

THE INFLUENCE OF BUILDING ENVELOPES TOWARDS INDOOR CLASSROOM TEMPERATURE (CASE: BINUS ALAM SUTERA CAMPUS)

Rivanus Dewanto
Program Studi Magister Arsitektur, Universitas Trisakti
email: rivanus.dewanto@gmail.com

ABSTRACT

The building façade of BINUS Alam Sutera campus is designed with wall variations of building envelope both in terms of material use and of openings volume. These conditions encourage the researcher to observe how much the indoor temperature difference in the classroom is correlated to the wall completion of the building envelope. The method used was by measuring indoor and outdoor temperatures at the same time periods (morning, midday, and afternoon) from the classrooms in different floors. The result of the study reveals that indoor temperature increases relatively towards the sun orientation of north-northeast and of west-southwest. The building envelope with precast concrete and window-wall affects indoor temperature relatively higher in the morning and lower in the afternoon. Whereas the building envelope with precast concrete of dead-glass variation affects indoor temperature relatively lower in the morning yet higher in the afternoon.

Keywords: *Building envelopes, indoor temperature, classrooms*

INTRODUCTION

The design of façade should be processed on the basis of building requirements that respond to aesthetics, climate, and weather conditions. Proper processing and selection of materials as well as forming these elements play an important role in the design of façade. Optimization becomes the basis of innovation. As technology develops to speed up the process of construction time, fabrication materials or precast system can be the

right choice which has been widely applied to tall buildings. In addition to aesthetics, the building façade has another important function as to block the heat-rate into the building. Apart from that, a good façade should also reveal the building needs as the basis of its approach. This study emphasises on a comparison between the use of several types of building envelope and the value of indoor temperature measurement. The question arises in terms of how much the indoor temperature value compares to different building envelopes.

Some similar studies conducted previously include: Energy conservation analysis through building envelopes Loekita (2006) which shows that building envelopes with WWR $\leq 0,40$ produce OTTV values that meet the standards. Naga Artha Prakoso and Alexius Kapitan Lamahala (2014) through the Study of material application in building envelopes that affect thermal and visual comfort demonstrate that thermal comfort is influenced by the quality of thermal comfort, the choice of building envelope material, and the extent of transparent material. Whereas visual comfort is influenced by the type of lighting system, the type of lamp used, and the direction and scope of the light. Through the Study of tradition and innovation of high building façade material, Priatman (2003) highlights that convention exterior materials used for building facades include *Cementitious Materials* (cement materials) cement as the main binder; which can be reinforced concrete (precast or cast in place) with additives, casting, and cement sheets.

The development of a relatively new cement material is *fibre reinforced*

concrete (FRC) which is the combination of Portland cement and special fibre, i.e. steel, glass, organic polymers, ceramics, and other materials. *Glass-fibre reinforced concrete* (GFRC) is a future façade material with its advantages that are lighter, more flexible, and can withstand more tensile strength as well as can save the cost of structure due to reduction in the weight of material. Handayani (2010) conducts research on Energy Efficiency in Building Design reveals that saving in energy use, among others are influenced by tropical climate, environmental quality, building direction, building plans, and building materials.

Indoor temperature measurement of classroom at BINUS Alam Sutera campus signifies the previous findings which are focusing on the influence of the type of building envelopes on the indoor temperature.

THEORETICAL FRAMEWORK

Vitruvius (M H Morgan, 1960) states that an architectural building needs to fulfil *Utilitas/function*, *Firmitas/sturdy*, *Venusitas/beauty* and *material*. *Utility* is influenced by site plan, spatial planning and module/spatial area. *Firmity* is influenced by safe material, strong structure and weather resistance. *Venusity* is influenced by phase, scale and proportion, and material used. *Material* is influenced by the type, the area of material, and the ability to withstand indoor heat temperature, and sun orientation. Building envelope is determined by the orientation and the height of the building (number and height among floors).

ASHRAE 5592 and SNI International Comfort Standard (ASHRAE Standard Project Committee, 2004) provide a reference to average air temperature that meets the required comfort zone which is between 23 °C to 26 °C. Several studies conducted by Nugroho (2011), Henry Feriadi (2004), Sahabuddin Latif and Baharuddin Hamzah (2014), as well as Santoso (2012), emphasize that in humid tropical regions with several types of

buildings, neutral temperatures range between 26.1°C – 29.8 °C. Studies show that the difficulty in achieving neutral temperatures in line with thermal comfort zone is affected by several factors. The factors include the design with high sun-radiation (Nugroho, 2011), air circulation caused by relatively small air velocity and high humidity due to climatic factors (tropical humid).

