BRNO UNIVERSITY OF TECHNOLOGY

Z 7008

FACULTY OF CIVIL ENGINEERING
institute of building testing

FINAL REPORT ON THE RESULTS OF PRECISION EXPERIMENT

Proficiency Testing Program
Strenght and Elasticity of Hardened Concrete
ZZB 2019/2

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1 Introduction and Important Contacts

In the year 2019, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZZB 2019/2 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

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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 12390-5** – Flexural strength of test specimens [2].
3. **EN 12390-6** – Tensile splitting strength of test specimens [3].
4. **EN 12390-7** – Density of hardened concrete [4].
5. **ISO 1920-10** – Determination of static modulus of elasticity in compression [5].
6. **EN 12390-13** – method A – Determination of secant modulus of elasticity in compression [6].
7. **EN 12390-13** – method B – Determination of secant modulus of elasticity in compression [6].
8. **EN 12504-4, ČSN 731371** – Non-destructive testing of concrete [7], [8].
9. **ČSN 731373, EN 12504-2** – Determination of rebound number [9], [10].
10. **EN 1542, ČSN 736242** – Appendix B – Measurement of bond strength by pull-off [11], [12].

Testing procedures No 6 – 8 were not open due to the low number 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 [13]. 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 [14] and with EN ISO/IEC 17043 [15]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

43 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/Method	1	2	3	4	5	6	7	8	9	10
900858	-	X	X	-	-	-	-	-	X	X
465f76	X	X	X	X	X	-	-	-	X	-
53579d	-	-	-	-	-	-	-	-	-	X
6f391d	-	-	X	-	-	-	-	-	-	-
b9fb9b	-	-	-	-	-	-	-	-	X	X
04fa2d	-	-	-	-	-	-	-	-	-	X
942572	X	X	-	-	-	-	-	-	X	X
f6bd93	X	X	X	X	-	-	-	-	X	-
736843	-	-	-	-	X	-	-	-	-	-
b3e025	X	-	-	-	-	-	-	-	-	X
a55d8a	X	X	X	X	-	-	-	-	-	-
433ef2	X	-	-	X	-	-	-	-	-	-
70bc11	X	X	-	X	X	-	-	-	-	-
4ef2c8	X	-	-	X	-	-	-	-	-	-
37d148	X	X	-	X	-	-	-	-	-	-
3eb7f4	X	-	-	X	-	-	-	-	-	-
6ea487	X	X	-	X	-	-	-	-	-	-
3d1003	-	-	-	-	-	-	-	-	-	X
6ea8c4	-	X	-	-	-	-	-	-	-	-
f4e14d	X	-	-	X	-	-	-	-	-	-
fca809	-	X	-	-	-	-	-	-	-	-
552a0e	-	-	-	-	-	-	-	-	X	X
6b093d	X	-	-	-	-	-	-	-	-	-
30b8d4	X	-	-	-	-	-	-	-	-	-
a78377	-	-	-	-	-	-	-	-	-	X
7a0f95	X	-	-	-	-	-	-	-	-	-
e63c8d	X	-	-	X	-	-	-	-	-	-
6d20e6	-	-	-	-	-	-	-	-	-	X
8d28dd	-	-	-	-	-	-	-	-	X	X
9c690e	-	-	-	-	-	-	-	-	X	-
26032f	X	X	-	X	-	-	-	-	X	X
6249f1	-	X	-	-	X	-	-	-	X	-
50bbc0	X	-	-	-	-	-	-	-	-	-
eb7928	-	-	-	-	-	-	-	-	X	-
5593ae	X	-	-	X	-	-	-	-	-	-
ed0db4	-	X	-	-	X	-	-	-	-	X
1d9b5e	-	X	-	X	-	-	-	-	X	X
937c97	X	X	X	X	-	-	-	-	X	X
b585e3	-	X	-	-	-	-	-	-	-	-
de4e03	-	-	-	-	X	-	-	-	-	-
cb17af	X	-	-	X	-	-	-	-	-	-
d551d0	-	-	-	-	X	-	-	-	-	-
6b6834	X	-	-	X	-	-	-	-	-	X

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

Laboratory	Address	Accreditation number
AG Institut d.o.o. Novi Sad	dr Djordja Joanovica 4, Novi Sad, 21000, Republika Srbija	01-457
BEST, a.s.	Lučice 87, Clumec nad Cidlinou, 50351, Česká republika	-
BETOTECH, s.r.o. - pracoviště Most	Beroun 660, Beroun, 26601, Česká republika	1195
BETOTECH, s.r.o.	Beroun 660, Beroun, 266 01, Česká republika	1195.3
BetónRacio, s.r.o., Skúšobné laboratórium, Pracovisko Lietavská Lúčka	Skladová 2, Trnava, 917 01, Slovenská republika	S-320
BetónRacio, s.r.o., Skúšobné laboratórium, Pracovisko Trnava	Skladová 2, Trnava, 917 01, Slovenská republika	S-320
BetónRacio, s.r.o., Skúšobné laboratórium, Pracovisko Veľký Šariš	Skladová 2, Trnava, 917 01, Slovenská republika	S-320
CEMEX Czech Republic, s.r.o.	Semtín 102, Pardubice, 53354, Česká republika	1302
CONSTRUCTION RESEARCH INSTITUTE OF MALAYSIA (CREAM)	LEVEL 29, SUNWAY PUTRA TOWER, NO 100, JALAN PUTRA, KUALA LUMPUR, 50350, KUALA LUMPUR	-
CONTROL-VHS-SK s.r.o.	Kamenná 14, Žilina, 010 01, Slovenská republika	437/S-317
CSS d.o.o.	Savska cesta 144a, Zagreb, 10000, Republika Hrvatska	HR 1106
Centrum dopravního výzkumu v.v.i.	Líšeňská 33a, Brno, 63600, Česká republika	1506
GEOSTAR, spol. s r.o.	Tuřanka 111, Brno, 627 00, Česká republika	1373
Geo Measuring & Analyses nv	Industriepark Rosteyne 1, Zelzate, 9060, Belgium	BELAC 296-TEST
Grean Consult BVBA	Winkelomseheide 223A, Geel, 2440, Belguim	Belac 575-TEST
Horský s.r.o.	Klánovická 286/ 12, Praha 9, 198 00, ČR	1207
Institut pro testování a certifikaci, a.s.	třída Tomáše Bati 5264, areál Svit, budova 113, Zlín, 760 01, Česká republika	1004
Itecons - Instituto de Investigação e Desenvolvimento Tecnológico para a Construção, Energia, Ambiente e Sustentatibilidade	Rua Pedro Hispano - Pinhal de Marrocos, Coimbra, 3030-289, Portugal	L0446
JKV TEST s.r.o.	Suhrady 148/4, Vřesina (u Hlučína), 74720, Česká republika	-
KARYDIS GEORIOS – DOMO+LYSISLAB	DISTOMOU 97, ATHENS, 10443, GREECE	-
Karla Ille	Janka Rakuše 1, Zagreb, 10000, Croatia	-
Koncept CB spol. s r.o.	nám. Švabinského 961/10, České Budějovice, 370 08, Česká republika	1534
Laboratoire Central des Travaux Publics - LCTP	1, rue Kaddour RAHIM - HUSSEIN DEY, ALGER, 16040, ALGERIE	-

Laboratory	Address	Accreditation number
MC-Bauchemie s.r.o.	Skandinávksá 990, Žebrák, 26753, Česká republika	208
Novostroy Control Ltd.	61, Todor Kableshkov Str., Sofia, 1680, Bulgaria	-
QUALIFORM SLOVAKIA s.r.o. - organizační složka - pracoviště BRNO	Lesní 693, Bílovice nad Svitavou, 66401, 28311060	S-301
SMP CZ, a.s. - Centrální laboratoř	Vyskočilova 1566, Praha 4, Michle, 140 00, Česká republika	1168
SQZ s.r.o.	U místní dráhy 939/5, Olomouc - Nová ulice, 779 00, Česká republika	1135.2
SQZ, s.r.o. - organizačná zložka Bratislava	Mlynské Nivy 68, Bratislava, 82105, Slovensko	566/S-376
Stachema CZ s.r.o., Zkušební laboratoř, Pracoviště 1	Hasičská 1, Zibohlavy, Kolín, 28002, Česká republika	L 1433
TESTAV-LAB s.r.o.	Chodská 7, Liberec 3, 460 10, Česká republika	1180
TPA EOOD CTC SOFIA	Rezbarska str. № 7, SOFIA, 1510, BULGARIA	-
TPA za obezbeđenje kvaliteta i inovacije d.o.o. Beograd	Milutina Milankovića 3B, Novi Beograd, 11070, Serbia	-
Testing Laboratory "LABKONSULT PLUS"Ltd.	kompl.Mladost-1, bl.43/vh.3/app.41, Sofia, 1784, BULGARIA	-
UAB "Testlita"	J. Basanavičiaus str. 160 D-2, Šiauliai, LT-76128, Lithuania	LA013
UNITE DE BOUIRA - Laboratoire Central des Travaux Publics	1, rue Kaddour RAHIM - HUSSEIN DEY, ALGER, 16040, ALGERIE	-
Universiteit Gent (Laboratorium Magnel voor Betononderzoek)	Technologiepark - Zwijnaarde 60, Zwijnaarde (Ghent), 9052, Belgium	220-TEST
Universität für Bodenkultur Wien, Department für Bautechnik und Naturgefahren, Institut für Konstruktiven Ingenieurbau	Peter Jordan Straße 82, Vienna, 1190, Austria	P0252
VIALAB CZ s.r.o.	MU CODE 1592, PO BOX 207, Praha 6, 160 41, Česká republika	1170
Z7008	Veveří 95, Brno, 60200, Česká republika	Z7008
Ústav stavebního zkušebnictví s.r.o.	Jiřího Potůčka 115, Pardubice, 53009, Česká republika	1115
Ředitelství silnic a dálnic ČR	Rebešovická 40, Brno-Chrlice, 643 00, Česká republika	1072
Ředitelství silnic a dálnic ČR, laboratoř Praha	Na Pankráci 546/56, Praha 4, 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.

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

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

3 Conclusions of the Statistical Analysis

The present report summarizes the results of the Proficiency Testing Program Strenght and Elasticity of Hardened Concrete (PT Program) organized by the PT Provider at the SZK FAST. 43 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of hardened concrete with emphasis on its strength and elasticity. 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	10
900858	-	✓	✓	-	-	-	-	-	✓	✓
465f76	✓	✓	✓	✓	✓	-	-	-	✓	-
53579d	-	-	-	-	-	-	-	-	-	✓
6f391d	-	-	✓	-	-	-	-	-	-	-
b9fb9b	-	-	-	-	-	-	-	-	✓	✓
04fa2d	-	-	-	-	-	-	-	-	-	✓
942572	✓	✓	-	-	-	-	-	-	✓	✓
f6bd93	✓	✓	✓	✓	-	-	-	-	✓	-
736843	-	-	-	-	✓	-	-	-	-	-
b3e025	✓	-	-	-	-	-	-	-	-	✓
a55d8a	✓	✓	✓	?	-	-	-	-	-	-
433ef2	✓	-	-	✓	-	-	-	-	-	-
70bc11	✓	✓	-	✓	✓	-	-	-	-	-
4ef2c8	!	-	-	✓	-	-	-	-	-	-
37d148	✓	✓	-	✓	-	-	-	-	-	-
3eb7f4	✓	-	-	✓	-	-	-	-	-	-
6ea487	✓	✓	-	✓	-	-	-	-	-	-
3d1003	-	-	-	-	-	-	-	-	-	✓
6ea8c4	-	✓	-	-	-	-	-	-	-	-

ID / Method	1	2	3	4	5	6	7	8	9	10
f4e14d	✓	-	-	✓	-	-	-	-	-	-
fca809	-	X	-	-	-	-	-	-	-	-
552a0e	-	-	-	-	-	-	-	-	✓	✓
6b093d	✓	-	-	-	-	-	-	-	-	-
30b8d4	✓	-	-	-	-	-	-	-	-	-
a78377	-	-	-	-	-	-	-	-	-	✓
7a0f95	✓	-	-	-	-	-	-	-	-	-
e63c8d	?	-	-	✓	-	-	-	-	-	-
6d20e6	-	-	-	-	-	-	-	-	-	✓
8d28dd	-	-	-	-	-	-	-	-	✓	✓
9c690e	-	-	-	-	-	-	-	-	✓	-
26032f	?	✓	-	✓	-	-	-	-	✓	✓
6249f1	-	✓	-	-	✓	-	-	-	✓	-
50bbc0	✓	-	-	-	-	-	-	-	-	-
eb7928	-	-	-	-	-	-	-	-	✓	-
5593ae	!	-	-	✓	-	-	-	-	-	-
ed0db4	-	✓	-	-	✓	-	-	-	-	✓
1d9b5e	-	✓	-	✓	-	-	-	-	✓	✓
937c97	✓	✓	✓	✓	-	-	-	-	✓	✓
b585e3	-	✓	-	-	-	-	-	-	-	-
de4e03	-	-	-	-	✓	-	-	-	-	-
cb17af	✓	-	-	✓	-	-	-	-	-	-
d551d0	-	-	-	-	✓	-	-	-	-	-
6b6834	✓	-	-	✓	-	-	-	-	-	✓

References

[1] EN 12390-3. *Testing hardened concrete - Part 3: Compressive strength of test specimens*. 2009.

[2] EN 12390-5. *Testing hardened concrete - Part 5: Flexural strength of test specimens*. 2009.

[3] EN 12390-6. *Testing hardened concrete - Part 6: Tensile splitting strength of test specimens*. 2010.

[4] EN 12390-7. *Testing hardened concrete - Part 7: Density of hardened concrete*. 2009.

[5] ISO 1920-10. *Testing of concrete - Part 10: Determination of static modulus of elasticity in compression*. 2016.

[6] EN 12390-13. *Testing hardened concrete - Part 13: Determination of secant modulus of elasticity in compression*. 2014.

[7] EN 12504-4. *Testing concrete - Part 4: Determination of ultrasonic pulse velocity*. 2005.

[8] ČSN 731371. *Non-destructive testing of concrete - Method of ultrasonic pulse testing of concrete*. 2011.

[9] ČSN 731373. *Non-destructive testing of concrete - Determination of compressive strength by hardness testing methods*. 2011.

[10] EN 12504-2. *Testing concrete in structures - Part 2: Non-destructive testing - Determination of rebound number*. 2013.

[11] EN 1542. *Products and systems for the protection and repair of concrete structures - Test methods - Measurement of bond strength by pull-off*. 2000.

[12] ČSN 736242. *Design and construction of pavements on road bridges*. 2010.

[13] EN 206. *Concrete - Specification, performance, production and conformity*. 2014.

[14] 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.

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

[16] ISO 13 528. *Statistical methods for use in proficiency testing by interlaboratory comparisons*. 2005.

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 [%]
5593ae	34.0	33.1	33.3	0.4	33.5	0.47	1.41
4ef2c8	35.4	34.3	34.3	0.3	34.7	0.59	1.71
26032f	32.7	36.7	36.7	3.0	35.4	2.31	6.53
e63c8d	37.1	34.7	35.8	0.5	35.9	1.2	3.35
433ef2	37.3	37.5	33.3	6.1	36.0	2.37	6.58
a55d8a	35.0	36.5	38.6	1.5	36.7	1.81	4.93
3eb7f4	37.8	36.0	36.9	-	36.9	0.9	2.44
f4e14d	36.9	37.2	37.9	2.4	37.3	0.51	1.37
37d148	37.3	37.0	38.9	-	37.7	1.02	2.71
cb17af	37.3	37.9	38.1	0.5	37.8	0.43	1.15
6b093d	37.8	37.3	38.3	0.3	37.8	0.5	1.32
30b8d4	38.0	38.2	37.4	0.3	37.9	0.42	1.1
50bbc0	38.2	36.8	38.7	0.2	37.9	0.96	2.53
7a0f95	37.5	38.8	37.5	3.0	37.9	0.75	1.98
f6bd93	37.1	39.7	37.5	3.9	38.1	1.4	3.67
6b6834	37.1	37.5	39.8	0.3	38.1	1.46	3.82
465f76	38.3	37.9	38.6	0.0	38.3	0.35	0.92
937c97	38.1	37.7	39.1	2.1	38.3	0.72	1.88
b3e025	38.8	38.2	38.2	1.5	38.4	0.35	0.9
942572	39.1	37.8	38.7	1.0	38.5	0.67	1.73
6ea487	36.9	40.5	38.2	-	38.5	1.82	4.73
70bc11	40.1	38.6	38.3	1.8	39.0	0.96	2.47

