Investigating of the Aesthetics and Performance in Contemporary Green Roofs

Seied Sajad Rahmatabady

Department of Architecture, Asadabad Branch, Islamic Azad University, Asadabad, Iran

ABSTRACT

Lack of open and green urban spaces and increasing land price, especially in city centers and high-density areas, has become a challenge for urban management. Since these spaces, often seen with no direct economic value, expanding them has less financial support in comparison with other investments. Whereas, constructions which will have greater benefit in short terms, in investment of local governments and public sector, have resulted increasing the amount of land using for short-term economic benefits. One of strategies that beside of Economy in the long term, resolves psychological and social needs of the citizens is phenomenon call roof garden or “green roof”. Green roofs allow optimal utilization of urban lands. In addition to looking at the performance measures, are also important in terms of aesthetic. Green roof is one of the new approach architecture and urbanism, derived from concepts of sustainable development that can be used to increase green space capitation, improve environmental quality and urban sustainable development. This study following the review of related researches, field studies, case studies and comparative analysis of samples, purposes to survey possibility of implementing and common methods of green roofs with transparency of limitation and challenges ahead, then describes economic, social and environmental advantages and achievements of this phenomenon. Findings from this study can be applied for design based on sustainable development sustainable architecture, green architecture, energy in Architecture and climatic design.

INTRODUCTION

Nowadays, green roof topic isn't a matter of taste in the world and we can't view it as same as the other styles. In other word green architecture isn't one of styles that are used as the suffix for different ages or ideas then be criticized by theories and finally, due to its deficiency in some issues be disappeared. Rather, green architecture or green roof is something universal and applies in each time period or architectural style.

Appropriating of quantity and quality of the architecture is become the first concern to architects and ecological approach as like “sustainable architecture” and “green architecture” is checked. Roof garden is one of new approaches in architecture and urbanism based on sustainable architecture concepts. Green roof encompasses a wide range of social, economic and environmental benefits. Undeniable ecological advantages of green roofs have repeatedly been examined by experts and researchers and statistic results of these researches is accessible and further investigation process continues.

Briefly the advantages and benefits of green roofs can be counted as follows: reducing the heat, filtering the pollution and carbon dioxide, thus reducing respiratory diseases, like asthma, filtering the heavy metals of rain, Reduction of rainfall runoff and Storm water volume reduction, to help insulate buildings against noise pollution, creation a natural habitat, especially for birds, Reduce the urban heat island effect, thermal balance in the internal and external environment of the building, raise per capita green space, Improvement of environmental quality and urban sustainable development [13]. The green roof is so significant that is considered as one of the five main architectural elements in modern architecture [12].

Roof garden in addition, aesthetic functions has also abundant ecological advantages. Therefore, to develop green space in height and improvement the quality of urban landscape, decoration of the roofs and using of the dead spaces on the roofs and terrace of multistory buildings, has been developed especially in downtown of macro polices and commercial cities, and as a necessity with economic justification should be considered by Iranian architectures, designers and planners. This study addition to, explaining roof garden as a vertical green

Corresponding Author: Seied Sajad Rahmatabady, Department of Architecture, Asadabad Branch, Islamic Azad University, Asadabad, Iran
E-mail: Rahmatabady@gmail.com
space that is accessible in urban spaces, tries to describe suitable places for creation roof garden as an approach of organic architecture.

1- History:

The first green roofs in human history are Babel suspended gardens. Babel tower is one of the most splendid monuments of human architecture that has had seven large towers with 200 meters high. These gardens had 5 terraces. This building has been built about 330 B.C [21]. But in modern architecture, application use of roof spaces returns to end of 19 and beginning of 20 century. Speeding urban constructing and increasing land prices, formed idea of functional usage of roof spaces in city centers [15]. Tendency to green roof in modern age, started in Germany in 1930 and then of complying with Hagrestrand law spread to other countries. In modern architecture Frank Lloyd Wright and Mies van der Rohe, have been of avant-garde in green roof field, however, neither of these two architects, had an idea of the many environmental, social and economic benefits of green roofs. Le Corbusier in 1952, in 19th floor of residential complex in Marseille, designed a roof garden for residents with an area of 3960 square meters, which play space for primary schools children in the complex, small pool, exercise space and outdoor theater for adults had been considered. Also in 1976 in Lyon, France, he designed a green roof with an area of 3960 square meters with the goal of building occupants [5].

