

Prototyping Evolution & Insights

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Prototype 1

Shortly after concluding the research at the Imvepi Refugee Settlement, work started on building a prototype that had 3 main features:

1. A sitting toilet suited for elderly and disabled inhabitants
2. A sludge extraction point
3. A ventilation pipe

These features were determined based on the field research, literature research and company requirements.

The product was limited to these 3 features, to ensure the products affordability and the feasibility to create a product in the timeline of the project.

Over several iterations of prototypes, the design developed into a product ready for production. In this chapter the 3 prototypes are discussed. Per prototype, the specific features are laid out, the insights and lessons learned from them are discussed and finally,

The first prototype featured a fixed sitting toilet mounted on the container lid, along with a ventilation pipe and an emptying connection that extended to the bottom of the container. However, this design required extensive modifications to the container, increasing the risk of leaks. To mitigate this issue, it was decided to develop a redesigned lid that integrates all necessary features, ensuring a more secure and reliable system.

In the first prototype, there was no frame. Testing demonstrated that the container could buckle under the weight of the toilet stall without this reinforcement.

For the first prototype, the Gentex water tank of 2000 L was found that matches the requirements for containing the sludge. A sitting toilet was placed on top of the lid and 2 holes were cut in the top of the tank. One to place a ventilation pipe on and one through which the sludge could be pumped out of with a pump. The pump hole had a a pipe extending to the container's bottom.

Insights:

Risk of clogging and manual repairs inside the container

PRACTICA, a bureau specializing in latrine solutions, highlighted clogging risks associated with the internal

pipe design. Such a configuration could lead to repairs requiring individuals to enter the container, posing significant health hazards. To mitigate these issues, the internal pipe was removed and replaced with a single hole capable of accommodating various emptying tools. This modification reduced clogging risks while allowing hoses to be thoroughly cleaned with water, detergent, and bleach, a standard practice identified by PRACTICA. Additionally, this change simplified the design by merging ventilation and emptying functions into a single connection hole.

Structural Integrity

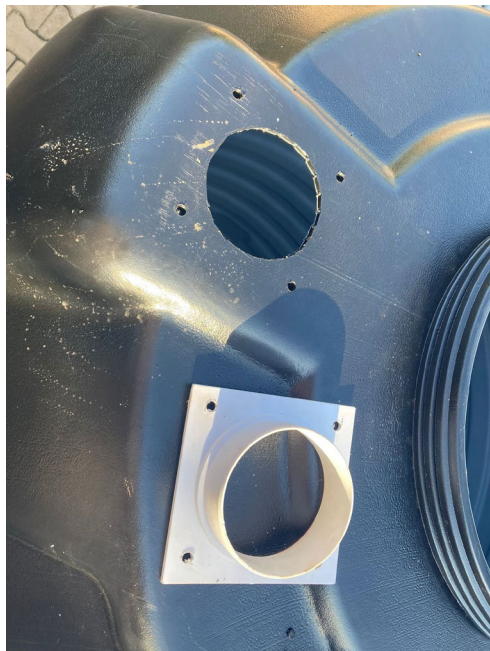
This prototype was shipped to Imvepi and installed in order to learn and improve upon it. In this prototype, there was no frame. Testing demonstrated that the container buckled under the weight of the toilet stall without this reinforcement. We would need a frame that could support both the toilet stall and the user's weight without putting that weight on the container, causing it to buckle.

Hole cutting in the container is messy and can cause leaks

The holes that were cut in the container for ventilation and emptying took a long time to cut and had messy edges. While I am sure there is a better way to cut holes into the container, I decided to incorporate all features into the lid of the container, so no extra cuts would be necessary.

Sitting toilets are associated with UTIs

While discussing the building of my prototype with the design agency Design Without Borders, they brought to my attention that sitting toilets, especially in crowded areas with a lot of use, are associated with UTIs. Whether this is true or not was cause for debate, but it became clear that the belief was there and that it could have a big influence on the acceptance and ownership of the product by the inhabitants if they were not given a choice between a sitting and a squatting toilet.





Prototype 2

The second prototype uses the same container, and uses the lid to incorporate all features.

The second prototype was initially planned for 3D printing, as this is a common practice in the Netherlands. However, consultations with G-Nex Engineers revealed that welding is the standard practice in Uganda, offering a cheaper, stronger, and more durable solution.

Consequently, the decision was made to construct the second prototype using stainless steel, ensuring greater longevity and local feasibility.

In the third and final prototype, the frame is structurally sound; however, the inner beams are too thick to fit the tight space between the container and the box. Therefore, in the final design, 20 mm square profiles are used for the inner beams.

The design was made to be injection moulded. The first prototype would be 3D printed.

However, when I sought out the consultation of G-Nex Engineering in Kampala, who generously helped me build the prototype, they pointed out that 3D printing is not common practice in Uganda, especially at this size, and it would be very costly.

To improve the design for reproduction in Uganda, we redesigned the prototype to be made from steel. Metalwork like welding and grinding is common practice in workshops throughout Uganda and can be done close to Imvepi and eventually other locations throughout Uganda and the rest of Eastern Africa, however, for large scale production, injection moulding could still be considered from a financial standpoint.

The injection moulding design was pretty much copied for metal prototype, which lead to some interesting challenges and insights.

Insights

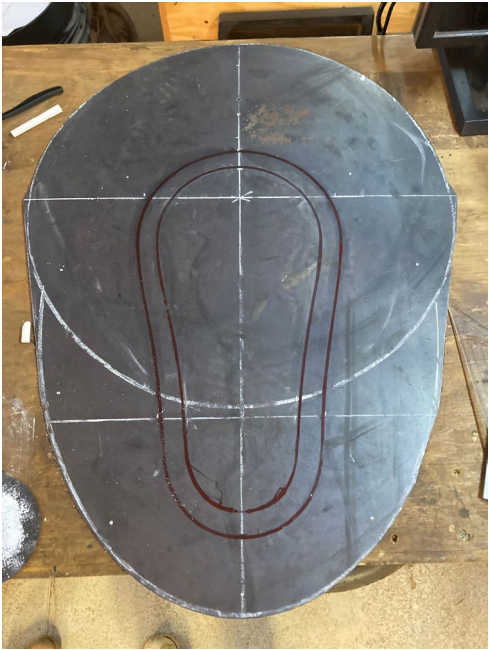
Square and simple where possible

The prototype had a lot of rounded edges, in order to save material and make it structurally strong when using injection moulded plastic. However, when working with metal, it is best to

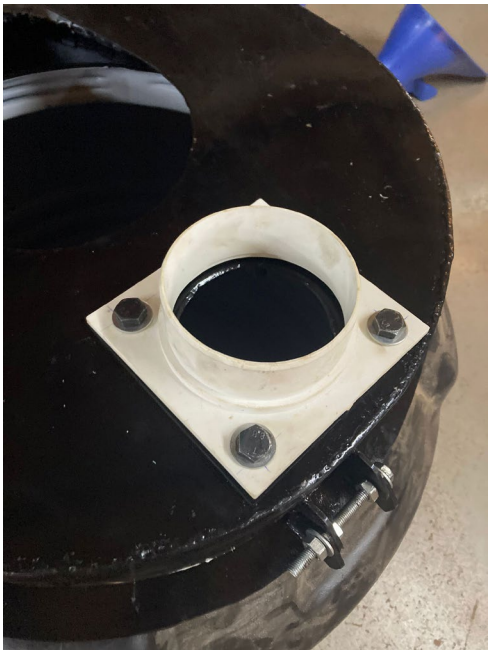
keep things as square as possible, since any rounding will require custom shaped parts. Also, when trying to waterproof the prototype, an elaborate rail system was made that could hold rubber strips in place. However, this design proved to not be watertight.

