TITLE 3. TECHNICAL CHARACTERISTICS OF MATERIALS

CHAPTER 6

MATERIALS

In the area of application of this Code, products of construction that are manufactured or marketed legally in the Member States of the European Union and in the signing States of the Agreement on the European Economic Space will be able to be used, and as long as these products, complying the regulations of any Member State of the European Union, assure as for the safety and the use in which they are purposed an equivalent level at which it requires this Code..

This level of equivalence will be credited according to has been established in the article 4.2 or, in its case, in the article 16 of the Directive 89/106/EC of the Council, of 21 of December 1988, related to the approach of the legal, statutory and administrative arrangements of the Member States on the products of construction.

Dispositions in the previous paragraphs will be also applicable to the products of construction manufactured or marketed legally in a State that has an Agreement of customs association with the European Union, when that Agreement recognizes to those products the same treatment that to the ones manufactured or marketed in a Member State of the European Union. In these cases the level of equivalence will be confirmed through the application, to these effects, of the procedures established in the mentioned Directive.

.Article 26. Cements

The cement shall be able to provide the concrete with the characteristics set out for concrete in Article 31.

Within the scope of this Code, cements that satisfy the following requirements may be used:

- Are in conformity with the specific regulations in force,
- Satisfy the limitations on use set out in Table 26, and
- Belong to a strength class of 32.5 or above.
-

Table 26 Types of cement that can be used

Type of concrete	Type of cement
Mass concrete	Ordinary cements apart from types CEM II/A-Q, CEM II/B-Q, CEM II/A-W, CEM II/B-W, CEM II/A-T, CEM II/B-T and CEM III/C ESP VI-1 cements for special purposes
Reinforced concrete	Ordinary cements apart from types CEM II/A-Q, CEM II/B-Q, CEM II/A-W, CEM II/B-W, CEM II/A-T, CEM II/B-T, CEM III/C and CEM V/B
Pre-stressed concrete	Ordinary cements of types CEM I and CEM II/A-D, CEM II/A-V, CEM II/A-P and CEM II/A-M(V,P)

The permitted use requirements in dictated in table 26 for each type of concrete shall be understood to include white cements and cements with additional characteristics (i.e. sulphate-, water-, and seawater-resistant cements and those with low hydration heat) and be of the same types and in the same strength classes

The requirements in 35.4.2 shall be taken into consideration with any cement used as a constituent of an injected bonding product.

The use of calcium aluminate cement shall always be subject to special study; the reasons recommending its use shall also be provided and it shall satisfy the specifications contained in Appendix No. 3.

The provisions in 31.1 as regards total chlorine ion content shall be taken into consideration with every type of cement and the requirements for the fines content of concrete shall be satisfied whenever a limestone filler cement is used.

For the purpose of this Code, cements with a strength class of 32.5N shall be deemed to be slow-hardening cements; those of classes 32.5R and 42.5N and 42.5R, 52.5N and 52.5R shall be deemed to be rapid-hardening cements.

Article 27. Water

The water used to mix and cure the concrete in situ shall not contain any ingredients which in sufficient amounts could adversely affect the concrete's characteristics or the corrosion resistance of any reinforcements.

As a general rule, any water considered acceptable in practice may be used.

When there were not precedent information on a particular water or, if there is any uncertainty as to its quality, it shall be analysed and, unless it can be specially evidenced that it does not adversely affect the characteristics required of the concrete, it shall satisfy the following requirements:

Hydrogen exponent (pH) (UNE 7234)	≥ 5
Dissolved substances (UNE 7130)	≤ 15 grams per litre (15,000 p.p.m)
Sulphates, expressed as $SO_4^{=}$ (UNE 7131), except for SR cement in which this limit is increased to 5 grams per litre (5,000 p.p.m)	≤ 1 gram per litre (1,000 p.p.m)
Chloride ion, Cl^- (UNE 7178):	
a) For pre-stressed concrete	≤ 1 gram per litre (1,000 p.p.m)
b) For reinforced concrete or mass concrete containing crack-reducing reinforcements	≤ 3 grams per litre (3,000 p.p.m)
Carbon hydrates (UNE 7132)	0
Organic substances soluble in ether (UNE 7235)	≤ 15 grams per litre (15,000 p.p.m)

Sampling shall be taken in accordance with UNE 7236 and the analysis methods shall be in accordance with the standards indicated.

Seawater or similar saline water may be used for the mixing or curing of concretes that do not contain any reinforcements. Unless special studies are conducted, the use of this water for the mixing or curing of reinforced or pre-stressed concrete is expressly prohibited.

Recycled water from the washing tanks belonging to the concrete plant itself may be used, provided that the specifications set out above in this article are satisfied. The density value of the recycled water shall not exceed 1.3 g/cm^3 and the total density of water shall not exceed the heat of 1.1 g/cm^3.

The density of recycled water is directly related to the amount of fines it introduces into the concrete, in accordance with the following expression:

$$M = \left(\frac{1-d_a}{1-d_f}\right).d_f$$

In which:

M Mass of fines present in the water in g/cm^3.
d_a Density of the water in en g/cm^3.
d_f Density of the fines, in g/cm^3.

The provisions in 31.1 shall be taken into consideration with regard to the fines content introduced into the concrete. When calculating the fines content introduced by the recycled water, a d_f value of 2.1 g/cm^3, may be used in the absence of an experimental value obtained by determination in a Le Chatelier Flask, based on an oven-dried sample subsequently pulverised until it can pass through a 200 μm sieve.

The provisions in 31.1 shall be taken into consideration as regards chloride ion content.

Article 28. Aggregates

28.1 General

The characteristics of its constituent aggregates shall enable a concrete of suitable strength and durability and with the other characteristics set out in the Project Technical Specifications for the project to be obtained.

Concretes may be made using coarse aggregates (gravels) or fine aggregates (sand), in accordance with UNE-EN 12620, which have either been gravels from natural deposits (river aggregates) or obtained from crushed rocks, or comprise air-cooled foundry slag, according to UNE-EN 12620 or, generally any other type of aggregate whose satisfactory performance has been confirmed in practice and which can be duly evidenced.

The provisions in Appendix No. 15 shall be followed. if recycled aggregates are used. Lightweight aggregates shall comply with the provisions in Appendix 16 of this Code and, in particular, the provisions in UNE-EN 13055-1.

If foundry aggregates (for example: granulated iron blast furnace slag) are used, these shall first be checked to ensure that they are stable, i.e. that they do not contain any unstable silicates or unstable ferrous compounds.

Due to the risk they pose, only aggregates with a very low proportion of oxidisable sulphides may be used.

28.2 Designation of aggregates

For the purposes of this Code, aggregates shall be designated in accordance with the following format:

d/D - IL

In which:

d/D Particle size fraction of between a minimum size d, and a maximum size D, in mm.
IL Format: R ,river aggregate; T, crushed; M, mixture.

With preference the nature of the aggregate will be also included (C, lime; S, siliceous; G, granite; O, offite; B, basalt; D, dolomitic; Q, trachyte; I, phonolite; V, various; A, artificial; R, recycled), being the format:

d/D - IL – N

When specifying the concrete at the design stage, only the aggregate maximum size in mm needs to be established in accordance with 39.2 (where it is called TM) and whether recycled aggregate and its percentage specified, as necessary.

28.3 Maximum and minimum aggregate sizes

The maximum size D of a coarse or fine aggregate refers to the minimum opening in a UNE EN 933-2 sieve which satisfies the general requirements set out in table 28.3.a, as a function of the aggregate's size.

The minimum size d of a coarse or fine aggregate refers to the maximum opening in a UNE EN 933-2 sieve which satisfies the general requirements set out in table 28.3.a, as a function of the aggregate's type and size.

The minimum size d and the maximum size D of aggregates shall be specified using two sieves from the basic series, the basic series plus series 1, or the basic series plus series 2 in table 28.3.b. Series 1 sieves may not be combined with those of series 2.

The sizes of the aggregates shall not have a D/*d* less than 1.4.

Table 28.3.a General requirements for maximum D and minimum d sizes.

		Percentage passing through the sieve (by mass)				
		2 D	1.4D[a)]	D[b)]	d	d/2[a)]
Coarse aggregate	D > 11.2 and D/d > 2	100	98 to 100	90 to 99	0 to 15	0 to 5
	D≤11.2 or D/d≤2	100	98 to 100	85 to 99	0 to 20	0 to 5
Fine aggregate	D≤4 and d>0	100	95 to 100	85 to 99	0 to 20	-

a) Like 1.4D and d/2 sieves, they shall be taken from the series chosen or the following size of the nearest sieve in the series.

b) The percentage by mass which passes through sieve *D* may be more than 99%, but in these cases the supplier shall document and confirm the representative particle size grading, including sieves *D, d, d/2* and intermediate sieves between *d* and D in the basic series plus series 1, or from the basic series plus series 2. Sieves with a ratio of less than 1.4 times the following lower sieve may be excluded.

Table 28.3.b Sieves series for aggregates size specification

Basic Serie mm	Basic Serie+ Serie mm	Basic Serie + Serie 2 mm
0,063	0,063	0,063
0,125	0,125	0,125
0,250	0,250	0,250
0,500	0,500	0,500
1	1	1
2	2	2
4	4	4
-	5,6 (5)	-
-	-	6,3 (6)
8	8	8
-	-	10
-	11,2 (11)	-
-	-	12,5 (12)
-	-	14
16	16	16
-	-	20
-	22,4 (22)	-
31,5 (32)	31,5 (32)	31,5 (32)
-	-	40
-	45	-
63	63	63
125	125	125

NOTE – In order to simplify, rounded sizes in brackets can be used to describe the size of aggregates.

