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
Masonry Units Testing
ZZP 2019/1

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: December, 3th 2019

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

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

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

Contents

1 Introduction and Important Contacts

In the year 2019, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZZP 2019/1 whose aim was to verify and assess the conformity of test results across laboratories when testing masonry units.

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. 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 772-1** – Compressive strength [1].
2. **EN 772-3** – Net volume and percentage of voids of clay masonry units by hydrostatic weighing [2].
3. **EN 772-6** – Bending tensile strength of aggregate concrete masonry units [3].
4. **EN 772-7** – Water absorption of clay masonry damp proof course units by boiling in water [4].
5. **EN 772-10** – Moisture content [5].
6. **EN 772-11** – Water absorption [6].
7. **EN 772-13** – Dry density of masonry units [7].
8. **EN 15435** – part 4.9.3, Appendix B - Flexural strength of side shutters [8].
9. **EN 15435** – part 5.2 - Density [8].

Testing procedures No 2, 4, 5, 8 and 9 were not open due to low number of participants.

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

9 laboratories from Europe 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
dae225	X	-	-	-	-	X	-	-	-
47822d	X	-	X	-	-	-	X	-	-
e9afee	X	-	X	-	-	X	X	-	-
e75c43	X	-	-	-	-	-	-	-	-
3e8e59	X	-	-	-	-	X	X	-	-
bd7cef	X	-	X	-	-	X	-	-	-
cedcfa	X	-	X	-	-	X	-	-	-
d26329	X	-	-	-	-	X	X	-	-
a08a23	X	-	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
BetónRacio, s.r.o., Skúšobné laboratórium, Pracovisko Trnava	Skladová 2, Trnava, 917 01, Slovenská republika	S-320
Ernestas	Studentu st. 48-276, Kaunas, 51367, Lithuania	-
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
Technický a zkušební ústav stavební Praha, s.p. (pobočka Ostrava)	U Studia 14, Ostrava - Zábřeh, 700 30, Česká republika	1018.3
Testing Laboratory "LABKONSULT	kompl.Mladost-1, bl.43/vh.3/app.41, Sofia, 1784, BULGARIA	-
Vysoké učení technické v Brně, Fakulta stavební, Akreditovaná zkušební laboratoř při ÚTHD FAST VUT v Brně	Veveří 331/95, Brno, 62100, Česká republika	L1396
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft.	Dózsa György út 26., Szentendre, 2000, Hungary	NAH-1-1110/2018
Ústav stavebního zkušebnictví s.r.o.	Jiřího Potůčka 115, Pardubice, 53009, Česká republika	1115
ČVUT v Praze - Kloknerův ústav	Šolínova 1903/7, Praha 6, 166 08, Česká republika	1061

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 Masonry Units Testing (PT Program) organized by the PT Provider at the SZK FAST. 9 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of masonry units. 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
dae225	✓	-	-	-	-	✓	-	-	-
47822d	✓	-	✓	-	-	-	!	-	-
e9afee	✓	-	✓	-	-	✓	!	-	-
e75c43	✓	-	-	-	-	-	-	-	-
3e8e59	✓	-	-	-	-	✓	✓	-	-
bd7cef	✓	-	✓	-	-	✓	-	-	-
cedcfa	✓	-	✓	-	-	✓	-	-	-
d26329	✓	-	-	-	-	✓	✓	-	-
a08a23	✓	-	✓	-	-	✓	✓	-	-

References

[1] EN 772-1. *Methods of test for masonry units - Part 1: Determination of compressive strength*. 2016.

[2] EN 772-3. *Methods of test for masonry units - Part 3: Determination of net volume and percentage of voids of clay masonry units by hydrostatic weighing*. 1999.

[3] EN 772-6. *Methods of test for masonry units - Part 6: Determination of bending tensile strength of aggregate concrete masonry units*. 2002.

[4] EN 772-7. *Methods of test for masonry units - Part 7: Determination of water absorption of clay masonry damp proof course units by boiling in water*. 1999.

[5] EN 772-10. *Methods of test for masonry units - Part 10: Determination of moisture content of calcium silicate and autoclaved aerated concrete units*. 1999.

[6] EN 772-11. *Methods of test for masonry units - Part 11: Determination of water absorption of aggregate concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units*. 2011.

[7] EN 772-13. *Methods of test for masonry units - Part 13: Determination of net and gross dry density of masonry units (except for natural stone)*. 2001.

[8] EN 15435. *Precast concrete products - Normal weight and lightweight concrete shuttering blocks - Product properties and performance*. 2009.

[9] 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.

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

1 Appendix – EN 772-1 (Compressive strength)

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 [%]
47822d	6.7	7.2	8.4	9.2	6.5	6.6	0.4	7.4	1.11	15.0
e9afee	8.5	8.6	8.9	8.1	8.9	8.8	1.3	8.6	0.31	3.56
cedcfa	9.8	10.1	9.8	10.3	10.1	10.5	0.2	10.1	0.28	2.73
3e8e59	11.2	8.0	11.3	11.0	10.4	10.0	1.4	10.3	1.24	12.02
bd7cef	9.9	10.7	9.8	10.7	11.3	12.0	0.5	10.7	0.84	7.79
e75c43	14.3	11.1	12.7	13.8	12.6	13.0	-	12.9	1.11	8.59
d26329	13.3	13.1	12.8	12.8	12.7	12.8	2.5	12.9	0.23	1.79
a08a23	12.4	11.8	13.4	14.3	13.6	12.8	2.0	13.0	0.9	6.88
dae225	15.2	12.9	14.7	13.1	14.9	12.3	0.4	13.8	1.23	8.85

1.2 The Numerical Procedure for Determining Outliers

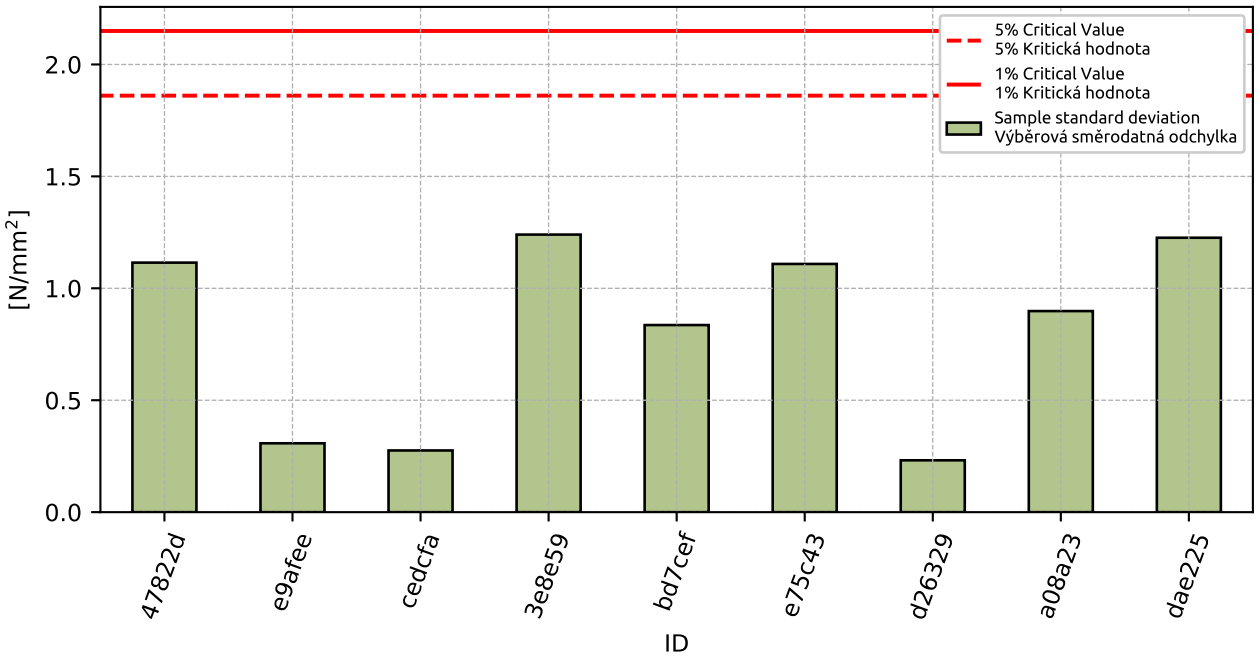

Figure 1: **Cochran's test** - sample standard deviations

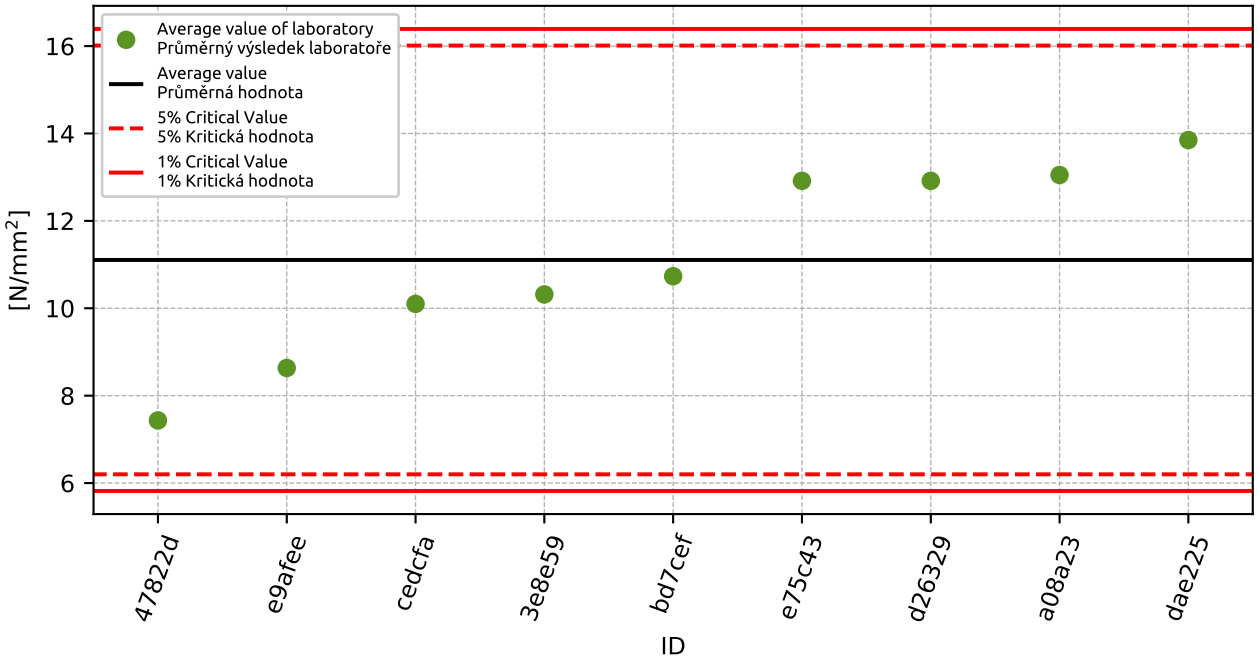

Figure 2: **Grubbs' test** - average values

1.3 Mandel's Statistics

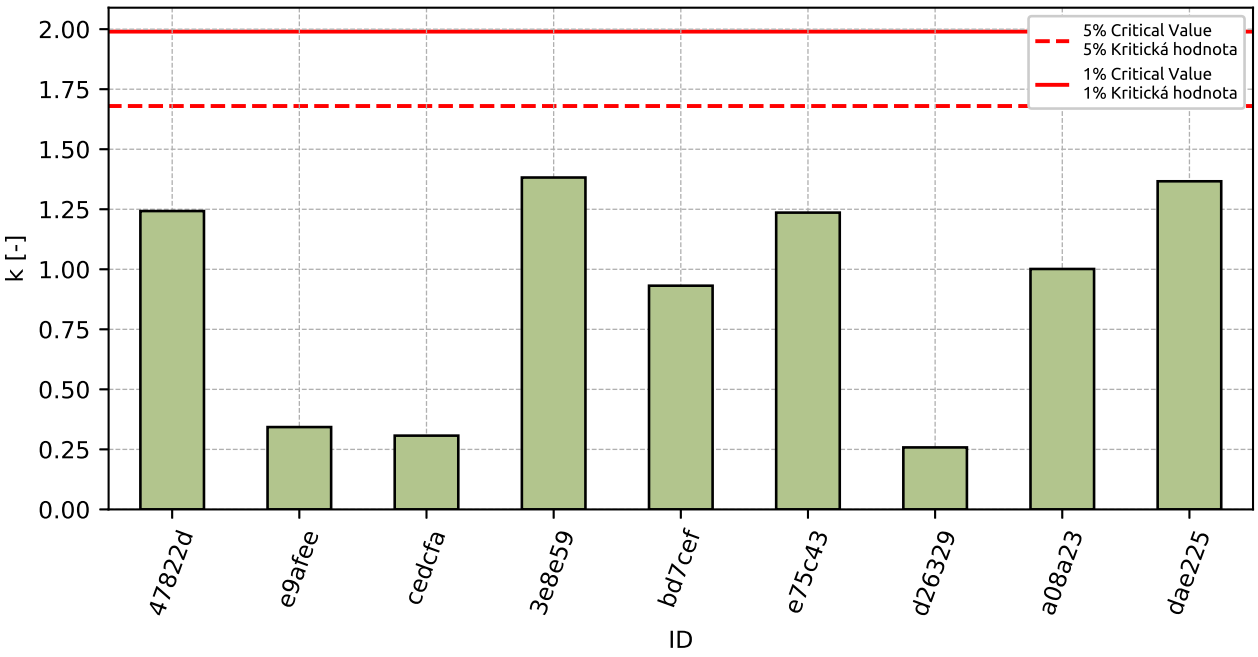

Figure 3: Intralaboratory Consistency Statistic

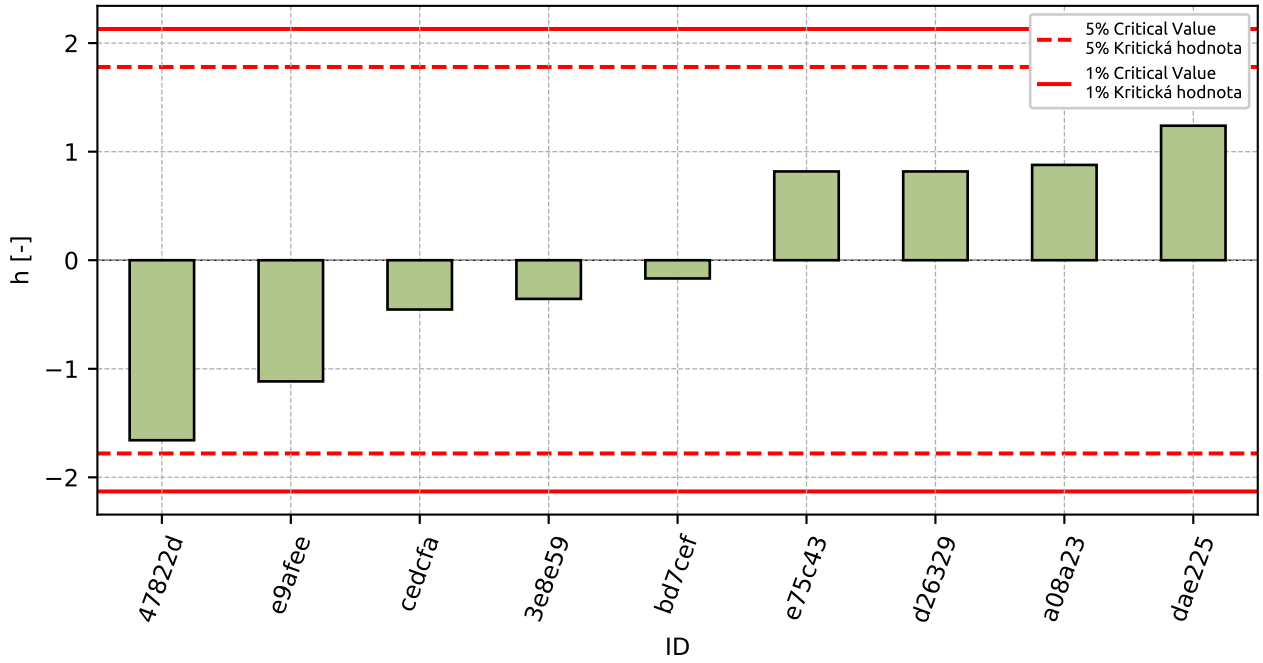

Figure 4: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

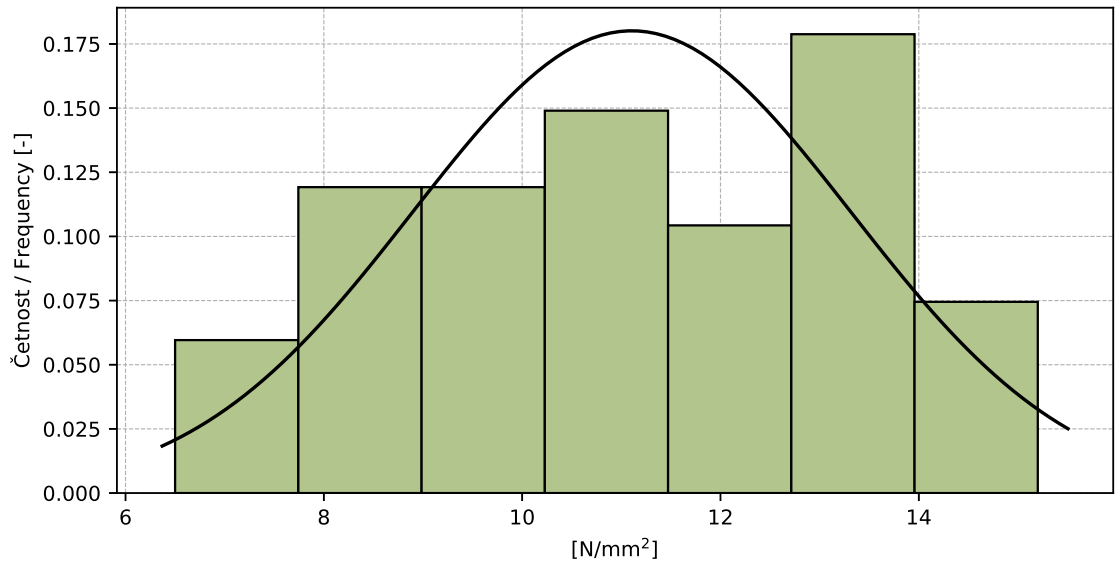

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[N/mm^2]
Průměrná hodnota / Average value – $\bar{x}$	11.1
Výběrová směrodatná odchylka / Sample standard deviation – s	2.21
Vztažná hodnota / Asigned value – x^*	11.1
Robustní směrodatná odchylka / Robust standard deviation – s^*	2.32
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.97
p-hodnota testu normality / p-value of normality test	0.215 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	2.18
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.9
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	2.36
Opakovatelnost / Repeatability – r	2.5
Reprodukovatelnost / Reproducibility – R	6.6

