CASE STYDY

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Determining the Thermal Insulation Thickness for Flat Roofs of Buildings in Jalalabad City Considering Different Seasons

Akhtar Mohammad Shenwari [1*], Mohammad Essa Tanha [2], Zalmay Khaliqi [3]

[1]Department of Architecture Engineering, Nangarhar University, Afghanistan

[2]Department of Civil Engineering, Nangarhar University, Afghanistan

[3]Department of Civil Engineering, Nangarhar University, Afghanistan

Abstract

This research was carried out under the title of Selection of Thermal Insulation Thickness for Flat Roofs in Jalalabad City in Different Seasons. The main purpose of this study is to determine the thickness of different thermal insulation materials in the structures according to the winter and summer climate conditions to ensure that the economically appropriate thickness of thermal insulation materials is selected in the flat roofs, and the selection of the thickness of the thermal insulation materials in the structure of the flat roofs is noticed by urban planners, structural engineers, and building owners. In addition, another importance of this research is that, based on the determination of the thickness of thermal insulation materials in the flat roofs of buildings, we can sufficiently reduce the consumption of gas, electricity, and natural fuel to provide mechanical energy in buildings in Jalalabad city.

In this study, three samples of flat roofs from the buildings constructed in Jalalabad city were considered. In the first sample, cement plaster, RCC slab, Vapor insulation(bitumen), heat insulation extrude polystyrene, cement concrete, and ceramics were used. In the second sample cement plaster, reinforced concrete, vapor insulation (batmen), heat insulation mineral Faber block and waterproof PVC sheet, were used, and also in the third sample, gypsum plaster, cement plaster, reinforced concrete slab, vapor insulation (batmen) heat insulation dry soil (silt) and bricks of chukka, have been used respectively.

The thickness of the different thermal insulation materials of flat roofs mentioned above in the three samples should prevent the loss of heat transfer from outside to inside in summer and from inside to outside in winter. With the help of reliable works of the world, it has been calculated that from the three samples mentioned above, the thickness of the thermal insulation material of the first sample, where polystyrene was used as the insulation material, is 0.055m; for the second sample, where mineral cotton boards were used as insulation material, it is 0.05 m; and for the third sample, where silt was used as insulation material, it is 0.1m. Insulation materials used in the second sample are superior considering the type and thickness of the material, technical-economical characteristics, and age characteristics.

Keywords: Flat Roofs, Heat Transfer Ability, Heat Transfer General Coefficient, Thermal Insulation layer, Thermal Resistance, and Thermal Inertia.

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Introduction

Jalalabad city is located between 34 degree and 26 minutes of Northern latitude and 70 degree and 27 minutes of Eastern longitude. This city is 570 meters higher than the sea level. The hottest season of the city starts on May 8 and lasts until September 6. In these months of the year, the average temperature is 35°C, and in June, the average temperature is (27–48) °C, which is the hottest month of the year. The driest and coldest season starts on the 6th of December, and it lasts until February 28. During this period the average

Corresponding Author: Akhtar Mohammad Shenwari, Department of Architecture Engineering, Nangarhar University, Afghanistan, e-mail: akhtarmohd333@gmail.com

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temperature is 20 °C. This city has the coldest weather from December until January 30, when the average temperature ranges from 3-16 °C. (Essa, 2014)

Jalalabad has hot semi-arid climate, and its summer season is longer than the winter season. The most annual rainfall occurs in the winter and spring seasons. Winter is warm, and in the month of June, the maximum temperature of Jalalabad city is about 48°C In summer, the difference between morning and afternoon temperatures is estimated to be around 20–25 °C..(lalzad, 1979).

Currently, for the summer and winter seasons, suitable ways have been considered to solve the heating problems of the citizens. This includes using thermal insulation materials to reduce heat transfer and absorption, which allows buildings to be warm for longer periods and reduces energy needs in buildings in hot and cold weather. The temperature of the indoor air in building rooms should be kept suitable and constant without the use of electricity, gas, or other materials of fuel, and soundproofing of the rooms should be provided. The main purpose of this study is to draw the attention of urban architects and structural engineers to the type, quality, and economy of thermal insulation materials.

Research Objectives

- Determining the thickness of different thermal insulation materials in the construction of flat roofs of buildings in the summer and winter climate conditions of Jalalabad city
- Choosing the economic thickness of thermal insulation materials in flat roofs according to winter and summer climatic conditions
- Reducing the energy demand in buildings in hot and cold weather and keeping the temperature of the indoor air in the rooms of the buildings suitable and stable without using electricity, gas, or other fuel materials, as well as providing sound insulation to the building rooms.
- To attract the focus of urban planners, structural engineers, and building owners in choosing the thickness of thermal insulation materials in the construction of flat roofs.

Research Question

How can we choose the type and thickness of the thermal insulation materials of the building roofs in Jalalabad city?

