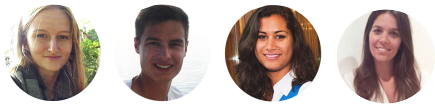
BAMBÚ SOCIAL 2.0

CONSTRUCTIONAL ANALYSIS

COLOFON



Bambú Social is a non-profit organization in collaboration with Delft University of Technology (The Netherlands) and the municipality of El Rama, Nicaragua. The knowledge shared in this report is a combination of literature studies, intervieuws with experts like Fernando Echeverria and the knowledge and experience of two years of research by Bambú Social in El Rama, Nicaragua (since 2014).

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CONTENT

INTRODUCTION

Since 2014, Bambú Social does research on local building materials and opportunities in Nicaragua, resulting in the design and construction of a bamboo model house on site. This house functions as a role model to show the various qualities of bamboo and help improving the image of bamboo as a construction material. But most importantly, the construction of the model house served as an experiment on constructing with bamboo in a local, sustainable and cost efficient way in Nicaragua. Based on the model house a first draft of a social house was designed, taking previous lessons into account. Because the aim is to make a design that is easily applicable on a larger scale, the social house has to be an affordable, easy-to-build house of good quality that matches to the building culture of Nicaragua.

Therefore, in this research, the constructional aspects of the model house and social house were analyzed. Together with students and craftsmen involved last year the physical aspects of the model house and the building process are investigated. Through a scaled model, the physical aspects of the social house are investigated with the "Manual de construcción sostenible" as a guide.
The team looked for challenges that could be improved in future designs. These concludes in constructional improvement suggestions. As a first step towards the physical improvements, the team already designed some alternative connections. Together with local craftsmen the team will test and improve them. The design improvements are presented to local students who will contribute to the design of the (new) social house.

The team describes the choices the architects made briefly. Elaborated design choices can be found in the project report of Bambú Social in 2014.

At last, through this research a lot of knowledge has been gained and the team wants to share this by giving insight of these design challenges the architects faced. Despite this report the team wants to emphasize the succeeded results and the design discussion that architects may face. By sharing, improving and discovering Bambú Social will keep developping towards a design of a bamboo social house for the people of Nicaragua.

MODEL HOUSE 2014

MAINTENANCE AND MEASUREMENTS

Bluefields, Indian & Caribbean University (BICU) is responsible for the maintenance of the model house.

Until November 2015 the house functioned as a university library. In December 2015 the university made other plans to use the house as a cafeteria and museum for students. The house is used every day. End of 2015 a fence is being constructed due to safety reasons. As BICU is the owner of the house, they have the right to decide how to use the house and maintain it. The most important part is the constructional maintenance to ensure safety. The BICU students treated the bamboo with linseed oil and removed fungus, according to the plan. The garden, as its original design, has not been maintained at all; accept from cutting abundant weed and clearing the drainage shafts.

In order to make an elaborated and complete research of the model house, some measurements had to be made, which is not the case. After the construction of the house a protocol should be made how to measure the physical and climatologic aspects. For the constructional research some measurements have been taken, but no correct conclusions could be drawn from these. It is also common that the deformations inside the construction are most likely to occur in the first year. Bamboo is a relatively new material, in that way that there is not a lot of knowledge and documented experience about bamboo in construction. To contribute to the bamboo research and the progress of the project, it is recommended to create a measurement protocol. This could be applied at each future constructed building of bamboo. Bambú Social must ensure that the protocol is performed in at least the first two years.

- Create a measurement protocol
- Ensure the protocol performance

PHYSICAL ANALYSIS

All physical aspects of the model house are investigated. This includes the (bamboo) structure as the different functioning system within the house.

FOUNDATION (A)

Concrete

Usually the foundation is designed to carry the load of the house; therefore it has to dissipate forces to the underlying ground. However, houses of bamboo weigh much less than 'normal concrete houses'. The ventilation system of the roof causes a suction effect that creates forces upwards. Therefore the foundations of the model house should be designed for tension forces. A local engineer dimensioned the foundation. Because of the fact that the wind flow through the house is not standard, is it too difficult to check if the dimensions of the concrete foot are right.

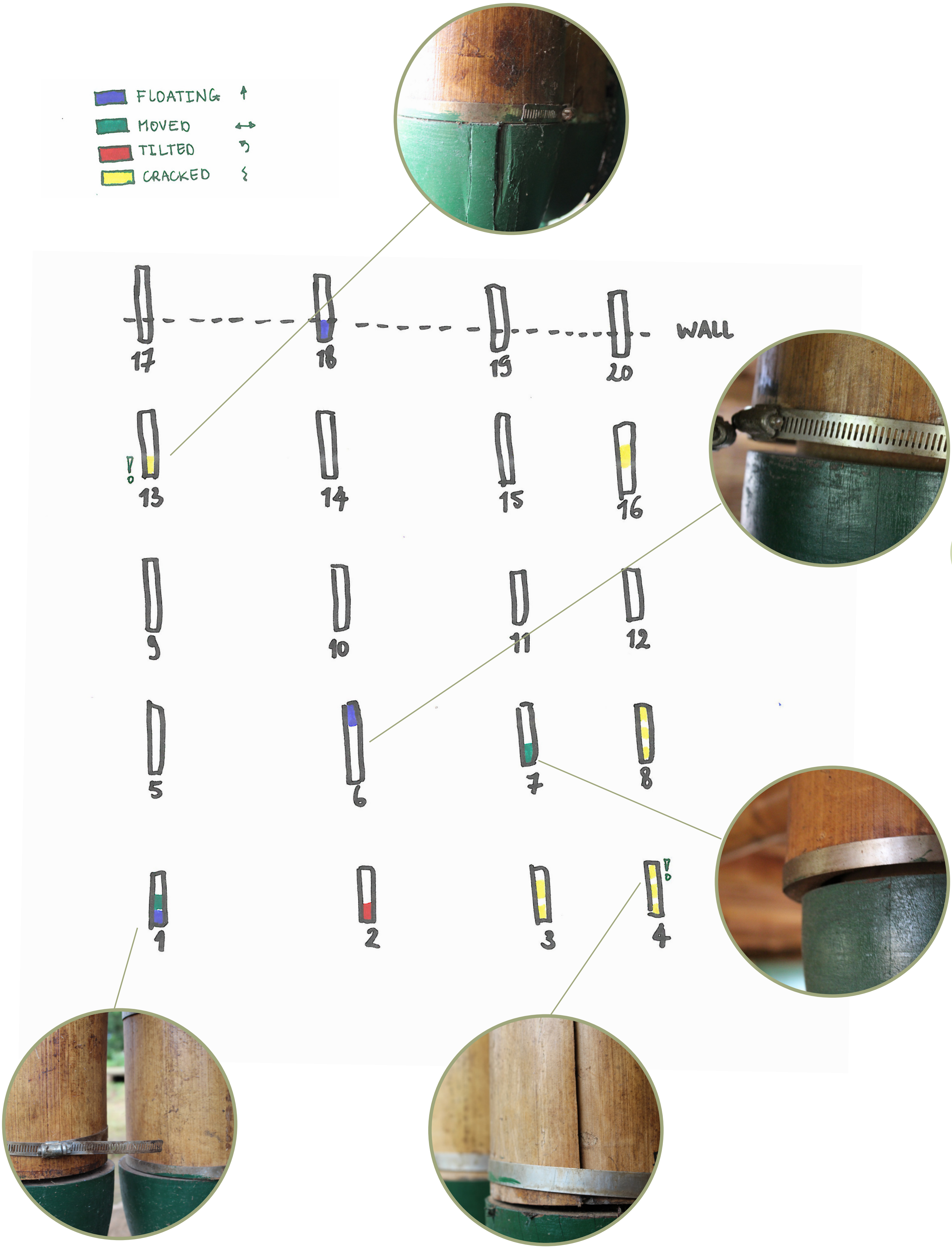
Connections

The connection of the foundation used for the model house has a very unique design. It consists of a spherical gag of wood that connects the concrete foundation with the bamboo column. The screw that goes into the gag is perforated before it is applied. This results in a gap of air inside of the gag. The connection between the screw and the wooden gag is therefore not entirely secure. A part of the gag has a smaller diameter and fits into the bamboo inside. This fixed part of the gag does not fit correctly into all bamboo columns (as the dimensions of bamboo are very irregular). To ensure this connection brackets are applied around the bamboo (with nail wires), but this does not ensure a better connection between the wood and bamboo. Therefore the connection between the wood and bamboo is not secure with extreme wind forces.
The screw is very well applied to the concrete, but it not ideally connected with the wood and bamboo. Therefore foundation can handle compression forces but less tension forces.
By measuring the space between the brackets, the shrinkage of the bamboo columns could be measured. Unfortunately some brackets have been tightened already by the BICU students without documenting. Therefore no data regarding the shrinkage of the columns is available. During investigation half of the brackets weren't tightened. In general this indicates that the bamboo shrinkage is significant during the first year.

Design

The foundation is designed by three columns that support different parts of the house (roof, beams, and floor). This works fine if the bamboo is able to pass on all forces. Some connections are dysfunctional and therefore some errors occur.
Floating: the load of the columns is not passed correctly, or the bamboo shrank too much and is cramped around the smaller part of the wood.

Moved: the smaller part of the wood is too small and the bamboo moved due to horizontal forces.
Tilted: the column is eccentrically loaded (by taking over the load of the other column).
Cracks: wood is overloaded or dried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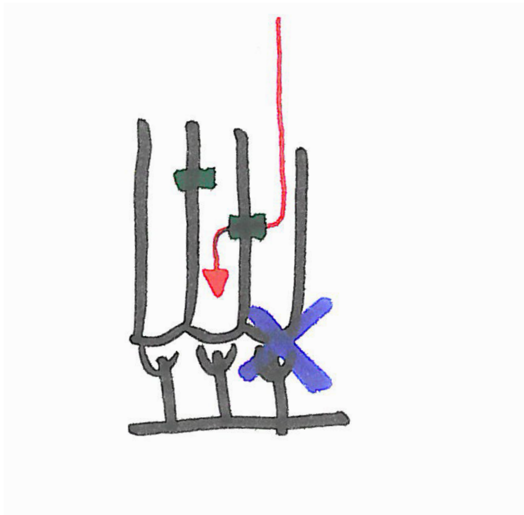

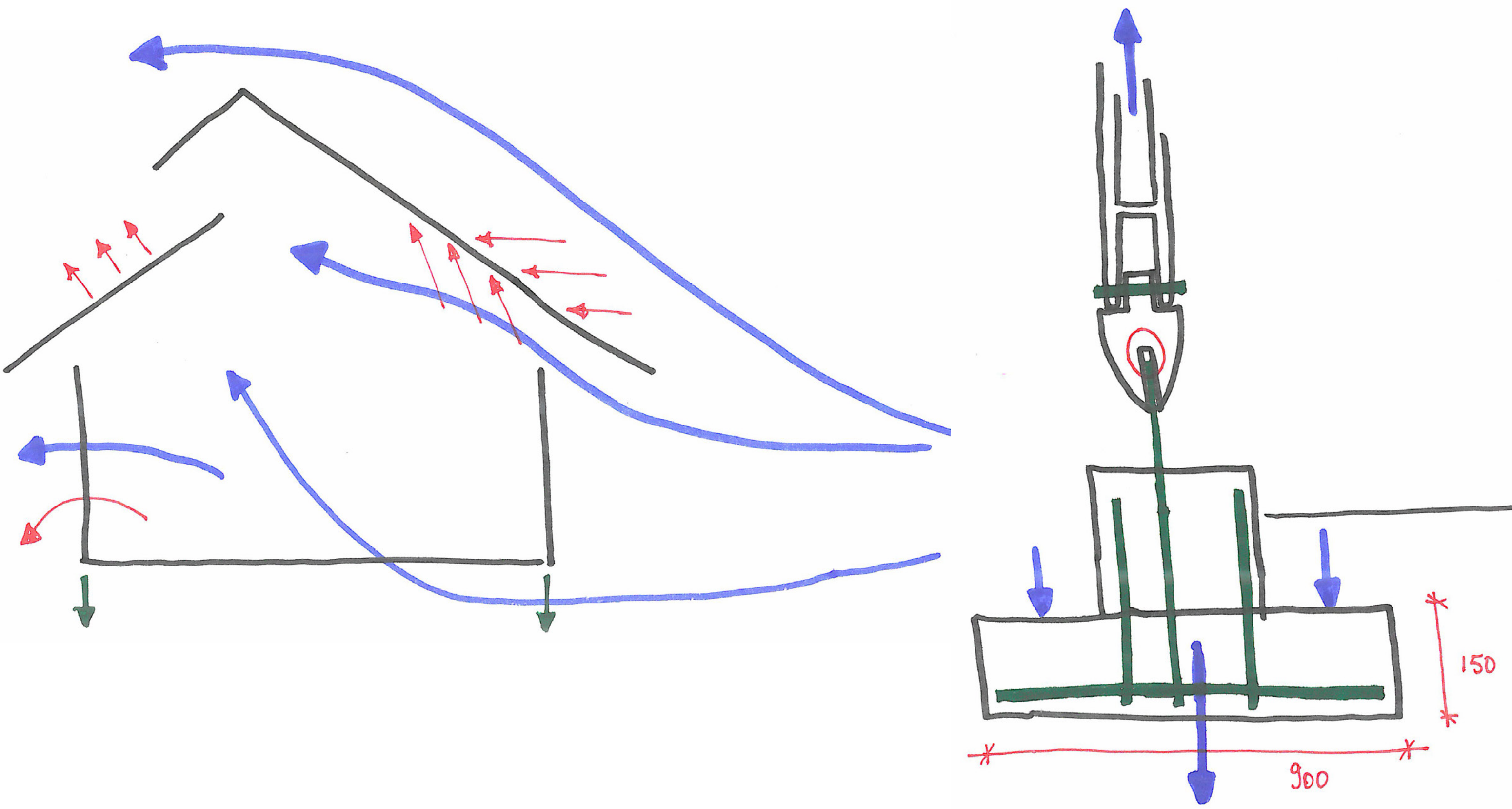
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Execution

The gags were made by a professional carpenter, Henky Borgstein, the only person in El Rama with the right tools and expertise. Therefore only experts could construct this kind of connection and is not applicable to standards families in Nicaragua. This connection requires relatively a lot of wood and is therefore expensive and must be avoided for ecological reasons.
After all, this connection is not recommended.
The gags are not easily adaptable to the irregular bamboos. The production of the gags is too difficult.