1.5 Evaluation of Performance Statistics

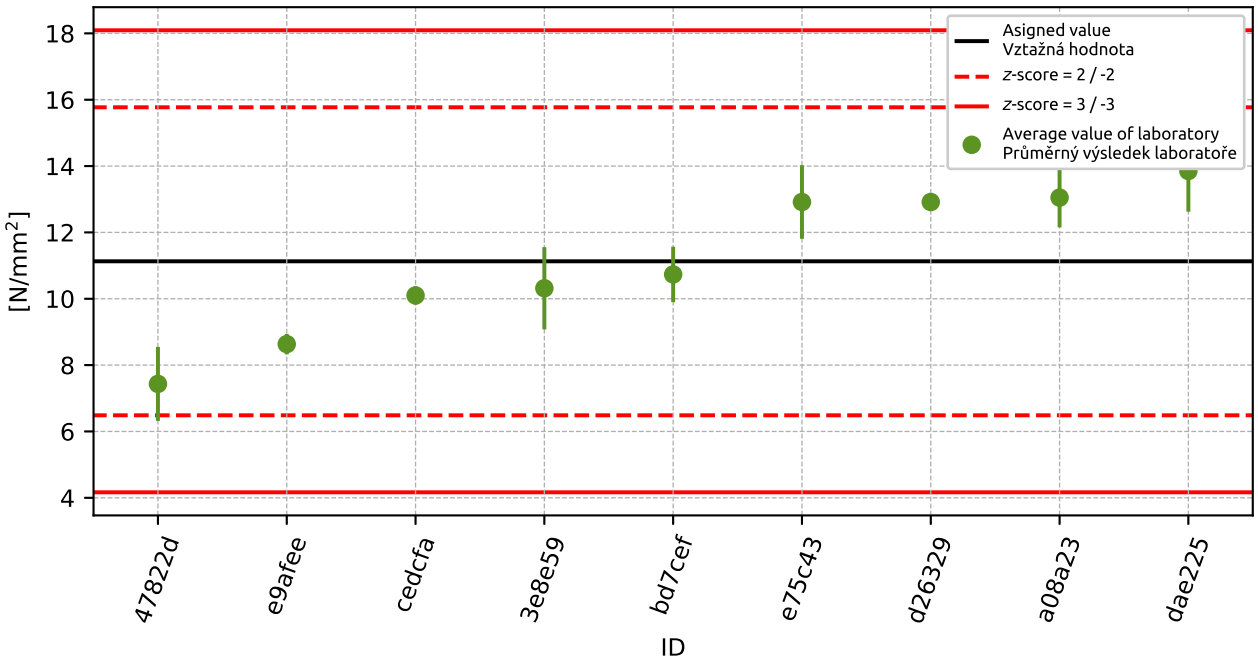

Figure 6: Average values and sample standard deviations

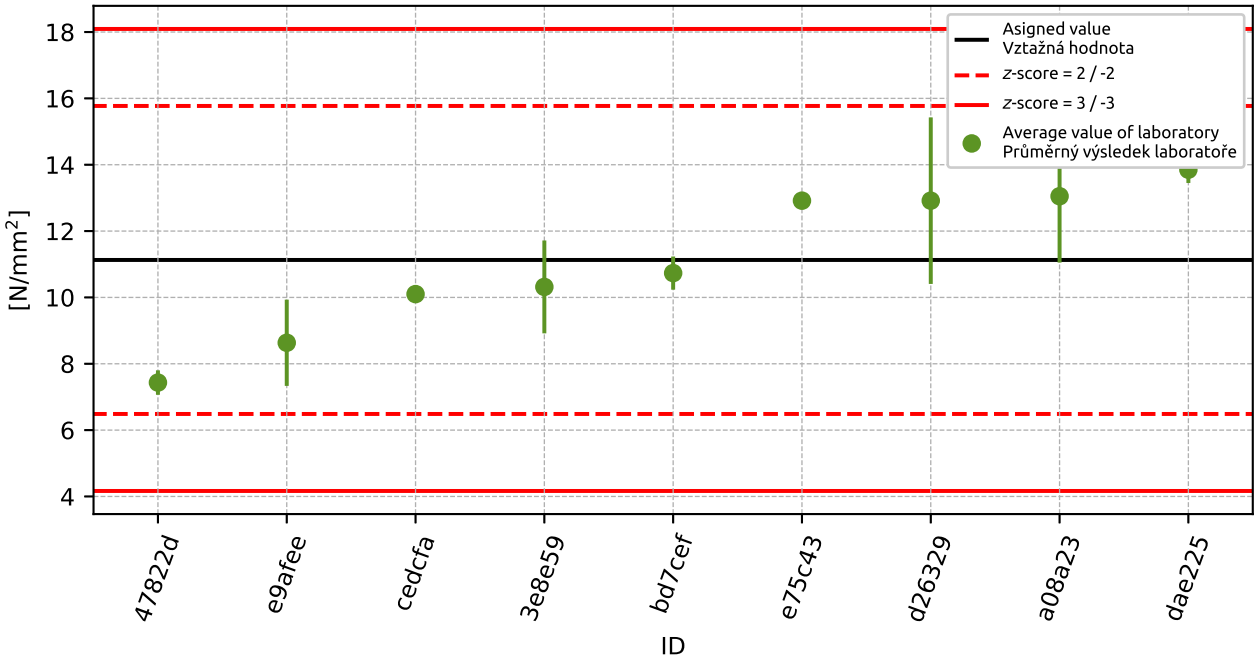

Figure 7: Average values and extended uncertainties of measurement

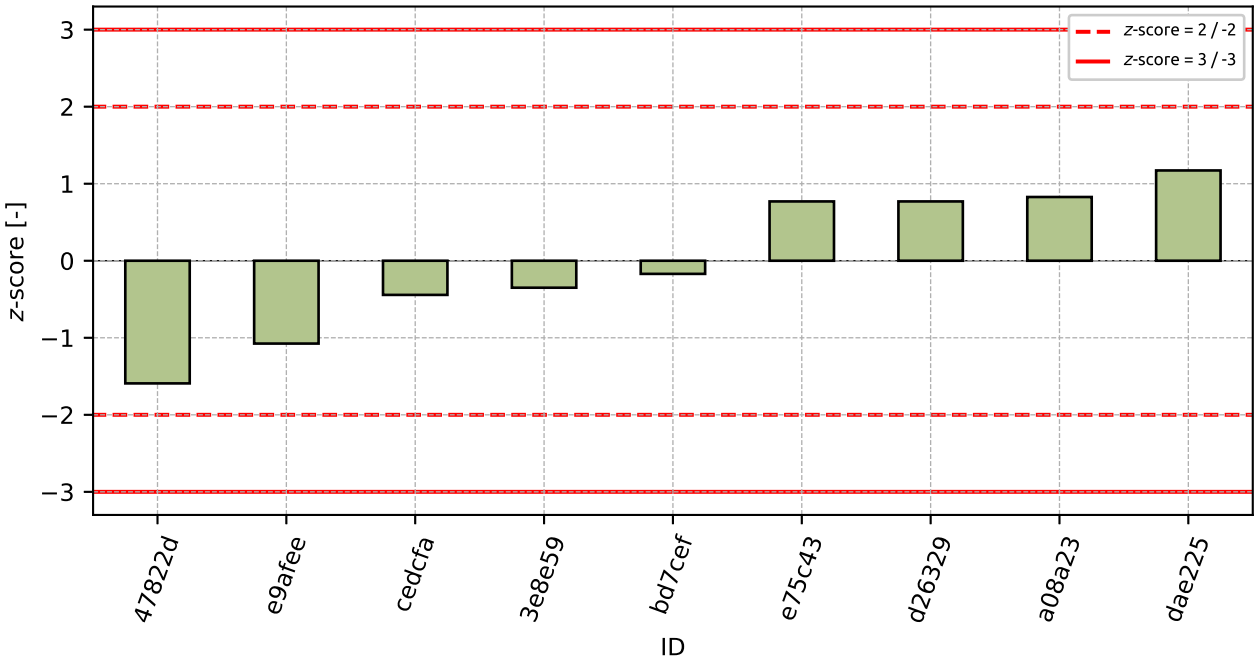

Figure 8: z-score

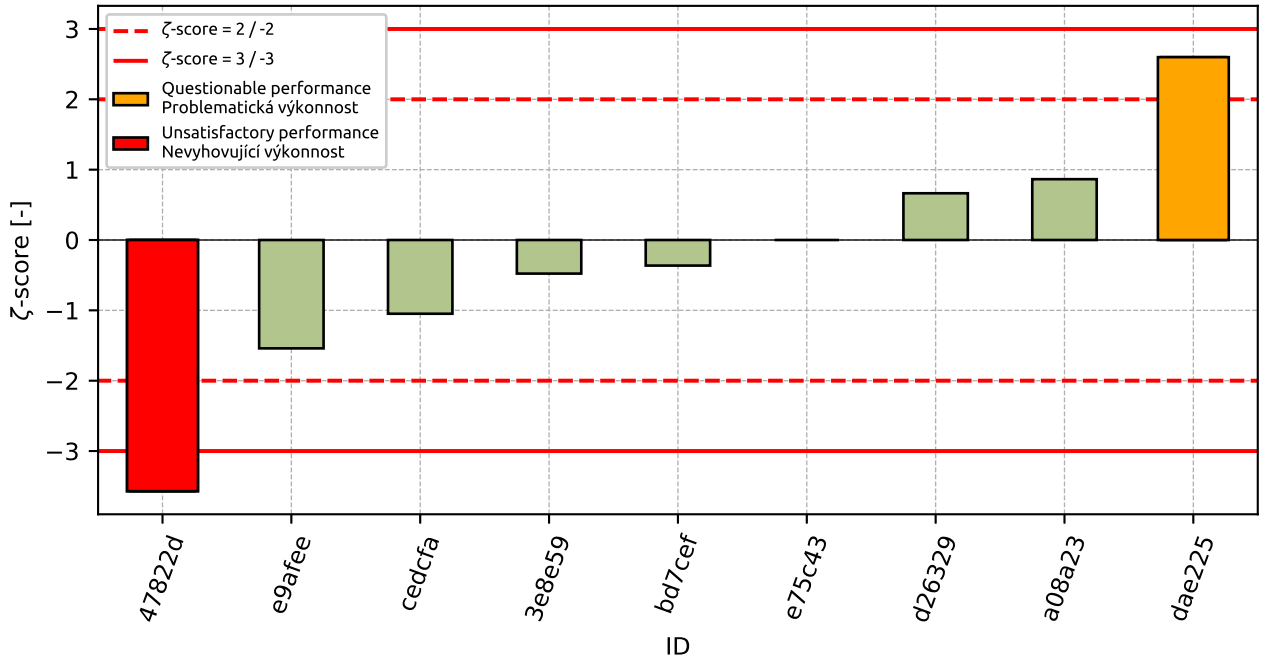

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
47822d	-1.59	-3.57
e9afee	-1.08	-1.54
cedcfa	-0.44	-1.05
3e8e59	-0.35	-0.48
bd7cef	-0.17	-0.36
e75c43	0.77	-
d26329	0.77	0.66
a08a23	0.83	0.86
dae225	1.17	2.6

2 Appendix – EN 772-3 (Net volume and percentage of voids of clay masonry units by hydrostatic weighing)

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

3 Appendix – EN 772-6 (Bending tensile strength of aggregate concrete masonry units)

3.1 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 [%]
e9afee	4.0	3.8	4.1	1.2	4.0	0.15	3.85
bd7cef	4.3	4.2	3.8	0.3	4.1	0.26	6.45
47822d	3.9	4.3	4.7	0.2	4.3	0.4	9.3
a08a23	4.1	4.8	4.2	0.6	4.4	0.38	8.67
cedcfa	4.8	4.9	4.5	0.1	4.7	0.21	4.4

