# CASE STUDIES IN THE PLANTING OF STRUCTURE SURFACES; ROOF GARDENS

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## ABSTRACT

Ever-growing high buildings cause also heating of the air as well as pollution by blocking the air circulation. Decreasing of the soil to be absorbed the rail as a result of concretion leads to fall more burdens on waste water systems of the cities, while increasing the use of water in the cities and industrial areas. Many cities have to struggle with floods due to selection of wrong location and inadequate infrastructure. Our environment, as a result of development of rapidly and irregular of especially our large cities, is covered with concrete and asphalt on a large scale. Use of many green roofs to be taken place in the urban centers as recreation and relaxation areas will be effective in the both economic and more livable formation of the urban environment. Having solved of structural problems in the facility of roof gardens in green structure surfaces in the large cities in terms of static causes giving more and more interest in this green surface type with each passing days. Roof gardens do not take place in only roofs of building where people live. It is possible to encounter with roof gardens in also various locations such as roofs of workplaces, on the buildings of industrial areas, underground car parks, hospital buildings or universities in the cities of the countries where this application is performed. Roof gardens are areas established for their environmental benefits nowadays, while roof gardens were an aesthetic object in previous years and this has generated the concept of "green roof". In today present situation, they are the type named as "ecological roofs" or "green roofs" and used for ecological purposes, as well as aesthetic purposes of the roof gardens. Green roof is a concept used for buildings to adapt to the environment living. In this study, general design principles related to planting with static properties of infrastructure were explained depending on these green types.

**Key Words:** Roof, Roof garden, Environment, Ecological roofs

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## 1. INTRODUCTION

High cost of lands and gradually increasing population in urban areas has led to multi-purpose utilization necessity of roofs. People have used roof gardens for both ecological and aesthetic purposes for centuries. These structures generate green environments for people in their surroundings for years. They are also used as a show off symbol and on occasion as a place protecting people from outer environmental conditions.
Roof gardens have become rather attractive during the last 50 years with the visual quality they provide owing to plantation and colorful ground covering designs, pools and fountains. City structure and life style changing during the years takes people away from the natural surroundings and leads to decreasing of green areas. Roof gardens are special green areas not only as a place realized with aesthetic thoughts and at the same time as special green areas contributing to urban ecology.

## 2. MATERIAL AND METHODS

Materials of the research include an explanation of the context of roof gardens and determination of infrastructure of roof garden concept and a systematic explanation of insulation and drainage, and information (plant material and structural elements) about the selection criteria of herbaceous and crown plants that are to be used for plantation purposes. Based on this purpose, text books, thesis studies, technical reports and papers, etc. about the application were examined. Applications about the plantation of roof gardens within the country and abroad and data such as visual materials, projects and sketches were included within the research content.
Primarily, similar samples realized domestically and internationally and roof garden designs and application studies realized by individual and special companies made up the methods. In this context, significance and functions of roof gardens were revealed primarily and materials, establishment techniques, plant species and utilization styles used in plantation of roof gardens were determined. In the second stage, proposals were developed according to the synthesis studies, theoretical and applied samples based on the revealed analytical studies.

## 3. GREEN ROOF SYSTEMS

When roof gardens, as urban greenery, are compared with other green areas, it is clear that there are significant differences in terms of both realization and healthy sustainability. Whereas existing areas are used in green areas other than roof gardens, an environment needs to be generated for roof gardens initially. Roof gardens are divided into intensive and extensive roof gardens in terms of function and benefiting properties. These categories are used in the explanation of different purposes, methods and different applications generally. Different ideas will reveal the type of method proper for the roof where the application will be made. Intensive roof gardens are flat roof arrangements, which require more than the growth

environment with intensive afford and excessive growth inputs such as grass, bushes, shrubs and small trees, and application of various nonliving materials (pavement, sitting elements and water surfaces, etc.) (Küçükerbaş 1991).
It is mandatory that isolation, filtering, drainage and watering systems must be perfect in intensive roof gardens, which have a thick growth environment (200mm or more). Main target of such type of roof gardens is to provide open areas, serving recreational activities for people (Johnston, et.al. 1993). Intensive roof gardens have a thick soil layer and watering and drainage systems and provide more proper growth conditions in comparison to extensive green roofs, and they have various advantages and disadvantages.

### 3.1 Advantages

- They provide growth of various vegetation on top of roofs.
- Soil and vegetation taking place in these gardens attribute to heat insulation of the buildings.
- Soil surfaces gained on structures provide new living environment for the fauna (birds, bees, butterflies, spiders, beetles, worms and ants, etc.) as well as for the plants.
- In addition to the functional benefits, they provide significant benefits for urban ecology and aesthetics. They have constructive effects for human health as well.
- They enable various utilization of roofs.

