International Journal of GEOMATE, Aug., 2022, Vol.23, Issue 96, pp.25-31
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2022.96.3061
Geotechnique, Construction Materials and Environment

THERMAL PERFORMANCE OF THE CLEAR BLOCK WALL FOR VENTILATION

*Thana Ananacha[1]

[1] Faculty of Architecture and Design, King Mongkut's University of Technology North Bangkok, Thailand

*Corresponding Author, Received: 16 Dec. 2021, Revised: 22 May 2022, Accepted: 12 June 2022

ABSTRACT: This research proposes a new type of clear block wall (CBW) based on natural ventilation to compare the temperature reduction caused by heat transfer into a building and indoor light, increasing the ventilation efficiency. A house with a single glass wall (SGW) and another with a CBW were considered. The SGW was composed of a clear glass pane. The CBW had three block types, a translucent upper block that served to ventilate the outside, a middle block that served as the vent gap, and a lower block that acted as an air vent from the test house, and each block was 0.20 × 0.20 × 0.08 m in size. The air gap and block openings were 0.068 m in width. The experimental comparative thermal performance between the houses with an SGW and CBW had a surface area of approximately 1.60 m^2. The wall faced south to obtain the most sunlight in the afternoon. Data were collected every 15 minutes. The experimental results showed that the CBW could reduce heat flux through the façade wall up to 58 W/m^2. With the CBW, velocity field measurements indicated that the airflow rate varied between 0.010- and 0.021 m^3/s. The indoor illumination level varied between 300- and 1,054 lx. The indoor temperature of the room equipped with the CBW was lower than that equipped with the SGW by 1.9°C on average and up to 2.9°C while receiving the natural light and reduced glare. A proposed configuration of the CBW is recommended for architecture.

Keywords: Clear block, Daylighting, Façade, Performance, Ventilation

1. INTRODUCTION

The energy crisis has become a crucial issue. The increase in energy demand in residential matters is mainly associated with more heating ventilating and air conditioning (HVAC) equipment. Today, under the present economic crisis, the government tries to reduce energy usage in buildings and industries. Thailand uses energy from many air conditioning systems to counteract the heat from local weather, which is a tropical type. The energy consumption of air conditioning systems is up to 65% of the total energy use in a building. Electrical energy consumption in residences tends to increase every year [1] due to the design of residences in Thailand, which should be consistent with the tropical environment. However, residences have been modified by applying the modern style as the eras change. This style involves an increase in the proportion of transparent or glass material in the building. Allowing natural light but less ventilation affects the heat inside the houses because of direct solar radiation that enters through the glass. The design guidelines for energy conservation state [2] that the amount of heat transferred through glass is 5 – 10 times higher than that of opaque materials. Therefore, transparent material such as glass block or glass is used to prevent heat accumulation inside the houses with natural ventilation by the use of a solar chimney, which has been promoted for the last decade in Thailand, The performance of a partially glazed solar chimney wall was studied [3] by testing the area of transparent material that affect the system by using glass blocks on the outer side with a gypsum aluminum foil board and an acrylic panel, and the opening vents of the wall are equal sizes. The test results show that the area of three-row glass blocks has the greatest effect on the ventilation of a solar chimney, reducing the heat accumulation inside the house while still allowing the natural light into the house. The design of the inclined chimney is with horizontal outlets that are integrated with a triangular roof [4]. Using solar radiation to heat and induce airflow through natural ventilation in the interior of the house by the simulation method to study the performance of the chimney, the effect of the channel depth of a solar chimney was investigated in six configurations under a roof with a slope of 45º. This study confirmed that the more significant the difference in temperature between the inside and the environment was, the more efficient the performance of ventilation. The thermal performance of glazed solar chimney walls (GSCW) [5] that consisted of a double glass pane was investigated. Each glass thickness was 6 mm, with an air layer in the middle compared to a single glass wall (SGW). The study confirmed that the GSCW is highly suitable for hot-weather countries. It could cause a lower room temperature and reduce the heat gain through glass walls, In addition, it allows natural light into the house. After that, double material was developed with an air gap in the middle by using materials other than glass to reduce the material cost. The design of a Trombe wall uses a concrete block [6] the hollow material. The ventilation of the system was studied by simulating solar heat with halogen bulbs. The results show that the highest thermal performance is 52%. From the above literature review, it can be concluded that transparent material can prevent heat accumulation by the natural methods of a solar chimney, and a hollow material is suitable for these methods. This paper introduces the design a of clear block wall (CBW) for heat gain reduction and enhancing natural ventilation performance.

