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HOW TO BUILD A SIMPLE THREE BEDROOM SHIPPING CONTAINER HOUSE

A Step-by-Step Guide by Bill Hebner

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By

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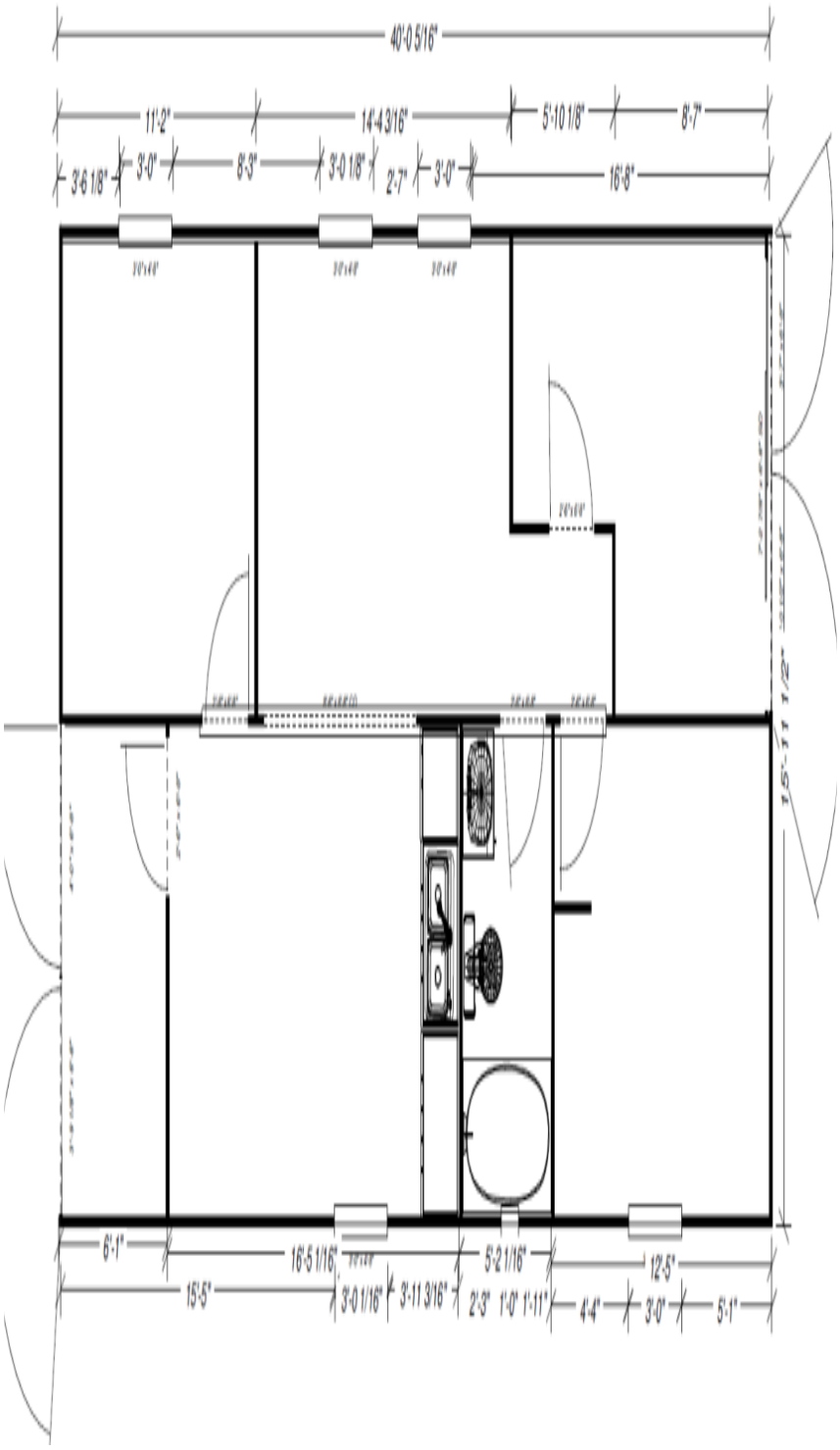
40'-0 5/16"
11'-2"
14'-4 3/16"
5'-10 1/8"
8'-7"
3'-6 1/8"
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3'-0 1/8"
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12'-5"
15'-5"
3'-0 1/16"
3'-11 3/16"
2'-3"
1'-0"
1'-11"
4'-4"
3'-0"
5'-1"

Construction Steps for a 60m^2 House

(Suitable for the RDP Reconstruction Development Program)

Introduction

The modular use of existing 12m (40ft) long, grade 2 shipping containers for housing has been building momentum in many countries in the developed world since the early 90's. Utilizing the containers, not as finished rooms but as complete structural components is opening the door for creative, fast and affordable housing and commercial spaces, for all parts of the developing world and particularly for Africa.

The Hebner house is not fancy. It does not require a lot of skill and is outrageously economical to build with the first unit costing just under $10,000 USD (£7,000). If you are looking for something more custom-made then I would suggest you talk to an architect as this house was tried and tested for humanitarian relief with very little access to power tools and skilled labour. At the end of this project you will have a simple 60m^2, 3 bedroom home that in its basic layout can occur in as little as 3 days with a team of 6 - 8 men or in well under a month by yourself with maybe a little help from a friend. This handbook is written as a simple step by step guide to help you speed up the process and to reduce waste in materials and time by avoiding the mistakes we made. This booklet is by no means exhaustive and assumes basic construction skills exist in at least one member of the construction team. For the DIY enthusiast that wants to give it a shot we will try to include additional supporting information where we can in each section to help you avoid simple first time builder mistakes. If at any time you need help with your project, we will try to do so, but this may be at a cost for our time. Feel free to contact us via Hebnerhouses.com.

I cannot emphasise enough that to get the most from this manual please watch the online video a few times at https://www.youtube.com/watch?v=rQkAQ8JMRmA and familiarize yourself with the basic construction techniques we are referring to before and while you are reading through this manual.

Building Order

There are slight variations between homes that are built on an assembly line basis and houses built on site. For this guide we will consider an onsite model with limited access to a crane aside from the delivery of the containers. Orders can vary, but the important point is that all aspects are addressed. Therefore, we would suggest a timeline as follows:

1. Source materials and permits
2. Concrete foundations
3. Locate First Fix Utilities
4. Prepare the undersides
5. Place the container
6. Sandblast or grind
7. Cut out and install windows
8. Weld the container tops together
9. Create opening and “Zipper Cut” walls
10. Cut out internal doors
11. Install door frames
12. Security door installation
13. Build roof gable ends and install roof purlins
14. Install electrics
15. Prep the container to receive insulation
16. Insulate the house
17. Spray internal insulation gaps and ceiling

18. Paint container internally
19. Install bathroom and kitchen plumbing
20. Second Fix Utilities
21. Spray external insulation
22. Paint or Render external insulation
23. Install roof sheeting
24. Hang doors and installing glass in windows
25. Install the bathroom partition wall
26. Final finishing and lay flooring

There are approximately 250 man hours represented in the basic house on the video from the digging of the foundations to “lockup” including functional electrics and a toilet. This includes the flooring, internal and external painting, windows and basic electric. Personal choice of higher levels of desired finish in the kitchen and bathroom will be in addition to the base construction time. We believe that working with the suggested jigs, prefabricated doors and windows as well as a suitable commercial compressor for spraying sand, foam and paint will reduce the base construction time by an additional 20 hours.

Tools Needed

Foundation and Placement
Wood saw
Laser level (rental 1 day only)or good water level
Cordless drill or hammer
50’ tape for squaring foundations
Brick trowel
300’ string
8 - 2’ stakes
Block and tackle (if container must be moved laterally into final position after delivery)

Container Prep

5’’ disk grinder (use 9’’ discarded disks to save cost here)
9’’ disk grinder 30 metal grinding disks
Sand blaster & Sand blasting grit
Stick, MIG or torch welder Appropriate rods
Marking pens and soap stone pencils (from welding supply shop)
6 - 6’’ steel clamps
Welder magnetic corners
Metal drill bits ¼’’ to ¾’’
Pressure washer
Chalk line
18V or electric drill
8’ scaffolding platform

Compressor tools (optional)

Sand blaster
HVLP Paint Gun
Pneumatic grinder and drill
Insulation
2x froth pak 600 Dow chemicals or 10 gallon compressor with closed cell 2 part application machine (rental or sub contracted)
4’’ masking or packaging tape
Old newspapers to cover windows
Roll of 2mm clear plastic drop cloth
Long blade Stanley knife

Painting

4’’ foam rollers or 4’’ brushes

Commercial electric paint sprayer or HVLP paint gun

Stages of Building

1. Source Materials and Permits

You will need the following to construct the Hebner House:

2 – 12 m HI cube containers (9’6’’ high by 40’ long) grade 2 or better (one use containers are more expensive but would allow for pristine internal and external finishes as the steel walls will have no scars from forklifts)

an access plan for a container truck with or without a Hiab to get to your work site

