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APPLICATION OF THE BENOR-MARK IN THE SECTOR OF CONCRETE REINFORCEMENTS - ASSESSMENT METHODS APPLICABLE TO THE "USERS OF THE MARK, PROCESSORS AND DISTRIBUTORS OF BENOR PRODUCTS" - TEST METHODS AND CONTROL EQUIPMENT

The valid version is available on the PROCERTUS-extranet.

CONTENTS

1 OBJECT

This document completes the provisions of the various Implementation Rules of the BENOR mark in the sector of the reinforcing steel products, describing the assessment methods applicable to the users of the mark:

- Producers of hot rolled and cold formed reinforcement, of welded fabrics and plane panels, of lattice-girders or of mechanical splices
- Processors (straightening, cutting, bending and welding, mechanical splices)
- Distributors of BENOR products.

2 GENERAL PROVISIONS CONCERNING THE TEST METHODS

The products according to the series of standards NBN A 24-301 to 304 and corresponding PTVs of PROCERTUS are tested with the test methods described in standard NBN EN ISO 15630-1 or -2 unless otherwise stipulated in the PTVs or in this document.

By consequence, the calculation of the tensile mechanical characteristics (R_{eH} or $R_{p0.2}$ and R_m), is made using the real section in accordance with the product standards.

3 GENERAL PROVISIONS CONCERNING TEST SPECIMENS

Unless otherwise specified in the Implementation Rules or PTVs, the test specimens shall be taken from the bar, rod or wire in the as-delivered condition. In the case of a test specimen taken from a coil (rod or wire), the test specimen shall be straightened prior to any testing, by a bend operation with a minimum amount of plastic deformation. The straightness of the test specimen is critical for the determination of the actual cross-section based on mass and length, the determination of the rib or dent mean spacing and for the tensile test at room temperature. The method of straightening the test specimen (manual, machine) shall be indicated in the internal documentation of the manufacturer.

4 TEST METHODS

4.1 Interpretation of results

The interpretation of results is carried out in accordance with the rules, either based on individual values - interpretation by attributes, or calculated statistics - statistical interpretation. When the value of the coefficients to be used for the statistical interpretation does not appear directly in the Table, it is advisable either to choose the most unfavourable value of "k", or to interpolate between the given values.

Concerning the comparison between values obtained and the values specified in the standards, it is required to compare the figures with the same number of decimals as the values quoted in the standards (example: a value of lengthening of 4.86% must be rounded to 4.9%, and is lower than the criterion of 5.0% quoted for instance by a given PTV[1].

The standards provide that the tests are carried out at a temperature ranging between 10 and 35 °C. This is why, except in case of doubt, the checking of the temperature of environment is not necessary.

[1] **PTV**: **P**rescriptions **T**echniques – **T**echnische **V**oorschriften

4.2 Tensile test

4.2.1 Preparation of the samples

The state in which the samples are tested is recorded (method of straightening, ageing or not).

4.2.2 Equipment

When ageing of the test piece by heating at 100 °C is required, a minimum heating time of 40 min in addition to the required time according to the test method can be considered sufficient to heat up the centre of the specimens, unless otherwise proven.

The identification of the tensile testing machine used must be recorded in the report (in particular when several machines are available with overlapping ranges).

In order to use the test results of the testing machines for evaluation tasks within the framework of BENOR-certification, the following conditions apply:

- The test results of at least one testing machine of the producer shall be the subject of a yearly paired comparison with the testing machine of a control laboratory[2].
- When the producer uses more than one testing machine within the framework of BENOR certification, those machines are annually compared with the machine for which the comparison with the control laboratory is carried out. Whenever this would not be possible (e.g. because of different measurement ranges), an annual comparison with a control laboratory shall be performed.
- Each testing machine used within the framework of the BENOR certification shall be subjected to a paired comparison with a control laboratory at least once every three years.

The paired comparison will be performed for the test results of the tensile strength and the yield strength by the method of the paired observations (see NRN 418). The comparison must show that the series of tests are statistically identical.

