IS 6874 (2008): Method of tests for bamboo [CED 9: Timber and Timber Stores]

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(पहला पुनरीक्षण)

Indian Standard

METHOD OF TESTS FOR BAMBOO

(First Revision)

ICS 79.060.20

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 2008

Price Group 5

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Timber and Timber Stores Sectional Committee had been approved by the Civil Engineering Division Council.

Bamboo occupies a prominent place in everyday life and is extensively used for both structural and non-structural purposes. Being a material that compares favourably with timber in strength, bamboo is increasingly being used in many structural applications like posts, pole fencing, scaffoldings, house building, etc. In order to ascertain the suitability of bamboo for various structural uses, their physical properties are required to be tested. IS 6874 : 1973 'Method of tests for round bamboo' and IS 8242 : 1976 'Methods of tests for split bamboos' were developed for this purpose.

This standard was first published in 1973. Based on technological advancements made in the field leading to increased use of bamboo and the experience gained, a need was felt to redefine the test methods and to develop new test methods for determining additional properties. Recent studies have indicated that the suggested method for testing round bamboo in static bending in smaller length specimens does not reflect the strength potential of bamboo in longer lengths. As round bamboo is used normally in longer lengths in structural applications, the method of test in static bending has accordingly been modified in this revision. Further, test methods for determining additional properties like tensile strength parallel to grain and shear strength parallel to grain have been incorporated. The revision has been undertaken with the assistance of National Mission on Bamboo Application and is based on studies carried out by Kerala Forest Research Institute, Peechi.

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

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to rounded off, it should be done in accordance with IS2 : 1960 'Rules for off numerical values *(revised)*'.

AMENDMENT NO. 1 JUNE 2012
TO
IS 6874 : 2008 METHOD OF TESTS FOR BAMBOO

(First Revision)

(*Foreword, last para*) — Substitute the following for the existing:

"In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated expressing the result of a test or analysis is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values *(revised)*'."

(*Page* 2, *clause* **5.2.3**) — Substitute the following for the existing formula for Basic mass per volume:

$$\text{'Mass per volume, in kg/m}^3 = \frac{m_o}{V_g} \times 1\ 000$$

where

m_o = oven dry mass, in g; and

V_g = green volume, in cm^3.'

(CED 9)

Reprography Unit, BIS, New Delhi, India

Indian Standard

METHOD OF TESTS FOR BAMBOO

(First Revision)

1 SCOPE

This standard lays down method of tests for determining the following physical and mechanical properties of round bamboo:

a) Physical properties:
   i) Moisture content,
   ii) Basic mass per volume or density, and
   iii) Shrinkage.

b) Mechanical properties:
   i) Static bending strength,
   ii) Compressive strength parallel to grain,
   iii) Tensile strength parallel to grain, and
   iv) Shear strength parallel to grain.

2 REFERENCE

The following standard contains provision, which through reference in this text constitutes provision of this standard. At the time of publication, the edition indicated was 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 edition of the standard indicated below:

IS No.	*Title*
707 : 1976	Glossary of terms applicable to timber technology and utilization (*second revision*)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 707 and the following shall apply.

3.1 Bamboo Clump — A cluster of bamboo culms.

3.2 Bamboo Culm — A single shoot of bamboo, fully grown and usually hollow, except at nodes which are often swollen.

3.3 Clear Span — The distance between the two supports in static bending test. This shall be at least 30 times the outside diameter at the middle of the test specimen.

3.4 Internode — The portion of a culm between two successive nodes.

3.5 Node — Thickening of bamboo at intervals along its length. The walls are thicker on both sides of the node or the place in a bamboo culm where branches sprout and where a diaphragm is inside the culm.

3.6 Outer Diameter — Diameter of a cross-section of a piece of bamboo measured from two opposite points on the outer surface.

3.7 Wall Thickness — Thickness of the culm wall. It is measured at two places at either end of a test specimen.

4 TEST CULMS

4.1 Sampling

For a particular bamboo species to be tested, at least six mature culms shall be randomly selected from a large population, one culm each from clumps located in representative areas covering the geographical range of the species. If the species have pronounced taper, variation in culms due to taper shall be minimum. The culms shall be sound and free from defects.

