The Laboratory Performance of Cylindrical Chamber Trap

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Abstract
Sediments are considered as one of the main sources of pollution in stormwater runoff. A heavy rainstorm often carries a high sediments load with other associated pollutants (untreated pollutants) into stormwater drainage systems. As a result, this inlet has a very detrimental impact on receiving watercourses. This paper presents the performance of a stormwater scale model of cylindrical chamber trap (CCT) intended for sedimentation applications. Laboratory tests were conducted to establish the hydraulic characteristics (i.e. head loss) and trapping efficiency. The CCT model with 2.5, 5, 7.5, 10, 12.5 and 15L/s flow rates were experimentally tested at Edith Cowan University. Data analysis proves that the head loss increases in proportion to flow rates. The trapping efficiency is inversely proportional to flow rates and particle sizes.
Keywords: *Hydraulic Characteristics; Trapping Efficiency*

Introduction

With the increase of urbanization, stormwater drainage system plays a significant contribution to pollution problems in most of the urban areas. The heavy rains storm always carries high loads of sediments which associated with other pollutants into the stormwater drainage. On Andon's studies showed that the stormwater runoff plays a significant role in the problems of 13% of polluted rivers, 21% of polluted lakes and 45% of polluted estuaries (Andoh, 2006). Walker et al. (1999) reported that urban stormwater pollutants include gross pollutants; trace metals and nutrients are associated with sediments and dissolved pollutants. There are many other studies such as Pitt and Amy (1973), Wilber and Hunter (1979), Baker (1980), Fergusson and Ryan (1984), Woodward-Clyde (1994) and Sansalone et al. (1997), all have reported that higher concentrations of pollutants such as heavy metals are associated with small particle size fraction of urban dust and dirt. Data presented by Pitt and Amy (1973) indicates that almost half of the heavy metals (i.e. copper, lead and zinc) found on street sediments are associated with particles of 60 to 200 μm in size and 75% are associated with particles finer than 500 μm in size. Dempsey et al. (1993) undertook a particle size distribution analysis for urban dust and dirt, and partitioned contaminants into a number of size fractions to determine the concentrations of contaminants in each particle size range. Results show that the highest recorded concentrations of copper, zinc and phosphorous are associated with particles between 74 μm and 250 μm in size. On the study of Colwill et al. (1994), 70% of oil and approximately 85% of polycyclic aromatic hydrocarbon are associated with the stormwater solids. The study demonstrated that over a period of dry weather conditions, the highest concentrations of oil content is found in the sediment range of 200 μm to 400 μm.

Treatment Mechanism & Experimental Setup

Cylindrical chamber trap (CCT) is designed to capture gross pollutants mainly sediments and solids from stormwater drainage system. Similar to most of gross pollutant traps (i.e. VersaTrap units); CCT is basically consists of two cylindrical chambers (internal & external) with no moving parts (Figure 1). CCT removes/traps sediments and solids using anti-clockwise vortex phenomena by directing the flow tangentially to the internal chamber. The upstream pipe (A) with 152.4 mm diameter is connected to the internal chamber whereas the downstream (B) with 152.4 mm diameter is also connected tangentially to external chamber and both pipes (A & B) are connected to both chambers in same elevation of 600 mm. The dimension of internal chamber is 300 mm of diameter with height of 600 mm leaving a 300 mm space from bottom/base for a basket to be installed if necessary. External chamber's diameter is 500 mm with height of 1000 mm.

