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How the Green Roof is Effective in Reducing the Ambient Temperature

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Abstract

The green roof is a roof that is mostly surrounded by vegetation and soil or is covered with a vegetative medium. Chlorophyll creation has a positive effect on the climate of the city and can also contribute positively to providing cool air inside the buildings. This cooling of air occurs by reducing the penetration of heat through the roof and providing stronger insulation to prevent indoor air to become warm. As a result, the indoor temperature can be efficiently decreased during summer and increased during winter. Decreasing power consumption is one of the major concerns for sustainability in cities. Making a roof garden is offered as one of the ways to reduce energy consumption in major cities. A roof garden or green roof - if properly designed and executed by considering climate issues - can greatly help to decrease energy consumption. Changing buildings roofs to green roofs could improve the exchange of air between areas of high building density and open spaces between them and accordingly adjust the city›s air moisture. This technology has several advantages including less wastage of heating and cooling, purification of air, reduction of noise corruption, and most importantly energy consumption efficiency – factors that can help the stabilization of city life. Due to the improvement in the social, economic, and environmental conditions, the development of green roofs has always been at the top of the agenda in advanced cities. Heat loss through the roof of the buildings is high and there is a lot of energy wastage in higher floors units. Therefore, the green roof is the answer to this problem. Green roofs by rising roofing coatings, act as thermal insulation and help control heat exchanges between the inside and beyond of the buildings. In the present research, behind recognizing the benefits of green roofs with this hypothesis that “green roof and how the design of the green roof has an effective role in reducing heat transfer” with help of analysis software called Ansys, three samples of conventional roofs, green roofs conventional and green roofs with a special detail (fiberglass layers) analyzed and heat transfer comparative compared. Also, installed heat sensors to confirm the thermal performance of green roofs for designed green tops and simple ample of normal green roof, point optimization of designed green roof respect to normal green roofs, heat performance-wise. With software analysis and laborato0000000000000000000000ry samples, green roof compared to 50%

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less heat transfer rather conventional roof and a green roof with fiberglass coatings to 40% rather green roof conventional optimized. Shading and evaporative cooling plants and the role of roof coatings that all perform like insulation have an effective role in reducing heat transfer. In research, methodology research related to the benefits of green roofs is a defining and qualitative approach. But in sectors related to software analysis, these had a quantitative approach and analytical process.

Keywords: Green Roof, Heat Transfer, Reduce Energy Consumption, Ansys Software.

Introduction

It is built with green to turn the dead space of the roofs into a dynamic space. Although these roofs are considered as private and semi-public spaces, but they have an effective role in urban ecological efficiency and creating the desired quality of urban life. The impact of green roofs on a city scale is significant. Turning the roofs of houses into green spaces improves air exchange between areas with high building density and open spaces between them and regulates the humidity of the city. [1], [2]

Green roofs, despite having functions in the city scale such as beautifying and entertaining the city landscape and eliminating urban pollution and reducing psychological stress; They are also very effective in exchanging power and heat from outside to inside spaces. Green roofs are one of the modern solutions to urban problems. This technology has many advantages, including reduced heating and cooling load, Air purification, wastewater protection, reducing noise pollution and, most importantly, reducing power consumption are all efforts to sustain cities. Emphasizing the role of green roof thermal function, this paper is interdisciplinary research that creates a link between fluid mechanics and architecture with a new perspective, and with the help of Ensis 2 software, analyzes the heat transfer of green roofs and compares it with roof.

Green roofs are generally classified into three types: "dense", "wide" and "semi-dense". Dense green roofs are primarily designed as public spaces and include trees, shrubs, and shrubs, and are like landscaping. They have a ship environment with a depth of 400-150 mm. They also need high maintenance. The typical weight of a dense green roof is between 500-180 kg per square meter. Due to the significant weight load of this type with the roof, the design of roof structures is of particular importance and is also more expensive. Due to the shallow green roof and limited root expansion, the type of vegetation is limited to grasses, perennial, annual and drought-resistant herbaceous plants. [1], [3], [4]

