UTILIZATION OF SUPER ABSORBENT POLYMERS (SAP) IN EXTENSIVE GREEN ROOF ASWATER RETENTION IN URBAN AREA

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Abstract

A green roof is formed by waterproof substrate covered with vegetation. It is capable of absorbing water and adding hydrogels may increase its water absorption. The objective of this study is to utilize hydrogel in extensive green roof as an aid in water retention in urban areas. There are four green roof models: Panel 1 has 0% of hydrogels, Panel 2 has 0.40% of hydrogels, Panel 3 has 0.50% of hydrogels and Panel 4 has 0.60% of hydrogels. Each green roof model undergo series of test through the rain simulator with rain gauge at the center of the panel to determine the rainfall intensity. Other than the percentage of hydrogel;; rainfall intensity, duration of rain event and moisture content of the substrate before testing are the factors that affect the water retention in the green roof. This study shows that the green roof with hydrogel has greater water retention than the green roof without hydrogel. It is determined that the hydrogels can absorb approximately 330 times more than its own weight in a day and 37.048 seconds shows the most probable value of water run--off that may occur in the rain event based from the data collected in this study. It was concluded that the maximum value of water that the soil can absorb is entirely dependent on the time the water system was used. The result of the data analysis shows that each of the independent variable has a positive correlation to the dependent variable which is the volume of the water retained in the substrate.

Keywords: Green roof, Hydrogels, Rain Gauge, Rain Simulator, Water Retention

1.0 INTRODUCTION

Philippines is prone to natural calamities, and one of these calamities is flood. Flood is a major problem of many people in different parts of the Philippines. Given the fact that global warming is getting worse, typhoons are becoming more intense and the probability of heavy flooding increases. Tropical countries like Philippines have greater chances of having super typhoons that caused terrible flooding. Most of the areas cannot contain the amount of flood that the typhoon brings in a certain period of time. This leads to destruction and massive damage to infrastructures and nature, causing serious problems to people.

Flooding in urban areas continues to worsen every day. These areas lack space that hinder citizens from planting trees that can alleviate flooding. A green roof is capable of controlling and shutting down storm water runoff. Adding hydrogels in the soil may increase the water absorption.

Philippines is considering to build infrastructure with vertical or horizontal garden. Some of the examples of infrastructures with green roof in the Philippines are SM North and SM Aura. According to Morakinyo (2017), there are two types of green roof system which are the intensive and extensive type. An intensive green roof has a soil depth of more than 20 cm to 200 cm. Based on greenroof.com, the vegetation that is used in intensive green roof are plants that require large amount of soil. This type of green roof may require a constant maintenance and an irrigation system. An extensive green roof has a soil depth of less than 20 cm. It is more cost efficient and lightweight compare with the intensive green roof. Having a smaller kind of plant on it requires less maintenance and do not require an irrigation system.

Green roof has many benefits. It serves as a thermal insulator and it can also reduce the noise and air pollution in urban areas. The past research of Uhl and Schiedt (2008) states that for sustainable urban drainage systems (SUDS), green roofs is among the options because they act as storage units imitating the hydrological behavior of the upper soil layer. Green roofs are proven to reduce the rain runoff yearly also when the climate is changing. The runoff occasionally occurs with huge time delay and significant reduction in volume and peak flows. The ranged of the annual runoff coefficient is between 23% to 38%. Through summer the range of the annual runoff coefficient is 16%--31% and through winter 40%--60%. The retention effect has been dominated by the layer depth in contrast to the construction details and is affected by the hydraulic conductivity and humidity of the substrate. The drainage system lateral flow characteristics are also affected. A two layers' construction and a steep slope roofs tend to rises the runoff in negligible order. In addition, Breuning (2011) states that extensive green roofs will be effective in controlling isolated rainfall, while intensive green roof will be effective in controlling large storms. The usefulness of green roof during storm events depends on the properties of the growing media and thickness of the system.

