BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF CIVIL ENGINEERING
institute of building testing

ilac-MRA

Z 7008

FINAL REPORT ON THE RESULTS OF PRECISION EXPERIMENT

Proficiency Testing Program
Masonry Units Testing
ZZP 2023/1

Brno University of Technology
Proficiency testing provider at the SZK FAST
Veveří 95, Brno 602 00
Czech Republic

www.szk.fce.vutbr.cz
www.ptprovider.cz

Date: January 12, 2024

Poskytovatel zkoušení způsobilosti při SZK FAST
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Assoc. Prof. Ing. Tomáš Vymazal, Ph.D.
Head of the PT Provider, PTP coordinator

Ing. Petr Misák, Ph.D.
Coordinator of PTP results assessment

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1 Introduction and Important Contacts

In the year 2023, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZZP 2023/1 whose aim was to verify and assess the conformity of test results across laboratories when testing masonry units.

The assessment of the results of the Proficiency Testing Program was carried out by a committee consisting of the following PT Provider employees:

Head of the PT Provider, PTP coordinator

Assoc. Prof. Tomáš Vymazal, Ph.D.
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Coordinator of PTP result assessment PrZZ

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The subjects of proficiency testing were the following testing procedures:

1. **EN 772-1** – Compressive strength [1].
2. **EN 772-3** – Net volume and percentage of voids of clay masonry units by hydrostatic weighing [2].
3. **EN 772-6** – Bending tensile strength of aggregate concrete masonry units [3].
4. **EN 772-7** – Water absorption of clay masonry damp proof course units by boiling in water [4].
5. **EN 772-10** – Moisture content [5].
6. **EN 772-11** – Water absorption [6].
7. **EN 772-13** – Dry density of masonry units [7].
8. **EN 15435** – part 4.9.3, Appendix B - Flexural strength of side shutters [8].
9. **EN 15435** – part 5.2 - Density [8].

Testing procedures No 2, 3, 4, 5, 6, 8 and 9 were not open due to low number of participants.

The specimens were taken from the same production with the same production date. The test results from individual PTP participants were compared via a method involving the statistical analysis of all their results in a manner complying with ISO 5725-2 [9] and with EN ISO/IEC 17043 [10]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

13 laboratories from Europe took part in the program. In order to maintain the anonymity of the PTP, each laboratory was given an identification number that will be used henceforth in this document. An integral part of the present final report is a Certificate of Participation in the Proficiency Testing Program. It is unique for each participant and includes the participant's ID used in this report. The following chart shows the participation of laboratories in individual parts of the PTP.

Table 1: Participation of individual laboratories in the PTP (tests designated according to part 1)

ID/Method	1	2	3	4	5	6	7	8	9
df7761	X	-	-	-	-	-	X	-	-
e8fcbd	-	-	-	-	-	X	-	-	-
405311	X	-	-	-	-	-	X	-	-
65ea6e	X	-	-	-	-	-	X	-	-
982072	X	-	-	-	-	-	X	-	-
f46489	X	-	-	-	-	X	X	-	-
7e42fa	X	-	-	-	-	-	X	-	-
9cbdea	X	-	-	-	-	-	-	-	-
014ec5	-	-	-	-	-	X	-	-	-
025ea0	X	-	-	-	-	-	X	-	-
65de30	X	-	-	-	-	-	X	-	-
4f98a3	-	-	-	-	-	-	X	-	-
f69f8c	X	-	-	-	-	X	-	-	-

Table 2: List of participants (laboratories) – the order in the table does not correspond to the identification number in Table 1

Laboratory	Address	Accreditation number
BEST, a.s.	Rybnice 148, Kaznějov, 331 51, Česká republika	1739
BHP Laboratories	New Road Enterprise Center, Unit 4, New Road, Thomondgate, Limerick, V94P9X4, Limerick/ Ireland	5T
Camillo Sitte Versuchsanstalt für Bautechnik	Leberstraße 4c, Vienna, 1030, Austria	0046
QUALIFORM SLOVAKIA s.r.o.	Pasienkova 9D, Bratislava, 82106, Slovenská republika	S-301
Solidbase Laboratory Limited	Tal-Handaq Industrial Estate, N/S in Handaq Road, Qormi, QRM 4000, Malta	-
TZÚS Praha, s.p. - pobočka České Budějovice	Nemanická 8/411, České Budějovice, 37010, Česká republika	1018.3
Technický a zkušební ústav Praha, s.p. Centrální laboratoř, zkušebna 0500 Předměřice nad Labem	Průmyslová 283, Předměřice nad Labem, 503 02, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s. p., Centrální laboratoř - zkušebna Brno	Hněvkovského 77, Brno, 617 00, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p.	U Studia 14, Ostrava - Zábřeh, 70030, Česká republika	1018.7
Technický a zkušební ústav stavební Praha, s.p.	Prosecká 76a, Praha 9, 190 00, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, sp - Pobočka Plzeň	Zahradní 15, Plzeň, 326 00, Česká republika	1018.3
Vysoké učení technické v Brně, Fakulta stavební, Zkušební laboratoř při ÚTHD FAST VUT v Brně	Veveří 331/95, Brno, 60200, Česká republika	L1396
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft.	Dózsa György út 26, Szentendre, 2000, Magyarország	NAH-1-1011/2023/K

Laboratory	Address	Accreditation number

2 Procedures used in the Statistical Analysis of Laboratory Results

The statistical analysis is based on the following steps:

1. Evaluation of intralaboratory variabilities by Cochran's C test: If 5% or 1% critical value is exceeded, the effect of the individual observations is first considered. If the results indicate that high participant variability is caused by a single observation, this value is excluded from the experiment, but the participant is not excluded as outlying. By overcoming 1% of the critical value, the participant's results can be marked as outlying and excluded from the experiment.
2. The numerical critical evaluation of the test results using Grubbs' test: By overcoming 1% critical value, the participant's results can be marked as outlying and excluded from the experiment.
3. Graphical determination of the consistency of laboratories (Mandel's statistics): The exceedance of the critical values of Mandel's statistics does not indicate that the results of the laboratories concerned are wrong; it only suggests minor inconsistencies.
4. Evaluation of descriptive statistics and, if possible, taking into account the number of observations, the repeatability and reproducibility.
5. Evaluation of the assigned value.
6. The performance evaluation: The most significant outcome of the PT Program is the so-called z-score and ζ-score (zeta-score).These characteristics assess the performance of individual participants by comparing it with the assigned value and measurement uncertainties. z-score and ζ-score are compared with limit values. The resulting ζ-score values are not taken into account during the final evaluation of the performance of participants as they are to a considerable degree dependent on the values of the measurement uncertainties of the assessed institutions.

Procedures used in the statistical analysis of proficiency testing programs can be found here: http://ptprovider.cz/?lang=en.

3 Conclusions of the Statistical Analysis

The present report summarizes the results of the Proficiency Testing Program Masonry Units Testing (PT Program) organized by the PT Provider at the SZK FAST. 13 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of masonry units. The test results are evaluated separately for each testing procedure examined. An evaluation of statistical characteristics is included in the Appendix, as well as test results and graphic presentations. Testing methods can be found in part 1 of this report.

Table 4: Evaluation of overall performance and outliers.
✓ – satisfactory performance; ? – questionable performance; ! – unsatisfactory performance; X – outlier;

ID / Method	1	2	3	4	5	6	7	8	9
df7761	✓	-	-	-	-	-	✓	-	-
e8fcbd	-	-	-	-	-	✓	-	-	-
405311	✓	-	-	-	-	-	✓	-	-
65ea6e	✓	-	-	-	-	-	?	-	-
982072	✓	-	-	-	-	-	✓	-	-
f46489	✓	-	-	-	-	✓	✓	-	-
7e42fa	✓	-	-	-	-	-	✓	-	-
9cbdea	✓	-	-	-	-	-	-	-	-
014ec5	-	-	-	-	-	✓	-	-	-
025ea0	✓	-	-	-	-	-	✓	-	-
65de30	✓	-	-	-	-	-	✓	-	-
4f98a3	-	-	-	-	-	-	✓	-	-
f69f8c	✓	-	-	-	-	✓	-	-	-

References

[1] EN 772-1+A1. *Methods of test for masonry units - Part 1: Determination of compressive strength*. 2015.

[2] EN 772-3. *Methods of test for masonry units - Part 3: Determination of net volume and percentage of voids of clay masonry units by hydrostatic weighing*. 1999.

[3] EN 772-6. *Methods of test for masonry units - Part 6: Determination of bending tensile strength of aggregate concrete masonry units*. 2002.

[4] EN 772-7. *Methods of test for masonry units - Part 7: Determination of water absorption of clay masonry damp proof course units by boiling in water*. 1999.

[5] EN 772-10. *Methods of test for masonry units - Part 10: Determination of moisture content of calcium silicate and autoclaved aerated concrete units*. 1999.

[6] EN 772-11. *Methods of test for masonry units - Part 11: Determination of water absorption of aggregate concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units*. 2011.

[7] EN 772-13. *Methods of test for masonry units - Part 13: Determination of net and gross dry density of masonry units (except for natural stone)*. 2001.

[8] EN 15435. *Precast concrete products - Normal weight and lightweight concrete shuttering blocks - Product properties and performance*. 2009.

[9] ISO 5725-2. *Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*. 1997.

[10] EN ISO/IEC 17043. *Conformity assessment - General requirements for proficiency testing*. 2010.

1 Appendix – EN 772-1 (Compressive strength)

1.1 Test results

Table 4: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [N/mm^2]						u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
f46489	10.4	10.9	15.0	-	-	-	-	12.1	2.52	20.86
982072	14.9	14.0	12.4	12.7	12.6	12.3	0.5	13.1	1.08	8.21
405311	13.1	13.2	13.8	13.7	13.4	13.5	0.1	13.4	0.27	2.04
7e42fa	13.7	13.9	13.5	15.0	13.8	14.0	0.2	14.0	0.53	3.77
df7761	14.4	13.9	12.9	14.5	16.7	14.0	14.4	14.4	1.26	8.76
65ea6e	15.3	15.2	15.2	13.9	13.7	14.7	2.0	14.7	0.71	4.81
f69f8c	14.8	15.8	14.7	14.6	14.4	14.6	0.9	14.8	0.5	3.37
65de30	16.0	16.9	14.0	14.1	13.9	14.4	1.0	14.9	1.26	8.45
025ea0	15.2	15.6	14.6	15.2	15.9	15.8	0.9	15.4	0.48	3.14
9cbdea	15.4	15.1	16.9	16.1	21.7	20.8	1.0	17.7	2.86	16.18

