भारतीय मानक
Indian Standard

IS 16481 : 2022

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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Technical Textiles for Build Tech Sectional Committee, TXD 34

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. (1)	**Characteristics** (2)	**Application for Concrete** (3)	**Method of test** (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. (1)	**Characteristics** (2)	**Gain, Percent** *Min* (3)	**Method of test** (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. (1)	Number of Fiber Pouches or Bags in the Lot (2)	Sample size (3)	Sub-sample Size (4)	Permissible No. of Defective Pouches (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. (1)	*Characteristic* (2)	*No. of Bags or Pouches* (3)	*Criteria for Conformity* (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

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
235 : 1989	Textile fibres — Tensile characteristics of individual fibres — Methods for determination (*first revision*)
383 : 1970	Specification for coarse and fine aggregates from natural sources for concrete (*second revision*)
456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
460 (Part 2) : 1985	Specification for test sieves: Part 2 Perforated plate test sieves (*third revision*)
516 : 1959	Methods of test for strength of concrete
667 : 1981	Methods for identification of textile fibers (*first revision*)
1070 : 1992	Reagent grade water — Specification (*third revision*)
1199 : 1959	Methods of sampling and analysis of concrete
2386 (Part 1) : 1963	Methods of test for aggregates for concrete: Part 1 Particle size and shape
6359 : 1971	Method for conditioning of textiles
7016 (Part 8) : 1975	Methods of test for coated and treated fabrics: Part 8 Accelerated ageing
7903 : 2011	Textiles — Tarpaulins made from high density polyethylene woven fabric — Specification *(fourth revision)*
9103 : 1999	Concrete admixtures — Specification (*first revision*)
10014 (Part 1) : 1984	Methods of test for man-made staple fibres: Part 1 Determination of length
IS 12269 : 2013	Ordinary Portland cement, 53 grade — Specification (*first revision*)

ANNEX B

(*Clause* 4.1.1)

TYPES OF SYNTHETIC FIBRES USED IN SECONDARY REINFORCEMENT OF CONCRETE

B-1 GENERAL

There are two different physical fibre forms: monofilament fibres/multifilament fibres and fibrillated fibres produced from tape. Most synthetic fibre applications are at the low doses 0.06 percent to 0.3 percent by volume depending upon the type of fibre. At this level, the strength of the concrete is considered unaffected, and crack control characteristics are improved.

B-2 IMPORTANT INFORMATION FOR USE OF SYNTHETIC FIBRES

B-2.1 Synthetic fibers can significantly enhance concrete performance at young age, but do not guarantee crack-free concrete which might be due to external actions. The guidelines given in **B-2.1** and **B-2.2** can help to decide their use for a particular application.

B-2.2 Do Specify Synthetic fibers for:

a) Reducing concrete cracking due to plastic shrinkage in concrete and plasters;

b) Replacing or supplementing wire mesh as secondary reinforcement for resisting early shrinkage cracking when considered important;

c) Reducing concrete permeability due to better control over opening of cracks;

d) Enhancing impact and abrasion resistance of concrete;

e) Fibre application requiring non-metallic or non-corrosive secondary reinforcement;

f) Cohesive mix designs and for reducing rebound loss in shotcrete (sprayed concrete) works; and

g) Applications requiring secondary reinforcement which resists alkalis, chemicals, and chlorides.

B-2.3 The use of synthetic fibers should be avoided for:

a) Controlling cracking in hardened concrete resulting from external actions and long term stresses;

b) Replacing structural steel reinforcement for its performance during service life;

c) Enhancing compressive, tensile or flexural strength of concrete; and

d) Eliminating or reducing curling or creep.

ANNEX C

(*Clause* 4.3.1)

METHOD OF TEST FOR ISOPHTHALIC ACID CONTENT OF THE VIRGIN POLYESTER FIBER

C-1 PRINCIPLE

This method is applicable to measure isophthalic acid content in polyethylene terephthalate sample. The polymer sample is digested in benzyl alcohol, depolymerized then esterified to dibenzyl isophthalate, dibenzyl terephthalate and glycol. Isopropyl titanate is added as a depolymerization catalyst. The sample is analyzed by gas chromatography and the peak areas of the two esters are used to estimate the weight percentage of dimethyl isophthalate using an internal standard.