An extensive green roof system is characterized of its vegetation, ranging from sedums to small grasses, herbs and flowering herbaceous plants, which need little maintenance and no permanent irrigation system. Extensive green roofs provide

attractive protection to the waterproof membrane and significantly reduce water run --off. When the green roof is completed, inspection once or twice per year shall be provided. The main purpose of an extensive green roof is storm water retention and delaying storm water run--off (Jörg Breuning, 2011). In addition, Yeung et al., (2014) says that extensive green roofs cost less and lightweight than intensive green roof which make it as often topic in scientific research. According to J.Y Lee et al., (2013), the rainfall intensity is inversely proportional to water retention because as the rainfall intensity increases, the water--retaining capacity decreases. The runoff efficiency in an extensive green roof ranged from 0 .44 to 0.52 compared to 0.9 for a concrete roof alone. They state that green roofs can be applied as a solution for the rainwater--harvesting tank and can be an impressive management to the storm water practice.
In the study of Yang (2013), the reformation of the soils with super absorbent polymers definitely increases the water uptake and use of water for plants growth. This study shows that adding 0.45% of super absorbent polymers give the best result in terms of increasing the water retention capability of the green roof compared to 0.15% and 0.30% of super absorbent polymer.

Natural and synthetic hydrogels are the two classifications of hydrogels. Natural hydrogels include collagen, fibrin, hyaluronic acid, matrigel, and derivatives of natural materials such as chitosan, alginate, and skill fibers (Yahia 2015). Hydrogels are widely present in everyday produ cts though their potential has not been fully explored yet. These materials already have a well--established role in contact lenses, hygiene products, and wound dressing markets but commercial hydrogel products in tissue engineering and drug delivery are still limited (Caló et al., 2014).

Vanwoert et al., (2005) says that greater amount of water was retained on platforms with 2% slope containing 4cm of media on both per rain occurring and for total rainfall than other platforms. An extensive green roof having a slope of 2%, gives a 78% of water retention efficiency from a 15 rainfall events (Volder et al., 2014).

2.0 METHODOLOGY

Research Design

This research has focused on the use of hydrogels as additive in an extensive green roof as an aid in water retention. The test results and empirical values that was gathered from several standard testing procedures will illustrate the effect of hydrogels to the engineering property of the soil, particularly to its permeability.

