THE STUDY OF THERMAL COMFORT OF I-SAN VERNACULAR BUDDHIST HOLY TEMPLES (SIMS) IN BURIRAM PROVINCE

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Abstract

This article described the local wisdom in orientation design providing thermal comfort in I-san Sims or vernacular Buddhist holy temples in the Northeast region of Thailand. The study examined the air temperature measurement, relative humidity, wind speed and Mean Radiant Temperature (MRT) of the three Sims since December 2014 to July 2015 by using scientific instruments. The results of the study showed that local beliefs have effected on the orientation of the Sims-they faced the east direction considered an auspicious direction. The narrow side of each building facing the east to the west direction was a crucial factor providing thermal comfort for the building users as building envelope area where is the heat storage as well as the quantity of the heat from the sun shining into each building can be reduced more than those Sims facing in the north to south direction. Throughout the day in winter, summer, and rainy season, the inside of the three Sims the thermal comfort was provided to the building users. In other words, the minimum/maximum temperature was in the range of 18.50˚C - 40.00˚C, the minimum/maximum relative humidity was in the range of 27.00 - 99.00%, and the minimum/maximum wind speed was in the range of 0.01 - 1.96 meters per second. Although the temperatures were above Victor Olgyay's Chart, the indoor and outdoor temperatures were not different. It

can be said that the local wisdom on Sim designing providing thermal comfort was based on orientation together with other factors.

Keywords: architecture; Sim; Buddhist holy temples; thermal comfort; local wisdom

Introduction

Vernacular architecture, since the ancient time, has been created in response to the needs of physical, social and functional desire, including belief, faith or satisfaction. This architecture is full of stories reflecting history and wisdom of ancestors as well as people living in the Northeast region (I-san) of Thailand who have faithfully built temples which are believed to be the house of the Triple Gem comprising of the Buddha, Dhamma, Sangha, as a community of faith. Therefore, construction of the temples attaches importance to concrete buildings housing the Triple Gem and comprising of Sims, Ubosots (Buddhist Holy Temples), and monk cells, as a Buddhist learning center for cultivating virtue and morality, a cultural centre of ethics and arts and crafts epitomizing fine arts, painting, sculpture, and architecture. The temples have played an important role as a community centre of activities and psychological gathering since the past to the present time. However, in the current situations, indigenous Sims or Ubosots constructed by ancestors in many communities are demolished. This becomes a crisis of Sims in I-san (Srisuro, 2004). This article aimed to study vernacular architecture of I-san Sims based on science disciplines. The writer raised the issue of Thai s' belief saying that,

"According to the temple orientation, the temple can face any direction, however, ubosot and vihara must always face water resource. This gives the direction second priority as the Buddha sat under the Bodhi tree and turned his face towards the river when he attained enlightenment. However, in case of impossibility that the ubosots face the water due to the drought in some areas, the ubosots must face only the east direction" (Jumsai na Ayudhya, 1986). When putting contact with concerning sectors, both political and religious sectors, *Sims in I-san area are influenced by the belief concerning facing Sim to the east direction.* This is widespread and become the rules every temple must follow (Srisuro, 1987). A reference to the principal Buddha image denotes the Buddha in the event of sorting out liberation. Before his enlightenment, he turned his face to the Oriental (East) despite devils, and overcame the devils with basis for success.

Thailand is located in between 5˚37' North latitude and 20˚ 27' North latitude. BuriRam province is located in the lower part of the Northeast region, (Figure 1) in between 15' North latitude and 15˚45' North latitude, and in between 102˚30' East longitude and 103˚45' East latitude with a tropical climate of high temperature all year round as it is the rain shadow of the mountains or the windshield of Dong Rak and San Kamphaeng mountain range which blocks the southwest monsoon. BuriRam is approximately 350 km. far from the east coast of the Gulf of Thailand taking small influence from the sea and causing low average relative humidity. The weather, in general, is quite cruel. The temperature is very low in winter and very high in summer, which are obviously different (BuriRam, 2013). This study examined 3 Sims in BuriRam, Borom Khongkha Sim, Maneejun Sim in Phuttasong District, and Tariep Sim in Napho District. These Sims' orientation faces the east direction. The study examined thermal comfort inside those Sims based on scientific disciplines to explain the positive effects from employing local wisdom, beliefs, and the orientation facing the east direction.

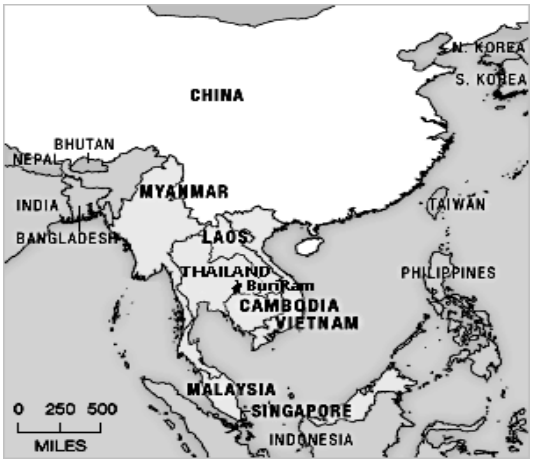


Figure 1: BuriRam Province, Thailand

Research Methodology

1. Survey by examining a reference line for measuring zero line, measuring the size using measurement tools based on the framework of vernacular architecture.

2. Create two-dimensional and three-dimensional architectural drawing by software consisting of floor plan, roof plan, elevation and section images, and three-dimensional images.

3. Measure heat radiation values, Temperatures, relative humidity, and wind speed Measure heat radiation values, Temperatures, relative humidity, and wind speed by using scientific instruments; thermometer, hygrometer, and anemometer. The measurement was conducted in 8 month, once a month. The data were defined in Bioclimatic Chart in order to specify period of time resulting in the thermal comfort of each building in each month.

4. Explain the principles of architectural design providing thermal comfort regarding orientation to create three-dimensional images from a computer program to compare the direction of sunlight entering the building when it faced other directions in each month of the year in order to explain the wisdom of orientation design causing a reduction in the amount of solar heat entering the building.

Results

1. Architectural style: These 3 Sims have different styles, Borom Khongkha Sim aged 106 years old was built with blind wall facing the east direction. Its rectangular floor plan contains 3 rooms surrounded with a veranda and columns carrying eaves. Indoor area is approximately 5.59 m. wide and 9.39 m. long. Total area is about 52.49 m^2. The floor is elevated about 1.20 m. from the veranda floor. The building base is decorated with lotus molds. There are front stairs. There is a pedestal base carrying the Buddha image inside the building. The masonry walls are 50 cm thick. The roof is a single-layer gable roof with a narrow roof at the base of the gable end decorated with tiles and Thai-style roof decoration (roof finial). The current building has been preserved by the Fine Arts Department to be used for Buddhist congregation.

