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Technical Procedure for Assessment of Uncertainty for Determining the Characteristic Compression Resistance of Ceramic Elements for Masonry

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ABSTRACT

This document is intended to describe in detail the technical actions that should be taken by authorized personnel in order to assess the uncertainty of measurement of compressive resistance. We try to fulfill the specific requirements of SSH ISO/IEC 17025 standard 5.4.6 paragraph "Assessment of uncertainty of measurements"

METHODS

Measurement Procedure and Calculation

Working standard SSH 548/1-87. Determination of strength limit in compression

Calculation

$Rc = F/S$ (1)

where F-maximum force applied from compression till failure

the S-base surface of the sample that is subjected to this force.

Identification of Uncertainty Sources

Since it is not possible to measure the true value of each measurement, it is important to report not only the measurement value but also the uncertainty of this value together with the level of reliability. All possible factual sources that really influence the assessment of measurement uncertainty should be evaluated and continuous measures should be taken to eliminate them as much as possible [1]. Based on the testing method and the real conditions of its implementation, we identify all the components of the uncertainty by making a metrological and statistically valid estimation.

The main factors influencing the measurement process are specified as follows:

Specimen geometry

Specimen dimensions

Planarity of the specimen surface

Angles between faces (plans) that form the sample

- Curing conditions that have to do with temperature and relative humidity

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- The conductivity of test mode
- The speed of application of load force of the compressor
- Temperature and air humidity condition during test performance
- Necessary corrections to be made regarding the reading of force transmitted by the testing machine according to calibration modalities

Measurement Model and Quantitative Assessment of Uncertainty Sources

Measurement model is called the function: Y=f(x1, x2, x3 ... xn) and x1, x2, x3 ... xn are the input values. Typical input values are those derived from measurement process, those that are reported from calibration certificates of used instruments as well as influenced values that are environmental variables such as air temperature, air humidity, and air pressure.

During this test, we have the uncertainty of category A and category B.

Category A. When value Xi can be estimated directly from the laboratory by repurposing a metering process under controlled conditions, resulting in a series of values.

Statistical theory tells us how to use the collected information. Practically because of cost and time, repeated measurements of a magnitude form a limited set of values. The variable that rationalizes exactly the limited series values is studied by the Student:

$$t_p = \left(\overline{x_i} - \mu_i\right) / \frac{s_i}{\sqrt{n_i}} \quad (2)$$

Category B. the estimation of uncertainty is based on a series of repeated observations. This kind of evaluation is based on scientific methods

These evaluations are carried out in a manner different from that based on a series of repeated observations. The minimum information situation is presented by an interval defined by two values of ximax and ximin outside which the possibilities are not to be found in the range of the magnitude, while within the interval all values have the same probability called quadratic width equal to ximax - ximin.

In this case, it can be attributed as an estimation of xi the average value of the interval:

$$\overline{X_i} = X_{i\,max} - X_{i\,min}/2 \quad and \quad U\left(\overline{x_i}\right) = X_{i\,max} - X_{i\,min}/2\sqrt{3} \quad (3)$$

Below is given the expression of composed uncertainty (absolute value). In frequent applications for simplicity, we assume the measurement function with no more than 3 input values.

The function Y=A/B in this case we have a ratio, ie composed uncertainty in absolute value:

$$U(y) = 1/B\sqrt{U_A^2 + A^2/B^2 U_B^2} \quad (4)$$

Below are the uncertainties associated with the flatness of the sample surface and the angles between its faces. From the equation: $R_c = F/S$

Considering factors of influence, the following model of measurement is derived:

$$R_c = F + \Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4 + \Delta F_5 + \Delta F_6 / S \quad (5)$$

Where: F is the value of the maximum force transmitted by the compressor, which corresponds to the load of the sample failure

ΔF1 Correction determined by the compressor setting

ΔF2 Correction determined by the application speed of the load

ΔF3 Correction determined by the conditions of aging

ΔF4 Correction determined by nonlinearity

Ssample base surface over which the fore is applied. This is determined by the equation: $S = (\ell_1 + \Delta\ \ell_1).(\ell_2 + \Delta \ell_2) = - - - - - - - - mm^2$(6)

In which ℓ1 and ℓ2 are the long and the width of the sample surface respectively and Δℓ1 and Δℓ2 are the corrections determined by relative uncertainty related to their measurement.

In the following equations, the two terms in denominator and numerator of formulas are considered statistically independent.

