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The effect of green roof in reduction of environment's temperature

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ABSTRACT

Roof garden is a garden which is covered by living plants. Planting on roofs has positive impacts on city and building climates, it also has effects on air conditioning by avoiding sun radiation. This temperature reduction happens by reducing climate inflammations through increasing heat capacity of roof which makes preferable climate in summer and winter. One way which is suggested to reduce energy consumption in metropolitan cities is making roof gardens. If roof garden is designed correctly by noticing climate considerations, will have effects on reduction of energy consumptions in addition to different advantages. Present study will consider benefits of roof gardens. To prove the assumption of "roof gardens and its design have effects on reduction of heat transfers", Ansys software was applied. 3 samples of roof, common green roof, and roof gardens with specific designs (fiberglass layer) were analyzed and compared from their heat transfer aspect. The results showed that roof gardens with specific designs had lower heat transfer till 50% in comparison with common roof gardens and it is indicated that green roofs with specific design was efficient till 40%. The approach of this study is scientific applicable. The method of this study was descriptive and qualitative in sections which were related to roof garden's advantages and it was analyzed and quantitative in software sections.

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INTRODUCTION

Roof gardens are constructed to change dead atmosphere of roofs in to a dynamic atmosphere. Although these roofs are private atmosphere, they have effects on city's ecological yields. Effectiveness of roof gardens is noticeable in city scales. Planting on homes' roofs improves air exchange between crowded zones and free spaces among buildings and makes the air more preferable. Roof gardens and reduction of have effects on city's appearance and pollution elimination mental tensions as well as effects on energy exchanges. This technology has many benefits such as air filtering, waste waters' preserving and sound pollution reducing, as well as energy consumption reducing.

This study is considered among inter disciplinary studies focused on roof gardens' heat roles, which makes a new link between mechanic and architecture fields by the help of Ansys software to compare green roofs with common roofs.

Roof gardens are classified in to "intensive, extensive and semi extensive" groups. Extensive ones are often design as public places and include trees, and bushes on the land. These roofs have cultivation area with 150 – 400 mm depth.

They also need high level of maintain and fixation. The typical weight of extensive green roofs are ranged between 180-500 kg/m^2. Because of their noticeable weight, their design is important, so it is more expensive. In intensive roof gardens, there is limitation in their depth and roofs' development, so their vegetation tissue is limited to grass, permanent annual and resistant plants in front of stresses. The bed of extensive green roof is mostly between 60-200mm. They don't need maintenance measures and they need low irrigation. Their common weight is between 60-150 kg/m^2, so they are suitable for wide places. But semi-extensive green roofs are placed between extensive and intensive ones. These roofs have deeper soil and plants and different varieties of plants. The soil depth is 200-250 mm and their weight is about 120-200 kg/m^2.

Significance of study:

Despite of the traditional usage of green roofs in rural homes, today the term of "roof garden" is considered a strange word by people. In development cities' programming, roof garden's construction is an applicable instruction. But this isn't mentioned in article 19 of national rules of construction. Regarding dusts and

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pollutions which are entering from southwest cities and pollutions which are related to fuel burns, it seems necessary to consider positive effects of green roofs. Moreover green roof has an effective role on energy consumption. Among other advantages of green roofs are reductions the effect of heat island noise absorbance, reduction of water pollutions.

Qualitative and quantitative benefits of green roofs in comparison with typical roofs:

Building preservation from heat is one of the features of roof gardens which can reduce temperature during summer. Construction of green roofs is an acceptable ecological solution which can help both in reduction of temperature outside the building and in improvement of crowded cities' quality. Plants' leaves and branches preserve building from sun radiation and control moisture and temperature. The differences between planted and common roofs are categorized in 2 groups of qualitative and quantitative. The process of heat transfer is totally different in green roofs.

Plants absorb a noticeable amount of sun radiation because of their biological activities such as photosynthesis, aspiration and evaporation. The rest of sun radiations transform to heat, so when they pass from building elements, have effects on air conditions inside the building.

Quantitative benefits:

a) Noise isolator:

The problems caused by street noises are crucial city issues. Although isolation can noticeably help in reduction of noise pressure, roof and its type are also effective on citizens' comfort.

Green roofs increase noise isolation in roof's system. Albeit this effect is somehow different in extensive green roofs which have lower depth of soil. The quality of noise isolator is due to system type and thickness of layer. Green roofs which their thickness is 12 cm, reduce sound infiltration till 40 dbl, and those with 20cm thickness, can reduce sound infiltration till 46 dbl (www.efbgreenroof.eu).

b) Reduction of heat island effects:

Metropolitan cities absorb sun heat and act as an emitter source of heat energy, because of their extensive surface without vegetation coverage. Such condition is called "Urban Heat Island" (UHI). In this situation, temperature differences in noticeable between those zones with asphalt zones and areas with vegetation coverage. Such temperature difference of urban and suburb under heat island effect can reach to 10^{o}F at summers (Luckett, 2009).