1.2 The Numerical Procedure for Determining Outliers

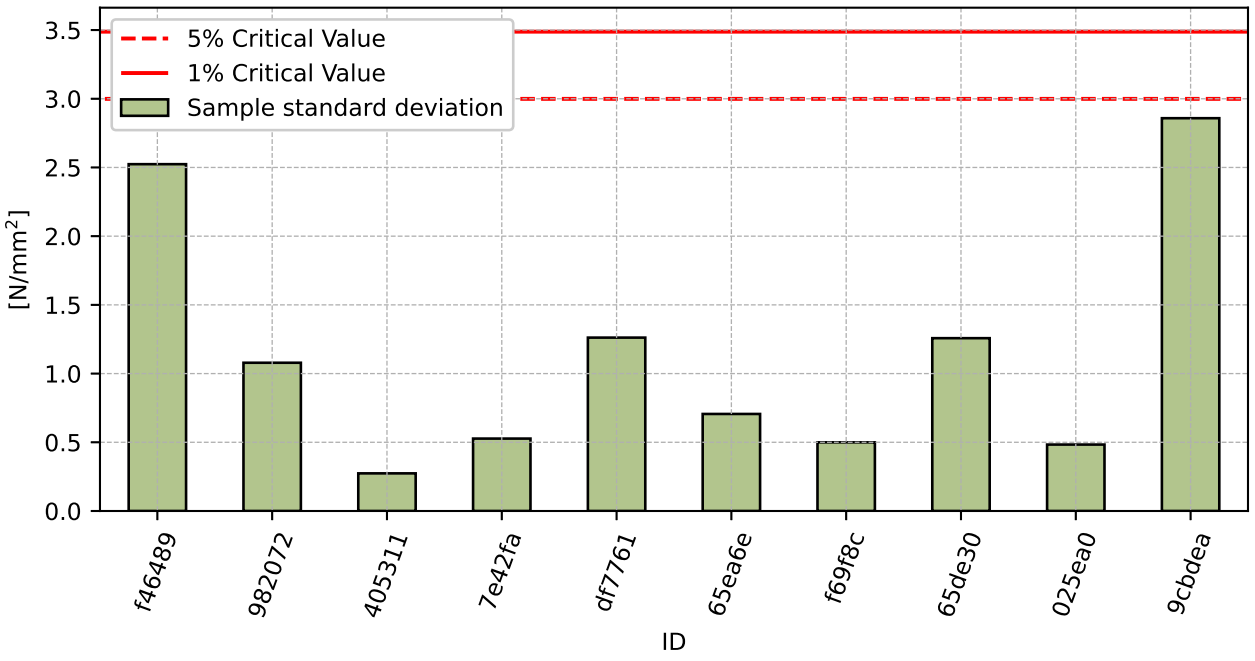

Figure 1: **Cochran's test** - sample standard deviations

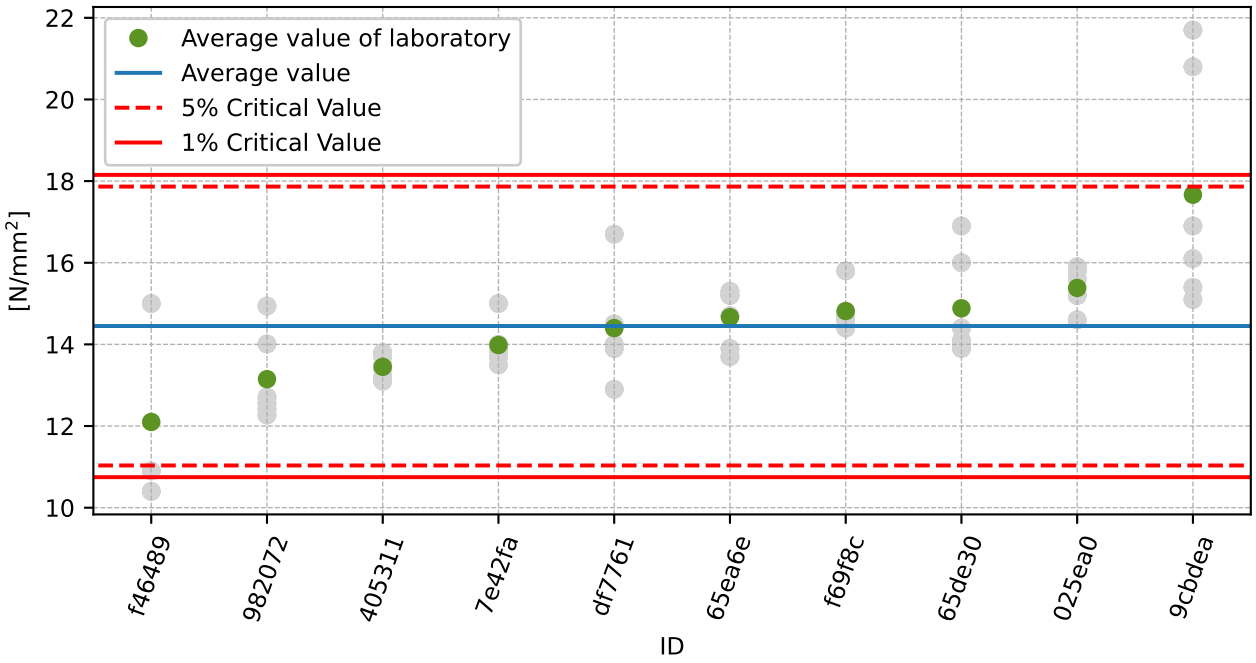

Figure 2: **Grubbs' test** - average values

1.3 Mandel's Statistics

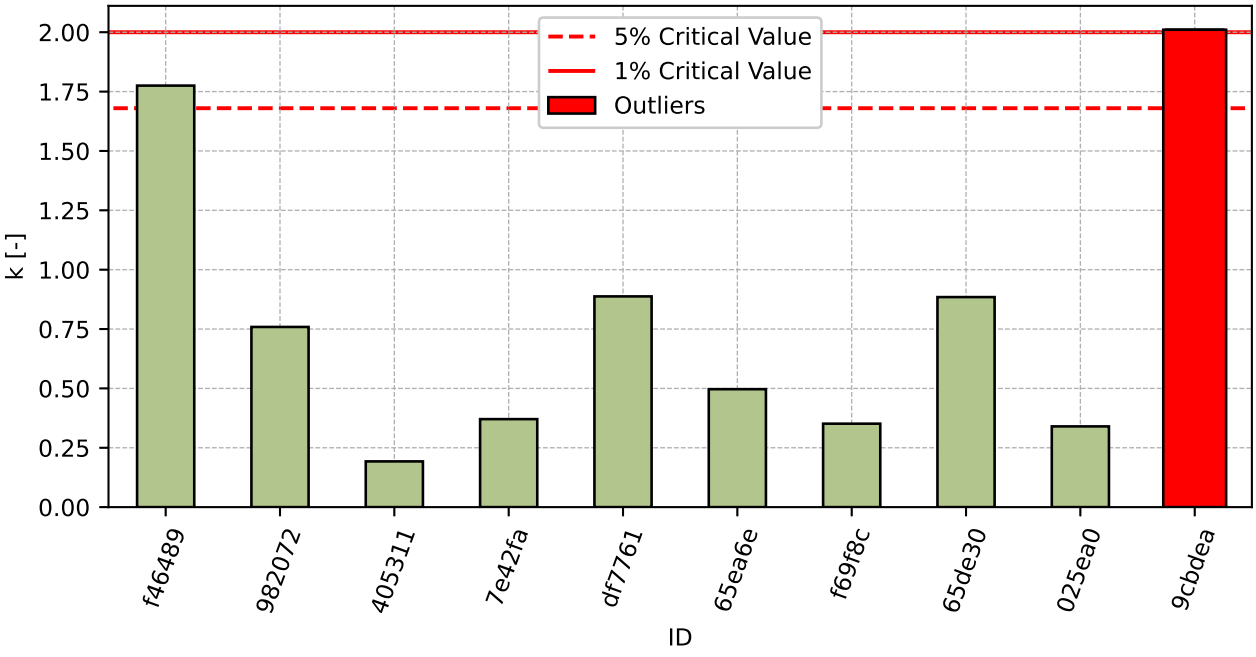

Figure 3: Intralaboratory Consistency Statistic

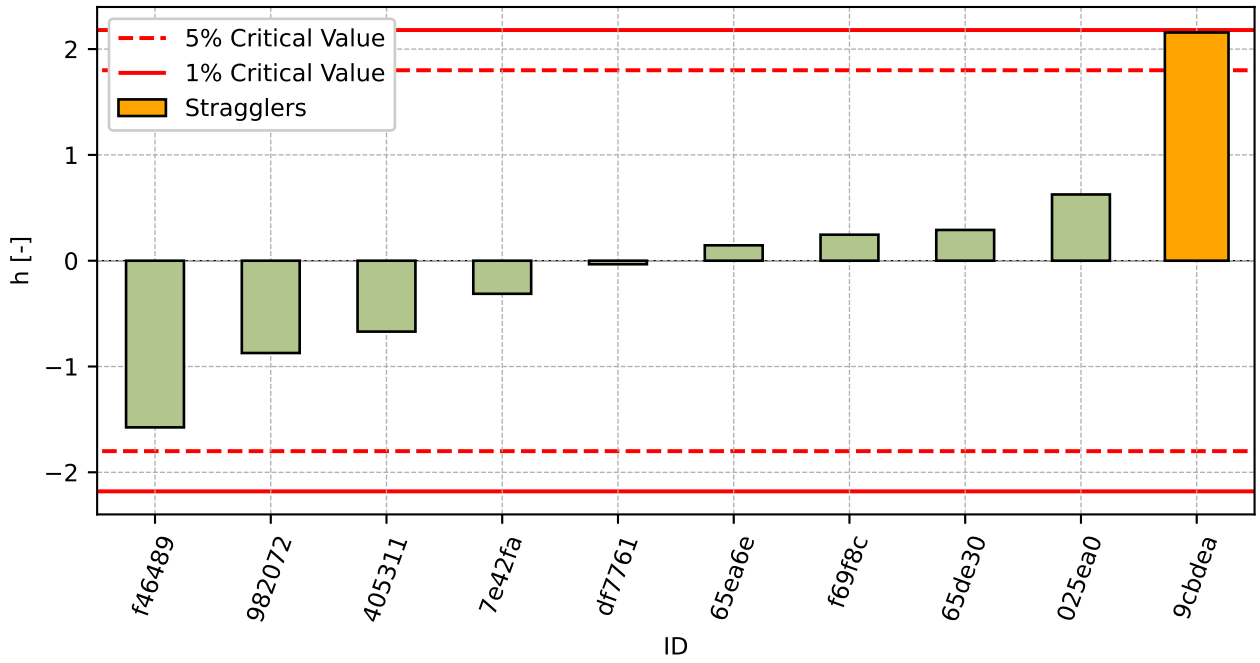

Figure 4: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

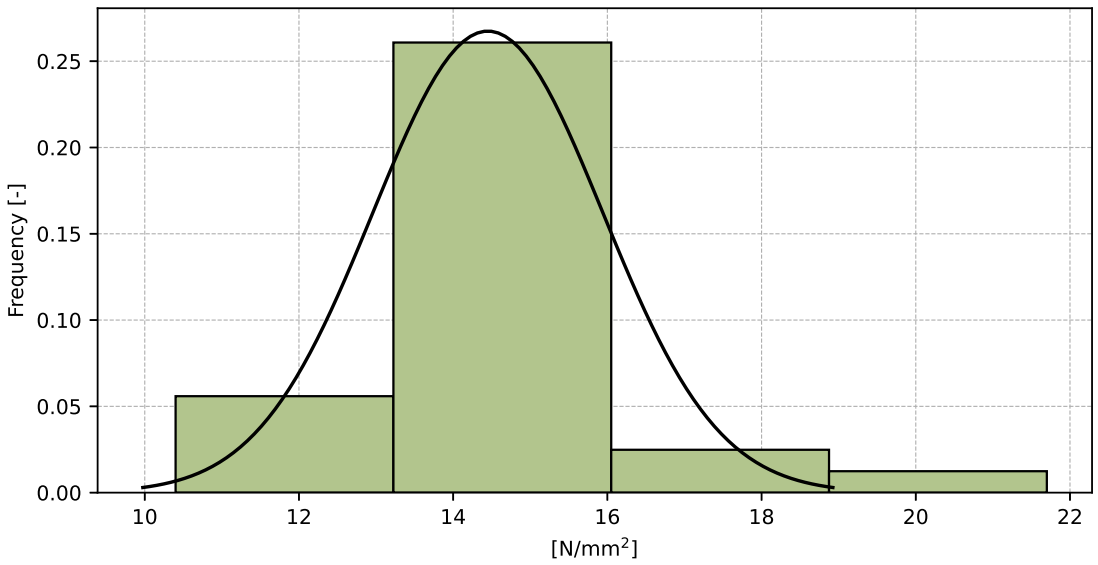

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	14.4
Sample standard deviation – s	1.49
Asigned value – x^*	14.5
Robust standard deviation – s^*	1.61
Measurement uncertainty of asigned value – u_X	0.58
p-value of normality test	1.0 [-]
Interlaboratory standard deviation – s_L	1.37
Repeatability standard deviation – s_r	1.42
Reproducibility standard deviation – s_R	1.98
Repeatability – r	4.0
Reproducibility – R	5.5

