Drainage Characteristics of Capiphon Belt™ & Pipe™: Some Comparisons with Slotted Pipe with Sock

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Summary

Initial studies showed that Capiphon drainage technology out performs slotted pipe with sock (Drain Coil) in soil. It also had a higher flow-rate in free water at low hydraulic head. In soil when flooded, Capiphon commenced flow before, and continued to drain long after Drain Coil had ceased. Its capillary and syphonic action resulted in drawing water upwards, pulling the water table down to at least 45 mm below the outlet. There is some evidence that Capiphon drains to a point just below saturation but this has not been quantified. Drain Coil stopped flowing when there was still 20 mm free water above the bottom of the pipe. Over a 47 day period of natural rain events Capiphon consistently started flowing earlier, flowed longer and delivered a greater volume of water than Drain Coil. A case study mirrored the flow characteristics found in the tank tests.

Introduction

The three most important characteristics of any subsurface drainage system are its ability to remove water from the soil, its longevity (susceptibility to blockage), and its cost including installation and maintenance.

The most common form of drainage is slotted pipe of various designs, sometimes called drain coil or aggie. Poly Drain™ is a popular brand in Australia, and is usually sold with a geotextile sock to prevent soil particles from entering through the slots (Figure 1a). It is recommended that it be installed in a deep trench and be covered by a transition layer of gravel. Although it is widely accepted that such systems will be blocked by tree roots and/or silt and have to be replaced within a few years, very few alternatives make their way into the market place, possibly because drainage failure is not immediately visible, and is usually someone else's problem.

An alternative system, Capiphon™ (sold as Smart Drain in the USA), is a capillary drainage technology developed by a Taiwanese engineer some 15 years ago. It consists of a belt of 2 mm PVC, usually 20 cm wide, with omega-shaped grooves running down its length (Figure 1b, 1c, 1d). A description of Capiphon, including examples of its use, can be found at www.capiphon.com. In some situations, such as installation into embankments, Capiphon is wrapped around a PVC pipe, is used in place of the belt.
The groves are omega shaped with an internal diameter of one millimetre. The opening to the grooves is approximately 0.3 mm. When placed in a saturated soil, water moves into the grooves by capillary action or "wicking", and is held within them as a capillary straw.

Figure 1a Poly Drain™ with Sock

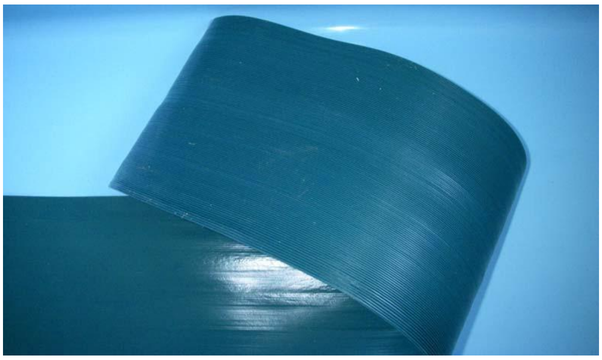

Fig 1b. Capiphon belt showing the grooves on the underside.

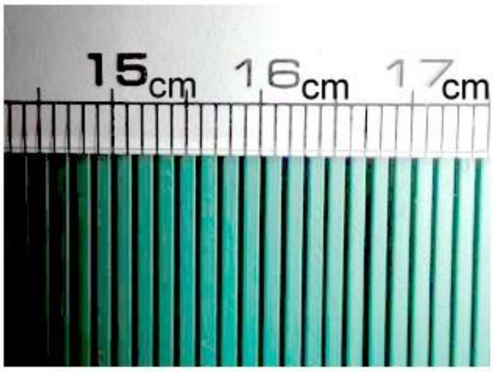

Fig 1c. A close-up of the underside.

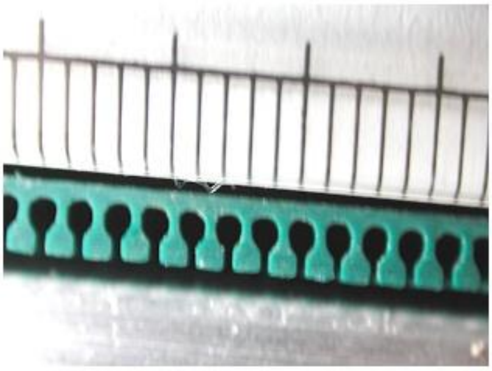
Fig 1d. Cross section (magnified).

When the belt is below the water table, or when the belt is on a slope (usually 1-2%), the critical capillary head is exceeded and causes the capillary straw within the groove to move down the belt. The movement of the capillary straw within the grooves creates a negative pressure that sucks up water from the soil. This siphoning effect continues to drain the soil for as long as there is an effective capillary straw within the soil.

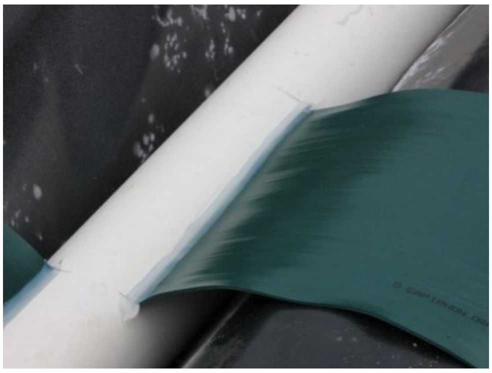
Figure 2. The Capiphon belt is usually inserted into a collection pipe laid some 10 cm below the level of the belt to increase the capillary head.

Capiphon drains best when the belt is in direct contact with the soil, obviating the need for a gravel transition layer.

An earlier study compared the installation costs of Capiphon belt with a number of other systems, showing that installation costs of Capiphon were not significantly different (Yates et al, 2005)

Two recent studies have established that Capiphon is less likely to block over time. Tests with excessive loadings by fine ground silica particulates (Sileshi et al., 2010b) and bio-fouling with extensive algal growth (Sileshi et al., 2010a) showed only a small effect on the discharge rates.

