MATERIALS CONTROL

CHAPTER XV

Article 81 Control of the concrete constituents

In the case of concrete produced in plant, whether this is for ready-mixed concrete or sit-mixed concrete, it shall be subject to some form of Production Control in accordance with the Ministry of Industry and Energy Order, dated the 21st December 1995 and the provisions that develop the same. This control shall be clearly documented at all times and the corresponding documentation shall be made available to the Project Management and the Laboratories that are to carry out the external control on the produced concrete.

Control of the concrete constituents shall be performed in the following manner:

a) If the concrete plant has a Production Control, and is in possession of an approved Quality Mark that is officially recognised by a Public Administration Management Centre (Central or Autonomous Governments), with powers in the construction area (public works or building), then on-site acceptance control of the concrete constituents is not required.

- Every six months, the above mentioned Management Centres shall provide the General Technical Office of the Ministry of Public Buildings and Works with a list for publication, of all concrete plants that are in possession of such recognised quality marks, together with all those that have been removed or cancelled.

b) If the concrete produced at a plant is in possession of a recognised quality mark or a CC-EHE certificate, both in the sense described in Article 1, then on site acceptance control of its constituents is not required.

- For the purposes of this Instruction, the concrete that is produced at plants where the concrete production is in possession of a recognised *quality mark* or a CC-EHE certificate, both in the sense described in Article 1, shall have the same consideration as the concrete produced at plants in possession of a quality mark in the sense described at a).

c) Where the concrete plant does not comply with the provisions of a) or b), the provisions of the following sub-sections of this Article shall apply.

81.1 Cement

The acceptance control of cement shall be made in accordance with the Instruction for the Acceptance Control of Cements in effect, whereby the benefits provided to the officially

recognised Quality Marks refer exclusively to those recognised marks and CC-EHE certificate, both in the sense described in Article 1.

In all cases, the person responsible for accepting the cement at the concrete plant or at -site shall keep a sample of cement from each supplied batch for a minimum period of 100 days.

81.1.1 Specifications

These are those contained in Article 26 of this Instruction, together with those detailed in the Technical Specifications.

Any batches of cement which, on delivery, are not accompanied by the corresponding guarantee certificate of the producer, signed by an individual, as specified in 26.2, shall not be used.

COMMENTS

The verifications described in these articles have a dual purpose:

- That of verifying the correspondingbatch, and whether to accept or reject the same.
- That of verifying the internal control for the employed cement, in order to compare the same with the certificates supplied by the producer.

81.1.2 Tests

Sampling shall be made as described in the Instruction on the Acceptance Control of Cements in effect.

Before commencing concreting operations, in the event of a change in the supply conditions, and when indicated by the Project Manager, the physical, mechanical and chemical tests specified in the above mentioned Instruction shall be performed, in addition to those specified, as applicable, in the Project Specifications, together with those corresponding to Cl ion determination, in accordance with Article 26.

The following shall be verified, at least on a three-monthly basis, during the works and when indicated by the Project Manager: the cement components, setting time, compressive strength and volume stability, in accordance with the test procedures established in the mentioned Instruction.

In the event that the cement is exempt from the acceptance tests, on the basis of the provisions contained in the Instruction on the Acceptance Control of Cements in effect, and in 81.1, the Project Management may, by means of a written communication, also exclude this from the requirements of the two previous paragraphs, with these requirements being substituted by the cement identification documentation and the available results of the production control.

In all cases, preventive samples are to be kept for 100 days.

81.1.3 Criteria for acceptance or rejection

Failure to comply with any of the specifications, unless it can be demonstrated that this does not involve any appreciable risk, both from the point of view of mechanical strength and from that of durability, shall be sufficient for the rejection of the batch of cement.

81.2 Mixing water

81.2.1 Specifications

These are the ones contained in Article 27 plus those in the Project Specifications, as applicable.

81.2.2 Tests

The tests described in Article 27 shall be carried out when no previous information exists on its use in concrete works, or in the case of any doubt,.

81.2.3 Criteria for acceptance or rejection

Failure to comply with the specifications shall be sufficient reason to consider the water as not being suitable for mixing concrete, unless there is a documented technical justification that this would not appreciably prejudice the required properties of the concrete, in either the short or the long term.

81.3 Aggregates

81.3.1 Specifications

These are the ones given in Article 28, plus those in the Project Specifications, as applicable.

81.3.2 Tests

Before commencing any work, whenever the conditions of supply vary, and in the absence of a certificate of suitability, issued at a maximum of one year before the date of use by an official or officially accredited laboratory, for the aggregates to be used, the identification tests described in 28.1 shall be carried out, together with those corresponding to the physical-chemical, physical-mechanical and grading conditions as specified in 28.3.1, 28.3.2 and 28.3.3.

Particular attention shall be paid during the work to ensure compliance with the maximum size of the aggregate, to the constancy of the fineness modulus of the sand and to the provisions of 28.2 and 28.3.1. In case of any doubt, the corresponding verification tests shall be carried out.

81.3.3 Criteria for acceptance or rejection

Failure to comply with the provisions of 28.1 or 28.3 will be sufficient to qualify the aggregate as being unsuitable for the production of concrete, unless there is special justification that this would not appreciably prejudice the required properties of the concrete, in either the short or the long term.

Failure to comply with the limitation of 28.2 will mean that the aggregate is not suitable for these specific members. If any element has been cast employing concrete produced using aggregates affected by this circumstance, the measures considered appropriate by the Project Manager shall be adopted in order to guarantee that no cavities or gravel pockets of any significance have formed in these elements that could affect their safety or durability.

81.4 Other concrete constituents

81.4.1 Specifications

These are as detailed in Article 29, plus any contained in the Project Specifications.

Any admixtures that are not supplied correctly labelled and accompanied by the guarantee certificate of the producer, signed by an individual, as specified in 29,1, shall not be employed.

In the case of reinforced or mass concrete, where fly-ash or silica fume has been used, a corresponding guarantee certificate, issued by an official or officially accredited laboratory containing the results of the tests specified in 29.2, shall be required.

COMMENTS

The provisions contained in the articles are intended to establish, while awaiting a general admixture certification, a certificate for each particular works, to permit the selection, at the outset, of the marks and types to be employed throughout the works period, without their effects being harmful to the quality of the concrete or the reinforcement. It is recommended that the tests that are performed on the admixtures be in accordance with UNE EN 480-1:98, 480-6:97, 480-8:97, UNE 83206:85, 83207:85, 83208:85, 83209:86, 83210:88EX, 83211:87, 83225:86, 83226:86, 83227:86, 83254:87EX, 83255:89EX, 83258:88EX and 83259:87EX.

