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EQUIPEMENTS DE CONTRÔLE	ECU	606
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ECU 606/5 (2020)

APPLICATION

DE LA MARQUE BENOR

DANS LE SECTEUR DES

PRODUITS EN ACIER POUR BETON

Modalités de contrôle applicables aux

Usagers de la Marque, Producteurs, Façonniers et Distributeurs de produits BENOR

EQUIPEMENTS DE CONTRÔLE

REVISION 5

BENOR asbl

Approuvé par le Conseil d'Administration le 12/06/2020

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Equipment of Control and Usage

ECU 606 Revision 05

Application of the BENOR-mark in the sector of concrete reinforcements - Methods of assessment applicable to the "Users of the mark, Producers, Processors and Distributors of BENOR products" - Equipment of control, determination of the "λ-value" for the computation of f_R or f_P, simplified procedure for the setting of a straightening machine[1]

1 Object

This regulation completes the provisions of the various implementing regulations of the BENOR mark in the sector of the reinforcing steel products, describing the methods of assessment applicable to the users of the mark:

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

2 Testing method

The products according to the series of standards NBN A 24-301 to 304 and corresponding PTVs of OCAB-OCBS must be controlled by respecting the testing methods described in standard NBN EN ISO 15630-1 or -2. Those replace the contrary regulations taken again in the above-mentioned documents. The implementing regulations must be regarded as adapted consequently.

[1] See Table of contents at the end of this document

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Website : www.ocab-ocbs.com

However, 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 products standards.

3 General provisions concerning test pieces

The test piece shall be taken from the bar, rod or wire in the as-delivered condition. In the case of a test piece taken from a coil (rod or wire), the test piece shall be straightened prior to any testing by a bend operation with a minimum amount of plastic deformation. The straightness of the test piece 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 piece (manual, machine) shall be indicated in the internal document of the manufacturer.

4 Interpretation of the results

4.1 General Information

The interpretation of the results is carried out in accordance with the regulations, either based on individual values - interpretation by attribute, or calculated statistics - statistical interpretation. When the value of the coefficients to be used 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 the 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[2].

Document TRA 418[3] clarifies the rules used for the various statistical tests (normality, comparison of sampling, …).

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 (feeling of discomfort due to a too low or excessive temperature), the checking of the temperature of environment is not necessary.

4.2 Tensile test

4.2.1 Preparation of the samples

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

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

[3] TRA 418 :

Règlement d'application de la marque BENOR dans le secteur des produits en acier pour béton - Modalités de contrôle applicables aux usagers de la marque - Annexes statistiques

Toepassingsreglement van het BENOR-merk in de sector van stalenproducten voor gewapend beton - Controlemodaliteiten toepasselijk op de gebruikers van het merk - Bijlage statistiek

4.2.2 Equipment

If the producer does not have an equipment to measure the internal temperature of steel, it is important to place the samples in the furnace for a duration ranging between the minimum and maximum given in Table 1 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.

The tensile testing machine used must be noted in the report (in particular when several machines are available with zones of covering).

4.2.3 Determination of R_e and R_m

The test results which must be communicated to OCAB-OCBS 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 noted; 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 a duration ranging between the minimum and maximum given in Table 1 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 mandrel of smaller diameter is allowed. The diameter of the mandrel used is noted.

4.3.3 Positioning

The longitudinal ribs of the rolled bars do not contact the mandrel.

4.3.4 Speed

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

4.3.5 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” is to be understood with the general sense of the dictionary and not in reference to a standard.

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 recognized 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, OCAB-OCBS 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 litigation, the specimen must be sawn and not sheared.

As an indication, the tensile specimens, generally 40 to 80 cm long, can be measured with a simple meter [possible reading with (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 with the tenth of 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 metre (linear density) indicated in the product standard: the reading of the measures being used to calculate this mass per metre (linear density) must make it possible to obtain a number of sufficient significance.

4.5.2 Method of calibration of the chemical 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 and decreasing load by applications to the centre of the plate of the balance of at least 5 successive loads (from zero to the authorized maximum loading of the balance), distributed most uniformly possible on the extent of calibration.
- Eccentricity: by weighing of a weight which corresponds roughly to half of the capacity of the balance, in an eccentric way on the plate of the balance and that in the 4 directions. A checking by weighing in the middle of the plate of the balance, is also carried out before and after the offset measures.
- Repetitivity: weighing at least 5 times of the same weight (corresponding roughly to half of the capacity of the balance) in the centre of the plate of the balance.

