3.428	2207	218	27.9	Normal	10/05/2023
T7	nil	SS WET	Temperate	Rubber	199	101.4	102.0	3.545	2193	217	26.7	Normal	10/05/2023
E5	nil	SS WET	Tropical	End Grind	197	99.9	100.2	3.380	2182	242.0	30.8	Conical F	10/05/2023
N4		SS WET	Temperate	Rubber	199	100.6	100.2	3.424	2173	220.5	28.0	Normal	10/05/2023
P3		SS WET	Tropical	End Grind	198	100.0	100.2	3.417	2190	230.0	29.3	Normal	10/05/2023
S4	No defect or damage	Wet	Tropical	Sulphur	198	100.2	100.4	3.430	2192	219	27.7	Normal	10/05/2023
J9	none	SS WET	Temperate	Rubber	199	99.8	99.8	3.399	2180	232	29.7	Normal	10/05/2023
R6	none	SS WET	Temperate	Rubber	201	100.0	100.0	3.480	2200	241	30.6	Normal	10/05/2023
Q9		SS WET	Tropical	Rubber	198	100.0	99.8	3.406	2195	237	30.2	Cap Failure	10/05/2023
T5	na	SS WET	Tropical	Rubber	201	100.0	99.8	3.410	2165	228	29.1	Shear F	10/05/2023
V2	nil	Wet	Temperate	Rubber	200.1	100.7	100	3.452	2201	212	27.0	Cap Failure	10/05/2023
U2	nil	SS WET	Temperate	Rubber	198	99.8	100.0	3.434	2218	205	26.2	Cap Failure	10/05/2023
M4	nil	SS WET	Temperate	Rubber	197	100.2	100.2	3.445	2217	195	24.7	Cap Failure	10/05/2023
Q5	nil	SS WET	Temperate	Rubber	198	100.4	100.0	3.457	2213	239	30.3	Cap Failure	10/05/2023
N6	nil	SS WET	Temperate	Rubber	197	99.8	99.8	3.428	2226	199	25.4	Cap Failure	10/05/2023
S6													
J4	na	Wet	Temperate	Rubber	198	100.0	100.0	3.423	2201	250	31.8	Normal	20/05/2023
A6	na	Wet	Temperate	Rubber	198	100.2	100.2	3.438	2202	217	27.5	Cap Failure	20/05/2023
K9	na	Wet	Temperate	Rubber	198	100.2	100.0	3.431	2202	212	26.9	Cap Failure	20/05/2023
M3	na	Wet	Temperate	Rubber	200	100.2	100.0	3.438	2184	235	29.9	Cap Failure	20/05/2023
Y9	na	SS WET	Temperate	Rubber	198	99.8	99.8	3.412	2203	207	26.5	Cap Failure	10/05/2023
X3	Few voids	SS WET	Temperate	Rubber	198	100.0	100.2	3.424	2198	209	26.6	Normal	12/05/2023
N2	A few air voids	wet	Temperate	Rubber	199	100.0	99.8	3.436	2203	228.54	29.2	Cap Failure	11/05/2023
E2	nil	Wet		Rubber	199	100	100	3.626	2320	322	41.0	Normal	10/05/2023

