MODERNIZING THE **PASSING JOINT:** A STANDARDIZED BUILDING SYSTEM TO FACILITATE CONTEMPORARY BAMBOO HOUSING CONSTRUCTION IN REGIONS OF ECONOMIC CONSTRAINT

YULIYA D. BENTCHEVA

MASTER OF ARCHITECTURE | MASSACHUSETTS INSTITUTE OF TECHNOLOGY | 02. 2012

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Submitted to the Department of Architecture in partial fulfillment of the requirements for the degree of:
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ABSTRACT

The thesis was inspired by the excellent mechanical properties of bamboo and its positive environmental effects. Despite its abundance and great qualities, the material has not been incorporated into the history of standard light frame wood construction and is therefore not used to its full potential, especially in regions of economic constraint in greatest need of housing structures.

Can we design a light-frame construction system that allows for the non-standard nature of bamboo members and is inspired by the unique properties of the material? Can we reveal its contemporary uses and therefore allow for its cultural acceptance?

The research investigates how a grid of members behaves as a system - incorporating imperfections and variations of individual elements. Along with the structural exploration, the work addresses the cultural misconception of bamboo as the “poor man’s lumber” The exercises are aimed towards creating a housing unit that incorporates available materials into contemporary design elements.

As the title of the book suggests, I am going to tell you a little bit about my obsession with bamboo. It all started about a couple of years ago when I went on a class trip to Hawaii and was first introduced to the material. I am still not sure whether it was the waikoloa magic of the islands or my inspirational team, but I immediately fell in love with the material - I loved the way it looked, the way it felt, its numerous applications in different aspects of life... Like every other fascination, I wanted to get to know it a little better. I kept studying its properties and behavior for the next few semesters through classes and individual workshops. As with every other relationship, there were the good times, and there were the bad times... My direct work with bamboo deepened my interest and revealed its amazing qualities. As I got to know it a little better however, I started finding out that all of the little things that made it special were actually quite difficult to deal with. I stuck through those hard times, and only after I truly understood its unique nature and accepted it for what it is, I started working with it as opposed to just using it.

Once the time came for submitting a thesis proposal, I met with my advisors and said "I wanna build a house." The response I received was "what's wrong with that?" I was incredibly fortunate to have the full support of two of the most influential people in my academic career, Jan and John F., who helped me pursue what I was most passionate about.

The thesis work in the book reveals the process I went through. While there was literature research, my understanding of bamboo's properties and performance was mostly based on direct exposure to the material through construction of models at different scales and sizes. I found that living on a bamboo farm for a few weeks is much more valuable that spending hours and hours of dry reading. Its not until you taste something that you truly understand its flavor.

The thesis consists of five main phases. The beginning was focused on design/build workshops along with pure research. After gaining some authority of the material, I focused on exploring a specific joinery technique and testing its effectiveness. This fieldwork was done in the summer of 2011 and was an incredibly important part of the thesis. The tests allowed me to prove the proposed concept and then lead to the third phase of the process – incorporating the isolated joint into a complete building system. The guidance of my advisors and my patience with making small scale redundant models allowed me to find the appropriate grid system and connections in order to build a complete structure. As the goal of my work was to bring a concept into reality, the next stage was the application of the system to a specific site + needs. The last few weeks of December, I spent on building a half scale model of my proposal. With the help of my wonderful crew, I was able to achieve my initial desire to build a house - well part of it as least.

So, I am now going to dive into the details, and share with you my experience with a material that is, I hope, worth your time.

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PHASE 1 .... A DIRECT E X P O S U R E TO THE MATERIAL THROUGH RESEARCH + WORKSHOPS

FALL 2009 - SPRING 2011

what are the physical + mechanical properties of bamboo? what are the processes it goes through before it can be used as a construction material? what types of bamboo structures exist in the world? how is the material joined together? can we bend it? what are some other materials it can be combined with? does it go through chemical treatments? why? where does it grow? what are the environmental effects? what is it used for besides for building?

these questions among many others were the guidelines for this part of the thesis. literature along with hands on construction exercises revealed the amazing qualities of bamboo and its slightly darker side,.....this exposure to the material allowed me to focus the work and develop a thesis proposal.

yes, yes, y'all..

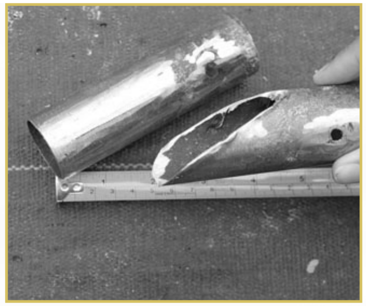
My first exposure to bamboo was building a hygiene unit for a farming family in Kapaau, Hawaii. With the guidance of Jan Wampler and Chris Dewart, the team was able to accomplish the task in 10 days (including a total of one hour of beach time).

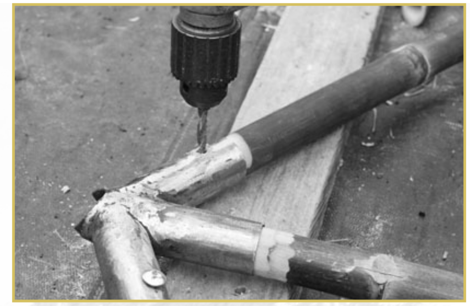
The design was based on low cost and locally available materials. We used common joinery techniques - bolts and cement mortar filled poles.

Building the structure revealed the difficulties of working with the material but it also proved to us that it was feasible to build with no previous experience. Even though it was a small structure, the joining techniques were applicable to larger buildings.

doone | juless | jay | fred | matt | amanda

Hawaii Hygene Hut | Fall 2009 | International Design Workshop



During the summer 2010, we did a series of custom made metal pipe joints and tested their strength when incorporated into a truss design. The experiments revealed that custom parts are very time and effort intensive and do not necessarily work well with the nature of bamboo. The dimensional inconsistency of the material and its fibrous nature do not allow for exact fit and strong connections. The workshop was helpful in directing our joinery exploration towards more traditional approaches that allow for the unique bamboo members.

Pipe Joint Truss Test | Summer 2010 | Independent Workshop with Reem Abuzeid + WWBoo - Rich, Virginia, Gabe, Ryan

A very important part of researching bamboo was being introduced to some of its strongest species. The table to the right shows a list of some of the species that are most suitable for building construction and compares their compressive and tensile strength as calculated by Jules Janssen's formula in Working With Bamboo. We took samples from different parts of the bamboo poles and found their yield strength by finding their densities.

The work was important as it revealed to us the different wall thicknesses of the different species. As the strength of each pole is dependent on its walls, the table was then used to find the most appropriate species for using in some applications - structural and non-structural elements.

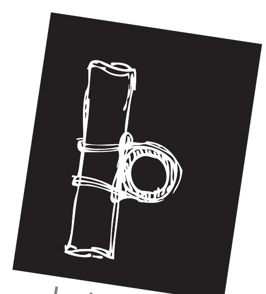
Table 2. Bamboo samples - mechanical properties.

Name	Height (mm)	Diameter (mm)	Wall thickness (mm)	Volume (m3)	Mass (kg)	Density (kg/m3)	Compression (N/mm2)	Bending (N/mm2)
Bambusa lako								
~ base			**13.76**					
~ 12'			**5.20**					
~ bottom of culm	148.00	55.90	8.90	0.000194	0.30	1543.27	**16.98**	**23.15**
~ 2/3 height of culm	199.00	42.40	4.22	0.000101	0.13	1241.59	**13.66**	**18.62**
Bambusa hirose								
~ base			**18.25**					
~ 12'			**7.75**					
~ bottom of culm	206.00	85.16	14.21	0.000652	0.75	1150.05	**12.65**	**17.25**
~ 2/3 height of culm	203.00	62.53	5.80	0.000210	0.28	1311.19	**14.42**	**19.67**
Bambusa oldhamii								
~ base			**14.76**					
~ 12'			**9.64**					
~ bottom of culm	206.00	64.25	10.70	0.000371	0.45	1214.15	**13.36**	**18.21**
~ 2/3 height of culm	202.00	62.00	5.62	0.000201	0.38	1865.90	**20.52**	**27.99**
~ 2/3 height of culm (dry)	202.00	62.00	5.62	0.000201	0.13	621.97	**8.09**	**12.44**
Dendrocalamus brandisii								
~ base			**16.32**					
~ 12'			**7.40**					
~ bottom of culm	200.00	69.55	12.47	0.000447	0.48	1062.63	**11.69**	**15.94**
~ 2/3 height of culm	204.00	53.94	6.33	0.000193	0.20	1036.02	**11.40**	**15.54**
~ bottom of culm (dry)	200.00	69.55	12.47	0.000447	0.24	536.91	**6.98**	**10.74**
~ 2/3 height of culm (dry)	204.00	53.94	6.33	0.000193	0.10	518.01	**6.73**	**10.36**
Dendrocalamus indo asper								
~ base			**26.06**					
~ 12'			**10.19**					
~ bottom of culm	111.00	111.94	17.07	0.000564	0.63	1107.30	**12.18**	**16.61**
~ 2/3 height of culm	179.00	96.72	7.83	0.000391	0.30	766.87	**8.44**	**11.50**

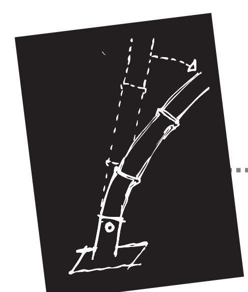
One of the biggest challenges of working with bamboo is to solve joinery issues. Due to the circular section of the material, standard connection techniques do not apply. Furthermore, each bamboo pole is unique in terms of its wall thickness and node distribution. As longer members are examined, a tapering effect is observed from one end to another which makes joining even more difficult.

The studies diagramed here are exploring both traditional and contemporary joinery techniques. Many cultures who used bamboo as a building material used a lashing method to stabilize their structures. The lashing was usually of an organic material, palm tree leaves or bamboo skins. The material was soaked in water and several members were tied together. As the lashing dried, it tightened and created enough friction to prevent the members from coming apart.

Modern joinery methods usually include the use of metal. There are many custom-made joints used by architects that are able to hold very large members together. Metal plates are inserted into the bamboo and held by metal bolts. The metal joints are sometimes accompanied by concrete - the concrete fills the node of the bamboo that receives the bolts in order to make the connection stronger.



lashing

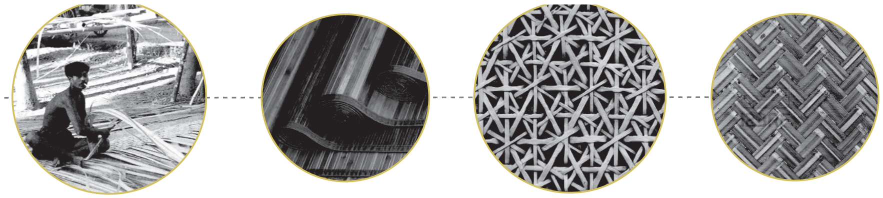


bending (tension)

process

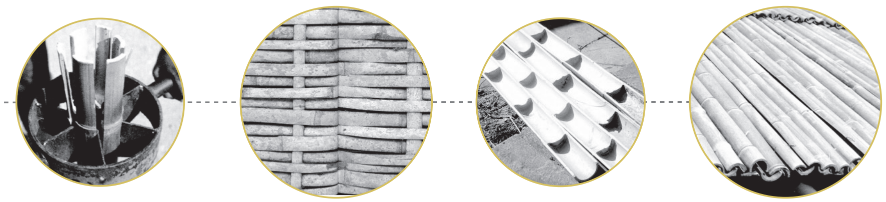
WEAVING

Bamboo skin is shaved off of the culm and used for weaving. Thickness varies with the desired use - walls, baskets, roofing etc



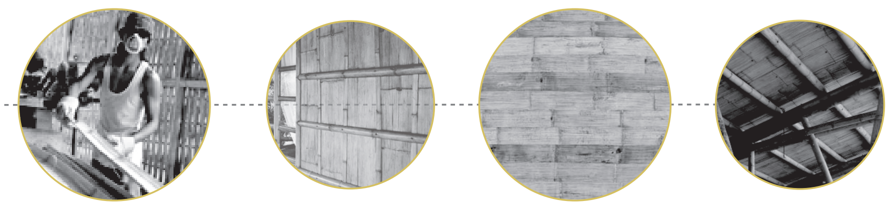
SPLITTING

Bamboo culms are split using a tool (right) into the desired number of parts. The pieces are arranged together to form surfaces.



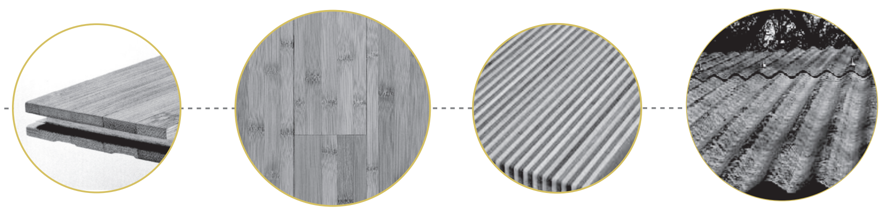
FLATTENING

Bamboo nodes are broken with a hammer and the pole is open and pressed to flatten. It is best used in cladding exterior surfaces.

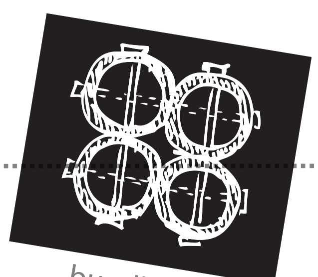


LAMINATING

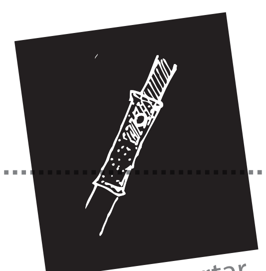
Bamboo poles are cut and laminated together either horizontally or vertically in order to create floor or wall boards.



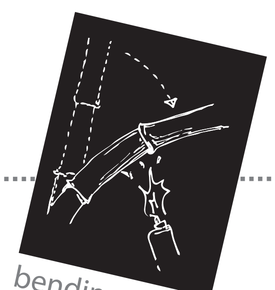
joinery



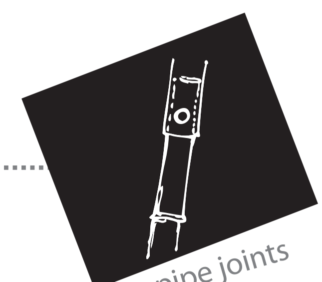
bundling



bolts + mortar



bending (permanent)

