BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF CIVIL ENGINEERING
institute of building testing

Z 7008

FINAL REPORT ON THE RESULTS OF PRECISION EXPERIMENT

Proficiency Testing Program
Fresh Concrete
ZCB 2021/2

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

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1 Introduction and Important Contacts

In the year 2021, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZCB 2021/2 whose aim was to verify and assess the conformity of test results across laboratories when testing fresh 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 12350-2**: Testing fresh concrete – Part 2: Slump-test, 2009. [1]
2. **EN 12350-4**: Testing fresh concrete – Part 4: Degree of Compactability, 2009. [2]
3. **EN 12350-5**: Testing fresh concrete – Part 5: Flow table test, 2009. [3]
4. **EN 12350-6**: Testing fresh concrete – Part 6: Density, 2009. [4]
5. **EN 12350-7**: Testing fresh concrete – Part 7: Air content - Pressure methods, 2009. [5]
6. **EN 12350-8**: Testing fresh concrete – Part 8: Self-compacting concrete - Slump-flow test, 2010. [6]
7. **EN 12350-9**: Testing fresh concrete – Part 9: Self-compacting concrete - V-funnel test, 2010. [7]
8. **EN 12350-10**: Testing fresh concrete – Part 10: Self-compacting concrete - L-box test, 2010. [8]
9. **EN 12350-11**: Testing fresh concrete – Part 11: Self-compacting concrete - Sieve segregation test, 2010. [9]
10. **EN 12350-12**: Testing fresh concrete – Part 12: Self-compacting concrete - J-ring test, 2010. [10]

Testing procedures No 2 and 6 – 10 were not open due to low number of participants.

Tests were performed on the same place in the same time on the October 14^{th} 2021. The tests were performed under the same conditions. PoZZ has ensured the homogeneity and stability of the tested material (fresh concrete) by the best available sampling technique. Fresh concrete was taken from a one production batch for all participants of the PTP, following the procedures in EN 206 [11], and the distribution of fresh concrete to the individual PTP participants was carried out evenly to avoid segregation.

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 [12] and with EN ISO/IEC 17043 [13]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

12 laboratories took part in the program. In order to maintain the anonymity of the PTP, each laboratory was given an identification number that will be used henceforth in this document. An integral part of the present final report is a Certificate of Participation in the Proficiency Testing Program. It is unique for each participant and includes the participant's ID used in this report. The following chart shows the participation of laboratories in individual parts of the PTP.

Table 1: Participation of individual laboratories in the PTP (tests designated according to part 1)

ID / Testing method	1	2	3	4	5	6	7	8	9	10
8b9a51	X	-	X	X	X	-	-	-	-	-
272b96	X	-	X	-	-	-	-	-	-	-
ed8c7b	X	-	-	X	X	-	-	-	-	-
b054b0	X	-	-	-	X	-	-	-	-	-
4e6581	X	-	X	X	X	-	-	-	-	-
f9b775	X	-	X	X	X	-	-	-	-	-
188eae	X	-	X	X	X	-	-	-	-	-
94be68	-	-	X	X	X	-	-	-	-	-
c34c93	X	-	-	X	X	-	-	-	-	-
25c806	X	-	-	X	X	-	-	-	-	-
c130c0	X	-	X	X	X	-	-	-	-	-
39363d	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
BETOTECH, s.r.o.	Beroun 660, Beroun, 266 01, Česká republika	1195.3
Camillo Sitte Versuchsanstalt für Bautechnik	Leberstraße 4c, Vienna, 1030, Austria	46
Cemex CR s.r.o.	Semtín 102, Praha 5, 15500, Česká republika	1302
Centrum dopravního výzkumu, v. v. i.	Líšeňská 33a, Brno, 636 00, Česká republika	1506
GEOSTAR, spol. s r.o.	Tuřanka 111, Brno, 62700, Česká republika	1373
JKV TEST s.r.o.	Suhrady 148/4, Vřesina, 747 20, Česká republika	1294
Master Builders Solutions CZ s.r.o.	K Májovu 1244, Chrudim, 537 01, Česká republika	1495
NIEVELT Labor CZ s.r.o.	Za Olomouckou 4184/17, Prostějov, 79601, Česká republika	1716
QUALIFORM, a.s.	Mlaty 672/8, BRNO, 64200, Česká republika	1008
Skanska a.s., divize Inženýrské stavitelství	Křižíkova 682/34a, Praha 8- Karlín, 186 00, Česká republika	1355
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 Fresh Concrete (PT Program) organized by the PT Provider at the SZK FAST. 12 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of hardened concrete with emphasis on its strength and durability. The test results are evaluated separately for each testing procedure examined. An evaluation of statistical characteristics is included in the Appendix, as well as test results and graphic presentations. Testing methods can be found in part 1 of this report.

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

ID / Method	1	2	3	4	5	6	7	8	9	10
8b9a51	✓	-	✓	✓	✓	-	-	-	-	-
272b96	✓	-	✓	-	-	-	-	-	-	-
ed8c7b	✓	-	-	✓	✓	-	-	-	-	-
b054b0	✓	-	-	-	✓	-	-	-	-	-
4e6581	✓	-	✓	✓	✓	-	-	-	-	-
f9b775	✓	-	✓	✓	✓	-	-	-	-	-
188eae	✓	-	✓	✓	✓	-	-	-	-	-
94be68	-	-	✓	✓	✓	-	-	-	-	-
c34c93	✓	-	-	✓	✓	-	-	-	-	-
25c806	✓	-	-	✓	✓	-	-	-	-	-
c130c0	✓	-	✓	✓	✓	-	-	-	-	-
39363d	✓	-	-	-	-	-	-	-	-	-

References

[1] EN 12350-2. *Testing fresh concrete - Part 2: Slump-test*. 2019.

[2] EN 12350-4. *Testing fresh concrete - Part 4: Degree of Compactability*. 2019.

[3] EN 12350-5. *Testing fresh concrete - Part 5: Flow table test*. 2019.

[4] EN 12350-6. *Testing fresh concrete - Part 6: Density*. 2019.

[5] EN 12350-7. *Testing fresh concrete - Part 7: Air content - Pressure methods*. 2019.

[6] EN 12350-8. *Testing fresh concrete - Part 8: Self-compacting concrete - Slump-flow test*. 2019.

[7] EN 12350-9. *Testing fresh concrete - Part 9: Self-compacting concrete - V-funnel test*. 2010.

[8] EN 12350-10. *Testing fresh concrete - Part 10: Self-compacting concrete - L-box test*. 2010.

[9] EN 12350-11. *Testing fresh concrete - Part 11: Self-compacting concrete - Sieve segregation test*. 2010.

[10] EN 12350-12. *Testing fresh concrete - Part 12: Self-compacting concrete - J-ring test*. 2010.

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

[12] 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.

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

1 Appendix – EN 12350-2 – Slump-test

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 [mm]			u_X [mm]	$\bar{x}$ [mm]	s_0 [mm]	V_X [%]
272b96	140	130	130	20	133.3	5.77	4.33
25c806	140	150	140	10	143.3	5.77	4.03
ed8c7b	140	150	150	10	146.7	5.77	3.94
188eae	150	150	140	20	146.7	5.77	3.94
c34c93	140	150	150	10	146.7	5.77	3.94
39363d	150	140	150	11	146.7	5.77	3.94
b054b0	155	145	150	12	150	5.0	3.33
8b9a51	150	160	150	3.7	153.3	5.77	3.77
c130c0	150	160	150	10	153.3	5.77	3.77
4e6581	160	160	150	-	156.7	5.77	3.69
f9b775	160	160	150	16	156.7	5.77	3.69

