CHAPTER 17

CONTROL OF THE CONSTRUCTION

Article 92. General criteria for the control of the construction

92.1 Control organization

The aim of the construction control, established as a requirement of this Code, is to check that the processes carried out during building of the structure are organised and carried out in such a way that the Project Manager may assume their compliance with the design in accordance with the provisions of this Code.

The Constructor shall process a work Plan and structural construction self-control procedure. The latter shall cover specific details of the work with regard to the methods, processes and activities that are to be carried out during monitoring of the construction in such a way that the Project Manager is able to check compliance with design specifications and the requirements laid down in this Code. For this reason, the results of all checks carried out shall be documented by the Constructor in self-control logs. It shall also manage stocks using a system that allows it to maintain and justify the traceability of batches and consignments received at the work in accordance with the level of control laid down in the design for the structure.

The Project Manager, representing the Owner, is obliged to inspect the construction, checking the constructor's self-control logs and carrying out a series of spot controls in accordance with the provisions laid down in this Code. The Project Manager may call on the technical assistance of a quality control body for this purpose in accordance with point 78.2.2.

Where appropriate, the Project Manager may exempt any structural construction processes covered by an officially recognised quality mark from external control.

92.2 Scheduling of the control of the construction

Before beginning the construction of the structure, the Project Manager shall approve the control Schedule, implementing the control Plan laid down in the design, taking into account the work Plan submitted by the Constructor for construction of the structure, and also the self-control procedures as laid down in section 79.1 of this Code.

The construction control schedule shall identify, inter alia, the following:

- Control levels
- construction batches
- control units
- check frequency

92.3 Levels of control of the construction

For the purposes of this Code, two control levels are considered:

a) Normal level construction control
b) Intense level construction control

The intensive level control level shall be applicable only when the Constructor holds a certified quality system in accordance with UNE-EN ISO 9001.

92.4 Construction batches

The control Schedule approved by the Project Manager shall consider the division of the work into construction batches in accordance with the implementation laid down in the work Plan for its construction and in accordance with the following criteria:

a) correspondence with the successive parts in the work construction process,
b) components of a structurally different type that belong to different columns of Table 92.4 shall not be mixed,
c) the batch size shall not exceed that shown in Table 92.4, depending on the type of components.

Table 92.4

Type of work	Foundations	Horizontal elements	Other elements
Buildings	- Ground plates, piles and pile caps corresponding to 250 m^2 of area - 50 m of screens	- Beams and flooring corresponding to 250 m^2 of ground plan	- Beams and pillars corresponding to 500 m^2 of area, not exceeding two storeys - Containing walls corresponding to 50 ml, without exceeding 8 places - "In situ" pillars corresponding to 250 m^2 of flooring
Bridges	- Ground plates, piles and pile caps corresponding to 500 m^2 of area, not exceeding three foundations - 50 m of diaphragm wall	- 500 m^3 of deck, not exceeding 30 linear m, neither a span or arch stone	- 200 m^3 of piles, not exceeding 10 m of pile length - two abutments
Chimneys, towers, silos	- Ground plates, piles and pile caps corresponding to 250 m^2 of area - 50 m of diaphragm wall	- Horizontal elements corresponding to 250 m^2	Elevationscorresponding to 500 m^2 of area or 10 m in height

92.5 Control units

For each construction batch, all processes and activities that may be controlled in accordance with the provisions in this Code shall be identified.

For the purposes of this Code, a control unit is intended to mean the maximum dimensional size of a process or activity that may be checked, in general, during an control visit to the work. Depending on the process development and activities required in the work Plan, each control visit to the work by the Project Manager or control body may check a given number of control units, which may correspond to one or more construction batches.

For each process or activity, the corresponding control unit shall be defined, whose dimension or size shall comply with the provisions in Table 92.5.

