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The Miracle of Insulation in Hot-Humid Climate Building

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Abstract

Building is a climate modifier for humans. Most designers today focus on functions in the buildings and leave the issue of human comfort conditions to engineers who use mechanical systems to modify the interior environment. Energy and CO_2 emissions are influencing factors in the global warming phenomenon. One alternative in the solution of these problems is reducing energy consumption by using insulation materials in the building envelope. Insulation materials provide many benefits to the building, such as reducing energy consumption, increasing comfort, ease of installation, light weight, and low cost. For instance, proper insulation in the roof should consider time lag, insulation property, condensation, and thermal bridge. As a result, the benefits include reduced cooling requirements up to 10 times that of a conventional building, and improving mean radiant temperature (MRT) by approximately 30% thereby increasing human comfort. The results show that properly installed insulation will save half of the cooling load from the building envelope.

Keywords: Thermal insulation materials, Building envelope, Energy conservation, Comfort, Application, Guidelines

1. Introduction

The buildings in cities usually use mechanical air-conditioning systems for thermal comfort in occupied spaces. This requires producing electrical energy to support the demand. This is an important factor contributing to CO_2 in the environment which in turn raises temperatures, i.e. the Green House Effect and Heat Island.

Most buildings in hot, humid climates have been designed without considering for materials and insulation. This is an important reason why heat influencing the temperature inside the building usually includes the heat gained from the outside air and the building's envelope, especially if the roof is directly exposed to sunlight all day. Inappropriate selection of material can cause the external heat to escape into the building, which, in turn, requires more energy to cool down the building. The proper application of insulation will reduce the heat transmission into the building and the heat gain during the hottest period of the day. This is one alternative to help in solving energy and environment problems.

This paper provides guidelines for insulation in hot-humid climate buildings. The envelope is of a material selected to save energy by applying the combination of mass and insulation to the envelope. The application suggests how to use insulation in hot-humid buildings to save energy and to improve quality of life.

2. Objective

How can we determine the correct application of insulation application to create an energy efficient building? Many parameters should be considered when selecting and combining insulation materials for the building envelope, as it is the major factor which impacts performance and energy-conservation issues.

3. Methodology

The following methodology was adopted to determine the proper application of insulation for hot-humid climate buildings in order to solve the energy problems and improve quality of life:

1. Find the materials and discern how to combine them to create insulation that can resist heat transfer from outside.
    - Properties and performance of insulating materials
    - Mass characteristics
    - Reflective cavity
    - Still air
2. Method for applying the insulation to control for all factors:
    - Resisting heat transfer from outside the building

- Low Mean Radiant Temperature inside the building
- Ensure the system of the envelope does not create environmental pollution and is safe for the health of occupants
- Save energy and increase human comfort

3.1 Properties and performance of insulating materials

The factors considered for selecting insulation[1]

1. Physical form
2. Bulk density and heat capacity
3. Suitability for service temperature
4. Thermal expansion
5. Thermal resistivity
6. Resistance to water penetration
7. Resistance to compaction
8. Mechanical strength
9. Fire hazard
10. Resistance to vermin and fungus
11. Acoustical resistance
12. Absence of odor
13. Corrosion and chemical resistance
14. Maintenance

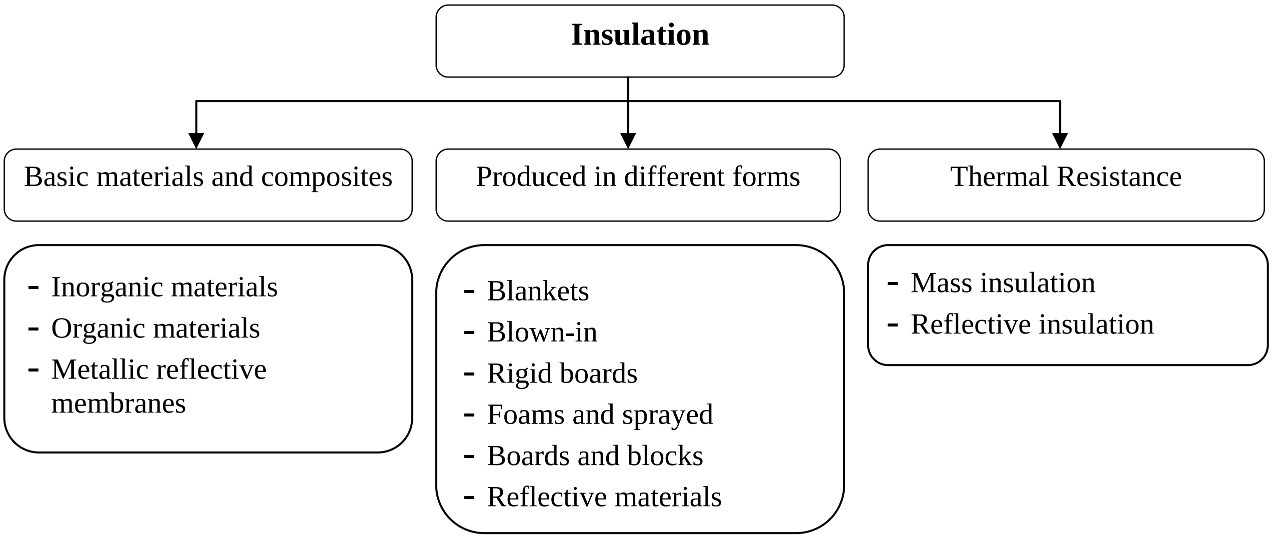

Fig 1. Classification of insulating materials

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[1] Soontorn Boonyatikarn. *Thermal Insulation Manual*. Bangkok, pp.31-35.

