भारतीय मानक

Indian Standard

IS 16391 : 2015

भूकृत्रिम — फूटपाथ संरचनाओं में सबग्रेड अलगाव में प्रयुक्त भूवस्त्रादि — विशिष्टि

Geosynthetics — Geotextiles Used in Sub-Grade Separation in Pavement Structures — Specification

ICS 59.080.70

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Geosynthetics Sectional Committee, TXD 30

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Geosynthetics Sectional Committee had been approved by the Textile Division Council.

A large variety of detrimental factors such as environmental conditions, sub-grade conditions, traffic loading, utility cuts, road widening, ageing, etc, contribute to distress in pavements which need to be addressed in the maintenance or rehabilitation of the pavements. Pavement maintenance treatments are often ineffective and short lived due to their inability to both, treat the cause of the problem and renew the existing pavement condition. The main cause of distress in pavements is the permeability of precipitated surface water infiltrating through the pavement, leading to softening and weakening of pavement sub-grade and base thus accelerating pavement degradation. Further, existing pavement distress such as surface cracks, rocking joints and sub-grade failures cause the rapid reflection of cracking up through the maintenance treatment.

The preferred strategy for long term road and pavement performance shall, therefore, be to build in safeguards during initial construction. These performance safeguards include stabilizing the sub-grade against moisture intrusion and associated weakening; strengthening road based aggregate with efficient drainage of infiltrated water; and, as a last resort, enhancing the stress absorption and moisture proofing capabilities of selected maintenance treatments.

The geogrids and the geotextiles are the most cost effective tools for safeguarding roads and pavements. Geotextiles extend the service life of roads, increase their load-carrying capacity, and reduce rutting. The most common method for quantifying the geosynthetic benefits is the determination of Traffic Benefit Ratio (TBR) which is defined as the ratio of reinforced load cycles to failure (excessive rutting) to the number of cycles that cause failure of an unreinforced road section. In general, geosynthetics have been found to provide a TBR in the range of 1.5 to 70, depending on the type of geosynthetic, its location in the road, and the testing scenario. The researchers have found that for weak sub-grades (CBR = 2 percent) the geotextile extends the service life of a flexible pavement section by a factor of 2.5 to 3.0 compared to a non-stabilized section. Further, a geotextile effectively increased the pavement section’s total AASHTO structural number by approximately 19 percent. Similarly, for pavement sections with moderate strengths (CBR = 4.2 to 4.5 percent), the geotextile increased the service life of the pavement section by a factor of 2.0 to 3.3 and the AASHTO structural number increased by 13 to 22 percent. Both geotextiles and geogrids thus can play an important role in extending the life of a roadway system

The four main applications of geosynthetics (geogrids and geotextiles) in roads are sub-grade separation, sub-grade stabilization, base reinforcement and overlay stress absorption and reinforcement. Sub-grade stabilization and base reinforcement involve improving the road structure as it is constructed by inserting an appropriate geosynthetic layer. Base reinforcement is the use of geosynthetics to improve the structure of a paved road.

Sub-grade separation and stabilization applies geosynthetics to both unpaved and paved roads. When serving as a separator, the geotextile prevents fines from migrating into the base course and/or prevents base course aggregate from penetrating into the sub-grade. The soil retaining properties of the geotextile are basically the same as those required for drainage and filtration. Therefore, the retention and permeability criteria required for drainage shall be met. In addition, the geotextile shall withstand the stresses resulting from the load applied to the pavement. The nature of these stresses depend on the condition of the sub-grade, type of construction equipment and the cover over the sub-grade. Since the geotextile serves to prevent aggregate from penetrating the sub-grade, it shall meet puncture, burst, grab and tear strengths required. At small rut depth, the strain in the geosynthetic is also small. In this case, the geosynthetic acts primarily as a separator between the soft sub-grade and the aggregate. Any geosynthetic that survives construction shall work as a separator. This application is limited to soils which either in initially or seasonably have a CBR > 3 but < 8. In this application the geotextile is a substitute for the choked subbase stone commonly used over plastic sub-grades. It is important to understand that this function may be required when geogrids are used to provide base reinforcement or confinement.

