RE-LOOKING AT BAMBOO:

[A journey into exploration of bamboo components for structural possibilities]

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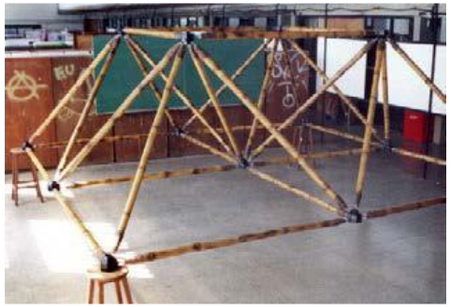
Research on bamboo



2005: Bamboo Space frame – University of Aachen

2007: Bamboo school – Anna Heringer

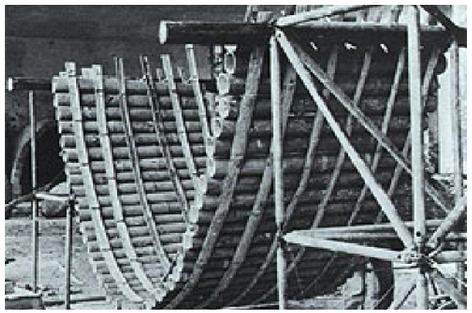
2011: Bamboo school – John Hardy

2011: Wind and Water café - Vo Trong Nghia Architects

2011: Bamboo Pavilion - Hirokazu Toki

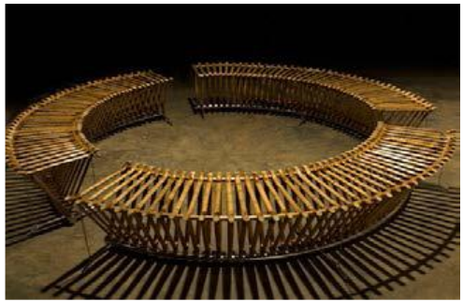
Research and explorations on bamboo

1930: Bamboo dome – Yona Friedman



1985 - 86 : Bamboo grid shell – Frie Otto

1997: Bamboo connection – Renzo Piano



1997: Bamboo furniture – Sandeep Sangaru

2000 : ZERI Pavilion – Simon Velez

Aim:

To explore various possibilities of deriving components in bamboo split sections for structural utilization.

Objectives :

Understanding different parameters which form components of bamboo split section in various bamboo craft.

Deriving a method for explorations of various bamboo components.

Exploring different components/ modules/ systems, using the derived methodology.

Testing of a particular component/ module/ system, using the derived methodology.

Parameter, in mathematics, a variable for which the range of possible values identifies a collection of distinct cases in a problem.
Component, a constituent part
Module, an independently operable unit that is a part of the total structure
System, a regularly interacting or interdependent group of items forming a unified whole

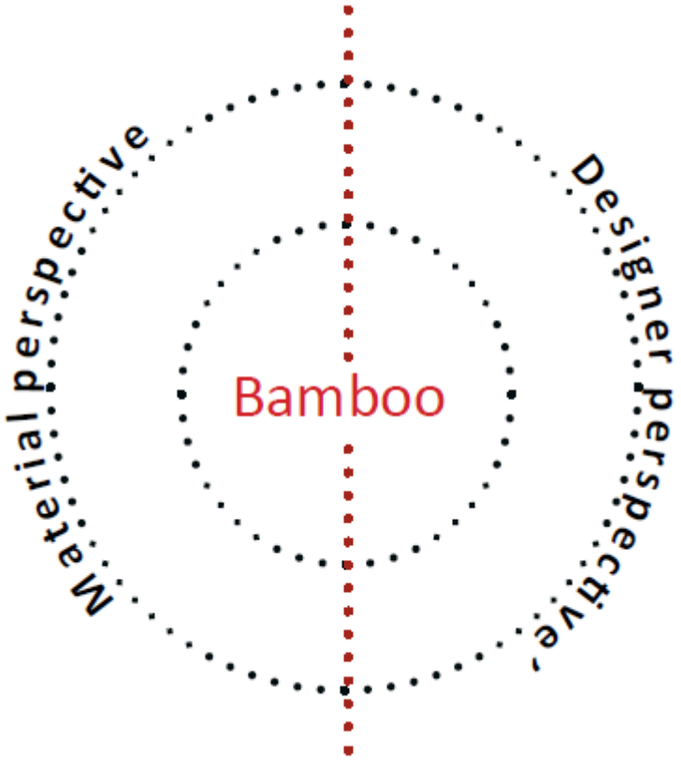
(source: Britannica Encyclopaedia)

According to Xiobing Yu -

Disadvantages of bamboo in two dimensions:

1. Material perspective
2. Designers perspective

Irregular structure and material properties

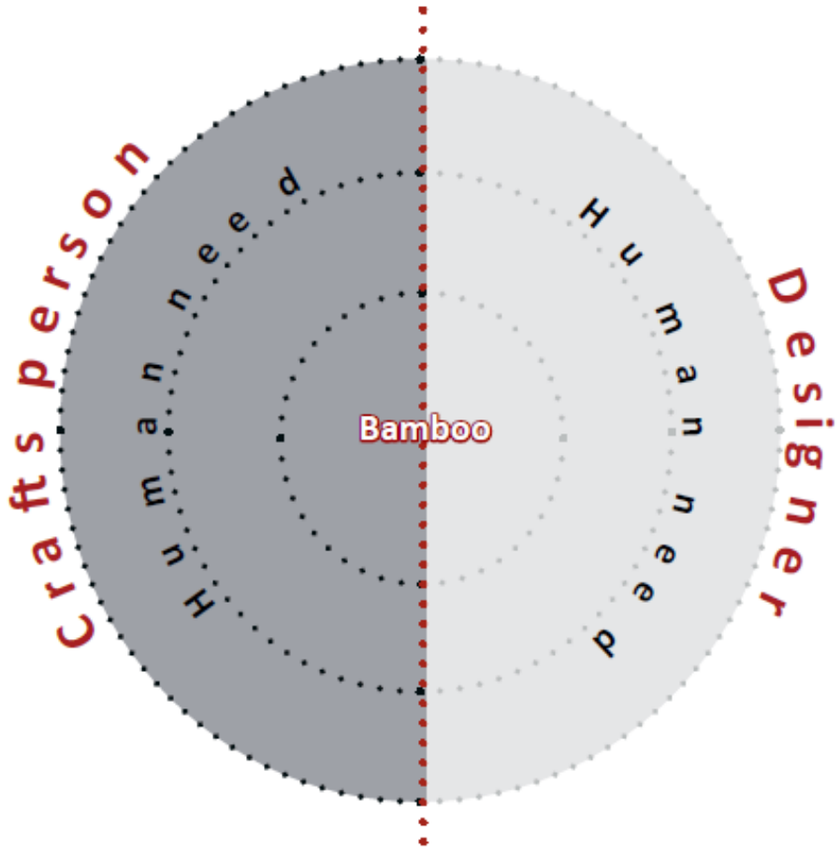


Lack of standardization

Need for the study

"Instead of industrialization, modernization should be the real solution for the problem of utilizing bamboo in the industrial context." - **Xiaobing Yu**

Pre-industrial period



Post-industrial period

Modernization of bamboo:

Building up a new identity of the material bamboo in industrial context.

Methodology

Stage 1: A study to find out various bamboo components formed out of bamboo split sections, in various bamboo crafts, prevailing in traditional and contemporary architectural practices, till now.

Stage 2: Analyzing and organizing the collected data, to extract various parameters which form bamboo components and further can be used to derive a method for experimentation.

Literature study

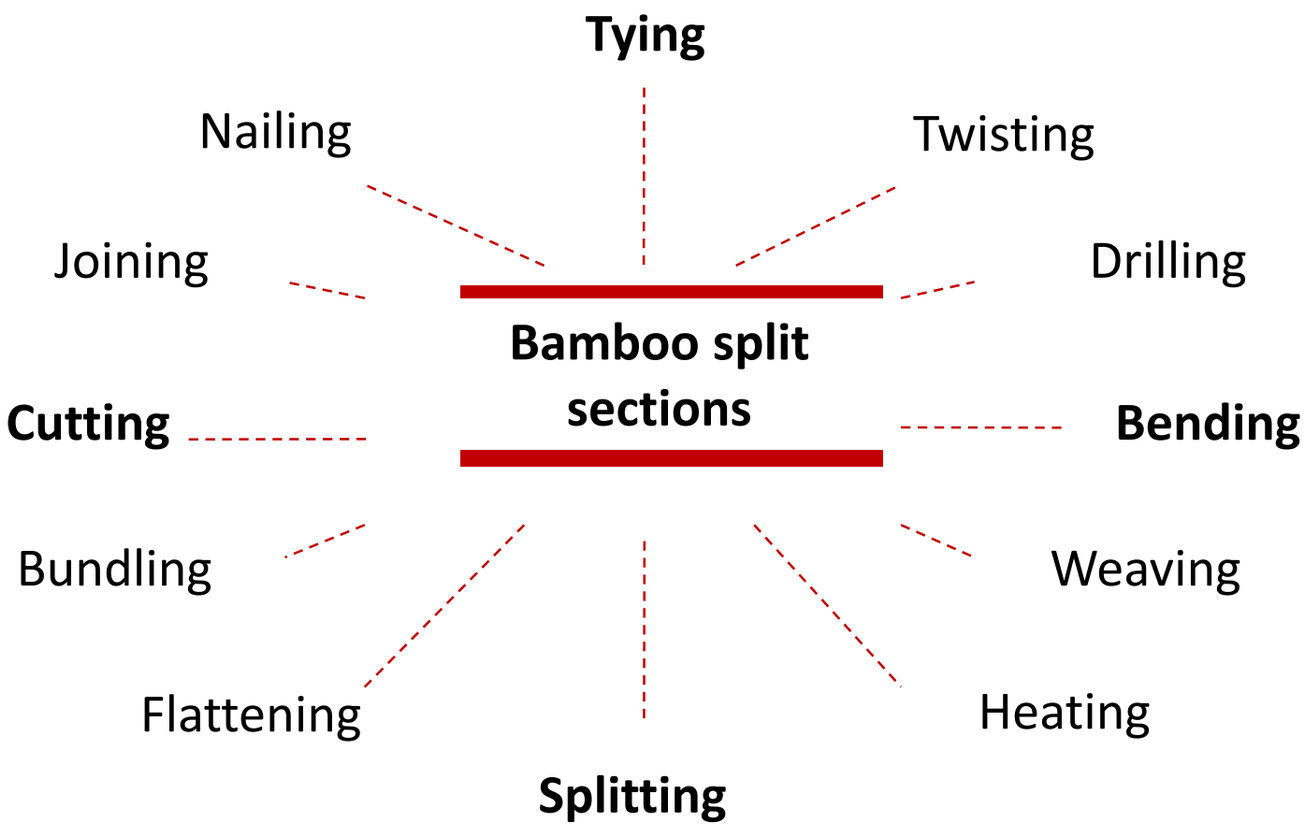
The extracted parameters :

1. Techniques used
2. The predetermined form
3. Connections between the split sections
4. Scale and proportions of different sections and their compositions

Stage 3: Derivation of methodology for further experimentations.

Literature study

List of techniques:



Predetermined form:

The directions for propagations are limited to:

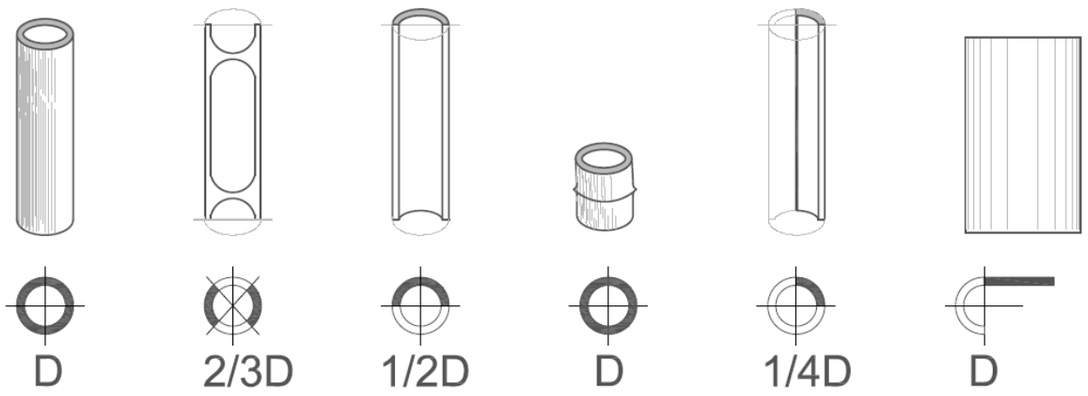
1. Horizontal
2. Vertical
3. Inclined
4. Curvilinear

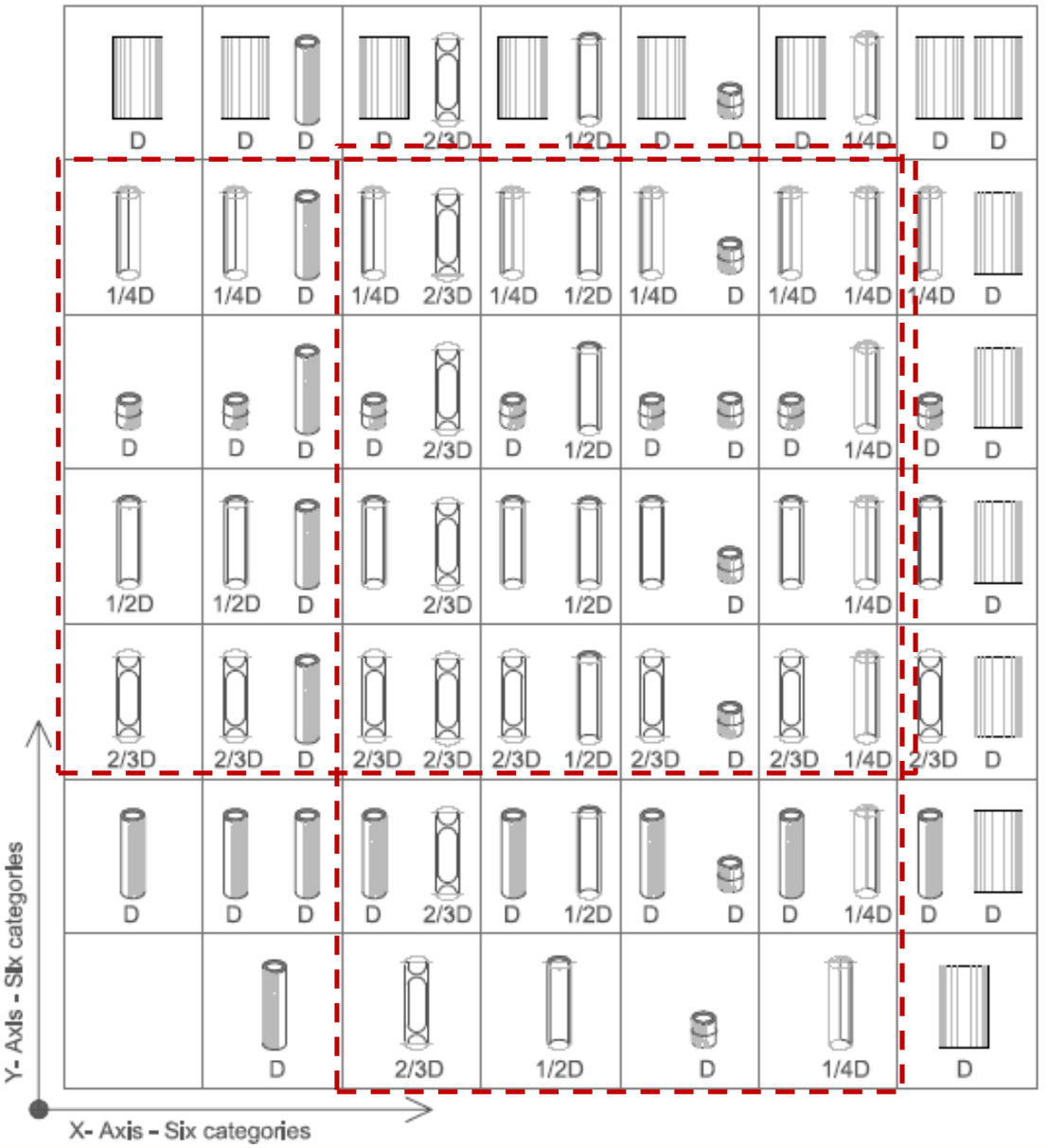
Connections between the sections:

Jute twine

Nut, bolts and rivets

Bamboo pin





Scale and proportions of different split sections:

Stage 4: Exploring different components/ systems, using the derived methodology.

