BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF CIVIL ENGINEERING
institute of building testing

Z 7008

FINAL REPORT ON THE RESULTS OF PRECISION EXPERIMENT

Proficiency Testing Program
Strength and Durability of Hardened Concrete
ZZB 2021/1

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

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www.ptprovider.cz

Date: July, 21st 2021

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1 Introduction and Important Contacts

In the year 2020, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZZB 2021/1 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.
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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 the lack of participants.

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.

64 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 (tests designated according to part 1)

ID / Testing method	1	2	3	4	5	6	7	8	9
225832	X	-	-	-	-	-	-	-	-
6071be	X	-	-	-	-	-	-	-	-
e0ee9b	X	-	-	-	-	-	-	-	-
7e08c8	X	X	-	-	-	-	-	-	-
2eeb1f	-	-	X	-	-	-	-	-	-
2556db	X	X	-	-	-	-	-	-	-
6f0416	X	X	-	-	-	-	-	-	-
7764ad	X	X	X	-	X	-	-	X	-
f9bf78	X	X	X	X	-	-	-	X	-
f75be2	X	X	X	-	-	-	-	-	-
2c2fcf	X	X	X	-	-	-	-	X	-
581c84	X	X	X	-	-	-	-	-	-
fcfa23	X	X	X	-	-	-	-	-	-
f86748	X	X	-	-	X	-	-	X	-
059531	X	X	X	-	-	-	-	-	-
5dd879	X	X	X	-	-	-	-	-	-
a171a1	-	-	X	-	-	-	-	-	-
6b1ac5	X	X	X	-	-	-	-	-	X
b2190d	X	X	-	-	-	-	-	-	-
232a18	X	X	X	-	-	-	-	-	X
6599c8	-	-	X	-	-	-	X	-	-
64697c	-	-	-	X	-	-	-	-	-
2143af	X	X	-	-	-	-	-	-	-
d4df6a	-	-	-	-	-	-	-	X	-
77997a	X	X	X	-	-	-	-	-	-
5929bf	X	-	-	X	-	-	-	-	X
85f7f5	X	-	-	-	-	-	-	-	-
8ad07f	X	X	-	-	-	-	X	-	-
1f6117	X	X	X	-	-	-	X	-	-
bb33c6	X	-	-	-	-	-	-	-	-
618446	-	-	-	-	-	-	X	-	-
be2d54	X	X	X	-	-	-	X	-	-
51ce24	X	X	-	-	X	-	X	-	-
9ff5a8	-	-	X	-	-	-	-	-	-
266221	-	-	X	-	-	-	-	-	-
855620	-	-	X	-	-	-	-	-	-
79c00a	-	-	X	-	-	-	X	-	-
61350f	X	X	X	-	X	-	X	-	-
913eaf	X	X	X	-	-	-	-	-	-
5ba60f	X	X	-	-	-	-	-	-	-
51c1ea	-	-	X	-	-	-	-	-	-
8346e6	-	-	X	-	-	-	-	-	-
29ab81	X	X	-	-	-	-	-	-	-
da051e	-	-	X	-	-	-	-	-	-
7d2092	X	X	X	-	-	-	-	-	-
0b2731	X	X	X	-	-	-	-	-	-
4f2922	X	-	-	-	-	-	-	-	-

ID / Testing method	1	2	3	4	5	6	7	8	9
3a2964	X	X	X	-	-	-	-	-	-
752de0	X	X	-	-	-	-	-	-	-
aaa4a9	X	X	-	-	-	-	X	-	-
ab05ce	X	X	X	-	-	-	-	-	X
048321	X	X	X	-	-	-	-	-	X
19145a	X	X	X	-	-	-	-	-	-
6ca58a	-	-	-	X	-	-	-	-	-
1685fd	X	-	X	-	-	-	-	-	X
121f38	X	X	X	-	-	-	-	-	-
8b603a	-	X	-	-	-	-	-	-	-
fa1905	-	-	-	X	-	-	-	-	-
efc9bd	X	X	X	-	-	-	X	-	-
9295f7	X	X	X	-	X	-	X	-	-
06774b	-	-	-	-	X	-	-	-	-
a4819b	-	-	X	-	-	-	-	X	-
17de8f	X	-	-	-	-	-	-	-	-
ea1d80	X	-	-	-	-	-	-	-	-

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

Laboratory	Address	Accreditation number
AG Institut doo Novi Sad, Laboratorija za ispitivanje AGI - Beograd	Đorđa Zličića 53A, Novi Sad, 21000, Republika Srbija	-
AG Institut doo Novi Sad, Laboratorija za ispitivanje AGI - Novi Sad	Đorđa Zličića 53A, Novi Sad, 21000, Republika Srbija	01-457
BETONTEST, spol. s r. o.	Trnkova 3083/162, Brno, 62800, Česká republika	1116
BETOTECH, s.r.o. - pracoviště Beroun	Beroun 660, Beroun, 26601, Česká republika	AZL 1195
BETOTECH, s.r.o. - pracoviště Brno	Beroun 660, Beroun, 26601, Česká republika	1195.3
BETOTECH, s.r.o. - pracoviště Cheb	Beroun 660, Beroun, 26601, Česká republika	AZL 1195
BETOTECH, s.r.o. - pracoviště Jindřichův Hradec	Beroun 660, Beroun, 26601, Česká republika	AZL 1195
BETOTECH, s.r.o. - pracoviště Klatovy	Beroun 660, Beroun, 26601, Česká republika	AZL 1195
BETOTECH, s.r.o. - pracoviště Most	Beroun 660, Beroun, 26601, Česká republika	AZL 1195
BETOTECH, s.r.o. - pracoviště Trutnov	Beroun 660, Beroun, 26601, Česká republika	AZL 1195
BG 131438909	j.k. Lagera, 2 Baba Iliica Str., bl. 80B, Sofia, 1612, Bulgaria	186-LI
Betosan s.r.o., ZL LABBET	Nová cesta 40/291, Praha 4, 14000, Česká republika	1687
BetónRacio s.r.o., Skúšobné laboratórium, Pracovisko Lietavská Lúčka	Skladová 2, Trnava, 917 01, Slovensko	S-320

Laboratory	Address	Accreditation number
BetónRacio s.r.o., Skúšobné laboratórium, Pracovisko Trnava	Skladová 2, Trnava, 917 01, Slovensko	S-320
BetónRacio s.r.o., Skúšobné laboratórium, Pracovisko Veľký Šariš	Skladová 2, Trnava, 917 01, Slovensko	S-320
Building Research Institute	86 Nikola Petkov Blvd., Sofia, 1618, Bulgaria	Reg.No. 88ЛИ
CEMEX Czech Republic, s.r.o.	Semtín 102, Pardubice, 53354, Česká republika	1302
CRH (Slovensko) a. s., 906 38 Rohožník	CRH (Slovensko) a. s., Technicko - kompetenčné centrum, Pestovateľská 2, Bratislava, 821 04, Slovenská republika	426/S-313
Cement Hranice, akciová společnost	Bělotínská 288, Hranice I - Město, 75301, Česká republika	1284
Central Regional Laboratory, Public Works Department Sarawak	Canna Road, Tabuan Jaya, Kuching, 93350, Sarawak, Malaysia	nan
Generalna Dyrekcja Dróg Krajowych i Autostrad Oddział w Białymstoku	Zwycięstwa 2, Białystok, 15-703, Poland	-
Geotec-GS, a.s.	Chmelová 2920/6, Praha 10, 10600, Česká republika	1514
Horský s.r.o.	Klánovická 286/12, Praha, 198 00, Česká republika	1207
INSTITUT IGH d.d., Janka Rakuše 1, Zagreb	Janka Rakuše 1, Zagreb, 10000, Hrvatska	-
INSTITUT IGH d.d., Laboratorij za beton i geomehaniku - lokacija Dubrovnik	Vukovarska 8, Dubrovnik, 20000, Croatia	-
Institut IGH d.d.	Kukuljanovo 182/2, Kukuljanovo, 51227, Croatia	1043
Institut IGH d.d., Laboratorij Pula	Janka Rakuše 1, Zagreb, 10000, Croatia	1043
Institut IGH d.d., Laboratorij za beton - RC Split	Matice hrvatske 15, Split, 21000, Croatia	-
Institut za ispitivanje materijala a.d.	Bulevar vojvode Mišića 43, Belgrade, 11000, Serbia	-
Instytut Podstawowych Problemow Techniki PAN	Pawinskiego 5B, Warszawa, 02-106, Poland	-
Itecons - Instituto de Investigação e Desenvolvimento Tecnológico para a Construção, Energia, Ambiente e Sustentabilidade	Rua Pedro Hispano, S/N Polo II da Universidade de Coimbra, Coimbra, 3030-289, Portugal	-
Kiwa GmbH	Voltastrasse 5, Berlin, 13355, Germany	D-PL-11217-01-01
Koridori Srbije doo	Kralja Petra 21, Beograd, 11000, Republika Srbija	-
LABORATOIRE DES TRAVAUX PUBLICS DU SUD	Zone des activités Bouhraoua- PB 332 GHARDAIA, GHARDAIA, 47000, ALGERIA	-
Laboratoire de Mécanique des Matériaux et Structures - Université de Liège - lab A	Place du XX août 7, Liège, 4000, Belgium	-

Laboratory	Address	Accreditation number
Laboratoire de Mécanique des Matériaux et Structures - Université de Liège - lab B	Laboratoire des Matériaux et Structure Université de Liège Quartier Polytech 1 Allée de la découverte 13 C B-4000 Liège 1 Bâtiment B52/8, niveau -2, p, Liège, 4000, Belgium	-
Laboratoire de Mécanique des Matériaux et Structures - Université de Liège - lab C	Laboratoire des Matériaux et Structure Université de Liège Quartier Polytech 1 Allée de la découverte 13 C B-4000 Liège 1 Bâtiment B52/8, niveau -2, p, Liège, 4000, Belgie	-
Lafarge Cement, a.s.	Lafarge Cement a.s., Čížkovice čp. 27, 41112, Česká republika	1426
MIRTEC S.A.	76 Km of Athens-Lamia National Road, Ritsona, Sximatari, 32009, Greece	-
Magnel-Vandepitte Laboratory	Technologiepark-Zwijnaarde 60, GENT, 9052, Belgium	220-TEST
Master Builders Solutions CZ s.r.o.	K Májovu 1244, Chrudim, 537 01, Česká republika	1495
Northern Regional Laboratory, JKR Sarawak	Canna Road, Tabuan Jaya, Kuching, 93350, Sarawak, Malaysia	-
SIBOTEC CVBA	Industriepark Oost 6 8730 Beernem, Beernem, 8730, West - Vlaanderen	BELAC 637-TEST
SMP CZ, a.s.	Vyskočilova 1566, Praha 4, 140 00, Česká republika	1168
SMP CZ, a.s.	Vyskočilova 1566, Praha 4, 140 00, Česká republika	1168
SMP CZ, a.s.	Vyskočilova 1566, Praha 4, 140 00, Česká republika	1168
STROYCONTROL 2003 LTD	Kostenetz str12, Sofia, 1612, Bulgaria	182LI
Stachema CZ s.r.o. - zkušební laboratoř - pracoviště 1	Hasičská 1, Zibohlavy, Kolín, 28002, Česká republika	1433
Stachema CZ s.r.o. - zkušební laboratoř - pracoviště 2	Hasičská 1, Zibohlavy, Kolín, 28002, Česká republika	1433
TESTAV-LAB s.r.o.	Chodská 7, Liberec 3, 466 10, Česká republika	1180
TPA Spoločnosť pre zabezpečenie kvality a inovácie s.r.o - pracovisko Geča	Neresnická cesta 3, Zvolen, 960 01, Slovenská republika	211/S-176
TPA Spoločnosť pre zabezpečenie kvality a inovácie s.r.o - pracovisko Podunajské Biskupice	Neresnická cesta 3, Zvolen, 960 01, Slovenská republika	211/S-176
TPA Spoločnosť pre zabezpečenie kvality a inovácie s.r.o - pracovisko Zvolen	Neresnická cesta 3, Zvolen, 960 01, Slovenská republika	211/S-176
Teknologisk Institut	Gregersensvej, Taastrup, 2630, Denmark	-
UAB LABORATORINIU BANDYMU CENTRAS	R. KALANTOS ST. 85A, KAUNAS, LT-52308, LITHUANIA	LA.01.002

Laboratory	Address	Accreditation number
University of Belgrade, Faculty of Civil Engineering, Laboratory for materials	Bulevar kralja Aleksandra 73, Belgrade, 11000, Serbia	-
University of Natural Resources and Life Sciences, Vienna	Peter-Jordan-Str. 82, Vienna, 1190, Austria	P0252
VIALAB CZ s.r.o.	U Michelského lesa 1581/2, Praha 4, 140 00, Česká republika	L1112
VIALAB CZ, s.r.o. - Laboratoř Morava, pracoviště LM 4 Ostrava	MUCODE 1593, PO Box 207, 160 41, Česká republika	1170
Vilnius Gediminas technical University	Saulėtekio al. 11, Vilnius, LT-10223, Lithuania	-
ZAPA beton a.s.	Vídeňská 495, Praha, 14200, Česká republika	-
Zkušební laboratoř Kloknerova ústavu	Šolínova 7, Praha 6, 16608, Česká republika	1061
Ředitelství silnic a dálnic ČR	Rebešovická 40, Brno-Chrlice, 643 00, Česká republika	1072
"COD Lab" Ltd.	Lozenets, str. Korab planina No. 8-10/2, Sofia, 1407, Bulgaria	-

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. 64 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 4: Evaluation of overall performance and outliers.
✓ – satisfactory performance; ? – questionable performance; ! – unsatisfactory performance; X – outlier;

ID / Method	1	2	3	4	5	6	7	8	9
225832	✓	-	-	-	-	-	-	-	-
6071be	✓	-	-	-	-	-	-	-	-
e0ee9b	✓	-	-	-	-	-	-	-	-
7e08c8	✓	✓	-	-	-	-	-	-	-
2eeb1f	-	-	✓	-	-	-	-	-	-
2556db	✓	✓	-	-	-	-	-	-	-
6f0416	✓	✓	-	-	-	-	-	-	-
7764ad	✓	✓	✓	-	✓	-	-	✓	-
f9bf78	✓	✓	✓	✓	-	-	-	✓	-
f75be2	✓	✓	✓	-	-	-	-	-	-
2c2fcf	✓	✓	✓	-	-	-	-	✓	-
581c84	✓	✓	✓	-	-	-	-	-	-
fcfa23	✓	✓	✓	-	-	-	-	-	-
f86748	✓	✓	-	-	✓	-	-	✓	-
059531	✓	✓	✓	-	-	-	-	-	-
5dd879	✓	✓	✓	-	-	-	-	-	-
a171a1	-	-	?	-	-	-	-	-	-
6b1ac5	✓	✓	✓	-	-	-	-	-	✓
b2190d	✓	✓	-	-	-	-	-	-	-
232a18	?	✓	X	-	-	-	-	-	✓
6599c8	-	-	✓	-	-	-	✓	-	-
64697c	-	-	-	✓	-	-	-	-	-
2143af	✓	✓	-	-	-	-	-	-	-
d4df6a	-	-	-	-	-	-	-	✓	-

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ID / Method	1	2	3	4	5	6	7	8	9
77997a	✓	✓	✓	-	-	-	-	-	-
5929bf	✓	-	-	✓	-	-	-	-	✓
85f7f5	✓	-	-	-	-	-	-	-	-
8ad07f	✓	✓	-	-	-	-	✓	-	-
1f6117	✓	✓	✓	-	-	-	✓	-	-
bb33c6	?	-	-	-	-	-	-	-	-
618446	-	-	-	-	-	-	✓	-	-
be2d54	✓	✓	✓	-	-	-	✓	-	-
51ce24	✓	✓	-	-	✓	-	✓	-	-
9ff5a8	-	-	✓	-	-	-	-	-	-
266221	-	-	✓	-	-	-	-	-	-
855620	-	-	?	-	-	-	-	-	-
79c00a	-	-	✓	-	-	-	X	-	-
61350f	✓	✓	✓	-	✓	-	✓	-	-
913eaf	✓	✓	?	-	-	-	-	-	-
5ba60f	✓	✓	-	-	-	-	-	-	-
51c1ea	-	-	✓	-	-	-	-	-	-
8346e6	-	-	✓	-	-	-	-	-	-
29ab81	✓	✓	-	-	-	-	-	-	-
da051e	-	-	✓	-	-	-	-	-	-
7d2092	✓	✓	✓	-	-	-	-	-	-
0b2731	✓	✓	✓	-	-	-	-	-	-
4f2922	✓	-	-	-	-	-	-	-	-
3a2964	✓	✓	✓	-	-	-	-	-	-
752de0	✓	✓	-	-	-	-	-	-	-
aaa4a9	✓	✓	-	-	-	-	✓	-	-
ab05ce	✓	✓	✓	-	-	-	-	-	✓
048321	✓	✓	✓	-	-	-	-	-	✓
19145a	✓	✓	✓	-	-	-	-	-	-
6ca58a	-	-	-	✓	-	-	-	-	-
1685fd	✓	-	✓	-	-	-	-	-	✓
121f38	✓	✓	✓	-	-	-	-	-	-
8b603a	-	✓	-	-	-	-	-	-	-
fa1905	-	-	-	✓	-	-	-	-	-
efc9bd	✓	✓	✓	-	-	-	✓	-	-
9295f7	✓	✓	✓	-	✓	-	✓	-	-
06774b	-	-	-	-	✓	-	-	-	-

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ID / Method	1	2	3	4	5	6	7	8	9
a4819b	-	-	✓	-	-	-	-	✓	-
17de8f	✓	-	-	-	-	-	-	-	-
ea1d80	✓	-	-	-	-	-	-	-	-

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. *Concrete - Specification, performance, production and conformity*. 2014.

[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/mm²]			u_X [N/mm²]	$\bar{x}$ [N/mm²]	s_0 [N/mm²]	V_X [%]
232a18	37.0	41.3	38.3	0.5	38.9	2.21	5.67
bb33c6	38.1	41.5	37.4	2.6	39.0	2.19	5.62
29ab81	36.6	42.5	43.7	10.1	40.9	3.8	9.28
aaa4a9	42.8	43.0	42.4	2.0	42.7	0.31	0.71
5ba60f	42.4	43.2	43.0	-	42.9	0.42	0.97
f75be2	43.0	43.3	42.3	0.5	42.9	0.51	1.2
85f7f5	43.2	42.6	43.0	1.0	42.9	0.31	0.71
225832	42.8	42.6	43.5	1.3	43.0	0.47	1.1
1f6117	42.8	42.1	44.3	1.5	43.1	1.12	2.61
3a2964	40.7	44.7	44.1	1.9	43.2	2.16	5.0
048321	43.3	44.3	42.8	0.7	43.5	0.76	1.76
6071be	44.4	44.2	42.3	0.8	43.6	1.16	2.66
f9bf78	44.0	43.7	43.4	0.5	43.7	0.3	0.69
61350f	44.9	42.1	44.6	-	43.9	1.54	3.5
77997a	42.5	44.5	45.1	1.7	44.0	1.36	3.09
8ad07f	44.8	43.6	43.7	1.5	44.0	0.67	1.51
fcfa23	44.6	44.8	44.1	1.5	44.5	0.36	0.81
5dd879	43.7	45.0	45.0	0.1	44.6	0.75	1.68
2c2fcf	45.3	44.1	44.6	1.0	44.7	0.6	1.35
059531	45.2	45.0	44.2	1.6	44.8	0.53	1.18
1685fd	45.1	46.3	43.1	1.2	44.8	1.62	3.61
2143af	45.9	42.9	45.8	1.2	44.9	1.7	3.8
9295f7	44.5	44.3	45.8	2.0	44.9	0.81	1.82
51ce24	45.1	45.2	44.8	0.7	45.0	0.21	0.46
581c84	44.3	45.2	45.7	1.2	45.1	0.71	1.57
efc9bd	44.3	45.1	46.2	2.2	45.2	0.95	2.11
f86748	45.6	45.5	45.1	1.6	45.4	0.26	0.58
913eaf	45.3	45.6	45.6	-	45.5	0.17	0.38
6b1ac5	46.0	45.1	46.4	1.4	45.8	0.67	1.45
6f0416	47.0	45.1	45.4	0.8	45.8	1.02	2.23
19145a	47.2	46.0	45.6	0.6	46.3	0.83	1.8
be2d54	48.1	46.3	44.4	3.0	46.3	1.85	4.0
752de0	47.0	46.4	45.7	0.3	46.4	0.65	1.4
17de8f	46.9	46.4	46.2	0.5	46.5	0.36	0.78
ea1d80	46.9	46.7	46.2	0.5	46.6	0.36	0.77
4f2922	46.4	45.6	47.8	0.5	46.6	1.11	2.39
5929bf	47.0	46.3	46.6	1.6	46.6	0.35	0.75
121f38	46.6	47.0	47.1	1.4	46.9	0.26	0.56
b2190d	46.5	47.5	48.5	0.4	47.5	1.0	2.11
ab05ce	47.5	48.3	46.9	1.4	47.6	0.7	1.48
7764ad	47.9	48.1	47.5	2.8	47.8	0.31	0.64
7e08c8	47.7	48.4	48.2	-	48.1	0.36	0.75
e0ee9b	50.2	46.4	48.4	2.2	48.3	1.9	3.93
7d2092	50.3	47.9	48.3	-	48.8	1.29	2.63
0b2731	48.6	48.0	50.0	-	48.9	1.03	2.1
2556db	49.5	49.3	47.9	0.4	48.9	0.87	1.78

1.2 The Numerical Procedure for Determining Outliers

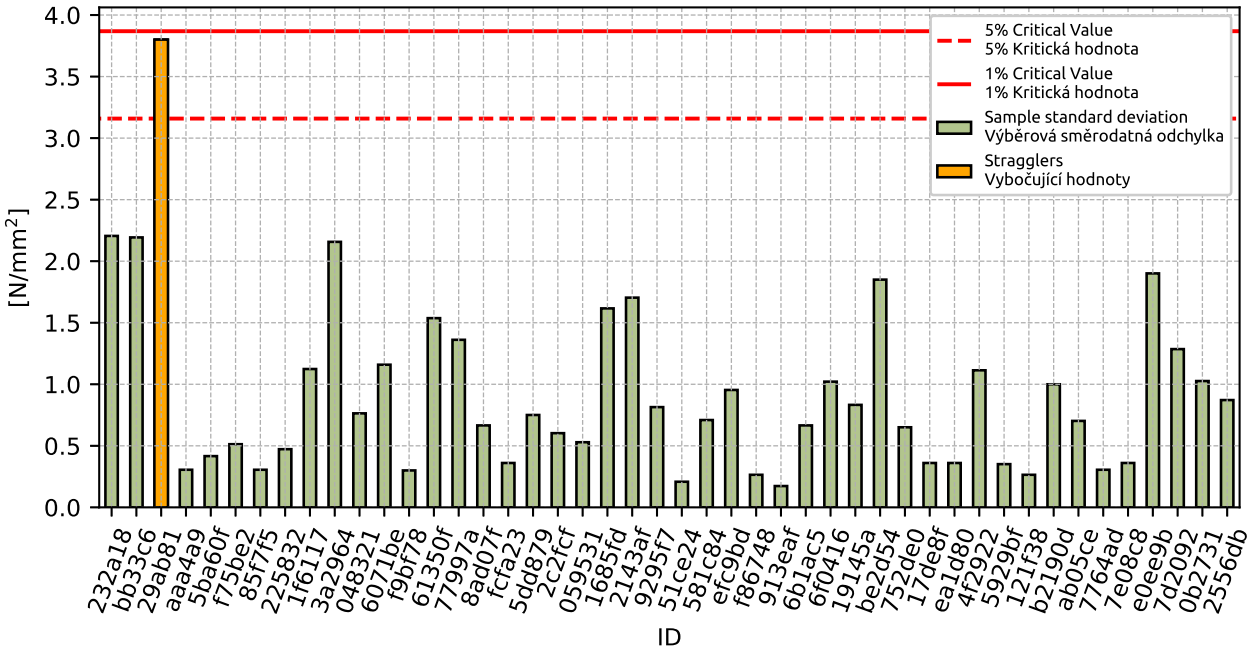

Figure 1: **Cochran's test** - sample standard deviations

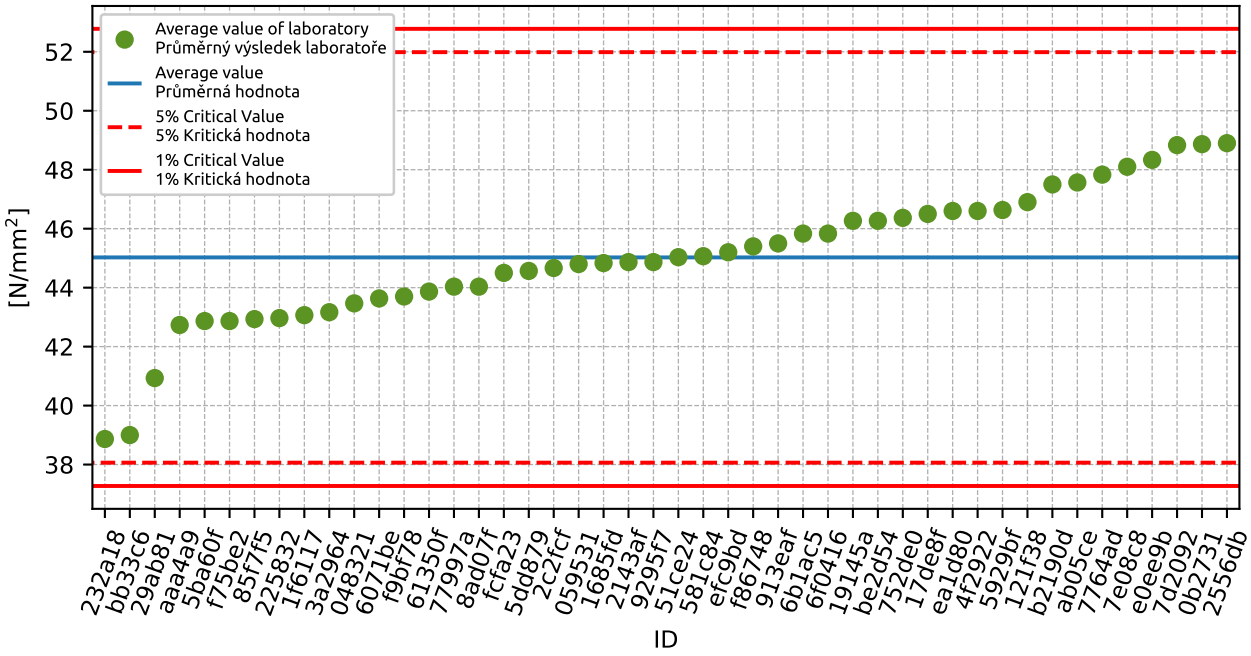

Figure 2: **Grubbs' test** - average values

1.3 Mandel's Statistics

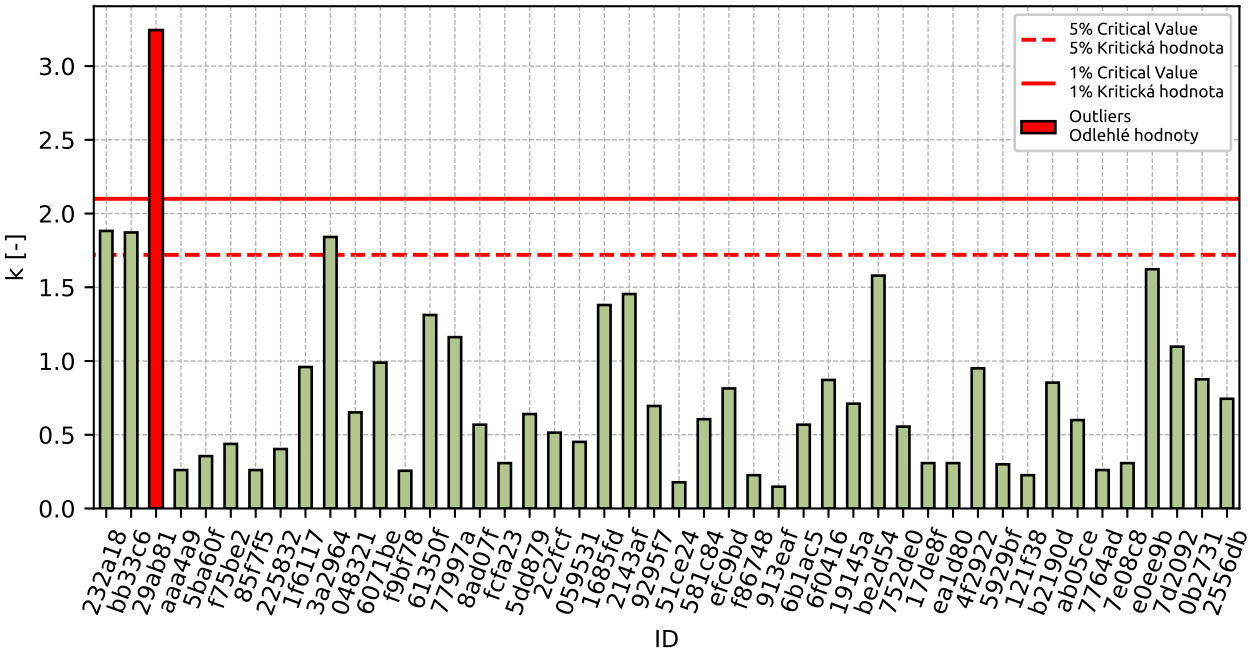

Figure 3: Intralaboratory Consistency Statistic

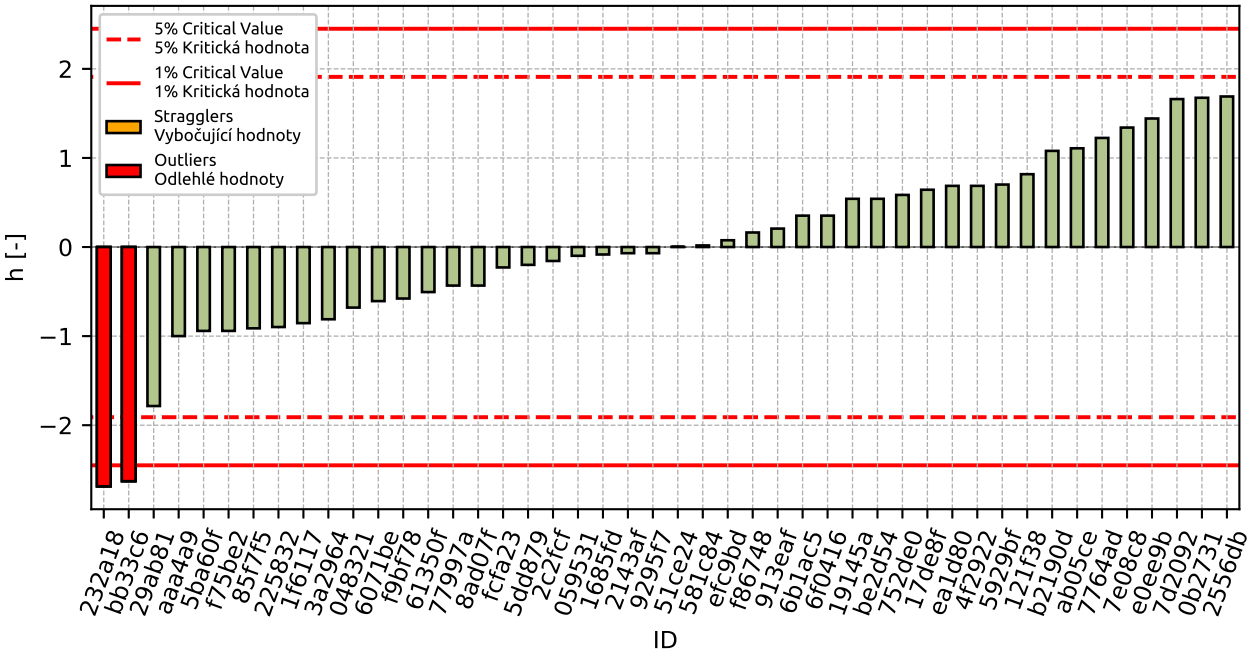

Figure 4: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

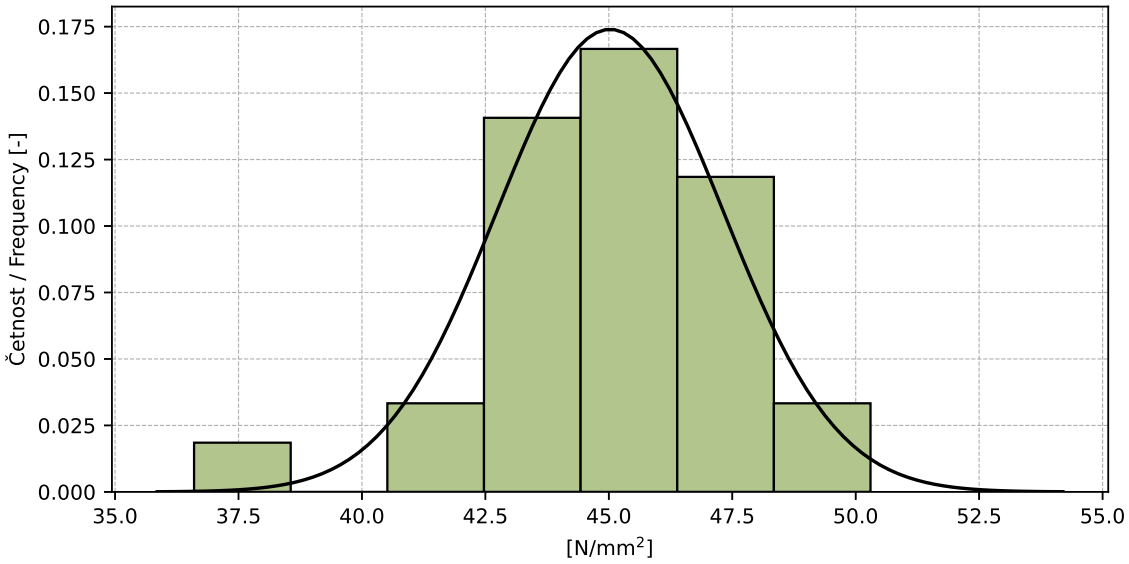

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[N/mm²]
Průměrná hodnota / Average value – $\bar{x}$	45.0
Výběrová směrodatná odchylka / Sample standard deviation – s	2.29
Vztažná hodnota / Asigned value – x^*	45.2
Robustní směrodatná odchylka / Robust standard deviation – s^*	2.16
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.4
p-hodnota testu normality / p-value of normality test	0.0 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	2.19
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	1.17
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	2.48
Opakovatelnost / Repeatability – r	3.3
Reprodukovatelnost / Reproducibility – R	7.0

1.5 Evaluation of Performance Statistics

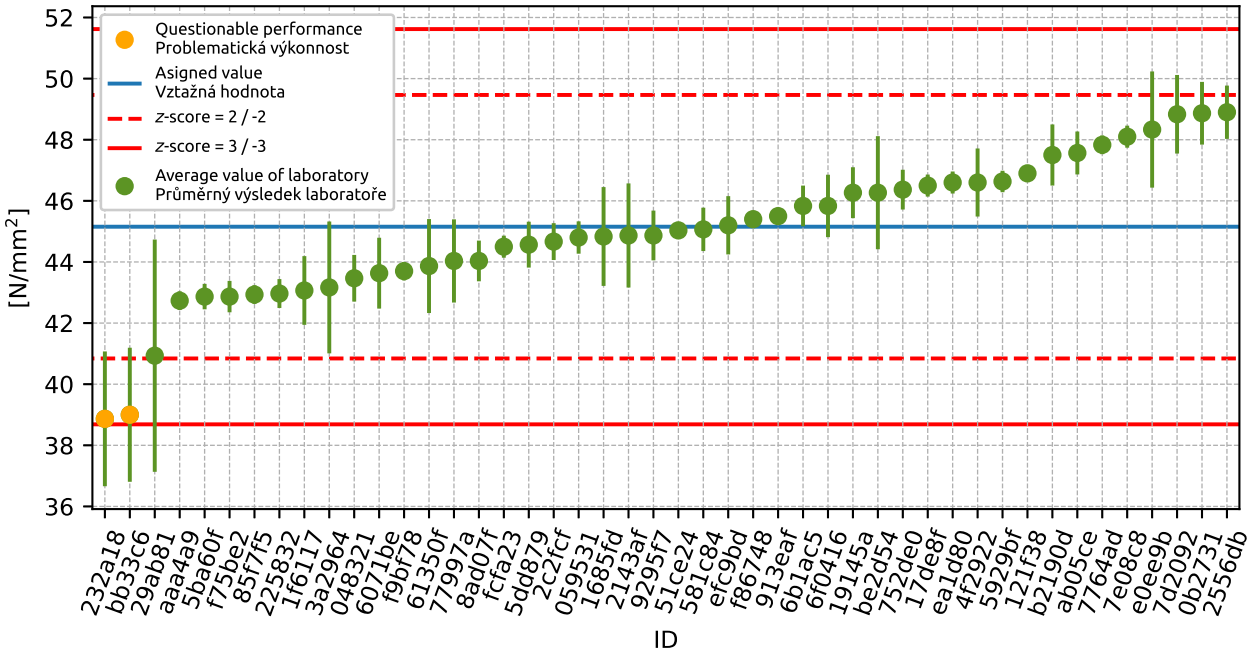

Figure 6: Average values and sample standard deviations

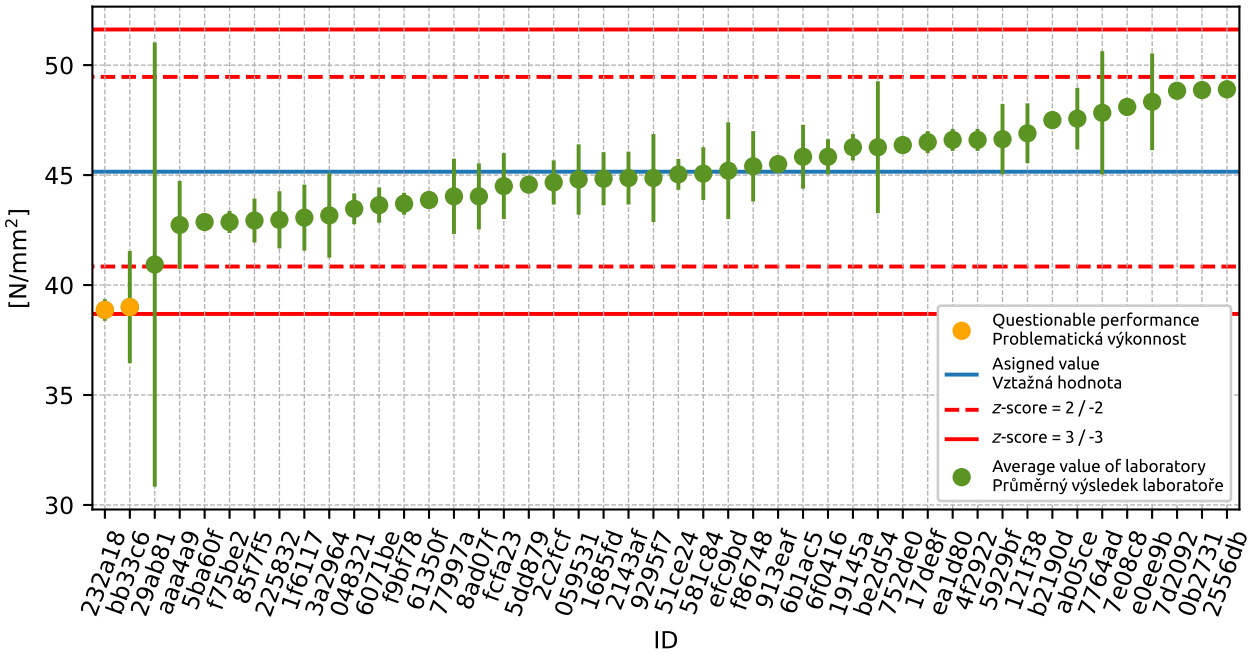

Figure 7: Average values and extended uncertainties of measurement

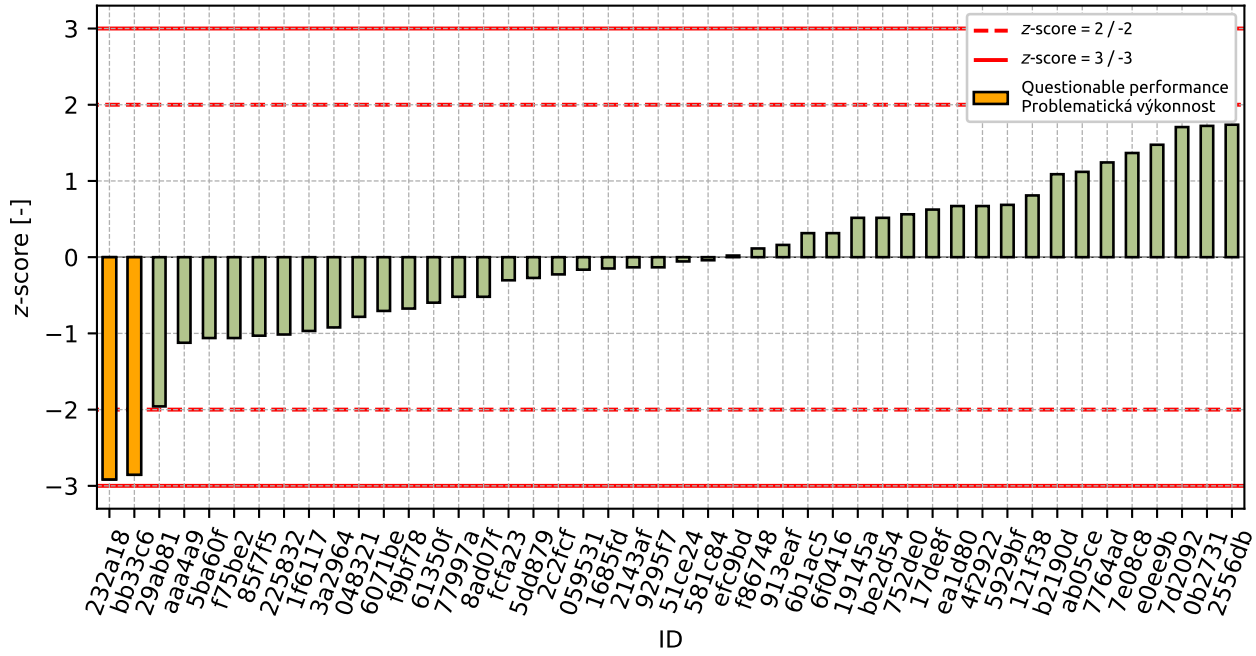

Figure 8: z-score

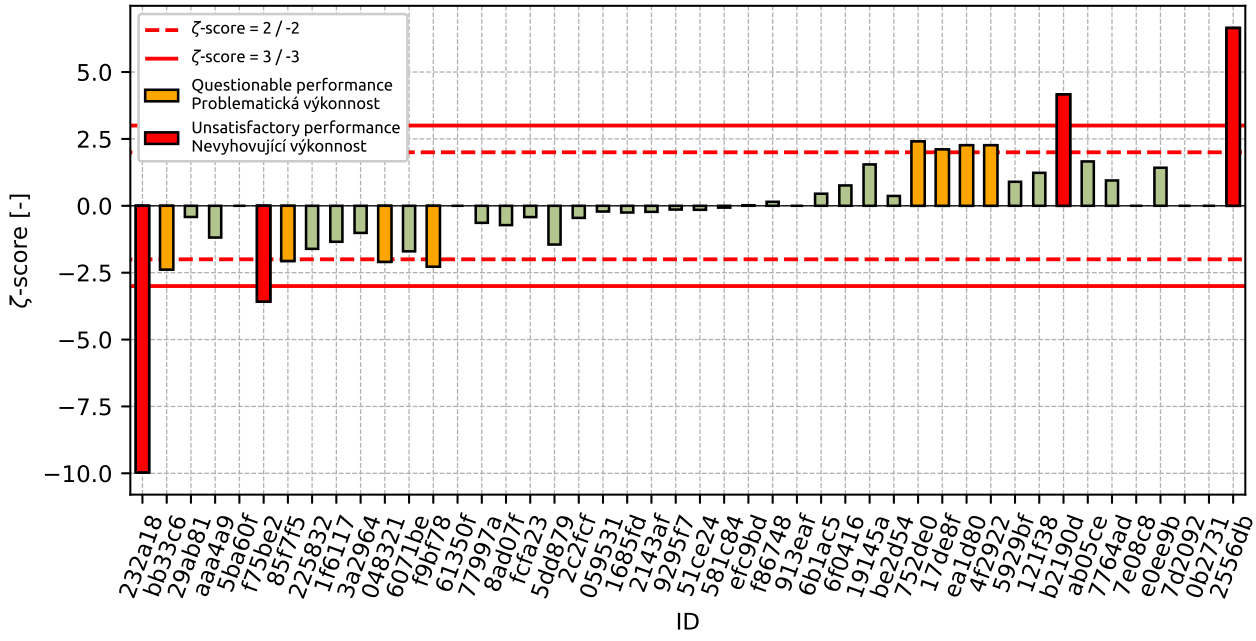

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
232a18	-2.92	-9.97
bb33c6	-2.85	-2.38
29ab81	-1.96	-0.42
aaa4a9	-1.12	-1.19
5ba60f	-1.06	-
f75be2	-1.06	-3.58
85f7f5	-1.03	-2.06
225832	-1.01	-1.61
1f6117	-0.97	-1.34
3a2964	-0.92	-1.01
048321	-0.78	-2.1
6071be	-0.71	-1.7
f9bf78	-0.67	-2.28
61350f	-0.6	-
77997a	-0.52	-0.64
8ad07f	-0.52	-0.72
fcfa23	-0.3	-0.42
5dd879	-0.27	-1.45
2c2fcf	-0.23	-0.45
059531	-0.16	-0.21
1685fd	-0.15	-0.25
2143af	-0.13	-0.23
9295f7	-0.13	-0.14
51ce24	-0.06	-0.15
581c84	-0.04	-0.07
efc9bd	0.02	0.02
f86748	0.11	0.15
913eaf	0.16	-
6b1ac5	0.32	0.45
6f0416	0.32	0.76
19145a	0.52	1.55
be2d54	0.52	0.37
752de0	0.56	2.41
17de8f	0.62	2.11
ea1d80	0.67	2.26
4f2922	0.67	2.26
5929bf	0.69	0.9
121f38	0.81	1.23
b2190d	1.09	4.16
ab05ce	1.12	1.66
7764ad	1.24	0.95
7e08c8	1.37	-
e0ee9b	1.48	1.42
7d2092	1.71	-
0b2731	1.72	-
2556db	1.74	6.65

