Design Considerations for Roof Garden Systems

[Excerpts from The NRCA Vegetative Roof Systems Manual, 2009]

1.0 Introduction

In the present sustainable development scenario, the roof garden concept has become an important component. Sustainability and energy efficiency of the built environment have become essential parameters of any development. A high performance roofing system is also based on the concept of 5 Es: Energy, Environment, Endurance, Economics and Engineering. The garden roof system includes the concept of the 5 Es and moves toward sustainable development. Based on the utility of the roof system, it can be categorised into a roof garden and a roof vegetable garden. Deciding which utilization to focus on is crucial and has to be considered as early as the planning stage. Estimation of the maximum load bearing capacity, maintenance, plant selection, substrates and expense budgeting must correspond with the desired roof garden type.

A roof garden system is a roof area where plants or a landscape is installed above a waterproofed substrate. It consists of a waterproofing system and its associated components such as a protection course, root barrier, drainage layer, thermal insulation and aeration layer, and an overburden of growth medium and plantings.

To understand the installation of the roof garden system, a few guidelines are available in some countries. The guidelines mainly cover the types of garden roofs, the various vegetation types, the requirement for the building techniques, the garden roof procedures and the upkeep and maintenance of the garden roof. . A terrace garden also called as roof garden or a green roof on the roof of a building. Besides the decorative benefit, roof gardens provide food, temperature control, hydrological benefits, architectural enhancement, habitats for wildlife, and recreational use. Apart from the roof the terrace garden can be created on balconies and other extended areas of a building. In rooftop garden, space becomes available for localized small-scale urban horticulture. Available gardening areas in cities are often lacking, which is likely the key requirement for many roof gardens. Roof gardens look good if they are proportionate with lawns, shrubs, ground covers, sitting area, bar, barbecue and small trees. One can also incorporate the concept of water bodies or rock garden or create a shady structure (Pergolas) on roof garden.

Terrace garden not only improves the aesthetic environment in both work and home settings but has various economical as well as environmental benefits as follows:

- **Economical benefits:**
  - » Doubles the life of the conventional roof.
  - » Reduces air conditioning cost by 25% to 50%.
- **Environmental benefits**
  - » Insulates the building against heat and cold.
  - » Reduces indoor temperature by 6 – 8 degree.
  - » Reduces sound pollution.
  - » Increases the amount of oxygen in air.
  - » Filters air borne particles from air.
  - » Controlling storm water runoff, erosion and pollution

2.0 Design Criteria Consideration

The roof garden waterproofing system criteria which need to be considered while installing the system are:

- Climate and geographical location
- A buildings intended use and design life expectancy
- Exterior and interior temperature, humidity and conditions for use
- Building code requirements
- Type and condition of substrate
- Structural system
- Slope and drainage
- Waterproofing membrane
- Garden roof system type, including overburden
- Accessibility and building configuration
- Building movement
- Type and amount of insulation, protection and drainage needed
- Need for ventilation during installation
- Compatibility with adjacent building and/or system components
- Construction sequencing
- Worker safety
- Potential building additions
- Odour generated by certain system application methods
- Water-retention loads
- Construction traffic
- Penetrations
- Landscape maintenance

The success or failure of the terrace garden assembly basically depends on the above considered criteria. It must be ensured that the terrace / roof is strong enough to bear the load of the terrace garden waterproofing systems.

Along with the mentioned criteria, the terrace garden application also depends on a structurally sound deck. Provisions which need to be included while designing a deck structure for the terrace garden are:

- Live loads such as snow, ice and rain

- Construction loads such as moving installation equipment, workers and materials
- Dead loads such as mechanical equipment, duct work and piping, and conduits such as fire sprinklers and electrical lines
- Dead loads such as waterproofing systems, saturated growth mediums, concrete toppings and pavers
- Deck strength (gauge, density, type and thickness)
- Expected deflection
- Drainage
- Placement of expansion joints
- Placement and structural support of the curb, and penetration members and details
- Attachment provisions for a deck
- Suitability for the adhesion/attachment of a waterproofing membrane
- Suitability for water test loads

3.0 Surface Preparation

Surface inspection is recommended before starting the installation of a terrace garden waterproofing system. Visual inspection is required to ensure a clean, smooth and dirt-free surface. All visible defects and unsound patches in the substrate should be noted and corrections should be made before installing the terrace garden.

4.0 Roof Garden System

A roof garden system comprises of a roof system, landscaping concepts and components and waterproofing.

