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
Masonry Units Testing
ZZP 2021/1

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

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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 2021, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZZP 2021/1 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, 3, 4, 5, 6, 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.

8 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
95504a	X	-	-	-	-	-	X	-	-
b400f4	X	-	-	-	-	-	X	-	-
4b8ede	X	-	-	-	-	-	-	-	-
a30484	X	-	-	-	-	-	-	-	-
5e707a	X	-	-	-	-	-	-	-	-
9acff8	X	-	-	-	-	-	X	-	-
d82da4	X	-	-	-	-	-	-	-	-
d505a2	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
BTI Bautechnisches Institut GmbH	Karl-Leitl-Strasse 2, Puchenau, 4048, Austria	-
BUILDING RESEARCH INSTITUTE (N I S I) Ltd	86 Nikola Petkov Blvd, Sofia, 1618, Bulgaria	47 LI
Bautechnische Versuchs- und Forschungsanstalt Salzburg	Alpenstrasse 157, Salzburg, 5020, Austria	-
CS-BETON s.r.o.	Velké Žernoseky 184, Litoměřice, 412 01, Česká republika	1500
Camillo Sitte Versuchsanstalt für Bautechnik	Leberstrasse 4c, Vienna, 1030, Austria	0046
Institut pro testování a certifikaci, a.s.	třída Tomáše Bati 299, Louky, Zlín, 763 02, Česká republika	1004
Vilnius Gediminas Technical University	Sauletekio al. 11, Vilnius, LT-10223, Lithuania	L.A. 086-01-5
Vysoké učení technické v Brně, Fakulta stavební, Zkušební laboratoř při ÚTHD FAST VUT v Brně - č. 1396	Veveří 331/95, Brno, 60200, Česká republika	L1396

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. 8 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
95504a	✓	-	-	-	-	-	✓	-	-
b400f4	✓	-	-	-	-	-	✓	-	-
4b8ede	✓	-	-	-	-	-	-	-	-
a30484	✓	-	-	-	-	-	-	-	-
5e707a	✓	-	-	-	-	-	-	-	-
9acff8	✓	-	-	-	-	-	✓	-	-
d82da4	✓	-	-	-	-	-	-	-	-
d505a2	✓	-	-	-	-	-	-	-	-

References

[1] EN 772-1+A1. *Methods of test for masonry units - Part 1: Determination of compressive strength*. 2015.

[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/mm²]						u_X [N/mm²]	$\bar{x}$ [N/mm²]	s_0 [N/mm²]	V_X [%]
a30484	8.6	9.0	10.2	8.9	9.0	8.9	0.5	9.1	0.54	5.96
95504a	10.1	10.8	9.9	8.6	9.9	9.9	1.1	9.9	0.71	7.21
4b8ede	11.6	10.0	13.0	13.4	12.0	10.0	0.4	11.7	1.45	12.39
d82da4	11.5	12.2	10.8	12.2	13.2	10.6	0.5	11.7	0.99	8.4
5e707a	11.9	11.9	12.1	11.8	13.2	12.8	0.1	12.3	0.58	4.7
b400f4	13.8	11.9	11.5	12.7	12.8	12.4	-	12.5	0.8	6.38
d505a2	12.9	13.1	11.3	14.0	12.8	12.0	2.3	12.7	0.93	7.35
9acff8	13.2	12.3	14.0	13.5	11.8	14.1	1.6	13.2	0.93	7.05

