BRNO UNIVERSITY OF TECHNOLOGY

Z 7008

FACULTY OF CIVIL ENGINEERING
institute of building testing

FINAL REPORT ON THE RESULTS OF INTERLABORATORY COMPARISON

PROFICIENCY TESTING PROGRAM
Strength and Durability of Hardened Concrete

ZZB 2018/1

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

www.szk.fce.vutbr.cz

Date: 6/4/2018

Head of the PT Provider, PTP coordinator

doc. Ing. Tomáš Vymazal, Ph.D.

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

Coordinator of PTP result assessment

Ing. Petr Misák, Ph.D.

Contents

1 Introduction and Important Contacts

In the year 2018, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZZB 2018/1 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

doc. Ing. Tomáš Vymazal, Ph.D.
Brno University of Technology
Faculty of Civil Engineering
Institute of Building Testing
Veveří 95, Brno 602 00
Czech Republic
Tel.: +420 603 313 337
Email: Tomas.Vymazal@vutbr.cz

Coordinator of PTP result assessment PrZZ

Ing. Petr Misák, Ph.D.
Brno University of Technology
Faculty of Civil Engineering
Institute of Building Testing
Veveří 95, Brno 602 00
Czech Republic
Tel.: +420 774 980 255
Email: Petr.Misak@vutbr.cz

The subjects of proficiency testing were the following testing procedures:

1. **EN 12390-3** – Compressive strength of test specimens [1].
2. **EN 12390-7** – Density of hardened concrete [2].
3. **EN 12390-8** – Depth of penetration of water under pressure [3].
4. **EN 480-11** – Determination of air void characteristics in hardened concrete [4].
5. **ČSN 73 1322** – Determination of frost resistance of concrete [5].
6. **ČSN 73 1324** – Determination of grindability of concrete [6].
7. **ČSN 73 1326** – Resistance of cement concrete surface to water and defrosting chemicals – Method A. [7].
8. **ČSN 73 1326** – Resistance of cement concrete surface to water and defrosting chemicals – Method C. [7].
9. **EN 12390-9** – Freeze-thaw resistance – Scaling [8].

Testing procedures No 4 – 6, 8 and 9 were not open due to low number of participants.

The supplier, BETOTECH s. r. o., was responsible for the preparation of hardened concrete for the PTP. Fresh concrete for the preparation of test samples was taken from one production batch prepared in accordance with methods stipulated in EN 206 [9]. Fresh concrete was poured into test molds, which were always of the same type, and after removal from the molds the test specimens were placed under identical conditions in storage rooms complying with the requirements for individual specifications.

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 [10] and with EN ISO/IEC 17043 [11]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

36 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
53b6af	X	X	X	-	-	-	X	-	-
3d5f87	-	-	X	-	-	-	-	-	-
cf32b9	X	X	X	-	-	-	-	-	-
2703fb	X	-	-	-	-	-	-	-	-
e123aa	X	X	X	-	-	-	-	-	-
48db09	X	X	-	-	-	-	-	-	-
389769	X	X	-	-	-	-	-	-	-
bc9be8	-	-	X	-	-	-	X	-	-
49d26d	X	X	-	-	-	-	-	-	-
61c683	X	X	X	-	-	-	X	-	-
fdce76	X	X	X	-	-	-	X	-	-
f97ed1	X	X	X	-	-	-	-	-	-
9b988b	X	X	-	-	-	-	-	-	-
4d33f0	-	X	-	-	-	-	-	-	-
76804e	-	X	-	-	-	-	-	-	-
7afbd4	X	X	X	-	-	-	X	-	-
871adf	X	X	X	-	-	-	-	-	-
473bde	X	X	-	-	-	-	-	-	-
cf22f5	X	X	X	-	-	-	X	-	-
3857c2	X	-	-	-	-	-	-	-	-
cc37b3	-	-	-	-	-	-	X	-	-
c61b13	X	X	-	-	-	-	X	-	-
a84a6a	X	X	-	-	-	-	-	-	-
99a33c	-	-	X	-	-	-	-	-	-
c1731c	X	-	X	-	-	-	-	-	-
6c9825	X	X	X	-	-	-	-	-	-
5aced5	X	X	-	-	-	-	X	-	-
fcad9e	X	X	-	-	-	-	-	-	-
bcb626	-	-	X	-	-	-	-	-	-
8ac9ce	-	X	-	-	-	-	-	-	-
5a6ad7	-	X	-	-	-	-	-	-	-
a4ef89	-	X	-	-	-	-	-	-	-
df4a81	-	X	-	-	-	-	-	-	-
387ddb	X	X	-	-	-	-	-	-	-
94927c	-	X	-	-	-	-	-	-	-
da579b	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
"Zavodski stroezhi Kozloduy" AD	ploshtadka AEC, BGR grad Kozloduy, 3321, Bulgaria	119LI
BASF Stavební hmoty Česká republika s.r.o. - ZLB Praha	K Májovu 1244, Chrudim, 53701, Česká republika	1495

Laboratory	Address	Accreditation number
Betón Racio, s.r.o., Skúšobné labotarórium, Pracovisko Lietavská Lúčka, Žilinská 49/25, 013 11 Lietavská Lúčka, Slovenská republika	Skladová 2, Trnava, 917 01, Slovenská republika	S-320
Betón Racio, s.r.o., Skúšobné labotarórium, Pracovisko Trnava, Skladová 2, 917 01 Trnava, Slovenská republika	Skladová 2, Trnava, 917 01, Slovenská republika	S-320
Betón Racio, s.r.o., Skúšobné labotarórium, Pracovisko Veľký Šariš, Železničná 9, 082 21 Veľký Šariš, Slovenská republika	Skladová 2, Trnava, 917 01, Slovenská republika	S-320
BETOTECH, s. r. o. - pracoviště Brno	Jihlavská 51, Brno, 64200, Česká republika	1195.3
CEMEX Cement, s.r.o.	Semtín 102, Pardubice, 53354, Česká republika	1302
CS-BETON s.r.o. Zkušební laboratoř CS-BETON	Velké Žernoseky 184, Litoměřice, 412 01, Česká republika	1500
DI Shahrokh Winter	Gewerbeparkstraße 5, Markgrafneusiedl, A-2282, Österraich	-
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft.	Pf. 180., Szentendre, 2001, Hungary	NAH-1-1110/2014
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft.	Pf. 180., Szentendre, 2001, Hungary	NAH-1-1110/2014
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft.	Pf. 180., Szentendre, 2001, Hungary	NAH-1-1110/2014
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft.	Pf. 180., Szentendre, 2001, Hungary	NAH-1-1110/2014
ENERGOPROJEKT NISKOGRADNJA AD BEOGRAD	Boulevard Mihaila Pupina 12, New Belgrade, 11070, Republic of Serbia	-
EUROVIA Services, s.r.o.	PO BOX 207, Praha 6, 16041, Česká republika	1170
Geo Measuring & Analyses	Industriepark Rosteyne 1, Zelzate, 9060, Belgium	BELAC 296-TEST
Horský s.r.o.	Klánovická 286/12, Praha 9, 198 00, Česká republika	1207
JSC "Konstrukciju bandymu centras"	J. Basanavičiaus g. 160C, Šiauliai, LT-76128, Lithuania	LA013
LABBET - Betosan s.r.o.	Na Dolinách 42, Praha 4, 140 00, Česká republika	1687
Lafarge Cement, a.s.	Čížkovice čp. 27, Čížkovice, 411 12, Česká republika	1426
MC-Bauchemie s.r.o.	Skandinávská 990, Žebrák, 26753, Česká republika	208
Ředitelství silnic a dálnic ČR	Rebešovická 40, Brno-Chrlice, 643 00, Česká republika	1072
SQZ, s.r.o.	K Výtopně 1226, Praha 5, 156 00, Česká republika	1135.2
STACHEMA Bratislava a.s., Skúšobné laboratórium STACHEMA	Rovinka 411, Rovinka, 900 41, Slovenská republika	S-275
STACHEMA CZ s.r.o., Zkušební laboratoř, Pracoviště 1	Hasičská 1, Zibohlavy, Kolín, 280 02, Česká republika	1433

Laboratory	Address	Accreditation number
STACHEMA CZ s.r.o., Zkušební laboratoř, Pracoviště 2	Hasičská 1, Zibohlavy, Kolín, 280 02, Česká republika	1433
Technický a zkušební ústav stavební Praha s.p.	Hněvkovského 77, Brno, 617 00, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p. (pobočka Ostrava)	U Studia 14, Ostrava - Zábřeh, 700 30, Česká republika	1018.7
Technický a zkušební ústav stavební Praha, s.p. (zkušebna Plzeň)	Zahradní 15, Plzeň, 326 00, Česká republika	1018.3
Technický a zkušební ústav stavební Praha, s.p., Centrální laboratoř, zkušebna 0500 Předměřice nad Labem	Průmyslová 283, Předměřice nad Labem, 503 02, Česká republika	1018.3
TPA za obezbeđenje kvaliteta i inovacije d.o.o. Beograd	Milutina Milankovića 3b, Novi Beograd (New Belgrade), 11070, Srbija (Serbia)	01-280
UAB "Šiaulių plentas" laboratorija	Išradėjų g. 11, Šiauliai, LT 78149, Lithuania	+37041540711
Univerzitet u Zenici, Metalurski institut "Kemal Kapetanovic"	Travnicka cesta br.7, Zenica, 72000, BiH	-
Ústav stavebního zkušebnictví s.r.o.	Jiřího Potůčka 115, Pardubice, 53009, Česká republika	1115
Vilnius Gediminas Technical University (Applied Laboratory of Buildings, Constructions and Materials of Vilnius Gediminas Technical University)	Saulėtekio al. 11, Vilnius, LT-10223, Lithuania	LA.01.098
Výzkumný ústav pozemních staveb - Certifikační společnost, s.r.o.	Pražská 810/16, Praha 10, 102 21, Česká republika	1234

2 Procedures used in the Statistical Analysis of Laboratory Results

To describe the accuracy of measuring methods, the terms trueness and precision are used. Trueness refers to the closeness to congruity between the arithmetic mean of a high number of test results and a real or accepted reference value. Precision means the closeness to congruity between test results. The necessity to consider precision is based on the fact that tests generally do not yield the same results even though they are supposed to be carried out on the same material and under the same conditions. This is caused by accidental errors that are impossible to avoid. These errors represent an integral part of every testing procedure and we are unable to control them fully. The comparative analysis of laboratory data does not focus on assessing the trueness of test results, but first and foremost on their precision. Results are thus compared with one another and not with any reference value or real value.

The basis of the statistical analysis is a critical data assessment complying with ISO 5725-2 [10], i.e. the determination of dubious and outlying values, and other irregularities. This assessment is carried out using mainly Grubbs' and Cochran's tests (numerical evaluation) as well as Mandel's statistics (graphical evaluation). Other observed statistical parameters are interlaboratory dispersion, repeatability dispersion, reproducibility dispersion and related characteristics of repeatability and reproducibility. The outcome of PTP is to assess the performance of participating laboratories in compliance with EN ISO/IEC 17043 [11], consisting of the determination of relative values and their uncertainties and a final comparison with the test results of PTP participants.

A prerequisite for using these methods is the unimodal probability distribution of measured data. Furthermore, p will stand for the number of participating laboratories marked by the index A prerequisite for using these methods is the unimodal probability distribution of measured data. Furthermore, p will stand for the number of participating laboratories marked by the index $i = 1, \ldots, p$, each of which carried out n number of tests., each of which carried out n number of tests.

2.1 The Numerical Procedure for Determining Outliers

To determine outliers, two basic statistical tests are used. One of them is Cochran's C test, which tests interlaboratory variabilities (in cases when the number of measurements of one quantity in one laboratory > 2) and is used first. If this test marks one participant's results as outlying, the laboratory is excluded and the test repeated. The second test (Grubbs' test) is first and foremost a test of interlaboratory variability and we can also employ it if Cochran's test raises the suspicion that only one of the test results is to blame for the high interlaboratory dispersion. Both tests assume a balanced experiment, i.e. the number of tests at one laboratory for the determination of one quantity must be constant.

When determining divergent or outlying values, three situations can occur:

- If the test statistic is within or equal to 5% of the critical value, the tested entity is considered to be *correct*;
- If the test statistic diverges from the critical value by more than 5%, but is within or equal to 1% of the critical value, the tested entity is considered to be *divergent*;
- If the test statistic diverges from the critical value by more than 1%, the tested entity is considered to be *outlying*.

2.1.1 Cochran's test

The Cochran's C statistic is given by the equation:

$$C = \frac{s_{max}^2}{\sum_{i=1}^{p} s_i^2} \tag{1}$$

where s_{max} is the highest sample standard deviation, s_i are sample standard deviations determined according to the results from all laboratories and p means the number of laboratories participating in the PT program.

The sample standard deviation is determined from the equation

$$s_i = \sqrt{\frac{1}{n_i - 1} \sum_{k=1}^{n_i} (y_k - \bar{y})^2}, \tag{2}$$

where n_i is the number of test results from the determination of one quantity in i-th laboratory, y_k is the k-th value and $\bar{y_i}$ is the average value measured in the i-th laboratory. If only two results were measured for the relevant quantity, we can use the simplified equation:

$$s_i = \frac{|y_1 - y_2|}{\sqrt{2}}. \tag{3}$$

2.1.2 Grubbs' test – One Outlying Observation

From the given set of x_i data for $i = 1, 2, ..., p$, ordered upward according to size, Grubbs' statistic G_p is calculated in order to use Grubbs' test to determine whether the largest observation is an outlier:

$$G_p = \frac{x_p - \bar{x}}{s}, \tag{4}$$

whereby $\bar{x}$ is the arithmetic mean of the observed feature. The observed feature can be the average value of the quantity determined within the laboratory. Furthermore, s is a sample standard deviation of the observed feature, which in this case is a standard deviation calculated for all the laboratories.

For significance testing of the smallest observation the test statistic is calculated:

$$G_p = \frac{\bar{x} - x_p}{s}. \tag{5}$$

2.2 Mandel's Statistics

In order to determine data consistency, two values called Mandel's h and k statistics were used. These indicators are commonly used for the graphical evaluation of laboratories in a similar way to a description of variability.

2.2.1 Interlaboratory Consistency Statistic h

For each laboratory, the interlaboratory consistency statistic h was evaluated according to the formula

$$h_i = \frac{\bar{y_i} - \bar{\bar{y}}}{\sqrt{\frac{1}{p-1}\sum_{i=1}^{p_j}\left(\bar{y_i} - \bar{\bar{y}}\right)}}, \tag{6}$$

where $\bar{y_i}$ is the average value for the i-th laboratory, $\bar{\bar{y}}$ is the arithmetic mean of all values and p is the number of laboratories. The values of the h_i statistics were plotted on graphs.

2.2.2 Intralaboratory Consistency Statistic k

The intralaboratory consistency statistic k is calculated from the equation

$$k_i = \frac{s_i\sqrt{p}}{\sqrt{\sum_{i=1}^{p} s_i^2}}, \tag{7}$$

where s_i is a sample standard deviation of values measured at the i-th laboratory. Just as with h statistics, the k values are plotted on graphs.

Study of the graphs displaying h and k values may indicate that certain laboratories show a significantly different ordering of results than other studied laboratories. This is caused by a permanently large and/or permanently small dispersion of results or extreme averages of results across all levels.

2.3 Calculation of Variances Estimates

After the elimination of outliers (of laboratories), we can proceed to the calculation of basic variability characteristics, i.e. repeatability dispersion, interlaboratory dispersion and reproducibility dispersion. These characteristics are stated in the form of standard deviations, i.e. after extracting the root. It is advantageous when the variability characteristics and the observed quantity are of the same physical dimensions.

2.3.1 Repeatability Variance

$$s_r^2 = \frac{\sum_{i=1}^{p}(n_i - 1)s_i^2}{\sum_{i=1}^{p}(n_i - 1)} \tag{8}$$

2.3.2 Interlaboratory Variance

$$s_L^2 = \frac{s_d^2 - s_r^2}{\bar{\bar{n}}}, \tag{9}$$

where

$$s_d^2 = \frac{1}{p-1}\sum_{i=1}^{p} n_i\left(\bar{y_i} - \bar{\bar{y}}\right)^2 \tag{10}$$

and

$$\bar{\bar{n}} = \frac{1}{p-1}\left[\sum_{i=1}^{p} n_i - \frac{\sum_{i=1}^{p} n_i^2}{\sum_{i=1}^{p} n_i}\right]. \tag{11}$$

2.3.3 Reproducibility Variance

$$s_R^2 = s_r^2 + s_L^2, \tag{12}$$

where s_r^2 is repeatability variance and s_l^2 is interlaboratory variance.

2.4 Repeatability and Reproducibility

Repeatability expresses the fact that the difference between two test results from the same sample from tests carried out by the same person at the same facility and within the shortest time interval possible will not exceed the repeatability value r on average more than once in 20 cases if the method is employed in the common and correct manner.

The repeatability value is expressed by the relation

$$r = 2,8 s_r, \tag{13}$$

where $s_r = \sqrt{s_r^2}$ stands for the standard deviation of repeatability.

Reproducibility expresses the fact that the reproducibility value R for test results from one sample obtained in the shortest time interval possible by two persons who used their own devices will not differ on average more than once in 20 cases if the method is employed in the common and correct manner.

The reproducibility value is expressed by the relation

$$R = 2,8 s_R, \tag{14}$$

where $s_R = \sqrt{s_R^2}$ stands for the standard deviation of reproducibility.

2.5 Assigned Values

The PT Provider will ensure the determination of assigned value X and its uncertainty for every PTP. Assigned values are always only imparted to PTP participants after they have submitted their PTP results so that they cannot obtain any benefit from the premature revelation of the values.

The assigned values are determined by the PT Provider as consensual values derived from the results of participants in compliance with Appendix B of EN ISO/IEC 17043 [11] using the statistical methods described in ISO 13528 [12] and ISO 5725-5 [13]. The assigned value X is therefore determined as a robust estimate of the average value x^* (the A algorithm mentioned in [12] and [13]):

Initial values x^* and s^* (robust standard deviation) are calculated as

$$x^* = \text{median } x_i, \tag{15}$$

$$s^* = 1,483 \cdot \text{median } |x_i - x^*|, \tag{16}$$

where $i = 1, \ldots, p$. The values of x^* and s^* are then processed as follows. First, $\varphi = 1,5 \cdot s^*$ is computed. For every x_i $(i = 1, \ldots, p)$ value, the following is calculated

$$x_i^* = \begin{cases} x^* - \varphi & \text{if } x_i < x^* - \varphi, \\ x^* + \varphi & \text{if } x_i > x^* + \varphi, \\ x_i & \text{in other cases.} \end{cases} \tag{17}$$

New values of x^* and s^* are calculated from the following equations

$$x^* = \sum_{i=1}^{p} \frac{x_i^*}{p}, \tag{18}$$

$$s^* = 1,134 \cdot \sqrt{\sum_{i=1}^{p} \frac{(x_i^* - x^*)^2}{p-1}}. \tag{19}$$

Robust estimates are derived by iteration until the estimate changes between calculations become small.

The standard uncertainty u_X of an assigned value determined in this manner is calculated from the relation

$$u_X = 1,25 \cdot \frac{s^*}{\sqrt{p}}. \tag{20}$$

In the case of a small number of PTP participants, the PT Provider sets the assigned values as consensual values obtained from expert participants who have proven their competence to determine the measured quantity that is the subject of testing.

Furthermore, if the number of participants is small ($4\ p\ 20$), the PT Provider can consider determining the relative values by using what is called **Horn's method**. This method consists in the determination of so-called pivots used as a basis for estimating location and variability. First, the assessed data are ordered upwards. The low pivot is then determined from the equation

$$x_D = x_{(H)}, \tag{21}$$

where H is an ordinal index given by the equation $H = \frac{\text{int}\left(\frac{p+1}{2}\right)}{2}$ or $H = \frac{\text{int}\left(\frac{p+1}{2}+1\right)}{2}$.

The upper pivot is then determined from the equation

$$x_H = x_{p+1-H}. \tag{22}$$

Using Horn's method, the assigned value is determined as a location estimate, i.e. as the so-called pivot half sum:

$$x^* = \frac{x_D + x_H}{2}. \tag{23}$$

The variability estimate is determined as the so-called pivot range

$$R_L = x_H - x_D \tag{24}$$

and the uncertainty of an assigned value calculated in this way is determined as a 95% interval estimate of the mean value

$$u_X = R_L \cdot t_{L;0,95}(p), \tag{25}$$

where $t_{L;0,95}(p)$ is the $(1-\alpha)$ quantile of the T_L probability distribution with p degrees of freedom.

2.6 Calculation of Performance Statistics

Proficiency test results often need to be transformed into performance statistics in order to aid interpretation and to allow comparison with defined objectives. The aim is to express the divergence from the assigned value in a way that enables its comparison with performance criteria. In compliance with the EN ISO/IEC 17043 standard [11], the performance of participating laboratories is evaluated according to the so-called z-score and ζ-score (zeta-score).

For every non-outlying laboratory (participant), the z-score is calculated according to the equation

$$z_i = \frac{|\bar{x_i} - x^*|}{s^*}. \tag{26}$$

ζ-score is calculated using the equation

$$\zeta_i = \frac{|\bar{x_i} - x^*|}{\sqrt{u_i^2 + u_X^2}}, \tag{27}$$

where u_i is a combined standard uncertainty of the i-th laboratory. Combined standard measurement uncertainties can be arrived at by dividing the extended uncertainty U by the extension coefficient k, which for normal probability division has the value $k = 2$. If the participant does not state the extended measurement uncertainty in their test result protocol, it is impossible to determine the ζ-score. For more about measurement uncertainties see document [14].

The following scales are applied for the z-score and ζ-score (to simplify the matter, only the z-score is shown):

$$z\text{-score} = \begin{cases} |z| \leq 2 & \text{shows that the laboratory performance is } \textbf{satisfactory} \text{ and generates no signal;} \\ 2 \leq |z| \leq 3 & \text{shows that the laboratory performance is } \textbf{questionable} \text{ and generates an action signal;} \\ 3 \leq |z| & \text{shows that the laboratory performance is } \textbf{unsatisfactory} \text{ and generates an action signal.} \end{cases} \tag{28}$$

3 Conclusions of the Statistical Analysis

The present report summarizes the results of the Proficiency Testing Program ZZB 2018/1 (PT Program) organized by the PT Provider at the SZK FAST, Brno University of Technology. 36 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.

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. The assigned value and its uncertainty were determined according to the procedures stated in the section 2.6. z-score and ζ-score are compared with limit values (see part 2.6). 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.

3.1 EN 12390-3 – Compressive strength of test specimens

The test results are shown together with graphic presentation and evaluated statistical characteristics in part 1 of the Appendix.

The numerical critical evaluation of the test results using Grubbs' test has shown that results of participants **fcad9e** and **5aced5** exceeded the 1% critical value. The test result of these participants were **excluded as outlying**. After removal the critical values of Grubbs' test were no longer exceeded. Graphical determination of the consistency of laboratories (Mandel's statistics) has not shown an exceedance of the critical values.