3.2 The Numerical Procedure for Determining Outliers

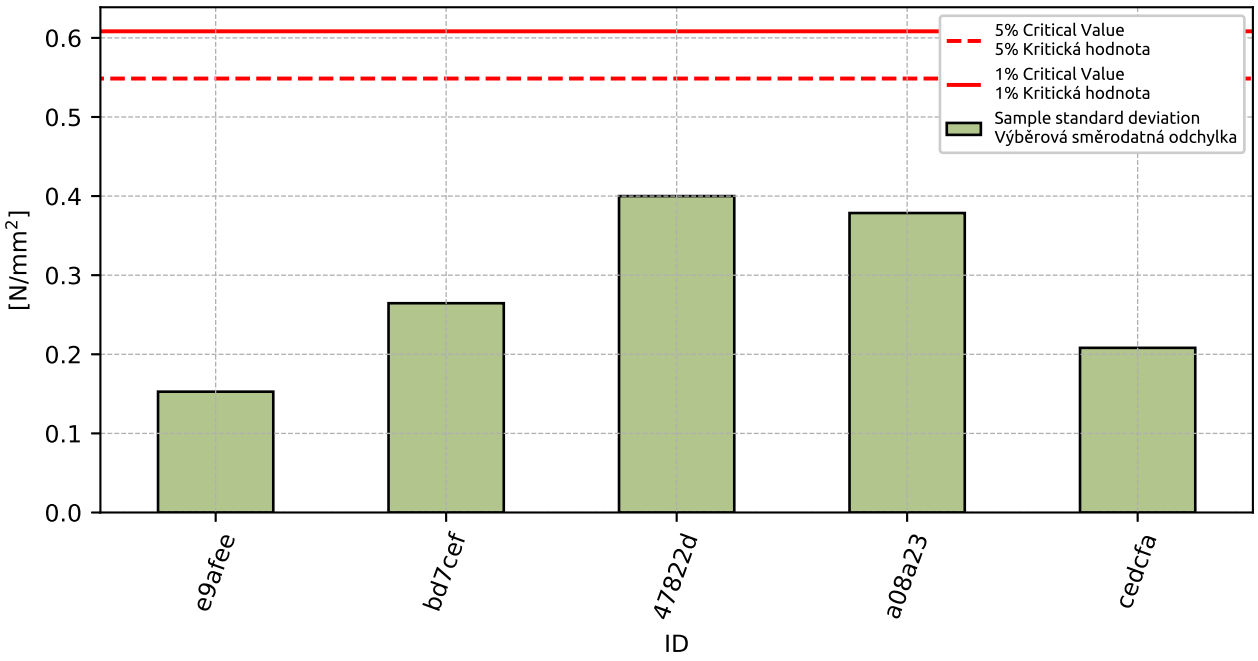

Figure 10: **Cochran's test** - sample standard deviations

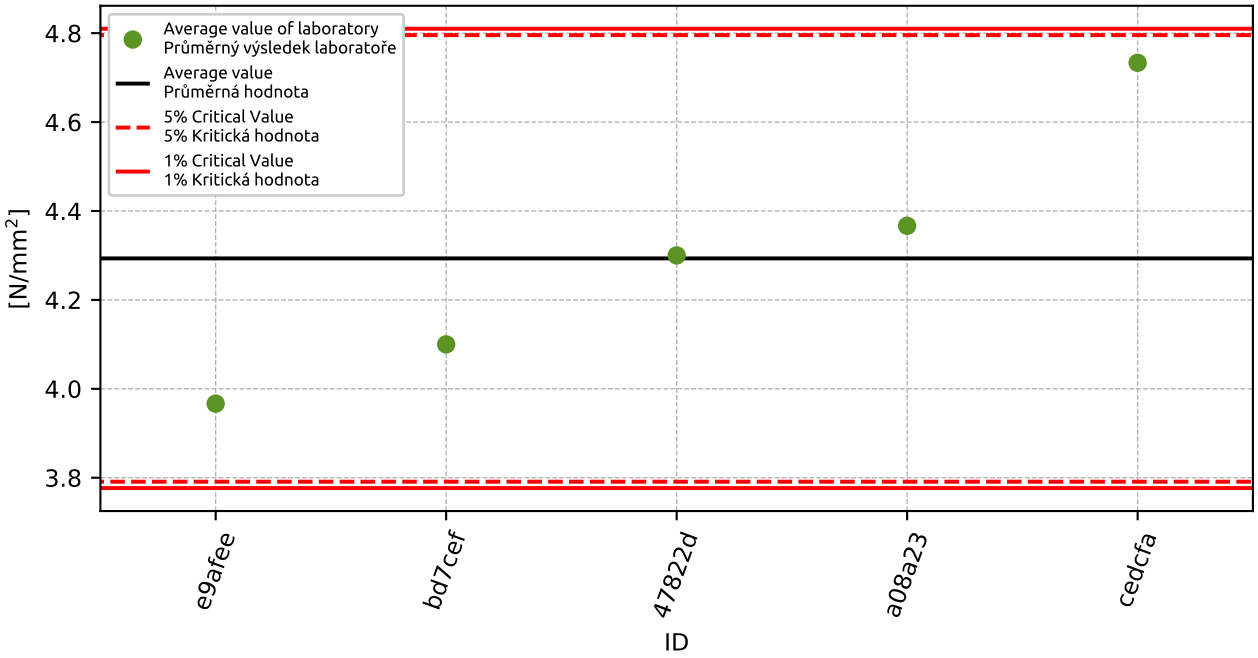

Figure 11: **Grubbs' test** - average values

3.3 Mandel's Statistics

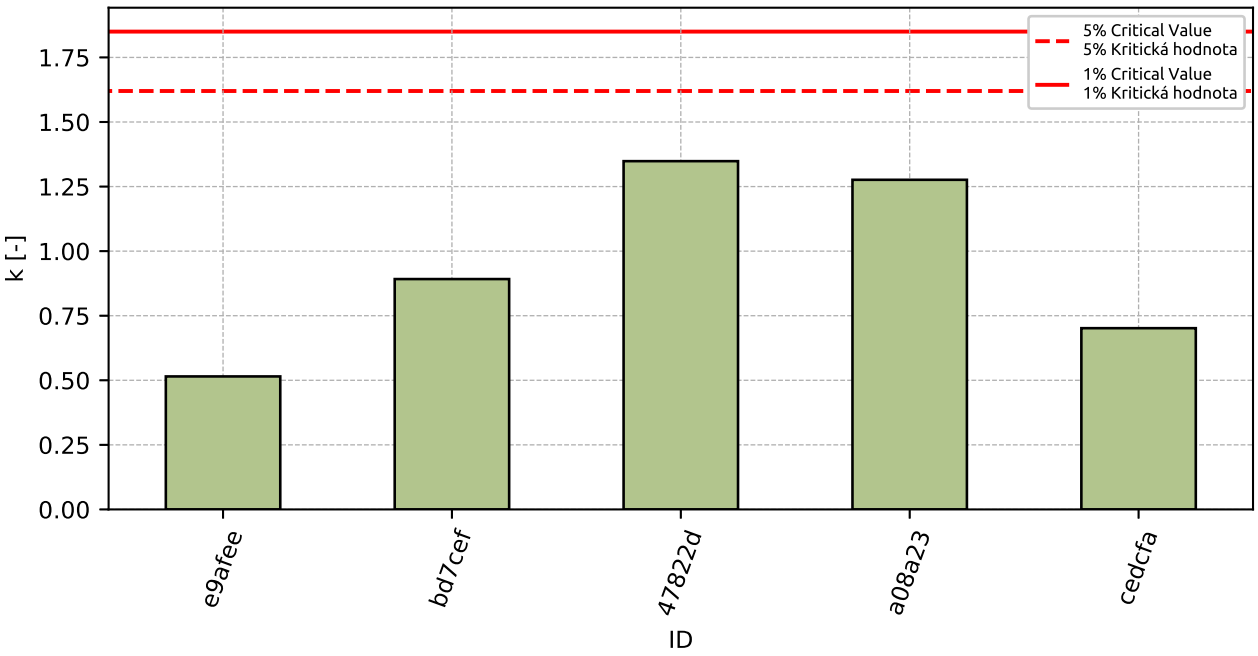

Figure 12: Intralaboratory Consistency Statistic

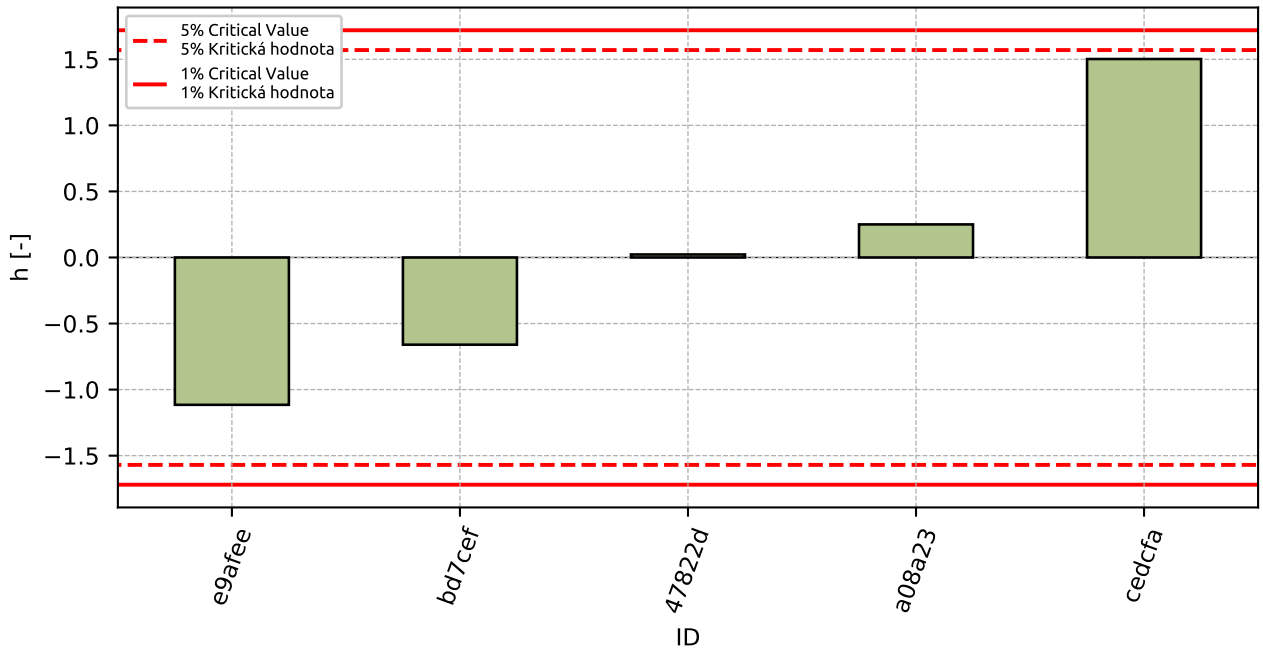

Figure 13: Interlaboratory Consistency Statistic

3.4 Descriptive statistics

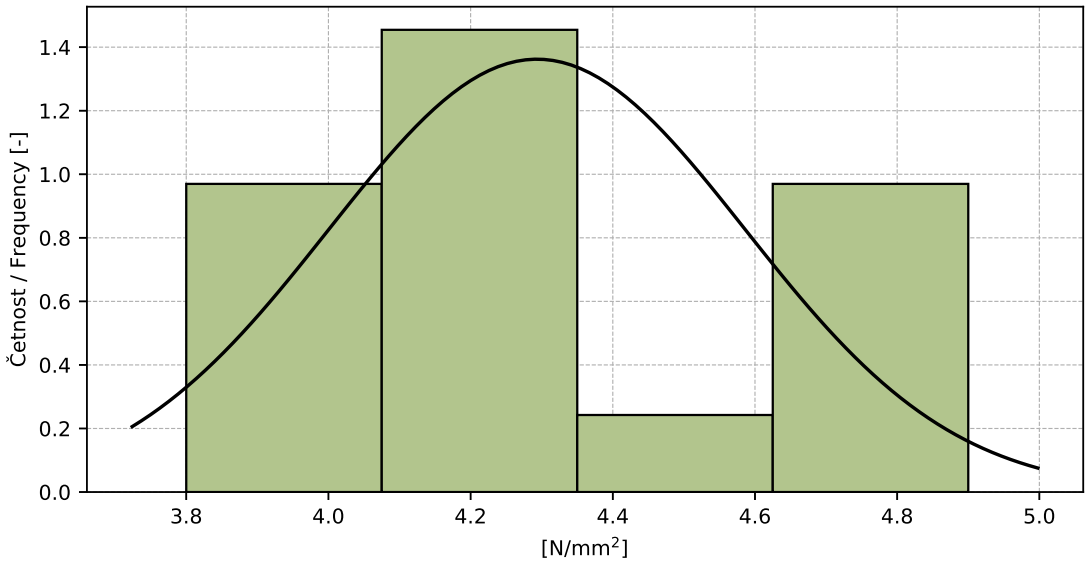

Figure 14: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[N/mm^2]
Průměrná hodnota / Average value – $\bar{x}$	4.3
Výběrová směrodatná odchylka / Sample standard deviation – s	0.29
Vztažná hodnota / Asigned value – x^*	4.3
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.3
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.17
p-hodnota testu normality / p-value of normality test	0.39 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.24
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.3
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.38
Opakovatelnost / Repeatability – r	0.8
Reprodukovatelnost / Reproducibility – R	1.1

