Energy saving in air conditioning systems, by using thermal insulators in an academic classroom

Ahorro de energía en sistemas de aire acondicionado, mediante el uso de aislantes térmicos en un aula académica

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Abstract

This article proposes a methodology of calculating the cooling load in an academic classroom at The Universidad Veracruzana located at Poza Rica, in the state of Veracruz, Mexico., using the ASHRAE CLTD / SCL / CLF method. The method of calculating the cooling load CLTD / SLC / CLF consists in applying the cooling load as accurately as possible so, in consequence the air-conditioning equipment will not oversize. By using thermal insulation, a decrease in energy consumption is achieved and thus contributes to sustainable development. Next, we will proceed to calculate the cooling load as follows, applying the proposed methodology in two cases: In the first case, it will be in a classroom with an air-conditioning unit without thermal insulation, first with 30 students and then with only 3 students in the classroom. In the second case we used the same method in a classroom with an air-conditioning unit but this time with thermal insulation, and we proceed to compare the results first with 30 students and then with only 3 students in the classroom. What we discovered when reviewing the results of these two cases is that based on energy consumption measurements, the saving is much greater using an air-conditioning unit with thermal insulation than an air-conditioning unit that is not thermally insulated

Energy saving, Thermal insulators, Academic classroom

Resumen

En este artículo se propone una metodología para el cálculo de la carga de enfriamiento, en una edificación objeto de estudio, utilizando el método CLTD/SCL/CLF de la ASHRAE. La edificación en la que se utiliza el método mencionado es un aula académica de la Universidad Veracruzana situada en Poza Rica, estado de Veracruz, en México. El método de cálculo de la carga de enfriamiento CLTD/SLC/CLF se aplica con la finalidad de obtener la carga de enfriamiento lo más exacto posible y de esa manera evitar el sobredimensionamiento en los equipos de aire acondicionado, y al utilizar el aislante térmico, lograr una disminución en el consumo energético y de esa manera contribuir al desarrollo sustentable. A continuación, se procede a calcular la carga de enfriamiento aplicando la metodología propuesta a dos casos: el aula académica sin aislante térmico, y con aislante térmico para 30 alumnos y para 3 alumnos. Se comparan los resultados para los dos casos de prueba en el aula académica, objeto de este estudio. Se realizan mediciones de consumo energético para realizar la comparación del consumo real energético respecto al calculado utilizando el método. Por último, se cuantifica el ahorro energético.

Ahorro de energía, Aislantes térmicos, Aula académica

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Introduction

Air conditioning has been one of man's most recent and valued services in his quest for a more comfortable existence. The primary purpose of an air conditioning system, whether heating or cooling, is to maintain suitable conditions, either to provide thermal comfort to the occupants of a building or conditions that are required for certain products and processes within industry. Central heating systems were developed in the 19th century while the development of cooling systems with comfort applications came in the 20th century. Since then, progress in this direction has achieved great advances with significant developments in various areas of science and technology.

The pioneering load calculation methods paid little attention to operating costs and the related aspect of environmental sustainability resulting in the calculation of oversized equipment. However, the increasing price of energy, construction materials and complex building structures, as well as the increasing concern for natural resources and the environment have required a continuous refinement of load calculation methods. Load calculation methods are nowadays directed more towards the dimensioning of appropriately sized minimum systems which result in economical systems with good energy performance and thus more in line with the philosophy of a sustainable environment.

On the other hand, the optimum degree of thermal protection depends on economic and technical criteria. Furthermore, it is determined by considerations of the cooling and heating demands of the building and the feasibility of the investment required to achieve the desired degree of thermal protection of the building. As all these parameters vary with respect to climatic conditions, fluctuating cost factors and the actual way in which buildings are designed and constructed, the determination of optimal thermal protection is always subject to discussion.

Improving the thermal protection of the building envelope could not only lead to a reduction of thermal losses during the winter period, but also lead to a reduction of the cooling load in the summer, a problem that has gained significant importance in the last decade.

Finally, the use of low-energy lighting systems, together with the application of shading devices, constitute new actions that can contribute to the reduction of energy consumption for air conditioning, despite the fact that they are not directly related to the thermal protection of buildings.

Therefore, an appropriate method for the calculation of the cooling load in a building together with the choice of an appropriate thermal insulation constitutes an effective way to properly size an air conditioning system in order to provide comfortable conditions while minimising energy consumption.

Therefore, the objective of this work is to propose a methodology for the calculation of the cooling load in a building under study, in this case an academic classroom of the Universidad Veracruzana located in the city of Poza Rica, state of Veracruz, in Mexico, in order to reduce the energy consumption of an air conditioning system by reducing its capacity.

