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The relationship between building design and indoor temperatures: A case study in three different buildings in Indonesia

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Abstract
Indonesia lacks of adequate building codes. There are no such sufficient codes to guide architects and builders to build buildings to be energy efficient. Many buildings have been built in such a way without considering local climate. Designing buildings merely aims to satisfy clients' aesthetical needs, whilst, on the other side sacrifices indoor thermal comfort and also wasting energy. Recent measurements on earthquake victims' settlement in Sleman, Jogjakarta, Indonesia, showed the dome shape houses performed unsatisfied indoor thermal conditions. Although the main aim to build the shelters was to secure building structure to be strong enough to restrain high earthquake magnitudes, occupants' thermal comfort must not be neglected. This paper discusses thermal study in this building and provides comparison with two other different buildings in different places in Indonesia. This study aims to highlight qualitatively the impact of building design, its envelope in particular, on indoor air temperature performances in the warm humid tropical climate of Indonesia.
Keywords: building envelope, indoor temperature, outdoor temperature, thermal performance, warm humid tropic.

1. Background

Indonesia, a country with thousands of islands, possesses warm humid climate in its majority regions. It has two seasons throughout the year: wet and dry seasons. In many parts of Indonesia, wet season occurs mostly between October and March and reduce outdoor temperatures a little bit, while dry season takes place between April and September.

There is very little climate variation throughout the year in this country. The prevailing air temperature can be divided into three regions, firstly, seaside or lowland regions possesses a monthly average maximum temperatures of 32 to 34^{o}C and monthly average minimum of 23 to 24^{o}C. Secondly, highland regions possesses a monthly average maximum temperature of 28 to 30^{o}C and monthly average minimum of 18 to 20^{o}C, and thirdly, regions in the mountains' feet with monthly average maximum temperature of 22 to 24^{o}C and monthly average minimum of 10 to 15^{o}C.

Many buildings in Indonesia have been built improperly, local climate is frequently be neglected by architects and builders, resulting indoor discomfort. In order to anticipate uncomfortable indoor environment and it was supported by an improvement of national economy, the number of households and buildings to be fully air conditioned have been increased recently.

Most of Indonesians, including architects, believe that it is impossible to build buildings in such lowland areas as Jakarta to be comfortable without being air conditioned. People believe that there is no chance for any building to have indoor temperature lower than 29^{o}C when outdoor temperature is higher than 32^{o}C. This belief has helped architects to leave their responsibility to design such comfortable buildings; buildings which provide comfort without consuming much energy. In such big cities as Jakarta, architects tend to build buildings with AC in mind, as they don't consider local climate as an important factor to be considered. The more AC machines are to be installed in buildings the more energy is wasted.

Building codes is another weakness in Indonesia building industry. There are not sufficient codes to guide architects to design appropriate buildings. Building codes are merely related to the very basic building requirements such as structural requirements. How building could stand safely with such standard loads either internal or external like wind, small earthquakes, etc., are some examples included in the codes. Codes related to building physics are very limited and not sufficient to help architects to provide comfortable buildings.

When the international agency, World Association of Non-Governmental Organization (WANGO) in association with Dome for the World Foundation (DFTW), provides shelters for the earthquake victims in Nglepen village in the province of Jogjakarta (http://delenger.wordpress.com/2008), there is weakness due to the lack of building codes. They built several dome shelters without any national or local guidance resulting uncomfortable indoor environment. It seems that a strong structure to restrain buildings from the earthquake is the only consideration to be taken in designing these buildings. As the indoor temperatures were recorded around 32^{o}C, which was much higher than the outdoors (about 26^{o}C), the shelters were too warm to be lived in.

The earthquake shelters is located at about 7^{o} 30' south latitude, consist of 80 buildings in which 71 were used to shelter earthquake's victims, six are used for public toilets and bathrooms, one is for kindergarten and another one is for mosque. One unoccupied shelter was selected as a case study.

To see how well this building works towards its surrounding climate, i.e. ambient temperature, such comparisons have to be made to another two different buildings with different architectural approaches and different locations. The last two buildings were about 450 km away from the Domes. The first building to be compared is an exhibition building, called ‘Menteng glass building’. This building is located in central Jakarta at 6^{o} 40’ south latitude. The second building is a dwelling which is called ‘Anggrek house’, is located at the outskirt of Jakarta, approximately at the same latitude as Menteng glass building.

