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Steel fibres for concrete — Definitions and specifications

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee ISE/106, Wire Rod and Wire.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Steel fibres for concrete — Definitions and specifications

Fibres d'acier pour béton — Définitions et spécifications

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Foreword

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ISO 13270 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 17, *Steel wire rod and wire products*.

INTERNATIONAL STANDARD **ISO 13270:2013(E)**

Steel fibres for concrete — Definitions and specifications

1 Scope

This International Standard specifies definitions and symbols, classification and codes, dimensions, masses and permissible variations, inspection methods, packing, delivery and storage for steel fibres for concrete.

This International Standard covers fibres intended for use in fibre-reinforced concrete, in all types of concrete and mortar, including sprayed concrete, flooring, precast, *in situ* and repair concretes

This International Standard can also be referred to for fibres used in fibre-reinforced engineering material, such as stainless steel fibre use in reinforced refractory material.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 404, *Steel and steel products — General technical delivery requirements*

ISO 1920-2:2005, *Testing of concrete — Part 2: Properties of fresh concrete*

ISO 5725-2:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 7989-1, *Steel wire and wire products — Non-ferrous metallic coatings on steel wire — Part 1: General principles*

ISO 10474, *Metallic products — Inspection documents*

ISO 22034-1, *Steel wire and wire products — Part 1: General test methods*

EN 197-1:2011, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

EN 206-1, *Concrete — Part 1: Specification, performance,production and conformity*

EN 933-2, *Tests for geometrical properties of aggregates — Part 2: Determination of particle size distribution — Test sieves, nominal size of apertures*

EN 934-2:2009, *Admixtures for concrete. mortar and grout — Part 2: Concrete admixtures — Definitions. requirements, conformity, marking and labeling*

EN 1008, *Mixing water for concrete — Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

EN 1766:2000, *Products and systems for the protection and repair of concrete structures — Test methods — Reference concretes for testing*

EN 1992-1-1, *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings*

EN 12350-1, *Testing fresh concrete — Part 1: Sampling*

EN 12350-3, *Testing fresh concrete — Part 3: Vebe test*

EN 12350-4, *Testing fresh concrete — Part 4: Degree of compactability*

EN 14651, *Test method for metallic fibre concrete — Measuring the flexural tensile strength (limit of proportionality (LOP). residual)*

EN 14845-2, *Test methods for fibres in concrete — Part 2: Effect on concrete*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
steel fibres
straight or deformed pieces of cold-drawn steel wire, straight or deformed cut sheet fibres, melt-extracted fibres, shaved cold-drawn wire fibres and fibres milled from steel blocks which are suitable to be homogenously mixed into concrete or mortar

Note 1 to entry: Steel fibres are suitable reinforcement material for concrete because they possess a thermal expansion coefficient equal to that of concrete, their Young's Modulus is at least 5 times higher than that of concrete and the creep of regular carbon steel fibres can only occur above 370 °C.

3.2
length
distance between the outer ends of the fibre

3.2.1
developed length
length of the deformed fibres after straightening the fibre without deforming the cross-section

3.3
equivalent diameter
diameter of a circle with an area equal to the mean cross-sectional area of the fibre

Note 1 to entry: For circular fibres, the equivalent diameter is equal to the diameter of the fibres.

3.4
aspect ratio
ratio of length (l) to equivalent diameter of the fibre

3.5
fibre shape
specific outer configuration of the fibres, both in the longitudinal direction and in the shape of the cross-section and also the possible surface coatings and/or bundling of fibres

3.6
tensile strength of fibre
stress corresponding to the maximum force that one fibre can resist

Note 1 to entry: The methods concerning how to determine the tensile strength are explained in 7.3. The tensile strength is calculated by dividing the maximum force a fibre can resist by the mean cross-sectional area of the fibre.