Construction characteristics of the academic classroom

Figure 1 Academic classroom at FIME, Poza Rica
Source*: UV FIME – Poza Rica*

Figure 2 Lateral view of the academic classroom at FIME, Poza Rica
Source*: UV FIME – Poza Rica*

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Figure 3 Meters provided by CFE for measuring energy consumption
Source: UV FIME - Poza Rica

The construction where the methodology of this work is applied, is an academic classroom located in the city of Poza Rica de Hidalgo, Edo Veracruz in Mexico, and its main characteristics are: Cement tile floor, Reinforced concrete slab, and both have an area of 53 m^2, East wall of apparent brick on the outside and cement plastered inside with an area of 12.65 m^2, Clear single glazed window with an area of 4. 8 m2 for the west wall is the same composition of materials as the east wall, including the entrance door, which is made of galvanised sheet metal with an area for the wall of 11 m^2, window 4 m^2 and for the door 1.7 m^2, south and north wall is made of brick and cement plaster on both sides with an area of 24.85 m^2, for each one.

The architectural plans of the academic classroom are shown below:

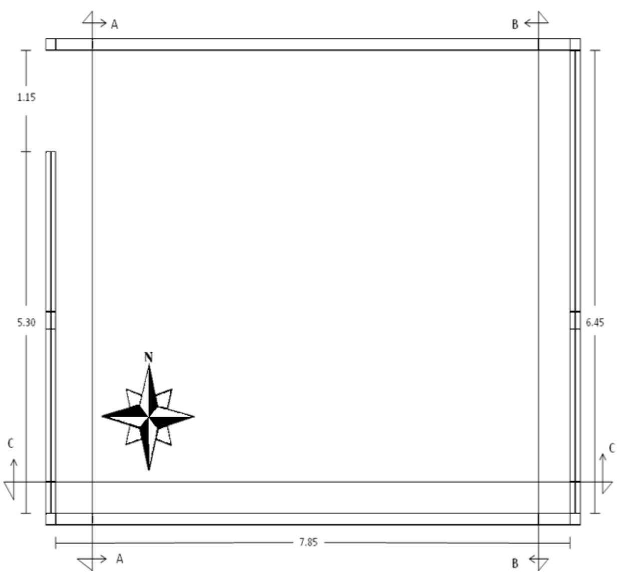

Figure 4 Floor plan of the academic classroom (in metres)
Source: Own elaboration

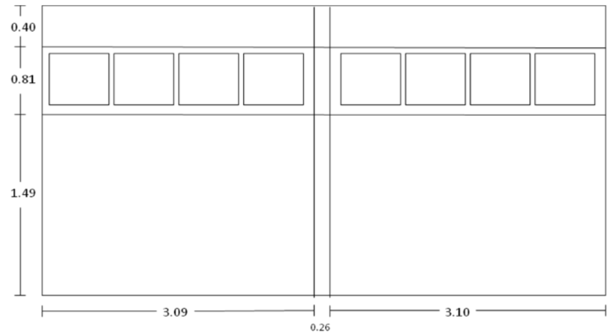

Figure 5 A-A section of the academic classroom (in metres)
Source: Own elaboration

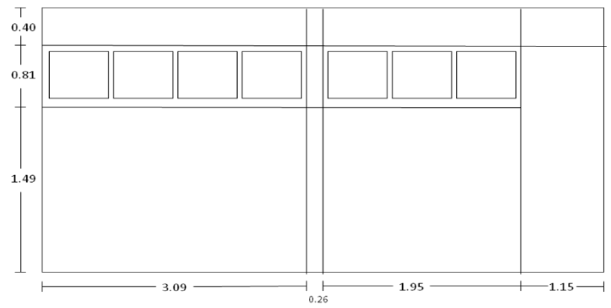

Figure 6 B-B section of the academic classroom (in metres)
Source: Own elaboration

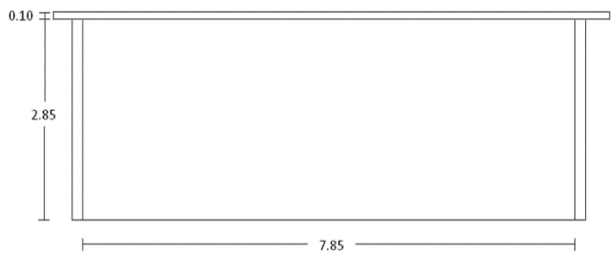

Figure 7 Cut C-C (metres)
Source: Own elaboration

The methodology was applied for two case studies using the academic classroom.