C-2 POTENTIAL ENVIRONMENT ISSUE

C-2.1 In case of spillage, it can lead to pollution near the workplace area and environment hazard. After analysis sample is disposed as per laid down procedure.

C-2.2 Hydrogen, nitrogen and instrument air are used during analysis. The hydrogen gas has no adverse ecological effects. Hydrogen does not contain any class I or class II ozone depleting chemicals. However hydrogen is explosive. Gaseous nitrogen is an inert non-flammable gas. High concentration in air may cause deficiency of oxygen with the risk of unconsciousness and death. Chloroform in high concentration in air can kill most animals in few minutes.

C-3 POTENTIAL SAFETY, OCCUPATIONAL HEALTH ISSUES

C-3.1 Proper PPE’s like safety goggles, apron, surgical hand gloves to be used.

C-3.2 Glassware is to be handled with care.

C-3.3 Leak check to be carried out while handling of gas cylinder.

C-3.4 Inhalation of chloroform causes dilation of pupils with reduced reaction to light as well as reduced intraocular pressure, Irritation of mucous membrane, conjunctiva. If contacted with skin and eyes, it causes irritation. Seek medical advice if inhaled.

C-3.5 Use leather hand gloves while handling hot apparatus and equipments.

C-4 APPARTUS

C-4.1 Gas Chromatograph (GC) - with flame ionization detector.

C-4.2 Capillary Column - 60m length and 0.53 mm ID MXT ® - 1.

C-4.3 Dispensette or Pipette - 2 ml, 5 ml and 10 ml.

C-4.4 Volumetric Flask - 100 ml, 500 ml.

C-4.5 Beaker

C-4.6 Funnel

C-4.7 50 ml Flask

C-4.8 Heating Mental - to maintain temperature of 250 °C

C-4.9 AR Grade Dimethyl Isopthalate (DMI)

C-4.10 AR Grade Benzyl Alcohol

C-4.11 AR Grade Chloroform

C-4.12 AR Grade Isopropyl Titnate

C-4.13 AR Grade Dimethyl Suburate

C-5 PREPARATION OF STANDARD SOLUTIONS

C-5.1 Stock Dibenzyl Suburate (Internal Standard) Solution

Take 1.0 ± 0.01 g of dimethyl suburate (DMS). Add 100 ml of benzyl alcohol and 6 to 7 drops of isopropyl titnate digest it for 2 h. Allow it to cool up to room temperature then make the volume to 500 ml by carefully rinsing the flask by isopropyl alcohol. Dimethyl suburate will get converted into dibenzyl suburate (DBS). Mark the stock solution as DBS per 2 ml ≈ X · XXXX mg.

C-5.2 Stock Dimethyl Isopthalate (DMI) Solution

Take 0.2 ± 0.01 g of dimethyl isopthalate (DMI). Add 40 ml of benzyl alcohol and 6 to 7 drops of isopropyl titnate digest it for 2 h. Allow it to cool up to room temperature then make the volume to 100 ml by carefully rinsing the flask by isopropyl alcohol. This will be converted to dibenzyl isopthalate (DBI). Mark the stock solution as DBI per 2 ml ≈ X · XXXX mg.

C-5.3 Standard Solution for Response Factor

Take 2 ml of solution prepared in **C-5.1** and 2 ml of solution prepared in **C-5.2**. Add 10 ml of chloroform.

C-5.4 2.0 *Percent standard IPA stock solution*

Weigh out accurately 0.200 ± 0.005 g of pure DMI powder into round bottom flask, add 30 ml of benzyl alcohol and 3 drops of isopropyl titante, reflux the solution for 5 h and dilute to 100 g by isopropyl alcohol, calculate actual DMI concentration by considering its purity and label the flask with actual weight taken. Consider this weight during calculation of IPA by GC.

C-5.5 2.1 *Percent standard IPA solution for GC injection*

Take 2.0 ml IPA stock solution and add 2 ml internal standard (*see* **C-5.1**) and further add 10 ml of chloroform, same bottle to be labelled as 2.0 percent IPA Inject 1 µl in GC.