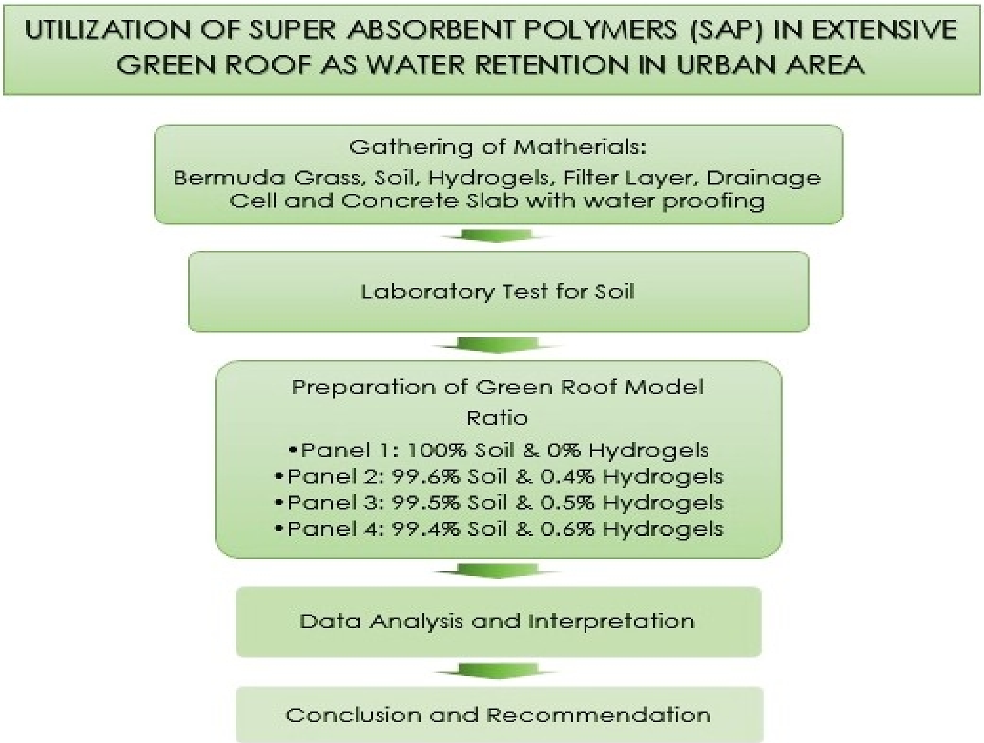

Figure 1: Research Framework

In Figure 1, the Bermuda grass and the soil were gathered from Ususan, Taguig while the drainage cell and filter layer were obtained in Romualdez, Mandaluyong. Hydrogels were obtained in Dongying City, Shandong Province, China. In this research, there are four green roof models: Panel 1 has 0% of hydrogels, Panel 2 has 0.4% hydrogels, Panel 3 has 0.5% hydrogels and Panel 4 has 0.6% hydrogels. Each green roof panels undergo series of test with the rain simulator that varies duration of test: 10 minutes, 20 minutes and 30 minutes, and in the same time rain gauge is set--up to determine the rainfall intensity of the rain simulator.

The data gathered from the rain simulation was analyzed through Multiple Linear Regression to determine the relativity of the data.

Extensive Green Roof Set--Up

The extensive green roof will be installed on a customize 4 roof slab with a dimension of 1 meter by 1 meter (Zhang 2014) and has a depth of 100 millimeters (Lee 2013). Each roof has a drain PVC pipe on the gutter with a diameter of 6 cm (Zhang 2014) and a basin to collect the run--off water.

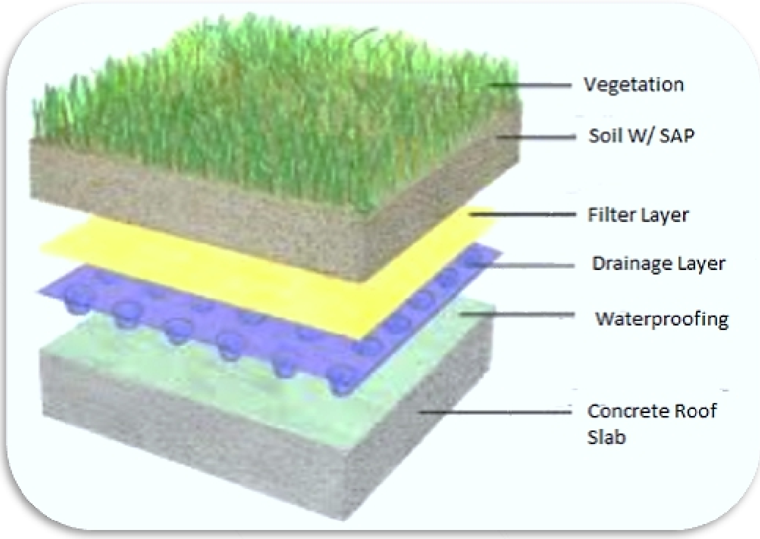

Figure 2: Layers of Green Roof

Figure 3 shows the layers of green roof which are the vegetation layer, growing medium layer, filter layer, drainage layer, and roof slab with water proofing. Bermuda grass will be the vegetation for its accessibility on local market and its ability to stand on being immerse and drought. The set--up has a 2% slope to maximize the delay run--off (Getter 2007). Adding 0.40%, 0.50%, and 0.60% of hydrogels in the growing media will be test in this research.

Testing

Figure 3 shows that the panels were tested by rainfall simulator that replicate the rainfall and the rainfall intensity record was comparable from the extreme value of rainfall intensity from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). Rainfall simulator was composed of bottles with holes at the bottom that was suspended and positioned 90 centimeters above the panels. Pump was used in order to have a uniform out--flow through--out the testing duration.