1.2 The Numerical Procedure for Determining Outliers

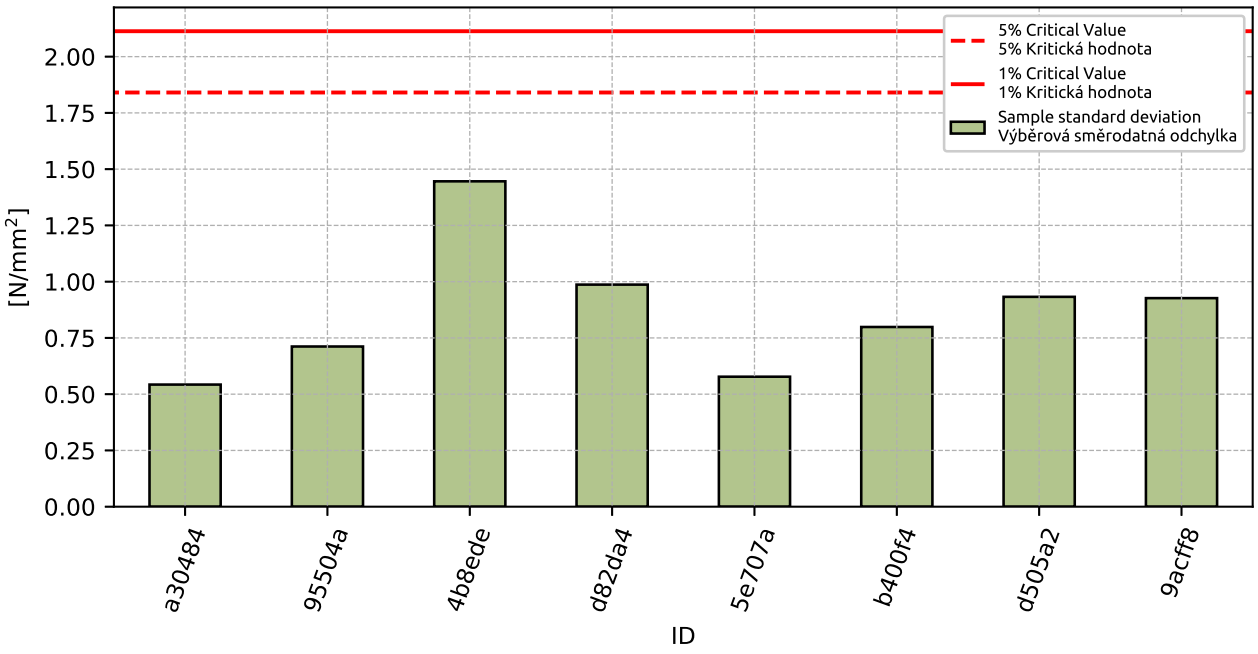

Figure 1: **Cochran's test** - sample standard deviations

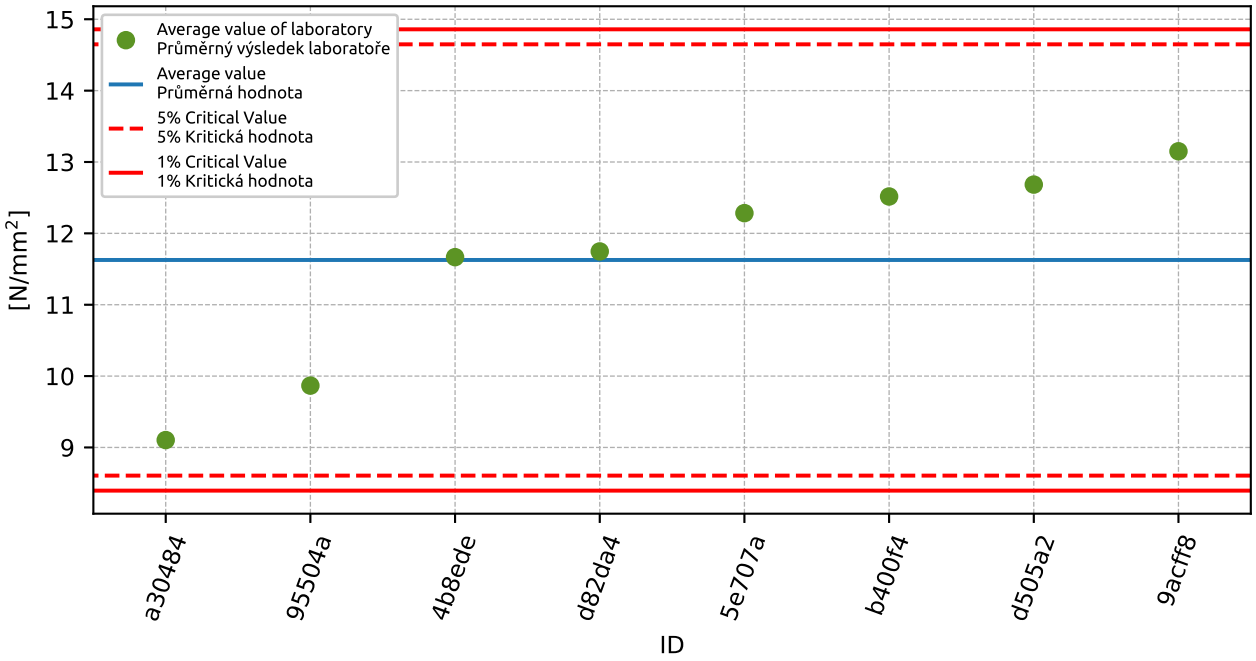

Figure 2: **Grubbs' test** - average values

1.3 Mandel's Statistics

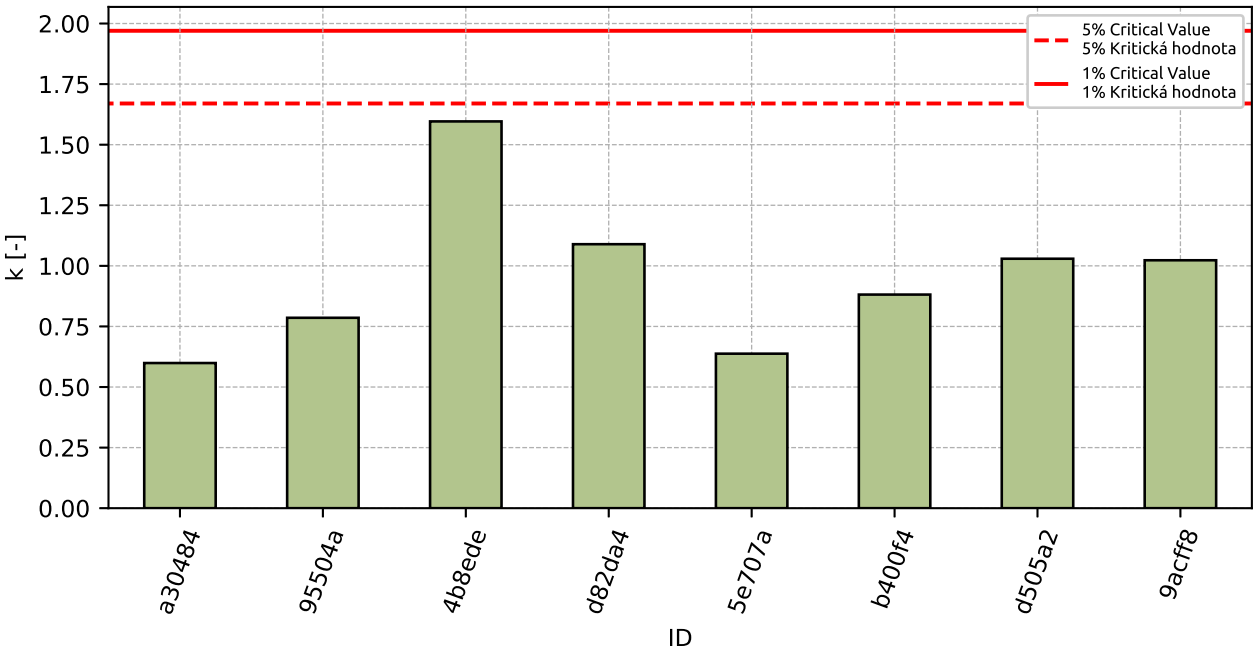

Figure 3: Intralaboratory Consistency Statistic

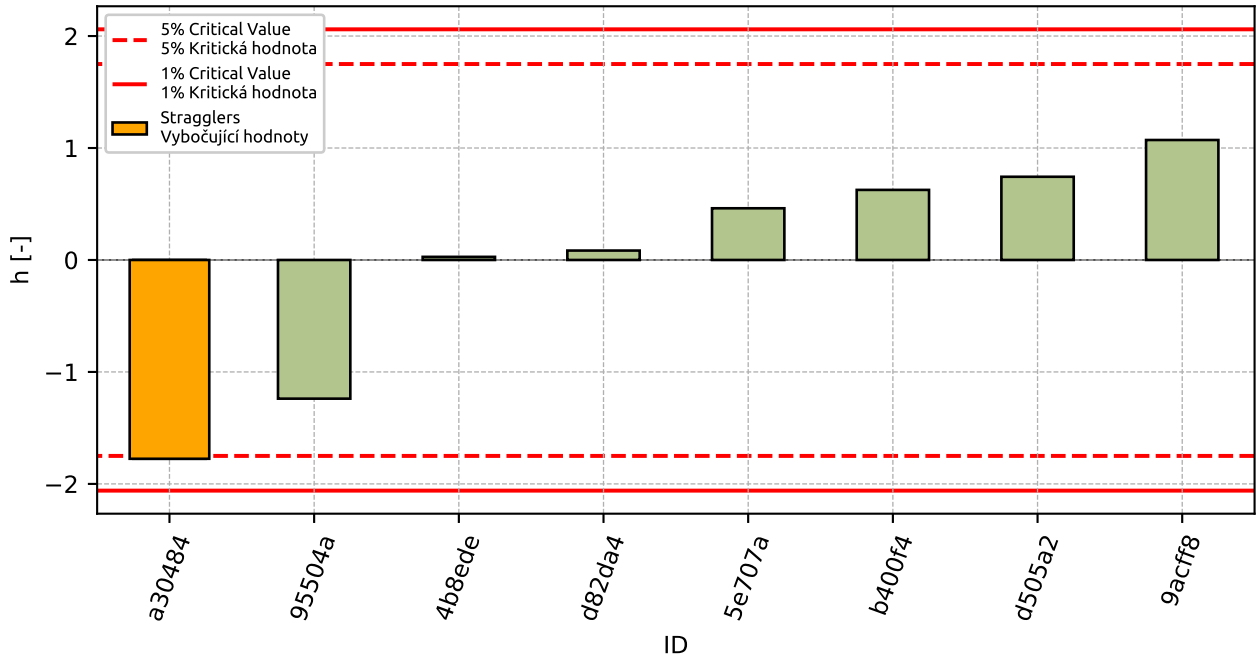

Figure 4: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

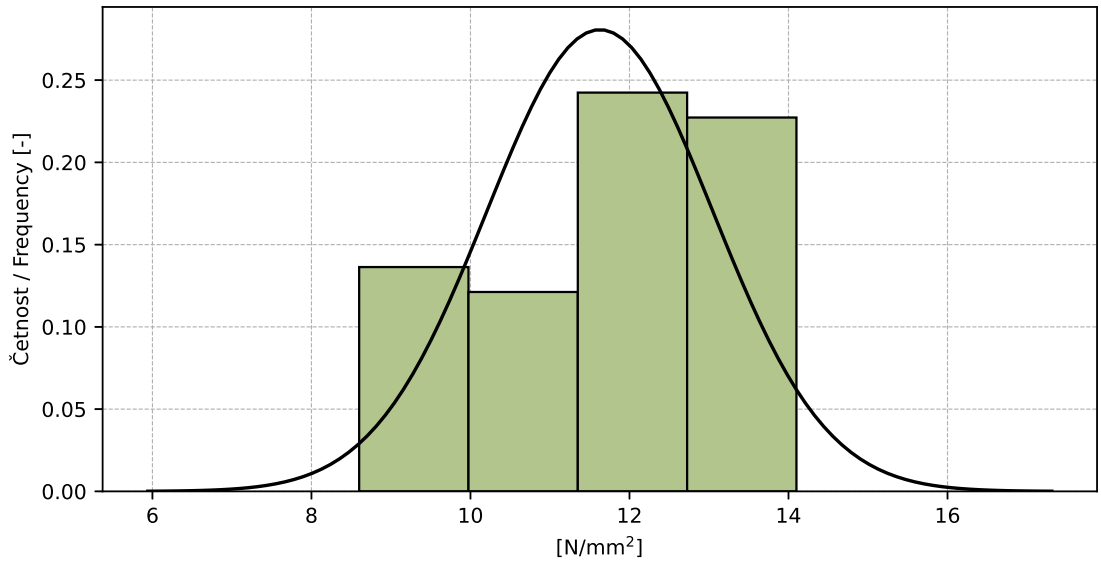

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[N/mm²]
Průměrná hodnota / Average value – $\bar{x}$	11.6
Výběrová směrodatná odchylka / Sample standard deviation – s	1.42
Vztažná hodnota / Asigned value – x^*	11.9
Robustní směrodatná odchylka / Robust standard deviation – s^*	0.95
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	0.42
p-hodnota testu normality / p-value of normality test	0.022 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	1.37
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	0.91
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	1.64
Opakovatelnost / Repeatability – r	2.5
Reprodukovatelnost / Reproducibility – R	4.6