As the number of air conditioner instruments increase, the amount of consumed energy enhances and green house phenomenon happens; this phenomenon is a crucial factor for ozone destruction. According to U.S. environmental preservation organization report, urban temperature can be 5.6^{o}c warmer than suburbs (US EPA, 2003).

c) Reduction of air pollution:

In urban zones, trees have noticeable portion in reduction of pollutions. In many cities' cites there is limited space for cultivation and this is because of impervious surface such as streets, garages, roofs etc. plants absorb pollutions through their osmosis, then separate their elements inside their leaves, they are also able to break specific organic components such as poly aromatic hydrocarbon inside plant or soil tissues (Baker and Brooks, 1989).

Moreover, they can reduce air pollution by shadowing which can reduce photochemical interactions in atmosphere (Bradly Rowe, 2010).

d) Reduction of Co_2:

Earth is becoming warm because of natural cycle and burning of fossil fuels. These fuels distribute Co_2 as a subsidiary product. Mostly Co_2 is acted as atmospheric gas which prevent from transference of heat energy from earth surface to upper levels, so it can increase green house effect as an interference factor and also can increase environmental temperature.

Green roofs are effective in Co_2 reduction through 2 ways:

1- Carbon is main element of plant structure, so it can be analyzed in plant tissues through photosynthesis or in soil bed through root's secretions naturally.

2- Energy reduction through building isolation and reduction the effects of urban heat island.

Carbon analysis can improve by changing specious, bed depth, bed compound, and management methods. Increasing bed depth not only can increase Co_2 storing capacity, but also provide possibilities for growing of greater plants and trees. Trees can play more effective role in absorbing Co_2 than gasses (Bradley Rowe, 2010).

However, analysis of Co_2 through plants and their beds is part of equation. Green roofs have effects on Co_2 reduction through Co_2 analysis, and reduction of heat island.

e) Reduction of waste water system weight:

Green roofs have effects on reduction of the amount of water flows on the surface and improvement of waters quality. Green roofs can absorb 70-80% of water in summers and 25-40% in winters (www.efbgreenroof.eu).

Moreover intensive roofs with 150 mm depth of bed absorb 75% of water annually, while extensive roofs with 100 mm depth of bed can absorb 45% of water annually. The amount of maintained water in winter is significantly lower than summers. These results are rooted in differences in evaporation amount and distribution of rainfalls (Berndsson et al., 2008).

f) Reduction of heat transfer through storage of building energy:

Green roofs prevent sun radiation there for, can be effective in energy transfer indirectly. According to this fact that heat transfers from higher temperature space to lower temperature, heat transfer happens from inside to outside of building in winters and from outside to inside in summers. Result of a study in Toronto University shows that green roofs have their effects in cold climate and can keep the space warm.

So following cases lead to reduction of transferred heat amount in designed green roofs:

I) Enhancement of roof heat capacity:

In winters, lower amount of energy transfer from inside to outside, and in summers lower heat comes from outside to inside. Green roofs can have more effective roles in green roofs with increasing layers.

II) Moisture maintenance:

Vegetation coverage can maintain moisture, and play effective role in adjustment of building temperature. Water acts as heat mass and prevents temperature inflammations and makes building cooler in summer and relatively warmer during winter. The amount of effectiveness varies by different years and different amount of moisture in roofs' nets.

III) Plants' photosynthesis (reduction of heat absorbance):

Mixture of plants' activities such as photosynthesis interactions, evaporation, can lead to reduction of absorbed solar energy, so the temperature of space below these roofs decreases during summer. During winter, these green roofs play there positive heating functions as well. Green plants act as heat isolator, though their efficacy is related to the amount of their maintained moisture.

Qualitative advantages:

a) Preservation of roof layer:

The lifelong of typical roof is about 20 years, while lifelong of green roof is estimated about 45 years or more. Tar layer of roofs are preserved by soil and vegetation coverage from ultra waves and heat inflammations between days and nights (Bradly Rowe, 2010).

b) Development of green space and animal habitats:

By the help of green roofs, animal habitat where are destroyed by constructions can be compensate, so that development of wild life which was limited can be developed (www.livingroof.org).

Green roofs have more benefits for environment and wild life in comparison with common roofs. Specifically when these roofs are correspondent with climate condition of an area, they can play a noticeable role in preservation of that zone's spacious.

c) Food production:

Green roof is an opportunity for agricultural development which also can develop food production. Green roofs' productions can have better and natural quality than market crops, because more attentions are paid to their fertilizer and pesticides.

d) Beauty, facility and entertainment:

Typical roofs mostly make unsuitable face by some chimney, tar layer and paving. Now by the means of planting, roofs' efficiency increase. These roofs provide favorable environment by shadow making.

e) Health promotion:

Studies show the importance of direct touch of human with nature. Such touch has effect on mental health of human, decrease heart, beats and blood pressures. In addition the effect of planting on temperature has indirect effect on residents' health.

