BAHAY KAWAYAN

A TRANSITIONAL HOUSE FOR THE PHILIPPINES

Ana Gatóo, Elizabeth Wagemann, Michael H. Ramage

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CONTENTS

INTRODUCTION

The proposal is a transitional house for the communities of the area of Roxas in the Philippines that were affected by Typhoon Haiyan in November 2013. This low-cost house is based on the traditional Filipino house called Bahay Kubo, and has been designed for improving the overall structure of typical transitional houses for increased resilience. The project has three main innovations: construction without nails or screws, resilience against strong winds and earthquakes, and a modular design for future extensions. A prototype was constructed at the Department of Architecture in Cambridge in July 2014 to test the feasibility of construction, the structural performance of the connections, and the spatial qualities of the design. The project featured as a winning entry in the international competition 'Versus: Lessons from vernacular heritage for sustainable architecture' held in September 2014.

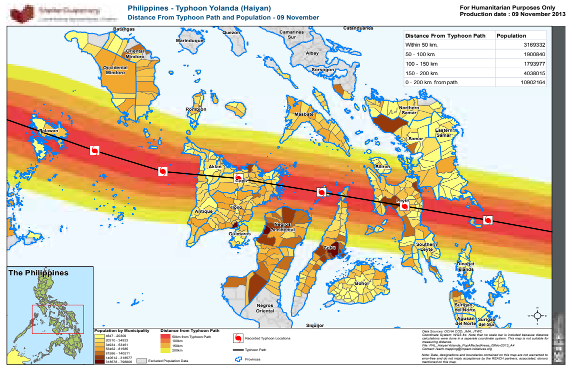


Image 1: *Distance from Typhoon Path and Population. 09 November 2013. Shelter Cluster Philippines*

Natural Hazards in the Philippines: Typhoon Haiyan.

'The Philippines is one of the world's most disaster-prone countries. One third of its population of 94.9 million people live below the poverty line and are vulnerable to the typhoons, floods, earthquakes and volcanic eruptions that plague the country.' [1]

On the 8th of November 2013, Typhoon Haiyan (locally known as Yolanda) ripped across the central Philippines. Yolanda is the most powerful storm ever recorded, estimated in some areas around 370 km/hr.[2] The typhoon caused extensive damage to life, housing, livelihoods and infrastructure across nine of the Philippine's poorest provinces (Image 1). From these provinces, the islands of Leyte and Samar were hardest hit. Around 90 percent of the infrastructure of Tacloban City, the Leyte's largest urban centre, was destroyed. [3]

The Government of the Philippines reported a total of 13,067,342 individuals affected by Typhoon Haiyan. [4] Of the affected population, around 4 million individuals were displaced (94,310 to formal evacuation centres and 3,906,654 to other locations).[5] Reports indicate more than 1 million damaged houses, of which 548,793 were totally destroyed by the typhoon. [6]

INTRODUCTION

Scope of Crisis and Profile of Affected

93.7 million
Total population Philippines (NSCB, 2013 projection)

14%
Of total population potentially affected (Calculation)

13.1 million estimated
Estimated number of people affected by Typhoon Haiyan (DSWD)

3.4 million (estimated)
Displaced (homeless) (DSWD)
Female: 1,000,000 Male: 970,000
Girls: 730,000 Boys: 700,000

241,000+
People inside evacuation centres (DSWD)

3.2 million+
People outside evacuation centres (DSWD)

9.6 million (estimated)
Non-displaced (calculation)
Female: 2,840,000
Male: 2,730,000
Girls: 2,055,000
Boys: 1,975,000

5,000 + (estimated)*
Fatalities (NDRRMC)

25,000+ (estimated)
Injured (NDRRMC)

1,600+ (estimated)
Missing (NDRRMC)

Table 1: *Scope of crisis and profile of affected. Source: Source: Multi-Cluster/Sector Initial Rapid Assessment (MIRA). Philippines Typhoon Haiyan. Nov. 2013. P.5*

* There are no complete gender-disaggregated data found on the number of lives lost or missing

Image 2: Tacloban. February 2014

Image 3: Tacloban. February 2014

Fieldwork in the Philippines

A fieldtrip was conducted three months after the typhoon to evaluate the situation. The areas visited were: Tacloban city, and the North of the Panay Island (Roxas City and the rural area of Estancia, another of the most affected areas). The aim of the visit was to find the needs of international and local NGOs, as well as local governments and communities to find possible ways for collaboration. Meetings were arranged with ADRA (Adventist Development and Relief Agency), Habitat for Humanity, CRS (Catholic Relief Services) the City Housing and Community Development Office and the Shelter Cluster.

At the time of meeting with ADRA, they had just received government approval for the endowment tool kits, materials and training in Disaster Risk Reduction (DRR) for 2,500 households. The programme implemented by ADRA is divided in two phases: training the community in construction and design in accordance with basic parameters in DRR; and supplying materials. Due to the recurrent natural hazards faced by the Philippines, the organisation asked our team to develop a transitional shelter design with local materials for sheltering in future disasters.

INTRODUCTION

Image 4: Tacloban. February 2014

Image 5: Roxas. February 2014

Although the organisation suggested coco lumber as main material for the design, we decided to develop a project with Bamboo for the area of Roxas. The decision was taken due to the expertise of the team members in bamboo, as well as the availability of the material in that region of the Philippines. The design and construction processes were led by Ana Gatóo, Elizabeth Wagemann and Daniel Jiménez. A prototype was constructed in the courtyard of the Department of Architecture in Cambridge in the months of July and August 2014 to test the feasibility of construction, the structural performance of the connections, and the spatial qualities of the design. The design will be refined for use in future disaster relief efforts, based on lessons learned in the construction process and feedback from NGO collaborators. The approximate cost of the building in the Philippines is around 469GBP, with an approximate construction time of 7 days by a team of 4 people. The cost of the house in the UK was: 3,556GBP due to the high cost of the imported materials.

Image 6: Tacloban. February 2014

Image 7: Tacloban. February 2014

DESIGN CONCEPTS

Transitional House for the Philippines

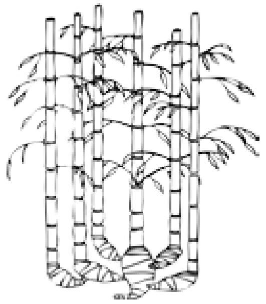
The proposal was designed to explore a resilient solution for future hazards, following four dimensions: Environmental: Available local materials and comfort. Natural Hazards: Earthquakes, typhoons, flooding and strong winds. Socio-Cultural: Traditional building method; and use of spaces. Socio-Economic: Modularity; flexibility; adaptability; durability and maintenance

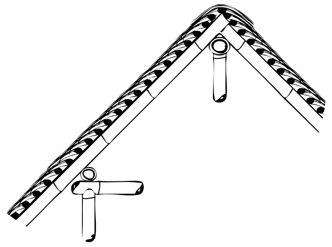
Environmental Dimension

Available Local Materials:

Full culm bamboo. The design uses full culm bamboo, a recognised sustainable construction material because of its rapid growth, readily availability, simple processing, and resulting low transportation costs and pollution. Moreover, full culm bamboo has been used in construction for centuries, and there is a long history of construction with the material in the Philippines.

Thatch roof. It was chosen as roofing material, because is biodegradable, renewable, and acts as an insulating waterproof layer.



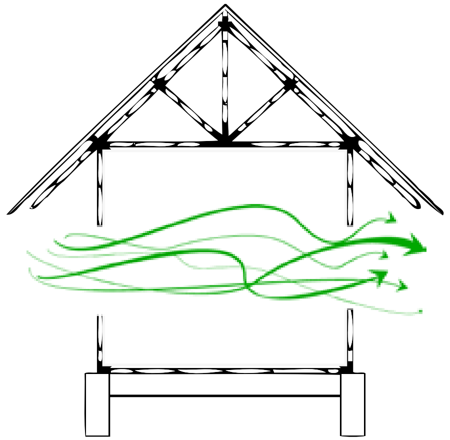


"Humanitarian Bamboo Guidelines"[7]

Comfort:

Natural ventilation. The design includes crossed ventilation to reduce the humidity of the house and the material, a feature found in most traditional Filipino houses.

Shading and intermediate spaces. Natural shading is created through long eaves, which protect bamboo from the rain and direct sunlight, and create shaded intermediate spaces.

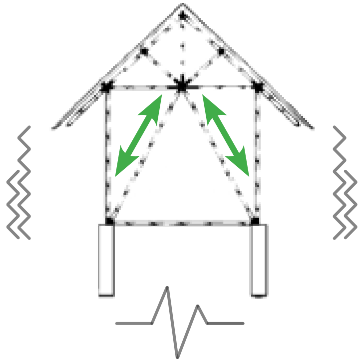


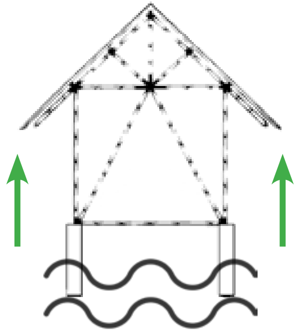
"Humanitarian Bamboo Guidelines"[7]

DESIGN CONCEPTS

Protection from natural hazards

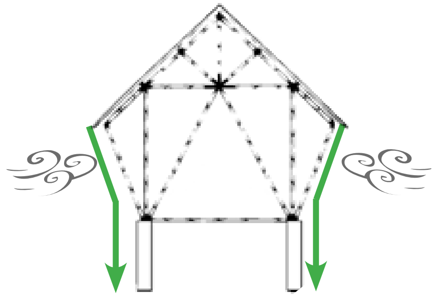
Earthquakes: Bamboo is not as durable as brick or stone, but its flexibility makes it a good choice for coping with earthquakes, a natural hazard in the Philippines. A well designed bamboo building, allows the structure to move with quakes without collapsing. In this project, seismic resistant elements have bracings in different planes, creating a system of triangulations for preventing deformations.





The hip roof that helps to prevent uplifts is counteracted by long hanging members for protecting the bamboo from the rain and sun. To solve this problem, in our design we created a system that connects the roof structure to the foundations through diagonal bracings. These connections prevent uplifts, a main concern during typhoons and storms. Although these are structural characteristics, they also affect the aesthetic of the house.

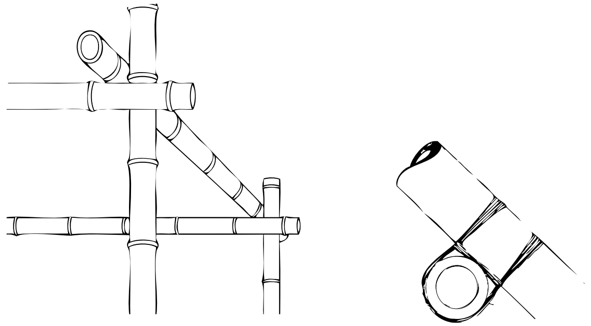
Flood damage: Traditional houses in the Philippines are elevated from the ground (stilt houses) for keeping the floor dry during rainy seasons. This design feature, based on local knowledge, is adopted in this proposal.



DESIGN CONCEPTS

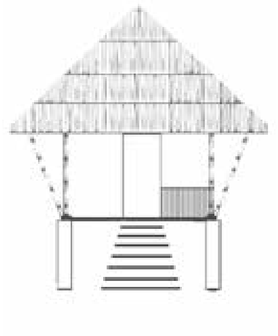
Socio Cultural Dimension (based on interviews and experience)

Lashing, a traditional building method:
Vernacular construction methods in the Philippines include the use of lashing, instead of nailing the bamboos, which in turn prevents the bamboo from splitting. The traditional knowledge has been adapted to available materials such as rattan, rope and fishing line. The latter is a strong material that improves the performance of the connections with greater durability, and it is also widely used in the area. Therefore, fishing line has been selected as material for this project. The selection of method and material has an influence on the design, as they define the connections in three dimensions instead of in-plane joints, consequently the geometry of the whole house.