Hinging causes trouble

Another issue that added to the design not being watertight was the hinge system meant to be used when emptying the toilet. This system put a hinge at the back of the prototype and a lock on the front. The lock would be taken off when emptying and the box opened to put the hose through and empty the toilet. However, this system made it so that only 2 points of contact between the bottom plate and the box where pressure was applied to press the rubber together and create a watertight seal. The bottom plate was not supported anywhere else and was able to bend and allow water to leak from the prototype. It became clear that this hinging system would not work and we would need to secure the box and the bottom plate together more securely and find a different way of emptying the toilet.







Prototype 3 (Final)

During the second prototype's development, the design shifted from a screw-on lid to a press-fit system with a rubber ring, improving watertightness and simplifying the structure. Testing of the first prototype showed that the tank couldn't support the toilet stall's weight, leading to the addition of a supporting frame for stability.

The third and final prototype for this project was made in Delft. It is built from regular steel for its affordability, however, the final product will be made from stainless steel to not rust due to the groundwater, urine or cleaning water it comes into contact with. It incorporates the insights from the previous prototype into a more square design. The hole for ventilation is also suitable for emptying, further simplifying the design as well as making sure the bottom plate can be tightly fastened to the box with bolts and nuts. The design incorporates a structural frame that supports the weight of the toilet stall as well as the users. This frame also forms the outline for the building of the toilet stall, to ensure all stalls are the same size and are structurally sound.

Insights

Watertightness

This prototype was tested for its watertightness, which is now actually working. There were no leaks found in testing the watertightness, but sustained use in the field will teach us if the design needs to be improved.

The inner profiles of the frame need to be smaller

The inner profiles of the frame are currently 40 mm square. This is too large to fit between the bottom plate and the container. These need to be smaller (max. 20 mm). For structural strength, the outside profiles of the frame will remain 40 mm.

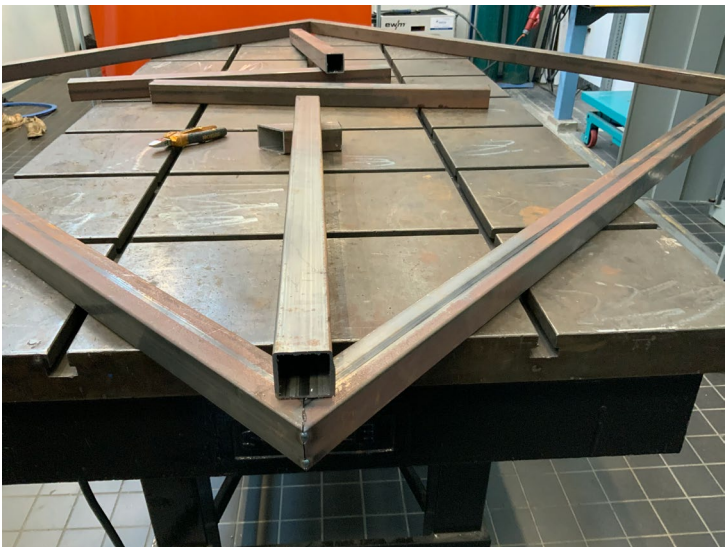
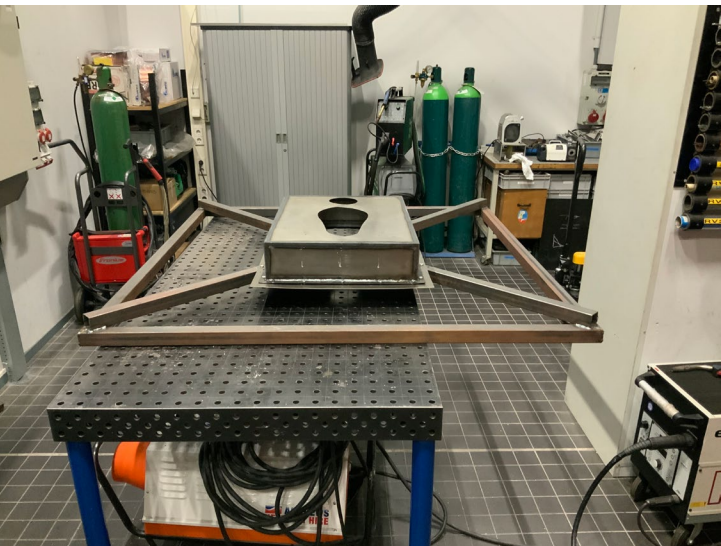
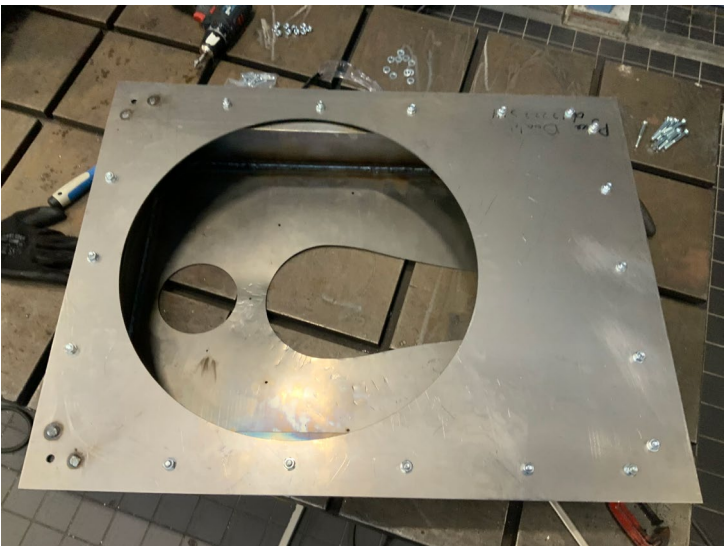
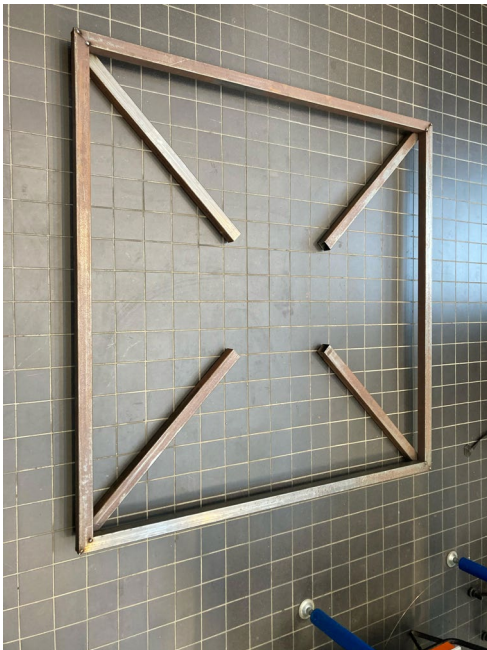
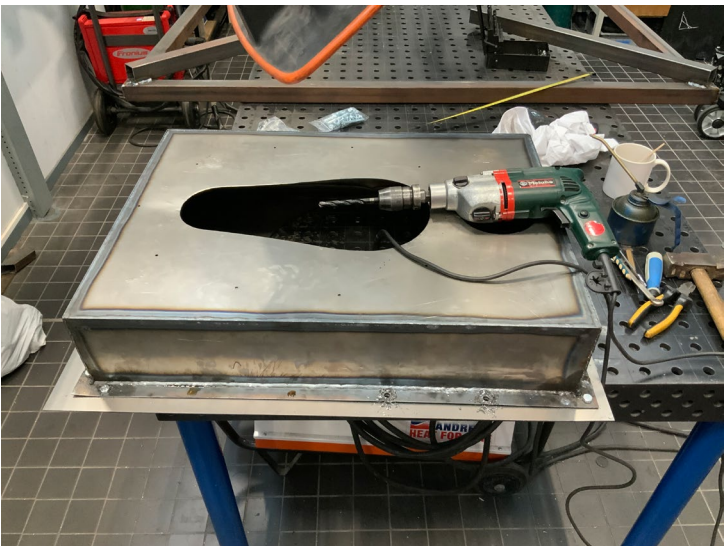
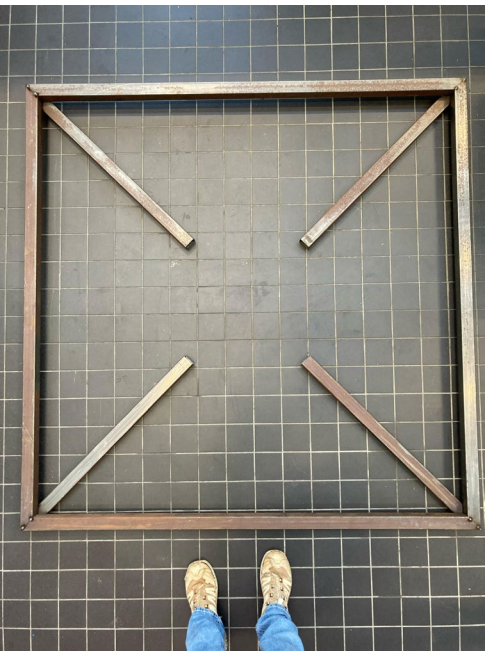
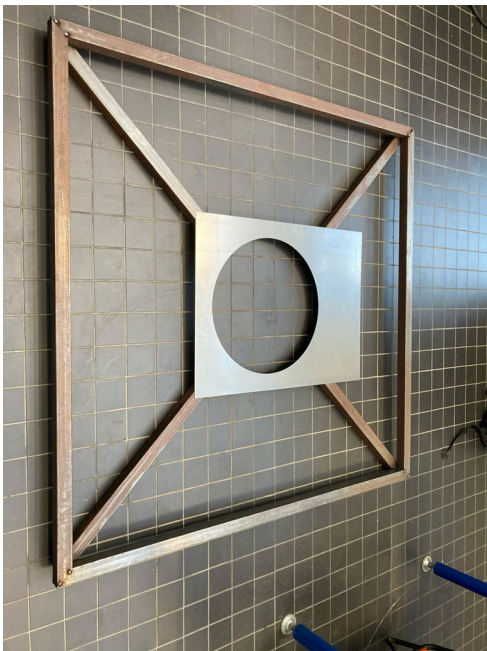
More simplification for minimal welds