1.2 The Numerical Procedure for Determining Outliers

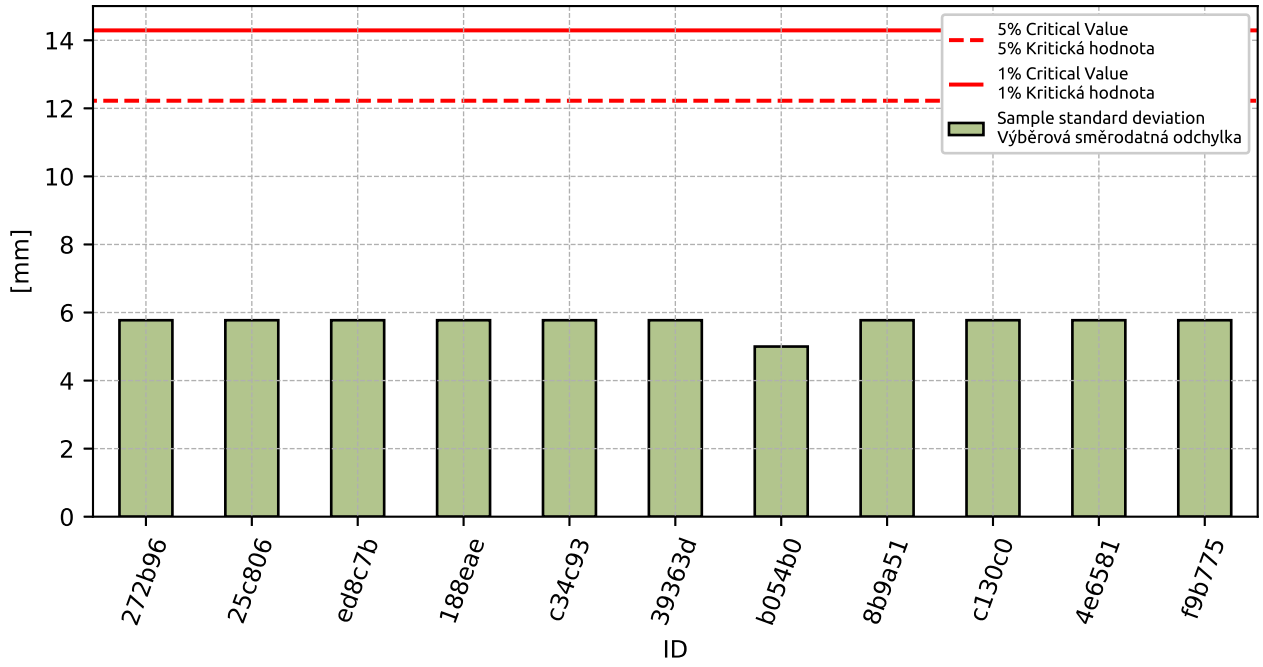

Figure 1: **Cochran's test** - sample standard deviations

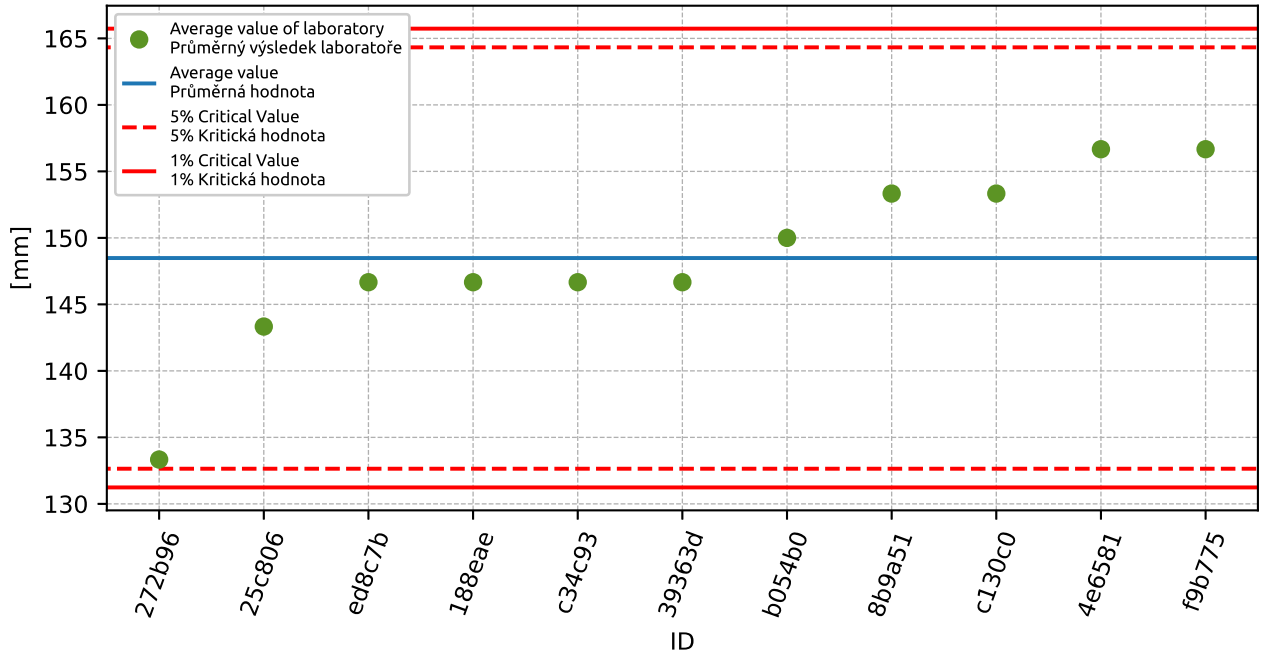

Figure 2: **Grubbs' test** - average values

1.3 Mandel's Statistics

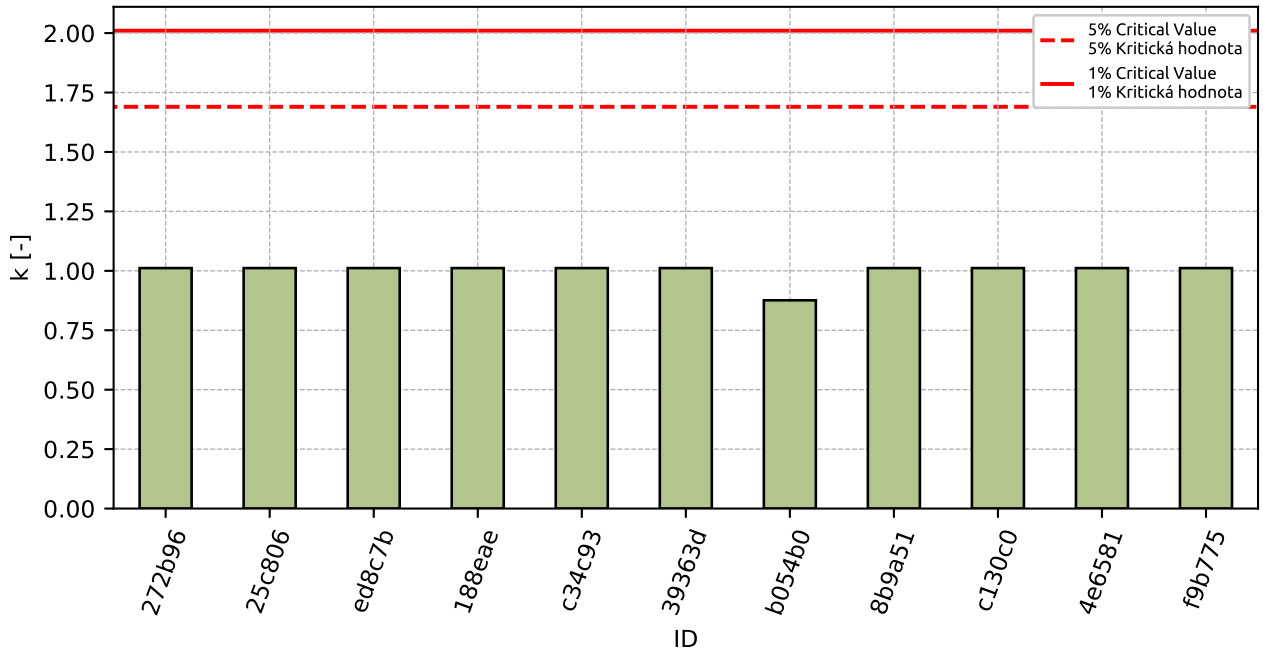

Figure 3: Intralaboratory Consistency Statistic

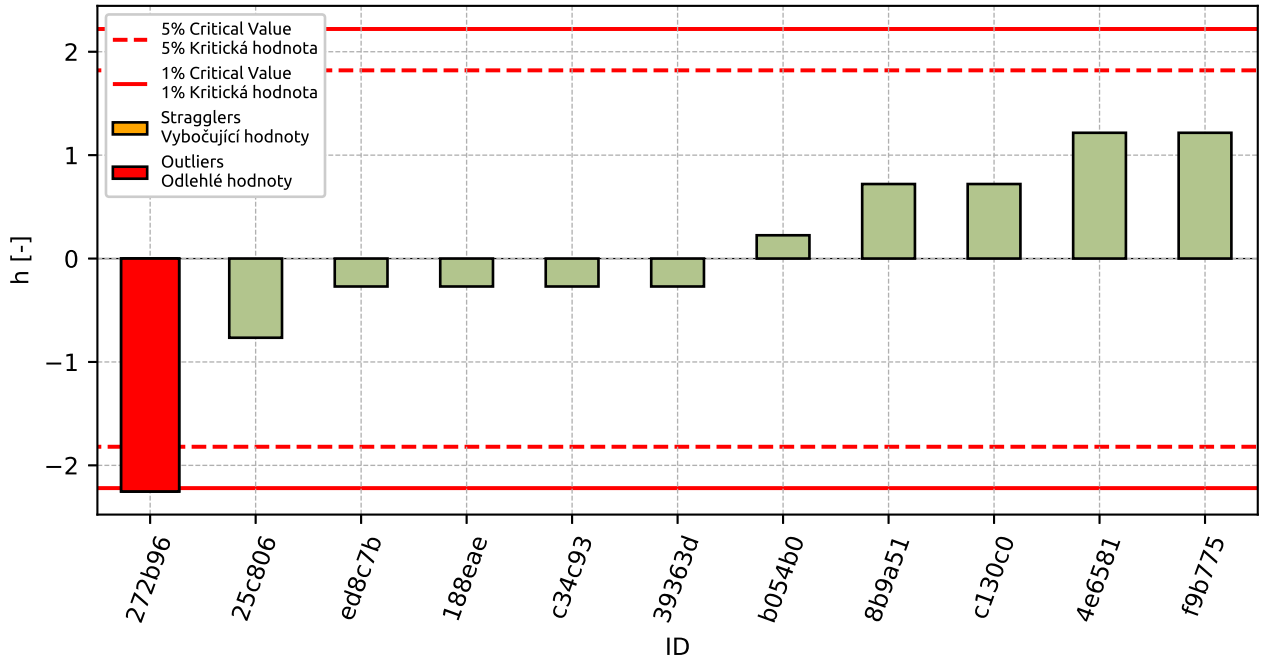

Figure 4: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

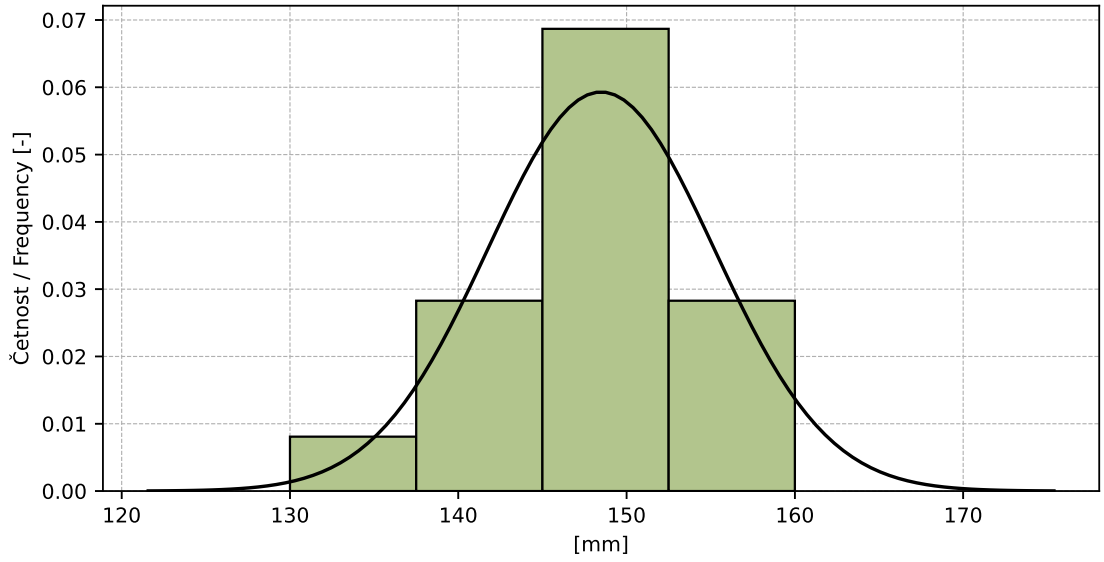

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[mm]
Průměrná hodnota / Average value – $\bar{x}$	148
Výběrová směrodatná odchylka / Sample standard deviation – s	6.7
Vztažná hodnota / Asigned value – x^*	149
Robustní směrodatná odchylka / Robust standard deviation – s^*	5.3
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	2.0
p-hodnota testu normality / p-value of normality test	0.001 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	5.9
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	5.7
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	8.2
Opakovatelnost / Repeatability – r	16
Reprodukovatelnost / Reproducibility – R	23

