

# An Engineering Approach to Roof top Gardening

## Abstract:

With the growing demand for vegetables and fruits in this world of urbanisation roof top gardening finds an insignificant place. The roof top gardening involves greater engineering application majorly in design of roof, irrigation management, arrangement of pots, waste management, moisture proofing etc. These factors contribute significantly in designing an effective roof top garden. Various problems faced in the engineering intervention were identified and suitable remedies were suggested in the research using a case study approach of roof top gardens in Bengaluru. A well maintained roof top garden is a positive sign of a healthy household.

**Keywords:** Roof top gardening, engineering interventions, moisture proofing, irrigation, load.

## Introduction:

Nature has been compared to a Mother for her selfless attribute of providing a wide variety of resources to humans. In lieu of all the procurements we have not only maligned the nature by excessive pollution, global warming, growing wastes disposal problems and many more but also have contributed to extinction of some of the vital resources. Along with this huge population migration from rural areas to cities is also prevalent in the country in order to gain opportunities. The increasing usage of pesticides, insecticides and herbicides has adversely affected the human health. The ill affects ranges from headache, giddiness, nausea to even endocrine disruption. The consumption of daily usage vegetables and the prices are also on an ever increasing hike. These issues have compelled us to search for some ways or practices so that the ill impacts can be minimised or at least controlled. A roof top garden can be one of the practices which if encouraged can help the society to minimize the bad effects produced by the above mentioned problems. Apart from production of wide range of vegetables for domestic purpose they offer numerous benefits ranging from reducing the surrounding temperature to decreasing the suspended impurities present in the air.

In Bangalore, 1.5 lacks hectare of land under agriculture before 20 years is under urbanization now. Due to Lack of daily consumable, vegetables and fruits at reasonable price 70% of the people in Russia and China are following the roof top gardening to fulfil their needs. [Britanica.com (1)]

Although India is the second largest producer of fruits and vegetables in the world, but only 50 g fruit and 130 g vegetables per capita is available according to NIN. According to National institute of nutrients, Hyderabad (NIN), 150 g fruit, 300 g vegetables are required per person. [agritrade.iift.ac.in (2)]

A roof top garden not only helps a family to get fresh organic vegetables but also keeps the home cool and helps in utilising the domestic organic waste. Having a roof top garden reduces the trouble of buying vegetables for family consumption and seeing the present price hike in the vegetables we can easily understand its importance. Organic (free from any hazardous pesticides, insecticides and herbicides) vegetables, fruits, and even fragrant flowers can be produced on the roof with little maintenance. A roof top garden on the roof reduces amount of suspended particles present in air. Green roofs can reduce indoor sound by as much as 30 db and providing particular benefits to buildings in noise infected areas such as close to airports or industries. There is a common term for the rise of temperature of urban areas compared to rural areas called as “Urban Heat Island Effect”, having a roof top garden can apprehensively help to reduce this phenomena and thus making the cities greener and pleasure to stay in. Balcony and roof top gardens give pleasure to city dwellers and provide an opportunity for enhancing creativity as well as provide psychological benefits. In addition, they change the visual appearance of the building and the aesthetic appeal of the building enhances.

Engineering interventions in a roof top gardening system includes design aspects involved in roof top garden along with the various systems present such as design of building, effect of dampness on the roof, irrigation system like drip and automatic irrigation and drainage system, green house for roof top garden etc. Information about the major crops grown in the roof top garden ,their common diseases and pesticides ,pots and materials for pot fillings ,composting and bio fertilisers and domestic waste utilisation.

In and around Bangalore several people have been practicing roof top garden and their responses are quite motivating and positive. One can grow at least six vegetables per season depending on the requirement of the family. Realising the importance of the above subject

and to identify the engineering parameters and their importance in roof top garden this study has been planned under the following objectives of studying the existing practices of roof top garden in Bangalore and identify the engineering parameters. Later part dealt with identification of problems relating to the engineering aspects involved in the roof top garden and providing suitable recommendations and remedies to the identified problems.