3.5 Evaluation of Performance Statistics

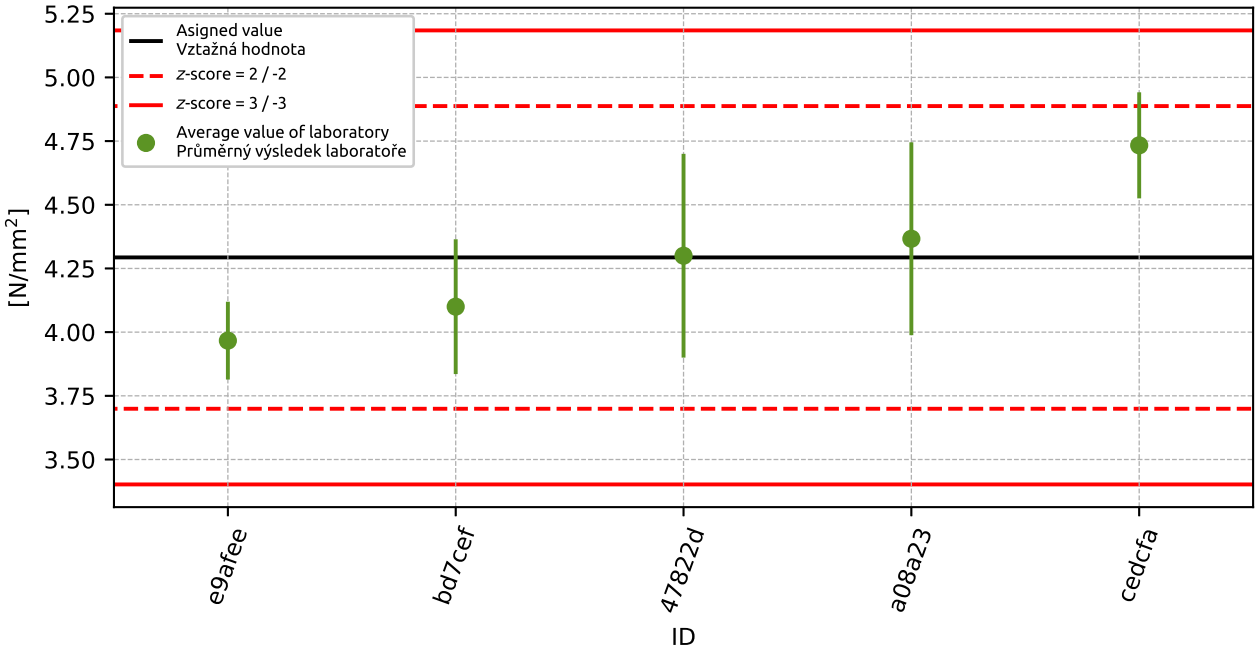

Figure 15: Average values and sample standard deviations

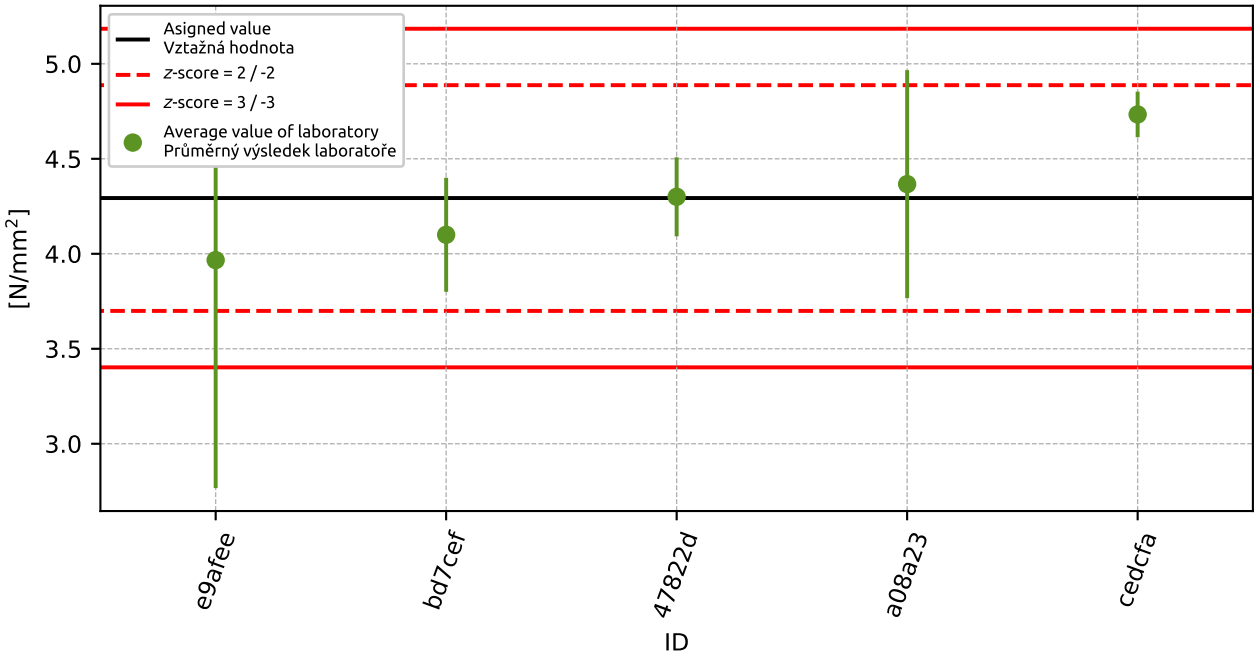

Figure 16: Average values and extended uncertainties of measurement

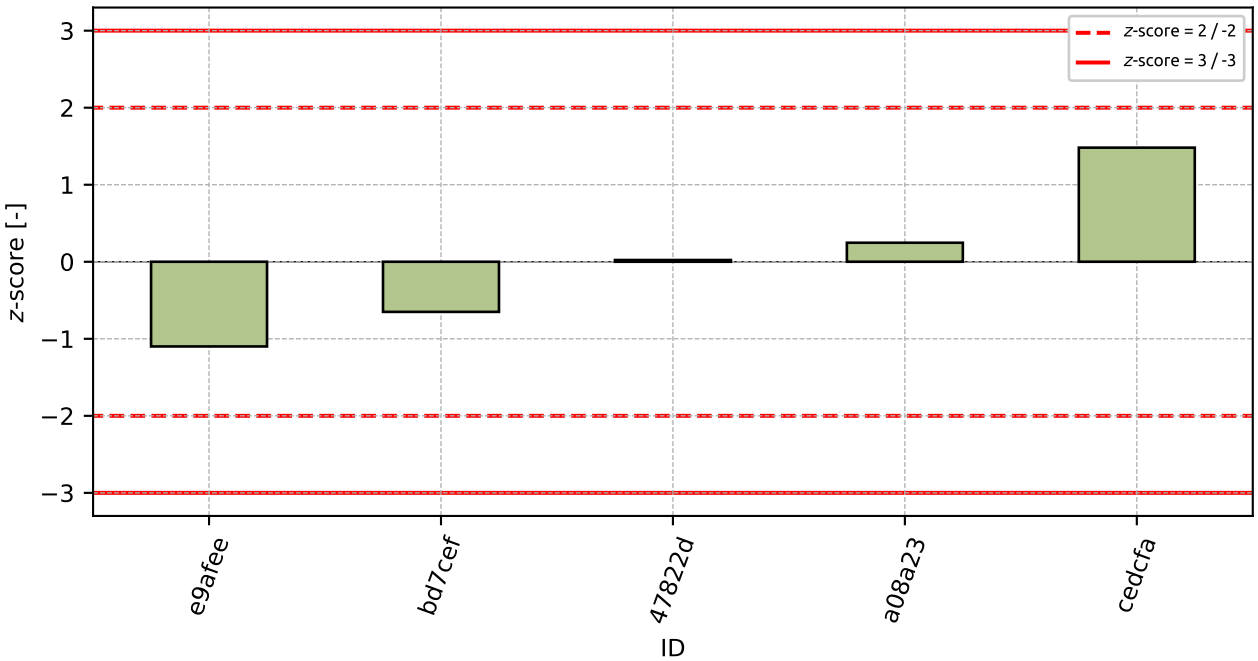

Figure 17: z-score

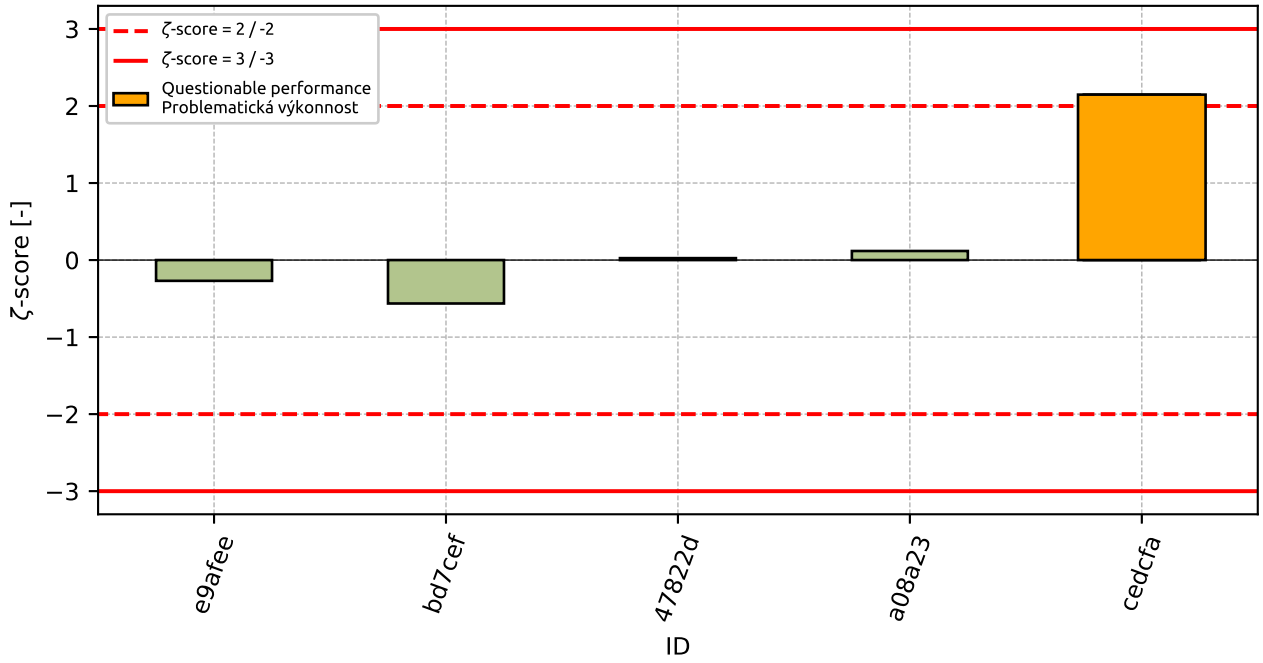

Figure 18: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
e9afee	-1.1	-0.27
bd7cef	-0.65	-0.56
47822d	0.02	0.03
a08a23	0.25	0.12
cedcfa	1.48	2.15

4 Appendix – EN 772-7 (Water absorption of clay masonry damp proof course units by boiling in water)

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

5 Appendix – EN 772-10 (Moisture content)

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

6 Appendix – EN 772-11 (Water absorption)

6.1 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 [kg/m^2 min]						u_X [kg/m^2 min]	$\bar{x}$ [kg/m^2 min]	s_0 [kg/m^2 min]	V_X [%]
dae225	0.055	0.06	0.062	0.057	0.058	0.06	0.002	0.059	0.0025	4.27
a08a23	0.067	0.068	0.058	0.058	0.053	0.05	0.005	0.059	0.0073	12.32
d26329	0.068	0.065	0.063	0.065	0.067	0.062	0.002	0.065	0.0023	3.51
cedcfa	0.07	0.063	0.063	0.065	0.068	0.062	0.004	0.065	0.0032	4.99
bd7cef	0.072	0.066	0.063	0.079	0.075	0.079	0.006	0.072	0.0067	9.24
3e8e59	0.077	0.067	0.073	0.077	0.073	0.073	0.005	0.073	0.0037	5.0
e9afee	0.077	0.072	0.075	0.077	0.073	0.078	0.018	0.075	0.0024	3.22