3.7
crack mouth opening displacement
CMOD
linear displacement measured by a transducer installed on a prism subjected to a centre-point load F

3.8
elastic modulus
initial slope of the tensile stress versus tensile strain curve

3.9
declared value
value for a product property, determined in accordance with this standard, that a manufacturer is confident of achieving within the given tolerances taking into account the variability of the manufacturing process

3.10
linear displacement
δ
displacement measured by a transducer installed on a prism subjected to a centre-point load F

3.11
residual flexural strength
notional stress at the tip of the notch which is assumed to act in an uncracked mid-span section, with linear stress distribution, of a prism subjected to the centre-point load Fj corresponding to CMODj where CMODj > CMODδ; or to δj where $\delta j > \delta F_L$ (j = 1,2,3,4)

Note 1 to entry: F_L is the load at LOP (see EN 14651).

4 Symbols

For the purposes of this document, the symbols and definitions in Table 1 apply.

Table 1 — Symbols and definitions

Symbols	Definitions	Unit
w[a]	width of the fibre	mm
t[a]	thickness of the fibre	mm
d	diameter or equivalent diameter of the fibre	mm
R_m	tensile strength of the fibre	MPa
l	length of the fibre	mm
λ	aspect ratio of the fibre ($\lambda = l/d$)	
l_d	developed length of the fibre	mm
m	mass of the fibre	g
ρ	density of steel	kg/m^3

[a] Description for rectangular fibres.

5 Classification

The steel fibres shall conform to one of the groups and one of the shapes listed below:

a) Group

Steel fibres shall be classified into one of the following groups, in accordance with the basic material used for the production of the fibres.

Group I: cold-drawn wire

Group II: cut sheet

Group III: melt extracted

Group IV: shaved cold-drawn wire

Group V: milled from blocks

b) Shape

Fibres shall be either straight or deformed. The manufacturer shall declare the shape of the fibre. The control and tolerances on the shape shall be specified for each different shape separately.

When applicable, the type of bundling shall be declared.

c) Coating

When steel fibres are supplied with a coating (e.g. zinc coating), the type and characteristic quantity in g/m^2 shall be declared. The control of the quantity shall be a function of the type of coating and shall be declared by the manufacturer. In the case of a zinc coating, the determination of the coating thickness shall be performed according to ISO 7989-1. In the case of a Zn or Zn/Al coating, a protection against the alkaline environment is recommended (passivation).

6 Ordering information

The purchaser shall clearly provide the following information concerning the product in his enquiry or order:

a) the desired quantity;

b) the number of this International Standard;

c) group, shape, coating if any, class A, class B for Group I and nominal tensile strength ;

d) diameter or equivalent diameter;

e) length;

f) the type of inspection document;

g) for stainless steel fibres, the steel grade shall be agreed at the time of ordering.

7 Requirements

7.1 Dimensions and tolerances

7.1.1 General

For fibres of group I and II, the length, equivalent diameter, the class (A or B), and the aspect ratio shall be declared. The tolerances shall be as given in Table 2.

Specimens of fibres, when sampled in accordance with 8.2 and 8.3, and measured in accordance with 7.1.2 and 7.1.3, shall not deviate from the declared value by more than the tolerances given in Table 2. At least 95 % of the individual specimens shall meet the specified tolerances.

For fibres of group III, IV and V, the range of lengths, equivalent diameters and aspect ratios shall be declared. Specimens of fibres, when sampled in accordance with 8.2 and measured in accordance with 7.1.2 e 7.1.3 shall be within the specified range. At least 90 % of the individual specimen fibres shall meet the specified tolerances in both cases.

Table 2 — Tolerances on fibre length and diameter

Property	Range	Deviation of the individual value relative to the declared value		Deviation of the average value relative to the declared value	
		Class A	Class B	Class A	Class B
Length and developed length l (or l_d)	>30 mm ≤30 mm	±3 mm ±10 %	±10 %	±5 % ±1,5 mm	
(Equivalent) diameter d	>0,30 mm ≤0,30 mm	±0,02 mm	±10 %	±0,015	±5 % ±0,015 mm
Length/diameter ratio λ		±15 %		±7,5 %	

7.1.2 Determination of length

The length shall be measured with a marking gauge (callipers) with an accuracy of 0,1 mm.