Experimentation

Stage 5: Analyzing different components/ modules, as follows:

Analysis

Structural virtuosity:

Structural behavior of the joint:

Rotation along any axes – if joinery allows rotation?

Behavioral pattern:

How a particular module behaves under compression and tension loading conditions?

Framework of analysis

What are the e strengths and weaknesses of the module?

How does the load transfer?

Further scope of the research:

What are the future possibilities/ scope of the study?
What are the possible ways to modify the module?

Possible direction of propagation:

Horizontal, Vertical, Inclined and Curvilinear

Probable application:

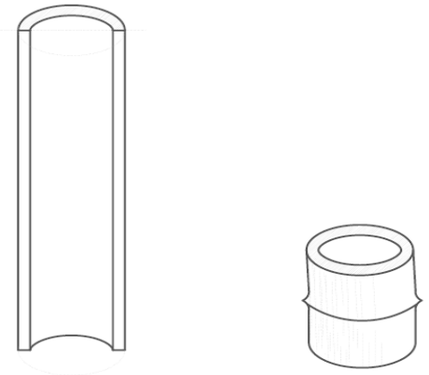
What can be the future applications of the systems?

Framework of analysis

Stage 6: Further explorations on the selected combination of the technique and one of the iterations from the chart.

Constants: Combination of half bamboo with one node
Bending technique

Variables: Angle of bending
Width of the strips



Stage 7: Compression testing on a selected module/ system.

Experimentation

Selected combination for detailed research

Testing

Selection of bamboo species

Selected species:

Bambusa Arundinacea:

- Commonly known as " Assam bamboo"
- Swollen nodes and long intranodes
- Medium wall thickness

Mechanical properties of the selected species:

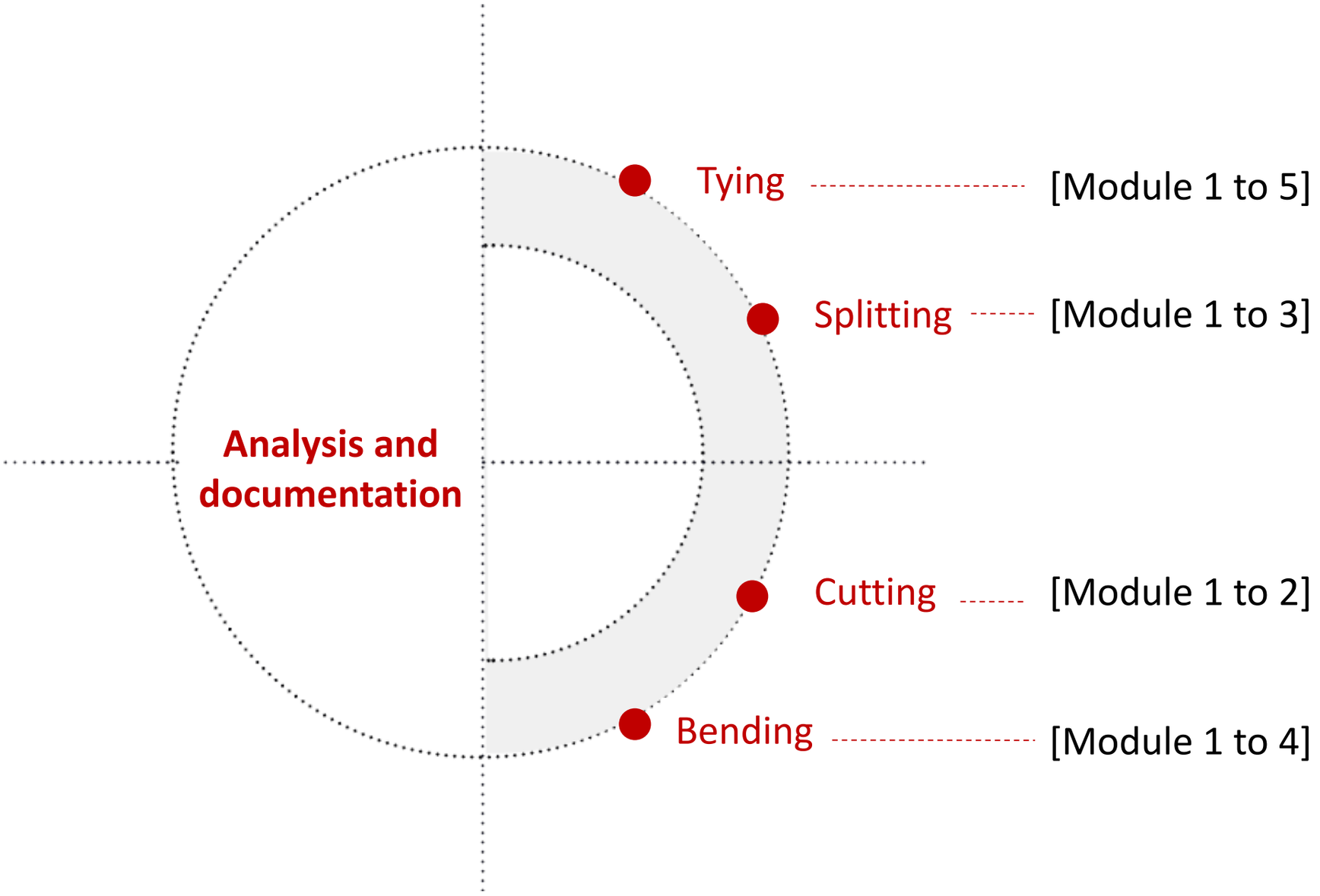
Green Condition:

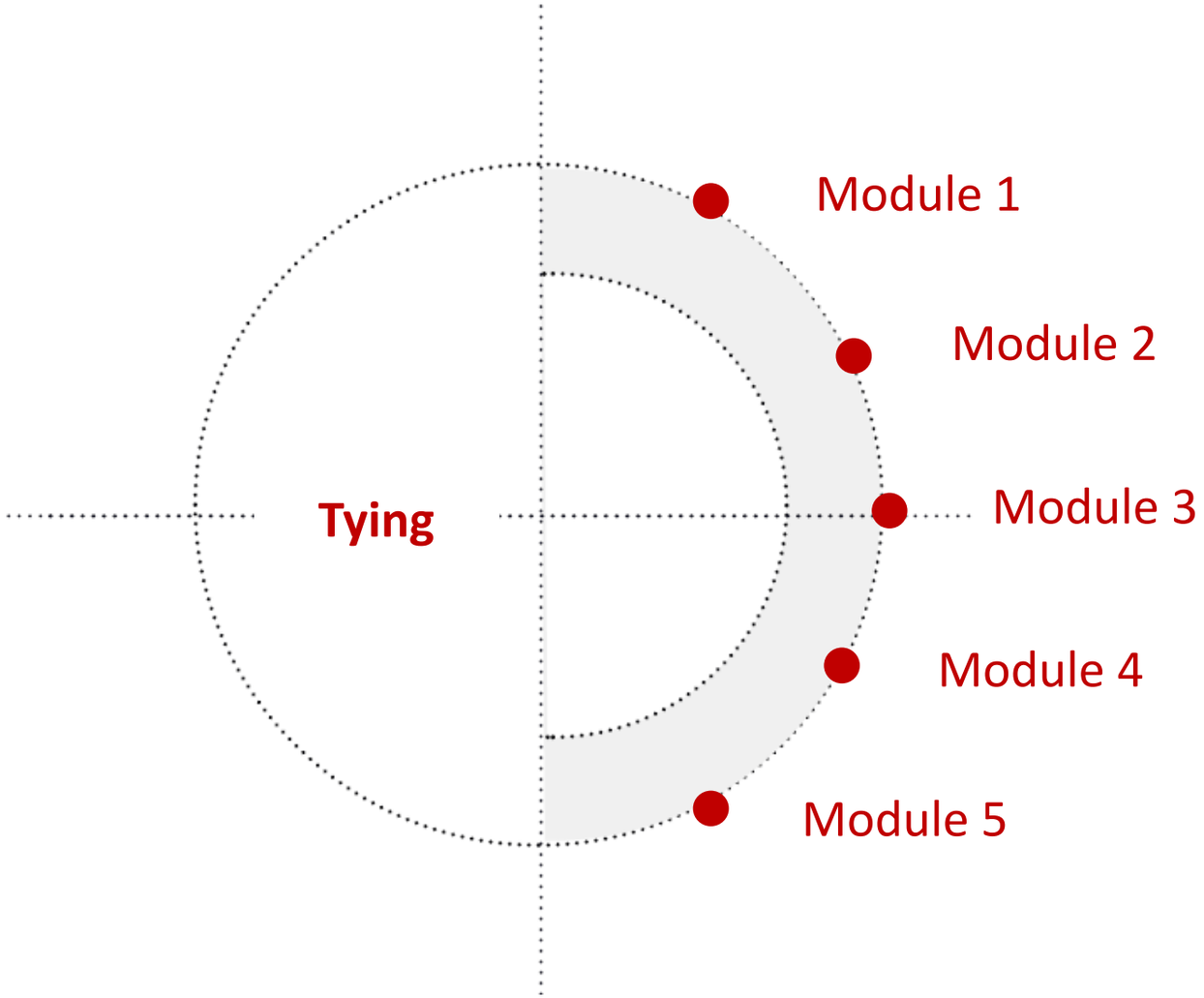
Density Kg/m^3	Modulus of rupture N/mm^2	Modulus of elasticity N/mm^2	Max. Com. strength N/mm^2
559	58.3	5.95	35.3

Dry Condition:

663	80.1	8.96	

Analysis and Documentation


Analysis and documentation
Tying
[Module 1 to 5]
Splitting
[Module 1 to 3]
Cutting
[Module 1 to 2]
Bending
[Module 1 to 4]


Module 1
Module 2
Module 3
Module 4
Module 5
Tying

Exploration 1:

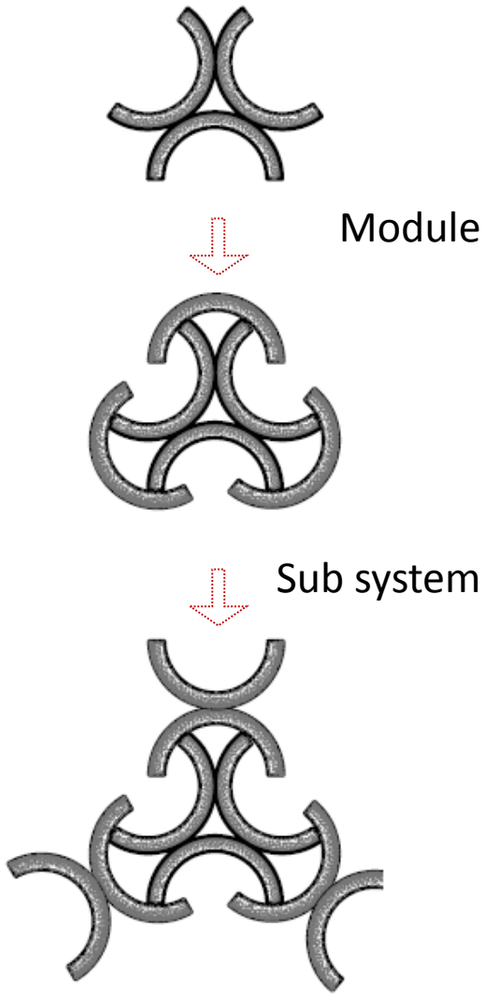
Plan

Perspective view

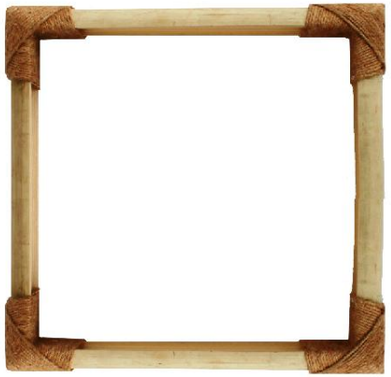
Perspective view

Orientation of the sections:	All the three sections - vertical
Structural behavior of joint:	Pin joint – restrains translations
The module will perform good under:	Compression And tension
Orientation of the module for better performance:	Vertical
Directions for propagation:	Horizontal
Probable application:	For vertical support systems in various space making elements
Further scope of research:	Tying pattern and other split Sections

Propagation possibilities:



Exploration 2:



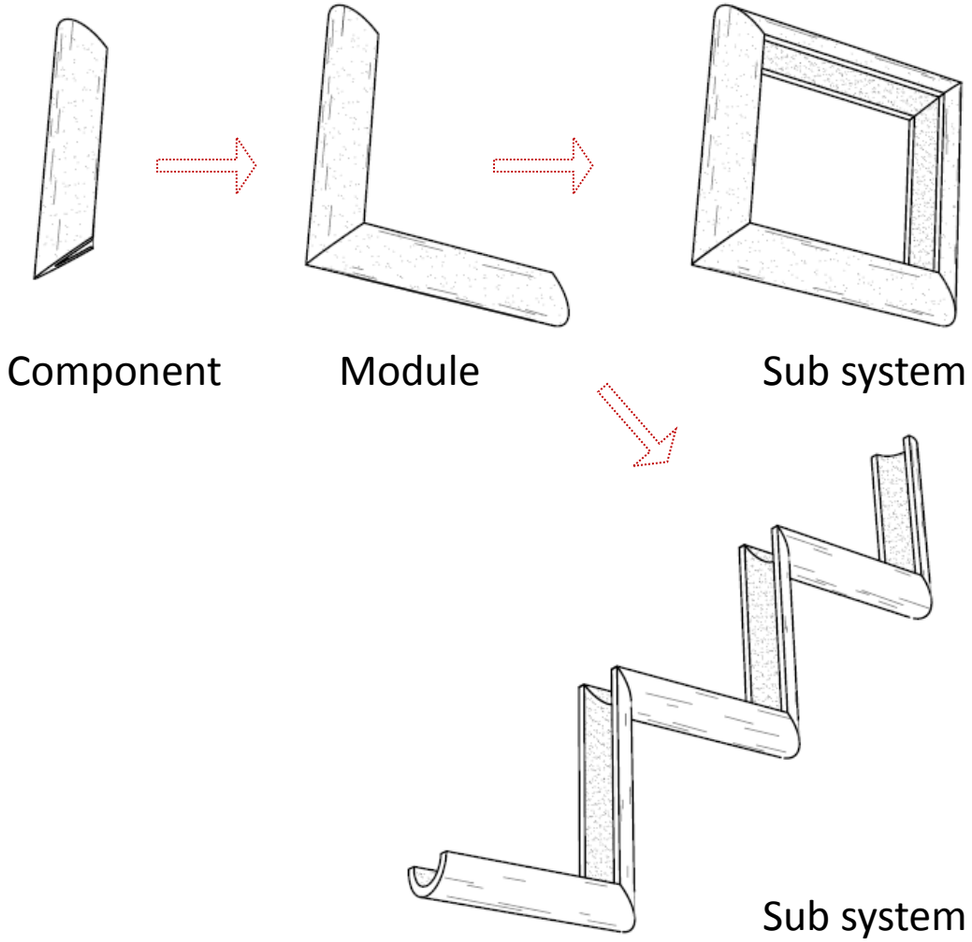
Plan

Perspective view

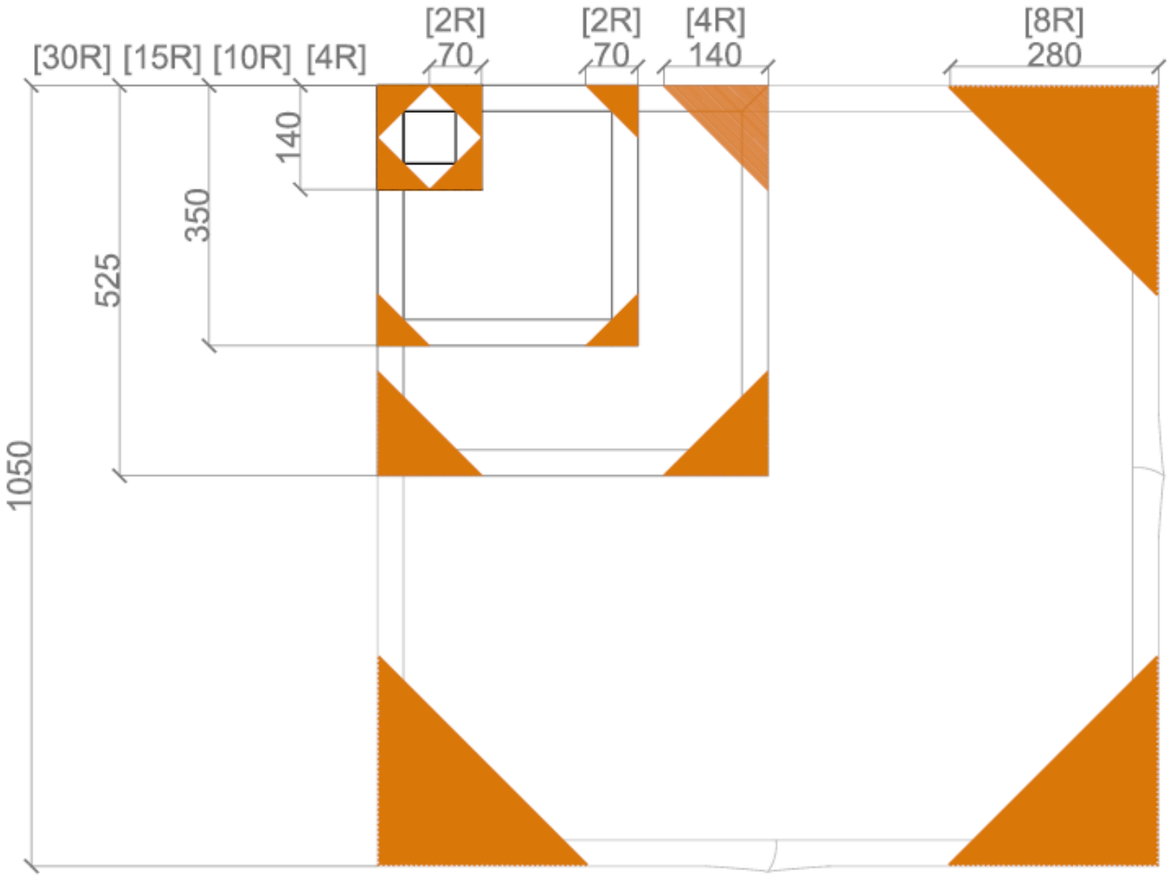
Perspective view

Orientation of the sections:	Two sections – Vertical Two sections – Horizontal
Structural behavior of joint:	Fix joint – restrains both rotations & translations
Directions for propagation:	Horizontal, vertical and inclined
Better performance of the module:	Under compression
Better orientation of module:	Vertical
Manually or machine based process:	Partially manual Partially machine based
Further scope of research:	Tying pattern, different angles and other split Sections

Propagation possibilities :



Maximum and minimum dimensions possible & Increment in layers of tying with respect to the changing dimensions



Exploration 3:

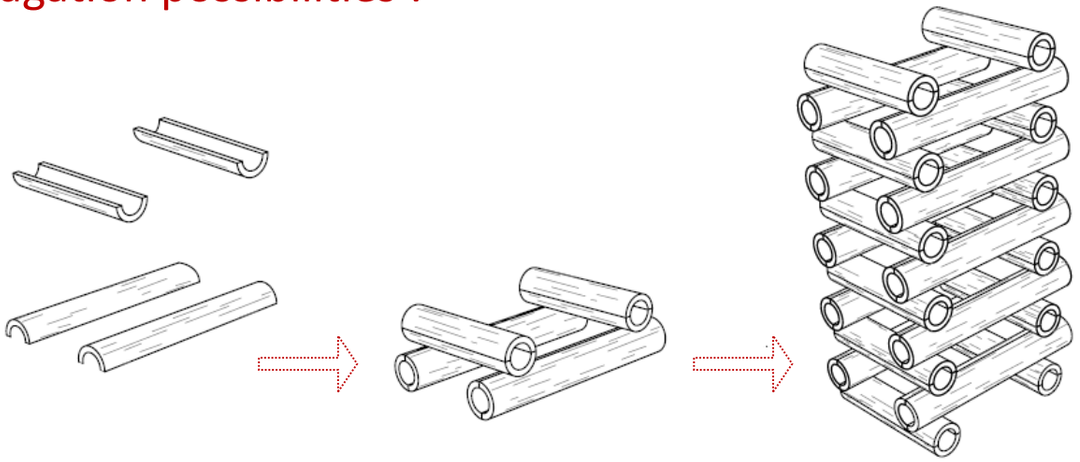
Plan

Perspective view

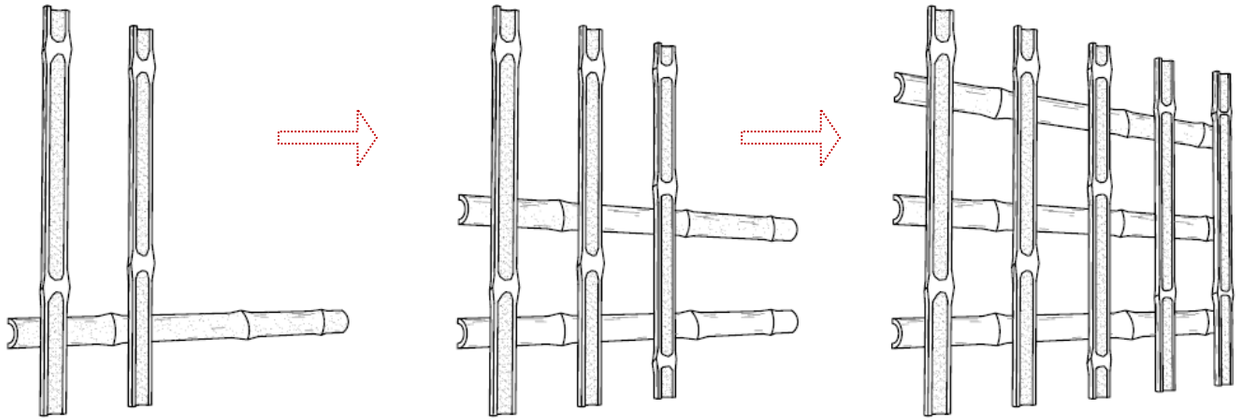
Perspective view

Orientation of the sections:	Two sections – Vertical Two sections – Horizontal
Structural behavior of joint:	Fix joint – restrains both rotations & translations
Directions for propagation:	Horizontal, vertical and inclined
Better performance of the module:	Under compression and tension
Better orientation of module:	horizontal
Manually or machine based process:	Partially manual Partially machine based
Further scope of research:	Tying pattern, different angles and other split Sections

Propagation possibilities :

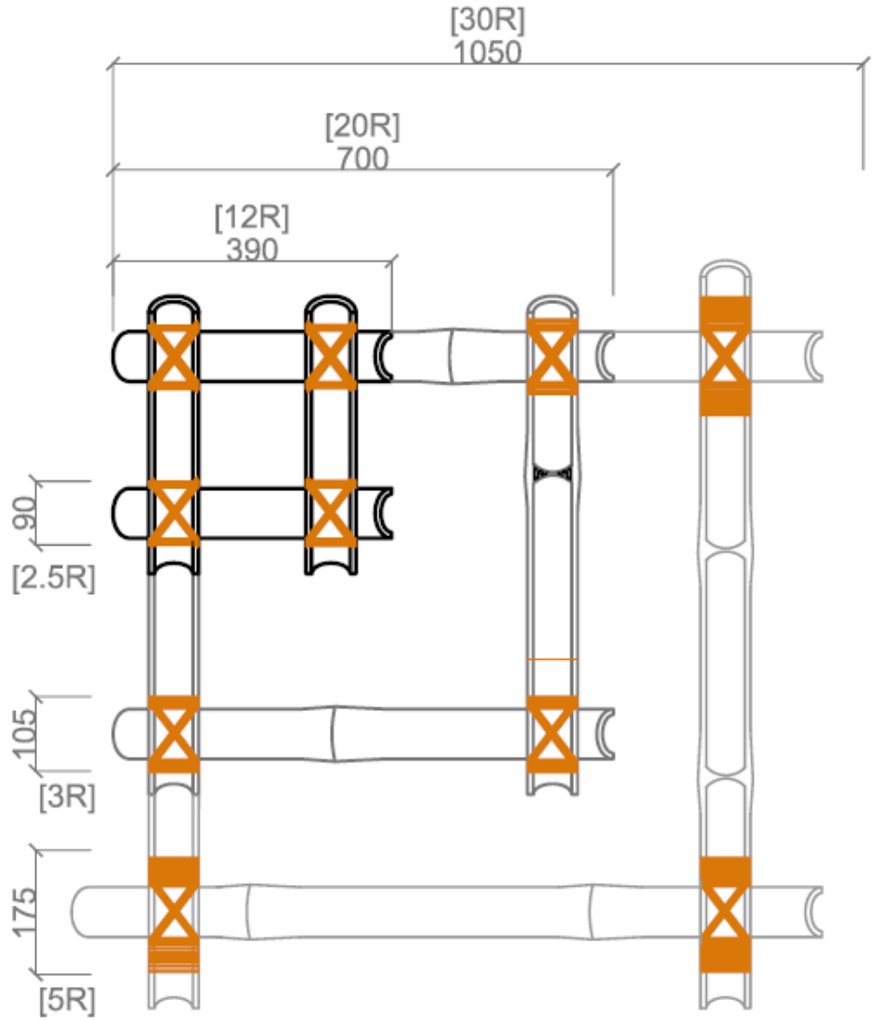


Component Module Sub system



Component Module Sub system

Maximum and minimum dimensions possible & Increment in layers of tying with respect to the changing dimensions



Exploration 4:

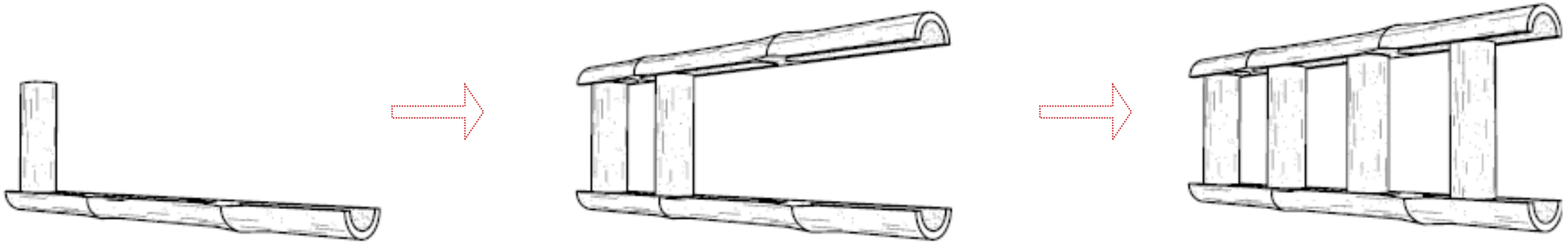
Plan

Perspective view

Perspective view

Orientation of the sections:	Two sections – Vertical Two sections – Horizontal
Structural behavior of joint:	Pin joint – restrains translations
Directions for propagation:	Horizontal
Better performance of the module:	Under compression
Better orientation of module:	Vertical
Manually or machine based process:	Partially manual Partially machine based
Further scope of research:	Tying pattern and other split Sections

Propagation possibilities :



Component

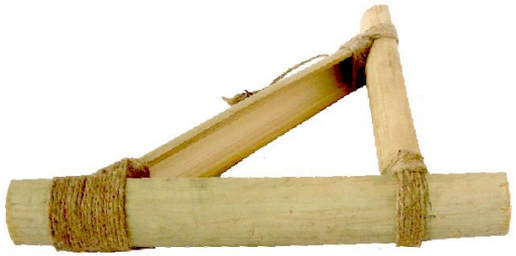
Module

Sub system

Exploration 5:

Plan

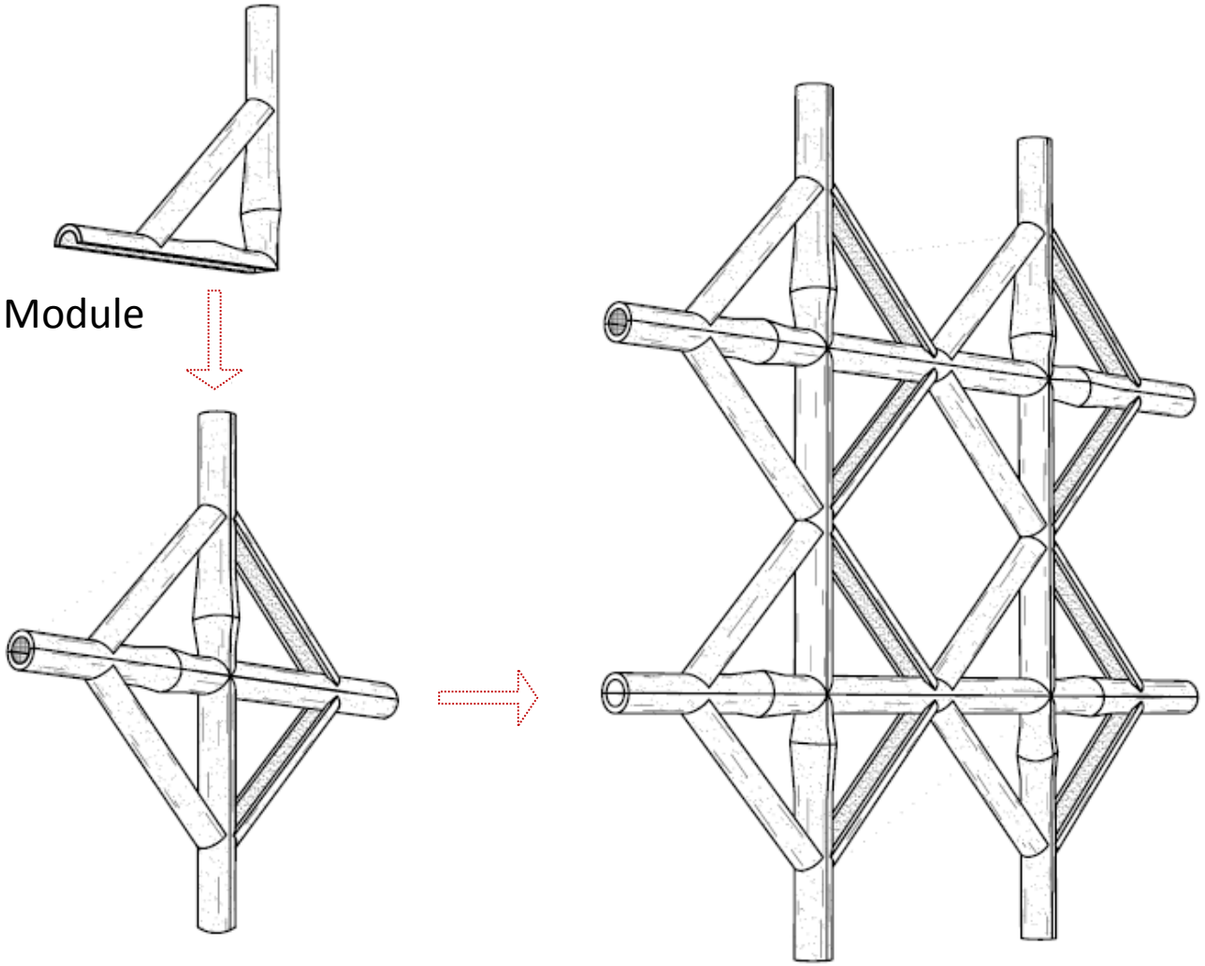
Perspective view



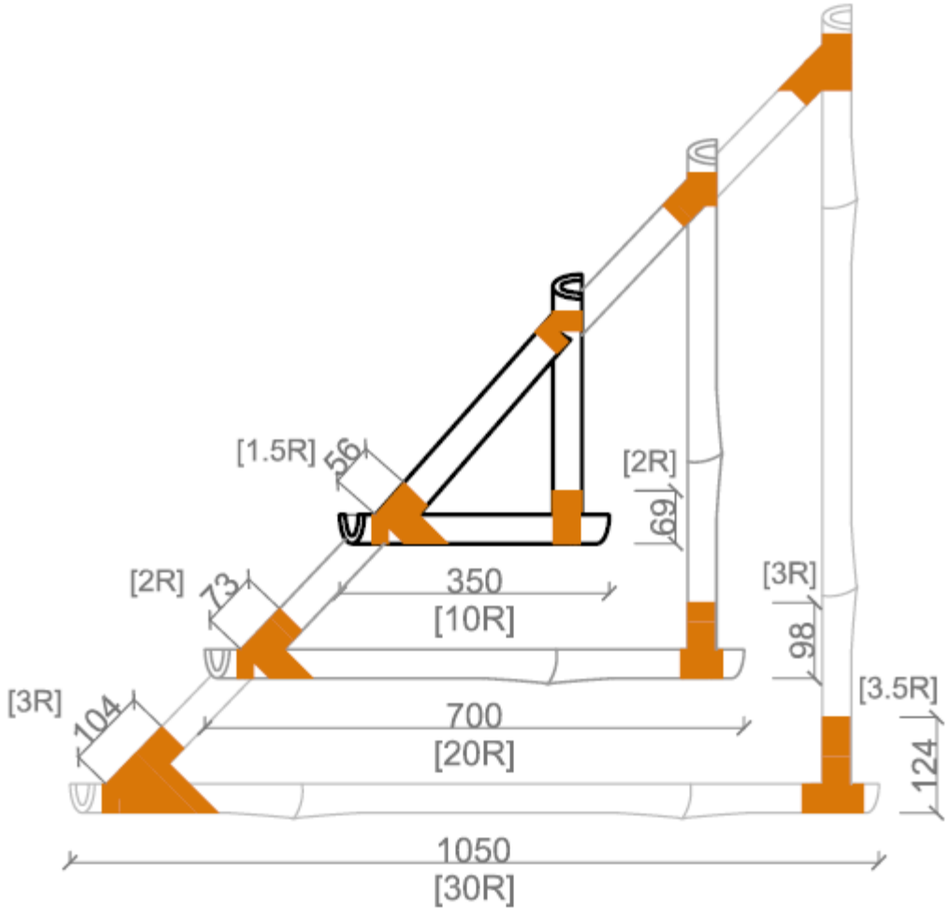
Perspective view

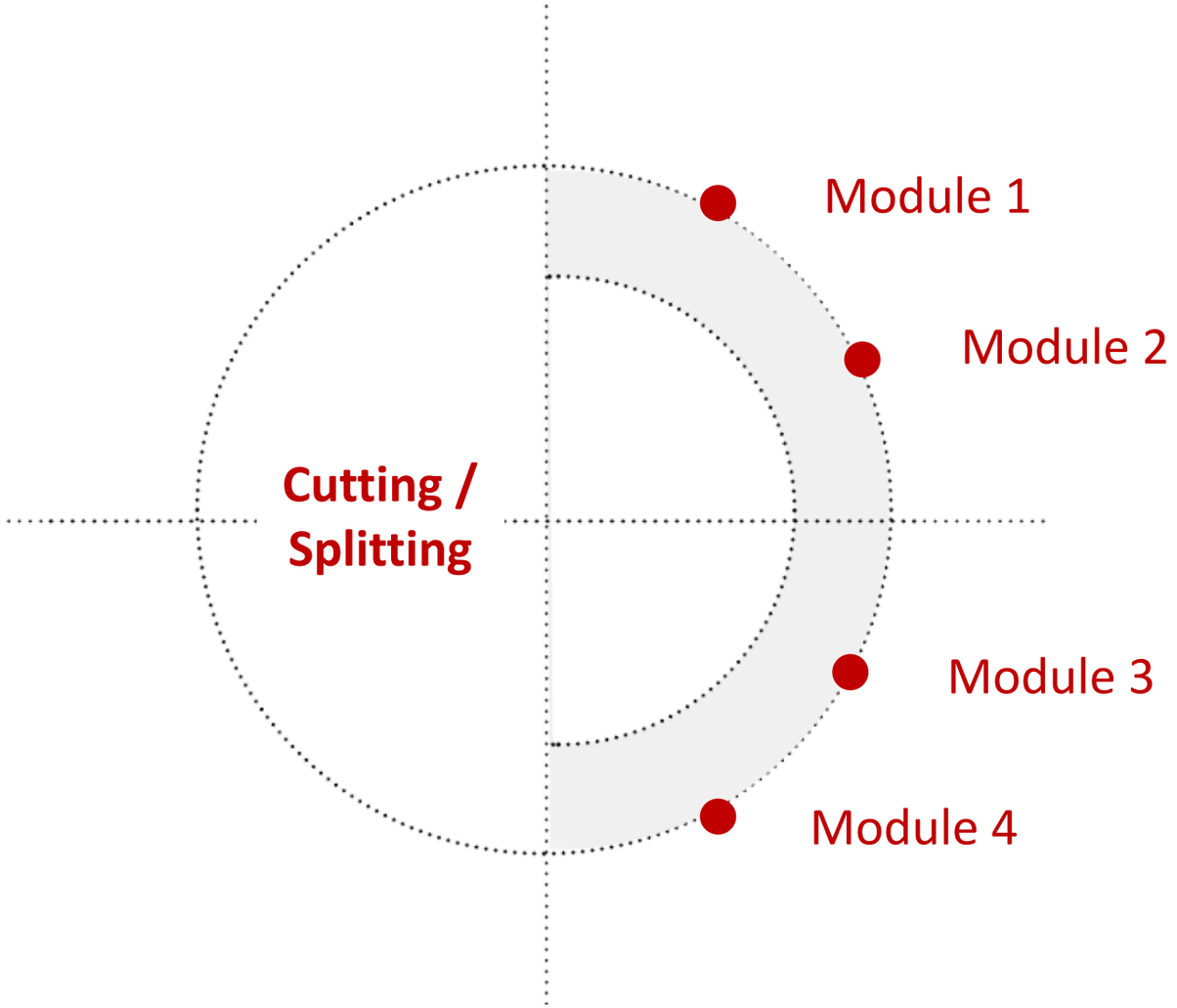
Orientation of the sections:	One sections – Vertical One sections – Horizontal One section - inclined
Structural behavior of joint:	Fix joint – restrains both rotations & translations
Directions for propagation:	Horizontal, vertical and inclined
Better performance of the module:	Under compression and tension
Better orientation of module:	Vertical
Manually or machine based process:	Partially manual Partially machine based
Further scope of research:	Tying pattern, different angles and other split Sections

Propagation possibilities :

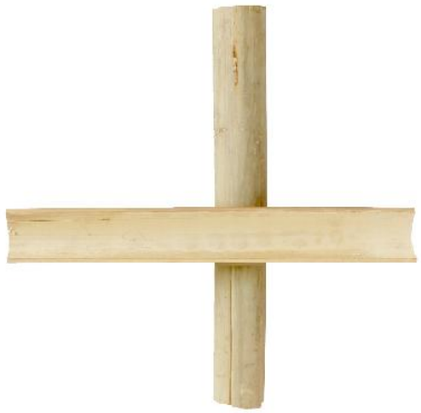


Maximum and minimum dimensions possible & Increment in layers of tying with respect to the changing dimensions



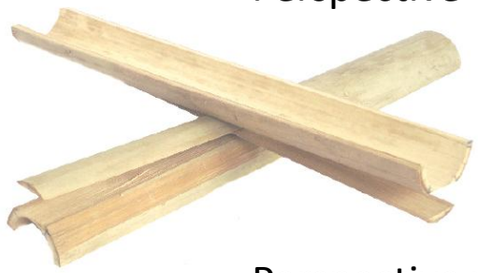

Module 1
Module 2
Cutting /
Splitting
Module 3
Module 4

Exploration 6:



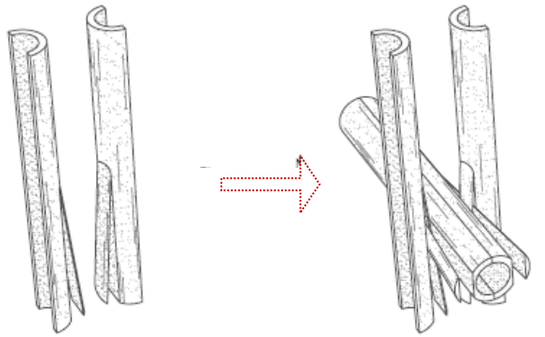
Plan

Perspective view

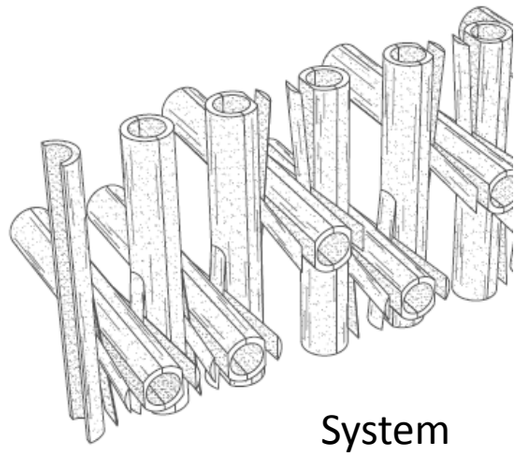


Perspective view

Orientation of the sections:	Two sections – Vertical Two sections – Horizontal
Structural behavior of joint:	Pin joint – restrains translations
Directions for propagation:	Horizontal and vertical
Better performance of the module:	-
Better orientation of module:	Horizontal
Manually or machine based process:	Machine based
Further scope of research:	Other ways of splitting and other split sections

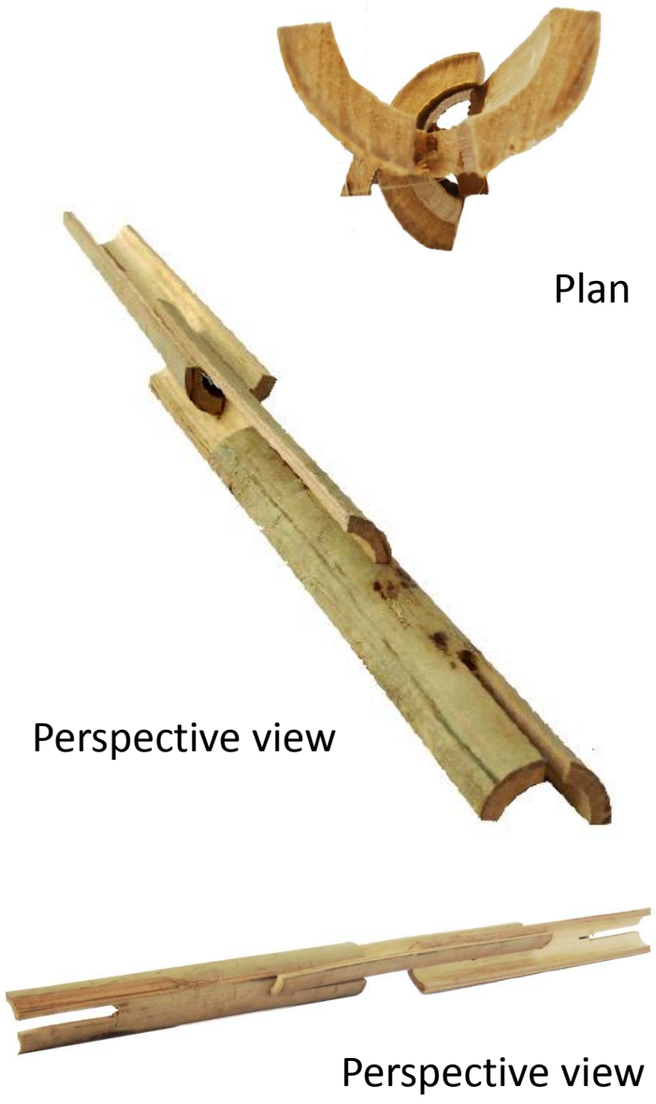


Module Sub system

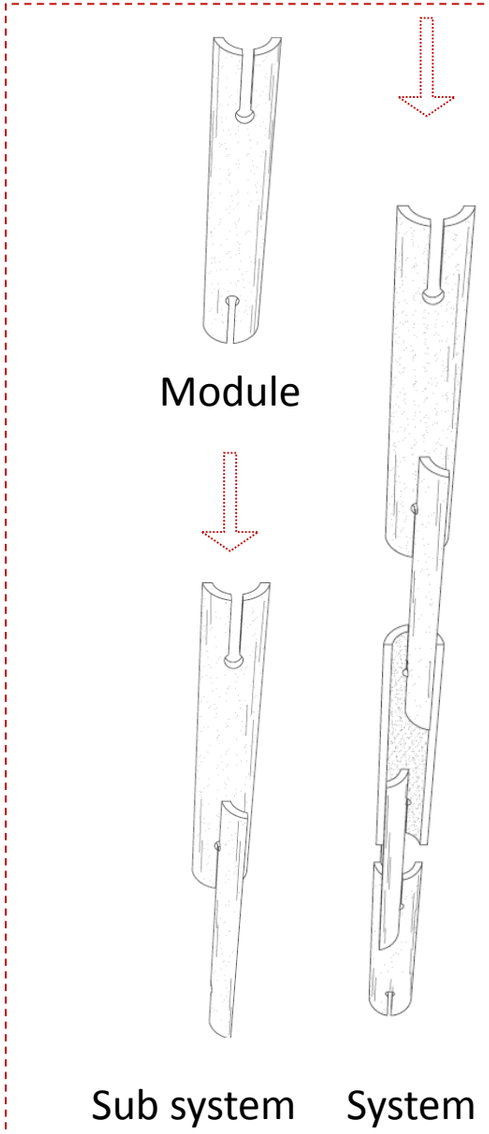


System

Exploration 7:



Orientation of the sections:	All three sections - vertical
Structural behavior of joint:	Fix joint – restrains both rotations & translations
Directions for propagation:	Vertical
Better performance of the module:	Under compression
Better orientation of module:	Vertical
Manually or machine based process:	Machine based
Further scope of research:	Other ways of splitting and other split sections



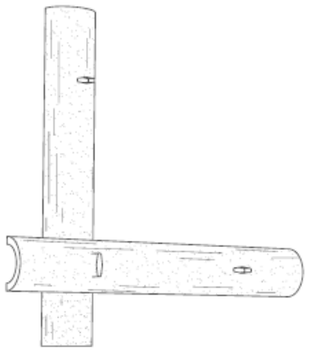
Exploration 8:

Plan

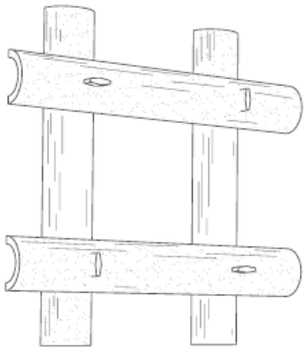
Perspective view

Perspective view

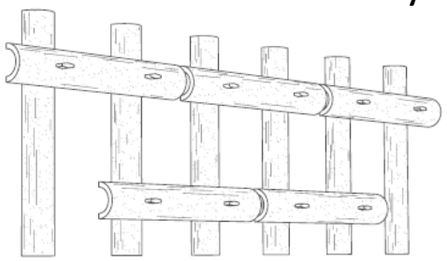
Orientation of the sections:	Two sections – horizontal One section - vertical
Structural behavior of joint:	Fix joint – restrains both rotations & translations
Directions for propagation:	Horizontal, vertical and inclined
Better performance of the module:	Under compression
Better orientation of module:	Horizontal
Manually or machine based process:	Machine based
Further scope of research:	Other shapes of bamboo pins and other split sections



Module



Sub system



System

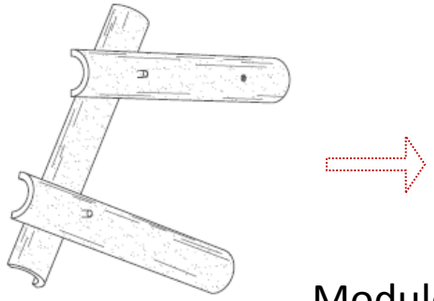
Exploration 9:

Plan

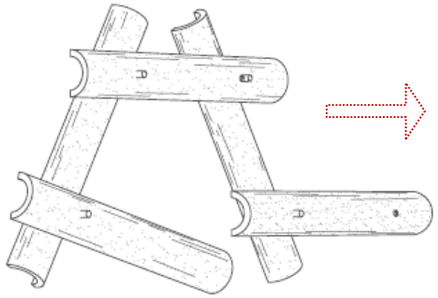
Perspective view

Perspective view

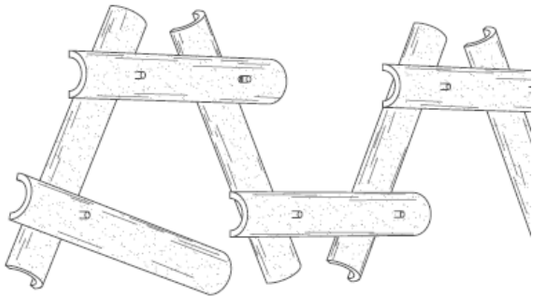
Orientation of the sections:	One sections – horizontal Two section - vertical
Structural behavior of joint:	Pin joint – restrains translations
Directions for propagation:	Horizontal, vertical and inclined
Better performance of the module:	Under compression
Better orientation of module:	Horizontal
Manually or machine based process:	Machine based
Further scope of research:	Other shapes of bamboo pins and other split sections



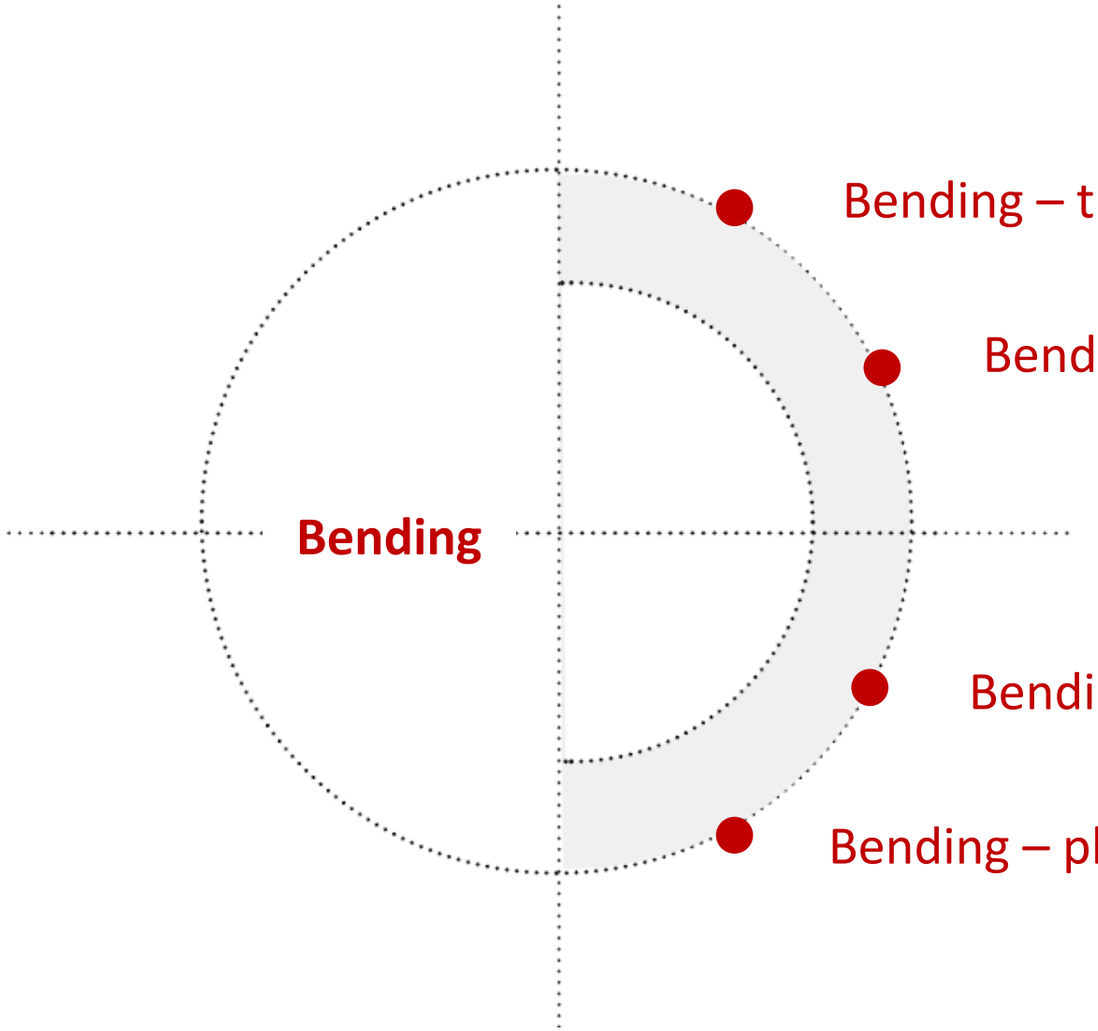
Module



Sub system



System



Bending – three strips ---------- [Module 1 to 4]

Bending – two strips ---------- [Module 1 to 4]

Bending – 90 degree component ---------- [Module 1 to 4]

Bending – platonic solids ---------- [Module 1 to 4]

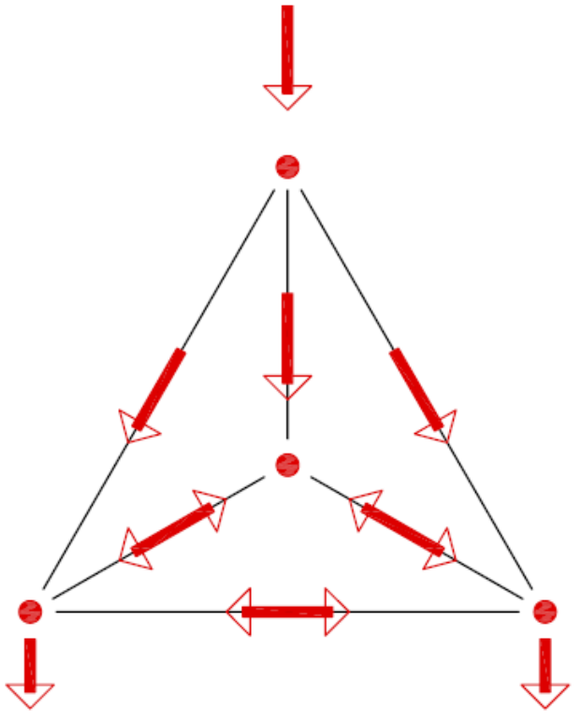
Exploration 10:

Perspective view

Plan

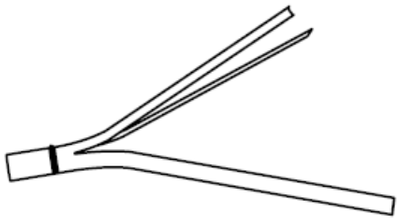
Elevation

Number of vertices:	4
Number of edges:	6
Angle between strips:	60
Surfaces:	Four equilateral triangle
Structural behavior of joint:	Fix joint – restrains both rotations & translations
Directions for propagation:	Horizontal Vertical
Better performance of the module:	Under compression
Manually or machine based process:	Partially manual Partially machine based
Further scope of research:	Other angle between the sections and other split Sections

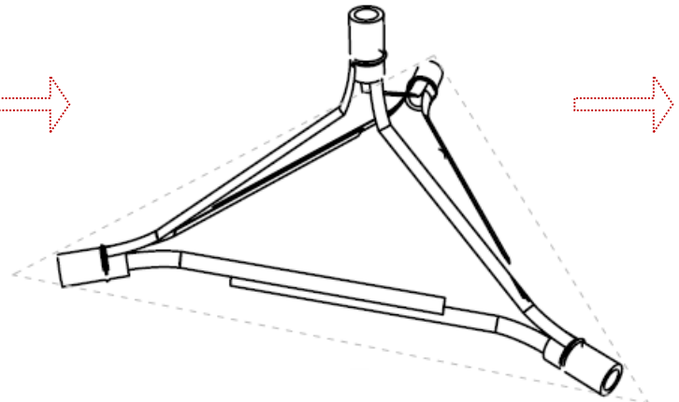


Structural behavior of module

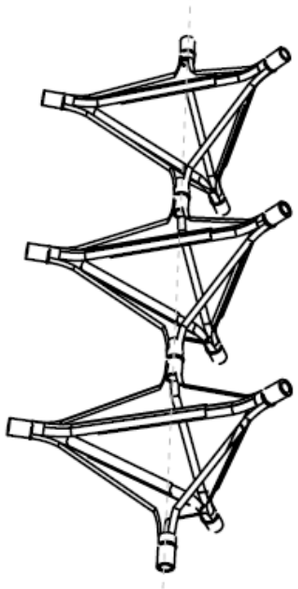
Propagation possibilities :



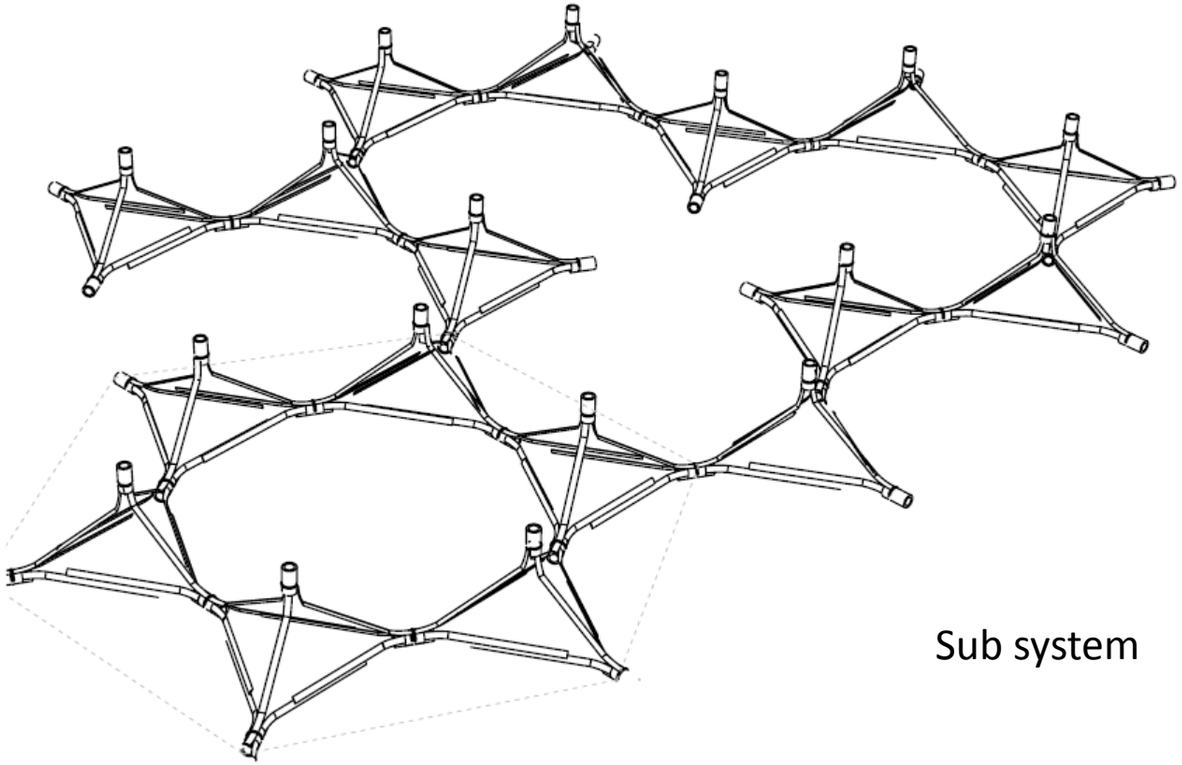
Component



Module



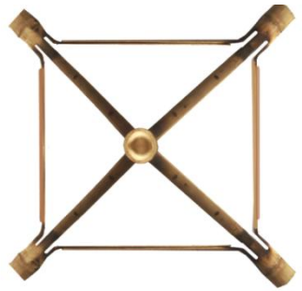
Sub system



Sub system

Exploration 11 and 12:

Perspective view



Plan

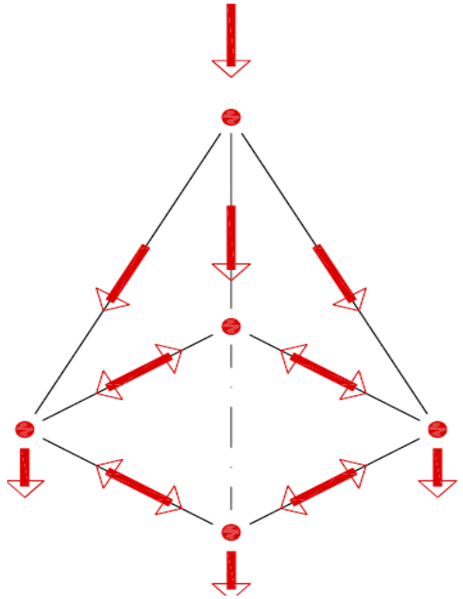
Elevation

Number of vertices: 5

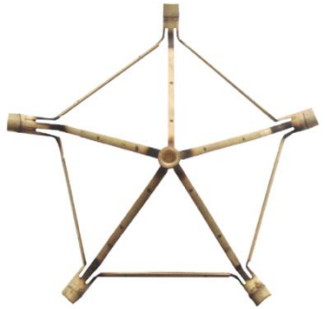
Number of edges: 8

Angle between strips: 90

Surfaces: Four equilateral triangles, one square



Perspective view



Plan

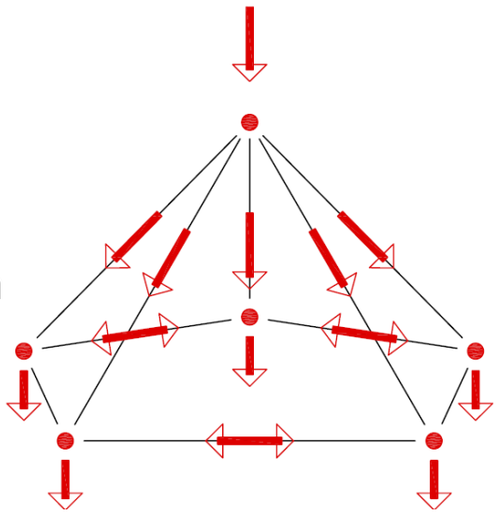
Elevation

Number of vertices: 6

Number of edges: 10

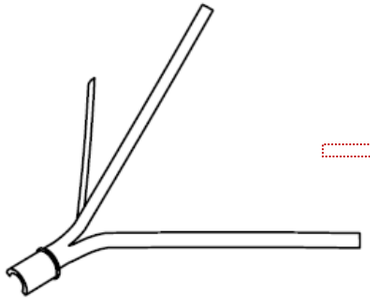
Angle between strips: 108

Surfaces: Five equilatera triangles, one pentagon

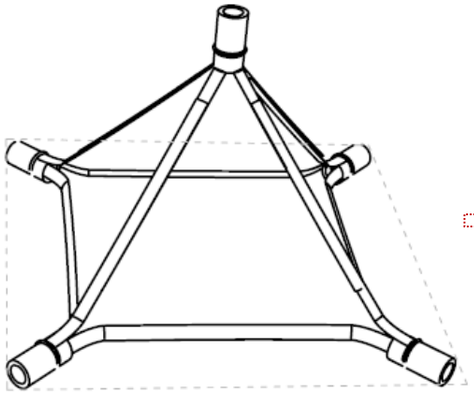


Structural behavior

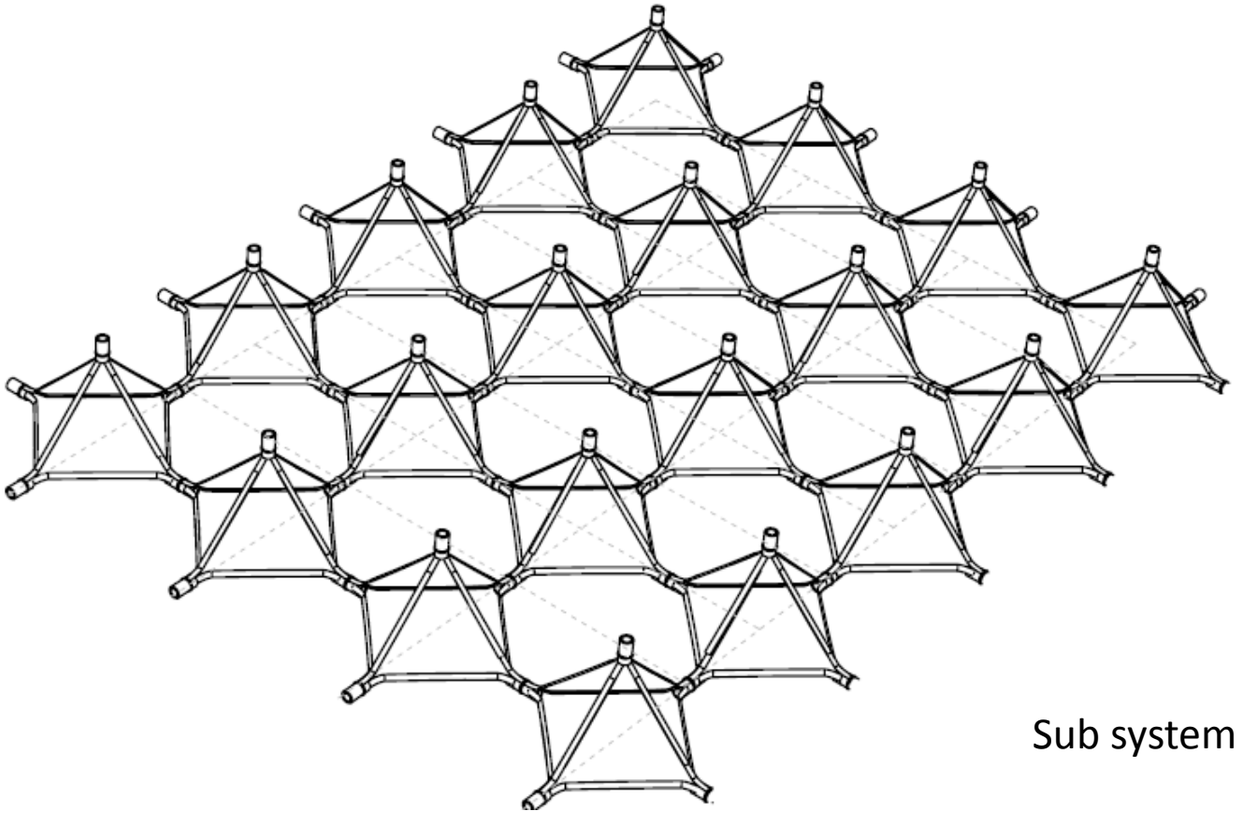
Propagation possibilities :