Table 92.5

Construction units	Maximum size of control unit
Stock management control	- Stock pile ordered by material, method of supply, manufacturer and batch supplied, where applicable
Operations prior construction. Layout.	- Level or storey to be constructed
Falsework	- 3000 m^3 of falsework
Forms and moulds	- 1 level of bracing - 1 level of support form work, - 1 level of bracing per construction storey - 1 span, in the case of bridges
Cut of plans for reinforcements designed in accordance with the design	- Plans corresponding to one reinforcement consignment.
Installation of reinforcements by means of ties	- Set of reinforcements processed each day
Installation of reinforcements by welding	- Set of reinforcements processed each day
Geometry of fitted reinforcement	-Set of reinforcements processed each day
Positioning of reinforcement in forms	- 1 level of support (storey) in building, - 1 level of flooring (storey) in building - 1 span, in the case of bridges
Prestressing application operations	- Prestressing arranged on the same anchorage plate in case of post-tensioning - Total prestressing in case of pre-tensining
Pouring and laying of concrete	- One day - 120 m^3 - 20 mixtures
Concrete finishing operations	- 300 m^3 of concrete volume - 150 m^2 of concrete surface
Concrete joint construction	- Joints constructed in the same day
Concrete curing	- 300 m^3 of concrete volume - 150 m^2 of concrete surface
Removing from forms and moulds	- 1 level of bracing, - 1 level of support formwork, - 1 level of bracing per building storey - 1 span, in the case of bridges
Removing the falsework	- 3000 m^3 of falsework
Joining of precast elements	- Joints carried out during the same day, - Floor plan

In the case of engineering works of minor importance and also building works without any special structural complexity (made of conventional beams, pillars and floors, not prestressed, with openings of up to 6.00 metres and a number of storeys no greater than seven) the Project Manager may opt to double the maximum size of the control units indicated in Table 92.5.

92.6 Checking frequencies

The Project Manager shall carry out the construction control by means of:

- a review of the Constructor's self-control for each control unit,
- external control of the construction of each batch by carrying out spot controls on processes or activities corresponding to some of the control units in each batch as indicated in this Article.

For each process or activity included in one batch, the Constructor shall carry out its self-control and the Project Manager shall carry out its external control by carrying out a number of controls that varies according to the control level laid down in the control programme and in accordance with the contents of table 92.6.

Table 92.6

Construction processes and activities	Minimum number of activities inspected externally per control unit			
	Normal control		Intense control	
	Constructor's self-control	External control	Constructor's self-control	External control
Falsework	1	1	All	50%
Forms and moulds	1	1	3	1
Cut of plans for reinforcements designed in accordance with the design	1	1	1	1
Installation of reinforcements by means of ties	15	3	25	5
Installation of reinforcements by welding	10	2	20	4
Geometry of allaborated reinforcement	3	1	5	2
Positioning of reinforcement in forms	3	1	5	2
Prestressing application operations	All	All	All	All
Pouring and laying of concrete	3	1	5	2
Concrete finishing operations	2	1	3	2
Concrete joint construction	1	1	3	2
Concrete curing	3	1	5	2
Removing from forms and moulds	3	1	5	2
Removing the falsework	1	1	3	2
Joining of precast elements	3	1	5	2

Article 93. Checks prior to the start of construction

Before the start of construction for each part of the work, the Project Manager shall check for the existence of a reception control programme for both products and the construction that has been drawn up specifically for the work, in accordance with the information given from the design and laid down in this Code.

Any breach in the previously established requirements shall delay the start of the work until the Project Manager obtains documentary evidence that the cause of the said non-compliance has been resolved.

Article 94. Control of the construction processes prior to the reinforcement being put in place

94.1 Control of the location of the structure

A check should be carried out that the components axis, dimensions and geometry of sections display position and dimensional parameters that deviate from the design to an extent compliant with the tolerances indicated in Annex 11, for safety coefficients of materials used in structural calculation.

94.2 Control of the foundations

Depending on the type of foundation, at least the following controls should be carried out:

a) In the case of surface foundations:
   - o check that in the case of ground plates adjacent to party walls the necessary precautions have been taken to prevent damage to existing structure,
   - o check that compacting of the ground on which the ground plate rests is consistent with requirements laid down in the design,
   - o check, where applicable, that appropriate measures have been adopted to eliminate water,
   - o check, where applicable, that blinding concrete has been poured to ensure the thickness is as specified in the design.

b) In the case of deep foundations:
   - o check the size of drillings in the case of piles constructed in situ, and
   - o check that the pile concrete head removal does not cause damage to the pile or to the anchorage reinforcement whose length shall be compliant with requirements set out in the design.

94.3 Control of the falsework and underpinning

During construction of the falsework, a check should be carried out to ensure that it corresponds with the design plans, with particular attention to bracing components and support systems. The said reviews of assembly and disassembly shall also be carried out, checking that requirements set out in the corresponding written procedures are complied with.

