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Cable-Stayed Bridge Structural Analysis

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This course was adapted from the “Composting Toilet Construction Manual” By Eric Tawny, which is in the public domain.

Introduction

Composting toilet (CT) technology is not new to Vanuatu. Before independence, some of the rural schools on Ambae and North Efate, like Onesua, were using these toilets.

The CT design in this manual was adapted from a toilet used in Tonga, Kiribati and Fiji.

There are many advantages CTs have over pit, VIP, water sealed toilets and septic systems.

- They do not smell when properly maintained.
- They do not pollute the environment or groundwater.
- They do not need to be moved when full.
- They do not use water.
- They are cheaper to build compared to septic systems.
- There is no bad smelling unhygienic septic waste to remove and dispose of.
- They require no digging of pits since they are built on top of the ground, except for the evapotranspiration (ET) beds for treating the urine/liquid.
- They can be built anywhere.

Tools & Materials List

As the availability of tools and materials varies from island to island, the lists shown here are for what was used at the CT workshop in Blacksands in August 2004 for building the chambers and ET beds. Suggestions for using local materials are included in the construction steps later in the manual. Materials used for constructing the toilet house on top of the chambers will differ from island to island, so a list was not provided.

Tools List	Construction Use
Hammers	Nailing wood & using chisel
Handsaws	Cutting wood
Trowels & wooden floats	Working concrete
Shovels	Preparing site, mixing concrete
Spirit Level	Leveling blocks and concrete
Plumb Bob and String	Leveling blocks and concrete
String Line	Marking out CT dimensions
Measuring Tape	Measuring CT dimensions
Cold Chisel	Breaking concrete blocks
Fly Screen	Separating sand from coral
Chicken Wire w/ 25mm holes	Separating small coral from large
Large bucket or wheelbarrow	Mixing concrete
No. 10 & 15 block mould	Making blocks for substructure
Bolt cutters or hacksaw	Cutting rebar to size
Pliers	Cutting and fastening tie wire
Carpenter's square	Accurate measurements
Drill	Drilling holes in wood for bolts

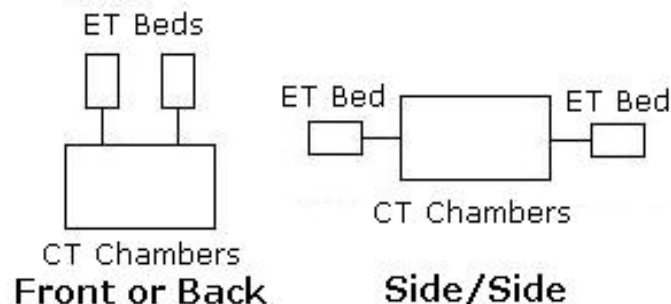
Materials	No.	Use
No.15 standard concrete block	95	Chamber Walls
No.10 standard concrete block	6	Chamber Walls
10mm Rod x 6m	4	Chamber / Foundation Slab
6mm Rod x 6m	2	Chamber / Foundation Slab
Arc Mesh F52 2.4m x 1.2m	2	Foundation Slab & Floor Slab
3/8" Anchor Bolt 6"	7	Toilet House
M12 Galv Washers	7	Toilet House
Cement (40 kg Bags)	6	Chamber / Foundation & Floor Slab
Black Plastic 4m wide (per m)	3	ET Bed / Foundation Slab
50mm galvanized nail (kg)	1	False Floor
sand (cubic meter)	2	Chamber / Base
aggregate (cubic meter)	1	Chamber / Base / ET Bed
100mm D.W.V. 6m	2	ET Bed / Vent Pipe
100mm D.W.V. access caps	4	ET Bed
100mm D.W.V. 90 Bend	4	ET Bed
100mm D.W.V. Junction 90 Bend	2	ET Bed
100mm Coupling Straight	2	ET Bed
D.W.V. Glue (125 ml)	1	ET Bed
Tie wire (g)	250	Chamber / Foundation Slab
Fiberglass Toilet Stool	1	Toilet Stool
3 x 10 hardwood or treated whitewood (3m)	1	False Floor
3 x 10 hardwood or treated whitewood (3m)	5	False Floor

Materials (Continued)	No.	Use
3 x 15 whitewood (3m)	3	Formwork
5 x 7.5 hardwood or treated whitewood (2.5m)	2	Access Door Frames
5 x 7.5 hardwood or treated whitewood (2m)	2	Access Door Frames
3/8" wing nuts	8	Access Doors
3/8" x 3" Bolt	8	Access Doors
3/8" x 2" Bolt	4	Toilet Stool
8' x 4' x 16mm plywood exterior (sheet)	1	Access Doors / Baffle Boards

Construction Steps

Select a Site

- Do not select a site where water is known to collect after rain.
- The toilet can be placed on flat ground, on a small hill or on the side of a hill.
- If possible, face the toilet so that cyclone winds hit on the sides of the toilet.
- Identify where the ET beds will be located in relation to the toilet. This will be important when laying the blocks since a space will have to be left for the pipe, which drains into the ET bed.