1.5 Evaluation of Performance Statistics

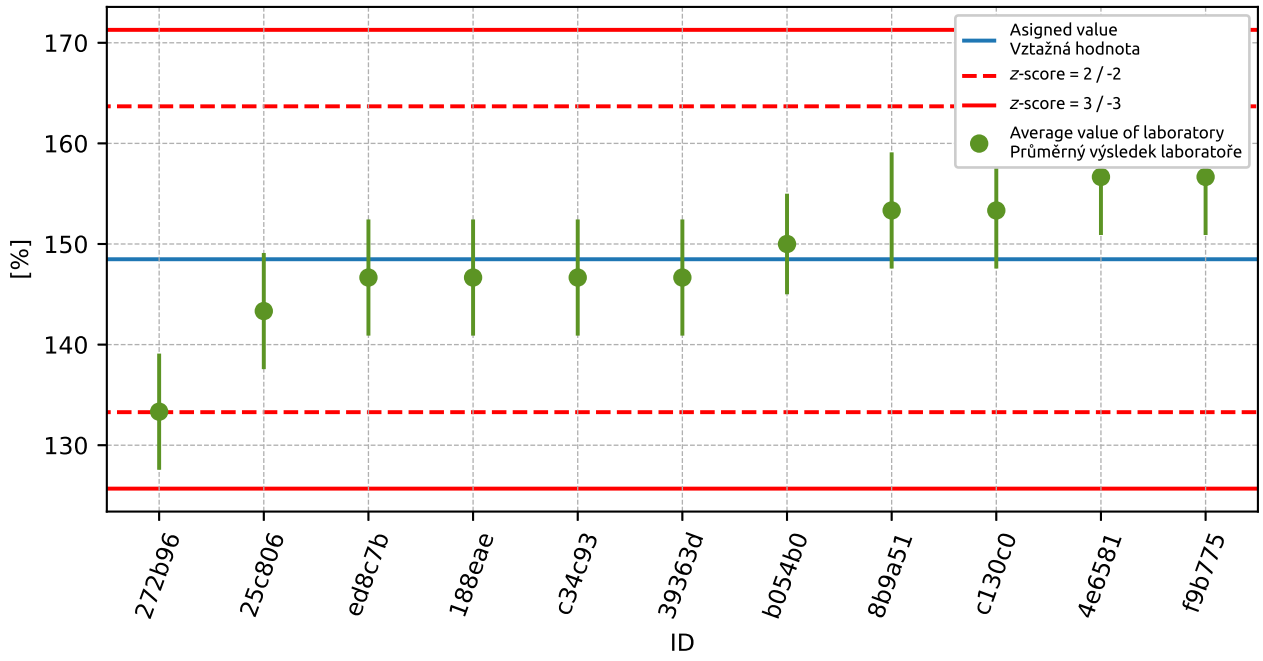

Figure 6: Average values and sample standard deviations

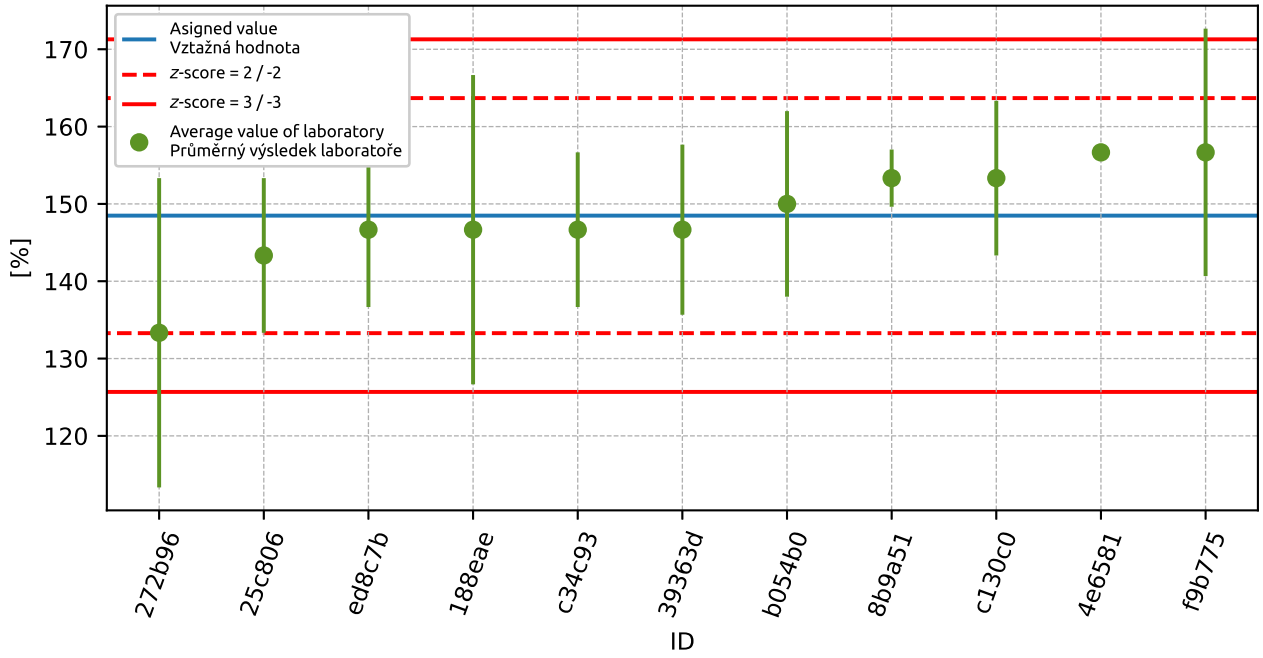

Figure 7: Average values and extended uncertainties of measurement

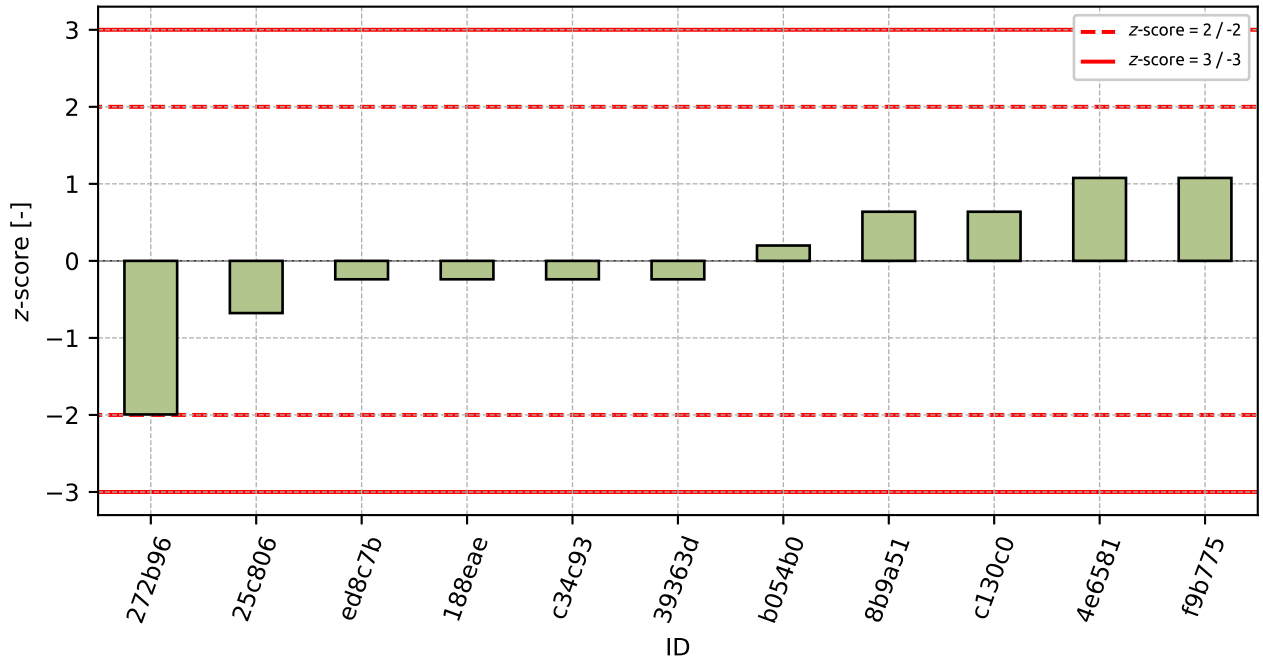

Figure 8: z-score

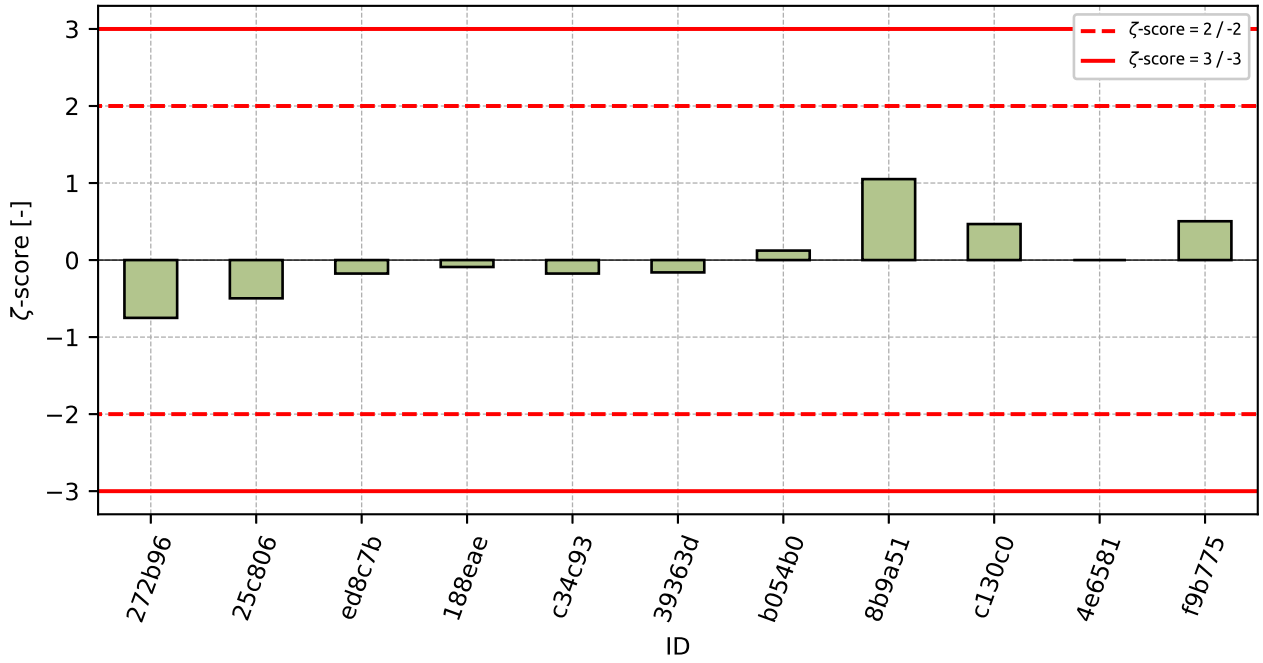

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
272b96	-1.99	-0.75
25c806	-0.68	-0.5
ed8c7b	-0.24	-0.18
188eae	-0.24	-0.09
c34c93	-0.24	-0.18
39363d	-0.24	-0.16
b054b0	0.2	0.12
8b9a51	0.64	1.05
c130c0	0.64	0.47
4e6581	1.08	-
f9b775	1.08	0.5

2 Appendix – EN 12350-4 – Degree of Compactability

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

3 Appendix – EN 12350-5 – Flow table test

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 [mm]			u_X [mm]	$\bar{x}$ [mm]	s_0 [mm]	V_X [%]
4e6581	430	445	430	-	435	8.7	1.99
c130c0	450	430	430	20	437	11.5	2.64
94be68	450	455	438	10	448	9.0	2.01
8b9a51	450	460	440	14	450	10.0	2.22
272b96	460	450	450	20	453	5.8	1.27
188eae	490	460	460	20	470	17.3	3.69
f9b775	480	470	470	20	473	5.8	1.22