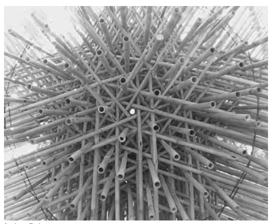


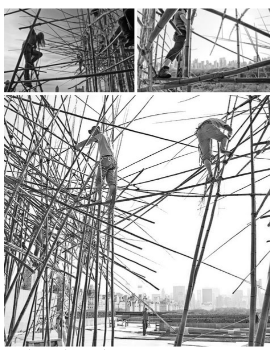
pipe joints

STRUCTURAL WEB


Burning Man Installation, Nevada


Bamboo Installation, Tetsunori Kawana

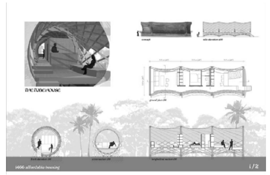

Art Installation


Big Bambu, New York, Doug + Mike Starn


Bamboo Restaurant DSA

DIAGRID


Bamboo Housing, Haiti, Laurent Saint-Val

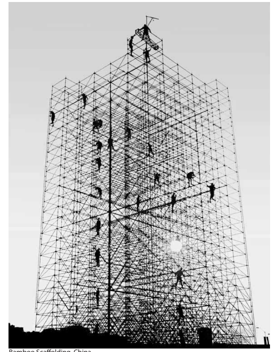

Bamboo Housing, Ghana, Chetry - Tournier

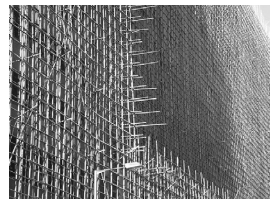

Bamboo diagrid structure

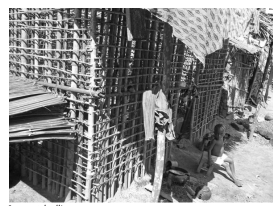

Sundanese House


Bamboo Bridge School, Li Xiaodong, China

SCAFFOLDING


Bamboo Scaffolding, China

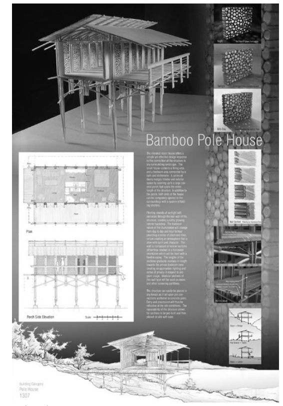

Bamboo Scaffolding, China


Low cost dwelling


Bamboo Scaffolding, China


Bamboo Housing, Valentin Oleynik

POST/BEAM/TRUSS



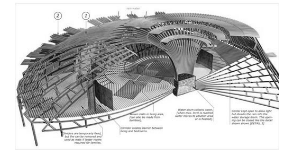
Bamboo Pole House


Bamboo House, Benjamin Garcia Saxe

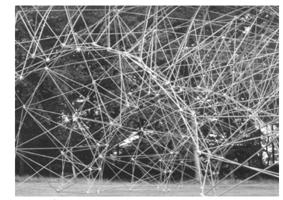

Bamboo Home Design

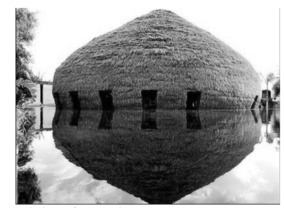

School, Anna Heringer, Bangladesh

TENSILE FRAME

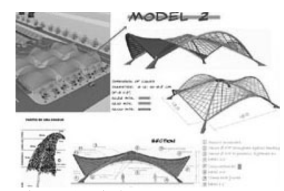

Pavilion, Indian Ocean, Esan Rahmani


Bamboo Structure


Tension Bamboo Structure


Wind and Water Cafe, Vo Trong Nghia


Bamboo hut, Pouya Khazaeli Parsa



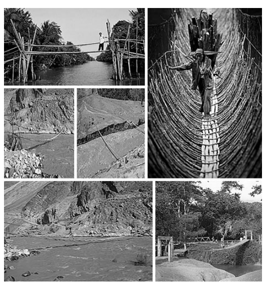
Bamboo Transport Station, Alejandro

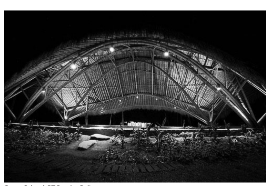
BRIDGE STRUCTURES


Roof Element


Ecolodge Bridge, Simon Velez


Bamboo Bridge, Malaysia


Hanging Bamboo Bridge, Vietnam


Green School, PT Bambu,Bali

ALTERNATING MEMBERS

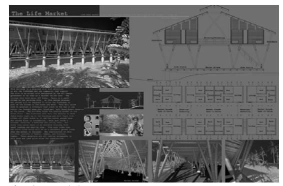

Bamboo Structure, Akio Hizume


Bamboo Sculpture


Tunner, Akio Hizume

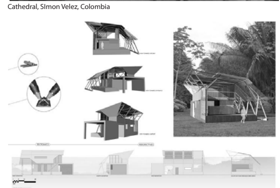
COLUMNS


German-Chinese Pavillion, Shanghai


Life Market Proposal, Ghana


Wind and Water Cafe, Vo Trong Nghia

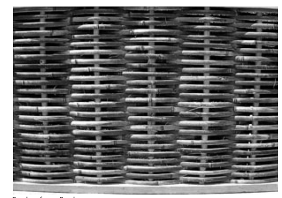

Cathedral, Simon Velez, Colombia


Bamboo House, Ghana, SPG Architects

SURFACES / PANELS

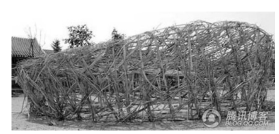

Bamboo Installation Surfaces


Bamboo Shelter, Ming Tang

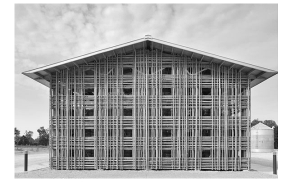

Bamboo fence, Bambusero


Eco Home, David Baker

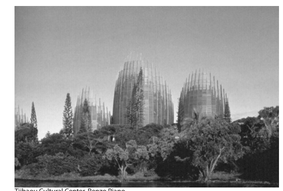

Bamboo Living, Hawaii


Olympic Stadium, China

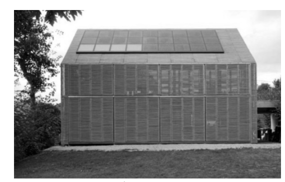
CLADDING


Mason Lane Farm, NC, De Leon + Primmer

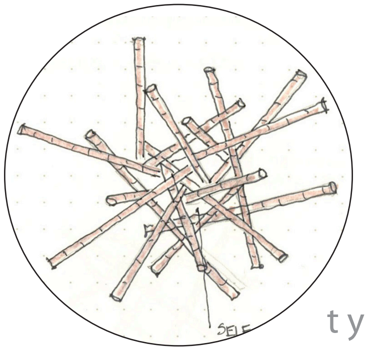

Bamboo House, Kengo Kuma, China


Tjibaou Cultural Center, Renzo Piano

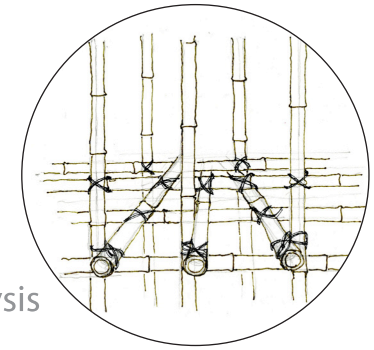

Bamboo House, Ghana

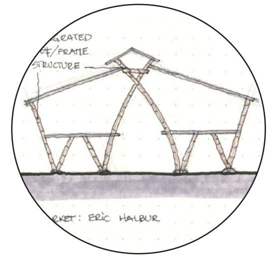

Passive House, France, Karawitz Arch

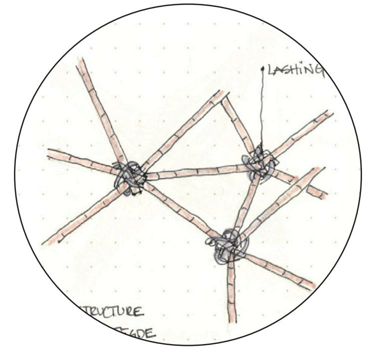

Bamboo House ROEWU Taiwan.jpg

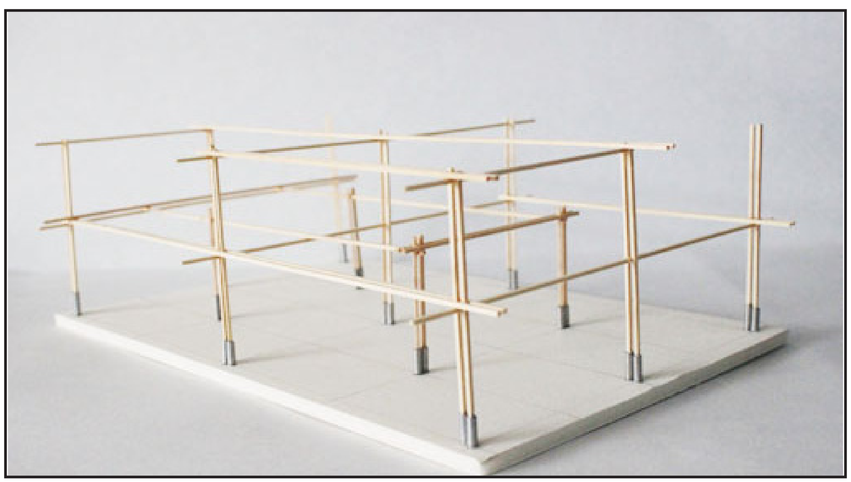


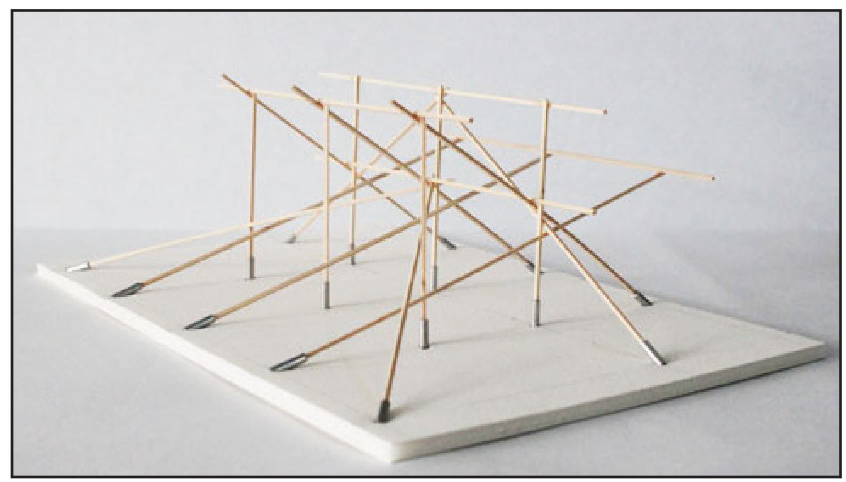
typology analysis

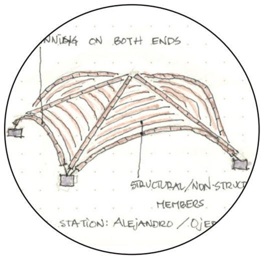


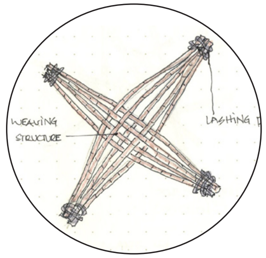


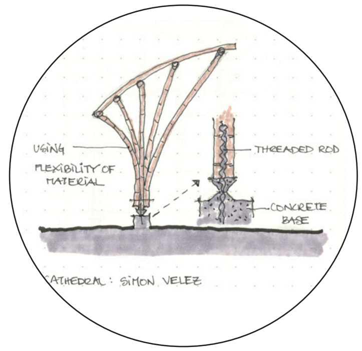


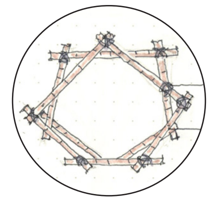


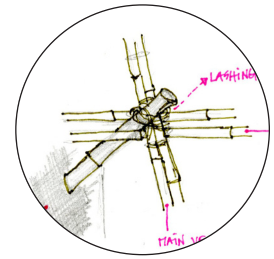


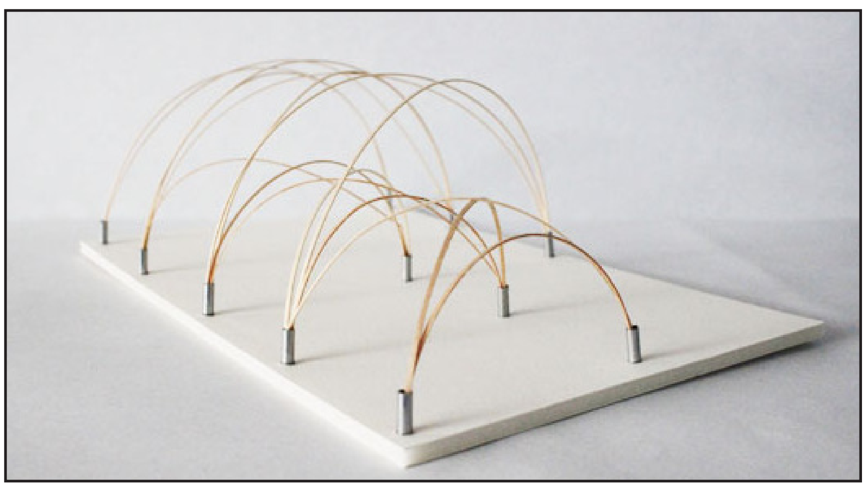

MEMBERS
STATION: ALEJANDRO /

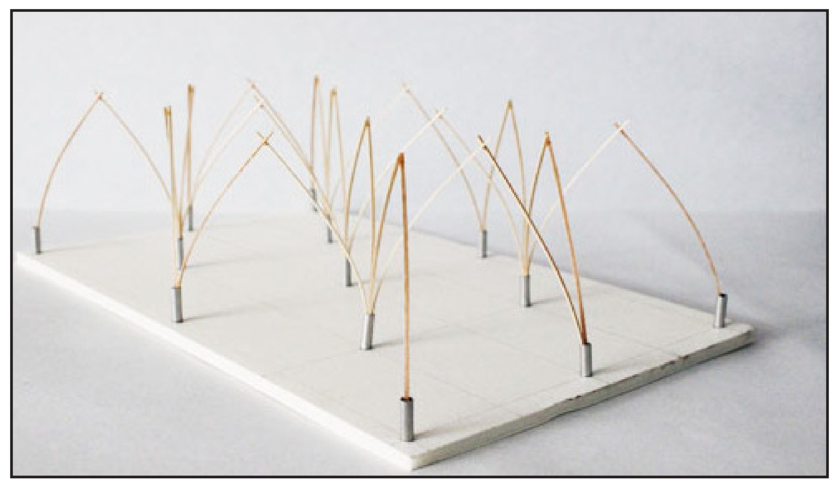

WEAVING
STRUCTURE


USING
FLEXIBILITY OF
MATERIAL
THREADED ROD
CONCRETE
BASE
SIMON VELEZ




MAIN

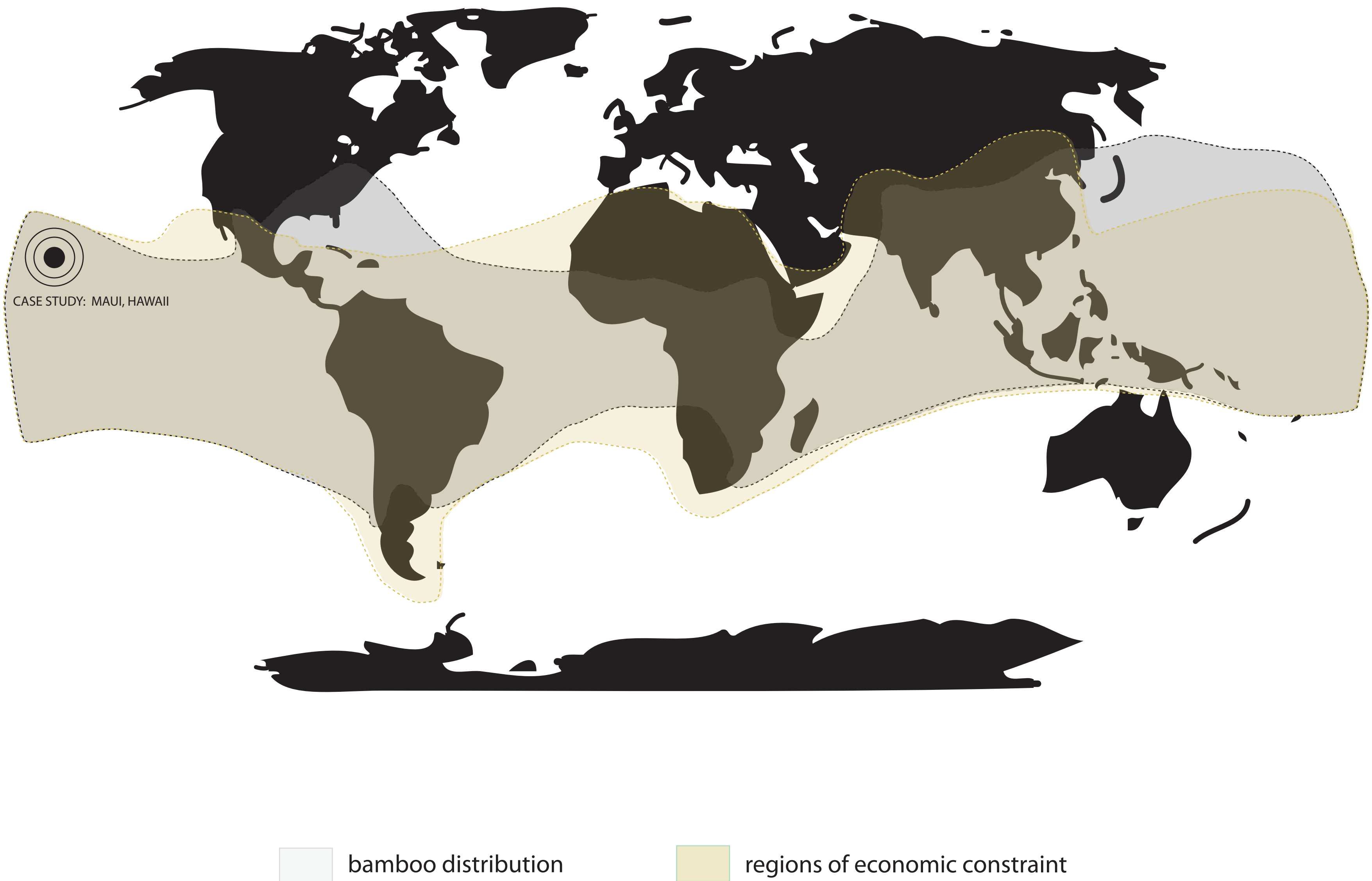


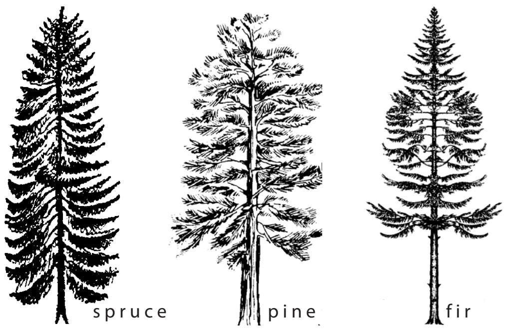


Although bamboo grows in most climates, its use for building construction is most appropriate in specific weather conditions – mostly tropical climates with high humidity. It is important for the moisture content in the material to stay constant as its variation causes cracks. The regions where it thrives best are along the equator.

The map on the right reveals bamboo's world distribution and therefore its possible applications. The other zone marked on this map shows the regions of the world with an economic constraint and with the greatest need for housing structures.

The great overlap between the two zones provides an opportunity for architecture to make a difference by improving living conditions. Developing a bamboo structure that is easy to build addresses the needs of communities in great poverty. This map was one of the motivating factors that inspired the thesis.


CASE STUDY: MAUI, HAWAII
bamboo distribution
regions of economic constraint



produces 35% more O

absorbs 4 X as much CO_2

matures in 3-5 yrs

environmental effects

SOFTWOODS - - - - - - - - - - BAMBOO

mechanical properties

compressive strength

8 000 - 14 000 psi

7 200 psi

tensile strength

10 000 - 30 000 psi

5 800 psi

bending strength

11 000 - 33 000 psi

7 200 psi

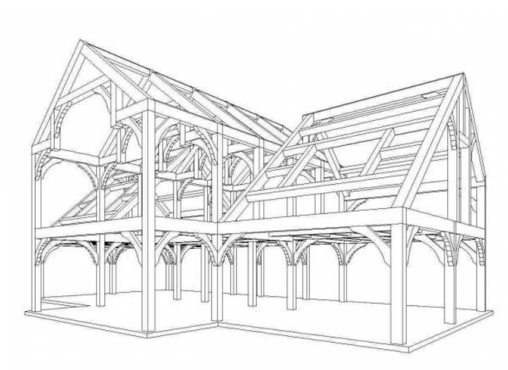
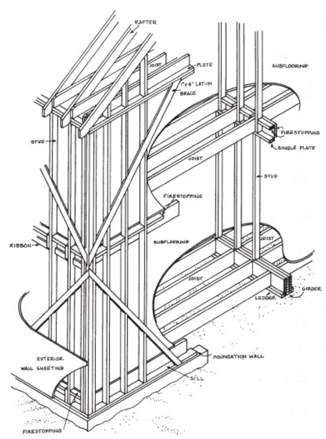
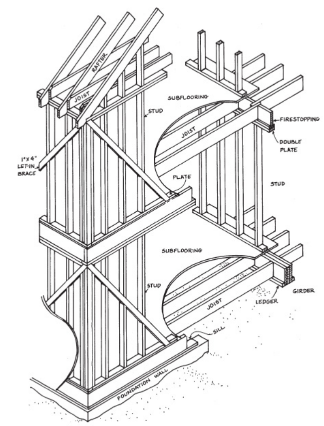
Although bamboo is classified as a grass (in fact, it is the fastest growing grass in the world), it is often placed in the same category as softwoods used for dimensional lumber in wood frame construction. It is interesting to note that although it has many advantages over softwoods, bamboo has not been used to the same extent.

This is unfortunate as its mechanical properties and environmental effects can be far superior. From over 1000 species, there are more than ten species that have greater tensile and compressive strength performance. Some types have tensile strength of 10 000 - 30 000 psi as compared to 6000 for softwoods. Compressive strength tests show that the bamboo fibers can hold up to 14 000 psi where softwoods generally range around 7000 psi.

Besides its mechanical performance, bamboo matures much faster - in 3 to 5 yrs versus 60-100 for softwoods. It also produces 35% more Oxygen and absorbs 4 times as much CO_2 than most trees.

If bamboo is such a great building material with all these advantages over most woods, it is inevitable to ask why it is not used as much as dimensional lumber? While the excellent building and environmental qualities are widely known, its unique nature makes it difficult to incorporate into a standardized building system. Its hollow, circular section, dimensional inconsistency, and fiber organization make it difficult to use with conventional building techniques such as using intrusive fasteners, butting joins. Bamboo poles vary greatly in their diameter, length, node distribution and wall thickness and therefore can't be used in a predecided manner - they need to be used in somewhat compromising conditions.

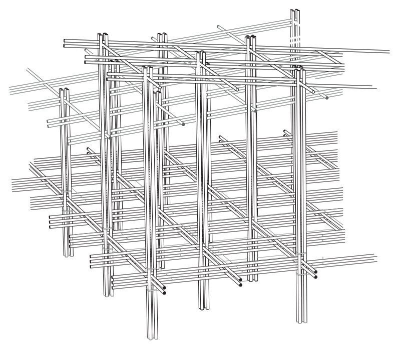
LIGHT-FRAME WOOD CONSTRUCTION

POST + BEAM		1830's BALLOON FRAMING	1950's PLATFORM FRAMING
			
■■■■■■■■■	skill level	■■■■■■□□□	■■■□□□□□□
■■■■■■■■■	construction time	■■■■■■□□□	■■■□□□□□□
■■■■■■■■■	cost	■■■■■■□□□	■■■■■■□□□
■■■■■■□□□	labor	■■■□□□□□□	■■■□□□□□□
■■■□□□□□□	use of tools / resources	■■■■■■□□□	■■■■■■□□□
■■■■■■□□□	fire resistance	■■■□□□□□□	■■■■■■■■■
■■■■■■■■■	custom materials (parts)	■■■■■■□□□	■■■■■■■■■
■■■■■■□□□	uniform dimension	■■■■■■■■■	■■■■■■■■■
■■■■■■□□□	intrusive fasteners	■■■■■■■■■	■■■■■■■■■

STANDARDIZED SYSTEM ?