Figure 3: Actual Rain Simulation Test

In the study of Graceson (2013), she stated that the deck has a catching basin underneath that will collect the runoff in each deck. A separate basin also simultaneously collecting rain water to determine the intensity of the rain event. Rain gauge is installed at the center of the panels;; the depth of the collected rainfall is measured to identify the rainfall intensity of the simulation. It has a dimension of 28.5 cm capacity depth and 9.4 cm diameter.

Data Gathering Techniques

The researchers used two data gathering techniques in this study;; documentary analysis and laboratory experiments in accordance with the American Society of Testing and Materials (ASTM).

Documentary Analysis

Documentary analysis is the process of gathering information from different sources such as from public and private documents, online publications, thesis paper, journals, books and several other sources of the same nature. This technique was applied in this research to gather information about the effectiveness of our study of green roof as water retention by adding Superabsorbent Polymers (SAP).

Grain size Analysis

Testing methods for Grain Size analysis is in accordance with ASTM D422. In performing the grain size analysis of the soil, mechanical sieving is used, and the soil is passed through a stack of sieves. Sieve no. 4, 8, 10, 16, 30, 40, 50, 100, 200 and pan. The coarsest sieve is at the top of the stack, followed by increasingly finer sieves below. This information was then used to classify the soil in accordance with the Unified Soil Classification System (USCS).

Liquid and Plastic Limit Test

Testing Methods for Liquid and Plastic limit is in accordance with ASTM D4318. The liquid limit and plastic limit tests provide information regarding the effect of water content (ω) on the mechanical properties of soil. Specifically, the effects of water content on volume change and soil consistency are addressed.

Moisture Content

Testing methods for Moisture Content is in accordance with ASTM D2216. The test was performed to determine moisture content of the soil before the rainfall simulation test start which determine the soil's condition. Moisture content is typically expressed as a percentage using two significant figures (e.g. 16%, 41%, etc.). Moisture content can range from zero percent to one hundred percent, soil with zero percent of moisture content is classified as dry soil and soils with >0 percent of moisture content is known as moist soil. Even soils that appear to be "dry" possess some moisture. The mass of the moist soil was obtained and later the mass of dry soil was obtained after oven dried in 105 °C.

Specific Gravity

Testing methods for Specific Gravity of soil is in accordance with ASTM D854. The result was used to classify the soil. Specific gravity is typically expressed using three significant figures. For sands, Gs ranges from 2.65--2.70 because this is the specific gravity of quartz. Since the mineralogy of clay is more variable, Gs for clay is more variable, and is often assumed to be somewhere between 2.70 and 2.80 depending on mineralogy. Non--engineering soil often has a <2 of Specific Gravity.

Falling Head

The falling head permeability test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of the tested soil. The test can be carried out in a Falling Head permeability cell or in an odometer cell. Falling head permeability normally tested at fine soil aggregates.

Mixture

In doing green roof, the main material is soil but in this study hydrogel were added to help the soil absorbed higher volume of water. The soil was separated into two groups: the control sample which was the raw soil and then the other group contained varying amount of hydrogel. Table 1 shows the ratio of soil formulation. The first sample was the controlled specimen, as there will be no variable addition to the soil mass. The other sample contains hydrogels mixture with 0.40%, 0.50%, and 0.60% of the soil's total weight. The test was conducted to determine the volume of water absorption in the soil.

Table 1: Ratio of Soil Formulation

Panel Number	Soil Medium	Added Hydrogel (%)
Panel 1	100 %	0
Panel 2	99.6 %	0.40 %
Panel 3	99.5 %	0.50 %
Panel 4	99.4 %	0.60 %

Hydrogels Water Capacity

A sample (5 g) of the SAP was immersed in 2 litters water at room temperature for 24 hours and drain the excess water using geotextile. Maximum water capacity was determined by weighing the swollen gel by draining the excess water from the mixture. The water capacity was determined by:

$$\text{Water Capacity} = M_1 - M_2$$

Water Capacity is expressed in grams of water absorbed;; M_1 and M_2 denote the weight of the 2 liters of water with hydrogels and the weight of the drained gel.

