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
Steel testing
ZO 2020/1

Brno University of Technology
Proficiency testing provider at the SZK FAST
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Czech Republic

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

Date: 1/12/2021

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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 2020, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZO 2020/1 whose aim was to verify and assess the conformity of test results across laboratories when testing hardened concrete.

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

Head of the PT Provider, PTP coordinator

Assoc. Prof. Ing. Tomáš Vymazal, Ph.D.
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
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Institute of Building Testing
Veveří 95, Brno 602 00
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Tel.: +420 774 980 255
Email: Petr.Misak@vutbr.cz

The subjects of proficiency testing were the following testing procedures:

1. **EN ISO 6892-1** – Tensile strength [1],
2. **EN ISO 6892-1** – Yield strength [1],
3. **EN ISO 6892-1** – Percentage elongation after fracture [1],
4. **EN ISO 6892-1** – Percentage reducation of area [1].

Test procedure number 4 was not open due to the low number of participants.

The preparation of test samples and their homogeneity and stability was ensured by PoZZ. The test samples were distributed among the individual participants of the PrZZ so that their properties could not be affected.

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 [2] and with EN ISO/IEC 17043 [3]. 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

ID/Method	1	2	3	4
73d5b9	X	-	-	-
693960	X	X	X	-
b7d5bc	X	X	X	-
1cf6e9	X	-	-	-
8b3abf	X	-	-	-
78940c	X	X	X	-
c95ffe	X	X	X	-
eebb26	X	-	X	-
2c1c3b	X	-	X	-

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ID/Method	1	2	3	4
d2cb5d	X	X	X	-
f857fa	X	-	X	-
199a66	X	X	X	-

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

Laboratory	Address	Accreditation number
”STROYCONTROL 2003” LTD	Kostenetz str12, Sofia, 1612, Bulgaria	182 LI
Assit Engeneering Ltd.	j.k. Lagera, 2 Baba Iliica Str., bl. 80B, Sofia, 1612, Bulgaria	186-LI
Building Research Institute - NISI	86 Nikola Petkov Blvd., Sofia, 1618, Bulgaria	88 ЛИ
CONSTRUCTION RESEARCH INSTITUTE OF MALAYSIA (CREAM)	LEVEL 29, SUNWAY PUTRA TOWER, NO 100, JALAN PUTRA, KUALA LUMPUR, 50350, KUALA LUMPUR	-
Central Materials Lab PWD Sarawak	Canna Road, Tabuan Jaya, Kuching, 93350, Sarawak, Malaysia	-
Technický a zkušební ústav Praha, s.p., Centrální laboratoř, zkušebna 0500 Předměřice nad Labem	Průmyslová 283, Předměřice nad Labem, 503 02, Česká republika	1018.3
Technický a zkušební ústav stavbení Praha, s.p.	Prosecká 811/76a, Praha 9, 190 00, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s. p. - Zkušebna Ostrava	U Studia 14, Ostrava-Zábřeh, 70030, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s. p., Centrální laboratoř - zkušebna Brno	Hněvkovského 77, Brno, 617 00, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p. Centrální laboratoř - zkušebna Plzeň	Zahradní 15, Plzeň, 326 00, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p., Centrální laboratoř - zkušebna České Budějovice	Nemanická 441, České Budějovice, 370 10, Česká republika	1018.3
ČVUT v Praze, Kloknerův ústav	Šolínova 7, Praha 6, 16608, 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 (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 Steel testing (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 steel. 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
73d5b9	✓	-	-	-
693960	✓	✓	✓	-
b7d5bc	✓	✓	?	-
1cf6e9	✓	-	-	-
8b3abf	✓	-	-	-
78940c	X	X	?	-
c95ffe	✓	✓	✓	-
eebb26	✓	-	✓	-
2c1c3b	✓	-	✓	-
d2cb5d	✓	✓	✓	-
f857fa	✓	-	✓	-
199a66	✓	✓	✓	-

References

[1] EN ISO 6892-1. *Metallic materials - Tensile testing - Part 1: Method of test at room temperature*. 2017.

[2] 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.

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

[4] EN 12390-3. *Testing hardened concrete - Part 3: Compressive strength of test specimens*. 2020.

1 Appendix – EN ISO 6892-1 – Tensile 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 [MPa]						u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
1cf6e9	638	637	618	637	626	662	26.0	636.0	14.9	2.34
c95ffe	638	666	628	661	651	602	10.0	641.0	23.8	3.71
199a66	601	682	686	674	675	605	42.0	654.0	39.6	6.06
73d5b9	628	642	645	652	678	679	20.0	654.0	20.5	3.14
d2cb5d	632	672	647	631	719	634	37.0	656.0	34.6	5.28
693960	681	729	638	641	634	637	33.0	660.0	38.1	5.77
f857fa	637	650	644	669	706	662	27.0	661.0	24.7	3.73
eebb26	646	669	638	648	704	666	25.0	662.0	23.9	3.62
8b3abf	688	696	675	535	679	723	27.0	666.0	66.5	9.99
b7d5bc	704	698	689	665	675	648	0.0	680.0	21.0	3.09
2c1c3b	693	701	703	737	668	647	81.0	692.0	31.1	4.49
78940c	745	856	719	844	886	692	-	790.0	81.4	10.3

