THE SUSTAINABLE ENERGY-SAVINGS SKYLIGHT IN SURABAYA-INDONESIA

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ABSTRACT

In the past ten years, there have been intense developments in the application of energy savings in buildings and high technology glass invented mainly for architectural façades and skylights in all over the regions of the world. The complexity of skylight use in buildings for obtaining day lighting is always crucial related to energy savings domain with the climatic nature in every region of the world, specifically in the tropical zone of Surabaya city of Indonesia. This paper is written mainly to the consideration of the world energy crisis and the green architecture domain. Another crucial factor is the sustainability of the man-made skylighting-atrium buildings which can also result in energy-savings in Indonesia. The sustainable energy savings dripped-water-skylight is the most suitable skylight installed in Surabaya's climate not only for optimizing the direct sunlight and daylight in a room but it is also aimed to reduce the direct and global solar radiation that has impacted on horizontal or slope skylights in every direction. Besides, the sustainable dripped-water-skylight will decrease dramatically the temperature of the skylight structures and louvers that will affect directly to the need of energy cooling in buildings—cooling load. The use of dripped-water on the sustainable energy-savings skylight is defined as the water friendly architecture because the water has important functions for cooling applications that will lead to save energies. First, series of sloping louvers on the dripped-water-skylight roof block the direct solar radiation to which will lead to the decreasing of the cooling load energy. Second, aluminum sloping louvers conduct as heat exchanger to reduce solar heat radiation from the skylight roof. Third, the dripping water over sloping aluminum louvers will act as cooling tower units for saving energy equipment. Lastly, series of the solar tubes installed over the skylight will get passively hot water for saving hot water energy. Obviously, the sustainability of the dripped-water-skylight roof in terms of energy-savings for obtaining daylight, minimizing cooling loads, acting as cooling tower units, and gaining hot water, could be achieved by simply installing the dripped-water-skylight roof in all buildings in Surabaya.

KEYWORDS

Sustainable skylight, energy-savings

INTRODUCTION

Climatic Condition

The city of Surabaya-Indonesia is sited closer to the equator. The latitude is 7^o 17'-21' to the South and the longitude is 112^o 47' to the West. The hot humid dry season starts from mid May to mid December. While, the wet or rainy season will usually be approximately from mid December to mid May. The percentages of sun-shine duration are still around 60% to 70% during the rainy seasons, and reach 80% to 95% during the dry seasons. These phenomena indicate good strategies for applying both

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daylighting and solar applications in buildings for all year round. Table 1 shows the percentages of sun-shine duration and temperature during the year of 2005 in two weather stations in town--Perak1 is on the Northern side of the weather station and Juanda is on the Southern side of Surabaya city boundary (air port place). The average maximum temperature is very high between 34°C to 35.2°C yearly, even during the rainy days. The temperature can reach 35°C.

Table 1 Monthly Temperature and Sun-shine Duration Year of 2005

	PERAK 1			JUANDA		
	Temperature (oC)		Sun-shine	Temperature (oC)		Sun-shine
	Max.	Min.	(%)	Max.	Min.	(%)
January	35	24	82	34.8	22.3	45
February	34.6	23.5	70	34.6	21	67.5
March	35.3	23.4	72	34.6	22.7	64.5
April	34.6	24	82	33.1	22.3	69.9
May	35	23.5	86	32.5	22	88.1
June	34.8	24	86	31.8	23.2	77.3
July	34	21.4	86	32.8	19.8	85.2
August	38	21	95	33.2	20.2	95.7
Sept.	36	23	93	34.5	21	93.8
Oct.	37.4	24	74	34.9	21.6	75.9
Nov.	37.4	24.2	71	35	20.1	77.9
Dec.	33.8	23.2	24	34.7	22.2	42.8
Average	**35.2**	**23.3**	**77**	**34**	**21.5**	**41.6**

Solar Radiation

The Global solar radiation on horizontal surface is arranging from almost 4,000 W/m^2 to 4,400 W/m^2 for the period of rainy seasons. The horizontal solar radiations are even higher throughout the dry seasons to over 6,000 W/m^2 in the year of 2006. These phenomena imply that any opening on horizontal surfaces will suffer huge amount of global solar radiation for the period of days, months, and years. Figure 1 demonstrates the 2006 of horizontal global solar radiation, and it has the yearly average solar radiation of 5,052 W/m^2.