The assigned value and its uncertainty was determined using the A algorithm (ISO 13258 [12]). The results of all non outlying participants did not exceed the limit value of z-score $= 2$ and thus can be rated as **satisfactory**.

3.2 EN 12390-7 – Density of hardened concrete

The test results are shown together with graphic presentation and evaluated statistical characteristics in part 2 of the Appendix.

The numerical critical evaluation of the test results using Cochran's test has shown that results of participant a4ef89 exceeded the 1% critical value. A more detailed analysis has revealed that the outlying variability of this participant was caused by one test result only; after its removal the critical values of Cochran's test were no longer exceeded.

The numerical critical evaluation of the test results using Grubbs' test has not shown the exceedance of critical values. Graphical determination of the consistency of laboratories (Mandel's statistics) has shown an exceedance of the critical value in the test results from some participants. 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. None of the participants were therefore excluded.

The assigned value and its uncertainty was determined using the A algorithm (ISO 13258 [12]). The limit value z-score $= 3$ was exceeded in the case of participants **a4ef89**, **fcad9e** and **473bde**. The performance of these participants was rated as **unsatisfactory**. The limit value z-score $= 2$ was exceeded in the case of participants **8ac9ce** and **e123aa**. The performance of these participants was rated as **questionable**. The results of all other participants did not exceed the limit value of z-score $= 2$ and thus can be rated as **satisfactory**.

3.3 EN 12390-8 – Depth of penetration of water under pressure

The test results are shown together with graphic presentation and evaluated statistical characteristics in part 3 of the Appendix.

The numerical critical evaluation of the test results using Cochran's test has shown that results of participant 871adf exceeded the 1% critical value. A more detailed analysis has revealed that the outlying variability of these participants was caused by one test result only; after its removal the critical values of Cochran's test were no longer exceeded. Participant 871adf was not therefore excluded. The numerical critical evaluation of the test results using Grubbs' test has not shown the exceedance of critical values.

Graphical determination of the consistency of laboratories (Mandel's statistics) has shown an exceedance of the critical value in the test results from some participants. 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. None of the participants were therefore excluded.

The assigned value and its uncertainty was determined using the A algorithm (ISO 13258 [12]). The limit value z-score $= 2$ was exceeded in the case of participant **da579b**. The performance of this participant was rated as **questionable**. The results of all other participants did not exceed the limit value of z-score $= 2$ and thus can be rated as **satisfactory**.

3.4 EN 480-11 – Determination of air void characteristics in hardened concrete

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

3.5 ČSN 73 1322 – Determination of frost resistance of concrete

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

3.6 ČSN 73 1324 – Determination of grindability of concrete

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

3.7 ČSN 73 1326 – Resistance of cement concrete surface to water and defrosting chemicals – Method A

The resistance of cement concrete surface to water and defrosting chemicals was tested in 4 levels given by number of freezing and thawing cycles – 25, 50, 75 and 100 cycles. The test results were evaluated separately for each level (see part 7 of appendix).

The numerical critical evaluation of the test results using Cochran's test has shown that results of participant 53b6af exceeded the 1% critical value. A more detailed analysis has revealed that the outlying variability of these participants was caused by one test result only; after its removal the critical values of Cochran's test were no longer exceeded. Participant 53b6af was not therefore excluded. The numerical critical evaluation of the test results using Grubbs' test has not shown the exceedance of critical values.

Graphical determination of the consistency of laboratories (Mandel's statistics) has shown an exceedance of the critical value in the test results from some participants. 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. None of the participants were therefore excluded.

The assigned value and its uncertainty was determined using the A algorithm (ISO 13258 [12]). The results of all participants did not exceed the limit value of z-score $= 2$ and thus can be rated as **satisfactory**.

3.8 ČSN 73 1326 – Resistance of cement concrete surface to water and defrosting chemicals – Method C

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

3.9 ČSN P CEN/TS 12390-9 – Freeze-thaw resistance – Scaling

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

References

[1] EN 12390-3. *Testing hardened concrete - Part 3: Compressive strength of test specimens*. 2009.

[2] EN 12390-7. *Testing hardened concrete - Part 7: Density of hardened concrete*. 2009.

[3] EN 12390-8. *Testing hardened concrete - Part 8: Depth of penetration of water under pressure*. 2009.

[4] EN 480-11. *Admixtures for concrete, mortar and grout - Test methods - Part 11: Determination of air void characteristics in hardened concrete*. 2006.

[5] ČSN 73 1322. *Determination of frost resistance of concrete*. 2003.

[6] ČSN 73 1324. *Determination of grindability of concrete*. 2003.

[7] ČSN 73 1326. *Resistance of cement concrete surface to water and defrosting chemicals*. 2003.

[8] CEN/TS 12390-9. *Testing hardened concrete - Part 9: Freeze-thaw resistance - Scaling*. 2007.

[9] EN 206. *Concrete - Specification, performance, production and conformity*. 2014.

[10] 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.

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

[12] ISO 13 528. *Statistical methods for use in proficiency testing by interlaboratory comparisons*. 2005.

[13] ISO 5725-5. *Accuracy (trueness and precision) of measurement methods and results - Part 5: Alternative methods for the determination of the precision of a standard measurement method*. 1999.

[14] EA 4/02. *Vyjadřování nejistot měření při kalibracích*. 2000.

1 Appendix – EN 12390-3 – Compressive strength of test specimens

1.1 Test results

Table 3: Test results - ordered by average value. Outliers are marked by star. 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
of participant	[N/mm^2]			[N/mm^2]	[N/mm^2]	[N/mm^2]	[%]
fcad9e*	44.0	44.0	47.1	0.5	45.0	1.8	3.97
5aced5*	49.0	50.9	47.0	3.9	49.0	2.0	3.98
49d26d	51.1	52.0	53.3	-	52.1	1.1	2.14
6c9825	51.2	51.8	53.5	2.1	52.2	1.2	2.29
53b6af	50.1	52.4	54.5	-	52.3	2.2	4.21
2703fb	53.2	52.9	51.2	0.2	52.4	1.1	2.06
871adf	53.5	51.0	53.0	0.1	52.5	1.3	2.52
7afbd4	52.0	52.2	54.6	2.6	52.9	1.4	2.73
473bde	52.5	54.6	52.6	-	53.2	1.2	2.23
c1731c	52.2	53.9	54.1	0.8	53.4	1.0	1.96
61c683	56.2	51.5	53.7	3.0	53.8	2.4	4.37
da579b	55.4	52.6	53.5	2.5	53.8	1.4	2.66
cf32b9	53.4	53.6	54.7	2.5	53.9	0.7	1.30
fdce76	52.6	55.5	53.8	-	54.0	1.5	2.70
e123aa	53.6	53.4	55.0	0.7	54.0	0.9	1.61
389769	53.6	55.7	53.4	0.7	54.2	1.3	2.35
48db09	54.6	56.1	52.1	0.6	54.3	2.0	3.72
c61b13	54.5	54.1	54.5	2.3	54.4	0.2	0.42
9b988b	53.7	54.4	55.1	2.6	54.4	0.7	1.29
f97ed1	51.4	55.6	57.1	-	54.7	3.0	5.40
a84a6a	56.4	53.8	54.2	1.4	54.8	1.4	2.55
387ddb	55.4	54.4	54.6	4.5	54.8	0.5	0.97
cf22f5	56.3	56.2	52.2	3.1	54.9	2.3	4.26
3857c2	57.7	55.2	53.6	2.5	55.5	2.1	3.72

1.2 The Numerical Procedure for Determining Outliers

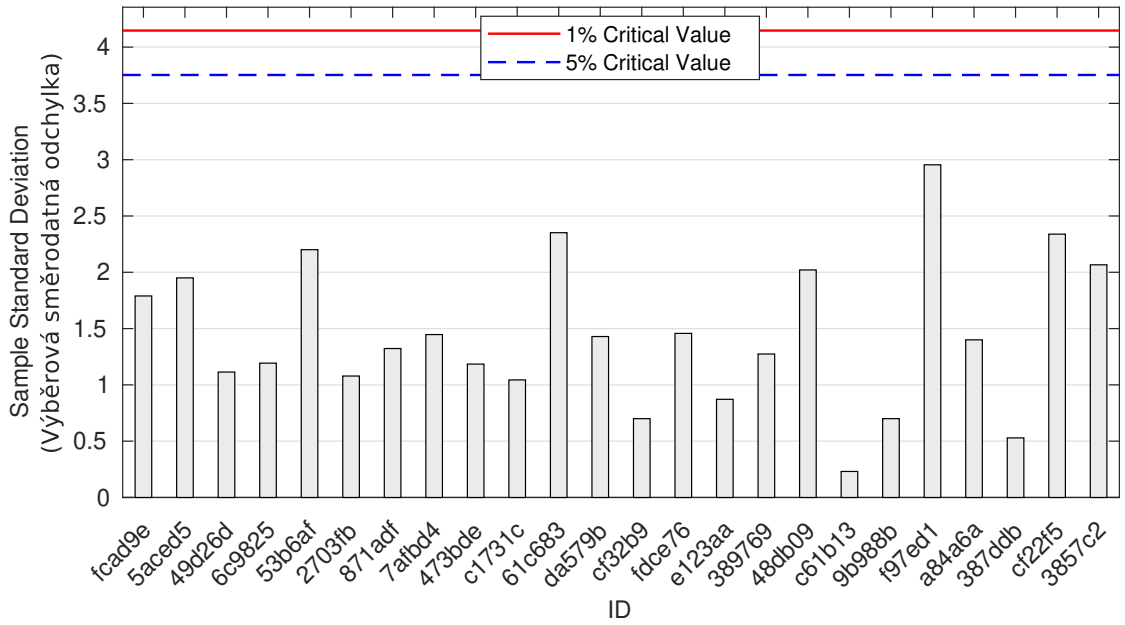

Figure 1: **Cochran's test** - sample standard deviations: 1% critical value - red color; 5% critical value - blue color

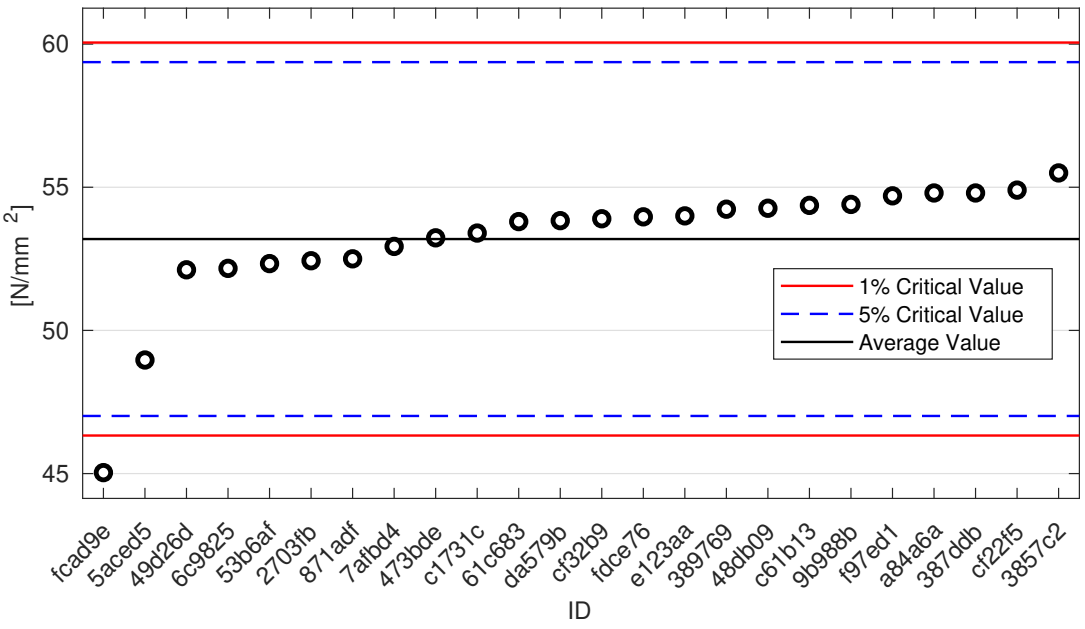

Figure 2: **Grubbs' test** - average values: 1% critical value - red color; 5% critical value - blue color

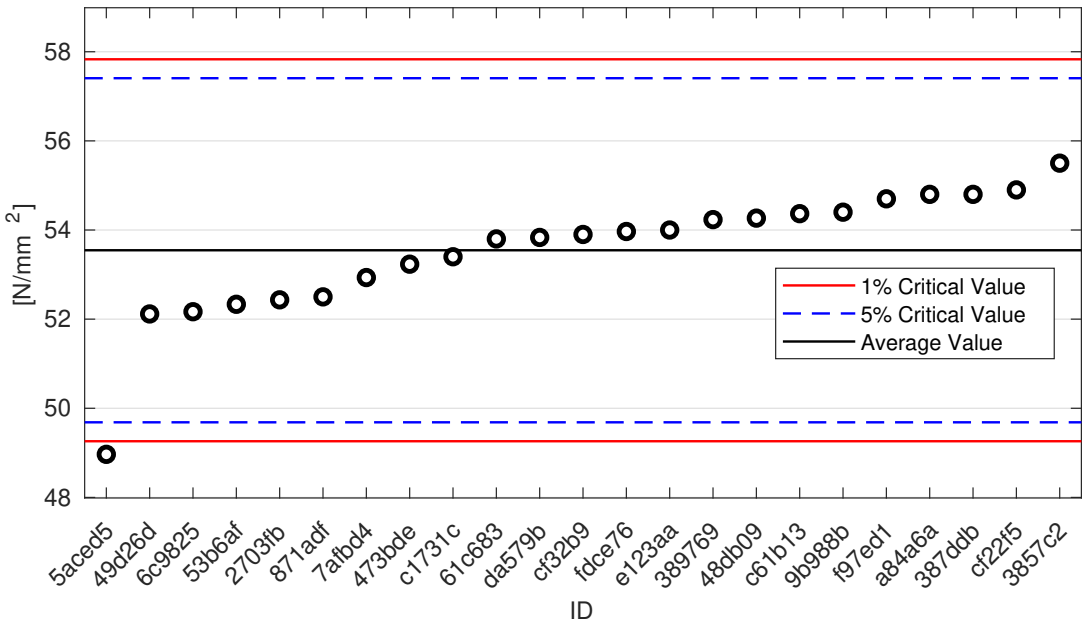

Figure 3: **Grubbs' test** - average values without outliers: 1% critical value - red color; 5% critical value - blue color

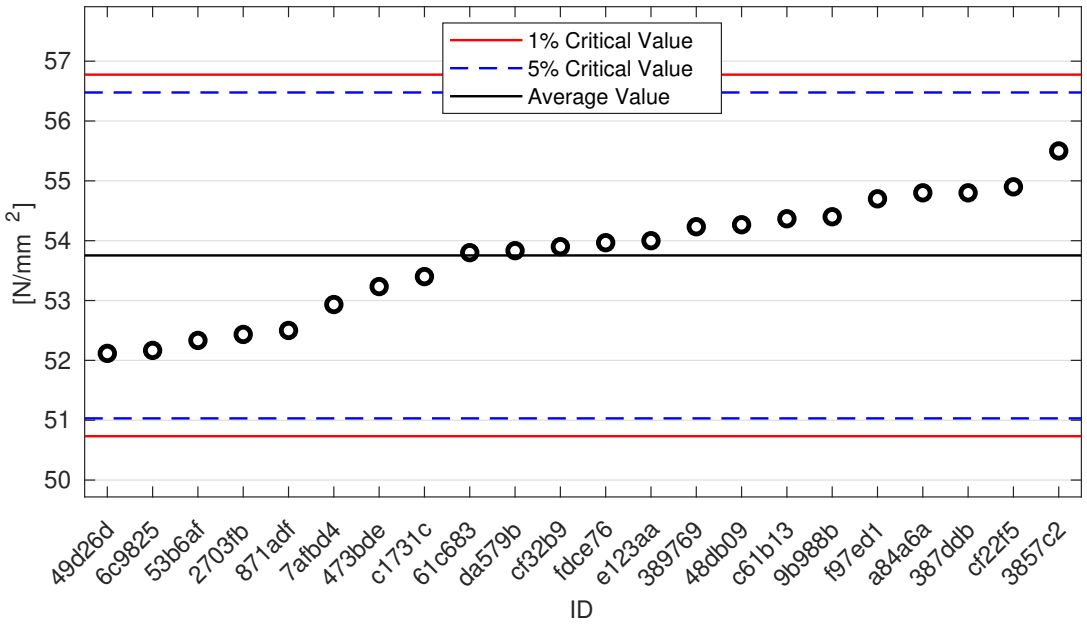

Figure 4: **Grubbs' test** - average values without outliers: 1% critical value - red color; 5% critical value - blue color

1.3 Mandel's Statistics

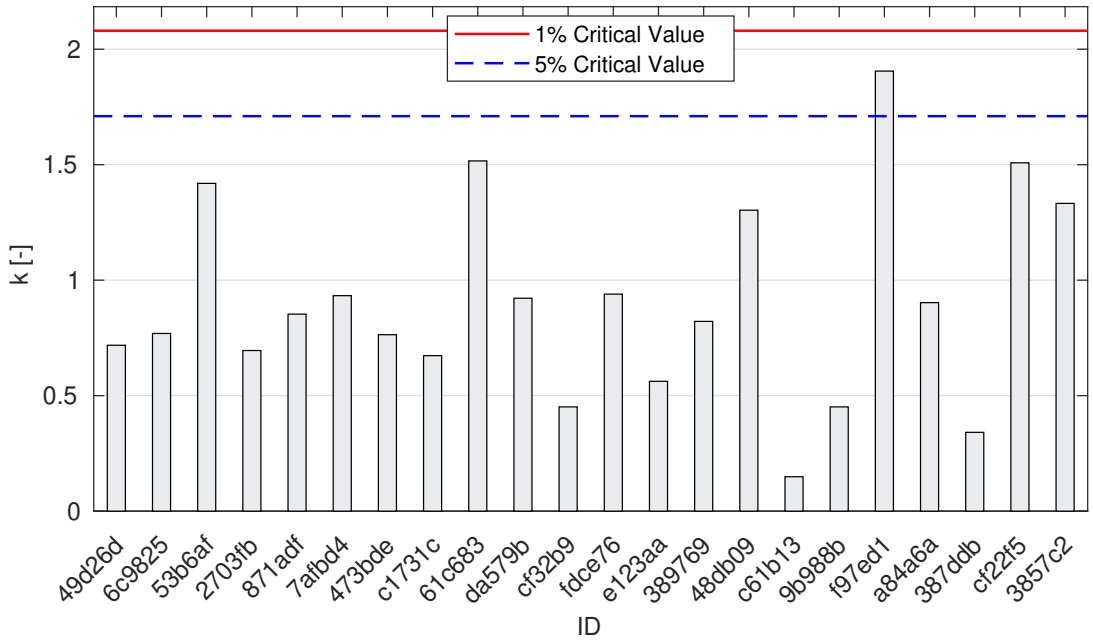

Figure 5: Intralaboratory Consistency Statistic k: 1% critical value - red color; 5% critical value - blue color

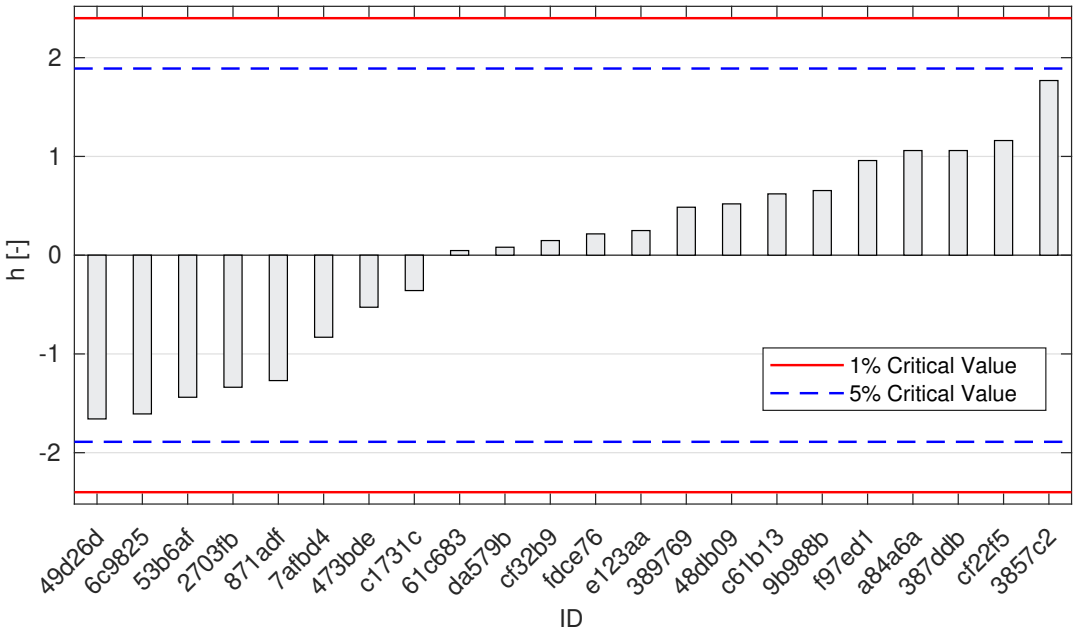

Figure 6: Interlaboratory Consistency Statistic h: 1% critical value - red color; 5% critical value - blue color

