OPTIMIZING RAINWATER HARVESTING SYSTEM FOR HOTEL DESIGN AT HUMID TROPICAL CLIMATE

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Abstract

Rainwater harvesting is one of strategies to supply of water demand for achieving sustainability in hotels. Optimization of rainwater harvesting on building affected by rainwater harvesting system such as: catchment system, storage system, and distribution system. There are some design problems in the practice of rainwater harvesting for hotel, that's include to: integrated between rainwater harvesting system (surface area for catchment system and storage system, and distribution system) and aesthetic function for optimation of rainwater harvesting process and building function. Therefore, the aim of this study is to generated some rainwater harvesting system models for hotel design that can be optimizing rainwater harvesting process and aesthetic function. This study was conducted by some models that integrated catchment system, storage system, and distribution sistem for hotel design. The results of this study is building model of hotel design that can be optimizing rainwater harvesting process and aesthetic function.

Keyword: Rainwater Harvesting, Building Models, Hotel

1. INTRODUCTION

Hotel is one of commercial buildings that high water demand to support their activities especially on the three star hotels upward (Ridwan, 2014) and aesthetic function. Today, the water conservation and water saving to achieving sustainability can be done by applying the rainwater harvesting concept in buildings. Rainwater harvesting is the concept of rainwater harvesting for water demand supply in building (Worm and Hattum, 2006).

Todays, the application of rainwater havesting concept on the building became integral part with water treatment management to achieve sustainability. It was that the application of rainwater harvesting in buildings can saving the cost and conserving of water (Ward dkk, 2012).

The application of rainwater harvesting as water conservation efforts in building was related to rainfall in some area. Rainfall is one of essential factor of rainwater harvesting concept (UNEP,

2001 dalam Yulistyorini, 2011). It was that the rainfall will impact on the rainwater volume that can be harvested by rainwater harvesting system in the building (Sundaravadivel dkk, 2001). Therefore, the fundamental problems in the application of rainwater harvesting concept on building are surface area for catchment system and storage system and fast distribution system to produce the largest water volume.

According to the description above, the design problems of application of rainwater harvesting for hotel design is integrated between rainwater harvesting concept and aesthetic function. Therefore, according to the design problem above, the ain of this study is to generated some building models of hotel design that can be optimizing rainwater harvesting process and aesthetic function.

2. LITERATURE REVIEW

2.1 Rainwater Harvesting

Rainwater harvesting is harvesting of rainwater concept that aimed to water demand supply in the household, agricultural, and environmental management that consist of catchment system, storage system, and distribution system (Worm and Hattum, 2006). Rainwater harvesting is the process of collecting rainwater from potential surface such as roofs to supply of high water demand for in toilets, laundry, landscaping, drinking, or cooking (Accetturo et al, 2012).

Rainwater harvesting also defined as the concept of rainwater harvesting by collecting and storing rainwater from the roof and the ground surface to be used as source of clean water. Reuse of rainwater is to reduce the problems of clean water and ground water supplies, especially in urban areas (Yulistyorini, 2011). Therefore, rainfall becomes an important factor in the application of rainwater harvesting concept (UNEP, 2001 in Yulistyorini, 2011).

Rainfall in some place would affected on the volume of rainwater that can be captured by rainwater harvesting system in buildings (Sundaravadivel et al, 2001). Therefore, in the application of rainwater harvesting system required the large surface area of rainwater catchment system and the fast and stable distribution system to produced large volumes of rainwater.

2.2 Water Catchment System

Rainwater catchment system is the surface area that directly affected by rainwater and divert rainwater into storage systems to reduce contamination of pollutants. Rainwater catchment system refers to the surface area that has been prepared for collecting rainwater (Worm and Hattum, 2006). The rainwater catchment system can use the roof, the design of the building, and landscaping (Sundaravadivel et al, 2001).

