Reshape, Inform, Inspire 2.0: Virginia Tech Architecture

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Reuse of Materials and Construction with a New Bus Stop Structure
Fall 2012

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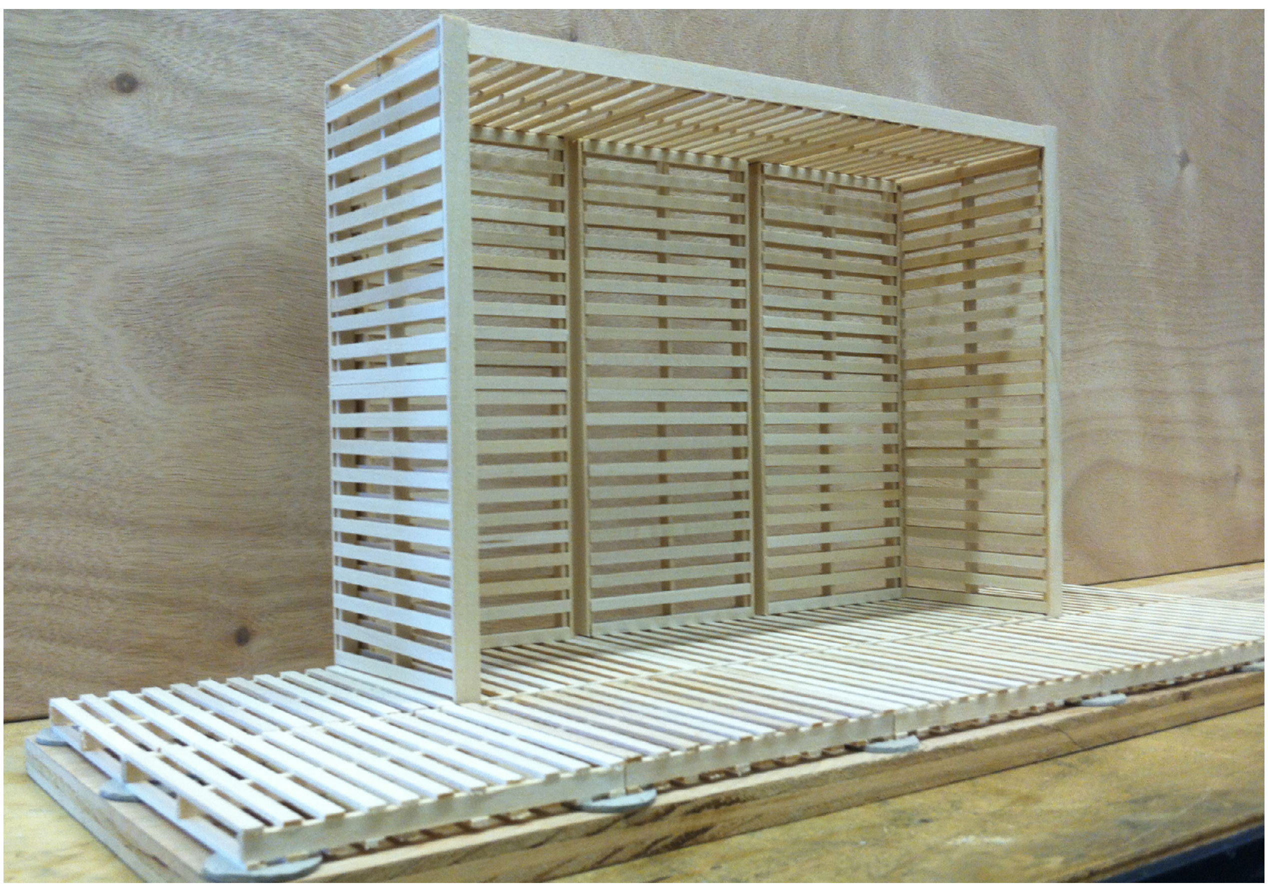
Abstract

Palletecture: Reuse of Materials and Construction with a New Bus Stop Structure

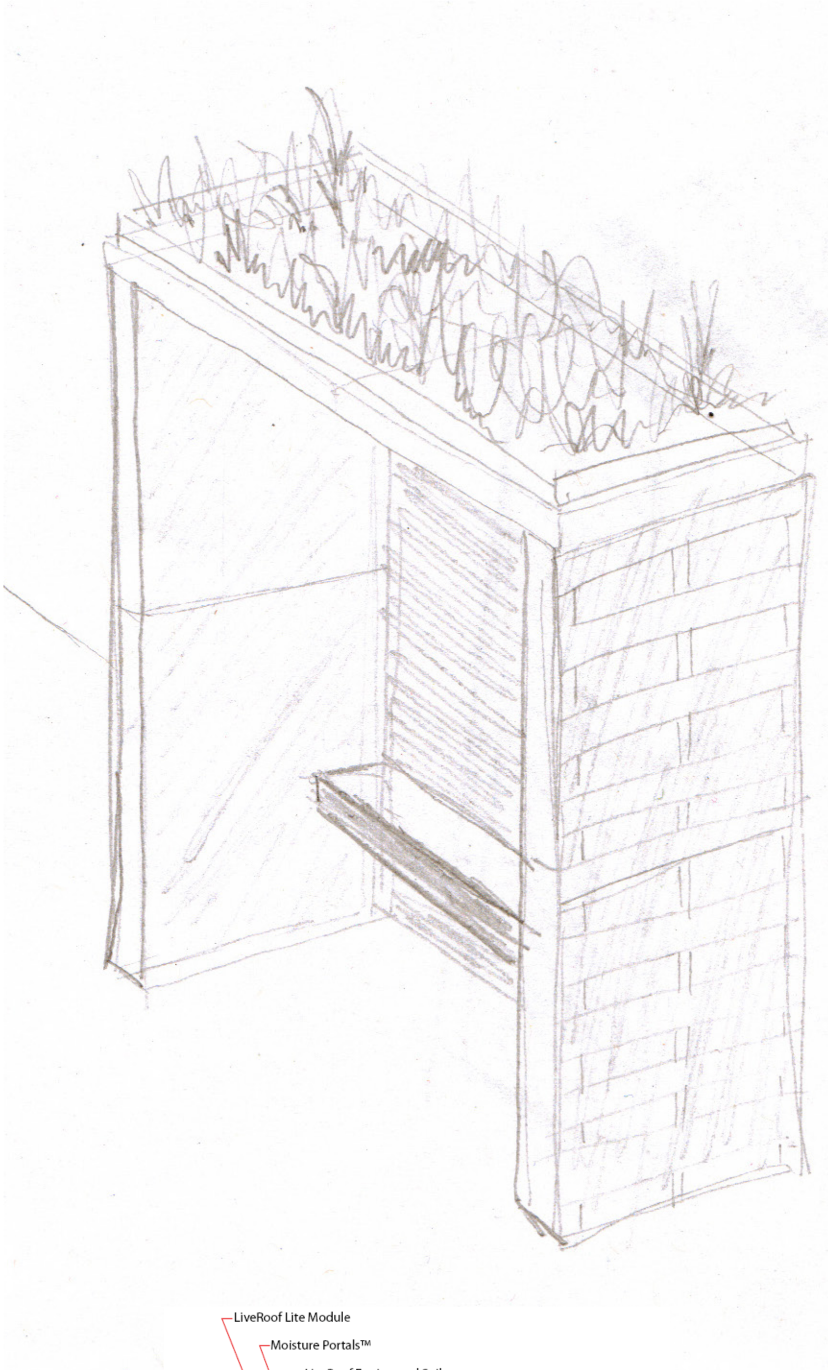
A team of undergraduate architecture students is pursuing innovative new uses for the wooden pallet, a byproduct of the shipping industry that is often discarded in landfills. After successfully designing and building both a deck and planter system and a bus stop shelter out of used pallets two years ago for a competition for Sustainable Blacksburg, they propose to create a new prototypical bus stop shelter. The new structure will be developed using lessons learned from the first two projects. The two emphases of material reuse and construction will guide the project's development as it is constructed in the fall of 2012.