1.4 Calculation of Performance Statistics

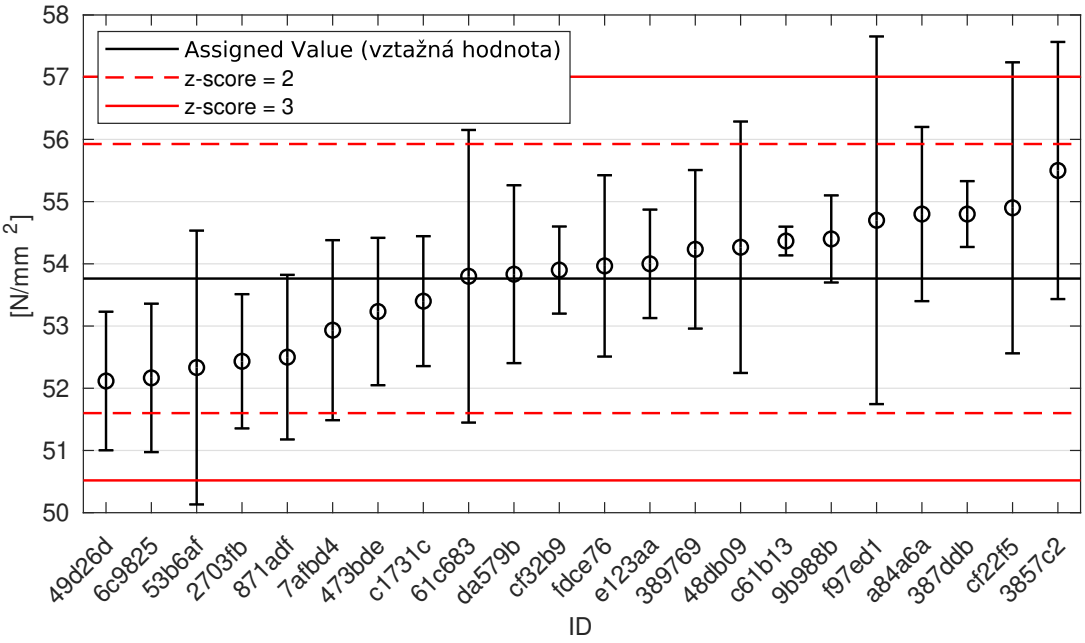

Figure 7: Average values and sample standard deviations

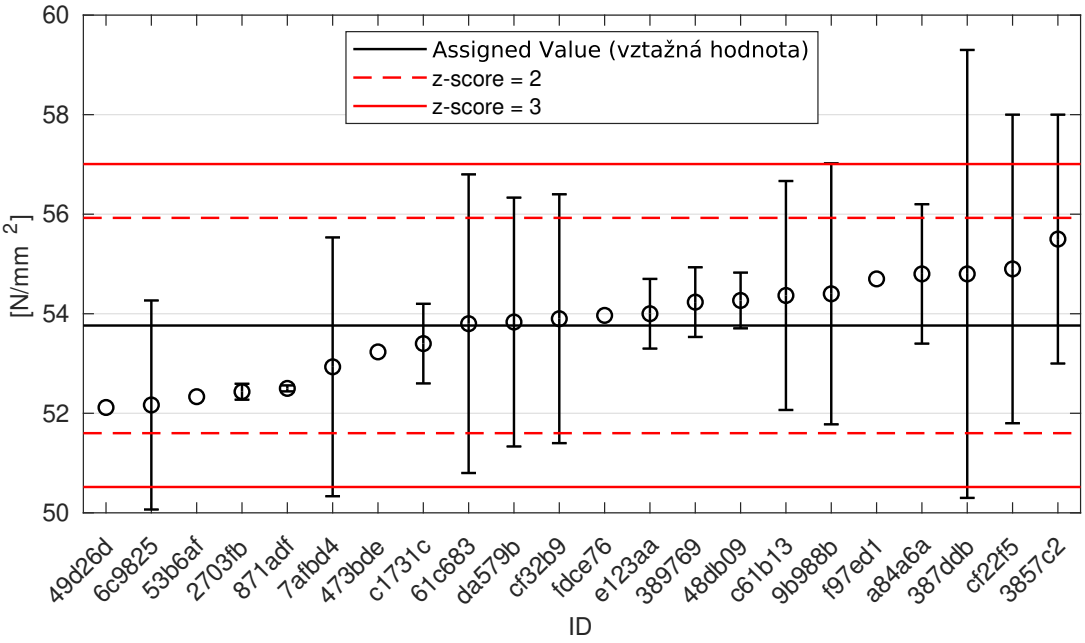

Figure 8: Average values and extended uncertainties of measurement

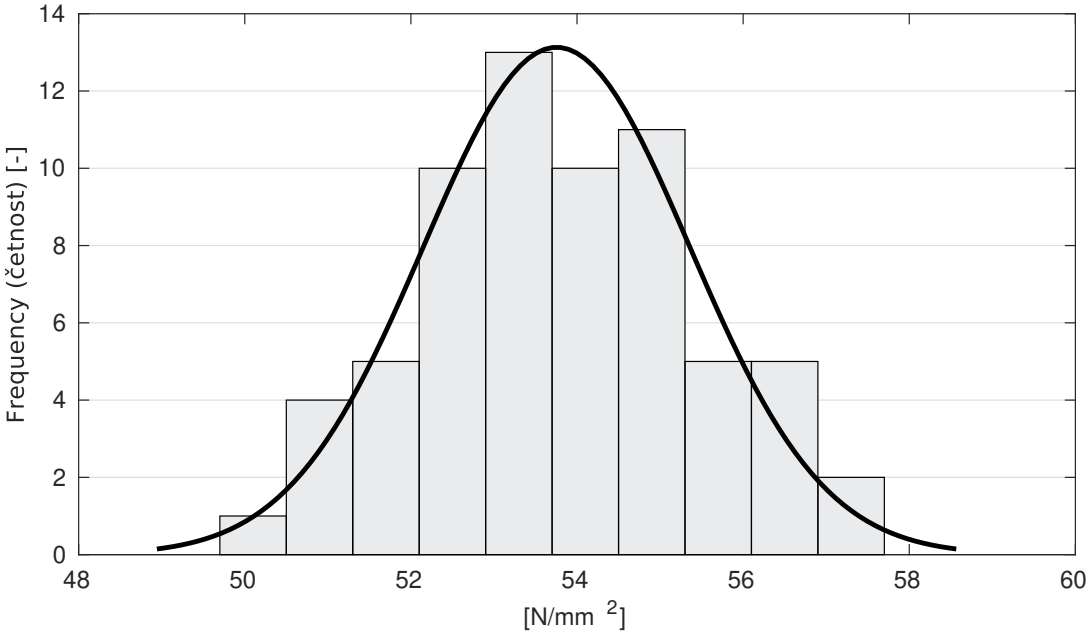

Figure 9: Histogram of all test results

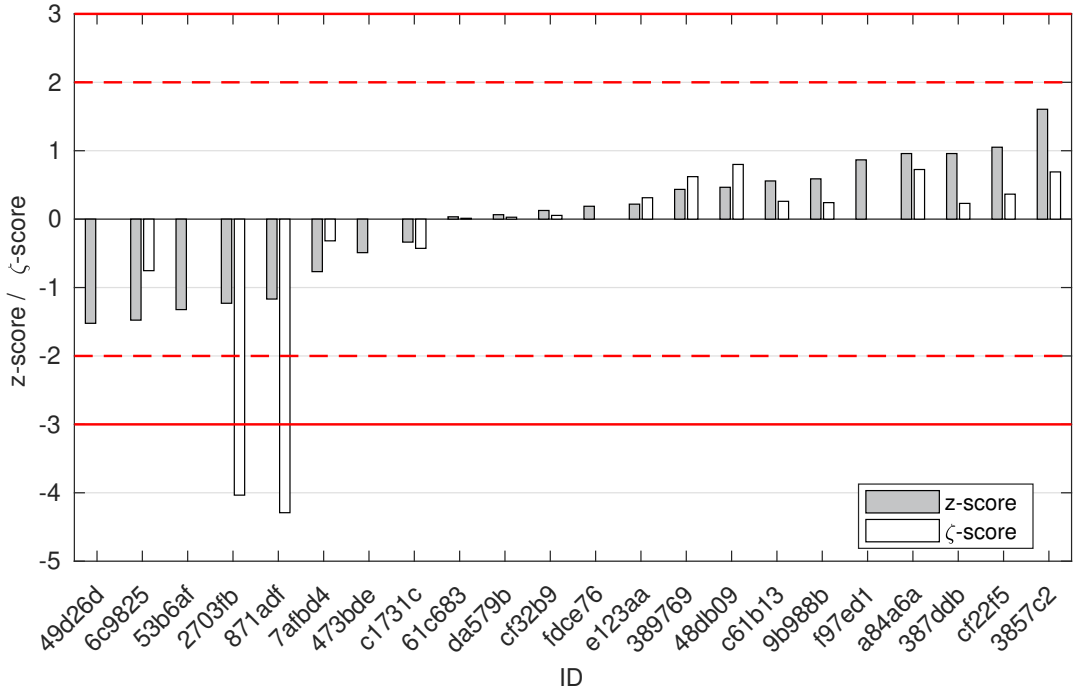

Figure 10: z-score and ζ-score

Table 4: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
49d26d	-1.52	-
6c9825	-1.48	-0.75
53b6af	-1.32	-
2703fb	-1.23	-4.03
871adf	-1.17	-4.29
7afbd4	-0.77	-0.32
473bde	-0.49	-
c1731c	-0.34	-0.43
61c683	0.03	0.01
da579b	0.06	0.03
cf32b9	0.13	0.05
fdce76	0.19	-
e123aa	0.22	0.31
389769	0.43	0.62
48db09	0.47	0.80
c61b13	0.56	0.26
9b988b	0.59	0.24
f97ed1	0.87	-
a84a6a	0.96	0.73
387ddb	0.96	0.23
cf22f5	1.05	0.37
3857c2	1.61	0.69

2 Appendix – EN 12390-7 – Density of hardened concrete

2.1 Test results

Table 5: Test results - ordered by average value. Outliers are marked by star. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID of participant	Test results [kg/m^3]			u_X [kg/m^3]	$\bar{x}$ [kg/m^3]	s_0 [kg/m^3]	V_X [%]
8ac9ce	2305	2306	2313	179	2308	4	0.19
e123aa	2320	2300	2310	10	2310	10	0.43
a4ef89	2310	2350*	2280	860	2313	35	1.52
9b988b	2310	2310	2330	111	2317	12	0.50
5aced5	2310	2310	2330	23	2317	12	0.50
fdce76	2320	2330	2320	-	2323	6	0.25
871adf	2320	2330	2320	0	2323	6	0.25
a84a6a	2320	2330	2320	60	2323	6	0.25
53b6af	2320	2320	2340	-	2327	12	0.50
cf32b9	2330	2310	2340	20	2327	15	0.66
c61b13	2320	2330	2330	16	2327	6	0.25
6c9825	2320	2330	2330	31	2327	6	0.25
df4a81	2330	2320	2339	235	2330	10	0.41
48db09	2330	2330	2330	4	2330	0	0.00
61c683	2330	2340	2330	10	2333	6	0.25
f97ed1	2310	2340	2350	-	2333	21	0.89
4d33f0	2330	2330	2340	20	2333	6	0.25
94927c	2326	2341	2334	-	2334	7	0.32
49d26d	2335	2339	2330	-	2335	5	0.19
389769	2327	2341	2342	19	2337	8	0.36
76804e	2330	2340	2340	20	2337	6	0.25
7afbd4	2340	2340	2330	41	2337	6	0.25
5a6ad7	2340	2320	2350	19	2337	15	0.65
cf22f5	2340	2344	2336	6	2340	4	0.17
387ddb	2330	2340	2350	100	2340	10	0.43
da579b	2340	2340	2340	18	2340	0	0.00
fcad9e	2370	2360	2360	2	2363	6	0.24
473bde	2380	2350	2370	-	2367	15	0.65

2.2 The Numerical Procedure for Determining Outliers

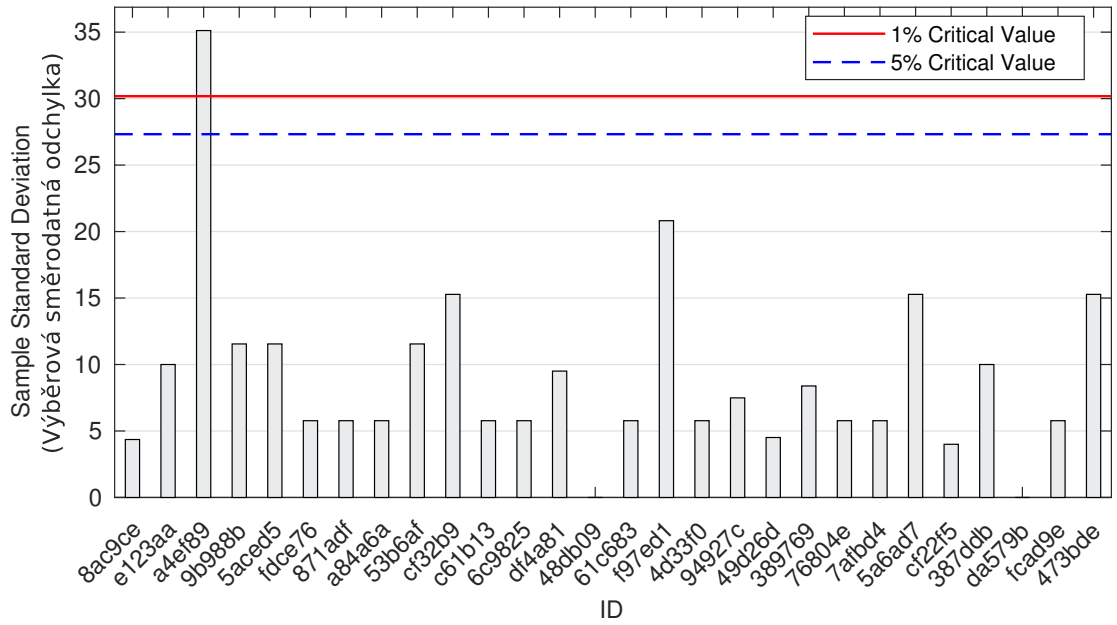

Figure 11: **Cochran's test** - sample standard deviations: 1% critical value - red color; 5% critical value - blue color

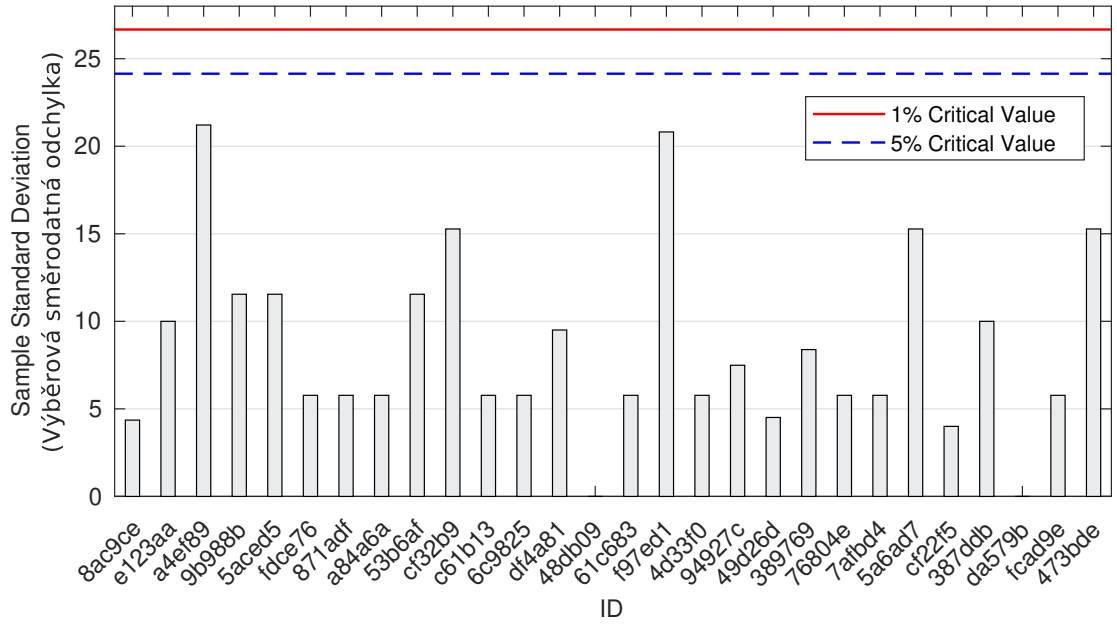

Figure 12: **Cochran's test** - sample standard deviations without outliers: 1% critical value - red color; 5% critical value - blue color

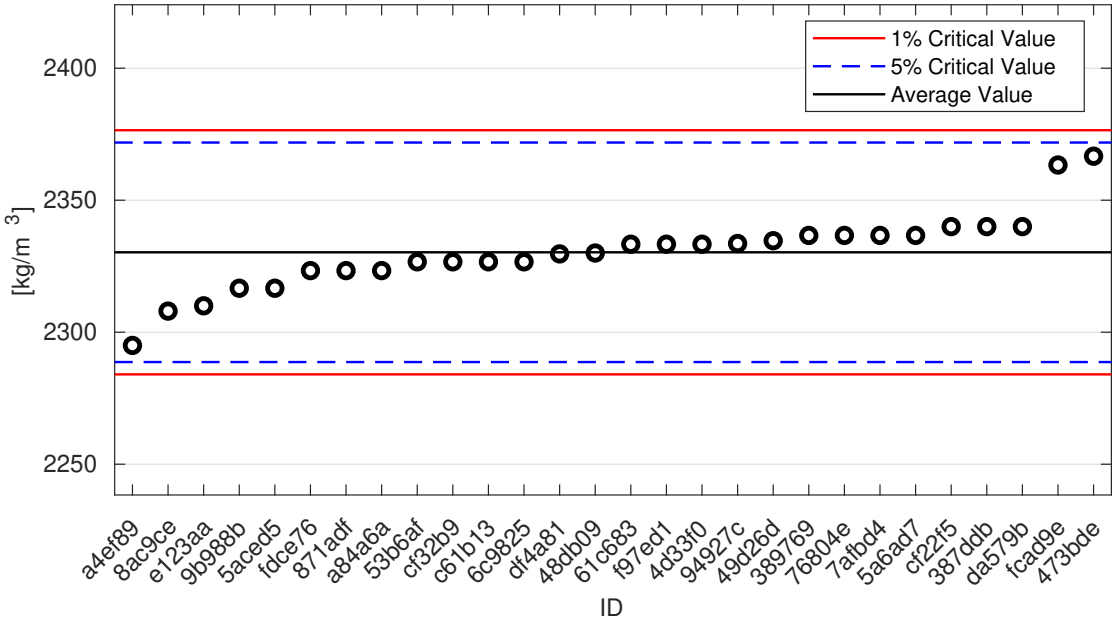

Figure 13: **Grubbs' test** - average values: 1% critical value - red color; 5% critical value - blue color

2.3 Mandel's Statistics

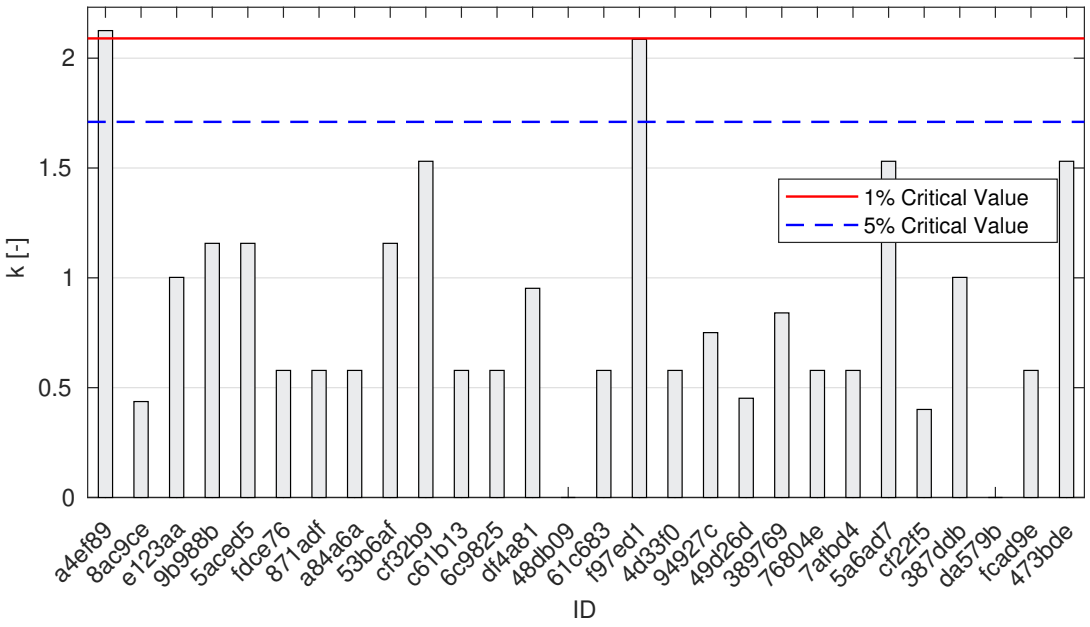

Figure 14: Intralaboratory Consistency Statistic k: 1% critical value - red color; 5% critical value - blue color

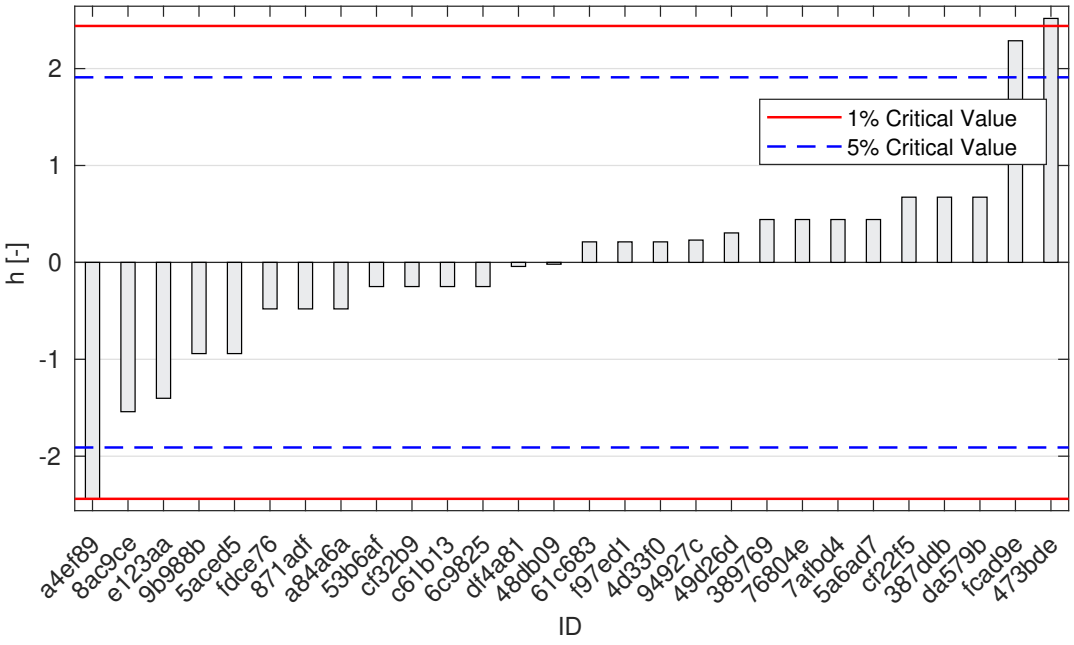

Figure 15: Interlaboratory Consistency Statistic *h*: 1% critical value - red color; 5% critical value - blue color

