

**14<sup>th</sup> Sarnet International RWH Conference – Mpumalanga, South Africa**

**Title**     **Ferro-cement rainwater harvesting tanks store rainwater and can simultaneously act as wells where there is a high water table, facilitating vegetable production and mitigating climate change.**

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**Abstract**

Generally RWH tanks that are situated above ground are positioned below a gutter to capture roof runoff – and providing a first flush system is installed, the water should be safe to drink. Underground tanks on the other hand may be more strategically positioned to additionally capture ground runoff, from virtually the whole property, and perhaps even from the street or some other watercourse/gully. While this water is not fit for human consumption, substantially more water can be captured - for irrigation of vegetable gardens – and of course such vegetation converts CO<sub>2</sub> into organic matter, mitigating climate change.

Furthermore it is possible to build these tanks from ferro-cement (FC), which are thin shelled structures, and as such use substantially less cement than conventional tanks made with concrete floors and concrete block walls. The FC structures also mitigate climate change, since for every kg of cement saved there is a corresponding saving in CO<sub>2</sub>. (In the production of cement approximately one kg of CO<sub>2</sub> is emitted into the atmosphere for each kg of cement produced).

It is also possible, even advantageous, to build such tanks in ground which has a high water table, and in this case the tank can simultaneously act as a well, providing certain features are added.

For example, to prevent the thin FC floor slab from bulging upwards owing to external water pressure (in the case of an empty tank and a high water table), a simple and cost effective non return valve can be installed in the floor. This allows water into the tank from below the floor up to the height of the prevailing water table, and this relieves the bulging pressure. This additional water can be quite substantial in the case where there is an underground aquifer, and can be used for a corresponding increase in crop production.

The non-return valve is designed to close the moment the level inside the tank exceeds the level of the water table outside, thus any incoming rain water into the tank will not escape via the valve. (In this case there will be a net downward pressure applied to the floor-slab, but there is no danger of it bulging downwards since it is supported by the ground).

The non-return valve also safeguards against flotation of the relatively light tank out of the ground, since flotation cannot occur so long as the water levels inside and outside the tank are equal.

The non-return valve and other features are illustrated by way of photographs and diagrams of a tank constructed in Mpumalanga province.

**Ferro-cement rainwater harvesting tanks store rainwater and can simultaneously act as wells where there is a high water table, facilitating vegetable production and mitigating climate change.**

### **Background**

Pastor Hendrik Mahlangu and Professor James Blignaut envisaged building a rain water harvesting cistern for the Alethea Bible College in a village, Siyabuswa, Mpumalanga, South Africa, with the idea of providing water to grow crops and for adding with the feedstock for a proposed biodigester <sup>(1)</sup>.

However, in April 2010, when construction was to commence, the excavation had partially filled with water. It was evident that the 2.3m deep excavation had intersected the path of an aquifer which had filled the excavation to a depth of approximately 700mm.



**Figure 1** – A view of the inundated excavation

It became evident that this ‘problem’ could be turned into a ‘blessing’ by installing a ‘non return valve’ (NRV) in the floor of the proposed cistern. Such a valve would allow ground water in when the water table was high, but not allow water out when the water table was low! In other words the cistern would then have the ability to function as a well and as a reservoir, depending on the relative level of the water inside and outside the structure.

The first step was to build a drainage layer at the bottom of the excavation. This was done by installing a layer of broken bricks that were available on site. The spaces between the bricks were filled in with a coarse river sand/gravel that was also available on site. The sand/gravel would allow water to move laterally towards a central sump.



**Figure 2** – Drainage layer consisting of broken bricks, with spaces filled in with sand/gravel.

Figure 3(a) shows a simple NRT valve in its closed configuration, and in 3(b) it is in its open configuration. The valve is screwed into an assembly of pipes and fittings – see 3(c) and 3(d) which includes a thin inner pipe that has a series of horizontal narrow slits (made with a sharp knife), and a thicker outer pipe which has small holes drilled into it. The latter keeps out most of the sand/gravel, while the former prevents finer particles from making their way through to the valve.



**Figure 3** – Moving clockwise: In (a) the valve is shown in its closed configuration, in (b) it is shown open, in (c) the various components of the valve may be seen, while (d) shows the components in their assembled configuration.