Statistical Analysis

This study will use Multiple Linear Regression, the variables that are going to be observe and/or study are water retained in the growing media, time of first run--off, hydrogel content and also the time of test.

The dependent variable is the water retained in the growing media and the remaining variables are considered independent variable. These variables will go through specific statistical to determine relationships within the variables.

3.0 RESULTS AND DISCUSSION

In this chapter, the data and results gathered from the tests performed will be discussed and presented. The results were shown in tables, graphs and figures. These were the basis for further analysis, understanding and conclusions as well as recommendations regarding the subject.

Unified Soil Classification System (USCS) for Soil

Table 2: Sieve Analysis

Grain Size Distribution	Percentage
Gravel	0.443
Sand	77.872
Fines (Silt/Clay)	21.685

Table 2 shows the percentage retained for each soil property. The following soil property were gravel, sand and fines(silt/clay) with Sieve numbers 4(4.750mm opening), 8--100(2.360--0.150 mm opening) and 200(0.075mm opening).

Table 3: Physical and Index Properties

PROPERTY	
Moisture Content ➢ 10 minutes ➢ 20 minutes ➢ 30 minutes	 36.52 % 35.9 % 15.19 %
Specific Gravity	2.637
PARTICLE SIZE ANALYSIS	
Percent passing the sieve no. 200	21.685 %
Percent retained on the sieve no. 200	19.992 %
ATTERBERG LIMITS	
Liquid Limit	30.01 %
Plastic Limit	22.58 %
Plasticity Index	7.43 %
Plasticity Index (A line)	7.31 %

Table 3 shows the physical and index properties of soil control sample which serves as a basis in order to determine the classification of the soil. (See Appendix A tabulated data and results). The result showed the percentage passing the no. 200 sieve, percentage retained on no.200 sieve, liquid limit, plastic limit, plasticity index, and plasticity index (A line) with the corresponding values of 21.685 %, 19.992 %, 30.01 %, 22.58 %, 7.43 % and 7.31 %.

The soil had more than half of material larger than #200 sieve size and classified as coarse grained soil, with more than half of coarse fraction is smaller than #4 sieve size it was categorized as sands with fines. Also with plasticity index greater than 7 and with the equation of plot "A" line which is 73% of liquid limit minus 20, the Unified Soil Classification System (USCS) symbol is SC. And lastly, with less than 15% retained on sieve no. 4 classified by Unified Soil Classification System (USCS) name clayey sand.

Water Absorbent Capacity

Table 4: Optimum Absorption Capacity of Hydrogels (1 day)

Trial	1	2	3
Percentage of Water Absorb by the hydrogels (%)	33720	32720	32400
Average(%)	32947		

Table 4 shows the average water absorb of the 5 grams of hydrogels in a day. The hydrogels samples with a weight of 5 grams were soaked in a two--liter of water in a container for 24 hours to let it absorb water. After 24 hours, the containers were drained and filtered with geotextile cloth. The data shows that a 5 grams of hydrogels can absorb 32947 percent of water after a day of being soaked in a water.

Graphical Representation of data
Figure 4 shows the rate of variables, that the time of run--off is faster without hydrogels in the growing media. It only shows the ability of hydrogels to absorb and hold water in a certain period of time. The relationship of water retained in the growing media and the hydrogel content is directly proportional given the situation that the soil was laid under the sun at least one day before conducting another test.