2.4 Calculation of Performance Statistics

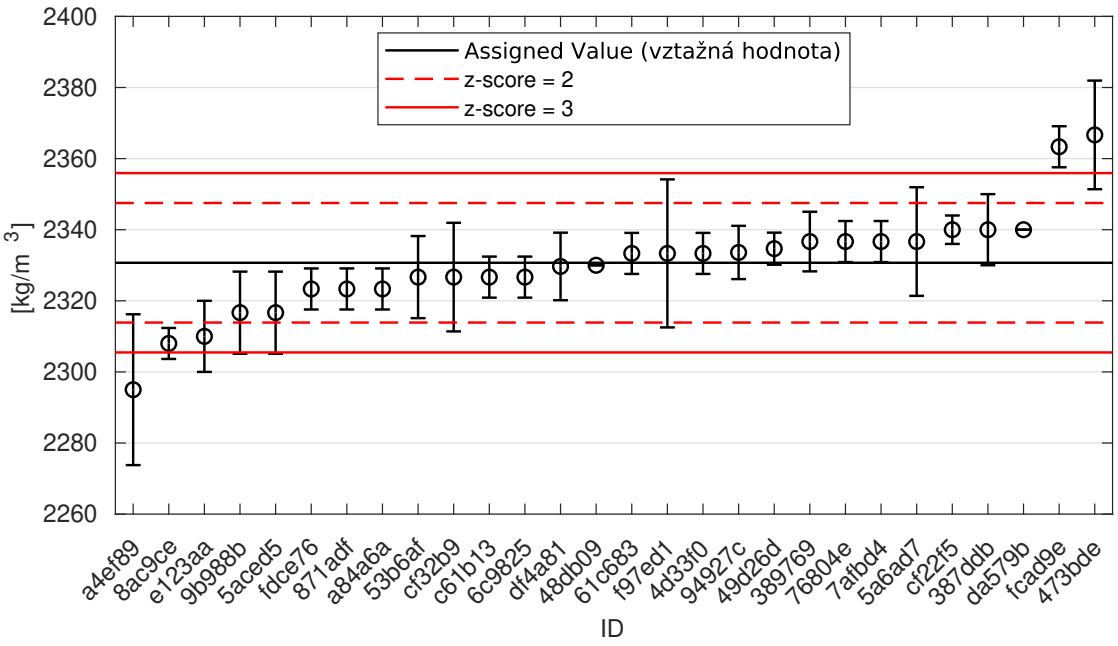

Figure 16: Average values and sample standard deviations

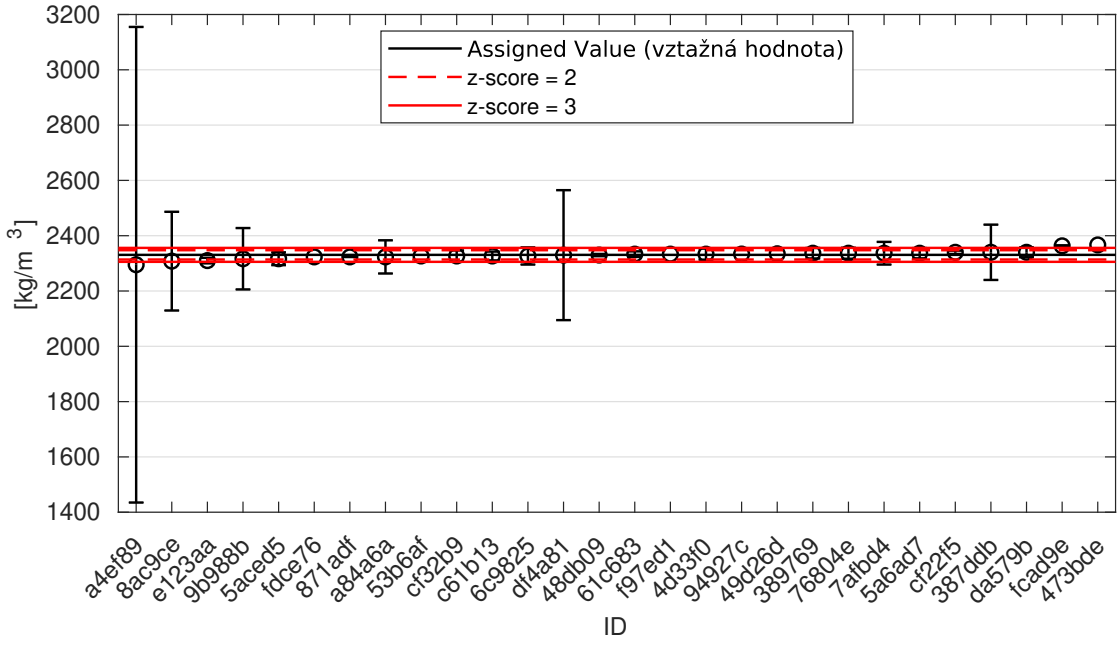

Figure 17: Average values and extended uncertainties of measurement

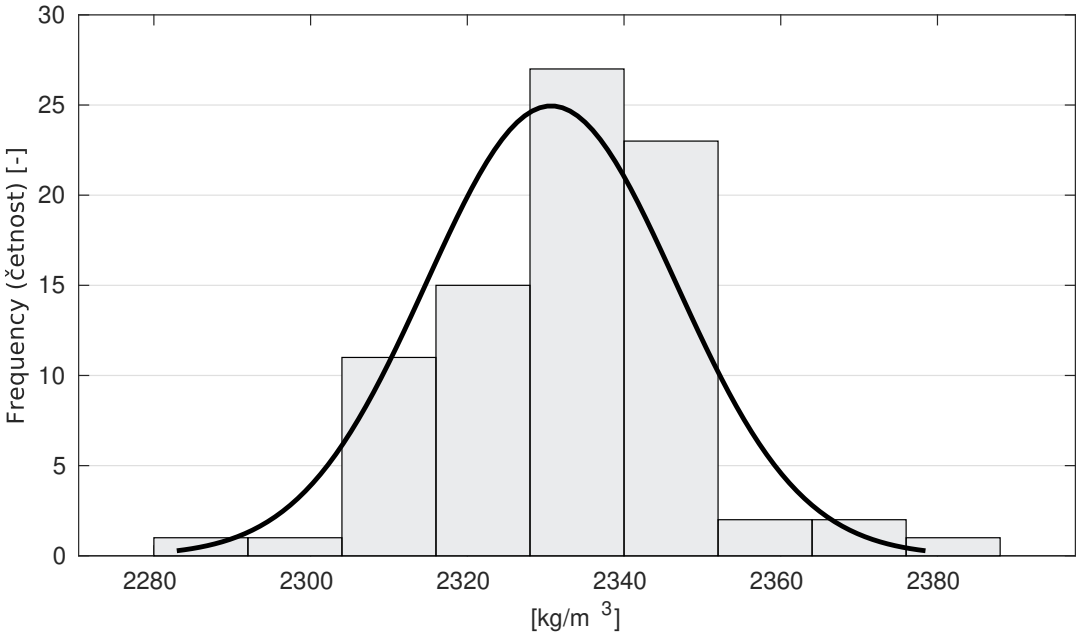

Figure 18: Histogram of all test results

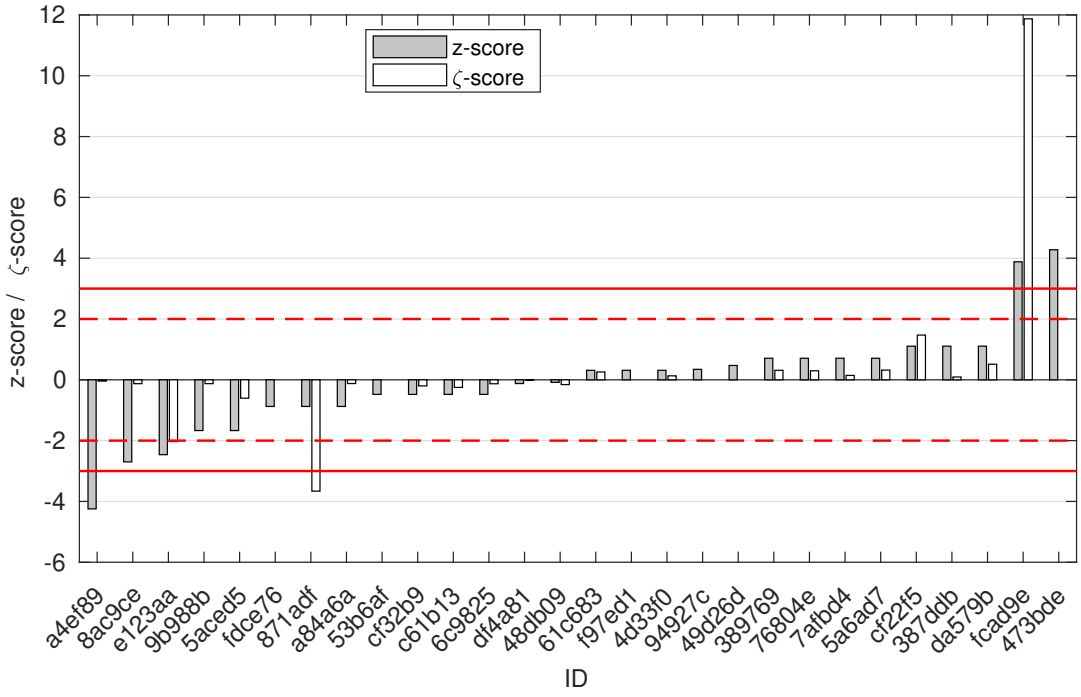

Figure 19: z-score and ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
a4ef89	-4.25	-0.04
8ac9ce	-2.70	-0.13
e123aa	-2.46	-2.03
9b988b	-1.67	-0.13
5aced5	-1.67	-0.60
fdce76	-0.88	-
871adf	-0.88	-3.66
a84a6a	-0.88	-0.12
53b6af	-0.48	-
cf32b9	-0.48	-0.20
c61b13	-0.48	-0.25
6c9825	-0.48	-0.13
df4a81	-0.12	-0.00
48db09	-0.08	-0.16
61c683	0.31	0.26
f97ed1	0.31	-
4d33f0	0.31	0.13
94927c	0.35	-
49d26d	0.47	-
389769	0.71	0.31
76804e	0.71	0.30
7afbd4	0.71	0.15
5a6ad7	0.71	0.32
cf22f5	1.11	1.47
387ddb	1.11	0.09
da579b	1.11	0.51
fcad9e	3.88	11.87
473bde	4.28	-

3 Appendix – EN 12390-8 – Depth of penetration of water under pressure

3.1 Test results

Table 7: Test results - ordered by average value. Outliers are marked by star. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID of participant	Test results [mm]			u_X [mm]	$\bar{x}$ [mm]	s_0 [mm]	V_X [%]
f97ed1	10	8	9	-	9	1	11.11
6c9825	10	11	12	2	11	1	9.09
e123aa	12	13	9	1	11	2	18.37
61c683	15	12	8	2	12	4	30.10
bc9be8	13	11	12	2	12	1	8.33
3d5f87	12	13	14	1	13	1	7.69
c1731c	21	9	11	0	14	6	47.04
bcb626	11	18	15	0	15	4	23.94
cf32b9	15	16	15	2	15	1	3.77
871adf	7	10	30*	0	16	13	79.81
fdce76	17	15	17	-	16	1	7.07
53b6af	17	17	18	-	17	1	3.33
7afbd4	18	17	18	3	18	1	3.27
cf22f5	20	16	17	2	18	2	11.78
99a33c	24	18	28	2	23	5	21.57
da579b	26	17	32	3	25	8	30.20

3.2 The Numerical Procedure for Determining Outliers

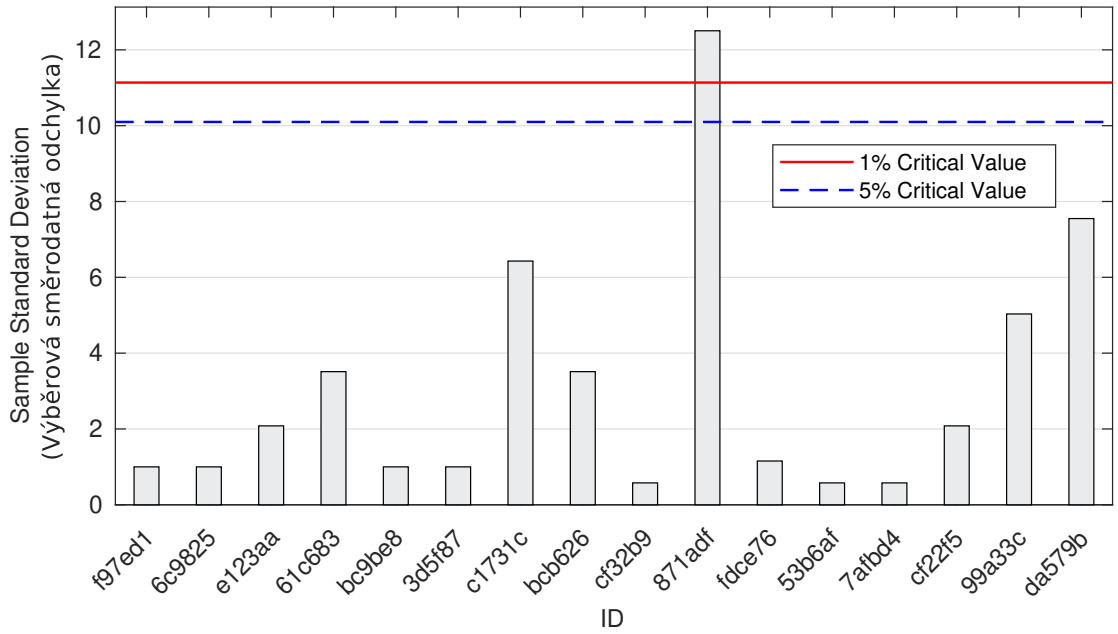

Figure 20: **Cochran's test** - sample standard deviations: 1% critical value - red color; 5% critical value - blue color

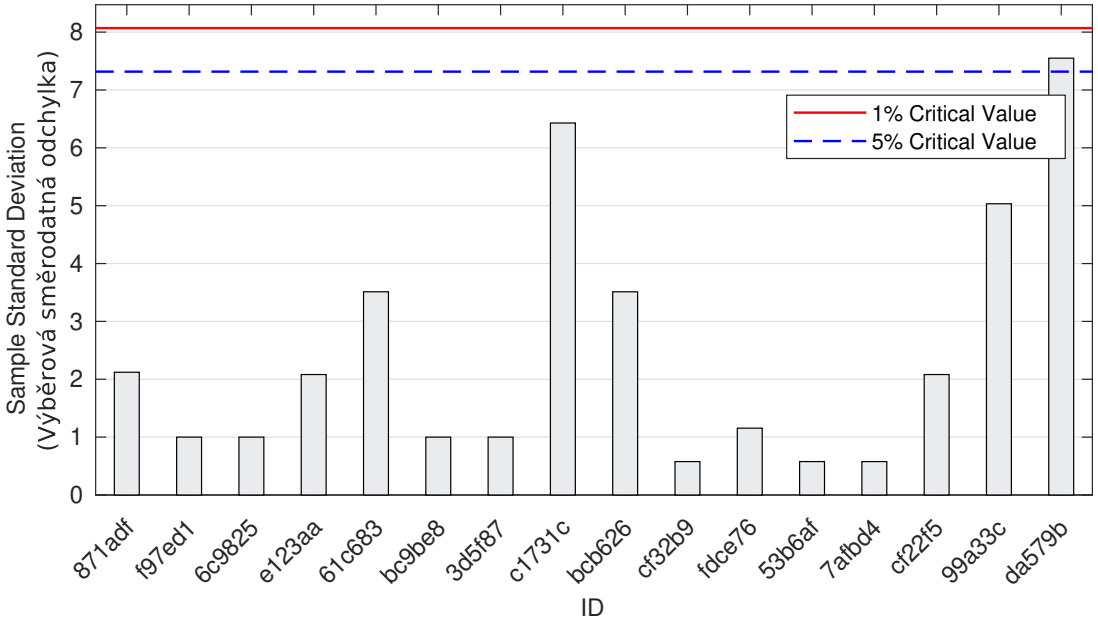

Figure 21: **Cochran's test** - sample standard deviations without outliers: 1% critical value - red color; 5% critical value - blue color

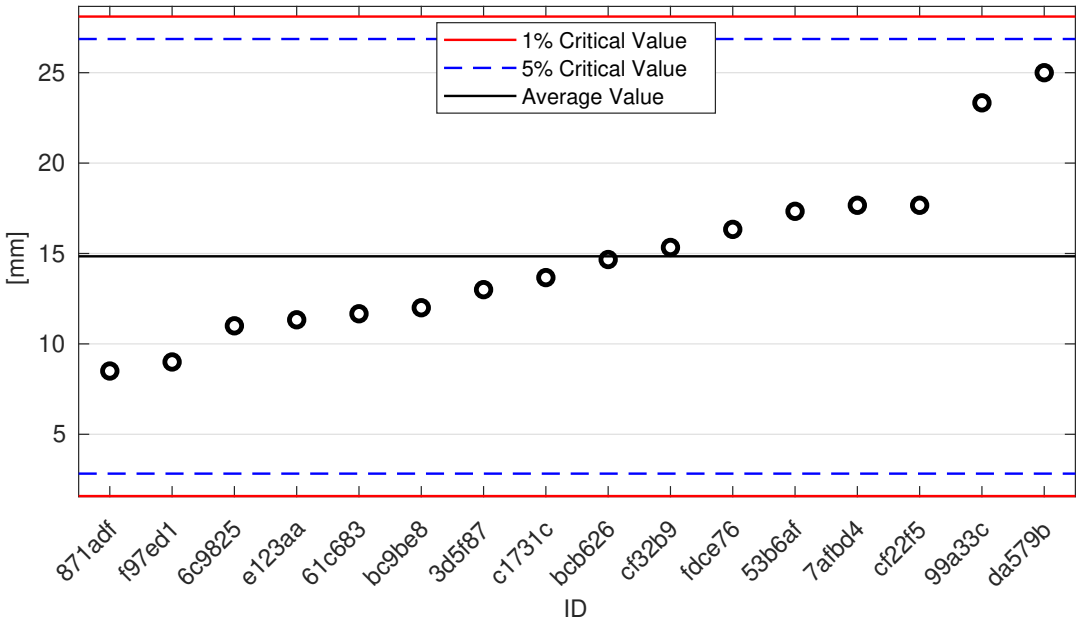

Figure 22: **Grubbs' test** - average values: 1% critical value - red color; 5% critical value - blue color

3.3 Mandel's Statistics

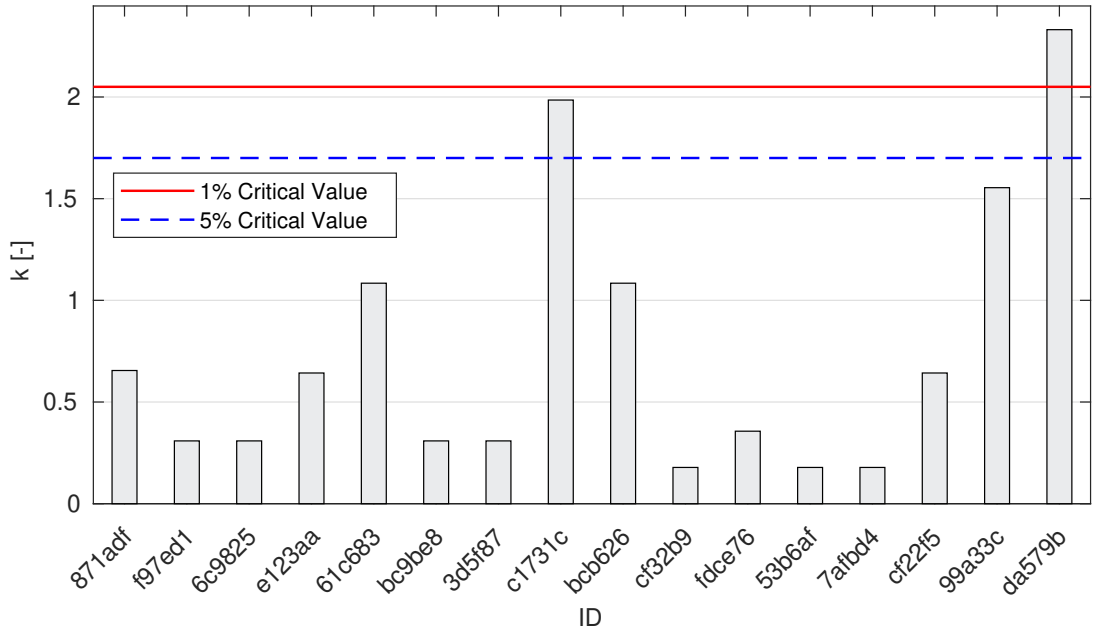

Figure 23: Intralaboratory Consistency Statistic *k*: 1% critical value - red color; 5% critical value - blue color

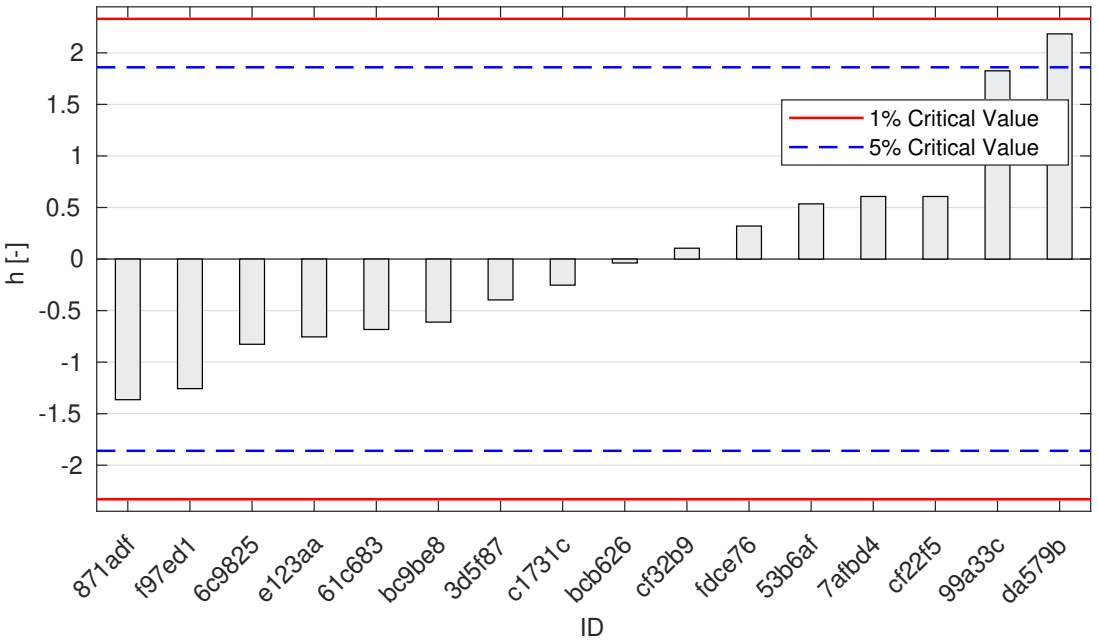

Figure 24: Interlaboratory Consistency Statistic *h*: 1% critical value - red color; 5% critical value - blue color