1.5 Evaluation of Performance Statistics

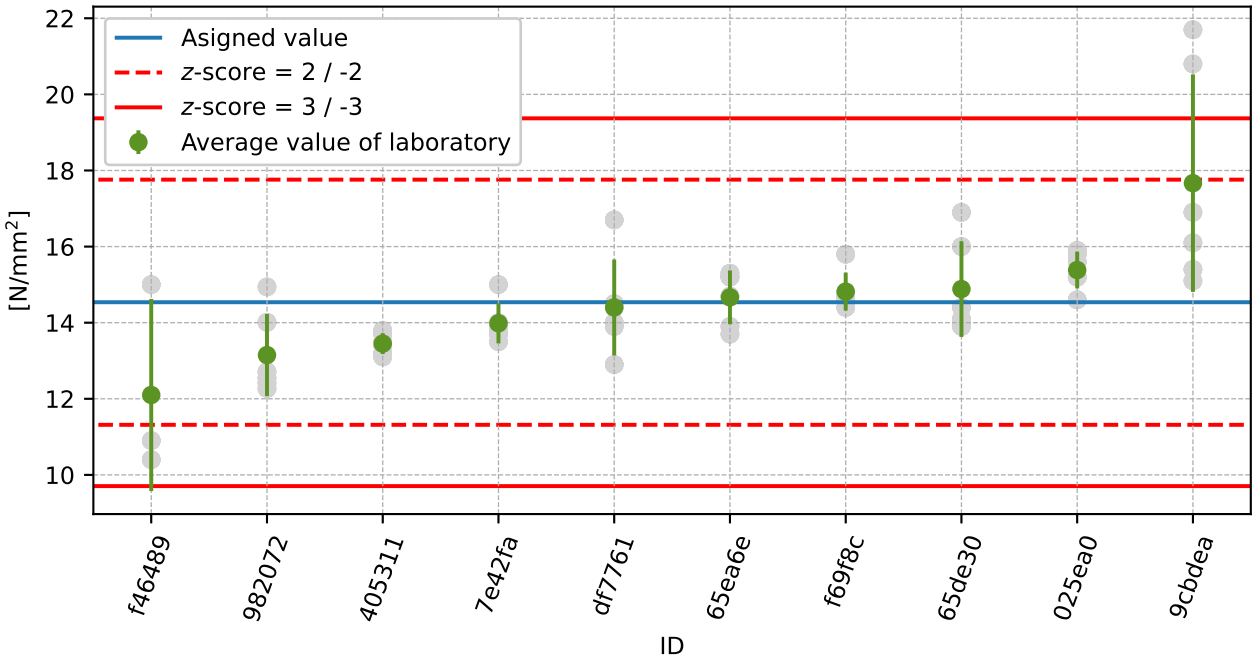

Figure 6: Average values and sample standard deviations

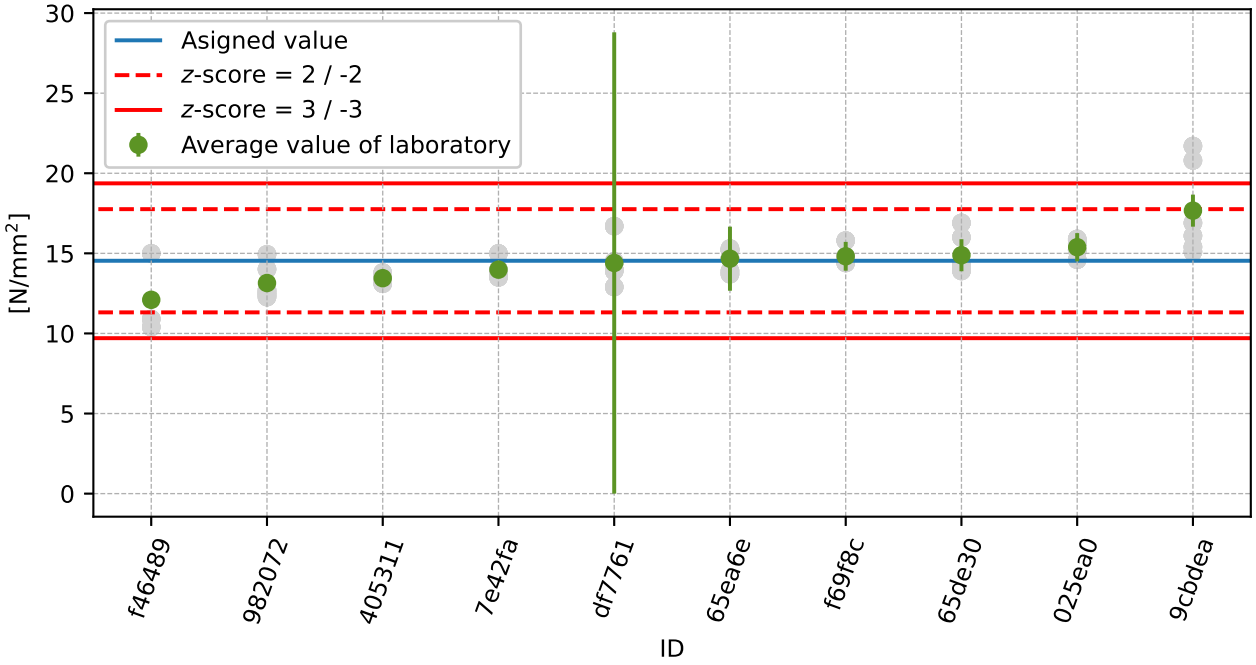

Figure 7: Average values and extended uncertainties of measurement

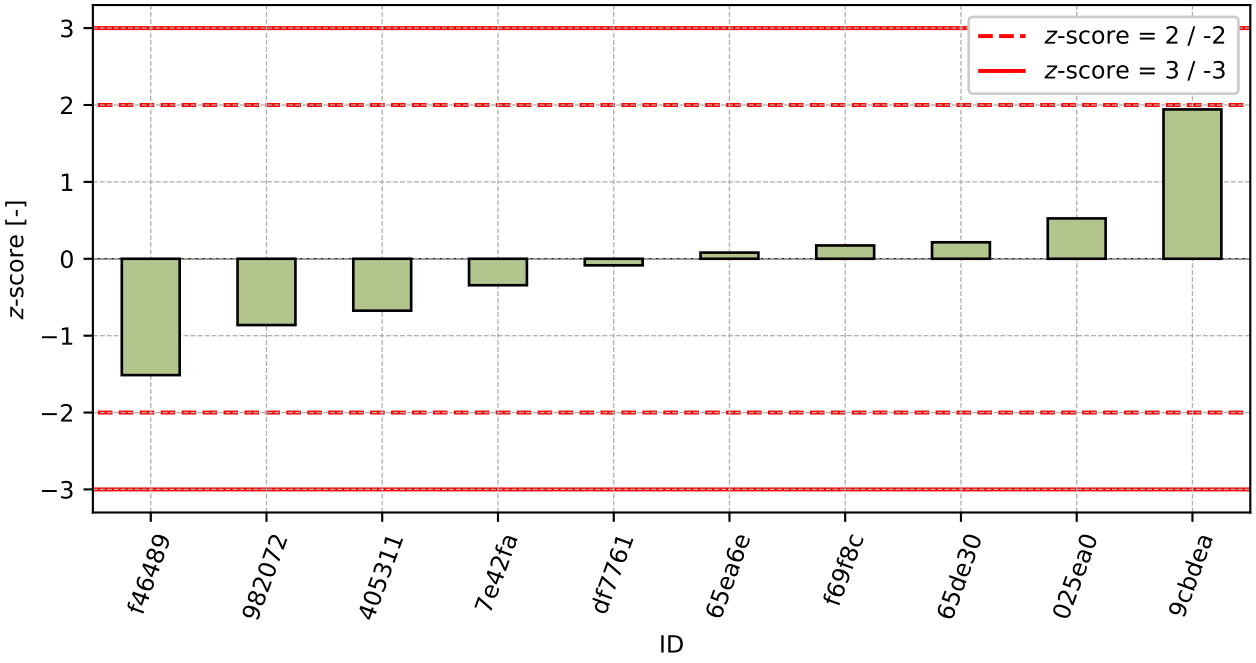

Figure 8: z-score

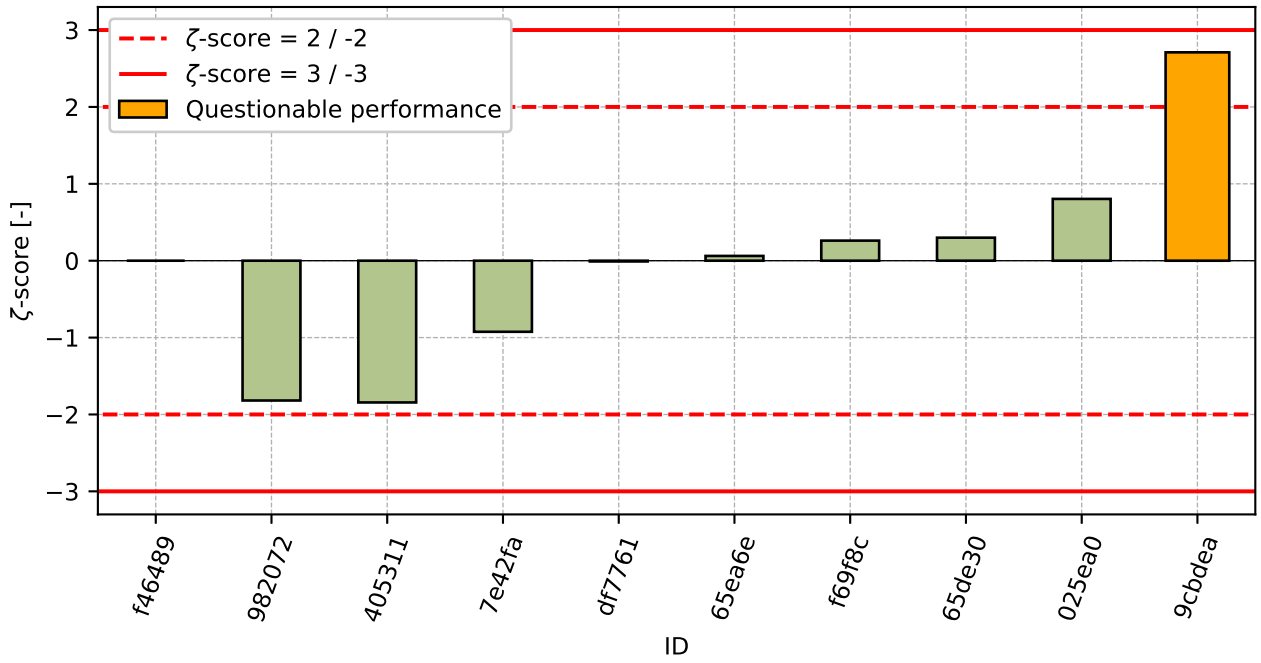

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
f46489	-1.51	-
982072	-0.86	-1.82
405311	-0.68	-1.84
7e42fa	-0.34	-0.92
df7761	-0.09	-0.01
65ea6e	0.08	0.06
f69f8c	0.17	0.26
65de30	0.21	0.3
025ea0	0.53	0.8
9cbdea	1.94	2.71

2 Appendix – EN 772-3 (Net volume and percentage of voids of clay masonry units by hydrostatic weighing)

This part of PT program was not open due to the low number of participants.

3 Appendix – EN 772-6 (Bending tensile strength of aggregate concrete masonry units)

This part of PT program was not open due to the low number of participants.

4 Appendix – EN 772-7 (Water absorption of clay masonry damp proof course units by boiling in water)

This part of PT program was not open due to the low number of participants.

5 Appendix – EN 772-10 (Moisture content)

This part of PT program was not open due to the low number of participants.

6 Appendix – EN 772-11 (Water absorption)

6.0.1 Test results

Table 7: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [N/mm^2]						u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
f46489	10.4	10.9	15.0	-	-	-	-	12.1	2.52	20.86
982072	14.9	14.0	12.4	12.7	12.6	12.3	0.5	13.1	1.08	8.21
405311	13.1	13.2	13.8	13.7	13.4	13.5	0.1	13.4	0.27	2.04
7e42fa	13.7	13.9	13.5	15.0	13.8	14.0	0.2	14.0	0.53	3.77
df7761	14.4	13.9	12.9	14.5	16.7	14.0	14.4	14.4	1.26	8.76
65ea6e	15.3	15.2	15.2	13.9	13.7	14.7	2.0	14.7	0.71	4.81
f69f8c	14.8	15.8	14.7	14.6	14.4	14.6	0.9	14.8	0.5	3.37
65de30	16.0	16.9	14.0	14.1	13.9	14.4	1.0	14.9	1.26	8.45
025ea0	15.2	15.6	14.6	15.2	15.9	15.8	0.9	15.4	0.48	3.14
9cbdea	15.4	15.1	16.9	16.1	21.7	20.8	1.0	17.7	2.86	16.18