Prepare the Site

- Clear and level the ground where the toilet will be located. If building on a slope, dig a space in the hill big enough to build the chambers.

- Do not remove any banana or pawpaw trees if they are close to the site. They will provide shade and privacy and will 'drink' the urine from the ET beds.
- Make sure all of the materials and tools are at the site before each construction step is started.

Mixing the Concrete

- Only use aggregate (stone or coral) that will pass through 25 mm chicken wire mesh. The concrete mix is 4 shovels aggregate, 2 shovels sand, and 1 shovel cement.



- The mix for the CT workshop was not good because the aggregate size was too big. More sand was added to make working the concrete easier, but this made it chalky and brittle after it had set.
- Do not add too much water during the mixing or the cement will collect in the bottom of the mix and not bind well with the sand and aggregate.
- When finished for the day, always sprinkle some water on the finished concrete before covering it in plastic, banana or laplap leaves, and wash concrete off your tools.

Construct the Foundation Slab

- Construct a box with the inner dimensions of 255cm by 135cm with a depth of 10cm. Put this box where you would like the toilet. Mark the ground around the inside of the box with a stick. Remove the box.



- The foundation at the CT workshop was too low and there is a possibility that water could get in the chamber from the access doors during a cyclone. To avoid this, I suggest building the formwork on top of the ground and digging out the footings afterward.
- Dig out the footings inside the marked area for the foundation making them 15cm deep and 25cm wide.
- There were many suggestions on how to build the foundation slab after the CT workshop. I will describe them all below including the one that was used.

Method A – (used at the workshop):

- Line the footings with black plastic.
- Cut 2 pieces of 10mm rebar 240cm long and 3 pieces 110cm long.
- Cut 8 pieces of 6mm rebar 50cm long and bend them all into an 'L' shape with one side at least 30cm long. These will be used as starter bars to connect the foundation with the chambers.
- Use tie wire to secure these starter bars to the 10mm bars.
- Space them 70cm from each other.
- Place the 10mm bars in the middle of the footings on small stones so they are not resting on the ground. Should be about 3cm above the ground.

- Do the same with the arc mesh wire for the concrete above the footing trenches. Use stones to put the wire about 7cm above the ground.
- Mix and pour the concrete.

Method B – (no wire):

- Fill in the footing trenches by ramming large stones in them.
- Fill the footings with concrete and half of the foundation slab.
- Cut long pieces of bamboo and place them in on the wet concrete to be used as reinforcement.
- Pour the rest of the concrete.

Method C – (for hard ground):

- Do not dig footing trenches.
- Inside the formwork, dig down 1 to 2 cm and level the ground.
- Fill this space with 1 to 2 cm of sand.
- Line the ground inside the formwork with black plastic.
- Mix and pour half of the foundation slab.
- Cut long pieces of bamboo and place them in on the wet concrete to be used as reinforcement.
- Pour the rest of the concrete.

Constructing Chambers

- After letting the foundation slab cure for a few days remove the plastic and formwork and clean the foundation with water.
- Cut 8 pieces of 10mm rebar into 85cm lengths and tie them to the 6mm starter bars already located in the foundation slab.



- The outer dimensions for the chambers are 245cm long by 125cm wide.
- Place No. 15 blocks using 3:1 mortar (3 shovels sand, 1 shovel cement) and filling them with same concrete mix used in the foundation construction.



- Blocks should be set 5cm from the edge of the foundation slab on every side.
- The chamber is four blocks high and should be 80cm from the surface of the foundation slab to the top of the last block.



- Remember to leave space in side of chamber for the drainage pipe for the urine to pass. The location depends on where the ET beds will be placed. The hole can be cut out with a cold chisel.



- Make the concrete base for the access doorframe using No. 10 blocks turned on their side or wood formwork. Should be 10cm high and 20cm wide.



- Make a small concrete ledge opposite the base for the access doorframe where the false floor will rest. It should be 50mm wide and 100mm high.



- Coat the inside of the chambers with a very thin coat (2-3mm) of 1:1 mortar mix. Be sure to wet the walls with a wet rag before applying the mortar.



- Avoid drilling the concrete after it has cured to install anchor bolts. Place them after the last layer of blocks are finished. Use the 175mm long bolts making sure they are sticking out at least 100mm above the layer of blocks.

Constructing ET Beds

- Dig the holes for the bed and the pipe.