4. Result

The insulation guidelines for the envelope should consider important factors needed to develop an appropriate combination of insulation.

- Materials that have high Thermal Resistance value (R-Value) to resist heat transfer from outside the building
- Insulation materials that are environmentally friendly and non-toxic
- Insulation application that prevents the absorption of water vapor
- Envelope that contributes to the occupants' comfort; Low MRT (Mean Radiant Temperature)

4.1 Insulation application guidelines for External Wall

Materials most commonly selected for constructing walls in Thailand today are brick and mortar walling with reinforced concrete. These materials cannot serve the following needs:

- Resistance of exterior walls to heat absorption
- Protecting the building's envelop from hot-humid weather
- Discomfort of the occupants due to high Mean Radiant Temperature (MRT)

Conducting a study to determine the wall selection is an important step for saving energy. The wall is the major structural element exposed to the external environment. Heat is transferred from outside through the wall to inside. This is what makes the inside temperature higher, thus affecting the energy consumption of the air conditioner.

4.1.1 Finding the materials can resist heat transfer from the outside.

The graphs (Fig. 2 and 3) illustrate heat transfer from the walls with different materials having thicknesses of 4 and 8 inches and exterior insulation and finished system (EPS 4 inches) into the west side of the building in April. A wall thickness of 4 and 8 inches absorbs the heat higher than the EIFS wall. The highest amount of heat absorbed by concrete wall is 76 Watt/m^2 (24 Btu/ft^2) whereas highest heat absorbed by brick wall is 73 Watt/m^2 (23 Btu/ft^2).. Similarly, the highest amount of heat absorbed by light weight concrete wall and exterior insulation and finished system (EIFS) wall is 38 Watt/m^2 (12 Btu/ft^2) and 9 Watt/m^2 (2.78 Btu/ft^2) respectively. Therefore, the highest heat at the roof is with the concrete wall followed bybrick wall, and light weight concrete wall, while the lowest is with the EIFS wall.

The graphs (Fig. 4 and 5) illustrate heat transfer from the conventional wall construction into each side of the building in April, and show that the one-layer masonry wall (4 inches) absorbs heat better than EIFSwall. The EIFS wall absorbs much less heat by approximately 9 times less.

From heat transfer data made to discover the properties of materials which have a thermal resistance value (R-Value), it is learned that we can reduce heat transfer through the wall. To accomplish this, the wall should have a high thermal resistance value.

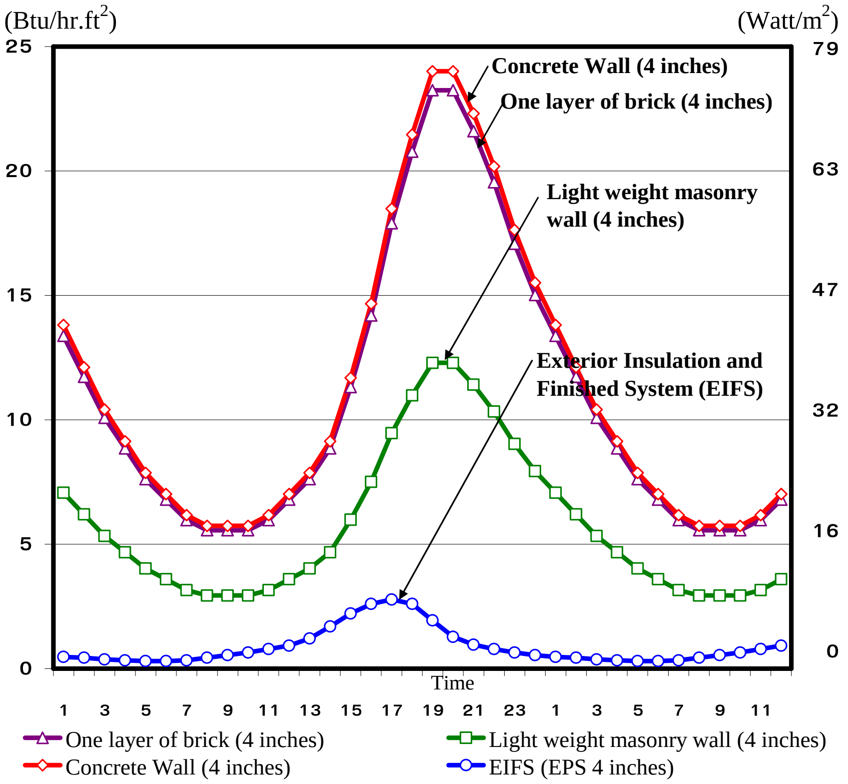

Fig 2. Comparison of heat transfer from the walls with different materials having thickness of 4 inches and exterior insulation and finished system (EPS 4 inches) into the west side of the building in April.