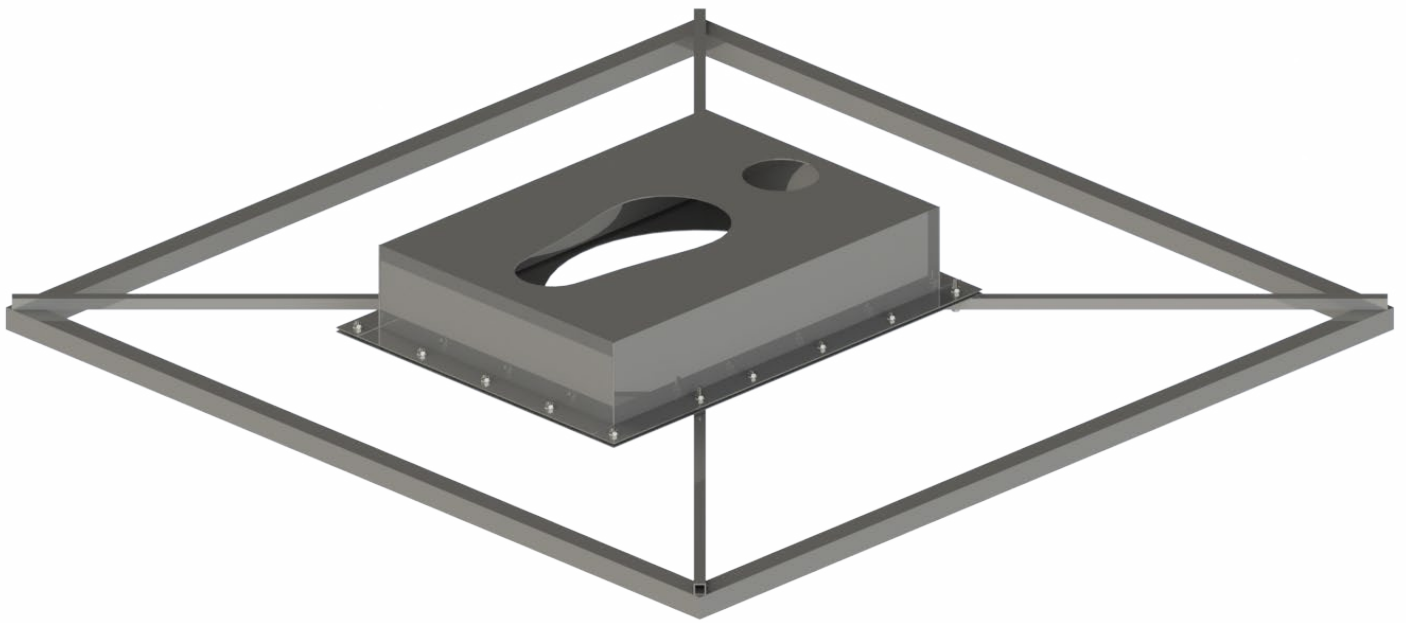
Through the consultation with the welding experts at the 3ME welding lab, it was found that

the box of the design could be simplified by cutting it out in one piece and folding it in the right shape. This would require much less welding and be more structurally sound than welding together the individual panels like is done now, since this causes the metal to warp and bend.

This final prototype **meets the requirements** for the toilet design and is therefore considered a **success**. In the following phase of the project, 40 SaniSecure toilets will be built and installed in the Imvepi Settlement for the installation of a pilot test, presented in chapter 5.

The design prioritizes simplicity and local manufacturability, utilizing accessible materials and common skills such as welding and drilling.