Maneejun Sim aged 76 years old was built with blind wall facing the east direction and the road leading from the village. Its floor plan contains 3 rooms with a front porch. The building is 1.15 m. elevated with base. Indoor area is about 7.50 m wide and 9.00 m. long. Total area is approximately 67.50 m^2. The roof is a double-gable roof made of Nypa

palm leaves. The building is renovated to be used for Buddhist congregation. Tariep Sim age 126 years old, was built with blind walls facing the east direction and there is a road passing in front of the temple. Its rectangular floor plan contains 3 rooms surrounded with a veranda and a front porch. Its hip roof is double-layer. The roof ridge is decorated with stucco (roof finials). Indoor area is about 3.29 m. wide and 7.34 m. long. Total area is about 24.15 m^2. The building base is elevated above ground level. There are 9-step stairs at the front. The building is constructed with wooden columns, masonry walls and lotus molds on top of the columns. The wooden columns are coated. External wall and columns are coated with cement and painted with mural painting. In front of the Sim stands a small building with hip roof. The edge of the room is made of crafted tin plate. The current building has been preserved by the Fine Arts Department. The walls are found cracked in some areas from the columns. Some roof tiles are damaged.

Borom Khongkha Sim Maneejun Sim Tariep Sim

Figure 2: Perspective and elevation of Borom Khongkha Sim, Maneejun Sim, and Tariep Sim

2. Explanation of local knowledge according to science disciplines.

2.1 The thermal comfort This research was conducted to measure Temperature, relative humidity, and wind speed of those 3 Sims since December 2014 to July 2015 by using scientific instruments. The conditions

were; the doors and windows were open during day and night time, turn off ventilators. Seasons were divided into 3 seasons as follows; winter; December, January, February, summer; March, April, May, and rainy season; June, July.

The results of indoor and outdoor temperature could be concluded that during 8 months of the experiment, the indoor temperature of each building presented small difference. In terms of outdoor temperature, the average maximum temperature was 39.80˚C, the average minimum temperature was 18.30˚C. In terms of indoor temperature, the average maximum temperature was 40.00˚C, the average minimum temperature was 18.50˚C. The temperatures were above Victor Olgyay's Bioclimatic Chart. When compared average indoor and outdoor temperatures, it was found that the average indoor temperature was 0.25˚C higher than the outdoor temperature. This temperature presented small difference affecting thermal comfort as shown in Table 1 presenting recorded data of the thermal comfort on 22nd December 2014, 18th April 2015, and 22nd June 2015.

Table 1: Temperature, wall temperature, roof temperature, and ceiling temperature

Date of Record	Position of Measurement	Borom Khongkha Sim		Maneejun Sim		Tariep Sim	
		Outdoor (˚C)	Indoor (˚C)	Outdoor (˚C)	Indoor (˚C)	Outdoor (˚C)	Indoor (˚C)
22 December 2014 Time: 15.00 pm.	T	25.30	24.20	28.20	26.40	28.90	28.00
	W	26.80	24.30	27.50	25.00	28.00	22.20
	N	24.60	25.00	25.80	24.50	23.40	22.20
	E	26.50	24.90	28.00	24.90	25.80	22.00
	S	26.60	25.10	32.80	25.30	28.00	22.20
	R	17.10	Cl 25.10	17.60	Cl 25.90	26.70	Cl 25.30
18 April 2015 Time: 17.00 pm.	T	34.30	33.90	35.90	34.80	36.50	36.70
	W	37.70	30.30	43.70	29.60	39.30	30.10
	N	36.30	30.20	38.70	28.20	39.70	29.50
	E	37.70	30.10	40.30	28.30	38.60	30.50
	S	36.50	30.10	41.70	28.60	39.00	32.10
	R	32.20	Cl 36.40	30.50	Cl 37.00	24.60	Cl 37.30
22 June 2015 Time: 15.00 pm.	T	31.60	31.30	34.00	33.90	33.60	33.80
	W	34.00	34.70	38.20	36.20	36.50	34.60
	N	34.10	35.20	36.80	36.20	37.60	34.70
	E	36.20	35.10	38.90	36.10	36.20	35.00
	S	36.20	35.10	38.50	36.20	36.20	34.60
	R	34.40	Cl 34.70	39.10	Cl 34.70	37.30	Cl 34.20

Note : T Temperature N North wall temperature S South wall temperature Cl Ceiling temperature
W West wall temperature E East wall temperature R Roof temperature

According to Jitkhajonwanich (2004), the suitable comfort zone for Thais is in the range of 25.6 - 31.5˚C, relative humidity is at 62.2 - 90.0%. The most comfortable temperature is 27.9 - 28.8˚C, especially in residential buildings with a wind speed of 0.1 - 1.0 m/s. When compared the thermal comfort with the results by the temperature and relative humidity recorded from actual site each day with 8 times, it was found that

Borom Khongkha Sim has high-mass wall with 6.7% openings on the wall. The ratio of the openings on the north or south walls was 1.77: 15.49, or about 11%. The outdoor temperature was with the average maximum temperature of 34.30˚C and the average minimum temperature of 19.00˚C. The average outdoor temperature was 27.68˚C. The indoor temperature was with the average maximum temperature of 33.90˚C and the average minimum temperature of 19.10˚C. The average indoor temperature was 27.25˚C. The Mean Radiant Temperature (MRT) was 29.56˚C. The indoor virtual temperature was 30.57˚C. There were 9 periods of time in each day representing 38% in winter, 6 periods of time representing 25% in summer, 6 periods of time representing 25% in rainy season that provide the thermal comfort. Throughout the year, there were 6 - 9 times a day providing the thermal comfort.

Maneejun Sim has high-mass wall with 8.9% openings on the wall. The ratio of the openings on the north or south walls was 3.24 : 32.63, or about 11%. The outdoor temperature was with the average maximum temperature of 37.90˚C and the average minimum temperature of 18.50˚C. The average outdoor temperature was 29.56˚C. The indoor temperature was with the average maximum temperature of 39.90˚C and the average minimum temperature of 19.00˚C. The average indoor temperature was 29.25˚C. The MRT was 32.27˚C. The indoor virtual temperature was 33.44˚C. There were 16 periods of time in each day representing 67% in winter, 10 periods of time in each day representing 42% in summer, 10 periods of time in each day representing 42% in rainy season providing the thermal comfort. Throughout the year, there were 10-16 times a day providing the thermal comfort.