3.2 The Numerical Procedure for Determining Outliers

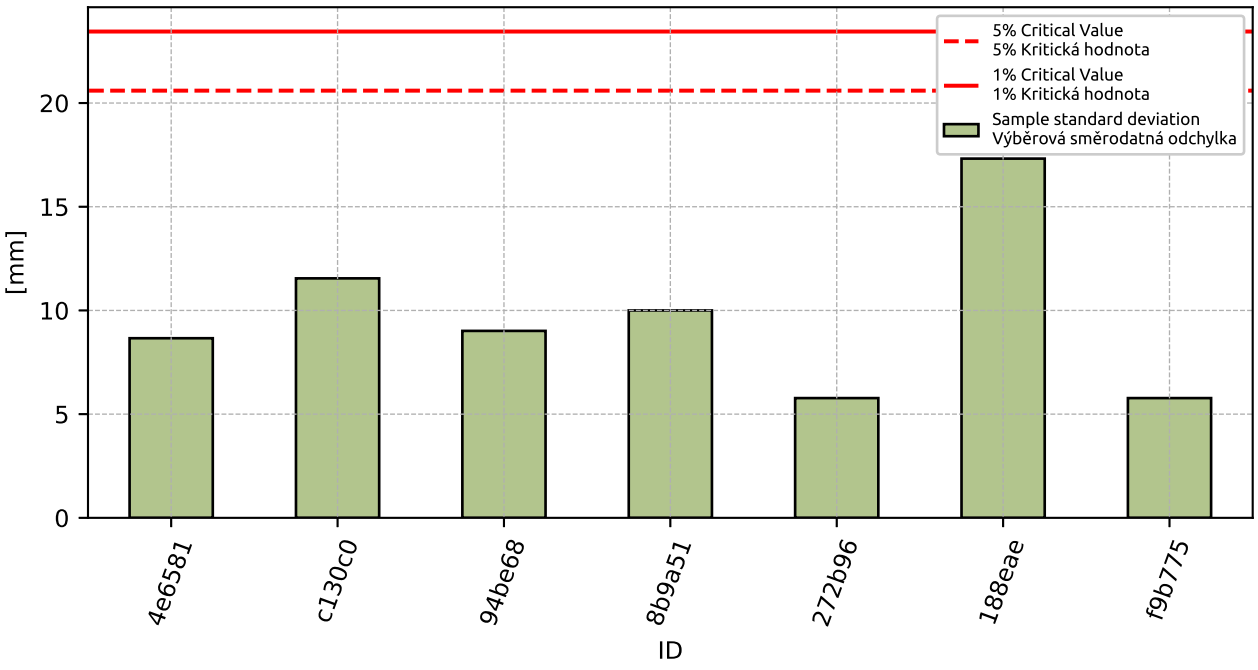

Figure 10: **Cochran's test** - sample standard deviations

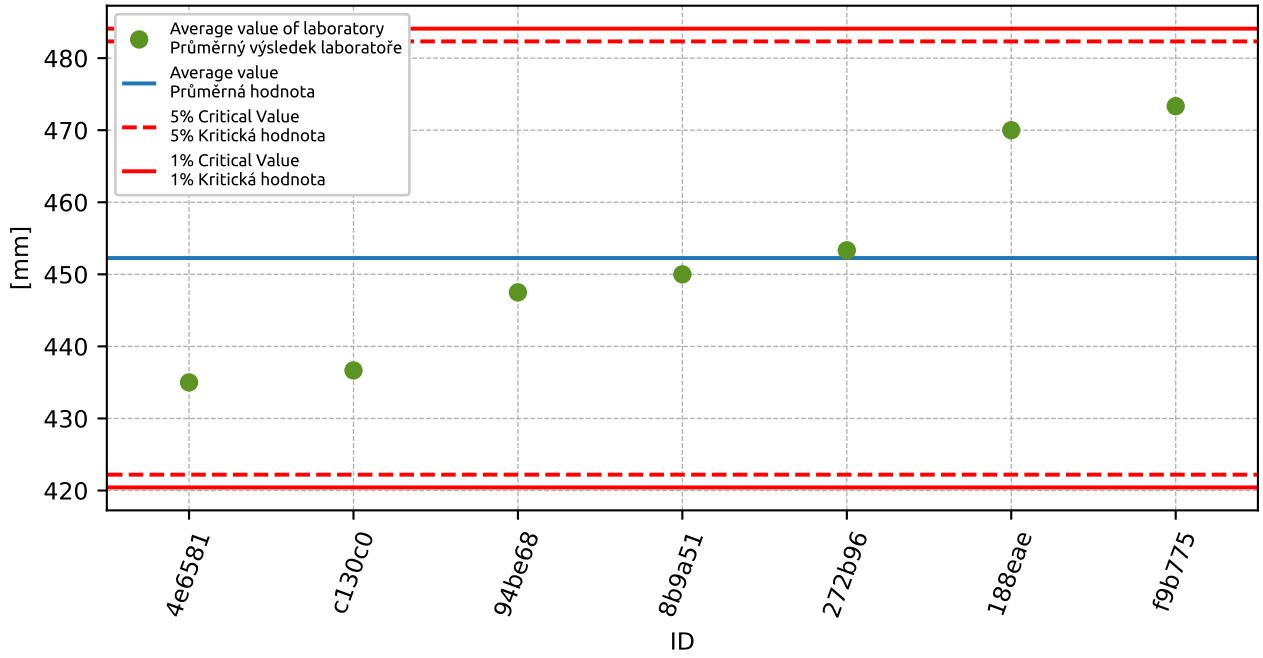

Figure 11: **Grubbs' test** - average values

3.3 Mandel's Statistics

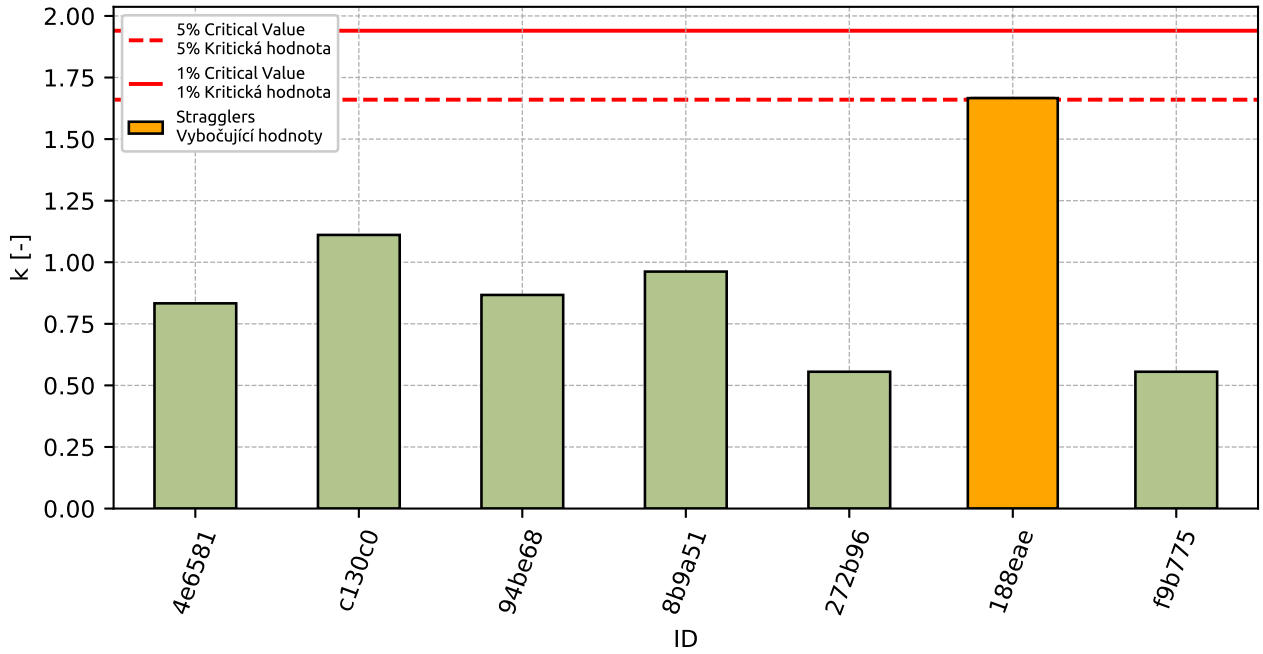

Figure 12: Intralaboratory Consistency Statistic

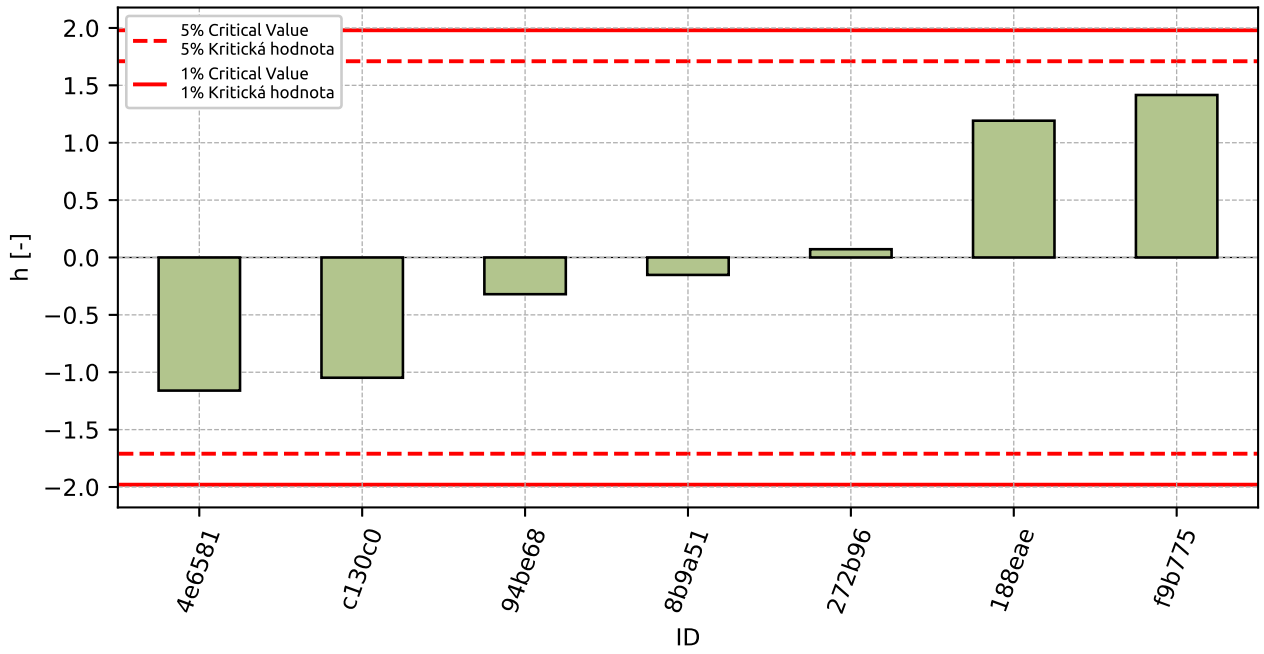

Figure 13: Interlaboratory Consistency Statistic

3.4 Descriptive statistics

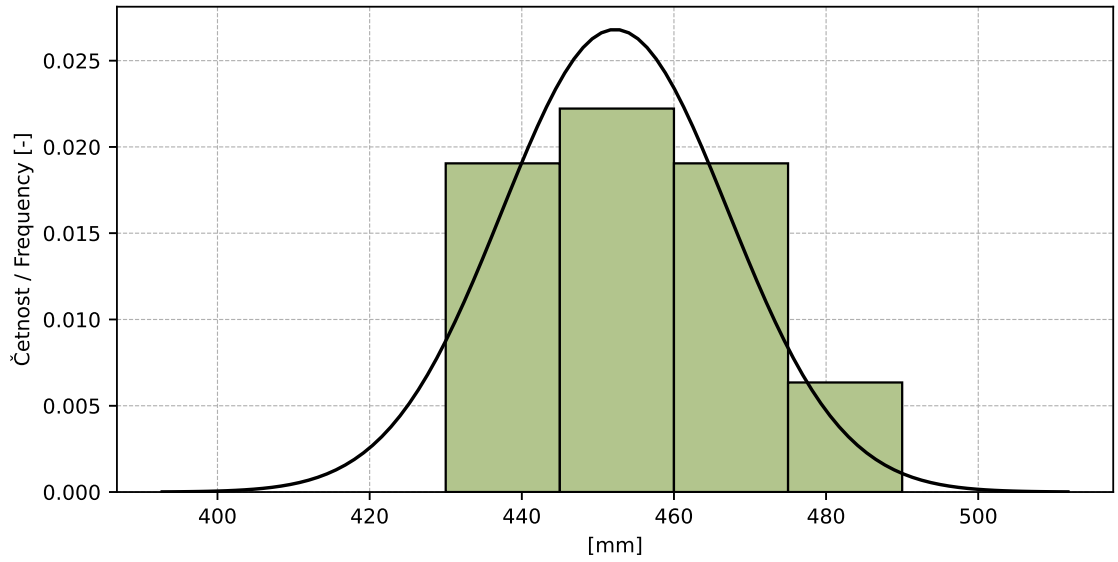

Figure 14: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[mm]
Průměrná hodnota / Average value – $\bar{x}$	452
Výběrová směrodatná odchylka / Sample standard deviation – s	14.9
Vztažná hodnota / Asigned value – x^*	452
Robustní směrodatná odchylka / Robust standard deviation – s^*	15.6
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	7.4
p-hodnota testu normality / p-value of normality test	0.235 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	13.6
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	10.4
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	17.1
Opakovatelnost / Repeatability – r	29
Reprodukovatelnost / Reproducibility – R	48