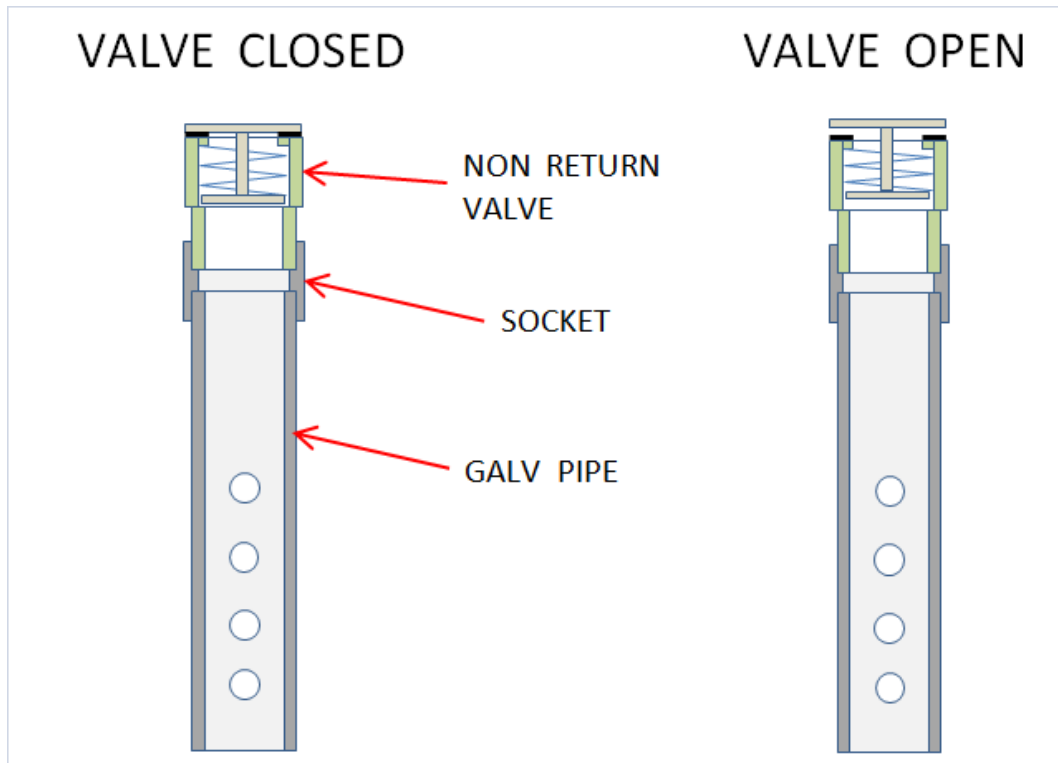
The next step was to put the assembly's filtration pipes into the sump that had been dug in the middle of the excavation. To increase the contact area of these pipes with the surrounding ground, it was decided to position the pipes inside portion of a plastic drum – see figure 4(a). A slot was made in the top of the drum, and this was used to introduce gravel into the cavity after the drum had been installed in the hole – see figure 4(b). Finally with the half-drum installed, filled and surrounded with gravel, see figure 4 (c), the reinforcing mesh was patched, see figure 4(d), in readiness for concreting. The valve, which protrudes above the surface of the floor, was covered with a filter fabric – see (e).



**Figure 4** – Clockwise: (a) a plastic drum cut in half, with the filter/suction pipes protruding through; (b) a hole is cut into the lid of the drum to allow grit to be poured inside; (c) gravel is swept into the cavity, and around the drum; (d) the opening in the reinforcing is repaired; (e) the NRV is covered with filter fabric.

A simplified arrangement of an equivalent valve assembly may be seen in figure 5, where the valve is shown in its open and closed configuration. The NRV is screwed into a plastic or galvanised steel socket, and this is screwed into a galvanised steel pipe. The valve operates on the principle of a simple plunger that is pressed down onto a rubber seat by a spring. This prevents water from above from flowing into the valve assembly, and it is evident that the greater the depth of the water above the valve, the greater will be the pressure exerted by the plunger on the rubber seal, and hence the better it seals.