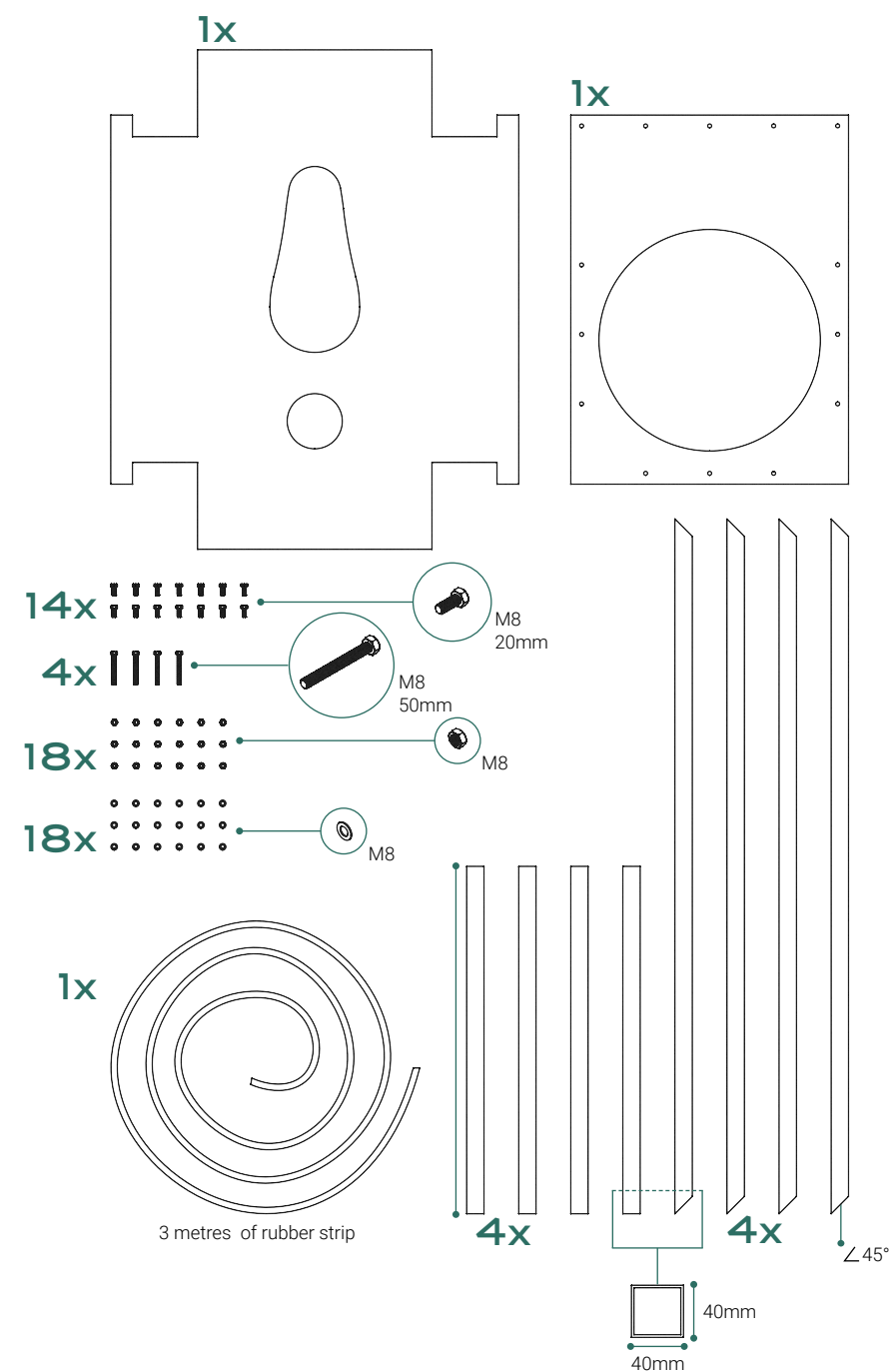




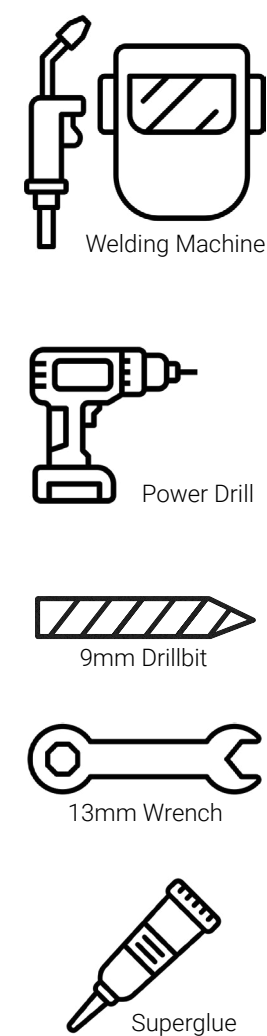
Building Manual SaniSecure Toilet

Supplies Needed

Materials



Tools

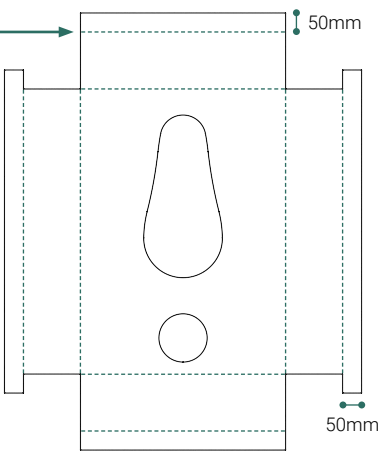


Step 1

- Fold the first sheet along the **marked lines** in a Z-shape:

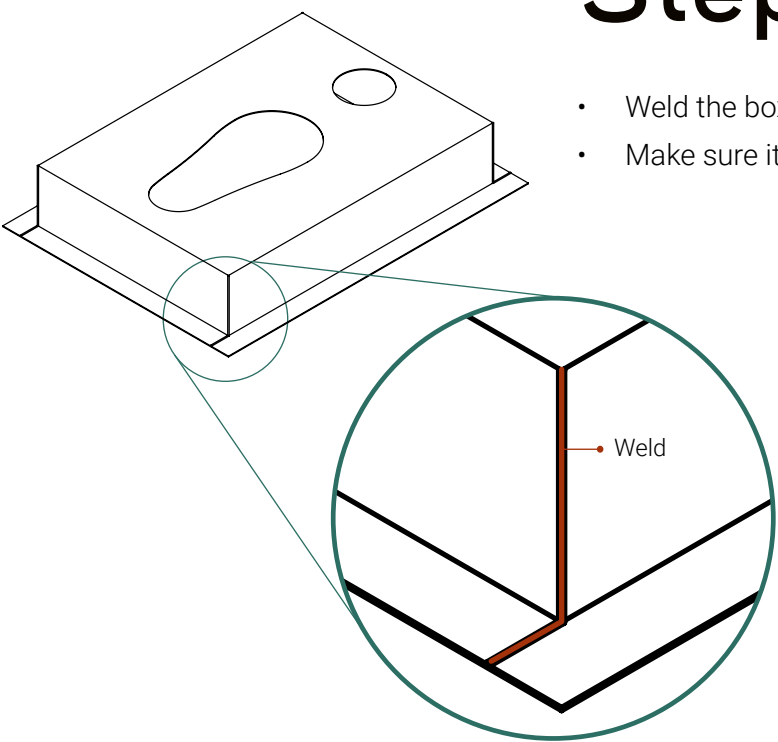


- To create this shape:



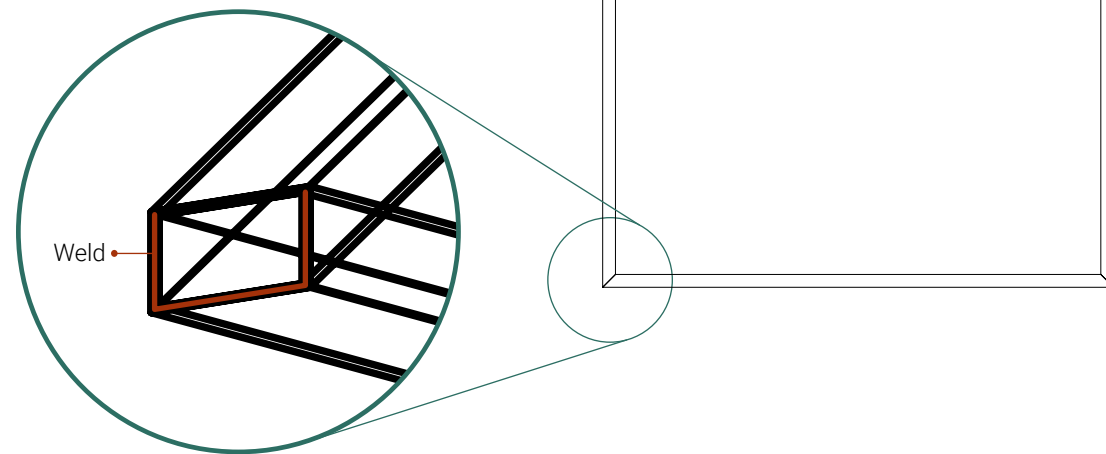
Step 2

- Weld the box shut on all sides.
- Make sure it is **WATERTIGHT**



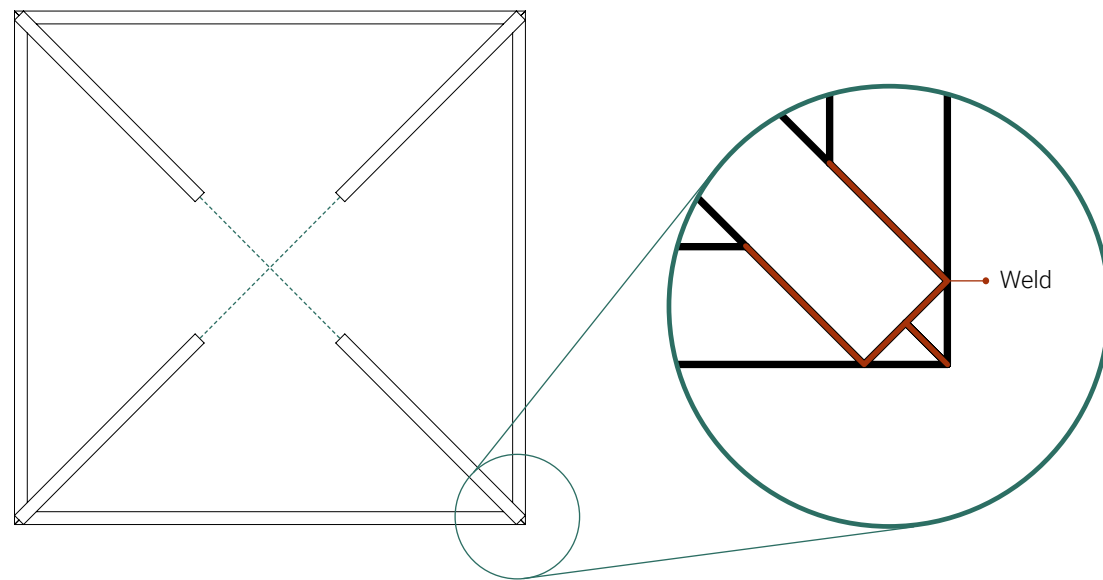
Step 3

- Weld the 4 long beams together into a frame, weld **only 3 sides**
- Welds need to be **strong**, not watertight