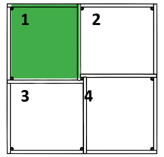
"Humanitarian Bamboo Guidelines"[7]

Use of spaces:
In traditional houses in the Philippines, it is frequent to find shaded intermediate areas between public and private spaces, usually as front porch. This concept of spaced is incorporated in this design.



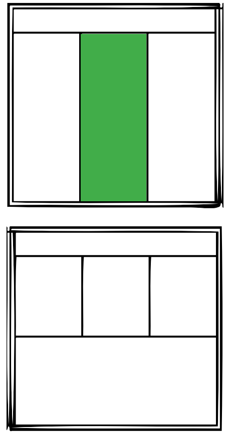
Socio Economic Dimension

Modularity and repetition defined by materials and dimensions.
The dimensions of the house are defined by a minimum module. The unit is determined by bamboo mats used in the Philippines for walls (8 x 7 feet = 2,44 x 2,13 m.). Therefore, a cube of 8'x 8' (2,44 x2,44 m.) is the minimum unit, which can be repeated in order to create different house sizes, for example, 12 m2 expandable to 24 m2, or 18 m2 expandable to 36 m2.

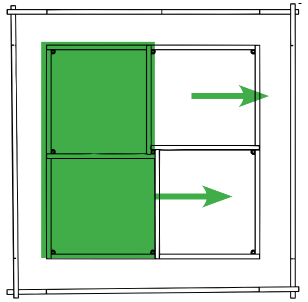


DESIGN CONCEPTS

Flexibility through doors and windows position:
The structure of the house is based on a framing system instead of load bearing walls, thus allowing for flexibility in the positioning of the doors and windows. Therefore, openings can be placed appropriately according to the orientation of the house and surrounding conditions of the settlement.



Adaptability, progressive housing and extensions: The design considers the possibility of expansion and adaptation to families' needs without compromising the integrity of the structural system. This is defined by a roof structure under which families can decide to expand the floor and wall panels to create porches or terraces as desired.



Durability and maintenance:
The lifespan of a bamboo building depends on proper protection of the material from rain, termites and direct sunlight. Nevertheless, the cost of replacement is not relevant due to the fertility and rapidness of bamboo growth. Moreover, due to the construction method (lashing), single elements of the house can be replaced without compromising the structure.

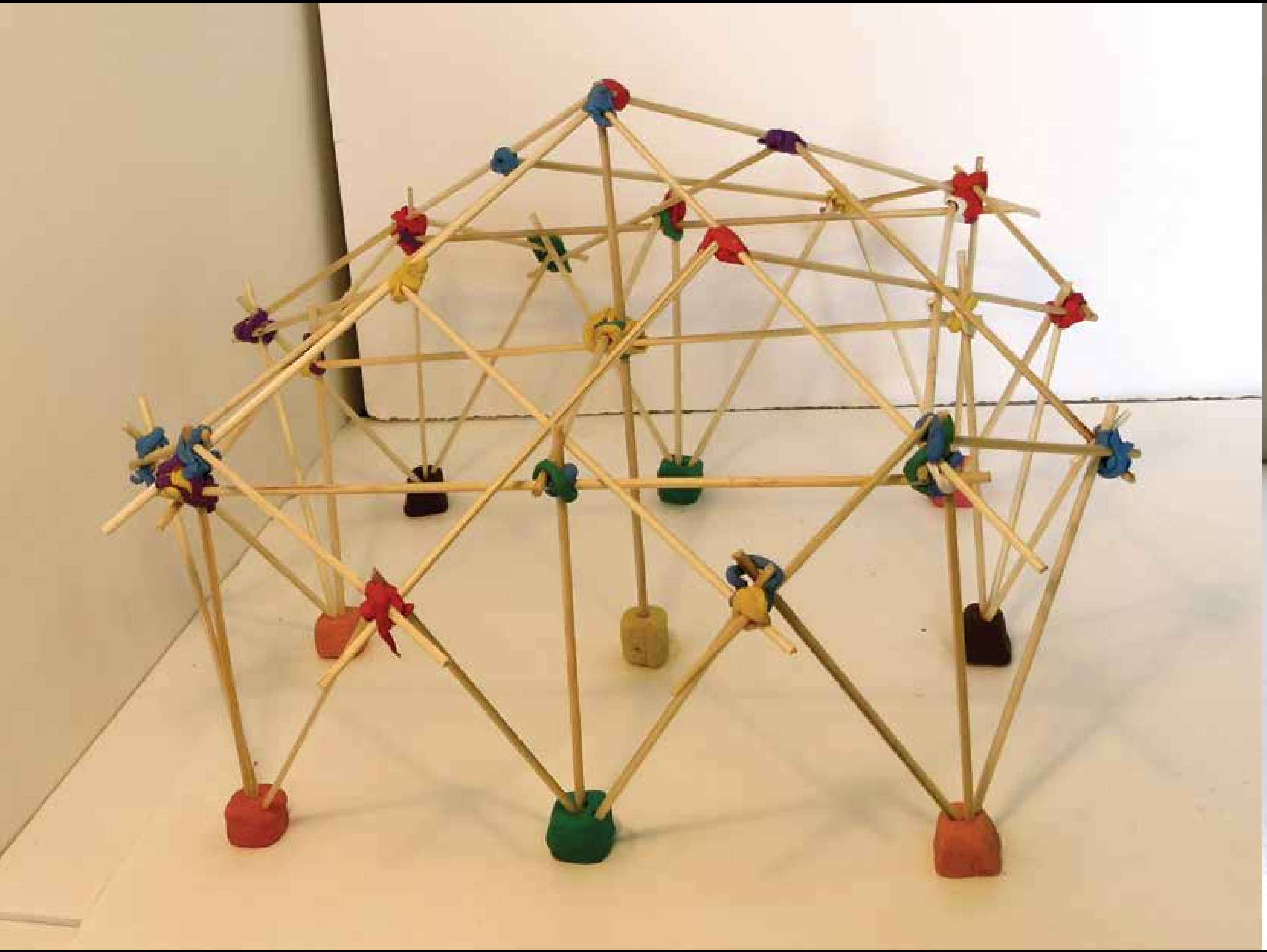
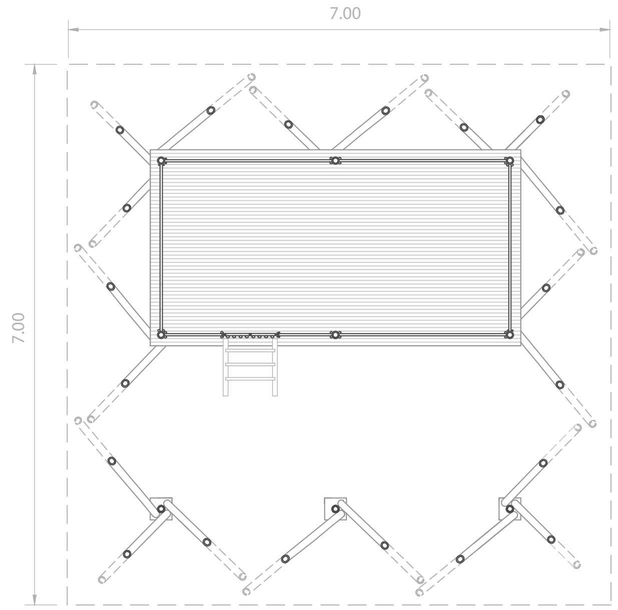


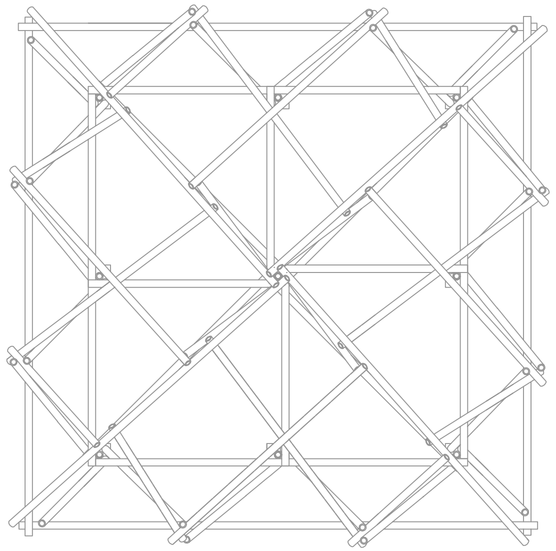
Image 8: Preliminary design. May 2014

Image 9: Final model of the house. June 2014

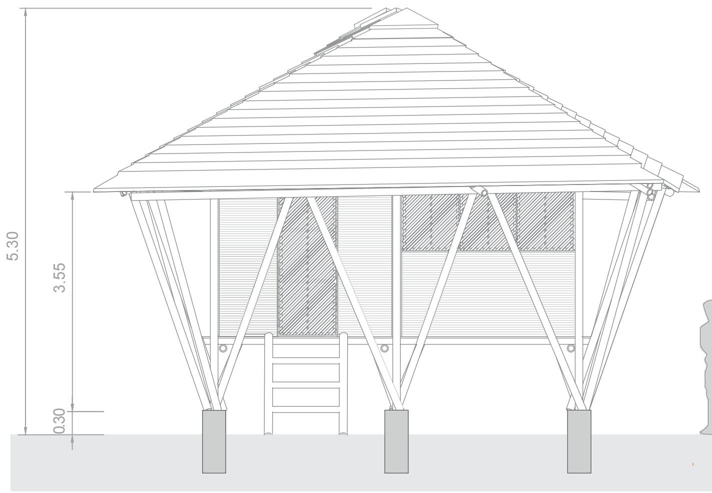
THE PROTOTYPE



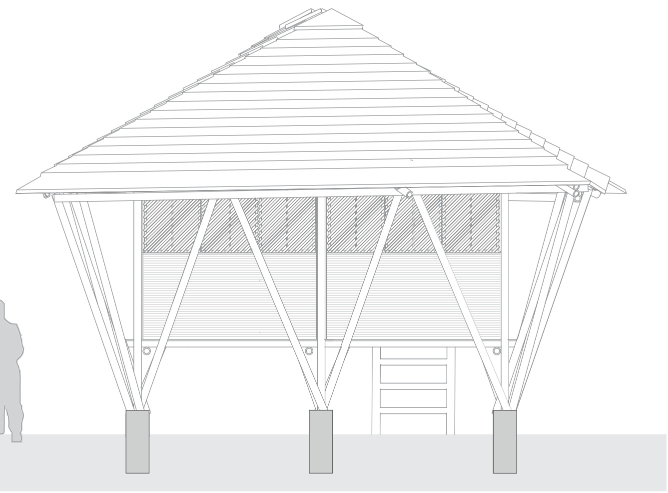
Floor Plan



Roof Structure Plan



Front Elevation

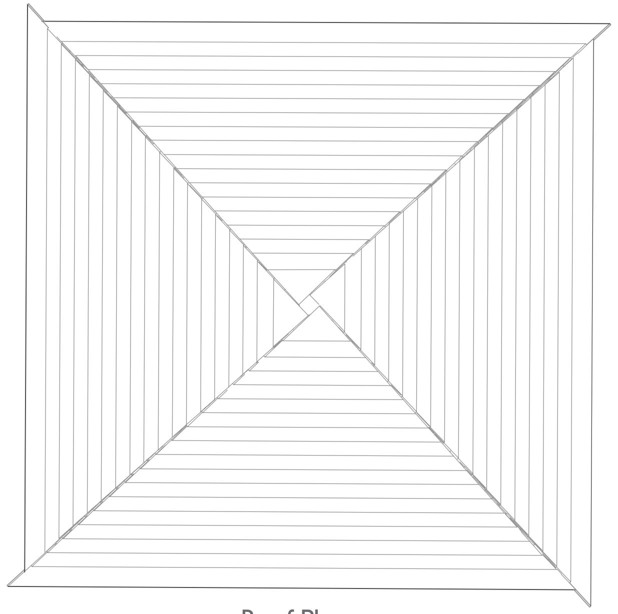


Rear Elevation

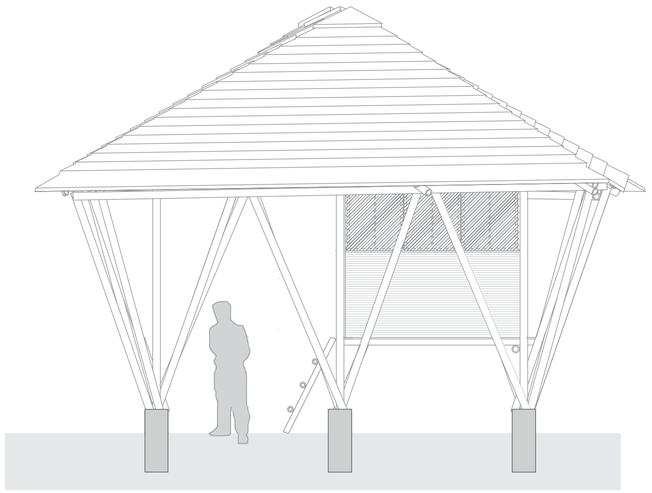
0 0.5m 1.0m 1.5m 2.0m

Scale 1/100

THE PROTOTYPE



Roof Plan



Side Elevation

0 0.5m 1.0m 1.5m 2.0m

Scale 1/100

Image 10, 11, 12: Renders of the prototype

THE PROTOTYPE

Lashing

Lashing is a vernacular construction method used in the Philippines, which prevents bamboo from splitting. Ten meter length fishing line was used for each connection.