1.5 Evaluation of Performance Statistics

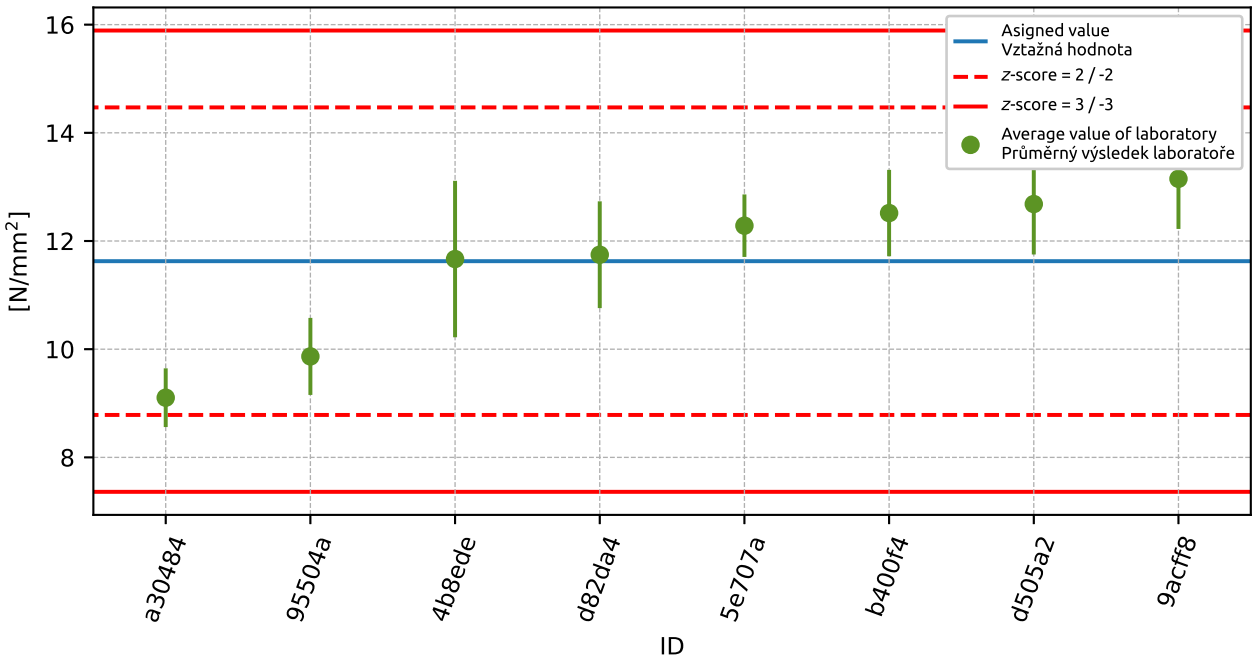

Figure 6: Average values and sample standard deviations

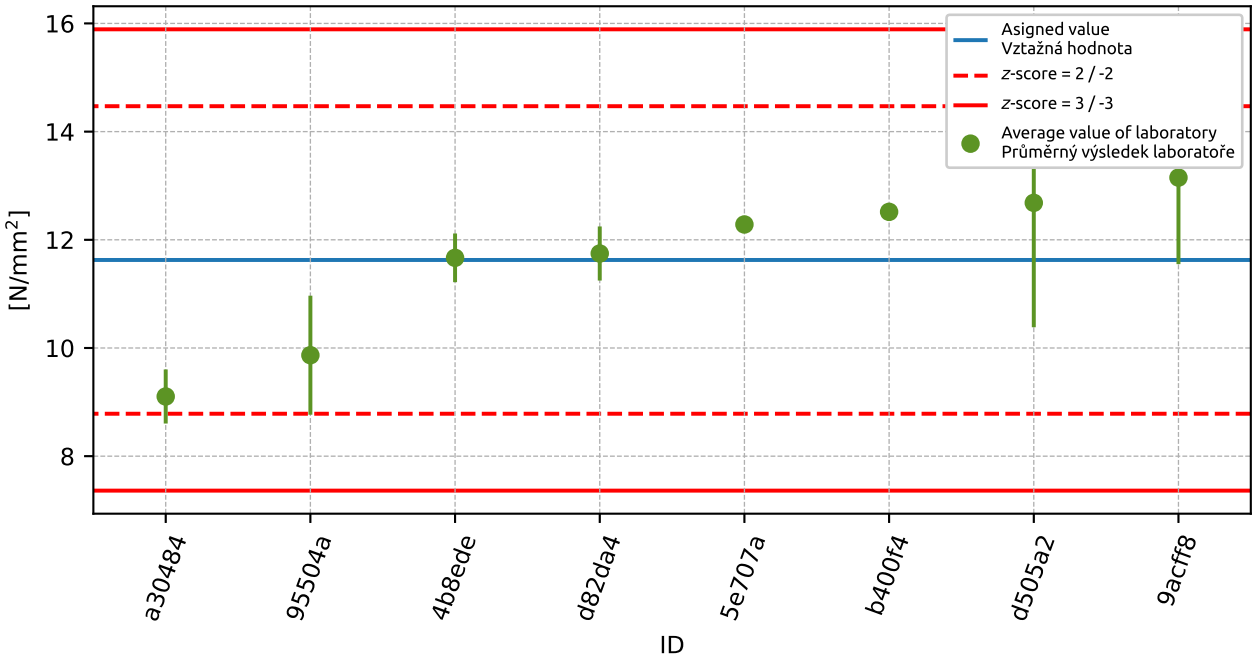

Figure 7: Average values and extended uncertainties of measurement

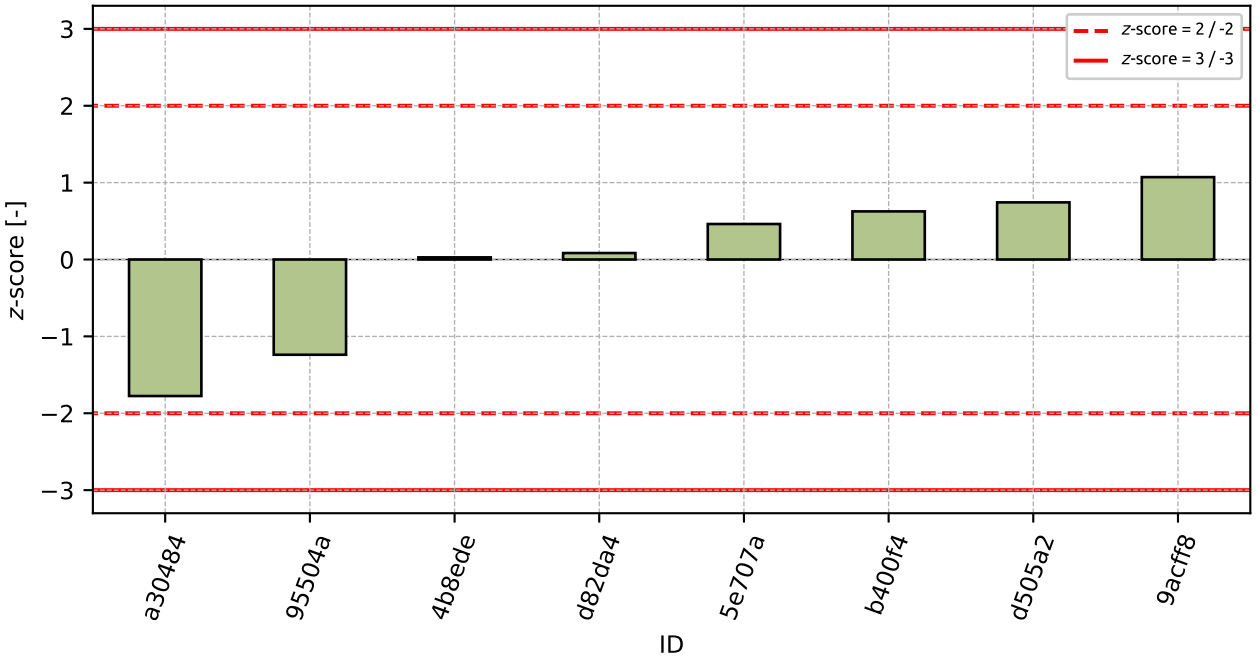

Figure 8: z-score

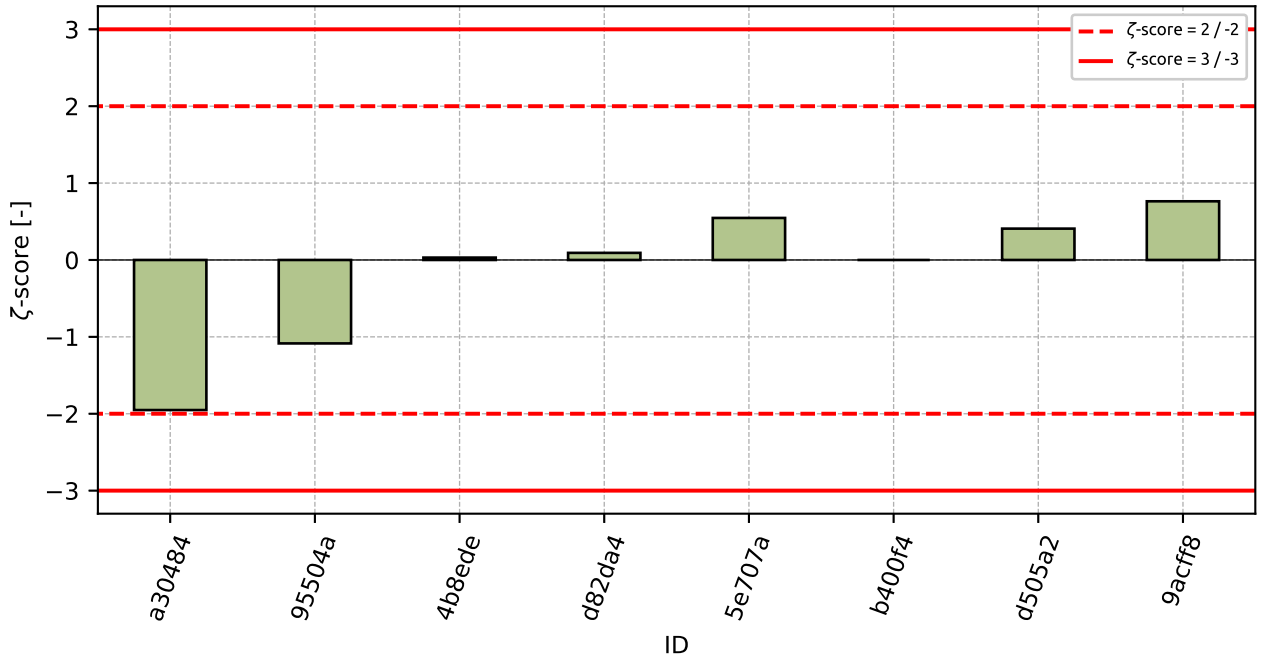

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a30484	-1.78	-1.95
95504a	-1.24	-1.09
4b8ede	0.03	0.03
d82da4	0.08	0.09
5e707a	0.46	0.55
b400f4	0.63	-
d505a2	0.74	0.41
9acff8	1.07	0.76

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)

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

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)

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

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

7.1 Net dry density of masonry units

7.2 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/mm²]						u_X [N/mm²]	$\bar{x}$ [N/mm²]	s_0 [N/mm²]	V_X [%]
9acff8	1370	1380	1370	1380	1390	1390	20.0	1380	8.9	0.65
b400f4	1650	1605	1600	1615	1650	1630	-	1625	21.9	1.35