C-6 CALIBRATION FOR PERFORMANCE CHECK — TWICE /MONTH STANDARD CHIPS

C-7 ANALYTICAL PROCEDURE

Inject 1 µl of standard solution for response factor (*see* **C-5.3**) and calculate response factor. Inject 1 µl of 2 percent standard IPA solution. If value of 2.0 percent standard IPA solution is varying in the range of 0.01 percent, then there is no need for change in response factor. If there is deviation in value then rerun standard solution for response factor (*see* **C-5.3**). Weigh 0.2 ± 0.02 g of chips into the round bottom flask. Add 2 ml of benzyl alcohol. Add 3 drops of isopropyl titanate. Digest the solution for 1 h. Allow it to cool up to room temperature. Add 10 ml of chloroform. Add 2 ml of internal standard solution that is solution prepared in **C-5.1** and shake vigorously. Inject 1 µl of sample solution into gas chromatograph.

C-8 CHROMATOGRAPH SETTINGS

Injector temperature : 300°C

Detector temperature : 320°C

Oven temperature : 270°C

Gas flow rates

Nitrogen : 20 psig

Hydrogen : 30 ± 10 ml/min

Air : 300 ± 20 ml/min

Attenuation : -4

Range : 1

C-9 CALCULATION

$$\text{Response factor (RF)} = \frac{A_1 \text{ x } W_2}{A_2 \text{ x } W_1}$$

where

A_1 = Area of dibenzyl suburate (DBS) (Internal standard) solution;

W_1 = Weight of DBS in solution, in mg;

A_2 = Area of DBI in standard solution; and

W_2 = Weight of DBI in standard solution, in mg.

$$\text{Percent IPA} = \frac{\text{RF} \times \text{mg Internal Standard} \times \text{Area of IPA in sample} \times 100}{\text{Weight of sample, in mg} \times \text{Area of internal standard in sample}}$$

ANNEX D

(*Clause* 4.4)

DETERMINATION OF RESISTANCE OF FIBRES TO ALKALIS

D-1 MATERIALS

D-1.1 Sample of synthetic fibres weighing about 100 g.

D-1.2 Solution of calcium hydroxide of *p*H 12 to 13.

D-2 PROCEDURE

D-2.1 Prepare 2 specimens of fiber each weighing about 20 g.

D-2.2 Prepare a solution of calcium hydroxide of *p*H from 12 to 13.

D-2.3 Keep one specimen as test specimens and **s**ubmerge it in the above solution (**D-2.2**) in a glass container maintained at *p*H of 12 to 13 and temperature of 30 ± 2°C. Cover the solution properly and maintain the temperature at 30 ± 2°C for 28 days. Keep the remaining specimen separately as blank in the standard atmosphere of 27°C ± 2°C temperature and 65 ± 2 percent relative humidityas control sample.

D-2.4 Remove the test specimen from the alkaline solution after 28 days, wash, dry and condition it for 24 hours at 27°C ± 2°C and 65 ± 2 percent relative humidity.

D-2.5 Find out the breaking strength of the 30 individual fibres from the test specimen according to IS 235 (*see* note). Calculate the average breaking strength for the test specimen. Similarly find out the breaking strength of 30 individual fibres from the control sample and then calculate the average breaking strength of the control specimen.

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.

D-2.6 Calculate the percentage breaking strength retained as follows:

$$\text{Breaking Strength retained in percent} = \frac{\text{Test Specimen Breaking Strength (Avg)} \times 100}{\text{Control Specimen Breaking Strength (Avg)}}$$

ANNEX E

(*Clause* 4.5)

DETERMINATION OF RESISTANCE OF FIBRES TO ACIDS

E-1 MATERIALS

E-1.1 Sample of synthetic fibres weighing about 100 g.

E-1.2 Solution of hydrochloric acid of *p*H 4 to 5.

E-2 PROCEDURE

E-2.1 Prepare 2 specimens of fiber each weighing about 20 g.

E-2.2 Prepare a solution of hydrochloric acid of *p*H 4 to 5.

