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RESEARCH PAPER

THE USE OF RAINFALL SIMULATOR IN THE MODELLING OF RAINFALL-RUNOFF ON A PAVING BLOCK SURFACE

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Abstract

Inaccuracies on the calculation of runoff discharge into the drainage system lead the design become overestimate or underestimate. Runoff discharge can be determined by using a rainfall-runoff relationship. The accurate rainfall-runoff relationship model can be obtained through direct field observation. Using natural rain for observation by relying on the actual rainfall event will be difficult. Therefore, a tool that can actualize the relationship between rainfall and runoff discharge as the response of rainfall to the catchment area is needed. The tool is a rain simulator that produces precipitation according to the needs of research, which is applied to a test plot. This study aims to calibrate rainfall intensity resulted from rainfall simulator that applied to a plot of paving blocks. Selection of paving block plot is driven by the increasingly use of paving blocks as roads, parking lots, etc. The research stages include review of rainfall simulator technology that already exists; creating a rainfall simulator that suitable to the research objectives; calibration and performance evaluation of the rainfall simulator. The results are a rainfall simulator with the distribution of uniformity about 78% and the calibration curve of pressure-rainfall intensity expressed by power function $I=2.6489P^{1.2183}$ (P: pressure, I: rainfall intensity).

Keywords: rainfall simulator, calibration, distribution of uniformity

INTRODUCTION

General Background

On the planning process of the drainage systems development, particularly in urban areas, it is important to accurately determine the runoff discharge estimation. Inaccuracies on the calculation of runoff discharge into the drainage system lead the design become overestimate or underestimate. Overestimate design would impact on inefficiency, while underestimate design would have an impact on the risk or loss due to flooding and inundation. Runoff discharge can be determined by using a model or graph of rainfall-runoff relationship. The accurate rainfall-runoff relationship model can be obtained through direct field observation. Rain is a probabilistic natural event. Using rain directly for observation by relying on the actual rainfall event will be difficult. Natural rain could not be set according to the intensity required by the researcher. Therefore, for this kind of research needs a tool that can show the relationship between rainfall and the response of the catchment area to the rainfall event in the form of runoff discharge. The tool is a rainfall simulator that produces precipitation according to the needs of research, which is applied to a test plot.

This study aims to calibrate rainfall intensity resulted from rainfall simulator that applied to a test plot of paving blocks. Selection of paving block test plot is driven by the increasingly widespread use of paving blocks as roads, parking lots, and open space. Technology of paving block is the implementation alternative of the concept of low impact development (LID) and sustainable urban drainage system (SUDS). The new concept mentioned above using environmentally friendly technology such as infiltration (Guillette, 2010 and Jones, 2001). So far, no studies have specifically investigated the relationship model of rainfall and runoff that occurs on the paving blocks surface.

Literature study

Some of the rainfall simulator technologies developed by former researchers are as follows.

1. Humphry (2002) created a rain simulator that applied to the 1.5 m x 2m up to 3.5 m x 4 m test plots in open space with a very mild slope toward flat.
2. Joshi (2010) applied a rainfall simulator on a test plot with a size of 2m x 2m, in isolated area with a steep slope and some types of land cover in particular the grass layer.

3. Grismer (2012) examined the performance of the two types of rainfall simulator, sprinkler-nozzle type and drop-former type.

4. Sanguesa (2010) examined the rainfall simulator that used to evaluate the underground decline on site. Performance of the rainfall simulator was firstly tested and evaluated in a laboratory, then was applied to the study location.

5. Corona (2013) developed a new technology simulator that equipped with a rain water collection system design. The frame of the rain simulator was 4m x 4m x 2m (height) and consisted of four lanes sprinkle-nozzle low-cost and operated at a pressure of 80 mbar. The number and position of the nozzle was arranged so that the rainfall intensity uniformly distributed throughout the test plots.