Importance and necessity of research

Even though the green roof was used in rural houses in Iran in the past, today green roof or roof garden is an unfamiliar word for many people. In planning more advanced cities the world of green roof construction has become an executive instruction. Green roofs are effective in North American urban planning in places like Chicago, Portland, Oregon, and Toronto, Canada, and are considered due to dust pollution. And the dust that enters Iran from southwestern countries, as well as the pollution caused by gasoline fuel that has endangered the health of people in big cities, it is necessary to pay attention to the environmental effects and the positive effects of green roofs. In addition, green roofs play an effective role in reducing energy consumption, and since optimizing fuel consumption has become one of the most important issues in the lives of citizens, its use can be useful. Other benefits include reduced heat island effects, noise absorption, environmental degradation, reduced water, and wastewater pollution. [1]

Overview of the quantitative and qualitative advantages of green roof compared to Ordinary roof

Heat protection of the building is one of the features of the green roof that can greatly reduce the heat load coming from above during the summer period. Creating a green roof is an acceptable ecological solution that not only helps to reduce the heat load on the outside of the building but also helps to improve the quality of dense urban centers that have little natural environment. The foliage of the plant protects the building from the sun's rays and controls the temperature and humidity of the indoor environment. In closed places where plants are planted on the roof, the air temperature below these plants is lower than the air temperature above them. Differences between plant roofs and conventional roofs can be divided into two categories: quantitative and qualitative differences. The process of heat transfer in plant roofs is completely different. Plants absorb significant amounts of sunlight due to their biological functions such as photosynthesis, perspiration, respiration, and evaporation. The rest of the sun's rays are converted into heat, and when it passes through the roof elements, it affects the indoor air conditions. [3], [4], [5], [7]

Quantitative benefits

1. Sound insulation

Street noise nuisance is a major problem in urban areas. However, insulating the facade in modulating its sound load means reducing the sound pressure level from outside It contributes significantly to the interior of the building, but the roof and its type also affect the impact of this factor on the comfort of citizens. With green lights, they increase the sound insulation in the roof system. Of course, this effect is different with broad green hairs that are shallow and have a thin layer of soil, and garden-like roofs with deeper soils. The quality of sound insulation performance depends on the type of system used and on the thickness of the layer. Green roofs with a soil layer thickness of 12 cm reduce sound penetration by up to 40 dB and green roofs with a soil layer thickness of 20 cm reduce sound penetration by up to 46 dB. Increasing the depth of the bed to 15 to 20 cm improves the project noise, but the green roof with a deeper layer does not provide any further benefit. The sound waves on the green roof are mostly emitted at frequencies in the range of 500 to 1000 Hz. In any case, these soil layers are known as soft sound conductors. Soil absorbs lower frequencies of sound and plants tend to absorb higher frequencies.

The soil, air, and vegetation layers used on green roofs are permeable, thus allowing sound to grow inside the environment. Due to the many interactions that take place between the particles of the layers and the sound, they reduce the intensity of the sound and cause the absorption, reflection, and propagation of sound waves. [6], [7]

2. Reducing the effects of heat islands

In large cities, due to having large hard and impenetrable surfaces and lack of vegetation, radiant heat acts as a source of heat energy are absorbed. Such a state or restaurant is called a heat island phenomenon. Their surfaces are covered with asphalt and gypsum and the areas are covered with vegetation. This difference in the effect of urban heat islands of this city and its suburbs in summer can be up to 10 degrees Fahrenheit. This increases energy consumption and creates the phenomenon of greenhouse gases, which are the most important cause of ozone depletion. According to the US Environmental Protection Agency, the temperature of the city can be up to 5, 6 degrees Celsius warmer than all-around for every 6 to 10 degrees Celsius increase in air temperature, the percentage may also increase. [6], [7], [8]

3. Reduce air pollution

In urban areas, trees have a significant role to play in reducing air pollution. However, in many urban sites, there is little space for planting trees due to a set of impermeable surfaces, including parking streets, etc. It absorbs through its pores and separates them from its leaves and is also able to break down certain organic compounds such as aromatic hydrocarbons in plant tissues or the soil. In addition, they are indirectly reduced by lowering the surface temperature. Reduces air pollution through cooling and shading exudates, which in turn reduce photochemical reactions of pollutants such as ozone in the atmosphere. Because different plant species have different abilities to eliminate air pollutants and reduce greenhouse gas emissions, more effective species can be selected to maximize air quality improvement. Evergreen pines, for example, may offer more benefits than deciduous species, as they retain their leaves and play a more effective role in reducing ozone, SOx, and NOx particles. Trees and shrubs are more effective at removing contaminants, mainly due to their larger bulb area than perennial grasses. Although dense green roofs with trees and shrubs are more desirable in terms of reducing pollution, wide green roofs can still play a complementary role in air quality. [7], [8]