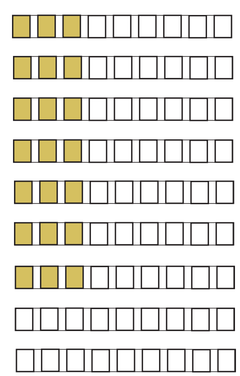
The history of tectonic culture reveals that bamboo, a major construction material, has not been incorporated into the progression of light-frame construction. While its excellent building qualities are widely known, its unique nature makes it difficult to incorporate into a standardized building system. The lack of such a system discourages architects and engineers from using the material despite its strength and positive impact on the environment.

The thesis is addressing this gap by proposing a light frame construction that allows for non-standard materials. The research investigates how they can be used to behave as a system - incorporating imperfections and variations of individual elements.



system

light-frame bamboo construction

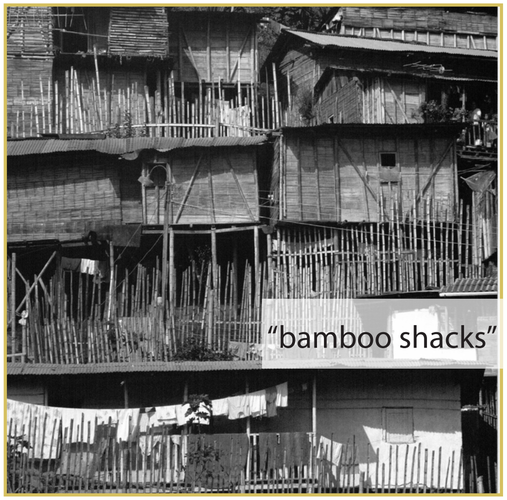


non-standard

individual members


custom design


$$$
$$
$


"bamboo shacks"

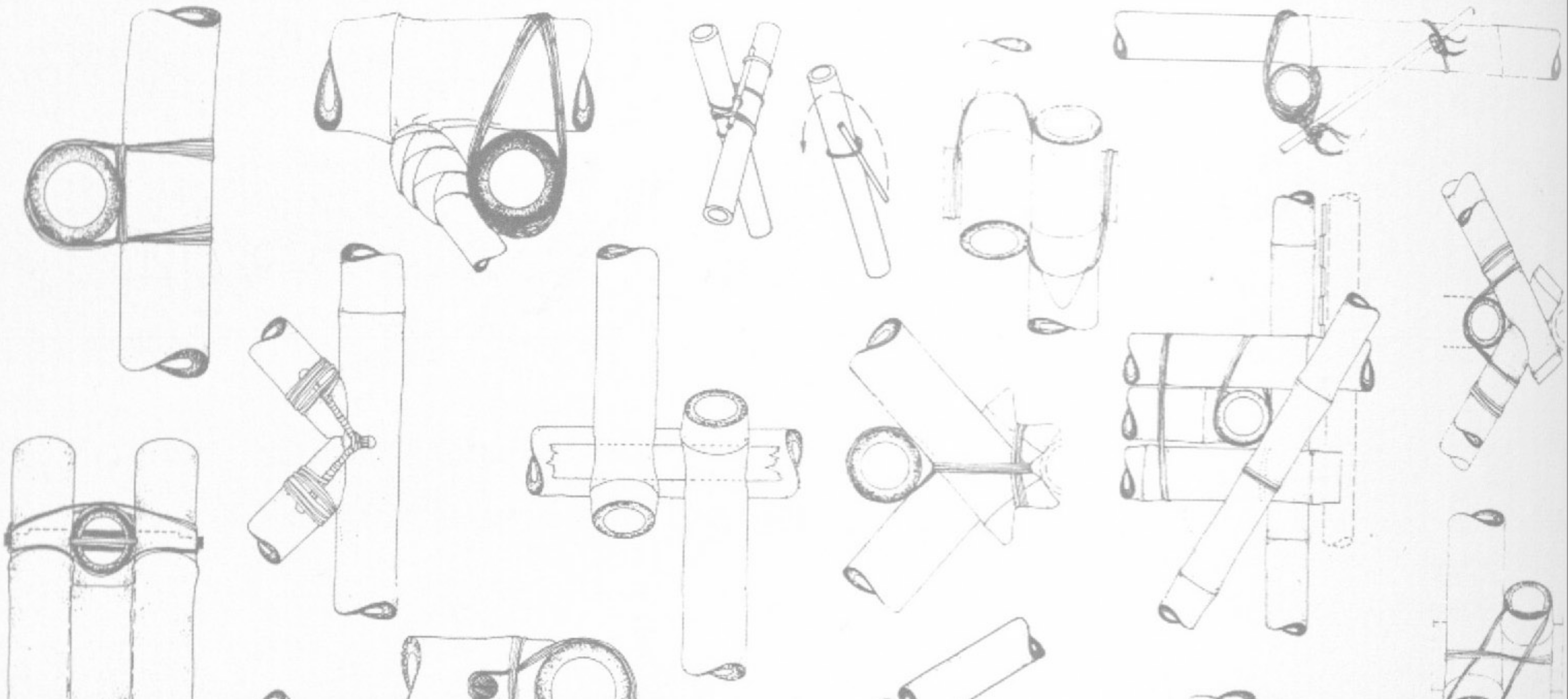
Research reveals that bamboo is mostly widely used in tropical regions that are economically constrained. The image library shows that most project can fall into two categories at the extreme ends of a spectrum. At the one end are structures found in extreme poverty conditions. At the other end are highly customized large structures built by skillful bamboo workers - cathedrals, schools and other large scale projects. There seems to be a gap for medium scale residential construction. The material is not commonly used for such purposes in developing regions. Besides the difficulties to work with bamboo, a large part of the issue lies within the social realm - the cultural perception of bamboo is still one of the "poor man's hut." Many urban and rural settlements in developing countries use bamboo for shelter. People in such regions are reluctant to inhabit structures that are associated with poverty. The thesis is challenging this misconception by proposing a contemporary house design to reveal the modern use of the traditional material. The research explores incorporating local materials in new ways in order to design housing units that will be culturally accepted. Cost and ease of building are also among the challenges.

SUMMER 2011

what are the modern and traditional techniques that bamboo poles are joined together? what are the advantages and disadvantages? what is more appropriate? can we use metal bands to bundle poles together? do metal straps hurt the bamboo poles? what are some ways to hold poles together? what are some of the forces the joint needs to withstand? what are the required forces for residential construction code?

the summer work allowed me to develop a joinery proposal and test its feasibility. the testing was done at Whispering Winds Bamboo, Maui, Hawaii with the kind help of Rich, Virginia, and Gabe von Wellsheim and the rest of the crew.

TRADITIONAL PASSING JOINTS | LASHING MOST SUITABLE FOR BAMBOO CONSTRUCTION



>3/8" wall thickness shows almost no sign of deformation as the steel band is tightened.

<3/8" wall thickness starts to crack before desired tension is achieved.

When applied at the node, the steel band stretches and takes the shape of the node when tightened.

bamboo poles <1" in diameter crush easily due to thin walls - they can be used as secondary structure.

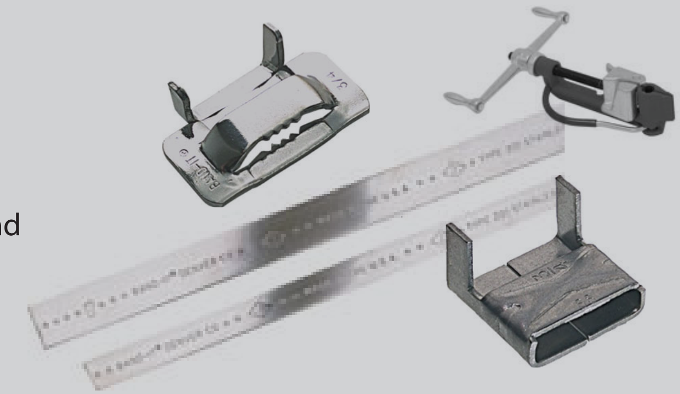
I found that traditional methods, such as passing joints and lashing members together, are much more appropriate for the nature of the material than some current techniques which involve custom made metal parts and intrusive fasteners with cement fillings. Due to the biological organization of the material – its fibers do not want to be disturbed as that may lead to longitudinal splitting and cause further structural failure. Based on these reasons, I focused on studying the traditional approach of the passing joint and explored ways to modernize its features in order to provide a longer lasting and stronger connection.

This past summer, I did a series of small scale design studies to find the most appropriate column design - which led to my proposal and the field work to test it. I focused on using small diameter members as there is an abundance of them (in fact, they very often go to waste) and they are much easier to handle. Instead of using organic or synthetic lashing to hold poles together, I am proposing using a steel band that is commonly used for traffic lights and street signs. The band allows for achieving a great amount of tension and longer lasting connection. It is easily placed with a tool above and below the jointing place to form a three-dimensional column.

TEST 0

BAND-IT
stainless steel band

3/4” x 0.030”
3/8” x 0.025”

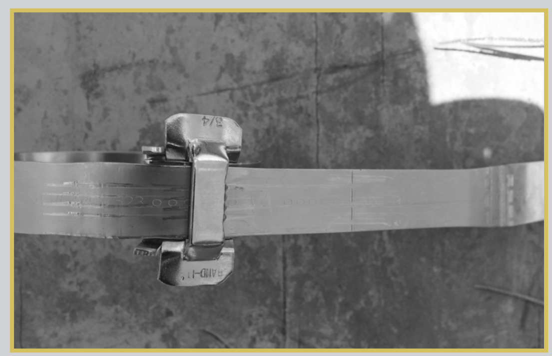


WALL THICKNESS

3/8”

TENSION

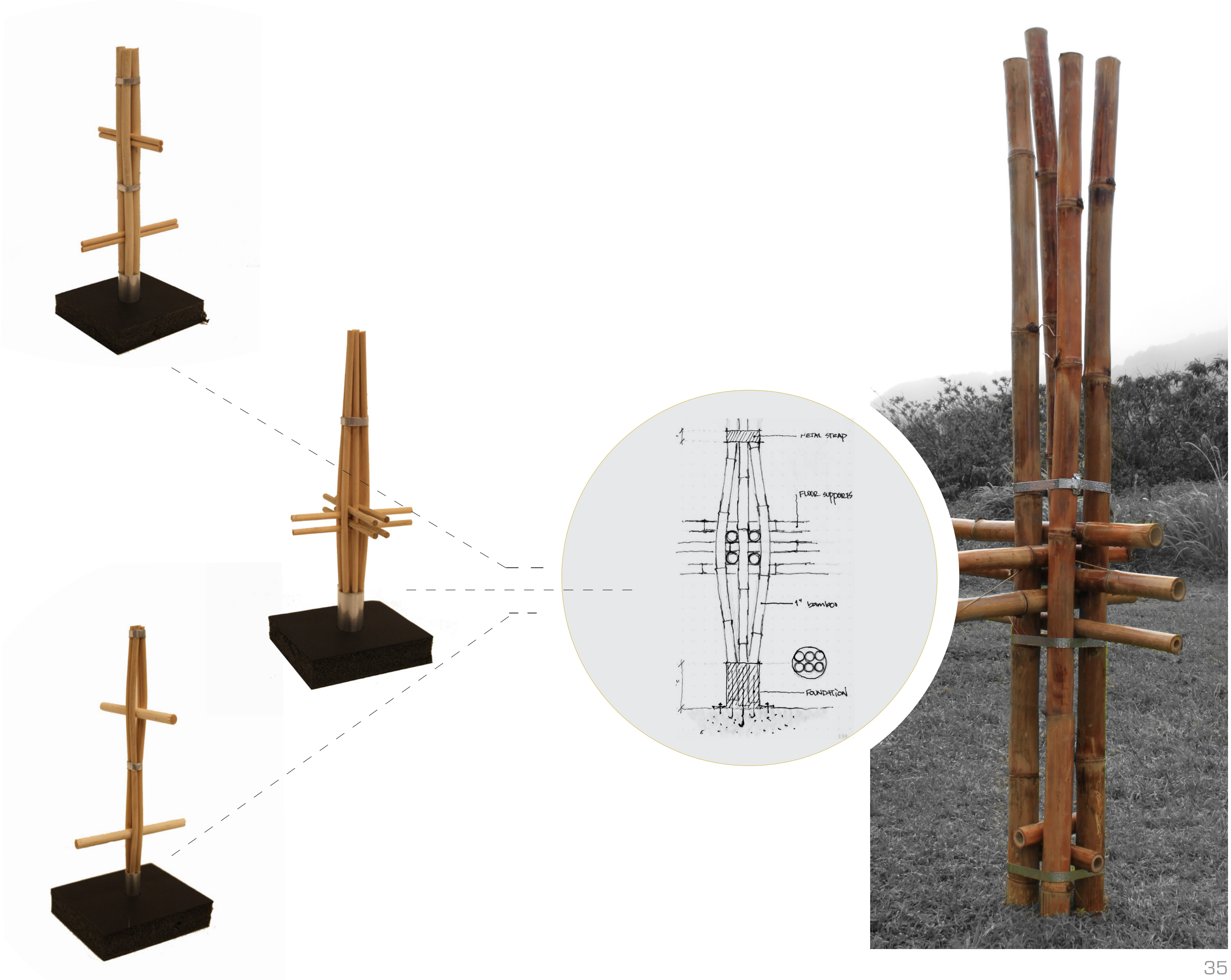
~7-10



BAND - IT TOOL

The technique shown to the right allows for incorporating the column, floor and wall primary elements into one connection. The spacing between the primary members also allows for the floor surface and wall elements to be attached easily.

After testing small scale models, the most appropriate column design was developed. It consists of four vertical members of 2" diameter and 5 horizontal members passing through. (as seen in the image to the right). The column is built as shown below. The horizontal members are placed between the vertical poles as soon as several columns are set-up. The steel bands below the horizontals are placed, the horizontals put in place, and the top bands are placed last.

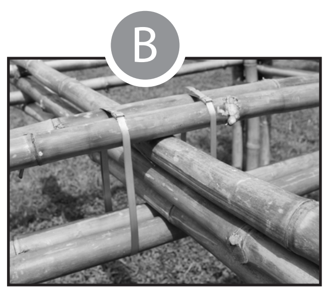

METAL STRAP
FLOOR supports
1" bamboo
FOUNDATION

floor :

The main floor supports were woven and strapped with the steel band. Since the forces in the supports are smaller than the main columns, the steel band used is 3/8".

solid wall:

The solid wall consists of 1" bamboo poles held together with the steel bands. It can be built separately and then inserted between vertical members of the columns. Because the wall is solid, it provides some sheer support. Some of the challenges included: curved bamboo poles sometimes make it difficult to keep the wall flat and dense enough. Also, attaching it to the main columns may need to be developed further.



truss wall:

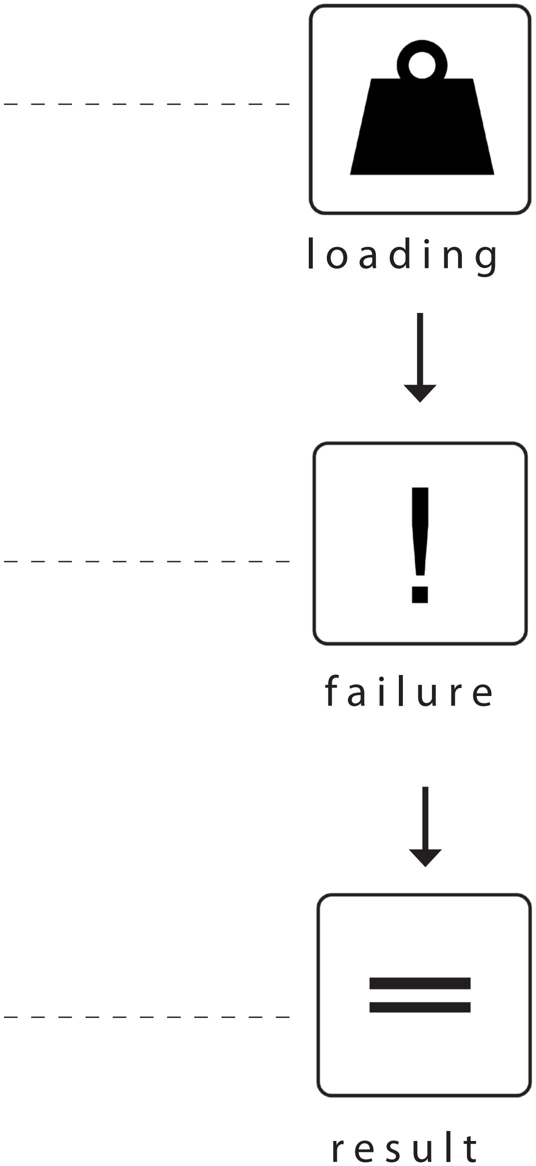
This type of wall is built as part of the structure. It is connected to the columns and acts as a truss. It provides a much stronger sheer support than the solid wall to the right. The attachment of the diagonal members needs to be developed further so that they are held to the columns (as opposed to just put in place). The weaving of the wall surface also needs to incorporate the 3-dimensionality of the wall structure.

structure 1

TEST 1

The first structure shown here had 4 columns, main floor supports and diagonal bracing for lateral support. It collapsed inward after 1700 lbs of weight due to a point load on one of the top members.

1700 lbs



A

steel bands hold

All of the steel bands were holding - they bent around the bamboo poles which dismisses the possibility of the steel cutting into the fiberes. Also, the horizontal poles did not slip down due to the weight which confirms the success of the steel band in holding the joint.

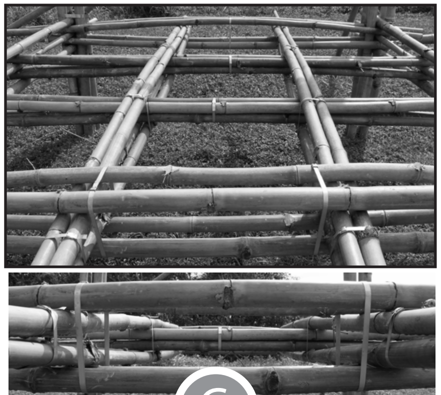
point load failure

The structure held 1700 lbs of load. It failed due to a point load on one of the top bamboo members that then caused failure on all four sides simultaneously. The structure collapsed inward.

B

compression

Theimage on the left shows the compression failure of the bamboo pole. It is important to note that the NONE of the pieces (fibers) actually tore apart. Once we uloaded the structure, the bamboos were able to take their original shape - the fibers were still holding!



C

D

The second structure was slightly different from the first attempt. It had much stronger floor support net of primary and secondary members so that the weight is distributed more evenly. The floor members were woven together in order to provide some lateral support and the structure needed for a floor surface. The columns consisted of four main horizontal members. The structure didn't have any lateral bracing, which was the main cause for its failure.

floor weaving

The design of the floor uses the flexibility of bamboo members and weaves the structure together. Each of the compound members resembles a truss and therefore the whole floor acts as one structure.

bundles

Doubling and quadrupling the horizontal members provided much more support and made the weaving possible. The bands hold the members together.

3 - dimensional column

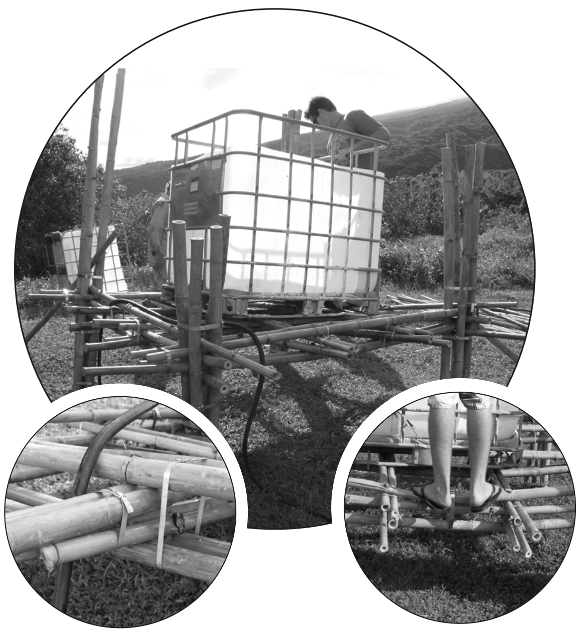
The image on the left shows the main column that incorporates horizontal elements that can be used for floor and wall supports. The bands hold the passing members together.

structure 2

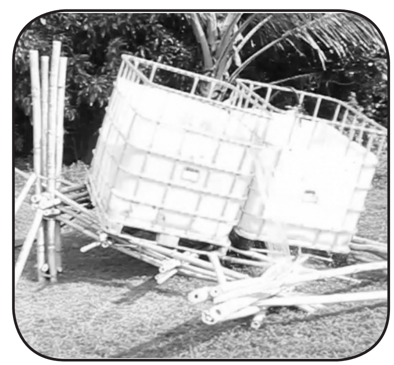
TEST 2

The failure cause was a lack of lateral support After the floor supports deflected for 2", the structure twisted and fell. However, before it failed, It held 2900 lbs of load which is the equivalent to 80 psf !!! where building code for residential construction generally requires 40 – 70 psf.

