

# ANNEX 22

## Preliminary and characteristics tests of concrete

### 1 Preliminary tests

This type of tests shall not be necessary, except in cases in which there has been no prior experience to provide documentary evidence for the use of concretes with the materials, composition and construction methods that are planned for specific works.

The aim of the preliminary tests is to demonstrate, through tests carried out on concrete manufactured in laboratories, that using the planned materials, dosage and construction methods it is possible to obtain concrete that presents the strength and durability conditions required by the design.

For the purposes of these tests, at least four series of samples shall be prepared from different mixes, each consisting of two samples for testing at 28 days old, for each dosage planned for use in the works, proceeding in accordance with the methods for the preparation of samples and for the performance of the strength and durability tests included in this Code.

In the case of compressive strength, the values obtained in this way shall be used to determine an average laboratory strength,  $f_{cm}$ , which must be sufficiently high in order that it may be feasibly expected that, with the scattering introduced by the planned manufacturing methods for its use in the works, the actual on-site characteristic strength will be greater, by a sufficient margin, than the characteristic strength specified by the design.

The preliminary tests provide information for estimating the average value of the property studied, but are not sufficient to determine the statistical distribution followed by the concrete of the works. Given that neither the specifications in this Code nor the additional specifications included in the design refer in general to average values, as in the case of strength, it is necessary to adopt a series of hypotheses to enable decisions to be made regarding the validity of the dosages tested.

In general, Gaussian distribution may be permitted, with a population standard deviation or coefficient of variation that must be based on the data obtained from the production inspection at the facility at which the concrete will be manufactured. Obviating the variation that exists between the populations of laboratory concrete and those actually manufactured for the works, in the case of strength, the following minimum requirements may be made:

$$\bar{x}_n \geq f_{ck} + 2\sigma$$

where  $\bar{x}_n$  is the average strength of the sample obtained during the tests and  $f_{ck}$  is the characteristic strength specified in the design.

Standard deviation,  $\sigma$ , is a basic piece of information required for this type of estimate. Where this value is not known for the manufacturing facility to be used, it may be assumed as an initial approximation that:

$$\sigma = 4\text{N/mm}^2$$

The formula above corresponds to certain average conditions of proportioning by weight, with separate and differentiated storage of all component materials and correction of the quantity of water for the humidity incorporated in the aggregates where, in addition, the scales and measuring devices are checked periodically and the raw materials are inspected on receipt or at source.

The information provided by the preliminary laboratory tests is key to the successful completion of the works, which is why the technical management needs to be aware of it. In particular, making up the maximum number of samples aged less than 28 days may prove very useful.

## 2 Characteristic tests for strength

This type of testing shall not be necessary, except in cases in which there has been no prior experience to provide documentary evidence for the use of concretes with the materials, dosage and construction methods that are planned for the works. The purpose of the tests is to check, before supply begins, that the characteristics of the concrete to be used in the works are not inferior to those specified by the design.

The tests shall be carried out on 28-day-old samples from six different mixes, for each type of concrete to be used in the works. Two samples shall be cast per mix, which shall be manufactured, stored and tested in accordance with the methods laid down in this Code.

For compressive strength, the average value corresponding to each batch shall be calculated from the individual failure results, enabling a series of six average results to be obtained:

$$x_1 \leq x_2 \leq \dots \leq x_6$$

The Project Management shall accept the dosage and corresponding construction method, for the purposes of strength, where:

$$\bar{x}_6 - 0,8.(x_6 - x_1) \geq f_{ck}$$

If this is not the case, the concrete shall not be accepted and the plant manager must make the appropriate corrections in order that the aforementioned conditions may be met. In the meantime, the start of the supply of concrete shall be postponed until new characteristic tests have shown that an acceptable dosage and manufacturing method has been achieved.

It may be useful to test different initial dosages, because if one dosage only is prepared and the required behaviour is not achieved with this mix, the process must begin again, causing the work to be delayed.

## 3 Characteristic tests for dosage

The aim of these tests is to check, before any concrete is supplied, that the dosages to be used comply with the durability criteria laid down in this Code. Where characteristic strength tests are also required, both sets of tests may be conducted at the same time.

Independent series of tests shall be carried out for each type of concrete to be used in the works, in order that their respective dosages may be characterised. The aforementioned tests shall include at least compressive strength tests and tests to determine the depth of water penetration under pressure.