4. Reduce carbon dioxide

The earth is warming due to the natural cycle and the burning of fossil fuels. Combustion emits fossil fuels, or carbon dioxide, as a by-product of combustion. Or carbon dioxide, often because it is one of the atmospheric gases that prevent the transfer of heat energy near the surface to higher levels, as an interfering factor increases the greenhouse effect and raises the ambient temperature. [7], [8]

Green roofs can be effective in reducing carbon dioxide in the atmosphere in two ways:

1. Carbon is the main component of plant structure and is naturally decomposed in plant tissues through photosynthesis and in soil substrate through plants and root exudates.
2. Reduce energy through building insulation and reduce the effect of the urban heat island.

Carbon decomposition can be generally improved by changing species selection, bed depth, bed composition, and management practices. Increasing the depth of the bed can not only provide more storage volume for carbon, but also with a larger volume of the soil allows larger perennials and even trees to grow, and trees, in turn, can make an effective contribution to reducing drought compared to grasses. In addition, the composition of the growth medium can change the extent of this effect. In studies, coal expanded in the growth medium contains 80% of the energy contained in the green roof. By using alternative materials, the energy involved can be significantly reduced. In the Pacific Northwest, for example, there is a volcano of pumice, often used as part of the layer. Pumice stone is an expanded stone that is obtained by the heat of nature and as a result, its contained energy is greatly reduced. In addition, management practices such as fertilization and irrigation will affect stored energy and carbon decomposition. [4], [5], [7], [8]

5. Reduce the load on sewer systems

The green roof has a 70% effect on reducing surface water flow, improving surface water flow quality, and reducing sewage overflow. Green roofs can retain 80% of water in summer and between 25 and 40% in winter, as well as with deep compacted roofs. The 150 mm bed holds about 75% of the water annually and with wide green hairs with a bed depth of 100 mm about 45% water. Water retention in winter is significantly lower than in summer. These results are due to differences in evapotranspiration and distribution of rainfall. But it depends on the type of green roof system, soil composition and depth, roof slope, plant species, soil moisture, and intensity and duration of rainfall. The water stored in the soil will eventually evaporate or return to the outside space. In addition, water flow is delayed due to soil saturation. Because the flow is released over a longer period, it can help protect the urban surface water system from flooding and reduce the wear potential of the landing. By maintaining surface water, the green roof reduces the likelihood of an overflow of wastewater costs as well as the costs associated with the surface water system. The green roof, on the other hand, affects the quality of these values. Of course, the amount of roof water flow affects the quality of the output water. The problem is that pollutant particle (especially heavy metals and nutrients) that adhere to the leaf surfaces are washed away by rain and enter the surface water system, resulting in air pollution and water pollution. There is a direct relationship between the amount of rainfall and the number of solids in the effluent. However, in more rainfall, the concentration of material increases from the green roof. In addition, plant selection, soil composition, substrate and penetration depth, age of the green roof all affect the quality of the effluent. Organic, the concentration of nitrogen and phosphorus in the soil decreases. [5], [6], [7], [9]

6. Reduce heat transfer through building energy storage

Green roofs protect from the sun's rays and indirectly play a role in cooling and reducing heat transfer. Because heat transfer always takes place from bodies and spaces with higher temperatures to spaces with lower temperatures, heat transfer on the roofs of buildings takes place from inside to outside in winter and from outside to inside in summer. Green roofs help to cool the roof space during the summer and keep it warm in the winter by reducing the heat fluctuations on the outer surface of the roof and by increasing the heat capacity of the roof layers. The results of a recent study at the University of Toronto show that green roofs in cold climates also have the necessary function to keep spaces warm. Plants help increase heat retention by reducing the cold winter wind and adjusting the microclimate on the roof. Of course, the effect of reducing the intensity of wind is greater than the effect of shading. Vegetation prevents freezing of the planting environment in winter, which increases the insulation of the roof. Frozen or snow-covered get double points. To conserve energy in winter, research by the University of Nottingham and the University of Trent in Peterborough, Canada on the temperature of ordinary roofs and green roofs in summer and winter shows the effect of these roofs in reducing heat transfer. (Tables 1 and 2), [7], [8], [9]

Table 1. University of Nottingham's research on the temperature of ordinary roofs and green roofs in summer.