## Non-return Valve

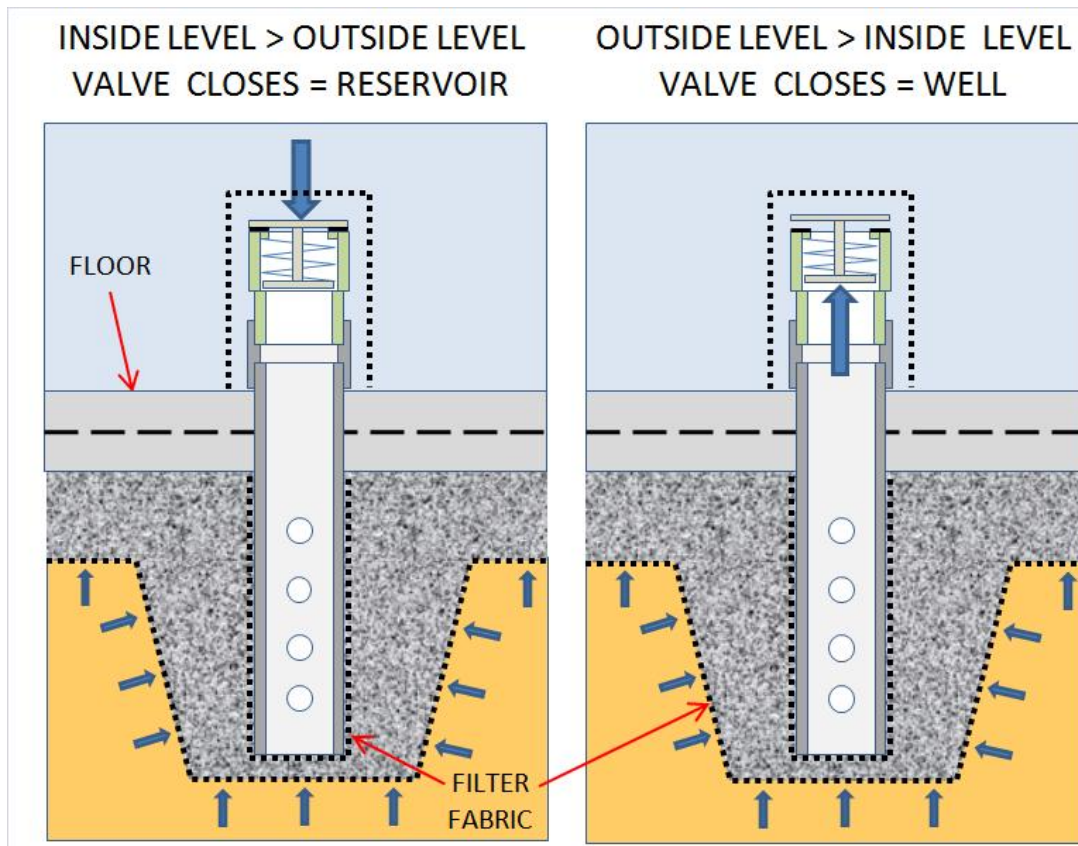


**Figure 5** – An alternative simplified version of the valve assembly, shown in its open and closed configurations.

Figure 6 shows the simplified valve assembly as it should be installed into the reservoir. Once again the NRV is shown respectively in its closed and open configuration. The galvanised pipe may be seen to be cast into the concrete floor, and since steel (or galvanised steel) bonds very strongly to concrete the connection will be watertight. Below the slab the pipe is covered with a filter fabric, and this is surrounded by gravel. The gravel also lies on a filter fabric which is in contact with the ground. The purpose of the former is to allow water to migrate towards the valve assembly, and the purpose of the latter is prevent the gravel from getting clogged with soil. Note that the NRV is also loosely covered with filter fabric on the top, to prevent any grit or dirt interfering with the workings of the valve.

When the level in the ground water is higher than the level of the water in the tank, then the pressure inside the NRV will lift the plunger in the valve off the rubber seat, and ground water will enter the cistern, making it function as a well. Thus the structure can be filled in two ways – either from

rainwater runoff entering the cisterns via its inlet, or from ground water entering via the NRV. Clearly this is most useful in the context of water harvesting – allowing more crops to be harvested.