### Materials and Methods:

In and around Bangalore the standard site allotted from BDA is 30' × 40', on an average we can get 700 to 800 sq. from 30' × 40' site and about 1500 sq. in 40' × 60'. these two sizes of roof top can be considered suitable for a roof top garden. One basic requirement of the roof suitable for a roof top garden is that it should be easily accessible. In order to study the various practices being followed in roof top garden practices in Bengaluru, three different roof top gardens were considered as case studies. Different aspects related to the cultivation practices, crops grown, arrangement of pots, irrigation systems, waste water utilisation and major challenges faced in the garden management were studied.

Table 1: Case studies of various roof top gardens in Bengaluru

Parameters	Case study 1	Case study 2	Case study 3
Location	UAS Layout, Sanjay Nagar, Bengaluru	Vidyaranya pura, Bengaluru	Richmond circle, Bengaluru
Crops Grown	Flowering plants: jasmine, marry gold, variety of roses, Aquatic plants grown in the pots, few vegetable crops tomato, coriander, carrot, berries. Apiculture	Tomato, brinjal (grafted), coriander, bitter gourd, onion, pudina, radish, lemon, chillies, field beans, kanakambara, jasmine, sugarcane, banana, drumstick, guava and pomegranate and also medicinal plants like aloe vera. Banana, lemon and sugarcane.	Vegetables: Tomato, green leafy vegetables, brinjal. Flowers: Rose, marigold. Pepper creep around the periphery of the garden.
Irrigation Practice	The soap water coming from washroom and kitchen water is mainly used for irrigation to plants in the roof top garden	Watering is also facilitated by this arrangement. One of the beautiful and interesting aspects about his roof top garden is self-growth of honey bee colony on the roof top garden.	Manual irrigation
Pots arrangement	stair casing	Mainly cement pots for	Vertical

	arrangement of wire with iron angles for placing pots	growing crops in their roof top garden and also they are using many types of plastics pots. With pots they are using stake arrangement in order give the strength and stability to the crops like tomato. Different earthen pots are also using for roof top garden. They are also using the waste buckets, polythene covers and polythene bags for growing plants in their roof top garden. The pots arrangement on their roof top garden depends on the seasons. They arrange the pots very closer during the summer and pots will be arranged freely during the winter.	arrangements for small pots, linear arrangement for larger pots.
Moisture proofing	Nil	Nil	Polythene sheet below the pots
Major challenges	Moisture Seepage, irrigation scheduling	Monkey menace, Moisture proofing	Moisture proofing



**Results and discussion:**

**I. Identification of Engineering aspects in a roof top garden**

**A. Load on the roof due to the roof top garden**

A suitable roof for a roof top garden should be strong enough to bear the dead as well as live loads occurring because of the roof top garden. Dead load is defined as the load occurring in vertical direction as a result of weight of permanent structural and non-structural components. It also includes the weight of attachments of a building such as walls, floors, ceilings, permanent partitions and fixed service equipment etc. Live load is defined as the load superimposed by the use or occupancy of the building not including the environmental loads such as wind load, rain load, earthquake load or dead load. Weight of soil on the roof and the plants or in pot system weight of pots are also added to dead loads. [https://law.resource.org/pub/bd/bnbc.2012/gov.bd.bnbc.2012.06.02.pdf (3)].