3.4 Calculation of Performance Statistics

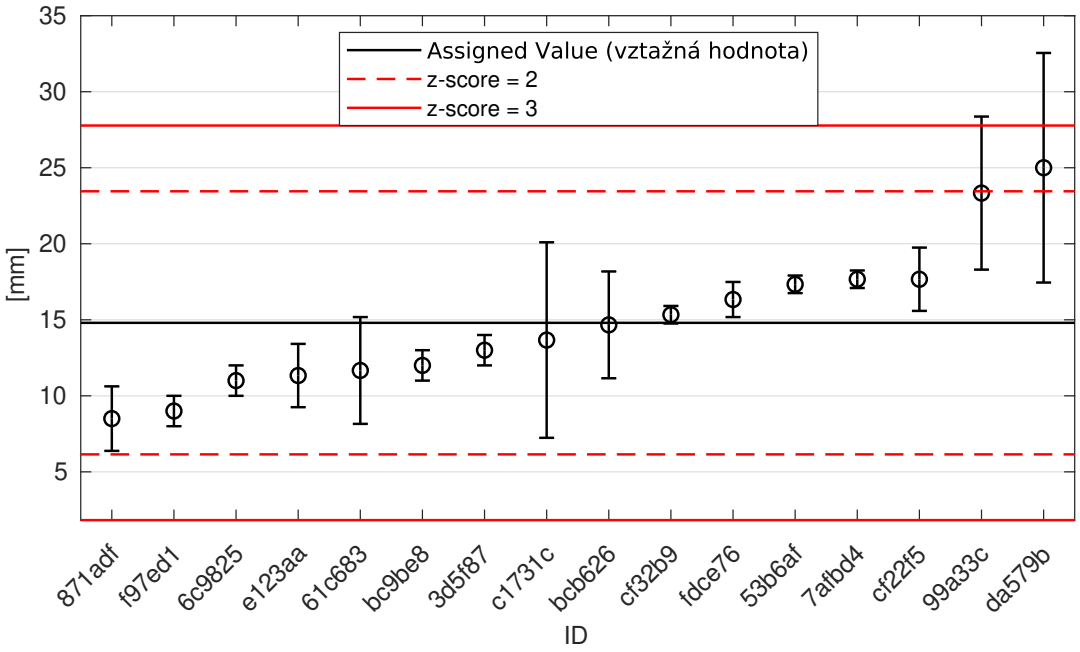

Figure 25: Average values and sample standard deviations

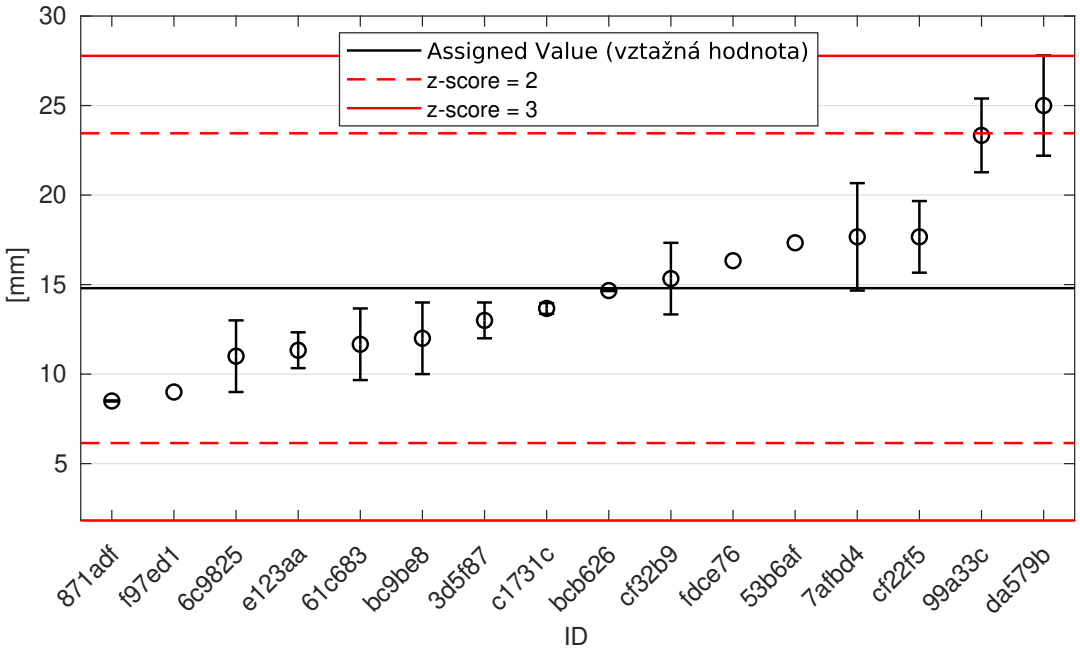

Figure 26: Average values and extended uncertainties of measurement

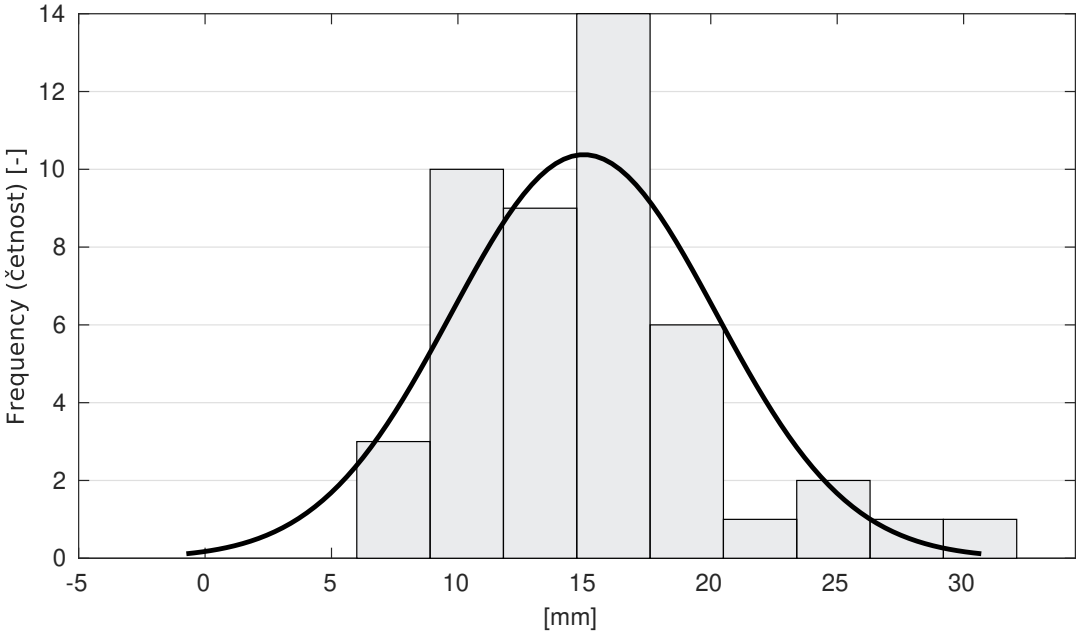

Figure 27: Histogram of all test results

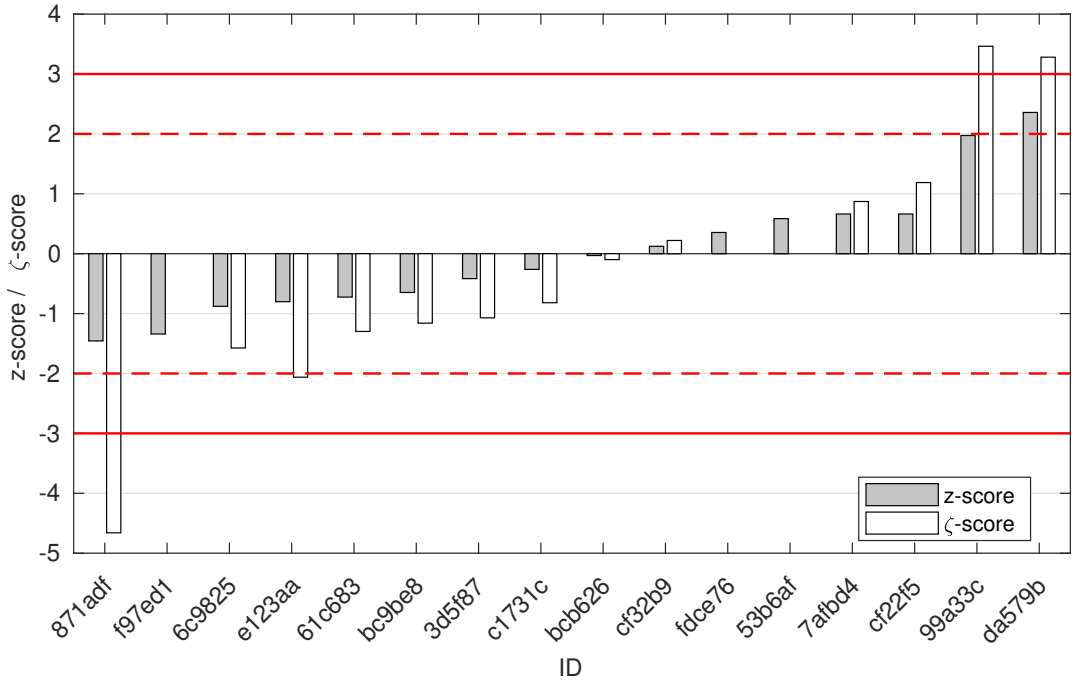

Figure 28: z-score and ζ-score

Table 8: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
871adf	-1.46	-4.66
f97ed1	-1.34	-
6c9825	-0.88	-1.57
e123aa	-0.80	-2.06
61c683	-0.72	-1.30
bc9be8	-0.65	-1.16
3d5f87	-0.42	-1.07
c1731c	-0.26	-0.82
bcb626	-0.03	-0.10
cf32b9	0.12	0.22
fdce76	0.35	-
53b6af	0.59	-
7afbd4	0.66	0.87
cf22f5	0.66	1.19
99a33c	1.97	3.46
da579b	2.36	3.28

4 Appendix – EN 480-11 – Determination of air void characteristics in hardened concrete

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

5 Appendix – ČSN 73 1322 – Determination of frost resistance of concrete

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

6 Appendix – ČSN 73 1324 – Determination of grindability of concrete

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

7 Appendix – ČSN 73 1326 – Resistance of cement concrete surface to water and defrosting chemicals – Method A

7.1 25 cycles

7.1.1 Test results

Table 9: Test results - ordered by average value. Outliers are marked by star. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID of participant	Test results [g/m^2]			u_X [g/m^2]	$\bar{x}$ [g/m^2]	s_0 [g/m^2]	V_X [%]
53b6af	62.0	8.2*	92.8	-	54.3	42.8	78.81
61c683	71.0	91.8	62.4	3.0	75.1	15.1	20.14
cf22f5	117.0	82.5	89.6	10.0	96.4	18.2	18.91
bc9be8	102.0	117.6	137.3	7.9	119.0	17.7	14.87
7afbd4	121.6	132.6	121.1	9.5	125.1	6.5	5.20
fdce76	143.0	120.0	143.0	-	135.3	13.3	9.81
c61b13	215.7	200.0	211.8	12.6	209.2	8.2	3.91
cc37b3	188.2	220.0	219.9	20.0	209.4	18.3	8.76
5aced5	212.7	217.5	212.9	5.4	214.4	2.7	1.27

7.1.2 The Numerical Procedure for Determining Outliers

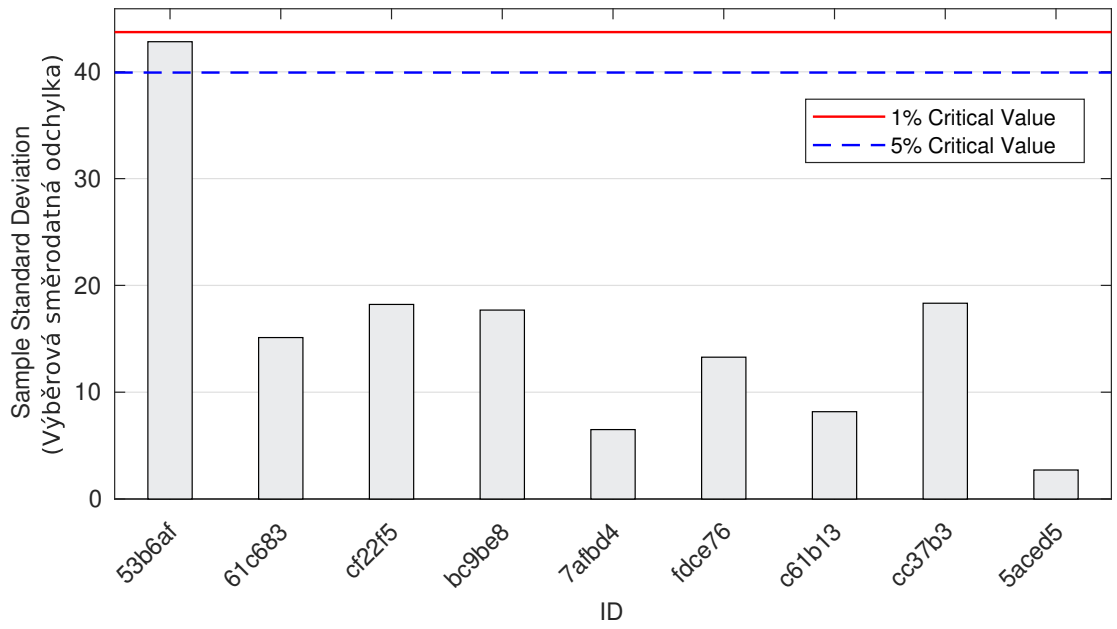

Figure 29: **Cochran's test** - sample standard deviations: 1% critical value - red color; 5% critical value - blue color

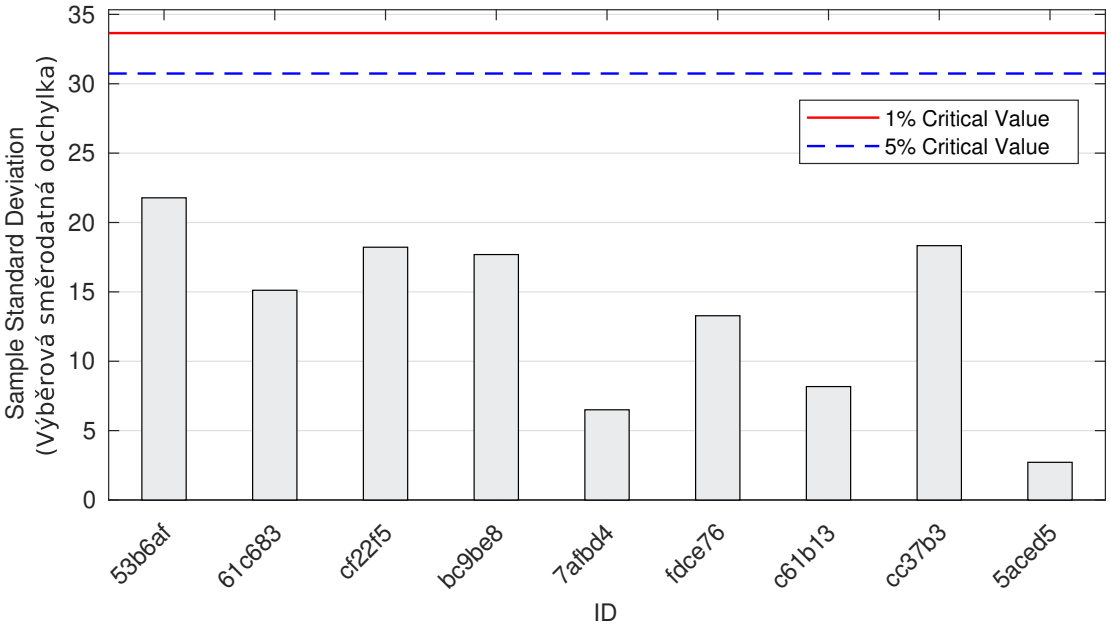

Figure 30: **Cochran's test** - sample standard deviations without outliers: 1% critical value - red color; 5% critical value - blue color

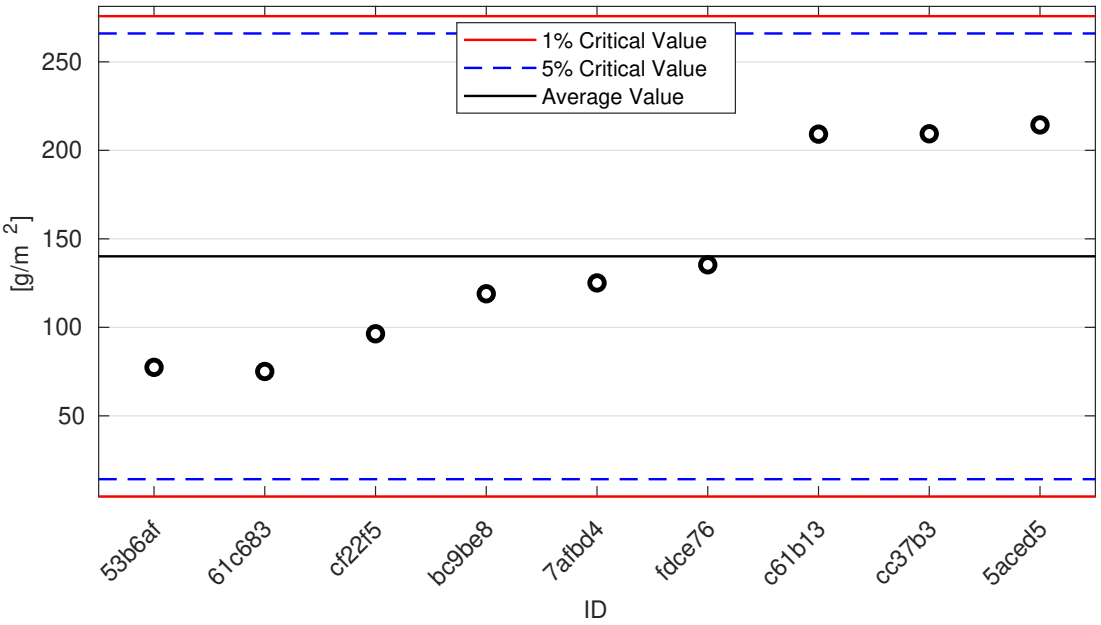

Figure 31: **Grubbs' test** - average values: 1% critical value - red color; 5% critical value - blue color

7.1.3 Mandel's Statistics

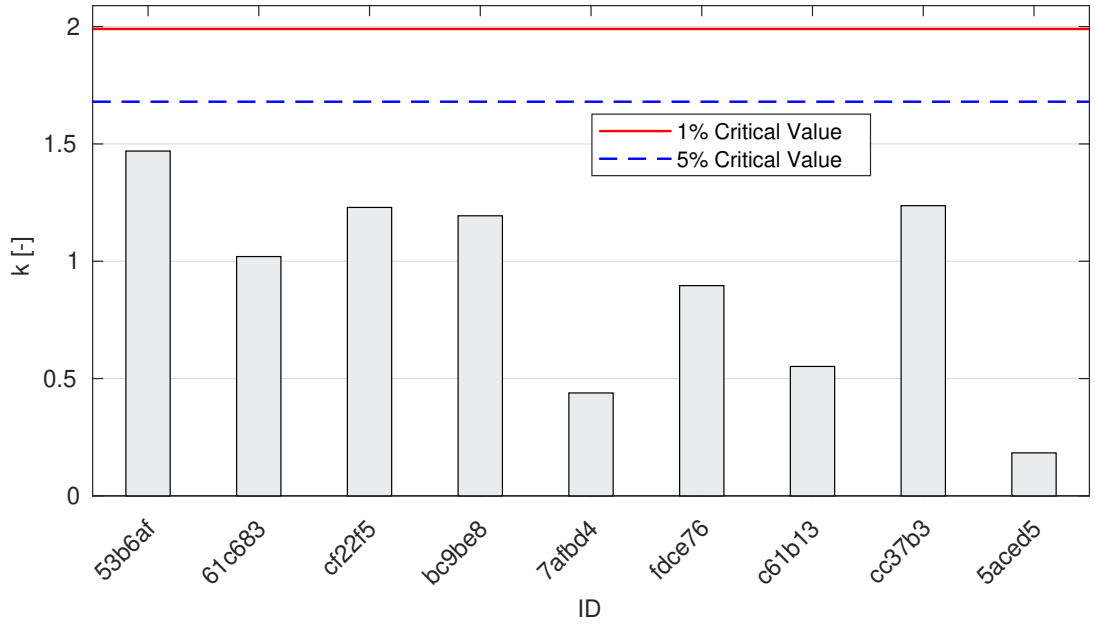

Figure 32: Intralaboratory Consistency Statistic *k*: 1% critical value - red color; 5% critical value - blue color

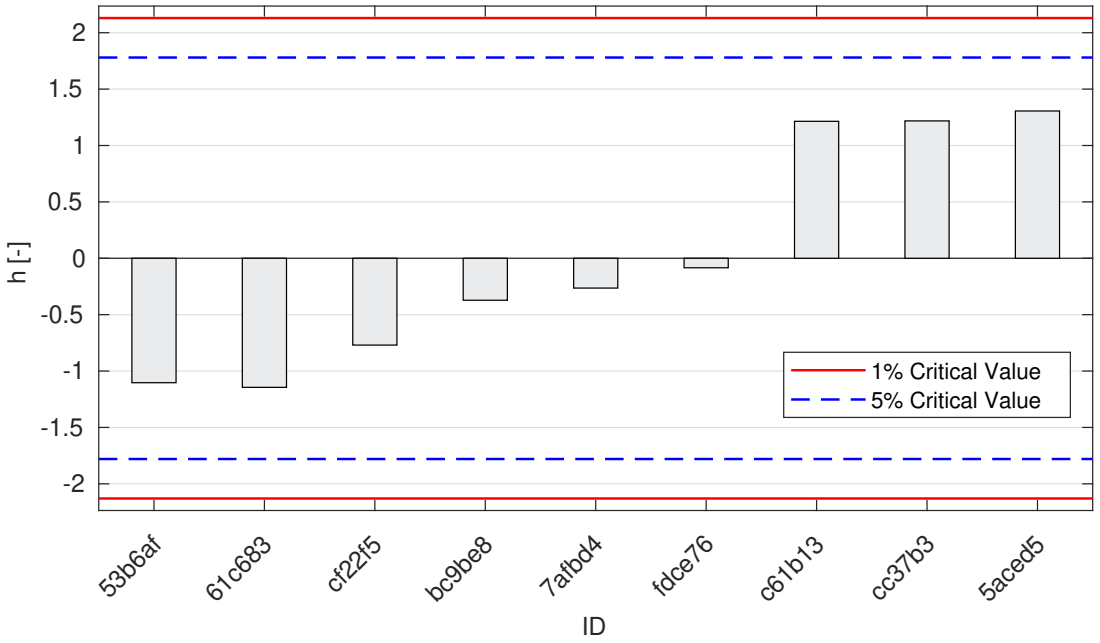

Figure 33: Interlaboratory Consistency Statistic *h*: 1% critical value - red color; 5% critical value - blue color