2. Methodology

This study based on the curiosity that the three selected buildings may have extremely different temperature performances between one to another. Temperature performance is defined in this study as the buildings’ ability to respond to the ambient (outdoor) temperatures. In the lowland or seaside regions of warm tropical country like Indonesia, good building is defined as a building where its indoor temperatures is much lower than its outdoors so that occupants will feel thermally comfortable.

The first two buildings, Nglepen dome shelter and Menteng glass building are buildings which are quite popular amongst architects and architectural students. Due to the forms and materials used in the two buildings, which do not match to the Indonesian local culture, these two buildings are frequently being discussed in many occasions. The third building is called Anggrek house, is a dwelling which was purposely designed to minimize energy consumption without sacrificing indoor thermal comfort.

To find out temperature performances of the three different buildings, some liquid (alcohol) thermometers were used to measure indoors and outdoors temperatures. All data were recorded and the different between indoor and outdoor temperatures of each building were then compared. The gaps between indoor and outdoor temperatures eventually showed how well building was performed to their surroundings temperatures. The bigger the gaps, in which indoor temperatures are lower than the outdoors, the better buildings are defined as good performers.

3. Data and Discussion

Based on practical reasons, data of temperatures of indoor and outdoor temperatures of three buildings are recorded in different times and durations. Each building is discussed separately in the following paragraphs.

3.1. Nglepen Dome Shelter

Nglepen dome shelters built in 10th October 2006 and occupied by the end of April 2007. The shelters complex consists of 71 dwellings and a number of public buildings like a mosque, a kindergarten, public toilets and showers.

Figure 1. Nglepen dome shelters

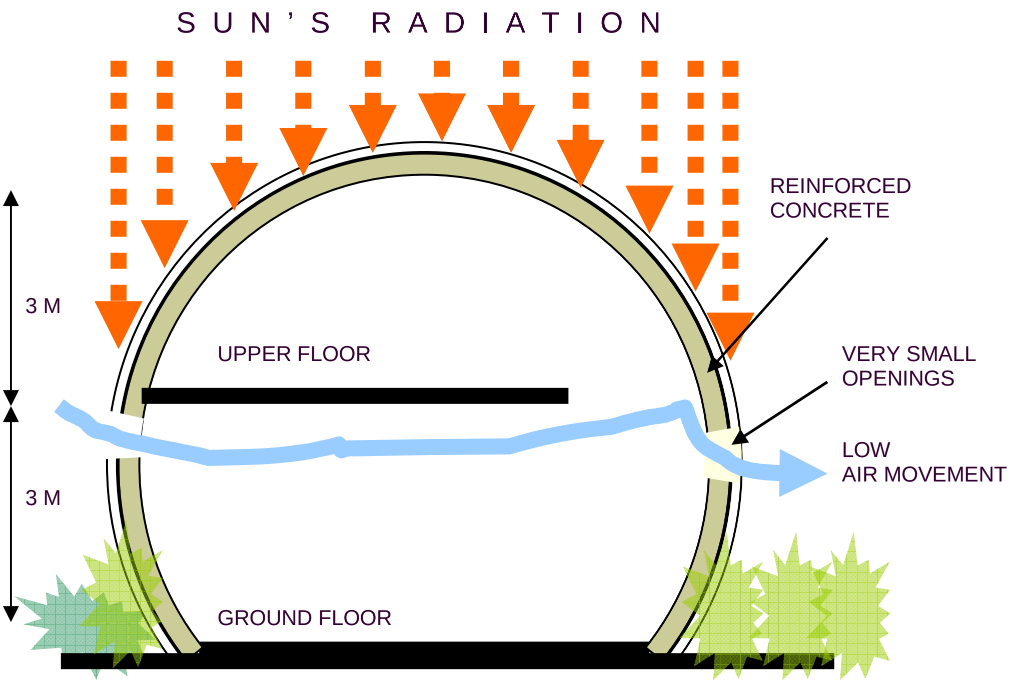

Figure 2. Section of Nglepen dome shelters

This shelter has a circle floor plan with diameter of 7m or a floor area of 38m2 and 6m ceiling height. The monolith structure of outer wall and roof is made by reinforce concrete and painted white. Except doors and windows, there are only small openings provided on the walls which seem inadequate to provide natural ventilation throughout the building (see Fig. 1&2).