Since, in general, it will not be possible to establish permanent control over the chemical components of the admixture in use at the works, the on-site control shall instead be established as the simple verification that admixtures accepted in the previous phase are employed, without any form of modification.

It shall be verified that the specification of the admixtures used do not vary throughout the works period. It is recommended that the sampling and control over the fly ash be performed in accordance with UNE 83421:87EX, 83414:90EX and EN 450:95.

81.4.2 Tests

a) In all cases, before commencing the work, the effect of the admixtures on the quality characteristics of the concrete shall be verified. This verification shall be carried out by means of initial tests on the concrete as described in Article 86. The absence of chemical compounds in the composition of the admixture, which could encourage reinforcement corrosion, shall also be verified, using the appropriate tests carried out in an official or officially accredited laboratory. In addition, the pH and dry residue shall be determined in accordance with UNE 83210:88 EX, 83227:86 and UNE EN 480-8:97.
The marks and types of admixture permitted in the works shall be selected in consequence to the previous paragraph The constancy of the composition and quality specifications shall be guaranteed by the corresponding producer.

b) During the works execution, it shall be verified that the types and marks of the admixture employed are exactly those accepted in accordance with the above paragraph.

c) With regards to the additions, before commencing the works, the tests described in Articles 29.2.1 and 29.2.2 shall be performed in an official or officially accredited laboratory. The activity index shall be determined using cement from the same source as that specified for the execution of the works.

d) The following verifications shall be carried out on the additions at least once every three months during the works: sulphur trioxide, loss on ignition and fineness for fly-ashes,

and loss on ignition and chloride content for silica fume, in order to verify the homogeneity of the supply.

81.4.3 Criteria for acceptance or rejection

Failure to comply with any of the specifications will be sufficient for the admixture or the addition to be classified as unsuitable for adding to concrete.

Any possible modification of the quality properties of the product to be employed, with regards to those accepted in the tests prior to the start of the work, will result that this product not being used until the tests specified in 81.4.2 permits its acceptance and use in the works.

Article 82 Concrete quality control

The concrete quality control shall normally consist of the verification of its strength, consistency and durability, independently of the checks on the maximum aggregate size, in accordance with 81.3, or of any other properties included in the Project Specifications.

The quality control on the concrete specifications shall be carried out in accordance with Articles 83 to 89. The sampling of the concrete shall be performed in accordance with UNE 83300:84.

Additionally, in the case of concrete produced at a plant, it shall be verified that each batch of concrete is accompanied by a correctly completed delivery ticket in accordance with 69.2.9.1 and signed by an individual.

The employment of the concrete at the works is not permitted without the delivery ticket, which should be recorded by the constractor and remain available to the Project Management until such time as the final control documentation is delivered.

COMMENTS

The person who signs the delivery ticket is responsible of the veracity of the data included, so it is understood that he must have a certain responsibility level in the production process, and never could be a person only concerning with the concrete transport service.

Article 83 Concrete consistency control

83.1 Specifications

The consistency shall be as established in the Project Specifications or as indicated by the Project Manager at the appropriate moment, in accordance with 30.6, for both concretes specified by a target value.

COMMENTS

Consistency control provides the Works Management with a criterion for conditioned acceptance or rejection of concrete batches, by enabling the detection of abnormalities in the mix, especially with respect to the amount of water.

In order to avoid the problem of the rejection of concrete already employed at the works (corresponding to the first quarter of the poured batch), its is recommended that the consistency be verified on the commencement of pouring, even when acceptance or rejection is based on the consistency measured in the middle, in accordance with

UNE 83300:84. However, this additional acceptance condition, and not performing the test between ¼ and ¾ of the pouring operation, shall be agreed with the supplier or constructor.

83.2 Tests

The consistency shall be determined by means of the slump test conforming to UNE 83313:90:

- Whenever specimens are made to check the strength.
- In the cases specified in 88.2 (reduced control).
- Whenever required by the Project Manager.

83.3 Conformity Criteria

Where the consistency is defined by its type, the arithmetic mean of the two values obtained, in accordance with UNE 83313:90, shall be within the corresponding interval.

If the consistency is defined by a target value, the average of the two results shall be within the tolerance.

The batch will be rejected and the mix design corrected if the above conditions are not fulfilled.

Article 84 Concrete strength control

Independently of the control tests of constituents materials and concrete consistency prescribed in Articles 81 and 83 respectively, and those which may be specified by the Project Specifications, the mandatory control tests on the strength of the concrete specified in this Instruction are those included in Article 88.

Other types of test are the ones known as Additional Information Tests, and are detailed in Article 89.

Finally, before commencing concreting operations, it may be necessary to carry out initial tests or characteristic tests as described in Articles 86 and 87 respectively.

The initial, characteristic and control tests require cylindrical specimens of 15 x 30 cm, made, cured and -tested at 28 days in accordance with UNE 83301:91, UNE 83303:84 and UNE 83304:84

COMMENTS

Table 84.1 contains the specifications for the tests established in the articles.

Table 84.1
Concrete strength control

Types of tests	Initial	Characteristic	Control	Additional information		
				Type a	Type b	Type c
Specimen production	In laboratory	On site	On site	On site	Cores from hardened concrete	Non-destructive tests (Widely varying tests)
Specimen conservation	In wet chambers	In water or wet chamber	In water or wet chamber	Under conditions similar to those of the works	In water or the environment, as applicable	
Specimen type	15 x 30 cylinders	15 x 30 cylinders	15 x 30 cylinders	15 x 30 cylinders	Cylindrical, with a slenderness greater than 1	
Test cylinder age	28 days	28 days	28 days	Variable		
Minimum number of specimens	4 x 2 = 8	6 x 2 = 12	See Article 88	To be established		
Mandatory	Mandatory except where previous experience exists	Mandatory except where previous experience exists	Always mandatory	In general, not mandatory		
Observations	They will be used to establish the initial composition	They will be used to establish the definitive composition with the production means to be employed	At times they shall be complemented with type “b or type “c” additional information tests	They will be used to estimate the real strength of the concrete at a specific age and under certain conditions		

As a general rule, initial tests are applied in the event of a concrete composition which has been established for this specific case. If experience exists in the use of the materials and the composition , but the means of production are new, then it is only necessary to perform the characteristic tests. When there is sufficient experience in the materials, as well as the concrete composition and means of production (for example, at ready-mixed concrete plants), then it is only necessary to carry out the control tests.

Article 85 control of concrete requirements related to durability

For the purposes of the requirements in relation to concrete durability, given in Table 37.3.2a., the following controls shall be performed:

a) Documentary control of the delivery tickets, in order to confirm compliance with the limiting values for the water/cement ratio and the cement content as specified in 37.3.2.
b) Control of the water penetration depth in the cases indicated in 37.3.2, in accordance with the procedure described in 85.2.