1.2 The Numerical Procedure for Determining Outliers

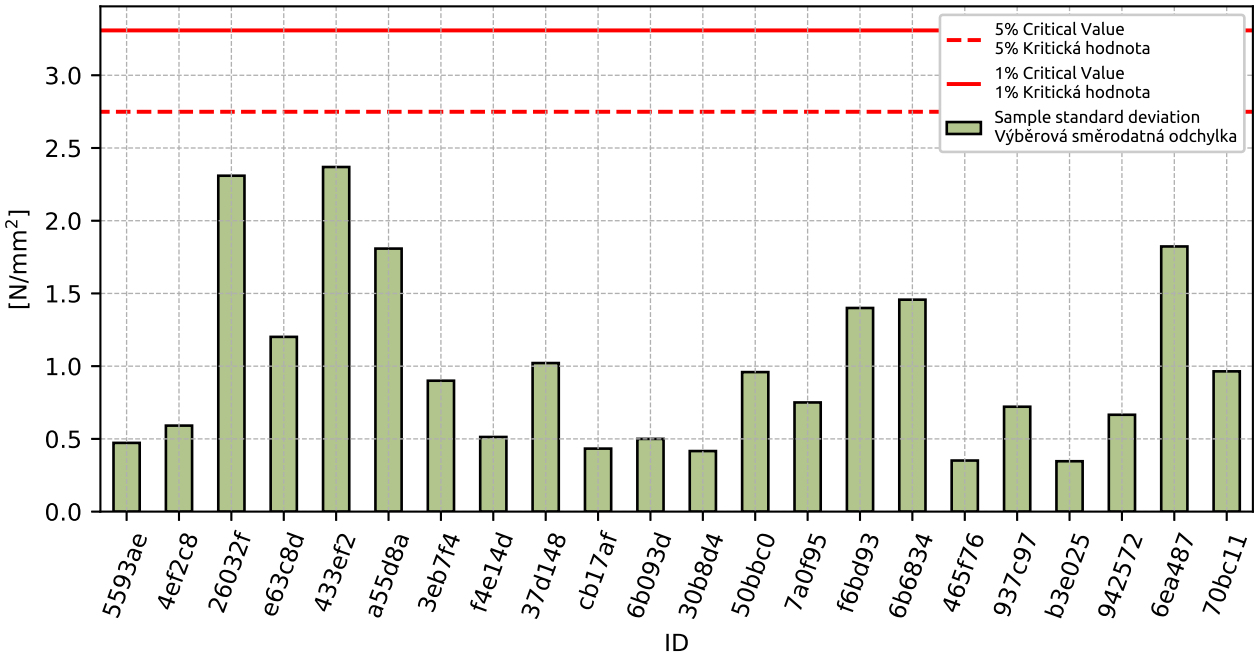

Figure 1: **Cochran's test** - sample standard deviations

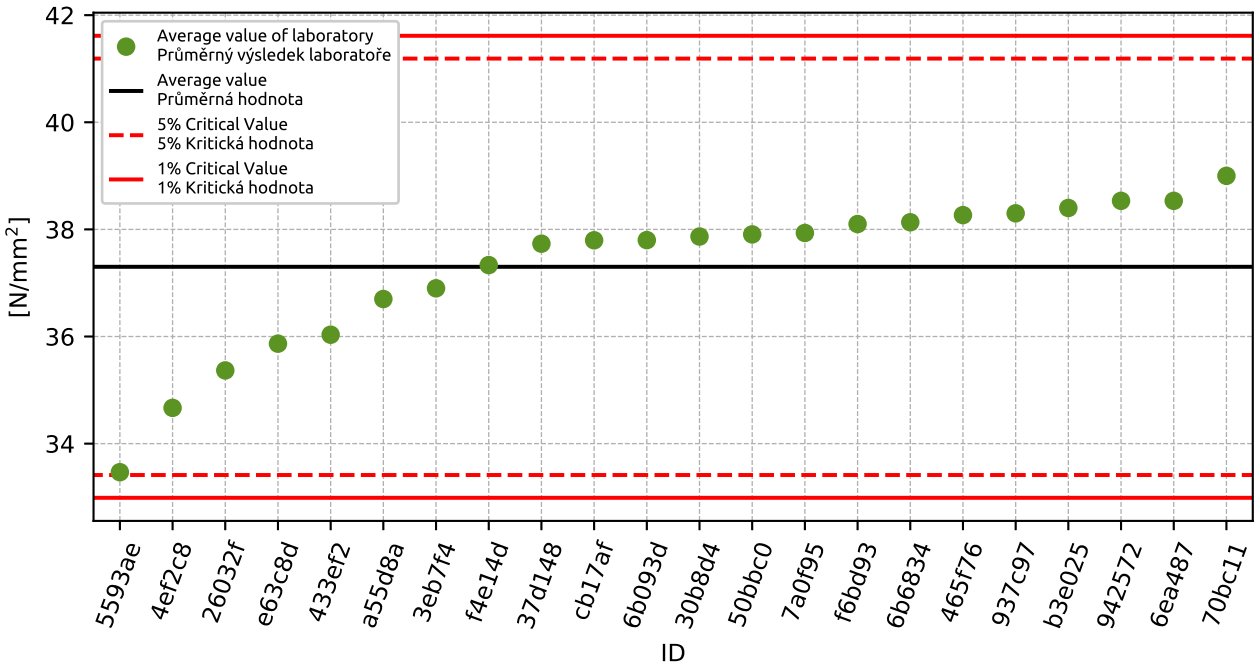

Figure 2: **Grubbs' test** - average values

1.3 Mandel's Statistics

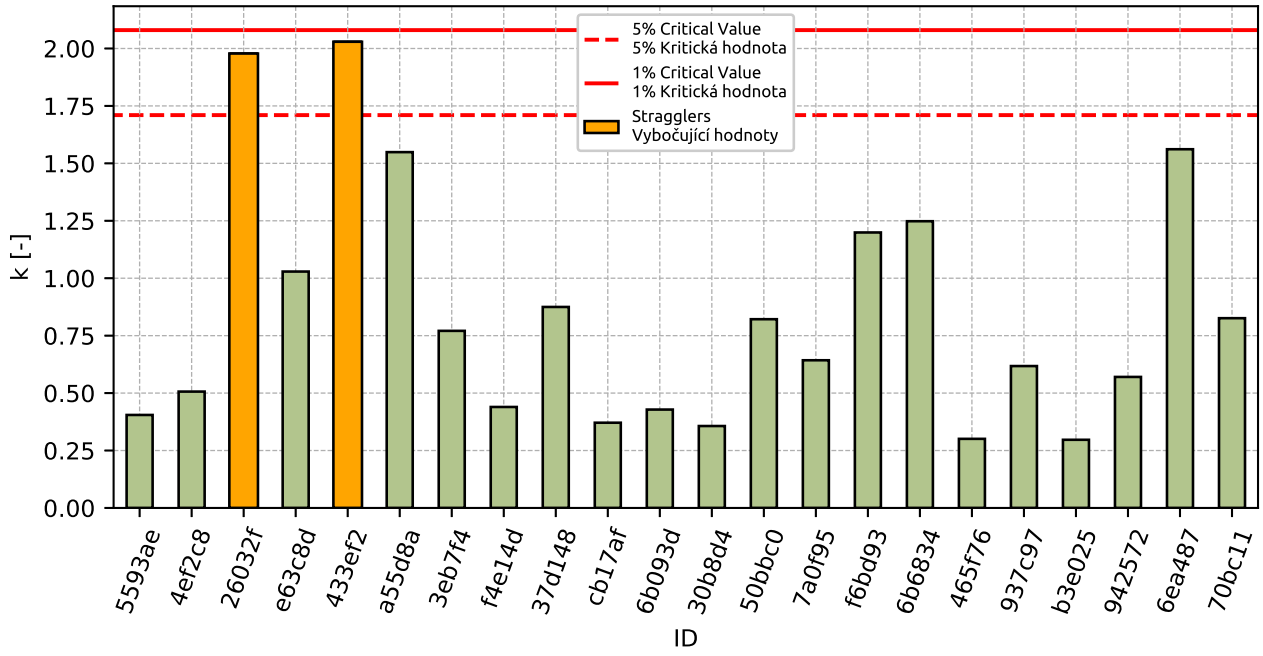

Figure 3: Intralaboratory Consistency Statistic

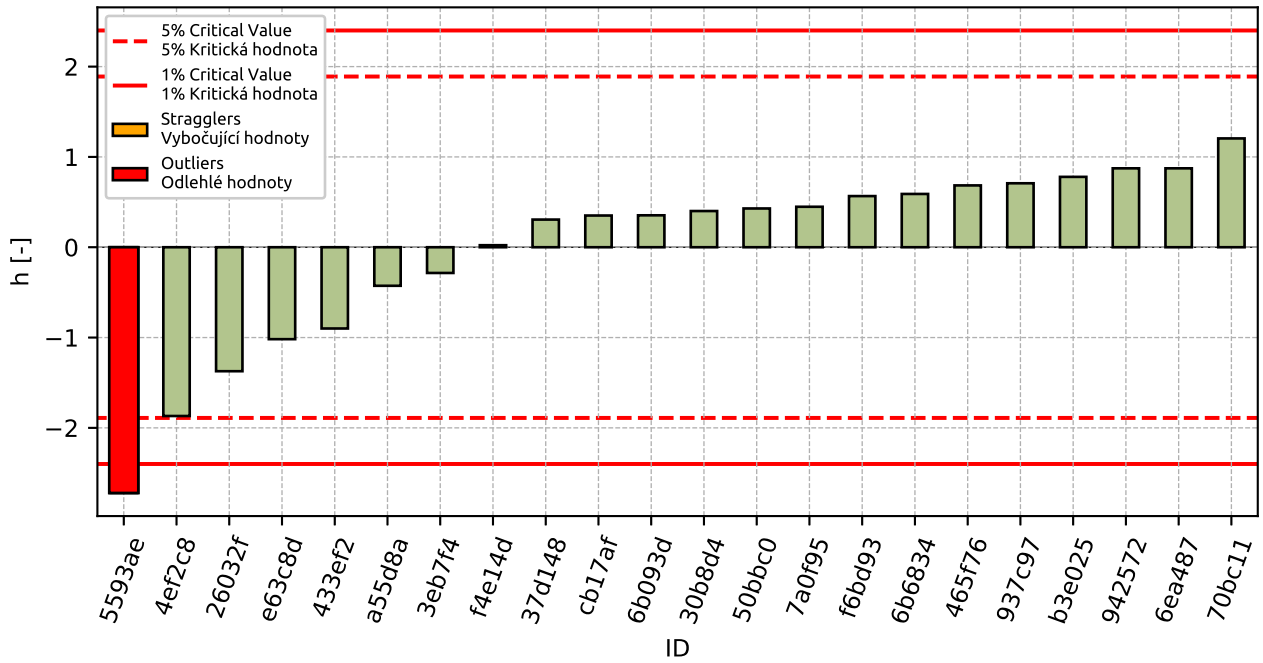

Figure 4: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

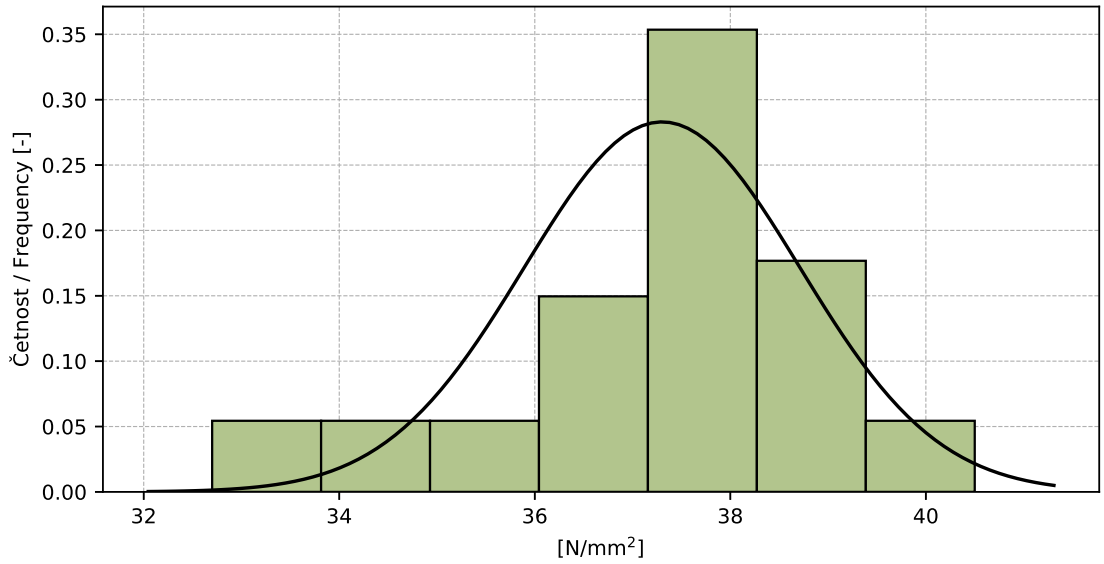

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	**[N/mm²]**
Průměrná hodnota / Average value – $\bar{x}$	37.3
Výběrová směrodatná odchylka / Sample standard deviation – s	1.41
Vztažná hodnota / Asigned value – x^*	37.7
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.84
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.22
p-hodnota testu normality / p-value of normality test	0.003 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	1.24
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	1.17
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	1.7
Opakovatelnost / Repeatability – r	3.3
Reprodukovatelnost / Reproducibility – R	4.8

1.5 Evaluation of Performance Statistics

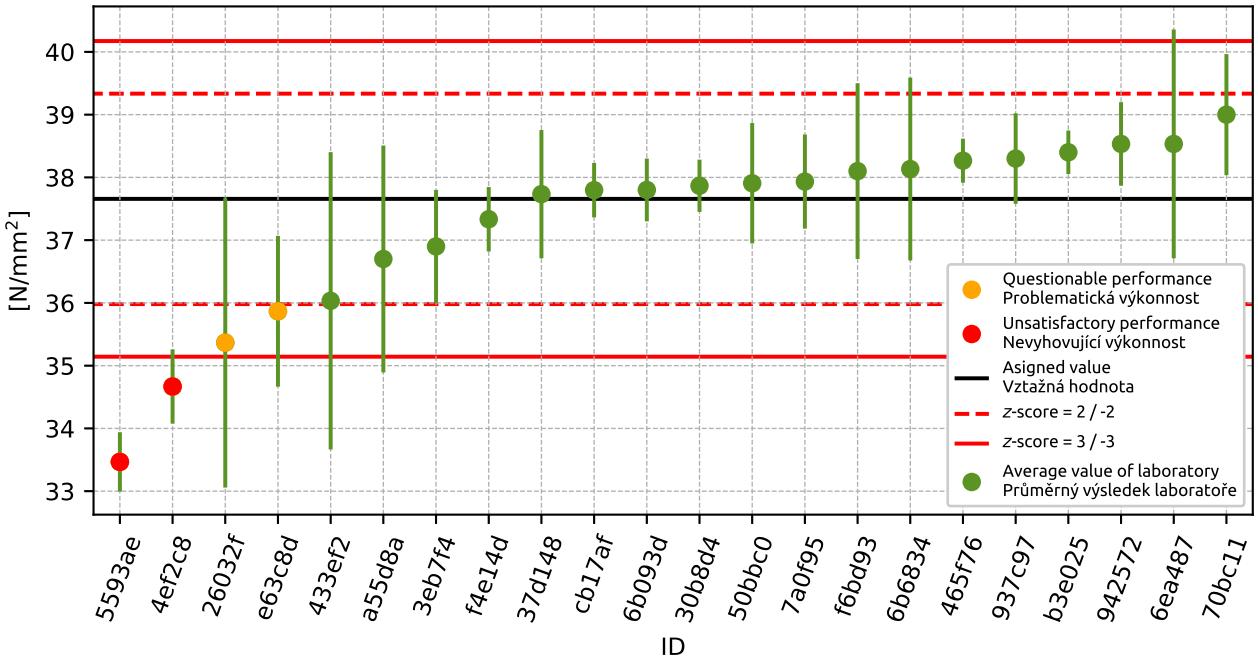

Figure 6: Average values and sample standard deviations

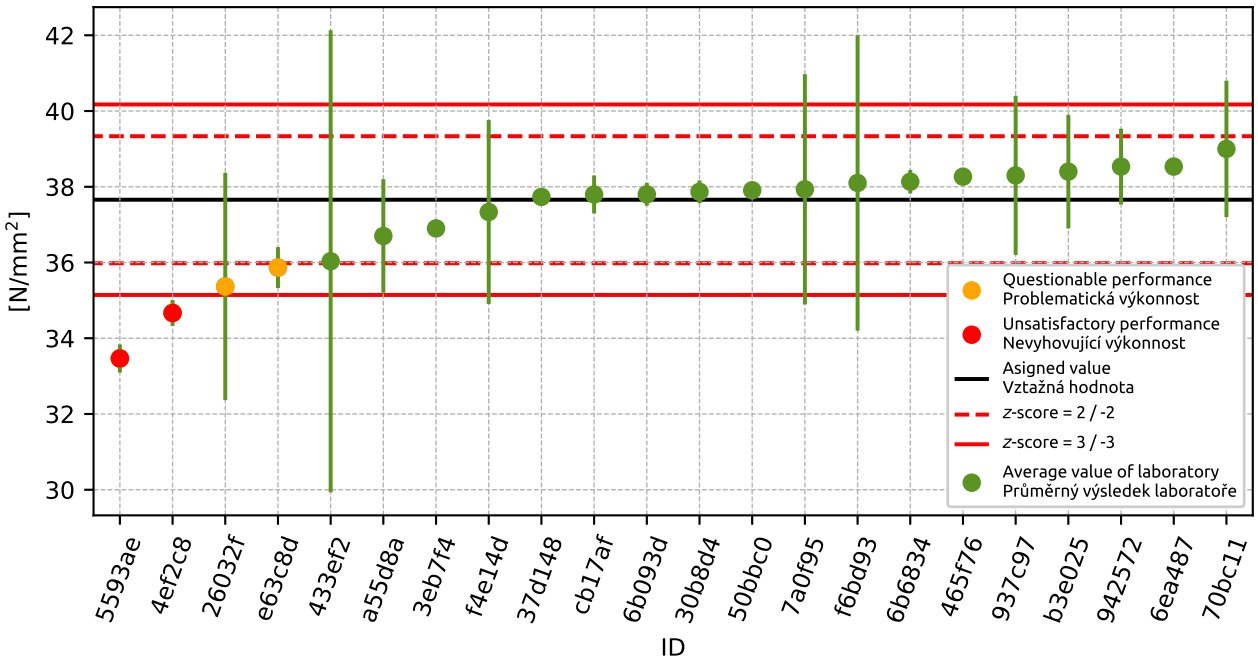

Figure 7: Average values and extended uncertainties of measurement

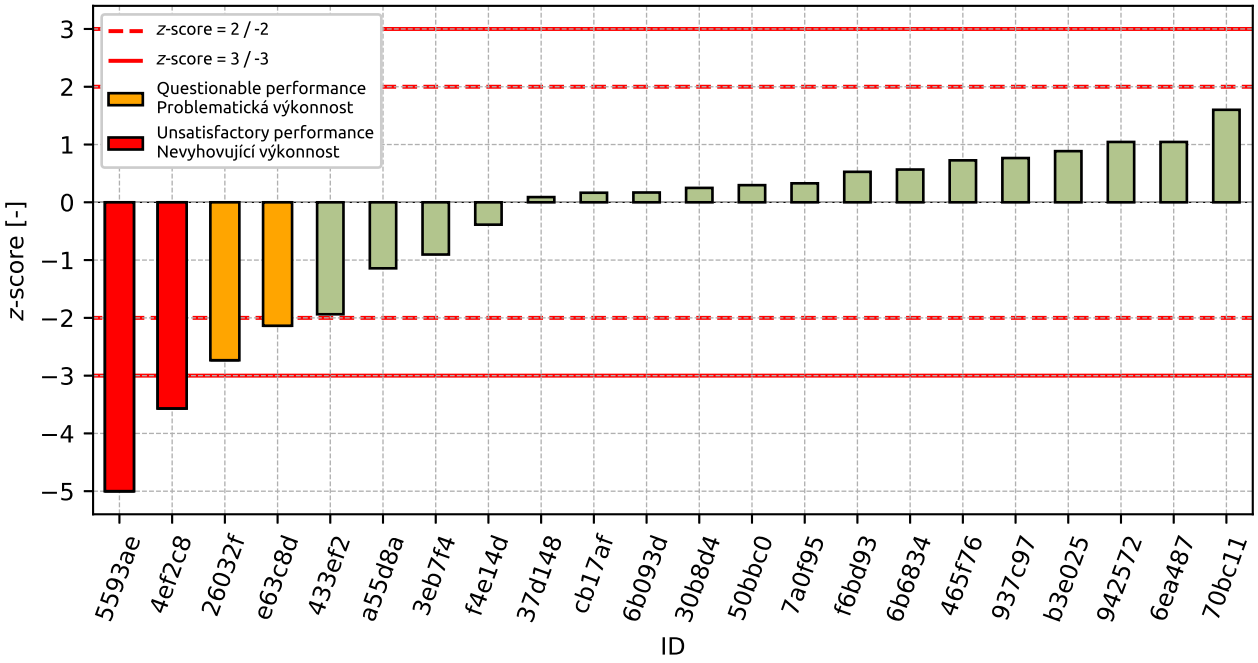

Figure 8: z-score

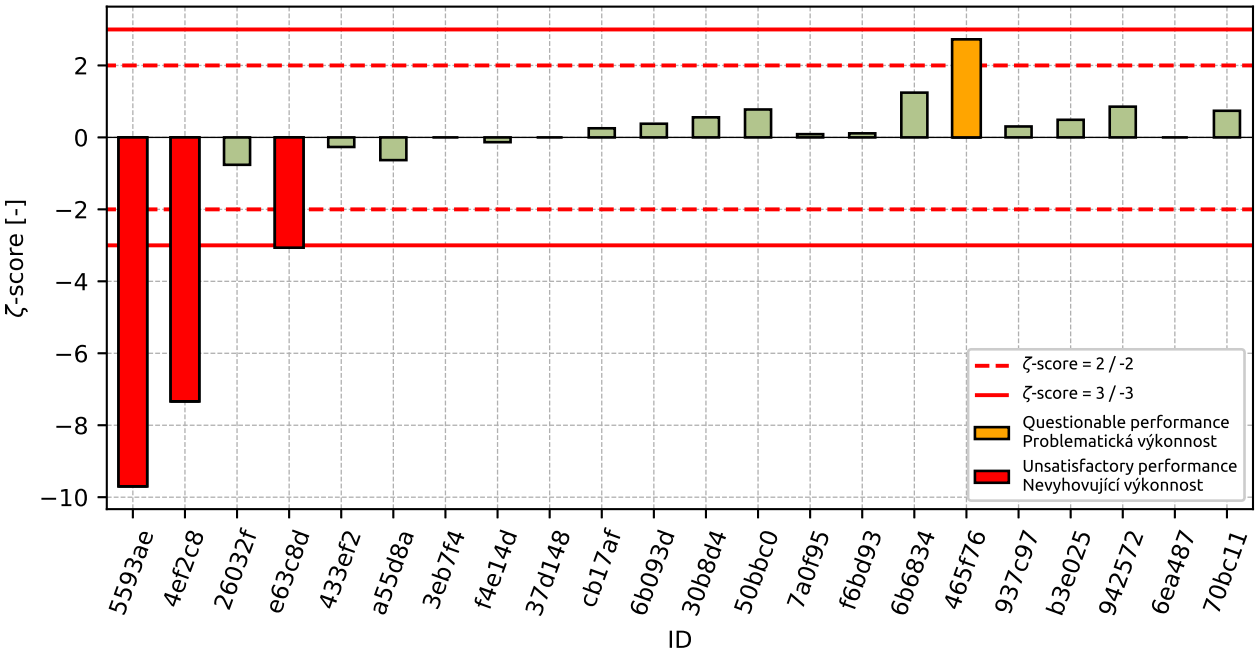

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
5593ae	-5.0	-9.7
4ef2c8	-3.57	-7.33
26032f	-2.73	-0.76
e63c8d	-2.14	-3.06
433ef2	-1.94	-0.27
a55d8a	-1.14	-0.63
3eb7f4	-0.9	-
f4e14d	-0.39	-0.13
37d148	0.09	-
cb17af	0.17	0.25
6b093d	0.17	0.38
30b8d4	0.25	0.56
50bbc0	0.3	0.78
7a0f95	0.33	0.09
f6bd93	0.53	0.11
6b6834	0.57	1.24
465f76	0.73	2.73
937c97	0.77	0.3
b3e025	0.89	0.49
942572	1.04	0.85
6ea487	1.04	-
70bc11	1.6	0.74

2 Appendix – EN 12390-5 – Flexural strength of test specimens

2.1 Test results

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

ID	Test results [N/mm^2]			u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
a55d8a	3.3	3.5	3.6	1.2	3.5	0.15	4.41
ed0db4	3.5	3.8	3.4	0.7	3.6	0.21	5.84
37d148	3.9	3.9	4.4	-	4.1	0.29	7.1
b585e3	4.2	4.0	4.1	0.3	4.1	0.1	2.44
900858	4.2	4.1	4.2	0.2	4.2	0.06	1.39
6249f1	4.4	4.4	4.6	0.3	4.5	0.12	2.59
937c97	4.2	4.8	4.4	0.1	4.5	0.31	6.84
6ea487	4.6	4.7	4.5	-	4.6	0.1	2.17
465f76	5.1	4.7	4.5	-	4.8	0.31	6.41
70bc11	4.6	4.2	5.5	0.1	4.8	0.67	13.97
26032f	5.0	4.6	5.0	0.4	4.8	0.23	4.85
6ea8c4	5.1	4.8	4.6	-	4.8	0.25	5.21
942572	4.9	4.7	5.0	0.1	4.9	0.15	3.14
1d9b5e	4.6	5.2	4.8	0.1	4.9	0.31	6.28
f6bd93	5.3	5.0	5.5	1.0	5.3	0.25	4.78
fca809	6.9	8.1	7.4	0.0	7.5	0.6	8.07

