INSPECTION OF EXECUTION

CHAPTER XVI

Article 95 Inspection of execution

95.1 General

Inspection of execution, which is established in this Instruction as being mandatory, is intended to guarantee that the works are carried out in accordance with the design and the requirements of this Instruction.

It is the joint responsibility of the Owner and Project Management to guarantee the performance of the external control of the execution, which must be adapted to the corresponding level, in accordance with the value adopted for γ_f in the design.

The following three levels are possible for carrying out inspection of execution:

- Reduced-level
- Normal-level
- Intense-level

which are related to the coefficient of increase in actions used in the design.

For the inspection of execution, a Inspection Plan shall be prepared, which divides the work into lots, as shown in Table 95.1.a.

Table 95.1.a

TYPE OF WORKS	LOT SIZE
Buildings	500 m^2, without exceeding the two floors
Bridges, aqueducts,tunnels, etc.	500 m^2 of floor, without exceeding 50 m
Large mass works	250 m^3
Chimneys, towers, and piers, etc.	250 m^3, without exceeding 50 m
Precast elements	
- Linear type	500 m of bed
- Surface type	250 m

The various aspects which are given in Table 95.1.b, shall be at least inspected in each lot.

Table 95.1.b
INSPECTION DURING EXECUTION

GENERAL FOR ALL TYPES OF WORKS

A) PRIOR TO COMMENCING THE EXECUTION

- Directory of agents involved.
- Existence of record books and statutory orders.
- The existence of archived materials, certificates, delivery tickets, control results, design documents and classifying system for any design changes or additional information.
- Review of plans and contractual documents.
- Existence of materials quality control in accordance with the specified levels.
- General check of equipment: Calibration certificates, where applicable.
- Supply and certificates of materials suitability

B) LAYING OUT AND GEOMETRY

- Checks of elevations, levels and geometry.
- Checks of permitted tolerances.

C) FALSEWORK AND SCAFFOLDING

- Existence of calculations, where applicable.
- Checks of plans.
- Checks of elevations and tolerances.
- Review of erection.

D) REINFORCEMENTS

- Type, diameter and position.
- Cutting and bending.
- Storage.
- Placement tolerances.
- Covers and separation between reinforcement. Use of spacers and chairs.
- Condition of sheaths, anchorages, joints, and accessories.

E) FORMWORK

- Tightness properties, stability and texture.
- Tolerances.
- Possibility of cleaning, including decks.
- Geometry and deflection.

F) TRANSPORT, PLACING AND COMPACTION

- Transport times.
- Placing conditions: method, sequence, maximum height, etc.
- Concreting in wind, cold weather, hot weather or rain.
- Concrete compaction.
- Surfaces finishing.

G) CONSTRUCTION, CONTRACTION OR EXPANSION JOINTS

- Arrangement and treatment of construction and contraction joints.
- Cleaning of contact surfaces.
- Waiting time.
- Connecting reinforcement.
- Position, slope and distance.
- Dimensions and sealant, where applicable.

H) CURING

- Method employed.
- Curing times.
- Surfaces protection.

I) REMOVAL OF FORMWORK AND FALSEWORK

- Control of the concrete strength before tensioning.
- Control of imposed construction loads.
- Check of deadlines for removing falsework.
- Repair of defects.

J) TENSIONING

- Tensioning and elongation programme for prestressing steel.
- Check of slipping and anchorages.
- Grouting of sheaths and protection of anchorages.

K) GEOMETRICAL TOLERANCES AND FINAL DIMENSIONS

- Dimensional verification.

L) REPAIR OF DEFECTS AND SURFACE CLEANING

SPECIFIC FOR BUILDING FLOOR SLABS

- Check of current Authorisation for Use.
- Dimensions of flat slabs, drops and column heads.
- Conditions of rib connection.
- Geometric check of the critical shear perimeter.
- Thickness of upper flat slab.
- Total depth.
- Cavities: position, dimensions and structural solution.
- Distribution reinforcement.
- Spacers.