This study compares the performance of Capiphon with Drain Coil in water and soil. It also illustrates the effectiveness of Capiphon in a case study. Further studies will follow to more closely examine the relative cost effectiveness of several drainage systems including installation and projected maintenance costs.

Methods and Materials

The initial trials compared Capiphon pipe, Capiphon belt, and Drain Coil.

The study was conducted in a wooden tank - approximately 2.4 m long, 1.2 m wide and 0.6 m high - lined with plastic sheeting to prevent leakage. The tank was carefully positioned to ensure that it remained horizontal across the tank, and on a 1-2% slope along its length. The position of the tank was checked twice during the trails to ensure that there had been no movement.

The frame of the tank was constructed from 45 mm timber. Figure 1a shows the tank and fittings. PVC couplings were used to connect the one metre lengths of Capiphon pipe. Right-angled couplings enabled up to four lengths to be tested. The timber frame set the level at which the pipes/belt passed through the end of the tank at 45 mm above the base (Figure 1b). Relative head is measured from zero at the top of the bottom frame. Figure 1c shows that there can still be water in the tank at a head less than zero.

Figure 1a

Figure 1b

Figure 1c

Test 1: Comparison in water

The tank was filled to capacity with water and allowed to drain into calibrated buckets. Flow rate measured was calculated for the Drain Coil, Capiphon pipe, and Capiphon belt in separate runs. In each instance, head was measured against a yard stick as the water drained.

Test 2: Comparison in soil

The tank was filled with screened loamy sand (USDA classification) of a type commonly used for top-dressing playing fields, lawns and gardens. Care was taken to tamp down the soil as it was placed into the tank before the belt and pipes were installed. Both the Capiphon belt and the Capiphon pipe were laid down on a thin layer (<10 mm) of medium sand according to the manufacturer's instructions. The Drain Coil with sock was laid directly on the soil as is common practice. All three were checked to ensure that they remained on a 1-2% slope before more soil was progressively added with tamping.

A one-metre length of Capiphon pipe was placed vertically in the tank on a piece of Capiphon belt before the soil was added. Water in the soil flowed freely into the pipe allowing the water table (head) to be measured throughout the tests.

Test 2 scenarios:

A. The first measurements of flow rates were made with just soil in the tank. Sufficient water (approximately 80 litres) was added to the tank to flood the soil. As far as possible, the water was distributed evenly across the surface of the tank.
B. Turf was then placed on top of the soil for subsequent tests to ensure that the soil was not disturbed by the flow of water when the tank was being filled with water. The tank was then flooded by uniformly pouring buckets (80 litres) of water with the equivalent of 30 mm rain. The flooding was repeated twice more approximately one week apart.
C. The tank was then monitored through a number of natural rain events.

Test 3: A Case Study

The playground at a local primary school has suffered from poor drainage for many years. It has a soft-fall layer of shredded bark, specified to be at least 30 cm deep. The soil underneath the soft-fall was “fill” with a high proportion of clay. The site was on a slight slope. The photograph (Figure 2) was taken some 48 hours after a 2.4 mm rain event, preceded by 10.6 mm a week earlier, and 5.6 mm two weeks before that.

Figure 2. Playground with persistent flooding.

The soft-fall was scraped back and 15 m lengths of Capiphon belt laid on a sprinkling of medium sand directly on the underlying soil between the swings. The space between the belts varied from one to two metres, and was determined by avoiding the swing supports and the depressions directly under the swings. The belt was inserted into a 50 mm OD PVC/Capiphon pipe lying in a narrow trench approximately 100 mm deep. The pipe led to a sump at which flow rate measurements could be made, before being pumped to the stormwater outlet (Figure 3a).

Figure 3a

Figure 3b

A second combined Capiphon (green) and PVC (white) pipe was laid on the upside of the swings to capture water coming down from the playing field above (Figure 3b).

Results & Discussion

Test 1. Comparison in water

Figure 5a shows the decreasing flow rate of all three technologies with decreasing head. It is obvious that Drain Coil had a higher flow rate than Capiphon belt until the head dropped to about 22 mm. Drain Coil ceased to flow, in fact, when the head was still around 20 mm (Figure 5b). Capiphon belt continued to flow until -45 mm, illustrating the effect of capillary action and siphoning. The Capiphon pipe continued to drain to - 5 mm. All measurements of head were taken from the outlets resting on the timber frame (relative zero).

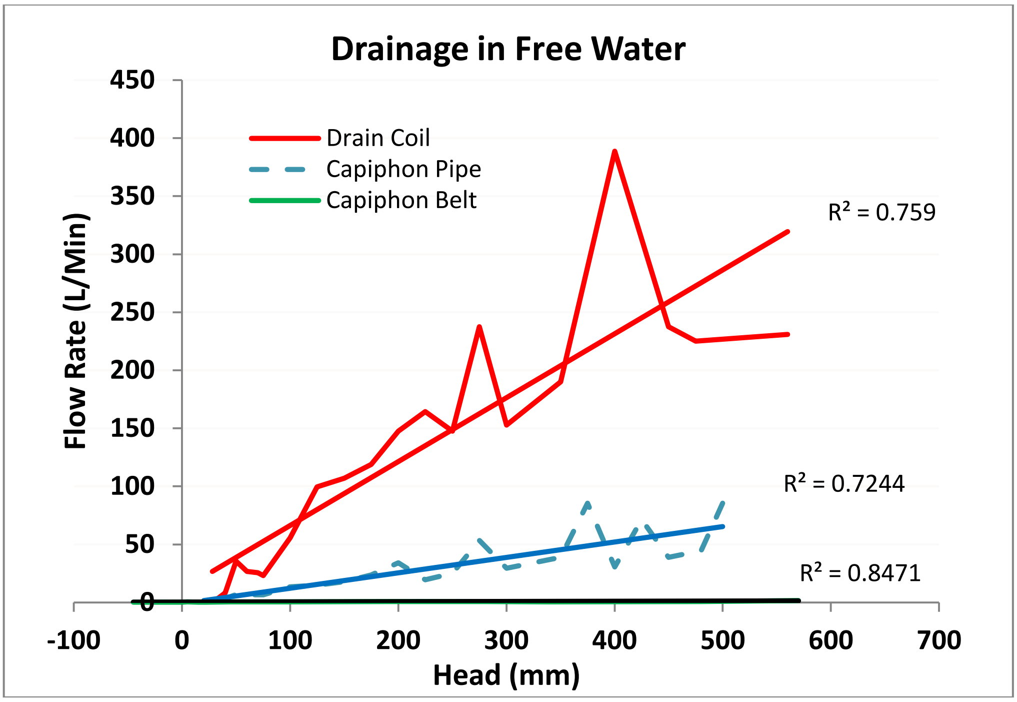

Figure 5a Decreasing flow rate of Drain Coil, Capiphon pipe, and Capiphon belt in water as the tank emptied.