COMMENTS

Concrete durability requires a good performance in the presence of a series of complex degradation mechanisms (carbonation, freeze-thaw attack, chemical attack, chloride diffusion, reinforcement corrosion, etc.) that cannot be reproduced or simplified in a single verifiable property. Concrete permeability alone is not a sufficient parameter for guaranteeing durability, although it is a necessary quality. Moreover, it constitutes, among other factors, a property linked to the water/cement ratio and to the cement content, which are specific concrete composition parameters for the control of the production of durable concrete. For this reason, and without prejudicing the future of other standardised methods in the area of durability, documentary control of the water penetration test is introduced as a procedure which forms part of the verification of the concrete composition to be employed at a work site, prior to the actual commencement of the works. All this is to be taken into consideration without forgetting the

importance of proper execution, the need for the correct performance of on-site compacting and curing operations, since, ultimately, the concrete cast on site should be as impermeable as possible.

85.1 Specifications

In all cases, the concrete shall be accompanied by the delivery ticket, on which the supplier shall indicate the values of the cement contents and the water/cement ratio of the concrete produced at the supplying plant, in accordance with the provisions contained in 69.2.9.1. In addition, in the case of concrete not produced at plant, the producer shall provide the Project Management with similar documents, signed by an individual, which enable both the cement content and the water/cement ratio to be recorded.

The water penetration depth shall be controlled for each type of concrete (of differing strengths or consistencies) used at the works for the cases indicated in 37.3.2 and when specified by the Project Specifications or when required by the Project Manager.

COMMENTS

Due to the importance of the limitations on the water/cement ratio and the minimum cement content in obtaining adequate concrete durability, the articles require that the documentation that guarantees this compliance be available at all times, whether the concrete comes from an off-site or on-site supply.

85.2 Controls and tests

The documentary control of the delivery tickets shall be carried out for all concrete batches that are produced during the works. The content of these delivery tickets shall comply with the provisions of 69.2.9.1 and shall be made available to the Project Management at all times.

The water penetration depth, in accordance with UNE 83309:90EX shall be verified prior to commencing work by carrying out tests, on a set of three concrete specimens of the same composition as that which is to be used in the works,. The sampling should be performed at the same installation where the concrete is to be produced during the works. The time of this operation and the selection of the laboratory to be responsible for making, storage and testing of these specimens shall be agreed in advance by the Project Manager, the concrete supplier and the user.

In the case of concrete produced at plant, the Project Manager may exempt from the performance of these tests in the event that the supplier presents documentation, prior to commencement of work, which permits the documentary control of the suitability of the concrete composition to be used. In this case, the control shall be carried out on the basis of documentation that shall include, at least, the following points:

- The composition of the concretes to be used in the works.
- The identification of the constituents materials of the concrete to be used in the works.
- A copy of the report containing the results of the test to determine the water penetration depth under pressure, in accordance with UNE 83309:90, which shall be performed by an official or officially accredited laboratory.
- The constituent materials and compositions used to produce the specimens used in the above tests.

All this data shall be made available to the Project Management.

Any tests that were carried out more than six months prior to the date on which the control is performed, or when it is detected that the constituent materials or compositions used in the tests are different from those declared for the work by the supplier, shall be rejected.

In the case of concrete produced at plant that holds the *quality mark* referred to in Article 81, and whenever this test is included as part of its quality system, then that plant shall be exempt from performing the tests. Under these circumstances, the documentation permitting documentary control shall be presented to the Project Manager, under the same terms as indicated above, and before the works commence.

COMMENTS

When performing the water penetration test, it is important to pay attention to the compaction and curing of the specimen, since poor execution could have an impact on the final test results.

85.3 Assessment criteria

Documentary control assessment of the water penetration depth test shall be carried out using a group of three concrete specimens. the obtained results, in accordance with the UNE 83309:90 EX, shall be ordered with the following criterion:

- the maximum penetration depths:

$$Z_1 \leq Z_2 \leq Z_3$$

- the average penetration depths:

$$T_1 \leq T_2 \leq T_3$$

The concrete tested shall also comply with the following conditions:

$$Z_m = \frac{Z_1 + Z_2 + Z_3}{3} \leq 50\ mm \qquad Z_3 \leq 65\ mm$$

$$T_m = \frac{T_1 + T_2 + T_3}{3} \leq 30\ mm \qquad T_3 \leq 40\ mm$$

Article 86 Initial tests on the concrete

These shall be performed in a laboratory, in accordance with the provisions contained in Article 68, before commencing work. Their purpose is to establish the concrete composition to be used, taking into account the materials available and admixtures which are to be used, together with the anticipated conditions of execution. Article 68 also indicates the circumstances under which the performance of these tests may be omitted.

In order to perform these tests, at least four sets of specimens shall be made from different batches, with two specimens in each set to be tested at 28 days for each composition that is to be used, and which shall be carried out in accordance with the test methods in UNE 83300:84, 83301:91, 83303:84 and 83304:84.

On the basis of the results obtained, the value of the average strength in the laboratory f_{cm} may be obtained. This valueshall exceed that required for the project strength by a sufficient margin to be reasonable to expect that, with the dispersion arising on the execution of the work, the real characteristic strength of the work will also exceed the project strength.

COMMENTS

The initial tests in this Article are contemplated from the point of view of strength, although it also covers all the other tests that are required in order to guarantee that the concrete being produced complies with all required specifications (for example, those in relation to durability).

The initial tests provide information for estimating the average value of the property under study, but they are, however, insufficient for the establishment of the statistical distribution of the concrete used at works. Since the specifications do not always refer to average values, for example, in the case of strength, a series of hypotheses must be adopted in order to enable decisions to be made with regards to the validity or otherwise of the tested compositions.

In general, a gaussian type distribution may be accepted for strength, with a variation coefficient of δ, depending on the execution conditions. In this case, the following condition shall be met:

$$f_{ck} \leq f_{cm}(1 - 1{,}64\delta)$$

where f_{cm} is the average strength and f_{ck} is the characteristic strength.

The variation coefficient δ is a fundamental required parameter when carrying out this type of estimation. When its value is unknown, the following may be assumed purely as a guideline:

$$f_{cm} = f_{ck} + 8 \quad [N/mm^2]$$

The situation represented by this formula corresponds to a composition by weight, with separate and different storage for all the constituent materials, together with correction of the amount of water incorporated by the aggregate. The bascules/weighing instruments and other measuring instruments should be periodically checked and there should also exist a constituent material control (at either origin or reception).