Literature Review

In this scientific research, the selection of a suitable economic thickness of thermal insulation in different systems of normal flat roofs in Jalalabad city is calculated on the basis of winter and summer climate parameters. From the calculation, the highest thickness of the insulation has been considered for the seasons. From the internet and Google, no research paper has been written for the thickness of thermal insulation materials in flat roofs of buildings based on the winter and summer climate parameters of Jalalabad city in our country.

In 1979, Lalzad and Цепелев, Department of ventilation and Heating Engineering, Nangarhar University of Afghanistan. They calculated the heat insulation thickness in their Heat Transfer Text Book for the flat roofs of the residential buildings in the capital of Afghanistan, Kabul, where perlite concrete was used as insulation thickness for the winter and the summer (July) temperatures. They have calculated the thickness of the insulation thickness, perlite concrete, 0.14m for the summer season and 0.16m for the winter season and have accepted the optimum thickness considering these values (Цепелев and Lalzad, 1979).

In the years 2011–2013, engineer Mohammad Omar Temuri installed a technical device inside and outside the building rooms in Herat city to record the air temperature and temperature of interior surfaces. Then he compared buildings that did not have thermal insulation materials with the ones that had thermal insulation materials. The research found that

Table 1: Primary data for calculating the thickness of insulation during winter on the flat roofs buildings of Jalalabad city (Lalzad, 1979)

N	Types of building	Roofs type	Δt^n (°C)	α_i $\frac{w}{m^2\,°C}$	α_o $\frac{w}{m^2\,°C}$	Room temperature t_i(°C)	n	Winter Temperature t_o (°C)			
								t_{min}	t_1	t_3	t_5
1	Residential and Public Buildings	Ordinary flat Roof	4	8.7	11.6	18	0.9	-4.2	6.2	6.7	7.2

Table 2: Primary data for calculating the thickness of insulation during summer for flat roofs buildings of Jalalabad city (Lalzad, 1979).

N:	Types of building	Roofs type	In Summer temperatures t_s (°C)		V (msec)	Maximum and minimum Sun radiation observe ting by roofs surfaces , $\frac{W}{m^2}$	
			$t_{s.max}$	$t_{s.v}$		I_{max} ,	I_v
1	Residential and Public Buildings	Ordinary flat Roof	48°C	39.2°C	1	960	385

in the summer season, the indoor temperature for buildings having thermal insulation was 4.27 °C less than the outdoor air temperature, and the indoor surface temperature was 4.7 °C less than the outdoor surfaces. In the winter, the indoor air temperature was 8.5–12.9 °C higher than the outdoor air, and the temperature of the inner surfaces was 7.6–12.9 °C higher than the outer sur well as well (Haydari, 2015).

In 2021 Andhra Pradesh, the Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, published a joint article by. under the title of the comparison analyses of various insulating materials for building envelope components. This study aims to provide a knowledge base on identified insulation materials for corresponding building components with respect to material properties and performance parameters and recommend best material. The study present comparative analysis of insulating option available for various building components ..

In 2022, Okan Kon and Ismal Caner from the Mechanical Engineering department of Balikesir university conducted investigation under the title of Calculation of Insulation Thickness Depending On the Coldest and Hottest Climate Conditions for Different Flat Roof Types of Buildings. (Kon and Caner, 2022). They calculated the insulation thickness of three samples, where polystyrene was used in five climatic conditions, they compared the higher and the lower values of the thickness and chose the optimum value as the insulation thickness.

In the year 2015, A.Shanmuga Sundaram and Kuber Nath Mishra conducted investigation under the title of Optimum Insulation Thickness of Roof for Energy Saving Hot Regions Of India.(Sundaram and Mishra, 2015).they calculated the insulation thickness for four different insulating materials in the different climatic conditions of five cities which are located in the southern region of India. The purpose of this investigation was to reduce the use of electricity for cooling rooms and prevent the heat transfer from the outside to the inside in the summer season.

In 2009, (Jingue yu. et al), from the college of civil Engineering of Hunan University conducted an investigation under the title of A Study On Optimum Insulation Thickness of External Walls in Hot Summer and Cold Winter Zone of China. (Jingue yu et al, 2009). They investigated five types of heat insulations, namely expanded polystyrene, extrude polystyrene, foamed polystyrene, perlite and foamed P.V.C in four cities, Shaoguan , Changsha, Shanghai and Chengdu. they calculated the insulation thickness with a typical residential wall using solar –air cooling and heating degree day analysis and he found that the optimum insulation thicknesses vary from 0,053 – 0.236m. Finally, he chose the economic heat insulation thickness comparatively.

Research Method and Materials

In this research paper, considering the summer and winter climatic conditions of Jalalabad city, the reliable resources of the world have been used to calculate the thickness of different insulating materials in the walls of buildings with flat roofs. The following have been utilized as insulation materials.