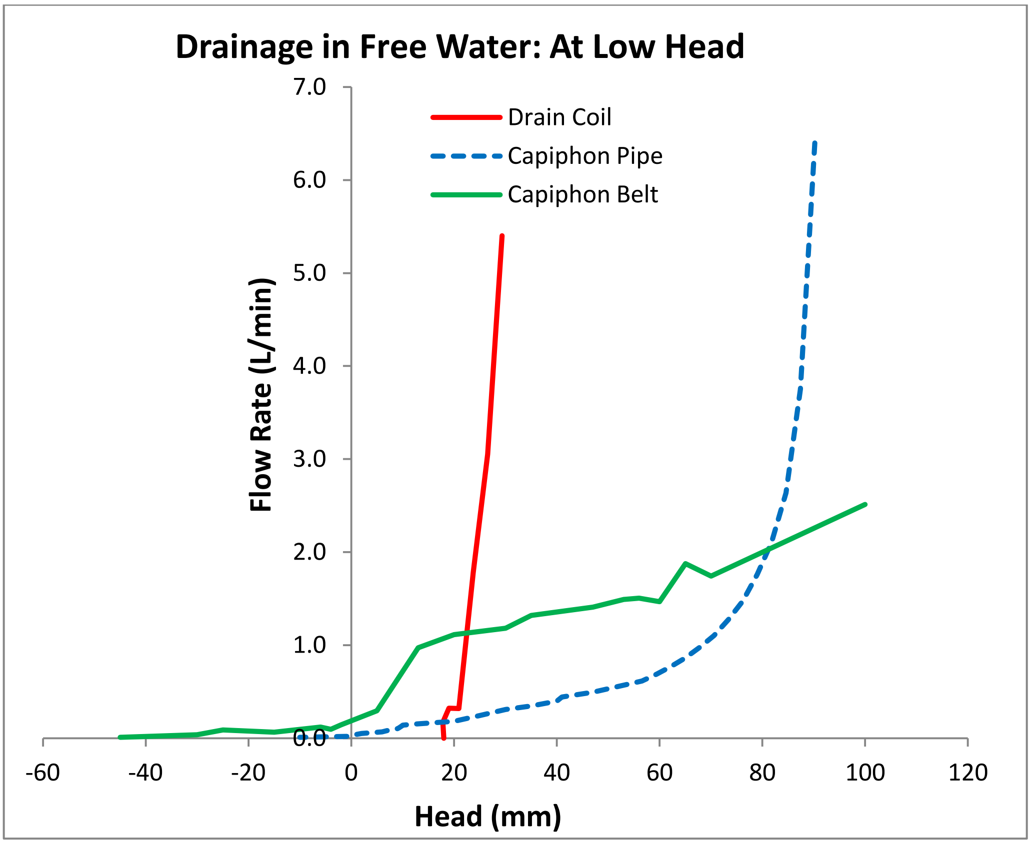

Figure 5b. Detail from Figure 5a. A negative head indicates drainage continues below the outlets.

The Drain Coil, Capiphon belt and Capiphon pipe were the same length – 2 metres. Flow rate within a pipe decreases with length due to friction losses. The rationale underpinning the pipe version of Capiphon is that water flowing inside the grooves moves into the inside of the PVC pipe, thus limiting the head loss in the grooves. The pipe form of Capiphon would therefore be expected to have a higher flow rate than the belt for more than one metre. This is borne out by the results in the Figure 5b, at least until the head falls to around 80 mm, at which time the siphoning effect has overtaken gravitational mass flow as the dominant force. The fact that the flow rate increases uniformly with the number of lengths of Capiphon pipe, as shown in Figure 6 is consistent.

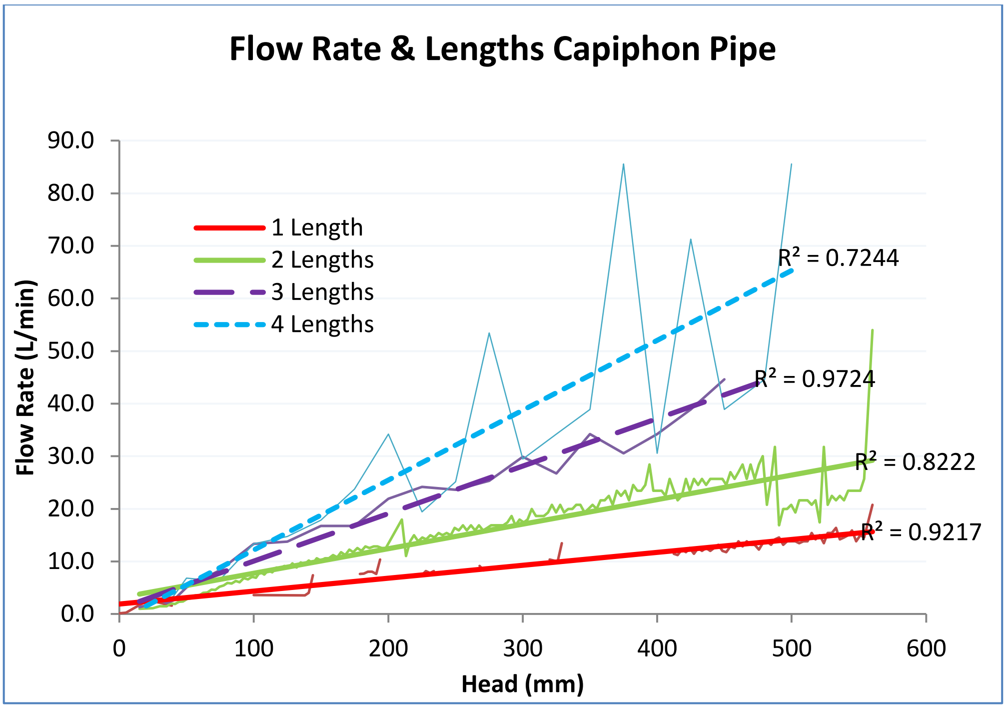

Figure 6. The effect of the number of one metre lengths on flow rate of Capiphon pipe in water.