4.1.1 *Permissible Defects*

Discolouration which is a change from the normal colour of the bamboo, which does not impair the strength, shall be permitted.

4.1.2 *Non-permissible Defects*

Borer attack and decay in the culms shall not be permitted. Splits/cracks and blue stains are also not permissible as these defects affect strength properties.

4.2 Marking, Felling and Conversion

Before felling, a ring shall be marked with paint on the culm at a height of one metre from the ground and also other details above the ring. The culms shall be felled according to standard harvesting practices. After felling the culm, the unusable parts from the culm bottom (crooked portion with very short internodes) and culm top (very low diameter and thin wall) shall be removed. The remaining culm length shall be measured and the culm shall be cut into two or three parts keeping in mind that for static bending, the length of the specimen shall be at least 30 times the outer diameter plus one metre. The parts to be used shall be marked with a ring at the lower end and its position in the culm shall be marked as *B* (bottom), *M* (middle) or *T* (top) along with other required details.

For the determination of physical properties like basic mass per volume and shrinkage, test specimens shall be prepared from freshly felled bamboo.

4.3 Air-Drying and Conditioning

For the determination of mechanical properties, the culms shall be air-dried to about 12 percent moisture content. To be able to compare test results, the culms shall be conditioned at 27 ± 2°C and 65 ± 5 percent relative humidity at least for a week, so as to reach an equilibrium moisture content of 12 percent, before they are tested. Care shall be taken to ensure that large changes in moisture content do not take place during testing. The number of specimens in each test shall be not less than 12 (two from each culm).

5 PHYSICAL PROPERTIES

5.1 Moisture Content

5.1.1 *Test Specimens*

The specimens for determining moisture content shall generally be taken from the tested specimens for mechanical testing, immediately after completion of each test and, as far as possible, from near the place of failure. It shall be about 25 mm in length and 25 mm in width and having full wall thickness. In the case of shear test, the detached portion shall be taken for determination of moisture content.

When moisture content of any other specimen, other than from the test specimens for mechanical tests, is to be determined, these shall be taken at least 150 mm away from the nearest edge of the culm.

The test specimens shall immediately be put in a polythene bag in order to ensure no loss of moisture.

5.1.2 *Procedure*

The test specimens shall be weighed (m_i) to an accuracy of 0.01 g and then dried in a hot-air oven at a temperature of 103 ± 2°C for 24 h. The test specimen shall then be weighed and drying continued thereafter. The weighing shall be carried out and recorded every 2 h until the difference between successive weighings does not exceed 0.01 g, when the drying shall be completed. The final mass shall be considered as the oven dry mass (m_o).

Care shall be taken to prevent any change in moisture content between the cutting of the specimen and the first weighing, and between the removal from the oven and subsequent weighings.

5.1.3 *Calculation*

The moisture content of each test specimen shall be calculated as the loss in mass, expressed as a percentage of the oven dry mass.

$$\text{Moisture content, percent} = \frac{m_i - m_o}{m_o} \times 100$$

where

m_i = initial mass of the test specimen, in g; and

m_o = oven dry mass, in g.

The moisture content shall be reported with values rounded to one-tenth of a percent.

5.2 Basic Mass per Volume or Density

5.2.1 *Test Specimens*

The test specimens for determining basic mass per volume shall be taken from freshly felled culms at different positions of the culm (base, middle and top). It shall be about 25 mm in length and 25 mm in width with full wall thickness. This test will also enable determination of the moisture content of the green specimen.

NOTE — For comparing reported values, basic mass per volume is the appropriate one as it depends only on green volume and oven dry mass which do not change due to weather conditions. However, if one is interested to determine mass per volume of a test specimen at any moisture content, for example, in air-dry condition, the volume is measured at that moisture content.

5.2.2 *Procedure*

The test specimens shall be weighed to an accuracy of 0.01 g. The green volume shall be measured by water displacement method. A simple way is to place a beaker containing water on a top-pan balance and tare the weight to zero. The test specimen attached to a sharp needle shall then be completely immersed in water while ensuring that the specimen does not touch the beaker. The reading in the balance would indicate the mass of the displaced water.