In the case of an irregular cross-section, the developed length of the fibre shall also be determined to calculate the equivalent diameter. If straightening of the fibre is necessary, it shall be done by hand or, if this is not possible, by hammering on a level of wood, plastic material or copper using a hammer of similar material. During the straightening, the cross-section should not be changed.

7.1.3 Determination of (equivalent) diameter

7.1.3.1 Round wire fibres

The diameter of the fibre shall be measured with a micrometer, in two directions, approximately at right angles, to an accuracy of 0,01 mm. The fibre diameter shall be the mean of the two diameters.

7.1.3.2 Rectangular fibres

The width (w) and thickness (t) of the fibres shall be measured with a micrometer with an accuracy of 0,01 mm.

The equivalent diameter (d) is calculated using the following formula:

$$d = \sqrt{\frac{4wt}{\pi}}$$

7.1.3.3 Fibres with irregular cross-section

The mass (m) and the developed length (l_d) of the fibre shall be determined. The mass shall be determined to an accuracy of 0,001 g. The equivalent diameter is computed from the mass and the developed length using the following formula:

$$d = \sqrt{\frac{4m \times 10^6}{\pi l_d \rho}}$$

Where ρ is the nominal density: for all steels except stainless steel, it may be taken as 7850 kg/m^3; for stainless steel, it may be taken as 7950 kg/m^3."

7.2 Surface condition

The surface of fibre should be kept dry and clean, with no greasy dirt substances and inclusions existing which may effect the consistence behaviour of steel-fibre concrete.

Seams and surface irregularities shall not be the cause for rejection, provided that tensile properties are not less than the requirements of this specification and mixing performance in concrete is not adversely affected.

Rust, mill scale, or other coatings shall not be the cause for rejection provided that the individual fibres separate when mixed in concrete, and tensile and bending properties are not less than the requirements of this specification.

7.3 Tensile strength of fibres

The tensile strength (R_m) shall be determined in accordance with ISO 6892-1, except as indicated below, and shall be declared.

For Group I (cold-drawn wire), the tensile strength shall be determined from the source wire before deformation. The acceptable tolerance on the declared value of R_m shall be 15 % for individual values and 7,5 % for the mean value. At least 95 % of the individual specimens shall meet the specified tolerance.

For Group II (cut sheet), the tensile strength shall be determined from the source plate before deformation.

The acceptable tolerance on the declared value of R_m shall be 15 % for individual values and 7,5 % for the mean value. At least 95 % of the individual specimens shall meet the specified tolerance.

For Group III (melt-extracted fibres), Group IV (shaved cold-drawn wire) and Group V (milled from steel blocks) the tensile strength shall be determined from fibres with a minimum length of 20 mm clamped within the jaws of the testing machine. These fibre types have an irregular cross-section and therefore the fibres will break at the minimum cross-section. The nominal tensile strength shall be determined by dividing the maximum load during the tensile test by the cross-section calculated from the equivalent diameter. The manufacturer may determine the cross-section at the break by an optical method, in which case the tensile strength, obtained by dividing the maximum tensile load during the tensile test by the fracture cross-section, may also be declared, giving the precision of the area measurement.

For Groups III, IV and V, the manufacturer may instead declare a minimum tensile strength and at least 90 % of the individual specimens of fibres shall then comply with this value.

7.4 Modulus of elasticity

The manufacturer shall declare the modulus of elasticity of the fibres.

The modulus of elasticity may be determined for Groups I and II fibres using the tensile test as described in ISO 6892-1. The test shall be done on the basic material before deformation of the fibre and the modulus of elasticity shall be calculated using the stress and the deformation at 10 % and 30 % of R_m.