For larger rut depths, more strain is induced in the geosynthetic where the stiffness properties of geosynthetic are essential. A considerable reduction in aggregate thickness is possible by the use of geosynthetic having a high modulus in the direction perpendicular to the road centerline; however, the benefits of the geosynthetics are dependent on the membrane action achieved with a stiff geosynthetic as well as the lateral movement. For very weak sub-grades, it is often beneficial to combine the benefits of both separation and stabilization. The following general conclusion can be drawn relating to a typical road base:

a) A geosynthetic element that functions primarily as a separator (typically when the sub-grade CBR > 3) will increase the allowable bearing capacity of the sub-grade by 40 to 50 percent (*separation geotextiles*)
b) A geosynthetic element that functions primarily to provide confinement of the aggregate and lateral restraint to the sub-grade (typically when the sub-grade CBR < 3) will both increase the allowable bearing capacity of the sub-grade and provide an improved load distribution ratio in the aggregate. The combined benefits can enhance load carrying capacity of the road by well over 50 percent (*stabilization geogrids and geotextiles*).

The general rules for use of geogrids and geotextiles in roadway system are as follows:

a) Temporary roads — Used for hauling and access roads that are subject to low volume of traffic including working platform for permanent road construction:
    1) *Clayey or silty sub-grade with California Bearing Ratio (CBR) < 4* — If a clean base aggregate is used, then a non-woven separator geotextile shall be used. If a "choked aggregate" like general crusher run is used, then use either a geotextile or a biaxial geogrid that has good aperture stability and appropriate size for a design ESAL (Equivalent Single Axle Loading) less than 1 000, a woven geotextile designed for both separation and membrane roles may be used; that is, consider the geotextile's modulus. For larger ESAL, use a woven or non woven geotextile designed simply for separation. The reinforcement role of the geogrid seems safe for approximately 10 000 ESAL.
    2) *Sandy sub-grade with CBR < 3* — Select a biaxial geogrid with good aperture stability and appropriate size or, a woven geotextile that has a reasonable interface friction with the sand and the aggregate. If a woven geotextile is considered, care shall be taken to ensure that it does not actually create a slick slip-plane beneath the aggregate, that is, look at the interface friction by using geotextiles with high surface roughness which leads to enhanced interface friction.
b) Permanent roads (ESAL > 200 000):
    1) *Clayey or silty sub-grade with CBR < 3* — Consider building a working platform using the temporary road methods upon which conventional road can be constructed.
    2) *Clayey or silty sub-grade with 3 < CBR < 8* — If there is any potential for degradation due to water intrusion, frost heave, etc. then include a separator geotextile to protect the base aggregate during these periods.
    3) *Sandy sub-grades with CBR < 3* — Use a biaxial geogrid that has good aperture stability and appropriate size to reinforce the base aggregate. This is particularly helpful when poor quality stone and small aggregate thickness is used, less than 25 cm.

Geosynthetics can also be used as inter layers by placing them below or within the overlay (asphalt concrete) and are thus helpful in rehabilitating distressed road surfaces. These may also provide a moisture barrier.

Survivability is very important from the viewpoint of its long term durability and is defined as resistance to mechanical damage during road construction and initial operation. The ability of a geosynthetic to survive installation and reasonable service loads shall be assured, if it is to perform as designed. Installation damage to a geotextile is a function of the following:

a) Geotextile thickness,
b) Compactive effort and lift thickness,
c) Type and weight of construction equipment used for fill spreading,
d) Grain size distribution of backfill,
e) Angularity of backfill,
f) Polymer used in the manufacture of geotextile, and
g) Geotextile manufacturing process.

Geotexiles are mainly made from polyester (PET) or polypropylene (PP). Polypropylene is lighter than water, strong and very durable. PET is heavier than water, has excellent strength and creep properties, and is compatible with most common soil environments. Geotextiles are mainly of two types, namely, woven and non-woven geotextiles. Knitted and stitch bonded geotextiles are occasionally used in the manufacture of specialty products. Non-woven geotextiles are highly desirable for subsurface in planer drainage, and erosion control applications as well as, for road stabilization over wet moisture sensitive soils. Out of woven geotextiles, slit film fabrics geotextiles are commonly used for sediment control, that is silt fence and road stabilization applications but are poor choices for subsurface drainage and erosion control applications. Monofilament woven geotextiles have better permeability making them suitable for certain drainage and erosion control applications. High strength multifilament woven geotextiles are primarily used in reinforcement applications.

The Committee has reviewed the provisions of the following International Standard referred in this standard and has decided that it is acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 10722 : 2007	Geosynthetics — Index test procedure for the evaluation of mechanical damage under repeated loading — Damage caused by granular material

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

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 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GEOSYNTHETICS — GEOTEXTILES USED IN SUB-GRADE SEPARATION IN PAVEMENT STRUCTURES — SPECIFICATION

1 SCOPE

1.1 This standard covers general and performance requirements for geotextiles used to prevent mixing of a sub-grade soil and an aggregate cover material (subbase, base, select embankment, etc) in pavement structures. This specification is also applicable to situations other than beneath pavements where separation of two dissimilar materials is required but where water seepage through the geotextile is not a critical function.