- Design a new foundation which connections resist better tension forces (A1)
- Ensure that the load is passed on correctly on each column (A2)

COLUMNS, BEAMS AND TRUSSES (B)

The bamboo used for the columns is Dendrocalamus Asper (Asper) with an average diameter of 20 cm at the bottom and 14 cm at the top. This bamboo is very conical with a thickness of 1 – 3.5 cm.
The bamboo used for the beams, trusses and rest of the structure is Gigantochloa Apus (Gigantochloa) with an average diameter of 10 cm at the bottom and 5 cm at the top. This bamboo is less conical but tends to bend much more.
The bamboo house is not only statically loaded, but also dynamically, mainly due to the ventilation flow. When the bamboo is connected with another part it is done by boring, taking away firmness. Bamboo is firm and gets its strength from the fiber, directed all in one, vertical way. The circular diameter forms a constructional benefit in constructions. Drilling holes could be risky with lateral (sideward) loads and has a higher risk at buckling.
The boring spot doesn't only create risks on a constructional level, but on material level as well. Almost all connections come with cracks in the bamboo. The connections form a crucial part in the construction.
The most common observation is the cracks in the columns and beams. Most cracks occur around connections.

Connections between beams (1)

The beams are mostly connected with espiches. Espiches small sticks made of bamboo to function as dowel pins. The bamboo is perforated and an espiche with a slightly bigger diameter is inserted which connects the two beams. The espiches are applied diagonally in a triangular angle for the shear forces to be ideally distributed.
Espiches work well with wood, but less with bamboo. This is because the fibers of bamboo are directed in the same vertical way and the intersection between the espiche and bamboo material is smaller due to the hollow characteristic.
The house is dynamically loaded and small vibrations cause the espiches to move. Also the fact that the bamboo could shrink after the construction and that the shrinkage is irregular over time and over different beams, cause that the espiches' position could not provide a secure connection.
A solution is to enforce every two espiche connections with a bolt. The bolt is applied

vertically to avoid damage of the beams surface. This way the separate culms now function as one beam, being able to distribute the forces ideally towards the beams and foundation.

• Apply bolts between every two espiche connection to ensure the separate beams to function as one beam (B1)

Connections between columns and beams (2)

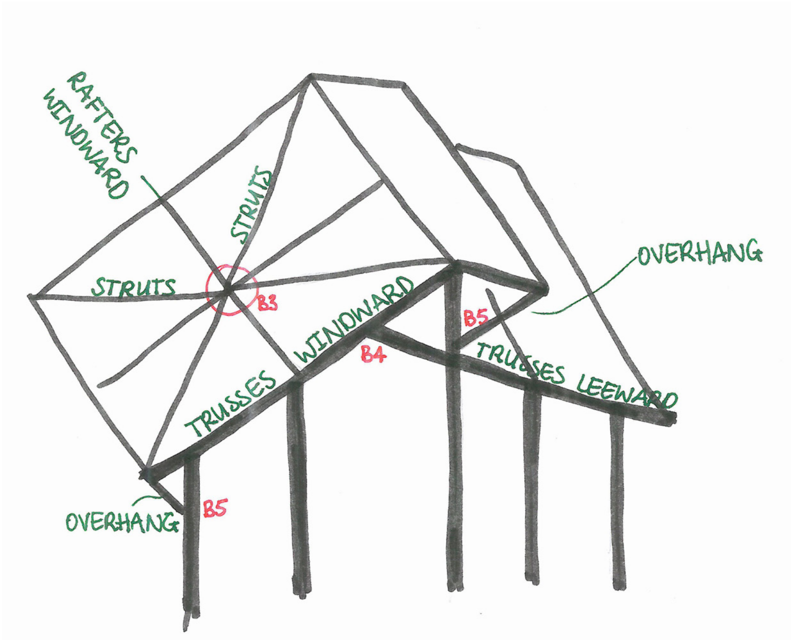
Because of the bigger diameter the beams could be easily attached to the columns by making a slot in which the diameter of the beams fit. The open spot of the column is secured by a belt that holds the two separate parts together.
This connection is firm and provides the beams to deliver the load to the columns. An executional remark has to be made that to make sure that this connection works, the bamboo culms used for the beams must have the right length to fit between exactly between the columns. If the culm ends mid-span without properly being connected to the following culm, forces are not ideally transmitted. This results in, in case of a double beam, cracks in the lower beam. Because of the irregular lengths and the conical character of the bamboo used the beams and its connection with the columns seem untidy and unprofessional.

• Secure that a good load transfer from beam to column (B2)

GAP BETWEEN BEAMS

CONNECTION COLUMNS AND BEAMS

CRACK LOWER CULM



Connections between trusses, rafters and struts (3)

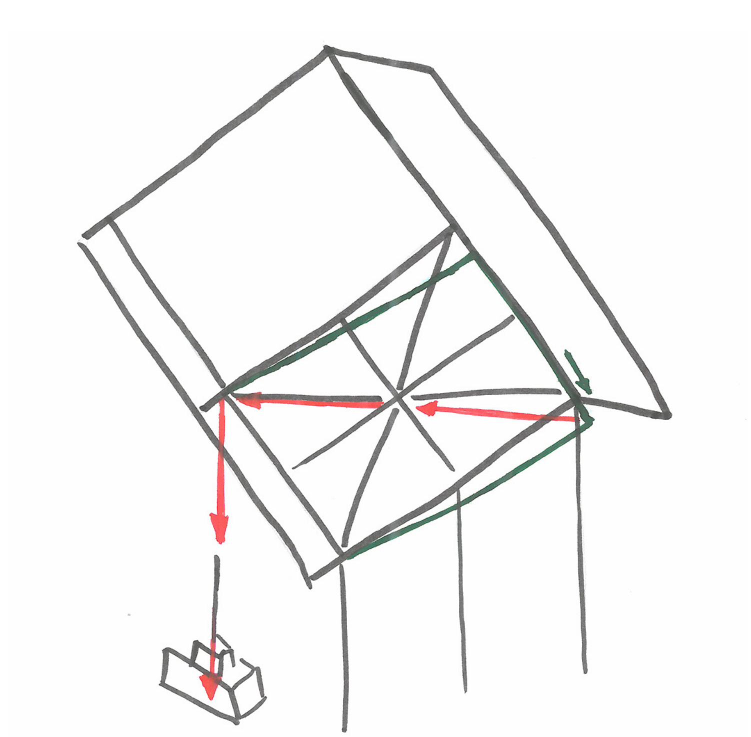
The connection between the rafters, trusses and struts supporting the roof on the windward side is remarkable because a lot of bamboo culms are connected. Seven pieces of bamboo are connected. The rafters support the trusses. Attached to them are the struts which entail stability in the roof plain. A strut must connect the two edges in a square (or quadrangular) to ensure pure force transfer and disables the plain to deform longitudinal.

The lower struts are connected with the rafter and the upper struts are connected with the lower struts. This does not secure the forces to be transferred purely towards the rafters and trusses. The team therefore questions the function of the struts applied. It's a risk whether this connection can resist the deformation caused by extreme wind load.

Over all this connection seems untidy. The question is whether bamboo is a good material to apply functioning struts, which are connected to the rafters which can transfer the forces towards the columns and foundation.

The material bamboo can resist high tension forces, only if the connection could transfer them correctly. With the bamboo this is challenge in both design and executional ways. The team therefore recommends looking for an alternative for bamboo struts.

- Look for an alternative (material and connection) for the struts (B3)



UNTIDY CONNECTION

Connections between rafters (4)
The rafters applied in transversely to resist deformation between the two roof plains on windward and leeward side are connected with the rafters with hemp rope and espiches. The choice made to use as much as local materials, is described in the principals of the foundation.
Between the two rafters a lot of movement seems to occur. The gap in the connection implies to leeward rafter to have slided down. The cracks in the windward rafters imply that rafters are colliding and the leeward rafters also move upward. The connection between the rafters must be a jointed connection, to transfer the load of each rafter directly to the columns without loading the other rafter.
The rope was applied tightly during the construction but after one year the rope seems to loosen up, not ensuring a tight connection between two different rafters.
The rafter on leeward is supported by the beam and beams and rafters connected to the columns.
Hemp rope is therefore not firm enough

and cannot ensure support. Because of the small rotations with a jointed connection, it is unsure whether rope is the right material. The small movements cause the rope to loosen up and lose grip. An ideal jointed connection would be one bolt connecting the two rafters enabling rotation and ensuring support.

• Design a jointed connection (using a bolt) enabling rotation and ensuring support (B4)

Connections between columns and overhang (5)

As said before, by removing a part of the surface, bamboo loses its strength, Juan Rafael explained. The connection used for connecting the column and overhang is a piece of wood inserted in both culms connected by one or two bolts. In the overhang one bolt is applied and in the column two bolts are applied. The piece of wood functions as a connecting part but also as a gag in the bamboo that secures the bolts from tearing out (fiber direction of bamboo).

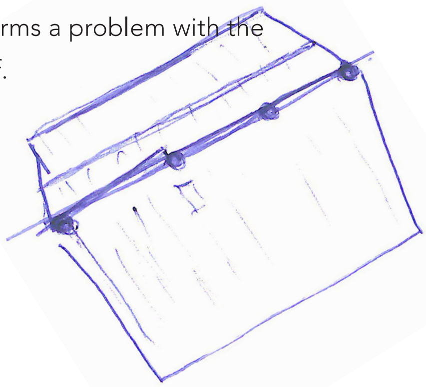
Because of the fact this connection took a lot of time to produce, it is recommended search for alternatives.

• Design a connection between a column and overhang (angular attachment) (B5)

A possibility is to attach two pieces of wood or steel on either side of the overhang and column. It is ideal for this connector piece to overlap a knot, to lower the risk of tearing out.

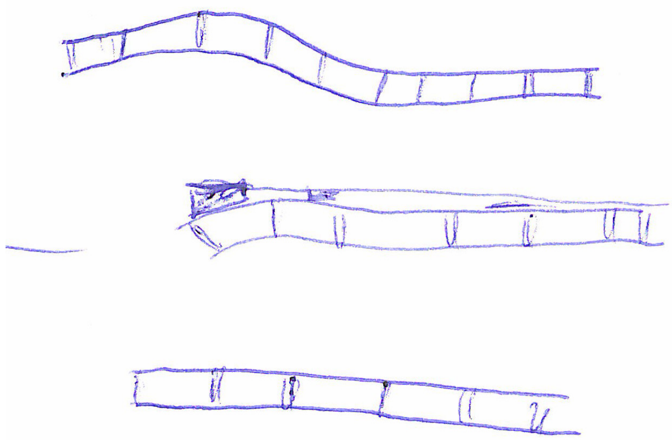
Bamboo curves

In general, the beams and are curved. Because of the fact that there were no measurements taken after the construction, it is difficult to conclude whether this curvature is due to the initial state of the bamboo, the delayed cure (drying) process or by the actual load.
This also occurs with the struts applied underneath the roof. These are bent a lot, but it is unlikely that this has something to do with the load, because of the dysfunctional connection.
The bamboo used, Gigantochloa, is a type that is known to be curved.
However, not only with this bamboo but with building with bamboo in general, a very strict selection procedure must be maintained, according to Theodoro. This could be done by setting a maximum of deflection over a standard of 3 meters bamboo.
This does not only cause a problem with the beams and trusses but also with the columns. The Asper seems to be straight but by using pieces over 5 meter results in great deflections. Theodoro explained that this caused problems with the roof. The top of the columns are not aligned straight, therefore the ridge of the roof is not a straight line. This forms a problem with the covering of the roof.



With bamboo it is unavoidable to work with curved pieces. When aligning the columns what support the ridge, the deflection must be in line with the ridge. In this way you can manipulate the curves and still use the bamboo properly. The columns must therefore be positioned correctly and the orientation checked with the other columns.

- Strict selection procedure of the culms used in construction
- Orientation and positioning of curved bamboo on site.



Beam strength

Aside from the connections, some remarks have to be made about the beams. As designed the beams must have be able to support the first and second floor. While executing it seemed that the beams did not have the proper strength and curved too much to apply a straight floor on them. The beams are reinforced by wooden beams, which are applied more frequently. Theodoro advised to use beams consisting of three culms instead of two. When using the same method in the construction, the support of the beams consisting of only bamboo has to be tested thoroughly. He states that Bambú Social must experiment with flection tests.

Until now Bambú Social is unable to conclude that the beams supporting a floor can exist just of bamboo. Using wooden beams are until now the best option.

- Test the strength of beams for floor support

General executional errors

By connecting one culm with another, most have to be cropped in the right size. This is often in an angular cut.

As Theodoro explained, the cut is ideal to be on a knot, as the bamboo fibers are orientated differently. By connecting the culms with a bolt it has a lower chance of tearing.

The bolts applied with the angular overhang connection, cause on one side (large) cracks. This is not caused by any load but by incorrect use of tools. The cracks seem the be splintered instead of split. When applying too much force while boring, the material can be damaged. This occurs at a lot connections. The team recommends a basic course about the tools and use to endure lifetime and less executional errors.

- Practical bamboo course
- Practical tool course (boring)

STABILITY (C)

The framework of the model house is made out of bamboo. The structure used can be compared by a steel framework; the structure provides the building of stability. This is often secured by a strut connection in both x and y direction. The same method is used for the model house.

During the construction the stability of the house soon seem to become a problem. When the main structure was finished, the constructors experienced movement of the connected elements. Even when the struts were applied the house could move. The constructors decided to solve this with rigid walls that provide a secure connection between the columns and beam.

They stated that the Gigantochloa used for the struts was too thin. Two types of struts were used: whole pieces of bamboo and two split halves of bamboo glued to each other. Another problem with the struts that was stated: no entire struts were used. Only one diagonal was applied, attached to this half a strut. This design obstructs the transfer of shear stresses.

The connection between the columns and the struts is comparable to the one described between the columns and overhang (5), only the strut has a smaller diameter and the gag inserted into the column is not secured with bolt.

Initially, when applying a strut, no forces occur in the strut. Only when the building tends to deform, tension forces occur in the struts, avoiding the building to deform. Therefore the connection between the struts and the must resist lots of tension load. The connection used does not. Because no bolt

is applied, the gag could lose grip and slip out of the column.
Because of the fibers of the bamboo, the material can resist a lot of tension forces. In this case bamboo would be an ideal material to use as a strut. Therefore the connection should be as strong as the material. When connecting bamboo, it is almost unavoidable to perforate the bamboo, losing its strength in longitudinal direction.
The conclusion that the bamboo used was too thin is therefore not entirely correct. The struts were not applied correctly. It is therefore difficult to say whether the bamboo was too thin and to determine what the thickness the bamboo should have been. The team recommends using steel cables as struts. The correct tension can be applied during and after constructing. The cable can be easily connected with eye bolts.

• Design and test an alternative strut connection (possibly with steel cables) (C1)

Another benefit of steel cables is smaller volume. The cables could be applied at the same level/depth, without bothering the crossing. This avoids the design complicated connections and executional errors included. A great example is explained in the previous chapter with connection (B3). Two individual steel cables can transfer the load directly towards the columns.
The rigid walls consist of wooden battens (45 degrees), covered with esterillas (bamboo mats), chicken wire, a rough coat of cement mortar, a fine layer of cement mortar, stucco and finally latex paint. Constructing a wall with these components, takes a lot of effort. During the construction last year an alternative was chosen, Plycem panels replaced the two layers of mortar.
By using an improved strut connection of steel cables, these can be inserted into the wall, which saves (more) time during the construction. By using only one cross of cable instead of a plain of battens leaves more space to create windows in the walls. Over all, the stability within the bamboo structure still has to test thoroughly. If one plain in both x and y direction are strutted well, the other walls don't need to be strutted. In the end this could save on (ecological) costs, by using steel cables only once correctly instead of wooden battens in multiple walls.