Note Denotes when units have been changed e.g Grams to Kilograms

Summary of Participants Results - Sample B

Code	Damage	Surface	Conditioning	Capping	Height mm	Diameter mm		Weight kg	Mass per unit volume kg/m3	Maximum Force kN	Compressive Strength MPa	Failure	Date Tested
V9	na	SS Wet	Tropical	Rubber	199	99.9	100.3	3.601	2299	330	41.9	Normal	10/05/2023
X6	na	SS Wet	Tropical	Rubber	199	100.3	101	3.616	2284	300	37.7	Cap Failure	10/05/2023
C3	6 air voids	WET	Temperate	Rubber	199.6	100.94	100.86	3.664	2298	399.1	50.0	Cap Failure	10/05/2023
G9		WET	Temperate	Rubber	200	99.8	99.8	3.617	2312	405.0	51.8	Shear F	10/05/2023
F8	some surface bubbles	SS Wet	Temperate	End Grind	198	99.6	99.8	3.586	2319	406	52	Shear F	10/05/2023
D2		SS Wet	Tropical	End Grind	197	100.4	100.4	3.348	2147	407	51.4	Shear F	10/05/2023
W8		SS Wet	Tropical	End Grind	197	100.0	100.2	3.588	2314	359	45.6	Conical F	10/05/2023
U7	na	SS Wet	Tropical	Rubber	198	99.8	99.6	3.600	2330	399	51.1	Conical F	10/05/2023
G6	none	SS Wet	Temperate	Rubber	198	100.4	100.4	3.599	2296	394	49.8	Shear F	10/05/2023
U3	na	SS Wet	Tropical	Rubber	200	100.2	100.2	3.617	2294	404	51.2	Shear F	10/05/2023
U8	none	SS Wet	Tropical	Rubber	200	99.8	100.2	3.575	2276	362	46.0	Normal	10/05/2023
D9	none	SS Wet	Tropical	Rubber	200	100.0	99.8	3.586	2287	367	46.8	Normal	10/05/2023
Y8	nil	SS Wet	Tropical	Rubber	200	99.8	99.6	3.589	2299	352	45.1	Normal	10/05/2023
Y3	na	SS Wet	Temperate	End Grind	196	99.9	99.8	3.561	2320	394	50.3	Normal	10/05/2023
M9	no defects	WET	Tropical	Rubber	198	100.0	100.0	3.576	2299	392	49.9	Normal	10/05/2023
P9	nil	SS Wet	Tropical	Rubber	199	100.0	100.0	3.621	2317	378	48.1	Cap Failure	10/05/2023
A7	none	WET	Temperate	End Grind	197	100.2	100.4	3.567	2292	411	52.4	Conical F	10/05/2023
Q6	good	SS Wet	Temperate	End Grind	197	100.0	100.2	3.569	2300	401.0	51.0	Normal	10/05/2023
B3		SS Wet	Tropical	Rubber	199	100.3	100.5	3.590	2279	394	49.8	Normal	10/05/2023
N9	none	SS Wet	Temperate	Rubber	199	100.0	100.6	3.619	2302	392	49.6	Normal	10/05/2023
T7	nil	SS Wet	Temperate	Rubber	199	99.8	100.4	3603	2301	390	49.6	Normal	10/05/2023
E5	(air bubbles) nil	SS Wet	Tropical	End Grind	199	99.9	100.4	3559	2270	408.0	51.9	Shear F	10/05/2023
N4		SS Wet	Temperate	Rubber	200	100	100.4	3.603	2284	385.2	49.0	Normal	10/05/2023
P3		SS Wet	Tropical	End Grind	197	100.0	100.0	3.593	2320	404.0	51.4	Normal	10/05/2023
S4	no defects undamaged	WET	Tropical	Sulphur	200	99.8	99.8	3.581	2289	385	49.2	Normal	10/05/2023
J9	none	SS Wet	Temperate	Rubber	199	100.2	99.8	3.399	2300	377	48.0	Normal	10/05/2023
R6	none	SS Wet	Temperate	Rubber	200	100.0	99.6	3.480	2300	393	50.3	Normal	10/05/2023
Q9		SS Wet	Tropical	Rubber	200	100.4	100.2	3.645	2307	395	50.0	Shear F	10/05/2023
T5	na	SS Wet	Tropical	Rubber	200	100.2	100.4	3.655	2313	393	49.7	Cap Failure	10/05/2023
V2	nil	WET	Temperate	Rubber	201	99.8	100	3.623	2296	380	48.5	Cap Failure	10/05/2023
U2	nil	SS Wet	Temperate	Rubber	196	99.8	99.8	3.596	2346	382	48.8	Cap Failure	10/05/2023
M4	nil	SS Wet	Temperate	Rubber	195	99.8	99.8	3.562	2336	396	50.6	Cap Failure	10/05/2023
Q5	nil	SS Wet	Temperate	Rubber	196	99.4	99.8	3.568	2336	372	47.7	Cap Failure	10/05/2023
N6	nil	SS Wet	Temperate	Rubber	197	99.8	99.8	3.605	2341	391	50.0	Cap Failure	10/05/2023
S6													
J4	na	Wet	Temperate	Rubber	200	100.2	100.0	3.603	2289	408	51.8	Normal	20/05/2023
A6	na	Wet	Temperate	Rubber	198	99.8	100.2	3.588	2307	389	49.5	Normal	20/05/2023
K9	na	Wet	Temperate	Rubber	199	100.2	100.8	3.609	2286	403	50.8	Normal	20/05/2023
M3	na	Wet	Temperate	Rubber	200	100.0	100.4	3.618	2294	385	48.8	Cap Failure	20/05/2023
Y9	na	SS Wet	Temperate	Rubber	201	100.0	99.6	3.624	2305	381	48.8	Conical F	10/05/2023
X3		SS Wet	Temperate	Rubber	201	100.0	100.0	3.596	2278	401	51.0	Cap Failure	12/05/2023
N2	a few air voids	WET	Temperate	Rubber	199	100.2	100.0	3.630	2318	389.83	49.5	Cap Failure	11/05/2023
E2	nil	WET		Rubber	200	100	100	3.483	2220	221.9	28.3	normal	10/05/2023