Table 2: Permissible load for various roofs

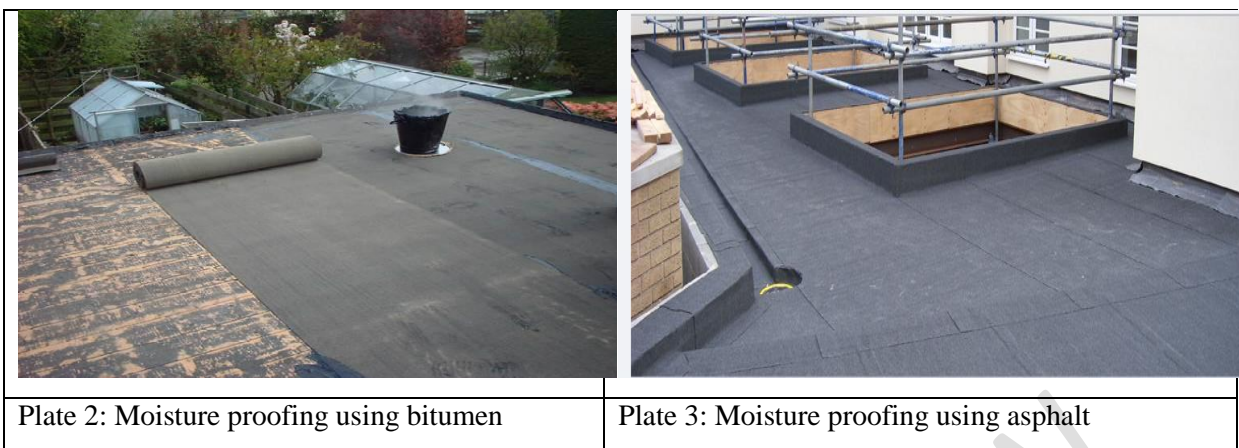
Roofs used for promenade purposes - 3.0 kN/m <sup>2</sup>
Roofs used for assembly purposes - 5.0 kN/m <sup>2</sup>
Roofs used for gardens - 5.0 kN/m <sup>2</sup>

**B. Dampness in building and Moisture proofing of the roof for a roof top garden**

A damp building creates unhealthy living and working conditions for the occupants. Presence of damp condition leads to efflorescence on building surfaces which finally results in the disintegration of bricks stones, tiles etc and ultimately reduction of strength. It also results in softening and crumbling of plaster. It also causes bleaching and flaking of the paint which results in the formation of colour patches on the wall surfaces and ceilings. Dampness may also result in corrosion of metals. The quality of timber also deteriorates when in contact with damp conditions. All the electrical fittings get deteriorated, causing leakage of electric current with the potential danger of a short circuit. Dampness promotes the growth of termites and hence creates unhygienic conditions. Dampness when accompanied by the warmth and darkness breeds the germs of tuberculosis and neuralgia sometimes result in fatal diseases. Dampness refers to building up of moisture in a structure leading to decrease in strength and unpleasant surrounding conditions. Dampness in building is generally due to one or more of

the following causes that include faulty structural design and poor workmanship. The usage of poor constructional materials, inappropriate drainage, and leakage through pipes around the roof. The moisture entering the building from foundation and roofs travels in different directions further under the effects of capillary action and gravity respectively. [<https://www.scribd.com/doc/23208583/Building-defects-caused-due-to-Dampness>, (4)]

Conventional methods of roof top waterproofing include brickbat cobalt or mud phuska. They are rigid and do not move with temperature variations, resulting in cracks and causing seepage. Depending upon the nature of the waterproofing membrane chosen (organic vs. synthetic), a root barrier layer may be needed to prevent the plant roots to penetrate and ultimately undermine the integrity of the waterproofing layer. For example, asphaltic bitumen is organic and roots could naturally attempt to penetrate the surface while seeking nutrients. A common practice on traditional roof gardens and intensive green roofs is to pour a concrete protection slab over the membrane layer. Generally if the roof has no leakage in the rainy season we consider the roof is safe to have a roof top garden. If we apply less water to pots no stagnant water is present on the roof but if we apply excess water then stagnation of water is a problem. For the raised bed system of roof top garden where the planting is done on a raised bed of soil we need to go for moisture proofing of the roof .generally a plastic sheet of sufficient thickness is spread before applying the soil layer in order to avoid dampness of the roof. This also enables us to have an efficient system of drainage. In areas of heavy rainfall moisture proofing of roof becomes a compulsion, dampness can also occur if proper drainage conditions are not given for the poured water. Moisture proofing solutions are available in market to seal the weep holes on the roof, if proper moisture proofing measures are not taken it leads to dampening of the roof and the strength of roof decreases. Various materials used for moisture proofing include flexible materials like bitumen felts (which may be Hessian based or fibre/glass fibre based), plastic sheeting (polythene sheet) etc. other materials include application of plastics, hot bitumen, material asphalt, mortar and cement concrete. A damp-proof course is a barrier through the structure by capillary action such as through a phenomenon known as rising damp.



