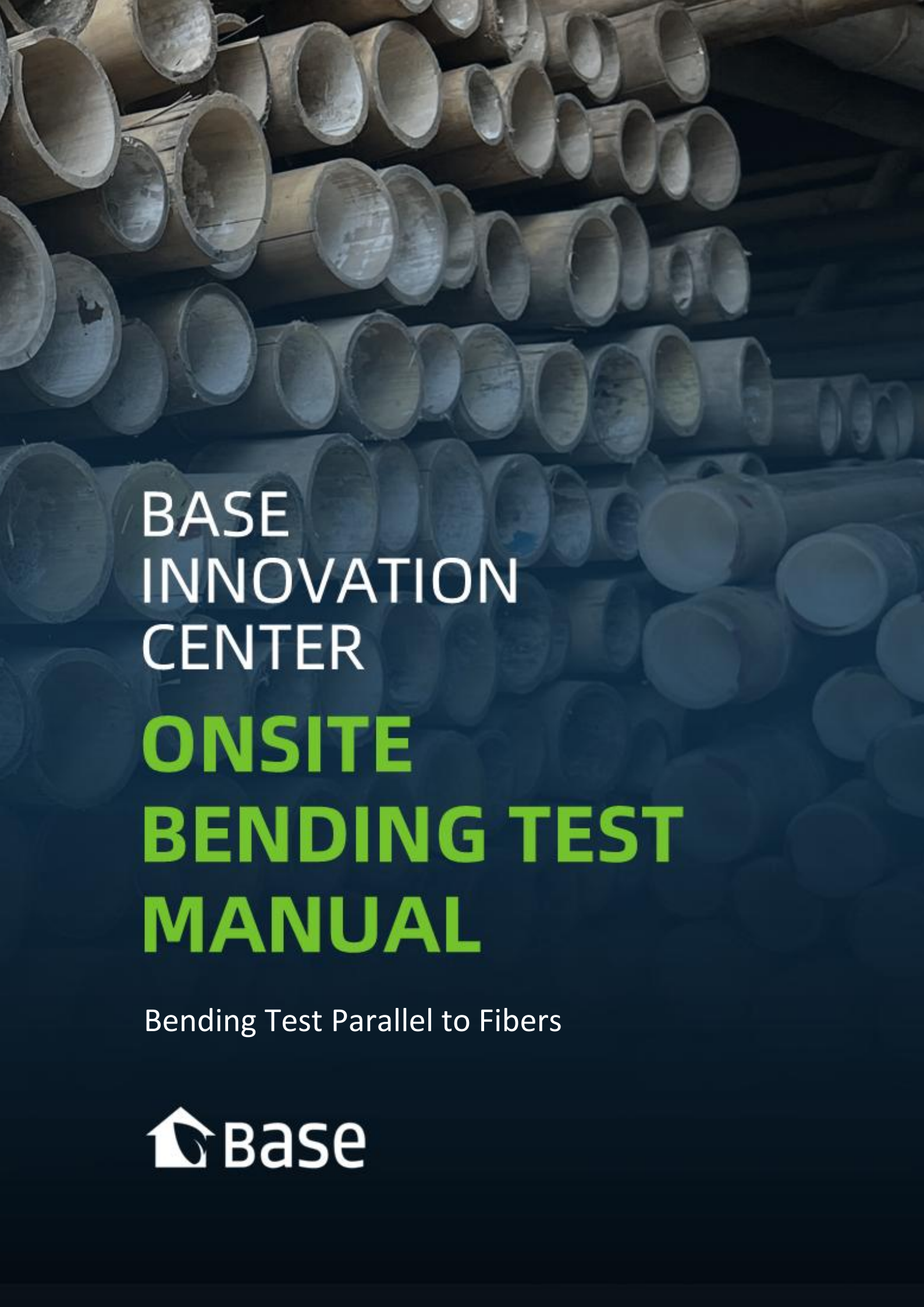


BASE
INNOVATION
CENTER

ONSITE BENDING TEST MANUAL

Bending Test Parallel to Fibers

Base

Table of Contents

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Executive Summary

This manual, developed by the Base Innovation Center, provides a standardized protocol for conducting onsite bending tests on bamboo culms parallel to their fibers in accordance with ISO 22157:2020 standards. The procedure is specifically designed for environments lacking specialized laboratory equipment, utilizing a simple test rig to evaluate critical mechanical properties such as the apparent modulus of elasticity, and flexural strength of structural bamboo species along its fibers.

The manual covers initial harvesting to final data analysis. It includes comprehensive guides for harvesting, grading, and selection of specimens suitable for testing. Detailed instructions for geometric characterization are provided, for determination of optimal pole lengths.

Accompanying this manual is a video tutorial, sample data spreadsheet, and assembly schematics with an item checklist.

