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
Strength and Durability of Hardened Concrete
ZZB 2024/1

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: July 31, 2024

Poskytovatel zkoušení způsobilosti při SZK FAST
Proficiency testing provider at the SZK FAST
Z 7008
Veveří 95
602 00 Brno
Czech Republic
szk.fce.vutbr.cz

Assoc. Prof. Ing. Tomáš Vymazal, Ph.D.
Head of the PT Provider, PTP coordinator

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

Contents

1 Introduction and Important Contacts

In the year 2024, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZZB 2024/1 whose aim was to verify and assess the conformity of test results across laboratories when testing hardened concrete.

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.
Brno University of Technology
Faculty of Civil Engineering
Institute of Building Testing
Veveří 95, Brno 602 00
Czech Republic
Tel.: +420 603 313 337
Email: Tomas.Vymazal@vutbr.cz

Coordinator of PTP result assessment PrZZ

Ing. Petr Misák, Ph.D.
Brno University of Technology
Faculty of Civil Engineering
Institute of Building Testing
Veveří 95, Brno 602 00
Czech Republic
Tel.: +420 774 980 255
Email: Petr.Misak@vutbr.cz

The subjects of proficiency testing were the following testing procedures:

1. **EN 12390-3** – Compressive strength of test specimens [1].
2. **EN 12390-7** – Density of hardened concrete [2].
3. **EN 12390-8** – Depth of penetration of water under pressure [3].
4. **EN 480-11** – Determination of air void characteristics in hardened concrete [4].
5. **ČSN 73 1322** – Determination of frost resistance of concrete [5].
6. **ČSN 73 1324** – Determination of grindability of concrete [6].
7. **ČSN 73 1326** – Resistance of cement concrete surface to water and defrosting chemicals – Method A [7].
8. **ČSN 73 1326** – Resistance of cement concrete surface to water and defrosting chemicals – Method C [7].
9. **CEN/TS 12390-9** – Freeze-thaw resistance – Scaling [8].

Testing procedure 6 was not open due to low interest from laboratories.

The supplier, BETOTECH s. r. o., was responsible for the preparation of hardened concrete for the PTP. Fresh concrete for the preparation of test samples was taken from one production batch prepared in accordance with methods stipulated in EN 206 [9]. Fresh concrete was poured into test molds, which were always of the same type, and after removal from the molds the test specimens were placed under identical conditions in storage rooms complying with the requirements for individual specifications.

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 [10] and with EN ISO/IEC 17043 [11]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

56 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/Method	1	2	3	4	5	6	7	8	9
4f1b57	X	-	-	-	-	-	-	-	-
2e7b6b	-	-	-	-	-	-	X	-	-
3513f0	-	-	-	-	-	-	X	-	-
a212b5	-	-	-	-	-	-	X	X	-
b7ba5c	X	X	X	-	-	-	-	-	-
2927a2	-	-	X	-	-	-	-	-	-
05ea87	X	-	X	-	-	-	-	-	-
eb7cc4	-	-	-	-	-	-	X	-	-
e4a2bc	-	X	X	-	-	-	-	-	-
e3a278	-	-	-	-	-	-	-	-	X
2327a1	X	-	X	-	X	-	X	-	-
b0d1be	-	-	-	-	-	-	X	-	-
e2e229	X	X	X	-	-	-	-	-	-
d4e812	X	X	X	-	-	-	X	-	-
05eca8	X	-	-	-	-	-	-	-	-
f27c19	-	-	X	-	-	-	-	-	X
a429d6	-	-	X	-	-	-	-	-	X
b76ab4	-	-	X	-	X	-	X	-	-
0fdb21	X	X	X	-	-	-	X	-	-
f88d81	-	-	X	-	X	-	X	-	-
90608c	X	-	-	-	-	-	-	-	-
76e728	X	X	-	-	-	-	-	-	-
57d070	-	-	-	-	X	-	-	-	-
157fe9	X	X	X	-	X	-	-	X	-
4f4698	X	X	X	-	-	-	-	X	-
133366	X	X	X	-	-	-	-	-	-
2434f9	X	X	X	-	-	-	-	X	-
007432	X	X	X	-	-	-	-	-	-
39d807	X	X	X	-	-	-	-	-	-
7eb42c	-	-	-	-	-	-	X	-	-
121655	-	-	X	X	-	-	-	-	X
fd2602	X	X	-	-	-	-	-	-	-
9a7dda	X	-	-	-	-	-	-	-	-
d147e7	X	-	-	-	-	-	-	-	-
3a378b	X	-	X	-	X	-	X	-	-
e5faa8	X	-	X	-	X	-	X	-	-
6a807e	X	-	X	-	X	-	X	-	-
4c358f	-	-	-	X	-	-	-	-	-
5a1f6a	X	X	-	-	-	-	-	-	-
891e67	X	-	-	-	-	-	-	-	-
92e29f	-	-	X	-	-	-	-	-	X
76cc78	-	X	X	-	-	-	-	-	X
5a3300	X	X	-	-	-	-	-	X	-
0a6482	-	-	-	-	-	-	-	-	X

Continued on next page

Continued from previous page

ID/Method	1	2	3	4	5	6	7	8	9
64846e	X	-	-	-	-	-	-	-	-
2e0a27	X	X	X	-	-	-	-	X	-
eca2dd	-	-	X	-	-	-	-	-	-
cea32b	X	-	-	-	-	-	-	-	-
ad394c	-	-	X	-	-	-	-	-	X
2c0aaf	-	-	-	X	-	-	-	-	X
1f6871	-	-	-	X	-	-	-	-	-
fe2c05	-	-	-	X	-	-	-	-	X
73885a	-	-	X	-	-	-	X	-	-
9bdf13	X	X	X	-	-	-	-	-	-
f44e68	X	X	X	-	-	-	X	-	-
a33d21	-	-	-	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
AQ TESTING BT SRL	PICULINEI 5A SECTOR 1, BUCURESTI, 012601, ROMANIA	-
BETONTEST, spol. s r. o.	Trnkova 3083/162, Brno-Líšeň, 62800, Česká republika	1116
BETOTECH, s.r.o. - pracoviště Beroun	Beroun 660, Beroun, 26601, Česká republika	1195
BETOTECH, s.r.o. - pracoviště Cheb	Beroun 660, Beroun, 26601, Česká republika	1195
BETOTECH, s.r.o. - pracoviště Jindřichův Hradec	Beroun 660, Beroun, 26601, Česká republika	1195
BETOTECH, s.r.o. - pracoviště Klatovy	Beroun 660, Beroun, 26601, Česká republika	1195
BETOTECH, s.r.o. - pracoviště Most	Beroun 660, Beroun, 26601, Česká republika	1195
BETOTECH, s.r.o. - pracoviště Ostrava	Beroun 660, Beroun, 26601, 25066153	1195.2
BETOTECH, s.r.o. - pracoviště Trutnov	Beroun 660, Beroun, 26601, Česká republika	1195
BOKU Wien, Institut fuer Konstruktiven Ingenieurbau	Peter-Jordan-Strasse 82, Vienna, 1190, Austria	-
BVFS Salzburg	Alpenstrasse 157, Salzburg, 5300, Österreich	0003
Banat Inženjering LBI	Makedonska 15, Zrenjanin, 23000, Republic of Serbia	01-540
Bauchemia T.B., s.r.o.	Stanekova 3, Bratislava, 841 03, Slovenská republika	-
Bautech Labor GmbH	7. Haidequerstrasse 5b, Wien, 1110, Austria	-

Continued on next page

Continued from previous page

Laboratory	Address	Accreditation number
Bechtel ENKA UK Limited Ogranak Beograd	Jasički put 52đ, Kruševac, 37000, Serbia	-
CEMEX Czech Republic, s.r.o.	Semtín 102, Pardubice, 53354, 27892638	1302
CENTER FOR TESTING AND EUROPEAN CERTIFICATION /CTEC/ Ltd.	Industrialna street 2, Stara Zagora, 6000, Stara Zagora	252 ЛИ
CONSULTEST s.r.o.	Medkova 974/4, Brno - Tuřany, 62700, Česká republika	1211
CSS d.o.o.	Savska cesta 141, Zagreb, 10000, Croatia	HR1106
Danucem Slovensko a.s., Skúšobné laboratórium Bratislava	Pestovateľská 2, Bratislava, 82104, Slovenská republika	426/S-313
Danucem Slovensko a.s., Skúšobné laboratórium Bratislava	Pestovateľská 2, Bratislava, 82104, Slovenská republika	426/S-313
Geomehanika d.o.o.	Dobropoljska 21, Beograd, 011, Serbia	-
Gradjevinsko-arhitektonski fakultet Univerziteta u Nišu	Aleksandra Medvedeva 14, Niš, 18000, Serbia	01-202
Holcim Česko, a.s.	Čížkovice 27, Čížkovice, 411 12, Česká republika	1426
Horský s.r.o.	Klánovická 286, Praha, 198 00, Česká republika	1207
KARYDIS G. & SIA E.E.	DISTOMOU 97, ATHENS, 10443, ATTIKA - GREECE	-
LABORATOIRE DES TRAVAUX PUBLICS DU SUD	Zone des activités Bouhraoua- PB 332 GHARDAIA, GHARDAIA, 47000, ALGERIA	-
Lukavac Cement	Lukavačkih brigada bb, Lukavac, 75300, Bosnia	-
M.I.S. a.s.	Resslova 956/13, Hradec Králové, 500 02, Česká republika	1197
MBS CZ-SK s.r.o	F.V.Veselého, Praha 9, 19300, Česká republika	1495
Mega Infrastructure d.o.o., Beograd-Savski Venac, 11000, Belgrade, Serbia	Potez Ružaš, Irig, 22406, Serbia	-
PILON LAB D.O.O.	Bulevar Nikole Tesle, Niš, 18000, Serbia	-
QCONTROL s.r.o., odštěpný závod - pracoviště Děčín	Lesní 693, Bílovice nad Svitavou, 66401, Česká republika	1737
QUALIFORM SLOVAKIA s.r.o.	Pasienková 9D, Bratislava, 821 06, Slovenská republika	S-301
SG Geotechnika a.s.	Geologická 4, Praha 5, 15200, Česká republika	1119
SIBOTEC	Industriepark Oost 6, Beernem, 8730, West - Vlaanderen	-
Stachema CZ s.r.o. - Zkušební laboratoř - pracoviště 1	Hasičská 1, Zibohlavy, Kolín, 28002, Česká republika	1433

Continued on next page

Continued from previous page

Laboratory	Address	Accreditation number
Stachema CZ s.r.o. - Zkušební laboratoř - pracoviště 2	Hasičská 1, Zibohlavy, Kolín, 28002, Česká republika	1433
Structum, d.o.o.	Tovarniška cesta 26, Ajdovščina, 5270, Slovenia	LP-108
TESTAV-LAB s.r.o.	Chodská 7, Liberec 3, 466 02, 272 80 551	1180
TIQU-Tiroler Qualitätszentrum für Umwelt, Bau und Rohstoffe GmbH	Gewerbestrasse 4, Ötztal Bahnhof, 6430, Austria	-
TPA Spoločnosť pre zabezpečenie kvality a inovácie s.r.o. - pracovisko Geča	Areál STRABAG ul. Priemyselná, Geča, 04410, Slovenská republika	211/S-176
TPA Spoločnosť pre zabezpečenie kvality a inovácie s.r.o. - pracovisko Podunajské Biskupice	Ul. Svornosti 69, Bratislava, 82106, Slovenská republika	211/S-176
TPA Spoločnosť pre zabezpečenie kvality a inovácie s.r.o. - pracovisko Zvolen	Neresnická cesta 3, Zvolen, 96001, Slovenská republika	211/S-176
Technický a skúšobný stavebný, n.o. (skúšobné pracovisko Košice)	Krmanova 5, Košice, 040 01, Slovenská republika	S-045
Technický a skúšobný ústav stavebný, n. o., Pobočka Prešov	Studená, 967/3, Bratislava, 82104, Slovenská republika	S-045
Technický a zkušební ústav stavební Praha, s.p. - Ostrava	U Studia 14, Ostrava - Zábřeh, 700 30, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p. - Teplice	Tolstého 447, Teplice, 415 03, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p. - České Budějovice	Nemanická 441/8, České Budějovice, 37010, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, sp - pobočka Plzeň	Zahradní 15, Plzeň, 326 00, Česká republika	1018.3
Technische Universität Graz	Rechbauerstrasse 12, Graz, 8010, Austria	-
VIAMATIKA	Granito st. 3, Vilnius, LT-02241, Lithuania	120721845
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft. Központi Vizsgáló Laboratórium	Dózsa György út 26., Szentendre, 2000, Hungary	NAH-1-1110/2023/K
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft. Északkelet-magyarországi Anyagvizsgáló Kirendeltség	Dózsa György út 26, Szentendre, 2000, Hungary	-
Ředitelství silnic a dálnic s. p.	Rebešovická 40, Brno - Chrlice, 64300, Česká republika	1072
Ředitelství silnic a dálnic s. p., Samostatné oddělení zkušebnictví Praha, Laboratoř Praha	Na Pankráci 546/56, Praha, 140 00, Česká republika	1734

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 Strength and Durability of Hardened Concrete (PT Program) organized by the PT Provider at the SZK FAST. 56 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of hardened concrete with emphasis on its strength and durability. 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 3 shows the evaluation of the laboratory performance according to EN ISO/IEC 17043 [11].

Test procedures 7 and 8 were evaluated as a multilevel experiment. The level of the experiment was always composed of the number of freeze-thaw cycles. Laboratory performance was marked other than satisfactory only when critical z-score values were exceeded at two or more experiment levels.

Table 3: 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
4f1b57	?	-	-	-	-	-	-	-	-
2e7b6b	-	-	-	-	-	-	✓	-	-
3513f0	-	-	-	-	-	-	?	-	-
a212b5	-	-	-	-	-	-	✓	✓	-
b7ba5c	✓	✓	✓	-	-	-	-	-	-
2927a2	-	-	✓	-	-	-	-	-	-
05ea87	✓	-	✓	-	-	-	-	-	-
eb7cc4	-	-	-	-	-	-	✓	-	-
e4a2bc	-	✓	✓	-	-	-	-	-	-
e3a278	-	-	-	-	-	-	-	-	✓
2327a1	✓	-	✓	-	✓	-	✓	-	-
b0d1be	-	-	-	-	-	-	✓	-	-
e2e229	✓	✓	✓	-	-	-	-	-	-
d4e812	✓	✓	✓	-	-	-	✓	-	-
05eca8	✓	-	-	-	-	-	-	-	-
f27c19	-	-	✓	-	-	-	-	-	✓
a429d6	-	-	✓	-	-	-	-	-	✓
b76ab4	-	-	✓	-	✓	-	✓	-	-
0fdb21	✓	✓	✓	-	-	-	✓	-	-
f88d81	-	-	✓	-	✓	-	✓	-	-
90608c	?	-	-	-	-	-	-	-	-
76e728	?	✓	-	-	-	-	-	-	-
57d070	-	-	-	-	✓	-	-	-	-
157fe9	✓	✓	✓	-	✓	-	-	✓	-
4f4698	✓	✓	✓	-	-	-	-	✓	-

Continued on next page

Continued from previous page

ID / Method	1	2	3	4	5	6	7	8	9
133366	✓	✓	✓	-	-	-	-	-	-
2434f9	✓	✓	✓	-	-	-	-	✓	-
007432	✓	✓	✓	-	-	-	-	-	-
39d807	✓	✓	✓	-	-	-	-	-	-
7eb42c	-	-	-	-	-	-	✓	-	-
121655	-	-	✓	✓	-	-	-	-	✓
fd2602	✓	✓	-	-	-	-	-	-	-
9a7dda	✓	-	-	-	-	-	-	-	-
d147e7	✓	-	-	-	-	-	-	-	-
3a378b	✓	-	✓	-	✓	-	✓	-	-
e5faa8	✓	-	✓	-	✓	-	✓	-	-
6a807e	✓	-	X	-	✓	-	?	-	-
4c358f	-	-	-	✓	-	-	-	-	-
5a1f6a	✓	✓	-	-	-	-	-	-	-
891e67	!	-	-	-	-	-	-	-	-
92e29f	-	-	✓	-	-	-	-	-	✓
76cc78	-	✓	?	-	-	-	-	-	✓
5a3300	✓	✓	-	-	-	-	-	✓	-
0a6482	-	-	-	-	-	-	-	-	✓
64846e	✓	-	-	-	-	-	-	-	-
2e0a27	✓	✓	✓	-	-	-	-	✓	-
eca2dd	-	-	✓	-	-	-	-	-	-
cea32b	✓	-	-	-	-	-	-	-	-
ad394c	-	-	✓	-	-	-	-	-	✓
2c0aaf	-	-	-	✓	-	-	-	-	✓
1f6871	-	-	-	✓	-	-	-	-	-
fe2c05	-	-	-	✓	-	-	-	-	✓
73885a	-	-	✓	-	-	-	✓	-	-
9bdf13	✓	✓	✓	-	-	-	-	-	-
f44e68	✓	✓	✓	-	-	-	✓	-	-
a33d21	-	-	-	✓	-	-	-	-	-

References

[1] EN 12390-3. *Testing hardened concrete - Part 3: Compressive strength of test specimens*. 2020.

[2] EN 12390-7. *Testing hardened concrete - Part 7: Density of hardened concrete*. 2020.

[3] EN 12390-8. *Testing hardened concrete - Part 8: Depth of penetration of water under pressure*. 2020.

[4] EN 480-11. *Admixtures for concrete, mortar and grout - Test methods - Part 11: Determination of air void characteristics in hardened concrete*. 2006.

[5] ČSN 73 1322. *Determination of frost resistance of concrete*. 2003.

[6] ČSN 73 1324. *Determination of grindability of concrete*. 2003.

[7] ČSN 73 1326. *Resistance of cement concrete surface to water and defrosting chemicals*. 2003.

[8] CEN/TS 12390-9. *Testing hardened concrete - Part 9: Freeze-thaw resistance - Scaling*. 2007.

[9] EN 206:2013+A2:2021. *Concrete - Specification, performance, production and conformity*. 2021.

[10] 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.

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

1 Appendix – EN 12390-3 – Compressive strength of test specimens

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 [%]
891e67	47.6	46.7	45.7	-	46.7	0.95	2.04
4f1b57	43.8	50.0	47.1	1.8	47.0	3.1	6.61
5a3300	46.1	53.7	49.4	2.8	49.7	3.81	7.66
cea32b	49.2	50.4	51.7	1.2	50.4	1.25	2.48
9bdf13	51.2	50.4	53.4	-	51.7	1.55	3.01
9a7dda	49.2	52.5	53.4	2.6	51.7	2.21	4.28
2e0a27	52.5	51.7	52.9	-	52.4	0.61	1.17
5a1f6a	53.1	55.7	49.7	3.0	52.8	3.01	5.7
64846e	53.6	53.4	51.9	1.9	53.0	0.93	1.75
2327a1	54.0	51.8	53.2	-	53.0	1.11	2.1
b7ba5c	55.1	54.5	51.6	1.5	53.7	1.87	3.48
6a807e	54.8	53.7	52.7	3.6	53.7	1.05	1.95
e2e229	51.5	54.3	55.5	1.9	53.8	2.05	3.82
d4e812	51.6	55.4	54.3	1.9	53.8	1.96	3.64
d147e7	54.3	53.0	54.1	1.5	53.8	0.7	1.3
fd2602	53.3	52.8	56.1	2.9	54.1	1.78	3.29
05ea87	54.2	54.4	54.1	2.2	54.2	0.15	0.28
3a378b	54.4	54.9	54.8	3.6	54.7	0.26	0.48
39d807	55.0	54.4	55.4	1.8	54.9	0.5	0.92
f44e68	57.8	52.5	54.7	2.7	55.0	2.66	4.84
e5faa8	55.4	55.1	54.8	3.6	55.1	0.3	0.54
05eca8	54.9	56.0	54.9	1.0	55.3	0.64	1.15
133366	55.1	54.7	56.2	0.5	55.3	0.78	1.4
4f4698	56.2	56.9	53.5	0.5	55.5	1.8	3.23
007432	55.7	55.1	56.7	1.4	55.8	0.81	1.45
2434f9	56.0	54.9	57.3	1.3	56.1	1.2	2.14
0fdb21	55.8	56.6	56.2	3.1	56.2	0.4	0.71
157fe9	58.2	58.4	57.5	3.1	58.0	0.47	0.81
76e728	57.0	62.2	61.3	1.1	60.2	2.78	4.62
90608c	59.8	60.9	60.1	2.7	60.3	0.57	0.94

1.2 The Numerical Procedure for Determining Outliers

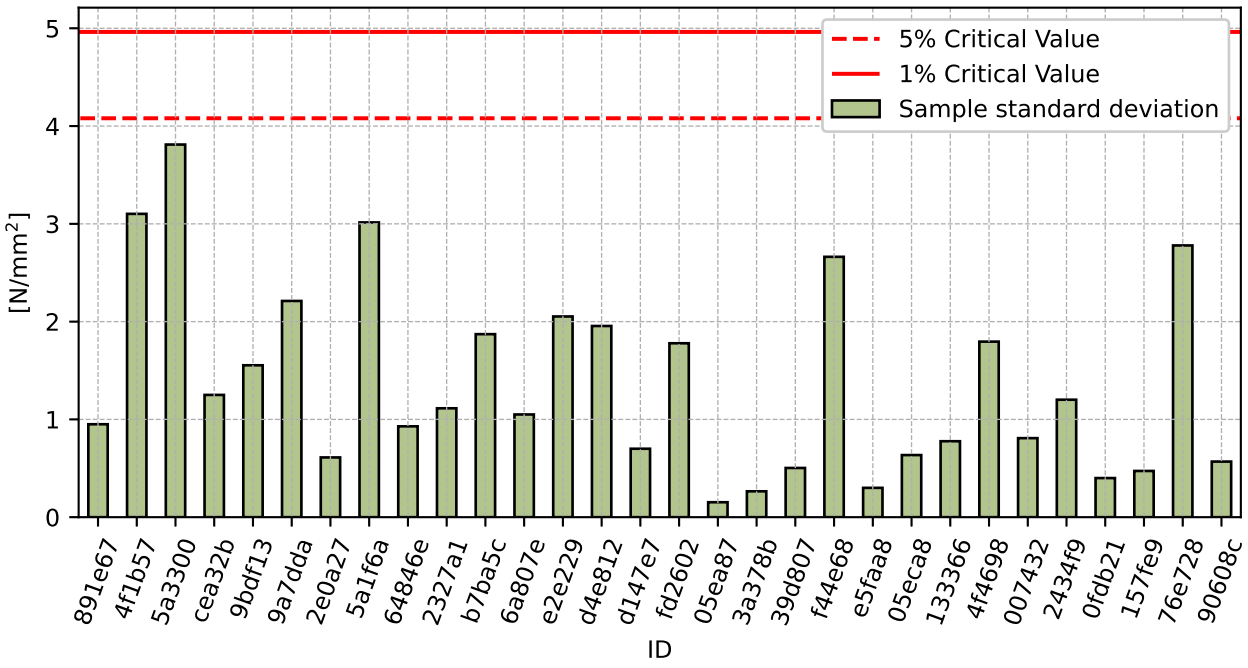

Figure 1: **Cochran's test** - sample standard deviations

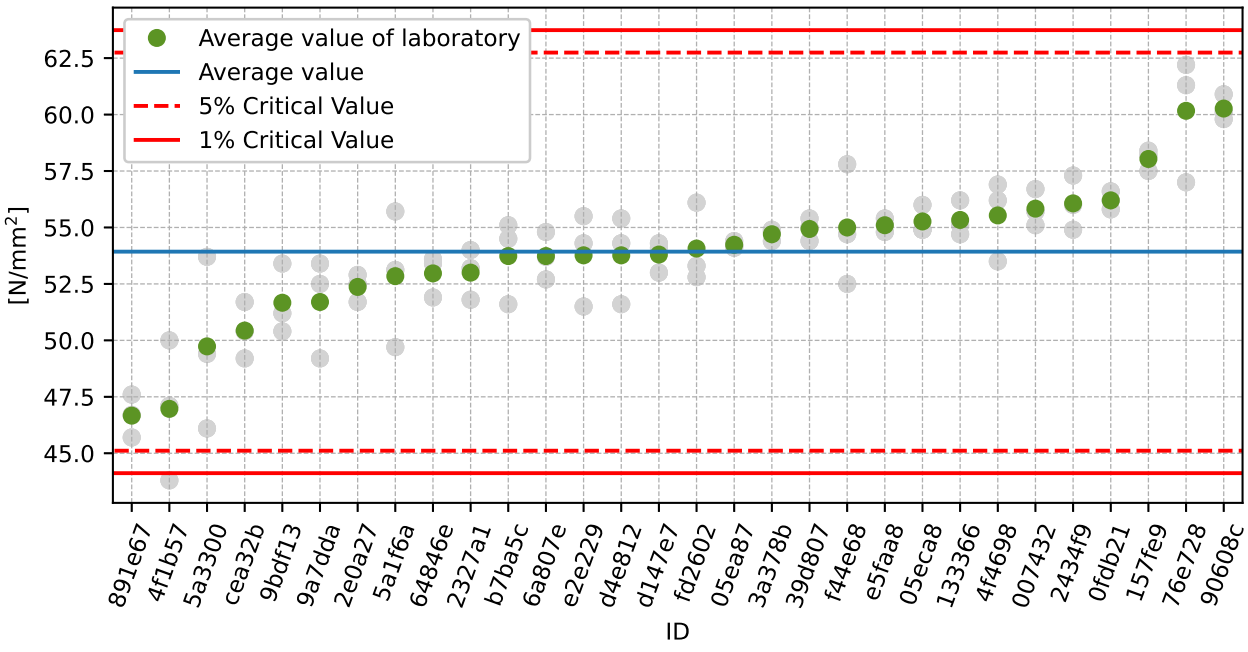

Figure 2: **Grubbs' test** - average values

1.3 Mandel's Statistics

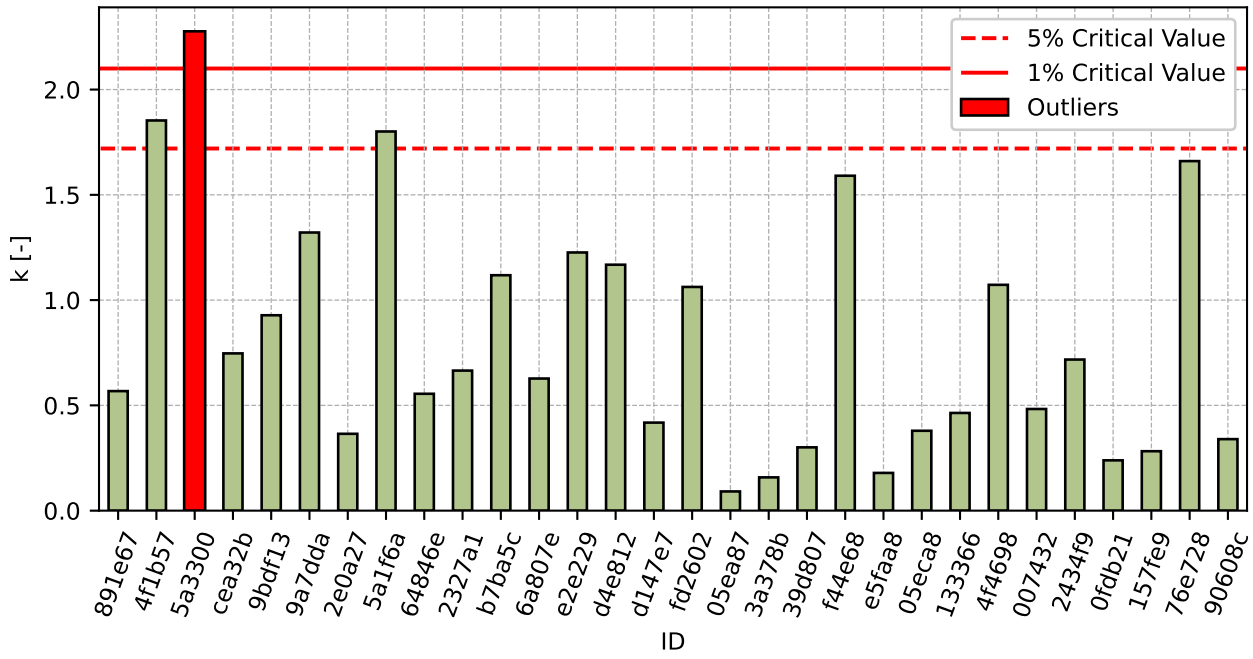

Figure 3: Intralaboratory Consistency Statistic

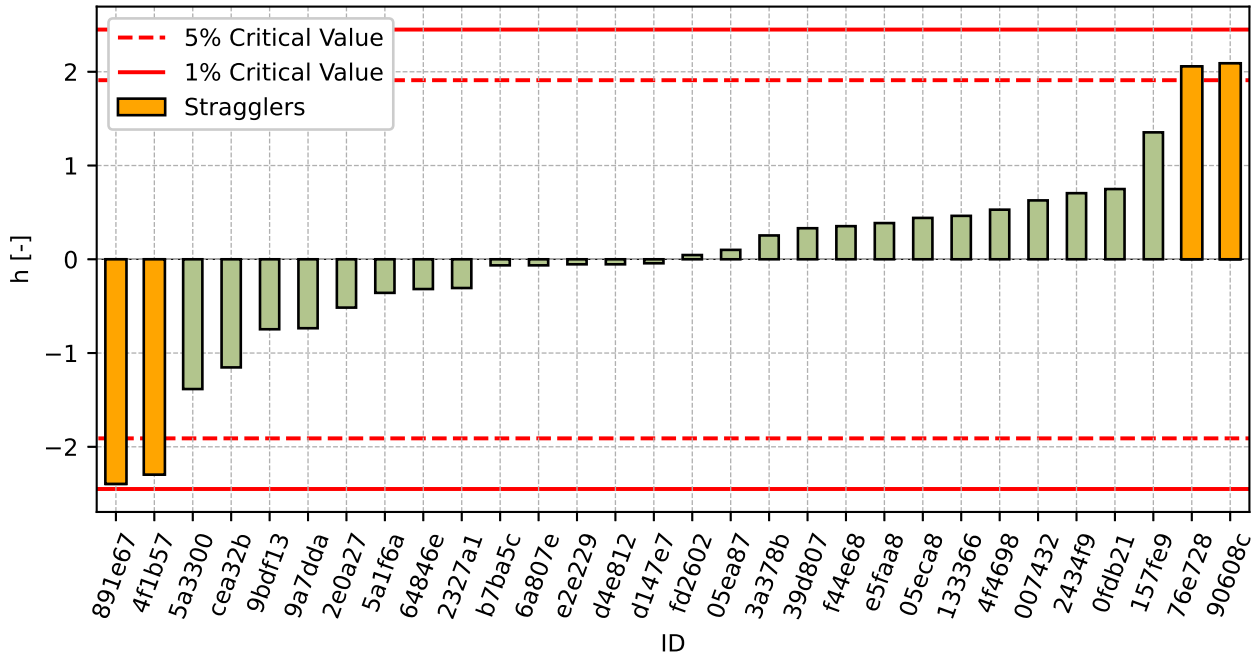

Figure 4: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

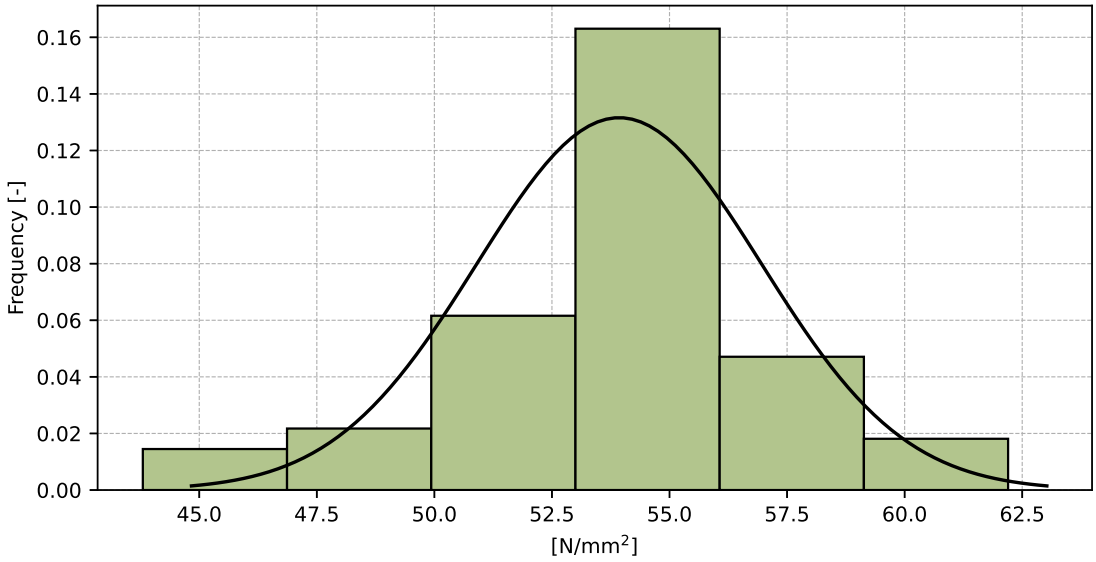

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[N/mm²]
Average value – $\bar{x}$	53.9
Sample standard deviation – s	3.03
Asigned value – x^*	54.1
Robust standard deviation – s^*	2.4
Measurement uncertainty of asigned value – u_X	0.55
p-value of normality test	0.01 [-]
Interlaboratory standard deviation – s_L	2.87
Repeatability standard deviation – s_r	1.67
Reproducibility standard deviation – s_R	3.33
Repeatability – r	4.7
Reproducibility – R	9.3

1.5 Evaluation of Performance Statistics

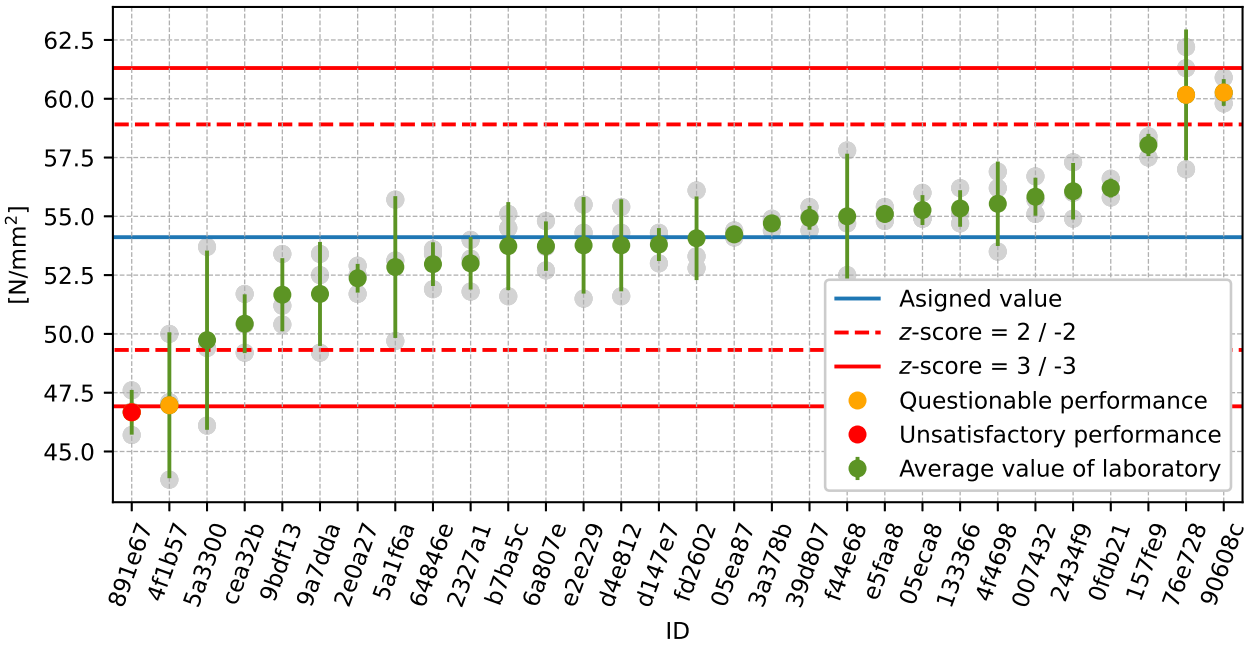

Figure 6: Average values and sample standard deviations

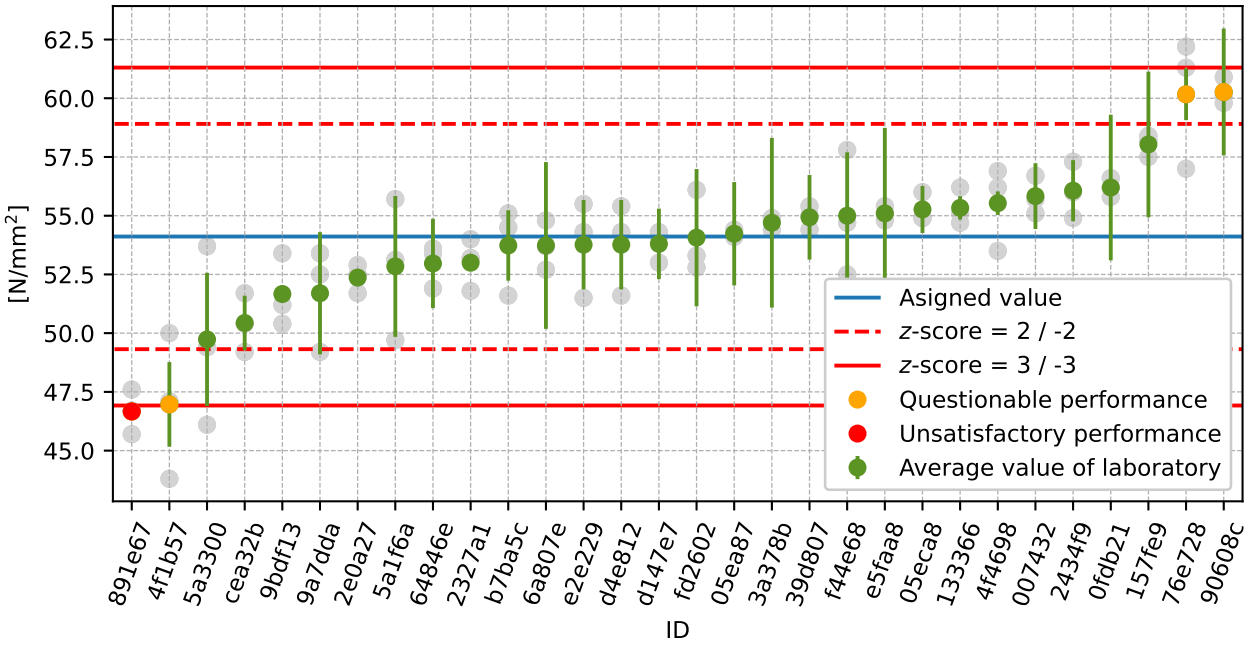

Figure 7: Average values and extended uncertainties of measurement

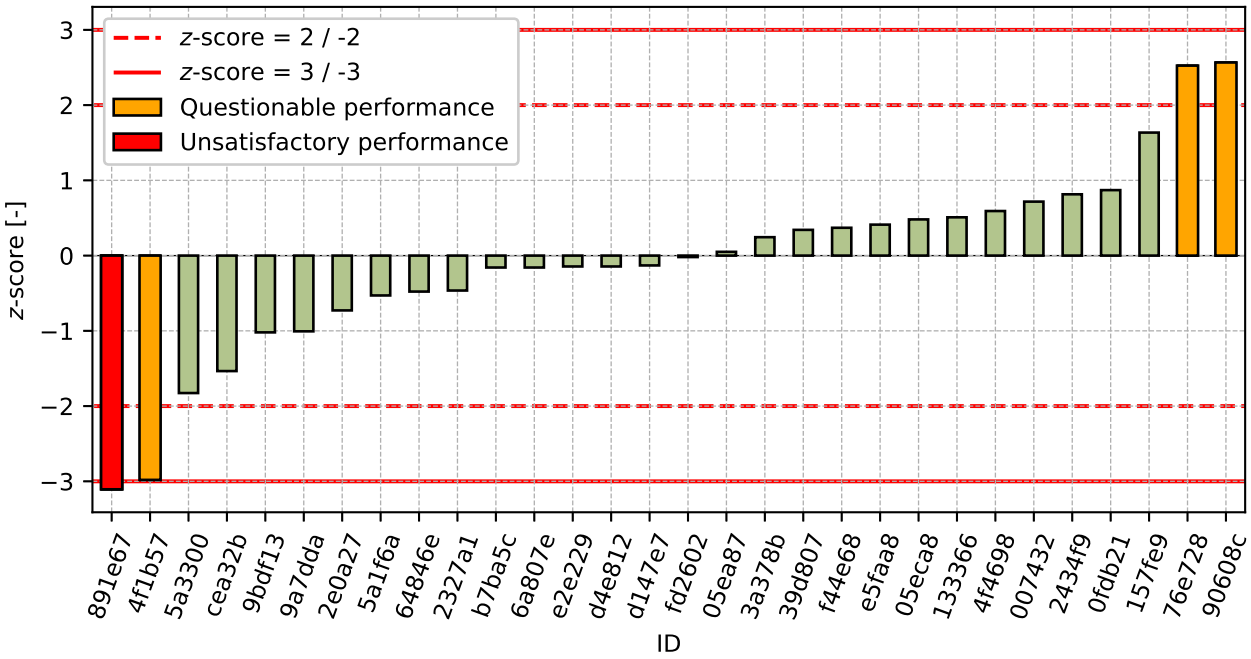

Figure 8: z-score

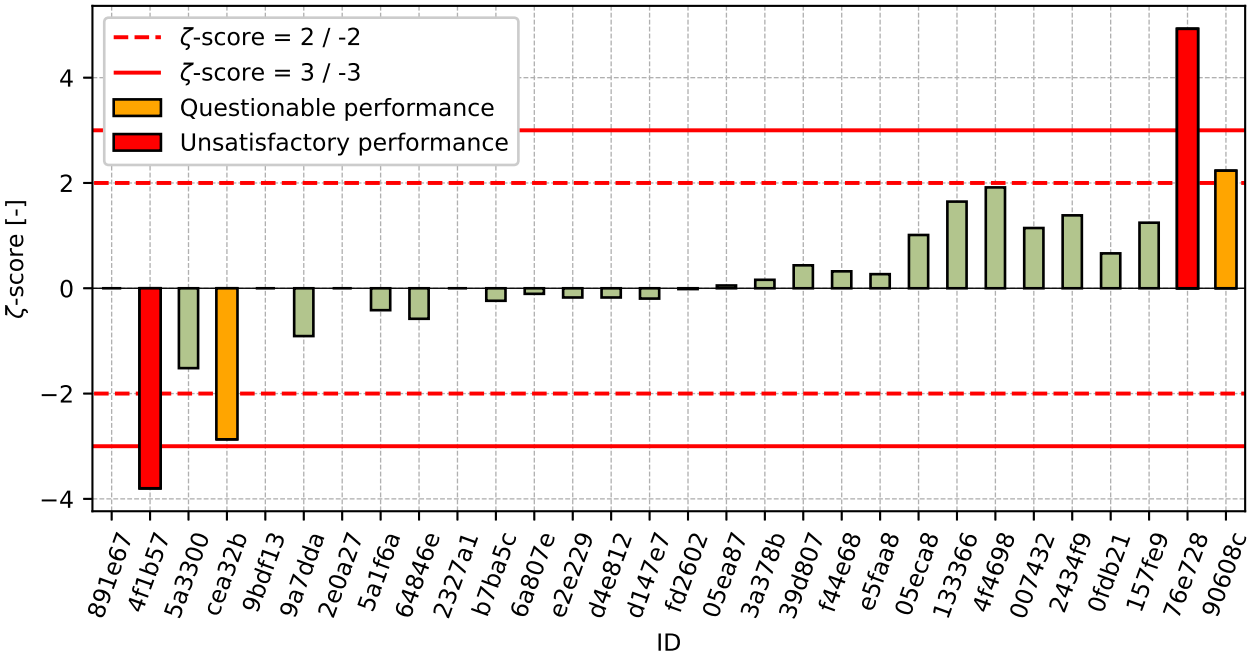

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
891e67	-3.11	-
4f1b57	-2.98	-3.8
5a3300	-1.83	-1.52
cea32b	-1.53	-2.87
9bdf13	-1.02	-
9a7dda	-1.01	-0.91
2e0a27	-0.73	-
5a1f6a	-0.53	-0.42
64846e	-0.48	-0.58
2327a1	-0.46	-
b7ba5c	-0.16	-0.24
6a807e	-0.16	-0.11
e2e229	-0.14	-0.18
d4e812	-0.14	-0.18
d147e7	-0.13	-0.2
fd2602	-0.02	-0.02
05ea87	0.05	0.05
3a378b	0.24	0.16
39d807	0.34	0.44
f44e68	0.37	0.32
e5faa8	0.41	0.27
05eca8	0.48	1.01
133366	0.51	1.65
4f4698	0.59	1.92
007432	0.72	1.14
2434f9	0.81	1.38
0fdb21	0.87	0.66
157fe9	1.63	1.25
76e728	2.52	4.93
90608c	2.57	2.23

2 Appendix – EN 12390-7 – Density of hardened concrete

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 [kg/m^3]			u_X [kg/m^3]	$\bar{x}$ [kg/m^3]	s_0 [kg/m^3]	V_X [%]
157fe9	2220	2240	2270	30	2243	25.2	1.12
2434f9	2260	2260	2270	32	2263	5.8	0.26
2e0a27	2270	2260	2270	-	2267	5.8	0.25
f44e68	2270	2270	2260	40	2267	5.8	0.25
5a1f6a	2280	2277	2252	15	2270	15.4	0.68
39d807	2260	2270	2280	11	2270	10.0	0.44
76cc78	2270	2280	2270	9	2273	5.8	0.25
76e728	2270	2280	2280	1	2277	5.8	0.25
007432	2280	2280	2270	32	2277	5.8	0.25
0fdb21	2280	2280	2280	20	2280	0.0	0.0
5a3300	2280	2270	2290	21	2280	10.0	0.44
9bdf13	2287	2273	2284	-	2281	7.4	0.32
b7ba5c	2280	2278	2287	4	2282	4.7	0.21
d4e812	2280	2290	2280	20	2283	5.8	0.25
e2e229	2290	2280	2290	20	2287	5.8	0.25
fd2602	2290	2290	2290	27	2290	0.0	0.0
4f4698	2290	2300	2290	20	2293	5.8	0.25
133366	2310	2280	2310	20	2300	17.3	0.75
e4a2bc	2308	2301	2304	25	2304	3.5	0.15