The information provided by the initial tests is of great importance in the subsequent correct execution of the works, and so it is recommended the Works Management be informed of these results. In particular, the confection of a larger number of specimens, to be tested at three, seven and ninety days would provide further data on the concrete which could be useful, both for providing information on the concrete members of the works before twenty-eight days, and for forecasting the performance of the concrete at greater ages.

Article 87 Characteristic tests on the concrete

Except in the case of the use of concrete produced at plant, or where there is prior experience of the same materials and execution methods, these tests are mandatory in all cases and are designed to verify, prior to the commencement of the concreting operations , that, , the real characteristic strength of the concrete which is to be employed at the works is not less than the project strength.

The tests shall be performed on specimens from six different batches of concrete for each type that is to be employed, with two specimens per batch, that shall be made, stored and tested at 28 days, in accordance with UNE 83300:84, 83301:91, 83303:84 and 83304:84.

the average value corresponding to each batch shall be calculated, in order to obtain the set of six average results:

$$x_1 \leq x_2 \leq \ldots\ldots \leq x_6$$

The characteristic test will be considered favourable if it can be established that:

$$x_1 + x_2 - x_3 \geq f_{ck}$$

In which case, the corresponding concrete composition and production process shall be accepted.

If this is not the case, then they shall not be accepted, with the adoption of the appropriate corrections, and the delay of the commencement of the concreting operations until

an acceptable concrete composition and production process would be established as a result of further characteristic tests.

COMMENTS

The aim of these tests is to guarantee, prior to the concreting operation, the suitability of the mix to be employed, , together with the production process to be used, in order to obtain concretes with the required project strength.

It may be useful to test various initial compositions, because if only one is prepared and does not reach the required strength, it will be necessary to start again, with the consequent delays in the works.

Article 88 Control tests on the concrete

88.1 General

These tests are mandatory under all circumstances and are intended to check throughout the execution that the characteristic strength of the concrete at the works is equal to, or higher than, the project strength,.

This control may be performed in accordance with the following procedures:

Procedure 1 Reduced-level control.
Procedure 2 100% control, where all batch strengths are known.
Procedure 3 Statistical control of the concrete, when only the strength of a percentage of the batches employed is known.

The tests shall be performed on specimens that have been made, stored and tested in accordance with UNE 83300:84, 83301:91, 83303:84 and 83304:84

For building works, the control tests on the concrete shall be performed by laboratories that comply with the provisions contained in Royal Decree 1230/1989, of 13 October 1989, and the regulations deriving from the same. In other works, the control tests on the concrete shall be preferably carried out by these laboratories.

COMMENTS

Attention is drawn (see 30.2) to the fact that, for the purposes of this Instruction, any measurable property of quality for a batch shall be expressed by the average value of a number of determinations (at least two) of the quality property itself, performed on parts or portions of the batch.

The objective of these control tests is to verify that the concrete quality properties, as cured under normal conditions and at 28 days of age, meet the project design specifications.

Independently of the control tests, those of information type a) (Article 89), as described in the Project Specifications or established by the Works Management, shall be performed to verify that, at a certain age and after a curing process similar to that of the elements under study, the concrete has a suitable strength, especially during the tensioning of prestressed concrete structures or to determine the time of removal of falsework.

From the point of view of acceptance of the batch being verified, the determining tests are those described in 88.3 and 88.4, or, where applicable, those corresponding to information type b) and c) (Article 89), which derive from 88.4.

88.2 Reduced-level control

At this level, control is carried out by measuring the consistency of the concrete produced in accordance with typical compositions.

Using the frequency stated in the Project Specifications or by the Project Manager, and with no less than four checks spread throughout the day, a test to measure the consistency shall be performed in accordance with UNE 83313:90.

The corresponding written records of the results of these tests, provided by the obtained values and decisions taken in each case, shall be maintained on site.

This level of control shall only be employed for small construction works, in the construction of housing with one or two floors with spans under 6.00 metres or in bending elements in housing with up to four floors, also with spans under 6.00 metres. Moreover, a design compressive strength value f_{cd} of no greater than 10 N/mm² shall be adopted

The use of this type of control is forbidden in concrete subject to exposure classes III and IV, in accordance with 8.2.2.

COMMENTS

This level of control presupposes the acceptance of a reduced design strength value and requires a systematic recording of the consistency values and a continuous monitoring by the Work Management in order to guarantee that the composition, batching and placing are correctly carried out,.

88.3 100% control

This control procedure can be applied to any works. The control is carried out by determining the strength of all the batches of the part of the work that is being monitored and by calculating the value of the real characteristic strength from these results, in accordance with 39.1.

For all the batches under control, it shall be verified that: $f_{c,real} = f_{est}$.

COMMENTS

At most works, this type of control is not normally used due to the very high number of specimens, the high degree of complexity involved in the works and the elevated control costs. Nevertheless, in certain special cases, such as isolated elements with a great deal of responsibility, formed by a small number of batches , it could be extremely significant to know the real value of $f_{c,real}$ in order to base the acceptance or rejection decisions on this figure, with the complete elimination of any error that inherent in all estimates. For taking into account these special cases, but without excluding any other this type of control is included in the Instruction.

In accordance with that defined in Article 39, the real characteristic strength corresponds to the 5% fractile of the distribution function of the population under control. Obtaining it is reduced to the determination of the batch strength value, which is exceeded in 95% of cases.

In general, for populations consisting of N batches, the value of $f_{c,real}$ corresponds to the batch strength of the batch which, once the N determinations are ordered from smallest to largest, occupies the position $n = 0.05\ N$, rounding n upwards.

When the number of batches to be controlled is equal to, or less than, 20, $f_{c,real}$ will be the lowest batch strength in the series.

88.4 Statistical control of the concrete

This control procedure can be generally applied to works using mass concrete, reinforced concrete and prestressed concrete.

For control purposes, unless there exist justifiable grounds for exception, the works shall be divided into successive parts known as lots, each one being smaller than the lower of the limits indicated in Table 88.4.a. Those elements having a different structural typology, i.e. those belonging to different columns in the table, shall not be mixed in the same lot. All the product units (batches) in the same lot shall come from the same supplier, and shall be produced using the same constituent materials and be the result of the same nominal composition.

In the case of concrete produced in a central plant bearing a *quality mark*, in the sense indicated in Article 81, then the limits of Table 88.4.a may be doubled, provided that the following conditions are also met:

- The production control results required by the *quality mark* are available to the customer and are also satisfactory. The Works Management shall review this point and include it in the final documentation for the works.

- The minimum number of lots which shall be sampled on site is three, corresponding, where possible, to lots relating to the three types of structural element indicated in Table 88.4.a.

- In a situation whereby in any lot, f_{est} is lower than the characteristic strength of the design project, then normal control shall be carried out without reducing the intensity, until satisfactory results are obtained from four consecutive lots.