Diagonal Lashing: it is used for keeping two culms together at a variety of angles. For securing the angle, the ends of the culms should also be lashed.

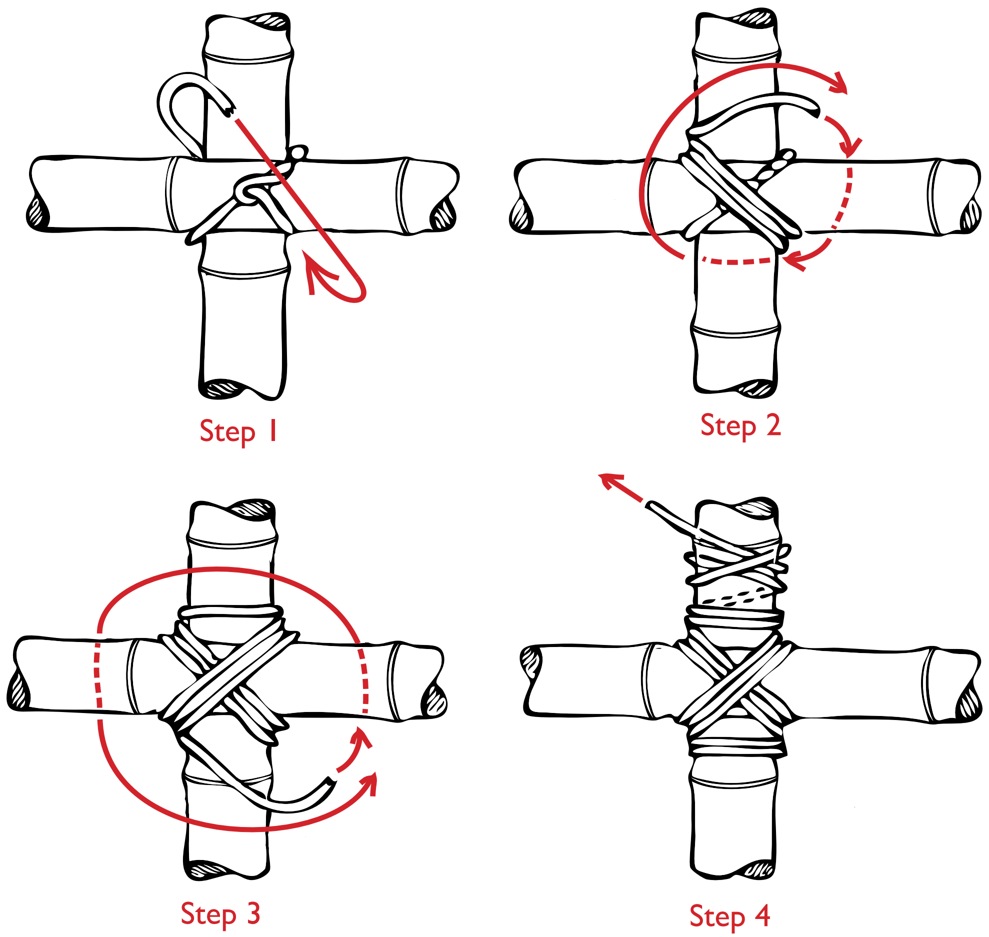


Image 13: Steps of diagonal lashing after "*Bush search and Rescue Victoria*"[8]

THE PROTOTYPE

Lashing

Square Lashing: It is used for binding two culms cross each other at 90 degrees (although it can be used for 45 degrees).

Image 14: Square lashing

Image 15: Diagonal lashing

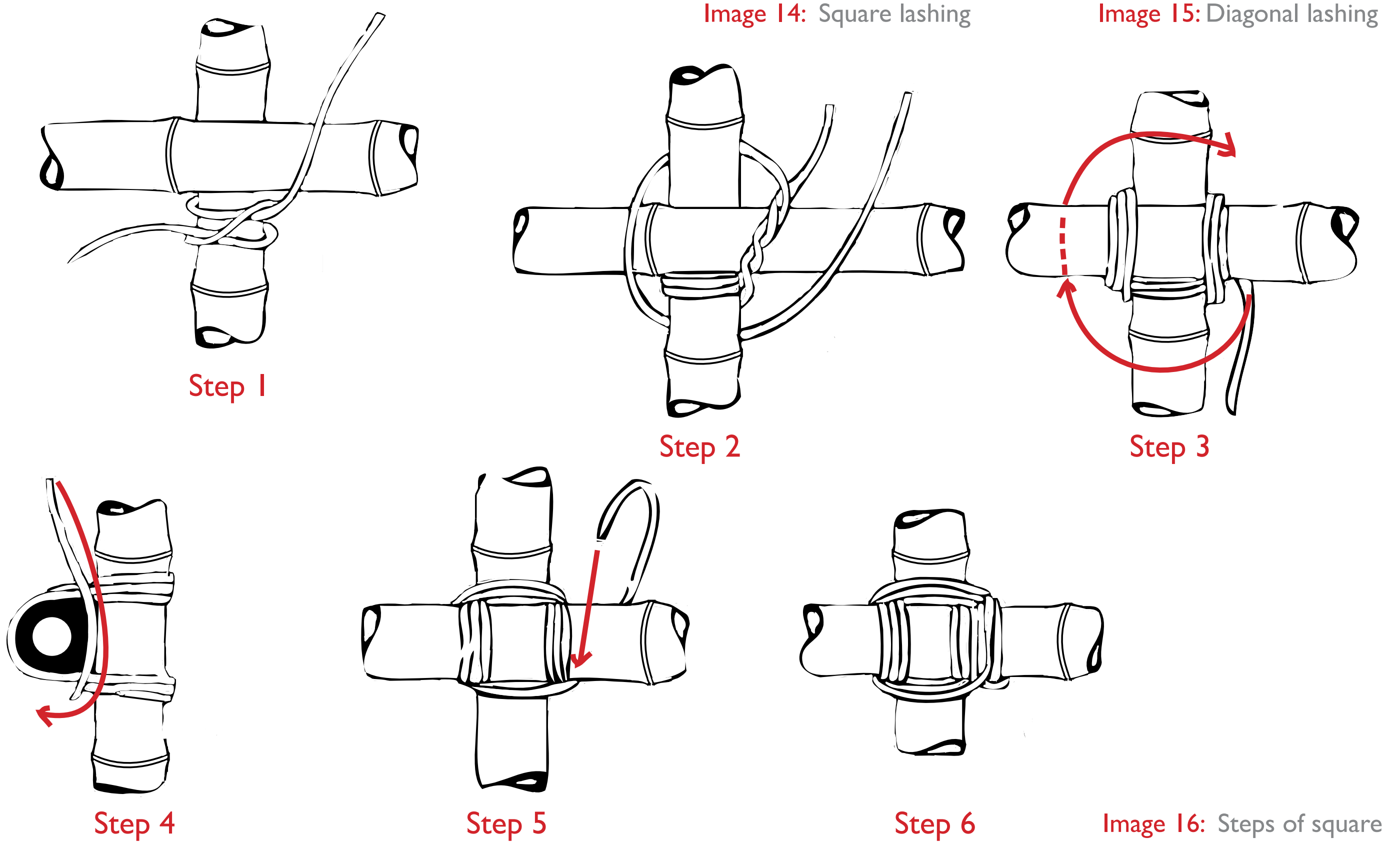
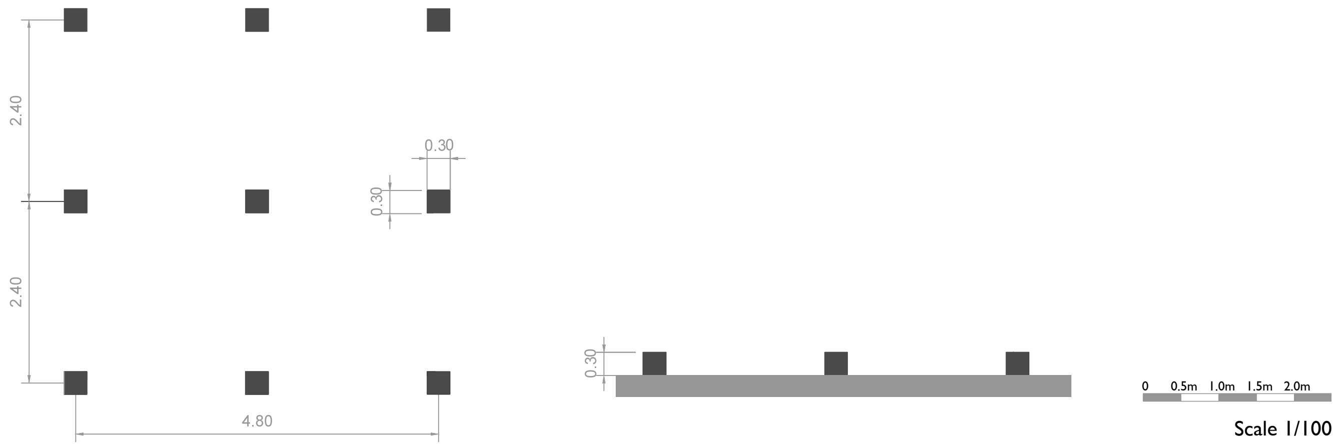


Image 16: Steps of square lashing after "*Bush search and Rescue Victoria*" [8]