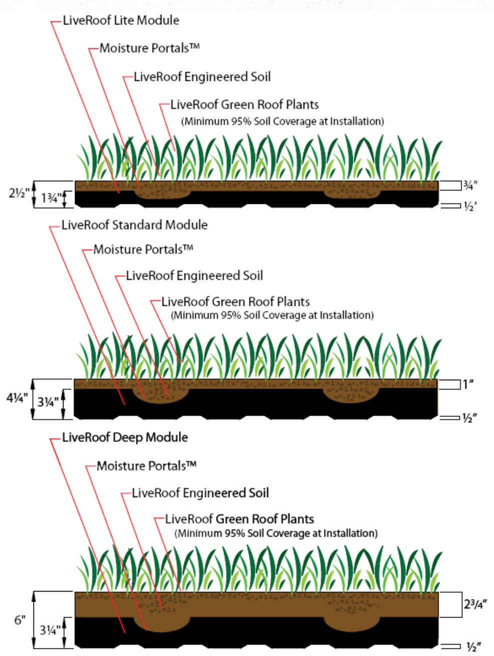
The significance of the study is to show the potential for a repeating frame of pallets to make almost any size of structure. That, as a frame, the structure would be extruded into any length using the width of the pallets as the increasing depth. As long as the structure had pallets of similar width per frame unit, you could build a deeper structure. Furthermore there was also the potential to hang installations within the structure, using it as a gallery space. The pallet has become a catalyst for discovery.

In this vein of discovery, the next step is to determine if the frame can be used at full scale to construct a non-rectilinear frame and enclose the space. Using the same properties as the bus stop frame of sandwiching pallets between two frames, the pallets will then become the rigidity and enclosing envelope for the space. If the structure proves stable, the pallets that carry other materials to the site can then be used in the structure to further minimize waste from construction sites. Furthermore, using the longer dimension of the pallet, it may even be possible to then have the width of each frame be approximately four feet, making a module in the building envelope.



Reshape, Inform, Inspire 2.0: Introduction





The purpose of the project is to combine the two methods of using pallets. In this way we use fully intact pallets to construct an alternate bus stop for the city of Blacksburg.

Furthermore, this structure will test the ability of individual green roof modules to survive outdoor conditions in order to determine if exposed conditions are prohibitive to modular green roofs. Finally, we hope that the structure is a interesting demonstration of green roof technology.

To the left are drawings of an initial proposal, implementing the LiveRoof® modules. Below it are several sections of green roof modules.

The proposal then aims to determine if green roof modules are appropriate to implement on reinforced pallet construction in a structural manner (static loads) and in an aesthetic and ecologic manner (growth of sedums).

Once this is tested in the short-term and is proven to be of sound construction, the growth of the system will be monitored and recorded to see if the green roof modules survive when not adjacent to other units

This temporary experiment can test the physical improvements prior to full implementation in the industry in order to test the efficacy of the system.

In this manner, the incremental implementation of the pallet bus stop, the building envelope can become a laboratory in which results are observed and measured in real time.

Images: LiveRoof®

Reshape, Inform, Inspire 2.0: Background: Tactical Urbanism

Tactical

1: of or relating to small scale actions serving a larger purpose

2: adroit in planning or maneuvering to accomplish a purpose

The question in Urbanism and therefore in building envelope design is:

how do we become tactical in nature as to perform the greatest service to the community at large as to inspire long term change with short term construction?

The lack of resources and material is no longer an excuse to act. The concept to only take action after every last variable is controlled is a plan for paralysis. How can you do anything is all you do is plan for every last minute detail?

The planning of a project needs to follow a balance, that as much as feasible is planned, in order to achieve the desired results, *then do the build*.

Only by building can an idea come into the world and become visible. It is the visibility of the envelope that we hope to achieve by incorporating a forgotten material, the pallet, with an emerging technology, the green roof. This combination aims to bring a plethora of smaller projects intended to showcase roofing technologies to the public.

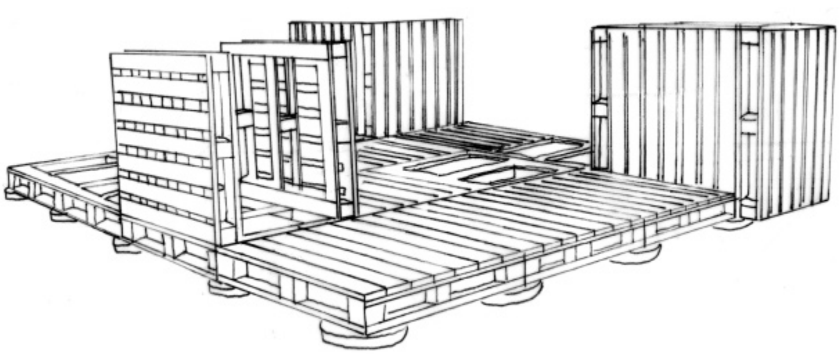
By rethinking the ubiquitous bus stop we hope to reshape the conventional notion of building envelope and inform others about envelope technologies, finally inspiring others to become:

TACTICAL.

Pallet Bus Stop Sub-Structure Test
Photo courtesy of: Kenneth Black

A heavily used custom oak pallet for concrete.
Photo courtesy of: Kenneth Black + Ross McFarland

A stack of reclaimed pallets from a construction site.
Photo courtesy of: Kenneth Black + Ross McFarland



Reshape, Inform, Inspire 2.0: Deck + Planter Module

The unaltered pallet is a modular element which can be improved and placed into the overall system.

Through sanding, the surface gains new clarity while still maintaining the scars and memory of its former uses.

The staining then gives the pallet a new aesthetic character in addition to practical protection from the elements. Finally, each renewed pallet is placed into a system which relates one to the other. This system then becomes an environment in which new growth arises.

The footing became an exploration rather than just a problem to be solved. We wanted to integrate another element into the project, in addition to the pallets, that originated from a reclaimed material.

The plastic flower pot became a mold which leaves its imprint on the concrete. The plastic, after the concrete has been removed, will ultimately become the liner for the low planters. This demonstrates the versatility of a material to be used in multiple forms.

The system reshapes the function and identity of the pallet, becoming more than landfill waste. The reshaped pallet informs the user of the possibilities by demonstrating a particular method of pallet reuse.

This then reshapes the user's notion of the pallet's potential, bringing innovative reuse to the forefront. Ultimately, this inspires the user to then improve upon the pallet and design new forms for a material previously disregarded. The pallet has become a catalyst for discovery.

All photos courtesy of: Kenneth Black + Ross McFarland

Reshape, Inform, Inspire 2.0: Bus Stop Shelter

The pallet. An overlooked moving mechanism manufactured specifically from rejected lumber, thrown away once it has reached the end of its worth. A set of components, each with its own purpose, but working together as a whole.