6.0.2 The Numerical Procedure for Determining Outliers

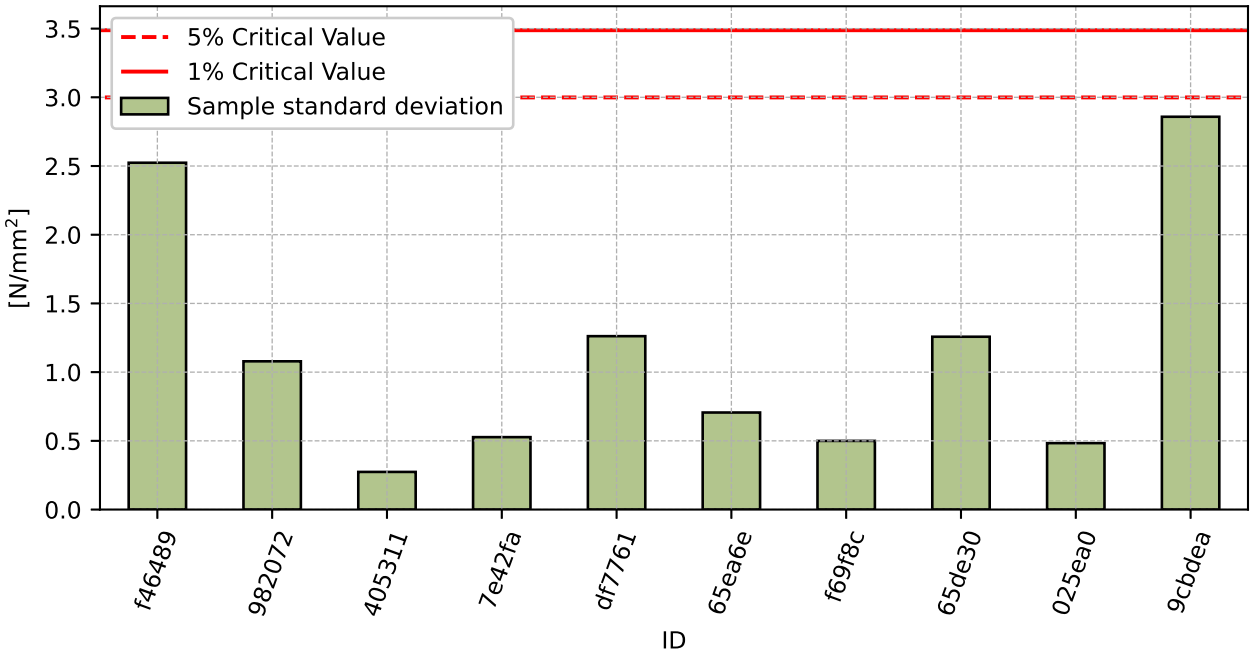

Figure 10: **Cochran's test** - sample standard deviations

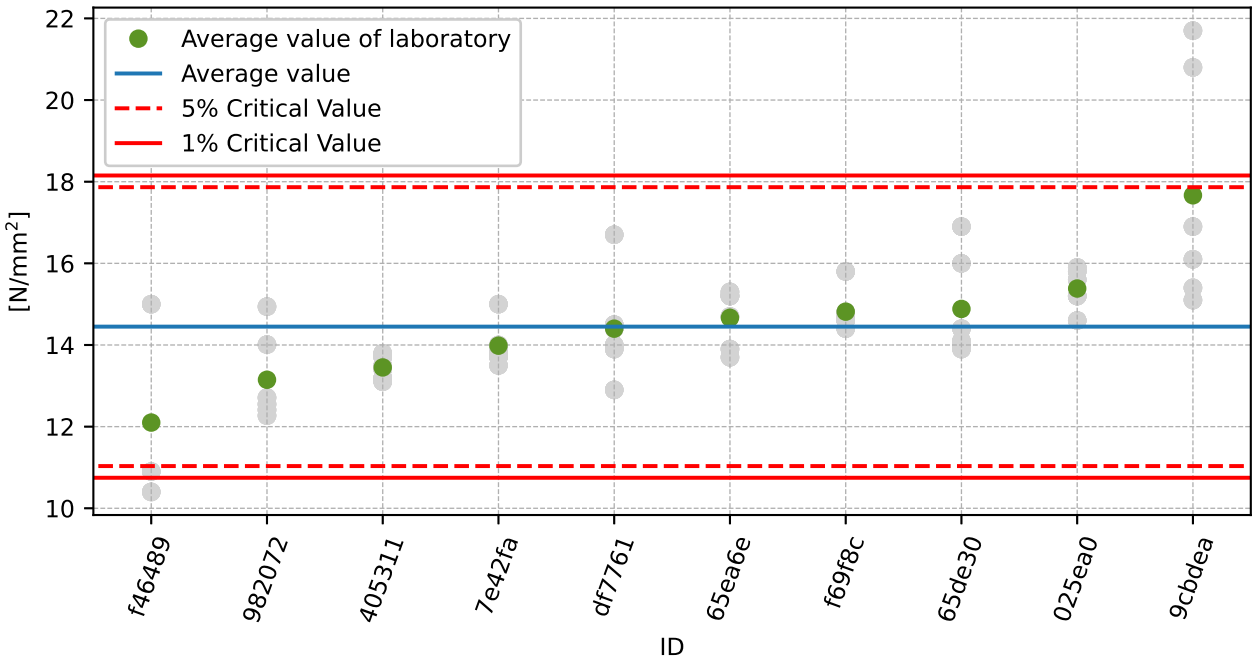

Figure 11: **Grubbs' test** - average values

6.0.3 Mandel's Statistics

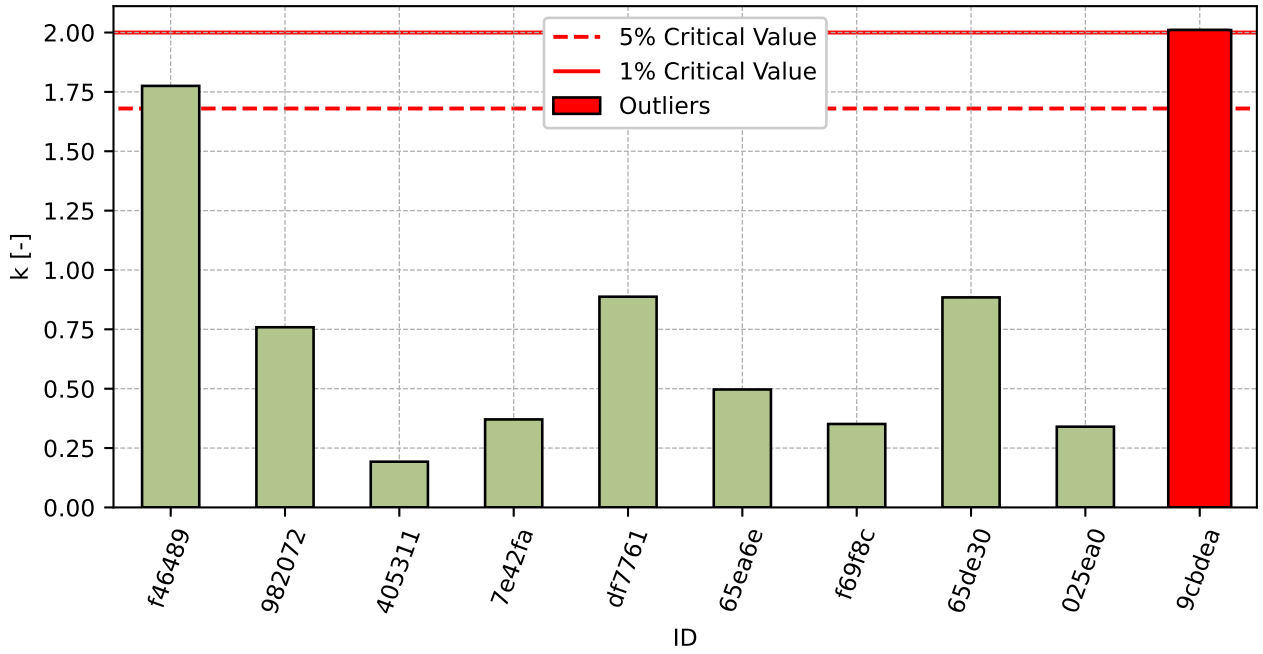

Figure 12: Intralaboratory Consistency Statistic

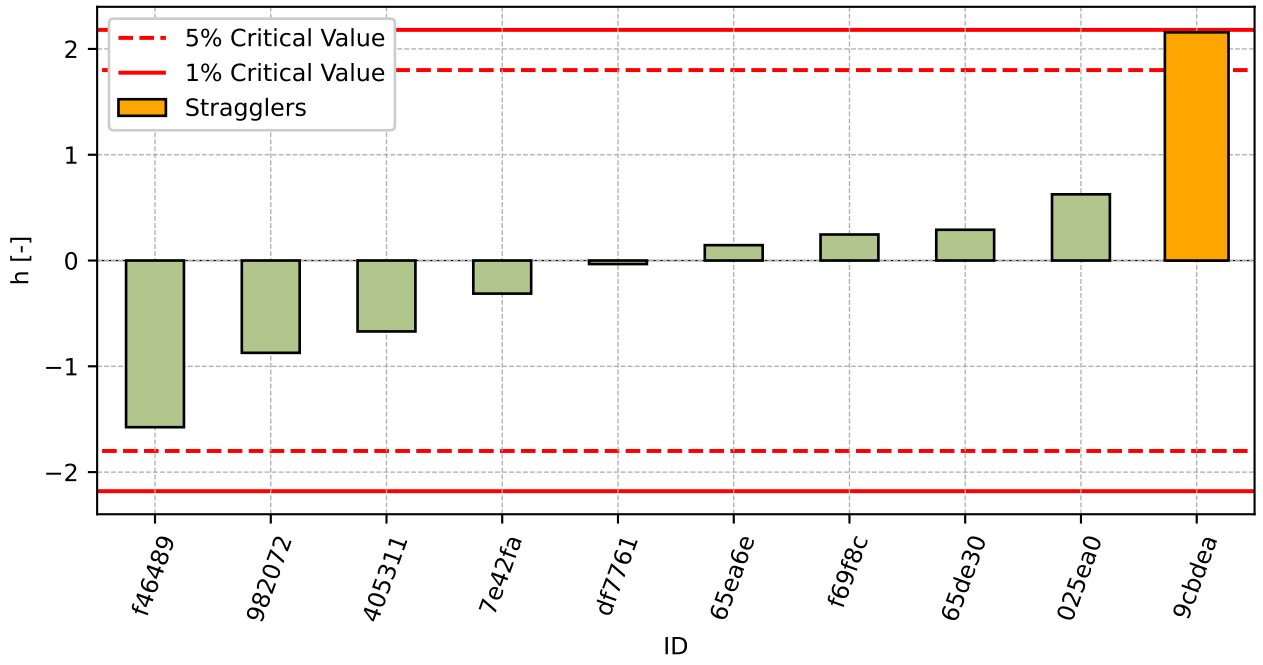

Figure 13: Interlaboratory Consistency Statistic

6.0.4 Descriptive statistics

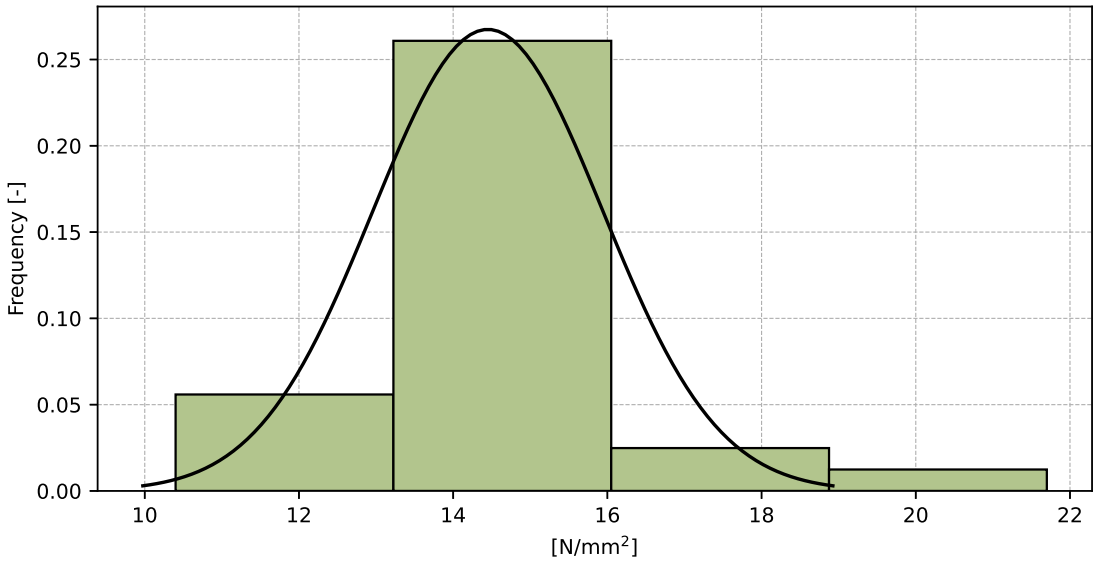

Figure 14: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[N/mm²]
Average value – $\bar{x}$	14.4
Sample standard deviation – s	1.49
Asigned value – x^*	14.5
Robust standard deviation – s^*	1.61
Measurement uncertainty of asigned value – u_X	0.58
p-value of normality test	1.0 [-]
Interlaboratory standard deviation – s_L	1.37
Repeatability standard deviation – s_r	1.42
Reproducibility standard deviation – s_R	1.98
Repeatability – r	4.0
Reproducibility – R	5.5

