



FINAL REPORT ON THE RESULTS OF PRECISION EXPERIMENT

Proficiency Testing Program Mortar, Cement and Fine-grained Cement Composites ZMC 2020/1

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

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

Date: 1/7/2021

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



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

Contents

1 Introduction and Important Contacts	3
2 Procedures used in the Statistical Analysis of Laboratory Results	5
3 Conclusions of the Statistical Analysis	6
Standards and Documents Used	7
Appendix	8
1 Appendix – EN 196-1 – Strength	8
2 Appendix – EN 196-2 (art. 4.4.1) – Determination of loss on ignition	8
3 Appendix – EN 196-2 (art. 4.4.2) – Determination of sulphate content	8
4 Appendix – EN 196-2 (art. 4.4.3) – Determination of the residue insoluble in hydrochloric acid and sodium carbonate	8
5 Appendix – EN 196-2 (art. 4.4.4) – Determination of the residue insoluble in hydrochloric acid and potassium hydroxide	8
6 Appendix – EN 196-2 (art. 4.4.5) – Determination of sulphite content	8
7 Appendix – EN 196-3 – Setting time, Soundness	8
8 Appendix – EN 196-10 – Determination of the water-soluble chromium (Cr^{6+})	8
9 Appendix – EN 1015-1 – Granularity	8
10 Appendix – EN 1015-3 – Consistency	8
11 Appendix – EN 1015-6 – Density of fresh mortar	8
12 Appendix – EN 1015-10 – Density of hardened mortar	9
13 Appendix – EN 1015-11 – Strength	9
13.1 Flexural Strength	9
13.1.1 Test results	9
13.1.2 The Numerical Procedure for Determining Outliers	9
13.1.3 Mandel's Statistics	10
13.1.4 Descriptive statistics	11
13.1.5 Evaluation of Performance Statistics	12
13.2 Compressive Strength	15
13.2.1 Test results	15
13.2.2 The Numerical Procedure for Determining Outliers	15
13.2.3 Mandel's Statistics	17
13.2.4 Descriptive statistics	18
13.2.5 Evaluation of Performance Statistics	19
14 Appendix – EN 1015-12 – Adhesion	22
15 Appendix – EN 1015-18 – Capillary absorption coefficient (C_m)	22
16 Appendix – EN 1015-19 – Water vapor flow	22

17 Appendix – EN 13892-2 – Determination of flexural and compressive strength	22
17.1 Flexural Strength	22
17.1.1 Test results	22
17.1.2 The Numerical Procedure for Determining Outliers	23
17.1.3 Mandel’s Statistics	24
17.1.4 Descriptive statistics	25
17.1.5 Evaluation of Performance Statistics	26
17.2 Compressive Strength	29
17.2.1 Test results	29
17.2.2 The Numerical Procedure for Determining Outliers	29
17.2.3 Mandel’s Statistics	30
17.2.4 Descriptive statistics	31
17.2.5 Evaluation of Performance Statistics	32
18 Appendix – EN 12004-2 (art. 8.1) – Open time	35
19 Appendix – EN 12004-2 (art. 8.2) – Slippage	35
20 Appendix – EN 12004-2 (art. 8.3.3.2) – Adhesion	35
21 Appendix – EN 12004-2 (art. 8.3.3.3) – Adhesion	35
22 Appendix – EN 196-2 (art. 4.4.6) – Determination of manganese content	35

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 ZMC 2020/1 whose aim was to verify and assess the conformity of test results across laboratories when testing mortar, cement and fine-grained cement composites.

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

Head of the PT Provider, PTP coordinator

Assoc. Prof. Ing. Tomáš Vymazal, Ph.D.

Brno University of Technology

Faculty of Civil Engineering

Institute of Building Testing

Veveří 95, Brno 602 00

Czech Republic

Tel.: +420 603 313 337

Email: Tomas.Vymazal@vutbr.cz

Coordinator of PTP result assessment PrZZ

Ing. Petr Misák, Ph.D.

Brno University of Technology

Faculty of Civil Engineering

Institute of Building Testing

Veveří 95, Brno 602 00

Czech Republic

Tel.: +420 774 980 255

Email: Petr.Misak@vutbr.cz

The subjects of proficiency testing were the following testing procedures:

1. EN 196-1 – Strength [1]
2. EN 196-2 (art. 4.4.1) – Determination of loss on ignition [2]
3. EN 196-2 (art. 4.4.2) – Determination of sulphate content [2]
4. EN 196-2 (art. 4.4.3) – Determination of the residue insoluble in hydrochloric acid and sodium carbonate [2]
5. EN 196-2 (art. 4.4.4) – Determination of the residue insoluble in hydrochloric acid and potassium hydroxide [2]
6. EN 196-2 (art. 4.4.5) – Determination of sulphite content [2]
7. EN 196-3 – Setting time, Soundness[3]
8. EN 196-10 – Determination of the water-soluble chromium (Cr^{6+}) [4]
9. EN 1015-1 – Granularity [5]
10. EN 1015-3 – Consistency [6]
11. EN 1015-6 – Density of fresh mortar [7]
12. EN 1015-10 – Density of hardened mortar [8]
13. EN 1015-11 – Strength [9]
14. EN 1015-12 – Adhesion [10]
15. EN 1015-18 – Capillary absorption coefficient (C_m) [11]
16. EN 1015-19 – Water vapor flow [12]
17. EN 13892-2 – Determination of flexural and compressive strength [13]
18. EN 12004-2 (art. 8.1) – Open time [14]
19. EN 12004-2 (art. 8.2) – Slippage [14]
20. EN 12004-2 (art. 8.3.3.2) – Adhesion [14]
21. EN 12004-2 (art. 8.3.3.3) – Adhesion [14]

22. EN 196-2 (art. 4.4.6) – Determination of manganese content [2]

Testing procedures No **13 and 17** were open. The other methods were not been open due to lack of participants (interested laboratories).

The specimens were taken from the same production with the same production date. The test results from individual PTP participants were compared via a method involving the statistical analysis of all their results in a manner complying with ISO 5725-2 [15] and with EN ISO/IEC 17043 [16]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

11 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/Part	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3d575b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
abd73a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
f31e27	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
722f5e	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
fdf1f5	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-
a61f7a	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-
b7173d	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-
d6bf8d	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
2bccad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
f99843	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-
67ef5b	-	-	-	-	-	-	-	-	-	-	-	-	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 No.
BETOSAN s.r.o.	Nová cesta 40/291, Praha 4 - Krč, 14000, Česká republika	1687
BETOTECH, s.r.o.	Beroun 660, 26601 Beroun, Ostrava, 70300, Česká republika	1195.2
BETOTECH, s.r.o. - pracoviště Beroun	Beroun 660, Beroun, 26601, Česká republika	AZL 1195
BUILDING RESEARCH INSTITUTE (N I S I) Ltd	Ilija Beshkov 1, Sofia, 1528, Bulgaria	47 ЛИ
CEMEX Czech Republic, s.r.o.	Semtín 102, Pardubice, 53354, Česká republika	1302
Cement Hranice, akciová společnost	Bělotínská 288, Hranice I - Město, 75301, Česká republika	1284
QUALIFORM, a.s.	Mlaty 672/8, Brno - Bosonohy, 642 00, Česká republika	1008
STACHEMA CZ s.r.o.	Hasičská 1, Zibohlavý, Kolín, 28002, Česká republika	L 1433
Universität für Bodenkultur Wien, Department für Bautechnik und Naturgefahren, Institut für Konstruktiven Ingenieurbau	Peter-Jordan-Str. 82, Wien - Vienna, 1190, AUSTRIA	P0252
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

2 Procedures used in the Statistical Analysis of Laboratory Results

The statistical analysis is based on the following steps:

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

evaluation of the performance of participants as they are to a considerable degree dependent on the values of the measurement uncertainties of the assessed institutions. The following scales are applied for the z-score values:

- $|z\text{-score}| < 2 \Rightarrow$ shows that the laboratory performance is **satisfactory** and generates no signal - ✓.
- $2 \leq |z\text{-score}| < 3 \Rightarrow$ shows that the laboratory performance is **questionable** and generates an action signal - ?.
- $|z\text{-score}| \geq 3 \Rightarrow$ shows that the laboratory performance is **unsatisfactory** and generates an action signal - !.

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

3 Conclusions of the Statistical Analysis

The present report summarizes the results of the Proficiency Testing Program Mortar, Cement and Fine-grained Cement Composites (PT Program) organized by the PT Provider at the SZK FAST. 11 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of mortar, cement, fine-grained cement composites. The test results are evaluated separately for each testing procedure examined. An evaluation of statistical characteristics is included in the Appendix, as well as test results and graphic presentations. Testing methods can be found in part 1 of this report.

Table 4: Evaluation of overall performance and outliers.

✓ - satisfactory performance; ? - questionable performance; ! - unsatisfactory performance; X - outlier;

ID / Method	13	17
3d575b	-	?
abd73a	-	✓
f31e27	✓	-
722f5e	✓	-
fdf1f5	✓	✓
a61f7a	X	✓
b7173d	✓	✓
d6bf8d	✓	-
2bccad	-	✓
f99843	✓	✓
67ef5b	✓	✓

References

- [1] EN 196-1. *Methods of testing cement - Part 1: Determination of strength*. 2016.
- [2] EN 196-2. *Method of testing cement - Part 2: Chemical analysis of cement*. 2013.
- [3] EN 196-3. *Methods of testing cement - Part 3: Determination of setting times and soundness*. 2009.
- [4] EN 196-10. *Methods of testing cement - Part 10: Determination of the water-soluble chromium (VI) content of cement*. 2006.
- [5] EN 1015-1. *Methods of test for mortar for masonry - Part 1: Determination of particle size distribution (by sieve analysis)*. 1999.
- [6] EN 1015-3. *Methods of test for mortar for masonry - Part 3: Determination of consistence of fresh mortar (by flow table)*. 2000.
- [7] EN 1015-6. *Methods of test for mortar for masonry - Part 6: Determination of bulk density of fresh mortar*. 1999.
- [8] EN 1015-10. *Methods of test for mortar for masonry - Part 10: Determination of dry bulk density of hardened mortar*. 2000.
- [9] EN 1015-11. *Methods of test for mortar for masonry - Part 11: Determination of flexural and compressive strength of hardened mortar*. 2000.
- [10] EN 1015-12. *Methods of test for mortar for masonry - Part 12: Determination of adhesive strength of hardened rendering and plastering mortars on substrates*. 2000.
- [11] EN 1015-18. *Methods of test for mortar for masonry - Part 18: Determination of water absorption coefficient due to capillarity action of hardened mortar*. 2003.
- [12] EN 1015-19. *Methods of test for mortar for masonry - Part 19: Determination of water vapour permeability of hardened rendering and plastering mortars*. 1999.
- [13] EN 13892-2. *Methods of test for screed materials - Part 2: Determination of flexural and compressive strength*. 2003.
- [14] EN 12004-2. *Adhesives for ceramic tiles - Part 2: Test methods*. 2017.
- [15] ISO 5725-2. *Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*. 1997.
- [16] EN ISO/IEC 17043. *Conformity assessment - General requirements for proficiency testing*. 2010.

1 Appendix – EN 196-1 – Strength

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

9 Appendix – EN 1015-1 – Granularity

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

10 Appendix – EN 1015-3 – Consistency

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

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

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

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

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

13 Appendix – EN 1015-11 – Strength

13.1 Flexural Strength

13.1.1 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 [%]
fdf1f5	1.25	1.5	1.3	0.04	1.35	0.132	9.8
f99843	1.37	1.29	1.48	-	1.38	0.095	6.91
722f5e	1.65	1.4	1.2	0.1	1.42	0.225	15.91
b7173d	1.5	1.6	1.6	0.1	1.57	0.058	3.69
67ef5b	1.56	1.68	1.63	0.1	1.62	0.06	3.71
a61f7a	1.94	1.96	2.02	-	1.97	0.042	2.11
f31e27	2.41	2.34	2.32	0.1	2.36	0.047	2.01
d6bf8d	2.75	2.6	2.65	0.1	2.67	0.076	2.86