Sustainability poses the question of how we can use recycled or reclaimed materials in place of new ones.

Using the Town of Blacksburg as a model for application, we took a discarded item, the pallet, and looked toward deisgning something that was lacking in town.

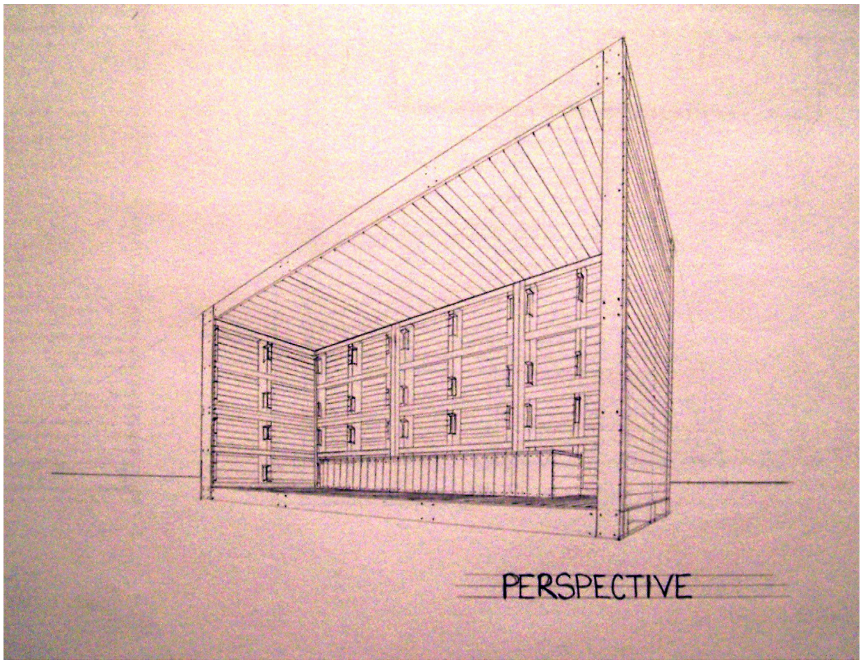
The idea for a bus stop shelter arose from the BT Transit stops that lack any shelter.

While the larger stops have shelters, the intermediate stops have none, leaving the riders exposed to the weather.

The driving force behind the bus stop shelter is to let the language of the pallet dictate the design, how the components interact and what function each serves. Stringers are the structure and slats holding the structure together.

A bus stop shelter composed of reclaimed material not only promotes sustainability in its construction, it also encourages the use of public transportation, by keeping riders out of the weather as they await the bus.

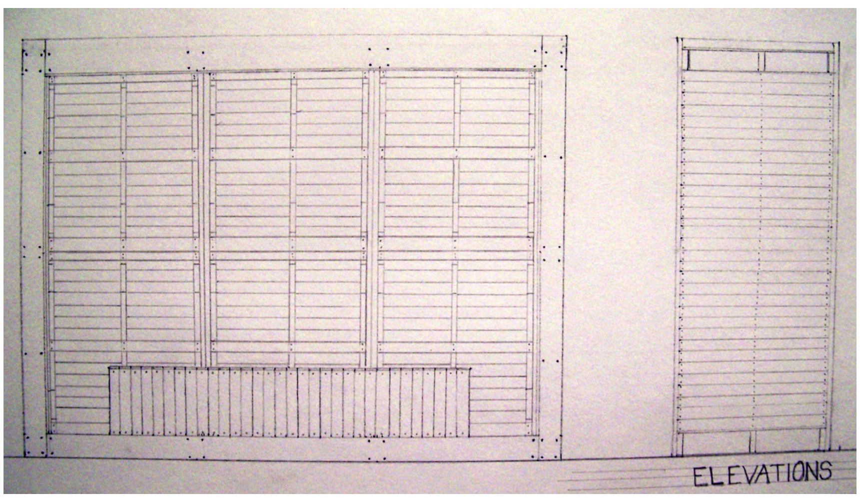
All photos courtesy of: James Trent, Logan Hoffman, David Quick



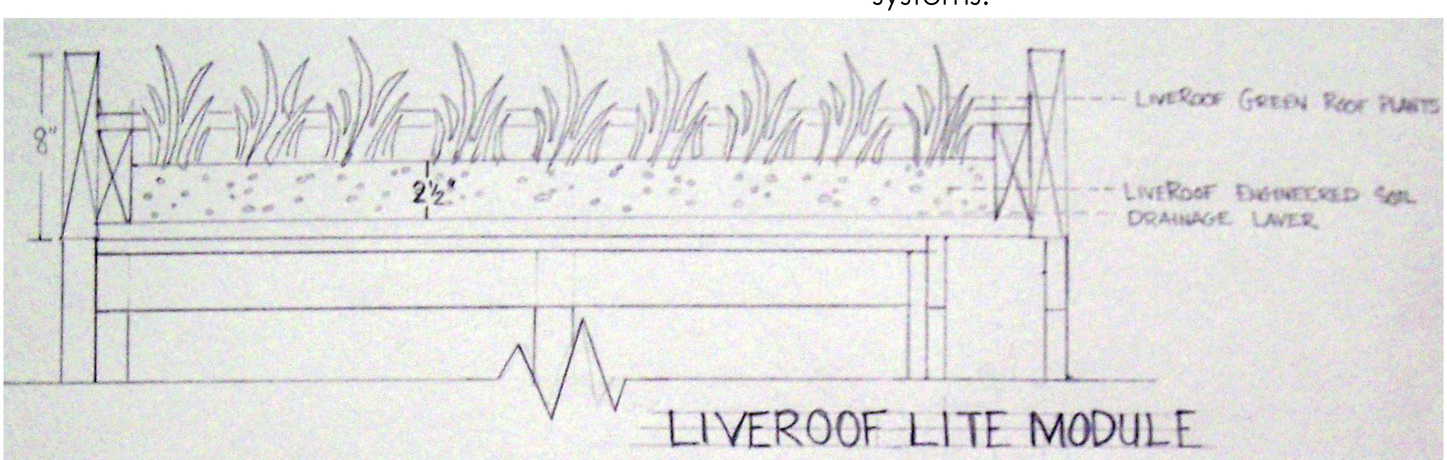
Reshape, Inform, Inspire 2.0: Intent: All

Design Group

As architecture and the building envelope become more technologically advanced, more products and methods will become available in the effort to create more and more sustainable environments. We intend to learn and explore what it means to be sustainable in design. We wish to discover new sustainable methods for the reuse of the pallet. By constructing this project we will discover the limits of their structural integrity as units and what method of construction best allows them to be used for a small structure.