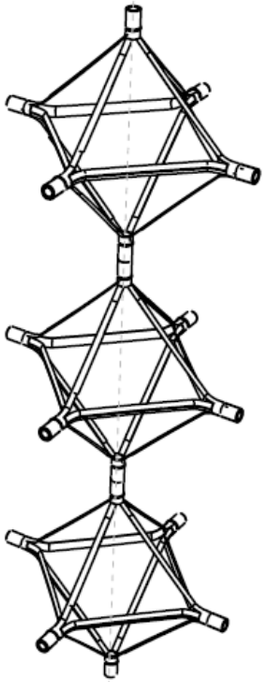
Component



Module

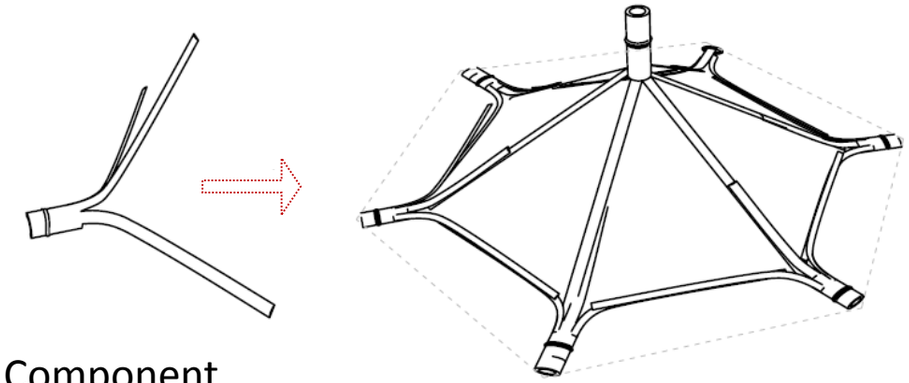


Sub system



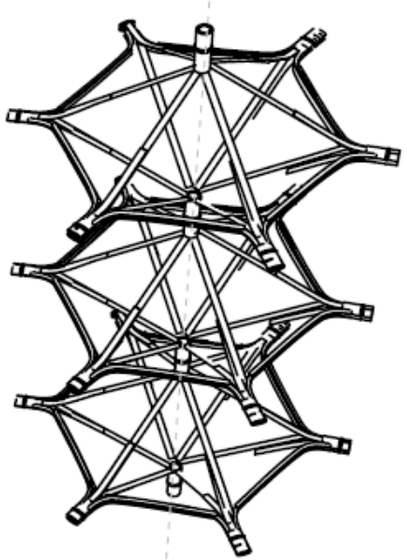
Sub system

Propagation possibilities :

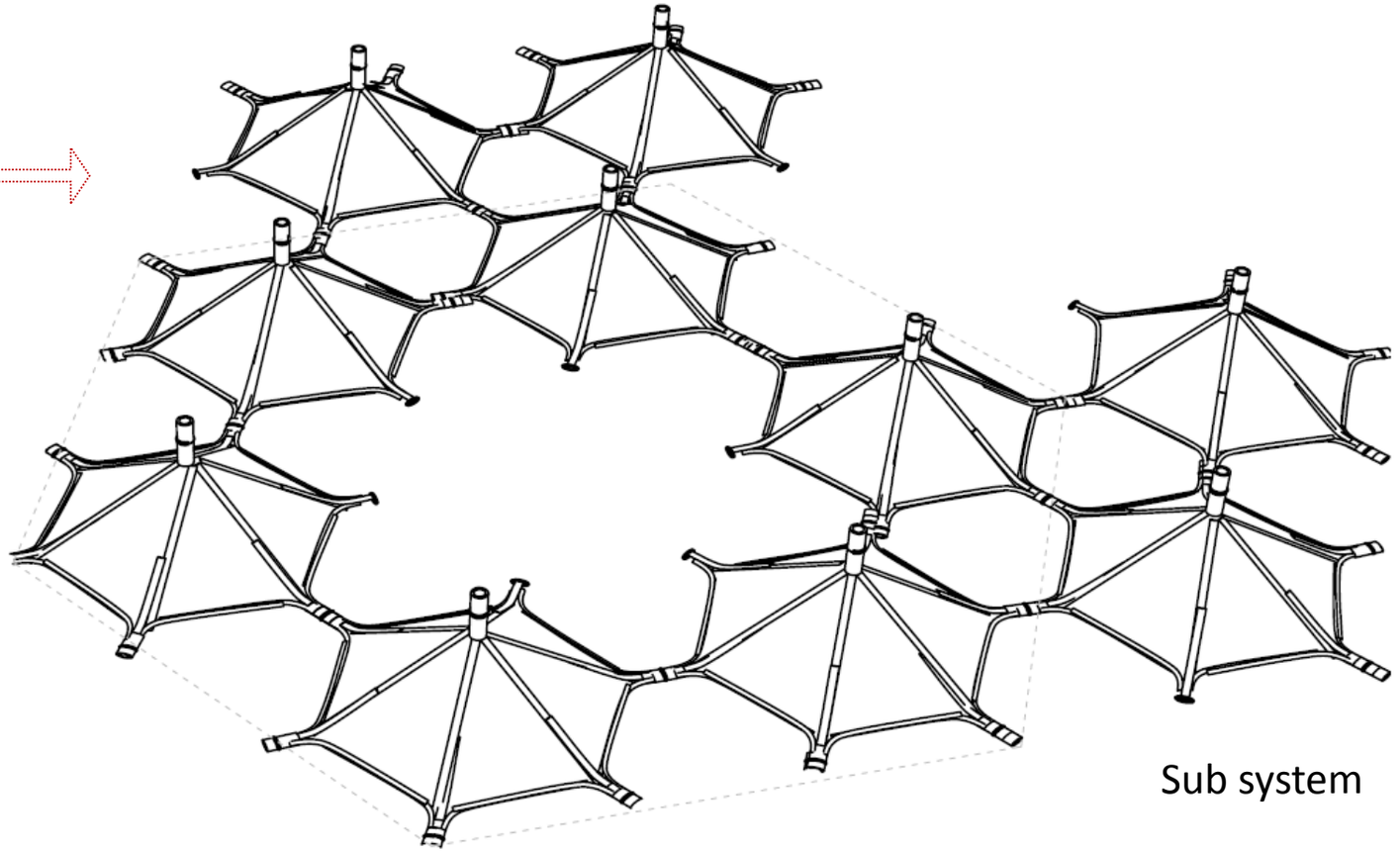


Component

Module



Sub system



Sub system

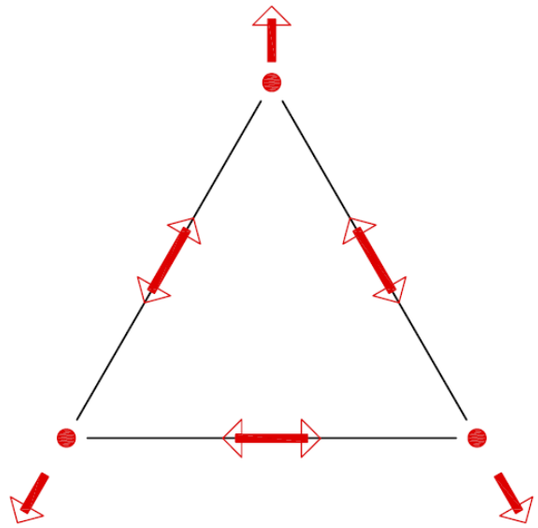
Exploration 13:

Perspective view

Plan

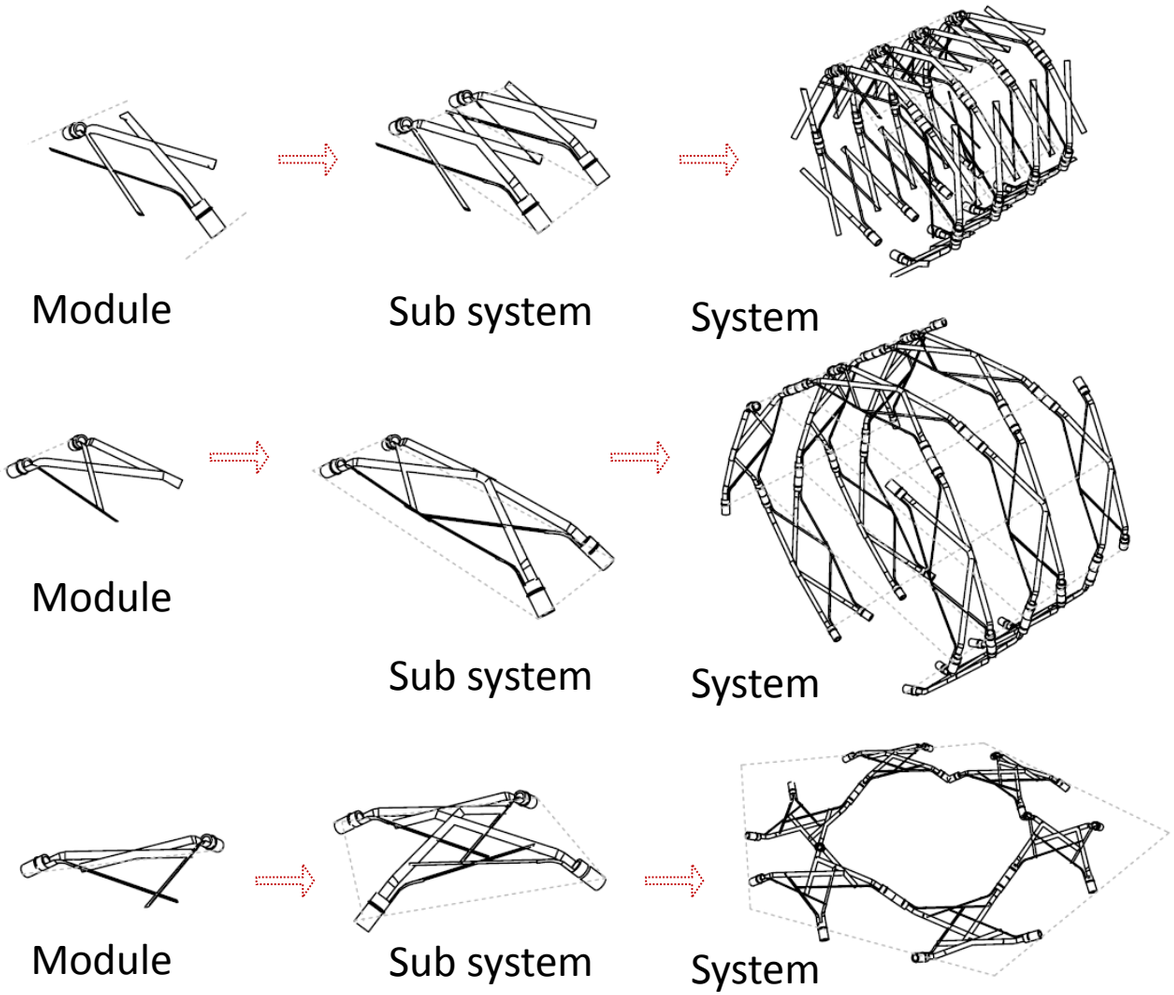
Elevation

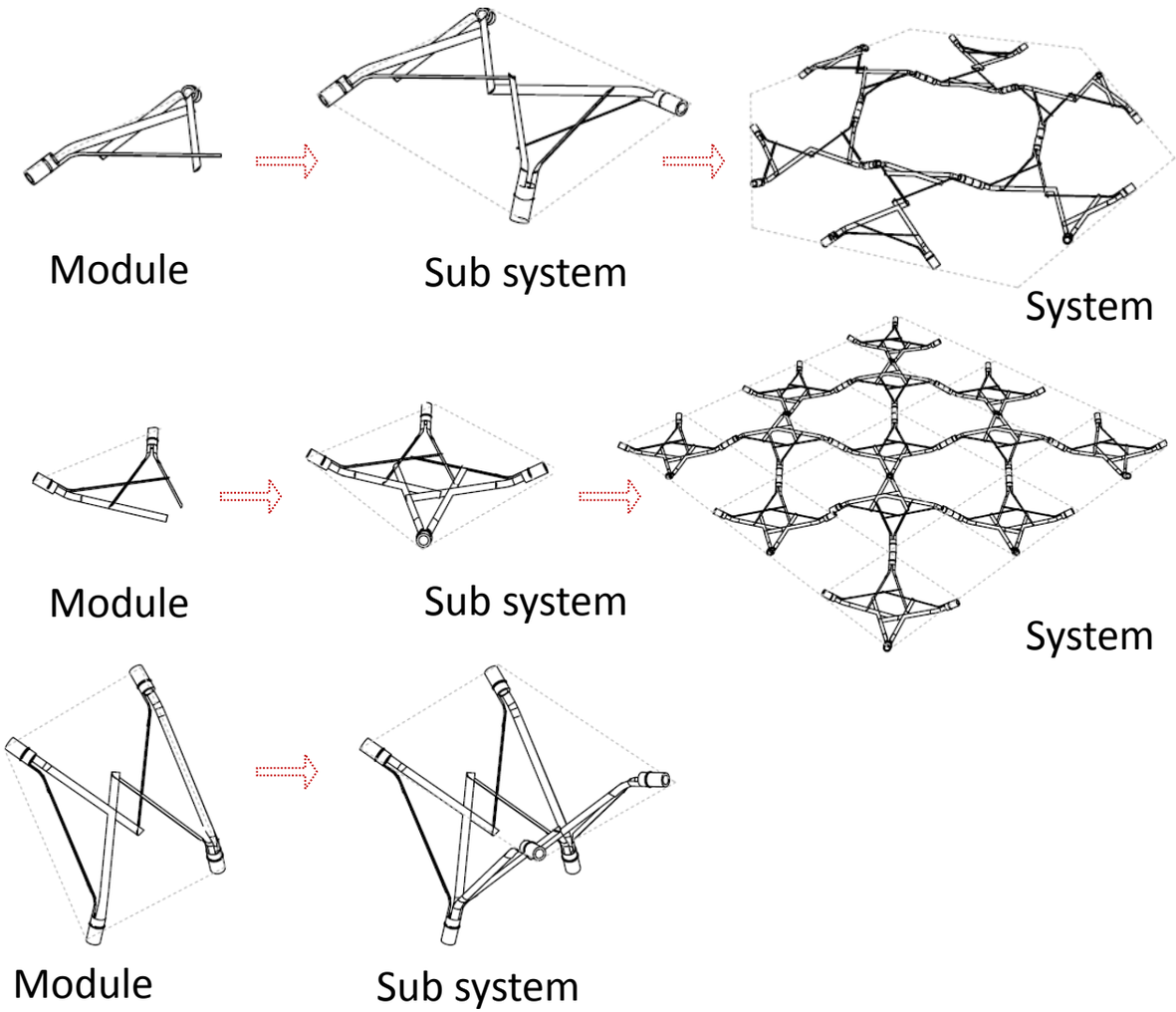
Number of vertices:	3
Number of edges:	3
Angle between strips:	60
Surfaces:	One triangle
Structural behavior of joint:	Fix joint – restrains both rotations & translations
Directions for propagation:	Horizontal, Vertical and inclined
Better performance of the module:	Under compression
Manually or machine based process:	Partially manual Partially machine based
Further scope of research:	Other angle between the sections and other split Sections