Calculation of Composed Uncertainty

Absolute composed uncertainty may be derived from the equation:

$$\left[U\left(R_c\right)\right]^2 = 1/S^2\{\left[U\left(F\right)\right]^2 + \left[U\left(\Delta F_1\right)\right]^2 + \left[U\left(\Delta F_2\right)\right]^2 + \left[U\left(\Delta F_3\right)\right]^2 + \left[U\left(\Delta F_4\right)\right]^2 +$$
$$\left[U\left(\Delta F_5\right)\right]^2 + \left[U\left(\Delta F6\right)\right]^2 + (1/S^2)^2\left(F + \Delta F_1 + \Delta F_2 + \Delta F_3\right)^2\left[U\left(S\right)\right]^2\} = N/mm^2$$

Defining the Best Evaluation of F and its Uncertainties

The distribution of the values of the measurement object, ie the resistance to compression, is evaluated by performing a series of repeated measurements Table 1.

Table 1. Distribution of the values of the measurement object.

Test number (n)	Fi (N)
1	135592.8
2	140865.2
3	125048
4	135592.8
5	126948
6	135593.4
7	128079
8	140762.4
9	138487
10	126072
	133304.1
s = u(Fi)	6178.3
U() =	s/1955.2
CV = s/	0.046
v = n-1	10-1=9

Determination of ΔF1 Value and Its Uncertainty U(ΔF1)

Correction obtained from reading the F value is 0.

In the case of evaluating relative uncertainty U(ΔF1) with B method, all values have the same probability called foursquare [2]. (In this case, it is not given the level of confidence). Uncertainty is given for a=1 kN=1000 N. This is the scale division of the testing machine.

$U(\Delta F1) = \sqrt{(U(Fkal)^2 + U(Ftare)^2)} = \sqrt{(125^2 + 577^2)} = \sqrt{348554} = 590N$ (8)

Where: $U_{read} = a//\sqrt{3} \quad = 1000/\sqrt{3} \quad = 577N$

(In our case the testing machine is calibrated and we obtain the specific value from the calibration certificate. According to calibration certificate no F-355/2009 with measuring range 0-500 kN and with 1 kN scale division, the expanded uncertainty is U=0.25 kN so the standard uncertainty is u=U/2 for 95% distribution level and k=2 covering factor.

$$U = U/2 = 0.025/2 = 0.125kN = 125N \qquad U\left(\Delta F_{compress}\right) = 125N \ (9)$$

Determination of ΔF2 Value and its Uncertainty U(ΔF2)

Value of ∆F2 = 0. As the technical documents highlight is difficult to evaluate quantitatively the effect of load application speed over compression resistance of a sample. For simplicity from technical documents that uncertainty values u(∆F2) to be 2% of the mean value of F.

$$U(\Delta F_2) = 2/100.\bar{F} \quad = 2\% \quad \bar{F} = 2/100^{\cdot}133304.1 = 2666.1N \qquad U\left(\Delta F_2\right) = 2666\ N\ (10)$$

Determination of ΔF3 Value and its Uncertainty U(ΔF3)

Correction mean value ∆F3 = 0. As the technical documents highlight is difficult to evaluate quantitatively the effect of curing conditions over compression resistance of a sample, it is supposed for simplicity from technical documents that uncertainty values:

$$U\left(\Delta F_3\right) = 1.5\bar{F} \quad = 1.5/100.133304.1 = 1999.6N \qquad U(\Delta F_3) = 2000N(11)$$

Determination of ΔF4 Value and its Uncertainty U(ΔF4)

Correction mean value is zero. As the technical documents highlight is difficult to evaluate quantitatively the effect of the planar condition over compression resistance of a sample, it is supposed for simplicity from technical documents that uncertainty values to be 1.5% of the mean value

$$U(\Delta F4) = 1.5\%\ F = 1.5/100^{\cdot}133304 = 2000N \qquad U(\Delta F4) = 2000N(12)$$

Determination of U(ΔF5) Value and its Uncertainty

Correction mean value is zero. Test methods specify conditions according to the plane surface angle between faces. From technical documents uncertainty values U(∆F5) to be 0.1% of F

$$U(\Delta F_5) = 0.1/100^{\cdot}133304 = 133N \qquad U\left(\Delta F_5\right) = 133\ N(13)$$