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/m³]			u_X [kg/m³]	$\bar{x}$ [kg/m³]	s_0 [kg/m³]	V_X [%]
29ab81	2263	2264	2264	40.0	2264	0.6	0.03
19145a	2280	2280	2270	9.0	2277	5.8	0.25
2c2fcf	2290	2270	2290	32.0	2283	11.5	0.51
9295f7	2285	2278	2294	6.0	2286	8.0	0.35
048321	2290	2300	2270	10.0	2287	15.3	0.67
aaa4a9	2290	2310	2260	20.0	2287	25.2	1.1
581c84	2290	2280	2290	32.0	2287	5.8	0.25
232a18	2290	2290	2280	2.0	2287	5.8	0.25
6b1ac5	2297	2300	2268	11.0	2288	17.7	0.77
61350f	2300	2280	2290	-	2290	10.0	0.44
1f6117	2310	2280	2280	30.0	2290	17.3	0.76
8ad07f	2300	2290	2290	30.0	2293	5.8	0.25
51ce24	2320	2290	2280	56.0	2297	20.8	0.91
efc9bd	2300	2300	2290	40.0	2297	5.8	0.25
5ba60f	2290	2290	2320	-	2300	17.3	0.75
121f38	2300	2310	2300	7.0	2303	5.8	0.25
7764ad	2310	2300	2300	50.0	2303	5.8	0.25
913eaf	2300	2310	2300	-	2303	5.8	0.25
7e08c8	2300	2290	2320	-	2303	15.3	0.66
fcfa23	2300	2310	2300	11.0	2303	5.8	0.25
77997a	2300	2300	2310	18.0	2303	5.8	0.25
2556db	2318	2297	2300	15.0	2305	11.4	0.49
2143af	2290	2320	2310	50.0	2307	15.3	0.66
f75be2	2310	2280	2330	25.0	2307	25.2	1.09
752de0	2320	2300	2300	20.0	2307	11.5	0.5
6f0416	2310	2300	2310	10.0	2307	5.8	0.25
f86748	2310	2310	2300	20.0	2307	5.8	0.25
059531	2310	2310	2310	20.0	2310	0.0	0.0
8b603a	2310	2310	2310	12.0	2310	0.0	0.0
b2190d	2310	2310	2320	13.0	2313	5.8	0.25
ab05ce	2320	2300	2320	7.0	2313	11.5	0.5
5dd879	2330	2300	2320	2.0	2317	15.3	0.66
f9bf78	2350	2300	2300	25.0	2317	28.9	1.25
7d2092	2320	2320	2310	-	2317	5.8	0.25
be2d54	2320	2320	2320	20.0	2320	0.0	0.0
3a2964	2330	2320	2320	25.0	2323	5.8	0.25
0b2731	2320	2330	2330	-	2327	5.8	0.25

2.2 The Numerical Procedure for Determining Outliers

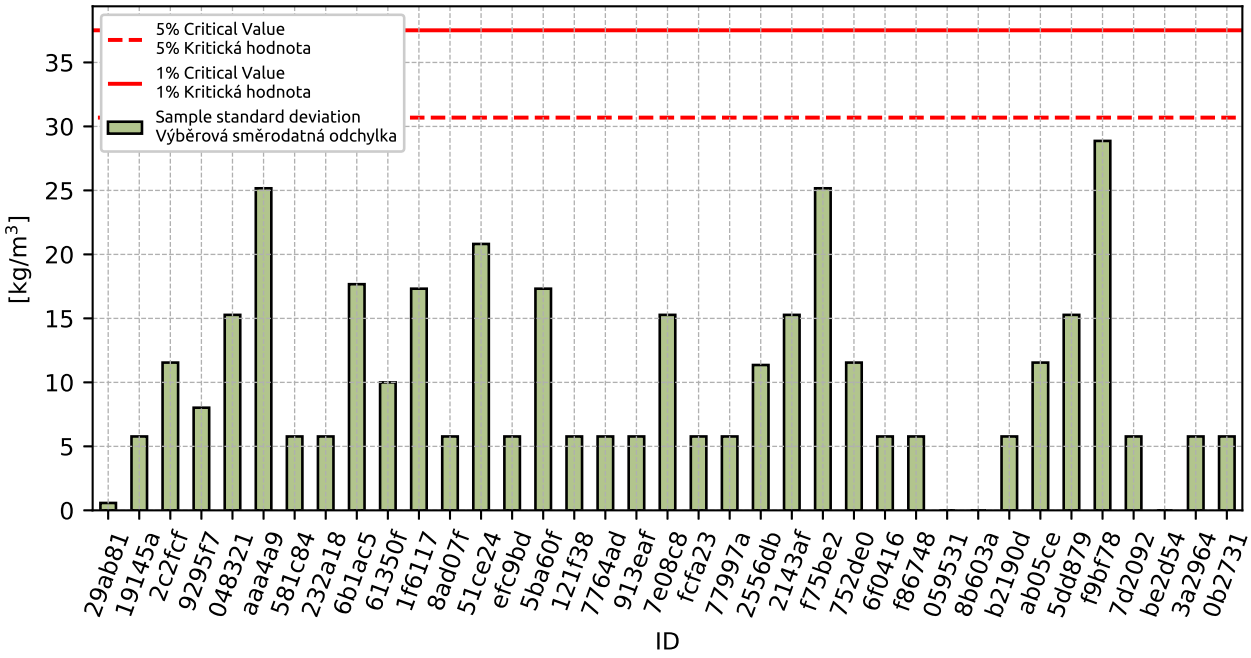

Figure 10: **Cochran's test** - sample standard deviations

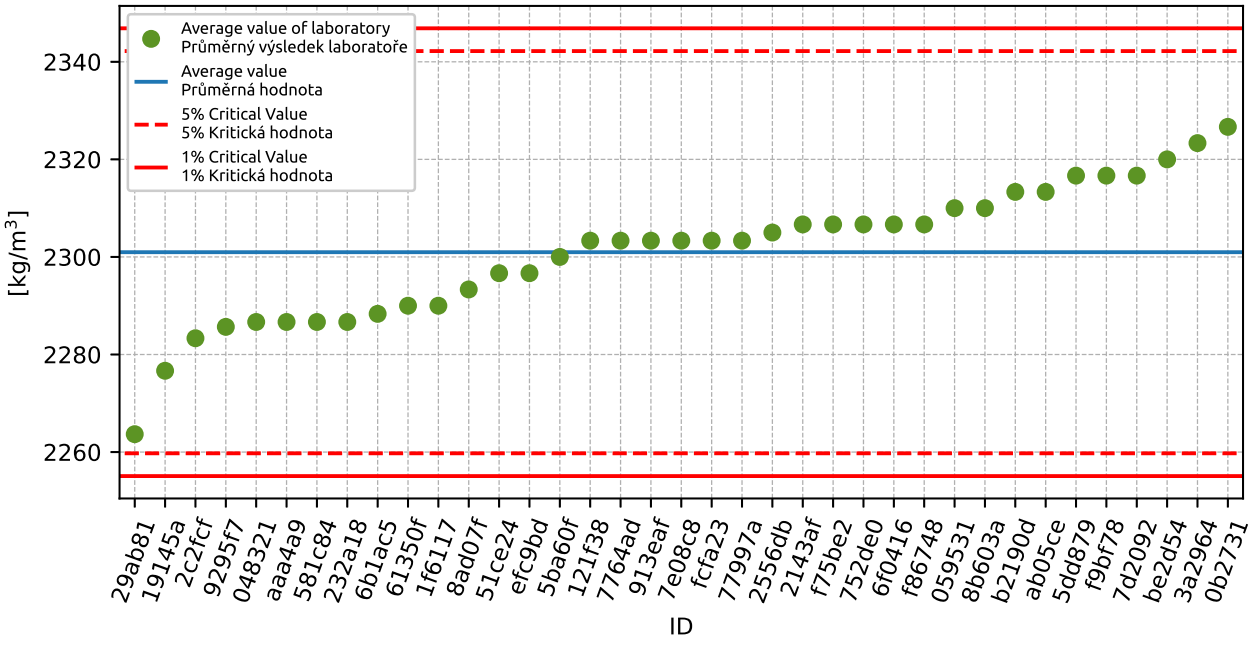

Figure 11: **Grubbs' test** - average values

2.3 Mandel's Statistics

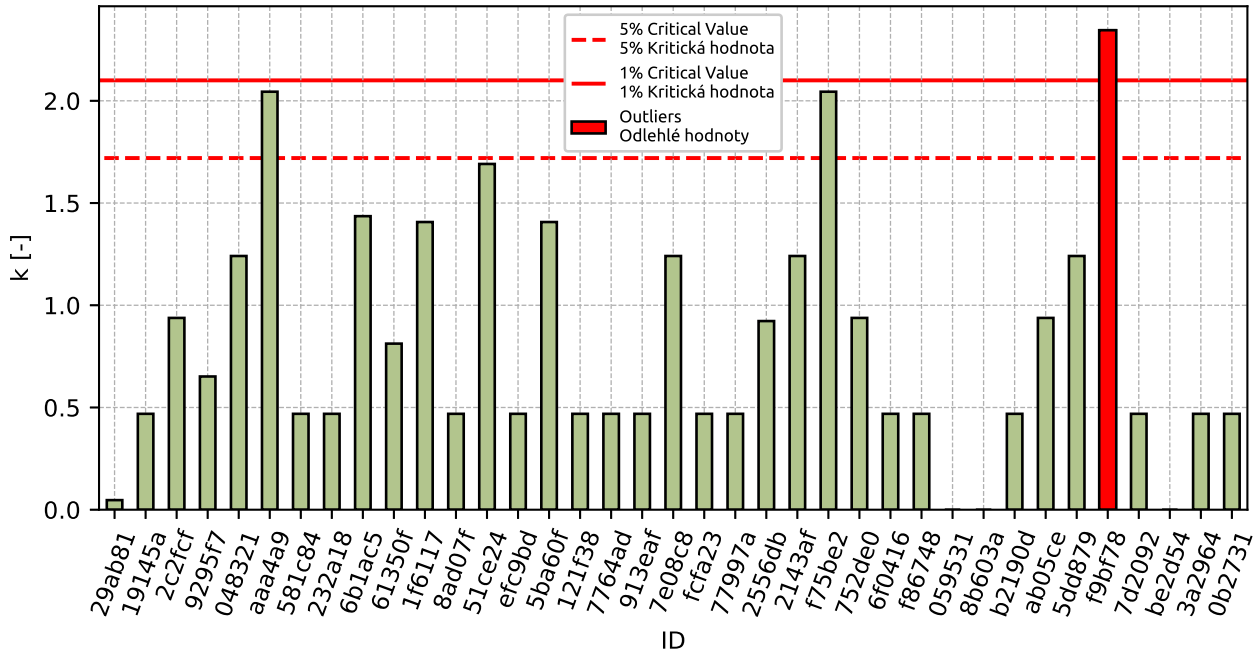

Figure 12: Intralaboratory Consistency Statistic

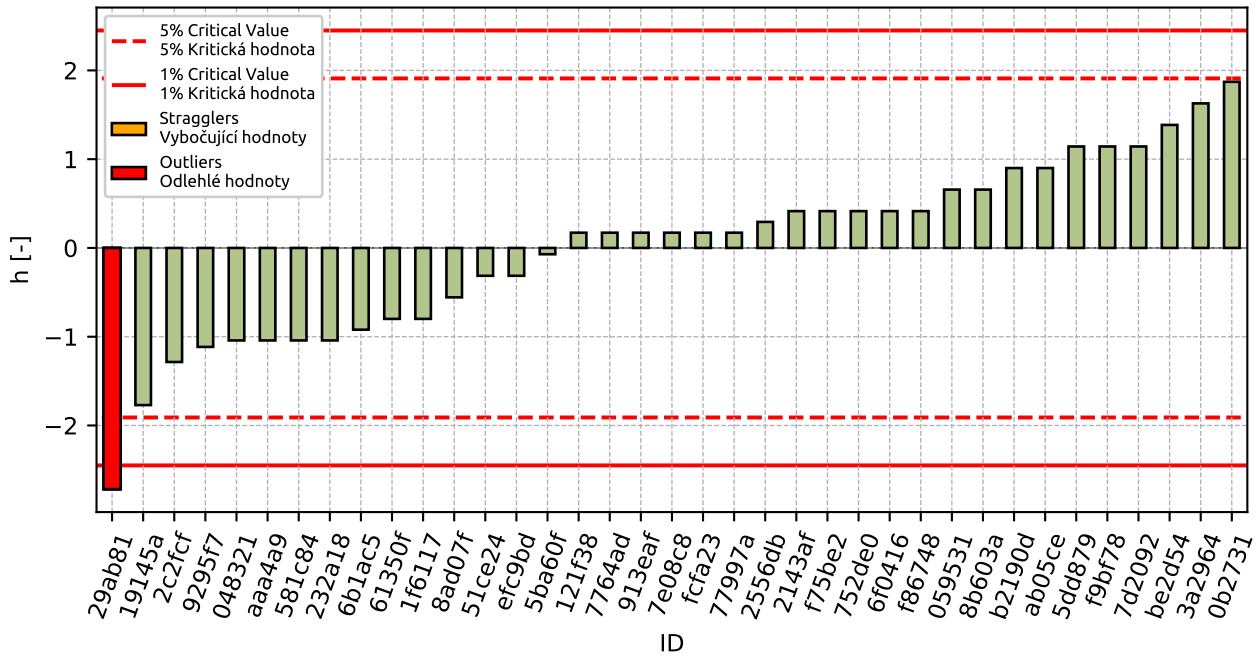

Figure 13: Interlaboratory Consistency Statistic

2.4 Descriptive statistics

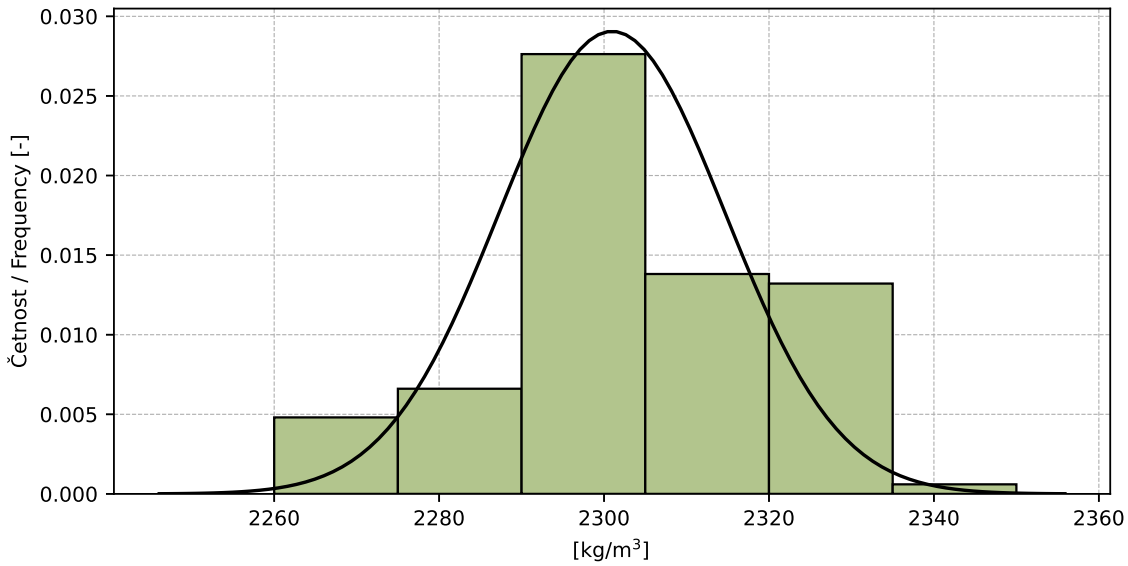

Figure 14: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[kg/m³]
Průměrná hodnota / Average value – $\bar{x}$	2301.0
Výběrová směrodatná odchylka / Sample standard deviation – s	13.7
Vztažná hodnota / Asigned value – x^*	2301.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	13.7
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	3.7
p-hodnota testu normality / p-value of normality test	0.006 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	11.7
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	12.3
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	17.0
Opakovatelnost / Repeatability – r	34.0
Reprodukovatelnost / Reproducibility – R	48.0

2.5 Evaluation of Performance Statistics

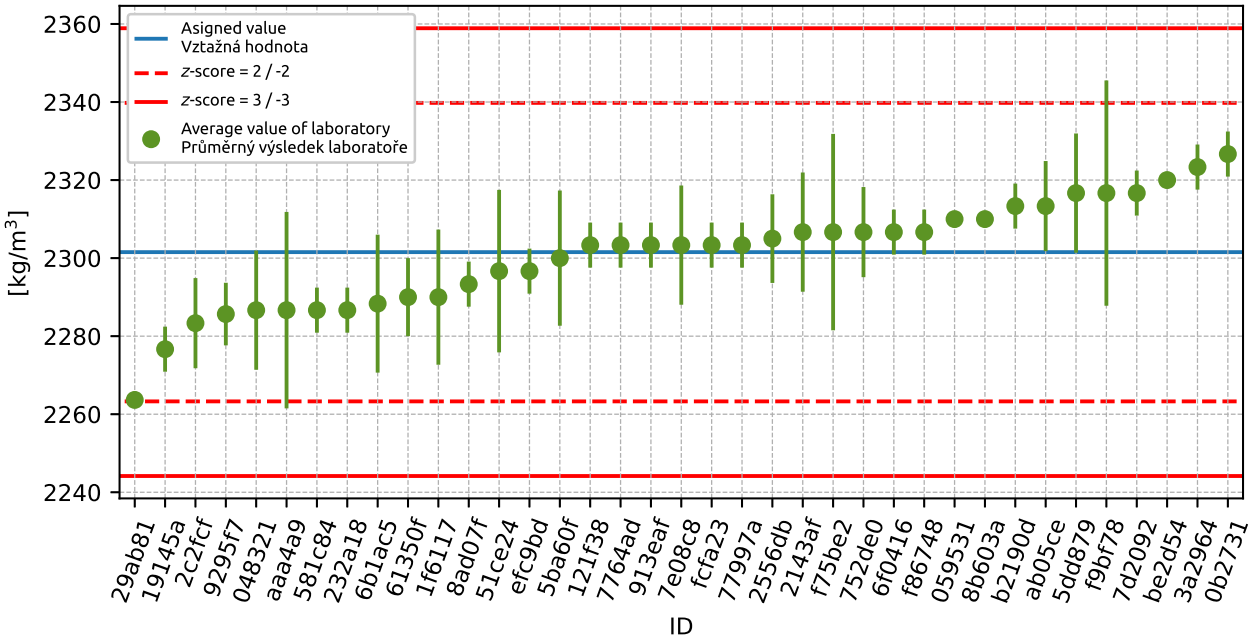

Figure 15: Average values and sample standard deviations

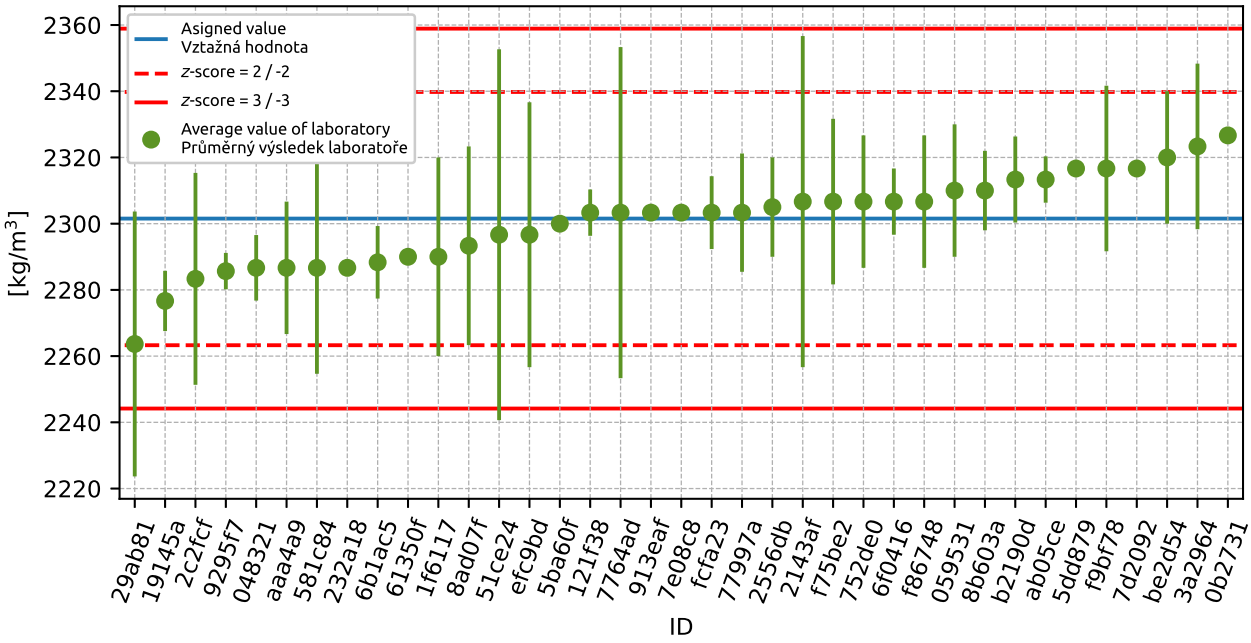

Figure 16: Average values and extended uncertainties of measurement

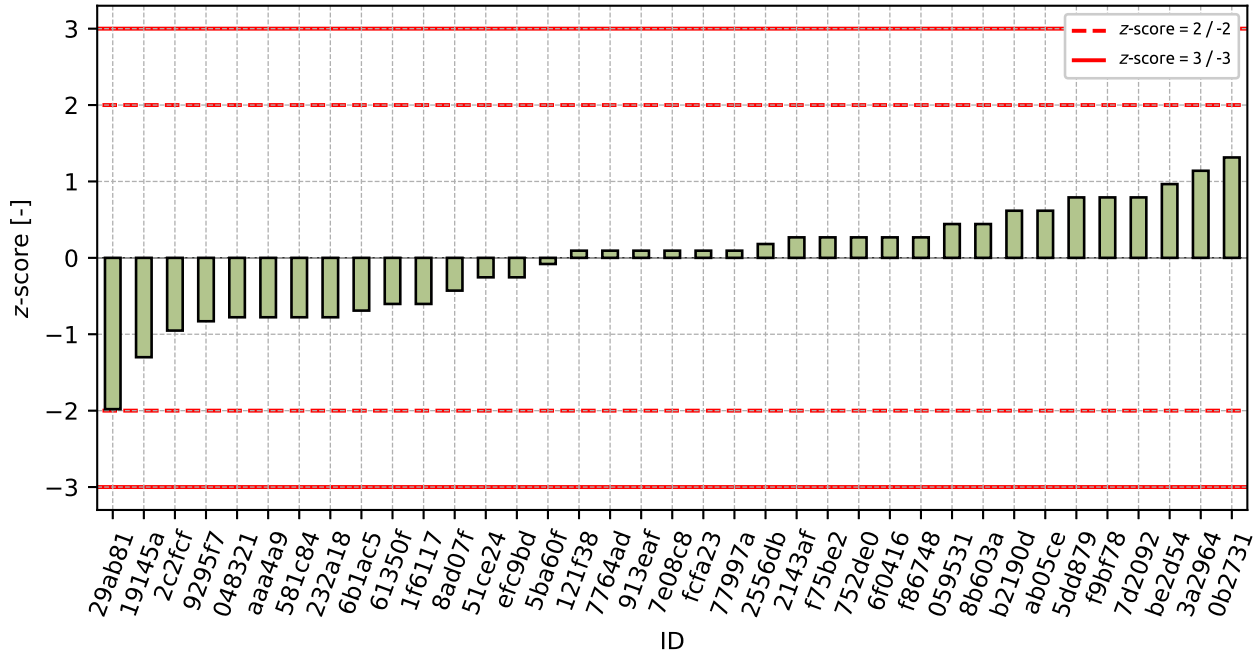

Figure 17: z-score

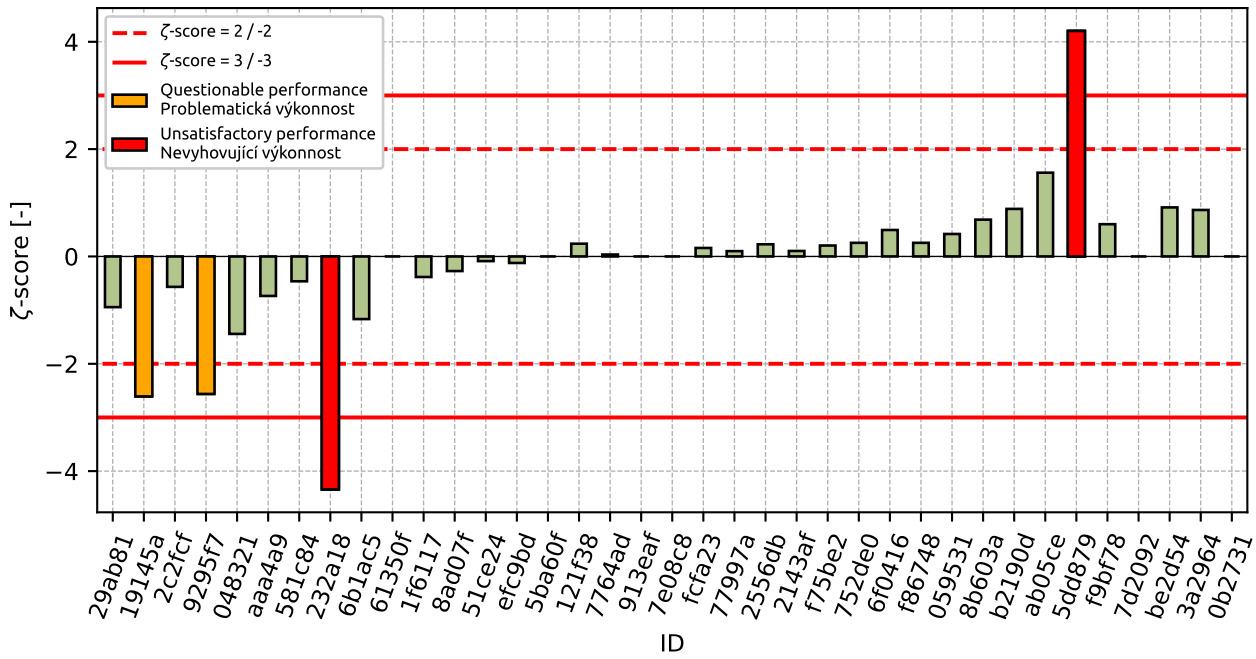

Figure 18: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
29ab81	-1.98	-0.94
19145a	-1.3	-2.61
2c2fcf	-0.95	-0.57
9295f7	-0.83	-2.56
048321	-0.78	-1.44
aaa4a9	-0.78	-0.74
581c84	-0.78	-0.46
232a18	-0.78	-4.34
6b1ac5	-0.69	-1.17
61350f	-0.6	-
1f6117	-0.6	-0.38
8ad07f	-0.43	-0.27
51ce24	-0.25	-0.09
efc9bd	-0.25	-0.12
5ba60f	-0.08	-
121f38	0.09	0.24
7764ad	0.09	0.04
913eaf	0.09	-
7e08c8	0.09	-
fcfa23	0.09	0.16
77997a	0.09	0.1
2556db	0.18	0.23
2143af	0.27	0.1
f75be2	0.27	0.2
752de0	0.27	0.25
6f0416	0.27	0.49
f86748	0.27	0.25
059531	0.44	0.42
8b603a	0.44	0.69
b2190d	0.62	0.89
ab05ce	0.62	1.56
5dd879	0.79	4.2
f9bf78	0.79	0.6
7d2092	0.79	-
be2d54	0.97	0.91
3a2964	1.14	0.87
0b2731	1.31	-

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 [%]
a171a1	0	0	0	0	0	-
581c84	10	8	1	9	1.4	15.71
2c2fcf	10	9	0	10	0.7	7.44
6599c8	10	9	1	10	0.7	7.44
5dd879	10	10	0	10	0	0
79c00a	11	10	0	10	0.7	6.73
121f38	10	12	2	11	1.4	12.86
efc9bd	12	11	2	12	0.7	6.15
9295f7	13	11	1	12	1.4	11.79
a4819b	16	10	6	13	4.2	32.64
f9bf78	15	11	2	13	2.8	21.76
da051e	13	14	7	14	0.7	5.24
266221	13	14	1	14	0.7	5.24
ab05ce	13	15	2	14	1.4	10.1
048321	15	14	4	14	0.7	4.88
51c1ea	14	15	7	14	0.7	4.88
fcfa23	11	19	1	15	5.7	37.71
8346e6	15	16	7	16	0.7	4.56
77997a	15	18	1	16	2.1	12.86
be2d54	19	14	4	16	3.5	21.43
2eeb1f	17	18	1	18	0.7	4.04
7764ad	20	15	4	18	3.5	20.2
059531	17	19	1	18	1.4	7.86
1f6117	18	20	2	19	1.4	7.44
9ff5a8	24	15	1	20	6.4	32.64
f75be2	20	19	2	20	0.7	3.63
6b1ac5	17	23	2	20	4.2	21.21
3a2964	22	21	4	22	0.7	3.29
19145a	24	22	3	23	1.4	6.15
61350f	32	15	-	24	12	51.15
1685fd	28	24	2	26	2.8	10.88
7d2092	30	28	-	29	1.4	4.88
0b2731	26	32	-	29	4.2	14.63
913eaf	35	27	-	31	5.7	18.25
855620	36	60	2	48	17	35.36
232a18	150	150	0	150	0.2	0.14

3.2 The Numerical Procedure for Determining Outliers

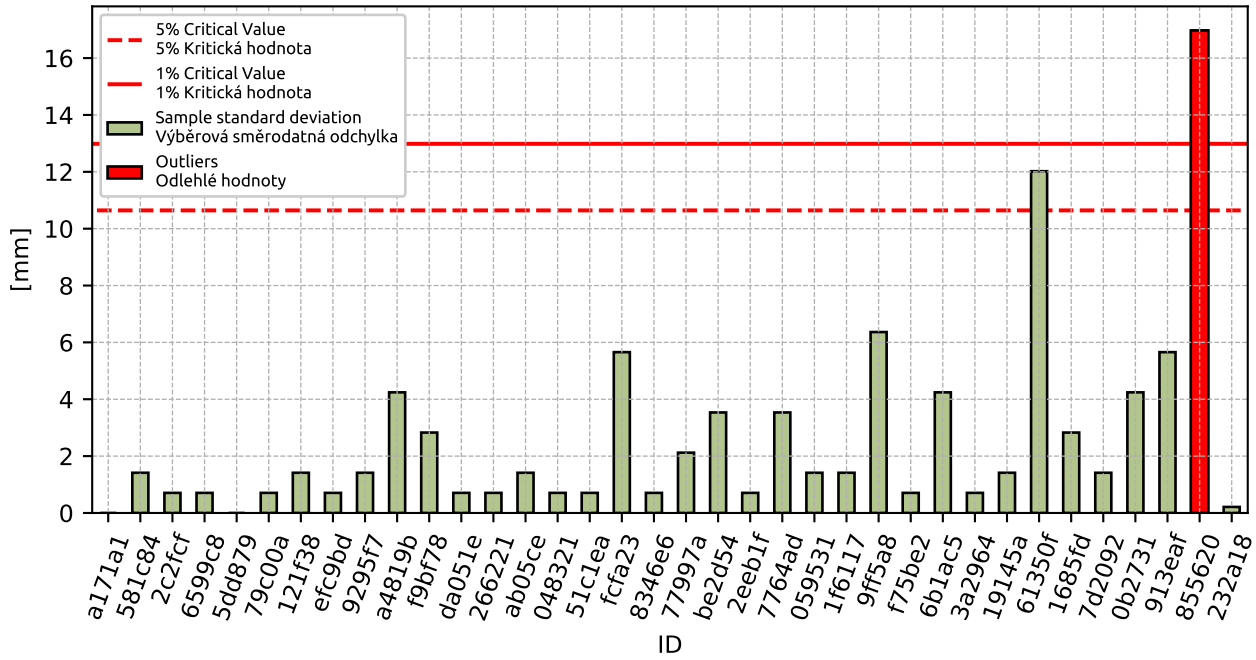

Figure 19: **Cochran's test** - sample standard deviations

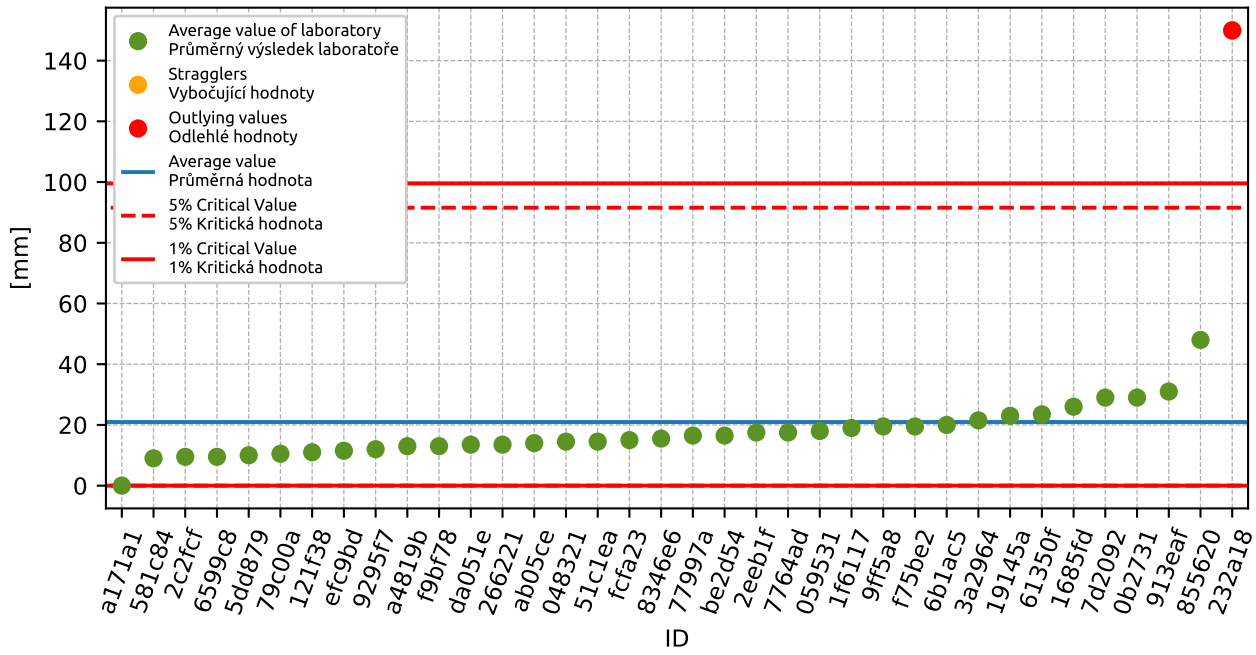

Figure 20: **Grubbs' test** - average values

3.3 Mandel's Statistics

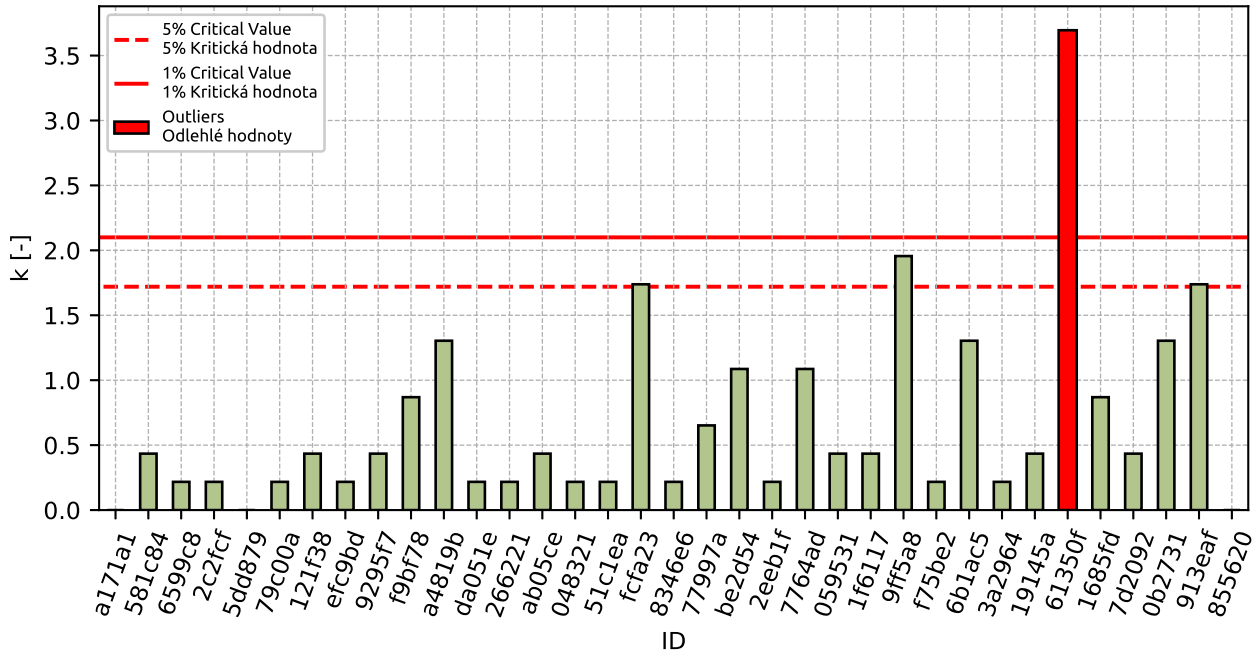

Figure 21: Intralaboratory Consistency Statistic

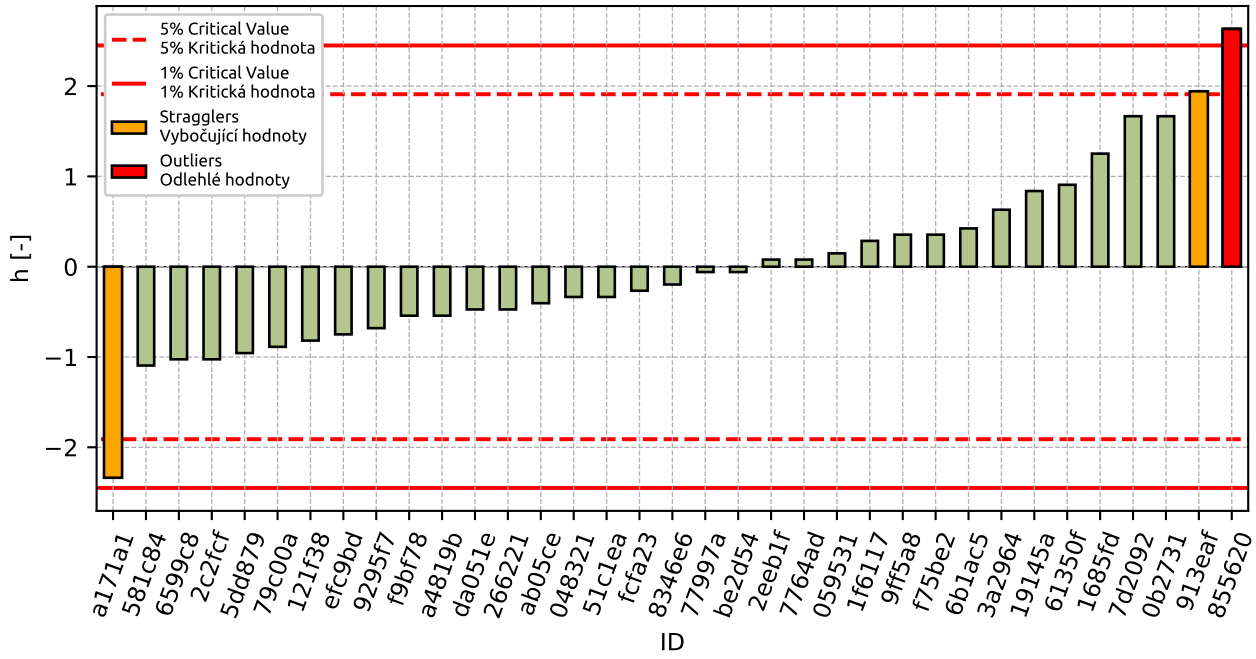

Figure 22: Interlaboratory Consistency Statistic

3.4 Descriptive statistics

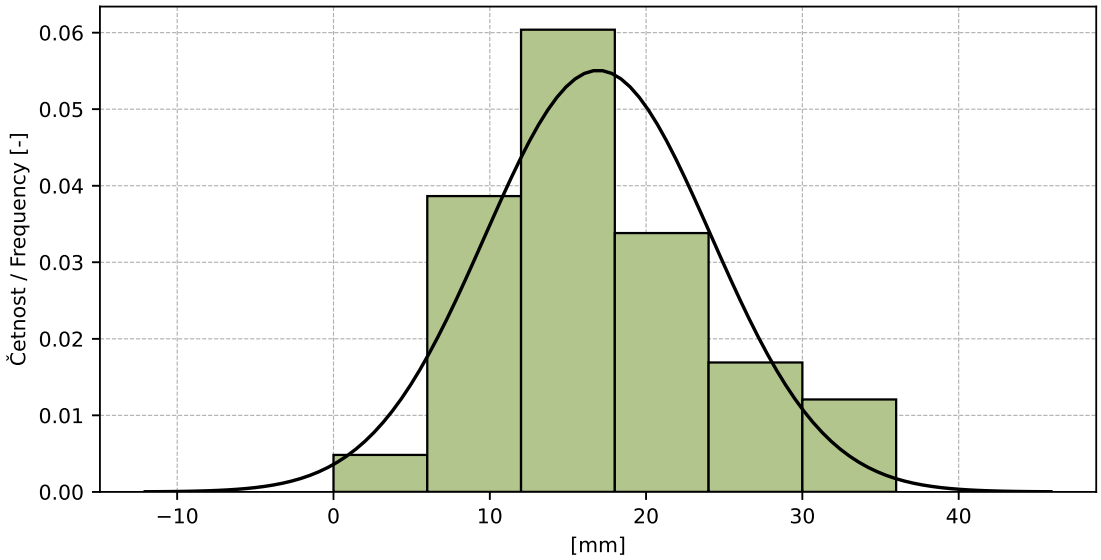

Figure 23: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	**[mm]**
Průměrná hodnota / Average value – $\bar{x}$	17.0
Výběrová směrodatná odchylka / Sample standard deviation – s	7.2
Vztažná hodnota / Asigned value – x^*	17.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	6.8
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	1.4
p-hodnota testu normality / p-value of normality test	1.0 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	6.9
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	3.3
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	7.6
Opakovatelnost / Repeatability – r	9.0
Reprodukovatelnost / Reproducibility – R	21.0

3.5 Evaluation of Performance Statistics

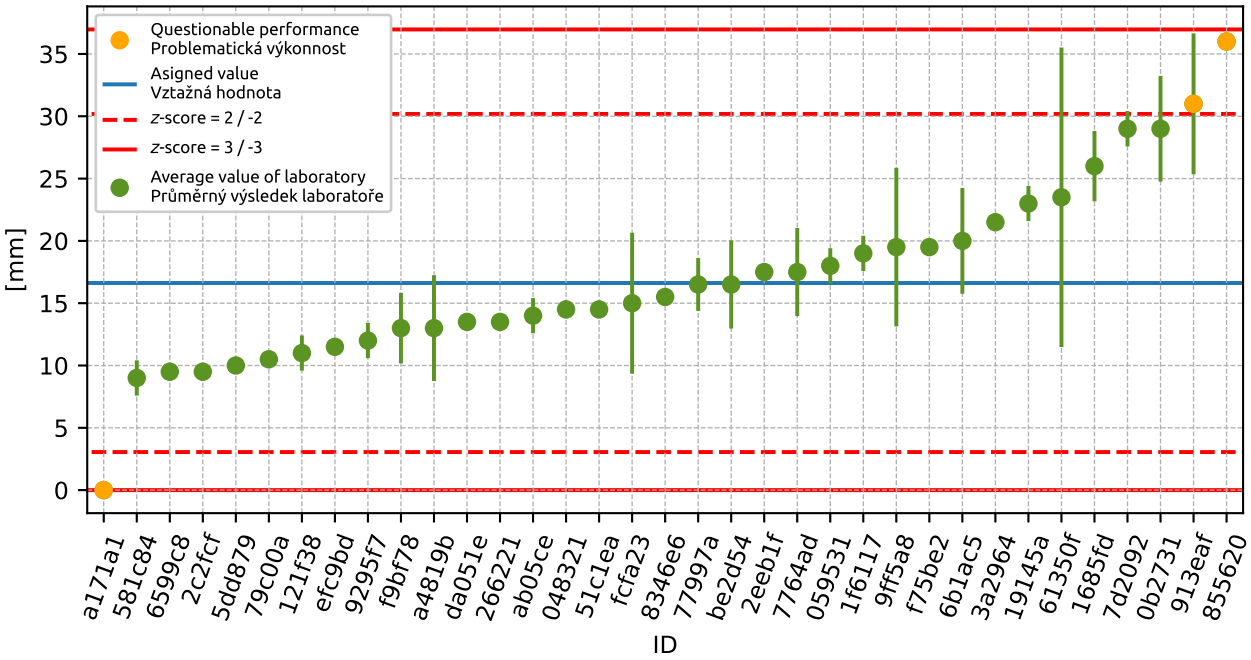

Figure 24: Average values and sample standard deviations

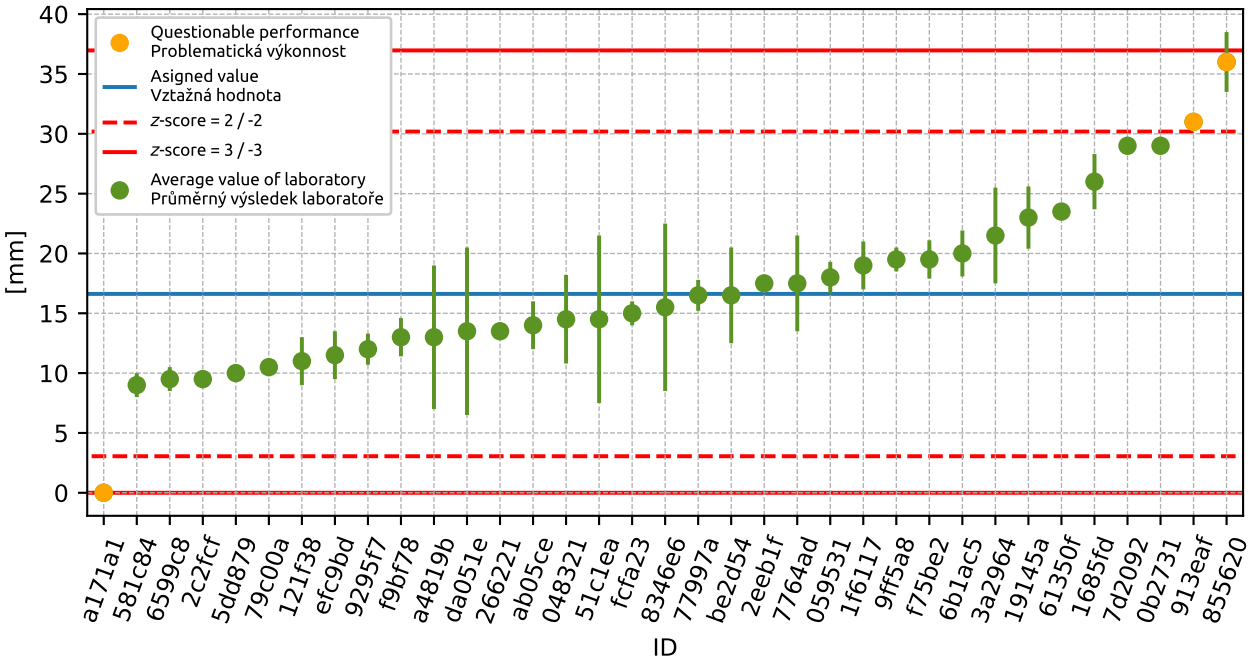

Figure 25: Average values and extended uncertainties of measurement

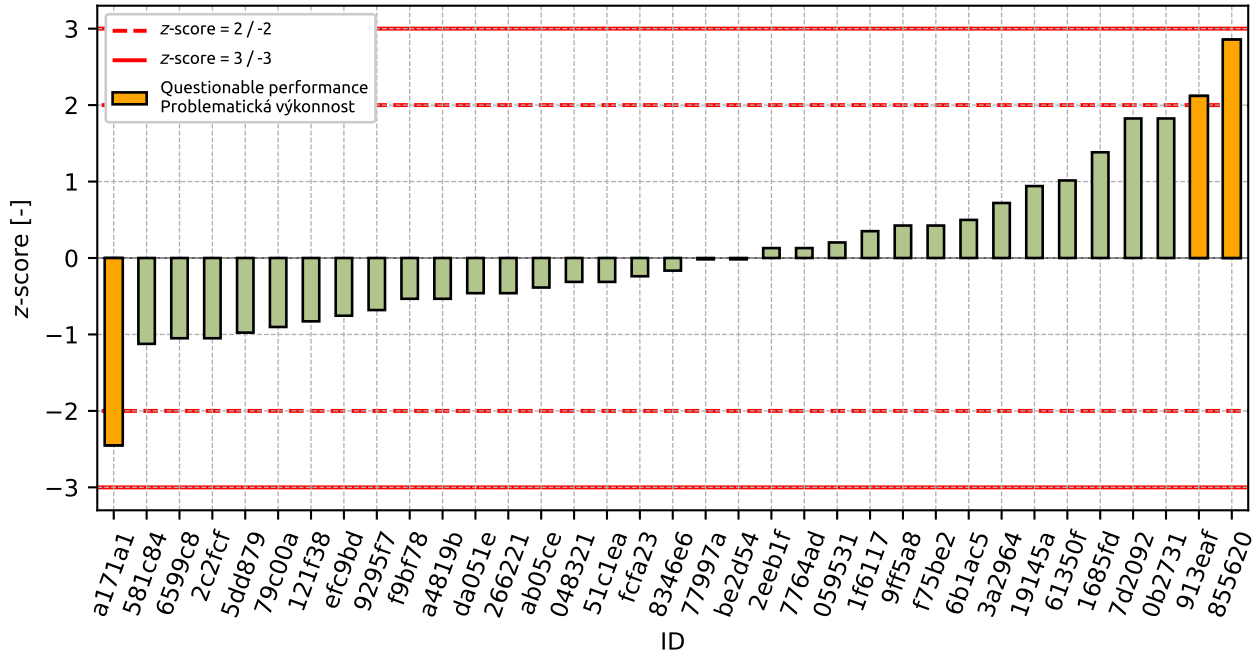

Figure 26: z-score

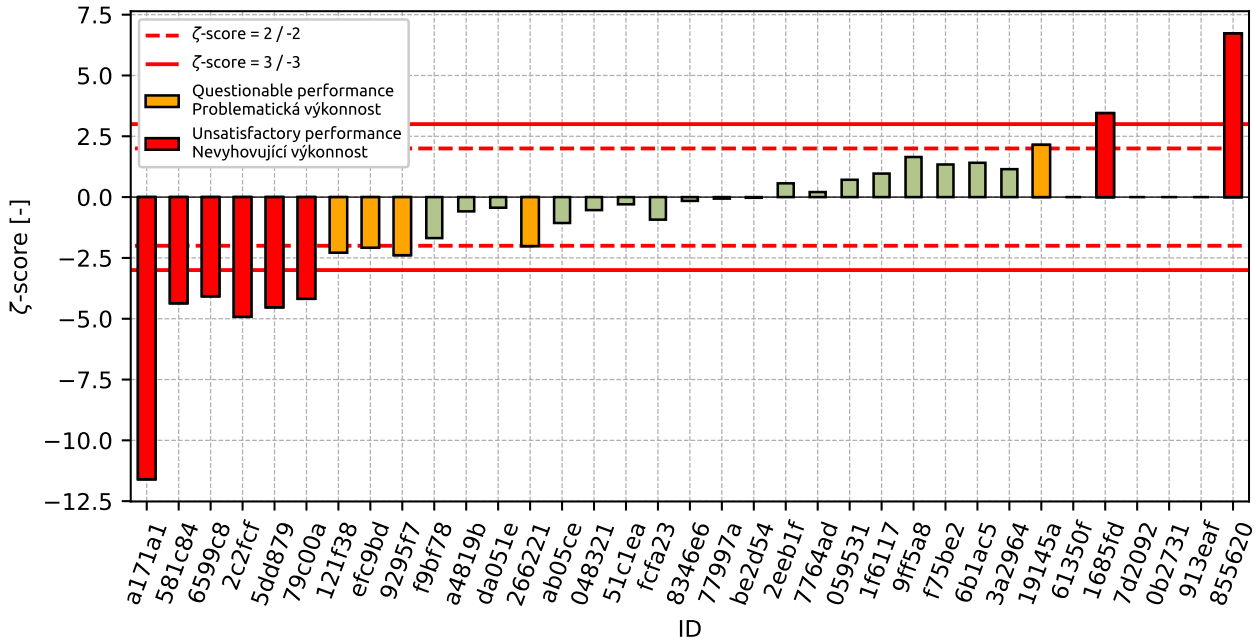

Figure 27: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a171a1	-2.45	-11.6
581c84	-1.12	-4.36
6599c8	-1.05	-4.07
2c2fcf	-1.05	-4.92
5dd879	-0.98	-4.53
79c00a	-0.9	-4.18
121f38	-0.83	-2.28
efc9bd	-0.75	-2.08
9295f7	-0.68	-2.39
f9bf78	-0.53	-1.69
a4819b	-0.53	-0.59
da051e	-0.46	-0.44
266221	-0.46	-2.01
ab05ce	-0.39	-1.06
048321	-0.31	-0.53
51c1ea	-0.31	-0.3
fcfa23	-0.24	-0.93
8346e6	-0.17	-0.16
77997a	-0.02	-0.06
be2d54	-0.02	-0.03
2eeb1f	0.13	0.57
7764ad	0.13	0.21
059531	0.2	0.71
1f6117	0.35	0.97
9ff5a8	0.42	1.65
f75be2	0.42	1.34
6b1ac5	0.5	1.41
3a2964	0.72	1.15
19145a	0.94	2.15
61350f	1.01	-
1685fd	1.38	3.45
7d2092	1.83	-
0b2731	1.83	-
913eaf	2.12	-
855620	2.86	6.73