THE PROTOTYPE

Construction Process

Step 1



Scale 1/100

Material	Dimensions	Quantity
Concrete	0.75x0.3x0.3m	9
Rebar	0.6m Ø 0.05m	9

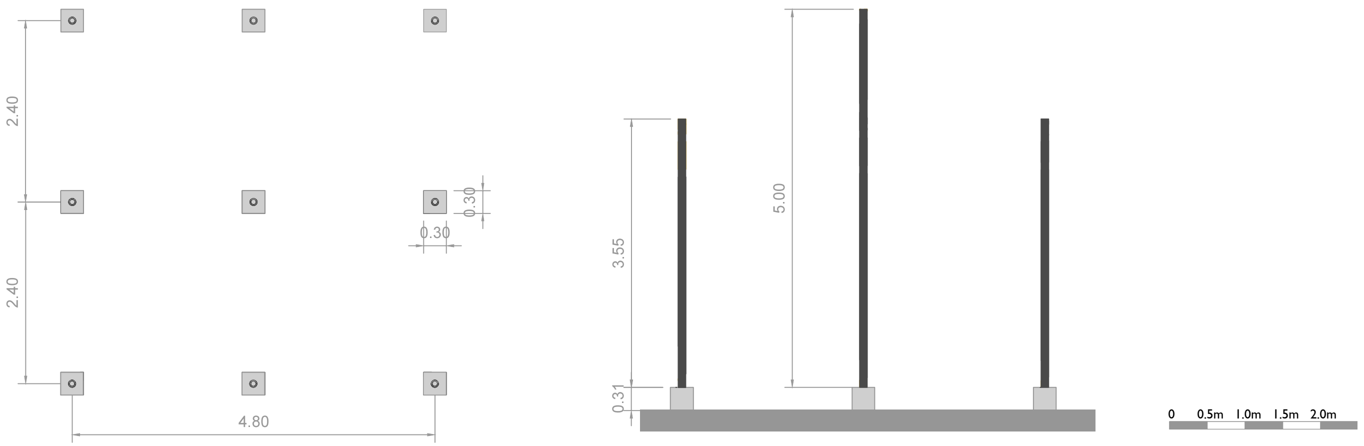





THE PROTOTYPE

Construction Process

Step 2



Scale 1/100

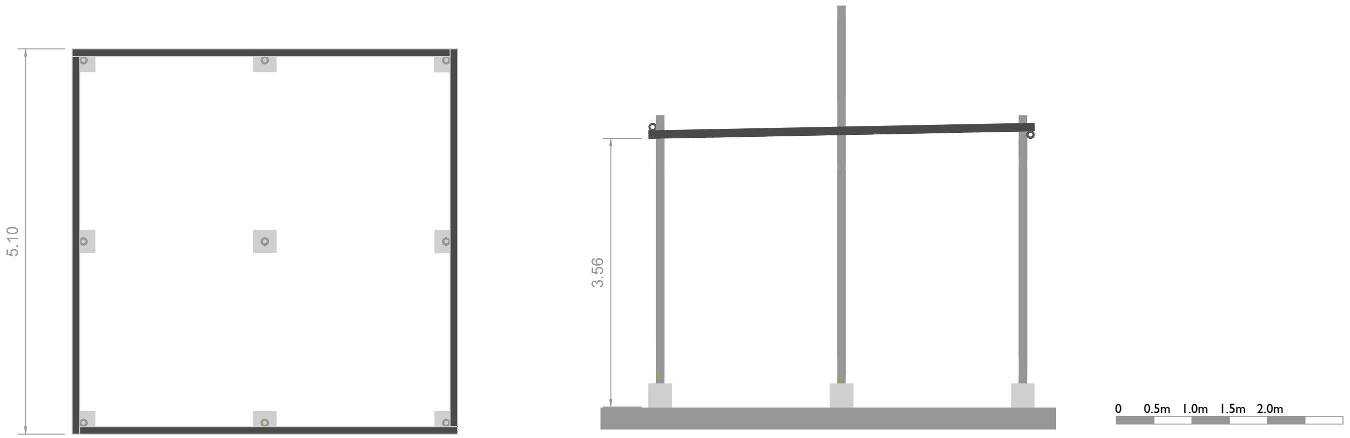
Material	Dimensions	Quantity
Bamboo	3.55 m Ø 0.10m	8
Bamboo	5.00 m Ø 0.10m	1



THE PROTOTYPE

Construction Process

Step 3



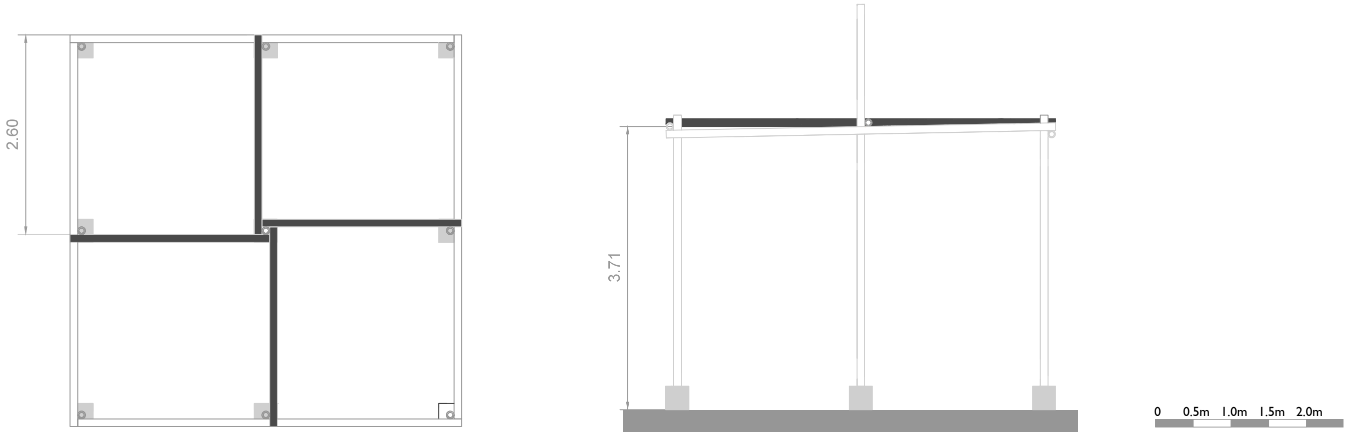
Scale 1/100

Material	Dimensions	Quantity
Bamboo	5.10 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 4



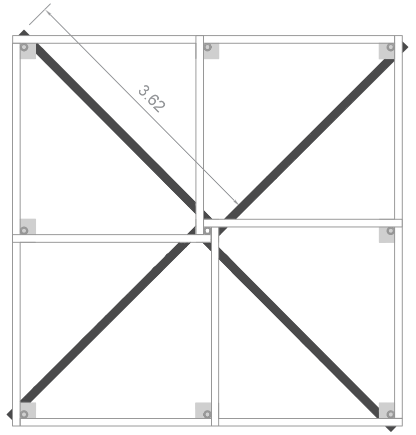
Scale 1/100

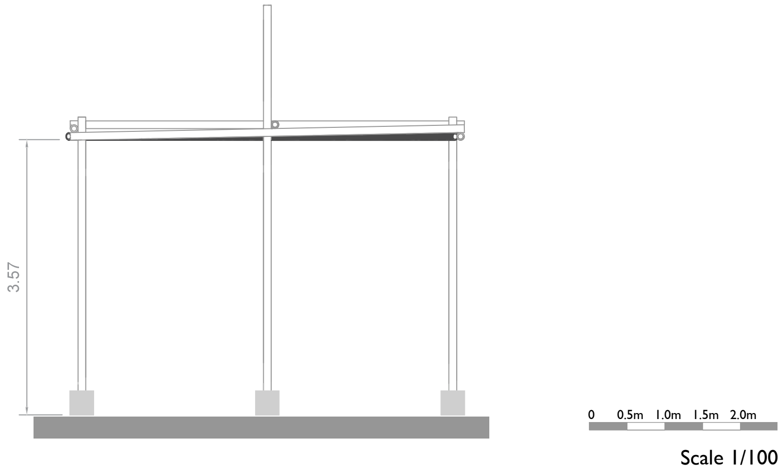
Material	Dimensions	Quantity
Bamboo	2.60 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 5



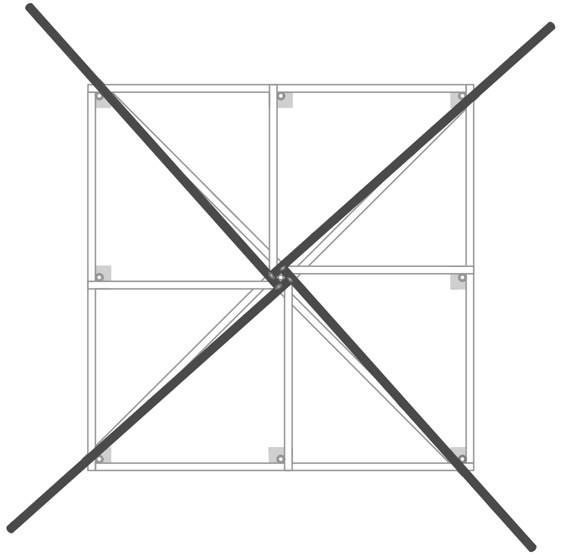


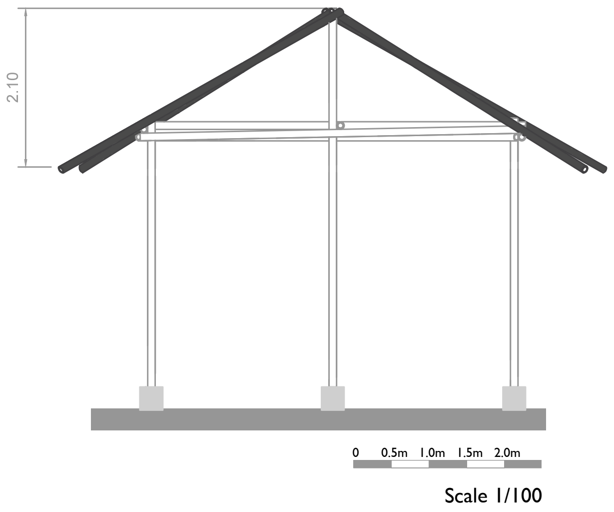
Material	Dimensions	Quantity
Bamboo	3.60 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 6



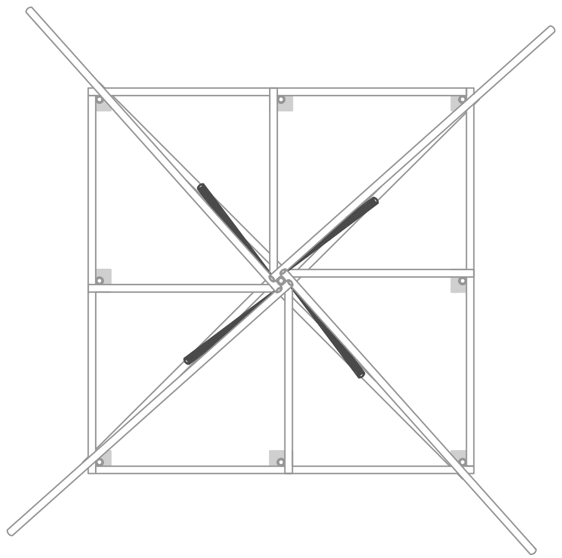


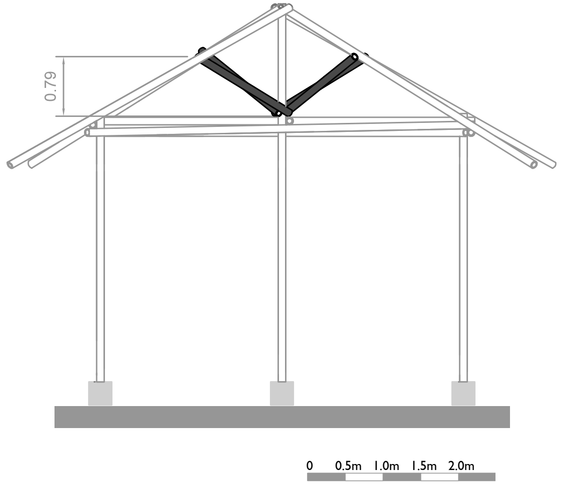
Material	Dimensions	Quantity
Bamboo	5.40 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 7