Tariep Sim has high-mass wall with 5.23% openings on the wall. The ratio of the openings on the north or south walls was 1.2 : 15.10, or

about 8%. The outdoor temperature was with the average maximum temperature of 39.80˚C and the average minimum temperature of 18.30˚C. The average outdoor temperature was 29.20˚C. The indoor temperature was with the average maximum temperature of 40.00˚C and the average minimum temperature of 18.50˚C. The average indoor temperature was 29.07˚C. The MRT was 30.31˚C. The indoor virtual temperature was 30.75˚C. There were 11 periods of time in each day representing 46% in winter, 9 periods of time in each day representing 38% in summer, 14 periods of time in each day representing 57% in rainy season providing the thermal comfort. Throughout the year, there were 9 - 14 times a day providing the thermal comfort.

When defined indoor temperature and indoor relative humidity on the day of measurement in Victor Olgyay's Bioclimatic Chart (dash line), Kitchai Jitkhajonwanich (solid line) with a Y-axis representing the temperature in degree Celsius and an X-axis representing a percentage of indoor relative humidity shown in Figure 3-5, it was found that throughout the year Borom Khongkha Sim had 58 periods of time in 192 hours representing 30%, Maneejun Sim had 78 periods of time in 192 hours representing 50%, Tariep Sim had 88 periods of time in 192 hours representing 46% providing the thermal comfort for the building users. These Sims had an average of 81 periods of time in 192 hours representing 46% providing the thermal comfort. According to measurement of wind speed, it indicated that most of the indoor average wind speed at the blind wall was less than outdoor wind speed. Still, the indoor average wind speed at the openings is greater than the outdoor average wind speed.

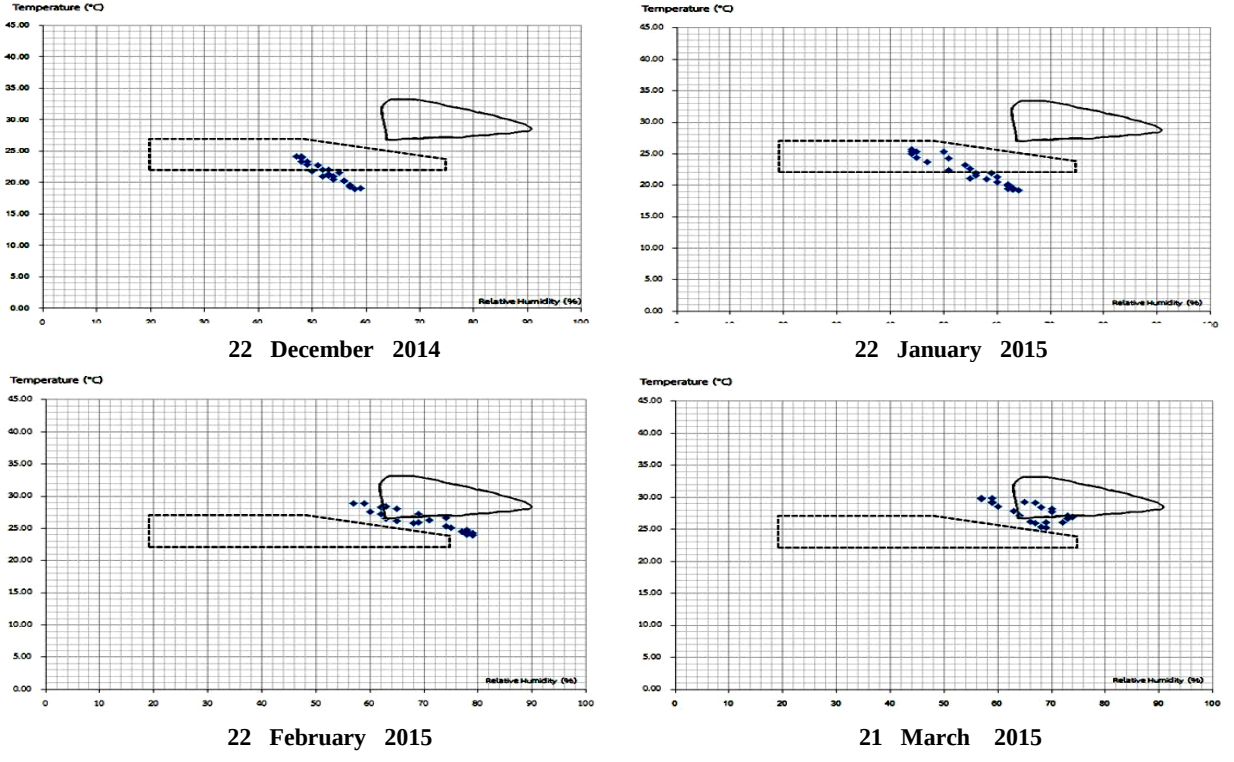
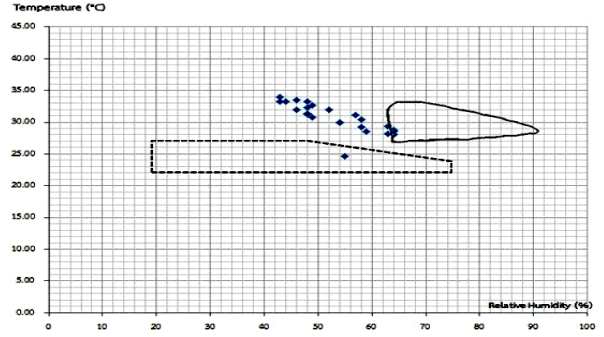


Figure 3: Temperature, relative humidity inside the building compared to comfort zone: Borom Khongkha Sim

Remark - - - - Thermal Comfort Zone of Victor Olgyay ____ Thermal Comfort Zone of Kitchai Jitkhajornwanich



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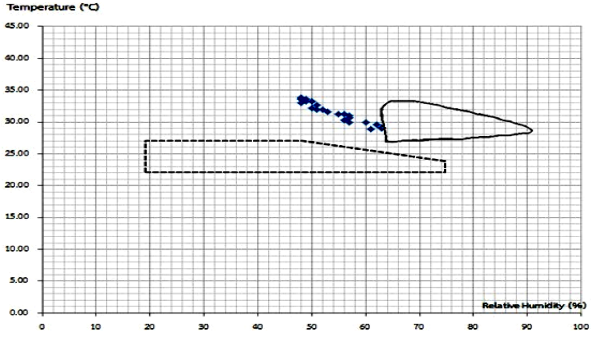