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 - outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [%]	u_X [%]
64697c	4.6	0.29
5929bf	6.96	1.24
fa1905	7.57	0.23
f9bf78	7.61	0.8
6ca58a	7.88	0.8

4.1.2 The Numerical Procedure for Determining Outliers

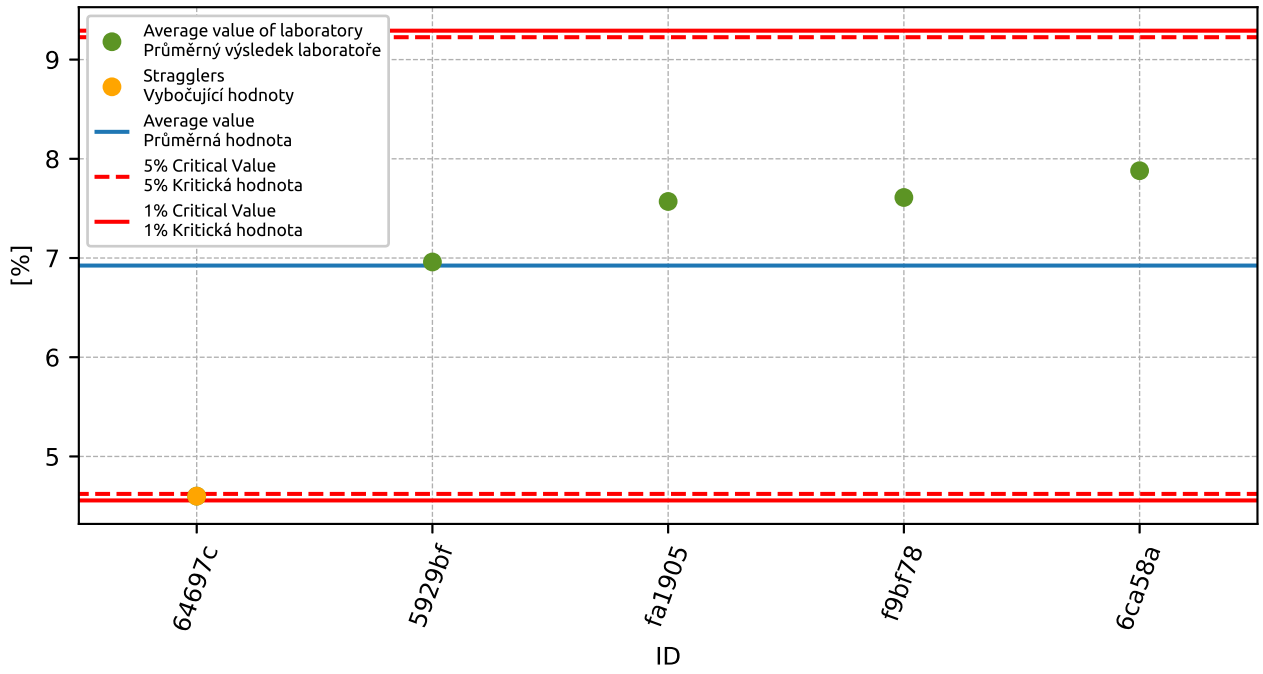

Figure 28: **Grubbs' test** - average values

4.1.3 Mandel's Statistics

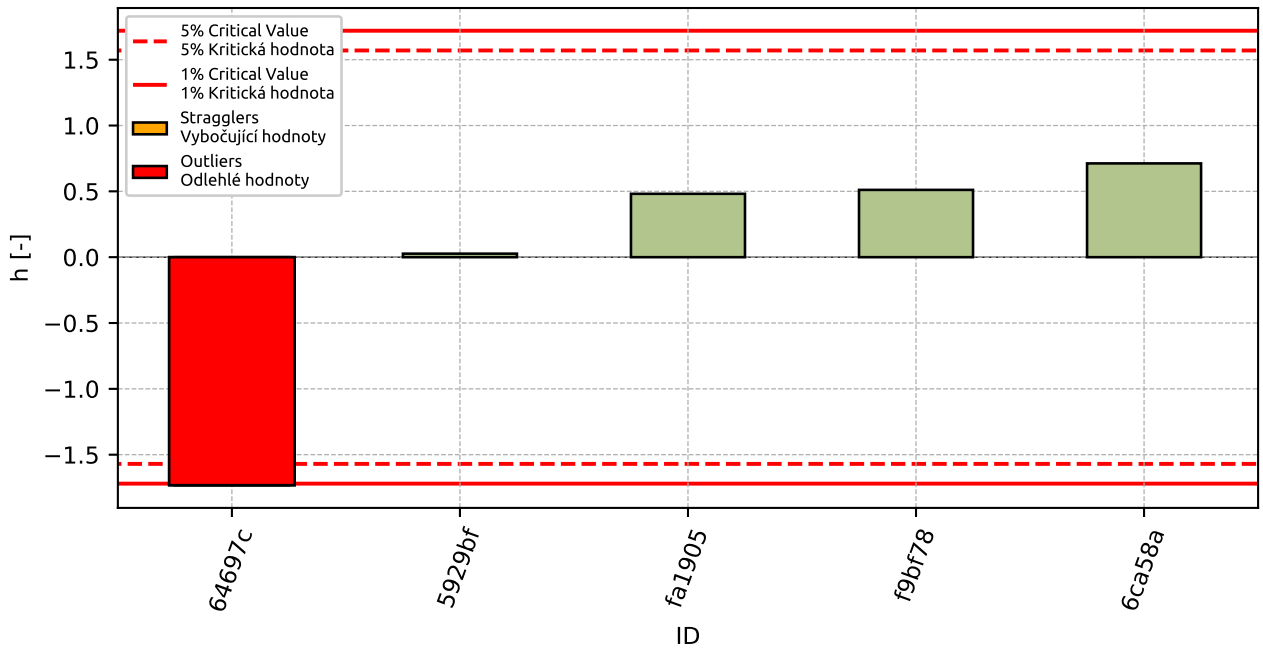

Figure 29: Interlaboratory Consistency Statistic

4.1.4 Descriptive statistics

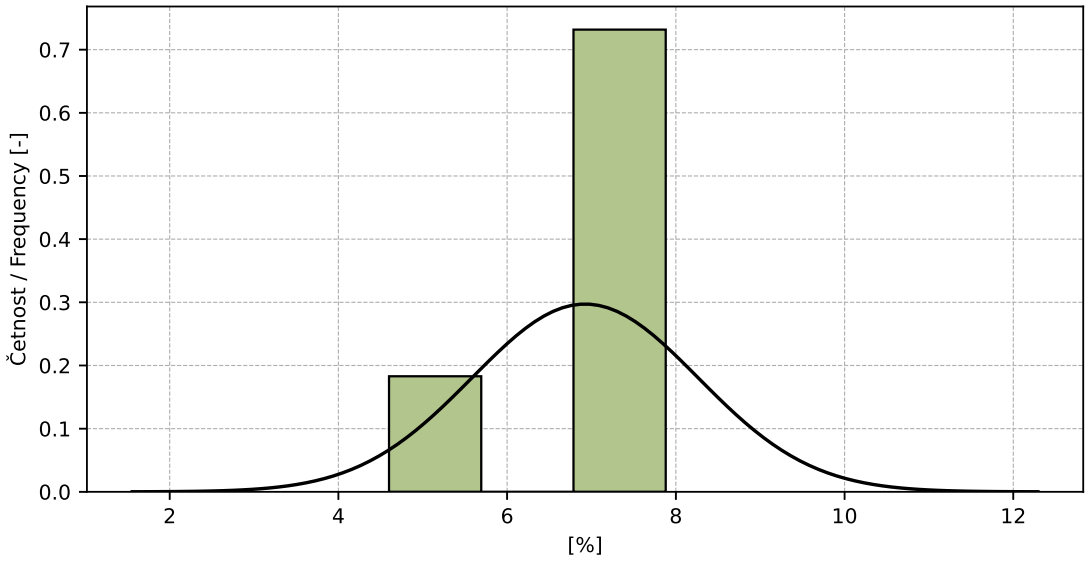

Figure 30: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	[%]
Průměrná hodnota / Average value – $\bar{x}$	6.92
Výběrová směrodatná odchylka / Sample standard deviation – s	1.342
Vztažná hodnota / Asigned value – x^*	7.38
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.444
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.248
p-hodnota testu normality / p-value of normality test	0.035 [-]

4.1.5 Evaluation of Performance Statistics

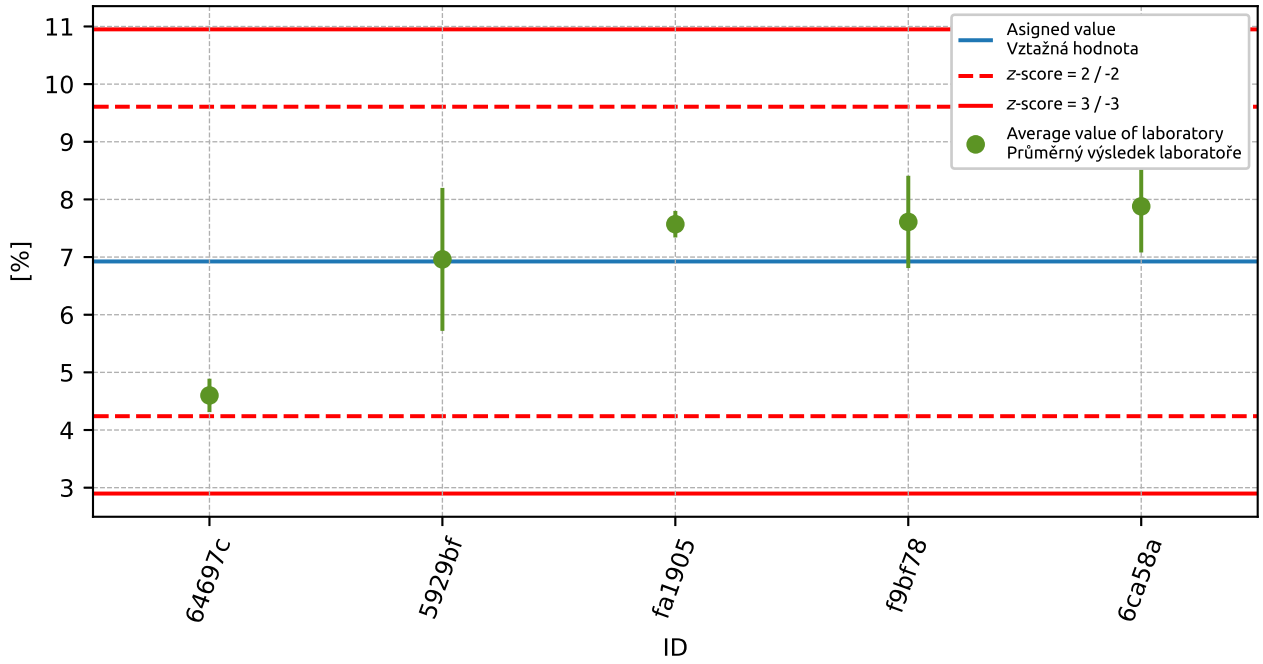

Figure 31: Average values and extended uncertainties of measurement

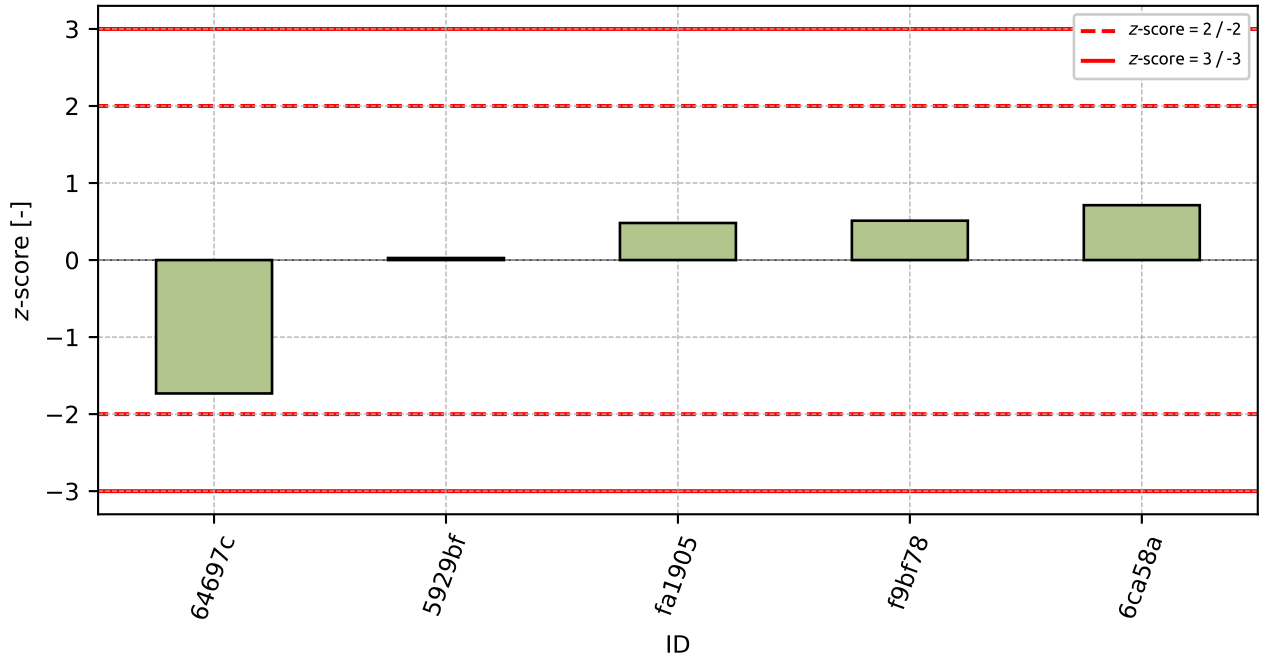

Figure 32: z-score

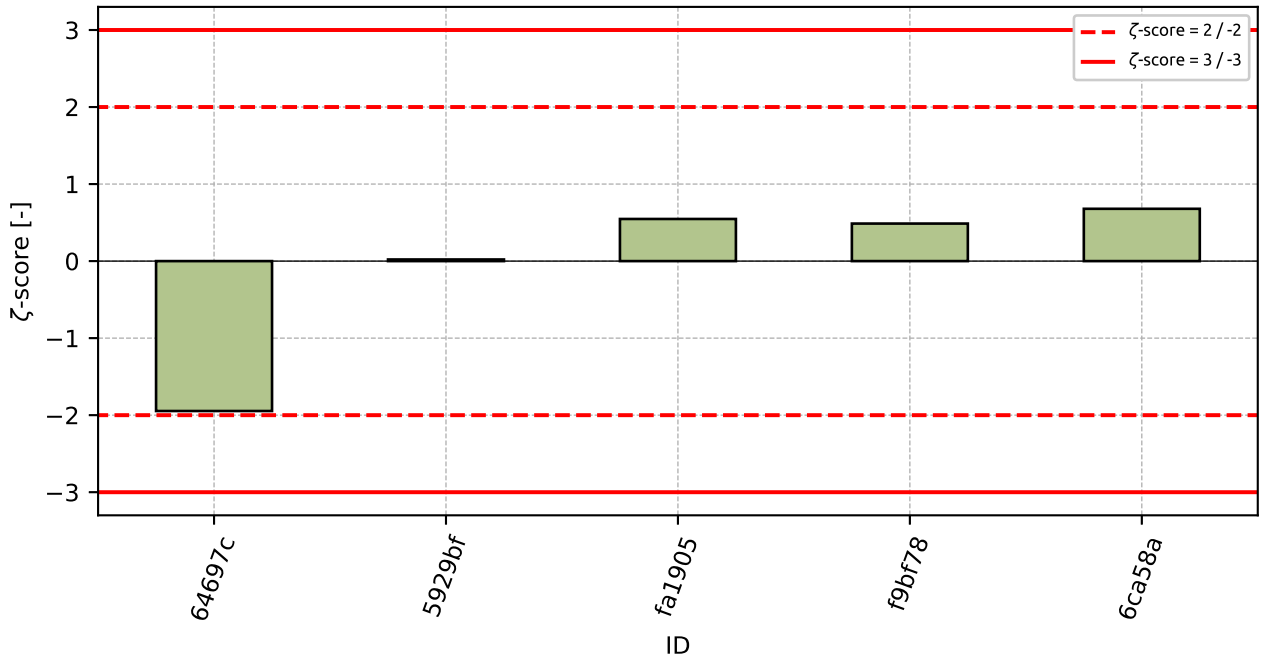

Figure 33: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
64697c	-1.73	-1.95
5929bf	0.03	0.02
fa1905	0.48	0.55
f9bf78	0.51	0.49
6ca58a	0.71	0.68

4.2 Micro air content A_{300}

4.2.1 Test results

Table 16: Test results - outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [%]	u_X [%]
64697c	1.82	0.35
6ca58a	2.63	0.2
5929bf	2.75	0.5
fa1905	3.03	0.17
f9bf78	3.77	0.4

4.2.2 The Numerical Procedure for Determining Outliers

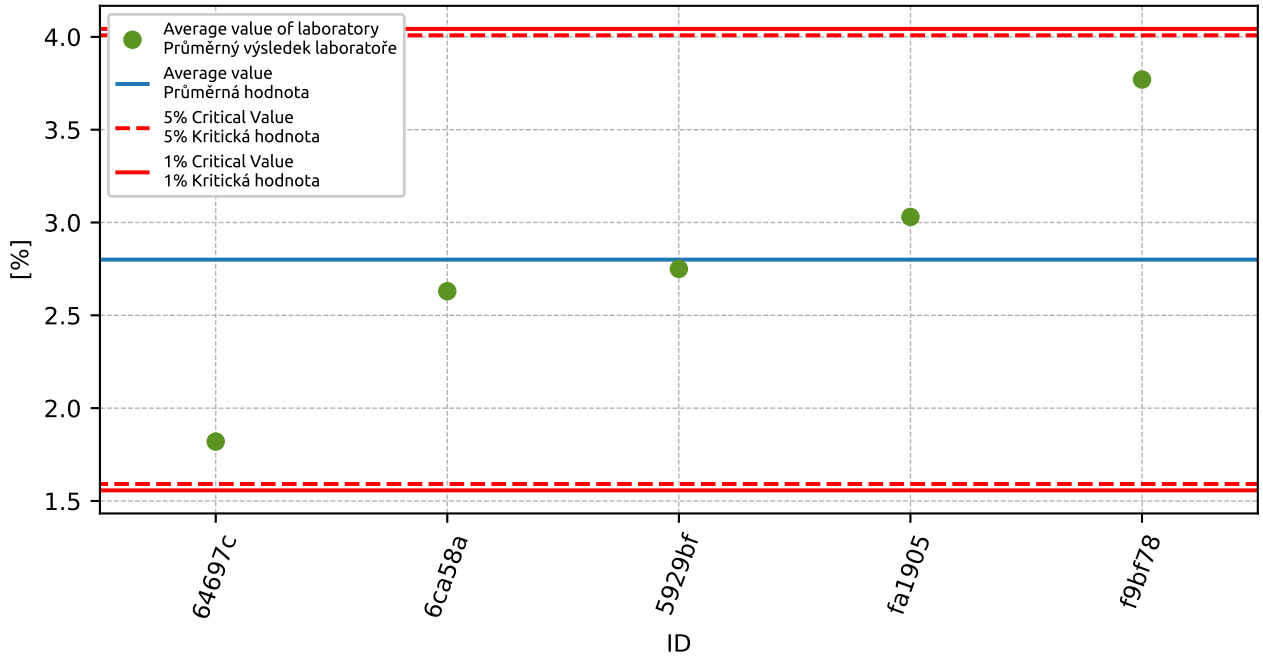

Figure 34: **Grubbs' test** - average values

4.2.3 Mandel's Statistics

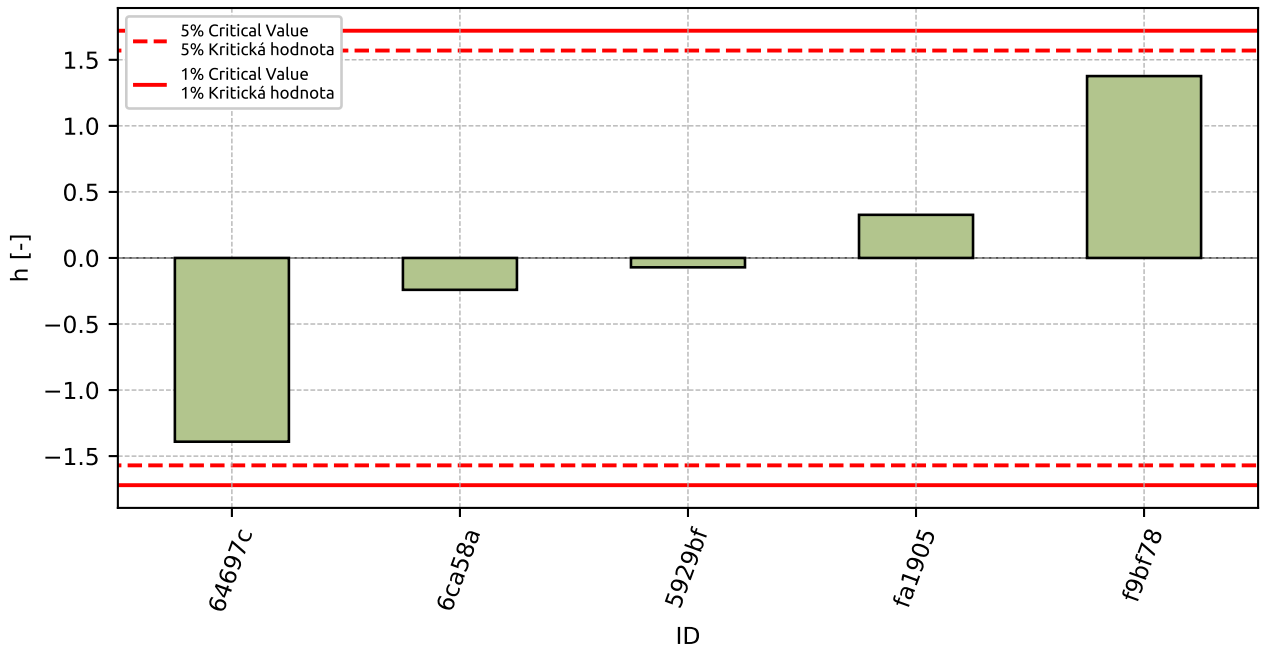

Figure 35: Interlaboratory Consistency Statistic

4.2.4 Descriptive statistics

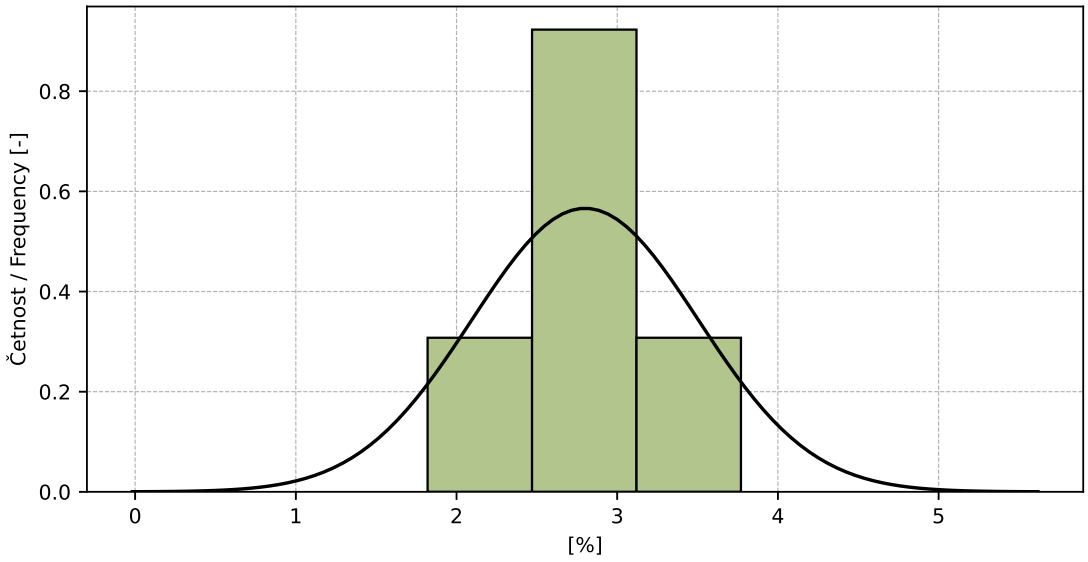

Figure 36: Histogram of all test results

Table 17: Descriptive statistics

Characteristics	[%]
Průměrná hodnota / Average value – $\bar{x}$	2.8
Výběrová směrodatná odchylka / Sample standard deviation – s	0.705
Vztažná hodnota / Asigned value – x^*	2.8
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.705
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.839
p-hodnota testu normality / p-value of normality test	0.916 [-]

4.2.5 Evaluation of Performance Statistics

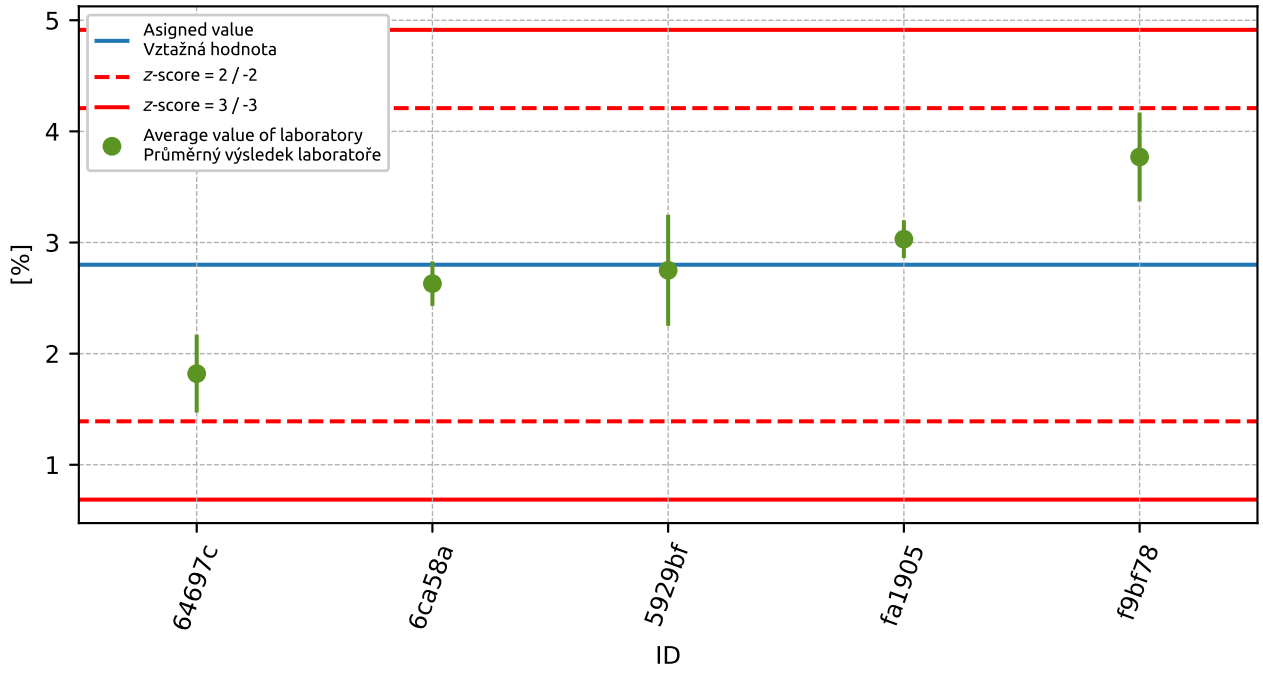

Figure 37: Average values and extended uncertainties of measurement

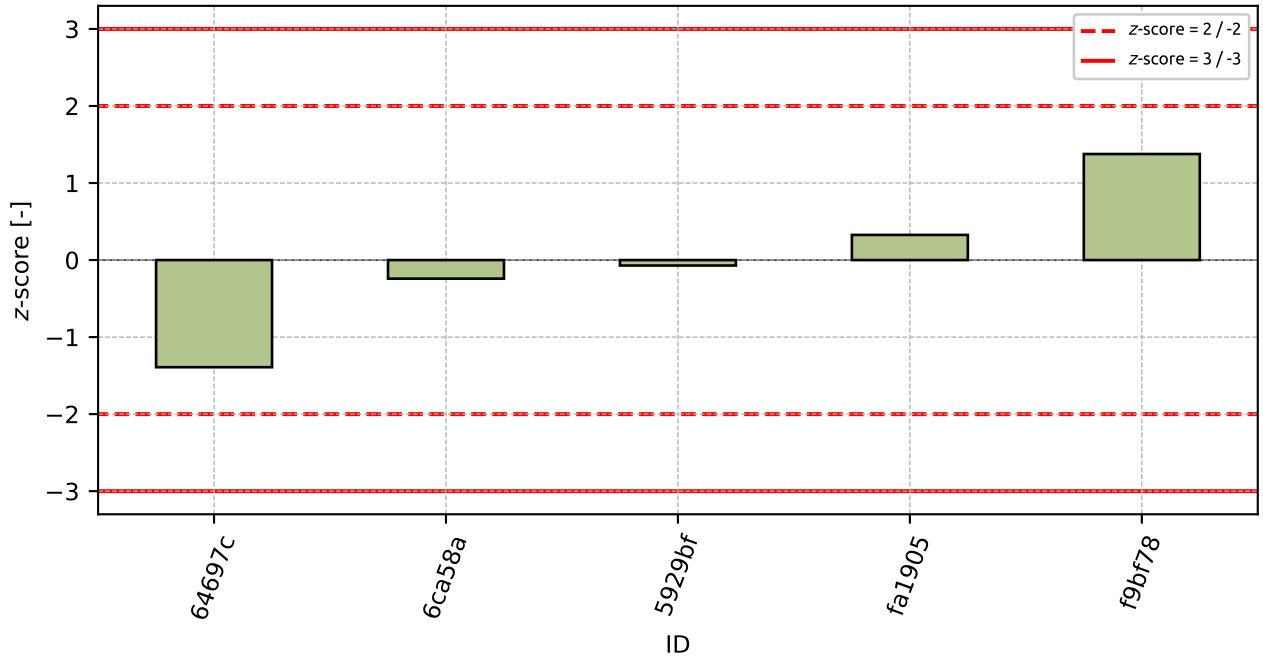

Figure 38: z-score

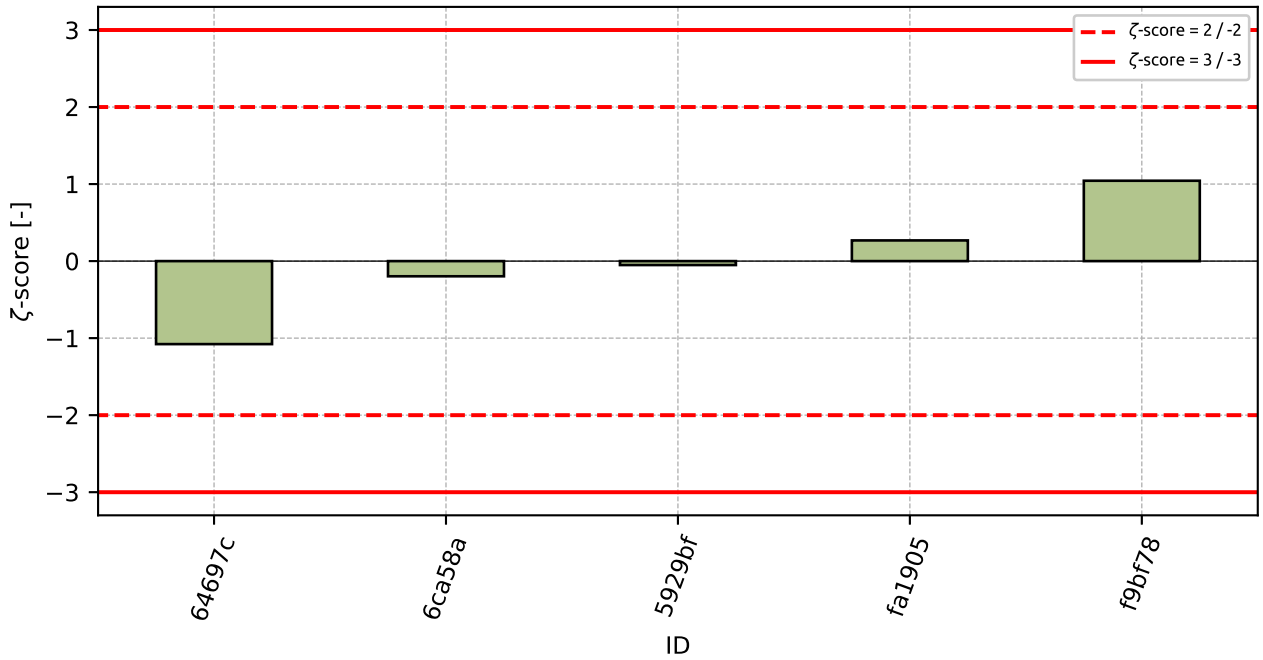

Figure 39: ζ-score

Table 18: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
64697c	-1.39	-1.08
6ca58a	-0.24	-0.2
5929bf	-0.07	-0.05
fa1905	0.33	0.27
f9bf78	1.38	1.04

4.3 Spacing factor L

4.3.1 Test results

Table 19: Test results - outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [mm]	u_X [mm]
f9bf78	0.14	0.01
5929bf	0.14	0.1
6ca58a	0.15	0.02
fa1905	0.16	0.01
64697c	0.22	0.02

4.3.2 The Numerical Procedure for Determining Outliers

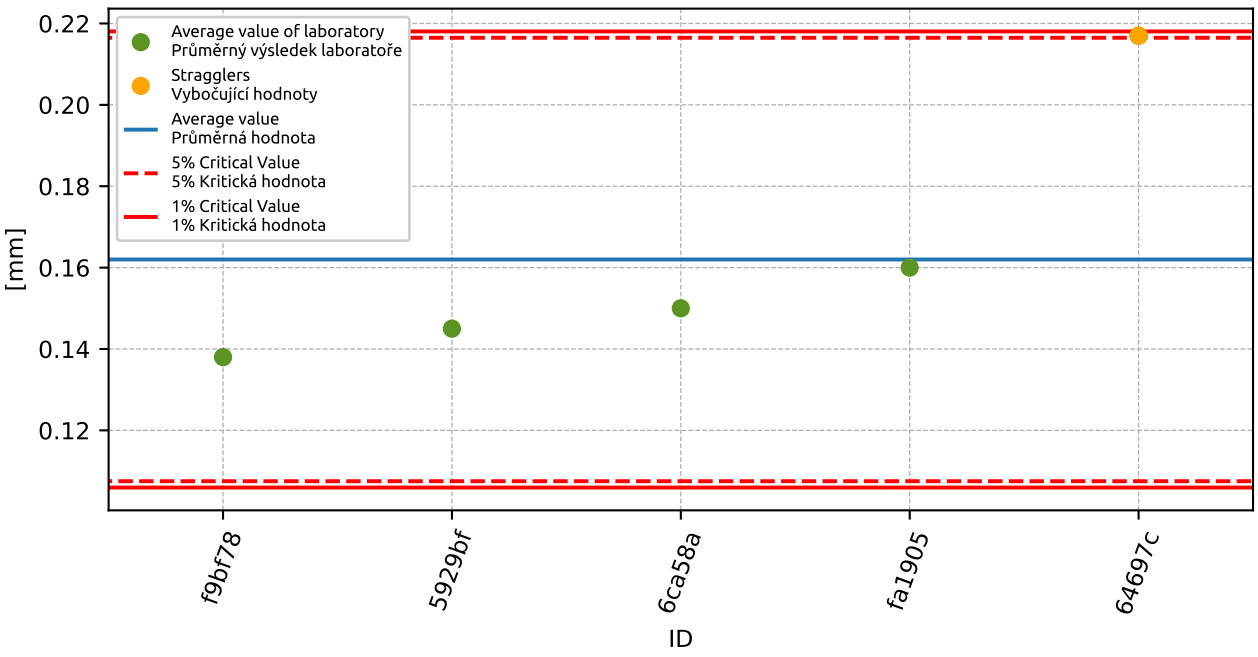

Figure 40: **Grubbs' test** - average values

4.3.3 Mandel's Statistics

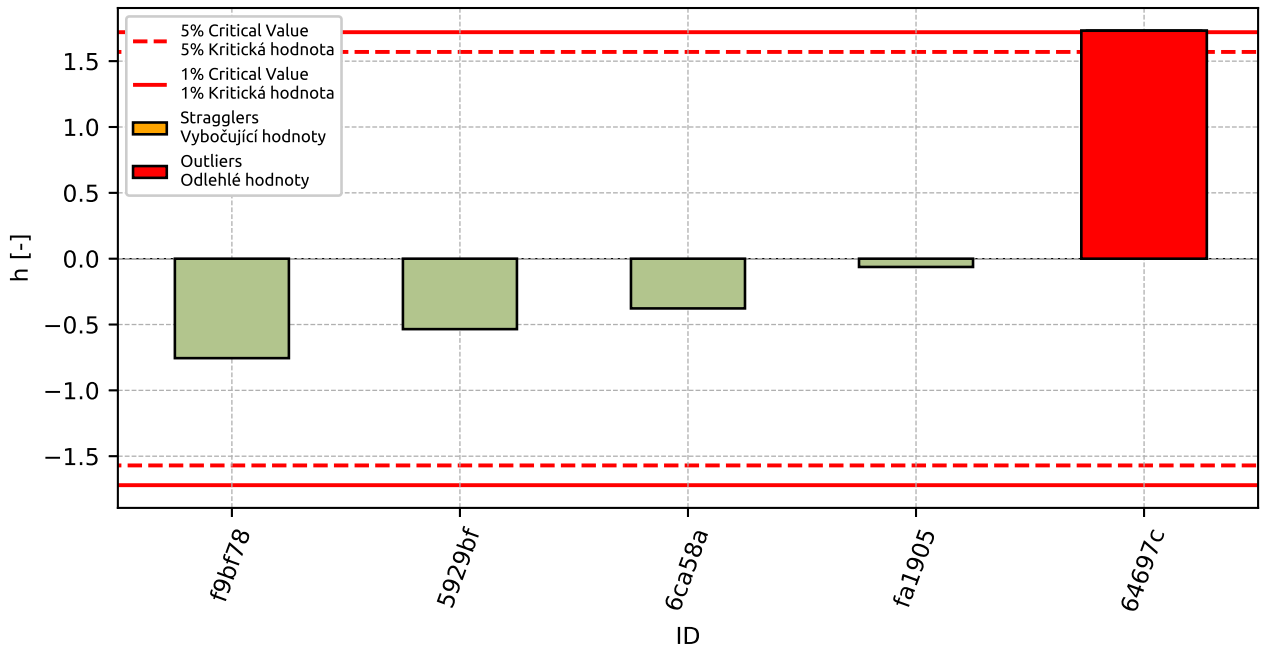

Figure 41: Interlaboratory Consistency Statistic

4.3.4 Descriptive statistics

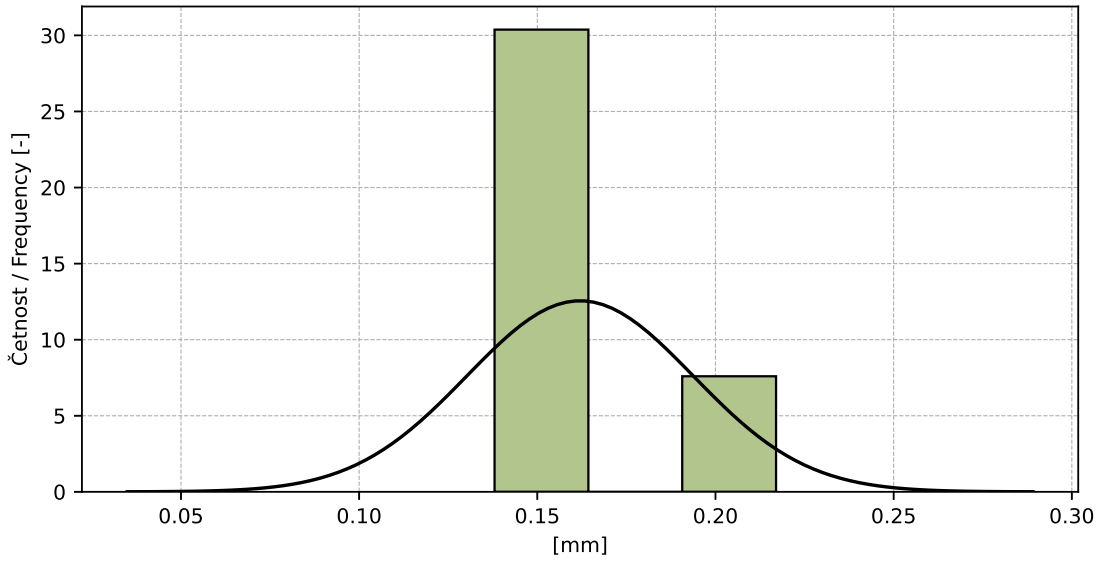

Figure 42: Histogram of all test results

Table 20: Descriptive statistics

Characteristics	[mm]
Průměrná hodnota / Average value – $\bar{x}$	0.16
Výběrová směrodatná odchylka / Sample standard deviation – s	0.032
Vztažná hodnota / Asigned value – x^*	0.16
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.032
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.178
p-hodnota testu normality / p-value of normality test	0.055 [-]