In the early sixties and by taking into consideration the environmental quality of urban and environmental challenges in major cities, new wave to green roofs in their present-day concepts, due to environmental advantages and as a ecologic solutions started from Northern Europe and rapidly spread in most European countries. In Germany in 1980s, the spread of green roofs on urban was quantitatively observable. So that it grows 15 to 20 percent annual. For example in Germany ten millions square meters of green roof was constructed in 1996. Today Germany is one of avant-garde countries in the field of research, technology and utilization of green roof, So that growth rate of green roof is 12 to 15 percent per year. Currently 13% of all of roofs in Germany are green [13].

In 70th Continental America a decade later than continental Europe, were interested and curious about this new technology. Today, green roofs in urban planning in Northern like Chicago, Portland, Oregon and Toronto, Canada, has been applied as an executive instruction. Today's world of Europe and America to Asia and even Africa increasingly observes cities that attempt to develop green roofs in urban scale.

Fig. 1: Green Roof on Chicago City Hall (resource: www.enwikipedia.org).

2- Technology and functional use of the roof space:

Roof of houses have rarely been considered as a functional space. However, in fact, these gray roofs, have involved a high percentage of the total urban area, and in contemporary metropolises where increasing of land price and lack of open and green urban spaces especially in downtown and high-density zones, has become a global challenge, functional use of roofs, can be considered as an optimal utilization of urban lands.

Term of “Green roof” refers to one ceiling system that is made by prefabricated layers and has formed one unique system with building roof. It creates suitable condition for plants to grow in specific growing medium in total or part of the roof. Planted layer is different from conventional soil and for growing different plants require less depth and is much lighter. Constituent layers of green roof from up to down respectively consist: Vegetation, planting medium, Stabilization and root protection, drainage layer air system and water storage, protective layer of waterproofing and insulating layers to protect the roof structure.
Important factors such as the slope of the roof, climate, topography, ice, orientation, perspective, shadow etc. are involved in the creation of a roof garden. A major factor is the slope of the roof; green roof construction in the 30 degrees slope does not work as well [19]. Because there will be a drop in material and runoff releases. Paved surfaces are not always good for green roofs; in flat surfaces, poor drainage, cause the root of plant to suffocate and damage to the roof [20].

3- Economic, social and environmental advantages of green roofs:
3-1 To absorb pollutants and suspended particles: Environmentally if green roof be widely implemented in large urban spaces, is able to absorb carbon dioxide and produce oxygen, and so causes filtration and reduction of pollution desirably. According to a study by a research group in Canada, 1.5 square meter plant with height of 40 cm is able to provide require oxygen for a human. Plant surfaces, absorbs suspend particles in the air. Then these particles go into planting layer by rain. Assuming that green roof vegetation is grass and grass acts serve only one-tenth of trees, 10 square meters of vegetative green roof can hold up to 2 kg of suspended particles in the air. Reduction of greenhouse gases is other environmental benefit of green roofs. The studies of Research National Council of Canada show that if only 6% of roofs in Toronto become green roofs, 2.18 tons greenhouse gasses and 30 tons pollutants are reduce annually and finally will result 5 to 10 percent reduction in smog annual [11].
3-2 Self-sufficiency: Major part of the missed soil due to construction can be used for making green roofs that is easy and economical way for compensation of lack of green space in the city [14]. In fact by utilization of that, the cost of preparation and displacement of soil will be reduced.
3-3 confronting with the heat island effect: "heat island effect" term is referred to the temperature difference between city and suburb and this difference in temperature can sometimes soar up to 10°C. Unsustainable urban development that one of its symbols is increasing in construction and reduction of urban green space, has
amplified the phenomenon of earth global warming. Increase in temperature can become more and more in future and will have Irreversible damage to the earth.