1. Without thermal insulation, single glazed window, which is how they are currently built.

2. With thermal insulation, 1" thick extruded polystyrene for walls and ceilings.

The first case represents the type of academic classrooms built by the University of Veracruz, the second case corresponds to the objective to be achieved by reducing energy consumption by up to 48.3 %.

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Calculation of the Global Heat Transfer Coefficient

The calculation of this coefficient is carried out considering each of the materials of which the walls and ceilings are composed.

The insulation used is extruded polystyrene 0.0254 metres thick with a thermal conductivity of 0.043 Watts - m °K. The values of the resulting overall heat transfer coefficient for each structural element and for the area to be air-conditioned are presented in table 1. These are derived from the materials and architectural plans that were used in the design and construction of the building, which are the case studies of this work.

Table 1 shows that the behaviour of the overall heat transfer coefficients depends on each case.

In the cases where there is no thermal insulation, the coefficients are high. In the case where thermal insulation is applied, a reduction in the values of the coefficients is shown.

Structural elements	Without thermal insulation	With thermal insulation
Brick wall with sand-cement filling on one face	2.874	0.8068
Brick wall with cement-sand filled on both faces	2.7864	0.80
Reinforced concrete slab	4.246	0.8873
Reinforced concrete castle	0.3281	
Cement floor	1.950	
Sheet metal door	5.624	0.9449

Table 1 Overall heat transfer coefficients of building elements (Watts /m^2 °K)
Source: Own elaboration

Determination of cooling demand

The cooling demand calculations were based on the ASHRAE CLTD/SCL/CLF method. The following conditions were considered: Latitude 20 °N, for July 21, indoor temperature 25 °C, outdoor temperature 37 °C, daily percentage temperature 32 °C, daily temperature range 12 °C, outdoor convective heat transfer coefficient 22.68 W/m^2-°K, indoor heat transfer coefficients 7.48 W/m^2-°K.

The corrected CLTD values were obtained according to the following equation:

$$CLTD_{Corr} = (CLTD + LM)\,K + (25.5 - T_i) + (T_{OAV} - 29.4\ °C) \quad (1)$$

Where:

LM: Correction factor for latitude and month

K: Colour adjustment factor

Ti and TOAV: Design values

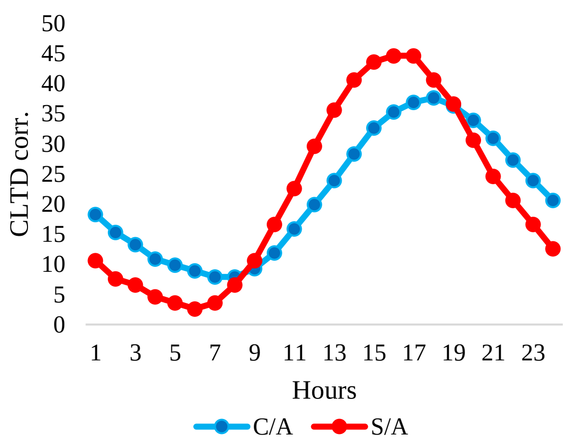
Ti: Indoor temperature

TOAV: Daily percentage of temperature

Figures 1 and 2 show the tables of the corrected CLTD values for the slab and the west wall.

Figures 3 and 4 show the tables of the cooling demands for the peak load hours, which in this case is considered to be from 15 to 19 hrs. Without thermal insulation, the cooling demand is higher, and in the other case, when thermal insulation is installed, the cooling load decreases.

HORAS	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00
S/A	10.6	7.6	6.6	4.6	3.6	2.6	3.6	6.6
C/A	18.3	15.3	13.3	10.9	9.9	8.9	7.9	7.9
HORAS	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
S/A	10.6	16.6	22.6	29.6	35.6	40.6	43.6	44.6
C/A	9.3	11.9	15.9	19.9	23.9	28.3	32.6	35.3
HORAS	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00
S/A	44.6	40.6	36.3	30.6	24.6	20.6	16.6	12.6
C/A	36.9	37.6	36.3	33.9	30.9	27.3	23.9	20.6



Graphic 1 Corrected CLTD values for uninsulated and insulated slabs, for 24 hrs
Source: ASHRAE Handbook of Fundamentals 1997