7.1.4 Calculation of Performance Statistics

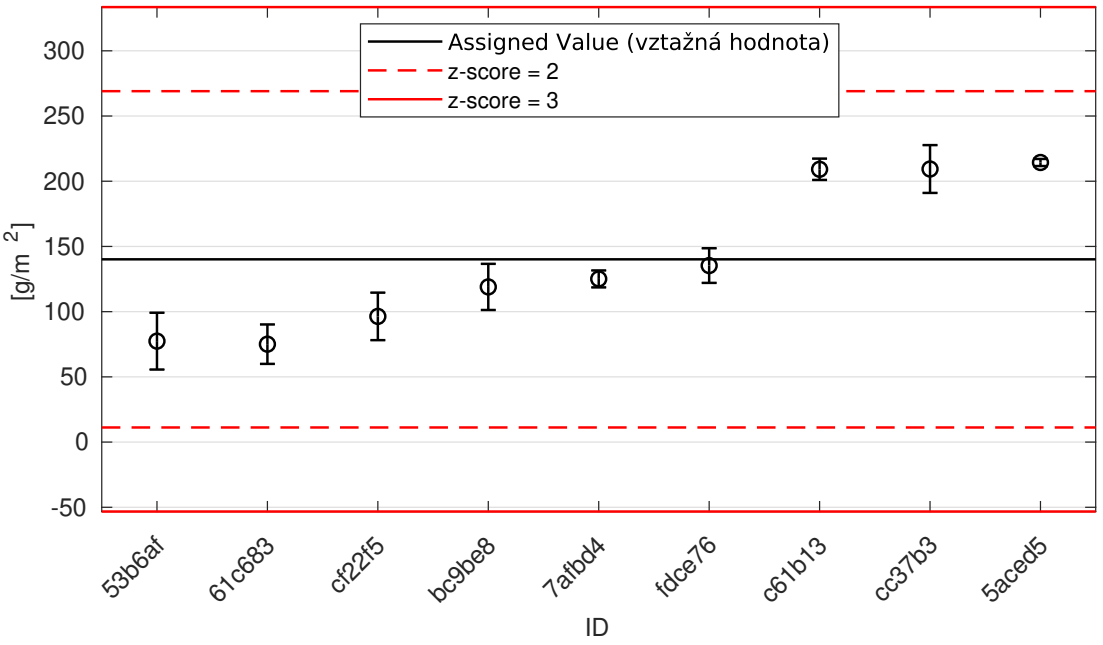

Figure 34: Average values and sample standard deviations

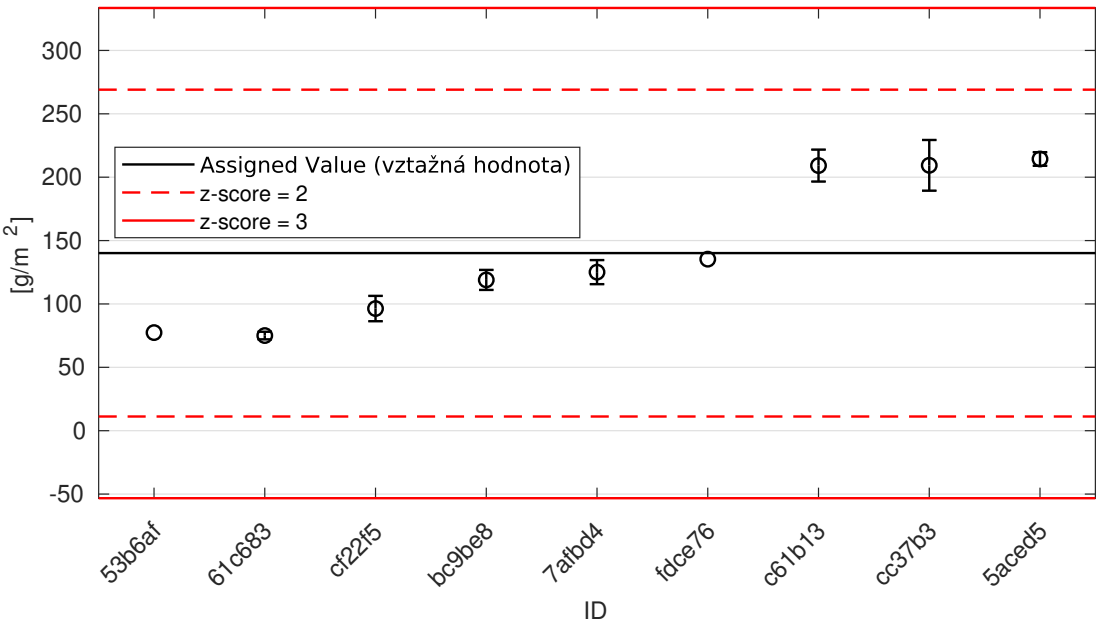

Figure 35: Average values and extended uncertainties of measurement

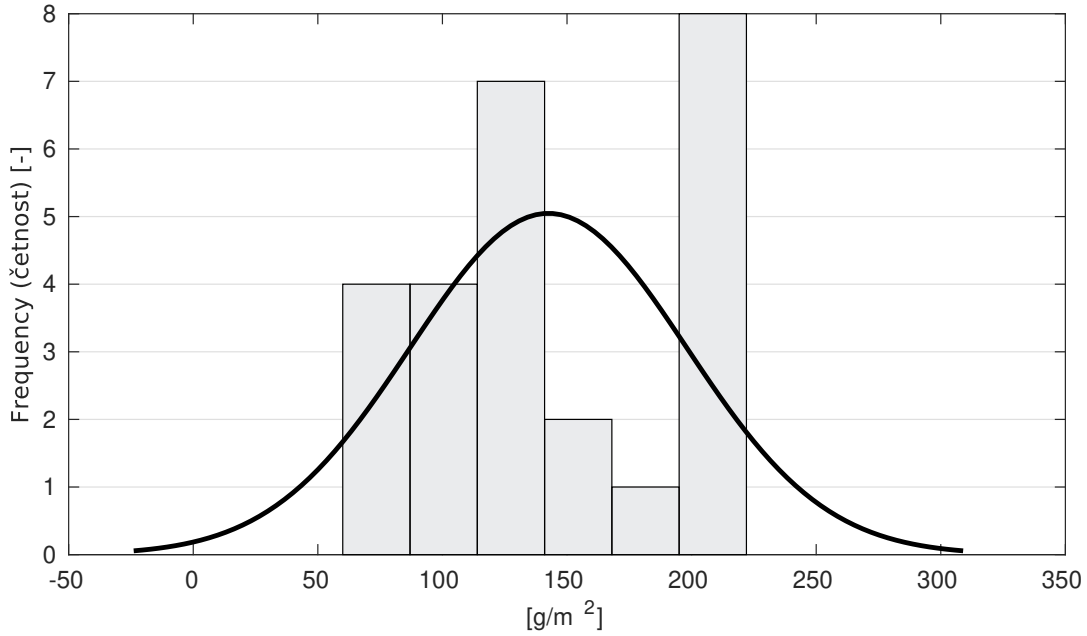

Figure 36: Histogram of all test results

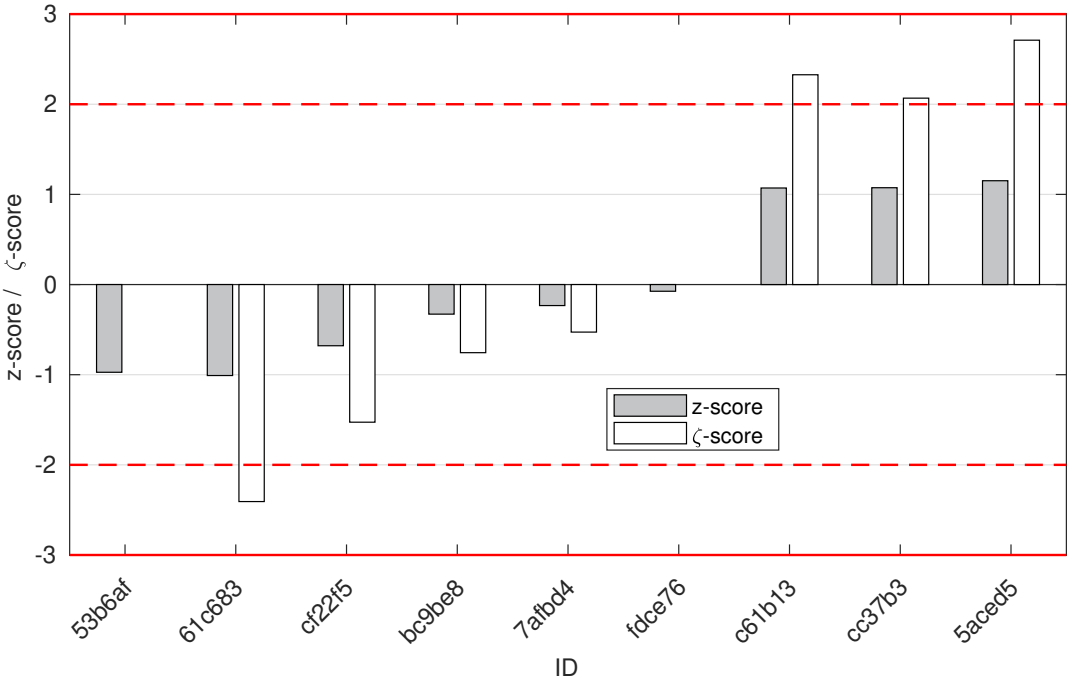

Figure 37: z-score and ζ-score

Table 10: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
53b6af	-0.97	-
61c683	-1.01	-2.41
cf22f5	-0.68	-1.53
bc9be8	-0.33	-0.76
7afbd4	-0.23	-0.53
fdce76	-0.07	-
c61b13	1.07	2.33
cc37b3	1.07	2.07
5aced5	1.15	2.71

7.2 50 cycles

7.2.1 Test results

Table 11: Test results - ordered by average value. Outliers are marked by star. 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
of participant	[g/m^2]			[g/m^2]	[g/m^2]	[g/m^2]	[%]
53b6af	141.7	14.3	145.9	-	100.6	74.8	74.33
61c683	129.8	134.5	126.7	5.2	130.3	3.9	3.01
cf22f5	257.5	208.1	260.9	20.0	242.2	29.6	12.20
7afbd4	273.5	273.5	291.1	21.2	279.4	10.2	3.64
bc9be8	258.8	298.0	337.3	35.2	298.0	39.3	13.17
fdce76	281.0	299.0	321.0	-	300.3	20.0	6.67
5aced5	432.7	398.8	376.7	56.4	402.7	28.2	7.00
c61b13	494.1	407.8	470.6	27.5	457.5	44.6	9.75
cc37b3	411.8	499.0	534.0	70.0	481.6	62.9	13.07

7.2.2 The Numerical Procedure for Determining Outliers

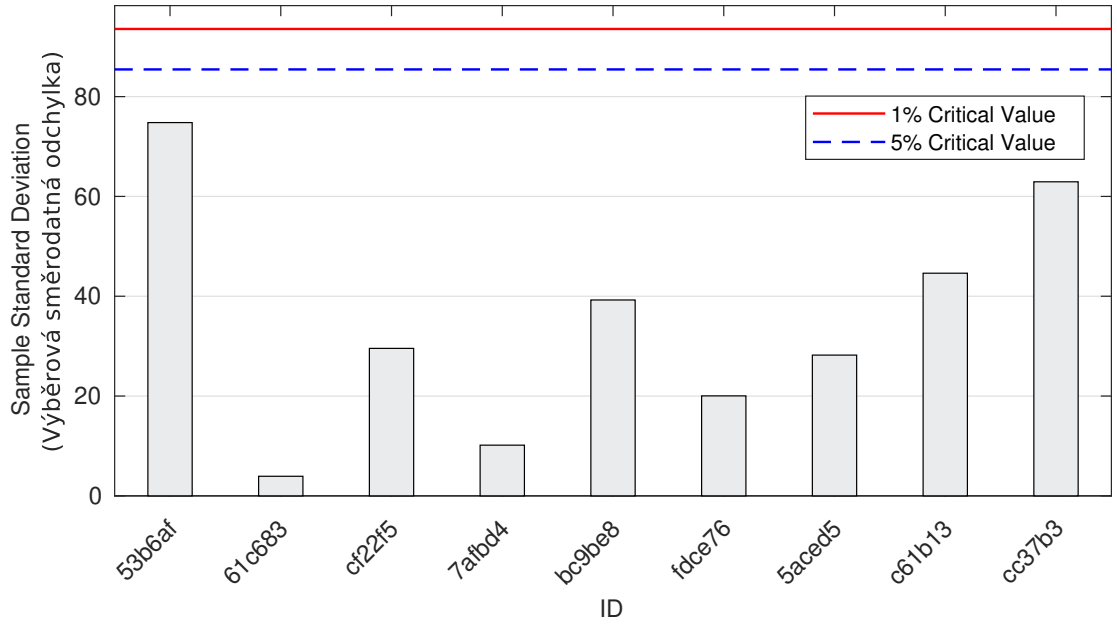

Figure 38: **Cochran's test** - sample standard deviations: 1% critical value - red color; 5% critical value - blue color

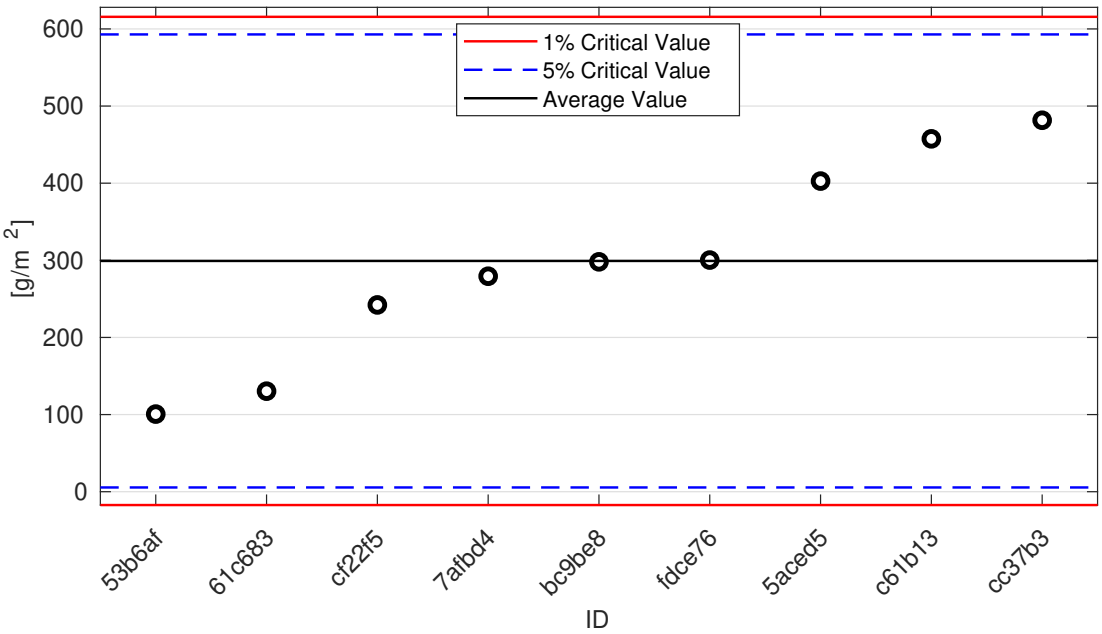

Figure 39: **Grubbs' test** - average values: 1% critical value - red color; 5% critical value - blue color

7.2.3 Mandel's Statistics

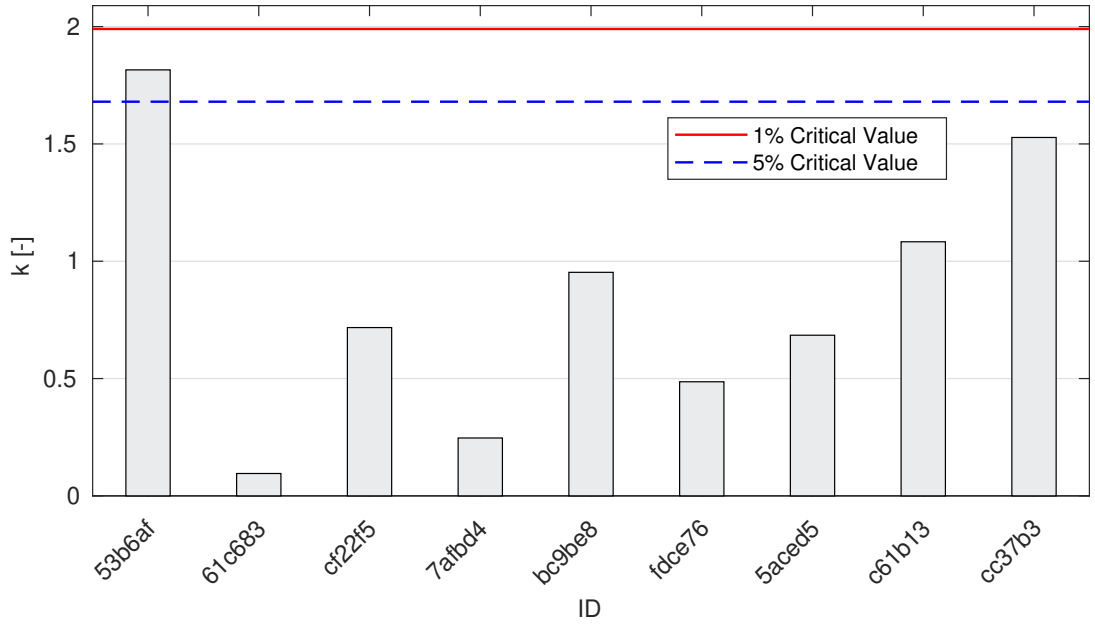

Figure 40: Intralaboratory Consistency Statistic *k*: 1% critical value - red color; 5% critical value - blue color

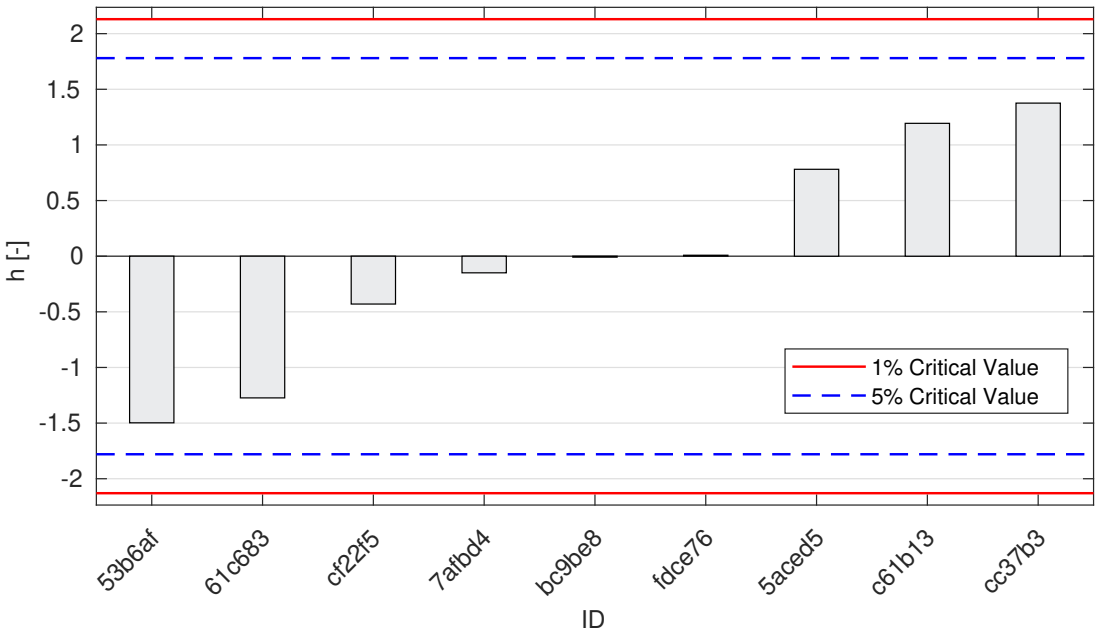

Figure 41: Interlaboratory Consistency Statistic *h*: 1% critical value - red color; 5% critical value - blue color