Conventional dark and asphalt roofs absorb solar energy and heat that is one of important effective factors in the heat island phenomenon. Green roof vegetation through the natural cycle of evaporation – transpiration makes cool its surroundings and if be widely implement in large-scale in urban and neighborhood scales, the city's temperature greatly reduces and help to health of urban air. According to the Research National Council of Canada, If only 6% of roofs in Toronto become green roofs, the weather temperature of city reduces 1 to 2 degrees.

3-4 reduces energy costs: another advantage of green roof in compare with roofs is energy saving and reduce heating and cooling costs of the building. Growing plants on rooftops reduces the heat and temperature around the building in summer and because of insulation layer of planting and plants, prevent the heat to enter. This insulation specification of green roof in winter reduces require to thermal energy in the building and help to construction energy saving. A one floor house with grassy roof and vegetation layer with 10 cm depth was been studied in Canada and researches showed that green roof has reduces 25 percent of cooling energy in winter.

Green roof is able to reduce suburb heat. Temperature reduction in summer months causes reduction in electricity requirement. According to experience of green roofs in Chicago, Reduction of 1 degree Fahrenheit temperature, the energy saving is 1.2%. With the development of green roofs on urban scale, broad aspects of energy efficiency in public and private sectors, according to the energy crisis of this century can be useful on a global scale. If we assume that the green roof drop air temperature only 1 degree, approximately one million dollars annually due to reduced demand is achieved for energy saving [13].

In terms of climate, green roof helps to residents comfort and adjusting temperature in the comfort zone:
1- Vegetation and grass on the roof surface creates the shadows.
2- Vegetation and grass reflect 20 to 30% of solar energy and absorb the rest, thus less energy is absorbed by the roof.
3- Well-watered vegetation, dissipates a lot of thermal energy through evaporation in the warm seasons, because evaporation was done in the surface of leaves of plants is causing coolness.
4- Thermal mass reduces soil temperature. It means due to soil mass, the less heat and with much delay is transferred.
5- Thermal mass reduces the daily temperature changes; hence the need for insulation compared to conventional roofs is reduced.
6- Due to the low mass of the Plants Less thermal energy is stored in the leaves of plants.
7- Air trapped between the wall (or roof) and plants as a thermal insulation prevent heat to transfer [28].

Fig. 4: Reduce temperature fluctuations in soil depth (Geo-thermic effect) (resource: Watson, 2002)

3-5 prevention of flooding: whatever roof surfaces has been built from synthetic and difficult materials, less water can naturally penetrate in soil, consequently sewage ducts will get heavier load. Layer of planting and green roof plants absorb and evaporate large quantities of water and if you have storage layer of water, the remaining water is used to irrigate again. According to a research report done for the Chicago in 2000, a green roof with soil depth between 20 to 40 cm and high plant density can store rain water between 10 to 15 centimeters. Another study conducted on Portland, shows that if only half of the roofs of the downtown buildings are covered with vegetation, can reduce 11 to 15 percent of load of urban rainwater drainage channels [7].
3.6 Reduction of noise pollution: green roofs through reduction and adjustment in intensity of noise pollution, especially in large cities act as an insulation to reduce the noise pollution by acoustically absorbent. Planting layer of green roof reduces low-frequency noises, and vegetation layer reduces high-frequency of noises. Thus these types of roofs especially for buildings in the vicinity of airports, train stations, highways, factories and other noisy industrial centers act effectively. According to the researches of "Canada Housing organization", planting layer with 12 cm depth is able to adjust 40 decibels (dB) noise [6].

3.7 Strengthening the Ecosystem: Green roofs also through providing habitats for species of plant and attraction of animal and bird species, in the terms of ecology and biodiversity is important. Green roofs, especially extensive types that aren’t commonly available and human presence is reduced. While creating a beautiful landscape in the urban environment, is the suitable habitat for growing a variety of insects, attracting birds and creating the suitable environment for them to lay eggs.

