ESR-1636
Reissued November 1, 2005
This report is subject to re-examination in one year.

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EVALUATION SUBJECT:

STRUCTURAL BAMBOO POLES

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2003 *International Building Code*® (IBC)
- 2003 *International Residential Code*® (IRC)
- 1997 *Uniform Building Code*™ (UBC)

Properties evaluated:

Structural

2.0 USES

The structural bamboo poles are used as structural elements in wall, roof and floor trusses (panels) or as individual compression and/or tension members, in Type V non-fire-resistance rated residential and commercial construction. The commercial construction is limited to one story and a maximum floor area of 2000 square feet (180 m^2).

3.0 DESCRIPTION

The structural bamboo poles covered in this report are from Quang Ngai, Vietnam, and are of the Tre Gai (*bambusa stenostachya*) species. The bamboo poles are typically $2^3/_4$ inches (70 mm) to $3^1/_4$ inches (82 mm) in diameter and 10 feet (3048 mm) to 14 feet (4267 mm) in length, depending on the building type. The structural bamboo poles have a nominal density of 42 pcf (673 kg/m^3) and are preservatively treated with a borate solution.

4.0 DESIGN AND INSTALLATION

4.1 General:

Design and construction practices shall take the following into account:

- A design shall be provided for lateral bracing to resist wind and seismic forces.
- The structural performance shall be assessed by calculating the action effects using a linear material model (elastic behavior).
- The effect of shrinkage shall be taken into account in the design of individual structural members, and in the design of the structure as a whole.
- The effects of long-term loading (creep) need to be considered in the design of individual structural members, and in the design of the structure as a whole. Long-term flexural creep in bamboo in bending may be assumed to be 3 to 4 percent of the immediate elastic deformation.

4.2 Design Considerations:

4.2.1 Allowable Design Stresses: Design stresses shall not exceed the values noted in Table 1. No adjustment for duration of load shall be made, except for permanent load and wind load conditions, as addressed in this section.

For a permanent load condition (more than 10 years), all stresses, except for MOE, shall be reduced by 25 percent. For a wind loading condition, the allowable design stresses, except for MOE, are permitted to be increased by 20 percent.

4.2.2 Bamboo Poles (Elements): The design of individual elements shall consider the following:

a. The element retains its elastic behavior, until failure (plastic behavior is considered to be not significant).

b. The elements are analyzed as variable-thickness, hollow-tube structures.

c. The elements are analyzed as not perfectly straight members.

d. The elements are analyzed as tapered members.

e. Design is conducted in accordance with the following:

1. Conventional structural analysis methods are used, with definitions of the initial curvature, the diameter and the wall thickness.
2. Any bamboo joint or support shall be considered to act as a hinge, unless substantiating data are submitted to justify consideration as a semi-rigid or a rigid joint.
3. Bernouilli's theorem (flat cross sections remain flat) is valid for bamboo.

f. Design of bamboo poles acting as beams shall be based on the following items, provided the load is symmetrical (for asymmetrical loads, applied stresses at critical points shall be calculated):

1. The moment of inertia, *I*, shall be determined as follows: The outside diameter and the wall thickness shall be measured at both ends. With these values, the mean diameter and the mean wall thickness for the middle of the beam shall be calculated. The moment of inertia, *I*, must be calculated using the mean values. If actual measurements are not available, a conservative approach is permitted assuming the wall thickness to be $^1/_2$ inch (12 mm) and the outside diameter to be $2^3/_4$ inches (70 mm).

2. The initial curvature shall be considered in the calculation of the deflection.

3. If the length of the beam is less than 25 times the diameter at the small end, the shear stress in the neutral layer at that end must be checked.

4. Forces acting on a beam (loads or reaction forces at supports) shall act at nodes or as near to nodes as possible, not exceeding 4 inches from the nodes.

5. For beams in which combined axial and bending loads occur, the interaction of applied stresses shall be considered.

g. Design of bamboo poles acting as columns shall be based on one of the following:

1. Results of compression buckling tests on full-size specimens.

2. Calculations based on the following:

(a) The moment of inertia (I) shall be determined in accordance with Section 6.6.1 of the INBAR document in Appendix A of the ICC-ES Acceptence Criteria for Structural Bamboo (AC162).

(b) The bending stresses due to initial curvature, eccentricities and induced deflection shall be taken into account.

(c) Buckling calculation shall be in accordance with the Euler equation, using a reduction to 90 percent of the moment of inertia. [The reduction to 90 percent takes into account the effect of the taper, provided the taper (defined as the ratio of the difference between the minimum and maximum outer diameters to the length) is less than 1:170.]

4.2.3 Connections: Connections shall be designed to achieve structural continuity between elements. Connection designs shall be based on complete full-size tests of the connector for a given load and geometry. This includes fastening elements.

5.0 CONDITIONS OF USE

The structural bamboo poles described in this report comply as an alternative material and method of construction as noted in those codes specifically listed in Section 1.0 of this report, subject to the following conditions:

5.1 Design and analysis shall comply with the details noted in this report.

5.2 Calculations, drawings and required reports of connection and compression tests, as noted in Sections 4.2 in this report, shall be furnished to the building official, verifying that the material is used in accordance with this report. The drawings and calculations shall be prepared by a registered design professional where required by the statues of the jurisdiction in which the project is to be constructed.

5.3 Special inspection may be required by the code official for the assembly of the finished product at the jobsite, in accordance with Section 1404.6 of the IBC.

5.4 The bamboo shall be limited to end-use locations at which the average equilibrium moisture content of the material is equal to or less than 16 percent.

5.5 The bamboo shall be processed at Bamboo Hardwoods Vietnam, Thoi Hoa Village, Ben Cat District, Binh Duong Province, Vietnam, with inspections by SGS Vietnam (AA-701).

6.0 EVIDENCE SUBMITTED

6.1 Descriptive details

6.2 A quality control manual

6.3 An analysis and results of tests verifying compliance with the ICC-ES Acceptance Criteria for Structural Bamboo (AC162), dated March 2000.

7.0 IDENTIFICATION

The structural bamboo poles shall be identified with a stamp indicating “Certified Pole,” the name of the inspection agency (SGS Vietnam), the evaluation report number (ESR-1636), and the words “Borate Treated.”

TABLE 1—ALLOWABLE DESIGN STRESSES

PRODUCT	BENDING STRENGTH, F_b (psi)	MODULUS OF ELASTICITY, *MOE* (psi)	COMPRESSIVE STRENGTH, F_c (psi)	HORIZONTAL (LONGITUDINAL) SHEAR STRENGTH, F_v (psi)	TENSILE STRENGTH, F_t (psi)
Structural bamboo pole	1,500	1.7×10^6	590	185	1,110

[1]Allowable design stresses are based on values derived from testing in accordance with AC162. Factors have been applied as noted in Sections 3.3.2 and 3.3.3 of AC162. No adjustment for duration of load shall be made, except for a permanent load condition, and as noted in Section 4.2.1 of this report. For a permanent load condition (more than 10 years), all stresses, except for MOE, shall be reduced by 25 percent.
[2]Allowable values are based on covered dry conditions of use, defined as those environmental conditions represented by sawn lumber with an equilibrium moisture content of less than 16 percent.
[3]Tensile strength noted is the result of small-scale tension tests. See Section 4.2.2 in this report for additional information.