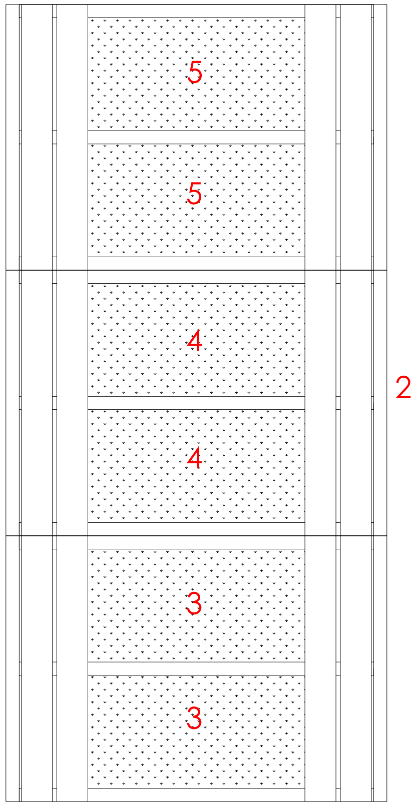


After having designed and successfully built a bus stop shelter out of pallets two years ago with two classmates, this is an opportunity to improve upon what we have already learned from that project. The previous shelter, however, was made from disassembled pallets rather than whole, adding a certain degree of difficulty (removing nails, dovetailing stringers, etc.) and extra work. I think this new shelter will be a great attempt to conserve material, curb labor, and hopefully make a sturdier and longer-lasting structure. I also hope to develop a greater understanding of green-roof systems and, if feasible, photovoltaic systems.

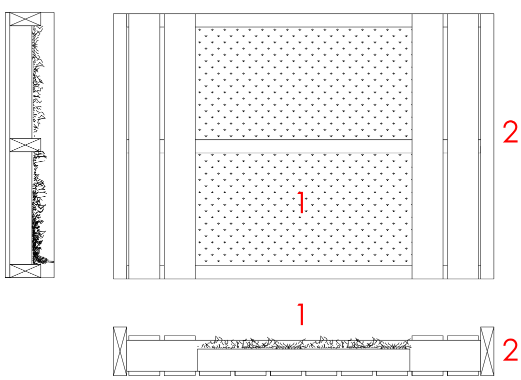


Adapted section through module

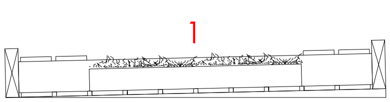
Reshape, Inform, Inspire 2.0: Methodology: Kenneth Black



Combined Roof Segments



Segment Sections + Plan



Pallet with 1/4" per foot slope

Legend

1 Module
2 2x6 Stringers
3 2.5" Lite Module
4 4.25" Standard Module
5 6" Deep Module

Methods: Observational Study of 9 modules

The method of evaluation will be the comparison of visual growth between six elevated green roof modules with an exposed underside on a roof deck compared to three non-exposed modules. Two modules of each depth, (2.5in, 4.25in, 6in) for a total of six modules will be mounted inside of the structure's roof pallets as shown at left. There will be one module of each depth located on the roof surface of the test cell building nearby. These three modules will be compared to the six elevated modules placed within the pallets on the structure for overall growth, and coverage of the module.

A number of factors can lead to the increased or decreased growth of the modules, therefore, general weather data will be collected from a datalogger and weather station atop of the test cell building from the current study of modular green roof water retention by Dr. Elizabeth Grant, in order to explain growth results due to climatic responses.

This data will then be used to determine if cooler temperatures and higher winds retard the growth of modules due to the chilling of the roots, and possible freezing of the medium. All of these measurements are taken with the intent of measuring performance of green roofs based on volume of medium as the indicator for improved growth performance. The study explores if the exposed application of individual modules is possible.

The hypothesis is that thicker medium could provide insulation for roots and increase growth amongst exposed modules, and the unexposed modules will perform better than exposed modules. At one week intervals, pictures will be taken of the structure and green roof modules and weather data will be recorded from the datalogger. Observational notes will be taken once a week as well to track the growth of the modules as well as recording any unforeseen results.

Reshape, Inform, Inspire 2.0: Methodology: James Trent

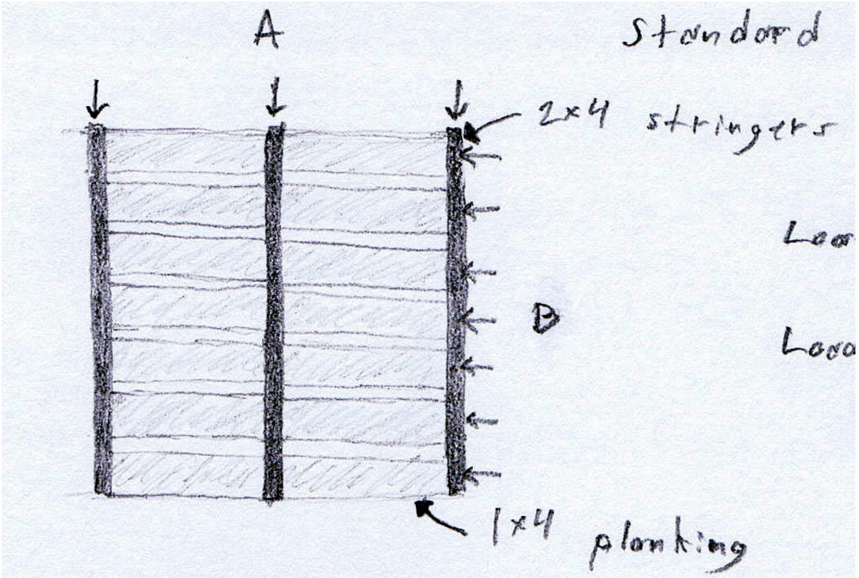
Structure: Deflection and Failure

With this project I want to discover new sustainable methods for the reuse of pallets and discover the limits of their structural integrity as a unit. I intend to primarily calculate the structural integrity of the pallet as a unit. I will do this by making assumptions in the calculations with the pallet is oriented with the 2x4 portion of the unit perpendicular to the ground. From this assumption I can derive where the weakest point in the 2x4 is and how much the primary unit can support.

This method could also be used for any other orientation of the pallet. It may also be useful to look at each of the different components in the pallet and find out what their load-bearing ability may be. Another important study to make is the testing of different joint connections such as a glued, bolted, screwed, and nailed joint. Theoretical locations of failure will be compared to actual locations of failure in order to discover how pallets to react to stresses.

The structure also contains a concrete base substructure in which both poured-in-place concrete and concrete masonry units will be tested under compression for failure. By doing so, the capacity for the structure will be determined and kept within a minimum 2.0 safety margin.

To discover the limits of the structural integrity of the bus stop I will need to calculate loads produced by the green roof units and use them to find out the deflection it will create on the roof structure. By examining these different aspects of the pallet and the bus stop I believe it will lead to a better understanding of how to construct a small and safe structure with pallets.



Pallet Bus Stop Sub-Structure Test
Photo courtesy of: James Trent

Pallet Bus Stop Sub-Structure Build
Photo courtesy of: Kenneth Black

Pallet Bus Stop Sub-Structure Test
Photo courtesy of: Kenneth Black

Reshape, Inform, Inspire 2.0: Timeline

June:	**Received Approval** from CAUS for Student Initiated Research Grant Research Project
July:	Request the Green Roof Modules from LiveRoof. [12 week wait]
August:	Begin collecting pallets from VCOM and CRC. Purchase materials [see budget] **Research and Demonstration Facility** Begin Buildout of bus stop Structure Simultaneous testing of structure
September:	Move structure to final destination
October:	Install green roof segments into structure Begin collecting baseline data for green roof analysis. Observational analysis of previous and Current bus stop designs Begin collecting data for all depths Make weekly visits and observations
November	Note reaction of modules to freezing temperatures and survival
Dec-Mar	Make and record observations
March	Finish collecting data and write conclusions.
May	Final Thesis presented based on work

Pallet Bus Stop Chair Testing
Photo courtesy of: Kenneth Black

Reshape, Inform, Inspire 2.0: Methodology: Logan Hoffman

Aesthetic: Method of Construction

The previous shelter was very time consuming, as we had to dismantle pallets and reconfigure them into a new structure. Many ideas, such as the cross-bracing and additional post, were devised during the process of construction instead of at the start. With this new shelter, I hope to begin with a better planning strategy and timeline. This will hopefully come with a simpler design and less intensive work schedule.