2. RESEARCH SIGNIFICANCE

This research is focused on the design and study of the thermal performance of a CBW with the solar chimney method expressed mainly in terms of ventilation, heat gain reduction, and indoor light. The glass blocks are materials that provide light transmission, and there is air insulation in the blocks, as shown in Fig 1. They are mainly used for decorating walls, such as masonry walls; therefore, air does not flow through the blocks.

Fig.1 Physical characteristics of glass blocks

3. RESEARCH METHODOLOGY

3.1 Solar Chimney

The double-skin, façade-induced ventilation application of the solar chimney concept is the most popular model, as it can be constructed in one of the building components. The basic principle of double planes may be understood by considering a rectangular shape with small ventilation openings. A solar chimney is a type of passive solar heating and cooling system that can be used to regulate building temperature, as well as provide ventilation, The process to prevent heating using a solar chimney is to bring heat from the sun to the building by heat transferred to the chimney. When the solar radiation hits the side of the chimney, it is heated and makes the air less dense. The air then rises to the outlet vent according to the convection principle, and the denser, cooler air flows into the chimney capacity through the inlet vent to create natural ventilation. As shown in Fig 2, several configurations were designed and tested using modern construction materials, including roof tiles, concrete blocks, and gypsum boards. The researchers studied the Trombe wall (TW) [7], the modified Trombe wall (MTW) [8], the metallic solar wall (MSW) [9], the roof solar collector (RSC) [10], the Thai modern façade wall with a fin (TMF-WF) [11], and the double translucent glass wall (DTGW) [12]. The Trombe wall is integrated with double layer phase change material (PCM) [13].

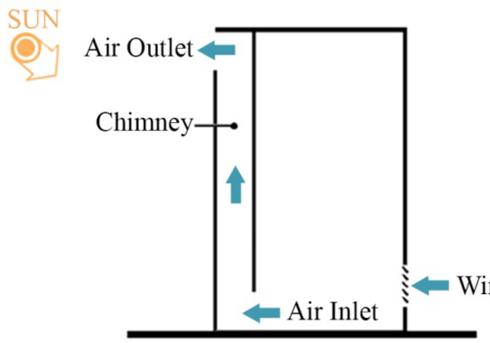

Fig.2 Solar chimney diagram

3.2 Materials Process

The materials process of design development provided the property of vertical stack airflow to the blocks by making a cavity to allow stack airflow, designed a joint between the block instead of using masonry, and providing video of the property of solar chimney performance by adding inlet and outlet vents of the same size based on the air gap sizes in the block. The CBW has three blockttypes: a translucent upper block that ventilates the outside, a middle block that serves as the vent gap, and a lower block that acts as an air vent from the test house. The clear blocks are 0.20 × 0.20 × 0.08 m in volume. The air gap and block openings are 0.068 m in width and are designed as shown in Fig 3.

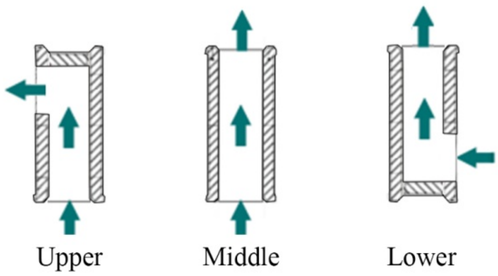

Fig.3 Cavity between the blocks to allow stack airflow

3.3 Experimental Process

The experimental set-up was built at the Rajamangala University of Technology, Suvarnabhumi Suphanburi Campus, 450 Moo 6 Suphanburi - Chainat Rd. Yanyaw, Samchook Suphanburi 72130, Thailand, as shown in Fig 4. The coordinates were 14°720’64” N 100°110’01” E to compare thermal performance in the environment during 2–4 October 2020. Data were collected continuously every 15 minutes for 3 days.