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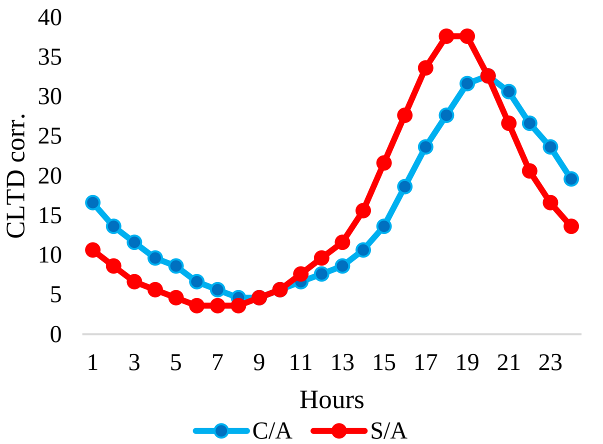
HORAS	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00
S/A	10.6	8.6	6.6	5.6	4.6	3.6	3.6	3.6
C/A	16.6	13.6	11.6	9.6	8.6	6.6	5.6	4.6
HORAS	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
S/A	4.6	5.6	7.6	9.6	11.6	15.6	21.6	27.6
C/A	4.6	5.6	6.6	7.6	8.6	10.6	13.6	18.6
HORAS	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00
S/A	33.6	37.6	37.6	32.6	26.6	20.6	16.6	13.6
C/A	23.6	27.6	31.6	32.6	26.6	20.6	16.6	13.6



Graphic 2 Corrected CLTD values for West walls, without insulation and with insulation, for 24 hrs
Source: ASHRAE Handbook of Fundamentals 1997

Figures 3 and 4 show the cooling demands of the academic classroom for 30 students and for 3 students.

It is shown that without thermal insulation the cooling demand is higher and for the case where thermal insulation is installed the cooling load decreases.

The calculation of the cooling load is obtained with the following equation:

$$Q = A\ U\ (\text{CLTD corrected}) \quad (2)$$

Where:

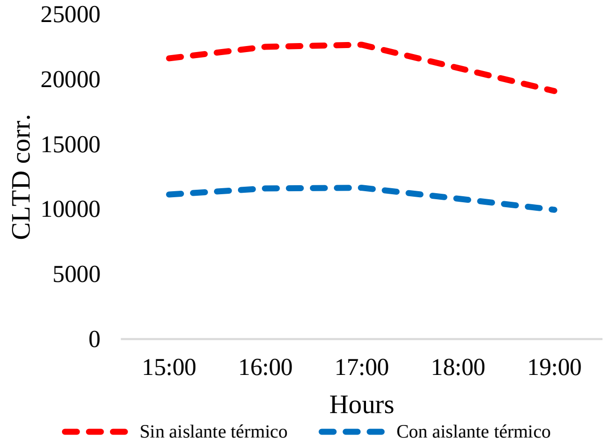
Q: Heat in Watts

A: Area in square metres

U: Overall heat transfer coefficient in W/m^2-°K.

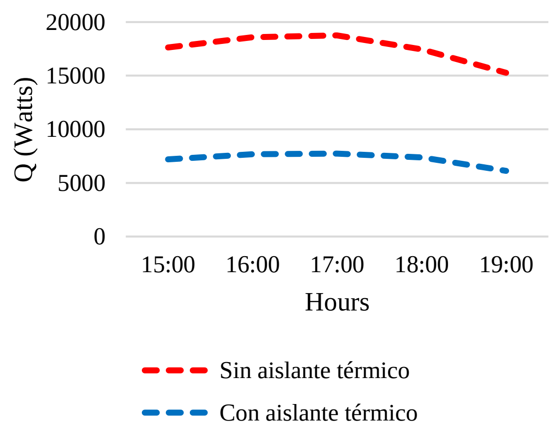
The cooling load will be calculated only for the hours of highest cooling load, which are from 15:00 to 19:00 hrs.

HORA	15:00	16:00	17:00	18:00	19:00	TOTAL
Sin aislante térmico	21639	22534	22683	20898	19110	106864
Con aislante térmico	11143	11612	11658	10820	9963	55196



Graphic 3 Cooling demand in the academic classroom considering 30 students (Watts)
Source: ASHRAE Handbook of Fundamentals 1997

HORA	15:00	16:00	17:00	18:00	19:00	TOTAL
Sin aislante térmico	17640	18583	18757	17467	15270	87717
Con aislante térmico	7194	7661	7732	7389	6123	36099



Graphic 4 Cooling demand in academic classroom considering 3 students (Watts)
Source: ASHRAE Handbook of Fundamentals 1997

Table 2 below shows a comparison of the decrease in cooling demand of the academic classroom with and without thermal insulation, for 30 students and 3 students in Watts.

Hours →	15:00	16:00	17:00	18:00	19:00	Total
30 students						
Without thermal insulation	2163	2253	2268	2089	1911	106864
With thermal insulation	1114	1161	1165	1082	9963	55196
3 students						
Without thermal insulation	1764	1858	1875	1746	1527	87717
With thermal insulation	7194	7661	7732	7389	6123	36099

Table 2 Comparative cooling demand in the academic classroom considering 30 students and 3 students, with and without insulation. (Watts)
Source: Own elaboration

The decrease in cooling demand of the academic classroom with insulation and those without insulation is presented in table 3, for both cases as a percentage.