3-8 Increase the life of the roof: Since planting and vegetation layer of green roof protect the roof skin against ultraviolet rays, this types of roofs have a much longer shelf life and therefore are economical compared to traditional roofing. Sealing the roof with tar has the average life about 20 years. Green roofs experience in Germany shows that some 40 years old green roofs have no need of any substitutes. The materials used in the manufacture of roof garden have had a very long life and does not need to be replaced periodically (between 30 and 50 years). Garden roofs as well as filtrate the air prevent roof insulation to be spoiled and thus periodic replacement will be eliminated. In fact, it is best cover for roof [17].

3-9 Cultivate crops: Roofs can be a good place to cultivate vegetables and Jats. Crops agriculture, horticulture and food production in addition to economic benefits from the standpoint of the citizens health is another social benefits of green roofs. Due to lack of urban open spaces, the idea of urban gardening looks an inaccessible and luxurious idea; Roofing can be a good way to achieve this activity. Using organic vegetables and herbs, healthy and newly planted on the roof, in addition to contributing to nutrition and health, save money, especially for low-income groups, will also save the time. It is useful and benefit for the body and soul also prevents the stress and can replace the lost relation with nature for metropolis citizens. A hotel in Vancouver has grown vegetables on green roof and with this method; the cost of food in its kitchen has been saved as $ 30,000 per year. Moreover, the rooms faced to green roof of the hotel are more expensive up to $ 80 per night than others. [11].

3-10: Increase in building prices: an increase in building value due to its added greenery and beautiful exterior landscaping are among economic benefits for the private sector, builders, homeowners and local governments. Indeed the initial cost to build a green roof against the rising value of the building is minimal.

3-11 beautification and enhancement of landscape: landscape beautification and improvement of the landscape around the building can be considered as social benefits of new technology [10]. Also the use of green roofs as a functional and entertaining green space is considered as social benefits. In a city where land is scarce, especially in high-density areas, use the gray roof takes an important step toward increasing urban green space. Therefore, aesthetics is the minimum benefit of the green roofs. For example we can mention five gardens on the roof of Rockefeller Center in New York that are not available and have only been designed and constructed for creating a pleasant viewpoint to the upper floors and surrounding buildings [4].

Table 1: Benefits and achievements of the green roof with different approaches in macro- and micro-scale (resource: author)

<table>
<thead>
<tr>
<th>Economic</th>
<th>In macro-scale</th>
<th>In micro-scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation and reduction in consumption of non-renewable fuels</td>
<td>Cultivate crops</td>
<td></td>
</tr>
<tr>
<td>Saving Fuel</td>
<td>Increase in roof life</td>
<td></td>
</tr>
<tr>
<td>Added value of urban settlements</td>
<td>Saving in costs of the household energy</td>
<td></td>
</tr>
<tr>
<td>Self-sufficiency</td>
<td>Performance allocation to green roof</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental</th>
<th>In macro-scale</th>
<th>In micro-scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beautification and enhancement of landscape</td>
<td>Reduction of noise pollution</td>
<td></td>
</tr>
<tr>
<td>Strengthening the ecosystem</td>
<td>Beautification the life place</td>
<td></td>
</tr>
<tr>
<td>Prevent flooding</td>
<td>Using the properties of the soil geothermic</td>
<td></td>
</tr>
<tr>
<td>Coping with the heat island effect</td>
<td>Air purification through absorb pollutants and suspended particles</td>
<td></td>
</tr>
<tr>
<td>Suitable alternative for open space and urban green space</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social</th>
<th>In macro-scale</th>
<th>In micro-scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>To help mental relaxation of users</td>
<td>Residents comfort</td>
<td></td>
</tr>
<tr>
<td>Conceivability for study and research</td>
<td>Presence of different spectrum of residents in semi-public areas</td>
<td></td>
</tr>
<tr>
<td>Gathering and meeting space for training</td>
<td>Garden - Health</td>
<td></td>
</tr>
<tr>
<td>Promoting social interaction of users</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4- Functionalism in green roof:

4-1 performance allocation: In buildings with educational applications such as schools, high schools and universities, the roof can be used as an outdoor education space and outdoor classes. If it is not possible to reach the street, in unused hours and school holidays, the roof space can be used as green space in the neighborhood.
In the Brook School in Toronto with accompany of students, parents and district officials, green roof on top floor of school building was constructed. Another example is Josiah Quincy School in Boston, which have become an outdoor classroom for students to scientific studies and children with accompany of neighborhood elders grow vegetables, jat, and some fruit plants on the roof. Green roofs can be used in professional universities for research applications. Department of Biological Sciences, in University of Vienna in Austria for his researches plants types of flowers and plants on its roof [5].