### C. Pots used for planting on a roof top garden

Various types of pots are used for growing plants on the roof top garden. At present earthen pots, plastic containers, RCC pots are most commonly used. Pots are selected depending mainly on depth of root of plant, water requirement of the plant and weight of the pot. It is advisable to go for locally or domestically available containers, water buckets, jars and drums to grow plants on the roof top garden. This unit briefs about various pots used in roof top garden along with their pros cons and special attributes.

Table 3: Various pots used in the roof top garden and their applicability

Various sizes of earthen pots are available in market, leakages in such pots are more but better root aeration occurs in them.
Plastic plots are light in weight and they are widely used in roof top garden.
RCC pots are quite durable but they are quite heavy to handle and load on roof increases.
Plastic bags are easy to handle and can be used for wide range of small root or shallow rooted crops. The leakage roots are also minimized by their usage.
Coconut fibre boxes are quite aesthetically pleasing and comfortable to handle but are costlier compare to other boxes
Wooden boxes of various sizes unlined with plastic covers are also mainly used in roof top garden. They provide natural look to the roof top garden
Usage of metal boxes is discouraged as they get corroded by moisture easily
Raised beds are also used on roof top garden for growing different crops
Small bottles can be used for growing small plants such as coriander and even onions
Thermo coal boxes can also be used as light weight boxes

#### D. Arrangement of pots on the roof top garden

Arrangements of pots mainly depend on purpose of making the roof top garden aesthetically pleasing and maximize the sunshine receiving duration for plants with protecting them from strong winds. Generally pots are linearly arranged in rows providing enough space for movement and avoid interference of shadows of adjusting plants special arrangements for hanging parts can be made which adds beauty to the gardens. Arrangements of pots mainly depend on purpose of making the roof top garden aesthetically pleasing and maximize the sunshine receiving duration for plants with protecting them from strong winds. Generally pots are linearly arranged in rows providing enough space for movement and avoid interference of shadows of adjusting plants special arrangements for hanging parts can be made which adds beauty to the gardens.

Firm wire mesh mechanism can be made in order to accommodate more pots in limited space. In areas where monkey problem is severe, wire netting can be done around the roof top garden. It is advisable to use the locally available cans, drums, tins for growing crops as roof top garden in order to minimize installation costs. Presently growing the plants in linearly arranged pots and placing of pots in raised beds of kadapa stones are getting lot of popularity. Apart from these arrangement hanging pots and stair arrangement is practiced commonly in Bangalore.

Various arrangements that can be followed for growing crops on the roof garden are

1. Open roof top with linear arrangement of pots is the most commonly used arrangement- This is the most common arrangement requires no additional cost for installation of structures.
2. Raised platforms of RCC or kadapa stones can be used for placing pots on the roof top.
3. Firm wire mesh staircases can also be given in order to accommodate large numbers of pots on the roof
4. Fencing arrangements for creepers on the roof with iron angles at the corners.

Wire netting stair cases can also be provided to keep the pots on the roof in order to provide sufficient sunshine. This arrangement also helps to accommodate a large number of pots on roof top garden.

#### E. Irrigation Management in the roof top garden

Application of right quantity of water at right time is important for growth of a crop in a roof top garden. Generally small kettles are preferred for application of water because application



is easy and uniform using them and convenient carriage is also possible. If shortage of time is there we can go for drip irrigation which is one of the most efficient irrigation methods.