7.3 Descriptive statistics

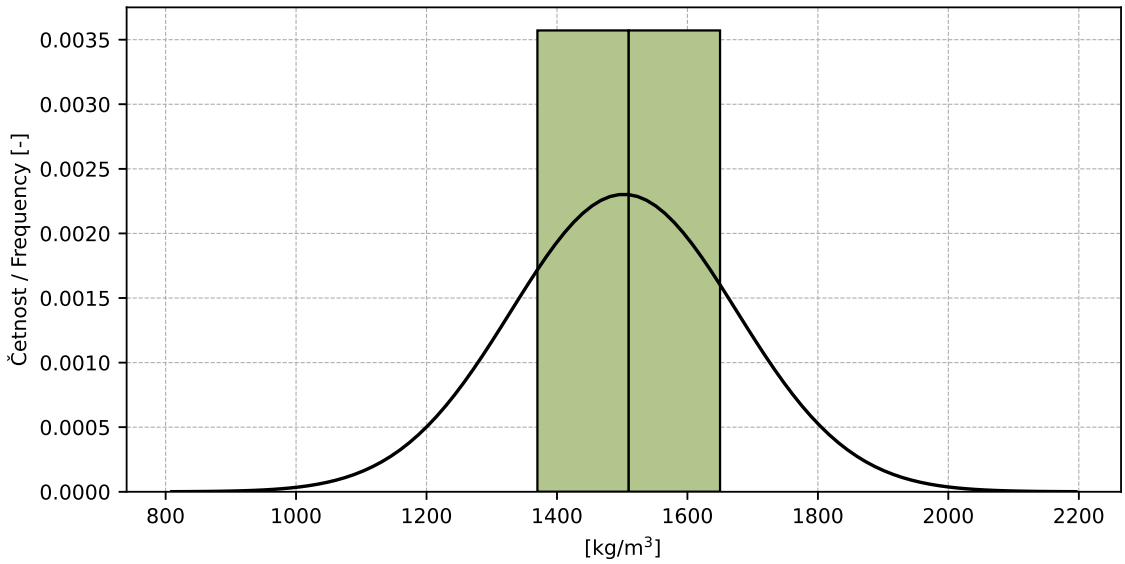

Figure 10: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[N/mm²]
Průměrná hodnota / Average value – $\bar{x}$	1502.0
Výběrová směrodatná odchylka / Sample standard deviation – s	173.2
Vztažná hodnota / Asigned value – x^*	1502.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	173.2
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	13.2
p-hodnota testu normality / p-value of normality test	0.002 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	173.1
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	16.7
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	173.9
Opakovatelnost / Repeatability – r	47.0
Reprodukovatelnost / Reproducibility – R	487.0

7.4 Evaluation of Performance Statistics

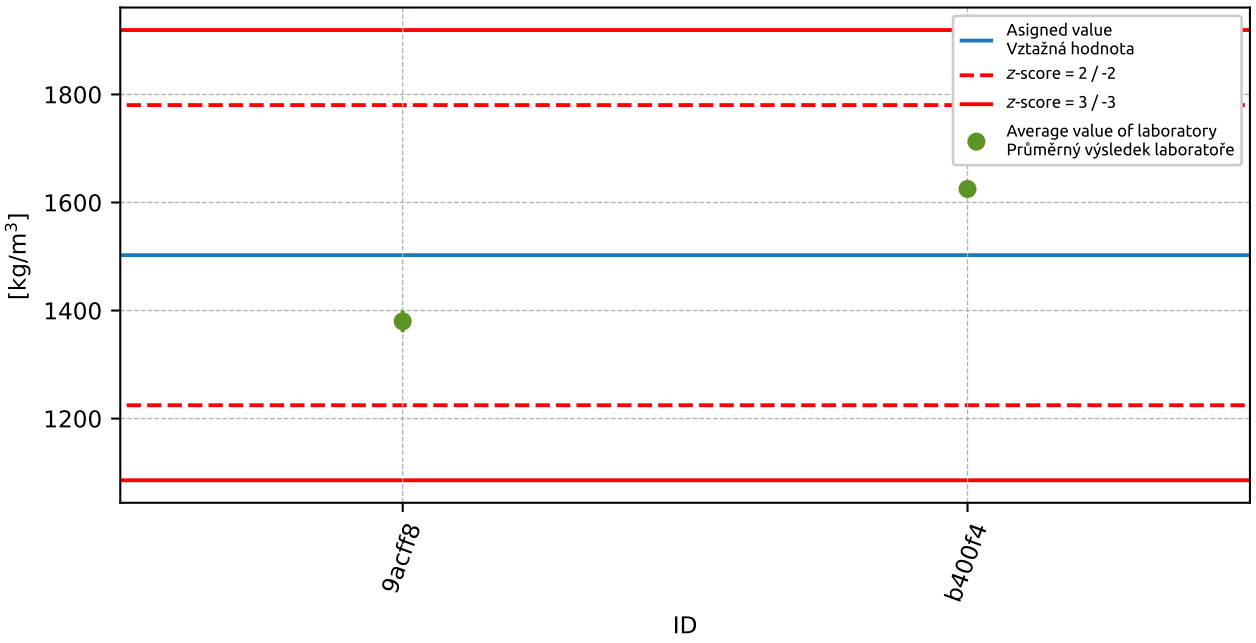

Figure 11: Average values and extended uncertainties of measurement

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
9acff8	-0.88	-0.98
b400f4	0.88	-

7.5 Gross dry density of masonry units

7.6 Test results

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

ID	Test results [N/mm^2]						u_X [N/mm^2]	$\bar{x}$ [N/mm^2]	s_0 [N/mm^2]	V_X [%]
9acff8	725	730	725	725	735	735	10.0	729	4.9	0.67
95504a	785	785	790	780	785	785	80.0	785	3.2	0.4
b400f4	805	780	775	790	800	790	-	790	11.4	1.44