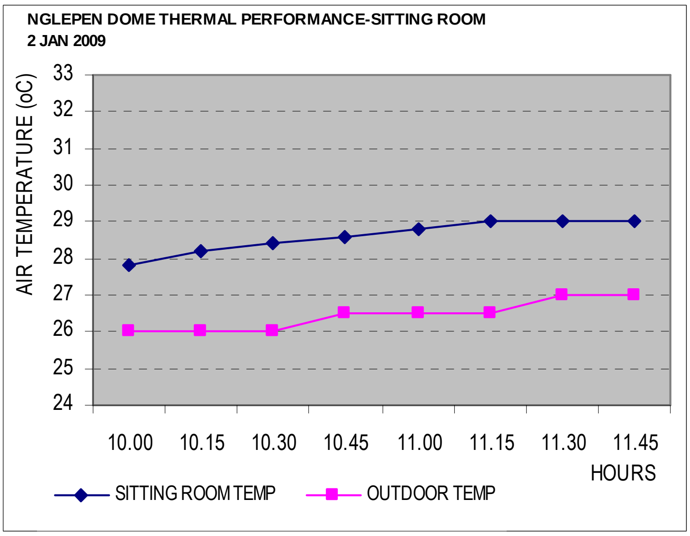

Figure 3. Nglepen dome shelter – Sitting room temperature performance (east)

Temperatures' measurements in this building were divided into three periods. The first measurements took place at sitting room (east side of building) between 10.00 and 11.45 hours. The second measurements took place at the north bedroom between 12.00 and 14.00 hours. The third measurements took place at the upper floor between 14.15 and 16.30 hours.

Figure 3 shows indoor and outdoor air temperatures in the sitting room (clear sky). The average indoor temperature was 28.6 and the average outdoor temperature was 26.4^{o}C. Indoor air temperature was 2.2^{o}C higher than the outdoor in average. This shows that in the presence of sun's radiation (at east side), building envelope has created indoor temperatures higher than the indoor.

Looking at the ambient temperatures' variations, Nglepen is comparable to Bandung, another city in Java which is located in a highland area. Bandung thermal comfort done in this city in 2008 showed that subjects' comfort range was between 23 - 26.5^{o}C T_a. The range of indoor temperatures in the sitting room was between 27.8^{o}C and 29.0°C, and this was outside the range of Bandung's comfort air temperature (Karyono, 2008).

Figure 4 shows measured indoor and outdoor air temperatures of north bedroom. During the measurements in January where the sun was at the south hemisphere, the average indoor temperature was 28.8°C and the average outdoor temperature was 27.4°C. The range of indoor temperatures in the north bedroom was between 28.6°C and 29.0°C, and it was outside the range of Bandung's comfort air temperature (23 - 26.5°C T_a) (Karyono, 2008). The fact that the average indoor temperature was 1.4°C higher than its outdoors has shown that even in the absence of direct sun's radiation, the nature of building envelopes has created indoor temperatures higher than that of the outdoors.