Considering the specific gravity of water as 1.0, this reading shall be considered as the volume of the test specimen, in cm^3 (V_g).

After determining the green volume, the test specimen shall be dried in a hot-air oven as described in **5.1.2** to obtain the oven dry mass (m_o).

5.2.3 *Calculation*

Basic mass per volume shall be calculated as given below:

$$\text{Mass per volume, in kg/m}^3 = \frac{m_o}{V_g} \times 100$$

where

m_o = oven dry mass, in g; and

V_g = green volume, in cm^3.

The mass per volume shall be reported with values rounded to the nearest kg/m^3. If V_w corresponds to the volume of the test specimen at a particular moisture content, w, then the mass per volume at that moisture content, shall be determined using V_w.

5.3 Shrinkage

5.3.1 *Test Specimens*

The test specimens shall be taken from freshly felled culms, preferably from the lowest section of the culm. Specimens shall be 100 mm in length and free from nodes.

5.3.2 *Procedure*

Shrinkage shall be determined along diameter, wall thickness and length of the test specimen. Length and diameter shall be measured correct to 1 mm while the wall thickness shall be correct to 0.1 mm.

Suitable marking shall be done on the specimens (*see* Fig. 1) to facilitate taking observations at the same place every time. On each specimen, dimensions of four diameters and four wall thicknesses (two at either end) and two lengths shall be measured. The specimens shall be allowed to dry slowly. Mass and dimensions of diameter, wall thickness and length of the specimens shall be recorded periodically until the readings are constant (air-dry condition). The specimens shall then be placed in a hot-air over at 103 ± 2°C till it reaches a constant weight (oven-dry condition). The mass and dimensions of the specimens shall be taken at the oven-dry condition.

5.3.3 *Calculation*

Shrinkage percentage (along diameter or wall thickness or length) correct to one decimal place shall be calculated as follows:

$$\text{Shrinkage along diameter, percent} = \frac{D_i - D_f}{D_i} \times 100$$

$$\text{Shrinkage along wall thickness, percent} = \frac{t_i - t_f}{t_i} \times 100$$

$$\text{Shrinkage along length, percent} = \frac{l_i - l_f}{l_i} \times 100$$

where

D_i, t_i, l_i = initial dimensions of outer diameter, wall thickness and length, respectively, in mm; and

D_f, t_f, l_f = final dimensions of outer diameter, wall thickness and length, respectively, in mm.

From the various readings of mass and finally the oven dry mass, corresponding moisture content of the test specimen and shrinkage at that moisture content can be determined.

6 MECHANICAL PROPERTIES

6.1 Static Bending Strength

6.1.1 *Test Specimens*

The test specimens, free from defects like cracks and crookedness, shall be taken from the air-dried and conditioned culms. The test specimens shall be free from wide varying taper. The length of the specimens shall be at least 30 times diameter at the middle point plus 1 m.

6.1.2 *Testing Machine*

A suitable testing machine capable of measuring load to the nearest 100 N and deflection to the nearest 1 mm shall be used.

The test shall be a four-point bending test. The test specimen shall be mounted on suitable saddles [*see* Fig. 2A] in such a way that the reaction forces at the supports are transmitted to the nearby nodes. The bamboo culm shall be allowed to rotate freely at the supports. The load shall be divided into two halves by