4.2.3 Determination of R_e and R_m

The test results which must be reported to PROCERTUS always include the measured values (forces, length and mass), in addition to the computed values (stresses).

4.2.4 Determination of A_{gt}

The method of determination of Agt must be mentioned: extensometer until rupture, displacement of the cross-pieces, measures direct on the specimen after rupture (apart from the necking area).

The length of the specimen, the extensometric base and, if necessary, the number and the position of the welds (interior or outside of the extensometer) must be recorded; as well as the position of the rupture compared to the clamping pieces of the machine, with the extensometer, and the nearest weld.

4.3 Rebend test

4.3.1 Equipment

If the producer does not have the equipment to measure the internal temperature of steel, it is important to place the samples in the furnace for the minimum duration in accordance with §4.2.2 and to maintain the temperature of the furnace within 100 ± 10 °C. The measure of this duration starts as soon as the temperature of the furnace, after having placed the samples there, has reached 100 °C.

4.3.2 Checking of the mandrel

The checking of the diameter of the mandrel is done using a measuring instrument precise to the mm. The use of a

[2] Laboratory accredited according to ISO/IEC 17025 and listed on the extranet.

mandrel of smaller diameter is allowed. The diameter of the mandrel used is recorded.

4.3.3 Speed

Speeds of bending-rebending currently of use remain accepted in so far as they do not exceed 60 °/s.

4.3.4 Criterion

Only frank separations of rib base, or cracks with depth higher than the tenth of the diameter of the examined reinforcement are regarded as a non-conform result.

4.4 Chemical Composition

4.4.1 Certificates of chemical analysis

The term "certificate of chemical analysis" refers to inspection documents type 3.1 or 3.2 following standard EN 10204, which contain test results for the production batch covered by the inspection document.

4.4.2 Samples of reference

For the chemical analyses by spectrometry, the reference samples put to provision by the producer can be used in so far as they are emitted by a recognised metallographic centre (IRSID, BAM, MPI, …). The calibration of the spectrometer is considered acceptable when the values (average of three measures) given are in the range of the value of the reference piece ± 2 σ.

Example: sample IRSID 1658 - contents of % in weight

Element	C	Mn	Si	S	P	Cr	Ni	Cu	Mo
Nominal Content	0,180	0,618	0,160	0,032	0,014	0,147	0,241	0,345	0,046
σ	0,010	0,018	0,009	0,003	0,001	0,007	0,009	0,022	0,004
Allowed range	0,160 0,200	0,582 0,654	0,142 0,178	0,026 0,038	0,012 0,016	0,133 0,161	0,223 0,259	0,301 0,389	0,038 0,054

4.5 Dimension and mass

4.5.1 Measuring Accuracy

Standard NBN EN ISO 15630-1 stipulates in its § 12.2 that length and mass are measured with an accuracy of at least ±0.5%. The precision of the measuring instrument is not defined in a univocal way but deduced from the purpose to measure. To guarantee this accuracy, PROCERTUS considers that the reading must be made with ± 0.25%.

The ends of the specimen must be cut in a clear way and perpendicular to the axis of the sample; in case of doubt or of dispute, the specimen must be sawn and not cut.

As an indication, the tensile specimens, generally 40 to 80 cm long, can be measured with a simple meter [possible reading to a (half)-millimetre]. On the other hand, the samples taken between welds for the determination of the section (specimens from 8 to 16 cm) are measured with the calliper rule (reading to one tenth of a mm).

In the same way, the precision of the balance will be function of the diameter:

- to 0.1 g for the small diameters (on the basis of L = 40 cm)
- to 0.5 g for the diameters equal or higher than 8 mm
- to 1 g for the diameters equal or higher than 10 mm
- to 2 g for the diameters equal or higher than 14 mm (diameter 12 if L ≥ 50 cm).

Moreover, the standard mentions in §12.3 that the effective mass per metre (linear density) must be compared with the nominal mass per meter (linear density) indicated in the product standard: the measurement values used to calculate this mass per meter (linear density) must therefore have a sufficient number of significant digits.

