भारतीय मानक
Indian Standard

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वस्त्रादि — सीमेंट आधारित मैट्रिक्स में उपयोग के लिए सिंथेटिक सूक्ष्म तन्तु — विशिष्टि

(पहला पुनरीक्षण)

Textiles — Synthetic Micro Fibres for Use in Cement Based Matrix — Specification

(First Revision)

ICS 59.060.20; 91.100.40

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Technical Textiles for Build Tech Sectional Committee had been approved by the Textile Division Council.

To support current high Gross Domestic Product growth in India, proper growth of infrastructure is very essential. From residential and commercial complexes, to surface Transport and Aviation, Special Economic Zones or Entertainment and Hospitality Industry, concrete structures are a must and have to be built up at a faster pace and preserved for its serviceability over longer periods. For durability concerns, plastic shrinkage cracks as well as the drying shrinkage and temperature cracks in concrete structures need attention of the structural engineers, builders, consultants and regulatory authorities.

Infrastructure is the backbone of development of any country which needs strong and durable constructions, which can serve with minimum maintenance over a long period. But traditional concrete is brittle enough, and needs to improve for ductile performance. The weakness of concrete in tension can be overcome to some extent by the inclusion of a sufficient volume of fibres. The use of synthetic fibres also alters the behaviour of the cement based matrix after it has cracked. Synthetic fibers are added to cement based matrix to reduce plastic shrinkage cracking and also to reduce shrinkage and temperature cracking. The fibers may be used in concrete over steel deck construction as well as to reduce fire damage in concrete.

Synthetic micro-fibres are used as secondary reinforcement in infrastructure construction and building and roofing material. Their application in such end uses increase the durability of cement based matrix.

The hot and humid climatic conditions prevalent in India, and sometimes saline water use in construction, leads to rapid deterioration of traditional concrete structures, which generally lack certain fundamental properties such as flexural toughness and resistance to moisture and water absorption, that results in corrosion of steel reinforcement leading to pre-mature failure of structures. Fiber reinforced concrete has many advantages such as improved tensile and flexural strength and toughness, crack resistance, minimized drying shrinkage cracks, reduced seepage of water; higher fatigue life; more ductility, increased abrasion and impact resistance; etc. It also tends to improve concrete towards homogeneous behavior. In case of spray concrete or shotcrete, rebound loss can be reduced using fibers.

For the effective use of fibres in cement based matrix:

a) Fibre content by volume shall be adequate;

b) Fibre length shall be optimal; and

c) Fibres shall have optimal aspect ratio in relation to method of dosing and mixing.

(Continued on third cover)

Indian Standard

TEXTILES — SYNTHETIC MICRO FIBRES FOR USE IN CEMENT BASED MATRIX — SPECIFICATION

(First Revision)

1 SCOPE

This standard prescribes physical, application and functional requirements for synthetic microfibres such as polyester, nylon and polypropylene fibres etc, for use in cement based matrix for secondary reinforcement in building and roofing material and other industrial applications such as concrete roads, pavements, industrial and commercial floorings, residential and commercial buildings, bridges and elevated structures, water retaining structures and dams, ports and undersea concrete structures, plaster, shotcrete, precast, mortar etc.

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated in Annex A.

3 TERMINOLOGY

For the purpose of this standard the following definition shall apply.

3.1 Abrasion Resistance — The ability of a surface to resist being worn away by rubbing and friction.

3.2 Admixture — A material such as synthetic fibre other than water, aggregate, or hydraulic cement used as an ingredient of concrete and added to concrete before or during its mixing to modify its properties.

3.3 Aggregate — Sand, gravel etc, mixed with cement to form concrete.

3.4 Aspect Ratio — The ratio of length to equivalent diameter of fibre.

3.5 Compressive Strength — The maximum value of uniaxial compressive stress reached when the material fails completely.

3.6 Concrete — Mixture of Portland cement, aggregate and water to form a stiff slurry that will chemically react and harden.