7.5 Bending requirements

Fibres shall withstand being bent, according to ISO 22034-1, around a 3,0 mm diameter pin to an angle of 90° at temperatures not less than 16 °C. At least no less than 90 % of the fibres being tested should be without breaking.

7.6 Mixing

Mixing instructions shall be supplied by the manufacturer which recommend the mixing sequence to be adopted when introducing the fibre into both a centrally mixed concrete plant and for a dry-batch truck mixed plant.

7.7 Reinforcing effect of the steel fibres in concrete

The minimum reinforcing effect of the steel fibres in concrete shall be determined according to Annex A, The unit volume of fibres in kg/m^3 shall be declared by the manufacturer that achieves a residual flexural

strength of 1,5 MPa at 0,5 mm CMOD (equivalent to 0,47 mm central deflection) and a residual flexural strength of 1 MPa at 3,5 mm CMOD (equivalent to 3,02 mm central deflection).

7.8 Effect on consistency of concrete

The effect of fibres on the consistency of a reference concrete conforming to Annex A (Clause A.1) shall be determined.

The consistence according to ISO 1920-2:2005, subclause 4.4 shall be determined on the reference concrete without fibres and then on an identical mix with fibres. The effect on consistency shall be declared.

The amount of fibres added shall be declared by the manufacturer and shall be the minimum amount of fibres needed to obtain the required strength specified in 7.7. If a plasticiser or superplasticer is needed in order to meet the consistence requirements when determining the required addition level of fibres, the amount and type shall also be declared by the manufacturer.

The fibre manufacturer may additionally declare the consistency for the reference concrete with a range of dosages of fibres.

7.9 Effect on air of concrete

Steel fibres, dosed at 30 kg/m^3, in a reference concrete, conforming with Annex A, but without the use of a water reducing agent or highly water reducing agent, should not increase the air content by more than 2 % versus the air content of the plain reference concrete. The air content of the reference concrete with or without steel fibres shall be measured in accordance to ISO 1920-2:2005, subclause 6.4.

8 Testing and Inspection

8.1 General

Products conforming to this International Standard shall be delivered with specific testing (see ISO 404) and the relevant inspection document, in accordance with ISO 10474, specified by the purchaser at the time of enquiry or order.

All steel fibres are intended to structurally reinforce the concrete. The conformity of the steel fibres with the requirements of this International Standard and with the declared values shall be demonstrated as ITT (Initial Type Test) + a continuous production control (FPC), both under the surveillance of a Certifying Body.

8.2 ITT (Initial Type Test)

Initial type testing, according to Table 3, shall be performed to show conformity with this International Standard.

The tests shall be repeated whenever a change in the basic materials or manufacturing procedure occurs, or a new product type is being produced.

Table 3 — Sampling number for ITT

Type test (Clause)	Normative (N) or Optional (O)	Characteristic	Min. number for ITT
5	N	Shape; tolerances	30 fibres
7.1	N	Dimensions; tolerances	30 fibres
5	N	Fibre coating	30 fibres
7.3	N	Tensile strength; tolerances	30 fibres
7.5	O	Bending requirements	30 fibres
7.7	N	Reinforcing effect in concrete	12 beams
7.8	N	Consistency	mean value of 3 tests
7.9	N	Air content	3 measurements

8.3 Factory production control (FPC)

8.3.1 General

The manufacturer shall establish, document and maintain a FPC system to ensure that the products placed on the market conform to the requirements of this International Standard and the declared performance characteristics. The FPC system shall consist of procedures, regular inspections and tests and/or assessments and the use of the results to control raw and other incoming materials or components, equipment, the production process and the product.

Subsequently, any fundamental changes in basic materials, manufacturing procedures or the control scheme that affects the properties or use of a product shall be recorded in the manual or relevant document, together with the test data that identifies the new characteristics of the fibre.

The results of inspections, tests or assessments requiring action shall be documented, as shall any action taken. The action to be taken when control values or criteria are not met shall be recorded.