2.2 The Numerical Procedure for Determining Outliers

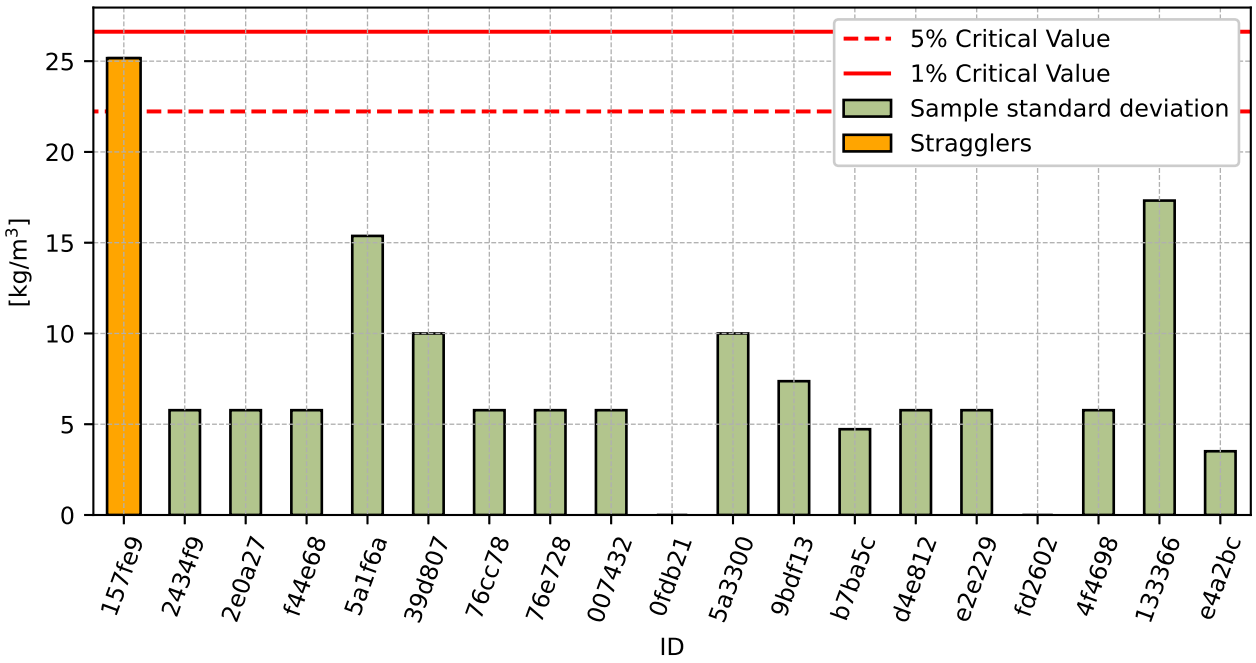

Figure 10: **Cochran's test** - sample standard deviations

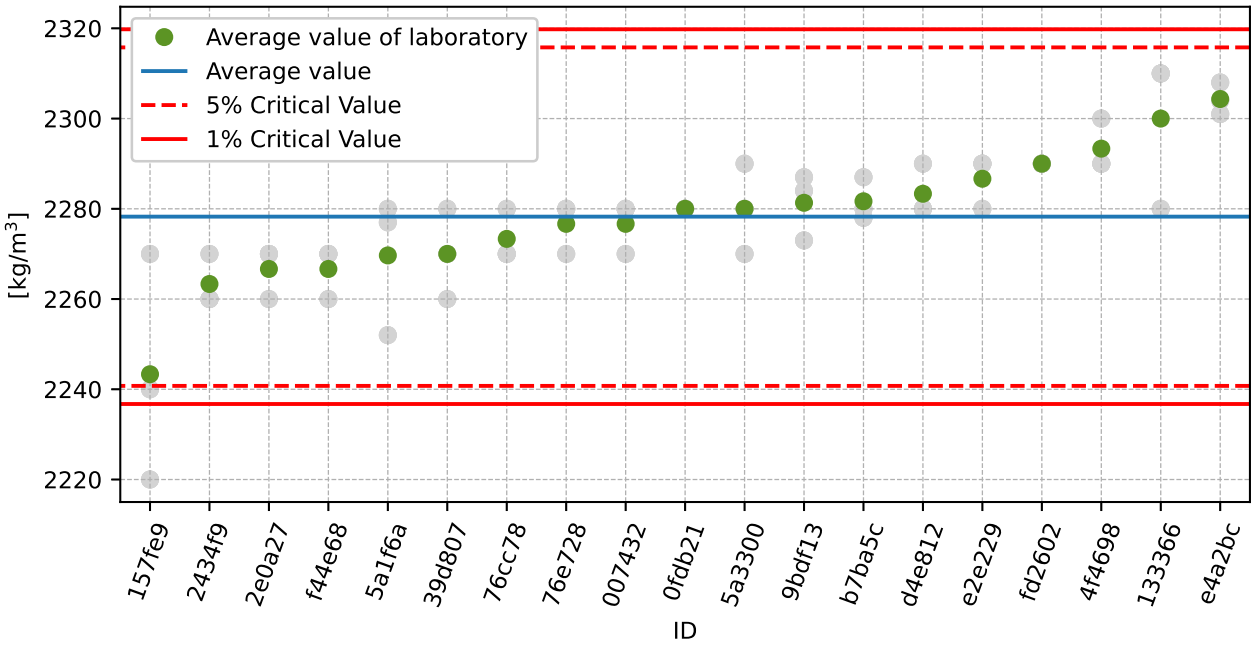

Figure 11: **Grubbs' test** - average values

2.3 Mandel's Statistics

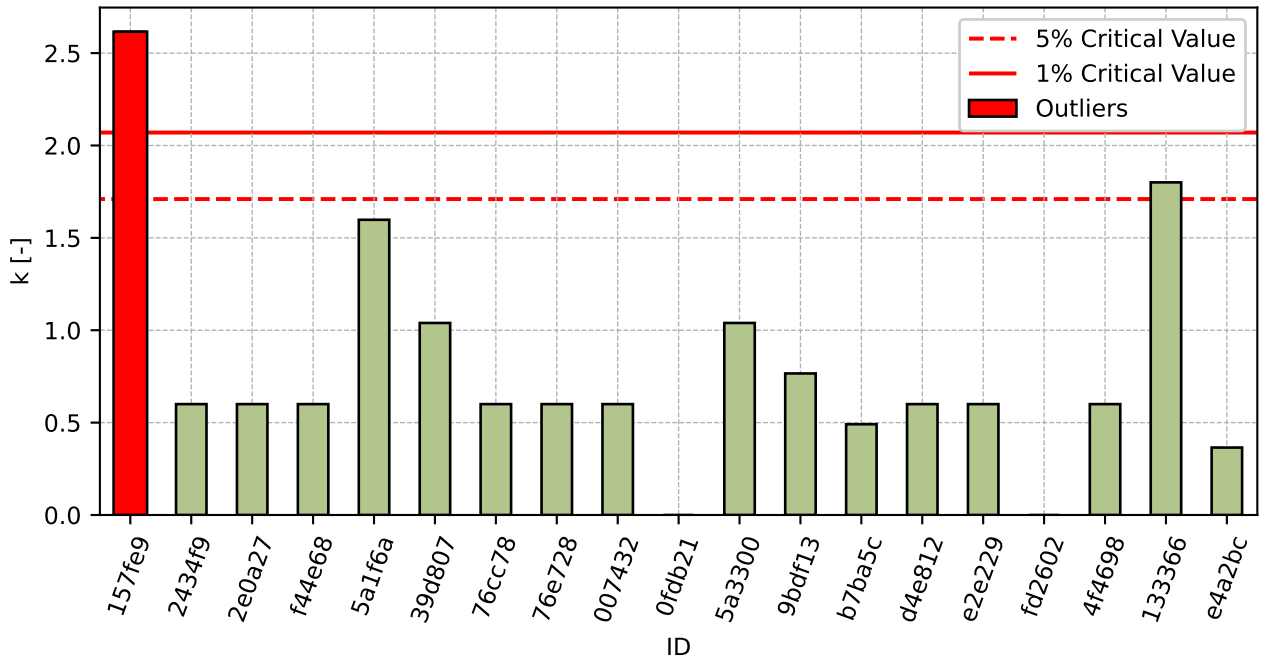

Figure 12: Intralaboratory Consistency Statistic

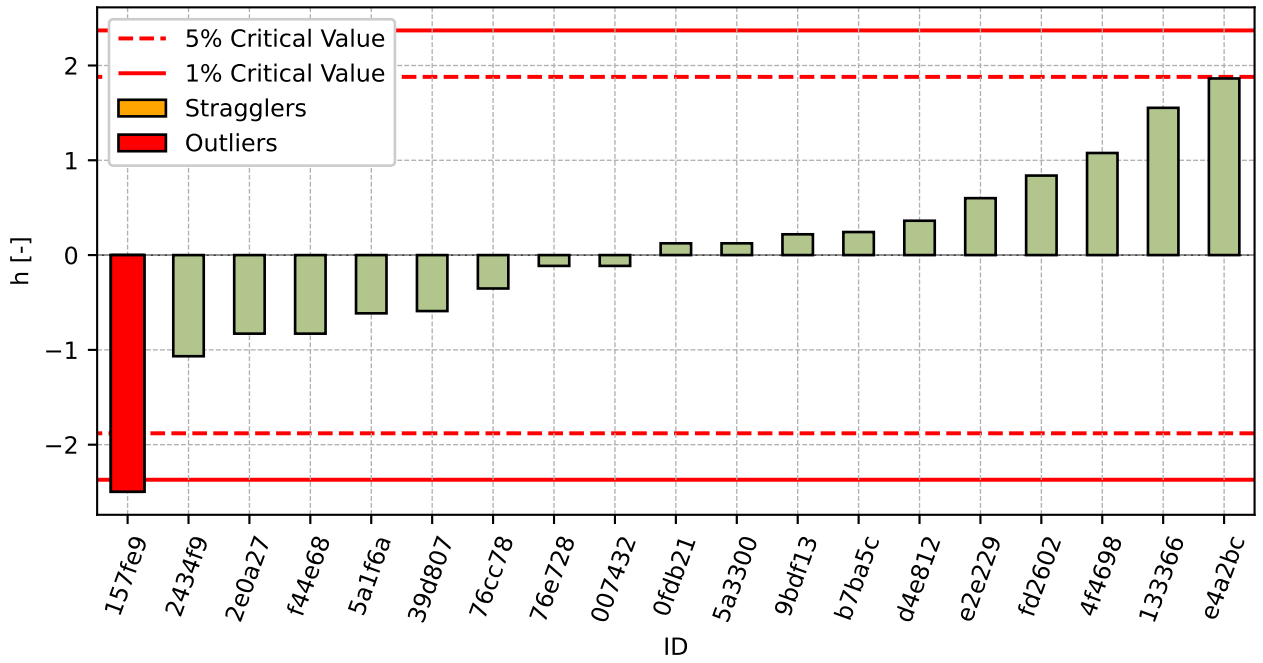

Figure 13: Interlaboratory Consistency Statistic

2.4 Descriptive statistics

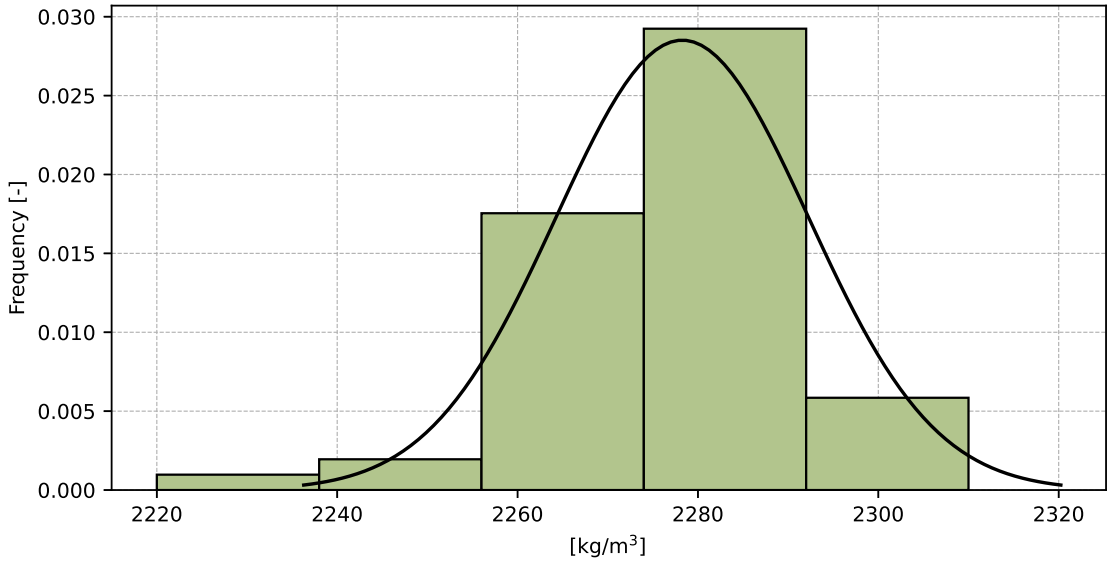

Figure 14: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	**[kg/m^3]**
Average value – $\bar{x}$	2278
Sample standard deviation – s	14.0
Asigned value – x^*	2279
Robust standard deviation – s^*	18.3
Measurement uncertainty of asigned value – u_X	3.8
p-value of normality test	0.002 [-]
Interlaboratory standard deviation – s_L	12.8
Repeatability standard deviation – s_r	9.6
Reproducibility standard deviation – s_R	16.0
Repeatability – r	27
Reproducibility – R	45

2.5 Evaluation of Performance Statistics

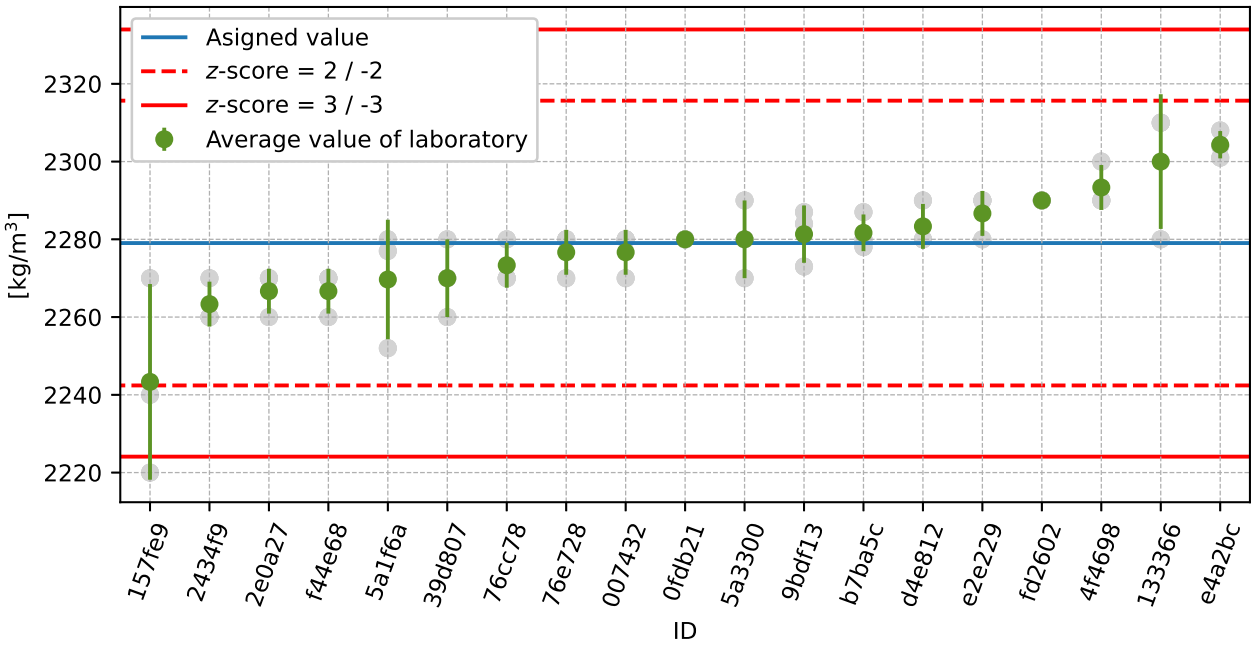

Figure 15: Average values and sample standard deviations

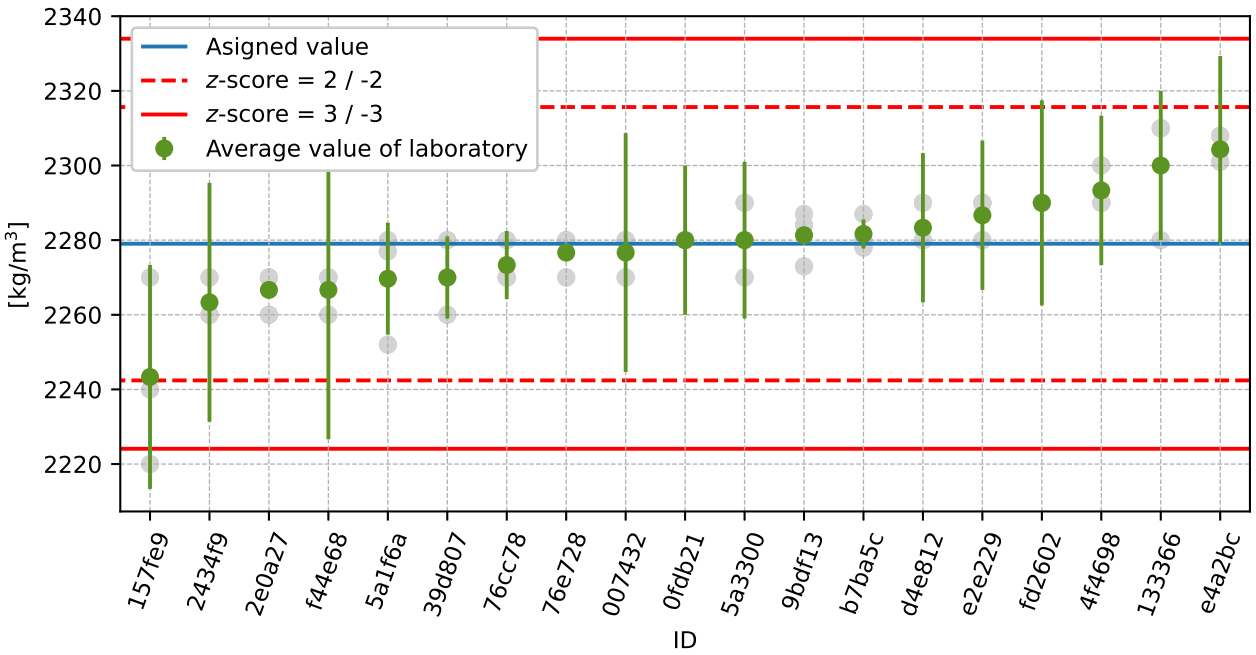

Figure 16: Average values and extended uncertainties of measurement

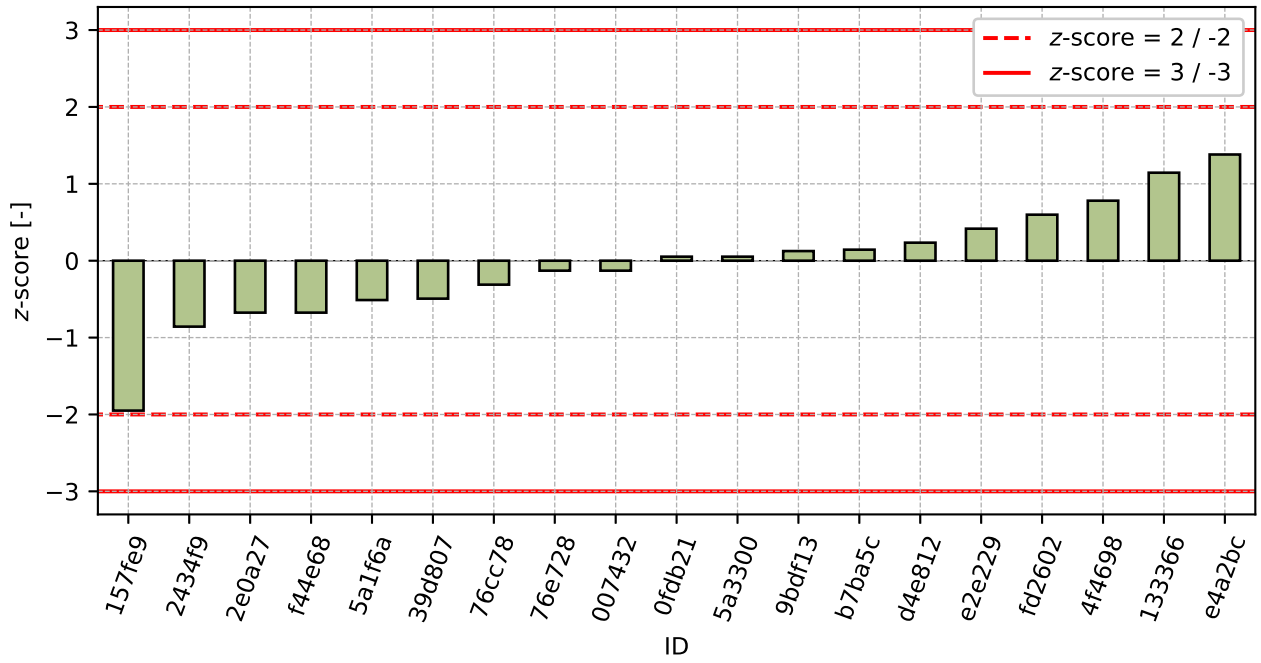

Figure 17: z-score

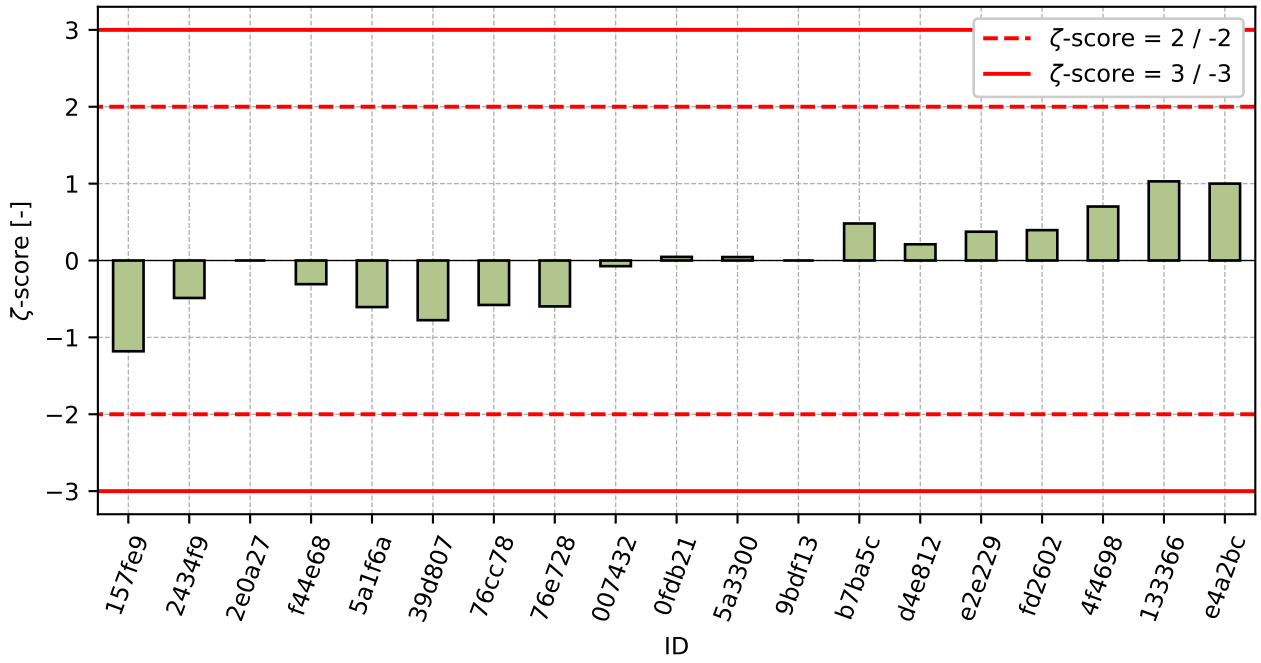

Figure 18: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
157fe9	-1.95	-1.18
2434f9	-0.86	-0.49
2e0a27	-0.68	-
f44e68	-0.68	-0.31
5a1f6a	-0.51	-0.61
39d807	-0.49	-0.78
76cc78	-0.31	-0.58
76e728	-0.13	-0.6
007432	-0.13	-0.07
0fdb21	0.05	0.05
5a3300	0.05	0.05
9bdf13	0.13	-
b7ba5c	0.14	0.48
d4e812	0.23	0.21
e2e229	0.42	0.37
fd2602	0.6	0.39
4f4698	0.78	0.7
133366	1.14	1.03
e4a2bc	1.38	1.0

3 Appendix – EN 12390-8 – Depth of penetration of water under pressure

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 [mm]			u_X [mm]	$\bar{x}$ [mm]	s_0 [mm]	V_X [%]
76cc78	0	0	0	0	0	0.0	-
f27c19	9	5	3	1	6	3.1	53.91
73885a	9	7	6	-	7	1.5	20.83
a429d6	10	7	5	1	7	2.5	34.32
157fe9	6	9	10	1	8	2.1	24.98
f88d81	12	7	7	8	9	2.9	33.31
d4e812	8	10	9	1	9	1.0	11.11
ad394c	12	6	11	3	10	3.2	33.25
2e0a27	11	8	10	-	10	1.5	15.8
e2e229	11	10	8	1	10	1.5	15.8
121655	7	9	15	0	10	4.2	40.29
39d807	12	10	11	1	11	1.0	9.09
9bdf13	8	12	13	-	11	2.6	24.05
007432	12	10	11	1	11	1.0	9.09
2434f9	13	10	12	1	12	1.5	13.09
0fdb21	16	6	13	3	12	5.1	43.99
f44e68	6	20	10	3	12	7.2	60.09
05ea87	14	12	12	3	13	1.2	9.12
4f4698	13	14	11	2	13	1.5	12.06
b7ba5c	9	18	13	4	13	4.5	33.82
133366	13	12	15	2	13	1.5	11.46
b76ab4	12	17	17	2	15	2.9	18.83
e4a2bc	15	14	17	3	15	1.5	9.96
2327a1	18	14	15	-	16	2.1	13.29
2927a2	15	18	16	2	16	1.5	9.35
3a378b	15	19	16	0	17	2.1	12.49
e5faa8	21	15	15	0	17	3.5	20.38
eca2dd	17	16	18	1	17	1.0	5.88
92e29f	14	22	17	-	18	4.0	22.88
6a807e	61	66	58	1	62	4.0	6.55

3.2 The Numerical Procedure for Determining Outliers

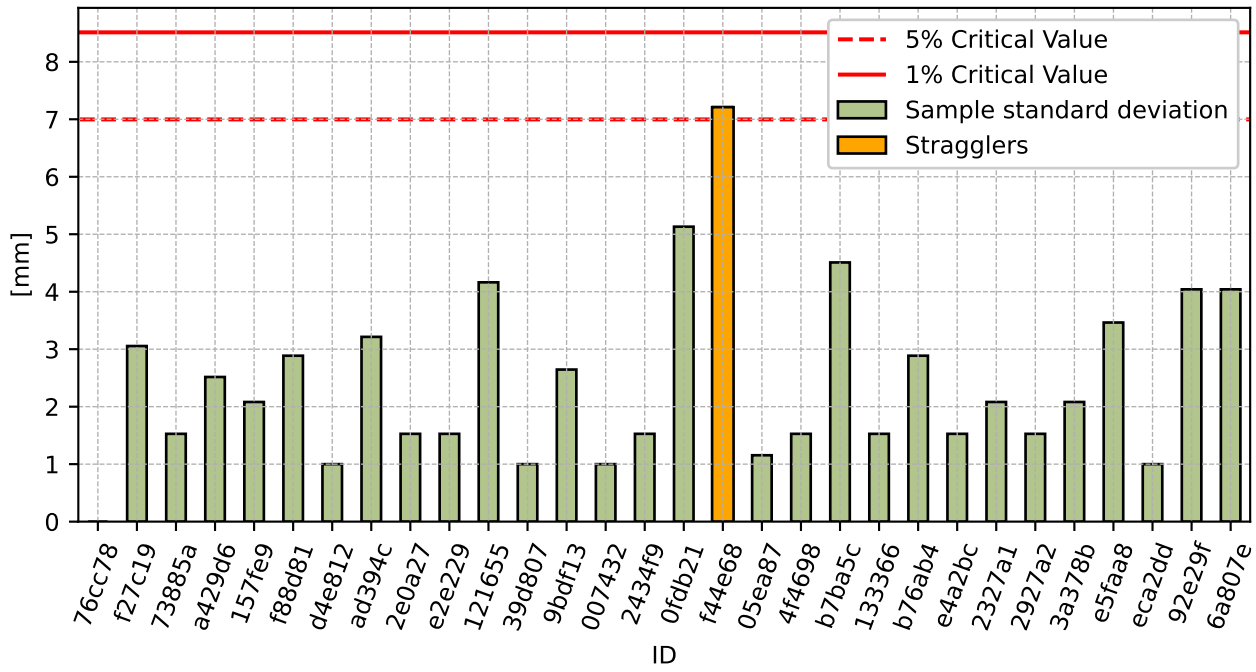

Figure 19: **Cochran's test** - sample standard deviations

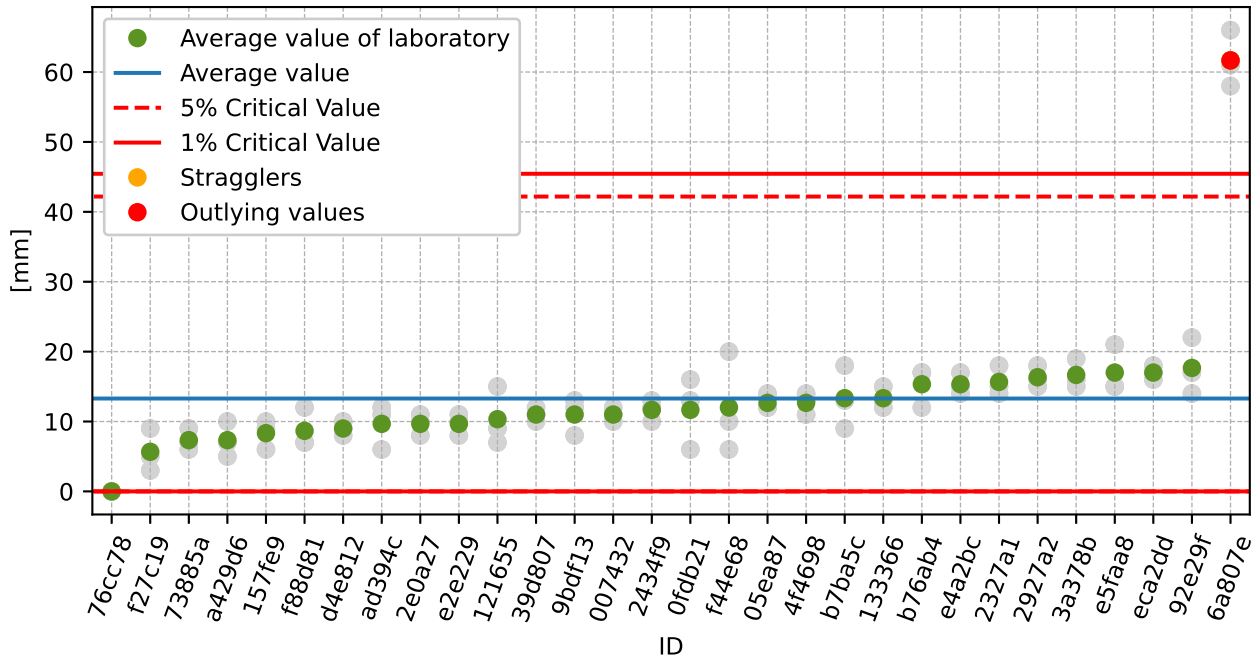

Figure 20: **Grubbs' test** - average values

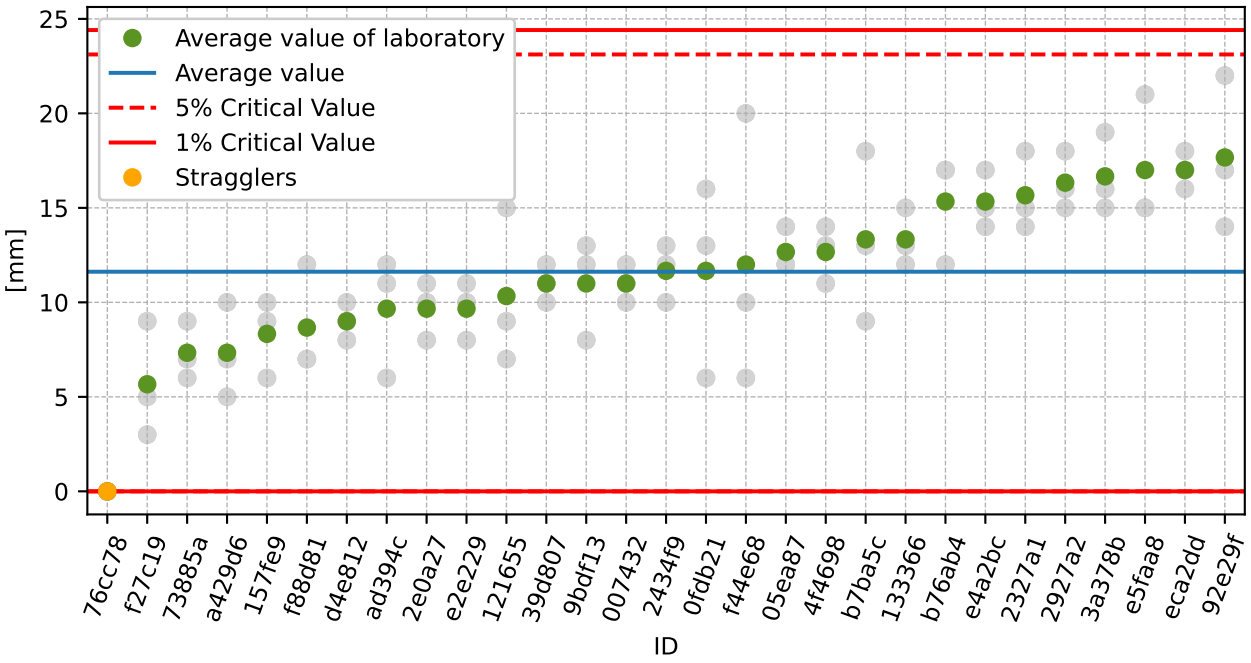

Figure 21: **Grubbs' test** - average values without outliers

3.3 Mandel's Statistics

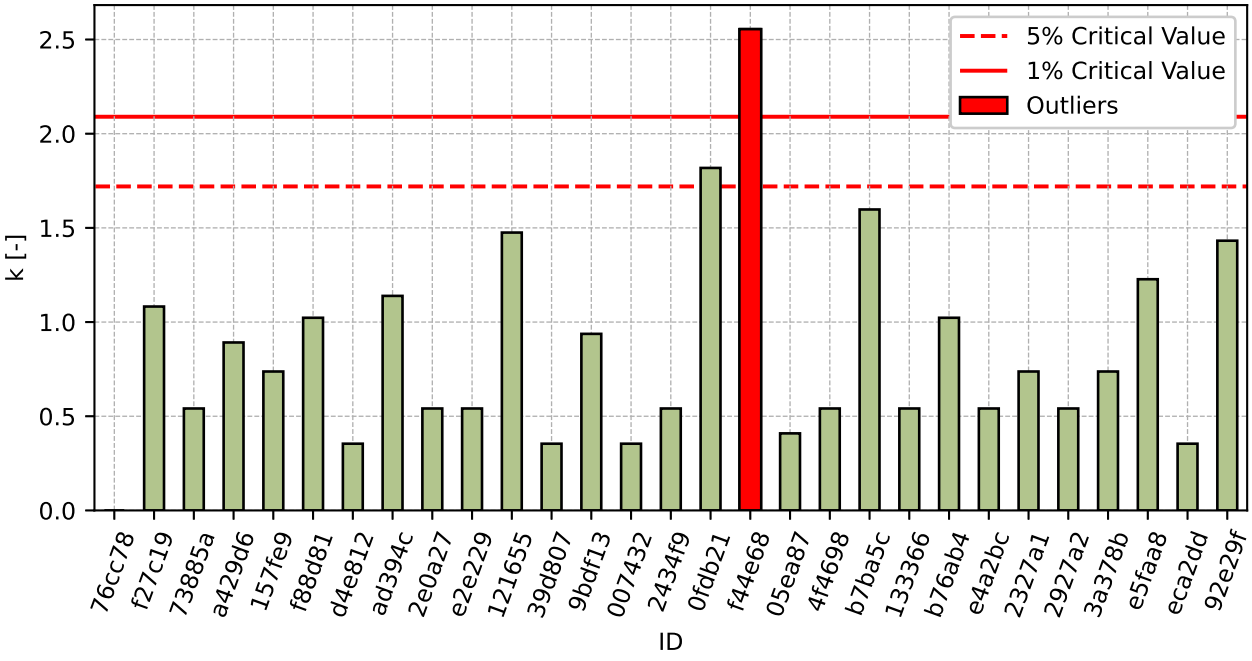

Figure 22: Intralaboratory Consistency Statistic

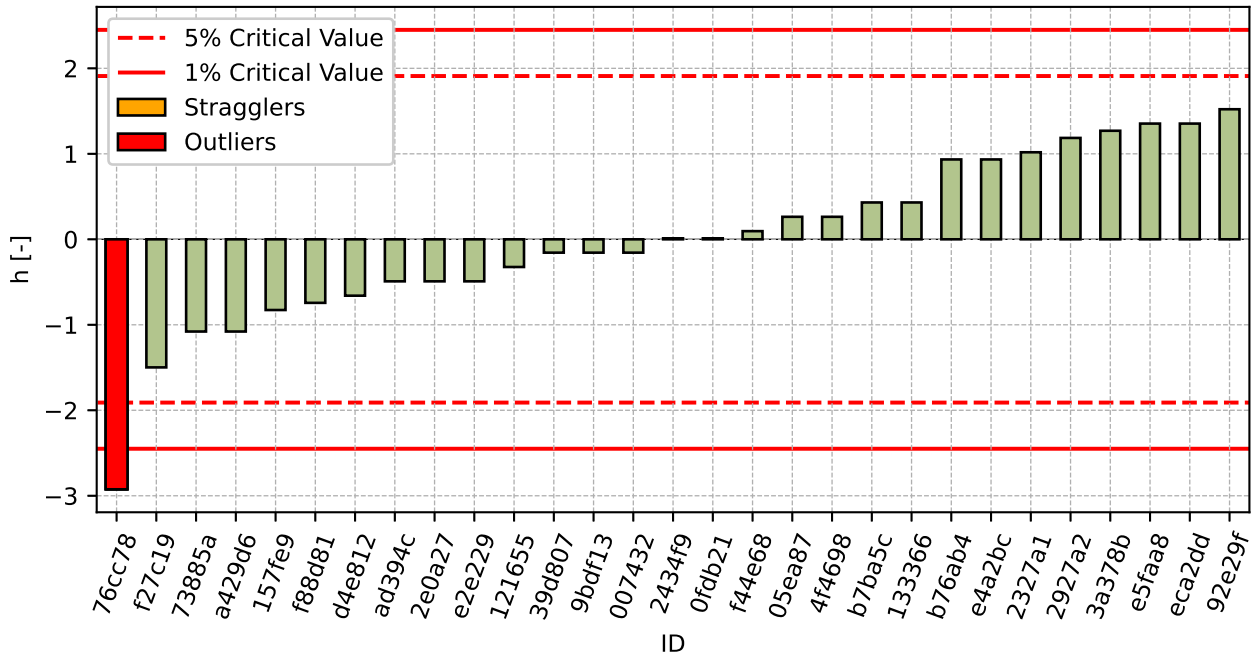

Figure 23: Interlaboratory Consistency Statistic

3.4 Descriptive statistics

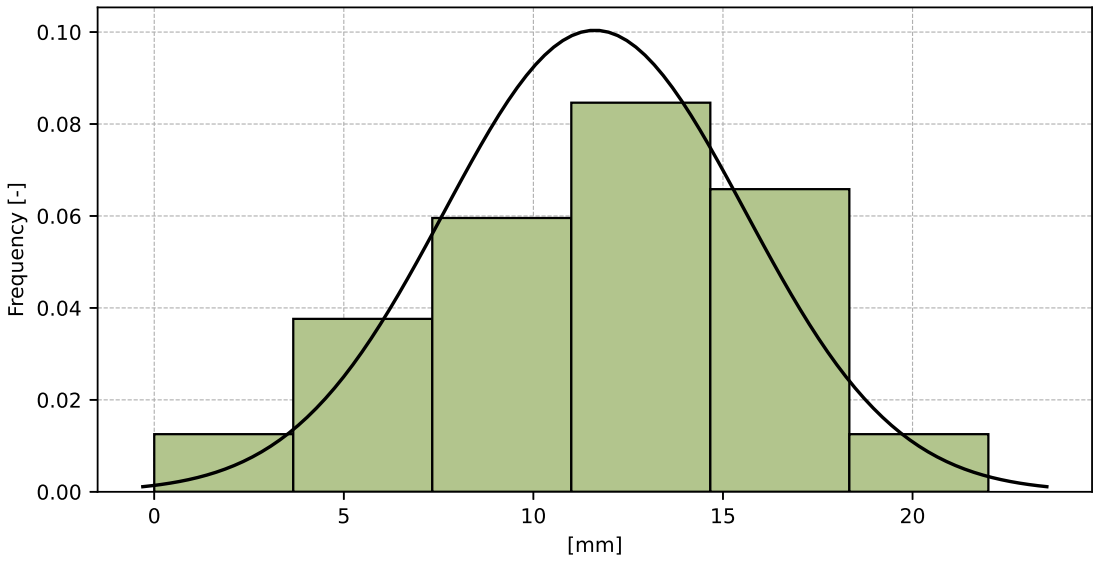

Figure 24: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[mm]
Average value – $\bar{x}$	12
Sample standard deviation – s	4.0
Asigned value – x^*	12
Robust standard deviation – s^*	4.0
Measurement uncertainty of asigned value – u_X	0.7
p-value of normality test	0.36 [-]
Interlaboratory standard deviation – s_L	3.6
Repeatability standard deviation – s_r	2.8
Reproducibility standard deviation – s_R	4.6
Repeatability – r	8
Reproducibility – R	13