ROOF (D)

In Nicaragua the people are mostly used to build with corrugated zinc sheets. Similar sheets are used, but an alternative, durable material. The team analyzed different aspects of the roof. The remarks are mostly executional tips and tricks.

Corrosion

The roof is made of steel which is first galvanized and later aluminized. This forms a durable roof protected from corrosion. The sheets are ordered from Ferromax and a can be delivered in the desired dimensions (with a maximum of 12 meters).
During the construction the sheets have been cropped to fit them correctly. While cutting the edge isn't provided with a protection layer for corrosion. Constructor must prevent cutting the sheets. If this is unavoidable, the edges must be treated with an anti-corrosive layer. If that is not available the sheets must be applied upwards, this way the cut side can be hidden underneath the ridge, and not at the bottom where the contact with water is maximum.

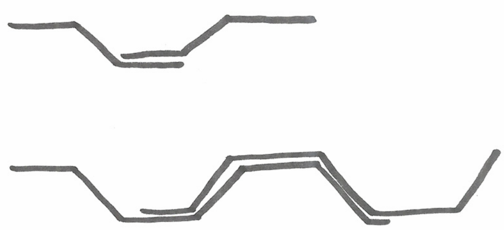
• Keep the anti-corrosive layer in mind when applying the roof sheets.

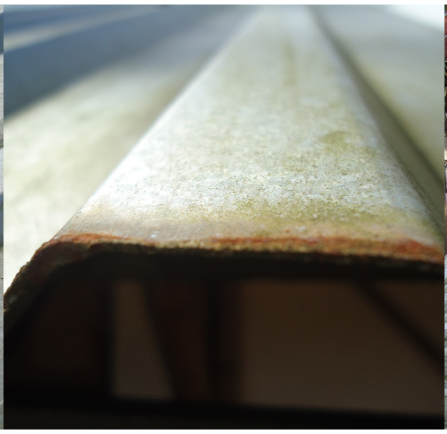
Around some bolts corrosion occurs as well. This is caused by the same reason describes above. The open spot (where the sheet is perforated) must be covered properly, to protect it from contact with water.
At leeward banana leaves cover the roof causing dirt. It is difficult to remove this dirt which attracts moist and obstructs water to flow away properly. Although the sheets have an anti-corrosive layer, the dirt make the sheets less durable and they will decay faster, Theodoro stated. The banana trees could be planted next to the house, but the leaves must not touch the roof, and therefore must be maintained.

Leakage

The roof sheets are overlapped to be connected. The manufacturer of the steel sheets claimed by connecting only the bottom parts of the wave is sufficient to avoid leakage. This saves a lot of material. After constructing some leakages did appear.
This is resolved by applying duct tape, which is of course a temporary solution, as duct tape putrefies when exposed to external conditions.
The sheets must overlapped by a greater surface to minimize gaps between the connected sheets.

• Connect the sheets with at least one "wave of steel"





Around the bolts some leakage occurred as well. The gap was filled with silicone, which is also a temporary solution, as silicone putrefies when exposing to the sun.
Most of the gaps around the bolts are caused by the fact that the hole in the sheet didn't fit precisely with the wooden outriggers.

The bolt is not applied perpendicularly to the sheet surface and an open spot appears. During constructing the bolts must be applied directly onto the outrigger and perpendicularly to the surface of the sheets.

Construction

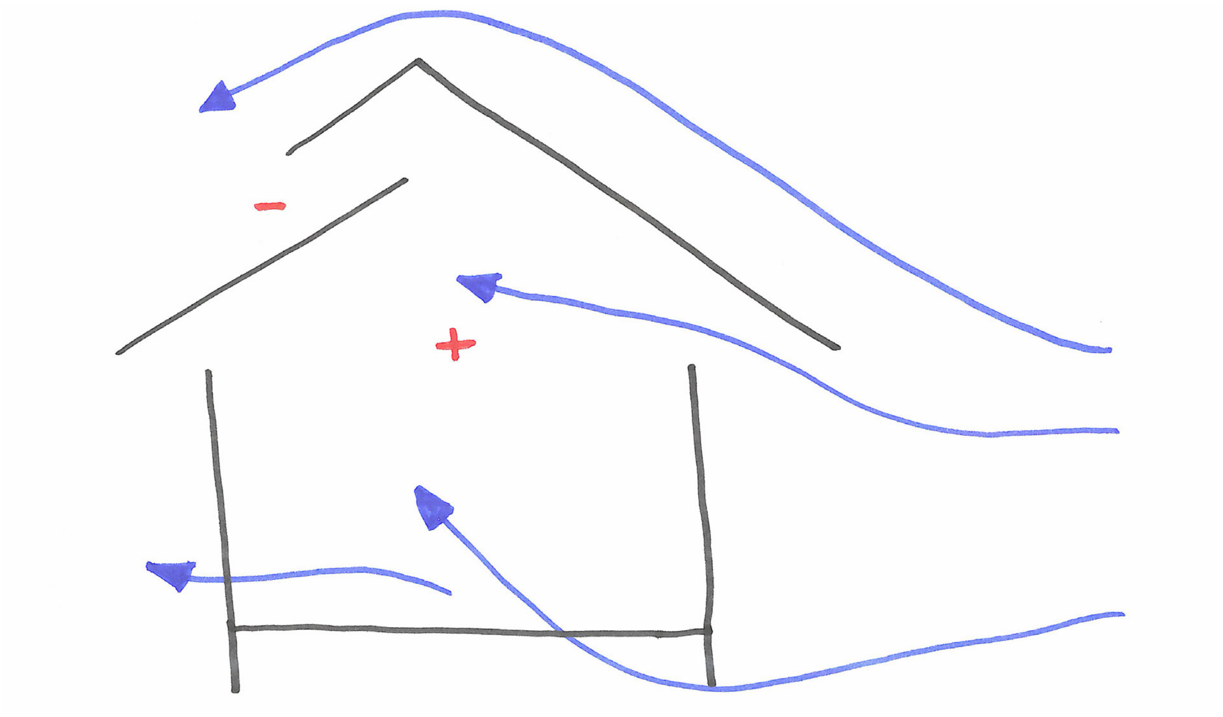
As mentioned in the previous chapter, the ridge is not one straight line, due to the deflection of bamboo columns. Also with the trusses of bamboo which are also not entirely straight it is difficult apply the roof sheets. The sheets are not connected directly to the bamboo, but to wooden outriggers. This is necessary to obtain a leveled plain.
At windward, the roof is bent around the height of the second floor. The team states possible causes. The bamboo used for the rafters was initially bended and the sheets are applied bended as well. The double culm rafters aren't sufficiently supportive for the load of the roof. The connection between the rafters at windward and leeward is not sufficiently supportive.
The team concludes that the sagging of the roof is caused by connection (4); because it only appears around the dysfunctional connection. In the previous chapter it has been stated that this connection is unsupportive.
To prevent sagging of the roof, the plain must be leveled. This means that the structure underneath must be sufficiently supportive.

- Improve the connection between rafters (B4)

RIDGE NOT ON A STRAIGHT LINE
FRONT SIDE

BACK SIDE

ATMOSPHERE (E)



Light, ventilation and openness

The design was initially made to obtain the most optimal ventilation flow. That characterizes the house as a bright and cool house. By a lack of official measure tools, the team had to base their findings and conclusions on impression and opinions of the members and people interviewed. The first impression of the team is therefore a pleasant atmosphere.

The light in the house is alright. Windows and doors have to be opened to get natural light. In areas with closed wall and no windows, you notice the absence of light. The library staff sometimes turns the light on during the day.

The house has a lot of open components. The walls at leeward on the first floor are diagonally applied bamboo culms. The front door has to the appearance.

On the second floor, the walls are made of wooden battens, the same used for the reinforcement of the closed walls. Between the roof and second floor, there's a gap of approximately 35 cm. This is not only done for the optimal ventilation flow and for the natural light, but also because of practical reasons, like cleaning Theodore explained. At the other hand, the open atmosphere has some down sides as well. There's a lack of privacy. The house built is not surrounded by other houses. But when this model is applied in neighborhood, privacy has to be taken into account. The architects must prevent that the inside of the house is too visible. There must be an obvious separation between public and private space in the house. Theodoro explained that the veranda provides contact with the street and

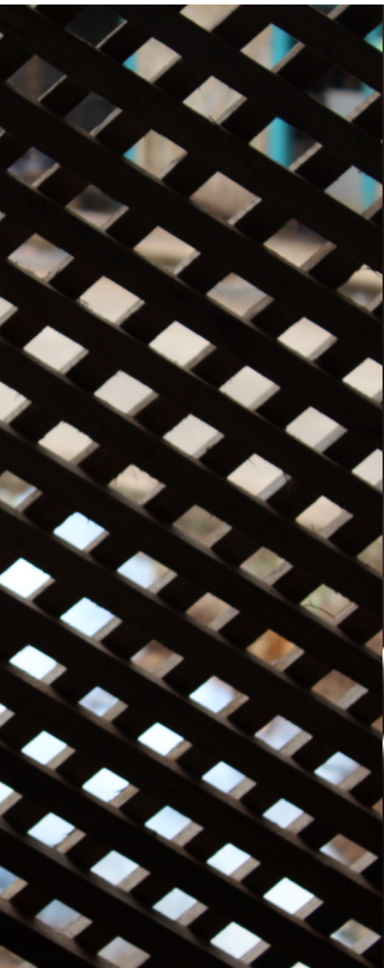
neighbors, but the living room mustn't.
The open characteristic of the house brings a lot of dust along with it. It mustn't be that the appearance of the house is like a garden shed compared to the original houses in Nicaragua. This open character could be more suitable for rural areas, but less for (semi-)civilized areas.
It is difficult to conclude whether to good ventilation is because of the air flow from beneath the floor and in the gaps between the walls and roof, or because of the open walls.
For privacy reason the team advises to provide more closed components of the house. This could be done by applying more windows that are closable (in the night no outer light is available), and by applying railing or grids between the roof and walls. In this way the occurrence of ventilation and natural light is not obstructed.

• Provide sufficient privacy without obstructing natural ventilation and light

To ensure maximum light through the window, the window hatch must be opened completely. Therefore windows must not be designed next to an overhang which obstructs the hatch from being opened completely.

• Provide enough space between the windows and the overhang

Another remark regarding the light: the bamboo lamps inside the house do not provide enough light. The management of the house installed some fluorescent tubes (TL-tube).



Temperature

The steel roof sheets absorb a lot of heat. As Octavio explained, the second floor is too close to the roof. When there's no wind, you can feel the warmth from the roof. There must be more space between the living space and the roof.

• Provide enough space between the roof and the living space.

Humidity

In a country with a sub-tropic nature, humidity avoidance is very important.
The initial function of the model house was to use it as a (public) library for BICU students. At the first floor scientific books were stalled. After one year BICU decided to remove the books and move the library up on the mountain with the rest of the university. The main reason for this is the humid area.
The books were rotting due to the moist climate inside of the house.
A moist atmosphere is not the first impression when entering the house. The architects tried to avoid this by an elevated construction.
What is quite noticeable is the moist air in the kitchen and washroom. This has mainly to do with the concrete floor and walls. Concrete attracts water from the soil. Also an executional error occurred; the height between the floor and the soil outside is too small. Water could easily enter the house during intensive rainfall, because the floor inside is too close to the ground level.

It is not recommended to construct the house directly onto the ground. Humidity in the Nicaraguan climate stays a challenge in the bamboo construction.

ELECTRICITY (F)

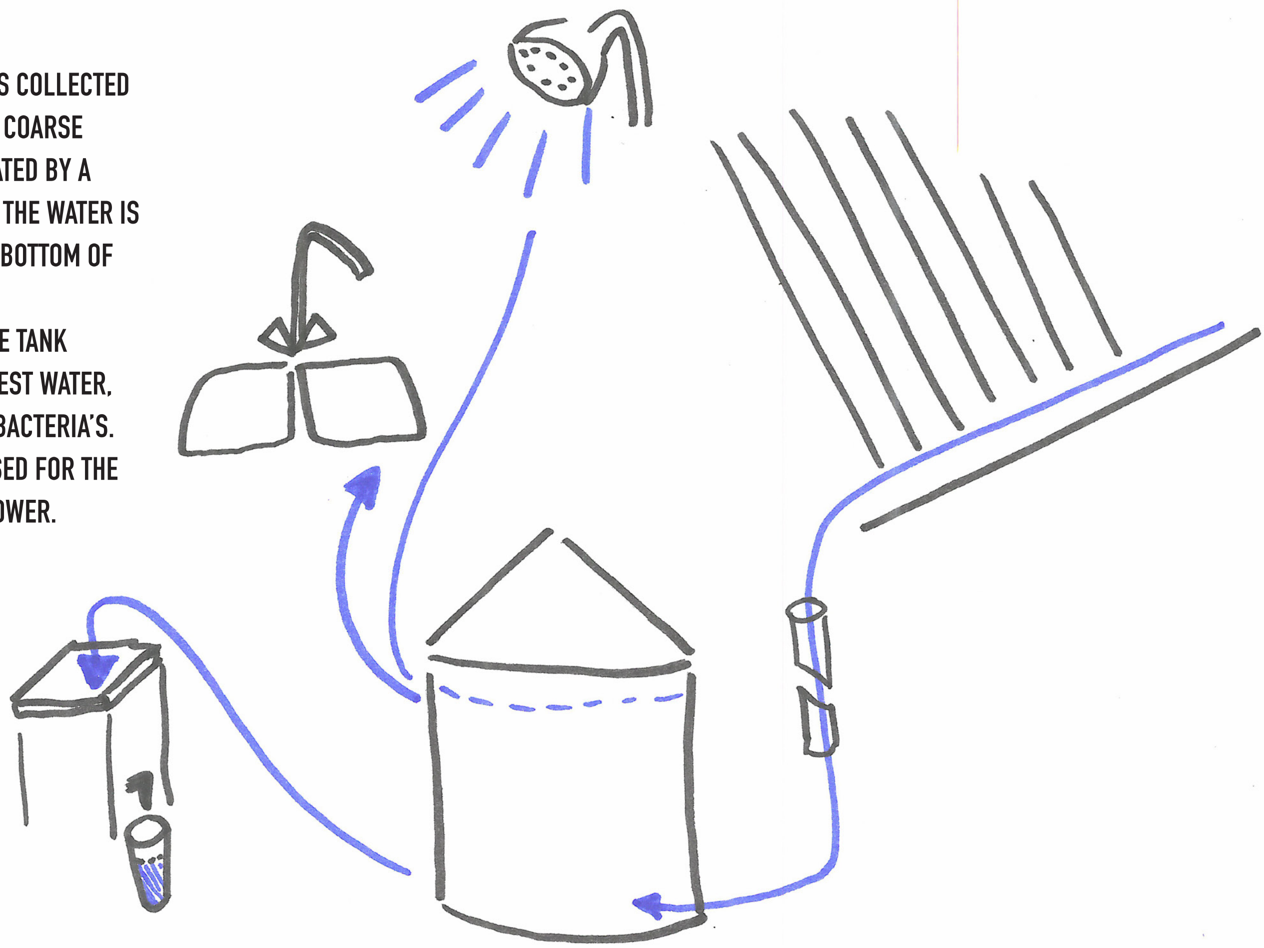
The team checked all the switches. The electricity system seems to work perfectly.
An executional remark: during the construction three different persons were responsible for the electricity system. Some knowledge seemed to lack. This wasn't efficient. During construction, make sure that one person with enough knowledge is responsible to prevent inefficiency and sloppy mistakes.
Make sure that the fuse box is in the driest area as possible. It is now constructed in the kitchen, which is less safe and durable.