Dripler is an automatic drip irrigation system attached with a timer which controls the frequency and run-time of water for the plants. This battery operated timer, once set, can take care of plant-watering automatically, regularly & efficiently, without any user intervention. This system is also called as Automatic plant watering care. In this system, a sensor is placed which automatically senses the moisture deficiency in the soil. According to pre-set timings, the irrigation will automatically start and used no manual cut off and starting. This method has two versions tap version and tank version, the tank version has more applicability. Tank Version is an automatic drip irrigation system with a battery operated timer, 25 Litre capacity water tank and drip irrigation accessories for 12 plants. The system controls the frequency and run-time of water for the plants according to the settings you set in the timer. Tank Version dripler has 1 Timer, a 12 mm pipe adaptor, 2 AAA batteries, 12mm Main line pipe 8 m, 4mm feeder line pipe 5 m., 2 litre/hour emitter 6 Nos (for smaller pots), 4 l/h emitter 6 Nos (for bigger pots), 12 No's feeder joint, 2 end caps, 1 T connector, 2 L connector , 1 straight connector, 2 end caps, 3 Dummy pins, teflon tape, 25 litre tank, tank attachment brackets, screws, bolts. The Tank version dripler as a kit will serve for only 12 plants, suppose you have more plants we provide dripler extension kit for additional 12 plants.

#### **F. Poly house/Green house for a roof top garden**

A low cost green house or a poly house can also be constructed on the roof of the building in order to collect the rain water efficiently and grow crops in controlled conditions. Generally if the crops are grown in a roof top garden the yield increases apprehensively and infestation due to insects are also less. The growth of plants in a green house is also uniform. It also facilitates the collection of rain water from the top of the greenhouse. The placement of tank should be on the roof itself if the green house arrangement is practiced. For common usage a shade net with 20 to 25% penetration can be used. This reduces the direct impact of sun rays on the plant as well as reduces the roof temperature. Green house can also be constructed on the roof top, but the roof should with stand the Load of greenhouse structure, also resisted by the wind velocity, the structure should covers maximum length in east and west direction, which helps get the maximum amount of sun light radiations for plants growing in green-house. Usually low cost greenhouse recommended for roof top gardening because it is effective technology and also helps for improve yield may be 10-12 time higher than that of

out-door cultivation so we grow different kinds of fruits and vegetable with less area by practicing low cost green house. It finds its varied application in providing protection to the plants from the adverse climatic conditions such as wind, cold, precipitation, excessive irradiation; extreme temperature, insects and diseases . It also creates an ideal micro climate around plants. Generally a green house or poly house is not a recommended structure for having on a roof top garden because our main aim is to produce for self-consumption rather than profit making. But in areas where the temperature is high and sun heat is scorching shade nets with 20 per cent penetration can be utilised. These structures should be strong enough to sustain the wind loads on the roof top as well as should be economical in construction.

Table 4: Greenhouse structures for roof top gardening

Lean-to type green house: In roof top garden this design makes the best use of sunlight and minimizes the requirement of roof support
Even span type green house: two pitches of roof slopes down that helps to collect the roof water effectively .this design is used for small type green house and on levelled roof
Pipe framed structure: Clear span is around 12 m the pipe framed green house is recommended for roof top garden
Truss framed greenhouse structure: Green house span is usually greater than or equal to 15 m in roof top we recommend it

## II. **Problems in roof top garden relating to the engineering aspects and their suitable remedies.**

Some of the common problems related to engineering aspects involved in roof top garden are identified and remedies for them have been discussed. The problem of dampness is the accumulation of even moisture on the roofs, because of inefficient and improper measures taken to remove the drainage water from the roof top this problem turn severely. The problem of dampness of the roof is mainly due to poor drainage conditions for the rainwater as well the water applied as irrigation for plants on the roof top garden .The pipes around the building also leads to dampness of the ceiling and walls. The damp roof decreases the strength of the roof. A filthy environment prevails around the house because of dampness which may lead to various diseases. Generally people avoid planning a roof top garden before

setting up hence because of improper arrangement of pots they don't receive the sufficient amount of sunlight. This leads to improper growth of plants. If the arrangement is not proper, the shadow of adjacent plants also gets overlap and this reduces their growth and chances of spread of diseases are also higher. The creeper require special arrangements, they need proper support for their growth and thus need firm support to grow on.