In general, a check shall be carried out to ensure that all assembly and disassembly processes and, if appropriate, falsework or rebracing operations are carried out in accordance with the requirements laid down in the corresponding design.

94.4 Control of formwork and moulds

Before pouring the concrete, a check shall be carried out to ensure that the geometry of sections complies with the requirements set out in the design, accepting the geometry provided it is within the tolerances laid down in the design, or otherwise in Annex 11 of this Code. The aspects indicated in section 67.3 of this Code shall also be checked.

In the case of formwork or moulds where external vibration elements are required, their location and operation shall be checked beforehand, accepting the components when the onset of problems is not foreseen once the concrete has been poured.

Before concrete pouring, a check should be run to ensure that the interior surfaces of the formwork and moulds are clean and that the corresponding mould removal product has been applied, if applicable.

Article 95. Control of the process of assembly of passive reinforcements

Before assembling the reinforcements, appropriate control shall be carried out to ensure that the reinforcement process, using wire ties or non-resistant welding, has been carried out in accordance with the provisions of Article 69 of this Code. A check should also be carried out to ensure that the anchorage and floor lengths correspond with the requirements set out in the design.

A specific check should be carried out to ensure that welds carried out in the work installations and in the case where mechanical connection devices are used, the Constructor shall be required to supply a corresponding certificate, signed by a natural person, guarantee its mechanical performance.

Preferably before positioning in the moulds or formwork and, in any case, before pouring the concrete, the true geometry of the fitted reinforcement and its correspondence with design plans shall be checked. The arrangement of separators, distance between separators and sizes shall also be checked to ensure that no actual overlaps less than the minimum laid down in this Code are present at any point in the structure.

In the event that any type of auxiliary steel elements have been used to facilitate the reinforcement of the steelwork, for example, to guarantee separation between stirrups, a check shall also be carried out to ensure that these also display an overlap of at least a minimum requirement.

Under no circumstances will the positioning of reinforcements with less cross section of steel than laid down in the design be accepted, even when this has occurred as a consequence of an accumulation of tolerances with the same sign.

Article 96. Control of the prestressing operations

96.1 Control of the tensioning of the active reinforcements

Before beginning the tensioning, the following shall be checked:

- in the case of post-tensioned reinforcements, that the tendons slide freely in their ducts or sheaths,
- that the concrete strength has reached, as a minimum, the value shown in the design for transfer of pre-tensioned force to the concrete. For this reason, if the concrete strength control test indicated in Article 88 shall be carried and the informative tests specified in Article 89 if these are not sufficient.

The magnitude of the prestressing force introduced shall be controlled in accordance with the requirements set out in section 70.3, simultaneously measuring the force exercised by the jack and the corresponding extension to which the reinforcement is subject.

To certify this check, the reading values recorded using the appropriate measuring equipment used shall be noted in the corresponding tensioning table.

During the first ten tensioning operations carried out in each work and for each prestressing equipment or system, the measurements required to find out the magnitude of movements caused by the penetration of wedges and their effects shall be measured with the effect of being able to carry out appropriate corrections in the force or extension values to be noted.

96.2 Control of the grouting process

Conditions to be met by performance of the injection operation shall be as indicated in section 70.4.

The time elapsing between the end of the first tensioning stage and performance of the injection shall be checked.

The following control shall be carried out on a daily basis:

- mixing time,
- water/cement ratio,
- quantity of admixtures used,
- viscosity, using the Marsch cone, at the time of beginning the injection,
- viscosity when the grout emerges from the final outlet pipe,
- a check to ensure all air has emerged from inside the sheath before sealing the various outlet pipes,
- injection pressure,
- leaks,
- recording of maximum and minimum environmental temperature on the days when injections are carried out and during the two subsequent days, particularly in cold weather.

Every ten days when injection operations are carried out and no less than once, the following tests should be carried out:

- grout or mortar strength by taking 3 samples to be broken after 28 days,
- exudation and reduction in volume, in accordance with 35.4.2.2.

In the case of pre-tensioning systems covered by an officially recognised quality mark, the Project Manager may exempt the products from any of experimental injection control check.

