

Survey of Split Bamboo as a Primary Structural Material in Construction from 1970 to 2020 and Future Directions for Exploration

Sankalpa

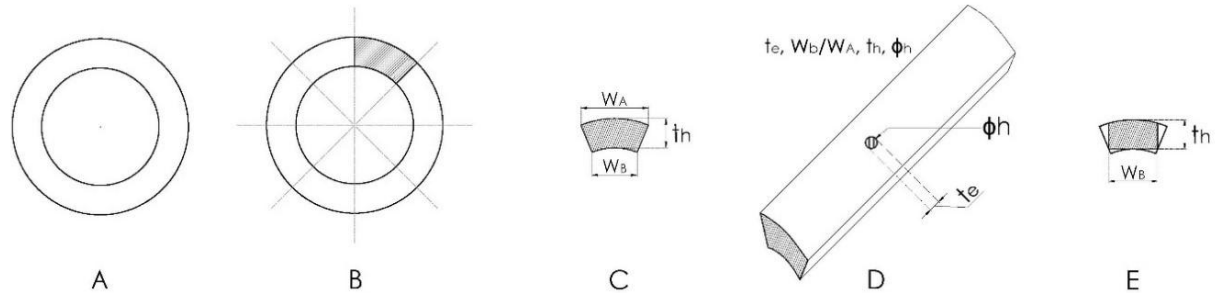
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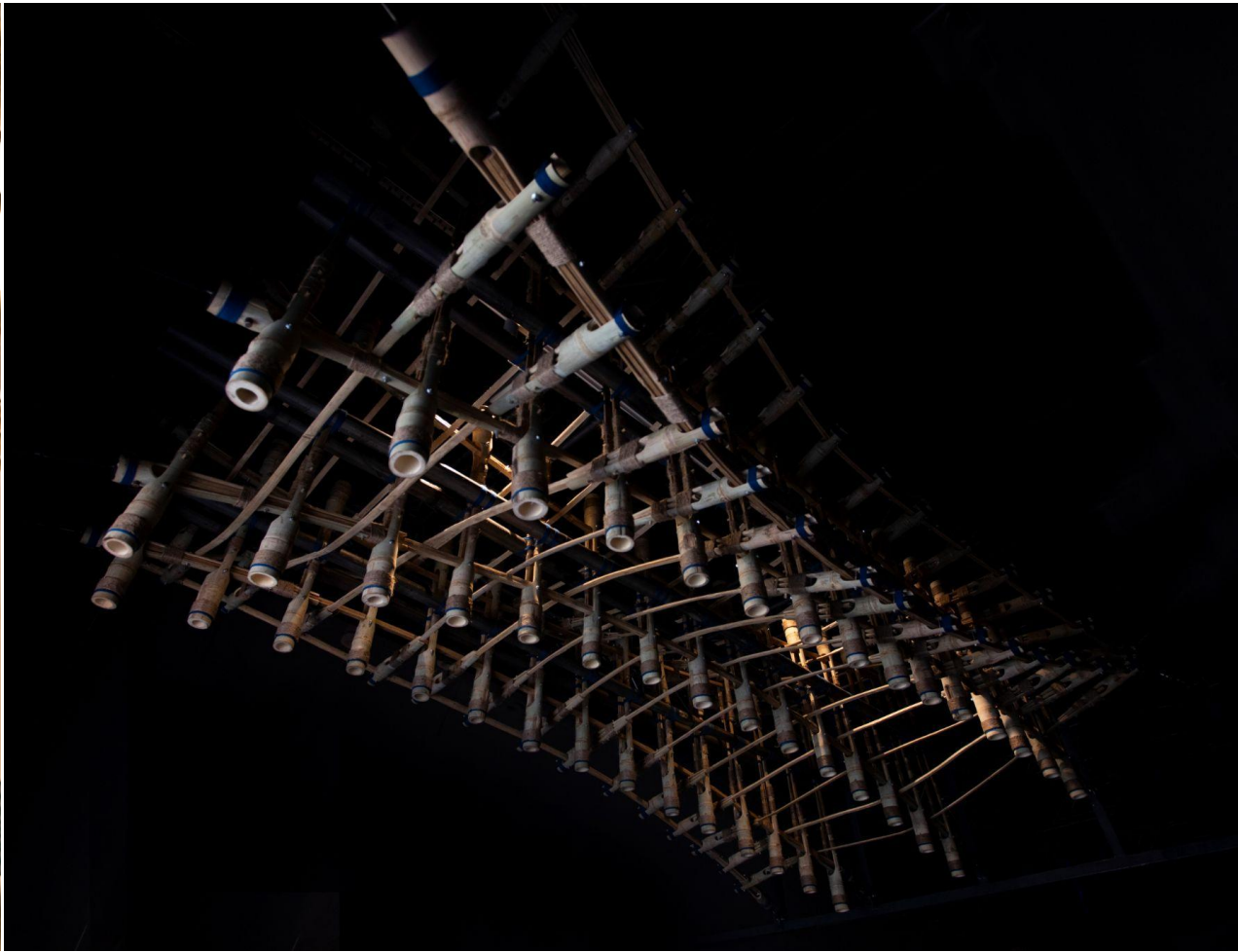
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Bamboo Poles