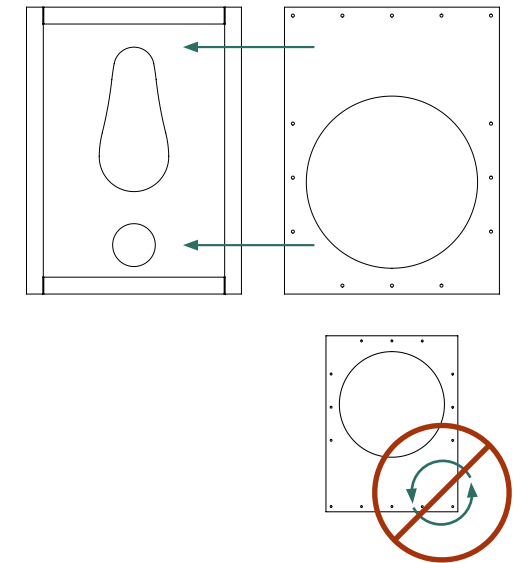
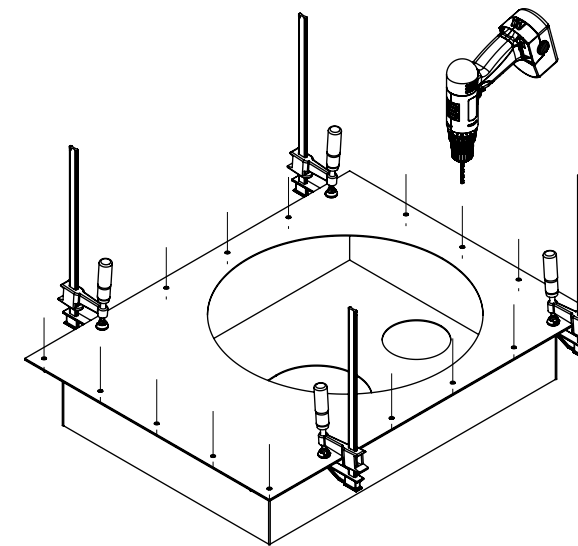
Step 4

- Weld the small beams to the frame, **align them very well**.



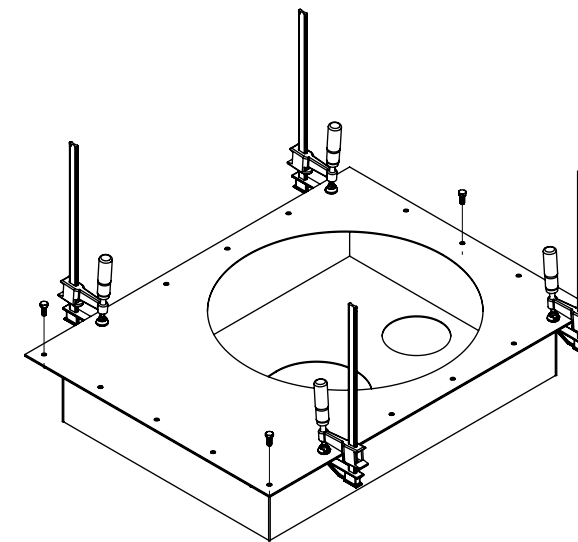
Step 5

- Clamp the second plate to the box and align all sides.
- Notice it is **the right way around**.
- Drill through all holes



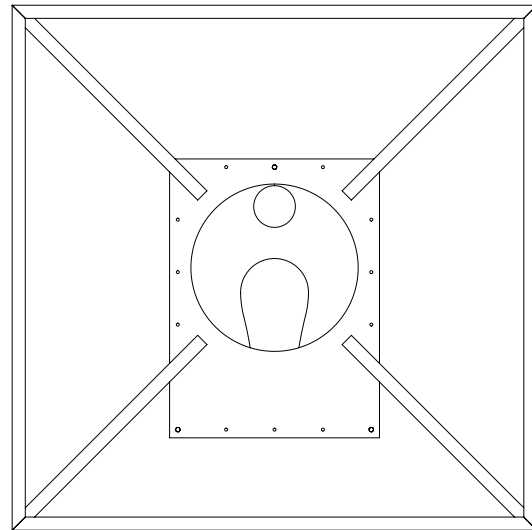
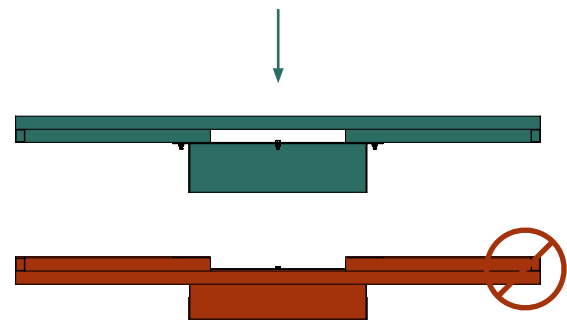
Step 6

- Put the parts together with 3 bolts and nuts, 3 bolts only are enough to keep the two together, because you will need to take them out later

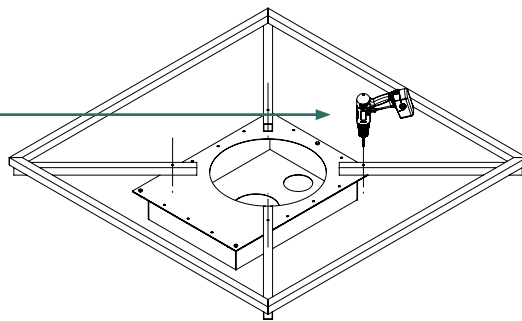


Step 7

- Put the box and the frame together
- Make sure the large circle on the box is in the middle of the frame
- Make sure you have stacked them in the correct position