Article 97. Control of the concreting processes

Before beginning to supply the concrete, the Project Manager shall check that the circumstances are correct for carrying out pouring accurately in accordance with the provisions of this Code. A check shall also be carried out to ensure that the appropriate equipment for installation, compacting and curing of the concrete is available.

In the case of extreme temperatures, under the terms of 71.5.3, a check should be run to ensure that the precautions set out in the said sections have been taken.

A check should be run to ensure that cold joint is not formed between different pouring layers and that segregation is avoided during pouring of the concrete.

The Project Manager shall check that curing is carried out appropriately during at least the time period indicated in the design or otherwise as indicated in this Code.

Article 98. Control for processes following concreting

Once the concrete has been removed from the mould or formwork, a check should be carried out to ensure the absence of significant defects on the concrete surface. If holes, honeycombing or other defects that, due to their nature, may be considered unacceptable with regard to requirements laid down, where applicable, in the design, the Project Manager shall assess the advisability of repairing the defects and coating the surfaces if necessary.

If the design has laid down any specific requirements relating to the appearance of the concrete and its finishes (colour, texture, etc.), these characteristics shall be subject to control once the component has been removed from the mould or formwork and under the conditions laid down in the corresponding special technical specifications for the design.

The Project Manager shall also check that stripping is carried out in accordance with the plan laid down in the design and checking that the mechanical conditions that may have been established for the concrete are met, where applicable.

Article 99. Control of the assembly and joints of precast elements

Before beginning to install precast elements, the Project Manager shall carry out the following checks:

a) precast elements should comply with design specifications and appropriately stored, where applicable, without displaying apparent damage,
b) plans should be available that sufficiently define the precast component assembly process and also possible additional measures (provisional bracing, etc.)
c) availability of a construction program that clearly defines the assembly sequence for precast elements, and
d) availability of the human and material resources, where necessary, for assembly.

During assembly, a check should be carried out to ensure that all design instructions are complied with. Particular attention shall be devoted to maintaining dimensions and construction conditions for support, links and joints.

Article 100. Control of the constructed components

Once construction of each stage of the structure has been completed, it shall be inspected with the aim of checking that it complies with design dimensional specifications.

If the design adopts in the calculations reduced materials adjustment factors in accordance with the information given in section 15.3, it shall be checked, in particular, that the geometrical tolerances laid down in the design are met or otherwise those indicated for the purpose in Annex 11 of this Code.

Article 101. Control of the structure by means of tests for additional information

101.1 General

When structures have been designed and built in accordance with this Code, where the materials and construction achieve the required quality, only the cases set out below need to undergo tests on additional information, in particular load tests:

a) when laid down in the Code, specific regulations for a type of structure or special

technical specifications,

b) when it is advisable to check that the structure meets certain specific conditions due to its nature, In this case the special technical specifications shall establish appropriate tests to be carried out, accurately indicating the test method and the results interpretation method.

c) when the Project Manager feels that reasonable doubt exists over the safety, function or durability of the structure.

101.2 Load tests

Many situations exist where it may be advisable to carry out load tests on structures. In general, load tests may be grouped in accordance with their purpose into:

a) Regulation load tests.

These are all the tests laid down in the Special Technical Specifications or Guidelines or Regulations, which involve carrying out a test to certify the behaviour of the structure in situations representing service actions. Regulations covering road and rail bridges establish, in all cases, the need to carry out load tests before the work is accepted. The purpose of such tests is to check the proper design and good construction of the structures with regard to standard service loads, checking whether the work behaves in accordance with the theoretical assumptions and thus ensuring its function.

It musts also be added that load tests can supply valuable research data that may be used to confirm design theories (load distribution, turning of supports, maximum deflection) and may be used in future designs.

These tests shall not be carried out before the concrete has reached the designed strength. Various load systems, both static and dynamic, may be considered.

Dynamic tests are required in road and rail bridges and structures where a considerable vibration effect may be predicted in accordance with corresponding action Guidelines. In particular, the latter point affects bridges with spans greater than 60 m or an unusual design, the use of new materials and slender walkways and transit areas where the onset of vibration that may even cause disturbance to users. The design and performance of this type of test shall be carried by technical teams experienced in this type of testing.