**Figure 6** - The simplified valve assembly shown in its installed configuration. In (a) the NRV is in its closed configuration, which occurs when the water within the cistern is higher than the ground water outside, and in (b) the NRV is open, which occurs when the ground water is higher than the water inside.

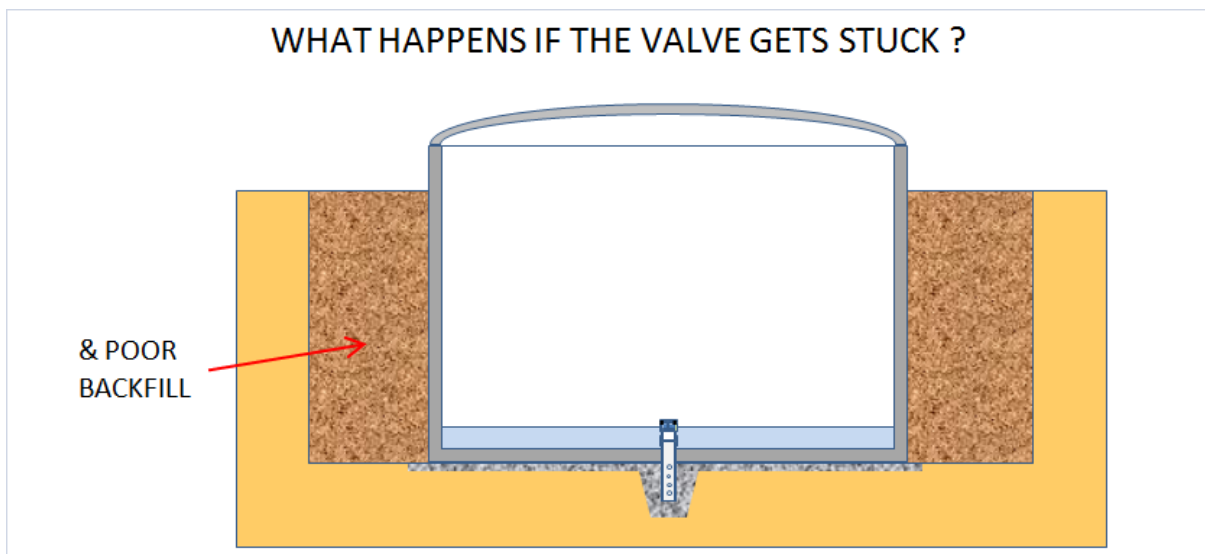
Apart from allowing the cistern to also function as a well, the NRV also guards against two other dangers that exist with a high water table.

**Bulging:** Firstly the floor of the reservoir may bulge upwards and eventually crack, allowing the ground water to enter the reservoir. (Bulging is especially a possibility in ferrocement structures that have thin walls and floors which are generally only lightly reinforced).

Later, when rain water fills the reservoir the slab will move down again, and the water inside the cistern will leak out through the cracks. The more this cycle is repeated the more the cracks will open up, and eventually the slab may begin to disintegrate.

**Flotation :** A second and even greater danger is that of flotation – illustrated in figures 7 through 9. This becomes a possibility if the ground water is high relative to the depth of water inside the cistern. According to Archimedes principle, the upward force acting on the cistern will be equal to the weight of the displaced water, which for a cylindrical cistern is equal to the area of the cistern (based on the outside diameter) multiplied by the height of the water table above the bottom of the floor slab.

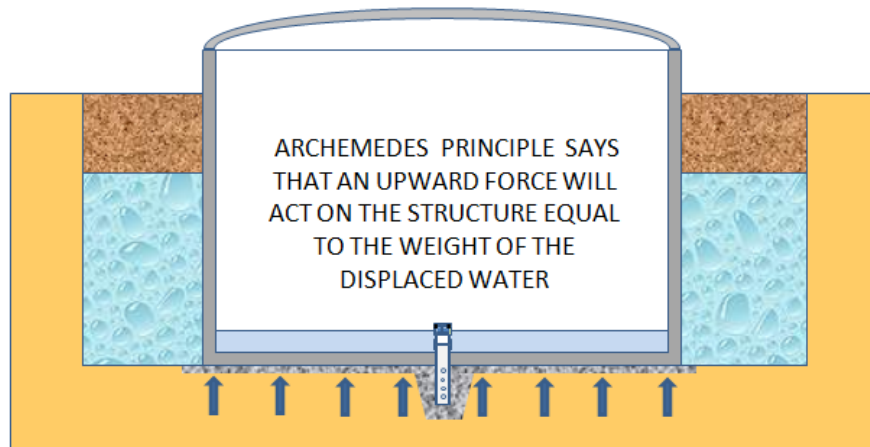
If this upward force exceeds the total weight of the cistern plus the frictional forces exerted by the ground on the walls, then the reservoir will float out of the ground, stopping only when the displaced volume is reduced to the weight of the cistern plus any frictional effects.