Structural behavior of module

Propagation possibilities :





Exploration 14 and 15:

Perspective view

Plan

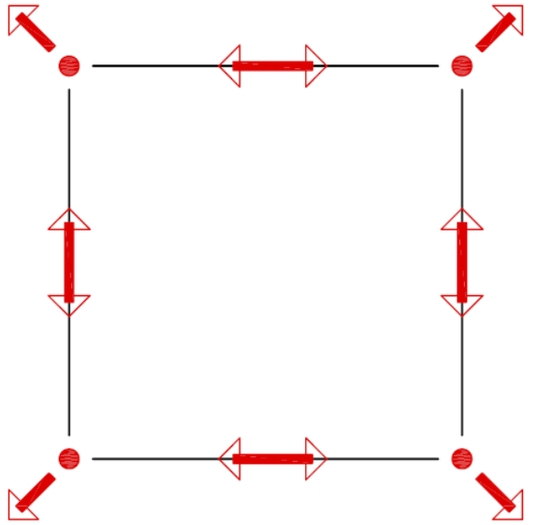
Elevation

Number of vertices: 4

Number of edges: 4

Angle between strips: 45

Surfaces: One square



Perspective view

Plan

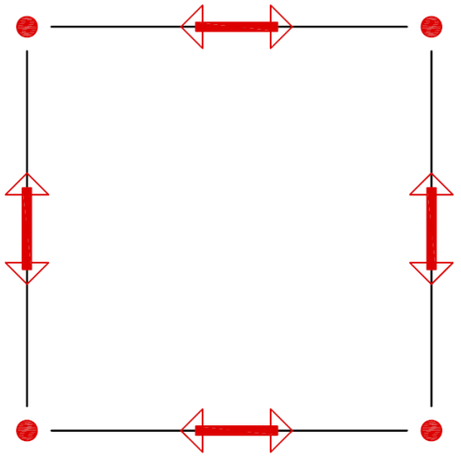
Elevation

Number of vertices: 4

Number of edges: 4

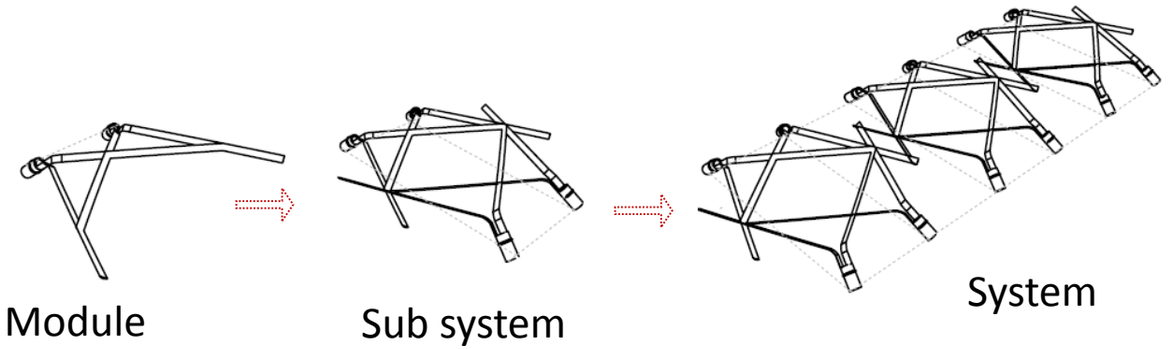
Angle between strips: 90

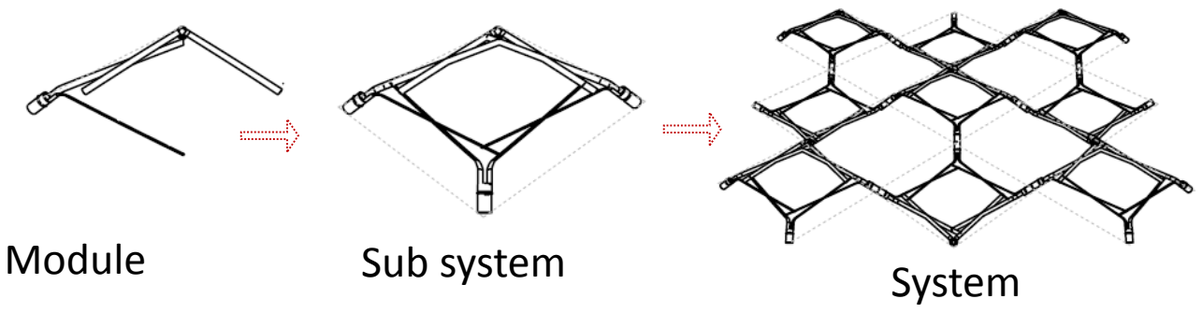
Surfaces: One square

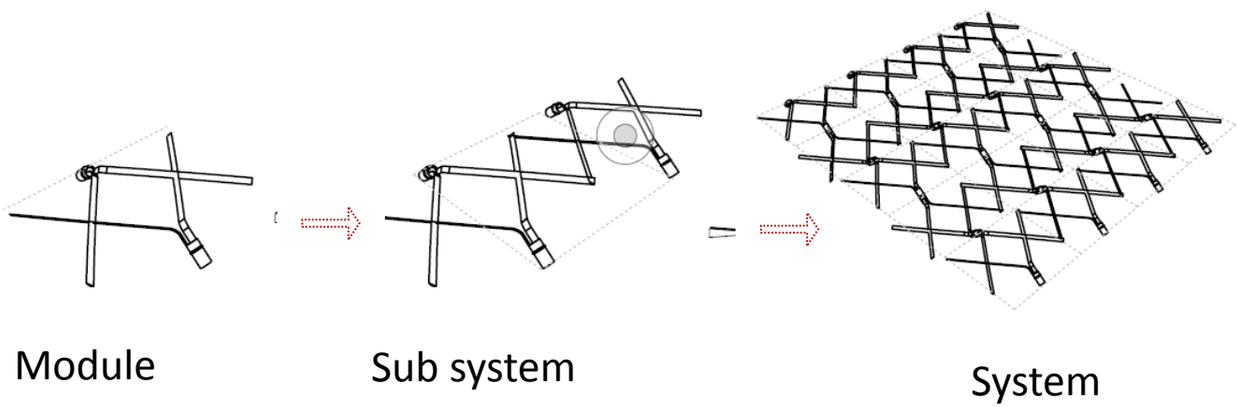


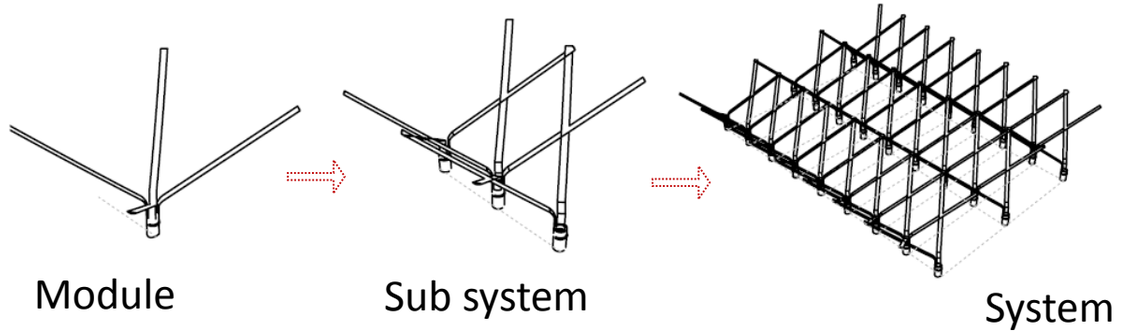
Structural behavior

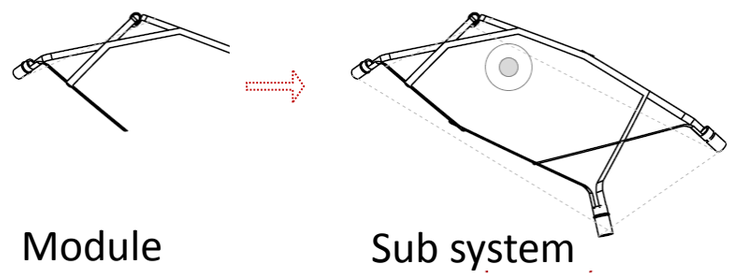
Propagation possibilities :

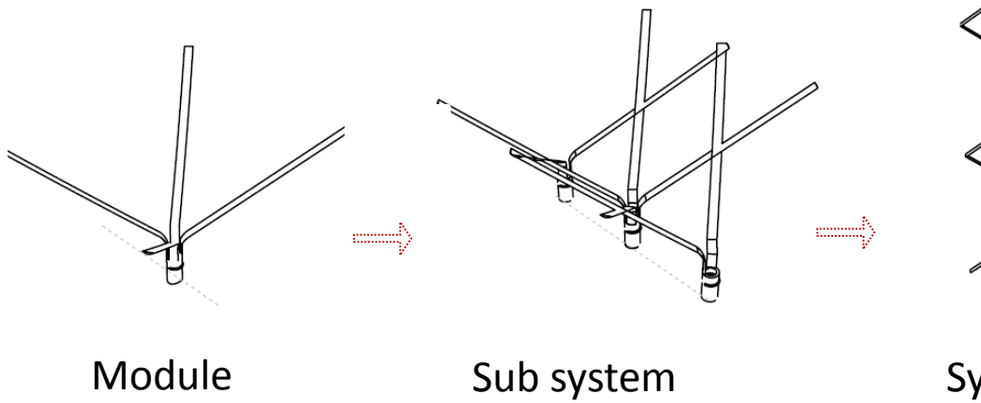




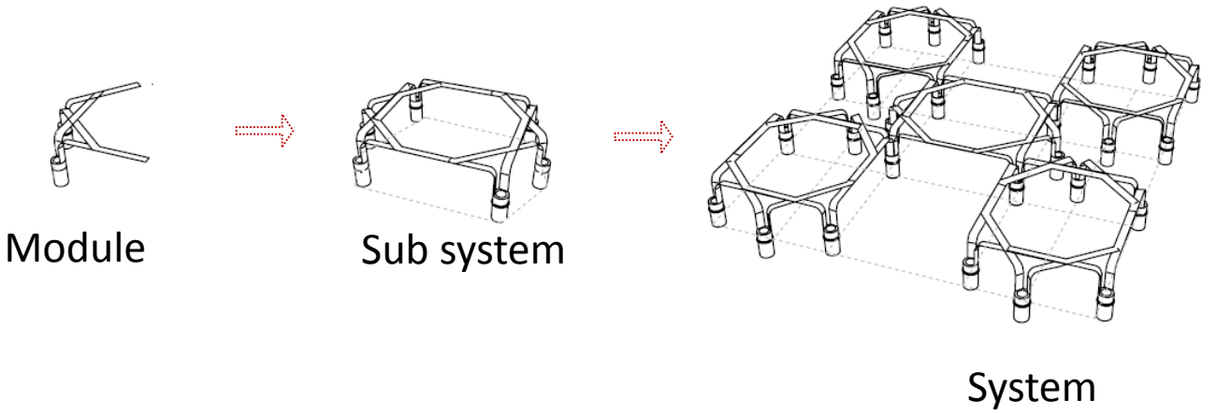


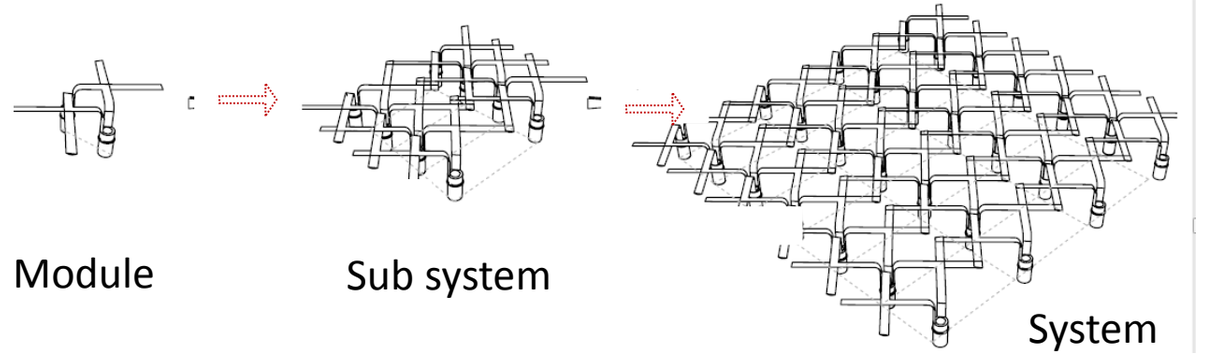


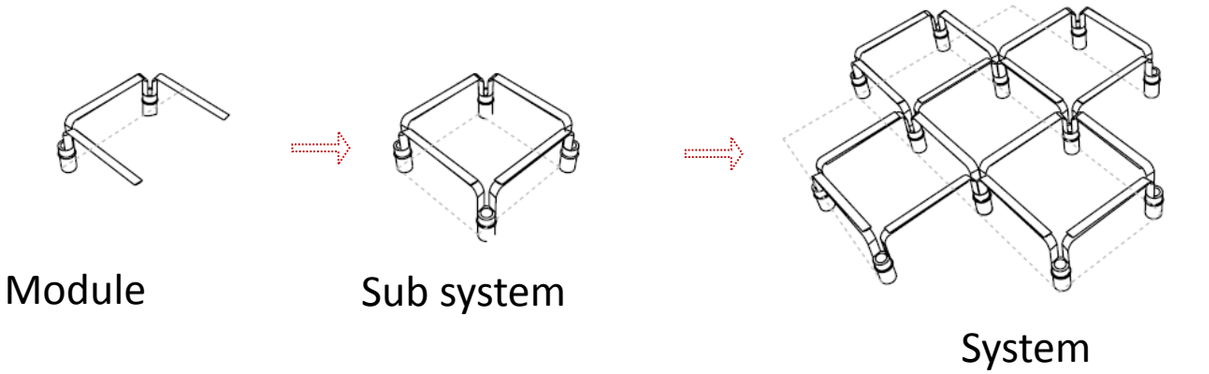


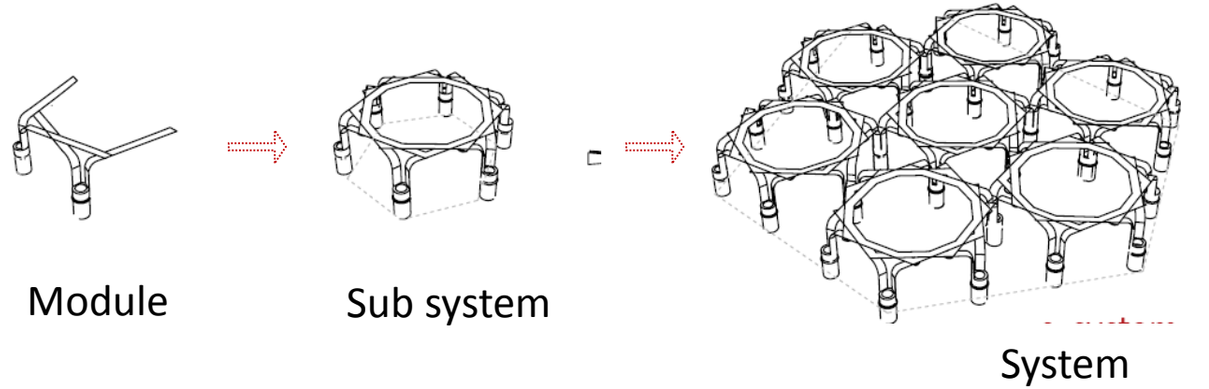


Propagation possibilities :