13.1.2 The Numerical Procedure for Determining Outliers

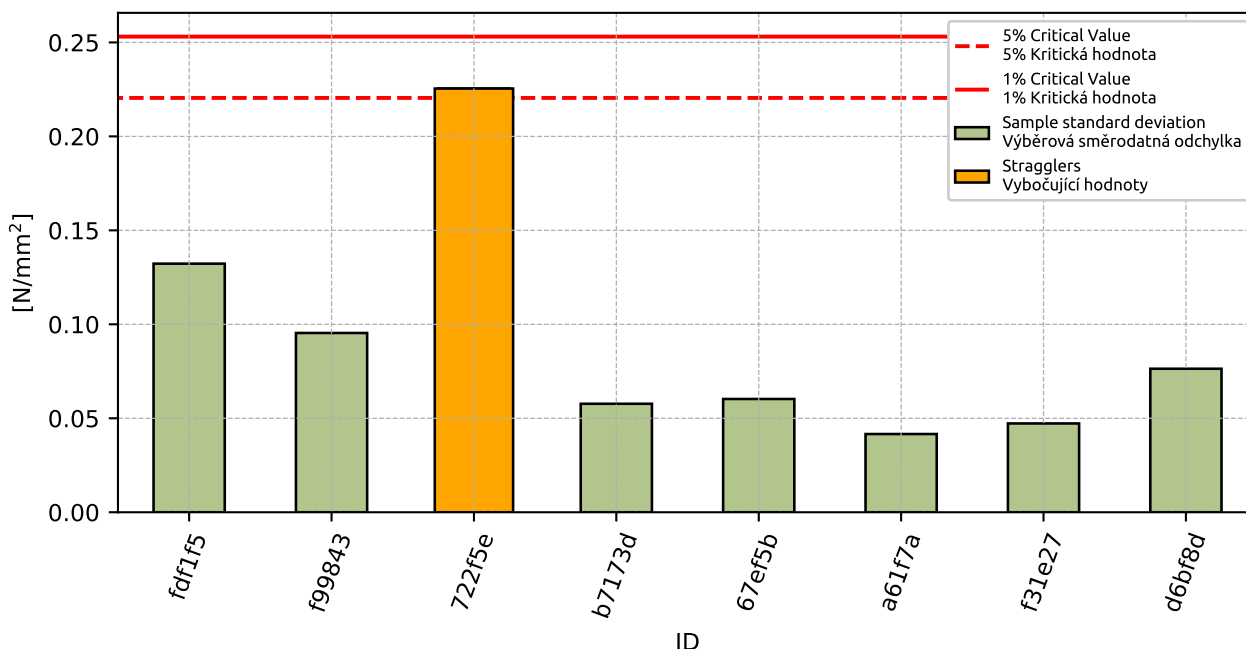


Figure 1: Cochran's test - sample standard deviations

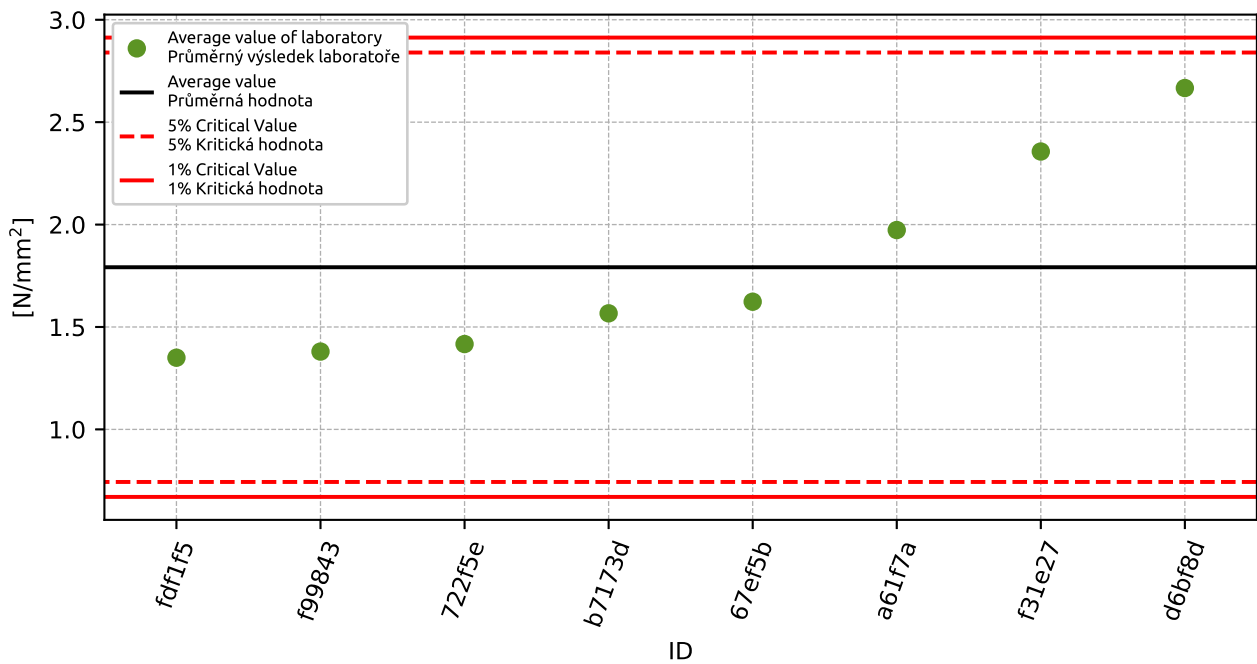


Figure 2: **Grubbs' test** - average values

13.1.3 Mandel's Statistics

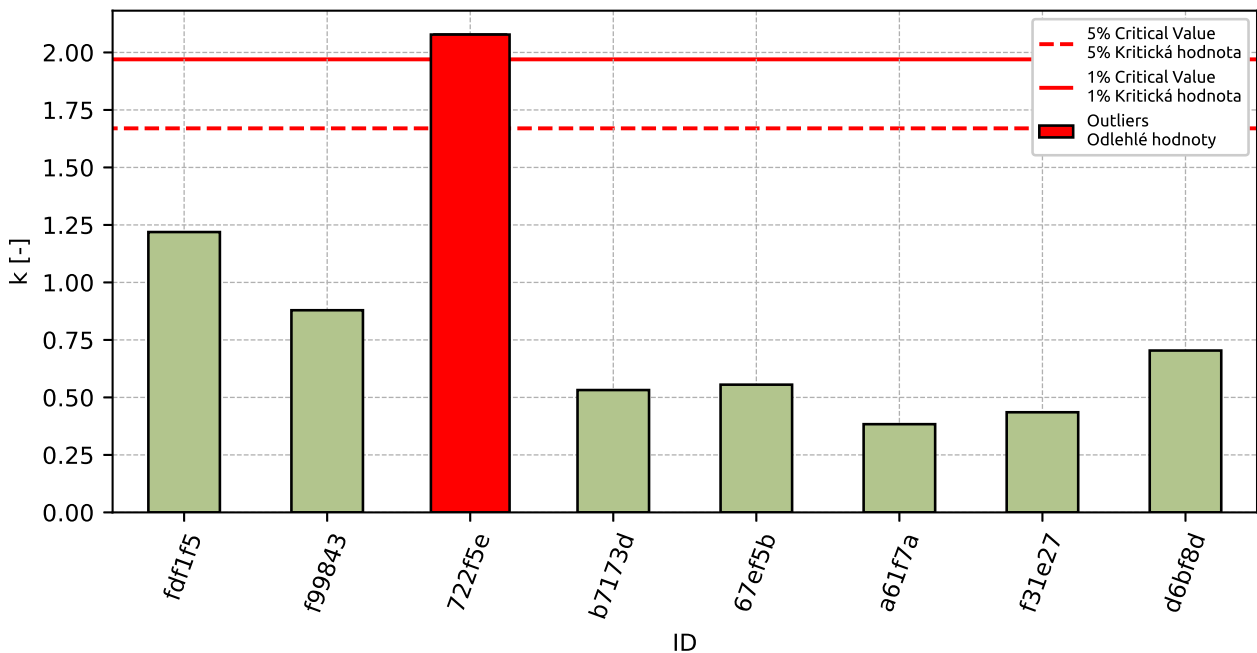


Figure 3: Intralaboratory Consistency Statistic

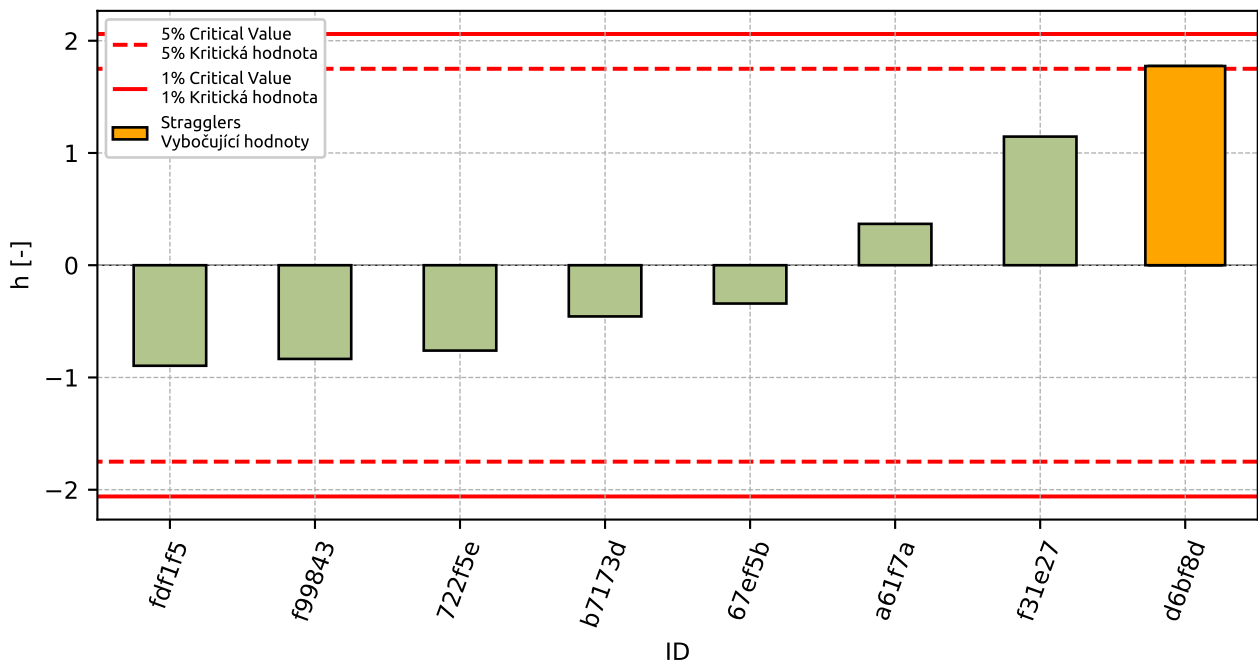


Figure 4: Interlaboratory Consistency Statistic

13.1.4 Descriptive statistics

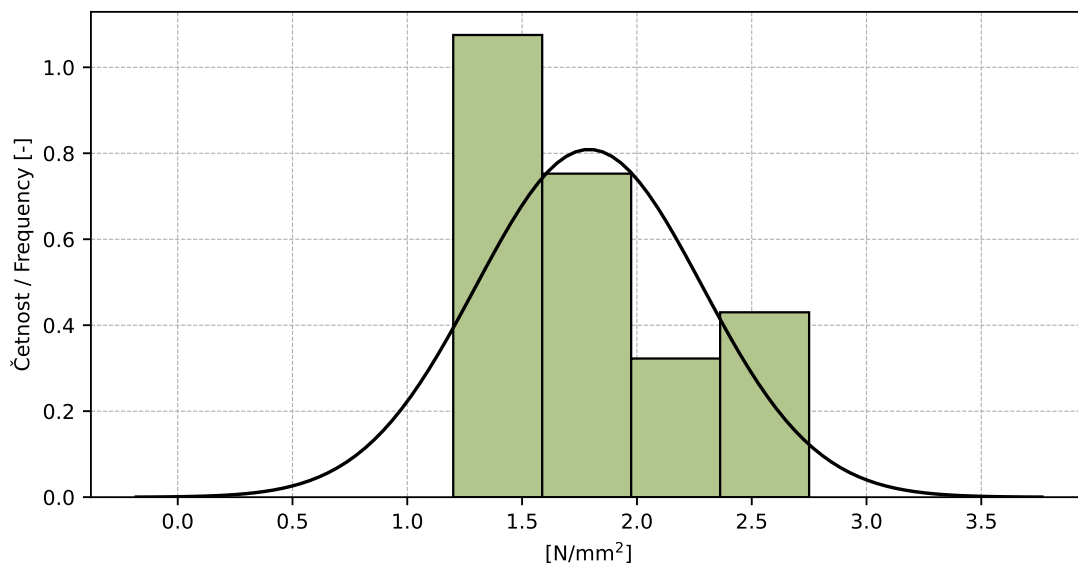


Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[N/mm ²]
Průměrná hodnota / Average value – \bar{x}	1.79
Výběrová směrodatná odchylka / Sample standard deviation – s	0.493
Vztažná hodnota / Assigned value – x^*	1.76
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.487
Nejistota měření vztažné hodnoty / Measurement uncertainty of assigned value – u_X	0.215
p -hodnota testu normality / p -value of normality test	0.015 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.489
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.109
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.501
Opakovatelnost / Repeatability – r	0.3
Reprodukovatelnost / Reproducibility – R	1.4