G/F UPRC III Building, 2289 Pasong Tamo Extension,
Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

1. Harvesting

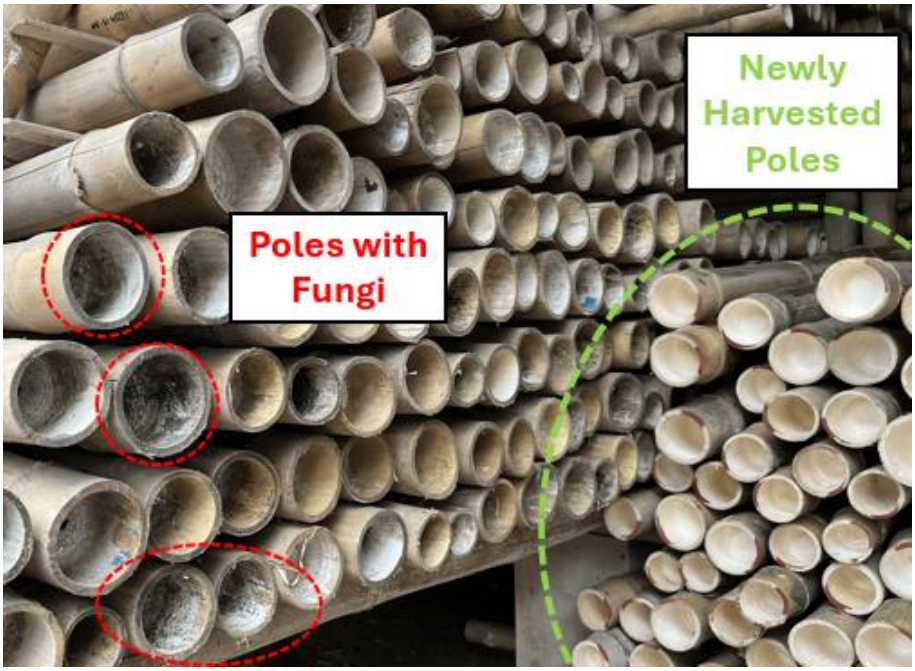
It is essential to select only matured poles between 3 to 5 years of age, as immature poles (1-2 years) lack the necessary strength and possess high moisture content. On the other hand, old poles (above 5 years) become weak and brittle. You can identify the mature poles by their darker color, the presence of lichens or "mossy" spots on the skin.

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Identify and discard poles with visible biological or mechanical defects. Any pole showing signs of insect or fungal attack must be rejected as they are not suitable for construction applications. Examples of insect damage includes:

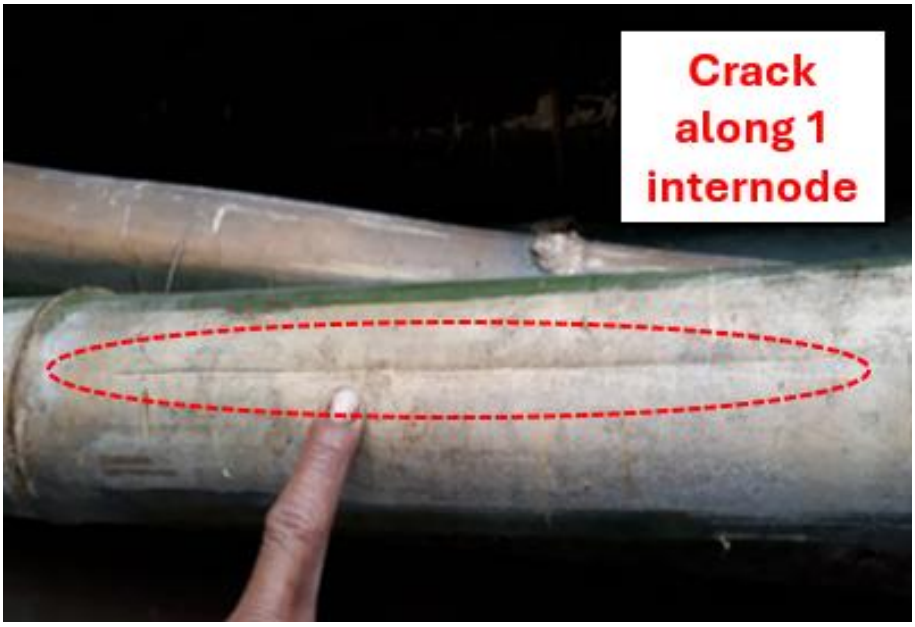
G/F UPRC III Building, 2289 Pasong Tamo Extension,
Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Examples of fungal attack includes:



G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

For the purpose of this study, avoid bamboo poles with cracks:



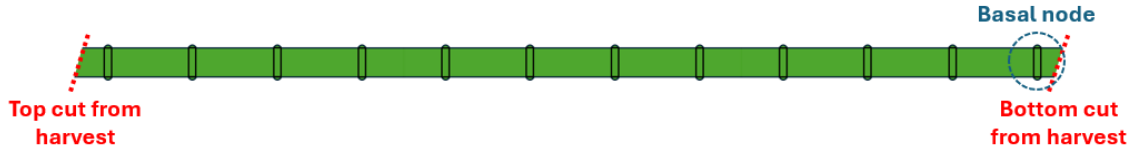
2. Geometric Characterization

Geometric Characterization is the process of measuring the variation of the physical dimensions of bamboo (diameter and wall thickness) along its length. This step allows us to understand the variability in the geometry of bamboo poles, and identify optimal locations of the initial pole for structural use.