Table 88.4.a
Maximum limits for the establishment of the control lots

Upper limit	TYPE OF STRUCTURAL ELEMENT		
	Structures that use compressed elements (columns, piers, load-bearing walls, piles, etc.)	Structures that only use elements subject to bending (concrete floor slabs with metal columns, decking, and retaining walls etc.)	Masses (footings, bridge abutments, blocks, etc.)
Volume of concrete	100 m^3	100 m^3	100 m^3
Number of batches (1)	50	50	100
Concreting time	2 weeks	2 weeks	1 week
Constructed surface area	500 m^2	1.000 m^2	---
Number of floors	2	2	---

(1) This limit is not mandatory in building works.

The control is performed by determining the strength of N batches per lot (see definition of batch in 30.2) where:

If $f_{ck} \leq 25$ N/mm²: $N \geq 2$
25 N/mm^2 < $f_{ck} \leq 35$ N/mm^2: $N \geq 4$
$f_{ck} > 35$ N/mm^2: $N \geq 6$

The sampling shall be carried out at random among the batches of the work under control. When the lot includes two floors, the concrete for each floor shall be subjected to at least one determination.

Having ordered the results of the strength determinations/tests of the *N* batches controlled in the form:

$$x_1 \leq x_2 \leq ..... \leq x_m \leq ..... \leq x_N$$

The estimated characteristic strength, at this level, is defined as that which complies with the following expressions:

$$\text{If } N < 6;\ f_{est} = K_N \cdot x_1$$

$$\text{If } N \geq 6;\ f_{est} = 2\,\frac{x_1 + x_2 + ... + x_{m-1}}{m-1} - x_m \not< K_N \cdot x_1$$

where:

K_N is the coefficient given in Table 88.4.b in function of N, and the class of the concrete plant.
x_1 the strength of the weakest batch.
m $N/2$ if N is even.
m $(N-1)/2$ if N is odd.

Table 88.4.b provides a classification of concrete plants in accordance with the coefficient of variation of the production, which is defined on the basis of the value of the relative range *r* of the strength values of the batches controlled in each lot. The operating method is as follows:

- On commencement of the works, the classification (A, B or C) proposed by the supplier, based on the production control results is accepted; .

- In order to establish the K_N value for the lot, the relative range is determined for the strengths obtained in the *N* batches that are controlled in this lot, which shall be less than the maximum relative range as specified for this class of plant. If this is met, then the corresponding coefficient K_N is applied.

- In the event that, in any lot, a value for the relative range is detected that is higher than the maximum established for this class of plant, the latter changes its classification to that corresponding to the maximum value established for *r*. Therefore, the K_N of the new column shall be used for the estimation, both for this and following lots. If, in successive lots, the relative range of the column corresponding to the new classification of the plant is also not met, then the procedure would be the same, applying the coefficient K_N of the corresponding level.

- In order to apply the value of K_N corresponding to the level immediately above (with less dispersion), it would be necessary to obtain in five consecutive lots results for the relative range lower than, or equal to, the maximum in the table., The new coefficient K_N could be applied to the fifth and subsequent results.

Table 88.4.b
Values of K_N

N	CONCRETE PRODUCED IN PLANT							OTHER CASES
	CLASS A			CLASS B		CLASS C		
	Maximum relative range, r	K_N		Maximum relative range, r	K_N	Maximum relative range, r	K_N	
		With Quality mark	Without Quality mark					
2	0.29	0.93	0.90	0.40	0.85	0.50	0.81	0.75
3	0.31	0.95	0.92	0.46	0.88	0.57	0.85	0.80
4	0.34	0.97	0.94	0.49	0.90	0.61	0.88	0.84
5	0.36	0.98	0.95	0.53	0.92	0.66	0.90	0.87
6	0.38	0.99	0.96	0.55	0.94	0.68	0.92	0.89
7	0.39	1.00	0.97	0.57	0.95	0.71	0.93	0.91
8	0.40	1.00	0.97	0.59	0.96	0.73	0.95	0.93

The plants are classified in accordance with the following:

- Class A corresponds to installations having a variation coefficient value ofδbetween 0.08 and 0.13.
- Class B corresponds to installations having a variation coefficient value of δbetween 0.13 and 0.16.
- Class C corresponds to installations having a variation coefficient value of δbetween 0.16 and 0.20.
- *Other cases* includes concrete mixers with a variation coefficient value of δbetween 0.20 and 0.25.

COMMENTS

In order to estimate the characteristic strength of a reduced sample, it is necessary to know the variation coefficient $\delta$of the population. This value is very difficult to establish with precision on the basis of the acceptance control information, since it must be established with at least 35 results, which would not be feasible to apply due to the changes which may potentially occur over the required period of time.

One suitable system would be to have the supplying plant dispersion controlled and accredited by external laboratories, on the base of a systematic control and a sufficient number of results. So the variation coefficient of each period would be certified for each plant, thus establishing its classification.

Due to the fact that currently none of the plant production control systems, either mandatory or voluntary, classify the plants on the basis of their dispersion, a statistical estimate has been made for the variation coefficient in function of the relative range r of the results of the strengths obtained in each lot, where

$$r = \frac{x_{\max} - x_{\min}}{x_m}$$

where:

x_{min} the strength of the weakest batch.
x_{max} the strength of the strongest batch.
x_m The average strength of the batches that are controlled in the lot.

From this hypothesis, the values that correspond to 97.5% confidence level of the relative path distribution for values of δequal to the central interval value have been determined. These values are taken as being maximum, assigning KN which corresponds to the smallest δ value of the interval .

A situation could potentially arise in which a decision is made to change the composition at the concrete plant for production reasons. In order for this controlled change to have no effect on the qualification of the lots pending completion, the value K_N corresponding to the previous plant classification may be employed, without computing the relative range in these lots. The application of this criterion requires the Works Management to be informed prior to the composition change, detailing the reasons for the change and the expected increase or reduction in average strength, so that the number of affected lots may be defined with sufficient advance notice.

88.5 Decisions resulting from strength control

When $f_{est} \geq f_{ck}$ in a lot that is subjected to strength control, then this lot shall be accepted.

If $f_{est} < f_{ck}$, in the absence of an explicit reference to this case in the Project Specifications , and without prejudice to the specified contractual penalties, (see 4.4), the adopted procedure shall be as follows:

a) If $f_{est} \geq 0.9\ f_{ck}$, the lot shall be accepted.
b) If $f_{est} < 0.9\ f_{ck}$, following a decision from the Project Manager or at the request of any of the parties, the relevant studies and tests from those detailed below shall be performed; and in this case, the decision will be based on the result of them.