13.1.5 Evaluation of Performance Statistics

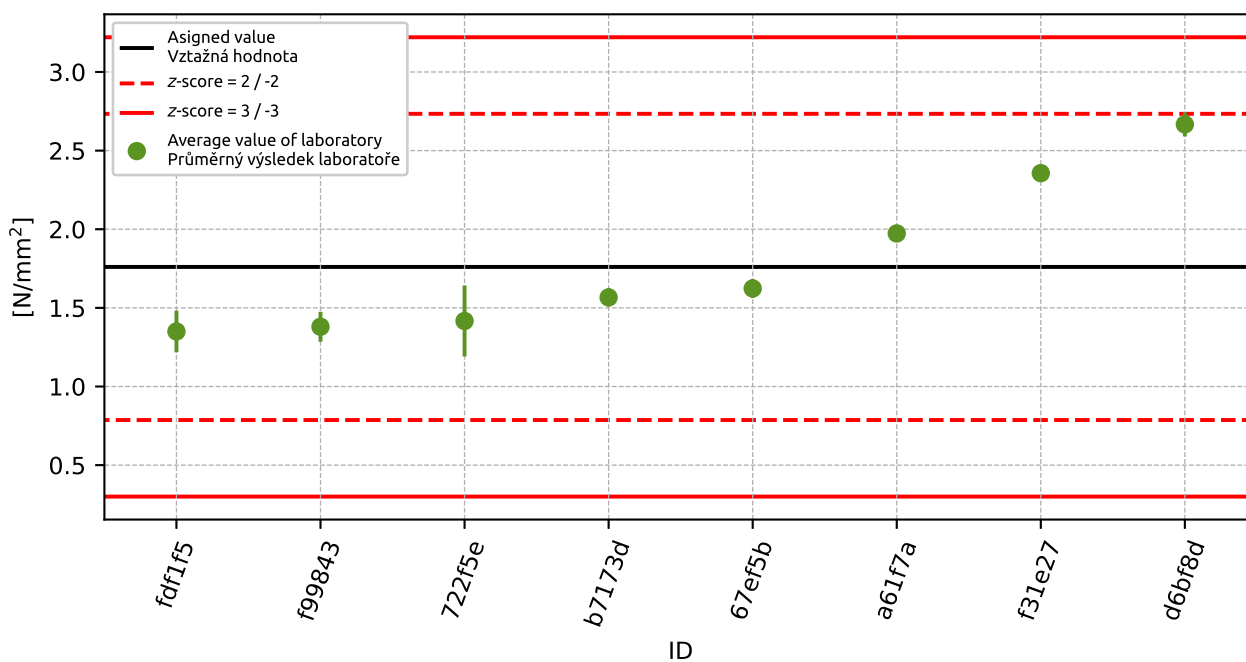


Figure 6: Average values and sample standard deviations

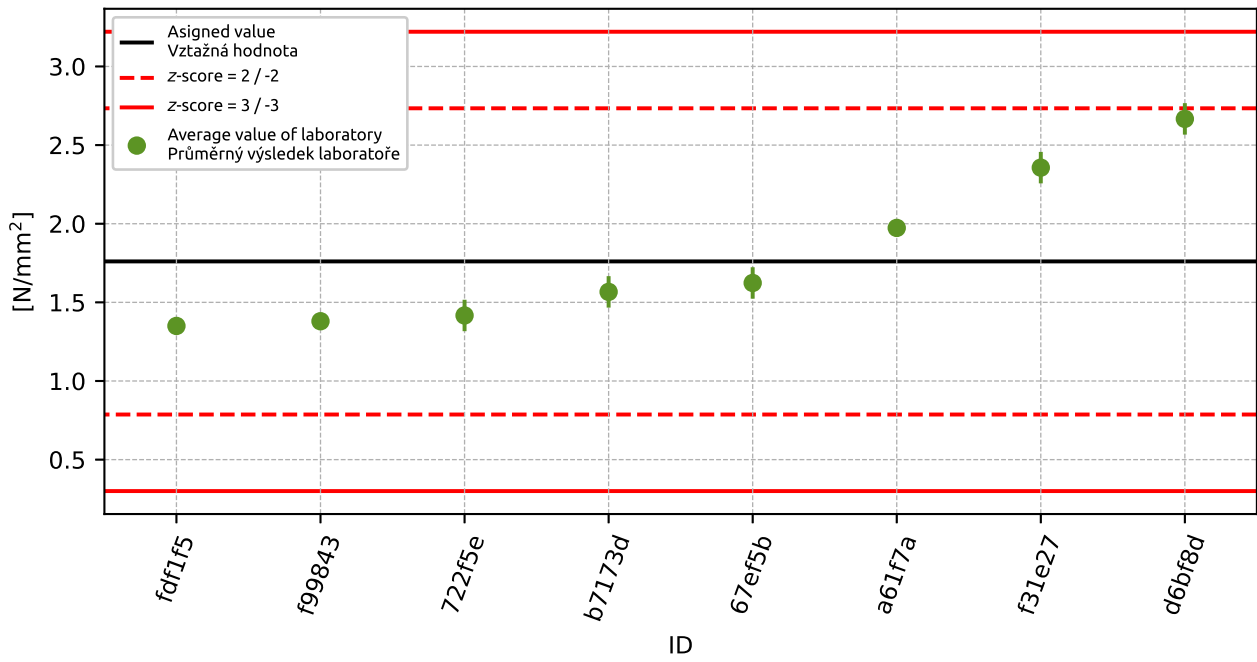


Figure 7: Average values and extended uncertainties of measurement

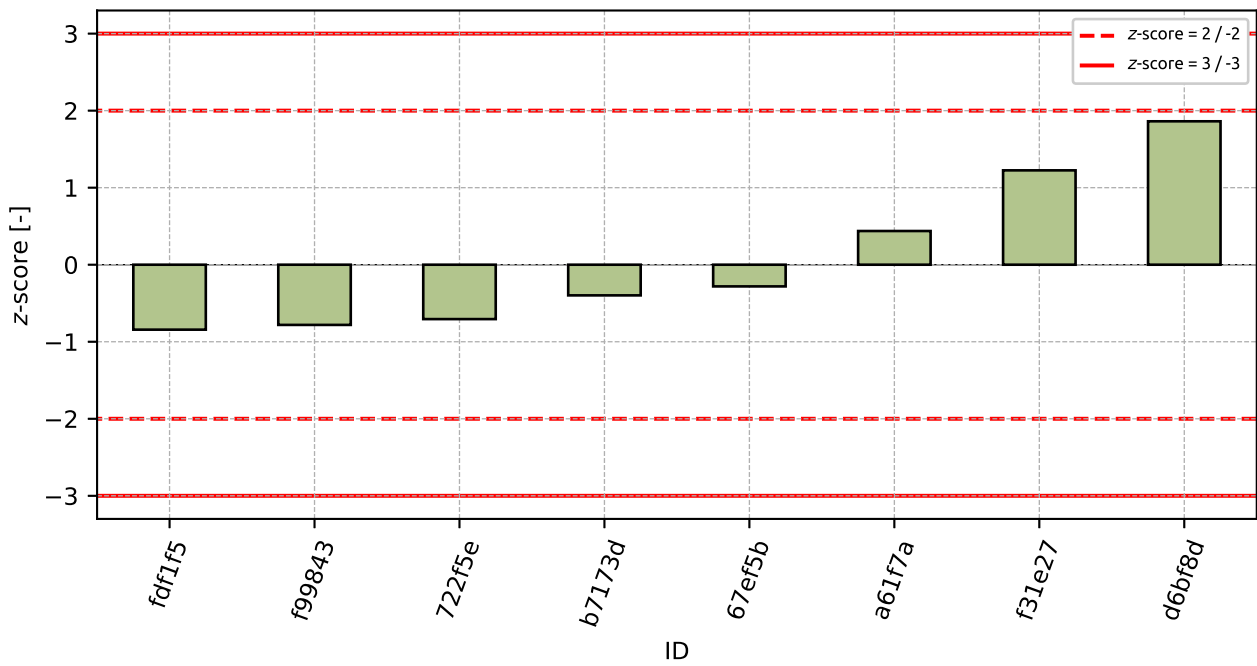
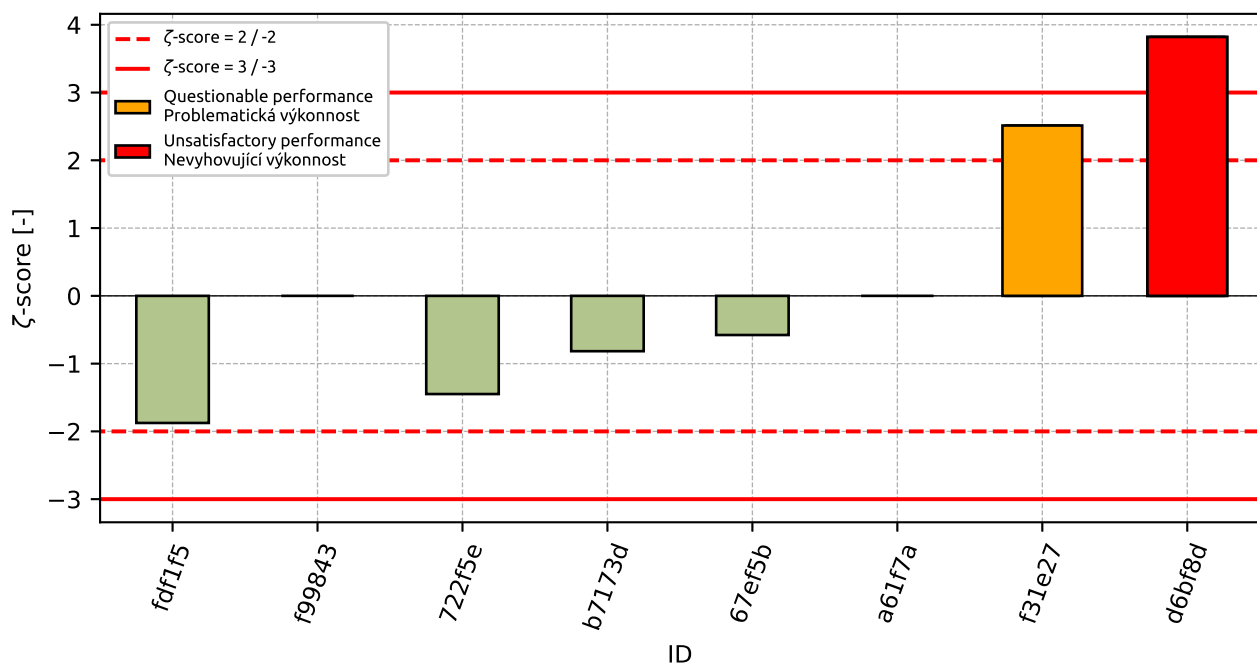


Figure 8: z-score

Figure 9: ζ -scoreTable 6: z-score and ζ -score

ID	z-score [-]	ζ -score [-]
fdf1f5	-0.84	-1.88
f99843	-0.78	-
722f5e	-0.71	-1.45
b7173d	-0.4	-0.82
67ef5b	-0.28	-0.58
a61f7a	0.44	-
f31e27	1.22	2.51
d6bf8d	1.86	3.82

13.2 Compressive Strength

13.2.1 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	\bar{x}	s_0	V_x
							[N/mm ²]	[N/mm ²]	[N/mm ²]	[%]
b7173d	5.3	5.5	5.9	6.0	5.6	5.5	0.1	5.63	0.266	4.72
722f5e	5.95	6.0	6.2	6.3	6.25	6.15	0.5	6.14	0.139	2.27
f31e27	6.65	6.68	6.71	6.71	6.68	6.71	0.1	6.69	0.024	0.37
f99843	7.05	6.89	6.93	6.42	6.54	6.78	-	6.77	0.242	3.58
fdf1f5	6.8	6.9	7.4	7.25	7.15	7.3	0.2	7.13	0.236	3.31
67ef5b	7.9	8.3	7.5	8.0	8.1	7.8	0.5	7.93	0.273	3.44
d6bf8d	7.8	8.7	7.8	8.0	8.1	8.5	0.2	8.15	0.373	4.57
a61f7a	12.7	12.9	12.0	11.6	12.8	12.4	-	12.4	0.51	4.11

