Design, Development and Preliminary Evaluation of Bamboo Connectors

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Why design bamboo connectors?

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Housing Characteristics in the Philippines
(Results of the 2015 Census of Population)

	Total HOUSING UNITS	Total OCCUPIED HOUSING UNITS	Occupancy RATE[1/]
2015 CENSUS	24.22 million	22.42 million	92.57 percent
2010 CENSUS	21.29 million	19.72 million	92.61 percent
2000 CENSUS	14.94 million	14.89 million	99.68 percent

We need more houses for a growing population

HOUSEHOLD
to occupied **HOUSING UNIT** Ratio[2/]

102 households...
in every **100** occupied housing units

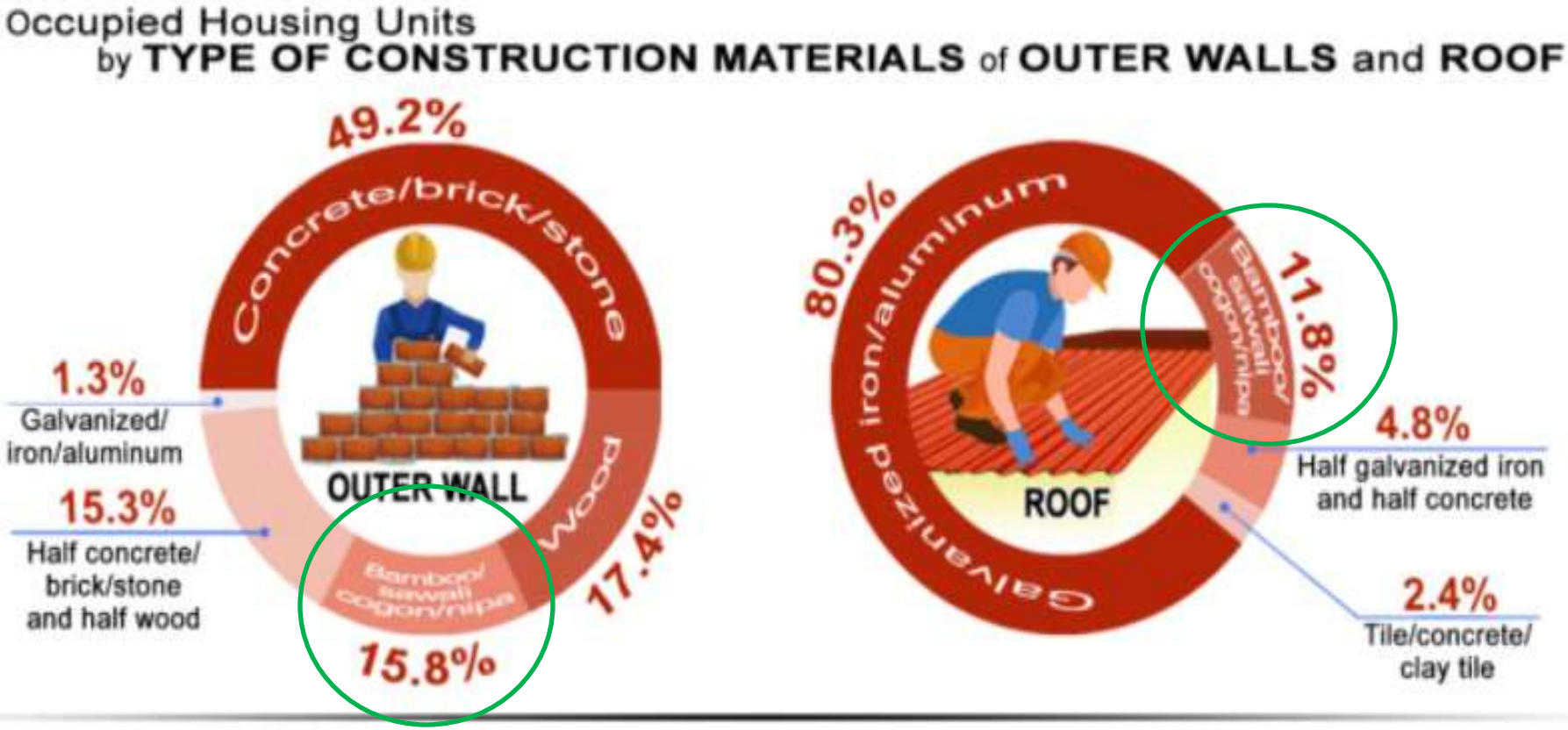
TOP 3 Regions with the highest
HOUSEHOLD
to occupied **HOUSING UNIT** Ratio[2/]