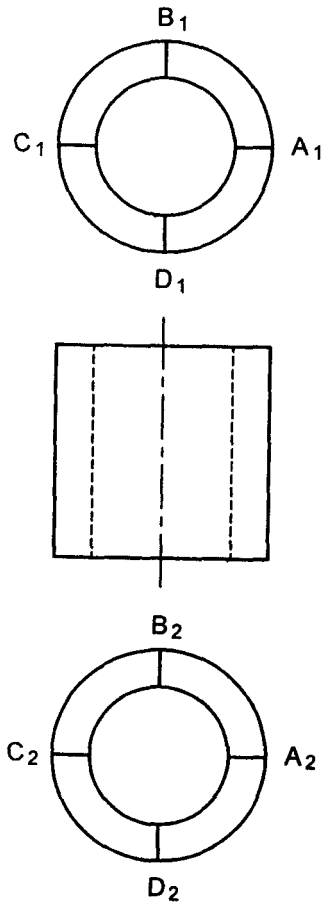


FIG. 1 MEASUREMENT OF DIAMETER AND WALL THICKNESS

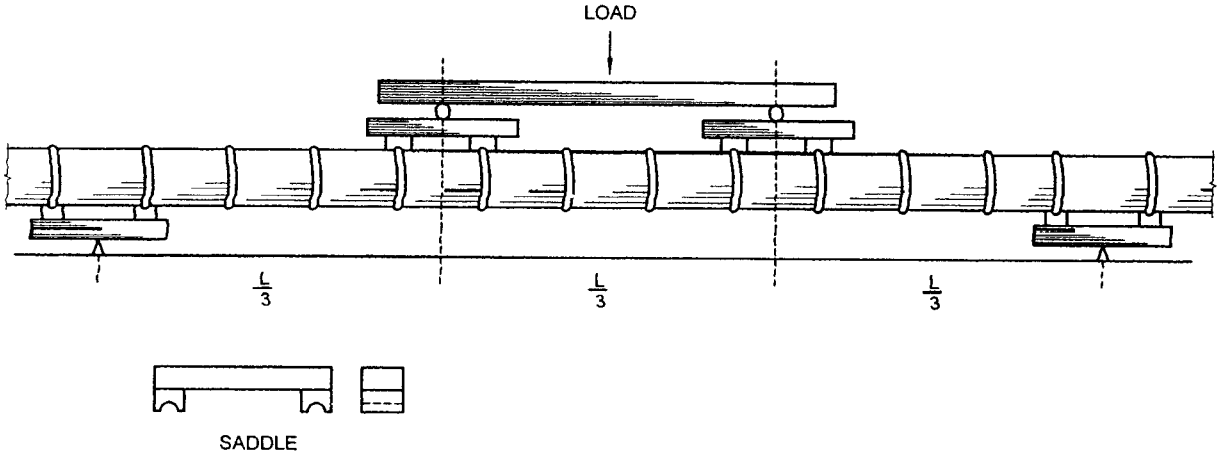
an appropriate beam resting on saddles in such a way that the loads are applied to the nodes [*see* Fig. 2B)]. The length of the specimen shall be suitable to have a clear span of 30 times its diameter at the middle point.

6.1.3 *Procedure*

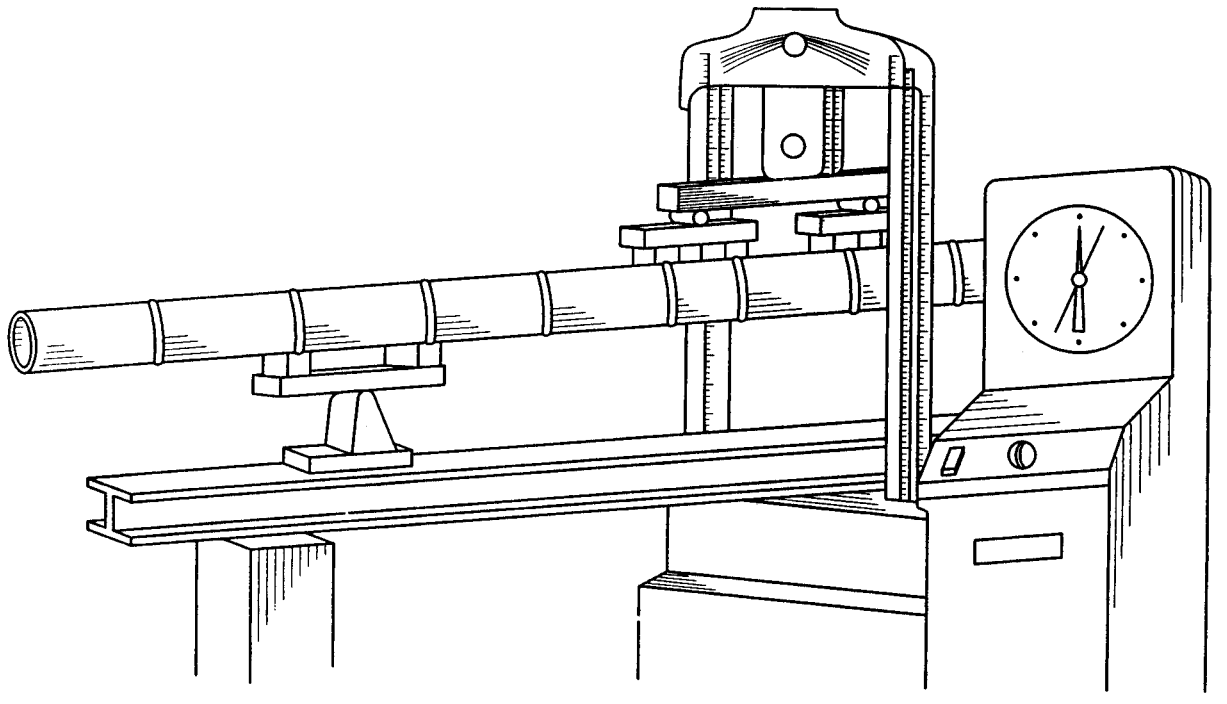
An I-beam of suitable length to support the test specimen shall be kept at right angle to the platform of the testing machine. As shown in Fig. 2, the test specimen shall be placed on supports with saddles and a wooden beam shall be placed over the specimen using saddles in such a way that load is applied through the loading head of the testing machine. The test specimen shall be allowed to find its own position; the specimen, saddles, load and supports shall be aligned visually in one vertical plane.