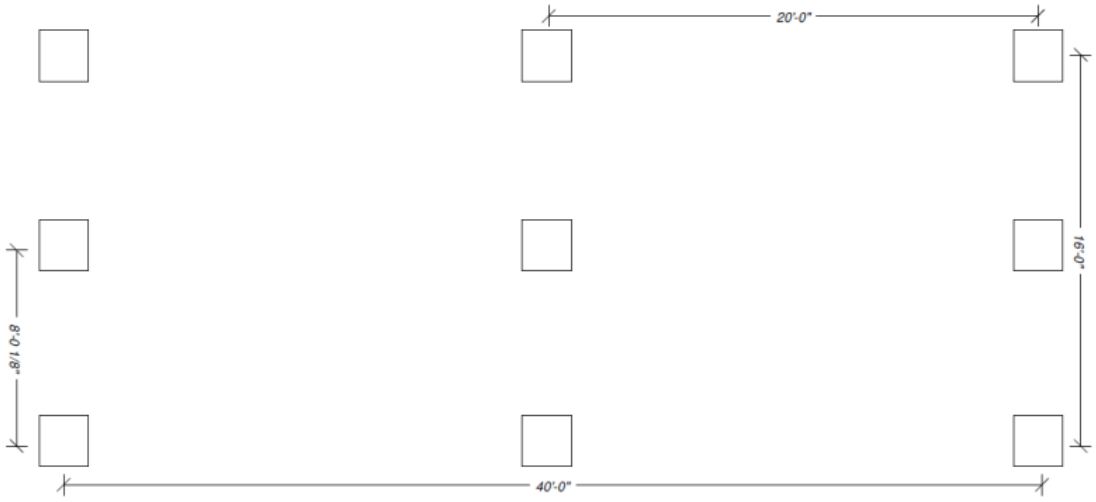
a local or portable power source that can produce a minimum of 5 KVA or better

the appropriate tools to begin (see list)

local planning permission and approvals

access to 400 gallons of water (min.) for foundations and cleaning

2. Concrete Foundations



a. The building requires 9 – 500mm x 500mm pads - see diagram for footing layout. These must be within +/- 2mm in elevation over 12m. It is strongly recommended therefore that a laser level is used.

b. Pads are constructed with 2 x 10mm diameter steel reinforcement bars horizontally and 2 x10mm diameter bars vertically. Pads should be dug a minimum of 500mm deep or until solid substrate is exposed. Please check with local building codes as foundations in areas with frost will require deeper foundations. (A screw in pile is an alternative that may prove more cost effective and faster depending on your geography)

c. Bricks may be used as permanent shuttering for a nice finish, (small little walls you fill with concrete) but care must be taken to allow the mortar between the bricks to dry for 24 hrs before pouring the pillars themselves.

d. The MPA (hardness of the concrete) should be at least 15 for this single story house. If mixing concrete by hand the mixture should be 1 shovel of cement with 2 shovels of sand and 3 shovels of rock.

e. We have found in a developing world context that old tires stacked in the hole will double as Sonotube© (round concrete forms) for footings and are usually available for free.

f. Foundations should cure for a minimum of 36 hrs before the placement of a container.

g. The midpoint of the containers should be shimmed to eliminate the potential bounce of the floor. (Be careful not to over shim the mid-point as you can create stress and or a rocking point in the floor over time.)

h. A damp course membrane, similar to that used in brick construction needs to be placed between the shipping container and the foundation pads in order to prevent electrolysis from occurring with the earth. This will greatly increase the life of the container as rust is the only enemy

i. Please avoid direct contact of the container with cement and earth at any point of your finishing as this will introduce electrolysis to the structure and

promote rusting.

j. If the foundations are not level, metal shims should be used to bring the unit to perfect level.

k. In high wind areas a metal plate to weld the container to the foundation may be required. This would involve welding the plate to a steel rebar anchor before installing it into the wet cement pile.

3. Locate First Fix Utilities

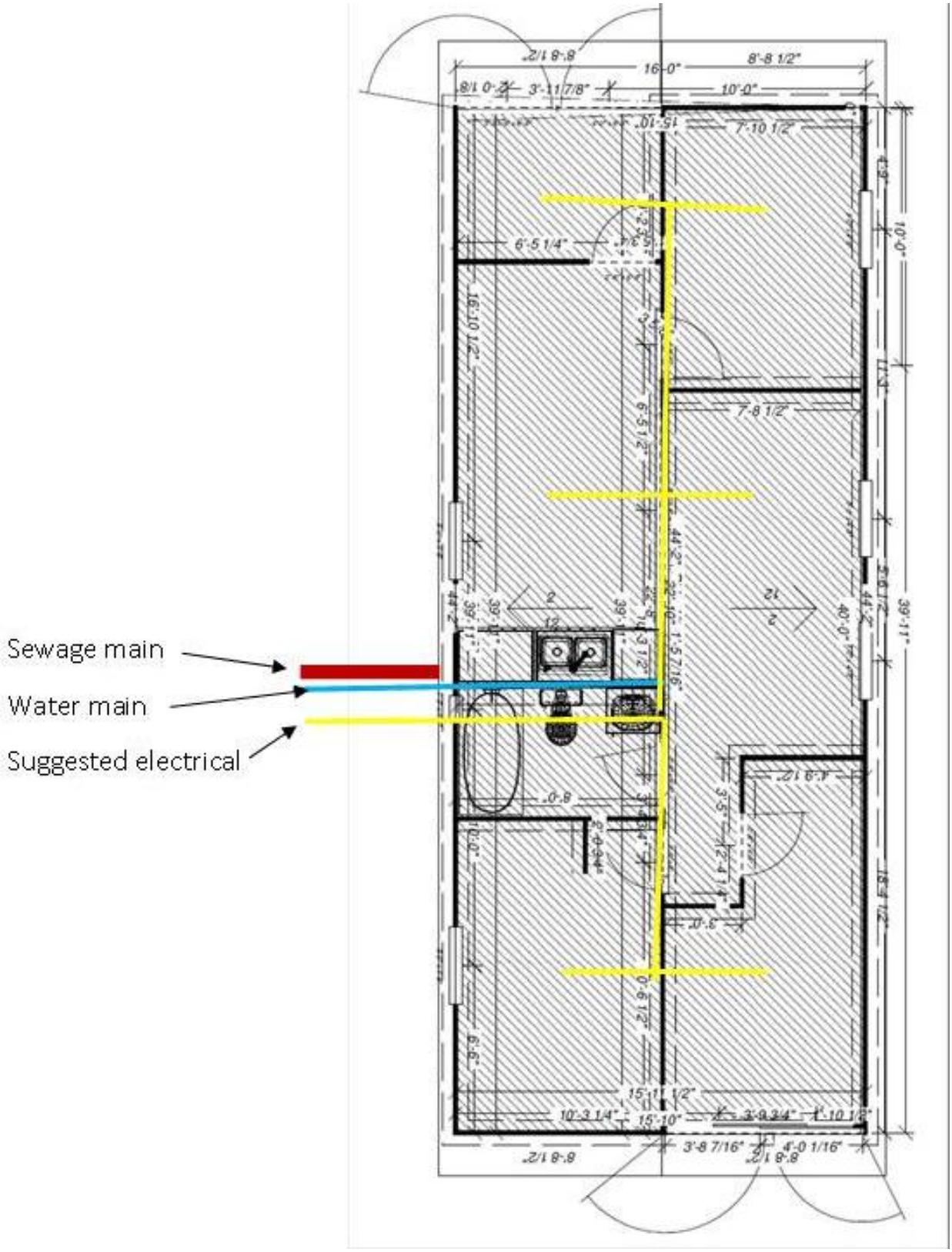
Since the house sits on foundations above grade in most places, location of the utilities can be done before or after the construction of the building. We would encourage you to know where and how you plan on running the utilities before you place the containers to avoid unnecessary grief in your build. Again consult local building codes on the depth of utilities as winter temperatures will change your requirements.

a. Drainage - The structure itself will be built just above the ground and will not rest directly on the soil. This allows for falls of drainage pipes and the prevention of condensation forming on the underside of the structure, thus extending the structure's life. Prior to construction these services should be installed to allow for access approximately 4.7m (16ft) from the sealed end of the container on the future outside wall.

b. Water main entry to the building will also be approximately 4.7m from the sealed end of the container. Water should not be contained in the same trench as other utilities and therefore should be run in a second ditch or at least 1 m from the sewage line. In warmer climates the waterline can be run in the gap under the containers once the footings are poured.

c. Electrics - The service panel is designed to be in the hall beside the kitchen (best for developing world situations and the least amount of cable needed). This will be 7m from the open end of the container. You may choose to run a ground service through the gap between the containers as you cut the walls out, or drop the supply through the gap from the top of the containers once the walls are in place. It is far simpler to come from above the container and house the traditional 6mm supply in conduit.

Please remember this is a metal building. It is advised that the whole structure should be earthed for safety. A standard earthing rod (grounding rod) should be purchased as part of the electrical package.


Sewage main
Water main
Suggested electrical

4. Prepare the Undersides

In some contexts this step is not possible or necessary; however, we feel that for your peace of mind and winter comfort it is worth the effort. Initial delivery should have the containers either laid on their sides for a day or blocked up 2 to 3 ft. while the undersides are cleaned, sealed and sprayed with closed cell polyurethane or Rock Wool baton insulation added to the base and fastened securely. Then call the lift truck back to place the containers in their final positions. If this will not be possible, have the insulation and the compressor ready at the time of container delivery and be prepared to pay for this service time.

With the air gun or sand blaster remove any loose debris from the underside and then spray at least 1’’ of insulation on the bottom of each container. Or for a cheaper but more time consuming solution install bats of rock wool. Continue the lift after the short 30 to 40 minute delay. Though this may be done when the containers are placed, the ease and quality of rustproofing and insulation greatly increases if you can access the full base and see what you are working with.

