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
Mortar, Cement and Fine-grained Cement Composites
ZMC 2022/1

Brno University of Technology
Proficiency testing provider at the SZK FAST
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Czech Republic

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1 Introduction and Important Contacts

In the year 2022, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZMC 2022/1 whose aim was to verify and assess the conformity of test results across laboratories when testing mortar, cement and fine-grained cement composites.

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. Ing. Tomáš Vymazal, Ph.D.
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The subjects of proficiency testing were the following testing procedures:

1. EN 196-1 – Strength [1]
2. EN 196-2 (art. 4.4.1) – Determination of loss on ignition [2]
3. EN 196-2 (art. 4.4.2) – Determination of sulphate content [2]
4. EN 196-2 (art. 4.4.3) – Determination of the residue insoluble in hydrochloric acid and sodium carbonate [2]
5. EN 196-2 (art. 4.4.4) – Determination of the residue insoluble in hydrochloric acid and potassium hydroxide [2]
6. EN 196-2 (art. 4.4.5) – Determination of sulphite content [2]
7. EN 196-2 (art. 4.4.6) – Determination of manganese content [2]
8. EN 196-3 – Setting time, Soundness[3]
9. EN 196-10 – Determination of the water-soluble chromium (Cr^{6+}) [4]
10. EN 1015-1 – Granularity [5]
11. EN 1015-3 – Consistency [6]
12. EN 1015-6 – Density of fresh mortar [7]
13. EN 1015-10 – Density of hardened mortar [8]
14. EN 1015-11 – Strength [9]
15. EN 1015-12 – Adhesion [10]
16. EN 1015-18 – Capillary absorption coefficient (C_m) [11]
17. EN 1015-19 – Water vapor flow [12]
18. EN 13892-2 – Determination of flexural and compressive strength [13]
19. EN 12004-2 (art. 8.1) – Open time [14]
20. EN 12004-2 (art. 8.2) – Slippage [14]
21. EN 12004-2 (art. 8.3.3.2) – Adhesion [14]

22. EN 12004-2 (art. 8.3.3.3) – Adhesion [14]

Testing procedures No **1, 15 and 16** were open. Other test methods were not opened due to low number of participants (interested laboratories).

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 [15] and with EN ISO/IEC 17043 [16]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

14 laboratories 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

ID/Part	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
829e9d	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
4a8a43	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b521a1	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1a7ce4	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
328a84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
556905	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
8071e6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
8cc150	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f52d29	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
900907	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
0bd276	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
77d808	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
540acb	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d94b49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
061ef1	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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

Laboratory	Address	Accreditation number
"LABKONSULT PLUS" Ltd.	compl."Mladost-1"/ bl.43/vh.3/ap.41, Sofia, 1784, BULGARIA	-
Building Rsearch Institute - NISI	86 Nikola Petkov Blvd, Sofia, 1618, BULGARIA	88 LI
Cement Hranice, akciová společnost	Bělotínská 288, Hranice I - Město, 75301, Česká republika	1284
Graz University of Technology	Rechbauerstraße 12, Graz, 8010, Austria	-

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Laboratory	Address	Accreditation number
Institut technologie a testování betonu, s.r.o., Zkušební laboratoř ITTB Brno	K Babě 609/9, Brno, 62100, Česká republika	L1778
Institut za ispitivanje materijala a.d.	Bulevar vojvode Mišića 43, Belgrade, 11000, Serbia	-
Institute IMS	Bulevar vojvode Misica 43, Belgrade, 11000, Serbia	-
MIRTEC S.A.	76 km of Athens-Lamia National Road, Ritsona, 32009, Greece	-
Magnel-Vandepitte Laboratory	Technologiepark-Zwijnaarde 60, Zwijnaarde (Ghent), 9052, Belgium	220-TEST
QUALIFORM SLOVAKIA s.r.o.	Pasienková 9 D, Bratislava, 82106, Slovenská republika	S-301
Skanska a.s.	Křižíkova 682/34a, Praha 8- Karlín, 186 00, Česká republika	1355
Technický a zkušební ústav stavební Praha, s. p., Centrální laboratoř - zkušebna Brno	Hněvkovského 77, Brno, 61700, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p.	Tolstého 447, Teplice, 415 03, Česká republika	L 1018.3
VIALAB CZ s.r.o.	U Michelského lesa 1581/2, Praha 4, 140 00, Česká republika	1112
Ředitelství silnic a dálnic ČR	Rebešovická 40, Brno-Chrlice, 643 00, Česká republika	1072

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 (symbol **X**).
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 (symbol **X**).
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. The following scales are applied for the z-score values:
   - $|z\text{-score}| < 2 \Rightarrow$ shows that the laboratory performance is **satisfactory** and generates no signal – ✓.
   - $2 \leq |z\text{-score}| < 3 \Rightarrow$ shows that the laboratory performance is **questionable** and generates an action signal – **?**.
   - $|z\text{-score}| \geq 3 \Rightarrow$ shows that the laboratory performance is **unsatisfactory** and generates an action signal – **!**.

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 Mortar, Cement and Fine-grained Cement Composites (PT Program) organized by the PT Provider at the SZK FAST. 14 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of mortar, cement, fine-grained cement composites. 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	15	16
829e9d	-	✓	✓
4a8a43	✓	-	-
b521a1	✓	-	-
1a7ce4	✓	-	-
328a84	-	✓	✓
556905	-	✓	-
8071e6	-	-	✓
8cc150	✓	-	-
f52d29	✓	-	✓
900907	✓	✓	✓
0bd276	✓	-	-
77d808	✓	✓	-
540acb	✓	-	-
d94b49	-	-	✓
061ef1	✓	-	-

References

[1] EN 196-1. *Methods of testing cement - Part 1: Determination of strength*. 2016.

[2] EN 196-2. *Method of testing cement - Part 2: Chemical analysis of cement*. 2013.

[3] EN 196-3. *Methods of testing cement - Part 3: Determination of setting times and soundness*. 2017.

[4] EN 196-10. *Methods of testing cement - Part 10: Determination of the water-soluble chromium (VI) content of cement*. 2017.

[5] EN 1015-1. *Methods of test for mortar for masonry - Part 1: Determination of particle size distribution (by sieve analysis)*. 1999.

[6] EN 1015-3. *Methods of test for mortar for masonry - Part 3: Determination of consistence of fresh mortar (by flow table)*. 2000.

[7] EN 1015-6. *Methods of test for mortar for masonry - Part 6: Determination of bulk density of fresh mortar*. 1999.

[8] EN 1015-10. *Methods of test for mortar for masonry - Part 10: Determination of dry bulk density of hardened mortar*. 2000.

[9] EN 1015-11. *Methods of test for mortar for masonry - Part 11: Determination of flexural and compressive strentgth of hardened mortar*. 2000.

[10] EN 1015-12. *Methods of test for mortar for masonry - Part 12: Determination of adhesive strength of hardened rendering and plastering mortars on substrates*. 2000.

[11] EN 1015-18. *Methods of test for mortar for masonry - Part 18: Determination of water absorption coefficient due to capillarity action of hardened mortar*. 2003.

[12] EN 1015-19. *Methods of test for mortar for masonry - Part 19: Determination of water vapour permeability of hardened rendering and plastering mortars*. 1999.

[13] EN 13892-2. *Methods of test for screed materials - Part 2: Determination of flexural and compressive strength*. 2003.

[14] EN 12004-2. *Adhesives for ceramic tiles - Part 2: Test methods*. 2017.

[15] 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.

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

1 Appendix – EN 196-1 – Strength

1.1 Flexural Strength after 2 days of ageing

1.1.1 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 [%]
061ef1	4.4	4.4	4.2	0.5	4.3	0.12	2.66
b521a1	4.9	4.6	4.7	0.4	4.7	0.14	2.96
900907	4.8	5.0	4.9	0.4	4.9	0.09	1.85
0bd276	4.8	5.3	4.9	0.7	5.0	0.26	5.29
1a7ce4	5.0	4.9	5.3	0.2	5.1	0.21	4.11
77d808	5.3	4.9	5.1	0.5	5.1	0.2	3.92
540acb	5.7	4.9	4.9	0.3	5.2	0.46	8.94
f52d29	5.4	5.3	5.3	0.4	5.3	0.06	1.08
8cc150	5.4	5.2	5.7	0.8	5.4	0.25	4.63
4a8a43	6.0	5.9	6.0	0.1	6.0	0.06	0.97

1.1.2 The Numerical Procedure for Determining Outliers

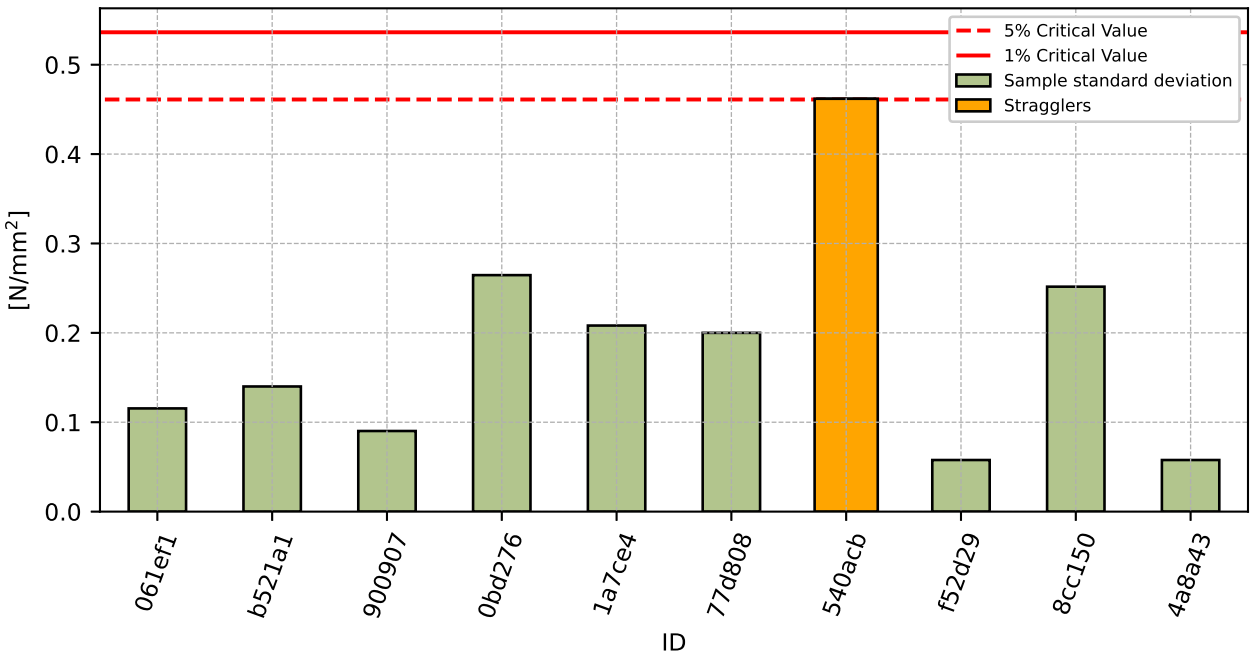

Figure 1: **Cochran's test** - sample standard deviations

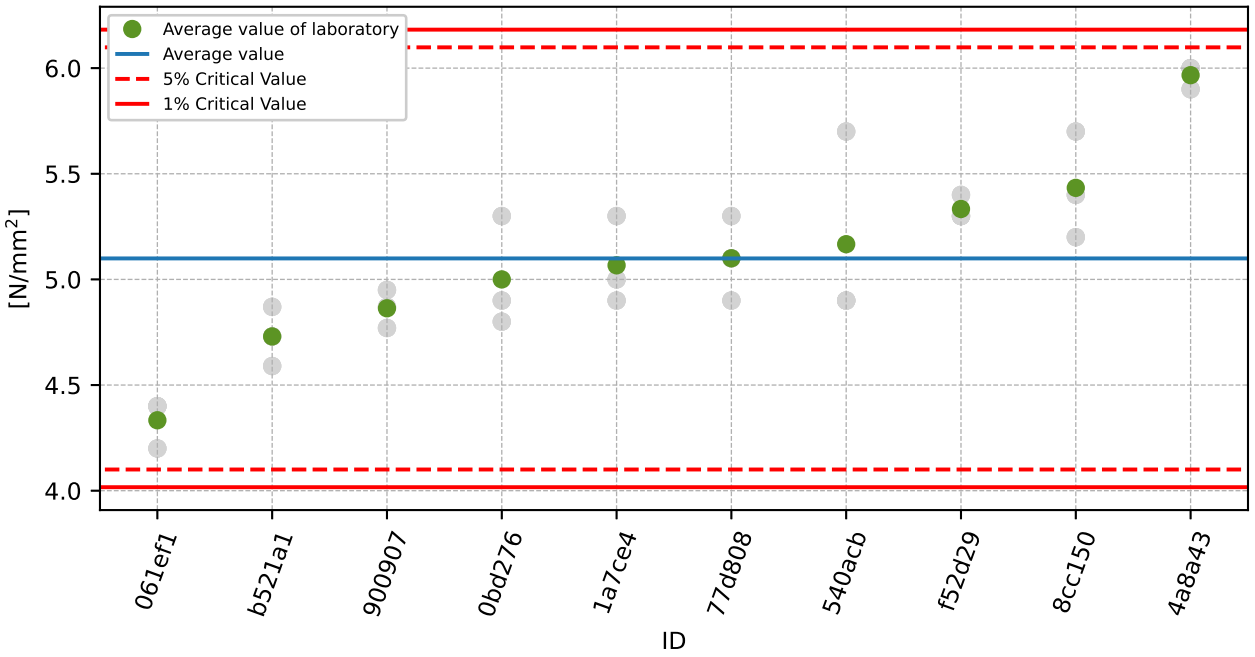

Figure 2: **Grubbs' test** - average values

1.1.3 Mandel's Statistics

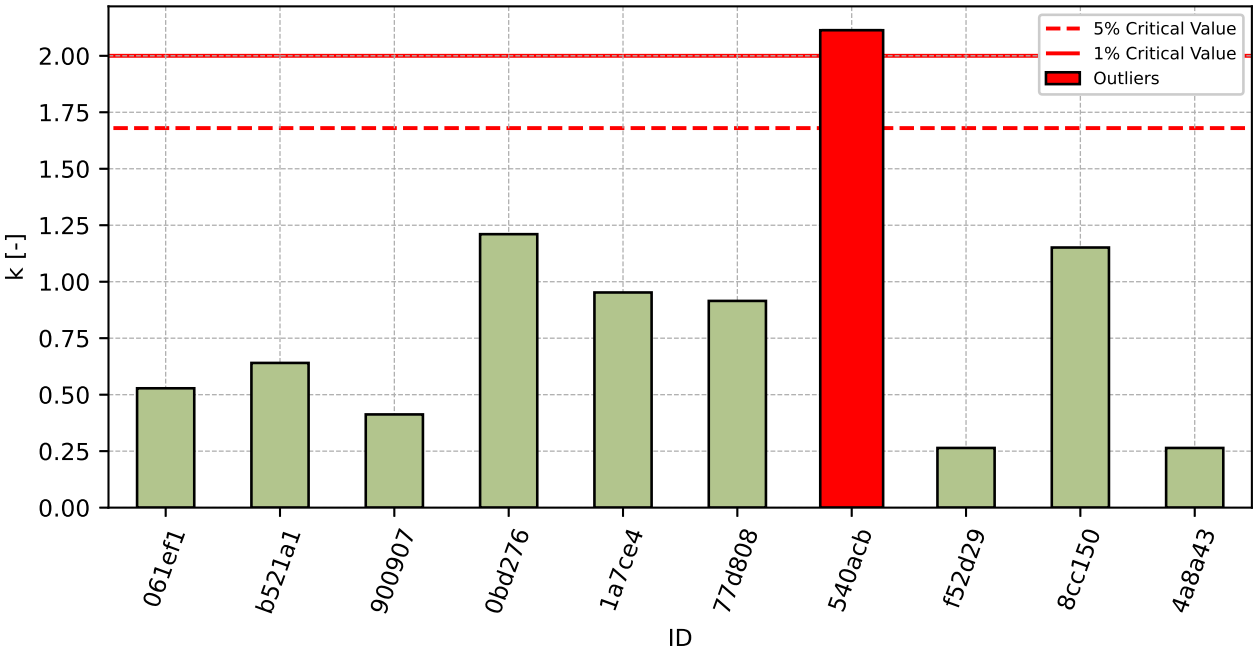

Figure 3: Intralaboratory Consistency Statistic

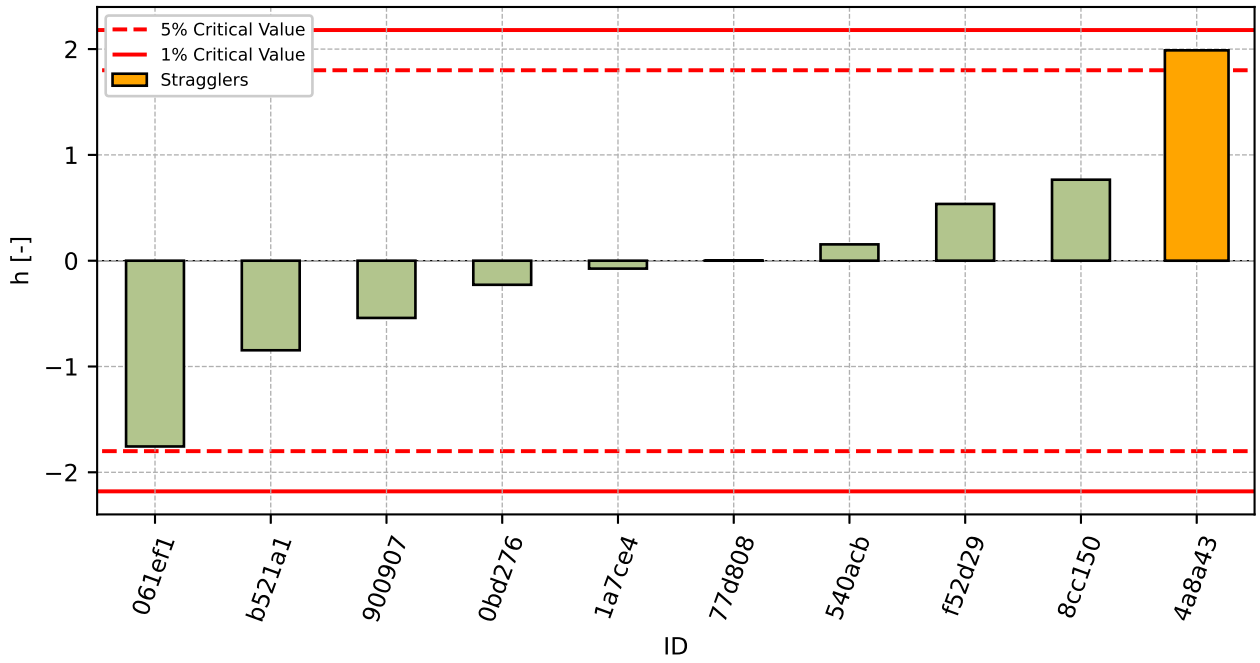

Figure 4: Interlaboratory Consistency Statistic

1.1.4 Descriptive statistics

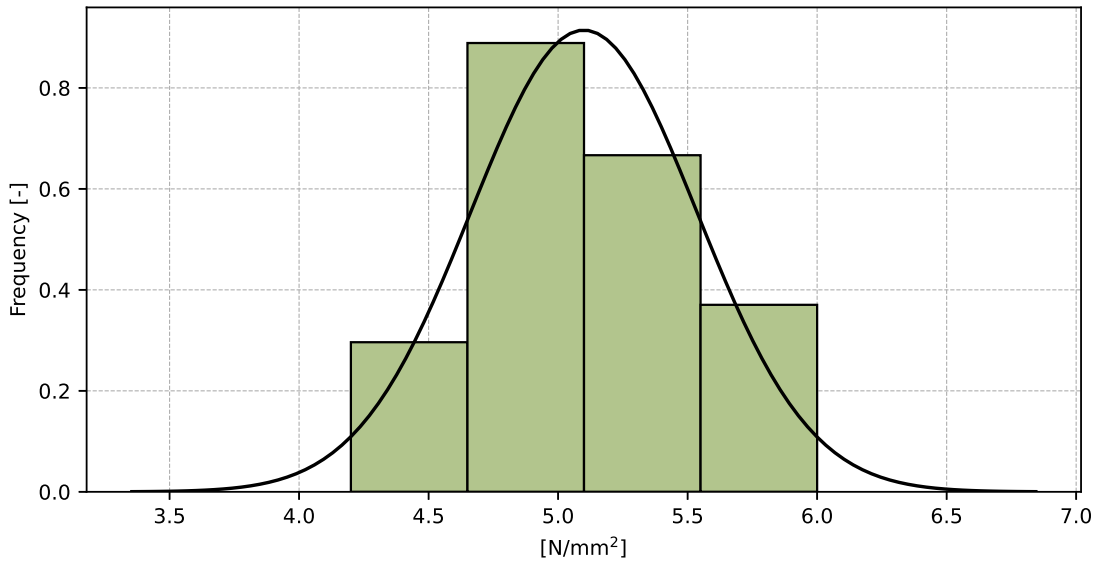

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	5.1
Sample standard deviation – s	0.44
Asigned value – x^*	5.1
Robust standard deviation – s^*	0.43
Measurement uncertainty of asigned value – u_X	0.17
p-value of normality test	0.296 [-]
Interlaboratory standard deviation – s_L	0.42
Repeatability standard deviation – s_r	0.22
Reproducibility standard deviation – s_R	0.47
Repeatability – r	0.6
Reproducibility – R	1.3