1.2 The separation application is appropriate for pavement structures constructed over soils with California Bearing Ratio greater than or equal to three (CBR ≥ 3) and shear strength greater than approximately 90 kPa. It is appropriate for unsaturated sub-grade soils. The primary function of a geotextile in this application is separation.

NOTES

1 The function of separation in this application refers to including a tensile member in the form of a geotextile between the aggregate cover material and the soft sub-grade soil with the intent of either increasing the structural support capacity of that component of the pavement structure and hence its life or reduce the initial cost. The geotextile separator may provide one or more of the following functions:

a) A filter to allow water but not soil to pass through it;
b) A separator to prevent the mixing of the soft soil and the granular material; and
c) A reinforcement layer to resist the development of rutting.

2 This is a material purchasing specification and design review of its use for intended applications is recommended. This is not a construction or design specification. Separation of the pavement section is a site specific design issue which shall be addressed by the engineers responsible for the pavement and embankment design. This specification is not appropriate for embankment reinforcement where stress conditions may cause global sub-grade foundation or embankment failure. Design details for geotextile separator, such as geotextile type, cover material thickness, pavement cross-section and associated details, shall be as shown on the contract drawings.

3 This specification is based on the minimum requirements of the geotextile to provide tensile reinforcement and survivability from installation stress. The physical properties listed in Table 1 are applicable for a minimum backfill thickness of 150 mm. However, in general, the geotextile shall be placed at the proper elevation, location and orientation as detailed on the plans and specification. Unless otherwise specified in the project specification, the contractor shall follow the construction/installation guidelines in relevant Indian standard.

2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text, constitute provision 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 DEFINITIONS

For the purpose of this standard the definitions given in IS13321 (Part 1) and the following shall apply.

3.1 Minimum Average Roll Value (MARV) — The average value of roll minus two times the standard deviation. Statistically, it yields a 97.7 percent degree of confidence that any sample taken during quality assurance testing shall exceed value reported.

3.2 Sub-grade Improvement — It is defined as the improvement of the bearing capacity and mitigation of deformation of the sub-grade soil by placing a geotextile immediately over a soft sub-grade soil. The goal of this application may be to reduce undercut requirements, improve construction efficiency, reduce the amount of aggregate subbase/base material required, provide a stiff working platform for pavement construction, or combination of these.

3.3 Traffic Benefit Ratio (TBR) — It is also known as Traffic Improvement Factor or TIF and is defined as the ratio of reinforced load cycles to failure (excessive rutting) to the number of cycles that cause failure of an unreinforced road section. Thus it compares the performance of a pavement cross-section with a geotextile-reinforced base course to a similar cross-section without geotextile reinforcement, based on the number of cycles to failure. The failure is defined as a selected depth of rut through repetitive loading applied by a passing wheel load of at least 2 041.2 kg (4 500 lbs) per single wheel or 4 082.4 kg (9 000 lbs) per dual wheel.

4 REQUIREMENTS

4.1 Geosynthetic materials shall be inert to commonly encountered chemicals, resistant to rot and mildew, and shall have no tears or defects which adversely affect or alter its physical properties. Materials required for complete and proper installation of geosynthetic materials that are not specifically described herein (such as pins, nails, washers, etc) shall conform to the manufacturer's recommendations and be as selected and supplied by the contractor subject to final approval by the engineer.

4.2 Polymers used in the manufacture of geotextiles, and the mechanical fasteners or threads used to join adjacent rolls, shall consist of long chain synthetic polymers, composed of at least 95 percent by weight of polyolefins(polyethylene or polypropylene) or polyesters when tested as per dissolution method in respective solvents as specified in IS 667. They shall be formed into a stable network such that the ribs, filaments or yarns retain their dimensional stability relative to each other, including selvedges. Polyolefin material shall be made resistant to ultraviolet light by adding 2-3 percent carbon black. Recycled polyester shall not be used in the manufacture of geotextiles and only virgin polyester shall be used for manufacture of polyester containing geotextiles. The isophthalic acid content of the virgin polyester shall be nil when tested according to the method prescribed in Annex B.

4.3 Geotextiles shall be dimensionally stable and able to retain their geometry under manufacture, transport and installation. Woven slit film geotextiles (that is, geotextiles made from yarns of a flat, tape-like character) shall not be allowed. Geotextiles used as separation geotextiles in pavement structures shall conform to the requirements specified in Table 1. Average of test results from any sampled roll in a lot shall meet or exceed the minimum values specified in Table 1.