Rainwater can be collected from various forms of the roof then collected in the gutter to be distributed into the rainwater storage system through out the pipes in the distribution system (Water Aid, 2013). Rainwater catchment model especially the roof serves to accelerate the rainwater flows (Liaw and Tsai, 2004). The following is some various form of roof on the building:

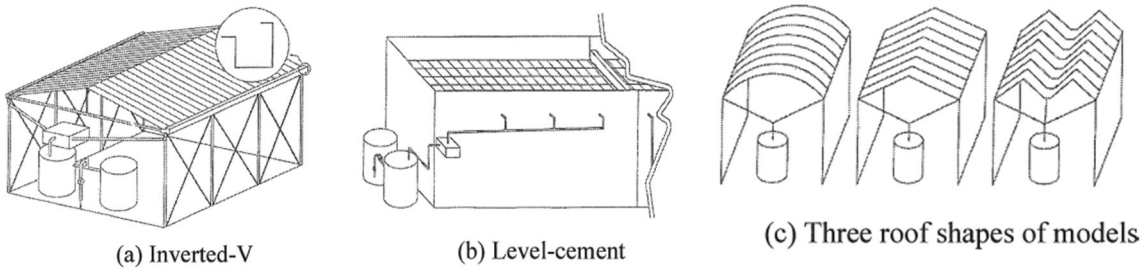


Figure 2. 1 Some Various Form of Roof (Liaw and Tsai, 2004)

According to the model form of roof above, the coefficient of run-off rainwater on the roof of the model include to: inverted-V of 0.84, Level-cement amounted to 0.81, Parabolic amounted to 0.81, and saw tooth of 0.83 (Liaw and Tsai, 2004). The run-off of water was also influenced by the coefficient of the materials used as roofing (Mathur et al, 2005). Selection of the material for catchment system that smooth and impermeable can reduce the contamination of rainwater that has been captured (Daily and Wilkins, 2012). The following is the coefficient some roofing materials:

Type of Catchment	Coefficient
Roof Catchments	
❖ Tiles	0.8 - 0.9
❖ Corrugated metal sheets	0.7 - 0.9
Ground Surface Coverings	
❖ Concrete	0.6 - 0.8
❖ Brick pavement	0.5 - 0.6
Untreated Ground Catchments	
❖ Soil on slopes less than 10 per cent	0.0 - 0.3
❖ Rocky natural catchments	0.2 - 0.5
❖ Green area	0.05 - 0.10

Figure 2. 2 Run-off Coeffient of Materials (Mathur et al, 2005)

According to the description above, the application of rainwater catchment system requires a large surface area to capture rainwater, form, and roofing material selection to optimize rainwater harvesting process. The amount of surface area of rainwater catchment system will affect to the total volume of rainwater that is collected by the rainwater cathment system so that the potential of

volume rainwater can be captured by rainwater catchment system can be determined by calculating using the formula:

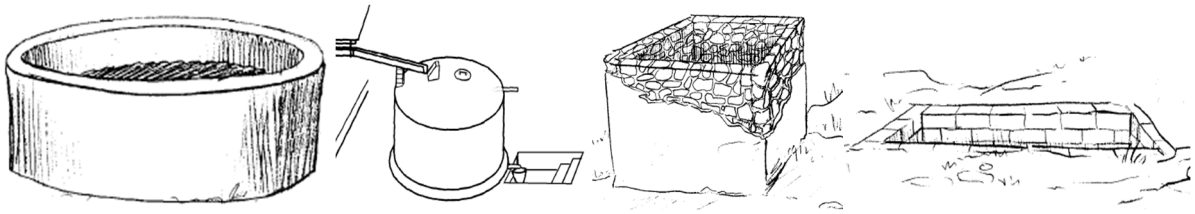
Water harvesting potential = Rainfall (mm) x Catchment Area x Runoff Coeffient

According to the formula above, it can be seen that the effect in the rainwater catchment is the intensity of rainfall, the catchment area, and the runoff coefficient of materials used (Mathur et al, 2005).

2.3 Storage System

Storage system for rainwater harvesting refers to the arrangement made for collecting and storing rainwater that has been caught by catchment system (Sundaravadivel dkk, 2001). The application of storage system on building could be designed to be one part of building or a separate unit with its own building. The materials of storage system on building can uses concrete materials, ferrocement, plastic, metal, fiberglass, polyethylene, and stainless steel (Mathur et al, 2005).