The second charge for a visit from a crane truck may provide peace of mind in the quality of the work done on the underside of the structure. As an absolute minimum, visually inspect the complete underside of the containers before setting them in place. You won’t get a second chance once they are down to reject an inferior unit or to prevent rusting issues.

5. Place the Container

If there is no space to move containers once delivered both units should be placed on the foundation pads in their final location. Care must be taken at this stage to ensure that there is no racking or deflection of the floor. Metal shims can be used for final levelling and should be installed prior to the departure of the transport vehicle.


If at all possible, the bathroom door should be cut out of the first container prior to the arrival of the second container. This creates a midpoint in which to visually confirm the alignment of the floor seam near the centre of the building before the second container is permanently placed. It also allows for the midpoint shimming of the containers without crawling under the building.


Please remember that you will need to have both containers from the same manufacturer to ensure that you will have the exact same internal floor height on your finished product. If possible have a visual inspection of the containers you have purchased before they arrive at the site. We are aware that this is often not possible in a developing world context. The visual conformation by having the door cut will allow you to adjust to any surprises while you still have the crane truck on site. The external alignment and tolerance is critical as it has a knock on effect right up to the roof. If the floor is not level underneath the containers, it will not be inside the containers, at the ceiling line, and as you go to put the sheeting on the roof.

If there is space to move containers the one with the water and electric feeds should be placed in its final location first to allow access to simplify and speed up utility installation. There is not generally a cost savings in getting

the containers delivered at the same time. You may wish to stagger the delivery time so as to have all openings cut in the service's container and the electrical trunking installed on the header wall before the arrival of the second unit. This will eliminate a great deal of stress for the DIY builder.

We have found that if containers are not placed on the foundations straight away that an automotive block and tackle can be used to slide the containers together laterally. The block and tackle may also be used to “tighten” the containers up if alterations have to be made or you have had an under skilled or uncooperative delivery truck driver.

6. Sandblast or Grind

There are - 2 goals of sandblasting. The first is to remove rust and residues from any previous use, inside, outside, on top and underneath of the container. The secondary purpose is to allow for a good bond between the existing marine paint and the insulation on the outside and for traction with the final internal coat of paint sprayed on later. If possible the interior should be sand blasted first as this will allow the grit to be recovered for use on the outside of the building. It is important to lightly sandblast the floor as well, preparing it to receive sealer and paint. As described above, if at all possible

sand blast and insulate the underside of the containers as well as this will increase the overall life of the building.

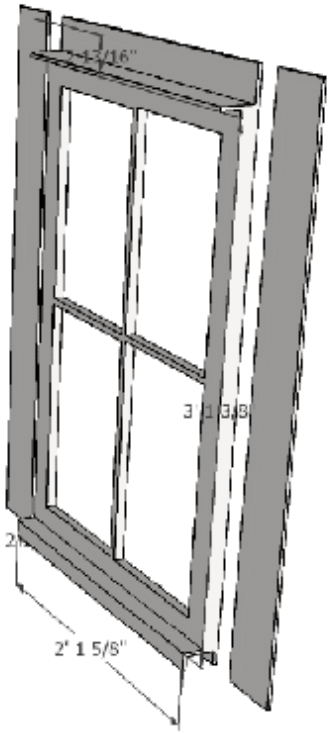
If industrial sandblasting equipment is not available a small automotive sand blaster will suffice. Barring that, don't worry a small grinder and wire brush can be used to remove the majority of surface rust as well. It is just a great deal slower but just as viable to get the job done. Prime the exposed areas with iron oxide paint before spraying the entire container with a final coat of paint. If working slowly over the project I would suggest priming sanded areas as you go on the day to eliminate oxidation as much as possible.

Take the time to treat the roof and ceilings for rust as well. Once they are buried under the false roof they are difficult to access for rust proofing and may work their way into the container over time. Though this would be cosmetic damage only, it is still unsightly.

The outside of the container will first be sprayed with closed cell foam, therefore only the touched up iron oxide primer will be needed until after external insulation. Do not insulate the external surfaces UNTIL all welding is done of walls and windows. The heat melts the insulation and distorts the finish of the house when this is done.

Though sandblasting is the optimum treatment for preparing the building, it is not the only way. A pressure washer and a wire brush may have to do the job in some situations of relief housing.

7. Cut Out and Install Windows



Slot in Window Configuration
U Chanel chosen for Exterior Wall thickness. Upper flange tac welded to frame

Shipping containers are surprisingly simple to cut up. You may use a torch or plasma cutter, however the skill and cost involved for using this kit cannot compare with the simplicity of a 9’’ angle grinder or even a 5’’ if you are concerned about the grinder getting away from you. If you are using all the same type of windows as we do in Africa there are 2 basic options. You can hang a template off the outside of the container and tack weld in place for each window. Or you may choose to simply mark the opening in welder’s chalk or felt pen with a cardboard template. Our choice was to simply mark the windows. But by using an oversized metal template made from 15mm square hollow section (SHS) you will gain peace of mind by providing backing to brace the grinding wheel against to ensure a clean and straight cut. We would suggest that you make your template oversized to cut from the INSIDE of the template so that there is no possible way of drifting into the finished wall of the house. Care must be taken to ensure the frame is correctly placed to flush mount the window in the corrugations on the INSIDE of the container. This allows for a better internal finish and the insulation can then fill the ridge difference from the outside.

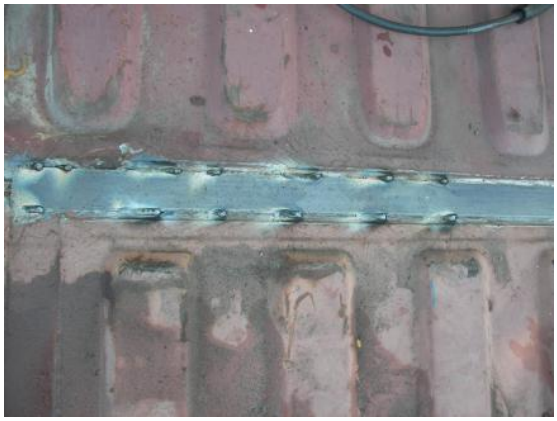
Prebuilt window frames are used to house the windows to prevent damage. The complete package can be secured with a tack weld at the top of the window (see window detail). Additional metal window trims should also be attached at this time to allow it to become the backing for the insulation on the outside. Insulation tape should also be placed on the inside of the window trim to ensure there is no leakage of the spray on insulation. Please note the metal facing in the diagram is on the INSIDE of the house. The angle iron on the top of the frame is designed also to become the drip edge for the window.

If you plan on having custom windows made for the house, the bulk of the windows should have an INSIDE flange attached that is designed to press flush against the larger flat sections of the corrugations of the wall material.

The outside of the window will later be filled with the insulation to form a smooth transition to the external wall without a seam.

If you are planning on using off the shelf store bought windows, before buying them take great care to understand how they will rest on the large flat surface of the corrugations. You must decide your finish at this point in time. If you are going to pre-weld the windows into a metal frame as we did and then inset the window and weld it into a frame, or if you are going to build a custom frame on the container and insert the window later check your overall window width (including the 40mm angle iron frame) so that it fits between corrugations on your specific containers.

8. Weld the Container Tops Together



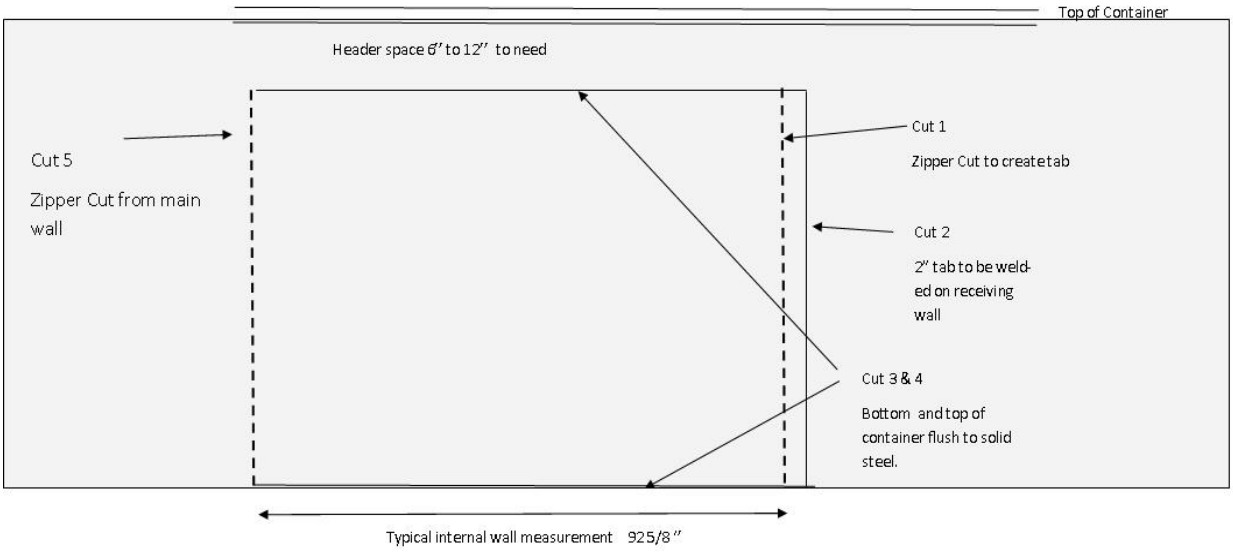
When placed together the containers will have less than a 10mm gap between them. To prevent buckling and deflection of the centre wall it is important to weld at least the tops of the 2 containers together before taking out the wall below. This is achieved by placing 40mm angle iron across the opening and welding both containers' tops together across the gap. You may also choose to use flat steel as the picture shows if you do not intend to put the false roof over the entire project and plan on just water sealing the flat roof. If you are going to install a false roof the angle iron should be facing

up so you have a larger tab to weld onto when you go to put the roof sections on. You may choose to locate the welds every 6 to 8 feet in keeping with where the roof uprights will eventually end up.