NOTES

1 All numeric values in Table 1 except Apparent Opening Size (AOS), represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values.

2 The property values in Table 1 represent default values which provide for sufficient geotextile reinforcement and survivability under most construction conditions.

5 SAMPLING AND CRITERIA FOR CONFORMITY

5.1 Lot

The quantity of the same class of geotextile manufactured from the same polymer under identical conditions and supplied to a buyer against one dispatch note shall constitute a lot.

5.2 Sampling for tests shall be done in accordance with IS 14706 from each lot. Acceptance shall be based on testing of conformance samples obtained using the procedure given in IS 14706.

5.3 Testing of samples shall be performed in accordance with the methods referred to in this standard for the indicated requirement(s). The number of test specimens shall be as specified in each test method. Product acceptance shall be determined by comparing the average test results of all the specimens within a given sample to the specified MARV.

5.4 Criteria for Conformity

The geotextile shall be tested for all the requirements as specified in Table 1 and in **4.1** to **4.3**. When any individual sample fails to meet any specification requirement, that roll shall be rejected and two additional sample rolls shall be selected from the same lot. The lot shall be declared conforming to the requirements of this standard, if neither of these two additional samples fails to comply with any part of this specification, otherwise the entire quantity of rolls represented by that sample shall be rejected.

6 MARKING AND LABELLING

6.1 The geotextile material shall be marked with the following by attaching the printed labels:

a) Identification of the geotextile material as per manufacturer's recommendation, for example, polyester multifilament woven geotextile for separation in pavement structures;
b) Class of geotextile material that is Class 1 or Class 2;
c) Batch number, lot number and roll number;
d) Date of manufacture of geotextile material;
e) Any other information/instruction prescribed by the manufacturer or by the law in force;
f) Manufacturer's name, initials or trade-mark; and
g) Country of origin.

6.2 BIS Certification Marking

The geotextile may also be marked with the Standard Mark.

6.2.1 The use of the Standard Mark is governed by the provisions of *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which a licence for the use of Standard Mark may be granted to manufacturers or producers, may be obtained from the Bureau of Indian Standards.

7 PACKING

The geotextile shall be packed in rolls or as per the contract or order. Each roll or package shall be protected by wrapping it in a LDPE film of minimum

Table 1 Requirements of Geotextiles for Separation Applications

(*Clauses* 1.2, 4.3 *and* 5.4)

Sl No.	Characteristic(s)	Requirement				Method of Test, Ref to
		Class 1		Class 2		
		Elongation < 50 percent	Elongation ≥50 percent	Elongation < 50 percent	Elongation ≥ 50 percent	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Index properties:					
	a) Type of geotextile	←Woven/non-woven→		←Woven/non-woven→		—
	b) Roll length, m, *Min*	←50 or 100 or as agreed→		←50 or 100 or as agreed→		IS 1954
	c) Roll width, m, *Min*	←2.0 or 5.0 or as agreed→		←2.0 or 5.0 or as agreed→		IS 1954
	d) Grab strength, N, *Min*	1 100	700	800	500	IS 16342
	e) Sewn seam strength, N, *Min*	990	630	720	450	IS 15060
	f) Trapezidal tear strength, N, *Min*	400	250	300	180	IS 14293
	g) CBR puncture strength, N, *Min*	400	250	300	180	IS 16078
	h) Burst strength, kPa, *Min*	2 700	1300	2 100	950	IS 1966 (Part 2)
ii)	Structural integrity properties:					
	a) Permitttivity, s^{-1}, *Min*	0.02	0.02	0.02	0.02	IS 14324
	b) Apparent opening size (AOS), mm, *Max*	0.60	0.60	0.60	0.60	IS 14294
iii)	Durability properties:					
	a) Pullout interaction coefficient, @ 6 mm displacement, Normal load = 5 kPa, *Min*(*see* Notes 1 and 2)	←0.8→		←Not applicable→		IS 16380
	b) Coefficient of direct shear @ Peak geotextile shear strength, Normal load = 5 kPa, *Min* (*see* Notes 3 and 4)	←5→		←Not applicable→		Annex C
	c) Resistance to installation damage, Percent retained strength, SC/SW/GP (*see* Note 5), *Min*	←95/93/90→		←95/93/90→		ISO 10722
	d) Ultraviolet stability at 500h, Retained strength, Percent of original strength, *Min*	70	—	70	_	IS 13162 (Part 2)

NOTES

1 The coefficient of interaction, C_i , is the ratio between the average shear stress on the geosynthetic specimen in the pullout test and the mobilized shear stress in the fill material in direct shear tests under the same confining stress and shall be calculated as follows:

$$C_i = \frac{F_p}{2LW(\sigma_n \tan\varphi + c)}$$

where

C_i = coefficient of interaction;

F_p = measured pullout force;

L = initial length of the geosynthetic specimen;

W = initial width of the geosynthetic specimen;

σ_n = applied normal stress;

φ = friction angle of the fill material; and

c = cohesive intercept of the fill material.