1.2 The Numerical Procedure for Determining Outliers

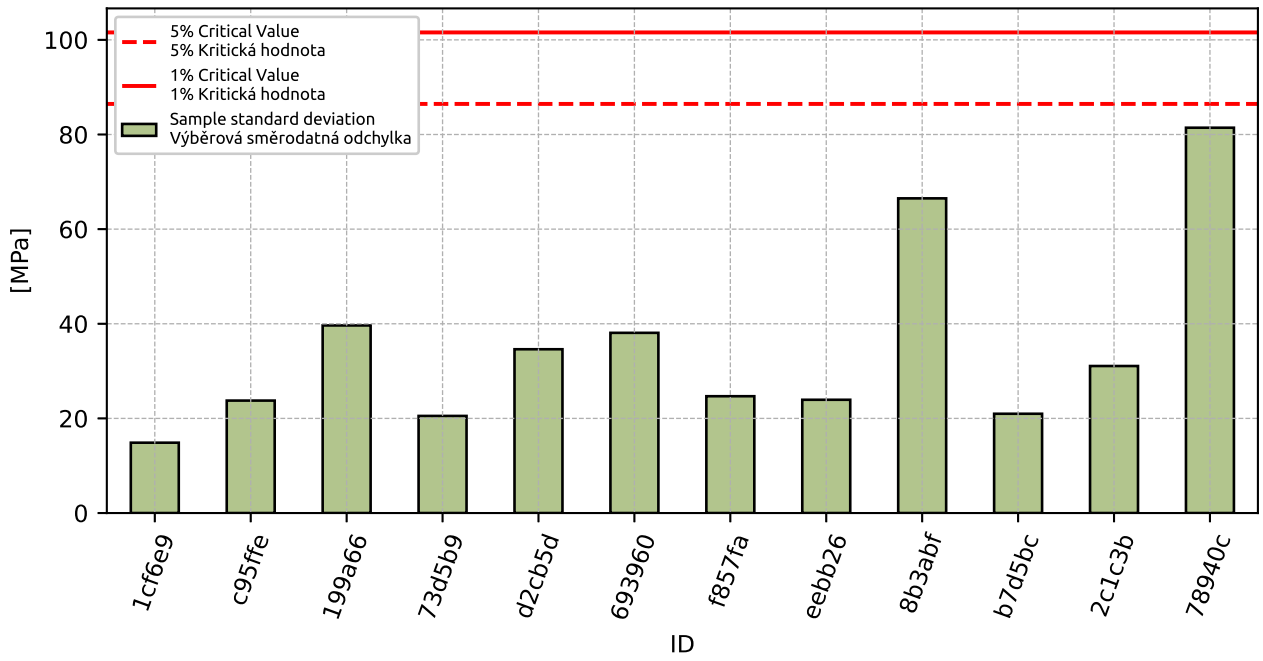

Figure 1: **Cochran's test** - sample standard deviations

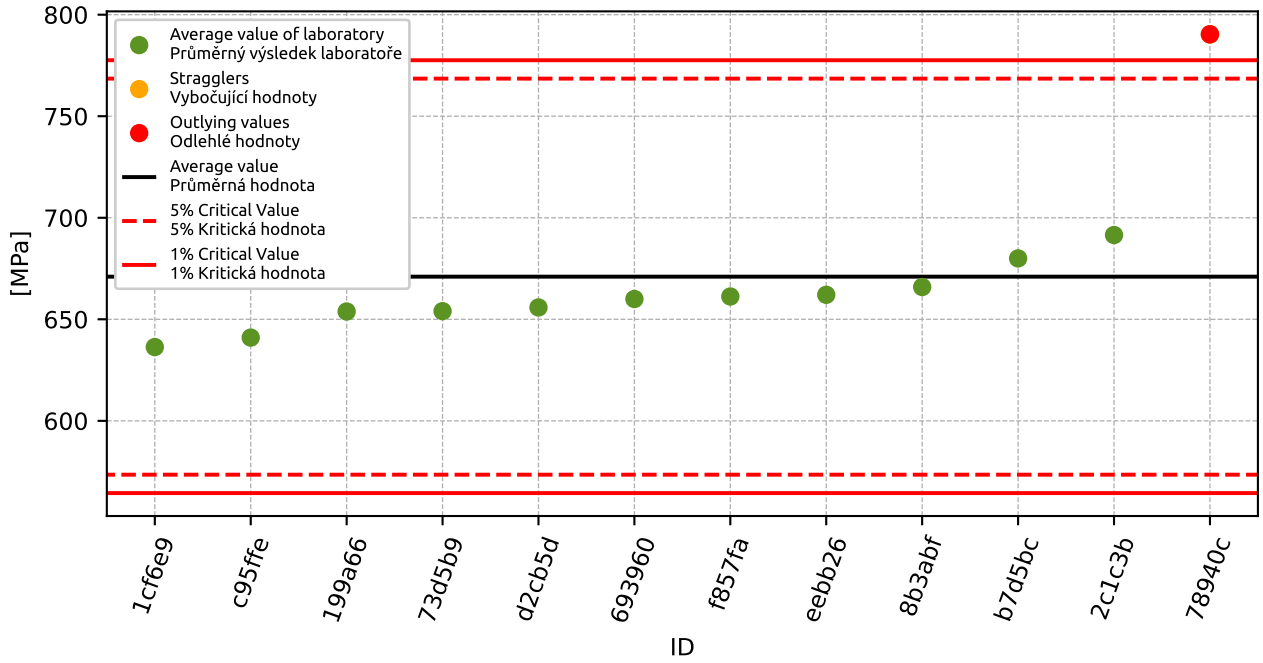

Figure 2: **Grubbs' test** - average values

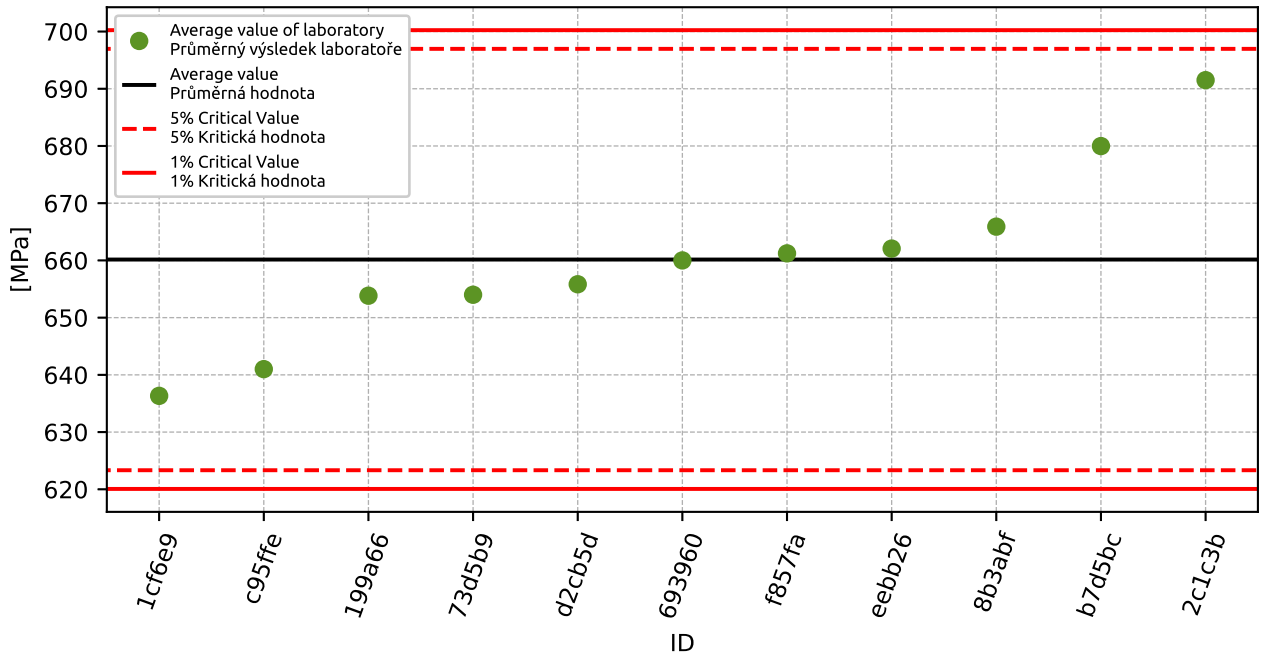

Figure 3: **Grubbs' test** - average values without outliers

1.3 Mandel's Statistics

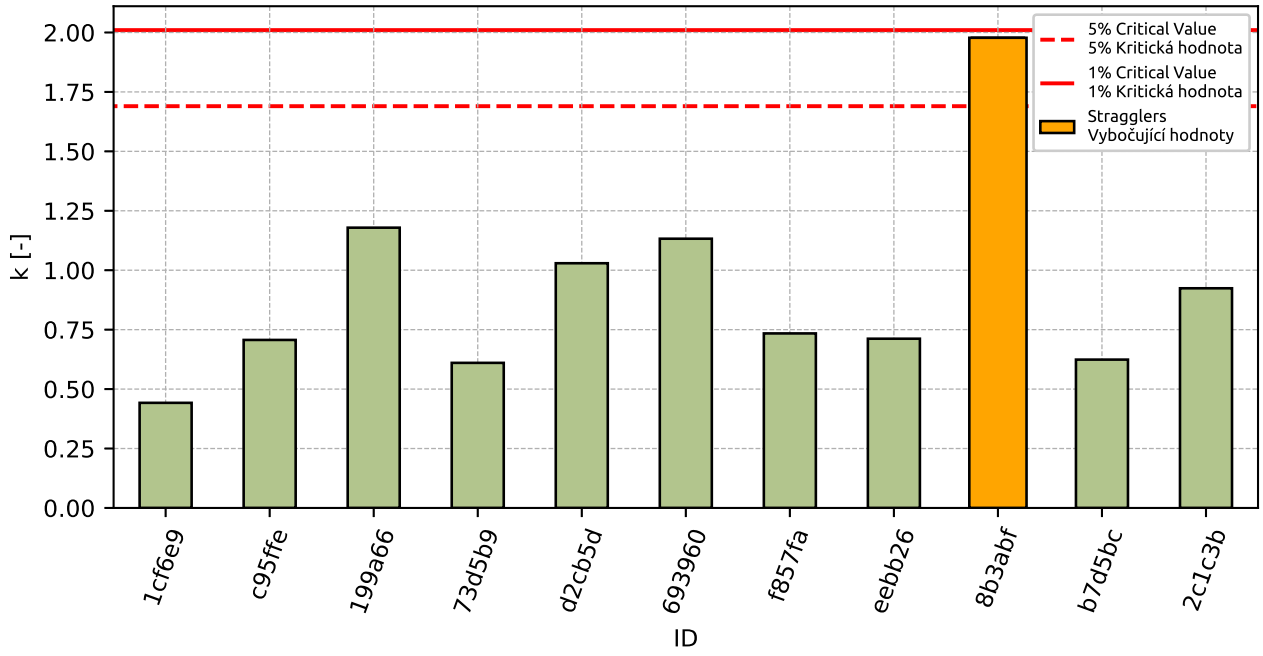

Figure 4: Intralaboratory Consistency Statistic

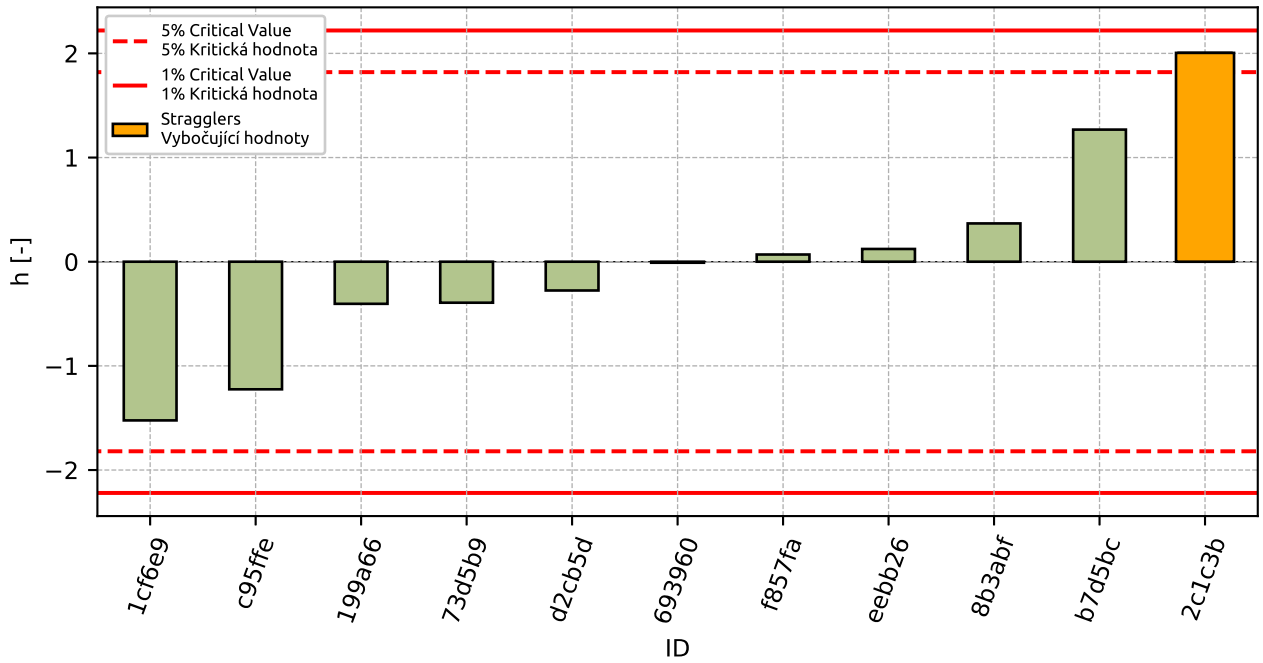

Figure 5: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

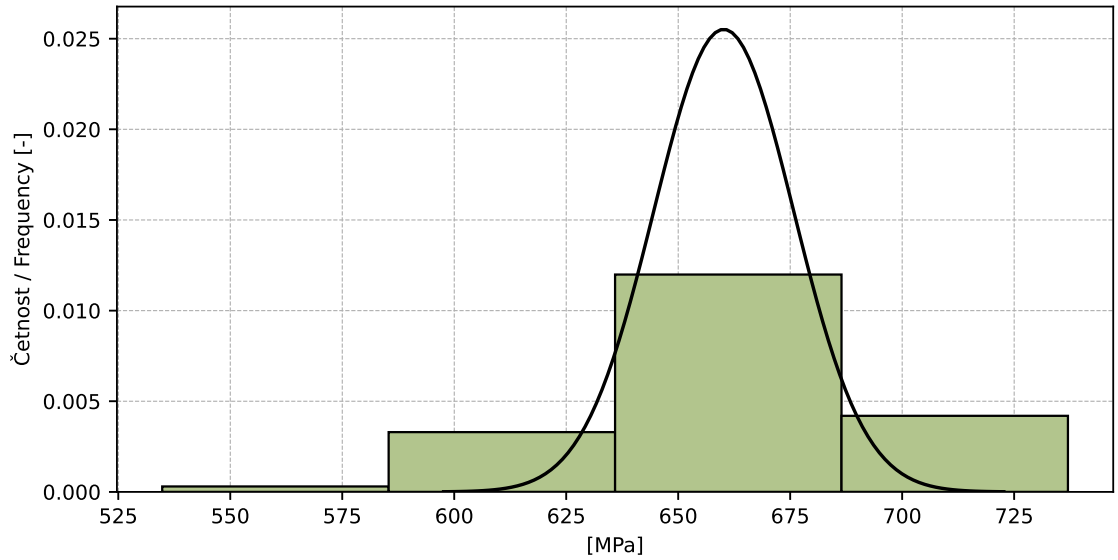

Figure 6: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[MPa]
Průměrná hodnota / Average value – $\bar{x}$	660.0
Výběrová směrodatná odchylka / Sample standard deviation – s	15.6
Vztažná hodnota / Asigned value – x^*	661.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	13.9
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	5.2
p-hodnota testu normality / p-value of normality test	0.055 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	7.5
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	33.6
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	34.4
Opakovatelnost / Repeatability – r	94.0
Reprodukovatelnost / Reproducibility – R	96.0