Fig.4 Houses in the experiment

The ambient air temperature, room temperature, and surface temperature at different positions were measured. Type K thermocouples connected to a data logger (Model 8422-52/Hioki) were used to record the temperature at different points of the materials, cavity, ambient air, and room. An air velocity meter (Model VT-100/Kimo) was used to measure the air velocity at the inlet and outlet of the cavity space (range 0.15 to 50 m.s^{-1}). The error of the hot wire anemometer was ±3%. A heat flux sensor (Model HFS-3/Omega) was installed to record the heat flux passing through the wall into the space room. (range: 1 to 1400 W/m^2). The error of the heat flux sensor was ±5%. A pyranometer (Model SP-110/Apogee) was used to measure the solar intensity on the wall (range: 0 to 350 mV). The error was ±5%. A lux meter (Model 545/Testo) was used to measure the indoor and outdoor illuminances on the horizontal plane (range: 0 to 100,000 lux). The error was ±5%, and the positioning is shown in Fig 5, with a description of the various positions as follows:

Temperature measurement positions

SGW

Tg1	=	Outside the clear glass wall
Tg2	=	Inside the clear glass wall
Troom1	=	Center of the room
HF1	=	Inside the SGW

CBW

Tc1	=	Outside the CBW
Tc2	=	Inside the CBW
Tf	=	Middle of the air gap
Troom2	=	Center of the room
HF2	=	Inside the CBW

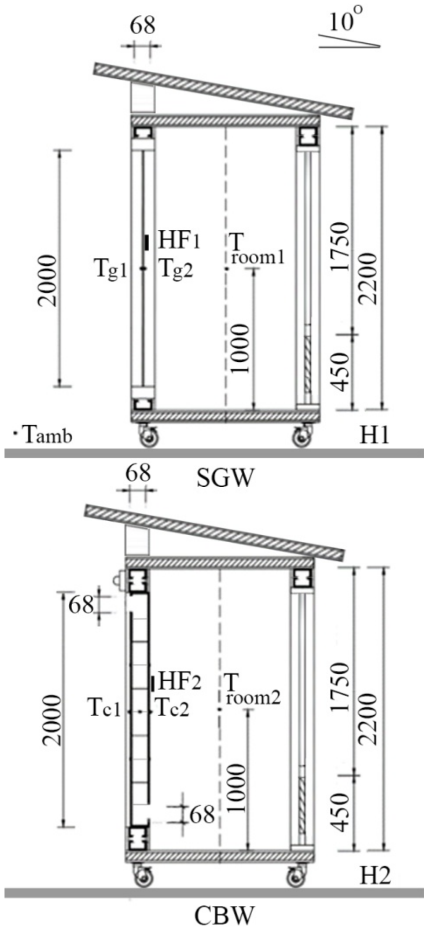

Fig.5 Detector positions outside and inside the house models

4. RESULTS AND DISCUSSIONS

A special focus is made to study the thermal performance and heat gain reduction in the space room. As mentioned, two house models were studied as follows:

4.1 Temperature Profile

Figure 6 compares the temperature of the SGW and CBW outside (SGW; Tg1 and CBW; Tc1) and inside surface (SGW; Tg2 and CBW; Tc2) surfaces on 4 October 2020 The highest temperature is Tg2, which is located on the inside surface, which is affected by the sunlight and heat accumulation in the evening period, while in the same location on the CBW surface (Tc2) is lower by 2 °C. Tc1, which is located on the outside surface of the CBW, is the lowest temperature because of the outside airflow, while the temperature at the same location on the SGW surface (Tg1) is higher by only 0.2 °C.

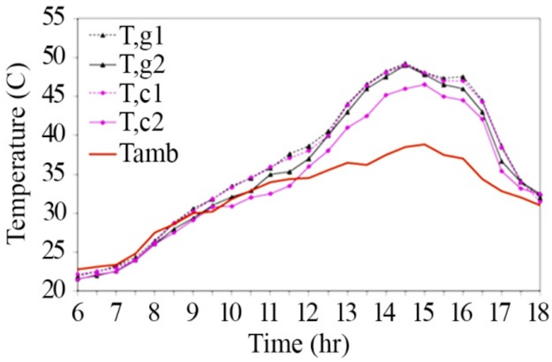

Fig.6 Comparison of the surface temperature of the single glass wall and clear block wall on 04/10/2020

4.2 Air Gap Temperature

Figure 7 compares the room temperature (Troom1, Troom2) and the CBW air gap temperature (Tf). The temperature of the CBW, including Tf, is always higher than Troom1 and Troom2 due to the airflow ventilation of the chimney, while Tf is nearest to Troom1 at 48°C–48.5°2.30–3.00 pm00 pm. The average difference in afternoon temperature between Tf and Troom2 is 2.7°C because of the accumulation of heat in the chimney.