E-2.3 Keep one specimen as test specimens and **s**ubmerge it in the above solution (**E-2.2**) in a glass container maintained at *p*H of 4 to 5 and temperature of 30 ± 2°C. Cover the solution properly and maintain the temperature at 30 ± 2°C for 28 days. Keep the remaining specimen separately as blank in the standard atmosphere of 27°C ± 2°C temperature and 65 ± 2 percent relative humidity as control sample.

E-2.4 Remove the test specimen from the alkaline solution after 28 days, wash, dry and condition it for 24 h at 27°C ± 2°C and 65 ± 2 percent relative humidity.

E-2.5 Find out the breaking strength of the 30 individual fibres from the test specimen according to IS 235 (*see* note). Calculate the average breaking strength for the test specimen. Similarly find out the breaking strength of 30 individual fibres from the control sample and then calculate the average breaking strength of the control specimen.

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.

E-2.6 Calculate the percentage breaking strength retained as follows:

$$\text{Breaking Strength retained in percent} = \frac{\text{Test Specimen Breaking Strength (Avg)} \times 100}{\text{Control Specimen Breaking Strength (Avg)}}$$

ANNEX F

(*Clause* 4.7)

DETERMINATION OF RESISTANCE OF FIBRES TO ULTRA VIOLET LIGHT

F-1 TEST SPECIMENS

The test specimens for tensile strength shall be taken from the sample as specified in IS 235.

F-2 TEST CONDITIONS

F-2.1 The test shall be carried out with fluorescent UV-B lamp (*see* IS 7903).

F-2.2 The duration of the test shall be 144 h (that is 6 days).

F-2.3 The test cycle shall be 8 h at 60 ± 3 °C with UV radiation alternating after 4 h at 50 ± 3°C with condensation.

F-2.4 Irradiation level throughout the test shall be maintained at 0.63 + 0.03 W/m².

F-3 TEST PROCEDURE

F-3.1 Determine the original average tensile strength of at least 30 individual fibres for each specimen as per IS 235 before exposure.

F-3.2 Expose the specimens alternately to ultraviolet light alone and to condensation in one respective cycle.

F-3.2.1 Te type of fluorescent UV lamp, the timing of the UV exposure and the temperature of condensation shall be as specified in **F-2**.

F-3.3 Determine the average tensile strength of at least 30 individual fibers for each specimen separately for all the six specimens separately as the tensile strength after UV exposure as given in F-3.2.

F-3.4 Determine the percent retention of original tensile strength for each specimen as follows:

$$\text{Retention of original tensile, percent} = \frac{\mathrm{b}}{a} \times 100$$

where

a = Average tensile strength before UV exposure as obtained in **F-3.1**, and

b = Average tensile strength after UV exposure as obtained in **F-3.3**.

NOTES

1 The UV source is an array of fluorescent lamps (with lamp emission concentrated in the UV range).

2 Condensation is produced by exposing the test surface to a heated, saturated mixture of air and water vapour, while the reverse side of the test specimen is exposed to the cooling influence of ambient room air.

ANNEX G

(*Sl No.*(iii), *Table* 1)

DETERMINATION OF SPECIFIC GRAVITY

G-1 Take a specimen of weighing about 1 gm of fibers from the sample and find out its mass (m) accurately to the nearest mg. Count the total number of fibers (n) in the test specimen.

G-2 Let *l* be the mean fiber length in cm correct to two decimal places as determined by the procedure described in IS 235 and *d* be the mean fiber dia in cm correct to two decimal places as determined in IS 6919**.**

G-3 For circular cross-section fibres, calculate the specific gravity of the fibre by the formula:

$$\text{Specific gravity of fibre} = \frac{4m}{\pi d^2 ln} \text{ Specific gravity of fibre}$$

G-4 For triangular cross section fibres, calculate the specific gravity of the fibre by the formula:

$$\text{Specific gravity of fibre} = \frac{m}{a\ x\ sin\ 60\ x\ a/2\ x\ l} = 0.433\ a^2\ x\ l$$

where

a = Side of the equilateral triangle of cross section of the fibre.