Test 2. Comparison in soil.

The comparative advantage of Drain Coil over Capiphon at high head disappears when the medium is soil rather than water as Figure 7 shows.

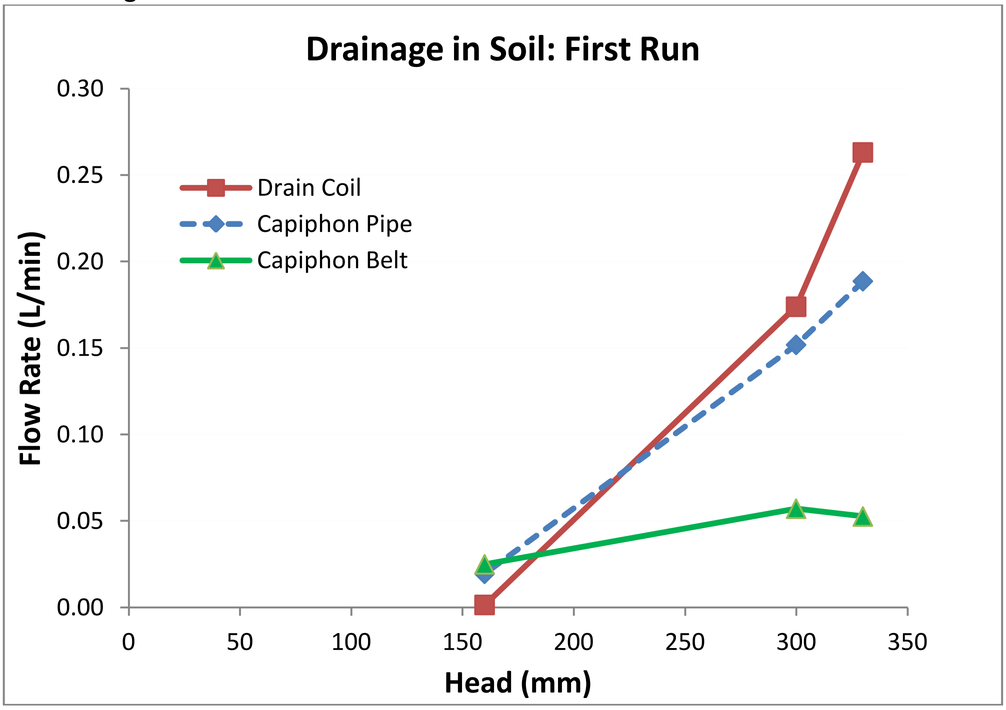

Figure 7

Note that the flow rate of both Drain Coil and Capiphon pipe have decreased by a factor of 1000, whereas the flow rate of the belt is only 1/10th of that in free water. This would indicate that the permeability of the soil is limiting flow rate, rather than the drainage method itself.

The flooding event was repeated after turf had been laid on top of the soil. Figure 8a shows that the head rose rapidly then fell as first the Capiphon pipe, then the belt and, lastly, the Drain Coil started to flow. Figure 8b uses a logarithmic scale (Log{minutes}) to better illustrate the responses.