3.7 Drying Shrinkage — Contraction of a hardened concrete mixture due to the loss of capillary water. This shrinkage causes an increase in tensile strain, which may lead to cracking, internal warping, and external deflection, before the concrete is subjected to any kind of loading.

3.8 Elongation of the Fibre — Elongation of the fibre is defined as the ratio of the length change of the fibre to the initial length expressed as a percentage.

NOTE — The length change should be measured on the fibre itself.

3.9 Equivalent Diameter — Equivalent diameter is the diameter of a circle with an area equal to the mean cross sectional area of the fibre. For circular fibres, the equivalent diameter is equal to the diameter of the fibres.

NOTE — The equivalent diameter shall be calculated as given in Annex J

3.10 Fibre Dispersion — Opening and distribution or scattering of bundle of fibres uniformly and homogeneously in a cement based matrix such that almost no bundles, agglomeration of fibres, clustering of fibres or bunches of fibres are visible in the cement based matrix after dispersion.

3.11 Fibre Reinforced Concrete — A cement based matrix reinforced with dispersed, randomly oriented fibres.

3.12 Flexural Strength — The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress.

3.13 Glass Transition Temperature (T_g) — The temperature of polymers above which the polymer is soft and below which it is hard and brittle like glass. The hard and brittle state is known as the glassy state and the soft flexible state is called the rubbery or visco-elastic state.

3.14 Impact Resistance — The energy consumed to fracture a specimen; or the number of blows in a "repeated impact" test to achieve a prescribed level of distress, or the extent of damage.

3.15 Melting Temperature — The temperatures at which a polymer melts that is the temperature at which change of state from plastic to liquid occurs.

3.16 Modulus of Fibres — The modulus is the ratio of stress to strain. It is expressed in Mpa.

3.16.1 *Modulus of Fibres, Initial* — The slope of the initial straight portion of a stress-strain curve. It is expressed in Mpa.

3.16.2 *Modulus of Fibres, Secant* — The ratio of change in stress to change in strain between the points of zero stress and breaking stress. It is expressed in Mpa.

3.16.3 *Modulus of Fibres, Tangent* — The ratio of change in stress to change in strain derived from the tangent to any point on a stress-strain curve. It is expressed in Mpa.

3.17 Permeability — The coefficient representing the rate at which water is transmitted through a saturated specimen of concrete under an externally maintained hydraulic gradient.

3.18 Precast — Concrete products cast at a site remote from the final installation.

3.19 Shrinkage and Temperature Cracking — Shrinkage moisture and temperature change causing cracking in tension due to a change in length or volume.

3.20 Specific Gravity — The ratio of the density of a polymer (fibre) to the density of water at 27 ± 2°C.

3.21 Synthetic Fibers — Straight or deformed pieces of extruded, orientated and cut material which are suitable to be homogeneously mixed into concrete or mortar for use for secondary reinforcement in concrete for various constructional applications. Synthetic fibers are fibers manufactured from polymer-based materials such as polypropylene, nylon, polyester and carbon etc.

3.22 Tenacity — Breaking force of a fibre divided by its linear density.

3.23 Tensile Strength — Stress corresponding to the maximum force a fibre can resist. The tensile strength is calculated by dividing the maximum force a fibre can resist by the mean cross sectional area of the fibre prior to loading.

3.24 Ultimate Elongation of the Fibre — Maximum ratio of the length change of the fibre to the initial length expressed as a percentage.

4 REQUIREMENTS

4.1 Types of Synthetic Fibres used in Secondary Reinforcement of Concrete

4.1.1 This standard mainly covers requirements for synthetic fibres such as polyester, polypropylene and nylon used for secondary reinforcement of concrete. However, the type of most commonly used synthetic fibres and general range of their physical properties and the fiber content in concrete applications is described in Annex B for information of the users.

4.2 The synthetic fibres used for secondary reinforcement in concrete shall comply with the requirements given in **4.3** to **4.7** and the physical, application and functional requirements as given in Tables 1, 2 and 3.