1.1.5 Evaluation of Performance Statistics

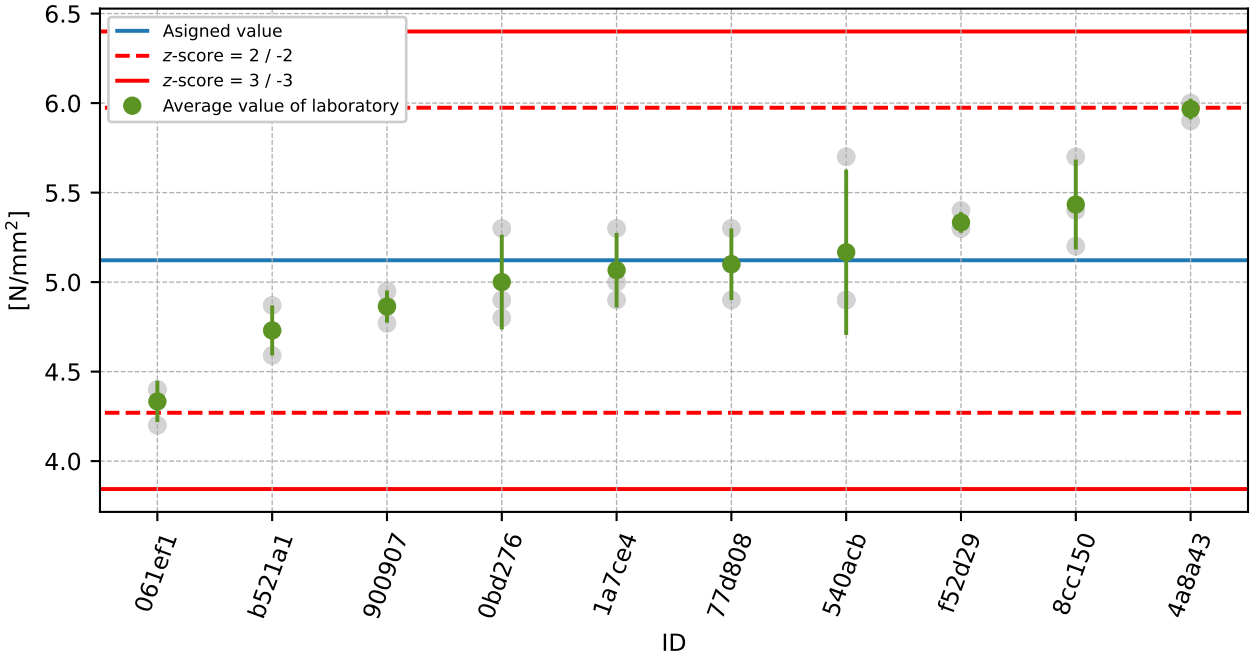

Figure 6: Average values and sample standard deviations

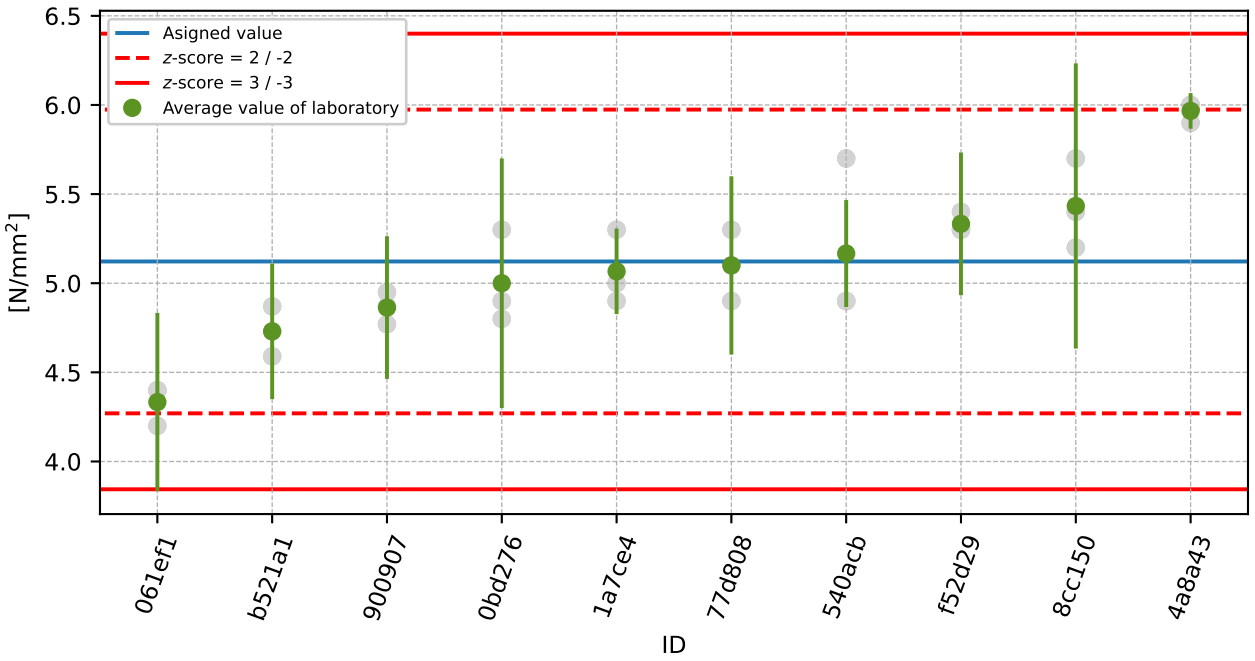

Figure 7: Average values and extended uncertainties of measurement

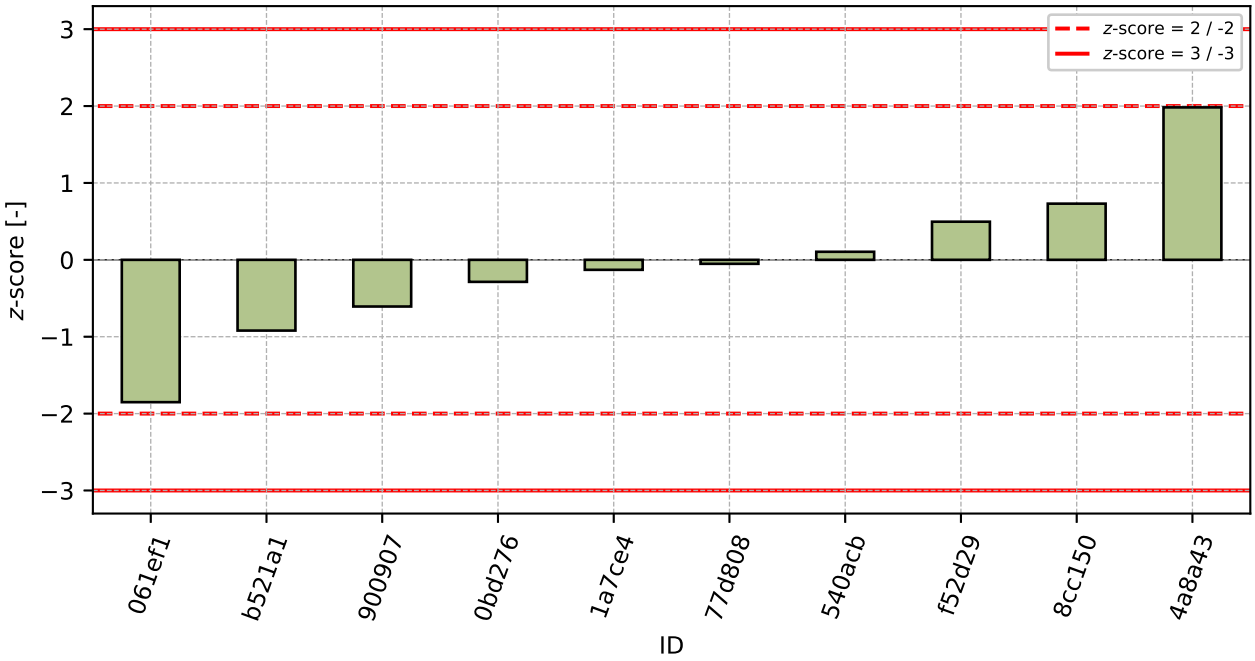

Figure 8: z-score

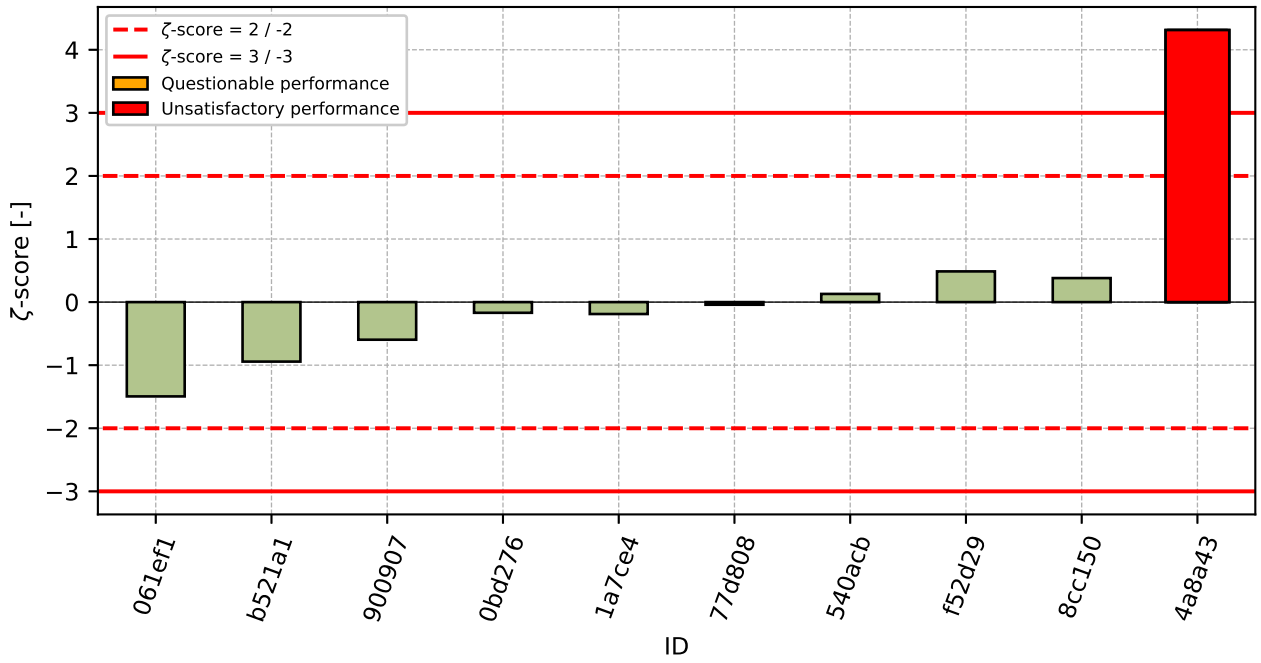

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
061ef1	-1.85	-1.49
b521a1	-0.92	-0.94
900907	-0.61	-0.6
0bd276	-0.29	-0.17
1a7ce4	-0.13	-0.19
77d808	-0.05	-0.04
540acb	0.1	0.13
f52d29	0.5	0.49
8cc150	0.73	0.38
4a8a43	1.98	4.31

1.2 Compressive Strength after 2 days of ageing

1.2.1 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/mm²]						u_X [N/mm²]	$\bar{x}$ [N/mm²]	s_0 [N/mm²]	V_X [%]
540acb	22.6	22.9	21.4	21.7	22.3	22.4	1.6	22.2	0.56	2.54
061ef1	22.9	22.6	23.4	22.4	21.4	20.8	1.4	22.3	0.97	4.36
0bd276	23.4	22.8	23.5	23.0	23.4	23.3	0.6	23.2	0.27	1.18
900907	24.6	24.4	24.1	24.0	23.6	22.9	1.0	23.9	0.61	2.56
77d808	24.2	24.1	24.3	24.1	24.2	24.3	2.0	24.2	0.09	0.37
b521a1	24.9	25.0	25.8	26.3	25.5	24.3	2.8	25.3	0.71	2.82
8cc150	26.7	27.2	26.6	26.9	27.2	27.3	0.8	27.0	0.29	1.08
f52d29	28.0	27.3	27.0	27.8	27.3	27.9	2.0	27.6	0.4	1.47
1a7ce4	27.4	27.4	27.6	27.9	27.7	27.5	0.9	27.6	0.19	0.7
4a8a43	29.5	29.8	30.6	29.4	28.2	29.2	0.7	29.4	0.78	2.66

1.2.2 The Numerical Procedure for Determining Outliers

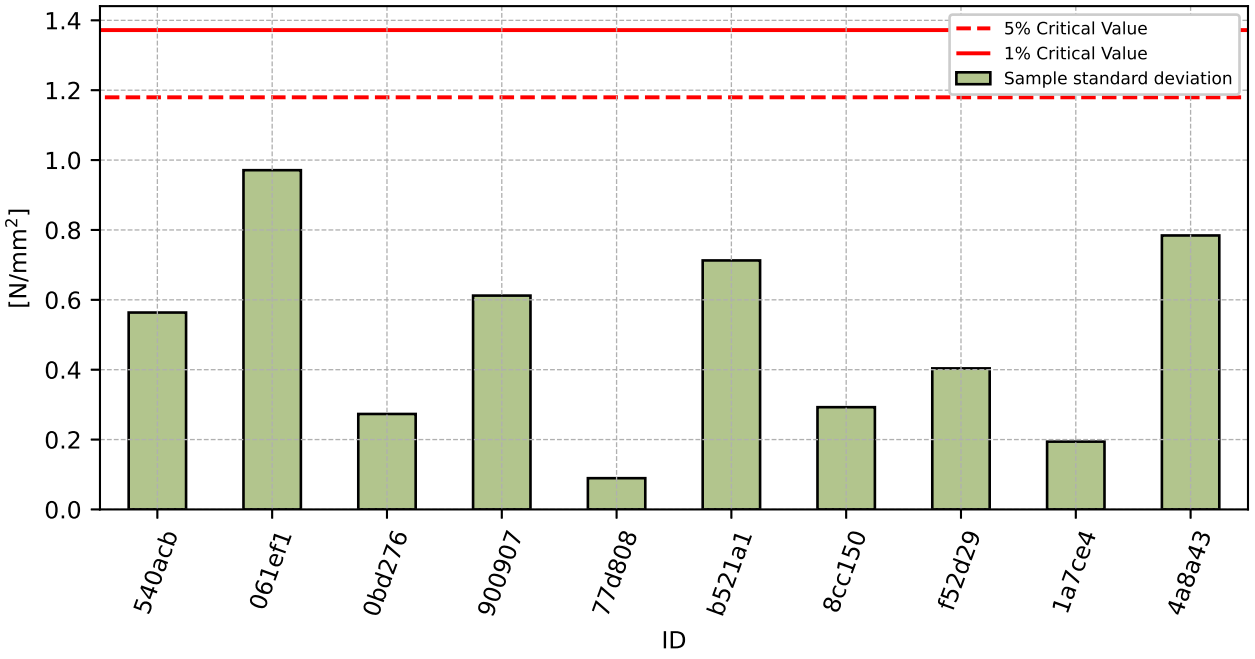

Figure 10: **Cochran's test** - sample standard deviations

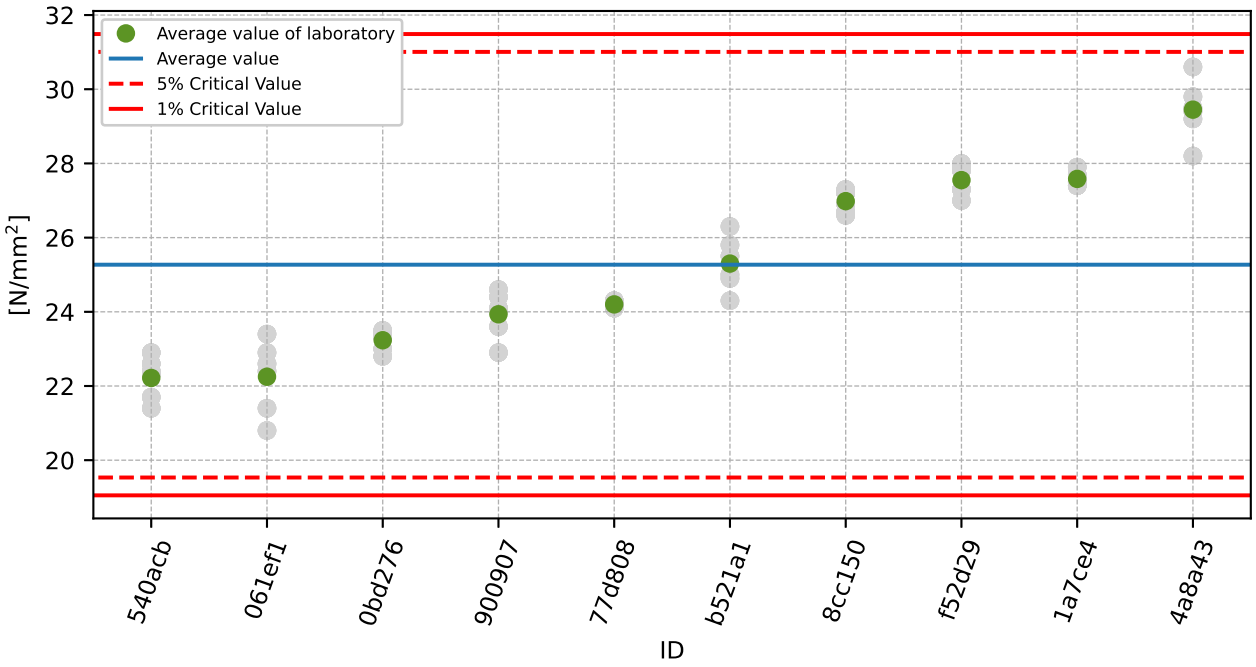

Figure 11: **Grubbs' test** - average values

1.2.3 Mandel's Statistics

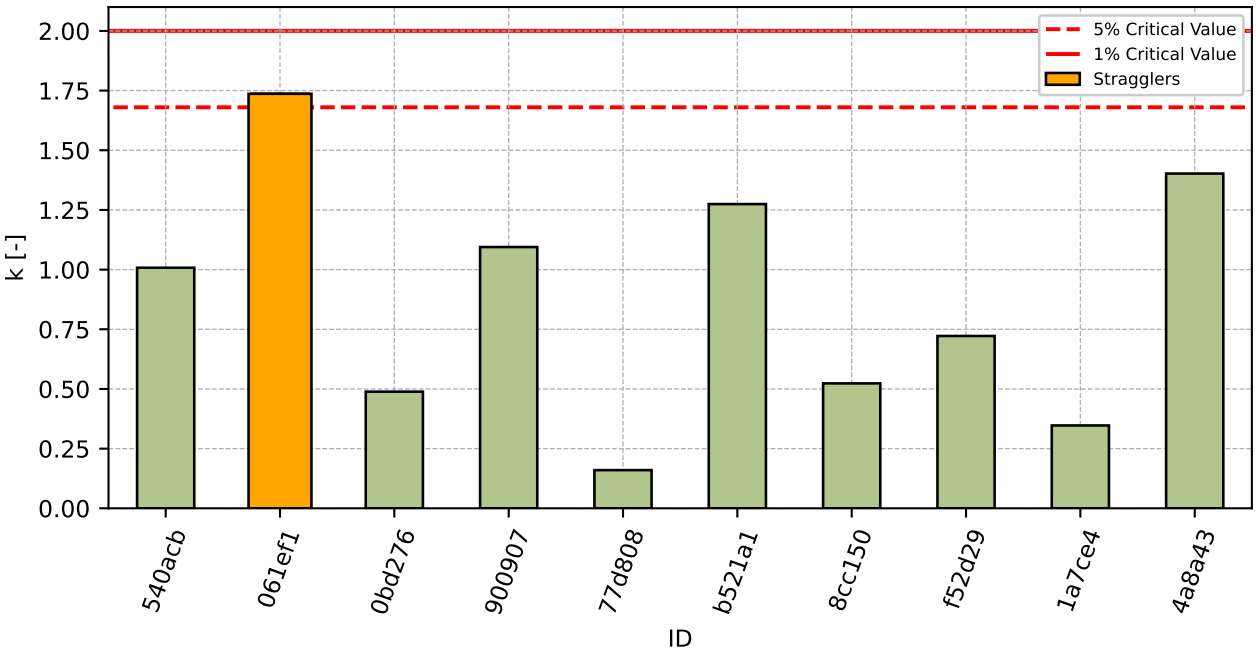

Figure 12: Intralaboratory Consistency Statistic

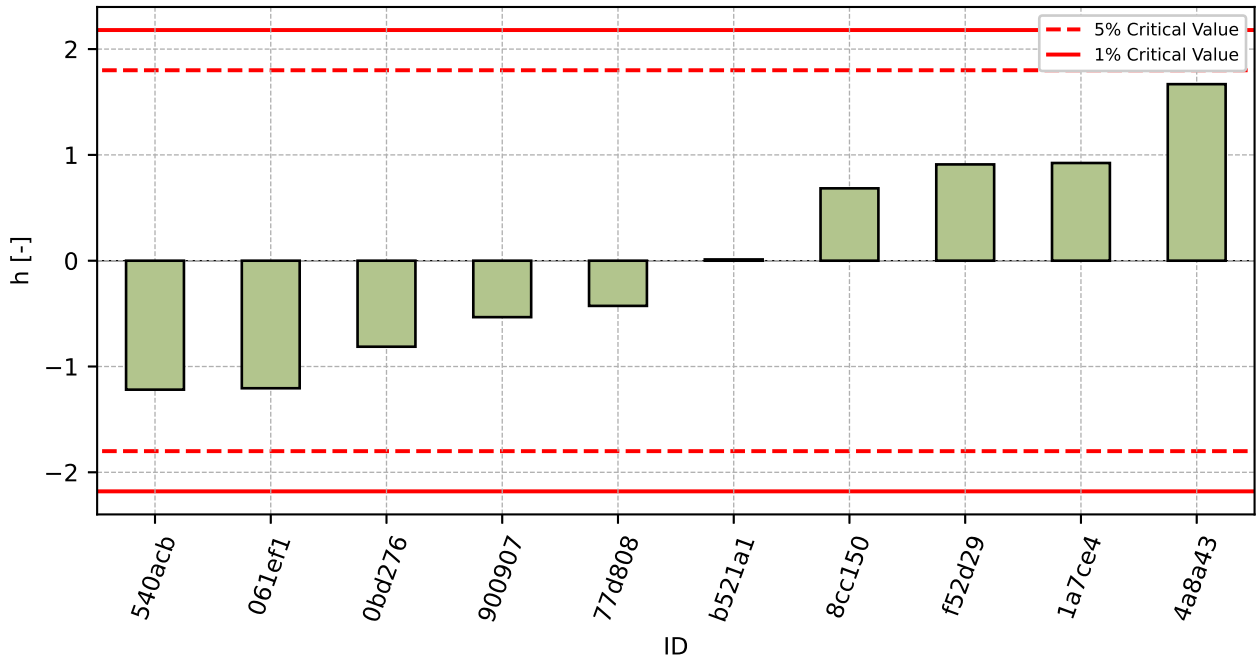

Figure 13: Interlaboratory Consistency Statistic

1.2.4 Descriptive statistics

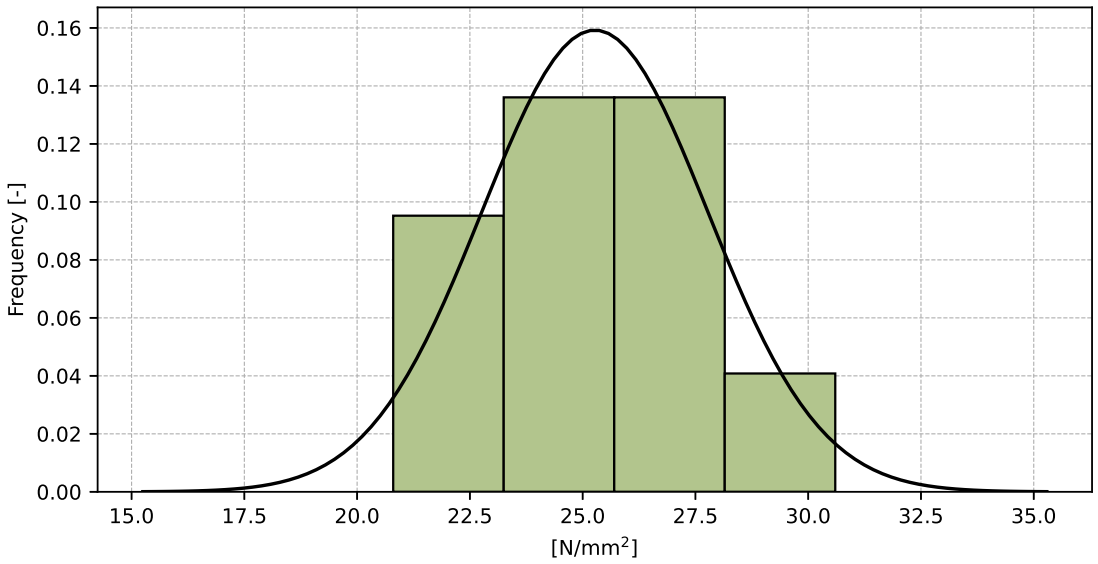

Figure 14: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	25.3
Sample standard deviation – s	2.51
Asigned value – x^*	25.3
Robust standard deviation – s^*	2.7
Measurement uncertainty of asigned value – u_X	1.07
p-value of normality test	0.023 [-]
Interlaboratory standard deviation – s_L	2.49
Repeatability standard deviation – s_r	0.56
Reproducibility standard deviation – s_R	2.56
Repeatability – r	1.6
Reproducibility – R	7.2

