BAHAY KAWAYAN
A TRANSITIONAL HOUSE FOR THE PHILIPPINES
Ana Gatóo, Elizabeth Wagemann, Michael H. Ramage
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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.

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 Philippines’ 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 3,906,644 to other locations).⁵ Reports indicate more than 1 million damaged houses, of which 548,793 were totally destroyed by the typhoon.⁶


| Total population Philippines (NSCB, 2013 projection) | 93.7 million |
| Of total population potentially affected (Calculation) | 14% |
| Estimated number of people affected by Typhoon Haiyan (DSWD) | 13.1 million estimated |
| Displaced (homeless) (DSWD) | 3.4 million (estimated) |
| Female: 1,000,000 | Male: 970,000 |
| Girls: 735,000 | Boys: 705,000 |
| Non-displaced (calculation) | 9.6 million (estimated) |
| Female: 2,840,000 | Male: 2,730,000 |
| Girls: 2,050,000 | Boys: 1,970,000 |
| People inside evacuation centres (DSWD) | 241,000+ |
| People outside evacuation centres (DSWD) | 3.2 million+ |
| Fatalities (NDRRMC) | 5,000+ (estimated)* |
| Injured (NDRRMC) | 25,000+ (estimated) |
| Missing (NDRRMC) | 1,600+ (estimated) |

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

¹ 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.

² The typhoon caused extensive damage to life, housing, livelihoods and infrastructure across nine of the Philippines’ 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 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.
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.

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.
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.

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.

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.

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.

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.

DESIGN CONCEPTS

"Humanitarian Bamboo Guidelines"
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.

**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.

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**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.

**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.

---

**“Humanitarian Bamboo Guidelines”**
THE PROTOTYPE

Floor Plan

Roof Structure Plan

Front Elevation

Rear Elevation

Roof Plan

Side Elevation

Image 10, 11, 12: Renders of 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.

Step 1
Step 2
Step 3
Step 4

THE PROTOTYPE

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

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6

THE PROTOTYPE
THE PROTOTYPE

Construction Process

Step 1

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<thead>
<tr>
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<th>Quantity</th>
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<td>0.75 x 0.3 x 0.3 m</td>
<td>9</td>
</tr>
<tr>
<td>Rebar</td>
<td>0.6 m Ø 0.05 m</td>
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Material | Dimensions | Quantity |
---------|------------|----------|
Concrete | 0.75 x 0.3 x 0.3 m | 9        |
Rebar    | 0.6 m Ø 0.05 m | 9        |

Step 2

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THE PROTOTYPE

Construction Process

Step 3

Material | Dimensions | Quantity
---|---|---
Bamboo | 5.10 m Ø 0.10m | 4

Step 4

Material | Dimensions | Quantity
---|---|---
Bamboo | 2.60 m Ø 0.10m | 4
### THE PROTOTYPE

#### Construction Process

**Step 5**

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**Step 6**

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![Diagram of Step 5](image1)

![Diagram of Step 6](image2)
THE PROTOTYPE

Construction Process

Step 7

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Step 8

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The Prototype Construction Process

Step 9

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Step 10

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THE PROTOTYPE

Construction Process

Step 11

Material | Dimensions | Quantity
---|---|---
Bamboo | 1.90 m Ø 0.10m | 4

THE PROTOTYPE

Construction Process

Step 12

Material | Dimensions | Quantity
---|---|---
Bamboo | 1.90 m Ø 0.10m | 4
### THE PROTOTYPE

#### Construction Process

**Step 13**

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THE PROTOTYPE

Construction Process

**Step 15**

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<td>6.35 m Ø 0.03m</td>
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<td>Bamboo</td>
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<td>Bamboo</td>
<td>5.30 m Ø 0.03m</td>
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<td>Bamboo</td>
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<tr>
<td>Bamboo</td>
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**Material** | **Dimensions** | **Quantity** |
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<tbody>
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<td>Bamboo</td>
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THE PROTOTYPE

Construction Process

**Step 16**

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<td>Thatch</td>
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<table>
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<tr>
<th>Material</th>
<th>Dimensions</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Bamboo</td>
<td>6.70 m Ø 0.03m</td>
<td>4</td>
</tr>
<tr>
<td>Bamboo</td>
<td>6.35 m Ø 0.03m</td>
<td>4</td>
</tr>
<tr>
<td>Bamboo</td>
<td>6.00 m Ø 0.03m</td>
<td>4</td>
</tr>
<tr>
<td>Bamboo</td>
<td>5.65 m Ø 0.03m</td>
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</tr>
<tr>
<td>Bamboo</td>
<td>5.30 m Ø 0.03m</td>
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<td>4.95 m Ø 0.03m</td>
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<td>4.25 m Ø 0.03m</td>
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<tr>
<td>Bamboo</td>
<td>3.85 m Ø 0.03m</td>
<td>4</td>
</tr>
<tr>
<td>Bamboo</td>
<td>3.50 m Ø 0.03m</td>
<td>4</td>
</tr>
</tbody>
</table>
Step 17

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

Step 18

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

Material (Panel 2: Door) | Dimensions | Quantity
--- | --- | ---
Bamboo | 0.70 m Ø 0.03m | 70 x 2 = 140
Split Bamboo | 4.00 m Ø 0.03m | 6

IMPROVEMENTS

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.