(a) (b)

Figure 1. (a) rainfall simulator, Humphry (2002); (b) rainfall simulator, Joshi (2010)

(a) (b)

Figure 2. (a) sprinkle-nozzle type, (b) drop former type, Grismer (2012)

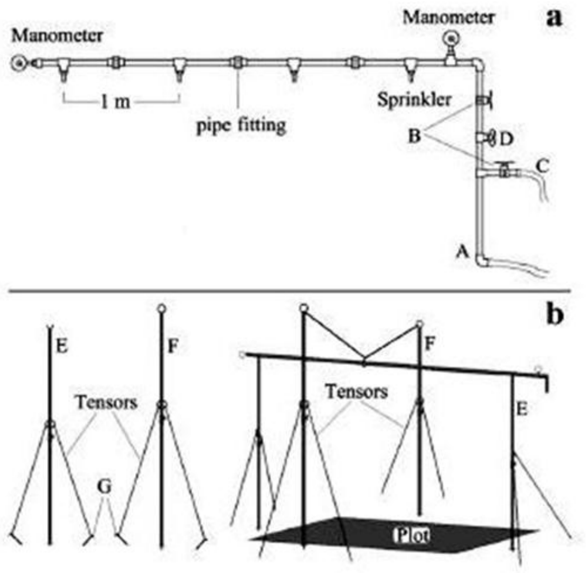

Figure 3. Diagram of rainfall simulator (Sanguesa, 2010)

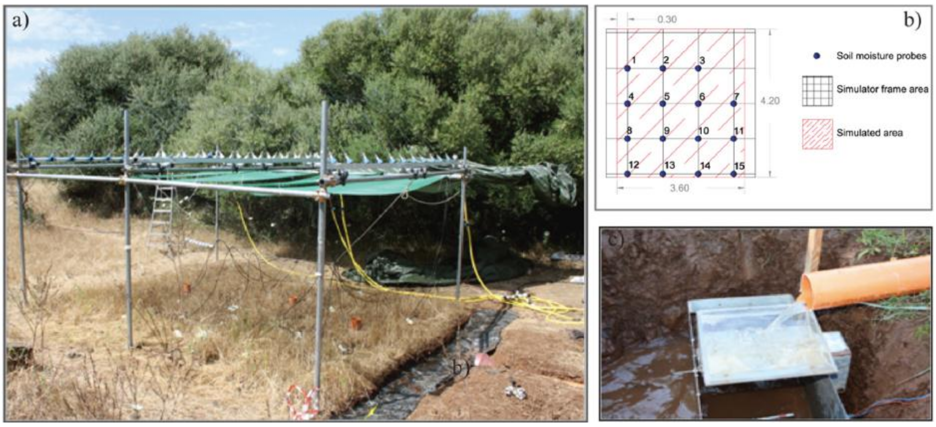

Figure 4. Field scale rainfall simulator (a), test plot scheme (b), Corona (2013)

This research is developing a rainfall simulator that adopting some of the technologies mentioned above. The differences of this study with the former research are on the size of the rainfall simulator, slope and type of the test plot surfaces The simulator is applied to the surface of the paving block plot with a variety of slope. Sprinkle-nozzle type is used to produce the rainfall. The plot size is 2m x 6m, so that the construction and the rainfall simulator unit should be adjusted. The size differences also lead to the modification of the existing technologies. This study also tries to obtain the rainfall-runoff relation based on the intensity of rainfall generated by the rainfall simulator. The rainfall intensity is expected to have a high level of uniformity and distribution in the entire area of test plots in order to provide accurate amount of surface runoff.

Methodology of Study

The research problems of this study are stated as follows:

1) How is the model of rainfall simulator that applied on 2m x 6m paving block test plot?
2) How is the relationship of the rainfall intensity and the pressure on the rainfall simulator?
3) How is the distribution of uniformity of rainfall intensity generated by the rainfall simulator?

To solve the research problems, this study is undertaken by some stages. The research stages included review of rainfall simulator technology that already exists, the making of rainfall simulator that suitable to the research objectives, calibration and performance evaluation of the rainfall simulator.

The study is conducted on a bare land in the city of Malang. A sloping plot test (Figure 5) and a rainfall simulator are made on the land. To avoid the influence of natural rain, then the above of test plot given a roof so that rainwater does not flow into the test plot area (Figure 6).

Figure 5. Installation of sloping plot of paving blocks.

Figure 6. Installation of rainfall simulator on the sloping plot

The study design is experimental research and correlation analysis. Stages of experimental research include the making of rainfall simulator, started by the stage of making a test plot, rainfall simulator construction, and testing of rainfall simulator. Performance evaluation of the rainfall simulator consisted of calibration of pressure and rainfall intensity; and evaluation of the distribution of uniformity of the rainfall.

Data Collection

The steps of data collection are as follows:

1. Measurement of rainfall intensity

    1) Connect the inflow pipe to the installation of the rainfall simulator.

    2) Place 5 units of rain gauge on test plot with the formation as the plan in Figure 7.

    3) Set the tap opening. Record the water pressure of the pipe following the tap using a manometer.