The loading of the test specimen shall be carried out uniformly at constant speed. The loading head of testing machine shall move at the rate of 0.5 mm/s.

Deflection at the middle of the span shall be noted by means of a dial gauge at load increments of every 500 N. The load shall be recorded at the points of sudden changes in deflection, at the time of failure and at maximum level, if different from the load at failure. Crack development and the form of failure shall be noted. A load-deflection diagram shall be plotted.



2A Method of Applying Load and Supporting Bamboo with Saddles



2B Four Point Bending Test

FIG. 2 STATIC BENDING STRENGTH TEST

After the test, the outer diameter D and wall thickness t, as close to the points of load as possible, shall be measured (*see* **5.3.2**).

6.1.4 *Calculation*

a) The moment of inertia I in mm^4, shall be calculated as follows:

$$I = \frac{\pi}{64}\left[D^4 - (D-2t)^4\right]$$

where

D = outer diameter, in mm; and

t = wall thickness, in mm.

b) The ultimate strength σ_{ult} in static bending, in N/mm^2, shall be determined as follows:

$$\sigma_{ult} = \left[\frac{1}{6I}\left(FL\frac{D}{2}\right)\right]$$

where

I = moment of inertia, in mm^4;

F = maximum load, in N;

L = effective span, in mm; and

D = outer diameter, in mm.

σ_{ult} shall be reported to an accuracy of 1 N/mm^2.

c) The modulus of elasticity (Young's modulus), E, in N/mm^2, shall be determined as follows:

$$E = \frac{23\,s\,L^3}{1\,296\,I}$$

where

L = clear span, in mm;

I = moment of inertia, in mm^4; and

s = slope of a linear part in the load-deflection diagram, in N/mm.

E shall be reported by rounding to the nearest 100 N/mm^2.

6.2 Compressive Strength Parallel to Grain

6.2.1 *Test Specimens*

Specimens for compressive strength tests shall be taken from the undamaged ends of specimens used in static bending tests. The test specimens shall be from internode.

The length of the specimen shall be taken equal to the outer diameter. Outer diameter and wall thickness shall be measured as described in **5.3.2**.

The end planes of the specimen shall be perfectly at right angles to the length of the specimen; the end planes shall be flat, with a maximum deviation of 0.2 mm.

6.2.2 *Testing Machine*

At least one platen of the testing machine shall be equipped with a hemispherical bearing to obtain uniform distribution of load over the ends of the specimen (Unlike while testing timber specimen, bamboo test specimens shall be dipped in molten sulphur or a layer of Teflon and wax shall be kept between bamboo test specimen and steel platens, to reduce friction to a minimum. This is mainly because of the hollow nature of bamboo).