2.2 The Numerical Procedure for Determining Outliers

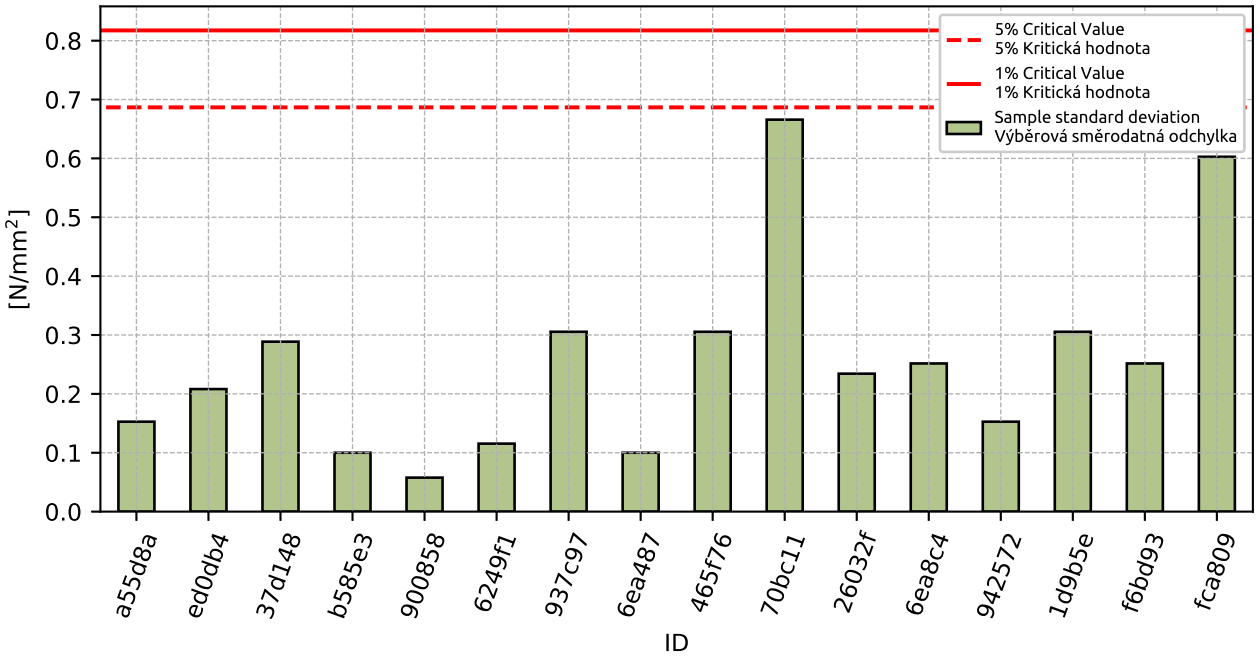

Figure 10: **Cochran's test** - sample standard deviations

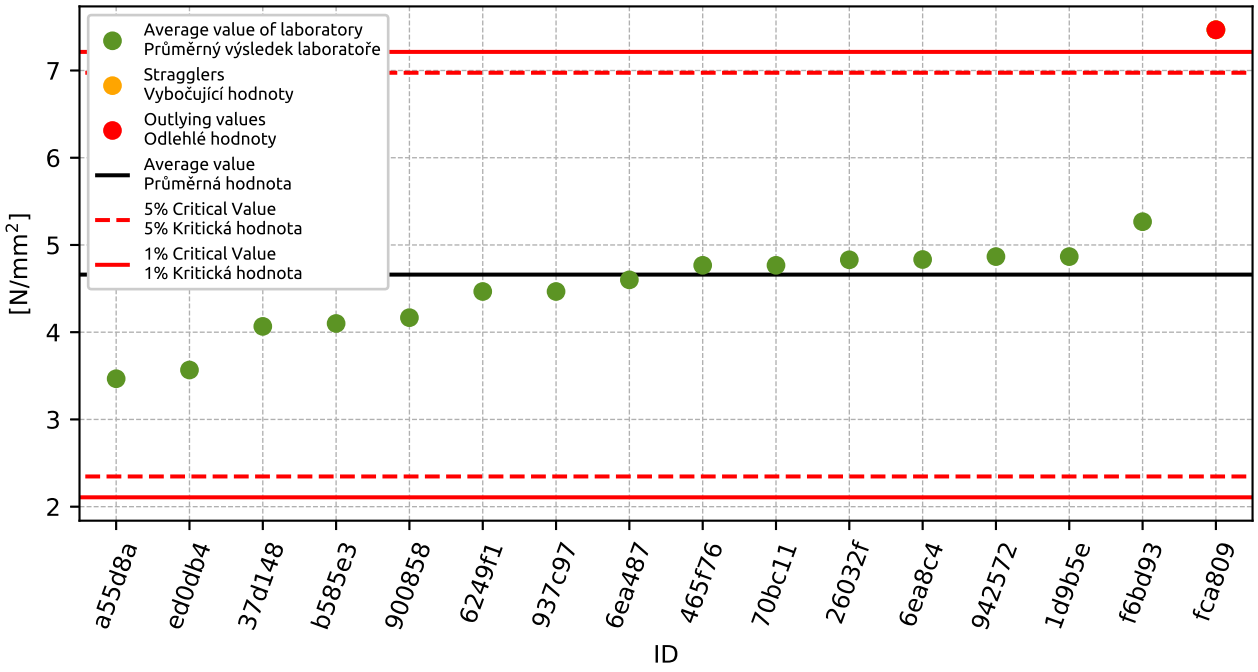

Figure 11: **Grubbs' test** - average values

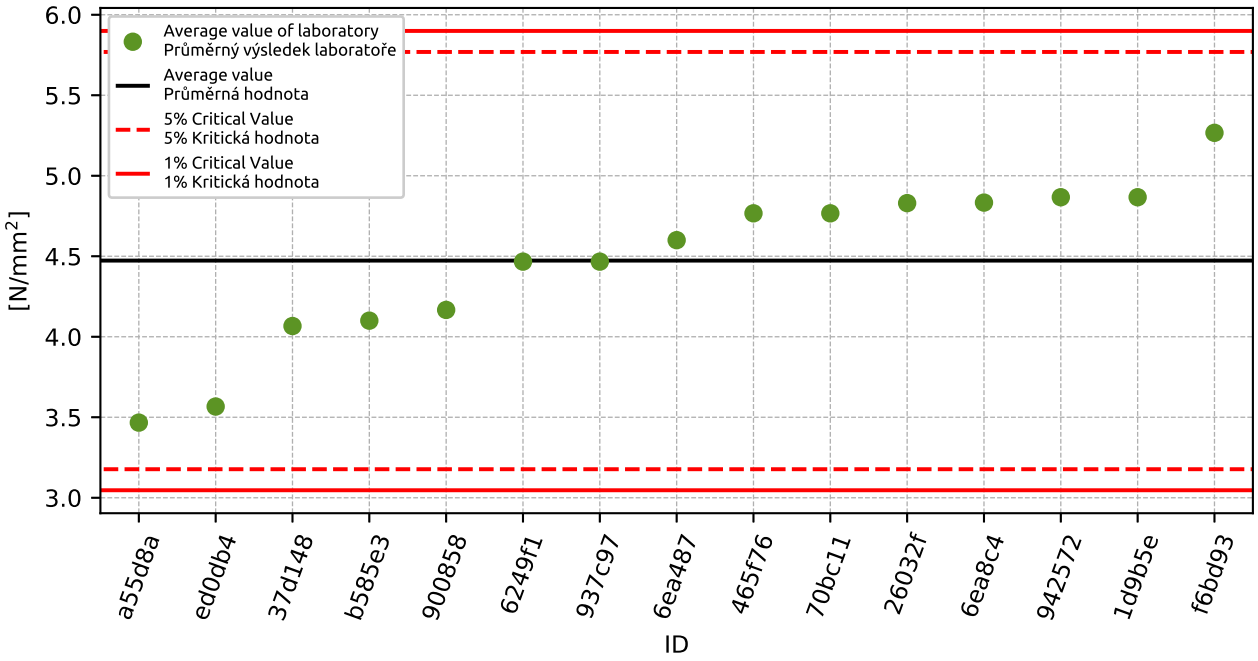

Figure 12: **Grubbs' test** - average values without outliers

2.3 Mandel's Statistics

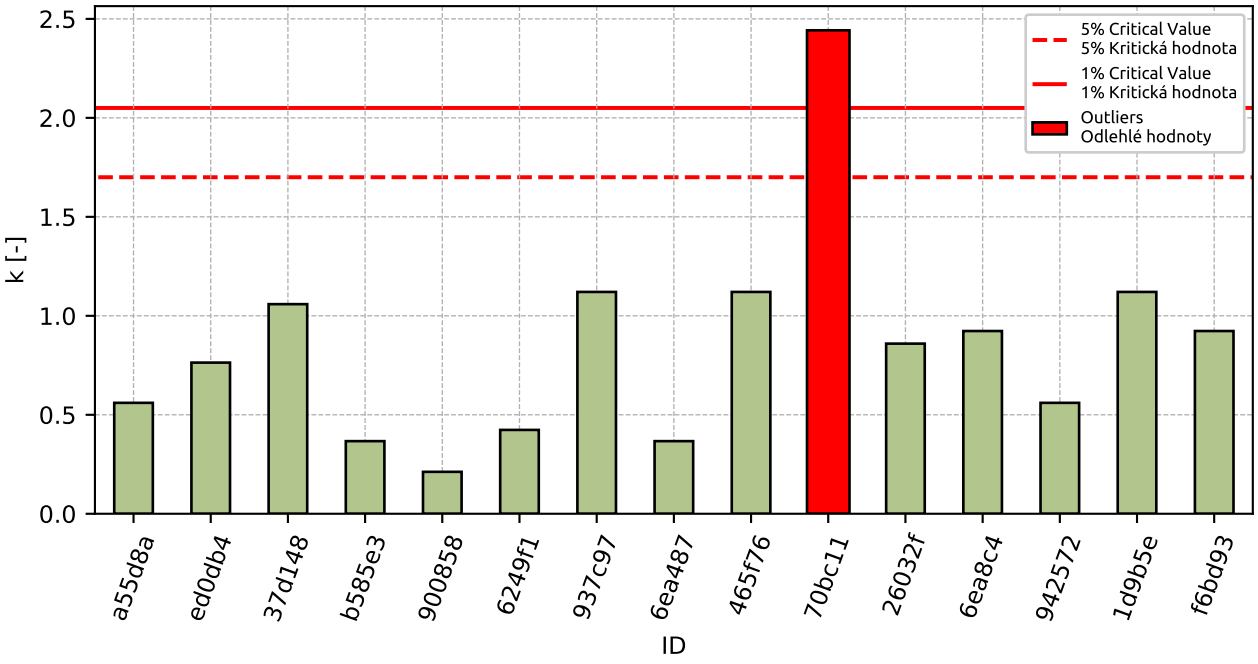

Figure 13: Intralaboratory Consistency Statistic

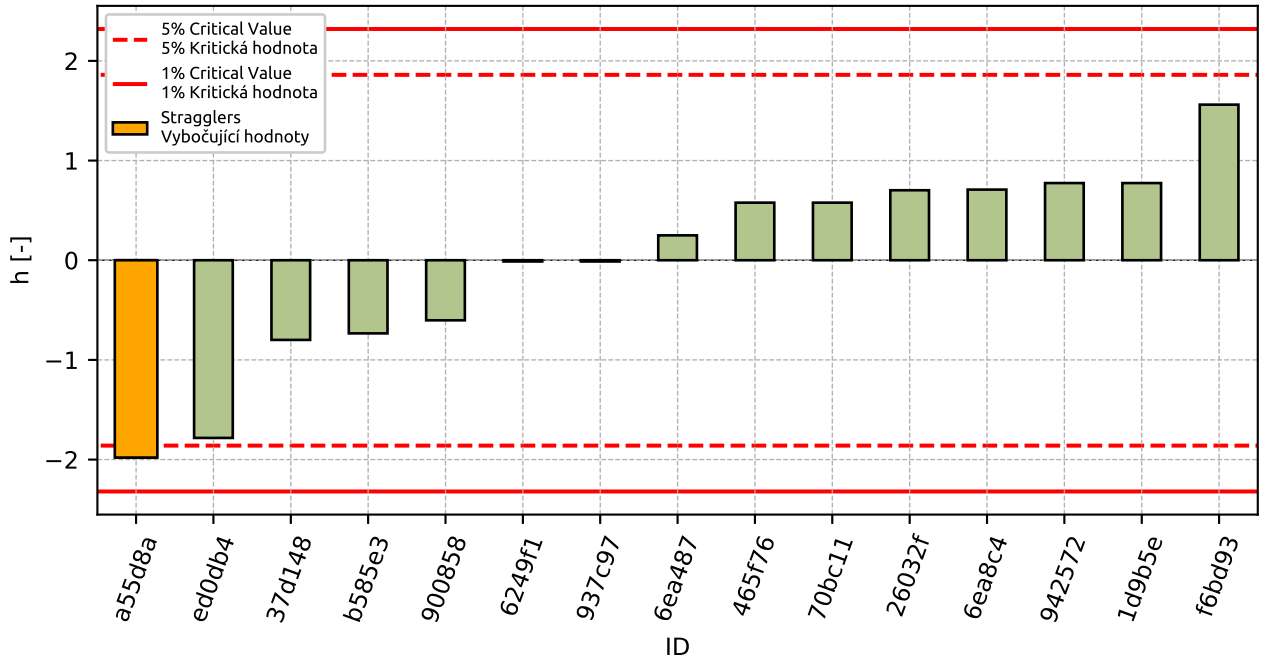

Figure 14: Interlaboratory Consistency Statistic

2.4 Descriptive statistics

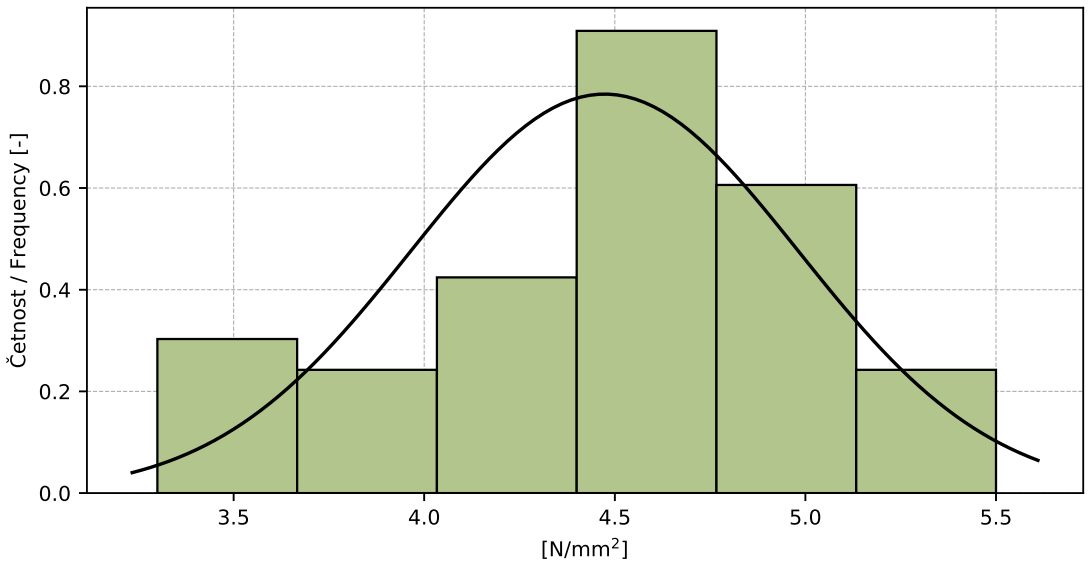

Figure 15: Histogram of all test results

Table 8: Descriptive statistics

Value	[N/mm^2]
Průměrná hodnota / Average value – $\bar{x}$	4.5
Výběrová směrodatná odchylka / Sample standard deviation – s	0.51
Vztažná hodnota / Asigned value – x^*	4.5
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.43
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.14
p-hodnota testu normality / p-value of normality test	0.645 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.48
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.27
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.55
Opakovatelnost / Repeatability – r	0.8
Reprodukovatelnost / Reproducibility – R	1.6

2.5 Calculation of Performance Statistics

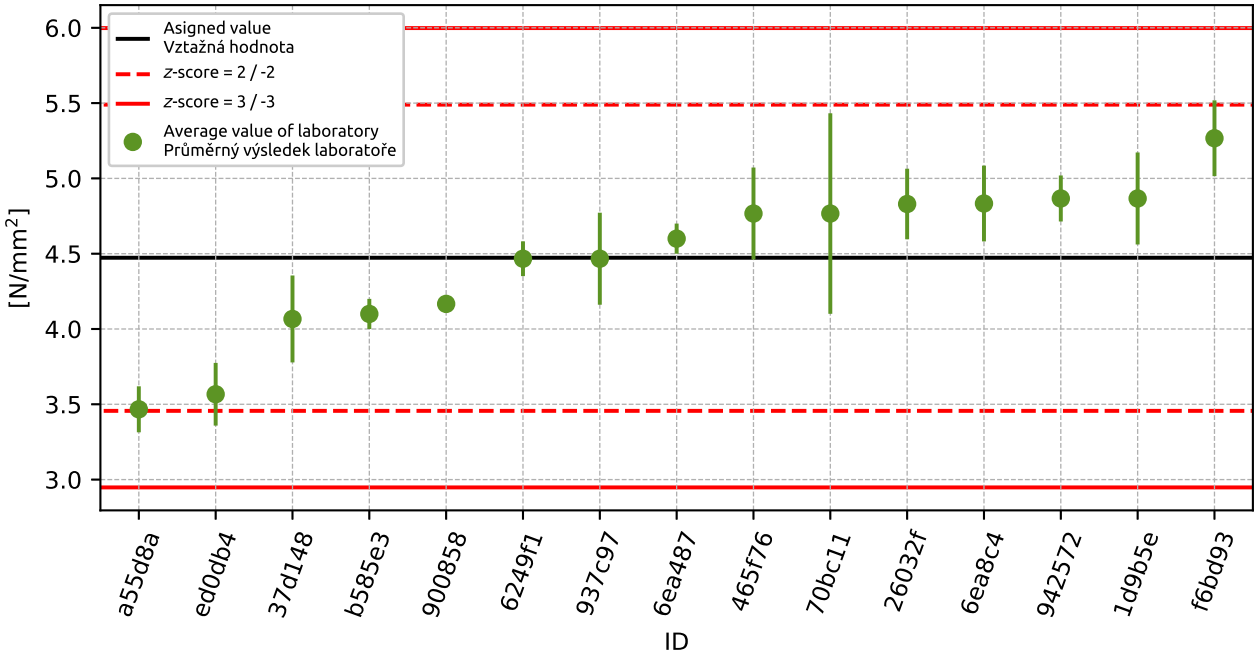

Figure 16: Average values and sample standard deviations

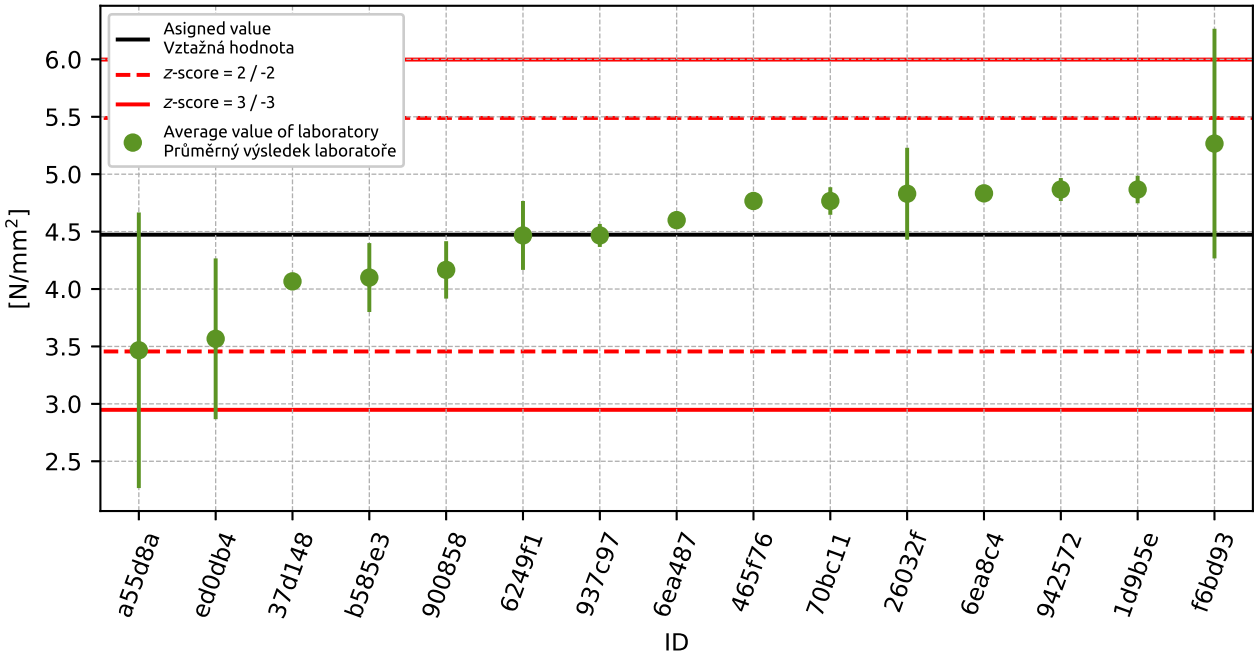

Figure 17: Average values and extended uncertainties of measurement

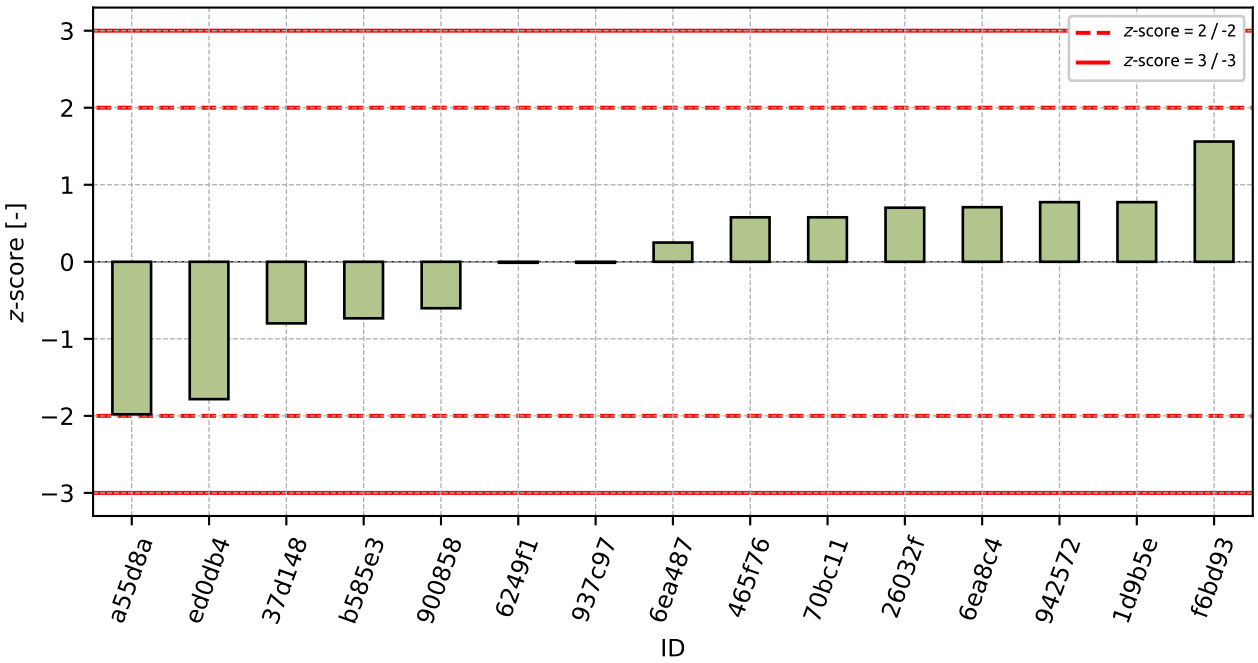

Figure 18: z-score

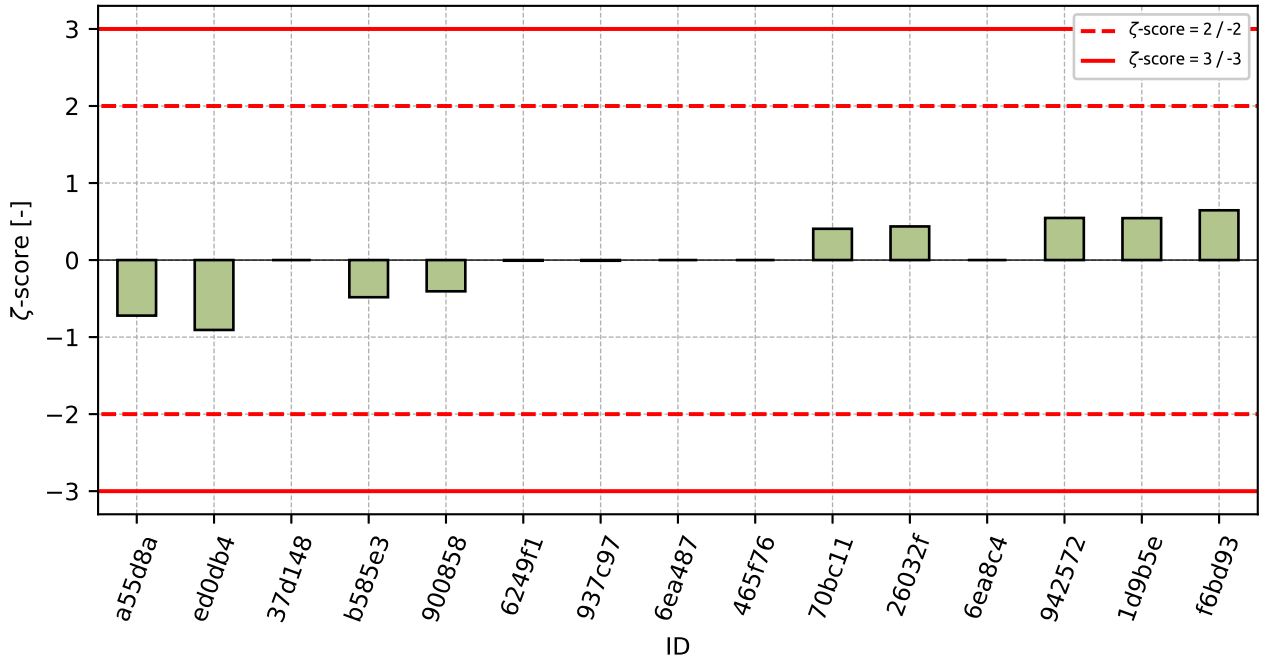

Figure 19: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a55d8a	-1.98	-0.72
ed0db4	-1.78	-0.91
37d148	-0.8	-
b585e3	-0.73	-0.48
900858	-0.6	-0.41
6249f1	-0.01	-0.01
937c97	-0.01	-0.01
6ea487	0.25	-
465f76	0.58	-
70bc11	0.58	0.41
26032f	0.7	0.44
6ea8c4	0.71	-
942572	0.77	0.55
1d9b5e	0.77	0.54
f6bd93	1.56	0.65

3 Appendix – EN 12390-6 – Tensile splitting strength of test specimens

3.1 Test results

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

ID	Test results [N/mm^2]			u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
937c97	3.09	2.83	3.06	0.14	2.99	0.142	4.75
f6bd93	3.05	3.15	3.2	-	3.13	0.076	2.44
465f76	2.95	3.0	3.65	-	3.2	0.391	12.2
a55d8a	3.29	3.26	3.34	0.1	3.3	0.04	1.23
6f391d	3.5	3.17	3.24	0.1	3.3	0.174	5.26
900858	3.4	3.4	3.55	0.25	3.45	0.087	2.51