G/F UPRC III Building, 2289 Pasong Tamo Extension,
Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Selection and Grading

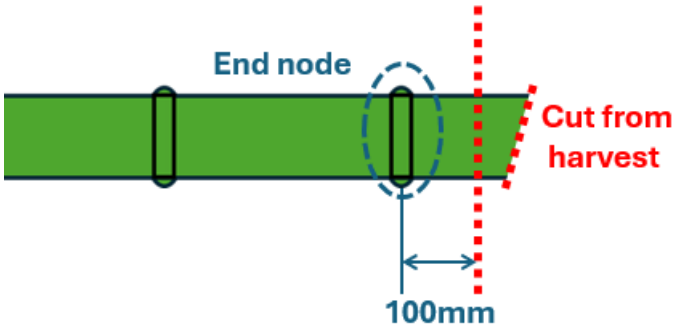
The geometric characterization study can be done on green poles. In this case, select minimum 30 healthy, mature full length poles. The selection should contain as much as possible, a wide variety of poles.



Measurement

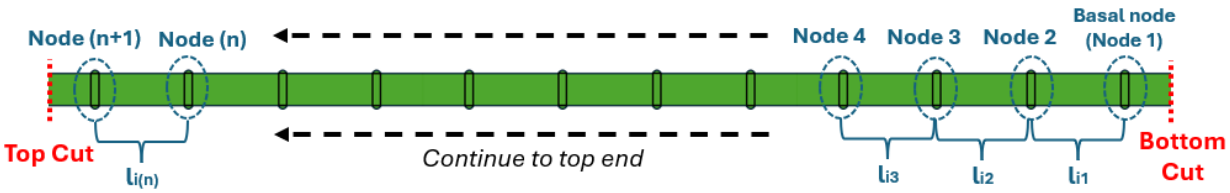
1. End Cutting

Cut the full culm poles at the ends cleanly post harvesting. Cut away at 100mm from top and basal nodes of ends of the harvested culms.



2. Node Mapping

Lay the poles down and name every node starting from the base (Node 1) all the way to the top and measure every internodal length, l_i using a tape measure.



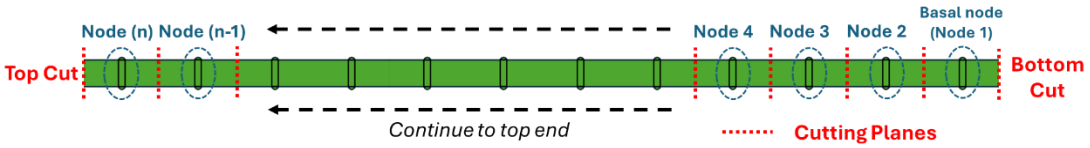
G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Internode number	Internodal length, il (mm)
IN1	l_{i1}
IN2	l_{i2}
IN3	l_{i3}
IN4	l_{i4}
…	…
IN(n)	$l_{i(n)}$

3. Diameter and thickness measurements

a. Sectioning

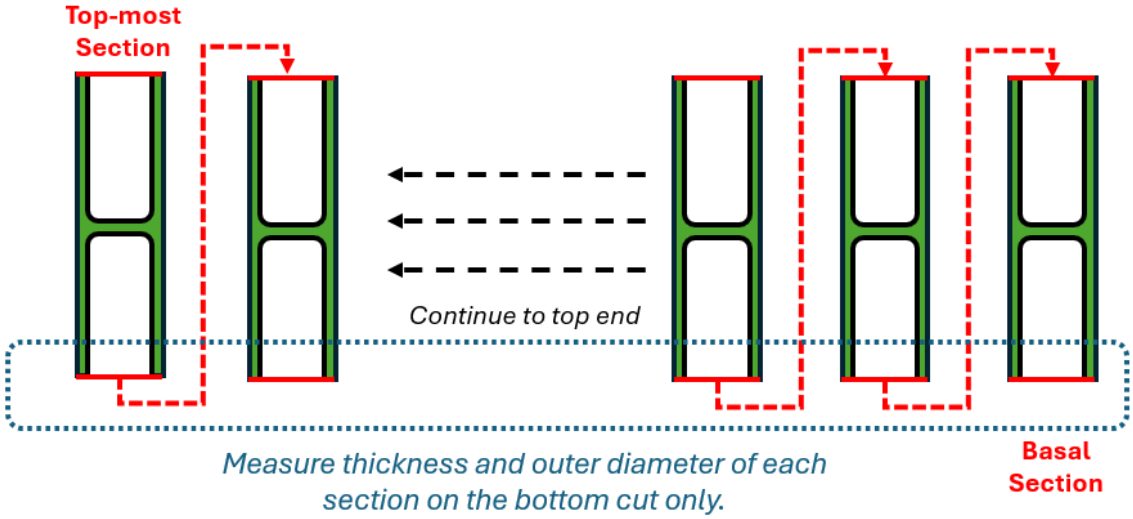
Mark the center of each internode to specify sections for cross-section measurement. Cut cleanly with a saw at each marked section, specify the top and bottom part of each cut section.