1. ARMM
   110 households...
2. NCR
   104 households...
3. Region I
   104 households...

...in every **100** occupied housing units

[1/] Occupancy Rate is the proportion of housing units occupied by households to total housing units, expressed in percent.
[2/] Household to Occupied Housing Unit Ratio is expressed as the number of households for every 100 occupied housing units.

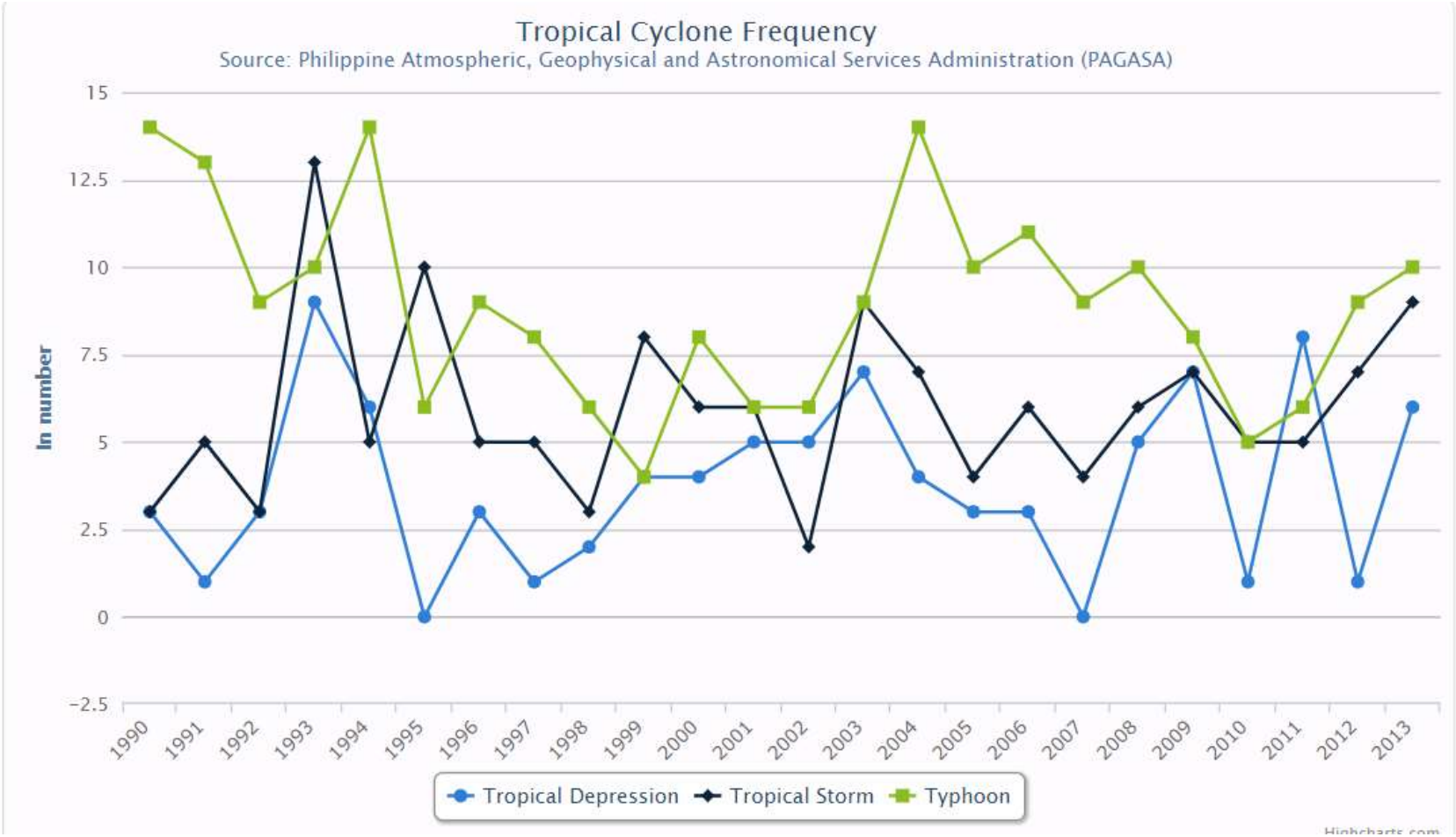
For every 100 occupied housing units, there are at least 2 units occupied by 2 families