28.3.1 Restrictions on coarse aggregate sizes for the making of concrete.

The term gravel or total coarse aggregate is applied, when making concrete, to the mixture of the various fractions of coarse aggregate used; sand or total fine aggregate is the term applied to the mixture of the various fractions of fine aggregate used; and the term total aggregate (or, when there is no risk of confusion, simply aggregate), is the term applied to the aggregate which on its own or when mixed, has the correct proportions of sand and gravel to make a particular concrete.

The maximum size of the coarse aggregate used to make concrete shall be less than the following dimensions:

a) 0.8 times the free horizontal distance between sheaths or reinforcements, or between an edge of the member and a sheath or reinforcement forming an angle of more than 45º with the direction of concreting.
b) 1.25 times the distance between an edge of the member and a sheath or reinforcement forming an angle of not more than 45º with the concreting direction.
c) 0.25 times the minimum dimension of the member, apart from in the following cases:

- Top slab whose maximum aggregate size will be less than 0.4 times its minimum thickness.
- Very carefully constructed members (for example, elements precast in factory) and any elements whose formwork has a reduced wall effect (e.g. in the case of slabs with formwork only on one side), when it shall be less than 0.33 times the minimum thickness.

The aggregate for a particular application may comprise the combination of one or more particle size fractions. If the D/d ratio is 2 or less, the aggregate may be considered to constitute a singular particle size fraction.

When the concrete has to be poured between several layers of reinforcements, an aggregate size smaller than the size shown for the limits a) or b), if size is a determining factor, should be used.

28.4 Aggregate particle size grading

The particle size grading of aggregates, determined in accordance with standard UNE-EN 933-1, shall satisfy the requirement corresponding to their d/D size.

28.4.1 Particle size requirements for total fine aggregate

The amount of fines passing through a 0.063 UNE EN 933-1 sieve, expressed as a percentage of the weight of the total coarse aggregate sample or the total fine aggregate sample shall not exceed the values in table 28.4.1.a. If one of these values is exceeded, compliance with the specification for the limitation on the concrete's total fines content in 31.1, shall be checked

Table 28.4.1.a Maximum fines content of aggregates

AGGREGATE	MAXIMUM PERCENTAGE WHICH PASSES THROUGH A 0.063 mm SIEVE	TYPES OF AGGREGATE
Coarse	1.5%	- Any
Fine	6%	- Rounded aggregates - Crushed non-limestone building aggregates subjected to general exposure classes: IIIa, IIIb, IIIc, IV or any of the specific exposure classes: Qa, Qb, Qc, E, H and F (1)
	10%	- Crushed limestone building aggregates subjected to general exposure classes IIIa, IIIb, IIIc, IV or any of the specific exposure classes: Qa, Qb, Qc, E and F (1) - Crushed non-limestone building aggregates subjected to general exposure classes I, IIa or IIb but not subjected to any of the specific exposures classes: Qa, Qb, Qc, E, H and F (1)
	16%	- Crushed limestone building aggregates subjected to general exposure classes I, IIa or IIb but not subjected to any of the specific exposure classes: Qa, Qb, Qc, E, H and F (1)

(1) See tables 8.2.2 and 8.2.3.a.

28.4.2. Quality of aggregate fines

Apart from in the case indicated in the following paragraph, fines whose sand equivalent (SE_4) determined on a 0/4 fraction, in accordance with Appendix A of standard UNE EN 933-8, which is less than the following shall not be used:

a) 70, in the case of structures subjected to general exposure classes I, IIa or IIb but which are not subjected to any specific exposure class. See tables 8.2.2 and 8.2.3.a.
b) 75, in all other cases.

Notwithstanding the foregoing, sands from crushed limestones or dolomites (with these terms being understood to relate to carbonate sedimentary rocks that contain at least 70% calcite dolomite, or both) that do not satisfy the specification for sand equivalent shall be validly accepted if they satisfy the following requirements:

- in the case of structures subjected to general exposure classes I, IIa or IIb, but which are not subjected to any specific exposure class:

$$AM \leq 0{,}6.\frac{f}{100}$$

Being AM the methylene blue (UNE EN 933-9) in grams of blue for every kilogram of the granulometric fraction 0/2 mm. and f the fines content of the 0/2 fraction.

- in other cases:

$$AM \leq 0{,}3.\frac{f}{100}$$

If, for the exposure class concerned, the methylene blue value is more than the limit value set out in the paragraph above and there is some uncertainty as to whether the fines contain any clay, its presence may be identified and qualitatively calculated in these fines, using the X-ray diffraction test. Fine aggregate may only be used if the clays are of the kaolinite or illite type and if the mechanical and pressurised water characteristics of the concretes made with this sand are at least the same as those of a concrete made using the same constituents but with sand without fines. the corresponding study shall be supplied with the evidencing documentation that shall always include a mineralogical analysis of the aggregate and, in particular, its clay content.

28.5 Form of coarse aggregate

The form of coarse aggregate shall be expressed using its flakiness index, with this being understood to be the percentage of aggregates by weight deemed to present flake shape in accordance with UNE EN 933-3, and which shall be less than 35.

28.6 Physical-mechanical requirements

The following limitations shall be satisfied:

- Resistance to wear of coarse aggregate determined by means of the Los Angeles test indicated in UNE EN 1097-2 <40
- Aggregate water absorption determined by means of the test method indicated in UNE EN 1097-6. < 5%

Coarse aggregates with an abrasion resistance of between 40 and 50 determined during a Los Angeles test (UNE-EN 1097-2) may be used to make mass or reinforced concrete with a specified strength characteristic not exceeding 30 N/mm^2, provided that previous experience in their use has been gained, and specific experimental studies have been carried out confirming that they will not adversely affect the concrete's performance.

When a concrete is subject to an exposure class of H or F and its aggregates have a water absorption of more than 1%, these shall not, when subjected to five treatment cycles using magnesium sulphate solutions (test method UNE EN 1367-2), exhibit a weight loss exceeding 15% in the case of fine aggregates, or 18% in the case of coarse aggregates.

A summary of the quantitative limitations is shown in table 28.6.

Table 28.6 Physical-mechanical requirements

Characteristics of the aggregate	Maximum amount as a % of the total weight of the sample	
	Fine aggregate	Coarse aggregate
Water absorption % Determined in accordance with the test method indicated in UNE	5%	5%
Abrasion test of coarse aggregate determined in accordance with the test method indicated in UNE EN 1097-2	-	40 (*)
% weight loss after five magnesium sulphate cycles Determined in accordance with the test method indicated in UNE EN 1367-2 in the case of coarse aggregates and in UNE 83116 in the case of fine aggregates	-	18%

(*) 50, in the case indicated in the article.

28.7 Chemical requirements

This paragraph defines the minimum requirements which aggregates for concretes must satisfy. A summary of the quantitative limitations are shown in table 28.7.

28.7.1 Chlorides

The water soluble chloride ion (Cl^{-}) of coarse and fine aggregates for concrete, as determined in accordance with Article 7 of Standard EN 1744-1:1999, may not exceed 0.05% by mass of the aggregate when used in reinforced concrete, or mass concrete containing crack reduction reinforcements, and may not exceed 0.03% by mass of aggregate, when used in pre-stressed concrete, in accordance with the information indicated in Table 28.7.

The requirements in 31.1 shall be taken into account with regard to the total chloride ion, Cl^{-}, content of concretes.

28.7.2 Soluble sulphates

The acid-soluble sulphate content of coarse and fine aggregates, expressed in SO_3 and determined in accordance with Article 12 of Standard UNE-EN 1744-1, shall not exceed 0.8% by mass of the aggregate, as indicated in Table 28.7. this specification shall be 1% for air-cooled blast furnace slag.

28.7.3 Total sulphur compounds

Total sulphur compounds in coarse and fine aggregates, as determined in accordance with Article 11 of standard UNE-EN 1744-1, may not exceed 1% by mass of the total weight of the sample. This specification shall be 2% for air-cooled blast furnace slag,

If oxidisable iron sulphides are present in the form of pyrrhotite, sulphur content introduced by these, and expressed in S, shall be less than 0.1%.

28.7.4 Organic material compounds that alter the setting and hardening rates of concrete.

If, in accordance with paragraph 15.1 of UNE EN 1744-1, the presence of organic substances is detected, their effect on setting time and compression strength shall be determined in accordance with paragraph 15.3 of standard UNE-EN 1744-1. The mortar prepared with these aggregates shall ensure that:

a) The increase in the setting time of the mortar test samples is less than 120 minutes.
b) The reduction in the compression strength of the mortar test samples at 28 days is less than 20%.

Fine aggregates with a proportion of organic material which, when tested in accordance with the test method indicated in paragraph 15.1 of UNE-EN 1744-1, produces a darker colour than the reference standard substance, shall not be used. Similarly, the lightweight organic particle content floating in a liquid with a specific weight of 2 and determined in accordance with paragraph 14.2 of standard UNE-EN 1744-1 shall not be less than 0.5% in the case of fine aggregates, and 1% in the case of coarse aggregates. Coarse aggregates shall be crushed prior to testing until they have a particle size of less than 4 mm.