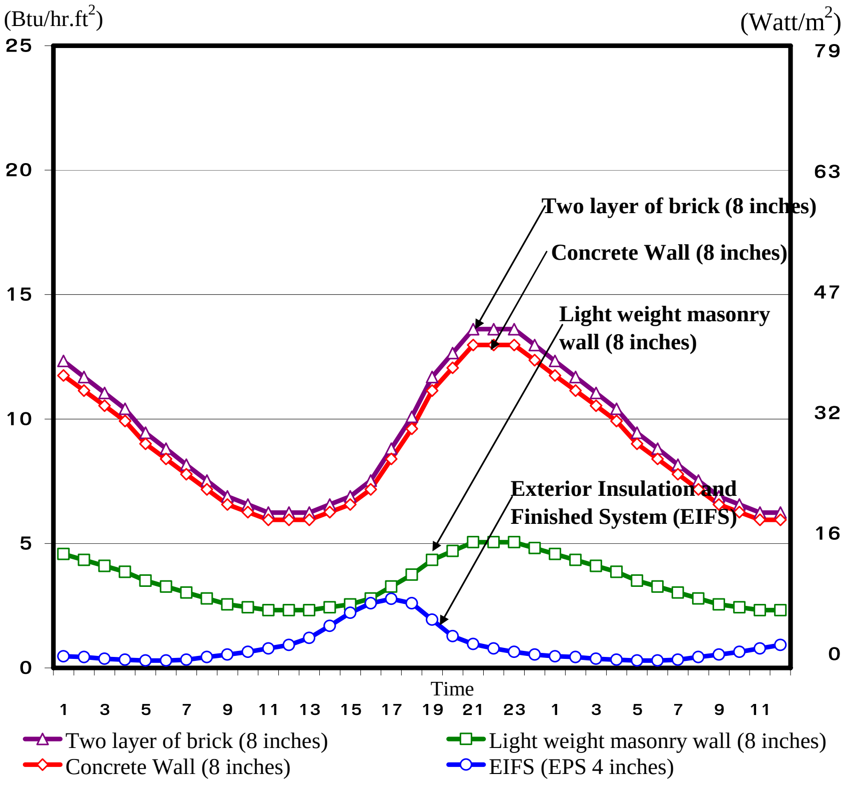

Fig 3. Comparison of heat transfer from the walls with different materials having thickness of 8 inches and exterior insulation and finished system (EPS 4 inches) into the west side of the building in April.

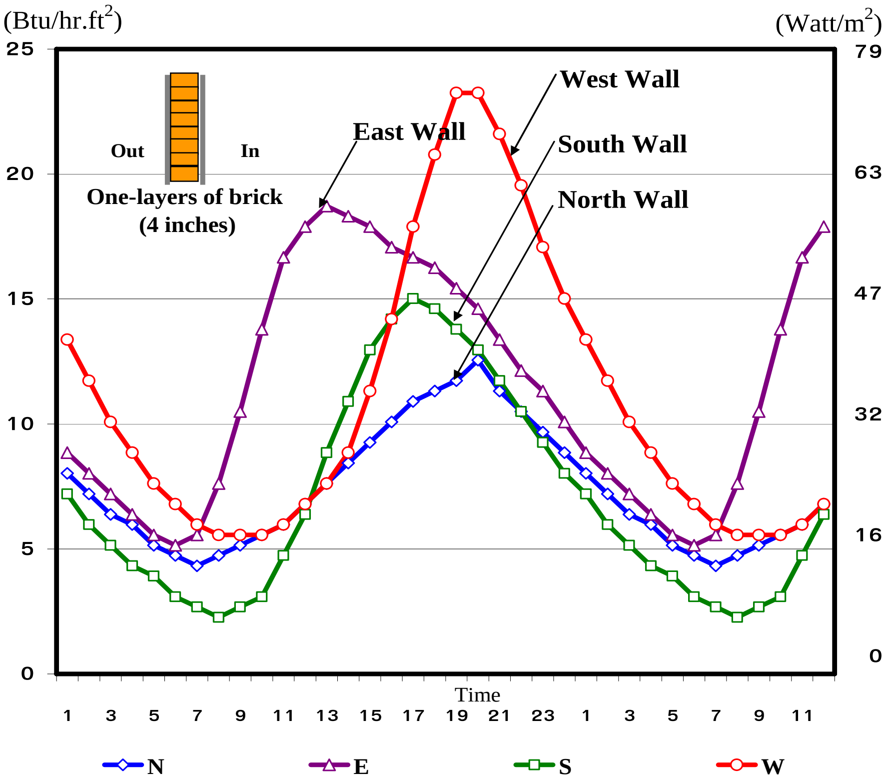

Fig 4. Comparison of heat transfer from conventional building wall (one-layer of brick) into the each side of building on April.