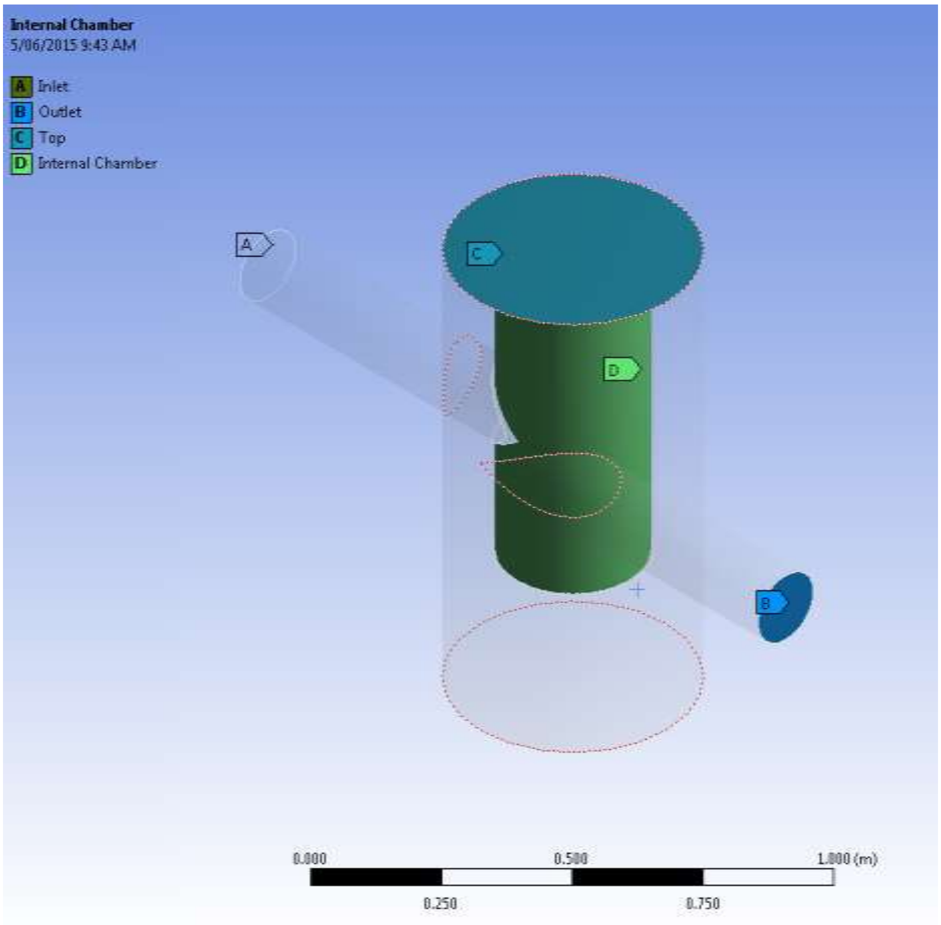

Figure 1 Cylindrical Chamber Trap Schematic

Figure 2 shows the set up/diagram of the experimental work conducted in the ECU's hydraulics lab. The water was pumped to CCT unit by a centrifugal pump and flow rates were adjusted and controlled via a speed controller switch/valve. In order to measure head loss, pressure and velocity head, a manometer was connected to CCT (up/down stream pipes). A tee junction was installed on the upstream pipe side for a purpose of injecting the sediments and solids.