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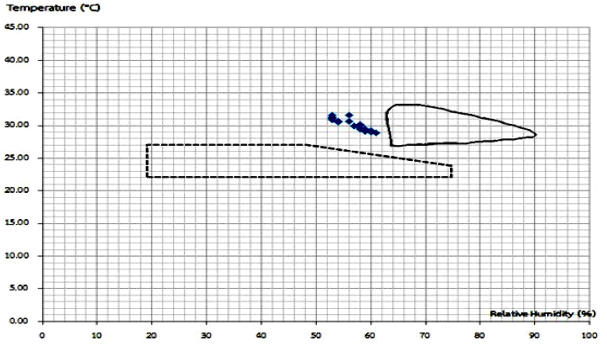

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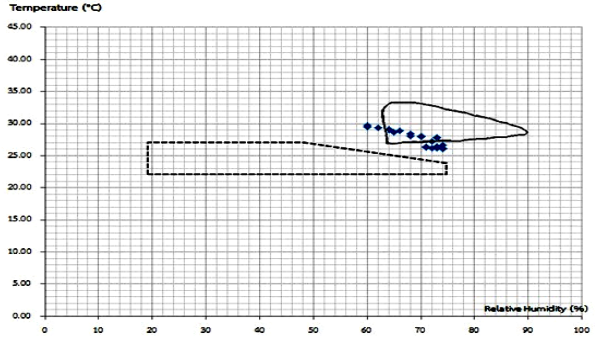

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Figure 3: (Continued)

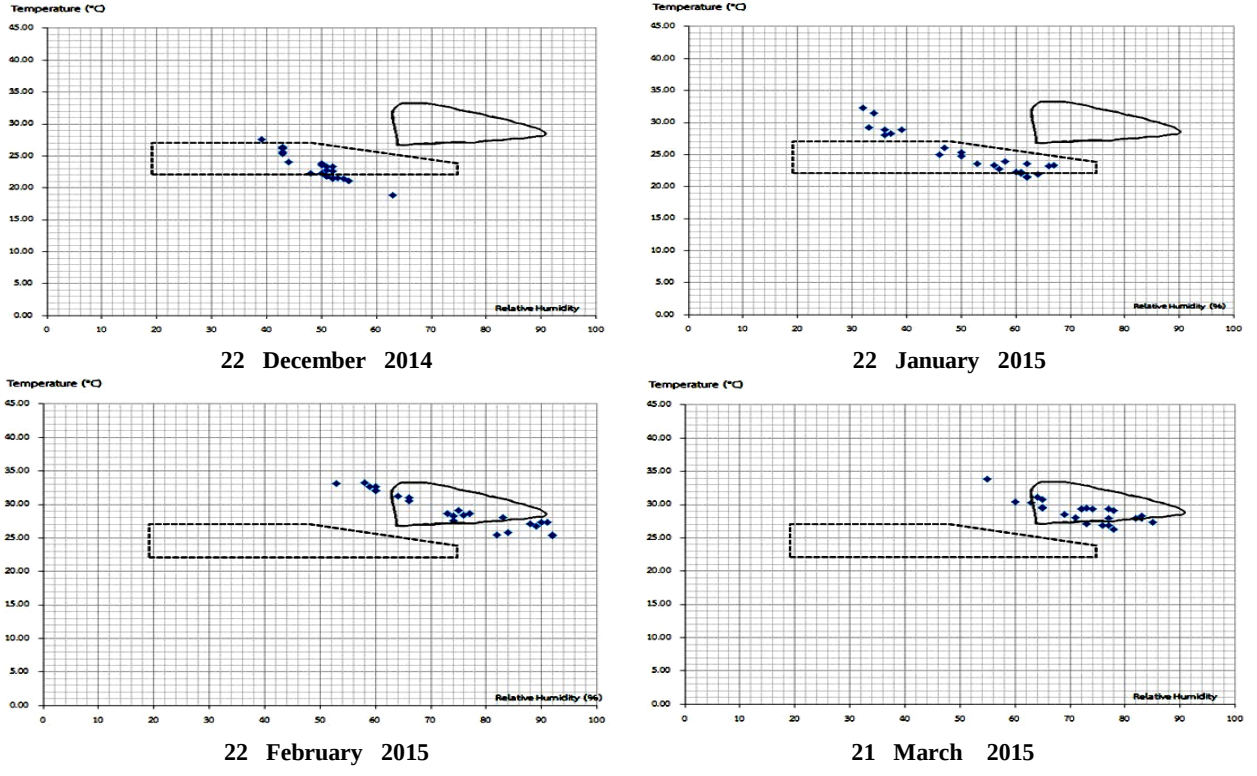
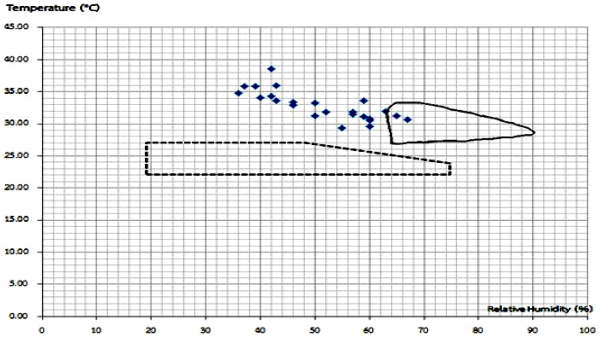


Figure 4: Temperature, relative humidity inside the building compared to comfort zone: Maneejun Sim

Remark - - - - Thermal Comfort Zone of Victor Olgyay —— Thermal Comfort Zone of Kitchai Jitkhajornwanich



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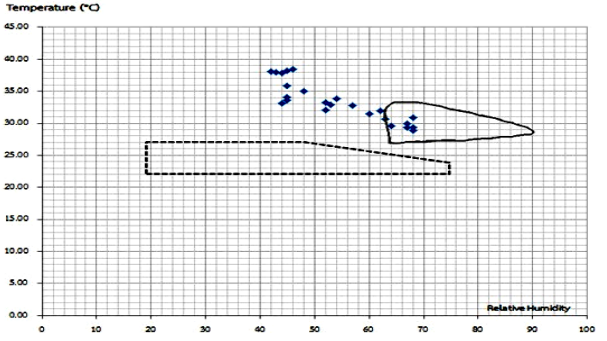