- The bed dimensions are 50cm wide by 100cm long by 30cm deep. The distance from the bed to the chamber depends on site conditions.
- ET bed can be lined with blocks, a ferrocement shell or just plastic.

Method A – (with Blocks):

- Line the inside of the trench with two layers of No.10 or No.15 blocks using the same methods for constructing the chamber.
- Lay black plastic inside trench and over the edge of the blocks.
- Fill with aggregate.

Method B – (with ferrocement shell):

- Lay black plastic inside the trench bottom and up over the sides.
- Line the bottom and sides of the trench with 25mm chicken wire mesh over the black plastic.
- Mix a 3:1 mortar (the same one used for the blocks) and cover the chicken wire.
- Cover the trench with plastic, banana or laplap leaves and sprinkle with water.
- After a day of curing, remove the cover and place a thin layer of 1:1 mortar (the same one used for lining the chambers) on the old 3:1 mortar.
- After covering and letting it set for another day, fill the trench with aggregate.

Method C – (with plastic):

- Lay plastic inside the trench bottom and up over the sides.
- Fill the trench with aggregate.



- Cut and fit the pipe to the different joints before putting glue.
- Drill holes in pipe for urine to drain into the ET bed.
- Fill the bed with large stones or aggregate no smaller than 25mm up to the bottom of the pipe.
- Make sure the pipe from the inside of the chamber to the edge of the ET bed is sloped slightly down into the bed.
- The pipe in the ET bed with the holes should be level.

- The access cap at the end of the pipe should be 600mm above the floor of the ET bed.
- Glue all of the pipe joints together remembering that the holes in the pipe should be placed down into the aggregate.
- Fill aggregate to the top of the pipe followed by 5cm of sand on top of that, then filled in with dirt.



- Make sure the ET bed is mounded so that water will run off and away from the bed during heavy rains.
- Line the ET bed with stones to identify the boundaries and plant flowers on it.
- Fill in the spaces with mortar around the pipe entering the chamber.



- Slope the chamber floor with mortar toward the pipe. (See pg 36, Technical Drawings)

Constructing Toilet House Floor Slab

- Using either local or imported materials construct formwork that covers the space over the chambers.

- Place wood all around the chambers about 5 to 6cm above the level of the top layer of blocks.



- Cover the top of the formwork with banana leaves or plastic.



- Place the arc mesh wire making sure it is about 2cm above the formwork. Also, place a 240cm long 10mm rebar at the back of slab where the access doors are located.



- Using the fiberglass toilet stool, mark out where the hole will be located for both chambers and cut the arc mesh.

- Using local or imported materials, form the hole over each chamber.



- Place small pipe cuttings in the slab to allow for vent pipe installation.



- Pour the concrete.
- Don't forget to install the 50mm long bolts around both holes for securing the toilet stool to the concrete.



- Cover the slab with plastic and let it sit for a few days.
- To ensure a tight fit for the toilet stool, when the house is built on the chambers, put the stool on one hole and put mortar sloping from the lip of the base to the slab. Do the same with the other hole and the vent pipes.

Constructing False Floor

- Measure the inner dimensions of each chamber. They will vary based on how much mortar is used when smoothing the inside of the chambers.
- It is good to use treated whitewood for the false floor, but this may be too expensive or not available at all on some islands. Other options mentioned during the workshop were natong, palm tree, natora and bamboo. Bamboo would have to be replaced every time the chamber is emptied as it breaks down quickly.
- The size of the timber is at least 50cm wide and 25cm thick and the spacing between the timber pieces is 15mm.



- After nailing all of the pieces together and ensuring there is a good fit, cut the floor in half to allow for easier removal during cleaning.



Constructing Access Doors

- The material used for constructing every part of the access doors should be constructed from treated timber, or from a local timber, which you know rots slowly.
- Dimensions for the access doorframes will depend on how much mortar is used on the inside of the chambers. The dimensions should be about 1m wide by 70cm high. The frame should be in the middle of concrete ledge.

- Nail the doorframe to the concrete using concrete nails or special concrete screws.
- Measure the frame and cut the access doors from the marine ply.
- Rest the door against the frame and drill four holes through the doors and frames for the bolts. Use a drill bit one size smaller than the bolt diameter.
- Hammer the 75mm long bolts in the holes from the inside of the chamber.
- Cut 4 baffle boards 20cm wide and the correct length to fit the doorframe from the left over marine ply.
- Cut 8 - 2 x 2 cm runners 35cm long to hold the baffle boards.
- Nail the runners into the doorframe and slide in the baffle boards.



- Nail two handles on each marine ply access door.
- Set the doors against their frames to block the chambers. Use the wing nuts to fasten the door closed tight.