4.3.5 Evaluation of Performance Statistics

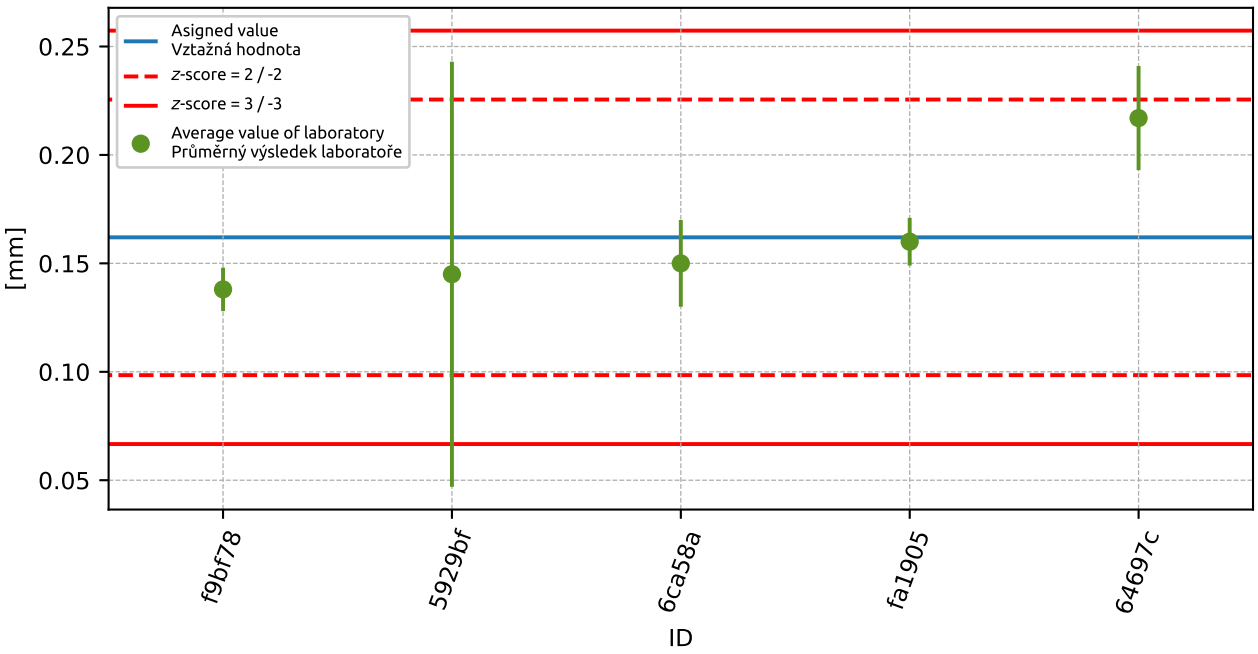

Figure 43: Average values and extended uncertainties of measurement

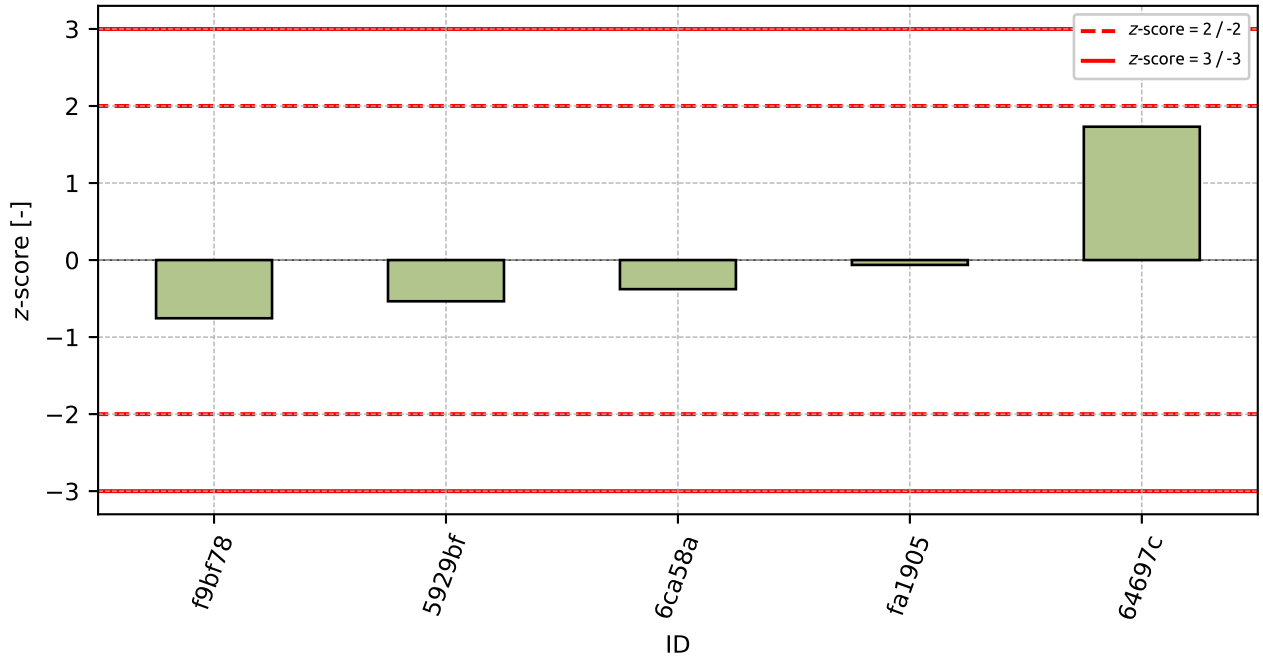

Figure 44: z-score

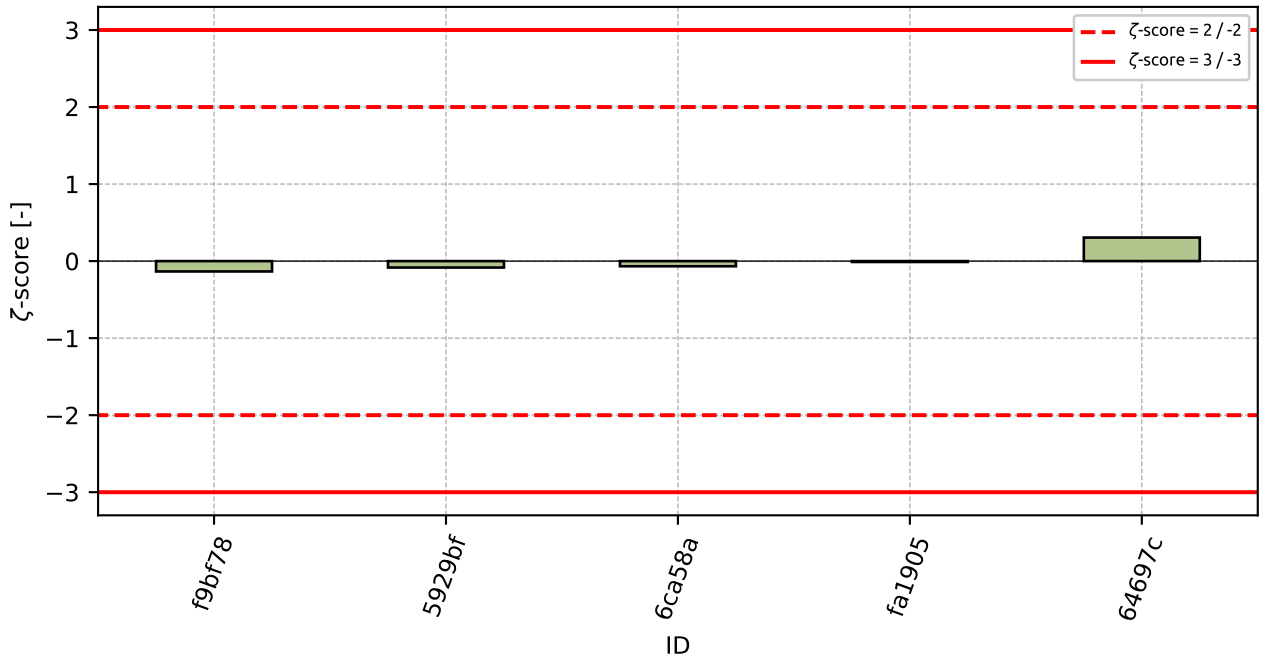

Figure 45: ζ-score

Table 21: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
f9bf78	-0.76	-0.13
5929bf	-0.54	-0.08
6ca58a	-0.38	-0.07
fa1905	-0.06	-0.01
64697c	1.73	0.31

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

5.0.1 Test results

Table 22: Test results - outliers are marked by red color. u_X - extended uncertainty of measurement.

ID	Test results [mm]	u_X [mm]
f9bf78	0.14	0.01
5929bf	0.14	0.1
6ca58a	0.15	0.02
fa1905	0.16	0.01
64697c	0.22	0.02

5.0.2 The Numerical Procedure for Determining Outliers

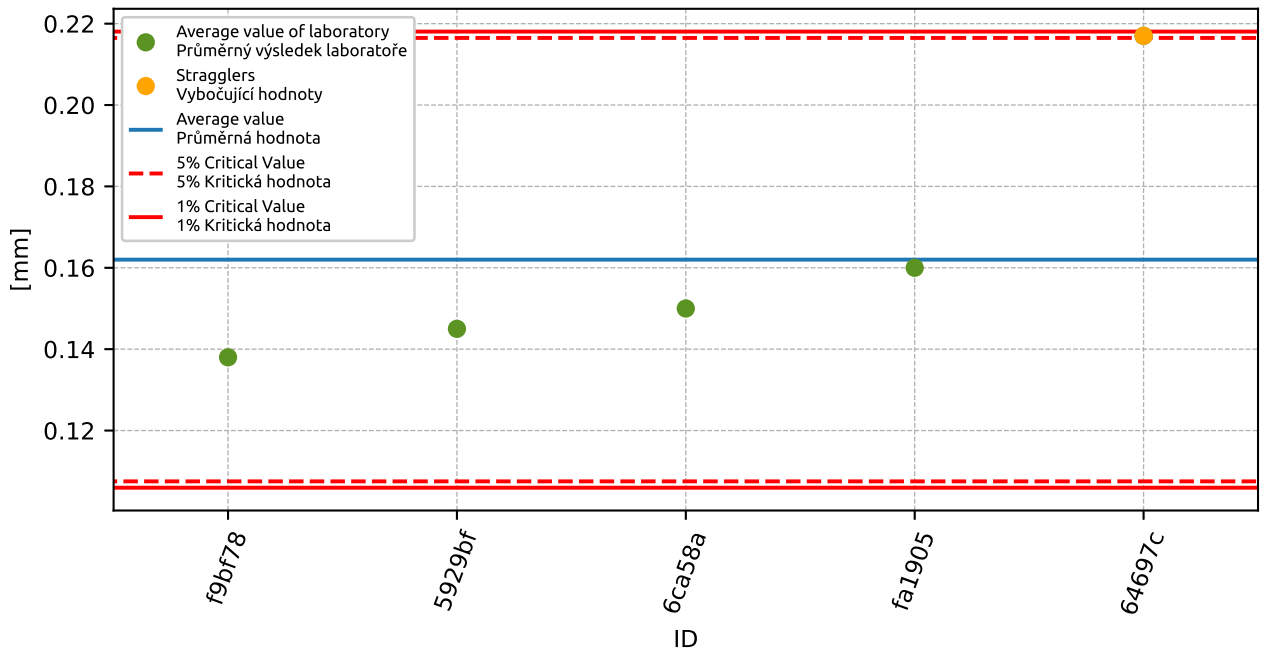

Figure 46: **Grubbs' test** - average values

5.0.3 Mandel's Statistics

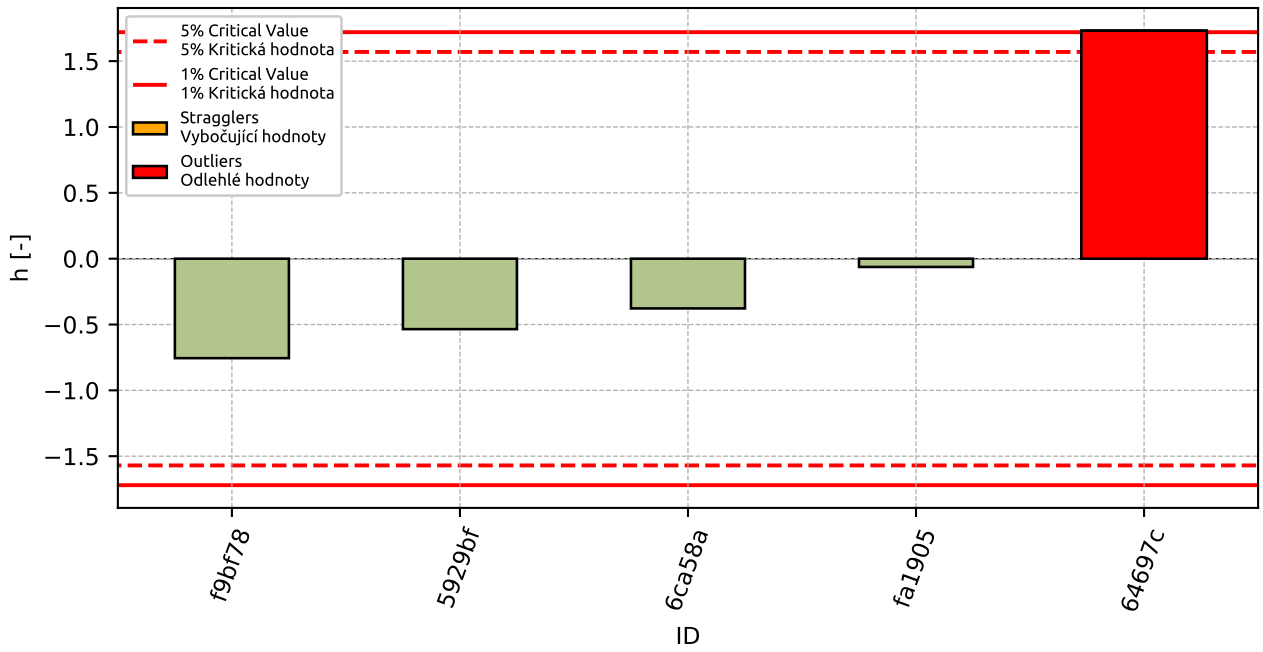

Figure 47: Interlaboratory Consistency Statistic

5.0.4 Descriptive statistics

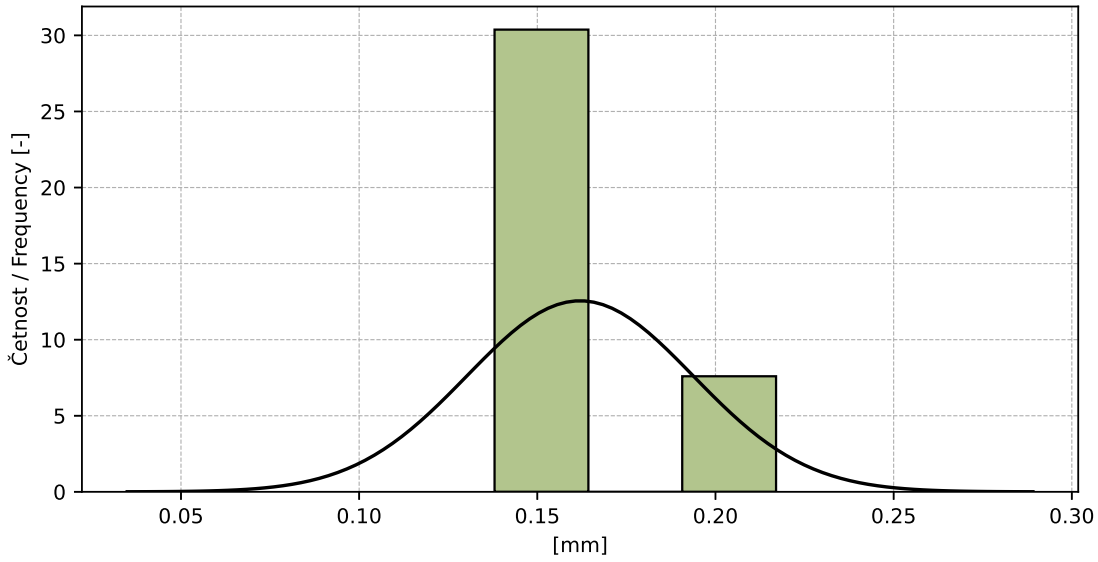

Figure 48: Histogram of all test results

Table 23: Descriptive statistics

Characteristics	[mm]
Průměrná hodnota / Average value – $\bar{x}$	0.16
Výběrová směrodatná odchylka / Sample standard deviation – s	0.032
Vztažná hodnota / Asigned value – x^*	0.16
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.032
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.178
p-hodnota testu normality / p-value of normality test	0.055 [-]

5.0.5 Evaluation of Performance Statistics

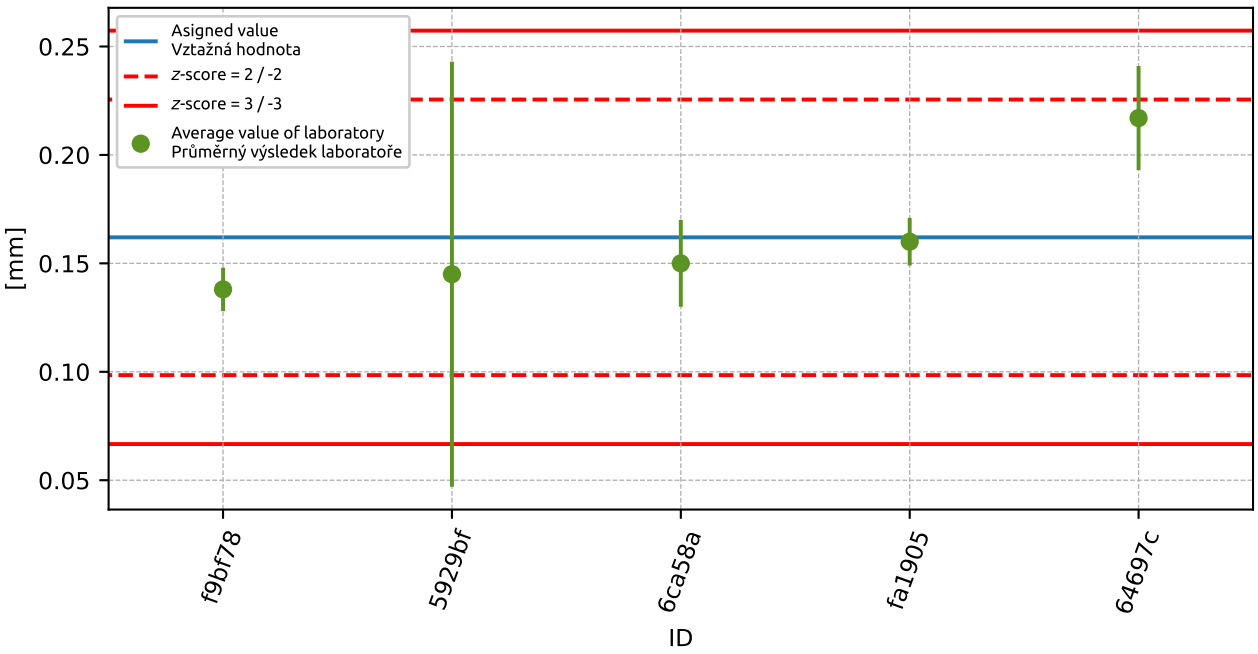

Figure 49: Average values and extended uncertainties of measurement

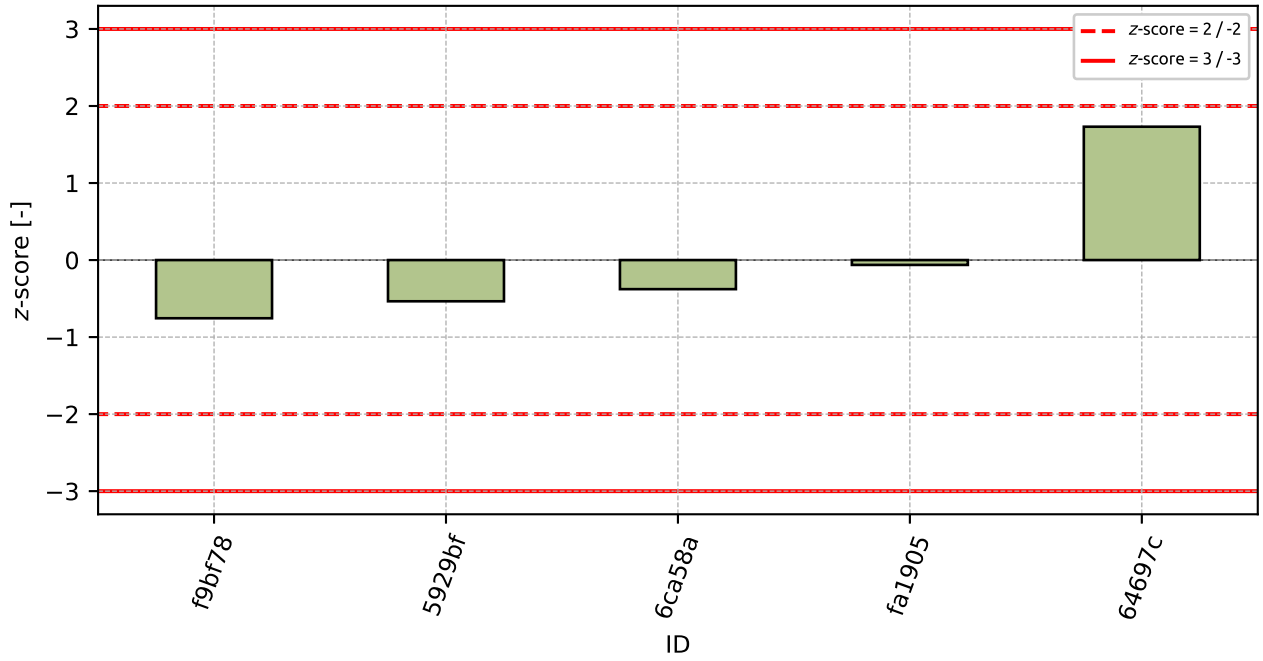

Figure 50: z-score

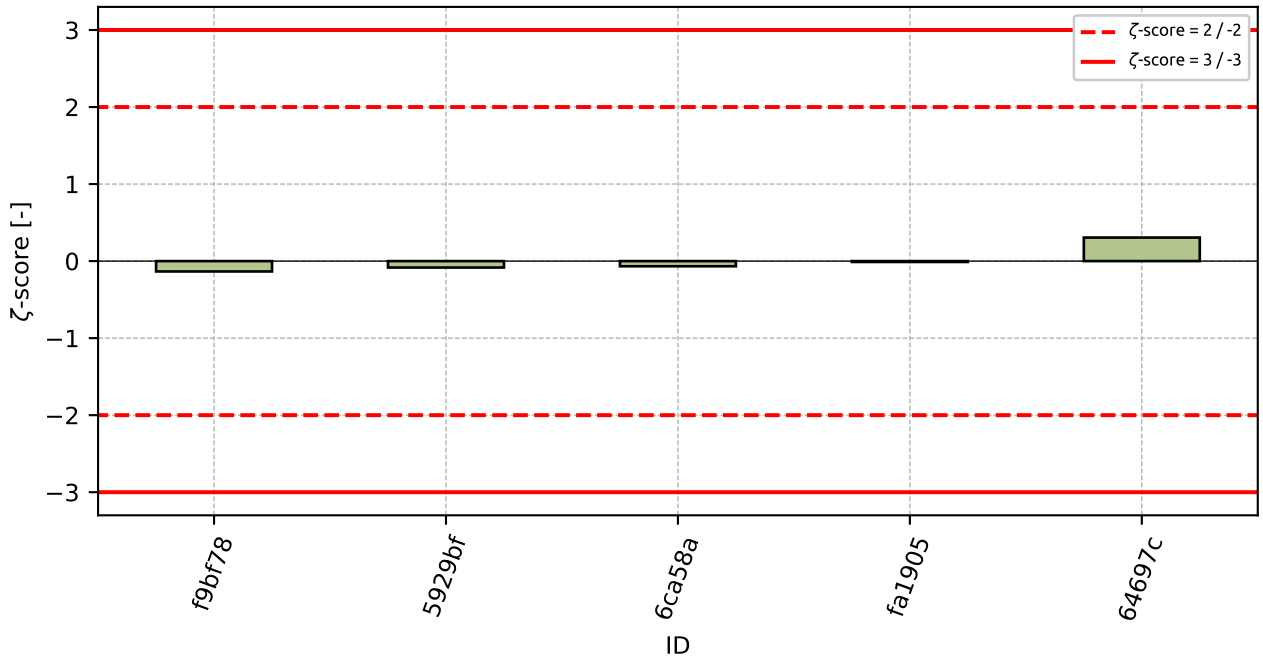

Figure 51: ζ-score

Table 24: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
f9bf78	-0.76	-0.13
5929bf	-0.54	-0.08
6ca58a	-0.38	-0.07
fa1905	-0.06	-0.01
64697c	1.73	0.31

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

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

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/m²]			u_X [g/m²]	$\bar{x}$ [g/m²]	s_0 [g/m²]	V_X [%]
6599c8	31.4	27.5	23.5	1.9	27.5	3.95	14.38
51ce24	11.8	23.5	94.1	119.0	43.1	44.52	103.23
9295f7	49.0	30.2	60.4	4.7	46.5	15.25	32.77
8ad07f	54.9	66.7	73.6	27.7	65.1	9.46	14.53
be2d54	80.5	85.1	135.8	4.1	100.5	30.69	30.54
efc9bd	100.8	93.5	129.4	-	107.9	18.97	17.58
1f6117	117.6	113.7	94.1	30.0	108.5	12.59	11.61
61350f	106.0	138.0	93.0	-	112.3	23.16	20.62
618446	141.2	125.5	164.7	8.6	143.8	19.73	13.72
aaa4a9	202.0	257.0	109.0	5.0	189.3	74.81	39.51
79c00a	441.8	493.6	419.3	23.9	451.6	38.1	8.44

7.1.2 The Numerical Procedure for Determining Outliers

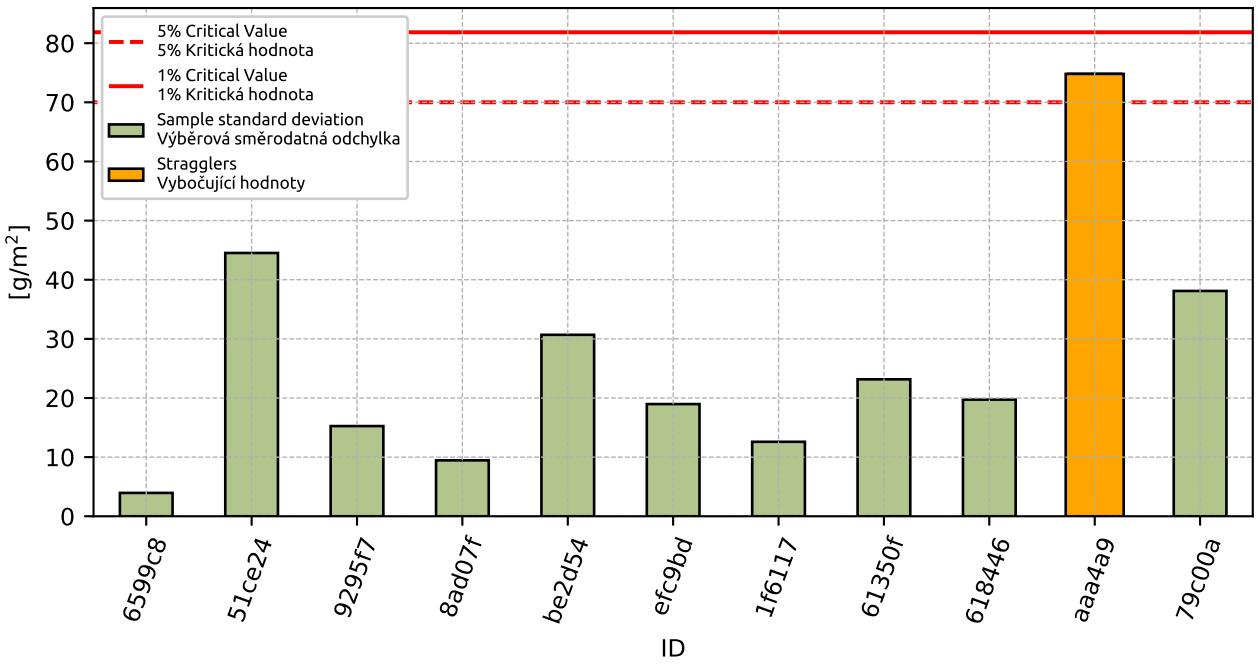

Figure 52: **Cochran's test** - sample standard deviations

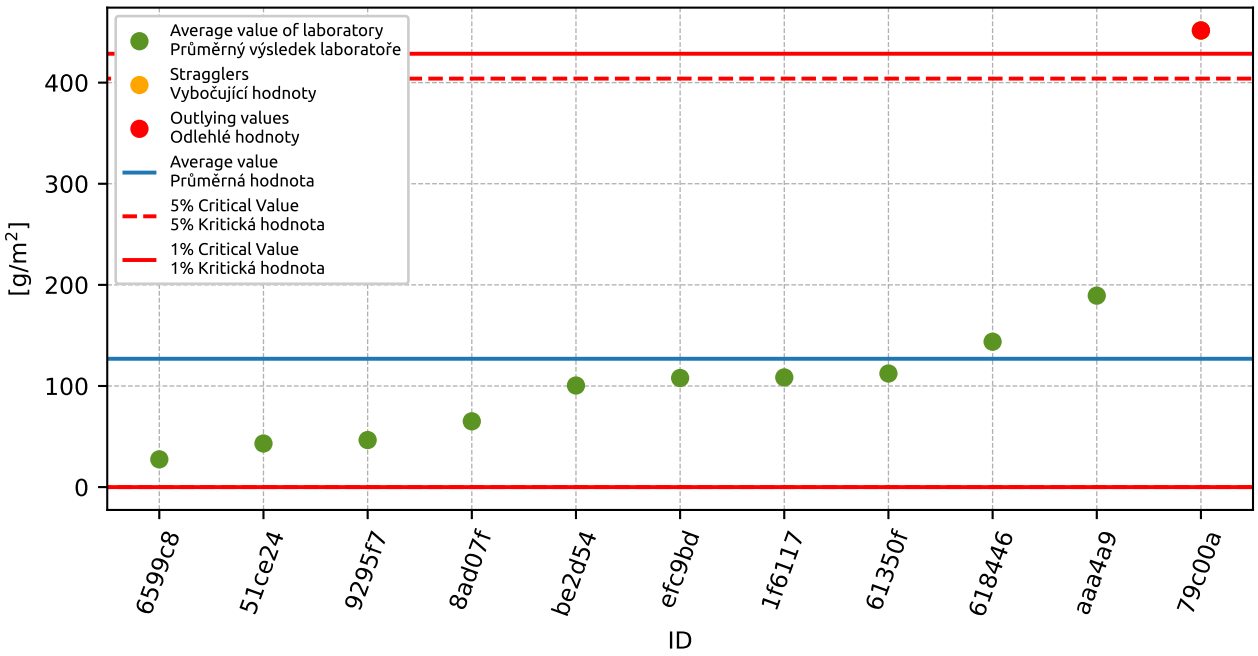

Figure 53: **Grubbs' test** - average values

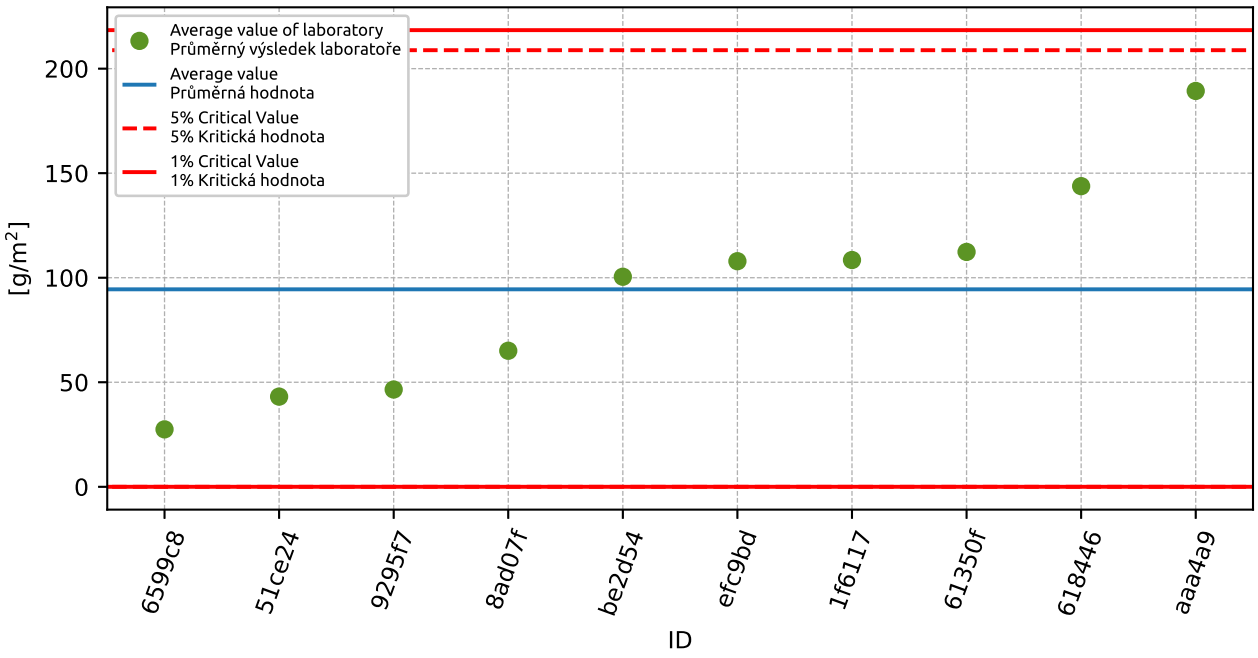

Figure 54: **Grubbs' test** - average values without outliers

7.1.3 Mandel's Statistics

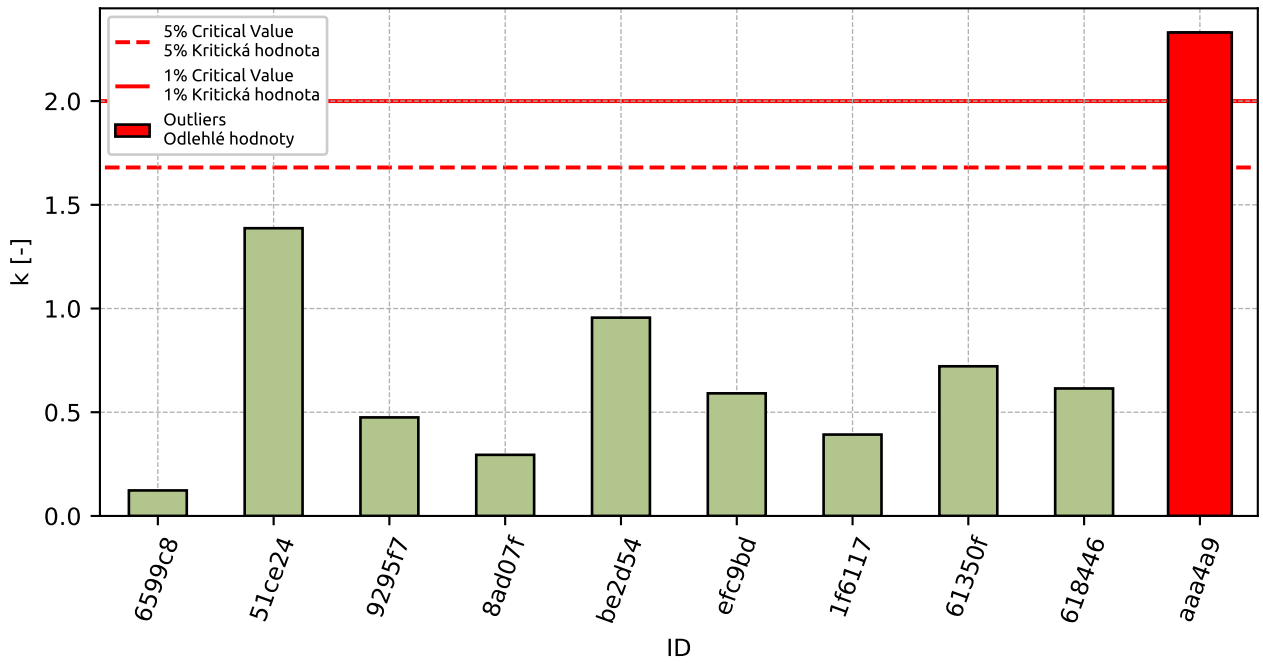

Figure 55: Intralaboratory Consistency Statistic

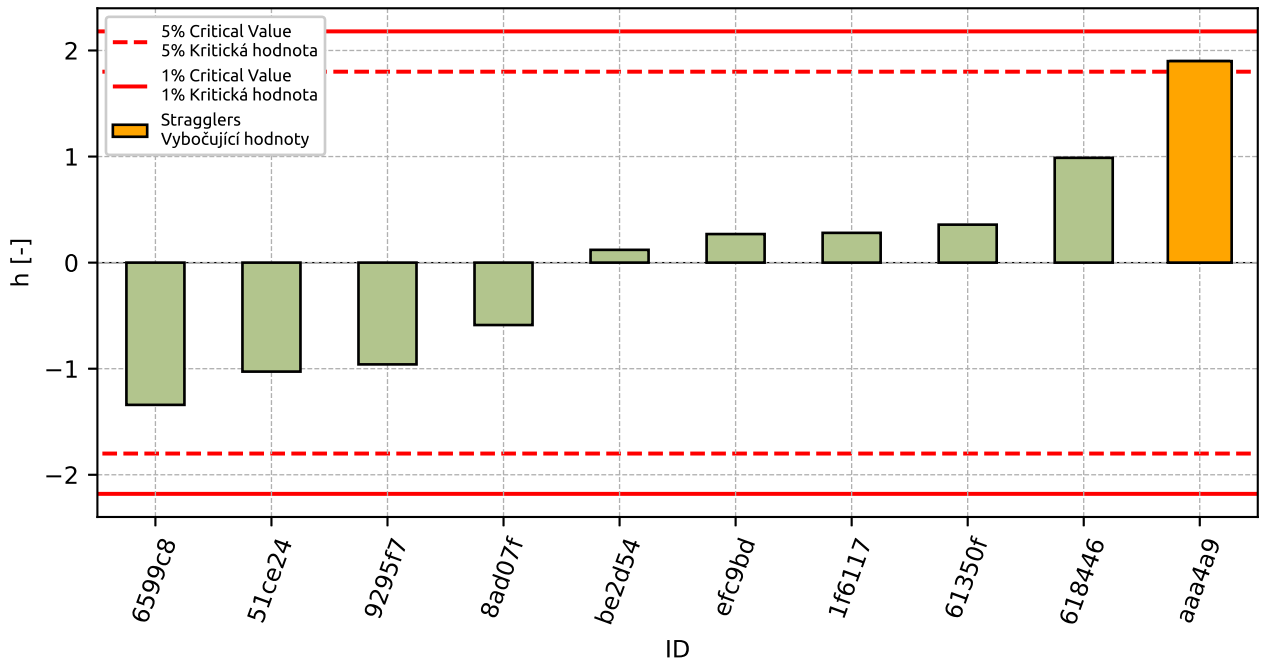

Figure 56: Interlaboratory Consistency Statistic

7.1.4 Descriptive statistics

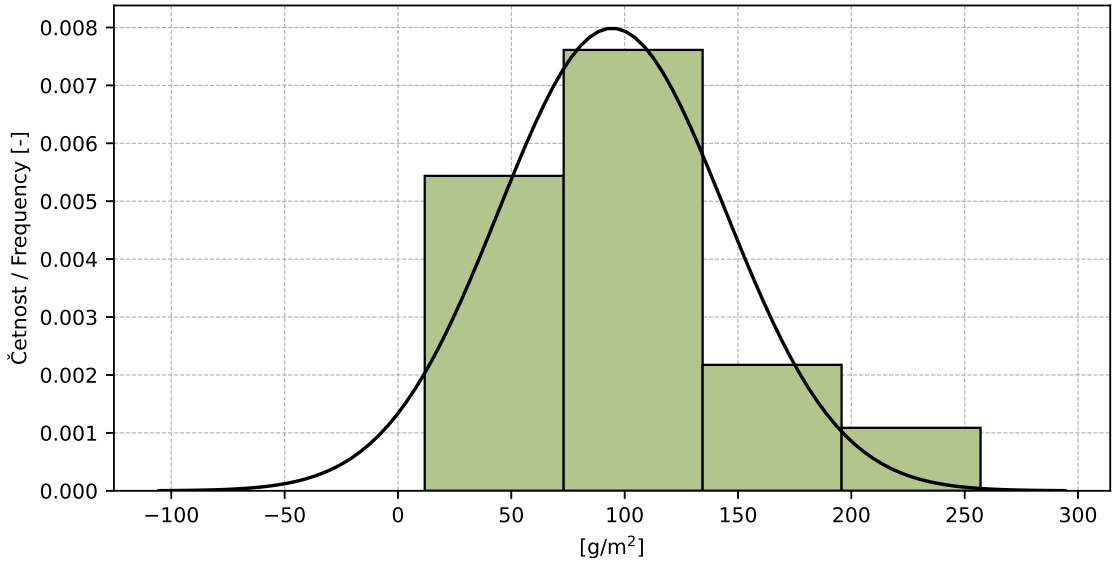

Figure 57: Histogram of all test results

Table 26: Descriptive statistics

Characteristics	**[g/m²]**
Průměrná hodnota / Average value – $\bar{x}$	94.4
Výběrová směrodatná odchylka / Sample standard deviation – s	49.95
Vztažná hodnota / Asigned value – x^*	94.4
Robustní směrodatná odchylka / Robust standard deviation – s^*	53.73
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	21.24
p-hodnota testu normality / p-value of normality test	0.109 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	46.38
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	32.1
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	56.4
Opakovatelnost / Repeatability – r	89.9
Reprodukovatelnost / Reproducibility – R	157.9

7.1.5 Evaluation of Performance Statistics

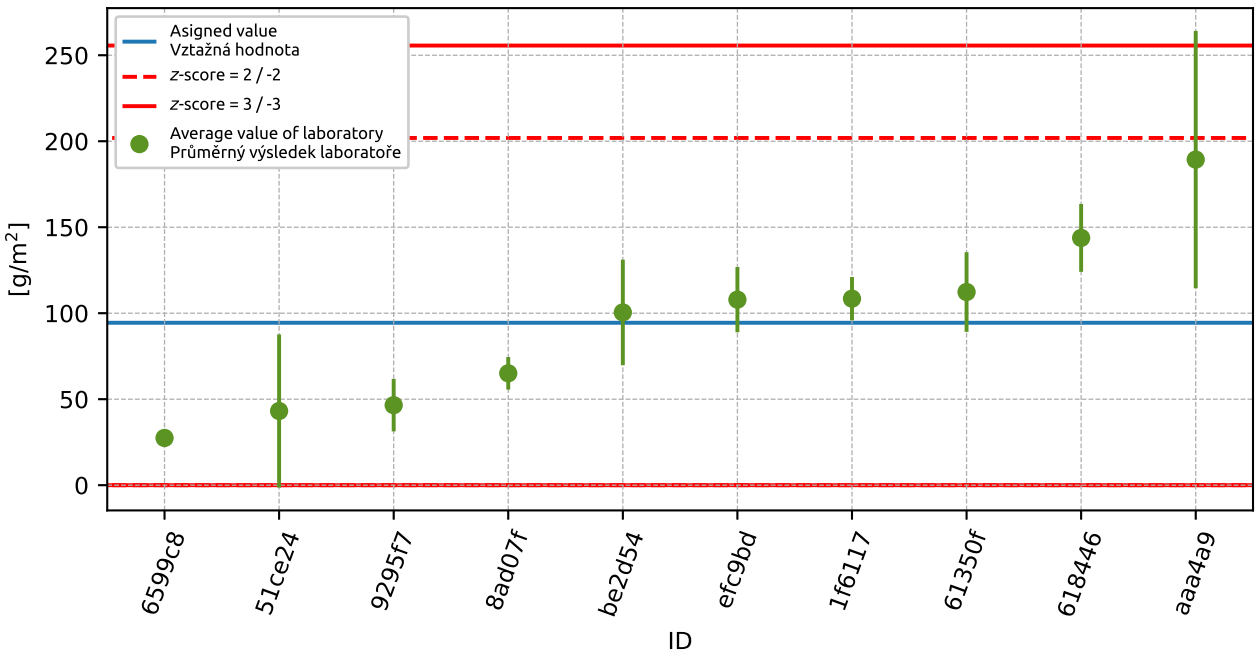

Figure 58: Average values and sample standard deviations

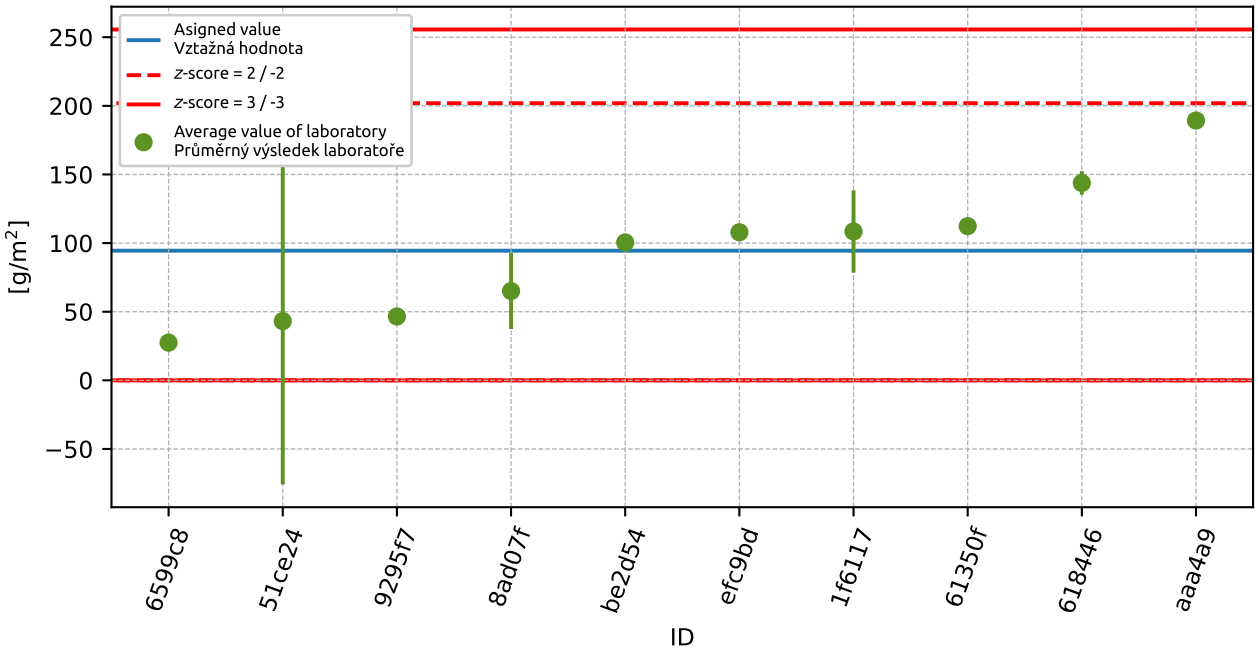

Figure 59: Average values and extended uncertainties of measurement

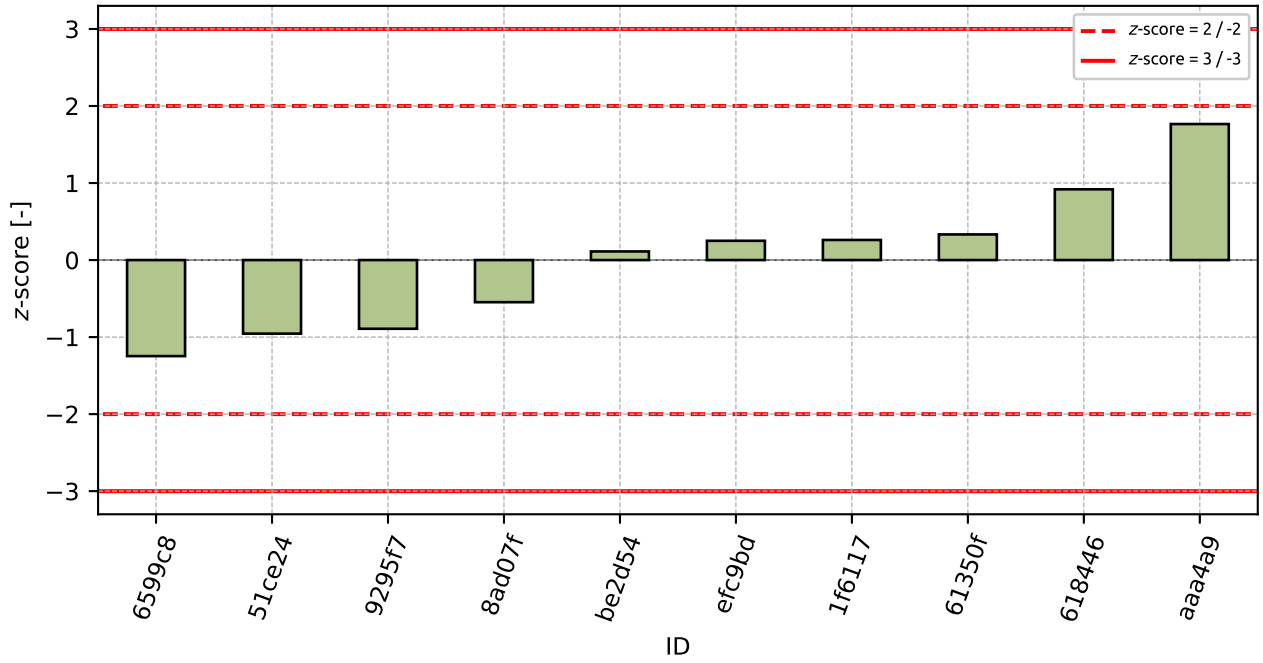

Figure 60: z-score

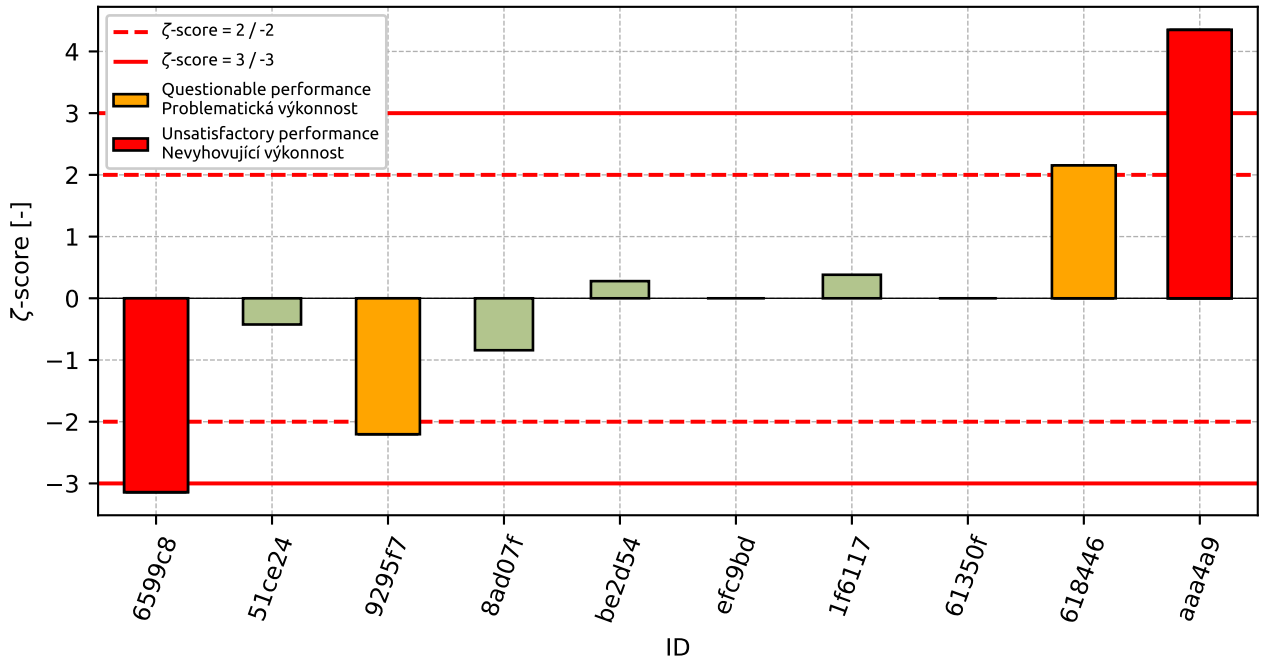

Figure 61: ζ-score

Table 27: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
6599c8	-1.25	-3.14
51ce24	-0.96	-0.42
9295f7	-0.89	-2.2
8ad07f	-0.55	-0.84
be2d54	0.11	0.28
efc9bd	0.25	-
1f6117	0.26	0.38
61350f	0.33	-
618446	0.92	2.15
aaa4a9	1.77	4.35