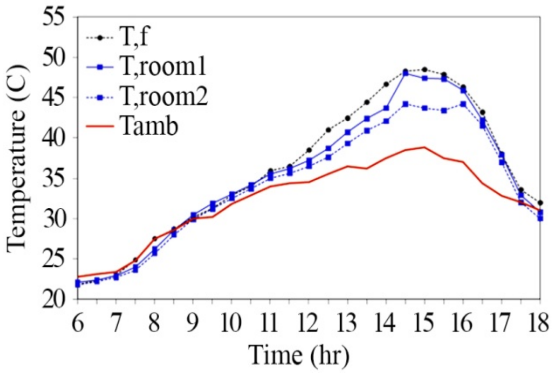

Fig.7 Comparison of room temperature variations in the house models and the clear block wall air gap temperature on 04/10/2020

4.3 Room Temperature

Figure 8 shows the temperature variation in house model H1. The temperature on the surface of the SGW was the highes3:00 pm00 pm, at 49.2°C, while the room temperature (Troom1) higher than the outside temperature during the day. At night, all inside temperature positions on the house model were similar to the outside temperature. Additionally, on the cloudy day of 4 Oct., the gap temperature between each sensor was low but still higher than the outside temperature.

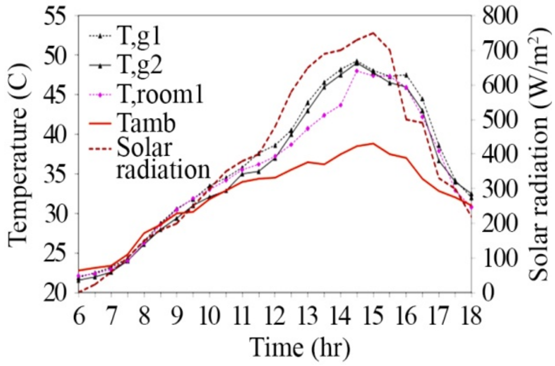

Fig.8 Temperature variations in house model H1 on 04/10/2020

Figure 9 shows the temperature variation in house model H2. The inside surface of CBW (Tc2) had the highest temperature of 46.1°C at 3:00 pm due to heat accumulation on the material, while the air gap temperature (Tf) in Fig 7 was higher than Tamb and Troom2 at 15:00 due to the working principle of the solar chimney. All the temperature positions were always higher than the outside temperature during the day and similar at night.

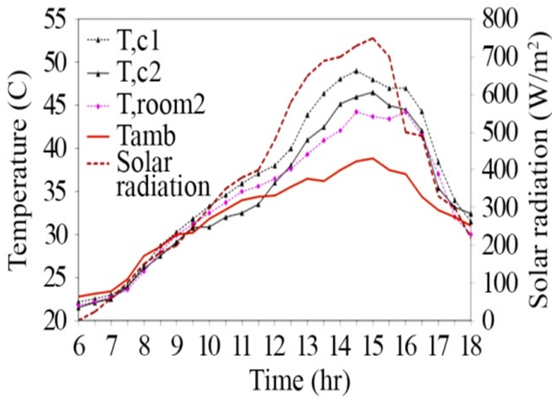

Fig.9 Temperature variations in house model H2 on 04/10/2020

Table 1 shows all the testing temperatures and the average temperature in each house models at the outside and inside surfaces of the material, room, and CBW air gap for 3 days continuously. The highest average temperature was on the inside of the single glass window surface, while the SGW had a higher average room temperature than the CBW by 2.9°C.