28.7.5 Volume stability of air-cooled blast furnace slag

Air-cooled blast furnace slag shall remain stable:

a) When the non-stable bicalcic silicate in its composition, as determined in accordance with the test described in paragraph 19.1 of UNE-EN 1744-1, is transformed.
b) When the iron and manganese sulphides in its composition, as determined in accordance with the test described in paragraph 19.2 of UNE-EN 1744-1, are hydrolysed.

Table 28.7 Chemical requirements

<table>
<tr><td colspan="2" rowspan="2">HARMFUL SUBSTANCES</td><td colspan="2">Maximum amount as a % of total weight of the sample</td></tr>
<tr><td>Fine aggregates</td><td>Coarse aggregates</td></tr>
<tr><td colspan="2">Material retained by the 0.063 UNE EN 933-2 sieve and which floats in a liquid with a specific weight of 2, as determined in accordance with the test method indicated in paragraph 14.2 of UNE EN 1744-1</td><td>0.50</td><td>1.00</td></tr>
<tr><td colspan="2">Total sulphur compounds expressed as S and with reference to the dry aggregate, as determined in accordance with the test method indicated in paragraph 11 of UNE EN 1744-1</td><td>1.00</td><td>1.00(*)</td></tr>
<tr><td colspan="2">Soluble sulphates in acids, expressed as SO_3 and with reference to the dry aggregate, as determined in accordance with the test method indicated in paragraph 12 of UNE EN 1744-1</td><td>0.80</td><td>0.80(**)</td></tr>
<tr><td rowspan="2">Chlorides expressed as Cl^- and with reference to the dry aggregate, as determined in accordance with the test method indicated in paragraph 7 of UNE EN 1744-1</td><td>Reinforced or mass concrete containing crack reduction reinforcements</td><td>0.05</td><td>0.05</td></tr>
<tr><td>Prestressed concrete</td><td>0.03</td><td>0.03</td></tr>
</table>

(*) This value shall be 2% in the case of air-cooled blast furnace slag.
(**)This value shall be 1% in the case of air-cooled blast furnace slag.

28.7.6 Alkali-aggregate reactivity

Aggregates shall not exhibit any potential reactivity with the concrete's alkali compounds, whether these are contained in the cement or in other constituents.

A petrographic study shall first be carried out to verify this aspect, which will provide information concerning the type of reactivity that may be exhibited in each case.

If the petrographic study on the aggregate reveals the possibility that alkali-silica or alkali-silicate reactivity will be exhibited, the test described in UNE 146508 EX (accelerated cement test piece method) shall be carried out.

If the petrographic study on the aggregate reveals the possibility that alkaline-carbonate reactivity will occur, the test described in UNE 146507-2 EX shall be carried out. This test shall be carried out on a limestone-dolomitic fraction of natural or artificial mixtures of limestone and siliceous aggregates.

If the results of any of the tests required to determine reactivity reveal that the material is potentially reactive, the aggregate may not be used in conditions that encourage an alkaline-aggregate reaction, in accordance with paragraph 37.3.7. Aggregate automatically identified as being potentially reactive, can only be used if satisfactory results are obtained from the long-term reactivity tests on concrete cubes, according to standard UNE 146509 EX, and if the latter's expansion at the end of the test does not exceed 0.04%.

Article 29. Admixtures

29.1 General

For the purposes of this Code, admixtures shall be understood to mean those substances or products which, once incorporated into concrete prior to or during mixing or additional mixing in individual proportions not exceeding 5% of the weight of the cement, ensure the desired alteration, in the fresh or hardened state, in any of the concrete's characteristics, usual properties or performance.

Calcium chloride and generally any product, whose constituents include chlorides, sulphides, sulphites or other chemicals that could corrode reinforcements or make corrosion of reinforcements more likely, may not be used as admixtures in reinforced or prestressed concretes.

Elements prestressed by reinforcements anchored solely by means of bonding may not comprise air-entraining type admixtures.

However, plastifiers which have a secondary air-entraining effect may be used in continuously cast elements with pre-tensioned reinforcements provided that it is ensured that they do not perceptibly adversely affect the bond between the concrete and its reinforcement, or the latter's anchorage. The total amount of entrained air measured in accordance with UNE EN 12350-7 shall never exceed 6% by volume,.

The requirements in 31.1 shall be taken into consideration with regard to the chloride ion content.

29.2 Types of admixtures

For the purposes of this Code, five types of admixtures, as indicated in table 29.2 shall be considered.

Table 29.2 Types of admixtures

TYPE OF ADMIXTURE	MAIN FUNCTION
Water reducers/plastifiers	To reduce the water content of a concrete without modifying its workability or increase workability without modifying the water content.
High-range water reducers/ superplastifiers	To significantly reduce the water content of a concrete without modifying its workability or significantly increase workability without modifying the water content.
Accelerators and retarders	To modify a concrete's setting time.
Air-entraining agents	To produce a controlled volume of fine air bubbles which are uniformly distributed in the concrete in order to improve frost resistance.
Multi-functional	To modify more than one of the main functions defined above.

Admixtures of any of the five types described above shall satisfy UNE EN 934-2.

Designations of admixtures in accordance with UNE EN 934-2 shall be indicated in original documents, and include their manufacturers' certificates guaranteeing that the products satisfy the requirements set out in the aforementioned standard, their efficiency ranges (the proportions to be used) and their main functions from those indicated in the table above.

Unless otherwise indicated in advance by the Project Manager, the Supplier may use any of the admixtures contained in Table 29.2. The use of admixtures other than those indicated in this Article shall be subject to the prior approval of the Project Manager.

The introduction of admixtures into a concrete, once in situ but prior to its incorporation, shall require the authorization of the Project Management and the concrete Supplier to be notified.

Article 30. Additions

For the purposes of this Code, additions are those inorganic or pozzolanic materials, or materials with latent hydraulicity, which, when finely divided can be added to concrete in order to improve one of its characteristics or to endow it with special properties. This Code only covers fly ash and silica fumes added to concrete at the time of casting.

Fly ash is the solid residue collected by electrostatic precipitation or mechanical trapping of the dust accompanying the combustion gases of pulverised coal-fed thermoelectric plant burners.

Silica fumes are a by-product obtained during the reduction of high-purity quartz, with carbon in electric arc furnaces for the production of silicon and ferrosilicon.

Additions may be used as concrete constituents provided that evidence can be provided of their suitability for use, and that the desired effect can be achieved without negatively impact on the concrete's characteristics or posing a risk to the concrete's durability or the corrosion-resistance of its reinforcements.

A CEM I type cement must be used if the concrete contains additions of fly ash or silica fumes. In addition, if fly ash is added, the concrete shall be covered by a guarantee level that conforms to the provisions in the article 81 of this Code, for example, has an officially recognised quality mark.

Fly ash, representing up to 20% of the weight of the cement, and silica fumes representing up to 10% of the weight of the cement, may be used in prestressed concrete.

In specific applications involving high-strength concrete cast using CEM I type cement, fly ash and silica fumes may be added simultaneously, provided that the percentage of silica fumes does not exceed 10% and that the total percentage of additions (total fly ash and silica fumes) does not exceed 20% (of the weight of the cement in both cases). In this case, fly ash shall be merely deemed to improve the compactness and rheology of the concrete, and its contribution to the binder in the form of its efficiency coefficient *K* shall be disregarded.

The maximum amount of fly ash added in non prestressed elements in building structures may not exceed 35% of the weight of the cement; the maximum amount of silica fumes added may not exceed 10% of the weight of the cement. The minimum amount of cement is specified in 37.3.2.

The chloride ion content requirements in 31.1 shall be taken into consideration.

30.1 Requirements and tests for fly ash

Fly ash may not contain harmful elements in amounts that could affect the durability of the concrete or cause corrosion in its reinforcements. It shall also comply with the following specifications in accordance with UNE EN 450-2:

- Sulphur trioxide (SO_3), according to UNE EN 196-2 ≤ 3.0%
- Chlorides (Cl^-), according to UNE-EN 196-2 ≤ 0.10%
- Free calcium oxide, according to UNE EN 451-1 ≤ 1%
- Fire loss, according to UNE EN 196-2 ≤5.0% (Cathegory A in UNE-EN 450-1)
- Fineness, according to UNE EN 451-2 ≤40%
- Amount retained by a 45 μm sieve
- Activity index, according to UNE-EN 196-1
    - At 28 days ≥ 75%

- o At 90 days ≥ 85%
- Expansion using the needle method,
- according to UNE EN 196-3 < 10 mm

The specification for expansion shall only be taking into consideration if the free calcium oxide content exceeds 1% but does not exceed 2.5%

The results of the analysis and the preliminary tests shall be made available to the Project Management.

30.2 Requirements and tests for silica fumes

Silica fumes may not contain any harmful elements in amounts such that they could affect the durability of the concrete or cause its reinforcements to corrode. They shall also comply with the following specifications:

- Silicon dioxide (SiO_2), according to UNE EN 196-2 > 85%
- Chlorides (Cl^-) according to UNE 80217 < 0.10%
- Fire loss, according to UNE EN 196-2 < 5%
- Activity index according to UNE-EN 13263-1 > 100%

The results of the analysis and the preliminary tests shall be made available to the Project Management.