Hours →	15:00	16:00	17:00	18:00	19:00	Average
Academic classroom with 30 students	48.5	48.5	48.6	48.2	47.9	48.3
Academic classroom with 3 students	59.2	58.8	58.8	57.7	59.9	58.8

Table 3 Reduction of cooling demand, compared to uninsulated construction (%)
Source: Own elaboration

In table 3, a clearer picture of the comparison of the cooling demand for the case without thermal insulation and for the case where insulation is applied is shown. The values shown are in percentages.

Determination of cooling energy consumption

For the determination of the energy consumption in the academic classroom for cooling, 120 V, 60 Hz, 2 F, 3 H wattmeters and 16 thermometers with a scale from -20 to 50 °C were used.

1. The indoor temperature was considered to be 25°C dry bulb and 50% relative humidity in both cases.

2. The academic classroom under study was occupied by 30 students and subsequently by 3 students.

3. The temperature and humidity conditions were taken from the climatological station belonging to the Faculty of Environmental Engineering of the Universidad Veracruzana in Poza Rica de Hgo.

Measurements were carried out for 28 days in each of the months of June and July 2018.

Cooling energy consumption (Results)

The cooling energy consumption calculations consisted of determining the total heat gains through the building structure, as well as the solar gain, sensible internal gain, due to occupants, lighting, ventilation and air infiltration. As a result, the energy requirements for the academic classroom during cooling were obtained.

The operating coefficient of the air conditioning equipment was considered to be 2.5. Table 4 shows the cooling energy in thermal Kw-hr and electrical Kw-hr calculated for the classroom without insulation and with thermal insulation, considering 30 students.

Hours →		15:00	16:00	17:00	18:00	19:00	Total
Without thermal insulation	Kw - hr Thermal	21.64	22.53	22.68	20.90	19.11	106.8
	Kw - hr Thermal	8.66	9.01	9.07	8.36	7.64	42.74
With thermal insulation	Kw - hr Thermal	11.14	11.61	11.66	10.82	9.96	55.19
	Kw - hr Thermal	4.46	4.64	4.66	4.33	3.98	22.07

Table 4 Cooling energy (Kw - hr Thermal) and (Kw - hr electrical) for the classroom without insulation and with insulation, considering 30 pupils
Source: ASHRAE Handbook of Fundamentals 1997

Table 5 shows the cooling energy in thermal Kw-hr and electrical Kw-hr calculated for the classroom without insulation and with thermal insulation, considering 3 students.

Hours →		15:00	16:00	17:00	18:00	19:00	Total
Without thermal insulation	Kw - hr Thermal	21.64	22.53	22.68	20.90	15.27	87.72
	Kw - hr Thermal	8.66	9.01	9.07	8.36	6.11	35.09
With thermal insulation	Kw - hr Thermal	7.19	7.66	18.76	17.47	6.12	36.09
	Kw - hr Thermal	2.88	3.06	3.09	2.96	2.45	14.44

Table 5 Cooling energy (Kw - hr Thermal) and (Kw - hr electrical) for the classroom without insulation and with insulation, considering 3 pupils
Source: ASHRAE Handbook of Fundamentals 1997

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Table 6 shows the cooling energy in thermal Kw-hr and electrical Kw-hr measured, for the classroom without insulation and with thermal insulation, considering 30 students.

Hours →		15:00	16:00	17:00	18:00	19:00	Total
Without thermal insulation	Kw - hr Thermal	21.64	22.53	22.68	20.90	19.11	106.8
	Kw - hr Electrical measured	9.12	9.49	9.55	8.80	8.04	45.00
With thermal insulation	Kw - hr Thermal	11.14	11.61	11.66	10.82	9.96	55.19
	Kw - hr Electrical measure.	4.64	4.84	4.86	4.51	4.15	23.00

Table 6 Cooling energy (Kw - hr thermal) and (Kw - hr electrical) measured for the classroom without insulation and with insulation, considering 3 students
Source: ASHRAE Handbook of Fundamentals 1997

Table 7 shows the cooling energy in thermal Kw-hr and electrical Kw-hr measured, for the classroom without insulation and with thermal insulation, considering 3 students.