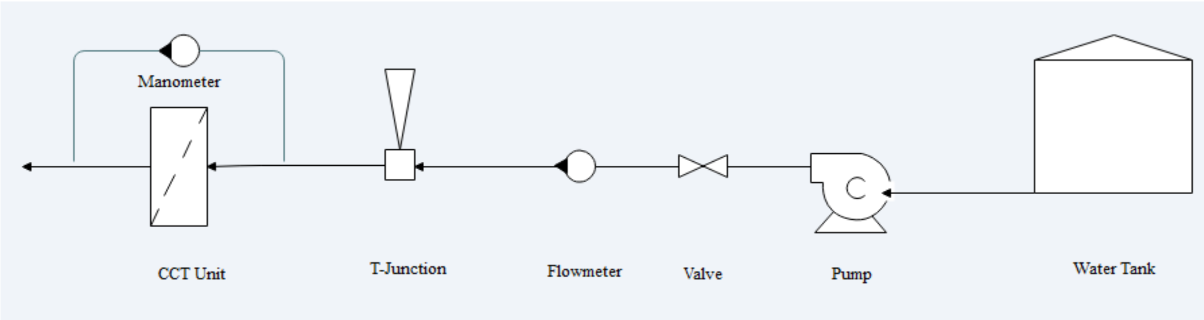

Figure 2 Experimental Setup Diagram

The Test Procedure

The method of hydraulic testing was to establish the relationship between head loss/head loss coefficient and flow rate (Ismail et al, 2006). To determine the hydraulic tests including pressure and velocity head, CCT was tested at the following flow rates; 2.5, 5, 7.5, 10, 12.5 and 15 L/s.

CCT trapping efficiency was obtained by comparing the amount of sediments/solids being recovered to one introduced before test (Ismail and Nikraz, 2008). Additional to sediments trapping efficiency test, there were two other trapping efficiency tests of gross pollutants have been accomplished; organics and suspended solids. The sediments trapping efficiency was achieved at different flow rates (7.5, 10 and 15 L/s) with five different sizes of sediments; 0.075, 0.15, 0.3, 0.6 and 1.18 mm. The organics and suspended solids trapping efficiencies were determined at all selected flow rates.

Results and Discussion

Hydraulic Results

Figure 3 shows that the head loss increases proportionally with the increase of flow rate. It starts from lowest value (0.005 m) at 2.5 L/s and reaches up to maximum (0.070 m) at 15 L/s where the flow is turbulent (Reynolds number = 125319). The maximum head loss is extremely low compared to other stormwater traps such as VersaTrap type A which was found 0.3 m at 10 L/s. To show the hydraulic performance of CCT, head loss coefficient (K_e) has been determined and found 2 which is similar to VTG (Ismail & Nikraz, 2007).

Water level has also been accomplished on this work. The water level increases proportionally with flow rate to achieve the maximum 0.81 m at 15 L/s. From Figure 4, the water level in the internal chamber is slightly higher than the external chamber. This was expected as the internal chamber has more pressure.