With a simpler design of whole pallets of a standard size and a more basic underlying structure, it would appear that this attempt will be easier to construct than the previous version of the bus stop. I also hope that less hardware (screws, nuts and bolts, etc.) will be needed to build the new shelter.

Thirdly, the integrity of the shelter is a major factor. While the previous structure did stand and could hold several people, it did tend to creak and move slightly. I would like to remedy this by ensuring that this structure is entirely sound. This could be measured by testing the durability in mockups of several parts of the structure. With the new design comes new challenges as well, such as ensuring the roof is effective and can drain properly.

Kenneth Black Logan Hoffman
Ross McFarland Michael Trent

Construction of a New Bus Stop Structure
Fall 2012

Reshape, Inform, Inspire 2.0: Results: Construction

Construction Facilities

The Research and Demonstration Facility (RDF) is located at the end of Plantation Road, is about a mile from the of the Virginia Tech campus in Blacksburg, RDF provides approximately 11,000 square feet of space, including a design studio, a seminar/lecture room, workshops, a testing facility for wall constructions, and testing laboratories for indoor air quality.

With the support of RDF's facilities and the award of a student initiated research grant, the project got underway. The wood shop allowed for the processing and shaping of the structural frame into which the pallets act as shear walls.

Our design group worked more heavily in the breezeway, as this space allowed for the temporary storage and then construction of the prototype and testing these assemblies at a range of scales from components through full-scale building assemblies.

The surrounding area, specifically the test cell building then will allow for the long-term testing of the green roof modules and growth analysis via Image J, as well as testing the survivability of the materials in the system over time.

From this beginning, the goal is to determine the stability of the structure, the effects of weathering on materials and the resultant green roof module growth as outlined in the proposal, as well as discover unexpected results; that the work performed is an exploration in design research.


Figure A Research and Demonstration Facility


Figure B The Wood Shop


Figure C The Breezeway

Figure 1 Sanding Pallets

Figure 2 Staining Pallets

Figure 3 Initial Base Layout

Reshape, Inform, Inspire 2.0: Results: Construction

Construction Process

The pallets were all reclaimed from Virginia Tech Forestry. The college has a pallet testing facility to test and evaluated different styles and materials of construction. The particular pallets we recovered were from a study of protective plastic inserts as compared to non-protected pallets.

The pallets were all in relatively good condition and required minimal to no structural reconstruction or bracing. As seen in figure 1, pallets were sanded for mainly aesthetic reasons, and to prepare the surfaces for protective stain.

After the pallets were sanded, the major surfaces were stained to extend the life of the wooden pallets. The critical end grains were often covered and protected by the plastic inserts, which simplified the process. Shown in figure 2, the stain was brushed onto the pallets which were elevated by concrete block.

After the pallets were stained, the initial layout of the base, show in figure 3, were uncovered a use for the cut pallets we recovered from VT Forestry, in the form of a bench. Once again, during the construction process, simpler forms of building were created instead of man-hour laden designs.

The bench is constructed out of three pallets stacked on top of each other, with the top pallet sanded for protection against splintering. The total height of the bench is 17.5 inches, about the height of a normal chair.

Once the footprint of the bus stop was confirmed we moved to building the roof module in order to prepare for the arrival of the green roof modules from Riverbend in Riner.

Figure 4 Roof Module

Figure 5 Roof Module with inserts

Figure 6 Cutting the frame

Reshape, Inform, Inspire 2.0: Results: Construction

Construction Process

We started with the roof module design and construction. The process began by setting up the pallets in order to minimize the difference in width in the pallets. Since the pallets were specifically engineered to be a similar as possible to be comparable in structural tests, the pallets lined up with negligible difference in width.

As shown in figure 4, the pallets were lined up on the ground and compared to the expected dimension of the conceptual design drawings. The structure is 12 foot long and 40 inches wide. The length is the same as the concept, but 8 inches thinner than the 4 foot planned width. This difference in width is not critical, but expected as pallets are not square.

After the pallets were lined up, reclaimed wood decking was cut down to the size of the openings in the bottom of the pallets as shown to the left. This completed the roof deck for the green roof modules without using any new materials.

Then the structural frame was measured and cut in the wood shop with a radial arm saw as shown in figure 6. The lengths of wood were chosen in order to cut less than 6 inches out of each length, as all of the spans are custom cut based on the dimensions of the pallets present.

The design of the frame by using the pallets as shear wall bracing allows any type or dimension of pallets to be used without needed to redesign the basic frame or green roof modules.

Reshape, Inform, Inspire 2.0: Results: Construction

Construction Process

After the 2x10 dimensional lumber was cut to size, the frame was attached with screws to the pallets. Figure 7 shows a structural test of the system over two weeks to determine if the design would result in undesirable defection or unsuitability.

The 2x10s did not deflect by a measurable amount and the roof module remained rigid while loaded with a 400 pound point load at the center. The entire load created by all six the roof modules is roughly 300 pounds saturated with water.

The screw connection details are shown in figures 8 and 9. Figure 8 shows the elevation of the screws and figure 9 shows the butt-joint between the pallets from above.

Each pallet is attached to the 2x10s with 5 screws at each corner. The 10 screws in figure 8 shows two pallets joined together with 3.5 inch weatherized decking screws.

The multiple screws at each joint keeps the pallet from rotating about any axis, and builds redundancy into the system in case a particular screw becomes stripped from the wood over time.

No glue or adhesive is used at the joints as over time, chemical connection deteriorate faster than mechanical connections.

Therefore, the design takes advantage of the rigidity of the pallets to stabilize the frame. Moreover, the stability of the pallets is crucial to the rigidity of the final structure.

Figure 7 Assembled Frame

Figure 8 Screw Connection

Figure 9 Pallet Butt-Joint

Figure 10 Attaching the rigid frame

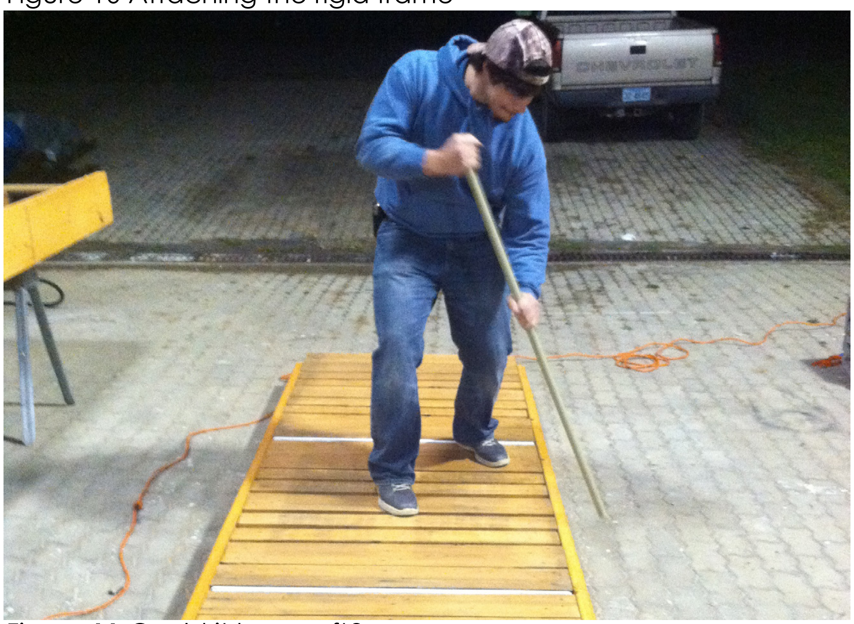


Figure 11 Could it be a raft?