1.2.5 Evaluation of Performance Statistics

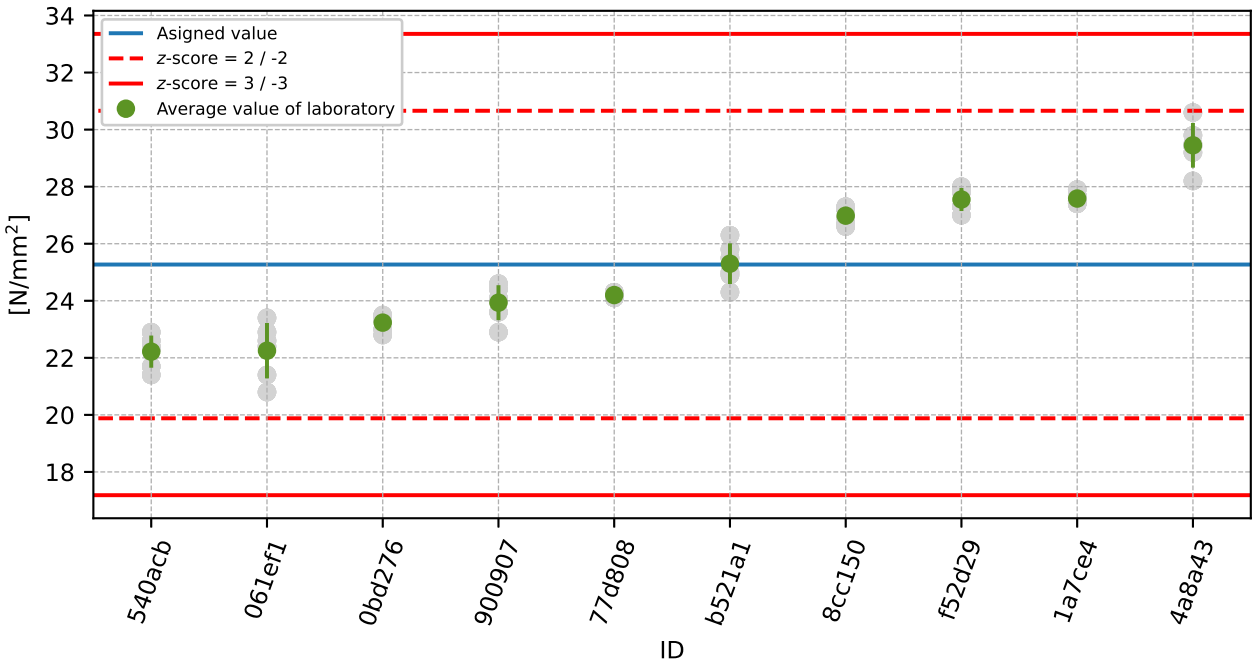

Figure 15: Average values and sample standard deviations

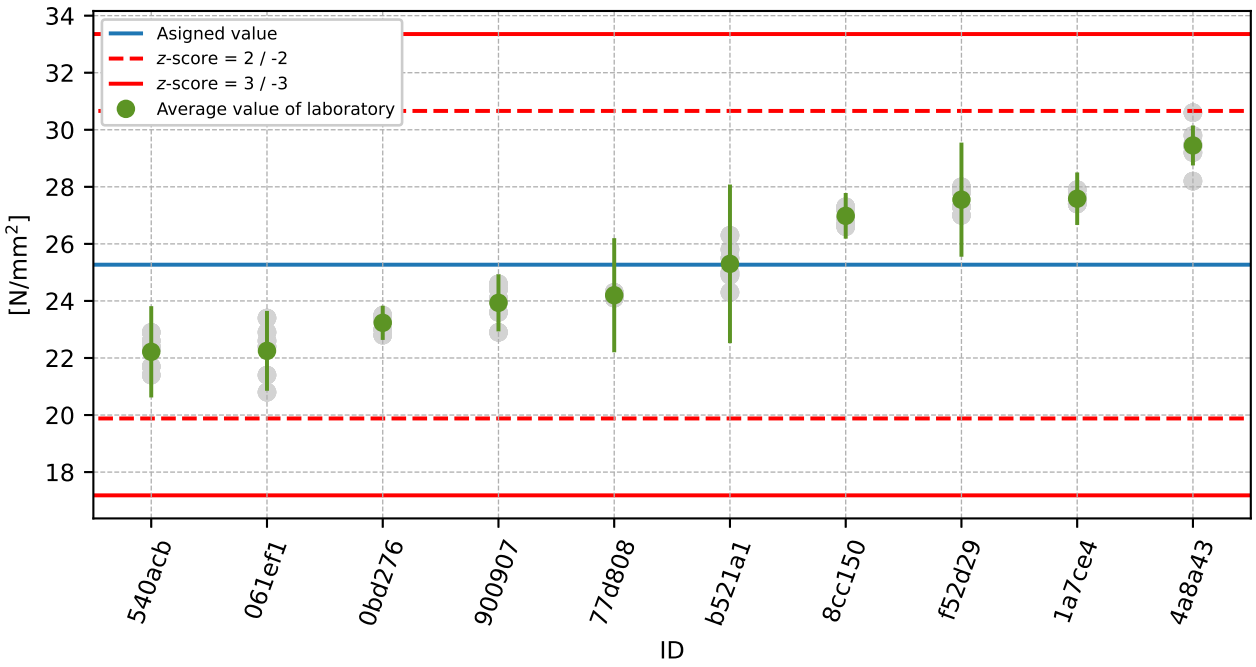

Figure 16: Average values and extended uncertainties of measurement

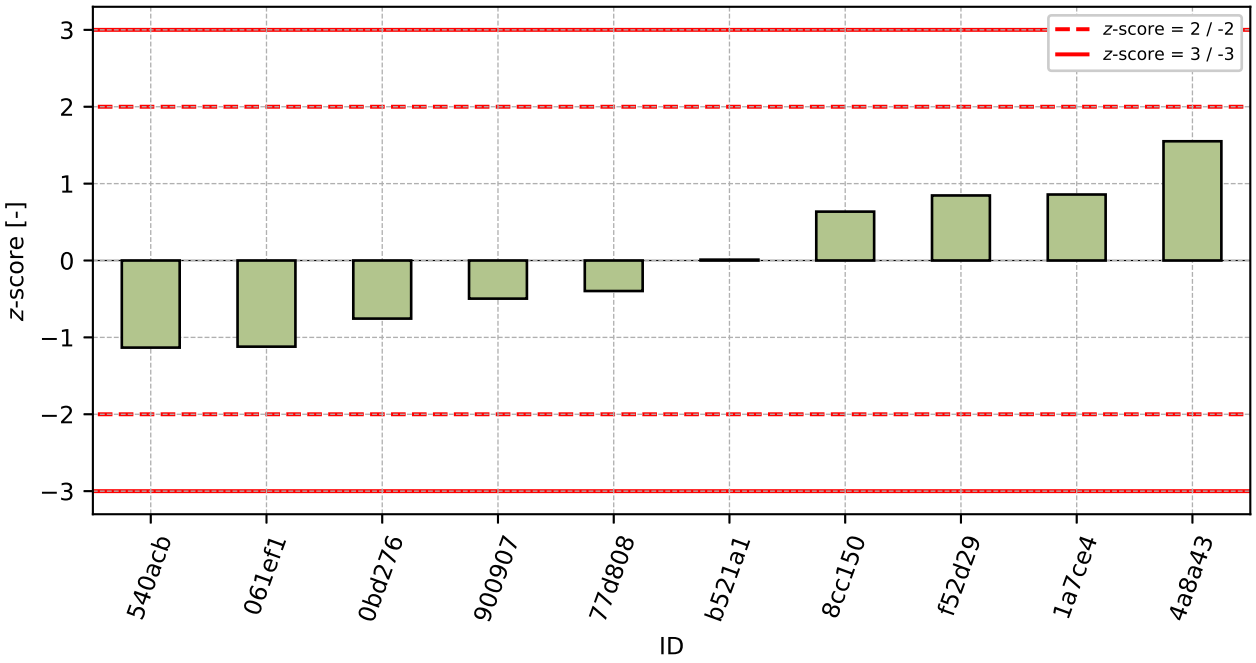

Figure 17: z-score

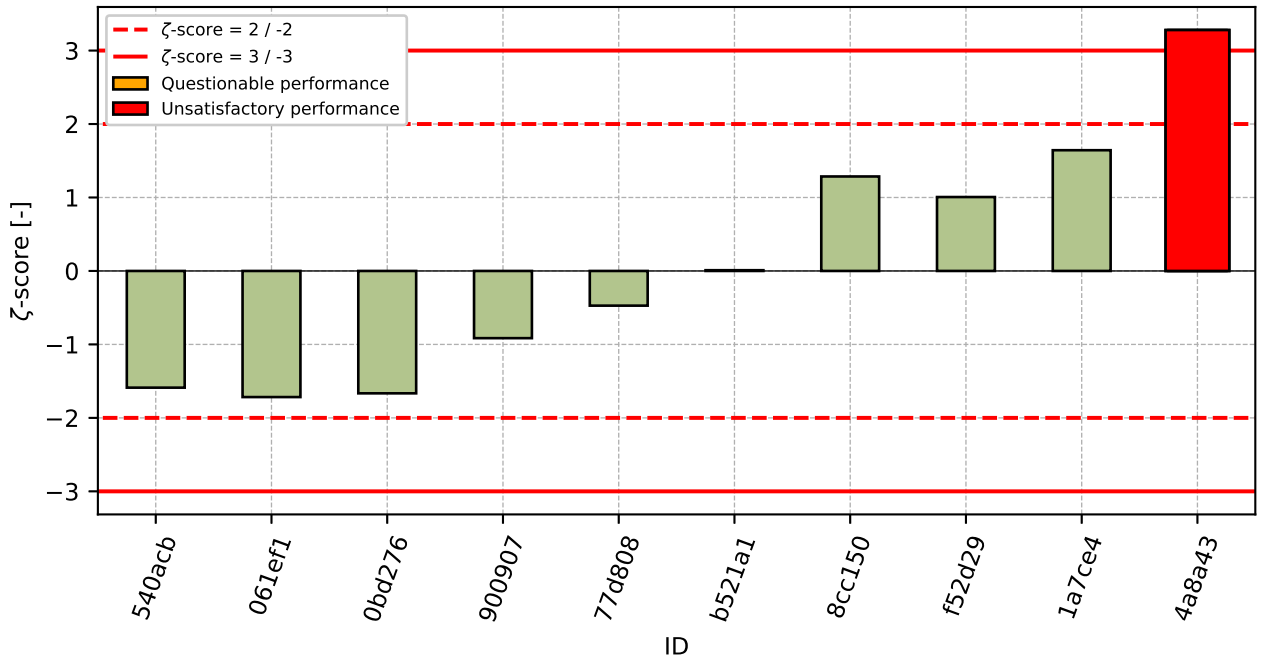

Figure 18: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
540acb	-1.13	-1.59
061ef1	-1.12	-1.72
0bd276	-0.76	-1.67
900907	-0.5	-0.91
77d808	-0.4	-0.47
b521a1	0.01	0.01
8cc150	0.64	1.29
f52d29	0.85	1.01
1a7ce4	0.86	1.64
4a8a43	1.55	3.28

1.3 Flexural Strength after 7 days of ageing

1.3.1 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 [N/mm^2]			u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
b521a1	6.0	5.9	6.9	0.5	6.3	0.59	9.35
1a7ce4	6.6	6.5	7.1	0.3	6.7	0.32	4.77
0bd276	6.9	6.8	7.0	0.4	6.9	0.1	1.45
061ef1	6.6	7.4	7.1	1.0	7.0	0.4	5.75
900907	7.3	7.3	7.1	0.5	7.2	0.12	1.7
f52d29	7.0	7.5	7.7	0.5	7.4	0.36	4.87
8cc150	7.9	7.6	7.3	0.9	7.6	0.3	3.95
77d808	7.0	8.1	8.0	1.0	7.7	0.61	7.9
4a8a43	7.8	8.0	7.9	0.1	7.9	0.1	1.27
540acb	8.3	8.4	7.7	0.4	8.1	0.38	4.65

1.3.2 The Numerical Procedure for Determining Outliers

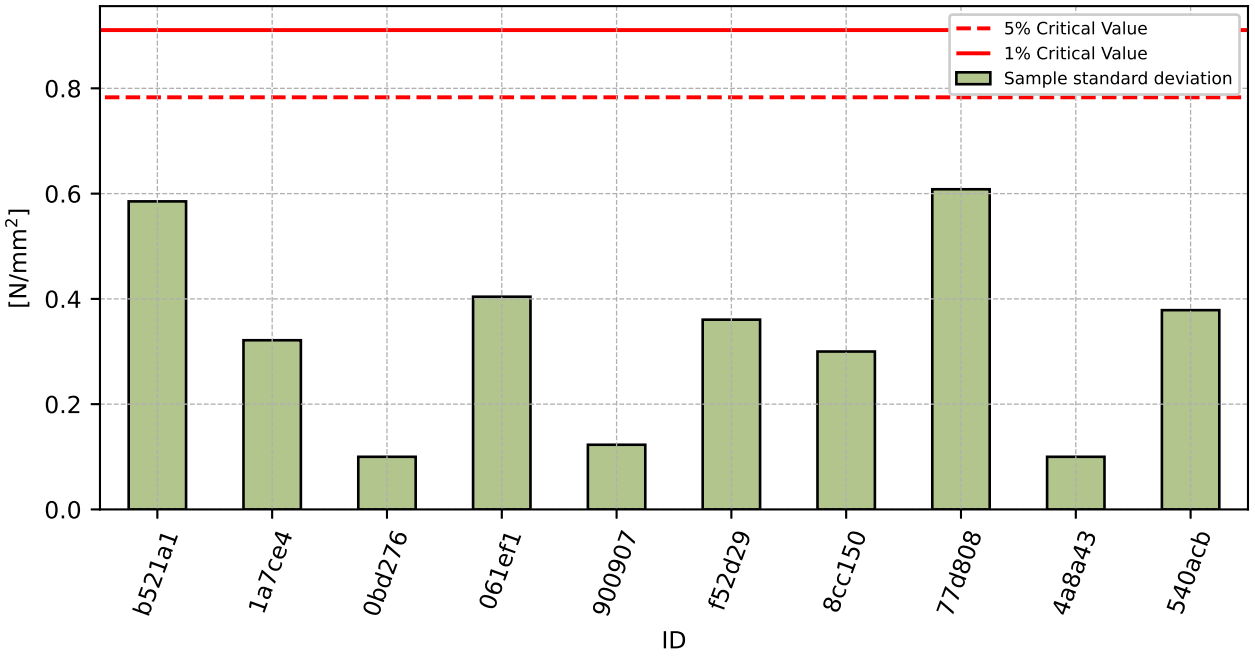

Figure 19: **Cochran's test** - sample standard deviations

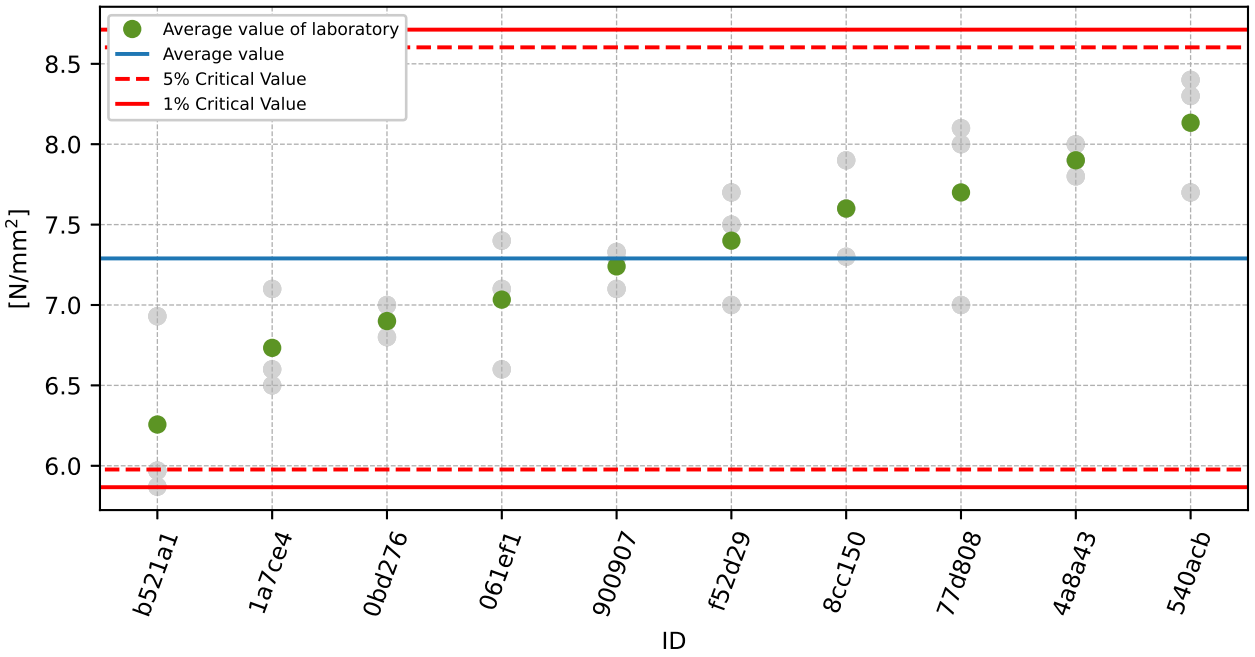

Figure 20: **Grubbs' test** - average values

1.3.3 Mandel's Statistics

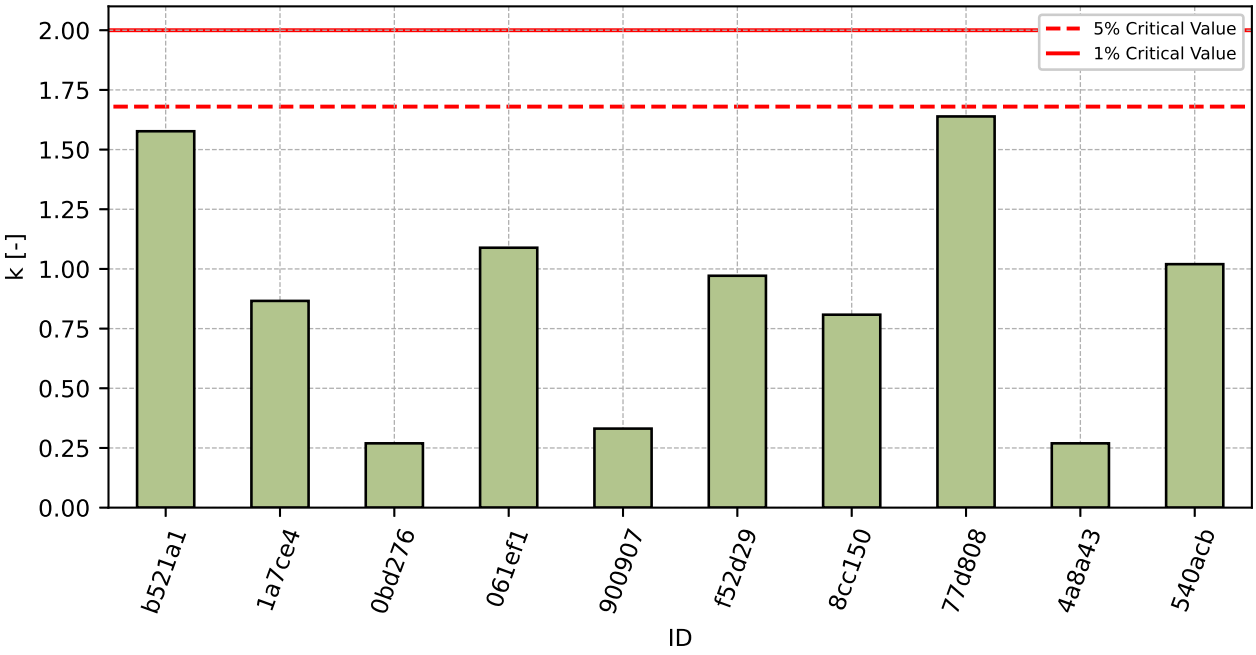

Figure 21: Intralaboratory Consistency Statistic

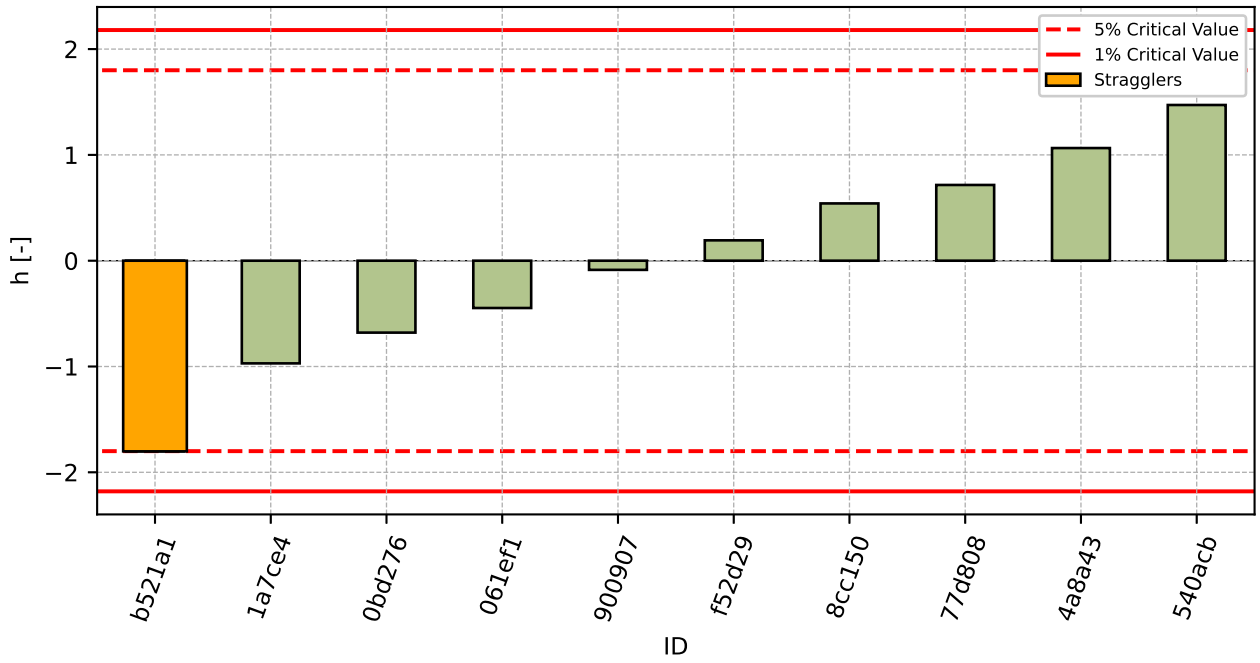

Figure 22: Interlaboratory Consistency Statistic

1.3.4 Descriptive statistics

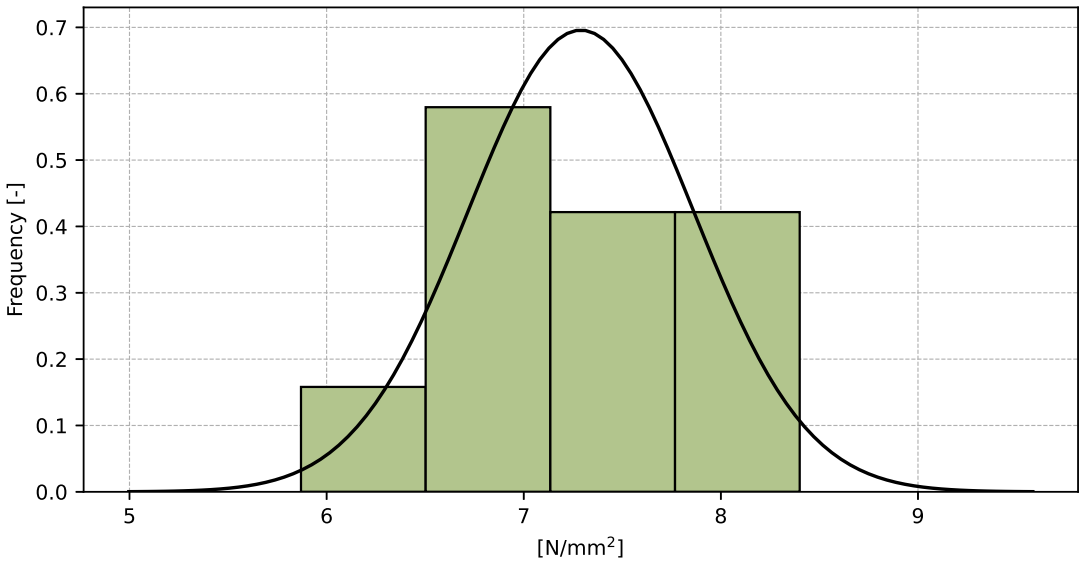

Figure 23: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	7.3
Sample standard deviation – s	0.57
Asigned value – x^*	7.3
Robust standard deviation – s^*	0.58
Measurement uncertainty of asigned value – u_X	0.23
p-value of normality test	0.686 [-]
Interlaboratory standard deviation – s_L	0.53
Repeatability standard deviation – s_r	0.37
Reproducibility standard deviation – s_R	0.65
Repeatability – r	1.0
Reproducibility – R	1.8