G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

4. Cross-section Measurement

At each internode mid-point cut, use vernier callipers to measure the wall thickness at four points (every 90 degrees around the circular section - N,E,S, and W) at the bottom cut. Average these four values to get the Wall Thickness, δ for the cut section.



G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Additionally, measure the outer diameter at two directions (up-down and left-right - N to S and E to W) at the bottom cut of the section as well. Average these two values to get the Outer Diameter, D for the cut section.

$$\delta_{ave} = \frac{\delta_1 + \delta_2 + \delta_3 + \delta_4}{4} \; [mm]$$

$$D_{ave} = \frac{D_1 + D_2}{2} \; [mm]$$

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Node Number	Bottom Wall Thickness, δ (mm)				Bottom Outer Diameter, D (mm)		Average Thickness, δ_{ave} (mm)	Average Diameter, D_{ave} (mm)
	δ_E	δ_W	δ_N	δ_S	D_{N-S}	D_{E-W}	δ_{ave}	D_{ave}
N1								
N2								
N3								
…	…	…	…	…	…	…	…	…
N(n)								

5. Data Analysis

Tabulate the cross-sectional dimension, δ and D relative to its position from the base for each culm.

3. Bending Parallel to Fiber Onsite Test

Introduction

This section presents onsite bending test intended to evaluate the strength of bamboo culms parallel to their fibers. It conforms to ISO 22157:2020 standards and

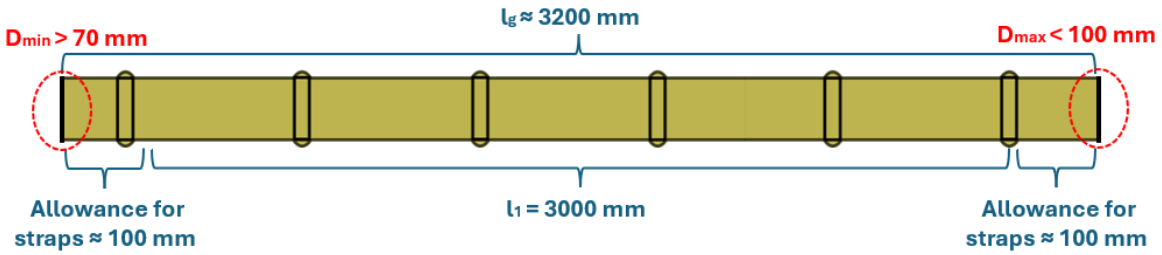
G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

is specifically designed for application in settings where specialized laboratory equipment is not available. The setup accommodates bamboo poles with external diameters of up to 100 mm and requires at least two operators to conduct the procedure.

To support implementation, the manual is accompanied by an item checklist, detailed assembly schematics, and a step-by-step guide for setting up the test. A video tutorial is also provided to demonstrate the testing process and data recording procedures. In addition, an accompanying spreadsheet for the protocol to facilitate data analysis and to extract the relevant mechanical properties from the recorded results will also be provided.

Selection and Grading

Harvest about 30 poles following the guidelines of Section 1. About 30 specimens shall be prepared for testing -- specimen shall originate from a different unique pole. The specimens shall follow the diameter requirements for structural use. Suggested minimum diameter is $D_{min} = 70\ mm$ and the maximum diameter is $D_{max} = 100\ mm$. The range of diameter may be changed based on data obtained from geometric characterization. The total gross length equals $l_g \geq 3200mm$.

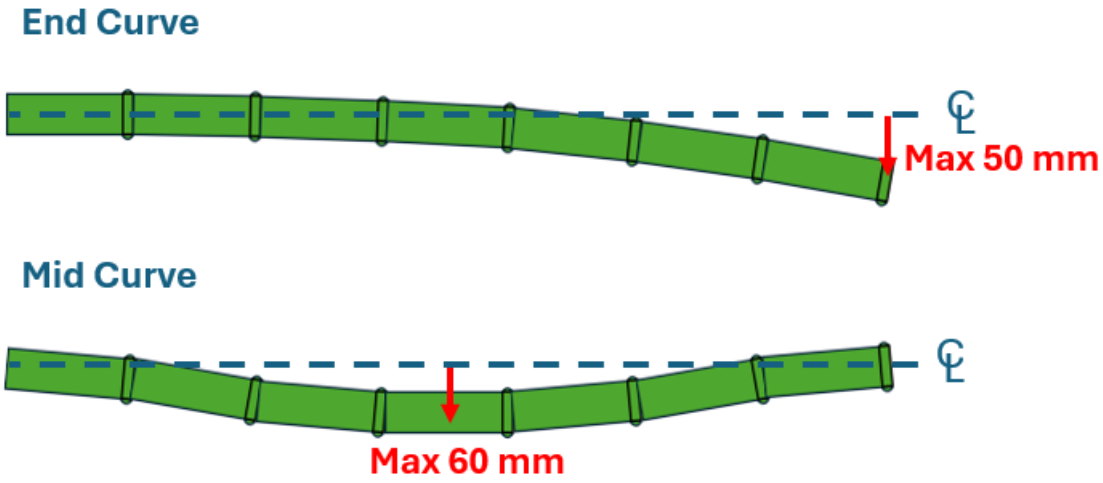


Crack and Curvature Limit

Cracks are a major concern for bending tests as they can lead to longitudinal splitting during loading. Ensure all test specimens are free of cracks.