Bamboo Splits

Based on the survey of existing literature on use of bamboo, split bamboo as construction materials, following gaps are identified

1. There is **limited research** on split bamboo as a **tension** member.
2. Similarly, existing research has **not focused on the standardization of split** for utilization in construction.
3. Though there is a lot of work on designing joints with **standard fasteners**, including a few patents for bamboo poles, there is **little work done for split bamboo**.
4. The **work on splits, mainly Indian Bambusa balcooa, is significantly less** and needs to be verified, particularly of the same species from two to three regions.
5. So far, no buildings other than the few **experimental** ones have been identified **using the tensile property of split** bamboo.

Advantage of using split bamboo over bamboo poles

Sr	Category	Comparison	
		Bamboo Poles	Splits
1	Straightness	Indian bamboo, e.g., Bambusa balcooa, for construction purposes, is not as straight as species like Dandrcalaums asper, Guadua angustifolia.	It is possible to derive straighter splits from non-straight bamboo. Within a limited deviation for straightness, there are more available samples of two-dimensional bent bamboo poles instead of three dimensions.
2	Standardization	Bamboo poles are not of a uniform cross-sectional area or sectional profile, which makes standardization of poles untenable.	It is possible to machine the split to get standard sections to overcome the morphological variability of bamboo poles.
3	Packaging	Currently, bamboo poles are transported on carriers based on their length . The maximum length of bamboo available in the market is usually twenty-four feet length.	With the standardization of split, the packaging for transport is accessible and readily achievable , unlike bamboo poles because of their morphological variability.
4	Structural form	Bamboo poles have limited ability to offer curvilinear structural elements .	Unlike bamboo poles, it is highly flexible to offer curvilinear elements potentially.

Sr	Category	Comparison	
		Bamboo Poles	Splits
6	Constructability	Bamboo poles, unlike splits, have more weight and need a strength-based tool to handle them.	The splits are lighter, flexible, safe, and easy to handle for construction.
7	Lightness	Unlike split, its use makes the spanning structure heavy.	It can be used to construct light-spanning structures like open web joists (Villegas, et al., 2015)
9	Line & Level	Being an elongated cone, the level is almost impossible to maintain if the line is maintained.	Such issues do not arise with a split, as it is possible to maintain both straightness and an approximate cross-sectional area.
10	Dimensional tolerance	It has high dimensional variability from top to bottom.	It can be standardized to get minimum variability from top to bottom.

Modern structure and experiments using split bamboo

Sr	Institution/Firm	Year	Form of Bamboo	Structural Form	Joinery
1	Schaur, Eda	1976-84	Split	Grid shell	Lashed nodal joints in jute
2	Studio Cardenas	2009	Split	Geodesic	Clamped neoprene joint with steel bolt
3	the Weak Architects	2009	Split	Shell	Woven
4	Albert, Heinz	2015	Split	Surface structure	Lashing
5	Villegas et al.	2015	Split	Truss	Metal curved washer with through bolts
6	Mehta, Yash	2018	Split	Doubly-curved	Pinned nodal joints; metal clamped bolted end joints
7	Setia, Abhimanyu	2019	Split	Doubly-curved	Metal clamped friction nodal joint; metal clamped bolted end joint
8	CO-Lab Design Office	2019	Bundled splits	Shell	Screwed and strapped
9	Pounamu	2019	Bundled split	Arch	Arched and bundled splits under compression
10	Villegas et al.	2019	Bamboo pole and splits	Truss	Metal connectors with through bolts

Challenges of using split bamboo and how the existing literature addresses

Morphological standardisation
Standardisation of fasteners
Constraints of split as a form giver



Type of joints tested using metal and bolts for splits

Sr	Author	Year	Form of Bamboo	Investigation	Findings
1	Sonar et al.	2009	Split (Dandarcalamous Strictus)	Studied the mechanical properties using half-split bamboo as structural members and joints with a mild steel plate gusset for single- and double-bolted bamboo joints under axial tension.	Different end distances and bolt diameters would influence the joint's ultimate bearing capacity. Double-bolt joints had a higher ultimate failure stress than single-bolt joints.
2	Villegas et al.	2015	Splits (Guadua angustifolia)	Studied the efficacy of a new joint developed to tackle the ductile behavior of bamboo split under compression along the thickness of the culm or radial direction. The joint connects two splits using two curved steel plates, a bolt, and a nut.	There is a significant increase in joint strength without radial compression when tested for truss.
3	Villegas et al.	2019	Splits (Guadua angustifolia)	Studied the structural performance of trusses made out of bamboo poles and splits using steel clamps.	The clamp design performed better to counter the longitudinal splitting in bamboo poles or splits and accommodated morphological variations in them. (fig.43)

Constraints of split as a form giver



Thank You