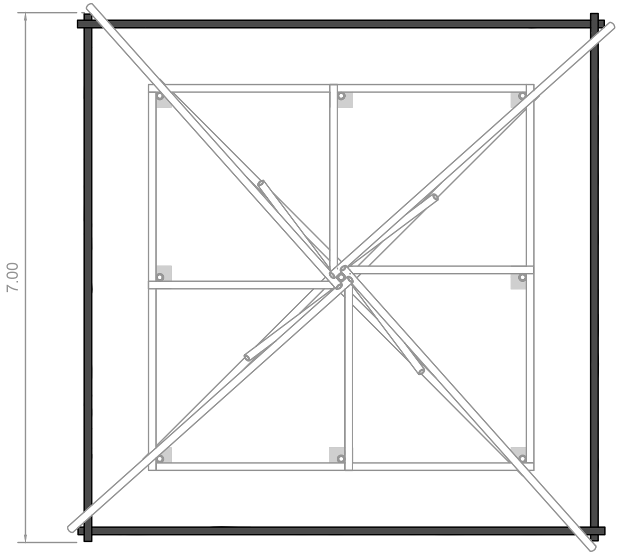
Scale 1/100

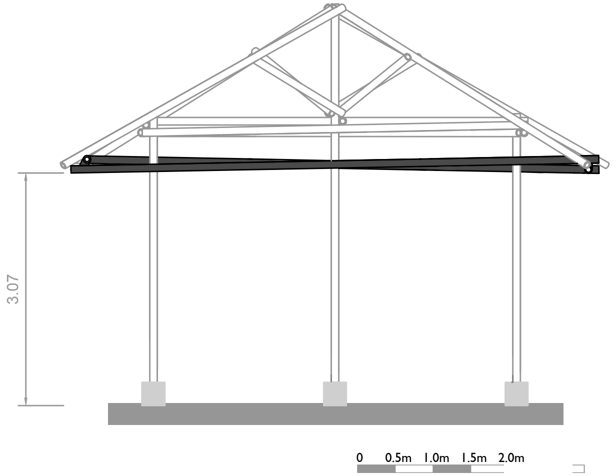
Material	Dimensions	Quantity
Bamboo	1.70 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

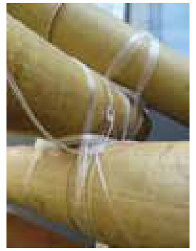
Step 8





Scale 1/100

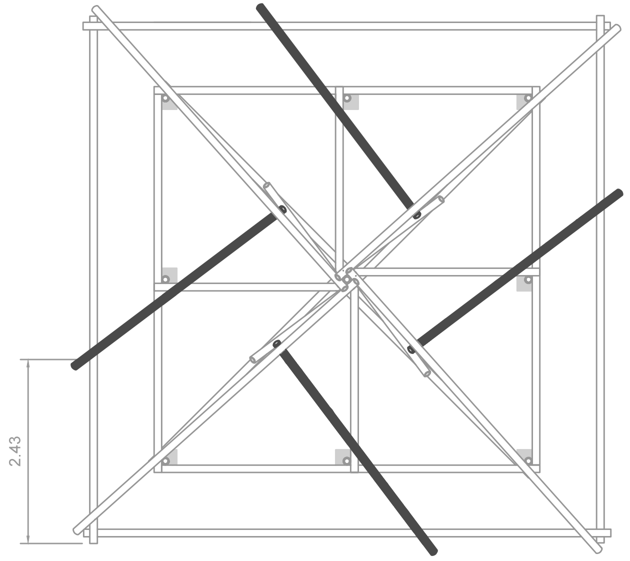
Material	Dimensions	Quantity
Bamboo	7.00 m Ø 0.10m	4

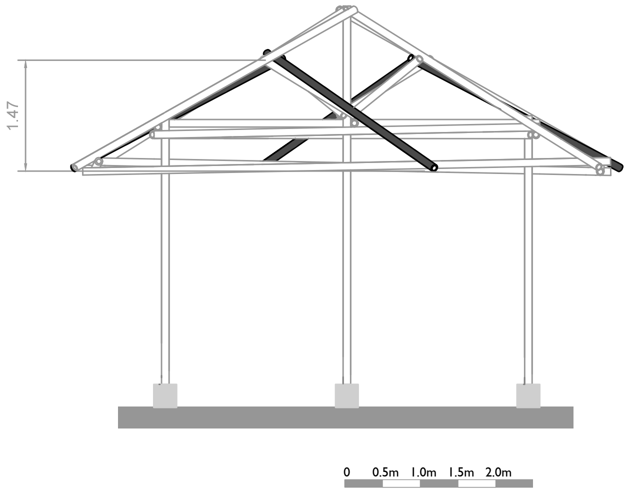


THE PROTOTYPE

Construction Process

Step 9





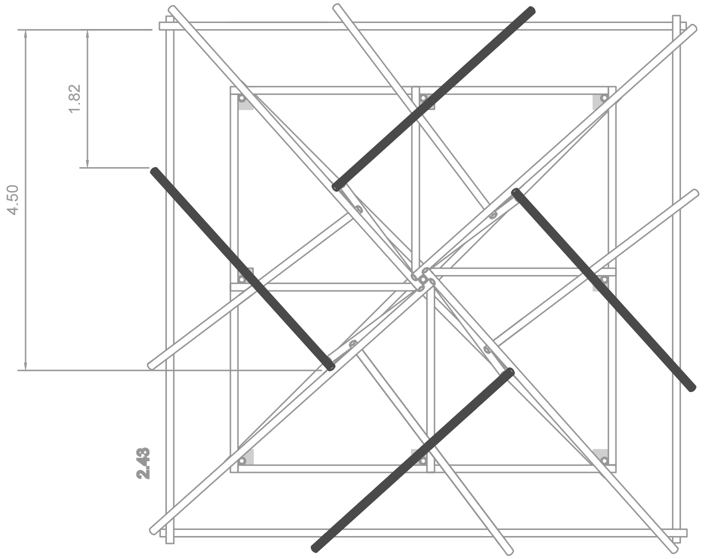
Scale 1/100

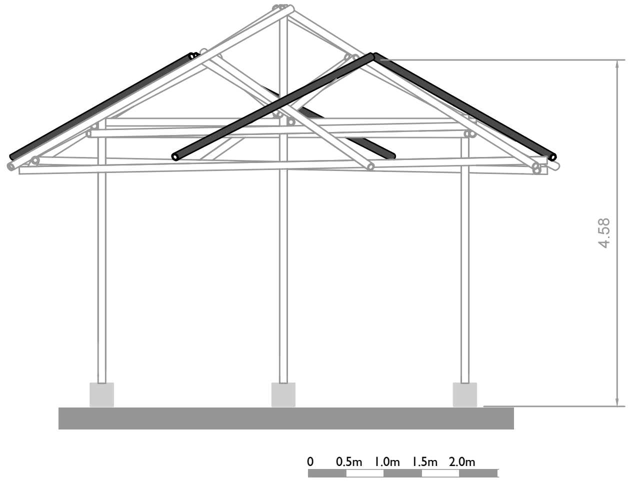
Material	Dimensions	Quantity
Bamboo	3.80 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 10





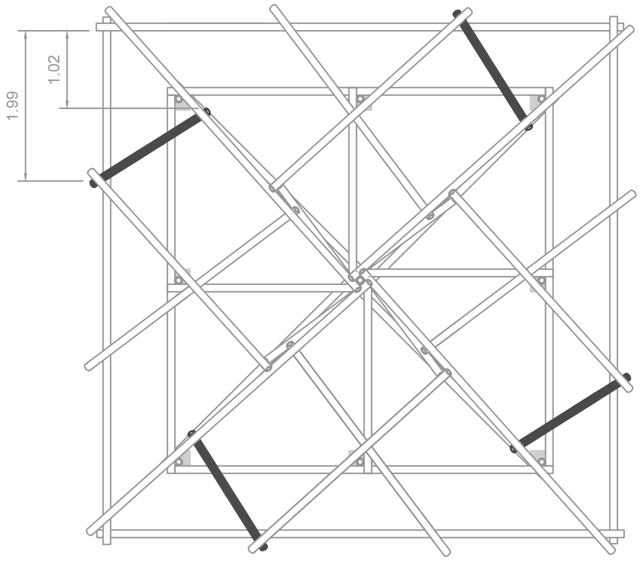
Scale 1/100

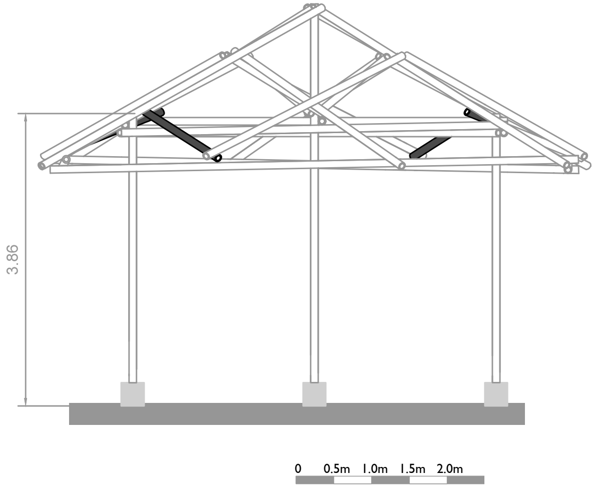
Material	Dimensions	Quantity
Bamboo	3.80 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 11





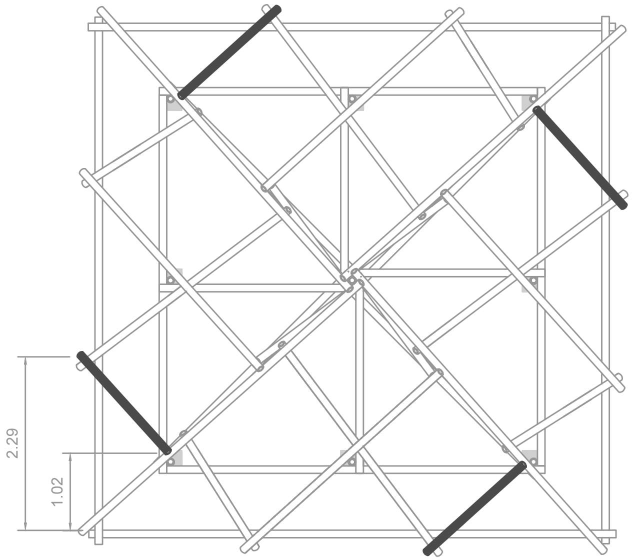
Scale 1/100

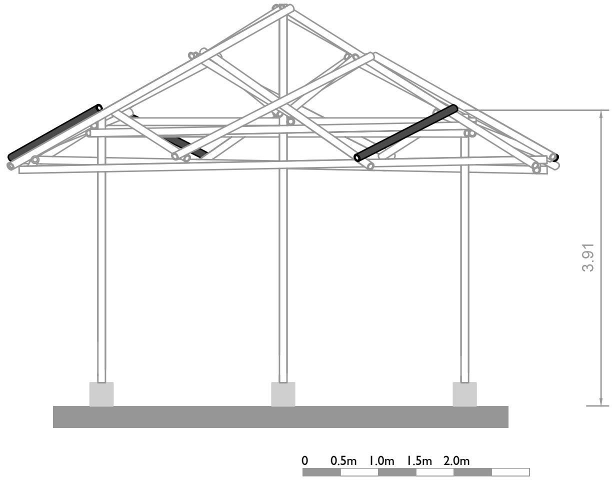
Material	Dimensions	Quantity
Bamboo	1.90 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 12





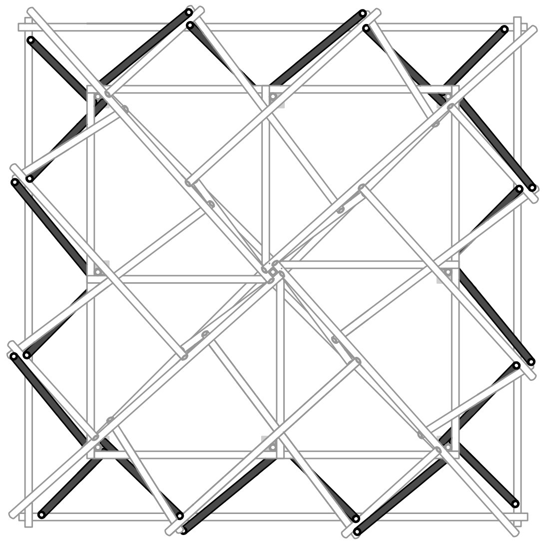
Scale 1/100

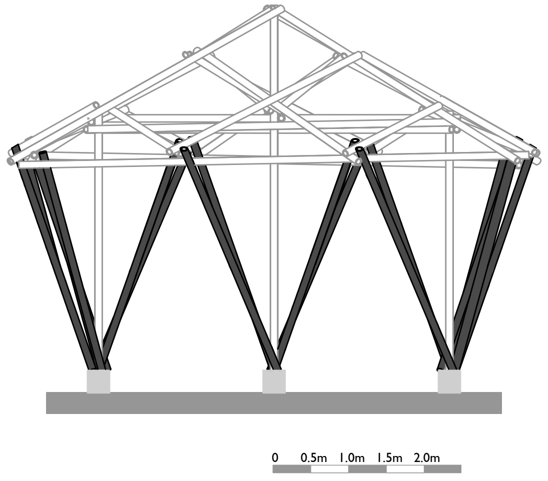
Material	Dimensions	Quantity
Bamboo	1.90 m Ø 0.10m	4