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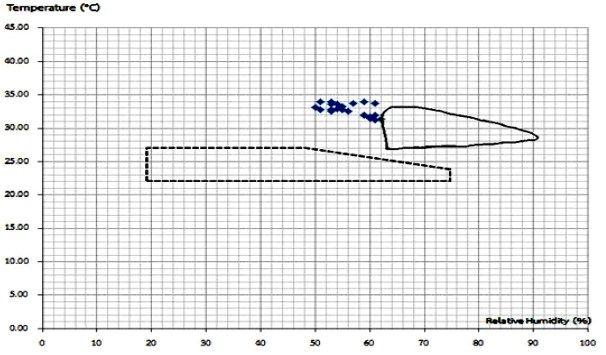

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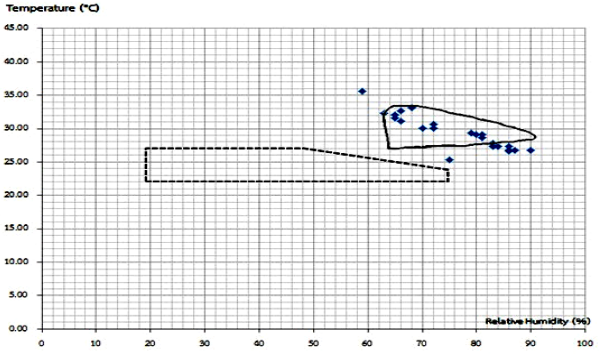

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Figure 4: (Continued)

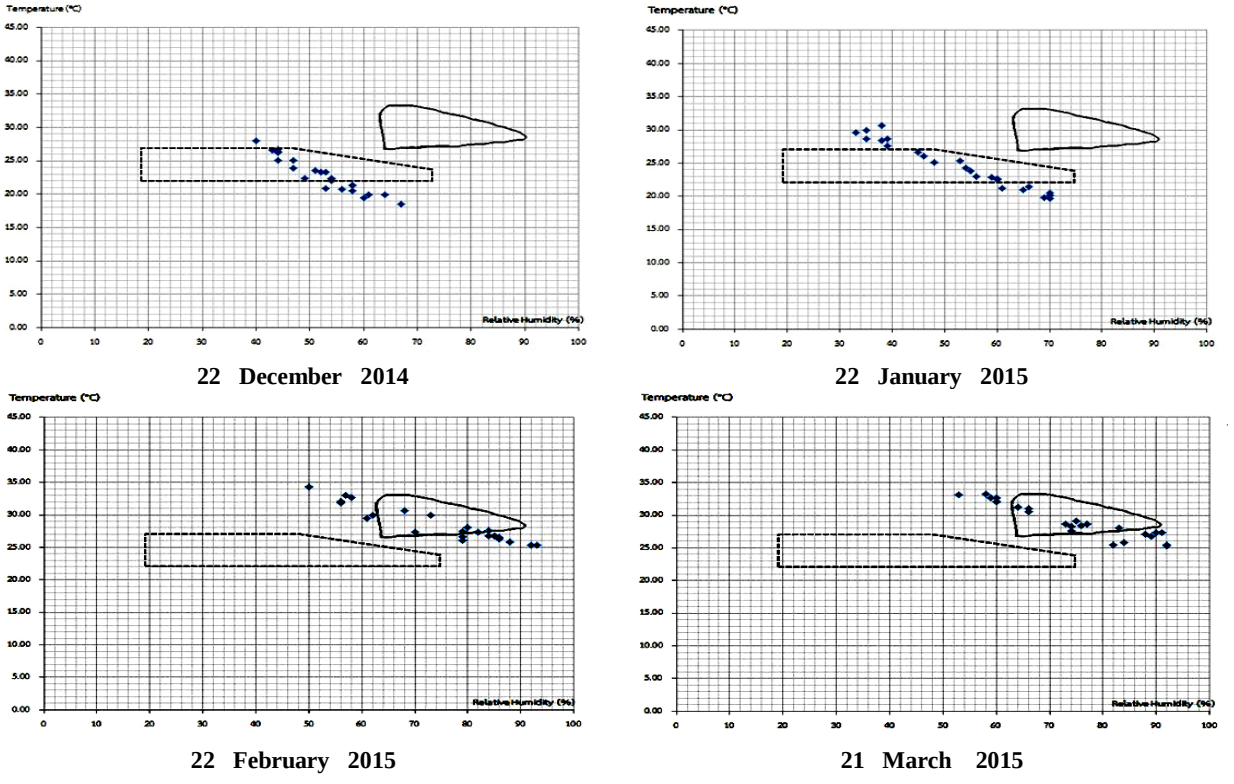
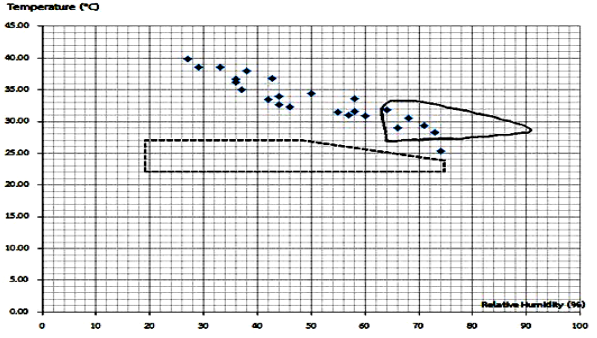


Figure 5: Temperature, relative humidity inside the building compared to comfort zone: Tariep Sim

Remark - - - - Thermal Comfort Zone of Victor Olgyay —— Thermal Comfort Zone of Kitchai Jitkhajornwanich



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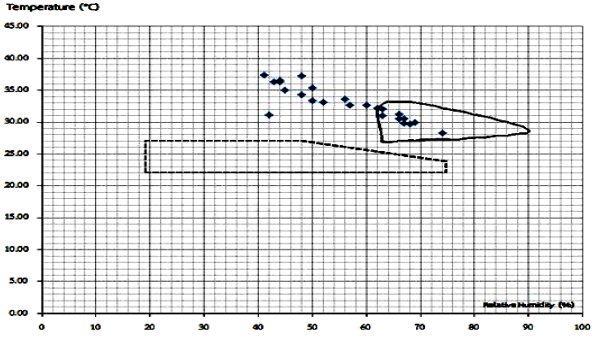

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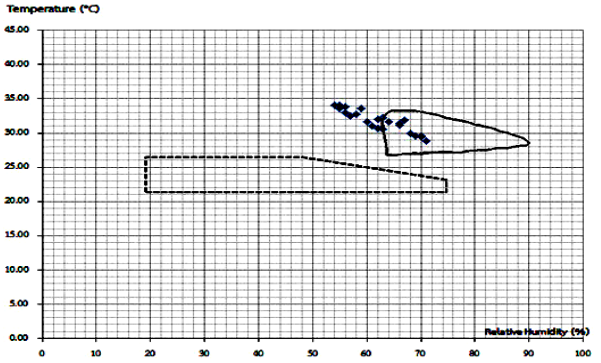