3.5 Evaluation of Performance Statistics

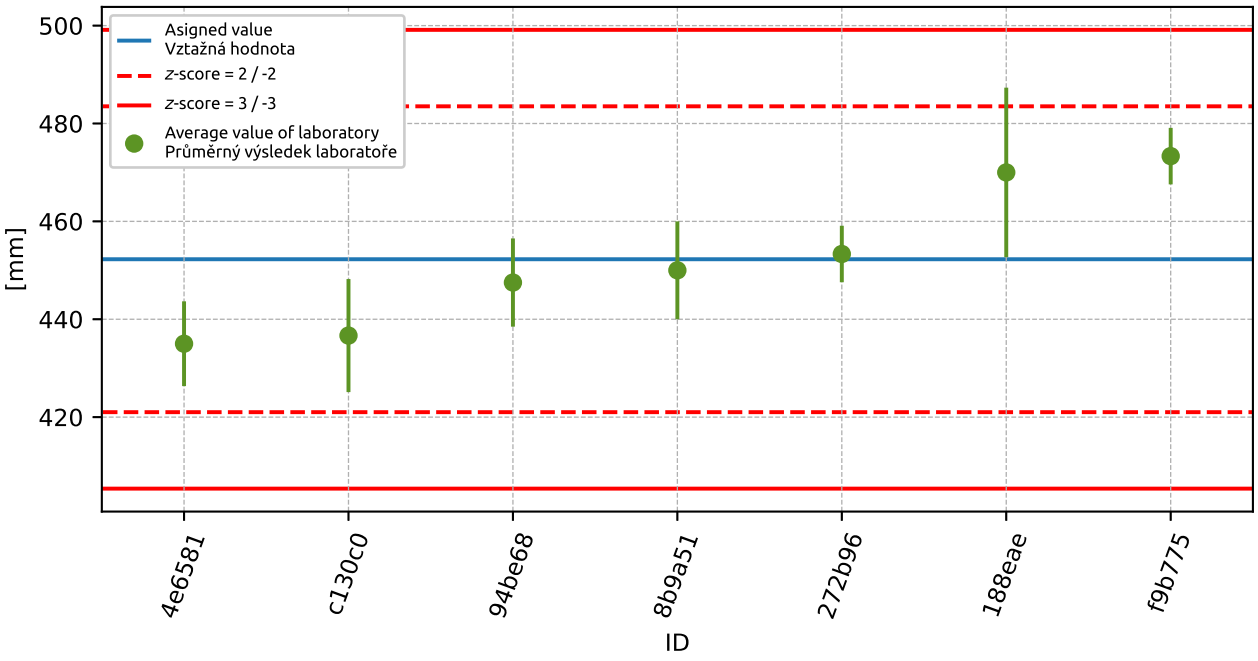

Figure 15: Average values and sample standard deviations

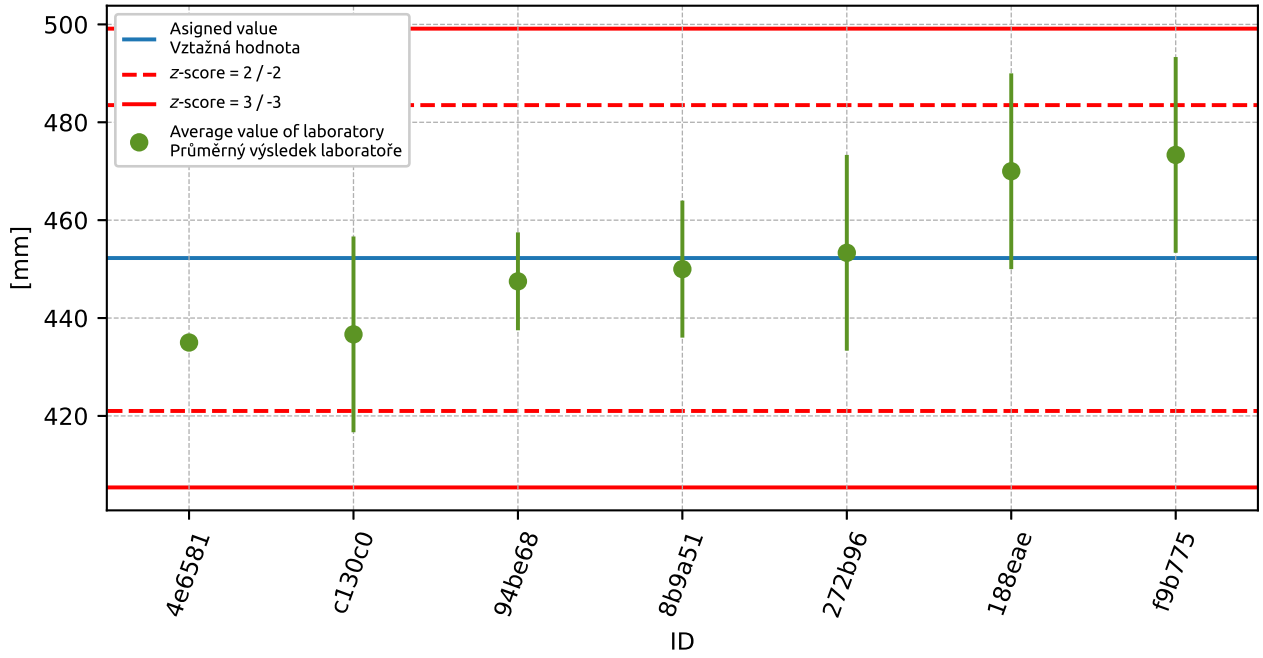

Figure 16: Average values and extended uncertainties of measurement

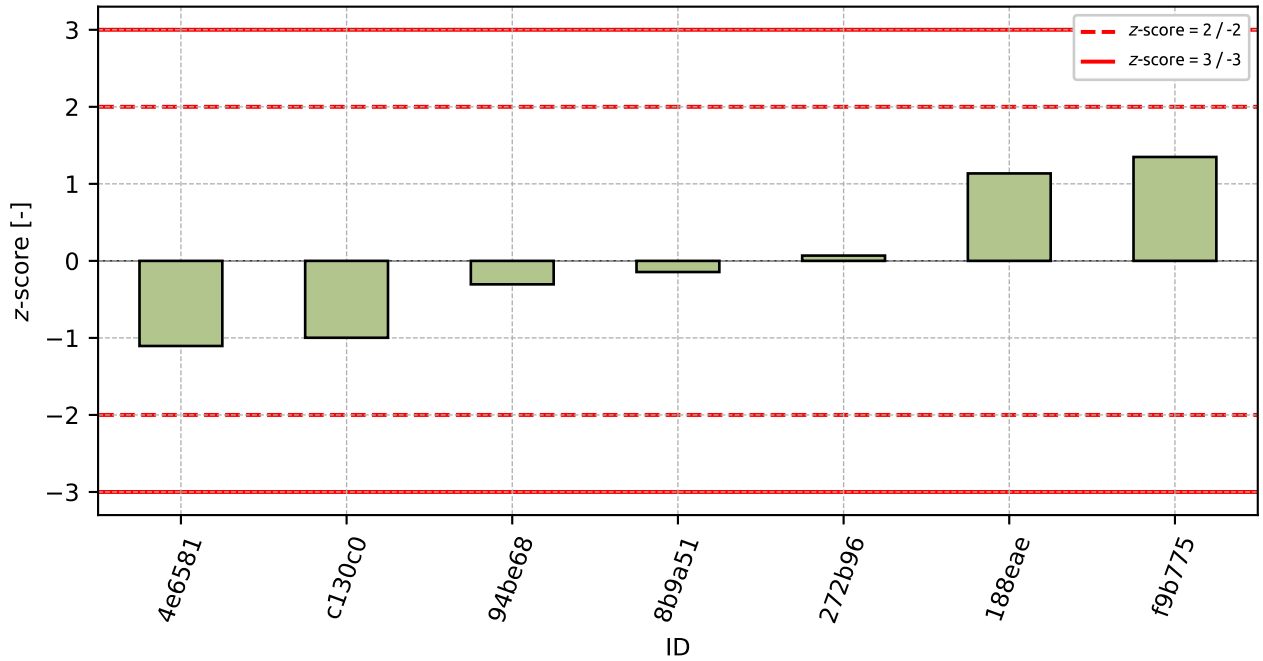

Figure 17: z-score

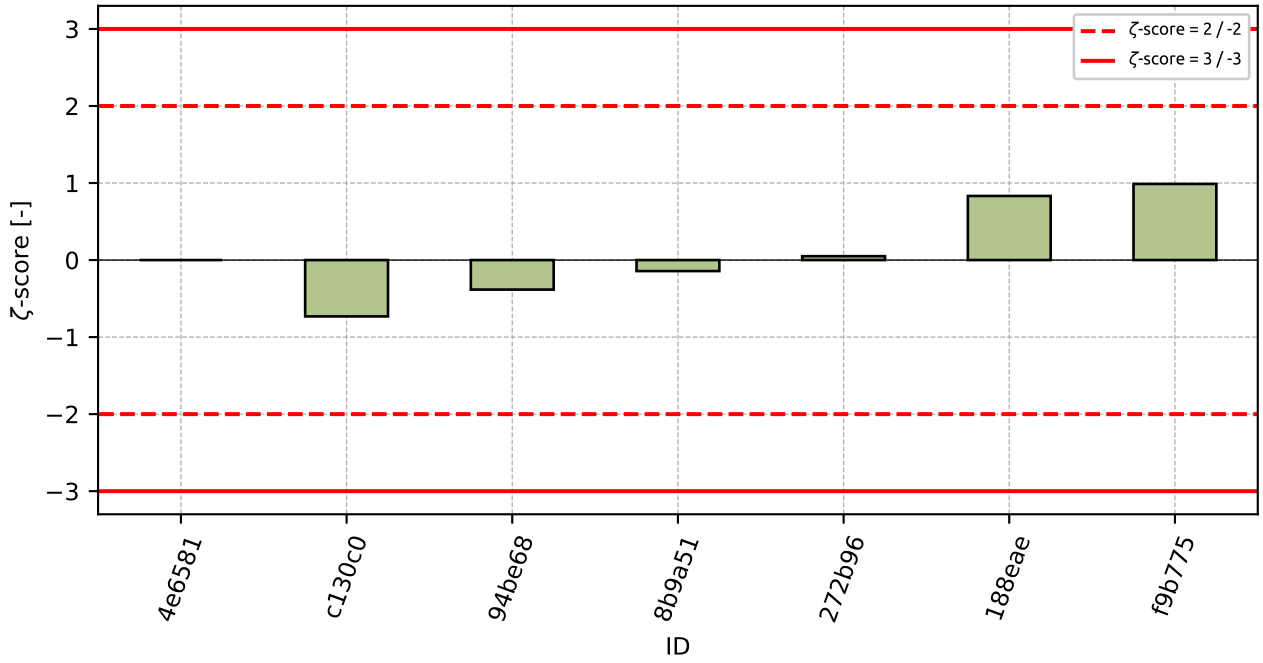

Figure 18: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
4e6581	-1.1	-
c130c0	-1.0	-0.73
94be68	-0.3	-0.38
8b9a51	-0.14	-0.14
272b96	0.07	0.05
188eae	1.14	0.83
f9b775	1.35	0.99

4 Appendix – EN 12350-6 – Density

4.1 Test results

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

ID	Test results [mm]			u_X [mm]	$\bar{x}$ [mm]	s_0 [mm]	V_X [%]
ed8c7b	2200	2190	2190	60	2193	5.8	0.26
25c806	2240	2220	2220	10	2227	11.5	0.52
8b9a51	2230	2240	2240	12	2237	5.8	0.26
c130c0	2240	2240	2240	20	2240	0	0
c34c93	2250	2250	2260	20	2253	5.8	0.26
f9b775	2270	2260	2260	50	2263	5.8	0.26
94be68	2271	2258	2266	20	2265	6.5	0.29
188eae	2270	2270	2270	20	2270	0	0
4e6581	2270	2270	2280	-	2273	5.8	0.25