Rainwater storage system is divided into storage tanks and cistern. Storage tank is storage systems that are on the surface, while the cistern is a storage system located in the ground or sub-surface (Worm and Hattum, 2006). The following is some various form of storage tanks and cistern for rainwater storage system:



Gambar 2. 4 *Storage Tank* dan *Cistern* (Worm dan Hattum, 2006)

The amount of rainwater storage system on the building was calculated based on the water supply to support the activities in it and the period of the dry season (Worm and Hattum, 2006). Therefore, the calculation of the amount of storage area for storage system can be counted by using the following formula:

Required Storage Capacity= Demand x Dry Period

Demand= Water Use x Household Members x 365

2.4 Distribution System

Distribution system refers to the a system that distributes rainwater from catchment system to the storage system and filtration system then flowed to part of bulding that water supply to support their activities. Distribution system consists to gutter and downpipe (Worm and Hattum, 2006).

Gutter on this system refers to system that drain and collecting of rainwater was captured by catchment system to reduce water loses when the movement of rainwater from the catchment system to the storage system and the filtration system. Downpipe and pipe on this system refers to the distribution of rainwater from the gutter to the storage system and filtration system Distribution system refers to the a system that distributes rainwater from catchment system to the storage system and filtration system then flowed to part of bulding that water supply to support their activities. Distribution system consists to gutter and downpipe (Worm and Hattum, 2006).

The distribution of rainwater harvesting to use these pipes using Earth's gravity and water pump (Sundaravadivel, 2001). Therefore, the basic principles of the installation of pipes in the distribution system is water flow that use gravity to distribute water into water storage system and water treatment system so the pipe installation can be done with vertical and tilted to help water flow be fast.

2.5 Water Demand for Hotel

Hotel is one of the commercial buildings that required a high water demand to support their activities which include to: swimming pool, toilet, laundry, kitchen, landscape, hydrant, and others. The quantity of water demand in hotels was affected by guests, employees, and facilities in hotels. On three star hotels upward needed more higher of water demand than the others hotel type (Ridwan, 2014). It was in three star hotels upward has facilities provided more than the others.

According to the New Mexico Office of the State Engineer, American Water Works Association (AWWA), AWWA Research Foundation, and the East Bay Municipal Utility District in EPA (2012), the percentage of water use on the hotel building is indicated by:

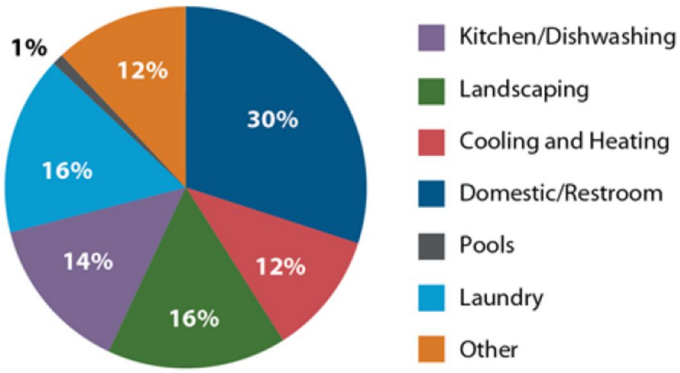


Figure 2. 3 End Uses of Water In Hotels (EPA,2012)

3. METHODOLOGY

3.1 Exploration of Models

The exploration of rainwater system on hotel design uses any criteria, they are: rainwater harvesting concepts to optimizing rainwater harvesting process and aesthetic function. The exploration is done by reference of princliples of catchment system, storage system, and distributon system wich has been elaborated in section 2.3, 2.4, and 2.5. The exploration of this models have same site in humid tropical climate especially in Malang City. In addition, the material for catchment system used metal and concrete and storage system used acrilic and concrete.