1.5 Evaluation of Performance Statistics

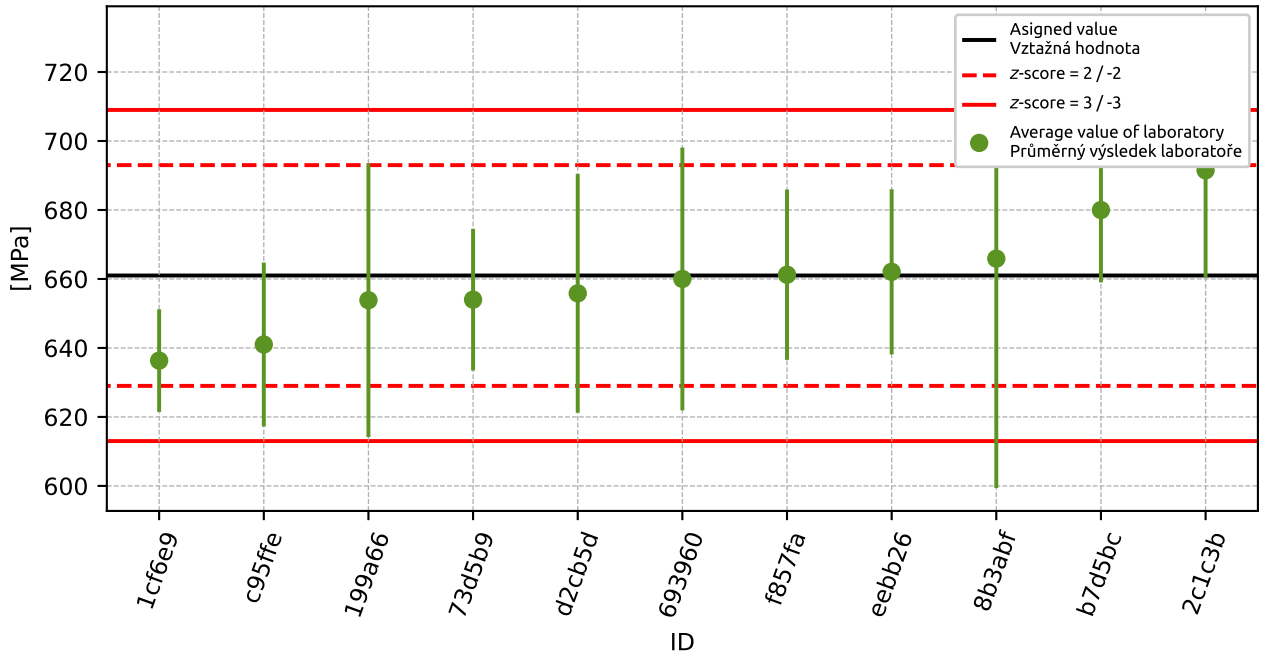

Figure 7: Average values and sample standard deviations

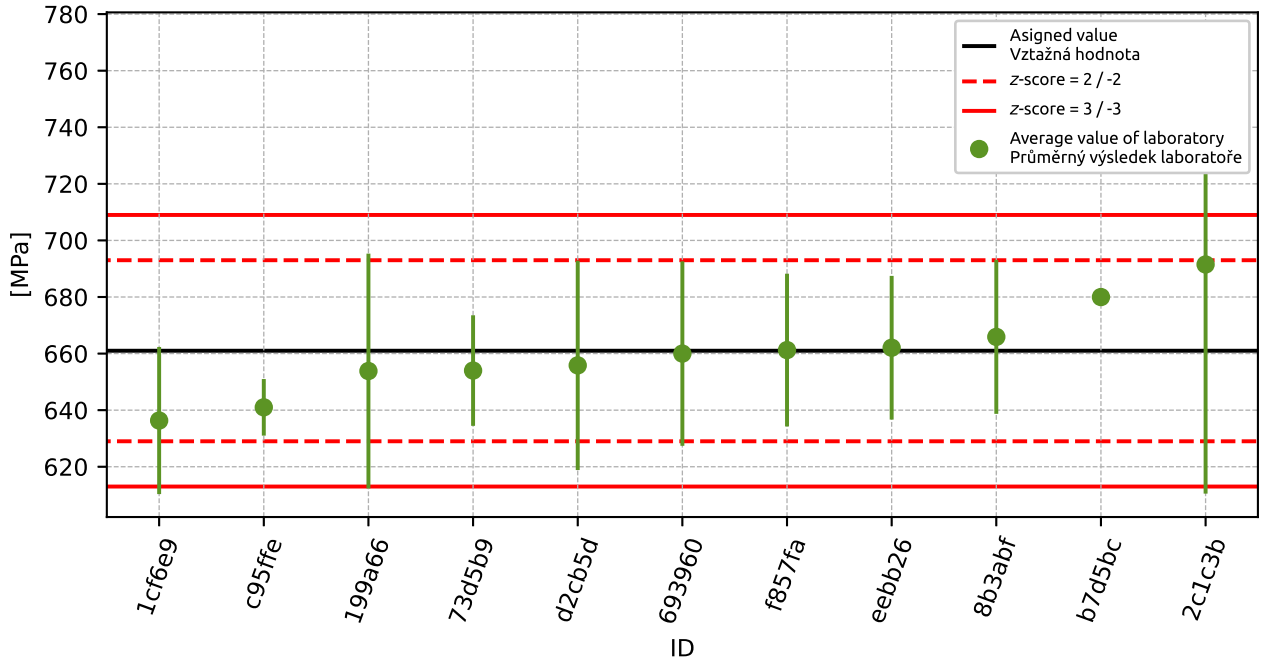

Figure 8: Average values and extended uncertainties of measurement

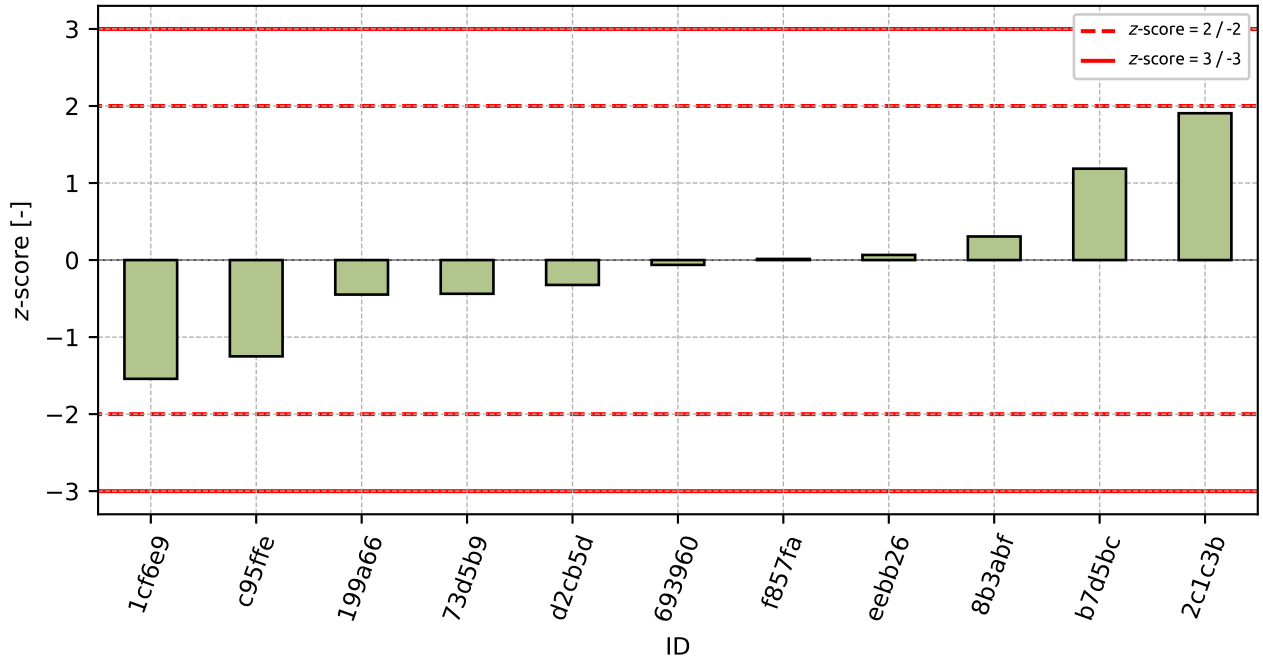

Figure 9: z-score

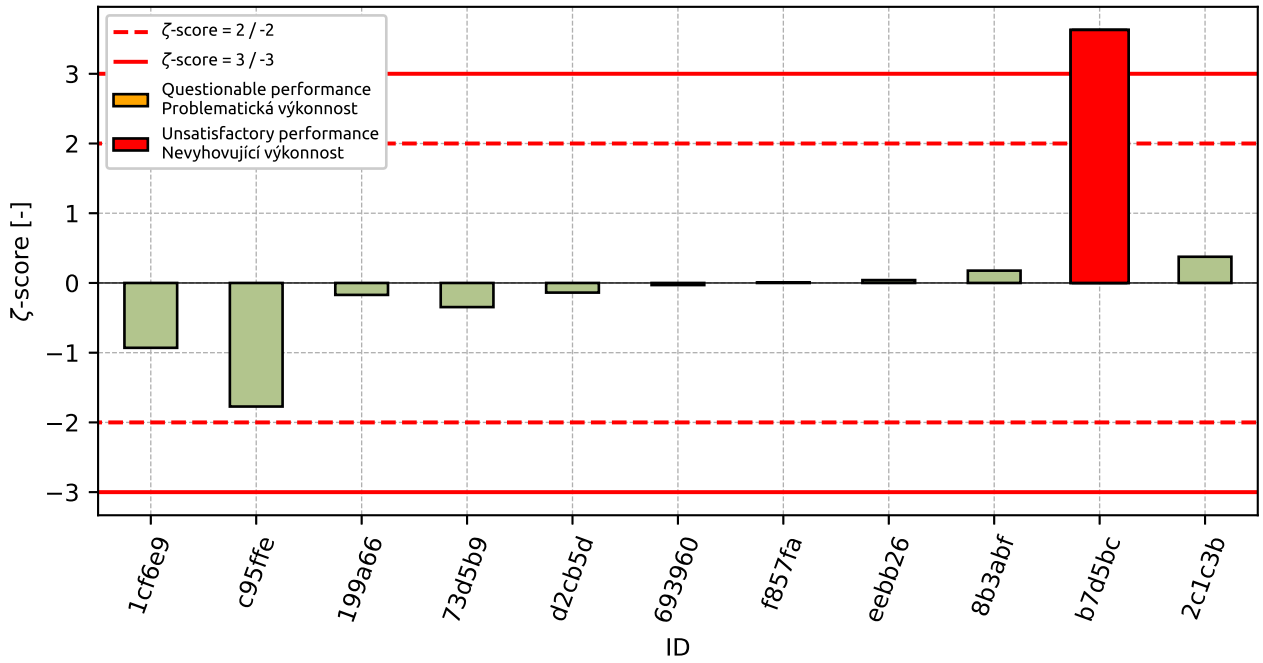

Figure 10: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
1cf6e9	-1.54	-0.93
c95ffe	-1.25	-1.77
199a66	-0.45	-0.17
73d5b9	-0.44	-0.35
d2cb5d	-0.32	-0.14
693960	-0.06	-0.03
f857fa	0.01	0.01
eebb26	0.07	0.04
8b3abf	0.31	0.18
b7d5bc	1.19	3.63
2c1c3b	1.91	0.38