Standard of thermal comfort zone in Indonesia (based on effective temperature) SNI T-14-1993-037:

Uncomfortable-cold (TE) $\leq 20.5^{\circ}\text{C}$

Cool-comfortable (TE) = $20.5^{\circ}\text{C} - 22.8^{\circ}\text{C}$

Optimal-comfort (TE) = $22.8^{\circ}\text{C} - 25.8^{\circ}\text{C}$

Warm-comfortable (TE) = $25.8^{\circ}\text{C} - 27.2^{\circ}\text{C}$

Uncomfortable-heat (TE) $\geq 27.2^{\circ}\text{C}$

As for the building envelope with reflective glass material, the aluminium composite panel has a maximum value of 29°C-30°C.

METHOD

The purpose of this study is to determine the differences between classroom temperature and façade settlement at BINUS campus building. This study conducted quantitatively by using a thermometer as a measurement instrument. The measurements were conducted within three-period of time (1) in the morning (09.15 – 09.30 WIB, sunshine from the East), in the middle of the day (12.00 – 12.30 WIB, sunlight is directly above the building) and in the afternoon (15.00 – 15.40 WIB, sun-ray is from the West).

Temperature measurements are carried out simultaneously at the specific time period in each room on different floors. Rooms measured are those with different façade settlements and different room positions. The height of the measurement point is of 1.2 meters from the floor. The height is based on the dominant activity of students' position while learning which is the dominant temperatures felt by the students. The measurement points in the classroom comprise three positions: (1) a point of two-meter distance from sun-

exposed, (2) a point in the middle of the classroom as the centre of students' sitting area, and (3) a point in a position adjacent to the whiteboard. The results of three points measurement are calculated in order to get the average point.

as well as reduce the noise levels from adjacent roads. There is a terrace and a balcony on each side of the building allowing light and air to enter into each side of the room. The building uses basic module of 8 x 8 (meter) and multiples so that the class are ranges from 64 to 80 m².

The building of BINUS campus consists of 22-floor on its tower and 5-podium floors and 1 basement floor. There are 2-floor of supporting facilities placed around the tower which provides open space given optimal air circulation. The height of the floor in the building varies from 4.25 to 6.25 meters which expected to reduce