- A study of the safety of the elements that make up the lot, in accordance with the f_{est} obtained from the control tests, in order to estimate the variation of safety factor with regards to that specified in the design.

- Additional information tests for estimating the strength of the concrete employed, in accordance with the provisions of Article 89, and for carrying out, where applicable, a similar study to that described in the above paragraph, based on the new strength values obtained.

- Loading tests (load test), in accordance with 99.2. The test load may exceed the characteristic value of the load taken into account in the calculation.

In accordance with the studies and tests ordered by the Project Manager and with the additional information which the constructor may provide at its own cost, the former shall decide whether the elements forming the lot may be accepted, rejected or demolished, also having taken the requirements relating to durability and the Serviceability Limit States into account.

Before deciding on whether to accept, reject or demolish, the Project Manager may consult the designer and specialised bodies.

COMMENTS

As an alternative to demolition or reinforcement, the Works Management may propose to the owner a limitation of service loads.

In order to decide that the safety margin of the structure will be sufficient in service from a load test, the test load shall be significantly larger that encountered during service. A total load of approximately the 85% of the design load is a sufficiently representative for making a decision on the safety of the tested elements. These tests shall be

performed employing specialised personnel and equipment, after drawing up a detailed Test Plan, and adopting all necessary safety measures.

It should be noted that the fundamental application of the test loads are those elements that work under bending forces, and their use is, for financial reasons, very restricted in other types of elements.

It should always taking into account that concrete strength, in addition to being a valuable quality in its own right, is also an indirect estimator of important properties that are intimately related to the quality of the concrete, such as the modulus of elasticity, and, although not in a sufficient manner, its resistance to aggressive agents. Consequently, when an estimated strength is obtained that is less than that specified, it is necessary to take into consideration not only the possible influence on the mechanical safety of the structure, but also the negative effect on other characteristics, such as deformation, cracking and durability.

Article 89 Concrete tests providing additional information

These tests are only mandatory in the cases specified by this Instruction in Articles 72, 75 and 88.5, or when indicated in the Project Specifications. Their purpose is to estimate the strength of the concrete in a specific part of the works, at a certain age or cured under similar conditions to those presented in the works.

The information tests on the concrete may consist of the following:

a) Making and testing specimens as indicated for the control tests (see Article 88), but keeping the specimens under similar conditions that the concrete which strength is to be estimated.
b) The test of cores from hardened concrete (in accordance with UNE 83302:84, 83303:84 and 83304:84). This type of test shall not be performed when the strength capacity of the element under study may be significantly affects , up to the point where it produces unacceptable risks. In these cases, the possibility of propping up the element prior to extraction should be studied.
c) The use of reliable non-destructive methods, as a supplement to those described above, and in correctly correlation with the same.

The Project Management shall consider the results in each case, taking into account that in order to obtain reliable results, these tests, which are always delicate to carry out, should be entrusted to specialised personnel.

COMMENTS

These tests should be carried out in the following situations, among others:

- When there is an insufficient number of control results available, or in those cases described in 88.5.

- When reasonable doubt exists as to the works execution conditions later than concrete specimens has been made (internal transport, placing, compaction and curing of the concrete).

- In order to follow the progressive development of strength in young concrete, thus estimating the ideal moment for the removal of formwork or falsework or the loading of structural elements.

- In structures showing signs of deterioration or those that have been subjected to certain situations that could have affected its strength capacity (excessive overloads, fire, freezing conditions, etc.).

Among those non-destructive tests authorised in section c) of the article, consideration may be given to the following tests: UNE 83307:86 "Bounce Index" and UNE 83308:86 "Ultrasound Propagation Speed", where the reliability is subject to comparison with the extraction of cores.

When cores are used to verify the strength of a lot controlled by means of specimens with a strength of $f_{est} < 0.9\ f_{ck}$, , these shall be extracted from locations that have been chosen on a strictly random basis, and not from those zones where it is presumed or is known as a fact, contain the concrete that formed part of the control test specimens, except for other purposes. It should be taken into account that, due to differences in compaction, and other effects, the cores demonstrate a strength that is at least 10% less with respect to specimens, with other factors (curing conditions, age, etc.) being equal.

Article 90 Steel quality control

90.1 General

The following levels have been established for controlling the steel quality:

- Reduced-level control.
- Normal-level control.

In works employing prestressed concrete, only the normal level of control shall be used, for reinforcement and prestressing steel.

For steel quality control purposes, a batch is the material of the same designation (although in several diameters) that is supplied at the same time. A lot is a subdivision that is made of a batch, or the material existing on site or in a workshop at any given moment which is taken as being indivisible for control purposes.

Any batches of steel which arrive without the corresponding guarantee certificate of the producer, signed by an individual, as specified in 31 and 32, shall not be employed.

In those cases in which the steel is not certified (Article 31 or 32, whichever applies), the established control shall be performed prior to concreting so that all batches used at the works have been previously classified. In the case of certified steels, the control shall be carried out before the structure is put into service.

COMMENTS

With regards to the various tests established in the sections of this Article, it is recommended that the following procedure be adopted: where it is possible to classify the material existing on-site of the same diameter into lots, in accordance with the various batches supplied, then the test results will be applicable to the material that comprises the lot from which the specimens were taken for the performance of such tests. In the event that it is not possible to classify the material with the same diameter into lots as indicated, then all the material having the same diameter will be deemed to form a single lot.

The prescribed sampling is weak, but sufficient in practice, since, although it does not represent a true acceptance test at each works, it is evident that any defective material will be quickly detected. In practice, this system is correct for the stated purpose, which is to make it difficult for defective materials to be used.

However, whenever agreement cannot be reached on the interpretation of the performed tests, further tests on a sufficient number of samples should be carried out to serve as a statistical base for an efficient estimation of quality.

90.2 Reduced-level control

This level of control, which only applies to reinforcements, may be contemplated in those cases where the steel consumption at the works is very low or when carrying out complete tests on the material is problematic.

In these cases, the steel to be used shall be certified (Article 31) and the following value (see 38.3) shall be employed for the design strength:

$$0,75\,\frac{f_{yk}}{\gamma_s}$$

The control consists in checking the following concepts, for each diameter:

- That the equivalent section complies with the provisions of 31.1, with two checks being performed on each batch of material supplied for the works.

- That cracks are not formed in the bending zones and anchorage hooks, by means of an on-site inspection

90.3 Normal-level control

This level of control applies to all reinforcement, and prestressing steel, with a distinction made between the cases indicated in 90.3.1 and 90.3.2.

In the case of reinforcement, all the steel of the same designation supplied by the same supplier shall be classified, on the basis of the diameter of the same, into a small series (diameters less than, or equal to, 10 mm), a medium series (diameters of 12 to 25 mm) and a large series (those greater than 25 mm). In the case of prestressing steel, it shall be classified in accordance with this same criterion, as applied to the nominal diameter.