7.2.4 Calculation of Performance Statistics

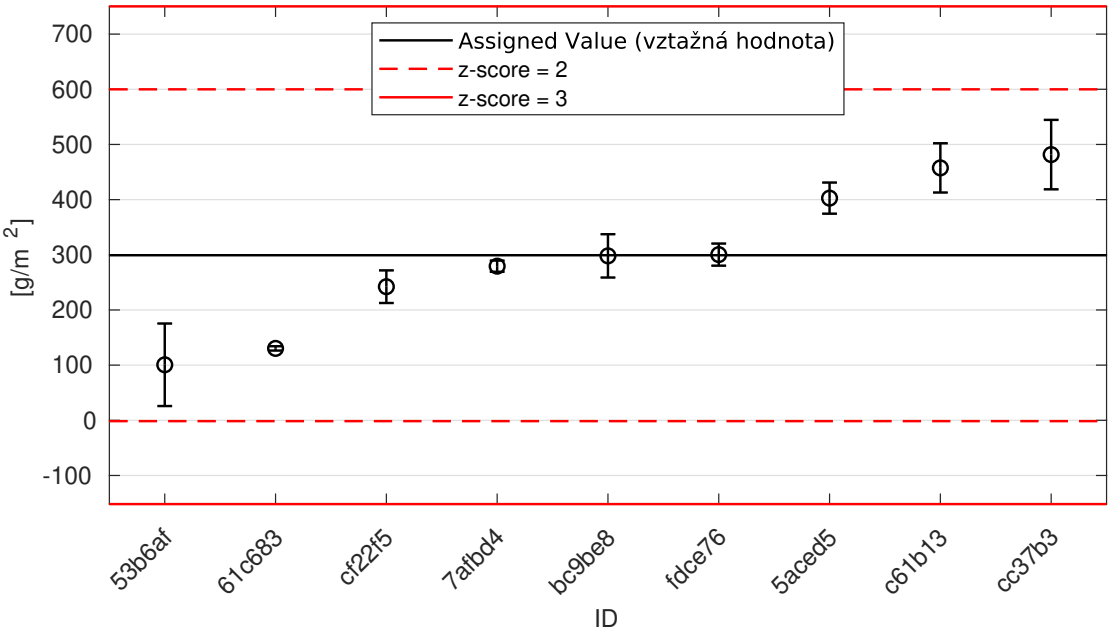

Figure 42: Average values and sample standard deviations

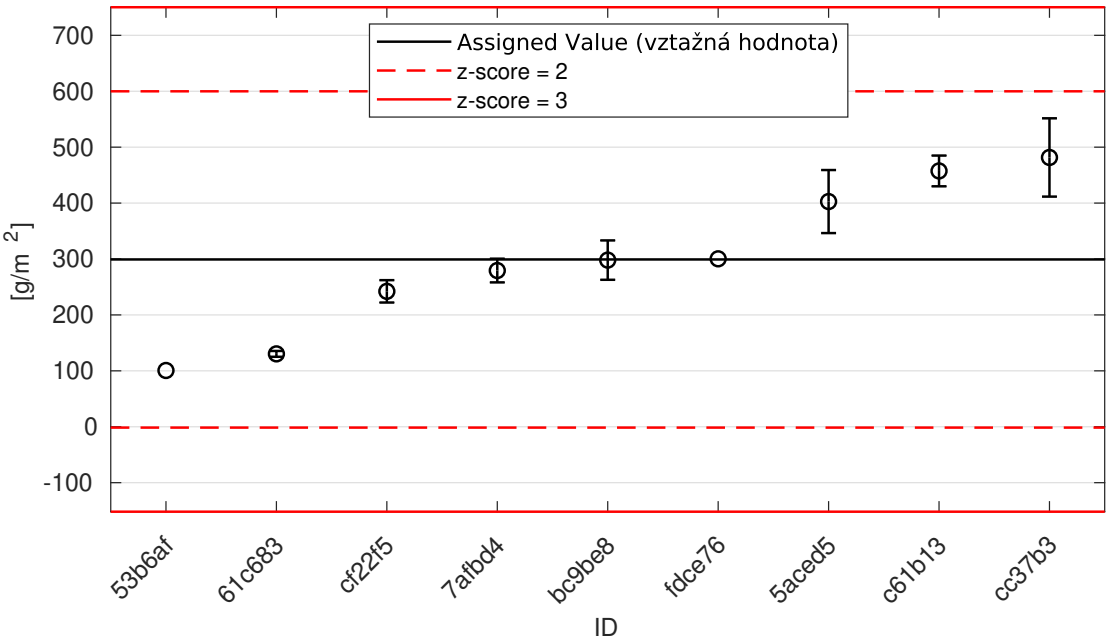

Figure 43: Average values and extended uncertainties of measurement

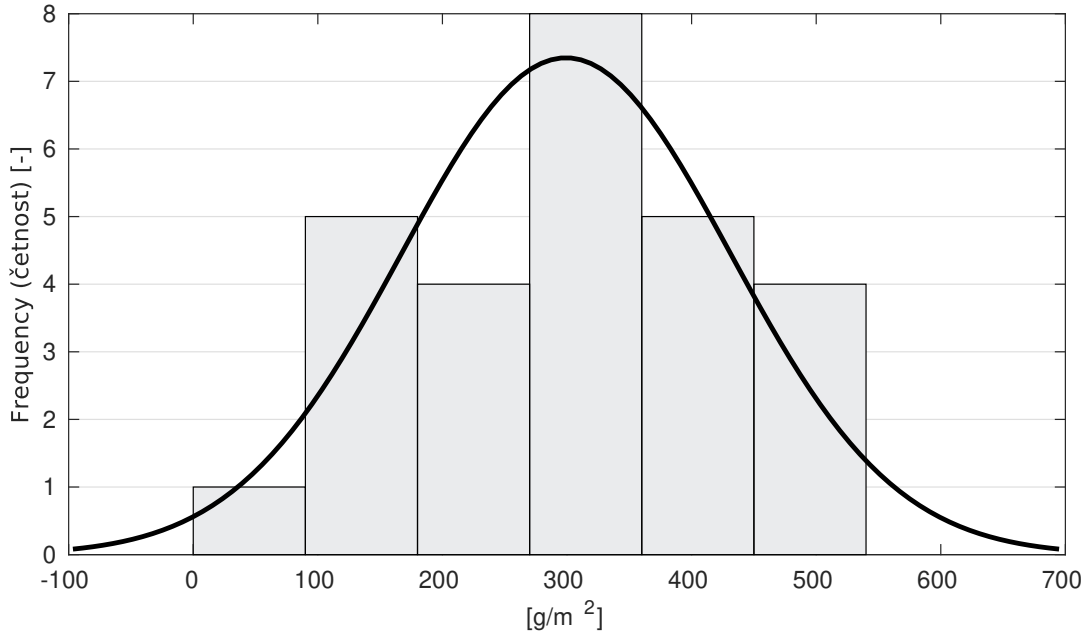

Figure 44: Histogram of all test results

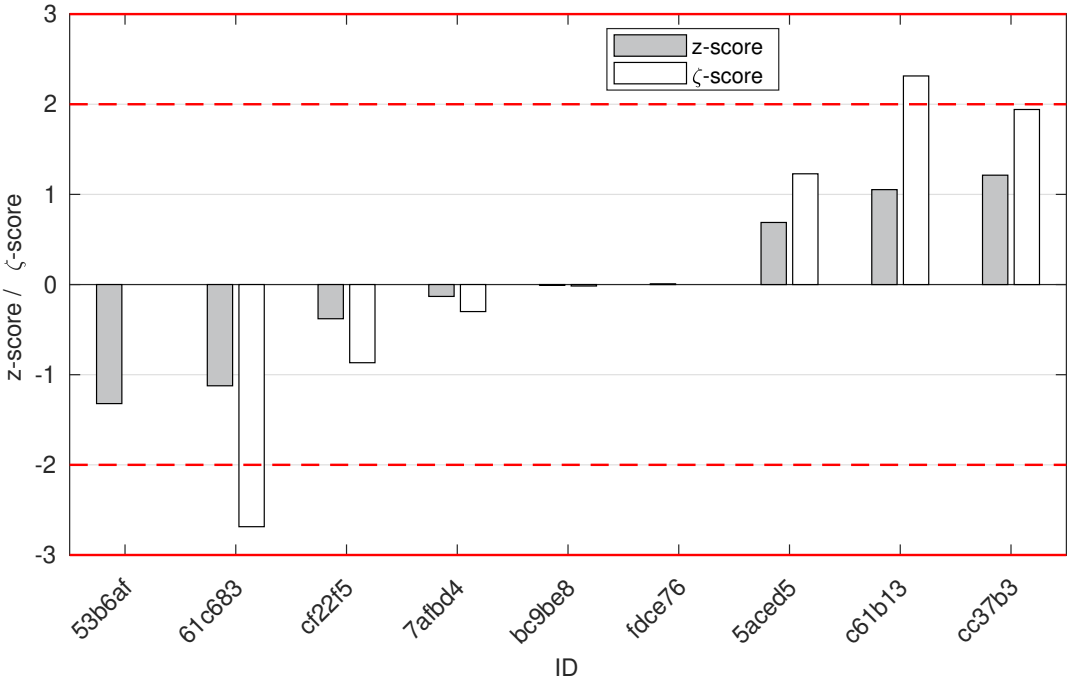

Figure 45: z-score and ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
53b6af	-1.32	-
61c683	-1.12	-2.69
cf22f5	-0.38	-0.87
7afbd4	-0.13	-0.30
bc9be8	-0.01	-0.02
fdce76	0.01	-
5aced5	0.69	1.23
c61b13	1.05	2.31
cc37b3	1.21	1.94

7.3 75 cycles

7.3.1 Test results

Table 13: Test results - ordered by average value. Outliers are marked by star. 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
of participant	[g/m^2]			[g/m^2]	[g/m^2]	[g/m^2]	[%]
53b6af	190.3	19.9	212.2	-	140.8	105.3	74.77
61c683	255.7	223.1	204.0	9.1	227.6	26.1	11.49
7afbd4	508.4	508.4	556.3	39.9	524.4	27.7	5.27
cf22f5	589.1	435.8	572.4	30.0	532.4	84.1	15.80
bc9be8	549.0	603.9	627.5	99.7	593.5	40.3	6.79
fdce76	639.0	584.0	584.0	602.0	602.3	31.8	5.27
c61b13	890.2	662.7	827.5	47.6	793.5	117.5	14.81
5aced5	858.8	823.9	755.5	105.7	812.7	52.5	6.47
cc37b3	890.2	1076.5	781.4	160.0	916.0	149.2	16.29

7.3.2 The Numerical Procedure for Determining Outliers

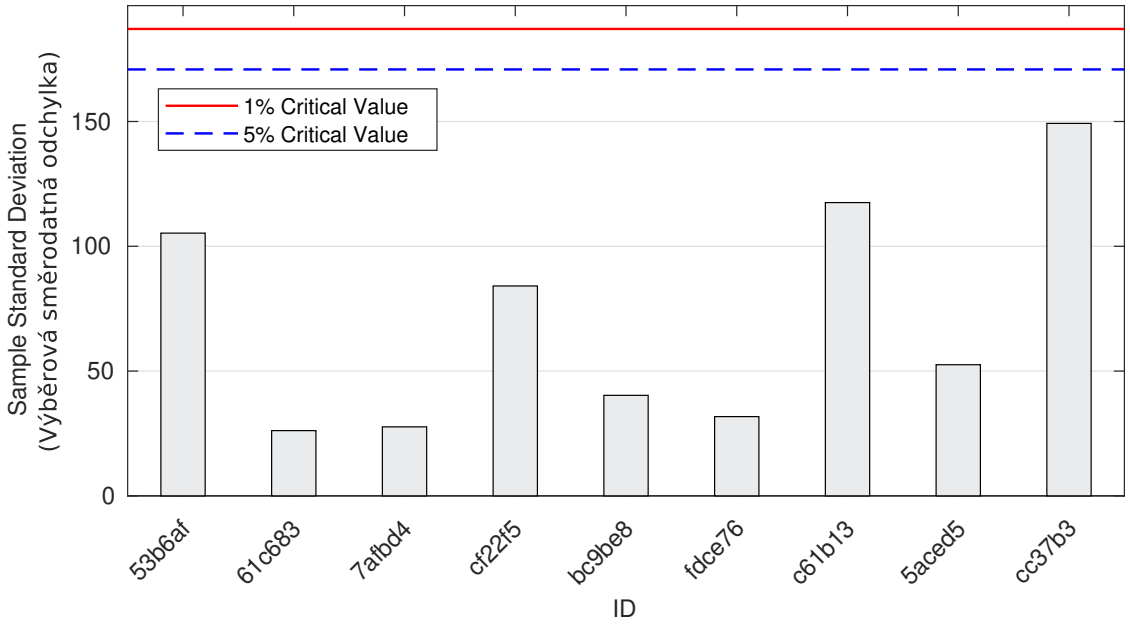

Figure 46: **Cochran's test** - sample standard deviations: 1% critical value - red color; 5% critical value - blue color

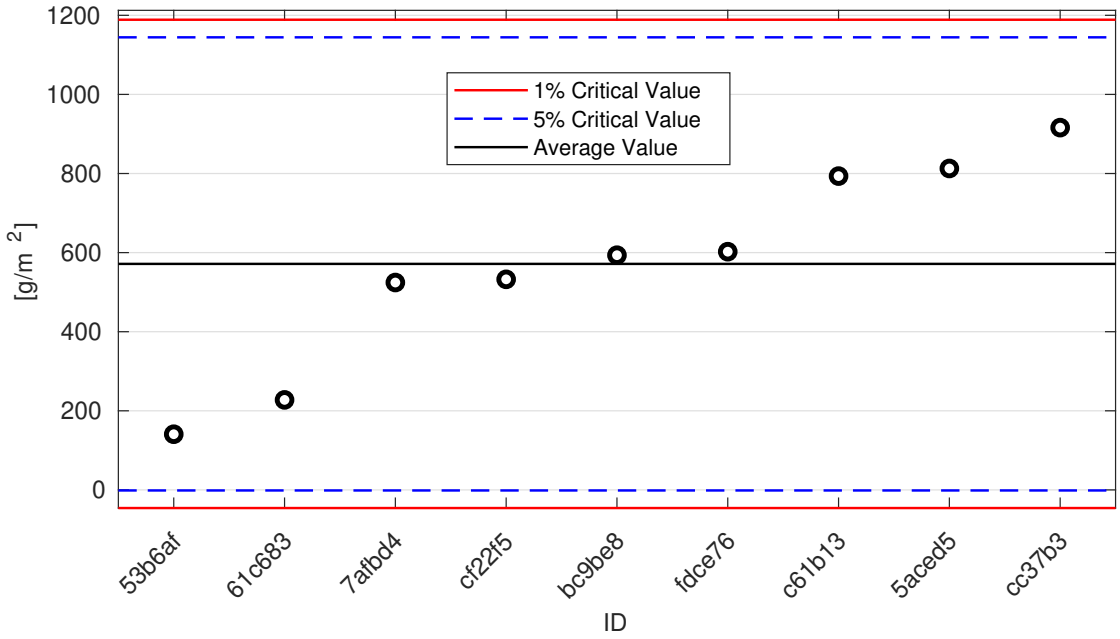

Figure 47: **Grubbs' test** - average values: 1% critical value - red color; 5% critical value - blue color

7.3.3 Mandel's Statistics

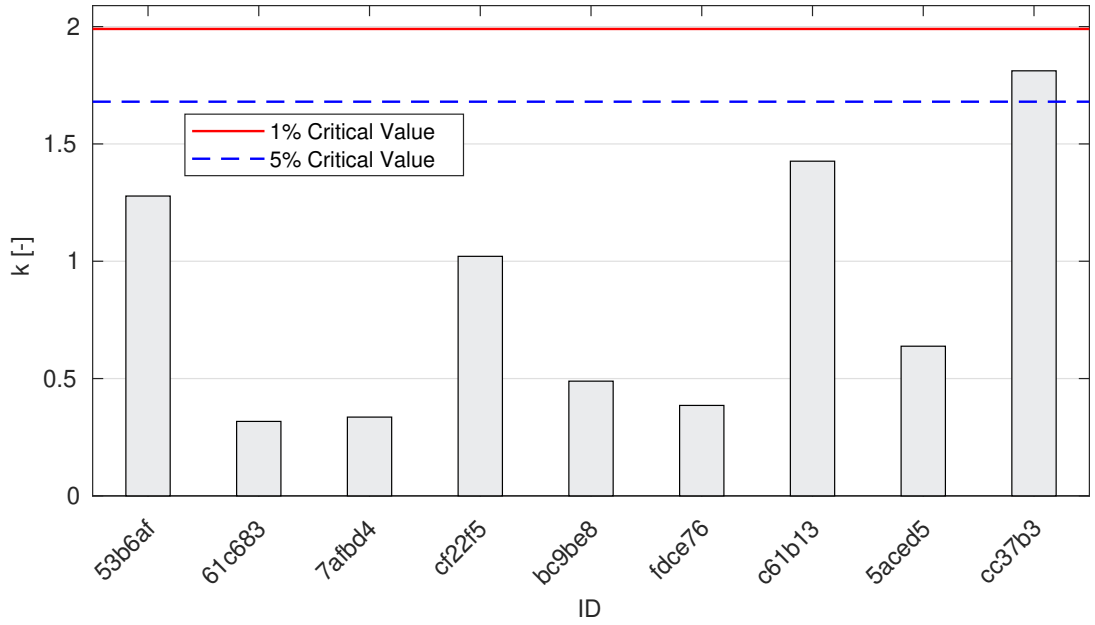

Figure 48: Intralaboratory Consistency Statistic k: 1% critical value - red color; 5% critical value - blue color

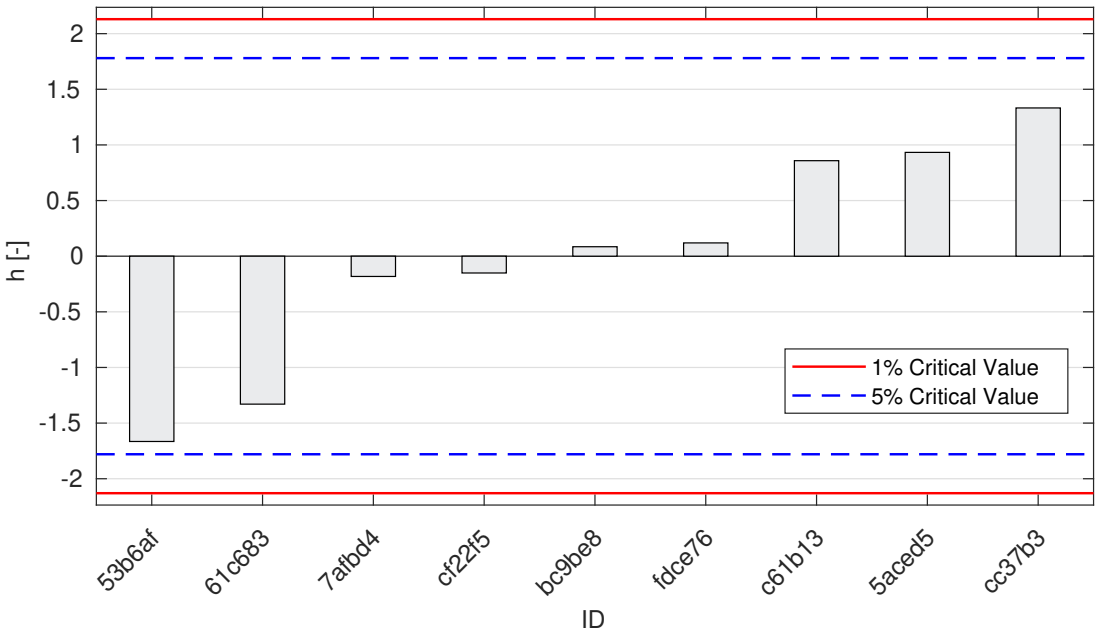

Figure 49: Interlaboratory Consistency Statistic h: 1% critical value - red color; 5% critical value - blue color

7.3.4 Calculation of Performance Statistics

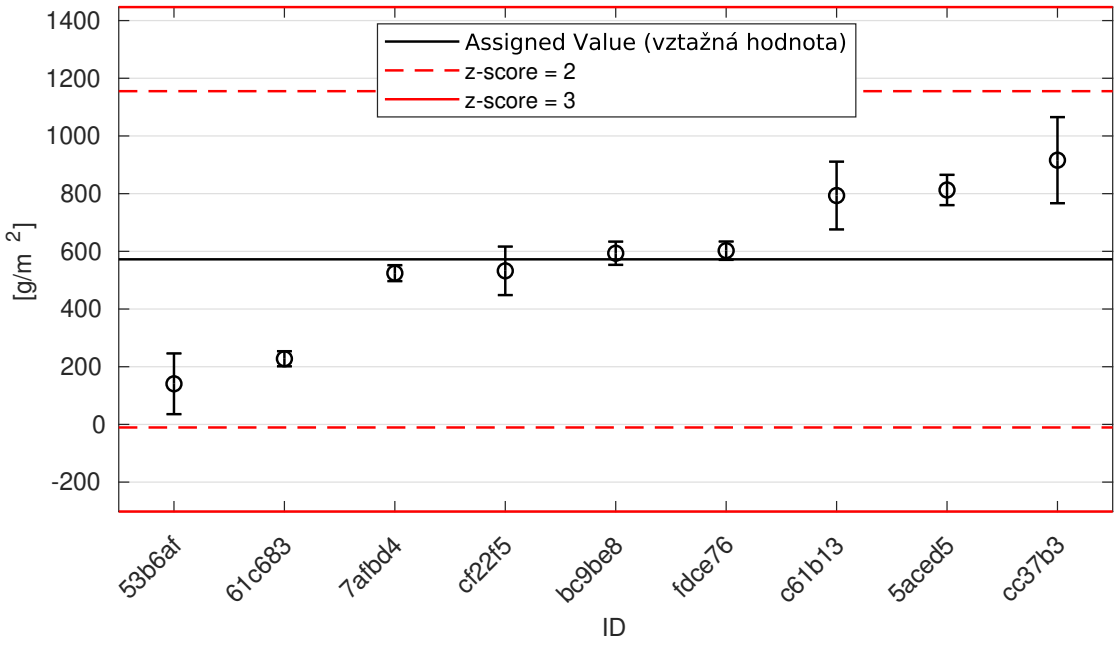

Figure 50: Average values and sample standard deviations

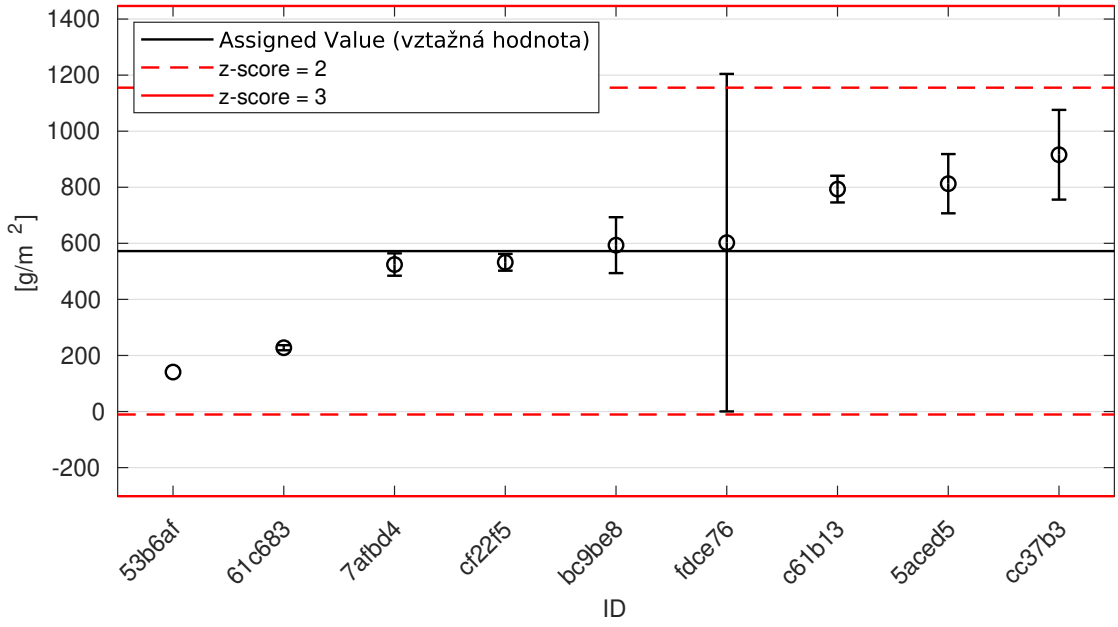

Figure 51: Average values and extended uncertainties of measurement

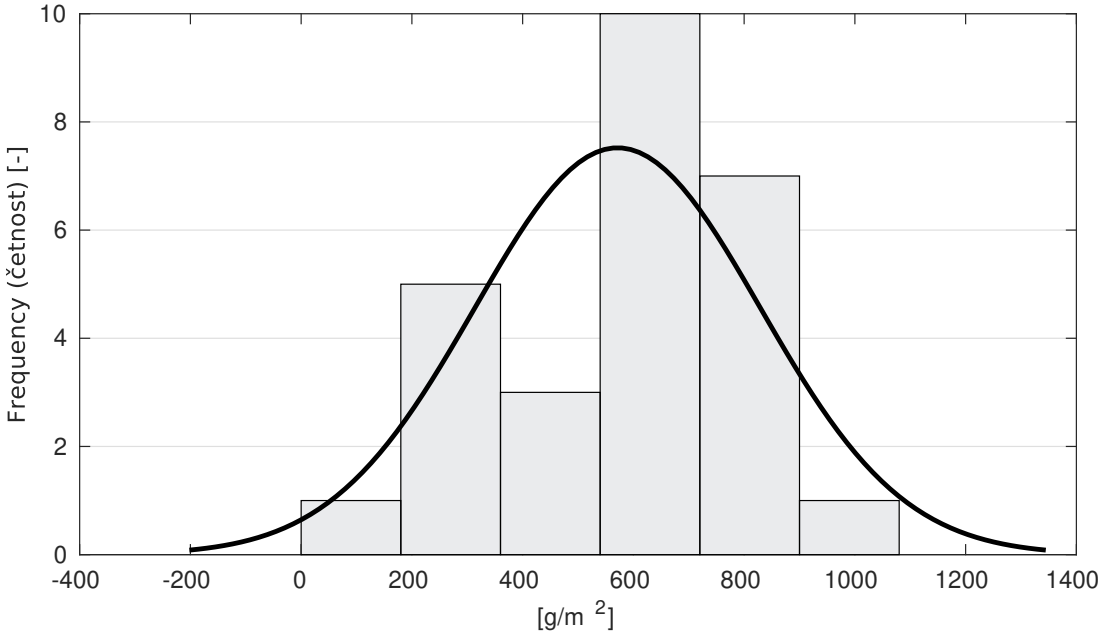

Figure 52: Histogram of all test results

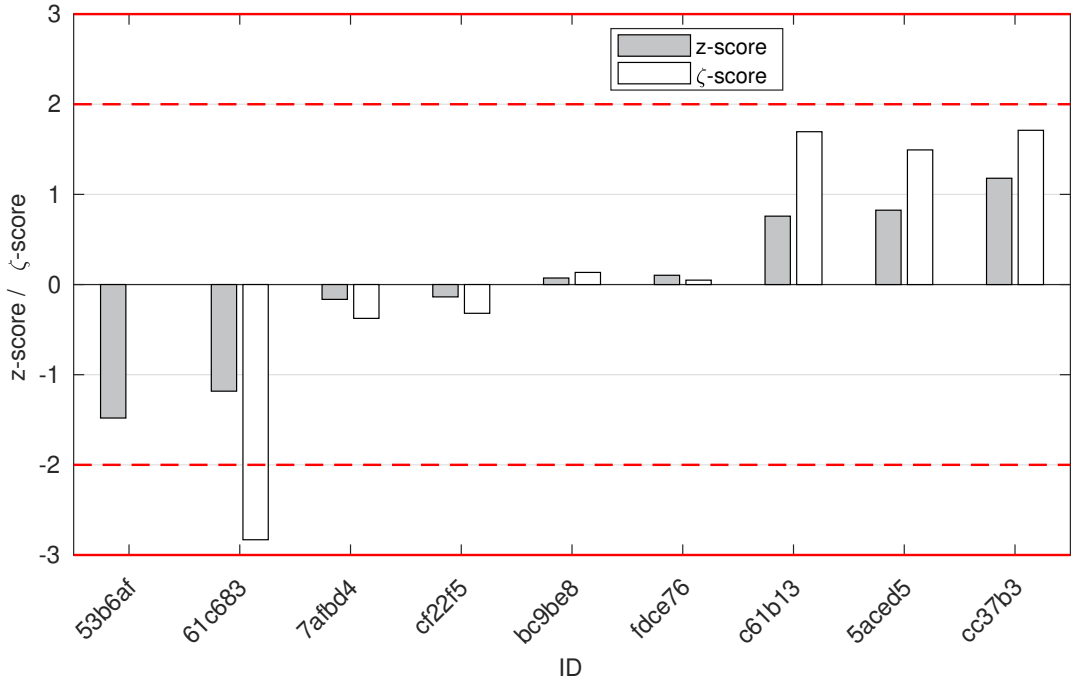

Figure 53: z-score and ζ-score

Table 14: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
53b6af	-1.48	-
61c683	-1.18	-2.83
7afbd4	-0.16	-0.38
cf22f5	-0.14	-0.32
bc9be8	0.07	0.13
fdce76	0.10	0.05
c61b13	0.76	1.70
5aced5	0.82	1.49
cc37b3	1.18	1.71

