SUSTAINABLE STORMWATER MANAGEMENT SYSTEM: A CONCEPTUAL DESIGN MODEL FOR SLIIT, MALABE CAMPUS, SRI LANKA

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ABSTRACT

In recent years, significant attention has been given to the utilization of water and its components. Management of the wastewater including run-off to maintain a balanced eco-system has been an irony issue mostly in urban areas. Conventional water management systems such as reducing peak flow rate, sewer systems, end of pipe mitigation measures do not tend to fulfill the tortuous developmental plan of growing cities. It is therefore, necessary to use the principle management concepts such as best management practices (BMPs), low impact developments (LIDs) focusing on micro-management design concepts to intensify the existing hydrological cycle. Structural practices such as perforated infiltration trench along with bio-retention pond is thought to control the storm water at Sri Lanka Institute of Information Technology (SLIIT) premises based on the biophysical, hydrological and ecological ascribes of the landscape. This was identified as a critical issue to the well-being of the students during the rainy periods. Impervious layers introduced in aesthetic purposes have reduced the infiltration and then, increase the temporary flooding / pooling of these impervious surfaces. Post-development water management requires multi-disciplinary understanding of watershed along with identification of pre-development functions and their constraints. Therefore, parameters of soil properties like permeability, grain size, and other parameters like soil profile analysis, water quality analysis, water table depth, soil moisture condition and trench geometry based on terrain at two different sites were analyzed. Field tests were performed to find infiltration rates to compute the performance of the trench and to determine the storage volume based on rainfall events. Thus, this paper imparts colors upon an affordable, pragmatic and long-term solution to meet the need of modern water management at SLIIT. An infiltration trench network is being proposed to overcome the flooding / pooling problems in SLIIT premises and the proposal is being presented to the management of the institution.

***Key words*:** Grain size LIDs, perforated infiltration trench, permeability, runoff management, storm water

1. INTRODUCTION

The portion of rainfall that is not abstracted by interception, infiltration, or depression storage is termed the excess rainfall or run-off [1]. Urbanization increases runoff quantity and affects stormwater quality, producing significant hydrologic changes that can potentially result in adverse impacts on streams, other receiving waters bodies with their habitats [2]. Increasing percentage area of the impervious surfaces significantly reduces the ground water recharge, which can lower the ground water table, increase run-off peak, run-off volume, and reduce time to peak [3, 4]. In addition, the urbanization has a profound influence on the quality of stormwater run-off [4, 5]. The impacts of the urban run-off pollution includes run-off pollution by solids, substances exerting an oxygen demand, toxic substances, bacterial nutrients, salts and temperature [5, 6]. Integration of urban planning with the management, protection and conservation of the urban water cycle can be a positive incentive to maintain biological integrity if principles such as Low impact development (LIDs), Best management practice (BMPs), Sustainable urban drainage system (SUDS), Low impact urban design and development (LIUDD), Water sensitive urban design (WSUD) are used [4, 6]. Even though these principles sound very different to each other at first instance, their philosophies tend to be similar, such that the principles are differently called as LID in USA, SUDS in Europe and WSUD in Australia [7]. The LID concept uses structural measures such as wetlands, ponds, swales, soakaways, infiltration trenches, roof storage systems, infiltration basins, bio-retention basins, vegetated filter strips, filter strips, and pervious pavements [1, 2, 4, 8]. Some measures such as detention, retention, infiltration, storage, and retardation can even be implemented to control stormwater at its source [2, 4]. Source control option in stormwater management is believed to improve the ecological integrity of rivers and streams, reduce flooding in downstream areas (especially in urban areas), reduce sediment transport, and mitigate erosion and eventually, this makes urban stormwater a useful resource instead of an infliction [1, 4]. Detention basin usually is being practiced from early times and is one of the common features found in literature [4, 9]. However, infiltration of stormwater through detention and even retention basins may increase the risk of ground-water contamination, especially in areas where the water table is shallow [4, 6, 10]. This increases the possibility of ground water contamination in absence of run-off water treatment.

Permeable pavement systems have been used globally for over two decades as a WSUD control measure to reduce both peak stormwater flows and pollution loads [7]. This concept of LIDs are popular nowadays as they are capable of improving water quality by means of filtration, and they provide dual benefits during its usage cycle [1, 2, 7]. However, performance of pavement structures is believed to reduce significantly due to clogging with time [11]. This leads to reduction in the life span, increased maintenance works such as need for use of vacuum or suction pump to remove sediments between the interlocking permeable pavements along with its replacement costs [2, 7].

The use of other LID concepts like Grass swales, Vegetative filter stripes/ buffers are effective methods to control stormwater away from roadways and rights-of-ways [1, 2]. However, they cannot be optimized to implement for post development landscape development. These concepts requires site planning at very beginning stage but the pre development site planning has not been carried out focusing the use of these concepts. For aesthetic output, it would be better if we can merge this concept together with concepts such as infiltration trench, rain water harvesting system, rain barrels. Moreover, they provide pre-treatment of the run-off water through the vegetative roots due to which they seem to be very fruitful.

Currently, SLIIT has approximately 7 acres of impervious surface out of 13 acres of used land .In current scenario, SLIIT has initiated using pervious pavements on driveways, parking lots and open spaces. However, most of the pervious driveways and front yards of buildings are covered by bricks where there is a slight gap among the surrounding bricks. Nevertheless, sediments fill the small gaps and the pervious behavior is hardly practiced. Therefore, the front yards and driveways are usually pooled in a rain event (refer Figure 1). Therefore, this research is carried out to identify the potential solutions to overcome this pooling or temporary flooding in bricked areas of SLIIT and then to propose it to the management of SLIIT.