A large percentage of occupied housing units are made of bamboo and light materials

Most of these are found in rural areas…

…and in city slums



The 20 storms that visit the country annually further compounds the issue.

Significance

- A storm-proof structure made of bamboo will have acceptance in a country visited by an average 20 storms annually.
- The development of bamboo connectors will make a highly renewable material easily utilized in construction through the “cut and paste” construction technique.
- The connectors may find valuable applications in low-cost mass housing, DIY construction and in emergency response where rapid shelter construction is needed.

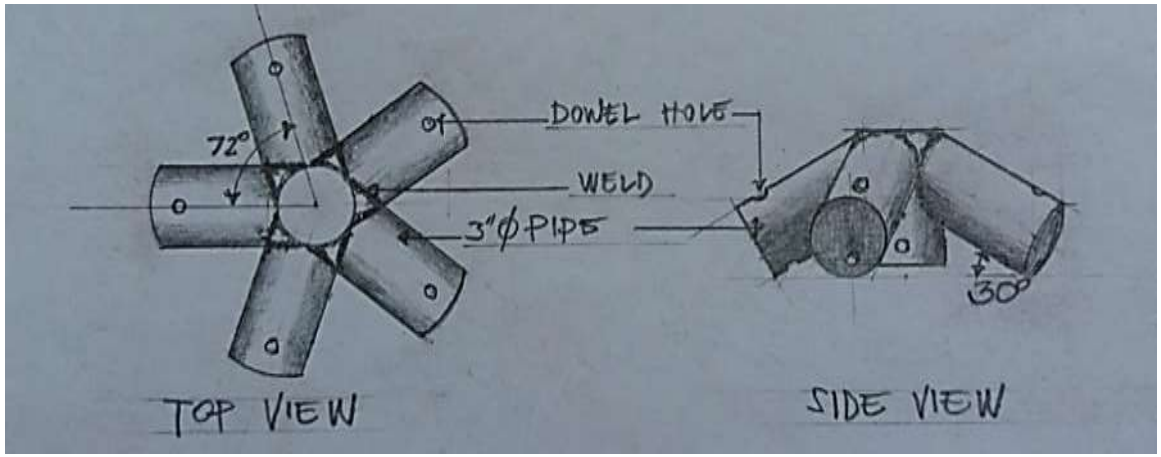
Criteria for Design

- Low cost
- Durability
- Standardized nature
- Ease of application
- Raw material availability
- Fabricated using available tools and skillsets
- Fit traditional Filipino construction techniques

