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A6_7 Insulating Britain

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Abstract

It was investigated how much of an effect adding insulation to your roof does to the heat transfer out of the house and how much of a financial gain can be made in the process. It was found that from adding 10cm of insulation heat loss out of the roof was reduced by 86.7%, and that this reduction in heat loss equated to saving £2.66 per day.

Introduction

For this investigation we look at the effect of adding insulation to help prevent heat loss from the roof of a house. It was assumed that the roof without insulation consisted of 0.05m of lightweight concrete tiles and 0.05m of hardwood oak. It was also assumed that the roof had dimensions of 10m by 5m in surface area. This set the initial parameters for the rest of the investigation.

Theory

Since the roof in this scenario is made up of multiple layers of different material, we can find the equivalent thermal resistance of these layers by adding each materials respective thermal resistances since they are in series, where R_1 and R_2 are the resistance of the roof tiles and wooden board layers respectively:

$$R_T{}' = R_1 + R_2 (1)$$

Where:

$$R = \Delta x / \lambda \quad (2)$$

$\Delta(x)$ is the thickness of the material and λ is the thermal conductivity. Lightweight concrete tiles have a thermal conductivity of $0.4 W/mK$ [1] and hardwood oak has a thermal conductivity of $0.16 W/mK$ [1]. This leads to an equivalent resistance of $0.4375 W/mK$.

We then do the same but with the insulation layer added on in the series leading to the following equation:

$$R_T = R_T{}' + R_3 (3)$$

Where R_3 is the thermal resistance of the insulation layer. In this investigation we will be using an insulation of glass mineral wool which is commonly used in roof insulation, it has a thermal conductivity of $0.035 W/mK$ [2]. Comparing the two resistances can give us a ratio of heat transfer before and after adding the layer of insulation.

$$R_T{}' / R_T = c (4)$$

Using this equation we get a value for c of 0.133 meaning a reduction in heat loss per unit area of 86.7%. Now that we know the respective change in thermal resistance we can now use this to work out the difference in thermal current and therefore work out the change in energy lost through heat transfer per unit time.

The equation for thermal current is given by:

$$I = \frac{A}{R_T}\Delta T \tag{5}$$

Where in this equation A is equal to the surface dimensions of the roof and ΔT is the difference in temperature either side of the roof, we have assumed inside the house is room temperature (20 degrees Celsius) and is winter conditions outside (5 degrees Celsius). Working out the thermal current for the scenario without insulation gives us a value of $1714.3W$. Then using our constant c, from equation 4 we can use this to get the thermal current with the insulation layer added, this results in a value of $228W$. This gives an overall change in thermal current of $1486.3W$.

If the house was being heated by propane gas we can then equate the amount of energy that is being saved every day to how much propane would be needed to supply that reduction in energy and find the total savings. It is currently saving 1486J/s which means it saves 128390400J per day. Propane's energy content is approximately 91330Btu per gallon [3], which equates to $96353150J$ per gallon [4]. This means that you would be saving 1.332 gallons of propane per day. Assuming that 1 gallon of propane costs £2 [5] then you would be saving £2.66 everyday due to the insulation layer.

Results and Conclusion

As you can see from the results, this shows that even just a small layer of insulation (10cm thickness) can significantly reduce the amount of heat lost through a surface, this is shown best though the ratio between resistances where we can see that the insulation layer resulted in a reduction in the heat loss per unit area of 86.7%.

It was also shown that this reduction in heat loss resulted in the thermal current from the inside to the outside of the house was greatly reduced (by the same factor), this meant that energy was able to be kept inside the house for a longer period.

The energy that would have been lost due to the lack of insulation was calculated to be $1468J/s$ and over the time period of 24 hours this amount of energy equated to 1.332 gallons of propane gas, which has a market value in the region of £2.66.

It should be noted that this would be in the ideal scenario, this does not take into account the inconsistencies within the layers, which may have things such as air trapped inside that would effect the resistance to thermal transfer in that layer. There were also approximations that had to be made for the dimensions of the layers and the roof itself that would effect these results.

References

[1] `https://www.electronics-cooling.com/2008/02/thermal-properties-of-building-materials/` [Accessed 29th November 2021]

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[4] `https://www.rapidtables.com/convert/energy/BTU_to_Joule.html` [Accessed 30th November 2021]

[5] `https://www.homeadvisor.com/cost/plumbing/propane-tank-prices/` [Accessed 29th November 2021]