The basic principle of a roof garden system is that it consists of a roof waterproofing membrane which prevents moisture from entering a habitable building or space.

Garden roof systems can be divided into three categories: extensive, semi-intensive and intensive, which are defined as follows:

- Extensive (shallow) roof garden system: Roof system with garden that has medium plants with approximately 50 mm to 150 mm deep roots
- Semi-intensive (moderate) roof garden system: Roof system with garden that hasmedium plants with approximately 150 mm to 250 mm deep roots
- Intensive (deep) roof garden system / roof garden: Roof system with a garden that has plants with roots that are more than 250 mm deep

The waterproofing membrane component is the same in all three types. However, the other system components vary based on the plants and landscapes placed above the waterproofing system.

The followings properties and requirements of a roof garden waterproofing system need to be satisfied:

- A roof garden system needs to be compatible with the plants and vegetation, and must resist contamination from fertilizers and other chemicals and materials used in conjunction with the vegetation.
- A roof garden system is more susceptible to mechanical damage and abuse, especially during installation.
- A roof garden system must be protected from the tools used to maintain the overburden / vegetation.
- A waterproofing roof membrane for a roof garden system is not readily accessible after the overburden is installed. Designers should be more conservative with their design, membrane selection and detailing.
- A roof garden system is exposed to landscaping, cultivation, vegetation work and human error. The landscape portion of a roof garden system will require periodic maintenance. Maintenance workers should be made aware that they should not damage exposed materials, especially the waterproofing layer and flashings. Specific safety precautions may need to be followed by maintenance and landscaping trades working in a roof environment.
- A roof garden system is protected from ultraviolet (UV) exposure and impact but is still exposed to thermal and environmental changes.
- The substrate for the roof garden waterproofing membrane should be sloped to provide positive drainage. To achieve the necessary slope throughout the entire surface area, a designer should consider the following:
  - » Structural framing for the deck
  - » Deck type and its characteristics
  - » Overburden material
  - » Type of membrane specified
  - » Penetration locations
  - » Varying deck deflections
  - » Building and deck layout
  - » Flashing termination heights

5.0 Components of a Roof Garden System

The various components of a roof garden system are as follows:

- Adhered roof waterproofing membrane
- Protection course
- Root barrier
- Drainage layer
- Moisture-resistant insulation (optional)
- Aeration layer
- Moisture-retention layer
- Reservoir layer
- Filter fabric layer
- Growth medium with plantings

5.1 Waterproofing Membrane

A roof garden system incorporates a waterproofing system that is directly adhered to the substrate. The membrane should be able to provide hydrostatic

resistance based on the expected amount of water drainage and retention. The types of membranes recommended are as follows:

- APP and SBS-polymer-modified bitumen sheet membrane
- EPDM membrane
- Polyvinyl chloride (PVC)
- One and two component liquid-applied elastomeric membranes

Regardless of the membrane type, the roof garden waterproofing membranes should have the following properties:

- Low water absorption
- Low vapour transmission
- Puncture resistance
- Chemical resistance (e.g., fertilizer)
- Ability to resist design forces through tensile strength or elongation

5.2 Protection Course

Protection course is a separate layer of material which is installed over the waterproofing membrane to protect it from damage after installation. The material of the protection course depends on the type of membrane and its thickness depends on the type of overburden. A roll of protection board is shown in Fig. 1. Materials that can be used as a protective course are:

- Asphaltic boards
- Asphaltic sheets
- Extruded polystyrene boards
- PVC sheets

Fig. 1: A protection board

5.3 Root Barrier

Roots can penetrate the waterproofing membrane and potentially create leak locations. A root barrier is typically a separate layer of material installed on top of the protection course, but it may be combined with a protection course or drainage course. It prevents the migration of plant roots from damaging the membrane. Its material type depends on the type of membrane and plants used for a roof garden system.

The following materials may be used as a root barrier:

- High-density polyethylene (HDPE) boards
- Granulated polymer-modified bitumen membranes with root-inhibiting additives (e.g., copper sulphates)
- Polyethylene sheets

5.4 Drainage Layer

Drainage layer provides a way or path for moisture to move laterally through the roof garden system. This layer enhances the performance of the waterproofing material by relieving hydrostatic pressure from the material's surface and its associated weight. The following are the most common types of drainage layers:

The following are the most common types of drainage layers:

- Drainage mat (Fig. 2)
- Insulating drainage panels

Fig. 2: A Drainage mat

5.5 Moisture-Resistant Insulation

Moisture-resistant insulation may be installed above the membrane. This provides thermal protection to the membrane, reducing the overall temperature gradient that a membrane experiences. Additional insulation may be considered because of the expected loss of R-value when insulation is located in a moist environment.