Average daily temperature	**Equivalent to 18.4 ° C**
The temperature of the space under ordinary roofs	**Equivalent to 32 ° C**
The temperature of the space under the green roofs	**Equivalent to 17.1 ° C**

Table 2. Trent University Research in Peterborough, Canada on the temperature of ordinary roofs and green roofs in winter

Average daily temperature	**Equivalent to 0 ° C**
The temperature of the space under ordinary roofs	**Equivalent to 0.2 ° C**
The temperature of the space under the green roofs	**Equivalent to 4.7 ° C**

Therefore, the following items decrease heat transfer in designed green roofs:

1. Increasing the heat capacity of the roof

In winter, there is less energy loss from inside to outside and in summer there is less heat transfer from outside to outside. In green roofs, by increasing the layers that increase the heat capacity of the roof layers, they play an effective role in reducing heat transfer, and in summer, they help to cool the space under the roof, and in winter, they retain more heat inside the building.

2. Moisture retention

Greenery and living vegetation retain moisture inside and thus play an effective role in controlling the temperature of the building. Water, as a thermal mass, prevents temperature fluctuations and cools the building in summer, and keeps it relatively warm in winter.

Of course, the amount of this effect varies according to the different seasons of the year and the amount of moisture in the roof network.

3. Plant photosynthesis (reduction of sun absorption)

The combination of reactions performed in the soil, including training and propagation, as well as photosynthetic reactions and plant transpiration, reduces the amount of solar energy absorbed by the top layer, and as a result, the temperature of the subsoil space with it decreases in summer. In winter, they also have a positive thermal function with green mosses. Plants constantly retain some air about their roots, which acts as a layer of thermal insulation. Of course, the performance of this layer of thermal insulation with green leaves depends on the amount of moisture they retain. [7], [8], [9], [10]

Advantages of quality

1. Roof shell protection

The lifespan of a typical roof is about 20 years. If the lifespan of the green roof is estimated at 45 years or more. Roof bitumen membrane is protected from UV rays and extreme temperature fluctuations between night and day by soil and vegetation. [9], [11]

2. Expansion of green area and habitat of living things

With green fishes, the habitats of plants and plants that fall victim to building development can be compensated, thereby reducing the number of plant-free areas and expanding the limited wildlife development. Compared to conventional fishes, green foxes have many benefits for the environment and wildlife, especially when they are compatible with the environment and climatic conditions of the region, they have a great contribution to the conservation of species in the same area. [11], [12]

3. Food production

A green roof is an option to develop farming on the roof that expands food production. Green roof products can have better quality and more natural production than market products due to attention to fertilizers and pesticides. [1]

4. Beauty and well-being and entertainment

With ordinary masonry, often with their ventilation equipment, chimneys and layers of bitumen and paving create an anomalous appearance on the fifth face of the building. Also, heat absorption due to the dark color and gender of the roofing material prevents the presence of the roof. Now, with a little greenery, the efficiency and role of this can be changed. With green leaves with cooling and shading properties, they provide a pleasant environment and can be used for public entertainment as well as developing urban open spaces. [11], [12]

5. Promoting health and well-being

Studies show the importance of direct human contact with natural and green areas and their role in human physical and mental health and show that the key to green space directly reduces heart rate and blood pressure and generally increases the health of individuals. You help. Also, the effect that green fogs have on regulating and regulating the temperature of the building indirectly affects the health of the residents.

6. Economic savings

Reducing construction materials by increasing the life of the roof and reducing roof repairs and renovations, energy conservation, surface water management, reducing greenhouse gas emissions, especially carbon dioxide, reducing fuel consumption improve economic conditions. Social and Environmental Benefits Green roofs reduce health care costs, improve water quality, and reduce cooling and heating energy costs. Also, the materials used to make green roofs are often sourced from recycled sources. The use of construction material debris saves the cost of constructing a green roof and eliminates or reduces the cost of burying debris as well as the cost of transporting it. Green roofs provide a unique opportunity to use roofs to improve the economic cycle. [10], [11]