6.0.5 Evaluation of Performance Statistics

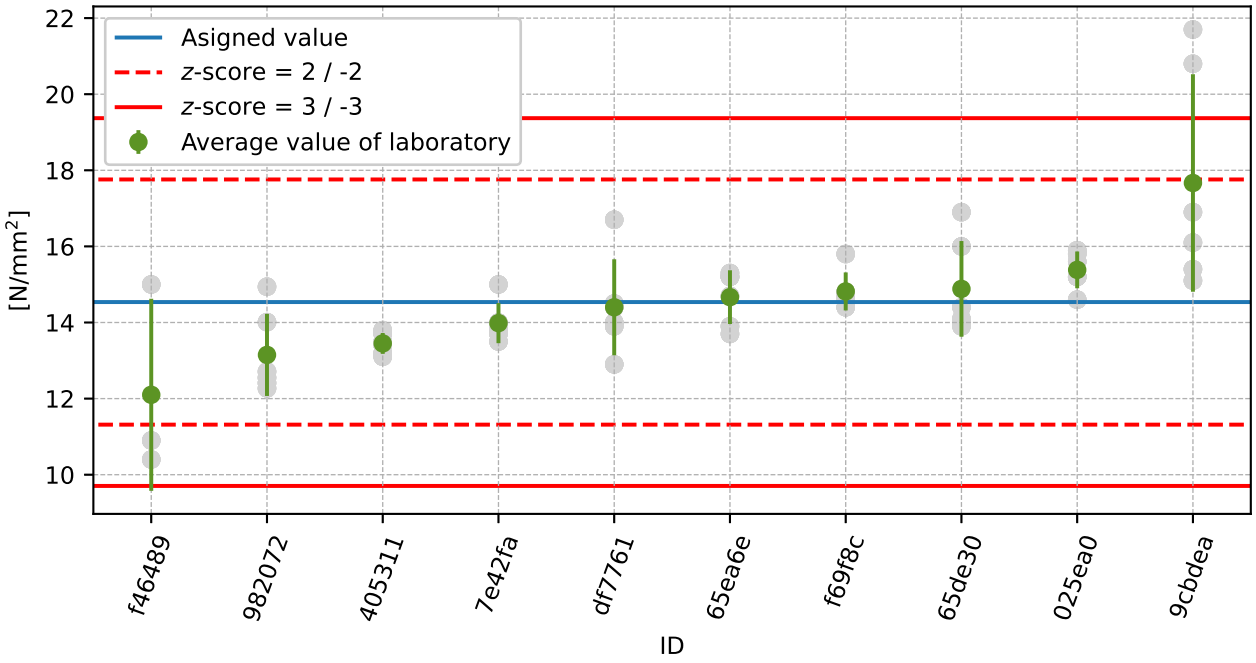

Figure 15: Average values and sample standard deviations

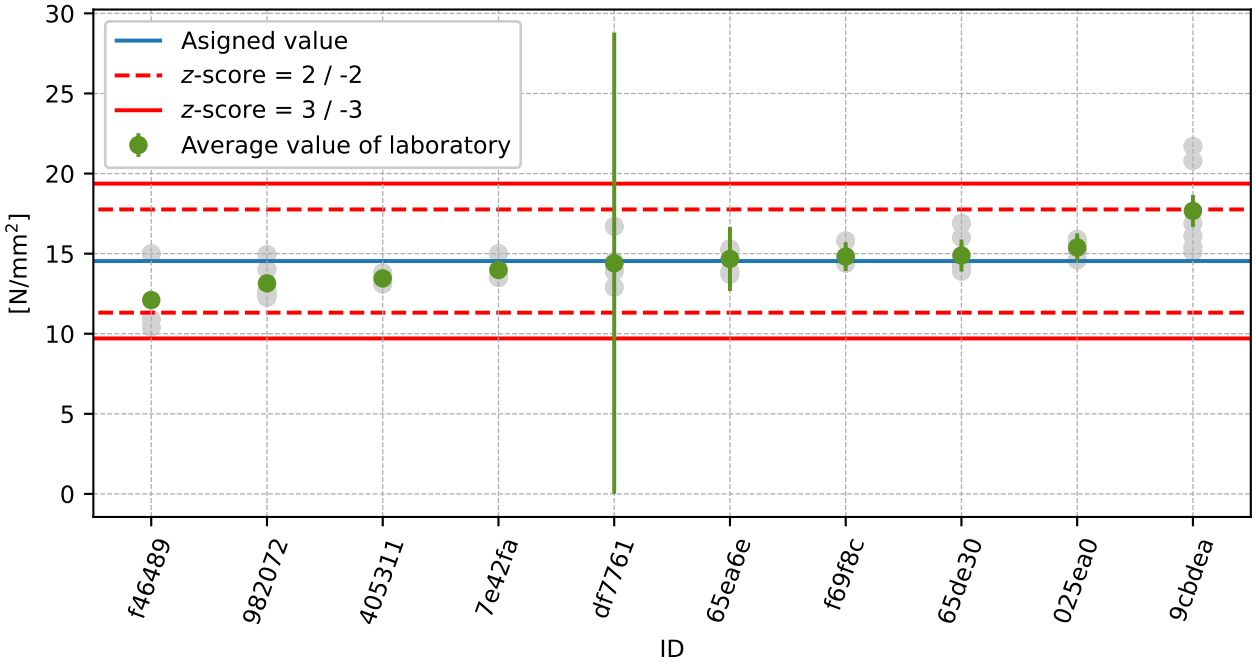

Figure 16: Average values and extended uncertainties of measurement

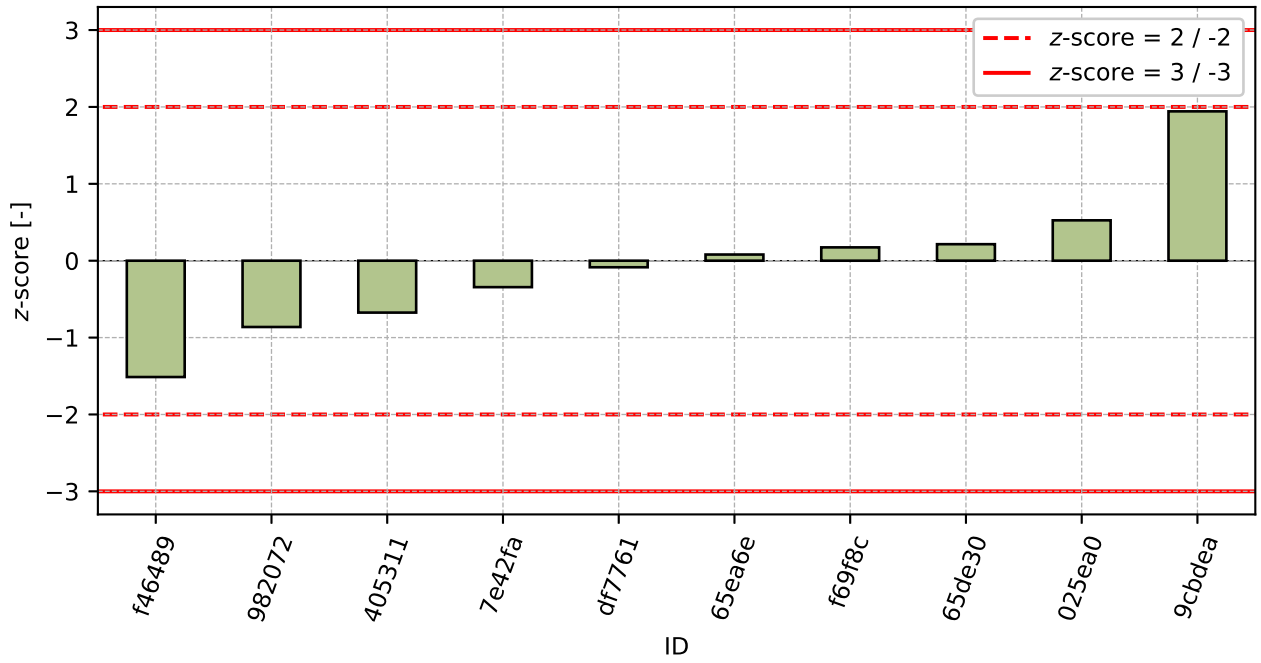

Figure 17: z-score

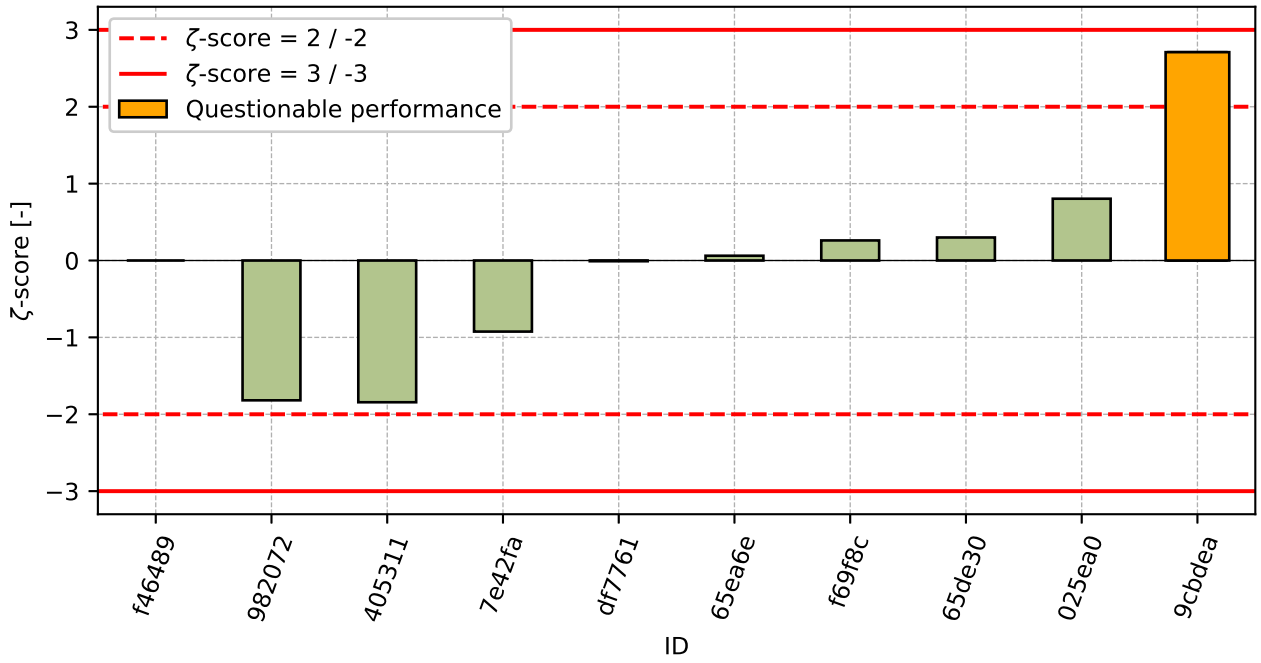

Figure 18: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
f46489	-1.51	-
982072	-0.86	-1.82
405311	-0.68	-1.84
7e42fa	-0.34	-0.92
df7761	-0.09	-0.01
65ea6e	0.08	0.06
f69f8c	0.17	0.26
65de30	0.21	0.3
025ea0	0.53	0.8
9cbdea	1.94	2.71

7 Appendix – EN 772-13 (Dry density of masonry units)

7.1 Net dry density of masonry units

7.2 Test results

Table 10: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [kg/mm^3]						u_X [kg/mm^3]	$\bar{x}$ [kg/mm^3]	s_0 [kg/mm^3]	V_X [%]
65ea6e	1600	1620	1620	1610	1620	1600	30	1612	9.8	0.61
405311	1667	1642	1673	1626	1616	1678	11	1650	26.1	1.58
65de30	1680	1680	1680	1670	1680	1680	10	1678	4.1	0.24
7e42fa	1680	1690	1660	1700	1690	1680	4	1683	13.7	0.81
4f98a3	1690	1680	1680	1690	1680	1690	10	1685	5.5	0.33
982072	1694	1668	1691	1698	1692	1670	20	1686	13.0	0.77
df7761	1670	1680	1680	1700	1720	1680	-	1688	18.3	1.09
025ea0	1710	1700	1720	1710	1710	1700	14	1708	7.5	0.44