13.2.2 The Numerical Procedure for Determining Outliers

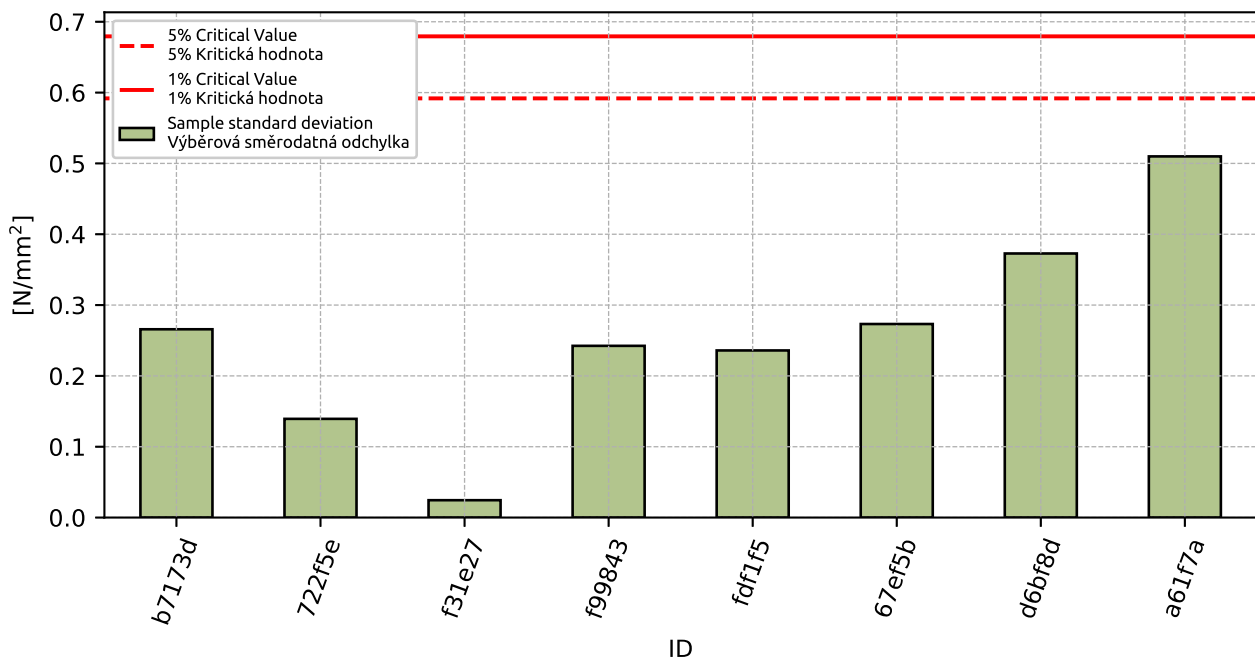


Figure 10: Cochran's test - sample standard deviations

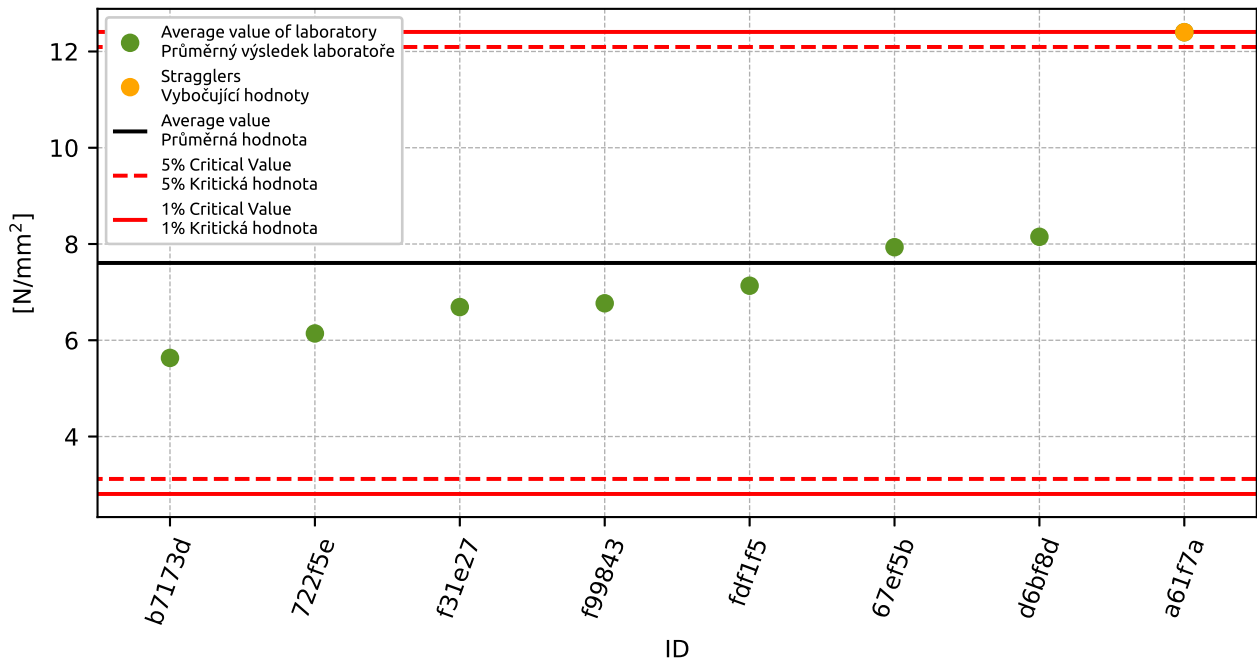


Figure 11: **Grubbs' test** - average values

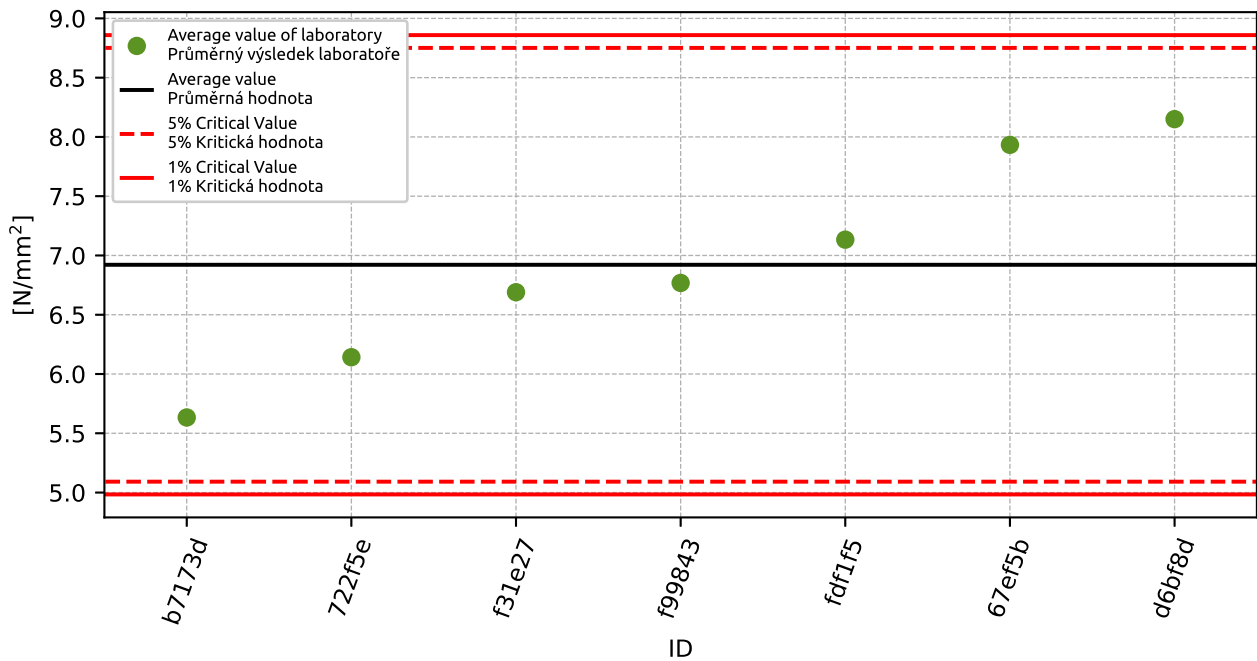


Figure 12: **Grubbs' test** - average values without outliers

13.2.3 Mandel's Statistics

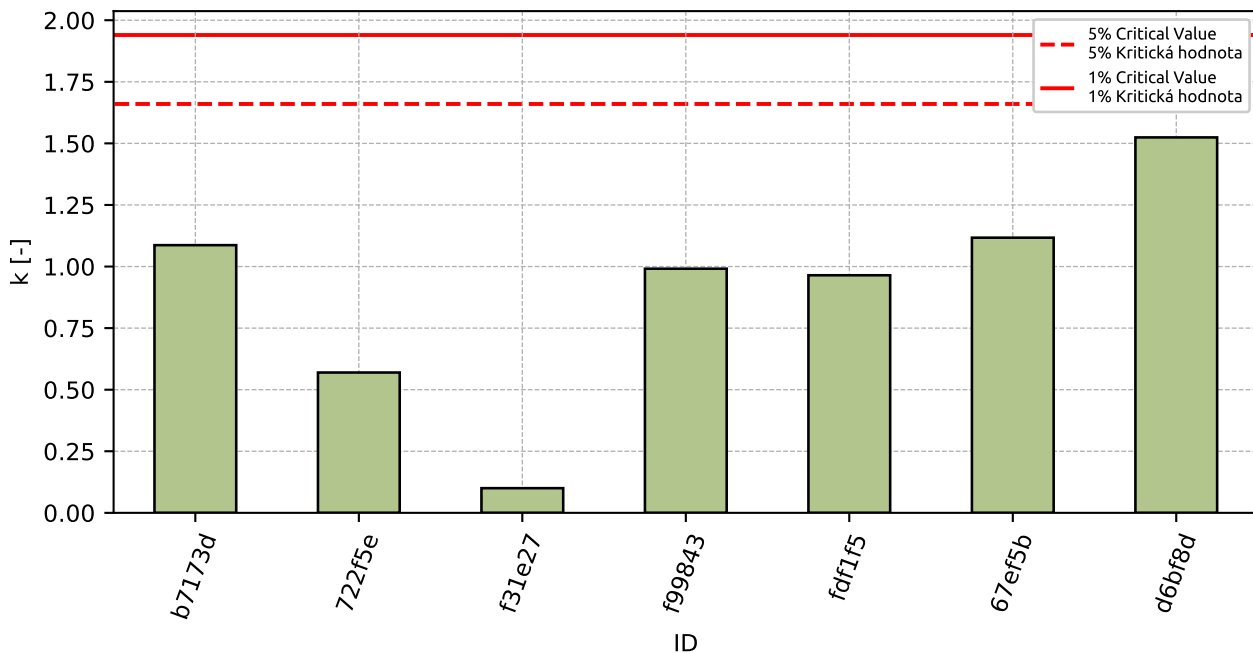


Figure 13: Intralaboratory Consistency Statistic

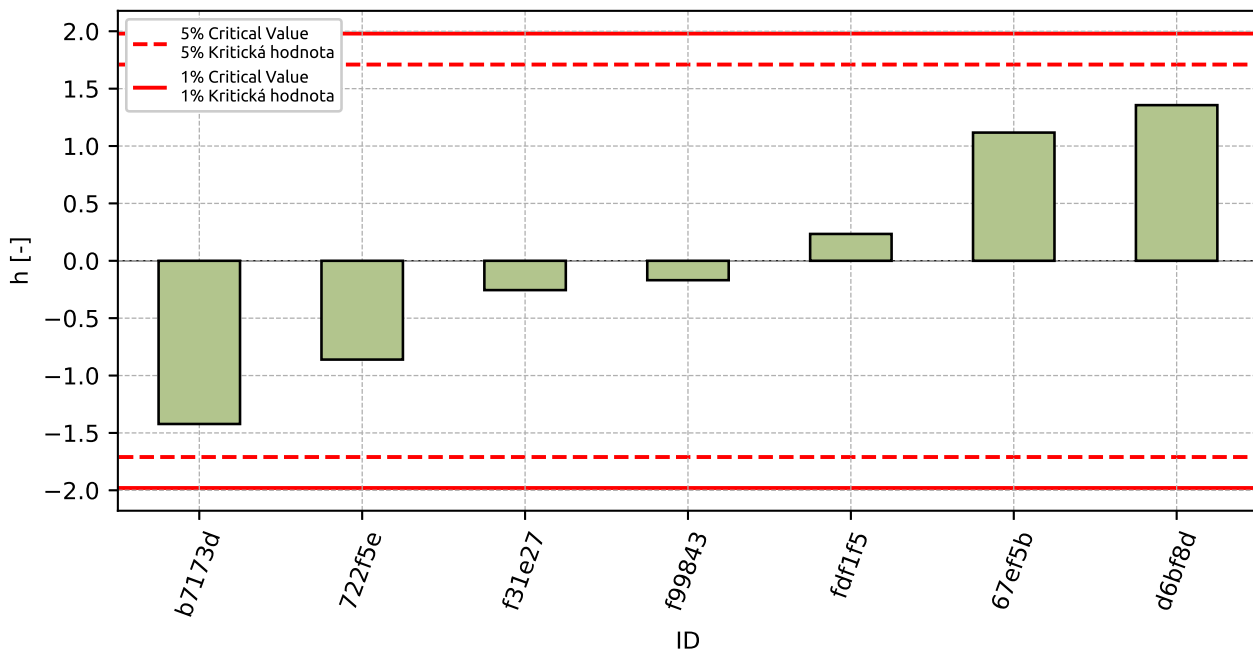


Figure 14: Interlaboratory Consistency Statistic

13.2.4 Descriptive statistics

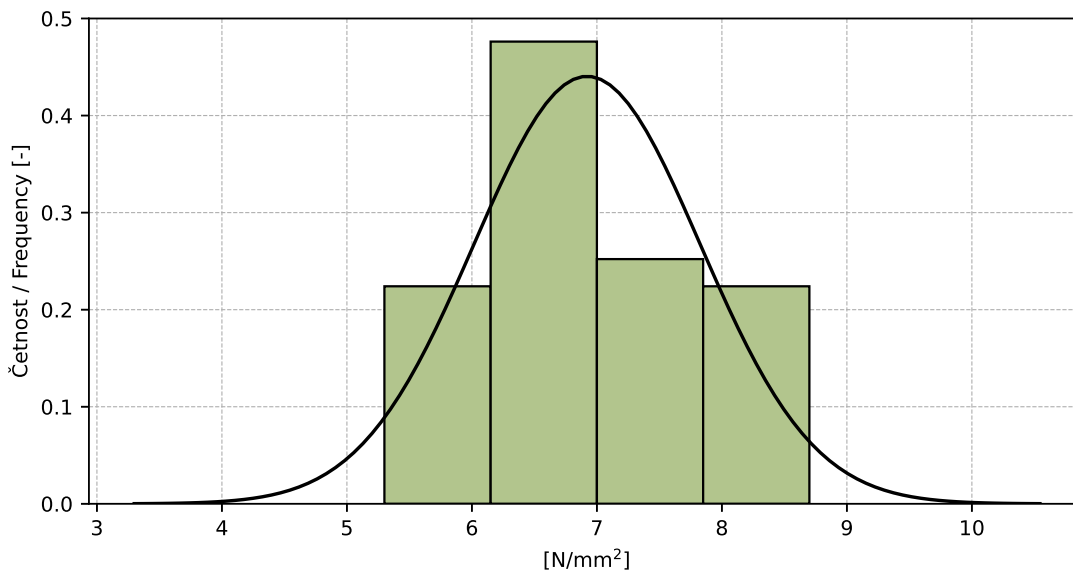


Figure 15: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[N/mm ²]
Průměrná hodnota / Average value – \bar{x}	6.92
Výběrová směrodatná odchylka / Sample standard deviation – s	0.906
Vztažná hodnota / Assigned value – x^*	6.92
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.951
Nejistota měření vztažné hodnoty / Measurement uncertainty of assigned value – u_X	0.449
p -hodnota testu normality / p -value of normality test	0.447 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.9
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.245
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.933
Opakovatelnost / Repeatability – r	0.68
Reprodukovatelnost / Reproducibility – R	2.61