6.2.3 *Procedure*

The specimen shall be placed so that the centre of the movable head is vertically above the centre of the cross-section of the specimen and a small load of not more than 1 kN shall be applied to set the specimen.

The load shall be applied continuously and the movable head of the testing machine shall travel at a constant rate of 0.01 mm/s.

The maximum load at which the specimen fails shall be recorded.

6.2.4 *Calculation*

The maximum compressive strength σ_{ult}, in N/mm^2, shall be determined as follows:

$$\sigma_{ult} = \frac{F_{ult}}{A}$$

where

F_{ult} = maximum load, in N;

A = area of cross-section of test specimen $\frac{\pi}{4}\left[D^2 - (D-2t)^2\right]$, in mm^2;

D = outer diameter, in mm; and

t = wall thickness, in mm.

σ_{ult} shall be rounded to the nearest 0.5 N/mm^2.

6.3 Tensile Strength Parallel to Grain

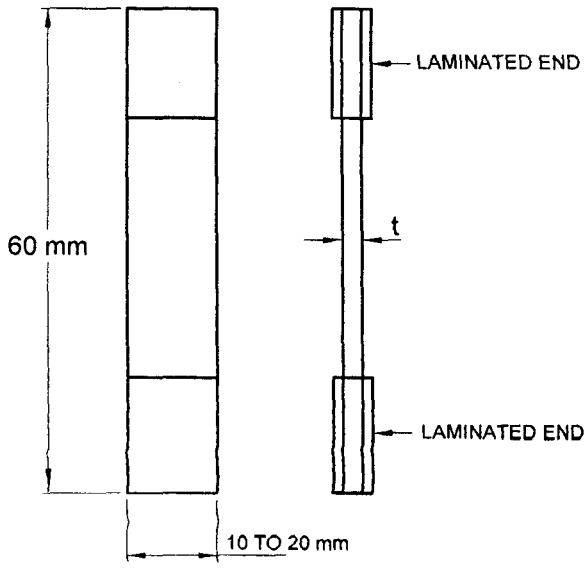
6.3.1 *Test Specimens*

Specimens for tensile strength test shall be taken from the undamaged ends of specimens used in static bending tests. The test specimens shall be with one node in the centre.

The general direction of the fibres shall be parallel to the longitudinal axis of the test specimen. The length of the specimen shall be 60 mm and the width shall be 10 to 20 mm, so that the test specimen is more or less flat. The thickness of the specimen shall be that of the

wall thickness or less, depending on the diameter of the culm. All the dimensions shall be measured to an accuracy of 0.1 mm.

It shall be permitted to use test pieces with laminated ends for better grip, as shown in Fig. 3.



t = Thickness of the test specimen

FIG. 3 TENSILE STRENGTH TEST SPECIMEN

6.3.2 *Testing Machine*

The grips of the testing machine shall ensure that the load is applied along the longitudinal axis of the test piece, and shall prevent longitudinal twisting of the test piece.

6.3.3 *Procedure*

The grips shall press the test specimen perpendicular to the fibres and in radial direction.

The load shall be applied continuously and the movable head of the testing machine shall travel at a constant rate of 0.01 mm/s. The maximum load shall be recorded.

6.3.4 *Calculation*

The maximum tensile strength σ_{ult}, in N/mm^2, shall be determined as follows:

$$\sigma_{ult} = \frac{F_{ult}}{A}$$

where

F_{ult} = maximum load, in N; and

A = area of cross-section of test specimen, in mm^2.

σ_{ult} shall be rounded to the nearest full number.

6.4 Shear Strength Parallel to Grain

6.4.1 *Test Specimens*

Specimens for shear strength tests shall be taken from the undamaged ends of the specimens used in static bending tests. The test specimens shall be from internode. The length of the specimen shall be taken equal to the outer diameter. Outer diameter and wall thickness shall be measured as described in **5.3.2**. The end planes of the specimen shall be at right angles to the length of the specimen; the end planes shall be flat.