7.3 The Numerical Procedure for Determining Outliers

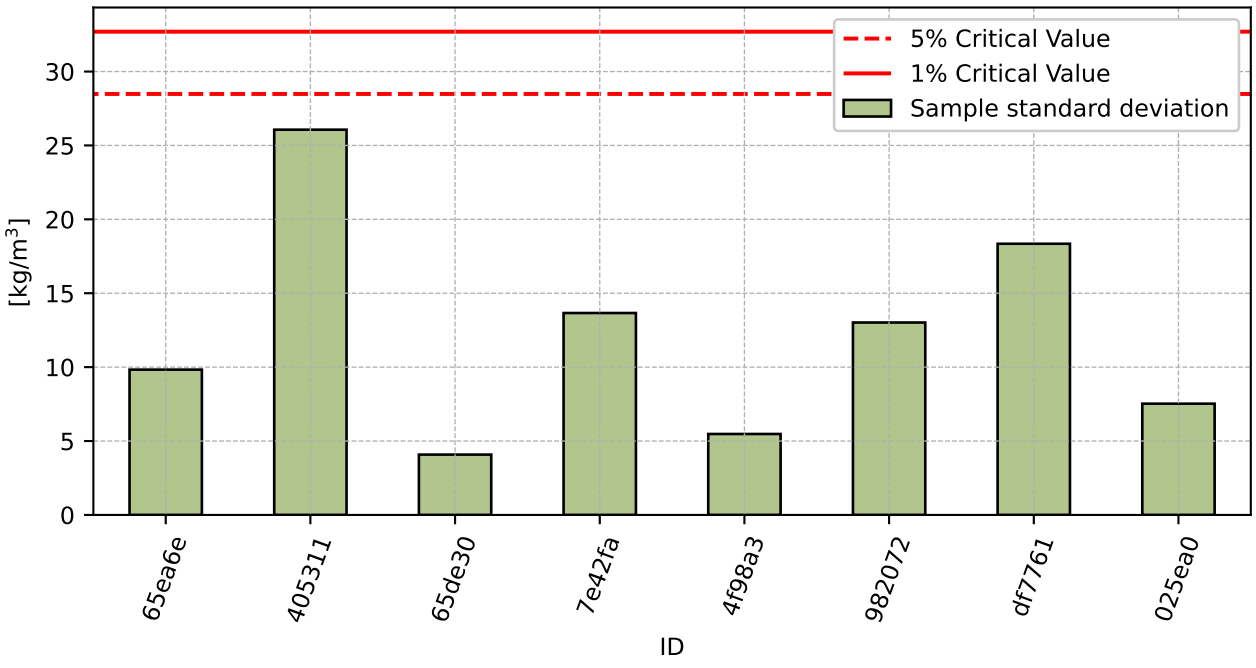

Figure 19: **Cochran's test** - sample standard deviations

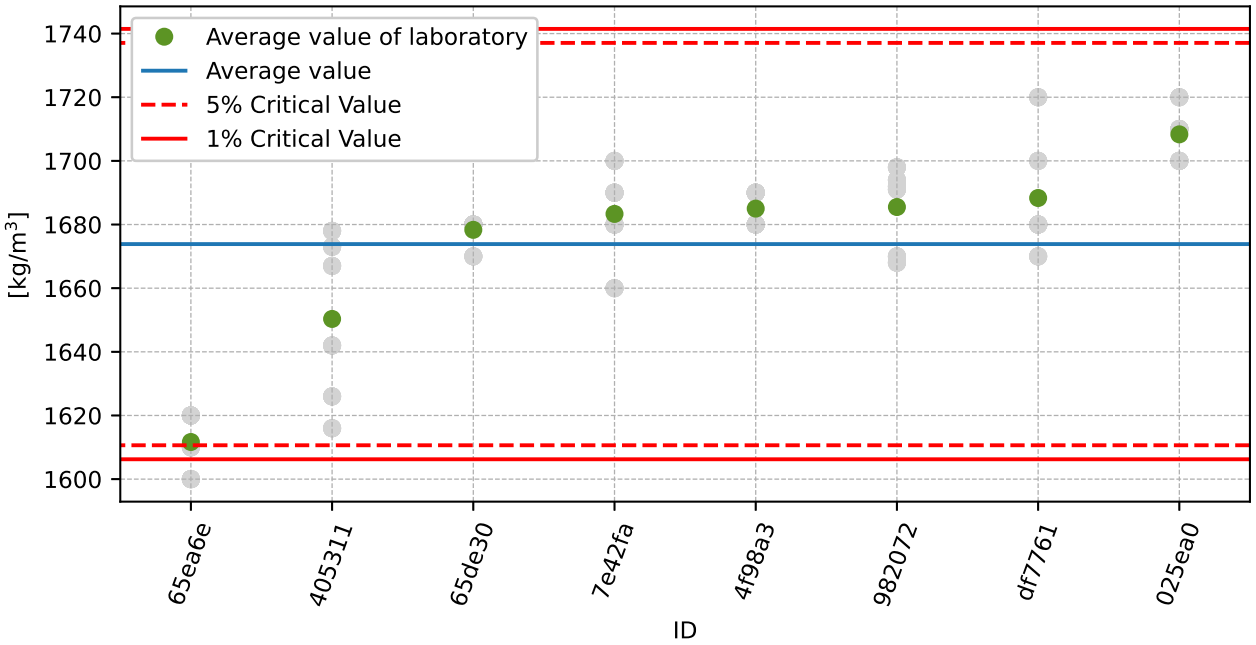

Figure 20: **Grubbs' test** - average values

7.4 Mandel's Statistics

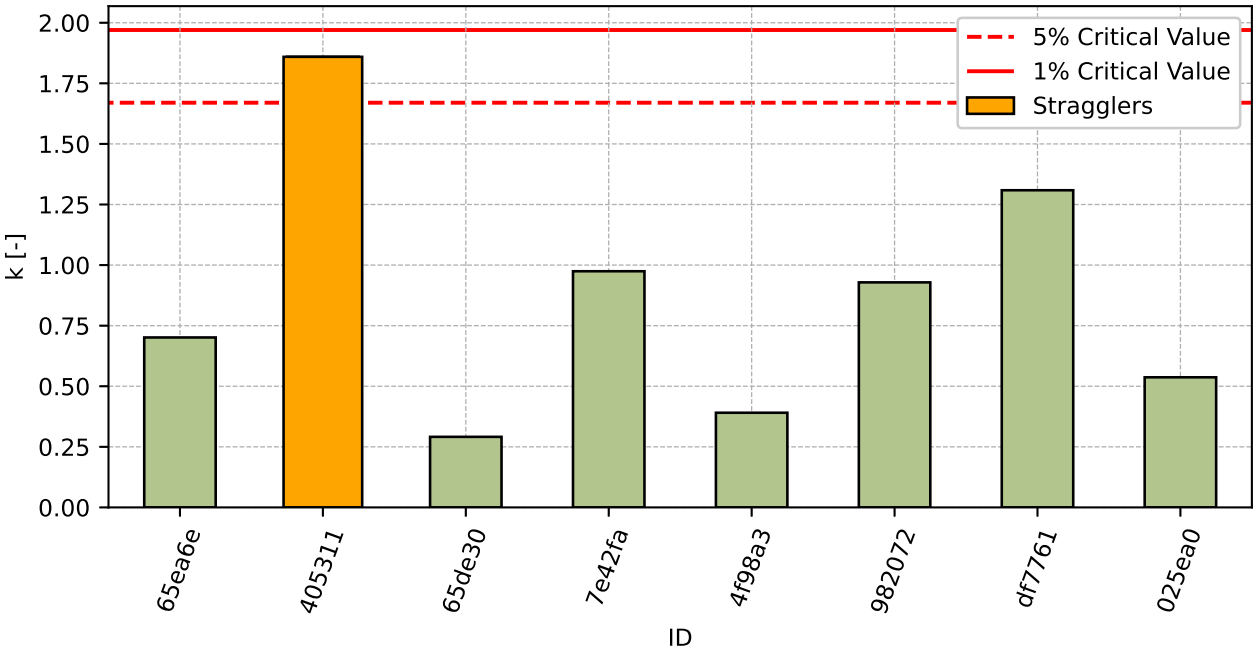

Figure 21: Intralaboratory Consistency Statistic

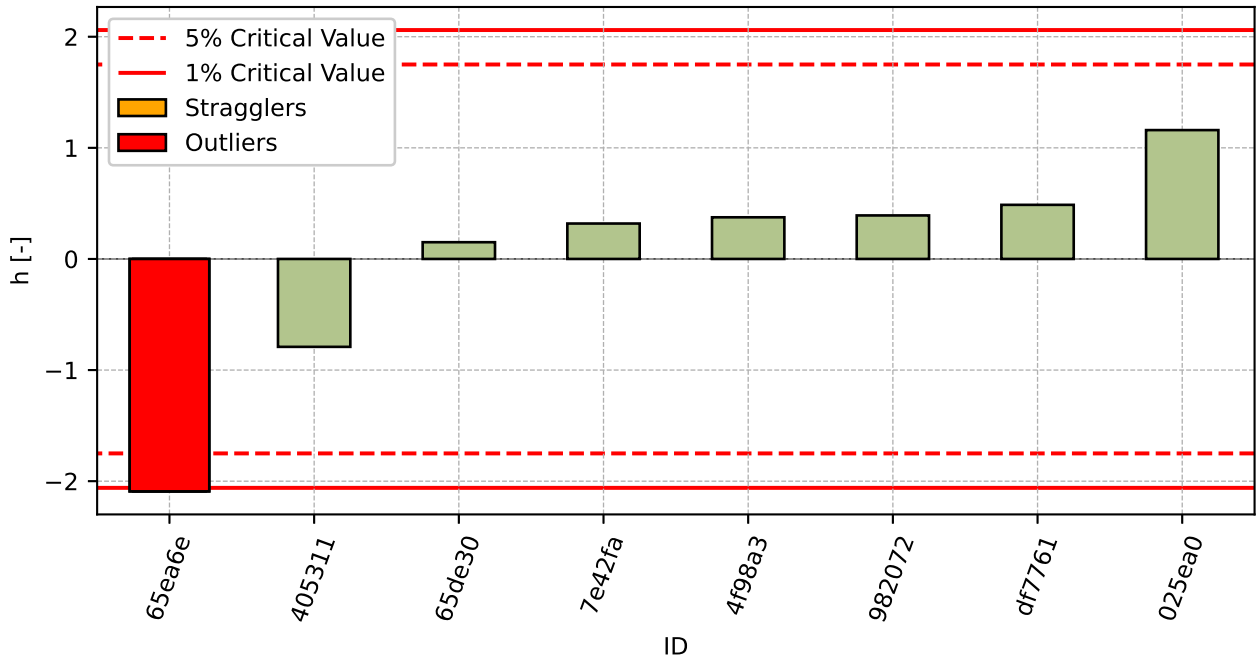

Figure 22: Interlaboratory Consistency Statistic

7.5 Descriptive statistics

Figure 23: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[kg/mm³]
Average value – $\bar{x}$	1674
Sample standard deviation – s	29.7
Asigned value – x^*	1674
Robust standard deviation – s^*	29.7
Measurement uncertainty of asigned value – u_X	10.5
p-value of normality test	0.0 [-]
Interlaboratory standard deviation – s_L	29.2
Repeatability standard deviation – s_r	14.0
Reproducibility standard deviation – s_R	32.4
Repeatability – r	39
Reproducibility – R	91

7.6 Evaluation of Performance Statistics

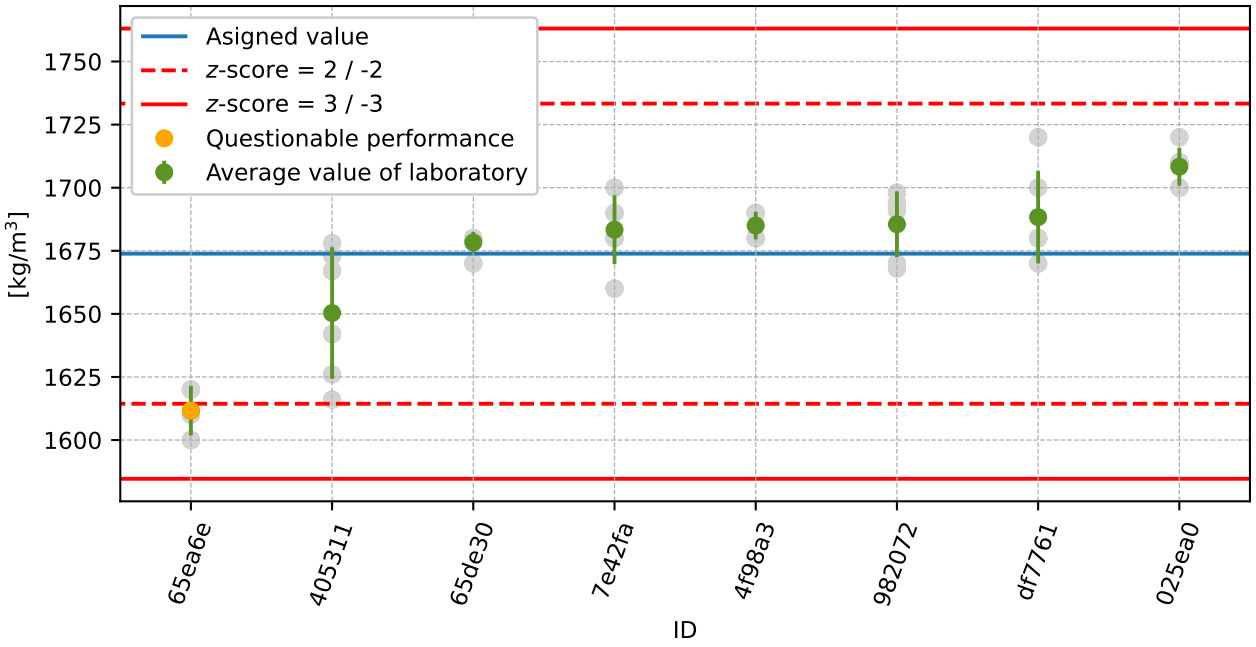

Figure 24: Average values and sample standard deviations

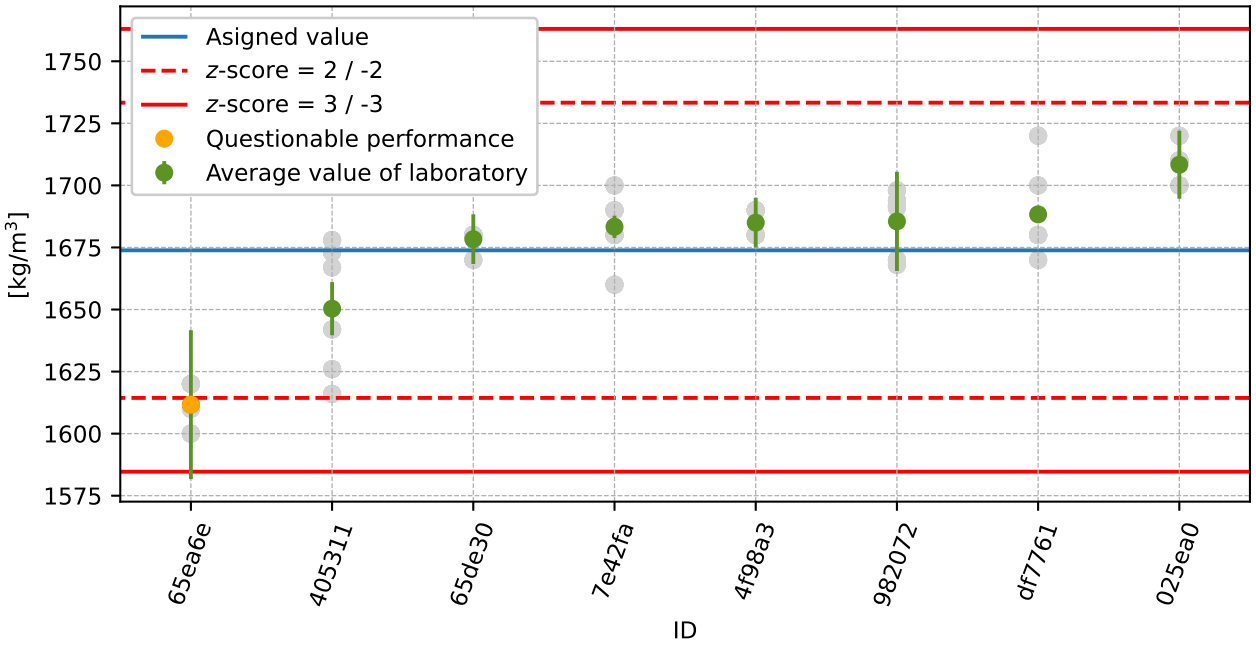

Figure 25: Average values and extended uncertainties of measurement

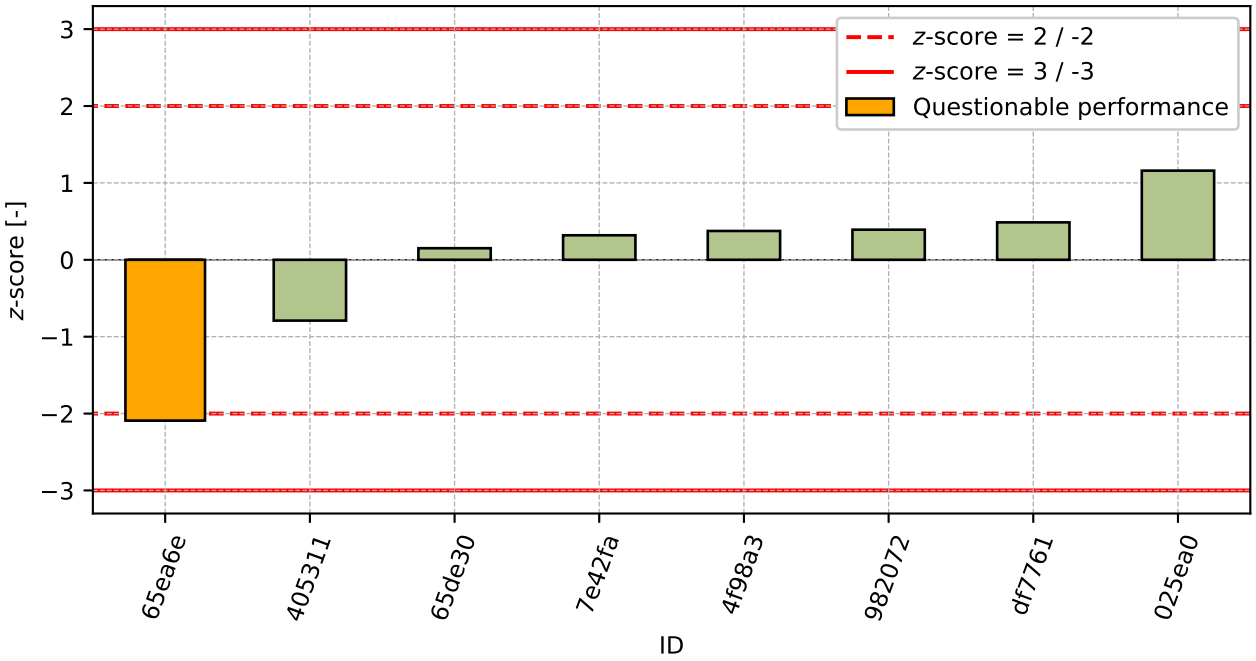

Figure 26: z-score

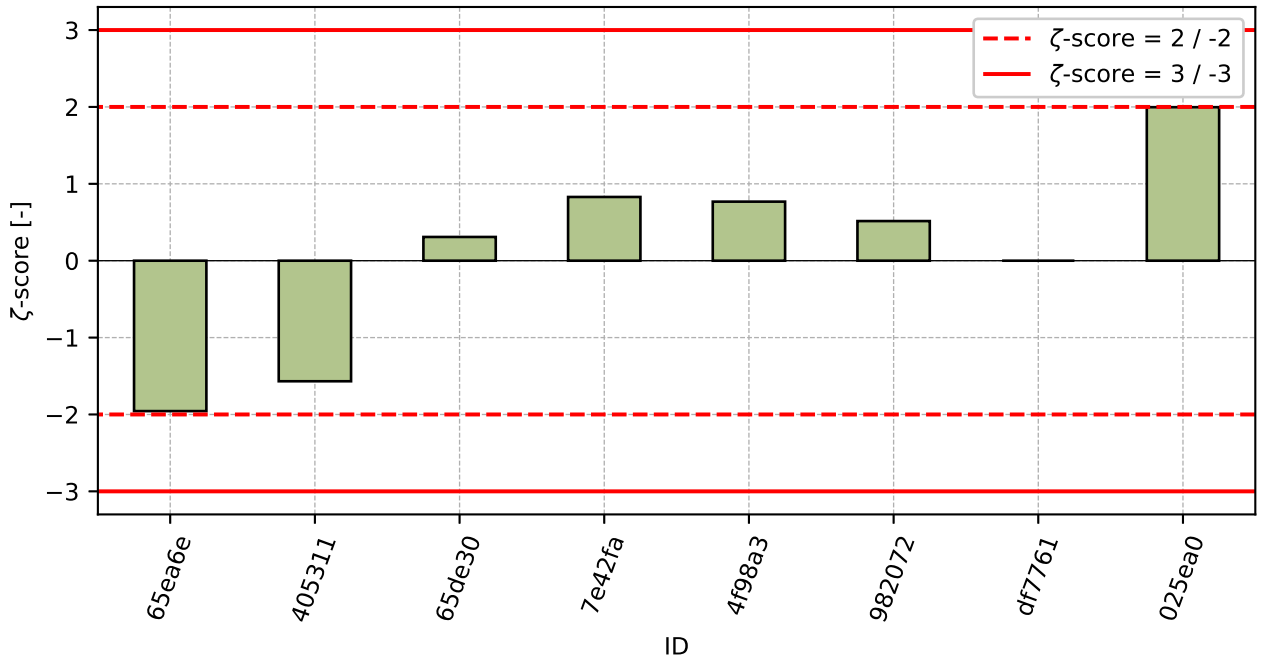

Figure 27: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
65ea6e	-2.09	-1.96
405311	-0.79	-1.57
65de30	0.15	0.31
7e42fa	0.32	0.83
4f98a3	0.37	0.77
982072	0.39	0.52
df7761	0.49	-
025ea0	1.16	2.0