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/m²]			u_X [g/m²]	$\bar{x}$ [g/m²]	s_0 [g/m²]	V_X [%]
6599c8	82.4	66.7	78.4	9.6	75.8	8.16	10.76
51ce24	31.4	105.9	176.5	193.0	104.6	72.56	69.37
9295f7	158.0	84.3	167.1	13.7	136.5	45.41	33.27
61350f	133.0	187.0	116.0	-	145.3	37.07	25.51
8ad07f	164.7	184.3	197.5	27.7	182.2	16.5	9.06
be2d54	173.9	153.7	252.9	7.8	193.5	52.42	27.09
efc9bd	179.2	183.3	237.1	-	199.9	32.31	16.17
1f6117	254.9	262.7	211.8	50.0	243.1	27.41	11.28
618446	266.7	235.3	290.2	15.8	264.1	27.54	10.43
aaa4a9	397.0	451.0	191.0	10.0	346.3	137.21	39.62
79c00a	705.0	782.5	652.7	37.8	713.4	65.31	9.15

7.2.2 The Numerical Procedure for Determining Outliers

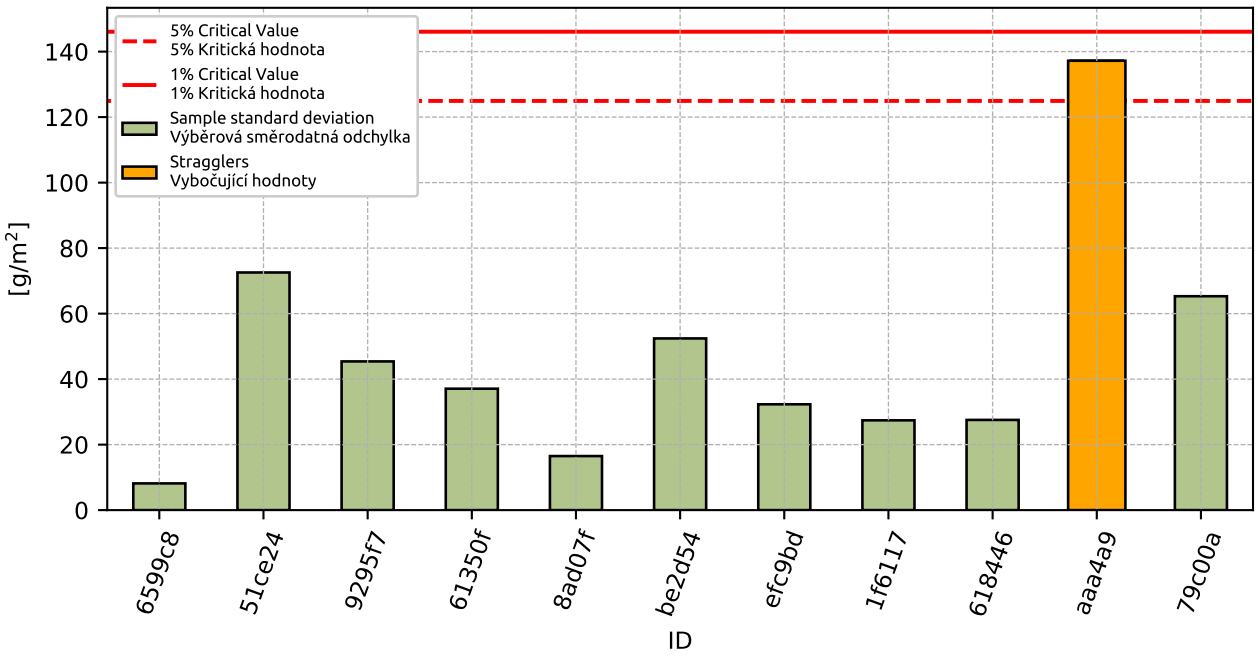

Figure 62: **Cochran's test** - sample standard deviations

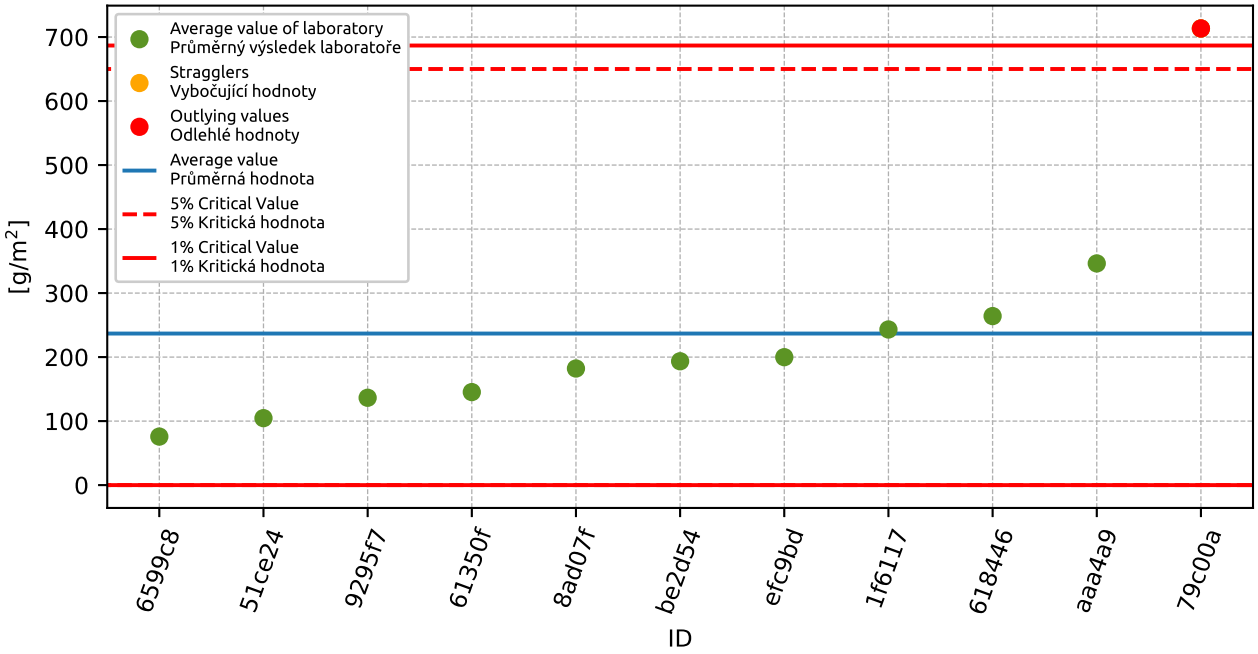

Figure 63: **Grubbs' test** - average values

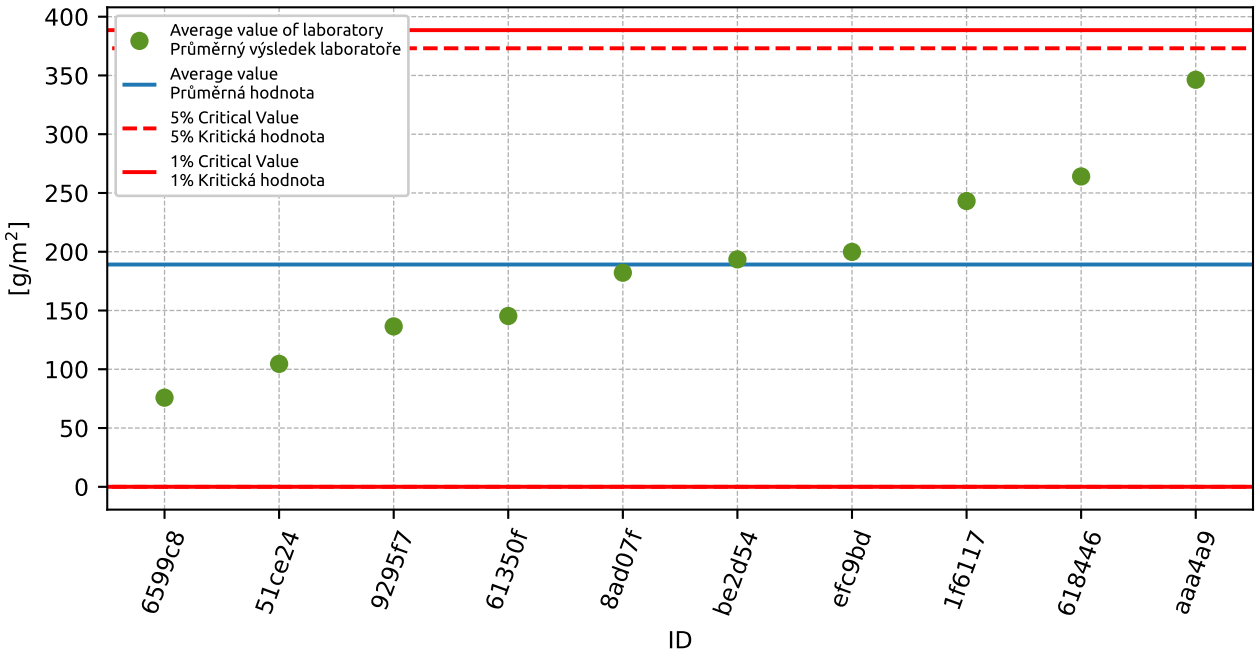

Figure 64: **Grubbs' test** - average values without outliers

7.2.3 Mandel's Statistics

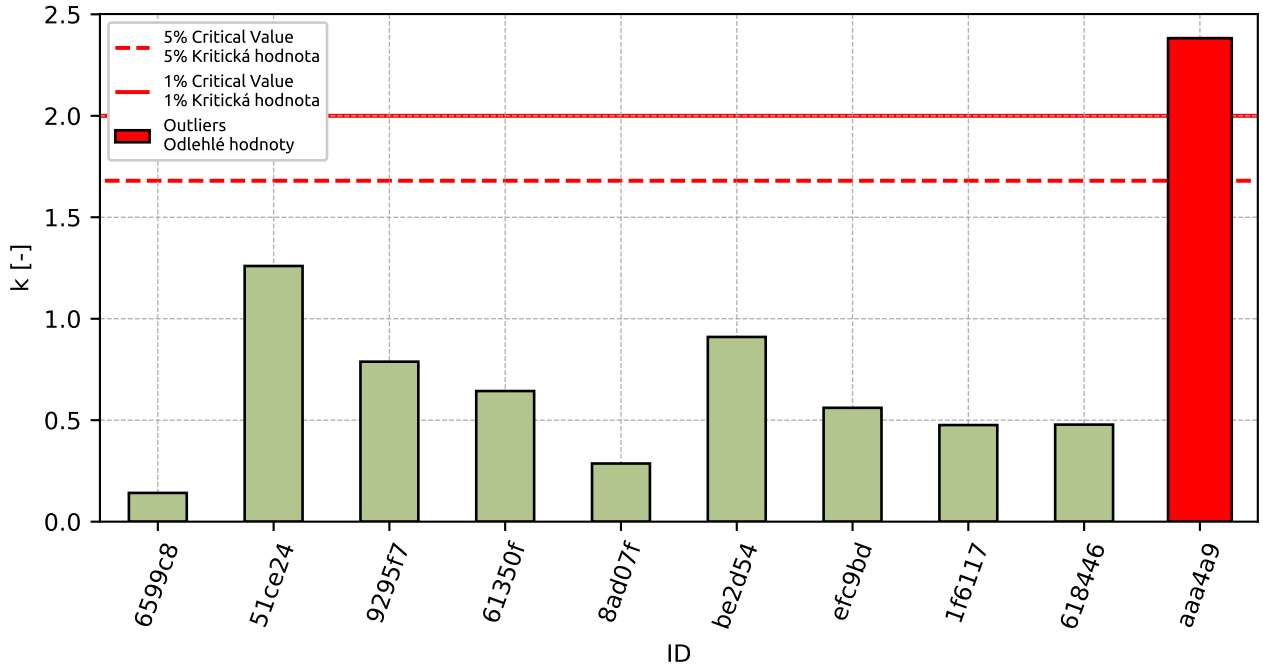

Figure 65: Intralaboratory Consistency Statistic

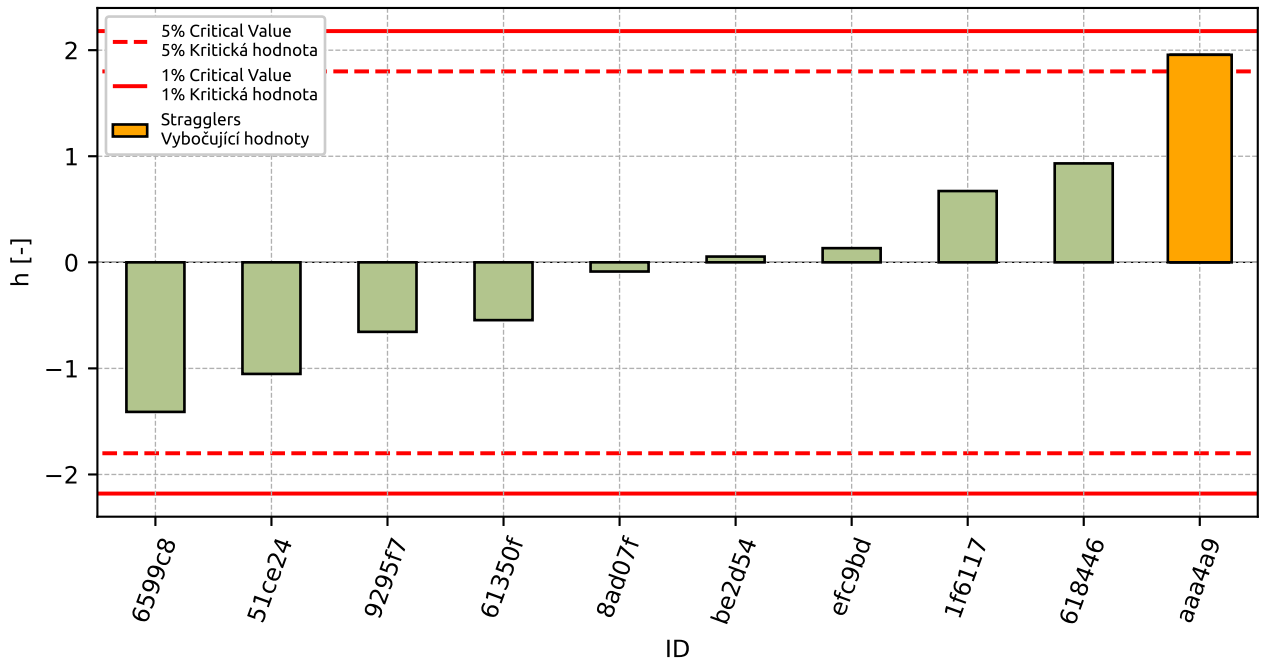

Figure 66: Interlaboratory Consistency Statistic

7.2.4 Descriptive statistics

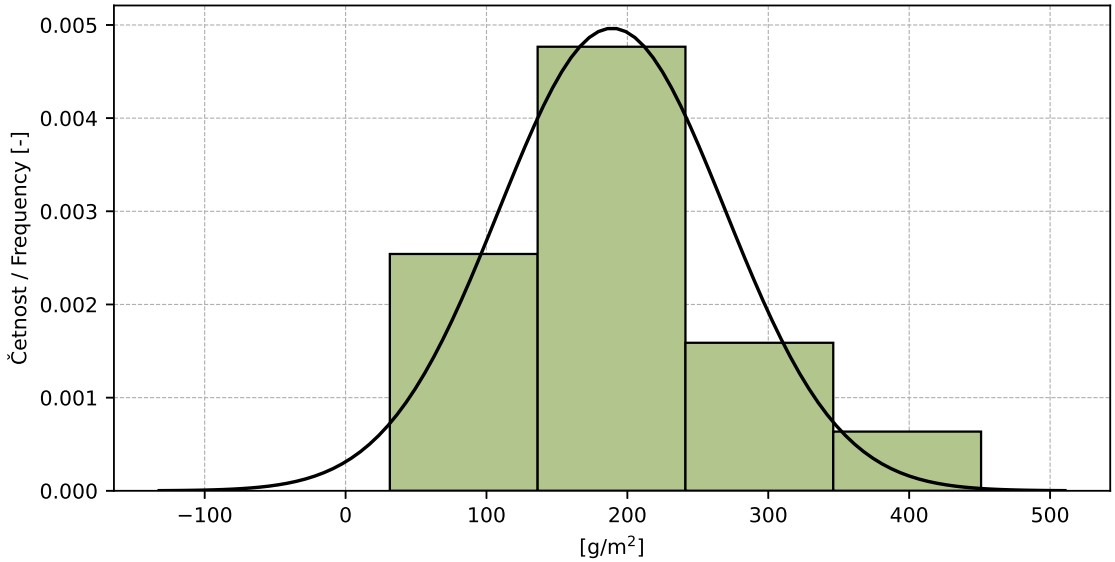

Figure 67: Histogram of all test results

Table 29: Descriptive statistics

Characteristics	**[g/m²]**
Průměrná hodnota / Average value – $\bar{x}$	189.1
Výběrová směrodatná odchylka / Sample standard deviation – s	80.35
Vztažná hodnota / Asigned value – x^*	189.1
Robustní směrodatná odchylka / Robust standard deviation – s^*	86.44
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	34.17
p-hodnota testu normality / p-value of normality test	0.079 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	73.14
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	57.59
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	93.1
Opakovatelnost / Repeatability – r	161.3
Reprodukovatelnost / Reproducibility – R	260.7

7.2.5 Evaluation of Performance Statistics

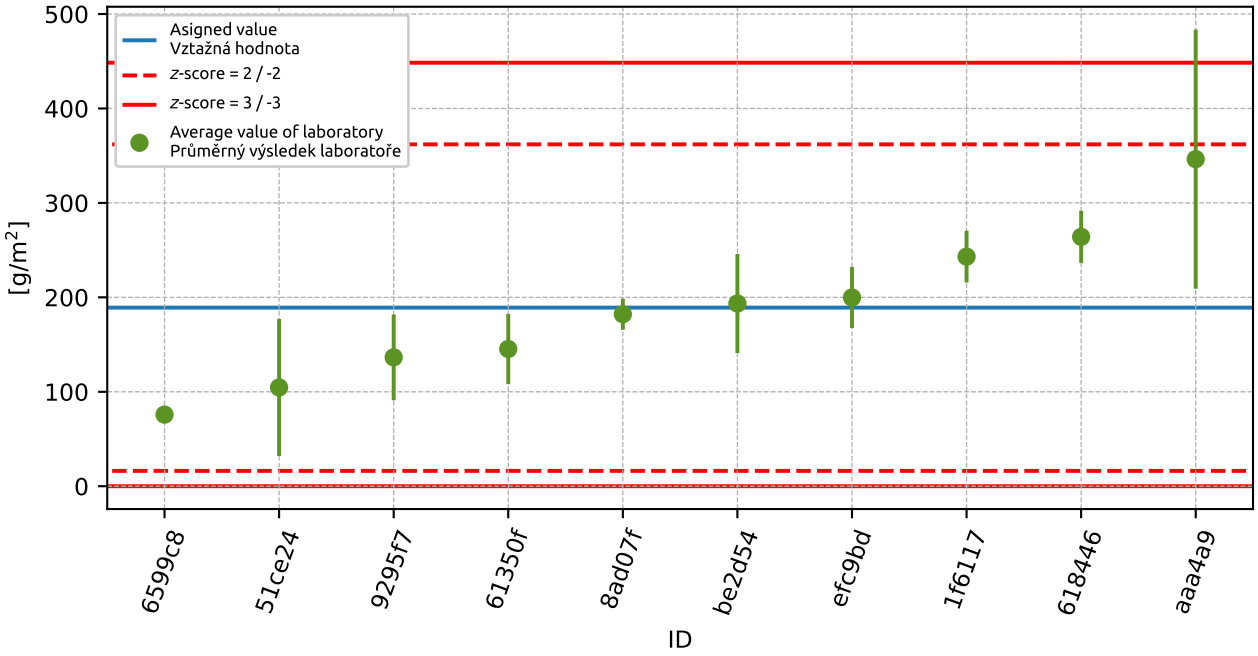

Figure 68: Average values and sample standard deviations

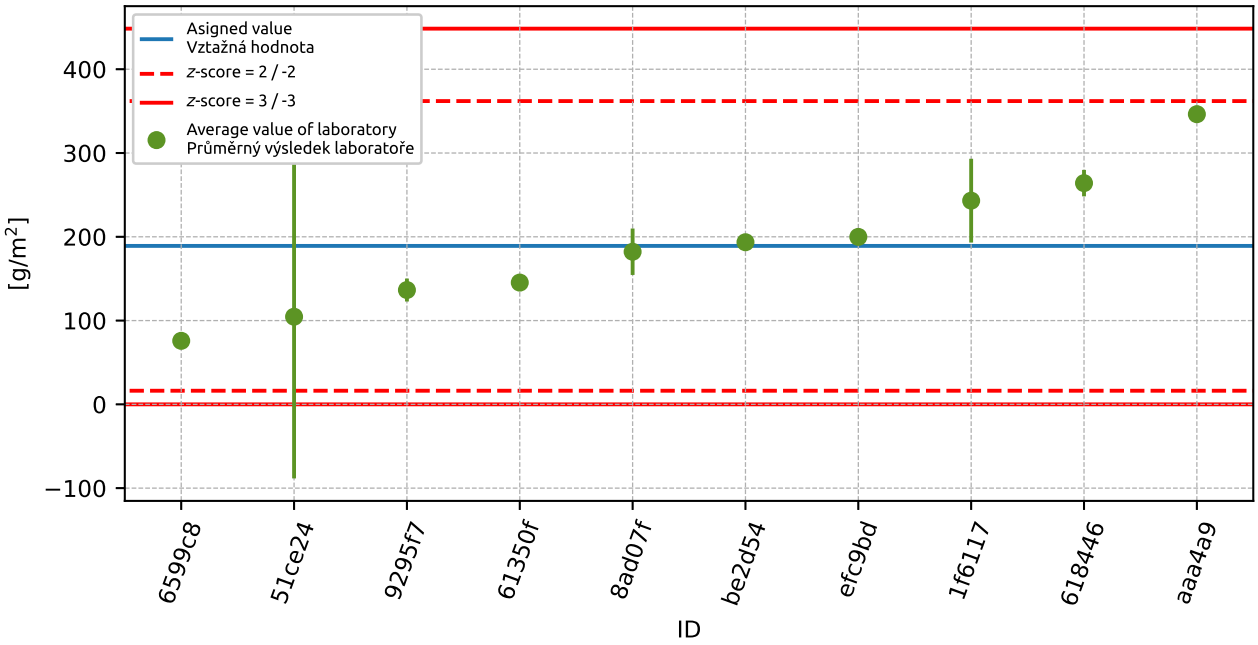

Figure 69: Average values and extended uncertainties of measurement

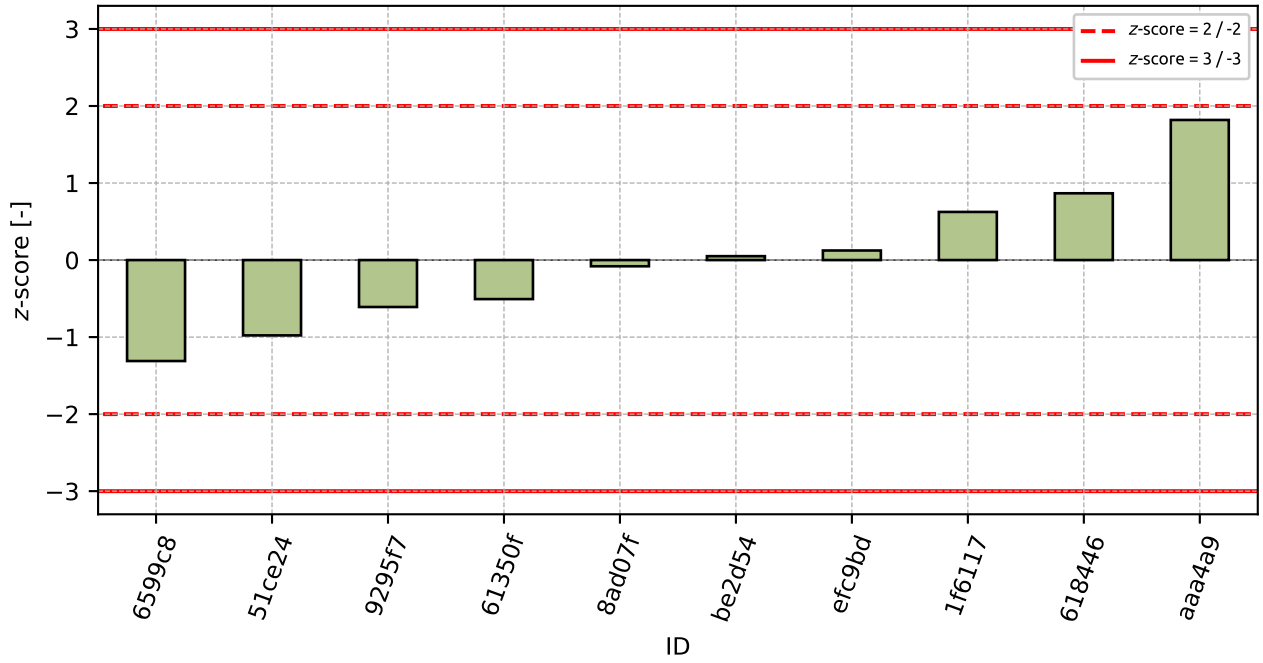

Figure 70: z-score

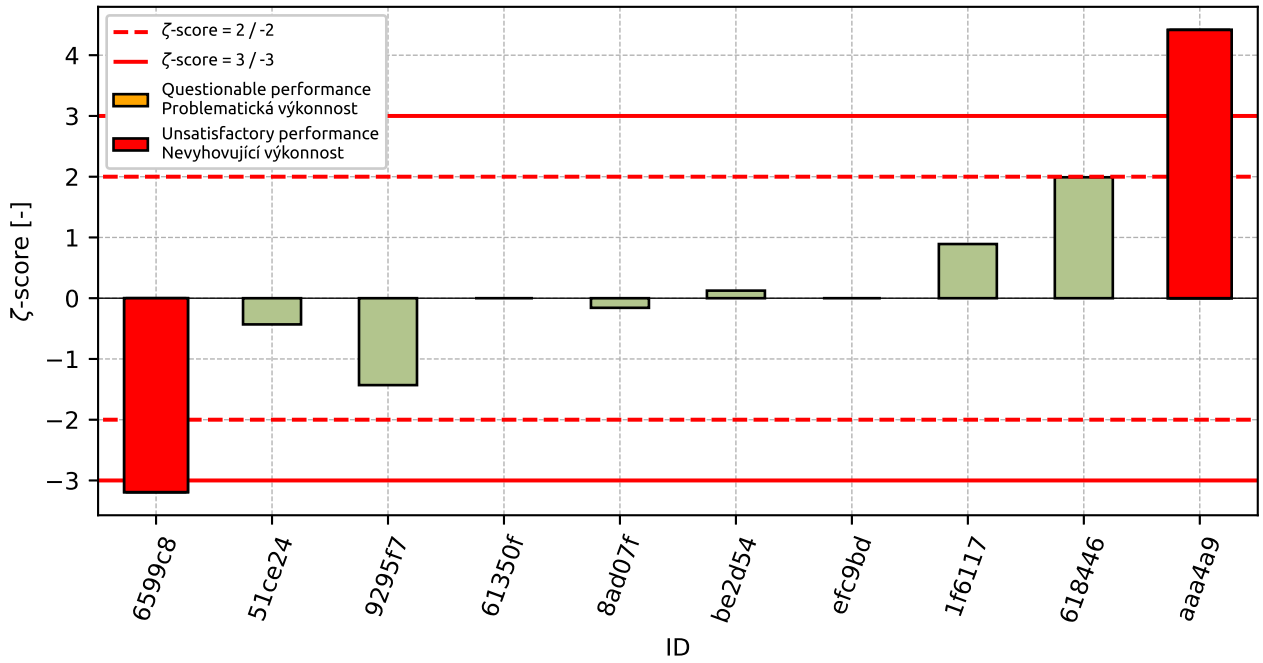

Figure 71: ζ-score

Table 30: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
6599c8	-1.31	-3.19
51ce24	-0.98	-0.43
9295f7	-0.61	-1.43
61350f	-0.51	-
8ad07f	-0.08	-0.16
be2d54	0.05	0.12
efc9bd	0.12	-
1f6117	0.62	0.89
618446	0.87	1.99
aaa4a9	1.82	4.42

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/m²]			u_X [g/m²]	$\bar{x}$ [g/m²]	s_0 [g/m²]	V_X [%]
6599c8	180.4	145.1	172.2	29.9	165.9	18.47	11.14
51ce24	102.0	203.9	243.1	194.0	183.0	72.83	39.8
61350f	208.0	258.0	187.0	-	217.7	36.47	16.76
be2d54	257.1	222.3	355.2	11.1	278.2	68.92	24.77
9295f7	299.2	189.0	347.8	27.9	278.7	81.37	29.2
efc9bd	272.3	295.5	319.8	-	295.9	23.75	8.03
8ad07f	333.3	341.2	348.6	27.7	341.0	7.65	2.24
1f6117	407.8	443.1	313.7	80.0	388.2	66.89	17.23
618446	407.8	364.7	419.6	23.8	397.4	28.9	7.27
aaa4a9	646.0	692.0	366.0	15.0	568.0	176.44	31.06
79c00a	994.4	1063.6	932.7	52.8	996.9	65.49	6.57

7.3.2 The Numerical Procedure for Determining Outliers

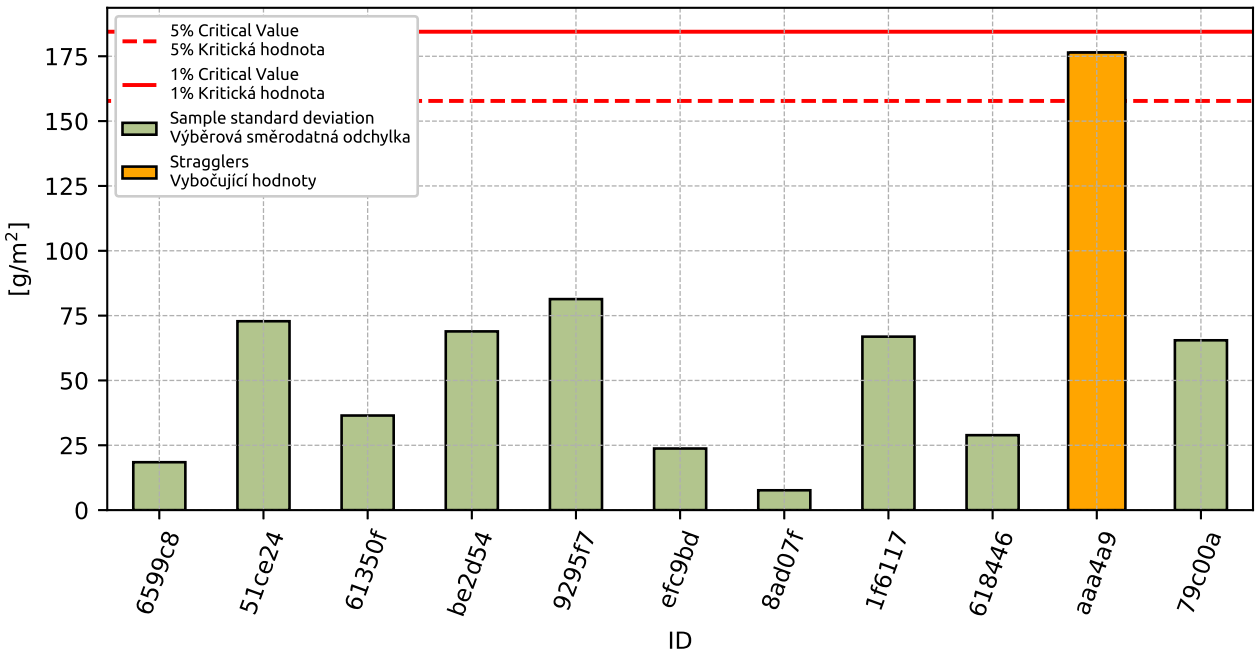

Figure 72: **Cochran's test** - sample standard deviations

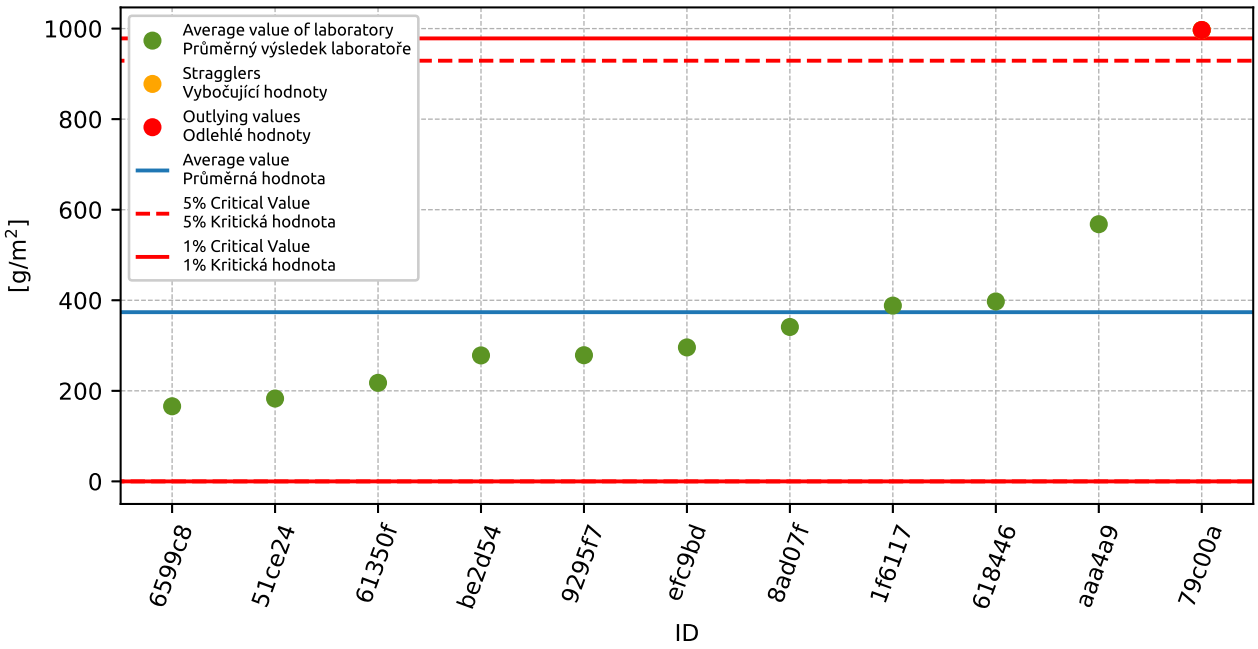

Figure 73: **Grubbs' test** - average values

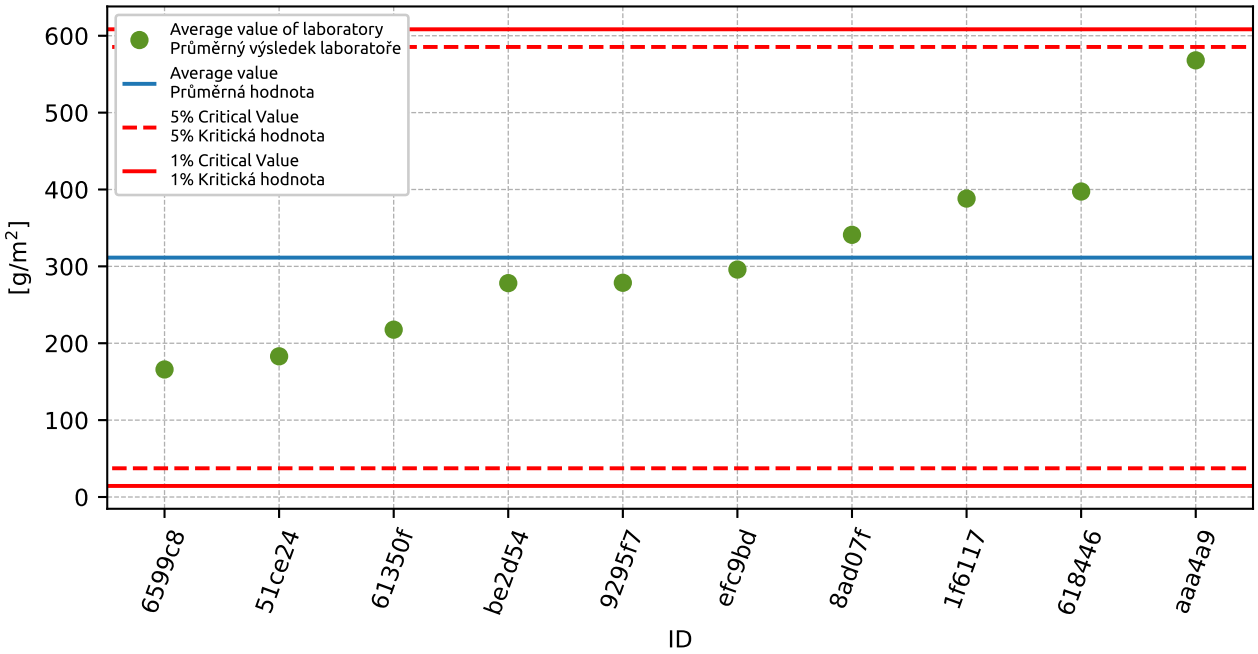

Figure 74: **Grubbs' test** - average values without outliers

7.3.3 Mandel's Statistics

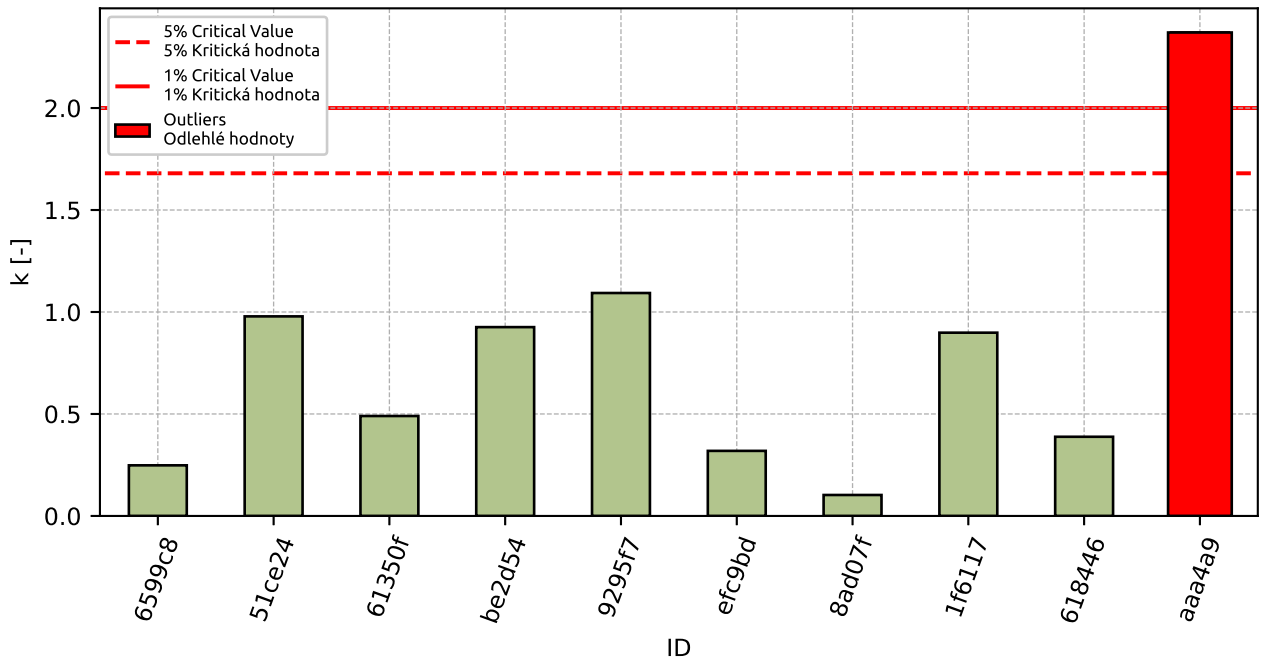

Figure 75: Intralaboratory Consistency Statistic

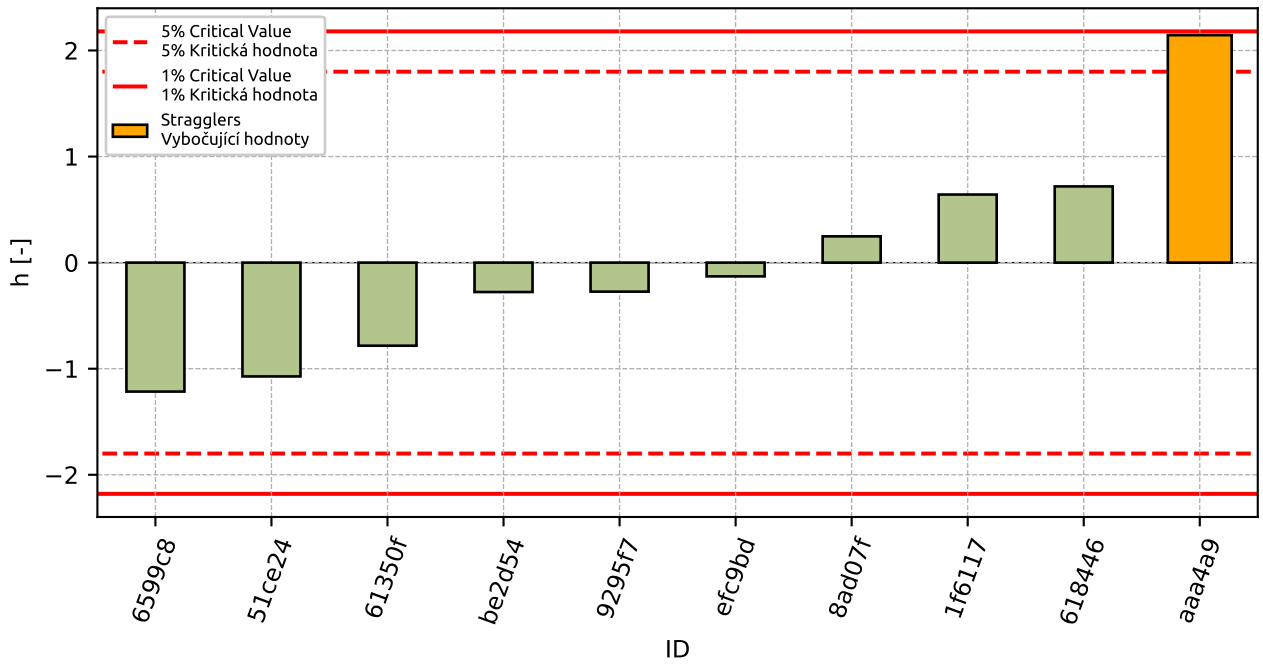

Figure 76: Interlaboratory Consistency Statistic

7.3.4 Descriptive statistics

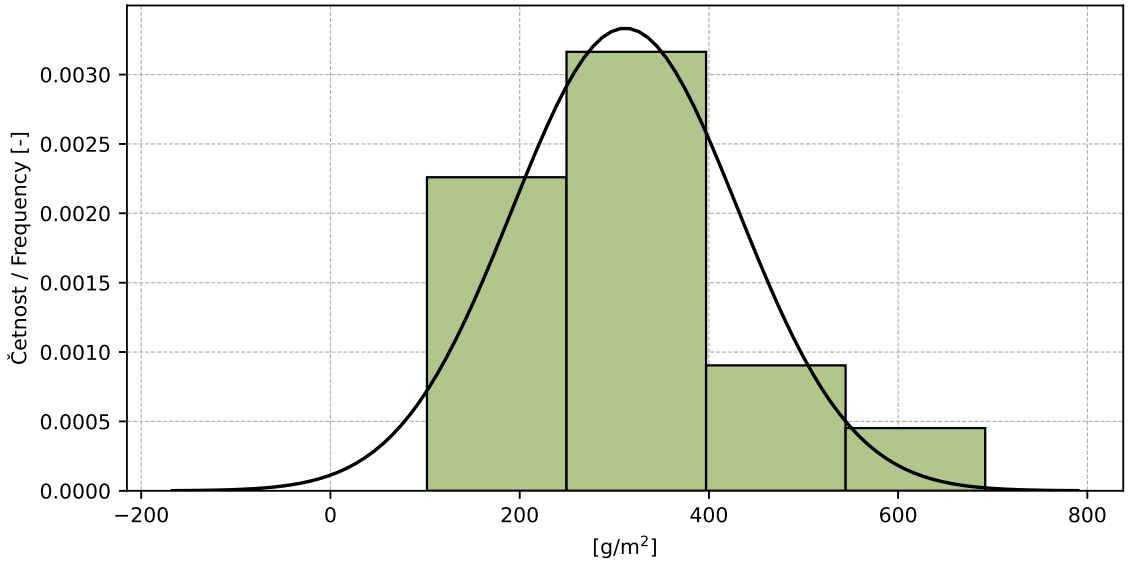

Figure 77: Histogram of all test results

Table 32: Descriptive statistics

Characteristics	**[g/m²]**
Průměrná hodnota / Average value – $\bar{x}$	311.4
Výběrová směrodatná odchylka / Sample standard deviation – s	119.66
Vztažná hodnota / Asigned value – x^*	311.4
Robustní směrodatná odchylka / Robust standard deviation – s^*	128.73
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	50.89
p-hodnota testu normality / p-value of normality test	0.015 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	111.68
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	74.44
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	134.21
Opakovatelnost / Repeatability – r	208.4
Reprodukovatelnost / Reproducibility – R	375.8