4.3 General — Only virgin synthetic fibers (monofilament/multifilament in case of polyester and nylon and monofilament/fibrillated in case of polypropylene) of cut length 6 mm to 25 mm, inert to concrete environment shall be used as secondary reinforcement in cement based matrix and no recycled material shall be permitted. Fibres shall be well dispersed in the cement based matrix so as to have uniform functional properties. Fibers shall be identified as per the dissolution tests specified in IS 667.

4.3.1 The user shall obtain a test certificate for every lot of fibre purchased from the fibre manufacturer along with a test report, if any indicating that the fibre supplied is virgin fibre. For checking polyester virgin fibres, a routine test may be conducted by examining them under ultraviolet light where recycled fibers appear blue while virgin fibers appear white. However, in cases of dispute, the maximum Isophthalic Acid (IPA) content shall be 'Not Detectable' when tested by the method prescribed in Annex C. The polymer content of all virgin polymers of polyester, polyamide and polypropylene shall be minimum 97 percent and other additives such as oxidation and UV stabilizers shall not be more than 3 percent and the same shall be validated by a certificate from the polymer supplier for each lot. The user shall also obtain a test certificate for every lot of fibre purchased from the fibre manufacturer along with a test report, if any indicating that the secant modulus values shall meet the requirements as given below:

Sl. No.	Type of fibre	Secant Modulus (As Declared, *Min*) (10^3 MPa) at 3% extension
(1)	(2)	(3)
i)	Polyester	1 - 3
ii)	Polypropylene	2 - 4
iii)	Nylon 6	2 – 4

NOTES

1 If required by the customer, fibres of cut length more than 25 mm are permitted.

2 The tested secant modulus value of the polyester fibre shall not be less than the declared value by the manufacturer.

3 The PP and Nylon are not recycled.

4.4 Resistance to Alkalis — Synthetic fibers shall retain at least 90 percent of their original breaking strength when tested by the method prescribed in Annex D.

4.5 Resistance to Acids — Synthetic fibers shall retain at least 90 percent of their original breaking strength when tested by the method prescribed in Annex E.

4.6 Resistance to Ageing — The test specimen of synthetic fibres in the form of

a sheet (*see* **4.6.1**) when subjected to ageing at 70 ± 2°C for 168 h by the procedure described in IS 7016 (Part 8) shall retain at least 90 percent of their original tensile strength.

4.6.1 Prepare five test specimens in the form of a uniform wadding or sheet of fibres each of size (100 ± 1) mm × (100 ± 1) mm.

4.7 Resistance to Ultraviolet Light — The synthetic fibers when tested for resistance to ultra-violet light as specified in Annex F shall not have tensile strength less than 90 percent of the original value.

Table 1 Physical Requirements

(*Clause* 4.2)

Sl. No.	Characteristics	Fiber Type							Method of Test, Ref to
		Polyester			Polypropylene			Nylon 6	
		Class I	Class II	Class III	Class I	Class II	Class III		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Cross section	Circular/Triangular/ Rectangular			Circular/Triangular/ Rectangular			Circular/Triangular	IS 667
ii)	Tensile strength, MPa (*see* Note), *Min*	180	300	500	180	300	500	460 - 800	IS 235
iii)	Specific gravity	----------1.34 - 1.39----------			----------0.90 - 0.91----------			1.14 - 1.20	Annex G
iv)	Ultimate elongation, percent, *Min*	15	15	15	15	15	15	15	IS 235
v)	Melting Temperature, ^{o}C, *Min*	----------250----------			----------160----------			180	Annex H
vi)	Glass Transition Temperature, ^{o}C	----------*Min,* 80----------			----------< −10----------			*Min,* 50	Annex H

NOTE – For testing fibres of length less than 10 mm, manufacture shall provide a skein from which fibres of the required length can be taken for testing tensile strength.