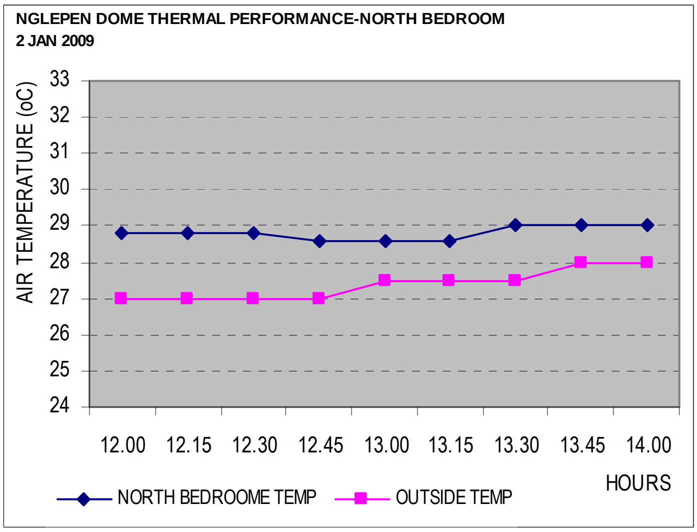

Figure 4. Nglepen dome shelter – North bedroom temperature performance

It may be informed that from 13.00 hours the sky began partly cloudy and little rain was started falling at about 13.30 hours and continued even when the measurements finished. Figure 5 shows measured temperatures of indoor and outdoor air temperatures between 14.15 and 16.30 hours in the centre of upper floor. It can be seen that the outdoor temperatures continuously drop from 14.30 hours till the end of measurements at 16.30 hours. The average indoor temperature was 31.3°C and the average outdoor temperature was 26.5°C. The average indoor temperature was 4.9°C higher than that the outdoors. This shows that the effect of direct sun's radiation on the roof before raining has increased indoor temperatures beneath the dome significantly high. The range of indoor temperatures at upper floor was between

30.8°C and 31.8°C, and this fell outside the range of comfort air temperature (23 - 26.5°C T_a) based on Karyono study in Bandung (Karyono, 2008).

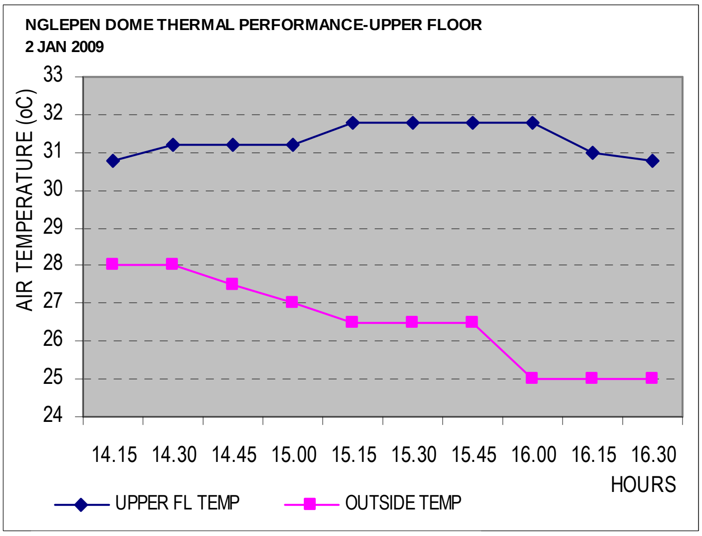

Figure 5. Nglepen dome shelter – Upper floor temperature performance (centre)

3.2. Menteng Glass Building

Menteng glass building is an exhibition building. It was built in 2006 as the alteration of Jakarta old football stadium (Fig.6). Even there was a huge protest from many parts of society construction process of this building went on. There is no adequate information about the reasons of why this building was designed in such a way which is completed sealed by glasses.

Figure 6. Menteng glass building

Temperatures' measurements in this building were divided into two time periods. The first measurements took place at the south side of the building, between 13.00 and

14.00 hours. The second measurements took at the north side of the building, between 14.00 and 15.00 hours.