6.2 The Numerical Procedure for Determining Outliers

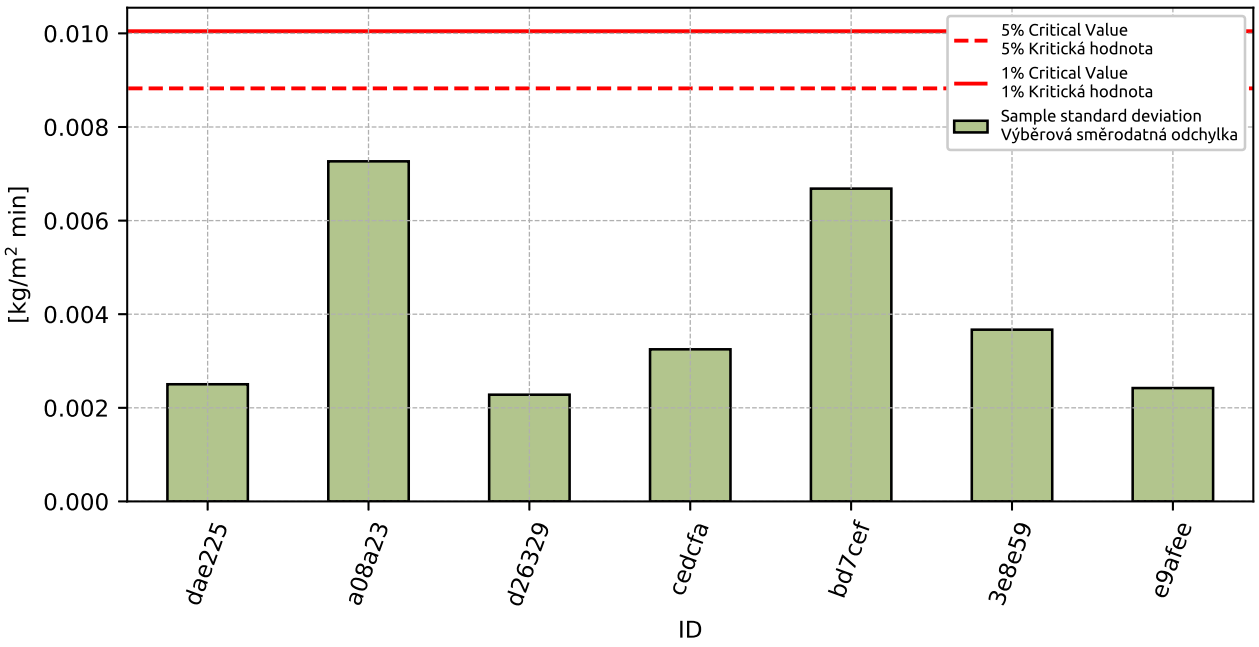

Figure 19: **Cochran's test** - sample standard deviations

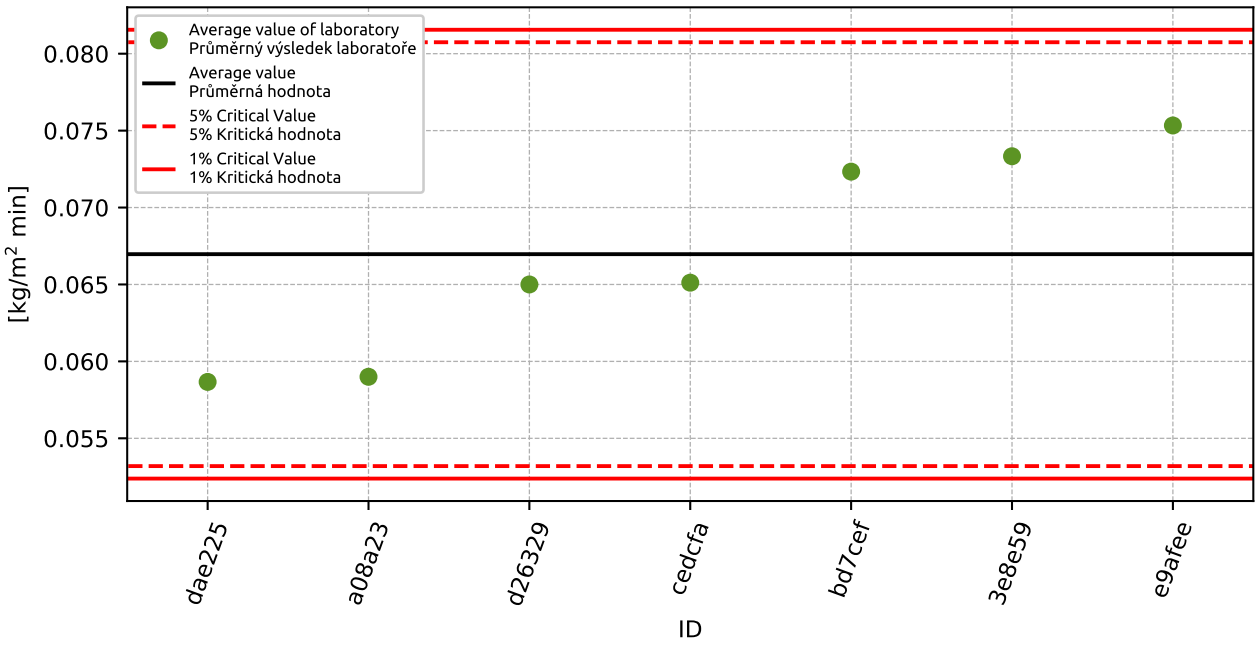

Figure 20: **Grubbs' test** - average values

6.3 Mandel's Statistics

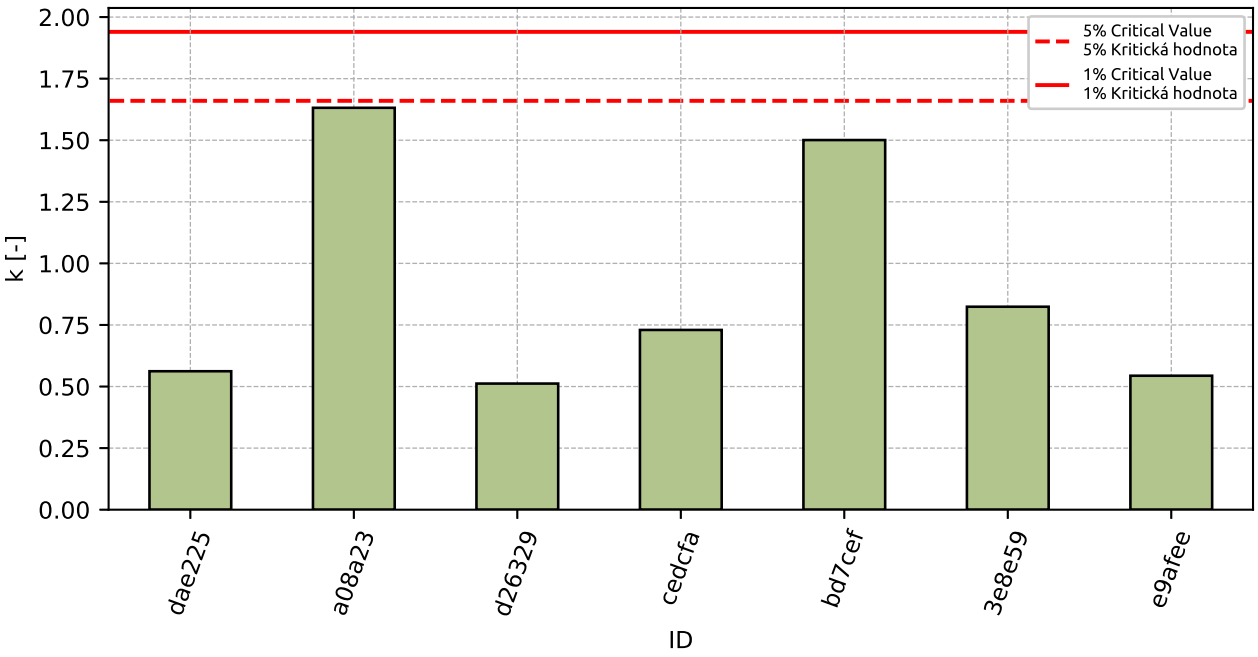

Figure 21: Intralaboratory Consistency Statistic

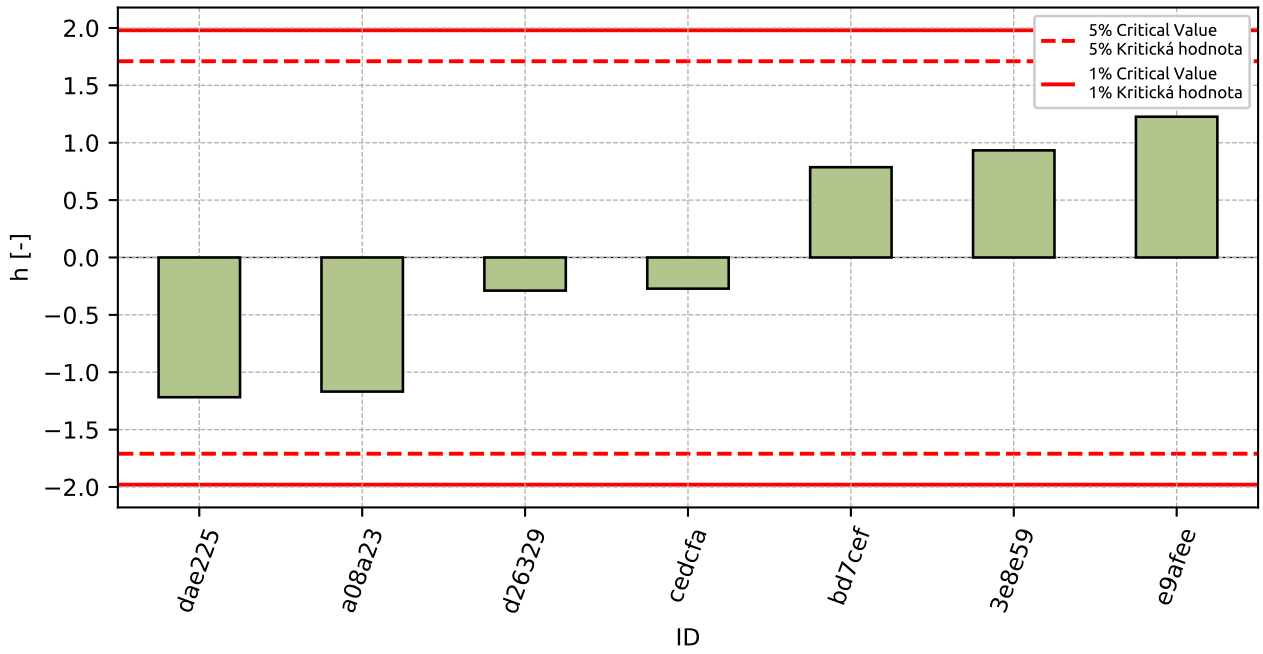

Figure 22: Interlaboratory Consistency Statistic

6.4 Descriptive statistics

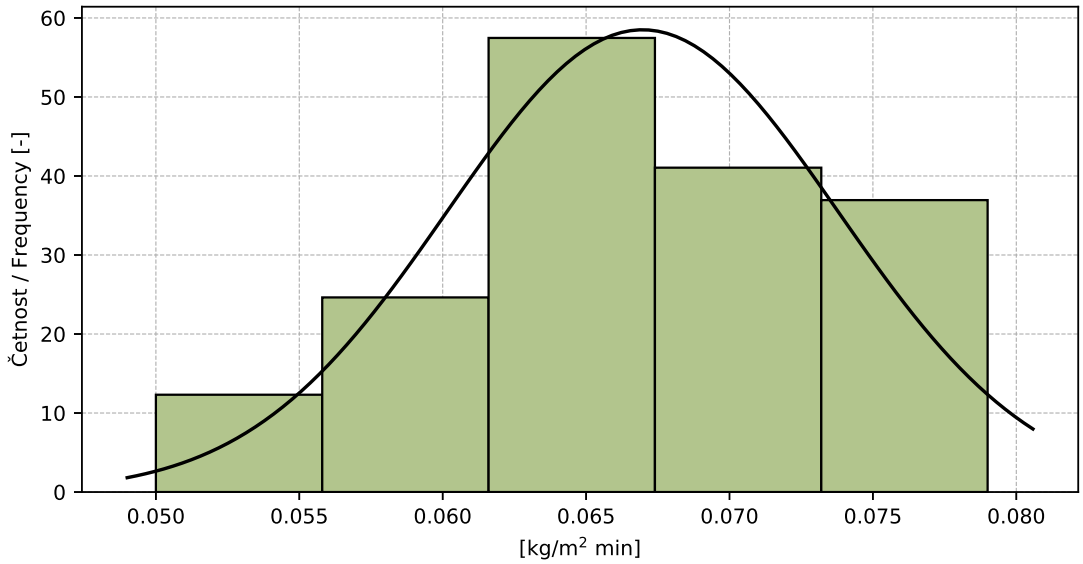

Figure 23: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[kg/m^2 min]
Průměrná hodnota / Average value – $\bar{x}$	0.067
Výběrová směrodatná odchylka / Sample standard deviation – s	0.0068
Vztažná hodnota / Asigned value – x^*	0.067
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.0072
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.0034
p-hodnota testu normality / p-value of normality test	0.35 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.0066
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.0045
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.0079
Opakovatelnost / Repeatability – r	0.012
Reprodukovatelnost / Reproducibility – R	0.022

6.5 Evaluation of Performance Statistics

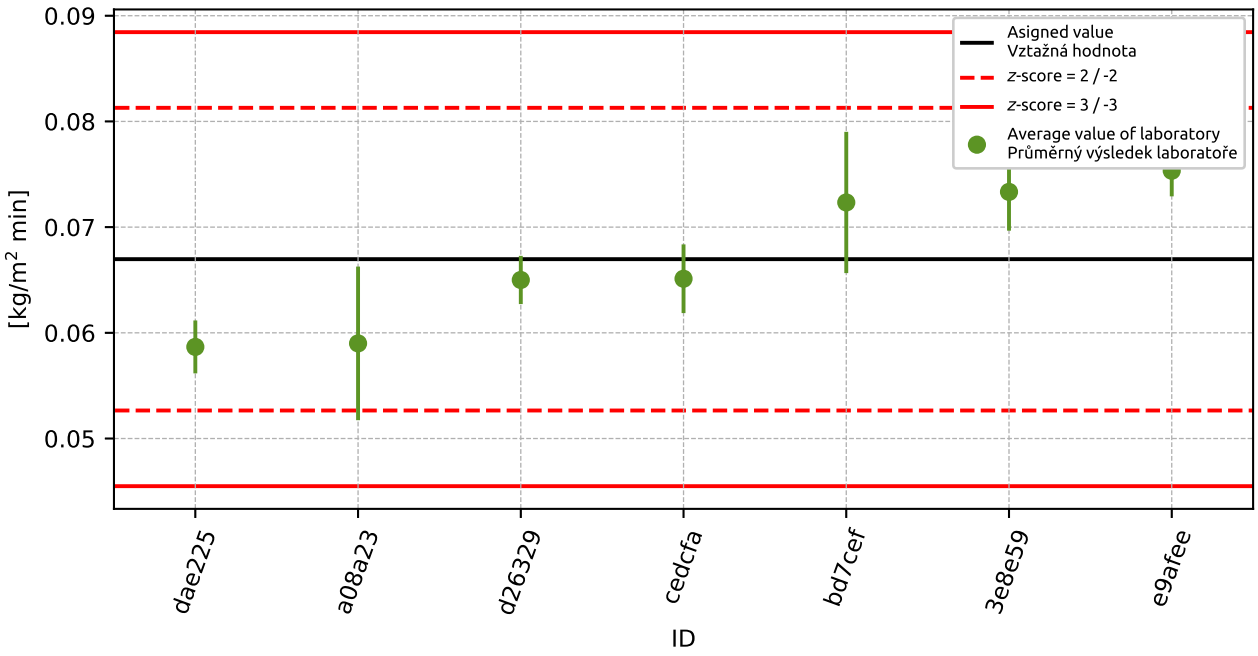

Figure 24: Average values and sample standard deviations

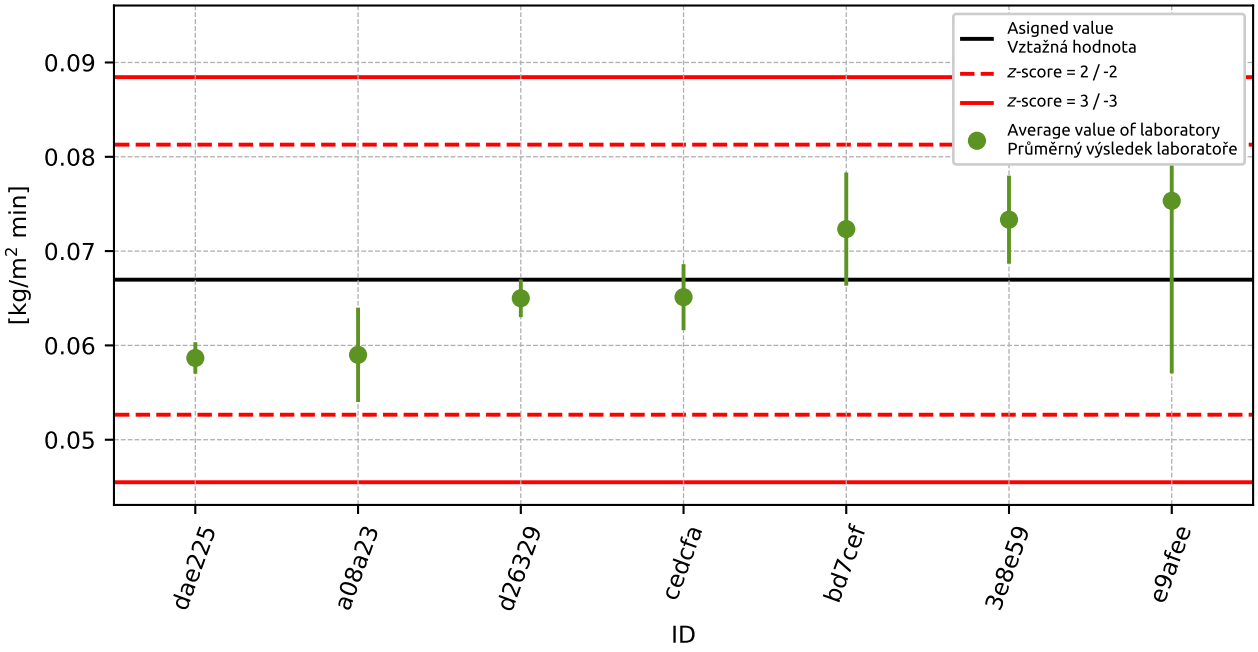

Figure 25: Average values and extended uncertainties of measurement

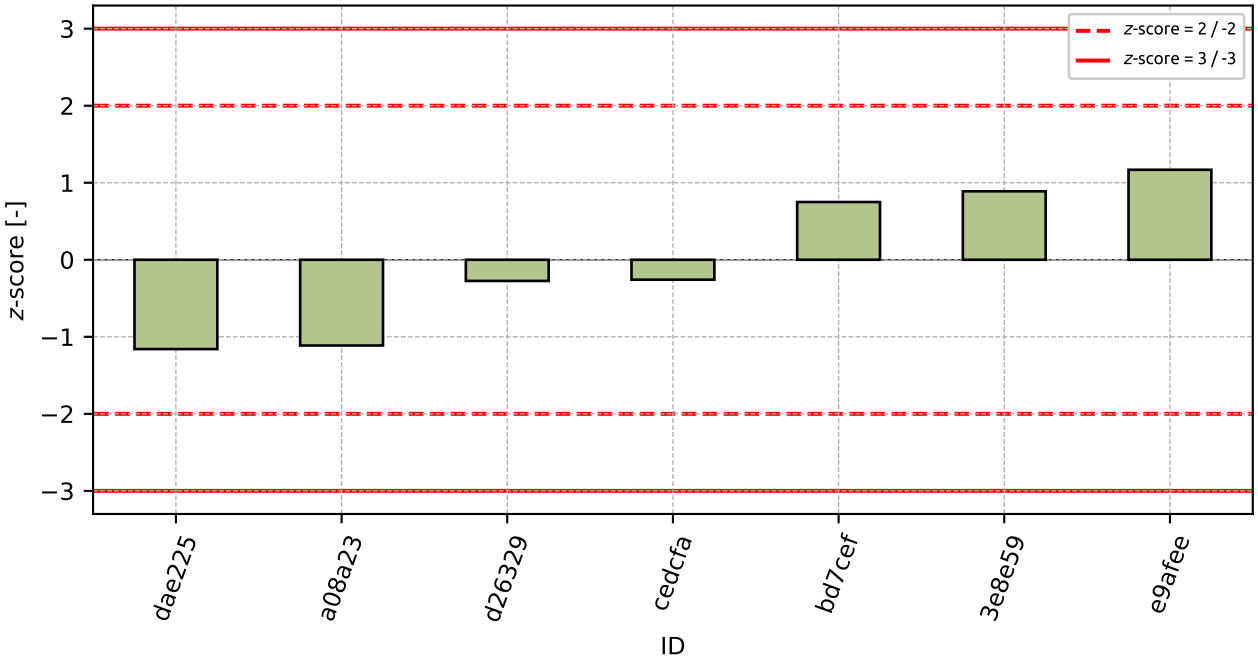

Figure 26: z-score

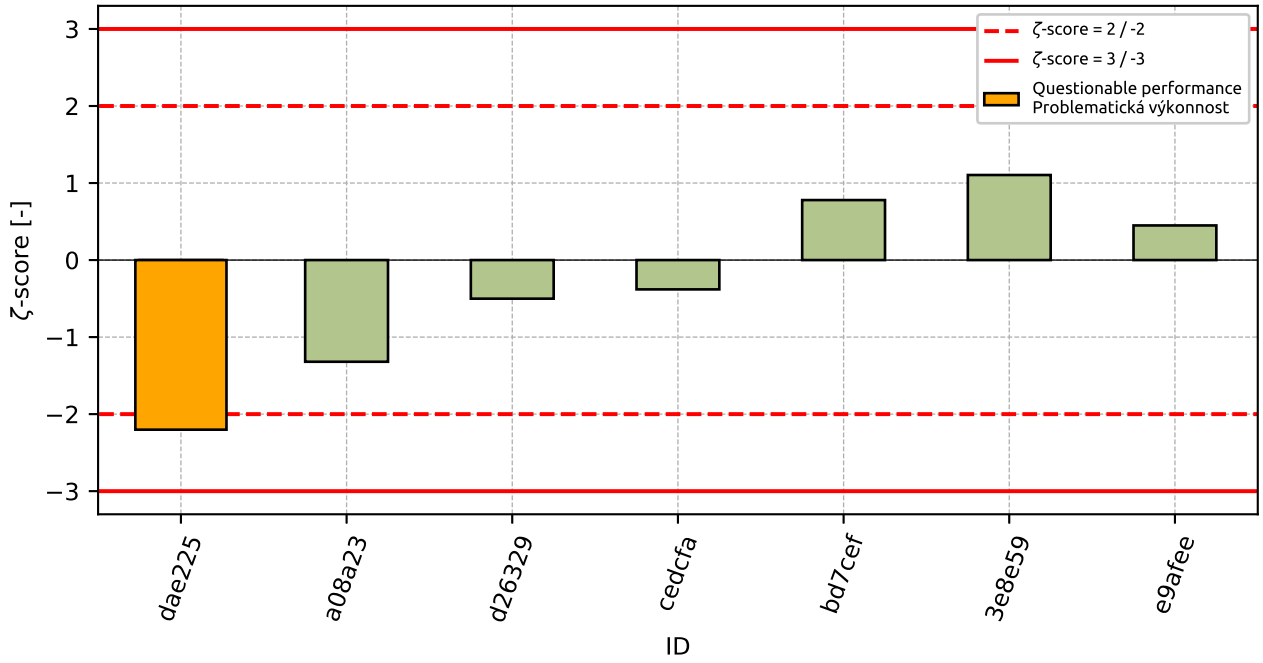

Figure 27: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
dae225	-1.16	-2.2
a08a23	-1.11	-1.32
d26329	-0.28	-0.5
cedcfa	-0.26	-0.38
bd7cef	0.75	0.78
3e8e59	0.89	1.1
e9afee	1.17	0.45

7 Appendix – EN 772-13 (Dry density of masonry units)

7.1 Net dry density of masonry units

7.1.1 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/m³]						u_X [kg/m³]	$\bar{x}$ [kg/m³]	s_0 [kg/m³]	V_X [%]
d26329	1290	1280	1280	1280	1300	1280	11.0	1285.0	8.4	0.65
47822d	1350	1350	1340	1350	1350	1350	44.0	1348.0	4.1	0.3
a08a23	1360	1350	1350	1360	1350	1360	30.0	1355.0	5.5	0.4
3e8e59	1360	1370	1360	1360	1360	1360	7.0	1362.0	4.1	0.3
e9afee	1649	1684	1679	1680	1728	1664	46.0	1681.0	26.6	1.58