THE PROTOTYPE

Construction Process

Step 13



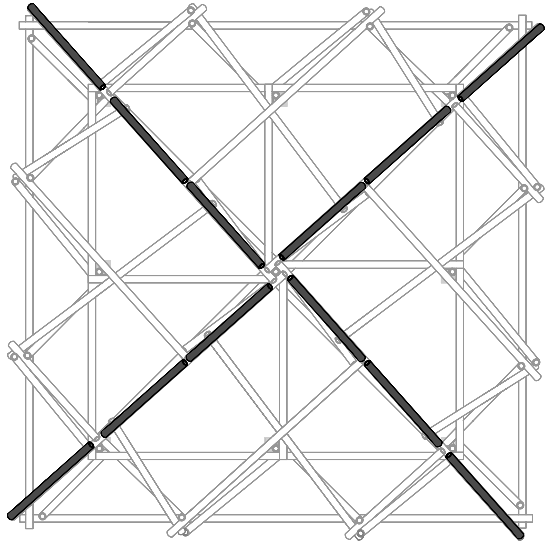


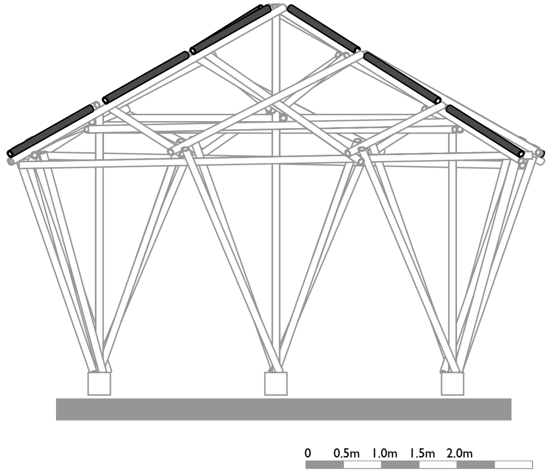
Material	Dimensions	Quantity
Bamboo	3.70 m Ø 0.10m	16

THE PROTOTYPE

Construction Process

Step 14



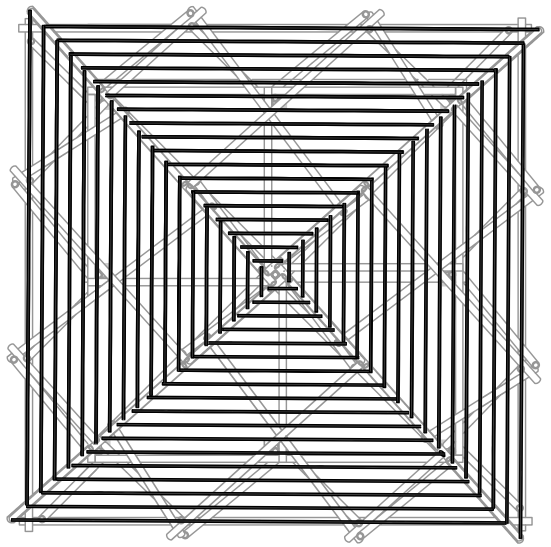


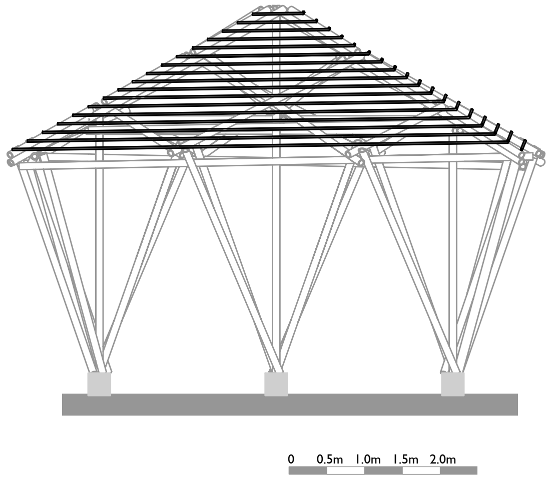
Material	Dimensions	Quantity
Bamboo	1.60 m Ø 0.10m	12

THE PROTOTYPE

Construction Process

Step 15





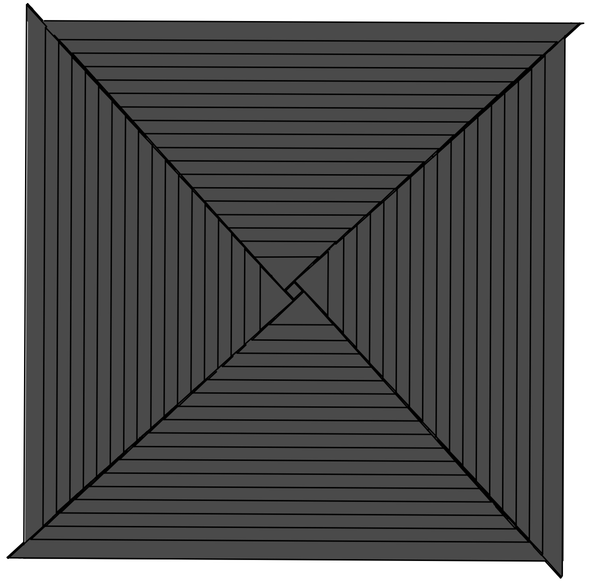
Scale 1/100

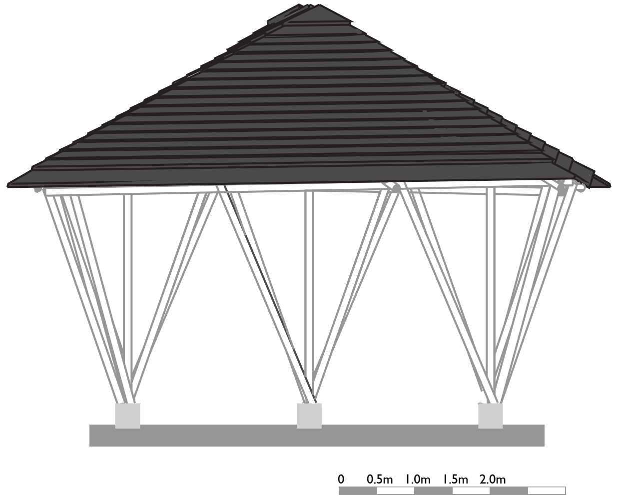
Material	Dimensions	Quantity
Bamboo	6.70 m Ø 0.03m	4
Bamboo	6.35 m Ø 0.03m	4
Bamboo	6.00 m Ø 0.03m	4
Bamboo	5.65 m Ø 0.03m	4
Bamboo	5.30 m Ø 0.03m	4
Bamboo	4.95 m Ø 0.03m	4
Bamboo	4.60 m Ø 0.03m	4
Bamboo	4.25 m Ø 0.03m	4
Bamboo	3.85 m Ø 0.03m	4
Bamboo	3.50 m Ø 0.03m	4

Material	Dimensions	Quantity
Bamboo	3.15 m Ø 0.03m	4
Bamboo	2.80 m Ø 0.03m	4
Bamboo	2.45 m Ø 0.03m	4
Bamboo	2.10 m Ø 0.03m	4
Bamboo	1.75 m Ø 0.03m	4
Bamboo	1.40 m Ø 0.03m	4
Bamboo	1.05 m Ø 0.03m	4
Bamboo	0.70 m Ø 0.03m	4

Construction Process

Step 16



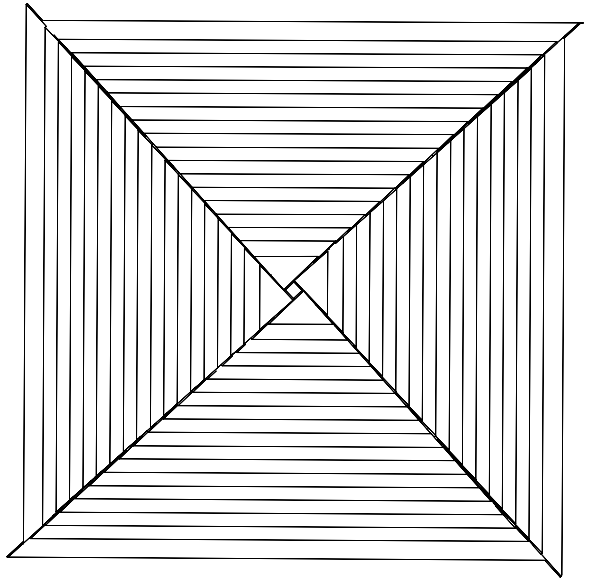


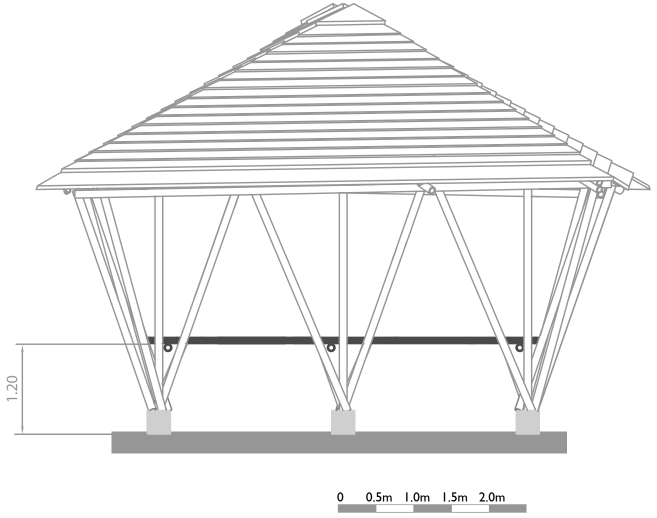
Scale 1/100

Material	Dimensions	Quantity
Cogan Grass Thatch	1.20m x 1.20m	136

Construction Process

Step 17





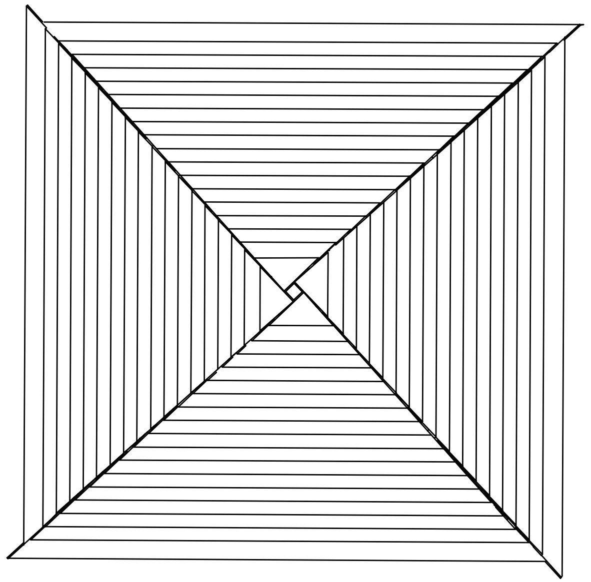
Scale 1/100

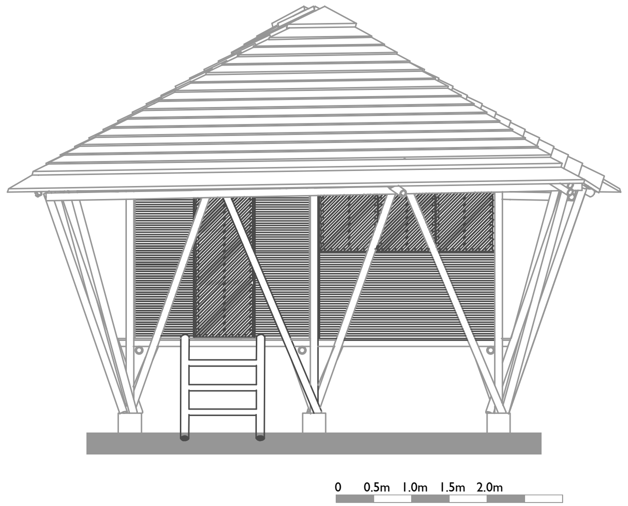
Material	Dimensions	Quantity
Bamboo	3.00 m Ø 0.50m	3
Bamboo	2.60 m Ø 0.50m	16
Bamboo	3.90m Ø 0.50m	2