Article 31. Concretes

31.1 Composition

The composition chosen for the preparation of the mixtures intended for the construction of structures or structural elements shall be studied in advance in order to ensure that it is capable of providing concretes whose mechanical, rheological and durability characteristics satisfy the requirements of the project. These studies shall be carried out bearing in mind, wherever possible, the actual features of the structure (diameters, surface characteristics and layout of reinforcements, compacting method, dimensions of members, etc.)

Concrete constituents shall comply with the requirements in Articles 26, 27, 28, 29 and 30. In addition, the total chloride ion content introduced by constituents shall not exceed the following limits (see 37.4):

- Prestressed concrete structures	0.2% of the weight of the cement
- Reinforced concrete structures or mass concrete structures containing crack-reduction reinforcements	0.4% of the weight of the cement

The total amount of fines in the concrete, obtained by adding the coarse aggregate particle content and the fine aggregate particle content that can pass through a UNE 0.063 sieve, plus any limestone constituent in the cement, shall not be less than 175 kg/m^3. If recycled water according to Article 27 is used, this limit may be increased to 185 kg/m^3.

31.2 Quality requirements

The quality requirements or characteristics required for the concrete shall be specified in the Project Technical Specifications and reference to their compression strength, consistency, maximum aggregate size, the type of atmosphere to which they are to be exposed and, whenever necessary, reference to requirements relating to admixtures and additions, the concrete's tensile strength, absorption, specific weight, compactness, wear, permeability, external appearance etc., shall be made.

These requirements shall be satisfied by all constituent product units with "product unit" being understood to be the amount of concrete cast at the same time. A product unit will normally be a batch, although for control purposes, it may instead be the amount of concrete made during a set period of time under the same basic conditions. The term "batch", as used in this Code, refers to a product unit.

In this Code, any measurable batch quality characteristic is expressed as the average value of a number of determinations (two or more) of the quality characteristic concerned, taken on parts or portions of the batch.

31.3 Mechanical characteristics

The mechanical characteristics of structural concretes shall satisfy the requirements set out in Article 39.

For the purposes of this Code, the compression strength of a concrete refers to the results obtained in the compression breaking strength tests at 28 days carried out on cylindrical test pieces 15 cm in diameter and 30 cm high, made, stored and tested in accordance with the provisions in this Code. The procedure set out in 86.3.2 shall be followed If cube test pieces are used for checking quality,.

The formulae contained in this Code relate to tests carried out on cylindrical test pieces; similarly, and unless otherwise expressly indicated, requirements indicated in this Code refer to cylindrical test pieces.

The compression strength of structural concrete that is not going to be loaded during the first three months following its incorporation may be tested at 90 days.

Project Technical Specifications may require the concrete's tensile and flexural strength to be tested on some structures or parts of structures using standardised tests.

In this Code, high strength concretes refer to concretes with a characteristic compressive design strength f_{ck} greater than 50 N/mm^2.

For the purposes of this Code, rapid hardening concretes are concretes: made using cement with a strength class of 42.5R, 52.5 or 52.,5R provided that their water/cement ratio is no more 0.60; made using cement with a strength class of 32.5R or 42.5, provided that their water/cement ratio is no more than 0.50; to which an accelerator has been added. All other concretes shall be deemed to be normal hardening concretes.

31.4 Minimum strength value

The design strengths, f_{ck} (see 39.1) of structural concretes, shall not be less than 20 N/mm^2 in the case of mass concretes, or less than 25 N/mm^2 in the case of reinforced or prestressed concretes.

Where the design so specifies, in accordance with 86.5.6, the strength of mass concrete or reinforced concrete structures for minor engineering structures or in one- or two-storey residential buildings with spans of less than 6.0 metres, and in elements of residential structures of up to four storeys that are subject to bending, also with spans of less than 6.0 metres, may be indirectly checked and a compression design strength of f_{cd} not exceeding 10 N/mm^2 (see 39.4) shall be adopted. When concrete strength is indirectly checked in these cases, the minimum amount of cement in the mix shall also satisfy the requirements in table 37.3.2.a.

Non-structural concretes (i.e. blinding concretes, fill concretes, kerbs and pavements) do not have to satisfy this minimum strength value, do not need to be identified using the standard structural concrete format (defined in 39.2), and shall not be subject to this article, since they have their own requirements set out in Annex No. 18 of this Code.

31.5 Concrete workability

A concrete's workability shall be sufficient to ensure, if the methods set out for its incorporation and compacting are used, that it surrounds the reinforcement without any continuity defects and fully fills formwork without leaving any cavities. The workability of a concrete shall be calculated by determining its consistency.

Concrete consistency is measured on the basis of its slump in an Abrams cone, in accordance with UNE-EN 12350-2, expressed as a whole number of centimetres.

It is generally recommended that the slump of structural concretes in an Abrams cone is at least 6 centimetres.

The various consistencies and the limits for the corresponding slump values in the Abrams cone shall be as follows:

Type of consistency	Slump in cm
Dry (S)	0 - 2
Plastic (P)	3 - 5
Soft (B)	6 - 9
Fluid (F)	10 - 15
Liquid (L)	16-- 20

Except for specific applications where required, consistency dry and plastic will be avoided. Liquid consistency can be used only if it is got by means of superplastifiers.

The concrete consistency used shall be as specified in the Project Technical Specifications and defined by their type or numerical value of slump in cm.

The provisions in Annex No. 17 of this Code shall be satisfied by self-compacting concretes,.

Article 32. Steels for passive reinforcements

32.1 General

For the purposes of this Code, the following steel products may be used to make passive reinforcements:

- Ribbed weldable straight steel bars and weldable ribbed steel supplied in coils
- Ribbed or indented weldable steel wires
- Plain weldable steel wires.

Plain wires may only be used as connection elements for basic electro-welded lattice reinforcements.

Steel products for passive reinforcements shall not exhibit any surface defects or cracks.

Nominal cross-sections and nominal masses per metre shall be as set out in Table 6 of UNE EN 10080. Equivalent cross-sections shall not be less than 95.5 percent of nominal cross-sections.

The nominal diameter of a steel product refers to the conventional figure that defines its circle and on which its tolerances are established. The area of the aforementioned circle is the nominal cross-section.

The equivalent cross-section of a steel product, expressed in square centimetres, refers to the division of its weight in newtons by 0.077 (7.85 if its weight is expressed in grams) times its length in centimetres. The diameter of the circle whose area is the same as its equivalent cross-section is called the equivalent diameter. Determination of the equivalent cross-section shall be undertaken after carefully cleaning the steel product to remove any mill scale and loose oxide.

For the purposes of this Code, the yield stress f_y, of a passive reinforcement steel is the stress sufficient to produce a permanent deformation of 0.2 percent.

The steel manufacturing method shall be at the manufacturer's discretion.

32.2 Bars and coils of weldable ribbed steel

For the purposes of this Code, only ribbed weldable steel bars and ribbed weldable steel supplied in coils conforming to UNE EN 10080 may be used.

Possible nominal diameters of ribbed bars shall be as defined in the following series, in accordance with Table 6 of UNE EN 10080:

6 - 8 - 10 - 12 - 14 - 16 - 20 - 25 - 32 and 40 mm.

Apart from in the case of electro-welded mesh fabrics or basic lattice reinforcements, diameters of less than 6 mm shall be avoided wherever any welding technique, either resistant or non-resistant, is used in the making or installation of passive reinforcements.

The types of ribbed steel are defined for the purposes of this Code in table 32.2.a:

Table 32.2.a Types of ribbed steel

Type of steel		Weldable steel		Weldable steel with special ductility characteristics	
Designation		B 400 S	B 500 S	B 400 SD	B 400 SD
Yield strength, f_y (N/mm^2)[(1)]		≥400	≥500	≥400	≥500
Ultimate tensile stress, f_s (N/mm^2)[(1)]		≥440	≥550	≥480	≥575
Elongation to failure, $\varepsilon_{u,5}$ (%)		≥14	≥12	≥20	≥16
Total elongation at maximum load, $\varepsilon_{máx}$ (%)	Steel supplied as bars	≥5.0	≥5.0	≥7.5	≥7.5
	Steel supplied as rolls [(3)]	≥7.5	≥7.5	≥ 10.0	≥10.0
f_s/f_y ratio [(2)]		≥1.05	≥ 1.05	1,20 ≤ f_s/f_y ≤ 1,35	1,15 ≤ f_s/f_y ≤ 1,35
$f_{y\ real}/f_y$ nominal ratio		-	-	≤1.20	≤1.25

(1) Nominal cross-sections shall be used when calculating unit values.

(2) Permitted ratio between Ultimate tensile stress and the yield strength obtained at the end of each test.

(3) Samples of ribbed steels supplied in rolls shall be prepared prior to testing, in accordance with the provisions in Annex 23. Considering the uncertainty of this method can be accepted steels with characteristic values of $\varepsilon_{máx}$,0.5% below to the corresponding in the table for those cases.

The minimum mechanical characteristics guaranteed by the Supplier shall be in accordance with the requirements in Table 32.2.a. In addition, bars shall be suitable for bending and unbending, as confirmed by the absence of cracks perceptible to the naked eye when undertaking the test according to UNE-EN ISO 15630-12, and using the mandrels in Table 32.2.b.

Table 32.2.b Diameter of mandrels

Bending-unbending a = 90. β = 20.		
d ≤ 16	16 < d ≤ 25	d > 25
5 d	8 d	10 d

In which:

d Nominal bar diameter in mm
α Bending angle
β Unbending angle

Instead of the bending-unbending suitability test the simple bending test, according to UNE-EN ISO 15630-1 may be carried out using the mandrels specified in table 32.2.c.