Figure 12 Portable discussion forum

Reshape, Inform, Inspire 2.0: Results: Construction

Construction Process

The next module of the frame was the floor assembly. The process of attaching the frame to the pallets is similar to the roof module, using screws, but without adding the roof decking.

As shown in figure 10, the position of the screws was first measured out, and then a hole was drilled to prevent the wood from splitting when the screw was drilled in afterwards. It became an assembly line process of measuring followed by drilling, and then attaching the 2x6 frame to the pallets.

The frame is cut short of the end of the pallets by 5.5 inches in order to accept the longer 2x6 frame that makes the wall modules, allowing the attachment the roof, wall, and floor modules together.

After the base floor assembly was constructed, we stood back and realized that the module could be used for a number of different uses.

The first we found was a raft or floating platform in lakes or ponds as shown in figure 11. The width of the platform would be increased, but the same properties of shear wall and frame still applied.

Perhaps a more likely use of the platform would be as a portable discussion stage. Figure 12 shows that when raised on concrete blocks, a series of floor modules could be added together to make a sizable platform.

This process of building and discovery allows the research process to remain dynamic and not become static. If the research process becomes static, unexpected results might be missed while trying to confirm desired results.

Reshape, Inform, Inspire 2.0: Results: Construction

Figure 13 Sanding to fit the modules

Figure 14 Ascending module depth

Figure 15 Elevated plastic trays

Construction Process

After testing the connection of the different floor, roof, and wall modules, the next step was to fit the green roof modules into the roof module. Unfortunately the pallet openings were smaller than the size of the modules and needed to the sanded to fit the plastic trays as shown to the left. While the spaces were too small, the different was only about an 1/8th on an inch.

The trays are placed in each of the openings for a total of 6 elevated modules. Figure 14 shows the modules in ascending depths, from 2.5 inches, then 4.25 inches, to the final 6 inches.

This configuration will also allow for the study of the erosion of grit and plant material. One of the concerns is that the material and girt will fall through the roof assembly and not drain to the edges as designed. This will also test the overall integrity of the individual module without direct contacted support from adjacent modules.

Figure 15 shows the modules installed with the airspace below the plastic trays. These are the same wooden boards from the construction of the roof module shown in figures 7 and 9. The trays fit into the space between the 1x6s that from the structure of the underside of the pallet.

These green roof modules will be evaluated over the course of a few months during the winter to determine if the initial hypothesis that elevated modules will perform more poorly than non-elevated modules. The modules will also be left alone during the summer to determine if drought conditions prove too difficult for individually separated modules.

Figure 16 The First Deck Pallet

Figure 17 Paver grid layout

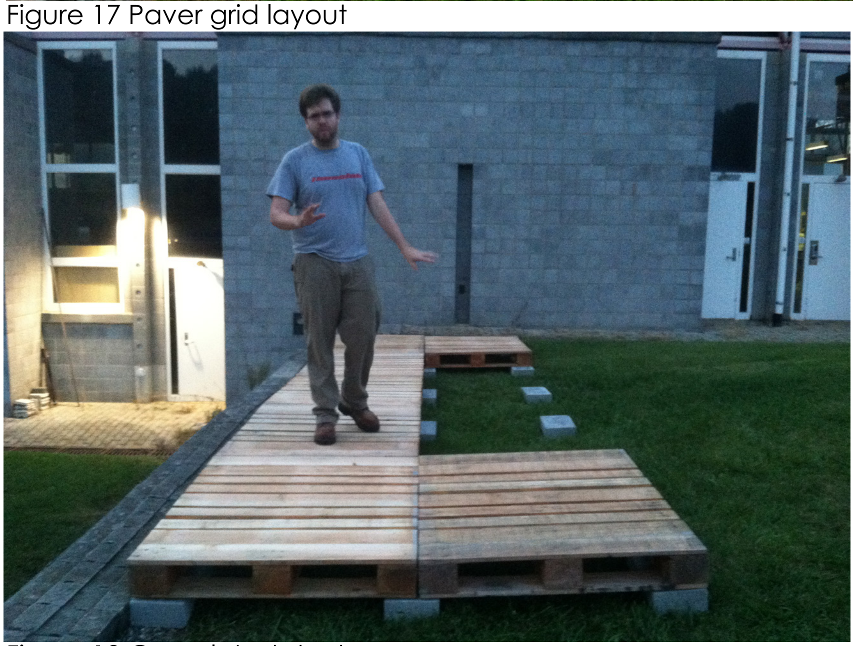


Figure 18 Completed deck

Reshape, Inform, Inspire 2.0: Results: Construction

Test Build of Deck and Bus Stop

The structure needed to be vetted before placed in a public setting, therefore the deck was constructed as a precursor to the bus stop.

We hypothesized that the pavers would not crack and the pallet structure would not splinter under such typical loading. Figure 16 shows the first set of four concrete pavers elevating the pallet with 25 pound per square foot live load successfully.

Other designs of pallets actually could fail in an acute manner over the secondary surface stringers. The pallets we had selected were designed for heavier loads, and not experimental designs. More research needs to be conducted to determine the lower limit of pallet selection when using them as a deck surface.

The pavers were laid out in a grid (figure 17) and the pallets were placed upon the pavers. The heaviest load would be incurred by three deck segments and a corner of the bus stop structure. The pavers were pushed under the plane of the pallets to avoid unnecessary trip hazards, but the deck can be as large as desired.

Figure 18 shows the completed deck and grid segments. During the final build the bus stop would be placed within the three pallet opening to the right. At that time, the bus stop will be constructed on its back modules and tilted up into place.


Figure 19 Overturn testing


Figure 20 Deck and Bus Stop connection


Figure 21 Tied down with rope

Reshape, Inform, Inspire 2.0: Results: Construction

The Edge Condition

The first set of testing aside from live load application, was overturn in the edge condition of the pallet deck. While overturn was not expected, confirmation was desirable.

Figure 19 shows an attempt of moving quickly over to the edge in order to place enough force to overturn the pallet. Due to the placement of the pavers along the edge, there is no lever or fulcrum created which enables to pallet to move.

Total failure of the pavers could occur under atypical loading, in which case the pallets could shift. The pallet itself is more likely to fail first in this condition, but this does not occur until almost 250 pounds per square foot over an individual secondary stringer. Also, the pallets are elevated to minimize wicking of moisture from the ground,

The bus stop is designed to fit into the edge of the deck system. Figure 20 shows three deck pallets and a void where the bus stop will be tilted into place.

The pallets are simply placed onto the system. The bus stop, as it is much taller, approximately 10 feet, overturn due to horizontal forces such as people or wind loads is a concern.