7.1.2 The Numerical Procedure for Determining Outliers

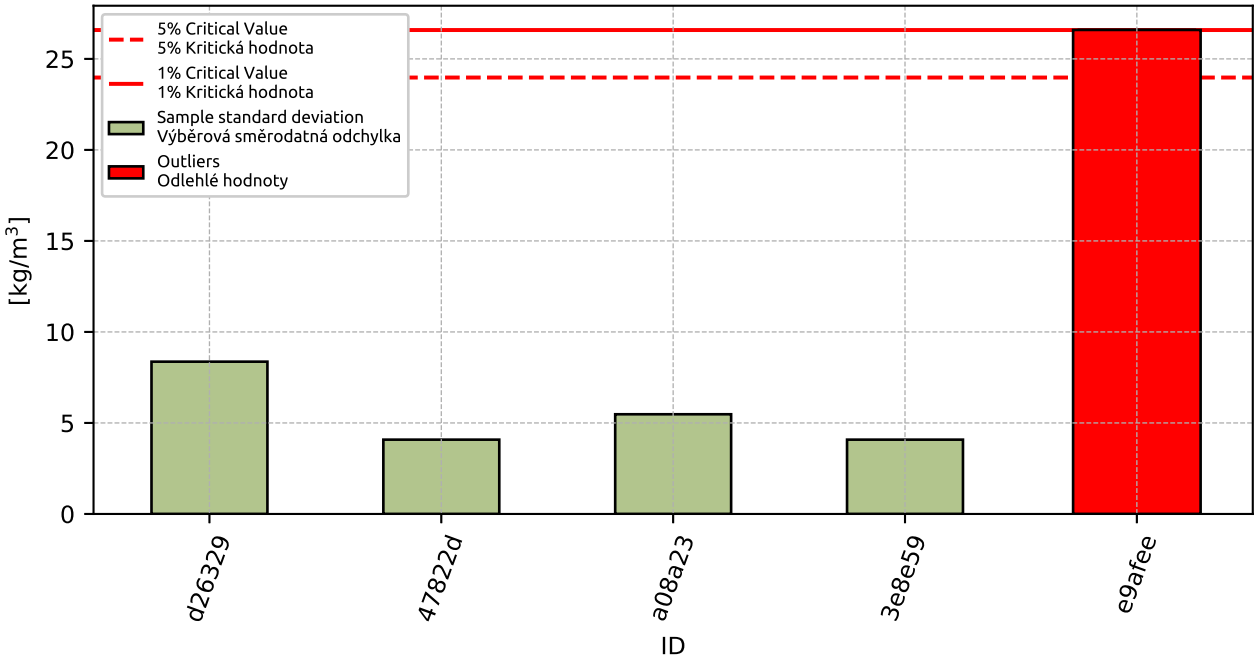

Figure 28: **Cochran's test** - sample standard deviations

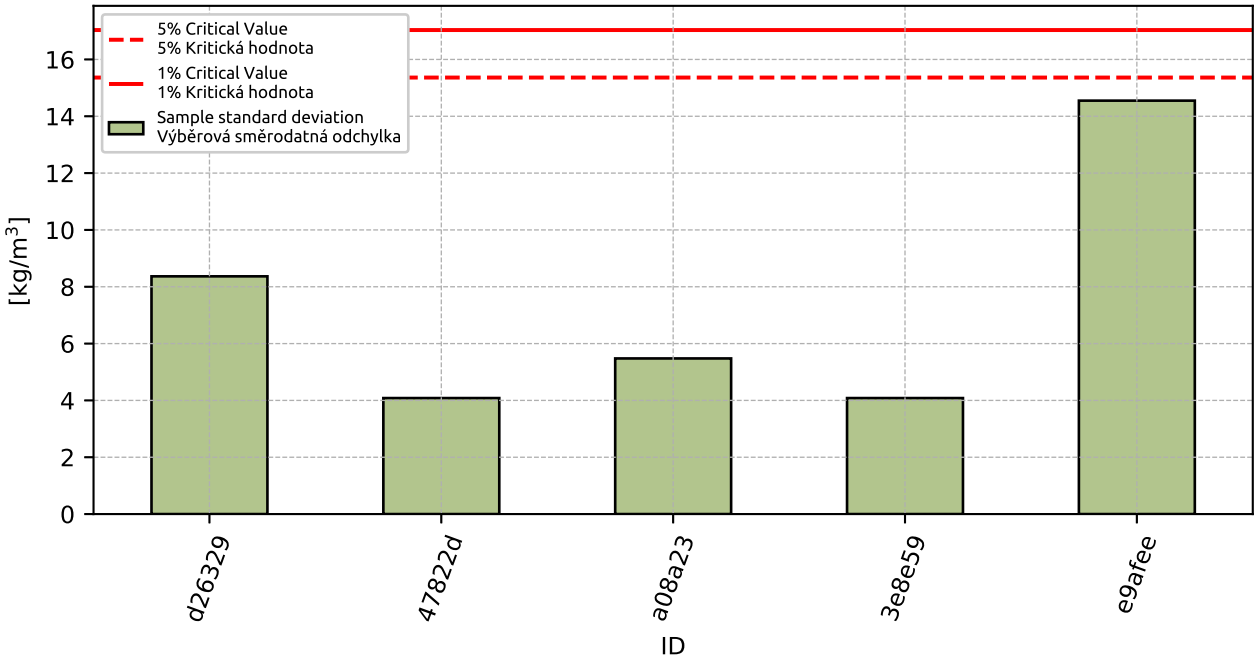

Figure 29: **Cochran's test** - sample standard deviations without outliers

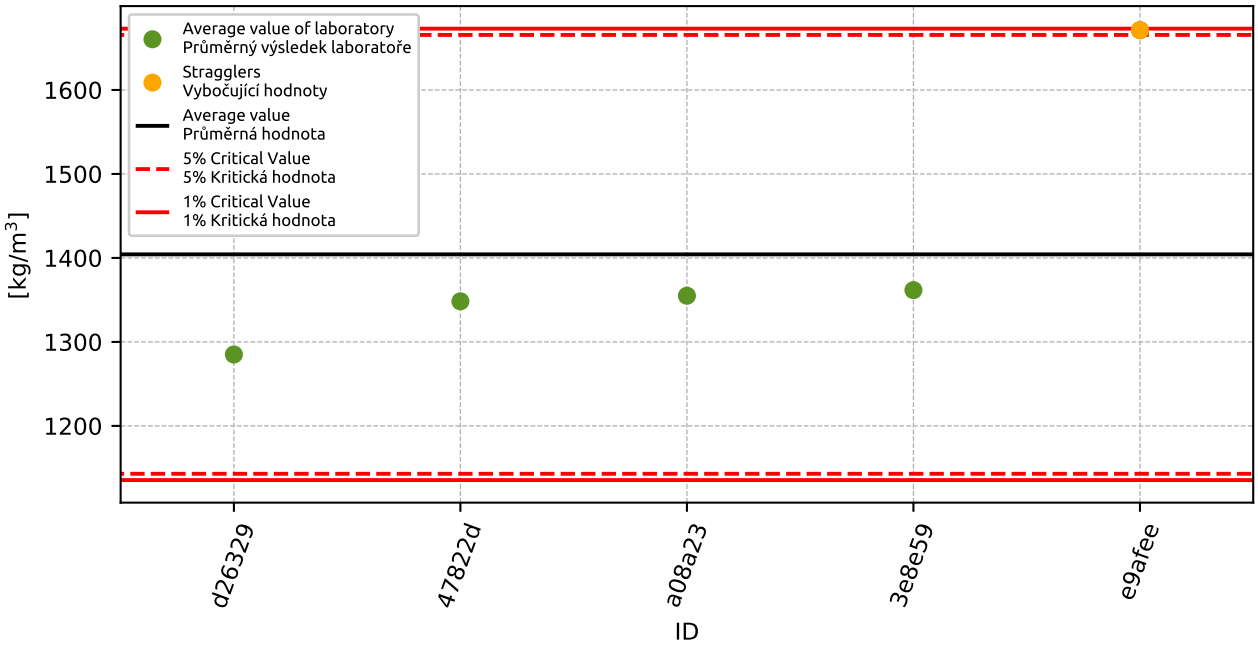

Figure 30: **Grubbs' test** - average values

7.1.3 Mandel's Statistics

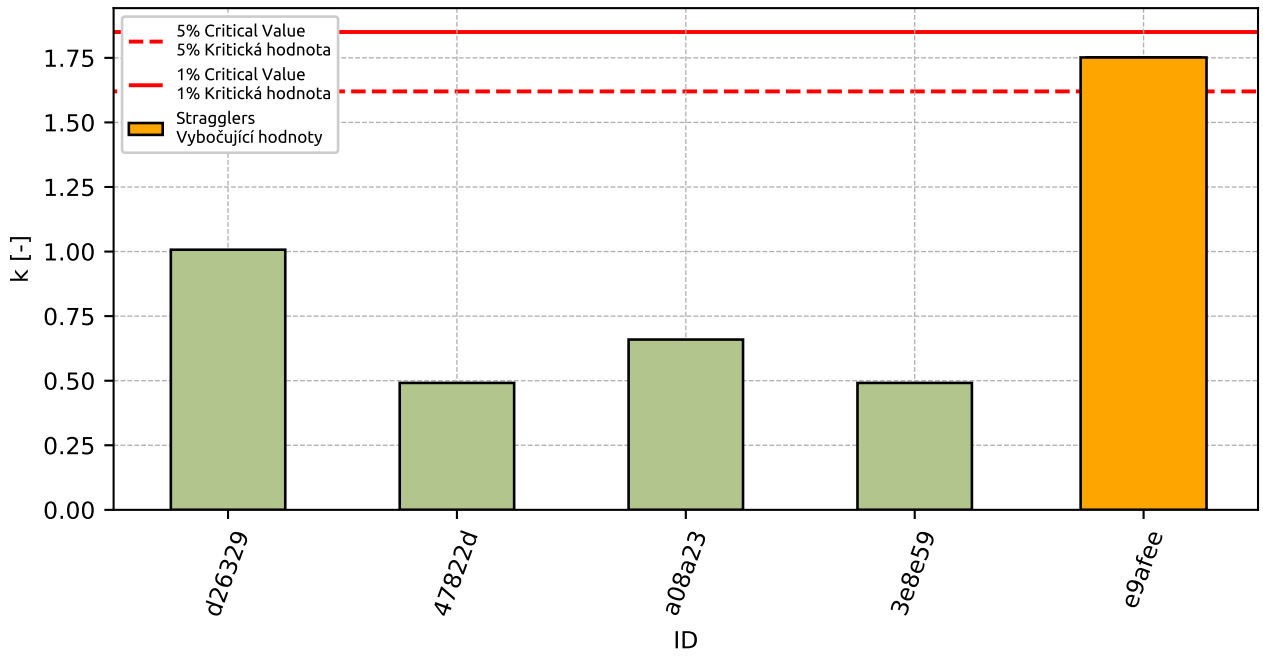

Figure 31: Intralaboratory Consistency Statistic

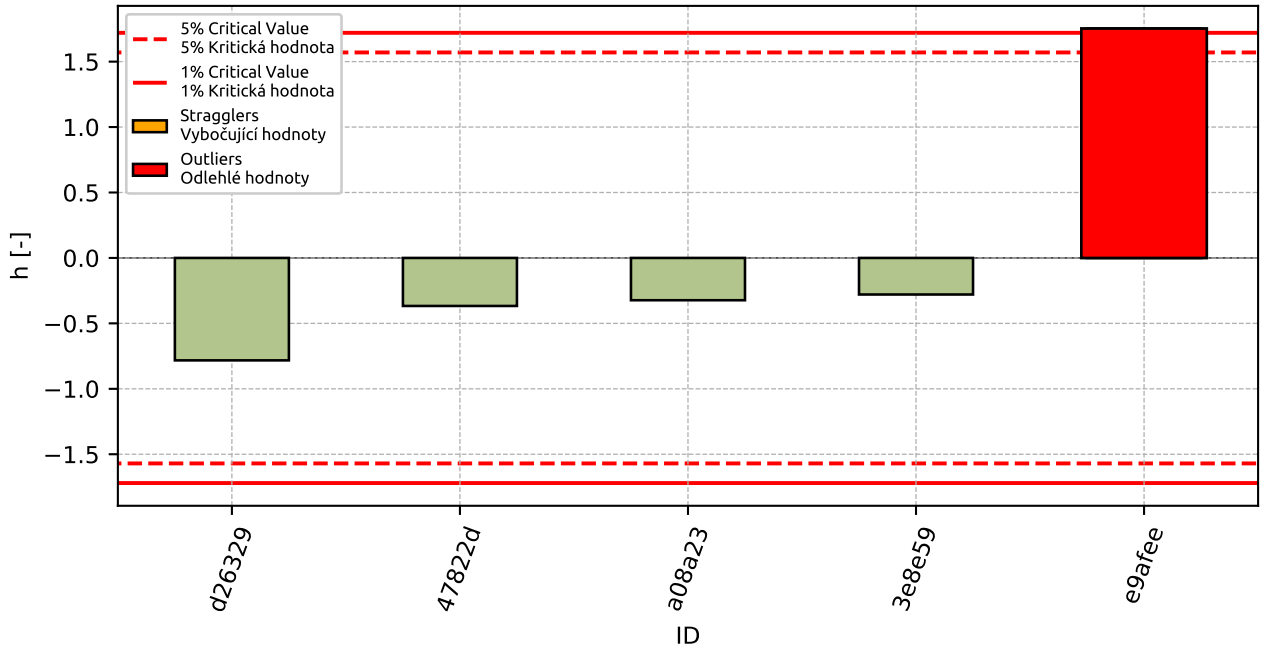

Figure 32: Interlaboratory Consistency Statistic

7.1.4 Descriptive statistics

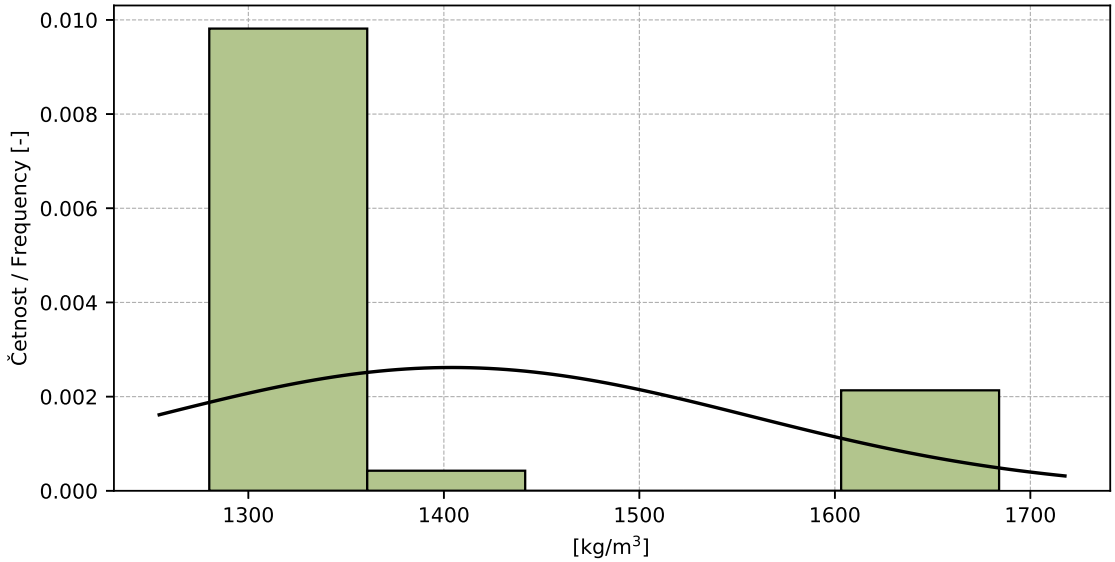

Figure 33: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	**[kg/m³]**
Průměrná hodnota / Average value – $\bar{x}$	1404.0
Výběrová směrodatná odchylka / Sample standard deviation – s	152.4
Vztažná hodnota / Asigned value – x^*	1415.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	145.3
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	81.2
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	152.3
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	8.3
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	152.5
Opakovatelnost / Repeatability – r	23.0
Reprodukovatelnost / Reproducibility – R	427.0