3.5 Evaluation of Performance Statistics

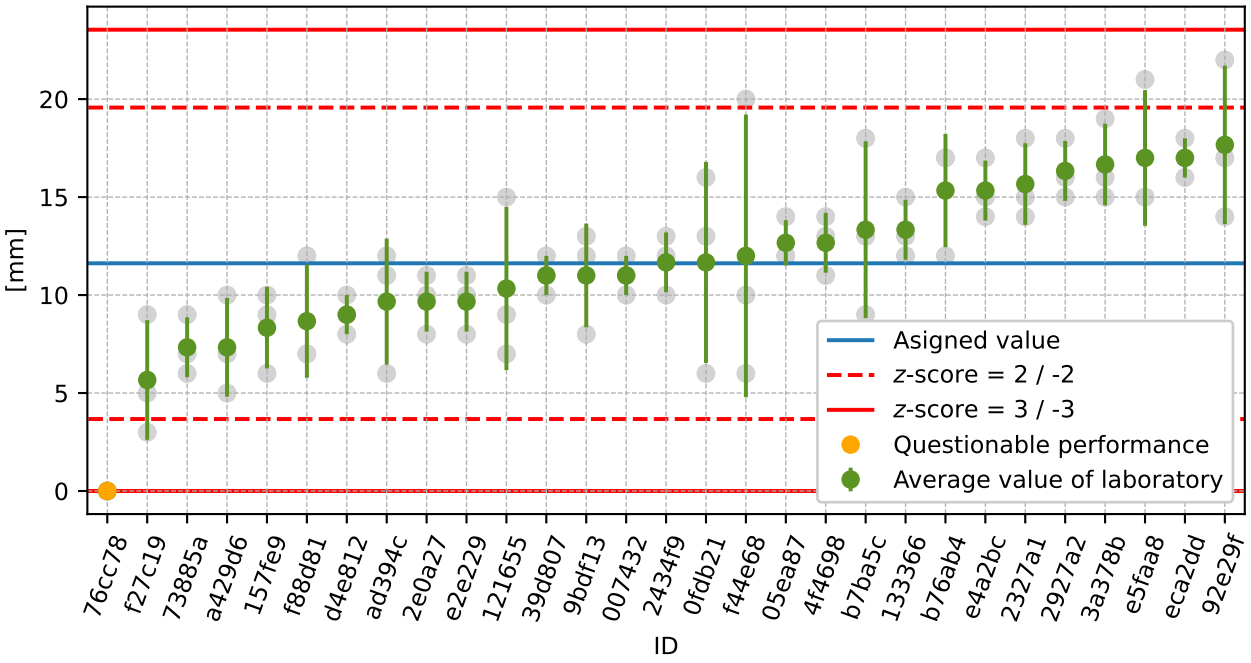

Figure 25: Average values and sample standard deviations

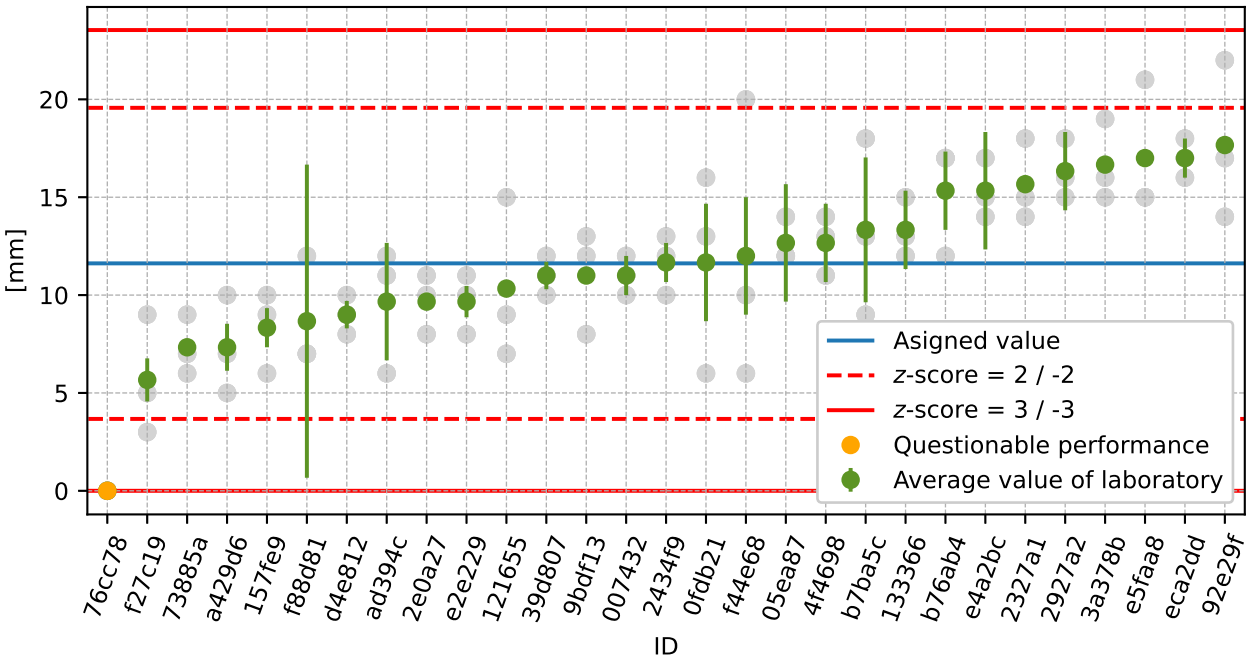

Figure 26: Average values and extended uncertainties of measurement

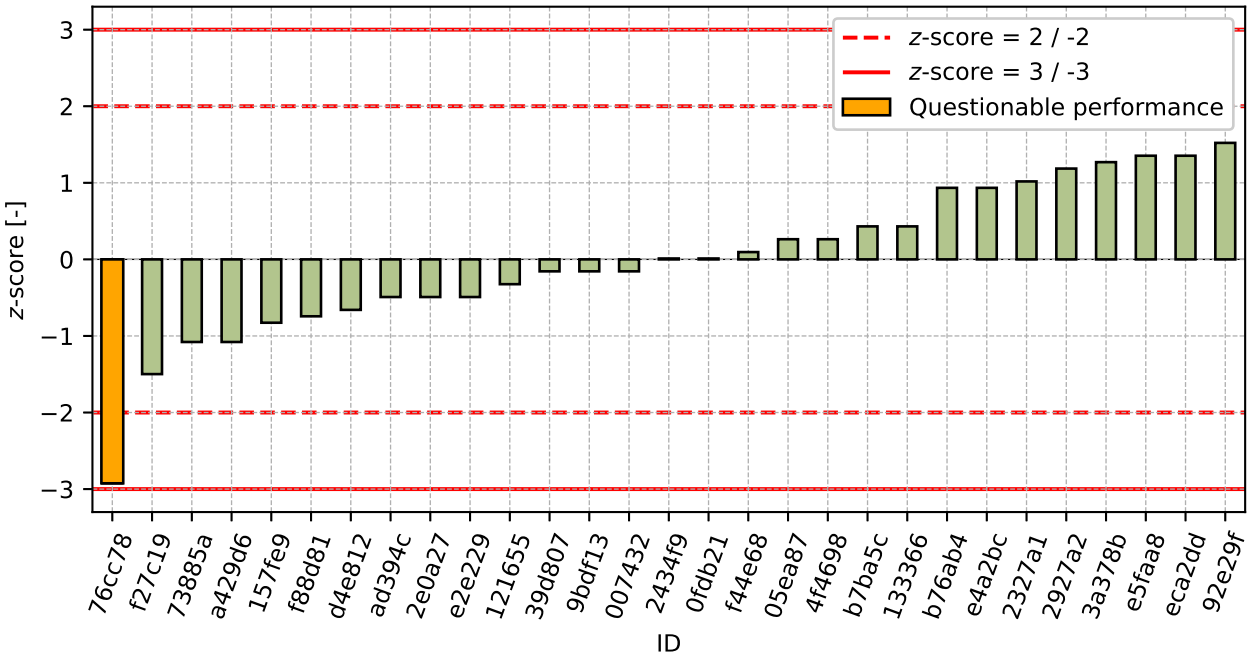

Figure 27: z-score

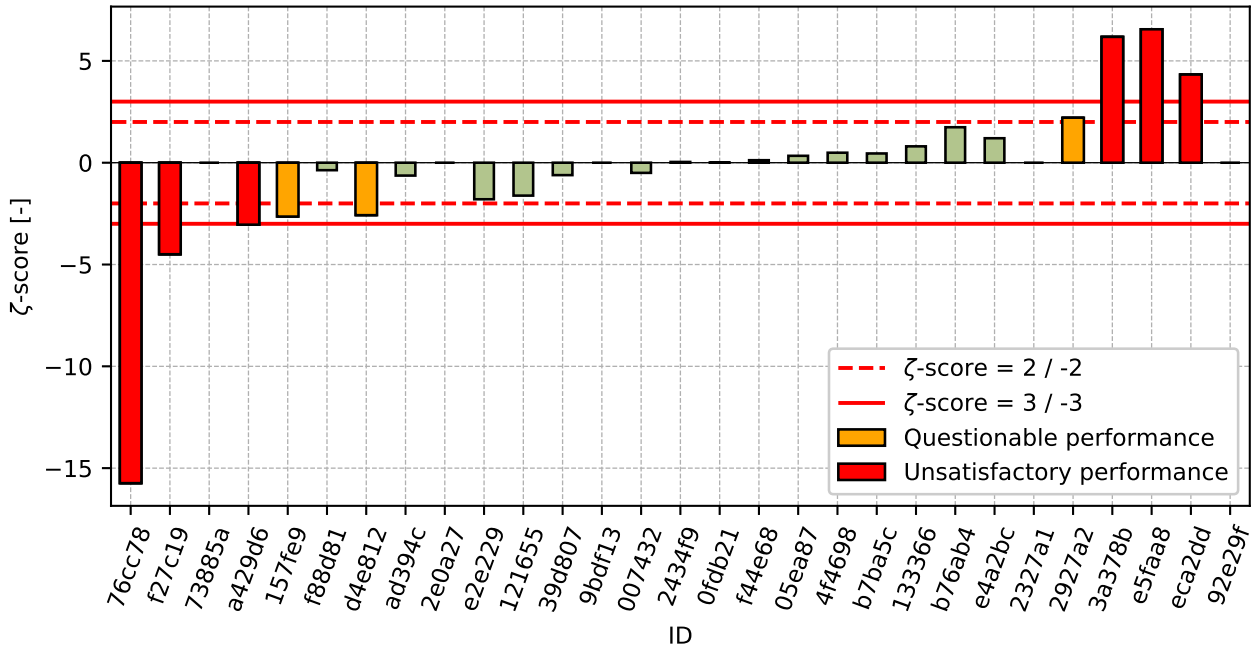

Figure 28: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
76cc78	-2.92	-15.74
f27c19	-1.5	-4.5
73885a	-1.08	-
a429d6	-1.08	-3.04
157fe9	-0.83	-2.65
f88d81	-0.74	-0.37
d4e812	-0.66	-2.58
ad394c	-0.49	-0.63
2e0a27	-0.49	-
e2e229	-0.49	-1.8
121655	-0.32	-1.62
39d807	-0.16	-0.61
9bdf13	-0.16	-
007432	-0.16	-0.5
2434f9	0.01	0.04
0fdb21	0.01	0.01
f44e68	0.1	0.12
05ea87	0.26	0.34
4f4698	0.26	0.49
b7ba5c	0.43	0.45
133366	0.43	0.8
b76ab4	0.93	1.74
e4a2bc	0.93	1.2

Continued on next page

Continued from previous page

ID	z-score [-]	ζ-score [-]
2327a1	1.02	-
2927a2	1.19	2.21
3a378b	1.27	6.18
e5faa8	1.35	6.55
eca2dd	1.35	4.33
92e29f	1.52	-

4 Appendix – EN 480-11 – Determination of air void characteristics in hardened concrete

4.1 Total air content

4.1.1 Test results

Table 13: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [%]	u_X [%]
a33d21	1.77	-
fe2c05	2.6	0.2
2c0aaf	3.9	3.0
4c358f	4.39	-
1f6871	4.89	-
121655	5.87	0.86

4.1.2 The Numerical Procedure for Determining Outliers

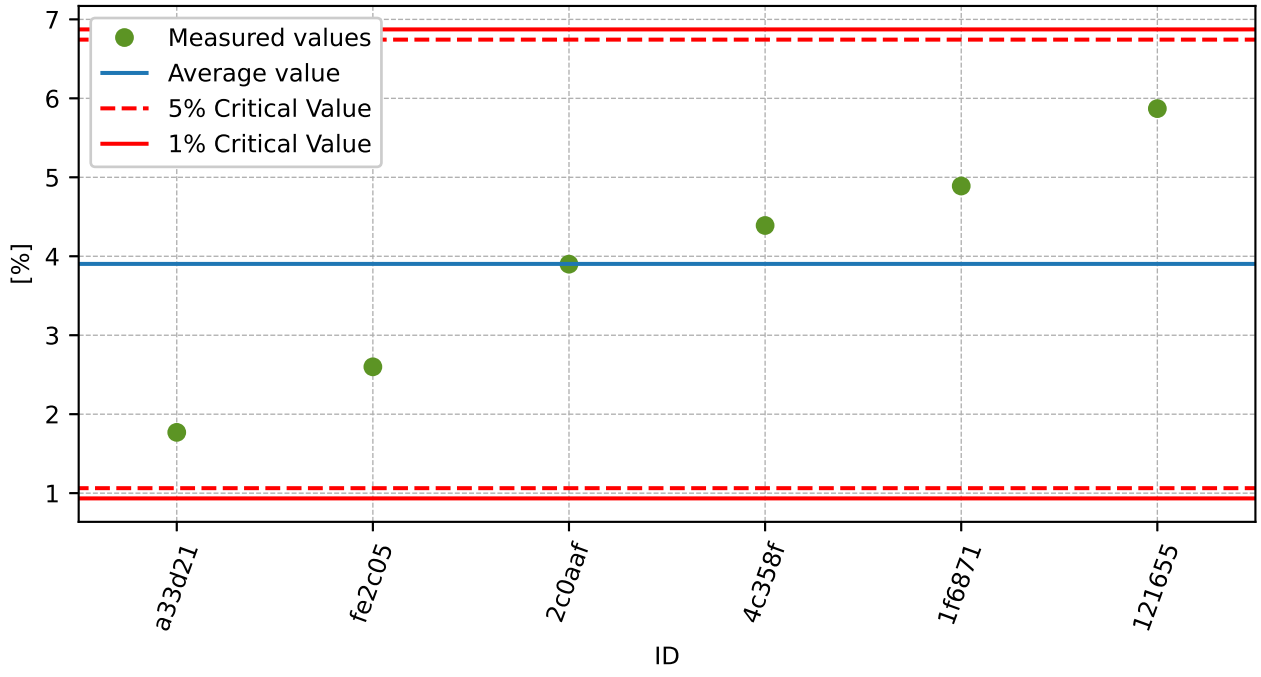

Figure 29: **Grubbs' test** - average values

4.1.3 Mandel's Statistics

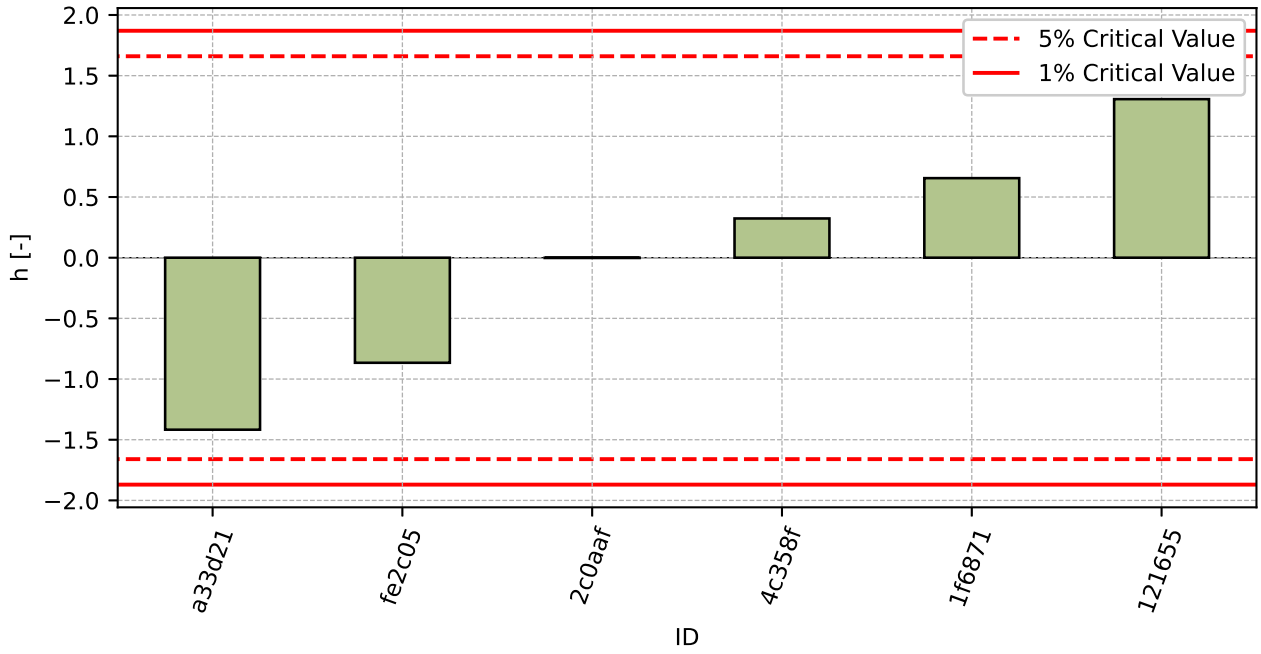

Figure 30: Interlaboratory Consistency Statistic

4.1.4 Descriptive statistics

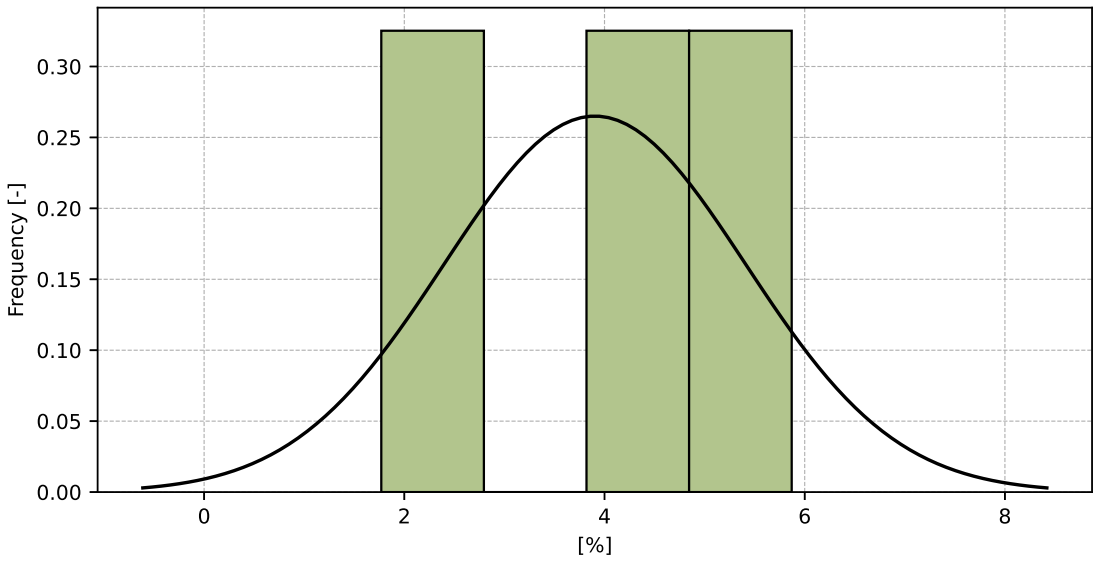

Figure 31: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	3.9
Sample standard deviation – s	1.505
Asigned value – x^*	3.9
Robust standard deviation – s^*	1.558
Measurement uncertainty of asigned value – u_X	0.795
p-value of normality test	0.92 [-]

4.1.5 Evaluation of Performance Statistics

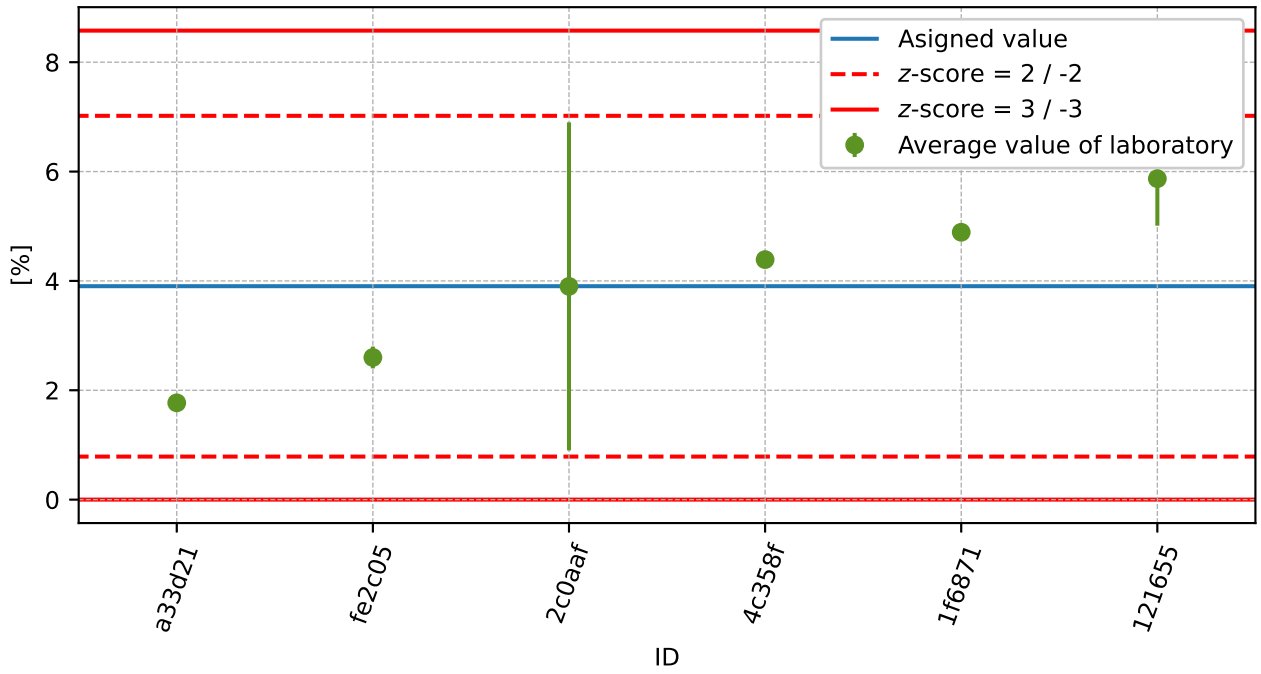

Figure 32: Average values and extended uncertainties of measurement

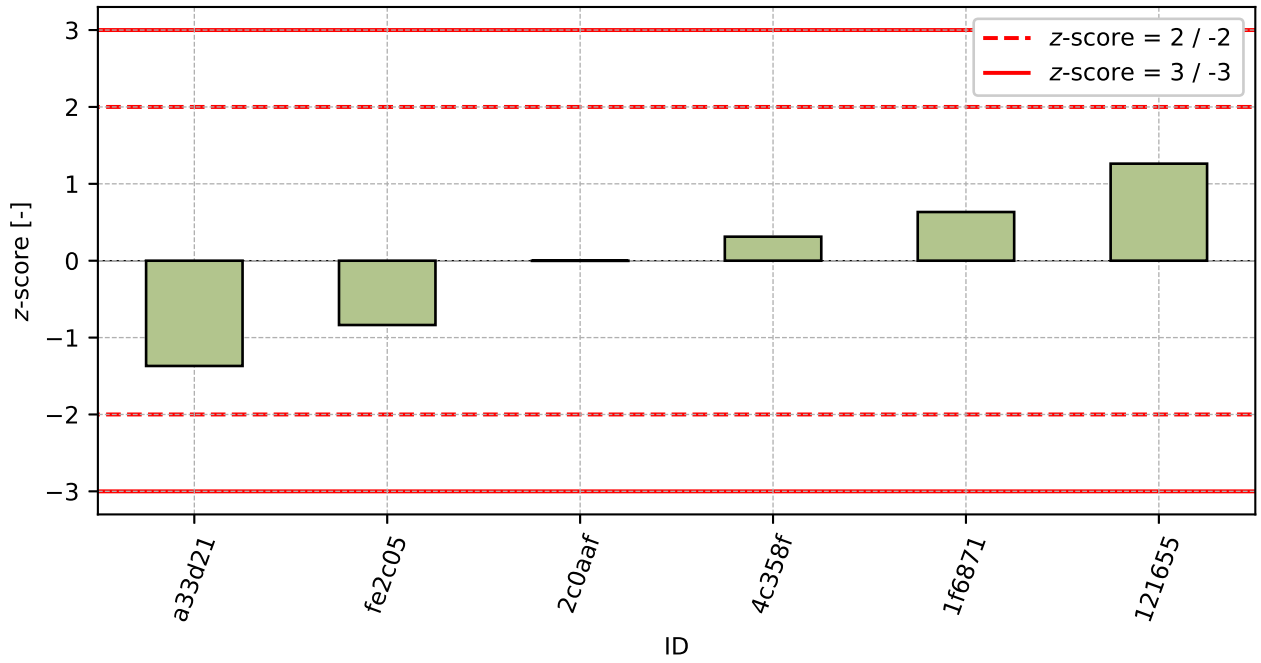

Figure 33: z-score

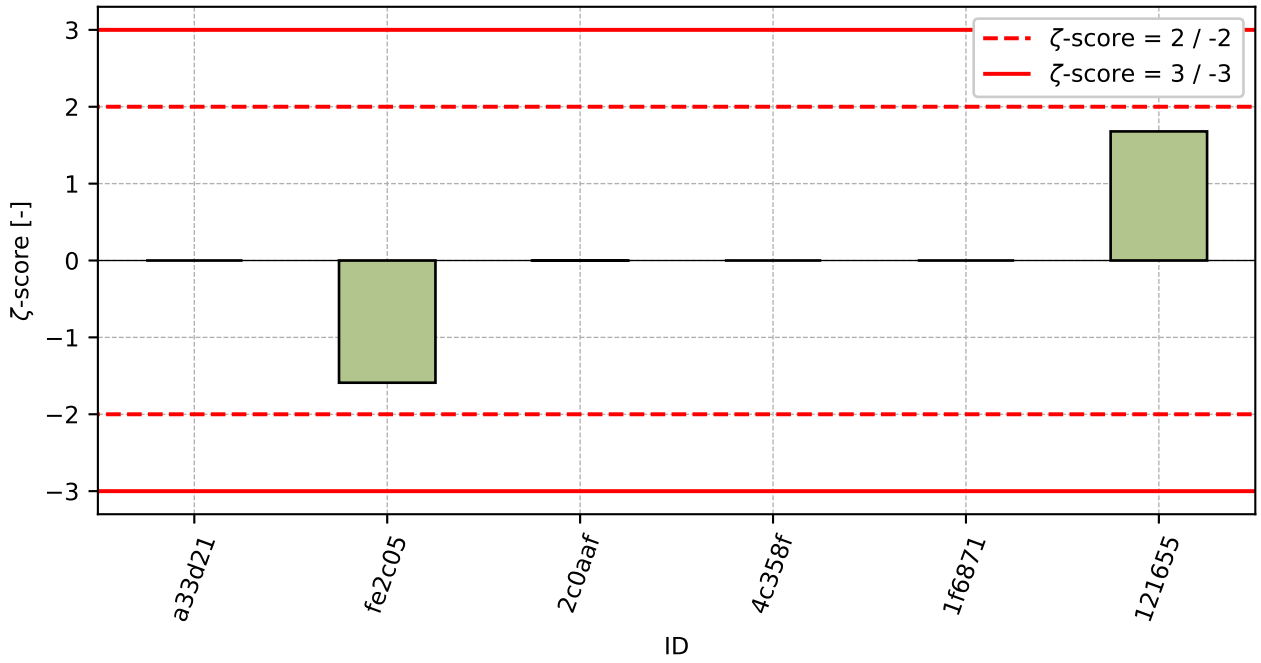

Figure 34: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a33d21	-1.37	-
fe2c05	-0.84	-1.59
2c0aaf	-0.0	-0.0
4c358f	0.31	-
1f6871	0.63	-
121655	1.26	1.68

4.2 Micro air content A_{300}

4.2.1 Test results

Table 16: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [%]	u_X [%]
a33d21	0.71	-
fe2c05	0.8	0.06
4c358f	0.93	-
1f6871	0.97	-
2c0aaf	1.4	3.0
121655	2.33	0.47

4.2.2 The Numerical Procedure for Determining Outliers

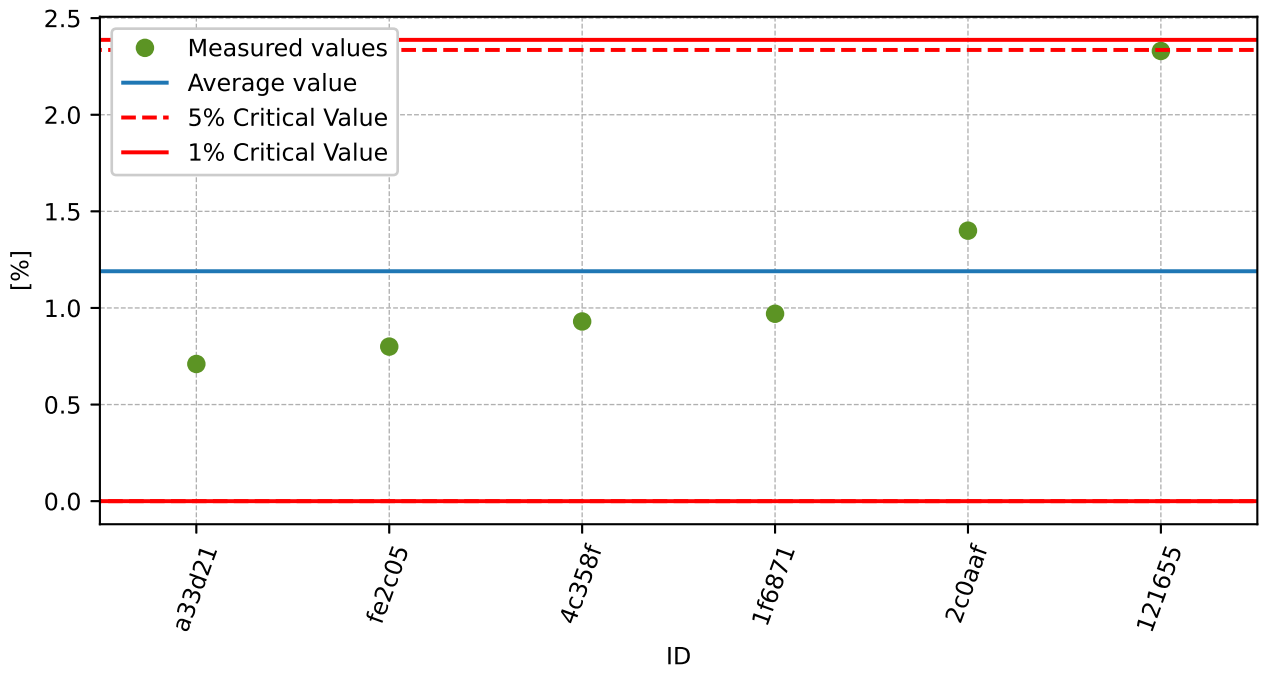

Figure 35: **Grubbs' test** - average values

4.2.3 Mandel's Statistics

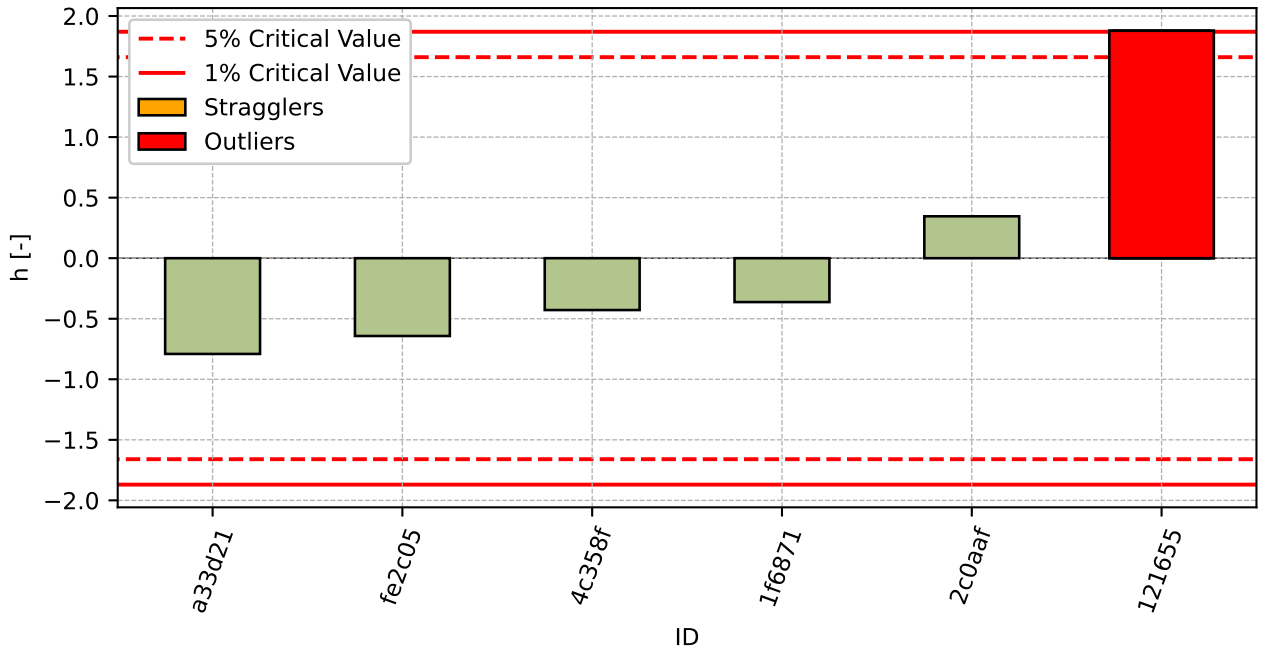

Figure 36: Interlaboratory Consistency Statistic

4.2.4 Descriptive statistics

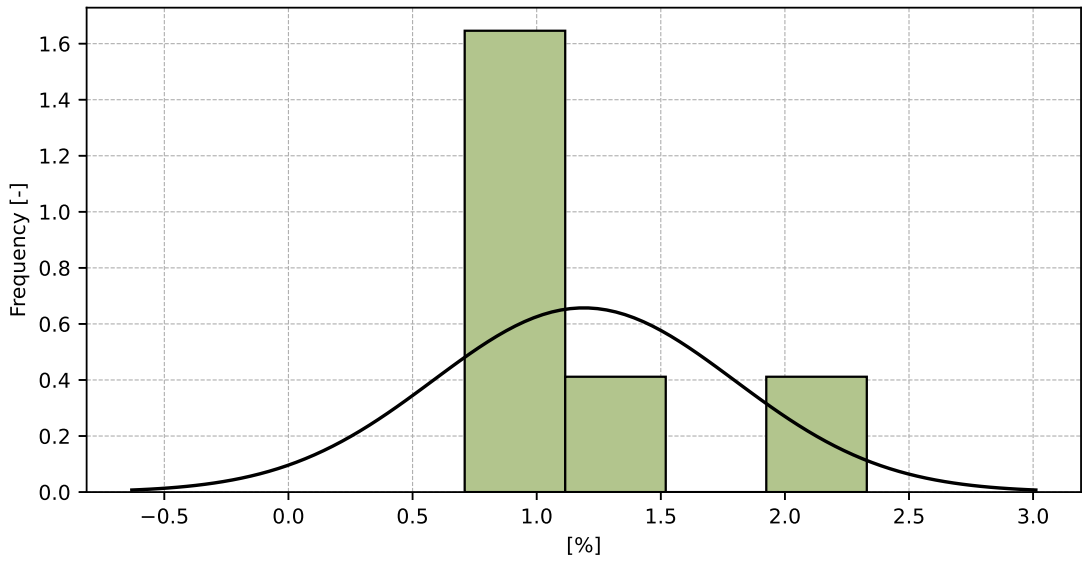

Figure 37: Histogram of all test results

Table 17: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	1.19
Sample standard deviation – s	0.607
Asigned value – x^*	1.19
Robust standard deviation – s^*	0.627
Measurement uncertainty of asigned value – u_X	0.32
p-value of normality test	0.058 [-]

4.2.5 Evaluation of Performance Statistics

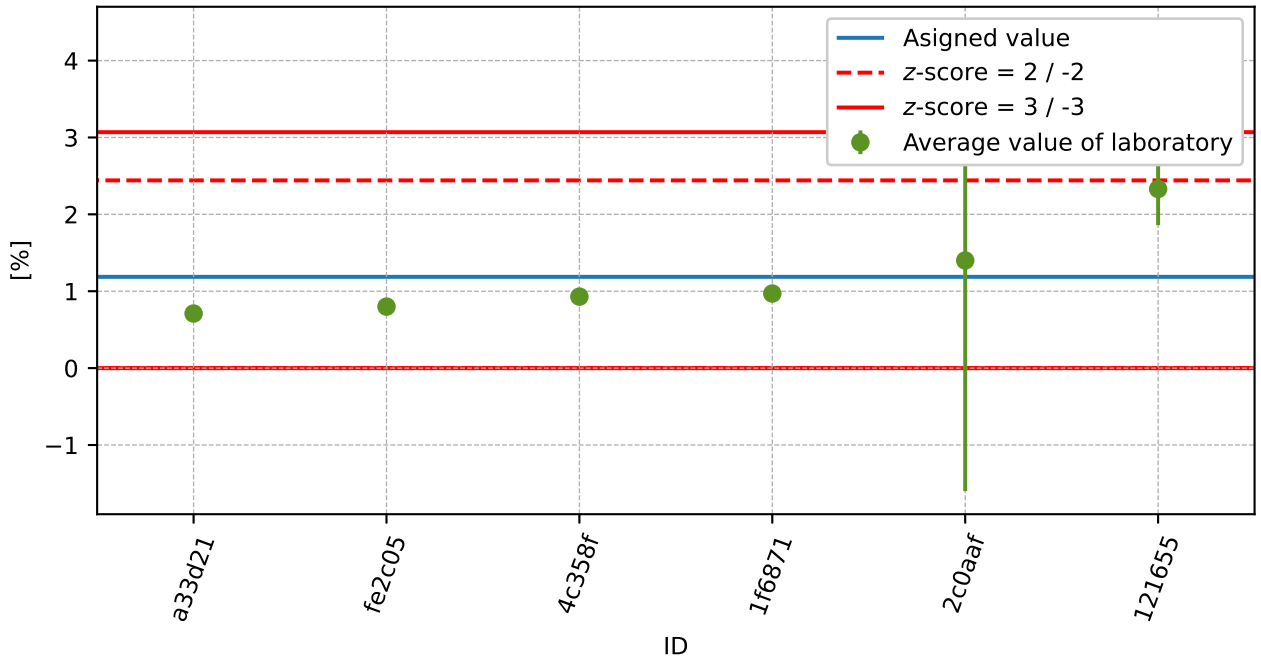

Figure 38: Average values and extended uncertainties of measurement

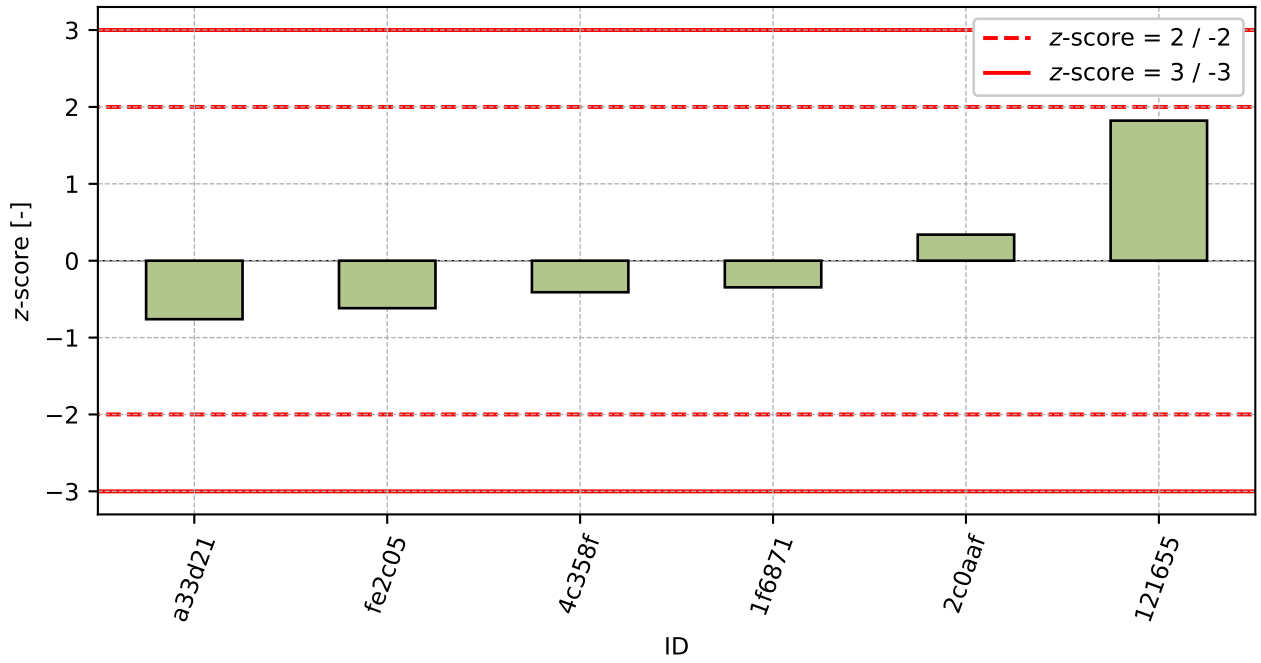

Figure 39: z-score

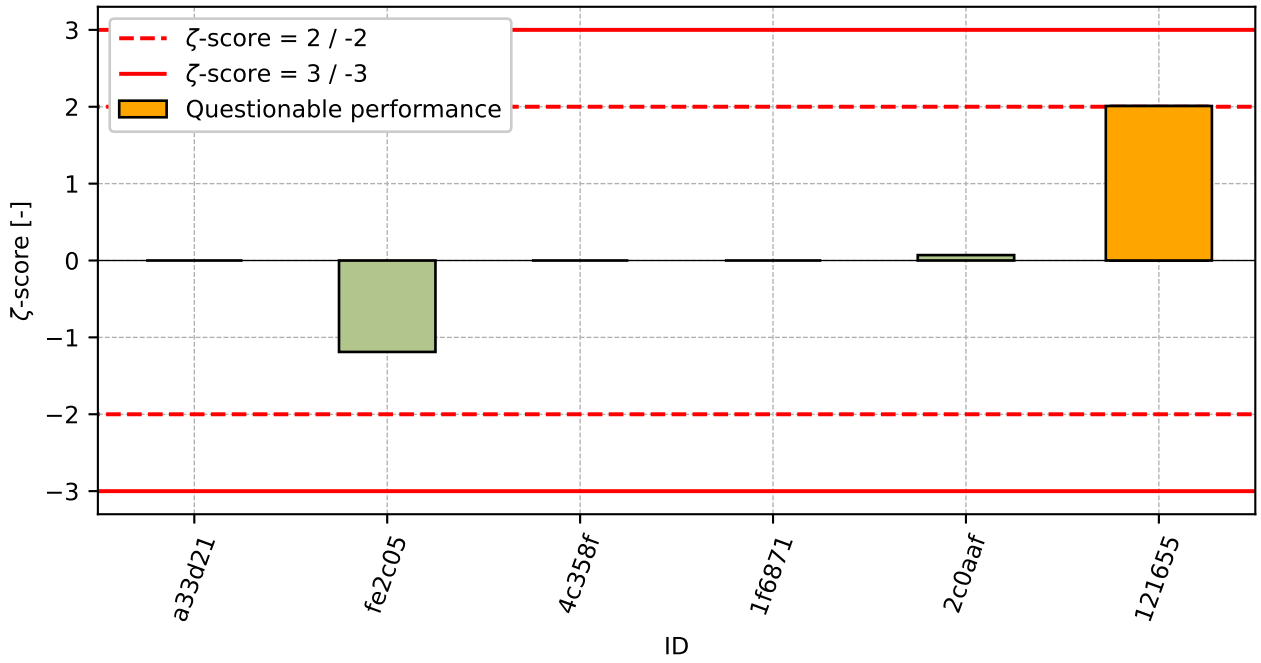

Figure 40: ζ-score

Table 18: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a33d21	-0.76	-
fe2c05	-0.62	-1.19
4c358f	-0.41	-
1f6871	-0.35	-
2c0aaf	0.34	0.07
121655	1.82	2.01

4.3 Spacing factor L

4.3.1 Test results

Table 19: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [mm]	u_X [mm]
2c0aaf	0.23	0.01
fe2c05	0.37	0.01
121655	0.38	0.06
a33d21	0.43	-
4c358f	0.45	-
1f6871	0.49	-

4.3.2 The Numerical Procedure for Determining Outliers

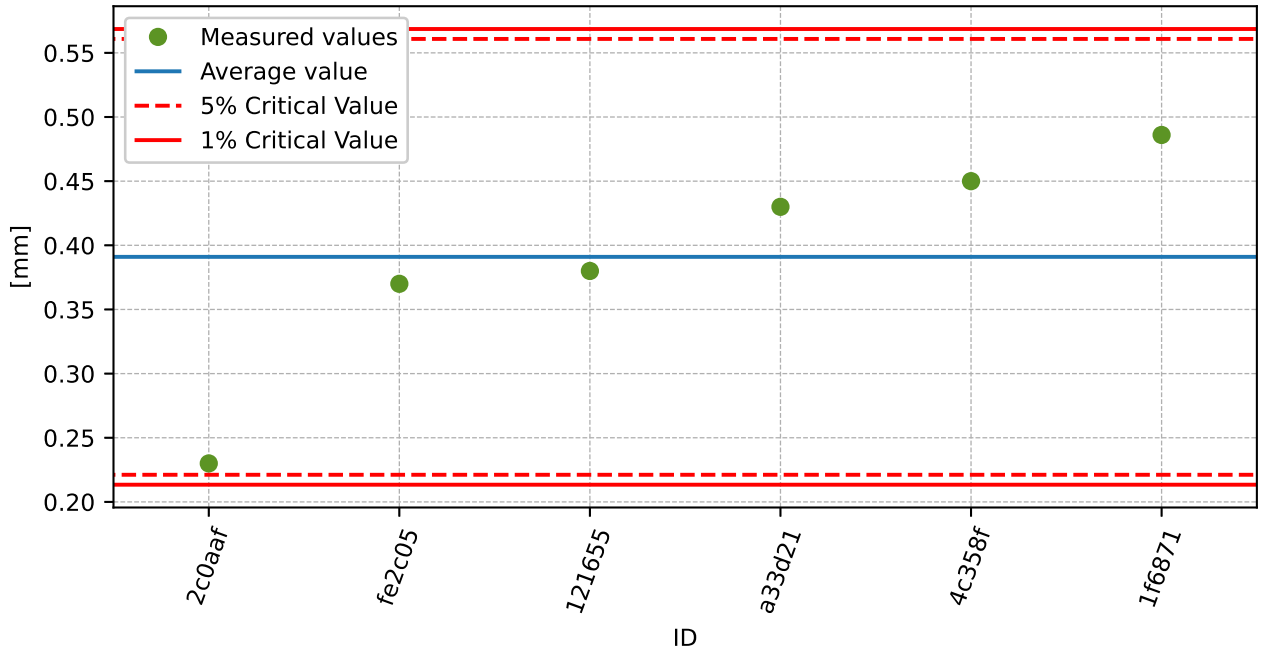

Figure 41: **Grubbs' test** - average values

4.3.3 Mandel's Statistics

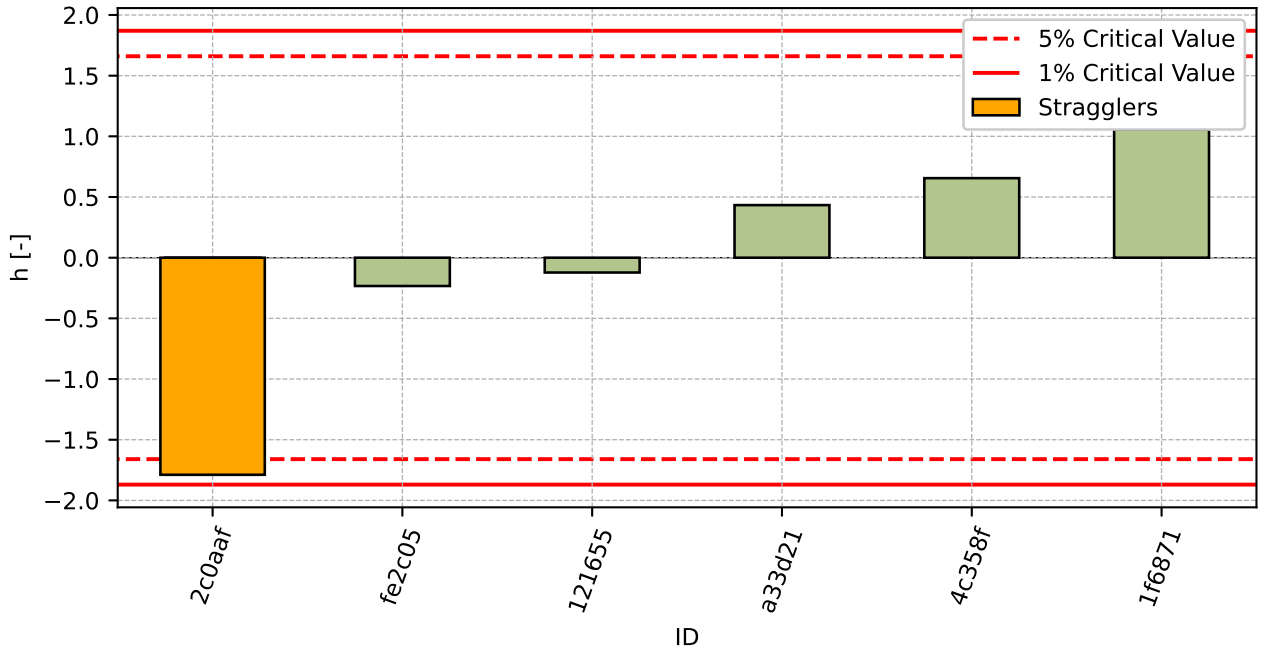

Figure 42: Interlaboratory Consistency Statistic

4.3.4 Descriptive statistics

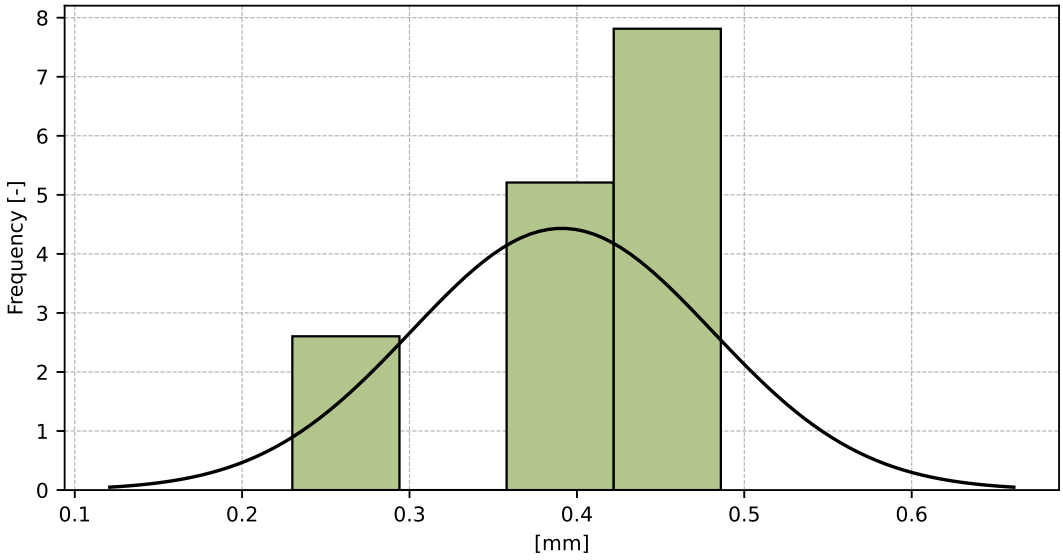

Figure 43: Histogram of all test results

Table 20: Descriptive statistics

Characteristics	[mm]
Average value – $\bar{x}$	0.39
Sample standard deviation – s	0.09
Asigned value – x^*	0.39
Robust standard deviation – s^*	0.09
Measurement uncertainty of asigned value – u_X	0.037
p-value of normality test	0.404 [-]