Table 32.2.c Diameter of mandrels

Simple bending a= 180.	
d ≤ 16	d > 16
3 d	6 d

in which:

d Nominal bar diameter in mm
α Bending angle

Wieldable steels with special ductility characteristics (B400SD and B500SD) shall satisfy the requirements in table 32.2.c with regard to the fatigue test in accordance with UNE-EN ISO 15630-1, and the requirements in table 32.2.e relating to the alternating deformation test, according to UNE 36065 EX.

Table 32.2.d Fatigue test specification

Characteristic	B400SD	B500SD
Number of cycles which the test piece must withstand without breaking.	≥ 2 millions	
Maximum tensile stress, σ_{max}= 0.6 fy nominal (N/mm^2)	240	300
Amplitude, $2\sigma_a = \sigma_{máx} - \sigma_{mín}$ (N/mm^2)	150	
Frequency, f (Hz)	$1 \leq f \leq 200$	
Free length between jaws, (mm)	≥14d ≥ 140 mm	

In which:

d Nominal bar diameter in mm

Table 32.2.e Alternating deformation test specification

Nominal diameter (mm)	Free length between jaws	Maximum deformation in tensile and compression (%)	Number of complete symmetrical hysteresis cycles	Frequency f (Hz)
$d \leq 16$	5 d	± 4	3	$1 \leq f \leq 3$
$16 < d \leq 25$	10 d	± 2.5		
$d > 25$	15 d	±1.5		

In which:

d Nominal bar diameter in mm

The bending characteristics of the steel shall be verified using the general method in Appendix C of UNE EN 10080 or alternatively, using the projections geometry in accordance with the provisions in the general method defined in paragraph 7.4 of UNE EN 10080. The following requirements shall be simultaneously satisfied if verification is undertaken using the beam test:

- Diameters of less than 8 mm:

$$\tau_{bm} \geq 6.88$$

$$\tau_{bu} \geq 11.22$$

- Diameters of between 8 mm and 32 mm, inclusive:

$$\tau_{bm} > 7.84 - 0.12\,\phi$$

$$\tau_{bu} \geq 12.74 - 0.19\phi$$

- Diameters of more than 32 mm:

$$\tau_{bm} > 4.00$$

$$\tau_{bu} \geq 6.66$$

in which τ_{bm} is expressed in N/mm^2 and φ in mm.

Until the CE mark comes into force, when verifying bonding characteristics using beam tests, steels shall be individually certified by an official or accredited laboratory in accordance with UNE-EN ISO 17025 for the test concerned. The certificate shall strictly contain, in addition to the commercial mark of the steel, its permitted variation limits for the geometric characteristics of the ribs if the steel is supplied in straight bars and with an express indication, if supplied in rolls, that the rib height is greater than the figure indicated in the certificate plus 0.1 mm in the case of diameters of more than 20 mm and plus 0.05 mm more in other cases. In addition, the other information referred to in Appendix C of UNE EN 10080 shall be included.

When bending is verified using the general method, the projected area of the ribs *(f_R)* or, as appropriate, the indentations *(f_P)* shall satisfy the requirements in table 32.2.2.f.

Table 32.2.2.f Projected area of ribs or indentations

d mm)	≤ 6	8	10	12 - 16	20-40
f_R *or* f_P *(mm),* in bars	≥ 0.039	≥ 0.045	≥ 0.052	≥ 0.056	≥ 0.056
f_R *or* f_P *(mm),* in rolls	≥ 0.045	≥ 0.051	≥ 0.058	≥ 0.062	≥ 0.064

The steel's chemical composition, as a percentage by mass, shall satisfy the limits set out in table 32.2.2.h, for weldability and durability reasons.

Table 32.2 2.h Chemical composition (maximum percentages, by mass)

Analysis	C (1)	S	P	N (2)	Cu	Ceq
On cast	0.22	0.050	0.050	0.012	0.80	0.50
On product	0.24	0.055	0.055	0.014	0.85	0.52

(1) The limit value of C will be increased by 0.03%, if C_{eq} is reduced by 0.02%.
(2) Greater percentages of N are permitted if there is a sufficient amount of N- fixing elements present

The equivalent carbon value, C_{eq}, in the table above, shall be calculated using:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

in which the symbols of the chemical elements indicate their content, either as a percentage or by mass.

32.3 Ribbed wires and plain wires

Ribbed wires are wires that satisfy the requirements set out for the manufacture of electro-welded meshes or basic electro-welded lattice reinforcements, in accordance with the provisions in UNE EN 10080.

Plain wires refers to wires that satisfy the requirements set out for the manufacture of connecting elements in basic electro-welded lattice reinforcements in accordance with the provisions in UNE EN 10080.

The nominal diameters of wires shall be as defined in table 6 of UNE EN 10080 and, hence, shall satisfy the following series:

4 - 4.5 - 5 - 5.5 - 6 - 6.5 - 7 - 7.5 - 8 - 8.5 - 9 - 9.5 - 10 - 11 - 12 - 14 and 16 mm.

Diameters 4 and 4.5 mm may be used in the cases indicated in 59.2.3. For the purposes of this Code, the following specification is for the type of steel to be used in ribbed and plain wires:

Table 32.3 Type of steel for wires

Designation	Tensile test [1]				Bending-unbending test according to UNE-EN ISO 15630-1
	Yield strength f_y,(N/mm^2) **(2)**	Ultimate tensile stress, fs (N/mm^2) **(2)**	Elongation to failure based on 5 diameters A (%)	Ratio fs/fy	α = 90. [5] β = 20. [6] Mandrel diameter D'
B 500 T	500	550	8 [3]	1,03 [4]	5 d [7]

(1) Lower characteristic values guaranteed.

(2) For determining the yield strength and ultimate tensile stress the nominal value of the area of the cross-section shall be used as the divider.

(3) The following shall also be satisfied:

$$A\% \geq 20 - 0.02 f_{yi}$$

In which:

A Elongation to failure

f_{yi} Yield stress measured in each test.

(4) In addition, the following shall be satisfied:

$$\frac{f_{si}}{f_{yi}} \geq 1,05 - 0,1\left(\frac{f_{yi}}{f_{yk}} - 1\right)$$

in which:

f_{yi} Yield stress measured in each test.

f_{si} Ultimate tensile stress obtained in each test.

f_{yk} Guaranteed yield strength.

(5) a Bending angle.

(6) β Unbending angle.

(7) d Nominal diameter of the wire.

As an alternative to the bending-unbending capability test, the single bend test may be used according to UNE-EN ISO 15630-1, for which a mandrel of diameter 3d shall be used, with d being the diameter of the wire in mm.

In addition, the wire shall satisfy the same chemical composition characteristics as those defined in paragraph 32.2 for ribbed weldable straight bars and ribbed weldable steel supplied in coils . Ribbed bars shall also satisfy the bond characteristics set out in the aforementioned paragraph.

Article 33. Passive reinforcements

Passive reinforcements refers to the assembly of standardised or fabricated reinforcements and constituent reinforced metal elements in a form or shuttering,, which, when suitably overlapped and covered perform a structural function.

The mechanical, chemical and bond characteristics of passive reinforcements shall be the same as those of standardised reinforcements or, as appropriate, as their constituent reinforced elements.

The nominal diameters and shapes of reinforcements shall be as defined in the corresponding design document.

For the purposes of this Code, the types of reinforcement are defined in accordance with the specifications in table 33.

Table 33 Types of steels and standardised reinforcements to be used for passive reinforcements

Type of reinforcement	Reinforcement made from low ductility steel		Reinforcement made form highly ductile weldable steel		Reinforcement made from weldable steel and special ductility characteristics	
Designation	AP400 T	AP500 T	AP400 S	AP400 S	AP400 SD	AP400 SD
Total elongation at maximum load, ε_{max} (%) (**)	-	-	≥ 5.0	≥ 5.0	≥ 7.5	≥ 7.5
Type of steel	-	-	B 400 S B 400SD (*)	B 500 S B 500SD (*)	B 400 SD	B 500 SD
Type of electro-welded mesh, as appropriate, according to 33.1.1	ME 400 T	ME 500 T	ME400S ME 400SD	ME500S ME 400 SD	ME400SD	ME500SD
Type of lattice electro-welded basic reinforcement, as appropriate 33.1.2	AB 400T	AB 500 T	AB400S AB 400 SD	AB500S AB 500 SD	AB400SD	AB500SD

(*) The margin of transformation of the steel in assemblies of AP400S or AP500S reinforced metal elements made from weldable steel with special ductility characteristics, in accordance with paragraph 69.3.2, refers to the specifications set out for that steel in Table 32.2.a.

(**) The specifications for $\varepsilon_{máx}$ of the table correspond with the classes of reinforcement B and C defined in the EN 1992-1-1. Considering 32.2 for steels in roll, can be accepted values of $\varepsilon_{máx}$ being lowers in a 0.5%.

Structures submitted to seismic loads, in accordance with the provisions in the earthquake resistance regulation in force, shall comprise passive reinforcements in the form of weldable ribbed bars made from steel with special characteristics (SD).

33.1 Standardised reinforcements

Standardised reinforcement refers to electro-welded mesh and basic electro-welded lattice work in accordance with UNE-EN 10.080 that satisfy the specifications in 33.2.1 and 33.2.2, respectively.