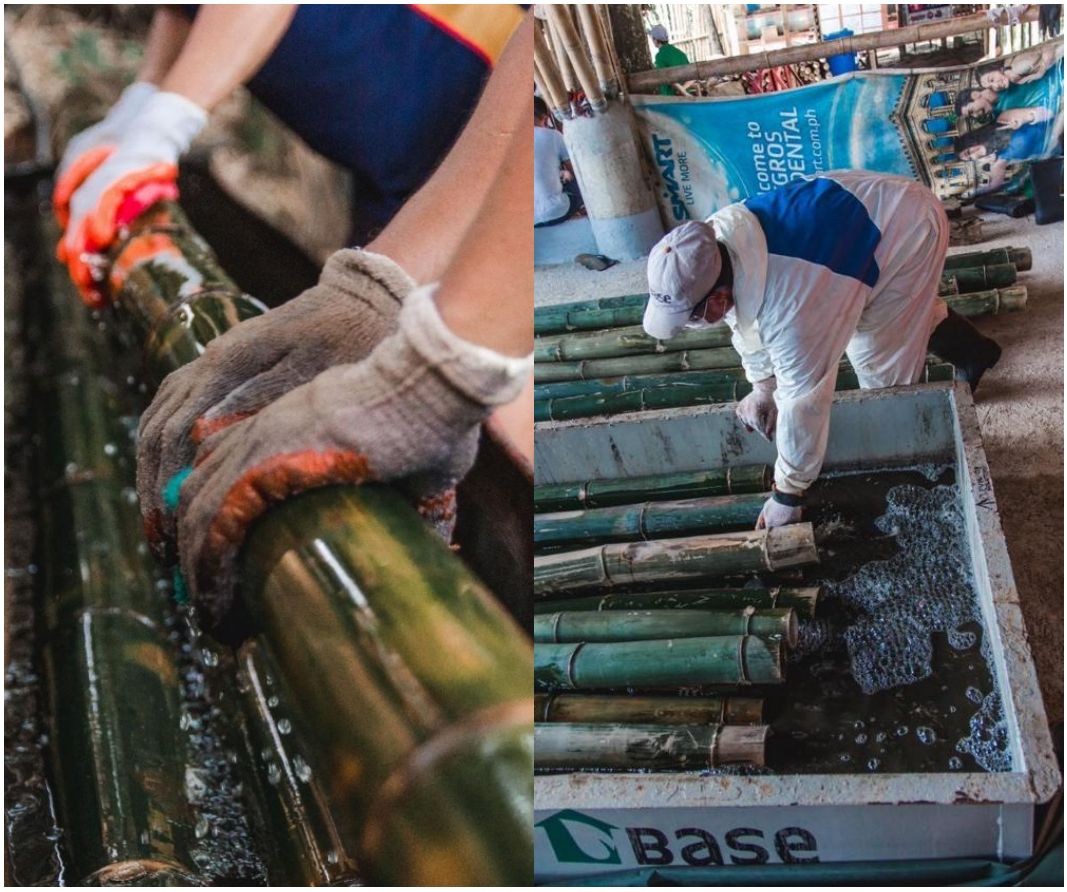
Ensure the test samples are straight elements. For a specimen measuring 3.2 m in length, the, maximum permissible out-of-straightness is 50 mm at the ends and 60 mm at mid-span.

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com



Treatment

It is recommended that the poles should undergo treatment (e.g. Borax-Boric Acid solution) shortly after harvest. This protects the bamboo from insect attack, molds and fungi and improving its long-term durability.



G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Air Drying

The poles should be stacked horizontally on racks, off the ground, and in a shaded, well-ventilated area. Air drying is essential to reduce the moisture content and ensure long term durability – only dried poles are used for construction. Properly air-dried bamboo culms should be golden brown in color. If the bamboo is still green, it requires more drying time before testing.

Specimen Measurement

After cutting to size, record the following parameters, and input to specimen geometric properties. Measure δ_1 to δ_8, l_{g1} to l_{g4}, D_1 to D_4, and m take the average values of geometry and mass for all 30 specimens. Use steel tape to measure the gross length, l_g from four points of each end of the bamboo specimen (every 90 degrees around the circular section - N,E,S, and W). Use a crane scale to measure the mass, m of the bamboo specimens.