2 For pullout interaction coefficient test, rate of displacement may be increased to 125 mm/min. A graded angular base material as described in Table 2 shall be used in laboratory testing. The test sample shall be at least 0.3 m in length and 0.3 m in width.

3 For coefficient of direct shear test, rate of displacement may be increased to 50 mm/min. A graded angular base material as described in Table 2 shall be used in laboratory testing. Test sample shall be at least 0.3 m in length and 0.3 m in width.

4 The coefficient of direct shear shall be determined using the peak geotextile shear strength with the shear strength of the graded angular base measured at the same displacement as the peak geotextile shear strength.

5 Resistance to installation damage (loss of load capacity or structural integrity) when subjected to mechanical installation stress in clayey sand (SC), well graded sand (SW) and crushed stone classified as poorly graded gravel (GP).

6 Class 2 geotextile may be specified for aggregate cover thickness of first lift over the geotextile exceeding 300 mm and aggregate diameter less than 50 mm or for aggregate cover thickness of first lift over the geotextile exceeding 150 mm, aggregate diameter less than 30 mm and construction equipment contact pressure less than 550 kPa based on field experience, laboratory testing and visual inspection of a geotextile sample removed from a field test section

7 Permittivity and permeability of geotextile shall be greater than that of the soil.

8 For Class 1, the required MARV tear strength for woven monofilament geotextiles shall be 250 N.

thickness of 40 µ to prevent it from the adverse impact of heat and moisture, oil, grease, dirt, dust and other stains during shipment and storage prior to deployment.

8 INFORMATION AND SAMPLES TO BE SUBMITTED BY THE MANUFACTURER

The manufacturer shall submit to the purchaser the following:

a) Geotextile product sample approximately one square metre or larger;
b) Geotextile product data sheet and certification from himself or by third party certification such as the use of the Standard Mark stating that the geotextile product supplied meets the requirements of this standard;
c) Manufacturer's installation instructions and general recommendations;

9 STORAGE AND PROTECTION

9.1 During storage, elevate the geotextile rolls off the ground and adequately protect them from the following:

a) Site construction damage;
b) Excessive precipitation;
c) Extended exposure to sunlight;
d) Aggressive chemicals;
e) Flames or temperatures in excess of 71°C;
f) Excessive mud, wet concrete, epoxy, or other deleterious materials coming in contact with and affixing to the geotextile material; and
g) Any other environmental condition that may damage the physical property values of reinforcement.

9.2 Store the geotextile material at temperatures above – 20°C

9.3 Lay the rolled materials flat or vertical on ends.

9.4 Do not leave the geotextile material directly exposed to sunlight for a period longer than the period recommended by the manufacturer.

9.5 Each geotextile roll shall be wrapped with a material that shall protect it from damage due to shipment, water, sunlight and contaminants.

9.6 Keep geotextile dry until installation, and do not store directly on the ground.

Table 2 Gradation of Base Material for Determining the Coefficient of Interaction and Direct Shear (Sliding)

(*Table* 1)

Sl No.	Sieve Size mm	Percent Passing
(1)	(2)	(3)
i)	37.5	100
ii)	25	95 - 100
iii)	19	60 - 100
iv)	4.75	30 - 60
v)	0.425	10 - 30
vi)	0.075	3 - 10

NOTE — LL < 30 and PI < 10

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
667 : 1981	Methods for identification of textile fibres (*first revision*)
1954 : 1990	Determination of length and width of woven fabrics – Methods (*second revision*)
IS 1966 (Part 2): 2009/ ISO 13938-2 : 1999	Textiles — Bursting properties of fabrics — Determination of bursting strength and bursting distension: Part 2 Pneumatic method (*second revision*)
6359 : 1971	Method for conditioning of textiles
13162 (Part 2) : 1991	Geotextiles — Methods of test: Part 2 Determination of resistance to the exposure of ultraviolet light and water (Xenon-Arc type apparatus)
13321 (Part 1) : 1992	Glossary of Terms for geosynthetics: Part 1 Terms used in materials and properties
14293 : 1995	Geotextiles — Method of test for trapezoid tearing strength
14294 : 1995	Geotextiles — Method for determination of apparent opening size by dry sieving technique
14324 : 1995	Geotextiles — Methods of test for determination of water permeability-permittivity
14706 : 1999	Geotextiles — Sampling and preparation of test specimens
15060 : 2001/ISO 10321 : 1992	Geotextiles — Tensile test for joints/ seams by wide-width method
16078 : 2013	Geosynthetics — Static puncture test (CBR test)
16342 : 2015	Geosynthetics — Method of test for grab breaking load and elongation of geotextiles
16380 : 2015	Geosynthetics — Method of test for measuring geosynthetic pullout resistance in soil

ANNEX B

(*Clause* 4.2)

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

B-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's. 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 dimethyl isophthalate using an internal standard.