4.3.5 Evaluation of Performance Statistics

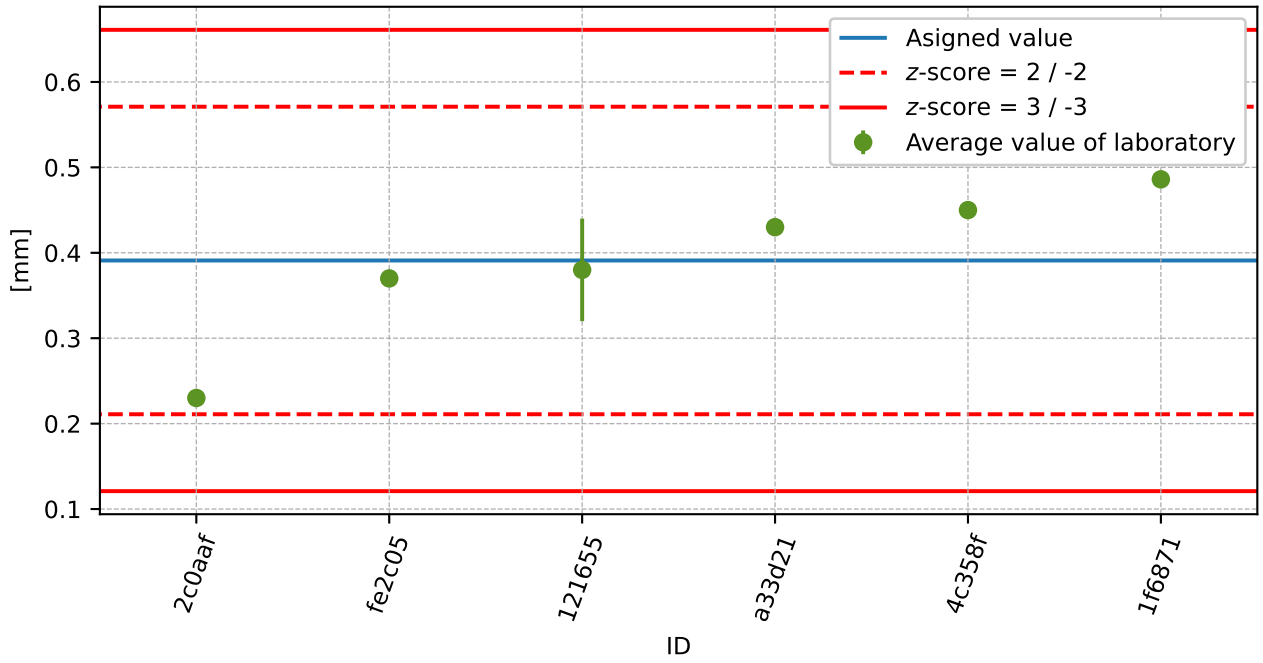

Figure 44: Average values and extended uncertainties of measurement

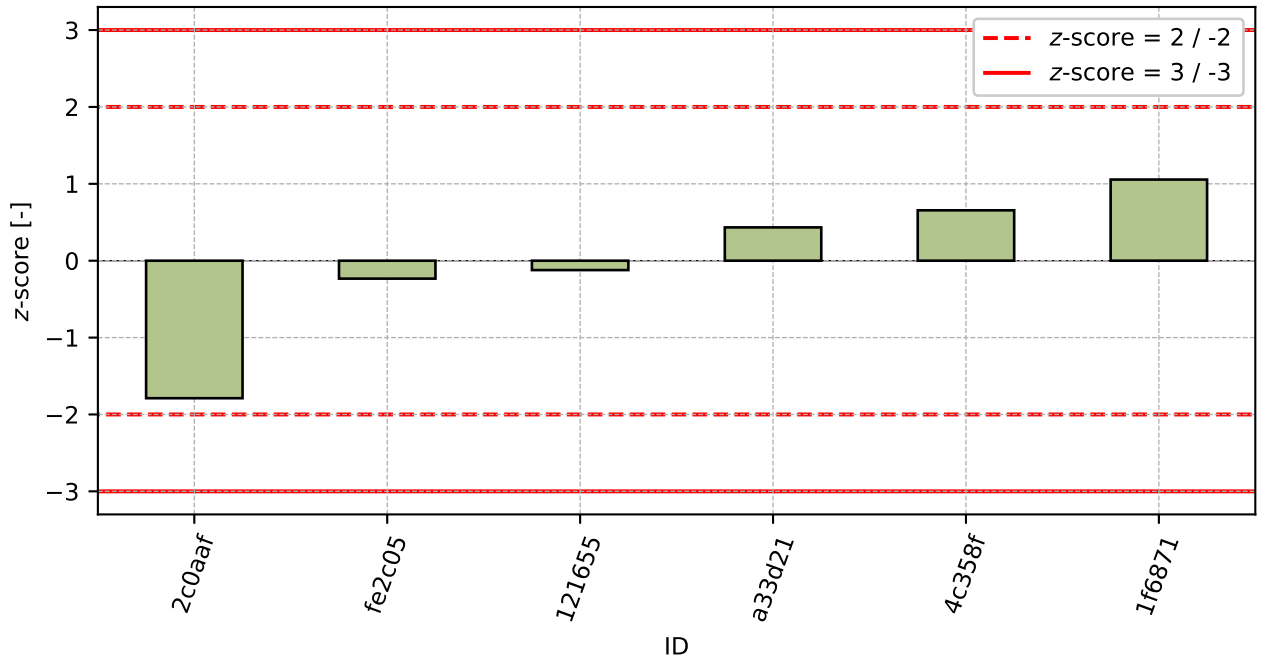

Figure 45: z-score

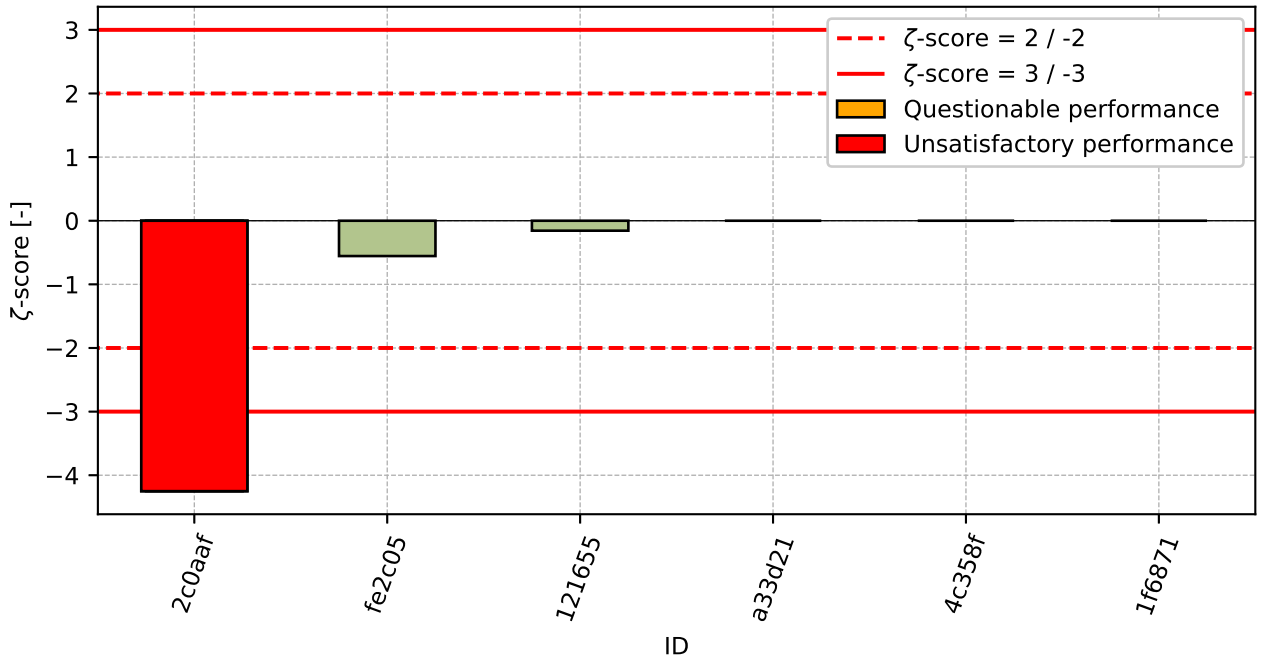

Figure 46: ζ-score

Table 21: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2c0aaf	-1.79	-4.25
fe2c05	-0.23	-0.56
121655	-0.12	-0.16
a33d21	0.43	-
4c358f	0.66	-
1f6871	1.06	-

5 Appendix – ČSN 73 1322 – Determination of frost resistance of concrete

5.1 Test results

Table 22: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [-]	u_X [-]
3a378b	0.71	0.05
157fe9	0.77	0.05
2327a1	0.78	-
e5faa8	0.82	0.05
57d070	0.87	0.1
6a807e	0.87	0.06
f88d81	0.9	0.5
b76ab4	0.95	0.03

5.2 The Numerical Procedure for Determining Outliers

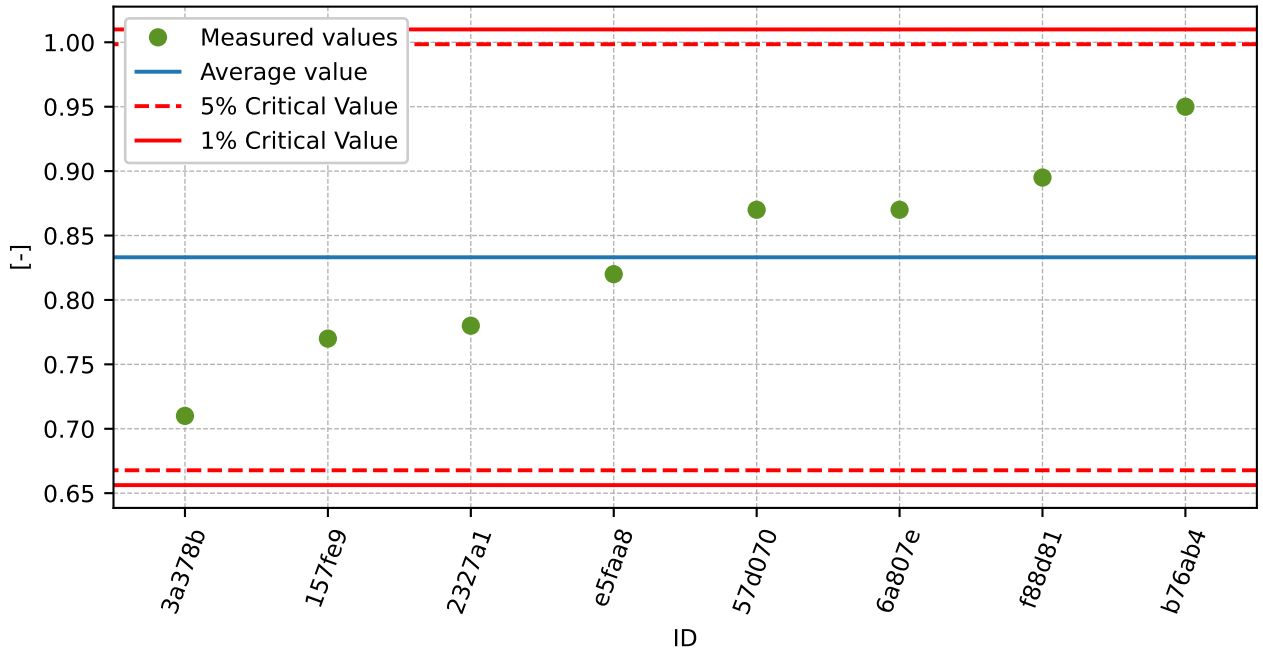

Figure 47: **Grubbs' test** - average values

5.3 Mandel's Statistics

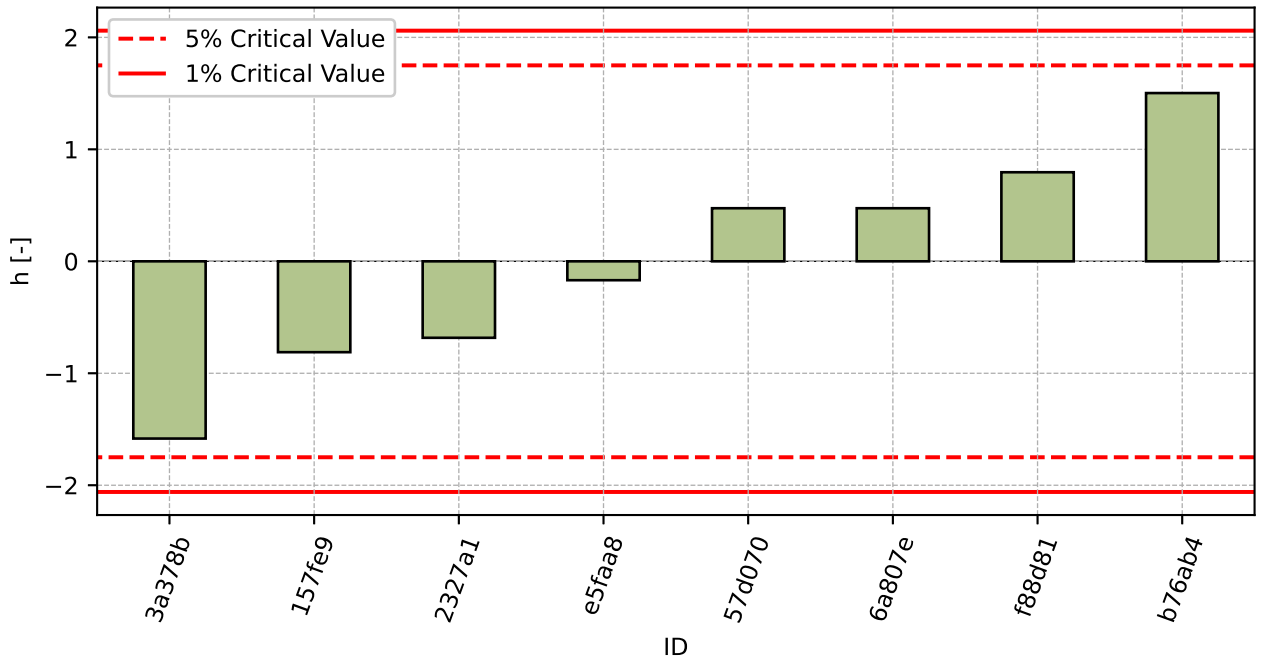

Figure 48: Interlaboratory Consistency Statistic

5.4 Descriptive statistics

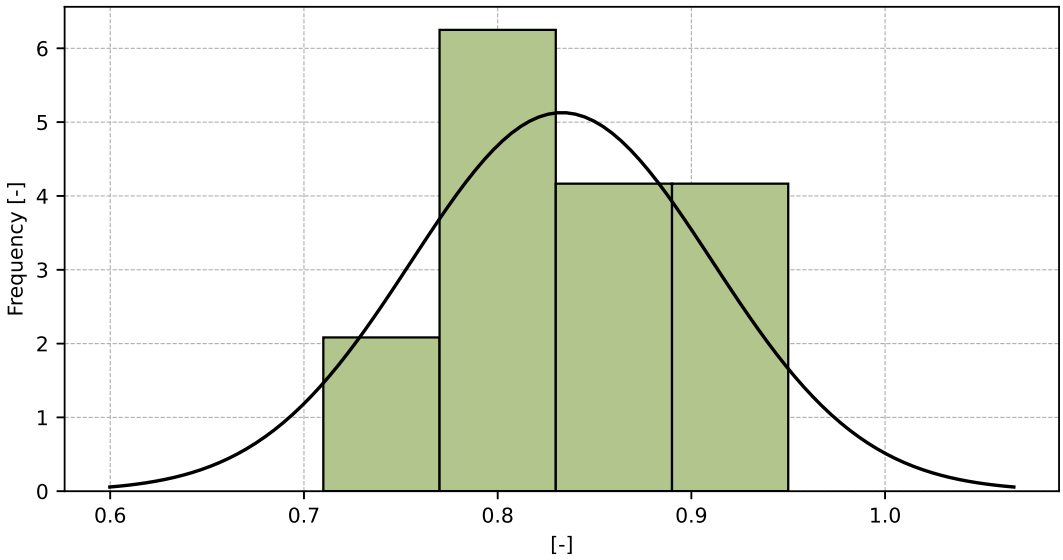

Figure 49: Histogram of all test results

Table 23: Descriptive statistics

Characteristics	[-]
Average value – $\bar{x}$	0.83
Sample standard deviation – s	0.078
Asigned value – x^*	0.83
Robust standard deviation – s^*	0.078
Measurement uncertainty of asigned value – u_X	0.027
p-value of normality test	0.943 [-]

5.5 Evaluation of Performance Statistics

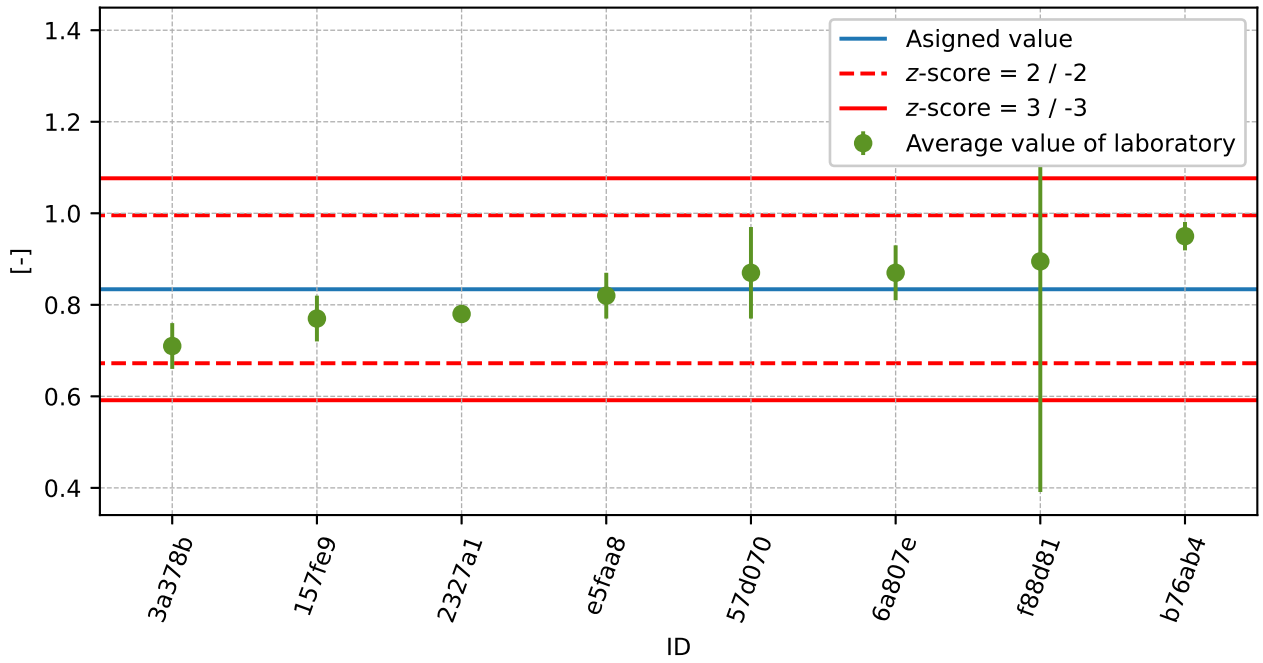

Figure 50: Average values and extended uncertainties of measurement

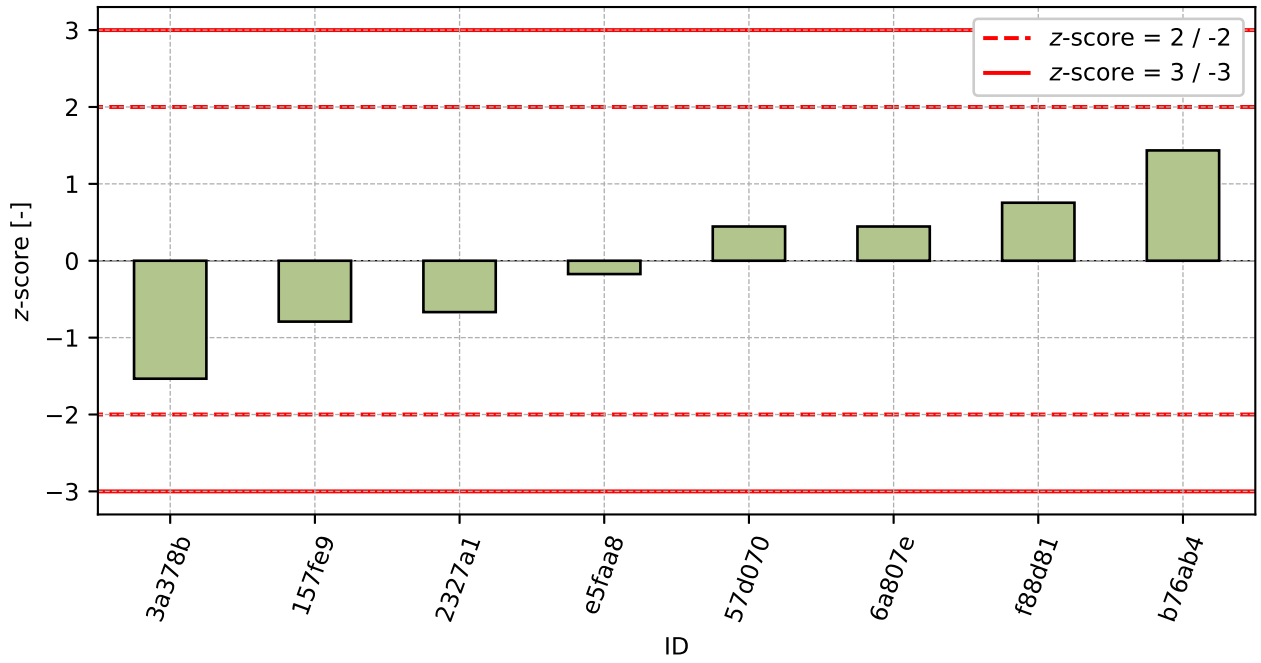

Figure 51: z-score

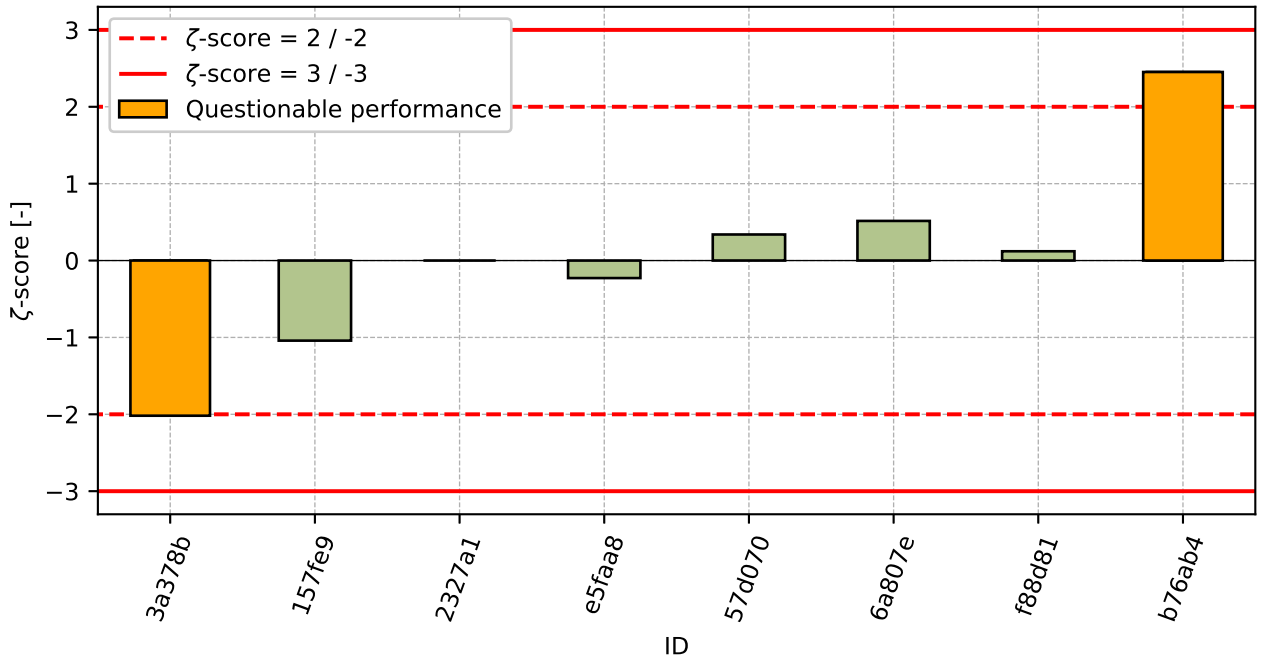

Figure 52: ζ-score

Table 24: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
3a378b	-1.53	-2.02
157fe9	-0.79	-1.04
2327a1	-0.67	-
e5faa8	-0.17	-0.23
57d070	0.45	0.34
6a807e	0.45	0.52
f88d81	0.75	0.12
b76ab4	1.43	2.45

6 Appendix – ČSN 73 1324 – Determination of grindability of concrete

This part of the PT program was not opened due to low interest from laboratories.

7 Appendix – ČSN 73 1326 – Resistance of cement concrete surface to water and defrosting chemicals – Method A

7.1 25 cycles

7.1.1 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 [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
3513f0	4.4	4.9	3.5	-	4.3	0.71	16.63
7eb42c	68.9	45.3	55.9	5.7	56.7	11.82	20.85
f44e68	77.0	53.0	79.0	36.5	69.7	14.47	20.77
e5faa8	148.8	82.1	155.2	0.4	128.7	40.51	31.47
eb7cc4	133.3	172.5	129.4	8.7	145.1	23.84	16.43
f88d81	106.0	133.0	197.0	124.0	145.3	46.74	32.16
3a378b	152.6	172.2	138.0	0.5	154.3	17.14	11.11
b0d1be	155.2	124.4	233.7	-	171.1	56.36	32.94
a212b5	245.0	138.0	141.0	8.7	174.7	60.93	34.88
0fdb21	183.6	196.1	145.1	7.0	174.9	26.58	15.2
2e7b6b	196.0	196.0	184.0	5.0	192.0	6.93	3.61
2327a1	133.2	248.6	270.8	-	217.5	73.87	33.96
b76ab4	204.8	274.6	194.4	1.6	224.6	43.61	19.42
73885a	224.0	259.0	220.0	-	234.3	21.46	9.16
6a807e	452.6	736.2	649.3	1.8	612.7	145.28	23.71

7.1.2 The Numerical Procedure for Determining Outliers

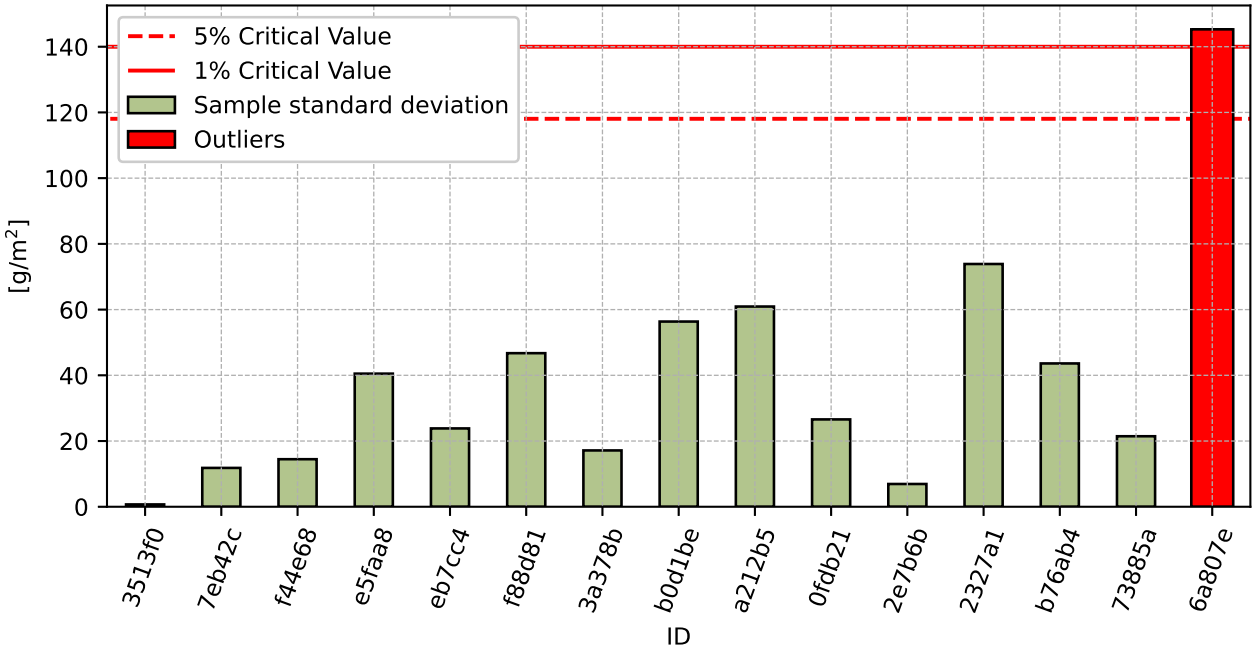

Figure 53: **Cochran's test** - sample standard deviations

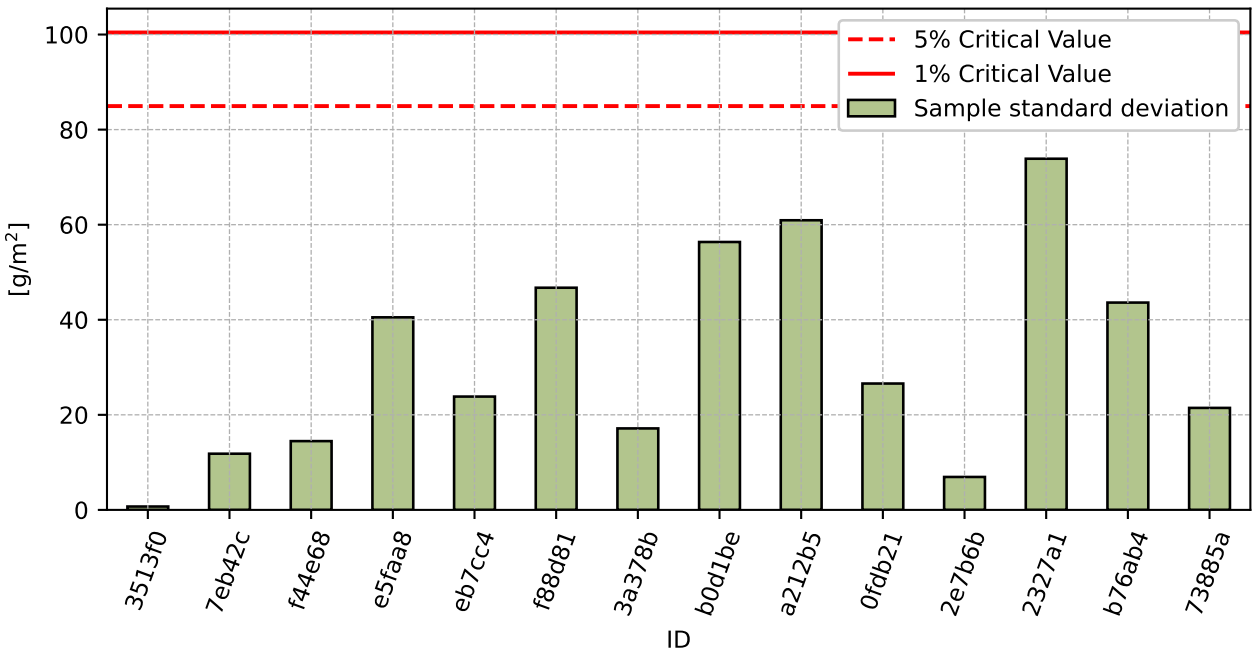

Figure 54: **Cochran's test** - sample standard deviations without outliers

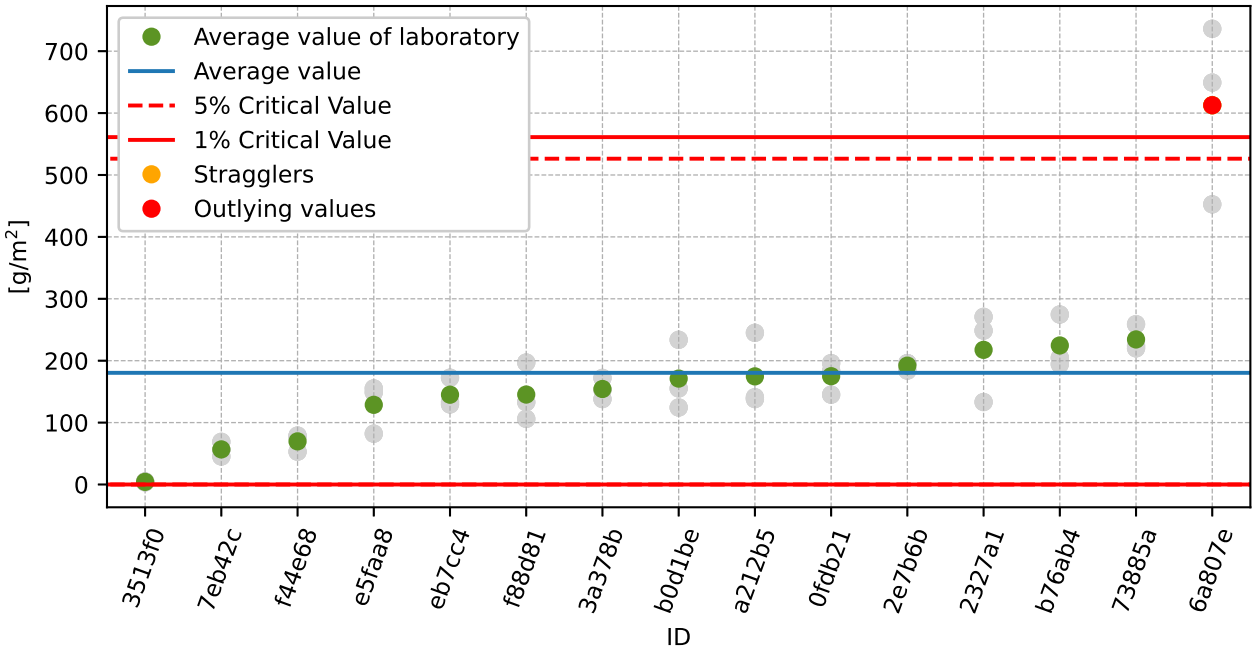

Figure 55: **Grubbs' test** - average values

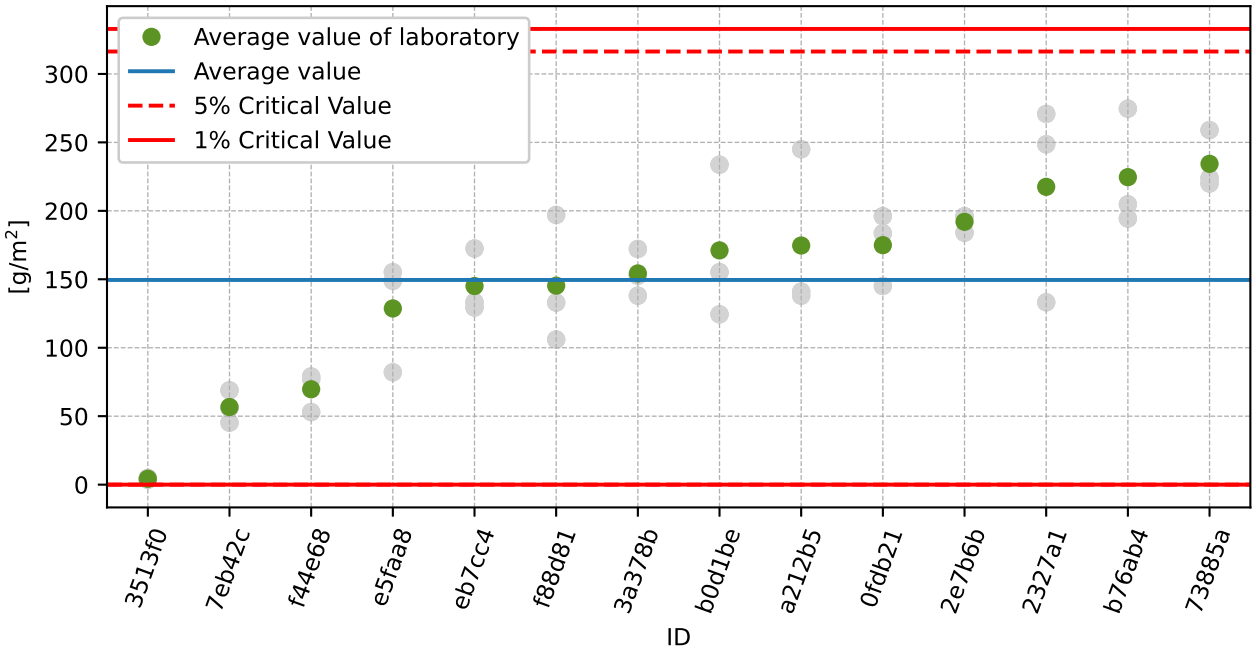

Figure 56: **Grubbs' test** - average values without outliers

7.1.3 Mandel's Statistics

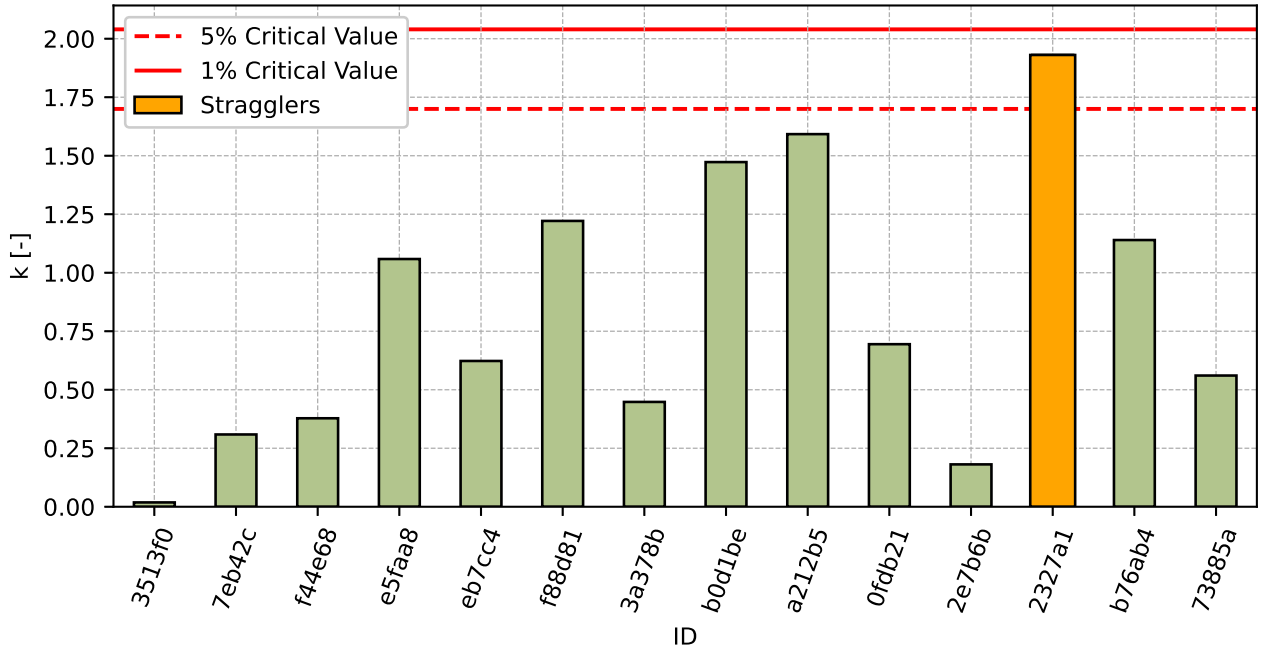

Figure 57: Intralaboratory Consistency Statistic

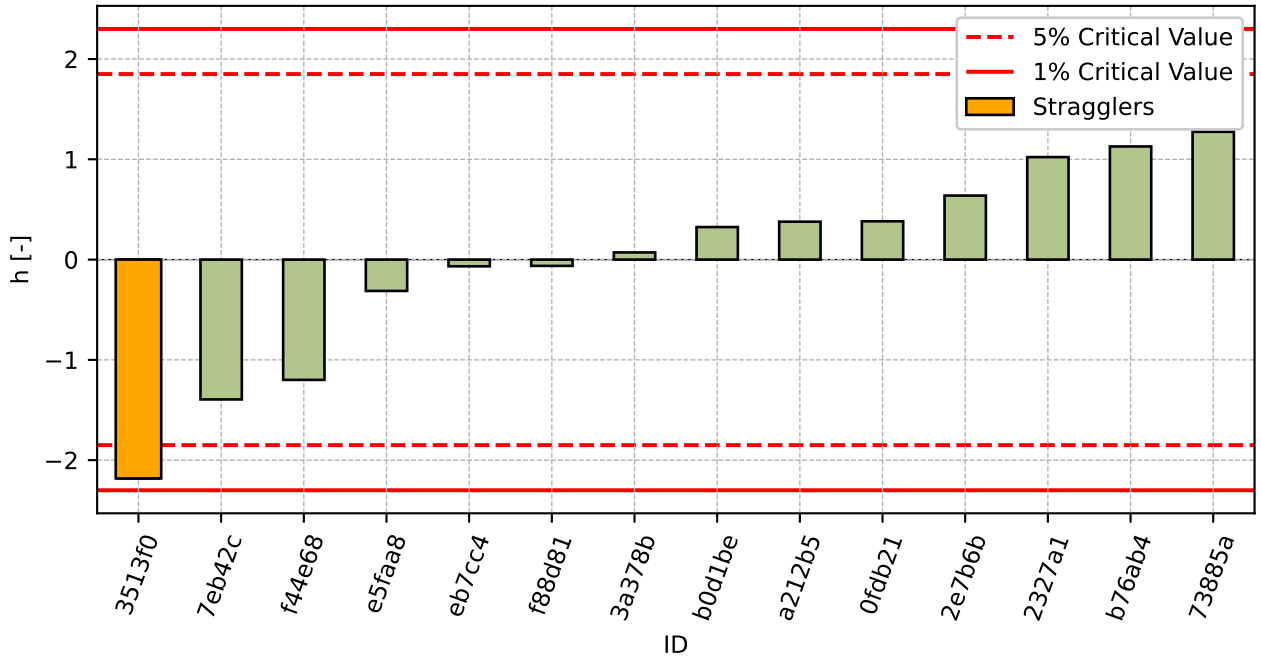

Figure 58: Interlaboratory Consistency Statistic

7.1.4 Descriptive statistics

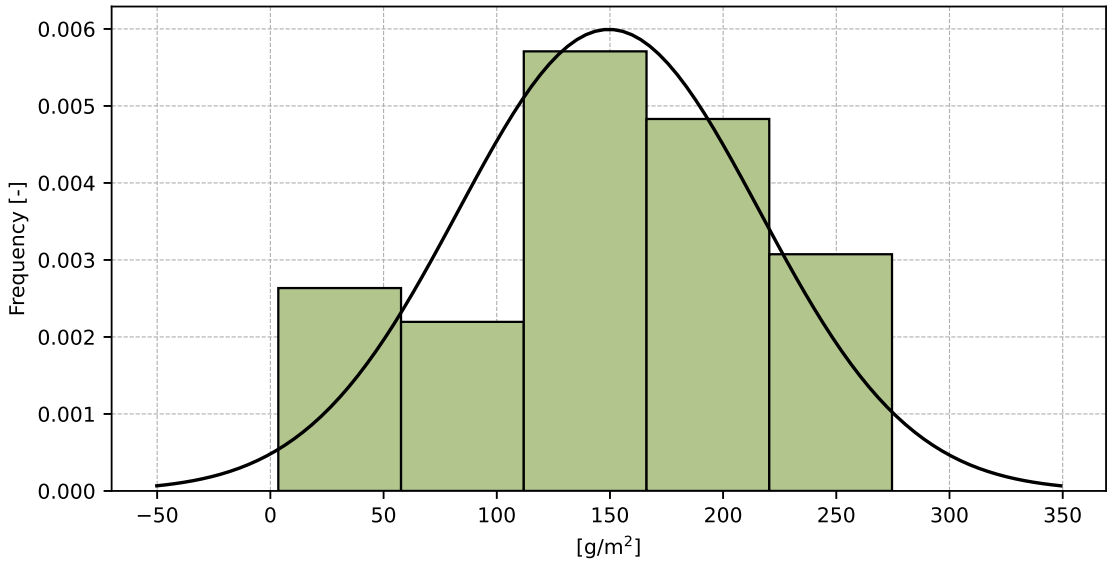

Figure 59: Histogram of all test results

Table 26: Descriptive statistics

Characteristics	**[g/m²]**
Average value – $\bar{x}$	149.5
Sample standard deviation – s	66.56
Asigned value – x^*	160.0
Robust standard deviation – s^*	52.32
Measurement uncertainty of asigned value – u_X	17.48
p-value of normality test	0.275 [-]
Interlaboratory standard deviation – s_L	62.78
Repeatability standard deviation – s_r	38.27
Reproducibility standard deviation – s_R	73.53
Repeatability – r	107.1
Reproducibility – R	205.9