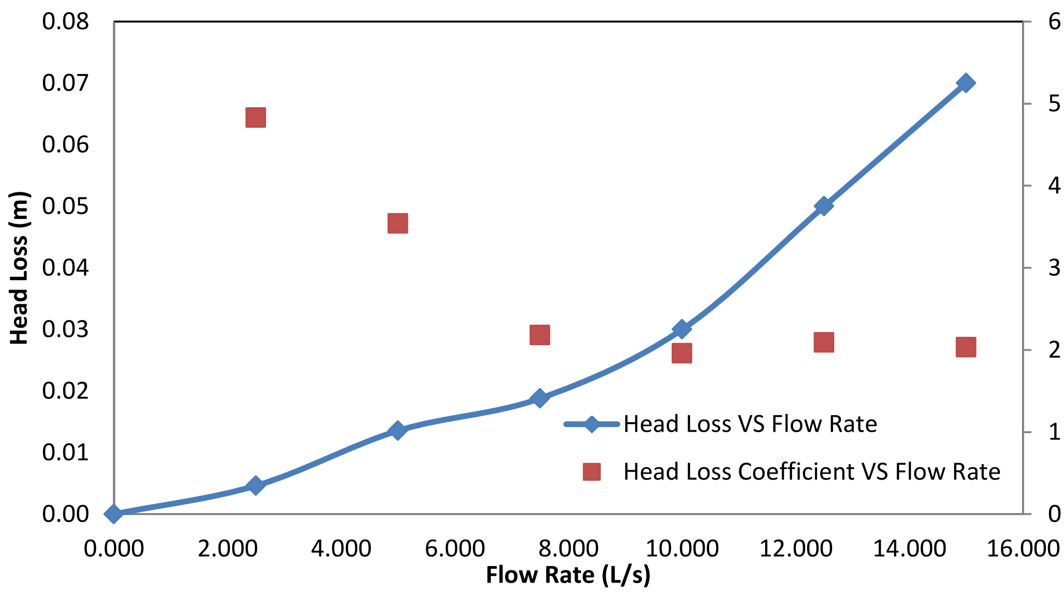

Figure 3 Head loss and Flow Rate

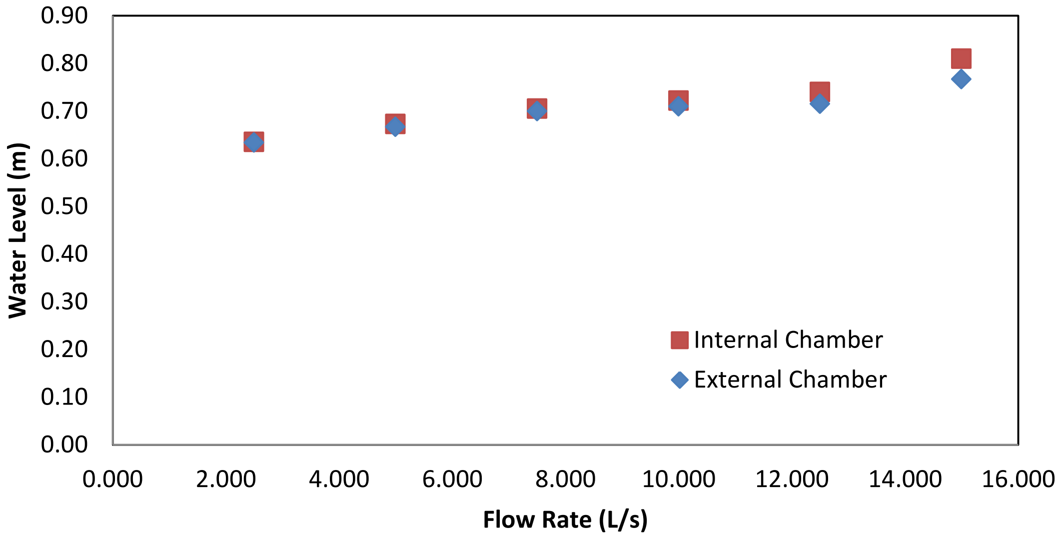

Figure 4 Water Levels at Selected Flow Rates

Trapping Efficiency

The capture rate of sediments was found higher than organics and suspended solids. This of course relates to the density as the sediments have density of 2650 kg/m^3. As shown on Figure 5, the captured rate of CCT unit decreases with the decrease of particle size. For instance, at 7.5 L/s, the highest mass capture rate of 1.18 mm particle size is 94.17% while 0.075 mm size is 5.65%. It has also been determined that the capture rate is inversely proportional to the increase of flow rate (Figure 6). The capture rate of 0.075 mm particle size is dropped from 14.93% at 7.5 L/s to 5.65% at 15 L/s. This outcome is similar to results found on other studies conducted by Ismail and Nikraz 2007 and Ismail and Nikraz, 2008.