4.5.2 Method of calibration of the laboratory balances

4.5.2.1 Annual checking

For the calibration of balances, the operator will carry out at least the three following checks:

- Linearity of the balance with increasing load by successive applications at the centre of the plate of the balance of at least 5 different test loads (from zero to the authorised maximum loading of the balance), distributed as evenly possible on the entire calibration range.
- Eccentricity of the balance by weighing of a test load, which corresponds roughly to half of the capacity of the balance, eccentrically placed on the balance plate and this in 4 directions. A weighing in the middle of the balance plate is also carried out before and after the offset measurements.
- Repeatability of the balance by weighing at least 5 times the same test load (corresponding roughly to half of the capacity of the balance) in the centre of the balance plate.

4.5.2.2 Quarterly Checking

For the calibration of balances, the operator will carry out four times at least a year the following check:

- Linearity of the balance with increasing load and decreasing load by applications at the centre of the balance plate of at least 3 different test loads (of zero with the authorised maximum loading of the balance), distributed as evenly as possible on the entire calibration range.

4.5.3 Roll meters and measuring tapes

The options are as follows:

- Either only roll meters or measuring tapes with calibration mark are used.
- Or the manufacturer has a metal reference ruler with calibration mark, by means of which the roll meters and the measuring tapes are controlled.

The roll meters and the measuring tapes belong at least to accuracy class II, the reference ruler belongs at least to accuracy class I according to the Regulation annexed to the Belgian Royal decree of 14 April 1977[3] concerning the material measures of length.

- If only roll meters and measuring tapes with calibration marks are used, they cannot be used more than one year.
- If the roll meters and the measuring tapes are controlled by means of a reference ruler, the difference between the overall length of the roll meter or the measuring tape and that of the reference ruler cannot be higher than (0.6 + 0.4 L) mm, where L is the length of the meter ribbon or the ruler in meter.

4.5.4 Control of radii of curvature

The producer must have the devices necessary for the control of the radii of curvature of the worked parts. These devices must be described in the technical file.

4.5.5 Control angle of bending

The manufacturer must have a protractor graduated to check the angle according to which the part was bent.

[3] Koninklijk besluit betreffende de stoffelijke lengtematen / Arrêté royal relatif aux mesures matérialisées de longueur

4.6 Measurement of the geometrical characteristics

4.6.1 Test equipment

The geometrical characteristics shall be measured with an instrument of an accuracy of at least the following:

- 0,01 mm for the height of transverse or longitudinal ribs and depth of indentations for the measurements less than or equal to 1 mm
- 0,02 mm for the height of transverse or longitudinal ribs and depth of indentations for the measurements greater than 1 mm
- 0,05 mm for the gap between the transverse ribs or indentations of two adjacent transverse rib or indentation rows
- For the distance between transverse ribs or indentations
  - either 0,5 mm when simply determining the transverse rib or indentation spacing
  - or 0,1 mm when determining the elongation of the reinforcement in the straightening process (see § 8)
- one degree for the inclination between the transverse rib or indentation and the longitudinal axis of the bar, rod or wire or the rib flank inclination.

In case of dispute, conventional direct-reading instruments, e.g. callipers, depth gauges, shall be used.

5 RECORDING

A summary list of all the measuring instruments used must be available. This list must show at least the following data: the identification number, the mark and the type, the date of commissioning (and of calibration).

6 OVERVIEW OF THE ACCURACY AND CONTROL OF THE EQUIPMENT

A list of the most current control equipment is given below, as well as the minimal frequency of the calibrations and required controls. PROCERTUS can authorise exemptions from the modes of enforcement of this reguirement on written request of a user and opinion of its qualified Technical Advice Bureau.

Except typical cases, PROCERTUS does not require to mention and justify the uncertainty of measurement as aimed for by the standard NBN EN ISO/IEC 17025.