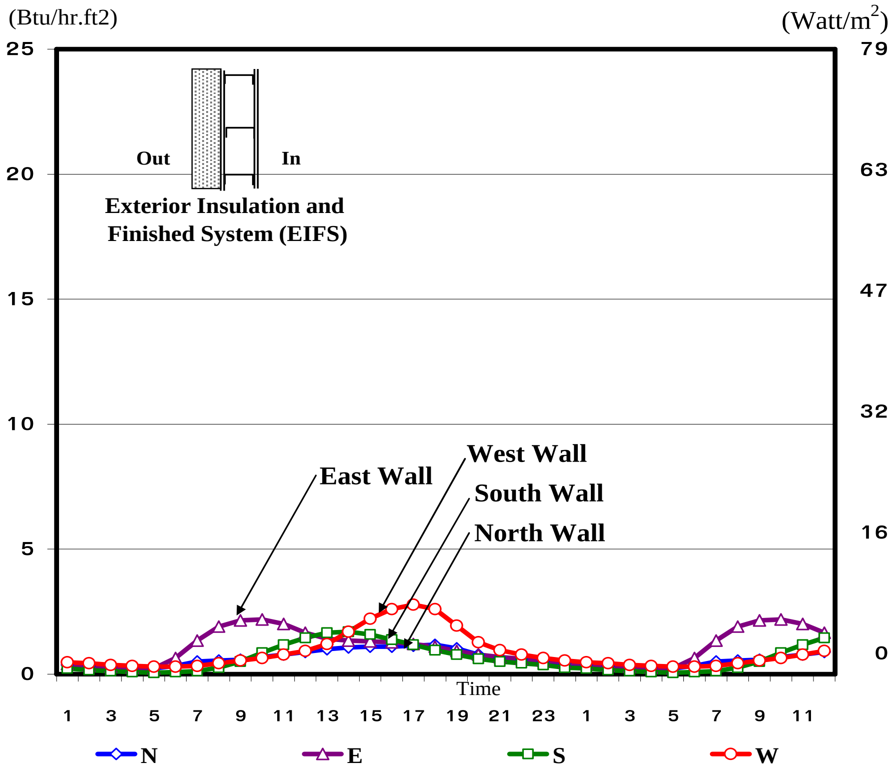

Fig 5. The comparison of heat transfer from exterior insulation and finished system (EIFS) wall into each side of the building in April.

4.1.2 How to combine to maximize the quality of insulation

The next study combines insulation in the wall in order to reduce heat transfer from the outside and to maintain the quality of insulation. The insulation can protect against heat through the wall when installed as an interior insulation for the building's envelope.

The graph (Fig 6) illustrates heat transfer from one layer of brick and 3-inch Glasswool (inside), which in an interior insulated wall absorbs the highest heat at 10 Watt/m^2 (3.15 Btu/ft^2). An interior insulation wall absorbs much lower near the EIFS wall.

An interior insulated wall can reduce heat transfer through the wall but cannot serve the following important needs:

- Reduction of condensation
- Thermal bridge

An interior insulated wall will have dew point at the insulation layer, which is the reason for lost quality of insulation, and may have fungus growth inside the wall that can cause illness in the occupants.

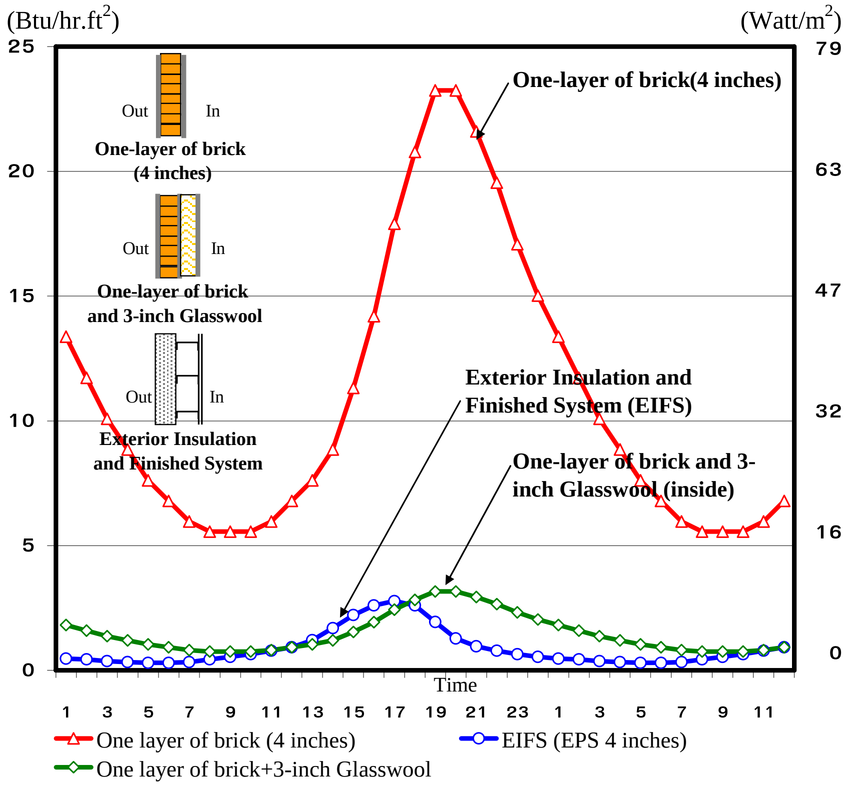

Fig 6. Comparison of heat transfer from conventional building wall (one-layer of brick) and improved wall with insulation inside in the west side of the building in April.