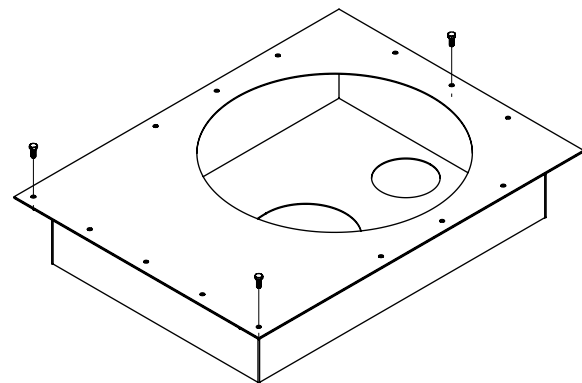


- Drill 4 holes like so:
- Make sure they go through all parts



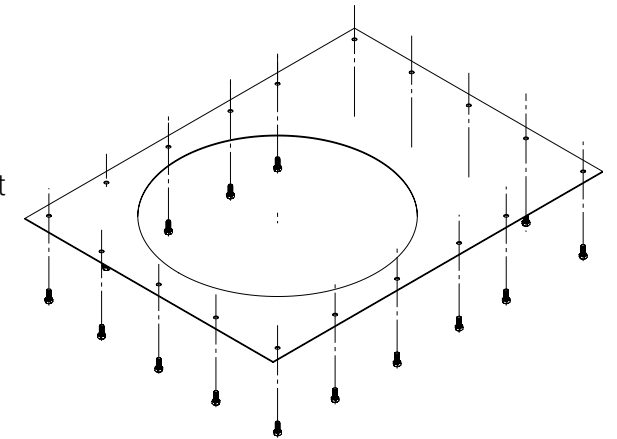
Step 8

- Take out the bolts and nuts
- Put the bottom plate off and turn it over



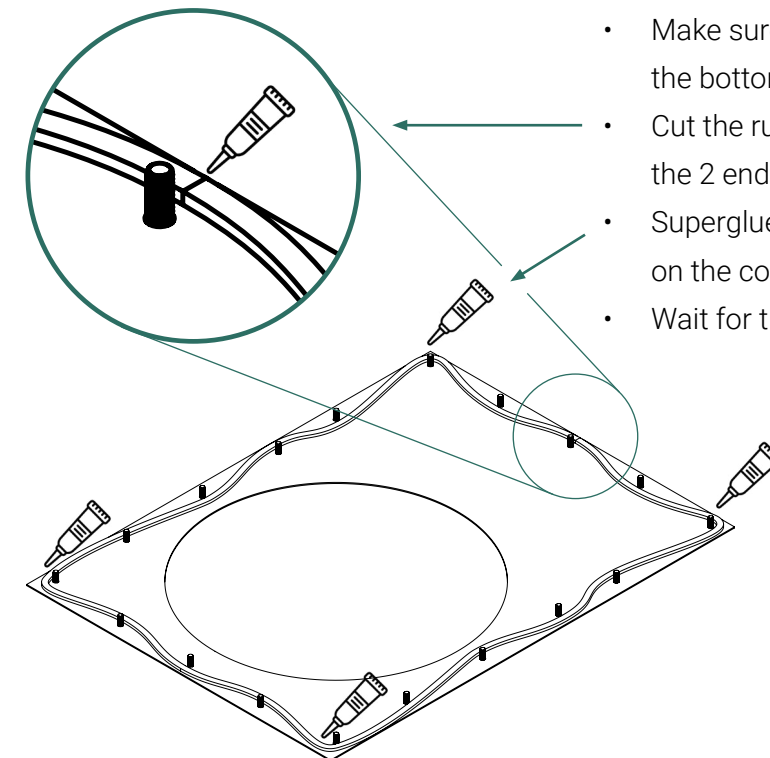
Step 9

- Take the bottom plate and put the bolts through all holes
- Make sure the bolts are sticking upwards to where the box will be put on it



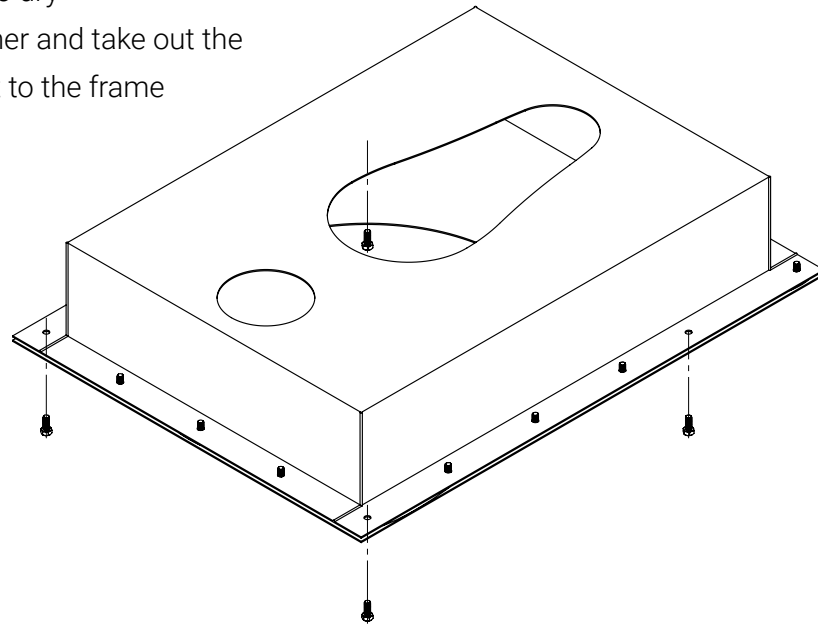
Step 10

- Put the rubber strip around the bolts
- Make sure the entire strip lays flat on the bottom plate
- Cut the rubber to size and superglue the 2 ends together
- Superglue the rubber strip to the plate on the corners and clamp them
- Wait for the glue to dry



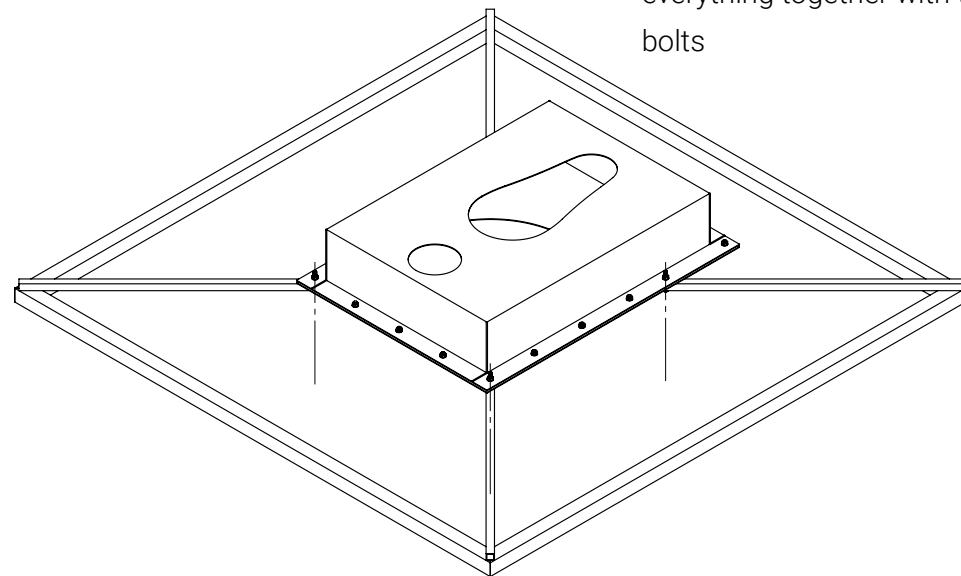
Step 11

- Wait for the glue to dry
- Put the box together and take out the bolts that connect to the frame