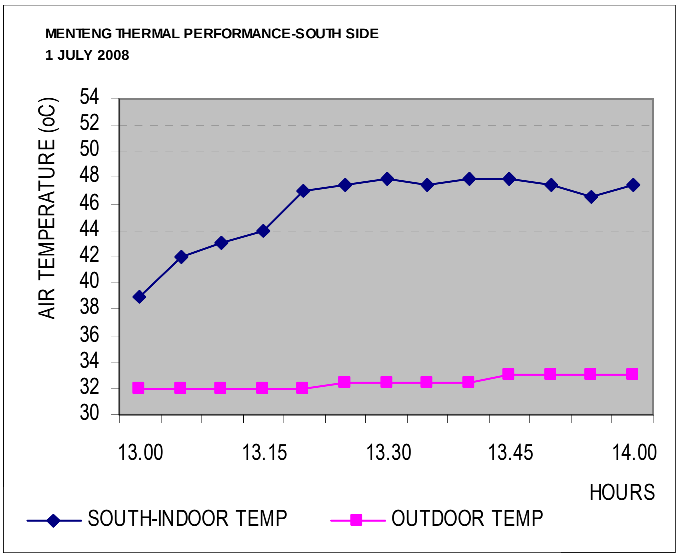

Figure 7. Menteng glass building – south side temperature performance

Figure 7 shows that in the clear sky the averages indoor temperature of building's south side and the outdoor air temperatures were recoded as 45.8 and 32.5^{o}C respectively. The greenhouse effect has created such an excessive heat increasing indoor temperatures significantly high. The difference between average indoor and outdoor temperatures was 13.3^{o}C. The range of indoor temperatures in the south side was between 39.0^{o}C and 48.0^{o}C, and it was outside the range of comfort air temperature (23.9 to 29.7^{o}C) based on Karyono study in Jakarta (Karyono, 2000).

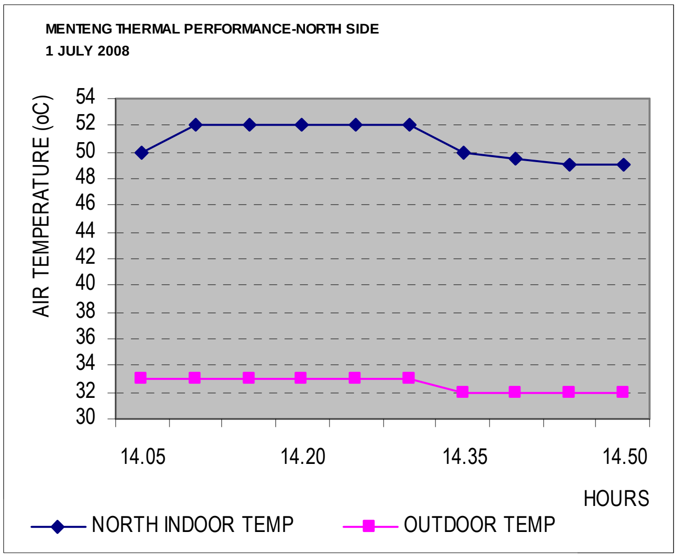

Figure 8. Menteng glass building – north side temperature performance

Figure 8 shows recorded indoor air temperatures in building's north side and the outdoor temperatures. The average indoor temperature was 50.5 and the average outdoor temperature was 32.5^{o}C. The range of indoor temperatures in the north side was between 49.0^{o}C and 52.0^{o}C, and this fell outside the range of comfort air temperature (23.9 to 29.7^{o}C) based on Karyono study in Jakarta (Karyono, 2000).

The difference between the average indoor and outdoor temperatures was 18^{o}C, and is quite big. Looking at this figure it seems impossible for anybody to conduct any activity inside the building. To make the room useable for activities there will be huge of energy to be consumed since the indoor temperatures need to be reduced as low as 30^{o}C or even below.

3.3. Anggrek House

This is a single story house designed by the author and located in the outskirt of Jakarta with a rectangular plan of 8 x 16m2. The brick building faces to the north-south with 3.5m ceiling's height.

Openings are provided by hollow bricks at most entirely outer walls, so that cross ventilation is adequately provided in all the rooms. Roofs are covered by red tiles (Fig. 9). The measurements took place in two different bedrooms, one faces to the north and the other one faces to the south.

Figure 9. Anggrek house

Figure 10 shows measured temperatures of indoor and outdoor air temperatures in the north bedroom between 6.00 and 17.30 hours. The range of indoor temperatures was between 26.0^{o}C and 29.5^{o}C, and this fell within the range of comfort air temperature (23.9 to 29.7^{o}C) based on Karyono study in Jakarta (Karyono, 2000). The average indoor temperature was 28^{o}C and the average outdoor temperature was 29.3^{o}C. On average, indoor temperature was 1.3 lower than the outdoors. The biggest gap was about 4^{o}C in which indoor temperature was lower that the outdoors.

