

Pupils Thermal Tolerance at School Buildings Cases At Tropical Country Indonesia

Luhur Sapto Pamungkas

Doctoral Program of Architecture and Planning
Faculty of Engineering, Universitas Gadjah Mada
Yogyakarta, Indonesia

Yoyok Wahyu Subroto

Doctoral Program of Architecture and Planning
Faculty of Engineering, Universitas Gadjah Mada
Yogyakarta, Indonesia

Abstract—This paper is a literature review from a number of thermal studies in the school environment in the tropics. Ideally a school is made for the convenience of students during the effective learning process in the classroom. The results showed that almost all schools in the tropics that use natural ventilation are thermally uncomfortable. The sensation of heat felt especially during the daytime provides thermal pressure which causes discomfort to students. It is interesting that school students in the tropics who are accustomed to high temperatures are able to tolerate thermal at least between 1°C to 12°C from the effective temperature ranging from 24°C - 26°C.

Keywords—School Building, Thermal, Thermal Adaptive, Tropic, Indonesia

I. INTRODUCTION

There are two dichotomies that have developed in a number of thermal studies, namely physiologically thermally and thermally adaptive which later also develop into thermo-adaptive physiologically adaptive and thermo-adaptive psychology. Adaptive thermals is the evolution of thermal research that is more dynamic than conventional thermal theories that are phenomenally developed by Fanger [1, 2]. Fanger put forward adaptive thermal by using thermal sensations PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) in addition to thermal measurements of temperature, humidity, air velocity, clothing, and metabolism.

Fanger made his theory with thermal experiments that would bring up the same thermal comfort standards at the same room temperature and activity. This theory then began to be criticized because humans generally have different activities, humans have close links with temperature and previous thermal experiences [3, 4]. This is the importance of the adaptive thermal position in the school environment in the tropics especially in classrooms when it is associated with Fanger's adaptive thermal theory. The reason is that currently schools in the tropics still use natural ventilation, and most students can adapt to tropical temperatures reaching 30°C or more. The thermal tolerance of students in tropical climate schools is quite high compared to standard thermal in general. This is because they are already accustomed to adapt to the thermals which are quite high as the opinion proposed by Auliciems[5] as thermos adaptive.

Antithesis of this condition is the existence of a number of studies in various parts of the world that have claimed that children, especially at the age of primary education, have a higher level of thermal sensitivity than adults [6-10]. Thermal

is thought not only to affect health but also mood, comfort in space, and achievement.

This paper is a review that will discuss the thermal conditions and the level of thermal tolerance of school children in Indonesia based on a number of previous studies. As a comparison, there will also be a review of research results related to thermal tolerance in the school environment in a number of countries that have a tropical climate such as Indonesia. As stated in the research of Karyono [11] that Indonesia is a tropical country that has a climate with high temperatures due to solar radiation falling on the surface almost perpendicular to daylight throughout the year. The high radiation results in high evaporation which triggers an increase in humidity as well as an average temperature between 20°C-30°C even at certain times outdoor temperatures can reach more than 36°C as often occurs in several cities in Indonesia today [12] which directly affects the temperature in the room.

II. LITERATURE REVIEW

A. Standard of Thermal Comfort in Tropical Regions

Thermal research conducted in Indonesia relating to thermal comfort standards is quite diverse. Stated by Karyono *at.all* Karyono, Sri [13] and Sugini [14] that international standard which admitted by ASHRAE-55 and ISO-7730 (at maximum temperature 24°C and humidity level 60%) not relevant is applied for use as a reference for thermal comfort in Indonesia which has a higher temperature. ASHRAE and ISO are thermal comfort standards that are widely used in the United States.

In Indonesia many of thermal comfort standard are refer to Indonesia National Standard (SNI) Number 6390-2011 i.e between 20°C until 27.2°C or provisions from the Ministry of Health Republic Indonesia Number 261/MENKES/SK/II/1998 which approximates the standard of ASHRAE/ISO by adding $\pm 2^\circ\text{C}$ from standard temperature and become $\pm 26^\circ\text{C}$ (normal was 24°C) and by adding $\pm 5^\circ\text{C}$ for level of humidity from 60% become 65% [11]. The standard from the Ministry of Health is indeed not through empirical research, although it is still widely used in the regulation of thermal comfort standards in Indonesia.

In its development this thermal comfort standard then continues to shift where thermal comfort is not necessarily only determined from the temperature range in the form of numbers and thermal units but involves dynamic factors relating to the temperature of the surrounding environment and also activities / metabolism, clothing, and psychology [2-4, 15].