Determination of U(ΔF6) Value and its Uncertainty

Correction mean value is zero. Test methods specify conditions according to the positioning of plates of load appliances in the center, and this uncertainty belongs to operators since it is difficult to evaluate quantitatively this effect it is supposed for simplicity from technical documents that uncertainty values to be 0.5% of F.

$$U\left(\Delta F_6\right) = 0.5/100^{\cdot}F = 0.5/100^{\cdot}133304 = 667N \qquad U\left(\Delta F_6\right) = 677N(14)$$

Determining the Surface of the Sample and Its Uncertainty

The sample surface is determined by the equation: $S = (\ell 1 + \Delta\ell 1)\ .\ (\ell 2 + \Delta\ell 2)$ (15)

In this case, we have:$Y = A$. B so we have obtained the input sizes composed uncertainty in absolute value: $U(y) = \sqrt{B^2U_A^2 + A^2U_B^2}$ (16)

So, in our case we can write:

$$U(S) = \sqrt{\begin{matrix}(\ell_2+\Delta\ell_2)^2\{[U(\ell_1)]^2+[U(\Delta\ell_1)]^2\}+ \\ (\ell_1+\Delta\ell_1)^2\{[U(\ell_2)]^2+[U(\Delta\ell_2)]^2\}\end{matrix}} \ (17)$$

Table 2. Measurement results for ℓ1 and ℓ2.

n	ℓ1 (mm)	n	ℓ2 (mm)
1	248	1	248

2	250	2	250
3	249	3	249
4	248	4	249
5	248	5	248
6	248	6	248
7	247	7	247
8	248	8	246
9	248	9	245
10	248	10	246
	248.3		246.3
S = u()	0.625		0.76
U()	0.198		0.241
v = n - 1	10 – 1 = 9		10 – 1 = 9

where:

$S = u(\ell)$Standard deviation or (standard uncertainty)$U(\bar{\ell}) = s/\sqrt{n}$ The absolute standard deviation of the mean$v$ The degree of freedom number

We evaluate the standard uncertainty U(Δℓ1) and U(Δℓ2) and corrections from readings Δℓ1 and Δℓ2. The corrections obtained from Δℓ1 and Δℓ2 readings are estimated zero **Table 2.**

Relative uncertainty type U(Δℓ1) and U(Δℓ2) are estimated to have a value of 0.05 mm.

$\Delta\ell_1 = 0; \quad \Delta\ell_2 = 0 \quad\quad U(\Delta\ell_1) = U(\Delta\ell_2) = 0.05mm$ (18)

In conclusion, we have:

$$S = (\ell_1 + \Delta\ell_1)\cdot(\ell_2 + \Delta\ell_2) = 248.3\cdot 246.3 = 61156\,mm^2 \quad (19)$$

$$U(S) = \sqrt{(\ell_2 + \Delta\ell_2)^2 \{[U(\ell_1)]^2 + [U(\Delta\ell_1)]^2 + (\ell_1 + \Delta\ell_1)^2 \{[U(\ell_2)]^2 + [U(\Delta\ell_2)]^2\}}$$

$$= \sqrt{(246.3)^2 \{[0.198]^2 + [0.05]^2\} + (248.3)^2 \{[0.241]^2 + [0.05]^2\}}$$

$$= \sqrt{60663.7 \,.\, (0.039 + 0.0025) + 61652.9(0.058 + 0.0025)}$$

$$= \sqrt{60663 \,.\, 0.042 + 61652 \,.\, 0.061} = \sqrt{2547.9 + 3730} = 79.23\,mm^2 = 79\,mm^2 \quad u(S) = 79mm^2 \quad (20)$$

The Best Estimation of Measurement and Calculation of Composed Uncertainty

We replace the founded values:

$$R_c = +\Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4 + \Delta F_5 + \Delta F_6 / = 133304.1N / 61156mm^2 = 2.18N / mm^2$$

$$R_c = 2.18N / mm^2$$

For calculation of composed uncertainty we apply the following equation:

$$[U(R_C)]^2 = 1/S^2 \{[U(F)]^2 + [U(\Delta F_1)]^2 + [U(\Delta F_2)]^2 + [U(\Delta F^3)]^2 + [U(\Delta F_4)]^2 + [U(\Delta F_5)]^2 + [U(\Delta F_6)]^2\} +$$

$$l/S^4 \,(F + \Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4 + \Delta F_5 + \Delta F_6)^2 \,[U(S)]^2 = 1/61156^2 \,.\, (1955^2 + 590^2 + 2666^2 + 2000^2 + 2000^2$$

$$+133 \quad +667 \quad) + (1/61156 \quad) \quad . (133304) \quad .79 \quad =$$

$$1/61156^2 \left(3.822025 \ +335929 + 7107556 \ + \ 4000000 \ + \ 4000000 \ +17689 \ + \ 444889\right) \ +5.94 =$$

$$0.005 \ +0.000000594 = 0.005 N/mm^2 \qquad U\left(R_c\right) = 0.07 N \ /mm^2$$