1(a)

1(b)

Figure 1: Water pooling in front of Faculty of Engineering due to a small rainfall

2. MODELING OF INFILTRATION TRENCHES

There are different approaches for modeling of the infiltration trenches. The variation in approaches can be due to the complexity in water redistribution after infiltration to the soil. One simple approach is to calculate the emptying time using empirical equations. Another possible approach is to assume a constant infiltration rate, which ultimately refers to soil permeability [3]. One another approach is to assume a clogged infiltration condition [3]. An infiltration trench model is being presented based on the field result of infiltration test, grain size analysis, antecedent moisture condition and surface run-off hydrograph. The result of the infiltration test is thereafter used to predict the suitable empirical equation for our site condition. Identification of different soil parameters can give us the infiltration rate resulting from different empirical equations and a regression analysis can be done to discover the best-fit equation for the proposed model. However, due to limited time and resource, attempt is only made to predict empirical equation based on infiltration behavior. Volume of the run-off along with run-off hydrograph was calculated using the HEC-HMS 4.1 software. This can be used to design the geometry of the trench.

3. RESULTS

Two sites were identified in SLIIT for soil tests and further analysis. The locations of the two sites can be seen in Figure 2(a) with drawn contour lines.

2(a) Contour map and selected sites

2(b) Site 2 Soil profile

Figure 2: Selected sites for soil analysis

Experiments were carried out to find the Particle size distribution and Figure 3 shows the obtained distributions for the tested samples. The distributions give us the soil profile as a poorly graded sand with silt and gravel.

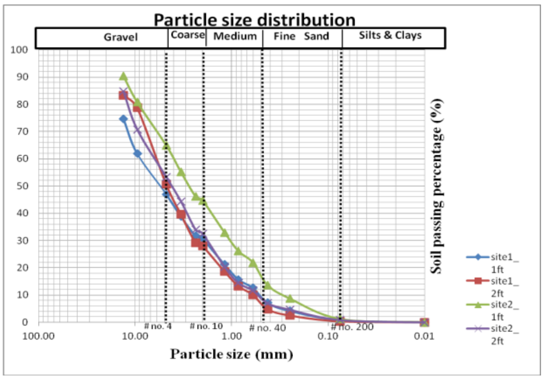
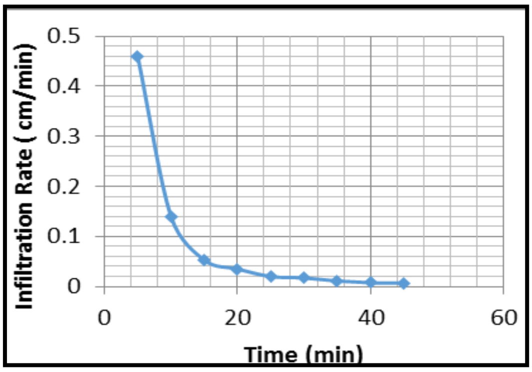
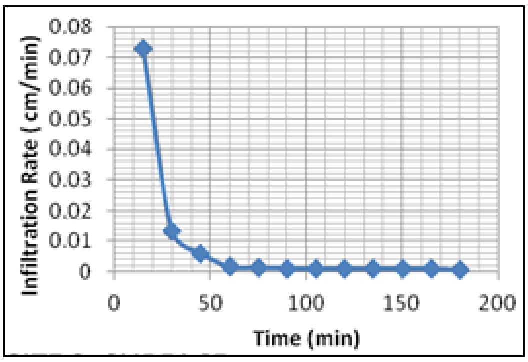


Figure 3: Particle size distributions

Figure 4 presents the infiltration test results for the site 1 at a depth of 1 foot and site 2 on surface. These clearly show the importance of proposing an infiltration trench to control the storm water around site 1 and 2.



4(a) Site 1 at 1 foot depth



4(b) Site 2 at surface

4. CONCLUSIONS

Based on the experimental findings and discussions, the following conclusions can be drawn.

- Storm-water is a useful resource that needs to be utilized to overcome calumnious effects of unplanned urbanization and concretization.

- Suitable integration methodology focusing on multi-disciplinary hydrological aspects based on sites pre and post development concepts is necessary to manage run-off.
- The percentage of fines present on the soil and the compaction/density of soil at different level of water content greatly influence the infiltration of the water into the soil. Compaction of filled type of soil with little fines decreases infiltration rate and the effect of moisture content at this condition seems to be negligible. However, it can be identified that the percentage of moisture content plays an important role for loosely arranged soil that has large void space.
- Field test is very important to check the infiltration rate rather than the laboratory test to get the literal concept of water infiltration and redistribution on the soil especially for filled type of soil.
- Double ring infiltration test can jointly be used to predict the permeability of the soil and the constant infiltration rate obtained after soil saturation underneath the ring can be used as the permeability value under certain condition.
- Compaction to soil plays a vital role especially for unsaturated type soil rather than initial level of moisture content for infiltration for run-off management.
- It is recommended to use soils having high permeability while filling to maintain the landscape of particular site to ease the post development process of water management.

Based on the test results, SLIIT premises is being modeled using and the infiltration trenches are proposed to overcome the issues in storm water in SLIIT premises.

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