Building House on Top of Chambers

- The house located on top of the toilet should be constructed using methods and materials common on the island.
- There are many choices for materials as well as design, a small sample of designs options are provided below.

Operation and Maintenance

Proposed sign to be placed in the toilet notifying guest about the toilet and how to use it.

- This is an eco-toilet
- No pollution goes into the environment
- Please add a handful of leaves after use
- Close the lid
- Wash your hands
- No water or chemicals should go in the toilet

Changing Chamber When One is Full

- Before moving the toilet stool to the other chamber open the access door and check the compost by looking over the baffle boards. If it is fully composted and inoffensive, remove the compost using a shovel.
- After removing the compost, check under the false floor to see if any compost fell through the false floor and may block the ET bed pipe. If there is any material, remove the false floor, remove the material and then replace the false floor.
- Prime the chamber by adding a thick layer (about 100mm deep) of dry brown leaves

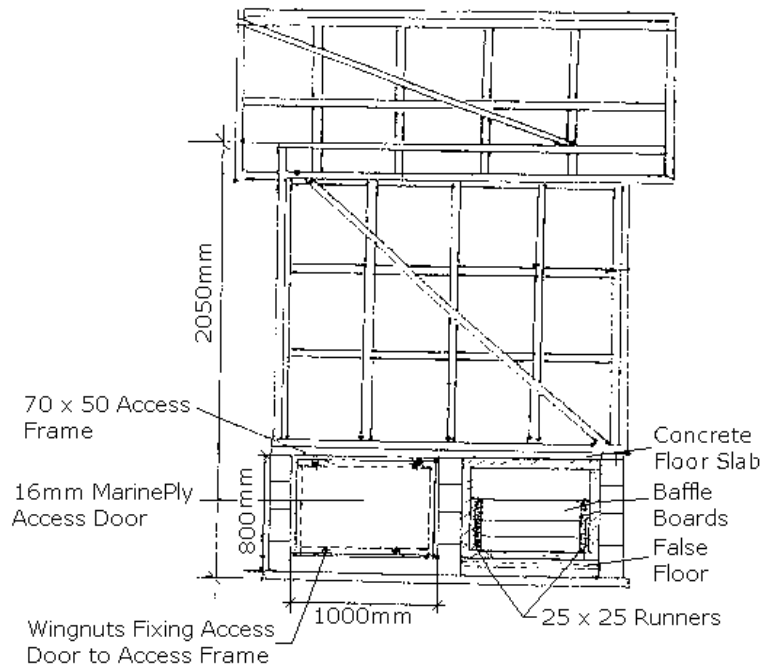
onto the false floor. Then put the baffle boards back and close the access door.

- Now move the toilet stool to the hole over the primed chamber.
- Before closing off the chamber that is full, fill it up with dry leaves up to the bottom of the floor slab.

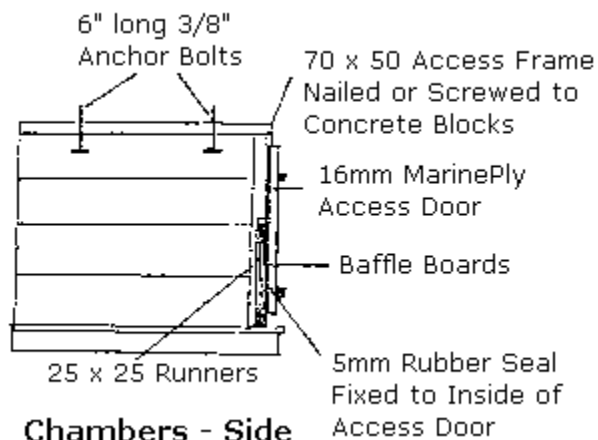
Maintaining/Cleaning the Toilet

- After using the toilet, throw one handful of dry leaves into the chamber and then shut the lid.
- Keep the area inside the toilet house clean.
- If the toilet has a bad smell it means that it is not working properly. Try throwing twice as many leaves as normal for a few days. If the smell is still there, the pipe may be blocked.
- Put a long piece of tie wire in one end of the pipe through the access cap and push it through to the other access cap. Tie an old piece of calico to the end of the wire and pull it back through to the other side. Also clean the pipe in the chamber with the tie wire. This should remove anything blocking this section of pipe. Throw the cloth in the composting chamber when you have finished.