CALCULATION OF EXTENDED UNCERTAINTY

Even though composed type uncertainty u(y) might be enough to characterize a measurement, in many applications we prefer to determine a wider interval U(y) round the result y in order to fall a greater part of values [3].

This broader interval is the extended uncertainty U(y)=k . u(y)

where: k is found in variables tp of Student given in the relevant table.

To choose the value of k in Student table we should decide the level of probability (generally 95%) and calculate the number of effective free degrees that are attributed to u(y). Such a calculation can be made with the equation below:

Weich-Satterthwaite: $V_{eff} = \left[U(y)^4 / \sum \{[(\partial y/\partial_{xi}) \quad U(x_i)]^4 . 1/v_i\} \right] = [U(y)]^4 / \sum \{[(\partial y/\partial_{xi}) \quad U(x_i)]^4 . 1/v_i\}$

From which if $\partial y/\partial_{xi} = 1$ we have: $V_{eff} = [U(y)]4 / \sum \left\{ [U(xi)]^4 \quad . \quad 1/v_i \right\}$

In our case we are calculating Veff with equation 1:

$$V_{eff} = [U(y)]^4 / \sum \{[U(x_i)] \quad 1/v_i\} = [U(Rc)]4/[(1/S).U(F)]4.1/vF + [(-F/l_1^2 l_2)U(l_1)]41/vl_1 +$$

$$[(-F/l_2^2 l_1)U(l_2)]41/vl_2 = \frac{0.07^4}{\left[\left(\frac{1}{61156}\right) \ 1955\right]^4 \frac{1}{9} + \left[-\left(\frac{133304}{248^2} \ 246\right) 0.198\right]^4 \frac{1}{9} + \left[-\left(\frac{133304}{248} 246^2\right) 0.241\right]^4 \frac{1}{9}} \quad (22)$$

Veff = 10.65

From Student table, we have k=2.18

We find the covering factor k from the table below. This table is based in a t distribution of Student for a credibility level of 95.45% **Table 3**.

Table 3. T distribution of Student for a credibility level of 95.45%.

Veff	1	2	3	4	5	6	7	8	10	20	50	∞
k	13.97	4.53	3.31	2.87	2.65	2.52	2.43	2.37	2.28	2.13	2.05	2.00

U(y)=k . u(y)

Considering the approaches that are not mentioned, it is considered when Veff=I0 can be substituted the exact value of tp with a covering coefficient k=2. This is due to the fact that the calculation of uncertainty constitutes a significant difficulty because the measurement object is influenced by both types A uncertainty and type B uncertainty. So k=2 for n=10 (**Table 4**).

Table 4. Calculation of uncertainty constitutes.

n	6	8	10	12	16	20	25	≥ 30
k	2.33	2.19	2.10	2.05	1.98	1.93	1.88	1.64

This mode is used for ease of calculation.

k=2.1 for n=I0   U=2.I . 0.07=0.147=0,15 N

$y = y \pm U$ this is the result $Rc = fc = 2.18 \pm 0.15 \, N = 2.2 \pm 0.2 \, N/mm^2$

This is the characteristic resistance to compression coupled with its uncertainty Table 5.

In percentage the uncertainty is: $0.15/2.18 \times 100 = 6.88\%$ $U\% = \mathbf{6.9}\%$Aaaa

Table 5. Characteristic resistance to compression coupled with its uncertainty.