SPECIFIC FOR PRECAST ELEMENTS

A) CONDITION OF BEDS

- Cleanliness.

B) LOCATION OF TENDONS

- Baffles.
- Cable routing.
- Spacers and joints.
- Tensioning flanges.
- Anchoring wedges.

C) TENSIONING

- Verification of the concrete strength before transfer.
- Load verifications.
- Tensioning and elongation programme.
- Transfer
- Tendon cutting.

D) FORMS / MOLDS

- Cleaning and release agents.
- Location.

E) CURING

- Thermal cycle.
- Protection of pieces.

F) REMOVAL OF MOLDS AND STORAGE

- Lifting of pieces.
- Storage at the factory.

G) TRANSPORT TO SITE AND ERECTION

- Suspension and hanging elements.
- Situation during transport.
- Loading and unloading operations.
- Erection methods.
- On-site storage.
- Verification of erection.

The results of all the inspections, and the corrective measures adopted, shall be included in the corresponding reports. These documents shall be included in the Final Works Documentation which the Project Manager should supply to the Owner, as specified in 4.9.

In prestressed concrete works, only the normal and intense levels of inspection of execution may be used.

COMMENTS

A concrete that meets all specifications when it leaves the mixer may undergo a reduction of these same specifications in the event of inadequate transport, placing or curing conditions. This also applies to the cutting, bending and location of steel reinforcement and prestressing steel, and the accuracy with which the initial tension is applied in accordance with the project design. It has already been explained that any irregularity in the prestressing steel trayectory, with respect to its correct position, would modify the tension distribution in the cross section of the member and could lead to stresses that were not taken into account in the design, and which could damage or crack the concrete. Due to the known risk of corrosion, it is very important that the maintenance of minimum required covering and that for the grouting of the ducts housing the tendons be carried out in a suitable manner. Moreover, even in the situation where the previous operations are correctly performed, it is essential to verify the spans and dimensions of the constructed elements in order to be able to guarantee that the quality of the finished works is as required by the project design.

Basically, the inspection of execution is entrusted to the visual inspection of those persons who carry it out, so common sense, technical knowledge and practical experience are fundamental requirements for achieving the planned level of quality. In spite of this, it is necessary to combine all these control operations into a single system in order to obtain a high degree of efficiency, since not all the defects that might occur will be detected unless the possibility of their presence is taken into consideration beforehand.

As has been stated in a general manner in Article 80 of this instruction, internal and external controls are also applicable to the works execution. Control as specified in the following articles refers to acceptance control (External Control).

95.2 Intense level of inspection

In addition to the external control of execution, this level of inspection requires that the construction company possesses its own externally-audited quality system, and that the production of the reinforcing steel and the precast elements, where applicable, is carried out at fixed industrial installations with a voluntary certification system.

If these conditions do not exist, the Project Management should require the construction company to provide certain specific procedures for performing the various internal control activities involved in the works construction.

This level of external control requires at least three inspections for each lot into which the works have been divided.

95.3 Normal-level of inspection

This level of external control is of general application, and requires at least three inspections for each lot into which the works have been divided.

95.4 Reduced-level of inspection

This level of external control is applicable when there is no continuous and repeated monitoring of the work and requires at least one inspection for each lot into which the works have been divided.

95.5 Application of the inspection levels

The partial safety factors for actions as defined in Table 12.1.a, require correction in accordance with the adopted inspection level, and for this reason, the values to be adopted in the event of any persistent or transitory situation with an unfavourable effect are those which are given in Table 95.5.

Table 95.5
values of the coefficients of increase in actions γ_f
in accordance with the inspection level

TYPE OF ACTION	INSPECTION LEVEL		
	INTENSE	NORMAL	REDUCED
PERMANENT	$\gamma_G = 1.35$	$\gamma_G = 1.50$	$\gamma_G = 1.60$
PRESTRESSING	$\gamma_P = 1.00$	$\gamma_P = 1.00$	$\gamma_P = 1.00$
PERMANENT WITH A NON-CONSTANT VALUE	$\gamma_{G^*} = 1.50$	$\gamma_{G^*} = 1.60$	$\gamma_{G^*} = 1.80$
VARIABLE	$\gamma_Q = 1.50$	$\gamma_Q = 1.60$	$\gamma_Q = 1.80$

Article 96 Execution tolerances

The designer shall adopt and define a tolerance system, which should be included in the Project Specifications for the works. This document shall also include any decisions and procedures that are to be followed in the event of non-compliance.