13.2.5 Evaluation of Performance Statistics

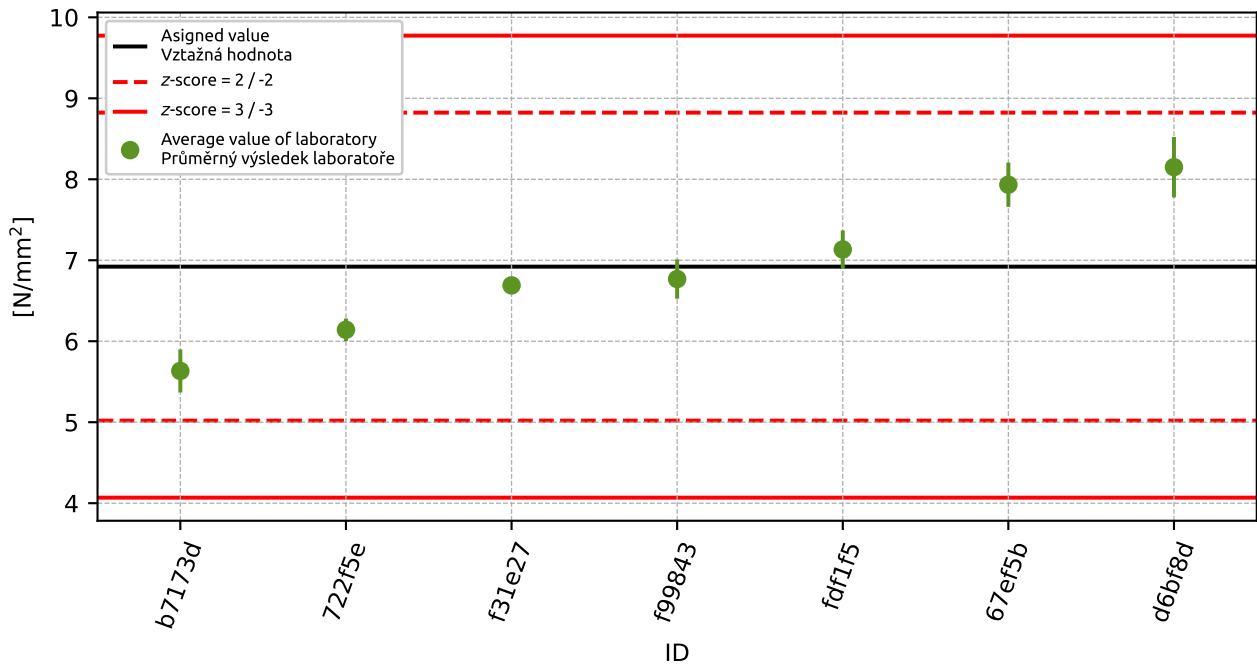


Figure 16: Average values and sample standard deviations

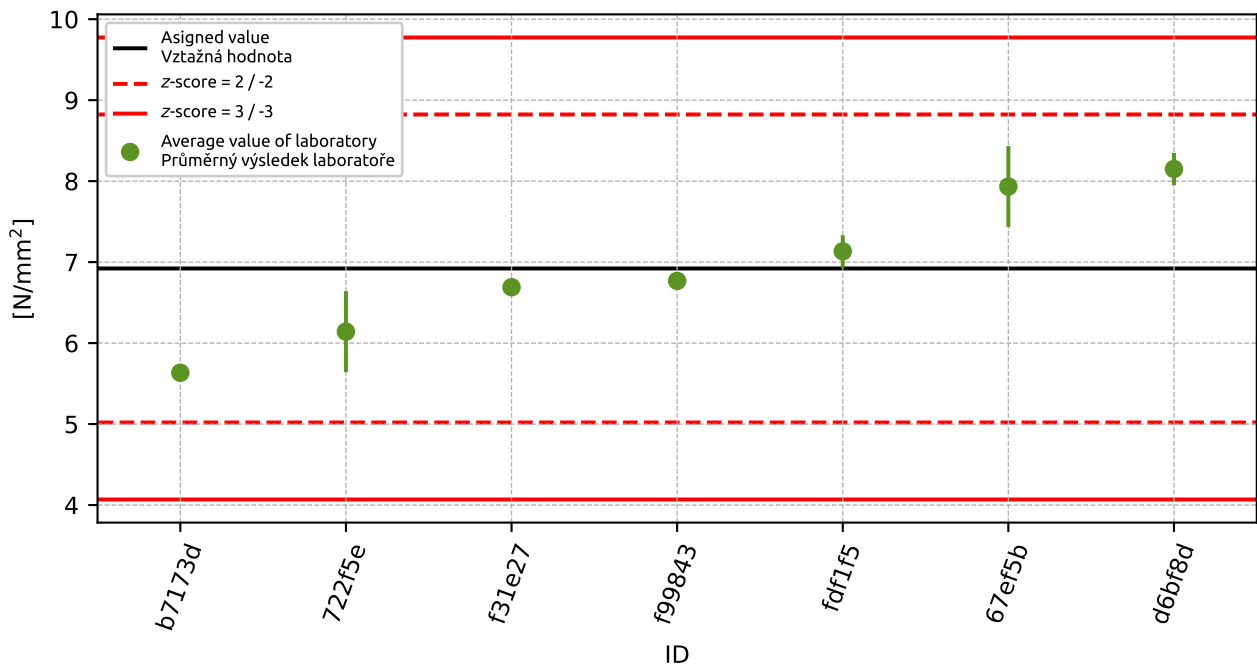


Figure 17: Average values and extended uncertainties of measurement

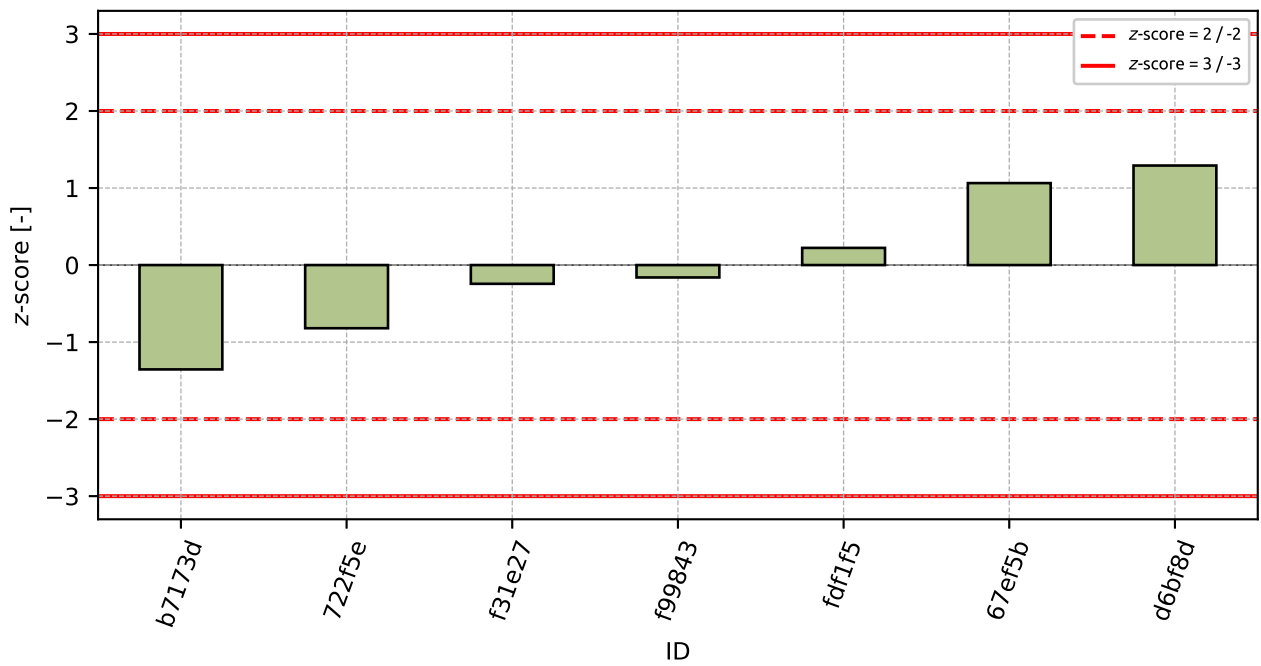


Figure 18: z-score

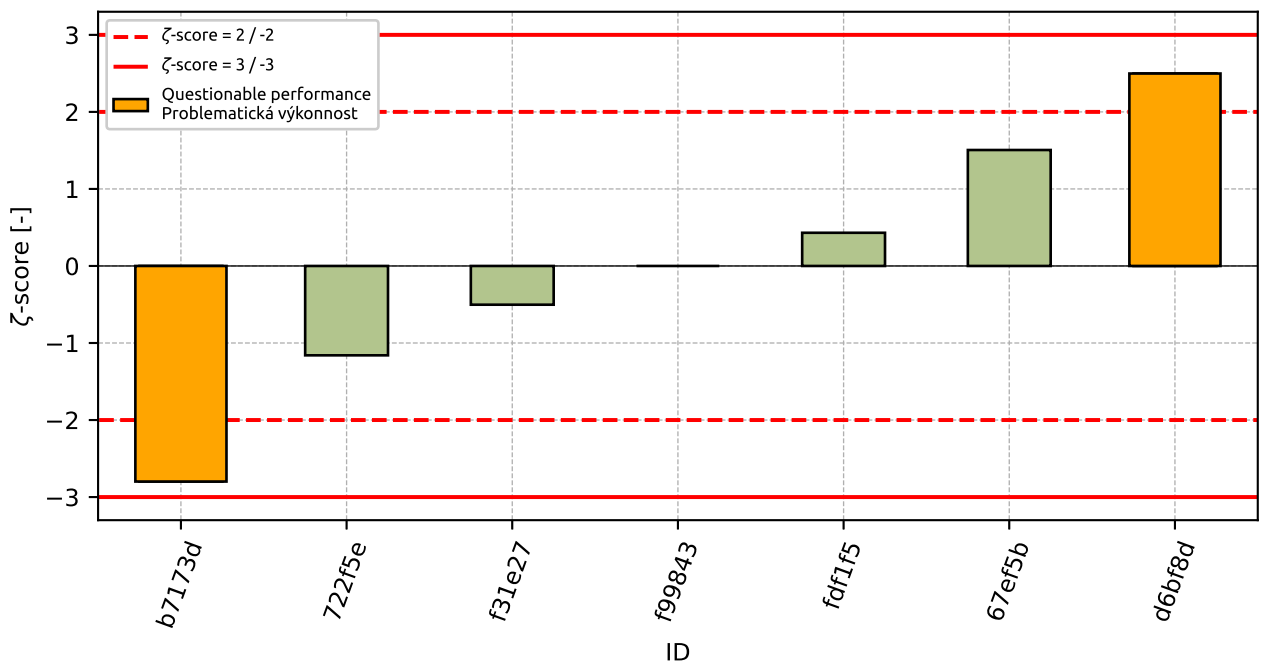


Figure 19: ζ-score

Table 9: z-score and ζ -score

ID	z-score [-]	ζ -score [-]
b7173d	-1.35	-2.8
722f5e	-0.82	-1.16
f31e27	-0.24	-0.5
f99843	-0.16	-
fdf1f5	0.22	0.43
67ef5b	1.06	1.51
d6bf8d	1.29	2.5

14 Appendix – EN 1015-12 – Adhesion

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

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

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

16 Appendix – EN 1015-19 – Water vapor flow

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

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

17.1 Flexural Strength

17.1.1 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			u_x [N/mm ²]	\bar{x} [N/mm ²]	s_0 [N/mm ²]	V_x [%]
	[N/mm ²]	[N/mm ²]	[N/mm ²]				
fdf1f5	5.8	5.6	6.0	0.2	5.8	0.2	3.45
f99843	5.9	6.2	5.8	-	6.0	0.2	3.4
a61f7a	6.1	6.3	5.6	-	6.0	0.35	5.77
b7173d	6.1	6.1	6.0	0.1	6.1	0.06	0.95
abd73a	6.3	6.0	6.4	0.5	6.2	0.21	3.34
67ef5b	6.7	6.9	7.3	0.3	7.0	0.31	4.41
2bccad	8.5	8.0	7.8	0.4	8.1	0.37	4.56
3d575b	8.6	8.8	9.0	0.5	8.8	0.23	2.55