Xi	Xi value	Uncertainty type u(xi)	Distribution	Uncertainty contribution
F	$\bar{F} = 133304$	$u(F) = 6178.3$	normal	$U\bar{F}(Y) = 1955$
$\Delta F1$	$\Delta F1 = 0$	$U(\Delta F1) = 577$	rectangular	$U(\Delta F1) = 577$
$\Delta F2$	$\Delta F2 = 0$	$U(\Delta F2) = 2\%$ $\bar{F} = 2660$	technical assessor	$U(\Delta F2) = 2666$
$\Delta F3$	$\Delta F3 = 0$	$U(\Delta F3) = 1.5\%$ $\bar{F} = 2000$	technical assessor	$U(\Delta F3) = 2000$
$\Delta F4$		$U(\Delta F4) = 1.5\%$ $\bar{F} = 2000$	technical assessor	$U(\Delta F4) = 2000$
$\Delta F5$		$U(\Delta F5) = 0.1\%$ $\bar{F} = 133$	technical assessor	$U(\Delta F5) = 133$
$\Delta F6$		$U(\Delta F6) = 0.5\%$ $\bar{F} = 667$	technical assessor	$U(\Delta F6) = 667$
ℓ_1	$\overline{\ell_1} = 248.3$	$U(\ell_1) = 0.63$	normal	$U(\ell_1) = 0.198$
ℓ_2	$\overline{\ell_1} = 246.3$	$U(\ell_2) = 0.76$	normal	$U(\ell_2) = 0.241$
$\Delta\ell_1$	$\Delta\ell_1 = 0$	$U(\Delta\ell_1) = 0.05$	technical	$U(\Delta\ell_1) = 0.05$
$\Delta\ell_2$	$\Delta\ell_2 = 0$	$U(\Delta\ell_1) = 0.05$	technical assessor	$U(\Delta\ell_2) = 0.05$

UNCERTAINTY BALANCE AND UNCERTAINTY CONTRIBUTIONS

From the values of the table we build the graph in Microsoft Excel and look which has the greatest contribution [4] Figure 1. Those that have a very small contribution are neglected. (Uncertainties that are 1/5 of the main uncertainty are neglected) Figure 2.

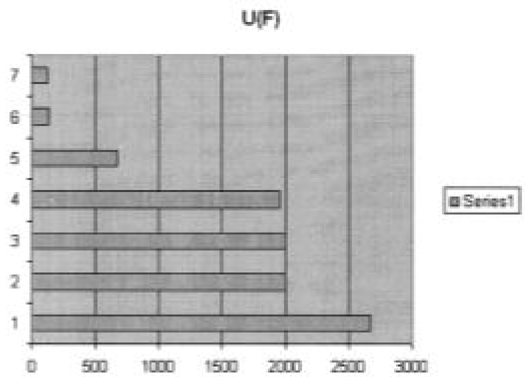

Figure 1. Uncertainty balance.

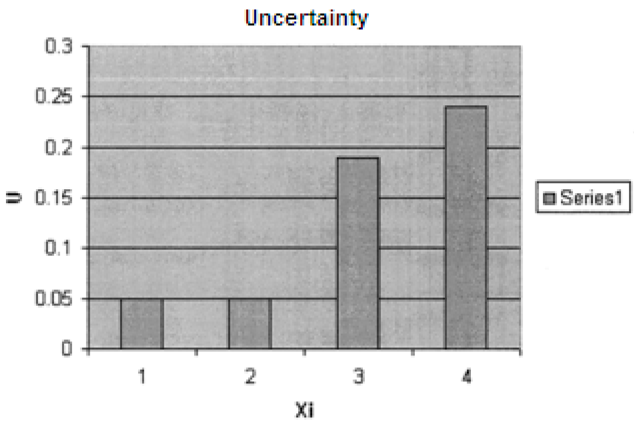

Figure 2. Uncertainty contributions.

REGISTRATION DOCUMENTS

For the implementation of this procedure, the measurement uncertainty assessment register is used in the SC-Rr management system [5].

REPORTING THE RESULT

(The uncertainty of the sampling process is not taken into account and it should be made clear that the result and the uncertainty associated are applied only to the samples being tested and not applied to any party from which the sample may have been taken)

The extended reported uncertainty is based on a standard multiplicity uncertainty with a coverage coefficient k=2.1 which for a margin of Veff =10.7 degrees of effective freedom provides a 95% confidence level of approximately.

REFERENCES

1. https://ec.europa.eu/jrc/en/eurl/ecvam
2. http://www.nab.lt/Files/EA%204-02%20Matavimo%20neapibr%C4%97%C5%BEties%20i%C5%A1rai%C5%A1ka%20kalibravime.pdf
3. https://european-accreditation.org/wp-content/uploads/2018/10/ea-4-16-g-rev00-december-2003-rev.pdf
4. Curtin WG, et al. Structural masonry designer's manual, Blackwell, Oxford. 1995.
5. Saileysh SS. Bibliography on masonry structures-technical report.