    4) Stop the flow to the sprinkle by closing the valve after 10-minute duration of rainfall.

    5) Record the increasing water level in the rain gauge.

    6) Flow water to the sprinkle by opening the valve for the second of 10-minute duration.

7) Repeat steps 4), 5), 6) untill five times of 10-minute duration of rainfall.

8) The rainfall intensity (I) is the increasing water level in the rain gauge in average divided by 10 minutes.

9) The result from point 8) is compared by the total water level in the rain gauge divided by 5x10 minutes.

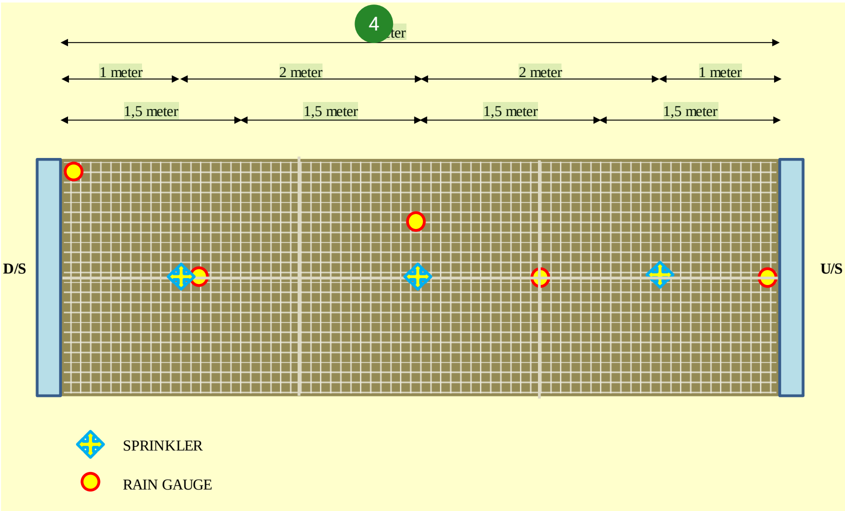

Figure 7. Position of sprinkles and rain gauges on the test plot.

2. Repeat steps 1 for other tap opening, until a total of 5 different variations of tap openings.
3. Calibration of the rainfall simulator with the rainfall intensity is the relationship between the pressure (P) and the rainfall intensity (I). The obtained relationship is I = f (P).

Performance of the rainfall simulator is evaluated by distribution uniformity (DU) value in % (Rahadi, 2008):

$$DU = \frac{quarter\ of\ the\ lowest\ volumes\ of\ rain\ water\ storage\ in\ average}{mean\ volumes\ of\ rain\ water\ storage}$$

Stages of analysis included statistical analysis of rainfall data and runoff to get empirical formula of the relationship between the rainfall intensity and runoff discharge that occurs in the paving block layer. At this stage also verified to determine whether the model was represented all appropriate parameters that affect the basic theories related.

RESULTS AND DISCUSSION

Data obtained from the observation of rainfall simulator are shown in Table 1 below.

Table 1. Rainfall data and distribution of uniformity

Pressure (psi)	Duration (minute)	Rainfall Depth (mm)					Rainfall Intensity (mm/hr)					Distribution of Uniformity (%)
		Gauge 1	Gauge 2	Gauge 3	Gauge 4	Gauge 5	Gauge 1	Gauge 2	Gauge 3	Gauge 4	Gauge 5	
4	10	2.5	3.5	3	2.5	2	15.0	21.0	18.0	15.0	12.0	0.85
	20	4	4.5	5	4	3	12.0	13.5	15.0	12.0	9.0	
	30	7	9.5	9	7	6	14.0	19.0	18.0	14.0	12.0	
5	10	3	4	3.5	3	2.5	18.0	24.0	21.0	18.0	15.0	0.66
	20	5	7	6	5	4.5	15.0	21.0	18.0	15.0	13.5	
	30	7	10	9	9	6.5	14.0	20.0	18.0	18.0	13.0	
6	10	3.5	4.5	5	5	3	21.0	27.0	30.0	30.0	18.0	0.68
	20	8	11	10	10	7.5	24.0	33.0	30.0	30.0	22.5	
	30	12	17	15	16	11	24.0	34.0	30.0	32.0	22.0	
7	10	4.5	6	5	5	4	27.0	36.0	30.0	30.0	24.0	0.84
	20	10	12	10.5	10.5	8	30.0	36.0	31.5	31.5	24.0	
	30	15	18.5	16.5	18.5	12	30.0	37.0	33.0	37.0	24.0	
8	10	6	7	6.5	7	5	36.0	42.0	39.0	42.0	30.0	0.85
	20	11	14	13	14	9	33.0	42.0	39.0	42.0	27.0	
	30	15.5	20	18	20	13.5	31.0	40.0	36.0	40.0	27.0	

This research produced a rainfall simulator model with a level of uniformity and intensity distribution of rainfall about 68% - 85% or 78% in average for all pressure. The calibration curve of pressure-rainfall intensity follows the power function $I=2.6489P^{1.2183}$ (Figure 8), where P:pressure, I:rainfall intensity.