NOTE An FPC system conforming with the requirements of ISO 9001, and made specific to the requirements of this International Standard, is considered to satisfy the above requirements.

8.3.2 Equipment

All weighing, measuring and testing equipment shall be calibrated and regularly inspected according to documented procedures, frequencies and criteria.

8.3.3 Raw materials

The specifications of all incoming raw materials shall be documented, as shall the inspection scheme for ensuring their conformity.

8.3.4 Design process

The factory production control system shall document the various stages in the design of products, identify the checking procedure and those individuals responsible for all stages of design.

During the design process itself, a record shall be kept of all checks, their results, and any corrective actions taken. This record shall be sufficiently detailed and accurate to demonstrate that all stages of the design phase, and all checks, have been carried out satisfactorily.

8.3.5 Product testing and evaluation

The manufacturer shall establish procedures to ensure that the declared values of the characteristics are maintained, as confirmed by the initial type tests.

The characteristics that shall be controlled are:

shape

fibre coating, if applicable

dimensions and tolerances

tensile strength

bending requirements.

The frequency and volume of testing shall be at least that given in Table 4.

Table 4 — Minimum number of units for production control

Characteristic	Clause	Assessment method	Minimum number of units		
			Tightened control (T)	Normal control (N)	Reduced control (R)
Shape	5 b)		12 fibres/10 t/ machine	12 fibres/ 50 t/ machine	3 fibres/week/ machine
Coating	5 c)	Depending on type of coating	at least 3 measurements for deliveries <15 t. 1 additional per 5 t	1 measurement per 5 t	1 measurement per 10 t
Dimensions and tolerances	7.1		12 fibres/10 t/ machine	12 fibres/ 50 t/ machine	3 fibres/week/ machine
Tensile strength	7.3				
Groups I,II and IV, Groups III and V		ISO 6892-1 See 7.4	1 measurement per 1 t	1 measurement per 5 t	1 measurement per 10 t
Bending requirements	7.5	ISO 22034-1	1 measurement per 1 t	1 measurement per 5 t	1 measurement per 10 t

NOTE The term “machine” means the final machine in the production process prior to packaging.

The data, together with details and results of inspection, checks and tests shall be recorded. The conditions for switching between the types of control are given in 8.3.8.

Where possible and applicable, the results of inspections, checks and tests shall be interpreted statistically by attributes or by variables to determine whether the corresponding production conforms with the requirements in this International Standard and the declared values for the products.

8.3.6 Traceability

Systems of traceability and control of designs, incoming materials, and the use of materials shall be given in the manual or relevant document.

The stock control system of manufactured products shall be given in the manual or relevant document.

8.3.7 Corrective actions for non-conforming products

The immediate actions to be taken when incoming materials or finished products do not conform to the specified requirements shall be described and recorded. These actions shall include the steps necessary to rectify the deficiency, modify the manual or relevant document if required, identify and isolate the deficient raw or incoming materials and finished products and determine whether they shall be discarded or re-specified under a concessionary system.

8.3.8 Conditions for switching between the control regimes T-N-R

The T-regime shall be applied when starting up a new plant and for at least 6 months.

The manufacturer may switch from the T- to the N-regime when all of the following conditions apply:

— testing has been undertaken for at least 6 months under the T-regime, and

— the fibres produced during the last 3 months of production conform to specification.

The manufacturer may switch from the N- to the R-regime when all of the following conditions apply:

— the fibres fall within Groups I or II, and

— testing has been undertaken for at least 12 months under the N-regime, and

— the fibres produced during the last 12 months of production conform to specification, and

— the Cpk's of tensile strength and dimensions, calculated from the 3-monthly period of production, are greater than 1 for the last two successive quarters.

The manufacturer shall switch back from R- to the N-regime if the Cpk on tensile strength or geometry for one quarter becomes smaller or equal to 0,67. Switching back to R is permitted if the Cpk for the next quarter is again higher than 0,67, and if the results are according to specification.