The most important area to support in the build is where the large cut-out will be for the main sitting room. Welds between the end bedrooms are to prevent spread only as the walls are not cut out and continue to carry full structural load to the floor below. The large opening is stiffened up by welding the bottoms of the 150mm of the wall left as a header together. By placing either angle iron or flat steel in the gap, you effectively create a 150mm RSJ steel header running across the length of this opening.

If you choose not to put a false roof on the building remember that you will need to seal the seam between the containers with a self-adhesive lead flashing and place at least 3’’ of foam over the entire inside ceilings to keep the heat out due to the exposed roof. Check with local building regulations in regards to the use of a flat roof. In areas with snow loads we would strongly suggest you complete the simple roof design to remove any doubts as to cave in possibilities.

9. Create Opening and “Zipper Cut” Walls



This is the most innovative “trick” in the construction of the Hebner house. By not cutting huge sections of the container away but just bending it, we can do two things:

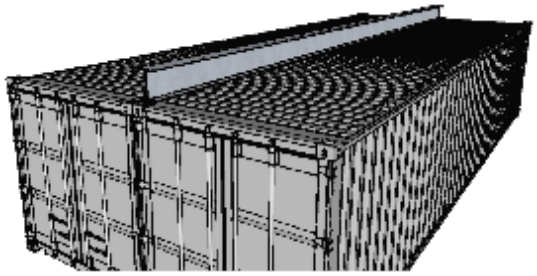
i. add structural rigidity to the building once it is welded in place

ii. create interior partition walls for free in no time at all

If done correctly with the tabs as described below, it will allow for a huge margin of error when it comes to welding interior walls to the exterior of the house.

a. Creating a “Header”

The initial cut of the container walls is 150 mm from the inside ceiling leaving the necessary material to create a header (beam) when the second container arrives. Leaving this material will prevent roof deflection even before the tops of both containers are welded together. This material along with the same being left on the second container will become a structural header or beam running through the house wherever the wall has been taken away. When the wall has been removed or folded away, insert either flat steel, or angle into the space between the containers and weld along the bottom edge of the gap as well as on the top of the containers between the roofs. This may be done in flat steel or angle iron on the roof depending on your final decision of what the roof will look like. These top and bottom welds in essence create just as much support as a rolled steel joist (RSJ) or box truss over the length of the containers.



If you want to cut the full height of the opening an alternative way to create the necessary support install an RSJ on the top of the container and weld it to the 60mm square tube upper frame of the containers. We would recommend doing so prior to taking walls out to avoid any deflection of the container once the sides are out. The steel beam is only required to extend over the cut out opening plus allowing for enough over hang for bearing on each side of the opening.

b. Sealing the Floor

A piece of thin flat steel may also be used as on the roof to secure the floor as one piece. If you have the ability the jointing steel should be welded below the floor level to allow easier installation of the floor finish later.

Remember that the gap between the containers on the floor is to be filled with closed cell polyurethane insulation prior to the placement of the steel.

NOTE

When taking out large sections of the side of the container, it is important to reinforce the opening until the containers are welded together to avoid any deflection from the container as the wall is removed. Many containers have been damaged and the walls are “stressed”. Therefore, they can spring out of

shape if you do not prepare for it. Notice the “pillar” in the photos on the large opening of the house. There is a section of wall approximately 1ft wide that remained in the house until after the containers were welded together and reinforced. Any span over 8 feet consider the same provision to eliminate problems.

c. Reinforce “Zippered” Interior Walls

Once the top of the “I” beam is established in the centre wall, the “excess” material can be folded back to create the interior rooms. We call this process “zippering”. It is done by creating a series of 2 plunge cuts and one clean cut. We can use the folded wall as a structural internal partition. The process is as follows:

Mark the bend point. This is where the largest section of wall will fold from. Keep in consideration how the fold will look before cutting. By cutting the outside ridge of the wall you make a slow sweeping corner. Cutting in the middle of the corrugation produces a square result and cutting on the bend down will create an acute angle which is not good.

Mark the end of the wall to be folded. This is typically 92 5/8’’ (235cm) from the bend point, but take the time to confirm this measurement. This line will be plunged cut. Plunge cutting is when you use the grinder to create a series of slits like a dotted line where you are going to fold the wall in future. This is very similar to a perforated tab on an envelope or stamp only done in steel.

Mark the end of the tab. Add an additional 2’’ extending forward to be used as the anchor for welding to the irregular corrugated wall of the container.

Over bend the end tab first. It will have most of the steel cut through and should be bent using vice grips or a snipe of some sort. You may choose to take a piece of steel pipe or tube and cut a slot into it for leverage.

We have found it easier to slightly over bend the main zippered wall over 90 degrees. This allows for the large piece to sit unstressed while working on securing it to the external wall for welding.

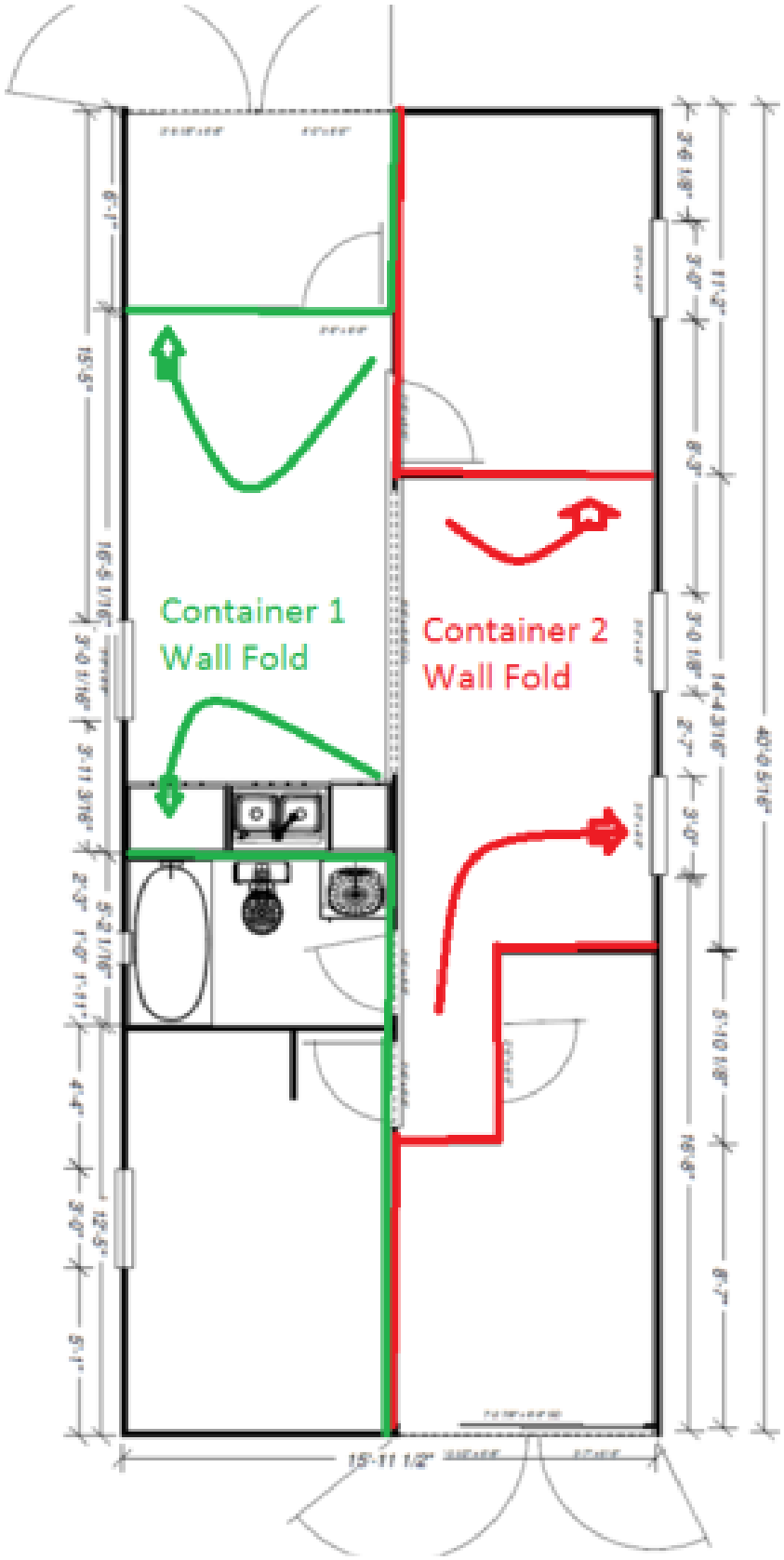
d. Secure the Wall to the Floor

Once over-rotated, place and screw wood battens to the floor to hold the wall in position. Tap screws may be used starting near the main bend to take the lower deflection out of the new wall section.