Check the heat transfer on the designed model

In this section, an example of a semi-dense executive green roof is studied to evaluate how heat is transferred. Specifications and executive details of this green roof sample include the following:

- Vegetation
- Culture medium (rock wool)
- Designed layer (fiberglass + perlite)
- Waterproof membrane
- Roof structure (Figure 1)

How to execute a green roof designed

The executive model is designed in the dimensions of 1 * 1 square meter. Initially, a concrete roof sample with a grade of 350 kg per cubic meter and a rebar grid with distances of 20 x 20 cm2 and a diameter of 10 longitudinal rebars and 8 transverse rebars was implemented. To provide insulation against the possible infiltration of water, an izogam covers the roof sample. contract. The materials used are in the form of fiberglass and perlite. Perlite is located between two layers of fiberglass. At a height of 5 cm, each hole is designed for water to exit and enter the drainage path of the mold. For both rows of pots, a gutter has been installed to collect excess water on the need for vegetation with a suitable slope. Inside the pots and 2 cm of space on the mold, Leica has been used for its lightness and high-water holding capacity. And on

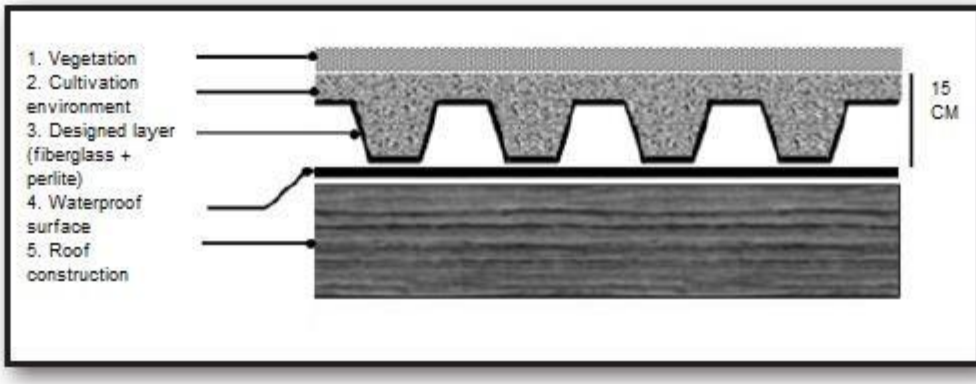

Fig1. Designed green roof detail.

Leica 2 cm of soil is considered as the culture layer and finally, Franconia is selected as the vegetation (Figures 2 and 3). [8], [10], [11], [12]

Fig2. Designed model.

Fig3. Designed model.

Experimental study In the executive model, first apply direct heat of the burner on the upper part of the sample for one hour and then wait a while for the heat exchange to take place between the upper and lower layers; One of the sensors was placed near the top layer and the other near the bottom layer nest, and the temperatures displayed on the display were recorded; Experimental study was performed by installing a self on it to be compared with the results of the software. In this board, a IM35 sensor is used. By changing the temperature, the output of the sensor creates a voltage proportional to the temperature. It is shown on the display that the heat transfer of the samples is measured by means of which, according to the obtained results, the temperature decreases by 17 degrees Celsius, ie it has changed from 45 degrees Celsius to 28 degrees Celsius. [6], [8]

A software study was performed with Ansys and numerical modeling was used. Numerical modeling is one of the common and optimal methods in solving engineering equations. The finite element method is used as one of the methods of numerical analysis in a wide range of problems in the field of engineering to solve problems accurately. This method is originally used to solve complex problems in stress analysis in solids, but today with the expansion of this method, it is widely used in many problems such as a numerical solution of heat transfer equations and various types of continuous mechanical problems.

The governing thermal equations

When there is a temperature difference in a static environment that can be solid or fluid, conduction occurs to transfer heat. Concepts such as atomic and molecular activity should be considered when discussing conduction because it is at these levels that the benefits perpetuate heat transfer. Conduction can be considered as the transfer of energy from highenergy particles to low-energy particles of matter due to the interactions between them. The heat transfer between the two levels is calculated by Fourier law (Table 3). The finite element method is gaining more and more attention in research centers due to its high derivability and flexibility. In this research, the finite element method has been used to solve the conduction heat transfer equations. To solve the equation, the finer the element, the more comprehensive and accurate the calculation for the required points. Finally, by solving the matrix, the coefficients of the temperature variables are obtained. In the study conducted in this research, an 8-node two-dimensional element has been used to solve the problem numerically. For example, an example of the elementation used on the designed green roof is shown (Figure 4). The details of the solution method are omitted here. The same temperature conditions were used for the thermal analysis of the studied models. Also, to investigate the thermal penetration of the roof, the temperature on the roof due to sunlight is