Table 1 Summary of measured temperatures

Outside / Inside	Temp. (°C)		Date 1	2	3	Te mp. (°C)
	Min/Max		1	2	3	.g.
Tamb	Min		21.6	22.2	21.5	21.6
	Max		34.6	36.6	37.1	36.2
	Avg.		.272	.284	.280	27.9
SGW	Tg1	Min	21.5	21.3	21.0	21.1
		Max	37.3	47.5	48.2	44.3
		Avg.	.275	30	.302	.291
	Tg2	Min	22.1	21.5	21.7	21.9
		Max	38.8	51.1	51.5	47.1
		Avg.	.287	.312	31.3	.304
	Tg3	Min	21.8	21.7	21.6	21.6
		Max	38.4	49.5	50.1	45.8
		Avg.	.284	30.7	.307	30.1
	Tg4	Min	22.1	22.0	21.8	21.8
		Max	38.8	50.2	52.1	47.1
		Avg.	.287	31	.311	.303
	T room 1	Min	22.1	21.9	21.9	21.8
		Max	38.1	48.5	49.5	45.4
		Avg.	28.4	30.3	31.3	30.1
CBW	Tc1	Min	22.7	22.3	22.1	22.3
		Max	38.4	47.1	48.7	44.4
		Avg.	.286	30.7	.314	.303
	Tc2	Min	22.2	21.9	21.9	21.8
		Max	37.1	48.4	49.7	45.1
		Avg.	.288	30.6	.318	.302
	Tc3	Min	22.1	21.1	22.1	21.6
		Max	38.2	50.2	51.3	46.4
		Avg.	.288	.308	32.1	.305
	Tc4	Min	22.2	21.8	21.7	21.8
		Max	37.7	48.2	50.1	45.4
		Avg.	28.7	30.7	.315	.301
	T room 2	Min	21.8	21.8	21.5	21.5
		Max	36.4	45.5	46.4	42.7
		Avg.	28.1	29.6	30.6	29.6
	T air gap	Min	22.2	22.1	22.2	22.3
		Max	36.3	47.8	48.2	44.3
		Avg.	28.4	30.4	.312	.302

SGW, single glass wall; CBW, clear block wall

4.4 Heat Flux

Figure 10 shows the hourly variations in the heat flux of the walls. The heat flux depended on soladiation. With global solar radiation of approximately 751 W/m^2, the heat flux of the SGW was approximately 32 W/m^2 above that of the CBW. Therefore, the CBW can reduce heat gain admission through the façade and decrease the indoor temperature to near the ambient temperature.

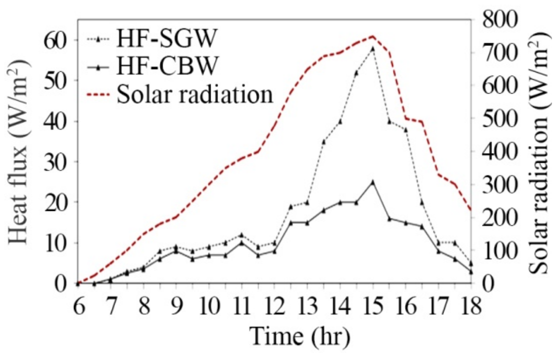

Fig.10 Hourly variations in heat flux and solar radiation of the SGW and CBW on 04/10/2020

4.5 Percentage heat flux reduction

Figure 11 compares the SGW and CBW. The heat flux of the CBW is lower than that of the SGW by 1–5 W/m^2. Between 6.00 am- and 13.01.00 pmen the natural ventilation was low, and the percentage of heat flux reduction varied between 17%- and 33%. In the afternoon, the CBW seems to perform much better than the SGW, as heat flux reduction is quite high, 2%–58%.