• Design the fuse box in the driest area as possible.

WATER SYSTEM (G)

A decentralized water collection and purification system has been developed during the construction of the model house. The water system analysis also includes the washroom with its sanitary facility (toilet). The water seemed very clear, had no smell and had no taste. Visitors of the house drink this water, as people are used to drink rain water in Nicaragua.
blueEnergy developed a filter of bio sand which is placed inside of the house.
The filter has not been used since. This has to do with the fact that it takes a month for the water to come out. The house is not being used intensively, therefore it takes more effort to wait and maintain the filter than to drink the pre filtered water with sufficient quality, states Octavio.
The used water (and urine from the toilet) is drained into soil filter Bananeras. This consists of a basin filled with stones and tires. Banana trees are planted above the filter. The combination of the basin and the roots of the trees remove toxins and bacteria's. The banana trees were in a very good state and grew a lot during one year. Unfortunately the team could not conclude whether this grey water filter functions well and if this is the reason why the banana trees grow well, because the water system is not being used regularly and the toilet is not being used at all.
Regarding the tank: where the pipes enter, the tank is not completely sealed. small insects could enter through the gaps.

THE RAINWATER IS COLLECTED IN A GUTTER, THE COARSE WASTE IS SEPARATED BY A PRE-FILTER, AND THE WATER IS INSERTED AT THE BOTTOM OF THE TANK.
AT THE TOP OF THE TANK THERE'S THE OLDEST WATER, WITH THE LEAST BACTERIA'S. THIS WATER IS USED FOR THE KITCHEN AND SHOWER.



SANITARY AND DRY TOILET (H)

The architects build the house as independent as possible from centralized systems like water, electricity and sewer. This was the reason the architects choose to experiment with a dry composting toilet. The toilet has not been used after the construction.

The people from El Rama have a negative experience with dry toilets. The government installed dry toilet in almost all houses in Nicaragua. These were installed badly and the families removed those themselves.

In Haulover, Pearl Lagoon, this project did succeed and nowadays people use the toilets every day (Henky).

Whether to design the toilet inside or outside the house is a complicated discussion. In this chapter only the constructional aspects will be mentioned. In the social research this topic is mentioned as well.

Location

The toilet the model house is situated next to the kitchen in the same concrete cell. A door separates the toilet from the kitchen. The distance between the toilet and kitchen is too small, which creates the feeling that the toilet is inside of the kitchen. Nor in civilized countries nor in development countries it is accepted to construct the toilet directly next to the kitchen. The water used for cleaning the washroom can easily get in the kitchen. When removing toiletries and other disposals this happens through the kitchen. If the toilet is used incorrectly, bad odors will spread and will enter the kitchen directly.

- Do not locate the toilet next to the kitchen. Take into account the hygienic risks around the toilet

VIEW FROM THE KITCHEN

VIEW FROM THE TOILET

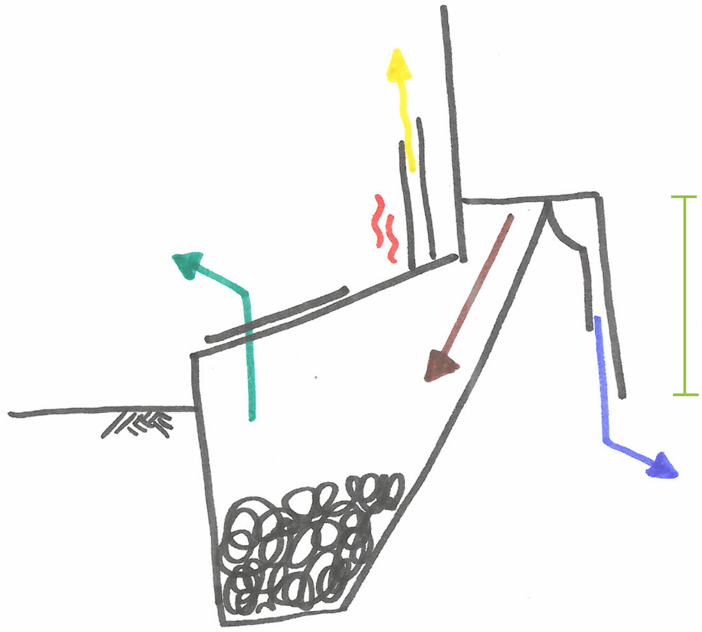
General design

The excrements are captured inside of the house. There's a division between the urine and faeces. The urine is drained into the so called grey water filter (Bananeras). The toilets exists of two separate basins. The first must be used six months. After six months the second one must be used and the faeces of the first one turns into compost. The toilet must be placed at a level high enough to secure a "safe" slope for the compost basin. No liquids must enter the basin, to promote the composter process.

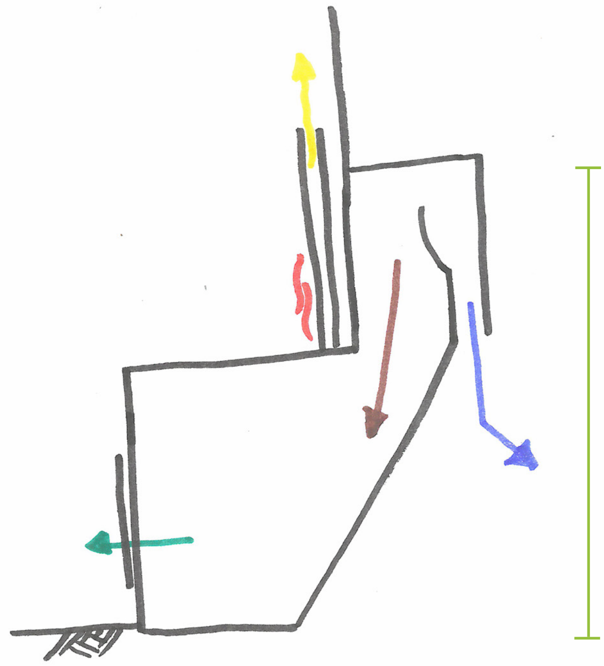
No faeces must remain lying on the slope to avoid stench (unpleasant odors) coming from the toilet. A tube connected to the basins is heated by the sun and generates an air flow that sucks air from within the basin, explained Theodoro.

Theodoro likes the idea of a dry toilet, but the one in the model house is not built correctly. The concrete separator between the urine and the faeces is constructed too close to the seat and it uncomfortable. There must be a proper distance between the seat and the separator.

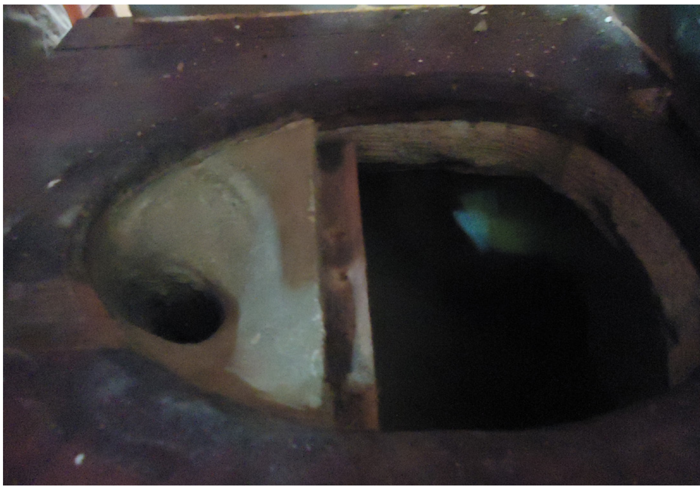
He also explained that it is difficult to collect to compost because the basin is below ground. He designed an alternative design. The toilet is constructed outside, as he preferred. It his constructed at a higher level to obtain a steeper slope and the compost can be collected just above the ground. The distance between the seat and the urine separator is also bigger.



CURRENT DESIGN



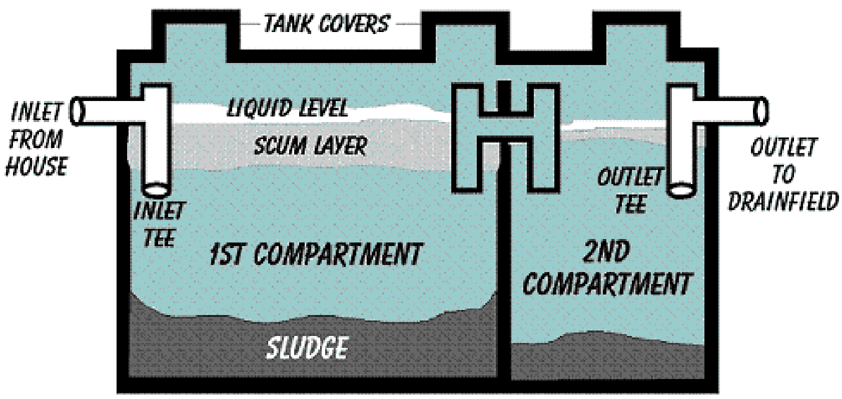
PROPOSED DESIGN



Detail design

The seat is designed as a wooden shelf with two holes in it. When using the toilet, there's a direct contact between the wood and the person. Wood as a material to sit on is not hygienic, and cannot be cleaned properly. When cleaning the shelf water will be used, and with the current design the person cannot avoid water from entering the dry compost basin.

The team advises to install a normal toilet seat and replace the wood with tiled concrete. By pouring the concrete bench with a gradient, the toilet can be easily cleaned without disturbing the composting process.

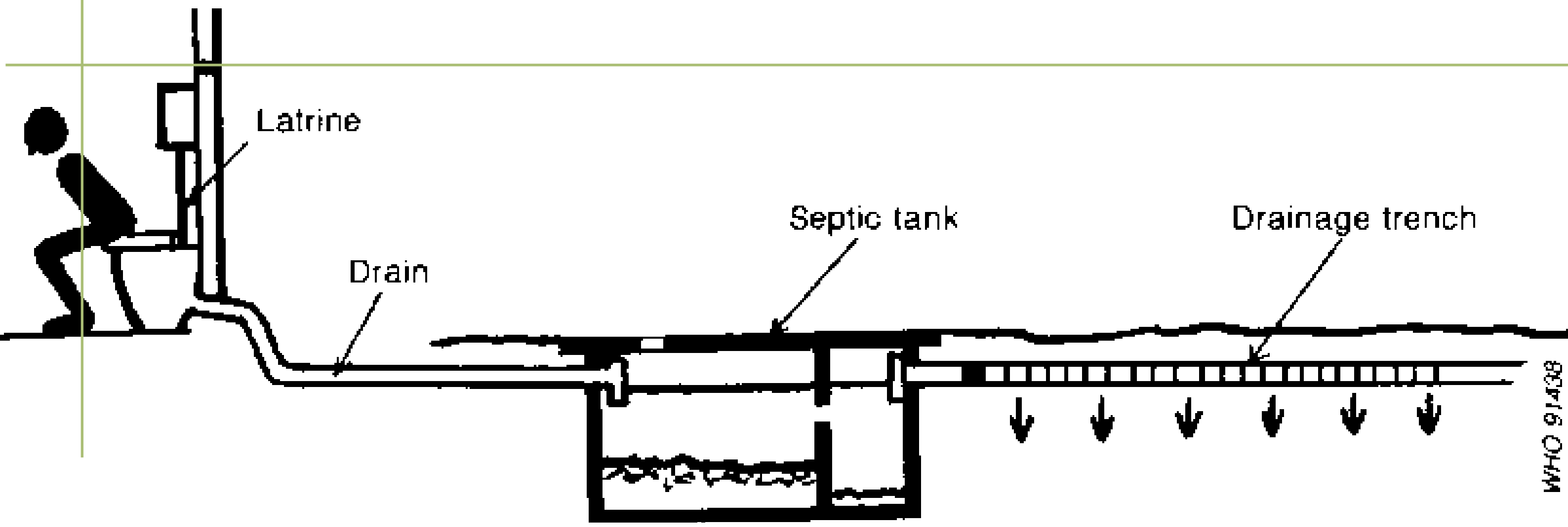


Septic tank

Looking for alternative sanitary systems; latrine lavatories and septic tanks are the current standards of El Rama. With the latrines being the cheapest toilet, can be mostly found in rural areas and poorer families. A toilet connected to the septic tank is costs more and occurs mostly in urban areas.

A septic tank could also fit with the principal to use local resources and be independent of centralized systems.

Toiletries cannot be disposed into septic tanks and therefore have to be collected in a container and removed afterwards.



Dependent of the use and cleaning of the toilet is can be stated whether this type of toilet is hygienic enough to place inside of a house.
A septic tank toilet is a wet toilet. For flushing water is used. This creates a humid area. The team does not recommend constructing such wet toilet inside of the house. The effect of humidity on bamboo is described later on.

Inside or outside?
The team concludes that it's better to construct the dry compost toilet outside of the house.

	Dry toilet	**Wet toilet**
Inside	Makes house unhygienic	Makes house less unhygienic Attracts moist in the house
Outside	Design preference: obtain height Saves space in the house Hygienically saver house	Prevents moist in the house Hygienically safer house

Finishing details washroom

Investigating the whole washroom the team has some remarks on the finishing.
It is better to add tiles on the kitchen walls up to a certain height. The walls could therefore easily be cleaned. Also the use of wooden plinth is not recommended in a wet area like a kitchen.
The tiles will protect the underlaying material (stucco and concrete), which will contribute to the durability.
The same counts for the walls in the shower. Tiles do not only contribute to the hygiene of the washroom but also protect the walls. The wood and even bamboo in the shower must be completely covered.
In the wet area the use of bamboo (and wood) must be avoided. If the bamboo column starts to rot it will quickly lose its strength and safety.