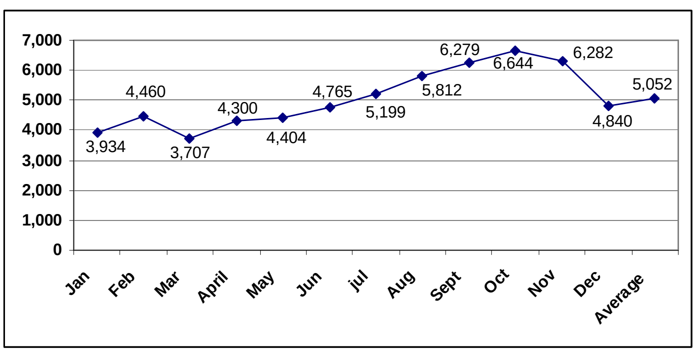

Figure 1 Monthly Horizontal Global Solar Radiation year of 2006 (W/m^2)

Problematic Design in Tropical Climate

The glass, is one of rapid development technology building materials, has been used for century and even beyond that manner on its climatic-domain. Many postmodern buildings have been built recently in Surabaya, and almost all of them have installed skylights which are covered with polycarbonate sheets or clear tempered glasses. Figure 2 displays one of the shopping malls built in the center town of Surabaya and it has slope-skylight covered with 15 mm tick of clear tempered glass. The dimension of the skylight opening is 36 meters length and 9.6 meters width. The area of skylight is 345 m^2, and the skylight will receive direct sunlight starting from 9 am to 3 pm (7 hours having global solar radiation intently). This case study data will be used for simulating the total energy savings annually later on.

Figure 2 Postmodern Shopping Mall Equipped with Slope Skylight in Surabaya

LITERATURE REVIEW

Skylighting design as defined by Hastings (1994) is either translucent or clear horizontal and inclined cover glasses on top of building in the subtropical zone; it could save 26 % to 30% of energy needed in the building. Monitor skylight are glazed in two directions vertically with a total glazing of about 13% of the floor area in accordance with saving energy domain in tropical zones.

One of advanced day-lighting projects conducted by a group my student (2006) is showing step-down louvers monitor system to bring daylight onto interior spaces. The monitor system is merely series of steps-down louvers for reflecting sunlight onto the space (without watering agent). The project has been demonstrated good distribution of daylight evenly in the tropical climate zone.

METHOD OF EXPERIMENT

The Objectives

- To investigate how much are the amount of global solar radiation passed through the dripped-water pyramid-skylight?
- To find out how many watts of cooling load per square meters are to be saved on behalf of the sustainable energy-savings designed of dripped-water pyramid-skylight?
- To observe how important the dripped-water over skylight louvers in lowering the temperature caused by the direct sun-heat solar radiation?
- To find out what is the temperature of the mounted solar water heater unit?
- To propose the possibility of the dripped-water pyramid-skylight which acts as water cooling tower units?

The Concepts

The most important concept for this project is the shape of the skylight itself—pyramid-skylight (avoiding horizontal skylight due to high intensity of solar radiation on horizontal surface; see figure 1). Whilst, the pyramid-skylight chosen with highly reflective slope louvers on both sides bouncing back the direct sunlight onto the room, all inclined louvers are also acting as shading devices to minimize the impact of global solar radiations which will cause the rising of the indoor cooling load. The first part of the concept such as shading the direct solar heat sun radiation, bouncing the sunlight, cooling heated skylight-structure (louvers), and getting hot water from the solar water heater panel as well as re-circulating and re-cooling the water through the louvers by passive cooling (natural wind flown on rooftop), are the major significant four concepts in this research. The second part is introducing the water agent. The water on pyramid-skylight has played important roles. The roles for cooling the skylight structure, getting hot water for utilization use, pre-cooling water for chillers (air conditioning systems—acting as water cooling unit), are energy-savings domain. Figure 3 shows the section of the pyramid-skylight completed with the incline fins, and tilted 20-degree solar water heater over the skylight. The low energy water-pump inside the scale model is used to pump the water up to the top water supply storage, then letting the water drips down to cool the heated fins. The two water storages beneath the pyramid-skylight are used to collect dripped-water then the water will be streamed by naturally down to the main water storage inside the scale model. Figure 4 exhibits the complete dripped-water pyramid-skylight (A), showing dripped-water-skylight which is dripping the water through skylight-louvers (B), and solar water heater panel has been installed on top the skylight (C).