XPS (Extruded Polystyrene) insulation can be used as the thermal insulating material for roof garden systems. The compressive strength of XPS should be based on the expected loading requirements, such as the weight of saturated medium growth plants.

Expanded Polystyrene (EPS) insulation is sometimes used as the filler material, not as the primary insulating material, to reduce the total weight of the roof garden

system and provide a contour of the final surface. EPS retains water, and, therefore additional weight should be accounted for when determining the total dead load of the system.

5.6 Aeration Layer

The composition of an aeration layer is similar to that of a drainage mat. An aeration layer allows air to move across the top surface of the insulation layer. Additionally, the aeration layer allows moisture to drain from the top side of the insulation. Aeration layers are needed when insulation is used above the garden roof waterproofing membrane, so that the insulation will retain its R-value.

Where insulation is used above the membrane without an aeration layer, the in-place R-value of the insulation will most lilely be less than the design R-value of the insulation, because of the moisture retained within the insulation.

5.7 Moisture Retention Layer

A moisture-retention layer is typically an absorptive mat consisting of recycled polypropylene fibers. A moisture-retention layer retains or stores moisture for plant growth. This layer is typically located above the drainage layer (or it can be combined with the drainage layer) in uninsulated systems or above the aeration layer in insulated systems. The materials for a moisture-retention layer depend on the overburden type.

5.8 Reservoir Layer

The reservoir layer is typically located above the moisture-retention layer. A reservoir layer retains or stores moisture for overburden growth. The materials for a reservoir layer depend on the overburden type, but typically consist of polyethylene-based panels, formed into a three-dimensional array of water reservoir cups and drainage channels. The panels are designed to hold a specific amount of moisture by using overflow holes which limit the capacity of the cups. The reservoir cups are graduated in size for differing amounts of water storage, as required for the growth medium and plantings. Reservoir layers typically include aggregate when used under intensive roof garden systems, because of the large water storage requirement.

5.9 Filter Fabric or Geotextile

This is a tightly woven fabric, typically polyester or polyethylene / polypropylene, used to restrict the flow of fine growth medium particles and other contaminants while allowing water to pass freely through, thereby protecting drainage systems from clogging. Filter fabric is often laid directly over the top surface of the drainage layer and is generally installed just prior to the placement of the growth medium.

5.10 Garden Growth Medium

Growth medium is typically a lightweight aggregate-based medium and is specially formulated to provide a proper growing environment for specific plants to be included in a roof garden system.

Growth media are mixtures of mineral, organic and synthetic components. The components are blended in appropriate ratios to provide the needed characteristics of the medium. Growth medium considerations include vegetation requirements, moisture and nutrient retention, drainage, pH level, porosity and compaction, erosion resistance, weight restrictions based on structure, resistance to fire propagation and structure for plant anchorage.

Keeping in mind all these, a schematic diagram of an advance roof garden system component is shown in Fig. 3, and a simplified roof garden system is shown in Fig. 4.