Next study analyzes materials which are usually used in conventional construction and other materials have qualification for hot-humid climate, such as two-layers of brick, light weight masonry wall, interior insulation, exterior insulation and finished system (EIFS). This study finds a solution for the wall in buildings in hot-humid climate and solves the energy and quality of life problems.

Consider the use of exterior insulation for the building's envelope; the exterior insulated wall can solve the following problems:

- Reducing heat transfer through the envelope
- Protecting thermal bridge from structure of building
- Preventing cracking of the wall by using flexible insulation
- Low Mean Radiant Temperature (MRT) inside the building

4.2 The insulation application guidelines for Roof

Materials commonly selected for constructing roofs in Thailand today are concrete tiles for houses and concrete roofing for commercial buildings. These materials can't serve the following needs:

- Protecting against heat absorption
- Prevent penetration of moisture from the outside
- Discomfort of the occupants due to high Mean Radiant Temperature (MRT)

The roof is the major structural element exposed to the external environment, especially direct sunlight during the entire day. The use of insulation in correct application reduces heat transfer and reduces heat gain during the hottest period of the day. This study finds a solution by combining insulation in building roofs in hot-humid climate and thereby solving the energy and quality of life problems.

4.2.1 Finding materials that can resist heat transfer from the outside.

This study analyzes materials usually used in conventional construction and other materials which qualify for hot-humid climate, such as concrete tile with air spaces, concrete tile with well-known insulation types, concrete roofing without ceilings and concrete roofing with insulation.

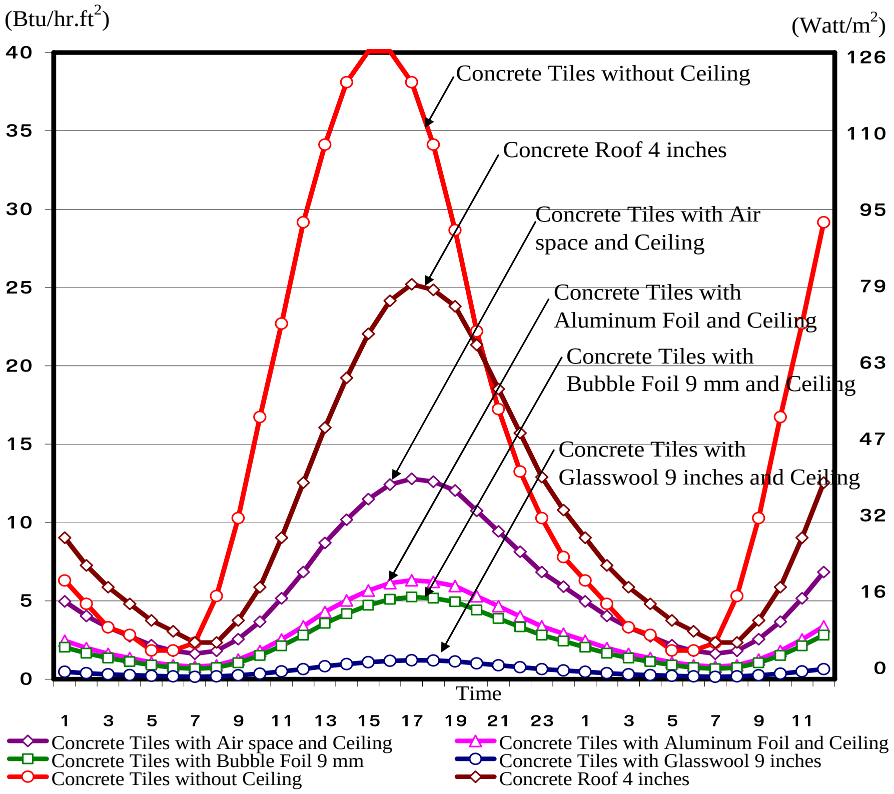

Fig 7. The comparison of heat entering through roof types in April.

The graph (Fig. 7) indicates heat transfer into the building in April with roof types that are usually used in conventional construction. The Concrete Tiles without Ceiling absorbs the highest heat at 126 Watt/m^2 (40 Btu/ft^2). The Concrete Tiles with Air spaces and Ceiling which is a common roof system today absorbs the highest heat at 41 Watt/m^2 (13 Btu/ft^2). This study shows heat transfer difference between concrete tiles roof combination with a well-known insulation types.