Thus suitable arrangements should be followed for placing the pots. Stairs arrangement made up of wire netting or concrete are recommended as they can accommodate large number of pots and the stairs also act as support for growth of the creepers. Various types of pots are available for growing plants on the roof top garden. Generally people prefer the earthen pots along with RCC pots and plastic bags. Metal containers and RCC containers are not commonly preferred because they increase the load on the roof. Locally available containers, boxes and jars should be preferably used for growing plants. Common among them are half cut boxes, thermo Cole boxes, plastic bottles and bags locally available covers. Various growing media can be used for pot filling in the roof top garden. Organic materials such as coconut pith and mixture of vermi compost can be used for pot filling. Crops can be grown directly on the soil bed but for better results different mixes are made that add fertility to the soil and can be prepared at home only. Panchagavya helps to increase yield of the plant as well as increases the resistance of plants against pests and diseases. Jeevamrutha, which is a traditional organic fertilizer, works as a cool drink for plants. It can be used as a fertilizer for each plant for every week, which boosts the plant growth and gives good yield.

Lack of irrigation scheduling and maintenance of the irrigation system is one important drawback in roof top gardening. Application of right quantity of water at right time is important for growth of a crop in a roof top garden. Generally, as a roof top garden is done on a small site so, irrigation can be done by a bucket and mug also or by small kettles. Generally small kettles are preferred for application of water because application is easy and uniform using them and convenient carriage is also possible. It also serves as a source to get some fresh air in this hectic schedule of urban life. Drip irrigation can also be recommended for the roof top garden, it is described as a regulated and slow application of irrigation water through emitters at frequent intervals near the root zone of the plants over a long period of time. Drip irrigation is a watering system that delivers a slow moving supply of water at a gradual rate directly to the soil. Drip irrigation, which is also sometimes referred to as micro-irrigation or trickle irrigation, consists of a network of pipes, tubing valves, and emitters. By practicing

drip irrigation we can minimise the water losses, maintain uniform growth of plants, minimise application losses and timely irrigation can be achieved.

In urban areas, because of busy schedule of people they find difficult to irrigate according to proper irrigational scheduling, thus automatic watering system can be brought in practice. This system has pre-set timers which start at particular time supplying the desired amount of water. The whole operation needs no human control and is fully automatic. With use of such modernised system maintaining a roof top garden becomes easy and the growth of plants is also unaffected. Mulching of the pots can also be done using black polythene covers in order to minimise the evaporation losses from the pots. A low cost green house or a poly house can also be constructed on the roof of the building. Generally if the crops are grown in a roof top garden the yield increases apprehensively and infestation due to insects are also less. The growth of plants in a green house is also uniform. For common usage a shade net with 20 to 25% penetration can be used. This reduces the direct impact of sun rays on the plant as well as reduces the roof temperature. It also facilitates collection of rainwater on the roof. If the green house arrangement is used the tank should be placed on the roof top itself. It is used to protect the plants from the adverse climatic conditions such as wind, cold, precipitation, excessive irradiation; extreme temperature, insects and diseases.