3.2 The Numerical Procedure for Determining Outliers

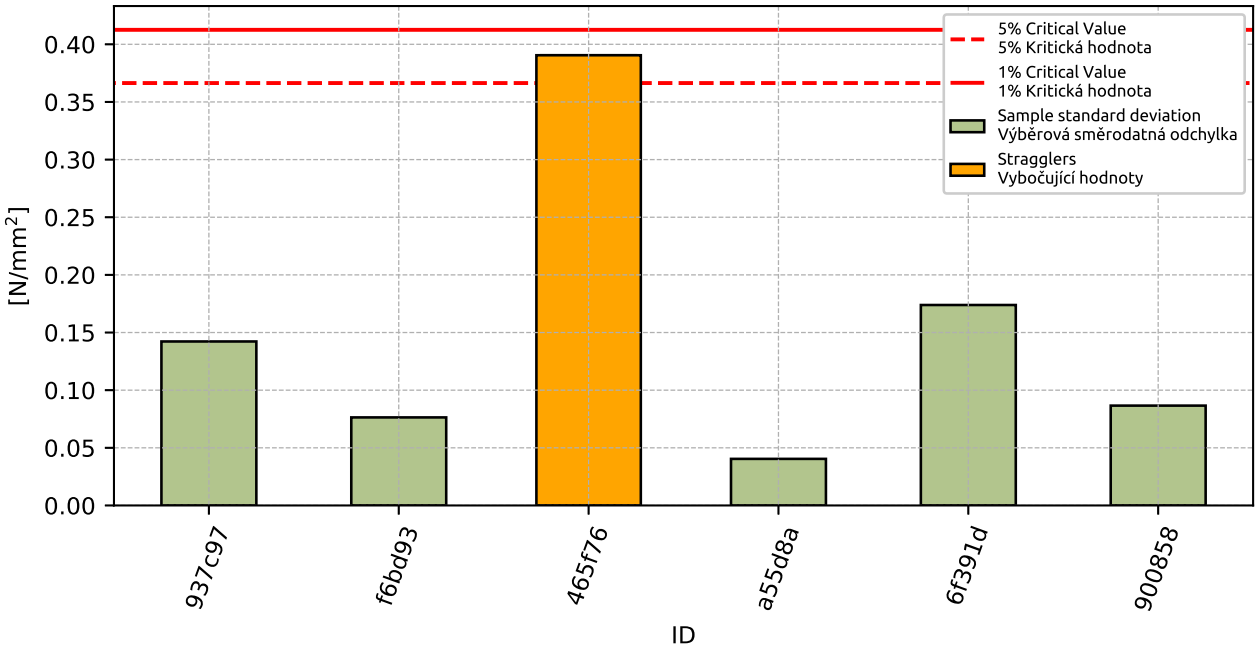

Figure 20: **Cochran's test** - sample standard deviations

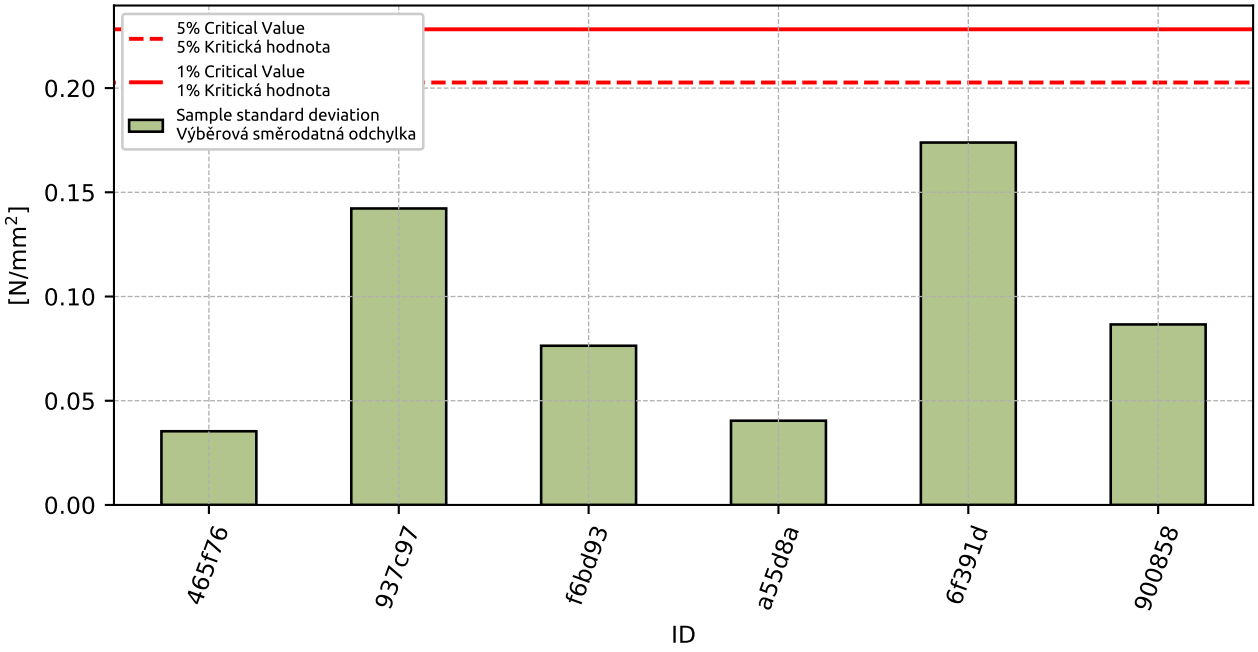

Figure 21: **Cochran's test** - sample standard deviations without outliers

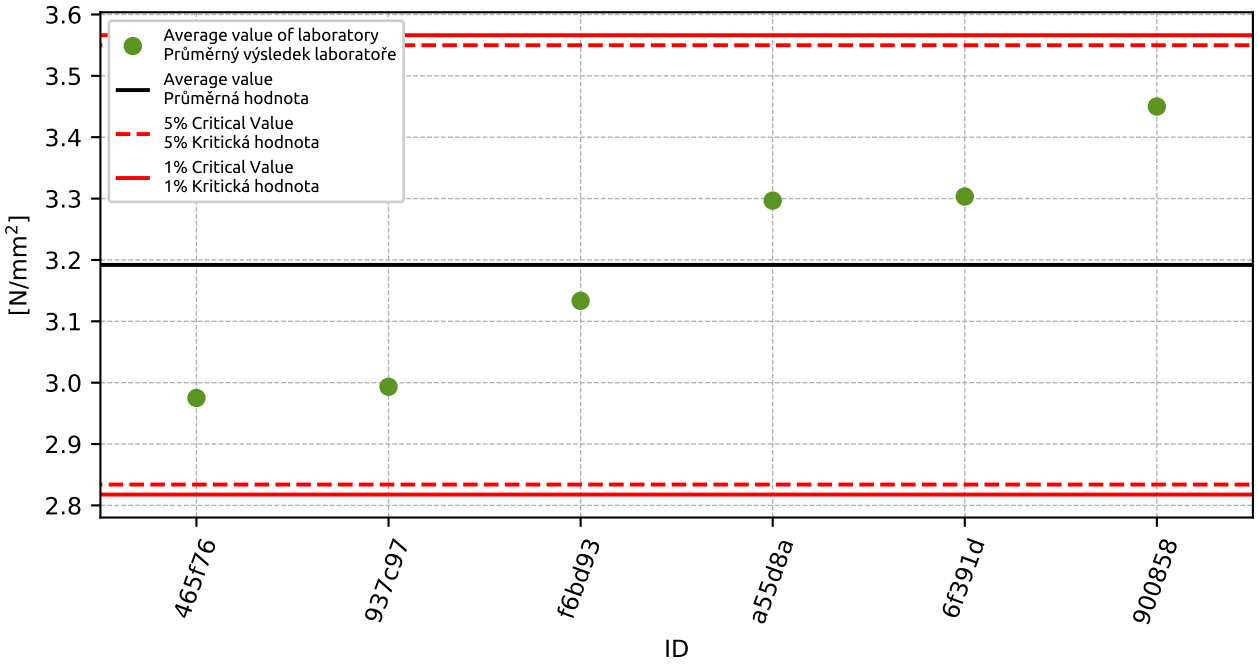

Figure 22: **Grubbs' test** - average values

3.3 Mandel's Statistics

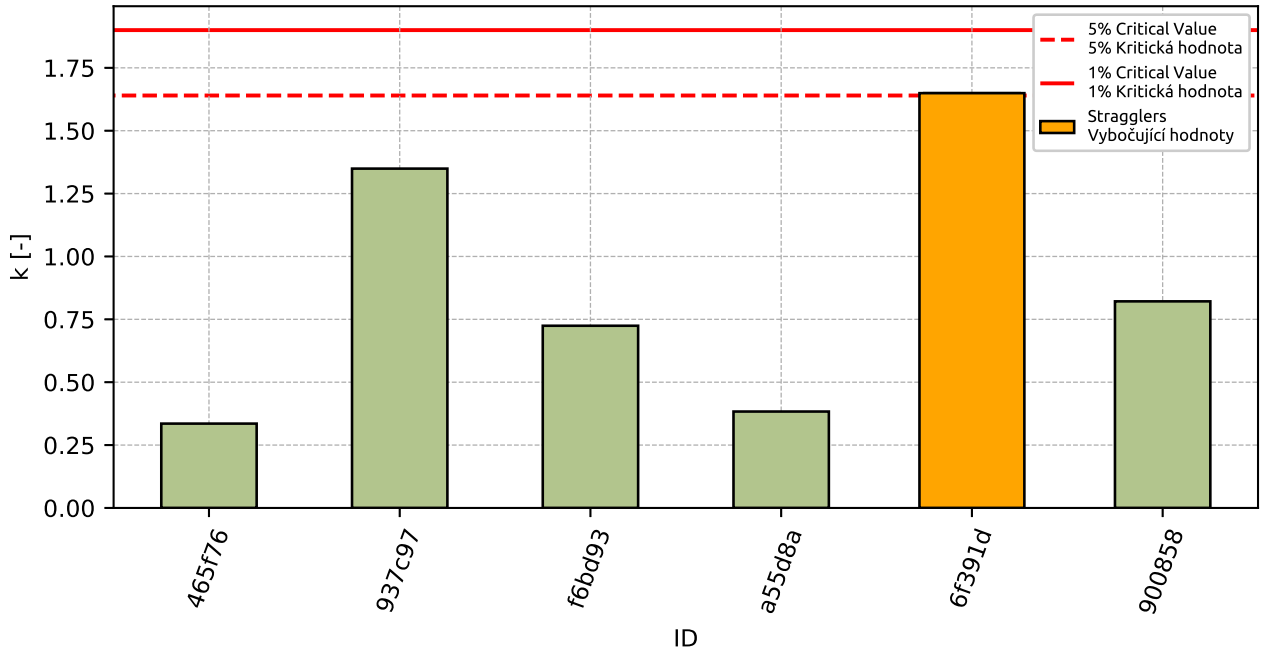

Figure 23: Intralaboratory Consistency Statistic

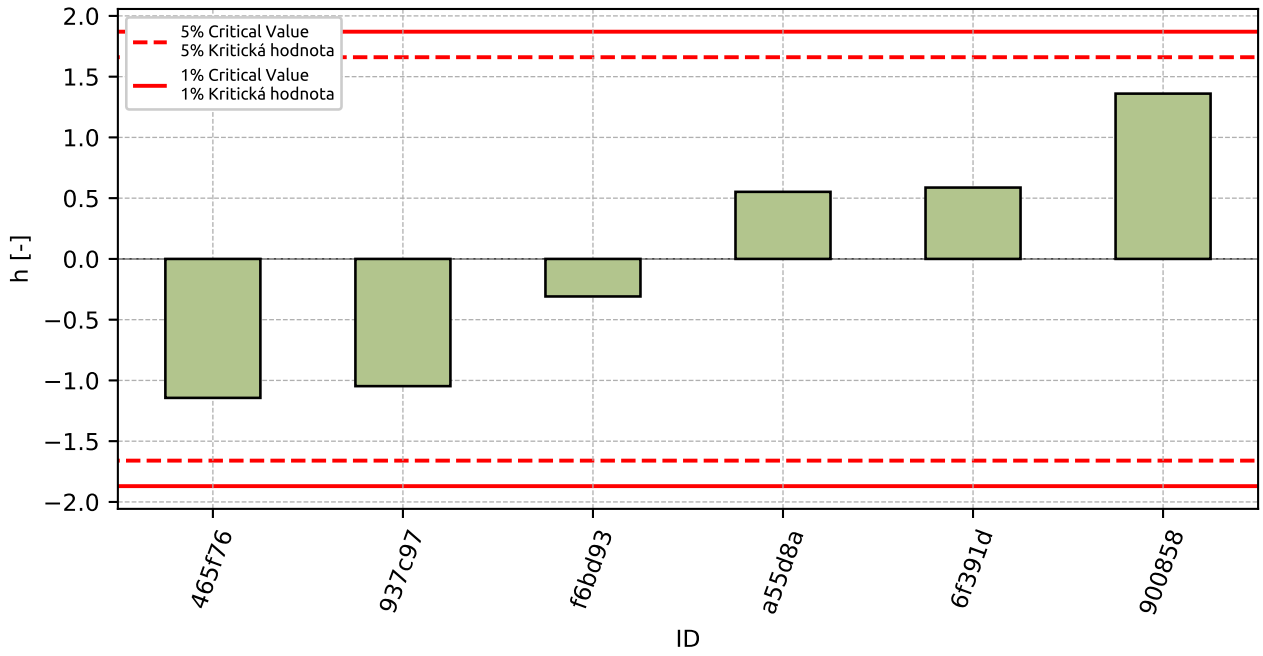

Figure 24: Interlaboratory Consistency Statistic

3.4 Descriptive statistics

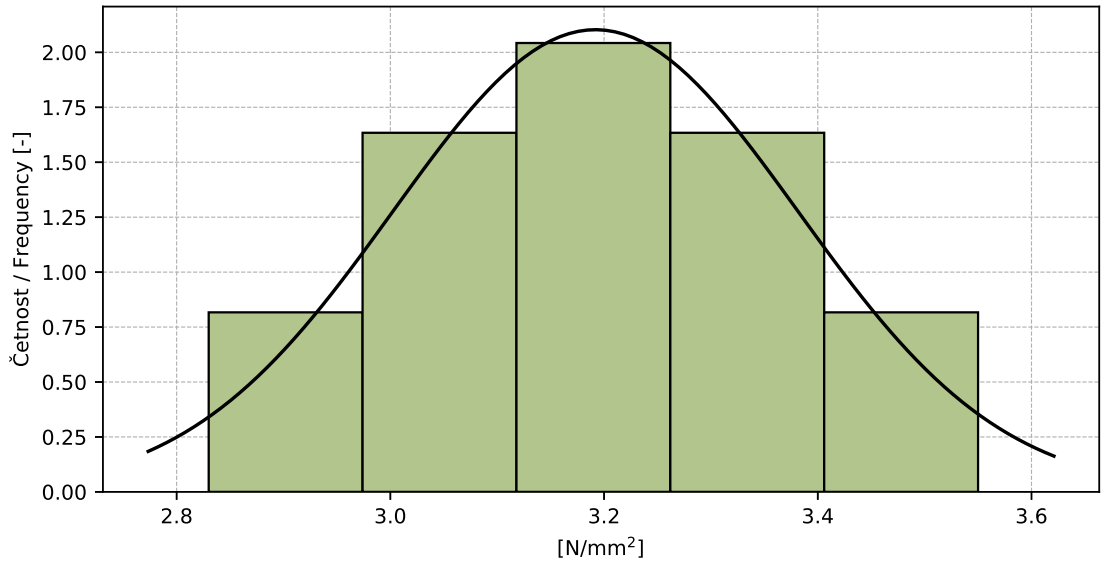

Figure 25: Histogram of all test results

Table 11: Descriptive statistics

Value	[N/mm²]
Průměrná hodnota / Average value – $\bar{x}$	3.19
Výběrová směrodatná odchylka / Sample standard deviation – s	0.19
Vztažná hodnota / Asigned value – x^*	3.19
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.196
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.1
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.18
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.105
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.208
Opakovatelnost / Repeatability – r	0.3
Reprodukovatelnost / Reproducibility – R	0.58

3.5 Calculation of Performance Statistics

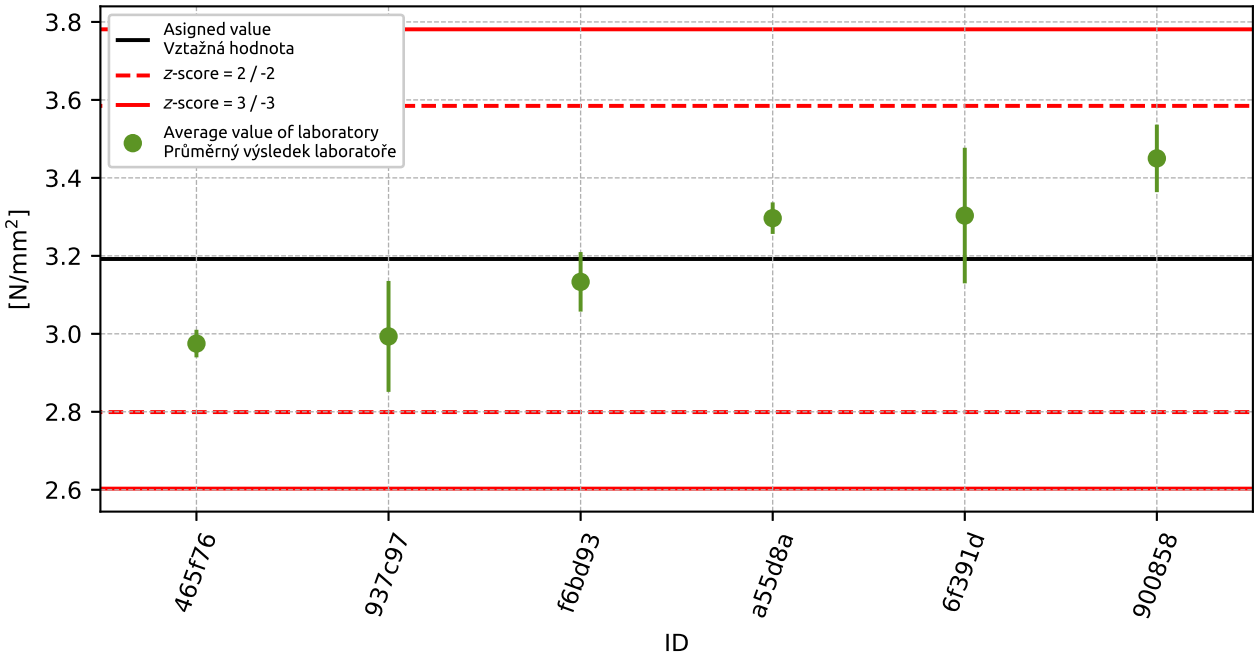

Figure 26: Average values and sample standard deviations

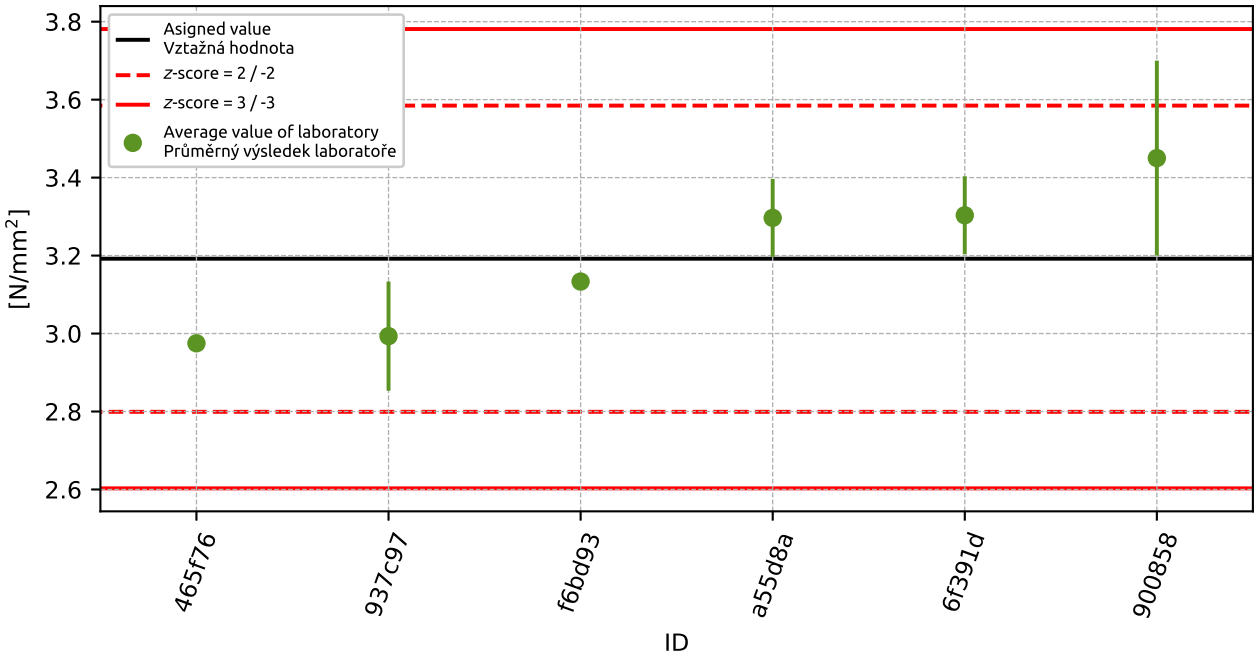

Figure 27: Average values and extended uncertainties of measurement

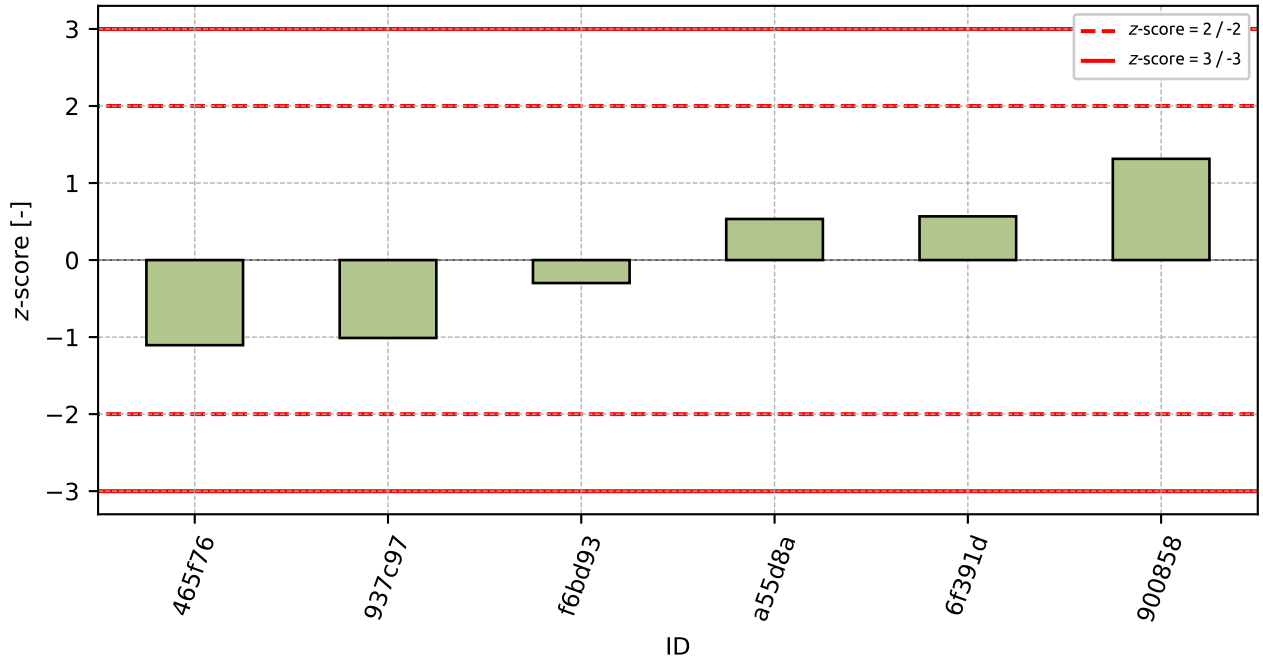

Figure 28: z-score

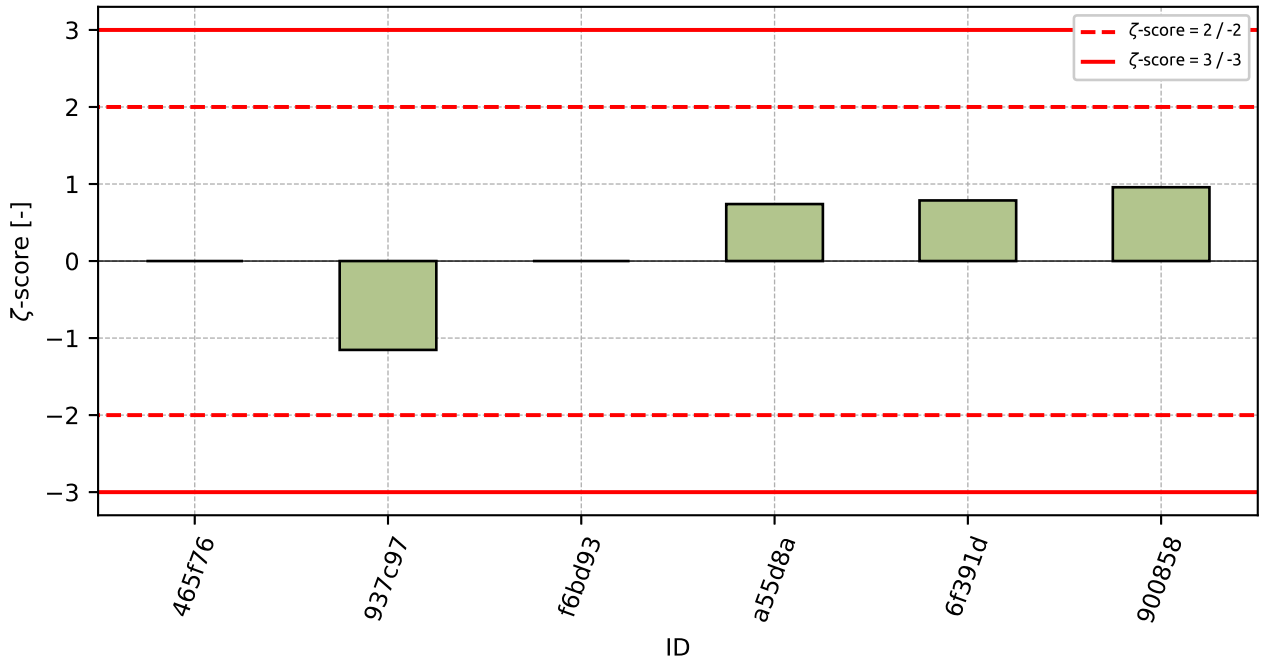

Figure 29: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
465f76	-1.1	-
937c97	-1.01	-1.15
f6bd93	-0.3	-
a55d8a	0.53	0.74
6f391d	0.57	0.79
900858	1.31	0.96

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

4.1 Test results

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

ID	Test results [kg/m^3]			u_X [kg/m^3]	$\bar{x}$ [kg/m^3]	s_0 [kg/m^3]	V_X [%]
a55d8a	2251	2256	2258	8	2255	3.6	0.16
1d9b5e	2280	2250	2280	47	2270	17.3	0.76
433ef2	2271	2260	2283	80	2271	11.5	0.51
4ef2c8	2277	2276	2261	5	2271	9.0	0.39
f6bd93	2280	2280	2260	13	2273	11.5	0.51
70bc11	2270	2270	2290	8	2277	11.5	0.51
465f76	2280	2280	2280	-	2280	0.0	0.0
6b6834	2270	2270	2300	10	2280	17.3	0.76
f4e14d	2290	2280	2280	18	2283	5.8	0.25
37d148	2280	2290	2300	-	2290	10.0	0.44
3eb7f4	2270	2290	2310	-	2290	20.0	0.87
6ea487	2300	2290	2280	-	2290	10.0	0.44
937c97	2300	2290	2280	10	2290	10.0	0.44
26032f	2290	2300	2300	90	2297	5.8	0.25
e63c8d	2302	2288	2303	2	2298	8.4	0.37
5593ae	2330	2290	2290	14	2303	23.1	1.0