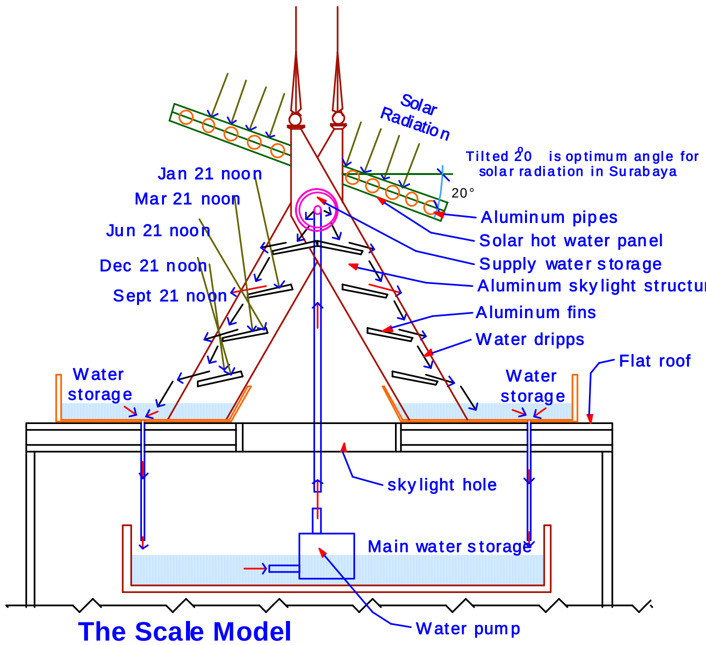

Figure 3 Section and Scheme of the Dripped-water Pyramid-skylight

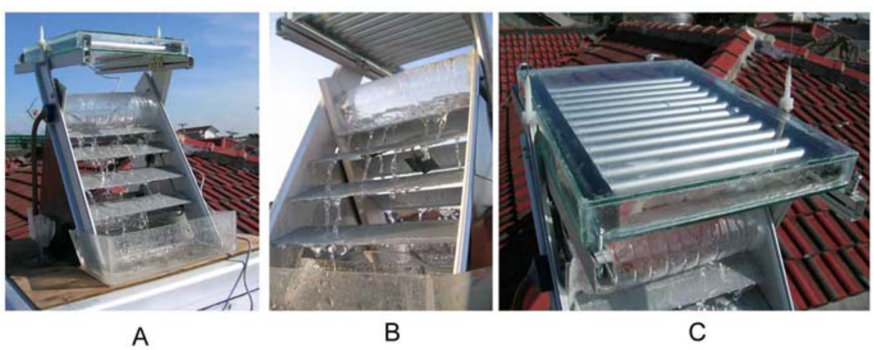

Figure 4 Model of the Dripped-water Pyramid-skylight and The Solar Hot Water Panel

Scale Models

The main body of the scale model is 1 : 8 which is 4 m x 4 m x 4 m, and has a horizontal opening of 0.8 m x 0.8 m. The other models are built smaller than the main one. The Models have been built to test the daylight levels and global solar radiation purposes, and all the horizontal openings have the same size. The first model skylight is covered with a polycarbonate sheet and the second one will be covered up with a piece of tempered glass. The last model skylight is installed with the dripped-water pyramid-skylight.

RESULTS

Solar Radiation and Daylight

The results of the assessment of the least suffered from the global solar radiation in each of the testing skylight models, using each of the skylight cover materials, are shown below (Table 2). Meanwhile, the daylight levels (Lux) for each skylight materials, showing hourly, are exposed on table 3. The Global solar radiation (w/m^2) results show the highest average solar radiation occurred inside the room by means of polycarbonate covered sheet skylight (178 w/m^2 /day), then followed by clear tempered glass cover skylight which has an average of 168 w/m^2 /day. Among the three tested skylights, the dripped-water pyramid shape skylight is the most countable skylight for the tropic zone; it has merely an average of 43 w/m^2 /day solar radiation values. For all the assessments of total solar radiation daily tested, the dripped-water pyramid-skylight has only one to four of other type of skylights values (510 w/m^2 /day compared to 2,131 w/m^2 /day (polycarbonate), and 2,019 w/m^2 /day (tempered clear glass)). This reflects that the target of sustainable energy-saving domain of cooling load will be successfully approached yearly (see chapter sustainable energy). For the time being, the dripped-water pyramid-skylight has achieved an average daylight level of 3,976 Lux/day. That daylight level it is far more than enough for doing moderate activities such as reading, writing, and drawing. (Table 3).