2 Appendix – EN ISO 6892-1 – Yield strength

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 [MPa]						u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
1cf6e9	638	637	618	637	626	662	26.0	636.0	14.9	2.34
c95ffe	638	666	628	661	651	602	10.0	641.0	23.8	3.71
199a66	601	682	686	674	675	605	42.0	654.0	39.6	6.06
73d5b9	628	642	645	652	678	679	20.0	654.0	20.5	3.14
d2cb5d	632	672	647	631	719	634	37.0	656.0	34.6	5.28
693960	681	729	638	641	634	637	33.0	660.0	38.1	5.77
f857fa	637	650	644	669	706	662	27.0	661.0	24.7	3.73
eebb26	646	669	638	648	704	666	25.0	662.0	23.9	3.62
8b3abf	688	696	675	535	679	723	27.0	666.0	66.5	9.99
b7d5bc	704	698	689	665	675	648	0.0	680.0	21.0	3.09
2c1c3b	693	701	703	737	668	647	81.0	692.0	31.1	4.49
78940c	745	856	719	844	886	692	-	790.0	81.4	10.3

2.2 The Numerical Procedure for Determining Outliers

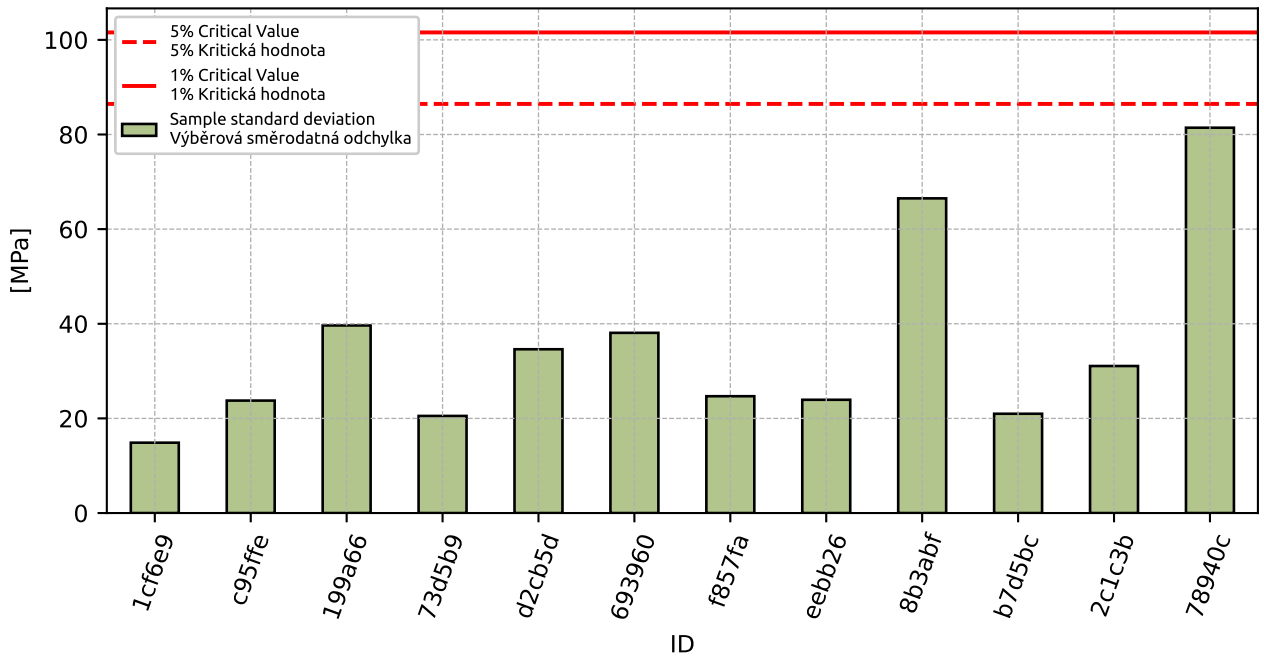

Figure 11: **Cochran's test** - sample standard deviations

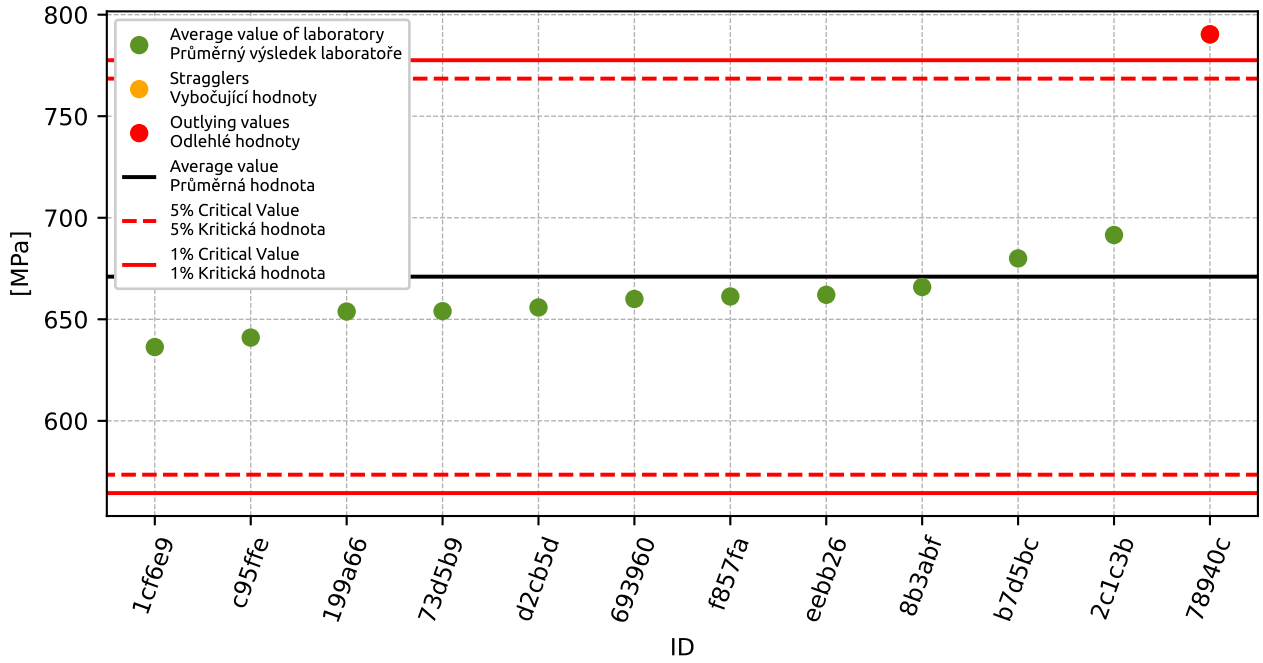

Figure 12: **Grubbs' test** - average values