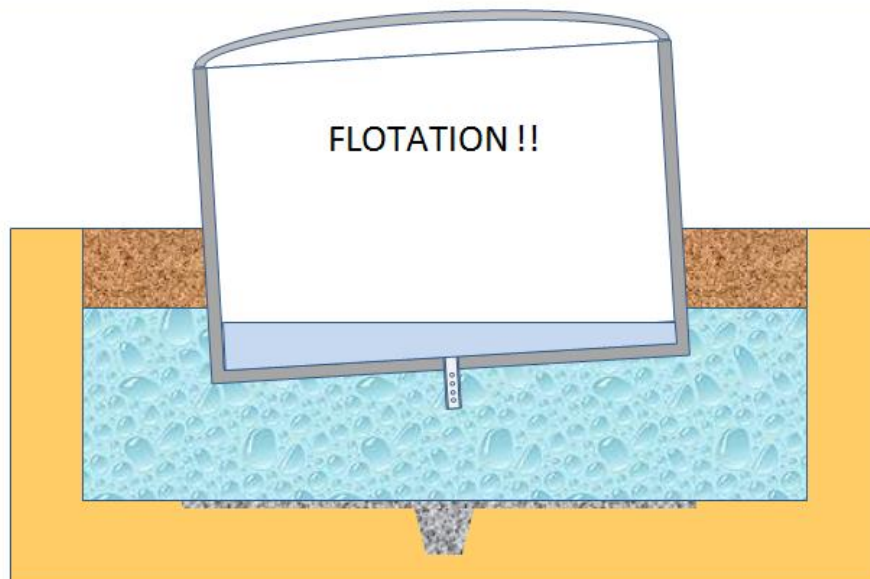
**Figure 7** – A cross section through a cistern made of ferrocement



AND THEN IT RAINS & THE WATER TABLE GOES UP !!



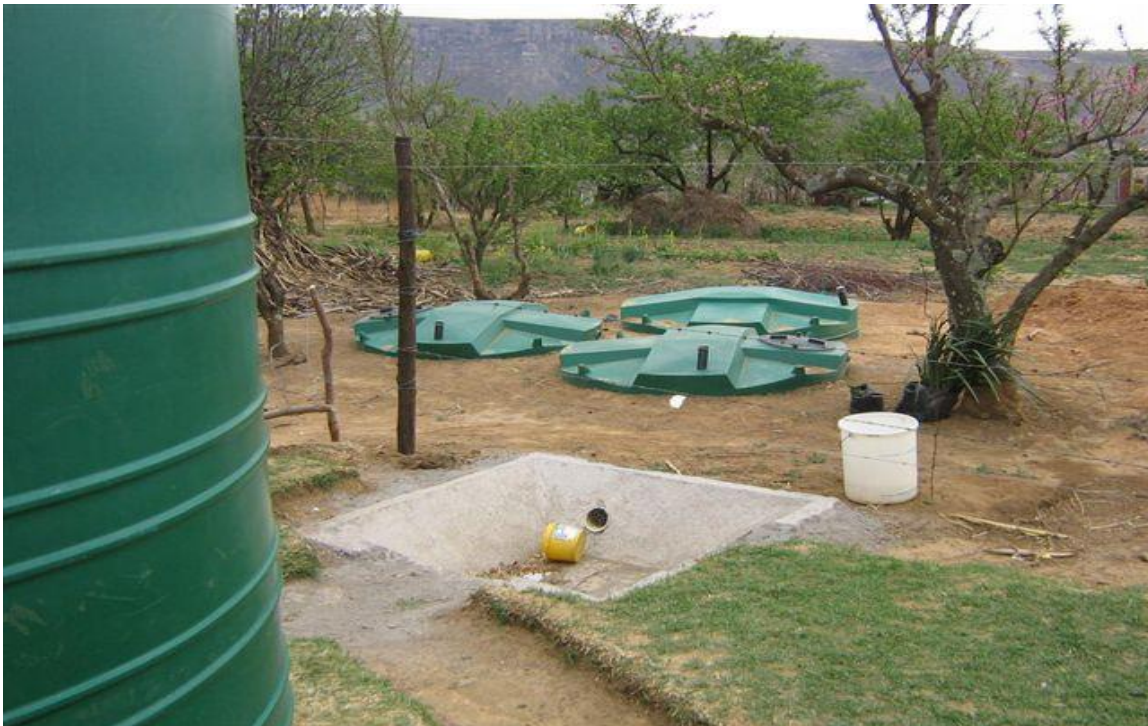
**Figure 8** – A high water table exerts substantial uplift pressures on the floor of the tank if the non-return valve does not allow the water levels inside and outside to equalise.