B-2 POTENTIAL ENVIORMENT ISSUE

B-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.

B-2.2 Hydrogen, nitrogen and instrument air are used during analysis. The hydrogen gas has no adverse ecological effects are expected. 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.

B-3 POTENTIAL SAFETY, OCCUPATIONAL HEALTH ISSUES

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

B-3.2 Glassware is to be handled with care.

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

B-3.4 Glassware is to be handled with care.

B-3.5 Inhalation of chloroform causes dilation pupils with reduced reaction to light as well as reduced intraocculat pressure, Irritation of mucous membrane, conjunctiva. If contacted with skin and eyes cause irritation. Seek medical advice if inhaled.

B-3.6 Use leather hand gloves while handling hot apparatus and equipments.

B-4 APPARTUS

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

B-4.2 Capillary Column, 60 m length and 0.53 mm ID.

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

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

B-4.5 Beaker

B-4.6 Funnel

B-4.7 50 ml Flask

B-4.8 Heating Mental, to maintain temperature of 250°C.

B-4.9 AR Grade Dimethyl Isopthalate (DMI)

B-4.10 AR Grade Benzyl Alcohol

B-4.11 AR Grade Chloroform

B-4.12 AR Grade Isopropyl Titnate

B-4.13 AR Grade Dimethyl Suburate

B-5 PREPARATION OF STANDARD SOLUTIONS

B-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 2ml ≈ X·XXXX mg

B-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.

B-5.3 Standard Solution for Response Factor

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

B-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 reagent 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.

B-5.5 2.0 Percent Standard IPA Solution for GC Injection

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

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

B-7 ANALYTICAL PROCEDURE

Inject 1 µl of standard solution for response factor (*see* **B-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* **B-5.3**). Weight 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 **B-5.1** and shake vigorously. Inject 1 µl of sample solution into gas chromatograph.

B-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

B-9 CALCULATION

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

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.

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

ANNEX C

(*Table* 1)

METHOD OF TEST FOR DETERMINING THE COEFFICIENT OF SOIL AND GEOSYNTHETIC FRICTION BY THE DIRECT SHEAR

C-1 PRINCIPLE

C-1.1 The shear resistance between a geosynthetic and a soil, or other material selected by the user, is determined by placing the geosynthetic and one or more contact surfaces, such as soil, within a direct shear box. A constant normal force representative of design stresses is applied to the specimen, and a tangential (shear) force is applied to the apparatus so that one section of the box moves in relation to the other section. The shear force is recorded as a function of the horizontal displacement of the moving section of the shear box.

C-1.2 The test is performed at a minimum of three different normal stresses, selected by the user, to model appropriate field conditions. The limiting values of shear stresses are plotted against the applied normal compressive stresses used for testing. The test data are generally represented by a best fit straight line whose slope is the coefficient of friction between the two materials where the shearing occurred. The y-intercept of the straight line is the adhesion.

C-2 APPARATUS

C-2.1 Shear Device — A rigid device to hold the specimen securely and in such a manner that a shear force without torque can be applied to the specimen. The device consists of both a stationary and moving container, both of which are capable of containing dry or wet soil and are rigid enough to not distort during shearing of the specimen. The travelling container shall be placed on firm bearings and rack, or other mechanism, to ensure that the movement of the container encounters low friction and is only in a direction parallel to that of the applied shear force.

NOTE — The position of one of the containers shall be adjustable in the normal direction to compensate for deformation of the substrate and geosynthetic. The container shall also be aligned to minimize any moment produced by non-colinear forces on the containers.

C-2.1.1 *Square or Rectangular Containers,* are recommended and they shall have a minimum dimension that is the greater of 300 mm, 15 times the d_{85} of the coarser soil used in the test, or a minimum of five times the maximum opening size (in plan) of the geosynthetic tested. The depth of each container that contains soil shall be a minimum of 50 mm or six times the maximum particle size of the coarser soil tested, whichever is greater.

NOTE — d_{85} is the equivalent grain diameter (mm) at which 85 percent of the soil is finer by weight.