ANNEX H

[*Table* 1, *Sl No.*(v) *and* (vi)]

DETERMINATION OF MELTING AND GLASS TRANSITION TEMPERATURES

H-1 GENERAL

This test method covers determination of melting and glass transition temperatures of polyester and polypropylene polymers by Differential Scanning Calorimetric (DSC). It is applicable to polymers in granular form or to any fabricated shape from which it is possible to cut appropriate specimens. The normal operating temperature range is from the cryogenic region to 600°C. Certain equipment allows the temperature range to be extended.

NOTE – This method does not purport to address all of the safety concerns, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

H-2 PRINCIPLE

The test material is heated or cooled at a controlled rate under a specified purge gas at a controlled flow rate and continuously monitoring with a suitable sensing device the difference in heat input between a reference material and a test material due to energy changes in the material. A transition is marked by absorption or release of energy by the specimen resulting in a corresponding endothermic or exothermic peak or baseline shift in the heating or cooling curve.

NOTES

1 Differences in heating or cooling rate as well as the final heating and cooling temperature have an effect on the measured results. Therefore, departure from conditions specified for a given polymer is not permitted.

2 The presence of impurities is known to affect the transition temperature, particularly if an impurity tends to form solid solutions or to be miscible in the melt phase.

3 Uncertain radiation losses at temperatures higher than 400°C have been known to affect the accuracy of results at time.

4 Since particle size has an effect upon detected transition temperatures, the specimens to be compared shall be approximately the same particle size.

5 In cases that specimens react with air during the temperature cycle, provision shall be made for running the test under an inert gas blanket to avoid any incorrect measurement. Since some materials degrade near the melting region. care must be used to distinguish between degradation and transition.

6 Since very small quantities of specimen are used. it is essential to ensure that specimen are homogeneous and representative.

7 It is possible that toxic or corrosive effluents are released when heating the material which may be harmful to the personnel or to the apparatus.

H-3 APPARATUS

H-3.1 Differential Scanning Colorimeter (DSC)

H-3.1.1 *DSC Test Chamber* — composed of the following:

H-3.1.1.1 *Furnaces* to provide uniform controlled heating (cooling) of a specimen and reference to a constant temperature or at a constant rate within the applicable cryogenic to 600ºC temperature.

H-3.1.1.2 *Temperature sensor* to provide specimen temperature to an accuracy of ± 0.01°C.

H-3.1.1.3 *Differential sensor* to detect heat flow difference between the specimen and reference equivalent to 1 mW

H-3.1.1.4 *Means of sustaining a test chamber environment* — of purge gas; at a purge flow rate of 10 to 50 ± 5 ml/min.

NOTE — Typically, 99+ percent pure nitrogen, argon or helium arc employed when oxidation in air is a concern. Unless effects of moisture are to be studied, use of dry purge gas is recommended and is essential for operation at sub-ambient temperatures.

H-3.1.2 *Temperature Controller,* capable of executing a specific temperature program by operating the furnace between selected temperature limits at a rate of temperature change of 0.5°C to 20°C/min constant to ± 0.1°C/ min or at an isothermal temperature constant to ± 0.1°C.

H-3.1.3 *Recording Device*, capable of recording and displaying any fraction of the heat flow signal (DSC curve) including the signal noise as a function of temperature.

H-3.1.4 *Software*, for integrating areas under endothermic valleys or exothermic peaks, or both.

H-3.1.5 *Containers* (pans, crucibles and so forth) that are inert to the specimen and reference materials and which are of suitable structural shape and integrity to contain the specimen and reference in accordance with the specific requirements of this method.

H-3.1.6 Cooling capability to hasten cool down from elevated temperatures, to provide constant cooling rates of 0.5°C – 20°C/min to obtain repeatable crystallization temperature to achieve sub-ambient operation or to sustain an isothermal sub-ambient temperature or combination thereof.

H-3.2 Balance capable of weighing to ± 10 µg.

H-4 TEST SPECIMENS

H-4.1 Powdered or Granular Specimens — Avoid grinding if the preliminary thermal cycle as outlined in **J-6.1.3** is not performed. Grinding or similar techniques for size reduction often introduce thermal effects because of friction or orientation or both, and thereby change the thermal history of the specimen.