1:1 tests proved that structure is able to hold the necessary loads for housing construction. The steel bands performed well - they did not break, slip or damage the bamboo poles.



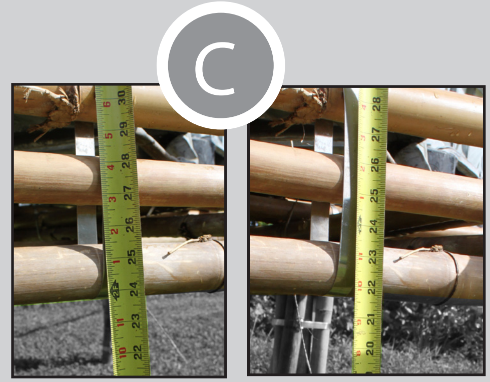
2900 lbs = 80 psf !!!



structure resumes shape after load removed

After removing the loads, the structure took its original shape! Even with some of the remaining load on it, the fibers did not break. This reveals the flexibility of the joinery technique.

C



2" deflection

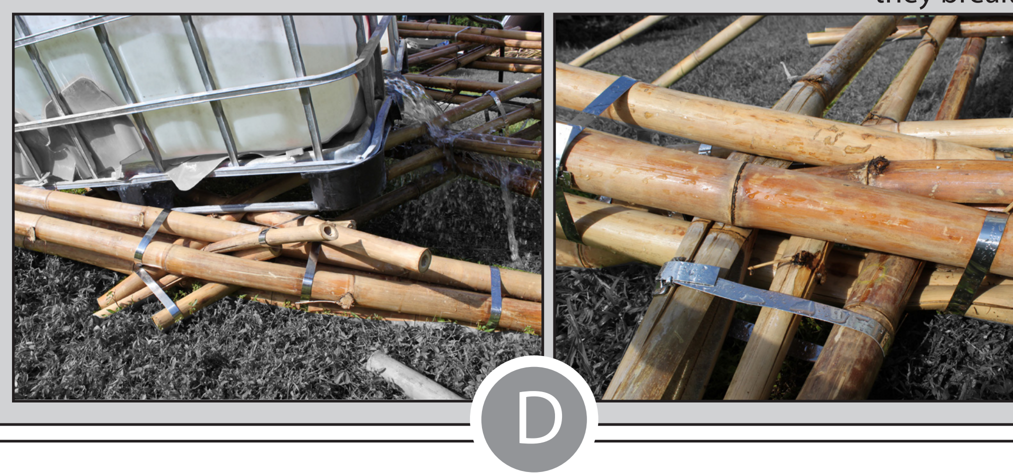
The horizontal members of the structure deflected a little over 2" before the structure started to twist due to lack of lateral support.

crushing + twisting

The load applied a point load and crushed one of the top horizontal members. (The bamboo species of that member had a thinner wall of 1/4" which caused the failure). As soon as the member failed, the whole structure twisted due to a lack of lateral bracing.

steel bands hold

Even though the structure collapsed, all of the steel bands were still in place and holding. They did not cut into the bamboo fibers, nor did they break.



D

FALL 2011

what is the appropriate spacing between columns? should the system follow a grid or should it be more free form? what are the maximum spans of the bamboo members? what about the height of the structure? what can be used for surfaces? what are the enclosures made of - roof and walls? what diameter members is best to use? how large can a structure be? what types of spaces does the structure allow for?

the system was developed by following a set of guidelines and mostly through building small scale models. it is based on long spans and single members passing through several connection points.

Based on my studies with bamboo, I was aware that there are many different variations to explore particular building strategies - the material allowed for several approaches. In order to focus and narrow my work to something applicable in real life, I developed a set of conditions to guide all of my design decisions. This way, I was bound to a limited set of joinery methods and materials.

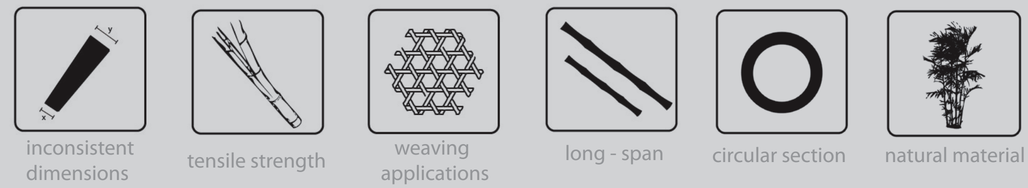
The system is low cost and is designed to meet the needs and resources of communities in economic hardship. It is inspired by the non-standard and organic nature of bamboo - its circular section, non-uniform dimensions, long span ability and weaving applications. Due to incompatibility issues, it avoids typical lumber construction methods. There is no use of intrusive fasteners, identical members, butting joints, or large number of custom parts. No electricity is necessary either.

The constraints I set lead to an innovative joinery approach. The conditions allowed me to focus on the few possible materials and techniques and develop a simple construction process with low skill level and very few hand tools.

INCORPORATING A

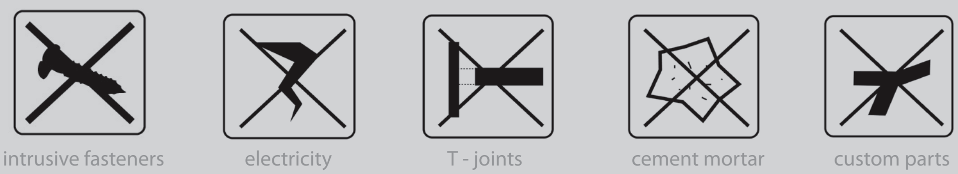
NATURAL NON-STANDARD

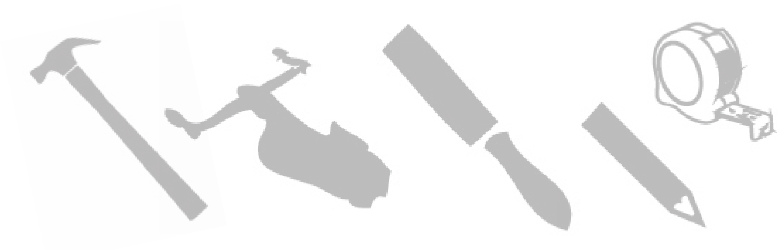
BUILDING MATERIAL



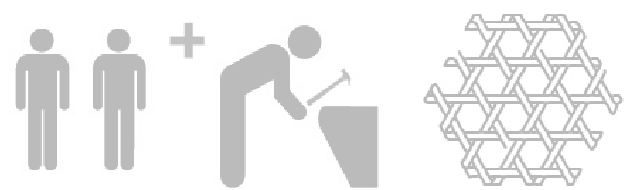
AVOIDING TYPICAL

LUMBER CONSTRUCTION



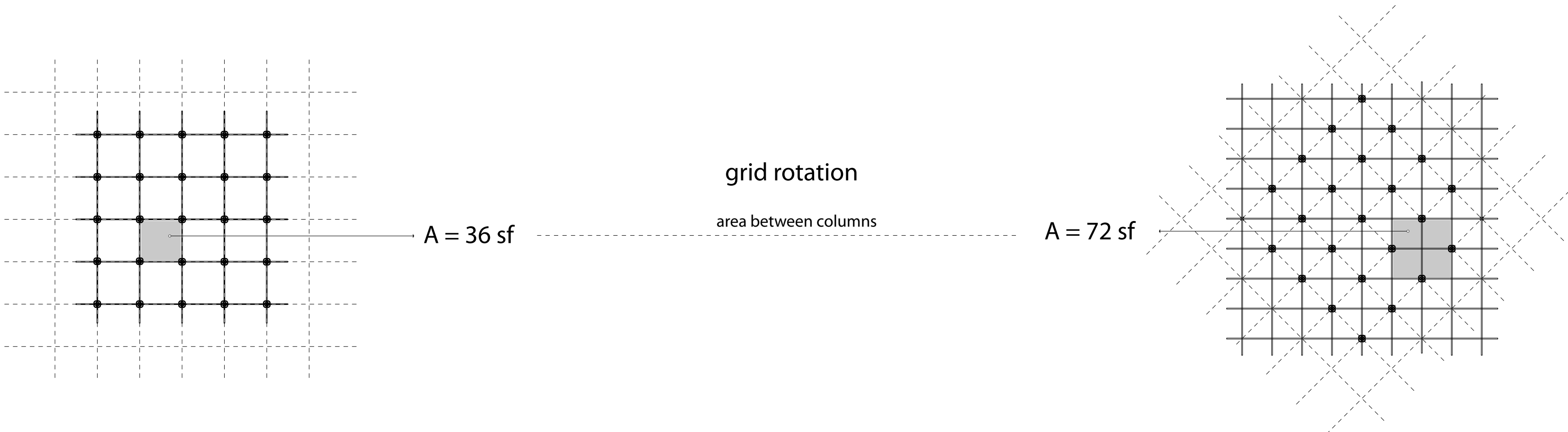


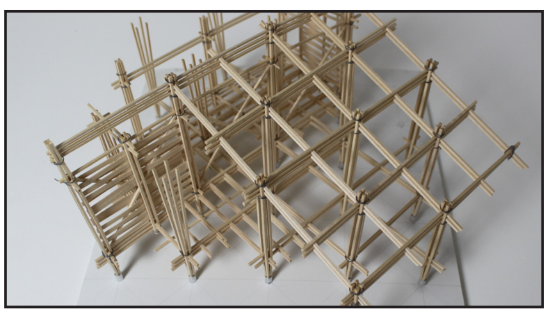
TOOLS

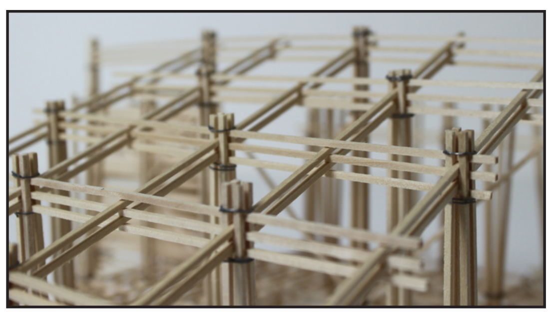


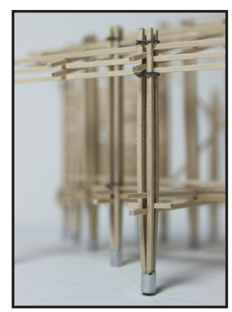
SKILLS | LABOR

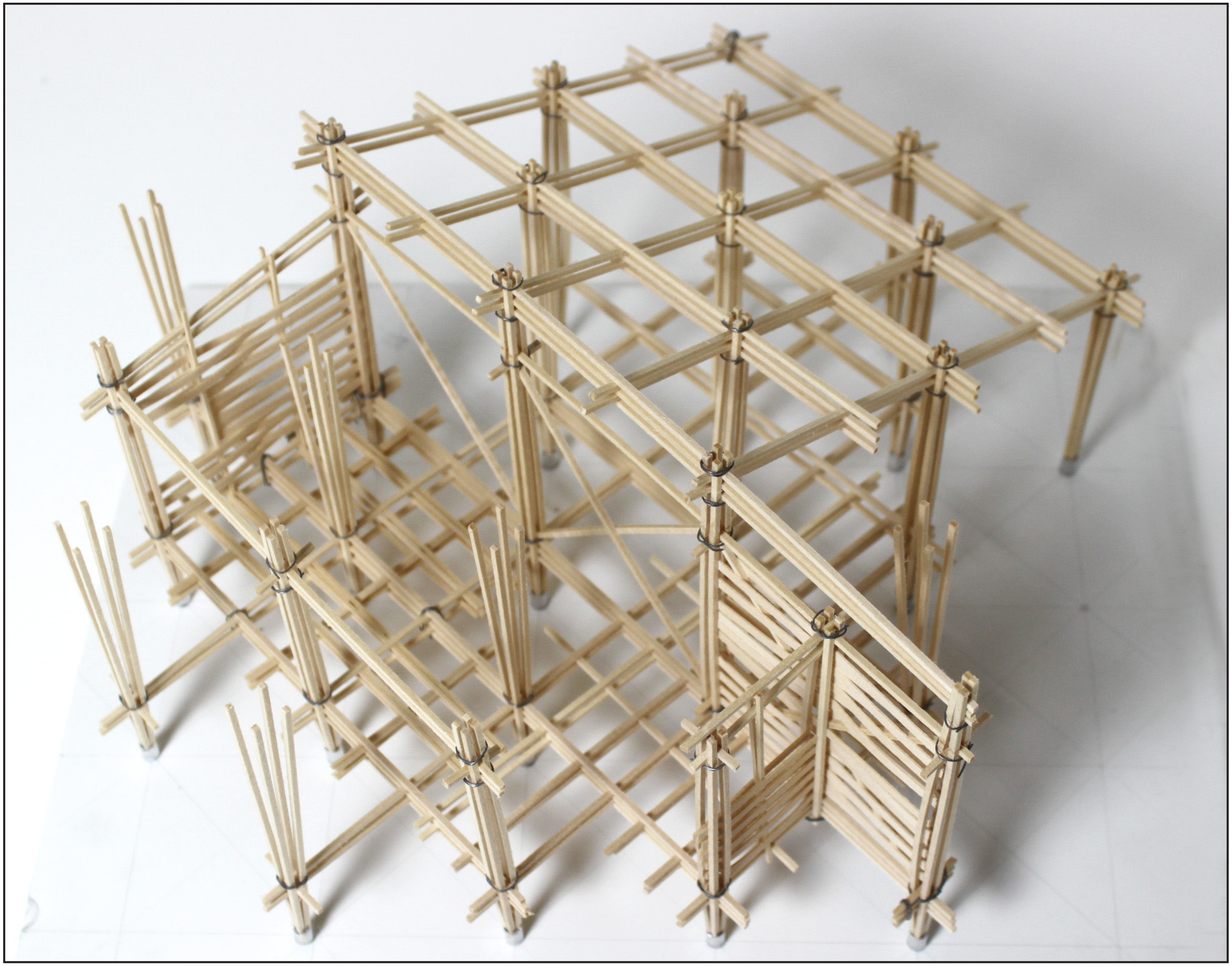
The system is based on a 4' staggered grid of columns, which allows for a maximum space of 8' x 8' between columns. Enclosed spaces can be larger, but may not be under 64 sf. Each column is composed of four vertical members and horizontals passing through. The individual horizontal members are spanning long distances so that a single member passes through several connection points to create a structure that acts as a truss. The maximum length of horizontal members is 30' and the vertical is 15'. The diameter of these long primary members is around 2". The joints are held together by the steel bands described earlier in the work. The system follows a strict grid in order to facilitate the building process and minimize the number of specialized elements. However, the grid can be broken if needed in order to allow for variation of spaces. In other words, the system can be customized to fit other needs.









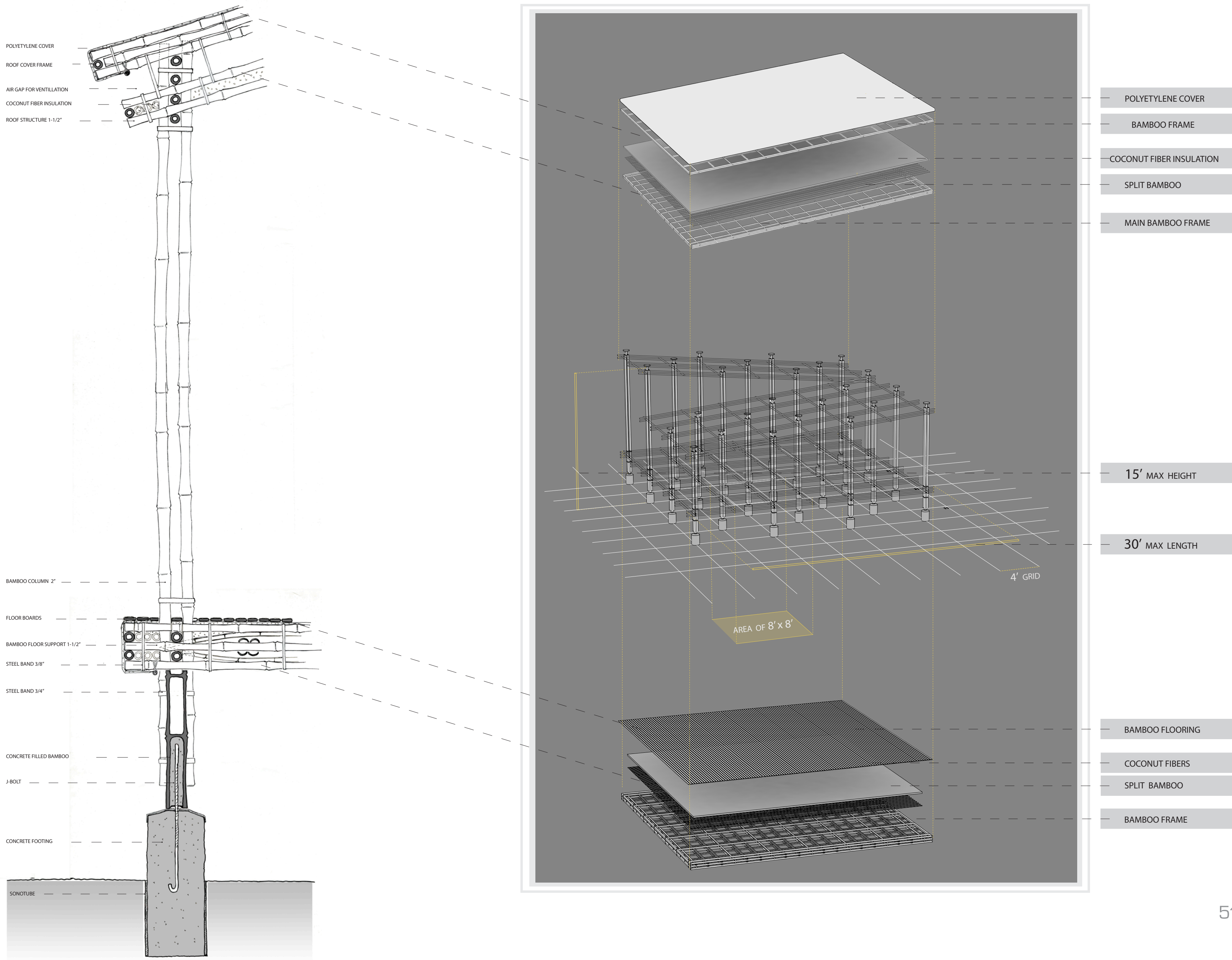


Once the general structure was developed, I focused on detailing the joinery techniques and enclosure strategies. It was important to incorporate the surfaces into the structure without disturbing it or adding more members. The floor and roof were developed in a similar fashion. As the column design consists of a 3-dimensional joint, it was interesting to explore ways to attach the secondary structure and surface layers.