7.4 100 cycles

7.4.1 Test results

Table 15: Test results - ordered by average value. Outliers are marked by star. 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
of participant	[g/m^2]			[g/m^2]	[g/m^2]	[g/m^2]	[%]
53b6af	221.3	25.5	287.4	-	178.1	136.2	76.49
61c683	420.0	294.9	317.3	13.8	344.1	66.7	19.39
bc9be8	752.9	898.0	968.6	188.6	873.2	110.0	12.59
cf22f5	1072.8	753.9	926.7	60.0	917.8	159.6	17.39
7afbd4	900.8	972.6	910.9	70.5	928.1	38.9	4.19
fdce76	911.0	945.0	1039.0	965.0	965.0	66.3	6.87
cc37b3	1223.5	1379.1	1017.0	200.0	1206.5	181.6	15.06
c61b13	1380.4	1000.0	1243.1	72.5	1207.8	192.6	15.95
5aced5	1445.3	1190.6	1154.1	315.8	1263.3	158.6	12.56

7.4.2 The Numerical Procedure for Determining Outliers

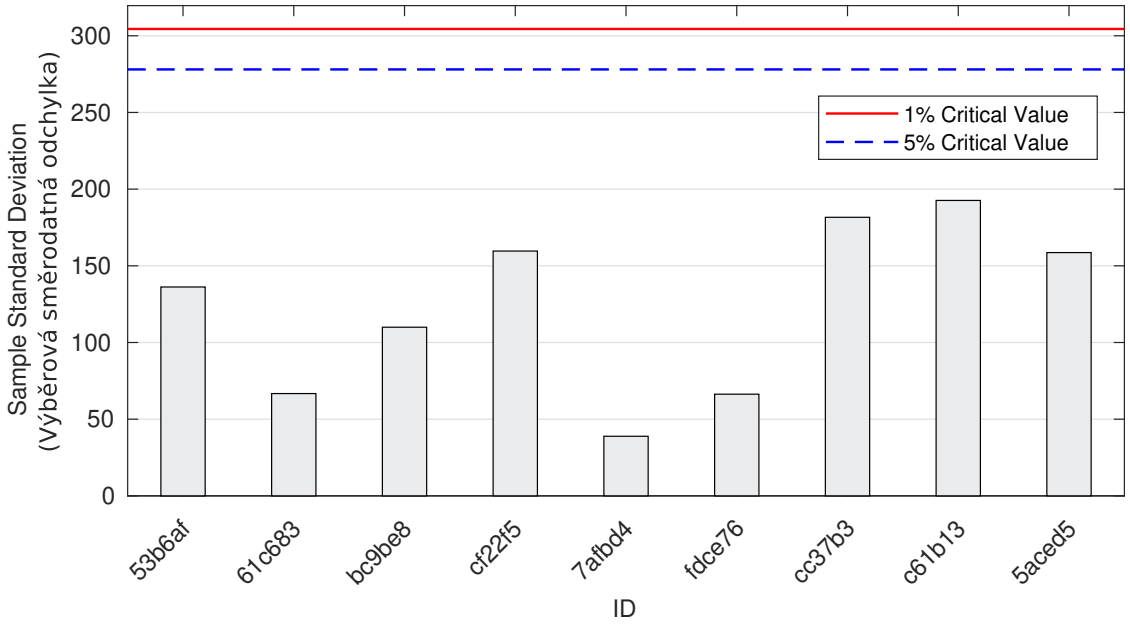

Figure 54: **Cochran's test** - sample standard deviations: 1% critical value - red color; 5% critical value - blue color

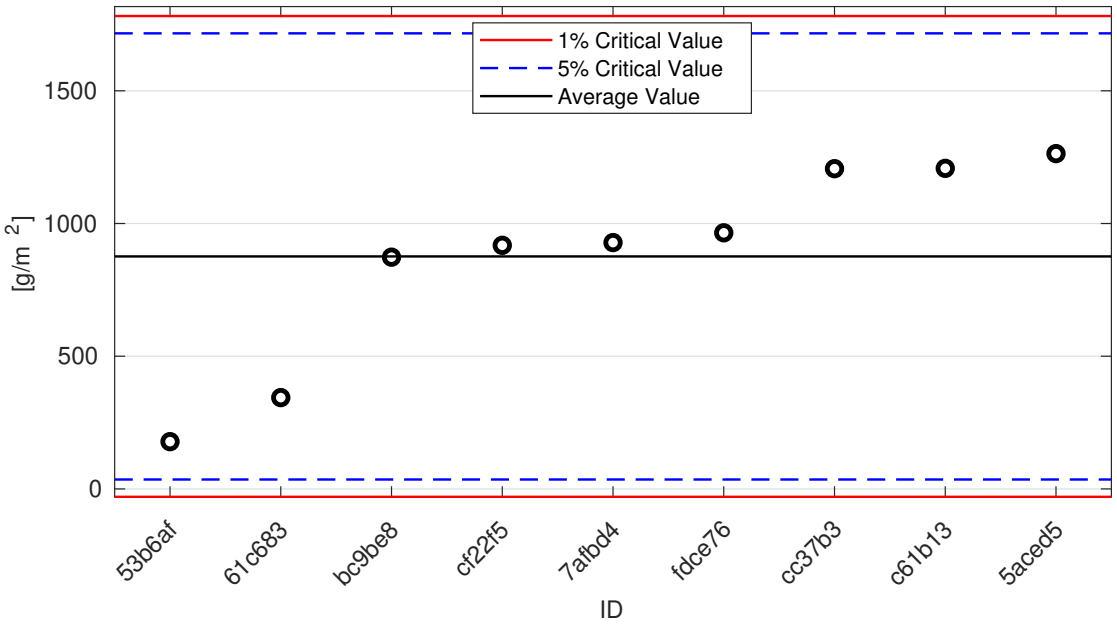

Figure 55: **Grubbs' test** - average values: 1% critical value - red color; 5% critical value - blue color

7.4.3 Mandel's Statistics

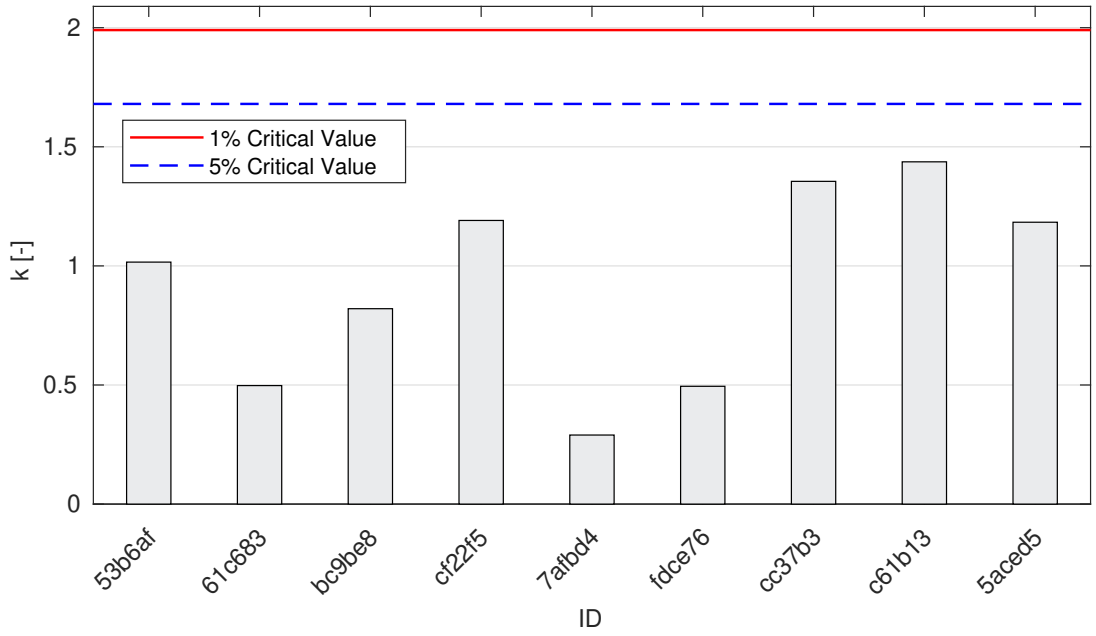

Figure 56: Intralaboratory Consistency Statistic k: 1% critical value - red color; 5% critical value - blue color

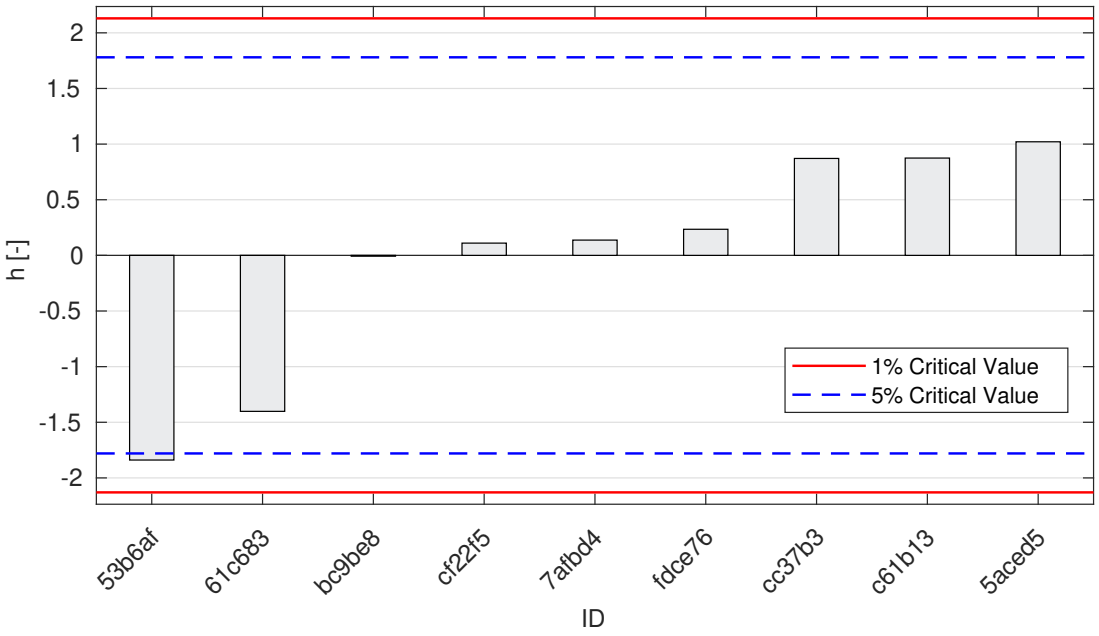

Figure 57: Interlaboratory Consistency Statistic h: 1% critical value - red color; 5% critical value - blue color

7.4.4 Calculation of Performance Statistics

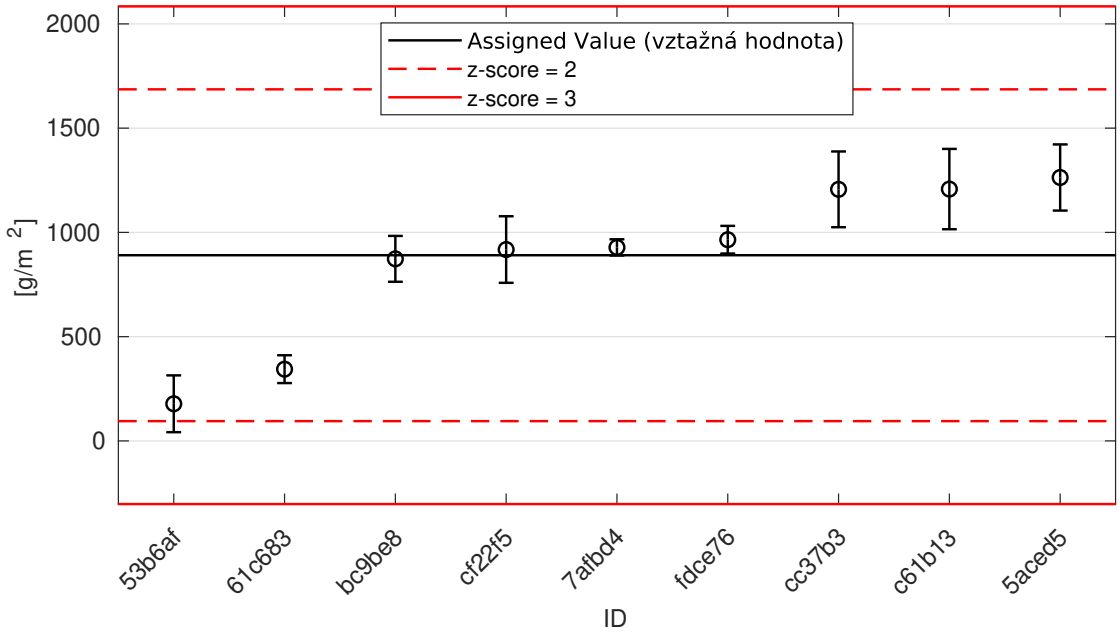

Figure 58: Average values and sample standard deviations

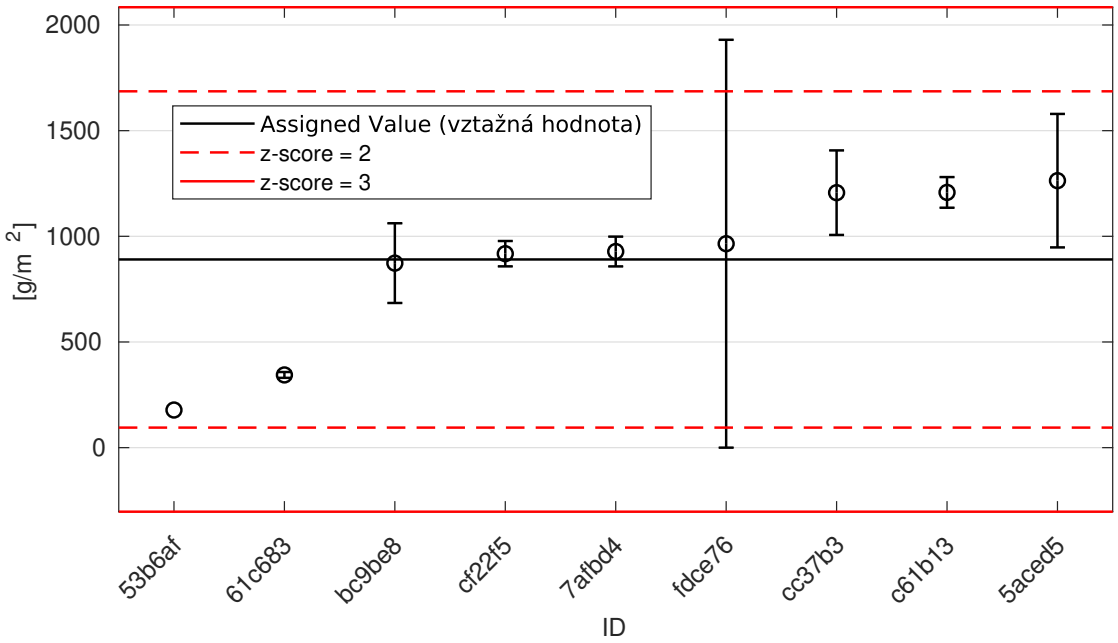

Figure 59: Average values and extended uncertainties of measurement

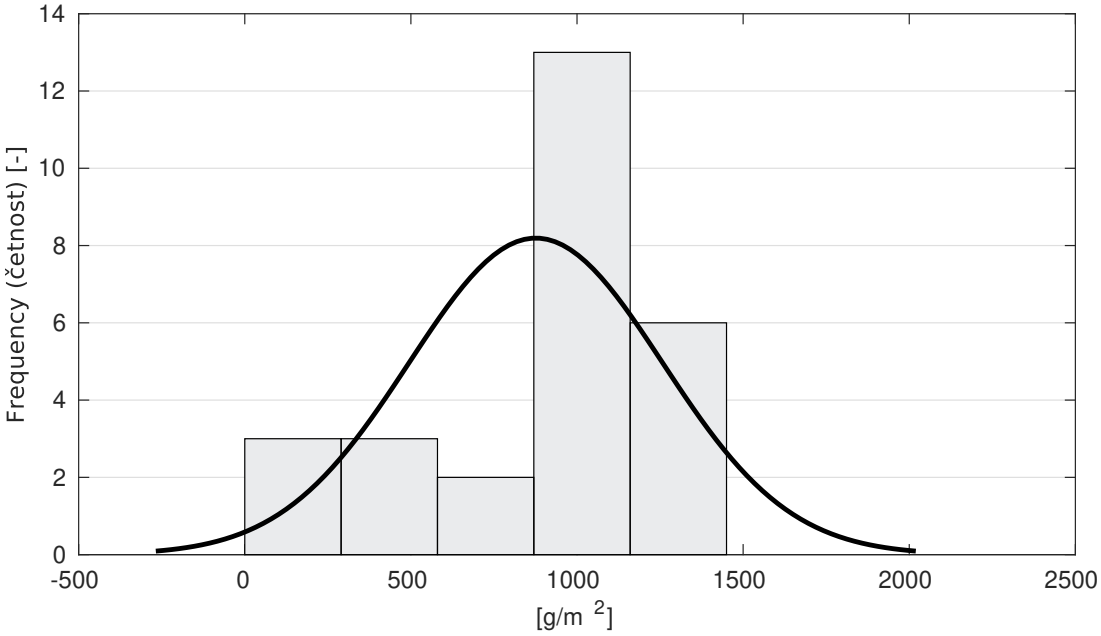

Figure 60: Histogram of all test results

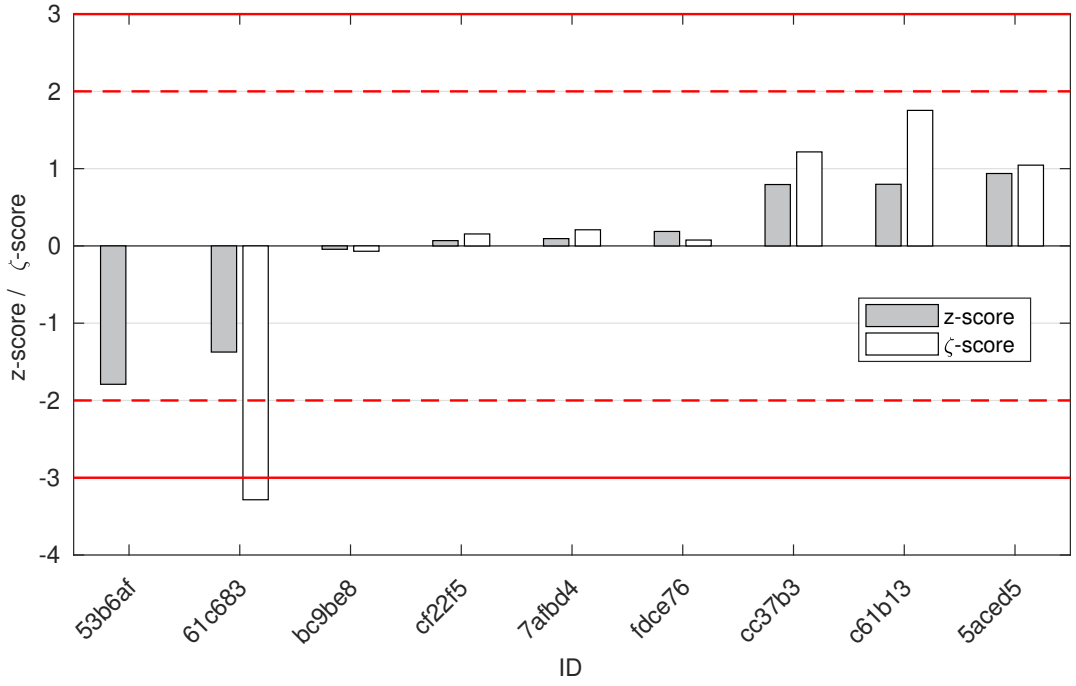

Figure 61: z-score and ζ-score

Table 16: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
53b6af	-1.79	-
61c683	-1.37	-3.29
bc9be8	-0.04	-0.07
cf22f5	0.07	0.15
7afbd4	0.09	0.21
fdce76	0.19	0.08
cc37b3	0.79	1.22
c61b13	0.80	1.75
5aced5	0.94	1.05

8 Appendix – ČSN 73 1326 – Resistance of cement concrete surface to water and defrosting chemicals – Method C

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

9 Appendix – ČSN P CEN/TS 12390-9 – Freeze-thaw resistance – Scaling

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