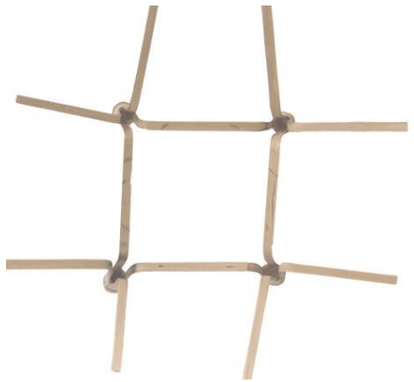






Exploration 16 and 17:

Perspective view



Plan

Elevation

Number of vertices: 4

Number of edges: 12

Angle between strips: 90

Surfaces: One square

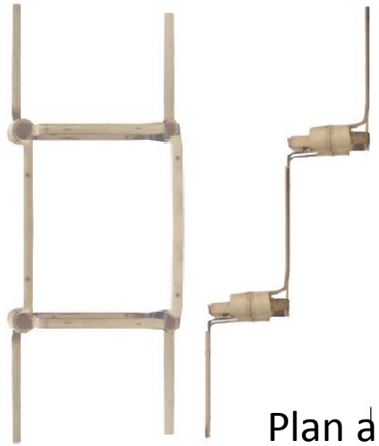
Number of vertices: 4

Number of edges: 12

Angle between strips: 90

Surfaces: One square and two rectangles

Perspective view



Plan and elevation

Exploration 18 and 19:

Perspective view

Plan

Part Plan

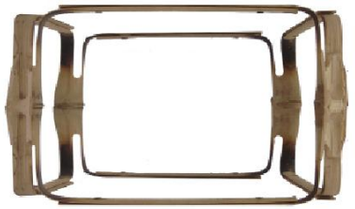
Elevation

Number of vertices:	10
Number of edges:	20
Angle between strips:	90
Surfaces:	Nine rectangles

Number of vertices:	8
Number of edges:	12
Angle between strips:	90
Surfaces:	Two squares and four rectangles

Perspective view

Plan



Elevation

Exploration 19 and 20:

Perspective view

Plan

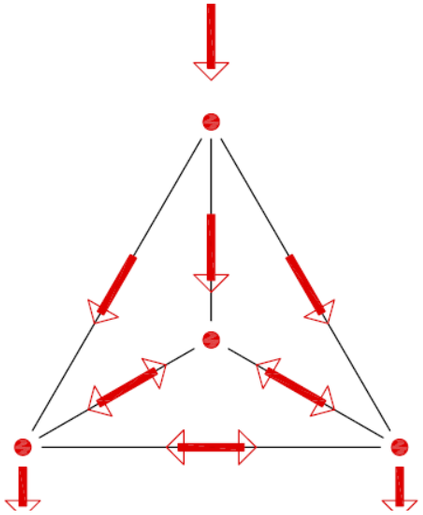
Elevation

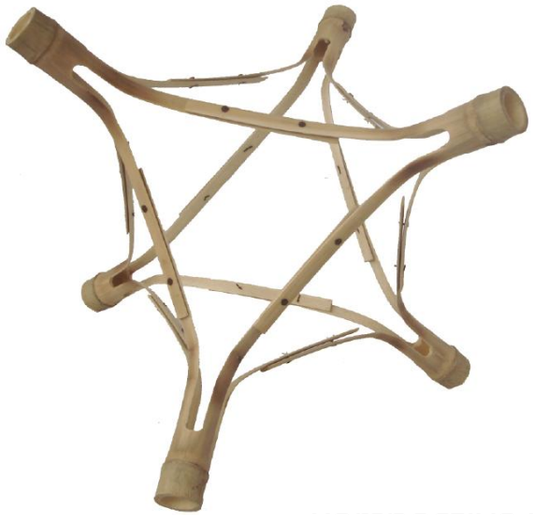
Number of vertices: 4

Number of edges: 4

Angle between strips: 60

Surfaces: Four equilateral triangles





Perspective view

Plan

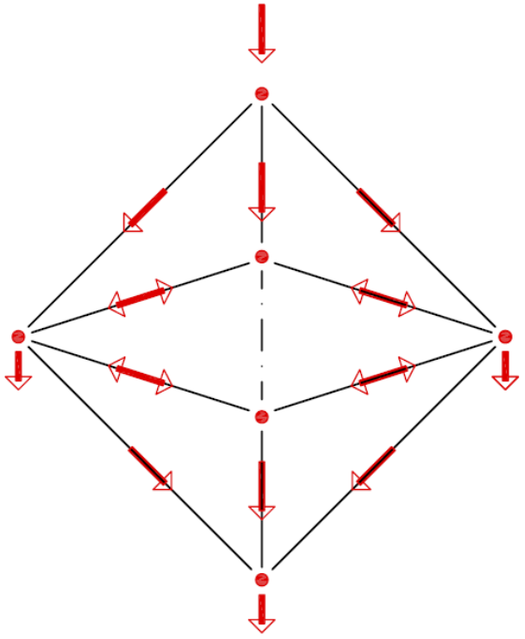
Elevation

Number of vertices: 6

Number of edges: 12

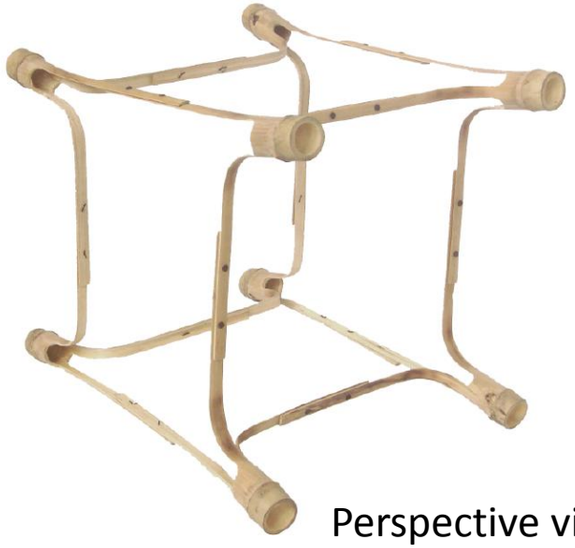
Angle between strips: 90

Surfaces: Eight equilateral triangle

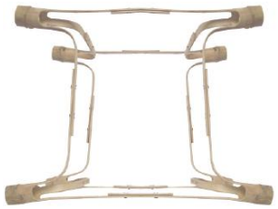


Structural behavior

Exploration 21 and 22:



Perspective view



Plan

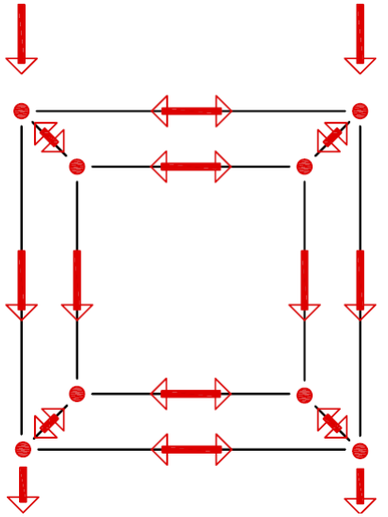
Elevation

Number of vertices: 8

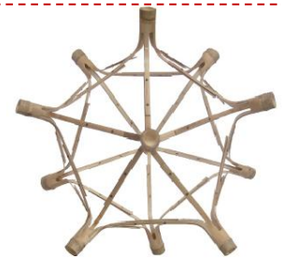
Number of edges: 12

Angle between strips: 90

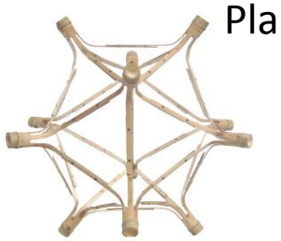
Surfaces: Six squares



Perspective view



Plan



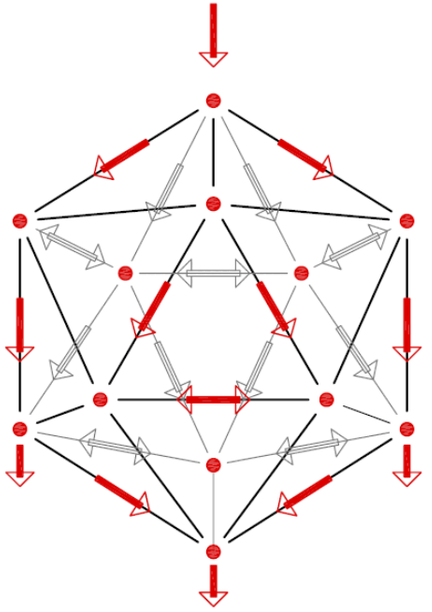
Elevation

Number of vertices: 12

Number of edges: 20

Angle between strips: 90

Surfaces: Twelve equilateral triangles



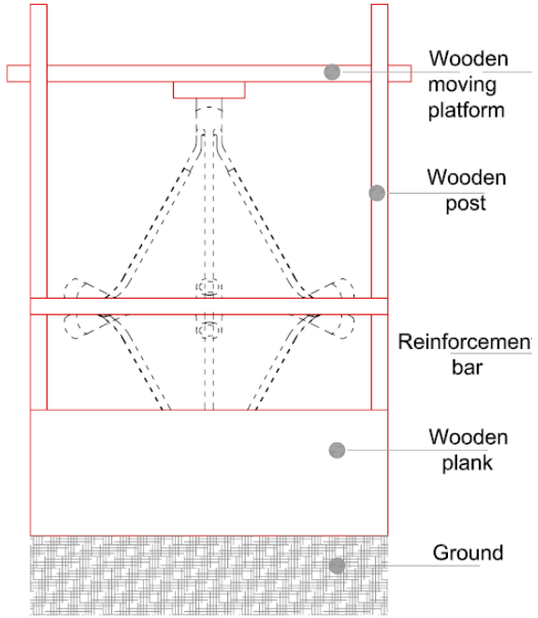
Structural behavior

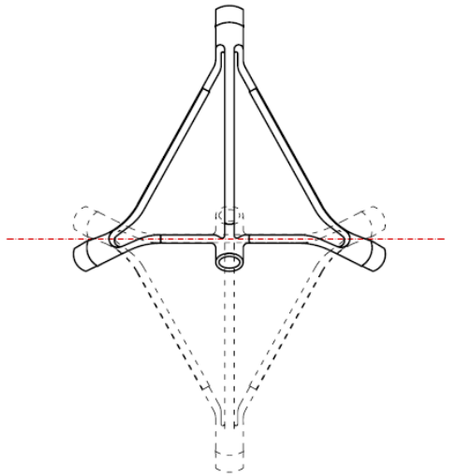
Constants:

Testing: compression testing
Propagation direction: vertical
Testing specimen
Testing equipment

Variables:

Amount of the UDL





Selected option of testing equipment and specimen


7.5 kg


37 kg


45 kg


69 kg


77 kg


85 kg

Inference:

Total time duration for the experimentation – 9:36 mins

Time duration for the failure – when the system fails – 1:06 mins

Strength to weight ratio of the system $= \frac{\text{force / unit area}}{\text{density}}$

$= 704.57$ N.m/ kg

The strength to weight ratio, derived here exhibits the structural potential of the system, made using the tetrahedrons.

Possible ways to modify:

The failure can be traced out at the bent junctions of the modules, where the strips are not laminated or overlapped. So overlapping at the junctions can make the system stronger.

Increment in the values of the considered width and thickness can also make the system stronger.

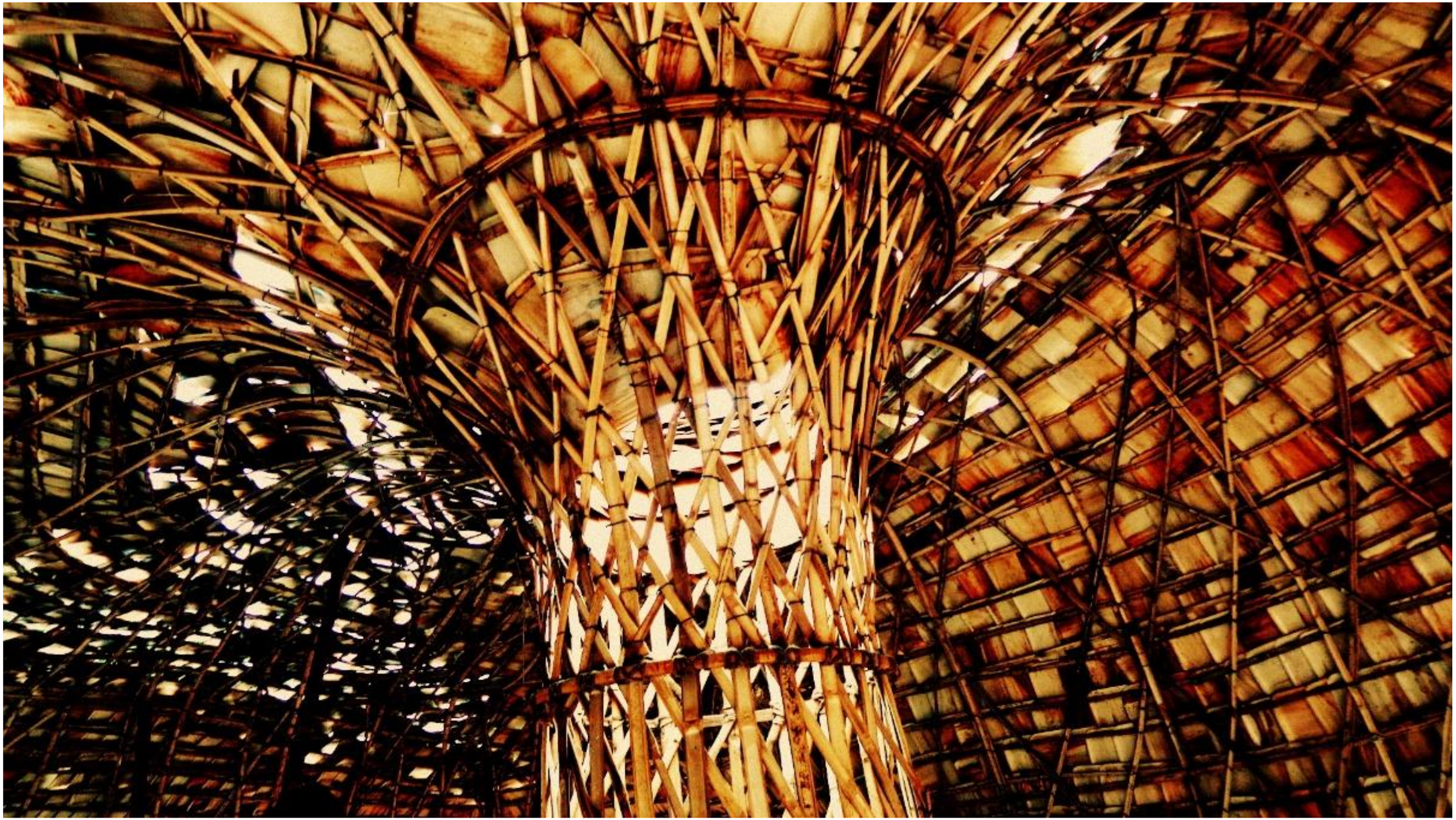
Further scope of the research:

Other load testing can also be done to evaluate the performance of the system under different loading conditions. For example tension, shear, torsion and bending.

It is possible to use bamboo split section for various structural applications...

“Cocoon Structure” – A workshop organized by C.A.R.E. School of Architecture, Trichy, India and AARHUS School of Architecture, Denmark.

Interior of the structure



Interior of the structure

A Bus Stop Module - A workshop organized by C.A.R.E. School of Architecture, Trichy, India.

A Bus Stop Module

A Bus Stop Module

Thank you…