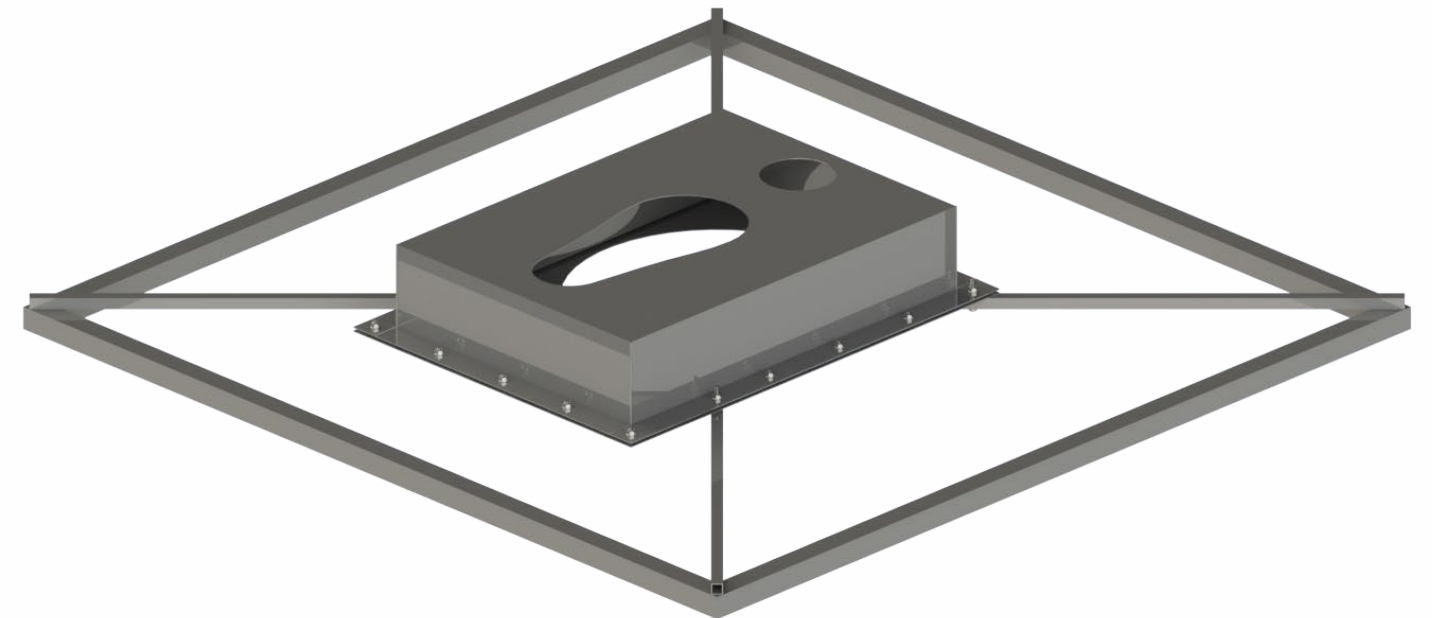


Step 12

- Connect the frame to the box and put everything together with the 50 mm bolts

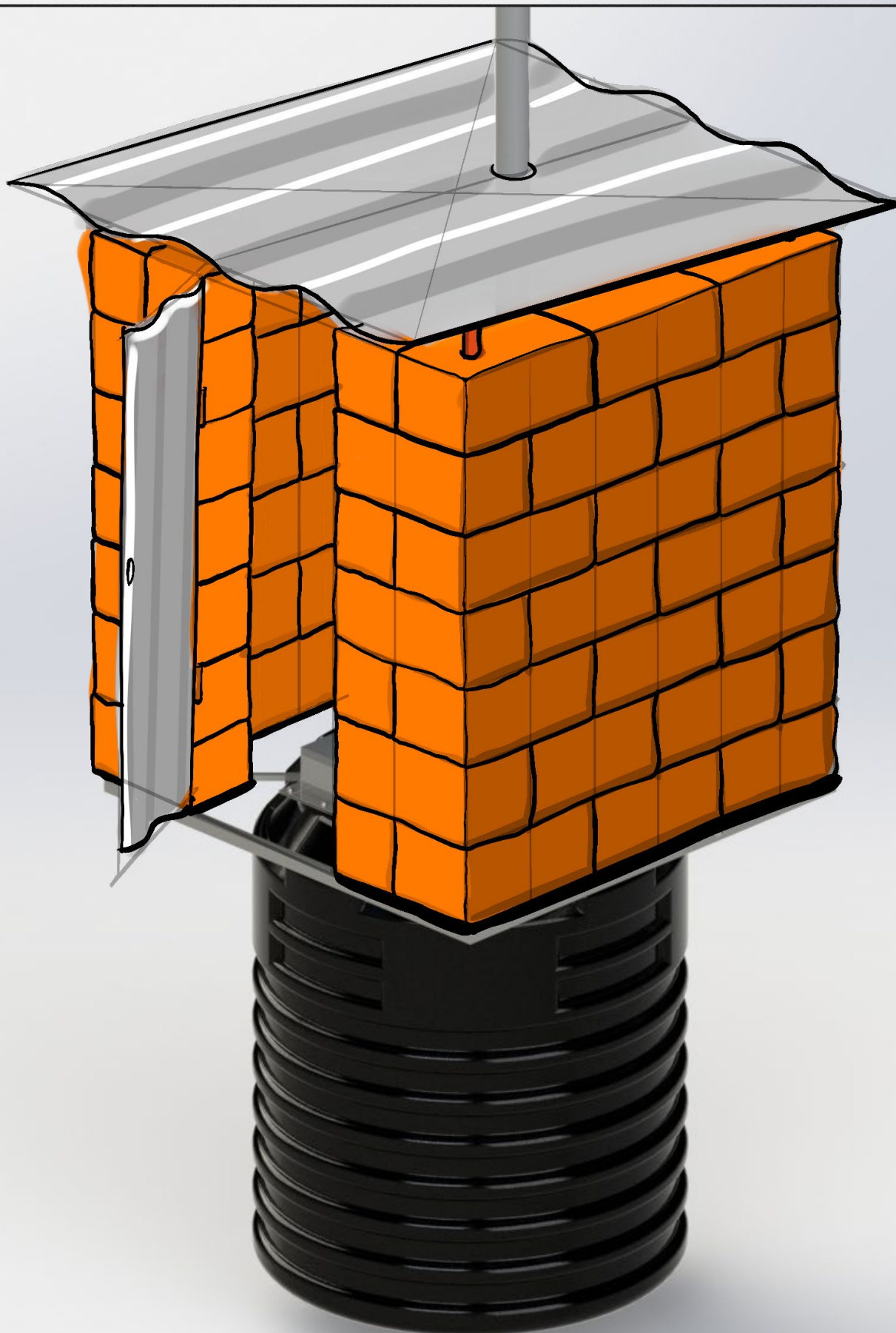


Finished



Installation Manual

SaniSecure Toilet



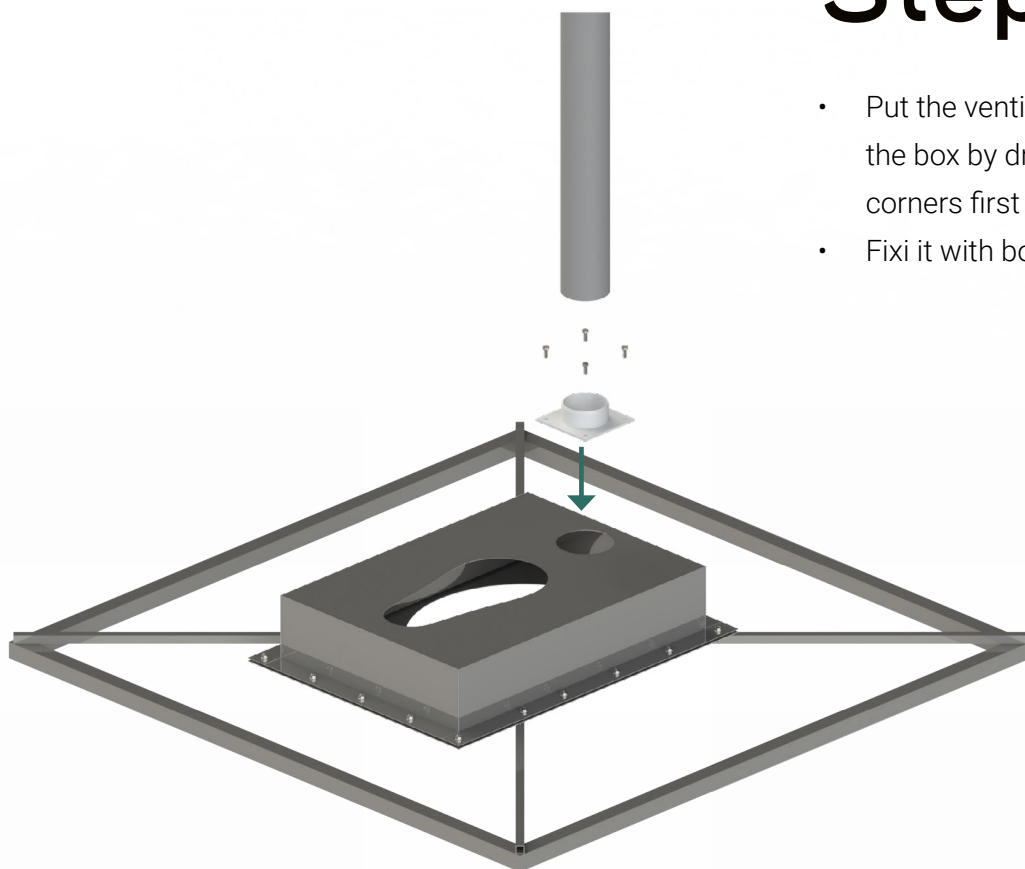
Step 1

- Put the container in the hole and put the rubber ring around the edge of the container, fill the gaps around the container with soil