Table 2 The Daily Solar Radiation on Dripped-water-skylight Compared with Others at Year of 2007

Date/Time	Outside Horizontal (W/m2)	Polycarbonate (W/m2)	Solar Glass (W/m2)	Dripped-skylight (W/m2)
05/05/07 06:00:00.0	44	7	12	7
05/05/07 07:00:00.0	228	24	82	32
05/05/07 08:00:00.0	424	146	168	42
05/05/07 09:00:00.0	604	244	238	48
05/05/07 10:00:00.0	724	323	286	49
05/05/07 11:00:00.0	771	343	296	48
05/05/07 12:00:00.0	738	314	269	49
05/05/07 13:00:00.0	779	322	272	49
05/05/07 14:00:00.0	631	232	207	47
05/05/07 15:00:00.0	457	133	133	57
05/05/07 16:00:00.0	242	38	53	78
05/05/07 17:00:00.0	14	4	3	3
05/05/07 18:00:00.0	1	1	1	1
Average	**471**	**178**	**168**	**43**
Total	**5,658**	**2,131**	**2,019**	**510**

Table 3 Daily Daylight Levels on the Three Models Tested of May, 2007 (Lux)

Time/Unit	Solar Glass (Lux)	Polycarbonate (Lux)	Dripped-water-skylight (Lux)
6	918	1,880	1,410
7	7,183	4,500	3,110
8	10,100	7,990	6,190
9	10,100	8,270	5,500
10	10,100	8,270	4,840
11	10,100	8,270	5,370
12	10,100	8,270	6,190
13	10,100	8,270	5,920
14	10,100	8,270	6,850
15	8,095	5,090	4,790
16	4,850	1,280	1,470
17	2,149	90	40
18	157	20	10
Average	**7,235**	**5,421**	**3,976**

Solar Hot Water

Figure 5 indicates the raw water filled in the solar hot water tubes at 6 am has temperature of 32 °C, and subsequently the hot water temperature rose hourly to the highest of 54 °C (at 11 am till 1 pm). The water temperature dropped after that to 22 °C at 12 midnight (marked 24 on time bar). Amazingly, the water temperature has been reached to 15 °C over night at 5 am in the next morning day. The hot water has an average of temperature 45 °C/day. This temperature is suitable for utilization in the toilet or other purposes demand.

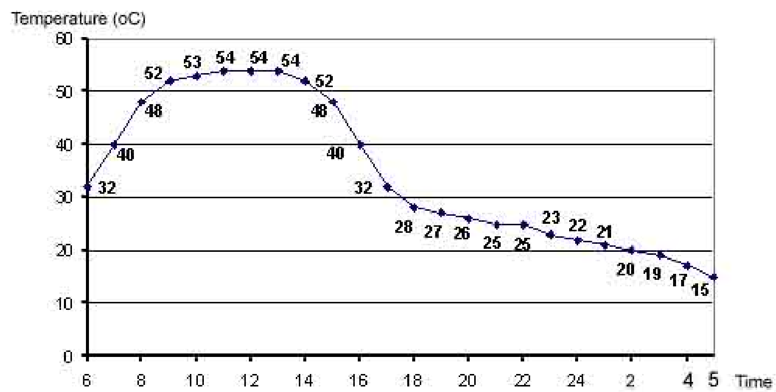

Figure 5 Solar Hot Water Temperature from 6 am to 5 am in May, 2007 (°C)

Temperature on Louvers of Skylight Structure

In order to find out how the water plays a major aspect for cooling the fins/louvers of the skylight, two strategy studies were conducted. On the first day, the water agent ran from 6 in the morning till 6 the next morning (28 °C on May 5, 2007 to 25 °C on May 6, 2007). The highest skylight louvers temperature was ranged from 29 °C to 30 °C. On the second day, the water-pump was terminated. After shutting down the water-pump at 6 in the morning, the skylight louvers temperature rapidly rose up to maximum 37 °C. This reflects that water agent has played a major role to cool down the skylight fins/louvers structure by means of 7 °C temperature differences (Figure 6 shows clearly the temperature changes at the same time being but different day).