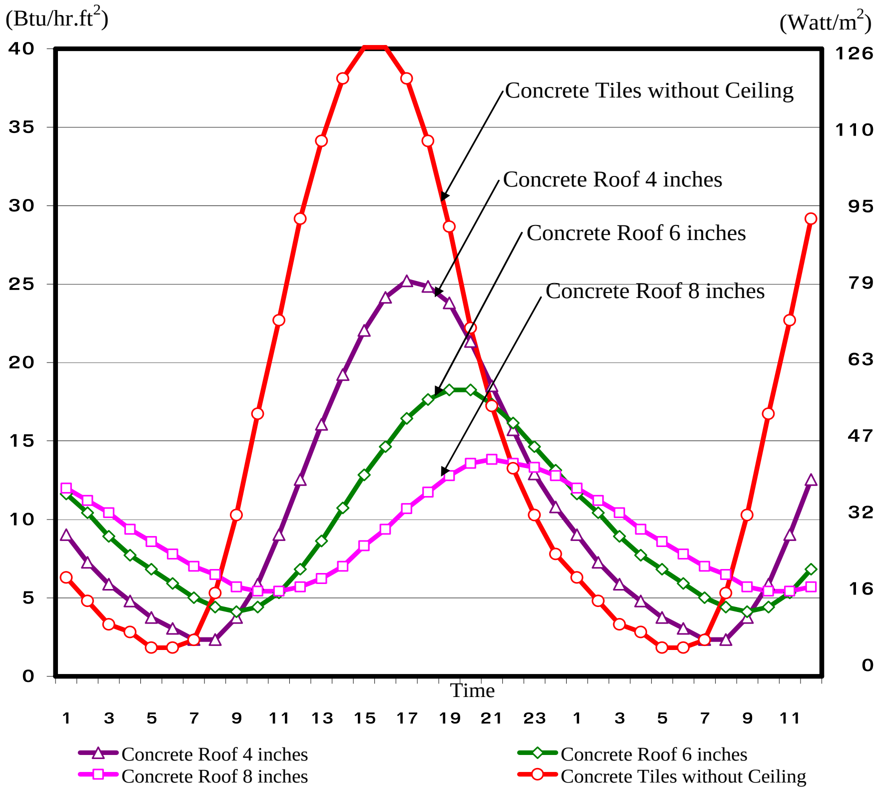

Fig 8. Comparison of heat entering through roof types and impact of mass on time lag and decrement factor.

The graph (Fig 8) illustrates heat transfer from the thermal mass roof. Concrete Roof of 4 inches absorbs the highest heat at 79 Watt/m^2 (25 Btu/ft^2) at 5 pm. Concrete Roof of 6 inches absorbs the highest heat at 57 Watt/m^2 (18 Btu/ft^2) at 7 pm. Concrete Roof of 8 inches absorbs the highest heat at 44 Watt/m^2 (14 Btu/ft^2) at 9 pm. The mass can reduce heat transfer and delay the peak load due to the thickness of the concrete roof. This study shows that the roof with combined insulation types can resist heat transfer while the impact of mass causes a time lag and decrement factor.

4.2.2 How to combine for efficient insulation

The next study combines insulation in the roof in order to reduce heat transfer from the outside and uses additional factors such as reflective air space, emissivity, and mass, to maximize insulation efficiency.

Reflective air space.

The roof system that combines insulation types wrapped in foil or finished with foil, having an air space on one side, creates a reflective air space. The value of air spaces as thermal insulation must include the character of the enclosing surfaces. Generally, 3.5 inches or more of reflective air space will have an R-value up to 1.77 m^2.K/W (10.07 h ft^2 F/Btu) during the day.

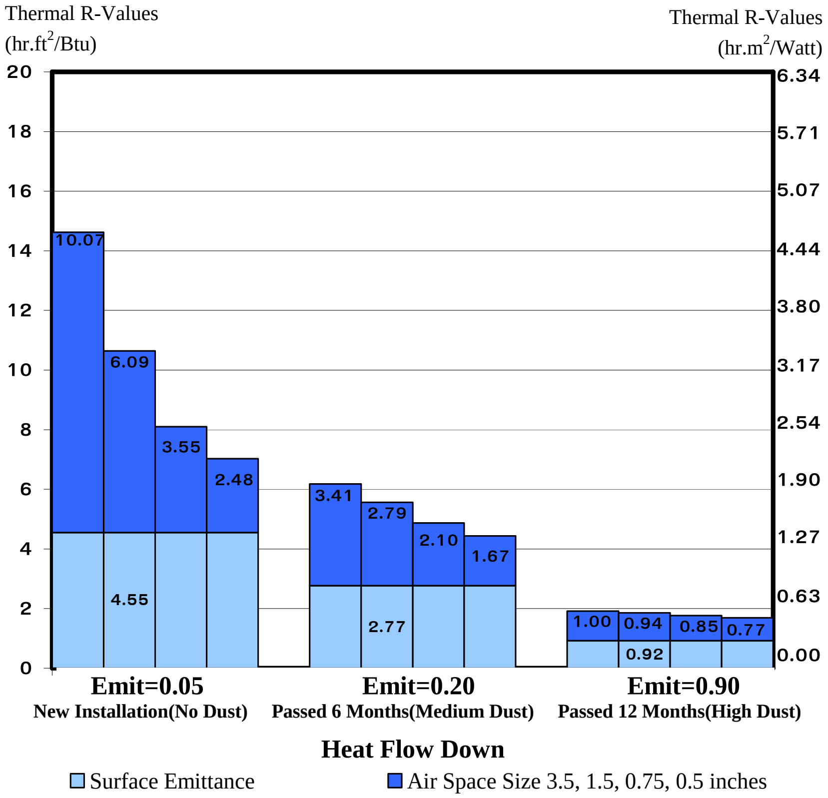

Fig 9. Comparison of thermal resistance values of surface and reflective air spaces when installing the reflect (foil) faced up, and lower R-value due to accumulation of dust.