The floor system is composed of several layers. First, a secondary structure is woven into the primary 2" members. It is composed of split pieces of smaller diameter bamboos (1") woven together to provide more lateral support and the beginning of a floor base. In order to even out the non-planar woven bamboo structure, a layer of packed coconut fibers is placed on the frame. The top most layer is bamboo flooring which, depending on the financial resources of the occupants, can be processed flooring or flattened bamboo pieces attached to the frame by straps. In order to protect the bamboo from getting wet, the edge detail includes a waterproof synthetic fabric.

The roof system uses a strategy similar to the floor. The difference is that it uses two separate frames with space between them. The lower frame holds a layer of coco fibers for insulation (both from sun rays and also noise during rain storms) and the top most frame is covered by waterproof synthetic fabric or corrugated metal depending on the financial resources and local availability. There is a 6" air gap between the two frames to allow for proper ventilation. The top frame is strapped to the lower frame in order to cover the columns (which hold the lower frame and therefore pass above it). Due to the circular section of the bamboo poles, the roof frames can be angled as necessary to shed water.

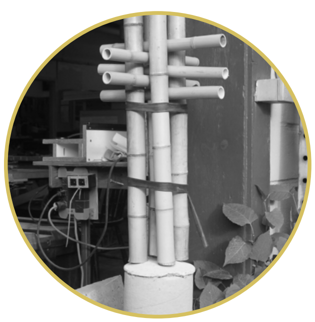
The composite sectional drawing along with the model on the next page reveal the connections from the foundation to the roof. All of the joints use the same strategy. Only the edges of the frames have some additional members and somewhat customized parts in order to add to the aesthetic part of the design.

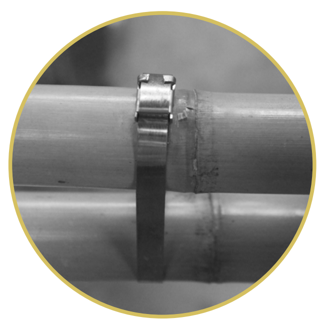

POLYETYLENE COVER
ROOF COVER FRAME
AIR GAP FOR VENTILLATION
COCONUT FIBER INSULATION
ROOF STRUCTURE 1-1/2"
BAMBOO COLUMN 2"
FLOOR BOARDS
BAMBOO FLOOR SUPPORT 1-1/2"
STEEL BAND 3/8"
STEEL BAND 3/4"
CONCRETE FILLED BAMBOO
J-BOLT
CONCRETE FOOTING
SONOTUBE
POLYETYLENE COVER
BAMBOO FRAME
COCONUT FIBER INSULATION
SPLIT BAMBOO
MAIN BAMBOO FRAME
15′ MAX HEIGHT
30′ MAX LENGTH
4′ GRID
AREA OF 8′ x 8′
BAMBOO FLOORING
COCONUT FIBERS
SPLIT BAMBOO
BAMBOO FRAME

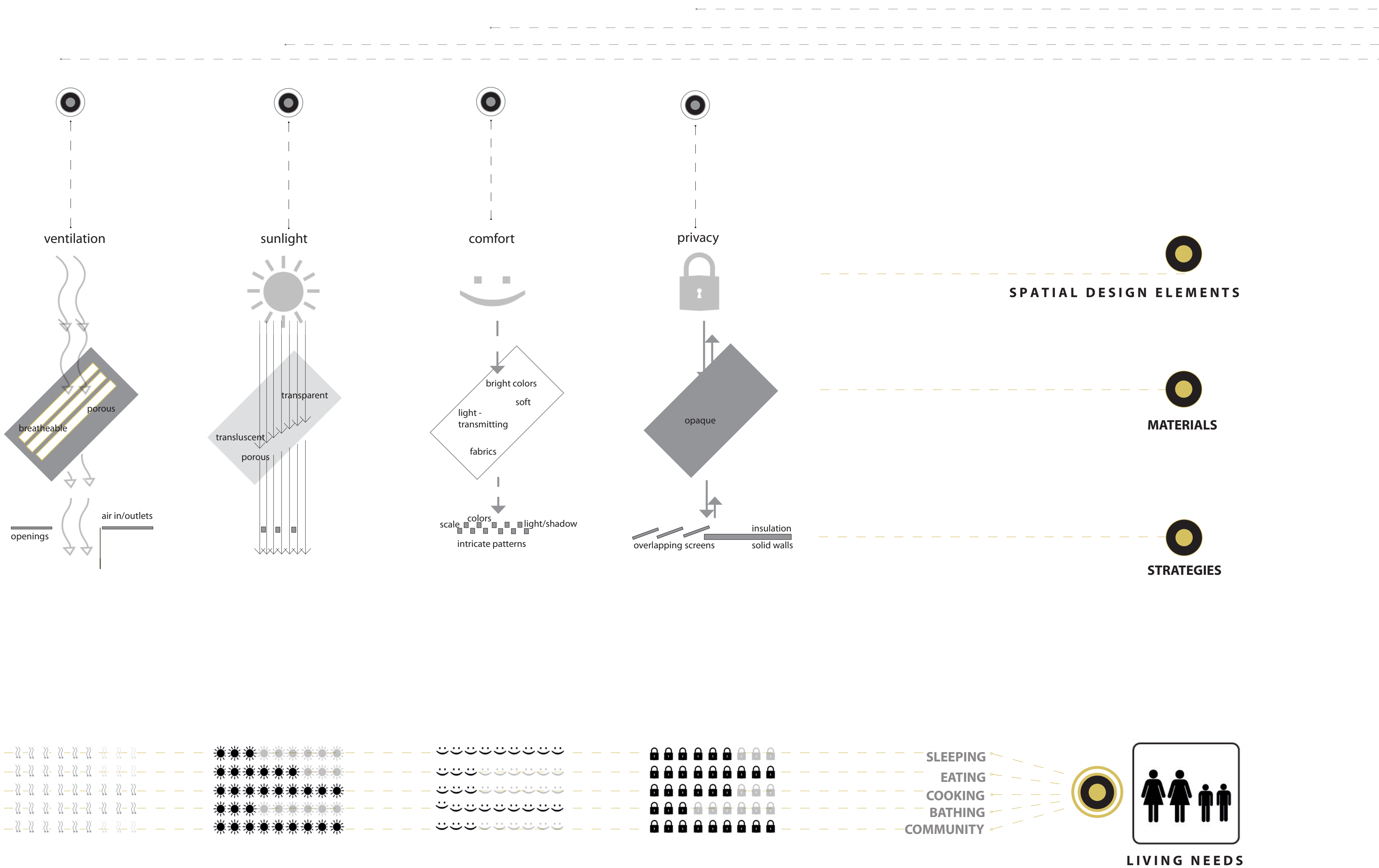
As most of the design, the column detail was also developed through construction. I built a full scale mock-up in order to test the proposed method. The structure allowed me to familiarize myself with the materials involved and the changes that need to be made when particular design details are difficult to fabricate.

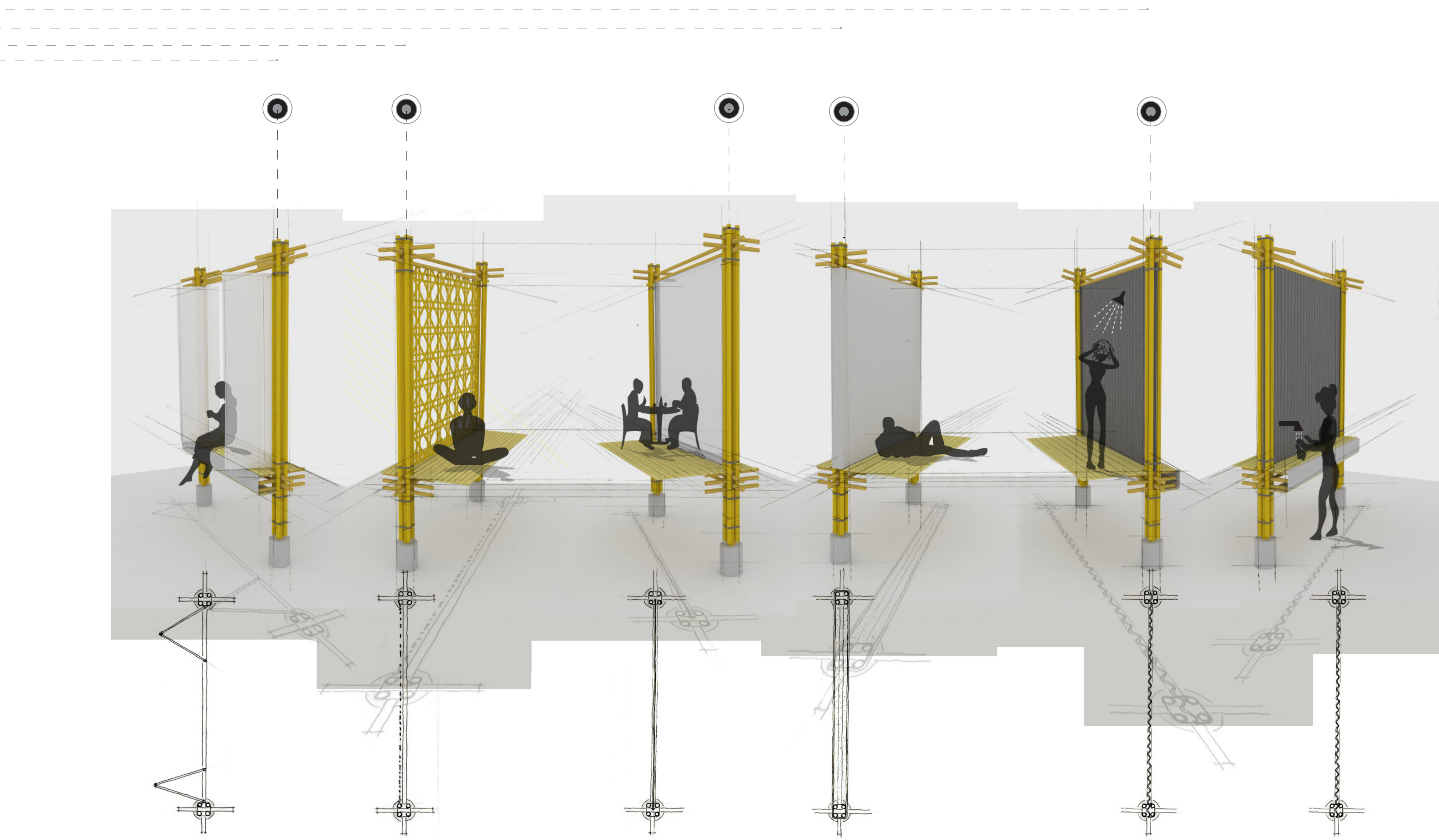
The construction process illustrated below reveals all the necessary steps. It involves a j-bolt that is precast into a main bamboo pole support that is 4" in diameter and 2' long. This support serves several purposes - it attaches the column to the concrete foundation, it provides a base for the verticals to be attached, and it takes the load of the horizontals of the floor that rest on it. This support is then cast into the footing, which uses an 8" diameter sonotube that is 1' above the ground level and 2' underground. The metal cap shown in the images is in order to shape the concrete footing with a slight slope for shedding water and preventing the bamboo from absorbing much moisture. Once the foundation is set, the rest of the verticals are attached and the horizontals placed in between. Innertubes from bicycle tires are used to hold the column elements all together and then finally all of the bands are placed and tightened.





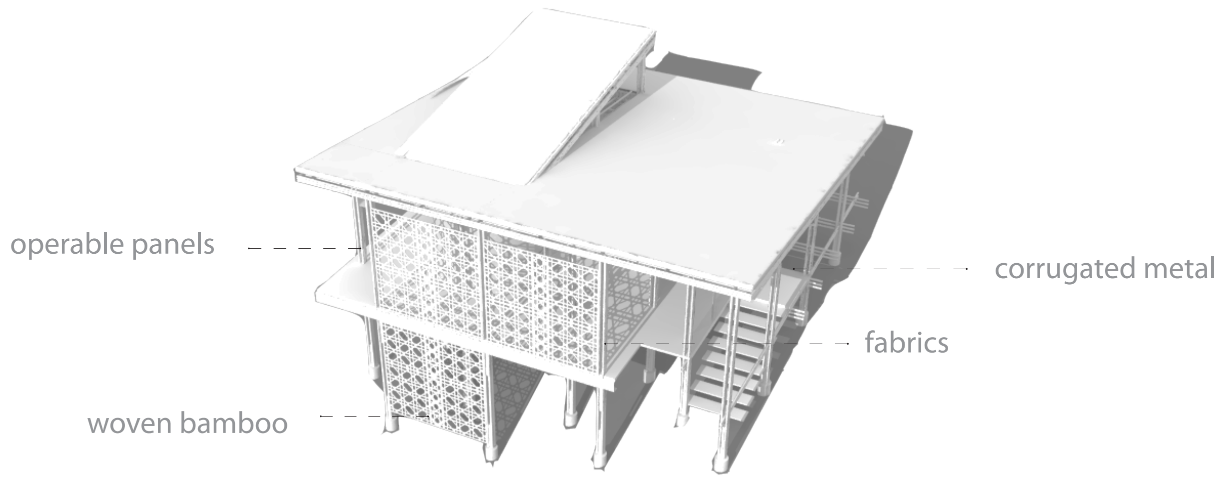

ventilation
breatheable
porous
openings
air in/outlets
sunlight
transparent
transluscent
porous
comfort
bright colors
soft
light -
transmitting
fabrics
scale
colors
light/shadow
intricate patterns
privacy
opaque
insulation
overlapping screens
solid walls
SPATIAL DESIGN ELEMENTS
MATERIALS
STRATEGIES
SLEEPING
EATING
COOKING
BATHING
COMMUNITY
LIVING NEEDS



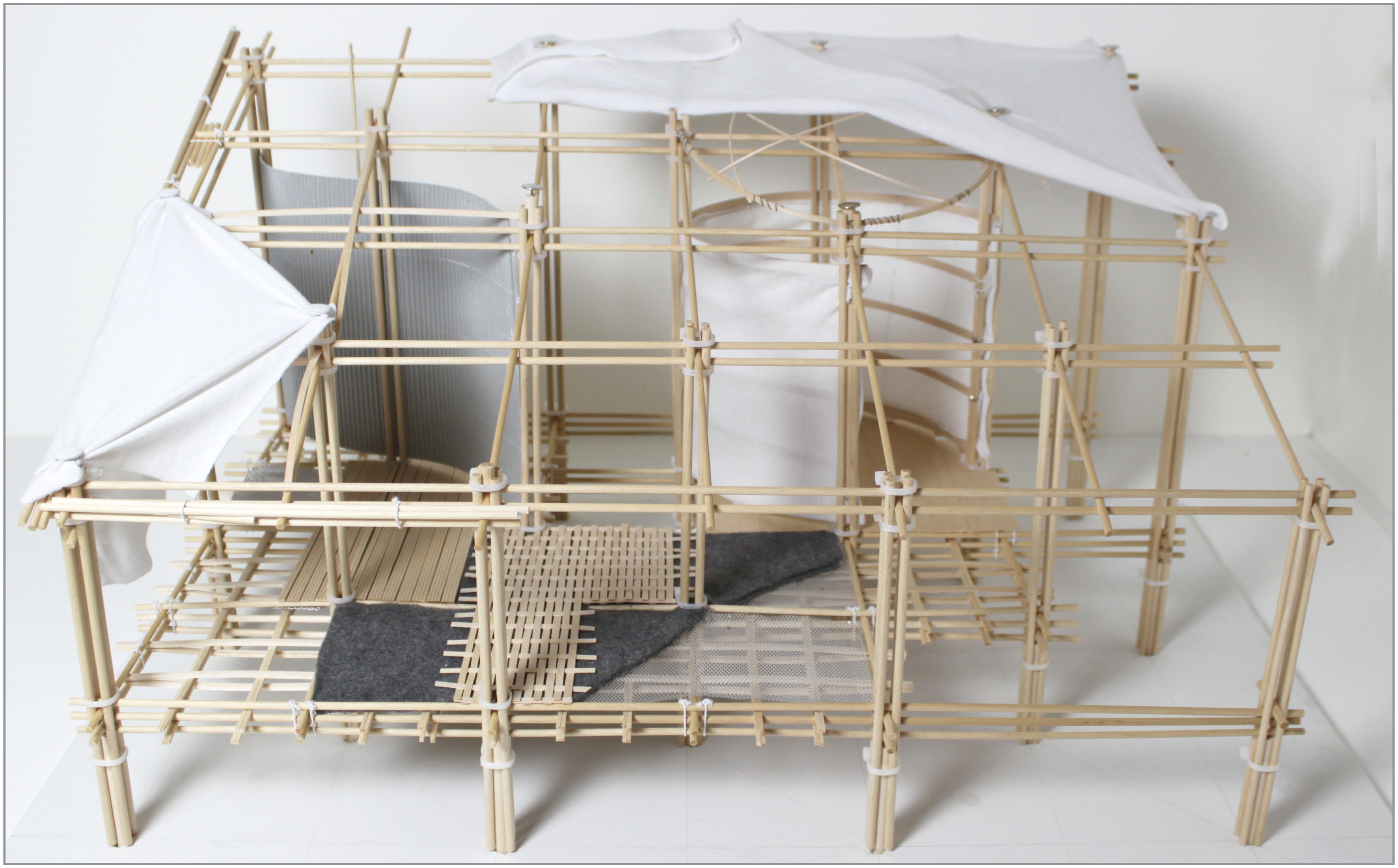
The enclosure strategies of the design are illustrated on the previous page and their possible application is shown below. I explored creative ways to use low-cost available materials to achieve the desired spatial qualities.

This part of the system is focused on the types of spaces, levels of ventilation, light, comfort and privacy. After a series of analytical diagrams and small scale models, I developed several options appropriate for the different spaces and orientations of the house. Operable panels are available to allow for proper ventilation in the cooking area, bamboo woven screens can be used for southern orientations to create light patterns, fabric walls with coco fibers for insulation create more private sleeping areas, and corrugated metal can be used for utility spaces like the kitchen and bathroom.

The 3-dimensional design of the column with four vertical members and space between them allows for all of the enclosure options to be easily installed. It is important to note that the enclosures can also be easily removed and replaced to create different spatial arrangements depending on the occupants' needs. The design of the floor plan is therefore quite flexible.



ENCLOSURE STRATEGIES



To conclude this section, the whole structure is based on redundancy. Main structural members are actually composed of several smaller poles. This redundancy in the system is necessary in order to work with the non-standard nature of the material. Several small diameter poles are easier to control than one large diameter pole. Also, the smaller members allow for the 3-d column design, which then incorporates the rest of the structure and enclosure of the house.

PHASE 4 .... CONTEMPORARY FARM LABOR DWELLING: BUILDING SYSTEM APPLICATION FOR CORE HOUSE + EXPANSION

FALL 2011

what are the climate conditions of the site? how do these conditions affect the design? what are the community needs? how does the community see bamboo construction? what are the costs associated with the project? what sort of time frame can a dwelling be built in? how many people are needed and how permanent is it? how do we make design decisions in order to create contemporary elements that receive cultural acceptance? who will be occupying the house? will the needs of the occupants change? what are the possible expansion strategies? what inspires the design of the house?