4.2 The Numerical Procedure for Determining Outliers

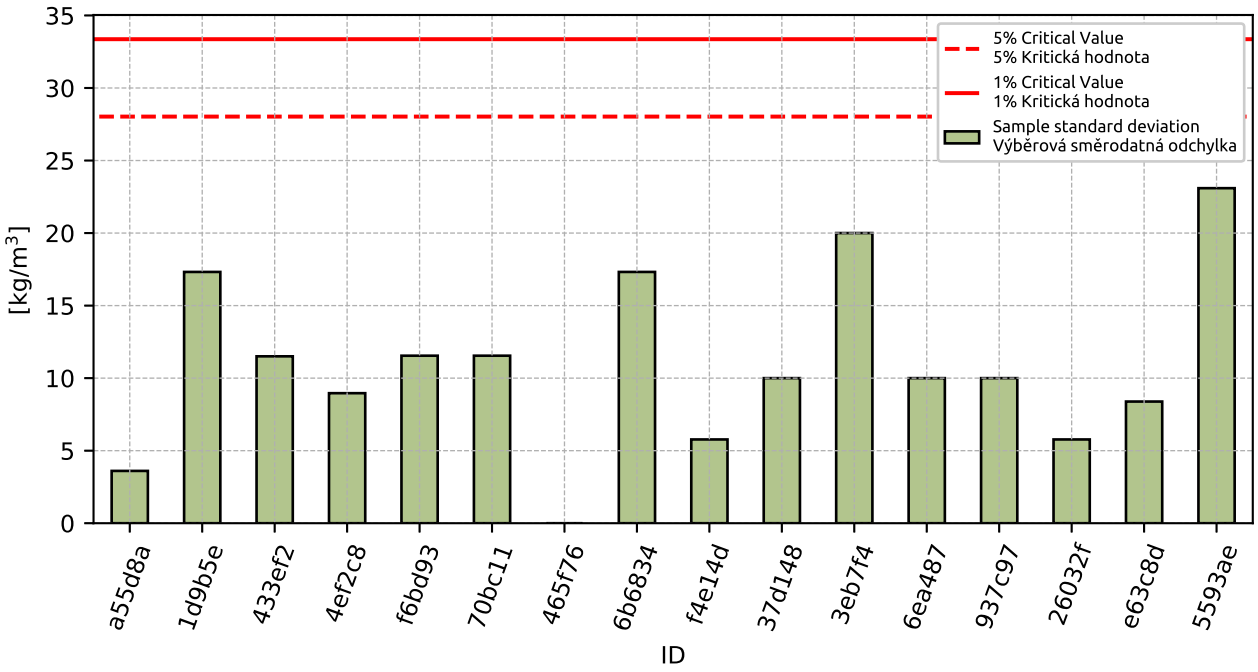

Figure 30: **Cochran's test** - sample standard deviations

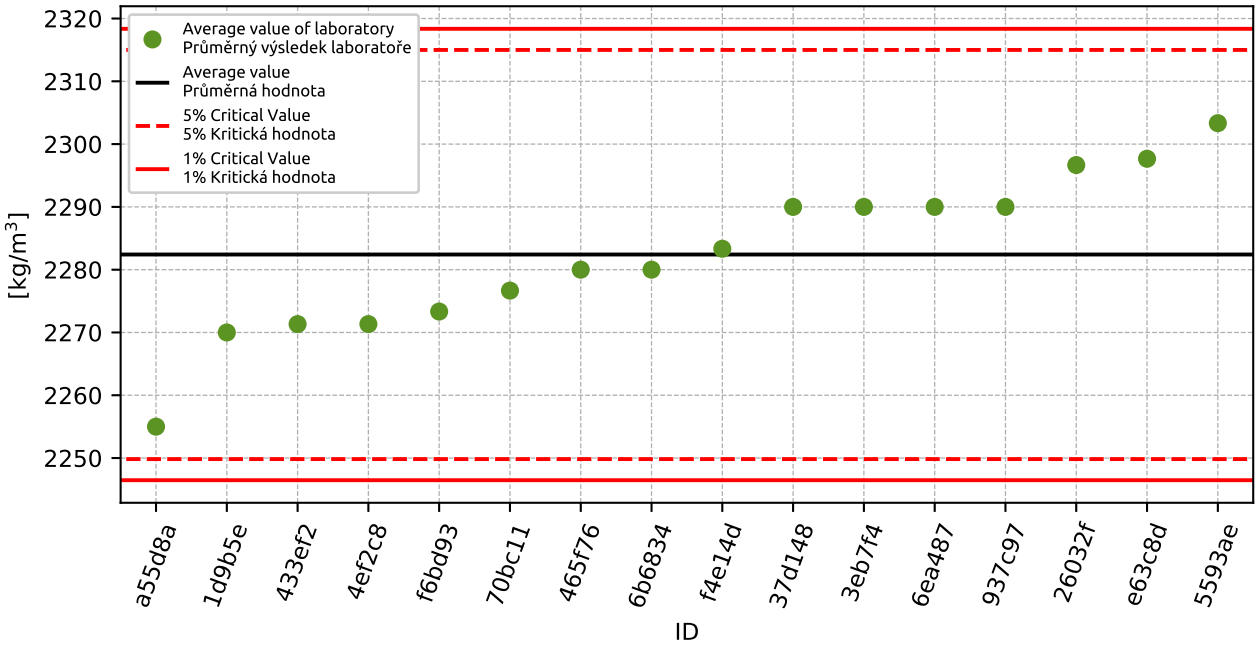

Figure 31: **Grubbs' test** - average values

4.3 Mandel's Statistics

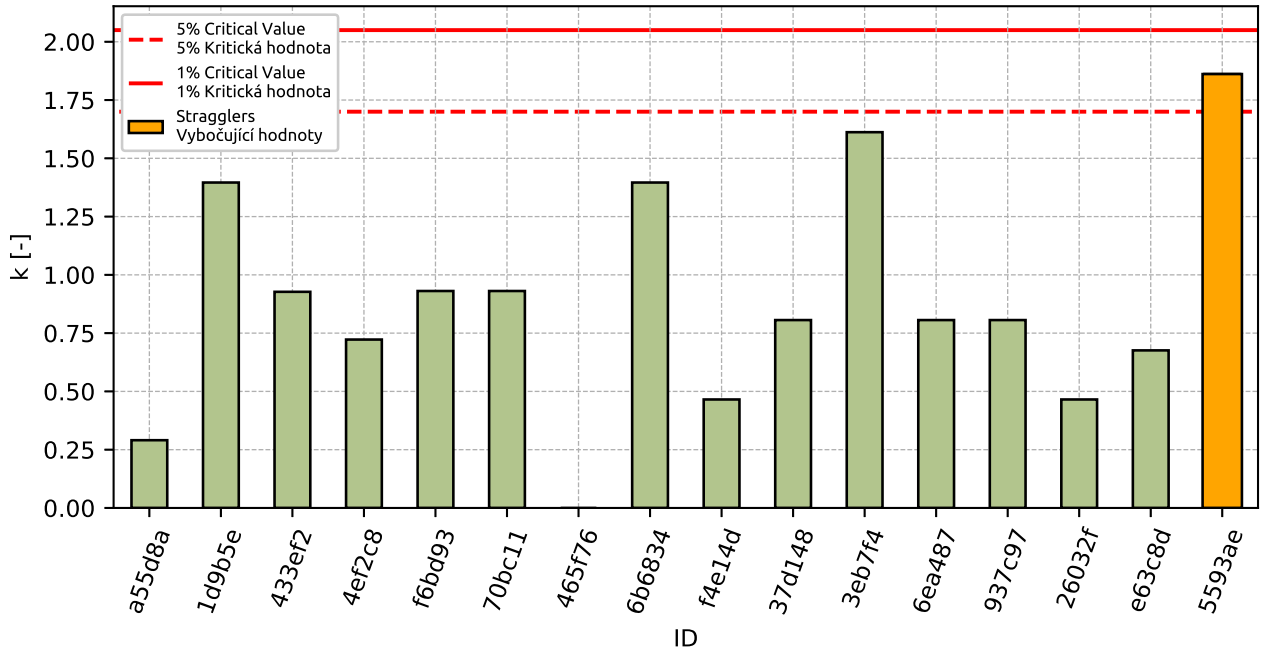

Figure 32: Intralaboratory Consistency Statistic

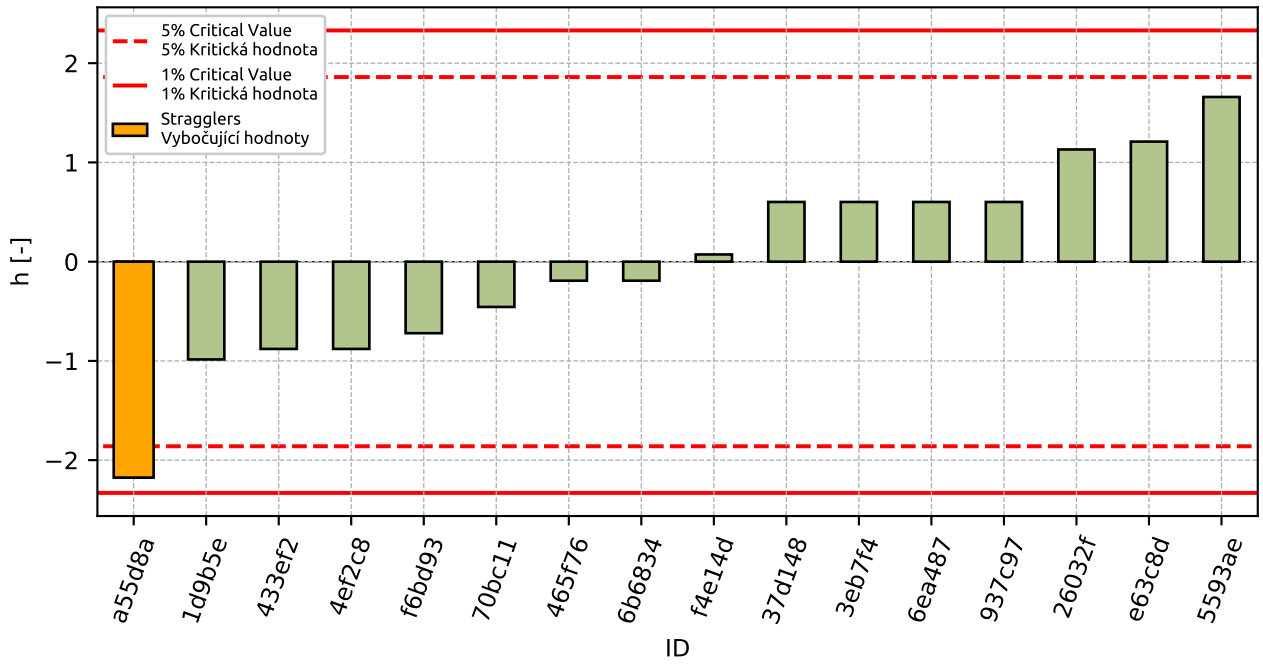

Figure 33: Interlaboratory Consistency Statistic

4.4 Descriptive statistics

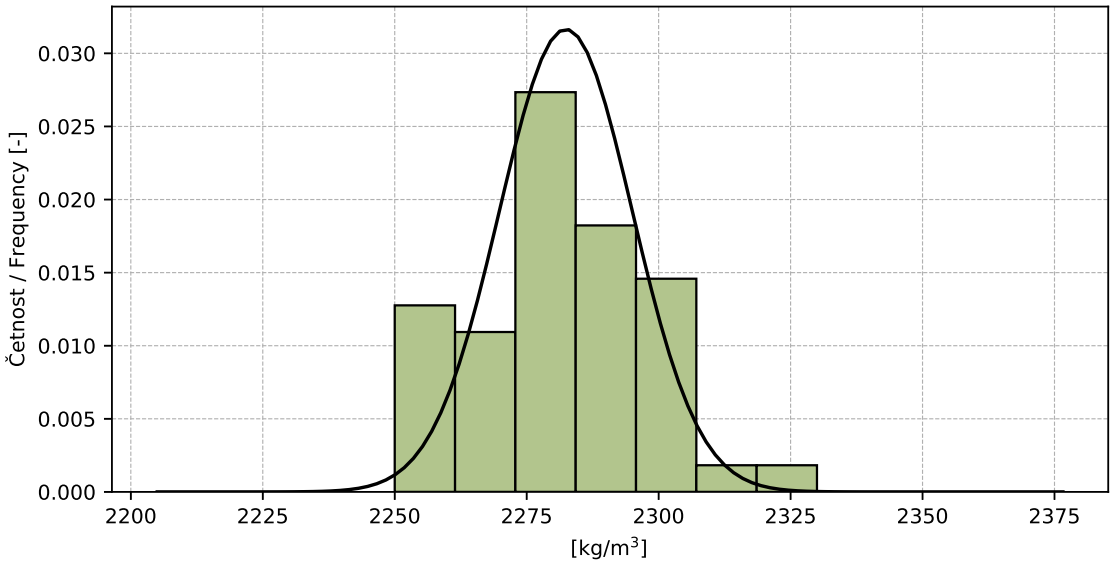

Figure 34: Histogram of all test results

Table 14: Descriptive statistics

Value	[kg/m³]
Průměrná hodnota / Average value – $\bar{x}$	2282.0
Výběrová směrodatná odchylka / Sample standard deviation – s	12.6
Vztažná hodnota / Asigned value – x^*	2283.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	12.5
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	3.9
p-hodnota testu normality / p-value of normality test	0.475 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	10.4
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	12.4
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	16.2
Opakovatelnost / Repeatability – r	35.0
Reprodukovatelnost / Reproducibility – R	45.0

4.5 Calculation of Performance Statistics

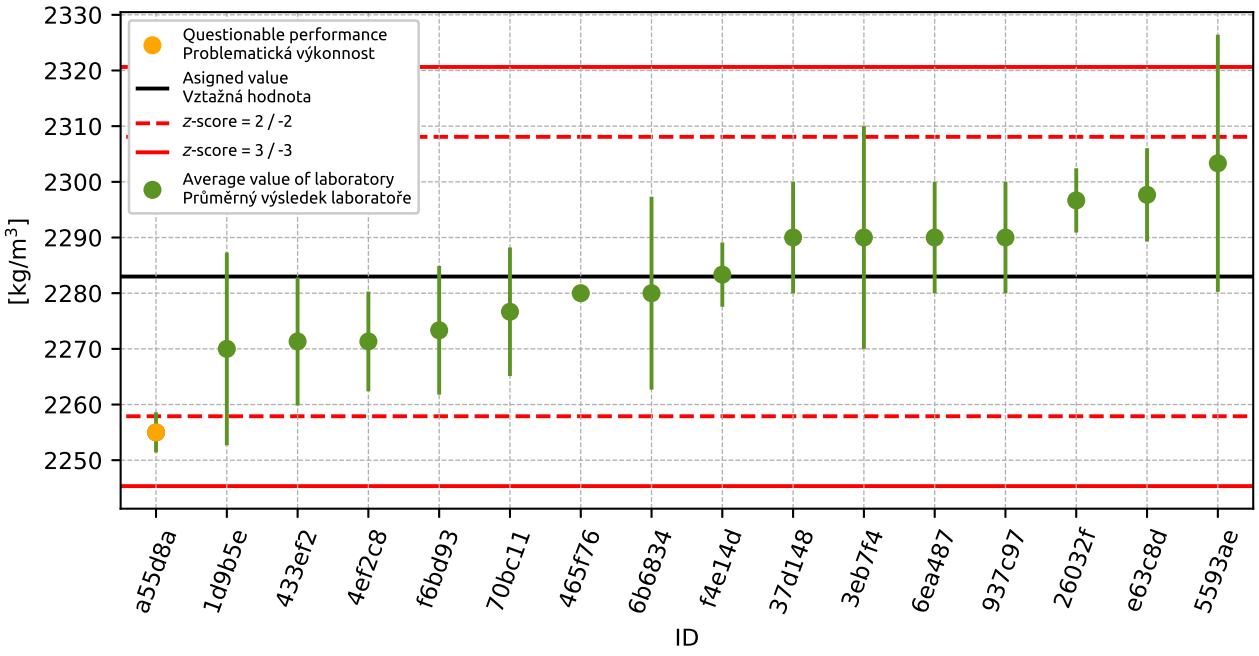

Figure 35: Average values and sample standard deviations

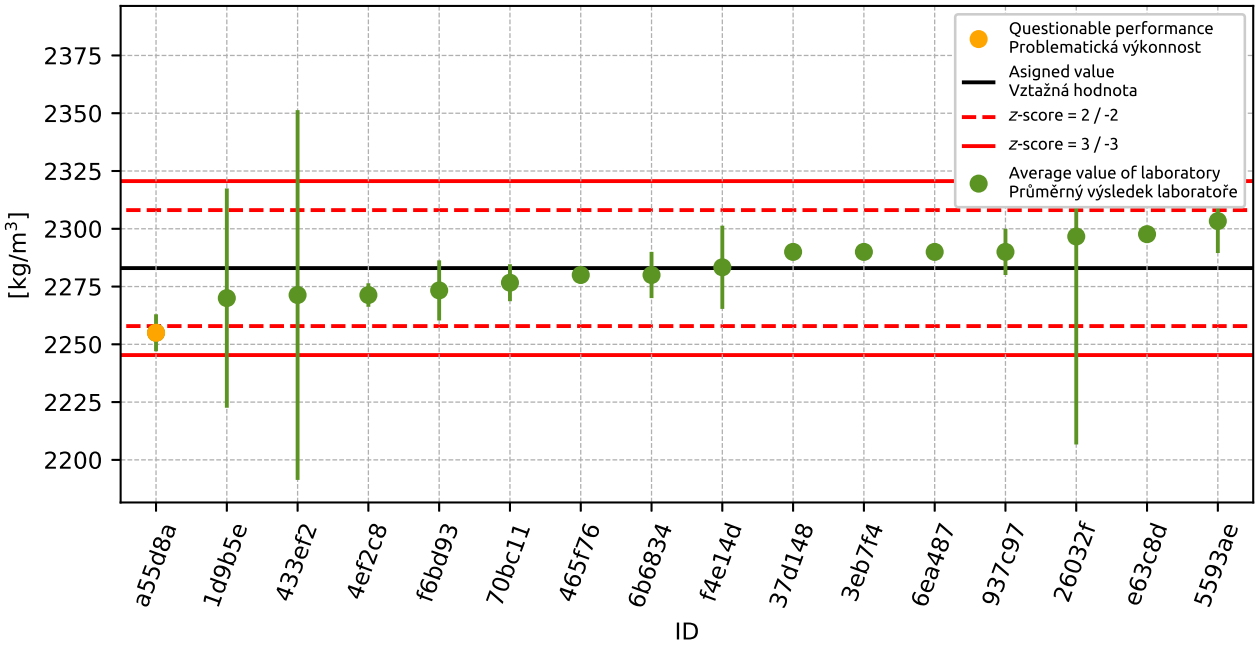

Figure 36: Average values and extended uncertainties of measurement

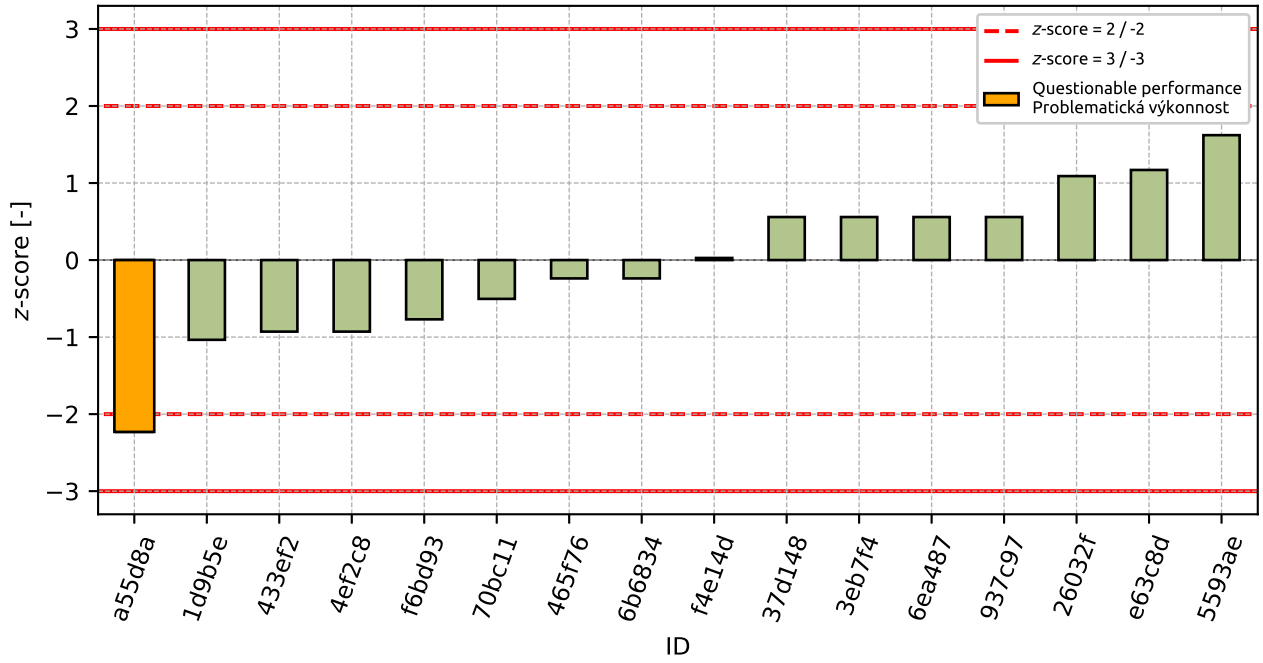

Figure 37: z-score

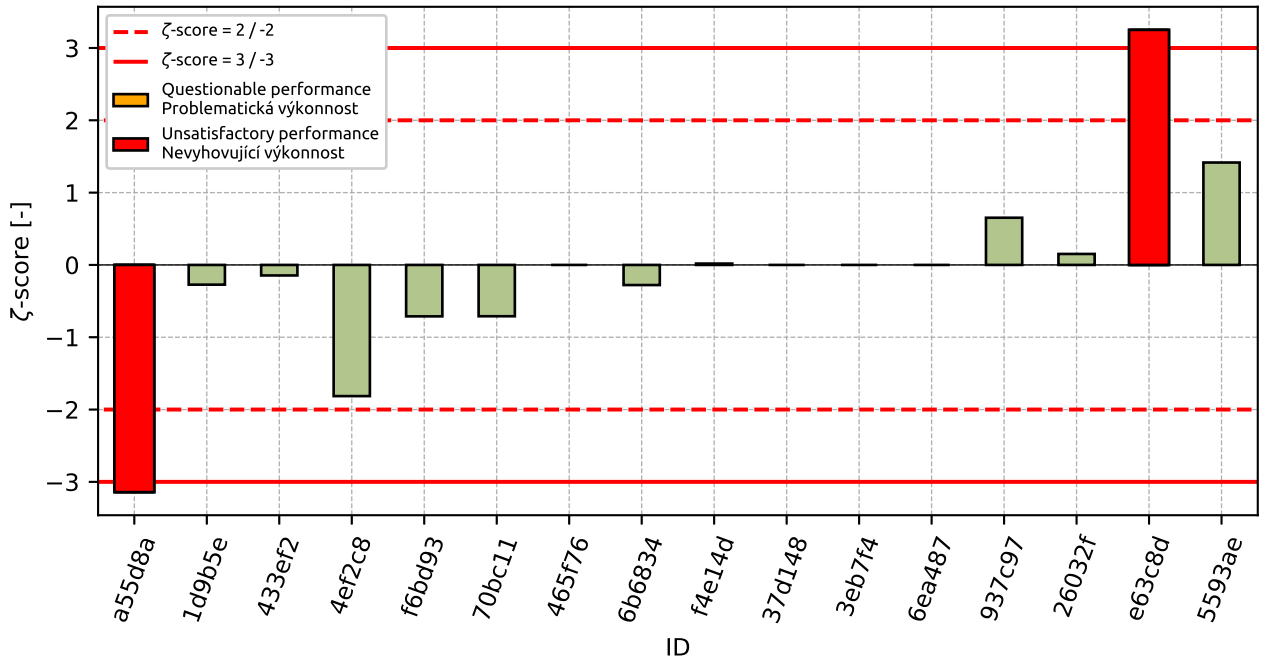

Figure 38: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a55d8a	-2.23	-3.14
1d9b5e	-1.04	-0.27
433ef2	-0.93	-0.15
4ef2c8	-0.93	-1.81
f6bd93	-0.77	-0.71
70bc11	-0.5	-0.71
465f76	-0.24	-
6b6834	-0.24	-0.28
f4e14d	0.03	0.02
37d148	0.56	-
3eb7f4	0.56	-
6ea487	0.56	-
937c97	0.56	0.65
26032f	1.09	0.15
e63c8d	1.17	3.25
5593ae	1.62	1.42

5 Appendix – ISO 1920-10 – Determination of static modulus of elasticity in compression

5.1 Test results

Table 16: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [N/mm^2]		u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
465f76	25700	27100	-	26400	989.9	3.75
d551d0	26515	26515	1760	26515	0.0	0.0
de4e03	27700	25800	650	26750	1343.5	5.02
70bc11	27132	26854	3240	26993	196.6	0.73
6249f1	27300	27200	1700	27250	70.7	0.26
736843	28300	27700	1600	28000	424.3	1.52
ed0db4	29936	28690	3500	29313	881.1	3.01