Furthermore, the Project Technical Specifications or the Project Management may stipulate that further tests shall be carried out in order to determine additional characteristics including, for example, to determine the carbonation speed or chloride ion diffusion coefficient where the design includes an estimate of the useful life of the structure, in accordance with Annex 9 in this Code.

Before supply begins, three series of four samples shall be made, from three mixes manufactured in the plant with the same dosage as that to be used in the works. In each series, two samples shall undergo the strength test and two further samples shall undergo the depth of water penetration test. Samples must be taken at the facility that will be used to manufacture the concrete during construction. The time at which this operation is to be carried out, and the laboratory responsible for manufacturing, storing and testing the samples, must be chosen with

the prior approval of the person responsible for accepting the concrete, the concrete supplier and, where appropriate, the constructor or prefabricator.

The tests shall be performed in accordance with Section 86.3 of this Code. A report shall be compiled of the results of both the strength tests and the tests to determine the water penetration depth. The actual dosage and raw materials used in the concrete tested shall also be specified.

The average values of the results of the water penetration depth tests obtained for each series shall be arranged in accordance with the following criterion:

- maximum penetration depths:  $Z_1 \leq Z_2 \leq Z_3$
- average penetration depths:  $T_1 \leq T_2 \leq T_3$

In order to be accepted, the concrete tested must comply with all of the following conditions:

Environmental exposure class	Maximum depth specifications	Average depth specifications
IIIc, Qc Qb (only in the case of prestressed elements)	$Z_m = \frac{Z_1 + Z_2 + Z_3}{3} \leq 30 \text{ mm}$ $Z_3 \leq 40 \text{ mm}$	$T_m = \frac{T_1 + T_2 + T_3}{3} \leq 20 \text{ mm}$ $T_3 \leq 27 \text{ mm}$
IIIa, IIIb, IV, Qa, E, H, F, Qb (in the case of plain or reinforced elements)	$Z_m = \frac{Z_1 + Z_2 + Z_3}{3} \leq 50 \text{ mm}$ $Z_3 \leq 65 \text{ mm}$	$T_m = \frac{T_1 + T_2 + T_3}{3} \leq 30 \text{ mm}$ $T_3 \leq 40 \text{ mm}$
I, IIa, IIb (no specific class)	This check is not required	This check is not required

The values obtained from the compressive strength tests shall be used to determine the average results for each series,

$$X_1 \leq X_2 \leq X_3 \dots$$

The minimum characteristic strength compatible with the durability criteria shall be defined by applying one of the following expressions:

- where characteristic strength tests are carried out simultaneously, with six series of samples:

$$f_{c,dosif} = \bar{x}_6 - 0,80 \cdot (x_6 - x_1)$$

- in other cases, with three series of samples:

$$f_{c,dosif} = \bar{x}_3 - 1,35 \cdot (x_3 - x_1)$$

where  $\bar{x}_i$  is the average strength of a number, "i", of series tested.

The Project Management shall allow the supply of concrete to begin when the following conditions are all met simultaneously:

- the value of  $f_{c,dosif}$  is not less than the corresponding value in Table 37.3.2.b,
- the value of  $f_{c,dosif}$  is not less than the value of  $f_{ck}$  laid down in the design.

The Project Management shall allow the supply of concrete to begin if the value of  $f_{c,dosif}$  is not below the value of  $f_{ck}$  laid down in the design, and is not more than 5 N/mm<sup>2</sup> below that specified in Table 37.3.2.b.

The Project Management may change the specification of the concrete ordered if the value of  $f_{c,dosif}$  corresponds to a strength classification, of the series recommended in 39.2, higher than that specified in the design. The acceptance inspection for strength will therefore be carried out in accordance with the new specification.

The laboratory that carried out the tests shall draw up a dosage certificate, providing at least the following information:

- laboratory accreditation,
- identification of the plant,
- classification name of the concrete,
- where appropriate, the quality mark of the concrete and the complete reference of the provision by which it was officially recognised,
- actual dosage of the concrete tested, including complete identification of the raw materials used,
- individual results of the compressive strength tests and the value calculated for  $f_{c,dosif}$ ,
- results of the water penetration depth tests,
- where appropriate, explicit statement of the conformity of the concrete tested with the requirements of this article,

date on which the tests were performed and period for which the certificate is valid, which may