### 3.2 Disadvantages

- They generate excessive load on roofs.
- Utilization of watering and drainage systems requires extra financial burdens.
- They are highly costly.
- They require more complex systems and technical perfection (Johnston1 et. al.1993).

## 4. HISTORICAL DEVELOPMENT OF GREEN ROOFS

People have planted roof areas for various purposes ever since the B.C. periods until today. Although they are used in terms of environmental and economic purposes today, constructive approaches this roof system brings to social lives of people caused the planted roof areas to be used throughout history. People have used landscaping elements in higher elevations from Ziggurats until today, along with the sufficient opportunities, chances and financial resources necessary for the application of vegetated roof systems (Tokaç 2009). Investigations point out that roof garden concept goes back to hanging gardens of Babylon established in B.C. 6000 although they are not in today's context. Roof terraces and roof gardens started in the Near East countries, where flat roofs were built. Holly books before Christ

include evidences about this type of roofs. The homeland of the gardens named 'hanging gardens' is Tigris and Euphrates basins, namely Mesopotamia (Kücükerbaş 1991).

**Figure 1.** Hanging gardens of Babylon (urbangardencasual 2012)

Following these preliminary applications, roof gardens or terraced garden applications are not encountered in early period civilizations and Anatolia until Roman period. Widely seen open place design was backyards in this period, which included prehistorically and Hellenic civilizations. When Roman period is reached (A.D. 1 century) roof garden applications are encountered in houses belonging to high level persons and civil architecture samples and especially in villa structures (for example Pompeii). Although Renaissance period garden designers were influenced by the past, they reflected the style of their period in their work (for instance Casime de Medici's Villa Careggi in Florence during the 1400s) (Johnston1 et al.1993).

Roof gardens or similar terraced garden applications are not seen in Turkish trite in Anatolia, Seljuk and Ottoman periods. 1867 Paris World Display was a significant milestone for roof garden design. In this display a constructor named Carl Rabite displayed a plaster cast of his house in Berlin which he thought for his house's roof in Berlin and he attracted great attention. French city planner Architect Le Corbusier, on the other hand, proposed that flat roofs of high buildings are used like gardens, and he contributed to the development of roof landscaping in terms of aesthetic and functional manners. Until 1960s, there was no roof garden sample comparable with the hanging gardens of Babylon in terms of dimension and size, Caiser Center roof garden was a mighty example overcoming this scale for the first time (Johnston1 et.al, 1993).

## 5. VEGETATION TYPES OF GREEN ROOF SYSTEM

There are two types of plantation in roof vegetation as 'intensive vegetation' and 'extensive vegetation' based on benefiting and function. Mixed vegetation manners according to the characteristics of the area can also be applied. These two major plantation techniques can be limited based on the criteria given below (Barışl et al. 2003).

### 5.1. Extensively Planted Roof Systems

Plant varieties used in this roof system are endlessly varied. When infra systems are provided such as plant carrier layer and drainage layer, which are necessary for plant growth, all plant varieties can be selected from bush types to tree types. There was no limitation in the plants that were used and this lead to unlimited aesthetic alternatives. Depending on the plant type, thickness of the plant carrier layer, and in turn, load to be brought to the system must be taken into consideration. Generally, load to be brought to the roof carrier system per square meter is accepted to be at least 290kg in densely planted roof systems. Furthermore, construction, maintenance and repair costs are high due to the plant types used. They spread into larger areas in comparison to sporadically planted roof types within the buildings. Depending on the area they cover and plant types they include, they enable more living varieties to live. Utilization targets are to generate public areas that are open to mutual usage within the buildings (Banting et al. 2005).

### 5.2. Intensively Planted Roof Systems

In this type of roof planting, plants that are preferred do not require maintenance, and continue existence and grow on their own. Especially rocky area plants fitting to this definition renew themselves gradually and enable new species to grow, and thus plant flora become widespread. Since the plant species do not require excessive maintenance, establishment, maintenance and repair costs are lower in comparison to the densely planted roof system. Moreover, depending on the requirements of the plant varieties used, plant-carrier layer thickness is higher in comparison to the densely planted roof system. Generally, densely planted roof system thickness is accepted to be more than 20cm and rarely planted roof system thickness is accepted to be less than 20cm. Thus, it may be regarded that weight per square meter does not exceed 290 kilograms (Liu 2004).