THE STRUCTURE ONLY STOPS MOVING UP WHEN THE DISPLACED WATER IS EQUAL TO THE STRUCTURE'S WEIGHT

**Figure 9** – The structure will be upwardly displaced until the weight of the displaced water is equal to the weight of the tank.

Flotation is an even greater possibility in the case of plastic tanks that are buried in the ground – see figure 10. Usually plastic tanks are not buried as they will tend to collapse inwards under the action of ground water or earth pressures. However, it is possible to reinforce them with circular steel bars, as indicated in figure 11, and over 100 plastic cisterns with these features have been successfully installed in South Africa by the company Rural Integrated Engineering (Pty) Ltd who developed the concept. In order to prevent flotation of the tanks, they also fitted them with non return valves in the sidewalls (not in view in figure 11), situated near the bottom of the tanks. A layer of gravel or stone is used to cover the filter pipes, which are similar to that shown in figure 3 (c) and (d)). This drainage layer goes horizontally all the way around the circumference of the cistern, directing groundwater to the NRV assembly.



**Figure 10** – 3 x 5000 litre buried plastic tanks in the background, receive water from the catch-pit/silt-trap, as well as the overflow from the 5000 litre elevated ‘under roof’ tank in the foreground.



**Figure 11** – To prevent the plastic tanks from collapsing under water or earth pressure, they are fitted with circular rings made of round bars.

### **Anchors**

As an addition precaution against floatation, it is possible to install anchors around the circumference of the cistern. These are shown in figure 12. Each anchor consists of a reinforced concrete slab that has two wires that are anchored higher up in the wall. Figure 13 shows that once the anchors are covered with backfilled ground the cistern is effectively weighed down against uplift forces.



**Figure 12** - Reinforced concrete anchor pads are constructed around the circumference of the cistern and are anchored to the walls. Once the backfill has been placed and compacted, the tanks is effectively restrained from floating out the ground.

### **How Ferrocement tanks and cisterns mitigate climate change.**

Ferro-cement structures are thin shelled structures, typically with floor, walls and roofs only 50mm thick, and as such use substantially less cement than conventional tanks made with reinforced concrete, or concrete blocks. Cement production worldwide is a major contributor to CO<sub>2</sub> emissions. On average for every kg of cement produced, one kg of CO<sub>2</sub> is emitted into the atmosphere. Thus any saving in cement reduces the greenhouse effect.

Secondly, RWH structures increase crop production. The completed ferrocement cistern at Siyabuswa is shown in figure 14. The corresponding crops may be seen in the background of the picture, and

since growing crops absorb CO<sub>2</sub> from the atmosphere during photosynthesis, they reduce CO<sub>2</sub> levels and the greenhouse effect.

## Completed Ferrocement RWH Structure / Well for Irrigation



**Figure 14** – The completed ferrocement RWH cistern showing the irrigated crops in the background.

### References

Papenfus, NJ, Blignaut, J. **Rain Water Harvesting and Biogas production working together synergistically for Empowerment of Rural Households and Climate Change Mitigation;** *Searnnet International RWH Conference – Mpumalanga, South Africa; Nov, 2011.*