In the first sample, the following materials were respectively used as insulation materials: cement plaster, reinforced concrete slab, Vapor Insulation (bitumen), heat insulation (polystyrene), cement concrete, and tiles of ceramics. In the second sample, cement plaster, reinforced concrete slab, vapor insulation (bitumen), heat insulation (wool mineral board), and waterproof PVC sheet were respectively used as insulation materials. In the third sample, gypsum plaster, cement plaster, reinforced concrete slab, vapor insulation(bitumen), heat insulation dry soil(silt) and brick of chukka ware used respectively as insulation materials.

Structural Types of Flat Roofs

Structural types of flat roofs are divided into three types, such as single skin (one layer) roof, double shell roof or cold roof and green roof (Malakzay, 2015). In this study, we calculated the thermal insulation thickness only for single skin roof (one layer) and ignored the other two types (double shell roof and green roof).

Flat Roof (one Layer) Flat Floor

flat roofs are load-bearing roofs in which the air does not flow and are made from several layers based on a tight connection with each other, and 100% located directly under sunlight (Katunska, 2015). In this study, for determining the thickness of single skin flat floors insulation materials, three samples were taken into consideration. In each sample, different insulation materials were used and their thicknesses were

Table 3: Primary data for materials used in the flat roof of first sample for calculating the thickness of insulation in winter and summer seasons.

No	Roof materials	Roof material thickness b(m)	Density (Kg /m^3)	Thermal conductivity λ (w/m °C)	Absorbed radiation material in (24hours) S (w/ m^2 °C)
1	Tile of ceramic	0.005m	2000	1.01	11.1
2	Cement concrete	0.05m	1800	1.74	16.69
3	Polystyrene insulation	x=?	35	0.036	2.5
4	Vapor Insulation (bitumen	0.01m	600	0.17	3.56
5	R.C.C -Slab	0.15m	2500	1.92	17.86
6	Cement Plastering	0.02m	1800	0.76	9.51

determined by calculation.

The primary data for determining heat insulation thickness materials in the summer and winter conditions of Jalalabad city are shown in the table below:

Calculation of the first sample

The bellow (figure. 1) shown as first sample material detail of built flat roofs of buildings in Jalalabad city.

Considering the above thermal insulation materials in table 3, the calculation of the thermal insulation thickness of the flat roof in the winter season is done as follows:

In the winter season, the thickness of the insulation in the external multi-layered roofs is calculated according to the following formula (Цепелв and lazad, 1979).

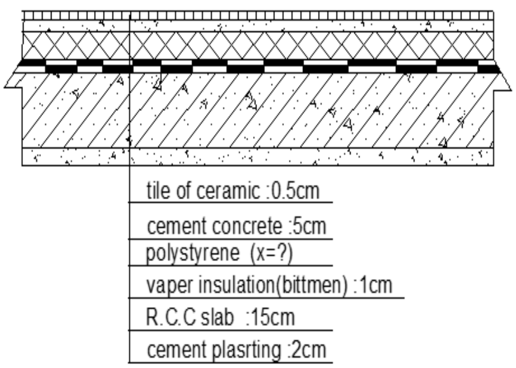

Figure 1: first sample material detail

$$b_{insu} = \lambda_{insu} (- R_0) \qquad (1)$$

In above formula:

λ_{insu} is the thermal conductivity of thermal insulation layer for different materials in (w/M°C) taken from tables (Цепелв and lalzad, 1979).

b_{insu} is thickness of thermal insulation layer i n flat roof in m.

R_0 is the thermal resistance without thermal insulation layer in(m^2°C$/w$) , calculating based on below formula (Holman, 2003), (Azezi,2010).

$$R_o = R_i + \Sigma R_{la} + R_{out} \qquad (2)$$

$$R_o = 1/\alpha_i + 1/\alpha_{out} + \Sigma X_1/\lambda_1 + X_2/\lambda_2$$

Also, in the above formula, R_{out} and R_i are the external and internal surface convective thermal resistances of the enclosure.

$$R_i = 1/\alpha_i \qquad (3)$$

$$R_{out} = 1/\alpha_{out} \qquad (4)$$

Here, is the convection heat transfer coefficient for internal surface of flat roof (α_i = 8.7w/m^2.°C) and is the convection heat transfer coefficient for outer surface of flat roof (α_{out}= 11.6 w/m^2.°C) (Цепелв and Lazad, 1979).

R_{la} is the thermal resistance of each layer of roofs material, and is calculated through following formula: (Bockh and wetzed, 2012; Cengle and Ghjar, 2015).

$$R_{la} = \frac{1}{\alpha_i} + \frac{1}{\alpha_{out}} \sum \frac{x_i}{\lambda_i} \qquad (5)$$

x_i − is thickness of different layers of flat roof material in m.

λ_i − is thermal conductivity of different layer of flat roof material in (w/M.°C).