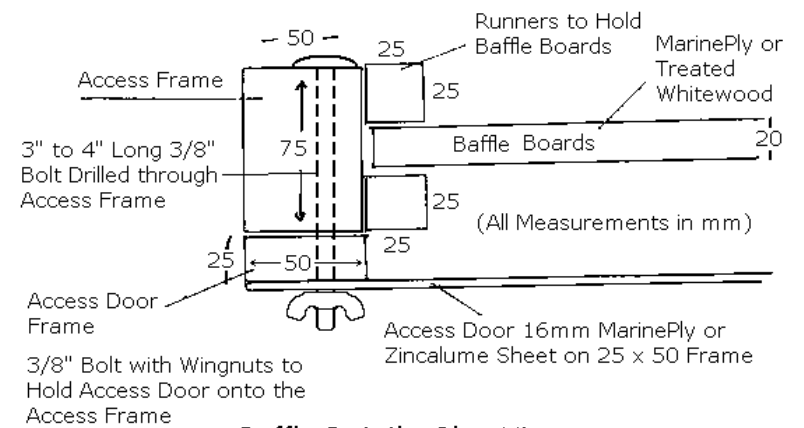
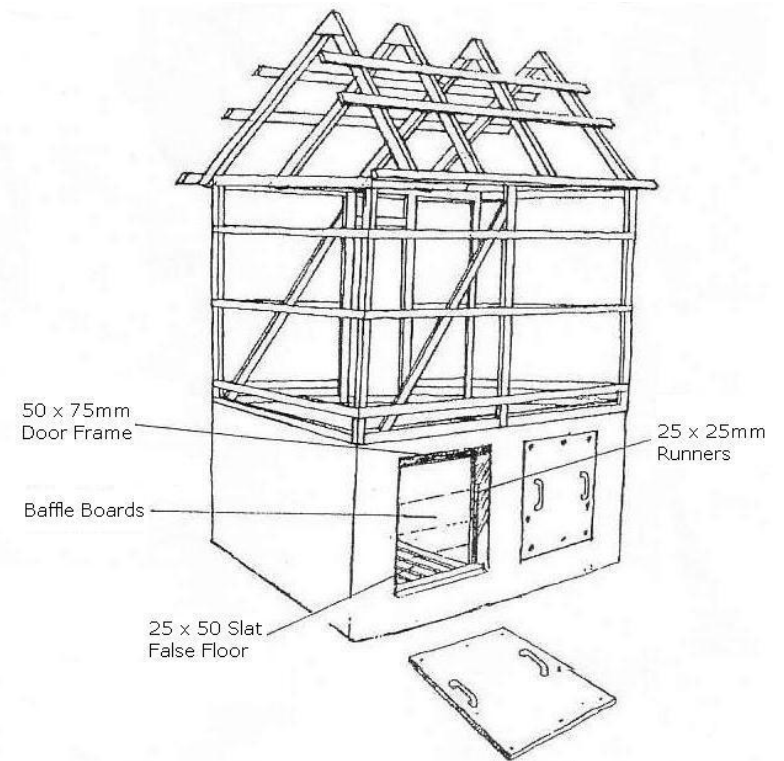
Technical Drawings