Screw or weld 1’’ wide tabs of 40mm right angle steel to the floor and wall placing them on the flat concave part of the corrugation. These will be permanent and can be covered with a skirting or covered over with carpet or flooring. If you keep the vertical profile low enough you may not see these tabs at all in your finished product.

Using either a weld or if necessary self-tapping metal screws, attach the tab to the outside wall of the container. This will take out any remaining “slack” in the wall at this time.

Note: Do not cut the doors out of the folded walls until the final wall is firmed up. It will create no end of problems later. If that space will be closed off for a time behind the wall prepare accordingly.


Container 1
Wall Fold
Container 2
Wall Fold
15'-11 1/2"
40'-0 5/8"

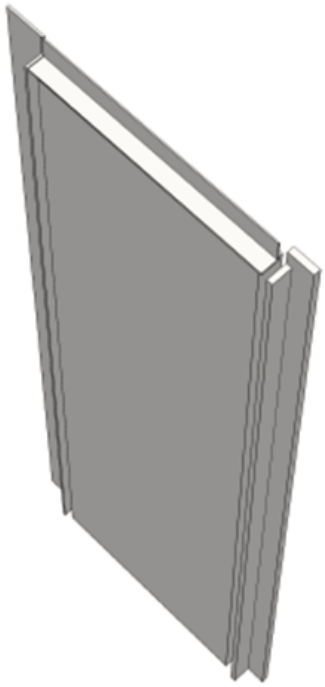
e. Sandwich the Top of the Wall

Depending on the size of the header you created the new wall will have a gap of 150mm left to be filled. This consists of a 40mm piece of timber frame mounted on the ceiling of the container used as a spacer and 2 pieces of 19 mm plywood bolted together. The timber is secured to the ceiling directly above the now located wall. Using the plywood catch the top of the wall between the 2 – 160mm x 2.4m plywood sheets and bolt through in 3 or 4 places. As the bolts are then tightened they bring rigidity to the wall.

You may also choose to reinforce the wall using scraps of 40mm angle iron on the ceiling as was done with the floor connections.

The plunged cut, zippered end of the wall is ground down and filled with mastic (silicone or latex caulk) to produce a smooth corner and then touched up with paint. If you want a higher end finish, these cuts may be filled with car filler (bondo) to become invisible.

10. Cut Out Internal Doors



40mm angle iron prefabricated door frames are the easiest way to save time and money

Just a reminder, door openings should NOT be cut into walls that are to be folded until after the wall sections are bent into place and welded into position otherwise it is impossible to secure the wall correctly allowing you to plumb and level the door.

Once the wall is secured the operation is very similar to that of the windows. The door frame will be made out of 40mm angle iron and is designed to slip into the slightly oversized opening. This gives you the opportunity to level and tack weld or screw the door frame into position. Because the flat side of the steel moves away from the door, the margin for error on this type of doorframe leads to its use (see diagram). When cutting the opening, centre the frame as much as possible on the flat surface of the corrugation so the lip may be welded to it and use 40mm flat steel to close up the gap left on the rear side of the door frame. It is aesthetically best to have the door flush from the outside of the room. As the frames are metal they can be tacked on the hinge side to secure level and swing, and then the opposite side of the frame tacked for square and catchment. Therefore, cut the opening the size of your door, plus allow 20mm tolerance on the sides and 15mm above the door for ease of installation.

11. Install Door Frames

We would suggest the following steps:

Mount a standard hinge on the door. This will hold the hinges in place for positioning on the frame.

Tap screw or weld the hinges to the angle iron. Remember to leave 5mm at the top of the angle iron as the clearance for the top of the door when finished.

2 options at this point:

Frame the door in stages:

Tack weld the angle iron to the wall in final position with swing and level as per any door.

Position with clamps and tack weld the top frame to wall and hinge side of frame keeping a consistent finished top gap.

Position the door handle side of the door (where the lock set will go) to maintain the correct clearance for the entire frame from floor to ceiling. Clamp this and weld.

Complete the door frame and then present:

Keeping the door flat tack weld the top and receiving side of the door completing the frame. Do not over weld the parts so as to allow for movement in the frame.

Install the handle set at this time.

Secure the door into the frame maintaining margins. This may be done with a temporary brace or a screw through the receiving door frame and into the door where the handle set will eventually be placed or at the bottom of the door where it will not be noticed when removed. Remember this will have to be removed so plan on how you will take it out.

Position the frame to the opening, taking time to level the hinge side of the door first. Tack weld the remaining 2 sides before removing the bracing on the door.

Consider purchasing or building pre-hung doors on 40mm steel frames as part of the production cost or prep process. This will allow for faster on site assembly and more accuracy if done in a controlled environment.

This process may be done at various times through the cut-out stage, and is adjusted according to the window and door frame/kits that are available in your area. If window frames are factory primed with no glass, cut-out and installation can be prior to sandblasting. If windows are factory finished, then they should be installed AFTER the main paint spraying.

Helpful Hint: Cutting out windows, doors and walls should always be done on the horizontal axis first. This will extend the life of the cutting wheels to 2 windows for each 9'' wheel and allow for the depth of the corrugation not to be a factor in the finish of the final cut.

12. Security Door Installation


In the construction of this house we set out to utilize and embrace all we could of the innate structure of the shipping container. That is why we use the full boxes and do not cut them down. The container doors offered an added bonus to the overall security and value of the project by providing a solid set of robust hinges that we could modify into doors. By cutting out the insides of the doors most of the weight was removed and we found that the doors without load were very easy to move. By adding 15mm square tube at 100mm (4’’) on centre we managed to create simple and elegant security doors. We did not explore other decorative options but any sort of metal work may be used to once again celebrate the container building rather than hiding its innate value. A simple coat of rust resistant paint on the bars transformed this simple modification to a functional highlight of the project.

13. Build Roof Gable Ends and Install Roof Purlins

Depending on internal design there should be enough surplus steel wall sheets to build the gable ends. These are tacked to 40mm square steel tube or angle iron welded to the roof as well as to the centre steel straps which hold the containers together (see earlier notes).

To allow for ventilation the top of the gable ends have either a wire mesh fixed in place or are plunged with a disk cutter several times to ensure ventilation. I would suggest you pick a pattern and try to make it look nice as once painted this will be a finished surface. A plunged cut diamond or chevron pattern is easy to do with a little care with the disc cutter.

Remember the importance of the air circulation to prevent condensation and a heat trap.

Standard 6m (20ft) long roof purlins are positioned to receive galvanized steel sheeting. The sheets allow for natural eaves ventilation via the corrugations. An internal attic hatch is located in the hallway of the house by cutting through the container roof.

The ridge height is set at 1m above the container roof in order to make the space above the ceiling usable for storage. You may make this angle steeper if you like. The loft space can be insulated either by spraying at the same time as the walls or by laying quilt insulation on the top of the container.

14. Install Electrics

Electrics should be installed by a qualified electrician. However, you may want to keep a few things in mind to make your life easier with the container house:

Plan on keeping the wires in a main trunk between the containers. You may want to leave a space between the welded angle iron on the container to fish these wires through before you seal off the opening between the boxes.

Self-adhesive plastic trunking has been ideal for this project. If installed first the final coat of paint locks the material into position.

Surface mount electrics can be placed in the concave part of the walls taking them away from distraction and allowing for sheet rock or drywall to be placed simply in front of the conduit with little or no adjustment in the build stage or in the future.

Ceiling drops seem to work best. If a secondary roof is planned for your home, very little waste and visual interference is generated by the covered conduit dropped in the recesses of the corrugation.

Install all drops and light fittings before insulating the ceiling. This will create a far cleaner finish for your house overall.

A minimum of a 60A service panel should be installed.

For the steel container material, drilled and riveted electrical boxes are best.

We chose to run power points on the inside wall only. By doing this we could put 1 light point and 2 double sockets per room directly below the switch to save costs in the humanitarian unit.

If photo-voltaic panels are used 2 batteries and the inverter are stored directly below the panels in the roof cavity for security and ventilation.

15. Prep the Container to Receive Insulation

We were amazed at how simple it was to direct the location of the foam. External gaps around windows and doors are simply filled using packaging tape from the inside of the building. Windows are covered with newsprint and taped with 2'' or 3'' masking tape to create the clean finished line for the outside of the window and again a bead of tape is run on the inside of the container creating a backing for the spray foam. The internal ceiling was prepared by using 3" masking tape with 1.5mm plastic covering the walls for overspray.

We strongly suggest that all electrics welding and sandwich boards between rooms are done before beginning to spray. You must also decide if you wish to put the bathroom wall in before or after this process. It is faster to do it later, but it does affect the overall finish of the ceilings. This is not only your insulation, but it can be the finished ceiling of the inside of the house depending if you choose to paint it. Make sure you use a level and measure when installing the masking tape internally for a consistent height. We chose to match the line with the sandwich boards on the top of the wall for two reasons:

- By doing so we could completely hide the boards and create a very attractive texturing throughout the house. This allowed overlap between the ceiling insulation and the external wall insulation to ensure a complete barrier.

- By extending the insulation down from the ceiling, it reduced the amount of steel in the building that would be susceptible to condensation when cooking in the house.