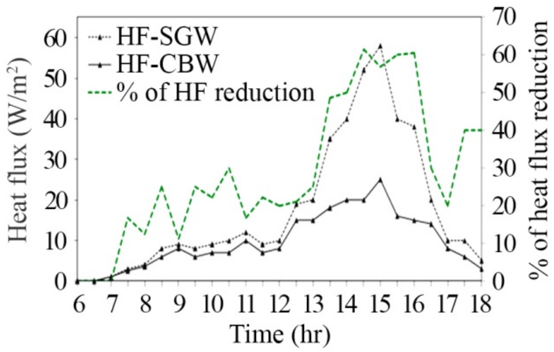

Fig.11 Hourly variations in heat flux and percentage heat flux reduction of SGW and CBW on 04/10/2020

4.6 Airflow Rate

The measured air velocity was used to calculate the air volume flow rate induced by the walls as follows:

$$Q = A \cdot v \quad (1)$$

where Q is the air volume flow rate (m^3/s), A is the surface area of an opening (m^2), and v is the average air velocity (m/s) of the measured data at the inlet and outlet airflows of the CBW. The number of air changes in the space room per hour (ACH) can be estimated by:

$$ACH = \frac{3600Q}{V} \quad (2)$$

where V is the volume of the space room.

The ventilation induced by the CBW is shown in Fig 12. The airflow rate varied by 0.01–0.02 m/s^3 or 4–10 ACH between 8.00 am and 5.00 pm, as shown in Fig 13, following the solar radiation. The highest induced ventilation was obtained by the CBW configuration because of higher heat admission. It is therefore well confirmed that CBW configurations can ensure a significant ventilation rate that can contribute significantly to improving the occupants' thermal comfort.

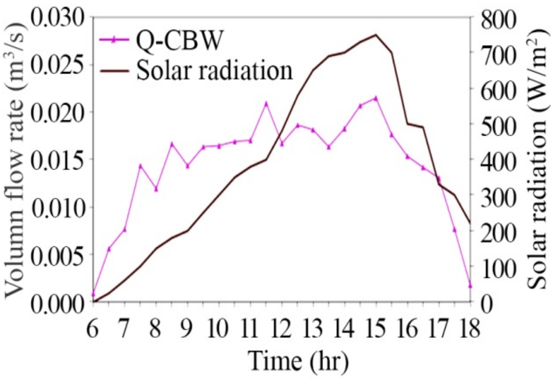

Fig.12 Hourly variations in the volume flow rate and solar radiation of the CBW on 04/10/2020

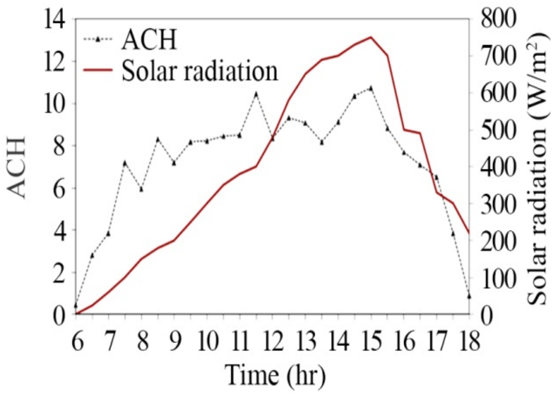

Fig. 13 Hourly variations in the air change and solar radiation of the CBW on 04/10/2020

4.7 Daylighting

Figure 14 shows plots of the measured indoor illumination at the reference point (center room) and the natural light in the space room for the SGW and CBW. The indoor illumination level varied depending on the outdoor illumination. The indoor illumination was approximately 1355 and 1054 lx at the center room at 15:00 and higher than that of the CBW in the same position. The fluctuation in indoor illumination depended closely on solar intensity. Finally, it can be concluded that the CBW can provide sufficient lighting for indoor tasks, satisfying the recommended illumination level of 300 lx.

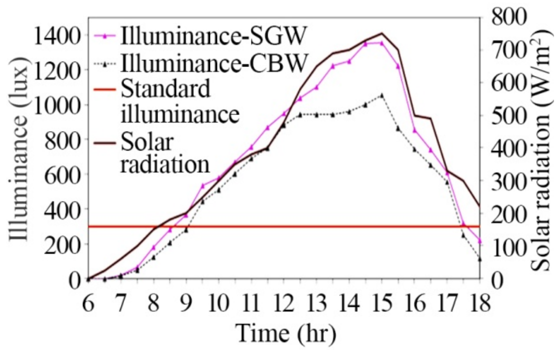

Fig.14 Hourly variations in illuminance and solar radiation of the SGW and CBW on 04/10/2020

5. CONCLUSION

The experimental results for the thermal performance of the SGW and CBW were presented. The room temperature of the CBW was always lower than that of the SGW. With this CBW, field testing indicated that no overheating was observed, as room temperature was always near or below the ambient temperature, which is extremely interesting. The induced ventilation and corresponding air change were quite high, varying between 2 and 11 per 1.6 m^2 of the surface area of the CBW. The amount of daylight delivery by the CBW through the translucent block wall was sufficient, as recommended by international standards. Its additional advantage is glare-free operation, as only indirect daylight was permitted. With these characteristics, the CBW should lead to achieving thermal comfort without any mechanical devices during the daytime when the outdoor temperature is not excessive. This innovative concept could be applied to other house components, such as the building envelope.

