Green Roof Design Considerations

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Author's Note: *We are living in an age of developments in plumbing technology in space and Earth. This is the first article for a regular column that will discuss the technologies introduced in the article "Sustainable Plumbing System Technology for Space and Earth" from* Plumbing Systems & Design's *September/October 2004 issue.*

I realize that as a society we are aware that we no longer can rely on the Earth's biosphere alone to clean our waste. We need plumbing technology to help the biosphere along. This is the future of plumbing technology: Building safe plumbing systems for the world while going beyond simply reducing the damage to the environment—respecting, studying, and replicating the biosphere's water- and air-recycling capabilities.

Plumbing technology currently is developing along two different and exciting tracts. One is space exploration. The research on plumbing systems in zero gravity that was conducted in the 1970s and 1980s now is being used in systems operating in the International Space Station. Research now underway includes plumbing systems for future lunar and planetary missions.

The second plumbing technology development tract is for systems here on Earth. Research conducted to purify drinking water and reduce human pollution in lakes and streams now is part of fully operational systems. Currently plumbing engineers are focusing on developing plumbing systems that will not compromise a safe environment for future generations.

The goal of both research tracts is sustainability. The plumbing systems of a facility on Earth or in space will need to use the resources available to be self-sustaining and reduce their impact on both interior and exterior environments.

The first "Plumbing Technology of the Future" columns will cover developments in green building, which makes facilities less invasive on the surrounding environment, reduces energy consumption, and contributes to pleasing interior environments. When applied to a facility's plumbing systems, green building methods reduce or eliminate the harmful effects of the facility's building materials, construction, air, energy, sanitary sewer, storm water, and potable water on the surrounding community and the building's interior.

Topics for future articles include water-reducing plumbing fixtures, storm water harvesting, plumbing Leadership in Energy and Environmental Design (LEED) calculations, LEED and codes, gray water, water filtration, and black water systems. This inaugural column discusses green roofs, their installation and benefits, and how they affect plumbing systems.

Know about any plumbing technology developments in space, Earth, or green construction? Send me an e-mail, and I may use your information in a future column.

Green roofs are one of a facility's most visible sustainable building methods. In addition to its environmental benefits, this unique feature creates a pleasant green focal point.

According to Greenroofs.com, "Basically, green roofs are vegetated roof covers, with growing media and plants taking the place of bare membrane, gravel ballast, shingles, or tiles." In this case the term *green* goes beyond just using sustainable/green building materials or manufacturing methods.

Green roofs offer many advantages when complying with sustainable/green recommendations, such as Leadership in Energy and Environmental Design (LEED), because they mimic the natural environment that existed prior to the facility being built. The roof's green or light color reduces the heat island effect that is a problem in many urban areas. The vegetative growth helps convert carbon dioxide into oxygen and remove pollutants from the air. Green roofs provide greater insulation than tar or membrane and can reduce a facility's energy use. In buildings where the roof is accessible, they also can provide needed places of respite for occupants who may want to stroll or sit among the pleasant, green environment.

Types and Materials

Extensive and intensive are the two main types of green roofs. Green roofs can be used for recreation, gardening, or ecological cover, and a roof's function determines its design. The type of green roof used is limited by the structure's capacity, the roof's slope, and the facility's budget.

Extensive. Installing plants on roofs is not a new technology—it has existed since ancient times, evidenced in the stories of the Hanging Gardens of Babylon—but the development of extensive green roofs *is* new. Extensive green roofs are thin and have few layers. As a result, they are lighter, less expensive, and easier to maintain than intensive green roofs. The depth of the growing media can be as thin as one inch when vegetative mats are used; however, the media is usually 2½ to 6 inches deep.

Extensive green roofs are intended for use as ecological covers to buildings with little access for building occupants. They are not designed for pedestrian traffic; however, designers can add pavers or aggregates for maintenance equipment access. Extensive green roofs use low-growing, horizontally spreading, and root ground covers with a typical maximum plant height of 16 inches to 24 inches. Fully saturated, they can weigh from 10 pounds to 50

Figure 1. Typical Extensive Green Roof Layers

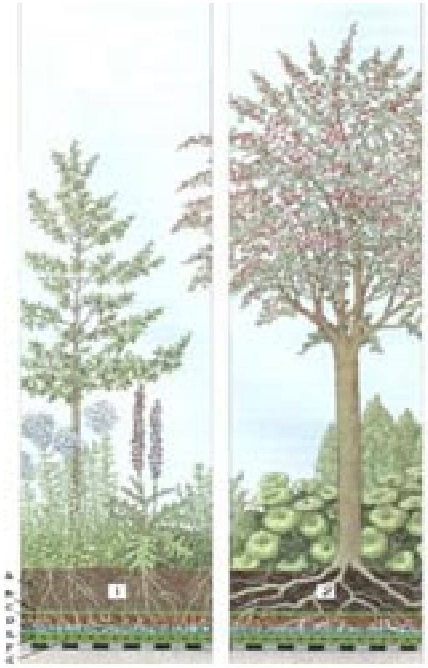
Source: American Hydrotech

Extensive roofs have layers including a waterproofing membrane, root stop, insulation, moisture retention mat, water storage aeration material, filter fabric, growing media, and vegetation.