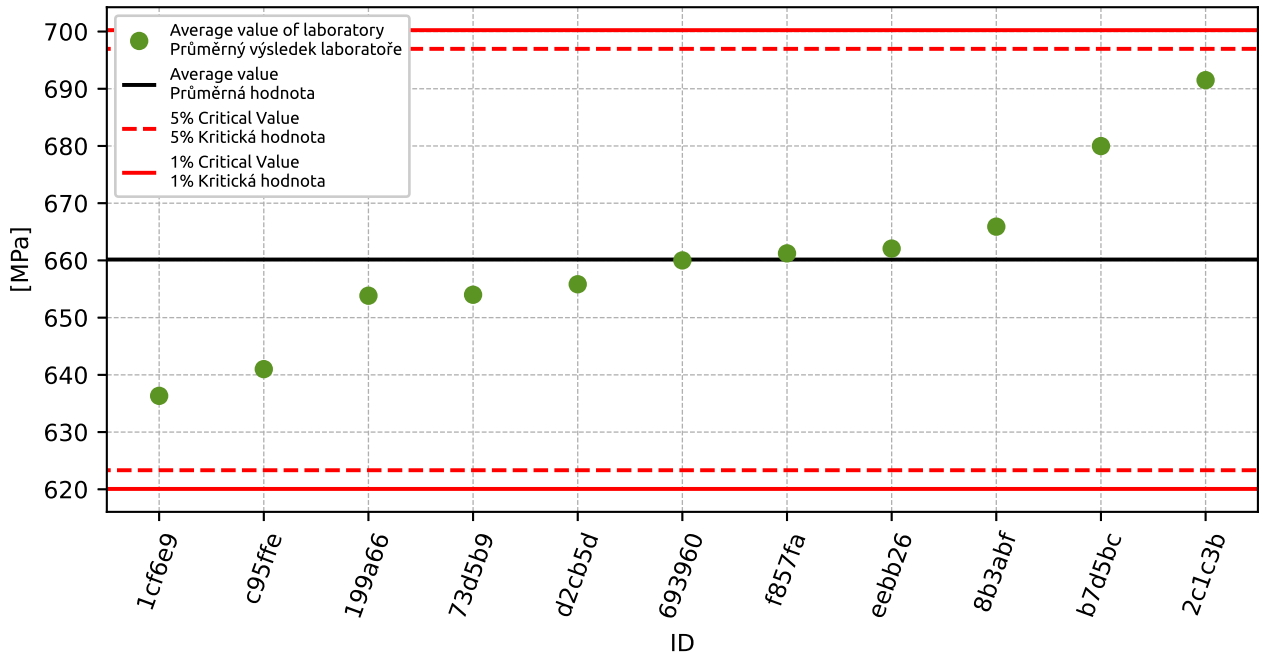

Figure 13: **Grubbs' test** - average values without outliers

2.3 Mandel's Statistics

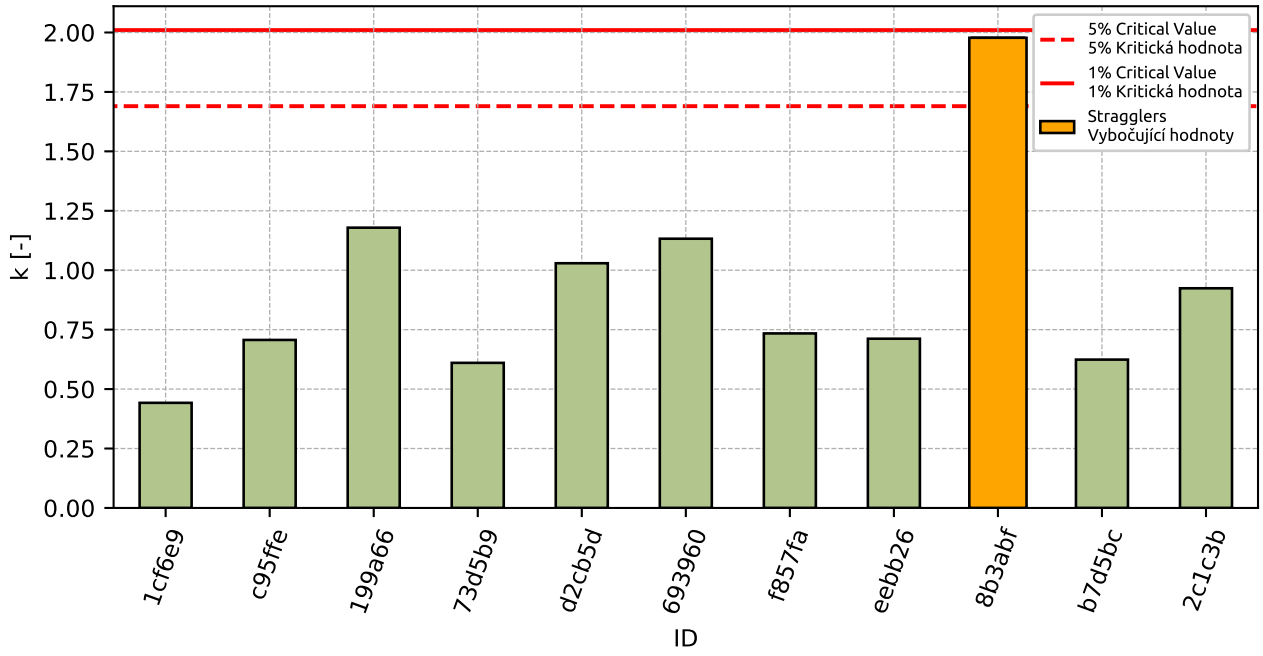

Figure 14: Intralaboratory Consistency Statistic

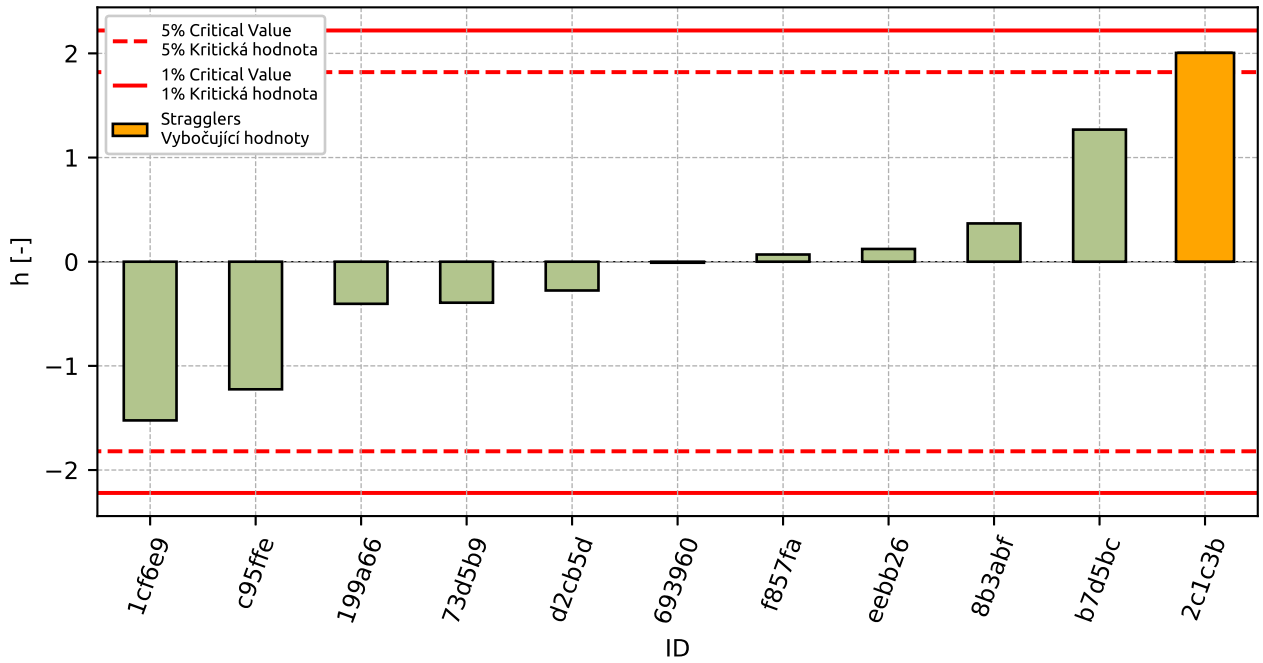

Figure 15: Interlaboratory Consistency Statistic

2.4 Descriptive statistics

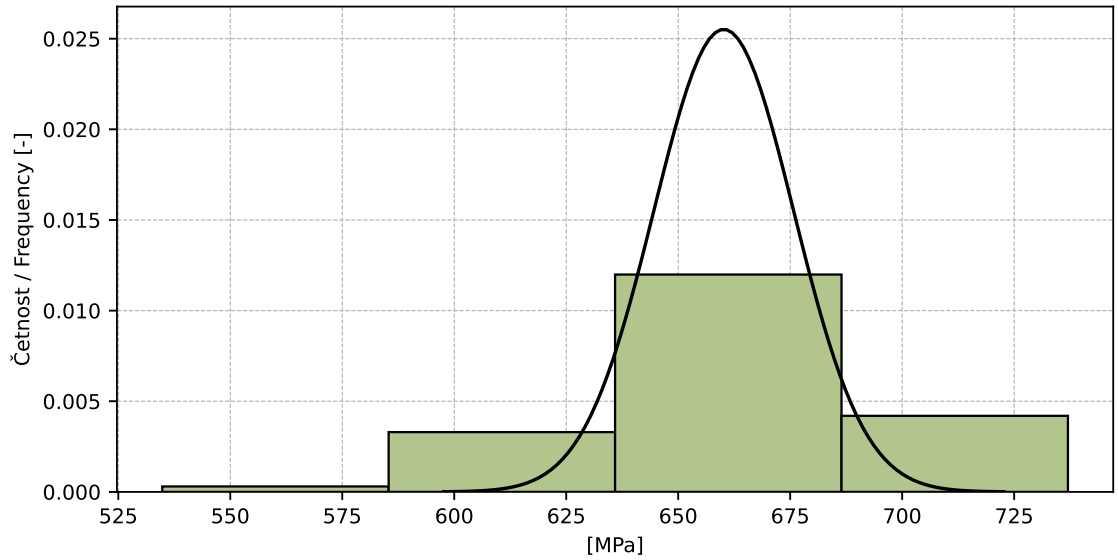

Figure 16: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[MPa]
Průměrná hodnota / Average value – $\bar{x}$	660.0
Výběrová směrodatná odchylka / Sample standard deviation – s	15.6
Vztažná hodnota / Asigned value – x^*	661.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	16
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	5.2
p-hodnota testu normality / p-value of normality test	0.055 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	7.5
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	33.6
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	34.4
Opakovatelnost / Repeatability – r	94.0
Reprodukovatelnost / Reproducibility – R	96.0