Cost effectiveness

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Reduction of building materials usage, reduction of needs for fixation, preservation of energy, management of surface water, reduction of consumed fuel all lead to improvement of economic conditions. Social and environmental advantages reduce health and cure costs, improve quality of water, and reduce costs of needed energy. Green roof is a unique opportunity to improve economic cycle.

Consideration of heat transfers on designed model:

In this section, a sample of designed green roof is studied to assess the way of heat transference. Features and details of this sample are listed as follows:

- Vegetation coverage
- Cultivation bed (rock wool)
- Designed layers (fiberglass, perlite)
- Anti water layer
- Roof structure

The method of designed green roof construction:

This model was designed in 1 × 1 m^2. First of all a concrete roof was constructed with 350 kg/m^3 alloy and rebar net with 20 × 20 cm^2 distance which diameters of longitudinal rebar was 10 and for transverse rebar it was 8. To make isolator against water, ruberoid covered on the roof.

After these 2 layers, network of green roof was designed with 12 plots in 4 rows. In each row there were 3 plots. Used materials were fiberglass and perlite, in which perlite was put among 2 layers of fiberglass. In the height of 5 cm of each plot a hole was designed for exiting water. Inside plots and 2 cm on the space of plot Leca was used, because it has light weight and can absorb noticeable amount of water. Then 2 cm soil covered on the Leca which acts as a bed for cultivation, eventually *Frankynia* was selected as vegetation specious.

Experimental study in applied model: At first direct heat was applied for 1 h on upper part of sample then let some time passes to transference of heat from upper to lower layers. Next, 2 sensor were put in upper and lower layers which should temperature of each location. At this board sensor IM35 was used. By changing temperature, proper voltage according to temperature was made, and then produced voltage was measured by entrance of micro analogue. According to results, temperature decreased till 17^{o}c (i.e. it decreases from 45^{o}c to 28^{o}c).

Software considerations were done by Ansys, and then numerical modeling was done. Numerical modeling is one of the common methods is solving engineering equations. Finite element method is used as a method for numerical analysis for exact solutions of problems. This method is widely used to solve heat transference equations and different types of continuum mechanics problems.

Dominant heat equations:

In conductivity discussions some terms such as molecular and atomic activities should be considered, because processes in these levels can sustain heat transfer. Conductivity is transfer of energy from more energetic particles to lower ones. Conducted heat among 2 levels is calculable by Fourier's law.

Finite element method because of its high level of flexibility draws attentions in scientific centers. In present study also to conduct heat transfers, finite element method was used. To solve the problem, comprehensive and exact distribution will calculate by making smaller elements. In present study to solve numerical problems 2-D elements with 8 nodes was used. Here, details of solving methods are not presented but for more information there are some suggested sources (14).

To consider heat infiltration in roof, temperature of roof was 50^{o}c and lower level which shows ideal temperature was considered about 20^{o}c. totally there were 30^{o}c temperature differences between 2 levels, the amount of heat infiltration in each layer was considered by temperature distribution contours.

Conclusion:

According to results, Green roofs had lower amount of heat transfer than common roofs which is because of using low conductive materials such as filter layers. It should bear in mind that conductivity coefficient of cultivation tissue (Leca) and sand which was drainage layer in wet condition is more than dry condition, so in wet situation its heat conductivity increases. For aforementioned green roof, fiberglass, perlite and air layers were used which all are almost isolators, therefore transference of heat decreased significantly, but in other layer because of clay which is air conduction, conductivity is more.

To analyze how green roof effect on heat environment and its transference 3 types of roof are compared:

1) Typical roof
2) Green roof without fiberglass
3) Green roof with fiberglass layer

To detailed consideration, nodes were studied in Y dimension, and then temperature distribution of nodes was compared in 3 roofs. By comparing temperature distribution graph in 3 roofs it was determined that, green roof with fiberglass had lower temperature in different points.

By equivalent method, equivalent of heat transference coefficient will be achieved. Comparison of conductivity coefficient's equivalent for 3 roofs shows that the lowest amount of conductivity coefficient was related to green roof with fiberglass. So the lowest heat transference was related to aforementioned roof. Table 4 indicates heat transference amount for each roof, and efficiency of green roof with fiberglass was considered experimentally, by the help of sensors. It seems that different results in experimental and software considerations are due to non consideration of shadow role in reduction of transferred heat during software study.

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