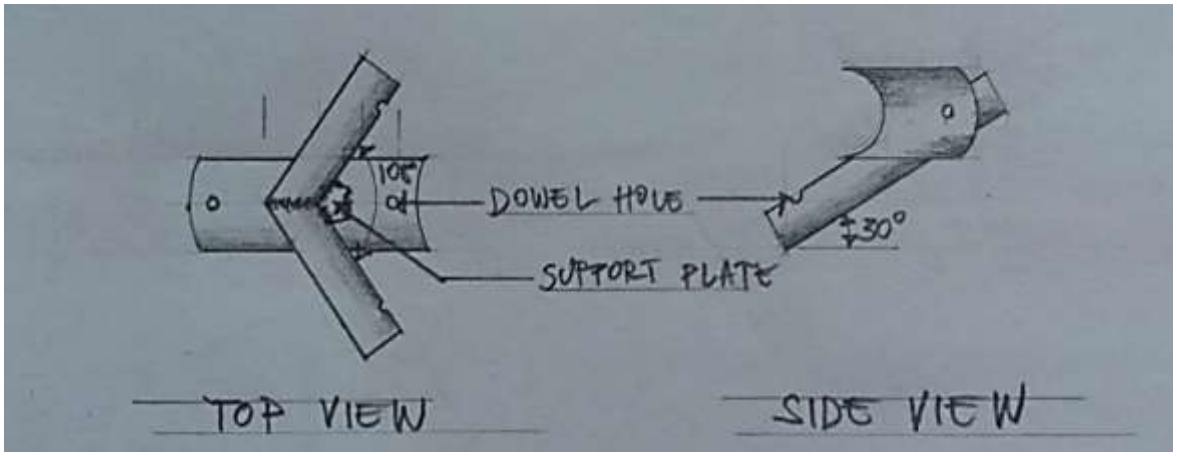
Traditional Filipino joinery finished in one day by a skilled carpenter

The same post-beam-top chord (rafter) joint construction using the connector finished in under an hour.