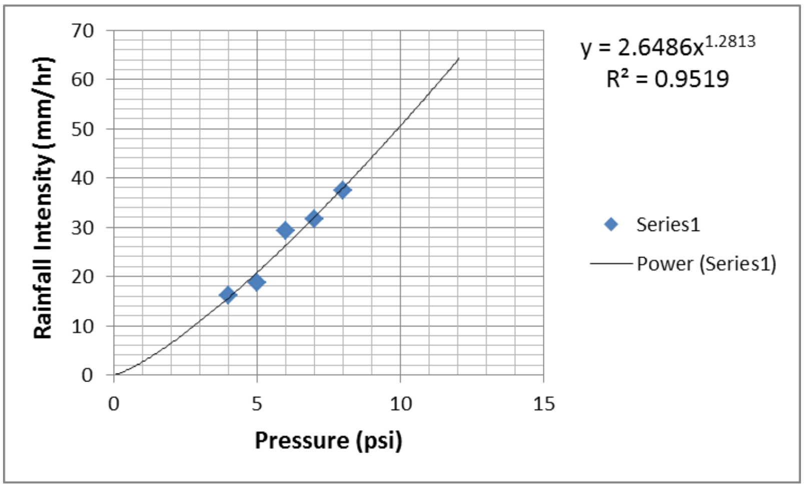

Figure 8. Calibration curve of pressure and rainfall intensity.

The distribution of uniformity of the rainfall on the entire test plot is about 78%. It is mean that 22% of the rainfall generated from the simulator is not uniform. This result shows that the rainfall simulator has good performance because the uniformity is more than 70%.

CONCLUSION AND RECOMMENDATION

This research concludes that the rainfall simulator is suitable to be used for simulating the response of the catchment area of paving blocks to the rainfall event in the form of runoff discharge. However, the uniformity of the rainfall need to be improved by using more data of observation so that the generated rainfall-runoff model can be more accurate.

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REFERENCES

Corona, Roberto, Tiffany Wilson, Leo Pio D'Adderio, Federico Porcu, Nicola Montaldo, John Albertson, 2013. On the Estimation of Surface Runoff Through a New Plot Scale Rainfall Simulator in Sardinia Italy, *Procedia Environmental Sciences* 19 (2013) 875 – 884, Elsevier

Grismer, M.E., U.C. Davis, 2012. Standards Vary In Studies Using Rainfall Simulators To Evaluate Erosion, *California Agriculture* 66(3):102-107. DOI: 10.3733/ca.v066n03p102. July-September 2012.

Guillette, Anne, 2010. Low Impact Development Technologies, LEED Accredited Professional, Low Impact Design Studio (formerly with the Low Impact Development Center), http://www.wbdg.org/resources/lidtech.php

Humphry, J. B., T. C. Daniel, D. R. Edwards, A. N. Sharpley, 2002. A Portable Rainfall Simulator For Plot–Scale Runoff Studies, *Applied Engineering in Agriculture* Vol. 18(2): 199–204, American Society of Agricultural Engineers ISSN 0883–8542.

Jones, J. 2001. Sustainable Urban Drainage Systems (SUDS), Presented on *CIWEM SUDS Symposium Part 2*, Midlands Engineering Centre, Austin Court, Birmingham

Joshi, Veena U and Devidas T. Tambe, 2010. Estimation Of Infiltration Rate, Run-Off And Sediment Yield Under Simulated Rainfall Experiments In Upper Pravara Basin, India: Effect Of Slope Angle And Grass-Cover, *Journal Earth Syst. Sci*. 119, No. 6, December 2010, pp. 763–773 © Indian Academy of Sciences.

Sangüesa, C., J. Arumí, R. Pizarro, O. Link, 2010. A Rainfall Simulator for the in situ Study of Superficial Runoff and Soil Erosion, *Chilean Journal of Agricultural Research* 70(1):178-182.

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