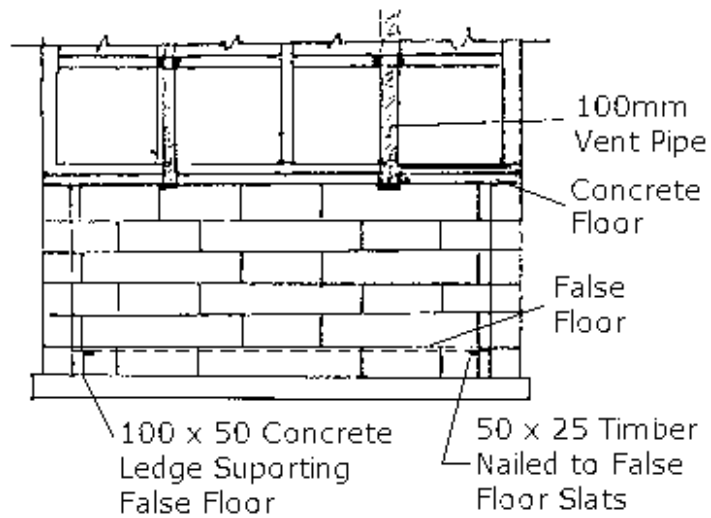
Chambers - Back



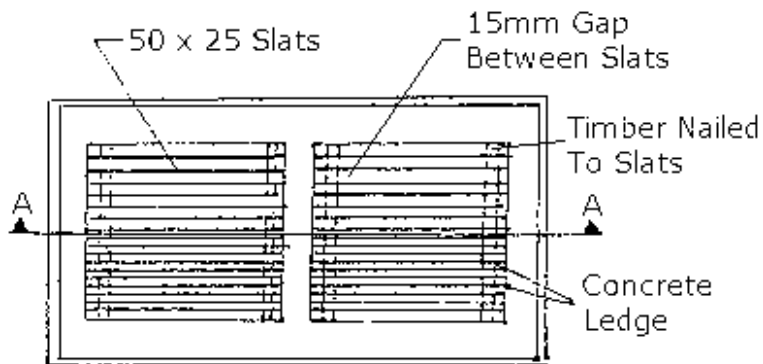
Chambers - Side



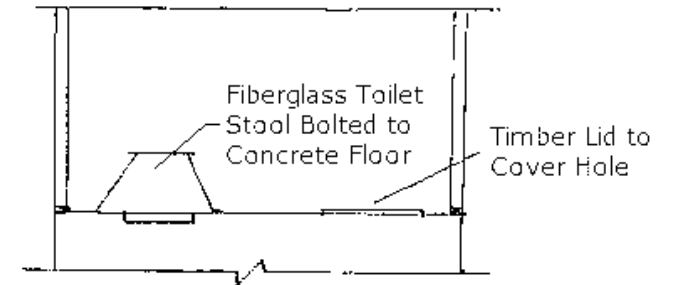
Baffle Detail - Plan View



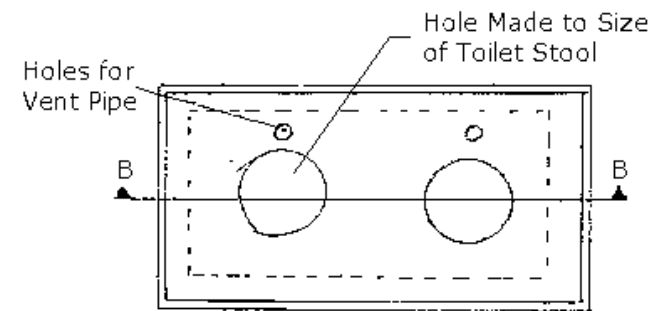
Section A-A



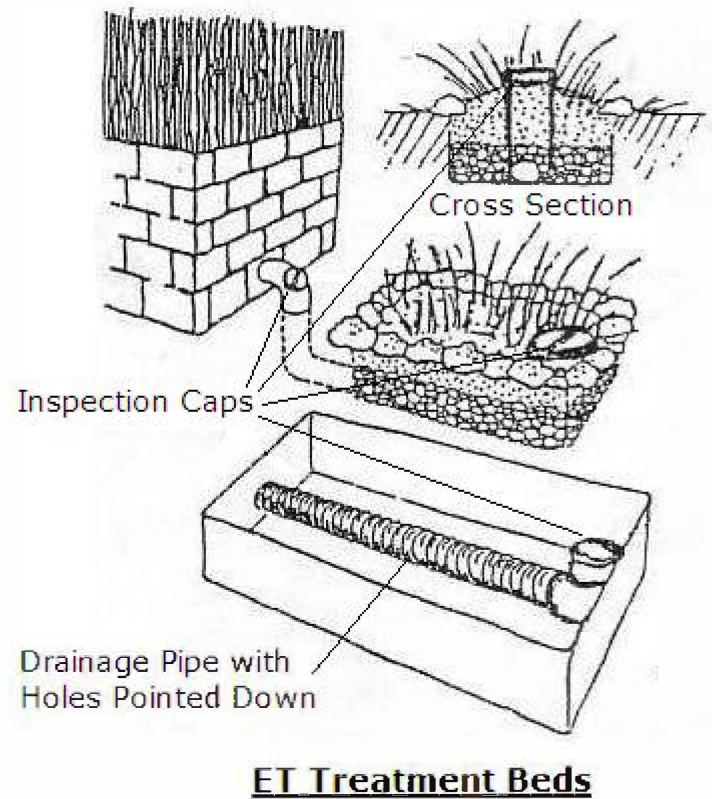
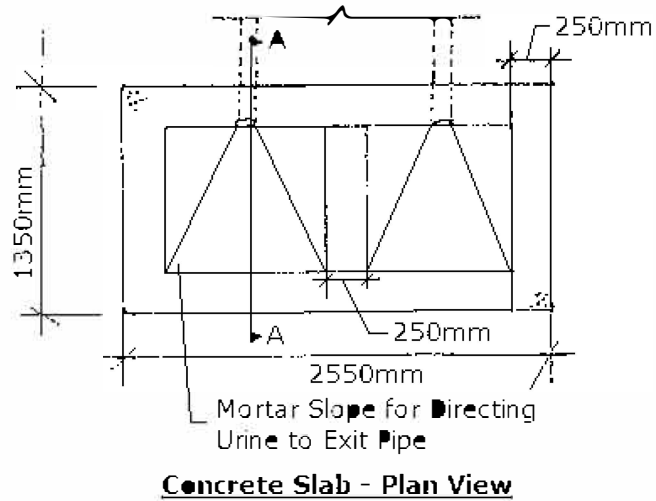
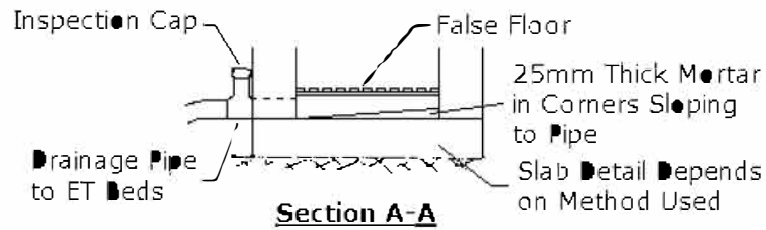
False Floor - Plan View