1.3.5 Evaluation of Performance Statistics

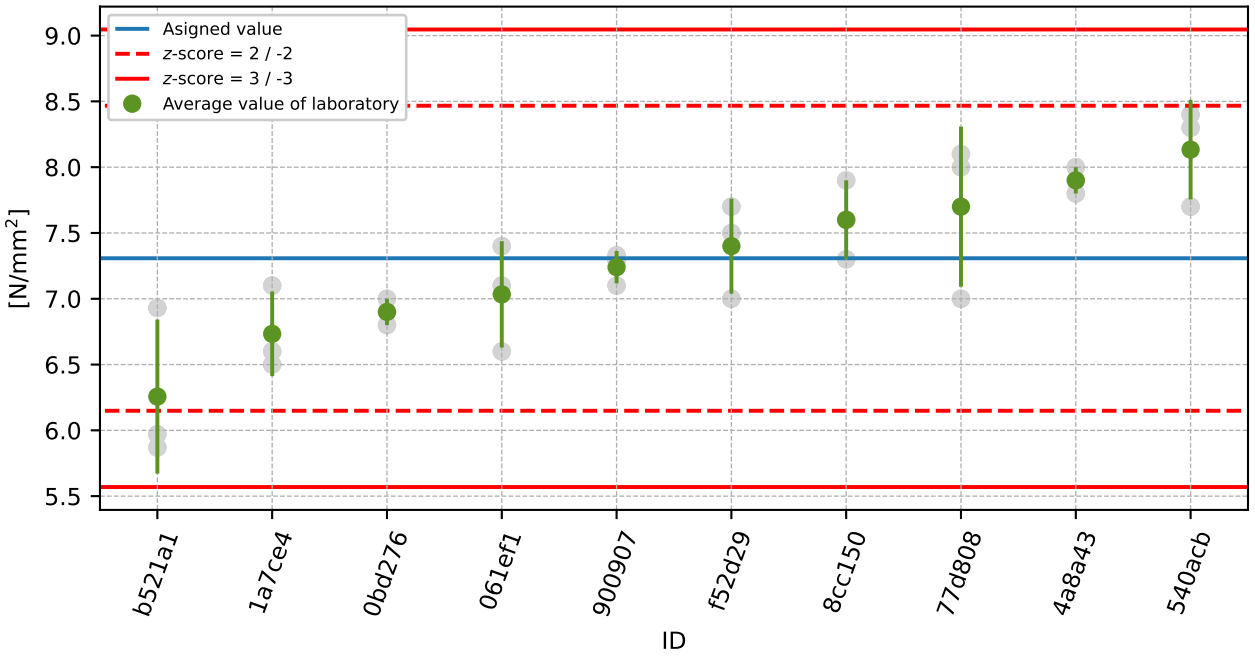

Figure 24: Average values and sample standard deviations

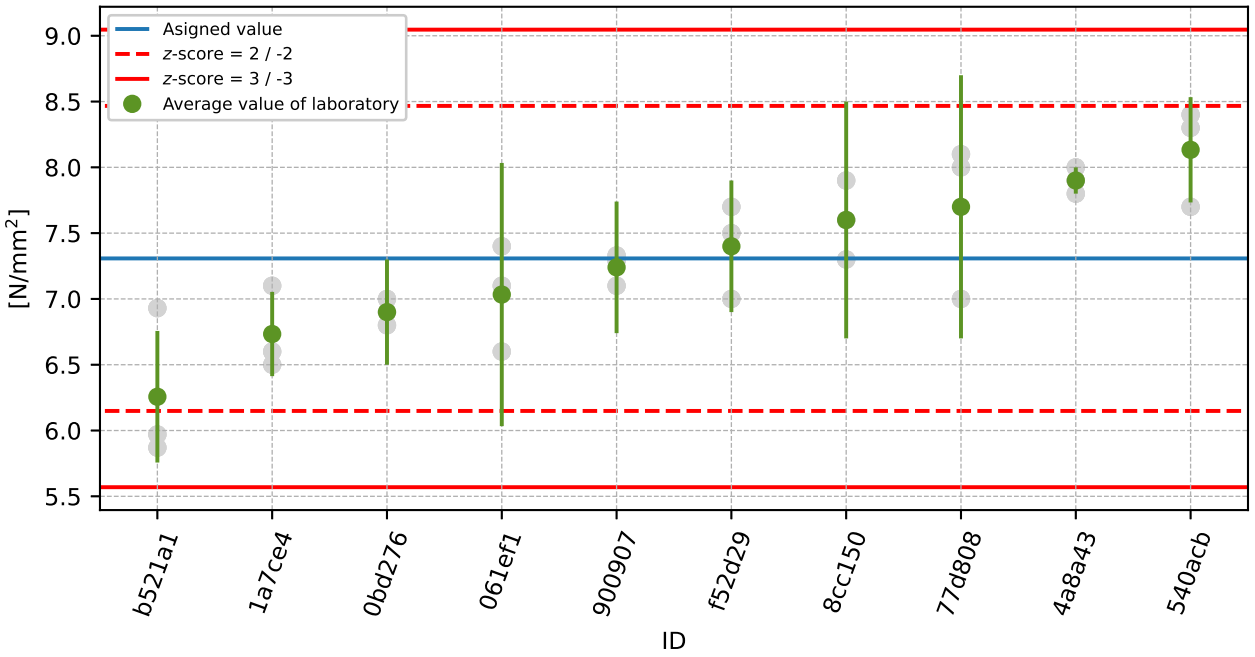

Figure 25: Average values and extended uncertainties of measurement

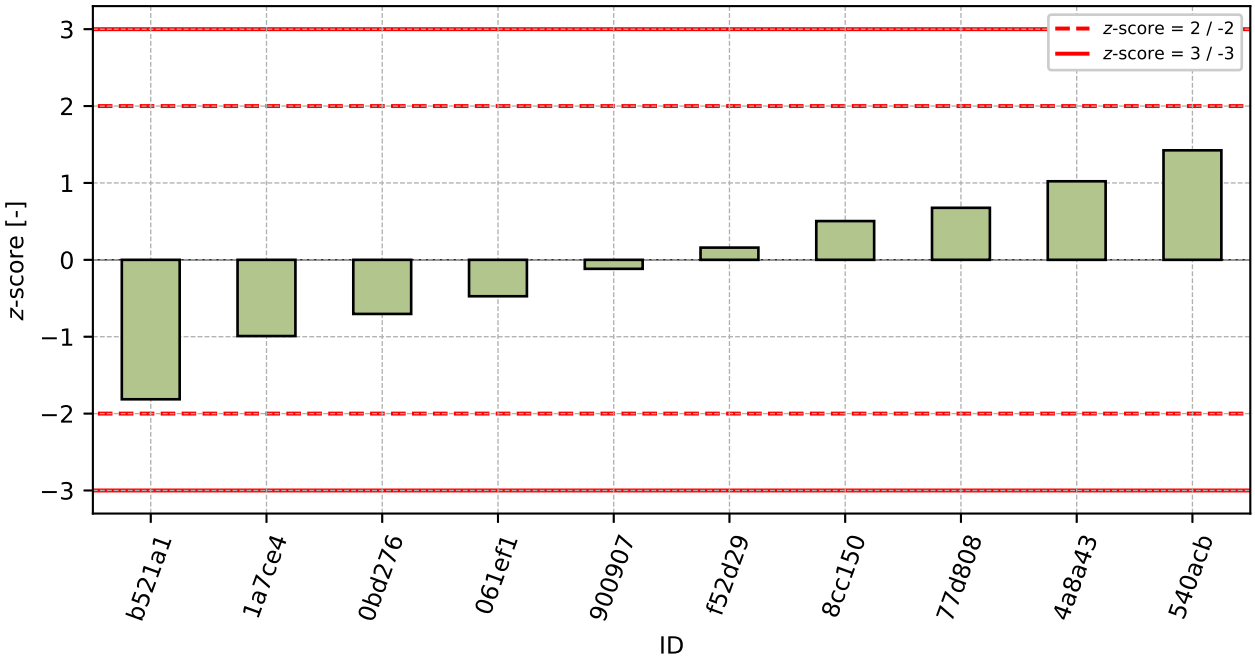

Figure 26: z-score

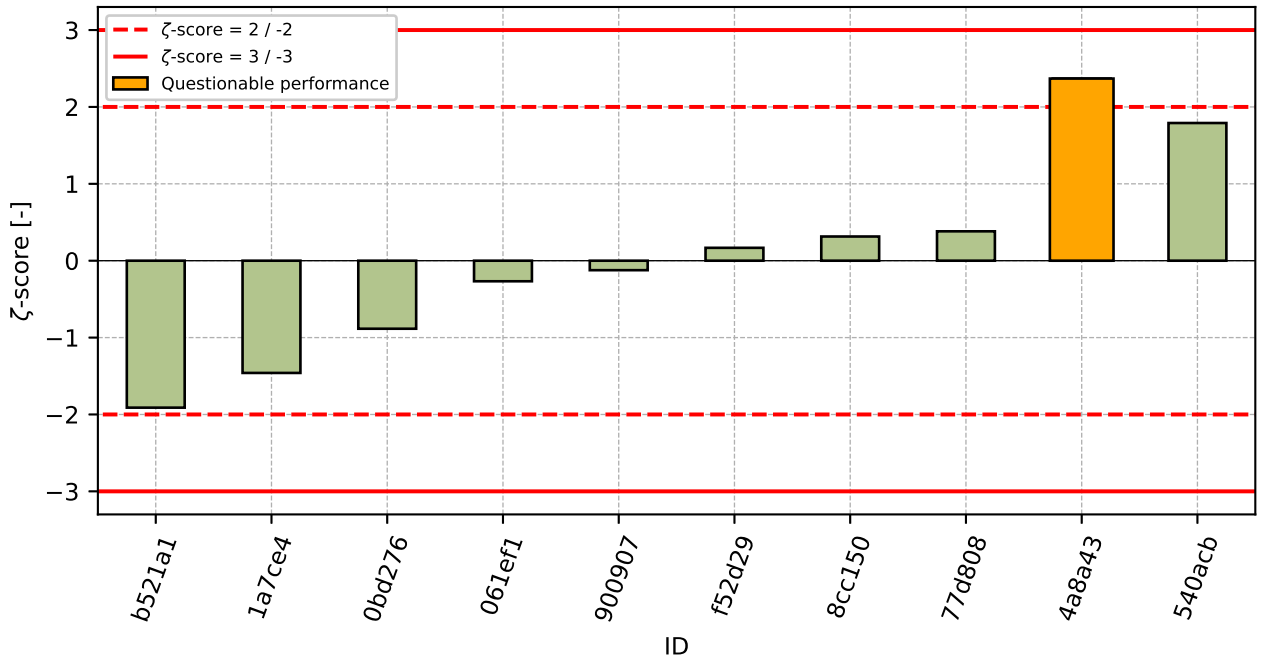

Figure 27: ζ-score

Table 12: *z*-score and ζ-score

ID	*z*-score [-]	ζ-score [-]
b521a1	-1.81	-1.91
1a7ce4	-0.99	-1.46
0bd276	-0.7	-0.88
061ef1	-0.47	-0.27
900907	-0.12	-0.12
f52d29	0.16	0.17
8cc150	0.5	0.31
77d808	0.68	0.38
4a8a43	1.02	2.37
540acb	1.42	1.79

1.4 Compressive Strength after 7 days of ageing

1.4.1 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 [N/mm²]						u_X [N/mm²]	$\bar{x}$ [N/mm²]	s_0 [N/mm²]	V_X [%]
b521a1	34.1	36.8	37.4	36.4	37.6	37.4	4.0	36.6	1.31	3.58
540acb	39.4	38.9	38.8	39.8	38.5	38.5	2.8	39.0	0.52	1.33
900907	40.6	39.3	40.4	40.4	40.1	41.5	1.1	40.4	0.71	1.77
1a7ce4	41.4	40.1	42.9	43.4	42.4	42.4	1.4	42.1	1.18	2.81
0bd276	42.0	42.2	42.1	41.9	42.2	42.9	0.9	42.2	0.35	0.84
061ef1	42.6	43.1	43.7	44.5	41.8	43.5	1.6	43.2	0.93	2.16
77d808	44.5	44.3	43.6	43.3	45.4	43.9	3.0	44.2	0.75	1.69
f52d29	45.0	44.3	45.8	47.2	46.2	49.6	2.0	46.4	1.88	4.05
8cc150	48.8	48.0	46.5	47.2	48.4	48.4	1.2	47.9	0.87	1.81
4a8a43	48.0	48.5	47.9	48.4	49.1	49.4	0.5	48.6	0.6	1.23

1.4.2 The Numerical Procedure for Determining Outliers

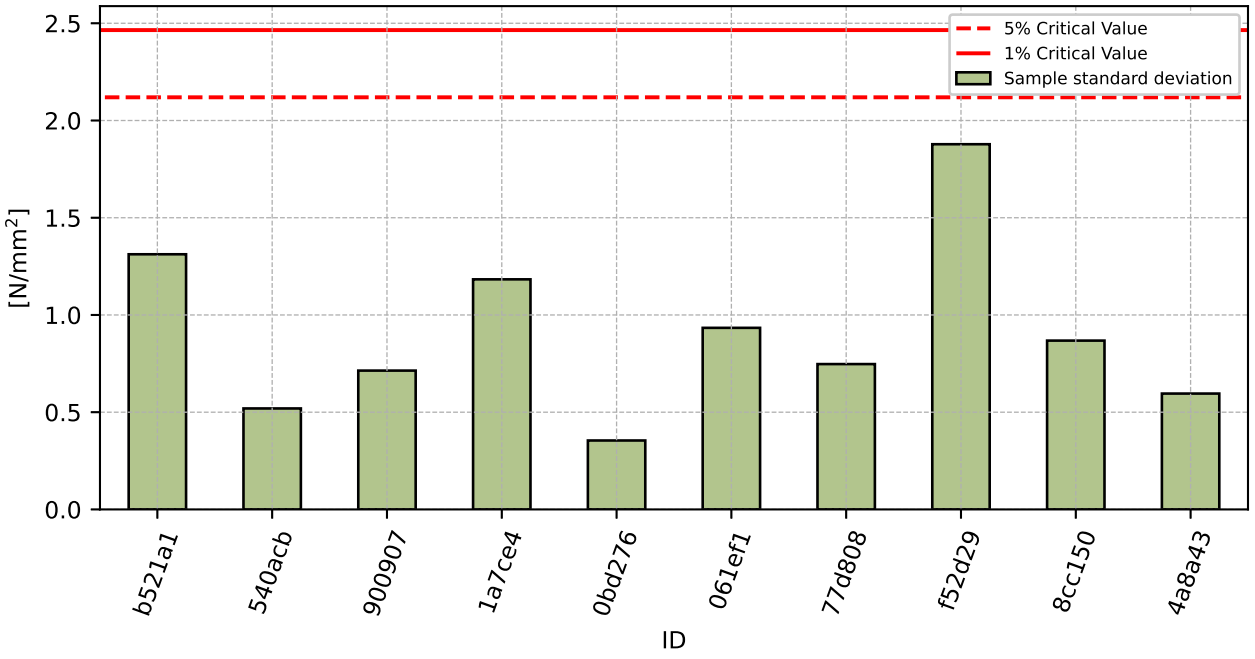

Figure 28: **Cochran's test** - sample standard deviations

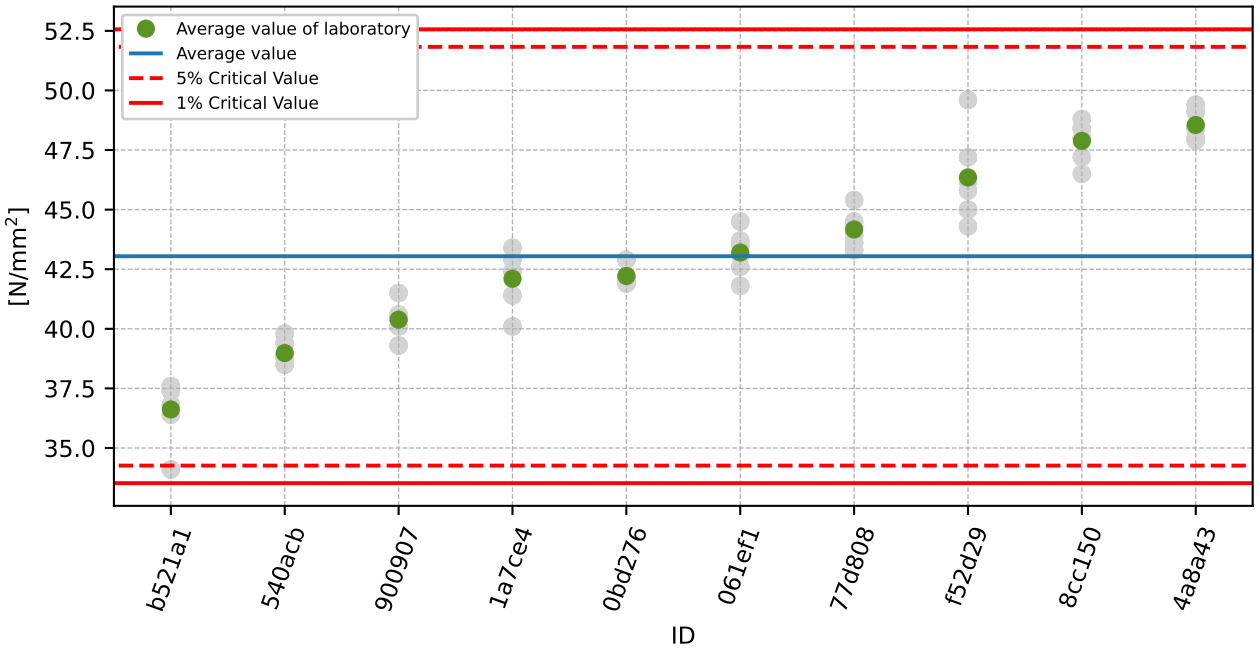

Figure 29: **Grubbs' test** - average values

1.4.3 Mandel's Statistics

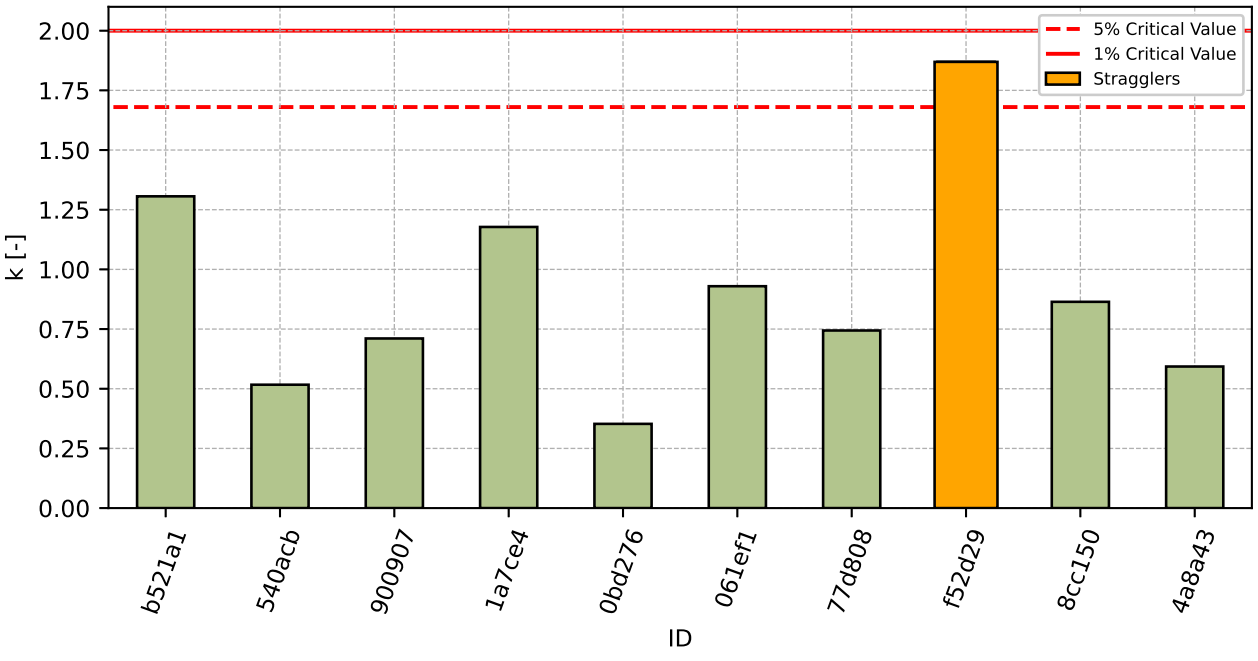

Figure 30: Intralaboratory Consistency Statistic

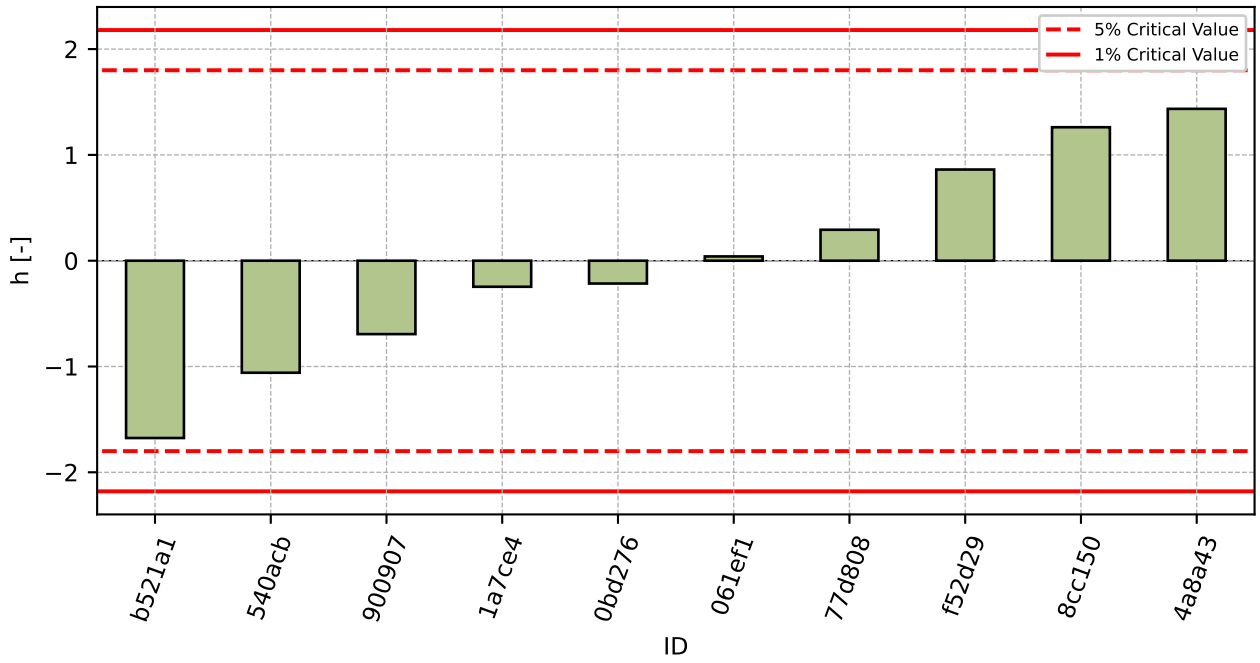

Figure 31: Interlaboratory Consistency Statistic

1.4.4 Descriptive statistics

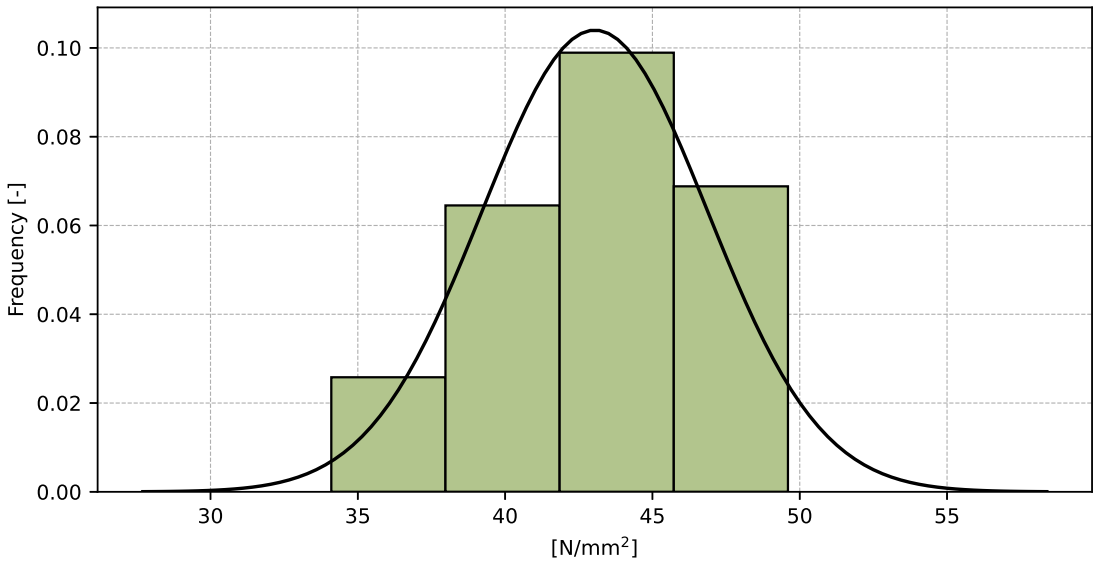

Figure 32: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	43.0
Sample standard deviation – s	3.84
Asigned value – x^*	43.1
Robust standard deviation – s^*	4.05
Measurement uncertainty of asigned value – u_X	1.6
p-value of normality test	0.218 [-]
Interlaboratory standard deviation – s_L	3.81
Repeatability standard deviation – s_r	1.0
Reproducibility standard deviation – s_R	3.94
Repeatability – r	2.8
Reproducibility – R	11.0

1.4.5 Evaluation of Performance Statistics

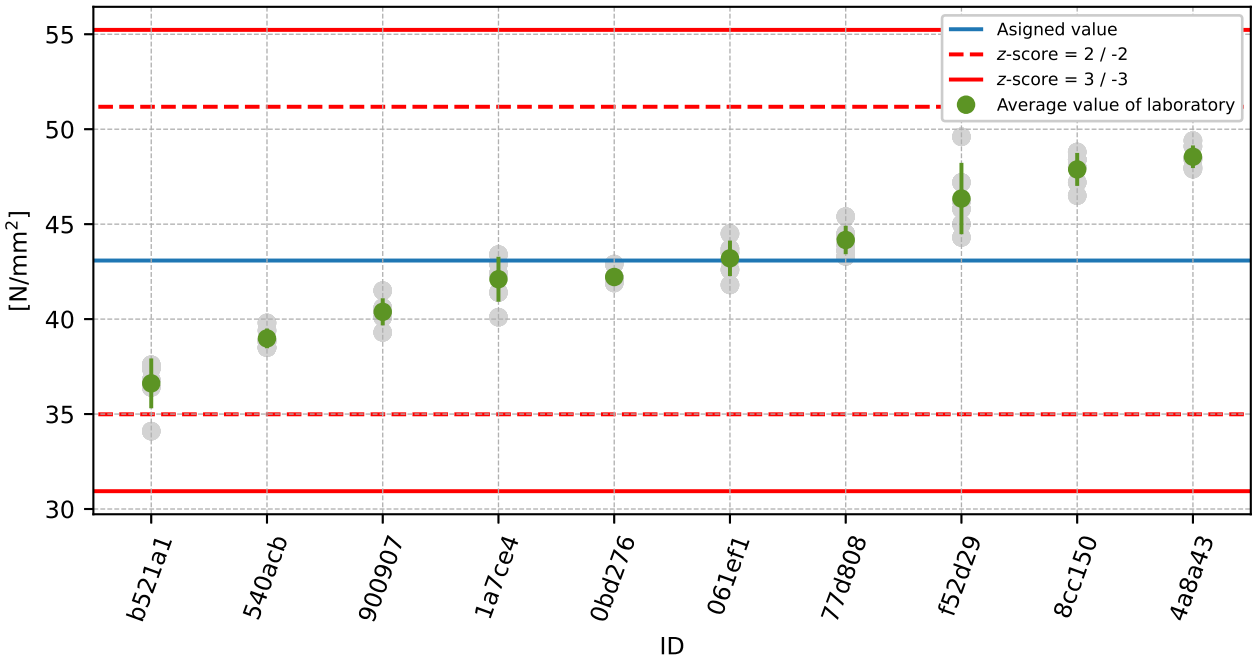

Figure 33: Average values and sample standard deviations

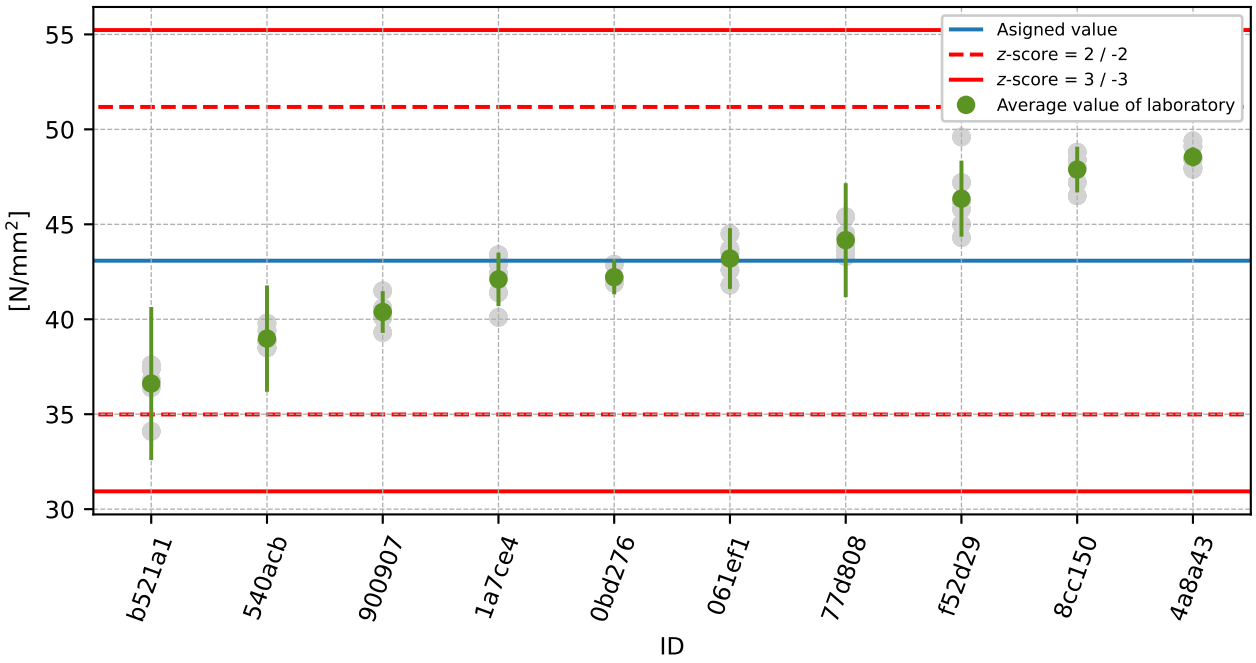

Figure 34: Average values and extended uncertainties of measurement

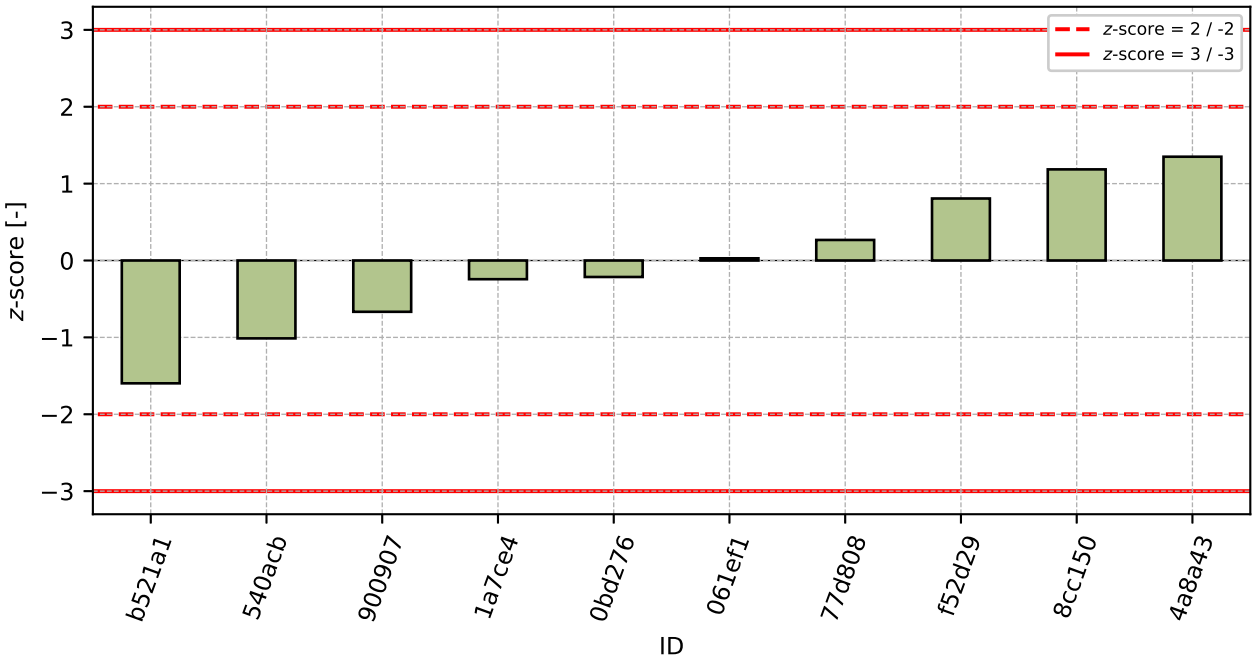

Figure 35: z-score

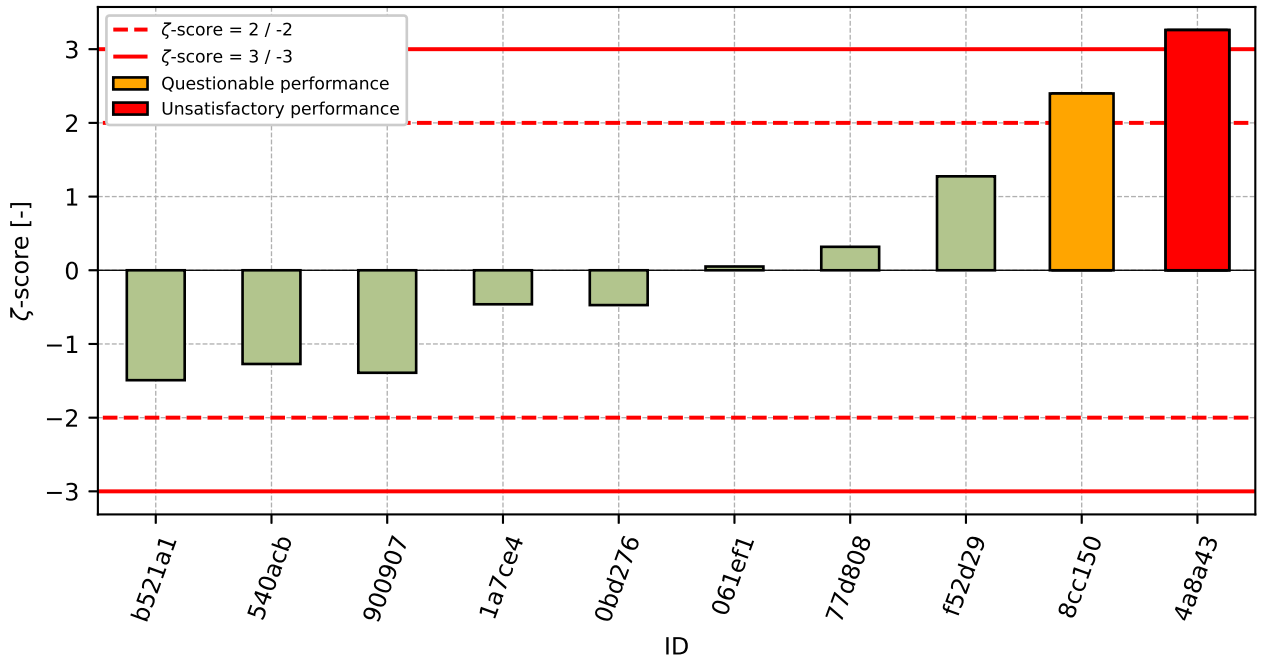

Figure 36: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
b521a1	-1.6	-1.49
540acb	-1.01	-1.27
900907	-0.67	-1.39
1a7ce4	-0.24	-0.46
0bd276	-0.21	-0.47
061ef1	0.03	0.05
77d808	0.27	0.32
f52d29	0.81	1.27
8cc150	1.19	2.4
4a8a43	1.35	3.26