pounds per square foot (psf), whereas ballasted single-ply roofs normally are between 10 pounds and 15 pounds psf. Extensive green roofs can be installed up to a 45-degree slope. Steeper slopes require raised grids or laths. Because extensive roofs are relatively light, easy to maintain, and inexpensive, they are increasing in popularity across the country.

Intensive. Also called high profile, intensive green roofs can include a

Figure 2. Intensive Green Roofs With Varying Plant Types and Heights



Source: Optigreen Roof Gardening

Intensive green roofs have many layers similar to extensive green roofs. As shown in 1 and 2, roots and growing material amounts can be different.

wide variety of plant material due to their deep media, which is typically between eight inches and 12 inches but can range to more than 15 inches. The roof designer can design these roofs to be pedestrian friendly with architectural accents such as waterfalls, ponds, gazebos, and walkways. A fully saturated intensive green roof will weigh between 80 pounds and 120 pounds psf. These roofs typically are relatively flat, and their maintenance requirements, including irrigation systems, are greater than extensive green roofs.

Fire Protection. When determining the type of vegetation, green roof designers and installers should choose plants that are inherently nonflammable, such as succulents that store water in their stems and can act as a fire barrier. Grasses are not recommended because they can provide fuel for fire in dry conditions. The roof designer should provide a 12-inch to 24-inch perimeter of hardscape with no vegetation at the edges of the roof as a firebreak and for fire-fighting access.

Irrigation and Water Supply Concerns

Extensive green roofs require some type of irrigation, at least until the plants are established. The latest trend is using drought-tolerant plants that are native to the area. For example, one green roof in Nashville uses an endangered native wildflower. The plant is well suited for survival and, at the same time, a local natural resource.

It is a good idea for design engineers to locate a non-freeze hose bibb on the roof to allow for simple irrigation and watering until the plants are established. Extensive green roof irrigation requirements may extend from six months to three years, according to Ralph Velasquez, a green roof consultant and president of Integrated Building Technologies in Murfreesboro, Tenn. However, if drought-tolerant plants are not used, a permanent irrigation system is required. If the building is LEED-registered it can obtain a water efficiency credit for reducing or limiting the amount of potable water used for green roof irrigation. As a result, it is in the building owner's best interest to use draught-tolerant plants that are not dependant on a permanent irrigation system.

Intensive green roofs usually require permanent irrigation systems that are similar to site irrigation systems. These systems usually are designed and installed by an irrigation system provider; thus, it is important to coordinate a green roof's layout with the irrigation system design. *ASPE Data Book Volume 3,* Chapter 4: Irrigation Systems is an excellent resource for these systems' design requirements. As in any plumbing system, water pressure and flow are very important parameters when designing a green roof irrigation system.

Green roof irrigation systems may be fed from a variety of sources. A city's potable water system is a common irrigation water source; however, with sustainable/green concerns in many areas of the country, plumbing engineers are incorporating alternate sources.

Purple Pipe Systems. Municipal water treatment plants now are offering reclaimed water as another choice for irrigation. This is recycled water from treatment plants that has been cleaned to a less rigid standard than potable water. It cannot be used for human consumption, but it works well for irrigation systems. In many cases, due to its lower chlorine content, reclaimed water is better for vegetation than potable water. The water commonly is distributed in high-density polyethelene pipe, which is purple in color, hence the term "purple pipe."

Before designing a purple pipe system, consult with local water companies and code officials concerning the system's projected flow and pressure demands. Some authorities having jurisdiction don't allow these systems to be installed inside a facility. However, most sustainable/green guidelines recommend using purple pipe systems for green roof irrigation.

Storm Water Irrigation. Another popular trend—and a good way to get a LEED water efficiency credit—is using collected storm water for irrigation. Also called storm water harvesting, this system uses cistern technology, whereby storm water is collected on site and used in the irrigation system.

Utilizing storm water systems for green roof irrigation offers two advantages. First, it reduces the amount of storm water runoff from a building into a municipal storm water system. Many urban areas have combined storm and sewer systems that potentially can pollute streams and lakes during heavy rains. Second, it reduces the amount of potable water used, which reduces a facility's operating costs.