Annex 10 contains a tolerance system for concrete works which may serve as a reference or be adopted by the designer.

COMMENTS

Tolerance systems are required in construction works in order to limit the permissible execution deviations with respect to the dimensions specified in the drawings and other project documents. This forms the only method for clarifying the construction contract, and it is also necessary to admit deviations in the works actually executed with regards to the specified theoretical values, while, at the same time, accepting that fact that such deviations should have clearly established limits.

The tolerance system should be established by taking the strength, aesthetics and functional aspects into consideration from the reality of experience. A overly strict tolerance system could lead to the systematic non-compliance of the same, and would lead to the loss of validity of the works, or a notable and unnecessary increase in their costs.

Article 97 Inspection of tensioning

The following shall be checked prior to tensioning:

- That the tendons slide freely in their ducts or sheaths in the case of post-tensioned reinforcement.

- That the strength of the concrete has at least reached the value indicated in the design for the transfer of the prestressing force to the concrete. In order to do this, the tests to control the strength of the concrete indicated in Article 88 shall be performed, and if these are not sufficient, the information tests indicated in Article 89, shall be carried out.

The magnitude of the applied prestressing force shall be monitored in accordance with the provisions of Article 67, by simultaneously measuring the force exerted by the jack and the elongation produced in the reinforcement.

In order to provide proof of this control, the values of the readings obtained using the appropriate measuring instruments shall be recorded in the corresponding tensioning table.

In the first ten tensioning operations that are performed at each works and with each prestressing equipment or system, precise measurements shall be taken in order to discover, where applicable, the magnitude of the movements caused by the draw-in of wedges or other phenomena, with the aim of being able to make the appropriate corrections to the values of the forces or elongation which shall be recorded.

Article 98 Inspection of grouting

The conditions which shall be met when carrying out the grouting operation shall be as detailed in Article 78.

The period of time elapsing between the completion of the first tensioning stage and grouting shall be controlled.

The following controls shall be performed on a daily basis:

- The batching time.
- The water/cement ratio.
- The amount of admixture employed.
- The viscosity, using the Marsch cone, when commencing the grouting operation.
- The viscosity on exit of the cement slurry from the final grout vent.
- That all the air from inside the sheath has been expelled before successively closing the various grout vents.
- The grouting pressure.
- Leaks.
- The recording of maximum and minimum ambient temperatures on the days when grouting operations are performed and on the two following days, particularly during cold weather.

Every ten days during which grouting operations are carried out, and at least once, the following tests shall be performed:

- The strength of the cement slurry or mortar by taking 3 specimens for testing at 28 days.
- The bleeding and reduction of volume, in accordance with 36.2.

COMMENTS

Special care shall be taken with vertical cables to avoid the danger of bleeding by following the recommendations of Article 78.

Article 99 Additional information tests on the structure

99.1 General

Within structures that have been designed and built in accordance with this Instruction, in which all the materials and the execution have achieved the specified quality and verified by means of the compulsory controls, solely those included in the list below are required to be subjected to information tests and, in particular, to load tests.

a) When required by the Instructions, specific structure regulations or the Project Specifications.

b) When, due to the particular nature of the structure, it is necessary to verify that the same complies with certain specific conditions. In this case, the Project Specifications shall establish the appropriate tests that are to be performed, indicating with absolute precision the procedure for performing these and the method for the interpretation of the results.

c) When, in the opinion of the Project Manager, there are reasonable doubts about the safety, functionality or durability of the structure.