4.2 Garden – Health: (Therapy through horticulture) is one way to treat and help mental condition of the patients and the elders for many years. Health care centers such as hospitals, clinics and nursing homes can use the roof of the buildings in order to work as their treatment program. The first example of roof gardens for garden-therapy dates back to 1930 and in Paris treatment clinic. In 1995, a hospital in Washington Bremerton in its development phase, allocated a green space on the roof, for garden-therapy and meditation and used medicinal plants as vegetation.

4.3 Meeting space: The roof of some buildings can be used for gathering (education, training, entertainment, exhibitions, and theme parties) in outdoor spaces. Example of this functional use of roof is observable in 6th floor of a commercial building in London in 1938. Access to roof space was via adjacent streets and the elevator. And it has been used in the spring and summer as a meeting space, special events and annual celebrations [4].

The roofs of such buildings can be used in the appropriate seasons for outdoor activities, celebrations and special events, exhibitions, opening, etc. One of the best and oldest examples of practical use of the roof of the Hotel can be seen on Broadway in the twentieth century. Astor Hotel with 500 rooms on 9 floors had a garden on its roof over 305 meters long, with three lines of walkway for customers. Fairmont Hotel in San Francisco is a contemporary example of it, which in 1962 added 792 meters roof - garden to its current building, for recreation the customers. In 17th floor of Bon Aventura Hotel in Montreal, part of the roof has been considered as the public green space for hotel and restaurant customers and other parts has been considered as private green space for rooms.

Fig. 5: The use of green roofs as a feature of contemporary buildings.

5 - Conclusions and policy suggestions:

Due to the high value of land in cities and consequently the vertical growth of the city, low area of green space and unfair urban green space distribution in the neighborhood, using green roof technology on the roof seemed to be a good option. According to topic 19 of National Building Regulations in Iran, concerning energy saving benefits of green roofs, it also can act in line with policies of national building. Green roofs because of their environmental benefits are regarded as an ecological solution.

Despite widespread environmental benefits of green roofs, High administrative costs of installation, maintenance and preservation of green spaces in such roofs, in a word economic problems prevented this new technology to find its rightful place in contemporary sustainable cities. The roofs in the last century due to their practical benefits and these days because of their environmental benefits become green. The integration of these two ideas and adding numerous social benefits resulting from the application of these spaces, local governments can support sustainable development and sustainable management of urban green roofs by taking important steps. This application can be synchronized with the application of the building. If the building is government office, the roof space can be in line with the needs of the neighborhood or at larger scale requirement of the city. With regard to the fundamental problem of most major cities in the development of urban green space and unfair segmentation and distribution of green space in the neighborhood, the practical use of roofs, as the public or private green space, has been considered an effective step towards the development and enhancement of
green space per capita and create safe green space for social people especially elders and children besides their living place.

In general, strategies that is considerable as practical and functional policies in order to achievement and utilization of this phenomenon, is suggested as:
- Professional communities working in the areas of urban green spaces and green roofs.
- Identify and explain the benefits of green roofs among urban planners and managers and private investors in the construction sector and the populace.
- Creating a motive, whether in public or private sector for implementation of projects.
- Sufficient knowledge and confidence, and ensure than this relatively new technology.
- Understanding the long-term economic benefits.
- Accept the risks and uncertainties resolve in technical issues.
- Funding by relevant devices in development programs.
- Advantageously attitude and long-term profitability and clarify different aspects of return the capital.
- Explain the importance of urban green space with respect to the current density.
- Holding conferences, seminars, scientific and professional meetings to clarify the importance of the subject.
- Strengthening the roof structure to resist the dead and live load.
- Provide materials for moisture insulating.

REFERENCES