R^{TR} is the theoretical(computational) thermal resistance capacity required for the external multi-layered enclosure of buildings in the winter season, which is calculated according to the following formula to meet the healthy requirements. (Lalzad, 1979), (Azezi, 2010)

$$R^{TR} = \frac{(ti-to)n}{\Delta t^n * \alpha_i} \quad \frac{m^2 °C}{w} \qquad (6)$$

In this formula:

n is the coefficient of exposure of the outer surfaces to the outside air for flat roofs (n= 0.9) taken from the table 2. (Azezi,2010).

t_i is the temperature of the inner air of main rooms of the building in °C, (t_i = 18°C) taken from table 3. (Lalzad, 1979).

t_o is the outdoor air temperature in winter, measured in °C, and is derived from table (14). (Lalzad, 1987**)** .

Δt^n is the difference between the temperature of the internal surfaces and the internal air in °C. = 4.5 °C and is taken from the (Azizzy, 2010).

when the insulation thickness is calculated for winter, the general (fact) thermal resistance () is calculated taking into account the calculated thickness by the following formula (Yunus and Afshin, 2015) . If the value for insulation thickness for winter is negative, it means that there is no need for insulation thickness in the composition, and the insulation thickness should be calculated for summer and we accept that calculated thickness of summer for winter too.

is the general (fact) thermal resistance of the roof, including the heat insulation layer of the roof. If the roof has (n) layers then we calculate the through the following formula:(Yunus and Afshin 2015).

$$R^F = R_{con.1} + R_{wall} + R_{con.2}$$

$$R^F = \frac{1}{\alpha_i} + \frac{1}{\alpha_{out}} + \Sigma \frac{X1}{\lambda 1} + \frac{X2}{\lambda 2} + \cdots + \frac{Xn}{\lambda n} \qquad (7)$$

When the general thermal resistances of the enclosure is calculated. then we calculate the thermal inertia of the flat roof. In the external enclosure with several layers of covers such as(walls, roofs and floors), the stability of thermal insulation thickness is controlled by the thermal inertia. The task of thermal inertia is the thickness of the external enclosures has shown.

Thermal inertia is calculated as follows (Temory, 2015);(Azezi, 2010).

$$D = R_I S_i = \sum \frac{b_i}{\lambda_i} S_i \qquad (8)$$

Here, $\Sigma bi/\lambda i$ is the general thermal resistance of all layers of a flat roof. It is calculated according to formula (6) for each layer of the roof.

s is the heat absorption coefficient of the material in 24 hours. It is shown with (S) and its unit is ($w/m2$ °C). It should

Table4: calculation of thermal insulation thickness in the winter season.

t_i °C	t_{out} °C	R^{TR} m^2°C/w	R_0 m^2°C/w	R^F m^2°C /w	(D)Thermal inertia In t_1 limited1.5< D < 4	insulation thickness in winterb(m)	Over heat coefficient U $=\frac{1}{R^F}$ w/ m^2	Q Watt
18	6.2	0.27	0.394	0.394	3.68	-0.0045	2.54	29.97

Table 5: thermal insulation thickness for the first sample in the summer season.

June t_v	Jun t_{max}	Aτ,am °C	$A\tau_{am}^{TR}$, °C	$A\tau_{am}^{F}$, °C	$A\tau_{am}^{F} \leq A\tau_{am}^{TR}$	Insulation thickness in summer	Over heat coefficient U $=\frac{1}{R^F}$ w/ m^2°C	Q watts
39.2	48	22.7	0.68	0.67	ok	0.055	0.52	15.6

be taken from table (Цепелв and lazad, 1979)

As in multi-layer enclosures (walls, coverings), the stability of the thickness of the insulation material is controlled by the thermal inertia, so the inertia is selected according to the temperature of the winter season as follows:(Azizy, 2010).

- If the temperature is selected in five coldest days and nights in the winter season, t_5=7.2c then D > 7.
- If the temperature is selected in three coldest days and nights in the winter season, t_3=6.7c then 4<d≤7.
- If the temperature is selected on the coldest day and night in the winter season, t1=6.2c, so 1.5<d≤4
- If the absolute minimum temperature of the coldest month (t_{min} = -4.1c) is selected, then D<1.5.

In the winter season, if the insulation thickness in the flat roof meets the selected temperature of the external air thermal inertia condition at the selected temperature, then the insulation thickness is correct. If the condition is not true, then the insulation thickness calculation is repeated again. So another outdoor air is chosen so that thermal inertia is true.

Over All Heat Coefficient Calculation

When the overall heat resistance of the flat roof is calculated, we then calculate the overall coefficient of heat transfer. The inverse value of temperature resistance is called the heat transfer coefficient and measured in (w/m^2 °C or w/m^{2}k) in SI. It is calculated based on below formula. (j. p. Holman, 2003), (Joel, 1999) and (Wetzel, 2012).

For multi-layer walls and floors, it is equal to:

$$U= I/R^F \quad (9)$$

k- is the temperature difference in the international system of units (Si). It is calculated according to the following equation, which is shown by (U) (Cengle and Ghjar, 2011).