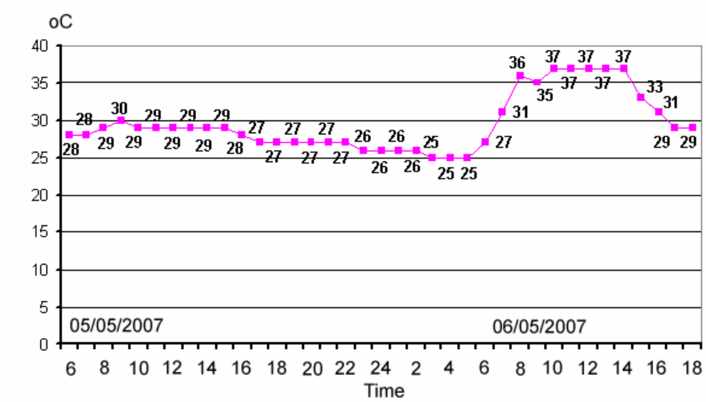

Figure 6 Dripped-water Pyramid-skylight Fins Temperature in May, 2007 (°C)

Acting as the Cooling Tower Unit

The water cooling tower unit has the function to cool the water agent for air conditioning with chiller systems. In the conventional ways of the water cooling tower unit, the water agent was re-circulating by pumping and spraying down using powerful fan which blowing from top to bottom. In contrary, the dripped-water pyramid skylight will cool the water agent by dripping down passively over the louvers skylight. By installing jet pump and having a full-scale dripped-water pyramid-skylight over rooftop buildings, the achievement for acting as water cooling tower can be easily accomplished. The saving energy and economically building cost efficient domains can be conducted (Figures 7 shows the real water cooling tower unit and its working realm at left-side, the dripping-water pyramid skylight roof is on the right-side).

Figure 7 The Genuine Water Cooling Tower and the Dripped-water Skylight Image on the Right-side

Sustainable Energy Savings

In order to figure out how much energy can be saved if the dripped-water pyramid skylight is installed at the building, the case study of problematic design atone shopping mall will be used. By applying solar water heater for hot water services in building, the energy-saving may be taken as 30 – 35% of the total energy consumption of building used (architecture, p. 55). Saving energy for reducing cooling load from skylight structure will be obtained by the use of water for day-time evaporative-cooling effects on all skylight louvers. Table 4 states the energy-saved to both polycarbonate skylight and clear tempered glass skylight annually in terms of their cooling loads from global solar radiation only. The average daily cooling load is getting from the average daily radiation times the area of skylight (345 m^2) times the 7 hours of gaining global solar radiation. Meanwhile, the average cooling load annually is derived from the daily average cooling load times the 360 working days.

Table 4 Daily and Annually Average Cooling Loads (watts) and Energy Saved (kilowatts)

	Daily Average Cooling Load	**Annually Average Cooling Load**	**Energy Saved Annually**	
Types of Skylight /Units ->	(Watts)	(Watts)	(Watts)	(Kilowatts)
Clear Tempered Glass	405,720	146,059,200	108,675,000	**108,675**
Polycarbonate	429,870	154,753,200	117,369,000	**117,369**
Dripped-water	103,845	37,384,200	<<<< >>>>	<<<< >>>>
* parameter: area of skylight 345 meter-squares; receiving solar radiation for 7 hours				

CONCLUSION

The main crucial aspect in this project is dripping the water over pyramid louvers skylight roof for saving energy realm likes, 30-35% of solar water heater energy, and water skylight structure cooling energy, as well as proposing simpler and lower energy of skylight water-cooling tower unit. The dripping water skylight has demonstrated a great energy savings for sustainable architecture building in the tropic. Further research is needed to certify the true working of dripped-water skylight acting as water cooling towers. Full scaled of the dripping-water skylight roof in buildings will also be acted as oases in the dense downtown areas to cool down the urban heat island in hot humid tropical climate of Surabaya's city of Indonesia.

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