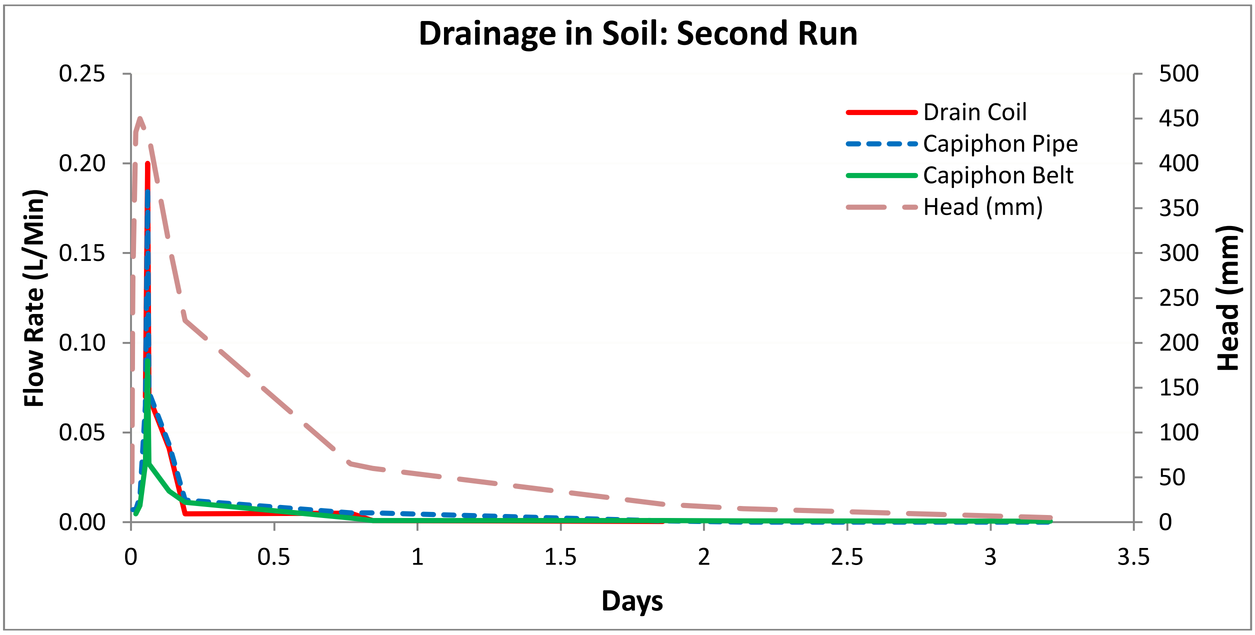

Figure 8a

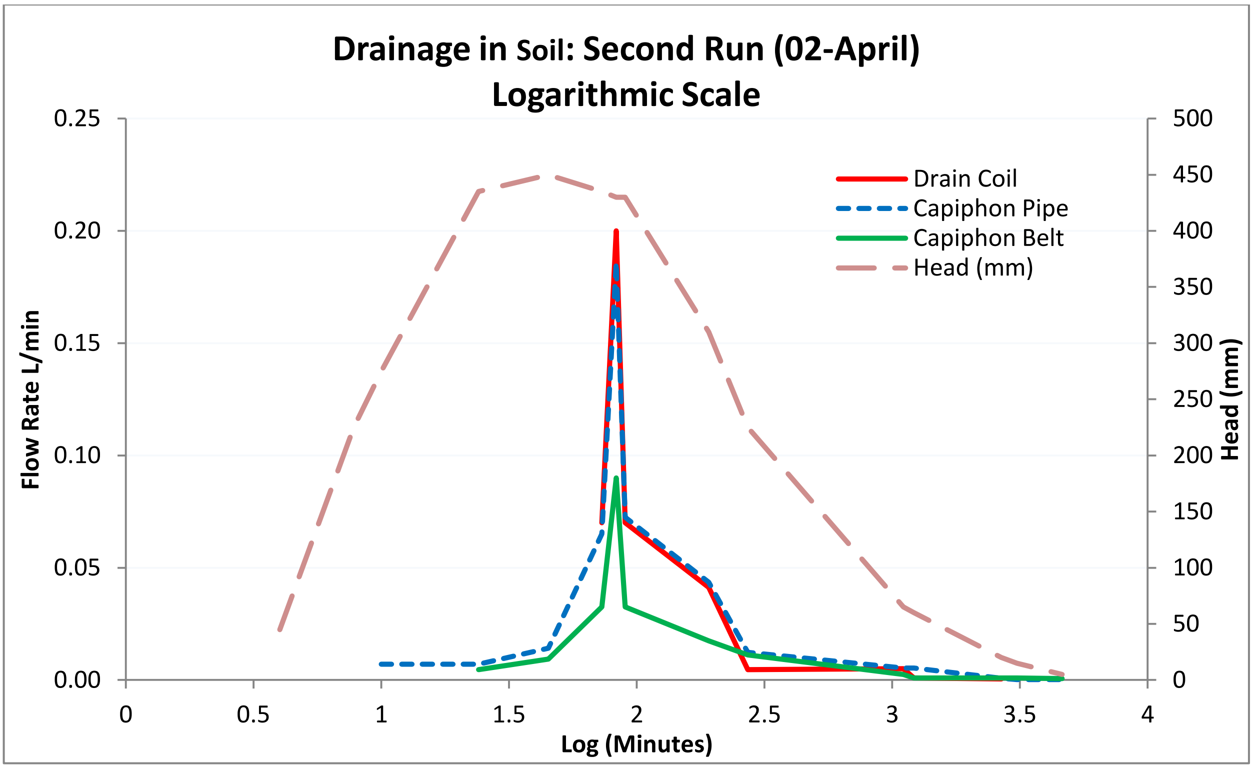

Figure 8b

The third flooding event clearly illustrates speed at which both Capiphon pipe and Capiphon belt begin to drain the tank (Figure 9). Table 1 shows how long it took each to start to flow.

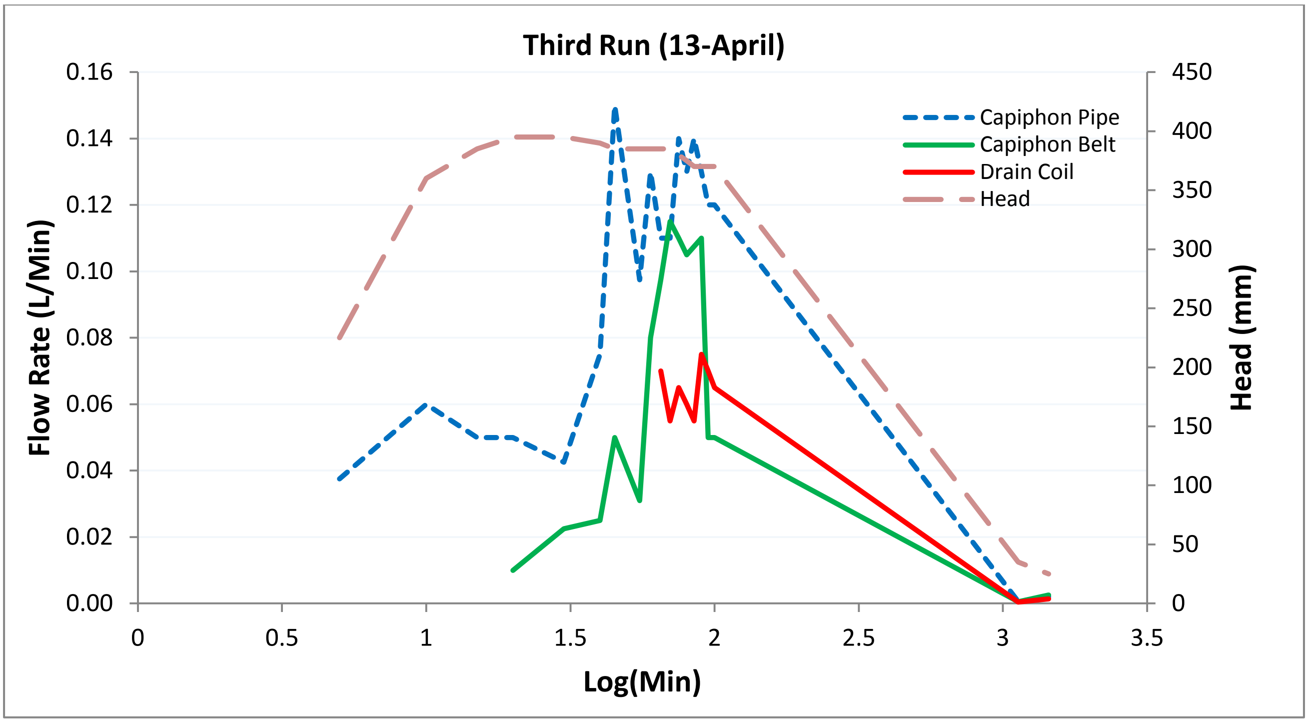

Figure 9. Flow rates after the third flooding event in soil – logarithmic scale.