Hours →		15:00	16:00	17:00	18:00	19:00	Total
Without thermal insulation	Kw - hr Thermal	21.64	22.53	22.68	20.90	15.27	87.72
	Kw - hr Electrical measured	7.45	7.83	7.91	7.37	6.44	37.00
With thermal insulation	Kw - hr Thermal	7.19	7.66	18.76	17.47	6.12	36.09
	Kw - hr Electrical measured	2.99	3.18	3.21	3.07	2.55	15.00

Table 7 Cooling energy (Kw - hr thermal) and (Kw - hr electrical) measured, for the classroom without insulation and with insulation, considering 3 students
Source: ASHRAE Handbook of Fundamentals 1997

As can be seen in tables 6 and 7, there is a considerable saving of electrical energy when thermal insulation is used in the walls and slab in the academic classroom. It can also be seen that there is a difference when 30 or 3 students are considered in the academic classroom.

The decrease of the calculated cooling demand of the academic classroom with insulation and those without insulation is presented in table 8, for the two cases in percentage.

Hours →	15:00	16:00	17:00	18:00	19:00	Average
Academic classroom with 30 students	49.12	48.99	49.10	48.75	48.38	48.86
Academic classroom with 3 students	59.86	59.38	59.42	58.34	60.40	59.48

Table 8 Measured electrical energy reduction, for the academic classroom without insulation and with insulation in (%)
Source: ASHRAE Handbook of Fundamentals 1997

As can be seen in table 8, there is a considerable saving of electrical energy when thermal insulation is used in the walls and slab of the academic classroom. It can also be seen that there is a difference when 30 or 3 students are considered in the classroom.

Annexes

- ASHRAE (1979, 1992). "Cooling and Heating Load Calculation Manual.

- ASHRAE (1967, 1972, 1972, 1985, 1989). "ASHRAE Handbook of Fundamentals". Atlanta, American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc.

- Thermal properties, and Code numbers of the coatings used in the description of walls and ceilings.

Numero de código	Descripción	Espesor y propiedades técnicas L	k	p	Cp	R	Masa
A0	Resistencia de la superficie exterior	0	0	0	0	0.059	0
A1	25 mm de estuco	25	0.692	1858	0.84	0.037	47.34
A2	100 de ladrillo	100	1.333	2002	0.92	0.076	203.5
A3	Acero forrado	2	44.998	7689	0.42	0	11.71
A4	12 mm de escoria	13	0.19	1121	1.67	0.067	10.74
A5	Resistencia de la superficie exterior	0	0	0	0	0.059	0
A6	Final	13	0.415	1249	1.09	0.031	16.1
A7	100 de ladrillo	100	1.33	2002	0.92	0.076	203.5
B1	Resistencia del espacio de aire	0	0	0	0	0.16	0
B2	25 mm de aislamiento	25	0.043	32	0.84	0.587	0.98
B3	50 mm de aislamiento	51	0.043	32	0.84	1.173	1.46
B4	75 mm de aislamiento	76	0.043	32	0.84	1.76	2.44
B5	25 mm de aislamiento	25	0.043	91	0.84	0.587	2.44
B6	50 mm de aislamiento	51	0.043	91	0.84	1.173	4.88
B7	25 mm de madera	25	0.121	593	2.51	0.207	15.13
B8	65 mm de madera	63	0.121	593	2.51	0.524	37.58
B9	100 mm de madera	100	0.121	593	2.51	0.837	60.02
B10	50 mm de madera	51	0.121	593	2.51	0.42	30.26
B11	75 mm de madera	76	0.121	593	2.51	0.628	45.38
B12	75 mm de aislamiento	76	0.043	91	0.84	1.76	6.83
B13	100 mm de aislamiento	100	0.043	91	0.84	2.347	9.27
B14	125 mm de aislamiento	125	0.043	91	0.84	2.933	11.71
B15	150 mm de aislamiento	150	0.043	91	0.84	3.52	14.15
B16	4 mm de aislamiento	4	0.043	91	0.84	0.088	0.49
B17	8 mm de aislamiento	8	0.043	91	0.84	0.176	0.49
B18	12 mm de aislamiento	12	0.043	91	0.84	0.264	0.98
B19	15 mm de aislamiento	15	0.043	91	0.84	0.352	1.46
B20	20 mm de aislamiento	20	0.043	91	0.84	0.44	1.95
B21	35 mm de aislamiento	35	0.043	91	0.84	0.792	2.93
B22	42 mm de aislamiento	42	0.043	91	0.84	0.968	3.9
B23	60 mm de aislamiento	62	0.043	91	0.84	1.408	5.86
B24	70 mm de aislamiento	70	0.043	91	0.84	1.584	6.34
B25	85 mm de aislamiento	85	0.043	91	0.84	1.936	7.81
B26	92 mm de aislamiento	92	0.043	91	0.84	2.112	8.3
B27	115 mm de aislamiento	115	0.043	91	0.84	2.64	10.74
C1	100 mm de placa de arcilla	100	0.571	1121	0.84	0.178	113.7
C2	100 mm de block de concreto de baja densidad	100	0.381	609	0.84	0.266	61.98
C3	100 mm de block de concreto de alta densidad	100	0.813	977	0.84	0.125	99.06
C4	100 de ladrillo común	100	0.727	1922	0.84	0.14	195.2
C5	100 mm de concreto de alta densidad	100	0.731	2243	0.84	0.059	227.9
C6	200 mm de placa de arcilla	200	0.571	1121	0.84	0.352	227.9
C7	200 mm de block de concreto de baja densidad	200	0.571	609	0.84	0.352	123.46
C8	200 mm de block de concreto de alta densidad	200	1.038	977	0.84	0.196	198.62
C9	200 mm de ladrillo común	200	0.727	1922	0.84	0.279	390.4
C10	200 mm de concreto de alta densidad	200	0.731	2243	0.84	0.117	455.79
C11	300 mm de concreto de alta densidad	300	0.731	2243	0.84	0.176	683.2
C12	50 mm de concreto de alta densidad	50	0.731	2243	0.84	0.029	113.7
C13	150 mm de concreto de alta densidad	150	0.731	2243	0.84	0.088	341.6
C14	100 mm de concreto de baja densidad	100	0.173	641	0.84	0.587	64.9
C15	150 mm de concreto de baja densidad	150	0.173	641	0.84	0.88	97.6
C16	200 mm de concreto de baja densidad	200	0.173	641	0.84	1.173	130.3
C17	200 mm de block de concreto de baja densidad	200	0.138	288	0.84	1.467	58.56
C18	200 mm de block de concreto de alta densidad	200	0.588	849	0.84	0.345	172.75
C19	300 mm de block de concreto de baja densidad	300	0.138	304	0.84	2.2	92.72
C20	300 mm de block de concreto de alta densidad	300	0.675	897	0.84	0.451	273.28
E0	Resistencia de la superficie interior	0	0	0	0	0.121	0
E1	20 mm de yeso o yesiforo	20	0.727	1602	0.84	0.026	30.74
E2	12 mm de escoria o piedras	12	1.436	881	1.67	0.009	11.22
E3	10 mm de fieltro o membrana	10	0.19	1121	1.67	0.05	10.74
E4	Espacio de aire en el techo	0	0	0	0	0.176	0
E5	Mosaico acústico	19	0.061	481	0.84	0.314	9.27