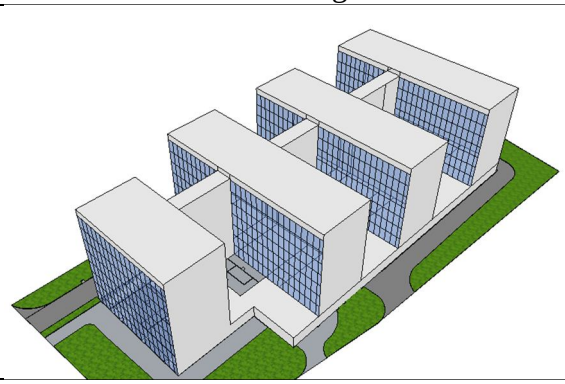
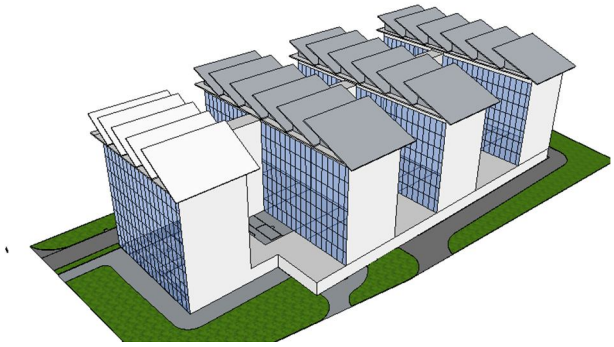
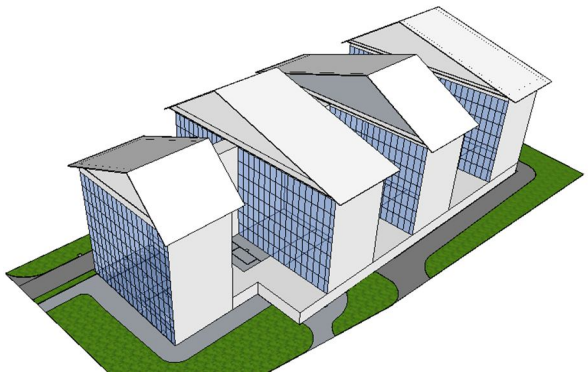
3.2 Evaluation

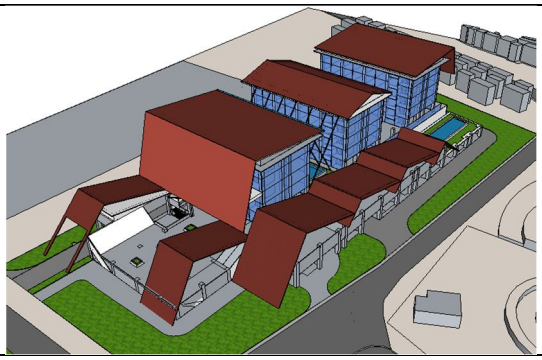
The scenario of evaluation the resuls of exploration hotels design is done by calculating the surface area for catchment system and storage system then comparing some alternative to look the comparation of water potential that has been captured. So according to the evaluation results will be known the hotel design that optimizing rainwater harvesting process and aesthetic function.

4. ANALYSIS

The exploration of building forms serves to optimize the rainwater harvesting process. The surface area for catchment system and storage system affected on the water volume that was captured. The largest the surface area, the greater the volume of water that was captured. Therefore, the aim of the exploration of building forms is to generated some building forms that optimizing rainwater harvesting process. The following is some alternative of building form models that includes to:

Tabel 4. 1 Alternative of Building Form Models

No	Alternative of Building Form Models	Specification
1		In the first alternative of models was used by concrete material for roof and was the total of surface area is 4140m². The storage system on this model located on ground floor with size 8x6x3m
2		In the second alternative of model, building roof consists to catchment systems and storage systems. Catchment system located in the side that's not shaded by overlapping of roof, while storage system located on the side shaded by overlapping of roof. The material used for the cathment system are concrete and metal, while the storage system are concrete. Therefore, the total area of catchment system: for concrete surface area are 270 m² and metal surface area are 4765.9 m². While the total area of storage system are 1529m² and storage system located on the ground floor with size 8x6x3m
3		In the third alternative of models was used combination material by the concrete and metal materials. The metal material on the sloping roof and the concrete material on the connecting building block. The total of the surface area of the concrete is 270m² and the sloping roof is 5082m². The storage system on this model located on ground floor with size 8x6x3m

4		In the fourth alternative model, the material used for catchment system are metal and concrete. The total area of catchment system: for concrete surface area are: 250m² and for metal surface area are 5516m². While the total area of storage system: for storage system on the wall 1228m² (indicated with blue colour) and for storage system on the ground floor with size 8x6x3m
5		In the fifth alternative of model, the material used for catchment system are metal with a total surface area: 5751m². The storage system on this model located on ground floor with size 8x6x3m