Table 1. Time for Flow Commencement (min:sec)

Date	Capiphon Pipe	Capiphon Belt	Drain Coil
3 March	3:00	5:15	20:30
8 March	5:15	7:00	20:45
2 April	2:45	7:50	51:15
13 April	3:00	9:55	61:45

After a fourth flooding event, the tank was left to stand, and flow rates from natural rain events were monitored (Figure 10).

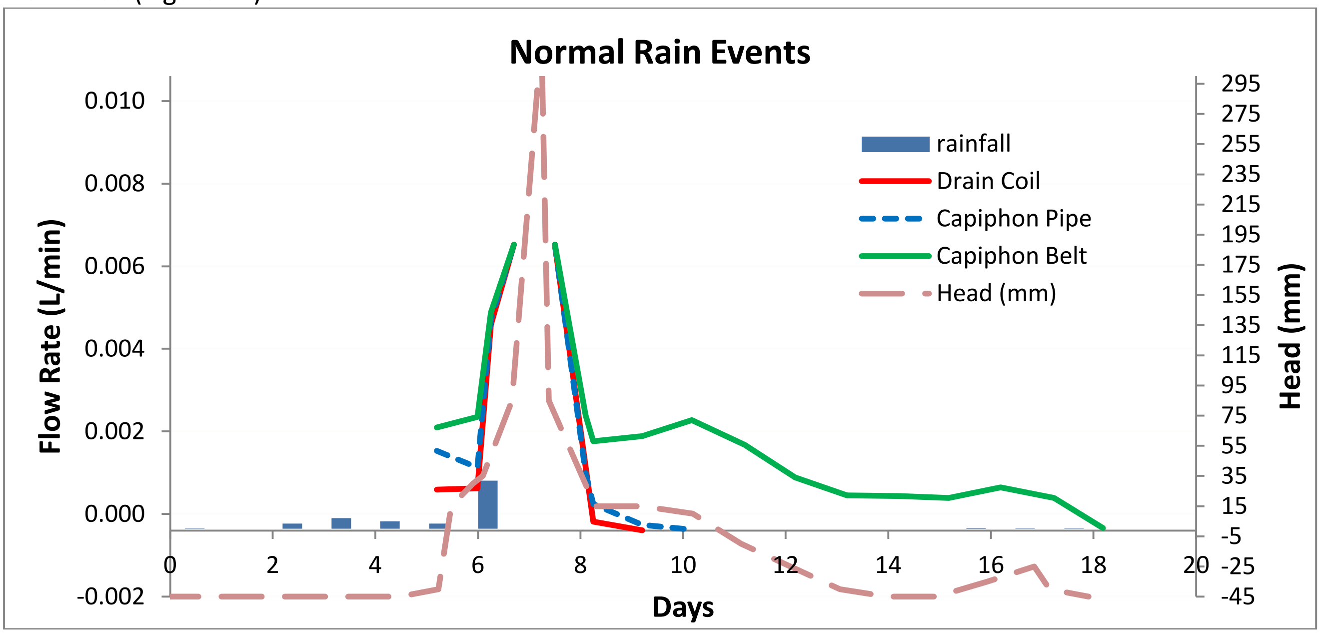

Figure 10. Flow rate and head within the tank during a period of natural rainfall events.

Note that the tank had drained completely (0 mm head) before the rain, and that several small rain events occurred before the head increased beyond zero. All three systems had started to flow by the time the head had increased to 60 mm. The major rain event (32 mm) caused the measuring containers to overflow and measurements of flow rate could not be taken.

In the 24 hours following the peak flow, Capiphon belt drained at a flow rate about twice that of Drain Coil. Drain Coil stopped flowing some 2-3 days after the rain cleared, Capiphon pipe kept flowing for another 2 days, while the Capiphon belt continued draining for a further 8 days. On three of those days, Capiphon belt continued to flow even though the tank had completely drained, perhaps drawing water held horizontally in capillary spaces within the soil. In total, and unfortunately discounting the day in which the buckets overflowed, Capiphon belt drained 78.8 litres, Capiphon pipe drained 28.1 litres, and Drain Coil 21.2 litres.

It was apparent that the flow rate of Drain Coil slowed with successive flooding and rain events, probably because the cloth surrounding it becomes progressively blocked. On the other hand Capiphon belt appeared to improve its performance, perhaps because silt had been displaced to make the capillary straws within the soil more effective (Figures 11 a, b, and c). Water flow into and out of Capiphon grooves is laminar (Reynolds Number of 100 to 600, Sileshi et al., 2010b) and therefore carries less sediment. This would, in turn, result in Capiphon being less prone to clogging.