7.1.5 Evaluation of Performance Statistics

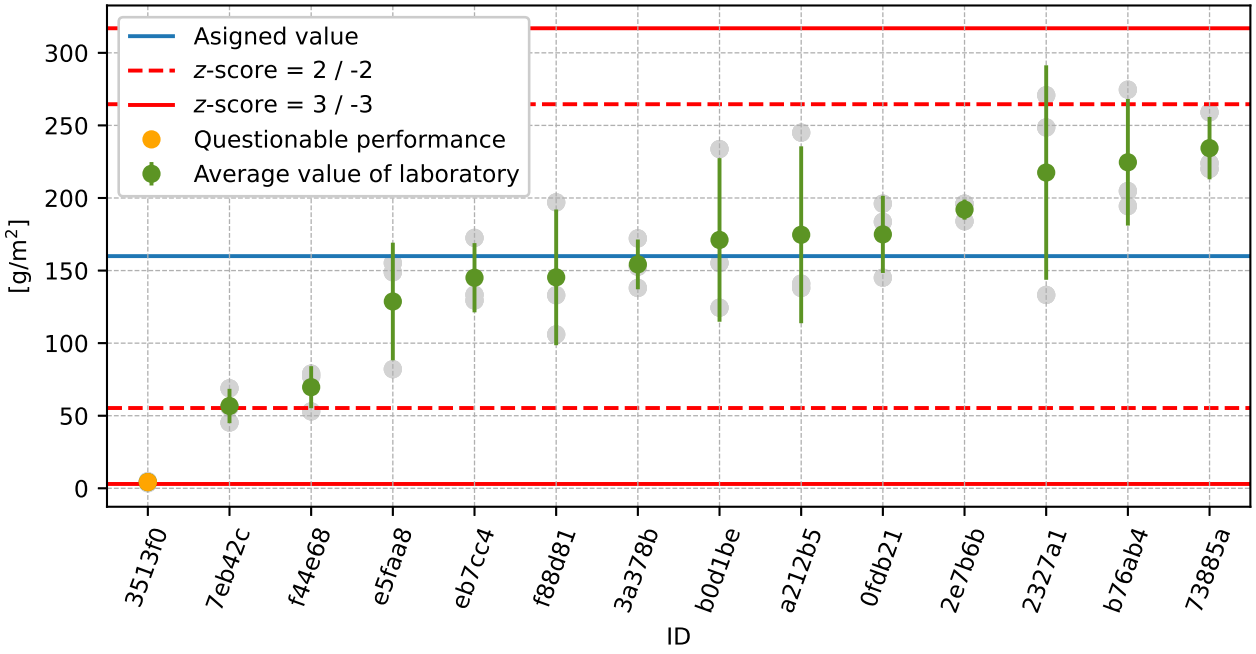

Figure 60: Average values and sample standard deviations

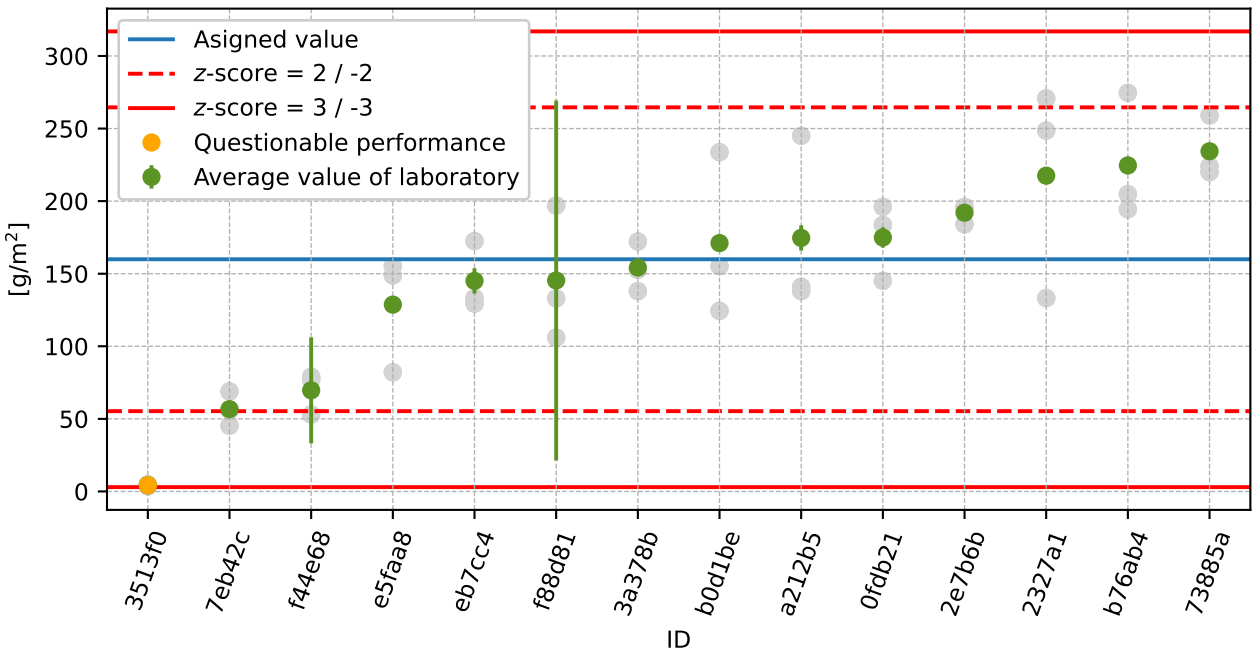

Figure 61: Average values and extended uncertainties of measurement

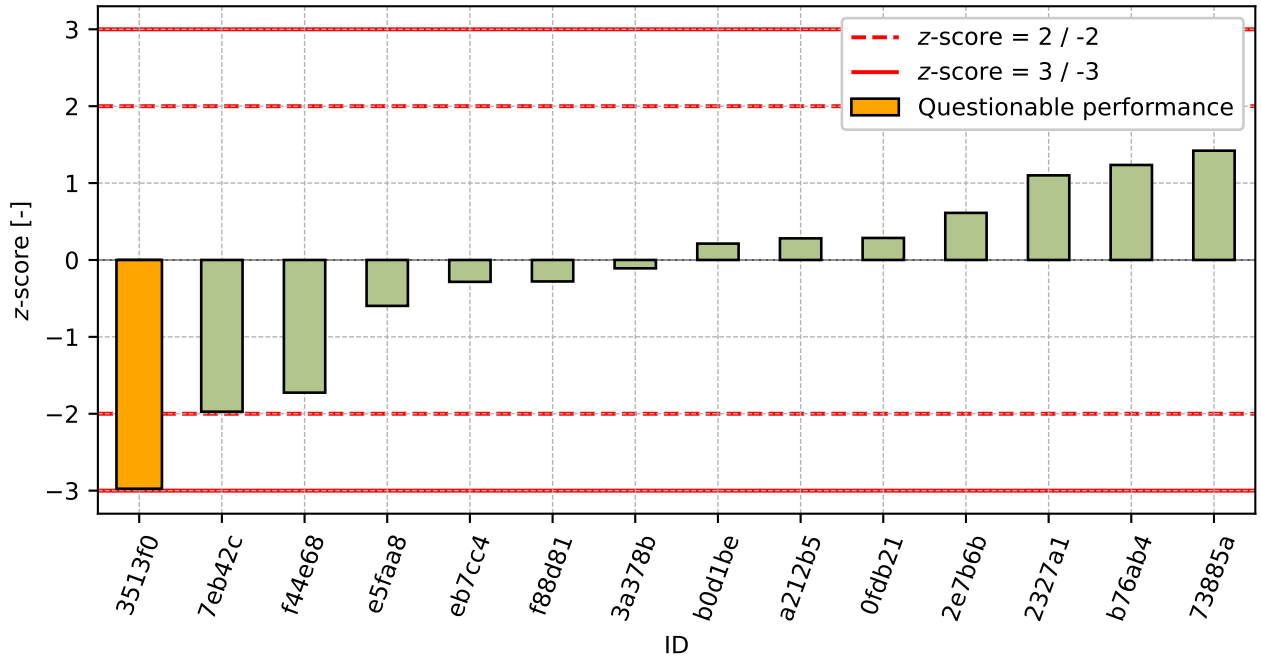

Figure 62: z-score

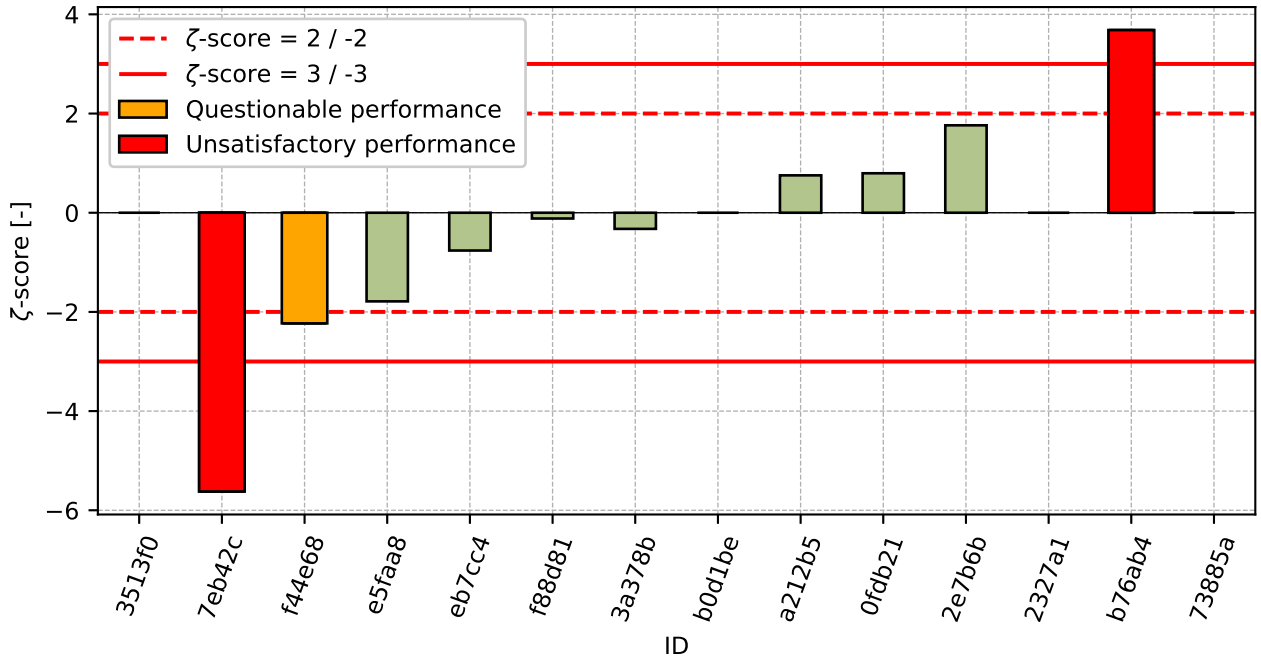

Figure 63: ζ-score

Table 27: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
3513f0	-2.98	-
7eb42c	-1.97	-5.62
f44e68	-1.73	-2.23
e5faa8	-0.6	-1.79
eb7cc4	-0.28	-0.76
f88d81	-0.28	-0.12
3a378b	-0.11	-0.33
b0d1be	0.21	-
a212b5	0.28	0.75
0fdb21	0.29	0.8
2e7b6b	0.61	1.76
2327a1	1.1	-
b76ab4	1.24	3.68
73885a	1.42	-

7.2 50 cycles

7.2.1 Test results

Table 28: 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 [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
3513f0	6.6	6.9	5.8	-	6.4	0.57	8.84
f44e68	176.0	116.0	176.0	36.5	156.0	34.64	22.21
e5faa8	180.9	304.6	255.4	0.8	247.0	62.26	25.21
3a378b	292.8	302.5	170.9	0.8	255.4	73.36	28.72
7eb42c	349.0	187.0	238.1	11.9	258.0	82.82	32.1
b0d1be	239.5	208.9	432.1	-	293.5	121.0	41.23
d4e812	325.5	294.1	266.7	59.1	295.4	29.42	9.96
f88d81	189.0	290.0	480.0	393.0	319.7	147.75	46.22
2e7b6b	318.0	364.0	341.0	5.0	341.0	23.0	6.74
2327a1	257.6	341.8	470.5	-	356.6	107.22	30.07
a212b5	441.0	327.0	349.0	18.6	372.3	60.48	16.24
0fdb21	414.1	392.2	325.5	15.1	377.3	46.15	12.23
eb7cc4	411.8	462.7	329.4	24.1	401.3	67.27	16.76
b76ab4	374.0	536.0	446.3	1.6	452.1	81.16	17.95
73885a	527.0	660.0	535.0	-	574.0	74.59	12.99
6a807e	584.2	794.6	869.6	2.2	749.5	147.99	19.75

7.2.2 The Numerical Procedure for Determining Outliers

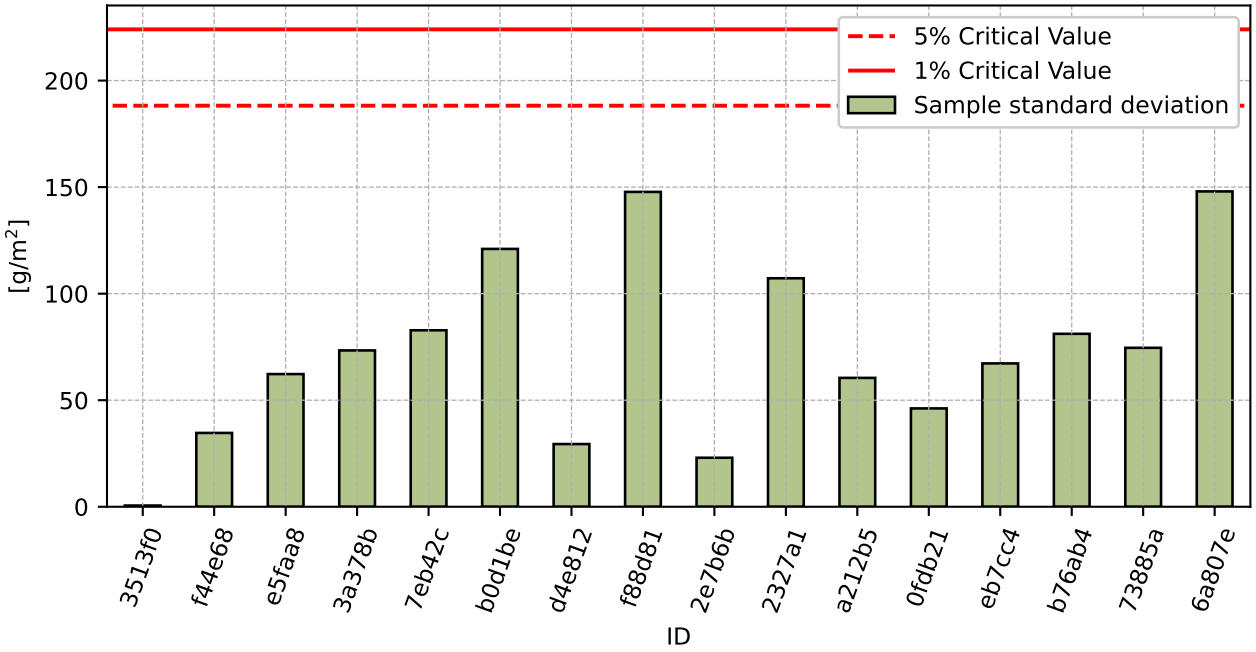

Figure 64: **Cochran's test** - sample standard deviations

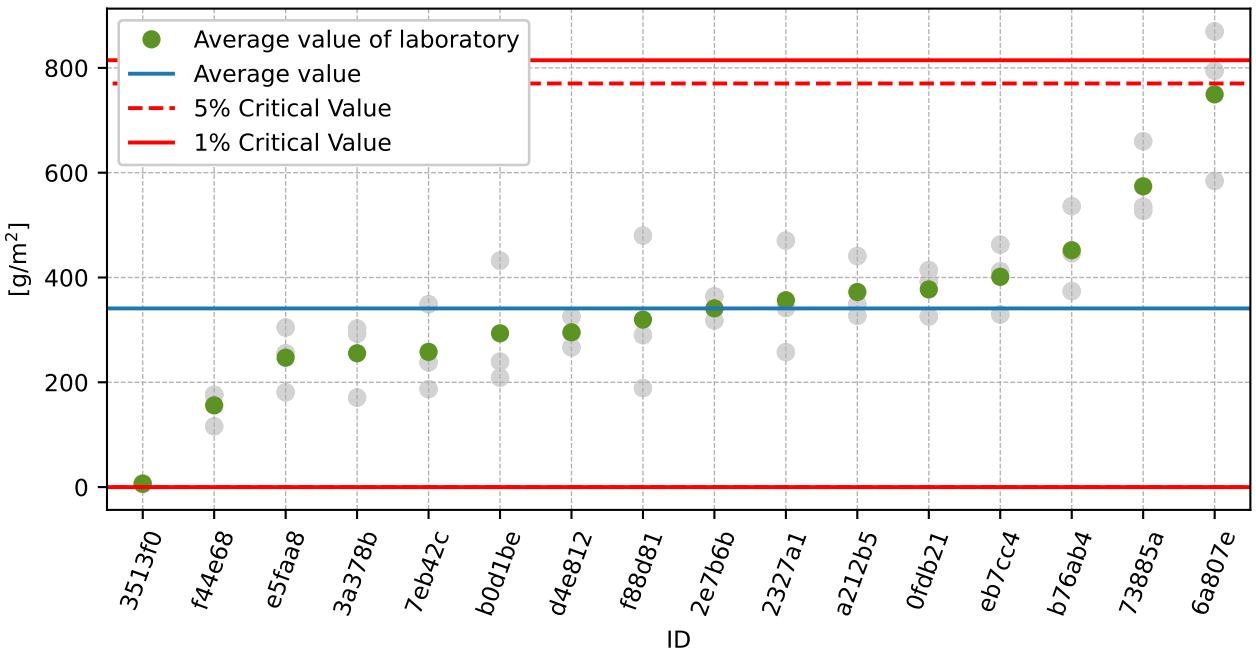

Figure 65: **Grubbs' test** - average values

7.2.3 Mandel's Statistics

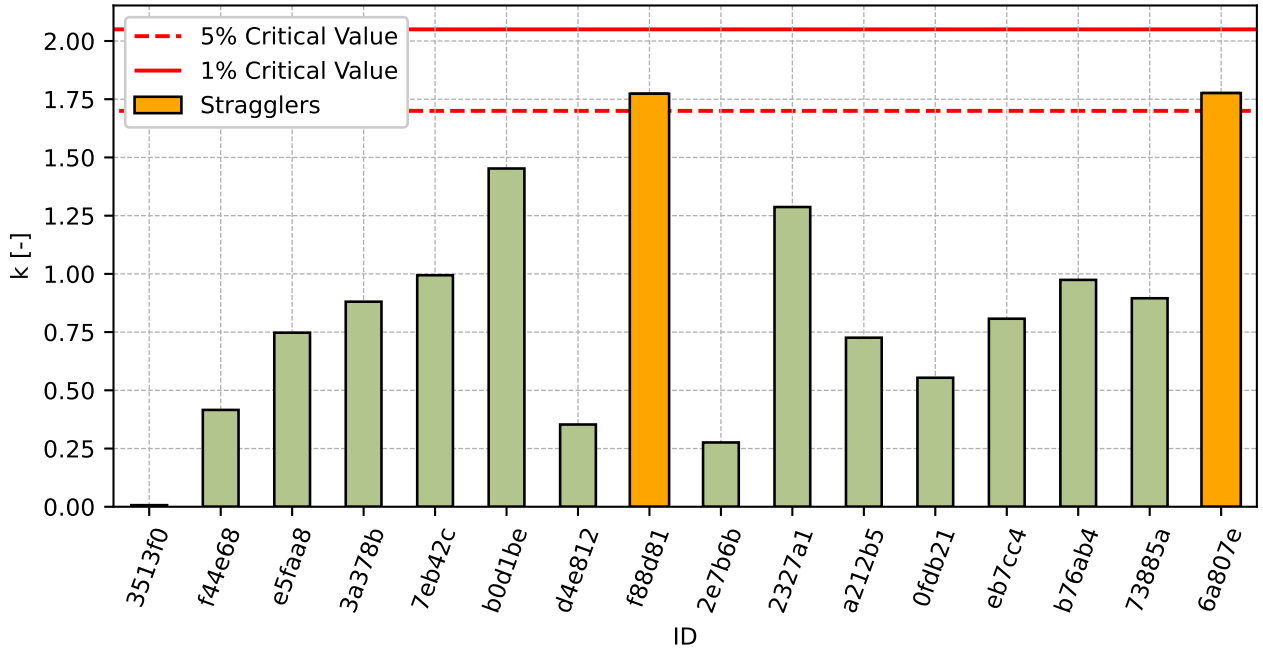

Figure 66: Intralaboratory Consistency Statistic

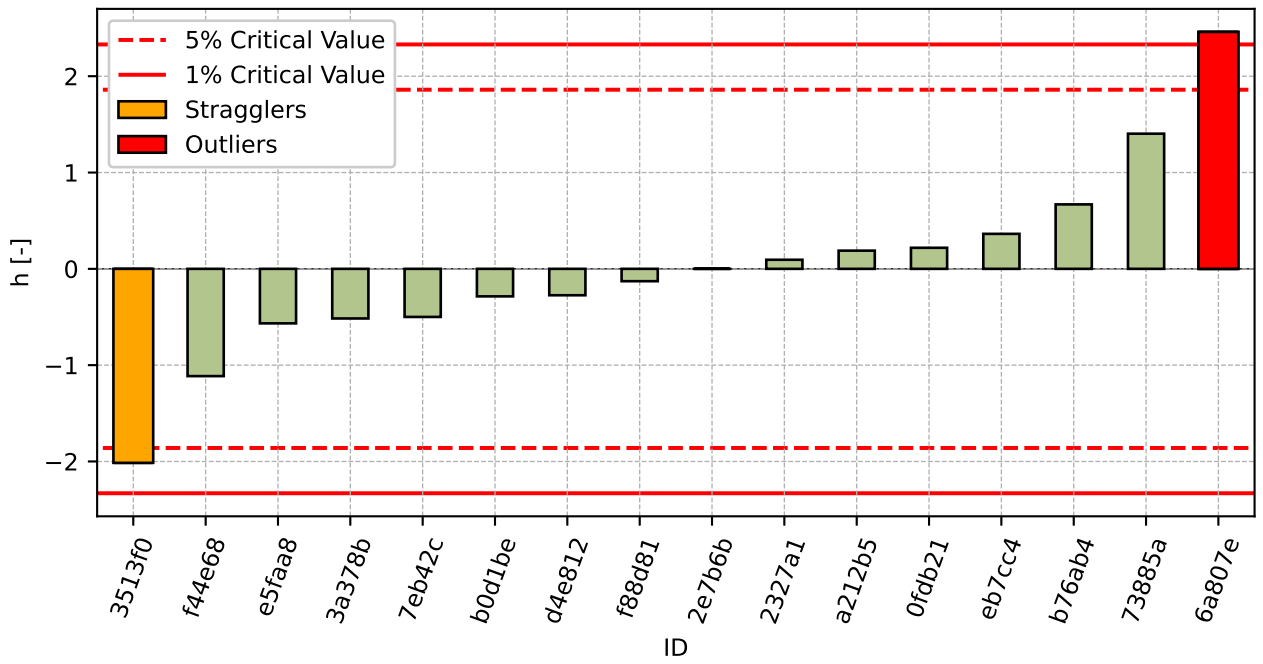

Figure 67: Interlaboratory Consistency Statistic

7.2.4 Descriptive statistics

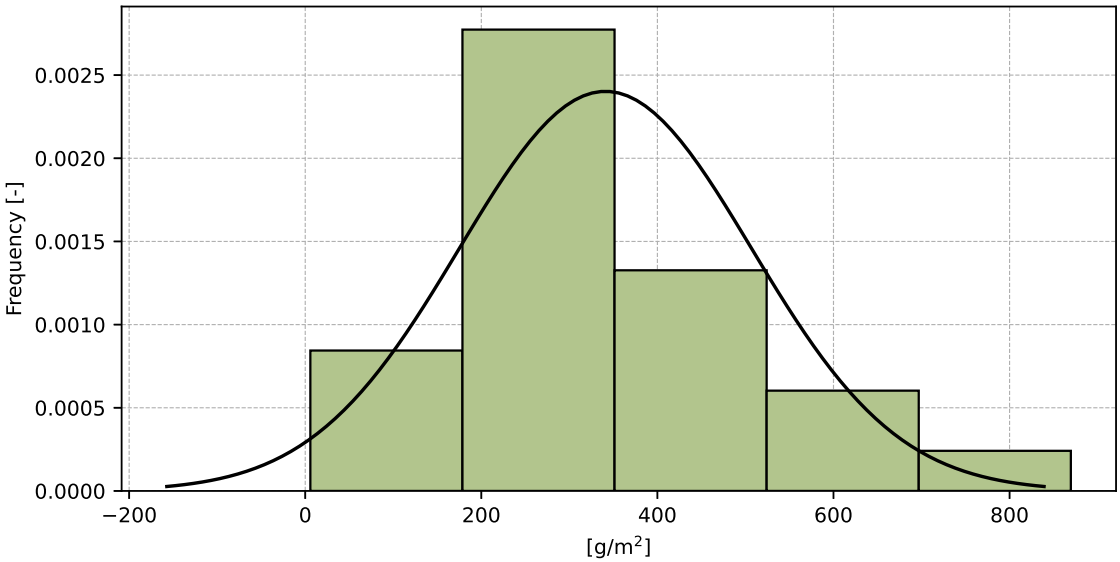

Figure 68: Histogram of all test results

Table 29: Descriptive statistics

Characteristics	[g/m²]
Average value – $\bar{x}$	341.0
Sample standard deviation – s	166.06
Asigned value – x^*	346.9
Robust standard deviation – s^*	153.34
Measurement uncertainty of asigned value – u_X	47.92
p-value of normality test	0.07 [-]
Interlaboratory standard deviation – s_L	158.94
Repeatability standard deviation – s_r	83.31
Reproducibility standard deviation – s_R	179.45
Repeatability – r	233.3
Reproducibility – R	502.5

7.2.5 Evaluation of Performance Statistics

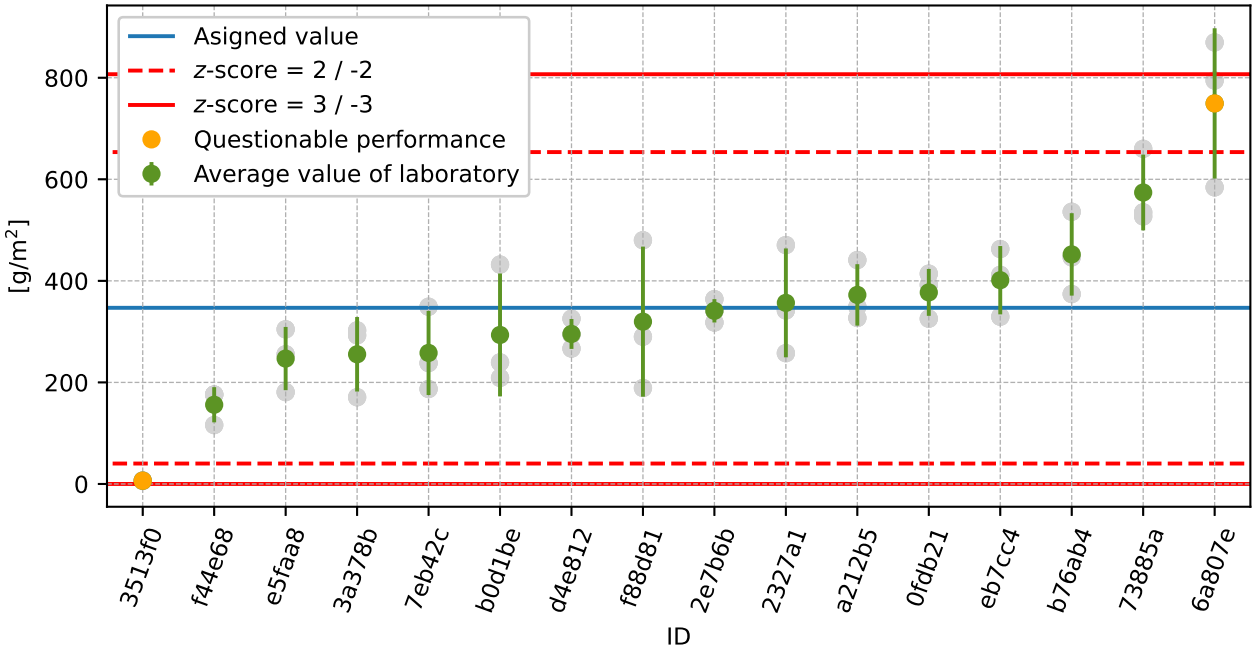

Figure 69: Average values and sample standard deviations

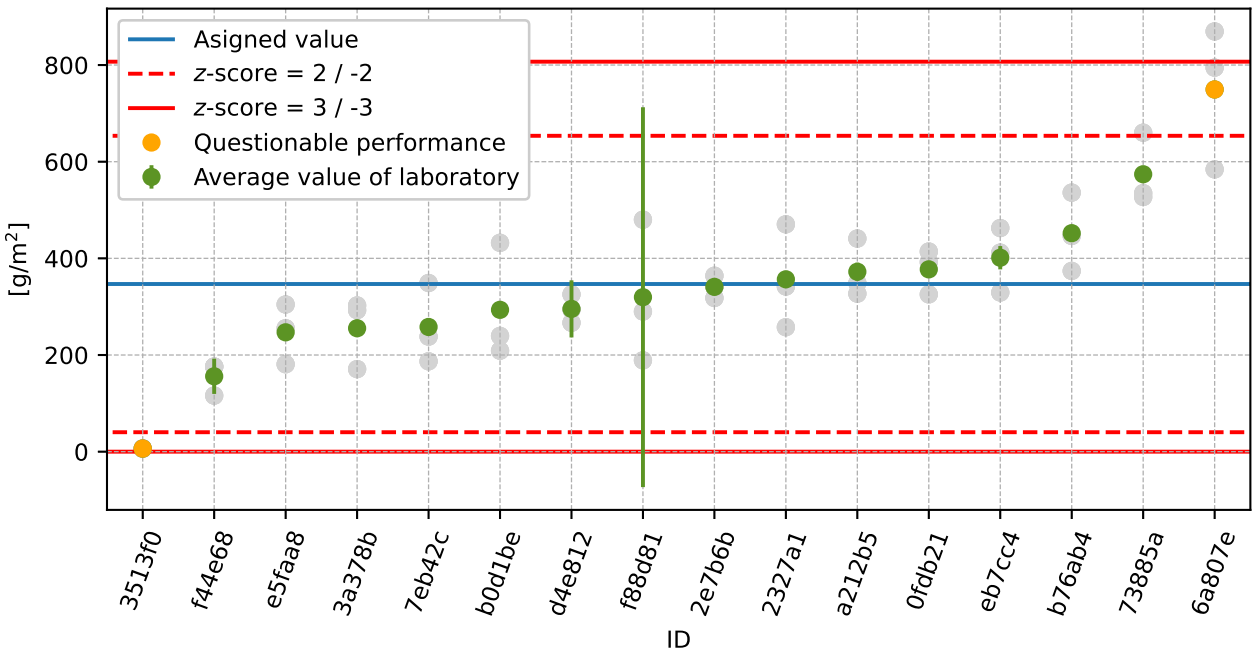

Figure 70: Average values and extended uncertainties of measurement

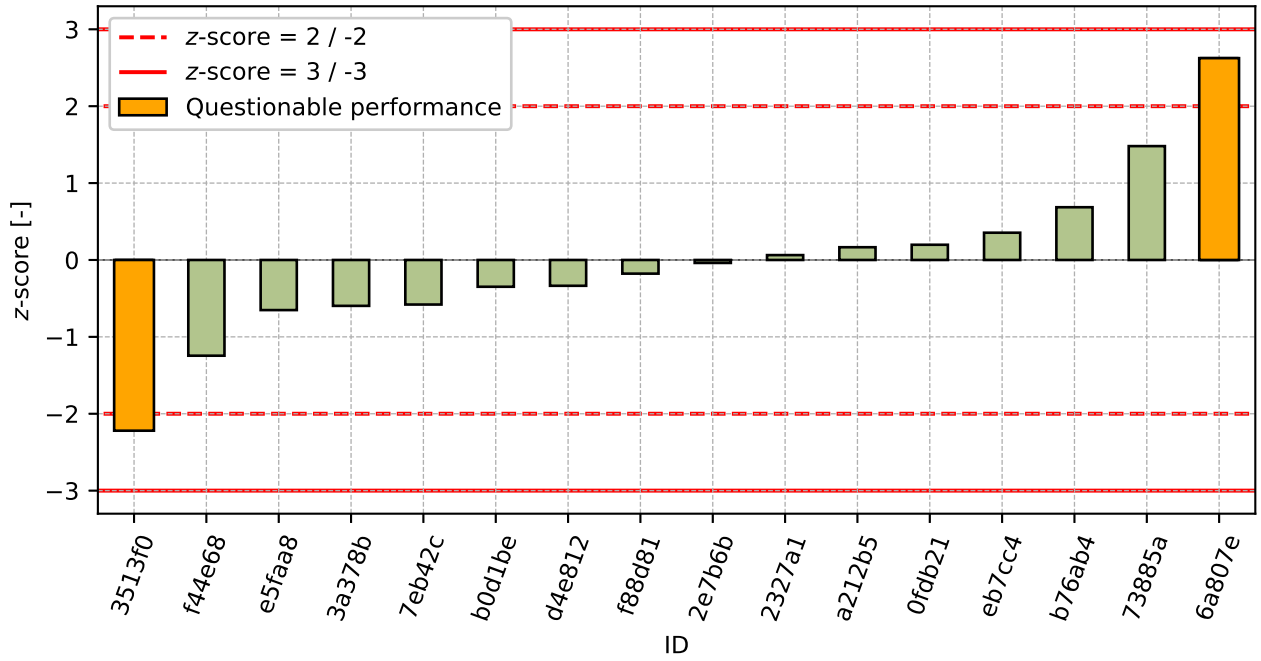

Figure 71: z-score

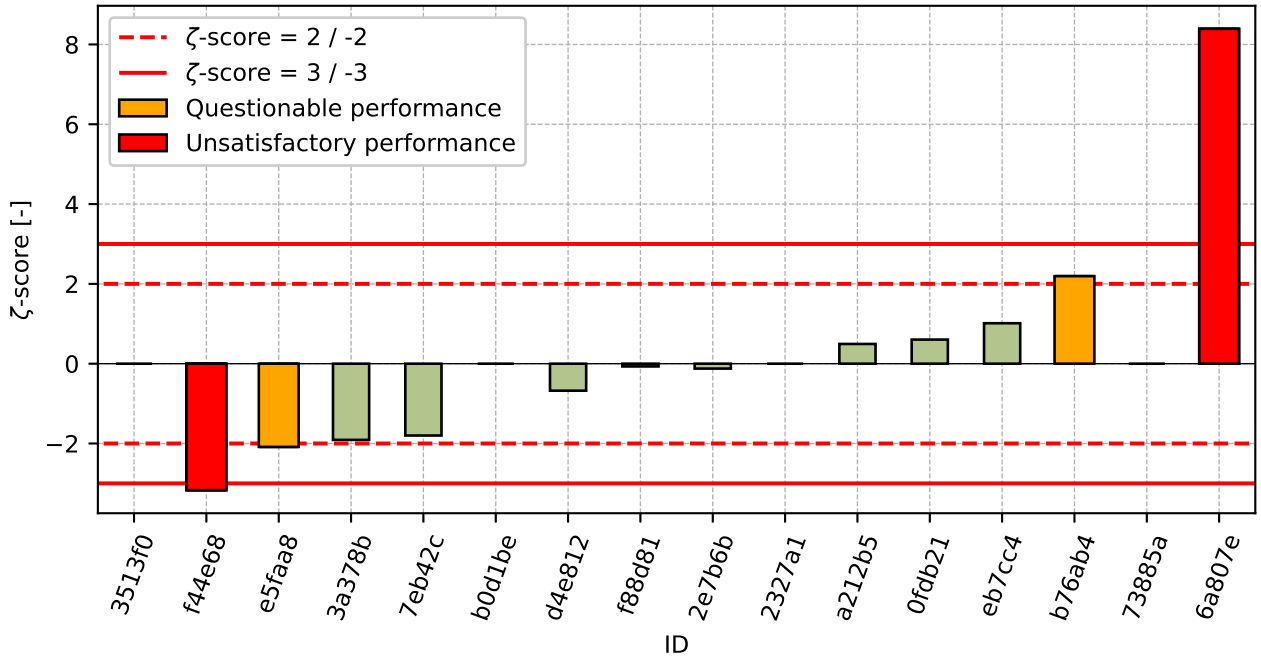

Figure 72: ζ-score

Table 30: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
3513f0	-2.22	-
f44e68	-1.25	-3.17
e5faa8	-0.65	-2.09
3a378b	-0.6	-1.91
7eb42c	-0.58	-1.8
b0d1be	-0.35	-
d4e812	-0.34	-0.68
f88d81	-0.18	-0.07
2e7b6b	-0.04	-0.12
2327a1	0.06	-
a212b5	0.17	0.49
0fdb21	0.2	0.6
eb7cc4	0.35	1.01
b76ab4	0.69	2.19
73885a	1.48	-
6a807e	2.63	8.39

7.3 75 cycles

7.3.1 Test results

Table 31: 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 [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
3513f0	9.6	9.5	9.9	-	9.7	0.21	2.15
f44e68	305.0	203.0	278.0	36.5	262.0	52.85	20.17
3a378b	469.0	466.1	256.3	1.2	397.1	121.98	30.72
e5faa8	457.3	362.1	395.0	1.2	404.8	48.33	11.94
b0d1be	337.1	333.3	630.5	-	433.6	170.5	39.32
7eb42c	537.2	367.4	409.6	22.5	438.1	88.41	20.18
2327a1	386.4	439.4	670.2	-	498.7	150.9	30.26
a212b5	625.0	507.0	482.0	26.9	538.0	76.37	14.2
2e7b6b	530.0	569.0	561.0	5.0	553.3	20.6	3.72
d4e812	643.1	611.8	517.6	118.2	590.8	65.32	11.06
0fdb21	648.5	623.6	517.7	23.9	596.6	69.45	11.64
f88d81	433.0	569.0	913.0	657.0	638.3	247.4	38.76
b76ab4	676.8	735.3	667.2	1.6	693.1	36.86	5.32
eb7cc4	666.7	866.7	580.4	42.3	704.6	146.86	20.84
6a807e	696.3	771.2	977.8	2.4	815.1	145.78	17.88
73885a	794.0	1088.0	1004.0	-	962.0	151.43	15.74

7.3.2 The Numerical Procedure for Determining Outliers

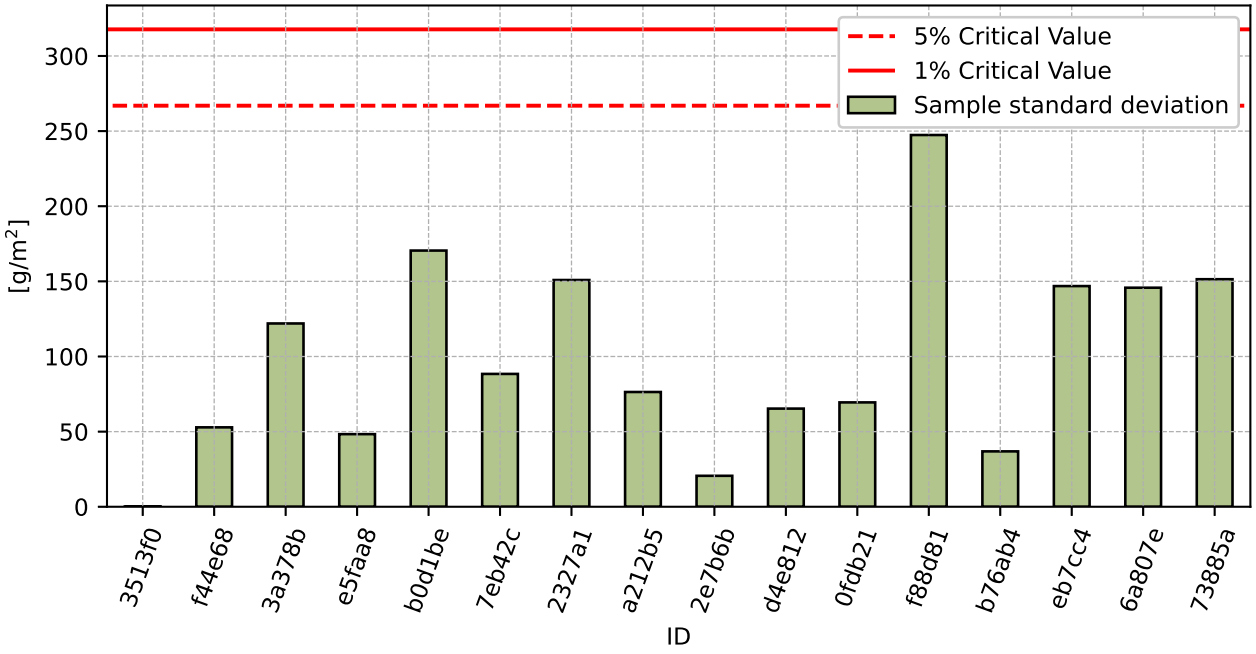

Figure 73: **Cochran's test** - sample standard deviations

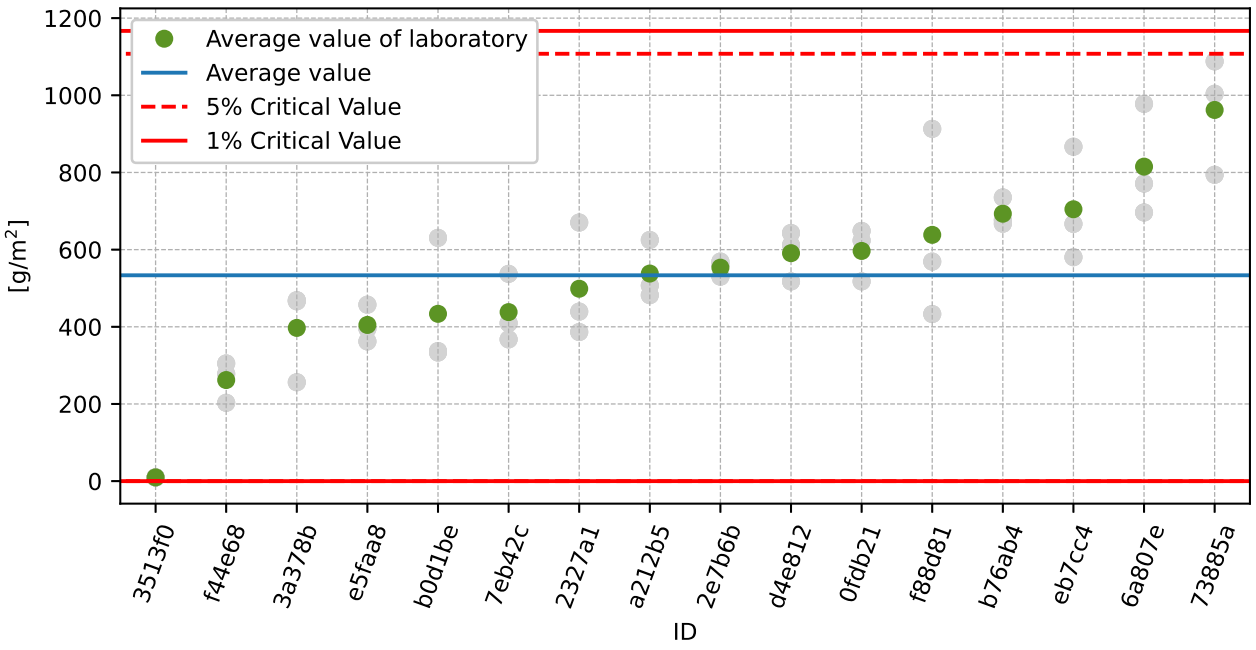

Figure 74: **Grubbs' test** - average values

7.3.3 Mandel's Statistics

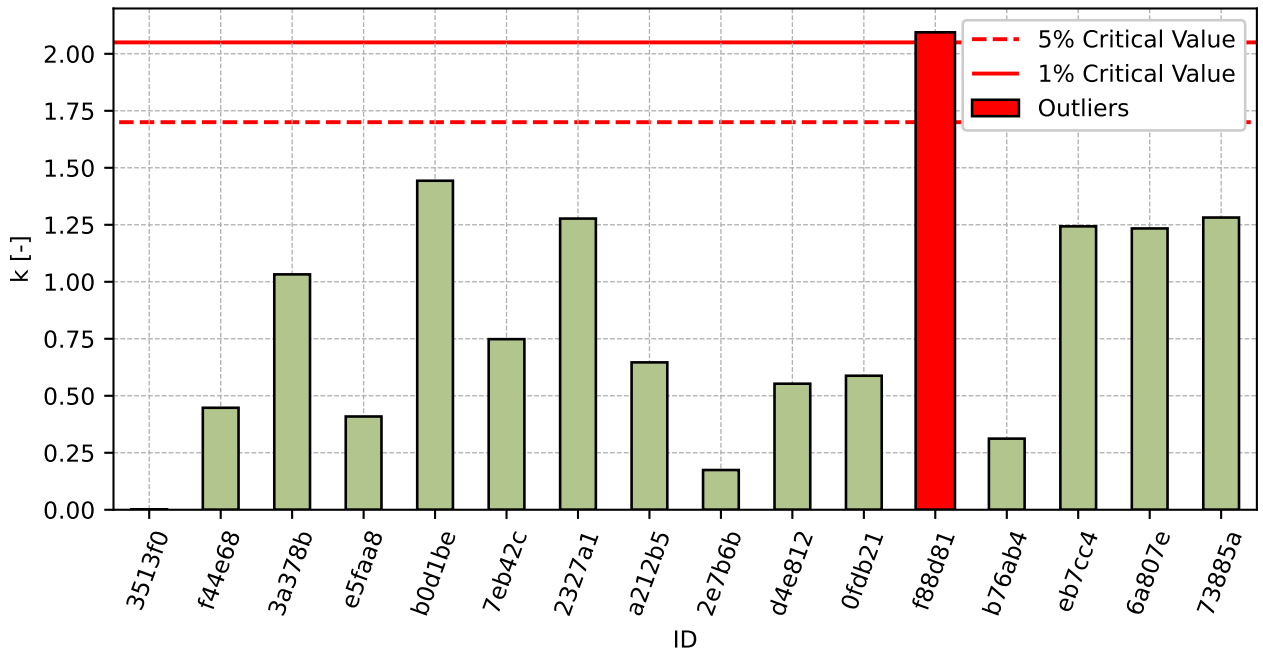

Figure 75: Intralaboratory Consistency Statistic

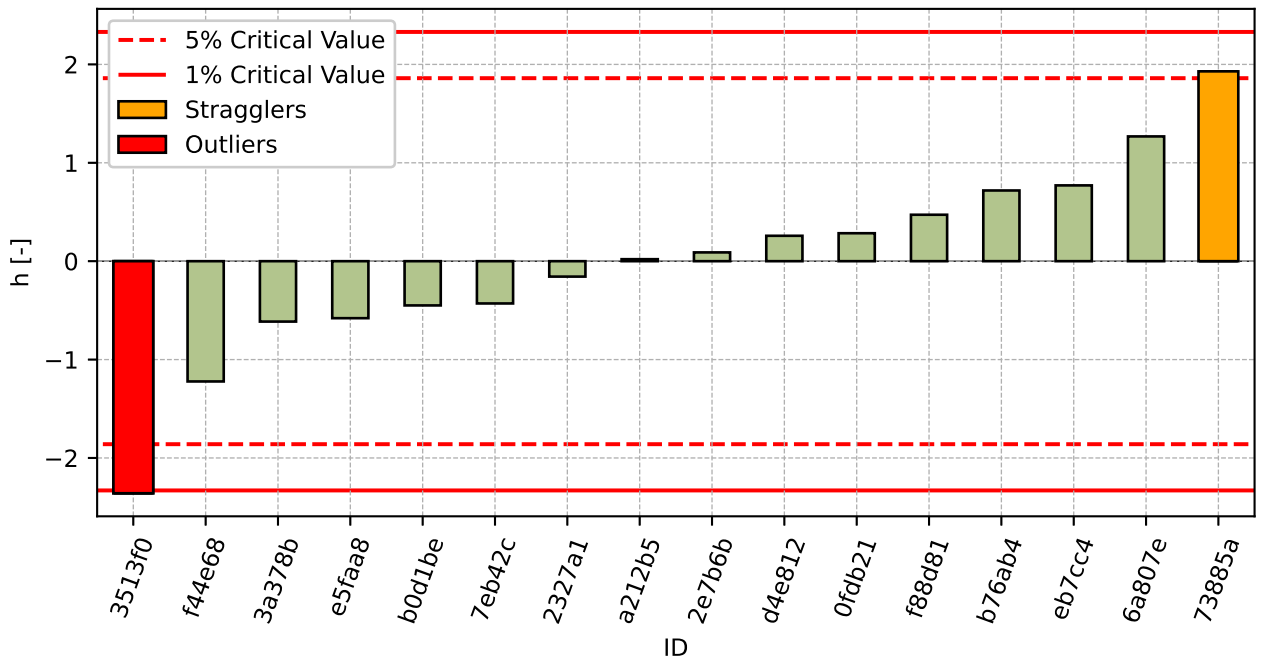

Figure 76: Interlaboratory Consistency Statistic

7.3.4 Descriptive statistics

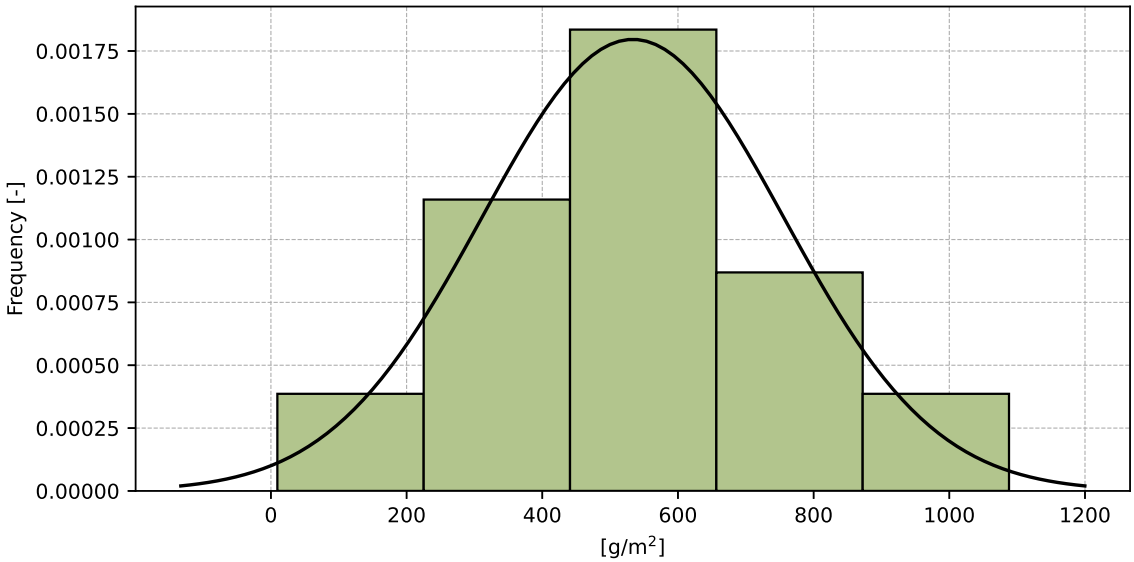

Figure 77: Histogram of all test results

Table 32: Descriptive statistics

Characteristics	**[g/m²]**
Average value – $\bar{x}$	533.5
Sample standard deviation – s	222.1
Asigned value – x^*	549.6
Robust standard deviation – s^*	206.88
Measurement uncertainty of asigned value – u_X	64.65
p-value of normality test	0.481 [-]
Interlaboratory standard deviation – s_L	211.36
Repeatability standard deviation – s_r	118.14
Reproducibility standard deviation – s_R	242.14
Repeatability – r	330.8
Reproducibility – R	678.0