6.4.2 *Testing Machine/Jig*

The tests shall be carried out in a suitable testing machine. The specimens shall be supported at the lower end over a steel block of two triangles opposite to one another. A square steel block shall be cut diagonally in such a way so that two opposite triangles are still intact and two other triangles are separate. The test specimen shall be loaded at the upper end over the other two independent triangular blocks (*see* Fig. 4). This results in four shear areas.

6.4.3 *Procedure*

The specimen shall be placed between steel triangular blocks as explained in **6.4.2**, in such a way that the centre of the movable head is vertically above the centre of the cross-section of the specimen. A small load of not more than 1 kN shall be applied to set the specimen.

The load shall be applied continuously and the movable head of the testing machine shall travel at a constant rate of 0.01 mm/s.

The maximum load at which the specimen fails and the number of shear areas that fail shall be recorded.

6.4.4 *Calculation*

The ultimate shear strength σ_{ult}, in N/mm^2, shall be determined as follows:

$$\sigma_{ult} = \frac{F_{ult}}{L\,t}$$

where

F_{ult} = maximum load, in N;

t = mean of wall thickness at four points, in mm; and

L = mean of length of test specimen at four points where wall thickness is measured, in mm.

σ_{ult} shall be rounded to the nearest whole number.

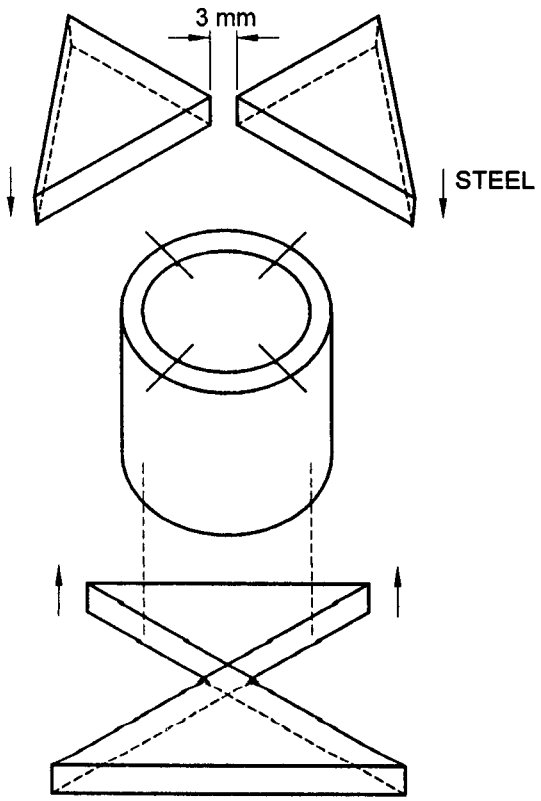


FIG. 4 TRINGULAR BLOCKS FOR SHEAR TEST

ANNEX A

(*Foreword*)

COMMITTEE COMPOSITION

Timber and Timber Stores Sectional Committee, CED 9

Organization	*Representative(s)*
In personal capacity *(2989/D, 12th Main, HAL II Stage, Bangalore 560008)*	SHRI SHYAM SUNDER (***Chairman***)
Andaman Chamber of Commerce & Industries, Kolkata	SHRI HARISH KHAITAN
Bamboo and Cane Technology Centre, Guwahati	PROJECT COORDINATOR
Bamboo Society of India, Bangalore	SHRI A. C. LAKSHMANA DR K. A. KUSHALAPPA (*Alternate*)
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Directorate General of Civil Aviation, New Delhi	DIRECTOR GENERAL
Directorate General of Supplies & Disposals, New Delhi	DIRECTOR GENERAL
Directorate of Standardization, New Delhi	DIRECTOR
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI C. R. SAHA SHRI N. B. SHELAR (*Alternate*)
Federation of Indian Plywood & Panel Industry, New Delhi	SHRI SAJJAN BHAJANKA SECRETARY (*Alternate*)
Forest Department, Bhopal	PRINCIPAL CHIEF CONSERVATOR OF FORESTS
Forest Department, Raipur	PRINCIPAL CHIEF CONSERVATOR OF FORESTS