17.1.2 The Numerical Procedure for Determining Outliers

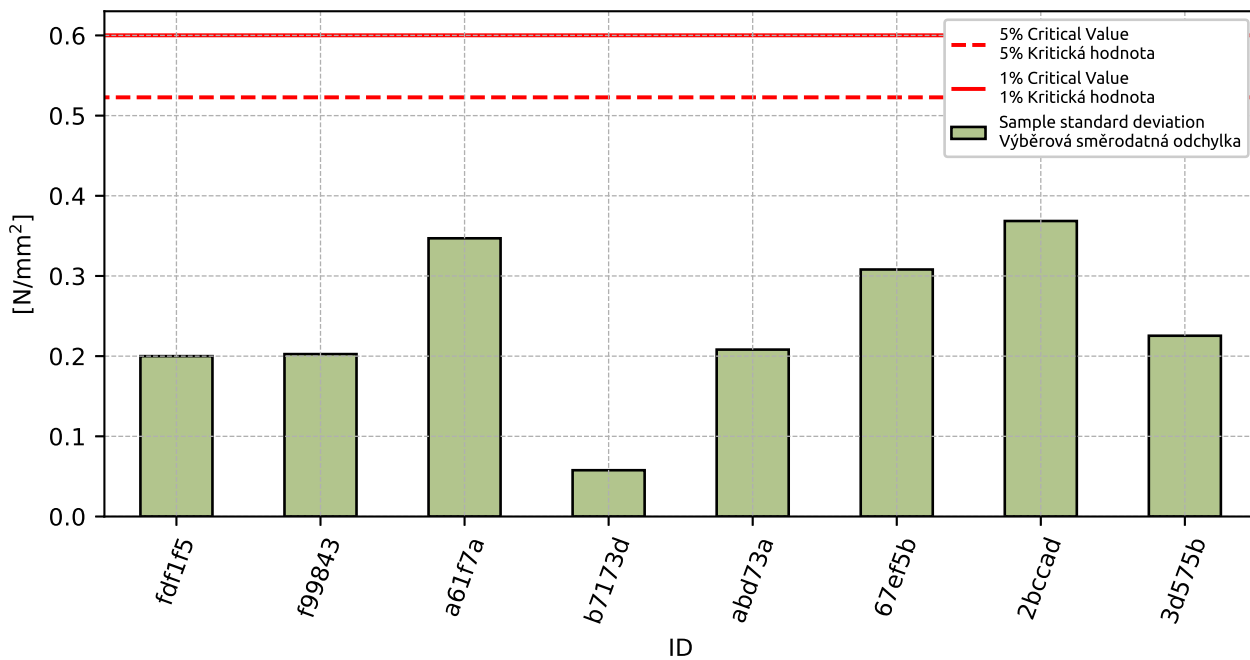


Figure 20: **Cochran's test** - sample standard deviations

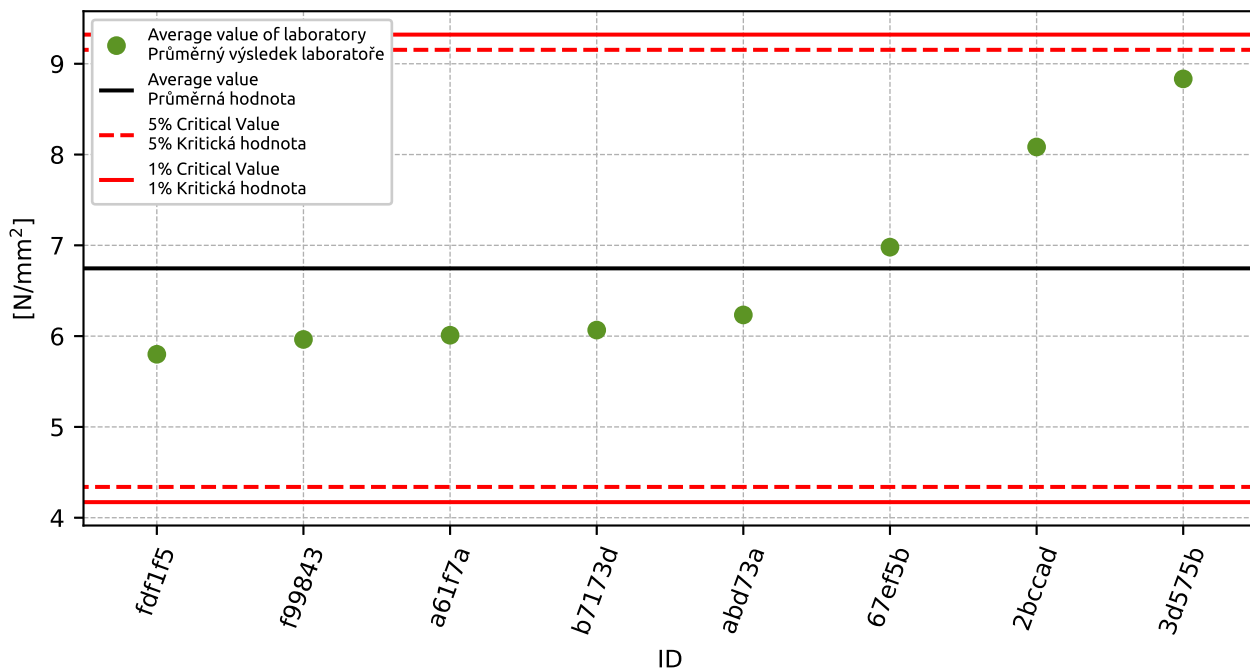


Figure 21: **Grubbs' test** - average values

17.1.3 Mandel's Statistics

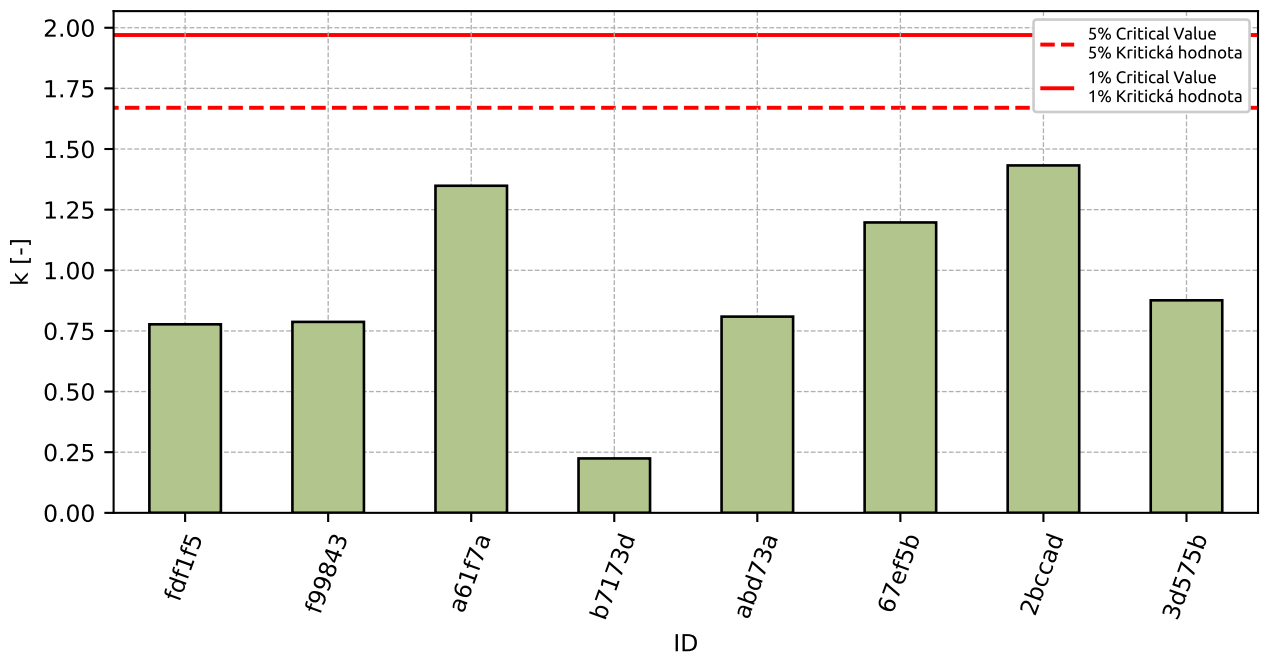


Figure 22: Intralaboratory Consistency Statistic

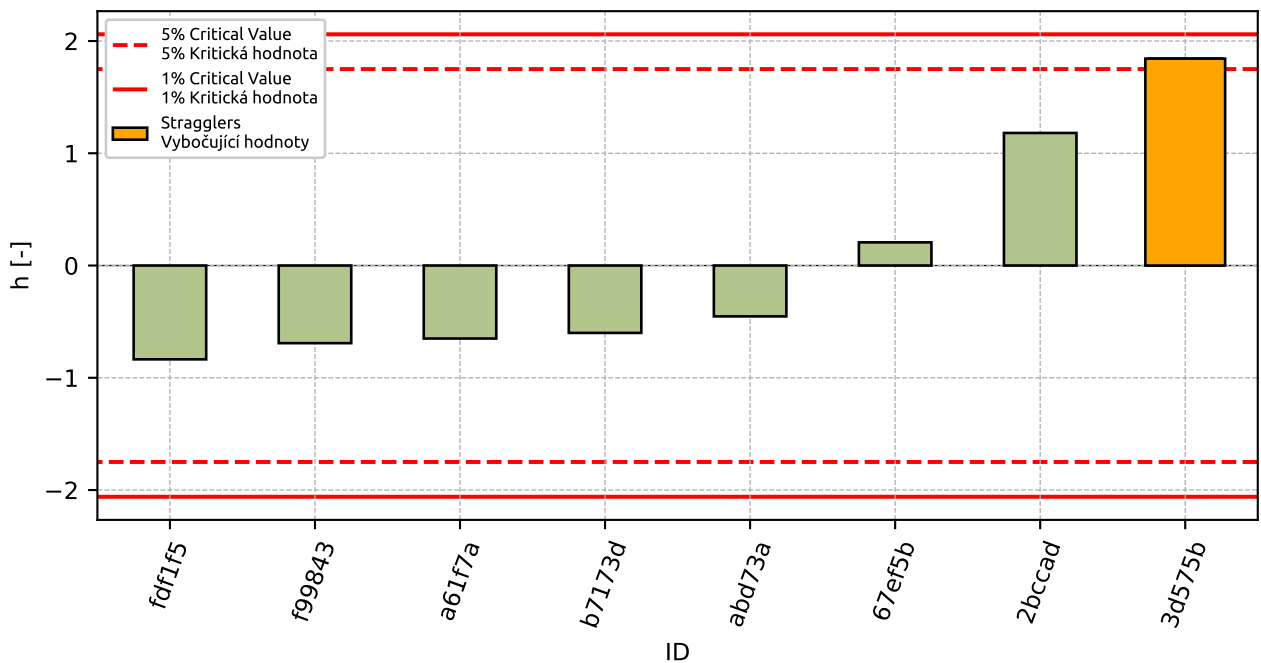


Figure 23: Interlaboratory Consistency Statistic

17.1.4 Descriptive statistics

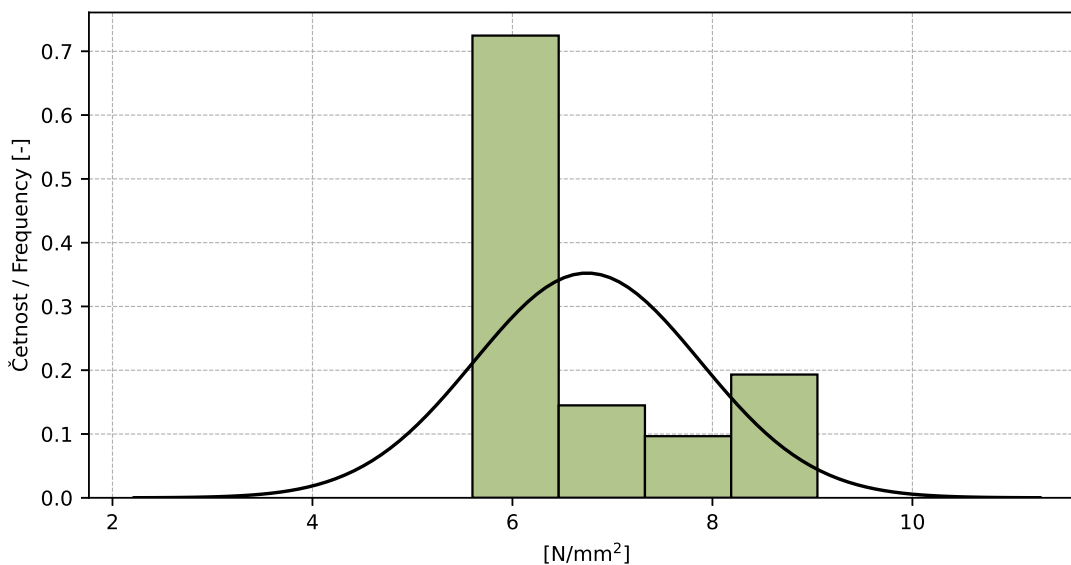


Figure 24: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[N/mm ²]
Průměrná hodnota / Average value – \bar{x}	6.75
Výběrová směrodatná odchylka / Sample standard deviation – s	1.132
Vztažná hodnota / Assigned value – x^*	6.55
Robustní směrodatná odchylka / Robust standard deviation – s^*	1.047
Nejistota měření vztažné hodnoty / Measurement uncertainty of assigned value – u_X	0.463
p -hodnota testu normality / p -value of normality test	0.001 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	1.122
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.257
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	1.152
Opakovatelnost / Repeatability – r	0.72
Reprodukovatelnost / Reproducibility – R	3.22