5.2 The Numerical Procedure for Determining Outliers

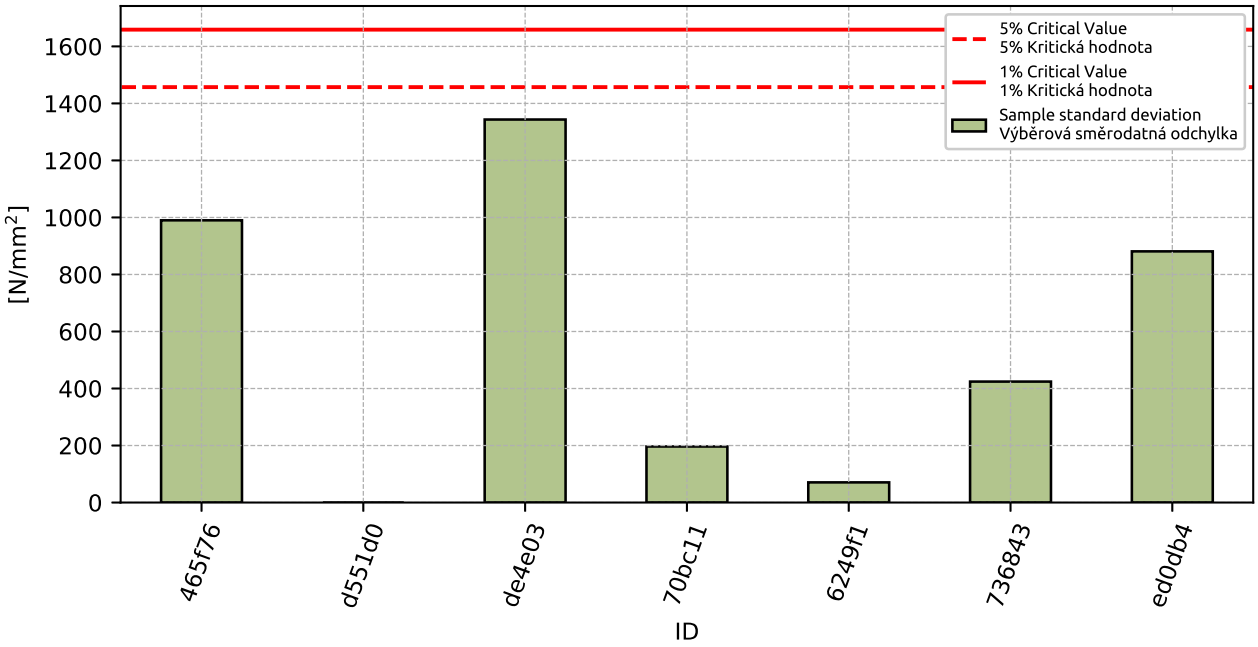

Figure 39: **Cochran's test** - sample standard deviations

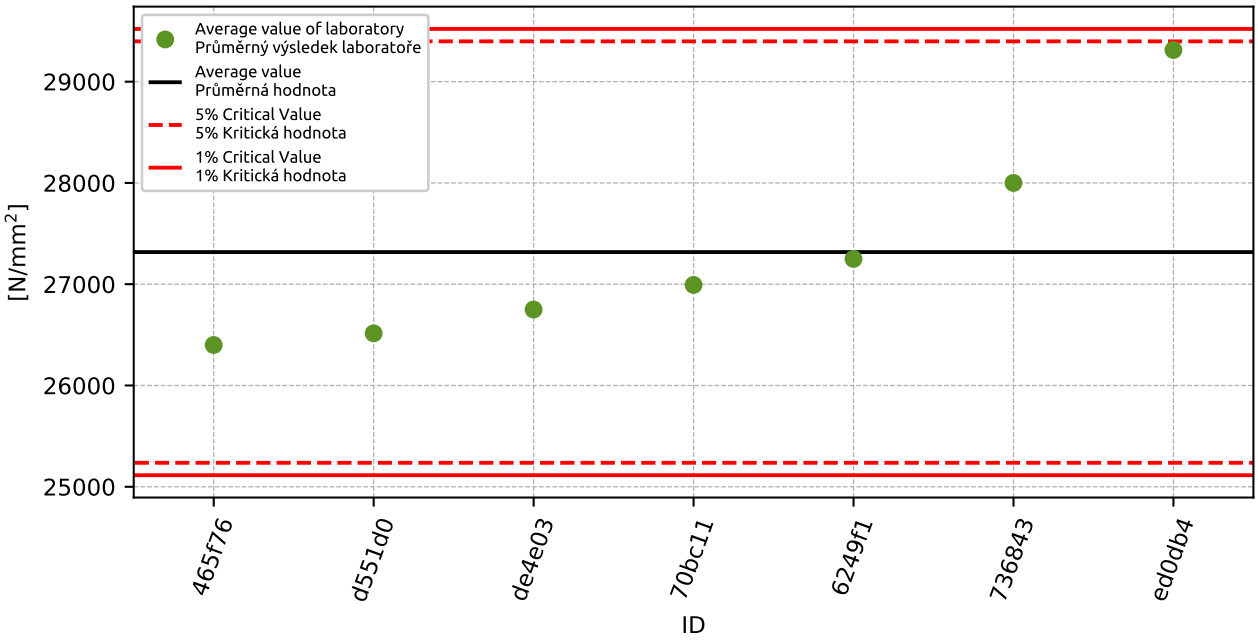

Figure 40: **Grubbs' test** - average values

5.3 Mandel's Statistics

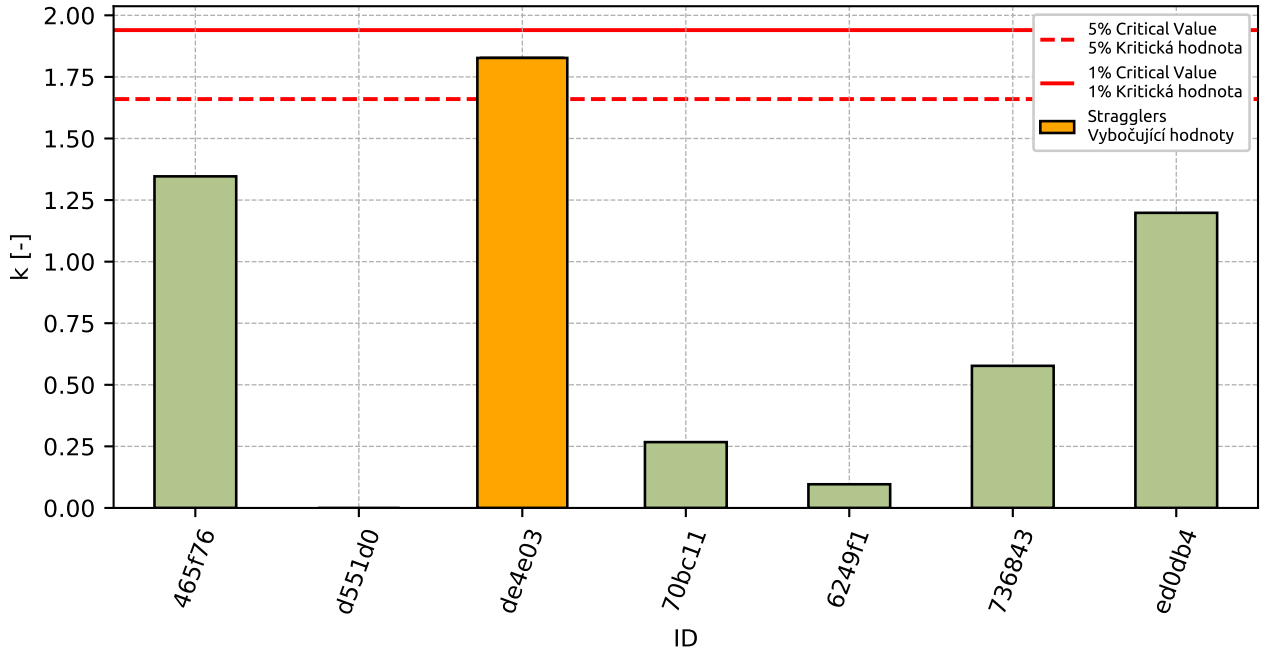

Figure 41: Intralaboratory Consistency Statistic

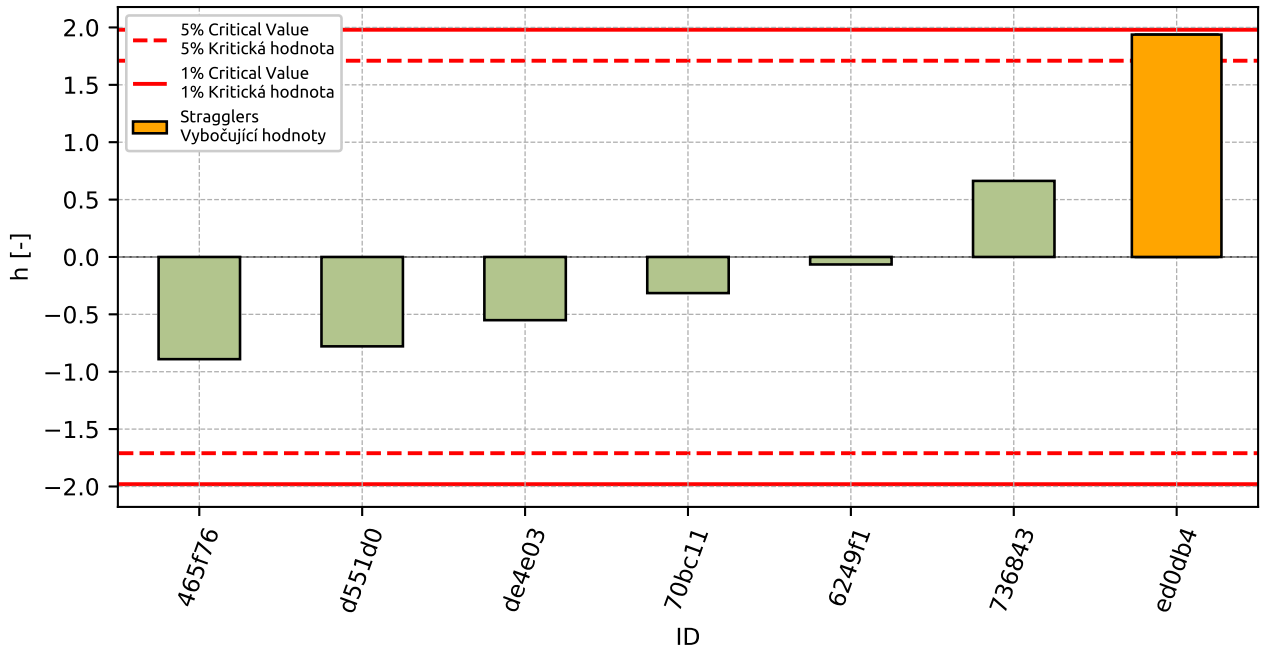

Figure 42: Interlaboratory Consistency Statistic

5.4 Descriptive statistics

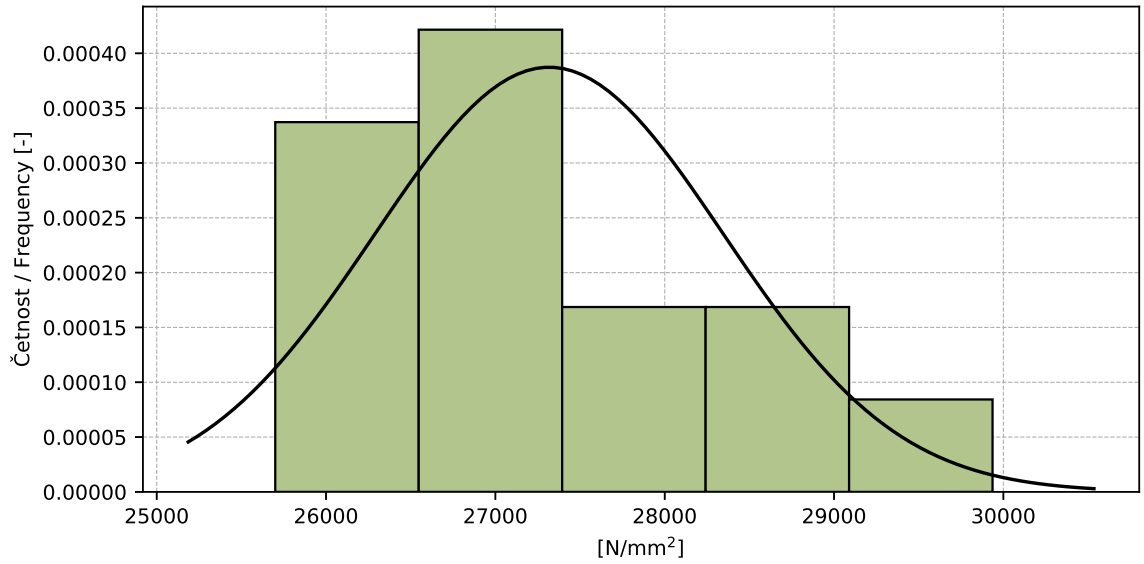

Figure 43: Histogram of all test results

Table 17: Descriptive statistics

Value	[N/mm²]
Průměrná hodnota / Average value – $\bar{x}$	27317.0
Výběrová směrodatná odchylka / Sample standard deviation – s	1030.0
Vztažná hodnota / Asigned value – x^*	27317.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	1081.4
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	510.9
p-hodnota testu normality / p-value of normality test	0.23 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	889.1
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	735.3
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	1153.8
Opakovatelnost / Repeatability – r	2059.0
Reprodukovatelnost / Reproducibility – R	3231.0

5.5 Calculation of Performance Statistics

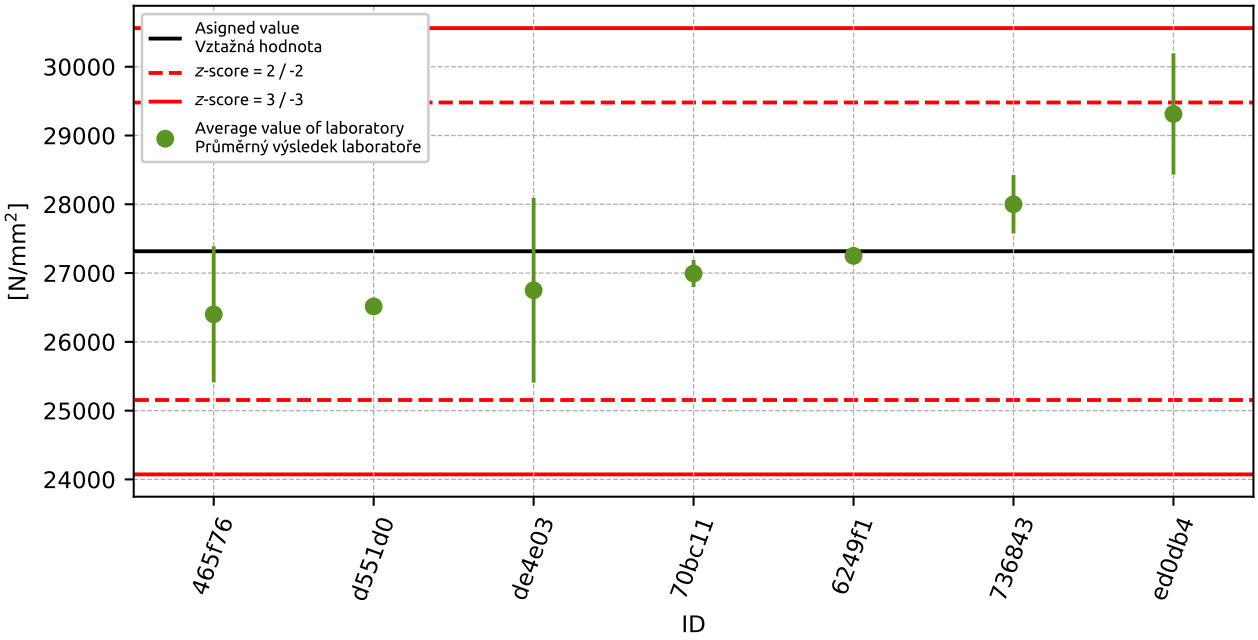

Figure 44: Average values and sample standard deviations

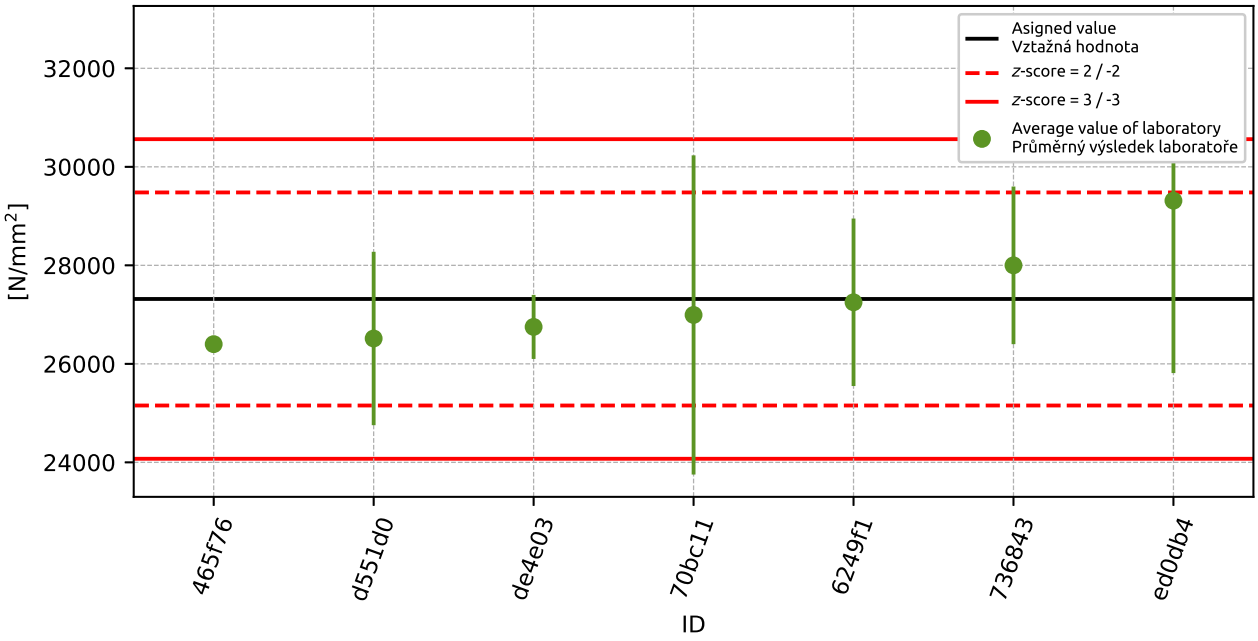

Figure 45: Average values and extended uncertainties of measurement

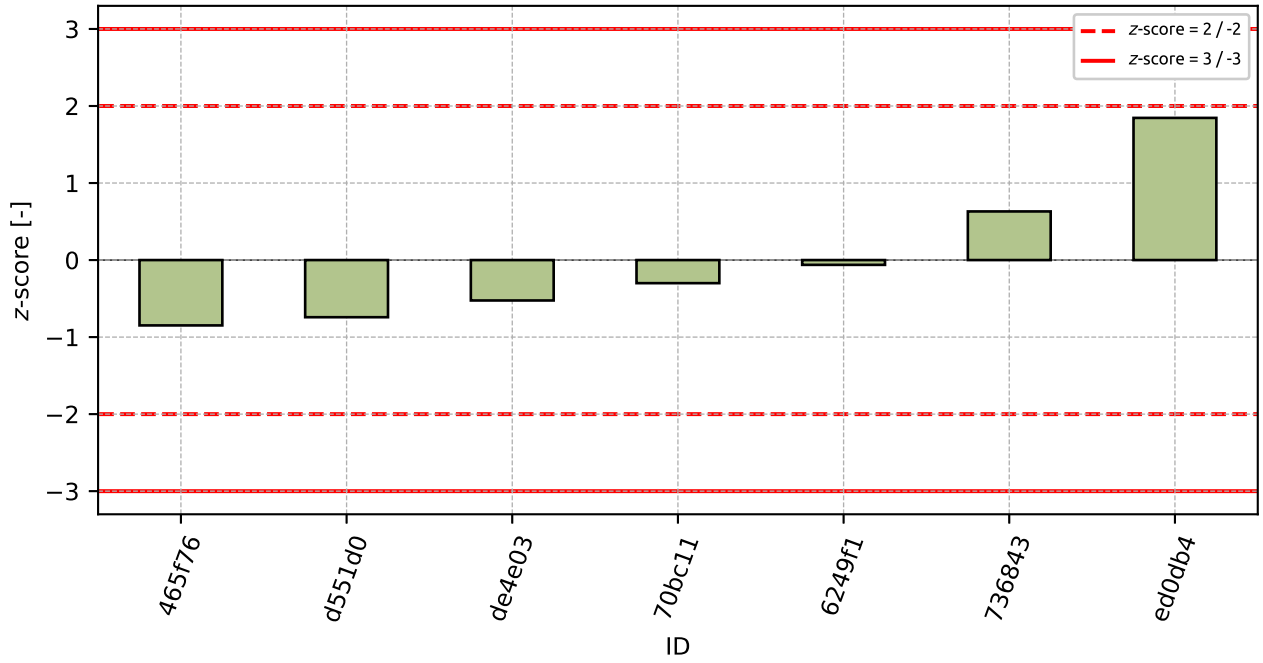

Figure 46: z-score

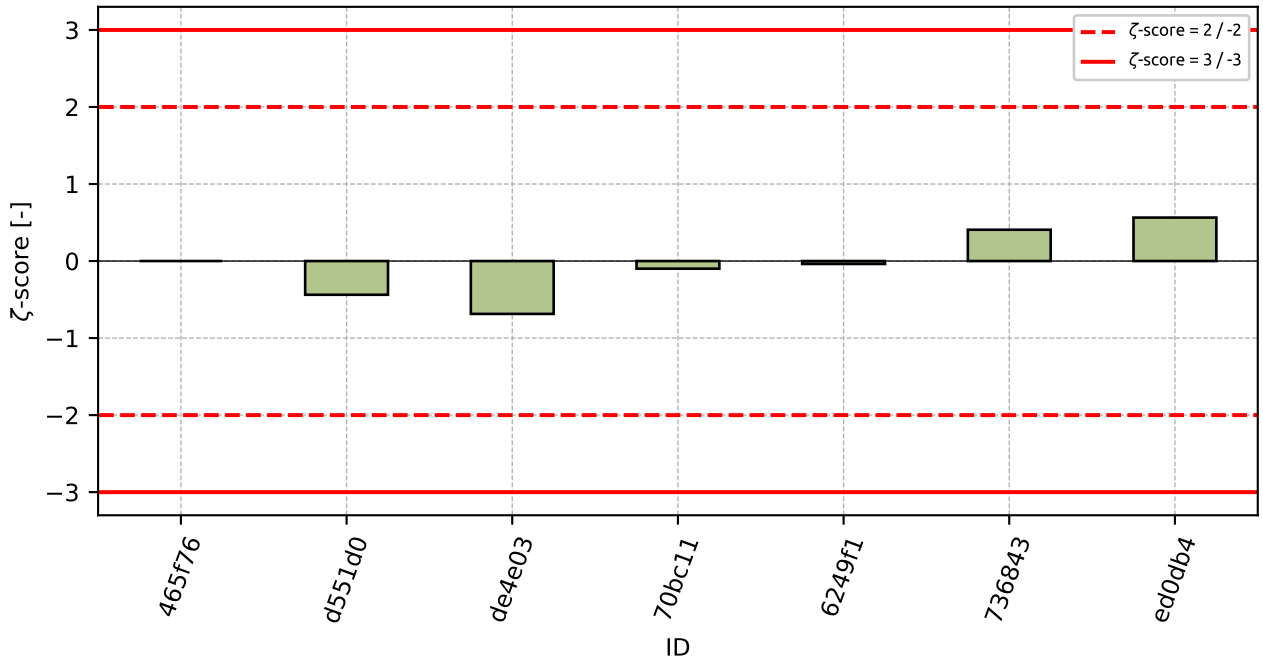

Figure 47: ζ-score

Table 18: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
465f76	-0.85	-
d551d0	-0.74	-0.44
de4e03	-0.52	-0.69
70bc11	-0.3	-0.1
6249f1	-0.06	-0.04
736843	0.63	0.41
ed0db4	1.85	0.56

6 Appendix – EN 12390-13, method A – Determination of secant modulus of elasticity in compression

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

7 Appendix – EN 12390-13, method B – Determination of secant modulus of elasticity in compression

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

8 Appendix – EN 12504-4, ČSN 731371 – Non-destructive testing of concrete

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

9 Appendix – ČSN 731373, EN 12504-2 – Determination of rebound number

9.1 Test results

Table 19: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [-]			u_X [-]	$\bar{x}$ [-]	s_0 [-]	V_X [%]
eb7928	22	22	23	-	22	0.5	2.35
552a0e	25	25	24	2	25	0.6	2.34
b9fb9b	24	26	24	3	25	1.0	4.19
1d9b5e	30	28	28	1	29	1.2	4.03
900858	30	31	31	1	31	0.6	1.88
465f76	31	31	31	-	31	0.4	1.16
937c97	32	32	32	2	32	0.0	0.0
942572	35	32	34	1	34	1.5	4.54
f6bd93	35	35	34	5	35	0.6	1.67
8d28dd	36	35	34	-	35	1.0	2.86
26032f	34	35	36	1	35	1.0	2.86
6249f1	35	35	35	2	35	0.0	0.0
9c690e	38	38	37	9	38	0.6	1.53