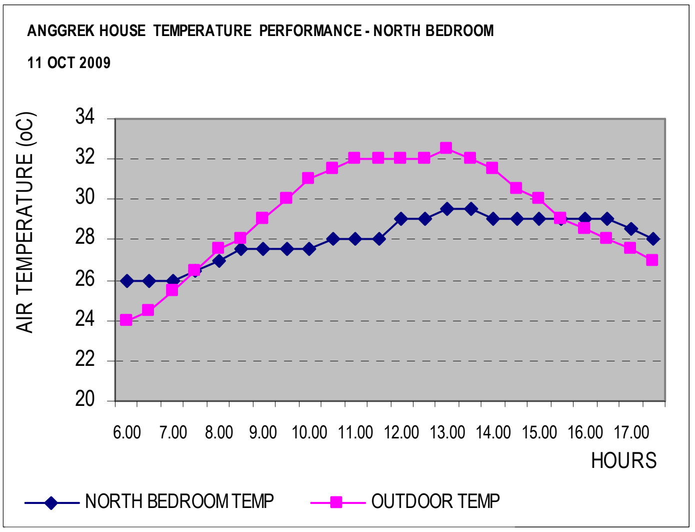

Figure 10. Anggrek house – north bedroom temperature performance

Figure 11 shows measured temperatures of indoor and outdoor air temperatures in the south bedroom, between 6.00 and 17.30 hours. The range of indoor temperatures was between 26.5^{o}C and 28.5^{o}C, and this fell within the range of comfort air temperature (23.9 to 29.7^{o}C) based on Karyono study in Jakarta (Karyono, 2000).

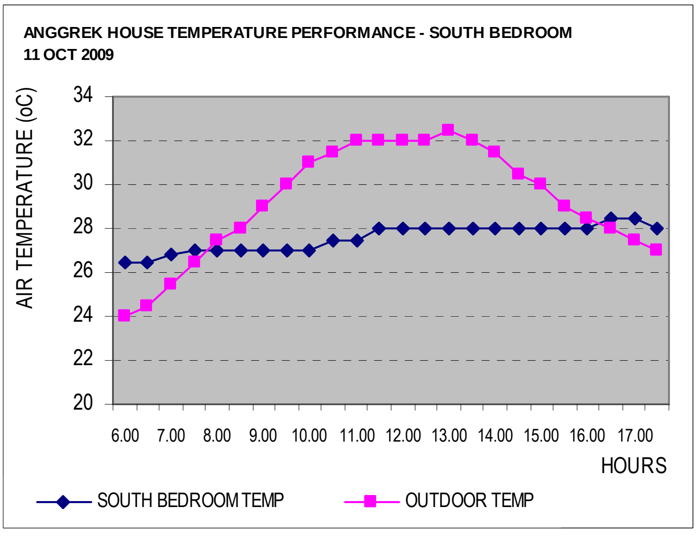

Figure 11. Anggrek house – south bedroom temperature performance

The average indoor temperature was 27.6^{o}C and the average outdoor temperature was 29.3^{o}C. On average, indoor temperature was 1.7^{o}C lower than the outdoors. The biggest gap was about 4.5^{o}C in which indoor temperature was lower that the outdoors.

3.4. Discussion

The fact that the measurements on indoor and outdoor temperatures in three different buildings took place at different date, time and duration, may raise some questions. Even in Nglepen's dome shelter, temperatures' measurements in three different rooms have been conducted at different times. The reasons are firstly, due to the limited number of instruments being used, and secondly, due to the fact that all measurements were conducted by myself, so that there was a little problem to manage the time if all the measurements were taken in the same time.

It is true that this kind of situation may create a number of questions of whether each group data could be compared amongst each other. All data are presented as is, and there was no vivid concept at the initial stage of measurements. The idea of making such comparison came late at the end of the works. Looking at the nature of data being collected therefore, this study looks unsystematic. However, considering all the weakness, this study tries to optimize the use of all data collected, and attempts to find out something from them and such conclusions may be drawn.

Table 1 showed that Nglepen dome shelter performed badly to its surroundings temperatures. Indoor temperatures in all rooms were higher than that of the outdoors. This showed that building envelope which might structurally resist to the earthquake was failed to provide indoor thermally comfortable. Some design alterations are required to improve building thermal performance.