(Q) is the amount of heat transferred from one surface to another as a result of the temperature difference (gradient) of multi-layer smooth coverings. Its unit is watts (watts), or it is equal to j/s.(Yunus and Afshin, 2015)

$$Q = UA\,(T_{a_1} - T_{a_2}) \quad (10)$$

$T_{a_1} > T_{a_2}$ are Ambien temperature on the inlet and on the exit side of surface.

Based on the(10) formula, we can calculate the heat transfer from the inside to the outside in the winter season and from the outside to the inside in the summer season.

Considering the thermal insulation materials from Table 3, the thermal insulation thickness of the flat roofs in the summer season is calculated as follows: (Цепелв and lalzad, 1979).

In order to ensure health standards in buildings, the actual amplitude of the temperature fluctuations of the surfaces of the external surrounding elements (A) must be smaller or equal to the calculated amplitude of the temperature fluctuations of the external surfaces ().

$$A_{\tau i}^{F} \leq A_{\tau 0}^{TR} \quad (11)$$

is the theoretical amplitude of the fluctuations of the temperature of the external surfaces in the summer season in (°C) and is calculated according to the following formula? (Цепелв and lalzad, 1979).

$$A_{\tau o}^{TR} = 2.5 - 0.1\,(t_{v,sum} - 21) \quad (12)$$

is the average temperature of Jalalabad city in the month of July and is taken from Table 1 and is equal to(= 39.2 .)

is the actual amplitude of temperature fluctuations on the internal surfaces of the flat roof in summer and is calculated with the following formula. (Цепелв and lalzad,1979)

$$A_{\tau i}^{F} = At_0^T / v \quad (13)$$

A is the calculated (theoretical) amplitude of outdoor temperature fluctuations in the summer season in Celsius and is calculated by the following formula: (Цепелв and lalzad,1979).

$$At_0^T = 0.5\, t_{s,max} + \frac{\zeta(I_{max} - I_v)}{\alpha_{os}} \quad (14)$$

In above formula:

$t_{s,max} = \frac{t_{max}}{2}$, =, is the half of the value of the maximum temperature of the hottest month of July in summer season.

ζ is the absorption ratio of solar radiation by the external surface of enclosure elements, which is taken from the table. (Lalzad, 1979)

I_{max} and I_v are the maximum and average values for sun radiation for horizontal parts of the roof, measured in $\frac{W}{m^2}$.($I_{max} = 960, I_v = 335$) .(lalzad,1979).

α_{os} is the convection heat coefficient from the external surrounding elements in summer climatic conditions and is taken from table .($\alpha_{OS} = 17.4 \frac{watt}{m^2}$)

In the winter season if D>1.5, V is equal to:. (Цепелв and lalzad,1979

$$v = 2^D * \beta_1 * \beta_2 * \beta_3 \quad (15)$$

$\beta1$ $\beta2$ and $\beta3$ are coefficients related to the thermal insulation materials, which are found as follows

$$\beta_1 = 0.85+0.15 \left(\frac{S_{ins}}{S_{out}}\right) \quad (16)$$

Here, is the heat absorption in (24hrs) by the insulation

Calculation of the second sample

The bellow (figure. 2) shown as first sample material detail of built flat roofs of buildings in Jalalabad city.

thickness and is the heat absorption in (24hrs) by the outer surface of the flat roof, which is derived from Table (3).

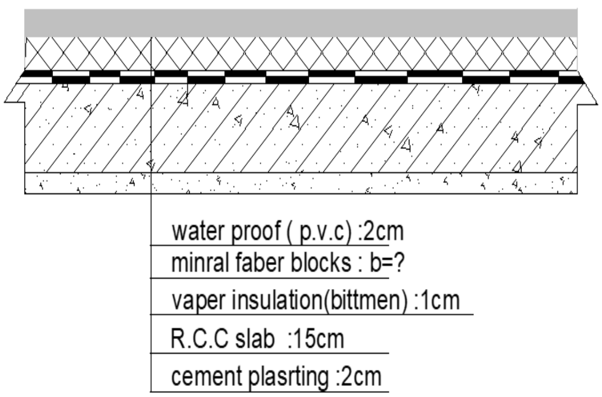

Figure 2: Second sample's roof material detail

(Цепелв and lalzad,1979)

$$\beta_2 = 1+0.5\, R_V * \frac{D}{R_0} \quad (17)$$

If there is no ventilated layer in the roof, then (R_v=0) and ($\beta2$ =1) $\beta3 = 0.83+3.5(\frac{R_0}{D})$

In the above formulas, (R_0) and (D) are the values of multi-layer thermal resistance and thermal inertia, respectively, in the winter season without insulation thickness.