7.3.5 Evaluation of Performance Statistics

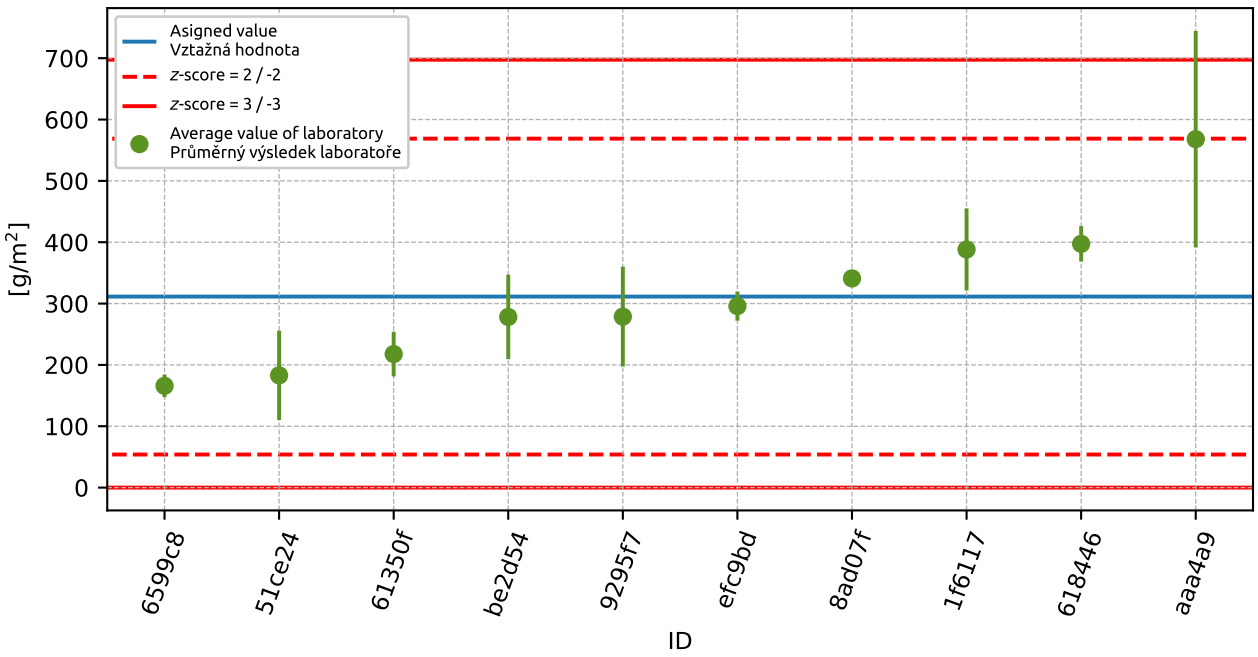

Figure 78: Average values and sample standard deviations

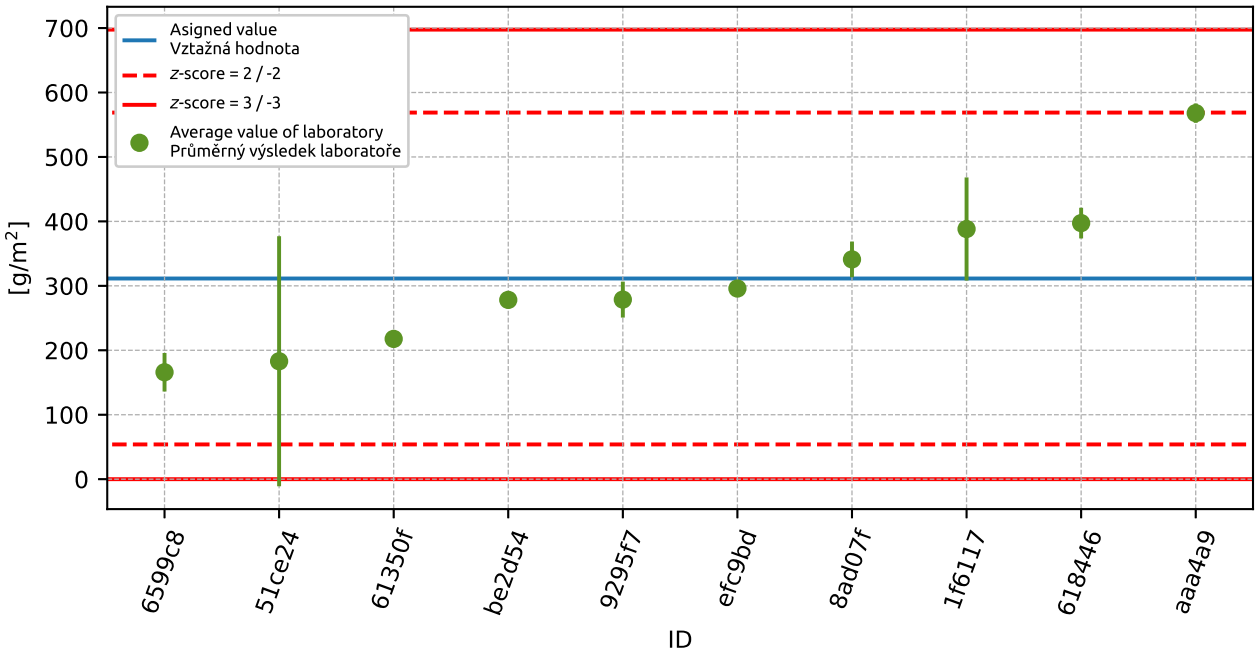

Figure 79: Average values and extended uncertainties of measurement

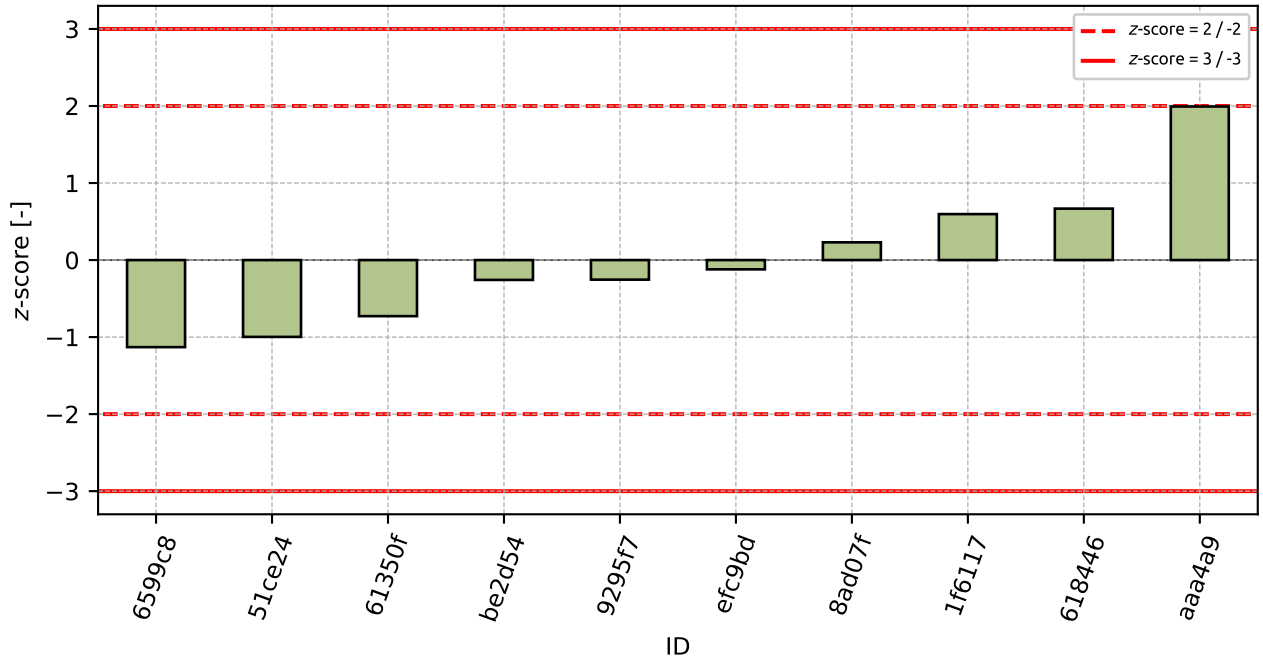

Figure 80: z-score

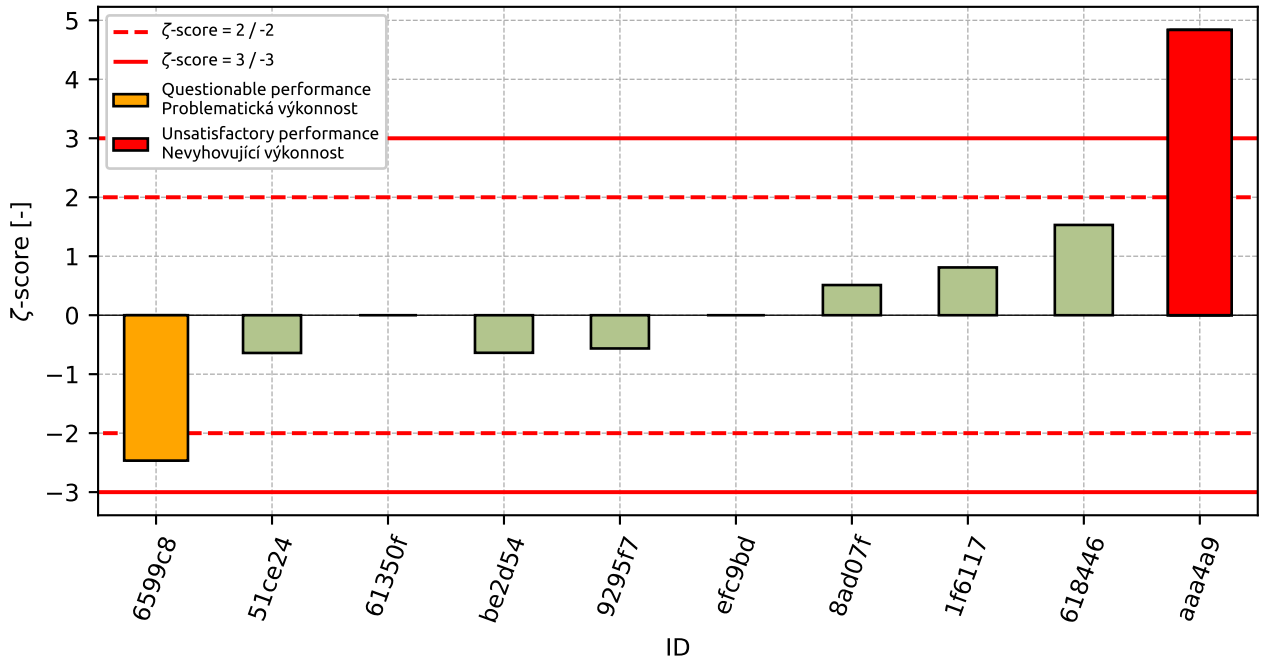

Figure 81: ζ-score

Table 33: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
6599c8	-1.13	-2.47
51ce24	-1.0	-0.64
61350f	-0.73	-
be2d54	-0.26	-0.64
9295f7	-0.25	-0.56
efc9bd	-0.12	-
8ad07f	0.23	0.51
1f6117	0.6	0.81
618446	0.67	1.53
aaa4a9	1.99	4.84

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/m²]			u_X [g/m²]	$\bar{x}$ [g/m²]	s_0 [g/m²]	V_X [%]
61350f	247.0	298.0	227.0	-	257.3	36.61	14.23
51ce24	188.2	278.4	321.6	181.0	262.7	68.07	25.91
6599c8	305.9	231.4	278.4	63.1	271.9	37.67	13.86
be2d54	407.1	348.6	512.0	16.9	422.6	82.79	19.59
efc9bd	410.7	430.2	434.8	8.2	425.2	12.79	3.01
9295f7	477.6	364.7	554.1	46.6	465.5	95.28	20.47
8ad07f	568.6	533.3	484.1	27.7	528.7	42.44	8.03
618446	588.2	552.9	580.4	34.4	573.8	18.54	3.23
1f6117	615.7	649.1	541.2	110.0	602.0	55.24	9.18
aaa4a9	840.0	906.0	548.0	20.0	764.7	190.52	24.92
79c00a	1288.4	1346.6	1204.4	67.8	1279.8	71.49	5.59

7.4.2 The Numerical Procedure for Determining Outliers

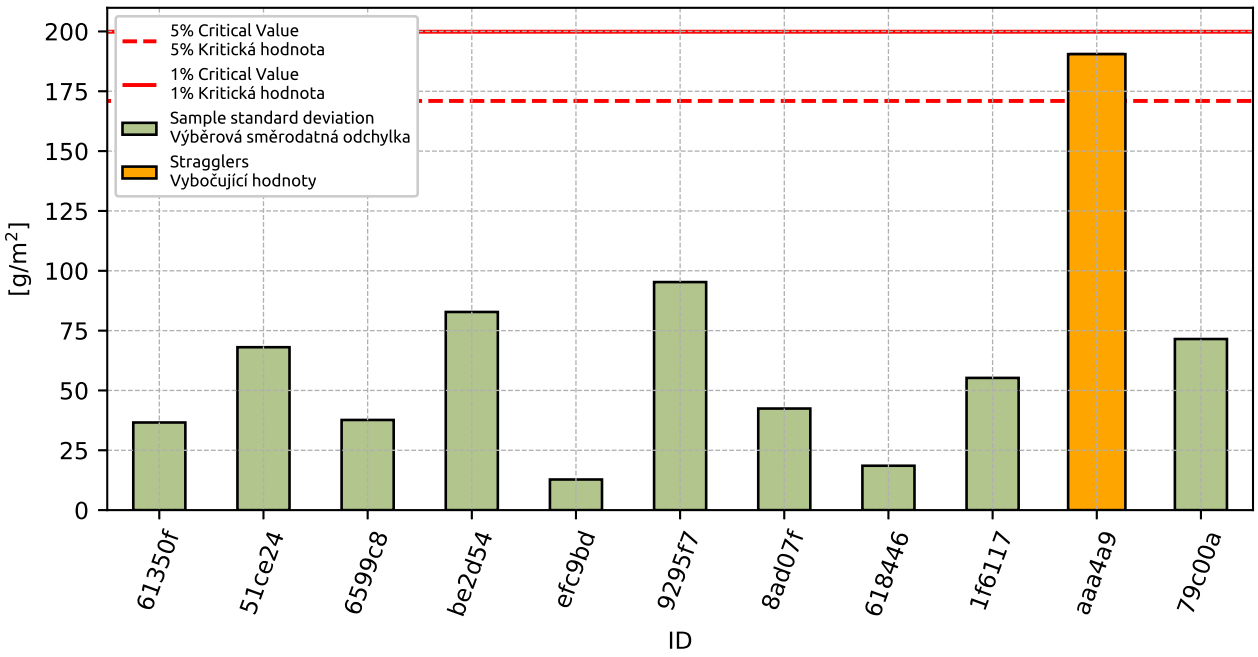

Figure 82: **Cochran's test** - sample standard deviations

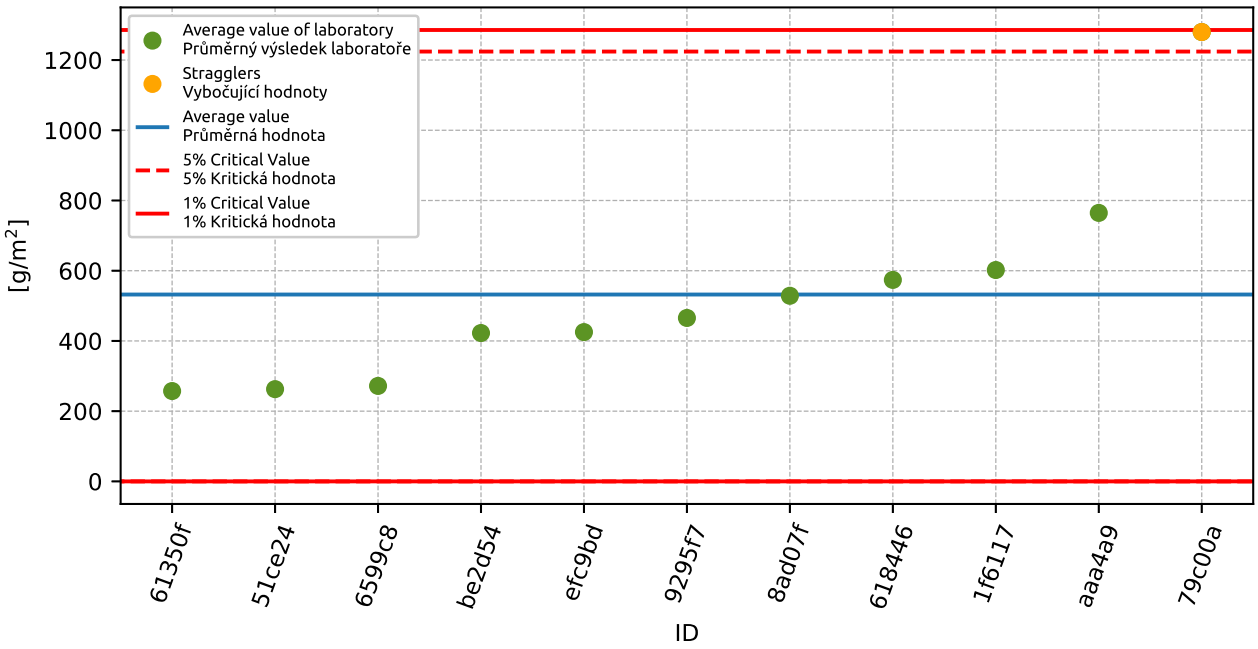

Figure 83: **Grubbs' test** - average values

7.4.3 Mandel's Statistics

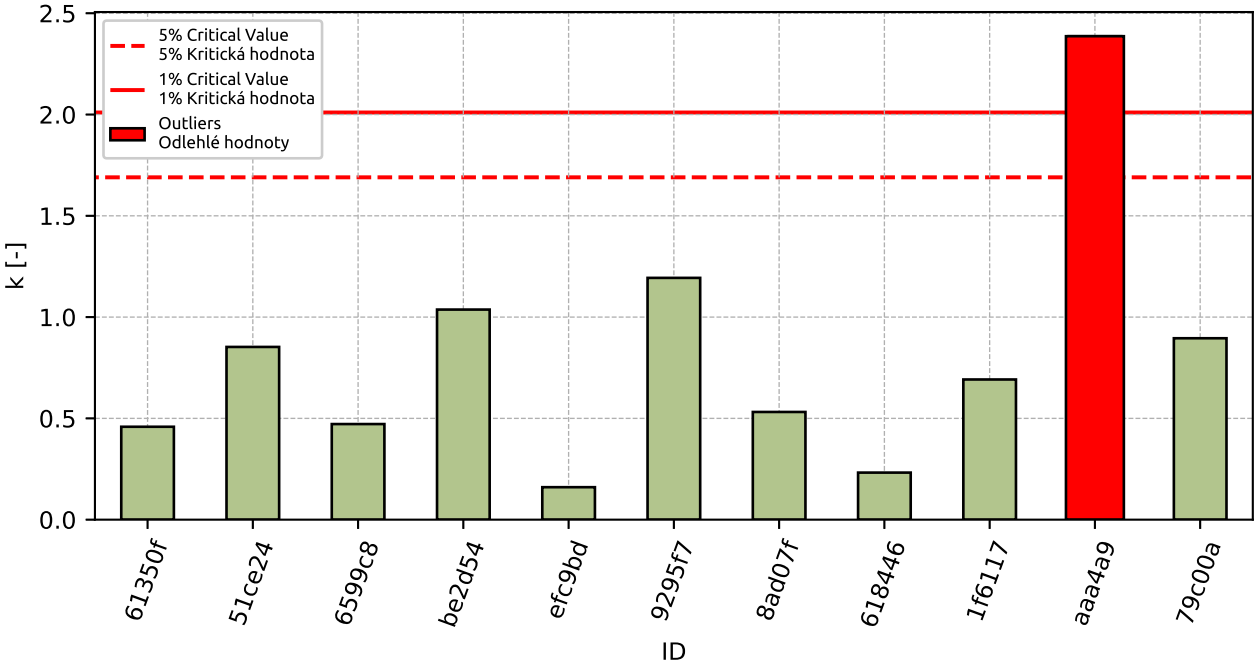

Figure 84: Intralaboratory Consistency Statistic

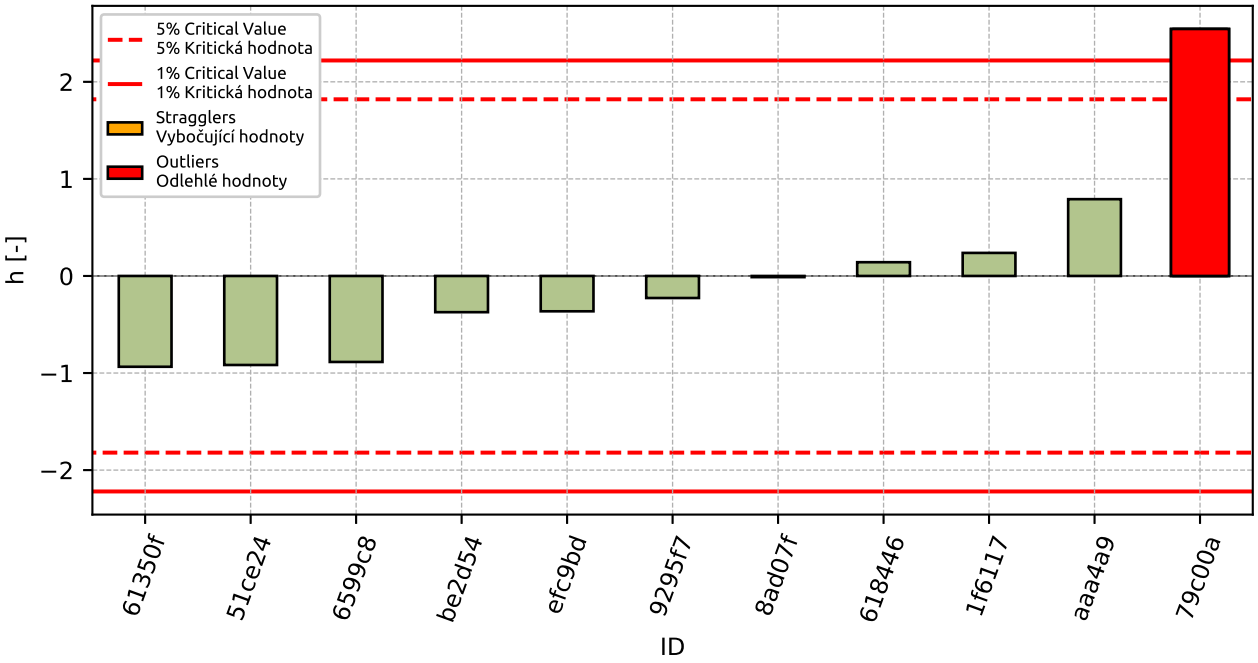

Figure 85: Interlaboratory Consistency Statistic

7.4.4 Descriptive statistics

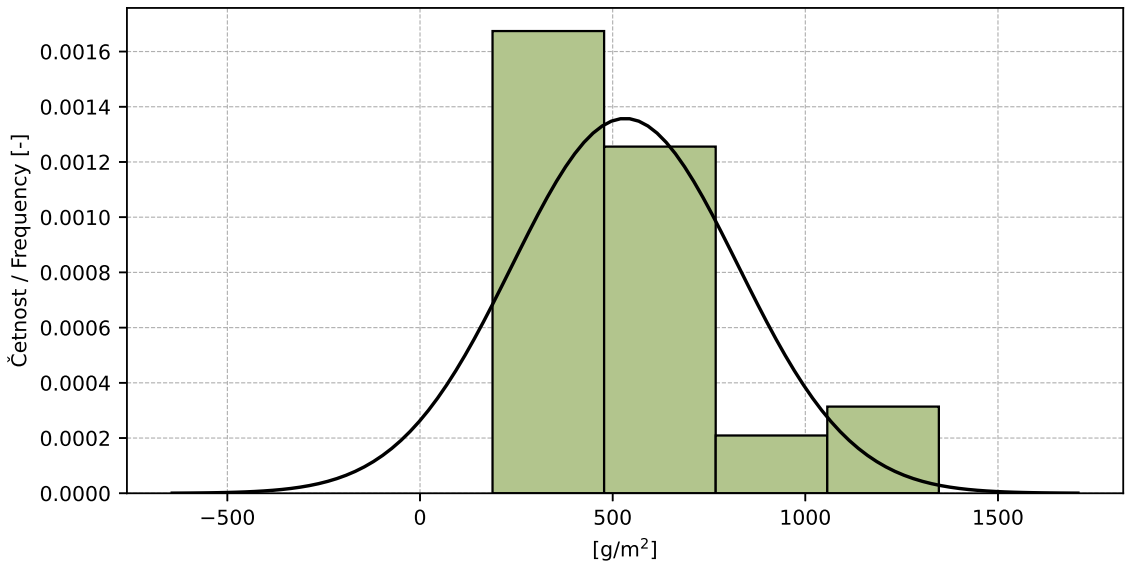

Figure 86: Histogram of all test results

Table 35: Descriptive statistics

Characteristics	[g/m²]
Průměrná hodnota / Average value – $\bar{x}$	532.2
Výběrová směrodatná odchylka / Sample standard deviation – s	293.84
Vztažná hodnota / Asigned value – x^*	532.2
Robustní směrodatná odchylka / Robust standard deviation – s^*	317.7
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	119.74
p-hodnota testu normality / p-value of normality test	0.0 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	290.2
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	79.83
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	300.98
Opakovatelnost / Repeatability – r	223.5
Reprodukovatelnost / Reproducibility – R	842.7

7.4.5 Evaluation of Performance Statistics

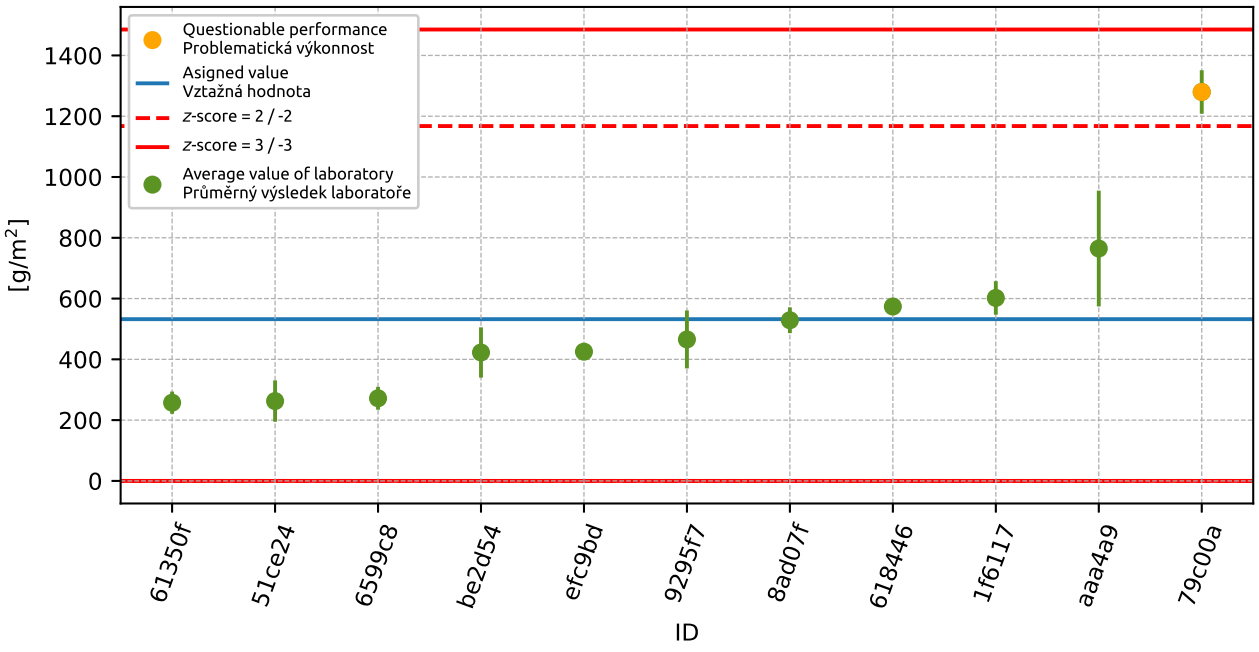

Figure 87: Average values and sample standard deviations

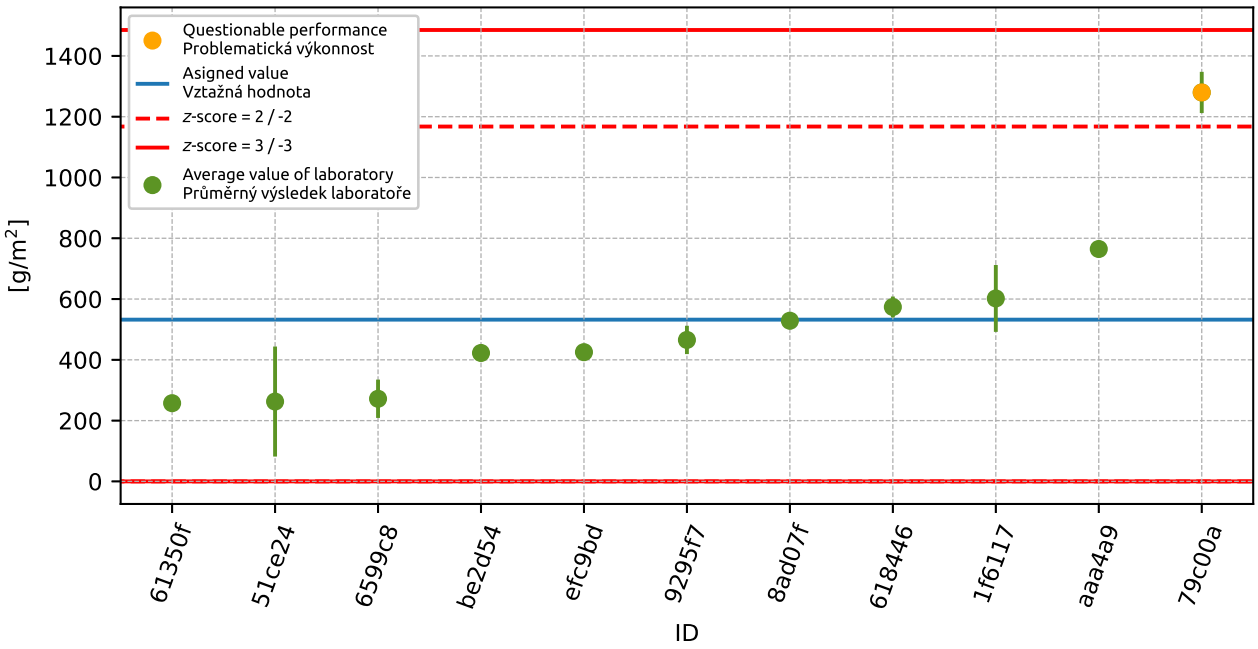

Figure 88: Average values and extended uncertainties of measurement

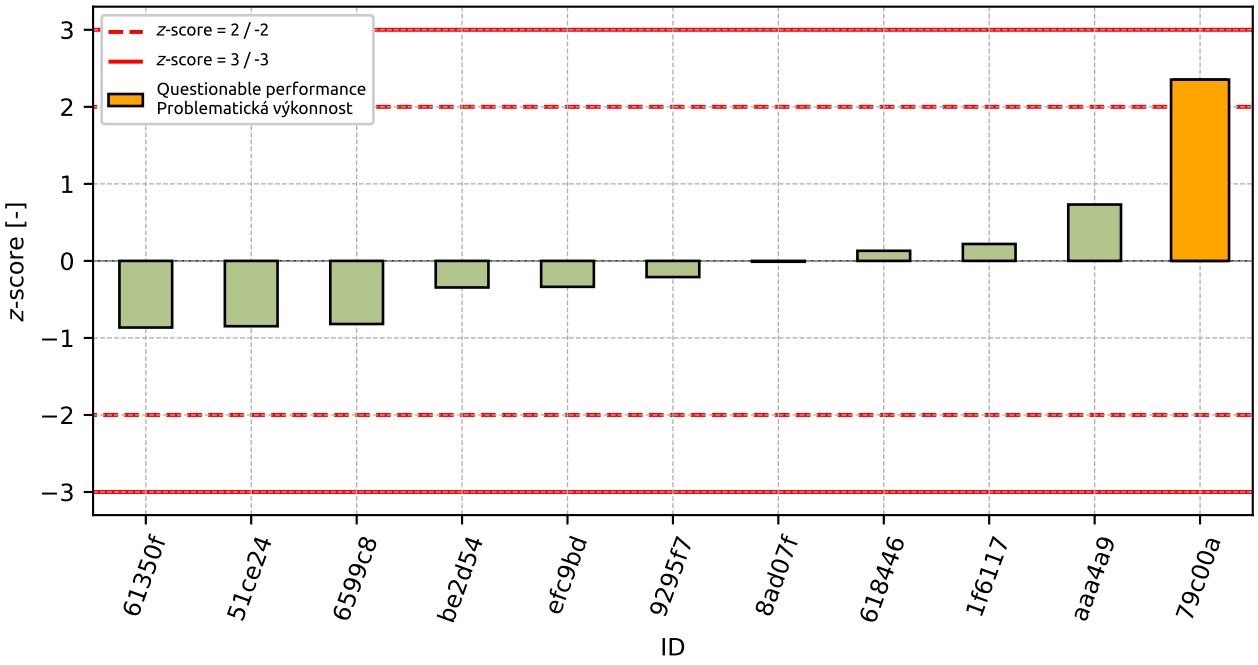

Figure 89: z-score

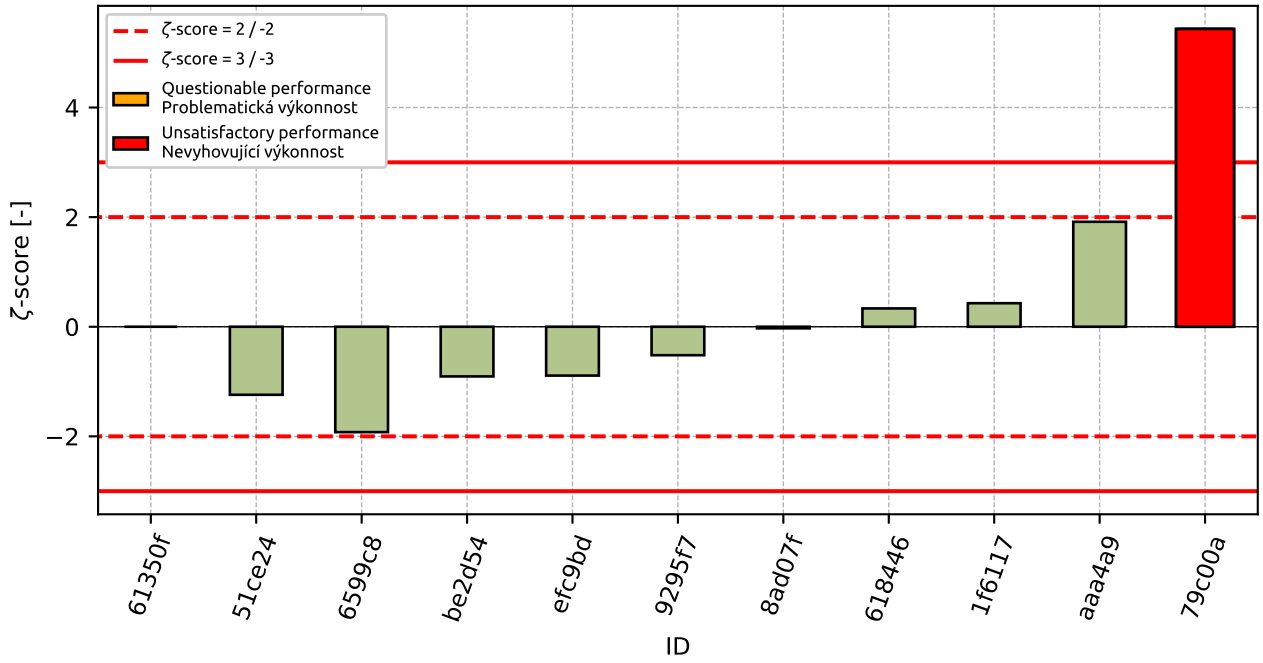

Figure 90: ζ-score

Table 36: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
61350f	-0.87	-
51ce24	-0.85	-1.24
6599c8	-0.82	-1.92
be2d54	-0.35	-0.91
efc9bd	-0.34	-0.89
9295f7	-0.21	-0.52
8ad07f	-0.01	-0.03
618446	0.13	0.33
1f6117	0.22	0.43
aaa4a9	0.73	1.91
79c00a	2.35	5.43

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/m²]			u_X [g/m²]	$\bar{x}$ [g/m²]	s_0 [g/m²]	V_X [%]
f9bf78	72.1	61.2	43.7	8.0	59.0	14.33	24.28
d4df6a	48.0	69.0	71.0	4.5	62.7	12.74	20.33
f86748	55.7	61.3	78.0	14.0	65.0	11.6	17.85
7764ad	135.8	104.7	109.2	5.1	116.6	16.81	14.42
a4819b	128.0	227.0	288.0	34.6	214.3	80.75	37.67
2c2fcf	240.5	264.8	204.9	29.6	236.7	30.13	12.73