7.1.5 Evaluation of Performance Statistics

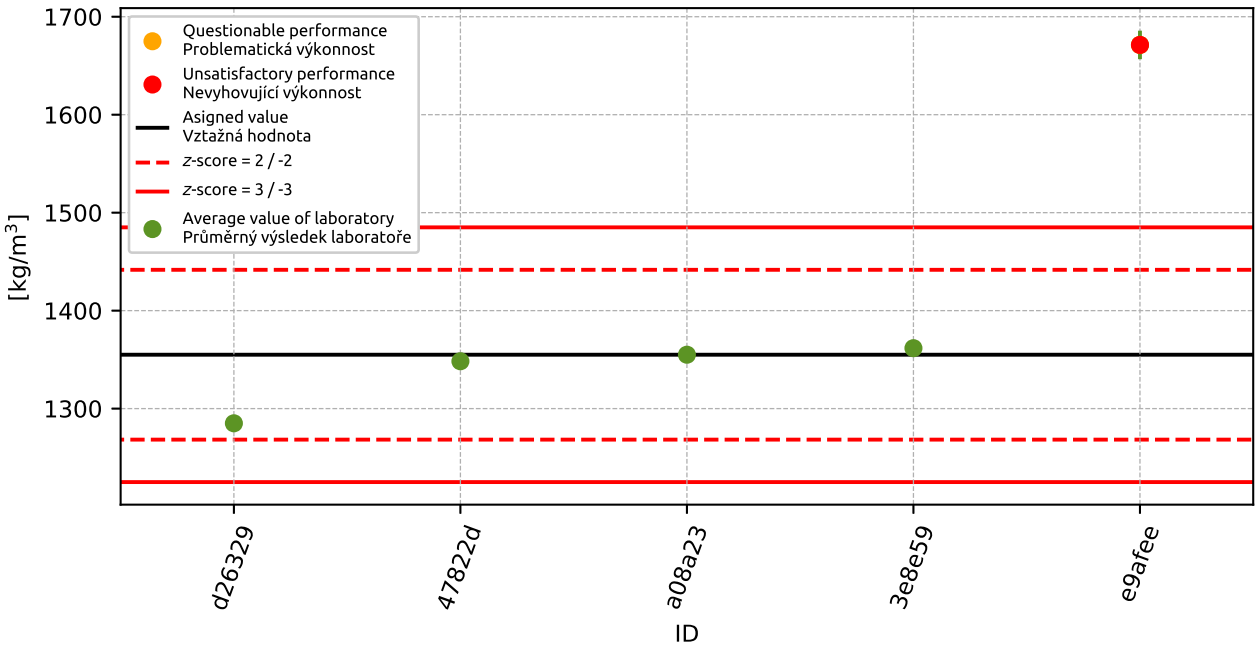

Figure 34: Average values and sample standard deviations

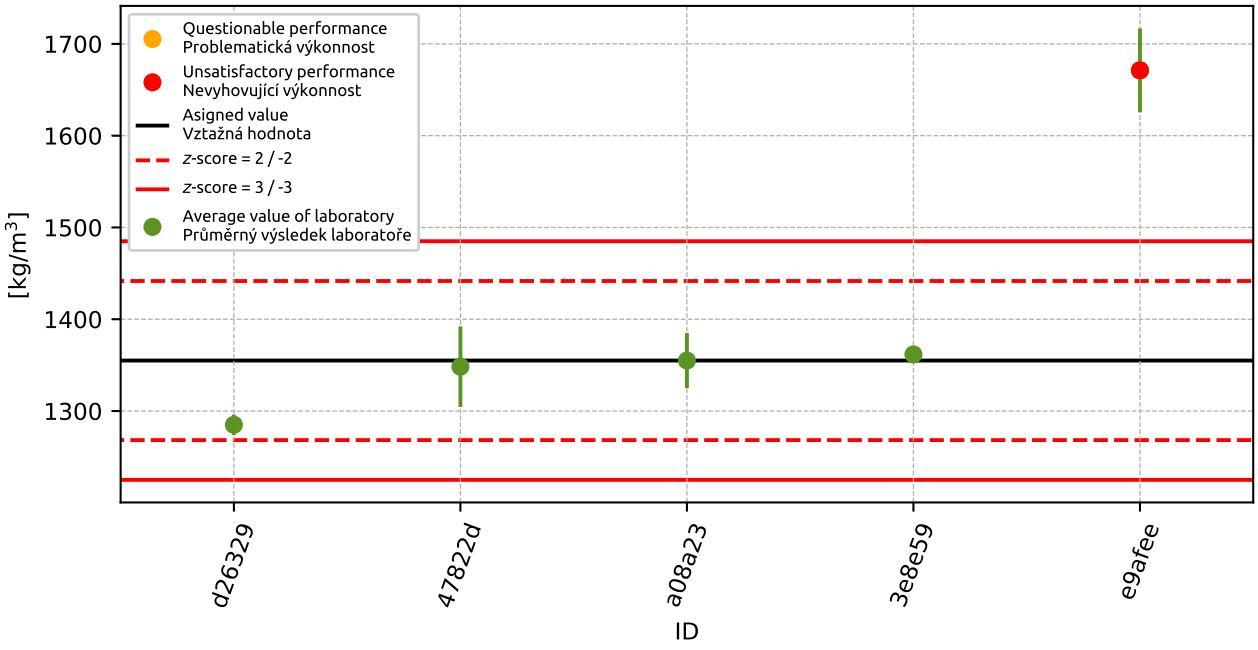

Figure 35: Average values and extended uncertainties of measurement

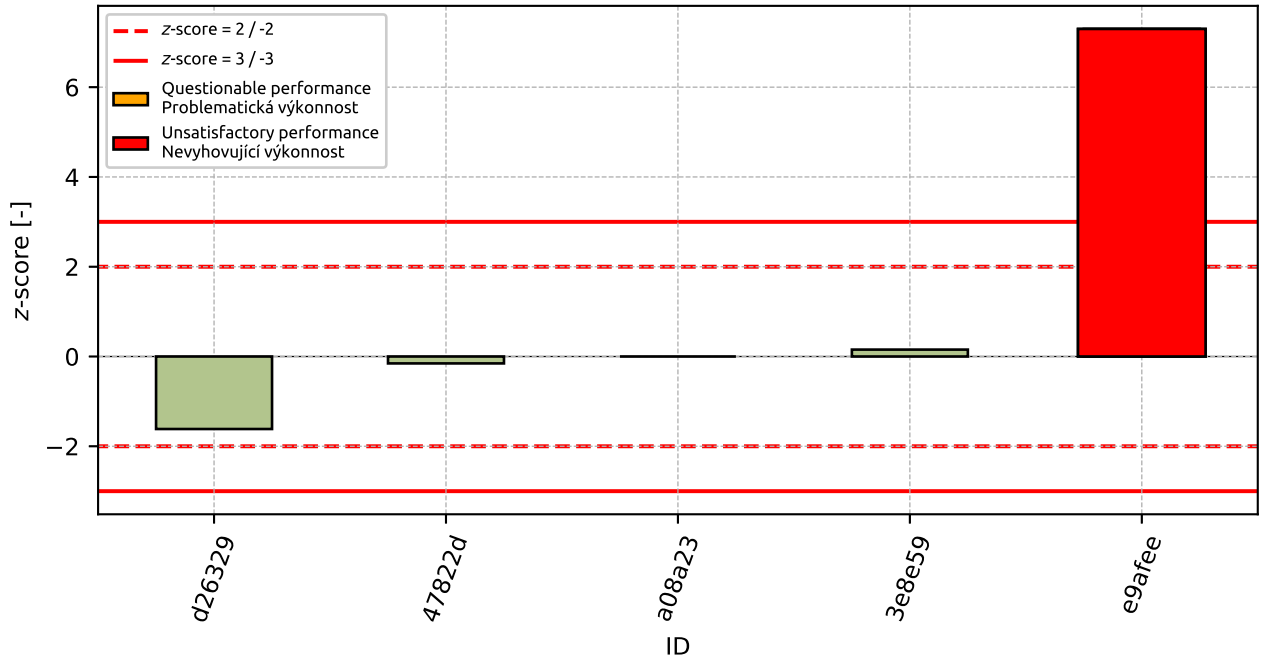

Figure 36: z-score

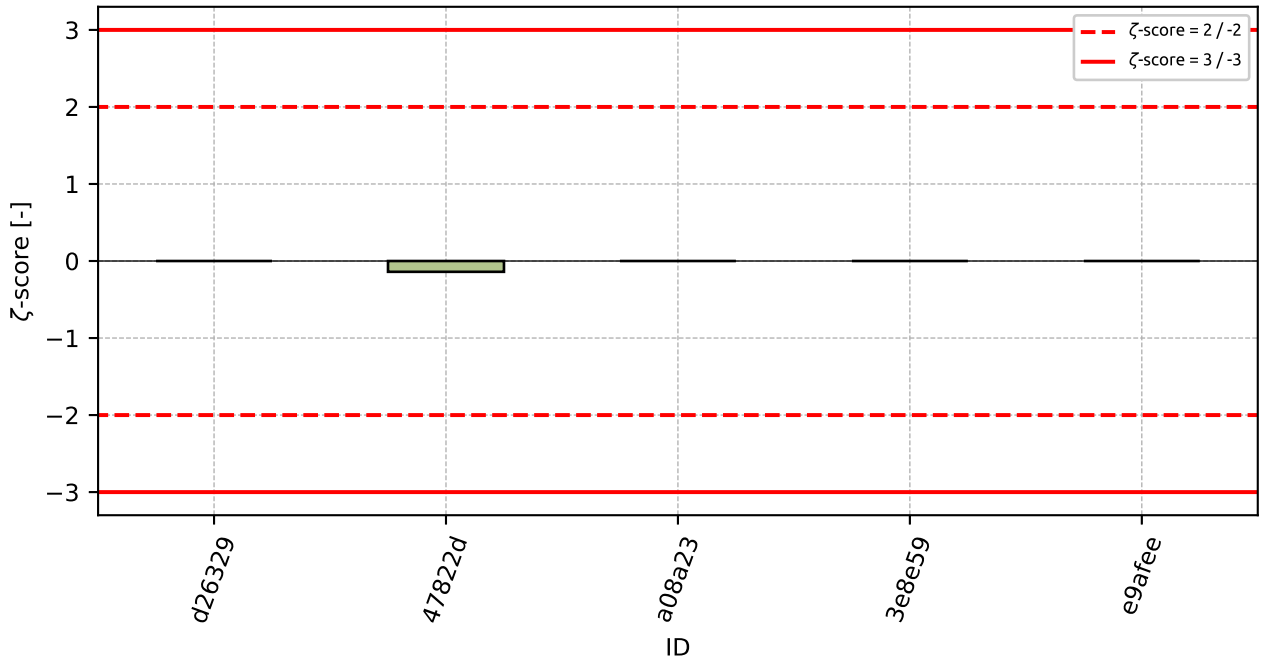

Figure 37: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
d26329	-1.62	-
47822d	-0.15	-0.14
a08a23	0.0	-
3e8e59	0.15	-
e9afee	7.3	-

7.2 Gross dry density of masonry units

7.2.1 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 [kg/m^3]						u_X [kg/m^3]	$\bar{x}$ [kg/m^3]	s_0 [kg/m^3]	V_X [%]
47822d	565	565	560	565	565	565	28.0	564.0	2.0	0.36
d26329	710	700	700	700	710	700	7.0	703.0	5.2	0.73
3e8e59	710	715	715	710	710	710	4.0	712.0	2.6	0.36
a08a23	715	715	715	715	710	715	15.0	714.0	2.0	0.29
e9afee	742	741	743	743	744	744	3.0	743.0	1.2	0.16