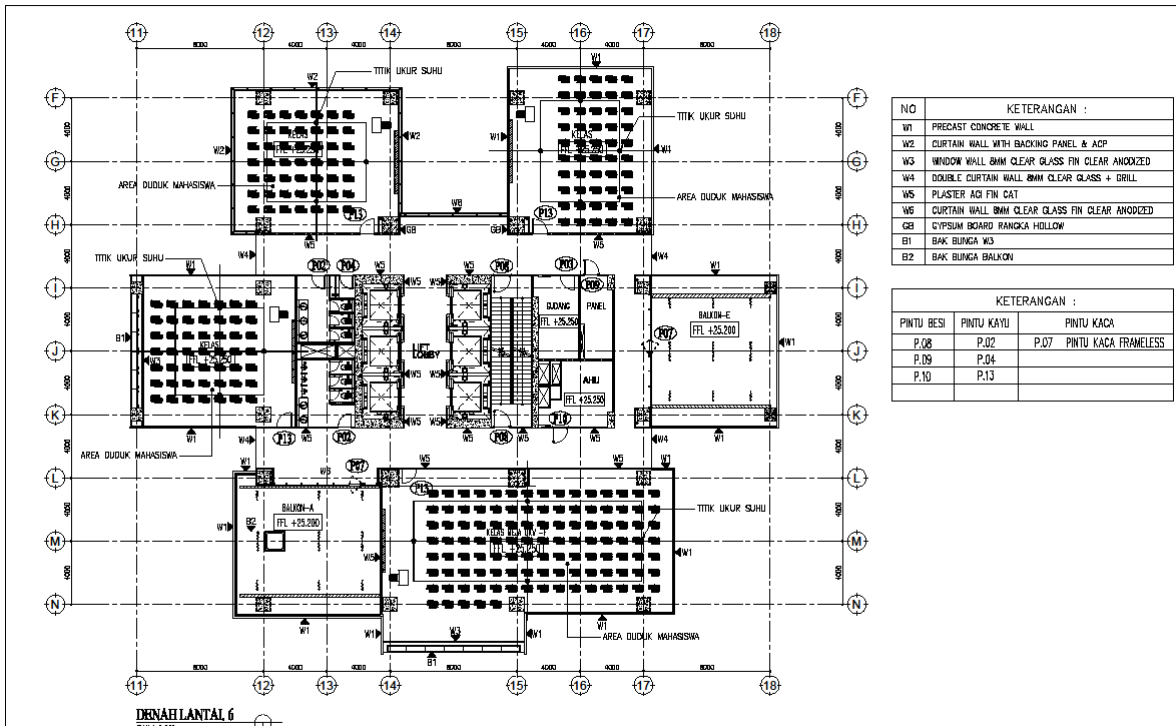


Figure 1: Examples of measurement at the position of the measuring point on the 6th floor plan

heat in the room.

DISCUSSION

The site of the building is rectangular with an area of approximately 5 hectares (50.000 m²), with the elevation of land contours ranging from minus 2 to 3 meters from the road elevation. The building mass is in the southern position adjacent to the lake with the hope that it can reduce heat and can contribute to visual comfort

Measurement was carried out within 3-period of time, first: in the morning at 09.15 – 09.30 WIB, when the sunlight is in the east position with an average outdoor temperature 33,1° C to 35.5° C. Second: in the middle of the day at 12.00 – 12.30 WIB, when the sunlight is directly above

the building and the average outdoor temperature is 35.8° C – 36,3 °C. Third: in the afternoon at 15.00 – 15.40 WIB, when the sun is coming from the west with an average outdoor temperature is 36,3°C – 36.8°C.

The material of building envelope whose room temperature is measured using 3-type of materials with variation in the openings in the form of dead-glass window and aluminium composite panels, namely:

- 1) Building envelope with precast concrete material, 10 cm thickness, K500 concrete quality and dead-glass window variations (8mm reflective glass) whose placement pattern is random, so that the calculated volume opening will vary on each floor.
- 2) Building envelope with lightweight brick material, 13cm thickness (including plastering) and opening variations in the form of 8mm clear-glass covered by roller-blind curtains.
- 3) Building envelope of curtainwall of reflective-glass 8mm and variation of aluminium composite panels with random placement pattern so that the volume is varied on each floor.

When referring to the results of classroom measurements in the morning, midday, and afternoon (see table-1), the concrete precast and light-brick plastering have obtained almost the same value that is an average of 26°C - 29° C (the average value is influenced by variations in the amount and the type of dead-glass measured by the time and position of sun orientation). However, the results of both measurements remained lower 1°C to 1.2°C compared to building envelope using curtainwall and 8mm reflective-glass, and varied with aluminium composite panel and roller-blind.

The following is an illustration of the results of temperature measurements in graphical form according to the position of southeast, south/southwest, southeast/south, southwest, and west position.