C-2.2 Normal Stress Loading Device, capable of applying and maintaining a constant uniform normal stress on the specimen for the duration of the test. Careful control and accuracy (62 percent) of the normal stress is important. Normal stress loading devices include, but are not limited to, weights, pneumatic or hydraulic bellows, or piston-applied stresses. For jacking systems, the tilting of loading plates shall be limited to 2° from the shear direction during shearing. The device shall be calibrated to determine the normal stress delivered to the shear plane.

C-2.3 Shear Force Loading Device, capable of applying a shearing force to the specimen at a constant rate of displacement in a direction parallel to the direction of travel of the moving container. The horizontal force measurement system shall be calibrated, including provisions to measure and correct for the effects of friction and tilting of the loading system. The rate of displacement shall be controlled to an accuracy of 610 percent over a displacement range of at least 6.35 mm/min to 0.025 mm/min. The system shall allow constant measurement and readout of the shear force applied. An electronic load cell or proving ring arrangement is generally used. The shear force loading device shall be connected to the test apparatus in such a fashion that the point of the force application to the traveling container is in the plane of the shearing interface and remains the same for all tests.

C-2.4 Displacement Indicators, for providing readout of the horizontal shear displacement and, if desired, vertical displacement of the specimen during the consolidation or shear phase. Displacement indicators such as dial indicators, or linear variable differential transformers (LVDT), capable of measuring a displacement of at least 75 mm for horizontal displacement and 25 mm for vertical displacement are recommended. The sensitivity of displacement indicators shall be 0.02 mm for measuring horizontal displacement.

C-2.5 Geosynthetic Clamping Devices, required for fixing geosynthetic specimens to the stationary section or container, the traveling container, or both, during shear. Clamps shall not interfere with the shearing surfaces within the shear box and shall keep the geosynthetic specimens flat during testing. Flat jaw-like clamping devices are normally sufficient. Textured surfaces or soil shall be used to support the top and/or bottom of the geosynthetic. These surfaces shall permit flow of water into and out of the test specimens. Selection of the type of texture surface shall be based on the following criteria:

a) The gripping surface shall be able to prevent the outside surface of the geosynthetic being sheared from slipping to the extent that the geosynthetic fails.
b) The gripping surface shall be able to completely transfer the shear stress through the outside surfaces into the geosynthetic.
c) The gripping surface shall not damage the geosynthetic and shall not influence the shear strength behavior of the geosynthetic.

C-2.6 Soil Preparation Equipment, for preparing or compacting bulk soil samples.

C-2.7 Miscellaneous Equipment, as required for preparing geosynthetic specimens. A timing device and equipment required for maintaining saturation of the geosynthetic or soil samples, if desired.

C-3 GEOSYNTHETIC SAMPLING

Take a minimum of three specimens for shearing in a direction parallel to the machine (or roll) direction of the laboratory sample and three specimens for shearing in a direction parallel to the cross-machine (cross-roll) direction. The specimens shall be sufficiently large to fit snugly in the container described in **C-2.1.1** and they shall be of sufficient size to facilitate clamping. All specimens shall be free of surface defects, etc. Take no specimens nearer the selvage or edge of the geosynthetic production unit than 1/10 the width of the unit.

C-4 CONDITIONING

Bring the specimens to moisture equilibrium in the atmosphere for testing textiles as specified in IS 6359.

C-5 PROCEDURE

C-5.1 Place soil or rigid substrate in the lower container, as required. Compact the soil at the specific moisture content to the density desired. If soil is used, fill the lower container with soil so that the surface of the soil specimen protrudes a distance equal to one-half of the d_{85} of the soil. A protrusion of 1 mm is sufficient for fine-grained soils. Level the soil surface carefully.

C-5.2 Place the geosynthetic specimen loosely over the substrate. Remove all folds and wrinkles in the geosynthetic. Clamp or otherwise fix the end of the specimen temporarily, and reset it to ensure that the geosynthetic specimen is in complete contact with the soil. Verify that the protrusion of the soil substrate is suitable as outlined in **C-5.1**.

C-5.3 Fix the two halves of the shear box in the start position. Clamp or fix the upper half of the shear box so that it cannot move during the next step of preparation.

C-5.4 Place the upper substrate or soil at the desired density and moisture content in a manner that minimizes damage to the geosynthetic specimen. Apply the seating normal stress.

C-5.4.1 Apply the normal seating load.

C-5.4.2 If the seating load does not equal the normal load for testing, apply the normal load for testing and monitor the vertical displacements until the sample comes to equilibrium. Verify that equilibrium is reached before proceeding.