16. Insulate the House

Closed cell polyurethane insulation is our preferred choice of materials. However, to keep costs down we would also suggest mineral wool insulation as a substitute for the roof cavity and for under the shipping container. You may apply the closed cell polyurethane (CCP) yourself and there are countless You Tube videos that come with the spray on insulation to show you how to apply the foam. For the DIY insulator I recommend the Froth Pak 600 or equivalent from Dow chemicals as a benchmark product to use. This two part mixture when applied at temperature (remember to heat the tanks before use) at a depth of 1 inch of insulation on the outside walls of the container and 1 inch on the inside ceiling dropped the temperature of the prototype house by 11 degrees C in just 1 hour. This effect was greatly due to taking the metal shell out of the direct sunlight. Insulation may be applied to depth as required by the environment the house is located in. Each inch of CCP has an R value of 7.5. Northern climates require R20 for Walls and R40 for ceilings. In a cold climate the underside of the container should be sprayed with R 40 or covered with suitable baton insulation. In a South African environment, a uniformed coat of 1’’ will be adequate in the majority of applications as well as in other desert and tropical regions. The use of rock wool in the floor will keep the costs down in regards to the amount needed in an Arctic environment. Not proven, but I would recommend filling the majority of the underside of the container with rock wool stapled to the bottom of the floor panels and friction fit. Then place 1’’ of CCP insulation over top as a sealer of the cavity. This will make the base air-tight and prevent the incursion of rodents as they detest the foam and all of its characteristics.

There are many places in the developing world today that have access to the spray foam technology in an on-site trucked in service. A simple google search for Dow chemicals, or local knowledge should reveal access if you would rather delegate this aspect of the build.

Note: This is the most important and definitely the most expensive part of the build. But I implore you, do not skimp on the insulation or you will end up living in a heated steel box or a permanently cold damp metal container. What allows this project to work with shipping containers is the insulation sprayed on the OUTSIDE of the building, on the INSIDE of the ceiling and UNDER the container. If the insulation is installed correctly:

It increases the insulation's effectiveness.

It allows the room sizes to remain a full functional 8' and develops a finished modern looking internal wall for free.

It creates an insect free continuous vapour protection for the building.

It prevents condensation from forming on the internal ceiling while cooking and using wash facilities.

It provides sound deadening to add warmth to the house.

17. Spray Internal Insulation Gaps and Ceiling


Start by filling the crack between the containers. This should allow you to learn the flow rate of the product, while getting on with the task. Fill the floor line shooting foam almost at the horizontal so as to not blow the material through the gap. Vertical spaces should also be approached from a slight angle as the material will stick to the surface and not simply be jettisoned to the end of the cavity. Take care to seal the internal gap between the containers as well as the corresponding outside gap to eliminate as much air transference as possible from the outside.

Here’s how to get a clean finished edge. Prep the wall with draped plastic taking great care to understand that where the tape comes in contact with the wall will be the final finish on the ceiling. Do not over apply on the wall. It is best to feather the lowest edge and build up mass as you approach the ceiling. Since the outside wall is insulated to the top of the container, the material sprayed on the inside side walls is for condensation and cosmetic purposes only. We suggest you spray the side walls as far down as the material protruding from the top of cut centre wall so as to conceal the plywood sandwich that is positioned at the top of the folded back partition walls. Experiment on some scrap materials before coming inside to ensure you achieve the type of finish you would like. By a simple mix and or nozzle adjustment you may have a pebbled or smooth finish on the surface of the closed cell polyurethane.

18. Paint the Container Internally

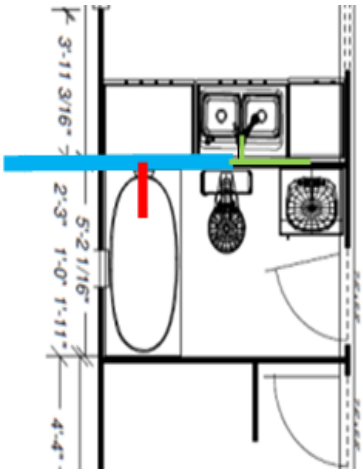
HVLP sprayers are stand alone or compressor driven

We are now into cosmetic choices as some people prefer to leave the ceiling foam to fade and yellow while others feel it should be painted. In either case a high volume, low pressure sprayer should be used to spray paint the containers internally and externally. This will minimize the drips that are created often by brush, roller or cheap electric sprayers on a metal surface. Ensure that the external paint is UV protected as this is important for the life of the insulation. Inside, always paint the entire ceiling first. The floor should also be painted to seal any contaminants in the original container. Spray everything, even primed doors and windows with a base coat.

The exterior of the containers should not be painted prior to the application of the CCP. DO prime the areas where the container has been treated for rust. Ensure it is a clean and smooth surface. But an undercoat would be a waste and even detrimental to the life of the CCP. Once the CCP is applied, wait at least 48 hrs before applying the final coat of paint to the house.

19. Install Bathroom and Kitchen Plumbing

Due to the variety of plumbing around the world we will not fill too much space with details here. All waste plumbing is minimized by running the bathroom with the kitchen sink attached through one common separating wall. In the humanitarian unit hot water, if added, is via a roof mounted solar heater. All supply plumbing is also limited to the bathroom/kitchen wall with an external tap.



To avoid the need to go through the floor a rear exiting toilet should be purchased. This is more common in Europe and Africa than the bottom exiting North American units. In humanitarian projects it is expected that these pipes will be left exposed with a simple 100mm hole drilled in the side of the container prior to insulation being sprayed.

There is no provision for a ceiling fan in the base unit, and sewer gas is vented with a one way check valve outside the building as the plumbing run is so short it is within tolerance to do so. Please check with your local building codes if this needs to be done differently where you build.

What is different here is that we do not put the bathroom wall in until all parts of the bathroom are installed first. This allows for an easy installation

of all materials before closing up the space. The bathroom wall is the only wood framed wall in the structure and may be constructed on the floor of the adjacent bedroom and then stood up. We would again encourage you to have this wall in place BEFORE spraying the inside ceiling to preserve a consistency in the texture.

Basic Drainage Needs

100mmx60mm x 100mm T

100mm x 100mm x 60mm T

100mm x 100mm x 100mm T

100mm cheater vent

60mm x 40mm x 40mm T

1 - 60mm trap

2 - 40mm traps

2 - 60mm 90 bends

4 - 40mm 90 bends

4m 40mm pipe

2m 100mm pipe 1m 60mm pipe

20. Second Fix Utilities

With the internal walls painted, second fixing of electrical points and plumbing fixtures may be completed while the external part of the house is

prepared for spraying. At this time all window and door trims must be on and welded as no welding can occur once the insulation is sprayed onto the container. All wall openings for water/electric, windows and doors must now be sealed to the outside using tape or finishing trims.

NOTE: This is a personal preference but before applying the CCP, electrical boxes and ceiling roses may be installed and taped off. This will allow for a more integrated look for the house, but if it ever needs replacing it will take its toll on the overall appearance as the rose would have to be dug out.

We chose to use a simple 5/16'' pop rivet for placing electrical boxes and fittings to the wall.

Basic Electrical Needs

100m 14/2 wire (UK 2.5 2 wire + ground)

1 - 60A Service Box with regionally specific breakers

8 x wall mounted light switches & boxes

5m (or what is need) 6mm shielded service cable

8 x 2m surface mounted conduit

Box of 5/16th pop rivets

8 x double wall sockets & boxes Grounding Rod

8 x ceiling roses and surface mount boxes

72 Box connectors

Box of 100 wire nuts or junction blocks

21. External Insulation

Spraying the container itself is a relatively simple process that will take just over an hour. We chose to put in a self-adhesive roof flashing between the two shipping containers as a secondary waterproof measure. A final walk around check should be carried out before you begin the spraying process. Though you may start and stop most insulation systems, consistency in application translates into consistency of finish on your final surface.

Before you begin ensure that:

The roof frame is on and all welding is complete. This includes the end gables and their ventilation cut-outs, but not the final corrugated sheeting of the roof as overspray can be a huge cosmetic issue.

Shipping door catches have been ground off and /or doors have been welded shut and prepared to receive insulation.

Sewage drain is connected (insulation will fill the cavity to create an airtight seal).

The water and electric connections are installed as they too will be sealed by the insulation.

All window and door frames are taped and masked over. Remember the line of the tape edge will be a final finish. Take care to make this look right by feathering the insulation at this point and not building it up too thick.

Application

Mask off and do NOT spray any container doors or hinges that will continue to be used.

Spray a minimum of 25mm (1”) closed cell insulation on all outside surfaces.

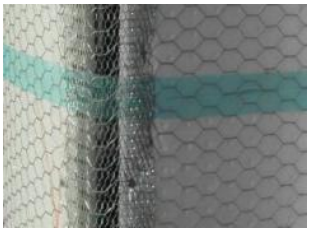
Spray over gap between containers first then spray over panels.

Concentrate the jet to soften the corrugations. (Spray the concave valley of the corrugation first).

I suggest practicing on a scrap piece of steel first to learn how the gun works so there are no application issues and you can work out how you want the texture to look.

Make sure you have a ladder available so you can ensure even coating at the top of the building as well.

22. Paint or Render External Insulation



Closed cell insulation is an amazing product but has the shortcoming that it degrades in ultra violet light (UV) which comes with sunlight. There are two ways to solve this. Either paint the insulated container with a UV protective paint (Don’t worry - most exterior paints are already built for this), or alternatively render (stucco) the exterior.

This is done by leaving the spray-on insulation on a coarse setting when applied to create an adhesion surface to receive stucco. Because of the nature of the foam standard cement rendering will stick on the surface with no additives required. It is best to apply the stucco with a Tyrolean applicator in 3 thin coats for a final finish. Let the insulation set between coats before

further application by hand held or compressed air applicator. Please note that during the first 2 coats of stucco there is some deflection still possible in the container walls. This will crack the brittle thin layer of rendering until it has enough substance to firm up the wall. Take care to not bang on walls until the rendering is complete.