NOTE The Cpk is the capability index which accounts for process centering and is defined as the minimum of

$$\frac{\mathrm{USL}-\overline{X}}{3\sigma_s} \text{ or } \frac{\overline{X}-\mathrm{LSL}}{3\sigma_s}$$

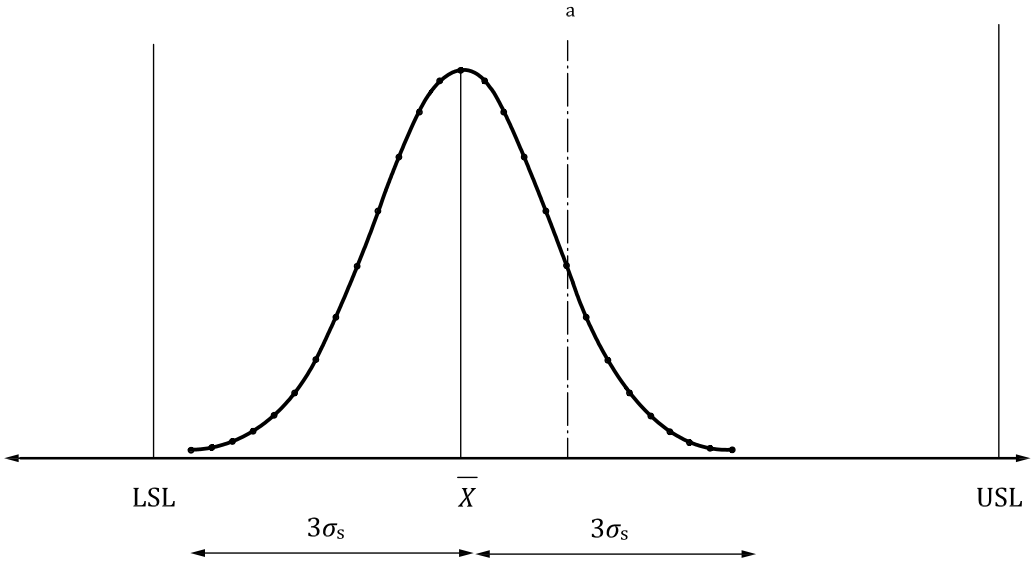
where

USL upper spread limit, is the declared value plus the deviation of the individual value from Table 1 (or 7.4) times the declared value;

LSL lower spread limit, is the declared value minus the deviation of the individual value from Table 1 (or 7.4) times the declared value;

$\overline{X}$ average value of the characteristic (dimension, tensile strength) of the group of individual results (the number of group given in Table 3), taken over one quarter;

σ_S standard deviation of the same group of results as the average value, taken over one quarter.



Key

a **Declared value.**

Figure 1 — Calculation of the Cpk-value

9 Packaging and package marking

The material shall be packaged to provide adequate protection during normal handling and transportation, and each package shall contain only one type and size of material unless otherwise agreed upon. The type of packaging and gross mass of containers shall, unless otherwise agreed upon, be at the manufacturer's discretion, provided that they can ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

Each shipping container shall be marked with the material, size, type, specification designation, net mass, standard No., manufacturing date, and the manufacturer's name or trademark.

It shall be marked with the following:

Steel fibres for structural use are produced under Factory Production Control under surveillance of a Certifying Body as described in ISO 13270:2012.

Any Co Ltd, PO Box 21, B-1050		*Name or identifying mark and registered address of the producer*
ISO 13270 Steel fibres for structural use in concrete, mortar and grout Group I, Class B Length: 50 mm Diameter: 1,00 mm Shape: deformed Tensile strength: 1200 N/mm^2 Effect on strength of concrete: 30 kg/m^3 to obtain 1,5 N/mm^2 at CMOD = 0,5 mm and 1N/mm^2 at CMOD = 3,5 mm. Air content of the plain reference concrete: 1,0 % Air content of the reference concrete with 30 kg/m^3 fibres: 2,3 %; Vebe time: 25 s with 30 kg/m^3.		*Description of product* *Information on regulated characteristics*

Annex A
(normative)

Reference concretes

A.1 Reference concretes

A.1.1 Scope

This clause specifies the composition and characteristics of reference concretes used to evaluate the performance of fibres in concrete.