4.2 The Numerical Procedure for Determining Outliers

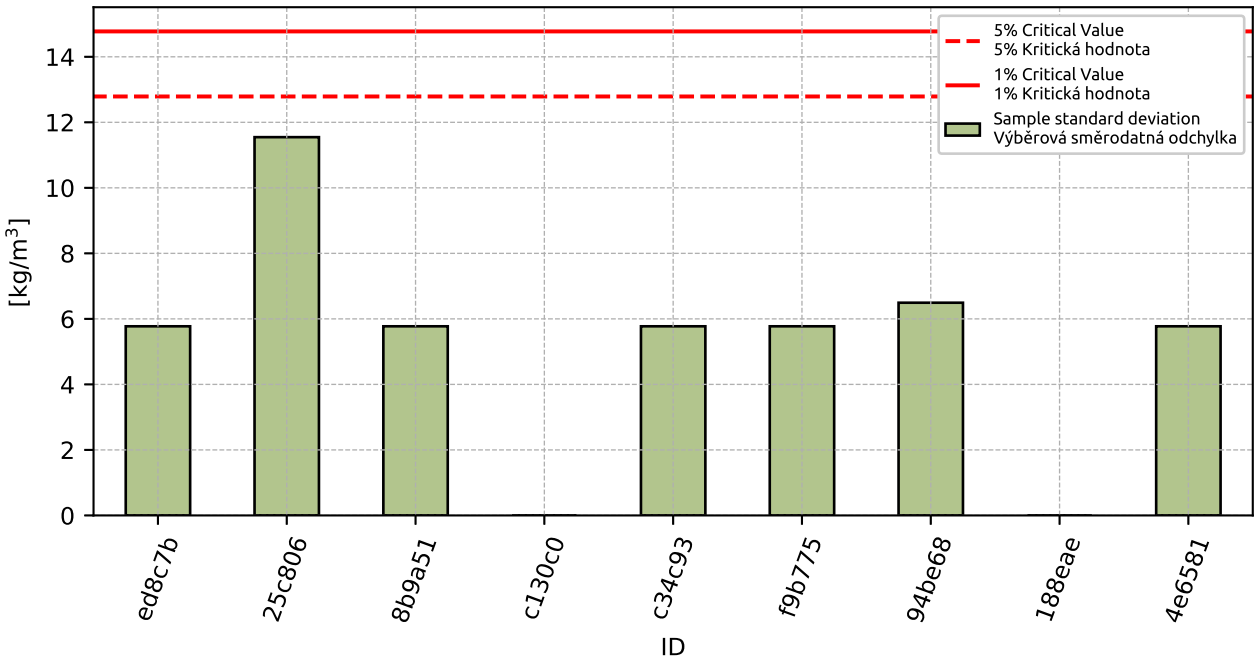

Figure 19: **Cochran's test** - sample standard deviations

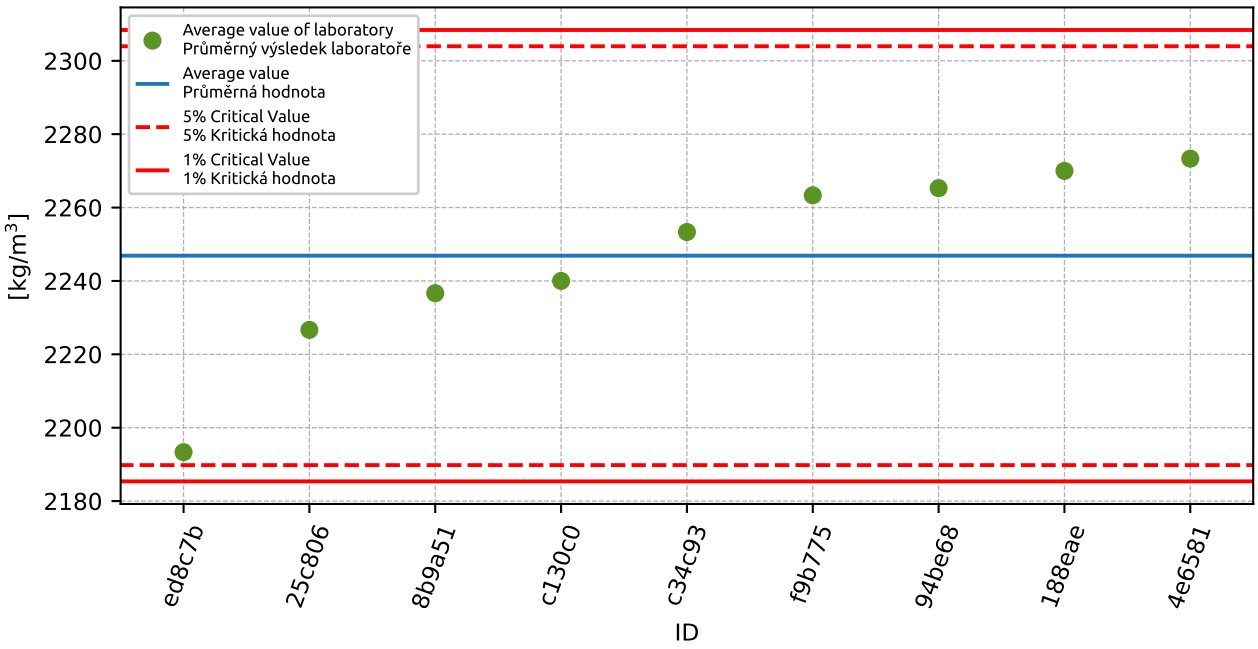

Figure 20: **Grubbs' test** - average values

4.3 Mandel's Statistics

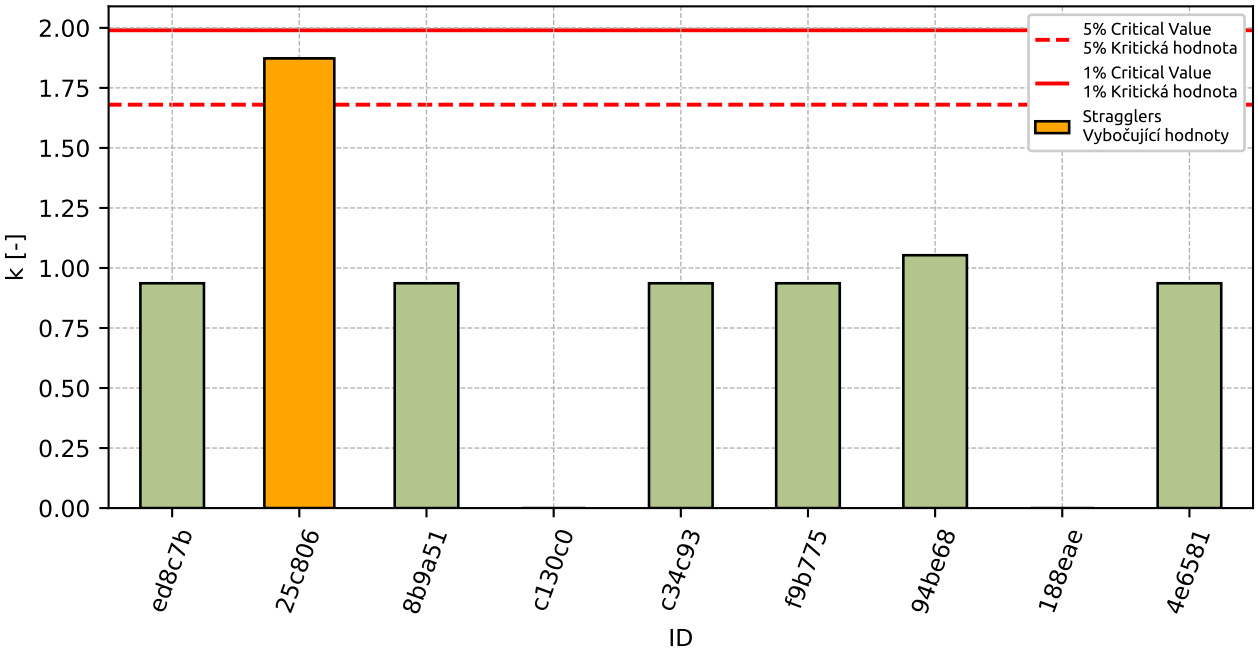

Figure 21: Intralaboratory Consistency Statistic

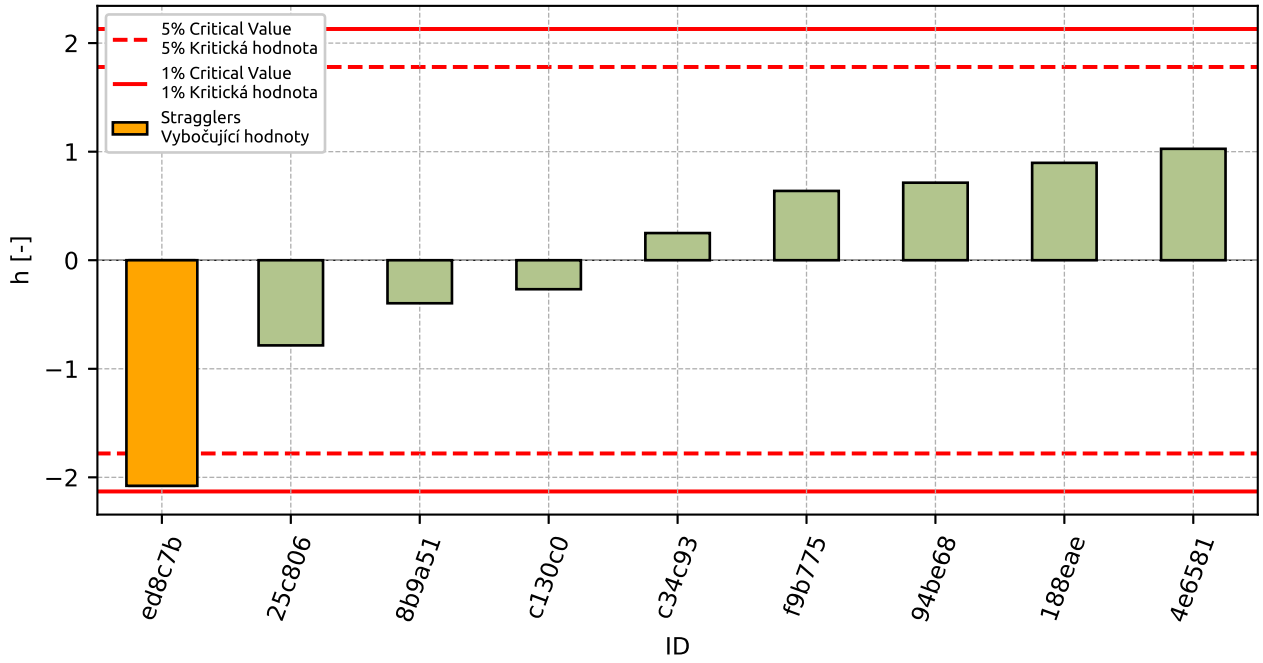

Figure 22: Interlaboratory Consistency Statistic

4.4 Descriptive statistics

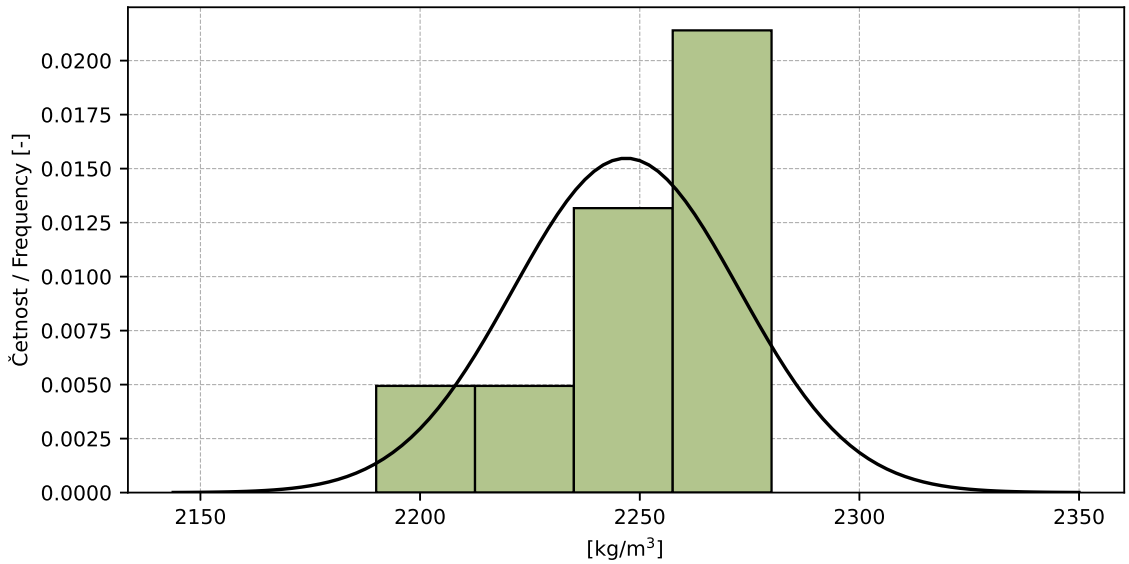

Figure 23: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[mm]
Průměrná hodnota / Average value – $\bar{x}$	2250
Výběrová směrodatná odchylka / Sample standard deviation – s	26
Vztažná hodnota / Asigned value – x^*	2250
Robustní směrodatná odchylka / Robust standard deviation – s^*	22
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	9.0
p-hodnota testu normality / p-value of normality test	0.006 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	26
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	6
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	26
Opakovatelnost / Repeatability – r	20
Reprodukovatelnost / Reproducibility – R	70

4.5 Evaluation of Performance Statistics

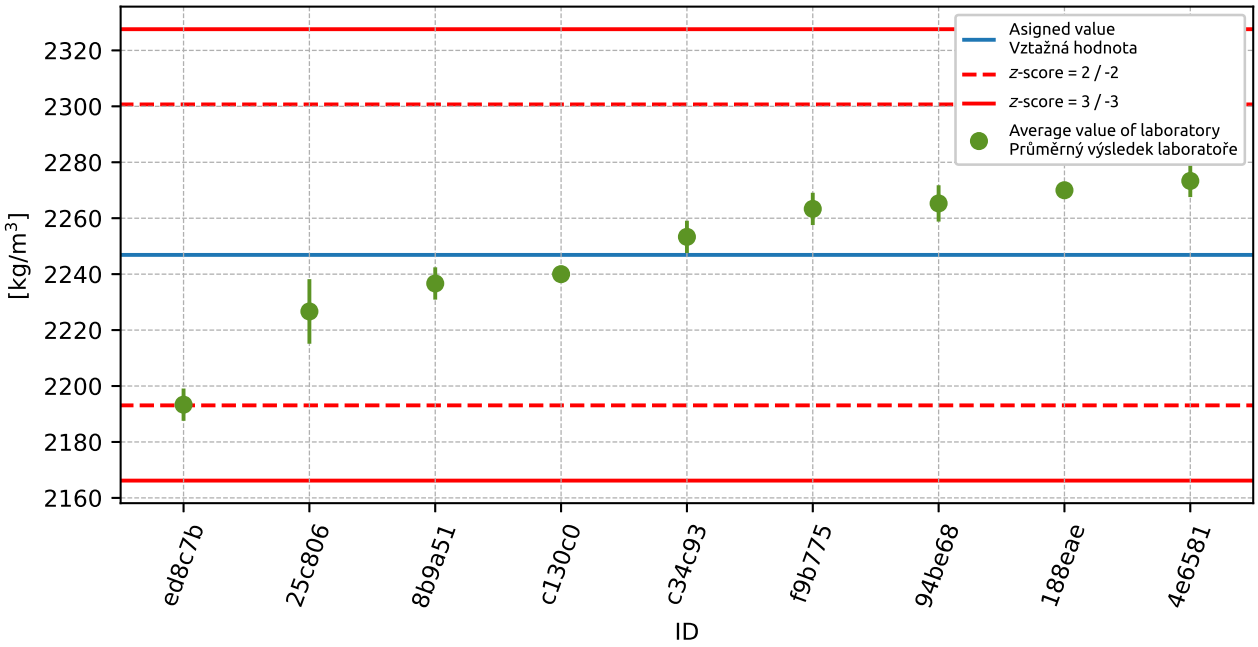

Figure 24: Average values and sample standard deviations

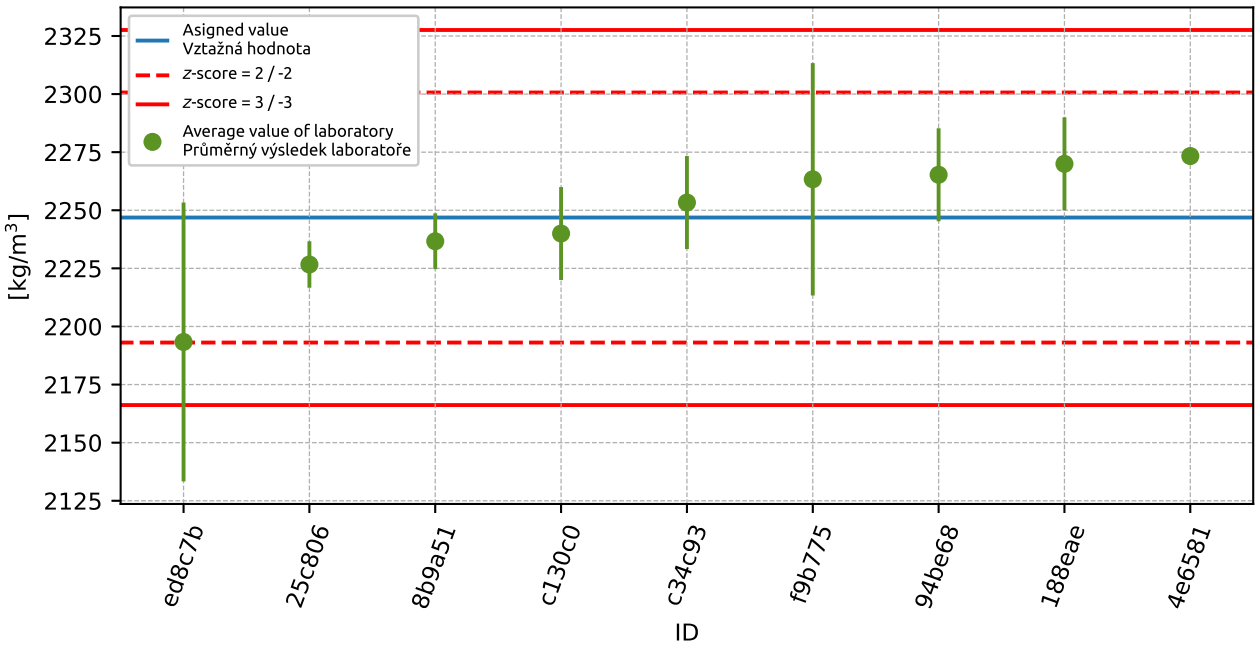

Figure 25: Average values and extended uncertainties of measurement

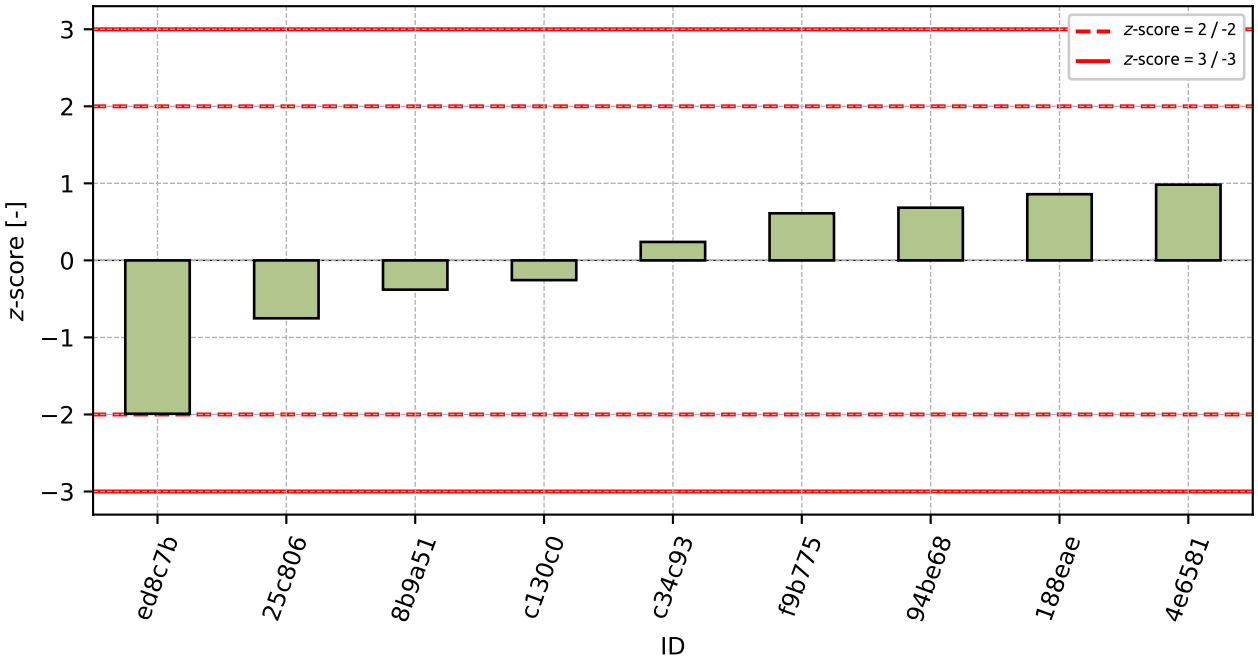

Figure 26: z-score

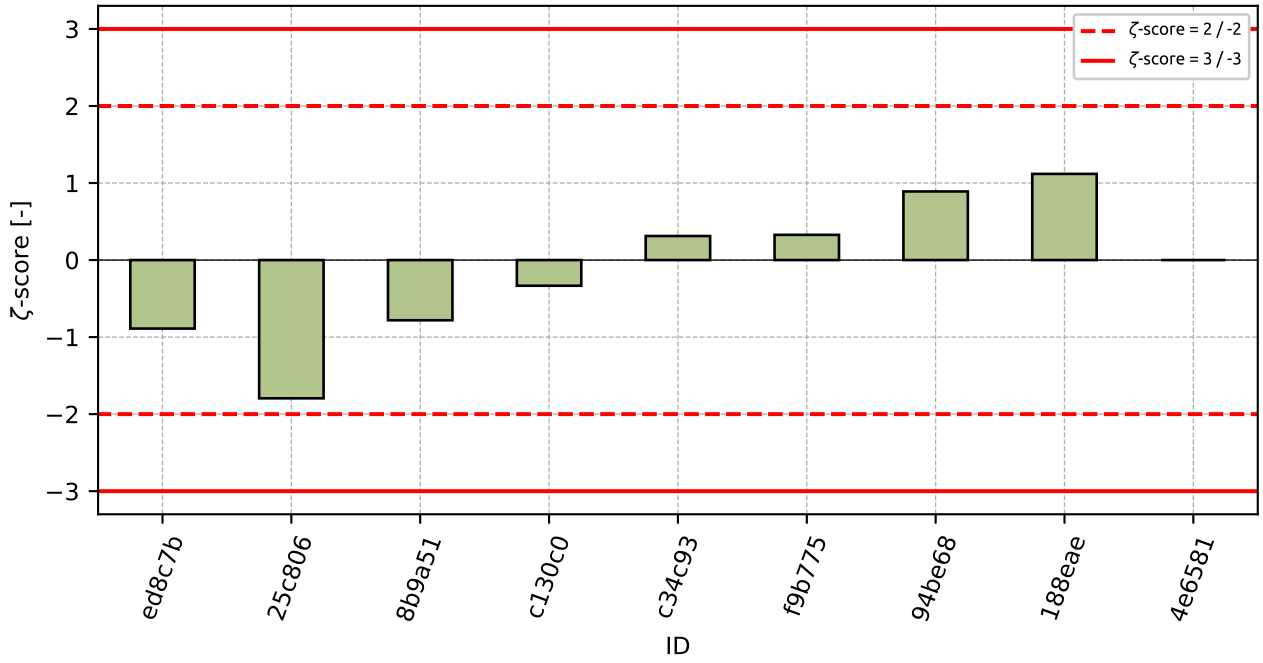

Figure 27: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
ed8c7b	-1.99	-0.89
25c806	-0.75	-1.79
8b9a51	-0.38	-0.78
c130c0	-0.26	-0.33
c34c93	0.24	0.31
f9b775	0.61	0.33
94be68	0.68	0.89
188eae	0.86	1.12
4e6581	0.98	-