For a smooth external finish, wrapping the building in chicken wire before spraying it with insulation will remove the trade mark ridges on of the exterior of the container. You can fasten the chicken wire by putting 2x1 batons in the concave spaces of the container EARLY in the build. If from the start you are planning on using stucco, wood batton should be fixed into the concave of the corrugations at least every 4’ in order to have places to tighten the wire and take the slack out of the final surface. We would install it at the time of initial welding and window cutting.

This is a picture of the foam covered with UV Paint 5 years after construction. There is no apparent ware.

23. Roofing


The roof for the containers has no structural value and is there as an insulator in a warmer climate and as a deterrent to snow load in colder climates. Therefore, in most cases the construction of a simple 3.2 mm galvanized sheet roof will be enough; however, it should be checked against your local building codes.

In the African model purlins run the 40’ (12m) length of building supported every 8’ (2.4m) at their midpoint with steel struts made of 1’’ (25mm) box steel that are welded to the ceiling of the house using angle iron. The centre strut should have been welded on to the seam between containers using 40mm angle iron and installed at the weld together phase of the build. Depending on how you want the finished project to look, you may increase the slope and or the height of the roof and use this space as we did for storage. The building allows for a loft hatch in the hallway ceiling for access. Ultimately the roof is not time sensitive. You may choose alternative styles or even create a photo voltaic panel array instead. The traditional roof is held on with either self-tapping screws or standard hook bolts using inexpensive galvanized sheeting.

Note: Make sure that struts are welded to the container BEFORE the application of the foam on the ceiling. If not, it will melt the foam and

separate from the substrate.

24. Hang Doors and Install Glass

There are so many window options we will not comment in this handbook. We do wish to remind you to be careful to do this at this point in the build. Though we love the foam insulation, the truth is it is very difficult to get off once the overspray has attached to anything. If your doors are pre-hung or the glass is pre-installed, take great care to keep all these surfaces covered until this point of time in the build.

25. Install Bathroom Partition Wall and Tiling

The only timber wall in the building is the non-water wall of the bathroom. We intentionally did not put the wall in until after all fixtures were installed and running. This allows for the plumbing to be installed in a non-confined space and the floor to be tiled without cutting tiles thereby saving time. We would encourage this step to be done before spraying the ceilings if you want to hold the pattern on the outside of the wall in the bedroom. We then simply paint the bedroom wall as a feature once the wall is installed. The bathroom side can be covered with either a laminate, PVC lapped panels or tile as preferred. The material used for the bath surround can continue for the rest of the wall though a custom made flashing must be made to fill the gap between the corrugations on the wall to prevent water damage along the side of the tub.

26. Final Finishing and Flooring

Because of the corrugations in the walls, skirting boards, though possible, are very time consuming. Carpet and other laminate floor finishes with a subjective cut line are favoured as they can be trimmed to the undulations on the wall easily.

Floor tiling is an option for the house but, as can be seen in the pictures of the prototype, care must be taken to create an expansion strip in the centre of the seam to prevent long term cracking of the floor. As well, unless you are

prepared to cut each and every tile with a curve, you will end up with grout pockets along every wall that will need to be filled.

Conclusion:

The pictures you see here are evidence that this project works. Taken 4 years after the house was built the structure shows very little signs of wear and degradation even while exposed to the constant abuse of the sunlight in South Africa. Container housing continues to build momentum as a world movement; there are lots of great concepts and ideas that may be used alongside this guide today.

Techniques and finishes are coming online and being refined as the industry expands in our current age. Our desire in getting this hand book out to people is to help the majority of the planet understand that it does not take a great deal of time, energy or money to have a quality secure home. Please let us know if you have found this guide helpful, and please forward us a picture of your finished project.

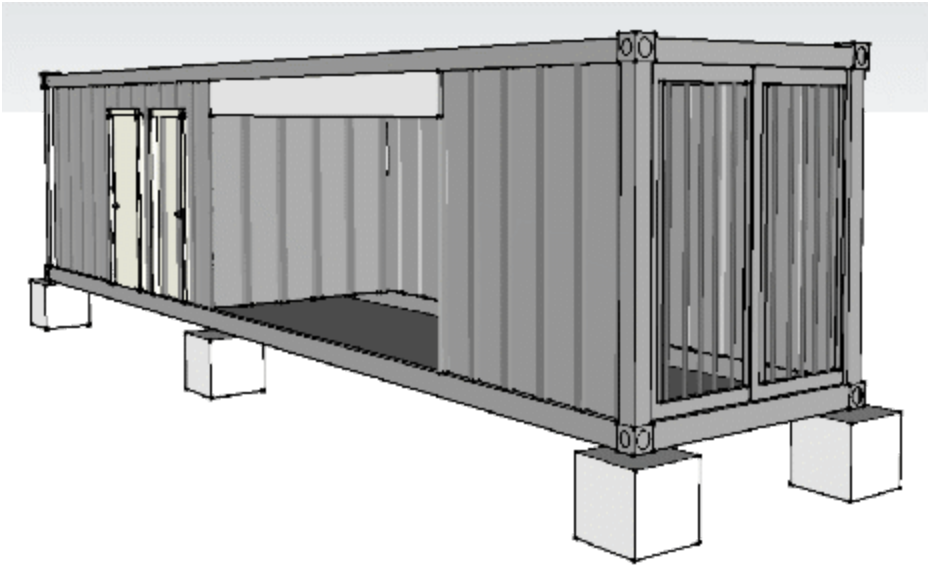
Appendix 1: Costings from Cashbuild April 2014

	Description	Units	Cost (ZAR)	Rand (ZAR)	USD $	GBP £
12m container	Grade 'B' or lower but structurally sound	2	33,000.00	66,000.00	$ 6,179.36	£ 3,791.56
Self-Adhesive Flashing	600mm self-adhesive roll flashing (Flash band)	2	200.00	400.00	$ 37.45	£ 22.98
Cut out trim	Riveted C channel 30m	5	100.00	500.00	$ 46.81	£ 28.72
Sand blasting grit	25kg bags	2	250.00	500.00	$ 46.81	£ 28.72
Pneumatic grinder wheels	Standard fibre reinforced	50	6.00	300.00	$ 28.09	£ 17.23
2 part polyurethane insulation	Local supply or Froth pak 600	2	7,000.00	14,000.00	$ 1,310.77	£ 804.27
Cement	For piles 2 bag average + steps	18	50.00	900.00	$ 84.26	£ 51.70
Aggregate/ Sand	For piles 2m average (3 ton)	2	200.00	400.00	$ 37.45	£ 22.98
Paint	50 litres, oil based	2	400.00	800.00	$ 74.90	£ 45.96
1 bathroom window frame	Traditional African ME1	1	260.00	260.00	$ 24.34	£ 14.94
Windows	Traditional African 2ftx 4ft MC2	6	500.00	3,000.00	$ 280.88	£ 172.34
2 entrance frames	Full window wall insert kits for end of crate	2	400.00	800.00	$ 74.90	£ 45.96
Sliding Glass patio doors	Full wall glass units	2	3,000.00	6,000.00	$ 561.76	£ 344.69

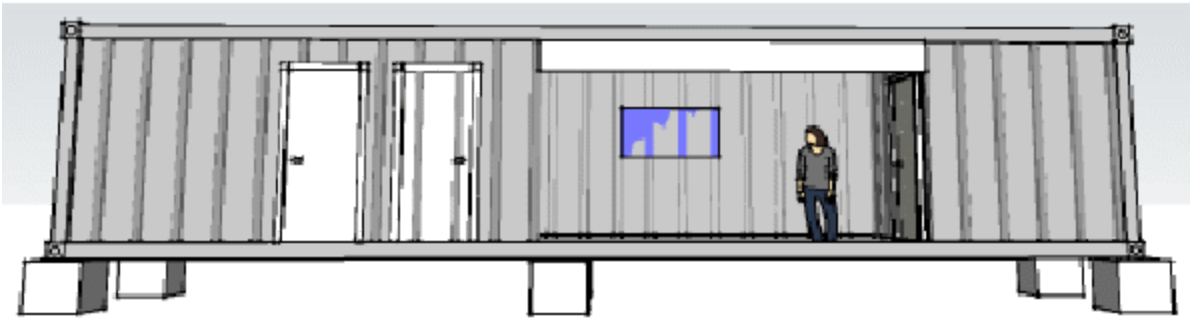
	Description	Units	Cost (ZAR)	Rand (ZAR)	USD $	GBP £
Doors	Hardwood	1	750.00	750.00	$ 70.22	£ 43.09
Door Hardware	3 lever lock	1	60.00	60.00	$ 5.62	£ 3.45
Internal doors	Hollow core internal	4	200.00	800.00	$ 74.90	£ 45.96
Internal door hardware	1 lever lock	4	30.00	120.00	$ 11.24	£ 6.89
Bathroom Suite	Standard White contractor grade	1	2,000.00	2,000.00	$ 187.25	£ 114.90
Interior wall supports	25mm L bracket or square channel in 6m lengths	4	80.00	320.00	$ 29.96	£ 18.38
Electrical wiring	40A service cabinet & 1 switch & plug per room	1	1,000.00	1,000.00	$ 93.63	£ 57.45
Floor Varnish	Sanded and varnished all units	1	400.00	400.00	$ 37.45	£ 22.98
Kitchen Cabinets	2x1000mm base units, 2 wall cupboards + sink	1	2,500.00	2,500.00	$ 234.07	£ 143.62
Container locks and holds	Crate locks to secure outside containers & lock open	1	300.00	300.00	$ 28.09	£ 17.23
Window Glass	6 windows per unit	5	100.00	500.00	$ 46.81	£ 28.72
Light fixtures	1 per room + 1 external	6	40.00	240.00	$ 22.47	£ 13.79