90.3.1 Certified products

In the case of certified steel (Article 31 or 32, as applicable), the control tests do not constitute an acceptance control, but an additional external control of the certification, given the major structural responsibility of the steel. The results of the control performed on the steel shall be known before placing in the structure.

For control purposes, the steel is divided into lots, each corresponding to a single supplier, designation and series, with a maximum quantity of 40 tonnes or fraction of steel reinforcement, and 20 tonnes or fraction of prestressing steel.

This type of control shall be carried out in the following manner:

- Two specimens are taken from each lot in order to perform the following:
    - To verify that the equivalent section complies with the provisions of 31.1 (reinforcement) or Article 32 (prestressing steel), as applicable.
    - To verify, In the case of ribbed bars and ribbed wires, that the geometric properties of the ribbing are within the permitted limits as established in the specific bonding certificate in accordance with 31.2.
    - After straightening, to carry out the reverse bend test as described in 31.2 and 31.3 (in accordance with the type of reinforcement), 32.3 (prestressing wires) or the bending test indicated in 32.4 (prestressed bars), whichever applies.

- The yield stress, breaking load and elongation (elongation after fracture for reinforcement; elongation under maximum load for prestressing steel) shall be

determined on at least two separate occasions during the construction, on at least one specimen of each diameter and type of steel employed, in accordance with UNE 7474-1:92 and 7326:88, respectively. In the particular case of wire fabrics, at least two tests shall be carried out for each main diameter used on each of the two occasions; and these tests shall include the pulling resistance of the welded node in accordance with UNE 36462:80.

- Where welded joints exist in reinforcements, weldability shall be checked in accordance with the provisions of Section 90.4.

90.3.2 Non-certified products

For control purposes, the steel shall be divided into lots, each corresponding to a single supplier, designation and series, with a maximum quantity of 20 tonnes or fraction of steel reinforcement, and 10 tonnes or fraction of prestressing steel.

the procedure will be as follows:

- Two specimens shall be taken from each lot in order to perform the following:
  - To verify that the equivalent section complies with the provisions of 31.1 (reinforcement) or Article 32 (prestressing steel), as applicable.
  - To verify, In the case of ribbed bars and ribbed wires, that the geometric properties of the ribbing are within the permitted limits as established in the specific bonding certificate in accordance with 31.2.
  - To carry out, after straightening, the reverse bend test as described in 31.2 and 31.3 (in accordance with the type of reinforcement), 32.3 (prestressing wires) or the bending test indicated in 32.4 (prestressed bars), whichever applies.

- The yield stress, breaking load and elongation (elongation after fracture for reinforcement; elongation under maximum load for prestressing steel) shall be determined on at least two separate occasions during construction, on at least one specimen of each diameter and type of steel employed, in accordance with UNE 7474-1:92 and 7326:88, respectively. In the particular case of wire fabrics, at least two tests shall be carried out for each main diameter used on each of the two occasions; and these tests shall include the pulling resistance of the welded node in accordance with UNE 36462:80.

- Where welded joints exist in reinforcements, weldability shall be checked in accordance with the provisions of Section 90.4.

In this case, the results of the control performed on the steel shall be known before starting concreting operations for the corresponding part of the works.

90.4 Verifying weldability

Where welded joints exist, it shall be verified that the material has a chemical composition which is suitable for welding, in accordance with UNE 36068:94, and the suitability of the welding procedure shall be verified in accordance with the following:

a) Butt welding.

This test shall be performed on the maximum and minimum diameters that are to be welded.

Six consecutive specimens from the same bar shall be taken for each diameter, with tensile strength tests being carried out on three of them, and the reverse bend test on the remaining three, in the following manner:

- Tensile strength test: From the first three consecutive specimens taken for this test, the central one shall be tested welded and the others non-welded, with the determination of their breaking load. The value obtained for the welded specimen shall not present a reduction greater than 5% of the average breaking load of the other two specimens, and shall not be less than the guaranteed breaking load.
  The verification of the corresponding force-elongation diagrams, shall provide results whereby, for any elongation, the force corresponding to the welded bar is not less than 95% of the value obtained from the diagram for the test bar in the lower diagram.
  The extensometer measuring base shall be at least four times the length of the olive.

- Reverse bend test: This shall be performed on three welded specimens, in the heat affected zone (HAZ) on the mandrel with the diameter given in Table 31.2.b.

b) Lap welding

This test shall be performed on a combination of the largest diameters to be welded, and on a combination of the smallest and largest diameters.
Three joints should be made for each case, with the tensile strength test being carried out on all three. The result shall be considered satisfactory if in all cases, the breakage occurs outside the lap zone or, in the case of occurring in the welded zone, this does not present a reduction of 10% in the breaking load, with regards to the average as determined for three specimens of the smallest diameter, from the same bar that was used to obtain the welded specimens, and under no circumstances shall it be under the nominal value.

c) Cross welding

Three specimens shall be employed, resulting from the combination of the largest diameter and the smallest diameter, with the smallest being subjected to the tensile strength test. The result shall be considered satisfactory if in all cases, the breakage does not present a reduction of 10% in the breaking load, with regards to the average determined for three specimens of this diameter, from the same bar which has been used to obtain the welded specimens, and under no circumstances shall it be under the nominal value.

Likewise, the suitability with respect to the pulling test on the welded cross shall be checked on another three test pieces, with the tensile strength test being carried out on the smallest diameter.

d) Other types of weld

In the event of the employment of types of welded strength joint other than the above, the Project Management shall require that tests be performed to check the welding for each type, before permitting their use at the works.

COMMENTS

The verification that the material possesses a suitable chemical composition for welding in accordance with UNE 36068:94, refers to the documentary proof of this requirement for each steel batch, and requiring the corresponding test certificates from the supplier. In a situation where the steel does not possess test results on its chemical composition, then it will be necessary to verify this with control tests.

90.5 Acceptance or rejection conditions for steel

The Project Management shall follow the following acceptance or rejection criteria in accordance with the obtained test results. Other criteria for specific cases will be established by Project Technical Specifications or by Project Management:

a) Reduced-level control

Verification of the equivalent section: If the two checks that were carried out are satisfactory, then the batch shall be accepted. If these two checks are not satisfactory, then the batch shall be rejected. If there is only one unsatisfactory result, then four new samples shall be checked corresponding to the batch being verified. If any of these four new checks is unsatisfactory, then the batch shall be rejected. Otherwise, it shall be accepted.
Formation of cracks in anchorage hooks: The appearance of cracks in anchorage hooks or bending zones of any bar will require that the entire corresponding batch be rejected.

b) Normal-level control

The procedure is the same for both certified and uncertified steel:

- Verification of the equivalent section: This shall be performed as per the reduced-level control.