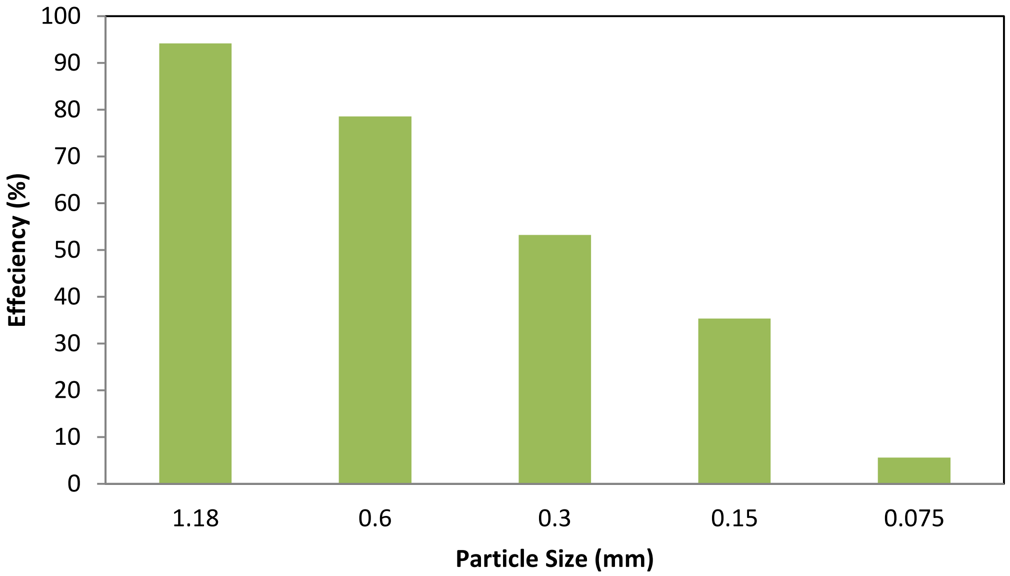

Figure 5 Sediment Trapping Efficiency at 15 L/s

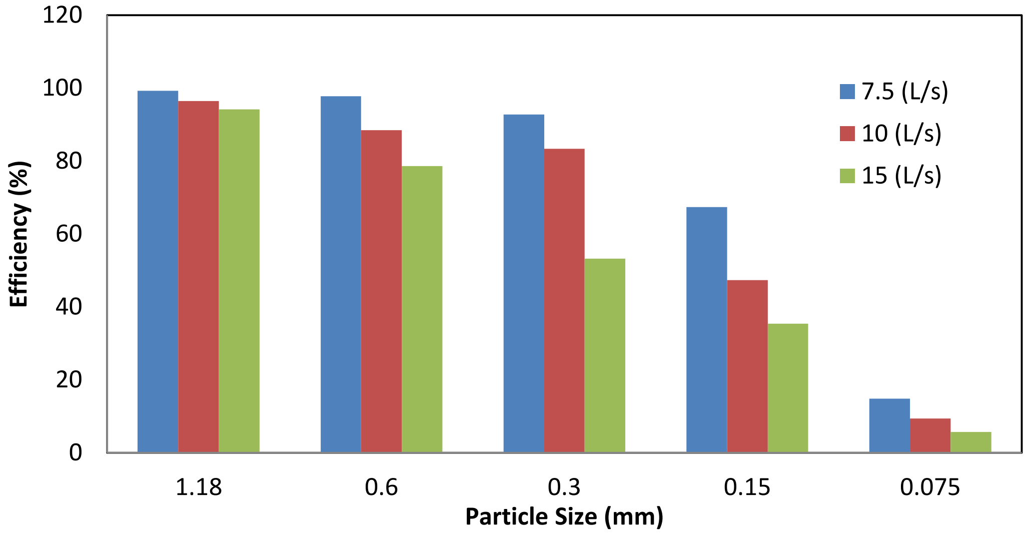

Figure 6 Sediment Trapping Efficiency at 7.5, 10 and 15 L/s

Although the organics trapping efficiency was performed without a basket, it is still achieved very good results. The highest trapping efficiency is found 92.9% at flow rate of 2.5 L/s however; the lowest was found 23.75% at 15 L/s (Figure 7). The suspended solids trapping efficiency has accomplished the highest results of 92.9% at 2.5 L/s and 0% from 7.5 L/s upwards (Figure 8).