Assessment of regulation load tests requires previous preparation of a load test design that shall consider the difference between the implementation of actions (dynamic or static) in each case. As a general rule, unless otherwise justified, the results shall be considered satisfactory when the following conditions are met:

- During the test, cracks do not arise that do not correspond with those envisaged in the design and that may compromise the durability and safety of the structure.
- The measured deflections do not exceed values laid down in the design as maximums compatible with the correct use of the structure.
- Experimental measurements determined in tests (rotations, deflections, vibration frequencies) do not exceed the maximum calculated in the load test design by more than 15% in the case of reinforced concrete and 10% in the case of prestressed concrete.
- The residual deflection after withdrawing the load taking into account the time the load was maintained is sufficiently small to be able to assume that the structure's behaviour is essentially elastic. This condition shall be satisfied after one load-unload cycle and, if it is not achieved, the results shall be acceptable if the criteria are met after a second cycle.

b) Load tests as additional information

Sometimes it is advisable to carry out load tests as a method to obtain additional information on changes or problems that could have arisen during construction. Except in cases where the

safety of the structure is questioned, service action shall not be exceeded in this type of test and the performance, analysis and interpretation criteria to be followed are similar to those describe in the previous case.

c) Load tests to evaluate bearing capacity

In some cases load tests may be used as a means of evaluating the safety of structures. In such cases, the loads to be applied shall be a fraction of the theoretical load greater than the service load. Such tests always require the drawing up of a Test Plan that evaluates the feasibility of the test and for the test to be conducted by an organisation experienced in this type of work and managed by a competent engineer.

The Test Plan shall include, inter alia, the following aspects:

- Test feasibility and purpose.
- Parameters to be measured and location of measurement points.
- Measurement procedures.
- Load and unload steps
- Safety measures.

This final point is very important because failure or partial or total breakage of the tested elements may occur in this type of test.

Such tests are basically applied to elements subject to bending. The following criteria shall be followed for their performance:

- Structural components subject to testing shall have aged for at least 56 days or it shall have been checked that the actual strength of the concrete in the structure has reached the nominal values laid down in the design. Provided it is possible and if the components to be tested will be subject to permanent loads not yet applied, 48 hours before the test, the corresponding replacement loads shall be arranged to act on the tested elements throughout the test.
- Initial reading shall be taken immediately before arranging the test load.
- The area of the structure subject to the test shall be subject to a total load, including permanent acting loads, equivalent to 0.85 (1.35 G + 1.5 Q), where G is the permanent load that it has been determined will act on the structure and Q are the foreseeable overloads.
- Load tests shall be organised into at least four approximately equal stages, avoiding impact on the structure and the formation of unload arches in the materials used to apply the load.
- 24 hours after the total test load has been positioned, readings shall be taken at the required measurement points. Immediately after recording the readings, unloading shall begin and final readings shall be recorded up to 24 hours after withdrawing all loads. Continual recordings shall be carried out of existing temperature and humidity conditions during the test with the aim of carrying out the appropriate corrections, if relevant.
- During the load tests, appropriate safety measures shall be adopted to prevent a possible accident during the course of the test. Safety measures shall not interfere with the load tests or affect the results.

The test results shall be considered satisfactory when the following conditions are met:

- None of the components in the test structural area displays unforeseen cracks that affect structural durability or safety. The maximum deflection obtained is less than

$l^2/20000$ h, where l is the theoretical span and h the component depth. If the tested element is a cantilever, l shall be twice the distance between the support and the end.

- If the maximum deflection exceeds $l^2/20000$ h, the residual deflection once the load has been withdrawn and 24 hours have passed, shall be less than 25% of the maximum in reinforced concrete components and less than 20% of the maximum in prestressed concrete elements. This condition shall be satisfied after the first load-unload cycle. If not complied with, a second load-unload cycle shall be carried out 72 hours after the end of the first cycle. In this case, the result shall be considered satisfactory if the residual deflection obtained is less than 20% of the maximum deflection recorded in this load cycle for all types of structure.

101.3 Other non destructive tests

This type of test shall be used to assess properties of concrete in the structure other than strength, or properties of reinforcement that may affect their safety and durability.

Article 102. Control of environmental aspects

The Project Manager shall ensure compliance with special environmental conditions that have been laid down in the design, where applicable, for construction of the structure.

If the Owner has laid down requirements relating to the structure's contribution to sustainability in accordance with Annex 13 of this Code, the Project Manager shall check that the same level (A, B, C, D or E) defined in the design for the ICES index is met with the actual methods and procedures used during the construction.