8.1.2 The Numerical Procedure for Determining Outliers

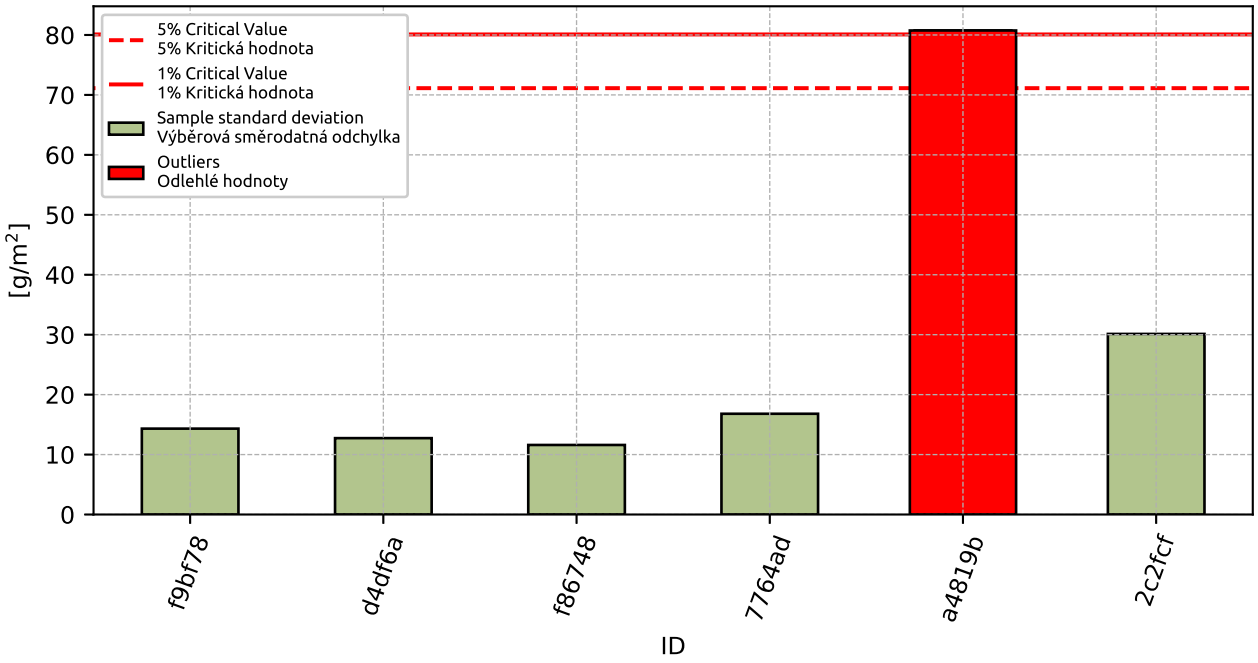

Figure 91: **Cochran's test** - sample standard deviations

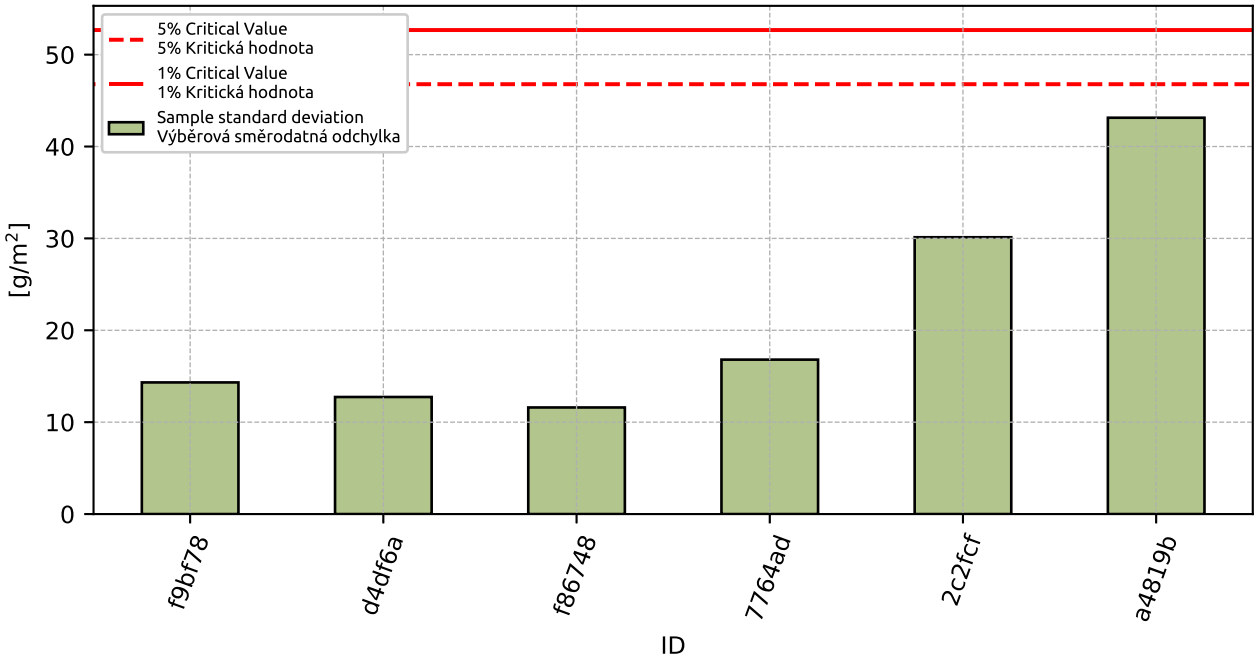

Figure 92: **Cochran's test** - sample standard deviations without outliers

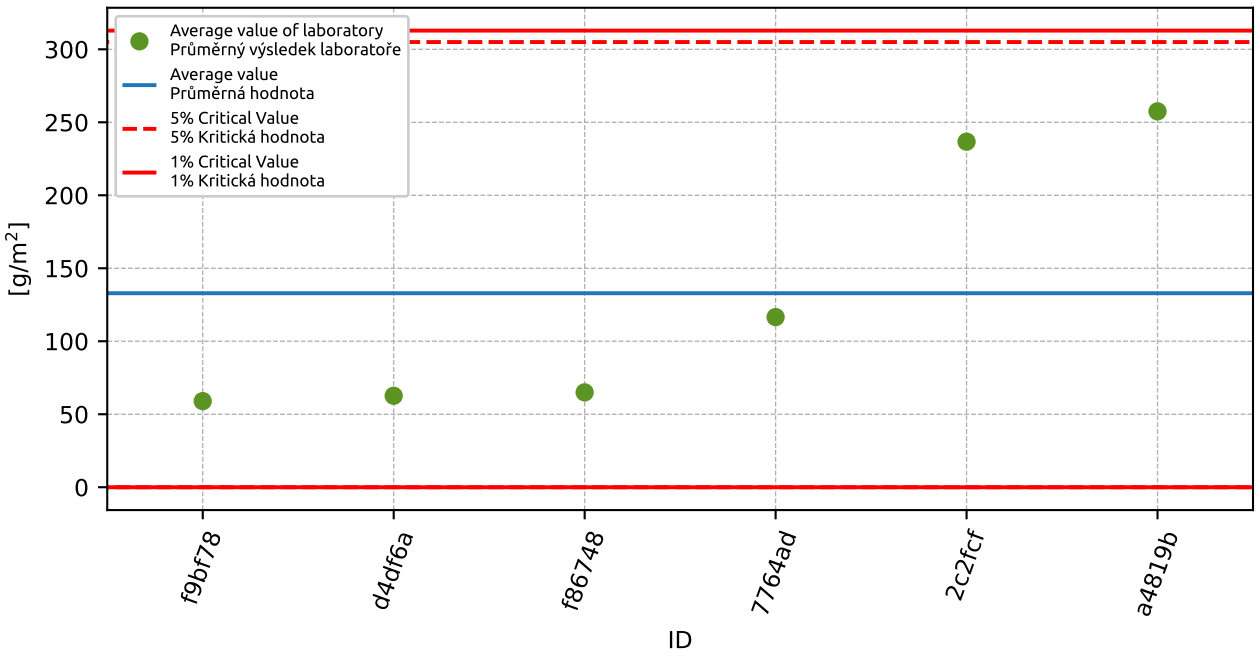

Figure 93: **Grubbs' test** - average values

8.1.3 Mandel's Statistics

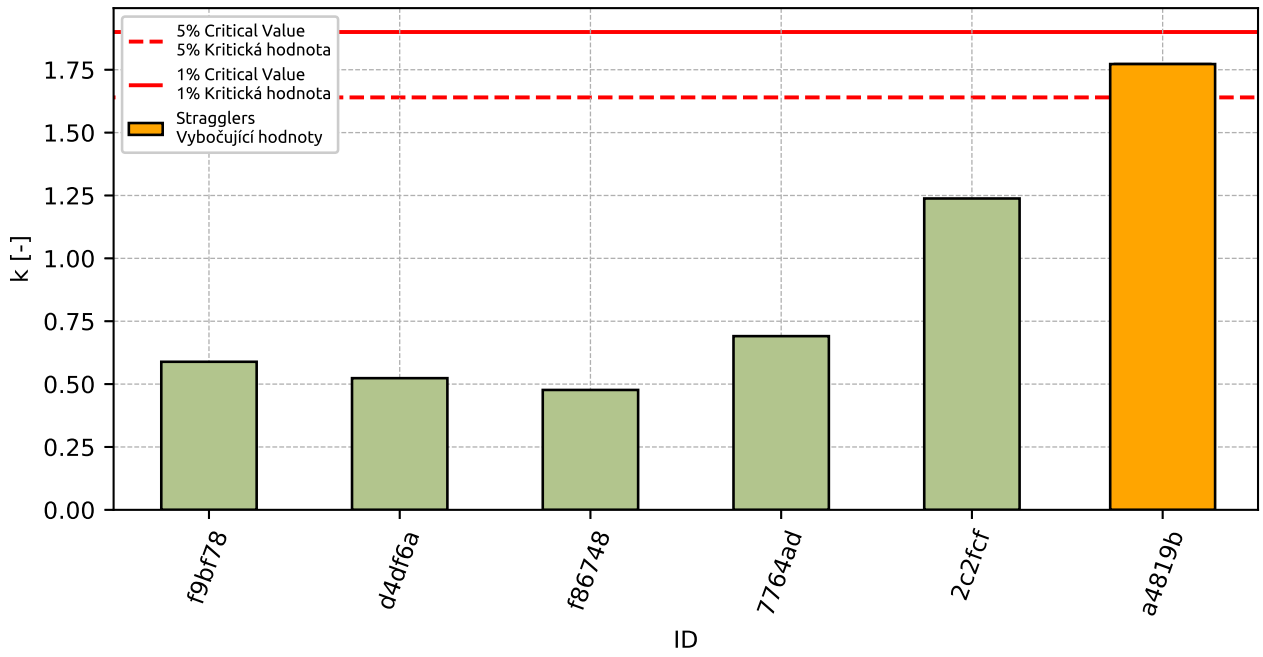

Figure 94: Intralaboratory Consistency Statistic

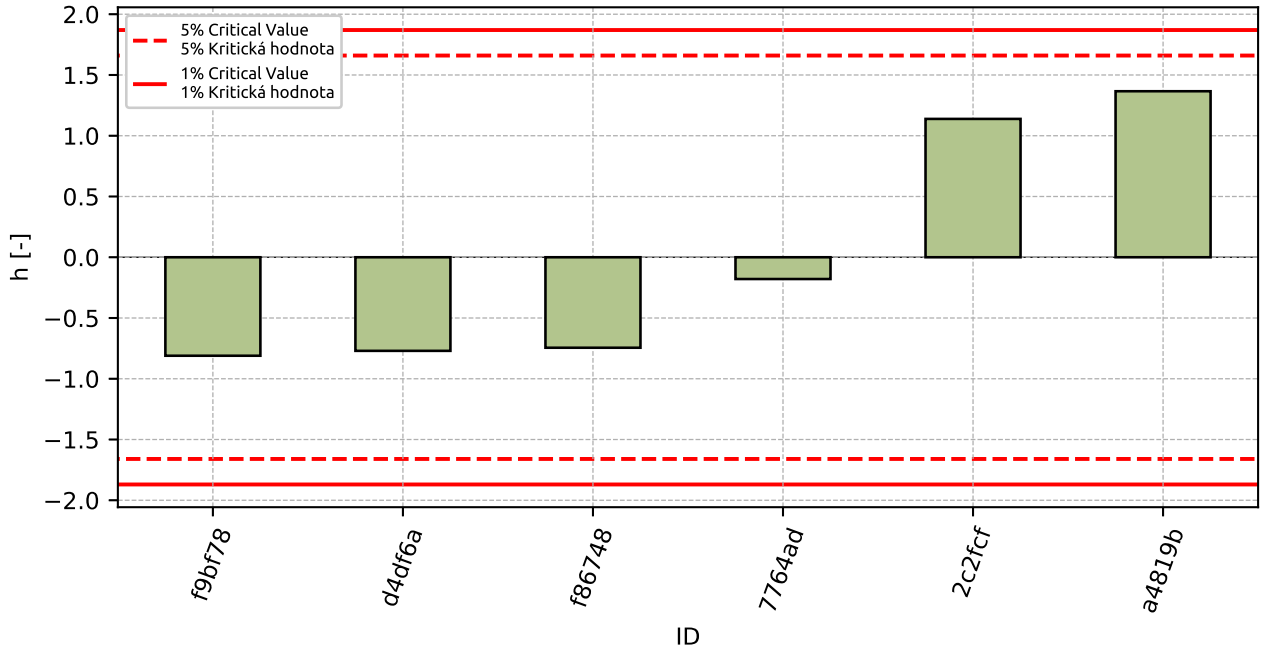

Figure 95: Interlaboratory Consistency Statistic

8.1.4 Descriptive statistics

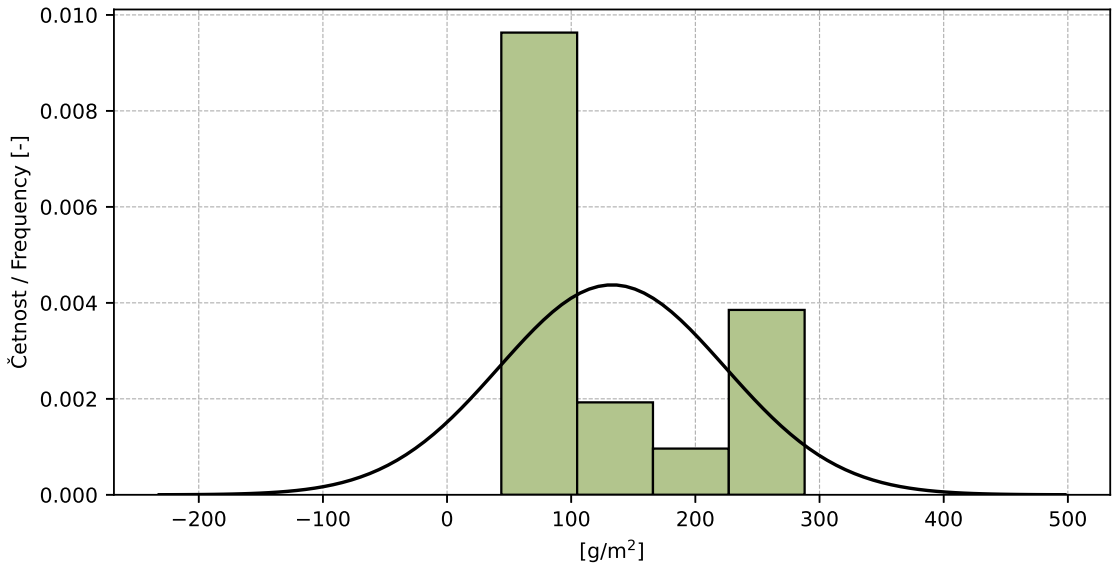

Figure 96: Histogram of all test results

Table 38: Descriptive statistics

Characteristics	**[g/m²]**
Průměrná hodnota / Average value – $\bar{x}$	132.9
Výběrová směrodatná odchylka / Sample standard deviation – s	91.19
Vztažná hodnota / Asigned value – x^*	119.7
Robustní směrodatná odchylka / Robust standard deviation – s^*	80.65
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	41.16
p-hodnota testu normality / p-value of normality test	1.0 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	90.1
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	24.33
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	93.33
Opakovatelnost / Repeatability – r	68.1
Reprodukovatelnost / Reproducibility – R	261.3

8.1.5 Evaluation of Performance Statistics

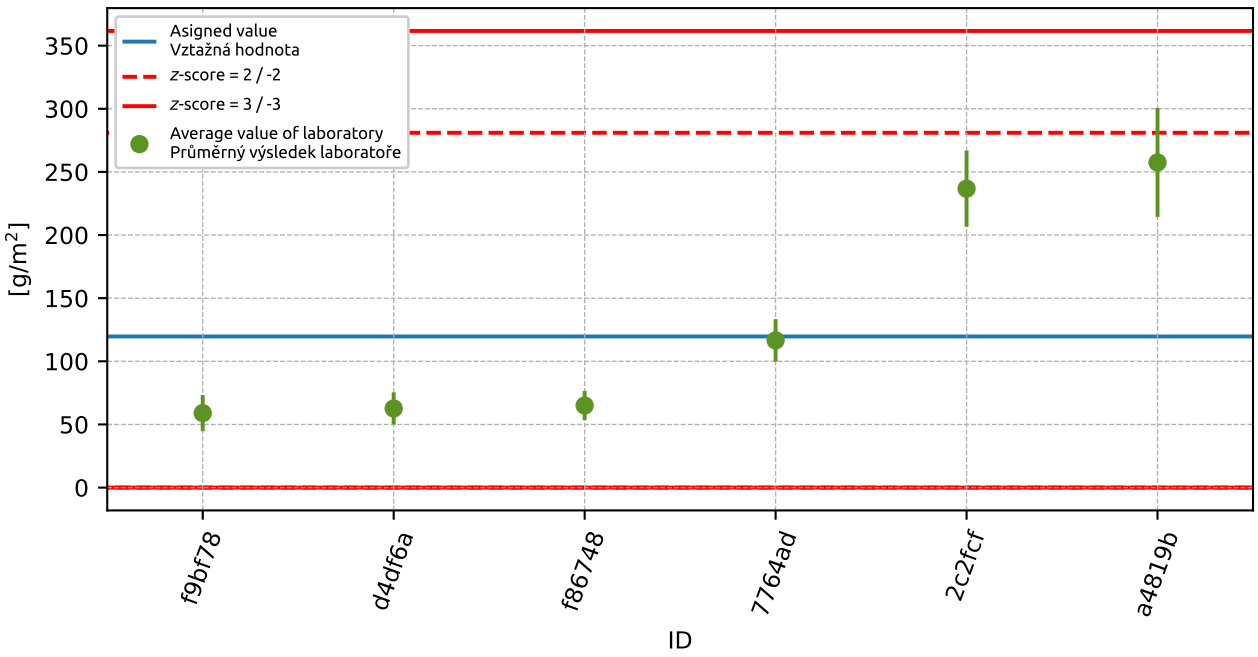

Figure 97: Average values and sample standard deviations

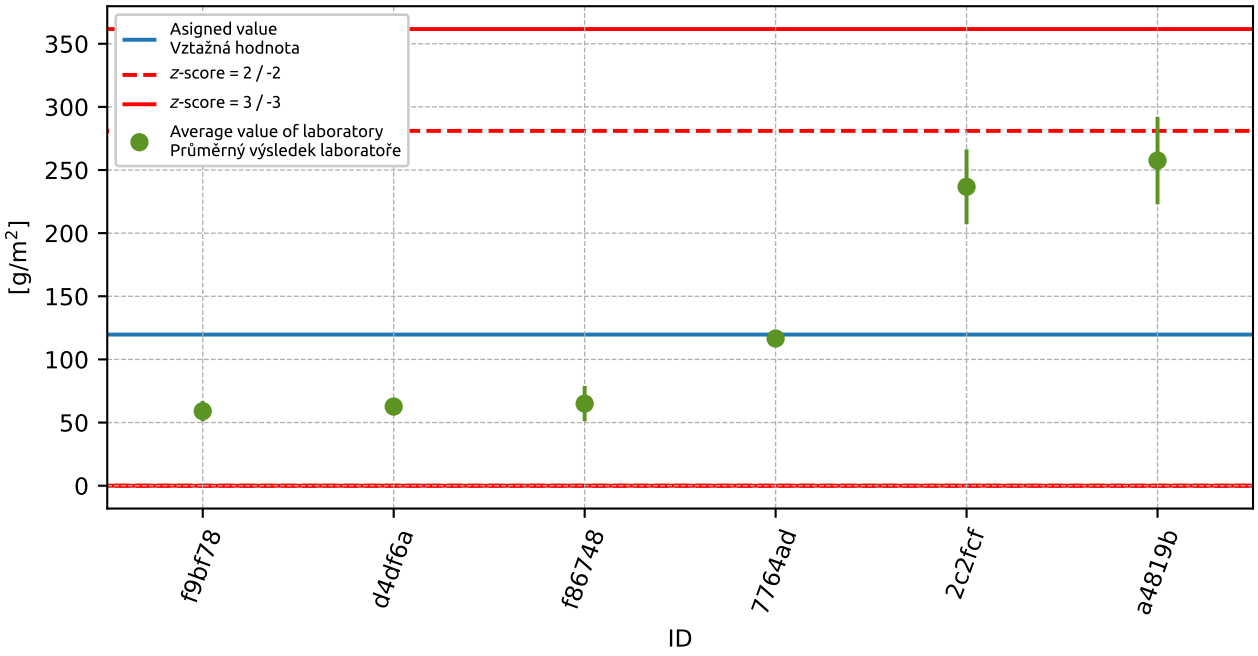

Figure 98: Average values and extended uncertainties of measurement

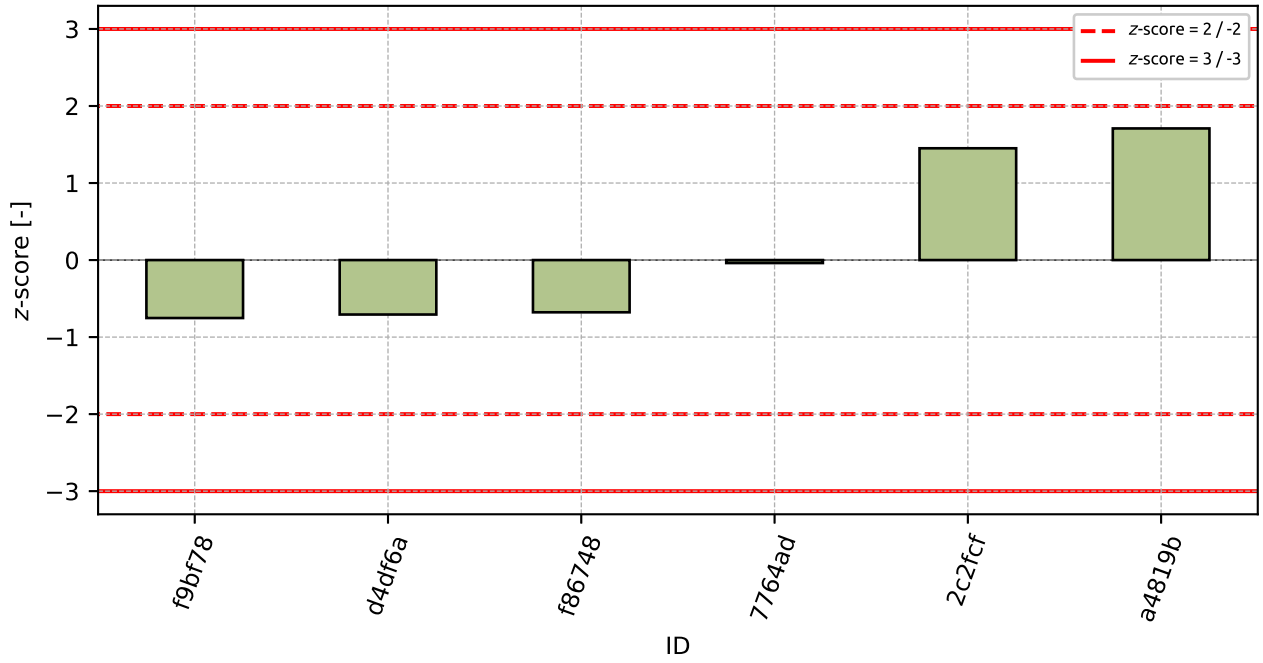

Figure 99: z-score

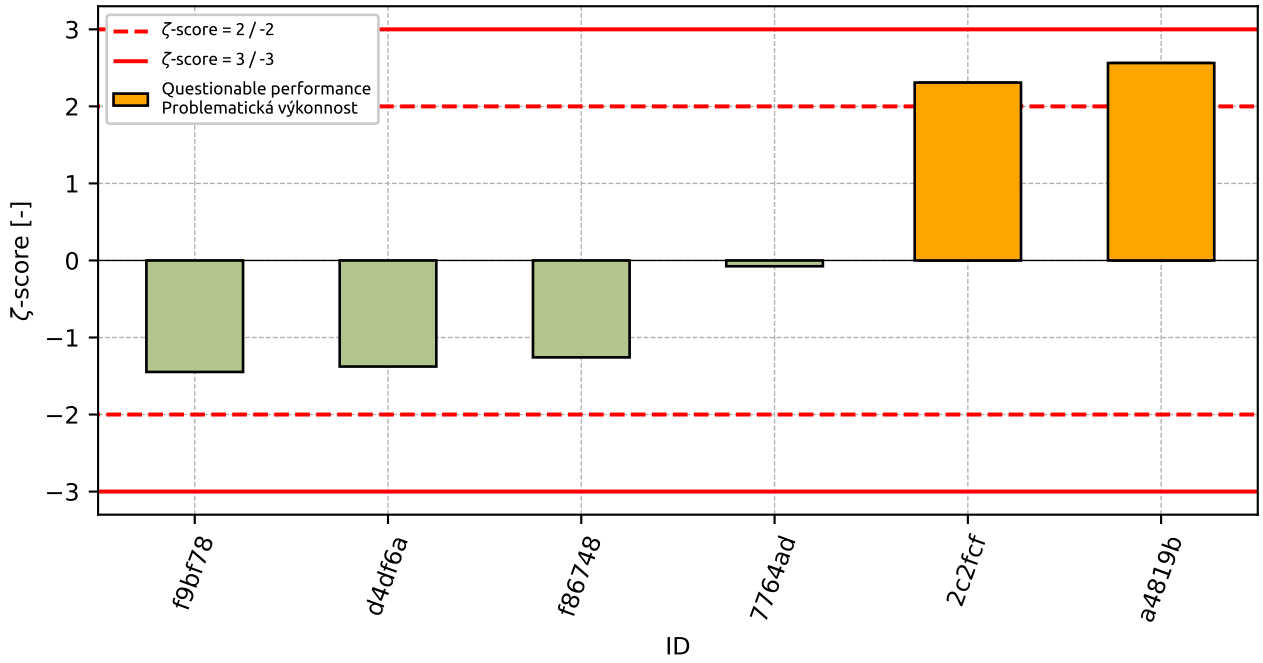

Figure 100: ζ-score

Table 39: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
f9bf78	-0.75	-1.45
d4df6a	-0.71	-1.38
f86748	-0.68	-1.26
7764ad	-0.04	-0.08
2c2fcf	1.45	2.31
a4819b	1.71	2.56

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 [%]
d4df6a	80.0	83.0	96.0	4.5	86.3	8.5	9.85
a4819b	48.0	88.0	145.0	17.4	93.7	48.75	52.04
f86748	100.2	111.5	133.7	24.0	115.1	17.04	14.8
f9bf78	138.7	116.9	98.4	14.0	118.0	20.17	17.1
2c2fcf	302.9	298.2	257.5	35.7	286.2	24.97	8.72
7764ad	439.1	332.2	150.5	20.5	307.3	145.91	47.49

8.2.2 The Numerical Procedure for Determining Outliers

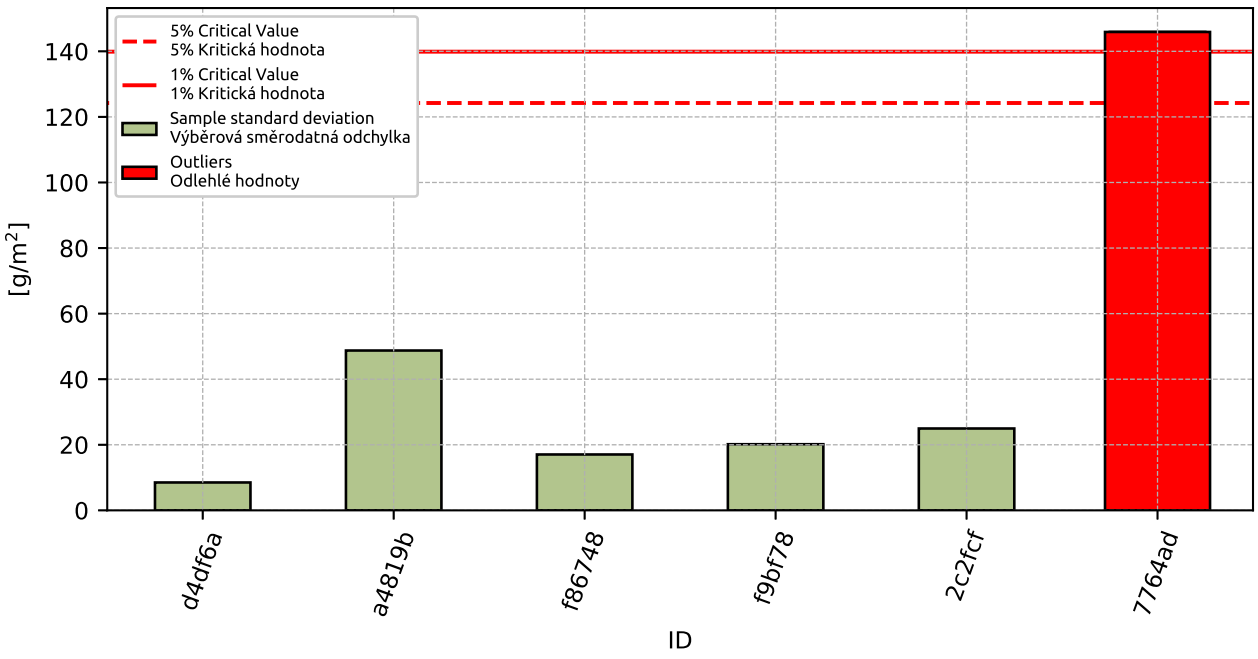

Figure 101: **Cochran's test** - sample standard deviations

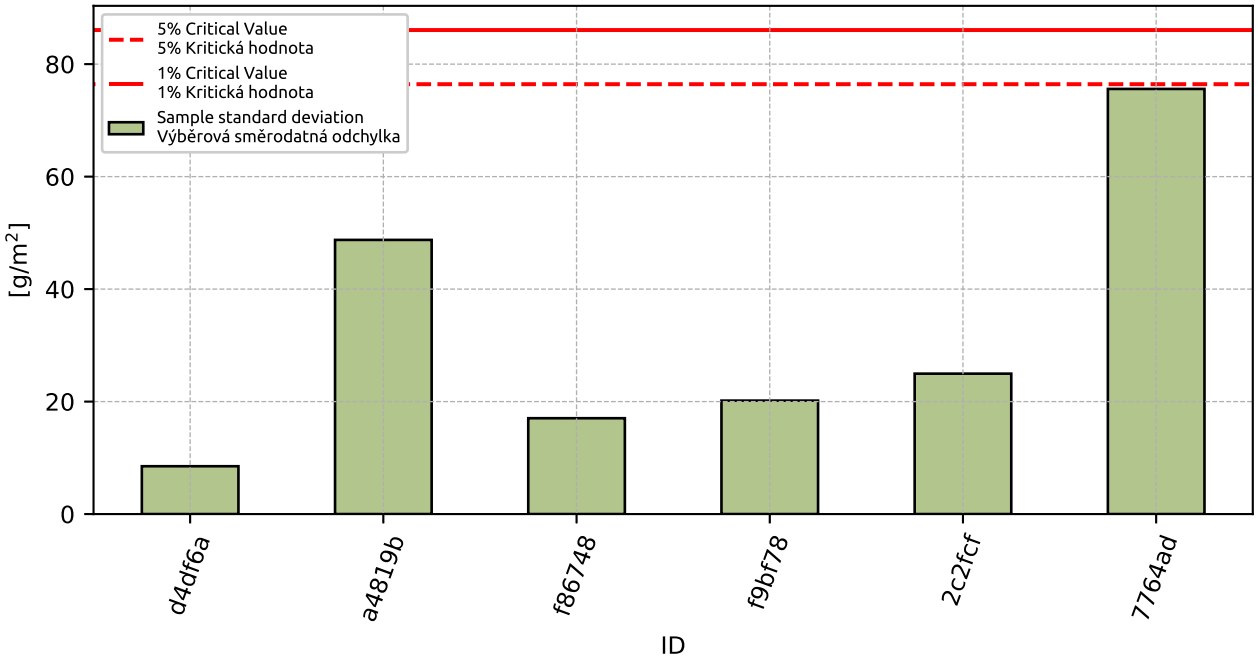

Figure 102: **Cochran's test** - sample standard deviations without outliers

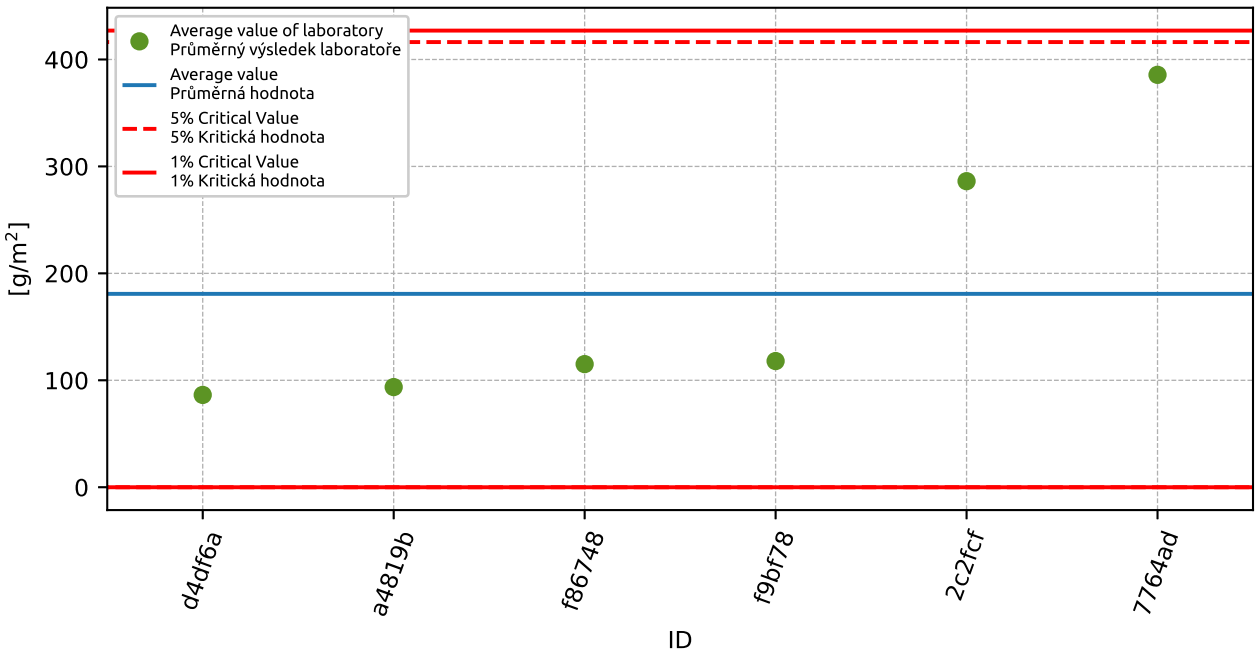

Figure 103: **Grubbs' test** - average values

8.2.3 Mandel's Statistics

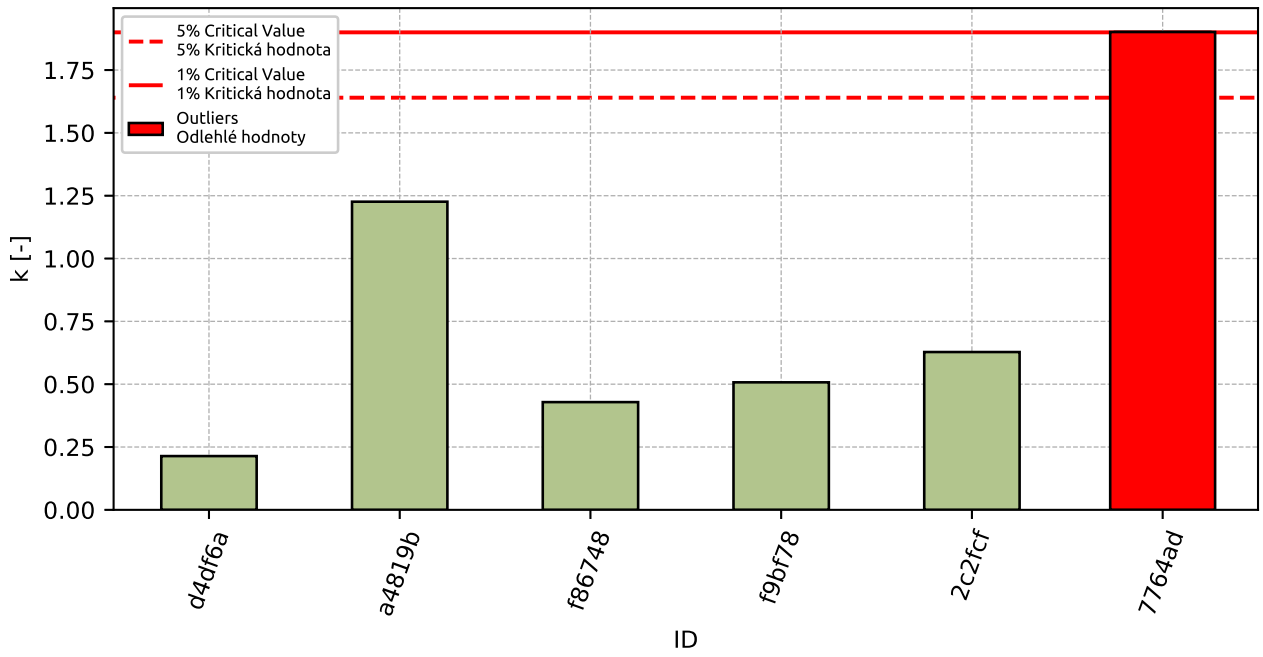

Figure 104: Intralaboratory Consistency Statistic

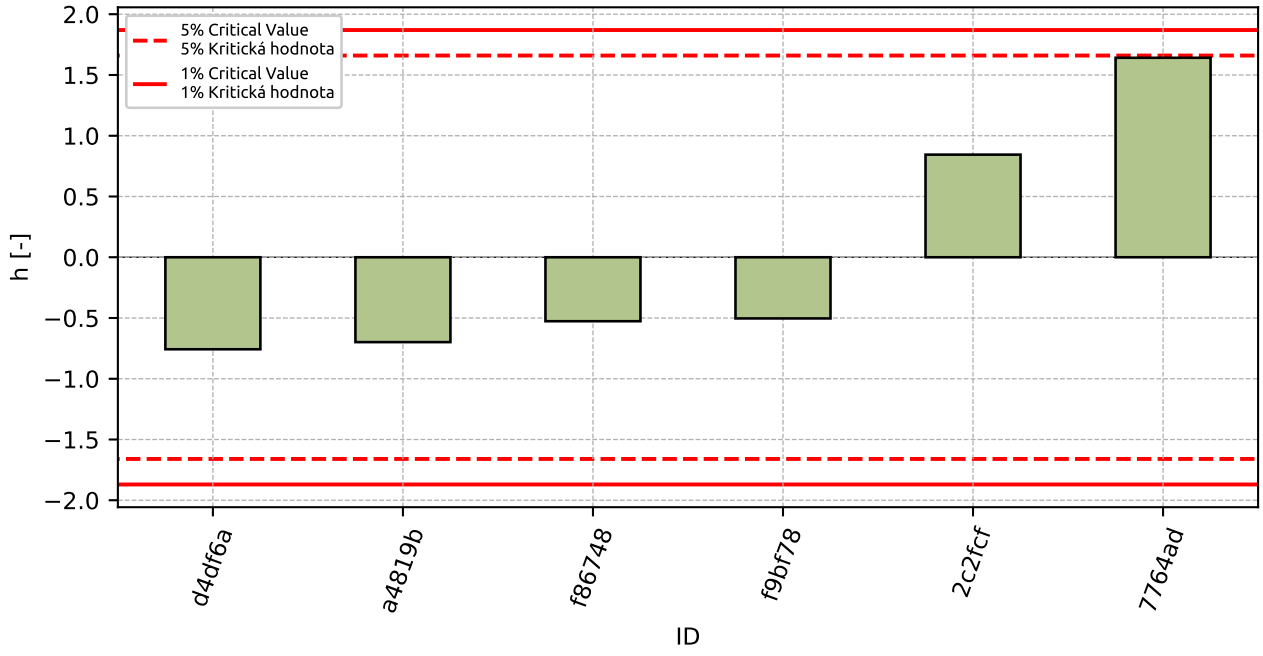

Figure 105: Interlaboratory Consistency Statistic

8.2.4 Descriptive statistics

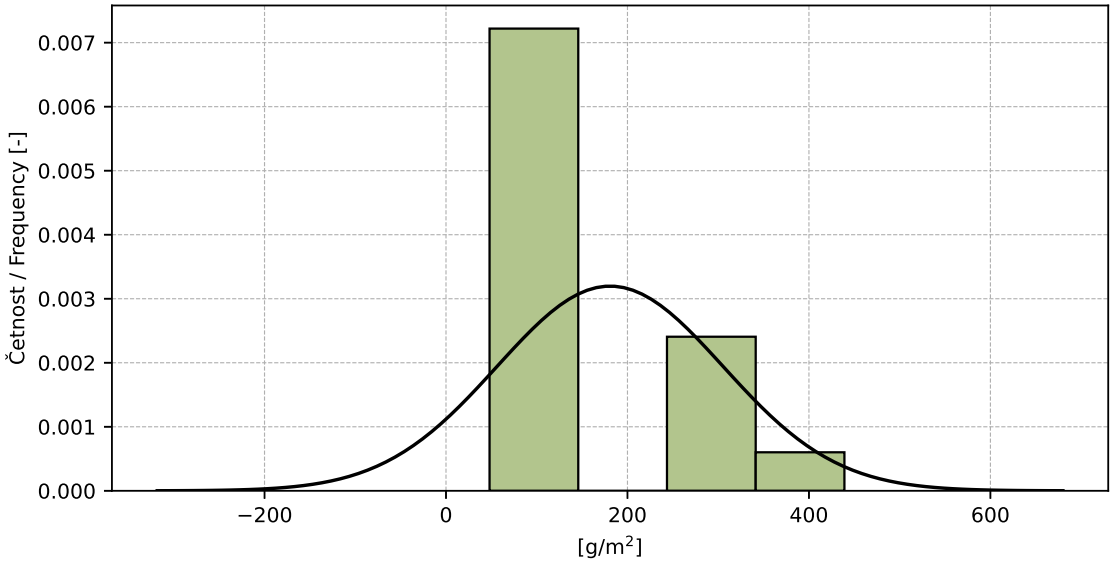

Figure 106: Histogram of all test results

Table 41: Descriptive statistics

Characteristics	[g/m²]
Průměrná hodnota / Average value – $\bar{x}$	180.8
Výběrová směrodatná odchylka / Sample standard deviation – s	124.78
Vztažná hodnota / Asigned value – x^*	162.4
Robustní směrodatná odchylka / Robust standard deviation – s^*	117.79
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	60.11
p-hodnota testu normality / p-value of normality test	1.0 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	122.65
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	39.76
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	128.93
Opakovatelnost / Repeatability – r	111.3
Reprodukovatelnost / Reproducibility – R	361.0

8.2.5 Evaluation of Performance Statistics

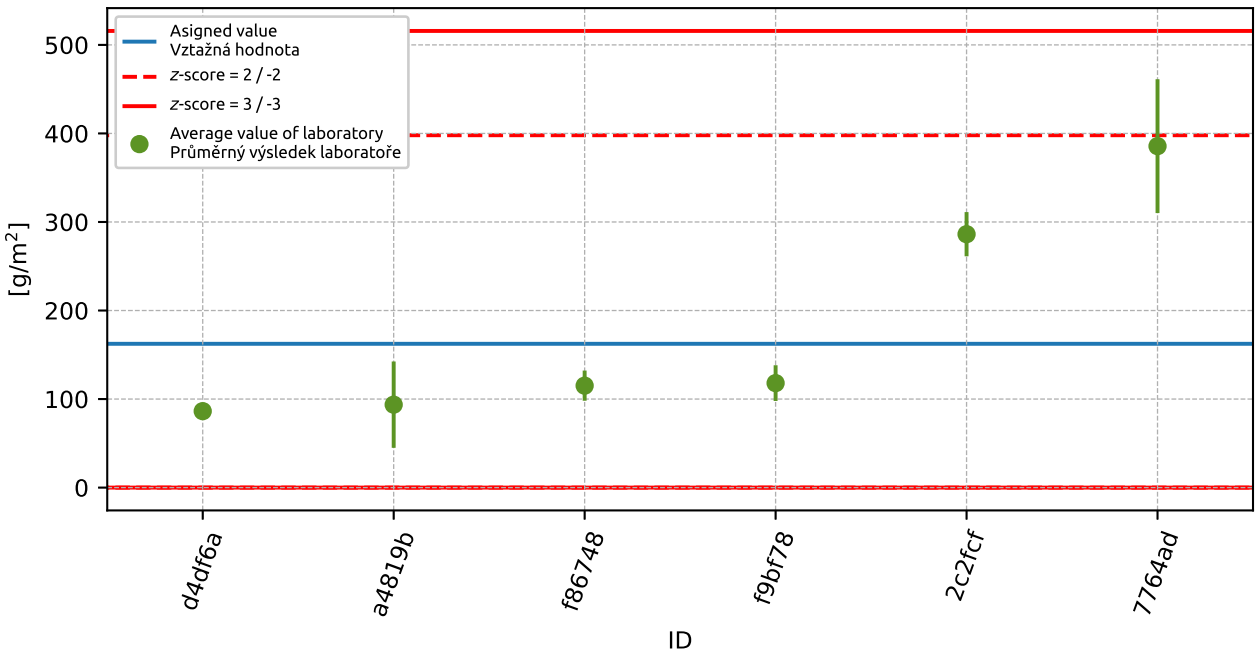

Figure 107: Average values and sample standard deviations

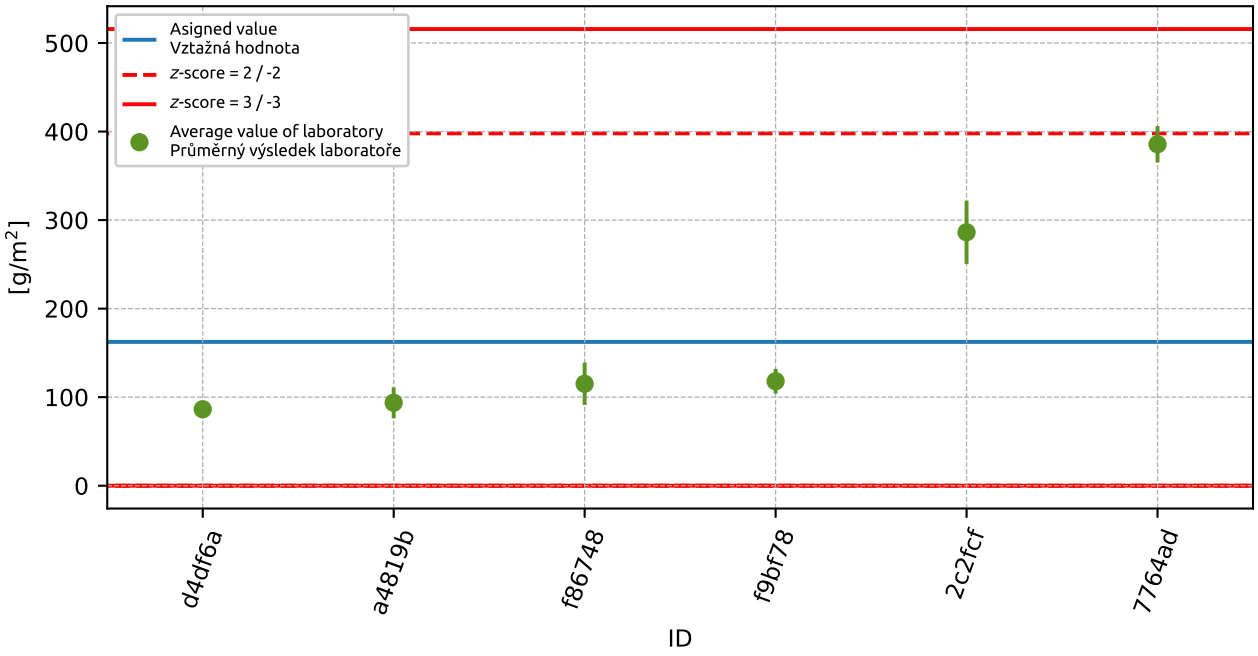

Figure 108: Average values and extended uncertainties of measurement

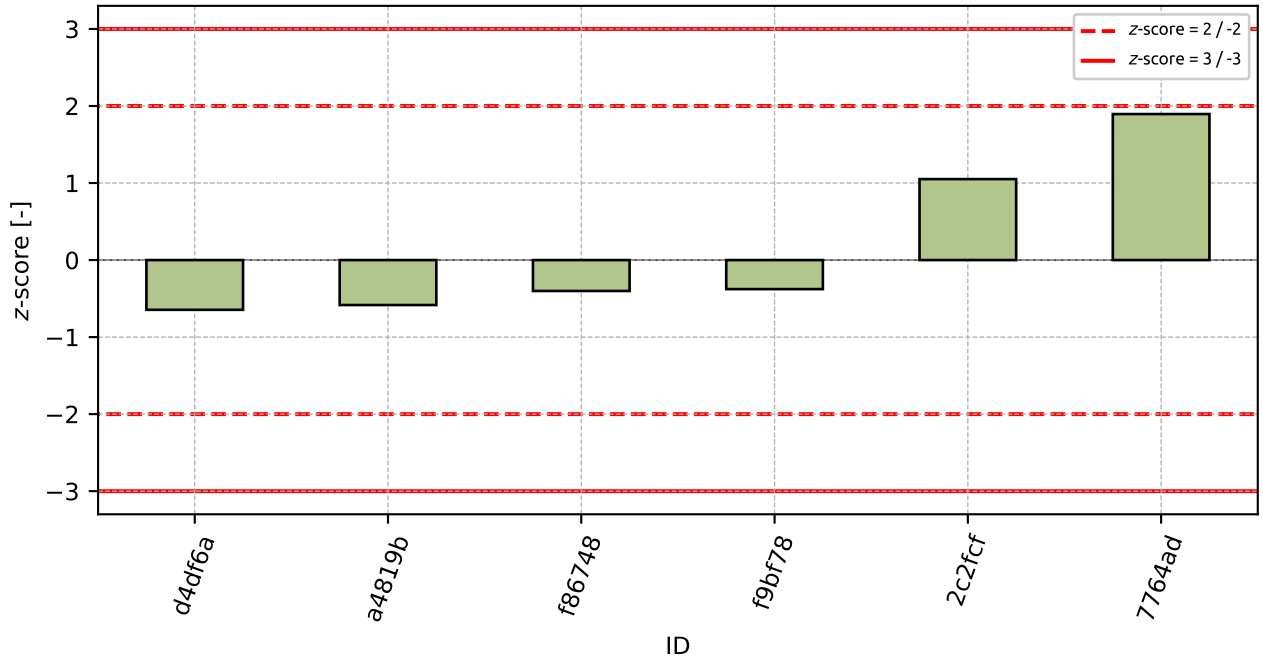

Figure 109: z-score

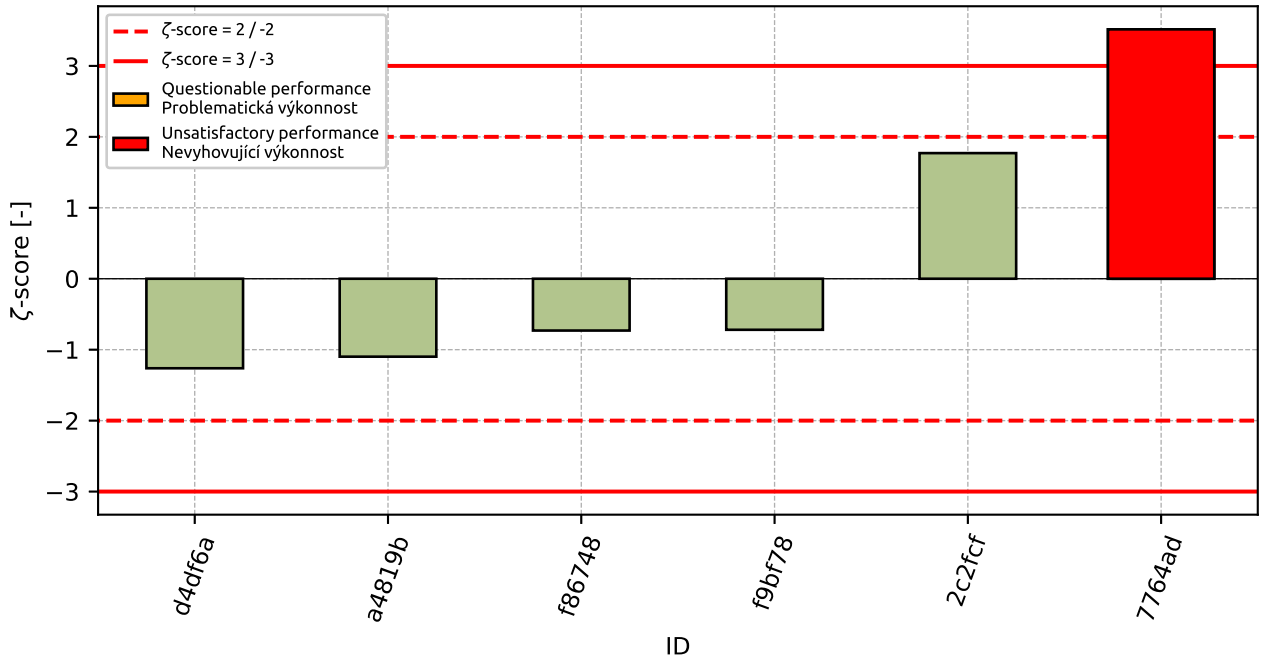

Figure 110: ζ-score

Table 42: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
d4df6a	-0.65	-1.26
a4819b	-0.58	-1.1
f86748	-0.4	-0.73
f9bf78	-0.38	-0.72
2c2fcf	1.05	1.77
7764ad	1.9	3.52

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 [%]
a4819b	27.0	57.0	118.0	14.2	67.3	46.37	68.87
d4df6a	85.0	98.0	113.0	4.5	98.7	14.01	14.2
f9bf78	194.2	166.9	158.5	20.0	173.2	18.67	10.78
f86748	167.1	172.9	189.4	36.0	176.5	11.57	6.56
2c2fcf	333.9	346.9	293.1	40.6	324.6	28.07	8.65
7764ad	878.8	650.2	217.9	29.8	582.3	335.64	57.64