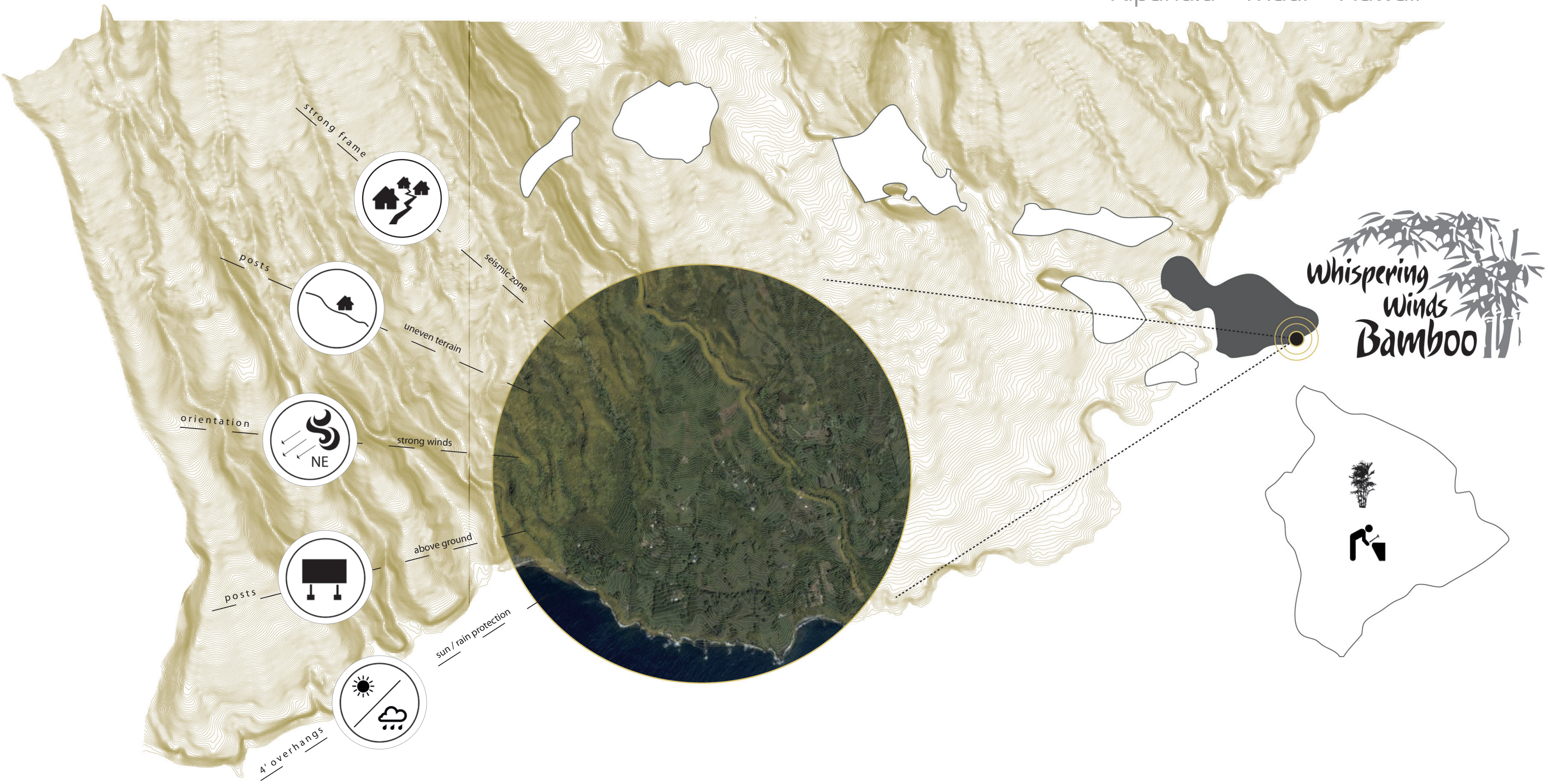
learning about the community and their needs was the main guideline for designing the dwelling. it was inspired by local Hawaiian architecture and the notion of outdoor living. Although the design is for a specific community, I am hoping to be able to apply the concept to other regions of the world.

The community I have been working with is located in ....well, paradise. It is in Kipahulu, on the island of Maui in Hawaii. It is primarily a farming community that grows bamboo, coffee, fruits and vegetables to sustain itself and support a micro economy. It is interested in reforestation of the region and a culture of living in harmony with the land.

The region has quite a strong topographical variation. It is located on the side of a silent volcano and is cut by a series of gorges. These conditions provide an uneven terrain and primarily northeast winds. It is a seismic area and on the wet side of the island. It is a rainforest with tropical storms and sun exposure.

The site conditions were important to understand as the design was developed. Such conditions are typical for tropical climates and therefore any of the decisions made could be used in other regions of the world having the same climate.

Kipahulu Maui Hawaii



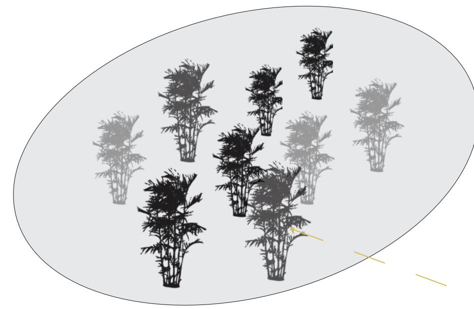

Mokupapa
Āhole Rock

The particular site I have chosen is on an organic farm, Whispering Winds Bamboo. It is a 20-acre bamboo farm working on reforestation of the region and supporting a bamboo culture on the islands – they are trying to incorporate bamboo in many aspects of life such as food, shelter, farming, and micro-economies. The farm is harvesting construction grade bamboo poles of various diameters and are interested in using it to build structures to house the staff but also to promote bamboo building on the islands.

The staff on the farm is primarily apprentices that are in a work/trade relationship and stay on the property anywhere from a few months to a few years. They are involved in all of the farming tasks and are therefore familiar with the bamboos. Apprentices currently live in houses made from dimensional lumber purchased from large corporations that buy the material from remote locations.

As the farm is interested in a self-sustaining community, they would like to build future structures using local materials - the bamboo harvested from the farm. The community needs what is best described as farm labor dwellings. The nature of this lifestyle sets certain living conditions – the structure units need to house several individuals that may be a family or unrelated adults. It needs to have a somewhat flexible floor plan and interchangeable partitions and the possibility of incremental expansion.

Since the material will be harvested from the farm, the construction of the house will depend on the availability of materials – the more material is harvested, the more structure can be added. As an example – in stage 1, the core house will be built for a couple. Stage 2 would involve the addition of a sleeping area for children. Stage 3 would involve more sleeping areas and the transformation of the core house into a communal space. Since the maximum lifespan of the treated bamboos is 25-50yrs, at the end of its life, the structure will be disassembled and recycled into mulch for the farm.



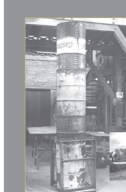
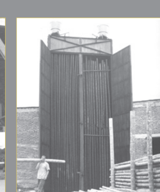
1 acre = 200 poles / yr

mulch

PHASE 0: 0-6 yrs

Before being used as a building material, bamboo is found in many other aspects of life - it is used as medicine, food, textiles, woven goods etc.

pressure treatment
borate solution
3 months to cure

treatment for building

farm labor

A young couple or two unrelated farmers are the most probable inhabitants of the dwelling in its initial stage. The core house accomodates bathing / cooking, community and one or two sleeping areas.

As children join the parents, more sleeping area is necessary and privacy becomes more of an issue. The separation of sleeping areas is an important part of this phase.

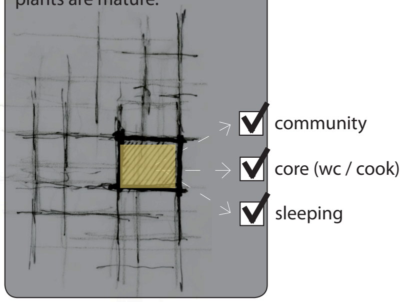
When more adults share the house, additional and separated sleeping spaces surround the core house which becomes only for communal use.

This phase marks the end and new beginning of the building process - also a new generation of inhabitants.

waste material

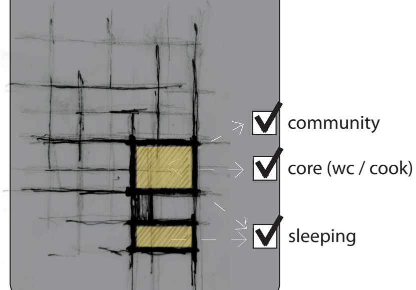
PHASE A: 6-8 yrs

Bamboo matures in 6-8 years after being planted and is therfore ready to be harvested. Since about an acre of bamboo plantation gives 100-200 culms a year (the main frame consists of ~200 poles), the core house can be constructed as soon as the plants are mature.



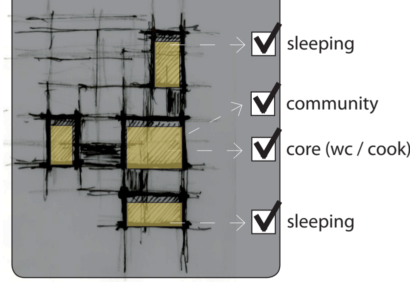
PHASE B: 8-10 yrs

As the needs of the occupants may have changed, a new addition to the core house is constructed. The few years have allowed for the necessary material to be harvested and ready for use.



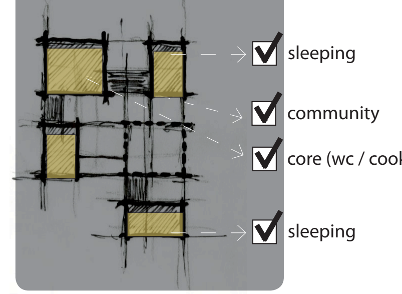
PHASE C:12-20 yr

In order to accomodate more adults that may be be unrelated, more sleeping spaces are added to the structure. The core house is now mainly community area with private spaces connected by bridges.



PHASE D:25-50yr

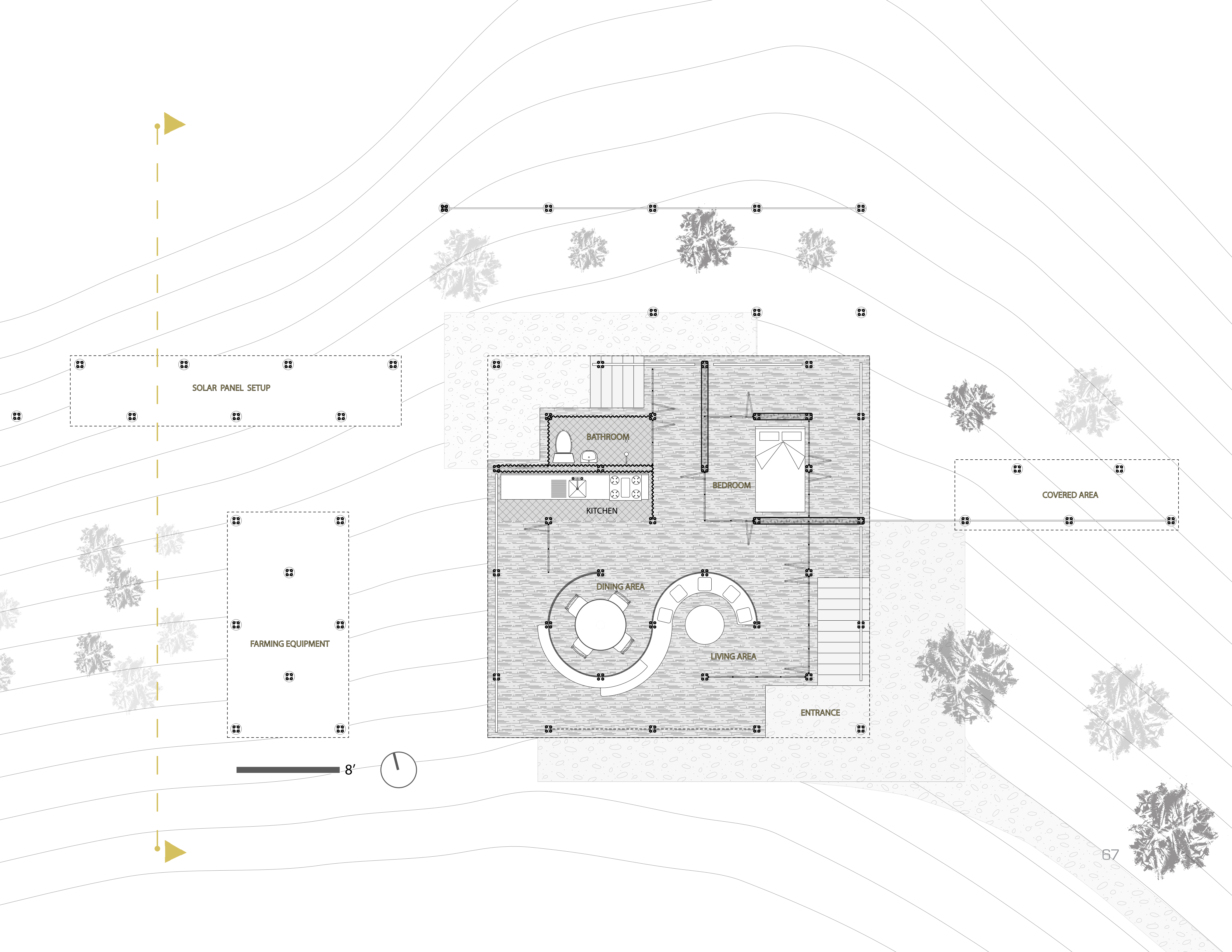
Since the lifespan of bamboo is between 25-50 years, a new core house replaces the old structure. The grid allows for the new communal area to stay connected to the private spaces. The waste material is used for nurturing the bamboo plantation.



The final stage of the design exercises was the core house dwelling. After examining the community needs and local architecture, the plan to the right was developed. It was inspired by the traditional Hawaiian lanai – a covered porch surrounding the whole house.

The proposal is composed of an open 30' x 30' square plan with 4' covered lanai. The house is mostly open with weatherproof areas for sleeping, bathing and gathering. Such areas will be enclosed during strong rains and wind. During calm weather, the whole house can be open. It has two entrances - main entrance for coming into the space from the road, and a back entrance for access to the outdoor area behind the house. The gathering space includes a kitchen, dining area and living room space. It acts as the focus of the house as it will be occupied the most.

Operable panels allow for some control of ventilation. There is a clerestory above the kitchen / bath for warm air to escape. During severe storm conditions, the house is mostly open so winds can pass through it.

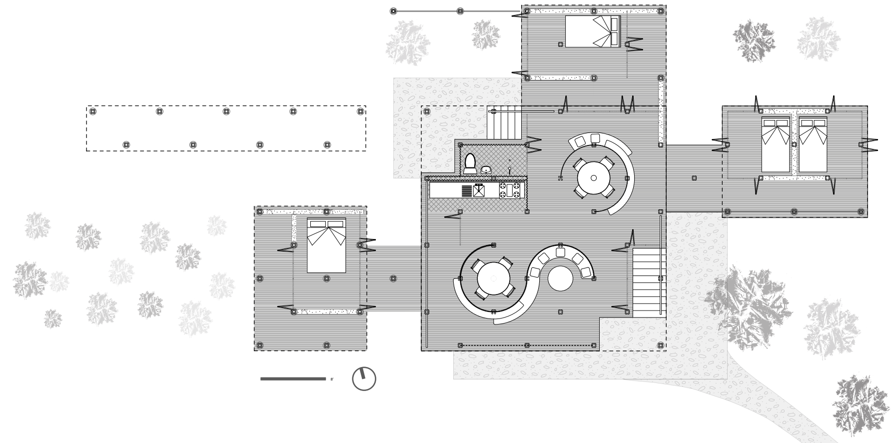

SOLAR PANEL SETUP
BATHROOM
BEDROOM
KITCHEN
COVERED AREA
DINING AREA
FARMING EQUIPMENT
LIVING AREA
ENTRANCE
8'

As the farming community changes, the dwelling needs to adapt to the different needs of the occupants.

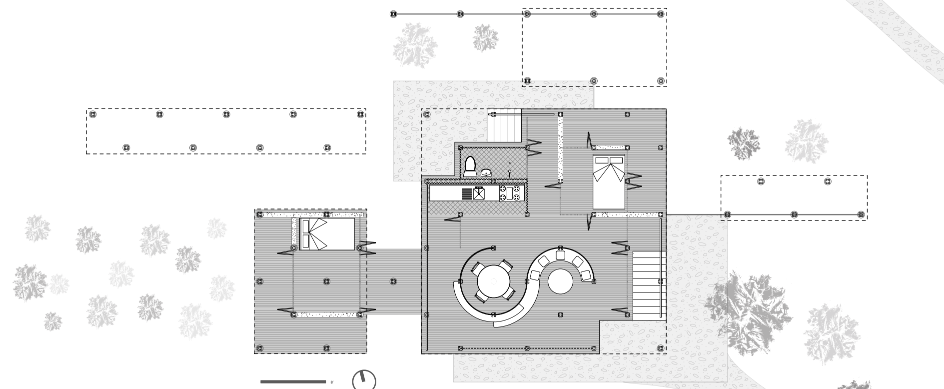
The structure allows for flexibility within the core house that can be achieved by changing the partition walls and rearranging the floor plan. It also allows for expansion by attaching more structure to the core house - either directly onto the existing structure or by building additional structures that follow the original grid and connecting them to the main house.

The plans to the right show how the core house can adapt as the spatial needs of the occupants change. The beginning phase includes several covered areas that are an extension of the column grid and can be used for farming tools / supplies. These areas can later be built into sleeping spaces that are connected to the main house. With more occupants, all of the sleeping spaces will eventually be additional structures in order to allow the core house to become larger communal space.