H-4.2 Molded or Pelleted Specimens — Cut the specimens with a microtome, razor blade, hypodermic punch, paper punch, or cork borer (size No. 2 or 3) or other appropriate means to appropriate size, in thickness or diameter and length that will best fit the specimen container, as in **H-3.1.5** and will approximately meet the desired weight in the subsequent procedure.

H-4.3 Film or Sheet Specimens — For films thicker than 40 µm (*see* **H-4.2**). Fur thinner films, cut slivers to fit in the specimen capsules or punch disks, if the circular specimen capsules are used.

H-4.4 Use any shape or form listed in **H — 4.1** to **H-4.3** except when conducting referee tests that shall be performed on films as specified in **H-4.3**.

H-5 CALIBRATION

H-5.1 The purge gas shall be used during calibration.

H-5.2 Calibrate the DSC temperature signal using a heating rate of 10°C/min.

H-5.3 Calibrate the DSC heat flow signal using heating rate of 10°C/min.

H-5.4 Some instruments allow for the temperature and heat flow calibration to be performed simultaneously. In such cases, use the same heating rate for this method (10°C/min) and follow the manufacturer's instruction.

H-6 PROCEDURE

H-6.1 Melting Temperature

H-6.1.1 The purge gas shall be used during testing. The flow rate of the gas shall be the same as used in the calibration (10°C/min).

H-6.1.2 Use a specimen mass appropriate for the material to be tested, In most cases, a 5 mg specimen mass is satisfactory. Avoid overloading. Weigh the specimen to an accuracy of ± 10 µg.

H-6.1.2.1 Intimate thermal contact between the pan and specimen is essential for reproducible results. Crimp a metal cover against the pan with the sample sandwiched in between to ensure good heat transfer. Take care to ensure flat pan bottoms.

H-6.1.3 Perform and record a preliminary thermal cycle by heating the sample at a rate of 10°C/min. from at least 50°C below to 30°C above the melting temperature to erase previous thermal history.

NOTE — In some cases it is possible that the preliminary thermal cycle will interfere with the transition of interest, causing an incorrect transition or eliminating a transition. Where it has been shown that this effect is present, omit the preliminary thermal cycle.

H-6.1.4 Hold the temperature for 5 min **(J-6.1.3).**

H-6.1.5 Cool to at least 50°C below the peak crystallization temperature at a rate of 10°C/min and record the cooling curve.

H-6.1.6 Hold the temperature for 5 min.

H-6.1.7 Repeat the heating at a rate of 10°C/min and record the heating curve.

H-6.1.8 Measure the melting temperatures on the curve (that is melting extrapolated onset temperature, melting extrapolated end temperature and melting peak temperature.

H-6.2 Glass Transition Temperature

H-6.2.1 The purge gas shall be used during testing. The flow rate of the gas shall be the same as used in the calibration.

H-6.2.2 Use a specimen mass appropriate for the material to be tested. In most cases, a 10 to 20 mg specimen mass is satisfactory. Weigh the specimen to an accuracy of ± 10 µg.

H-6.2.3 Perform and record a preliminary thermal cycle by heating the sample at a rate of 20°C/min from at least 50°C below to 30°C above the melting temperature to erase previous thermal history.

H-6.2.4 Hold the temperature for 5 min.

H-6.2.5 Quench cool to at least 50°C below the transition temperature of interest.

H-6.2.6 Hold the temperature for 5 min.

H-6.2.7 Repeat heating at a rate of 20°C/min and record the heating curve until all desired transitions have been completed.

H-6.2.8 The glass transition is more pronounced at faster heating rates. A heating rate of 20°C/min is used for Tg measurements. The instrument shall be calibrated at this heating rate. If both first and second-order transition (Tm and Tg respectively) arc to be determined in the same run, use procedure **J-6.1** and determine results from the second heating step (**G-6.1.7**).

H-6.2.9 Measure Tg (extrapolated onset temperature, midpoint temperature and extrapolated end temperature).

ANNEX J

(*Table* 2, *Sl No.*(i) *and Note under clause* 3.9)

DETERMINATION OF EQUIVALENT FIBRE DIAMETER

J-1 FIBRE WITH CIRCULAR CROSS SECTION

J-1.1 For fibres with a diameter less than 0.3 mm, the diameter shall be measured using optical microscope. 30 individual fibres diameter shall be measured and then mean fibre diameter shall be calculated.