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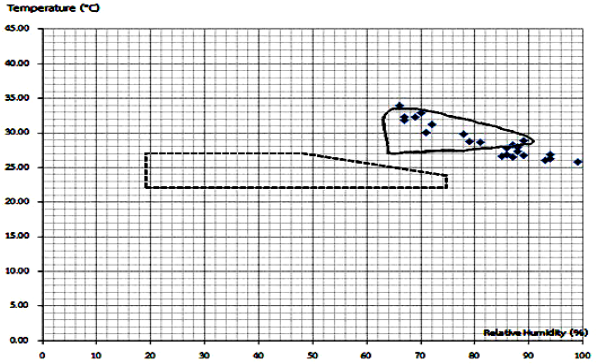

22 July 2015

Figure 5: (Continued)

Table 2: Temperature classified by seasons and buildings

Temperature (˚C)	Borom Khongkha Sim				Maneejun Sim				Tariep Sim			
	Outdoor temperature	Indoor temperature	MRT	Indoor virtual temperature	Outdoor temperature	Indoor temperature	MRT	Indoor virtual temperature	Outdoor temperature	Indoor temperature	MRT	Indoor virtual temperature
Winter												
Minimum	19.00	19.10	21.42	21.37	18.50	19.00	20.18	16.15	18.30	18.50	22.69	22.12
Maximum	30.40	28.90	27.67	28.51	36.90	33.30	30.10	32.07	33.00	34.30	28.81	29.36
Average	23.98	23.34	24.49	24.96	25.53	25.63	26.68	27.16	25.32	25.38	25.42	25.43
Summer												
Minimum	25.00	25.30	29.73	30.02	25.50	26.30	32.17	30.61	25.60	25.00	30.99	30.93
Maximum	34.30	33.90	35.37	36.64	37.90	39.90	37.27	39.68	38.40	40.00	36.63	38.17
Average	30.36	30.07	32.91	34.04	31.80	31.67	35.23	36.70	31.86	31.95	33.93	34.73

Table 2: (Continued**)**

Temperature (˚C)	Borom Khongkha Sim				Maneejun Sim				Tariep Sim			
	Outdoor temperature	Indoor temperature	MRT	Indoor virtual temperature	Outdoor temperature	Indoor temperature	MRT	Indoor virtual temperature	Outdoor temperature	Indoor temperature	MRT	Indoor virtual temperature
Rainy Season												
Minimum	25.90	26.00	29.75	30.48	26.50	25.40	32.06	31.04	25.90	25.80	28.57	28.32
Maximum	32.20	31.60	34.66	36.35	36.90	35.50	36.37	38.70	39.80	34.20	35.16	37.06
Average	29.21	28.90	31.63	32.73	31.35	31.04	34.91	36.45	30.42	30.29	31.58	32.09
Average annual temperature												
Minimum	19.00	19.00	21.42	21.37	18.50	19.00	20.18	16.15	18.30	18.50	22.69	22.12
Maximum	34.30	37.30	35.37	36.64	37.90	39.90	37.27	39.68	39.80	40.00	36.63	38.17
Average	27.68	27.25	29.67	30.57	29.56	29.25	32.27	33.44	29.20	29.21	30.31	30.75

According to Table 2, the outdoor temperature of Borom Khongkha Sim had the average maximum temperature of 34.30˚C and the average minimum temperature of 19.00˚C. The average outdoor temperature was 27.68˚C. The MRT was 29.56˚C. The indoor virtual temperature was 30.57˚C.

The outdoor temperature of Maneejun Sim had the average maximum temperature of 37.90˚C and the average minimum temperature of 18.50˚C. The average outdoor temperature was 29.25˚C. The MRT was 32.27˚C. The indoor virtual temperature was 33.44˚C. And outdoor temperature of Tariep Sim had the average maximum temperature of 39.80˚C and the average minimum temperature of 18.30˚C. The average outdoor temperature was 29.20˚C. The MRT was 30.31˚C. The indoor virtual temperature was 30.75˚C. However, the average maximum temperature in summer at the wall of those Sims did not exceed 2˚C higher or lower than the outdoor temperature. It was noticed that the MRT of Borom Khongkha Sim and Tariep Sim were less than Maneejun Sim due to the building shape surrounded by a veranda covered with a narrow roof at the base of the gable end.

2.2 For creating a 3D model by using a computer program to determine the distance of the sun shining in each month, overheat period was during 1-6 pm on 22nd December 2014 (winter), 22nd June 2015 (rainy season), and 18th April 2015 (summer). The results of an orientation model and an analysis of architectural features found that when the orientation of Borom Khongkha Sim faced the east direction, the sunlight could not enter the building as it has a floor plan surrounded with a veranda and covered by a narrow roof at the base of the gable end with a width of 2.83 m. from the wall. However, when the orientation faces the west direction in summer and rainy season, the sunlight entered the front entrance. When the orientation faces the north or south direction, the sunlight entered the windows. The distance of the sun shining reached almost the middle of the building in all seasons. This makes the benefits of placing the Sim facing the east direction that helps in reducing the amount of heat entering the building.

When the orientation of Maneejun Sim faces the east direction, the sunlight could not enter the building in summer and rainy season, but in winter, the sunlight entered the building as it has a gable roof with 1 m. short eaves. When the orientation faces the north or south direction, the sunlight

entered the building in all seasons. When the orientation of Tariep Sim faces any directions, no sunlight entered the building in every season as the building has a floor plan surrounded with a veranda and covered by a narrow roof at the base of the gable end with an approximate width of 4.00 m. from the wall. The front of the building stands another building with roof helps in preventing the sunlight from the front entrance better than Borom Khongkha Sim as shown in Figure 6.