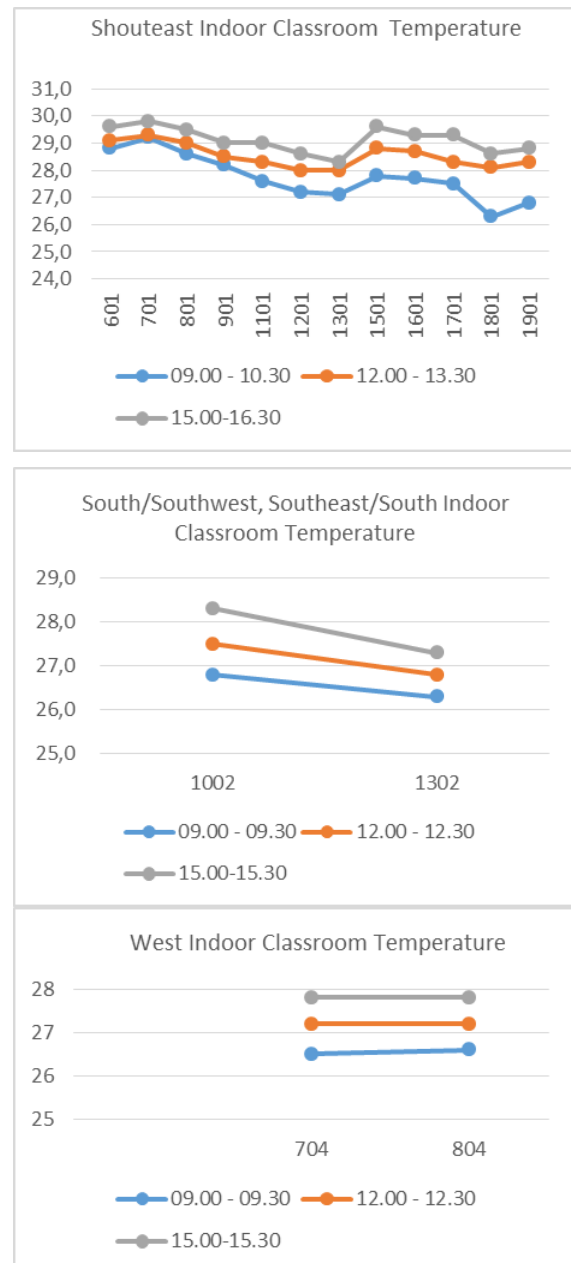


Figure 2. Indoor classroom temperature and classroom position -1

Table 1. The results of classroom measurement from 6th to 19th floors of BINUS Alam Sutera Campus (Measurements were conducted in the classrooms prior to the air conditioner is operated).

NO	FLOOR NUMBER	ROOM NUMBER	FACADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
1	6	601	CW glass variations of Aluminum Composite Panel	Southeast	28,8	29,1	29,6
	7	701	CW glass variations of Aluminum Composite Panel	Southeast	29,2	29,3	29,8
	8	801	CW glass variations of Aluminum Composite Panel	Southeast	28,6	29	29,5
	9	901	CW glass variations of Aluminum Composite Panel	Southeast	28,2	28,5	29
	10	BALCONY					
	11	1101	CW glass variations of Aluminum Composite Panel	Southeast	27,6	28,3	29
	12	1201	CW glass variations of Aluminum Composite Panel	Southeast	27,2	28	28,6
	13	1301	CW glass variations of Aluminum Composite Panel	Southeast	27,1	28	28,3
	14	BALCONY					
	15	1501	CW glass variations of Aluminum Composite Panel	Southeast	27,8	28,8	29,6
	16	1601	CW glass variations of Aluminum Composite Panel	Southeast	27,7	28,7	29,3
	17	1701	CW glass variations of Aluminum Composite Panel	Southeast	27,5	28,3	29,3
	18	1801	CW glass variations of Aluminum Composite Panel	Southeast	26,3	28,1	28,6
	19	1901	CW glass variations of Aluminum Composite Panel	Southeast	26,8	28,3	28,8
NO	FLOOR NUMBER	ROOM NUMBER	FACADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
2	6	VOID					
	7	BALCONY					
	8	BALCONY					
	9	BALCONY					
	10	1002	Precast Concrete with window wall variations	South/Southwest	26,8	27,5	28,3
	11	BALCONY					
	12	BALCONY					
	13	1302	Precast Concrete with window wall variations	southeast/South	26,3	26,8	27,3
	14	BALCONY					
	15	BALCONY					
	16	BALCONY					
	17	BALCONY					
	18	void					
	19	Void					
NO	FLOOR NUMBER	ROOM NUMBER	FASADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
3	6	603	Precast Concrete with glass variations	Southwest	26,7	27,3	28,1
	7	BALCONY					
	8	803	Precast Concrete with glass variations	Southwest	27,1	27,8	28,6
	9	903	Precast Concrete with glass variations	Southwest	27,2	27,8	28,6
	10	BALCONY					
	11	1103	Precast Concrete with glass variations	Southwest	27	27,7	28,6
	12	1203	Precast Concrete with glass variations	Southwest	27,1	27,8	28,6
	13	BALCONY					
	14	1403	Brickwall with window wall variations	South/Southwest	27	27,3	27,8
	15	1503	Precast Concrete with glass variations	Southwest	26,8	27,5	28,6
	16	1603	Precast Concrete with glass variations	Southwest	26,8	27,7	28,5
	17	1703	Precast Concrete with glass variations	Southwest	28,1	28,8	29,8
	18	1803	CW glass variations of Aluminum Composite Panel	Northeast	28	29	30,1
	19	1903	CW glass variations of Aluminum Composite Panel	Northeast	29,3	29,7	31,3
NO	FLOOR NUMBER	ROOM NUMBER	FACADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
4	6	BALCONY					
	7	704	Precast Concrete with window wall variations	West	26,5	27,2	27,8
	8	804	Precast Concrete with window wall variations	West	26,6	27,2	27,8
	9	BALCONY					
	10	BALCONY					
	11	BALCONY					
	12	BALCONY					
	13	BALCONY					
	14	BALCONY					
	15	BALCONY					
	16	BALCONY					
	17	BALCONY					
	18	BALCONY					
	19	BALCONY					