J-1.2 For fibres with a diameter greater than 0.3 mm, the diameter of the fibre shall be measured with a micrometer to a precision of 0.001 mm. 30 individual fibres diameter shall be measured and then mean fibre diameter shall be calculated.

J-2 FIBRE WITH TRIANGULAR/IRREGULAR CROSS SECTION

J-2.1 Take a sample of fibres weighing about 5 g and weigh it accurately to the nearest mg. Count the number of total fibres in the sample and find out the average mass of individual fibre by dividing the mass of sample by the total number of fibres in it. Measure the length of 50 fibres accurately and calculate average fibre length. The average mass, m_f in g, and the average (developed) length, l_d in mm, of the fibre shall be determined to an accuracy of 0.001 g and 0.01 mm, respectively. The equivalent fiber diameter shall be computed from the mass and the developed length using the following formula with the nominal density of the fibre, ρ, in g/cm^3:

$$d_e = \sqrt{\frac{4 \cdot m_f \cdot 10^6}{\pi \cdot l_d \cdot \rho}}$$

ANNEX K

[*Table* 2, *Sl No.*(iii)]

DETERMINATION OF ASPECT RATIO OF FIBRES

From the equivalent fiber dia as determined by the procedures described in **J-2.1**, determine the aspect ratio by the formula:

$$\text{Aspect Ratio} = \frac{Mean\ fiber\ length\ in\ mm}{Equivalent\ fiber\ dia\ in\ mm}$$

Length of the synthetic fiber shall be determined by the method given in IS 10014 (Part 1).

ANNEX L

(*Note* 3 *under Table* 3)

PREPARATION OF REFERENCE CEMENT BASED MATRIX TO BE USED FOR EVALUATING SYNTHETIC FIBRES FOR REINFORCEMENTIN CEMENT BASED CONSTRUCTIONS

L-1 SCOPE

The composition and characteristics of reference cement based matrix for construction used to evaluate the performance of synthetic fibres under standard laboratory conditions.

L-2 REQUIREMENTS OF REFERENCE CEMENT BASED MATRIX FOR CONSTRUCTION

L-2.1 Flexural Strength

The reference concretes shall be designed to meet a prescribed flexural strength, as defined in Table 5.

Table 5 Parameters of Reference Cement Based Matrix for Construction

(*Clause* L-2.1)

Sl. No.	Reference Matrix	Average flexural strength in MPa	Nominal maximum size of aggregate	Maximum cement content	Maximum water cement ratio
(1)	(2)	(3)	(4)	(5)	(6)
i)	Requirements	4.3 ± 0.3	20 mm	400 kg/m³	0.50

L-2.2 Dosage of Fibres

Tests using reference cement based matrix are used for performance of fibres by comparing the properties obtained with the reference matrix to which fibres are added with those of the same reference cement based matrix without the addition of fibres. Dose of fibres shall be 0.06 percent by volume of the cement based matrix.

L-2.3 Workability

The workability of the reference cement based matrix, without fibres, shall be 100 mm ± 20 mm. The matrix shall be free from bleeding or segregation. Workability shall be measured at 20 ± 5 minutes from the end of mixing process.

L-3 MATERIALS TO BE USED FOR CEMENT BASED MATRIX

L-3.1 Aggregates

L-3.1.1 Coarse aggregates shall be crushed stone, with water absorption less than 2 percent by mass. The coarse aggregate shall have elongation and flakiness index together not more than 30 percent. The aggregates shall be from hard rocks, such as basalt or granite.

L-3.1.2 Fine aggregate shall be the sand conforming to zone II as defined in IS 383, with a maximum of 3 percent of the material passing through the 75 micron sieve.

L-3.1.3 The aggregate grading, measured according to IS 2386 (Part 1) shall conform to IS 383.

L-3.2 Mixing Water

Water for mixing in concrete and for curing shall conform to the requirements of IS 456 (*see* Clause **5)**.

L-3.3 Cement - Ordinary Portland cement 53 grade conforming to IS 12269 shall be used.

L-3.4 Admixtures - A plasticizer or super plasticizer, as chemical admixture, complying to IS 9103 may be used to control the workability. If an admixture is used, its generic name and dosage must be mentioned with all the results.