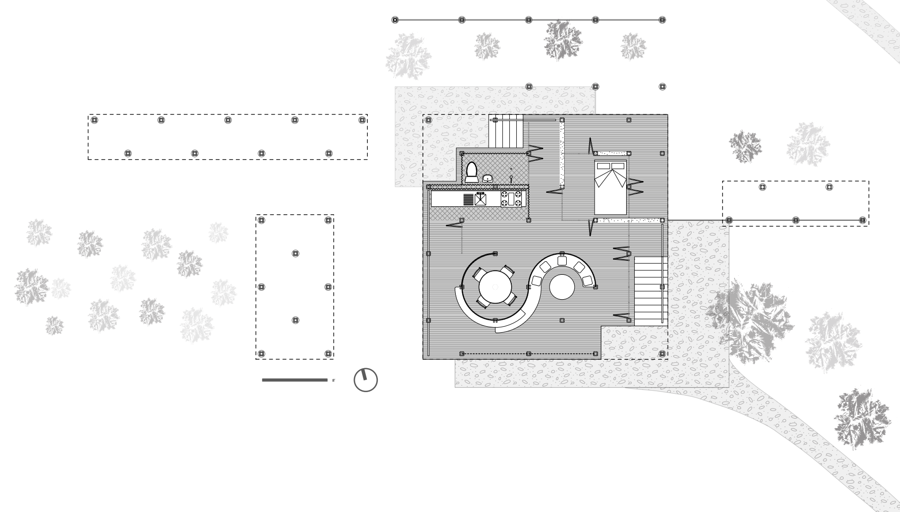
PHASE C



PHASE B



PHASE A



~ $400

28 bamboos 3" | 2'
28 sonotubes 10" | 4'
concrete
28 j-bolts

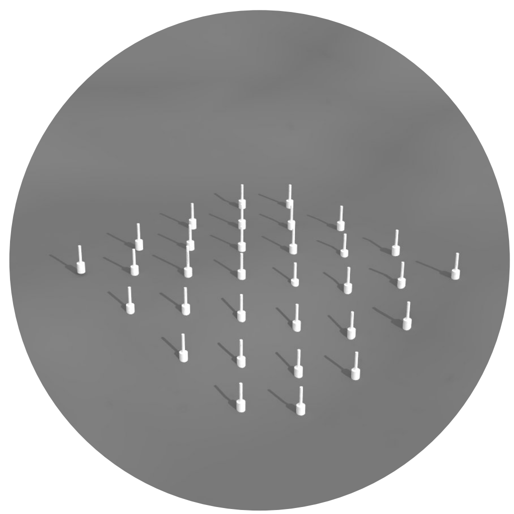
~ 3 DAYS

~ $1200

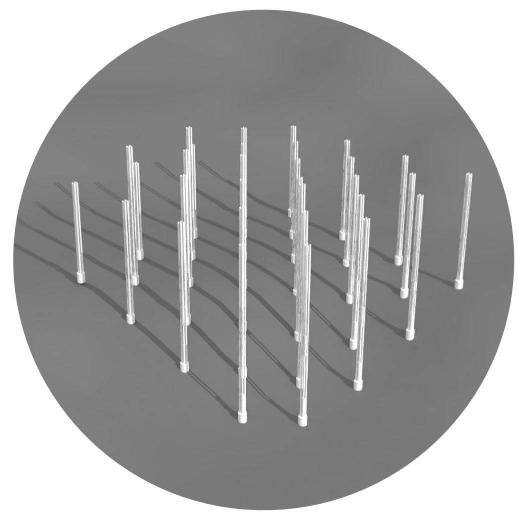
100 bamboos 2" x 10'
steel band 100'
steel buckles 56

2 DAYS

STAGE 1



STAGE 2

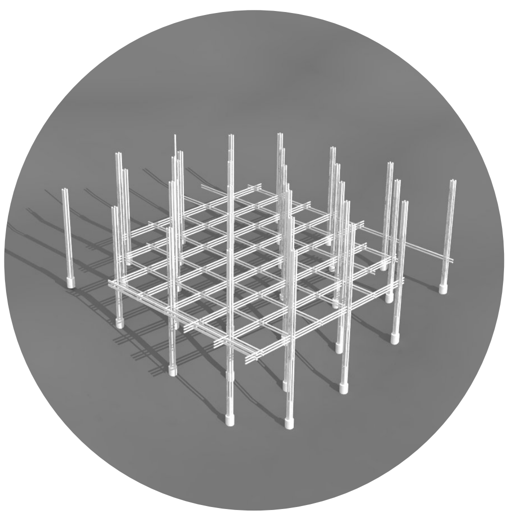


~ $1600

35 bamboos 1.5" x 30'
100 bamboos .5" x 30'
steel band 3/4" | 50'
steel buckles 28
steel band 3/8" | 100'
steel buckles 100

2 DAYS

STAGE 3

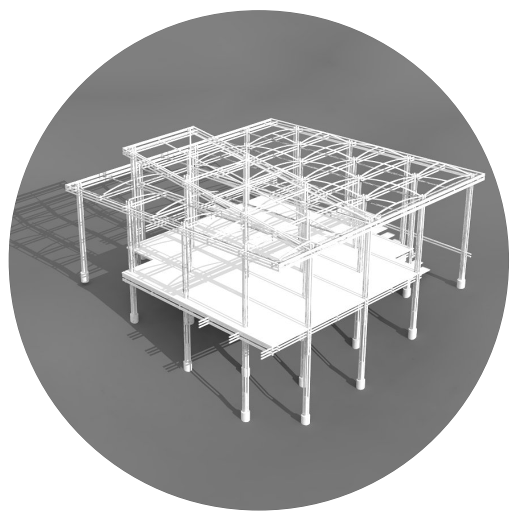


~ $2400

35 bamboos 1.5" x 30'
50 bamboos .5" x 30'
steel band 3/4" | 100'
steel buckles 50
steel band 3/8" | 100'
steel buckles 100
coconut fibers
bamboo slats | 2" split

5 DAYS

STAGE 4

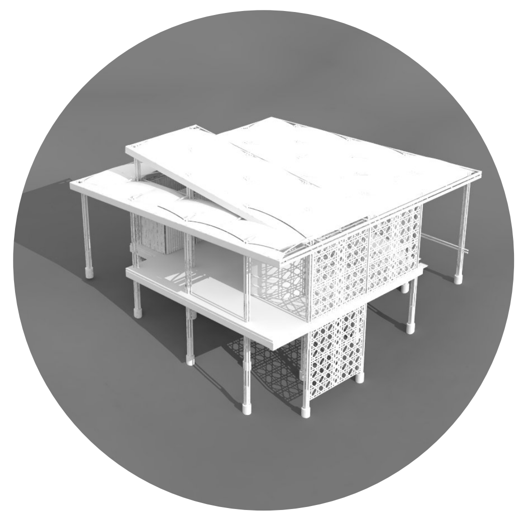


~ $1500

polyethylene
coconut fibers
corrugated metal
fabrics
woven bamboo

4 DAYS

STAGE 5



Since one of the conditions I set for myself in the beginning was to keep the house at a low-cost, I did a cost analysis.

The construction process was divided into five stages and I estimated the necessary materials, cost and time for each stage. It is assumed that four to six people are working on building the house. The images show the breakdown of necessary materials, cost, and time for each stage.

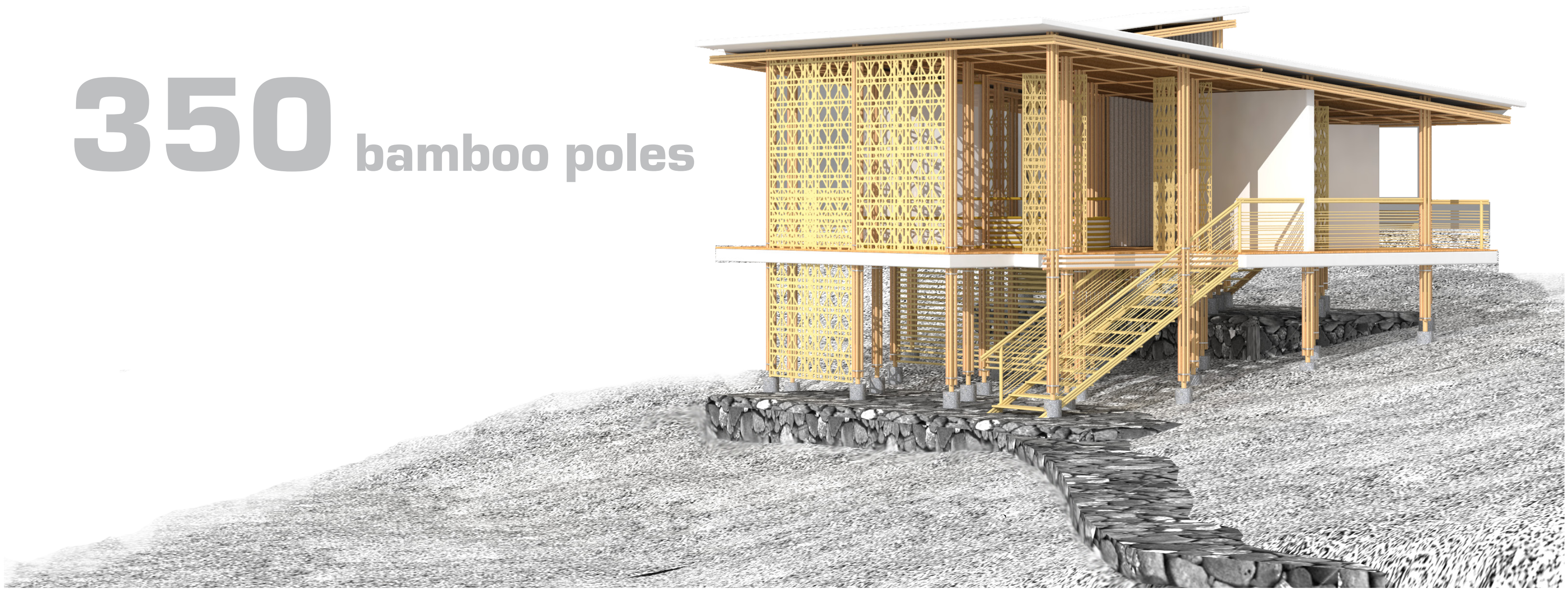
The core dwelling is estimated to cost around $7000 and take close to 350 construction grade bamboo poles erected in a little over 2 weeks. Since the structure is built on the bamboo farm, its incremental additions will happen as more material is harvested from the farm. It is estimated that 1 acre of bamboo plantation gives around 200 poles per year. Depending on the size of the plantation and housing needs, the community can build what they need.

TOTAL

16 days

$ 7000

350 bamboo poles



PHASE 5 ....BUILDING A 1/2 SCALE MODEL TO TEST THE FEASIBILITY OF THE DESIGN

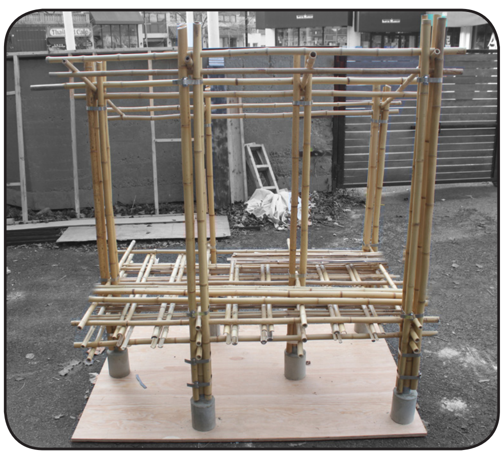
FALL 2011

what are the challenges of building with the actual material? how large of a structure needs to be built in order to test the system? will the smaller diameter bamboo behave the same as the larger ones? how many people are needed to build the structure? how are the details designed and constructed? is the structure stable enough to hold the necessary weight? what types of issues will arise while building the structure? what are the surfaces made from? floor layers and roofing?

building the large scale model helped me solve many of the issues I dealt with in the design. however, it also revealed the challenges that arise when building full scale structures.

The final two weeks of the thesis were spent in exploring the details of the design in a half scale model (shown in the images below). The model was constructed by a crew of non-architects with no previous building experience. This was important to the project as it proved that the system is easy to use by people with no particular skill set.

Constructing the model was very helpful for the process. It helped me achieve my original goal of realizing my proposed concept. By building it, I was forced to solve many questions I had about the design details and certain connections. It also provided me with the opportunity to work with the real material and explore its behavior. The slightly larger scale and size of the actual piece was a step closer to building an actual house.





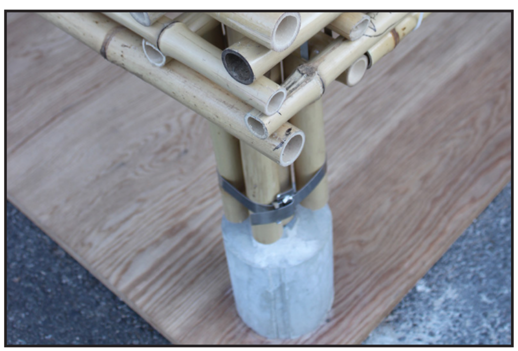






Building the model clarified many issues about certain connections and details, and of course, revealed many design decisions that needed further exploration.

The edges of the floor and wall structures, for example, needed additional bamboos and different strapping strategies in order to complete the design. Attaching the roof fabric required a bamboo pole to be inserted in a sleeve and then tightened and wrapped around the structure. Also, the floor top most surface (flattened bamboos) was satisfactory for the moment but in reality needed to be much more even and carefully attached to the frame.



Unfortunately, the weather did not allow for much wall exploration. The main idea was that they would be easily incorporated into the space between the columns. The image to the left shows how fabrics can be wrapped around the columns to create some partitions.

The model was built by six people in a timeframe of six days. It did not require any special skill, nor did it use any electricity. It allowed me to explore the material a bit further and to deal with its unique nature. Building the large model was extremely valuable for the thesis work. It proved that the concept has the potential to be developed into a real life application.

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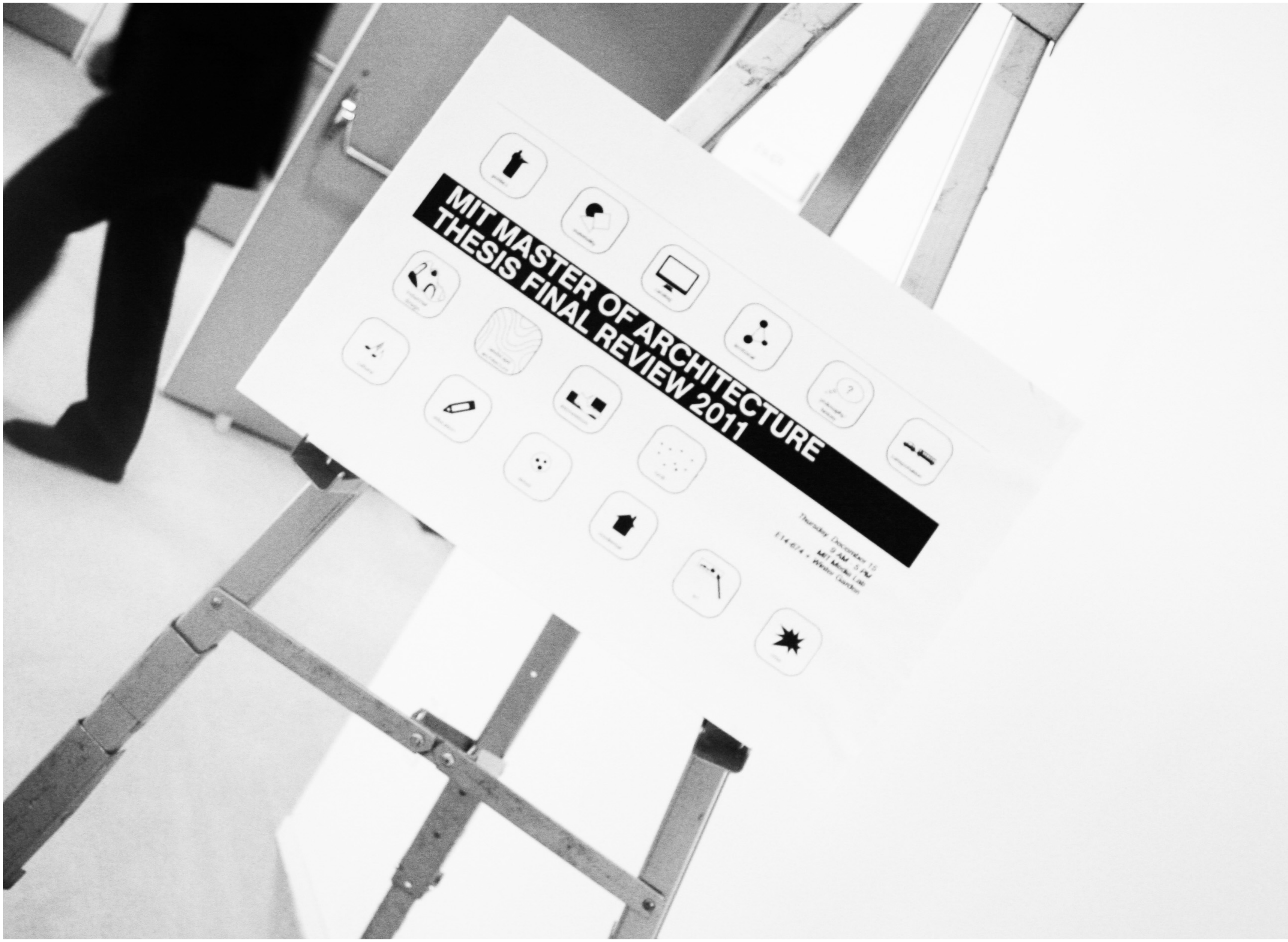
Conversations with: Jay Tapis, Rich von Wellsheim, Chris Dewart, Darrel DeBoer, Anna Heringer, Reinhart Goethert


MIT MASTER OF ARCHITECTURE
THESIS FINAL REVIEW 2011

DECEMBER 15, 2011 @ 11:00 AM

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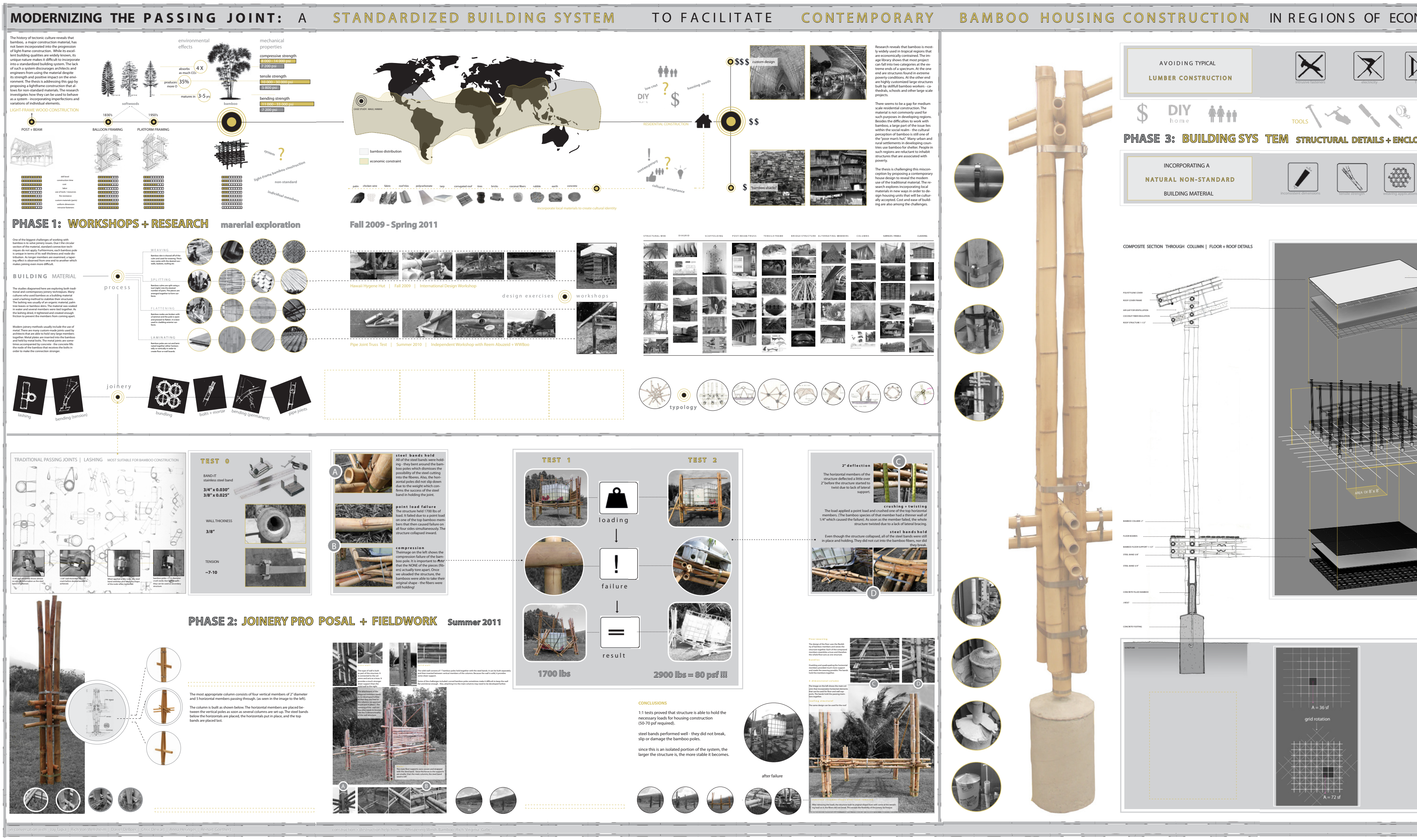
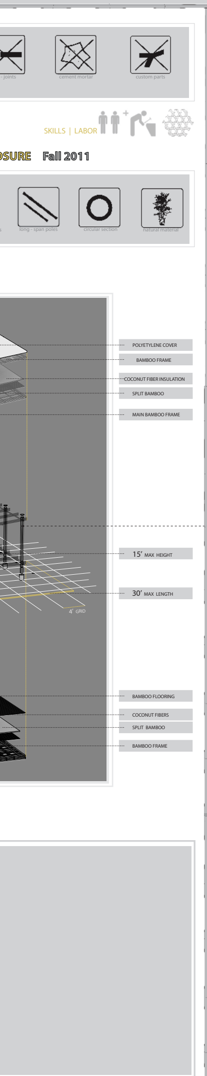
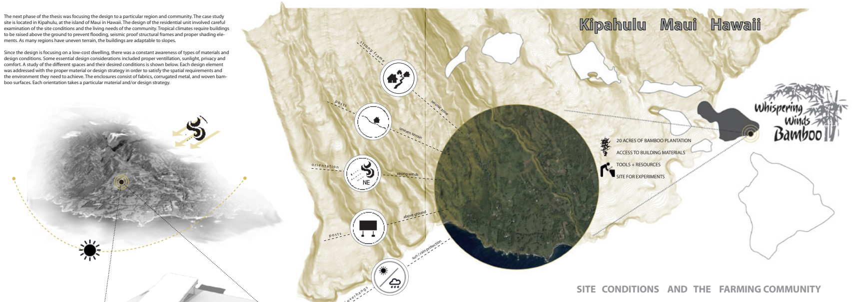
the conversation...