L = Espesor, mm
k = Conductividad térmica, W/(m°K)
p = Densidad, kg/m³
Cp = Calor especifico, kJ/(kg°K)
R = Resistencia térmica, (m²°K)/W
Masa = Masa x unidad área, kg/m²

- Roof group numbers.

Techo sin cielo

Materiales del techo[a] No	Códigos	Masa interior – Números del rango del valor R[b] 1	2	3	4	5	6	Masa integral – Números del rango del valor R[b] 1	2	3	4	5	6	Masa exterior – Números del rango del valor R[b] 1	2	3	4	5	6
1	B7							1	2	2	4	4							
2	B8							4	5	9	10	18							
3	B9							19	21	27	27	28							
4	C5	6	7	7	10	10		3						6	7	7	10	11	
5	C12	2	2	4	4	5		2						2	3	4	5	5	
6	C13	7	12	13	13	20		5						7	12	13	13	20	
7	C14		4	5	9	9		2	2						4	5	9	9	
8	C15		5	10	18	18	18		4						5	10	10	18	18
9	C16		9	19	20	27	27		9						9	18	20	27	27
10	A3							1	1	1	2	2							
11	Ático							1	2	2	2	4							
Sistemas de azotea																			
12	C12-C12							4	5	9	9	9		5	5	7	9	9	
13	C12-C5							6	11	12	18	18		7	12	12	12	20	
14	C12-C13							11	20	20	21	27		12	13	21	21	21	
15	C5-C12							5	10	10	17	17		5	10	11	11	18	
16	C5-C5							10	20	20	26	26		10	13	21	21	21	
17	C5-C13							20	27	28	28	35		20	22	22	22	28	
18	C13-C12							10	18	20	20	26		10	13	20	29	21	
19	C13-C5							18	27	27	28	35		20	22	22	28	28	
20	C13-C13							21	29	30	36	36		21	29	30	31	36	