Geometric Properties											
Enter wall thicknesses (mm) here:	δ1	δ2	δ3	δ4	δ5	δ6	δ7	δ8	δ ave (mm)		A (mm^2)
	9.23	9.3	9.74	8.35	8.35	8.55	8.29	7.82	8.70		2760.14
Enter gross lengths (mm) here:	lg1	lg2	lg3	lg4			m (kg)		lg ave (mm)		ρ (kg/m^3)
	3200	3202	3198	3201			7.25		3200.25		820.77
Enter outer diameters (mm) here:	D1	D2	D3	D4			Δ20 (mm)		D ave (mm)		I (mm^4)
	112	111	106.56	109.23			12.52		109.70		3547018
Enter test span (mm) here:	l1						Δ60 (mm)		span (mm)		a (mm)
	3000						36.94		3000		1000.00

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

$$\delta_{ave} = \frac{\delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 + \delta_6 + \delta_7 + \delta_8}{8} \ [mm]$$

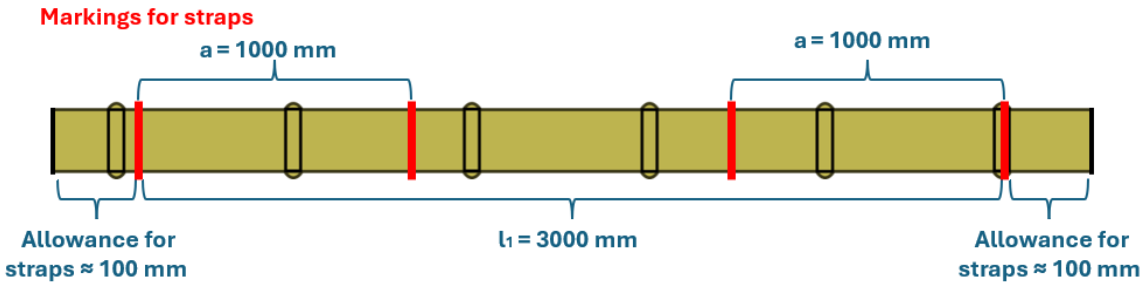
$$l_{g-ave} = \frac{l_{g1} + l_{g2} + l_{g3} + l_{g4}}{4} \ [mm]$$

$$D_{ave} = \frac{D_1 + D_2 + D_3 + D_4}{4} \ [mm]$$

$$A = \frac{\pi}{4}((D_{ave})^2 - (D_{ave} - 2 * \delta_{ave})^2) \ [mm^2]$$

$$\rho = \frac{m}{A * l_{g-ave}} * 10^9 \ \left[{}^{kg}/_{m^3}\right]$$

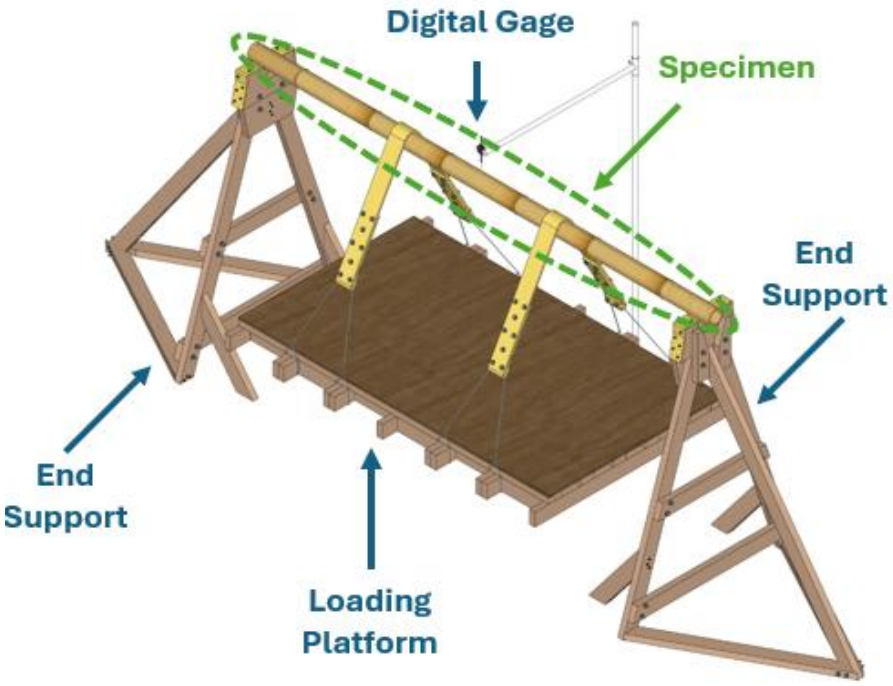
Mark the ends of the cut bamboo specimens to guide its placement when loaded onto the straps of the supports and loading platform. Take a clear span of $l_1 = 3000$ mm relative to the middle span of the cut pole and measure the ends for the supports. Divide the clear span into thirds to mark the length of the shear span ($a = 1000$ mm) from the free ends. When loaded in the setup, the markings should be placed at the center of the straps.