2.5 Evaluation of Performance Statistics

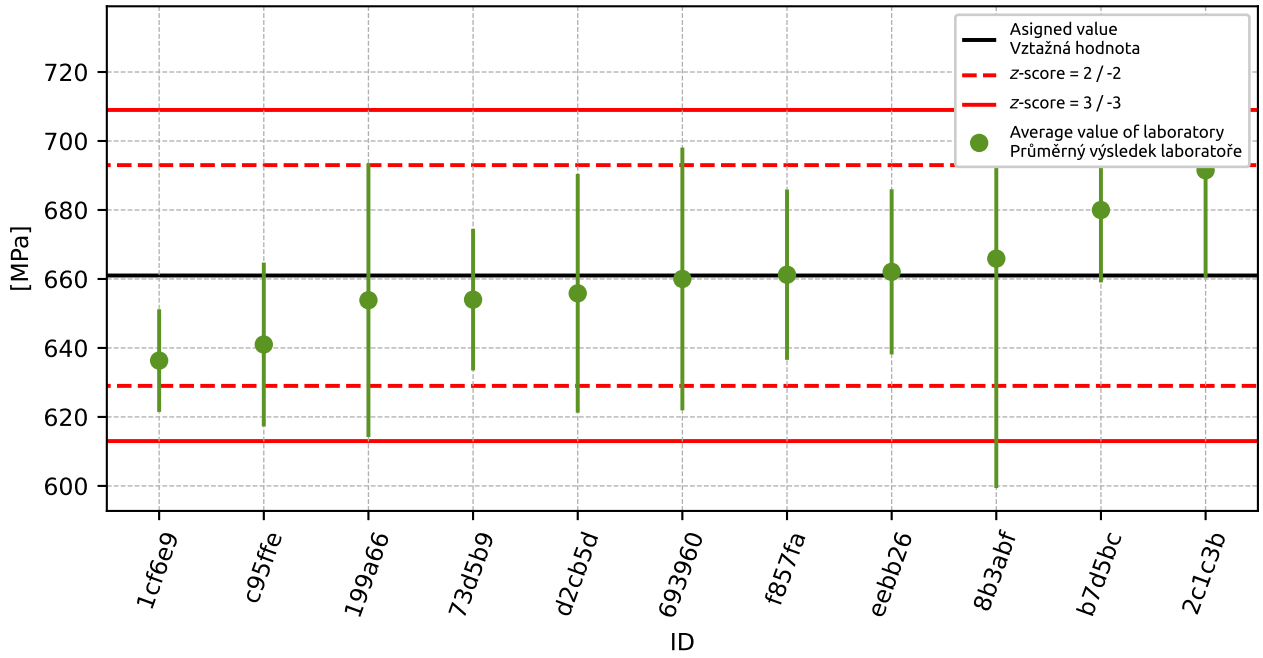

Figure 17: Average values and sample standard deviations

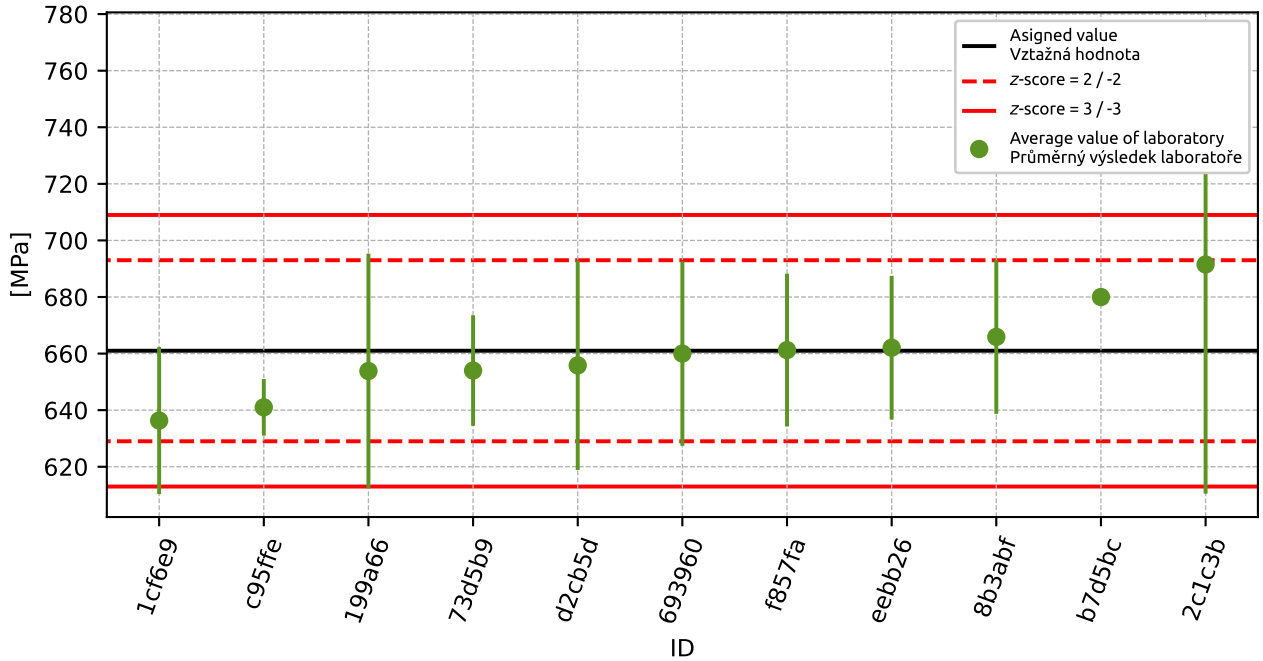

Figure 18: Average values and extended uncertainties of measurement

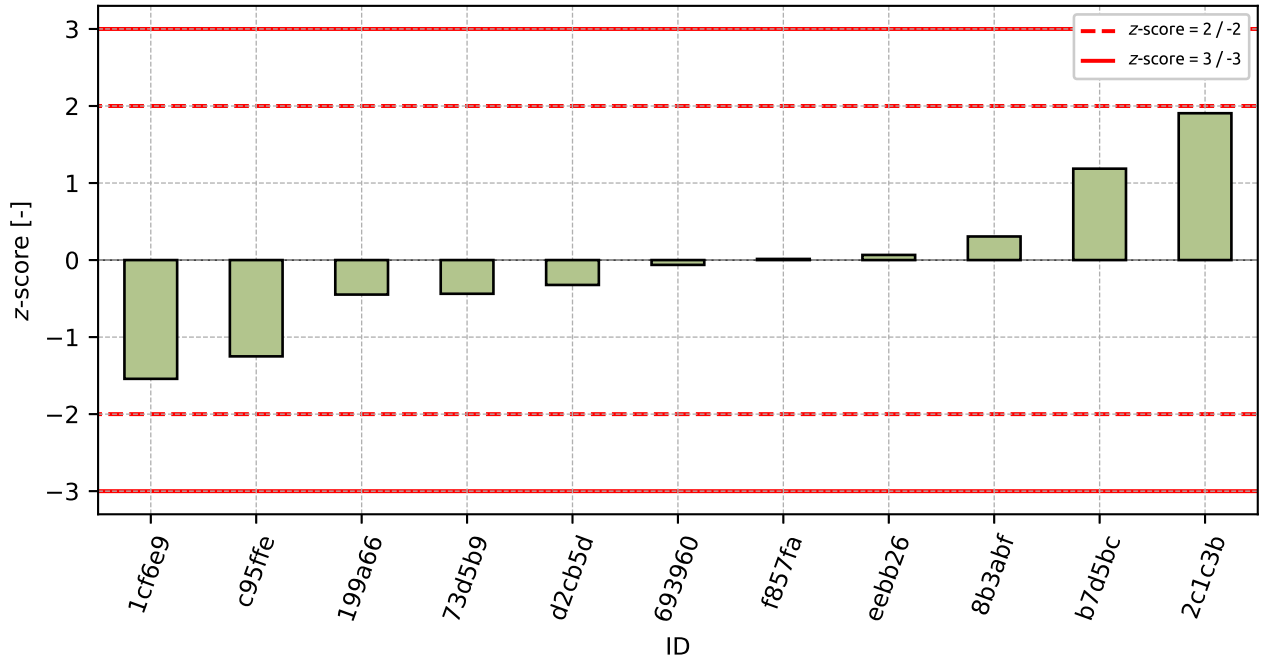

Figure 19: z-score

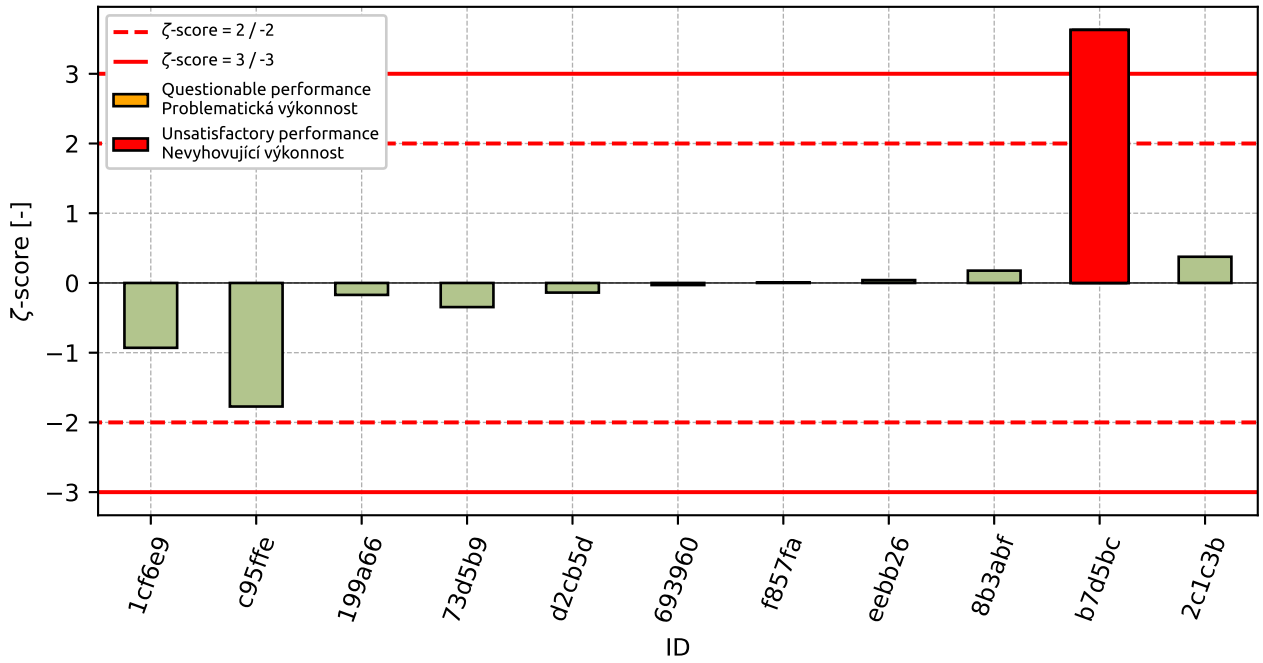

Figure 20: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
1cf6e9	-1.54	-0.93
c95ffe	-1.25	-1.77
199a66	-0.45	-0.17
73d5b9	-0.44	-0.35
d2cb5d	-0.32	-0.14
693960	-0.06	-0.03
f857fa	0.01	0.01
eebb26	0.07	0.04
8b3abf	0.31	0.18
b7d5bc	1.19	3.63
2c1c3b	1.91	0.38

3 Appendix – EN ISO 6892-1 – Percentage elongation after fracture

3.1 Test results

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

ID	Test results [%]						u_X [%]	$\bar{x}$ [%]	s_0 [%]	V_X [%]
b7d5bc	7.3	11.6	9.9	6.7	6.9	11.0	0.0	8.9	2.2	24.67
78940c	7.5	7.2	11.9	12.6	9.4	12.7	-	10.2	2.52	24.7
2c1c3b	20.0	18.4	20.3	17.7	17.7	15.7	4.4	18.3	1.7	9.27
199a66	21.0	16.0	18.0	18.5	17.5	22.5	0.4	18.9	2.4	12.67
693960	27.8	23.6	19.6	19.8	22.0	21.2	1.3	22.3	3.06	13.69
f857fa	22.8	23.6	24.8	24.2	25.2	23.6	1.0	24.0	0.88	3.66
d2cb5d	21.0	29.0	30.2	20.2	23.2	21.6	4.6	24.2	4.31	17.83
eebb26	24.8	22.4	27.2	25.0	24.8	26.0	1.7	25.0	1.59	6.36
c95ffe	30.0	29.0	27.5	28.0	32.0	26.5	0.0	28.8	1.97	6.82