1.5 Flexural Strength after 28 days of ageing

1.5.1 Test results

Table 16: 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/mm²]			u_X [N/mm²]	$\bar{x}$ [N/mm²]	s_0 [N/mm²]	V_X [%]
0bd276	7.4	7.7	7.7	0.6	7.6	0.17	2.28
1a7ce4	7.9	7.7	7.6	0.4	7.7	0.15	1.98
900907	7.6	7.7	8.0	0.5	7.8	0.24	3.05
b521a1	8.0	7.8	8.0	0.6	7.9	0.11	1.35
061ef1	8.5	8.3	8.1	0.7	8.3	0.2	2.41
f52d29	8.4	9.1	8.8	0.5	8.8	0.35	4.01
77d808	9.5	9.4	8.4	1.2	9.1	0.61	6.68
540acb	8.6	9.6	9.2	0.5	9.1	0.5	5.51
4a8a43	9.3	8.9	9.2	0.2	9.1	0.21	2.28
8cc150	9.3	8.7	10.2	2.2	9.4	0.75	8.03

1.5.2 The Numerical Procedure for Determining Outliers

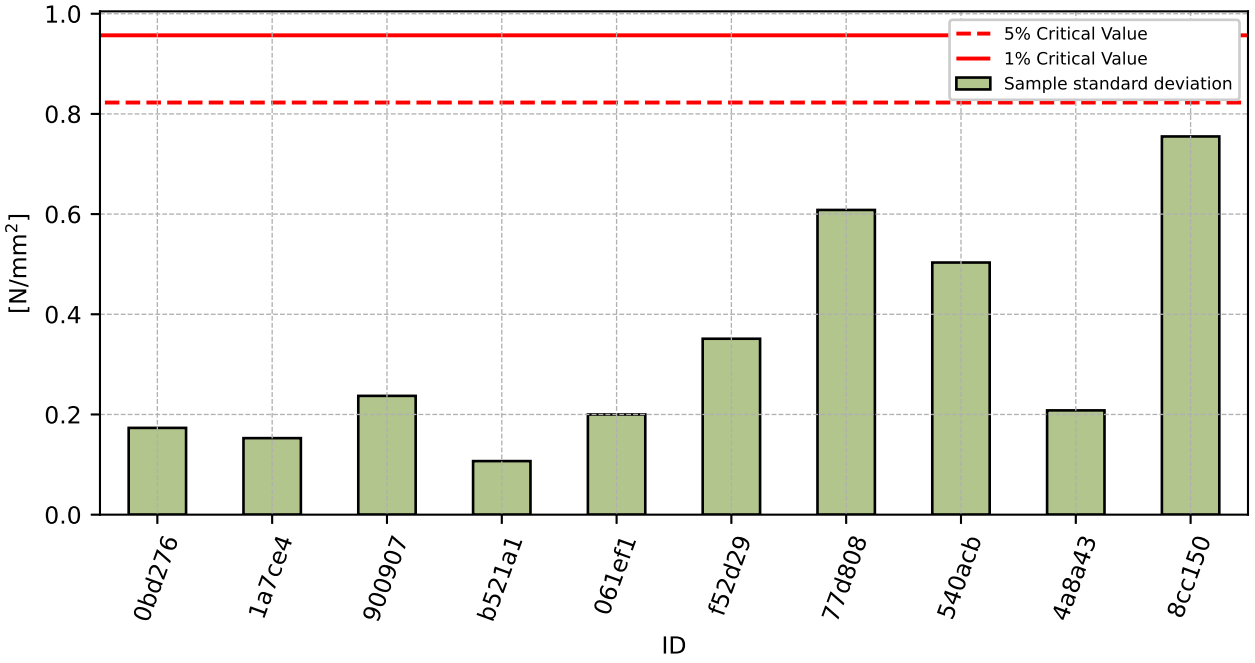

Figure 37: **Cochran's test** - sample standard deviations

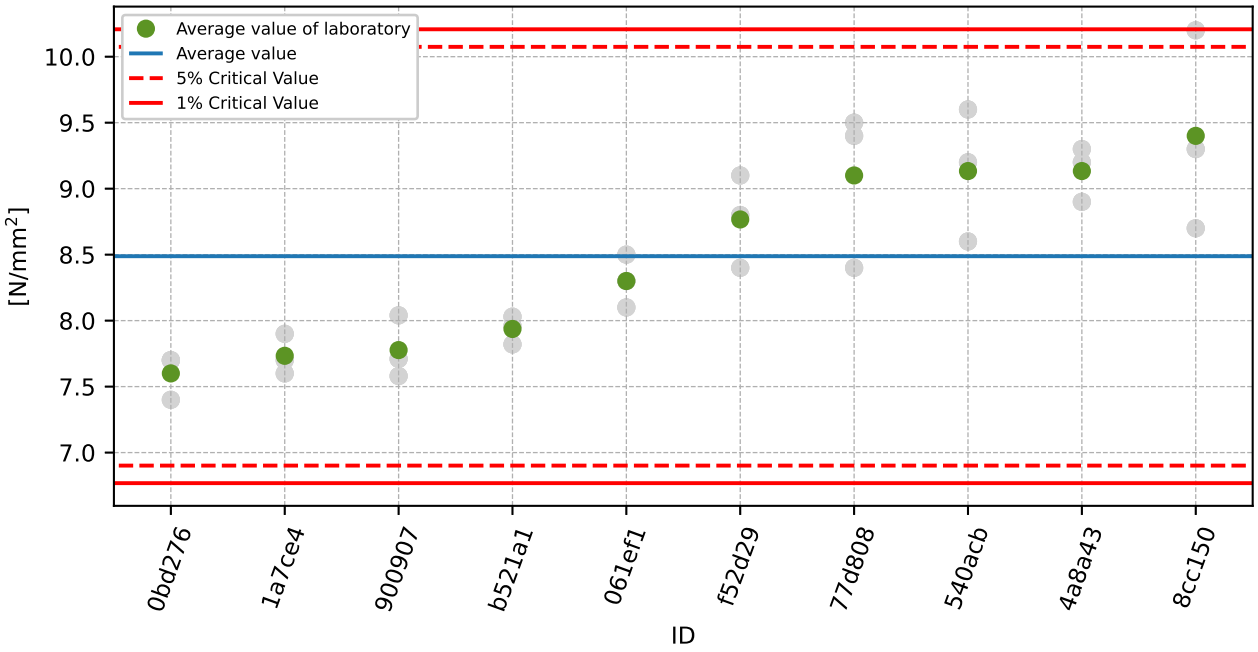

Figure 38: **Grubbs' test** - average values

1.5.3 Mandel's Statistics

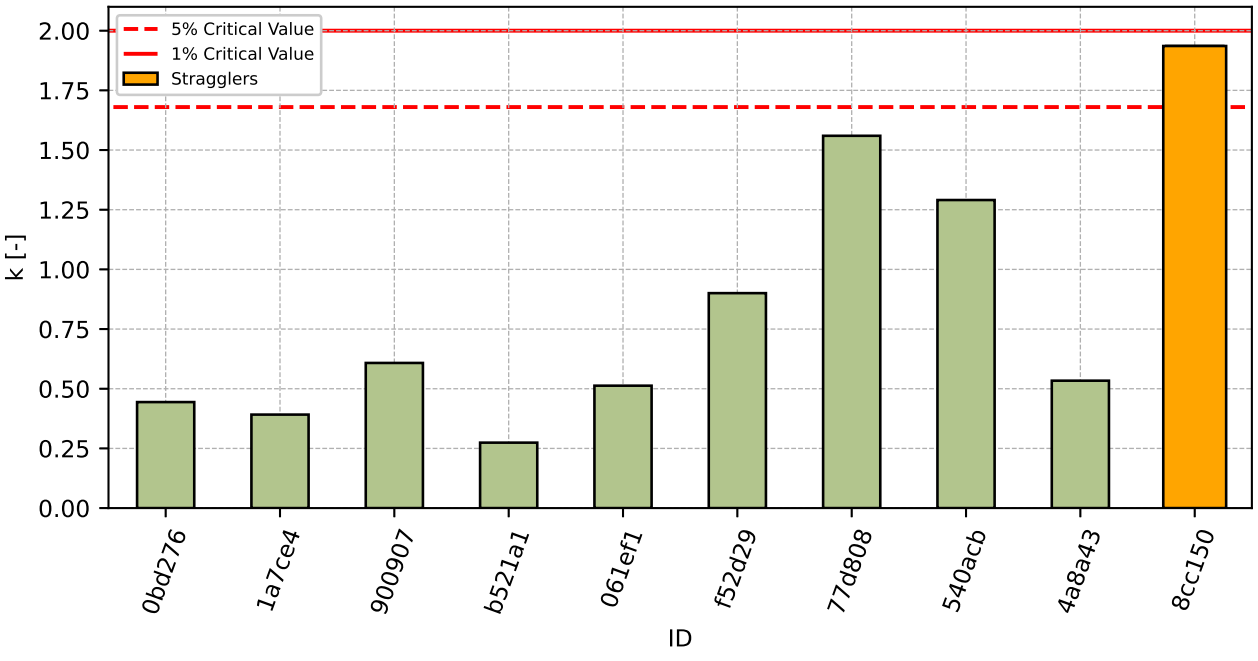

Figure 39: Intralaboratory Consistency Statistic

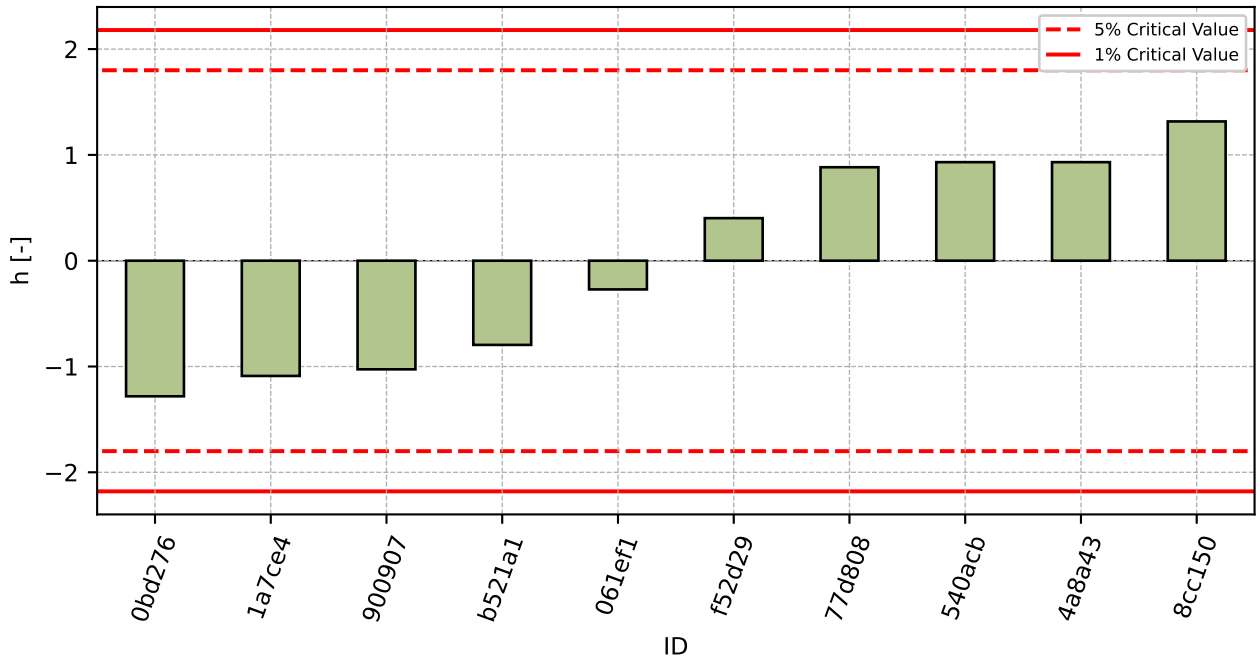

Figure 40: Interlaboratory Consistency Statistic

1.5.4 Descriptive statistics

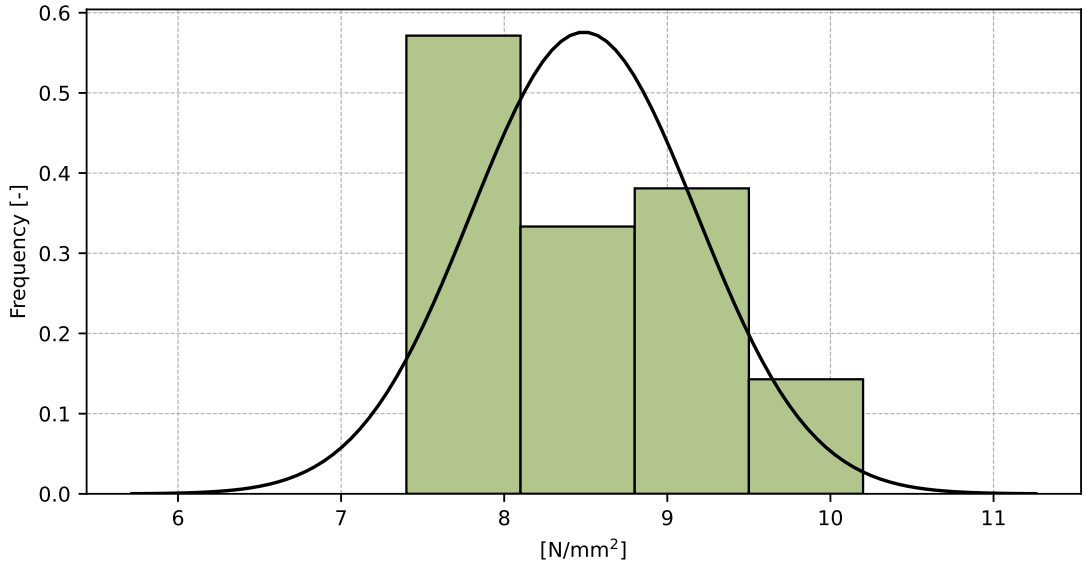

Figure 41: Histogram of all test results

Table 17: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	8.5
Sample standard deviation – s	0.69
Asigned value – x^*	8.5
Robust standard deviation – s^*	0.75
Measurement uncertainty of asigned value – u_X	0.29
p-value of normality test	0.113 [-]
Interlaboratory standard deviation – s_L	0.66
Repeatability standard deviation – s_r	0.39
Reproducibility standard deviation – s_R	0.76
Repeatability – r	1.1
Reproducibility – R	2.1

1.5.5 Evaluation of Performance Statistics

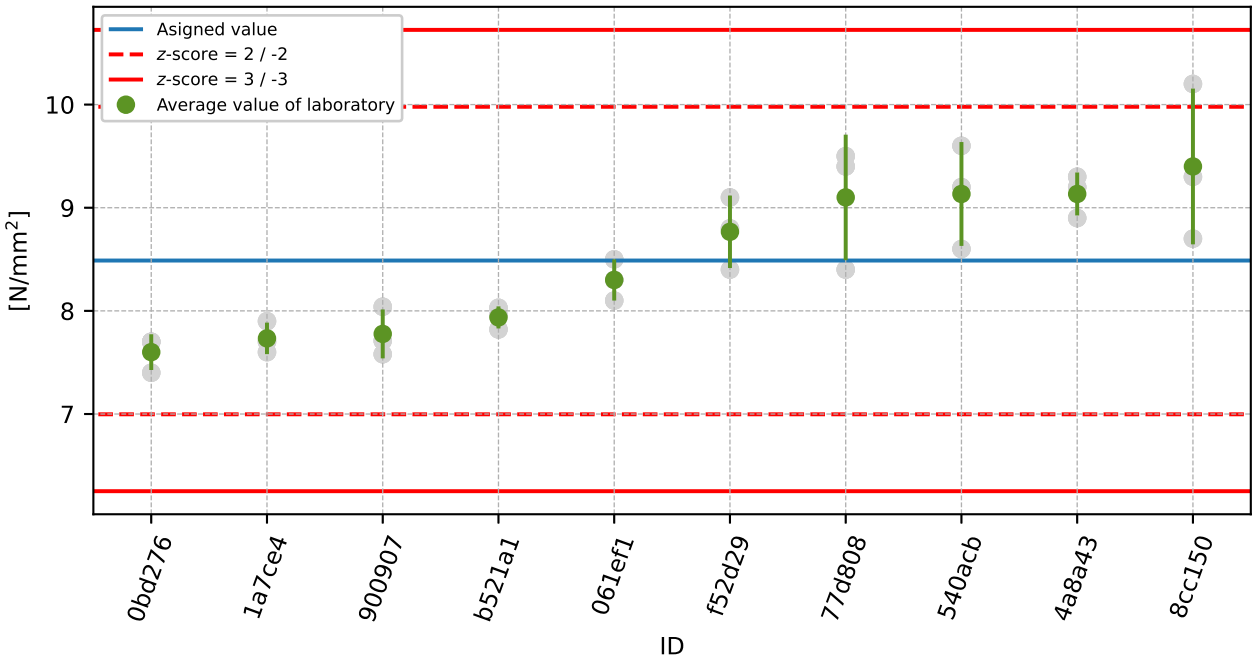

Figure 42: Average values and sample standard deviations

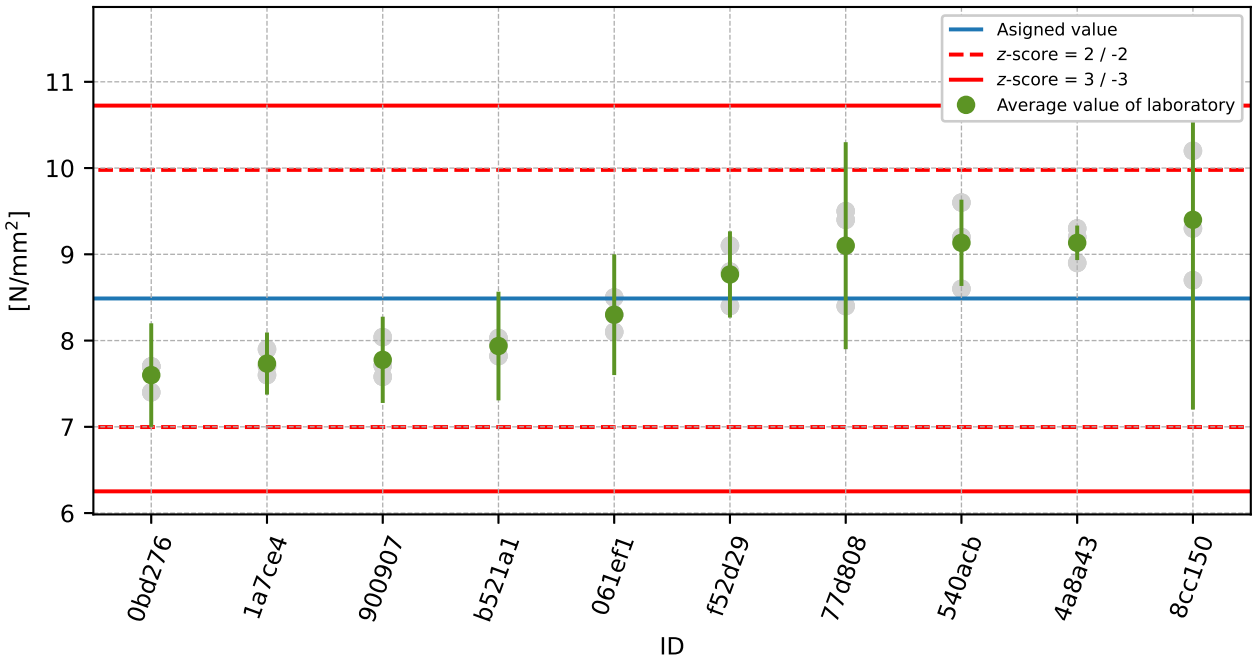

Figure 43: Average values and extended uncertainties of measurement

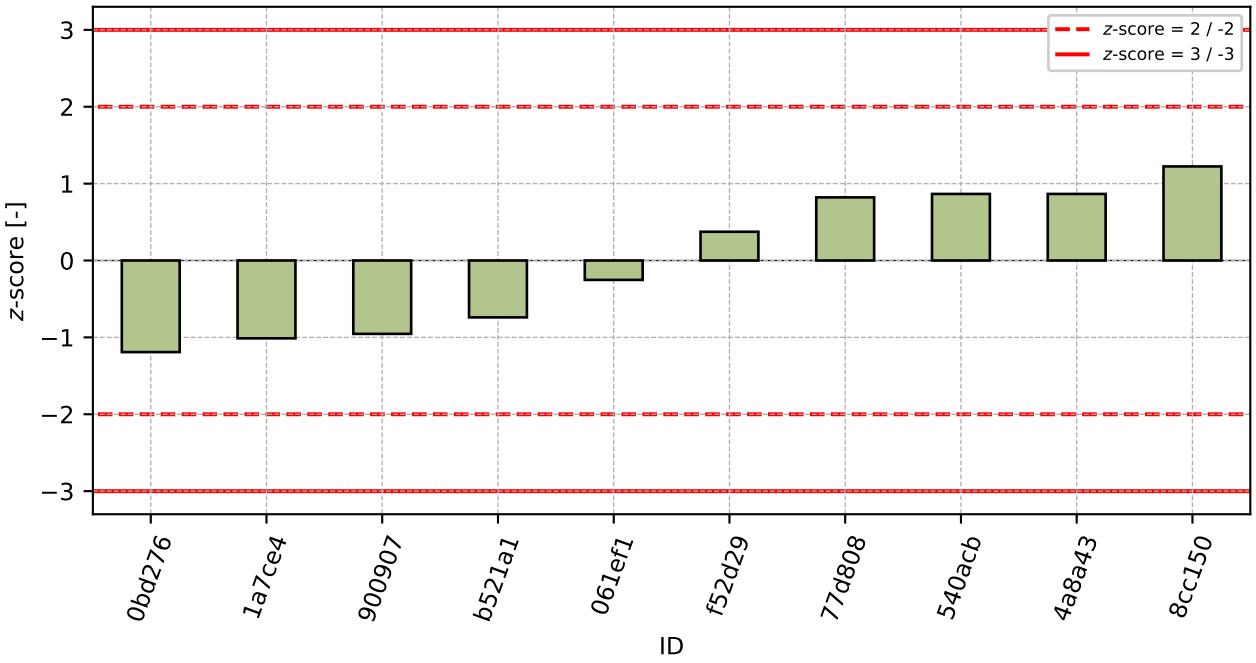

Figure 44: z-score

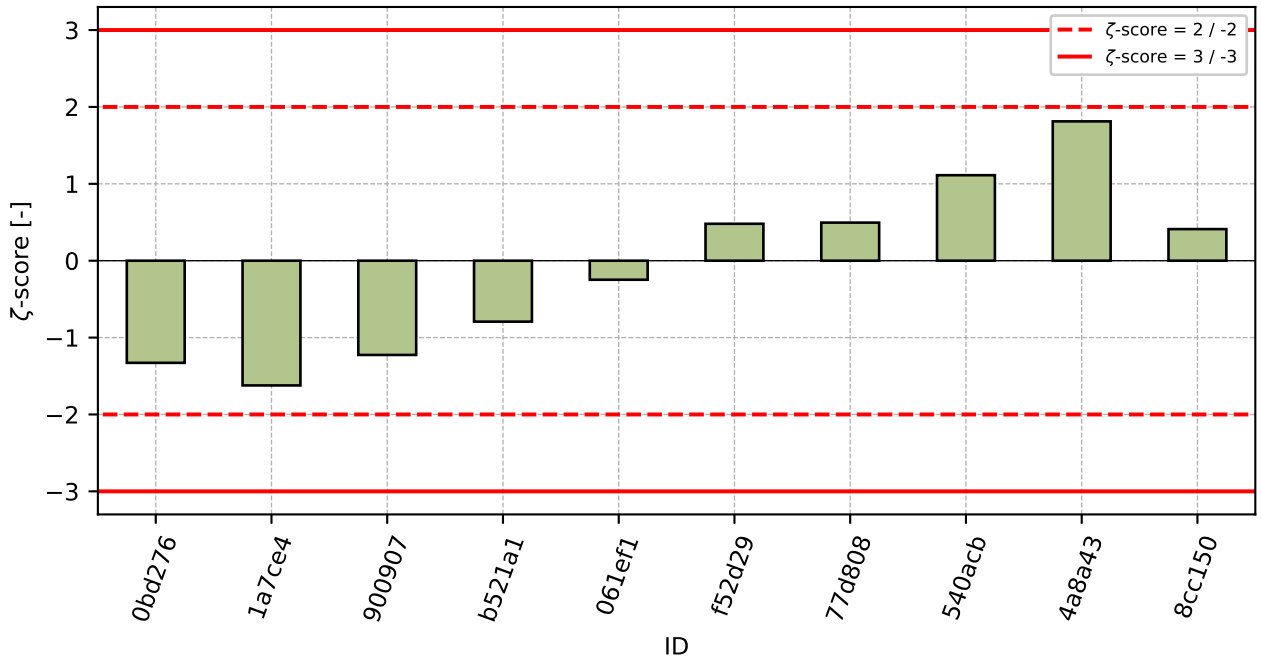

Figure 45: ζ-score

Table 18: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
0bd276	-1.19	-1.33
1a7ce4	-1.01	-1.62
900907	-0.95	-1.23
b521a1	-0.74	-0.79
061ef1	-0.25	-0.25
f52d29	0.37	0.48
77d808	0.82	0.5
540acb	0.87	1.11
4a8a43	0.87	1.81
8cc150	1.22	0.41