NO	FLOOR NUMBER	ROOM NUMBER	FACADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
5	7	705	Precast Concrete with glass variations	Northwest	26,2	26,8	27,7
	8	805	Precast Concrete with glass variations	Northwest	26,5	27,2	28,1
	9	905	Precast Concrete with glass variations	Northwest	26,7	27,5	28,3
	10	1005	Precast Concrete with glass variations	Northwest	27,1	27,8	28,8
	11	1205	Precast Concrete with window wall variations	Northwest/North	26,5	27,1	27,7
	12	BALCONY					
	13	1305	Precast Concrete with glass variations	Northwest	25,8	26,6	27,3
	14	1405	Precast Concrete with glass variations	Northwest	28,6	27,3	28,2
	15	BALCONY					
	16	1605	Precast Concrete with glass variations	Northwest	25,8	26,6	27,6
	17	1705	Precast Concrete with glass variations	Northwest	25,8	26,8	27,7
	18	1805		Northwest	29,1	30,1	29,7
	19	1905		Northwest	29,1	30,2	28,8
NO	FLOOR NUMBER	ROOM NUMBER	FACADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
6	6	BALCONY					
	7	BALCONY					
	8	BALCONY					
	9	BALCONY					
	10	BALCONY					
	11	1106	Precast Concrete with glass variations	Northwest/North	26	26,5	27
	12	BALCONY					
	13	BALCONY					
	14	BALCONY					
	15	1506	Brickwall with window wall variations	North	26	26,5	27,1
	16	1606	Precast Concrete with window wall variations	North	26,3	27	27,6
	17	BALCONY					
	18	BALCONY					
	19	BALCONY					
NO	FLOOR NUMBER	ROOM NUMBER	FASADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
7	6	BALCONY					
	7	707	Precast Concrete with glass variations	Northeast	27,3	28,1	28,6
	8	807	Precast Concrete with glass variations	Northeast	27	27,8	28,3
	9	907	Precast Concrete with glass variations	Northeast	26,3	27,2	27,7
	10	1007	Precast Concrete with glass variations	Northeast	25,6	26,3	26,8
	11	1107	Precast Concrete with glass variations	Northeast	27,2	28	28,5
	12	BALCONY					
	13	1307	Precast Concrete with glass variations	Northeast	26,8	27,7	28,3
	14	1407	Precast Concrete with glass variations	Northeast	27	27,8	28,5
	15	1507	Precast Concrete with glass variations	Northeast	27	28	28,6
	16	BALKON					
	17	1707	CW glass variations of Aluminum Composite Panel	Northeast	28,6	28,6	29
	18	BALCONY					
	19	BALCONY					
NO	FLOOR NUMBER	ROOM NUMBER	FACADE MATERIAL	ROOM POSITION	ROOM TEMPERATURE		
					09.00 - 10.30 AM °C	12.00 - 13.30 PM °C	15.00 - 16.30 PM °C
8	6	608	Precast Concrete with window wall variations	East	27,1	28,1	28,3
	7	708	Precast Concrete with window wall variations	East	27,6	28,1	29
	8	BALCONY					
	9	908	Precast Concrete with window wall variations	East	28,8	29,5	29,6
	10	1008	Precast Concrete with window wall variations	East	28,2	29	29,3
	11	BALCONY					
	12	1208	Precast Concrete with window wall variations	East	32,7	33,2	33,7
	13	lab secretary	Precast Concrete with window wall variations	East	27	27,8	28,1
	14	BALCONY					
	15	BALCONY					
	16	lab secretary	Precast Concrete with window wall variations	East	27,3	28,3	28,7
	17	lab secretary	Precast Concrete with window wall variations	East	28,1	29,1	29,3
	18	BALCONY					
	19	BALCONY					