	Description	Units	Cost (ZAR)	Rand (ZAR)	USD $	GBP £
C channel for roof facade	6m 75mm	8	100.00	800.00	$ 74.90	£ 45.96
Roof Fasteners	75mm hooks	1	50.00	50.00	$ 4.68	£ 2.87
Roof end braces FOS	Container scraps formed to hold C channel	4	100.00	400.00	$ 37.45	£ 22.98
Security Bars for windows	Prefabricated at extra cost	5	200.00	1,000.00	$ 93.63	£ 57.45
Roof Sheeting	sheets @ 4.2m x 2.7mm Galvanized steel	24	180.00	4,320.00	$ 404.47	£ 248.17
Transport Costs	Per unit moved	2	3,000.00	6,000.00	$ 561.76	£ 344.69
Flooring	Ceramic tiles and grout (200/m^2)	60	200.00	12,000.00	$ 1,123.52	£ 689.37
Sundries	brushes/brooms/plastic sheets plywood			2,000.00	$ 187.25	£ 114.90
Total				127,420.00	$ 11,929.90	£ 7,320.01
Contingency 10%				12,742.00	$ 1,192.99	£ 732.00
Total Cost excluding land clearance labour and hook-ups				**140,162.00**	**$ 13,122.89**	**£ 8,052.01**

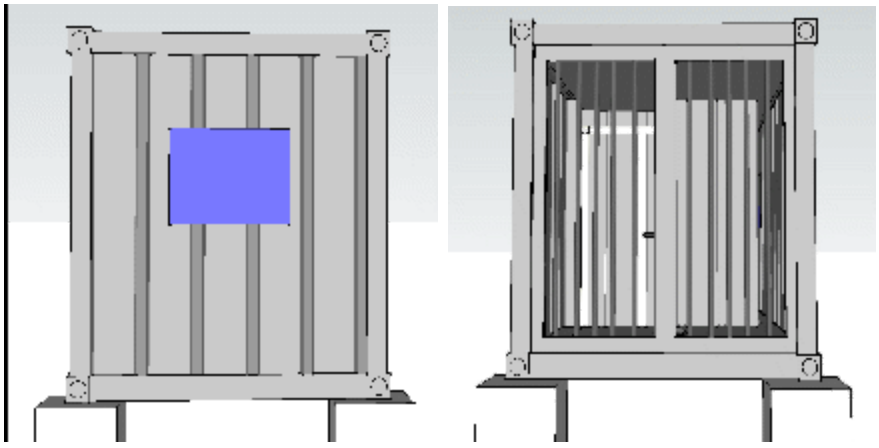
Appendix 2 – Additional Visuals



Container 1 ¾ View

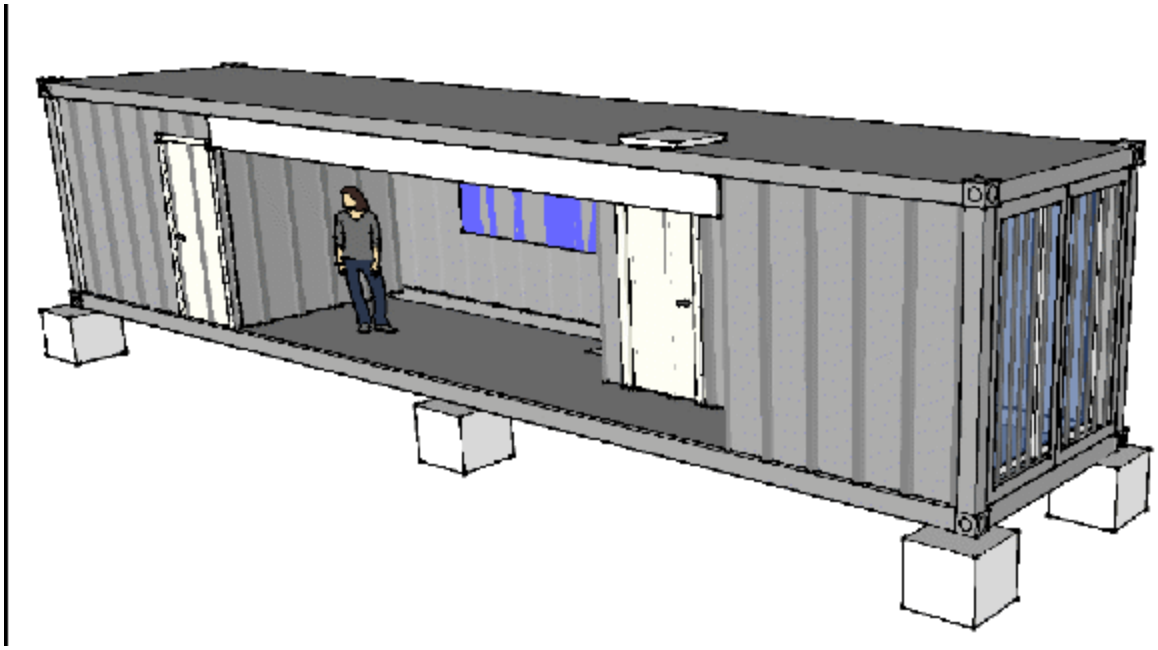


Side View

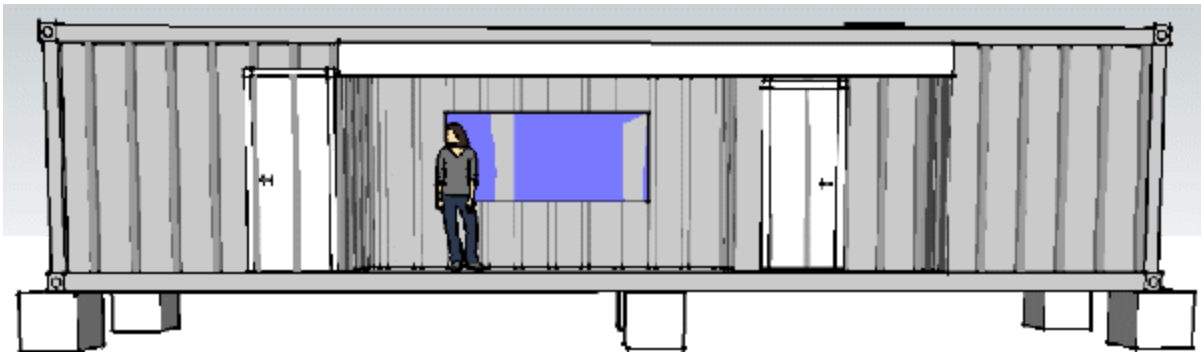


Front View and Back View

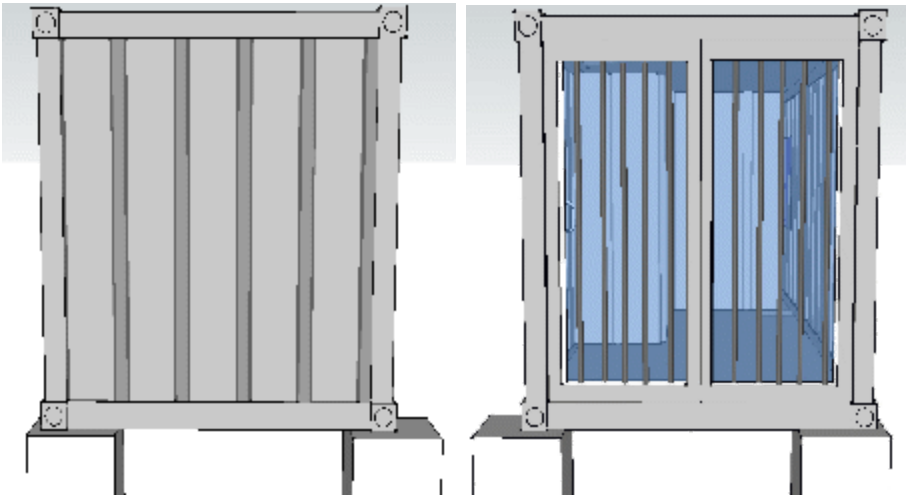
Container 2 ¾ View



Side View



Front View and Back View



A Note from the Author

This handbook is based upon a project that worked in South Africa in 2010. It is not meant to be a certified building book, nor does it take into account all the variables that may or may not change the effectiveness of the home in your location. It is a guide proving that a secured simple house can be constructed at a $1/10^{th}$ normal estimated construction costs and in a fraction of the time currently billed out by average construction companies. We take no liability in regards to your attempts to replicate this building. We will not be responsible for any damages or injuries incurred due to using this resource. We encourage you to check with your local building control officers and to seek their guidance where possible. In most countries there are no building regulations as yet that apply to shipping containers. However, it would be prudent to seek advice where possible.

My dream is that in some small way this manual may be used to develop low cost practical housing solutions for the poor in developing countries. If you use this manual in this way please be so kind to send us a picture of your work.

'Truly I tell you, whatever you did for one of the least of these brothers and sisters of mine, you did for me.' Matt 25:40

In His Service,

Bill Hebner