33.1.1 Electro-welded mesh fabrics

Within the scope of this Code, electro-welded mesh fabrics refers to the reinforcement formed by the arrangement of ribbed bars or wires, both longitudinal and transversal, with the same or differing nominal diameters, that intersect one another perpendicularly, and whose contact points are joined by electric-welded in series at an off-site industrial plant, and which conforms to the provisions in UNE-EN 10080.

Electro-welded mesh shall be produced from ribbed bars or wires, which shall not be combined with one another, and which shall satisfy the requirements set out for them in Article 31 of this Code.

The designation of electro-welded mesh shall conform to the provision in paragraph 5.2 of UNE EN 10080.

For the purposes of this Code, the types of electro-welded mesh included in table 33.2.1, are defined as a function of their constituent steel.

Table 33.2.1 Types of electro-welded mesh

Types of electro-welded mesh	ME 500 SD	ME 400SD	ME 500 S	ME 500 S	ME 500 T	ME 400 T
Type of steel	B500SD, according to 32.2	B400SD, according to 32.2	B500S, according to 32.2	B400S, according to 32.2	B500T, according to 32.3	B400T, according to 32.3

Depending on the type of electro-welded mesh concerned, elements shall satisfy the applicable specifications in accordance with the provisions in UNE-EN 10.080 and in the corresponding paragraphs of Article 32.. Electro-welded mesh shall also satisfy the separation load requirement (F_s) for welded joints,

$$Fs_{min} = 0.25.\ f_y.A_n$$

In which f_y is the specified yield stress, and A_n is the nominal cross-section of the larger of the joining elements or of one of the paired elements, depending on whether the mesh is of the single or double type, respectively.

33.1.2 Basic electro-welded lattice

Within the scope of this Code, basic electro-welded lattice refers to the spatial structure formed by an upper rod and one or more lower rods, all in ribbed steel, and a set of transverse elements, either plain or ribbed, continuous or discontinuous, electrically welded to the longitudinal rods. They shall be produced in series at an off-site industrial plant, and conform to the provisions in UNE-EN 10080.

Longitudinal rods shall be made from ribbed bars in accordance with 32.2 or ribbed wires, in accordance with 32.3, whereas the connecting transverse elements shall be made from plain or ribbed wires, in accordance with 32.3

The designations of electro-welded basic lattice framework shall conform to the provisions in paragraph 5.3 of UNE EN 10080.

For the purposes of this Code, the types of basic electro-welded lattice are defined in table 33.2.2.

Table 33.2.2 Types of basic electro-welded lattice reinforcement

Types of basic electro-welded lattice reinforcement	AB 500 SD	AB 400SD	AB 500 S	AB 500 S	AB 500 T	AB 500 T
Type of steel in longitudinal rods	B500SD, according to 32.2	B400SD, according to 32.2	B500S, according to 32.2	B400S, according to 32.2	B500T, according to 32.3	B400T, according to 32.3

In addition, the separation load (F_w) for welded joints, tested in accordance with UNE-EN ISO 15630-2, shall be greater than:

$$Fw_{min} = 0.25.f_{yL}.A_{nL}$$

$$Fw_{min} = 0.60.\,fy_D.A_{nD}$$

In which:

f_{yL} Value of the yield stress specified for the longitudinal rods.
A_{nL} Cross-section of the longitudinal rod.
f_{yD} Value of the yield stress specified for the diagonals.
A_{nD} Nominal cross-section of the diagonals.

33.2 Assembled Reinforcement

Within the scope of this Code, an assembled reinforcement element is defined as:

- Finished reinforcement, each of the formats or configurations of elements after they have been straightened, cut or bent, as appropriate, and made from ribbed steel in accordance with paragraph 32.2 or, as appropriate, from electro-welded mesh according to 33.1.1.
- Assembled reinforcement, the product resulting from reinforcing fabricated reinforcements using wire or non-resistant welding for their attachment.

The specifications relating to the fabrication, reinforcement and installation processes for reinforcements are contained in Article 69 of this Code.

Article 34. Steels for active reinforcements

34.1 General

For the purposes of this Code, the following steel products are specified for active reinforcements:

- Wire: product with solid cross section, plain or ribbed, normally supplied in coils. Table 34.1 indicates the normal dimensions of the indentations of the wires (figure 34.1) according to standard UNE 36094.
- Bar: product with solid cross-section supplied solely as rectilinear elements.
- Strand: Product formed by a number of spiral-wound wires with the same pitch and twisted in the same direction around an ideal shared core (see UNE 36094). Strands may comprise various numbers of wires (2, 3 or 7) with the same nominal diameter and spiral-wound around an ideal shared core.

Strands may be plain or ribbed. Plain strands are made using plain wire. Ribbed strands are made using ribbed wires. The central wire may be plain in the latter case. Ribbed wires improve bonding with the concrete. Table 3.1 shows the nominal dimensions of the indentations of wires for strands according to standard UNE 36094.

The set of parallel prestressing reinforcements housed in a single tube are termed a tendon, and considered as a single reinforcement in calculations. Each of the individual reinforcements in pre-tensioning reinforcements is called a tendon.

Steel products for active reinforcements shall be free from surface defects produced at any stage in their manufacture and which would render them not fit for purpose. oxidised wires and strands are not permitted unless they receive a thin non-bonding surface oxide coating.

Table 34.1.a Nominal dimensions of wire indentations

Nominal diameter of the wire in mm	Normal dimensions of indentations			
	Depth (a) in hundredths of a mm		Length (l) mm	Separation (p) mm
	Type 1	Type 2		
3	2 a 6		3.5 ± 0.5	5.5 ± 0.5
4	3 to 7	5 to 9		
5	4 to 8	6 to 10		
6	5 to 10	8 to 13	5.0 ± 0.5	8.0 ± 0.5
≥7	6 to 12	10 to 20		

Table 34.1.b Nominal dimensions of wire indentations for strands

Depth (a) in hundredths of a mm	Length (l) mm	Separation (p) mm
2 to 12	3.5 ± 0.5	5.5 ± 0.5

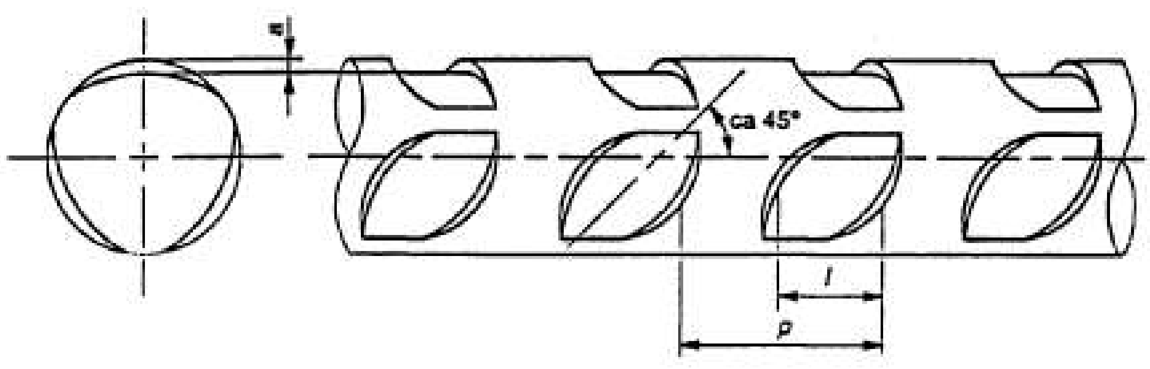

Figure 34.1 Indentations

34.2 Mechanical characteristics

For the purposes of this Code, the following fundamental characteristics are used to define the performance of active reinforcement steel:

a) Maximum unit tensile strength *(f_{max})*
b) Yield strength *(f_y)*
c) Elongation at maximum load *($\varepsilon_{máx}$)*
d) Modulus of elasticity *(E_s)*

e) Coefficient of reduction of area (η) expressed as a percentage
f) Suitability for alternate bending (only for wires)
g) Relaxation
h) Fatigue resistance
i) Susceptibility to corrosion when stressed
j) Skewed tensile strength (only for strands with a nominal dimension of 13 mm or more)

Manufacturers shall guarantee at least the characteristics indicated in a), b), c), d), g), h) and i).

34.3 Prestressing wires

For the purpose of this Code, prestressing wires refer to wires that satisfy the requirements set out in UNE 36094, or as appropriate, in the corresponding harmonised product standard. Their mechanical characteristics obtained from the tensile test carried out according to UNE-EN ISO 15630-3 shall satisfy the following requirements:

- Maximum unit load shall not be less than the values shown in table 34.3.a

Table 34.3.a Types of prestressing wires

Designation	Series of nominal diameters in mm	Maximum unit load f_{max} in N/mm^2 not less than:
Y 1570 C	9.4 - 10.0	1,570
Y 1670 C	7.0 - 7.5 - 8.0	1,670
Y 1770 C	3.0 - 4.0 - 5.0 - 6.0	1,770
Y 1860 C	4.0 - 5.0	1,860

- The yield strength f_y shall be between 0.85 and 0.95 of the maximum unit load f_{max}. This ratio shall be satisfied not only by the minimum guaranteed values but also by the values for each of the wires tested.
- Elongation at maximum load measured on a longitudinal base of 200 mm or more shall not be less than 3.5%. In the case of wires intended for the manufacture of tubes, this elongation shall be 5% or more.
- The reduction in area at break shall be at least 25% in the case of plain wires and visible to the naked eye in the case of ribbed wires with indentations.
- Their modulus of elasticity shall be the value guaranteed by the manufacturer, with a ±7% tolerance.