In a research which conducted by Karyono [13] at least it has been discussed how comfortable temperature in a room in the tropics based on a number of previous studies as shown in Table 1 below :

TABLE I. PREVIOUS RESEARCH RELATED TO THERMAL COMFORT IN THE TROPICAL REGIONS

No	Principal Researcher	Location	Comfort Temperature
1	Mom, Wiesebron (1947)	Jakarta	26°C
2	Ellis (1953)	Singapore	24 °C- 27°C
3	Da Dear (1990)	Singapore	25.4 °C
4	Karyono (1913)	Indonesia	26.4 °C

Source : Karyono's Research [13]

B. Thermal Research at The School Buildings

A number of thermal studies in Indonesia generally state that existing schools do not provide thermal comfort. In general, students in schools in Indonesia are accustomed to high daily temperatures, exceeding comfortable temperatures ranging from 24°C-26°C as well as the provision of SNI thermal standards or the Indonesian Ministry of Health. However, such conditions are apparently quite common in tropical regions. A number of the same studies about thermal in schools in other countries that have the same climate also produce the same thermal perception as the conditions in Indonesia [7, 16-19] (see Table 3).

Measurement of thermal comfort that is commonly used in research today is adaptive thermal is a condition of thermal comfort that is influenced by individual thermal and external thermal as well [4]. On this basis it is very understandable why humans in tropical climate regions tend to have higher thermal tolerances compared to humans who normally live in sub-tropical climates. Likewise humans who are accustomed to living with sub-tropical temperatures will more easily tolerate lower temperatures than higher temperatures.

III. DISCUSSION

A. Thermal in The School Building in Indonesia

The lack of thermal research in school buildings in Indonesia is one of the obstacles in examining in depth the problem solving creating effective thermal comfort in school buildings. Based on 13 results of research conducted in Indonesia all stated that classrooms are generally uncomfortable and even very hot (see table 2).

If related to the ASHRAE Thermal Standard which consists of 7 thermal scales (*Cold, Cool, Slightly Cool, Neutral, Slightly Warm, Warm, Hot*) that the thermal sensation that is felt is between *slightly warm, warm, and hot* which then led to a generalization that in general thermal comfort in schools did not really exist for the current tropical climate [20-25].

It is typical in thermal research in the tropics that students as room users have a high tolerance for existing thermal conditions. The average temperature in the effective hours of study ranges from 27°C-33°C and some even reach 35°C during the day. Humidity varies between 60 - 80%, wind speed is 0-0.1m / s, all can still be tolerated although in general students express heat sensation especially during the daytime.

Meanwhile, related to the conditions in Indonesia, it refers to the regulation of the Minister of National Education Regulation No. 24 of 2007 concerning Facilities and Infrastructure Standards for SD / MI, SMP / MTs, and SMA / MA indeed not specifically mentioning the requirements for creating thermal comfort in schools. The regulation only mentions the provisions that buildings meet the comfort requirements of vibration and noise that interfere with learning activities; each room has a temperature and humidity that does not exceed outdoor conditions and each room is equipped with lighting. Thus, it is certain that the majority of schools in Indonesia still depend on natural ventilation, although a number of schools in urban areas are already using air conditioning to condition the thermal comfort of the room.

To find out more about the average temperature of classrooms in schools in Indonesia, the following is a review of a number of thermal studies that have been carried out:

TABLE II. PREVIOUS RESEARCH RELATED TO THERMAL COMFORT IN THE SCHOOL ENVIRONMENT OF INDONESIA

No	Principal Researcher	Location	Temperature /Thermal Sensation
1	Razak, Gandarum [26]	Jakarta	29,5°C - 36,8°C
2	Susanti and Aulia [20]	West Sumatera	27 °C - 30°C
3	Gunawan and Ananda [21]	Riau	29°C - 30°C
4	Oktavia, Arisanty [27]	South Kalimantan	Quitely Hot to Hot
5	Aienna, Adyatma [28]	South Kalimantan	Quitely Hot to Hot
6	Ridho [22]	Yogyakarta	Quitely Hot to Hot
7	Latif, Rahim [25]	South Sulawesi	29,0°C - 32,5°C
8	Hamzah, Mulyadi [23]	South Sulawesi	30,3°C - 33,5°C
9	Tayeb, Rahim [24]	South Sulawesi	29,4°C - 29,9°C
10	Yunita, Hamzah [29]	South Sulawesi	Quitely Hot to Hot
11	Hamzah, Mulyadi [30]	South Sulawesi	28,3°C - 34,3°C
12	Rachmad and Amin [31]	South Sumatera	32 °C - 35°C
13	Rahmawati [32]	West Java	25,0°C - 30,2°C

In general, research conducted in Indonesia is indeed not a comprehensive study discussing the conditions of thermal comfort along with the implications of handling and its solutions. Many studies only measure temperature or assess thermal sensations from students.

The table above presents what is the room temperature in the class in each study area or just concludes the thermal sensation response of the students. Based on the temperature range and thermal sensation, generally school buildings in Indonesia are not comfortable, either school buildings for elementary, junior high, or high school, all are on average thermally uncomfortable. If someone says it's comfortable then it only happens in the morning and becomes uncomfortable the next time

B. General Thermal Comfort in The School Building In Tropical Countries Outside Indonesia

To be objectively assess that school buildings in the tropics in general including are not comfortable, it is worth looking at a number of studies conducted in other countries that have the same climate as Indonesia (Table 3).