Table 1 – Equipment and requirements

Calibration of the measuring equipment						
Equipment	**Property**	**Method**	**Frequency**	**Criterion**	**Carried Out by (*)**	**Measures in the event of exceeding the control criteria**
Balance	Mass	See § 4.5.1	1x/year	0.25%	1,2 or 4	Fitting or downgrading
		See § 4.5.1	4x/year (when no annual calibration by 1 or 2)	0.25%	3	Fitting or downgrading
Measure	Length	See § 4.5.3	See § 4.5.3	See § 4.5.3	1, 2 or 4	See § 4.5.3
Ovens	Temperature	Determination of the temperature in minimum 4 points of the drying oven	1x/year	±3 °C around the set value	1, 2 or 4	Fitting or downgrading
Extensometer	Elastic Limit	EN ISO 9513	1x/year	Class 1	1	Fitting or downgrading
	Total Lengthening	EN ISO 9513	1x/year	Class 2	1	
Engraver		Checking of engravings: parallelism, variation and smoothness of the features. Repetition of the reading on a basis of 10 slipping features	1x/year		1, 2 or 3	
Tensile Testing Machine		EN ISO 7500	1x/year (+after any repair or moving)	Class 1	1	Fitting or downgrading
Bending mandrel			No mandatory			
Calliper	Length	Using calibrated standard blocks	1x/year	0.1 mm	1, 2 or 4	Correction of the values read, fitting or downgrading
Callipers, depth gauges	Geometrical characteristics	- Using calibrated standard blocks - External calibration by a certified laboratory	1x/year	See § 4.5.3	1, 2 or 4	Correction of the values read, fitting or downgrading
Profile Projector	Factor of profile	Using calibrated profiled bar-standards (with a certified f_R or f_P value for the devices computing these characteristics)	1x/3 month	See (**)	4	Correction of the values read, fitting or downgrading
Bars, holds and weight reference		Comparison with the standard	1x/5 years		1	Fitting or downgrading
Thermometer for ambient temperature			Not mandatory 1 x/year	±1 °C ±0.5 °C	4 1	Fitting or downgrading

(*) The calibrations are carried out by:

1 = an external laboratory
- accredited by BELAC or by another organisation member of EA or
- failing this, accepted by the certification body of for the calibration of the concerned equipment

2 = the supplier of measuring equipment

3 = the producer himself under the supervision of the inspection body and according to a procedure described in the technical dossier

4 = the producer himself following a procedure described in the technical dossier and respecting the prescribed method.

Note: in all cases, the calibration can be carried out by an organization of higher category.

(**) The maximum deviation allowed for the average and the standard deviation is: vertically (height) 0.01 mm / horizontally (longitudinally) 0.10 mm

7 DETERMINATION OF THE "Λ-VALUE" FOR THE COMPUTATION OF F_R OR F_P

This procedure details the methodology to determine a coefficient "λ" for one diameter of one product as defined by ISO 15630-1 in the chapter 11 dealing with the *Empirical formula*:

d) Empirical formula:

$$f_R = \lambda \frac{a_m}{c} \quad (8)$$

where λ is an empirical factor, which may be shown to relate f_R to a_m/c for a particular bar, rod or wire profile.

$$f_P = \lambda \frac{a_m}{c} \quad (14)$$

where λ is an empirical factor, which may be shown to relate f_P to a_m/c for a particular bar, rod or wire profile.

c	mm	Transverse rib or indentation spacing
a_m	mm	Rib height at the mid-point or indentation depth in the centre

The procedure consists in the following steps for each certified diameter:

- To define the exact shape of ribs or indentations of the profile
- To measure all geometrical parameters necessary to be able to make an accurate calculation of f_R / f_P of each sample selected for the quality check with the complete formula (see EN ISO 15630-1 § 11).
  - When certain assumptions are adopted concerning the exact shape of ribs or indentations for the ease of calculation, those assumptions shall be as such that the calculated values of f_R / f_P are more conservative.
  - This above-mentioned measurement shall include at least 30 values of these parameters for samples from at least 3 test units from different representative productions taking into account the wearing of the rolling devices.
- To compute the corresponding "λ" values, thanks to the parameters f_R, a_m and c or f_P, a_m and c for each sample.
- To perform a statistical computation of the calculated "λ" values to determine the "m-ks" value (see k values in the table below for an acceptable quality level (AQL) of 10% with a risk of 10%) of all samples[4] (see Table 2)
- The obtained "m-ks" value is the coefficient "λ"value for the specific diameter of the product.