5 Appendix – EN 12350-7 – Air content

5.1 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 [mm]			u_X [mm]	$\bar{x}$ [mm]	s_0 [mm]	V_X [%]
188eae	4.1	4.3	4.3	0.4	4.2	0.12	2.73
4e6581	4.5	4.5	4.6	-	4.5	0.06	1.27
25c806	4.8	4.7	4.8	0.2	4.8	0.06	1.21
f9b775	4.6	5.0	4.8	0.6	4.8	0.2	4.17
c34c93	4.9	4.7	4.9	0.4	4.8	0.12	2.39
b054b0	4.8	4.9	5.2	0.6	5.0	0.21	4.19
94be68	5.1	5.4	5.1	0.2	5.2	0.17	3.33
c130c0	5.4	5.3	5.3	0.2	5.3	0.06	1.08
8b9a51	6.4	6.1	5.9	0.5	6.1	0.25	4.1
ed8c7b	6.5	6.6	6.6	0.1	6.6	0.06	0.88

5.2 The Numerical Procedure for Determining Outliers

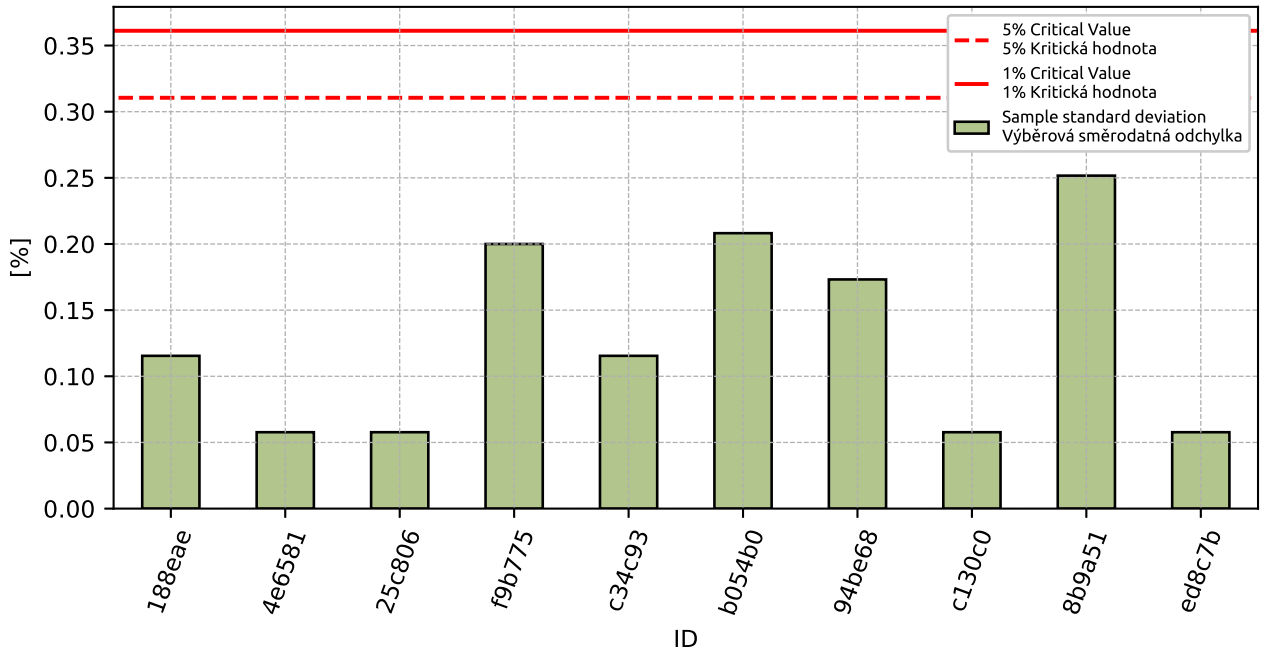

Figure 28: **Cochran's test** - sample standard deviations

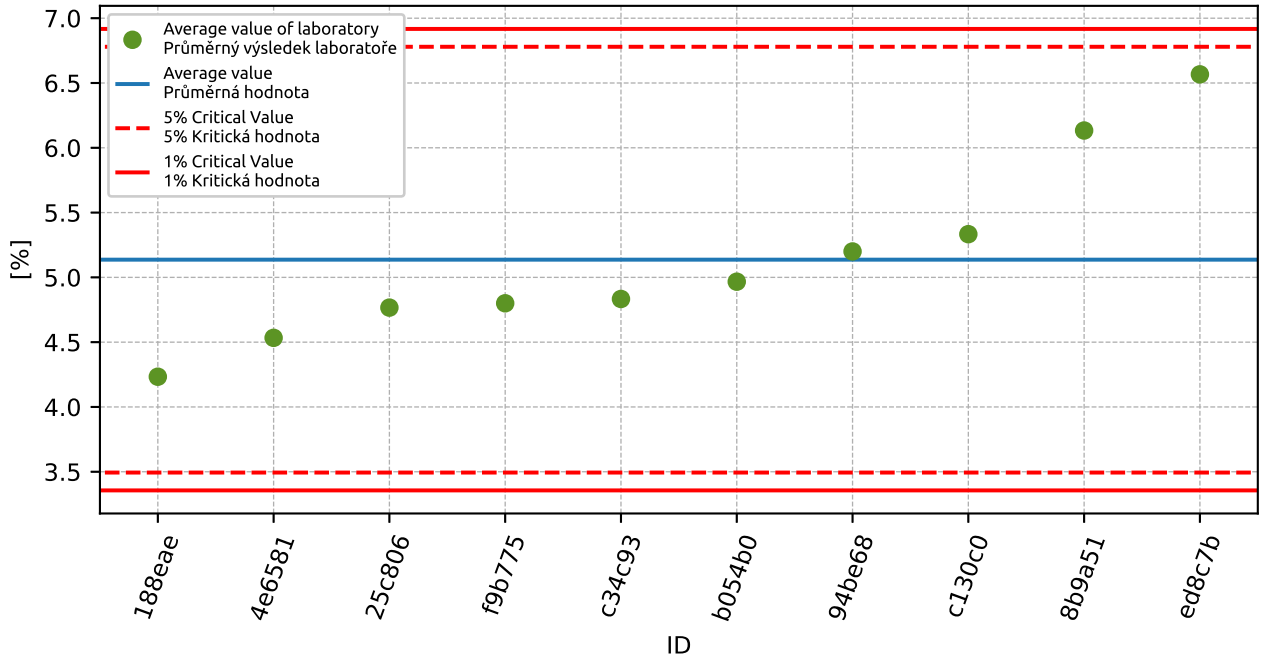

Figure 29: **Grubbs' test** - average values

5.3 Mandel's Statistics

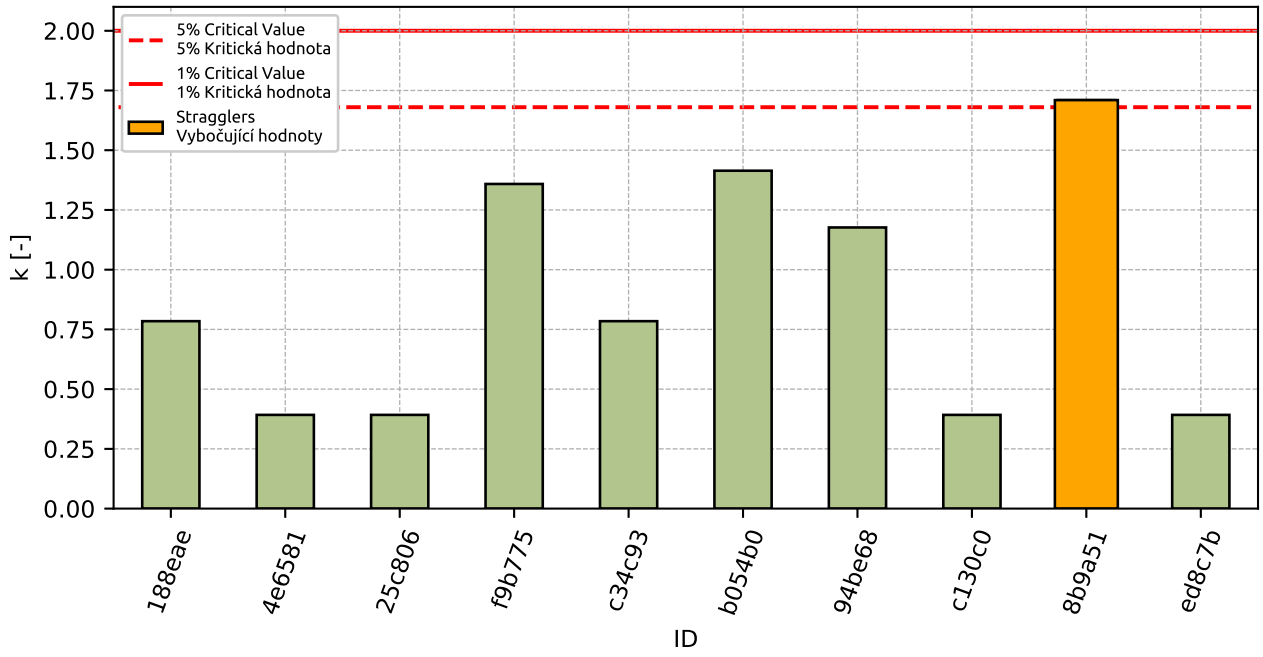

Figure 30: Intralaboratory Consistency Statistic

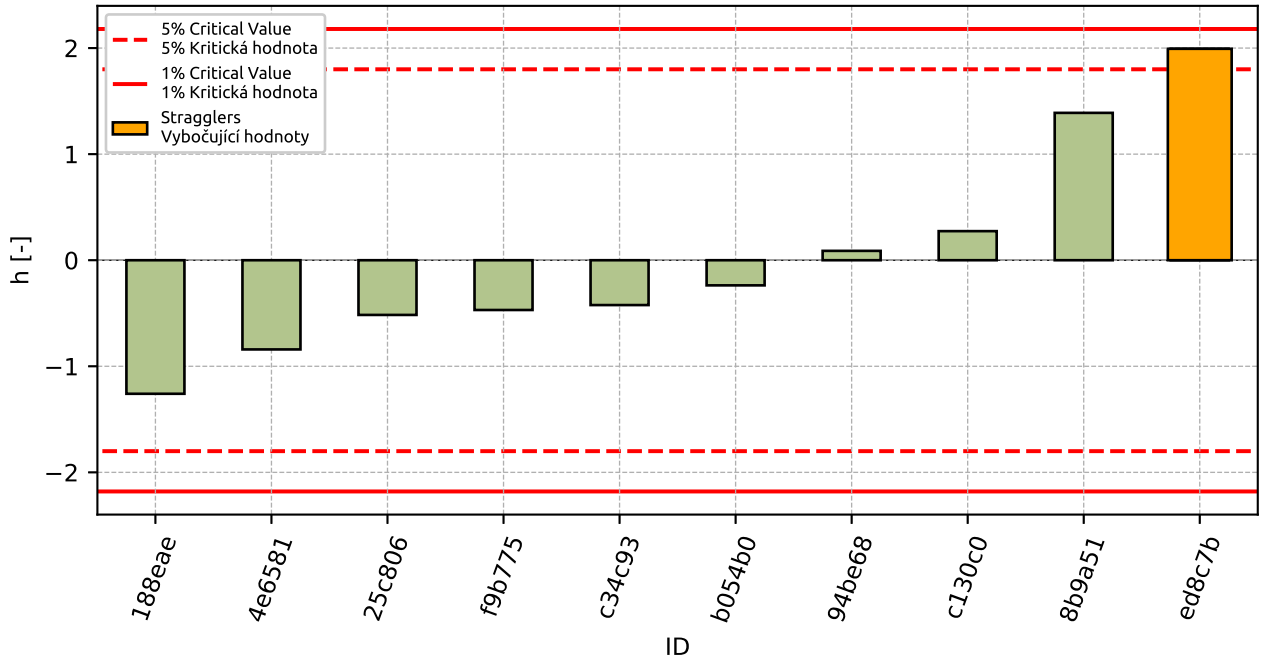

Figure 31: Interlaboratory Consistency Statistic

5.4 Descriptive statistics

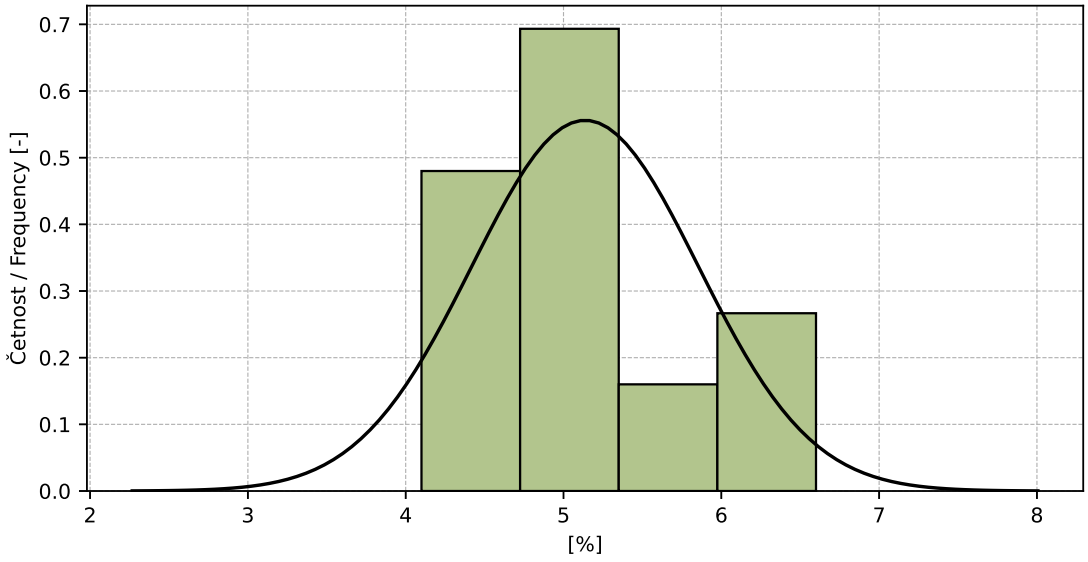

Figure 32: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	[mm]
Průměrná hodnota / Average value – $\bar{x}$	5.1
Výběrová směrodatná odchylka / Sample standard deviation – s	0.72
Vztažná hodnota / Asigned value – x^*	5.1
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.72
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.85
p-hodnota testu normality / p-value of normality test	0.005 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	0.71
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.15
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	0.73
Opakovatelnost / Repeatability – r	0.4
Reprodukovatelnost / Reproducibility – R	2.0