Test Rig Components

These are the components required for doing the onsite test. Refer to attached drawings for material specifications and how to assemble them.

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com



1. Loading Platform

Serves as the platform where weights are applied to simulate a four-point bending test. The platform transfers the applied load onto the bamboo through the straps. The platform should be weighed prior to testing.

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

2. End Supports

Saddles for the end supports of the four-point bending test, constructed using 50 mm x 100 mm timber components and connected using 12 mm threaded rods. A strap saddle is attached using Tek screws on top to load the bamboo.

3. Safety Scaffold/Sandbags

A safety support positioned beneath the loading platform. When the bamboo pole fails and the platform drops, the scaffold will hold it in place, preventing accidents and protects the operators from injury. The top of the platform is designated as a hazardous area and shall be kept clear of obstructions or objects. Sandbags shall be used as an alternative to absorb the impact force of the loading platform in the event of failure.

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

4. Digital Gage

Recommended to be wireless/battery-powered and accurately measures deflections to a precision of 0.01mm. The gage must be attached to a rigid stand with adjustable height to account for the variability of the outer diameter of the bamboo specimens.

5. Loading Weights

The weights can be bricks, cement bags, sandbags, etc. Measure and record their weight before putting on the loading platform. Do not load more than 20 kg per step.

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Test Procedure

1. Tools and Materials

Aside from the test rig components, the following tools are required for conducting the onsite bending test:

- Vernier Calipers – for cross sectional measurements
- Steel Tape – for longitudinal measurements
- Digital Crane Scale – for measuring loading platform and weights
- Trolley – for moving multiple weights

2. Safety and PPE

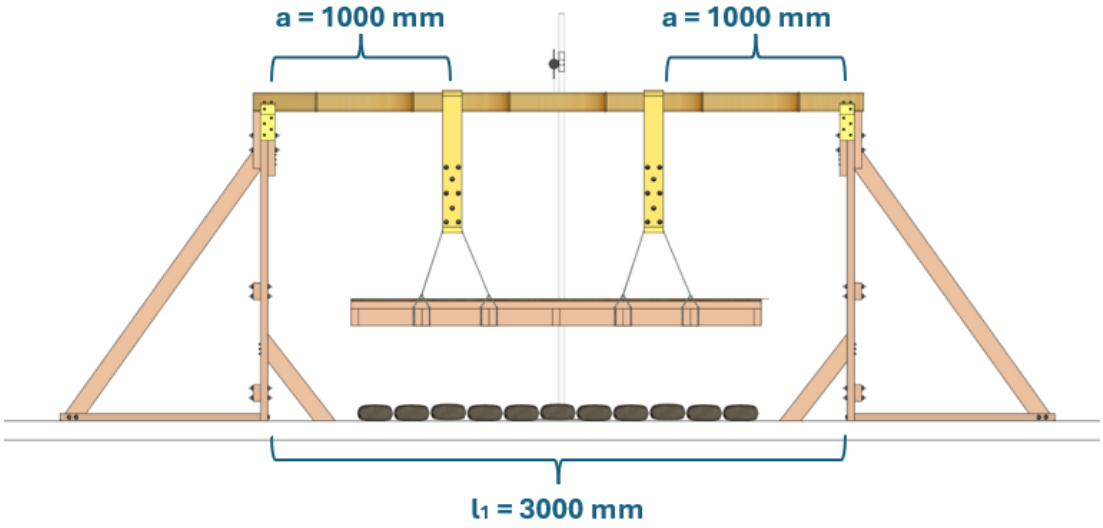
The test requires a minimum of two operators. For efficient and safe operation, three to four operators are recommended. Operators are required to wear the following PPE: hardhats, gloves, and shoe protection.

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Loads, whether bricks, sandbags, or cement bags, shall be lifted carefully and slowly. Components exceeding 20 kg are lifted by two or more operators.

The area above the safety scaffold and below the bamboo pole is designated as a hazardous area and shall be kept clear of obstructions or objects. When placing loads onto the loading platform, operators shall not position their heads beneath the bamboo pole nor pass under it.

3. Test Setup



The figure above presents the test setup. Note that the setup allows to test bamboo poles with external diameters up to 100 mm. The span length is $l_1 = 3000$ mm, the shear span $a = 1000\ mm$ for all specimens.

1. Setup the test rig on a level surface, ideal location is a paved or concrete floor. The center of the straps of the end supports is set to $l_1 = 3000$ mm

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

2. Ensure that the safety scaffold is placed below the loading platform.
3. Lift the loading platform with the bamboo pole to hang the straps of the platform off the pole.
4. Place the bamboo and the hanged platform between the straps of the end supports.
5. Align the loading straps at third points between the end supports (shear span $a = 1000\ mm$), the platform must be level as well.
6. Adjust and brace the dial gauge support structure until the gauge is aligned with the topside of the culm and the shaft is fully retracted when the bamboo is not loaded with the platform.