6. ACKNOWLEDGMENTS

The authors are grateful to the Faculty of Architecture and Design and King Mongkut's

University of Technology North Bangkok for the experimental equipment to do the research work.

7. REFERENCES

[1] Randazzo T., De Cian E., Mistry M.N. (2020). "Air conditioning and electricity expenditure: The role of climate in temperate countries", Economic Modeling, Vol.90, pp.273-287.

[2] ManokarA ., Winston D. (2017). "Experimental Analysis of Single Basin Single Slope Finned Acrylic Solar Still", Materials Today, Vol.4(8), pp.7234-7239.

[3] Shi L., Zhang G., Yang W., Huang D., Cheng X., Setunge S. (2018). "Determining the influencing factors on the performance of solar chimney in buildings", Renewable and Sustainable Energy Reviews, Vol.88, pp. 223-238.

[4] Sahabuddin L., Baharuddin H., Ramli R., Rosady M., Andi Erwin Eka P. (2019). "Study of the heat ventilation with an inclined chimney in the Attic", International Journal of geomate, Vol.17(64), pp.178-184.

[5] Chantawong P., Hirunlabh J., Zeghmati B., Khedari J., Teekasup S., Win M.M. (2016). "Investigation on the thermal performance of glazed solar chimney walls", Solar Energy Vol.80(3), pp.288-297.

[6] Souayfane F., Fardoun P., Farouk F. (2018). "Thermal behavior of a translucent superinsulated latent heat energy storage wall in the summertime", Applied Energy, Vol.217, pp.390-408

[7] Rabani M., Rabani M. (2019). "Heating performance enhancement of a new design Trombe wall using rectangular thermal fin arrays: An experimental approach", Journal of Energy Storage, Vol.24, pp 1-15.

[8] Khedari J., Lertsatitthanakorn C., Pratinthong N., Hirunlabh J., (1998), "The Modified Trombe Wall: A simple ventilation means and an efficient insulating material", The International Journal of Ambient Energy, Vol. 19(2), pp. 104-110.

[9] Hirunlabh J., Kongduang W., Namprakai P., Khedari J., (1999), "Study of natural ventilation of houses by a metallic solar wall under tropical climate", Renewable Energy, Vol. 18, pp. 109-119.

[10] Khedari J., Mansirisub W., Chaima S., Pratinthong, N., Hirunlabh, J. (2000), "Field measurements of the performance of roof solar collector", Energy and Building, Vol. 31, pp. 171-178.

[11] Ananacha T., Puangsombut W., Hirunlabh J., Khedari J. (2013). "Field Investigation of the Thermal Performance of the Thai Modern Façade Wall", The International Journal of Ventilation, Vol.12(3), pp. 223-234.

[12] Ananacha T. (2014). "Experimental Performance and Numerical Simulation of Double Glass Wall", International Journal of Architectural and Environmental Engineering Vol. 8(11), pp.1184-1190.

[13] Shanshan L., Na Z., Pingfang H., Lei F., Renjie D. (2019). "Numerical study on the thermal performance of PCM Trombe Wall", Energy Procedia, Vol.158, pp.2441-2447.

CBW	= Clear Block Wall
SGW	= Single Glass Wall
GSCW	= Glazed Solar Chimney Walls
TW	= Trombe Wall
MTW	= Modified Trombe Wall
MSW	= Metallic Solar Wall
RSC	= Roof Solar Collector
TMFWF	= Thai Modern Façade Wall with Fin
DTGW	= Double Translucent Glass Wall
PCM	= Phase Change Material
ACH	= Air Change per Hour
HVAC	= Heating Ventilation and Air Conditioning