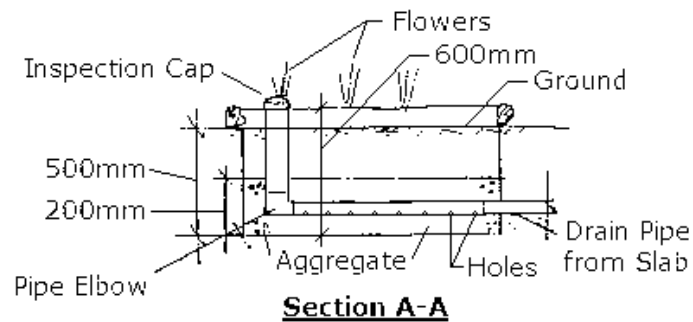


Section B-B

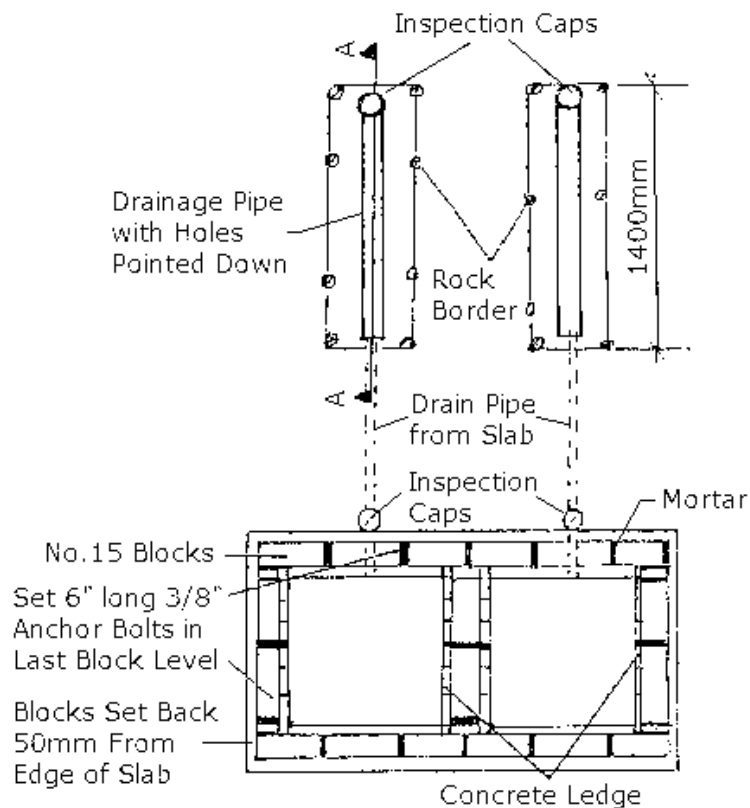


Concrete Floor - Plan View





Section A-A



ET Bed Drainage Trenches - Plan View

Technical Specifications

1. Specifications for installation as freestanding unit, or retrofit into a house

The design includes the composting system and a superstructure for a freestanding toilet building. The composting chambers as shown, including ventilation and the drainage system can also be installed beneath a bathroom or toilet room, within a house or amenities block. The design of the superstructure can be adapted to local requirements, but should be durable.

a). Two concrete composting chambers, each of approximately a cubic meter internal volume, in a side by side configuration on 100 mm concrete slab. Dimensions of the chambers can be reduced but height should not be less than 800mm and width of a chamber should not be less than 650mm. Walls can be in 400 x 150 mm concrete blocks, or constructed on site using formwork. Chambers must be insect and vermin proof and water-resistant. Foundations of chambers should comply with local specifications for weather conditions and site soils. All timber should be treated pine or durable local timber, unless otherwise stated. The internal walls, roof and plenum floor of the concrete chambers should be sealed with a moisture-proofing agent. All nails and screws should be galvanized or otherwise corrosion proof.

b). Plenum floor of chambers falls 25 mm to 90 mm drainage outlets from each chamber.