If D > 1.5 in the winter season, then the heat insulation thickness for summer season is calculated as following: (Цепелв and lalzad,1979).

$$b_{ins} = \frac{\lambda_{ins}}{s_{ins}} \left(1.44\, m \frac{\beta_1*\beta_2*\beta_3}{A\tau_T^{o}/A\tau_{TR}^{ii}} - \sum \frac{s_i}{b_i} s_i \right) \quad (18)$$

Calculation of the third sample:

The bellow (figure. 3) shown as first sample material detail of built flat roofs of buildings in Jalalabad city

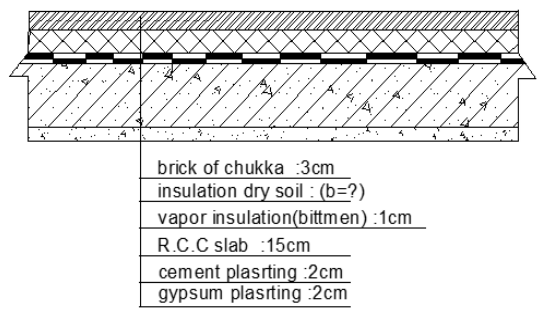

Figure 3: third sample roof material detail

Table 6: Primary data for materials used in the flat roof of second sample for calculating the thickness of insulation in winter and summer seasons.

No	Roof materials	Roof materia lthickness b (m)	Density Kg/ m^3	Thermal conductivity λ (w/ ^{0}C)	Absorbed radiation material in (24hours) sw/ $m^{2\,0}$C
1	water proof p.v.c	0.02m	1380	0.2	5.26
2	mineral Faber blocks	x=?	350	0.09	1.66
3	Vapor Insulation (bitumen	0.01m	600	0.17	3.56
4	R.C.C SLAB	0.15	2500	1.92	17.86

Table 7: thermal insulation thickness for the winter season.

t_i °C	t_{out} °C	R^{TR} m^2°C /w	R_0 m^2°C/w	R^F m^2°C /w	(D)Thermal inertia In limited 1.5< D≤ 4	insulation thickness in winterb(m)	Over heat coefficient U = $\frac{1}{R^F}$ w/ m^2	Watt
18	6.2	0.27	0.464	0.464	3.68	-0.0173	2.15	25.4

Table : thermal insulation thickness for the summer season.

June t_v	Jun t_{max}	Aτ,am ^{0}C	$A\tau_{am}^{TR}$, °C	$A\tau_{am}^{F}$, °C	$A\tau_{am}^{F} \leq A\tau_{am}^{TR}$	Insulation thickness in summer	Over heat coefficient U = $\frac{1}{R^F}$ w/ m^2°C	Q watts
39.2	48	26	0.68	0.67	ok	0.05	0.90	27

Table 9: Primary data for materials used in the flat roof of third sample for calculating the thickness of insulation in winter and summer seasons.

No	*Roof materials*	*Roof material thickness b (m)*	*Density Kg /m^3*	*Thermal conductivity λ (w/m ^{0}C)*	*Absorbed radiation material in (24hours) s w/ m^2 ^{0}C*
1	brick of chukka	0.03m	1800	0.7	9.51
2	insulation dry soil	x= ?	1200	0.24	4.78
3	Vapor Insulation (bitumen	0.01m	600	0.17	3.56
4	R.C.C Slab	0.12m	2500	1.92	17.86
5	cement plaster	0.02m	1800	0.76	9.51
6	gypsum plaster	0.02	800	0.21	3.29

Table 10: thermal insulation thickness for the winter season.

N0	t_i °C	t_{ou} °C	R^{TR} m^2°C/w	R_0 m^2°C/w	R^F m^2°C /w	Thermal inertia In limited 1.5< D≤ 4	insulation thickness in winterb(m)	Over heat coefficient $U = \frac{1}{R^F}$ w/ m^2	Q Watt
1	18	6.2	0.27	0.4	0.4	2	-0.031	2.5	29.5

Table 11: thermal insulation thickness for the summer season.

June t_v	Jun t_{max}	Aτ,am ^{0}C	$A\tau^{TR}_{am}$, °C	$A\tau^{F}_{am}$, °C	$A\tau^{F}_{am} \le A\tau^{TR}_{am}$	Insulation thickness in summer	Over heat coefficient $U = \frac{1}{R^F}$ w/ m^2°C	Q watts
39.2	48	26	0.68	0.67	ok	0.10	1.22	51

Conclusion

In the first sample, taking into account the materials of the smooth covering, the thickness of the insulating materials in the winter season has been calculated as (-0.0045m). Therefore, the layers of the flat roofs in the winter season do not require thermal insulation materials in the structure. However, due to the use of polystyrene insulation as thermal insulation material in the layers of this model, the thickness of the insulation materials is calculated to be 0.055m in the summer season. Thus, the thermal insulation thickness of the smooth covering is selected for the summer season, and it is also suitable for the winter season.