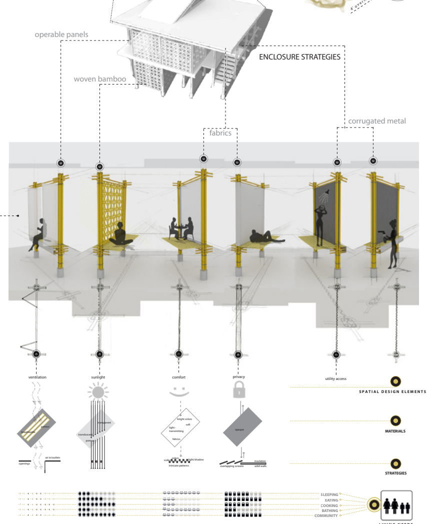

MODERNIZING THE PASSING JOINT: A STANDARDIZED BUILDING SYSTEM TO FACILITATE CONTEMPORARY BAMBOO HOUSING CONSTRUCTION IN REGIONS OF ECON
PHASE 1: WORKSHOPS + RESEARCH
mareial exploration
Fall 2009 - Spring 2011
BUILDING MATERIAL
process
joinery
design exercises
workshops
typology
AVOIDING TYPICAL
LUMBER CONSTRUCTION
DIY
home
PHASE 3: BUILDING SYS TEM STRUCTURAL DETAILS + ENCLO
INCORPORATING A
NATURAL NON-STANDARD
BUILDING MATERIAL
COMPOSITE SECTION THROUGH COLUMN | FLOOR + ROOF DETAILS
TEST 0
TEST 1
TEST 2
loading
failure
result
1700 lbs
2900 lbs = 80 psf !!!
PHASE 2: JOINERY PRO POSAL + FIELDWORK
Summer 2011
A = 36 sf
grid rotation
A = 72 sf

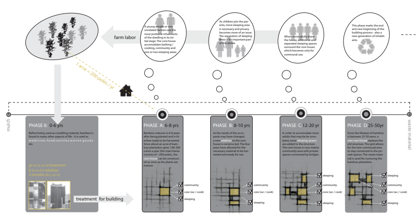


The next phase of the thesis was focusing the design to a particular region and community. The case study site is located in Kipahulu, at the island of Maui in Hawaii. The design of the residential unit involved careful examination of the site conditions and the living needs of the community. Tropical climates require buildings to be raised above the ground to prevent flooding, seismic proof structural frames and proper shading elements. As many regions have uneven terrain, the buildings are adaptable to slopes.

Since the design is focusing on a low-cost dwelling, there was a constant awareness of types of materials and design conditions. Some essential design considerations included proper ventillation, sunlight, privacy and comfort. A study of the different spaces and their desired conditions is shown below. Each design element was addressed with the proper material or design strategy in order to satisfy the spatial requirements and the environment they need to achieve. The enclosures consist of fabrics, corrugated metal, and woven bamboo surfaces. Each orientation takes a particular material and/or design strategy.







A CULTURE OF BAMBOO: MATERIAL LIFECYCLE CLOSELY RELATED TO THE LIFESTYLE OF THE COMMUNITY

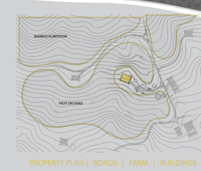
This rural area of the island is focused on living with nature and trying to promote an eco-friendly lifestyle. The community is primarily farmers growing fruits, vegetables, coffee, bamboo etc. They are a mixture of local Hawaiians and mainlanders who live on the islands.

There is a need for low-cost farm labor dwellings that uses eco-friendly materials to preserve the plantlife of the area. The community is supporting a culture of bamboo and encourages its use in many aspects of life. The occupants of the dwelling will be apprentises who live and work on the farm and therefore are there for a short period of time. The housing unit needs to be flexible and accomodate the changing needs of the inhabitants.

The design addresses this need by providing a frame that can be enclosed in a variety of ways. Depending on the available materials and spatial requirements, the space can be built to serve the purposes of sleeping, bathing, cooking and gathering areas.

STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5
~ $400	~ $1200	~ $1600	~ $2400	~ $1500
28 bamboos 3" | 2' 28 sonotubes 10" | 4' concrete 28 j-bolts	100 bamboos 2" x 10' steel band 100' steel buckles 56	35 bamboos 1.5" x 30' 100 bamboos .5" x 30' steel band 3/4" | 50' steel buckles 28 steel band 3/8" | 100' steel buckles 100	35 bamboos 1.5" x 30' 50 bamboos .5" x 30' steel band 3/4" | 100' steel buckles 50 steel band 3/8" | 100' steel buckles 100 coconut fibers bamboo slats | 2" split	polyethylene coconut fibers corrugated metal fabrics woven bamboo
~ 3 DAYS	2 DAYS	2 DAYS	5 DAYS	4 DAYS

TOTAL = $ 7,100
TOTAL = 350 bamboo poles
TOTAL = 16 days



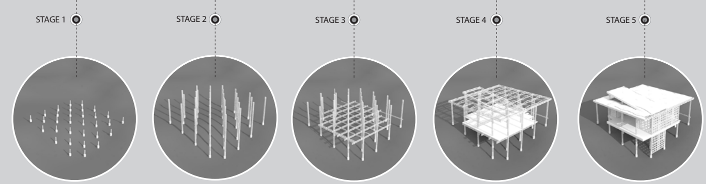
PHASE 4: CONTEMPORARY FARM LABOR DWELLING building system application: core house + expansion

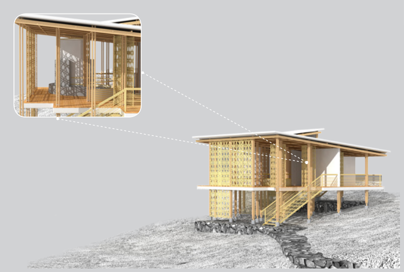
The construction process is done is several stages outlined to the right. It is assumed that four to six people are working on building the house. The images show the breakdown of necessary materials, cost, and time for each stage.

The core dwelling is estimated to cost around $7000 and take close to 350 construction grade bamboo poles erected in a little over 2 weeks. Since the structure is built on the bamboo farm, its incremental additions will happen as more material is harvested from the farm. It is estimated that 1 acre of bamboo plantation gives around 200 poles per year. Depending on the size of the plantation and housing needs, the comunity can build what they need.

The core house is assumed to expand as the occupants change. The fisrt stage includes a space for sleeping, lavatory/kitchen core, and community space. As more people join, additional structures can be added and attached to the structure.

The lifecycle of the material is closely related to the lifestyle of the occupants. As bamboo lasts for 25-50 years, the structure is going to need maintenance and repairs. The availability of material and type of system allows for such changes to take place.





The final thesis presentation is a moment every masters student fears and is greatly excited for. It is the moment of fame, and the moment which marks freedom.

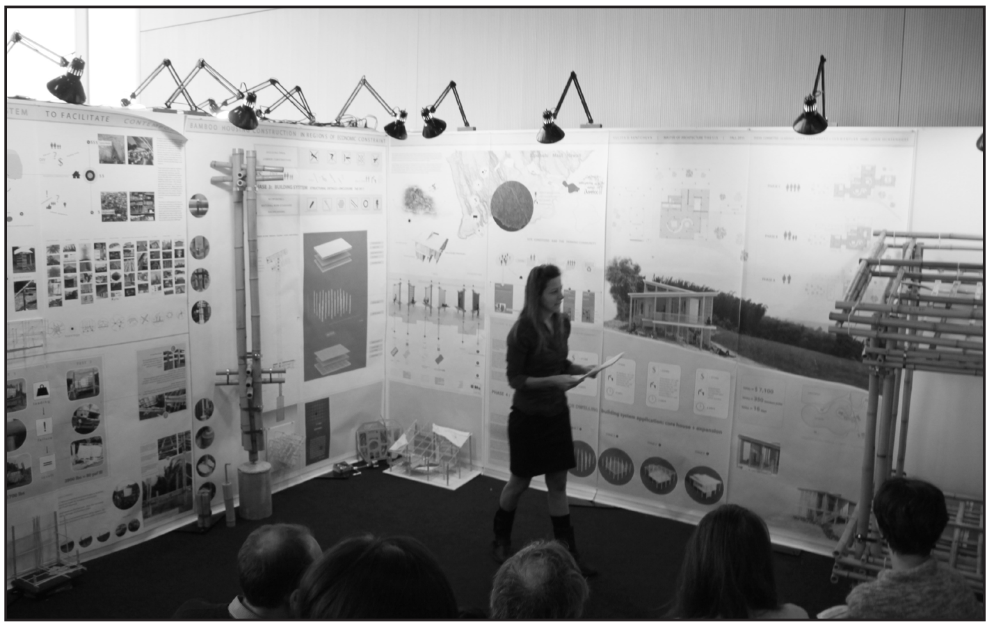
The combination of having slept a bit the night before, having my family and friends there and the support of my thesis committee made the presentation exactly what I had hoped for - a time to share with the audience what I had been working on so passionately for the last two years and to receive their comments and feedback.

The discussion took a couple of different directions that were all valuable to mention. The strict grid of the system was questioned and if there is a potential for a more free form and therefore some customizing. The joinery techniques and the properties of the material do allow for this direction to be explored at the expense of skill level and cost. Another important comment was the application of the system in other regions of the world. As mentioned in the book, the design of the dwelling was to serve the farming communities in Hawaii but the general system concepts are applicable for other regions sharing the same site and climate conditions.

The discussion concluded with a question on what the next step of the work is - how the new knowledge will be distributed to reach individuals interested in this type of building. Whether is it in the form of a pamphlet, a kit of parts, or workshops, the work has the potential to reach real life applications.


MODERNIZING THE PASSING JOINTS: A STANDARDIZED
PHASE 1: WORKSHOPS + RESEARCH

IN THE SPOTLIGHT



LIVING MY PASSION

FALL 2004 - FALL 2011: 7 YEARS @ MIT

this part of the book is for all of the people in my life who made this possible.

To Jan,

Thank you, thank you thank you for all that you have done for me throughout these years. Thank you for convincing me to come to Hawaii with you and for that one hour of beachtime that made me fall in love with the islands... =) Thanks for the crazy car rides, even more crazy stories and for teaching me to believe in myself and my abilities.

For helping me find something I am so passionate about and guiding me through the process of making it a reality. Thank you for believing in me and always being there in the good and bad moments. Thanks for helping me believe in architecture and its endless possibilities.

I truly admire and appreciate you and am so happy you were part of my academic career in the past 7 years!

To John F.,

Thank you so so so much for always being there for me since day 1 @ MIT. I still remember that first day in your office and your warm welcome into this crazy environment and the opportunity to work with you for what came to be seven years! Thanks for believing in me and seeing the potential and helping me find my way around. Thanks for all of the financial support without which I would have had a bit more of a stressful time here =)

Thanks for being such an important part of my thesis work, for your guidance and inspiration throughout the last 7 months. Thanks for your valuable feedback and direction which made the final presentation what it was and helped me be confident and show my passion at the end.

I am so lucky to have had the chance to work with you and hope to stay in touch in the future. Thanks for the being one of the most respected, influential and inspiring figures in my MIT experience!

To John O.,

Thank you for all of your support and valuable feedback. Ever since that midreview and your constructive comments, i worked and worked and worked on that presentation until I was able to show that excitement, and the passion that I truly feel for my work. Thank you for being there and guiding me through it.

Your presence and inspiration during both my undergrad and grad MIT experience helped me shape who I am. Thank you!


YULIYA D. BENTCHEVA
MASTER OF ARCHITECTURE THESIS
FALL 2011
Kipahulu Maui Hawaii
Whispering Winds Bamboo
SITE CONDITIONS
ENCLOSURE STRATEGIES
PHASE C
PHASE B
PHASE A

BICI

BROTHER

To the most special people in my life, the fantastic 6 who just simply rock. Thank you for your construction help in the freezing ass cold! Thanks for helping me realize my goal and building that damn little house. Thanks for putting up with me in the stressful time when I wasn't at my friendliest... Without you guys, I would not have been able to do this important part of my work...

THANK YOU

TO MY CONSTRUCTION CREW

KIKI

NASKO

LILLY

And more importantly, Thanks for being part of my life for the last almost 27 years for some of you and as little as 12 years for others =) You have been next to me in the good and bad times, and I really really really love and appreciate you!!!
m a i n i 4 k i i i i i i i . . . .









To my parents

Thanks for,........well for so many things that wont fit in this little text box. Thank you for believing in me and encouraging me every step of the way. Thanks for giving me the courage and inspiration to continue when all I wanted to do is run away to an island (which is what I will end up doing anyways =). Thanks for your financial and more importantly for your unconditional love, understanding and moral support . I love and appreciate you and thank you from my heart for being who you are and helping me create who I am.

To Bici

Thanks for being my best friend and partner in life for the last 10 years. Thanks for your love, support and understanding especially throughout the last few months. Thanks for being part of my life even when you only got to see me at random times of the day and night. Thanks for supporting me though the rough times and always always always understanding and valuing the importance of school and architecture in my life and letting me be what I want and do what I want. Obi4am te !!

Whispering Winds Bamboo

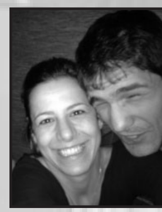
M A H A L O

Thanks to the whole crew for the CONSTRUCTION and DESTRUCTION help you willingly provided me with!! Gabe, thanks for helping me build my little house and nearly getting killed by it ;-) Rich and Virginia, I thank you from the heart for giving me the opportunity to stay on the farm and be part of the community. Mali, thanks for sharing some of my most memorable moments and always bringing the aloha spirit with you. Ryan, Seth and the rest of the crew, thanks for letting me work with you and be part of the team.

a l o o o o o o o o o o o h h a a a a . . . .

Zahraa Ella Travis Runo Flooooo Em Lo

Jay, thanks so much for all of your support and inspiration. Thanks for finding the time to help me work throughout the last year of MIT, your guidance helped me stay sane and believe in my work. Thanks so so so much!!



Sloboooo, cheers man!! For all the good and ridiculous times =)

Adwoooo, thanks chale, for the sunshine and happiness that you carry around you. Thanks for being there for me when I needed a friend and thanks for all of the beautiful moments we shared. Love you and kiss you and hugggg you!

Doone !! Hi =) I did it, island girl built something! Thanks for sharing the 5232 waikoloa spirit and Big Island Love with me. Jamming the hell of those bamboos would have not been the same without you. Thanks for being the best world travel buddy and for tennis balling all of those islands and some mainlands with me. We keep it movin', rocking the van...as you say 'as it should be...' =)

CHEERS

Reems, thanks for being the happy you, and making the days brighter with your smile. Thanks for being up for the goofy adventures we went on and sharing fun fun fun times with me. Whether it was HI flowers or going up to the dome, you made my days here filled with moments to cherish! Love you!

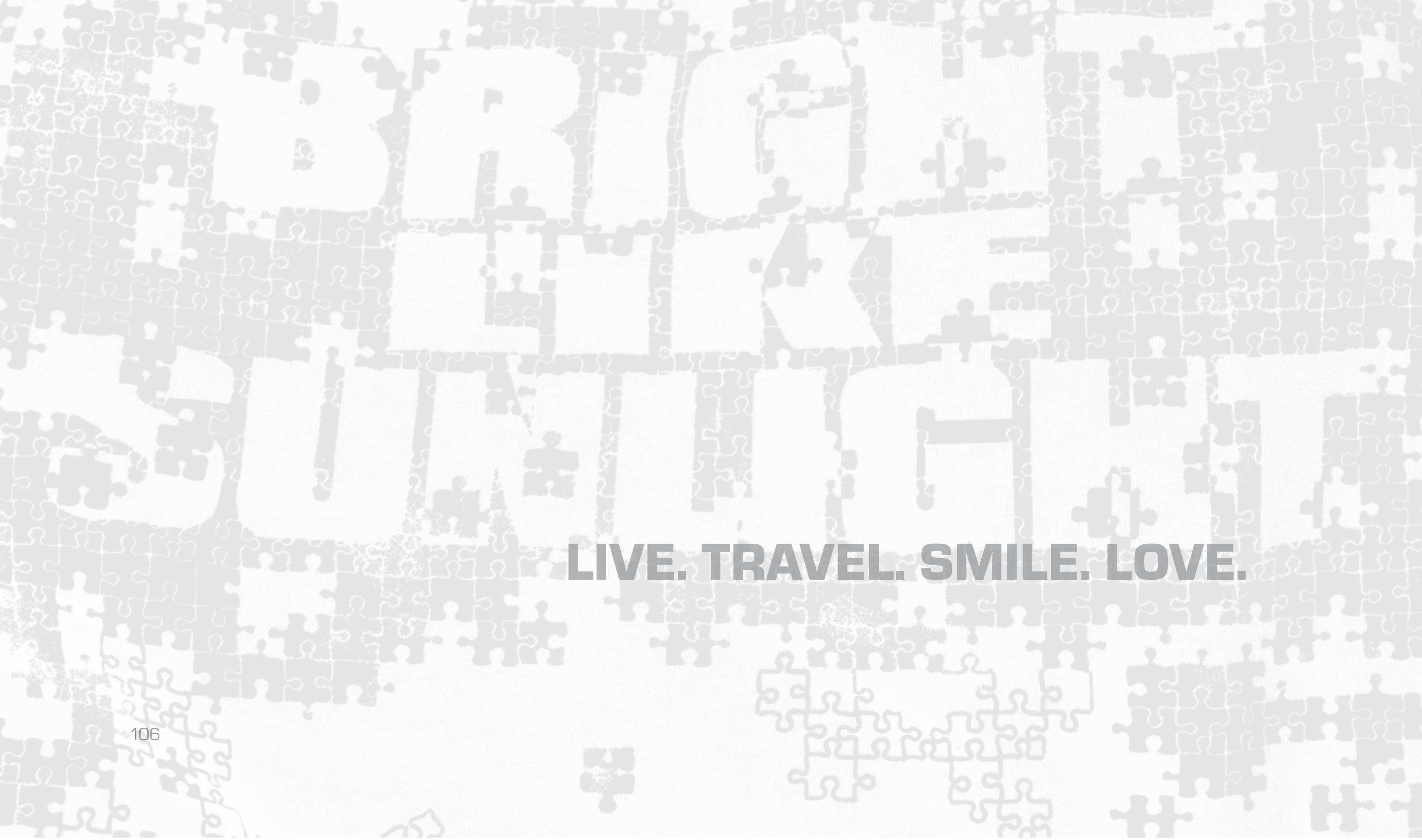
As John F. said during my defence, the master's degree is completed in order to explore a subject in great depth and become somewhat of a master at it. This thesis work allowed me to achieve that by learning a great amount about a material and its possible applications.

Working with bamboo for the last couple of years made me really passionate about it and interested in pursuing its applications even further. Building a full scale prototype house and testing its feasibility is going to be the goal down the road. As for the immediate future, I am moving to Hawaii and working with the community in Kipahulu. I am going to build a couple of small scale structures including an ice-cream stand / pavilion.

So, the end for me is actually the beginning of something challenging and very exciting. So, I am out to

"Live my Passion."

Life isn't about f i n d i n g yourself.... Life is about CREATING yourself.



LIVE. TRAVEL. SMILE. LOVE.


ILTFP
@ THE DOME...