TABLE III. PREVIOUS RESEARCH RELATED TO THERMAL COMFORT IN SOME TROPICAL COUNTRIES OUTSIDE INDONESIA

No	Principal Researcher	Location	Temperature
1	Wong and Khoo [16]	Singapura	27,1°C – 29,3°C
2	Kamaruzzaman and Tazilan [18]	Malaysia	> 26,5 °C
3	Gupta, Buddi [33]	India	26 °C - 36 °C
4	Emir [19]	Turki	27,5 °C - 29 °C,
5	Porrás-Salazar, Wyon [7]	Middle America	26 °C - 32 °C
6	Le, Gillott [34]	Vietnam	29°C - 31,8°C
7	Appah and Koranteng [35]	Ghana	29,4°C – 32,3°C

The results of studies in a number of schools in other countries that have the same climate as Indonesia, namely the tropical climate turned out to be the same condition, thermal discomfort in the classroom. Regarding the response of thermal sensation it turns out the results are also the same as in Indonesia, respondents have a high tolerance to daily thermal conditions that are on average above the optimum temperature threshold of the room.

Based on the results of the study, if it is associated with thermal standards as discussed above, for example the standards of the Indonesian Ministry of Health 26°C, school students in Indonesia have a thermal tolerance level between 1°C - 9°C if the lowest room temperature is at 27°C and the temperature is reached highs for example during the day are at 35°C. Meanwhile, for school students in the tropics outside Indonesia using the American standard ASHRAE with a comfortable maximum temperature of 24°C, the thermal tolerance will be 2°C - 12°C if a minimum temperature of 26°C is reached and a maximum temperature of 36°C.

C. *The Strategy of Buildings Thermal Conditioning*

In a number of schools abroad, many may already have specific guidelines in creating thermal conditioning in the school environment. But this has not been specifically practiced in Indonesia, there are no specific guidelines on managing the thermal comfort of school buildings. According to Karyono [11] each reduction of 1°C temperature in the room will have an impact on energy consumption and operational savings of up to 10%. This is certainly an interesting thing related to the design of a building which should also pay attention to thermal comfort for its inhabitants.

As proposed by Auliciems [36] that thermal in the classroom has an impact on the quality of learning, so it is necessary to do the thermal conditioning of school buildings. Common thermal controls include thermal insulation to control heat in and out, air conditioning for cooling, heating and dehumidification to reduce air humidity [37].

Thermal insulation in buildings for hot climates is used to limit the heat from outside does not easily enter the room by providing insulation material that is able to withstand heat transfer either by convection, induction or radiation. Wall insulation can use wood or stone, brick. Roof insulation for example uses aluminum foil coatings. In connection with air movement in addition to the design of the roof construction can also use the help of fans, and cross ventilation. A good combination of thermal insulation and air movement will increase the thermal comfort of space.

A popular practical way is to use active design control by utilizing 1) active ventilation technology such as exhaust fans, blowers, 2) fans of various types, 3) air conditioners with all its variations, 4) dehumidifier devices, and 5) refrigerators. All of these equipment will certainly have an impact on waste and the threat of environmental sustainability which is very much avoided by the building designers. These methods are not recommended especially for school buildings which indeed most still use natural ventilation.

Passive thermal control or conditioning methods are expected to be able to support environmental sustainability. This method is recommended by many experts [38, 39] and building planners related to creating natural thermal comfort. According to Talarosha [40] passive control can be done by considering the orientation of buildings to the sun and wind, the use of architectural elements, building landscape, and the use of building materials by adjusting the climate character

IV. CONCLUSION

Based on a number of literature studies related to thermal comfort in school buildings, it can be concluded that school buildings in tropical climates are generally not specifically designed to obtain thermal comfort. The thermal comfort of the school is likely to have an impact on learning performance and the quality of teaching and learning as well as children's health has not been the focus of attention of school building planners and related authorities. School buildings are more focused on the principle of functional fulfillment of buildings rather than comfortable school buildings.

Most school students in tropical climates have a high tolerance to thermal. Able to adapt to hot temperatures beyond the standard thermal comfort threshold and even tolerate reaching 1°C to 9°C for students in Indonesia and 1°C to 12°C for students in schools outside Indonesia.

To support the thermal conditioning of school buildings a thermal control strategy can be carried out including adjusting the building's orientation to the sun and wind direction, utilizing architectural elements such as secondary skin / shading, structuring landscaping with protective plants, selecting materials and building designs that can help the room's thermal conditioning.

V. FURTHER RESEARCH

Until now there has been no research in Indonesia that comprehensively discusses thermal comfort in the school environment, especially in elementary, junior and senior high schools. Most of the research just knows the thermal conditions and sensations but never specifically discusses how to create a comfortable school environment. Current regulations do not accommodate this. Future research related to thermal comfort in the school environment is very important to do with the consideration that children have thermal vulnerability, students are intensive in the space during the teaching and learning process, and opportunities to obtain a more conducive learning atmosphere and improve achievement.

Future research is also needed to compare how the responses and thermal tolerance of children in the sub-tropical school environment, so that the objectivity of thermal tolerance can be studied more comprehensively

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