Table 2 Application Requirements

(*Clause* 4.2)

Sl No.	Characteristics	Application for Concrete	Method of test
(1)	(2)	(3)	(4)
i)	Equivalent fibre diameter, Micron	7 to 100	Annex J
ii)	Length, mm	5 to 25	IS 10014 (Part 1)
iii)	Aspect ratio	100 to 1 000	Annex K

Table 3 Functional Requirements

(*Clause* 4.2)

Sl No.	Characteristics	Gain, Percent *Min*	Method of test
(1)	(2)	(3)	(4)
i)	Drying shrinkage for concrete only	30	IS 1199

NOTES

1 The gain percent in Table 3 shall be calculated by the formula:

$$\text{Gain Percent} = \frac{(V_2 - V_1) \times 100}{V_2}$$

where

V_1 = Value of each parameter for the control sample of cement based matrix, and

V_2 = Value of each parameter for the fiber reinforced cement based matrix sample.

2 For preparation of test specimen for above functional property of cement based matrix, the manufacture shall declare the optimum dosage percent of the fibre to be used in cement based matrix. However, in general, fibers are added from 0.06 to 0.3 percent by volume depending upon the type of fiber and the end use for which concrete is used.

3 Method for preparing reference concrete for evaluating the drying shrinkage gain percent is specified in Annex L.

5 PACKING AND MARKING

5.1 Packing

The synthetic fiber shall be packed in tight polyethylene film bags of minimum 40 micron thickness or paper pouches of minimum 60 g/m^2 or as agreed to between the buyer and the seller such that it is well protected from outside weather.

5.2 Marking

5.2.1 The marking on the bags/pouches shall be clearly readable. The bags or paper pouches shall be marked legibly with the following information by printing with an indelible ink in english alphabets of minimum size of 5 mm:

a) Indication of the source of manufacture and the source of packing;

b) Type of synthetic fiber that is polyester, polypropylene or nylon;
c) Average length of fiber;
d) Net mass of fibers in the bag or pouch;
e) Batch No and date of manufacture;
f) Country of origin; and
g) Any other information desired by the law.

5.2.2 BIS Certification Marking

The fiber bag or pouch may also be marked with the Standard Mark.

5.2.2.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 2016 and Rules and Regulations made there under. The details of conditions under which the license for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

6 SAMPLING

6.1 Lot

All fiber bags or pouches containing same type of fiber and of same length and diameter dispatched to a buyer against one dispatch note shall constitute a lot.

6.2 The conformity of the lot to the requirements of this standard shall be determined on the basis of the tests carried out on the samples selected from it.

6.3 The fibers from the bags or pouches selected from the lot shall be tested for various requirements specified in **4.1** to **4.7** and Tables 1 to 3 of this standard. Any fiber bag or pouch failing to meet one or more of the corresponding requirements prescribed in **4.1** to **4.7** and Tables 1 to 3 shall be considered as defective.

Table 4 Scale of Sampling
(*Clause* 7.1)

Sl No.	Number of Fiber Pouches or Bags in the Lot	Sample size	Sub-sample Size	Permissible No. of Defective Pouches
(1)	(2)	(3)	(4)	(5)
i)	Up to 1 200	2	1	0
ii)	1 201 to 3 200	3	1	0
iii)	3 201 to 10 000	5	2	0
iv)	10 001 to 35 000	8	2	1
v)	150 001 to 500 000	20	3	2
vi)	500 001 and above	32	5	2

7 NUMBER OF TEST SPECIMENS AND CRITERIA FOR CONFORMITY

7.1 The number of test specimens to be drawn from the lot and the criteria for conformity shall be as given below:

Sl No.	*Characteristic*	*No. of Bags or Pouches*	*Criteria for Conformity*
(1)	(2)	(3)	(4)
i)	Length, equivalent fibre dia, aspect ratio, cross section, tensile strength, secant modulus and ultimate elongation.	According to col 3 of Table 4	The defective bags/pouches do not exceed the corresponding number given in col 5 of Table 4
ii)	Resistance to alkalis, resistance to acids, resistance to ageing, resistance to UV light, water absorptive capacity and functional properties	According to col 4 of Table 4	The defective bags/pouches shall not exceed the corresponding number given in col 5 of Table 4
iii)	General including virginity of fibers, specific gravity, melting temperature, glass transition temperature and intrinsic viscosity	According to col 4 of Table 4	All the test specimens shall meet the requirements