BIO SYSTEMS (I)

Fungus

The bamboo used for the columns, Asper, is known to be less durable. In the model house this appears to be the case as well. The Asper is often encountered darker than it should be. This brownish color is a trace of fungus.

At one spot between the column and the second floor a very toxic white colored mold occurred. This has been removed immediately (Henky).

On the Gigantocloa used traces of fungus with a black color could also be found.

The bamboo used for the construction was not completely dry and the rain during the construction didn't promote the drying process. The fungus was therefore not killed completely. The humidity for fungus to grow is around 40 to 80 percent. Nicaragua's humidity is 84% during the rainy season and 62% during the dry season.

At the second floor almost nothing to any fungus was encountered. At the second floor there's a better ventilation flow which prevents fungus growth.

It is really important to keep the bamboo as dry as possible. Even this cannot avoid fungus to appear. It is therefore very important to treat the bamboo as soon as possible, to avoid decay.

TRACES OF FUNGUS ON THE COLUMN

Termites and woodworms

(foto henky in Recreo)

The most common type of termite is Comejen. These were not encountered during the last year. The bamboo is treated by a Borax solution which makes the ingredients unattractive to eat for the animals.

The most common type of woodworm is Polya. These were not encountered as well.

Insects, vermin and reptiles

No vermin has been and reptiles have been encountered. This does not mean they cannot enter the house, but that there's nothing interesting in the house, which depends on what the house is used for. Because of the open character, vermin and reptiles could easily enter into the house. Wasps have been a problem since the construction of the house. To avoid these animals an attempt has been made to fill up all hollow bamboo culms with pur. This does actually not avoid the animals to nest, because their nests could also be attached

to flat surfaces. It is important to maintain and remove the nests with dangerous types of wasps.
The pur used to fill up the holes appear not to be suitable for the Nicaraguan climate. The pur inserted in the bamboo shrank and begins to fall out of the bamboo culms.

BUILDING PROCESS ANALYSIS

Recovering the building process of the construction last year has been done by interviewing people involved. The team interviewed Henky Borgstein, Theodoro, Octavio and Juan-Rafael.
By analyzing the building process the team wanted to investigate whether the combination of cultures on the construction site resulted in remarkable developments.
It is interesting to investigate whether the management and foreman of the team, not-Nicaraguan, fit with the Nicaraguan construction style and what influence this had on the students and constructors.
The team was not able to collect all experience, but tried to interview as much as different people involved.

Henky Borgstein: Dutch carpenter living in El Rama
Octavio: archeological student
Theodoro: architecture student
Juan-Rafael: apprentice carpenter

After all, during constructing, an obvious difference in work style was not noticeable. Even the language barrier did not form the main obstruction on the construction site.

The chapter is mostly based on Henky's experience as his story is better substantiated and elaborated than the other interviews. In the appendix the full interviews are captured, they are included in this chapter as well. Every part concludes the problems and possible solutions.

The BICU University

One of the most important aspects of the Bambú Social project was sharing knowledge with the local people of El Rama. This was the main reason for the cooperation with the BICU University. Bambú Social organized the course 'Construction Sostenible Bambú' at the BICU in order to share the knowledge. This course was an opportunity for the local students and other interested people to help in the building process in exchange for study points. For Bambú Social this was a useful initiative because the involvement of the students in the process contributes to the continuation of the project. Eventually a total of 20 persons signed up for the course; however a lot of students did not complete the course.
Henky states that the main reason for this negative outcome was the motivation of the students. Most of them were not really dedicated to the project; instead they were more interested in the study points. However, there were some students who were a real contribution to the project, for instance Alfredo and Theodoro. For the next time it would be a good idea to also involve the teacher and keep them updated on the work of their students. More intense feedback to the BICU would force the students to be more active.
Another problem was the size of this group of students. Henky explained that there were too many students which made it difficult to really involve them in the project. Instead, a lot of students where hanging around and making jokes, which had a bad influence on the motivation of other students and the ambience at the building site.

It would be a good idea to involve a smaller group of student who can be more involved in the process.

The third problem was the background of the student. Because most were agriculture or archaeological students, they had no real knowledge that could contribute to the project. Instead they needed a lot of guidance and help. Therefore it would be more useful to involve students whose study is more in line with the project so they can have a bigger impact and be of more use. An appreciated student will be more motivated.

Beside the negative experiences with some of the student, Henky is very positive on the work and dedication of Theodoro and Alfredo. These students were more interested in the continuation of the project and they were a real contribution. There is still contact with these two students and they like to stay involved in the project. It is a very positive sign that some of the local student would like to stay involved in the project. Even during Bambú Social 2.0 we noticed that the project was still very a live under most of the students.

"I felt very motivated for this project, as it was my first experience in construction with a new material, bamboo"

Octavio explained that he really liked being involved in a new kind of project like this. He's very glad with the official certificate and conscious of its value. There might has missed a connection between the field of study, but Bambú Social did contributed to the education of these students and gave them a useful experience.

"By introducing bamboo as a construction material, Bambú Social contributed to the education and development of students"

Bambú Social should think about the reason involving the student. Was it because they wanted to provide knowledge and education or needed help on the construction site. The involvement must focus more on contributing to the development of the students involved and introducing bamboo as a construction material, than the added value of the students' knowledge to the project. Involving students may be seen as full time occupation and mustn't be underestimated.

Problems:

- A large group of students lacked the motivation
- The group of students was too big
- The study of the students did not match entirely with the work on the building site
- Lacked personal attention and feedback towards the students

Solutions:

- More intense feedback to the BICU on the progress of the students
- Smaller group of students so the more motivated students can be more involved
- Select students who's study is more in line with the work on site
- Put one person responsible for the communication and coaching the students

The Communication

Henky explains that during the project the communication was a bit chaotic. This was mostly due to the lack of a real foreman. At the start of the project both Max and Laurens functioned as foreman but this did not ease the communication. This had an effect on the building site, it was messy and there was a lack of coordination. Also when Laurens took the job as executive on him the coordination was still lacking some structure. According to Henky this had to do with the language barrier and Laurens personality. An executive should have a natural influence on people and should demand respect. It is clear that being an executive is a real job and not everybody is capable for it. This became clear when Arie van der Ziel came from the Netherlands to work as the new foreman. His lack of Spanish and ridged communication skills were not accepted by most of the employees. According to Henky, Arie was a bad influence on the motivation of the people and this caused some tensions. For the next time Henky recommends a Spanish speaking and motivating person to work a foreman. The second problem that caused communication problems on the building site was the lack of technical drawings. The people who were constructing the house did not have access to the basic drawings that explained how the house should be constructed. This caused delays and some frustrations. Henky explained that it would have saved a lot of trouble if there were some decent drawings at site. These drawings can be used as a communication tool for the foreman and between the builders.

Problems:

• No real foreman who organized the construction process
• Lack of communication between the employees and the designers
• No technical drawings available at the building site.

Solutions:

• Make one person responsible for the organisation and communication between the different parties (foreman) (fulltime job, good Spanish and communication skills)
• There should be technical drawings available at the construction site which corresponds with the work to do, which will improve the communication with the foreman and speed up the construction process

The design process

Like all the people involved in the project Henky agrees with the beauty of the design. The house looks fantastic and it is an advertisement for bamboo. However, unlike the esthetical part, the construction and technical design could have been prepared more properly. According to Henky, the design was more a concept than a complete thought through design. This caused some communication problems between the builders and the designers (Max). Certain details were not thought through and had to be designed on site. This takes a lot of time and causes delays in the building process. However, the bamboo framework prepared and designed very well and it could be constructed in no time. For the next time it would be good if the whole design was as well designed as the bamboo framework. Because the design was not complete when the construction started there were some complications. The concrete floor in the kitchen for instance, was poured without the tubes. For the next time it would be good to have a complete design that the builders can follow step for step.

The students had to draw their dream house and based on that the design was finished. During the design the students were able to contribute to the design. However some students did had some alternative ideas, but during the construction weren't able to share their ideas.

Problems:

• No complete design available

• Lack of communication between the employees and the designers

• No technical drawings available at the construction site

Solutions:

• One person responsible for the communication with the organisations on site (foreman)

The Meetings

Henky explained that the Bambú Social team came together every night for a meeting at the BICU. Some critical points on these meetings were that they were not organized or structured. Again it seems that there was not a real foreman who takes charge and leads the meeting. The positive side of the meetings was that every person was equal and everybody could bring up point to discuss. However, this equality had a bad influence on the structure of these meetings. The meetings were late in the evening, when everybody had been working for a whole day. Because everybody was tired some people did not join the meetings. Henky explained that he often skipped the meetings because he was too tired, since he already worked for a whole day. Instead of a meeting in the evening he proposes a meeting in the morning before work. When you meet in the morning you can discuss the work that has to been done that day while everybody is still energized. It would be good to meet in the morning anyway, because you can discuss the planning for the day so that everybody is on the same page. Henky explains that this was not always the case, some days it was unclear what had to be done.

Problems:

- The evening meetings were tiring and unorganized
- The evening meetings were not effective because everybody was tired from a whole day of work
- No morning meetings in which the planning of the day was discussed

Solutions:

- During every meeting there should be one person in charge who leads the discussions. This is creates a structure that is organized. It will also save time
- Organize a meeting in the morning in which the work for the day is discussed, so everyone is up to date about their tasks. If certain points come up during the day, which have to be discussed you can discuss them fast and quick directly after work (with one person, the foreman, in charge)

SOCIAL HOUSE

Based on the design of the model house and the lessons learned during construction and after construction, the architects of Bambú Social made a design for a social house. The team is not able to construct the house, but a scaled model of the social house was built. During the "construction" of this scaled model some errors occurred and just like on site the constructor invented solutions to solve these errors.
Some improvements suggested in the previous chapter are already been improved in the design of the social house and some not. These are not mentioned again.
The scaled model is constructed based on the manual.

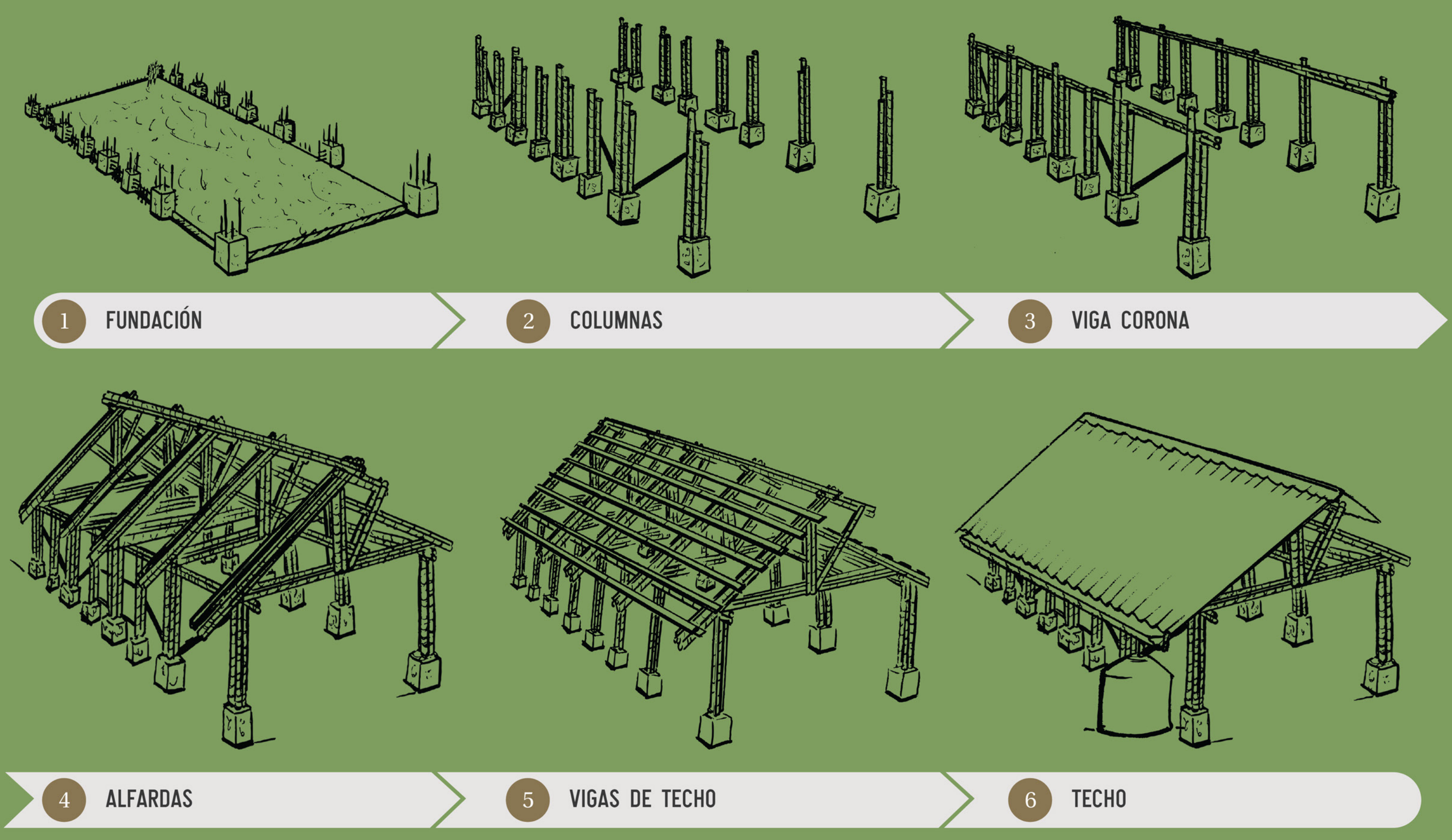
CONSTRUCTION MANUAL

In the manual all construction steps are described and explained with drawings. Some general remarks on the manual:

- The drawings are sometimes incorrect and unclear which makes the manual disordered
- A clear floor plan with measurements is missing
- Measurements (of the prefab elements) are missing or not clearly mentioned

This makes it difficult for a constructor to build according to the manual. Not an elaborated evaluation has been done as the manual is a draft and the design of the social house is not final yet.

ETAPAS DE CONSTRUCCION



PHYSICAL ANALYSIS

Outriggers

In the current design of the Social House a bamboo culm is used as a ridge. However, due to the irregularity of bamboo columns, we advise to make the ridge out of wood like the outrigger. The main advantage of using wood is the precision with which you can construct this ridge. Furthermore, it will be easier to place the zinc sheets on the wooden outriggers as it would be on the bamboo.

- Design the outriggers out of wood (J1)

Rafter connection

The rafter construction of the social house looks really solid and strong. It seems to be really thought through. However, the team doubts that the connection at the bottom corner at leeward of the rafter is supportive enough. This connection isn't loaded with a lot of force, but using only espiches, the strength and stability of the construction could not be ensured.