1.6 Compressive Strength after 28 days of ageing

1.6.1 Test results

Table 19: 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 [%]
900907	49.8	49.5	48.3	49.7	49.8	49.5	1.1	49.4	0.57	1.16
540acb	49.4	50.2	51.3	53.2	52.4	51.1	3.7	51.3	1.39	2.71
0bd276	52.0	53.1	52.5	52.2	51.9	52.5	1.1	52.4	0.44	0.83
1a7ce4	52.6	52.8	53.1	52.8	52.8	52.2	1.8	52.7	0.3	0.57
4a8a43	53.9	53.7	54.9	53.7	54.4	53.0	0.6	53.9	0.65	1.21
b521a1	53.7	53.3	54.9	55.7	53.2	54.7	6.0	54.2	1.0	1.85
061ef1	53.4	52.3	54.1	57.5	55.8	56.9	2.5	55.0	2.06	3.74
77d808	55.7	55.0	55.4	53.9	56.4	56.7	3.4	55.5	1.01	1.82
8cc150	59.9	60.4	59.6	59.4	59.8	58.8	1.4	59.6	0.54	0.9
f52d29	63.3	59.4	60.8	61.0	63.0	58.0	3.0	60.9	2.04	3.35

1.6.2 The Numerical Procedure for Determining Outliers

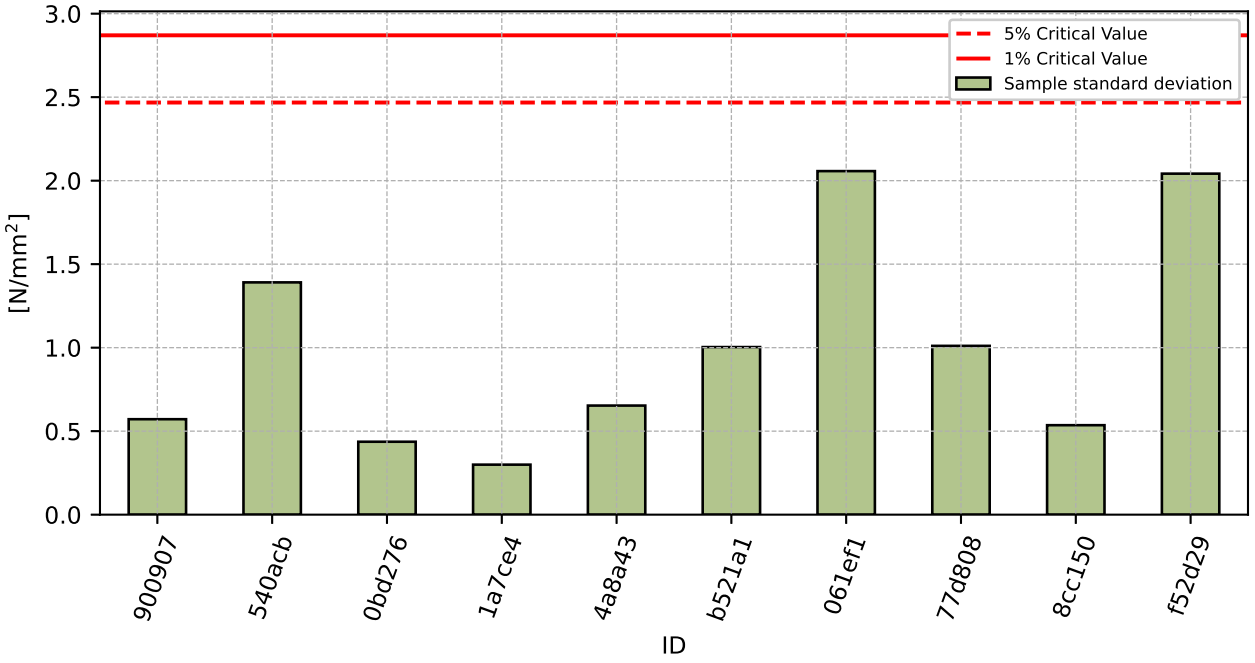

Figure 46: **Cochran's test** - sample standard deviations

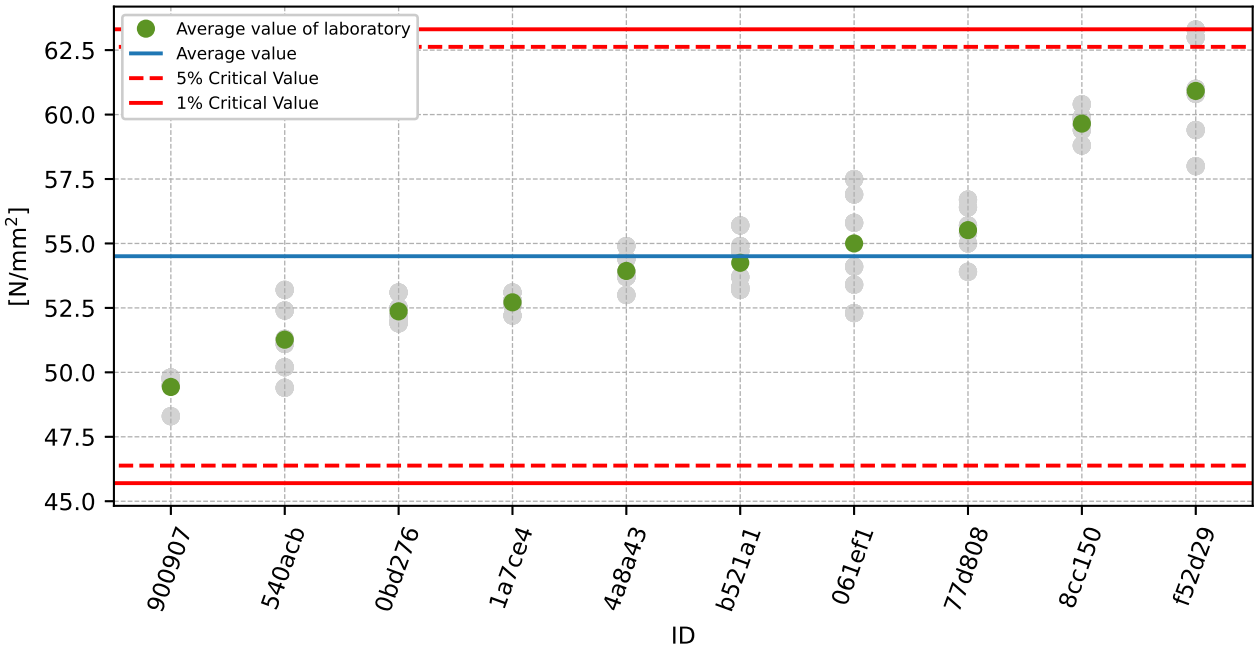

Figure 47: **Grubbs' test** - average values

1.6.3 Mandel's Statistics

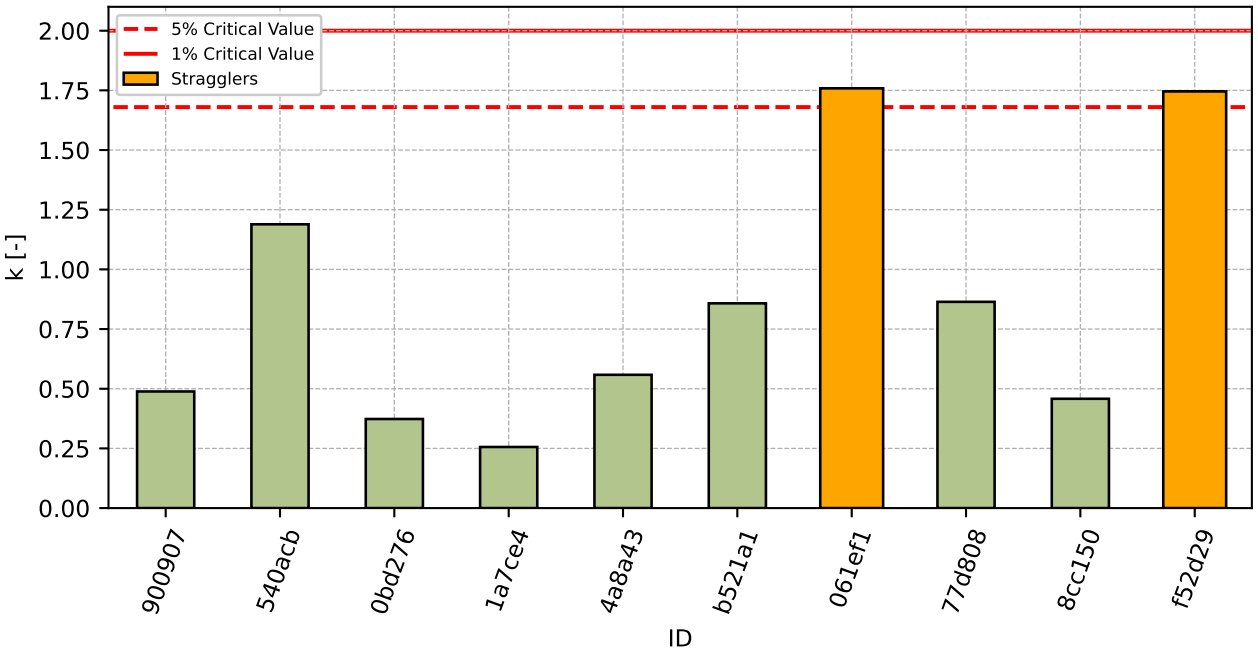

Figure 48: Intralaboratory Consistency Statistic

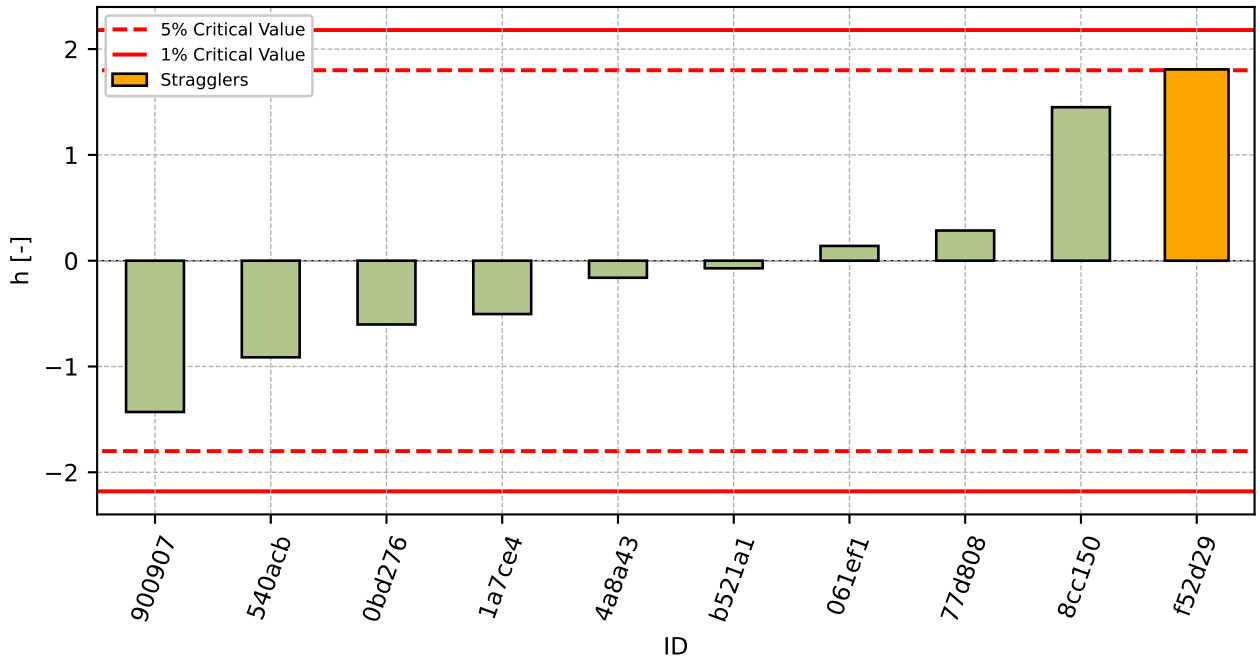

Figure 49: Interlaboratory Consistency Statistic

1.6.4 Descriptive statistics

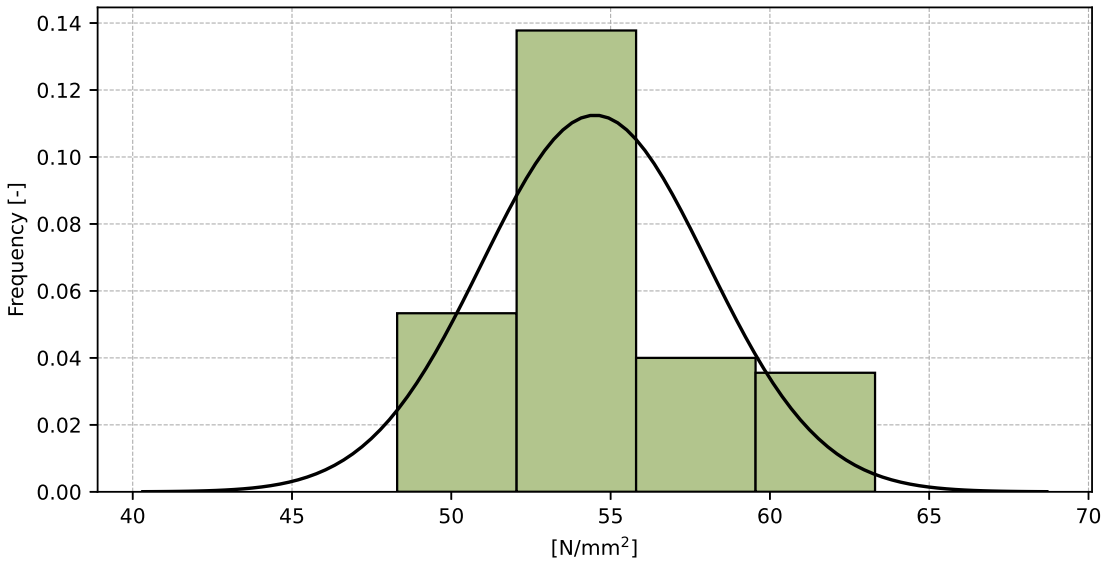

Figure 50: Histogram of all test results

Table 20: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	54.5
Sample standard deviation – s	3.55
Asigned value – x^*	54.4
Robust standard deviation – s^*	3.32
Measurement uncertainty of asigned value – u_X	1.31
p-value of normality test	0.011 [-]
Interlaboratory standard deviation – s_L	3.51
Repeatability standard deviation – s_r	1.17
Reproducibility standard deviation – s_R	3.7
Repeatability – r	3.3
Reproducibility – R	10.4

1.6.5 Evaluation of Performance Statistics

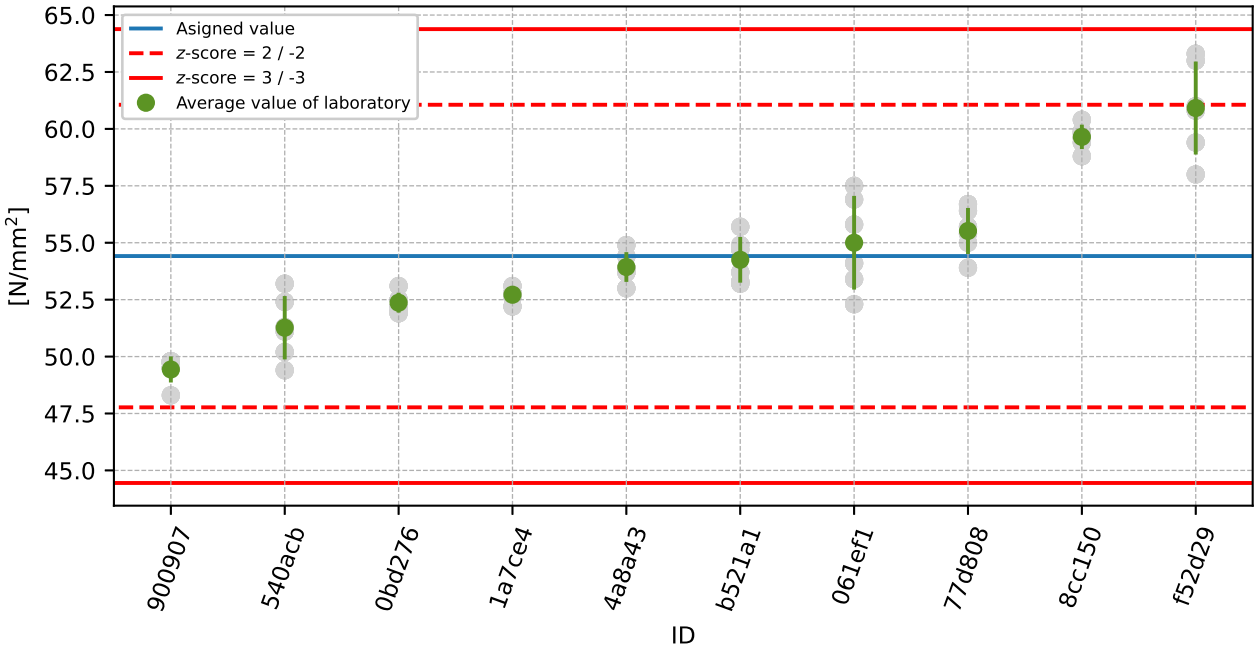

Figure 51: Average values and sample standard deviations

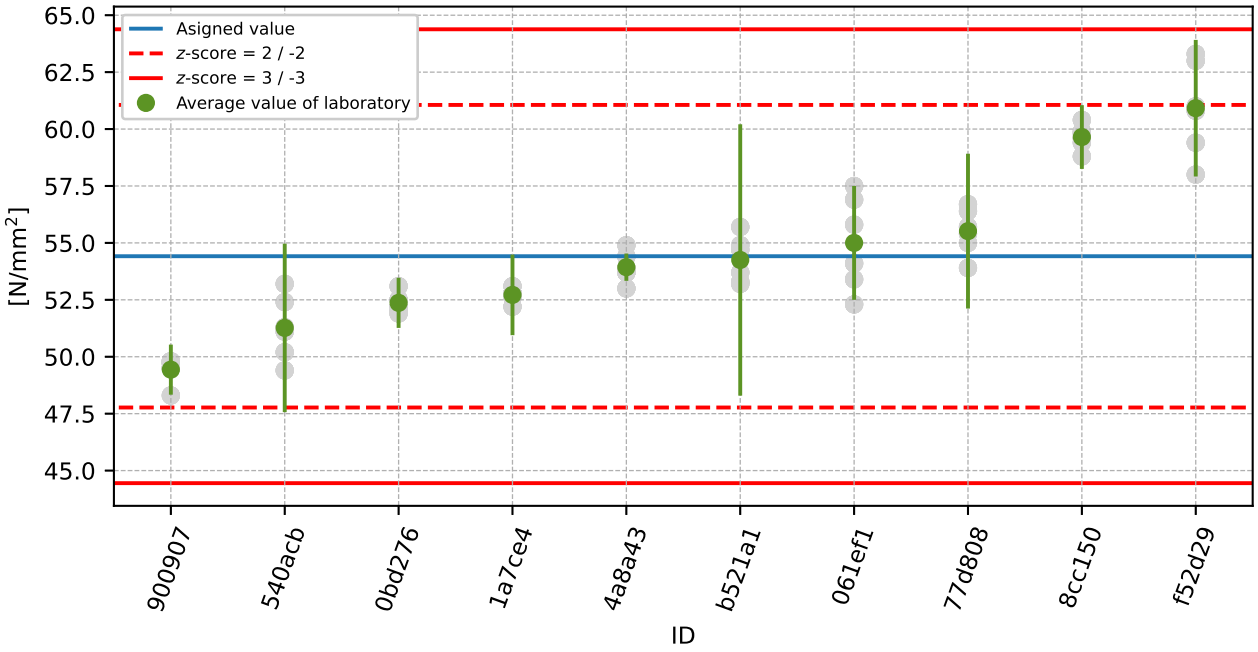

Figure 52: Average values and extended uncertainties of measurement

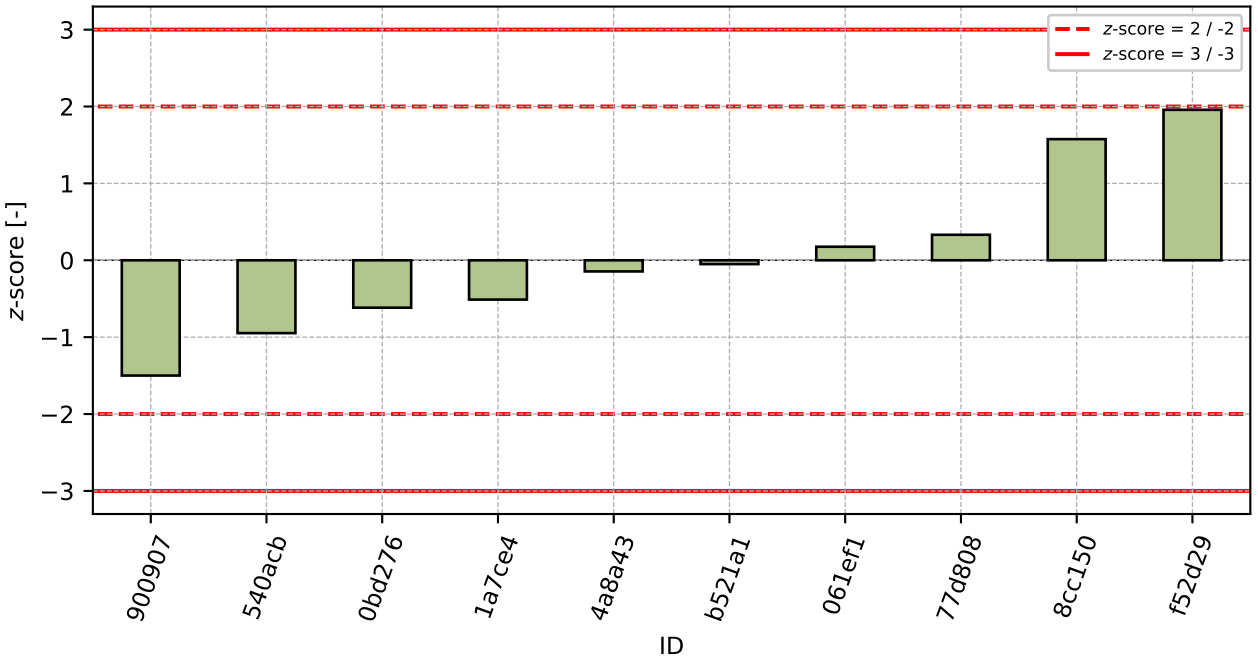

Figure 53: z-score

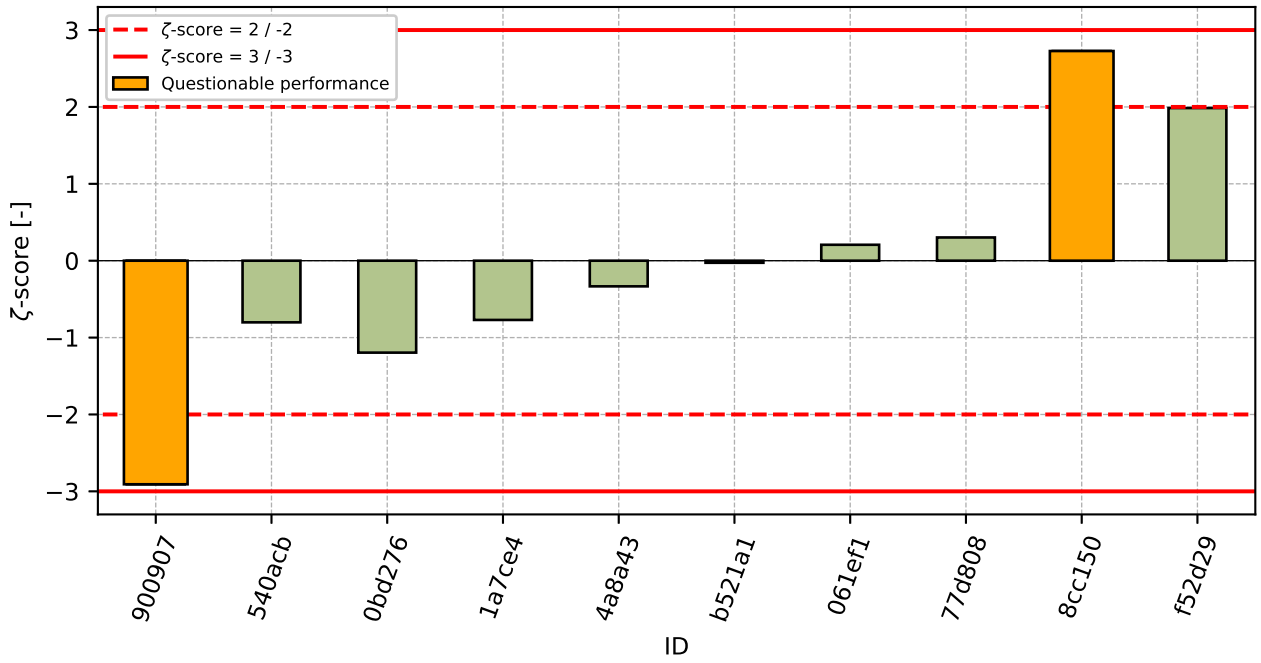

Figure 54: ζ-score

Table 21: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
900907	-1.5	-2.91
540acb	-0.95	-0.8
0bd276	-0.62	-1.2
1a7ce4	-0.51	-0.77
4a8a43	-0.14	-0.33
b521a1	-0.05	-0.03
061ef1	0.18	0.21
77d808	0.33	0.3
8cc150	1.58	2.73
f52d29	1.96	1.99