Considering the flat roof material of the first sample, the heat transfer in the winter season in the absence of insulation thickness from the inside to the outside is 29.5 watts per meter square of the roof, and in the summer season, (in the month of July), it is 104.5watts from the outside to the inside. These numbers indicate that heat transfer in the summer season is 71% greater than the winter's heat transfer.

If we select the insulation thickness of the summer season for the winter, then in the winter season, 3.34 watts of heat transfers from the inside to the outside per meter square of the roof, and in summer season, July, 15.6 watts of heat transfers from the outside to the inside. These numbers indicate that the heat transfer in the summer is 86.5% higher than in the winter.

Considering the material of the flat roof of the second sample, the insulation thickness is calculated to be (-0.0173m) in the winter season. Taking this value into account, there is no need to place thermal insulation materials in the layers of the roof structure in the winter season, but mineral cotton blocks (mineral Faber blocks) have been considered as thermal insulation materials in the same flat roof layers. The thickness of the insulation material is 0.05 mm for the winter season. Thus, the thickness of the insulation material of the flat roof is selected based on the summer season, and this is also suitable for the winter season.

Considering the flat roof material of the second sample, the heat transfer in the winter season in the absence of insulation thickness from the inside to the outside is 25.4 watts per meter square of the roof, and in the summer season, (in the month of July), it is 64.5 watts from the outside to the inside. These numbers indicate that heat transfer in the summer season is 60.62% greater than the winter's heat transfer.

If we select the insulation thickness of the summer season for the winter, then in the winter season, 10.62 watts of heat transfers from the inside to the outside per meter square of the roof, and in summer season, July, 27 watts of heat transfers from the outside to the inside. These numbers indicate that the heat transfer in the summer is 60.70% higher than in the winter.

considering the material of the flat roof of the third sample, the thickness of the insulating material in the winter season has been calculated to be (-0.031 m), and therefore, there is no need for thermal insulation materials in the structure, but in the layers of this sample, silt has been used as a thermal insulation material. According to calculations, the thickness of the insulation materials in the summer season is 0.1 m. As a result, the thermal insulation thickness of the flat roof is selected for the summer season, which is also suitable for the winter season.

Considering the flat roof material of the third sample, the heat transfer in the winter season in the absence of insulation thickness from the inside to the outside is 29.5 watts per meter square of the roof, and in the summer season, (in the month of July), it is 75 watts from the outside to the inside. These numbers indicate that heat transfer in the summer season is 60.70% greater than the winter's heat transfer.

If we select the insulation thickness of the summer season for the winter, then in the winter season, 14.4 watts of heat transfers from the inside to the outside per meter square of the roof, and in the summer season, July, 36.6 watts of heat transfers from the outside to the inside. These numbers indicate that the heat transfer in the summer is 61% higher than in the winter.

From the thicknesses of the thermal insulation material of the three samples mentioned above, it was 0.055m for the first sample, where polystyrene was used as the insulating material; 0.05 m for the second sample, where the insulating material was mineral cotton boards; and 0.1 m for the third sample, where silt has been used as an insulating material. The roof material of the second sample and the type and thickness of thermal insulation material are the best options considering technical, economic, and age characteristics.

The thermal insulation thickness for the winter season has been calculated by aforementioned equations (from 1 to 10) and the result of each factor is mentioned below in Table 4 (all specifications has been taken from figure. 1).

The thermal insulation thickness for the summer season has been calculated by aforementioned equations (from 11 to 18) and the result of each factor is mentioned below in Table 5 (all specifications has been taken from figure. 1).

The thermal insulation thickness for the winter season has been calculated by aforementioned equations (from 1 to 10) and the result of each factor is mentioned below in Table 7 (all specifications has been taken from figure. 2).

The thermal insulation thickness for the summer season has been calculated by aforementioned equations (from 11 to 18) and the result of each factor is mentioned below in Table 8 (all specifications has been taken from figure. 2).

The thermal insulation thickness for the winter season has been calculated by aforementioned equations (from 1 to 10) and the result of each factor is mentioned below in Table 10 (all specifications has been taken from figure. 3).

The thermal insulation thickness for the summer season has been calculated by aforementioned equations (from 11 to 18) and the result of each factor is mentioned below in Table 11 (all specifications has been taken from figure. 3).

Discussion

In the year 2013, engineer Muhammad Umar Temuri used only EXS as a thermal insulation material in the walls and roofs of buildings in Herat city. During his research, he chose a 40mm thickness of EXS for walls and 100mm for roofs. In order to compare the internal air and surface temperatures with the externals, he used the DMICI technical device of the Department of Physics, Faculty of Construction, Slovak University, and he did not calculate insulation thickness according to the temperature. However, in this article, the thickness of the thermal insulation has been calculated on the roofs, and accordingly, it has been concluded that, considering the climatic conditions of Jalalabad city, there is no need for insulation materials in winter. However, thermal insulation materials are needed on the roofs during the summer season. The thickness of the thermal insulation material (55mm) has been achieved by using the same thermal insulation material (EXS).