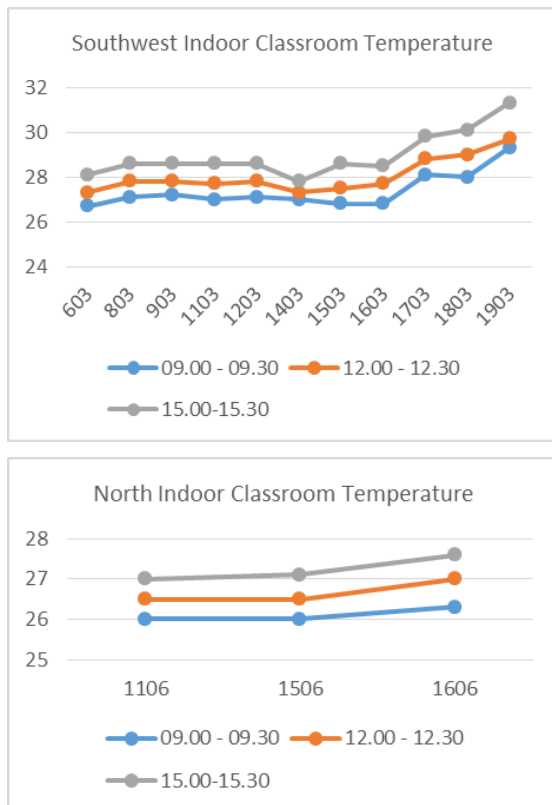


Figure 3. Indoor classroom temperature and classroom position -2

The above graphs demonstrate the increasing temperature towards afternoon of all measurement positions and measurement times. The dynamics of the measurement results are influenced by the size of the windowpanes on each side of the building envelope.



Gambar 5. Precast concrete-walls and dead-window variations

In addition to the quality factor in the classroom and the material of building envelope, the value of room temperature is affected by outdoor temperature which is directly related to sun orientation.



Gambar 4. Lightweight-brick wall finishing with plaster variation of window-wall (above) and reflective-glass curtainwall with ACP variation and roller-blind (below)

The measurement of outdoor temperature in the morning (09.00 WIB) was 35.1°C. This temperature continued to increase so that at 12.00 noon was 35.8°C – 36.3°C, and increased again at 15.00 WIB to 36.8°C. The range of measurement results for each settlement of building envelope and its position was the same as the findings on Table 2.

The relative temperature values of the measurement results indicate that the room temperature in the position of north-west-south-south direction is relatively lower than the room temperature in the relatively higher east-northeast-west-southwest position. A room with a precast concrete wall-sheath and window-wall has a relatively higher indoor temperature compared to varying glass-precast sheaths with the direction of sun orientation and the difference in the volume of openings on the wall. Thus, further research is needed to prove (1) whether the completion of the precast wall with a certain window wall and volume is more effective in lowering the room temperature compared to the precast sheath wall with dead-glass variations; (2) whether the two solutions, based on the measurement results, determine the

decision in which direction the placement of

Table 2. The range of measurement results of each building envelope and class position

Classroom position	Building skin types finishing	Indoor Classroom Temperature Range (09.00 WIB to 15.00 WIB)	Difference of Indoor Classroom Temperature	Outdoor Classroom Temperature
East	Precast concrete with window-wall	27.1°C-33.7°C	6.6°C	09.00 WIB: 35.1°C 12.00 WIB: 35.8°C – 36.3°C 15.00 WIB : 36.8°C
Northeast	Precast concrete of dead-glass variation	25.6°C-29°C	3.4°C	
North	Precast concrete with dead-glass variation	26°C-27.6°C	1.6°C	
West	Precat concrete with Window-wall	26.5°C-27.8°C	1.3°C	
Southwest	Precast dead-glass variation	26.7°C-31.3°C	4.6°C	
South/Southwest	Precast with window-wall	26.3°C-28.3°C	2°C	

the building envelope is more appropriate so that it can reduce the temperature in the room.

CONCLUSION

Based on the preliminary research, it can be concluded that the increase in the classroom temperature at BINUS Alam Sutera Campus is in the west-southwest and east-northeast. The indoor relative temperatures are ranging from 25.6°C (lowest) to 33.3°C (highest), with the absence of air conditioner and based on the standard thermal comfort zone in Indonesia (effective temperature): SNI T-14-1993-037 is categorized as warm-comfortable to uncomfortable hot temperature. The findings of this preliminary research reveal that the sun orientation in the direction of west-southwest and east-northeast have a major effect on the increasing of room temperature. Classroom with concrete precast and window walls have a relatively higher indoor temperature in the morning and lower in the afternoon. Whereas classrooms with precast concrete dead-glass variations have a relatively lower temperature in the morning but are higher in the afternoon.

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