3.2 The Numerical Procedure for Determining Outliers

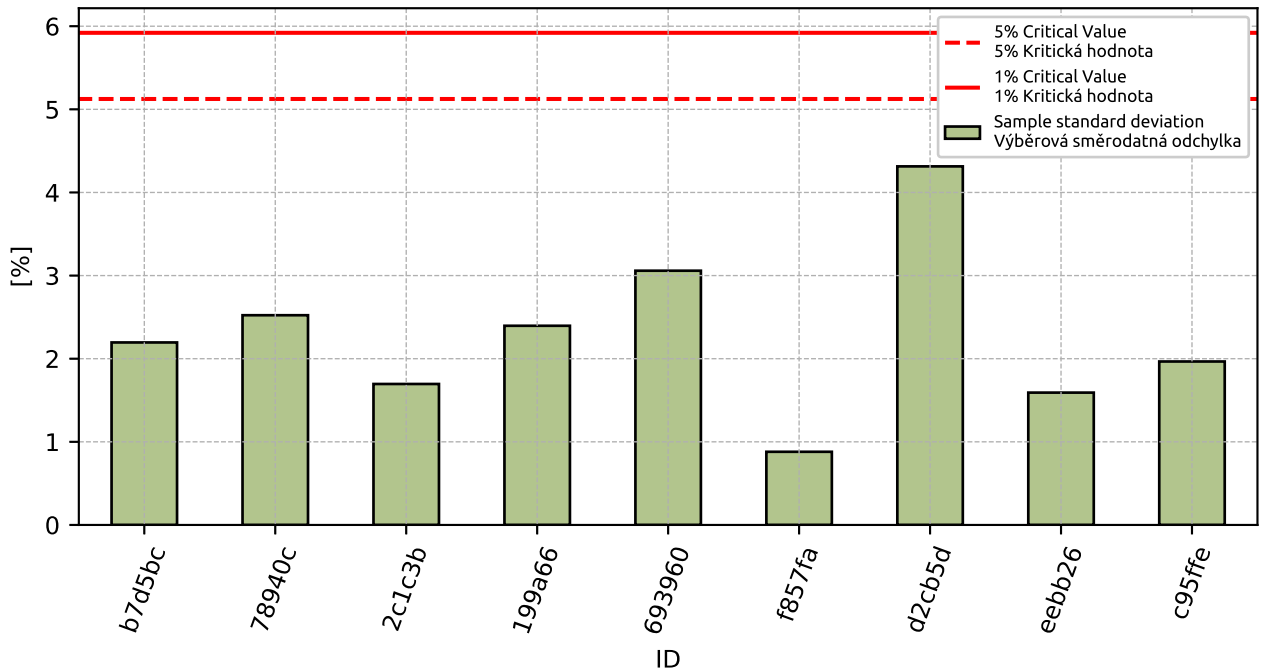

Figure 21: **Cochran's test** - sample standard deviations

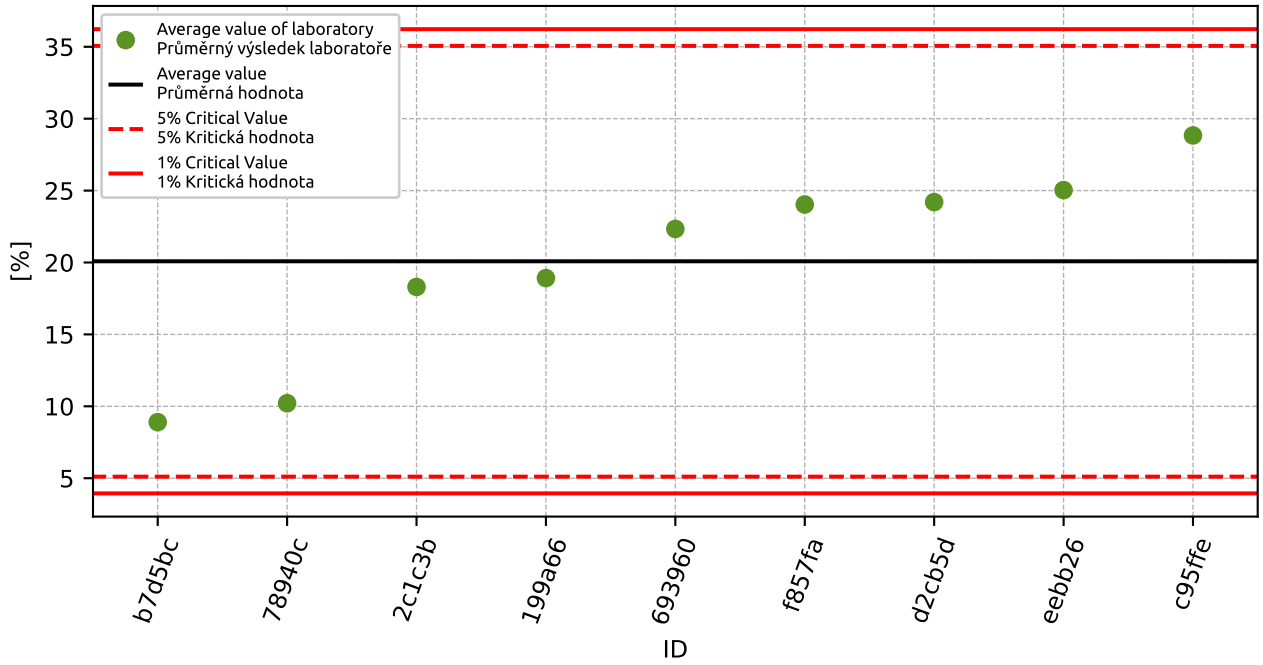

Figure 22: **Grubbs' test** - average values

3.3 Mandel's Statistics

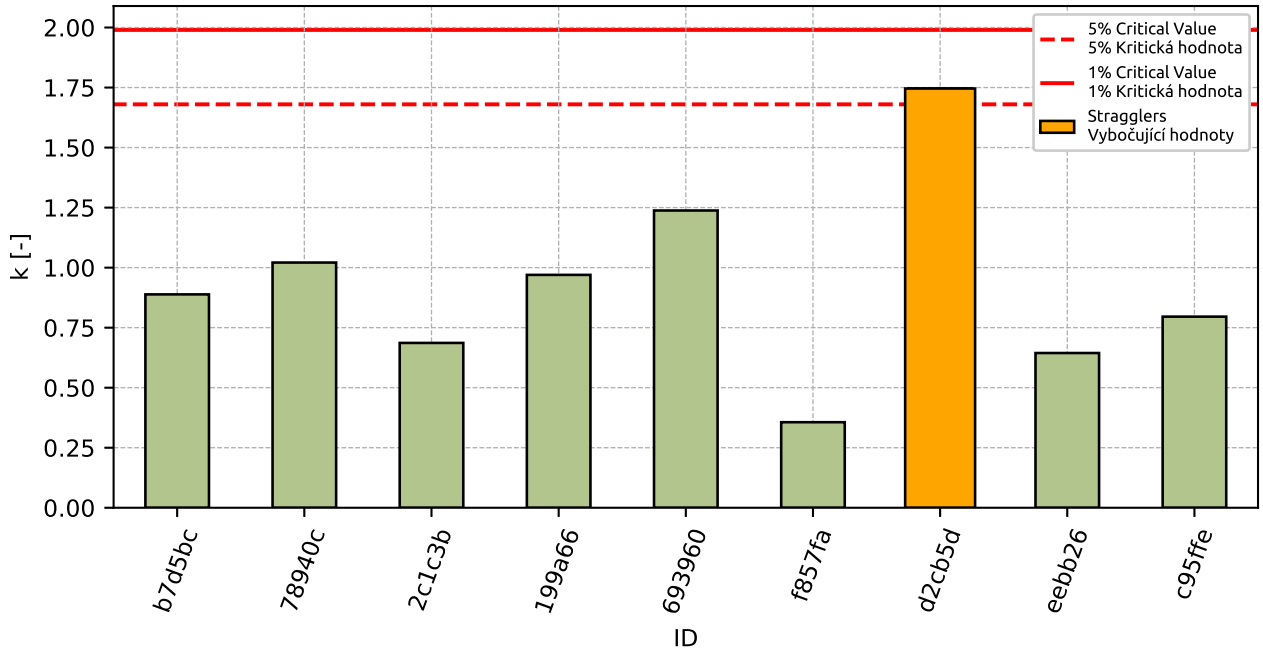

Figure 23: Intralaboratory Consistency Statistic

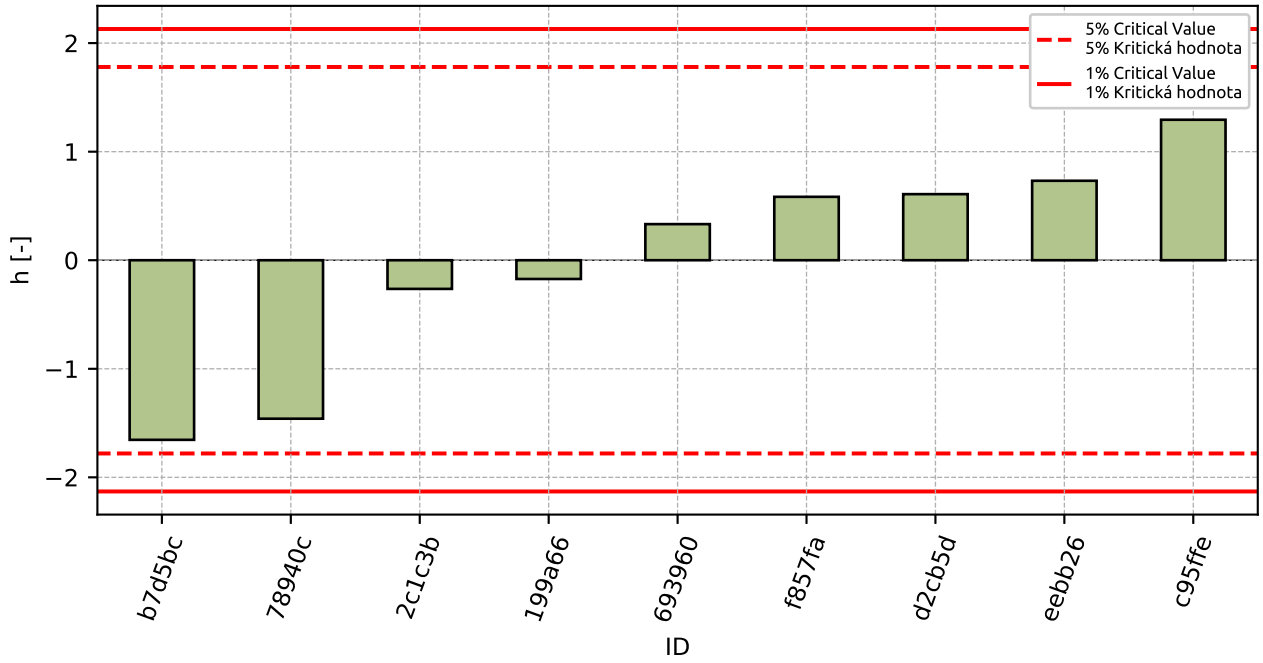

Figure 24: Interlaboratory Consistency Statistic

3.4 Descriptive statistics

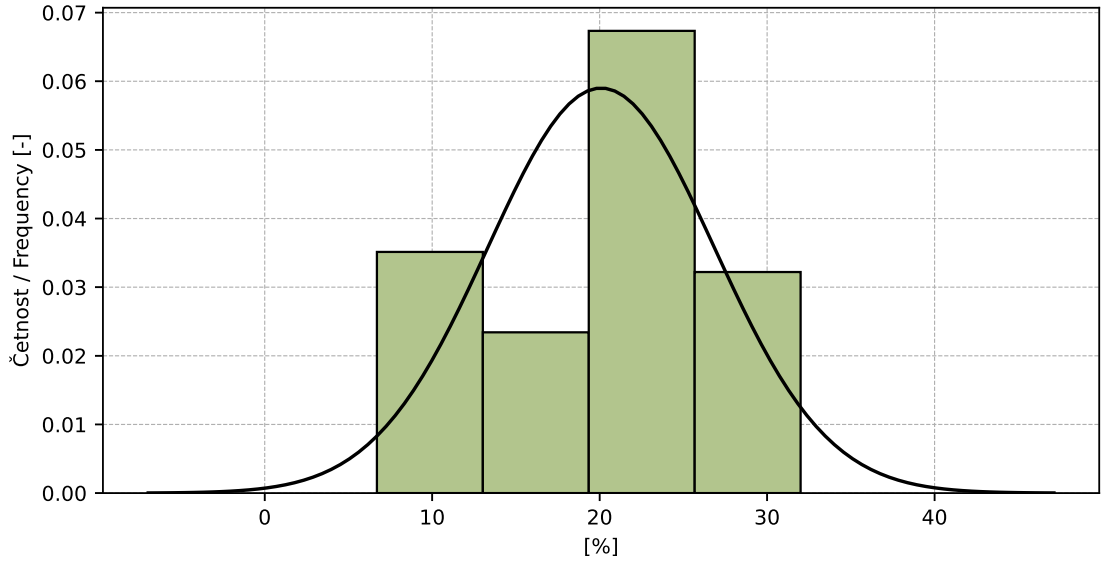

Figure 25: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[%]
Průměrná hodnota / Average value – $\bar{x}$	20.1
Výběrová směrodatná odchylka / Sample standard deviation – s	6.76
Vztažná hodnota / Asigned value – x^*	21.2
Robustní směrodatná odchylka / Robust standard deviation – s^*	5.19
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	2.16
p-hodnota testu normality / p-value of normality test	0.021 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	6.68
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	2.47
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	7.13
Opakovatelnost / Repeatability – r	6.9
Reprodukovatelnost / Reproducibility – R	20.0