7.7 The Numerical Procedure for Determining Outliers

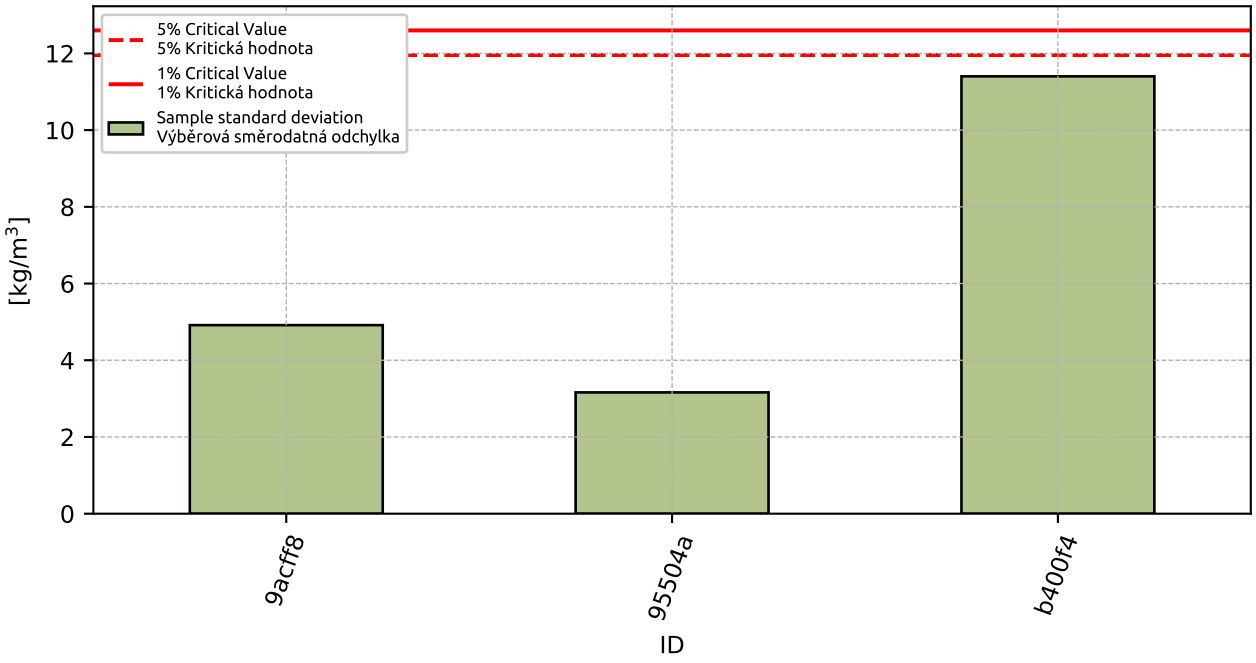

Figure 12: **Cochran's test** - sample standard deviations

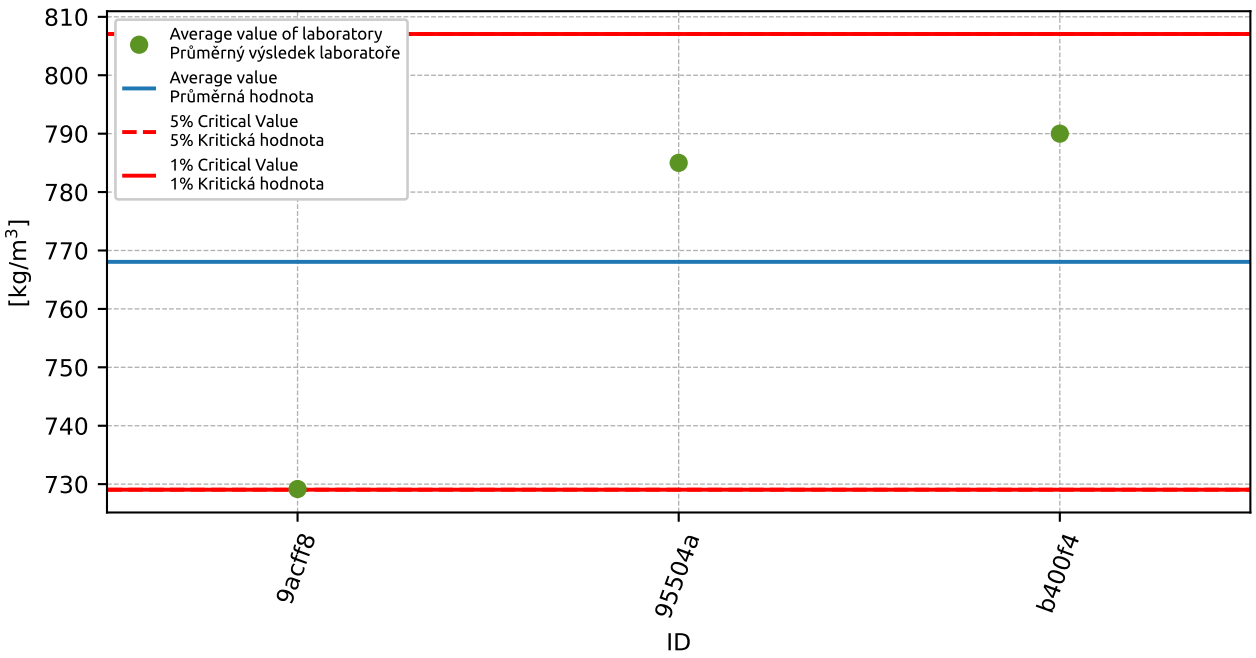

Figure 13: **Grubbs' test** - average values

7.8 Mandel's Statistics

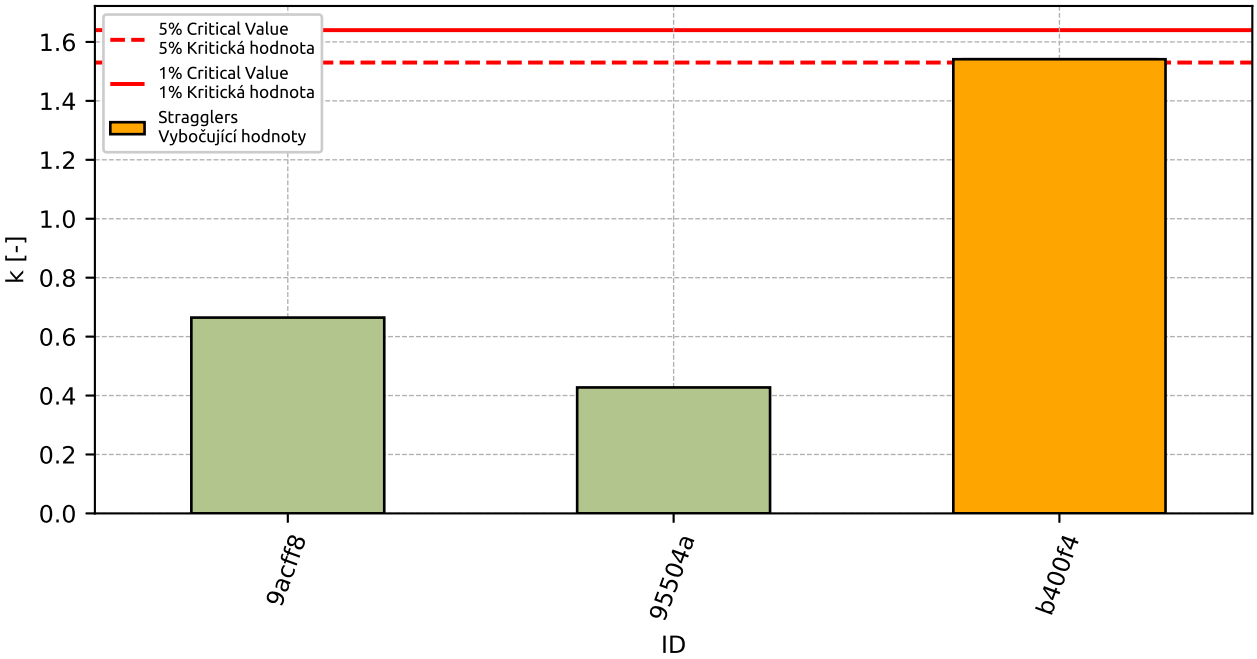

Figure 14: Intralaboratory Consistency Statistic

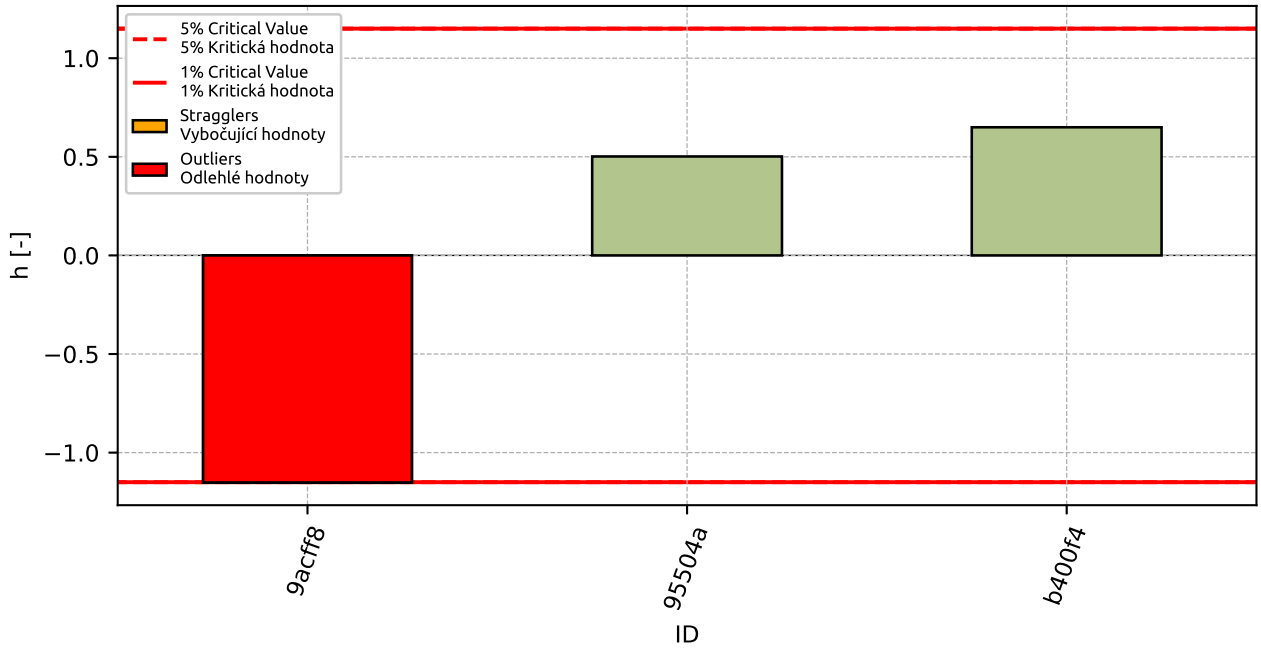

Figure 15: Interlaboratory Consistency Statistic

7.9 Descriptive statistics

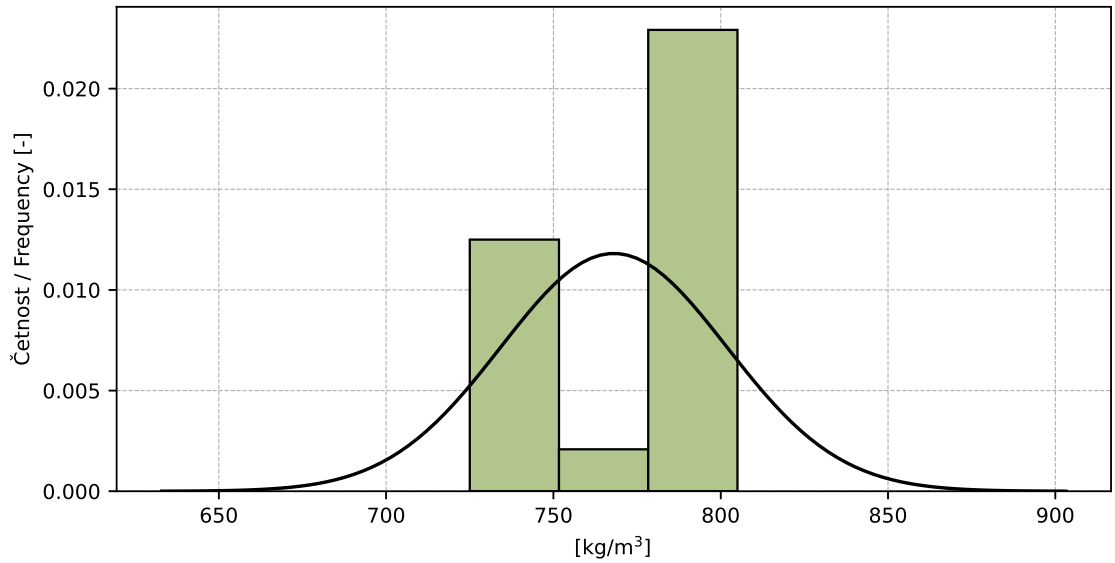

Figure 16: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[N/mm²]
Průměrná hodnota / Average value – $\bar{x}$	768.0
Výběrová směrodatná odchylka / Sample standard deviation – s	33.8
Vztažná hodnota / Asigned value – x^*	783.0
Robustní směrodatná odchylka / Robust standard deviation – s^*	7.6
Nejistota měření vztažné hodnoty / Measurement uncertainty of asigned value – u_X	5.5
p-hodnota testu normality / p-value of normality test	0.002 [-]
Mezilaboratorní sm. odch. / Interlaboratory standard deviation – s_L	33.6
Směrodatná odchylka opakovatelnosti / Repeatability standard deviation – s_r	7.4
Směrodatná odchylka reprodukovatelnosti / Reproducibility standard deviation – s_R	34.4
Opakovatelnost / Repeatability – r	21.0
Reprodukovatelnost / Reproducibility – R	96.0