[4] This characteristic value is the lower limit of the statistical tolerance interval at which there is a 90 % probability (1 - α = 0,90) that 90%(p = 0,90) of the values are at or above this lower limit. This definition refers to the long-term quality level of production.

Table 2- AQL 10 % (p = 0,90) – β-risk 10 % (1 – α = 0,90)

n	k	n	k
5	2,74	30	1,66
6	2,49	40	1,60
7	2,33	50	1,56
8	2,22	60	1,53
9	2,13	70	1,51
10	2,07	80	1,49
11	2,01	90	1,48
12	1,97	100	1,47
13	1,93	150	1,43
14	1,90	200	1,41
15	1,87	250	1,40
16	1,84	300	1,39
17	1,82	400	1,37
18	1,80	500	1,36
19	1,78	1000	1,34
20	1,77	∞	1,28

Based on the table listing the so computed "λ"value for each BENOR-certified diameter of the concerned product, the producer will make a proposal for the "λ" value to be made public. The producer has the option to group diameters with the same public "λ"value, when the values for each individual diameter are more conservative.

The assessment of this computation is performed by PROCERTUS and will lead to the publication of the validated "λ" values when accepted.

8 SIMPLIFIED PROCEDURE FOR THE VERIFICATION OF THE SETTINGS OF A STRAIGHTENING MACHINE

The procedure consists in applying the empirical formula of ISO 15630-1 on the concerned reinforcement before (index 1) and after (index 2) the straightening process and to compute not only the f_R or f_P ratio, but also the a_m and c ratio:

- f_R or f_P ratio = f_{R2} / f_{R1} or f_{P2} / f_{P1} [5]
- a_m ratio = a_{m2} / a_{m1}
- c ratio = c_2 /c_1

The amount of relative decrease of rib height or indentation depth gives information about the radial pressure exerted to the reinforcement during the straightening. When too high or too much repeated by bending/unbending sequences, this pressure is detrimental not only for the geometry of the reinforcement but also for its mechanical properties (possibility of Bauschinger's effect and decrease of yield stress).

It is important also to measure the possible extension induced by the straightening process on the reinforcement and this can be measured by the c ratio. To the end of measuring a reliable "c ratio", the spacing of ribs or indentations should be measured on a length of at least 100 mm.

As regards the necessary measurements to be carried out,

- a_m should be measured with an accuracy of ± 0,01 mm
- c should be measured with an accuracy not less than ± 0,1 mm on a length not less than 100 mm.

[5] It is important to observe that this ratio does not depend on the "λ-value" of the empirical formula. That means that **the computation of f_R or f_P ratio does not require the knowledge of the "λ-value"**.

The last version of EXCEL file BENOR reinforcements Geometry before and after straightening is linked to the present document and displays for each type of steel a sheet enabling to input the necessary measurements and output the conclusions of those measurements. To be noted is the fact that this software can be used with or without the "λ" value.

9 HISTORY OF REVISIONS

Revision 0 to 4, creation, update

Revision 5, update of Table1 and inclusion of two chapters on

- Determination of the "λ-value" for the computation of f_R or f_P
- Simplified procedure for the verification of the settings of a straightening machine for a given diameter of a given product type

Revision 6, update of

- Simplified procedure for the verification of the settings of a straightening machine for a given diameter of a given product type, so as to include the ratio of f_R or f_P after and before straightening and to introduce maximum limits as defined by PTV 302 and PTV 303.

Revision 7, general revision

Revision 8, §4.2.2, §4.5.2.1

Revision 9

- Transfer of asbl OCAB-OCBS vzw to asbl PROCERTUS vzw
- Editorial corrections

Revision 10, §4.4.1 Certificates of chemical analysis