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Technical paper

A Rainfall Simulator Used for Testing of Hydrological Performances of Micro-Detention Permeable Pavement

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Abstract

A rainfall simulator for laboratory experimentation is developed to test hydrological performances of micro-detention pond permeable pavement, MDPP. Rainfall characteristics consisting of rainfall intensity, spatial uniformity, raindrop size, and raindrop velocity show that natural rainfall is simulated with sufficient accuracy. The rainfall simulator used pressure nozzles to spray water for rainfall intensity from 40 to 220mm/hr. Uniformity distribution test gives coefficient of uniformity of 95% over an area of $1m^2$. The raindrops falling at velocity ranging from 0.5 to 15m/s with drop sizes diameter between 2 to 5mm. Free drainage system below the rainfall simulator is accompanied with outlet tanks attached with ultrasonic sensor devices to record the outflow data. During the experiments, the outflow received is 98% in average. Experiment results in typical runoff hydrograph and percolation rate of the MDPP system. This shows the ability of the rainfall simulator to obtain initial hydrology data to aid in the design of the MDPP prototype.

Keywords: *On-site detention; Raindrop size; Raindrop velocity; Rainfall uniformity; Runoff.*

1. Introduction

Rainfall simulator had been extensively used for study on rainfall, runoff, soil erosion, and infiltration for laboratory and field experiments [1-3]. Rainfall simulators are devices to duplicate the physical characteristics and reproduction of natural rainfall. The advantages include the possibility to vary the system configuration for simulating different scenarios of rainfall field characteristics [4]. Other than that, the advantages encompass the fact that rainfall can be produced quickly on demand, wherever necessary without having to wait for natural rain at the intensity and duration required, thereby, eliminating the erratic and unpredictable variability of natural rain [5], as well as the rapid data collection under relatively uniform conditions [6].

Rainfall characteristics for rainfall simulators applied in hydrological studies include drop size, spatial uniformity and terminal velocity [7]. Other important criteria are the accurate control of rainfall intensity, repeatability of applying the same simulated rainstorms, and ease of operation within the research area covered [8]. Rainfall intensity varies according to the study area, where most researchers choose to investigate in an area that is less than $5m^2$. Many rainfall simulators are designed with the nozzle at a height of 3 m or less to replicate the velocity and kinetic energy of natural rain [9]. There are two types of rainfall simulators; namely, drop former and nozzle simulators. Drop former is a drop-forming type, which simulates the rainfall through a drip tank with uniform arrays of holes. The water flow produces a distribution of drops with an intensity that is controlled by the diameter of the holes and the pressure in the tank. Its limitations are drop size distribution, velocity of the drops that is dependent on tank height, and impractical for large area. On the other hand, the nozzle type generates drops that force water into the nozzles and produce higher velocities and rainfall intensities at larger scales with uniform spatial distribution and reasonable drop size distribution [4]. As for spatial uniformity, it is calculated based on Christiansen uniformity coefficient (CU) where higher than 80% is considered as uniform [5].

Rainfall simulator model parameterization was designed and fabricated by designers to provide no limitation on frequency, duration and intensity for the objectives of their research [10-11]. Designers will make comparisons between study of rainfall simulators in use; its specifications and performance characteristics, standard evaluation and test methodology from data collected by various studies [5],[12-13]. It is factual that no standard rainfall simulator that is applicable for all situations exists. Thus, the design of each rainfall simulator is specific for each condition and for the aim of the study. Investigation on urbanization and sustainability awareness on green pavement leads to the usage of the rainfall simulator as a tool to evaluate hydrological performance of green pavement system [12],[14-17]. Furthermore, rainfall simulator offers the database needed for computational model simulation; runoff and infiltration process for permeable pavement surfaces [18-19].

In this study, a rainfall simulator was needed for an artificial rainfall experiment done within a laboratory scale that is used to simulate infiltration processes and rainfall hydrograph of a new design of permeable pavement named micro-detention permeable pavement (MDPP) system. The advantage of laboratory investigations in comparison to field measurements is the ability to control the determining factors and to concentrate research on specific processes to fill the existing knowledge gaps [11]. The required properties of the simulator consist of producing: i) A wide range of