THE PROTOTYPE

Construction Process

Step 18





Material	Dimensions	Quantity
(Panel 1:Windows)		
Bamboo	2.40 m Ø 0.03m	43 x 5 Panels = 215
	1.00 m Ø 0.03m	3 x 15 Windows = 45
	0.75 m Ø 0.03m	2 x 15 Windows = 30
Split Bamboo	4.00 m Ø 0.03m	3 x 15 Windows = 45
(Panel 2: Door)		
Bamboo	0.70 m Ø 0.03m	70 x 2 = 140
Split Bamboo	4.00 m Ø 0.03m	6

Image 17: Front view of the finalised prototype. Full structure and partial wall system. July 2014. Department of Architecture. Cambridge

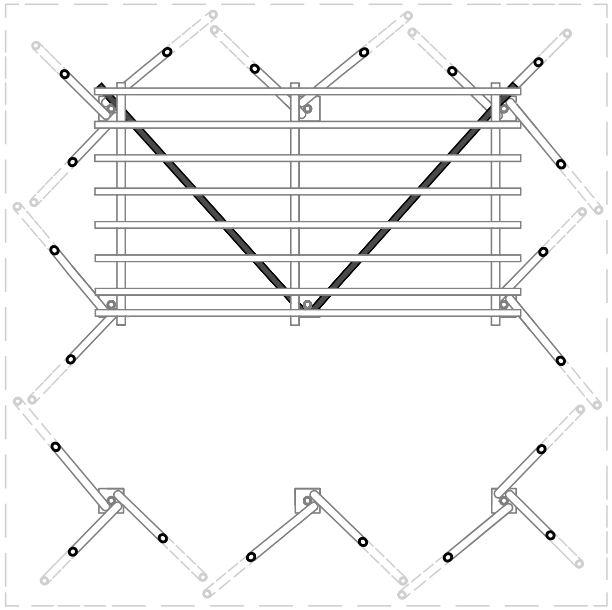
Image 18 Side view of the finalised prototype. Full structure and partial wall system. July 2014. Department of Architecture. Cambridge

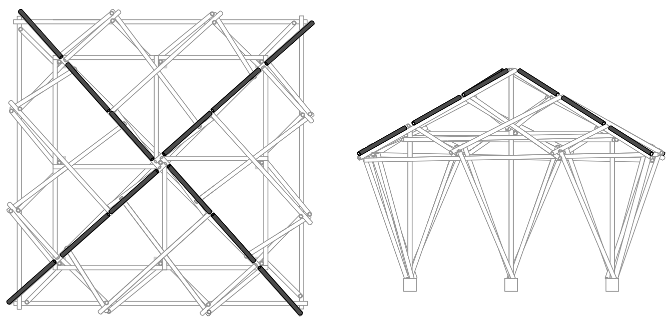
Changes to the design

The construction of the prototype helped us to improve the initial design and therefore some changes were made based on this experience.

a) Floor: the initial structural design of the floor was insufficient to support the loads, and the floor beams suffered deflection. To overcome this, we added diagonal beams to the floor structure, which helped to support the main beams, and also created a triangulation to prevent deformations.

b) Roof: the inclination of the structure, due to the 3D connections and the reciprocal structure, had an influence on the substructure connections to support the thatch roof. The elements could not reach the same points, and therefore, we added auxiliary members on top of the rafters to have the connections on the roof in the same plane.



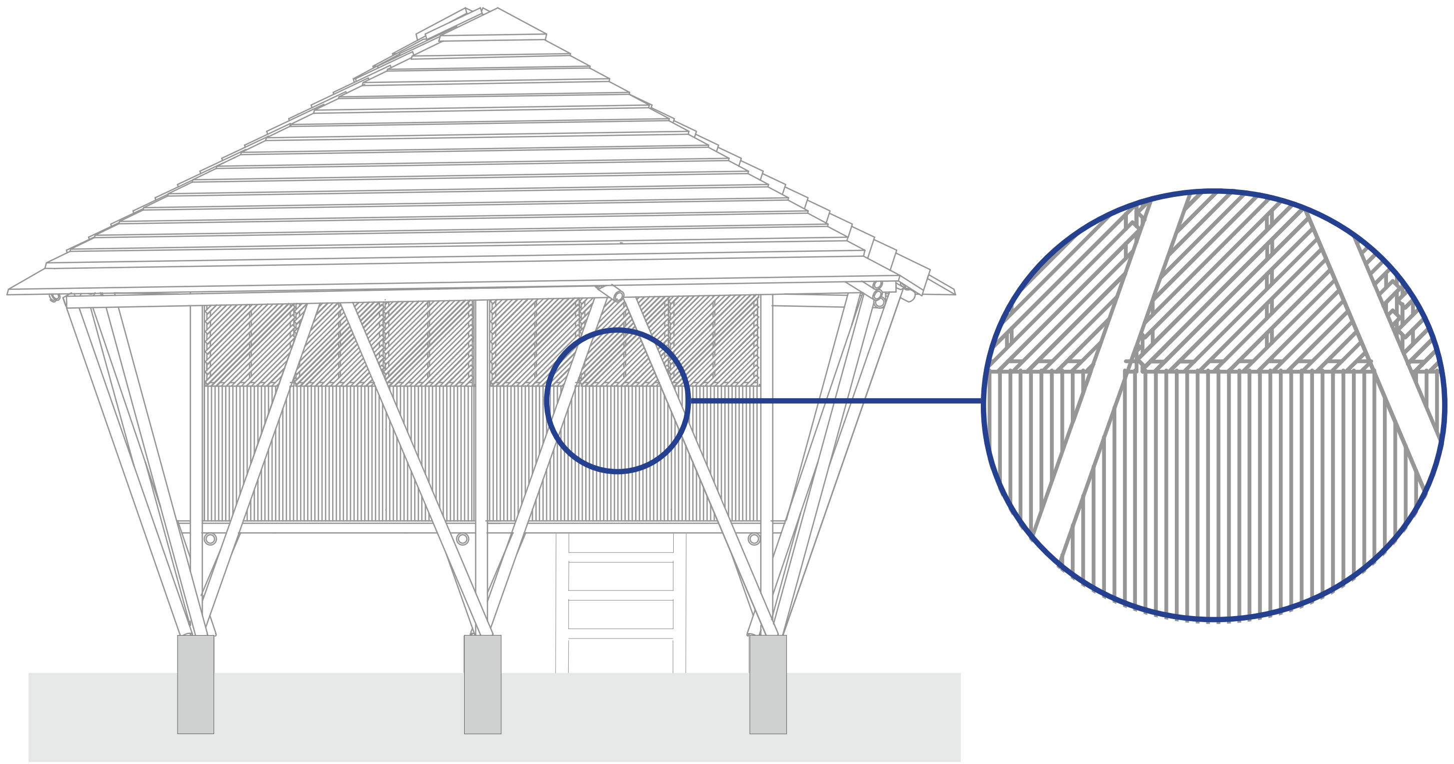


IMPROVEMENTS

Changes to the design

c) Panels: the bamboos inside the panels were initially designed to be placed horizontally, but this was not the most efficient way, because of the loads they needed to support. The improved design considers the bamboo culms placed vertically inside the panel.

d) Foundations: the surface area of the foundation has to be increased in a 33 % in order to resist uplifts. Therefore, instead of 30 x30 cm, the foundations should have a base of 40x40 cm.



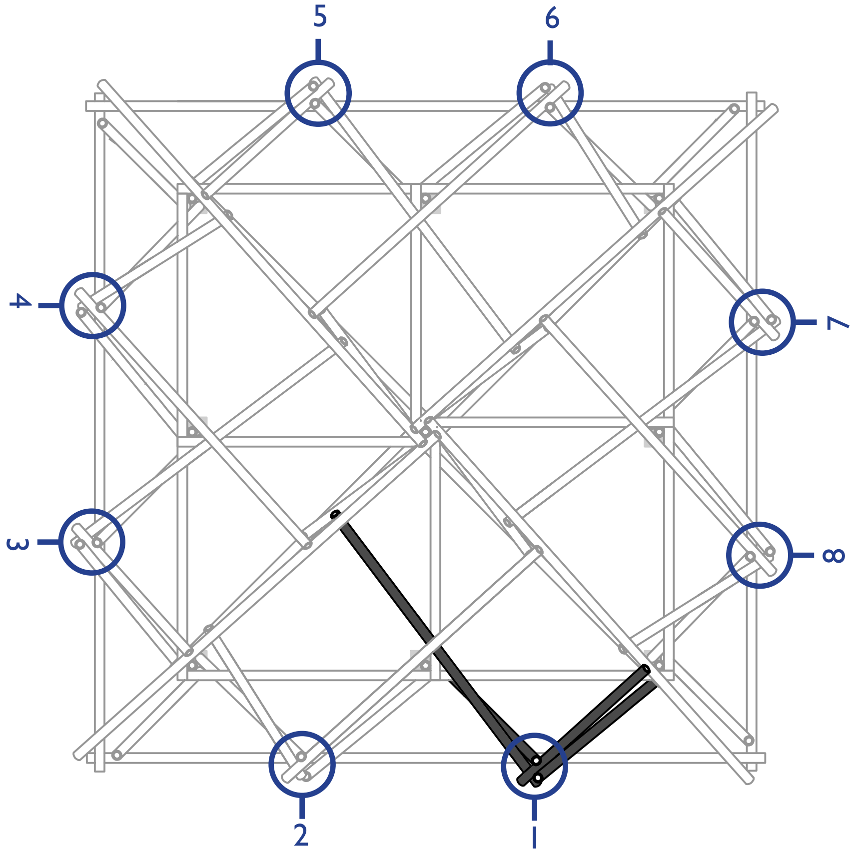
IMPROVEMENTS

Changes to the construction

The building process defined initially was not followed step by step, and the team spent time deciding about changes in the schedule and the process.

a) Shape and sizes: one of the main reasons to change the building process was the inaccuracy created by different shapes and sizes of the culms.

Therefore, when building the inclined columns and their correspondant beams we decided to do them all together instead of step by step. This way it was easier to find the point where all the members came together touching each other.



IMPROVEMENTS

Changes to the construction

b) Beams: Another reason for modifying the process was the UK safety building requirements. Because of this, the team had to use metal scaffolding for attaching the roof members. This meant that the scaffold remain standing in the way of beams and other members, making it impossible for the construction of the beams when it was expected and so, we positioned them once the rest of the structure was built.