7.10 Evaluation of Performance Statistics

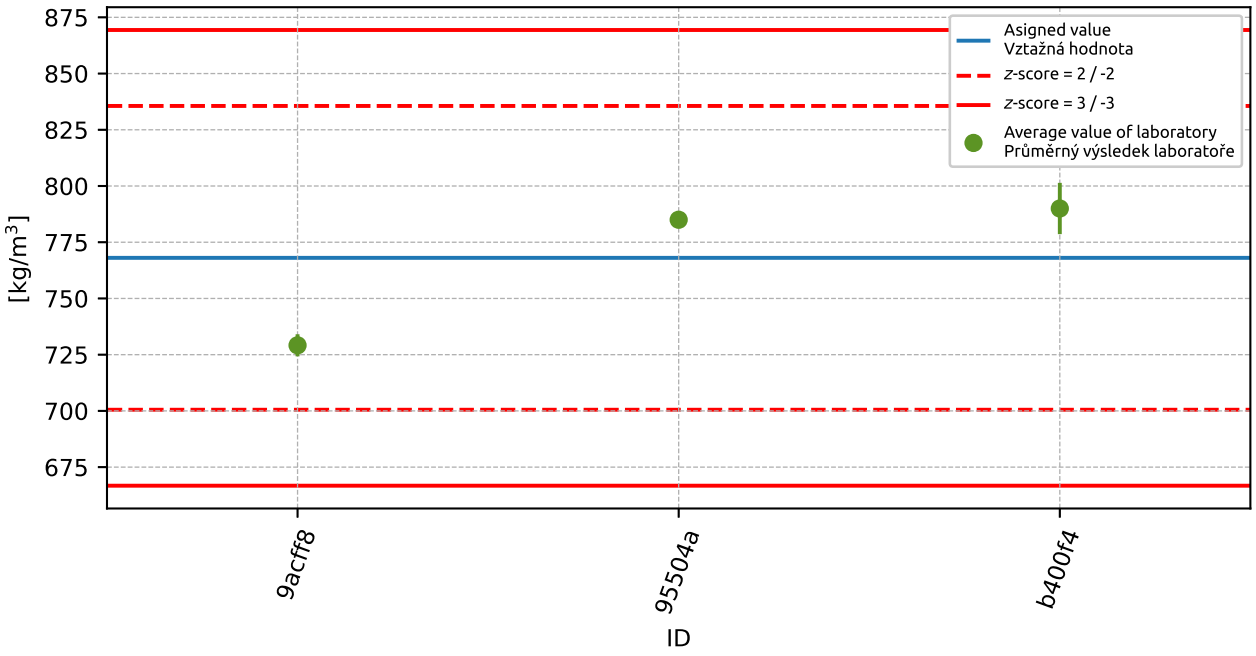

Figure 17: Average values and sample standard deviations

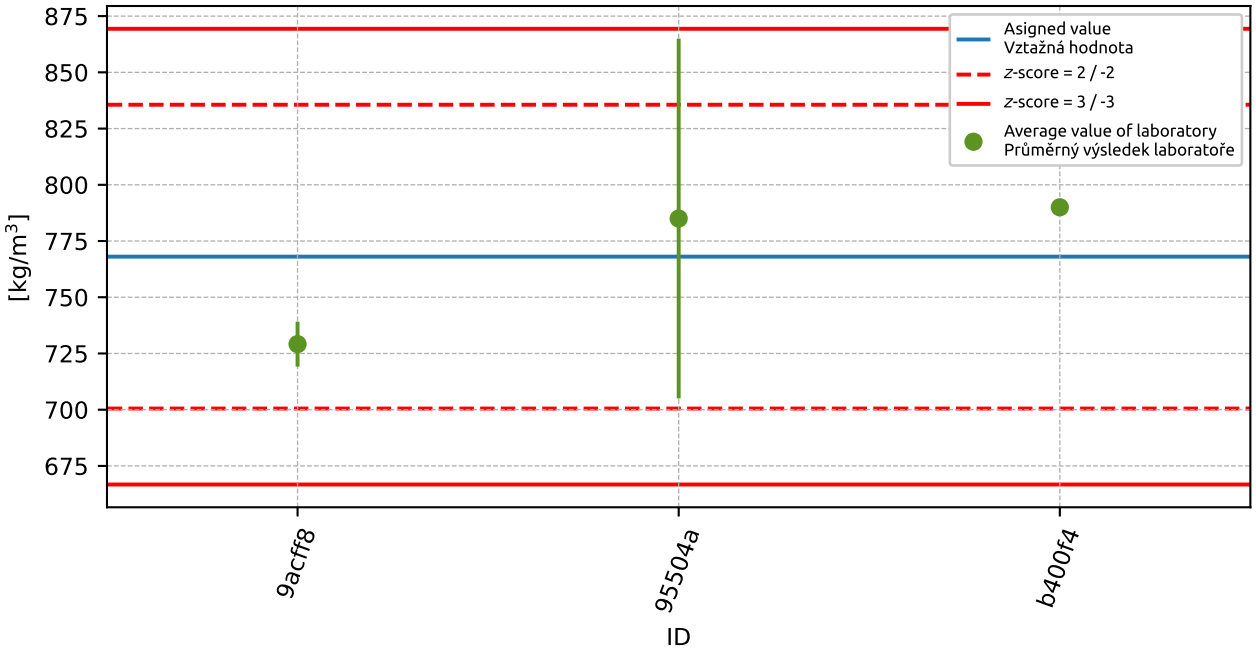

Figure 18: Average values and extended uncertainties of measurement

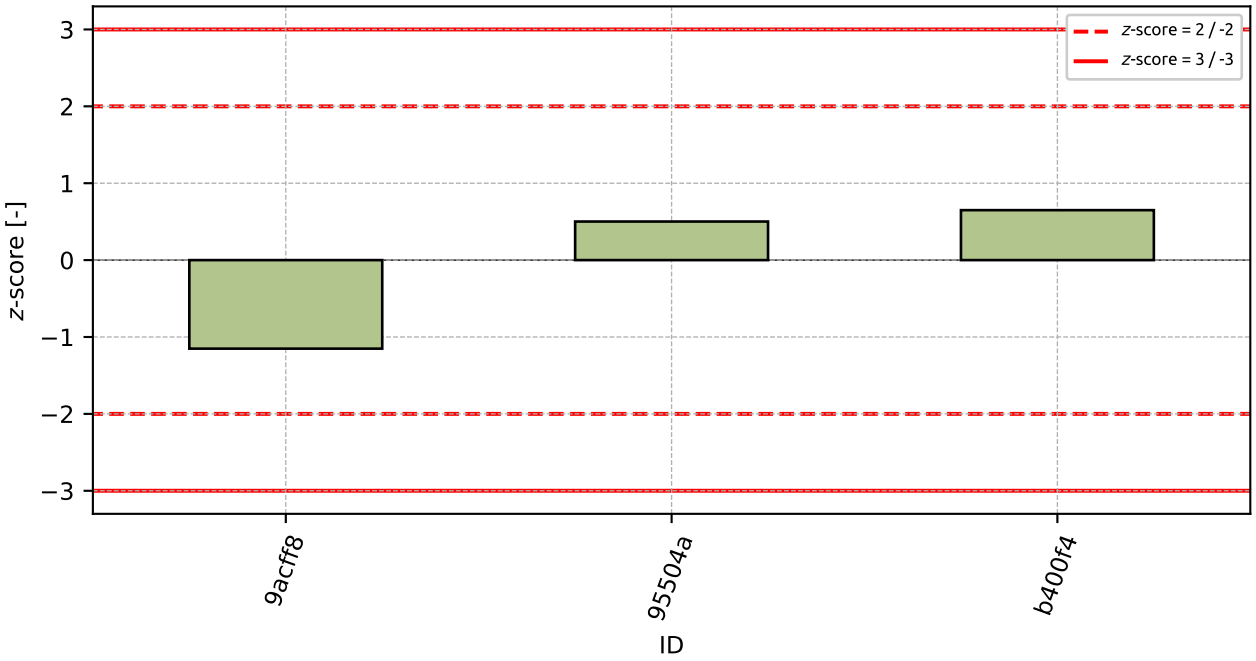

Figure 19: z-score

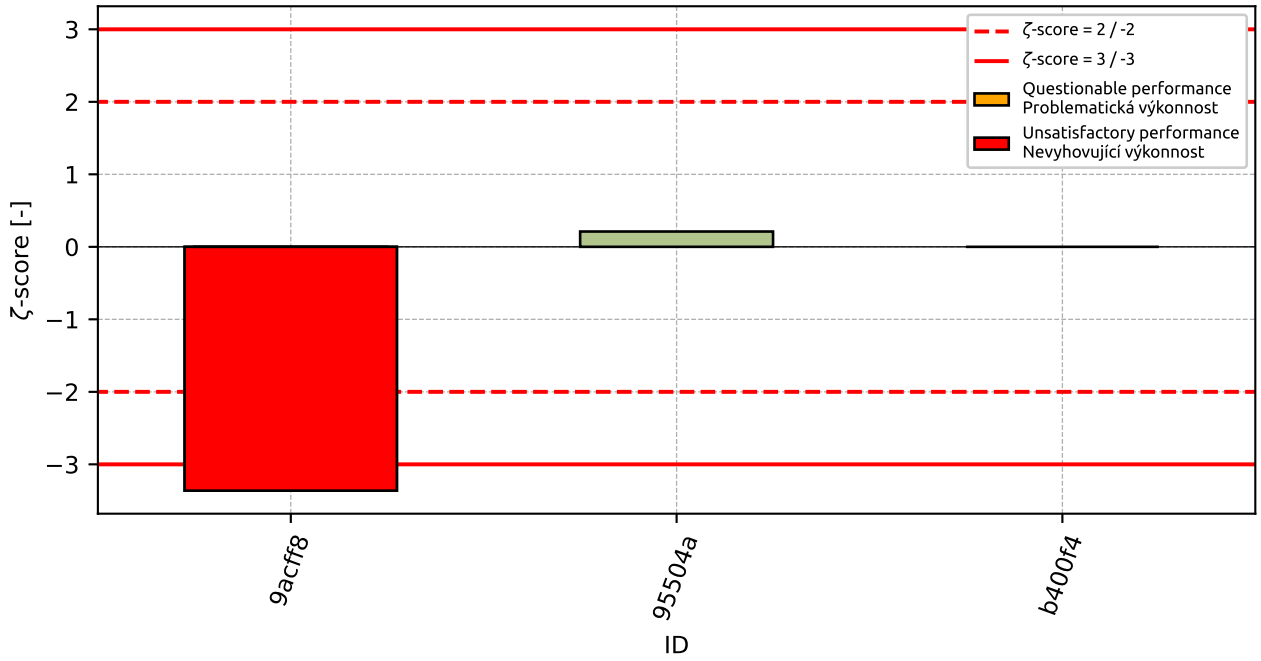

Figure 20: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
9acff8	-1.15	-3.36
95504a	0.5	0.21
b400f4	0.65	-

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.