4. Specimen Loading

Measure the mass of the platform and rest on the bamboo. The figure above shows the actual initial test setup prior to loading. Incrementally add loading weights not exceeding 20 kg and record corresponding displacement until failure.

Loads shall be placed evenly across the platform to prevent tilting, and the platform must reach a stable condition before the next load is applied.

The digital displacement gage has a 50 mm range. Most specimens exceed this displacement at failure, causing the gage shaft to reach full extension before

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

ultimate failure. At that point, displacement recording stops, and only the applied incremental loads are noted until failure.

5. Data Tabulation

During specimen loading, the data must be tabulated using the provided spreadsheet to record each applied load together with the corresponding displacement.

1. Input the specimen test number and species

Test no:	Species:	Dendrocalamus asper		
	Additional Load (k	Total Load (kg	Total Load (kN	Displacement (mm)
0	78.5	78.5	0.77	5.65
1	9.6	88.1	0.86	5.93
2	9.6	97.7	0.96	6.43

2. Record the initial displacement due to the loading platform

Test no:	Species:	Dendrocalamus asper		
	Additional Load (k	Total Load (kg	Total Load (kN	Displacement (mm)
0	78.5	78.5	0.77	5.65
1	9.6	88.1	0.86	5.93
2	9.6	97.7	0.96	6.43

3. Record added loads and corresponding displacement until failure

Test no:	Species:	Dendrocalamus asper		
	Additional Load (k	Total Load (kg	Total Load (kN	Displacement (mm)
0	78.5	78.5	0.77	5.65
1	9.6	88.1	0.86	5.93
2	9.6	97.7	0.96	6.43
3	9.6	107.3	1.05	6.96
4	9.6	116.9	1.15	7.54
5	9.6	126.5	1.24	8.06
91	9.6	951.1	9.34	0.00
92	9.6	961.7	9.43	0.00
93	9.6	971.3	9.53	0.00
94	9.6	980.9	9.62	0.00
95	9.6	990.5	9.71	0.00
96	9.6	1000.1	9.81	0.00
97	9.6	1009.7	9.90	0.00

Displacement records stop

Max Force

4. Take F_{20} and F_{60}, The sheet will derive it from F_{ult}.

$$F_{20} = 0.2 * F_{ult}$$

$$F_{60} = 0.6 * F_{ult}$$

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com

Mechanical Properties			
Fult (kN)	Mult (kNm)	F20 (kN)	F60 (kN)
9.90	4.95	1.98	5.94

5. Identify the force and displacement values corresponding to F_{20} and F_{60}. For Δ_{20} select the larger displacement within the interval. For Δ_{60} select the smaller displacement within the interval. If F_{60} falls within the range with no corresponding displacement recorded, take the last entry of displacement instead.

Test no:	Species:	Dendrocalamus asper				
	Additional Load (k	Total Load (kg	Total Load (kN	Displacement (mm)		
11	9.6	184.1	1.81	11.36		
12	9.6	193.7	1.90	11.92		
13	9.6	203.3	1.99	12.52	F20	1.98
14	9.6	212.9	2.09	13.14		
15	9.6	222.5	2.18	13.59		

Test no:	Species:	Dendrocalamus asper				
	Additional Load (k	Total Load (kg	Total Load (kN	Displacement (mm)		
52	9.6	577.7	5.67	35.87		
53	9.6	587.3	5.76	36.42		
54	9.6	596.9	5.85	36.94	F60	5.94
55	9.6	606.5	5.95	37.64		
56	9.6	616.1	6.04	38.30		

6. Input the corresponding values of Δ_{20} and Δ_{60} into the geometric properties section.

Geometric Properties										
Enter wall thicknesses (mm) here:	δ1	δ2	δ3	δ4	δ5	δ6	δ7	δ8	δ ave (mm)	A (mm^2)
	9.23	9.3	9.74	8.35	8.35	8.55	8.29	7.82	8.70	2760.14
Enter gross lengths (mm) here:	lg1	lg2	lg3	lg4			m (kg)		lg ave (mm)	ρ (kg/m^3)
	3200	3202	3198	3201			7.25		3200.25	820.77
Enter outer diameters (mm) here:	D1	D2	D3	D4			Δ20 (mm)		D ave (mm)	I (mm^4)
	112	111	106.56	109.23			12.52		109.70	3547018
Enter test span (mm) here:	l1						Δ60 (mm)		span (mm)	a (mm)
	3000						36.94		3000	1000.00

7. Apparent modulus of elasticity parallel to fibers, $E_{m,0}$, ultimate bending moment M_{ult}, and flexural strength parallel to fibers $f_{m,0}$ for the specimen will be displayed on the results section

Results	
Apparent modulus of elasticity, Em,0 (GPa)	21.91
Ultimate bending moment, Mult (kNm):	4.95
Flexural strength, fm,0 (MPa):	76.56

G/F UPRC III Building, 2289 Pasong Tamo Extension, Barangay Magallanes, Makati City 1231, Philippines
info@base-bahay.com
www.base-builds.com