c). 90 mm PVC pipe from each chamber drains to HDPE or concrete lined trench 500 x 1400 x 750 mm. Trench contains 25 mm aggregate and is fed by 90 mm slotted pipe. Screw capped inspection points in 45° bend between building and trench in 90 mm drainage pipe and at end of trench to allow for cleaning. The trenches can be sited at any side of the chamber as long as the plenum floor falls in that direction.

d). Appropriate vegetation or trees should be planted on or adjacent to trench to assist evapotranspiration of any liquid that may drain into the lined trench (eg. banana trees). Completed trenches should be mounded to assist surface runoff.

e). 50 x 25 mm timber slats provide removable false floor to support compost pile. Removable false floor rests on 50 mm wide concrete block work 100 mm above plenum floor of concrete chambers. A 50 x 25 mm frame is screwed to the underneath of the slats 80 mm from side edge of the false floor. 15 mm gap is required between the slats. A sheet of galvanized expanded metal with similar size gaps can be substituted for the timber slat false floor. The access port to the chambers is framed by 70 x 50 mm timber. The top of the false floor is 10 mm below the base of the 70 x 50 mm timber frame to which access doors are bolted.

f). The access port should be sufficient depth and width to allow removal of the false floor from the chamber, for maintenance. This can be achieved by building the false floor in two sections, or the false floor can be removed from the port by turning it

onto the diagonal. 19 mm marine ply doors or framed zincalume sheet doors are fixed to the 70 x 50 mm timber frame that is recessed into concrete walls of each chamber. The access doors are secured onto the frame by 10 mm galvanized or stainless steel bolts screwing into T-nuts in timber frame. It is essential that the chamber doors are easy to open by an adult but are well secured against access by children. The chamber doors should be black or a dark color to absorb heat.

g). Three 20 x 150 mm marine ply or treated pine baffle boards are supported by 25 x 25 mm runners at port of chambers. The runners are nailed to the inside of the 50 x 75 mm doorframe allowing a gap of 25 mm for baffle boards to slide out of the runners. These allow for expansion when wet. The baffle boards prevent the pile from falling out of the chamber when the door is removed. The gap at the top of the boards permits inspection of the pile and easy removal of the three baffle boards.

h) 75 mm ferrocement slab, or 19 mm marine ply sheet on frame, forms ceiling of concrete chambers and the floor of toilet room, protected by damp course. The ferrocement slab usually provides more permanent and effectively sealed chambers and is the preferred option.

i). A splayed fiberglass pedestal/seat is screwed into a hole in the floor of the toilet room above the chamber that is being used. A fiberglass blanking plate or framed zincalume plate or timber lid is screwed into the hole above the chamber that is not being used. The seat and the blanking plate/lid should be easy for householders or maintenance

staff to exchange. Seats can also be in timber or molded concrete.

j) The frame of the toilet room, or superstructure, should be storm resistant and suitable for cladding with natural materials such as pandanus thatch or permanent materials such as fibro, form ply, or corrugated iron. Form ply walls should be painted for waterproofing. The hinged door of the toilet room is secured on the outside with a sliding bolt that will allow a padlock to be attached if required. A sliding bolt or similar should also be attached to the inside of the toilet room door.

k). The toilet room should be well ventilated and allow for natural light. If possible the building should be sited so that the access chambers at the back of the building are north facing.

l). The roof can be in zincalume, corrugated iron, or thatched, on a skillion frame or gabled. The materials and design of the superstructure toilet room can be varied to suit local building regulations and the practicalities and aesthetics of the site, as long as it does not compromise the function of the composting chamber and the drainage system.

m). One 90 mm PVC vent pipe insert 20 mm into each chamber through the toilet room floor, and extends 1 m above the roof line. The ventilation pipes are painted black to facilitate convection. The vent pipes can be placed behind the pedestal to support the open toilet lid.

n). Stairs with 200 x 50 mm treads and 200 x 500 mm stringers and handrail would provide stable

and safe entry to toilet room for adults and children. Alternatively a ramp can be installed across the front of the building to provide wheelchair access. Concrete blocks can also be used to build the steps. If the site has a raised area that is an appropriate site, the building can be set into the bank so that access to the toilet room is level. The back of the composting chambers and access doors must be above ground level to enable easy maintenance and ensure the drainage system does not threaten groundwater.

o) The walls of the pedestal or toilet seat should be splayed to avoid adherence of faecal matter to sides and to reduce necessity for cleaning. The pedestals used in the CT construction workshop were purchased from a Port Vila fiberglass shop. The unit had a wide lip at the base of the pedestal, which allowed for it being bolted onto the toilet room floor. For future installation of CTs on an extended scale, production of pedestals and seats could be undertaken by a local fiberglass industry.

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