3.5 Evaluation of Performance Statistics

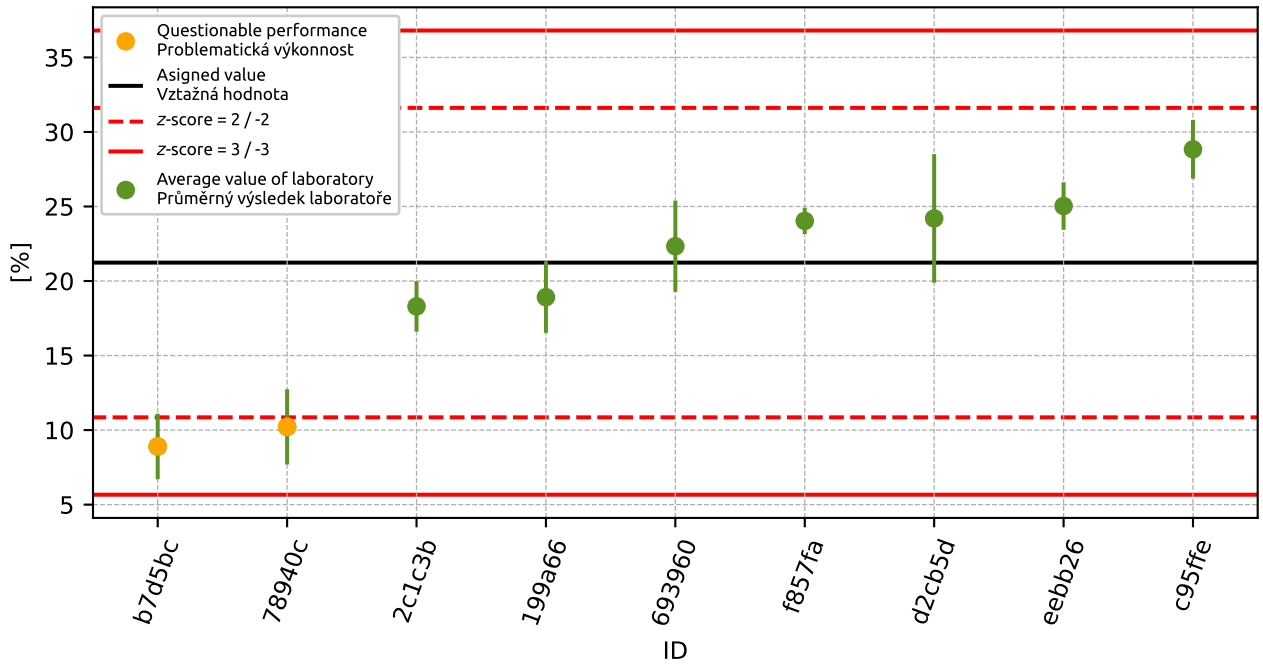

Figure 26: Average values and sample standard deviations

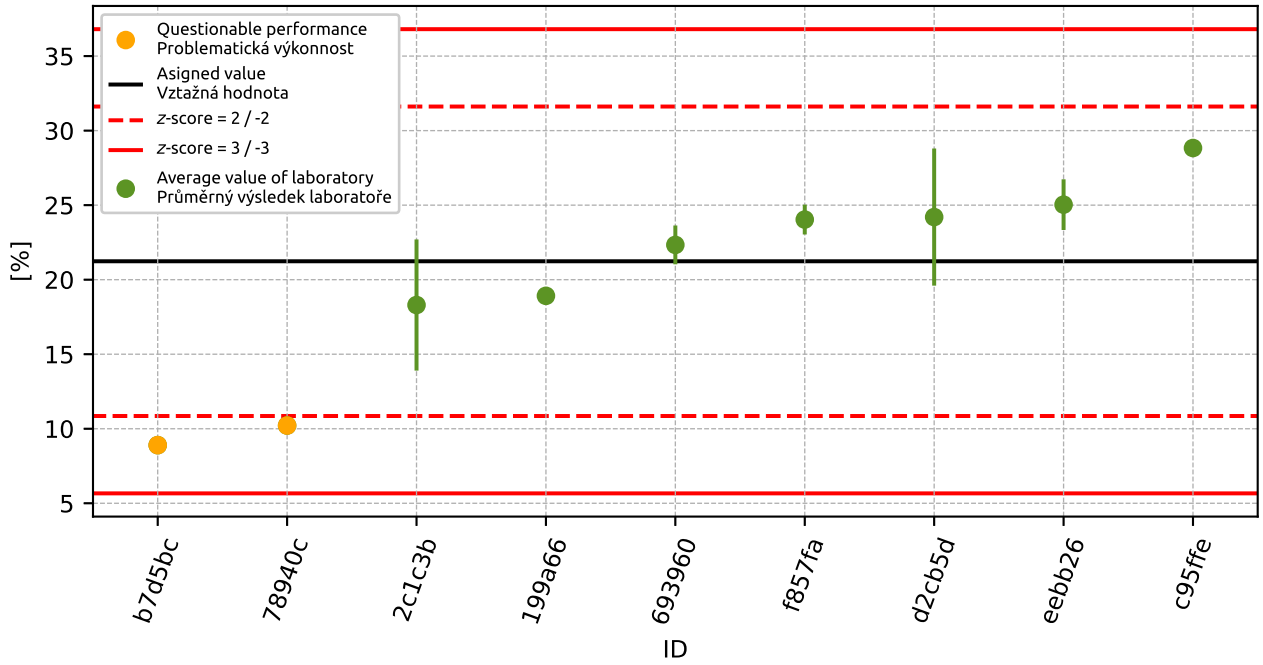

Figure 27: Average values and extended uncertainties of measurement

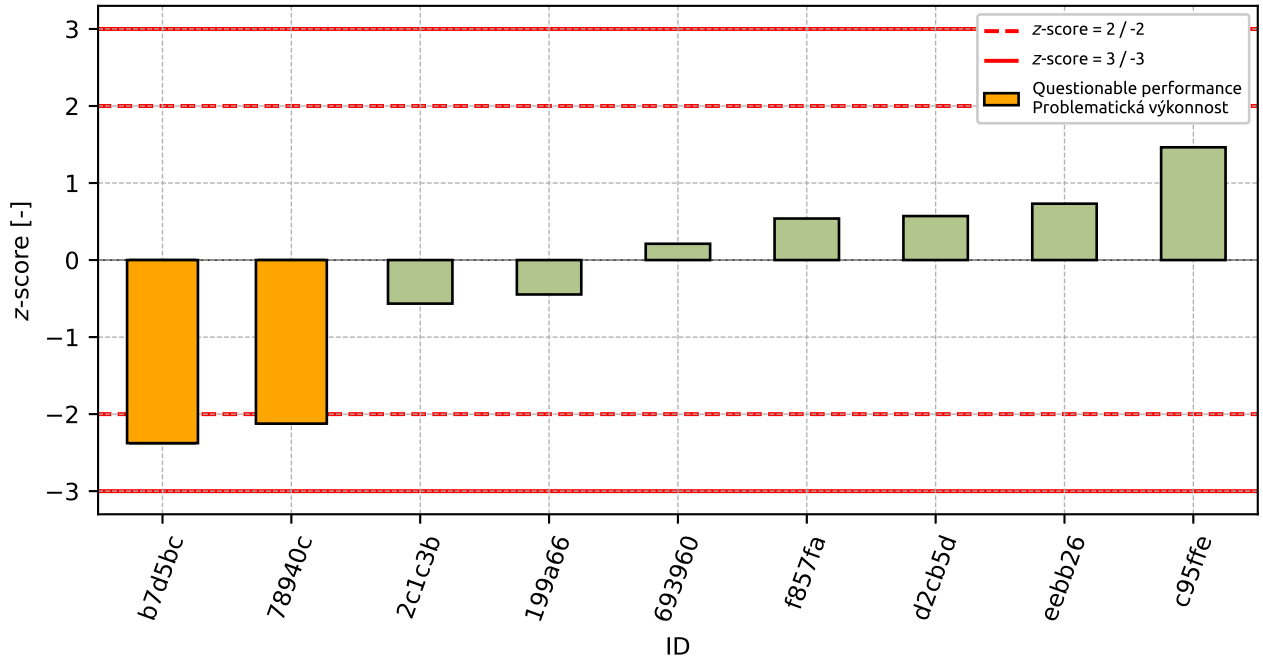

Figure 28: z-score

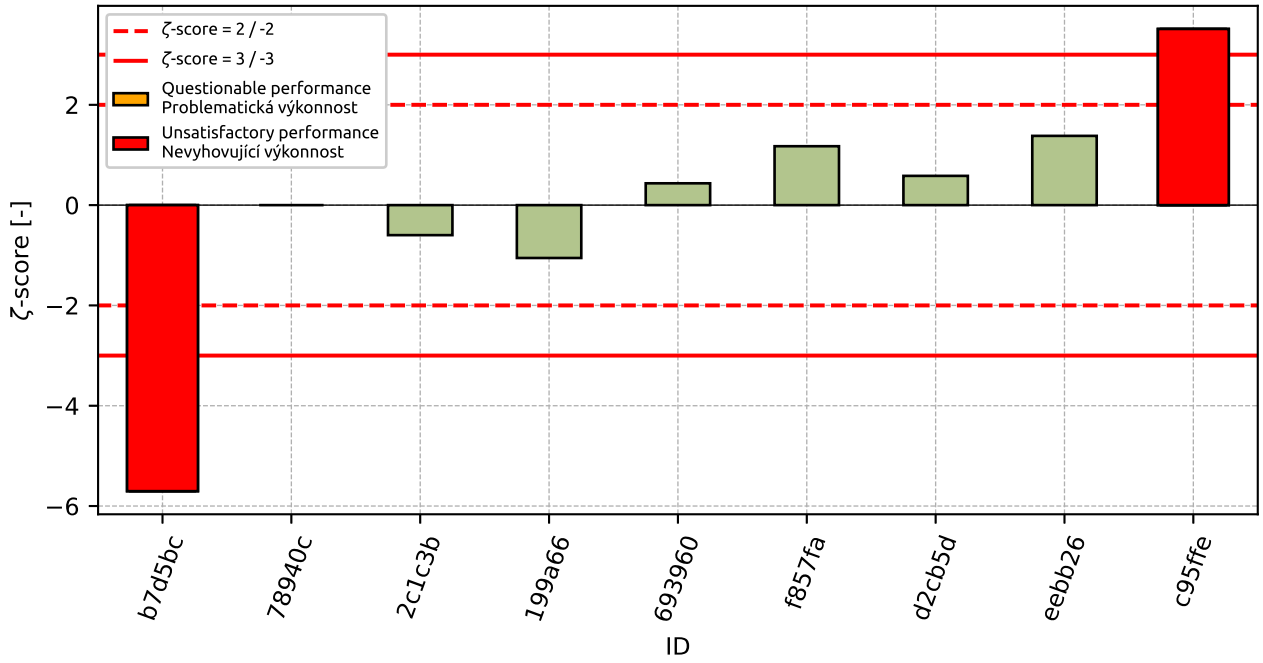

Figure 29: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
b7d5bc	-2.38	-5.7
78940c	-2.12	-
2c1c3b	-0.57	-0.6
199a66	-0.45	-1.05
693960	0.21	0.44
f857fa	0.54	1.17
d2cb5d	0.57	0.58
eebb26	0.73	1.38
c95ffe	1.46	3.51

4 Appendix – EN ISO 6892-1 – Percentage reducation of area

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