COMMENTS

The tests on specimens, whatever the quality of the concrete they are used to measure, are a useful procedure, but they are not totally representative of the final performance of the concrete in the structure itself. In addition, the behaviour of the concrete when exposed to certain agents is dependent on several variables, which are sufficiently complex to mean that is not possible to quantitatively reproduce the phenomena in the laboratory. For this reason, it can be particularly useful, under certain circumstances, to employ tests on the works during execution or after completion.

99.2 Load tests

There are many situations that could advise the carrying out of load tests on structures. In general, load tests may be grouped in accordance with their purpose into:

A) Prescribed load tests.

All those established in the Project Specifications, Instructions or Regulations. They tray to perform a test that indicate the behaviour of the structure under representative situations of its service actions. The regulations on road and railway bridges establish the requirement to perform loading tests prior to the acceptance of the works, in all cases. The purpose of these tests is to check the appropriate design and the correct execution of the works with regards to normal operating loads, checking whether the work behaves in accordance with the design assumptions, thereby guaranteeing its functionality.

It should be added that, in the load tests, useful investigation data can be obtained which should confirm the design theories (load distribution, support rotation, maximum deflections) and which should be employed in future designs.

These tests should not be performed before the concrete has reached the design strength. Various loading systems, both static and dynamic, may be considered.

The dynamic tests are mandatory for railway and road bridges and for those structures in which considerable vibration effects are expected, in accordance with the relevant

Instructions of actions. In particular, this last point affects bridges with spans higher than 60 m or an unusual design, the use of new materials, footbridges and transit zones in which, due to their slenderness, the appearance of vibrations is expected that could cause problems for users. The design and execution of this type of test shall be entrusted to technical teams with experience in the specific type of test.

The assessment of the prescribed load tests requires the prior preparation of a Load Test Plan which shall consider the difference in how the actions (whether dynamic or static) act in each case. In general, and unless specifically justified, the results shall be considered satisfactory when the following conditions are met:

a) If, during the test, no cracks are produced which do not correspond to the foreseen of the design and which could compromise the durability and safety of the structure.

b) The measured deflections do not exceed the values established in the design as being the maximum compatible with correct use of the structure.

c) The experimental measurements as established in the tests (rotations, deflections, vibration frequencies) do not exceed the maximum values calculated in the load test plan by more than 15%, in the case of reinforced concrete, and by 10% in the case of prestressed concrete.

d) The residual deflection after removal of the load, taking into account the time during which this load has been maintained, is sufficiently small to consider that the structure has an essentially elastic behaviour. This condition shall be met following an initial loading-unloading cycle, and if not met, it is permitted for the criteria to be met after performing a second cycle.

B) Load tests as additional information

On occasions it is appropriate to perform load tests to obtain additional information in the event of changes or when problems have been encountered during construction. Except where the safety of the structure has been affected, the service actions shall not be exceeded in this type of test, in accordance with criteria relating to the performance, analysis and interpretation similar to those described in the previous case.

C) Load tests for the assessment of strength capacity

In certain cases, the load tests may be employed as a means to assess structure safety. the load to be applied shall be a fraction of the design load which is higher than the working load. These tests always require the preparation of a Test Plan that assesses the viability of the test, and its carrying out by an organisation with experience in this type of work, and guided by a competent engineer.

Among others, the Test Plan shall include the following aspects:

- Test viability and purpose.
- The magnitudes that are to be measured and the location of the measuring points.
- Measuring procedures.
- Loading and unloading steps.
- Safety measures.

This last point is extremely important given that, due to their specific nature, any failure, partial or total rupture of the element being tested could occur in this type of test.

These tests are basically applicable to elements that are subject to bending. The criteria listed below shall be followed when they are performed:

-The structural elements being tested shall be at least 56 days old or following confirmation that the real strength of the concrete employed in the structure has reached the nominal values specified in the design.

-Whenever possible, and if the element to be tested is to be subject to permanent loads that have not yet been applied, the appropriate replacement loads which are to be applied to the tested element should be applied 48 hours before the test.

-The initial readings shall be taken immediately before applying the test load.