7.3.5 Evaluation of Performance Statistics

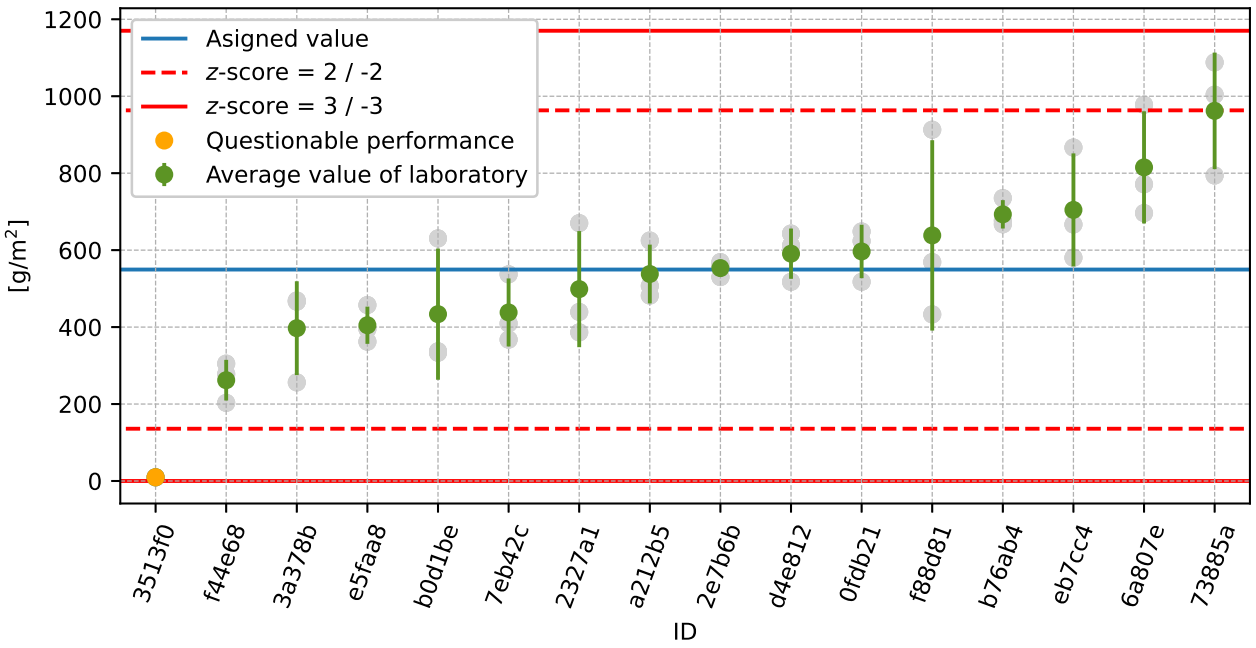

Figure 78: Average values and sample standard deviations

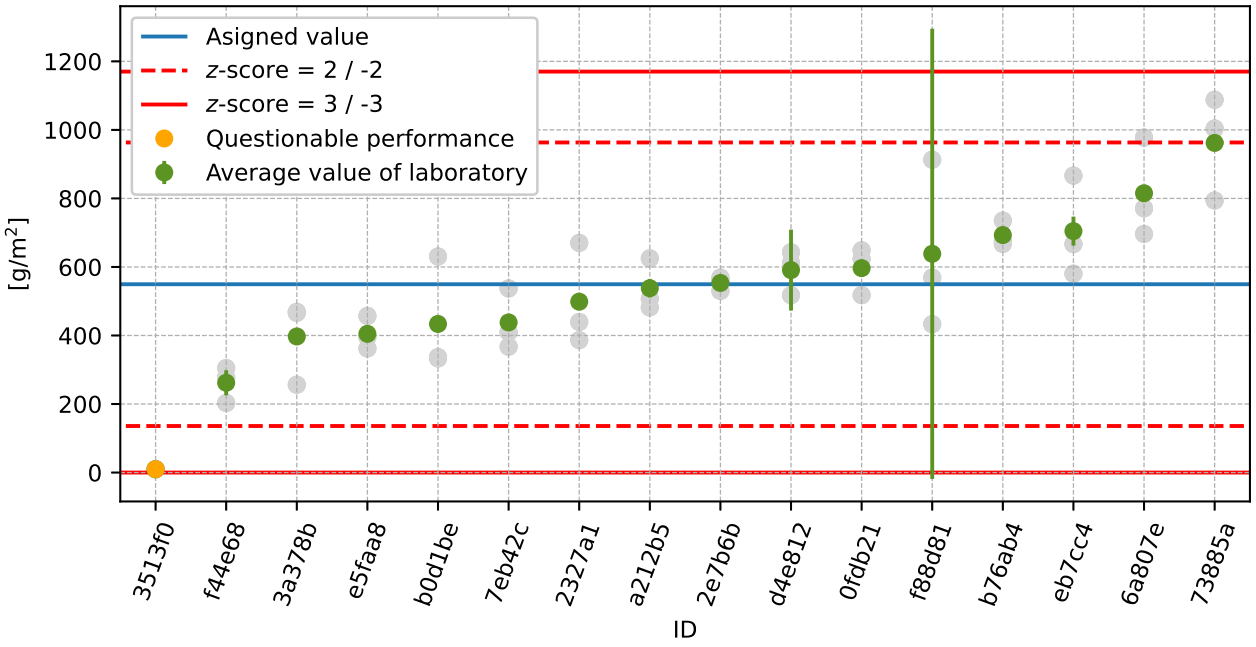

Figure 79: Average values and extended uncertainties of measurement

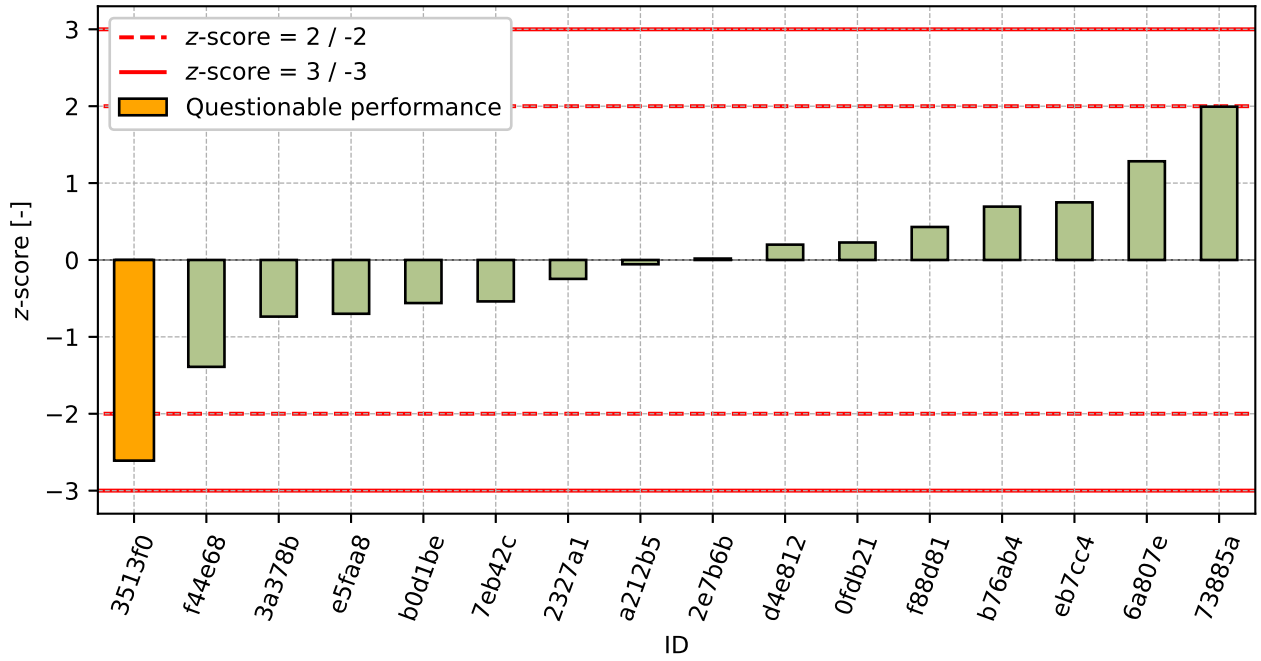

Figure 80: z-score

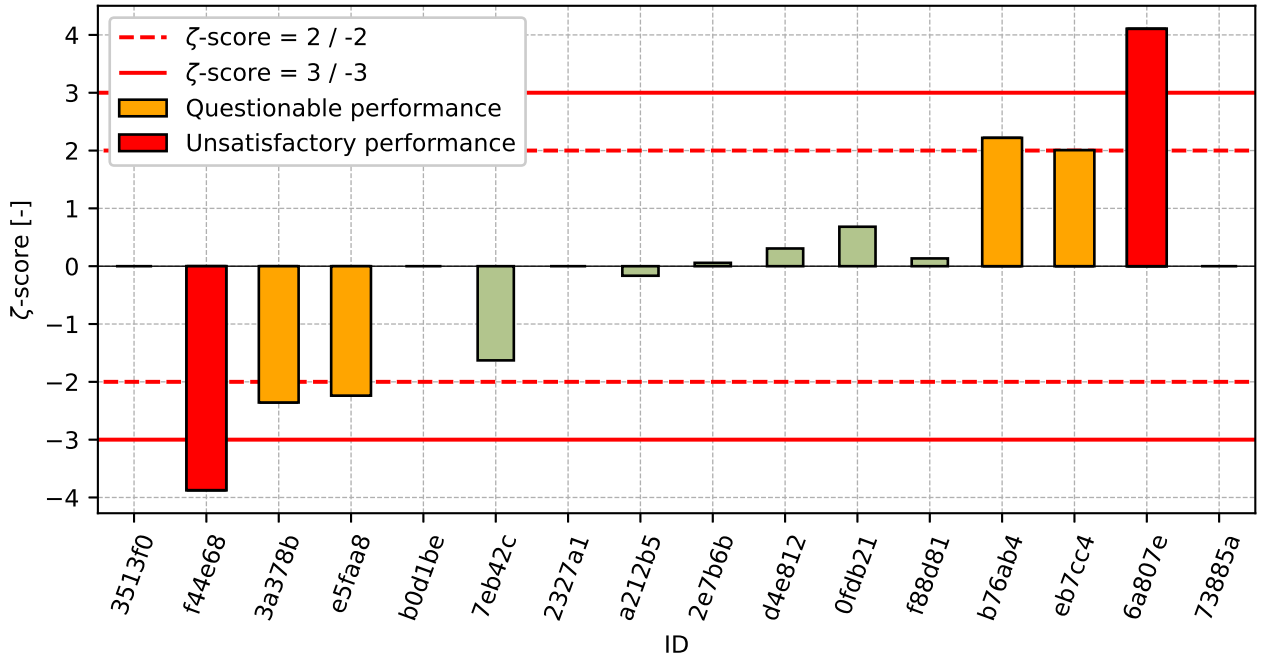

Figure 81: ζ-score

Table 33: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
3513f0	-2.61	-
f44e68	-1.39	-3.87
3a378b	-0.74	-2.36
e5faa8	-0.7	-2.24
b0d1be	-0.56	-
7eb42c	-0.54	-1.63
2327a1	-0.25	-
a212b5	-0.06	-0.17
2e7b6b	0.02	0.06
d4e812	0.2	0.31
0fdb21	0.23	0.68
f88d81	0.43	0.13
b76ab4	0.69	2.22
eb7cc4	0.75	2.01
6a807e	1.28	4.1
73885a	1.99	-

7.4 100 cycles

7.4.1 Test results

Table 34: 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 [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
3513f0	14.1	13.7	15.0	-	14.3	0.67	4.67
e5faa8	262.1	242.7	300.6	0.8	268.5	29.49	10.98
3a378b	307.9	319.5	290.7	0.9	306.0	14.51	4.74
f44e68	462.0	372.0	398.0	36.5	410.7	46.32	11.28
b0d1be	465.7	457.8	903.9	-	609.1	255.31	41.91
7eb42c	769.6	602.4	590.5	33.4	654.2	100.15	15.31
2327a1	497.4	554.8	914.3	-	655.5	225.96	34.47
a212b5	762.0	735.0	682.0	36.3	726.3	40.7	5.6
6a807e	715.7	697.2	850.3	2.3	754.4	83.54	11.07
2e7b6b	756.0	761.0	792.0	10.0	769.7	19.5	2.53
0fdb21	828.2	855.0	733.4	32.3	805.5	63.89	7.93
d4e812	949.0	902.0	815.7	177.8	888.9	67.61	7.61
b76ab4	908.3	916.9	879.3	1.6	901.5	19.7	2.19
f88d81	752.0	863.0	1366.0	867.0	993.7	327.19	32.93
eb7cc4	937.3	1305.9	898.0	62.8	1047.1	225.02	21.49
73885a	1041.0	1567.0	1495.0	-	1367.7	285.18	20.85

7.4.2 The Numerical Procedure for Determining Outliers

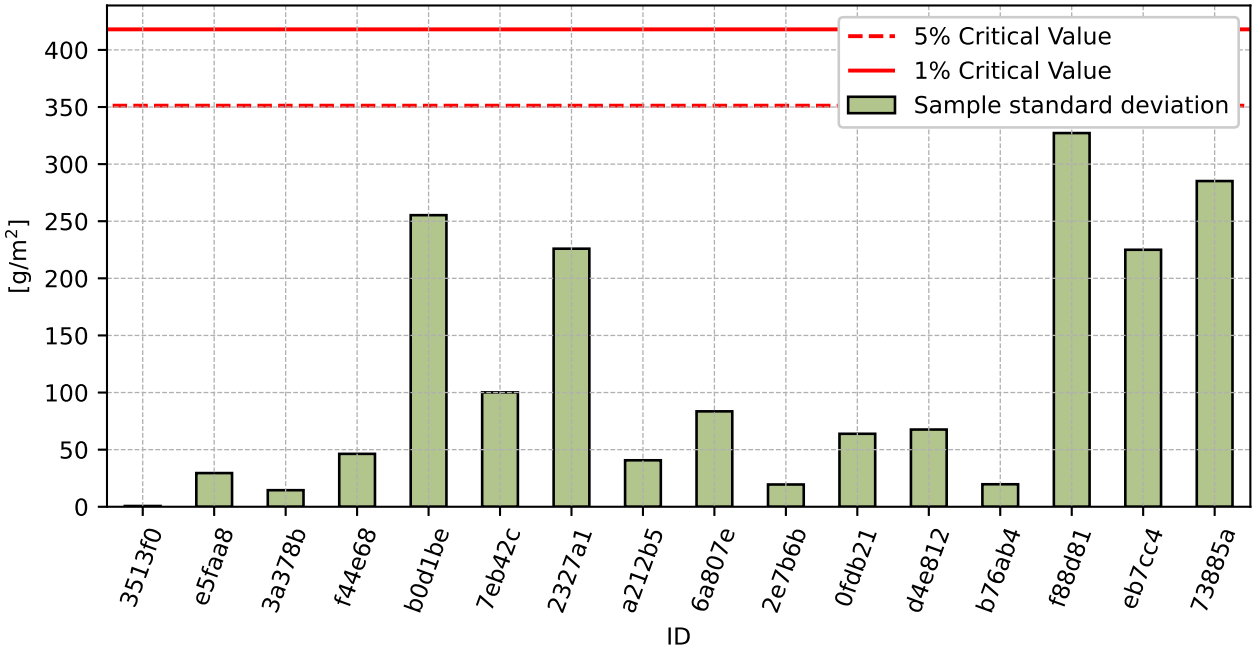

Figure 82: **Cochran's test** - sample standard deviations

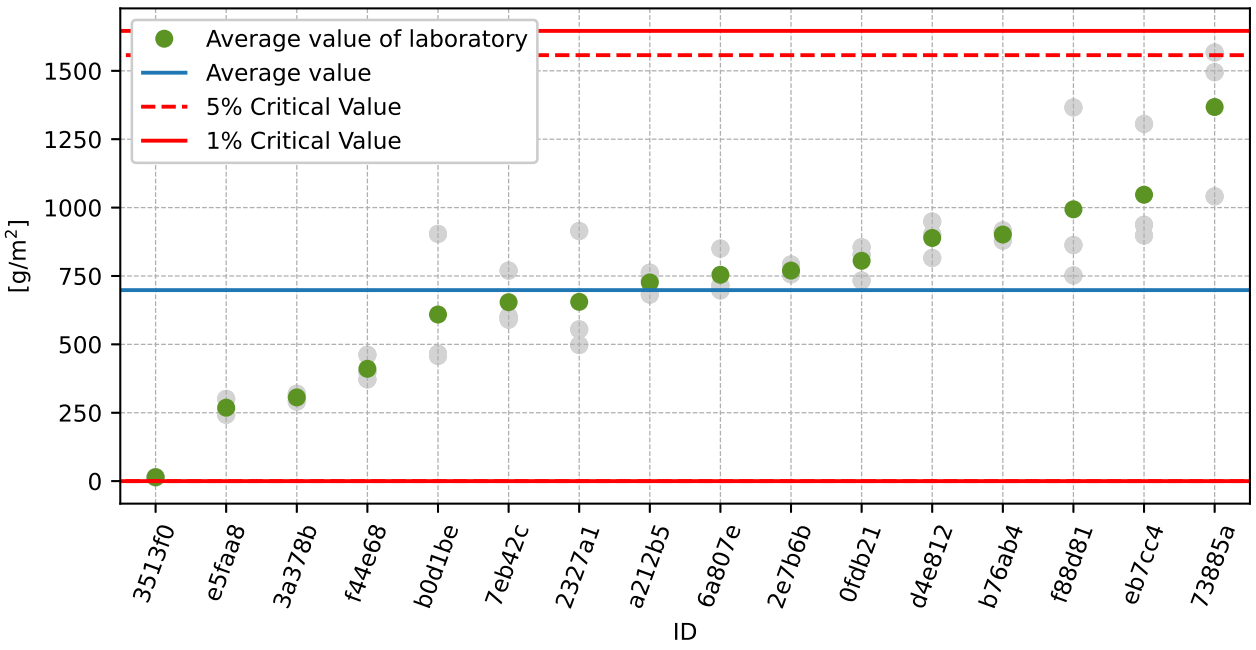

Figure 83: **Grubbs' test** - average values

7.4.3 Mandel's Statistics

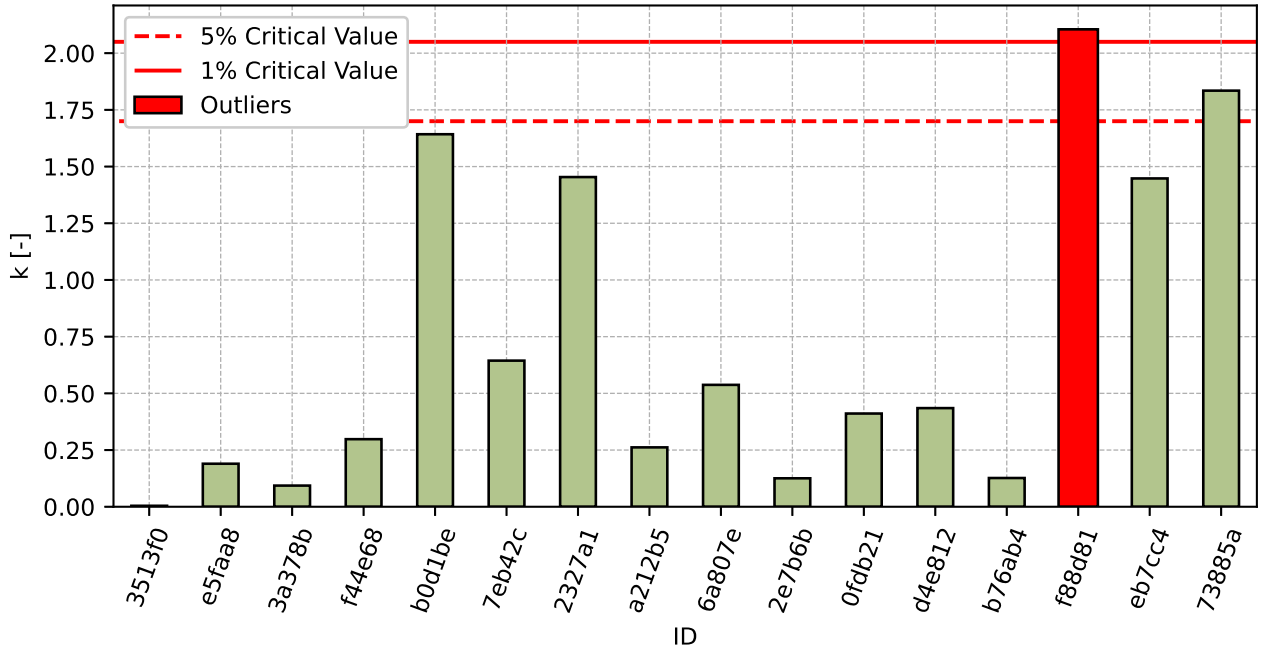

Figure 84: Intralaboratory Consistency Statistic

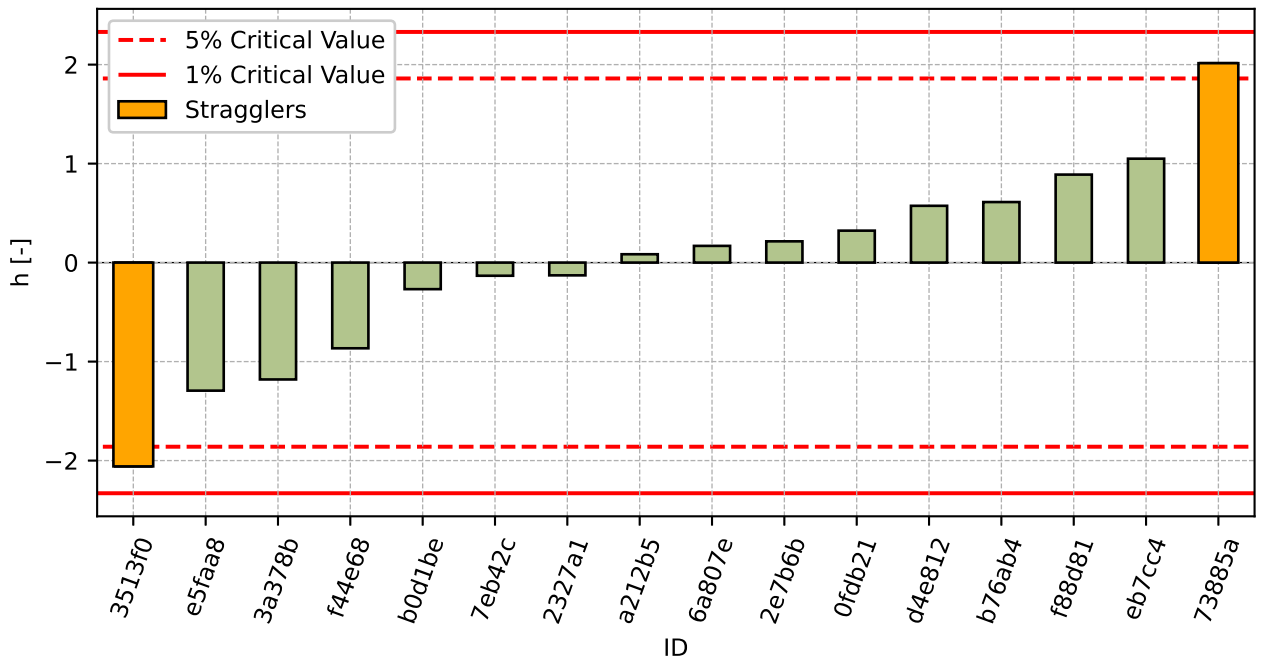

Figure 85: Interlaboratory Consistency Statistic

7.4.4 Descriptive statistics

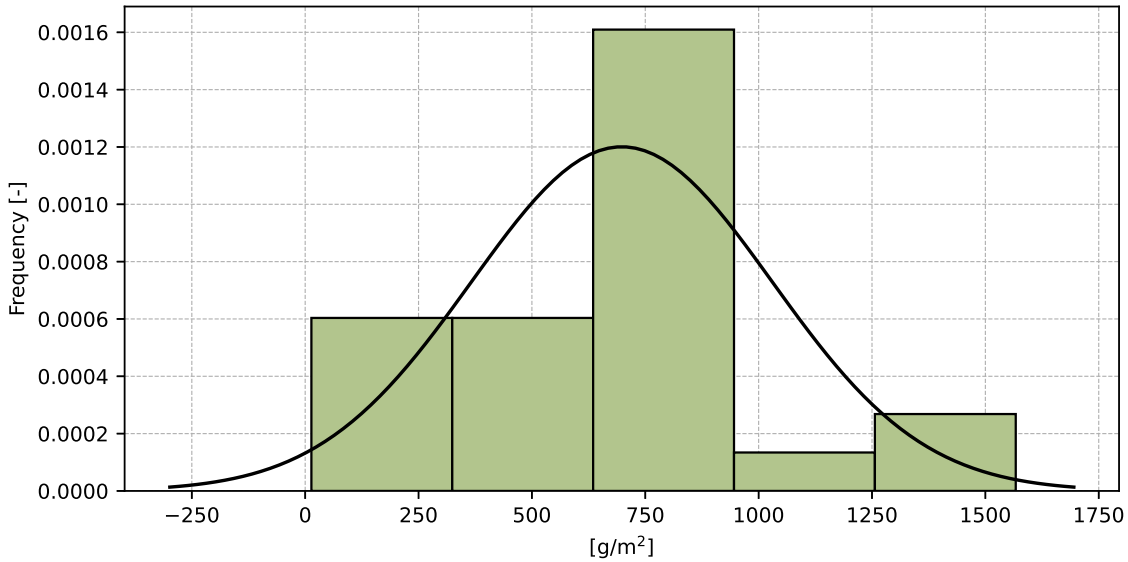

Figure 86: Histogram of all test results

Table 35: Descriptive statistics

Characteristics	**[g/m²]**
Average value – $\bar{x}$	698.3
Sample standard deviation – s	332.27
Asigned value – x^*	735.7
Robust standard deviation – s^*	297.52
Measurement uncertainty of asigned value – u_X	92.98
p-value of normality test	0.081 [-]
Interlaboratory standard deviation – s_L	319.92
Repeatability standard deviation – s_r	155.44
Reproducibility standard deviation – s_R	355.68
Repeatability – r	435.2
Reproducibility – R	995.9

7.4.5 Evaluation of Performance Statistics

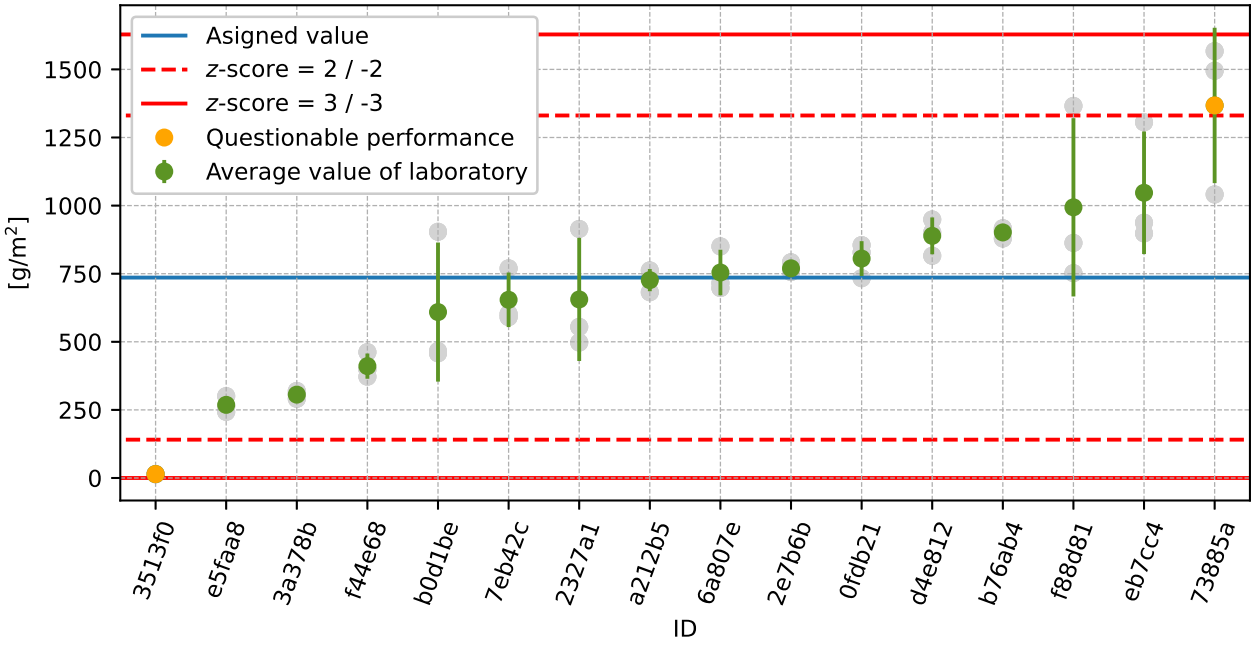

Figure 87: Average values and sample standard deviations

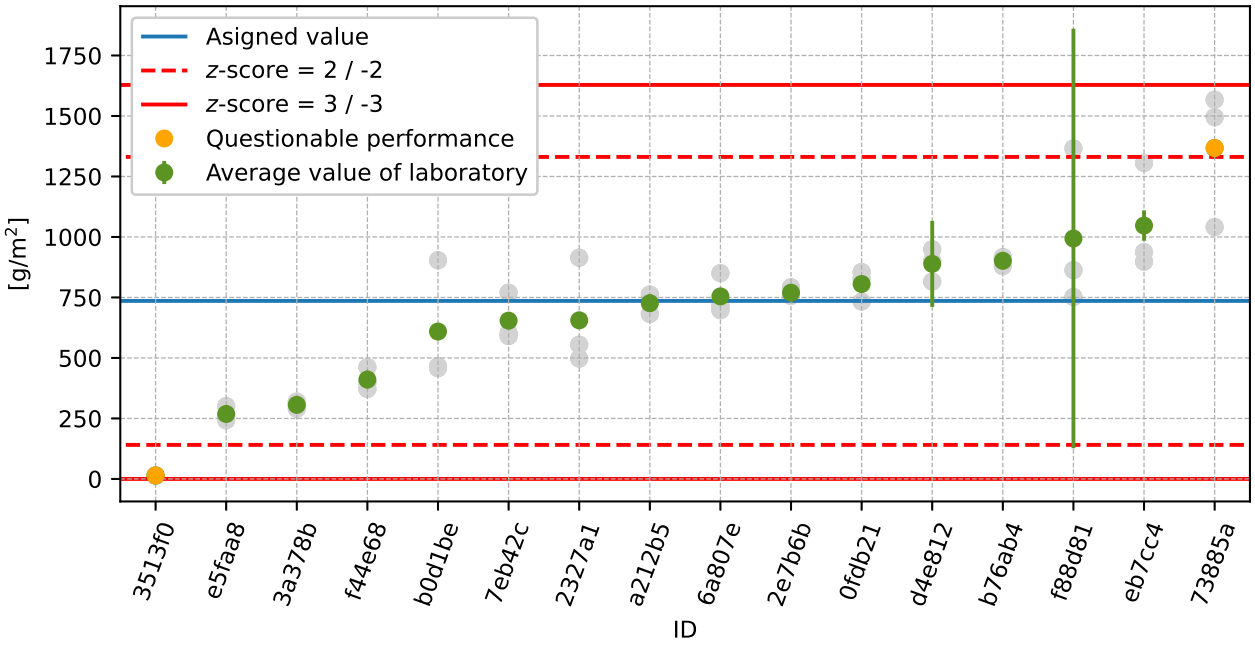

Figure 88: Average values and extended uncertainties of measurement

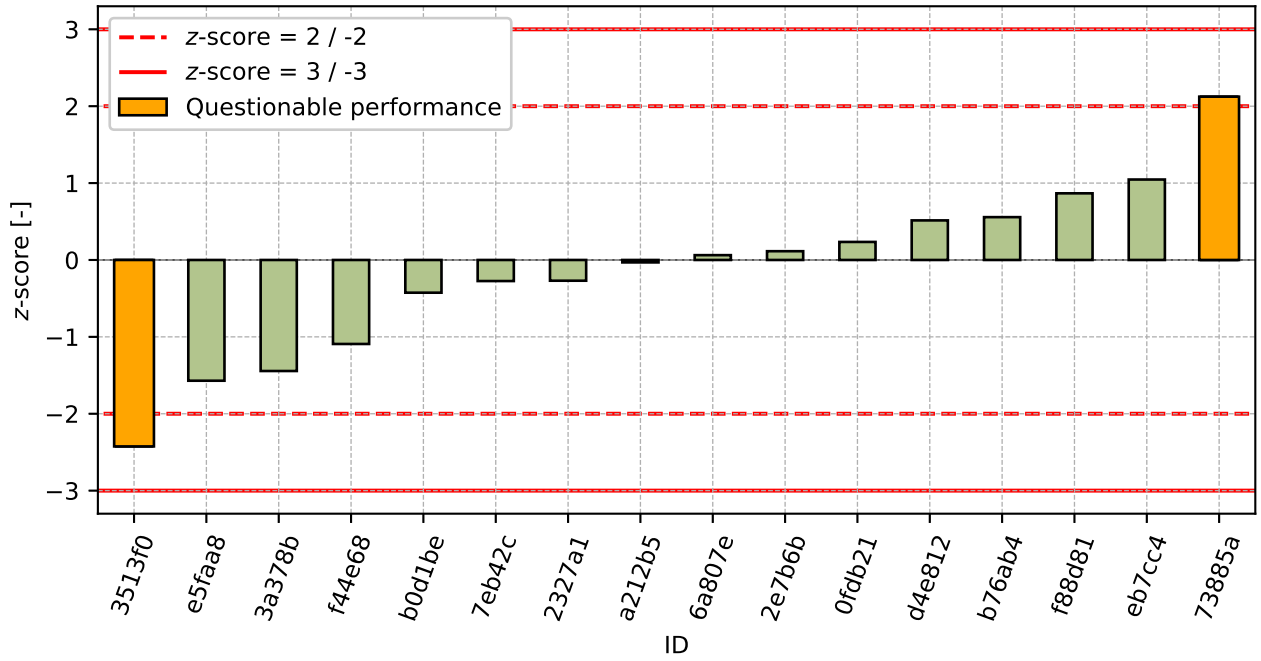

Figure 89: z-score

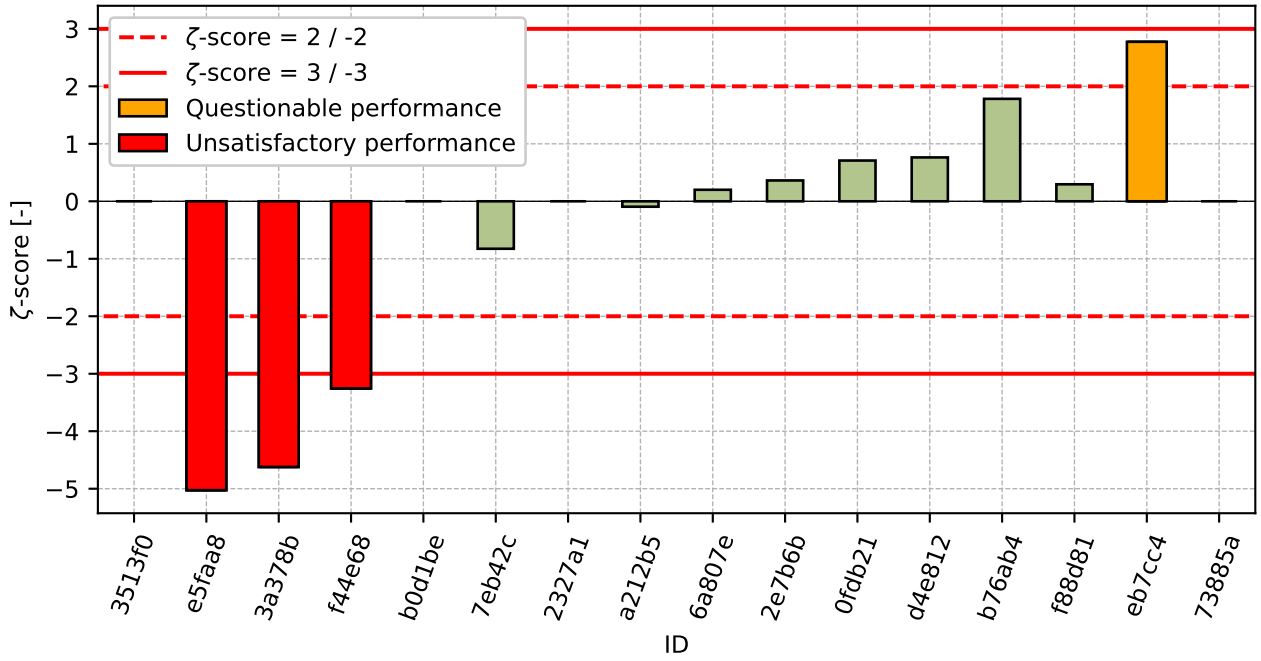

Figure 90: ζ-score

Table 36: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
3513f0	-2.42	-
e5faa8	-1.57	-5.03
3a378b	-1.44	-4.62
f44e68	-1.09	-3.25
b0d1be	-0.43	-
7eb42c	-0.27	-0.83
2327a1	-0.27	-
a212b5	-0.03	-0.09
6a807e	0.06	0.2
2e7b6b	0.11	0.36
0fdb21	0.23	0.71
d4e812	0.51	0.76
b76ab4	0.56	1.78
f88d81	0.87	0.3
eb7cc4	1.05	2.77
73885a	2.12	-

8 Appendix – ČSN 73 1326 – Resistance of cement concrete surface to water and defrosting chemicals – Method C

8.1 25 cycles

8.1.1 Test results

Table 37: 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 [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
a212b5	0.0	0.0	0.0	0.0	0.0	0.0	-
4f4698	39.1	44.7	39.1	10.0	41.0	3.23	7.89
2434f9	77.0	58.4	88.3	5.9	74.6	15.1	20.25
2e0a27	57.0	85.0	108.0	-	83.3	25.54	30.65
5a3300	129.0	144.0	94.0	24.5	122.3	25.66	20.97
157fe9	131.9	130.7	198.6	6.1	153.7	38.86	25.28

