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Cooling Load Calculation For *Smart Classroom* Concept On X Building Using CLTD Method

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Abstract. To obtain thermal comfort in the *Smart Classroom*, an Air Conditioner (AC) is required. AC cooling load needs to be calculated beforehand in order to make the AC performance optimum and avoid waste of energy. The purpose of this study was to calculate the cooling load of the Smart Classroom using the Cooling Load Temperature Difference (CLTD) method so that the AC capacity is obtained according to the needs of the Smart Classroom. As a result, the Smart Classroom concept that is 9.3 m in length, 8.3 m in width, and 3 m in height, with a capacity of 21 persons plus various types of equipment inside, has a cooling load of 11364,169 Watt or equivalent to 38776,159 Btu/hour. Thus, in order to achieve and maintain a comfortable condition in the Smart Classroom, 2 units of AC with a capacity of 19000 Btu/hour per unit are required, with power consumption of 2 HP for each unit.

INTRODUCTION

Educational concept by using *Smart Classroom* starts to become an alternative for teaching and learning activities. The integration of digital technology and education becomes the concept of Smart Classroom. The application of Smart Classroom is expected to support productivity improvement in the process of teaching and learning activities. [1].

The design and concept of Smart Classroom do not only take into account the equipment and technology used; there are several factors that support the teaching and learning process in such room. Thermal comfort becomes one of the factors that affect teaching and learning process in a classroom. Comfort really depends on climate variables, such as radiation due to sunlight exposure, air humidity, air temperature, and wind velocity around the building [2].

Being passed by the equator, geographical location of Indonesia makes the country's climate very humid which tends to cause temperature and humidity high [3]. This results in dependency on the use of Air Conditioners (AC) to create thermal comfort in rooms [4].

Based on the study conducted by a company that produces Direct Digital Control for the use of energy in the US, besides lighting, the use of HVAC is one of the needs that consume the most of energy in buildings or rooms [5]. Hence, the use of AC is an important thing that must be taken into account in order for the AC to work optimally or avoid waste of energy [6]. Thus, this study is aimed at calculating the cooling load for the Smart Classroom using

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Cooling Load Temperature Difference (CLTD) method, so that the power capacity of the AC to be used in such room can be obtained.

RESEARCH METHODOLOGY

Dimension of The Room

The dimension (l x w x h) of the room is 9,3 x 8,9 x 3 m as shown in Fig.1. The data are taken from direct calculations and tables in the literature.

Area of West Wall:

Concrete column area = 1,5 + 1,5 + 0,9 = 3,9 m^2

Total area of windows and frames= 2 x 4,68 = 9,36 m^2

Total area of glass = 2 [3 (0,72 x 1,1) + 2 (0,62 x 1,1)] = 7,48 m^2

Total area of brick wall = 14,4 m^2

Area of South Wall:

Area of concrete columns = 1,5 + 1,5 + 1,8 = 4,8 m^2

Area of brick wall = 25,5 m^2

Area of East Wall:

Area of concrete columns = 1,5 + 1,5 + 0,9 = 3,9 m^2

Area of doors = 2,25 m^2

Area of glass = 0,44 m^2

Area of brick wall = 19,95 m^2

Area of North Wall:

Area of concrete columns = 0,345 + 1,5 + 1,5 + 0,3 = 3,645 m^2

Area of brick wall = 24,9 m^2

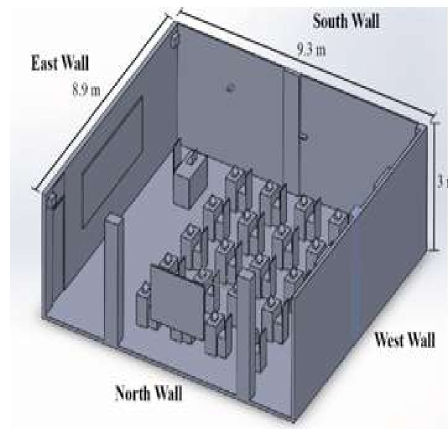

FIGURE 1. Room Dimension

Room thermal Condition

The west side of the room directly connects with open air with minimum daily temperature of 24,4°C and maximum daily temperature of 35°C. Thus, the temperature outside the room (Tm) is 29,7°C. The temperature of the adjacent room is 26°C. The room temperature to be achieved is 22°C. The average relative humidity is 74,34%. During peak hours the highest external heat loads are taken at 10.00, 11.00, 12.00, 13.00, 14.00, 15.00, 16.00, and 17.00 WIB.