8.3.2 The Numerical Procedure for Determining Outliers

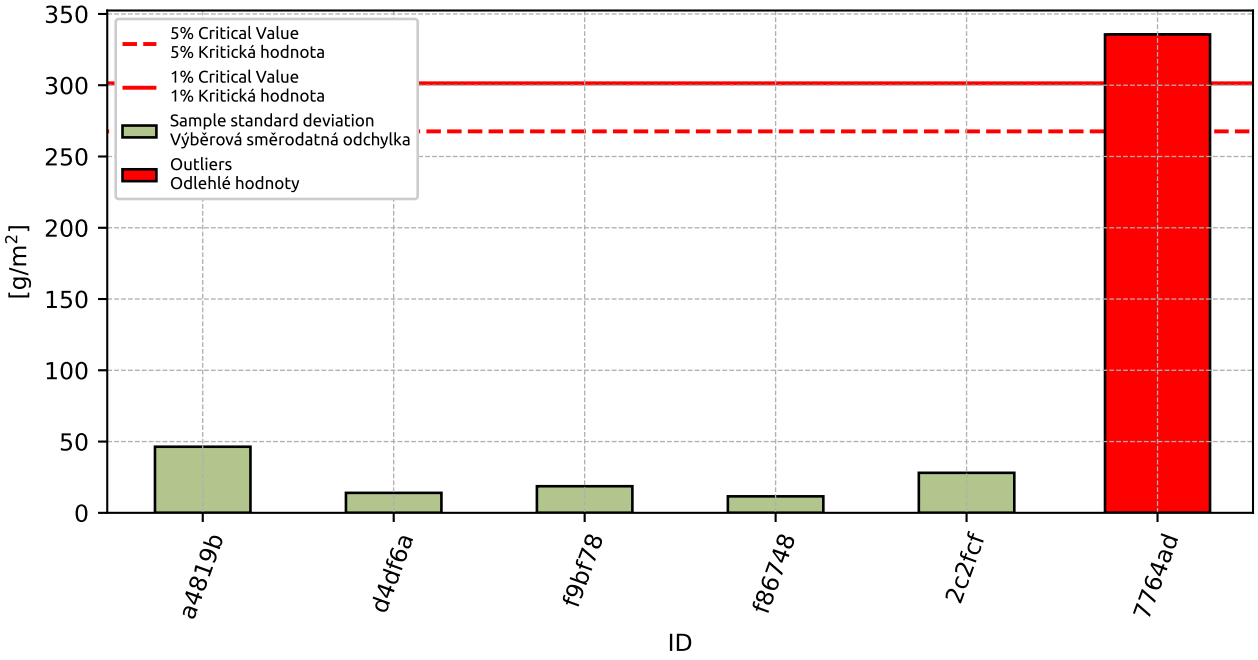

Figure 111: **Cochran's test** - sample standard deviations

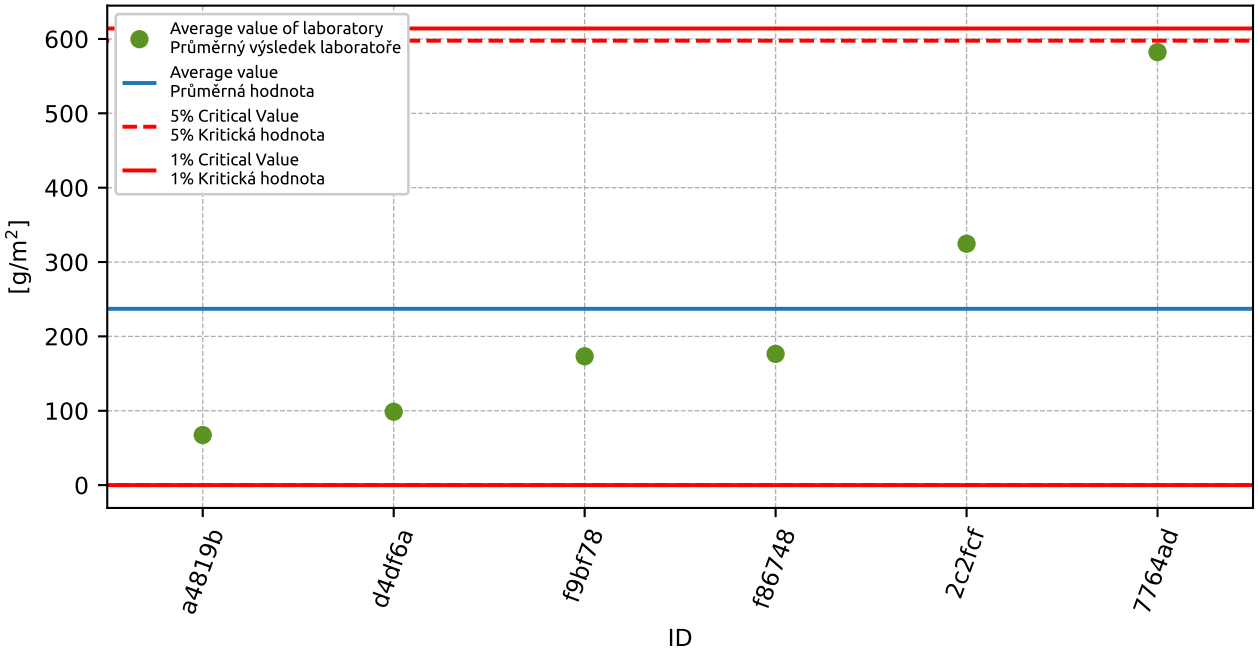

Figure 112: **Grubbs' test** - average values

8.3.3 Mandel's Statistics

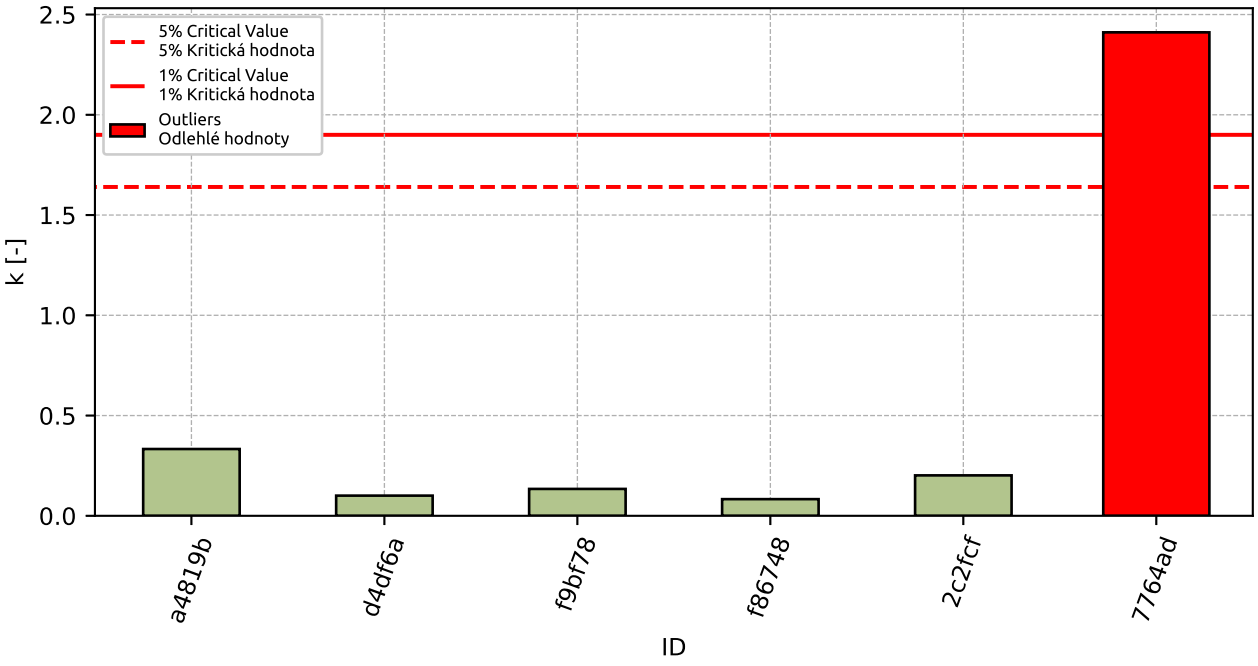

Figure 113: Intralaboratory Consistency Statistic

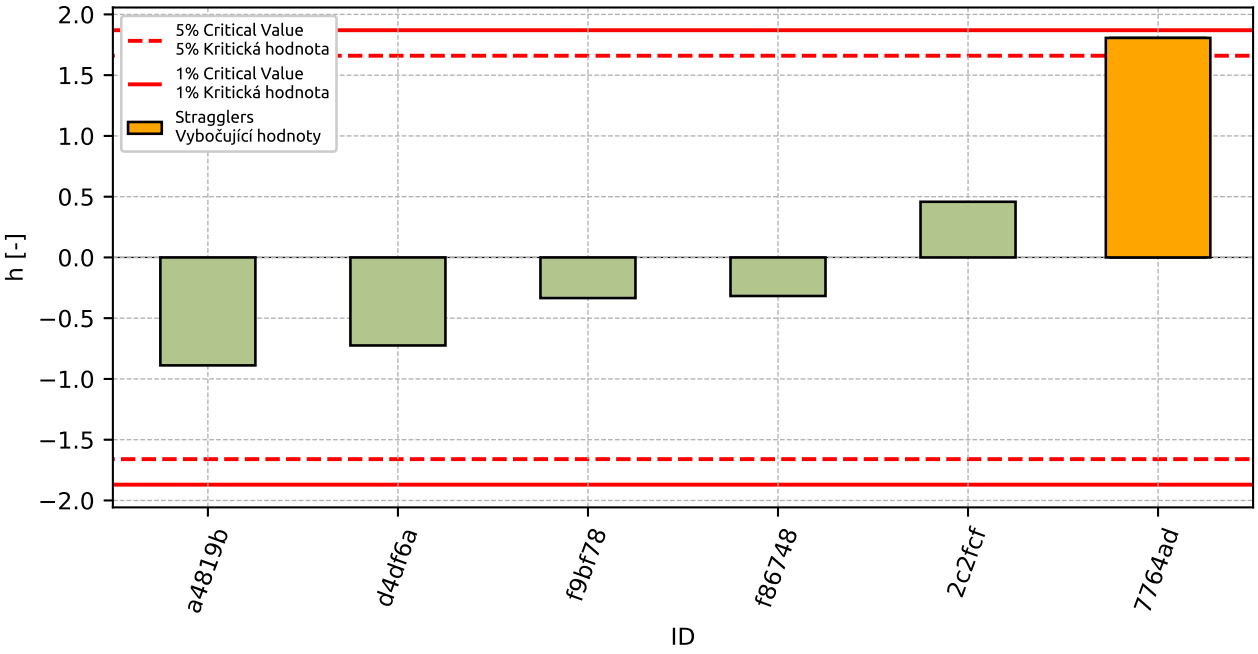

Figure 114: Interlaboratory Consistency Statistic

8.3.4 Descriptive statistics

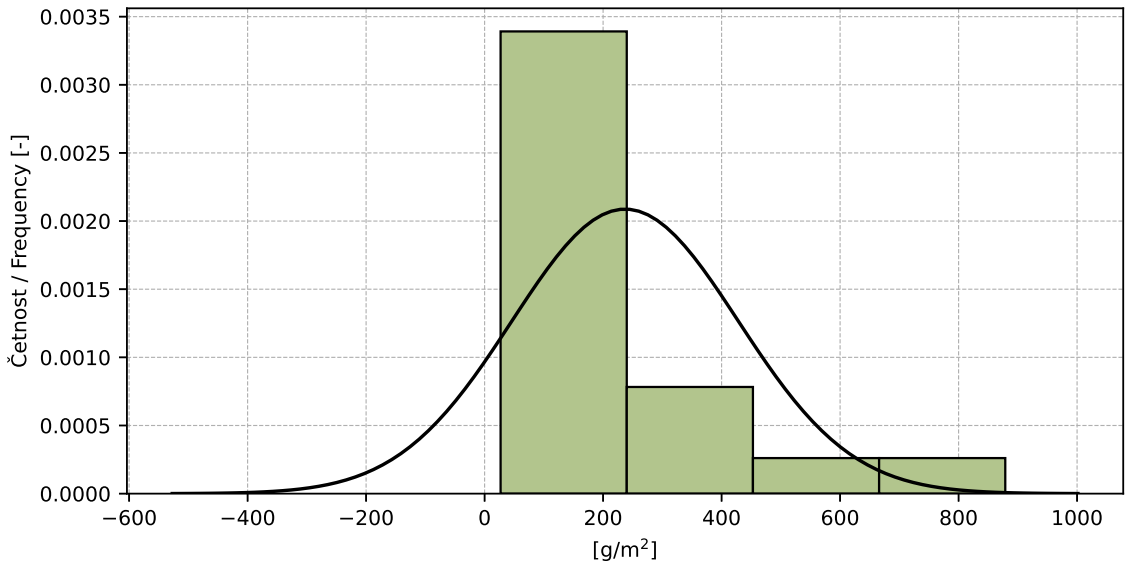

Figure 115: Histogram of all test results

Table 44: Descriptive statistics

Characteristics	[g/m²]
Průměrná hodnota / Average value – $\bar{x}$	237.1
Výběrová směrodatná odchylka / Sample standard deviation – s	191.09
Vztažná hodnota / Asigned value – x^*	237.1
Robustní směrodatná odchylka / Robust standard deviation – s^*	197.81
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	100.95
p-hodnota testu normality / p-value of normality test	0.0 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	173.36
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	139.21
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	222.34
Opakovatelnost / Repeatability – r	389.8
Reprodukovatelnost / Reproducibility – R	622.5

8.3.5 Evaluation of Performance Statistics

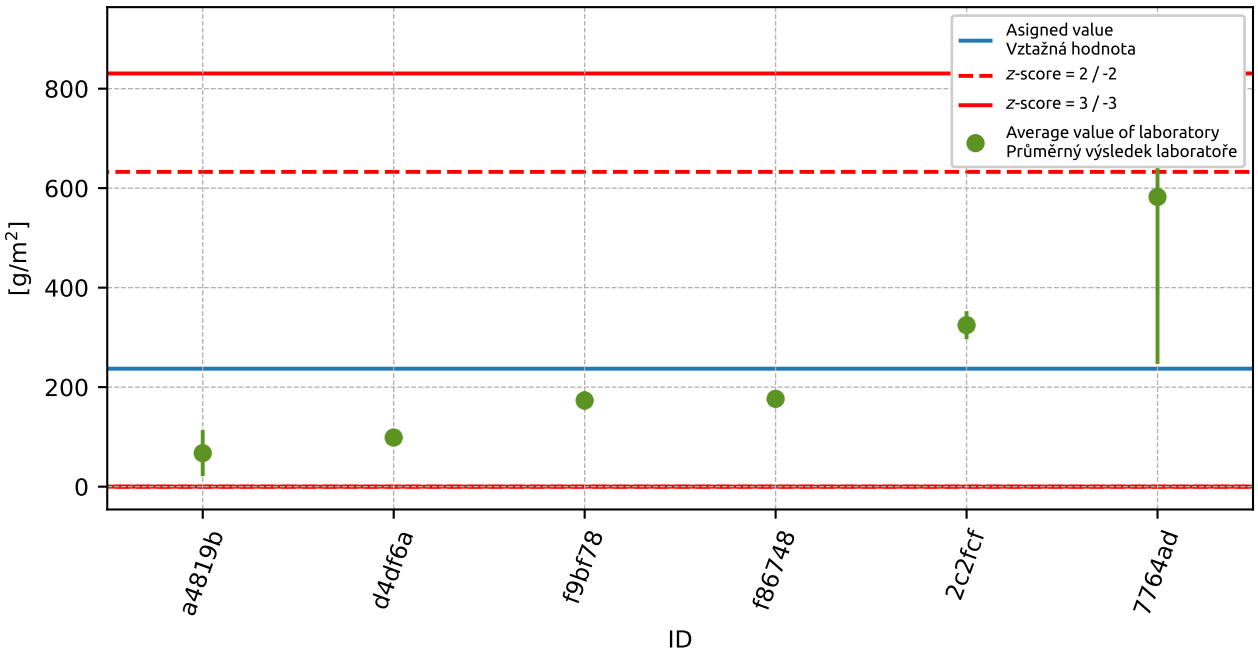

Figure 116: Average values and sample standard deviations

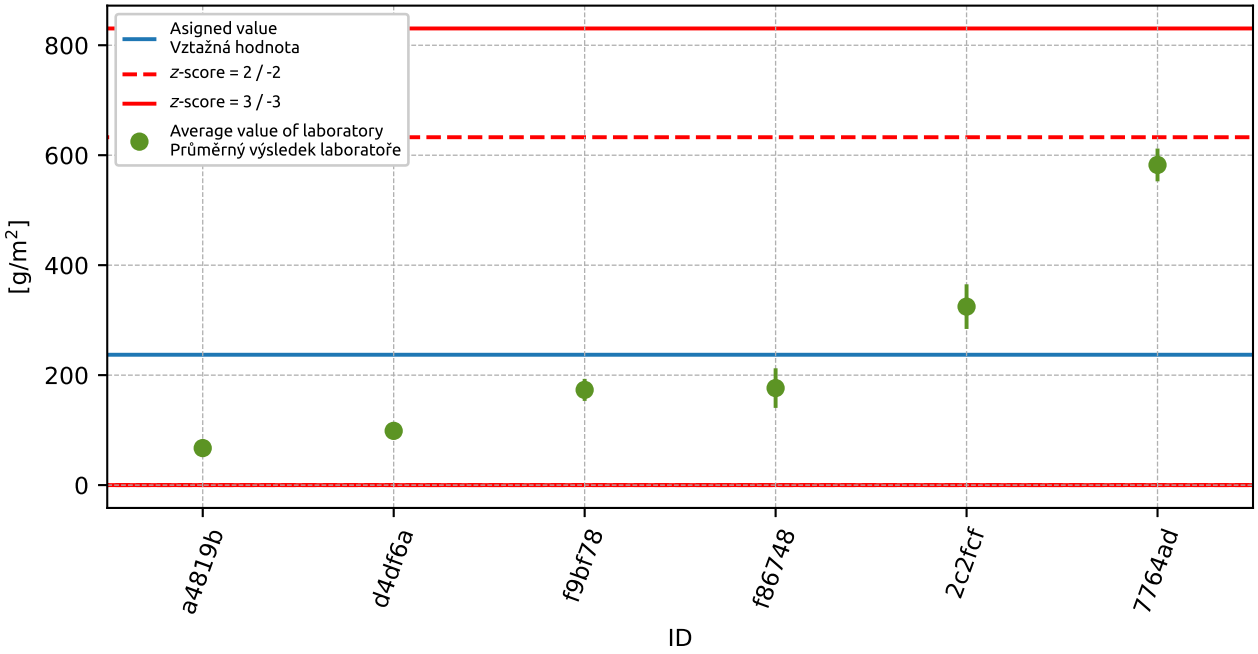

Figure 117: Average values and extended uncertainties of measurement

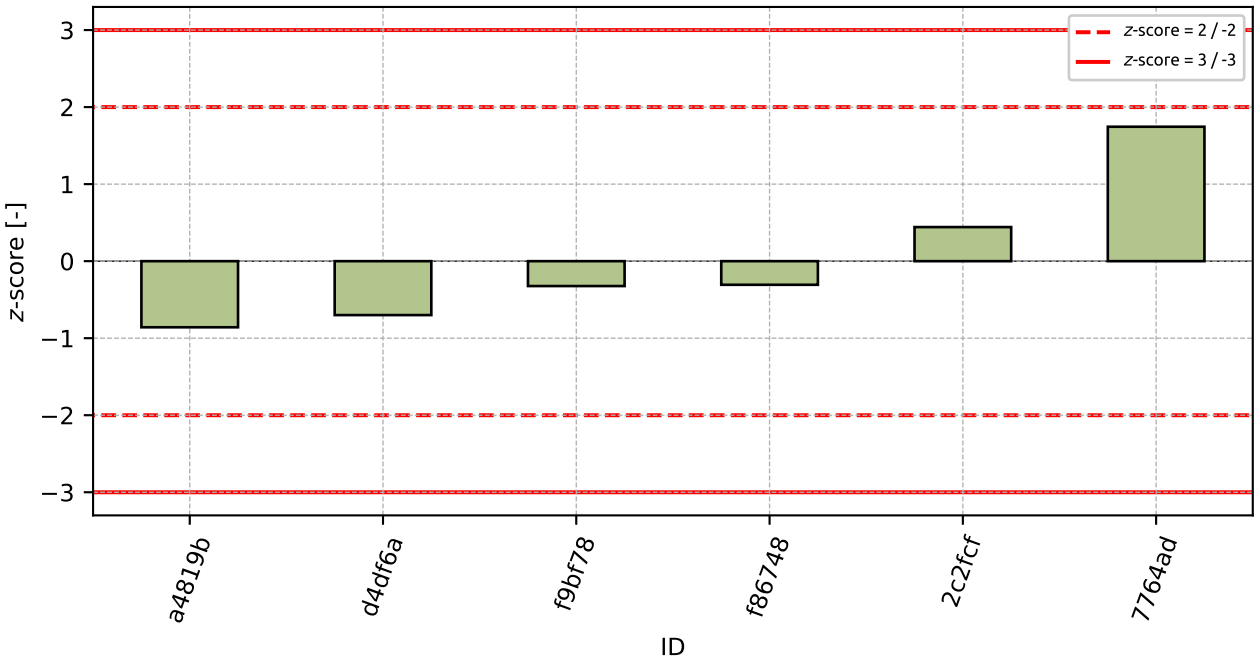

Figure 118: z-score

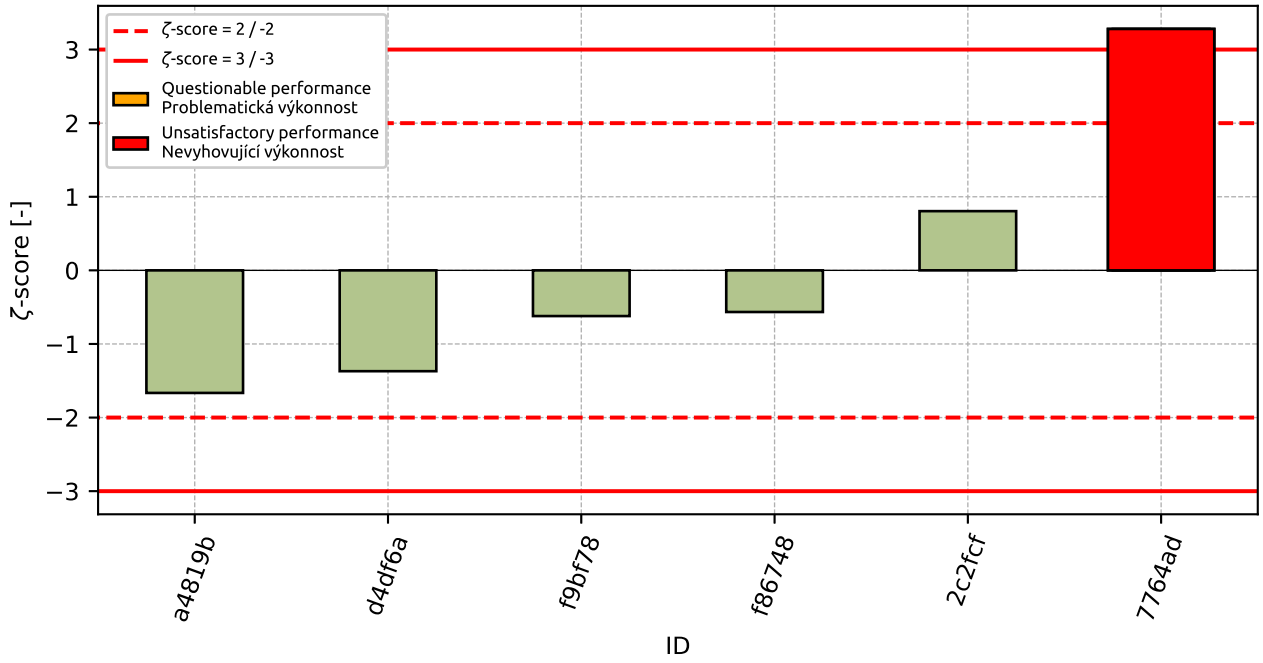

Figure 119: ζ-score

Table 45: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a4819b	-0.86	-1.67
d4df6a	-0.7	-1.37
f9bf78	-0.32	-0.62
f86748	-0.31	-0.57
2c2fcf	0.44	0.8
7764ad	1.75	3.28

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 [%]
048321	20.0	0.0	-	-	20.0	10.0	14.1	141.42
1685fd	14.0	10.0	-	-	4.0	12.0	2.8	23.57
ab05ce	15.0	11.0	-	-	4.0	13.0	2.8	21.76
6b1ac5	44.0	89.0	62.0	71.0	-	67.0	18.5	27.8
5929bf	59.0	77.0	-	-	42.0	68.0	12.7	18.72
232a18	162.0	104.0	131.0	142.0	6.0	135.0	23.9	17.75

9.2 The Numerical Procedure for Determining Outliers

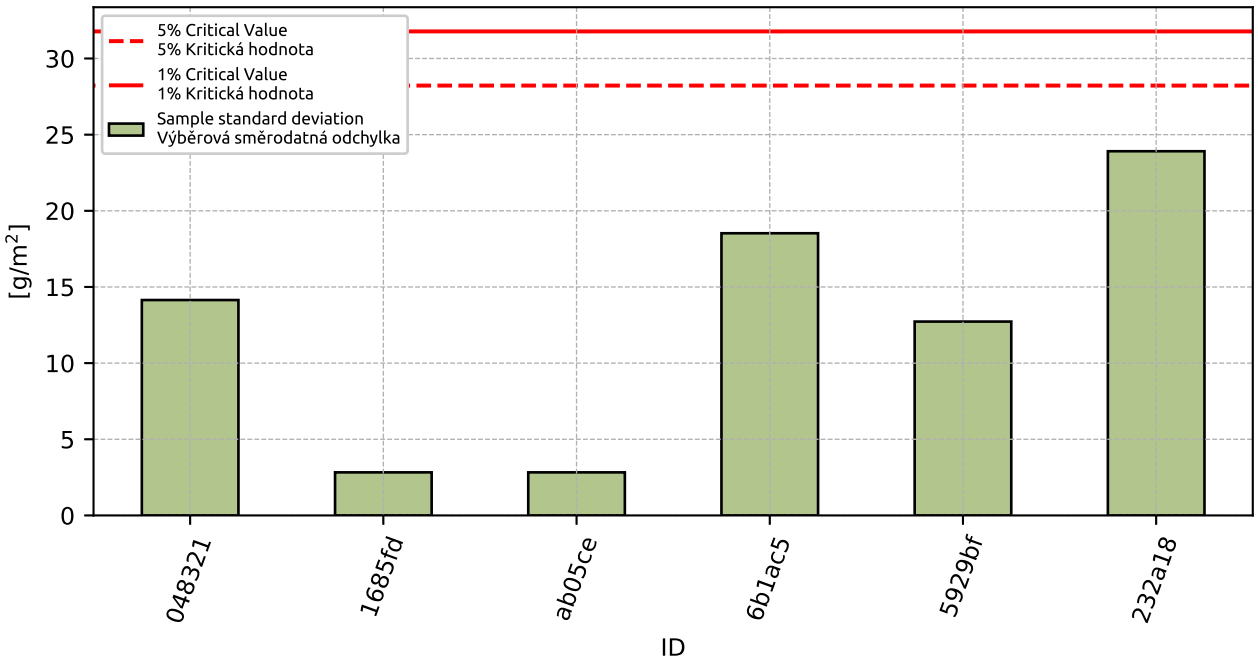

Figure 120: **Cochran's test** - sample standard deviations

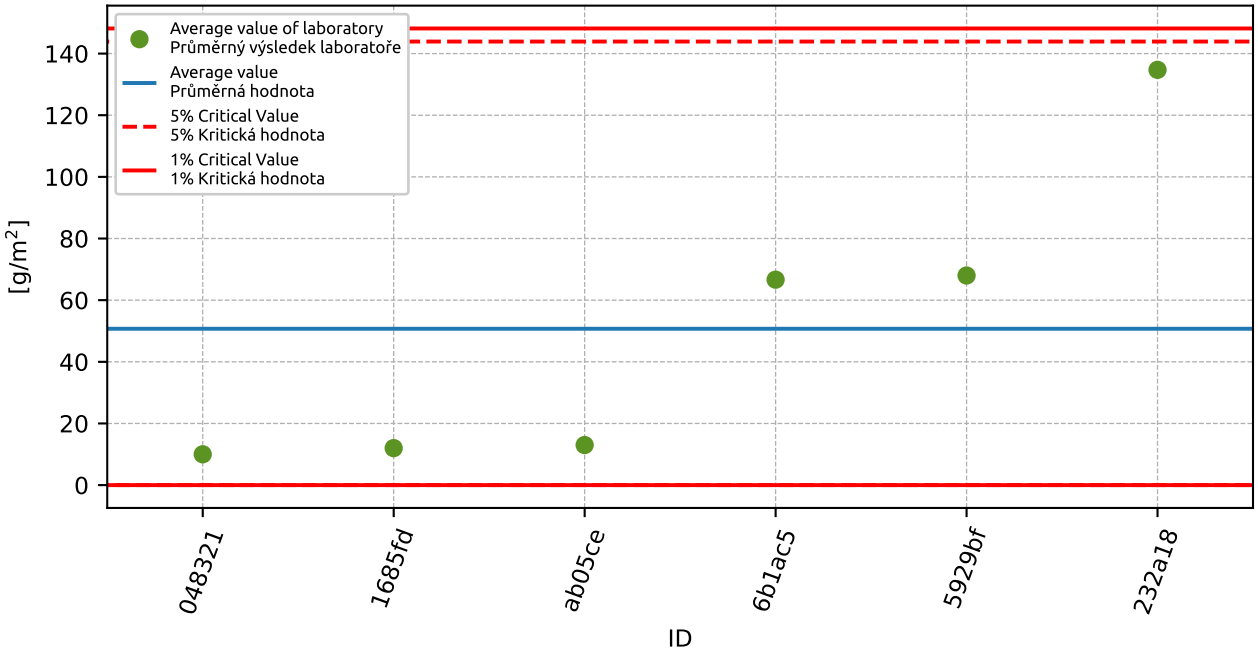

Figure 121: **Grubbs' test** - average values

9.3 Mandel's Statistics

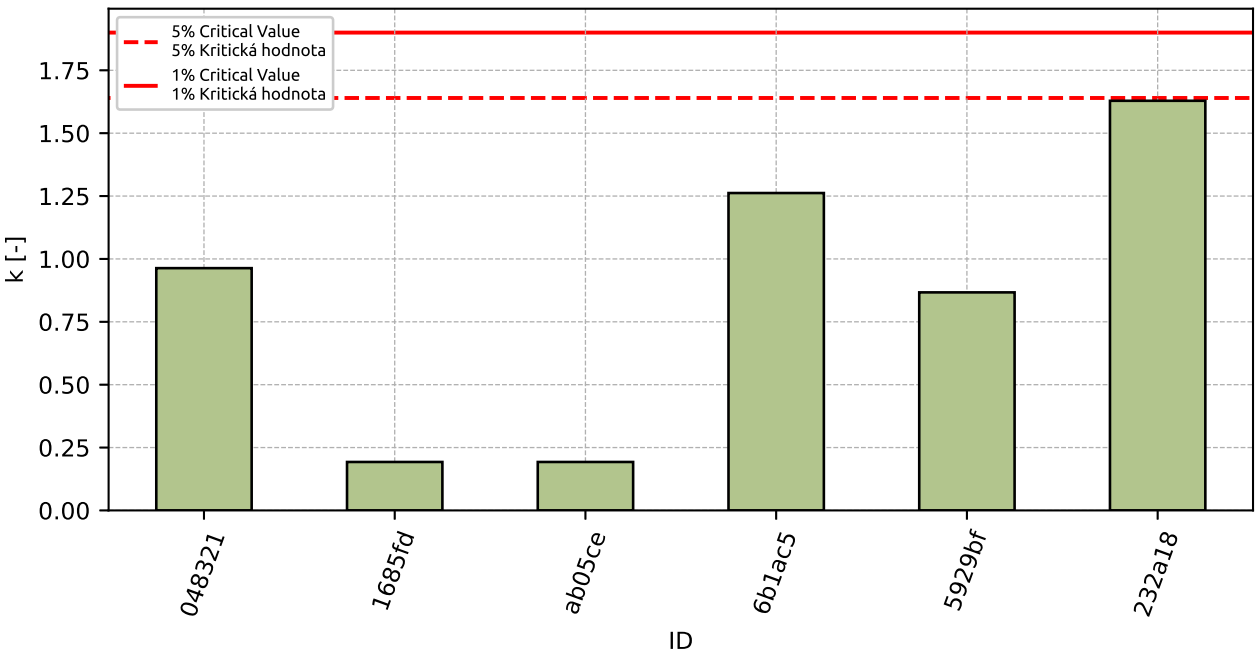

Figure 122: Intralaboratory Consistency Statistic

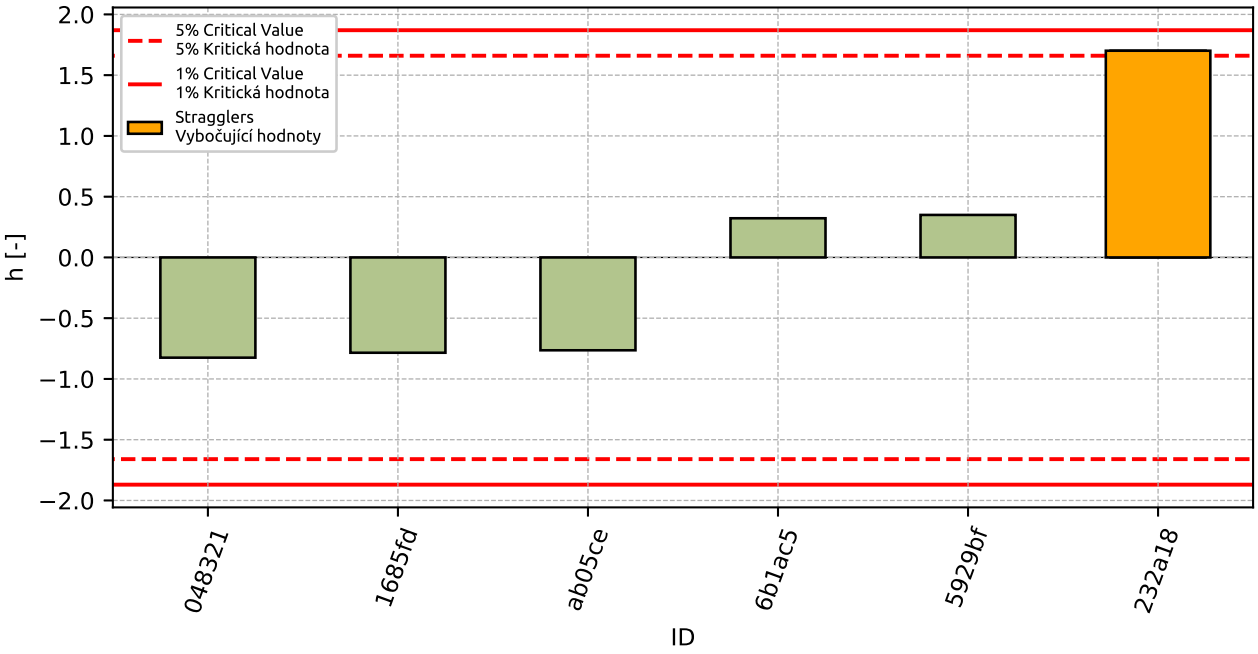

Figure 123: Interlaboratory Consistency Statistic

9.4 Descriptive statistics

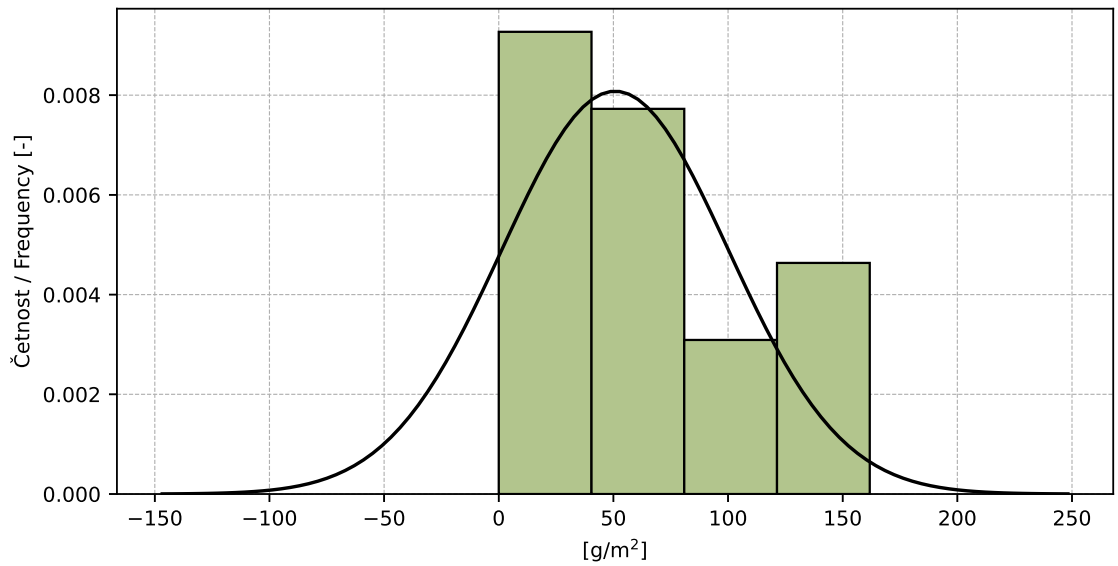

Figure 124: Histogram of all test results

Table 47: Descriptive statistics

Characteristics	[%]
Průměrná hodnota / Average value – $\bar{x}$	51.0
Výběrová směrodatná odchylka / Sample standard deviation – s	49.4
Vztažná hodnota / Asigned value – x^*	51.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	51.1
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	26.1
p-hodnota testu normality / p-value of normality test	1.0 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	48.8
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	14.7
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	51.0
Opakovatelnost / Repeatability – r	41.0
Reprodukovatelnost / Reproducibility – R	143.0

9.5 Evaluation of Performance Statistics

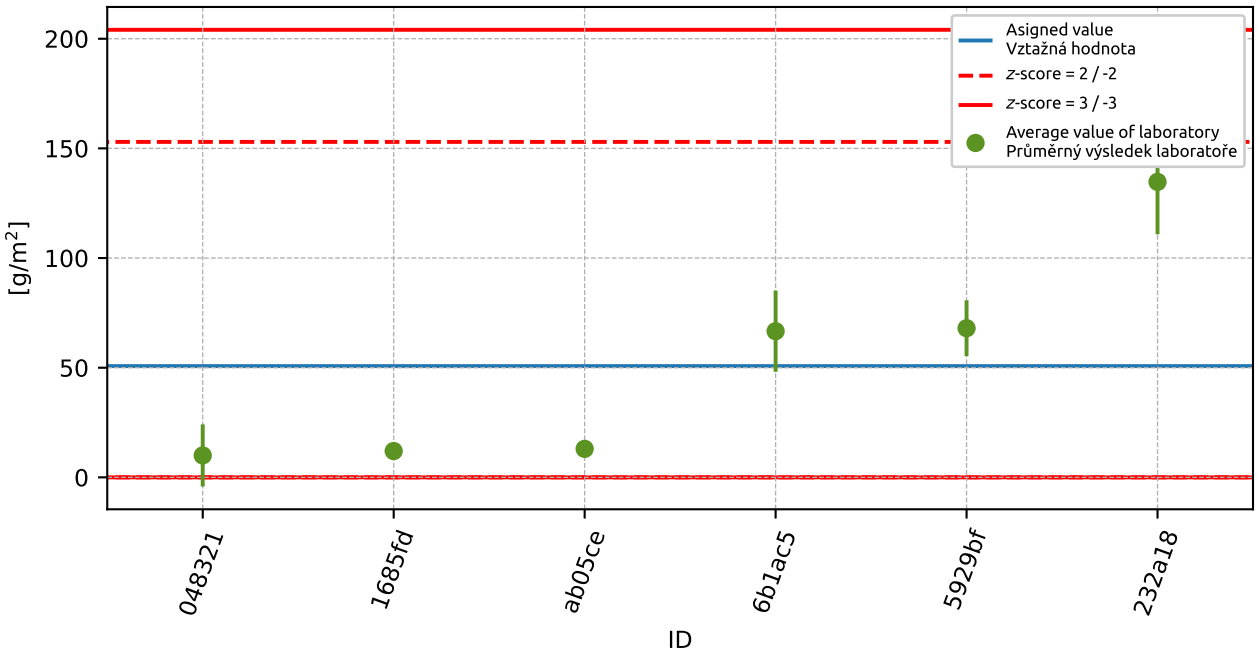

Figure 125: Average values and sample standard deviations

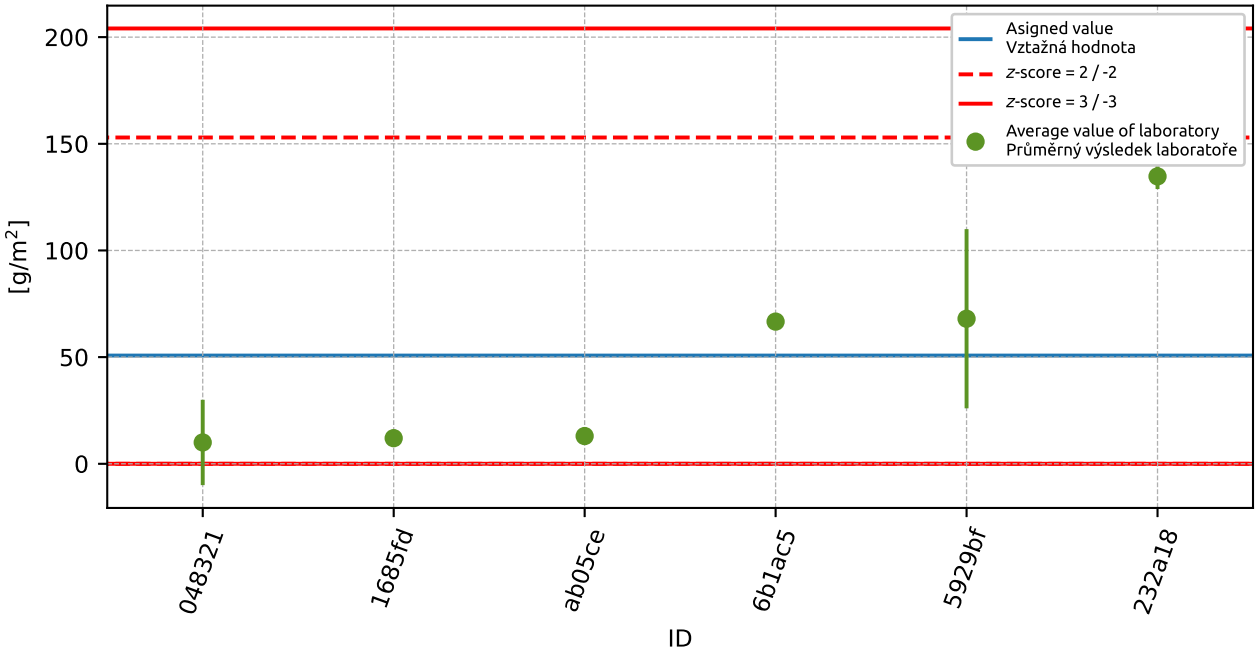

Figure 126: Average values and extended uncertainties of measurement

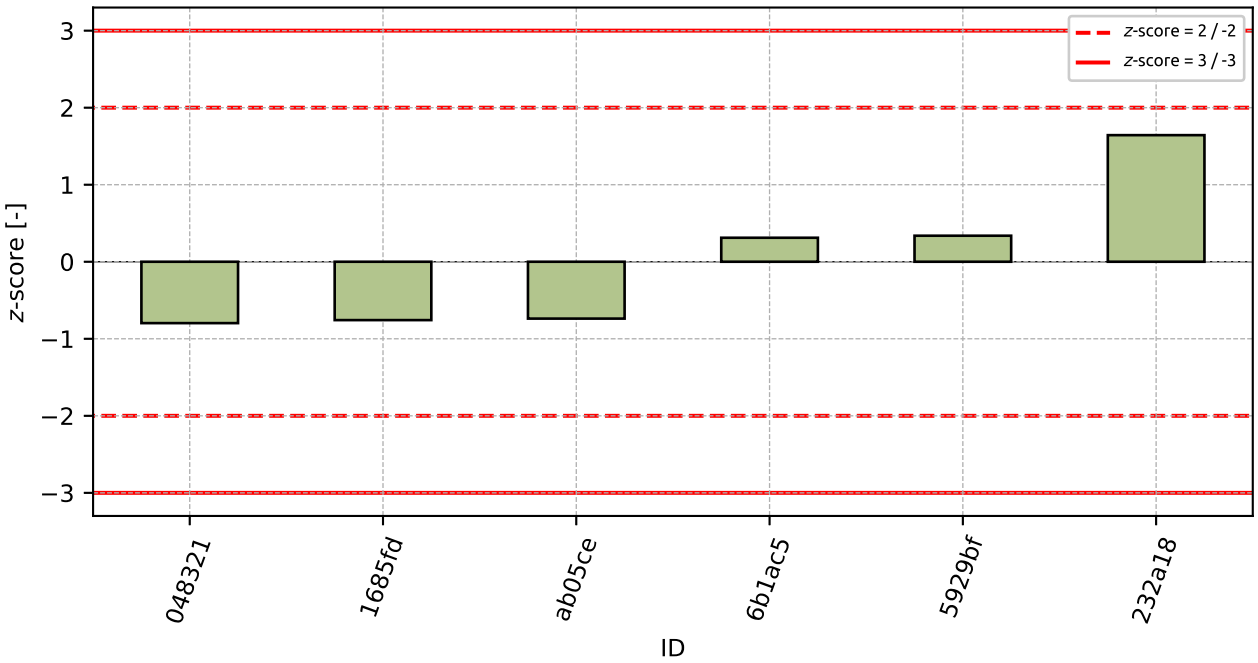

Figure 127: z-score

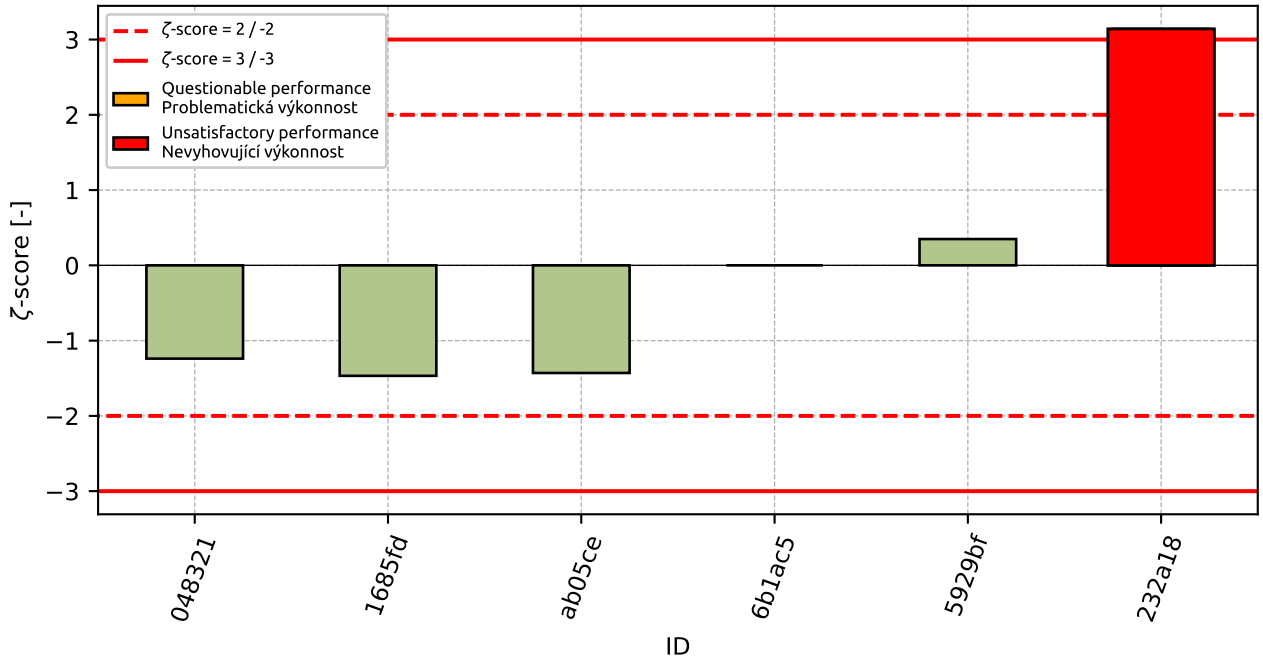

Figure 128: ζ-score

Table 48: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
048321	-0.8	-1.24
1685fd	-0.76	-1.47
ab05ce	-0.74	-1.43
6b1ac5	0.31	-
5929bf	0.34	0.35
232a18	1.64	3.14