C-5.4.3 After the consolidation period, reclamp the geosynthetic specimen to the upper or lower container, as required.

C-5.5 Place the displacement indicators and assemble the shear loading device. Create a gap between the upper box and lower box. The gap shall be large enough to prevent friction between the boxes during shear but small enough to prevent soil particles from entering into the gap and creating friction. If necessary, adjust the location of the horizontal loading ram to minimize the induced moment.

C-5.6 Apply the shear force at a rate of 1 mm/min.

C-5.7 Record the shear force as a function of horizontal displacement. Record a minimum of 50 data points per test.

C-5.8 Run the test until the applied shear force remains constant with increasing displacement. Displacements ranging from 25 to 75 mm are generally required to generate a constant shear force for shearing between geosynthetic and soil interfaces.

C-5.9 Remove the normal stress and disassemble the device at the end of the test. Carefully inspect and identify the failure surface and the area of the clamp. Failures shall be consistent for all tests in order for the test data to be comparable.

C-5.10 At the end of the test, remove the soil specimen (if used) to determine the density and moisture content.

C-5.11 Repeat the procedure for a minimum of two additional normal compressive stresses.

C-5.12 Plot the test data as a graph of applied shear force versus horizontal displacement. For this plot, identify the limiting value(s) of shear force. Determine the horizontal displacements for these shear forces.

C-6 CALCULATION

C-6.1 For tests using soil, calculate the initial and final water content, unit weight, and degree of saturation, if required.

C-6.2 Calculate the apparent shear stress applied to the specimen for each recorded shear force as follows:

$$T = \frac{F_s - F_{cor}}{A_c}$$

where

T = shear stress, in kPa;

F_s = shear force, in KN;

F_{cor} = correction to shear force for friction, in kN; and

A_c = corrected area, in m^2.

C-6.2.1 For tests in which the area of specimen contact decreases with increased displacement, a corrected area shall be calculated. This shall occur in test devices in which the stationary and travelling containers have the same overall plan dimensions. In this case, the actual contact area will decrease as a function of horizontal displacement of the travelling container. For square or rectangular containers, the corrected area is calculated for each displacement reading using the following equation:

$$A_c = A_o - (d \times W)$$

where

A_c = corrected area, in m^2;

A_o = initial specimen contact area, in m^2;

d = horizontal displacement of the travelling container, in m; and

W = specimen contact width in a direction perpendicular to that of shear force application, in m.

C-6.2.2 No area correction may be required for tests in which the stationary container is larger than the travelling container, provided that the horizontal displacement of the travelling container does not result in a decrease in specimen contact area.

NOTE — For devices which apply the normal stress to the interface as a constant force, for example by dead weights, any area correction applied to the shear force shall also be applied to the normal force.

C-6.3 Plot the limiting values of shear stress *versus* applied normal stress for each test conducted. Limiting values are typically at peak shear stress and at the end of the test. Other limiting values may be specified by the user. The shear stress and normal stress axes shall be drawn to the same scale.

C-6.4 Connect the data points with a straight line. Some judgment and experience may be required to construct this line, which is referred to as the strength envelope. The slope of the failure envelope is the coefficient of friction. The angle of friction is determined using the following equation:

$$d_p = \tan^{-1} (W_p)$$

where

d_p = angle of friction corresponding to the limiting shear stress (degrees), and

W_p = coefficient of friction corresponding to the limiting shear stress. Friction angle and adhesion intercept are typically reported for the peak shear stress condition.

C-6.5 Additionally, the coefficient of friction may be calculated at some condition other than peak horizontal force, such at a specific value of shear displacement or at the end of the test. The procedure given in **C-6.4** can be used to determine a friction angle and adhesion intercept, using the shear stress and normal stress for this other condition. Parameters obtained for a condition other than peak horizontal force shall be clearly defined and the condition for which they apply defined.

ANNEX D

(*Foreword*)

COMMITTEE COMPOSITION

Geosynthetics Sectional Committee, TX 30

Organization	*Representative(s)*
The Bombay Textile Research Association, Mumbai	Dr A. N. Desai (***Chairman***) Shri V. K. Patil (*Alternate*)
Business Coordination House, New Delhi	Shri Samir Gupta Shrimati Ritika Gupta (*Alternate*)
Central Road Research Institute, New Delhi	Shri Sudhir Mathur Shri Jai Bahagwan (*Alternate*)
Central Soil and Materials Research Station, New Delhi	Shri Nripendra Kumar Shri Manish Gupta (*Alternate*)
CIDCO, Mumbai	Representative
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Member Secretary
SHRI J. K. GUPTA
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