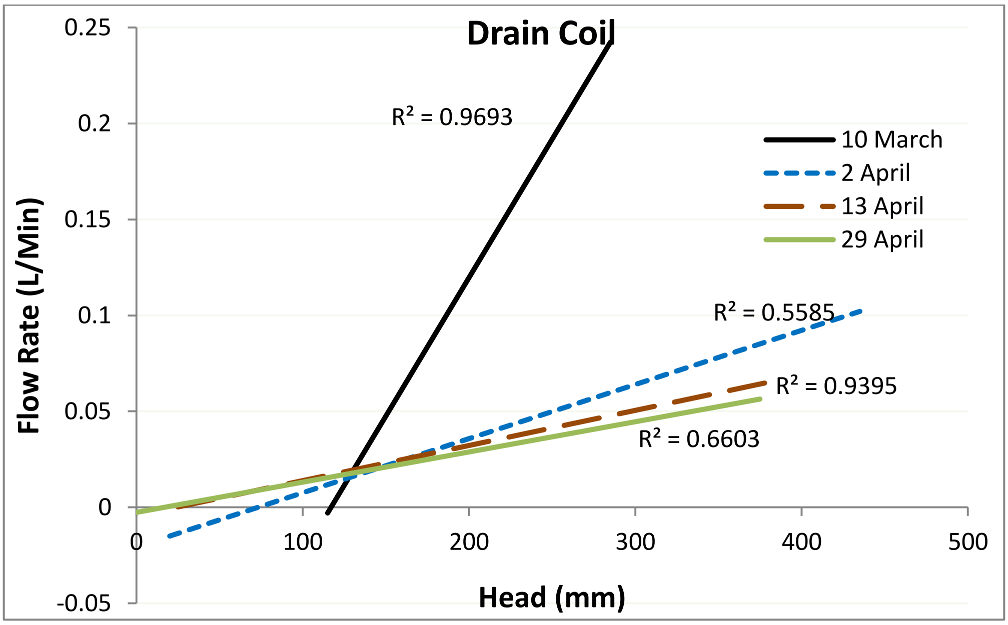

Figure 11a. Flow rate decline over time: Drain Coil

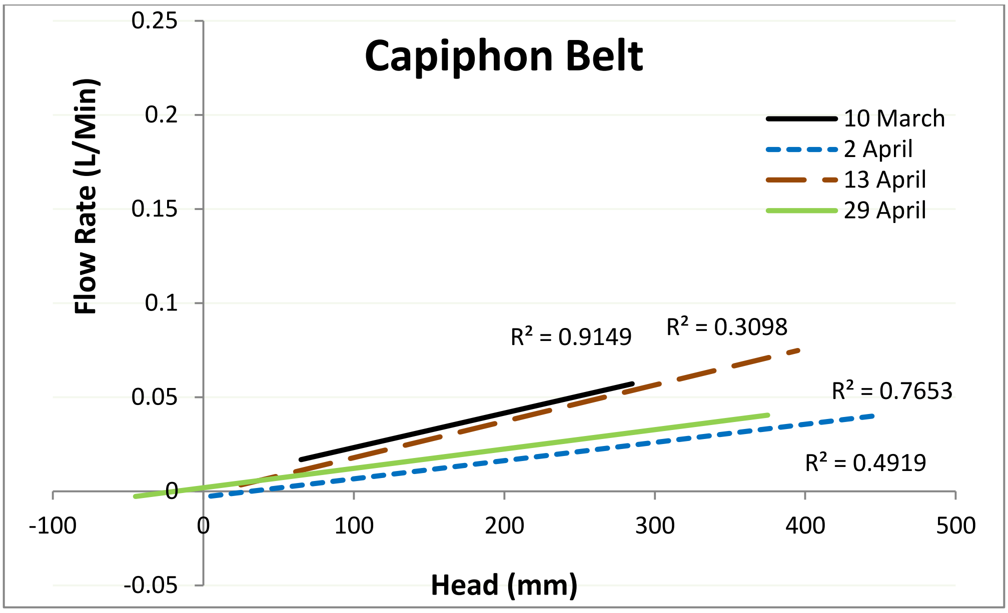

Figure 11b. Flow rate decline over time: Capiphon belt

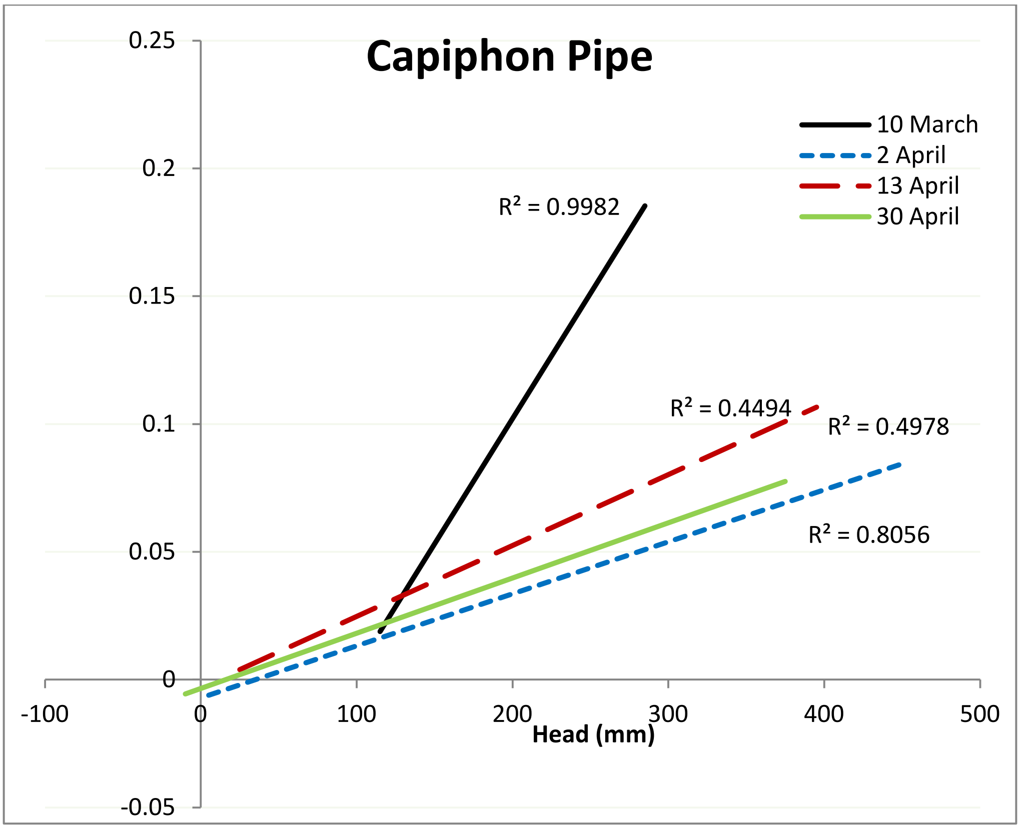

Figure 11c. Flow rate decline over time: Capiphon belt

Test 3. A Case Study.