7.7 Gross dry density of masonry units

7.7.1 Test results

Table 13: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [kg/mm³]						u_X [kg/mm³]	$\bar{x}$ [kg/mm³]	s_0 [kg/mm³]	V_X [%]
982072	751	751	750	757	751	751	10	752	2.7	0.36
65ea6e	755	760	755	755	760	755	20	757	2.6	0.34
4f98a3	755	755	755	760	760	760	5	758	2.7	0.36
df7761	750	755	755	760	770	760	-	758	6.8	0.9
65de30	760	760	760	755	760	760	5	759	2.0	0.27
7e42fa	760	760	755	770	765	765	6	762	5.2	0.69
f46489	760	760	770	-	-	-	-	763	5.8	0.76
025ea0	765	770	760	765	765	770	7	766	3.8	0.49
405311	776	776	777	780	776	777	1	777	1.5	0.2

7.7.2 The Numerical Procedure for Determining Outliers

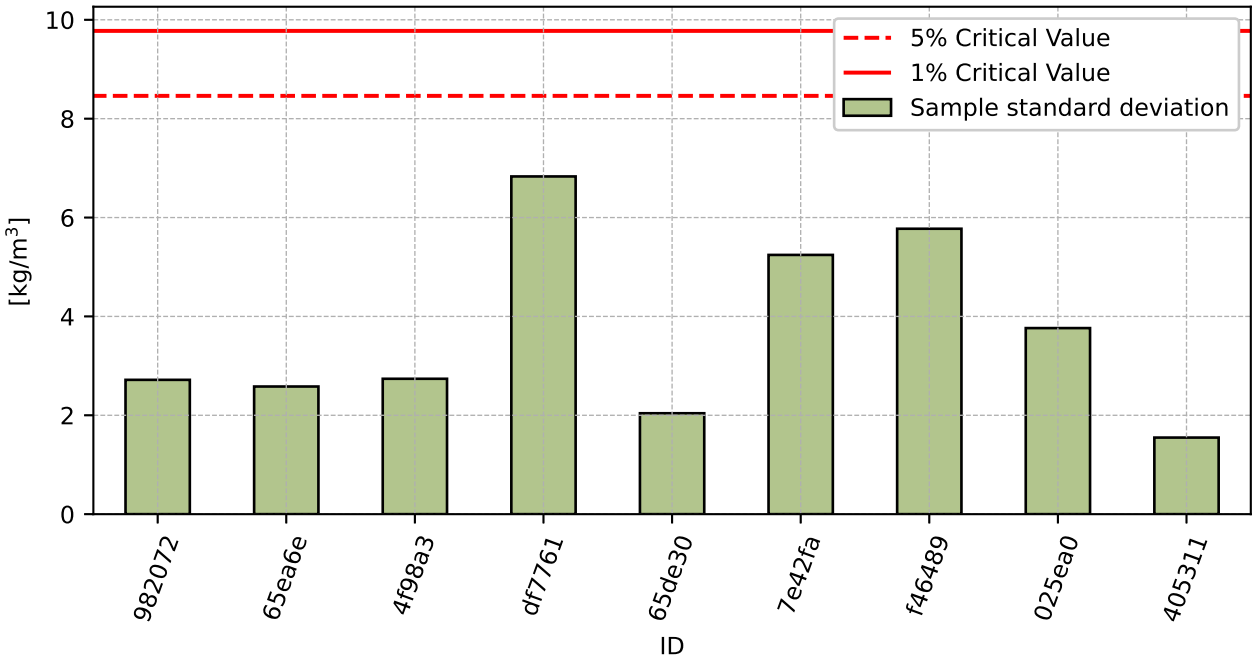

Figure 28: **Cochran's test** - sample standard deviations

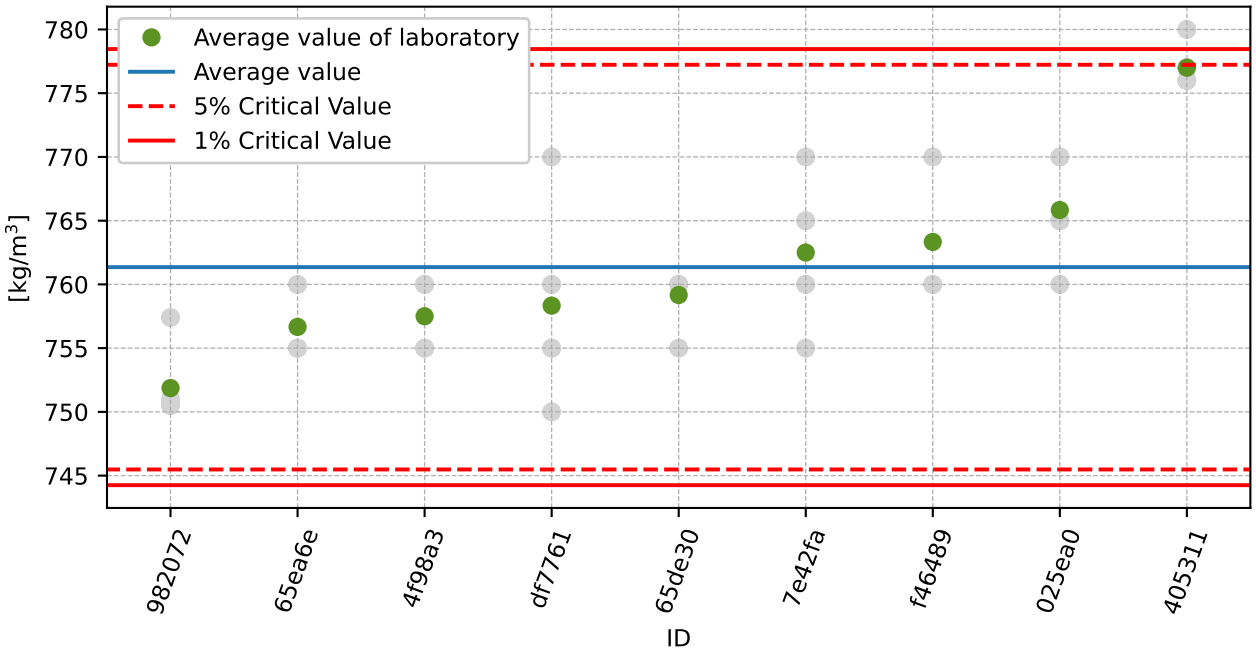

Figure 29: **Grubbs' test** - average values

7.7.3 Mandel's Statistics

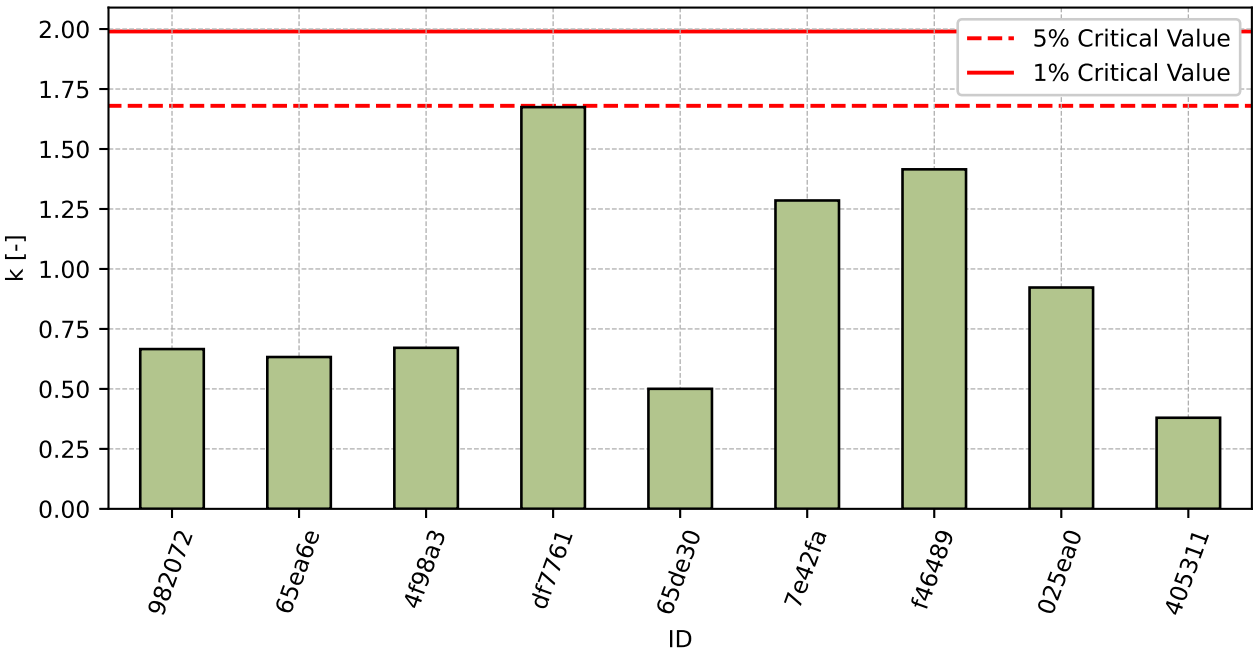

Figure 30: Intralaboratory Consistency Statistic

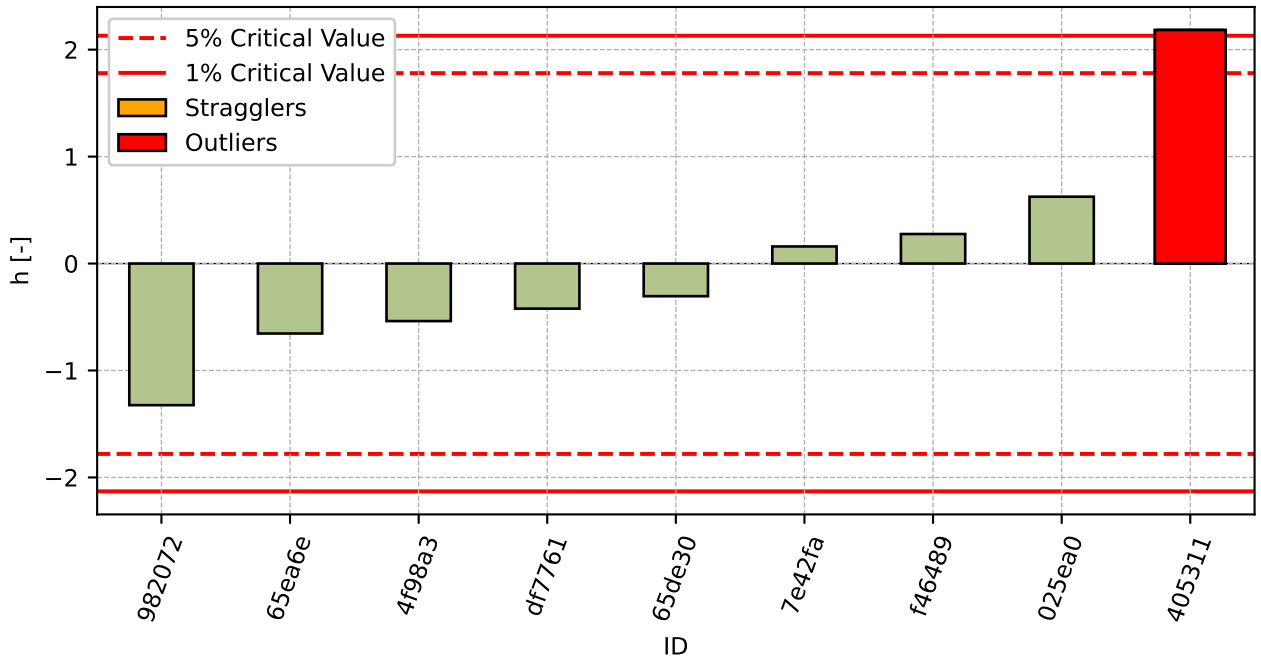

Figure 31: Interlaboratory Consistency Statistic

7.7.4 Descriptive statistics

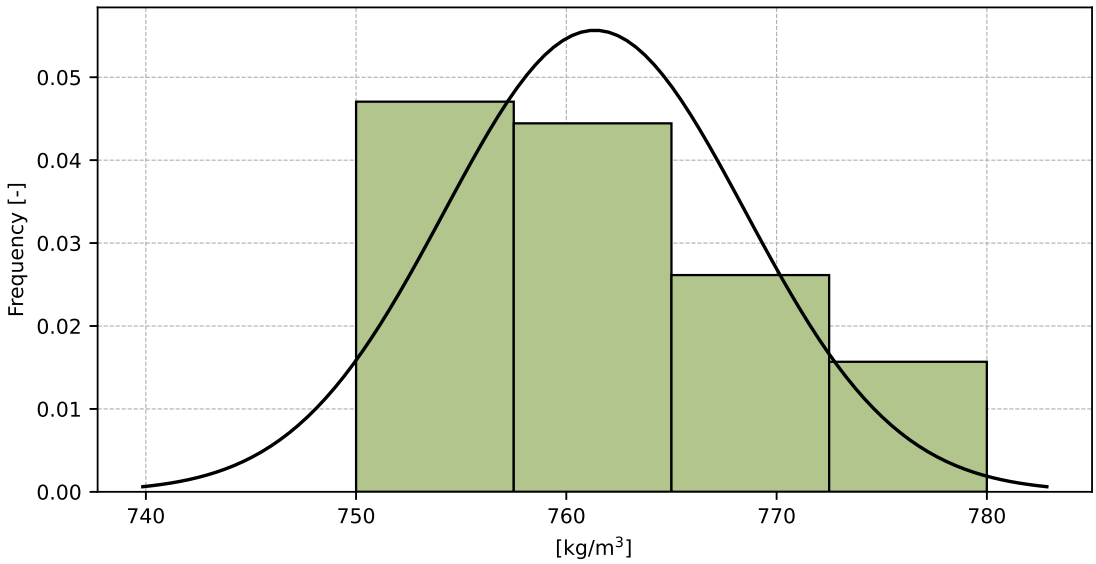

Figure 32: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	[kg/mm³]
Average value – $\bar{x}$	761
Sample standard deviation – s	7.2