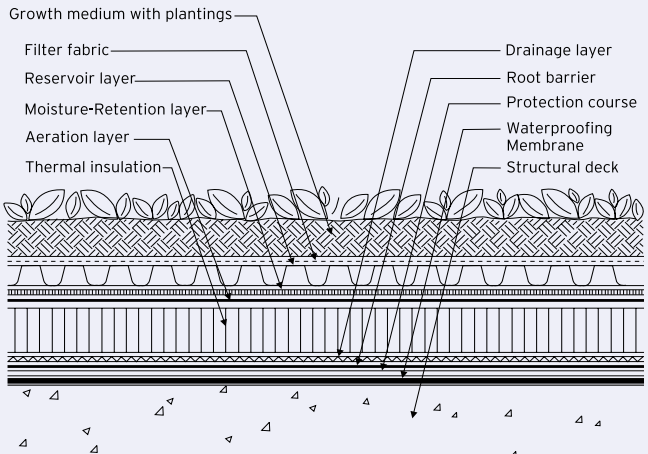

Fig. 3: A schematic diagram of an advanced roof garden component system

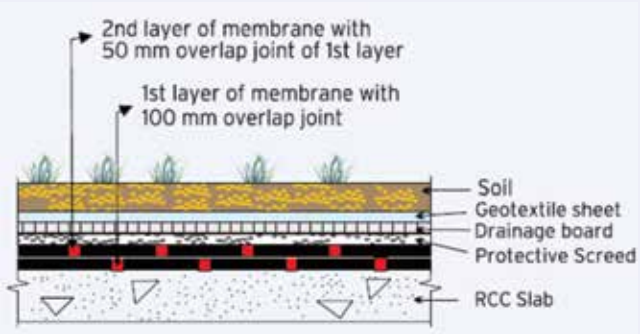

Fig. 4: A schematic diagram of a simplified roof garden component system

5.10.1 Extensive (Shallow) Roof Garden Systems

Extensive roof garden systems use a narrower range of species limited to herbs, low-growing grasses, mosses and drought-tolerant succulents such as the sedum—a plant variety, which is known for its tolerance to extreme conditions. Extensive roof garden systems require a root barrier and moisture-retention layer and generally do not require irrigation.

5.10.2 Semi-Intensive (Moderate Depth) Roof Garden Systems

Semi-intensive roof garden systems use a combination of plant species that may include small shrubs and species like grasses and herbs. They are generally limited to low-slope structures of 2:12 or less. Semi-intensive roof garden systems have landscaping that require more regular maintenance than an extensive system, but have limited plant selection because of shallower growth medium depths, such as a sod grass lawn. These systems will require a reservoir layer and may require an irrigation system.

5.10.3 Intensive (Deep) Roof Garden Systems

Intensive garden roof systems use a wide variety of plant species that may include trees and shrubs, and are generally limited to low-slope structures of 1/4:12 or less.

The use of large plants requires a deeper growth medium layer, typically 250 mm or more, which results in greater weight and the need for an increased structural load capacity of the building. Intensive garden roof systems typically require a heavy root barrier and often require irrigation. These systems require a reservoir layer.

Additionally, an efficient drainage layer may be required because of the quantity of water from irrigation and project conditions.

6.0 Cost of Green Roofing

The cost of a green roof varies considerably depending on the type and factors such as site location, depth of growing medium, selected plants, use of irrigation, water proofing area, and requirement of different garden elements and accessories. The initial cost of terrace garden is higher than a normal roof, though in the long run the saved energy pays the investment back.

7.0 Conclusions

Earlier, roof garden systems were considered only for high-end luxury projects for luxury purposes. However, now days most medium to large projects are adopting roof garden systems. They are also being considered energy efficient and eco-friendly and have achieved a green rating, due to which more and more builders and developers have started building green roofs. However sometimes this becomes miserable when the right approach towards designing and waterproofing such a system is not adopted. It will be immensely helpful if one pays attention to all these components while designing a roof garden system. This will help in providing a durable service life for such green roofs.

Podium Waterproofing

[Excerpts from Dr. Fixit Booklet "A Systems Solution to Waterproofing", 2013, pp.28-31; http://www.doctor-fixit.com/professional-podium.html]

1.0 Introduction

Many high rise buildings today incorporate landscaped basements and roofs commonly known as plazas or podiums. The basement can vary from habitable space to car parking, however, whatever the usage, it is vital the correct waterproofing system is selected when waterproofing the podium deck. There are many considerations to be taken in to account including deck movement, differential movement, drainage, waterproofing continuity at expansion joints, drainage outlets, landscaping, and most important utilities below the deck. The various usages of over deck slab of podium can be selected based on the client's requirement. Podium slabs is an area where one can plan for facilities such as water bodies, landscape, children play area, sports facilities and car parking etc.

Proper waterproofing system helps to keep out water and pollutants thereby preventing leakages and also protecting structural elements and embedded steel reinforcement from corrosion damage.

2.0 Functional Requirements

There are various functional requirements of a podium slab which need to be satisfied depending on the utility and requirement. The some of the major functional requirements need to be considered are given as follows:

- Large open areas-Excellent tensile and elongation properties to accommodate thermal movements
- Water bodies-Excellent barrier to water ingress and continuous exposure to water
- Landscaping-Resistant to root penetration even for intensive roots
- Sand Filling-Enable sand filling directly on the membrane without protection screed
- Chemical Resistance-Resistance to pesticides
- Medium duty traffic-Resistance to dynamic and Impact load
- Very high impact and puncture resistance-Able to sustain mechanical abuse during construction
- Zero VOC-Environmental friendly, meet the norms of Garden products for waterproofing

3.0 Waterproofing of Podium Slab

The bare podium means the slab which does not provide any service such as water bodies, children play area, roof garden and vegetative garden etc. but only acts as space for car parking has to be waterproofed for rain water only while other podium slabs require much more