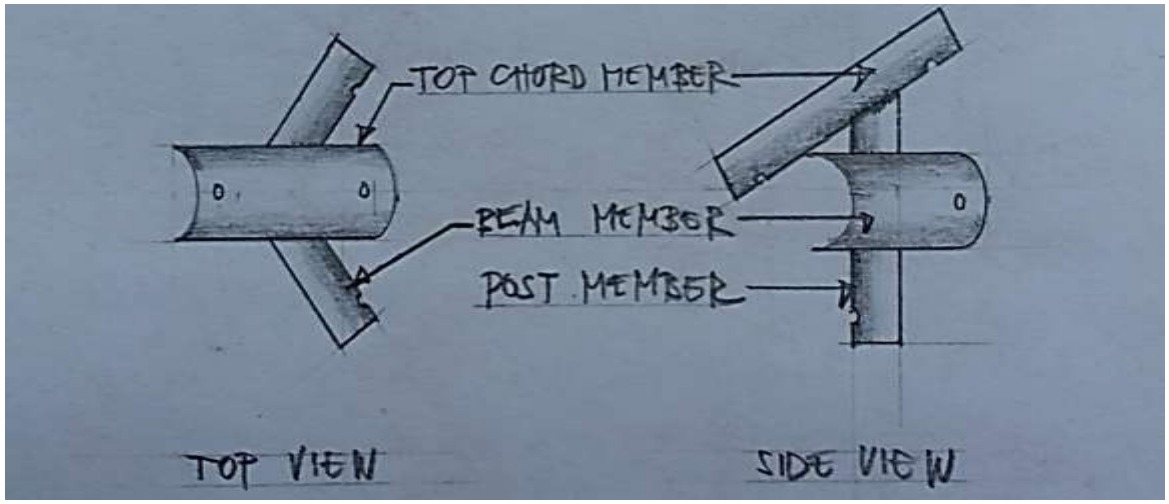
The Connectors



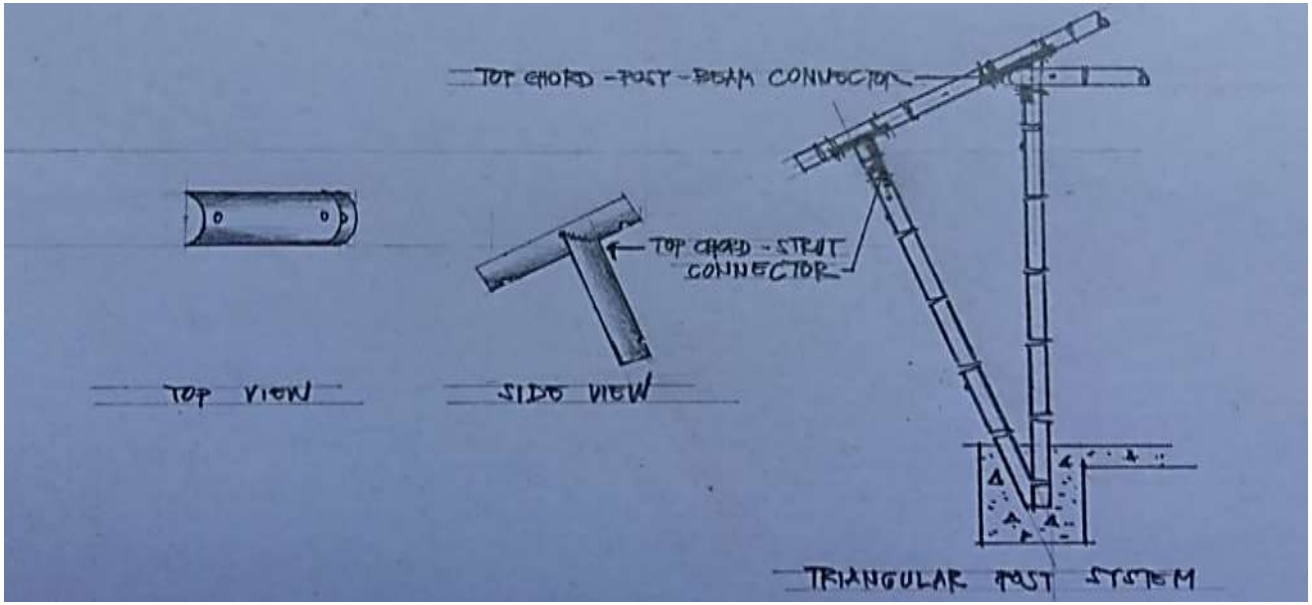
Starfish Connector
-connects the top chords of the pentagon structure together