L-3.5 Fibres - The fibre used and its type that is, monofilament/ multifilament/ fibrillated shall be reported.

L-4 SPECIMEN PREPARATION

The reference cement based matrix shall be prepared as follows:

L-4.1 Prepare a matrix batch, the volume of which shall be of 50 to 90 percent of the mixer capacity

L-4.2 Pour all dry aggregates into the mixer, add half of the batch water and mix for a minute.

L-4.3 While continuing the mixing, add the cement and the other half of the batch water during the next minute of mixing.

L-4.4 After adding the admixture (if applicable) mix for a minimum 2 minutes.

L-4.5 The fibres shall be added at the appropriate stage in accordance with the manufacturer's instructions. Generally, fibres can be added after the aggregates have been added to the mixer. The mixing time after adding all the ingredients shall not be more than 3 minutes.

L-4.6 For the matrix with fibres, care shall be taken to ensure that the fibres are evenly distributed throughout the mix.

L-5 STRENGTH EVALUATION

L-5.1 Compressive strength shall be determined using 150 mm × 150 mm × 150 mm cubes at the age of 28 days, for both the concrete mixes without and with fibres.

L-5.2 If the reduction in compressive strength of the matrix with fibres is found to be more than 5 percent than that of the matrix without fibres, the reference matrix shall be checked for cohesiveness, air entrainment and voids, and the reference mix may be corrected, if necessary. Normally, statistically significant reduction in compressive strength, indicates inappropriate mix proportion, and needs revision of the aggregate grading.

L-5.3 Six prismatic 150 mm × 150 mm × 550 mm (or even longer) specimens, made from a reference matrix without incorporating fibres will be tested for flexural strength after 28 days under third-point loading (at one third span) on a 450 mm span as per IS 516, for reporting the average flexural strength.

L-6 REPORT

The following information shall be recorded for the reference concrete:

a) Origin and particle size distribution of coarse and fine aggregates, and brand and type of cement and admixtures used;
b) Mix composition including dry aggregates and admixtures in kg/m^3 and details of mixing procedure;
c) Fibre type and properties described according to this standard/norm/guide;
d) Workability and compressive strength, of the plain and fibre cement based matrix
e) Date and time of casting and testing of specimens;
f) Drying shrinkage as per IS 1199; and
g) Flexural strength to the nearest 0.05 MPa (average of specimens) for the plain cement based matrix.

ANNEX M

(*Foreword*)

COMMITTEE COMPOSITION

Technical Textiles for Build Tech Sectional Committee, TXD 34

Organization	*Representative(s)*
Indian Institute of Technology, New Delhi	Prof (Dr) Abhijit Majumdar (***Chairman***)
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BIS Directorate General	SHRI J. K. GUPTA, SCIENTIST 'E' AND HEAD (TXD) [REPRESENTING DIRECTOR GENERAL (*Ex-officio*)]

Member Secretary
SHRI MAYUR KATIYAR
Scientist 'B' (TXD), BIS

(Continued from second cover)

Though synthetic fibers are most commonly used in cast-in-situ concrete, their use in shotcrete and precast products is growing. Adding synthetic fibers to shotcrete can reduce rebound and material waste, permit thicker layers per pass, reduce sagging, and inhibit plastic shrinkage cracking. Precast manufacturers use synthetic fibers in their products to facilitate handling at early age, help reduce concrete breakage during handling, and save on labor. They also report fewer shrinkage cracks when using the fibers. Some precast manufacturers use synthetic fibers in unusually shaped precast products, such as planters and urns, instead of wire reinforcing. If not carefully placed, wire reinforcing in these products is sometimes exposed when the products are removed from the forms.

This standard was first published in 2016 and has been revised to incorporate following changes:

a) Amendment has been incorporated;
b) Table for application requirements has been modified;
c) Calculation for the specific gravity of circular cross section fibre has been modified; and
d) References to Indian Standards have been updated.

The composition of the Committee responsible for the formulation of this standard is given in

Annex M.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Review of Indian Standards

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This Indian Standard has been developed from Doc No.: TXD 34 (18996).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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