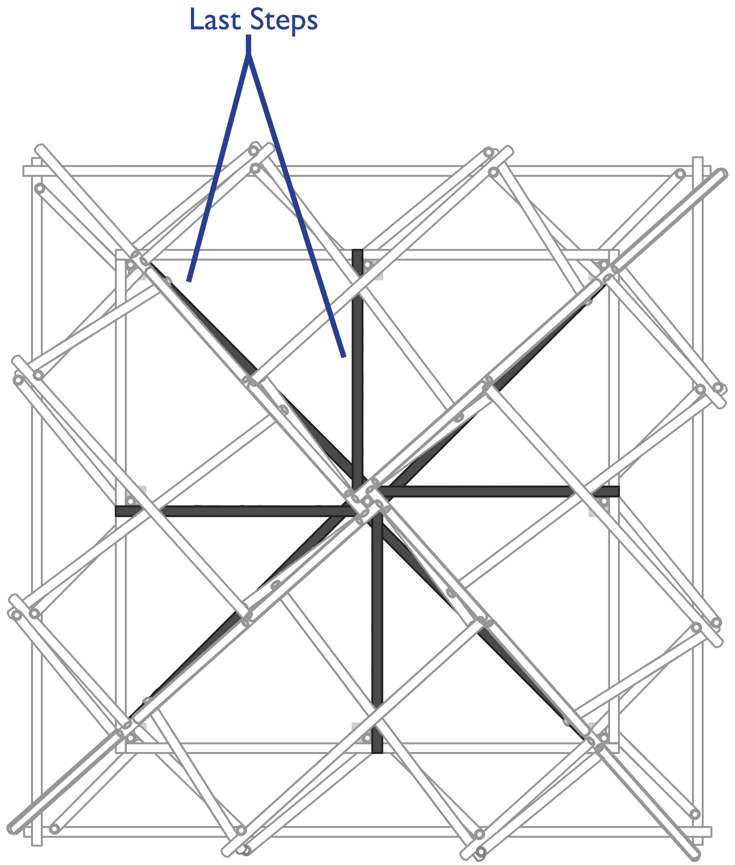


Image 19: Front view of the structure. July 2014. Department of Architecture. Cambridge

Image 20: View of the floor structure. July 2014. Department of Architecture. Cambridge

QUANTITY OF MATERIALS

	Material	Diameter	Dimensions	Quantity	Total
Foundation	Concrete		0.75x0.3x0.3m	9	9
	Rebar	Ø 0.05m	0.60 m	9	9
Structure	Bamboo	Ø 0.10m	3.55 m	8	
		Ø 0.10m	5.00 m	1	
		Ø 0.10m	5.10 m	4	
		Ø 0.10m	2.60 m	4	
		Ø 0.10m	3.60 m	4	
		Ø 0.10m	5.40 m	4	
		Ø 0.10m	1.70 m	4	
		Ø 0.10m	7.00 m	4	
		Ø 0.10m	3.80 m	4	
		Ø 0.10m	3.80 m	4	
		Ø 0.10m	1.90 m	4	
		Ø 0.10m	1.90 m	4	
		Ø 0.10m	3.70 m	16	
		Ø 0.10m	1.60 m	12	
	3m Bamboo	Ø 0.10m			27
	4m Bamboo	Ø 0.10m			55
Roof	Bamboo	Ø 0.03m	6.70 m	4	
		Ø 0.03m	6.35 m	4	
		Ø 0.03m	6.00 m	4	
		Ø 0.03m	5.65 m	4	
		Ø 0.03m	5.30 m	4	
		Ø 0.03m	4.95 m	4	
		Ø 0.03m	4.60 m	4	
		Ø 0.03m	4.25 m	4	
		Ø 0.03m	3.85 m	4	
		Ø 0.03m	3.50 m	4	
		Ø 0.03m	3.15 m	4	
		Ø 0.03m	2.80 m	4	
		Ø 0.03m	2.45 m	4	

QUANTITY OF MATERIALS

	Material	Diameter	Dimensions	Quantity	Total
	Bamboo	Ø 0.03m	2.10 m	4	
		Ø 0.03m	1.75 m	4	
		Ø 0.03m	1.40 m	4	
		Ø 0.03m	1.05 m	4	
		Ø 0.03m	0.70 m	4	
	4m Bamboo	Ø 0.03m			20
	Cogan Grass Thatch		1.20m x 1.20m	136	136
Floor	Bamboo	Ø 0.50m	3.00 m	3	
		Ø 0.50m	2.60 m	16	
		Ø 0.50m	3.90 m	2	
		Ø 0.50m	3.90 m	2	
	Bamboo	Ø 0.50m	4.00 m		21
	Bamboo Screen		2.00 m x 2.00 m	6	6
Panel 1:Windows	Bamboo	Ø 0.03m	2.40 m	215	
	Bamboo	Ø 0.03m	1.00 m	45	
	Bamboo	Ø 0.03m	0.75 m	30	
	Split Bamboo	Ø 0.03m	4.00 m	45	
Panel 2: Door	Bamboo	Ø 0.03m	0.70 m	140	
	Split Bamboo	Ø 0.03m	4.00 m	6	
	Twine		50.00 m	12	
	Bamboo	Ø 0.03m	4.00 m		120
	Split Bamboo	Ø 0.03m	4.00 m		51
Connections	Fishing line	Ø 1.80mm	20.00 m	200	200

Summary of total bamboos used

EXPENSES

Expenses in the UK

Foundations	Amount	Rate	Total Amount
Concrete 20kg	28	£5.49	£153.72
Yield Steel Rod 12mmx6m	2	£10.08	£20.16
Total (+20% VAT)			£208.66
Bamboo (Structure & Panels)	**Amount**	**Rate**	**Total Amount**
100/120mm x 3m	27	£12.99	£350.73
100/120mm x 4m	55	£15.60	£858.00
50/55mm x 4m	21	£6.37	£133.77
30/35mm x 3m	14	£3.46	£48.44
30/35mm x 4m	111	£4.33	£480.63
20/25mm x 3m split	70	£2.25	£157.50
Bamboo screens 2x2m	3	£49.99	£149.97
Delivery		£270.00	£270.00
Total (+20% VAT)			£2,351.08
Fishing Line	**Amount**	**Rate**	**Total Amount**
300lb monofilament 1.8mm (20m)	200	£1.99	£398.00
Delivery			£16.00
Total (+20% VAT)			£414.00
Roof	**Amount**	**Rate**	**Total Amount**
Cogan Thatch	34	£12.50	£425.00
Delivery			£65.00
Total (+20% VAT)			£490.00
Miscellaneous	**Amount**	**Rate**	**Total Amount**
Masking Tape 24mm x 50m	1	£1.03	£1.03
Electrical Tape 19mm x 33m	3	£0.79	£2.37
Jubilee Clips 90-120mm	52	£1.07	£55.38
Twine 50m medium	6	£1.98	£11.88
Total (+20% VAT)			£84.79

Total Spent	£3,548.53

NOTE: The budget presented corresponds to the prototype built at the Department of Architecture on July 2014 of the full structure with a partial wall system

BUDGET

Budget in the Philippines

Foundations	Amount	Rate	Total Amount
Concrete 20kg	62	125.00 php	7,750.00 php
Yield Steel Rod 12mmx6m	5	85.00 php	425.00 php
Total (+12% VAT)			9,156.00 php
Bamboo (Structure & Panels)	**Amount**	**Rate**	**Total Amount**
100/120mm x 3m	27	55.00 php	1,485.00 php
100/120mm x 4m	55	75.00 php	4,125.00 php
50/55mm x 4m	21	30.00 php	630.00 php
30/35mm x 3m	28	20.00 php	560.00 php
30/35mm x 4m	222	25.00 php	5,550.00 php
20/25mm x 3m split	70	15.00 php	1,050.00 php
Bamboo screens 2x2m	6	135.00 ph	810.00 php
Total (+12% VAT)			15,915.00 php
Fishing Line	**Amount**	**Rate**	**Total Amount**
300lb monofilament 1.8mm (20m)	200	22.00 php	4,400.00 php
Total (+12% VAT)			4,928.00 php
Roof	**Amount**	**Rate**	**Total Amount**
Cogan Thatch	136	24.00 php	3,264.00 php
Total (+12% VAT)			3,665.68 php
Miscellaneous	**Amount**	**Rate**	**Total Amount**
Masking Tape 24mm x 50m	1	18.00 php	18.00 php
Electrical Tape 19mm x 33m	3	16.00 php	48.00 php
Twine 50m medium	6	20.00 php	120.00 php
Total (+12% VAT)			223.20 php

Total budget	33,887.88 php = £496.68

NOTE: The prices are approximate due to lack of information. A proper budget is recommended to do in The Philippines in the area where the house will be built.

Image 21: Front view of the finalised prototype. Full structure and partial wall system. July 2014. Department of Architecture. Cambridge

Image 22: Full amount of materials used for the prototype. July 2014. Department of Architecture. Cambridge

CONCLUSION

Positive aspects of the experience

Interdisciplinary design process. The design was done by a team comprised by architects and engineers. Knowledge from both disciplines was incorporated into the design, considering space quality, shapes and structural performance.

Simple construction process. The whole construction was made mainly by four people without previous experience, showing the feasibility of building a strong structure without specialised skills. The only knowledge needed was acquired through simple training on how to make knots (lashing) and where to make the connections between the bamboos.

Flexibility. The model showed that different types of walls and floors can be used because the structure was designed independently to the enclosure system. This decision opens a variety of options for beneficiaries to choose the ways to customise the house and to adapt it to particular needs.

Replacement of elements. During the construction process the team moved and changed elements without difficulty and without compromising the structure. Although all the elements are attached, the no-use of nails or screws facilitates the replacement of parts.

Quick to disassemble. The building was designed to be transitional, with the possibility of being moved to another place and the material recycled or reused. The entire house was dismantled by two people in three days, without damaging the material, proving the capacity of recycling the bamboo used in the construction.

Design award. This prototype has already created interest and recognition, although was the result of a short-term project developed by a new team. The project was awarded Third Prize in the international conference on Vernacular Heritage, Sustainability and Earthen Architecture, held in Spain in September 2014. The competition was called 'Versus: Lessons from vernacular heritage for sustainable architecture' and the results can be seen in: http://www.esg.pt/versus/

Constraints and limitations of the construction process

The main learning from this experience was that a natural material such as bamboo makes the building process less precise and, to some extent, slower. Nevertheless, due to the need of using local materials and vernacular techniques, these constraints have to be reviewed and incorporated as part of the design and building criteria for future designs.

Shape of material. Bamboo culms have different diameters and the distance between nodes varies. Therefore, the team had to spend time selecting similar dimensions for columns and beams, a time that was not considered in the initial schedule. This selection process is crucial for two reasons: it allows getting the right dimensions following the design, and the knots are made in the right place in relation to the nodes, for preventing the bamboos from slipping.

Prefabrication. In initial phases of the design, the idea was to prefabricate some parts of the house in order to decrease construction time. Nevertheless, the prefabrication of structural frames was not possible due to different reasons: the geometry of the house, to the three-dimensional connections, and the different sizes and shapes of the bamboo culms. An attempt was made to prefabricate wall panels, doors and windows by part of the team while the structure of the house was being erected. Nevertheless, the lack of knowledge and experience in building with bamboo made the process slower and maybe less efficient. In a revision of the design, this point will be considered as crucial because can save construction time.

Knots. The way of using the material for the lashings needs to be better planned. When using long threads, they tend to tangle making the process more difficult. Better ways to tighten the knots and to have the thread 'tidy' need to be thought.

Future steps

The following steps are: to make some tests, to evaluate the design, to build an improved version in the Philippines, and to disseminate the experience.

Test. The prototype will be tested through connection tests for loads and uplifts. The results will contribute to the process of learning and will help to corroborate structural analysis developed in the digital model.

Evaluation. The house will be evaluated in the following aspects: structural resistance, feasibility of construction, costs, construction timeline, lifespan and cultural appropriateness. Discussion with ADRA and people from the Philippines will be crucial for this evaluation.

Construction of an improved version. The plan is to build a new version of the model in the Philippines, to train people from ADRA to build the house, and to teach the way to connect bamboo culms. In addition, the team of students collaborating with TECHO-Ecuador is evaluating the use of this experience for developing a house for the Tropical areas of Ecuador.

Disseminate the experience and project. Although the project was developed with the organisation ADRA in mind, the experience and the structural concepts are relevant to other situations. The team has planned to send short articles to architecture websites such as Designboom, Archdaily and InHabitat, and longer academic articles to specialised journals.

Image 23: View of the roof structure. July 2014. Department of Architecture. Cambridge

Image 24: Diagonal lashing. July 2014. Department of Architecture. Cambridge

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Image 25: Side view of the finalised prototype . Full structure and partial wall system. July 2014. Department of Architecture. Cambridge