- Reinforce the rafter (J2)

Columns

The prefabrication possibility of the social house is a very important factor of the current design. It will save a lot of time when you have the possibility to construct the main parts of the construction in a workplace. Besides, it will also lower the chances of mistakes at the building site and it makes the constructer less dependent on the weather conditions.
However, the team believes that prefabricating bamboo elements can cause some problems. Constructing the prefab elements must be done very precise and well management. It could easily happen for some inadequate pieces not to fit within the construction.
Connecting the ridge and beams with the rafters onto the columns can cause such problems. The beam could differ in size and might bend. Therefore the prefabricated columns must be 50 – 100 mm longer as needed. On site the excess can be cut off. Untidy connections (using gags) are

therefore prevented. For the middle height column, it is imported to first place the beam before cutting the excess, because when placing the rafter it is important for the beam and the middle height column are at the same level.

Regarding the connections between the bamboo columns and the concrete the team made one adjustment. In the current design the bamboo columns are on individual wooden columns that separate the bamboo from the concrete. However, it would be better to use only one wooden plate on which you can place all three bamboo columns. This will make the construction less vulnerable for water and it will be easier to construct.

Connection between the foundation and column

In the current design the connections are made with a reinforcement rod poured within the concrete. The rod is bent around the bolt what comes out of the bamboo column. This connection is not fixed, but functions as a jointed connection, which will have major consequences for the stability of the house.

• Design a fixed connection between the foundation and column (J3)

Foundation

By analysing the foundation the team concluded to improve some aspects. The dimensions of the foundation and the

materials used do not correspond with the load it has to carry.

• Improve the foundation dimensions (J4)

CONSTRUCTIONAL IMPROVEMENTS

All improvement, tips and tricks are summed up in this chapter. All physical improvements are tagged by a code related to the topic mentioned in the previous chapters. The physical improvements regarding the model house and social house are put together.
In the next chapter the team designed alternative connections.

GENERAL IMPROVEMENTS

- Create a measurement protocol
- Ensure the protocol performance

CONSTRUCTION MANUAL IMPROVEMENTS

- The drawings are sometimes unclear which makes the manual disordered
- A clear floor plan with measurements is missing
- Measurements (of the prefab elements) are missing or not clearly mentioned

BUILDING PROCESS IMPROVEMENTS

- More intense feedback to the BICU on the progress of the students
- Smaller group of students so the more motivated students can be more involved
- Select students who's study is more in line with the work on site
- Put one person responsible for the communication and coaching the students
- Make one person responsible for the organisation and communication between the different parties (foreman) (fulltime job, good Spanish and communication skills)
- There should be technical drawings available at the construction site which corresponds with the work to do, which will improve the communication with the foreman and speed up the construction process
- During every meeting there should be one person in charge who leads the discussions. This is creates a structure that is organized. It will also save time.
- Organize a meeting in the morning in which the work for the day is discussed, so everyone is up to date about their tasks. If certain points come up during the day, which have to be discussed you can discuss them fast and quick directly after work (with one person, the foreman, in charge)

PHYSICAL IMPROVEMENTS

Connection improvements

- Design a new foundation which connections resist better tension forces (A1)
- Ensure that the load is passed on correctly on each column (A2)
- Apply bolts between every two espiche connection to ensure the separate beams to function as one beam (B1)
- Secure that a good load transfer from beam to column (B2)
- Look for an alternative (material and connection) for the struts (B3)
- Design a jointed connection (using a bolt) enabling rotation and ensuring support (B4)
- Design a connection between a column and overhang (angular attachment) (B5)
- Design and test an alternative strut connection (possibly with steel cables) (C1)
- Design the outriggers out of wood (J1)
- Reinforce the rafter (J2)
- Design a fixed connection between the foundation and column (J3)
- Improve the foundation dimensions (J4)

Practical and building improvements

- Strict selection procedure of the culms used in construction
- Orientation and positioning of curved bamboo on site
- Test the strength of beams for floor support
- Practical bamboo course
- Practical tool course (boring)
- Keep the anti-corrosive layer in mind when applying the roof sheets.
- Connect the sheets with at least one "wave of steel"

Design improvements

- Provide sufficient privacy without obstructing natural ventilation and light
- Provide enough space between the windows and the overhang
- Provide enough space between the roof and the living space
- Design the fuse box in the driest area as possible
- Do not locate the toilet next to the kitchen, take into account the hygienic risks around the toilet

PHYSICAL IMPROVEMENT SUGGESTIONS

During the investigations, the team began designing some new connections as an alternative for the existing and current ones. These connections are not tested yet, but will be soon during the experimental phase of the project. The connections are therefore not final and might be improved by together with local craftsmen.

FOUNDATION (J4)

Section A

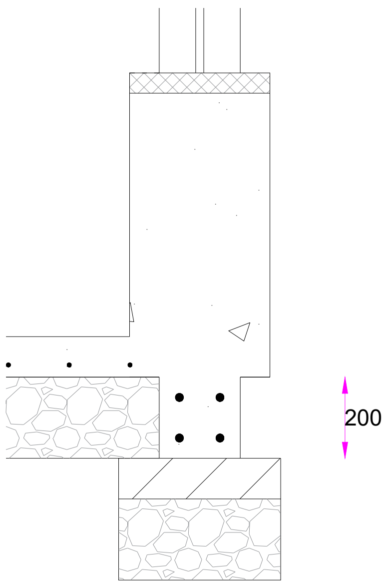
The concrete columns of 346 x 346 mm that support the three bamboo columns have not been changed, but the concrete beam has.
Beam: 200 x 200 mm with woven reinforcement bars with a diameter of 10 mm. The reinforcement mesh should be 100 x 100 mm.
The beam widens to a width of 346 mm at the point where it meets the concrete columns. The reinforcement bars of the beam and the columns should be woven together. The steel mesh in the floor should also be woven to the reinforcement bar in the beam and the column of the foundation.

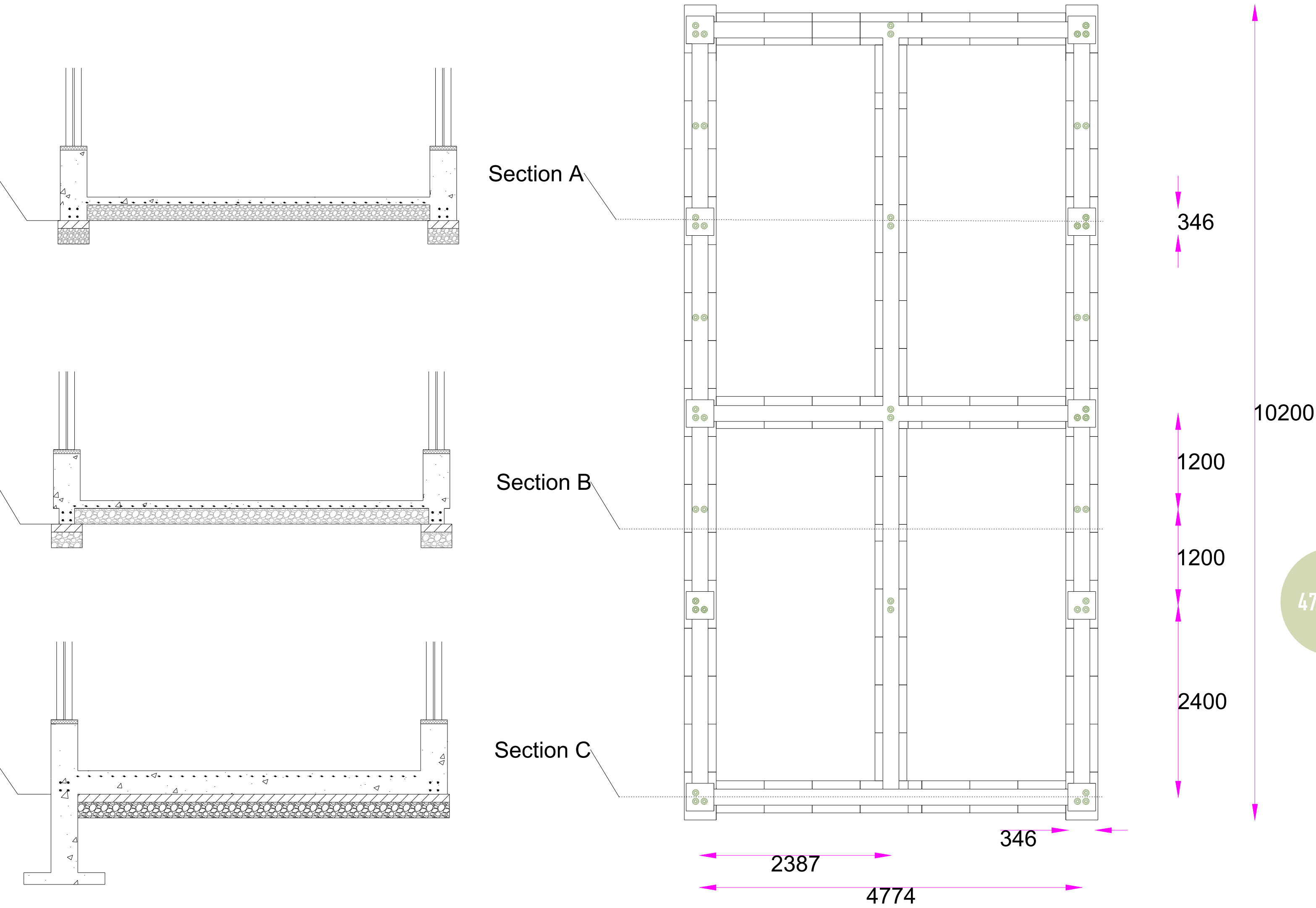
Section B

Under the beam the team advises to place two layers of stabilisation. The lowest layer is gravel of 200 mm high and the second layer is a row of sandstone tiles of 100 x 400 x 600 mm.
Because of the wet climate in Nicaragua it is recommended to elevate the concrete floor. To make constructing easy layers of gravel and sandstone tiles can be places under the ground while the beam is above ground level. This means that there is 200 mm of space in between the concrete floor and the ground. It would be wise to fill this space with gravel and a top layer of sand. This double layer underneath the floor does not only create a stable underground to construct on but it also separates the concrete from the dirt. This makes the construction less vulnerable for floods or heavy rainfall.

Section C

Another nature factor we have taken into account is the wind. The current design of the social house has a very large roof surface that can catch a lot of wind. The forces created by the wind create a momentum that wants to lift the house at the wind side while pushing the other side of the house. To prevent this from happening we designed a foot at the end of the three main columns at the wind side of the house. These feet will absorb most of the tension forces that are caused by the wind.




Section A
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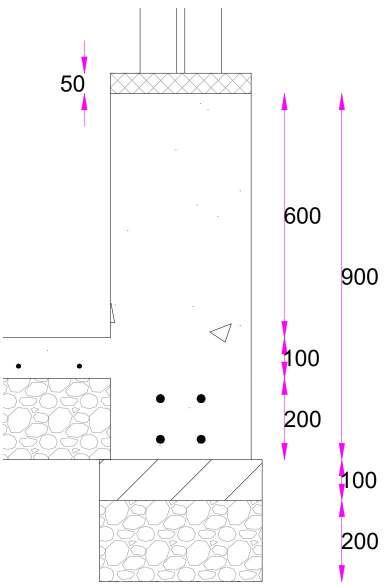
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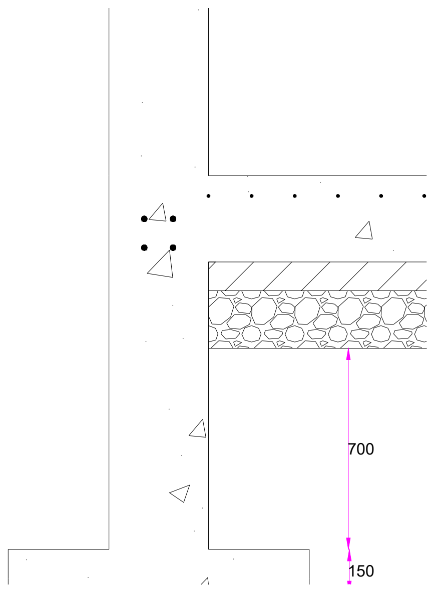

700
150

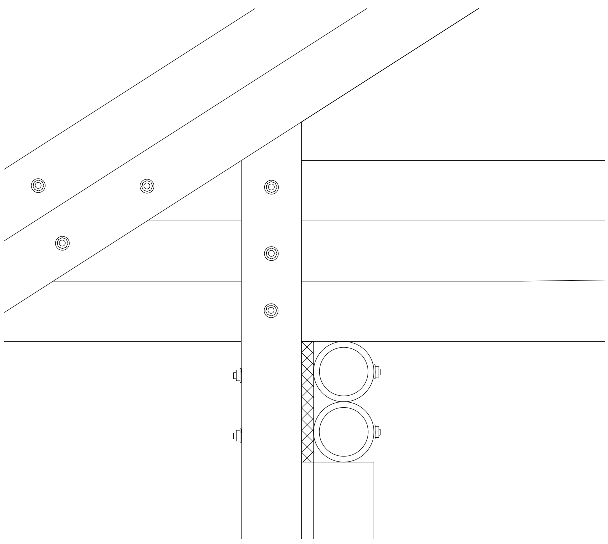
PANEL FOUNDATION (A1, J3)

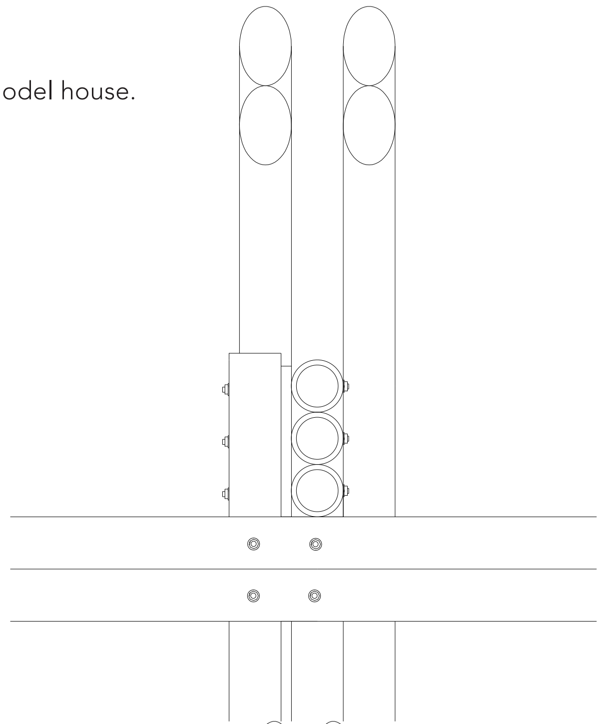
An alternative is to pour a gusset (edged piece of panel) within the concrete. This way a fixed connection is created and the lateral load of the house is transferred to the concrete foundation.