8.1.2 The Numerical Procedure for Determining Outliers

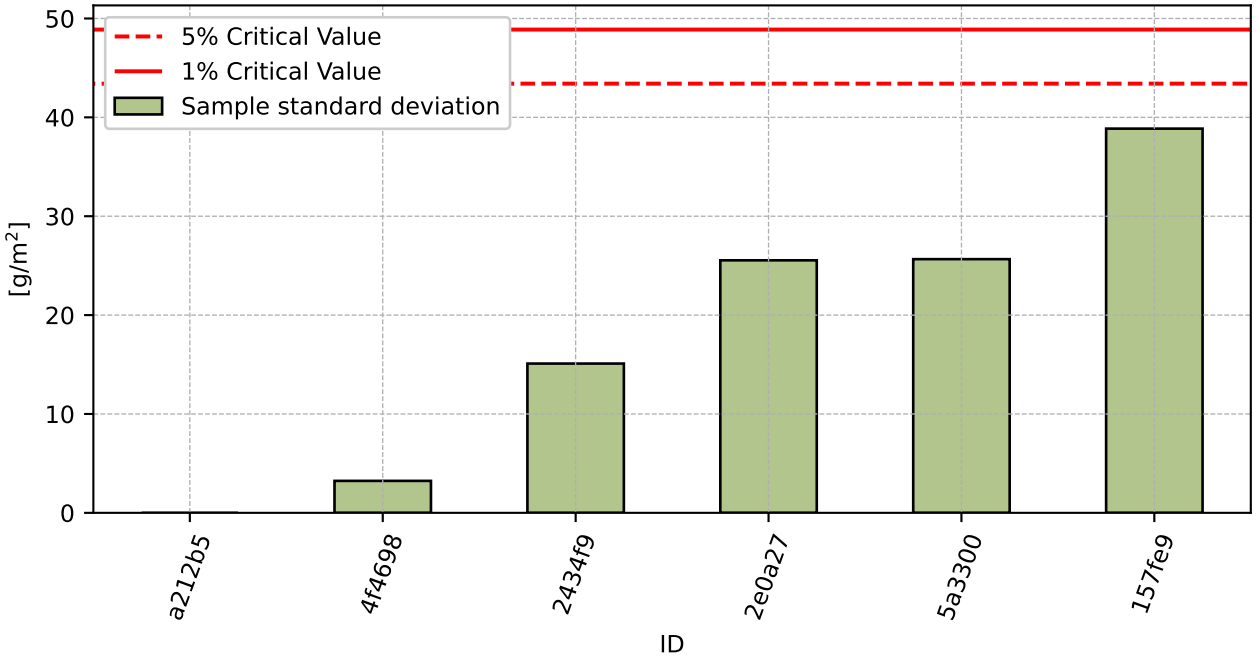

Figure 91: **Cochran's test** - sample standard deviations

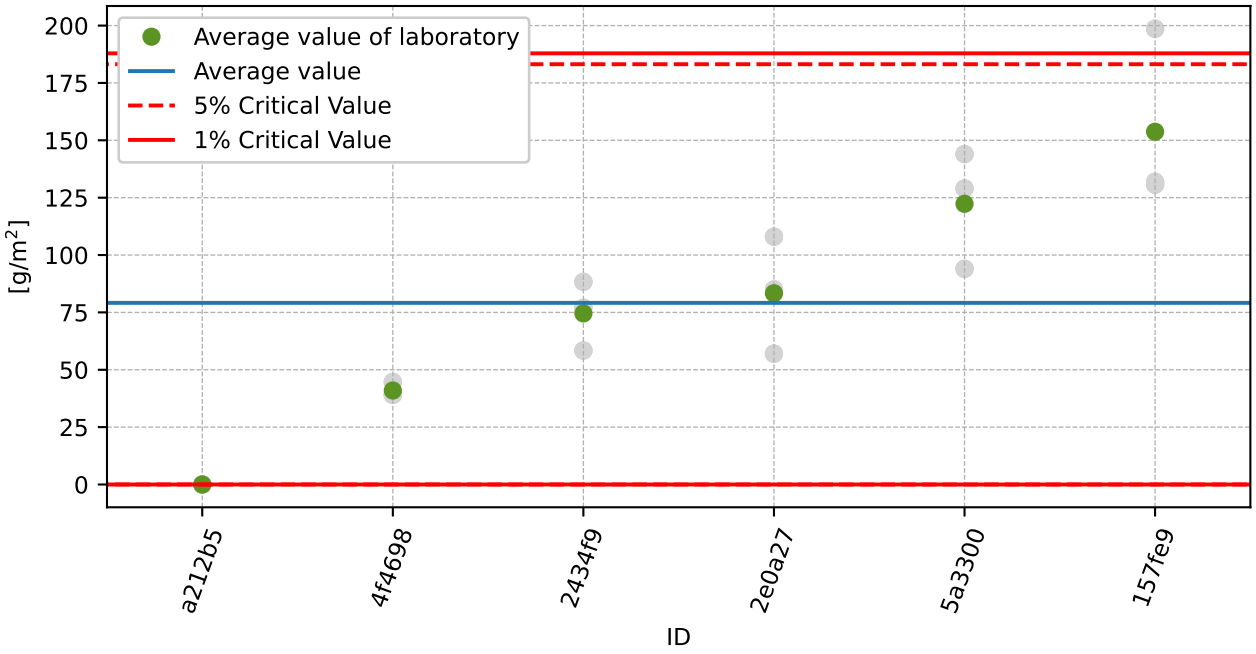

Figure 92: **Grubbs' test** - average values

8.1.3 Mandel's Statistics

Figure 93: Intralaboratory Consistency Statistic

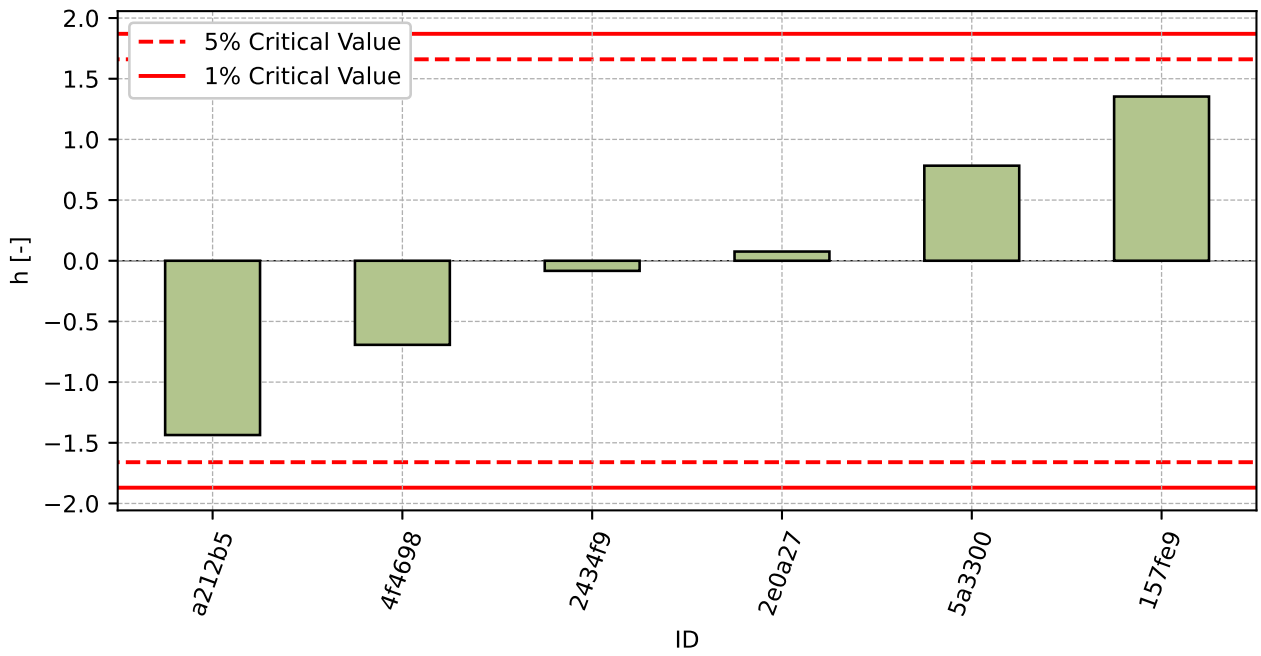

Figure 94: Interlaboratory Consistency Statistic

8.1.4 Descriptive statistics

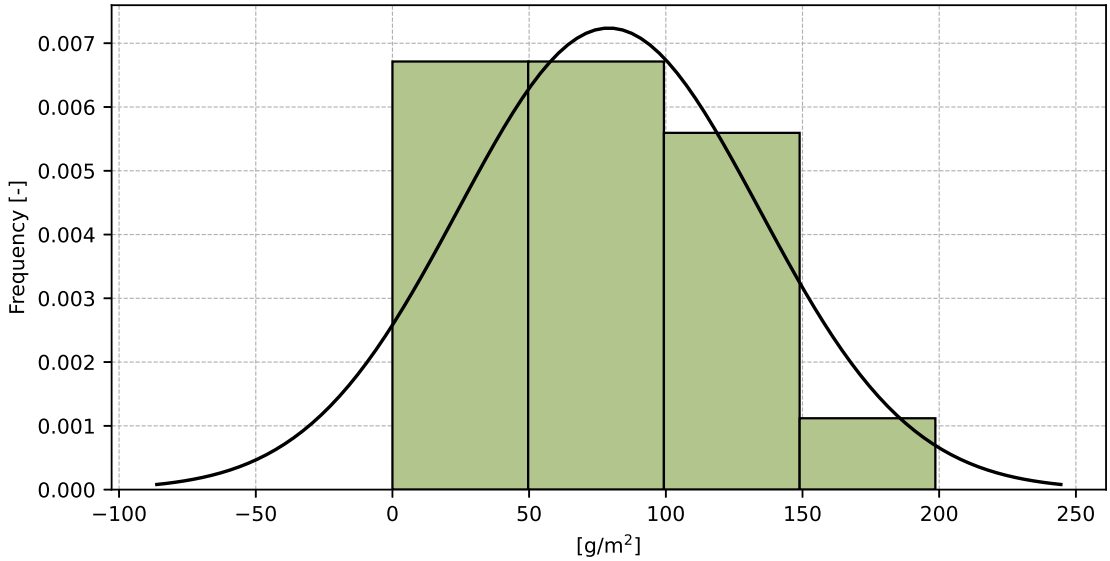

Figure 95: Histogram of all test results

Table 38: Descriptive statistics

Characteristics	[g/m^2]
Average value – $\bar{x}$	79.2
Sample standard deviation – s	55.12
Asigned value – x^*	79.2
Robust standard deviation – s^*	57.06
Measurement uncertainty of asigned value – u_X	29.12
p-value of normality test	0.586 [-]
Interlaboratory standard deviation – s_L	53.55
Repeatability standard deviation – s_r	22.58
Reproducibility standard deviation – s_R	58.12
Repeatability – r	63.2
Reproducibility – R	162.7

8.1.5 Evaluation of Performance Statistics

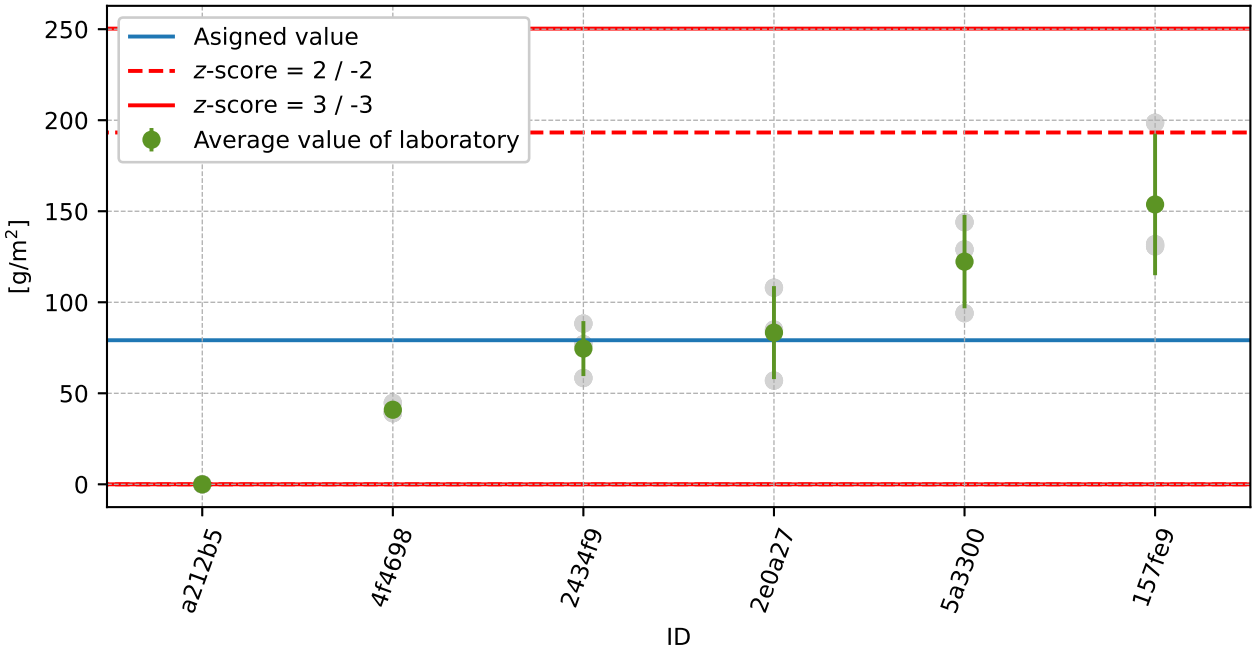

Figure 96: Average values and sample standard deviations

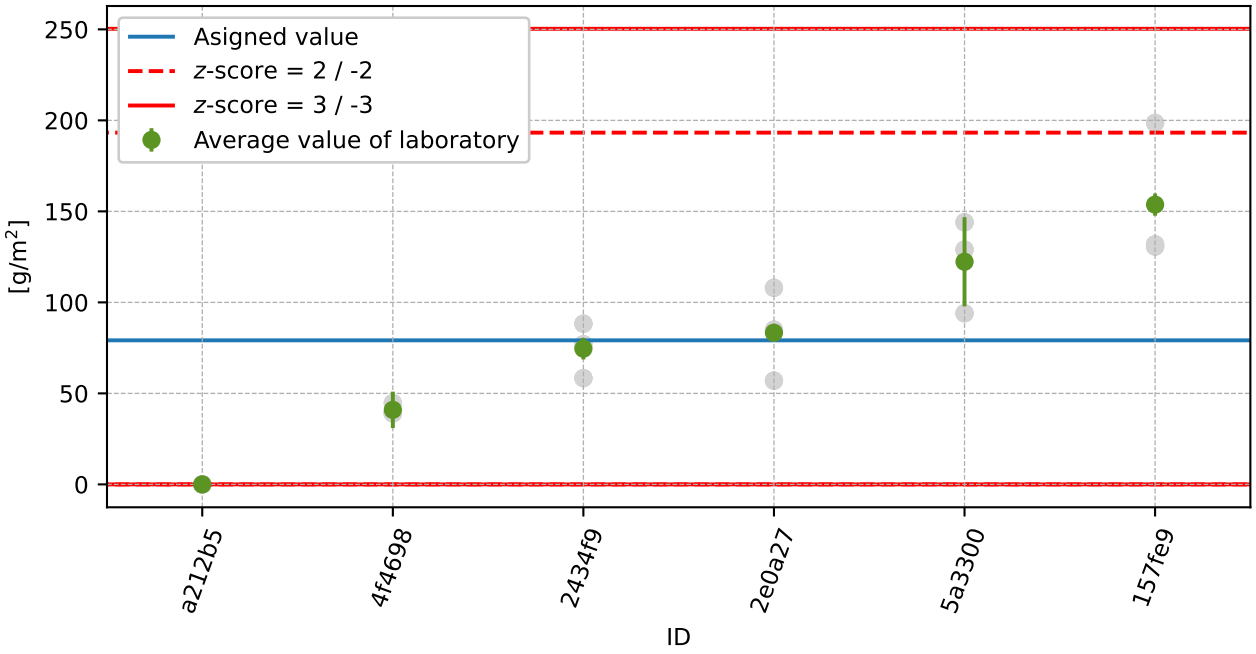

Figure 97: Average values and extended uncertainties of measurement

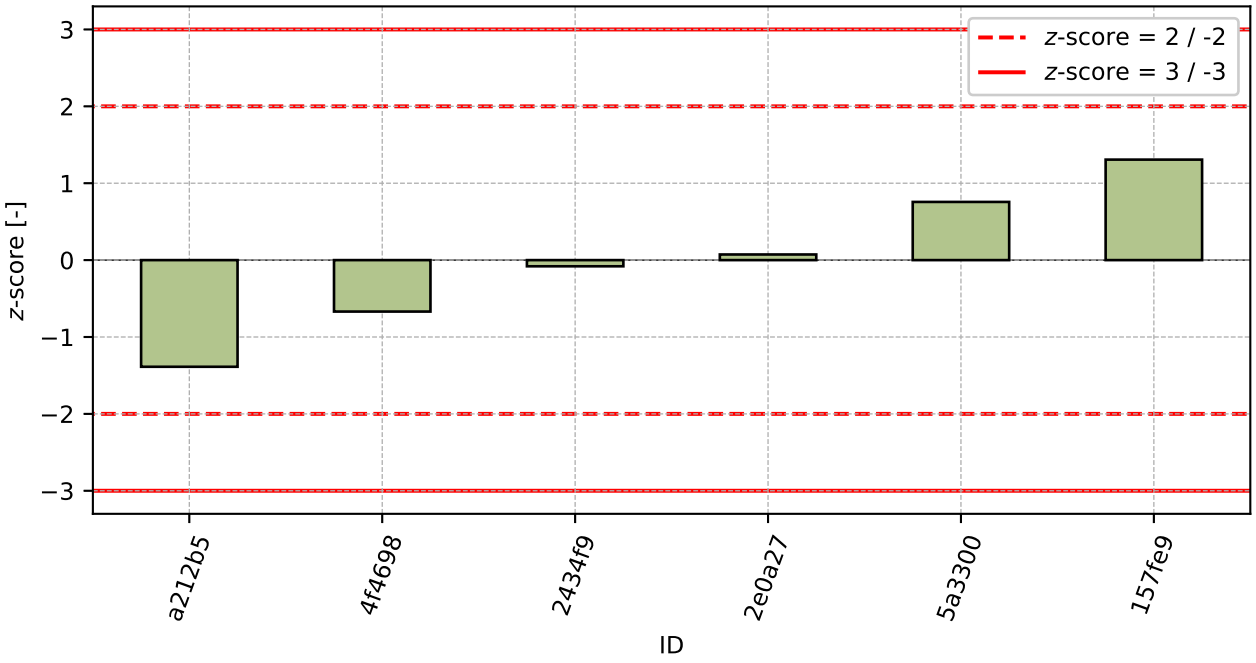

Figure 98: z-score

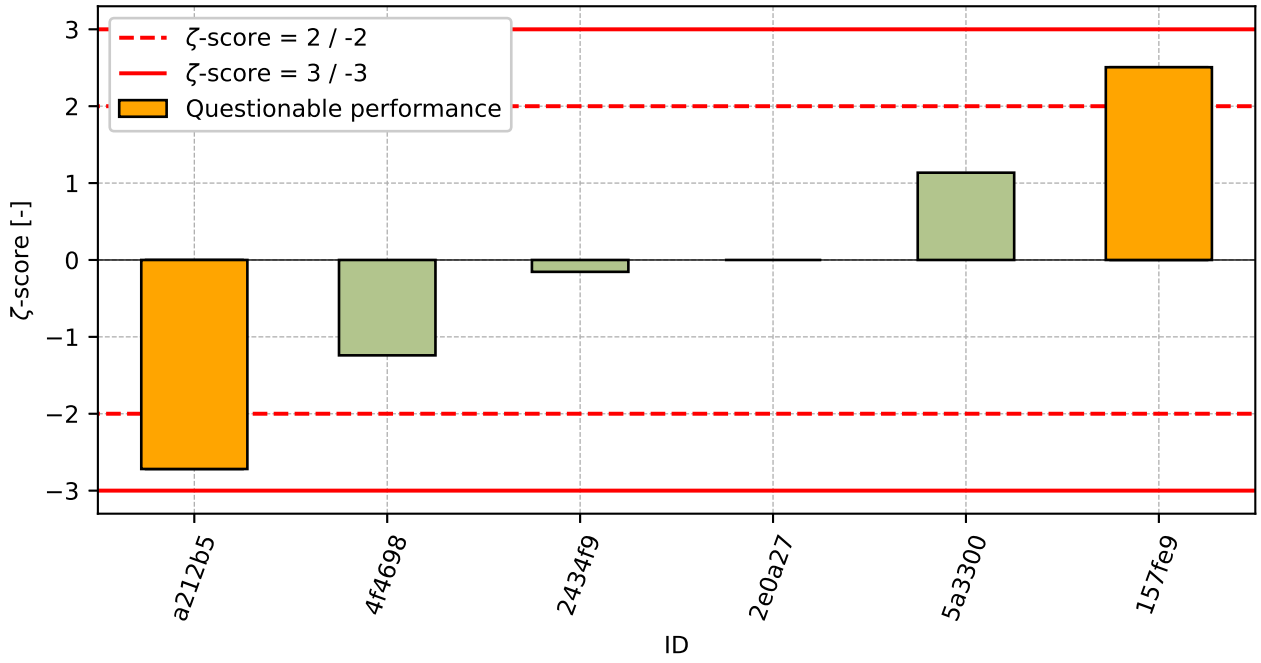

Figure 99: ζ-score

Table 39: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a212b5	-1.39	-2.72
4f4698	-0.67	-1.24
2434f9	-0.08	-0.15
2e0a27	0.07	-
5a3300	0.76	1.14
157fe9	1.31	2.51

8.2 50 cycles

8.2.1 Test results

Table 40: 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 [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
a212b5	56.0	0.0	0.0	0.9	18.7	32.33	173.21
4f4698	55.8	55.8	55.8	20.0	55.8	0.0	0.0
2434f9	106.2	111.9	135.8	9.3	118.0	15.7	13.31
2e0a27	96.0	119.0	153.0	-	122.7	28.68	23.38
5a3300	202.0	239.0	154.0	39.7	198.3	42.62	21.49
157fe9	200.3	159.0	361.6	28.8	240.3	107.06	44.55

8.2.2 The Numerical Procedure for Determining Outliers

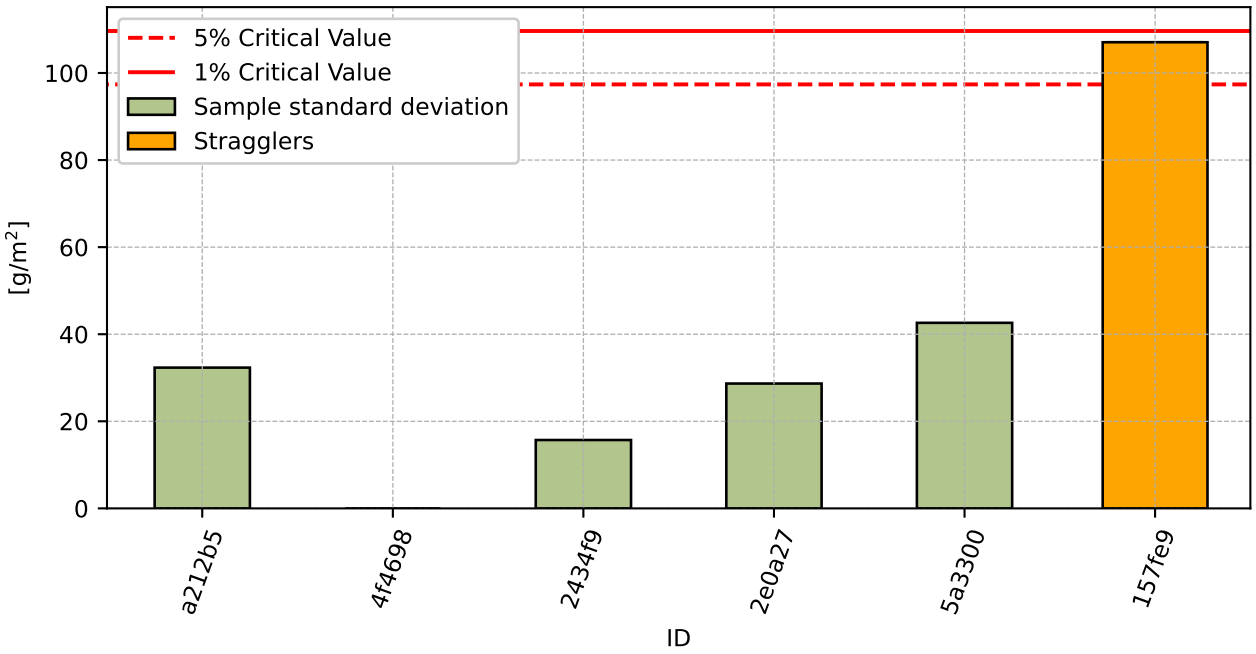

Figure 100: **Cochran's test** - sample standard deviations

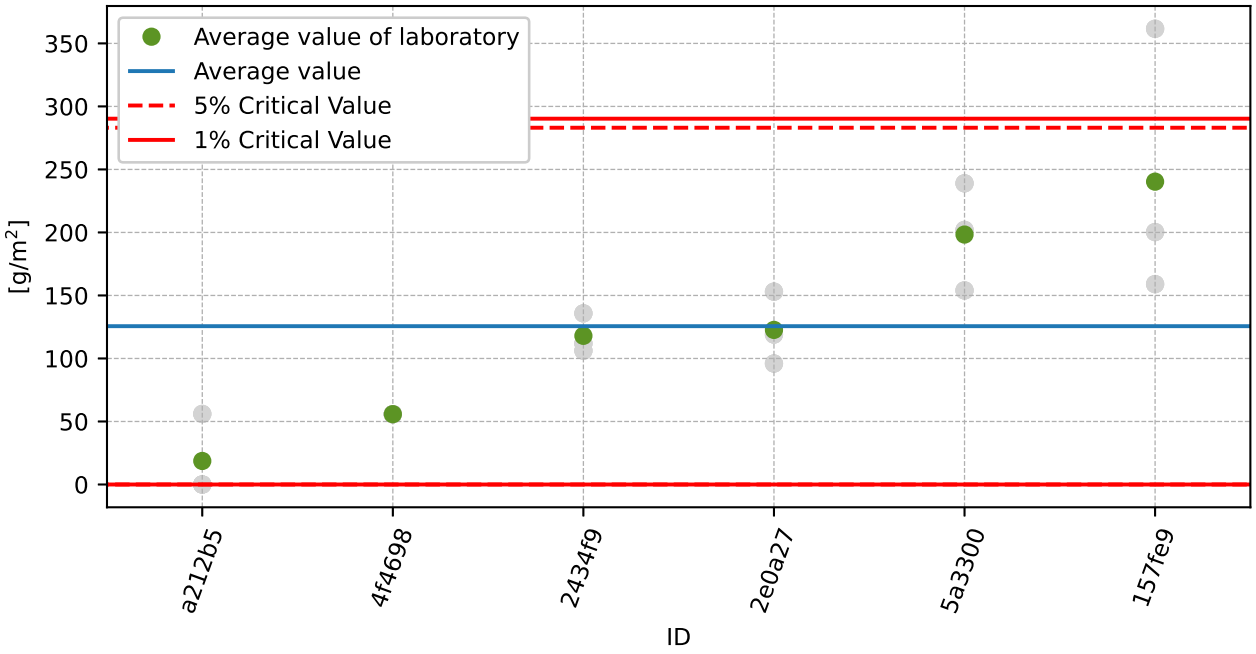

Figure 101: **Grubbs' test** - average values

8.2.3 Mandel's Statistics

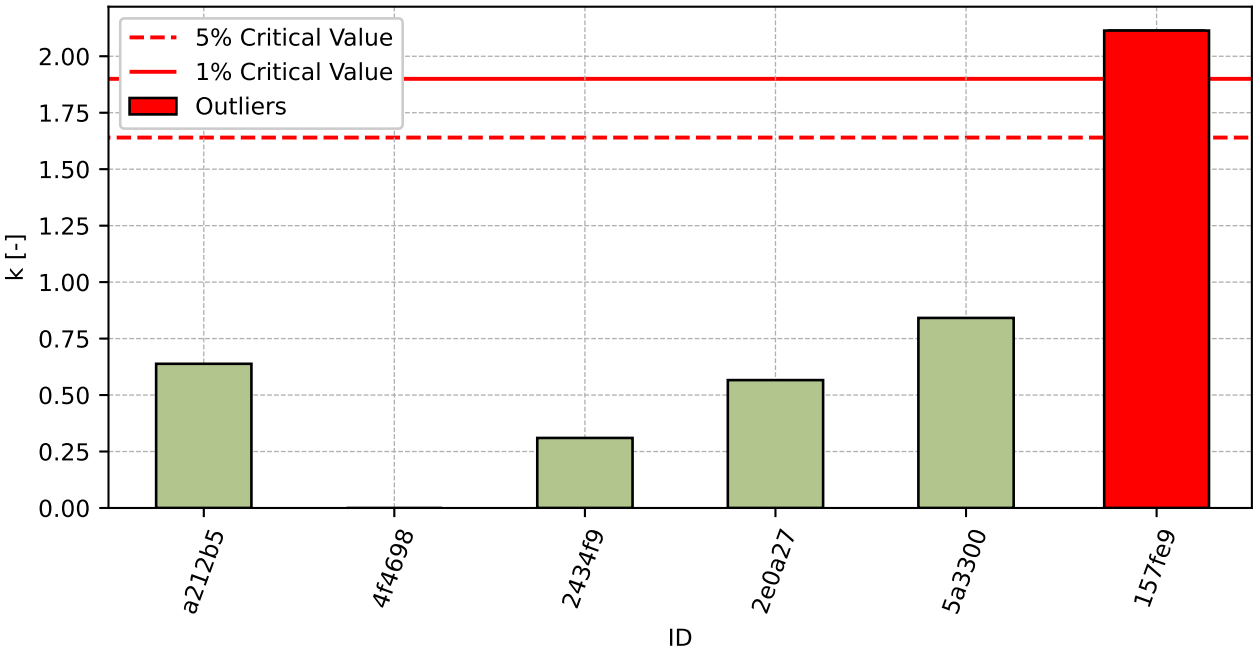

Figure 102: Intralaboratory Consistency Statistic

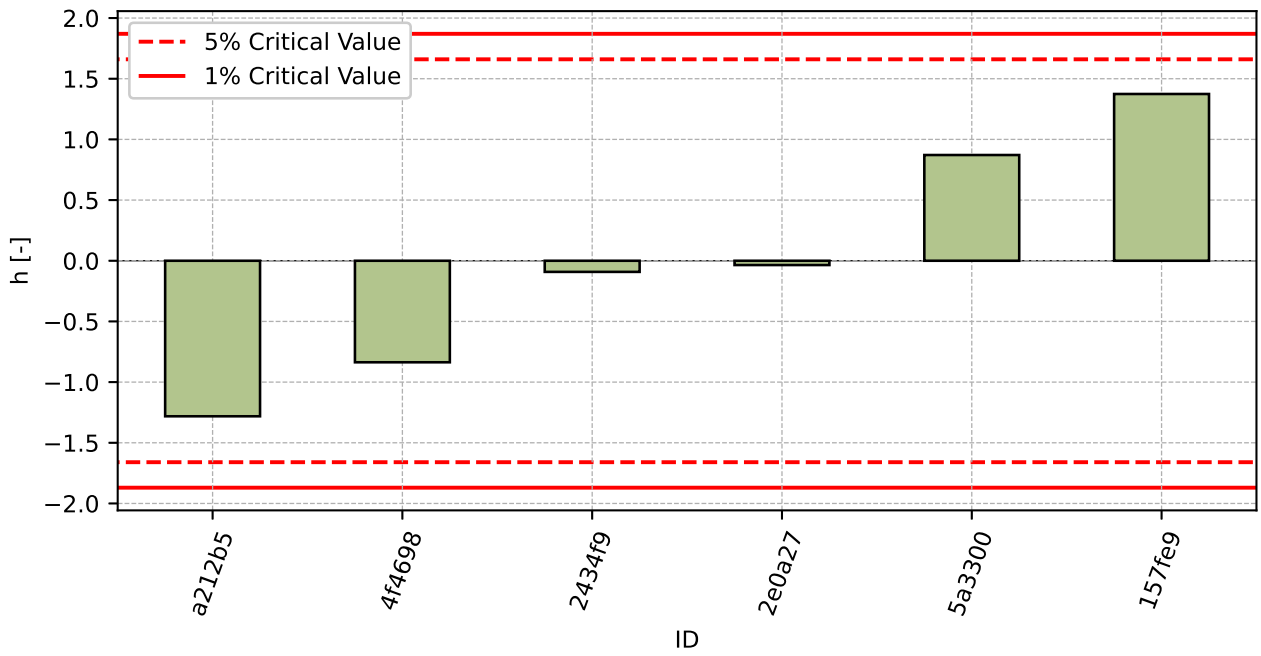

Figure 103: Interlaboratory Consistency Statistic

8.2.4 Descriptive statistics

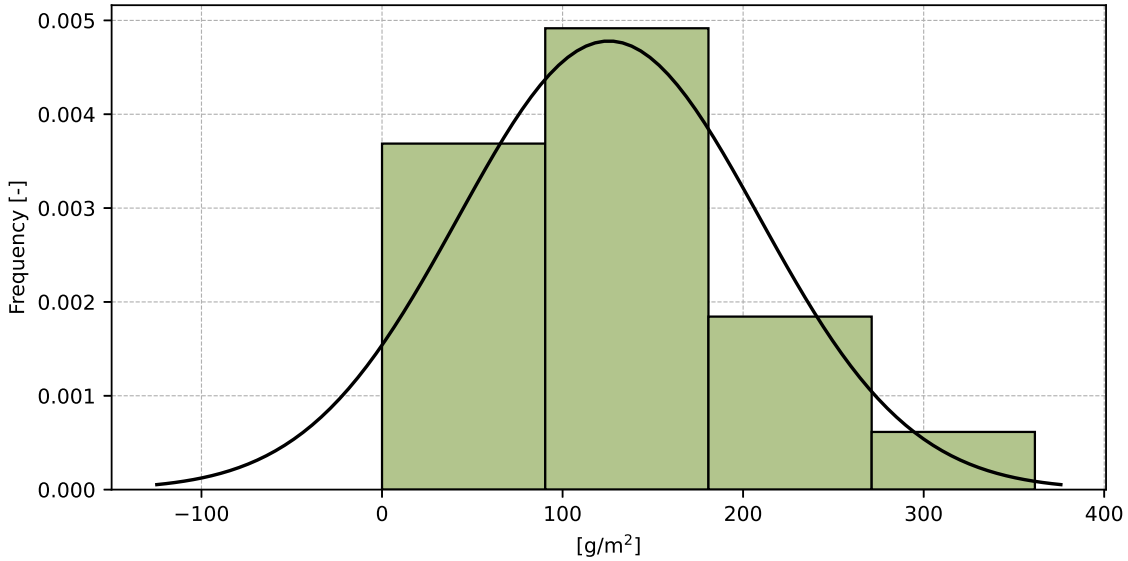

Figure 104: Histogram of all test results

Table 41: Descriptive statistics

Characteristics	[g/m^2]
Average value – $\bar{x}$	125.6
Sample standard deviation – s	83.45
Asigned value – x^*	125.6
Robust standard deviation – s^*	86.39
Measurement uncertainty of asigned value – u_X	44.08
p-value of normality test	0.233 [-]
Interlaboratory standard deviation – s_L	78.16
Repeatability standard deviation – s_r	50.65
Reproducibility standard deviation – s_R	93.14
Repeatability – r	141.8
Reproducibility – R	260.8

8.2.5 Evaluation of Performance Statistics

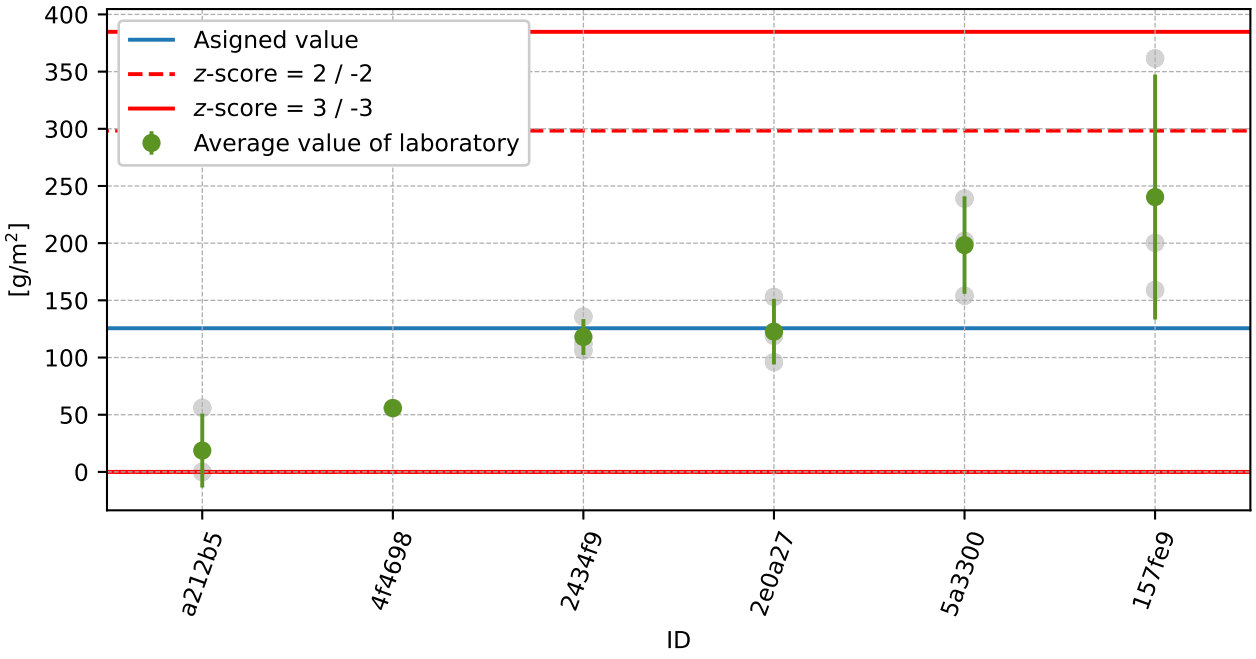

Figure 105: Average values and sample standard deviations

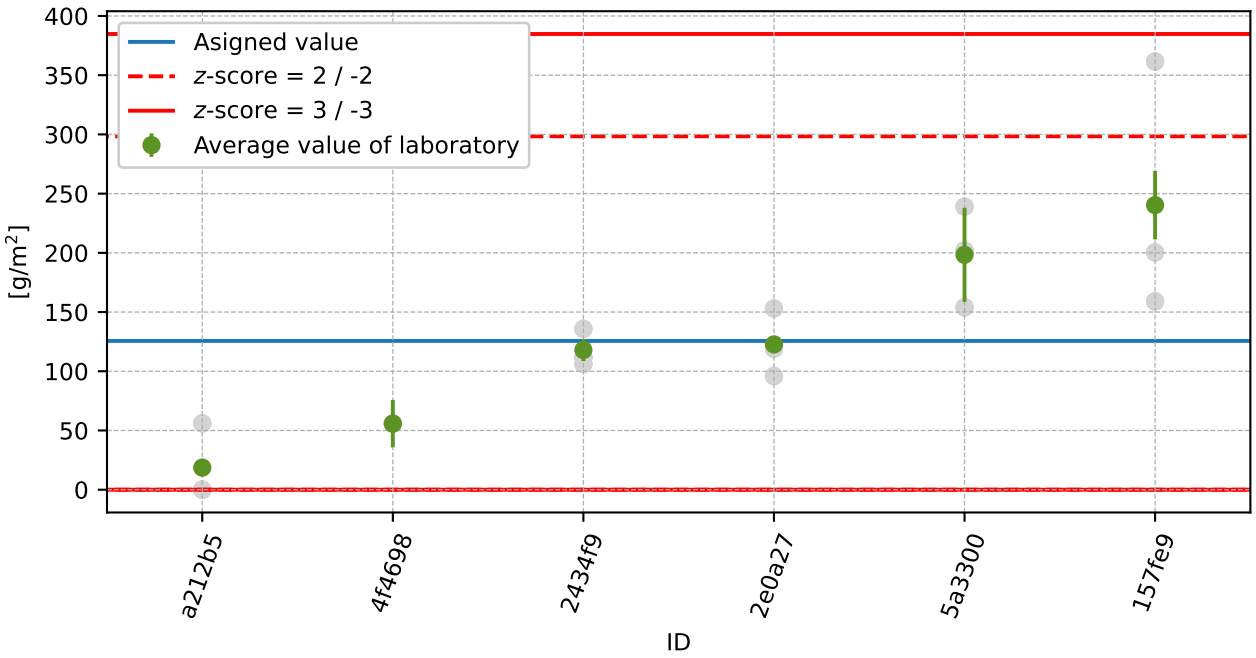

Figure 106: Average values and extended uncertainties of measurement

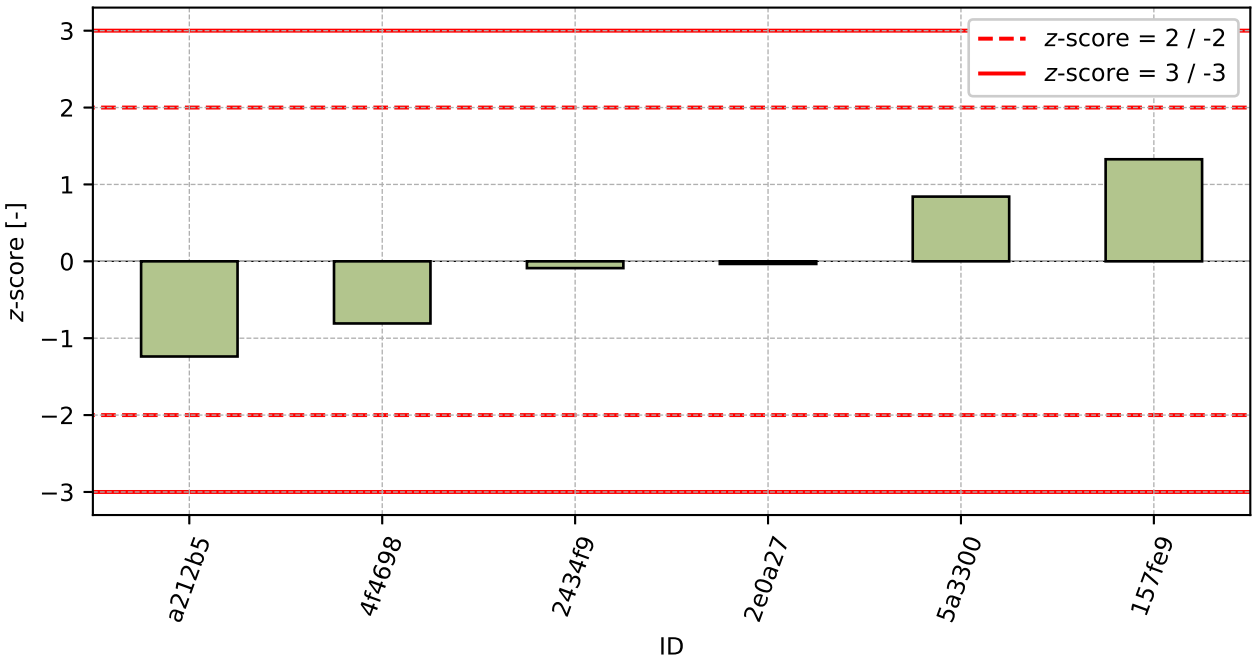

Figure 107: z-score

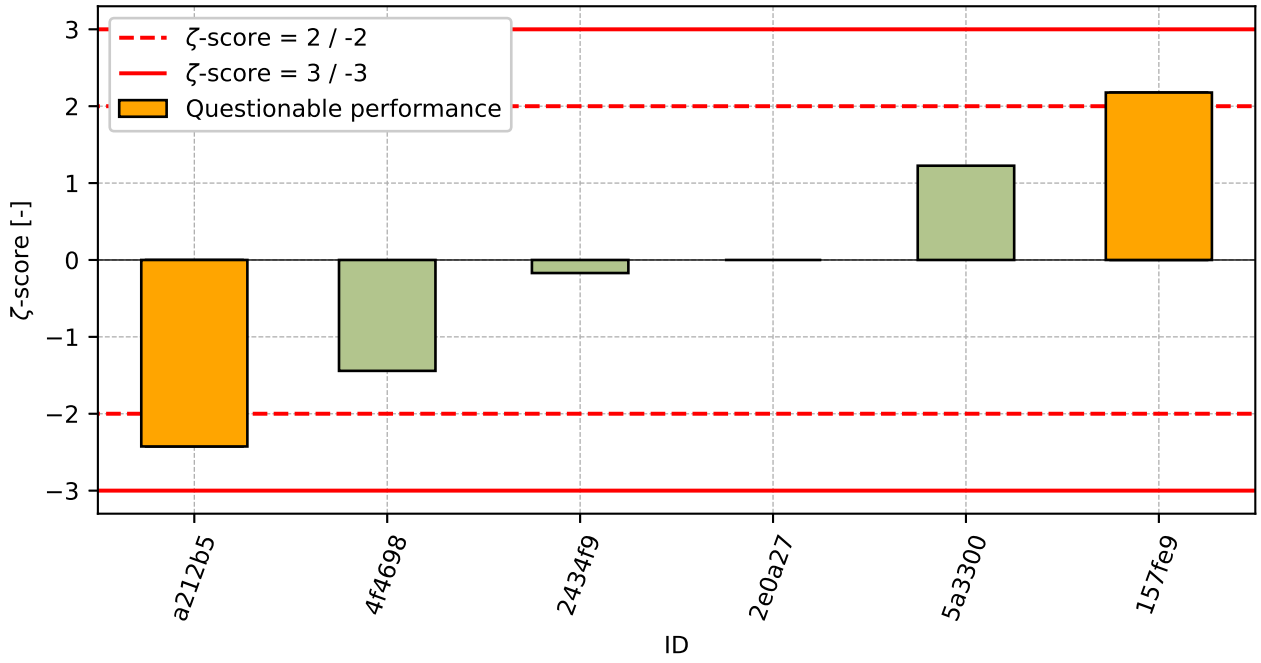

Figure 108: ζ-score

Table 42: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a212b5	-1.24	-2.43
4f4698	-0.81	-1.44
2434f9	-0.09	-0.17
2e0a27	-0.03	-
5a3300	0.84	1.23
157fe9	1.33	2.18

8.3 75 cycles

8.3.1 Test results

Table 43: 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 [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
a212b5	112.0	55.0	56.0	3.7	74.3	32.62	43.89
4f4698	94.9	150.8	78.2	40.0	108.0	38.02	35.22
2434f9	144.2	166.4	194.5	13.3	168.4	25.21	14.97
2e0a27	141.0	164.0	204.0	-	169.7	31.88	18.79
5a3300	292.0	378.0	242.0	60.8	304.0	68.79	22.63
157fe9	365.6	222.4	511.0	38.2	366.3	144.3	39.39