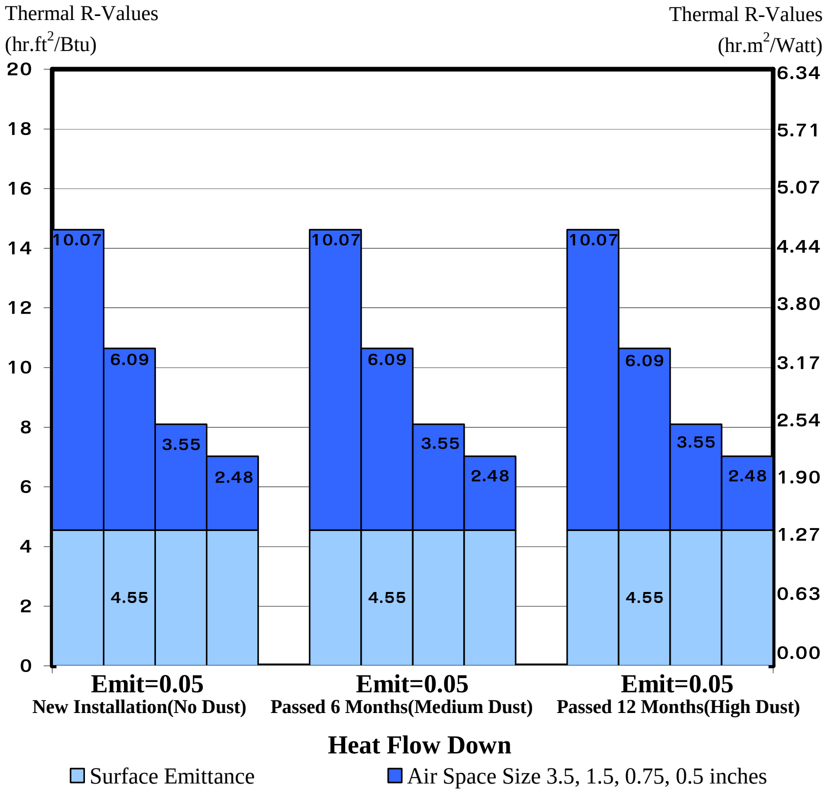

Fig 10. Comparison of thermal resistance values of surface and reflective air spaces when installing the reflect (foil) faced down which have high R-value.

The emissivity factor of the source's surface

Emissivity is the rate at which radiation (emission) is given off. Absorption of radiation by an object is proportional to the absorptive factor of its surface, which is the reciprocal of its emissivity.

Installing insulation wrapped in foil has effects to the R-Value of a reflective air space and emissivity. The graphs (Fig. 9 and Fig. 10) have shown the R-Value of surface and reflective air space when installing the reflector (foil) faced up and down. The correct installation for high R-Value is to install the reflector (foil) faced down, which minimizes the accumulation of dust which, in turn, reduces the heat reflection in the long run. On the other hand, if the reflect (foil) was installed faced up, dust in the air would fall onto the reflect causing lower R-Value of the surface and reflective air space.

Applying insulation to the roof

The graph (Fig 11) illustrates that heat transfer from the roof of concrete tiles without ceiling is greater than in the concrete roof of six inches. The highest temperature difference between these two types is approximately 70 Watt/m^2 (22 Btu/ft^2) and delays the peak load to after working hours (approx. 8pm). Then, the study shows that combining concrete roof of 6 inches with Glasswool of 9 inches reduces heat by 53 Watt/m^2 (17 Btu/ft^2).

The mass can reduce heat transfer from the outside and timing of heat entering the building. Mass will help to reduce and delay the heat transfer through the roof. Thermal insulation will reduce the magnitude of the heat gain into the building. The study has shown the effects of the application of mass and insulation. The amount of heat passing into the building during working hours will drop tremendously. Moreover, the peak load that occurs during the middle of the day will be delayed.

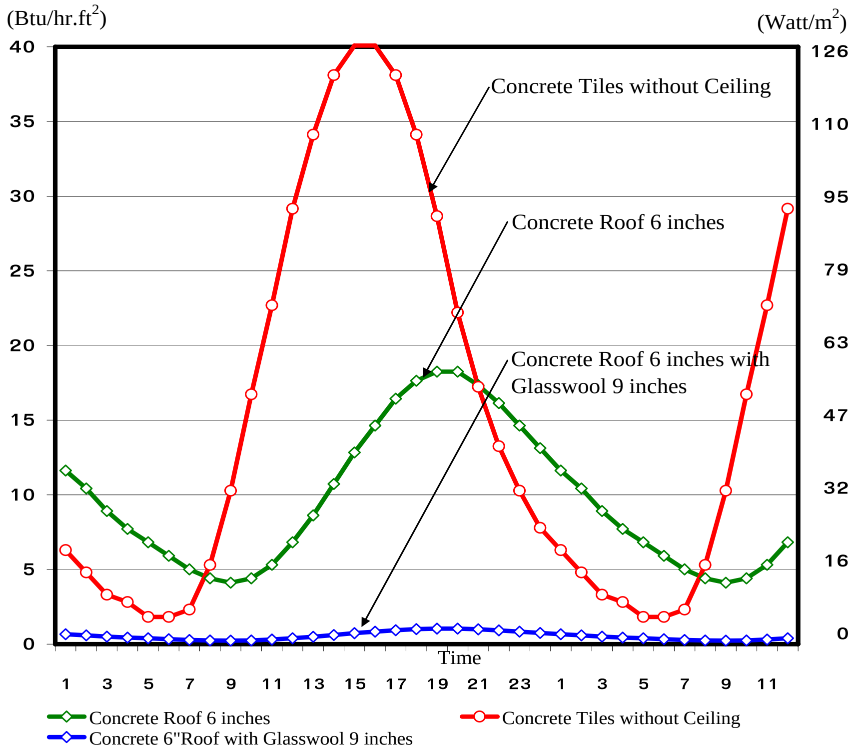

Fig 11. Comparison of heat entering through roof with the application of mass and insulation.