2 Appendix – EN 196-2 (art. 4.4.1) – Determination of loss on ignition

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

3 Appendix – EN 196-2 (art. 4.4.2) – Determination of sulphate content

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

4 Appendix – EN 196-2 (art. 4.4.3) – Determination of the residue insoluble in hydrochloric acid and sodium carbonate

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

5 Appendix – EN 196-2 (art. 4.4.4) – Determination of the residue insoluble in hydrochloric acid and potassium hydroxide

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

6 Appendix – EN 196-2 (art. 4.4.5) – Determination of sulphite content

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

7 Appendix – EN 196-2 (art. 4.4.6) – Determination of manganese content

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

8 Appendix – EN 196-3 – Setting time, Soundness

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

9 Appendix – EN 196-10 – Determination of the water-soluble chromium (Cr^{6+})

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

10 Appendix – EN 1015-1 – Granularity

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

11 Appendix – EN 1015-3 – Consistency

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

12 Appendix – EN 1015-6 – Density of fresh mortar

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

13 Appendix – EN 1015-10 – Density of hardened mortar

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

14 Appendix – EN 1015-11 – Strength

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

15 Appendix – EN 1015-12 – Adhesion

15.1 Test results

Table 22: 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 [%]
328a84	0.3	0.3	0.3	0.3	0.3	0.0	0.3	0.02	6.6
900907	0.4	0.4	0.3	0.3	0.3	0.1	0.4	0.03	8.14
829e9d	0.4	0.5	0.4	0.5	0.4	0.0	0.5	0.04	9.09
77d808	0.5	0.6	0.5	0.5	0.6	0.1	0.5	0.03	5.27
556905	0.7	0.8	1.0	0.9	0.7	0.2	0.8	0.13	15.06

15.2 The Numerical Procedure for Determining Outliers

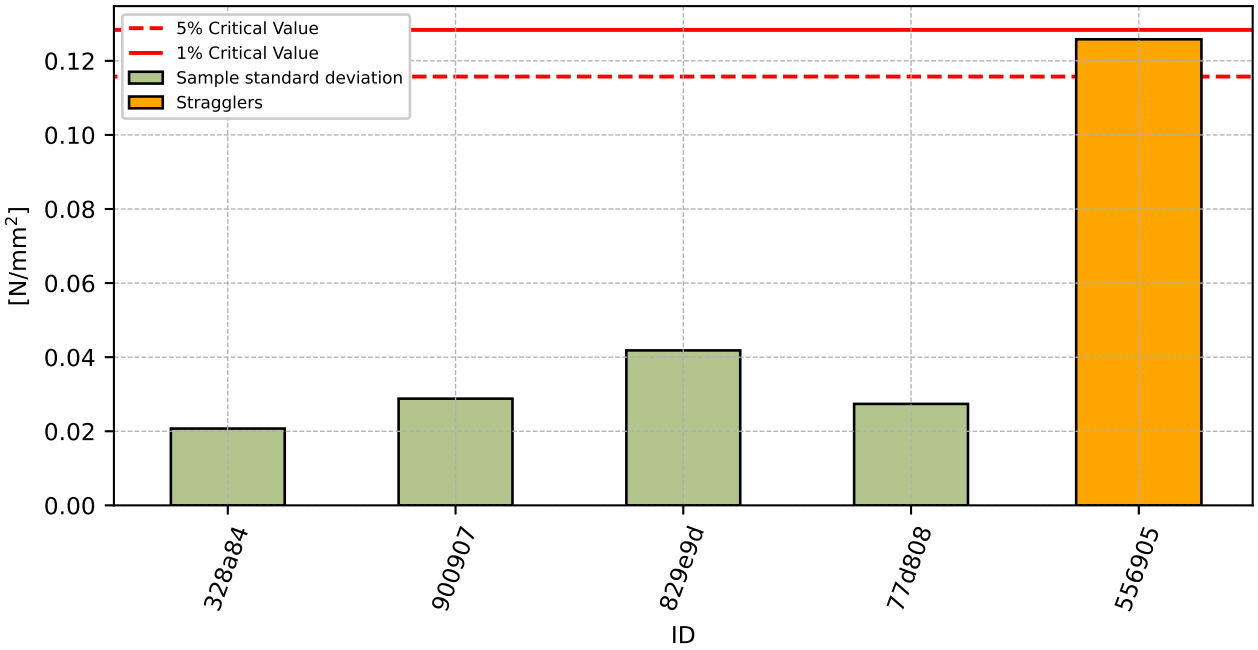

Figure 55: **Cochran's test** - sample standard deviations

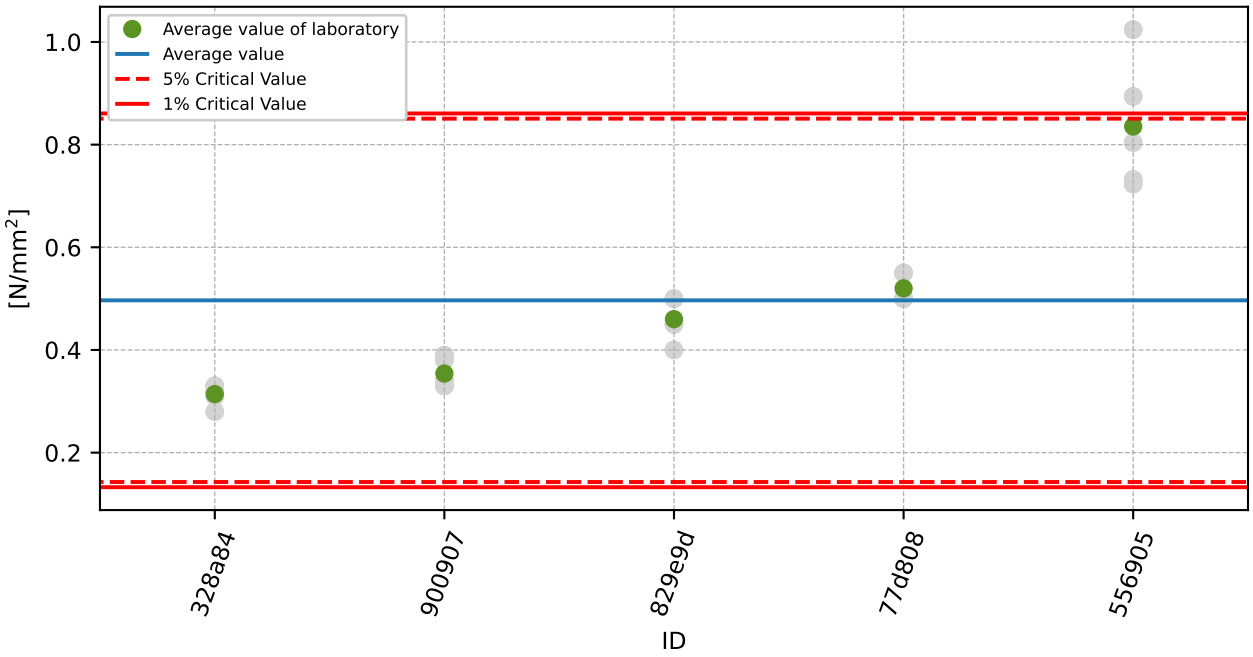

Figure 56: **Grubbs' test** - average values

15.3 Mandel's Statistics

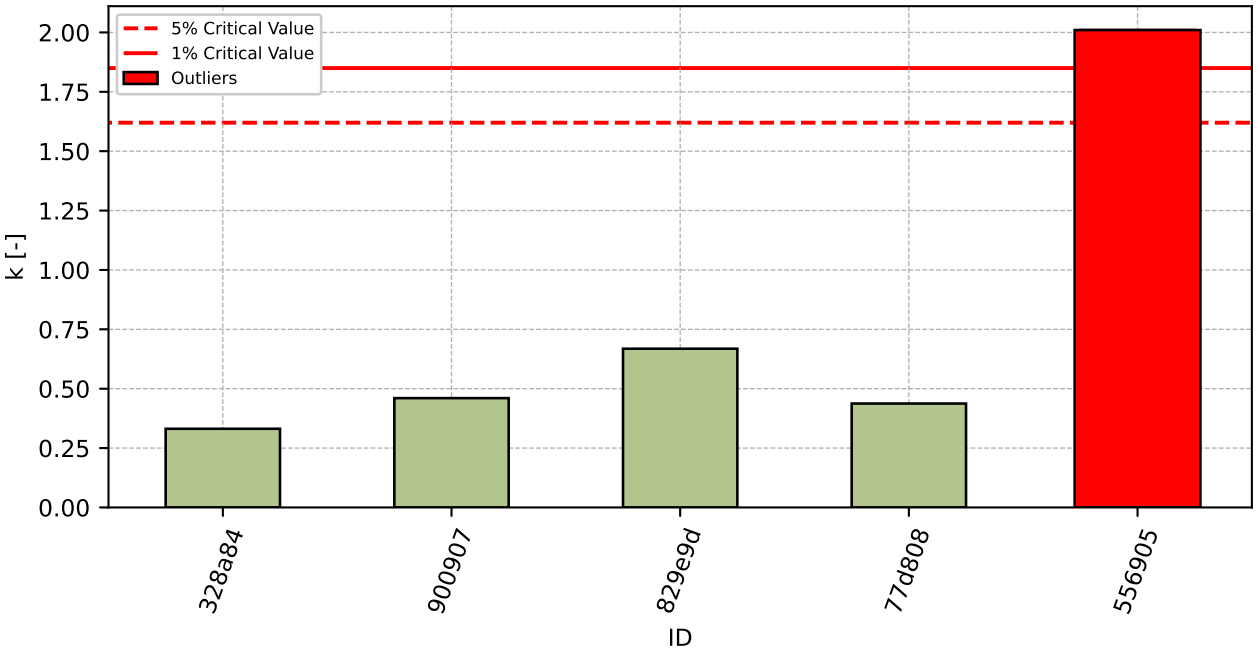

Figure 57: Intralaboratory Consistency Statistic

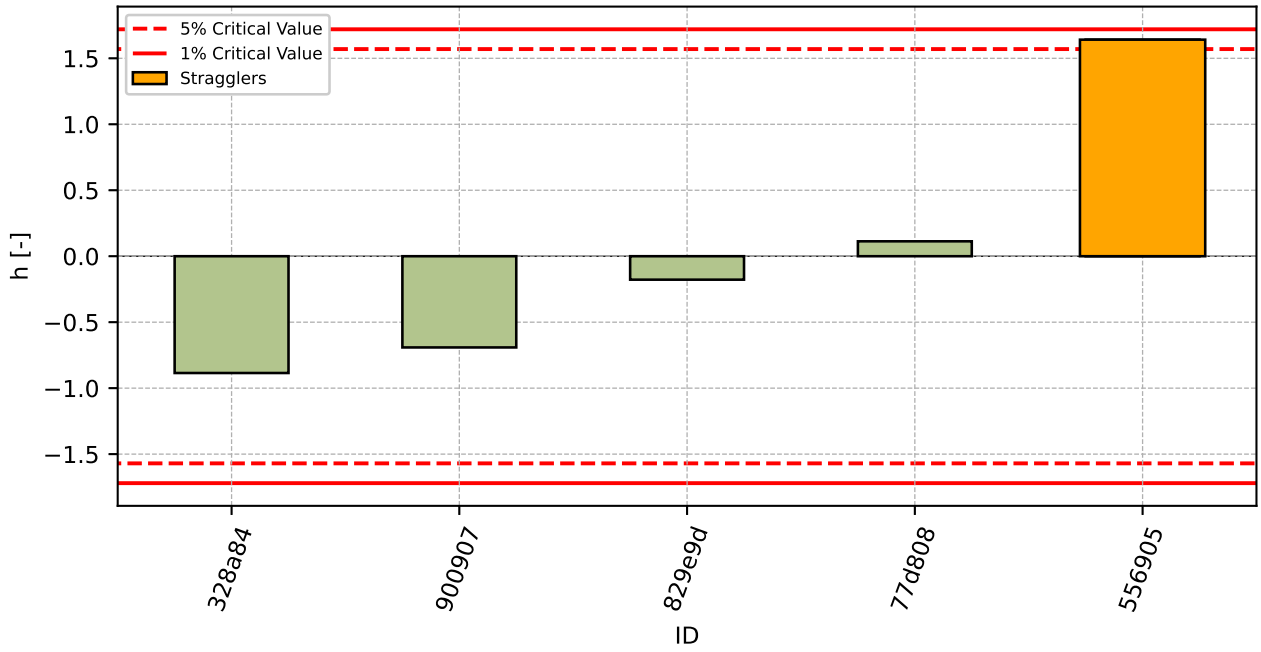

Figure 58: Interlaboratory Consistency Statistic

15.4 Descriptive statistics

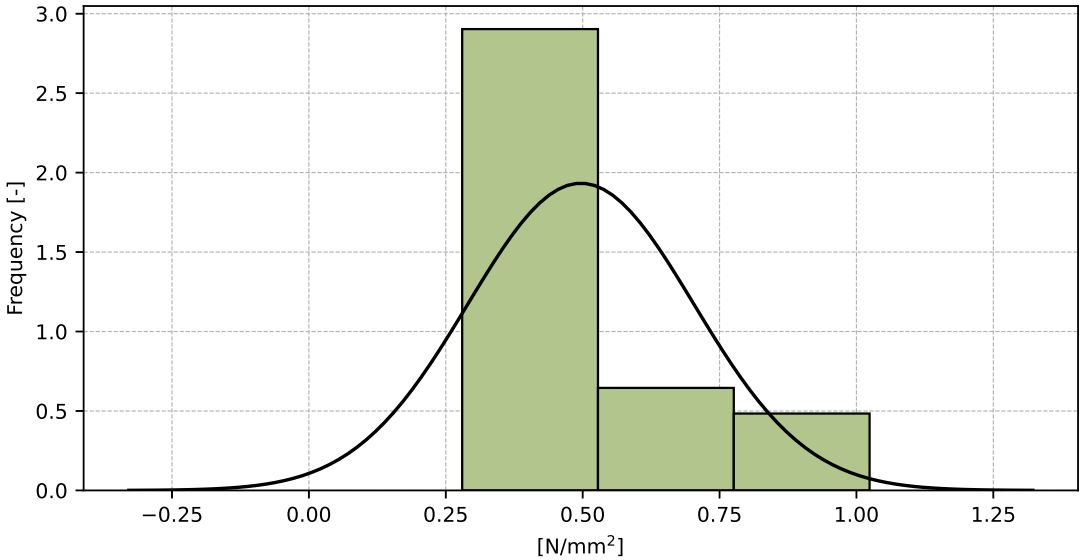

Figure 59: Histogram of all test results

Table 23: Descriptive statistics

Characteristics	[N/mm^2]
Average value – $\bar{x}$	0.5
Sample standard deviation – s	0.21
Asigned value – x^*	0.5
Robust standard deviation – s^*	0.21
Measurement uncertainty of asigned value – u_X	0.12
p-value of normality test	0.002 [-]
Interlaboratory standard deviation – s_L	0.2
Repeatability standard deviation – s_r	0.06
Reproducibility standard deviation – s_R	0.21
Repeatability – r	0.2
Reproducibility – R	0.6

15.5 Evaluation of Performance Statistics

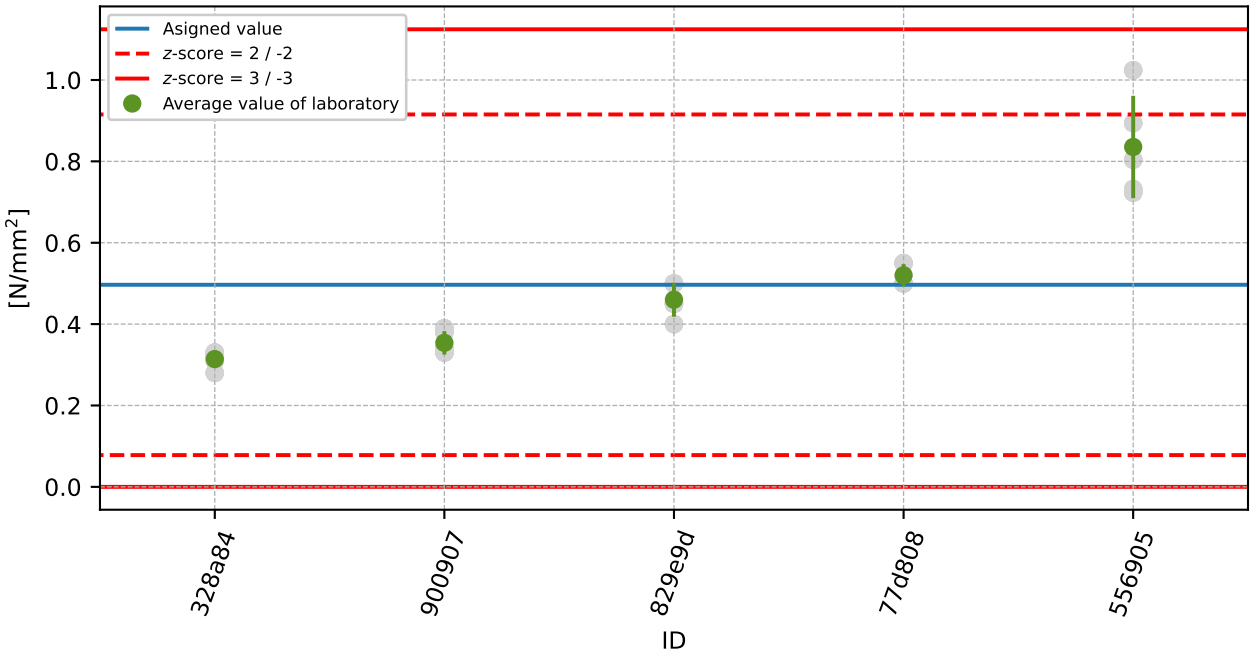

Figure 60: Average values and sample standard deviations

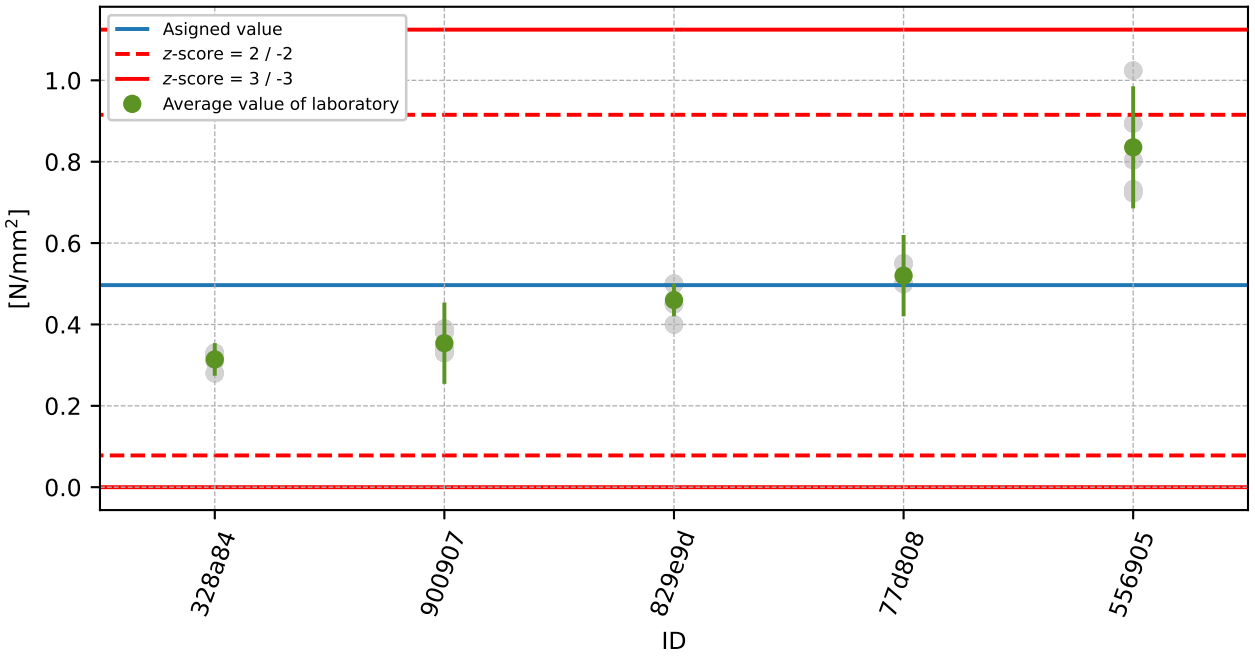

Figure 61: Average values and extended uncertainties of measurement

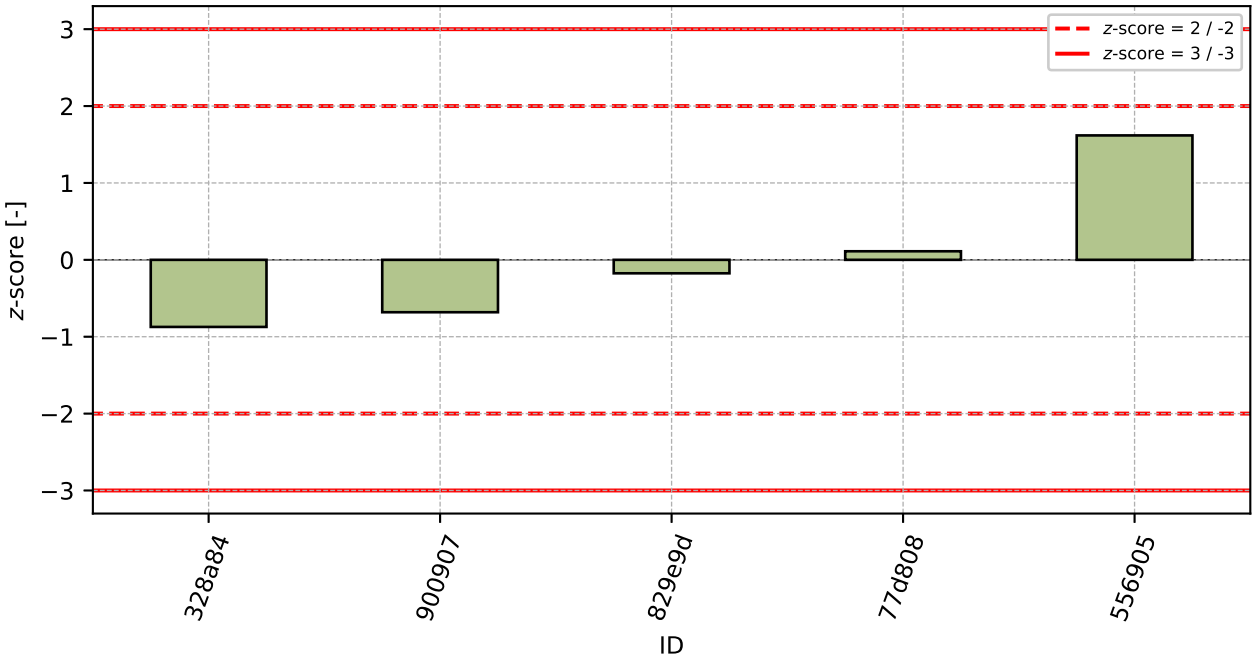

Figure 62: z-score

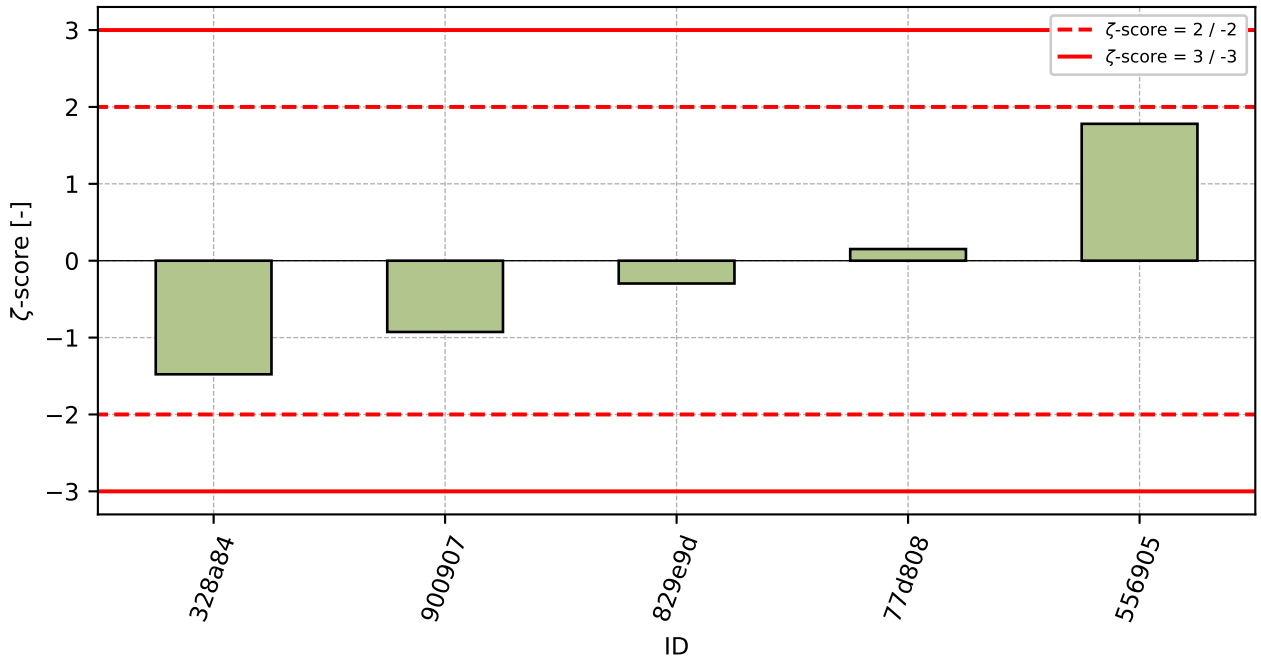

Figure 63: ζ-score

Table 24: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
328a84	-0.87	-1.48
900907	-0.68	-0.93
829e9d	-0.18	-0.3
77d808	0.11	0.15
556905	1.62	1.78