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 x 30 cm, the foundations should have a base of 40 x 40 cm.
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.

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 remained 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.
## QUANTITY OF MATERIALS

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<td>0.60 m</td>
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<tr>
<td>Structure</td>
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<td>Ø 0.10 m</td>
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</tr>
<tr>
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<td>1.70 m</td>
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<tr>
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### Summary of total bamboos used

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<tr>
<th>Material</th>
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<th>Quantity</th>
<th>Total</th>
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<td>4</td>
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<td>Cogan Grass</td>
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<td>6</td>
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<td>bamboo</td>
<td>Ø 0.03 m</td>
<td>0.75 m</td>
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<tr>
<td></td>
<td>split bamboo</td>
<td>Ø 0.03 m</td>
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<td>45</td>
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<tr>
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<td>0.70 m</td>
<td>140</td>
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<td></td>
<td>split bamboo</td>
<td>Ø 0.03 m</td>
<td>4.00 m</td>
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</tr>
<tr>
<td></td>
<td>twine</td>
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<tr>
<td>Panel 2: Door</td>
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<td>120</td>
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<td>split bamboo</td>
<td>Ø 0.03 m</td>
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<td>51</td>
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<tr>
<td>Connections</td>
<td>fishing line</td>
<td>Ø 1.80 mm</td>
<td>20.00 m</td>
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</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Diameter</th>
<th>Dimensions</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>T wine</td>
<td></td>
<td>50.00 m</td>
<td>12</td>
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</tr>
<tr>
<td>Bamboo</td>
<td>Ø 0.03 m</td>
<td>4.00 m</td>
<td>120</td>
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</tr>
<tr>
<td>split bamboo</td>
<td>Ø 0.03 m</td>
<td>4.00 m</td>
<td>51</td>
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</table>

**Summary of total bamboos used**
### EXPENSES

#### Expenses in the UK

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
<th>Rate</th>
<th>Total Amount</th>
</tr>
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<tbody>
<tr>
<td>Concrete 20kg</td>
<td>28</td>
<td>£5.49</td>
<td>£153.72</td>
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<tr>
<td>Yield Steel Rod 12mmx6m</td>
<td>2</td>
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<td><strong>Total (+20% VAT)</strong></td>
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<td><strong>£208.66</strong></td>
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<tr>
<td>Bamboo (Structure &amp; Panels)</td>
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<td></td>
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</tr>
<tr>
<td>100/120mm x 3m</td>
<td>27</td>
<td>£12.99</td>
<td>£350.73</td>
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<tr>
<td>100/120mm x 4m</td>
<td>55</td>
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<td>50/55mm x 4m</td>
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<td>30/35mm x 3m</td>
<td>14</td>
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<tr>
<td>30/35mm x 4m</td>
<td>111</td>
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<tr>
<td>20/25mm x 3m split</td>
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<td>£157.50</td>
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<tr>
<td>Bamboo screens 2x2m</td>
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<td>£149.97</td>
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<td><strong>Total (+20% VAT)</strong></td>
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<td><strong>£2,351.08</strong></td>
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<td><strong>Fishing Line</strong></td>
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<tr>
<td>300lb monofilament 1.8mm (20m)</td>
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<tr>
<td><strong>Total Spent</strong></td>
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<td><strong>£3,548.53</strong></td>
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**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

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Concrete 20kg</td>
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<tr>
<td>Yield Steel Rod 12mmx6m</td>
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<td><strong>Total (+12% VAT)</strong></td>
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<td></td>
<td><strong>7,156.00 php</strong></td>
</tr>
<tr>
<td>Bamboo (Structure &amp; Panels)</td>
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</tr>
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<td>100/120mm x 3m</td>
<td>27</td>
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<td>20/25mm x 3m split</td>
<td>70</td>
<td>15.00</td>
<td>1,050.00 php</td>
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<td>Bamboo screens 2x2m</td>
<td>6</td>
<td>135.00</td>
<td>810.00 php</td>
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<tr>
<td><strong>Fishing Line</strong></td>
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<td>300lb monofilament 1.8mm (20m)</td>
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<td>22.00</td>
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<td><strong>Total budget</strong></td>
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<td><strong>33,887.88 php = £496.68</strong></td>
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</table>

**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.

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 specialists. 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 to customise the 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 it 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.

Positive aspects of the experience

Constraints and limitations of the construction process

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.
REFERENCES AND ACKNOWLEDGEMENTS

References


Acknowledgements

We would like to acknowledge Allan McRobie, Patrick Fleming and Bhavna Sharma for their reviews about the structural system, and special thanks to Miguel López for his support during the trip to the Philippines, to Moises Musico from ADRA for all his assistance, to Mark Breeze for participating in the initial stages of the design and to Daniel Jiménez for participating in the whole process. We would like to thank the EcoHouse Research Cluster and AngloAmerican Group Foundation for supporting this project and the EcoHouse Initiative students for helping in the construction, in special Max and Sarah. We also would like to acknowledge students from the MPhil in Engineering for Sustainable Development in Cambridge for their collaboration in the construction process. Finally we would like to thank the University of Cambridge, in specific the Department of Engineering for their support on making the foundations and the Department of Architecture for allowing us to build the prototype in the courtyard.