4.5.2.2 Quarterly Checking

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

- Linearity of the balance with increasing load and decreasing load by applications to the centre of the plate of the balance of at least 3 successive loads (of zero with the authorized maximum loading of the balance), distributed most uniformly possible on the extent of calibration.

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 § 9)
- 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 cases of dispute, conventional direct-reading instruments, e.g. callipers, depth gauges, shall be used.

4.6.2 Test procedure

The maximum height of transverse ribs or depth of indentations (a_{max}) shall be determined as the mean value of the average maximum heights of transverse ribs or average maximum depths of indentations for the different rows. This average maximum height or average maximum depth per row shall be determined from at least three measurements on individual transverse ribs or individual indentations not used for the identification of the bar, rod or wire. If, in a row, there are different transverse rib or indentation angles (β) to the longitudinal bar, rod or wire axis, at least three measurements on individual transverse ribs or individual indentations shall be made per transverse rib or indentation angle.

The height of transverse ribs or depth of indentations at a given position, e.g. at the quarter-point or at the mid-point or at the three-quarters point, respectively designated $a_{1/4}$, a_m and $a_{3/4}$, shall be determined as the mean value of the average heights of transverse ribs or average depths of indentations at this given position for the different rows. This average height or average depth at this given position per row shall be determined from at least three measurements on individual transverse ribs or individual indentations not used for the identification of the bar, rod or wire.

If, in a row, there are different transverse rib or indentation angles (β) to the longitudinal bar, rod or wire axis, at least three measurements on individual transverse ribs or individual indentations shall be made per transverse rib or indentation angle.

For each row, the spacing of the transverse ribs or indentations (c) shall be determined from a measured length divided by the number of the rib gaps or protrusions between indentations included in the measured length. The measured length is deemed to be the interval between the centre of a rib or indentation and the centre of another rib or indentation of the same transverse rib or indentation angle on the same row of the test piece determined in a straight line and parallel to the longitudinal axis of the test piece. The measured length shall

- include at least 10 rib gaps or protrusions between indentations, or
- be at least 100 mm when determining the elongation of the reinforcement in the straightening process (see § 9).

The part of the circumference without ribs or indentations (Σe_i) shall be determined as the sum of the average gap (e) between each pair of two adjacent ribs or indentation rows. The average gap (e) shall be determined from at least three measurements.
The transverse rib or indentation angle (β) to the longitudinal bar, rod or wire axis shall be determined as the mean of the individual angles measured for each row of ribs or indentations with the same nominal angle.

5 Measuring instruments used within the framework of the autocontrol

5.1 Unrolling meters and rulers

The options are as follows:

- Either only meter ribbons or rulers with marking of calibration are used.
- Or the manufacturer has a gauged metal ruler of reference, by means of which the meter ribbon and the rulers are controlled.

The meter ribbons and the rulers answer at least class II, the ruler of reference answers at least class I according to the Regulation taken again to the Royal decree of 14 April 1977[4] concerning the materialized measures length. If all the instruments used bear a punch of calibration, they cannot be used more than one year. If the meter ribbon and the rulers are controlled by means of a ruler of reference, the difference between the overall length of the meter ribbon or the ruler and that of the ruler in reference cannot be higher than (0.6 + 0.4 L) mm, where L is the length of the meter ribbon or the ruler in meter.

5.2 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.

5.3 Control angle of bending

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

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

5.4 Recording

A summary list of all the measuring instruments used must be at disposal. 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 Checking and control of the equipment of control

A list of the most current equipment of control is given below, as well as the minimal frequency of the calibrations and controls necessary. OCAB-OCBS can authorize exemptions from the modes of enforcement of this regulation on written request of a user and opinion of its qualified Technical Bureau.

7 Accuracy of the measurements

Except typical cases, OCAB-OCBS does not require to mention and justify the uncertainty of measurement within the meaning of standards NBN EN ISO 17025.