## 6. BENEFITS OF GREEN ROOF SYSTEM

- Green roofs decrease annual flow volume and aid in rain water to reach administration targets
- Soil layers, and over the roof top, vegetation maintains building-interior heat in a medium level, and in addition, they insulate against hot and cold. As a result, energy amount required to heat and cool the building decreases and this in turn enable the building owner to save energy. Increasing

insulation decreases HVAC infrastructure requirements and thus building construction costs drop.

- Additional roof insulation protects the materials against ultraviolet rays, which ruin standard roof materials, and against excessive heat changes. It is estimated that green roofs increase roof life up to 20 years.
- Green roofs are designed to isolate building interior from outer noises as well; noise-insulating properties of the green roof infrastructure may make the surrounding areas less quite.
- Completely saturated green roofs may provide resistance against fires and may prevent the fires to spread nearby buildings.
- Green roofs cool and humidify the weather, and may diminish urban heat island effect.
- Green roofs improve air quality and aid in filtration of dust particles and other particles hanging in the air and help in preventing them
- Roof planting made in cities or environments away from cities provide a natural living environment for birds and butterflies.
- One of the benefits of extensive green roofs is that pedestrians have access to areas within an urban area.

## 7. STRUCTURAL CHARACTERISTICS OF GREEN ROOF SYSTEM

Certain characteristics are sought in the roof overlay, due to both structural properties of the roof and growth environment to be prepared for vegetation. Since all of these characteristics cannot be found in a single layer, an overlay method is applied as layers. In this overlaying, the layer is ranged as carrying layer, insulation layer (water, heat and steam blocking insulation layers), separation layer, filter layer, substrate and vegetation layer. Structural walls such as flooring, windows, wind blockers, pergolas, steps and pools, which are thought as materials other than the plant material in roof gardens, should be designed based on the carrying capacity of the roof carrier system. Very light material should be used in roof gardens and strong yet light materials should be selected such as light concrete and light aluminum (Barış et al. 2003).

### 7.1 Plant

Selection of the plants that are to be used in a planted roof varies according to the planted roof type that is to be used.

### 7.2 Plant Bearer Layer

Plant species used in different climate conditions for green roof systems are as follows;

**7.2.1. Lichens**

*Brachytecium rutabulum*
*Bryum argenteum*
*Ceratodon purpurcus*
*Campothecium sericeum*

**7.2.2. Single year herbaceous**

*Anthemis tinctoria*
*Arabbiodpsis thaliana*
*Arenaria scrpyllifolia*
*Campanula rotundifolia*
*Cardamine hirsute*
*Centaurea seabiosa*
*Cerastium pumilum ssp pallens*
*Chrysanthemum sp*
*Daucus carota*
*Erigeron annuus*
*Galium verum*
*Hieracium pilosella*
*Holosteu umbeliatum*
*Medicago lupulina*
*Potentiall argentea*
*Senecio vernalis-vulgaris*
*Tragopogon dubius*
*Trifolium campestre*
*Tunica prolifera*
*Veronica arvensis*
*Vicia sativa*

**7.2.3. Perennial Herbaceous**

*Achillea nobilis*
*Anthemis tinctoria*
*Anthericurn liliago*
*Anthyllis vulneria*
*Arthemisia campestris*
*Aster linosyris*
*Cerastium holosteoides*
*Dictamnus albus*
*Dianthus deltoids*
*Epilobium angustifolium*
*Gallium album*
*Garanium sanguineum*
*Herniaria glabra*
*Inula conyza*
*Iris germanica*
*Linaria vulgaris*
*Linum perenne*
*Lychnis viscaria*
*Ononis repens*
*Plantago lanceolata*
*Rumex acetosella*
*Senecio erucifolius*
*Solidago gigantean*
*Taraxacum officinale*
*Trifolium pretense*
*Veronica serpyllifolia*

**7.2.4. Grass**

*Agrostis tenuis*
*Avenella flexuosa*
*Bromus mollis, B. sterilis*
*Festuca rubra, F. ovina, F. tenuifolia*
*Melica ciliate*
*Phleum phleoides*
*Poa bulbosa, P.pratensis*
*Stipa capillata, S. pennata*
*Vulpia myurus*

**7.2.5. Alliaceous, tubercular and rhizome plants**

*Allium*
*Tulipa sp.*
*Schoenoprasum*
*Muscari sp.*

**7.2.6. Succulents**

*Sempervivum tectorum*
*Sempervivum ruthenicum*
*Scmpervivum marmoreum*
*Sempervivum caucasicum*

| | |
|---|---|
| *Sedum ruperstre* | *Sedum acre* |
| *Sedum album* | *Sedum cauticolum* |
| *Sedum reflexum* | *Sedum kamtschatikum* |
| *Sedum sexangulare* | *Sedum spurium* |
| *Sedum ewersii* | *Sedum floriferum* |

**7.2.7. Short Ligneous**

| | |
|---|---|
| *Calluna vulgaris* | *Genistra linetoria* |
| *Cylisus scoparius* | *Helianthemum mummularium* |

(Mansuroğlu 1998)

### 7.3. Filter Layer

Today, geotextiles that are not braded are preferred as a material in the filter layer. Non-braded geotextiles are made of regularly or irregularly stacked fibers of various lengths. These fibers may form an overlay brought together with various mechanical, chemical or heat effects. Or they may be protected naturally and produced due to the structural characteristics of the tree itself used as a raw material.