Note Denotes when units have been changed e.g Grams to Kilograms

Appendix A: Instructions for testers

LabSmart Services

Concrete Proficiency Program 2023 (115)

NATA

INSTRUCTIONS FOR TESTER

1. **Do not open the plastic bags until the 10th of May. Store at room temperature away from fluctuating temperatures and sunlight.**
2. Please read these instructions carefully on receipt of samples.
3. Please check that the package you have received contains the following:
   - Results Log sheet
   - Two nominal 100 mm Ø by 200 mm concrete cylinders sealed in plastic bags marked 'Sample A' and 'Sample B'.
4. Inspect packaging on arrival for damage or leakage. Contact LabSmart Services if the box is wet, or damaged, or if anything is missing (Phone 0439 208 406).
5. It is strongly recommended that participants follow AS 1012, Method 9 when testing the concrete cylinders, but an alternative equivalent method may also be used.
6. On the 10th of May, remove each cylinder from the plastic bag. Remove the paper covering. Inspect each cylinder and record its condition on the proficiency testing results log sheet (AS 1012, clause 4.1 (a) to (h)). If surface bubbles appear excessive, record it on the log sheet but continue with the test. If cylinders show any chipping or damage caused by transport, please contact LabSmart Services before testing.
7. Within 10 minutes of opening the plastic bag, immerse each concrete cylinder into the curing tank. Allow the cylinders to pre-condition for at least three hours prior to capping and testing by full immersion in water at 23 ± 2° C temperate zone or 27 ± 2° C tropical zone.
8. Follow AS 1012, Method 9. Test both cylinders within 15 minutes of each other.
9. Record all information and calculations as per AS 1012, Method 9 on the proficiency testing results log sheet **but to the accuracy shown on the results log sheet.**
10. Ensure to have the Laboratory Supervisor check & approve prior to signing the log sheet.
11. **Please E-mail the "Results Log" to LabSmart Services by 12th May 2023**
    E-mail: info@labsmartservices.com.au
12. Please retain the completed "Results Log" as this contains your participation code that will identify your results in the technical report covering the proficiency testing program. It is also recommended that a copy of completed worksheets be kept with the results log in your proficiency file. Results can also be used for technical auditing or training.
13. Have a query? Contact LabSmart Services. Phone 0439 208 406.

Thank you for participating in this proficiency testing program.

Concrete PT Instructions V2023.1 (115).docx

Appendix B: Results Log

LabSmart Services

Concrete Compression Proficiency Program – 2023 (115)

RESULTS LOG

For XXXX Participation Code: XX

Please test cylinders on the 10th of May 2023

Please E-mail the completed results log by 12th of May 2023

E-mail: info@labsmartservices.com.au

TEST		Sample A		Sample B	
Date samples received					
Describe the condition of the samples	List defects, damage				
	SS Wet or Dry				
Test Method used	AS 1012.9 OR				
Conditioning	Temperate or Tropical				
Capping Method #	Rubber or Sulphur				
Height	Report to 1 mm				
Diameter	Report to 0.2 mm				
Weight	Report to 0.001 kg				
Maximum Force	Report to 1 kN				
Compressive Strength	Report to 0.1 MPa				
Type of cylinder failure ❖	Normal – CON F Abnormal – SF, CAP F				
Test Method used	AS 1012.12.1 OR				
Tested	Capped or Uncapped				
Weight	Report to 0.001 kg				
Mass per unit volume	Report to 1 kg/m³				
Date Tested					
Tested by:					

COMMENTS:.....

.....

Supervisor Name (Please Print)	Signature	Date
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In signing the above, I acknowledge that the above results are approved and have been checked. I will also ensure that the results are kept confidential, both internal and external, to the laboratory until the issue of the final technical report covering this program.

Thank you for participating. Please retain this sheet for your records

If cylinder end grinding only is available, please report.
For a description of cylinder failures, please see the next page.

XX Concrete PT Results Log V2023.1 (115).Docx

LabSmart Services

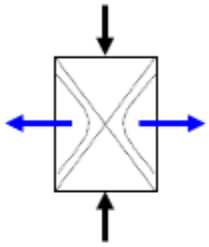
Concrete Compression Proficiency Program – 2023 (115)

Concrete Cylinder Failure Modes

"Normal"

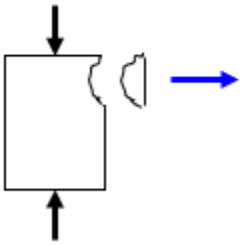
OR

"Conical Failure"



"Shear Failure"

"Cap Failure"



Have a query? Contact LabSmart Services. Phone: 0439 208 406

XX Concrete PT Results Log V2023.1 (115).Docx