-The test structure zone to be tested shall be subject to a total load, including the permanent loads acting thereon, equivalent to 0.85 (1.35 G + 1.5 Q), where G is the permanent load that has been determined as acting on the structure and Q is the planned imposed load.

-The load tests shall be arranged in a minimum of four approximately-equal stages, avoiding impacts on the structure and the formation of relieving arches in the materials used to produce the load.

-24 hours after the total test load has been applied, the readings shall be taken at the specified measuring points. Immediately after recording these readings, the unloading shall begin, with the recording of the readings continuing up to 24 hours after all the loads have been removed.

-Continuous recordings shall be made of the temperature and humidity conditions existing during the test, in order to perform any appropriate corrections, if required.

-During the load tests, all appropriate safety measures shall be adopted to prevent any possible accident during the test. These safety measures shall not interfere in any way with the load test ,nor should they affect the results.

The test results may be regarded as being satisfactory when the following conditions are met:

-None of the elements within the tested structure zone present unexpected cracks that could compromise the durability or safety of the structure.

-The maximum deflection obtained is less than $l^2 / 20.000\ h$, where l is the design span and h is the element depth. Where the tested element is a cantilever, l should be twice the distance between the support and the element.

-If the maximum deflection exceeds $l^2 / 20.000\ h$, the residual deflection, having removed the load and after 24 hours, shall be less than 25% of the maximum deflection in reinforced concrete elements and less than 20% of the maximum deflection for prestressed concrete elements. This condition shall be satisfied after the first loading-unloading cycle. If it is not met, a second loading-unloading cycle is permitted after 72 hours have elapsed, calculated from the end of the first cycle. In this event, the result shall be considered as being satisfactory if the residual deflection obtained is less than 20% of the maximum deflection recorded in this loading cycle, for each type of structure.

COMMENTS

In addition to those cases where they are prescribed, load tests are recommended for structures or parts of structures that have suffered some form of deterioration or that have been subjected to actions that could have had an impact on their strength capacity (fire, freezing weather conditions, etc.). and also when a determined structure, or a part of it, is going to support actions that were not included in the initial project (high usage loads, intermittent high loading, etc.).

These loads should be applied so that they produce maximum forces in those sections that are considered as being critical. It should be taken into consideration that neighbouring elements may collaborate in the strength of the member/element of the test. Additionally, all required precautions should be adopted to prevent the occurrence of any possible accidents during the course of the test.

In those tests where the service loads are not exceeded, and as a general rule, it is recommended that the total residual deflection after the first load-unload cycle be less than one fifth of the total deflection measured under total load. If this condition is not met, then a second load-unload cycle may be employed, after which the stabilised residual deflection should be less that one eighth of the total deflection measured under load in this second cycle.

Small variations in the mentioned values may be accepted, depending on the type of element that is undergoing testing and in accordance with the relative importance of the overloads with respect to the permanent load.

For the improved interpretation of results, it is recommended that the more characteristic movements that are produced during the testing are measured and recorded, together with the environmental temperature and humidity and the sunshine conditions and any other information that might influence the results of the measurements. It should be noted that a deflection estimate should always be made for those structures having behaviour that is considered to be rigid, since the non-tensional movements may be significant and do not have the same criteria as the residual deflection.

The direction of all the operations that make up the test, the careful recording of all relevant data and the interpretation of the results should be carried by personnel specialised in this type of work.

99.3 Other non-destructive tests

This type of test is used to estimate in the structure other properties of the concrete than strength, or properties of the reinforcement, , which could affect its safety or durability.

COMMENTS

There are non-destructive test methods (gammaradiography, magnetic probes, ultrasound, etc.), that allow to determine the real situation of reinforcement and the thickness of the coverings that may have been altered by placing, stirring or vibration of the concrete and the greater or lesser permeability of the concrete or the formation of internal air pockets due to incorrect compaction.

In general, it is recommended that these tests be carried out and interpreted at a specialised centre, since they usually have significant limitations, and require very specific practical experience.