Top chord-purlin Connector

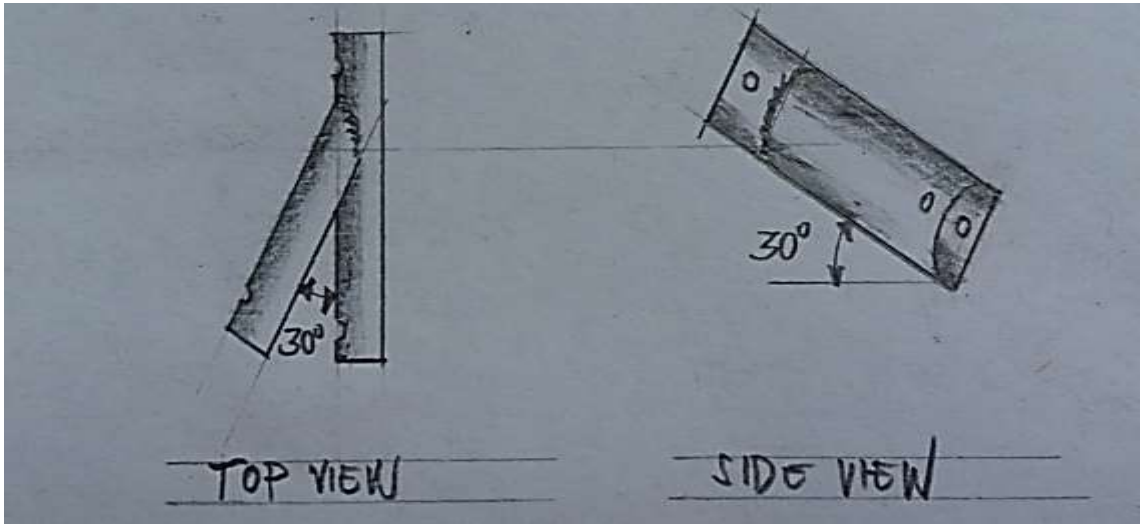


Post-Top chord-Beam Connector

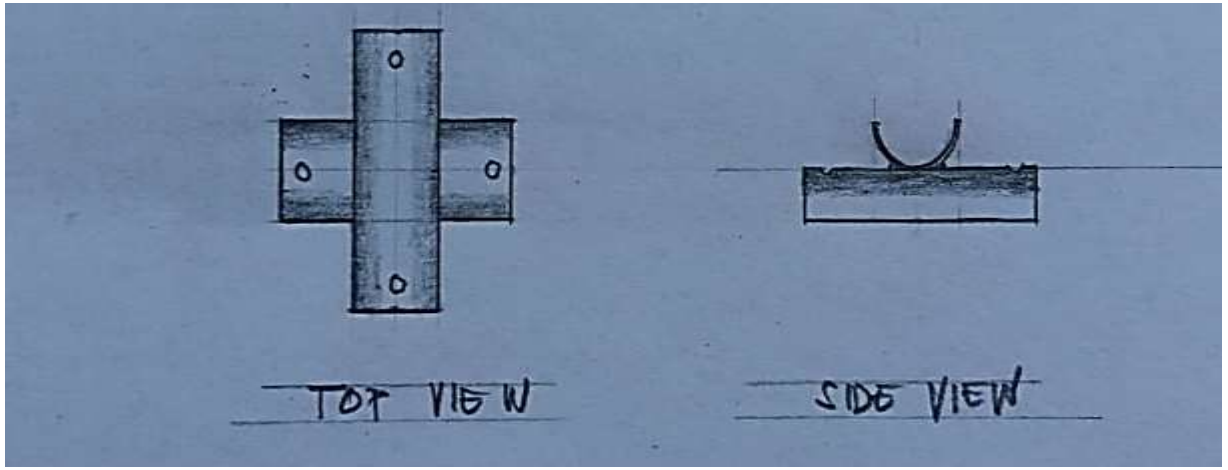


Top chord-strut Connector and Post-strut Connector

these connectors make a triangular element in the pentagon post structure



Top chord-rafter Connector
this connector is necessary for large roofs



Beam-Rafter Connector

Constructing a model unit

-to **assemble the beams**, *cut the bamboos* to length and with the right angles of cut, then *paste them together* using the connectors, the dowels and the lashings

-to **assemble the top chords**, cut the pieces to exact lengths and insert into the starfish connector and secure with dowels

-to **assemble the purlins**, cut the purlins according to length and its angles and paste them together using the connector, the dowels and the lashings