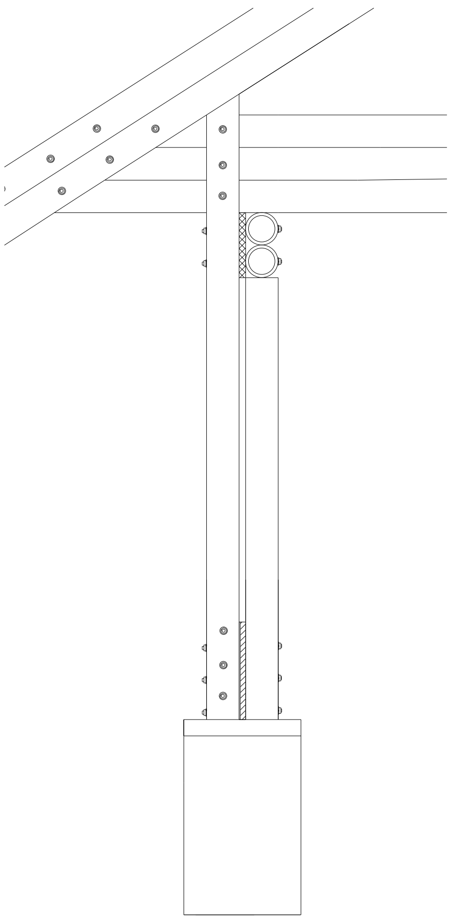
The bamboo columns are, of course, connected to the gusset.

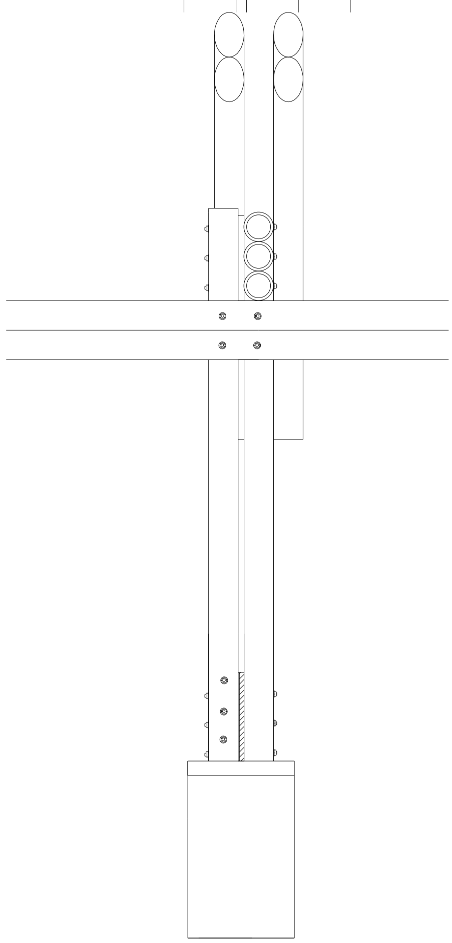
CONNECTION BETWEEN COLUMN AND BEAM (B2)

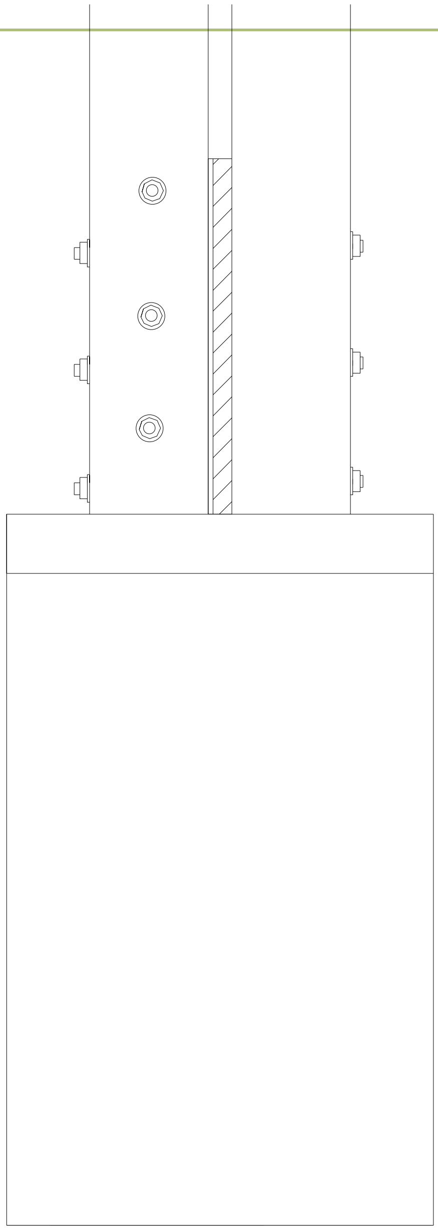
This connection is already improved in the design of the model house.

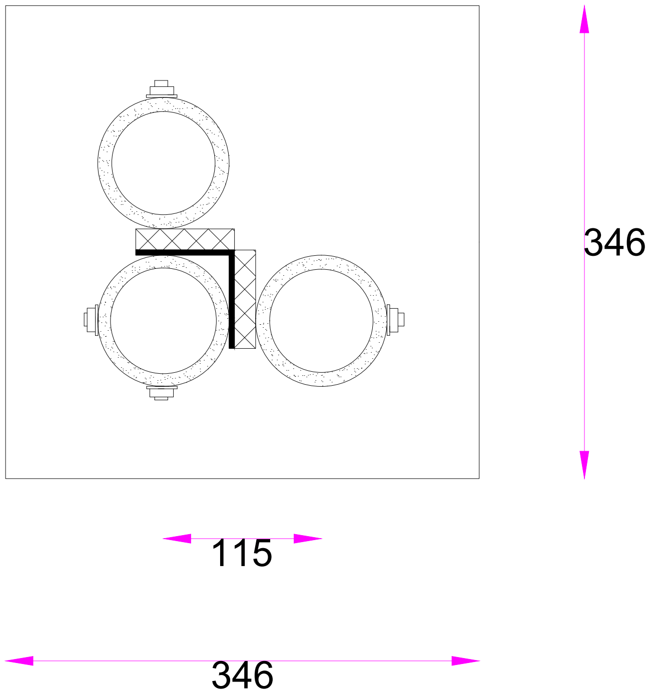








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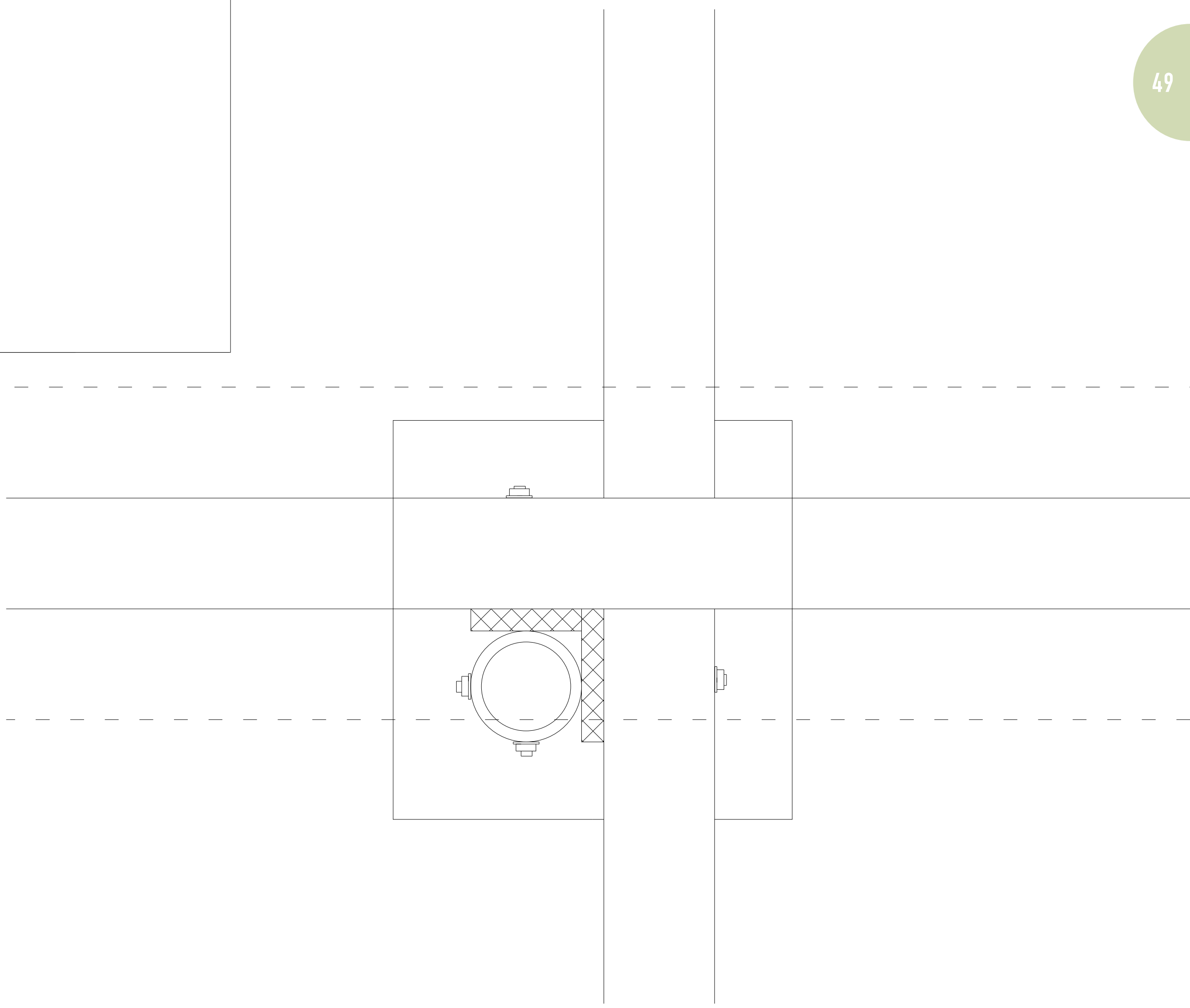
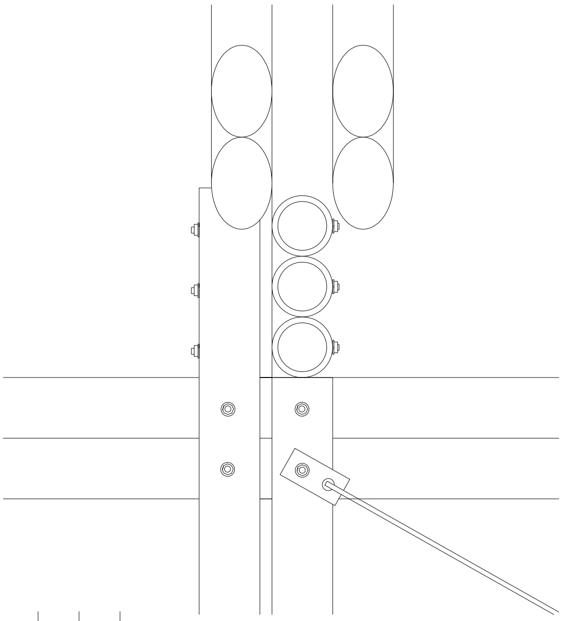
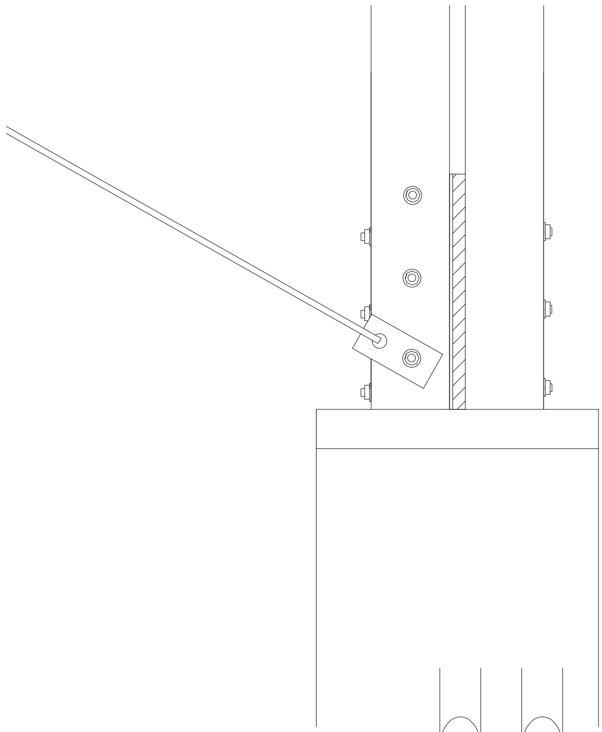
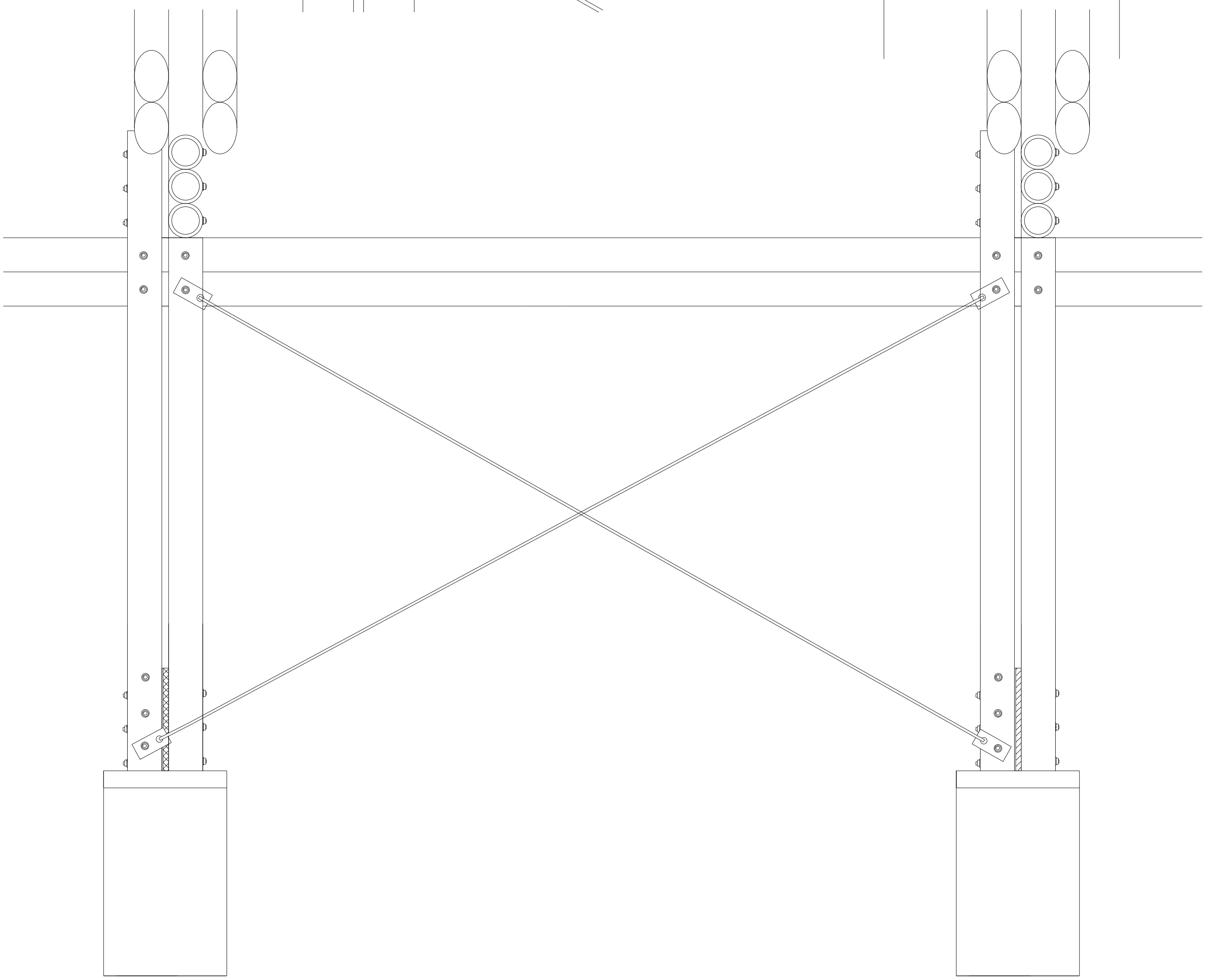