### 7.4. Drainage Layer

It is necessary that a drainage layer and drainage system is used for storing water requirement of plants and taking away the excess water from the buildings. In case excess water coming to the roof is not stored, plants cannot meet their water requirement when they need water and this leads to their death. If excess water is not drained away from the buildings, this leads to an excess load in the building carrier system, and water accumulating on the surface may also harm the plant layer (Toydemir, 2002).

### 7.5. Root Retaining Layer

The purpose of the root retaining layer is to prevent water reaching to the layers and materials as a water insulating layer first of all, and thus preventing plant root harming and losing their function. Root retaining layer may be generated in two ways. In the first method, a protective layer is used for this requirement, similar to other layers. In the second method, root-retaining characteristics are gained with the aid of various chemicals on roof-carrier layover or on concrete surfaces like stems (Toydemir, 2002).

### 7.6. Water Isolation Layer

Water isolation materials are used for the roof system sub layers and inner environment not to be harmed by rainwater. Water isolation material makes the roof system impermeable to water. Furthermore, a slope shaft can be used to collect the water accumulating on the roof, and a rainwater removal system can be used to take away the collected water.

### 7.7. Roof Carrier System Component

The function of the roof carrier system is to transfer the vertical loads in the roof to the building carrier system safely (Toydemir 2002).

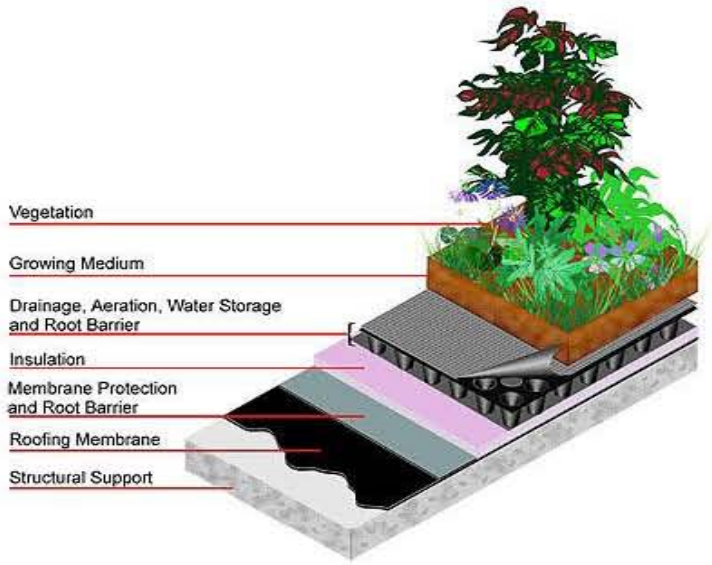


**Figure 2.** Green Roof System Constructions (greenspec.co.uk 2012)

## 8. CONCLUSION

There is a rapidly increasing need for roof gardens today due to rapidly increasing population and gradually decreasing green areas in large cities. Roof gardens balance surface flows, and regulate heat balances in the buildings and regulate excessive temperatures or other extreme climatic conditions generated by hard surfaces in cities. Roof gardens create green areas similar to natural areas in towns owing to their ecological and creative functions, and they have a vital role in the increase of green areas per person. However, roof gardens never take the place of a forest or any ecosystem in the nature. Green areas diminish in parallel to increased structuring today, and it is approved that green areas are won back by establishing roof gardens in buildings, which are actually supposed to be green areas. Roof gardens, which play an accessory role in the establishment of green area integrity in cities, have a significant role in people's lives owing to their economic and creative functions.

It may not be always possible to include a garden, which is to be established in the roof, ever since the design stage. It is possible to vegetate the area with plant containers of various dimensions and materials instead of a garden integrated with the structure in such type of roofs. Roofs planted this way do not bring excessive loads to the roof, and at the same time, they provide aesthetic and ecological benefits

same as the roof gardens. It is necessary to allow more space to such special gardens, completing the urban greenery and reducing problems, in order to diminish traffic noises and air pollution in modern urban life today. It is inevitable that city planners, architects and landscaping architects operate in coordination in this respect.

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