8.3.2 The Numerical Procedure for Determining Outliers

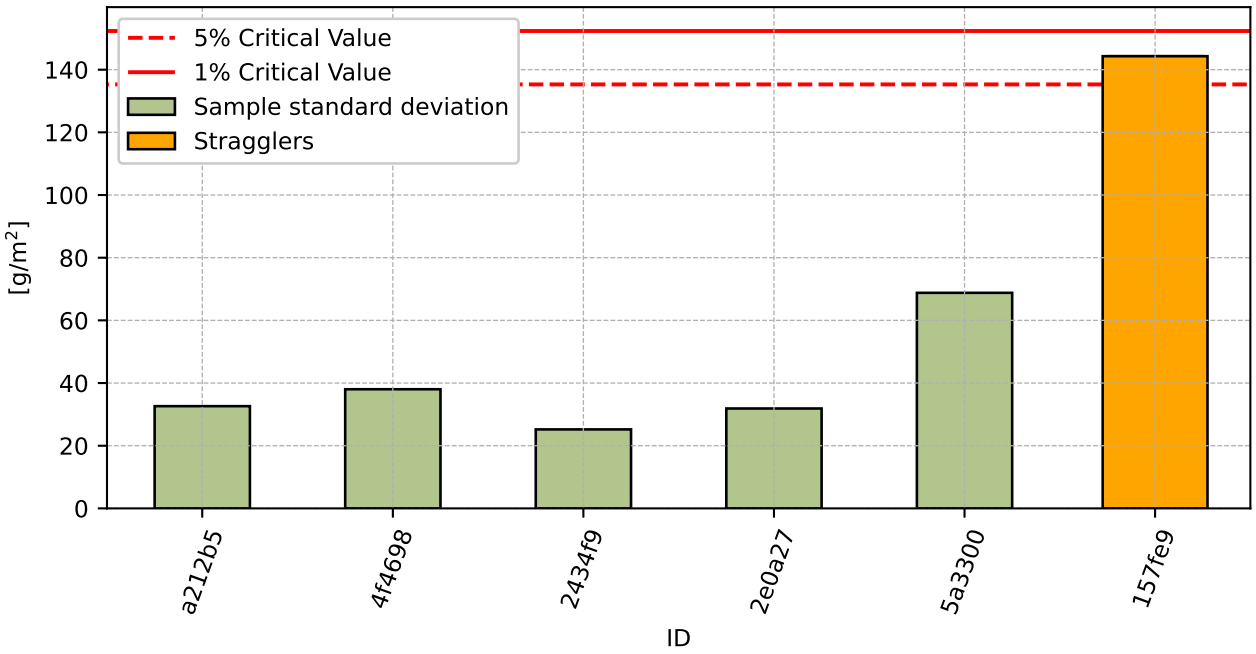

Figure 109: **Cochran's test** - sample standard deviations

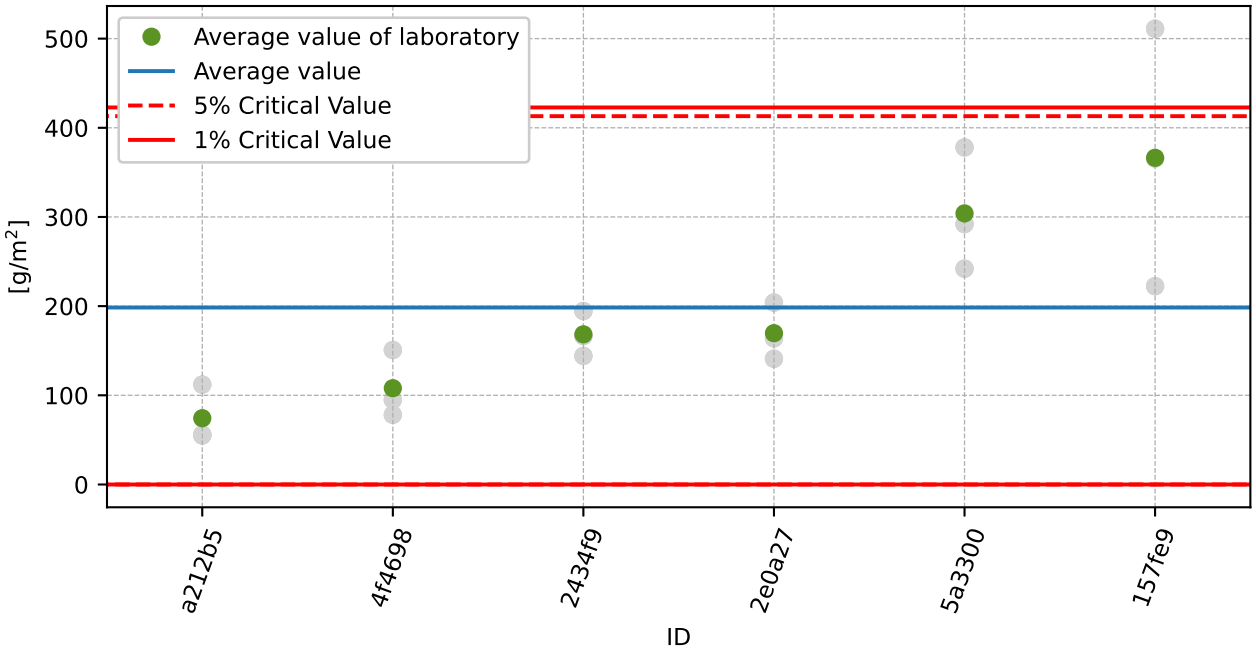

Figure 110: **Grubbs' test** - average values

8.3.3 Mandel's Statistics

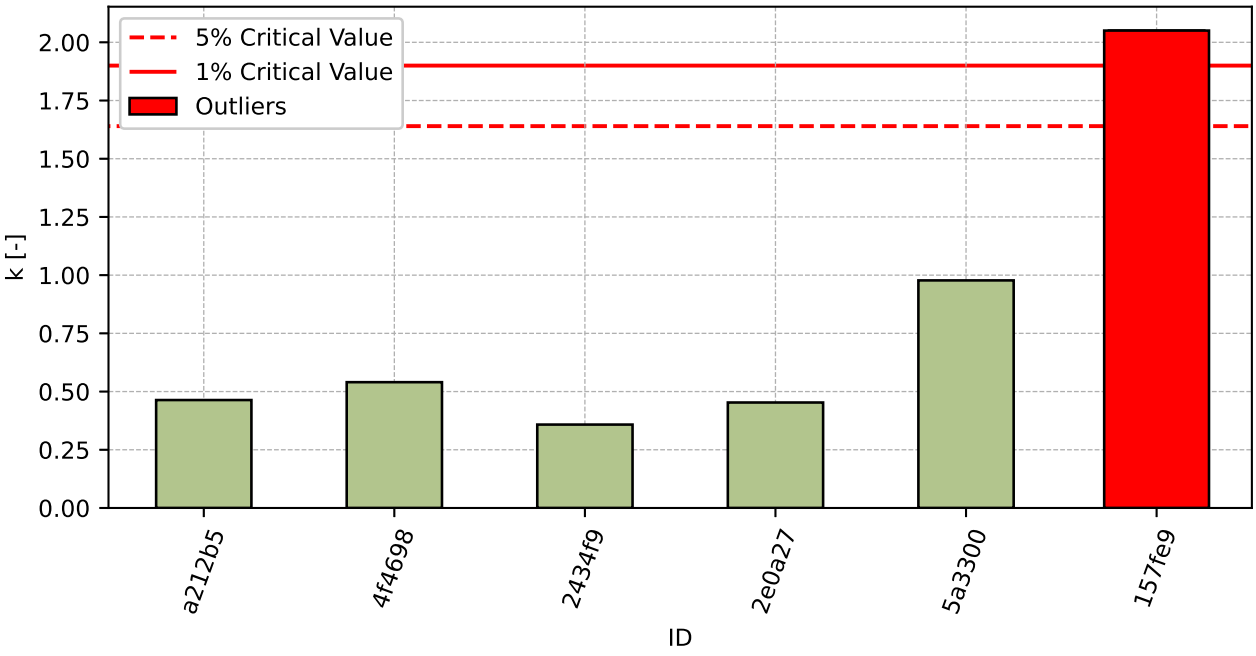

Figure 111: Intralaboratory Consistency Statistic

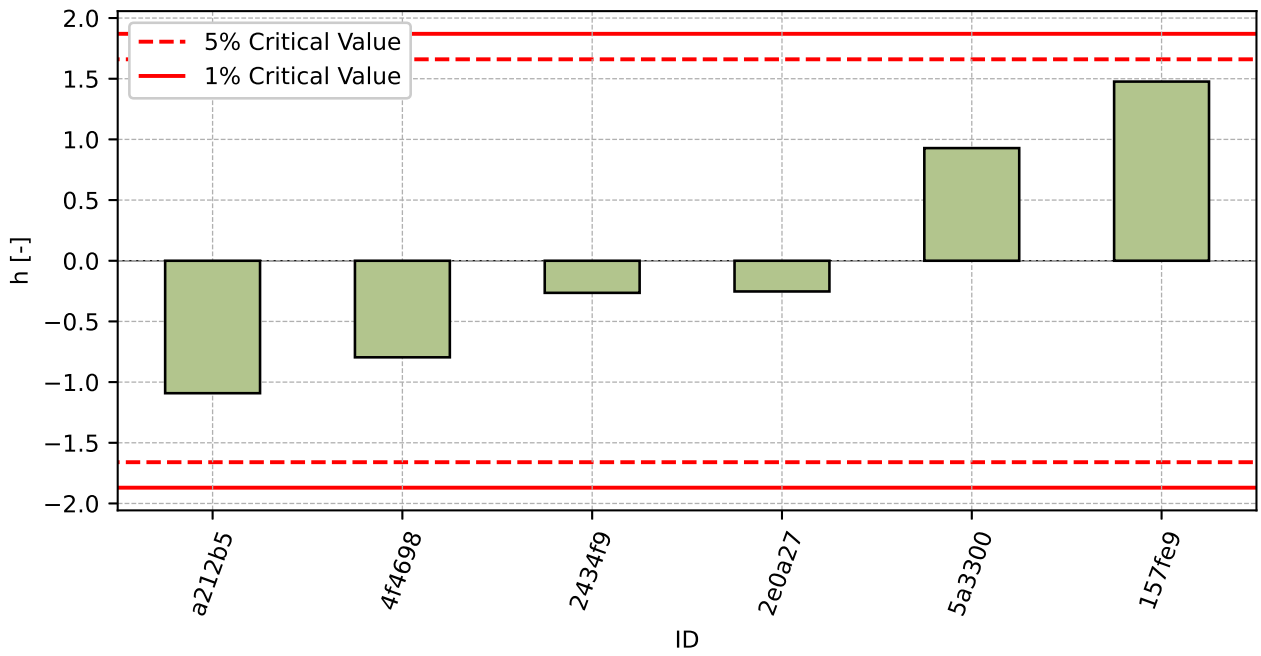

Figure 112: Interlaboratory Consistency Statistic

8.3.4 Descriptive statistics

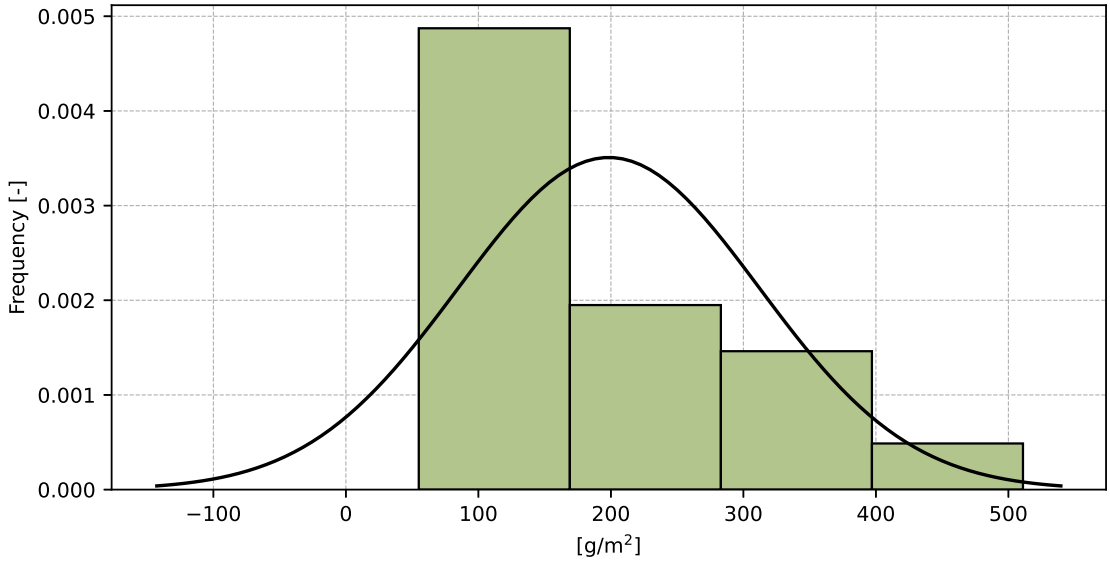

Figure 113: Histogram of all test results

Table 44: Descriptive statistics

Characteristics	[g/m^2]
Average value – $\bar{x}$	198.4
Sample standard deviation – s	113.71
Asigned value – x^*	198.4
Robust standard deviation – s^*	117.71
Measurement uncertainty of asigned value – u_X	60.07
p-value of normality test	0.065 [-]
Interlaboratory standard deviation – s_L	106.2
Repeatability standard deviation – s_r	70.38
Reproducibility standard deviation – s_R	127.41
Repeatability – r	197.1
Reproducibility – R	356.7

8.3.5 Evaluation of Performance Statistics

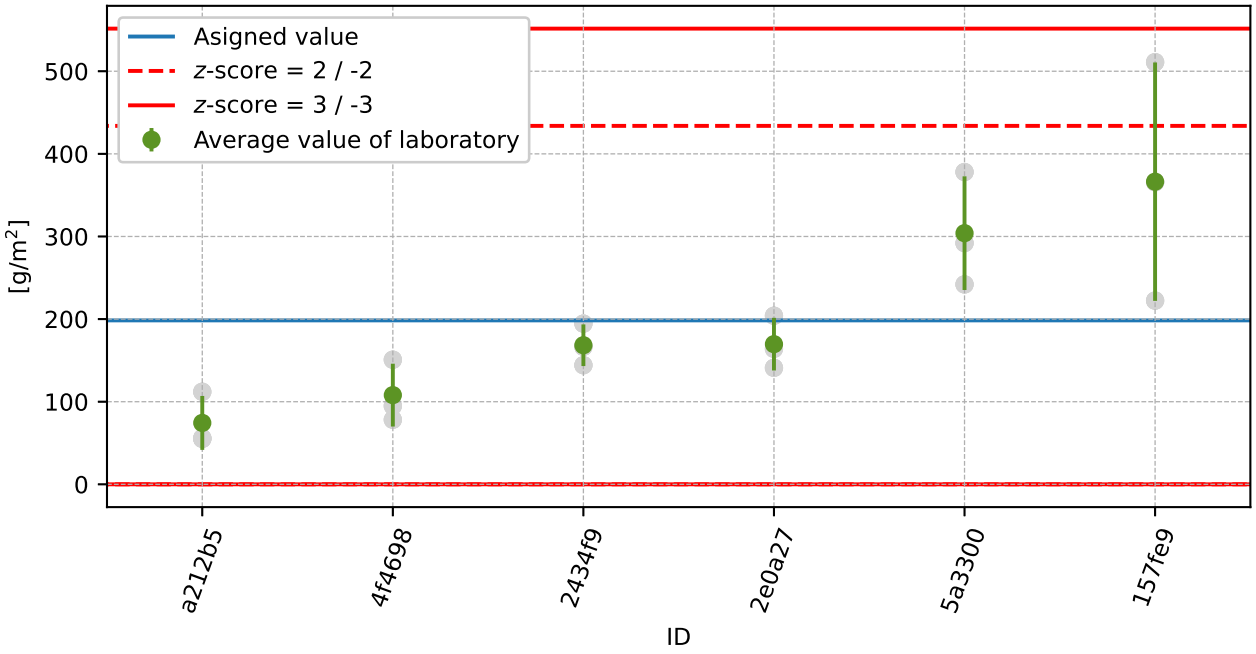

Figure 114: Average values and sample standard deviations

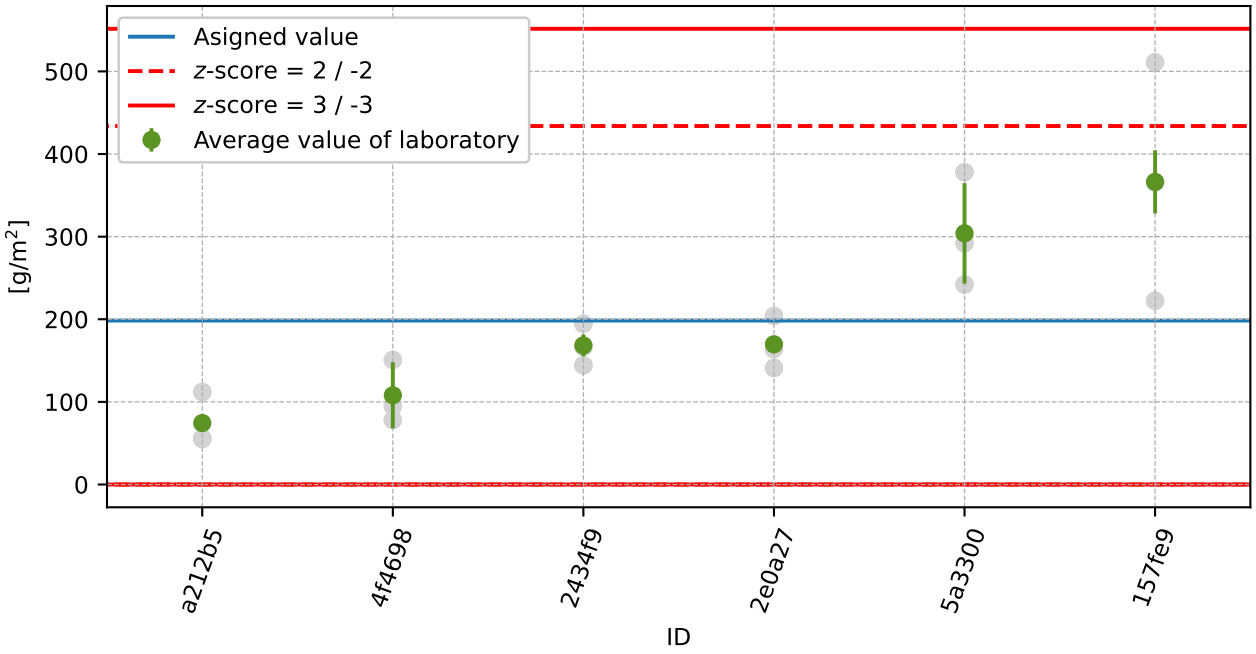

Figure 115: Average values and extended uncertainties of measurement

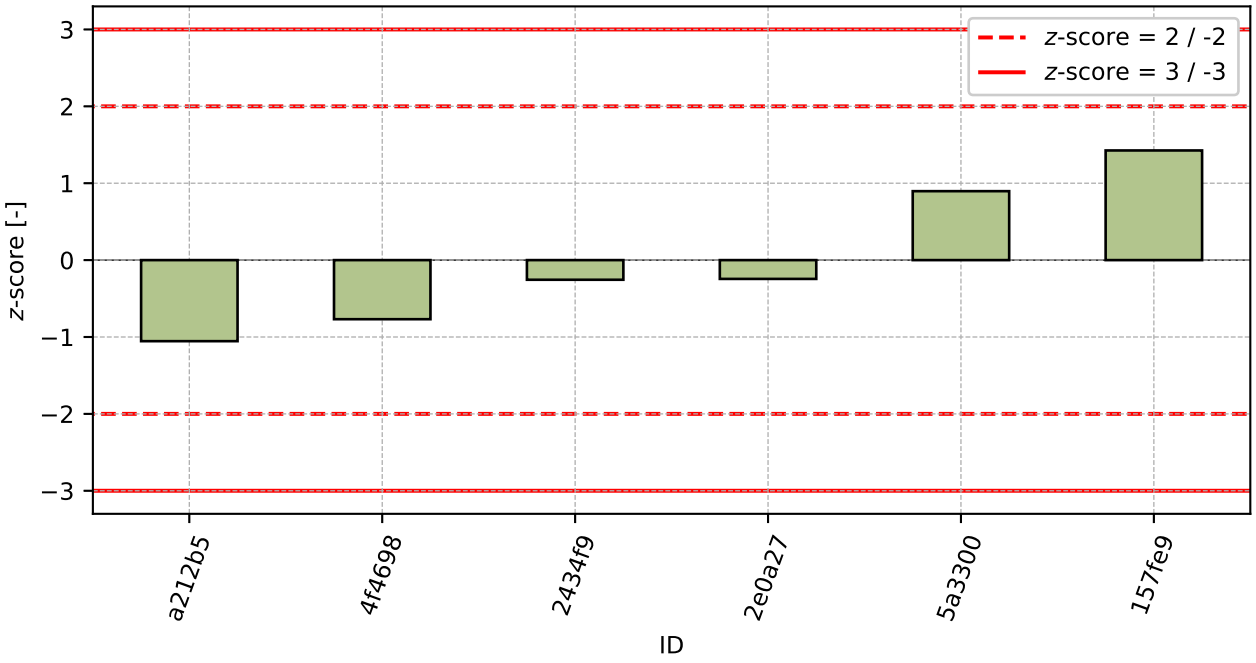

Figure 116: z-score

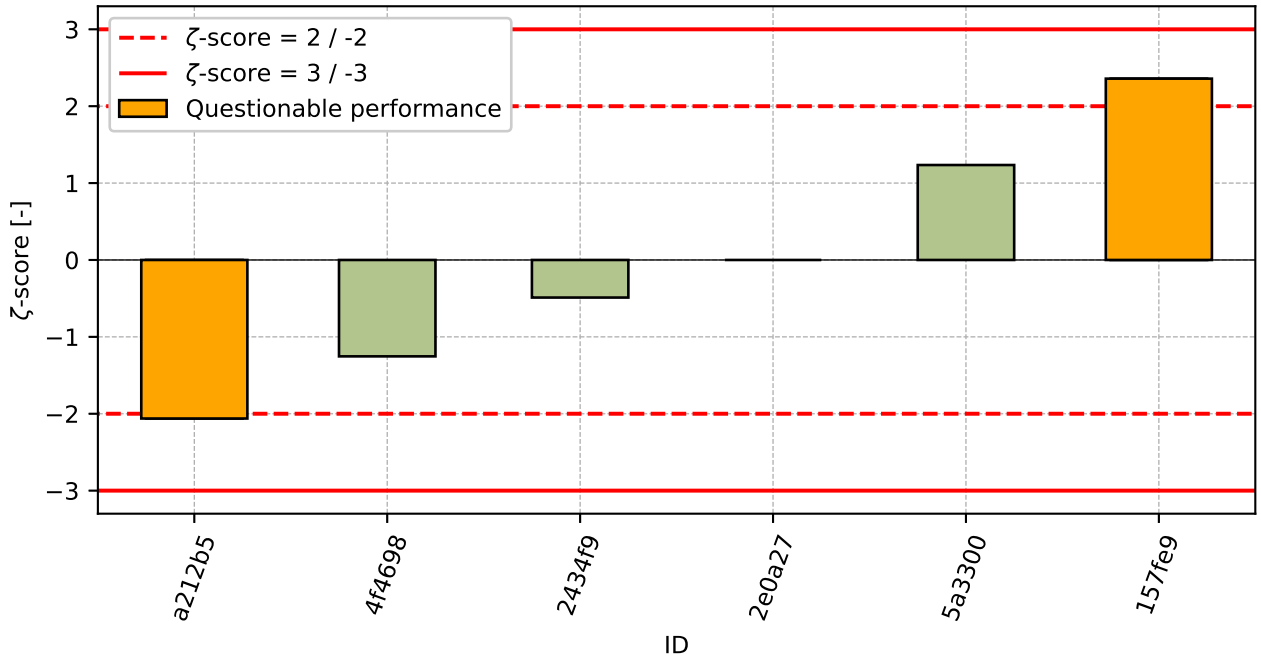

Figure 117: ζ-score

Table 45: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a212b5	-1.05	-2.06
4f4698	-0.77	-1.25
2434f9	-0.26	-0.49
2e0a27	-0.24	-
5a3300	0.9	1.24
157fe9	1.43	2.36

9 Appendix – CEN/TS 12390-9 – Freeze-thaw resistance – Scaling

9.1 Test results

Table 46: 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 [%]				u_X [%]	$\bar{x}$ [%]	s_0 [%]	V_X [%]
76cc78	135	105	461	175	50	219	163.9	74.82
a429d6	420	360	240	180	31	300	109.5	36.51
f27c19	440	520	240	200	24	350	154.5	44.14
121655	560	500	440	520	10	505	50.0	9.9
ad394c	260	280	820	1280	160	660	488.0	73.94
0a6482	1212	972	1218	1266	-	1167	132.4	11.34
fe2c05	2482	451	824	2773	293	1632	1165.0	71.37
2c0aaf	1983	2053	1942	2501	42	2120	258.3	12.18
e3a278	4139	2837	3340	3019	404	3334	575.7	17.27
92e29f	7697	5785	2250	5071	-	5201	2258.1	43.42

9.2 The Numerical Procedure for Determining Outliers

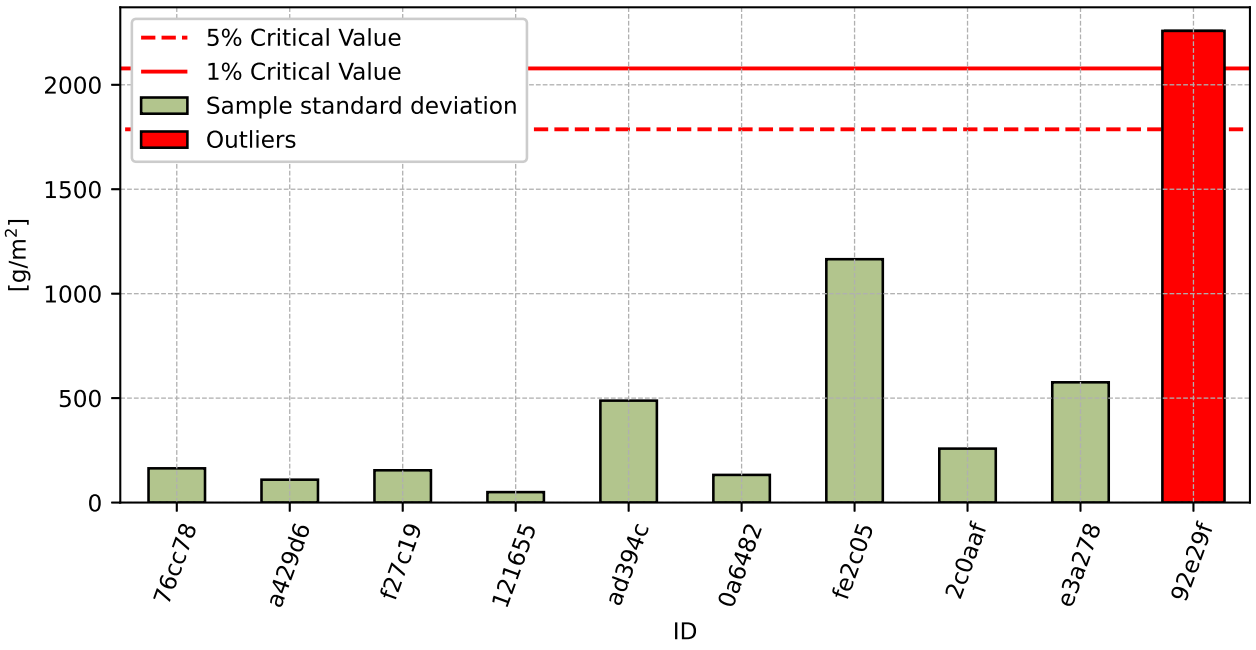

Figure 118: **Cochran's test** - sample standard deviations

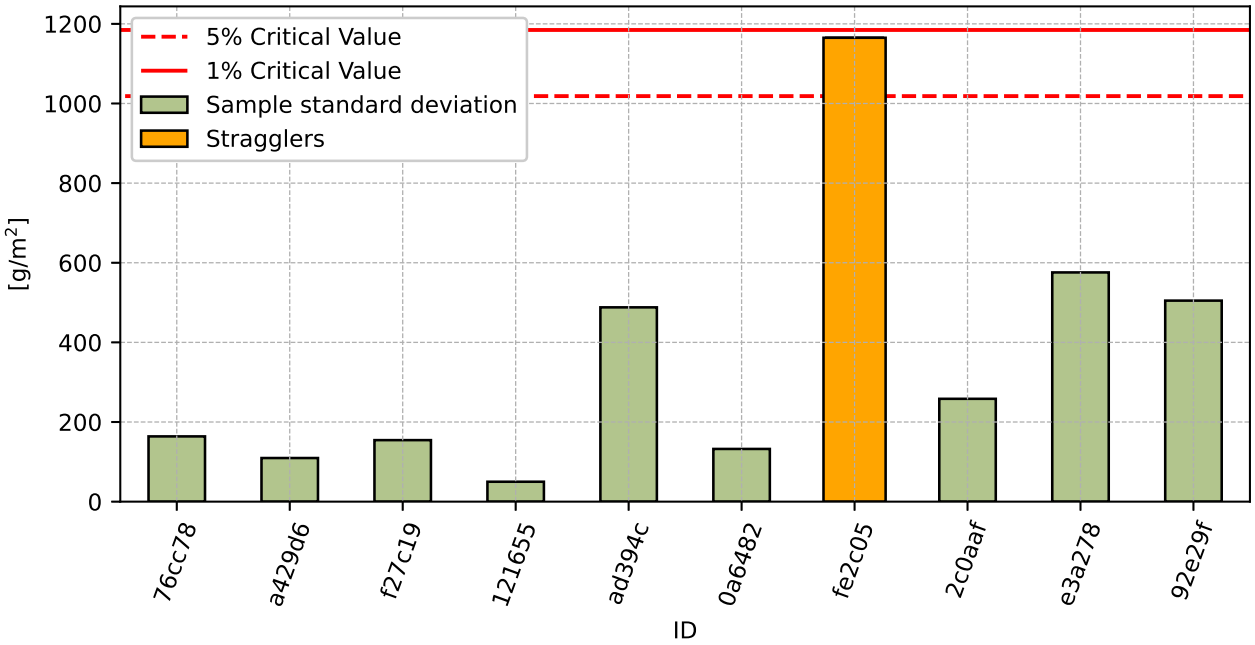

Figure 119: **Cochran's test** - sample standard deviations without outliers

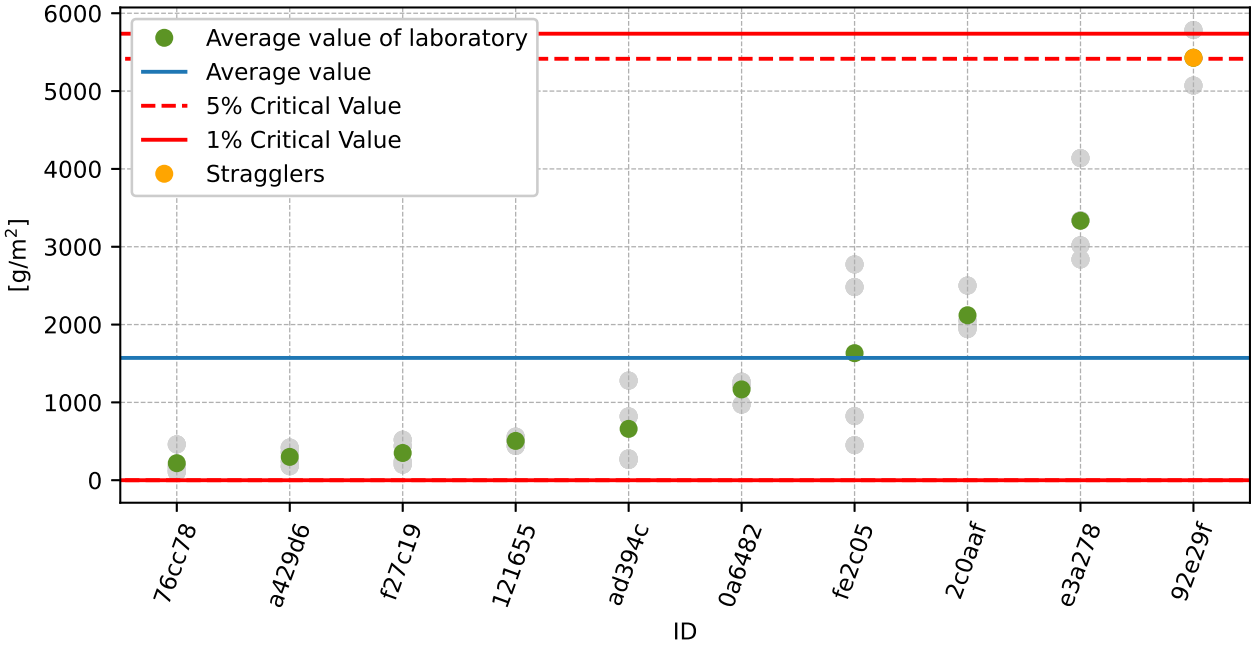

Figure 120: **Grubbs' test** - average values

9.3 Mandel's Statistics

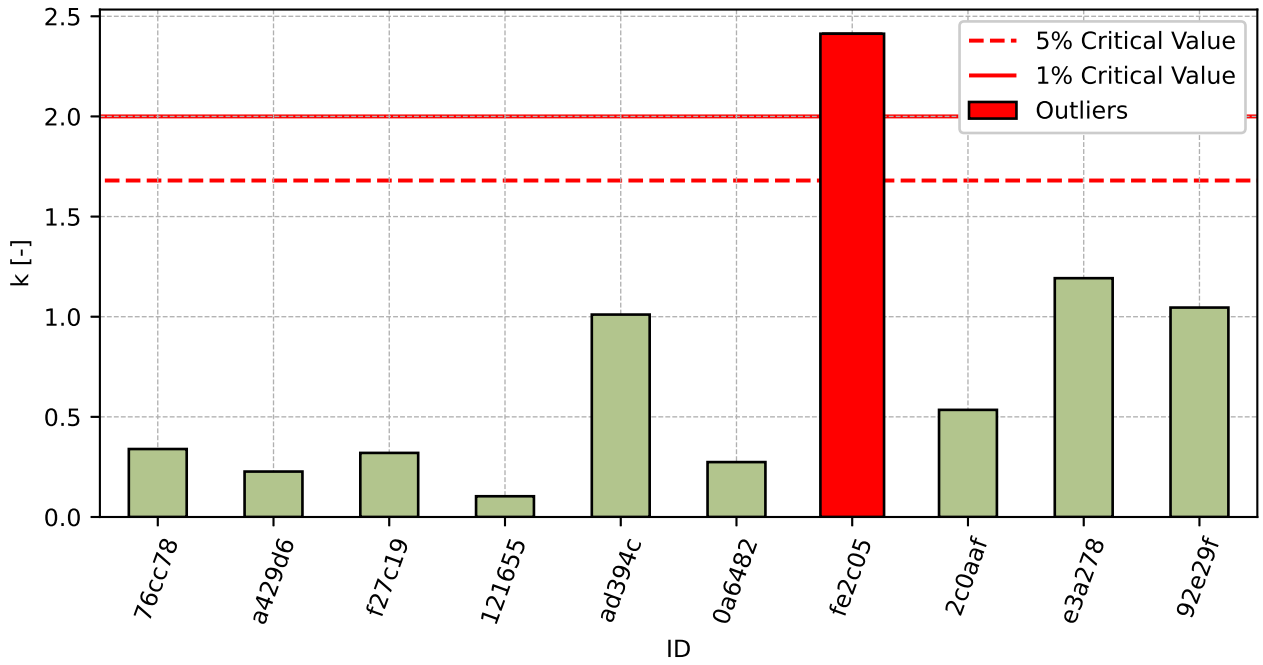

Figure 121: Intralaboratory Consistency Statistic

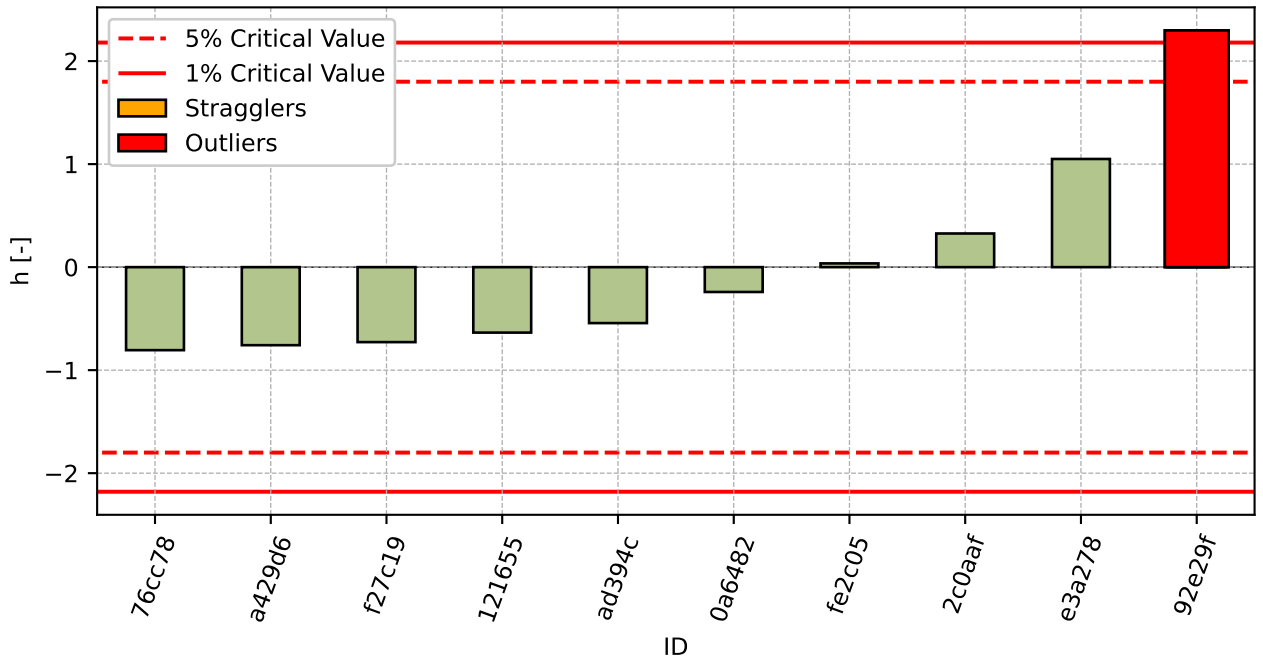

Figure 122: Interlaboratory Consistency Statistic

9.4 Descriptive statistics

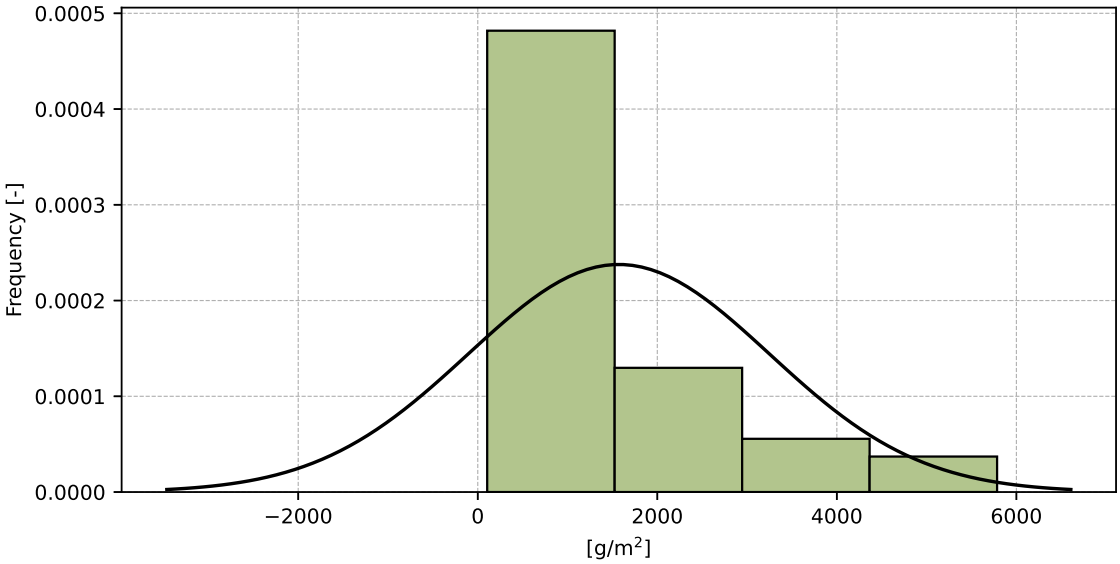

Figure 123: Histogram of all test results

Table 47: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	1571
Sample standard deviation – s	1678.4
Asigned value – x^*	1475
Robust standard deviation – s^*	1721.9
Measurement uncertainty of asigned value – u_X	676.7
p-value of normality test	1.0 [-]
Interlaboratory standard deviation – s_L	1660.9
Repeatability standard deviation – s_r	482.8
Reproducibility standard deviation – s_R	1729.7
Repeatability – r	1352
Reproducibility – R	4843

9.5 Evaluation of Performance Statistics

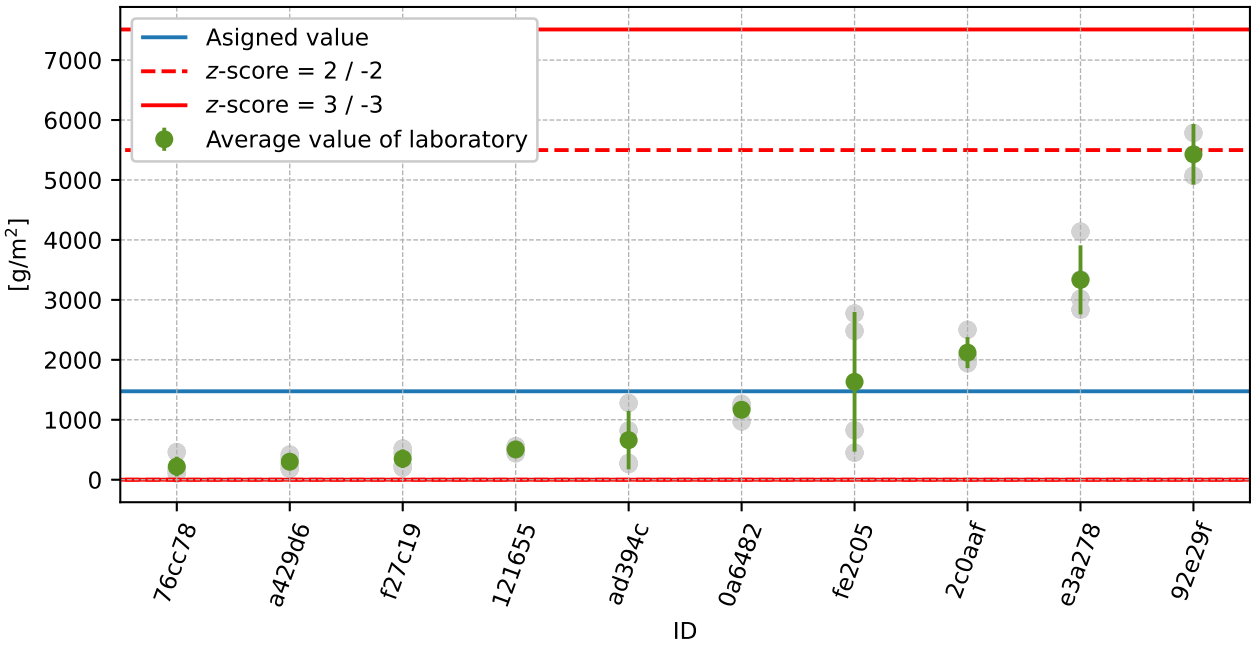

Figure 124: Average values and sample standard deviations

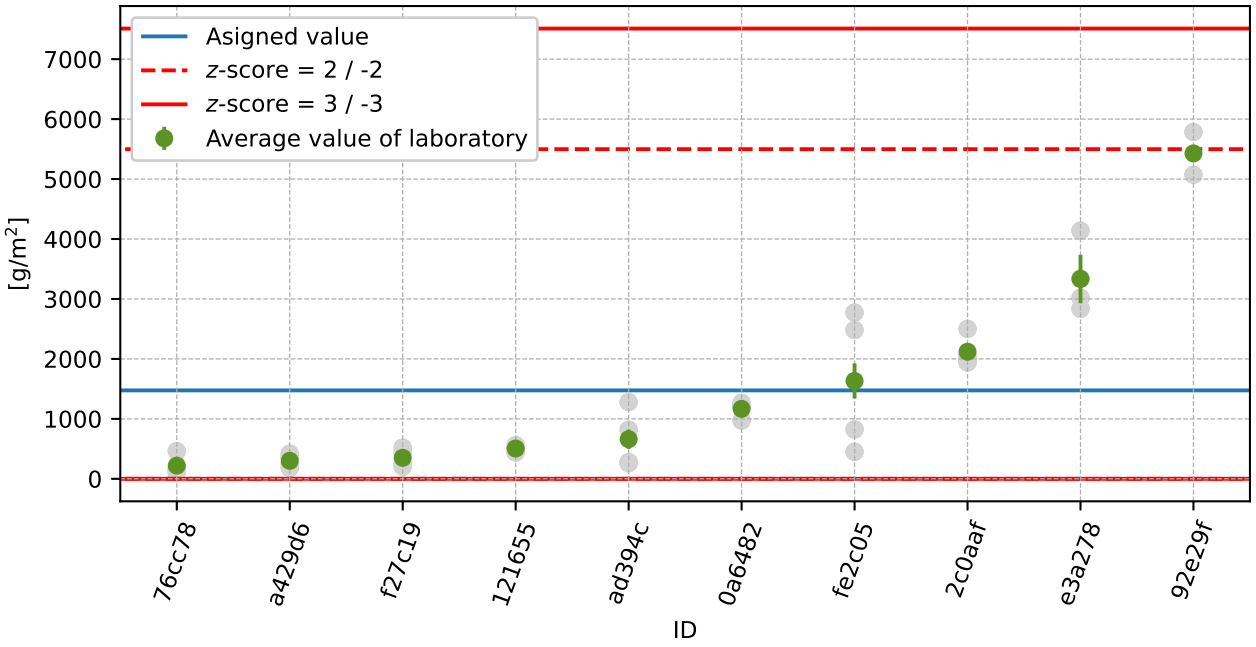

Figure 125: Average values and extended uncertainties of measurement

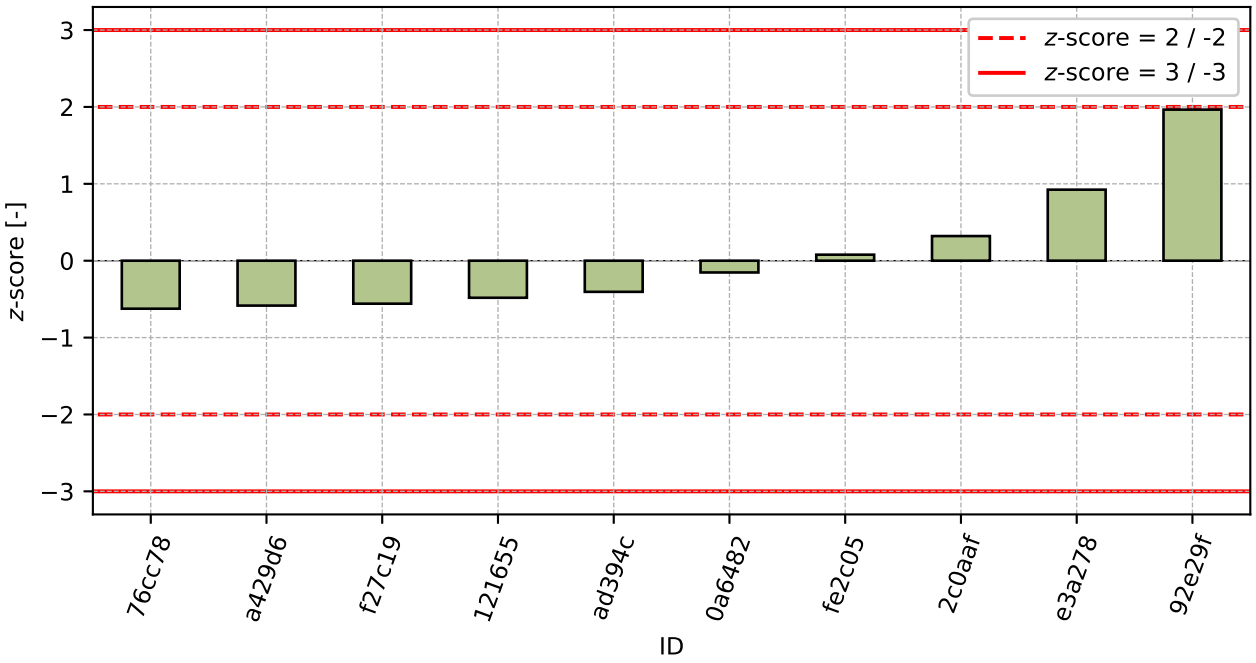

Figure 126: z-score

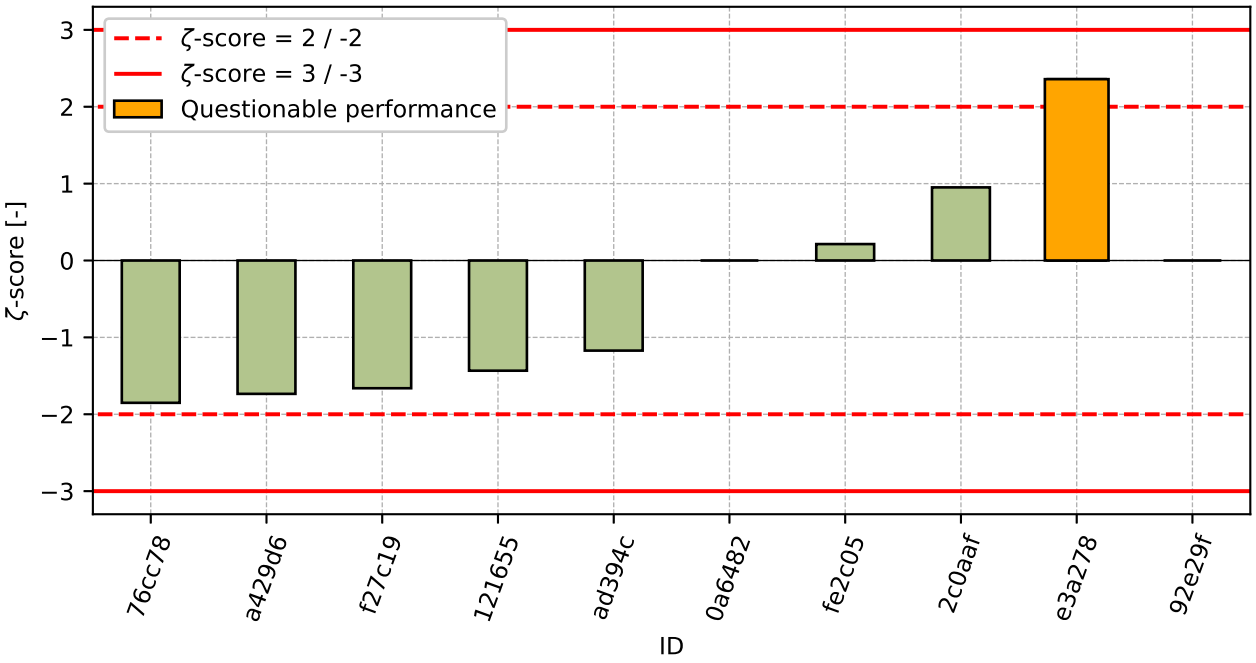

Figure 127: ζ-score

Table 48: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
76cc78	-0.62	-1.85
a429d6	-0.58	-1.73
f27c19	-0.56	-1.66
121655	-0.48	-1.43
ad394c	-0.41	-1.17
0a6482	-0.15	-
fe2c05	0.08	0.21
2c0aaf	0.32	0.95
e3a278	0.92	2.36
92e29f	1.96	-