50 degrees Celsius and at a low level, which indicates the temperature in ideal conditions, 20 degrees Celsius is considered. In general, there is a temperature difference of 30 degrees between

the two levels, and the amount of thermal penetration in each layer is checked from the temperature distribution counters. [8] ,[13], [14]

Table 3:

The Fourier equation	**q=kAΔϴ**
Conductivity	**K**
Conduction area	**A**
Temperature changes over length	**Δϴ**

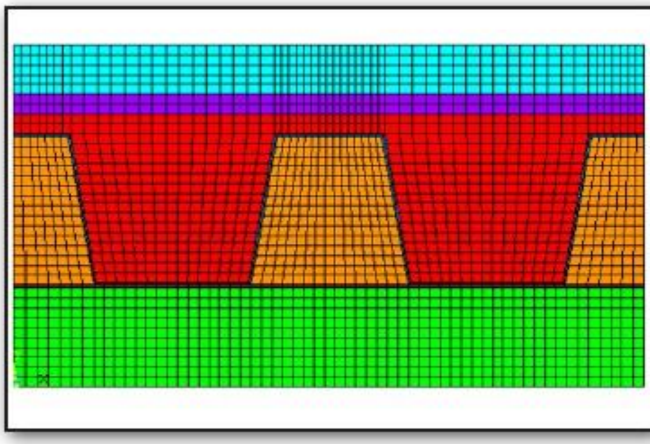

Fig4. Setting elements of designed green roof for seven layers.

Conclusion

According to the results, in the executive roof, in the isogum layer due to the lower conductivity, Heat transfer is lower. Of course, it should be noted that the thickness of isogum is less than concrete and concrete is more conductive than bitumen. For the executive green roof, the results show a lower rate of heat transfer than the executive roof, which is due to the use of low-conductive materials such as filter layer-geotextile fibers. It should be noted that the conductivity of the culture medium (Lycia) and the drainage layer, aggregate (sand) is higher in the wet state (dry conditions are modeled) and naturally increases in wet conditions of thermal conductivity. For the green roof, layers such as fiberglass + perlite and air are used, which is almost insulated, and therefore heat transfer is significantly reduced. It is clear from the temperature distribution that there is less heat transfer in the air part and more conduction in the side layer due to the presence of clay which is more conductive than air.

To analyze how green roofs affect ambient temperature, thermal behavior, and heat transfer, three types of roofs have been compared with each other:

1. Ordinary roof
2. Green roof without fiberglass layer
3. Green roof designed with fiberglass layer (Figure 5)

For a more detailed study, in this part, in the direction and in the center, a line of nodes is considered and the temperature distribution of the nodes in the three roofs is also compared (Figure 6). On average, designed green roofs have lower temperatures in different places, which results in lower heat transfer than the surfaces. An equivalent heat transfer coefficient can be used for a more complete study. Equivalent heat transfer coefficient is obtained by using equation methods and heat transfer with equivalent coefficient is equal to the heat transfer of the desired porcelain layer. Comparison of equivalent conduction coefficients for three roofs shows that the lowest conduction coefficient for green roofs designed with fiberglass layer. As a result, there will be minimal heat transfer to the roof (Figure 7). In Table 4, the obtained values of heat transfer for each of them, as well as the values of optimization in heat transfer, are clearly mentioned, and the optimally designed green roof is completely understandable compared to the executive green roof design. The heat transfer in the green roof with fiberglass layer was also experimentally studied and by installing sensors, the software results were confirmed with some differences. It seems that the difference between the experimental results and the software results is due to not considering the role of shadow in reducing heat transfer in the software results.