Load Data

Heat load of the room covers west wall, glass, and partitions. The internal heat load includes Tube (fluorescent) lights: 36 Watt x 25, Occupants: 21 persons, LCD Smart Board: 7 Watt x 3, Smart Tablets: 15 Watt x 25, censor cameras: 10 Watt x 2, Wall speakers: 6 Watt x 4, and Wifi router 10 Watt. Heat load of the infiltration includes ceilings, doors, and outlets. The teaching and learning activities are the main activities in the smart classroom. Such activities are performed from 08.00 Western Indonesia Time (WIB) up to 17.00 WIB.

The main door is used as an access to enter and exit the room. The door is kept open for the students and teachers to enter the room in the first hour, exit at the break time, and enter it again after the break time, and exitvia the door after the activities are finished. It is assumed that the door is opened five times before the break time and 5 times after the break time. The open-and-close interval of the door is assumed as 3 seconds/person.

Cooling Load Calculation

The cooling load is calculated using CLTD method based on the procedure as set forth in ASHRAE Handbook: 2012 Fundamentals [7] dan SNI 03-6572-2001 [8] that includes calculations of external heat loads, internal heat loads and the heat loads due to infiltration and ventilation. The CLTD/CLF/SCL Method is regarded as a reasonably accurate approximation of the total heat gains through a building envelope for the purposes of sizing HVAC equipment. This method was developed as a simpler calculation alternative to difficult and unwieldy calculation methods such as the transfer function method and the Sol-air temperature method [9].

External Heat Load Calculation

The external heat load calculation consists of load calculation of the heat passing through the wall which is exposed by sun light, glass, and partition. The sensible external heat load is calculated as follows [7]:

$$Q = U\,(A)\,(CLTD_{corr}) \qquad (1)$$

Where,

A : Area of wall or glass surface

U : Coefficient of wall or glass heat transfer $= \frac{1}{Thermal\ resistance\ of\ the\ material}$

$CLTD_{corr}$ = CLTD + (25,5 – Ti) + (Tm – 29,4)

The value of CLTD is obtained from the tabel in ASHRAE handbook (2012) based on types of the materials and orientations to the sun light. Ti means the indoor temperature (or the temperature to be achieved) and Tm means outdoor average temperature, namely maximum temperature – (daily temperature limit/2).

The load of the radiant heat passing through the glass is as follows [9]:

$$Q_{rad,kaca} = A \cdot Sc \cdot SHG \cdot CLF \qquad (2)$$

Where,

SC : Shading coefficient of the glass

SHG : Sensible heat gain of the sunlight

CLF : Cooling load factor

Load of the heat passing through the partition is as follows [7]:

$$Q_{partition} = U_{partition}\,(A)\,(Tr-Ti) \qquad (3)$$

Where,

Tr : Temperature of adjacent room

Internal Heat Load Calculation

The internal heat load calculation consists of heat loads of the occupants, lighting, equipment, and air exchange due to opening and closing of the door. There are sensible (Q_{sp}) and latent (Q_{lp}) heat loads of the occupants, as follows [7]:

$$Q_{sp} = \text{Number of occupants}\,(SHG)\,(CLF_{sens}) \qquad (4)$$

$$Q_{lp} = \text{No. of occupants}\,(SHG)\,(CLF_{laten}) \qquad (5)$$

Where,

SHG : Sensible heat gain of the occupants

CLF_{sens} : Cooling load factor for sensible heat load

CLF_{laten} : Cooling load factor for latent heat load

Heat load of the lighting is as follows [7]:

$$Q_{lights} = W\,(F_U)\,(F_b)\,(CLF) \qquad (6)$$

Where,

W : Total power of lights

F_U : Usage factor

F_b : ballast factor

Heat load of the equipment is as follows [7]:

$$Q_{equip.} = Q_{input}\,(L_F)\,(CLF) \qquad (7)$$

Where,

Q_{input} : Total input power of the equipment

There are sensible and latent heat loads of air exchange due to opening and closing of the door, as follows :

$$Q_{doorsens} = 1{,}23\,(q_{door})\,(Tr-Ti) \qquad (8)$$

Dimana,

Q_{door} = Flow rata of the air entering the door when opened $= \frac{ACH\ (Room\ Volume)}{60}$

ACH = value of air exchange in one hour $= \frac{F_{pintu}\ (\text{door open time})}{3600}$

F_{door} = Frequency of door opening-and-closing

Calculation of Heat Load due to Infiltration and Ventilation

There are sensible and latent heat loads due to air leakage through the building slits or so called infiltration and the needs for air for the occupants through ventilations, as follows [7]:

$Q_{sens,inf/vent}$ = 1,23 . $q_{inf/ventilasi}$. () (9)

$Q_{laten,inf/vent}$ = 3010 . $q_{inf/ventilasi}$. ($W_o - W_i$) (10)

Where,

q_{inf} = air flow rate due to infiltration

$= \frac{A_L}{1000}\sqrt{C_S \Delta T + C_W V^2}$

where,

A_L : Area of air leakage

C_S : Coefficien of stacks

C_W : Coefficient of wind

V : Wind welocity

As for the ventilation, the flow rate of the air (q_{vent}) is obtained from the table of ventilation air needs in SNI 03-6572-2001 [8].