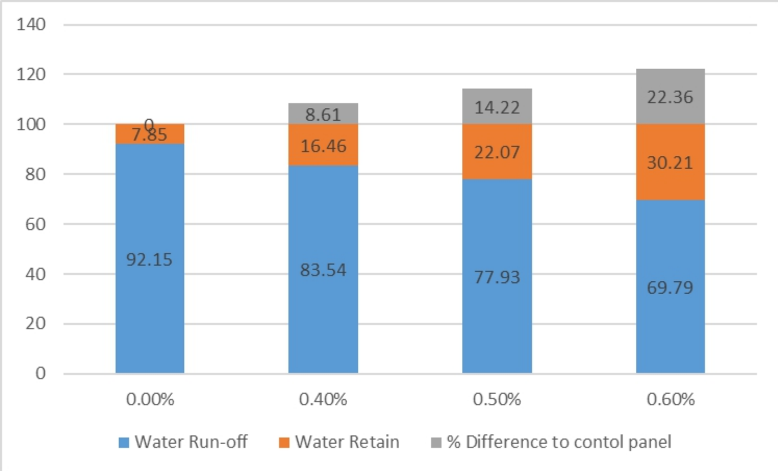

Figure 4: Results of 10--minute Test

Figure 5 shows the results of 20-- minute test water retention. The water retained in the panel with 0.60% hydrogels declines because the initial moisture condition of the growing media at 0.60% was significantly greater than the other panels. It shows that the moisture content is inversely proportional to water retention of the green roof and has a great effect in the water retention of the green roof.

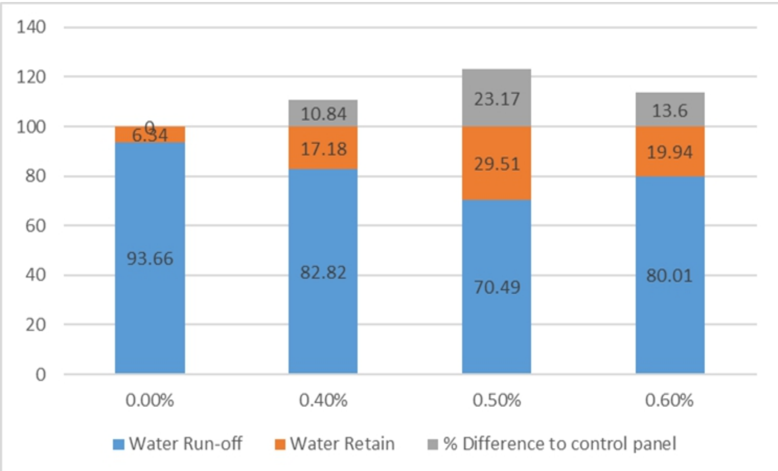

Figure 5: Results of 20--minute Test

Figure 6 shows the results of 30--minute test water retention of 0%, 0.40%, 0.50% and 0.60%. Same as the Figure 3.3.1, the greater amount of hydrogels is incorporated in the growing media the more volume of water retains.

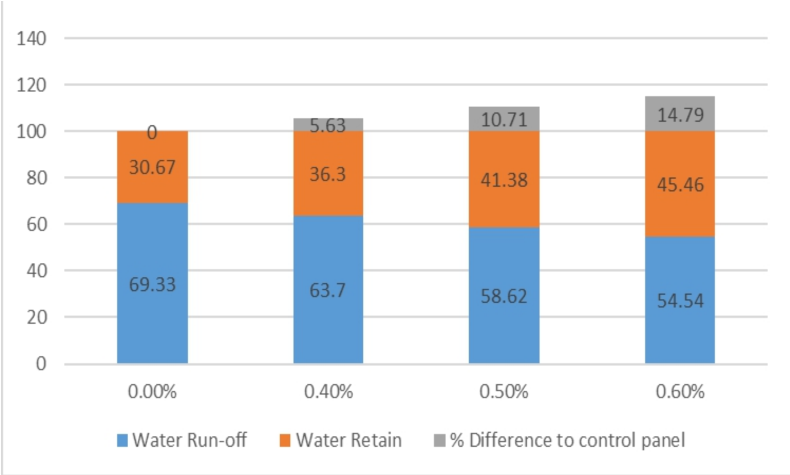

Figure 6: Results of 30--minute Test

Figure 7 shows the percent increase run --off time of the panels with hydrogels compare to the control panel. The results were supported by the study of Stovin (2009) that green roof can delay the run--off and the soil store water until it reaches its reservoir stage. Adding hydrogels increases the water store in the green roof and delay the run--off more than the control panel shown in the result.