When analyzed the data obtained from the orientation model with the recorded temperature from actual site, it was found that no matter what direction the Borom Khongkha Sim and Tariep Sim face, the eaves prevented the sunlight entering the buildings in all seasons. This blocked the heat from outside by the openings. On 22nd December 2014 at 15.00 pm, the day that passes under the sun angle, the distance of the sun shining into the building was the longest distance of the year. The temperature at the external wall surface in the west and south direction had no difference. The outdoor temperature of the Borom Khongkha Sim was 25.30˚C, the indoor temperature was 24.20˚C, the temperature of the external wall surface in the west direction was 26.80˚C and in the south direction was 26.60˚C. The outdoor temperature of the Tariep Sim was 28.90˚C, the indoor temperature was 28.00˚C, the temperature at external-wall surface to the west direction was 28.00˚C and to the south direction was 28.00˚C. This was because the sun did not shine into the buildings and generated heat at the wall. Still, there were no eaves at the Maneejun Temple Sim. No matter the building was placed to any directions, the sunlight entered the building through the openings. According to the orientation to the east direction from the recorded temperature in actual site, it was found that the outdoor temperature was 28.20˚C. The indoor temperature was 26.40˚C. The temperature at the external wall surface to the west direction was 27.50˚C and the south direction was 32.80˚C. This presented an obvious difference as the sun orbited to the south direction in winter. The Maneejun Sim had no eaves, the external wall got the sunlight and generated heat.

On 18th April 2015 at 17.00 pm, it was found that no matter what direction Tariep Sim faces, the eaves of the Sim were longer than the eaves of Borom Khongkha Sim, it helped in preventing the sunlight and heat into the

openings in all seasons. From the measurement, the temperature at the external wall surface in each side presented a small difference. The outdoor temperature of the Borom Khongkha Sim was 34.30˚C, the indoor temperature was 33.90˚C, the temperature at the external wall surface to the west direction was 37.70˚C and in the north direction was 36.30˚C. The difference was 1.4˚C. The outdoor temperature of the Tariep Sim was 36.50˚C, the indoor temperature was 36.70˚C, the temperature at external wall surface to the east direction was 38.60˚C and to the north direction was 39.70˚C. This was because the sun did not shine into the buildings and generated heat at the wall. However, the sun shined to the west, north, and south wall. According to the measurement, it indicated that the outdoor temperature of the Maneejun Sim was 35.90˚C, the indoor temperature was 34.80˚C, the temperature at the external wall surface to the west direction was 43.70˚C and to the north direction was 38.70˚C. The obvious difference was 5.00˚C as the external wall to the west direction obtained more sunlight than the north wall.

On 22nd April 2015 at 15.00 pm, it was found that no matter what direction the Tariep Sim faces, the eaves of the Sim prevented the sun shining into the buildings in all seasons. This blocked the heat from outside through the opening area. The temperature at the external wall surface to the west, south, and north direction were different. The outdoor temperature of the Tariep Sim was 33.60˚C, the indoor temperature was 33.80˚C, the temperature at external wall surface to the west direction was 36.50˚C, to the south direction was 36.20˚C, and to the north direction was 37.60˚C. The difference was only 1.40˚C. The outdoor temperature of the Borom Khongkha Sim which had shorter eaves than Tariep Sim was 31.60˚C, the indoor temperature was 31.30˚C, the temperature at the external wall surface to the west direction was 34.00˚C, to the south direction was 36.20˚C, and to the north direction was 34.10˚C. The difference was 2.20˚C. The outdoor temperature of the Sim at Maneejun Temple was 34.00˚C, the indoor temperature was 33.90˚C, the temperature at the external wall surface to the west direction was 38.20˚C, to the south direction was 38.50˚C, and to the north was 36.80˚C. The different temperature was 1.70˚C.

It was noted that the MRT inside the buildings of Borom Khongkha Sim and Tariep Sim was less than Maneejun Sim although the orientation faced the east direction. This was because the building shape of Borom Khongkha Sim and Tariep Sim covered with a narrow roof at the base of the gable end made the sunlight unable to reach the wall. So, no heat was generated in the wall. This was considered the wisdom on the design providing the thermal comfort to the building users.

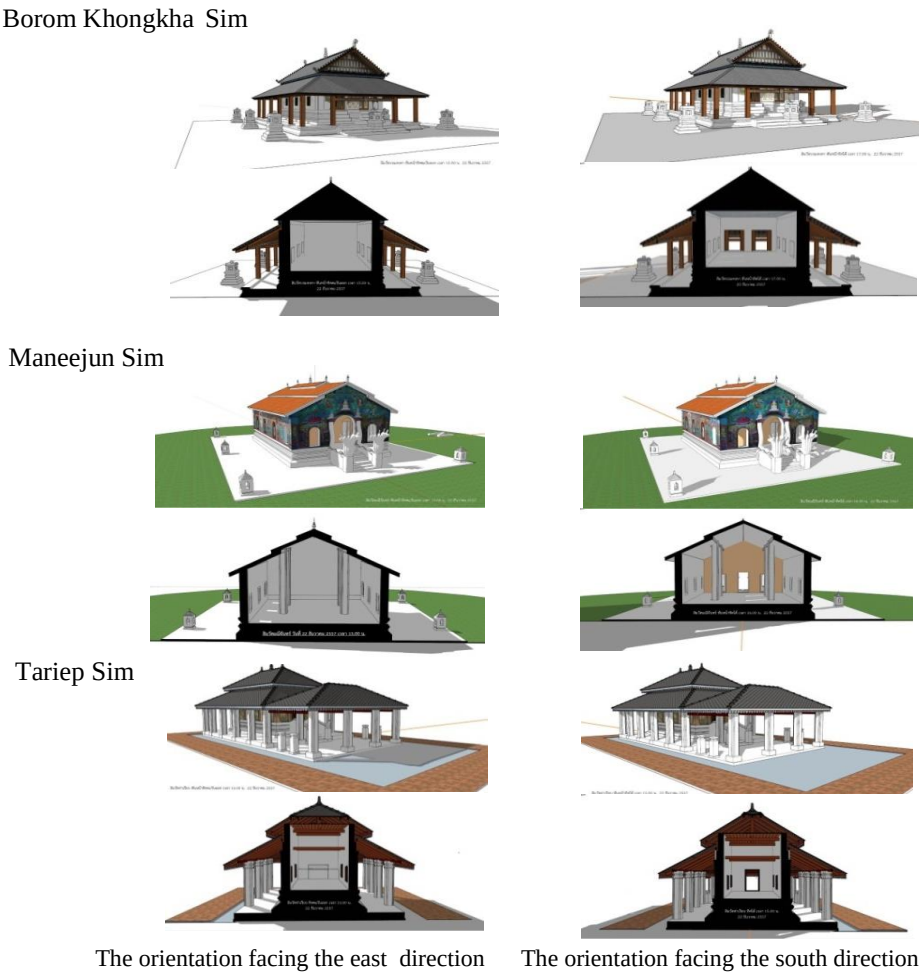

Figure 6: The orientation facing the east direction compared to an orientation model facing the south direction on December 22, 2014. 3 pm.