Based on the joint work of (N. Sugandha et al), which has been published under the title "The Effects of Environment on Thermal Insulation Materials in Flat Roofs," In their work, the insulating materials on flat roofs have been evaluated in terms of properties, volume weights, and age. This is important because more mechanical energy is consumed to heat rooms in buildings, and modern buildings are designed in such a way that the cost of providing mechanical energy is reduced. However, they did not calculate the thickness of the insulation material on the roofs. In this article, the thickness of the insulation on the roofs has been calculated considering the weather conditions.

In 1979, Lalzad and Цепелев, from department of ventilation and heating Engineering in Nangarhar University of Afghanistan calculated the heat insulation thickness in their Heat Transfer Text Book for the flat roofs of the residential buildings in the capital of Afghanistan, Kabul, where perlite concrete was used as insulation thickness for the winter and the summer (July) temperatures. They have calculated the thickness of the insulation thickness, perlite concrete, 0.14m for the summer season and 0.16m for the winter season and have accepted the optimum thickness considering these values.

The main differences of this investigation with the above one is that, this investigation is for Jalalabad city, which is hotter than Kabul and has a lengthier summer season than Kabul. In addition, heath insulation thicknesses are calculated for three samples. The heat insulation thickness for the first sample where polystyrene is used as insulation is 0.055m ; for the second sample, where mineral Faber blocks were used, it is 0.05m, and for the third sample, where dry soil was used, the insulation thickness is calculated to be 0.10m. In all of the three samples, the heat insulation thickness for the summer season is higher than for the winter, thus the thickness for the summer season is accepted for the winter.

In 2022, Okan Kon and Ismal Cener from the Mechanical Engineering department of Balikesir university conducted investigation under the title of Calculation of Insulation Thickness Depending On the Coldest and Hottest Climate Condition for Different Flat Roof Types of Buildings. (Kon and Cener, 2022). They calculated the insulation thickness of three samples, where polystyrene was used in five climatic conditions, they compared the higher and the lower values of the thickness and chose the optimum value as the insulation thickness.

The main difference of this investigation with the above one is that in the above investigation only polystyrene was used as insulation material in all of the three samples. In contrast, in this investigation, different insulation materials were used in the three samples and the insulation thicknesses for each sample is different.

In the year 2015, A.Shanmuga Sundaram and Kubar Nath Mishro calculated the insulation thickness for four different insulating materials in the different climatic conditions of five cities which are located in the southern region of India under the title of Optimum Insulation Thickness of Roof for Energy Saving Hot Regions Of India. The purpose of this investigation was to reduce the use of electricity for cooling rooms and prevent the heat transfer from the outside to the inside in the summer season.

The main difference of this investigation with the above on is that this investigation is carried out for one city in three sample, having different insulation material.

In 2009, Jingue yu, from the college of civil Engineering of Hunan University conducted an investigation under the title of) A Study On Optimum Insulation Thickness of External Walls in Hot Summer and Cold Winter Zone of China((Jingue yu. et al, 2009). They investigated five types of heat insulations, namely expanded polystyrene, extrude polystyrene, foamed polystyrene, perlite and foamed P.V.C in four cities, Shaoguan , Changsha, Shanghai and Chengdu. they calculated the insulation thickness with a typical residential wall using solar –air cooling and heating degree day analysis and he found that the optimum insulation thicknesses vary from 0,053 – 0.236m. Finally, he chose the economic heat insulation thickness comparatively.

The main difference of this investigation with the above on is that this investigation is carried out for one city in three sample, having different insulation material.

Results

In this study, the thickness of the insulating materials of the flat roofs of the buildings in the climatic conditions of Jalalabad city was investigated in three samples.

First, calculations were made for choosing the thermal insulation thickness of the three samples, and their technical-economical and aging characteristics were compared, and then compared with the world's reliable research on the subject. As a result, it was found that:

From the thicknesses of the thermal insulation material of the three samples mentioned above, it was 0.055m for the first sample, where polystyrene was used as the insulating material; 0.05 m for the second sample, where the insulating material was mineral cotton boards; and 0.1 m for the third sample, where silt has been used as an insulating material.

The roof material of the second sample and the type and thickness of its thermal insulation material are superior considering technical, economic, and age characteristics.

Recommendations

- Urban planners, construction engineers, and building owners should use thermal insulation materials for heating buildings in the winter, cooling them in the dry season, and saving energy. In addition, they should determine the thickness of the coatings and the thickness of the insulating material through calculations.
- It was found in this study that the use of boards made of mineral wool as a thermal insulation material is technically and economically superior to the use of other thermal insulation materials, as well as in terms of longevity, so it is recommended to use mineral wool boards as thermal insulation materials.
- Construction engineers and architects must first find out the climatic characteristics of the regions and design the buildings accordingly.

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