9.2 The Numerical Procedure for Determining Outliers

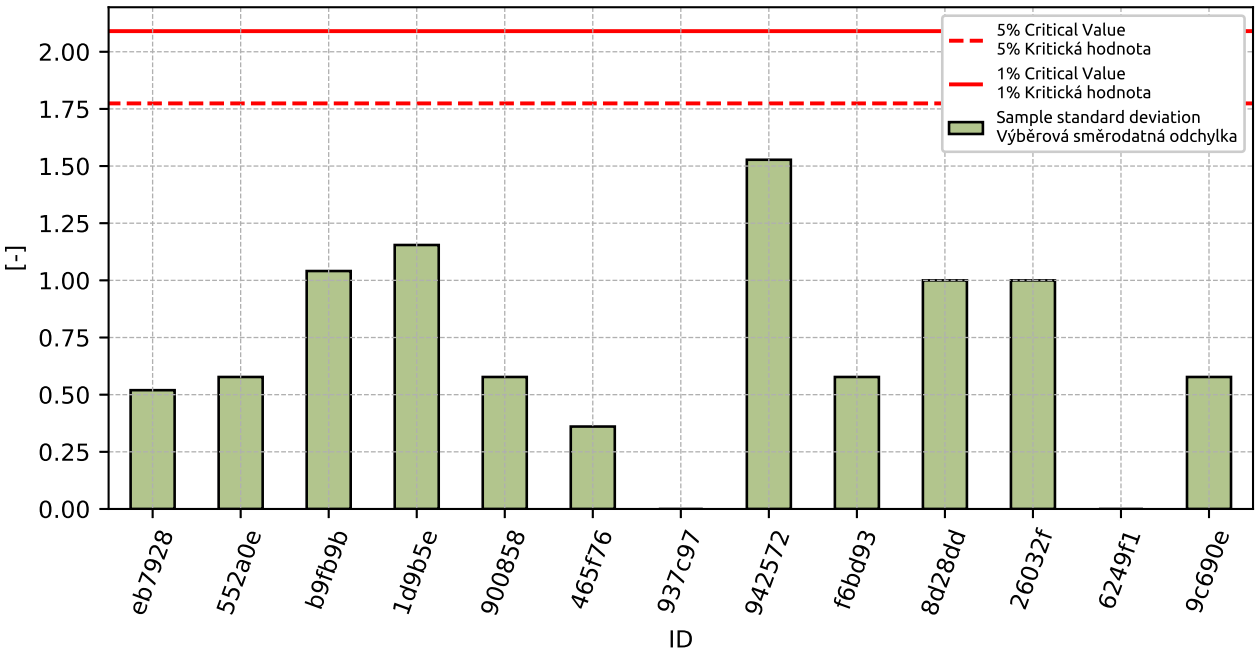

Figure 48: **Cochran's test** - sample standard deviations

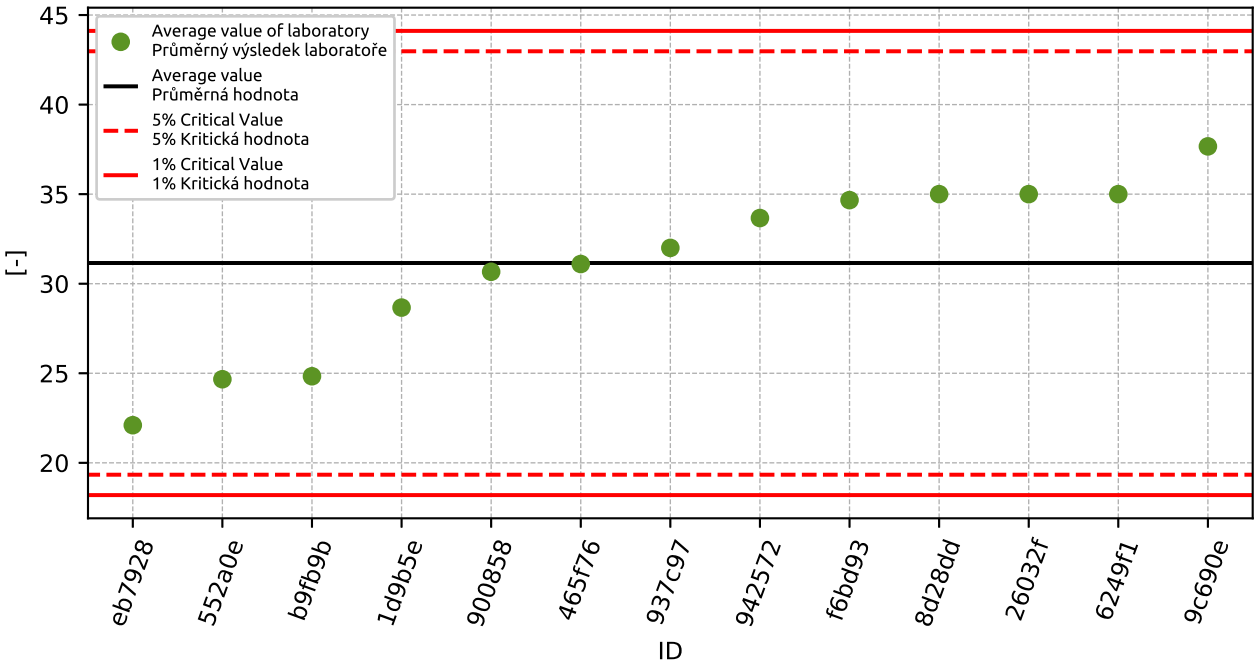

Figure 49: **Grubbs' test** - average values

9.3 Mandel's Statistics

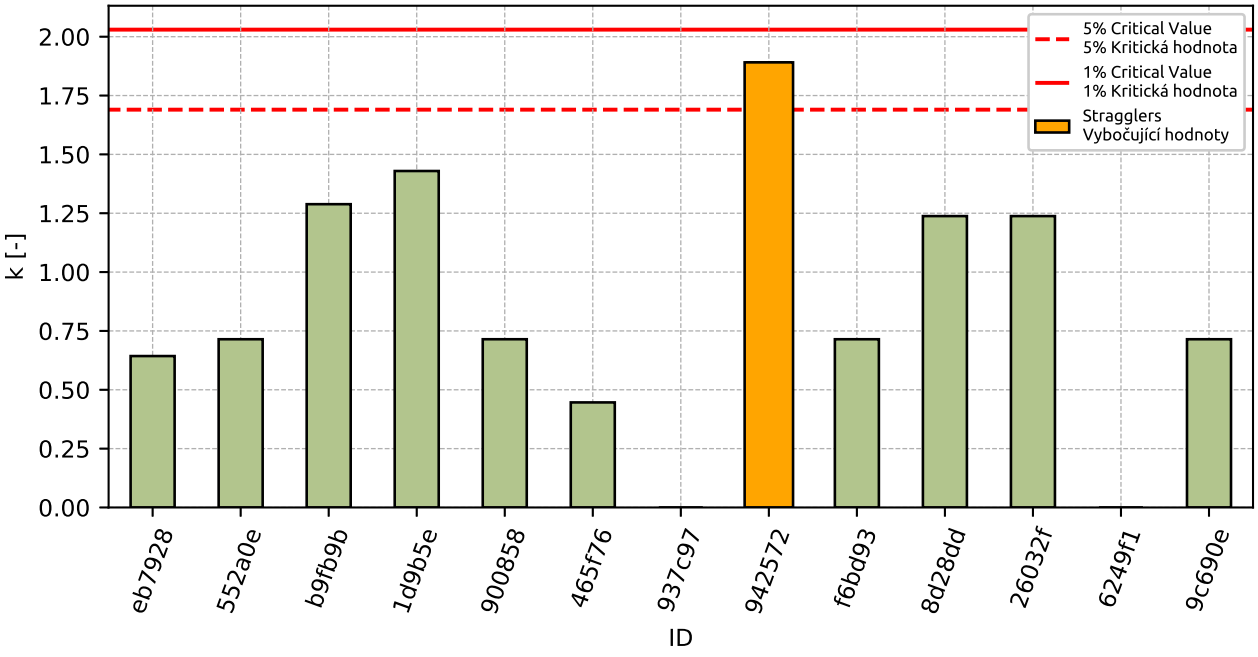

Figure 50: Intralaboratory Consistency Statistic

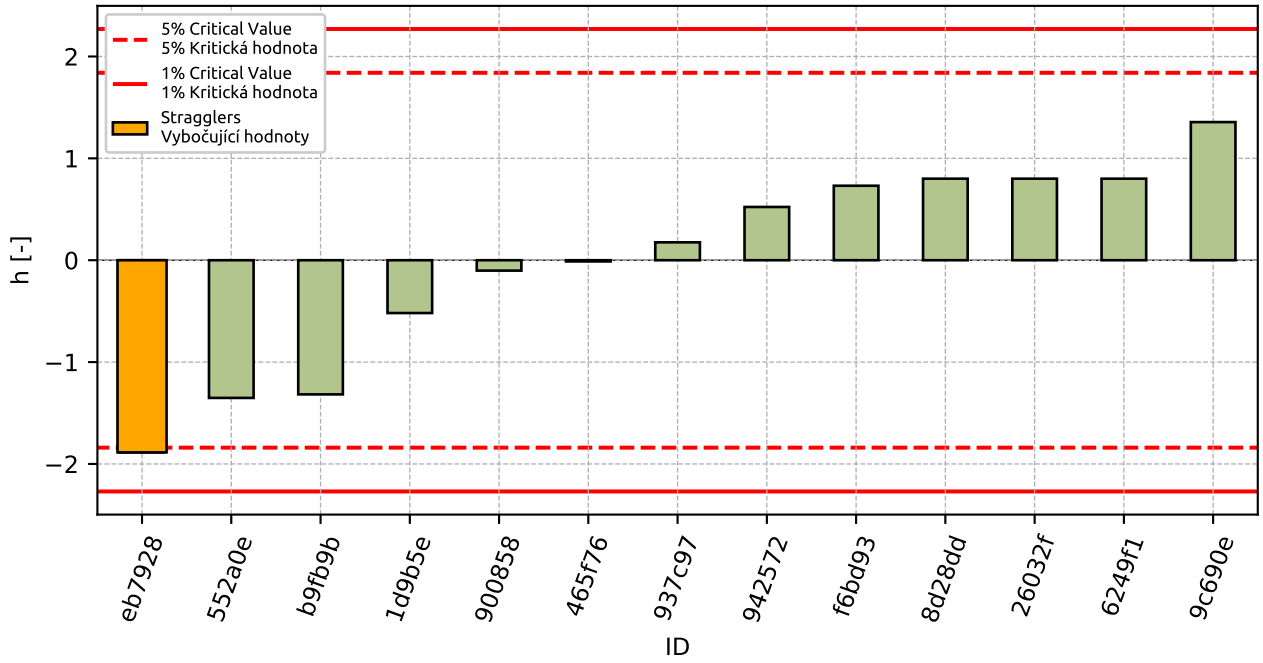

Figure 51: Interlaboratory Consistency Statistic

9.4 Descriptive statistics

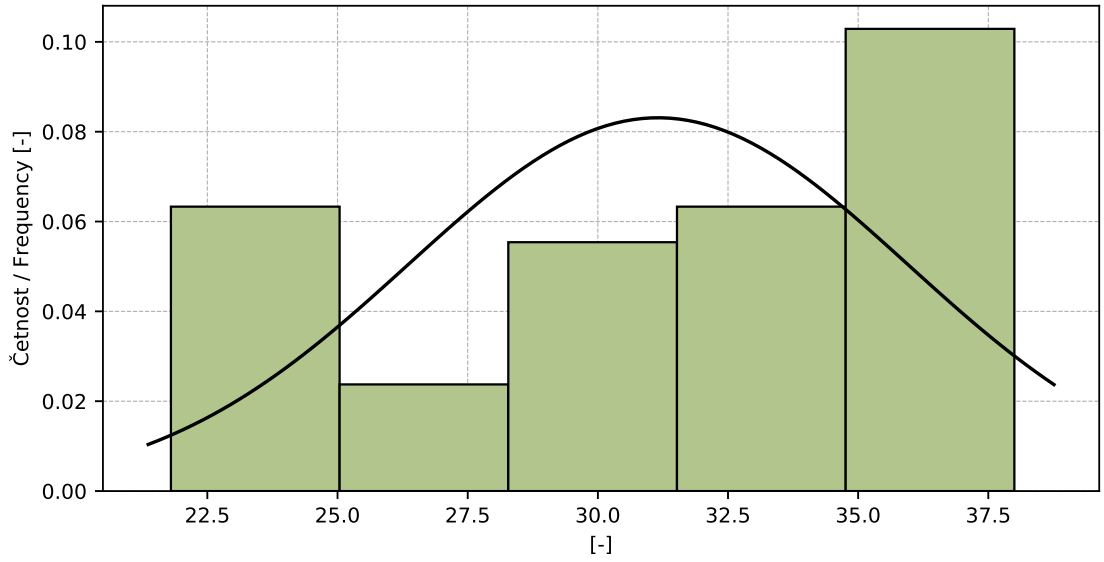

Figure 52: Histogram of all test results

Table 20: Descriptive statistics

Value	[-]
Průměrná hodnota / Average value – $\bar{x}$	31.0
Výběrová směrodatná odchylka / Sample standard deviation – s	4.8
Vztažná hodnota / Asigned value – x^*	31.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	4.6
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	1.6
p-hodnota testu normality / p-value of normality test	0.116 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	4.8
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.8
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	4.8
Opakovatelnost / Repeatability – r	2.0
Reprodukovatelnost / Reproducibility – R	14.0

9.5 Calculation of Performance Statistics

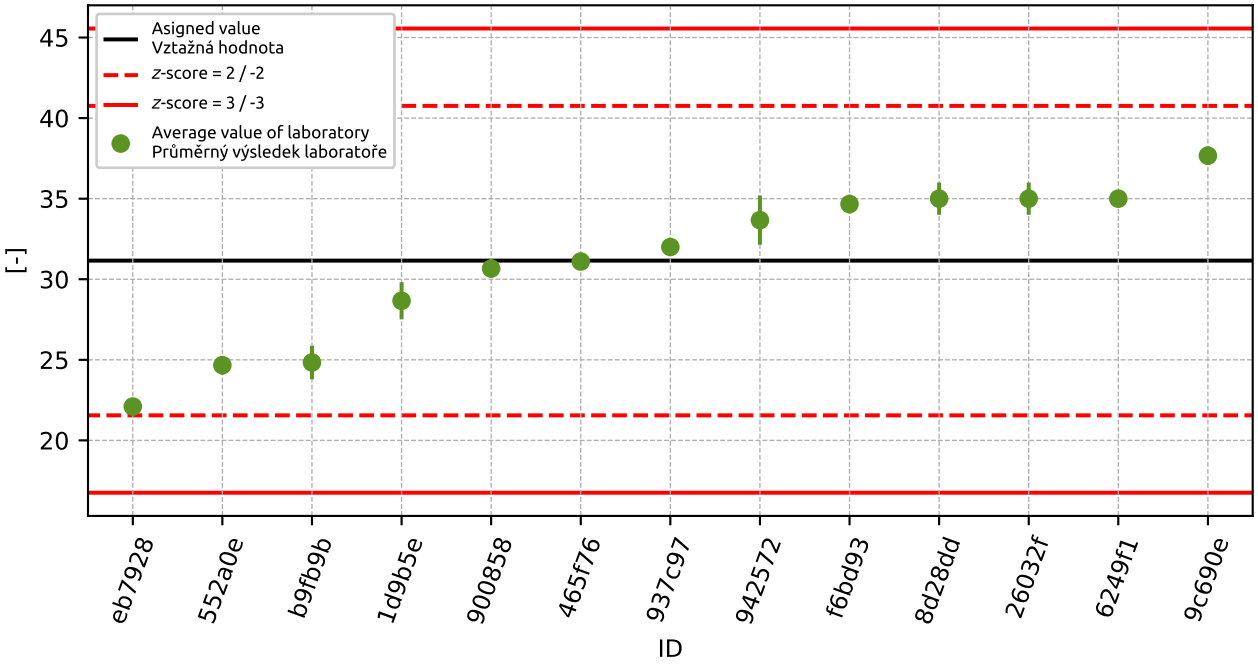

Figure 53: Average values and sample standard deviations

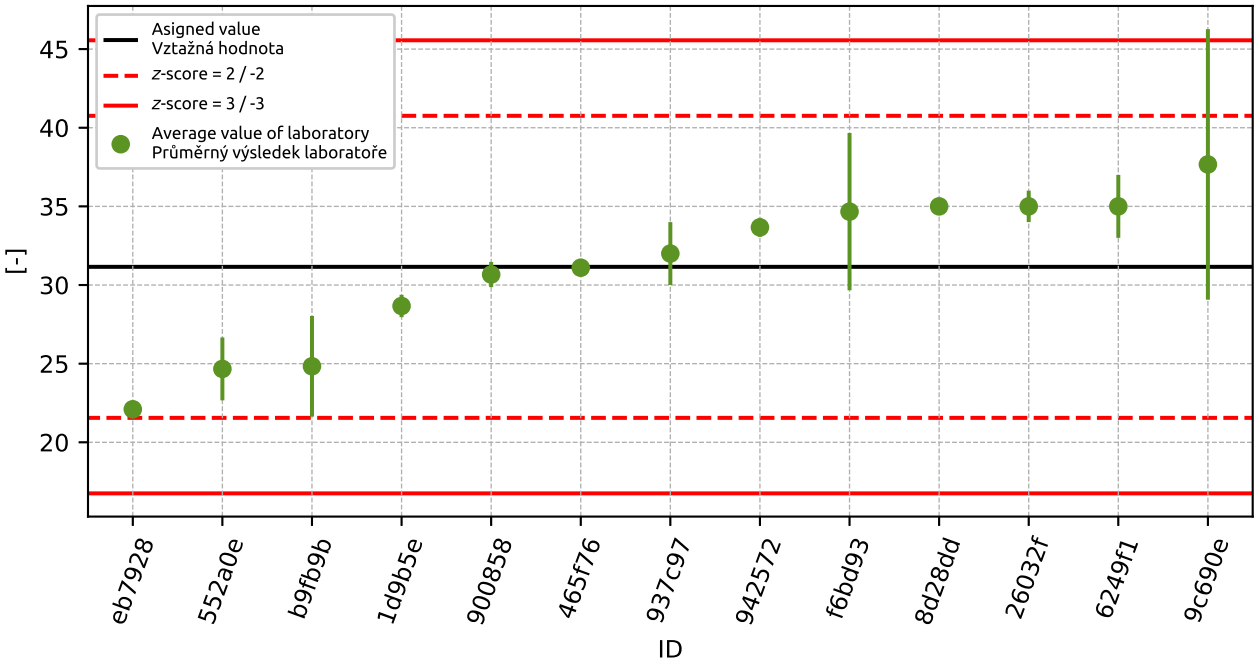

Figure 54: Average values and extended uncertainties of measurement

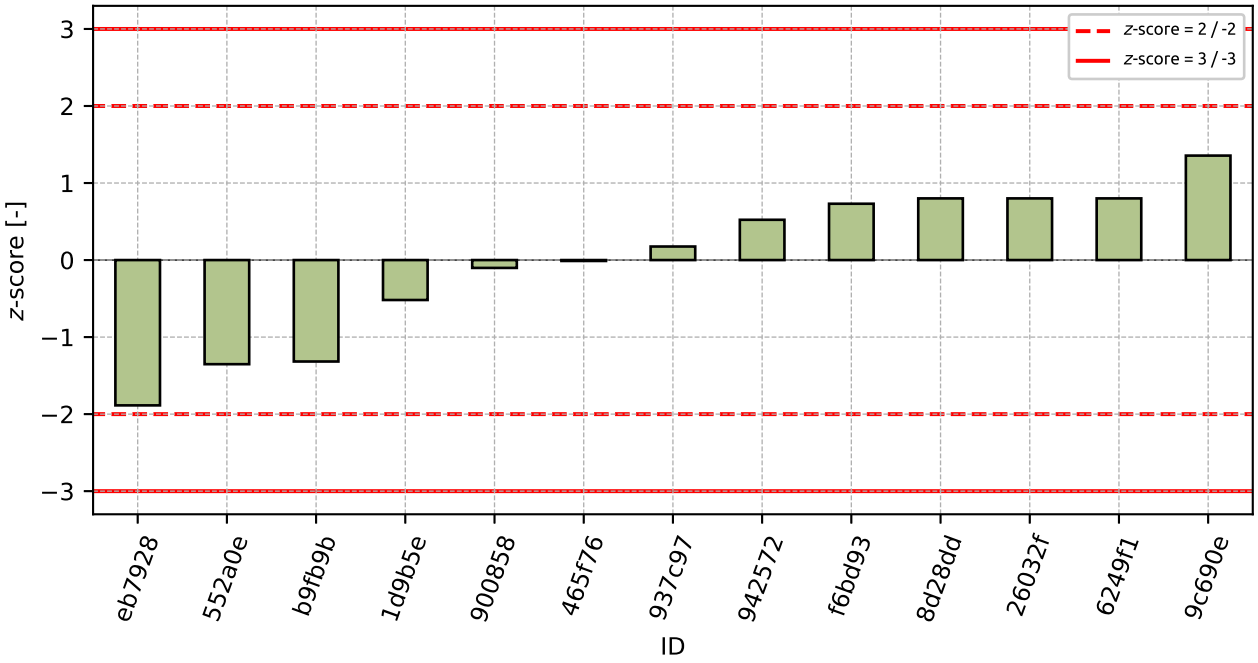

Figure 55: z-score

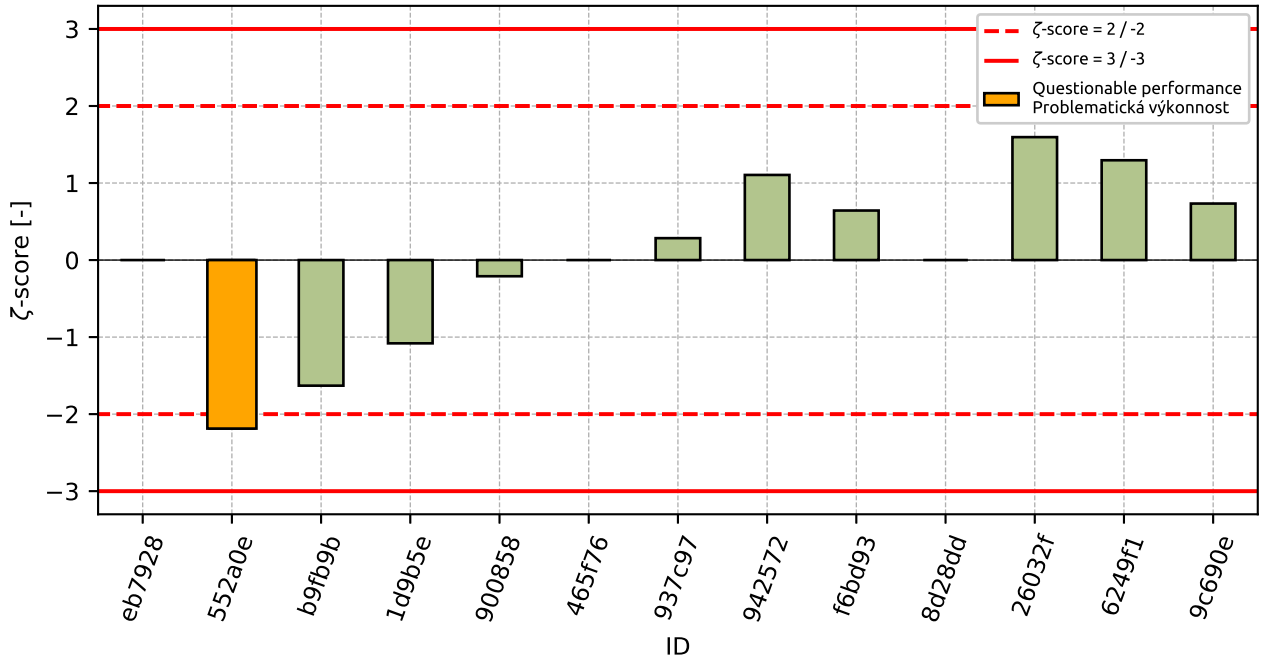

Figure 56: ζ-score

Table 21: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
eb7928	-1.89	-
552a0e	-1.35	-2.19
b9fb9b	-1.32	-1.63
1d9b5e	-0.52	-1.08
900858	-0.1	-0.21
465f76	-0.01	-
937c97	0.18	0.28
942572	0.52	1.1
f6bd93	0.73	0.64
8d28dd	0.8	-
26032f	0.8	1.6
6249f1	0.8	1.3
9c690e	1.36	0.73

10 Appendix – EN 1542, ČSN 736242, Appendix B – Measurement of bond strength by pull-off

10.1 Test results

Table 22: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [N/mm^2]					u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
04fa2d	2.93	2.64	2.28	1.77	2.42	0.04	2.41	0.433	17.98
1d9b5e	2.31	2.35	2.61	2.35	2.47	0.04	2.42	0.121	5.01
937c97	2.34	3.46	2.5	1.73	2.39	0.36	2.48	0.623	25.07
b9fb9b	2.63	2.41	2.68	2.64	2.92	0.1	2.66	0.181	6.83
53579d	2.1	2.75	2.72	3.48	2.7	0.5	2.75	0.49	17.8
6d20e6	2.3	3.3	3.2	3.1	3.0	0.52	2.98	0.396	13.3
b3e025	2.7	2.8	3.4	3.1	3.0	0.3	3.0	0.274	9.13
942572	3.0	3.2	3.2	3.0	3.1	0.1	3.1	0.1	3.23
3d1003	2.79	2.98	2.84	3.38	3.59	-	3.12	0.352	11.29
a78377	3.4	3.5	3.5	3.0	3.3	0.2	3.34	0.207	6.21
ed0db4	3.8	3.4	2.8	3.5	3.5	0.5	3.4	0.367	10.81
900858	3.5	3.4	3.6	3.6	3.6	0.05	3.54	0.089	2.53
26032f	3.5	3.77	4.03	3.7	3.47	0.3	3.69	0.227	6.15
6b6834	4.27	3.95	3.95	4.08	4.67	0.1	4.18	0.302	7.21
8d28dd	4.6	4.6	4.1	4.2	4.3	0.55	4.36	0.23	5.28
552a0e	4.3	4.4	4.4	4.5	4.3	0.4	4.38	0.084	1.91