Discussion

1. The thermal comfort when considered the temperature and the relative humidity recorded from real places in each day, it was found that the average indoor temperatures in those Sims are higher than Victor Olgyay' s comfort zone. This is consistent with Jindawanic (1999 : 45-51) stating that despite the tropical climate of Thailand, Thai architecture has an influence on providing interior comfortable condition through natural ways. The interior comfortable condition means the indoor condition that is cooler than outdoor condition. Although some periods of time of seasons do not meet the thermal comfort created by westerners, the acclimatization and adaptation of Thais make them feel comfortable with friendly environment. Jitkhajonwanich (2007 : 217) concluded that there were some researches revealing that the thermal comfort of people living in tropical regions presented higher temperature and relative humidity than standard value. The main reason is that thermal comfort is strongly correlated with local weather. And most important thing is the adaptation of people making people feel comfortable at all times.

The adaptation and life style of the locals to the thermal comfort plays an important role to create coexistence of human being and environment. This is resulted from the accumulated wisdom as a natural solution, such as adaptation of clothing, adaptation of activity, making use of wind, water, and trees, the change of locations, and modification of architectural elements. Pinkaew and Thongkamsamut (2014) also stated that in summer the air temperature was not in the scope of thermal comfort. So, the I-san people relied on the adaptation by adapting routine activity to the use of building area, and wearing low insulated clothes providing thermal comfort to the body. Jitkhajonwanich (2007) also supported that e acceptable weather conditions of the locals was not in the scope of Victor Olgyay's Bioclimatic Chart (1963). This means that the actual weather does not provide comfortable conditions for the people. The comfortable condition must be resulted from the wind speed of 0.1 - 1.0 m/sec. If the air temperature is above the comfort zone, the wind speed can make it back to the comfortable weather. The wind current touching the skin created high rate of heat loss from evaporation of sweat. This made the body feel cooler. Typically, the indoor wind speed was

about 30-40% of the outdoor wind speed when the ratio of the openings on the wall in that area (Window to Wall Ratio : WWR) was 25-35% (Olgyay, 1962, cited in Thongkamsamut 2014). However, the results found that the average indoor wind speed at the opening area was 121% of the outdoor wind speed, and the indoor wind speed at the blind wall was around 32% of the outdoor wind speed although WWR was less than 25%. This was probably because of the elements that encourage the indoor wind speed due to outdoor wind speed such as outdoor wind speed, wind direction, elements of surrounding location, building orientation, building shape, open space, and indoor decoration.

2. When compared with Jitkhajonwanich's comfort zone (2004) stating that the suitable comfort zone for Thais was within the temperature of 25.6 - 31.5˚C with a relative humidity of 62.2 - 90.0% and the most comfortable temperature of 27.9 - 28.8˚C, the results found that throughout the year those Sims provided the thermal comfort at 30-50%. The results indicated that those Sims were double-layer masonry with the thickness of 40-50 cm. and with the opening area less than 30% when compared with the north or south walls. From the measurement of indoor temperatures which was closed to the outdoor temperature, it was consistent with the researchers' previous study studying the thermal comfort in Sims at Khun Khong Temple, Chaimongkol Temple, and Nongbua Chaopa Temple. It found that the indoor temperature was only 1˚C different from the outdoor temperature. Both temperature and relative humidity were higher than Victor Olgyay's Bioclimatic Chart (Prajonsant et al., 2015), Prajonsant, S. et al. (2016). The results was different from Jiamjit's (2005) stating that the indoor temperature of high-mass building (double-layer masonry and pargeting wall) was quite stable throughout the day. The indoor temperature, during night time, was still higher than the outdoor temperature under the condition of 30% opening area. Or the study of Jindawanic (1999) stated that the masonry wall with the thickness of 0.80 - 1.00 m. and the floor were also high-mass. The very thick masonry wall also had a high thermal resistance. Therefore, the MRT (Mean Radiant Temperature) and the indoor temperature during day time were lower or cooler than the outdoor temperature. However, the air had greatly less specific heat capacity than the mass of the building. So during the night, the

air temperature is dropping faster than the mass of the building. And thermal energy accumulated in the building material during the day evolved into the building. This made the indoor temperature higher than the outdoor temperature. During the day, the indoor temperature was lower than the outdoor temperature, and during the night the indoor temperature was higher than the outdoor temperature.

The reasons why the indoor temperatures at Borom Khongkha Sim, Maneejun Sim, and Tariep Sim were closed to the outdoor temperature during day time and night time might be resulted from the amount of the opening area which were less than 30%, or the thickness of the wall or other factors. However, the average maximum temperature of the wall surface in summer was higher or lower than the outdoor temperature that was less than 2˚C. The buildings using natural solution applied evaluating assumption to compare MRT with the outdoor temperature. It was considered a normal condition when the indoor surface temperature or MRT had the same value as the air temperature. However, it was considered a better condition when the MRT was lower (Jindawanic, 1999). Borom Khongkha Sim and Tariep Sim had lower average indoor temperature at the wall surface than Maneejun Sim although the orientation of these Sims faced the east direction. As the Borom Khongkha Sim and Tariep Sim were surrounded with a veranda and covered with a narrow roof at the base of the gable end, this prevented the sunlight and heat at the wall. When entering the Sim during day time, it provided comfortable condition with the indoor temperature which was 2˚c lower than the outdoor temperature. This was different from the research results probably because the temperature measurement of this research was operated during a period of time when pressing the measurement instrument which was different from standing in the sun with its heat. So, the heat increased constantly over the period of time when standing in the sun.

The results regarding the record of the thermal comfort that the thermal comfort in the Sims was resulted from the use of local wisdom of design and other factors. This was consistent with Thongkamsamut (2014) stating that the local wisdom that creates the thermal comfort use all common factors. This is consistent with Suwannarat (1994), Buranasompop (1996), Suriyothin et al. (1998), Boonyathikarn (1999), Thipyopas (2000), Thongkamsamut (2014).

Conclusion

Local wisdom of architectural design creating thermal comfort in I-san Sims can be explained with the principles of tropical architecture regarding the orientation facing the north-south direction by placing the narrow side of the building to the east-west direction, choosing the shape of the roof which reduces the area contacting the sunlight, using high roof with ventilators under the roof, using narrow and shallow building shape, arranging an indoor space as a hall for ventilation, selecting materials, using ceiling boards which helps in conserving and saving energy, and openings to the north and south direction with ventilation area in opposite position and the same size, building the east-west wall as a blind wall.

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