7.2.2 The Numerical Procedure for Determining Outliers

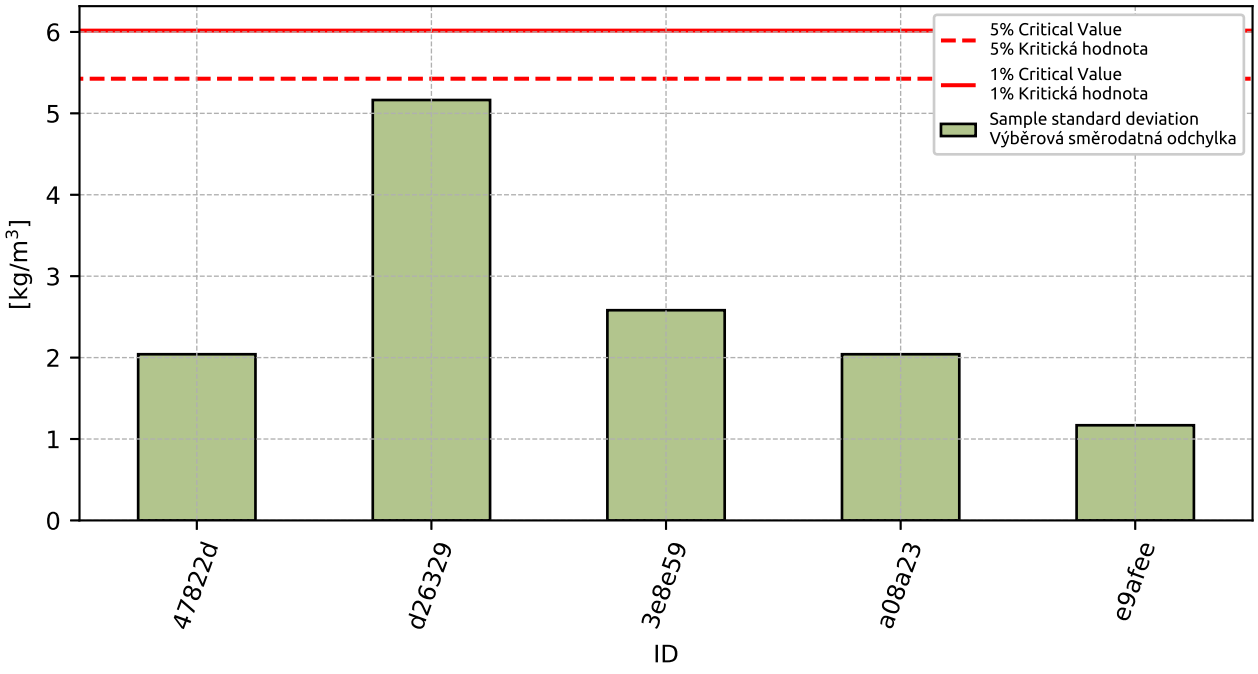

Figure 38: **Cochran's test** - sample standard deviations

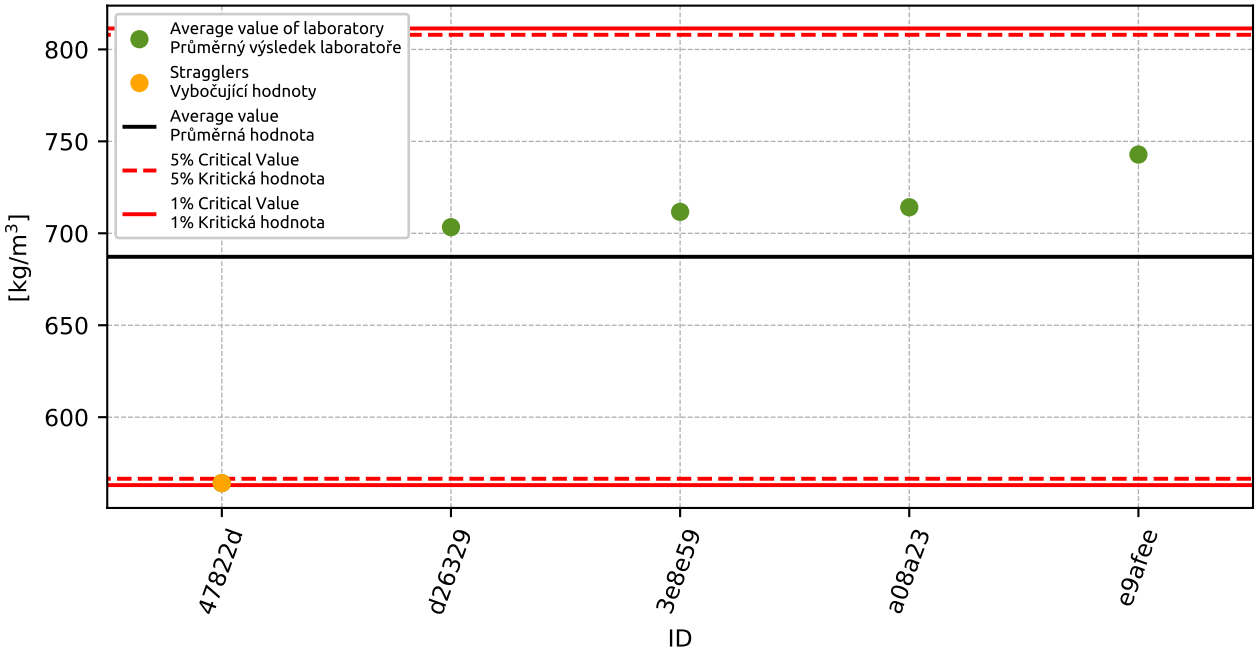

Figure 39: **Grubbs' test** - average values

7.2.3 Mandel's Statistics

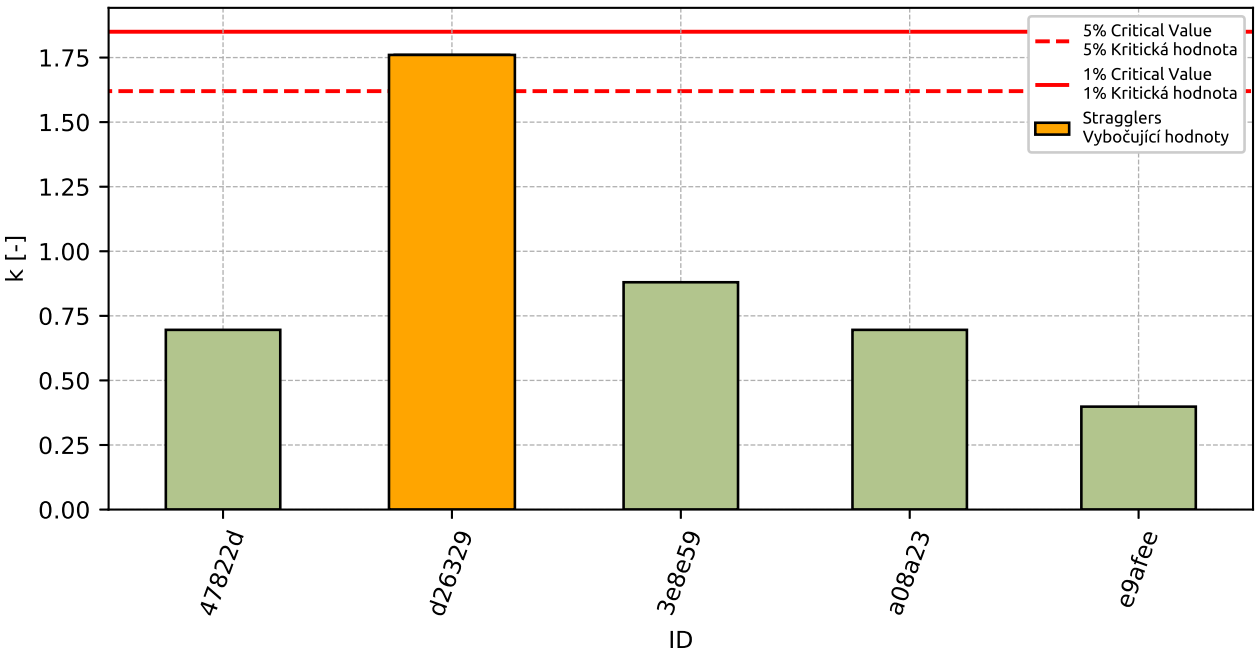

Figure 40: Intralaboratory Consistency Statistic

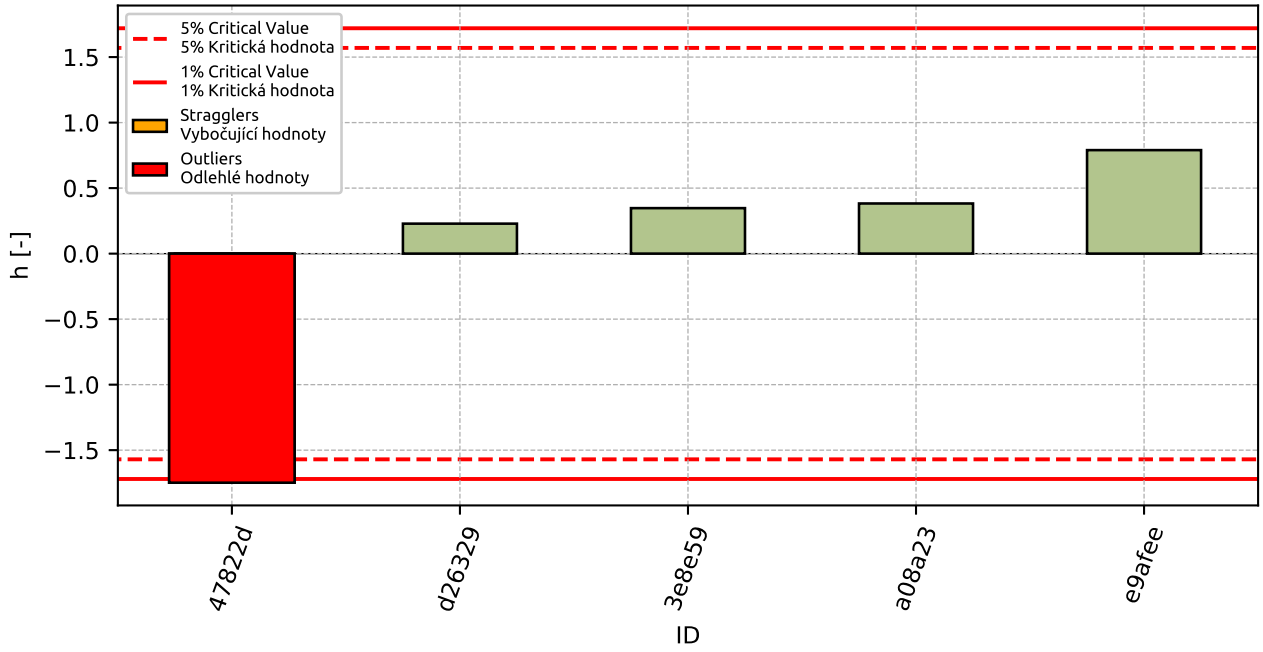

Figure 41: Interlaboratory Consistency Statistic

7.2.4 Descriptive statistics

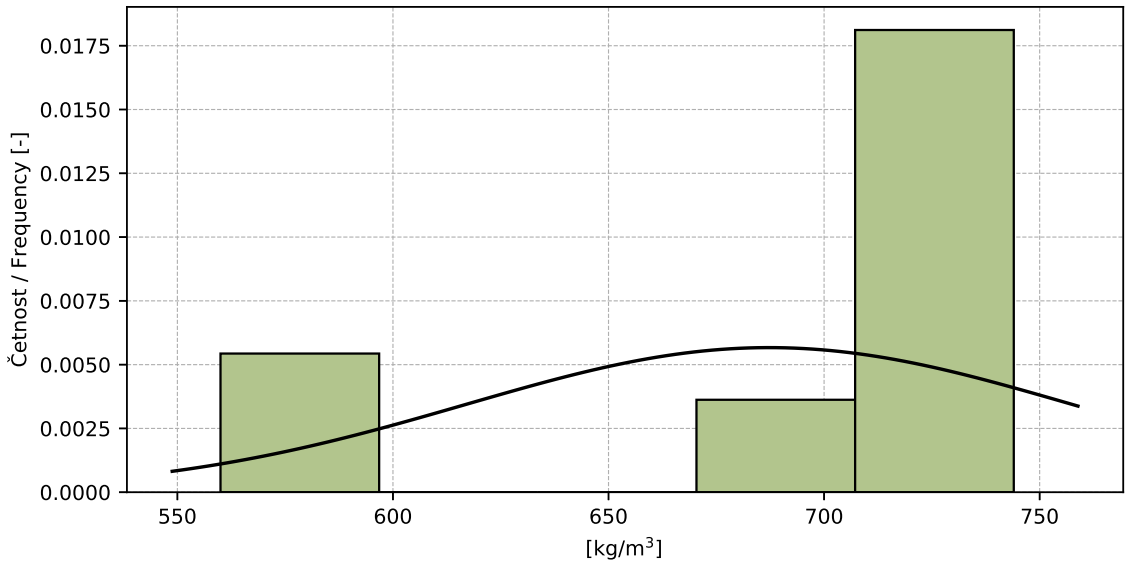

Figure 42: Histogram of all test results

Table 17: Descriptive statistics

Characteristics	[kg/m³]
Průměrná hodnota / Average value – $\bar{x}$	687.0
Výběrová směrodatná odchylka / Sample standard deviation – s	70.4
Vztažná hodnota / Asigned value – x^*	709.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	10.8
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	14.8
p-hodnota testu normality / p-value of normality test	0.011 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	70.4
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	2.9
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	70.4
Opakovatelnost / Repeatability – r	8.0
Reprodukovatelnost / Reproducibility – R	197.0

7.2.5 Evaluation of Performance Statistics

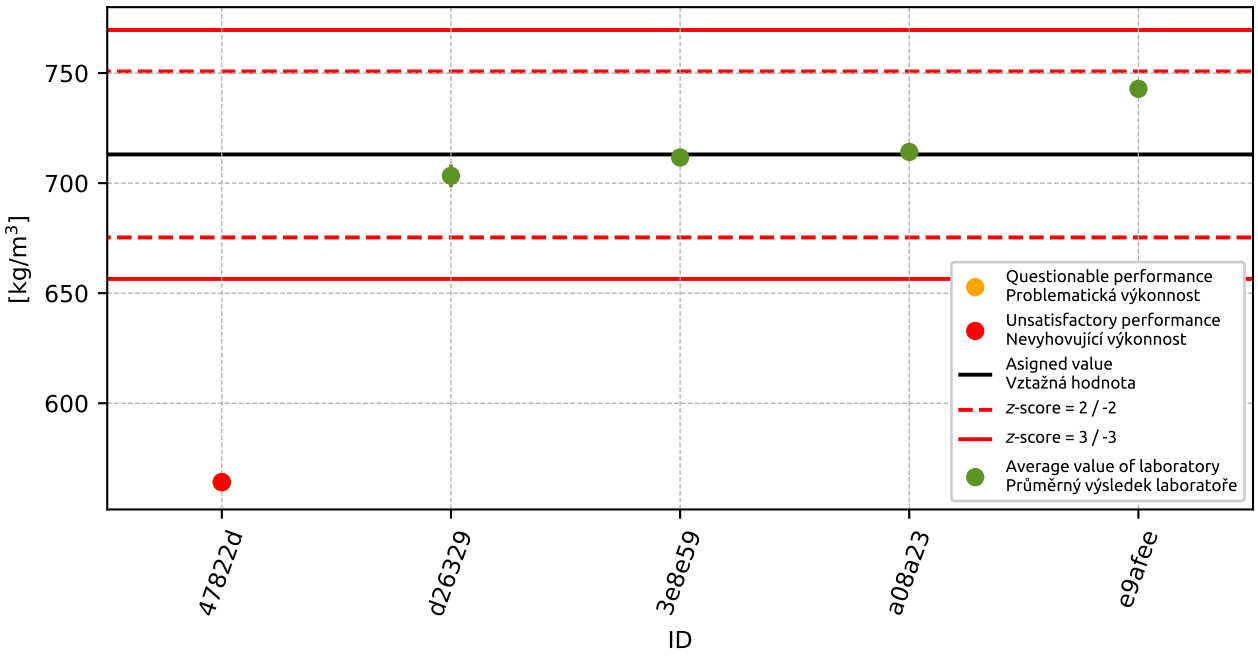

Figure 43: Average values and sample standard deviations

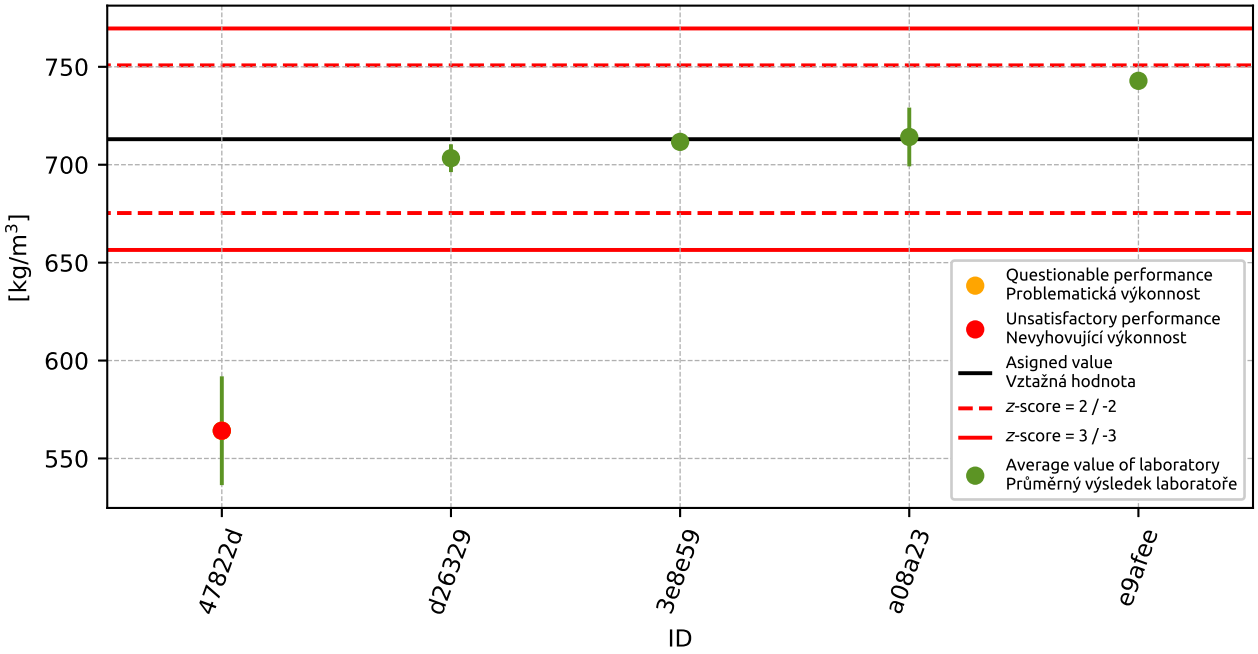

Figure 44: Average values and extended uncertainties of measurement

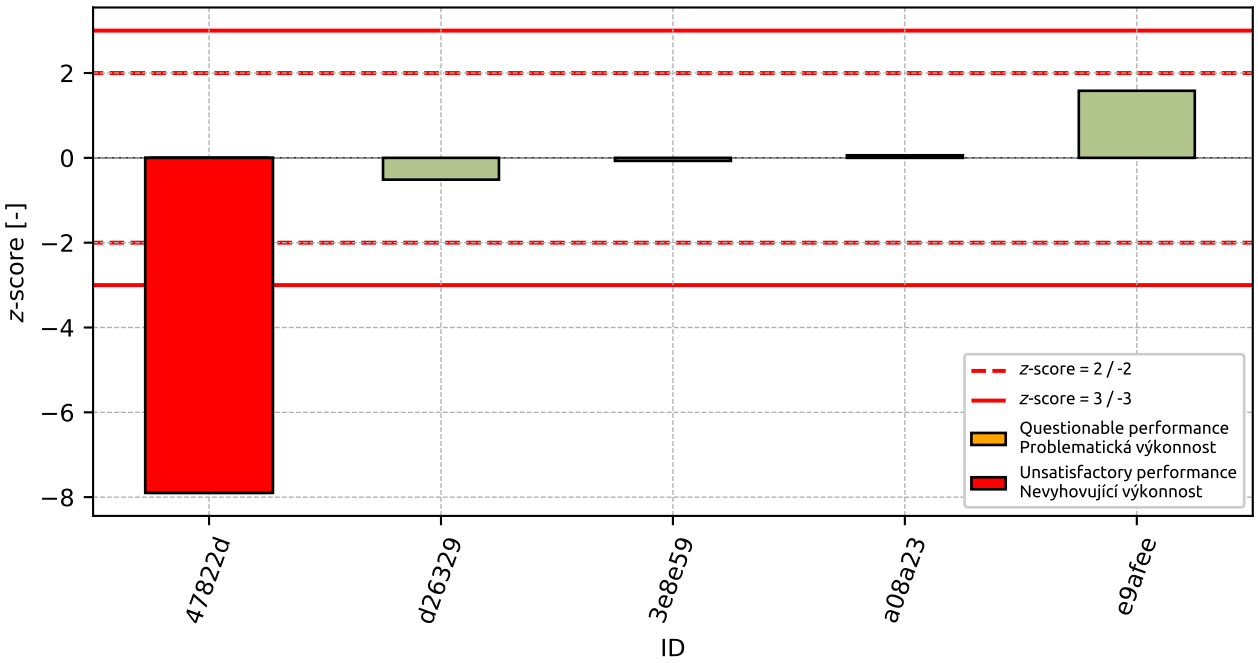

Figure 45: z-score

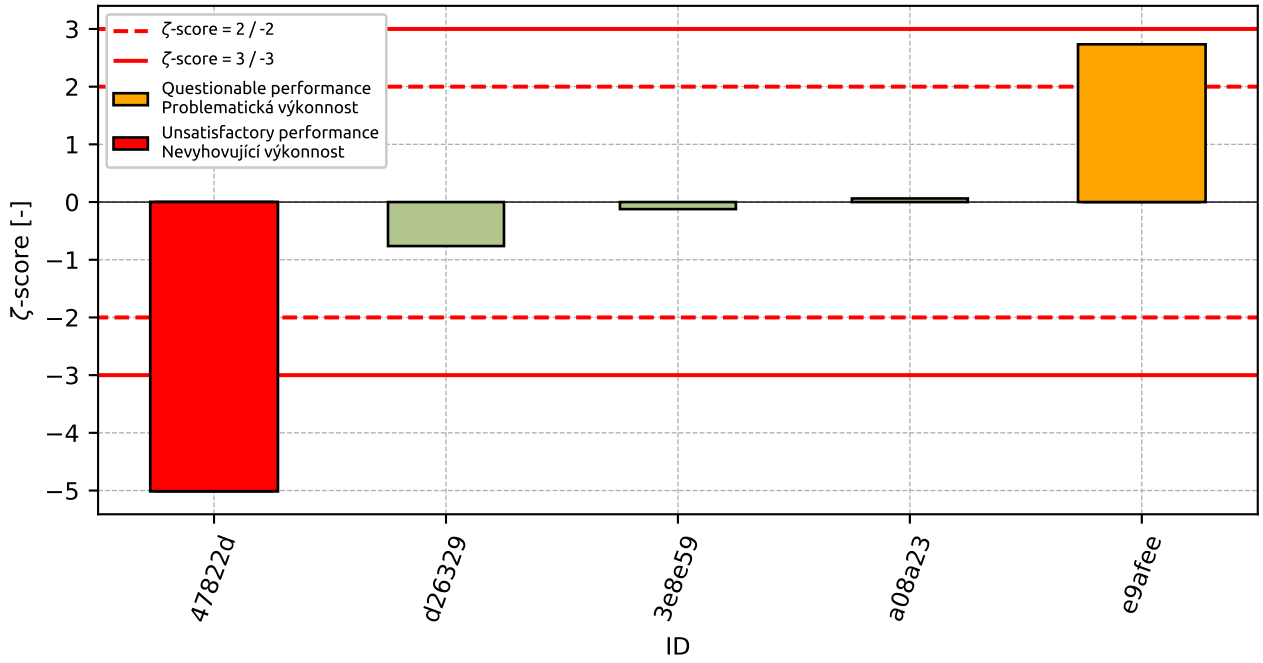

Figure 46: ζ-score

Table 18: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
47822d	-7.9	-5.01
d26329	-0.51	-0.76
3e8e59	-0.07	-0.12
a08a23	0.06	0.06
e9afee	1.58	2.73

8 Appendix – EN 15435, part 4.9.3, Appendix B (Flexural strength of side shutters)

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

9 Appendix – EN 15435, part 5.2 (Density)

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