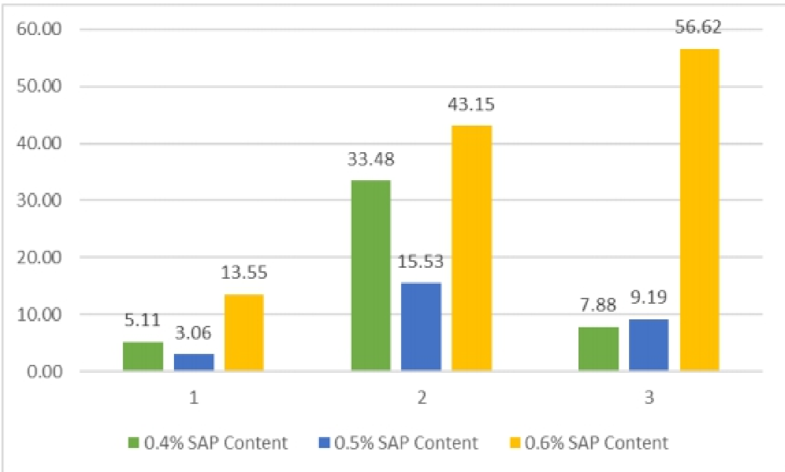

Figure 7: Percent increase of run--off with respect to Control Panel

In comparison with the controlled panel, the panels with hydrogels show a greater amount of water retained and significant difference in water run--off in the green roof. As the amount of hydrogels increases the difference in water retention and water run--off also increases.

Statistical treatment of Data

Figure 8 shows the best fit line from regression analysis of SAP content and water retained in the green roof. The highest r value is 0.843 with this Pearson Correlation the researchers can say that these variables have positive correlation and very strong in association. This 'r' value wants to show that if there is going to be any movement in the percentage of sap it will only have a large effect to our Dependent variable which is the "Water Retained in Media".

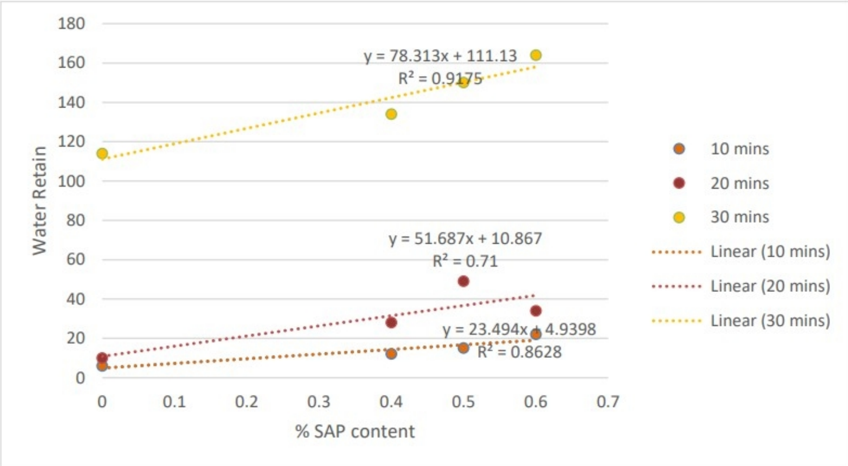

Figure 8: Best Fit Line from Regression Analysis of X2 and Y

Figure 9 shows the best fit line from regression analysis of run--off time and water retained in the green roof. The R value is equal to 0.982 which means that the "time of first runoff" very strong association with the "water retained in media". This result shows that the longer it takes before the runoffs happen, the more volume of water retained in the growing media. For this analysis, the researchers use the time of first run off in minutes just to be in the same unit with the duration of time of test.