17.1.5 Evaluation of Performance Statistics

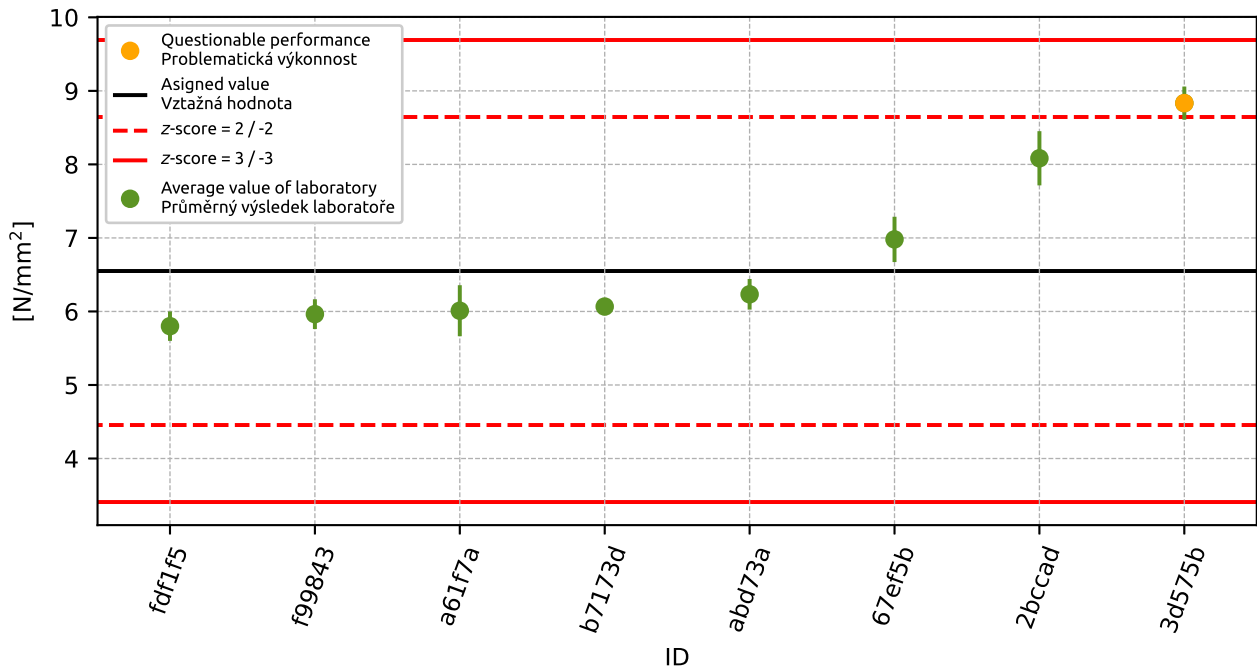


Figure 25: Average values and sample standard deviations

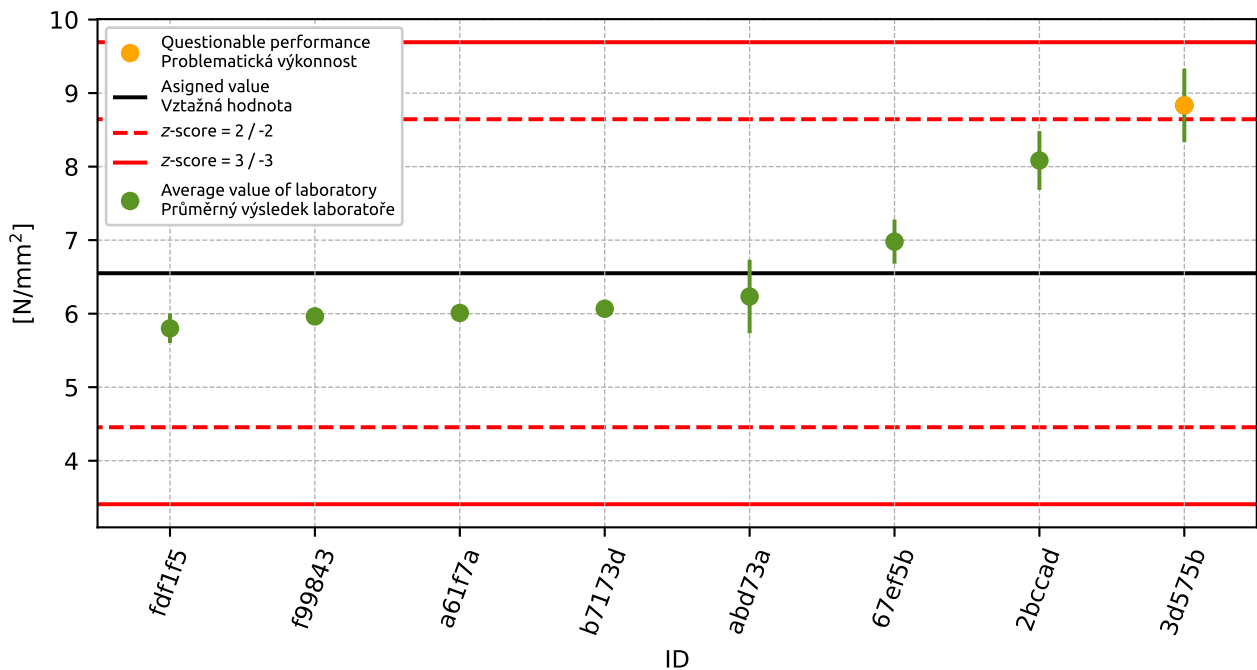


Figure 26: Average values and extended uncertainties of measurement

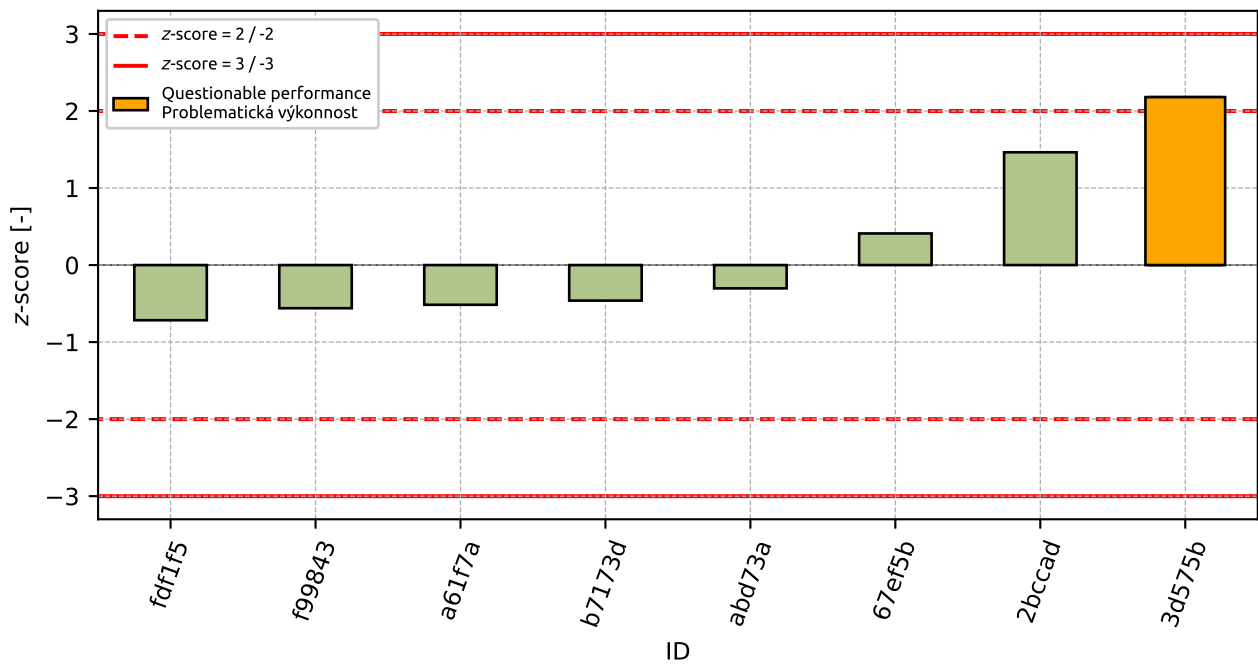


Figure 27: z-score

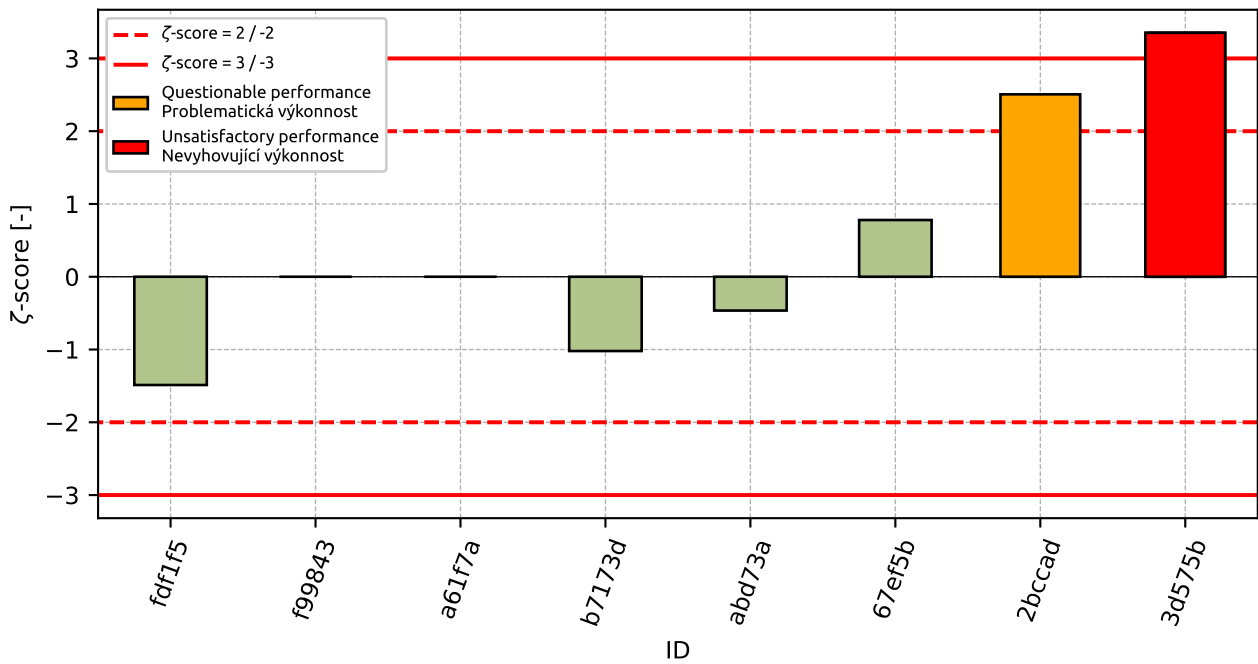


Figure 28: zeta-score

Table 12: z-score and ζ -score

ID	z-score [-]	ζ -score [-]
fdf1f5	-0.72	-1.49
f99843	-0.56	-
a61f7a	-0.52	-
b7173d	-0.46	-1.02
abd73a	-0.3	-0.46
67ef5b	0.41	0.78
2bccad	1.46	2.51
3d575b	2.18	3.35

17.2 Compressive Strength

17.2.1 Test results

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

ID	Test results [N/mm ²]						u_x [N/mm ²]	\bar{x} [N/mm ²]	s_0 [N/mm ²]	V_x [%]
fdf1f5	32.6	32.8	33.0	33.8	33.2	33.8	1.0	33.2	0.52	1.56
f99843	33.7	32.9	33.9	33.5	33.8	33.0	-	33.5	0.42	1.26
b7173d	35.5	35.2	34.6	34.8	35.6	35.8	0.5	35.2	0.47	1.34
3d575b	39.5	41.2	40.7	40.5	39.4	38.3	1.4	39.9	1.08	2.71
abd73a	37.6	40.1	39.9	44.5	40.3	41.7	4.4	40.7	2.29	5.63
2bccad	45.4	45.2	45.7	46.0	44.1	45.5	2.3	45.3	0.66	1.45
67ef5b	48.3	47.5	48.7	47.7	49.9	47.8	2.1	48.3	0.89	1.84
a61f7a	57.3	55.1	55.6	56.8	56.0	58.9	-	56.6	1.37	2.43