According to the table above it can be seen that the total of surface area of catchment on the alternative model 1 is 4140m²; alternative model 2 that the concrete roof is 270m² and the metal roofs is 4765.9 m²; alternative model 3 that the concrete roof is 270 m² and the metal roofs is 5082m²; alternative model 4 that the concrete roofs is 250 m² and the metal roofs is 5516 m²; and alternative model 5 that the metal roofs is 5751 m²;. Therefore, the potential of rainwater to be captured by the five alternative models of rainwater catchment system above is as following:

Table 4. 1 Water Harvesting Potential

No	Alternative of Models	**Water harvesting potential = Rainfall (mm) x Catchment Area x Runoff Coeffient** *Rainfall in this calculation refers to the rainfall occurs in humid tropical climate especially Malang City*					
		Rainfall		Catchment Area	Run-off	Water Harvesting Potensial	
		min	max			min	max
		138.78	193.47				
1	**Alternative Model 1**			4140	0.7	**402184. 44**	**560676.06**
2	**Alternative Model 2**						
	Concrete roofing			270	0.7	26229.42	36565.83
	Metal roofing			4765.9	0.8	529129.28	737646.93
	Total					**555358.70**	**774212.76**
3	**Alternative Model 3**						
	Concrete roofing			270	0.7	26229.42	36565. 83
	Metal roofing			5082	0.8	564223.97	786571.63
	Total					**590453.39**	**823137.46**
4	**Alternative Model 4**						
	Concrete roofing			250	0.7	24286.50	33857.25
	Metal roofing			5516	0.8	612408.38	853744.41
	Total					**636694.88**	**887601.66**
5	**Alternative Model 5**						
	Concrete roofing			0	0.7	0	0
	Metal roofing			5751	0.8	638499.02	890116.77
	Total					**638499.02**	**890116.77**

According to the Table 4.1 and Table 4.2, it can be concluded that the fifth alternative of model is more optimizing of rainwater cathment model than others and the second alternative of model is more optimizing of rainwater storage model than others with storage system on roof and ground floor.

5. CONCLUSION

Optimization of rainwater harvesting process can be done by expanding of the surface area of catchment system and storage system will affect to the forms and compotition of building. Therefore, optimizing rainwater harvesting process on the hotel design can be reached with exploration of the forms and the composition of the building to optimize rainwater harvesting system and embody aesthetic function

6. REFERENCES

Accetturo, Anitra dkk. (2012), *Rainwater Harvesting-Guidance Toward a Sustainable Water Future*, City of Bellingham-Public Works Department: Bellingham.

Daily, Cado, dan Wilkins, Cyndi. (2012), "Basics Component of A Rainwater Storage System", *Cooperative Extension: College of Agriculture and Life Sciences, The University of Arizona*, vol, Oktober, AZ1565.

Internet EPA, (2012), Saving Water in Hotels, www.epa.gov/watersense/ commercial. Akses 20 Februari 2015.

Internet, Water Aid. (2013), Rainwater harvesting,www.wateraid.org/technologies. Akses 20 Februari 2015

Liaw, Chao-Hsien, dan Tsai, Yao-Lung. (2004), "Optimum Storage Volume of Rooftop Rain Water Harvesting System for Domestic Use", *Journal of The American Water Resources Association*, Agust, hal. 901-912.

Mathur, P.S. dkk. (2005), *Rainwater Harvesting and Utilisation Book 2,*UN-HABITAT: Nairobi, Kenya.

Ridwan, Andry. (2014), *Studi Analisis Kebutuhan Air Sektor Nondomestik Kategori Hotel di Wilayah Kecamatan Ujung Pandang,* Tugas Akhir Sarjana, Univesitas Hasanuddin, Makassar.

Sundaravadivel, M. (2001), *Concepts and Practices for Rainwater Harvesting,* Central Pollut ion Control Board: Delhi-India.

Ward, dkk. (2012),"Performance of Large Building Rainwater Harvesting System", *Elsivier: Water Research* 46, hal. 5127-5134.

Worm, Janette dan Hattum, Tim Van. (2006), *Rainwater Harvesting for Domestic Use*, Agromisa Foundation and CTA: Wageningen, The Netherlands.

Yulistyorini, Anie. (2011), " Pemanenan Air Hujan sebagai Alternatif Pengelolaan Sumber Daya Air di Perkotaan", *Teknologi dan Kejuruan*, Vol. 34, No. 1, hal. 105-114.