Water shortage is one of the serious problems in urban areas such as Bangalore. As the rainfall here is also medium and unevenly distributed, roof water harvesting becomes a necessary practice to be followed. The water falling on the roof top must efficiently utilized, this water can be used for efficiently the pots and the roof top garden as well as for domestic purpose such as washing utensils etc. the water from kitchen and Hand wash (containing mainly soap water) also goes waste in majority of households. This can be a source of nutrients for plants. Rain water harvested from the roof top can be sufficient to satisfy the domestic needs as well as irrigation for pots on the roof top garden. Generally lots of inorganic pesticides and fertilizers are used on the plants grown on roof top garden which is not suitable for human health. These chemicals can damage immune system as well as the nervous system of the humans. Organic waste composting, vermi compost, usage of bio fertilisers are a suitable solution to limit their usage.

Usually domestic wastes are not properly utilized they may lead to loss of natural resources, it can be utilized in the form of composting by utilizing the leftover of foods, plants matter waste, pods, leaves etc. Dumping of such waste also creates an unpleasant environment in the

locality and provides a breeding place for flies and mosquitoes. Such domestic wastes can be converted into slurry using shredders and can be used for composting. This adds nutritional value to the soil. Generally, a practice of having a compost pit on the roof is considered a good practice. A drum composting unit is another simple equipment to convert the organic waste into compost. It consists of a rotating drum where waste materials are fed. They are rotated and moisture is added time to time. After 2 months the compost is prepared and can be directly applied to the plants.

### **Conclusion:**

Effective planning of a roof top garden is needed before setting up a roof top garden. The general concepts that must be considered before setting up a roof top garden are as following- Planning is an essential process before setting up a roof top garden, the main planning considerations are about selection of medium for growing plants, selection and arrangement of pots, selection of crops to be grown, irrigation design for the roof top garden, waste utilisation and if needed rain water harvesting system design. A small roof top of a house constructed on a plot of 30 ×40 ft. is more than sufficient for growing the daily requirement of vegetables and flowers, apart from some fruits. It is advisable to grow taller plants towards northern/southern side of the roof top, so that the shade does not fall on other pots. Smaller plants can be located in middle of roof top garden with sufficient space between the rows for movement and watering of plants. A roof top room can also be provided for recreational activities and a place to take rest. The entire roof top is placed with rows of convenient number of pots, by leaving sufficient space for walking between each row of pots, this walking space is utilised for watering and weeding plants whenever necessary. The perennial plants such as lime, banana, fig, sapota and drum stick etc. should be grown in big cement pots or old plastic barrels with drainage hole. These perennial plants should be placed on the northern/southern side of the roof top, so that the shade does not fall on other pots. The wall of roof top will prevent the plants from strong winds and the barbed fencing can serve the dual purpose of support for the creepers as well as protection from monkey attacks. Selection and planning the layout of an irrigation system mainly depend on the schedule and ability of an individual to maintain the roof top garden. As discussed earlier if schedule is hectic automatic irrigation can be practiced. In a quarter portion or half portion a greenhouse

arrangement can be provided so that rain water can be collected efficiently. One should plan a roof top garden if possible well before construction of a house so that excellent results can be obtained. The roof top garden can be a boon for the family environment and holistically speaking a certain blessing to mankind. Since, while designing the roof, we are going to take the consideration of factor of safety (3 to 4 times). Hence there is no need to worry about the weight on the roof. Planning for a roof top garden also includes selection of suitable pots for growing plants in the roof top garden. Generally it is recommended to go for locally available pots and half cut drum to make the entire process cost effective. Planning for water management of the rain water as well as the waste water from hand wash and kitchen should be done before setting up the roof top garden. Estimation of the capacity of the tank for the rain water harvesting system and selection of filters are main steps for planning the rain water harvesting system. One can go for a 20% penetration shade net or a small poly house in a part of roof top. This can facilitate water collection and crops can be grown disease free in them. The waste produced in the domestic household can be used in form of compost to enhance yield of the plant. Before setting up a roof top garden a compost pit should also be planned on the roof. Maintenance of a roof top garden includes proper management of irrigation, removal of dry leaves from the roof top as well ensuring moisture proofing of the roof top. A well maintained roof top garden is a positive sign of a healthy household.

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