The loss of tensile strength in wires with a diameter of 5 mm or more, or of equivalent cross-section, following bending/unbending carried out in accordance with UNE-EN ISO 15630-3 shall not be more than 5%.

The minimum number of bending-unbending cycles which the wire can withstand during the alternating bending test carried out in accordance with UNE-EN ISO 15630-3 shall not be less than:

Steel product for active reinforcement	Number of bending and unbending operations
Plain wires	4
Deformed wires	3
Wires intended for hydraulic structures or to be submitted to a corrosive atmosphere	7

Relaxation at 1,000 hours at a temperature of $20^{o} \pm 1^{o}C$, and for an initial tensile stress of 70% of the actual maximum unit load shall not exceed 2.5% (hardened wires which have received a stabilisation treatment).

The average value of the residual tensile stresses shall be less than 50 N/mm^2, in order to ensure suitable performance when subjected to stress corrosion.

The values of the nominal diameter in mm of wires shall satisfy the following series:

3 – 4 – 5 – 6 – 7 – 7.5 – 8 – 9.4 – 10

The geometric and weight characteristics of prestressing wires and their corresponding tolerances shall satisfy the requirements in UNE 36094.

34.4 Prestressing bars

The mechanical characteristics of prestressing bars, determined from the tensile test carried out in accordance with UNE-EN ISO 15630-3 shall satisfy the following requirements:

- Maximum unit load $f_{máx}$ shall not be less than 980 N/mm^2.
- The yield strength f_y shall be between 75 and 90% of the maximum unit load f_{max}. This ratio shall be satisfied not only by the minimum guaranteed values but also by each of the bars tested.
- Elongation at maximum load measured on a longitudinal base of 200 mm or more shall not be less than 3.5%.
- Their modulus of elasticity shall be the value guaranteed by the manufacturer, with a ± 7% tolerance.

Bars shall withstand the bending test specified in UNE-EN ISO 15630-3, without breaking or cracking.

Relaxation at 1,000 hours at a temperature of 20. $\pm 1^{o}C$ and for an initial tensile stress of 70% of the guaranteed maximum unit load shall not exceed 3%. Tests shall be carried out in accordance with UNE-EN ISO 15630-3.

34.5 Pre-tensioning strands

For the purpose of this Code, prestressing strands refer to those that satisfy the requirements set out in UNE 36094, or as appropriate, in the corresponding harmonised product standard. Their mechanical characteristics obtained from the tensile stress carried out at UNE-EN ISO 15630-3 shall satisfy the following requirements:

- Maximum unit load f_{max} shall not be less than the values shown in table 34.5a in the case of strands of 2 or 3 wires, and 33.5.b. in the case of strands of 7 wires.

Table 34.5.a Strands of 2 or 3 wires

Designation	Series of nominal diameters in mm	Maximum unit load f_{max} in N/mm^2 not less than :
Y 1770 S2	5.6 - 6.0	1,770
Y 1860 S3	6.5 - 6.8 - 7.5	1,860
Y 1960 S3	5.2	1,960
Y 2060 S3	5.2	2,060

Table 34.5.B Strands of 7 wires

Designation	Series of nominal diameters in mm	Maximum unit load f_{max} in N/mm^2 not less than :
Y 1770 S7	16.0	1,770
Y 1860 S7	9.3 – 13.0 – 15.2 – 16.0	1,860

- The yield strenth f_y shall be between 0.88 and 0.95 of the maximum unit load f_{max}. This limitation shall be satisfied not by only the minimum guaranteed values but also by each of the elements tested.
- Elongation at maximum load measured on a longitudinal base of 500 mm or more shall not be less than 3.5%.
- The reduction in area at break shall be visible to the naked eye.
- Their modulus of elasticity shall be the value guaranteed by the manufacturer, with a ±7% tolerance.
- Relaxation at 1,000 hours at a temperature of 20^o ± 1^{o}C, and for an initial tensile stress of 70% of the actual maximum unit load shall not exceed 2.5%
- The average value of the residual tensile stresses for the central wire shall be less than 50 N/mm^2 in order to ensure suitable performance when subjected to stress corrosion.

The value of the deviation coefficient *D* in the skewed tensile test according to UNE-EN ISO 15630-3 shall not exceed 28, in the case of strands with a normal diameter of 13 mm or more.

The geometric and weight characteristics and the corresponding tolerances of the strands shall satisfy the requirements in UNE 36094-3.

The wires used in the strand shall withstand the number of bending and unbending operations indicated in 34.3.

Article 35. Active Reinforcements

Active reinforcements refer to the configurations of high strength steel elements by means of which the structure is prestressed. These may comprise wires, bars or strands that conform to Article 34 of this Code.

35.1 Prestressing systems

Only prestressing systems which satisfy the requirements set out in the European Technical Suitability Document produced specifically for each system by an authorised body within the scope of Directive 89/106/EEC and in accordance with the ETAG 013 Guide produced by the

European Organisation for Technical Approvals (EOTA) may be used for post-tensioned active reinforcements.

All the equipment used in tensioning operations shall be appropriate for its purpose and hence:

- Each type of anchorage will require tensioning equipment to be used which shall generally be the equipment recommended by the system's supplier.
- Tensioning equipment shall be in good condition so that it operates properly, provides continuous tensioning and maintains the pressure without any loss or posing any risk.
- The measurement equipment incorporated in the tensioning equipment shall enable the corresponding readings to be made to an accuracy of 2%. They shall be verified prior to use and subsequently whenever necessary, but at least once a year.

The corrosion protection of prestressing system components shall be guaranteed during their manufacture, transport and storage, when being incorporated and throughout the service life of the structure.

35.2 Anchorage and splicing devices for post-tensioning reinforcements.

35.2.1 Characteristics of anchorages

Anchorages shall be capable of effectively retaining the tendons, resisting their unit ultimate load and transmitting to the concrete a load which is at least the same as the maximum load which the corresponding tendon can introduce. The following requirements shall therefore be satisfied:

a) The coefficient of efficiency of an anchored ribbed or plain tendon shall be at least 0.95. In addition to their efficiency, the criteria for the non-reduction in the reinforcement's strength and ductility shall be verified in accordance with the ETAG 013 Guide, produced by the European Organisation for Technical Approvals (EOTA).
b) Slippage between anchorage and reinforcement shall cease when the maximum tensioning force is reached (80% of the tendon's breaking load). Therefore:

The wedge anchoring system shall be capable of retaining the tendons so that once the wedges are in place no slippage relative to the anchorage occurs.

Anchorage by bonding systems shall be capable of retaining the strands so that once tensioning has been completed no cracks or abnormal or unstable deformations occur in the anchorage zone,

a) In order to ensure resistance against variations in tensile stress, dynamic loads and the effects of fatigue, the anchorage system shall resist 2 million cycles, using a tensile stress variation of 80 N/mm^2 and a maximum tensile stress equivalent to 65% of the maximum tensile unit load of the tendon. In addition, no breaks in the anchorage zone or breaks of more than 5% of the reinforcement cross-section in its free length shall be admitted.
b) The anchorage zones shall resist a breaking load that is 1.1 times that of the anchorage, with a coefficient of efficiency indicated in sub-paragraph a) of this article.

Anchorage plates and devices shall be designed so that there are no offset areas, eccentricity, or loss of orthogonality between tendons and plates.

The tests necessary for verifying these characteristics shall be as indicated in UNE 41184.

The anchorage's constituent elements shall be subjected to effective and rigorous control and be fabricated so that all members of the same type, system and size are interchangeable. They shall also be capable of absorbing the dimensional tolerances set out for the cross-sections of reinforcements without any loss of effectiveness.

35.2.2 Splice elements

Splice elements in active reinforcements shall satisfy the same requirements set out for the strength and retention efficiency of anchorages.

35.3 Sheaths and accessories

35.3.1 Sheaths

Suitable ducts must be installed in structural elements comprising post-tensioned reinforcements to house these reinforcements. Sheaths that are either left embedded in the concrete or recovered once the member has hardened are usually used for this purpose.

They shall resist being crushed or scratched by tendons, ensure uniform continuity in the duct's trajectory and good leak tightness along their entire length, not exceed the designed friction coefficients during tensioning, satisfy the design bonding requirements and not chemically attack the tendon.

Cement grout or mortar shall never be allowed to penetrate their interior during concreting. Splices between the various sheath sections and between sheaths and anchorages shall therefore be completely watertight.

The internal diameter of sheaths, bearing in mind the type and cross-section of the reinforcement which is to be housed therein, shall be suitable so that the concrete can be placed correctly.

35.3.2 Types of sheaths and selection criteria

The most commonly used type of sheaths are:

- Sheaths comprising ribbed spiral-wound metal hoops These are in the form of metal tubes with projections or ribs at their surface to encourage their bonding with the concrete and injection grout and increase their transverse rigidity and longitudinal flexibility. They shall have sufficient crush resistance so that they do not deform or buckle during in situ handling, under the weight of the fresh concrete or due to the effect of accidental blows, etc. they shall also withstand contact with internal vibrators without any risk of perforation. The minimum thickness of hoops shall be 0.3 mm. They shall satisfy the provisions in standard UNE EN 523 and UNE EN 524.