16 Appendix – EN 1015-18 – Capillary absorption coefficient (C_m)

16.1 Test results

Table 25: 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/(m²√min)]						u_X [kg/(m²√min)]	$\bar{x}$ [kg/(m²√min)]	s_0 [kg/(m²√min)]	V_X [%]
f52d29	0.29	0.29	0.28	0.26	0.28	0.28	0.03	0.28	0.011	3.91
d94b49	0.35	0.4	0.35	0.35	0.4	0.4	0.02	0.375	0.0274	7.3
829e9d	0.65	0.6	0.55	0.6	0.6	0.55	0.04	0.592	0.0376	6.36
900907	0.67	0.69	0.61	0.64	0.62	0.67	0.05	0.65	0.0316	4.87
328a84	0.847	0.839	0.783	0.904	0.849	0.857	0.065	0.846	0.0388	4.58

16.2 The Numerical Procedure for Determining Outliers

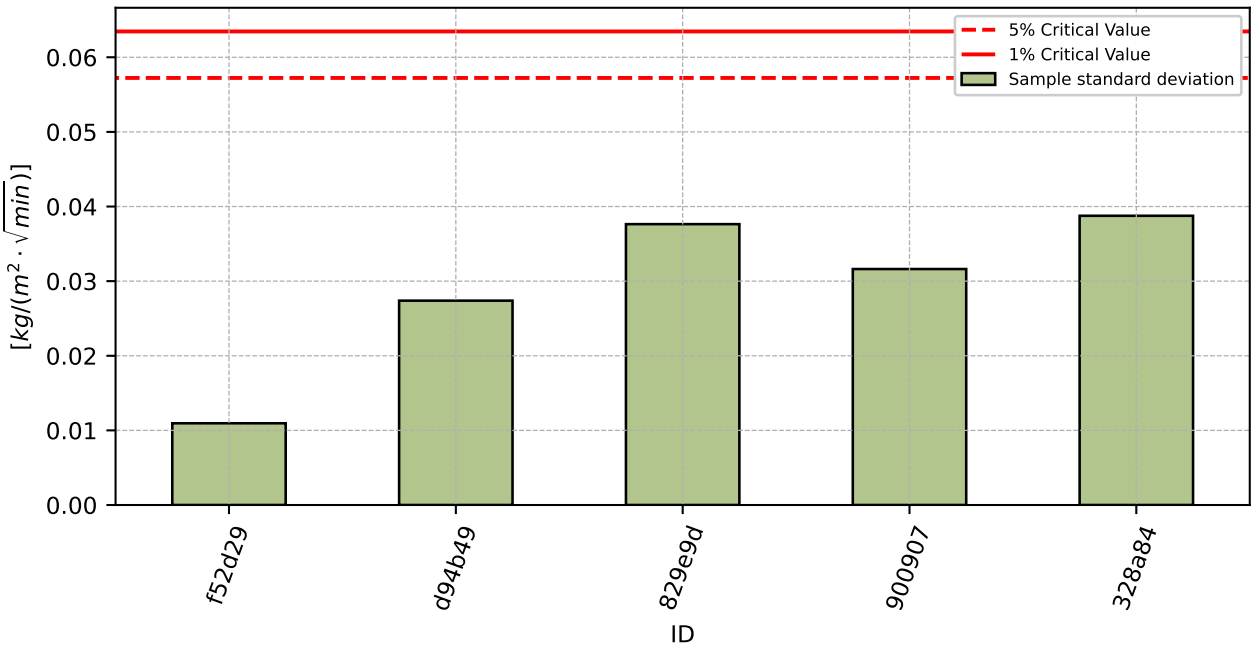

Figure 64: **Cochran's test** - sample standard deviations

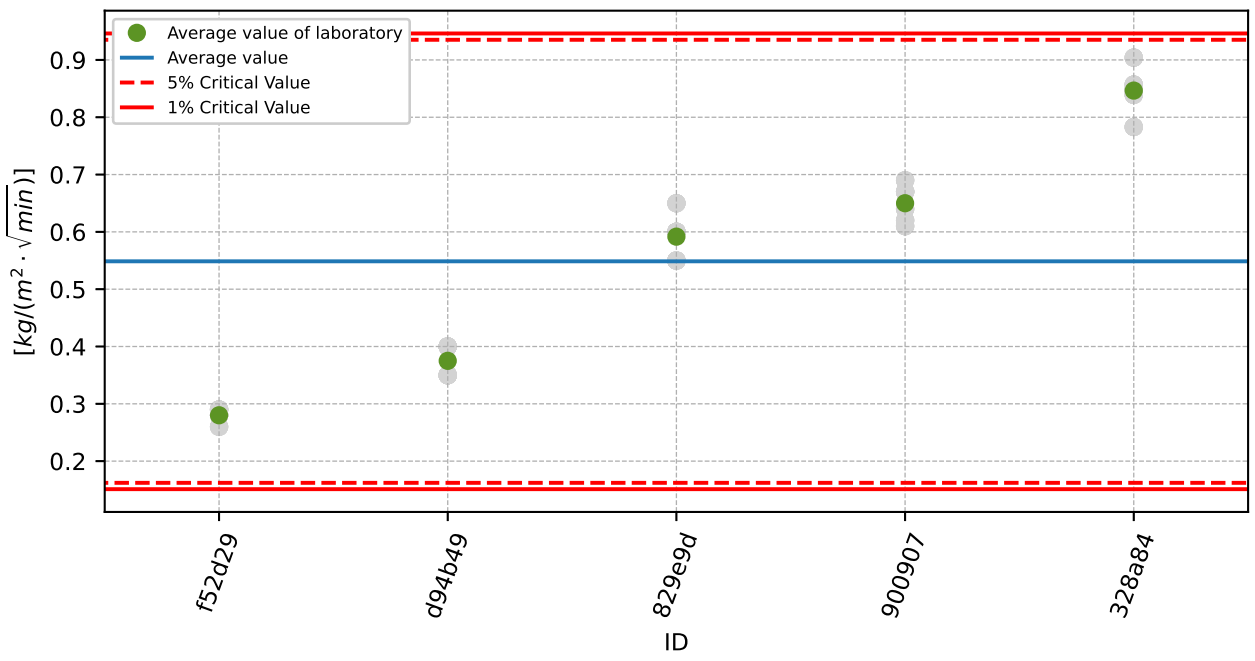

Figure 65: **Grubbs' test** - average values

16.3 Mandel's Statistics

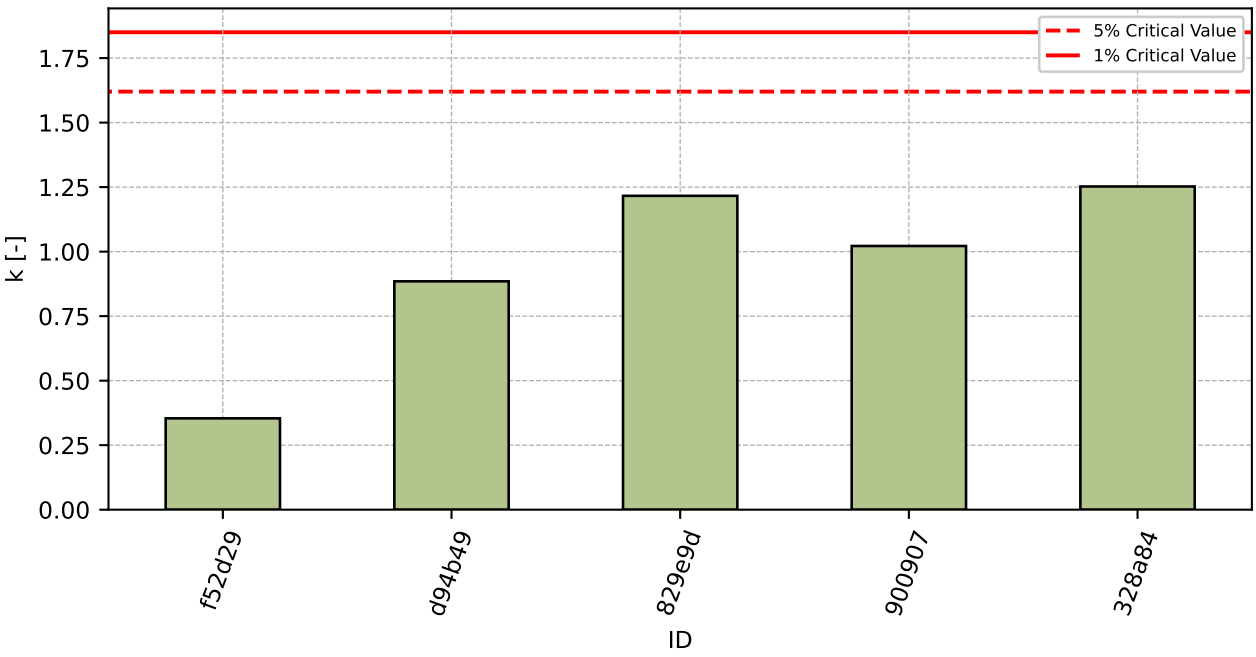

Figure 66: Intralaboratory Consistency Statistic

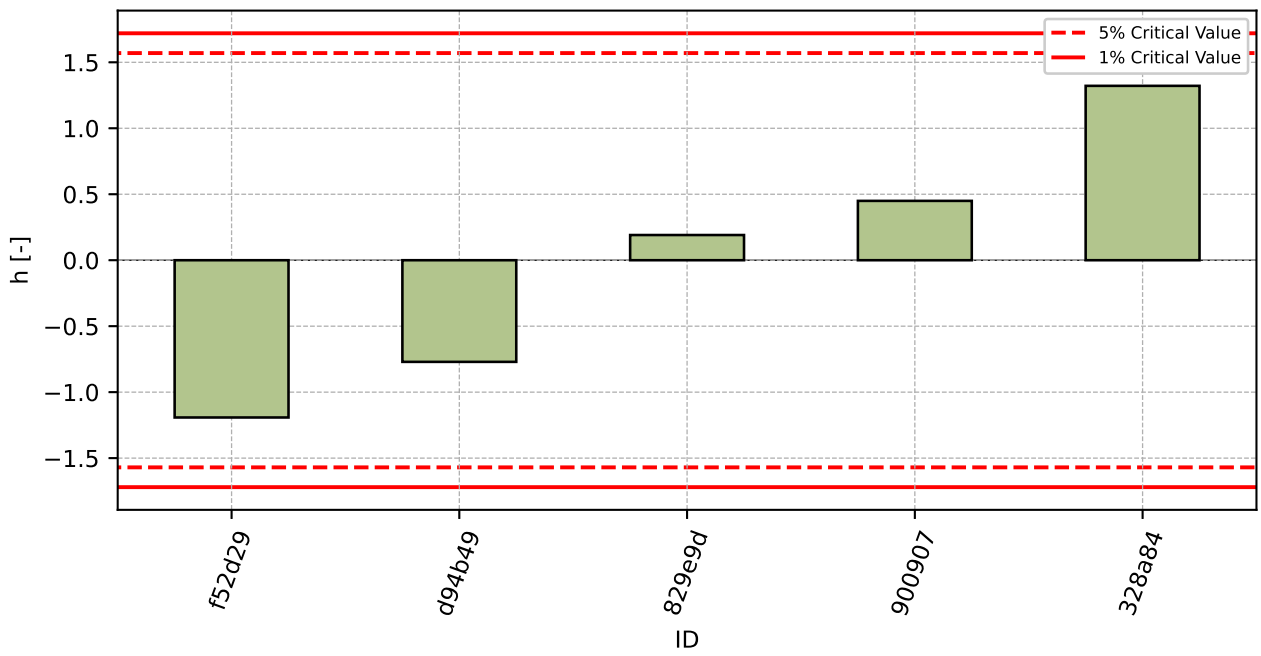

Figure 67: Interlaboratory Consistency Statistic

16.4 Descriptive statistics

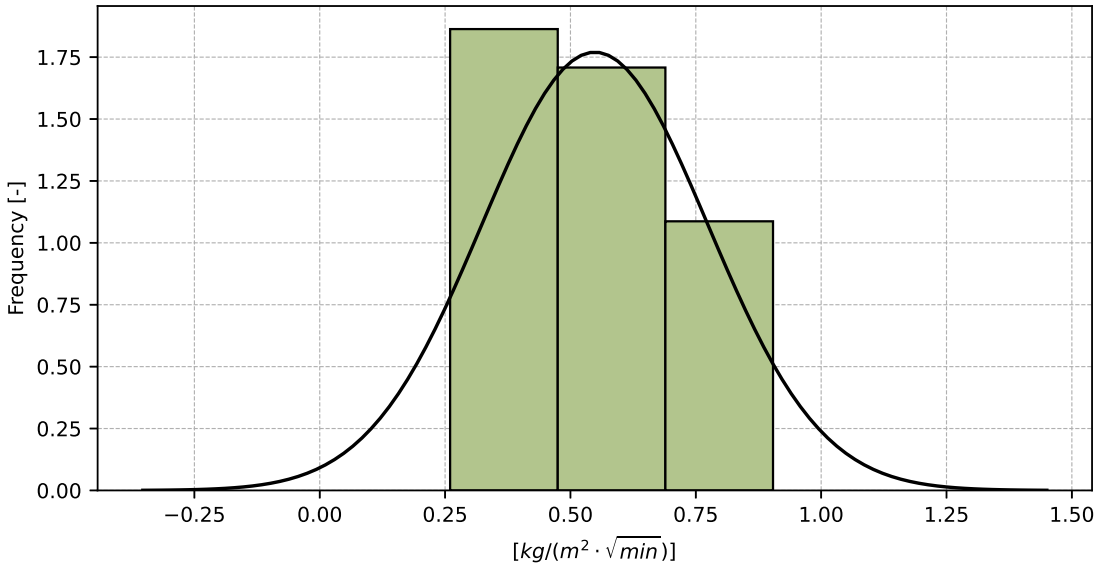

Figure 68: Histogram of all test results

Table 26: Descriptive statistics

Characteristics	[kg/(m²√min)]
Average value – $\bar{x}$	0.549
Sample standard deviation – s	0.2254
Asigned value – x^*	0.549
Robust standard deviation – s^*	0.2286
Measurement uncertainty of asigned value – u_X	0.1278
p-value of normality test	0.021 [-]
Interlaboratory standard deviation – s_L	0.225
Repeatability standard deviation – s_r	0.0309
Reproducibility standard deviation – s_R	0.2271
Repeatability – r	0.087
Reproducibility – R	0.636

16.5 Evaluation of Performance Statistics

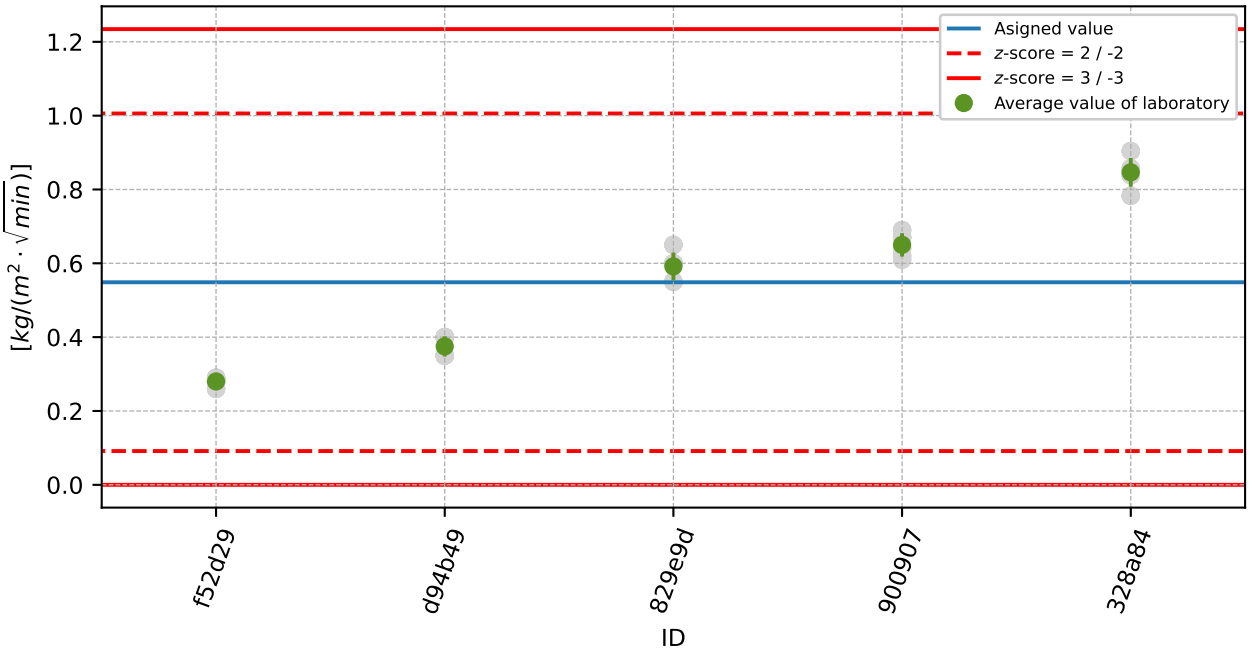

Figure 69: Average values and sample standard deviations

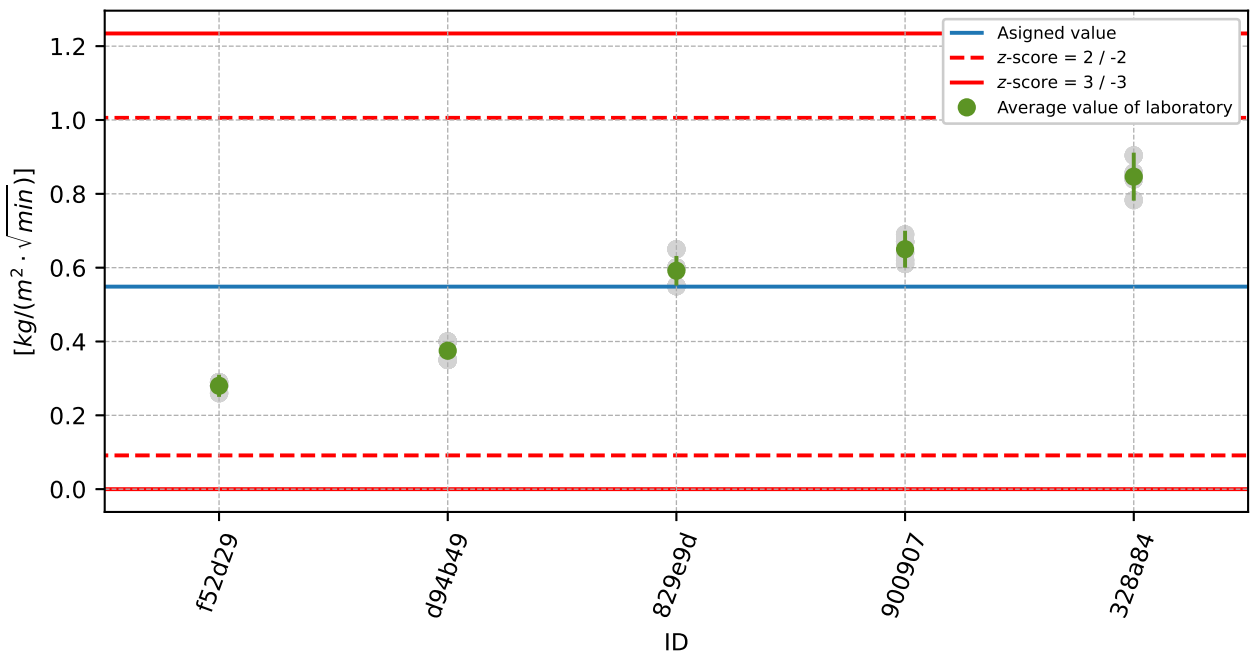

Figure 70: Average values and extended uncertainties of measurement

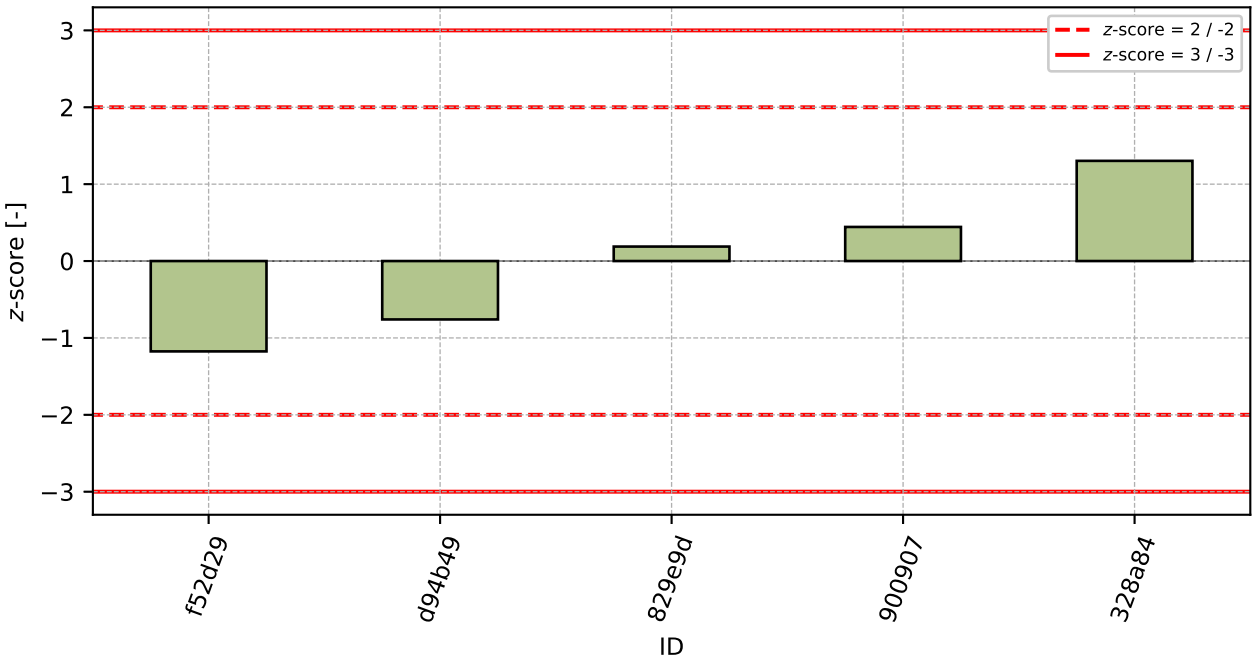

Figure 71: z-score

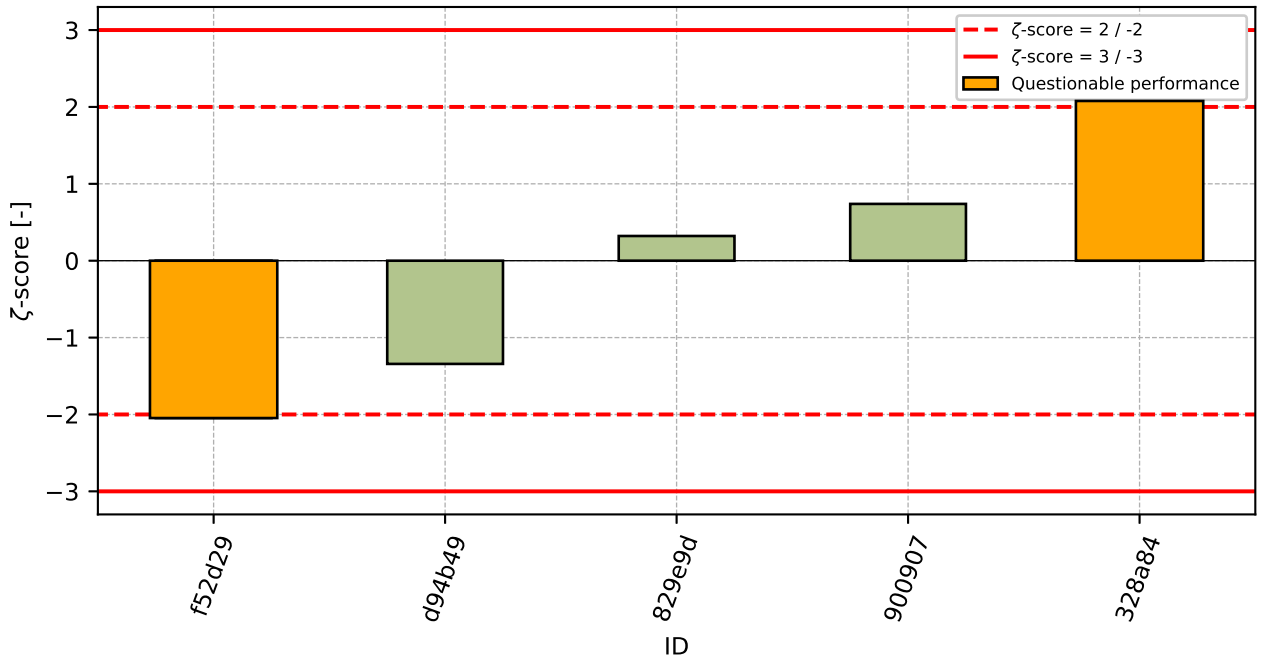

Figure 72: ζ-score

Table 27: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
f52d29	-1.18	-2.05
d94b49	-0.76	-1.34
829e9d	0.19	0.32
900907	0.44	0.74
328a84	1.3	2.08

17 Appendix – EN 1015-19 – Water vapor flow

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

18 Appendix – EN 13892-2 – Determination of flexural and compressive strength

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

19 Appendix – EN 12004-2 (art. 8.1) – Open time

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

20 Appendix – EN 12004-2 (art. 8.2) – Slippage

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

21 Appendix – EN 12004-2 (art. 8.3.3.2) – Adhesion

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

22 Appendix – EN 12004-2 (art. 8.3.3.3) – Adhesion

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