RESULTS AND DISCUSSION

Result of External Heat Loads

Table 1 shows the result of external heat loads with maximum load is 4633.333 Watt at 5 PM o´clock.

TABLE 1. External Heat Load

Time	Sensible Heat Load (Watt)				Total
	$Q_{partisi}$	$Q_{partisi}$	$Q_{partisi}$	$Q_{partisi}$	
10:00	471.541	255.966	189.338	2234.071	3150.915
11:00	471.541	344.230	201.960	2234.071	3251.801
12:00	471.541	388.362	214.583	2234.071	3308.556
13:00	525.125	476.626	391.298	2234.071	3627.119
14:00	525.125	476.626	668.993	2234.071	3904.814
15:00	632.294	520.758	908.820	2234.071	4295.942
16:00	739.462	520.758	1035.045	2234.071	4529.335
17:00	900.215	476.626	1022.423	2234.071	4633.333

Result of Internal Heat Loads

Table 2 shows the result of internal heat loads. Total of internal heat loads are 2511.24 Watt for sensible heat and 1949.8 Watt for latent heat.

TABLE 2. Internal Heat Load

Media	Sensible Heat Load (Watt)	Latent Heat Load (Watt)
Occupants	1323	1837.5
Lighting	752.76	-
Equipment	385	-
Air Exchange due to Door Opening and Closing	50.48	112.3
Total	2511.24	1949.8

Result of Heat Load due to Infiltration and Ventilation

Table 3 shows the result of heat load due to infiltration and ventilation

TABLE 3. Heat load due to infiltration and ventilation

Media	Sensibel Heat Load (Watt)	Latent Heat Load (Watt)
Infiltation	38.84	86.40
Ventilaton	497.23	1106.78
Total	536.07	1192.58

Result of Total Heat Loads

Effective Room Sensible Heat (ERSH):

External sensible heat load	=	4633.333	Watt	
Internal sensible heat load	=	2511.24	Watt	
Sensible heat load due to infiltration and ventilation	=	536.070	Watt	+
Total		7680.643	Watt	
Safety Factor 5%		384.032	Watt	+
Effective Room Sensible Heat		8064.675	Watt	

Effective Room Latent Heat (ERLH):

Internal latent heat load	=	1949.8	Watt	
Latent heat load due to infiltration and ventilation	=	1192.575	Watt	+
Total		3142.375	Watt	
Safety Factor 5%		157.119	Watt	+
Effective Room Latent Heat		3299.494	Watt	

Thus, the value of the total internal heat load is as follow:

Grand Total = ERSH + ERLH
= 8064.675 + 3299.494
= 11364.169 Watt
= 38776.159 Btu/hour

Discussion

Based on the above results, the total internal heat load of the Smart Classroom is 11364.169 Watt or equivalent to 38776.159 Btu/hour. Such heat load amount represents the amount of heat that must be eliminated by the air conditioner (AC), or so called the cooling load. In order to avoid waste of energy, the number of AC units needed to achieve and maintain such comfortable condition is 2 (two) with the cooling capacity of 19000 Btu/hour, where the power capacity of the AC is 2 HP.

The value of the heat load is influenced by several factors, namely external sensible heat loads, internal sensible and latent heat loads, and sensible and latent heat loads due to infiltration and ventilation. The external sensible heat loads have a quite big influence because one of the wall sides directly contacts with the sun light, that is the west side of the wall, having the surface area of 27.66 m^2. Besides, the partitions having direct contacts with the environment surrounding the room also affect the heat load value. Such partitions are dominated by the three sides of the wall that have the total surface area of 83.36 m^2.

CONCLUSION

The total internal heat load of the smart classroom is 11364.169 Watt or equivalent to 38776.159 Btu/hour. To avoid waste of energy, the number of AC units required for achieving and maintaining the comfortable condition is 2 units, with the cooling capacity of 19000 Btu/hour, where the AC power capacity is 2 HP.

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