Asigned value – x^*	761
Robust standard deviation – s^*	8.2
Measurement uncertainty of asigned value – u_X	3.2
p-value of normality test	1.0 [-]
Interlaboratory standard deviation – s_L	7.0
Repeatability standard deviation – s_r	4.1
Reproducibility standard deviation – s_R	8.1
Repeatability – r	11
Reproducibility – R	23

7.7.5 Evaluation of Performance Statistics

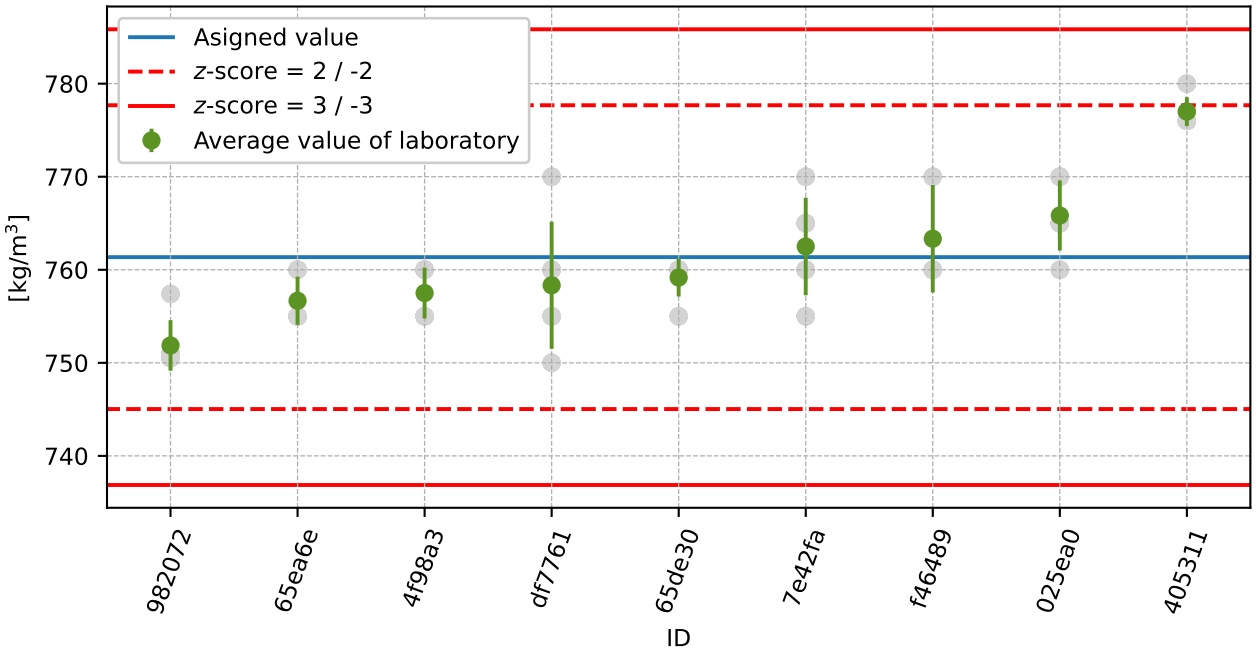

Figure 33: Average values and sample standard deviations

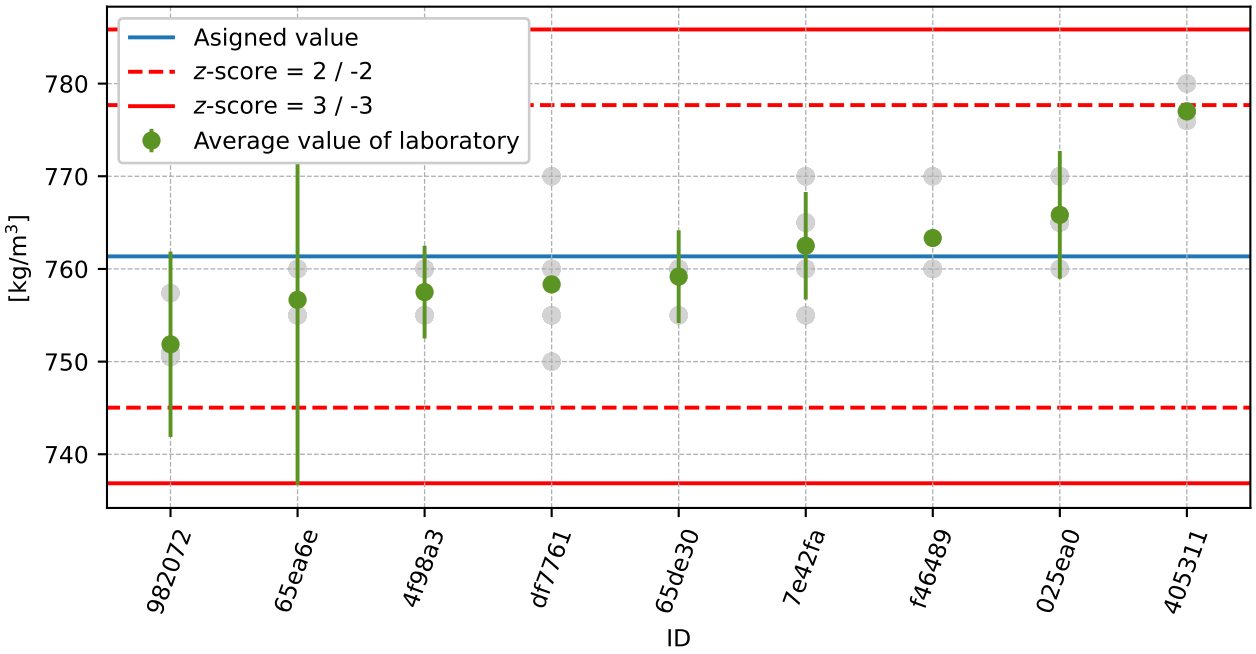

Figure 34: Average values and extended uncertainties of measurement

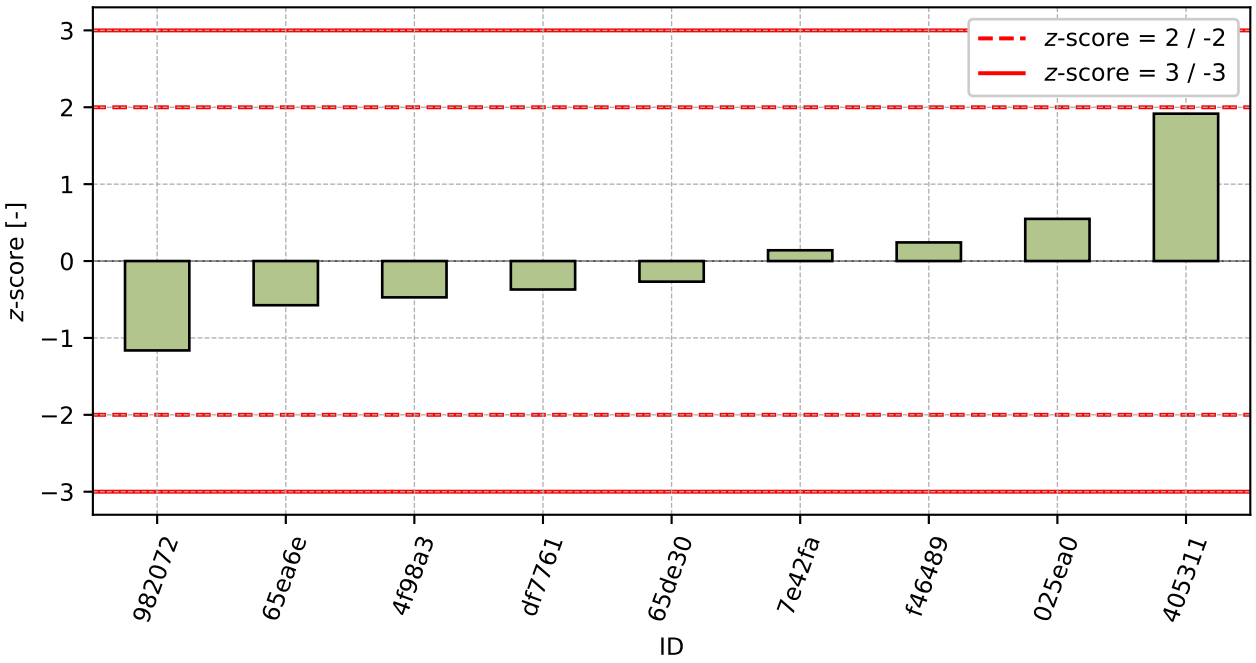

Figure 35: z-score

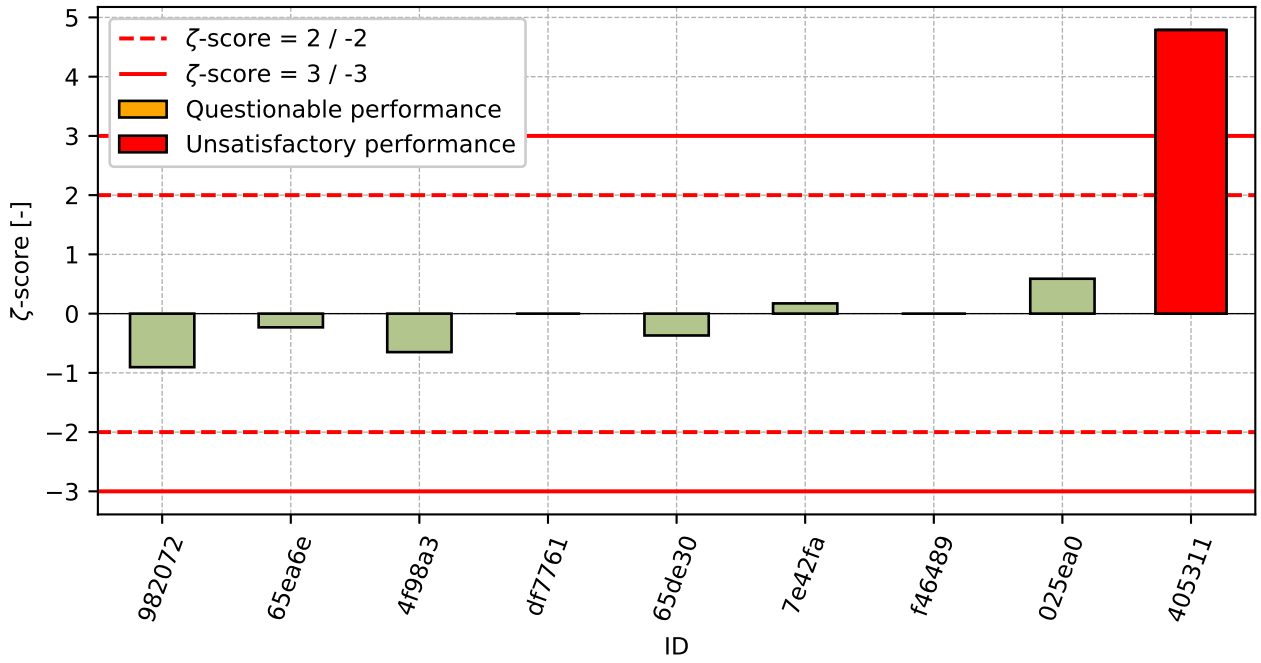

Figure 36: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
982072	-1.16	-0.9
65ea6e	-0.57	-0.23
4f98a3	-0.47	-0.65
df7761	-0.37	-
65de30	-0.27	-0.37
7e42fa	0.14	0.17
f46489	0.24	-
025ea0	0.55	0.59
405311	1.92	4.79

This part of PT program was not open due to the low number of participants.

8 Appendix – EN 15435, part 4.9.3, Appendix B (Flexural strength of side shutters)

This part of PT program was not open due to the low number of participants.

9 Appendix – EN 15435, part 5.2 (Density)

This part of PT program was not open due to the low number of participants.