17.2.2 The Numerical Procedure for Determining Outliers

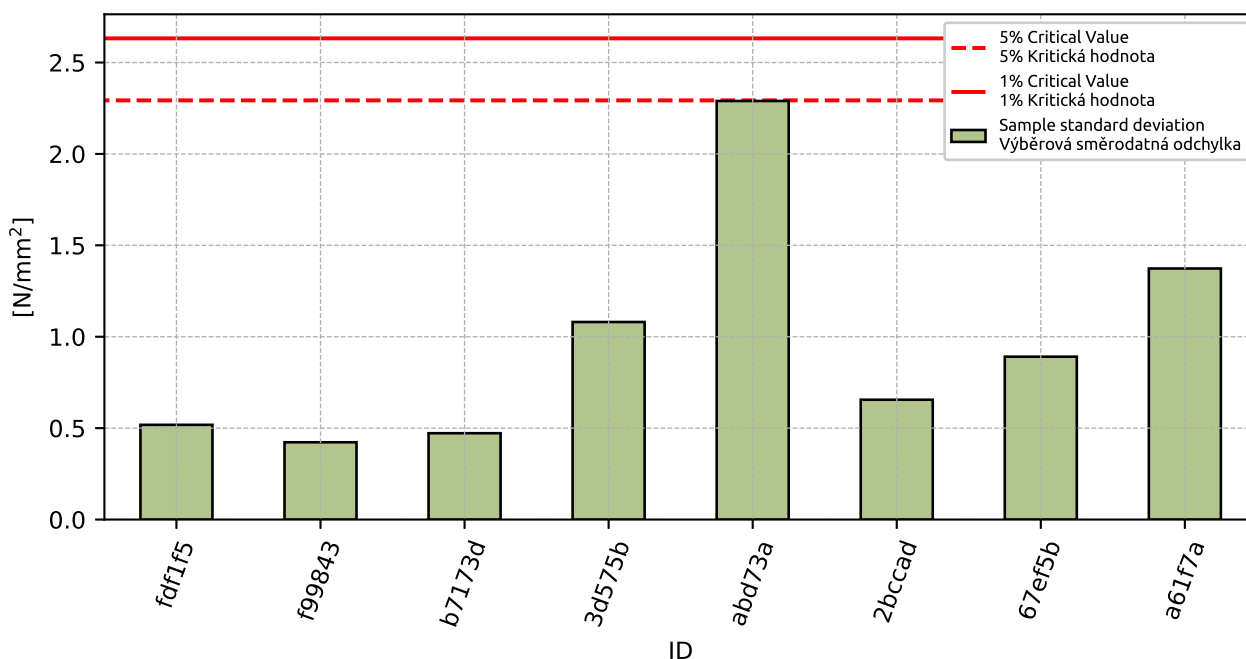


Figure 29: Cochran's test - sample standard deviations

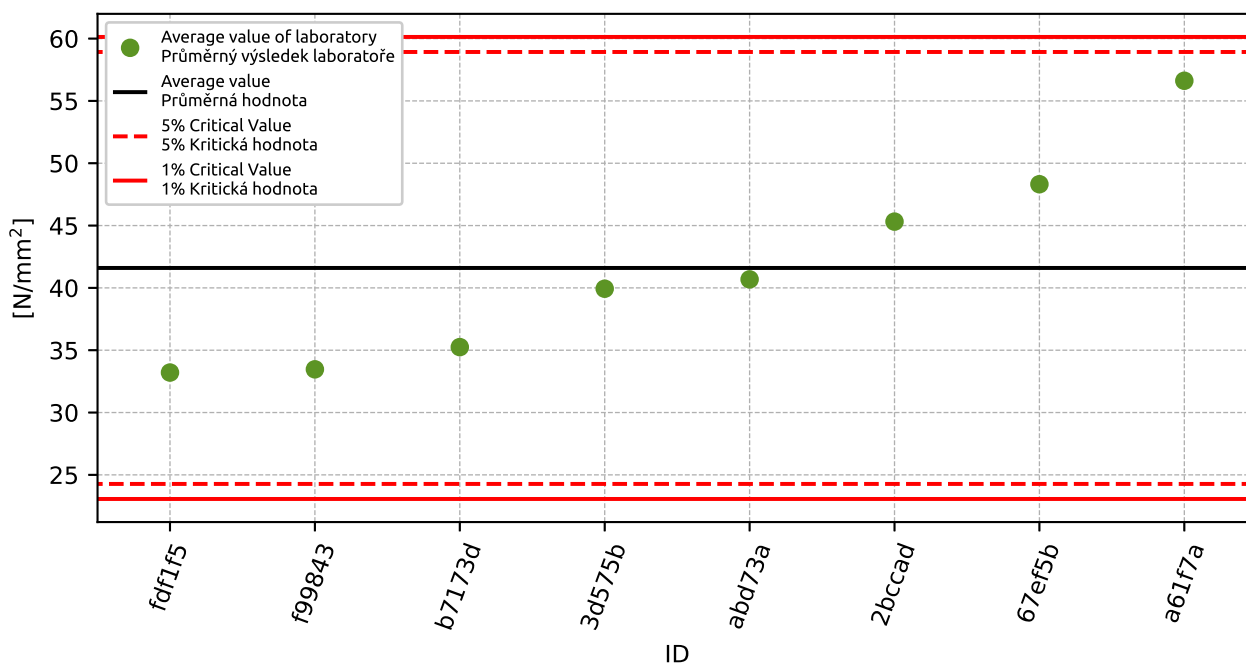


Figure 30: Grubbs' test - average values

17.2.3 Mandel's Statistics

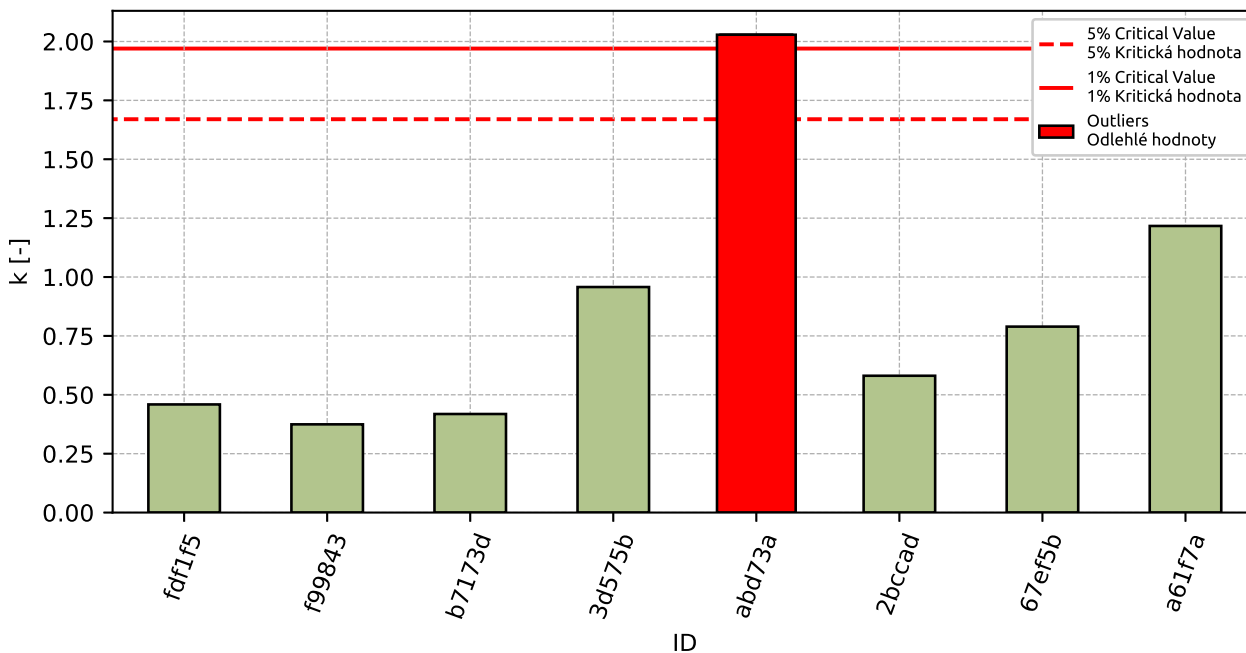


Figure 31: Intralaboratory Consistency Statistic

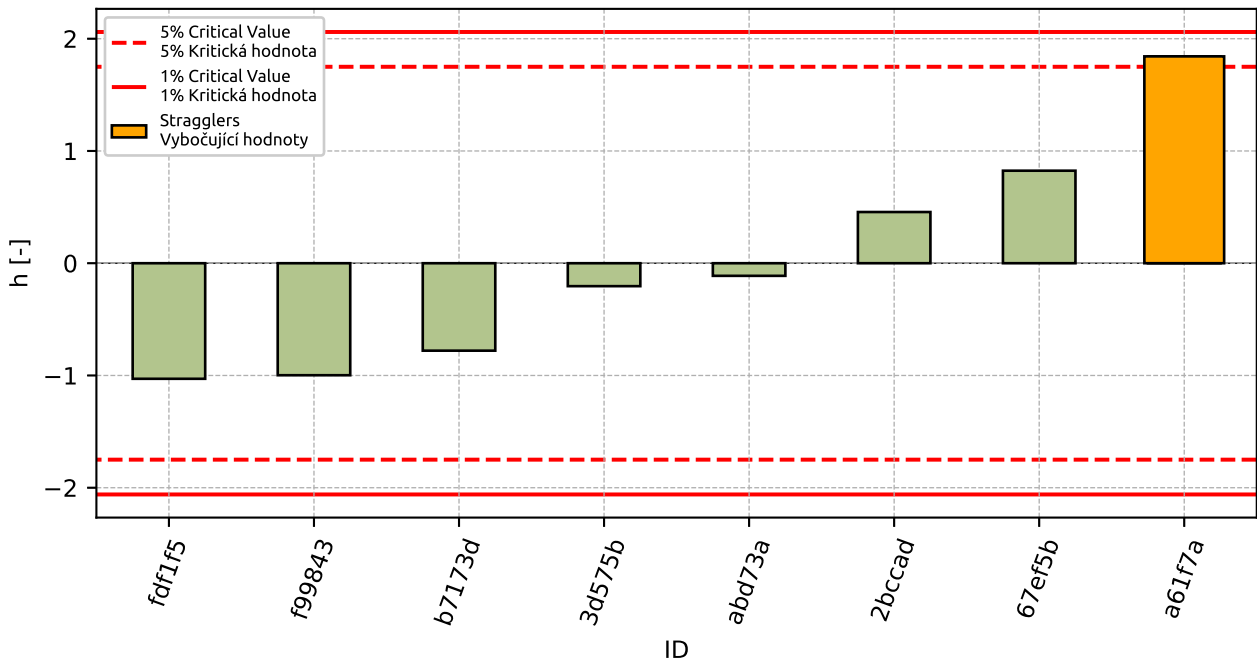


Figure 32: Interlaboratory Consistency Statistic

17.2.4 Descriptive statistics

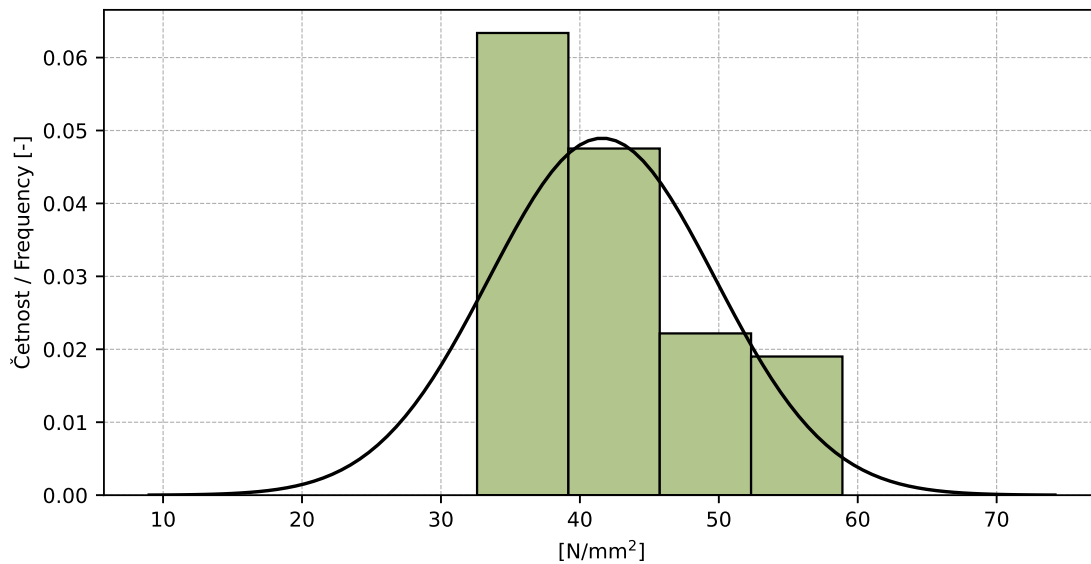


Figure 33: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	[N/mm ²]
Průměrná hodnota / Average value – \bar{x}	41.6
Výběrová směrodatná odchylka / Sample standard deviation – s	8.15
Vztažná hodnota / Assigned value – x^*	41.6
Robustní směrodatná odchylka / Robust standard deviation – s^*	8.645
Nejistota měření vztažné hodnoty / Measurement uncertainty of assigned value – u_X	3.821
p -hodnota testu normality / p -value of normality test	0.001 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	8.137
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	1.129
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	8.215
Opakovatelnost / Repeatability – r	3.16
Reprodukovatelnost / Reproducibility – R	23.0

17.2.5 Evaluation of Performance Statistics

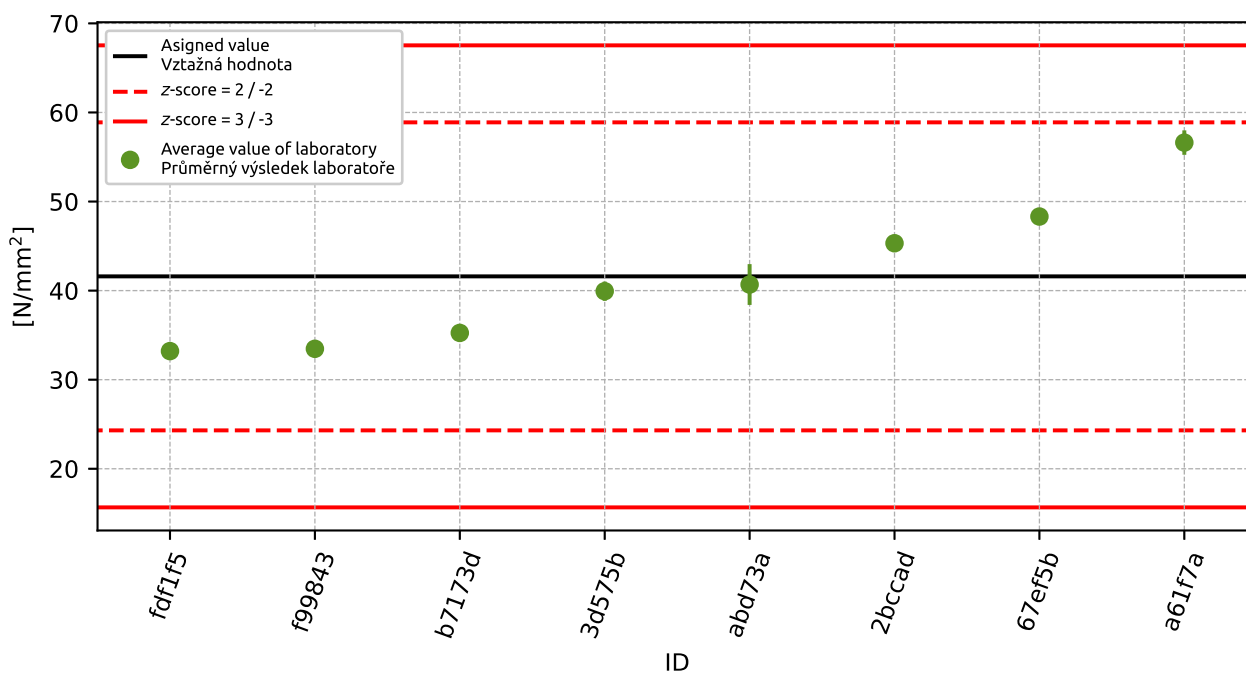


Figure 34: Average values and sample standard deviations

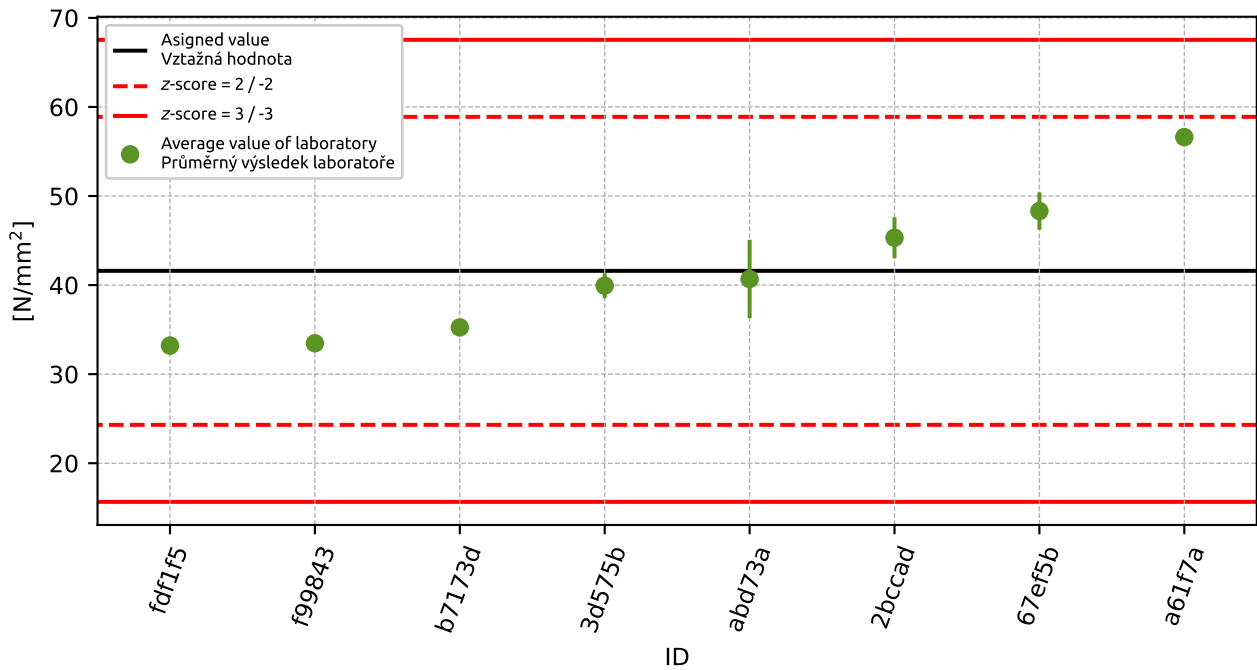


Figure 35: Average values and extended uncertainties of measurement

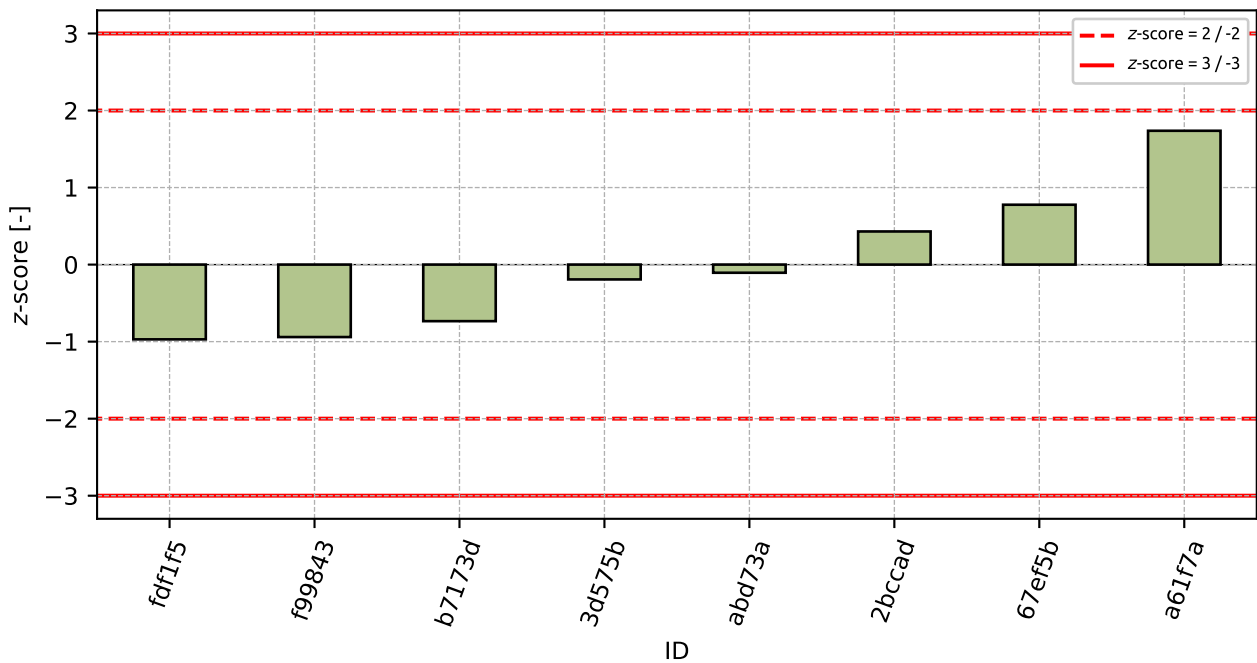
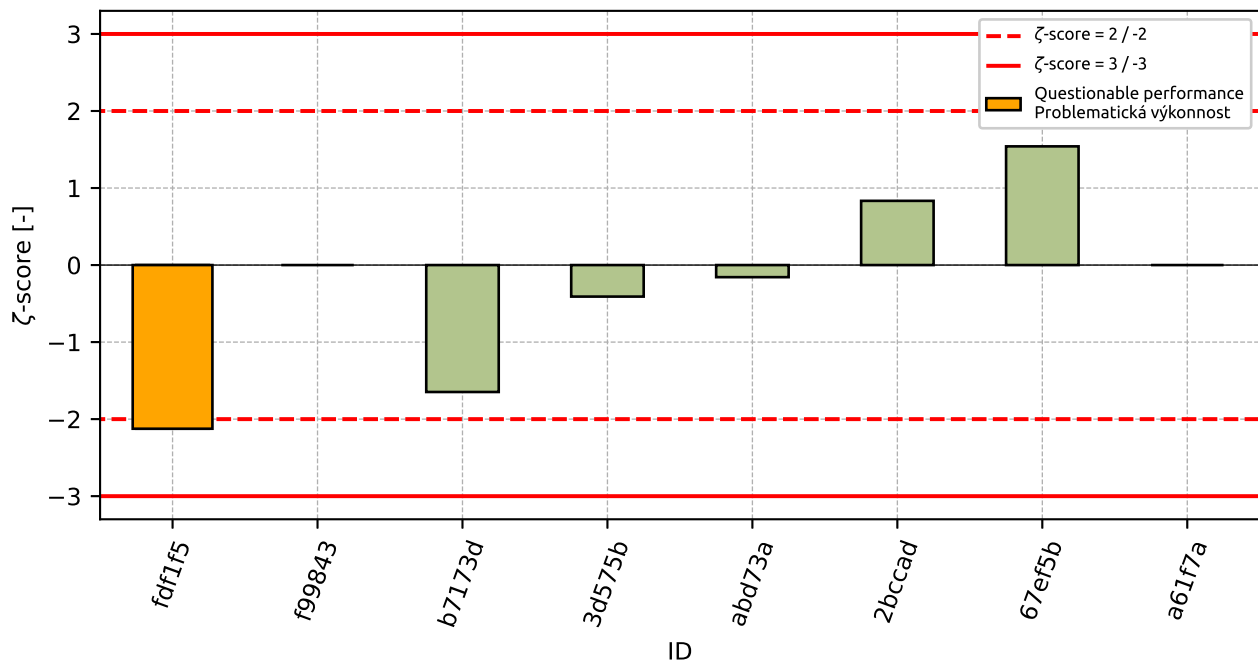


Figure 36: z-score

Figure 37: ζ -scoreTable 15: z-score and ζ -score

ID	z-score [-]	ζ -score [-]
fdf1f5	-0.97	-2.12
f99843	-0.94	-
b7173d	-0.73	-1.65
3d575b	-0.19	-0.41
abd73a	-0.11	-0.16
2bccad	0.43	0.83
67ef5b	0.78	1.54
a61f7a	1.74	-

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

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

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

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

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

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

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

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

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

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