Organization	*Representative(s)*
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Indian Academy of Wood Science, Bangalore	PRESIDENT
Indian Council of Forestry Research and Education, Dehra Dun	DIRECTOR GENERAL
Indian Plywood Industries Research & Training Institute, Bangalore	DIRECTOR SHRI S. PADMANABHAN (*Alternate*)
Institute of Wood Science & Technology, Bangalore	DIRECTOR DR R. V. RAO (*Alternate*)
Karnataka State Forest Industries Corporation Ltd, Bangalore	SHRI V. P. HIRAMATH SHRI S. SHIVA PRAKASH (*Alternate*)
Kerala Forest Research Institute, Peechi	DIRECTOR DR GNANAHARAN (*Alternate*)
Kutty Flush Doors & Co Pvt Ltd, Chennai	SHRI K. SANKARA KRISHNAN COL Y. G. KRISHNAN (*Alternate*)
Ministry of Defence, Gwalior	DIRECTOR SHRI H. C. PANT (*Alternate*)
Ministry of Environment & Forests, New Delhi	DEPUTY INSPECTOR GENERAL OF FORESTS
Rubber Board, Kottayam	DIRECTOR
Timber Development Association of India, Dehra Dun	SECRETARY
Wimco Limited, Mumbai	CHIEF EXECUTIVE OFFICER
In personal capacity (*606 B, I Block, III Stage, UVCE Layout, WOC Road, Basaveshwaranagar Bangalore-560079, Karnataka*)	SHRI K. DAMODARAN
BIS Directorate General	SHRI A. K. SAINI, Scientist 'F' & Head (CED) [Representing Director General (*Ex-officio*)]

Member Secretary
SHRI J. ROY CHOWDHURY
Scientist 'E' (CED), BIS

Timber Terminology, Conversion, Seasoning, Preservation, Grading and Testing Subcommittee, CED 9 : 1

Institute of Wood Science & Technology, Bangalore	DR R. V. RAO (***Convener***)
Andaman Timber Industries, Kolkata	SHRI HARISH KHAITAN
ASCU Hickson Limited, Kolkata	SHRI RAJIV AGARWAL SHRI J. BASU (*Alternate*)
Borax Morarji, Coil	SHRI H. T. KAPADIA SHRI S. RANGARAJAN (*Alternate*)
Building Materials Technology Promotion Council, New Delhi	REPRESENTATIVE
Central Building Research Institute, Roorkee	DIRECTOR SHRI B. S. RAWAT (*Alternate*)
Central Mining Research Station (CSIR), Dhanbad	DIRECTOR
Controllerate of Quality Assurance, Kanpur	DIRECTOR
Directorate General of Civil Aviation, New Delhi	DIRECTOR GENERAL
Directorate General of Supplies & Disposals, New Delhi	DIRECTOR GENERAL
Directorate of Standardization, New Delhi	DIRECTOR
Federation of Indian Plywood & Panel Industry, New Delhi	SHRI JAYDEEP CHITLANGIA SECRETARY (*Alternate*)
Forest Department, Bangalore	PRINCIPAL CHIEF CONSERVATOR OF FORESTS
Forest Department, Dehra Dun	PRINCIPAL CHIEF CONSERVATOR OF FORESTS
Forest Department, Gandhinagar	PRINCIPAL CHIEF CONSERVATOR OF FORESTS

Organization	*Representative(s)*
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Institute of Wood Science & Technology (Wood Properties & Uses Division), Bangalore	REPRESENTATIVE
Karnataka State Forest Industries Corporation, Bangalore	SHRI V. P. HIREMATH SHRI S. SHIVA PRAKASH (*Alternate*)
Kerala Forest Research Institute, Peechi	DIRECTOR REPRESENTATIVE (*Alternate*)
Kutty Flush Doors & Furnitures Co Pvt Ltd, Chennai	SHRI K. SANKARA KRISHNA COL Y. G. KRISHNAN (*Alternate*)
Madhya Pradesh Rajya Van Vikas Nigam Ltd, Bhopal	SHRI A. K. DUBEY
Ministry of Environment & Forests, New Delhi	DR BIPIN BEHARI
Ministry of Railways (Represented by RDSO), New Delhi	DIRECTOR GENERAL
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