Techo con cielo

Materiales del techo[a] No	Códigos	Masa interior – Números del rango del valor R[b] 1	2	3	4	5	6	Masa integral – Números del rango del valor R[b] 1	2	3	4	5	6	Masa exterior – Números del rango del valor R[b] 1	2	3	4	5	6
1	B7								4	5	9	10	10						
2	B8								9	20	21	22	28						
3	B9								20	28	30	37	38						
4	C5	8	15	18	18	23		6						7	7	7	10	10	
5	C12	5	8	13	13	14		3						3	3	4	5		
6	C13		18	24	25	25		11	11						12	13	13	20	
7	C14		4	10	11	18	20		4						4	5	9	9	17
8	C15		10	18	21	21	28		9						9	10	18	19	26
9	C16			20	28	29	36			18						18	26	27	27
10	A3							1	1	2	2	4							
11	Ático																		
Sistemas de azotea																			
12	C12-C12							6	13	22	22	22		5	5	7	9	9	
13	C12-C5							10	21	23	24	31			12	12	18	20	
14	C12-C13							13	23	24	33	33			13	21	21	21	
15	C5-C12							10	20	22	28	29			10	12	18	18	
16	C5-C5							13	23	32	32	33			20	21	21	21	
17	C5-C13							21	32	34	40				22	22	28	28	
18	C13-C12							12	28	30	31	37			13	20	20	21	
19	C13-C5							21	31	39	40	40			22	22	28	28	
20	C13-C13								39	41	41	42	42		29	30	31	36	37

[a]Los espacios en blanco denotan un techo que no es posible con las combinaciones de los parámetros elegidos.
Los números 12 a 20 son sistemas de azoteas. El primer material es una capa exterior, el segundo material es una capa interior. Los números de los materiales masivos son: 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19 y 20.
Los números de los materiales no masivos son: 1, 2, 3, 10 y 11.

Rangos del valor R en m²°K/W

No	Rango	No	Rango	No	Rango
1	0 a 0.88	3	1.76 a 2.64	5	3.52 a 4.40
2	0.88 a 1.76	4	2.64 a 3.52	6	4.40 a 5.28

- Different cooling load temperatures for the month of July for the calculation of the cooling load of flat roofs at 20° north latitude.

Techos No	Hora 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	-1	-2	-3	-3	-3	0	7	16	25	33	41	46	49	49	46	41	33	24	14	8	5	3	1
2	1	0	-1	-2	-3	-3	-2	2	9	18	27	34	41	46	48	47	44	39	31	22	14	8	5	3
3	7	4	3	1	0	-1	0	3	7	13	19	26	32	37	40	41	41	37	33	27	21	17	13	9
4	9	6	4	2	1	-1	-2	-2	0	4	9	16	23	30	36	41	43	43	41	37	31	25	19	13
5	12	9	7	4	3	2	1	1	3	7	12	17	23	28	33	37	38	38	36	33	28	23	19	15
8	16	13	12	9	8	7	6	6	7	9	12	16	19	23	27	29	31	32	31	29	27	24	21	18
9	18	14	12	9	7	5	3	2	2	4	7	11	15	20	25	29	33	35	36	35	32	29	25	21
10	21	18	15	13	11	8	7	6	5	6	7	9	13	17	21	24	28	31	32	32	31	29	26	23
13	19	17	16	14	12	11	10	9	9	9	11	13	16	18	21	23	26	27	27	27	26	24	22	21
14	19	18	17	15	14	13	12	11	11	11	12	13	16	18	20	22	23	24	25	25	24	23	22	21

Nota: 1. Aplicación directa de datos
Superficie obscura
Temperatura interior de 25.5 °C
Temperatura máxima exterior de 35 °C con temperatura promedio de 29.5 °C y rango diario de 11.6 °C
Radiación solar tipica de un día claro el día 21 del mes
Resistencia de la película de la superficie exterior de 0.059 m^2K/W
Con o sin techo suspendido y sistemas de cámaras de retorno de aire
Resistencia de la superficie interior de 0.121 m^2K/W

Nota: 2. Ajuste de la tabla de datos
Diseño de temperaturas: Corr: CLTD = CLTD + (25.5 - t_r) + (tm - 29.4)
Donde:
t_r = temperatura interior y te = temperatura exterior promedio
tm = temperatura exterior máxima - (rango diario)/2
Ningún ajuste recomendado para el color
Ningún ajuste recomendado para la ventilación del aire del espacio sobre el techo

Conclusions

By applying the methodology developed for the calculation of the cooling load, derived from the CLTD/SCL/CLF method, the exact dimensioning of the required air conditioning equipment is achieved, avoiding over-dimensioning, which implies sustainable energy savings.

Additionally, the use of thermal insulation combined with the aforementioned method will allow energy savings of 48.86 % when the classroom is occupied by 30 students and 59.48 % when it is occupied by 3 students, which represents a considerable saving in energy consumption, thus justifying the use of these materials in building construction from the energy point of view.

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