5.5 Evaluation of Performance Statistics

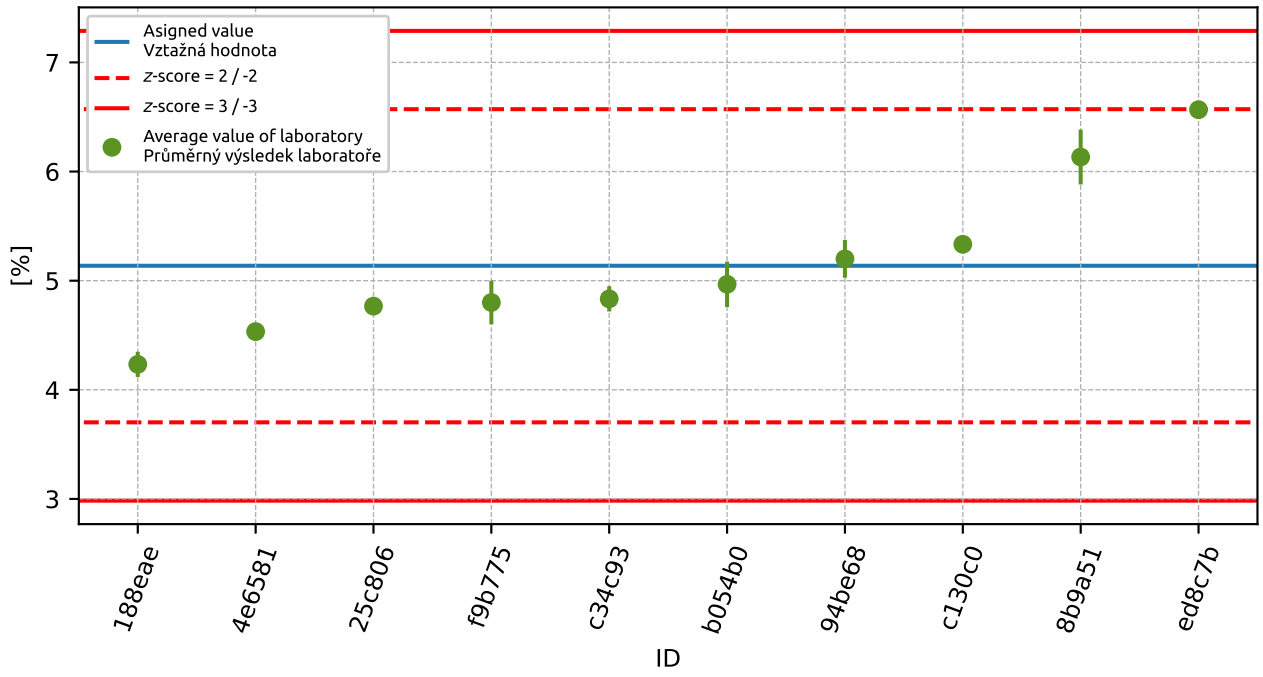

Figure 33: Average values and sample standard deviations

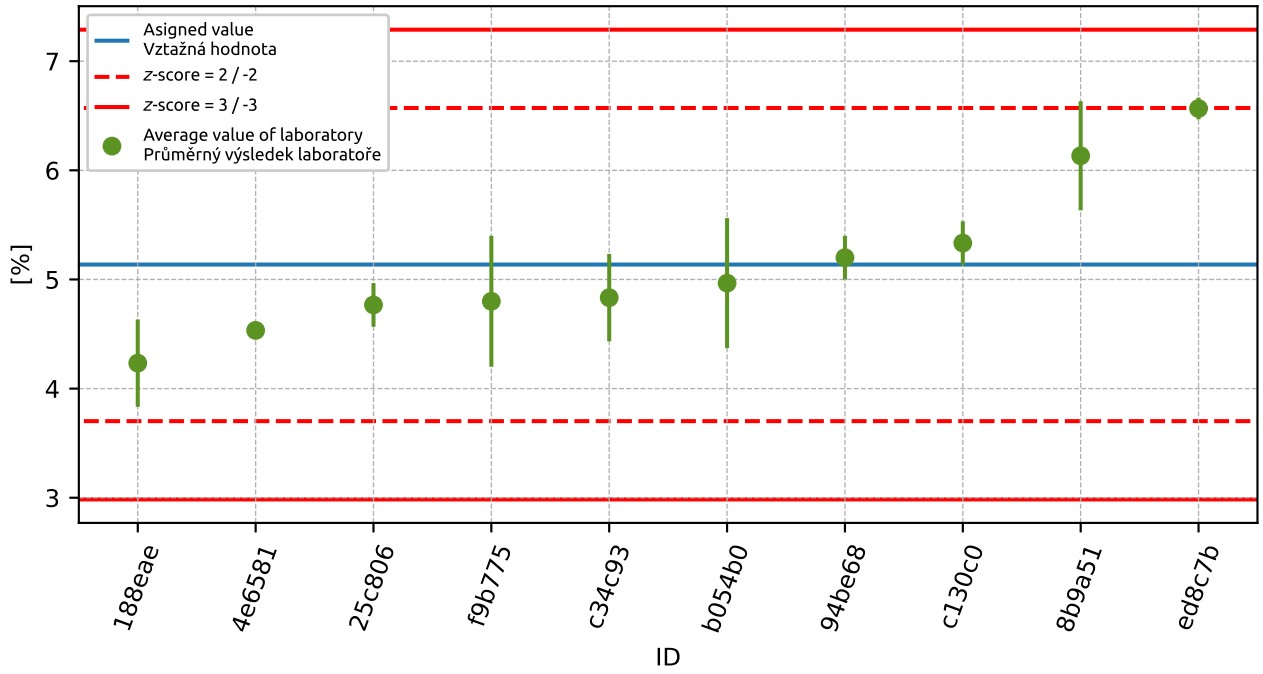

Figure 34: Average values and extended uncertainties of measurement

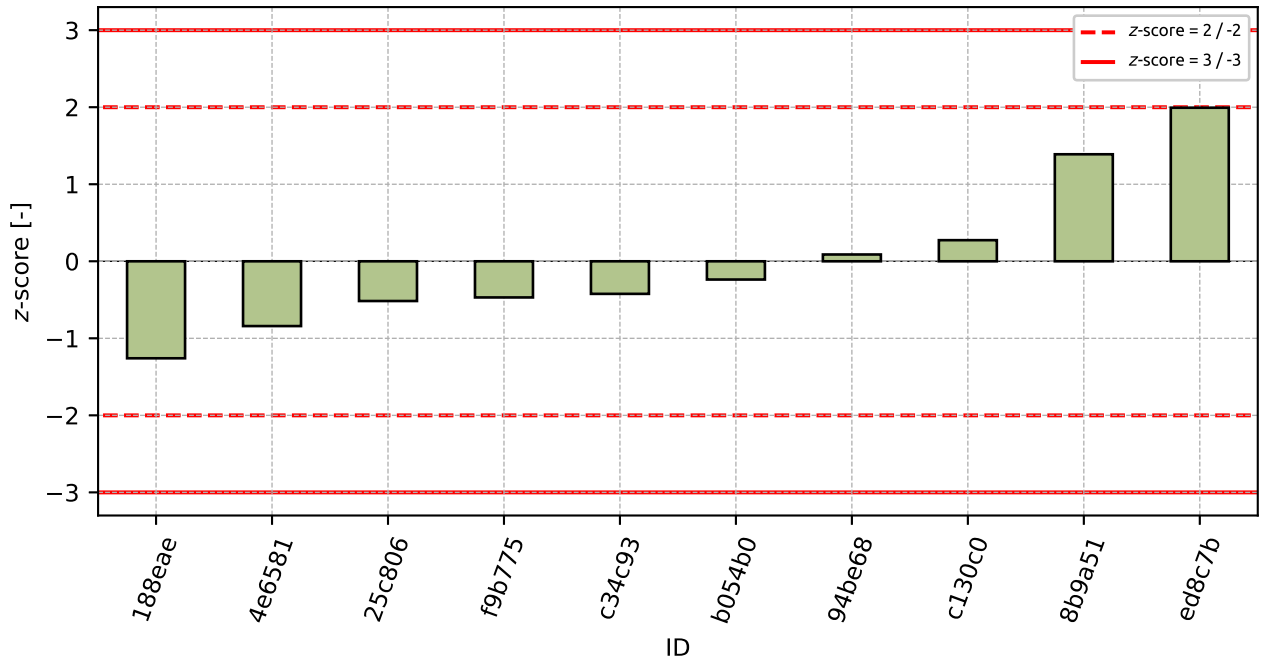

Figure 35: z-score

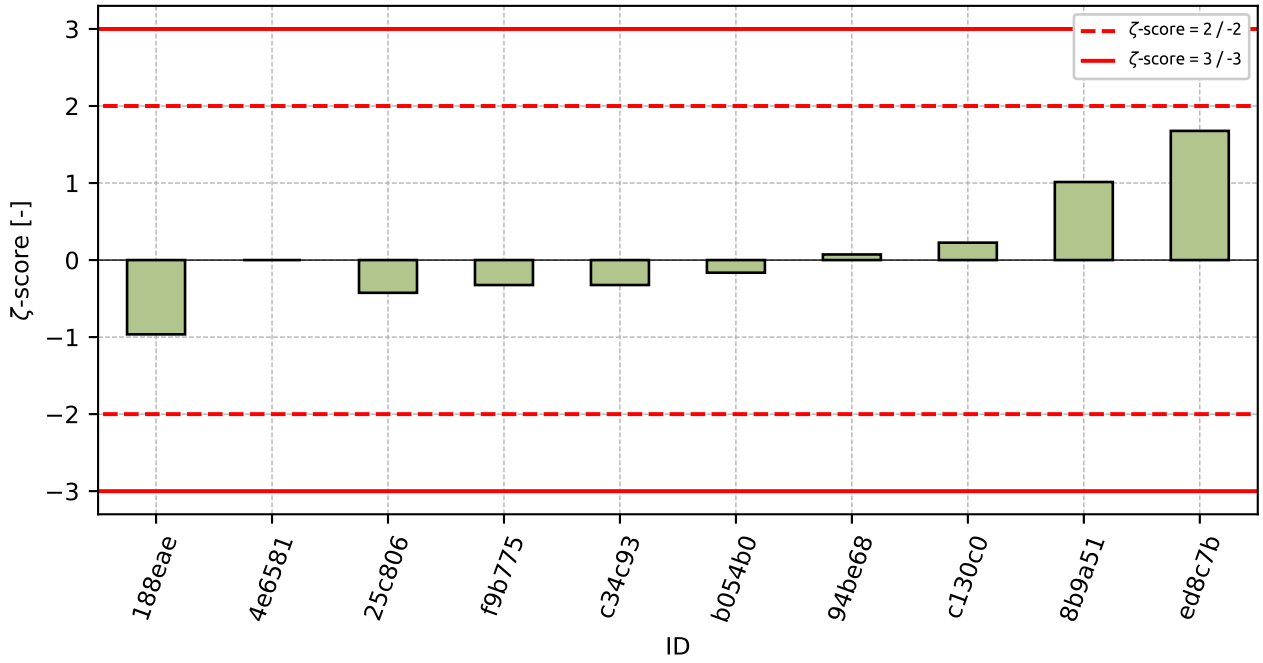

Figure 36: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
188eae	-1.26	-0.96
4e6581	-0.84	-
25c806	-0.52	-0.43
f9b775	-0.47	-0.32
c34c93	-0.42	-0.32
b054b0	-0.24	-0.16
94be68	0.09	0.07
c130c0	0.27	0.23
8b9a51	1.39	1.01
ed8c7b	1.99	1.68

6 Appendix – EN 12350-8 – Self-compacting concrete - Slump-flow test

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

7 Appendix – EN 12350-9 – Self-compacting concrete - V-funnel test

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

8 Appendix – EN 12350-10 – Self-compacting concrete - L-box test

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

9 Appendix – EN 12350-11 – Self-compacting concrete - Sieve segregation test

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

10 Appendix – EN 12350-12 – Self-compacting concrete - J-ring test

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