The roof is appropriate for a hot-humid climate; it is capable of protecting against heat flow down and ***allows minimal heat conduction and moisture penetration.*** Its properties are:

- Characteristic of mass - it decreases heat transfer by conduction

- Low conductivity (U-value) - An air space between two materials of roof layers, Reflective cavity and Still air
- Low moisture penetration – a desiccant is installed in a perimeter frame inside air space to prevent the penetration of moisture

Combining the qualities of insulation and mass in the building envelope will not only reduce heat transmission into the building, but will also make it possible to avoid heat gain during the hottest period of the day.

4.3 Insulation application guidelines for hot-humid climate buildings

From **insulation application** for walls and roofs, the next study is the human perception of the surrounding temperature with the goal of improving human comfort and reducing cooling load needed to modify the interior environment.

The graph compares Mean Radiant Temperature (MRT) between the conventional construction and insulation application construction

- Conventional construction: *Concrete Tiles with Air space and Ceiling*
  One-layer of brick (4 inches)
- Insulation application construction:
  Concrete Roof of 6 inches with Glasswool of 9 inches
  Exterior Insulation and Finished System (EIFS)

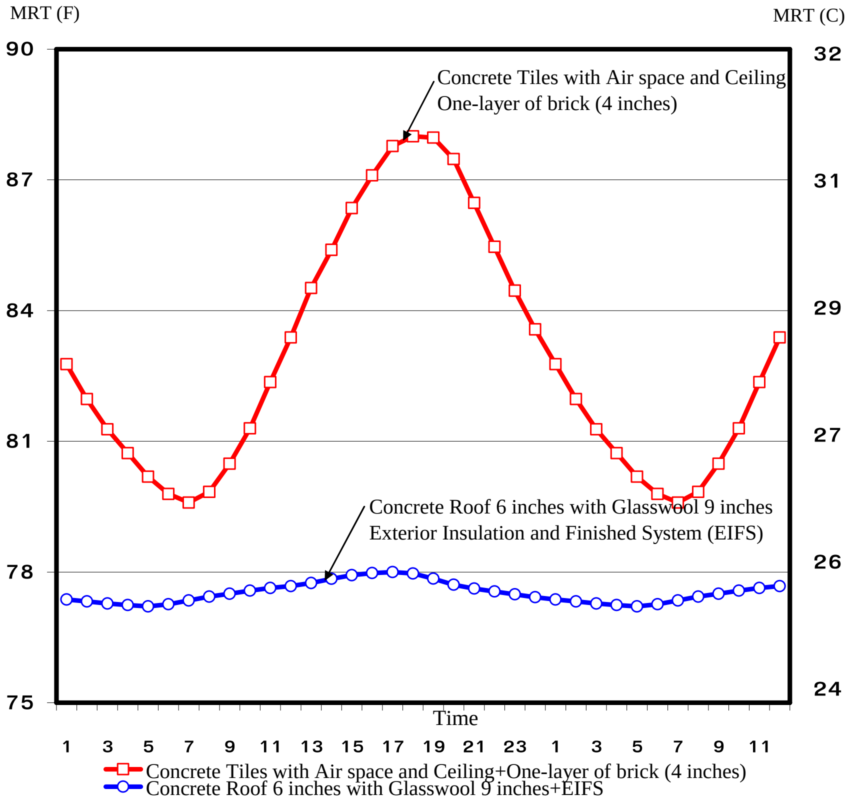

Fig 12. Comparison of Mean Radiant Temperature (MRT) inside the conventional building and the insulation application building in April.

The graph (Fig. 12) is a comparison of Mean Radiant Temperature (MRT) inside the conventional building and the insulation application building in April. The result indicates that MRT of the conventional building is higher than that of the insulation application building. The highest temperature difference between these two buildings is approximately 5.5 degrees Celsius.

This study shows that the application of insulation reduces heat transfer from the outside and makes the space more comfortable for the occupants by achieving a lowered MRT inside the building and reducing air-conditioning requirements and thereby saving energy.

5. Conclusion

The insulation application guidelines in this paper suggest how to use insulation wisely in order to decrease heat and energy use. A wall with exterior insulation absorbs much less heat by approximately 9 times. The mass and insulation roof can reduce heat transfer and delay peak load of heat entering the building. This application of insulation can resist heat transfer from outside the building, resulting in low Mean Radiant Temperature (MRT) in order to improve the comfort of occupants and to prevent heat transfer approximately 10 times more efficiently than a conventional building. This allows a reduction the requited required size of the air-conditioning system and reduces annual energy costs. The application of insulation decreases heat added to the environment and improves the future energy outlook. The application of insulation can, thus, alleviate energy problem and environment problems.

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