  These are most frequently used for internal prestressing to withstand normal pressures in sections with a radius of curvature of more than 100 times their internal diameter. In thin structural elements (prestressed slabs) this type of sheath may have an oval cross-section in order to better fit the available space.

- Plastic ribbed hoop sheathes. The morphological characteristics of these sheathes are similar to those above, with a minimum thickness of 1 mm. The plastic parts and accessories shall be chloride-free (see 37.3).

If internal prestressing tendons with radii of curvature and at pressures similar to those for metal hoops need to be electrically insulated, the following may be used:

- Metal rigid pipes. These shall be at least 2 mm thick, have strength characteristics greatly superior to sheaths comprising spiral-wound hoops, and may be used for both internal and external prestressing. the poor bonding between plain pipes and concrete or grout shall be taken into consideration with internal prestressing.

  These are also acceptable on their own with internal pressures of more than 1 bar, and varying according to their thickness. They are therefore recommended to ensure full watertightness in structures with considerably high placing heights. These are also suitable for paths with curvature radii less than 100 ϕ (ϕ = internal diameter of the tube). They shall be curved with suitable mechanical means, and may have minimum radii at their perimeter as small as 20 ϕ provided that the following are satisfied:

  a) The tensioning in the tendon in the curve zone does not exceed 70% of the ultimate load.

  b) The sum of the angular deviation along the tendon does not exceed *3π/2,* or the deviation zone (minim radius) is deemed to be a passive anchorage point, and tensioning takes place at both ends.

- High density polyethylene pipes. These shall have the necessary thickness to withstand an internal nominal pressure of 0.63 N/mm^2 if they are low pressure pipes, made from PE80, and 1 N/mm^2 if they are high pressure pipes from PE80 or PE100.

  These are usually used for the protection of external prestressing tendons.

- Inflatable rubber pipes. These shall be sufficiently strong for their purpose and be removed once the concrete has hardened. To remove them, they shall be inflated and removed from the element or structure by pulling one end. They may even be used in long elements with straight, polygonal or curved tendons.

  Unless otherwise demonstrated, this type of device is not recommended as a protection sheath, since their corrosion screening function is lost. This type is recommended in pre-cast elements with mated joints, but with the rubber tube being inserted inside the actual metal hoop sheaths during concreting, in order to ensure the continuity of the trajectory of the tendon at joints, and avoiding inflexion points or small displacements.

3.5.3.3 Accessories

The most commonly used injection accessories are:

- Drainage pipe: Small piece of pipe that connects the prestressing ducts with the outside; generally fitted at the highest and lowest points of their trajectory, in order to facilitate air venting and water drainage from their interiors, and so that the gradual advance of the injection substance can be followed.

- Injection nozzle: Part used to introduce the injection product into the ducts housing the active reinforcements. Special T-shaped parts are used to install injection nozzles and drainage pipes.

- Separator: A generally metal or plastic part, which sometimes is used to uniformly distribute the various constituent reinforcements of the tendon inside the sheaths.

- Trumpet: This is generally truncated in shape and links the distribution plate with the sheath. In some prestressing systems, the trumpet is incorporated in the distribution plate.

- Master tube: Generally a polyethylene tube with an external diameter slightly less than the internal diameter of the sheath, fitted to ensure a smooth trajectory.

All these devices shall be correctly designed and produced so that they can be correctly sealed, and their water tightness ensured at nominal injection pressure with the due safety coefficient. In the absence of a specific specification from the supplier, these accessories shall withstand a nominal pressure of 2 N/mm^2.

The location for these devices and their characteristics shall be defined in the design document and their suitability shall be checked by the supplier of the prestressing system.

35.4 Filling materials

35.4.1 General

In order to prevent the corrosion of active reinforcements, tendons housed in ducts or sheaths fitted inside members shall be filled using a suitable injection product.

Filling materials may be either adhesive or non-adhesive, but shall always satisfy the requirements indicated in 35.4.2 and 35.4.3.

Filling materials shall not contain any substances such as chlorides, sulphides, nitrates etc., which could pose a risk to the reinforcements, the injection material itself, or the member’s concrete.

35.4.2 Adhesive filling materials

These products shall generally be cement grout or mortars that conform to 35.4.2.2, whose constituents shall satisfy the specifications in 35.4.2.1. Other materials may be used as adhesive filling materials, provided that they satisfy the requirements of 35.4.2.2. and it is ensured that they do not adversely affect the passivity of the steel.

35.4.2.1 Constituent materials

The constituents of injection grouts and mortars shall satisfy the specification in Articles 26, 27, 28 and 29 of this Code. They shall also comply with the requirements indicated below, in which the constituents are expressed by mass, apart from water, which may be expressed by mass or volume. The accuracy of the mixture shall be ± 2% in the case of cement and admixtures, and ± 1 % in the case of water.

Cement:

The cement shall be CEM 1 type Portland cement. The use of other types of cement shall be specially justified.

Water:

This shall not contain more than 300 mg/l of ion chloride nor more than 200 mg/l of ion sulphate.

Aggregates:

When aggregates are used for the preparation of an injection material, they shall comprise siliceous or calcareous grains, and be free from acid ions or laminar particles, such as mica or slate.

Admixtures:

These may not contain any substances that are harmful to pre-tensioned steel, in particular: thiocyanates, nitrates, formicates and sulphurs. They shall also comply with the following requirements:

- content < 0.1%
- Cl^- < 1 g/l of liquid admixture
- Their pH shall be within the limits defined by the manufacturer
- Their dry extract shall be ± 5% of the figure defined by the manufacturer

35.4.2.2 Requirements for filling materials

Injection grouts and mortars shall comply with the following:

- Their chloride ions (Cl-) content shall not be more than 0.1% of the cement mass.
- Their sulphate ions (SO3) content shall not be more than 3.5% of the cement mass.
- Their sulphur ions (S^{2-}) content shall not be more than 0.01% of the cement mass.

Injection grouts and mortars shall additionally have the following properties, determined by means of UNE-EN 445.

- Their fluidity measured using the Marsh cone method, with a cone of 100 mm diameter, shall be less than 25 s, within the temperature range specified by the manufacturer, both immediately following mixing and 30 minutes afterwards, or until injection has been completed, or until the period of time defined by the manufacturer or prescribed by the designer has elapsed. The fluidity of thixotropic grouts shall be measured using a viscosity meter and be between 120 g/cm^2 and 200 g/cm^2.
- The amount of water exuded after 3 hours shall be less than 2% during the exudate tube test, within the temperature range defined by their manufacturer.
- Their reduction in volume shall not exceed 1%, and any volumetric expansion shall be less than 5%. No reduction in volume is permitted in grouts containing expanding agents.
- The water/cement ratio shall be at least 0.44.
- Their compression strength shall be at least 30 N/mm^2 at 28 days.
- Setting shall not start within 3 hours in the temperature range defined by the manufacturer. Setting time shall not exceed 24 hours.
- Capillary absorption at 28 days shall be less than 1g/cm2.

35.4.3 Non-adhesive filling materials

These products shall comprise greases, wax, polymers, bituminous products, polyurethane or, generally, any material suitable for providing the active reinforcements with the necessary protection, but without any bonding between the products and the ducts.

The manufacturer shall guarantee the physical and chemical stability of the material selected throughout the structure's useful life, or of the product's service life, as specified in the design document, if it is going to be periodically replaced during the life of the structure.

Any non-adhesive filling material shall be chosen from the European technical suitability document for prestressing systems, and hence shall conform to the ETAG 013 Guideline, Annex C.4.

Article 36. Infill elements in floor slabs

An infill element is a pre-fabricated element of a composite or lightweight floor slab, intended to form, together with their associated beams, ribs, in situ upper slab and structural reinforcements the resisting unit of a floor slab.

Collaborating infill elements may be ceramic or concrete or made from any other resistant material. Their compression strength shall not be less than the design strength of the floor slab's in situ concrete. The vertical parts of these elements bonded to the concrete, may be deemed to form part of the slab's resistant cross-section.

Lightweight infill elements may be made form ceramic, concrete, expanded polystyrene or other sufficiently rigid materials. These members shall satisfy the conditions set out below:

- The breaking load under flexure for any infill element shall be greater than 1.0 kN determined in accordance with UNE 53981 in the case of expanded polystyrene elements, and according to UNE 67037, in the case of elements made from other materials.
- The average expansion value due to moisture in ceramic elements, determined in accordance with UNE 67036, shall not be more than 0.55 mm/m, and no individual measurement shall exceed 0.65 mm/m. Infill elements that exceed the total expansion limit value may be used, however, provided that their mean potential expansion value, according to UNE 67036, and determined prior to their incorporation, is no more than 0.55 mm/m.
- The fire reaction behaviour of the elements that are, or may be, exposed to the outside during the structure's useful life, shall satisfy the applicable fire reaction classification. If used in buildings, they shall conform to paragraph 4 of Section SI.1 of the Basic Building Document "Fire safety" of the Technical Building Code, depending on the location of the slab. This classification shall be determined in accordance with standard UNE EN 13501-1 depending on the final conditions of use, in other words, in conjunction with the coatings that the elements are going to receive. Blocks made using flammable materials shall be fire protected using efficient protective layers. The suitability of the protective layers shall be empirically confirmed for the temperature range and foreseeable deformations at the design fire load.