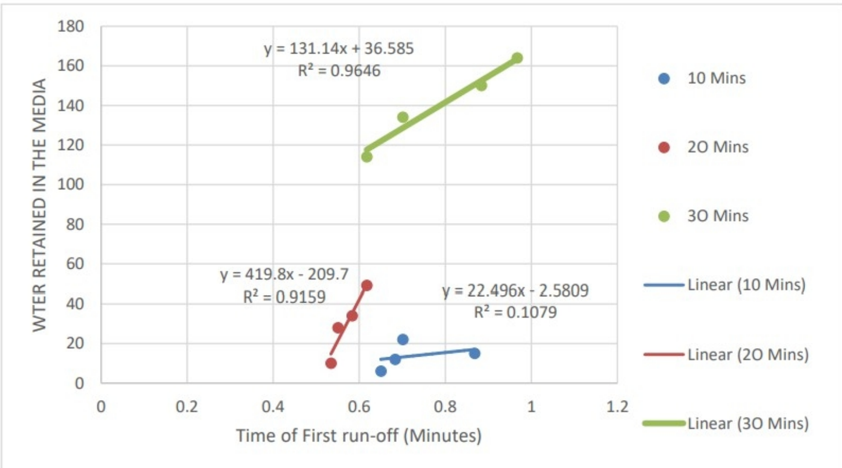

Figure 9: Best Fit Line from Regression Analysis of X1 and Y

Figure 10 shows the best fit line from regression analysis of time of test and water retained in the green roof. With Pearson Correlation Value of 0.9641, this Pearson 'r' implies that the two variables have very strong association with each other. This result implies that the longer the time of precipitation, the more water retained in the media, it will greatly affect the Dependent variable because that is the source of the water, as long as the water pours in and the media doesn't reach its capacity, the water will still accumulate in the media.

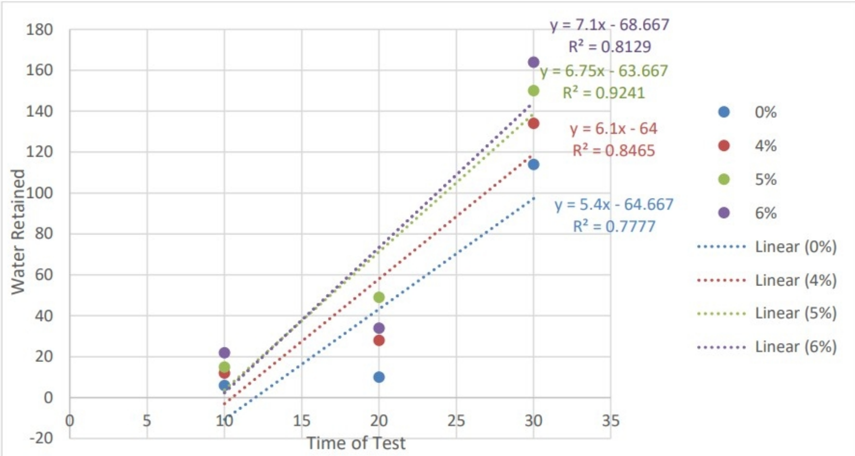

Figure 10: Best Fit Line from Regression Analysis of X3 and Y

4.0 CONCLUSION

This study confirmed that Hydrogels as water retention agent was proven to be effective in reducing floods in urban city. Its ability to absorb 330 times its own weight in a day is commendable. The 37.048 seconds shows the most probable value of water run--off that may occur in the rain event based from the data collected. Initial moisture content of the green roof, duration of the rain event and its intensity are the factors that affects the water run--off in the green roof based from the results. The set up with 0.60% of hydrogels which is the highest was observed to gives the largest value of 45.46% of water retention. The result of data analysis shows that each of the independent variable has a positive correlation to the dependent variable which is the volume of water retained in the growing media (Liters). Using Multilinear regression, the researchers come up with equation that will help predict the output with respect to the changes to the independent variables.

5.0 RECOMMENDATION

The building and setting up of green roof is very important to have accurate data. Leakages in sides of slab can be prevented by water sealant or epoxy. Pump must be good enough to last throughout the testing. High walls can prevent water from overflowing in case the soil has low permeability. Instead of using concrete as slab, other type of materials like glass or metal roofing can be used but make sure it is strong enough to carry the loads. Relative studies can be done using different amount of hydrogels, different soil type, different soil thickness or different type of vegetation in green roof etc.

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