STRUT CONNECTION (B3, C1)







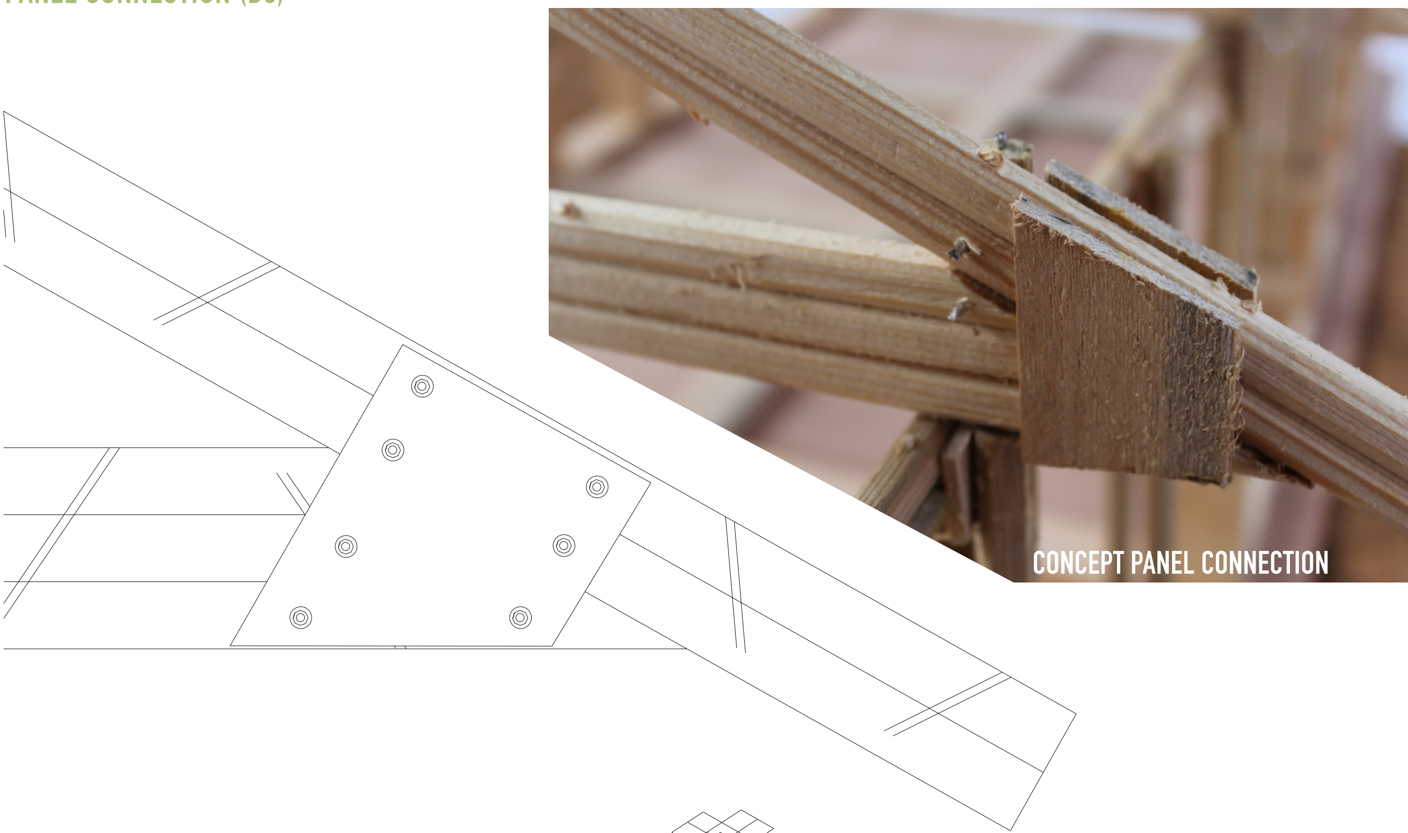
RAFTER CONNECTION - JOINTED (B4)

This connection is already improved in the design of the model house (rafters connected with a bolt).

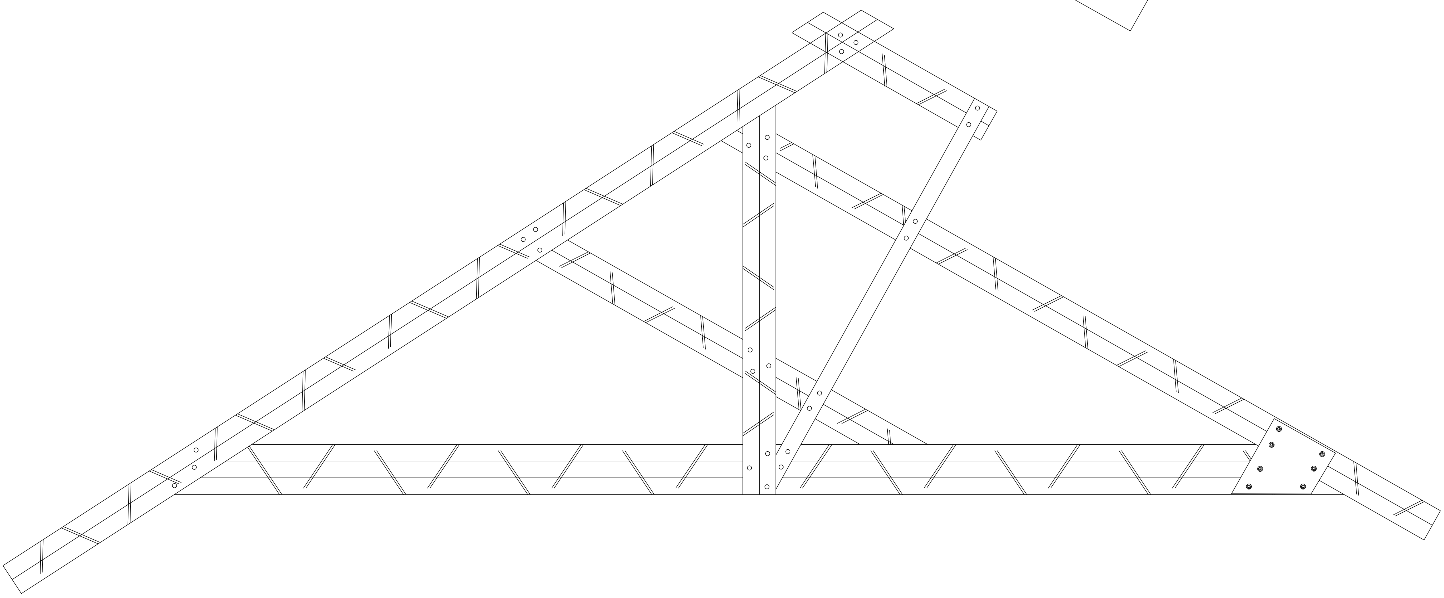
RAFTER CONNECTION - FIXED (J2)

By strengthening this corner with a wooden panel and some bolts, a fixed connection will be created. The panel must be applied perpendicular to the rafter as maximum tension load could be transfer by the panels.

PANEL CONNECTION (B5)

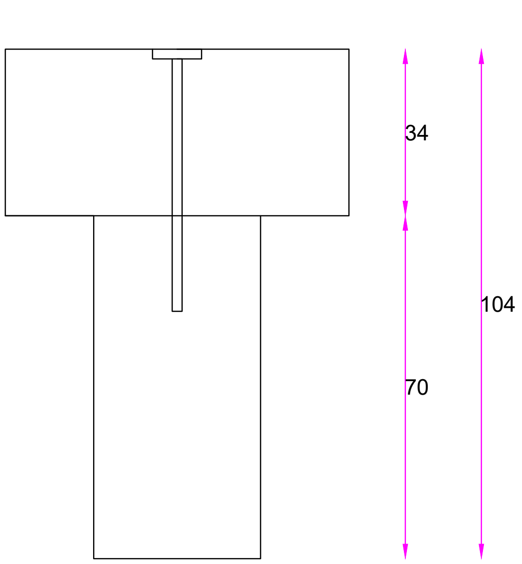


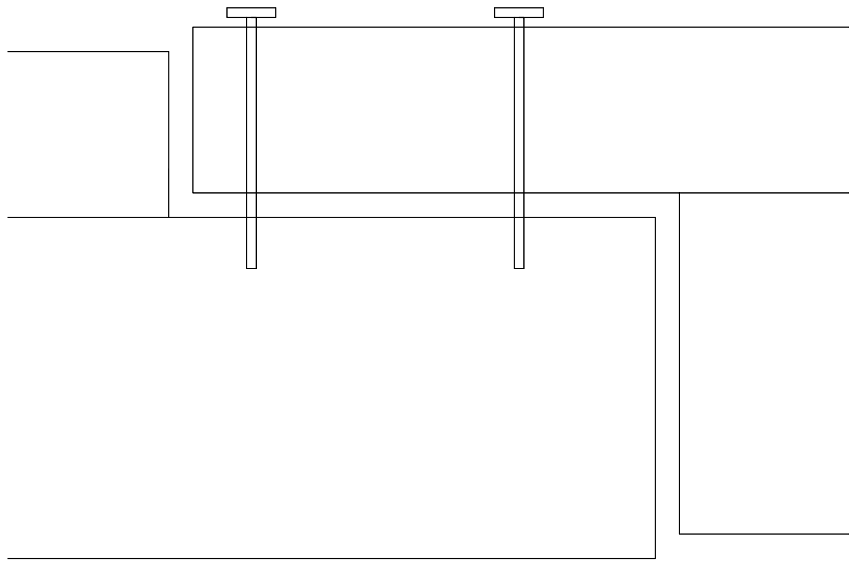
CONCEPT PANEL CONNECTION

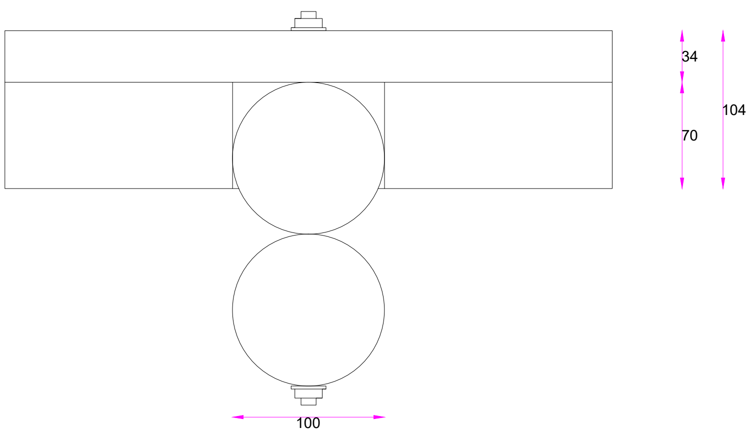


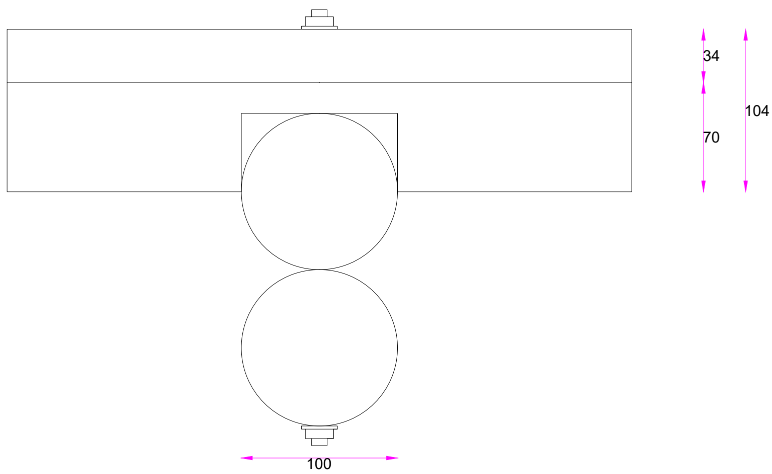
OUTRIGGERS (J1)

The new design for the ridge and outrigger has a small effect on the rafter. The bamboo culms for the ridge and rafters should be cut so the top of the outriggers lay on the same level.
For these outriggers the team advises a different dimension, since the team foresees that the current outriggers are not strong enough and will probably bend. In the picture new dimensions are proposed. A major advantage of these outriggers is their ability to compensate the irregularities of the bamboo rafters.
The drawings below show how you can use the outrigger to construct an even levelled roof.
Another advantage of the new solution for the outrigger is the possibility to create very long outriggers over the whole length of the house.









DISCUSSION

The team analyzed the model house and (scaled) social house throughly. Most of the topics resulted in design improvements, but other topics the team was not able to decide what's best for the (new) design of the social house. These design challenges are summed up in the final discussion chapter.

Elevated or on the ground

Is it possible to provide enough ventilation i the house is constructed on the ground?
How do you provide enough ventilation while obtaining privacy and safety?
How much will it cost extra?
Will it cost more to level the ground in hilly areas or ?

Toilet inside or outside

How do you combine wet or dry toilets within the design of the house?
How to obtain a hygienically safe house?
Is it possible to lower the humidity with a washroom inside?

Replaceable parts

Bamboo is a natural material and may decay and rot due to climate exposure, fungus and termites.
Is decay unavoidable? How?
If decay occurs, what is the solution?
Is it possible to construct the house with bamboo culms that can be replaced over time?

Design with principles of Bambú Social

How do you design a house with respect to the principles?
What are the design priorities regarding safety, functionality and sustainability?

1. Share knowledge and skills
2. Use local resources
3. Create local systems
4. Make it environmentally prospering
5. Dare to play, dare to discover

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