Since this proof of concept is temporary the project is protected against wind loads with stakes and rope. The final location will be leveled and secured in place with four leveling screws. These leveling screws not only level the project quickly, but allow the structure to be placed in almost any terrain, provided the screws are long enough.

Figure 22 Erecting the side

Figure 23 Both sides vertical

Figure 24 Tipped over for roof connection

Reshape, Inform, Inspire 2.0: Results: Construction

Final Build Observations

After testing the deck portion of the bus stop, we moved into the full scale construction of the bus stop structure. Figure 22 shows that we started with the structure upright and placed the vertical walls.

We found that the wall modules shifted into place with little difficulty and were held together as friction joints. However, over time the stability of these joints is in question.

The walls are attached to the floor with five screws per side. We made the calculation of the number of screws to provide redundancy if a screw were to strip from the wood over time. The number of screws required would amount to the approximate number of screws in a standard box, 260.

It was discovered that the walls, under no horizontal stresses, only axial forces, could actually remain vertical without support. While this is true, there is no margin for error, and is easy to torque the screws out and break the structure. As shown in figure 23, we were able to move to the other side with confidence that the other side would remain vertical.

After both sides were attached, we tilted the structure over to mount the roof module to the wall modules. In figure 24, the structure is in the background and the shear wall modules are in the foreground. Since the roof module was significantly heavier than the other module pieces, the design team had to determine how to move the final module to the construction site.

Thus, it is recommended that the structure be built on site as close as possible to the final location of the bus stop.

Reshape, Inform, Inspire 2.0: Results: Construction

Figure 25 Attaching ratchet straps

Figure 26 Tilted up and concept discussion

Figure 27 Final attachment of roof module

Final Build Observations

At about the time that we began to attach the roof modules to the structure, Chip Clark, a visiting professor at the school of architecture, helped us attach the roof and tilt the structure up safely.

First we slid the roof module into the two walls and then secured the roof via ratchet straps. We then tilted the structure back up vertically with Chip acting as a counterweight to make sure the structure did not rotate past vertical.

Chip mentioned that we were on to something. He mentioned that our shear walls were a must, that the screws alone could not act as a sufficient moment connection.

However, as a frame, the structure would be extruded into any length using the width of the pallets as the increasing depth. As long as the structure had pallets of similar width per frame unit, you could build a deeper structure. There was also the potential to hang installations within the structure, using it as a gallery space.

After the discussion, the roof module was secured to the walls with the remaining screws. Once we tilted up the frame and attached the roof, we realized that the structure was much taller than we envisioned.

Figure 27 shows that the overall size required the use of a ladder to get the roof module attached. Other methods of assembly could allow for the attachment of the roof module without the need for a ladder. Specifically, that the structure could be raised on block while horizontal and secured with screws, before tilting the structure vertical.


Figure 28 Preparing green roof modules


Figure 29 Green roof visibility


Figure 30 Green roof visibility

Reshape, Inform, Inspire 2.0: Results: Construction

Final Build Observations

After leveling the structure, the green roof modules were placed into the roof segment. As seen in figure 28, the weight of the green roof modules necessitated that a pair of two people had to be present. One to take the modules up the ladder, the other to be on the roof making the final adjustments. The weight of the 6in module would have made it impossible for most individuals alone.

While the specific study only required 6 modules on the roof, it is recommended that the entire roof be covered in modules to allow them to grow together and prevent unnecessary erosion of the medium.

To have the green roof modules work well, a second frame would need to be inserted around the modules to make up for the varying width of the pallets in different structures. This would hold the green roof modules together securely and be place into a new larger module.

As shown in figures 29 and 30, the 2.5 inch module is hidden by the structure, the 4.25 inch module is barely visible over the edge, and the 6 inch module is too tall for the structure.

We believe that a 2x8 instead of a 2x10 across the top, combined with the new frame for the modules using only the medium depth of 4.25 inches, would be the best combination of visibility from the ground, distribution weight evenly, and ability of placing the modules on the complete structural frame.


Figure 31 Inserting the first shear panel


Figure 32 The rigid structure


Figure 33 Proof of concept: one panel

Reshape, Inform, Inspire 2.0: Results: Construction

Final Build Observations

The attachment of the shear panels was more difficult than the wall modules. The shear walls were mounted by angling the shear wall into the structure with the top in place and then using a mallet to tap the bottom into place.

The placement of the shear wall required all four people present to hold the module in place. As such, a minimal crew of four, but preferably six could make the structure without difficulty.

After the shear wall was tapped into place, it was secured with four angled brackets, as shown in figure 31.

As soon as the shear wall was in place, the structure became rigid. This meant that potentially, this configuration of the modules could be used as a design for a minimal bus stop. The shear wall also effectively halves the distance of the roof span, eliminating the deflection in the beam.

Also, since the pallets are not designed or rated for crushing forces as used as walls, the dimensional lumber is necessary to prevent the collapse of the structure, while the pallets act as cross-bracing for the entire frame.

While it was a positive effect in this prototype, the added weight of the first shear wall settled the bricks and leveled the structure. This is something that needs to be addressed in later designs.

Figures 32 and 33 show the structure with three people, but without the final bench added. The structure appears to be more than sufficient for the five user capacity goal for the bus stop.


Figure 34 Small Racking


Figure 35 Racking eliminated


Figure 36 Two panel situation

Reshape, Inform, Inspire 2.0: Results: Construction

Final Build Observations

After the placement of the second shear panel, we found that there was a slight racking of the structure of about a quarter of an inch.

Before we bracketed the structure in place, we used the ratcheting straps to hold the sides vertical in order to remove the racking. Figure 34 shows the setup as we were bracketing the second shear wall in place.

The two shear wall design revealed what had been expressed earlier, that if the frame had an increased depth, this could be an example of an entrance.

The structure in that instance could become a porch for a larger shelter, gallery, or bus stop. At that point, a closed envelope may be necessary depending on the intent of the structure.

Figure 35 shows the second panel in place with the racking removed. By having a shear wall in corner in conjunction with roof, wall, and floor segments, the structure is kept square.

After the second shear wall was placed, the ratcheting straps was removed and the structure was confirmed square with a level and the racking had been sufficiently fixed.

The structure is then ready for the final shear wall to be placed. Given that the first shear wall removed the deflection in the beam, and the second shear wall made the structure square, the final shear wall should fit into place easily.


Figure 37 Placing the final panel


Figure 38 Mounting the final brackets


Figure 39 Three panel situation

Reshape, Inform, Inspire 2.0: Results: Construction

Final Build Observations

The final shear wall was placed quickly into the frame without difficulty, finishing the designed frame. Figure 37 shows all three of the shear wall in place.

While the pallets are almost covered completely by the smaller secondary slats, it is actually possible to see through the structure.

Expanding on the porch from the two-panel situation, this three panel situation could be the end of a structure, completing the enclosed space.

Figure 38 shows the final bracket being mounted, closing the final corner of the structure. Twelve brackets were used to mount the shear walls to the structure.

The structure was then complete. As shown in figure 39, the main structure was complete, but the leveling of the platform to reduce shifting in the pallets was not completed.

While the envelope is not completely enclosed, it functions as shelter from the weather. Rain is slowed, wind is blocked, sun is mitigated. During one storm, rain was delayed by 40 minutes before seeping through the roof, even when only using the combination of green roof modules and reclaimed wood.

While moisture should not come through most envelopes, the bus stop has no sealed joints in the structure and is completely open in the front. As shown above, the bus stop has the large potential to become a prototypical element for growing bus transit systems.