The purpose of the reference concrete is to determine the general suitability of a fibre for use in concrete.

NOTE The end users need to satisfy themselves about the effectiveness of the fibre in their own concrete.

A.1.2 Principle

This clause prescribes the constituents and proportions for plain reference concretes to be used to evaluate the performance of fibres in concrete under standard laboratory conditions.

The reference concretes shall be designed to meet a prescribed flexural tensile strength, as defined in Table A.1.

The performance of a fibre shall be determined in a mandatory 16 mm or 20 mm maximum aggregate size mix using the test method described in EN 14651 and by one of the consistence methods specified in A.2.

A.1.2.1 Concrete mixer

A forced-action concrete pan-mixer shall be used to mix the concrete.

A.1.2.2 Moulds

Moulds for producing hardened concrete specimens, of non-absorbent, rigid material, not attacked by cement paste, with a size 150 × 150 × min. 550 mm.

A.1.2.3 High-frequency vibrating table

Suitable for compaction of the concrete in beam moulds for testing EN 14651.

A.1.3 Materials

A.1.3.1 Aggregates

Aggregates shall be natural, uncrushed and silica-based with low water absorption (less than 2 % by mass) and oven-dried. The aggregate grading, measured according to EN 933-2, shall conform to EN 1766:2000, Annex A, except for the limits for a 16 mm or 20 mm aggregate at 0,25 mm shall be 5 % to 10 % (not 3 % to 8 %).

A.1.3.2 Mixing water

Water according to EN 1008 shall be used.

A.1.3.3 Cement

Portland type CEM I class 42,5 R according to EN 197-1:2011 shall be used.

A.1.3.4 Admixtures

A plasticizer or superplasticizer or superplasticizer admixture according to EN 934-2:2009 may be used to control the workability.

A.1.3.5 Steel fibres

Where steel fibres are to be tested, the fibres shall be sampled in accordance with 8.2.

A.1.4 Reference concrete composition and properties

A.1.4.1 General

This Annex specifies four types of reference concrete, defined by the flexural tensile strength, maximum size of the aggregate and maximum cement content. The reference concrete(e)s are selected according to the type of product or system in which the fibre is to be applied. However, all fibre manufacturers shall declare the performance of their product, using the test method described in EN 14845-2 for the effect on strength and by one of the methods specified in 7.8 for consistence in the mandatory 16 mm or 20 mm aggregate mix (with a flexural tensile strength of 4,3 MPa ± 0,3 MPa), but have the option to evaluate it in any of three other optional reference concretes that have different maximum cement content and/or aggregate size.

The proportions of the reference concrete shall be adjusted within the limits prescribed below to achieve an average flexural tensile strength within the range defined in Table A.1. The average flexural tensile strength shall be taken as the average limit of proportionality of at least 12 beams tested to EN 14651.

A.1.4.2 Water/cement ratio

The water/cement (W/C) ratio as defined in EN 206-1 shall be as specified in Table A.1.

Table A.1 — W/C ratio and cement content limits

Flexural tensile strength (MPa)	**Water/cement ratio**		**Maximum cement content**(kg/m^3)
	Maximum aggregate size		
	8 mm or 10 mm	16 mm or 20 mm	
4,3 ± 0,3 (25/30) [c]	0,55 [b]	0,55 [a]	350
5,8 ± 0,4 (40/50)	0,45 [b]	0,45 [b]	400

[a] Mandatory mix.

[b] Optional mixes.