-place the top chords atop the beam structure resting on the connectors



-put the purlins on top of the top chords; then secure the pieces with lashings

-this structure is strong and may carry several persons working on a roof

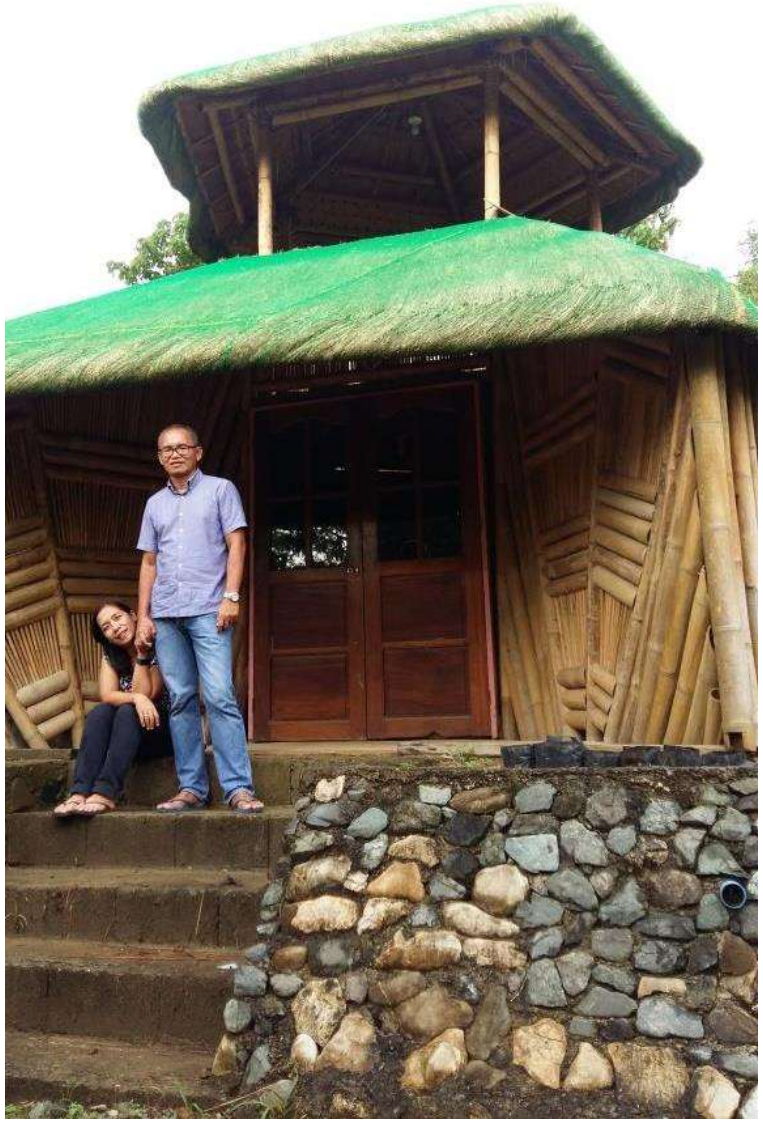
-or you may hang loads on a roof structure without a center post and it will still hold

Our Works

Pentagon 1. Using our starfish connector and traditional joinery we constructed the skeletal structure (pictured on top) in ten days employing three carpenters. The structure weathered Typhoon Haiyan in 2013 and is still existing. We recently gave it a new roof hopefully to last for another 5 years.

Pentagon 2. Using all our developed connectors, students without prior training in construction work erected the skeletal structure two days. The house collapsed due to termite infestation.

Burning Pentagon 2. The collapsed Pentagon 2 was burned to test the durability of connectors in a fire. All connectors were recovered.



Pentagon 3. Using the recovered connectors, a two-storey bamboo structure was built by the author and a helper. The skeletal structure alone was finished in three days.

Pentagon 4. Using improved connectors, a fourth pentagon model structure was built resting on a cement pavement. It was used as a showcase for University researches during a festival. The skeletal structure was done in two days. We also developed a new technique for attaching the roof.

Reassembling Pentagon 4. To test DIY construction, the fourth pentagon structure was disassembled and reassembled in an engineering challenge. Teams of eight students took turns in reassembling the skeletal structure. Shortest assembly time among the three teams was 24 minutes.

A-Frame 1. We developed connectors for A-frames and constructed a dryer for arrowroot starch.

At the University, we are not only developing new ways of construction but we are also **climate-change proofing** the traditional Filipino ***bahay kubo*** made of bamboo.

Our Way Forward

- Conduct mechanical tests for strength between bamboo and connector bonds
- Establish a school factory for commercializing the technology

Our Vision

A secure home for every Juan, built by any Juan

Maraming Salamat
Thank You
Gracias

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