The combined Capiphon belt/pipe system (under the swings Figure 3) began to flow almost immediately it had been connected to the pit, although the Capiphon pipe alone (Figure 4) did not begin to flow until a significant rain event. Figure 12 shows the flow rate, along with rainfall, over the ensuing 30 days.

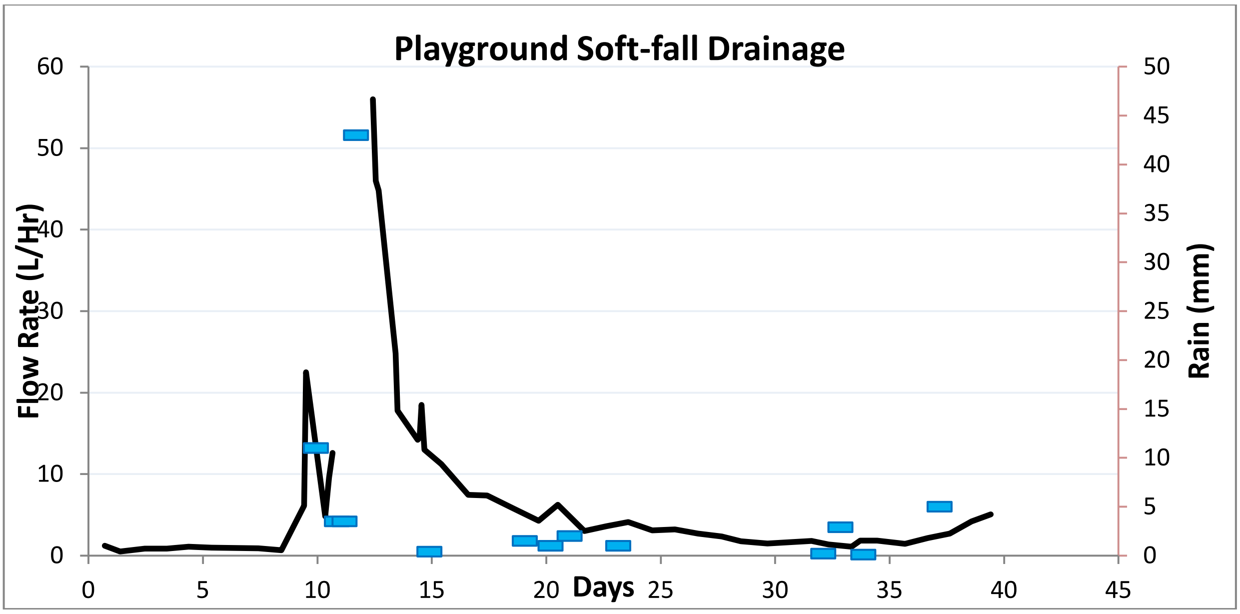

Figure 12. Drainage over 30 day period. Covers several rain events including one of 43 mm.

It is apparent that the flow rate through the system(s) closely mirrors, and in fact responds to, the rain falling on the playground. The gap in the chart is due to the inability to measure the accumulated flow because the water overflowed the sump.

Despite the heavy downpour, Capiphon so effectively drained the playground that it could be used immediately afterwards (Figures 13a, 13b, 14). The drainage was active from both the Capiphon pipe and the Capiphon belt systems on that occasion (Figure 15).


Figure 13a. A shallow hole under the swings area that had not been drained shows free water just below the surface.


Figure 13b. A deeper hole under the swings in the drained area shows no sign of free water.


Figure 14. The playground some two hours after the 43 mm rain event ceased.


Figure 15. Water flowing from the Capiphon pipe system (left) and the belt system (right) two hours after the rain.

Conclusion

The results of these tanks tests show that Capiphon is not only effective at draining free water but also water held within capillary voids in soils. They also showed that, for the most part, Capiphon belt and Capiphon pipe outperformed Drain Coil. The exception is in free water when the water level exceeds 20 mm. For subsurface drainage applications, however, Capiphon is clearly superior.

Drain Coil stopped flowing at a 20 mm head, leaving free water behind. Both Capiphon pipe and Capiphon belt continued to drain below zero head resulting in better aerated soil. This would make Capiphon an ideal drainage technology for rooftop gardens and sports fields. As well as being able to get heavy rainfall away quickly, Capiphon would continue to drain thereby increasing the capacity of the soil to absorb the next rain event.

The capillary drainage effect would also make Capiphon ideal for the protection of built structures. Not only would it ameliorate flooding but it would reduce the susceptibility of buildings, roads, and railway tracks to salinity due to the rise and fall of the water table. Urban salinity is a significant but often invisible cost in Australia, and no doubt elsewhere.

The decline in performance of the Drain Coil is most likely associated with occlusion of the sock by fine soil particles. The manufacturers of Capiphon have long claimed that their product does not block (some installations draining over 15 years). These studies lend support to that claim.

The case study described herein can be applied to any playground or sports field where lost time is inconvenient and/or expensive. The ability of Capiphon to continue to draw capillary soil water means that the field is better able to handle the next large downpour, and play can resume earlier.

Comparative costing is being undertaken on the playground case study amongst others, and will be reported later. Further studies are underway with other drainage technologies. Other studies will investigate comparative performance in different soils and plant media.

References

Sileshi, R., R. Pitt, and S. Clark. (2010a) "Enhanced biofilter treatment of urban stormwater by optimizing the hydraulic residence time in the media." ASCE/EWRI, Watershed: Innovations in Watershed Management under Land Use and Climate Change. Madison, WI, Aug 23-27, 2010. Conference CD (peer reviewed) .

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