10.2 The Numerical Procedure for Determining Outliers

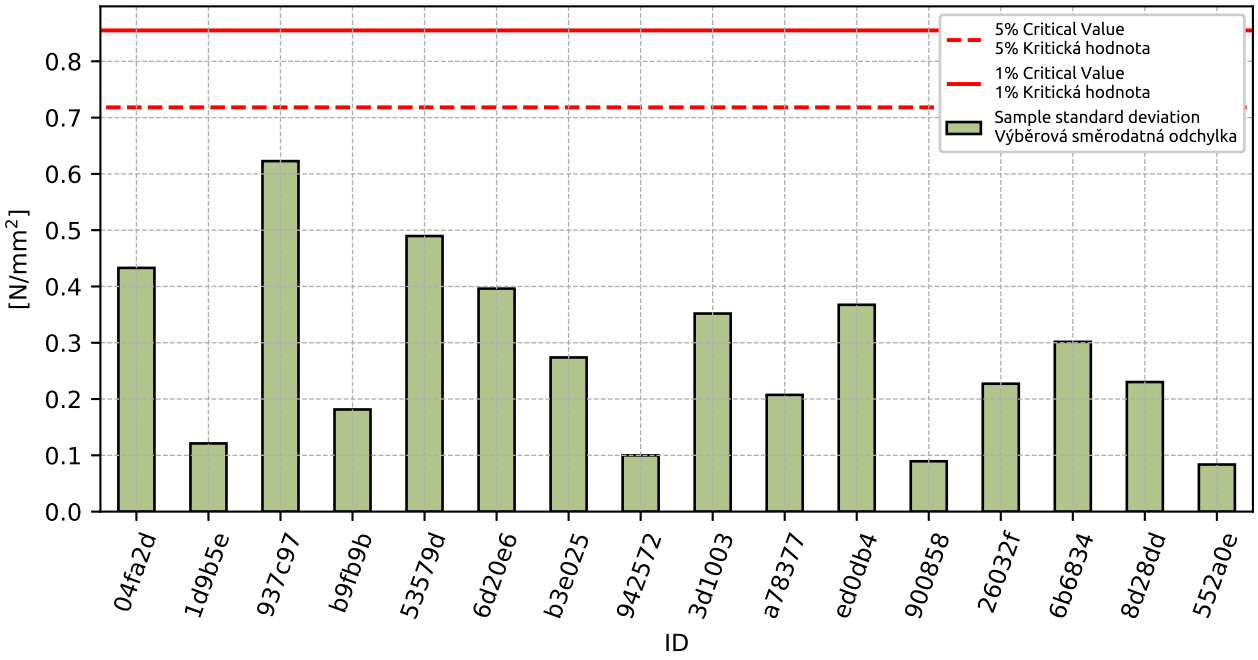

Figure 57: **Cochran's test** - sample standard deviations

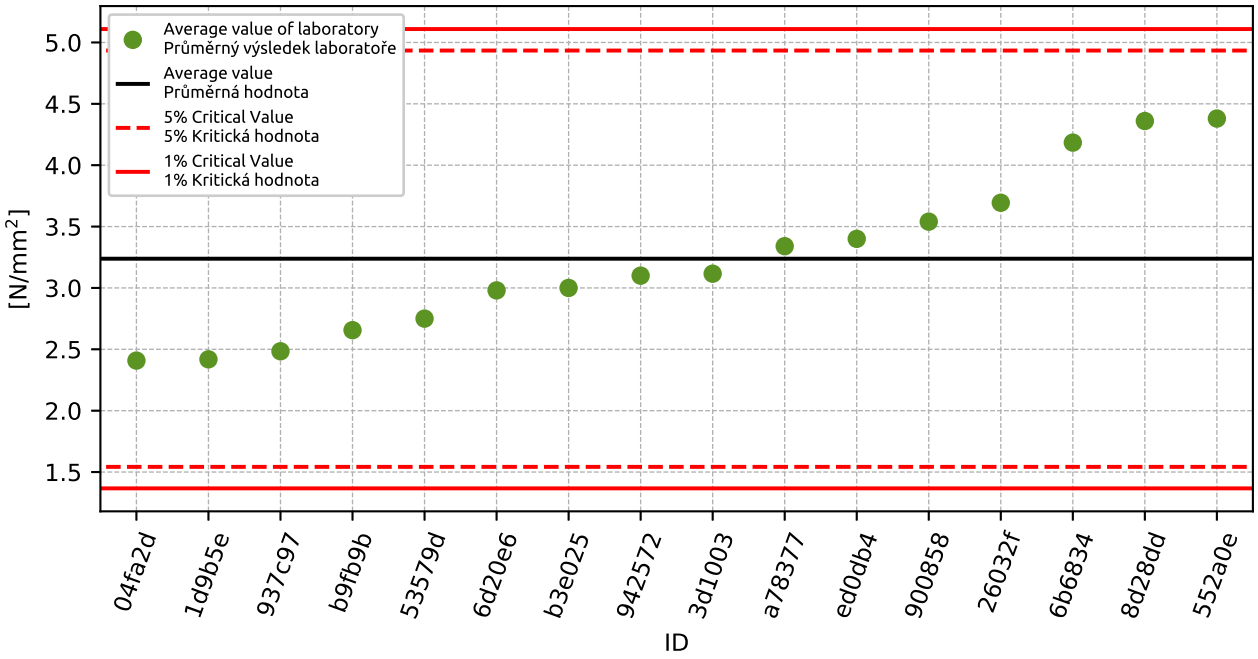

Figure 58: **Grubbs' test** - average values

10.3 Mandel's Statistics

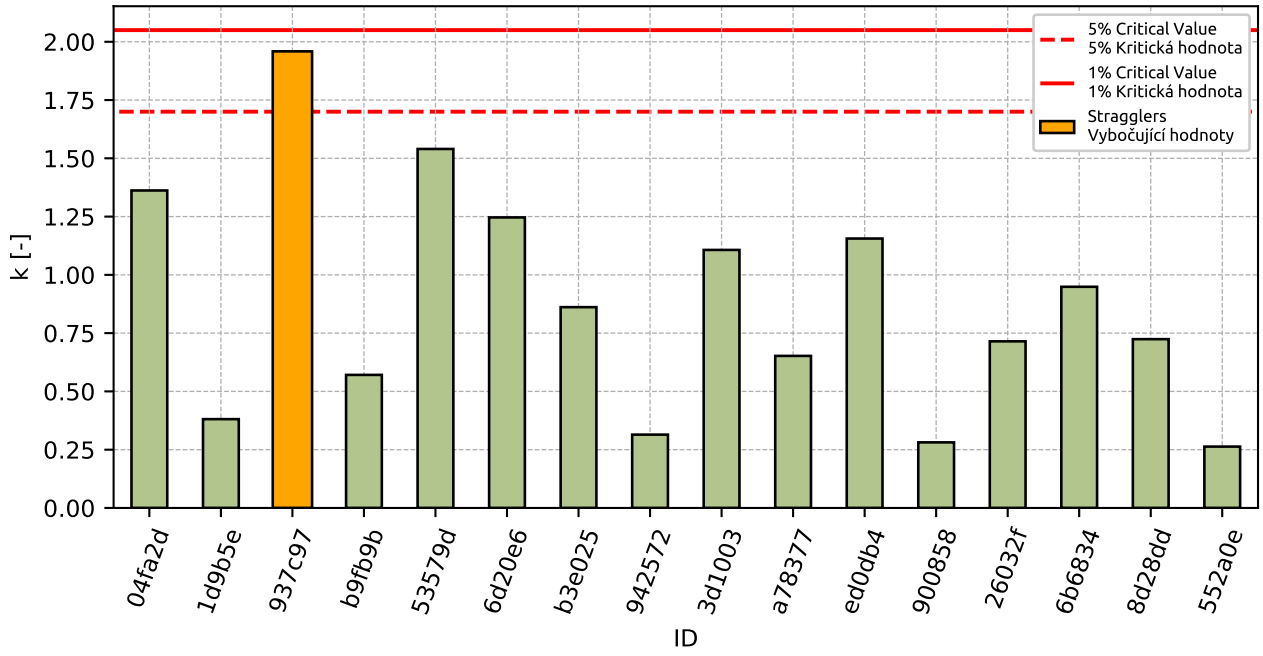

Figure 59: Intralaboratory Consistency Statistic

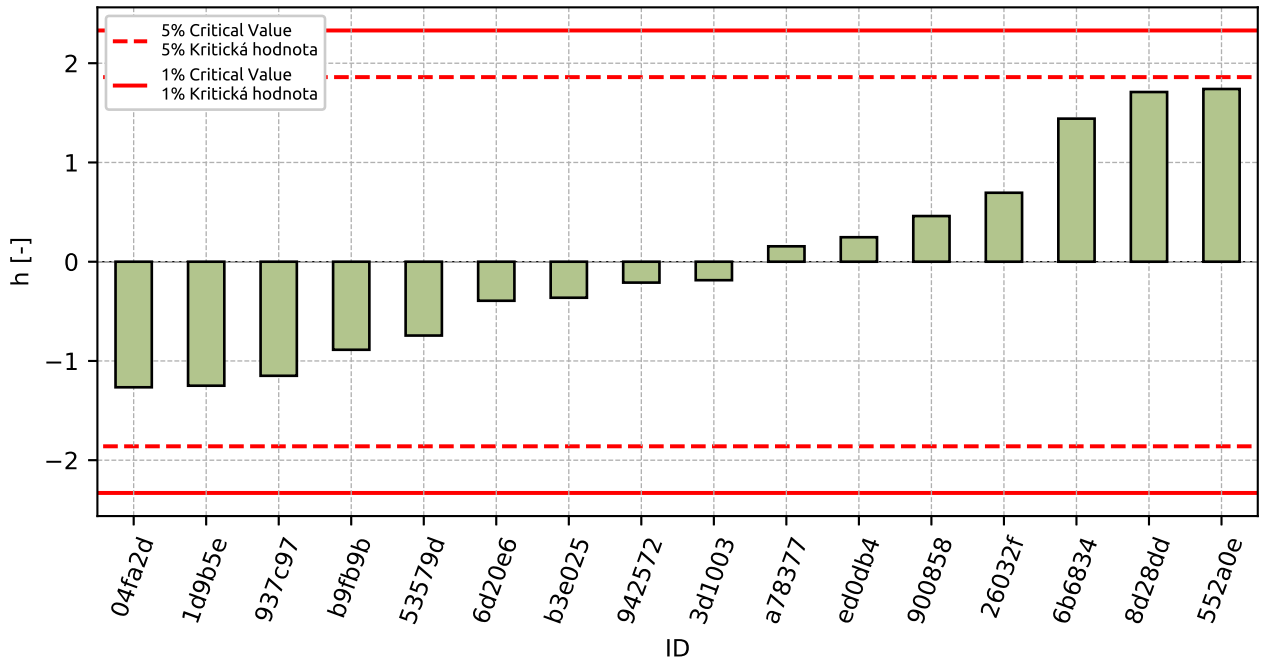

Figure 60: Interlaboratory Consistency Statistic

10.4 Descriptive statistics

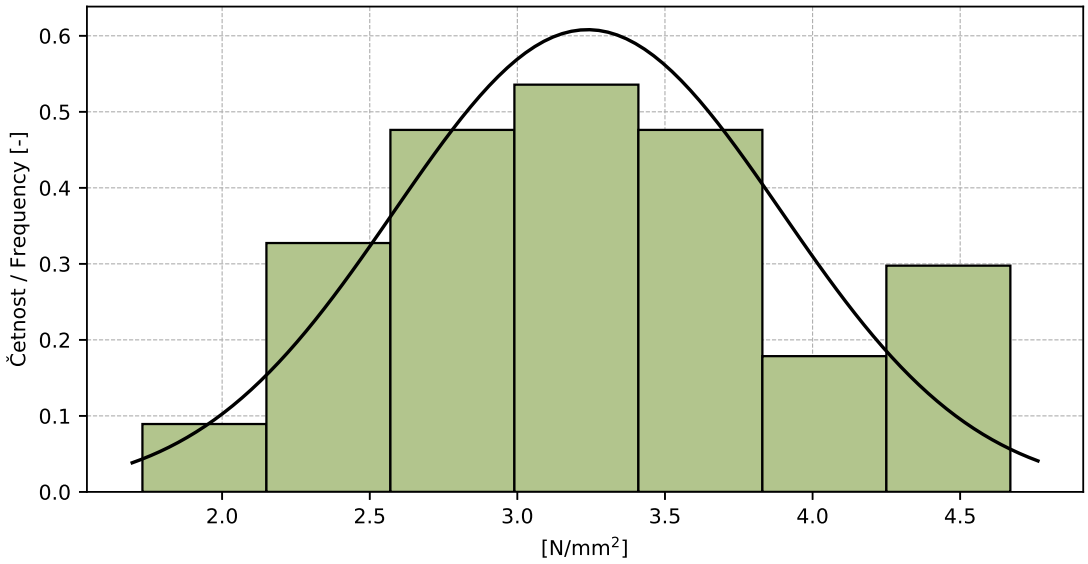

Figure 61: Histogram of all test results

Table 23: Descriptive statistics

Value	[N/mm²]
Průměrná hodnota / Average value – $\bar{x}$	3.24
Výběrová směrodatná odchylka / Sample standard deviation – s	0.656
Vztažná hodnota / Asigned value – x^*	3.24
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.656
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.81
p-hodnota testu normality / p-value of normality test	0.301 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.641
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.318
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.715
Opakovatelnost / Repeatability – r	0.89
Reprodukovatelnost / Reproducibility – R	2.0

10.5 Calculation of Performance Statistics

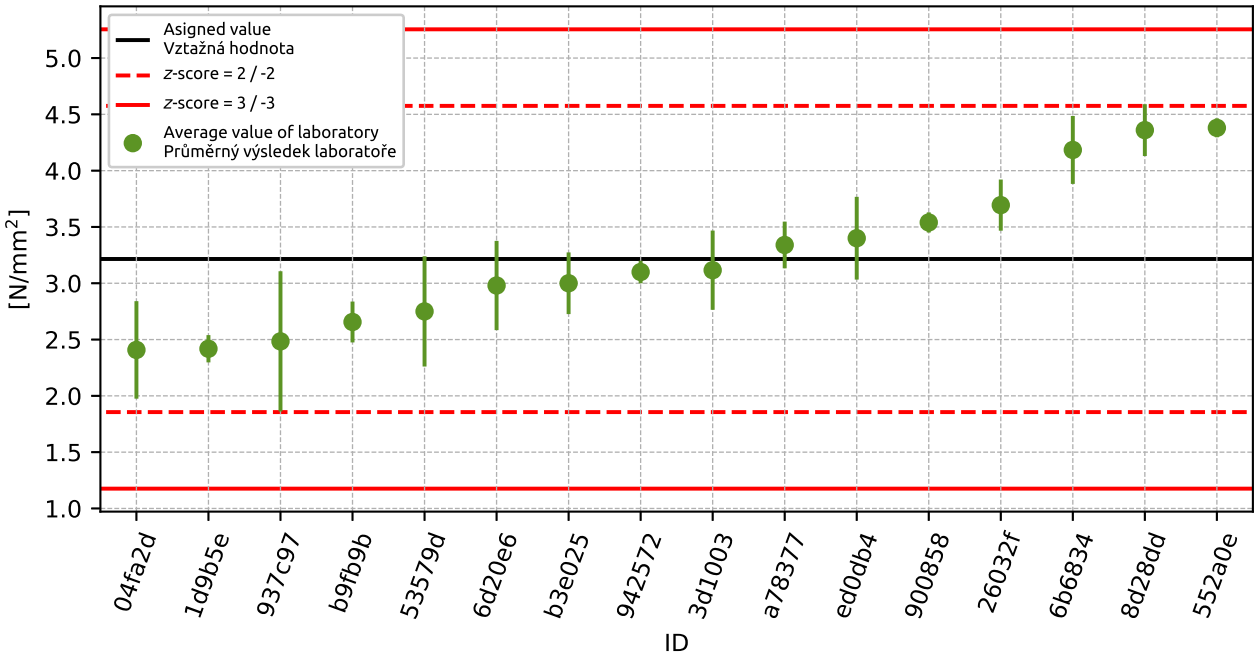

Figure 62: Average values and sample standard deviations

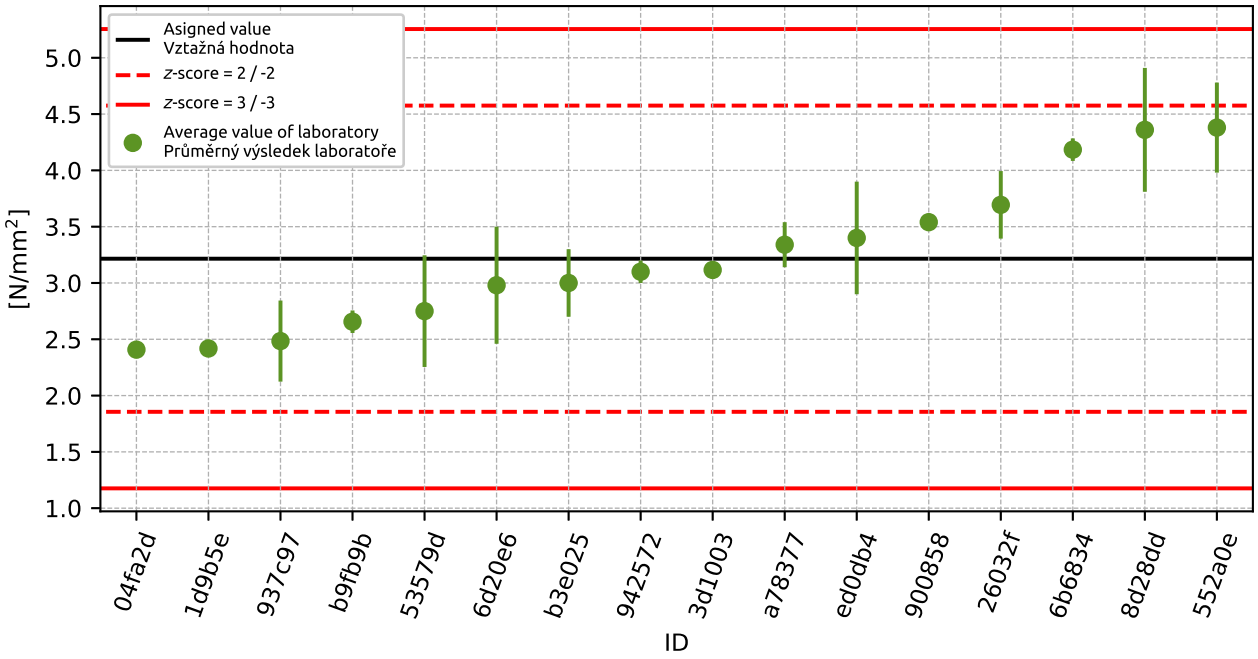

Figure 63: Average values and extended uncertainties of measurement

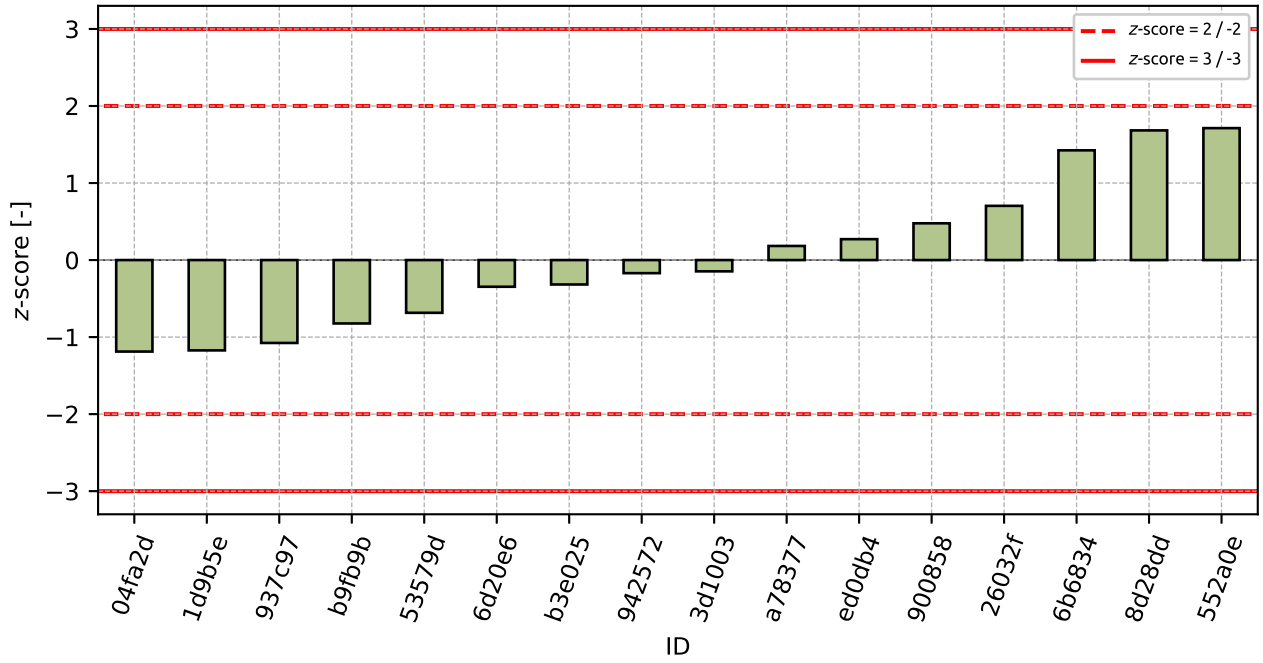

Figure 64: z-score

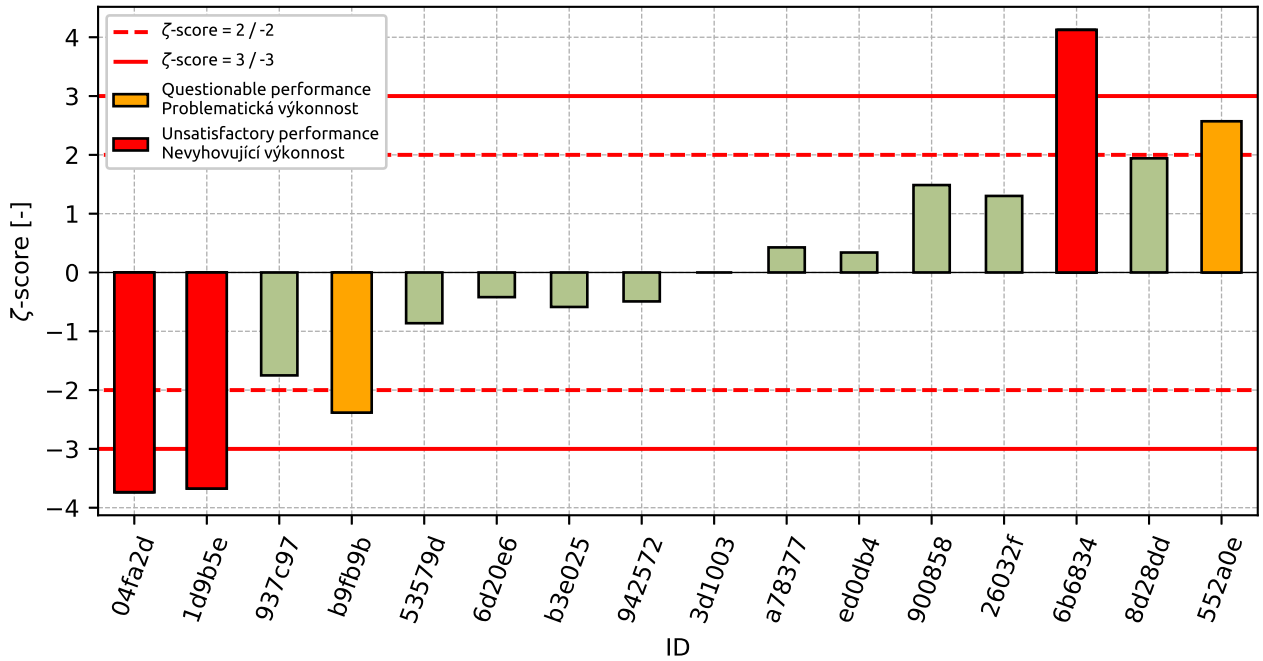

Figure 65: ζ-score

Table 24: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
04fa2d	-1.19	-3.74
1d9b5e	-1.17	-3.67
937c97	-1.08	-1.75
b9fb9b	-0.82	-2.38
53579d	-0.68	-0.86
6d20e6	-0.35	-0.42
b3e025	-0.32	-0.59
942572	-0.17	-0.49
3d1003	-0.15	-
a78377	0.18	0.43
ed0db4	0.27	0.34
900858	0.48	1.49
26032f	0.7	1.3
6b6834	1.42	4.12
8d28dd	1.68	1.94
552a0e	1.71	2.57