Table 1 – Equipments and requirements

Calibration and Calibration of the equipment of measure						
Equipment	**Property**	**Method**	**Frequency**	**Criterion**	**Carried Out by (*)**	**Measures in the event of going beyond the criteria of checking**
Balance	Mass	See § 3.5.1	1x/year	0.25%	1,2 or 4	Fitting or downgrading
		See § 3.5.2	4x/year (if annual calibration step by 1 or 2)	0.25%	3	Fitting or downgrading
Measure	Length	See § 4.1	See § 4.1	See § 4.1	1, 2 or 4	See § 4.1
Ovens	Temperature	Determination of the temperature in minimum 4 points of the drying oven	1x/year	±3 °C by report with regulated 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 (+après any repair or displacement)	Class 1	1	Fitting or downgrading
Bending mandrel			No obligatory			
Slide 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 § **4.6**	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 of reference	1x/5 years		1	Fitting or downgrading
Thermometer for ambient temperature			No obligatory 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 organization member of the EA or
- failing this, accepted by the organization of certification for the calibration of the equipments in question

2 = the supplier of measuring equipment

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

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

Note: in all the 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

Table 2 – Thermal ageing, required durations of treatment

Thermal Ageing				
Ø (mm)	1 hour (Tensile test)		30 min (Rebend test)	
Nominal	Minimum (h:min)	Maximum (h:min)	Minimum (h:min)	Maximum (h:min)
5	1:03	1:18	0:33	0:48
5.5	1:04	1:19	0:34	0:49
6	1:04	1:19	0:34	0:49
6.5	1:05	1:20	0:35	0:50
7	1:05	1:20	0:35	0:50
7.5	1:06	1:21	0:36	0:51
8	1:06	1:21	0:36	0:51
8.5	1:07	1:22	0:37	0:52
9	1:08	1:23	0:38	0:53
9.5	1:09	1:24	0:39	0:54
10	1:09	1:24	0:39	0:54
11	1:11	1:26	0:41	0:56
12	1:13	1:28	0:43	0:58
14	1:18	1:33	0:48	1:03
16	1:22	1:37	0:52	1:07
18	1:28	1:43	0:58	1:13
20	1:33	1:48	1:03	1:18

22	1:39	1:54	1:09	1:24
25	1:48	2:03	1:18	1:33
28	1:57	2:12	1:27	1:42
32	2:14	2:29	1:44	1:59
36	2:27	2:42	1:57	2:12
40	2:48	3:03	2:18	2:33
50	3:40	3:55	3:10	3:25

8 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[5] (see Table 3)
- The obtained "m-ks" value is the coefficient "λ"value for the specific diameter of the product.

Table 3 - 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

The producer then proposes a Table listing the so computed "λ"value for each BENOR-certified diameter of the concerned product-type. The producer has the option to group diameters each "λ"value referred to is conservative.

The assessment and acceptance of this Table is made by OCAB-OCBS and published in the certificate of the producer.

[5] 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.

9 Simplified procedure for the verification of the settings of a straightening machine for a given diameter of a given product type

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}
- ✓ a_m ratio = a_{m2} / a_{m1}
- ✓ c ratio = c_2 /c_1

PTV 302 and PTV 303 define the maximal acceptable decrease

- either of the rib height and of the f_R
- of the indentation depth and of the f_P.

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. The plastic extension of a reinforcement during the straightening process induces a strain hardening of the metal, with

- ✓ an increase of the yield stress (R_e),
- ✓ a decrease of the R_m/R_e ratio and
- ✓ a decrease of the uniform elongation (A_{gt}).

For a reinforcement with a nominal yield stress of 500 MPa, a plastic elongation may be considered significant as soon as the "c ratio" exceeds 0,5 %. The acceptable amount of plastic elongation has to be evaluated as a function of the uniform elongation displayed by the coiled reinforcement in the as-received condition, that means:

- ✓ either at least 2,5 % for low ductility steels
- ✓ or at least 5,0 % for high ductility steels.

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.

The appended EXCEL file displays for each type of steel a sheet enabling to input the necessary measurements and output the conclusions of those measurements.

10 History of revisions

10.1 Revision 0 to 4, creation, update

10.2 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

11 Table of contents