[c] Equivalent compressive class according to EN 1992-1-1.

A.1.4.3 Maximum cement content

The maximum cement content shall be as defined in Table A.1.

A.1.4.4 Steel-fibre content

Where the performance of a steel fibre is being evaluated by incorporating it in a reference concrete, the quantity of fibres added shall be that required to achieve the level of performance in 7.8.

A.1.4.5 Consistency

The consistency of the reference concrete, without fibres, shall be determined either:

according to EN 12350-3 and shall achieve Vebe class V3 (10-6 s) from EN 206-1, or

according to EN 12350-4 and shall achieve Compaction class C2 from EN 206-1.

A plasticizer or superplasticizer admixture conforming to EN 934-2 is permitted to give a workable concrete mix to meet the requirements of Table A.1.

Consistency should be appropriate to achieve adequate placing of concrete with freedom from bleeding or segregation.

Any special requirements for surface finish of placed specimens for particular test methods using reference concrete samples will be stated in those test methods.

A.1.4.6 Specimen preparation

The preparation of a reproducible reference concrete shall be done as follows:

Prepare a concrete batch, the volume of which shall be of 50 % to 90 % of the mixer capacity;

Pour all dry aggregates into the container of the mixer, add half of the batch water and mix for 2 min;

Carry on the mixing and add the cement and the other half of the batch water containing possible admixtures during the next minute.

The total mixing time shall not be more than 5 min.

In reference concretes to which fibres are added, care shall be taken to ensure that the fibres are evenly distributed throughout the mix by adding the fibres at the appropriate stage in accordance with the manufacturer's recommendations.

Test specimens shall be made according to the relevant test method of the EN 14845 series for the property under consideration. The sample of the mixed concrete shall be taken in accordance with EN 12350-1.

A.1.4.7 Concrete curing and storage

The concrete specimens shall be cured in the moulds for 24 h after casting at (20 ± 2) °C, either under polyethylene sheeting or at not less than 95 % relative humidity, then demoulded and cured for a further 27 days under water at (20 ± 2) °C.

After the curing period, the specimens shall be taken for testing.

A.1.4.8 Report

The following information shall be recorded for each set of reference concrete specimens:

h) Mix composition including dry aggregates and admixtures in kg/m^3 and details of the mixing procedure;

i) Water/cement ratio;

j) Steel-fibre type (including, length, diameter and tensile strength) described according to ISO 13270;

k) Date and time of production;

l) Origin and particle size distribution of aggregates;

m) Curing and storage conditions;

n) Limit of proportionality strength to nearest 0,01 MPa (average and individual values);

o) Reference to this International Standard;

p) Any deviation from this International Standard.

A.2 Test method

See EN 14651.

A.3 Evaluation

Twelve notched 550 mm x 150 mm x 150 mm beams, made from a reference concrete according to A.1 and incorporating steel fibres, shall be tested for 28 days in centre-point loading on a 500 mm span in accordance with the test method for metallic fibre concrete of EN 14651.

A series of concrete mixes shall be made and tested with different fibre contents until the strength performance specified in 7.7 is achieved.

The content of fibres shall be determined that achieves an average residual flexural strength of at least 1,5 MPa at 0,5 mm CMOD (equivalent to 0.47 mm central deflection) and an average residual flexural strength of at least 1 MPa at 3,5 mm CMOD (equivalent to 3,02 mm central deflection).

When calculating the average performance of the 12 beams, the effect of any outlier (unrepresentative) results should be excluded. Outliers should be identified by the Grubb testing according to ISO 5725-2:1994 for a probability of 5 %.

NOTE Statistically with an assumed variation of 25 %, the mean value of a test series of 12 beams will not deviate by more than 10 % from the real mean value with a confidence level of 90 %.

Bibliography

[1] ISO 9001, *Quality management systems — Requirements — test*

[2] EN 934-1:2008, *Admixtures for concrete. mortar and grout — Part 1: Common requirements*

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