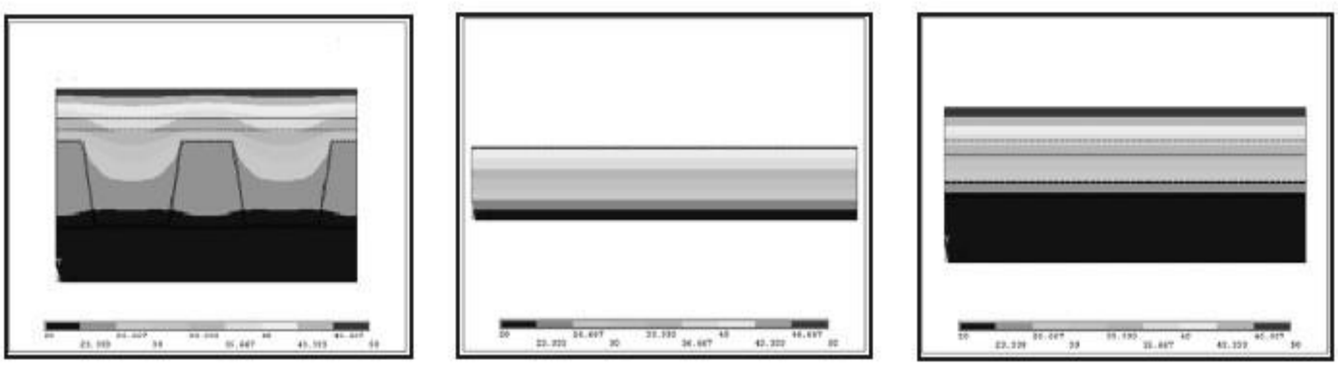

Fig5. Contours of temperature distribution for three roofs: A) Conventional roof B) Conventional green roof C) designed green roof.

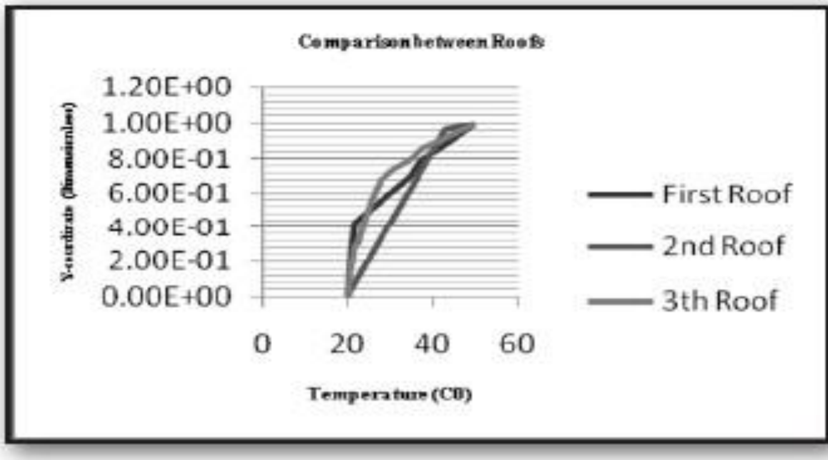

Fig6. Comparison of temperature distribution roofs, for line of nodes, along Y.

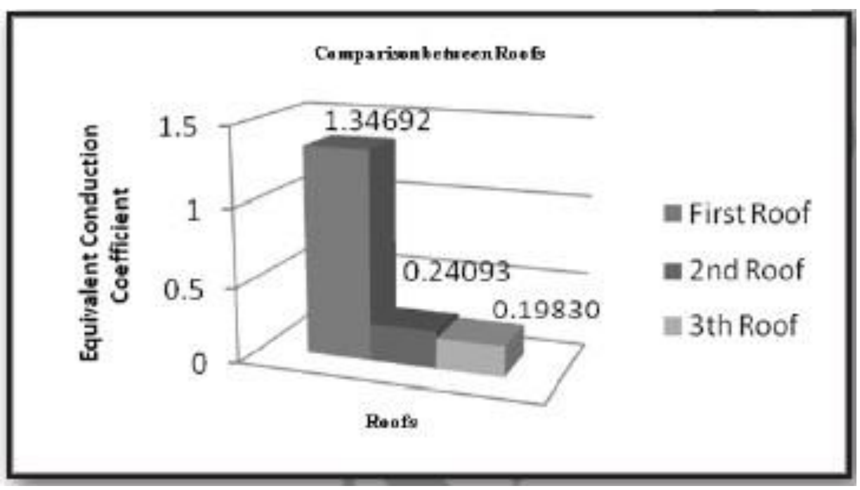

Fig7. Comparison of equivalent conductance coefficient of roofs

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