Reshape, Inform, Inspire 2.0: Conclusions + Continuation

Proof of Concept: Structure

The significance of the study is to show the potential for a repeating frame of pallets to make almost any size of structure. That, as a frame, the structure would be extruded into any length using the width of the pallets as the increasing depth. As long as the structure had pallets of similar width per frame unit, you could build a deeper structure. Furthermore there was also the potential to hang installations within the structure, using it as a gallery space.


Figure 40 Final Concept 1

This structure also furthers many of the concepts that fall within tactical urbanism, specifically, that the materials are present and there is no need to wait in order to make something visible. Pallets are thrown away everyday. Dimensional lumber is readily available. Highly skilled construction crews are not required. If there is not a bus stop or shelter or even a structure, this can be constructed quickly and can potentially revitalize a space and make green roof systems more visible. That many small green roofs can perform in the manner of on large roof in urban environments.


Figure 41 Final Concept 2

This frame also shows that with mostly reclaimed material, another structural envelope can be created. What was destined for the landfill is given a new life as the pallet bus stop. The system reshapes the function and identity of the pallet, becoming more than landfill waste. The reshaped pallet informs the user of the possibilities by demonstrating a particular method of pallet reuse. This then reshapes the user's notion of the pallet's potential, bringing innovative reuse to the forefront. Ultimately, this inspires the user to then improve upon the pallet and design new forms for a material previously disregarded. The pallet has become a catalyst for discovery.


Figure 42 Final Concept 3


Figure 43 Joint 1

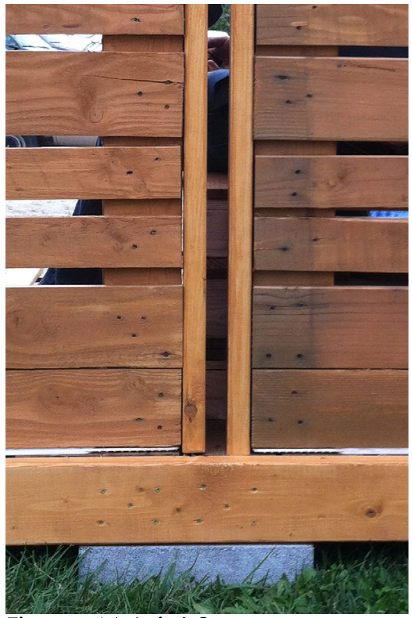


Figure 44 Joint 2

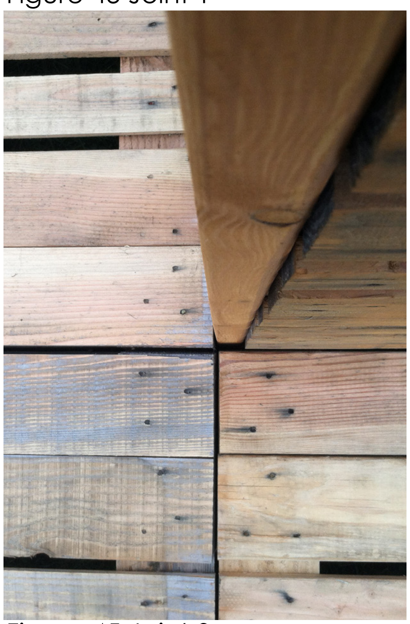


Figure 45 Joint 3


Figure 46 Joint 4

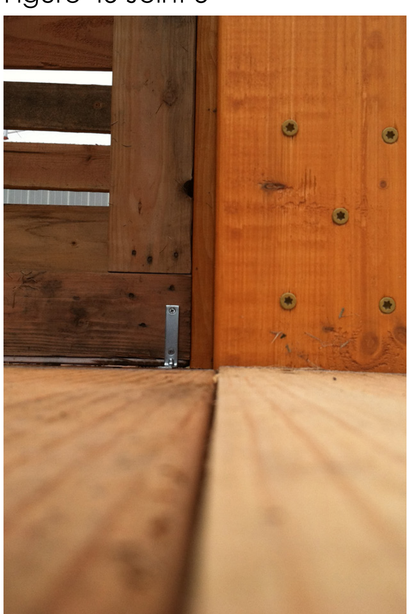


Figure 47 Joint 5

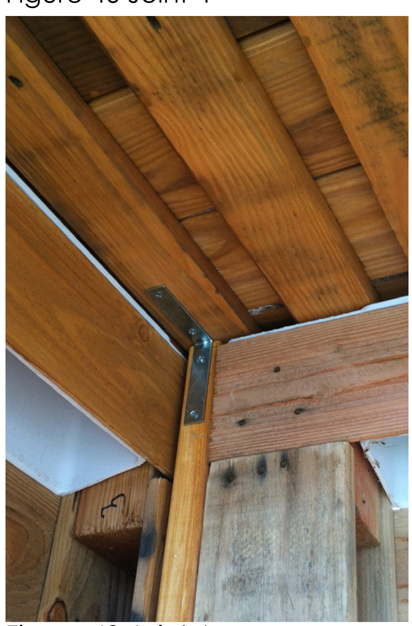


Figure 48 Joint 6

Reshape, Inform, Inspire 2.0: Conclusions + Continuation

Proof of Concept: Joints

In this vein of discovery, the next step is to determine if the frame can be used at full scale to construct a non-rectilinear frame and enclose the space. Using the same properties as the bus stop frame of sandwiching pallets between two frames, the pallets will then become the rigidity and enclosing envelope for the space.

If the structure proves stable, the pallets that carry other materials to the site can then be used in the structure to further minimize waste from construction sites.

Furthermore, using the longer dimension of the pallet, it may even be possible to then have the width of each frame be approximately four feet, making it a unit for a module that most materials come in or are divisible by, reducing the need to cut materials down to size.

There are many different connections that are used in the structure. To the right are a number of examples of how materials come together, and the attached. While many of these connections may not be glamorous, they keep a larger idea of a pallet frame and bus stop intact.

Results + Conclusion

At this point in time, the construction of the bus stop frame from reclaimed pallets and dimensional lumber is complete and the study of the green roof modules is underway. The structure is stable, the green roof modules are placed, and the structure functions as a bus stop. While this specific experiment with the green roof modules has not be completed, the hypothesis that exposed modules will have stunted growth as compared to unexposed modules is still supported in the comparison of 8 foot by 8 foot test elevated exposed structures and extra unexposed modules on the top of a nearby test cell building from a runoff mitigation study conducted by Dr. Grant. The main difference in the two is to see if the completely exposed underside prohibits growth of the modules even further.

While the green roof study is just beginning, the construction of the bus stop was successful. Not only was the cost of the entire structure low, $305.66, but the amount of time invested, 104 man-hours was reasonable. While these amounts may appear too expensive and take a lot of time, if the structure is not stained or sanded the cost drops to $190.20 and 38 man-hours over four individuals. This means that if the materials are present, the entire structure can be completed in a single day, or more realistically, over a weekend.

While the envelope is not enclosed, it functions as shelter from the weather. Rain is slowed, wind is blocked, sun is mitigated. During one storm, rain was delayed by 40 minutes before seeping through the roof, even when only using the combination of green roof modules and reclaimed wood. While moisture should not come through most envelopes, the bus stop has no sealed joints in the structure and is completely open in the front. As shown above, the bus stop has the large potential to become a prototypical element for growing bus transit systems.