- Geometric characteristics of the ribbing on ribbed bars: Failure to comply with the permitted limits established in the specific bonding certificate will constitute sufficient cause for the rejection the corresponding lot.

- Reverse bend test: If any type of failure occurs, four new specimens from the corresponding lot shall be tested. Any failure in these new tests will require the rejection of the corresponding lot.

- Tensile strength tests for determining yield stress, the breaking load and the elongation after fracture: Where the test results are satisfactory, the bars of the corresponding diameter shall be accepted. If any failure is noted, all the reinforcement of this same diameter existing at the works and any received later shall be classified in lots corresponding to the various batches supplied, without any single lot exceeding 20 tonnes for steel reinforcement and 10 tonnes for prestressing steel. Each lot shall be verified by means of tests carried out on two specimens. If both test results are satisfactory, then the lot shall be accepted If both results are unsatisfactory, then the lot shall be rejected, but if only one is unsatisfactory, a new complete test shall be carried out on all the mechanical properties which shall be checked using a further16 specimens. The result shall be considered satisfactory if the mean of the two lowest result values exceeds the guaranteed value and all results exceed 95% of this same value. Otherwise, the lot shall be rejected.

- Welding tests: In a situation whereby failure in the control of the on-site welding is noted, then all welding operations shall be suspended and a complete review of the entire process shall be performed.

COMMENTS

Whenever it is necessary to increase the number of provided tests, the new ones shall always be performed on steel that come from the same batch as those for which the results have not been satisfactory. Where this is not possible, then the Works Management shall decide on the measures to be adopted.

The arithmetic mean of the lowest eight of a set of results is a good estimate of the 5% fractile of the population distribution to which these results belong. This estimate is the one to be used in the case of tensile strength tests, as applied to 16 specimens.

Where a failure is noted in the control tests for a steel batch that has already been used in part of the works, on the decision of the Works Management and at expense of the constructor, tests taken from those listed below may be performed.

- Tests providing additional information on samples taken from existing stocks or the structure itself. These tests may be used to determine the mechanical properties of the placed steel, or special tests may be carried out to decide on the importance of this non-compliance in the ribbing geometry or in the single and reverse bending tests.

- A study of the safety of the affected components in function of the values determined in the control tests or in those carried out for additional information mentioned in the previous point.

- Loading tests in accordance with 99.2.

The Works Management shall decide which elements shall be reinforced or demolished based on the tests and studies that are carried out. Before adopting this decision, and in order to estimate the reduction in safety for the various elements, the Works Management may consult the Designer and other specialised bodies.

Article 91 The control of anchoring and coupling devices for post-tensioned reinforcement

The devices for the anchoring and coupling of post-tensioned reinforcements shall be received on site together with a certificate issued by a specialised laboratory independent of the producer, certifying compliance with the conditions specified in Article 34.

With this requirement satisfied, the on-site control will be limited to checking the visible characteristics, such as dimensions and interchangeability of the pieces, together with the absence of cracks or burrs which could imply defects in the production process etc. In particular, a check shall be made of the condition of the surfaces which fulfil the function of retaining the tendons (bonding key and thread, etc.) and of those surfaces that are to slide together during the wedge draw-in process.

The number of elements under control shall be the larger of the following values:

- Six for each batch received on site.
- 5% of those that are to fulfil a similar function in the tensioning of each piece or part of the works.

When the circumstances mean that the storage duration or conditions may have affected the condition of the surface areas above mentioned, their condition shall be checked again before their use.

COMMENTS

Emphasis is placed on the fact that the Test Certificate may be used to justify the use of the corresponding anchoring and coupling devices under certain conditions, but not in others, for example, under static loads, but not dynamic loads, up to a determined value of the tensioning force.

Article 92 Control of sheaths and accessories for prestressing steel

The sheaths and accessories shall be received on site together with the guarantee certificate of the producer, signed by an individual, which guarantees that they comply with the conditions specified in Article 35, and by the technical documentation which establishes the conditions for use.

With this requirement met, the on-site control shall be limited to check the visible characteristics, such as dimensions, crushing stiffness of the sheaths, absence of dents, cracks or perforations that could endanger the tightness properties of these, etc.

In particular, it shall be verified that when the sheaths are curved in accordance with the radii that are to be used at the works, no appreciable local deformation takes place or breakage that could affect the tightness properties of the sheaths.

It is also recommended that the tightness properties, crushing strength and shock resistance of the sheaths and connecting pieces, grouting nozzles, coupling sleeves, etc., are checked in accordance with the conditions under which they are to be employed.

With respect to the spacers, it is recommended that it be verified that no shoring of the reinforcements or significant difficulty in the grouting is produced.

In the case of long-term storage or under poor conditions, a careful check shall be made in order to ascertain whether the oxidation of the metal elements could cause problems with the tightness properties or of any other type.

COMMENTS

Because of the diversity and heterogeneity of accessory components that are used in the prestressing techniques, it is not possible to provide more specific rules on its control, however, it should be remembered that they may greatly influence the correct operation of the tensioning system, and on the operation of the final member.

Article 93 Control of the tensioning equipment

The tensioning equipment shall consist of at least two measuring instruments (pressure gauges and dynamometers etc.) in order to be able to check the forces applied on the prestressing steel.

Before starting the tensioning operations, at each works, the existing correlation between the readings of both instruments on different tension scales shall be verified.

The tensioning equipment shall undergo on-site checks, using an independent calibration device, in the following cases:

- Before using it for the first time.
- Whenever abnormalities are observed between the readings of the two instruments that make up the equipment.
- When the elongation obtained in the reinforcements differ from those specified by an amount which is greater than that established in Article 67.
- When more than two weeks have elapsed since the last check at the time of tensioning.
- When it has been used more than one hundred times.
- When the equipment has suffered from any form of impact or abnormal shock.

The calibration devices shall be checked, at least once a year, by a specialised laboratory that is independent of both constructor and producer.

Article 94 Grouting control

The grout shall comply with the requirements given in Article 36.

If the materials, cement and water, used in the preparation of the grout, are of a different type or category to those employed in the production of the concrete for the works, then they must necessarily be subject to the tests indicated in Article 81.

With regards to the admixture composition, a check shall invariably be made on the impact of the intended admixture on the quality properties of the cement slurry or mortar, before commencing the works, by employing the appropriate laboratory tests, so that the same comply with the specifications given in 29.1. The particular works conditions with respect to the temperature must be taken into account in order to specify, where applicable, that admixture have air-entraining properties.