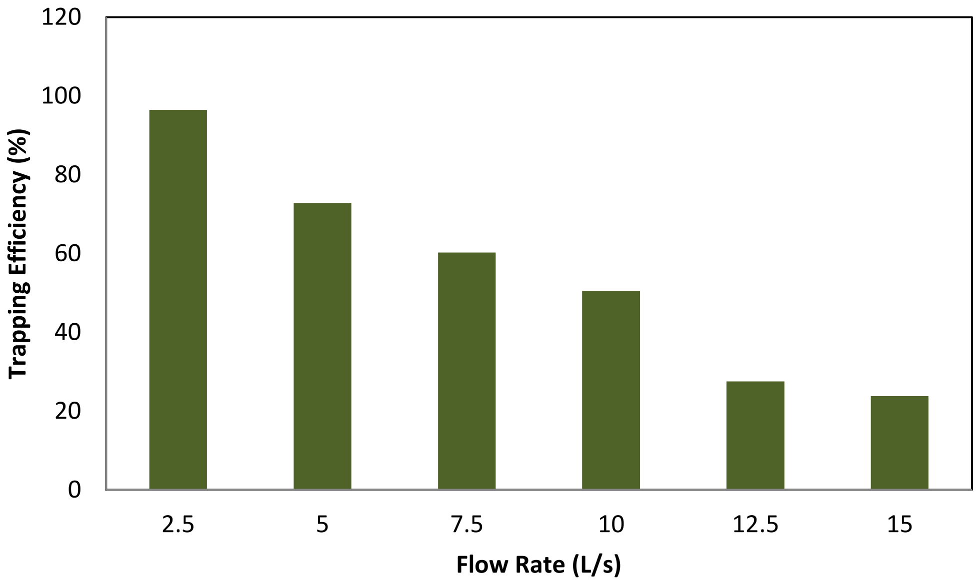

Figure 7 Organics Trapping Efficiency

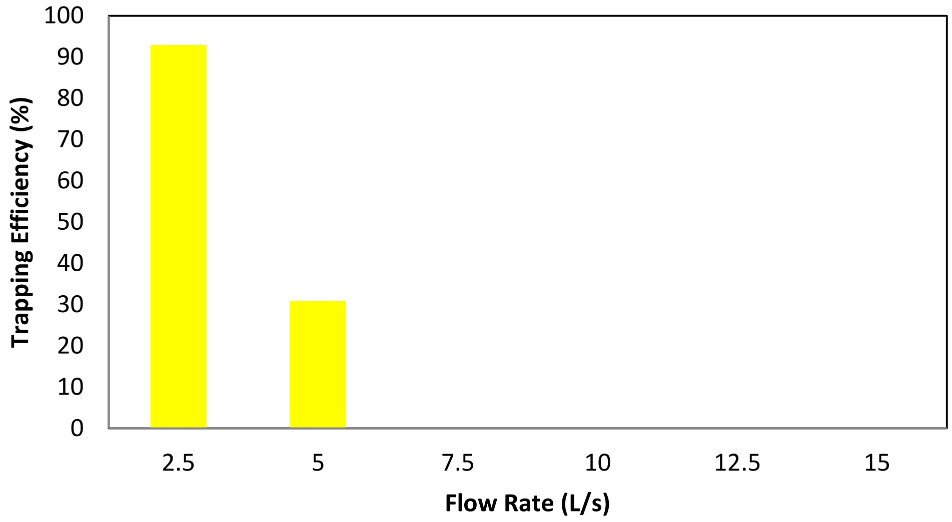

Figure 8 Suspended Solids Trapping Efficiency

Conclusion

The cylindrical chamber trap (CCT) performance has been experimentally studied on this paper. The hydraulics characteristics (head loss and head loss coefficient) and trapping efficiency were achieved. It is found that the head loss increases proportionally with the increase of flow rate to reach the maximum 0.07m at 15 L/s. The efficiency results approve that CCT trapping efficiency declines with the increase of flow rate. It is also drops with the decrease of particle size. Comparing CCT performance to stormwater traps such as VTA and VTG, CCT has approved an excellent results overall tests despite without having a basket. To achieve a higher organic and suspended trapping efficiency, it is recommended to install a basket in the internal chamber.

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