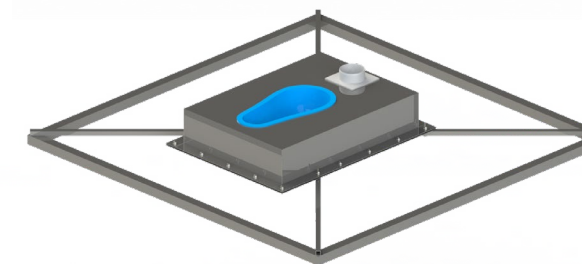
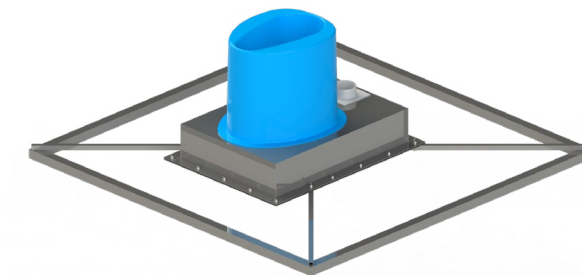
Step 2

- Put the ventilation pipe holder on the box by drilling holes through all 4 corners first
- Fixi it with bolts and nuts



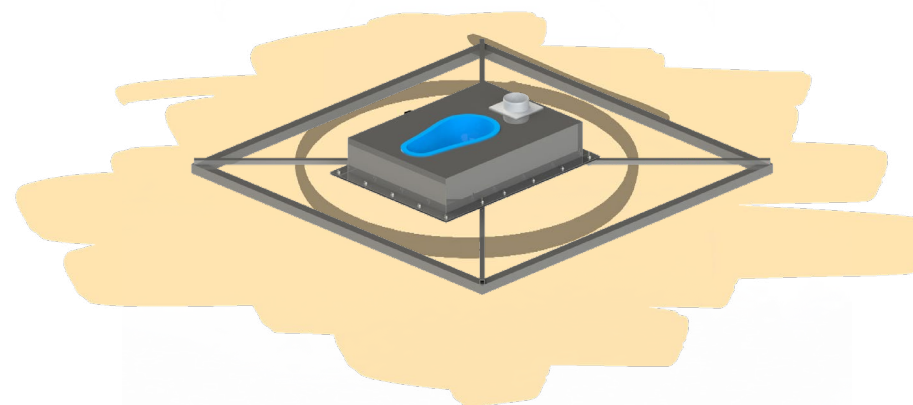
Step 3

- Put the sitting or squatting toilet on the box, depending on client preference
- The squatting toilet can be pressed in, the sitting toilet needs to be drilled through the holes on the toilet and installed on the box with bolts and nuts



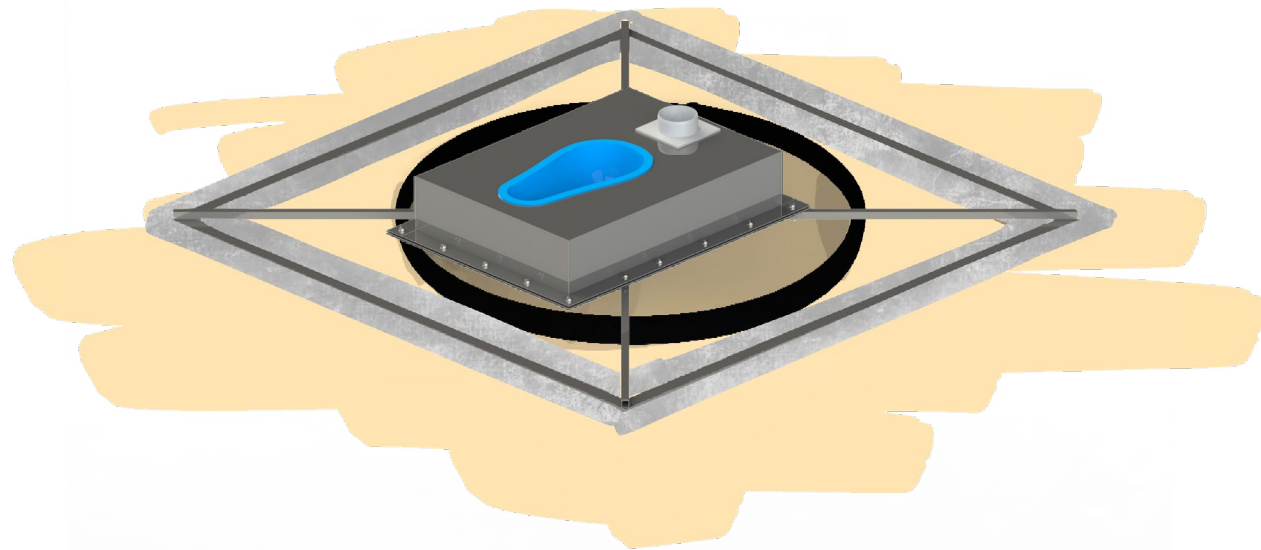
Step 4

- When this is assembled, put the frame over the container and put the container edge through the hole.
- Put the toilet in the preferred orientation
- Dig underneath the frame to make it flush with the ground.

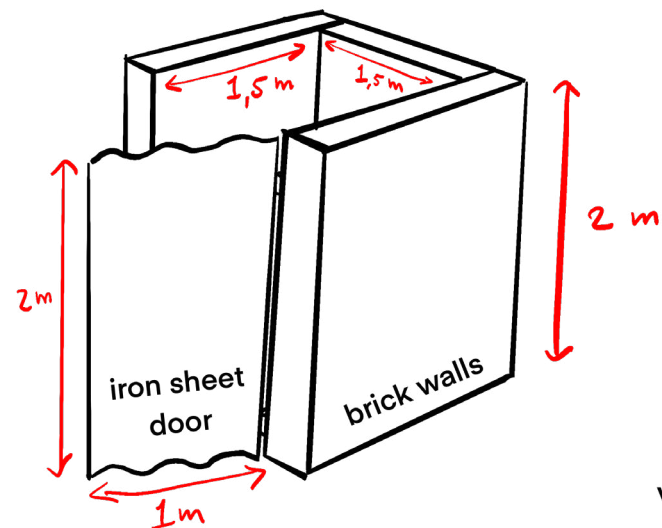


Step 5

- Encase the frame in cement



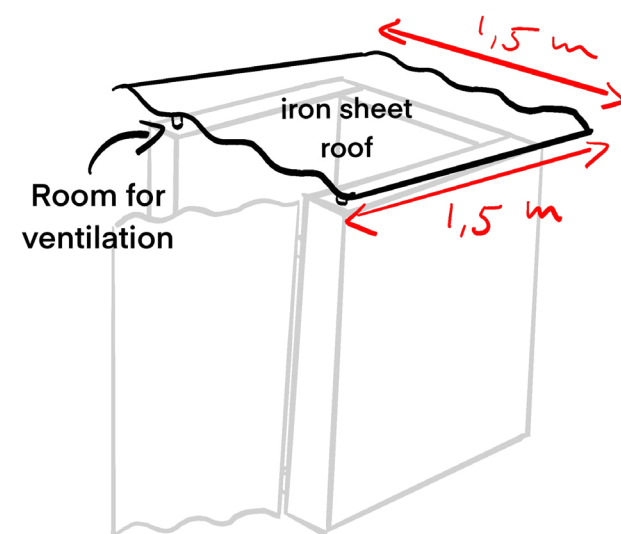
Toilet walls and door



Step 6

- The cement is the foundation for the walls.
- Build the toilet stall with the dimensions seen here

Toilet roof



Finished