Table 1. Comparison of all measured temperatures in all buildings

	Nglepen dome shelter			Menteng glass building		Anggrek house	
Latitude	7°30' SL			6°21' SL		6°23' SL	
Location	highland			Lowland		lowland	
Date of measurements	2 January 2009			1 July 2008		3 October 2009	
	Sitting room (east side)	North bedroom	Upper floor	South side	North side	North bedroom	South bedroom
Hours of measurements	10.00-11.45	12.00-14.00	14.15-16.30	13.00-14.00	14.05-14.50	6.00 -17.30	
Indoor temp. (°C)	28.6	28.8	31.3	45.8	50.5	28	27.6
Outdoor temp. (°C)	26.4	27.4	26.5	32.5	32.5	29.3	29.3
Difference (°C)	+ 2.2	+ 1.4	+ 4.8	+ 13.3	+ 18	- 1.3	- 1.7

It can also be seen from the Table that Menteng glass building was the worst building in terms of its thermal performance. Its air indoor temperatures were excessively high and could reach 52°C. This showed that covering building in such tropical climate like Jakarta with all glass materials is completely inappropriate.

Table 1 also showed that the only building possessed lower indoor temperatures than that of its outdoors is Anggrek house. The average indoor air temperature of Anggrek house was 1.3^{o}C lower at north bedroom than that the outdoors and 1.7^{o}C lower at south bedroom than that the outdoors. The range of indoor temperatures both in north and south bedrooms were within the range of comfort air temperature based on Jakarta thermal comfort study in 1993 (Karyono, 2000). This has proofed that even in such a tropical climate as Jakarta, building can be thermally comfortable (in the absence of air conditioning machine) when it is properly designed adjusting to the local climate.

4. Conclusions

The three different buildings showed vivid evidence that building design through its envelope have played an important role in creating indoor thermal performance. Whether indoor building is thermally comfortable or vice versa is very much influenced by the nature of its building envelope. No single receipt can be used as a strong formula to design good buildings. However, understanding local climate is the most important things for architects when the are aiming to create such comfortable buildings in tropical climate by minimizing the use of AC and thus, minimizing energy consumption.

The first two buildings being studied showed that they were too warm to be occupied. The problem raised is due to the inappropriate design of the building envelopes, as well as the lack of openings. The dome shelter which is almost entirely sealed by a concrete dome were just too warm to be lived in. More extreme case occurred in the second building, the Menteng glass building, which is entirely sealed by glasses. The building was extremely hot and it seemed impossible to be used for any human activities inside. The third building, Anggrek house, showed a different example. By considering local climate, the house was designed in such a way to be thermally comfortable even without any single AC machine being installed.

This study shows also that by comparing all the three buildings it was revealed that building envelopes took an important role to determine indoor air temperatures of buildings in this warm tropical region. Beside the type of envelope materials, wall opening is one of the important parts to affect building indoor thermal performance. With such high ceilings and adequate openings, Anggrek house was well performed in terms of its indoor temperatures. Its indoor air temperatures were much lower than its outdoors and provided comfortable thermal condition.

Rooms' position to the sun has an impact to indoor temperatures. Measurements of two bedrooms of Anggrek house in July, in which the sun was at the north latitude, north bedroom possessed about 0.5^{o}C air temperature higher, on average, than that of the south bedroom. Study by Givoni (Givoni, 1976) in the month of July showed that north room of his building model located in the semi-arid zone in Israel, possessed the lowest air temperature than the other rooms at different orientations.

5. References

Givoni, B (1976). *Man, Climate and Architecture (2nd ed)*, Applied Science Publishers Ltd, London.

http://delenger.wordpress.com/2008/11/17/dome-sweet-dome/

Karyono, T.H. (1996), Thermal Comfort in the Tropical South East Asia Region, *Architectural Science Review*, vol. 39, no. 3, September, pp. 135-139, Australia.

Karyono, T.H. (2000), Report on Thermal Comfort and Building Energy Studies in Jakarta, *Journal of Building and Environment*, vol. 35, pp 77-90, Elsevier Science Ltd., UK.

Karyono, T.H. (2008), Bandung Thermal Comfort Study: Assessing the Applicability of an Adaptive Model in Indonesia, *Architectural Science Review*, vol. 51.1, March, pp. 59-64, Australia.