Many creative methods are available to store storm water, including locating aboveground tanks next to gutters and downspouts. In some systems, solar-powered pumps are used to pump the water up to the green roof irrigation system. Access into the vessel for cleaning is necessary if storm water will be stored for extended periods of time. Water monitoring and treatment also may be required. (For more information on rainwater catchment systems, see this issue's cover story, "Harvesting the Rain" on page 42.)

Drip Irrigation. A new technology for green roof irrigation is drip-type systems, which comprise pipes with drip outlets to release small amounts of water near the plants' roots, thus reducing the amount of water lost to evaporation.

Drainage Design Considerations

Many extensive green roofs use the same type of roof drains as a built-up ballast-type roofs. The plant material is not installed around the roof drains, thus little soil or growing material flows into the drains. As with any other roof system, overflow- or secondary-piped systems are required.

Intensive green roofs could require planter-type drains that are installed under the roof's components. These drains have protective screens to minimize the amount of soil or plant material that enters the drain. You will need to coordinate with the green roof designer to determine the location and type of drains required.

For roofs that have walkway pavers installed, a promenade-type roof drain is required. It collects water on the pavers and has a perforated collar to collect water from the roof insulation layer.

AHJs usually don't allow roof drain system size reduction when a green roof is installed. You should coordinate all system concepts with local municipality and code officials who, when storage tanks are used, may require the overflow from a storage tank system to connect to the building's storm water system. You also need to determine the irrigation system's required flow and pressure. In addition, you must separate the irrigation system from the domestic water system with backflow preventers or an air gap.

Green roofs often are located at a domestic water distribution system's most hydraulically remote location. Irrigation systems can require up to 90-pounds-per-square-inch residual pressure, which is too high for domestic water systems. Installing an irrigation booster pump at the end of the system's longest run of pipe, far from the domestic water entrance, can cause pressure and flow problems in the domestic water system. To reduce this risk, you may want to install a separate irrigation supply line from the building's water service entrance to the green roof irrigation system with a dedicated booster pump.

LEED Green Roof Plumbing Calculations

The LEED Green Building Rating System is a proprietary program of the U.S. Green Building Council. It is a voluntary rating system with five different levels of certification. A total of 69 possible points can be earned for applying sustainable building practices. Sustainable plumbing systems can help a facility obtain several points for certification. For more information on the Green Building Council and the LEED program, visit www.usgbc.org.

All commercial buildings as defined by standard building codes are eligible for certification. Project teams interested in obtaining certification must register with the USGBC. Once a project is registered, the design team can collect information and perform calculations to satisfy the prerequisite and credit submittal requirements.

You can obtain a Stormwater Management credit toward LEED certification by using a green roof. The intent of this credit is to "Limit disruption of natural water flows by minimizing storm water runoff, increasing on-site infiltration, and reducing contaminants," according to *LEED Rating System Version 2.0*. You can obtain one point if the green roof results in no net increase in storm water runoff rate and quantity. If existing imperviousness is greater than 50 percent, implementing a storm water management plan that results in a 25 percent decrease in storm water runoff rate and quantity is another way to earn the one-point credit, according to the guide.

This credit uses the Environmental Protection Agency's *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, No. 840B92002 (www.epa.gov/OWOW/NPS/MMGI/index.html).

The calculation required to obtain this credit involves identifying the different surface types on the site and calculating the total area for each of these surfaces.

For example, a project site has an existing baseline of paved parking with a runoff coefficient of 0.95. If the new building has a less-than-four-inch-thick extensive green roof, the runoff coefficient is rated 0.50. LEED credit requirements state that imperviousness must be reduced by 25 percent over the baseline case, which equals an imperviousness of 71 percent or less. Thus, this design earns a one-point credit.

The calculation tables are included in the LEED registration material. Refer to the LEED material for exact information.

Green Roof Benefits

The construction, facility management, and municipal management industries are encouraging the use of green roofs because they help solve some persistent problems that have plagued the construction industry for decades, such as combined storm and sanitary sewer flooding.

The City of Chicago is an example of a major metropolitan area that is requiring green roofs on buildings receiving public money to combat sewer flooding. The city has outlined nine benefits: Green roofs are aesthetically pleasing, reduce the heat island effect, reduce the carbon dioxide effect, reduce air pollution, reduce heating and cooling loads, extend roof life, reduce sound reflectance and transmission, reduce rainfall runoff, and help remove nitrogen pollution in storm water runoff.[1]

Green roofs are a relatively new technology in the United States. However, as more localities require green roofs and as new technology develops, the number of green roofs is certain to increase. Major standards organizations, such as the American Society for Testing and Materials, are developing standards for green roofs. After these standards are complete, the green roof industry should grow at an even faster rate.

Although most roof manufacturers don't offer warranties on the plant material, they do guarantee their roofs from leaking into interior spaces. Some manufacturers are starting to guarantee the plant material under a separate con-

...continued on page ***33***

Photo: Alan Mars

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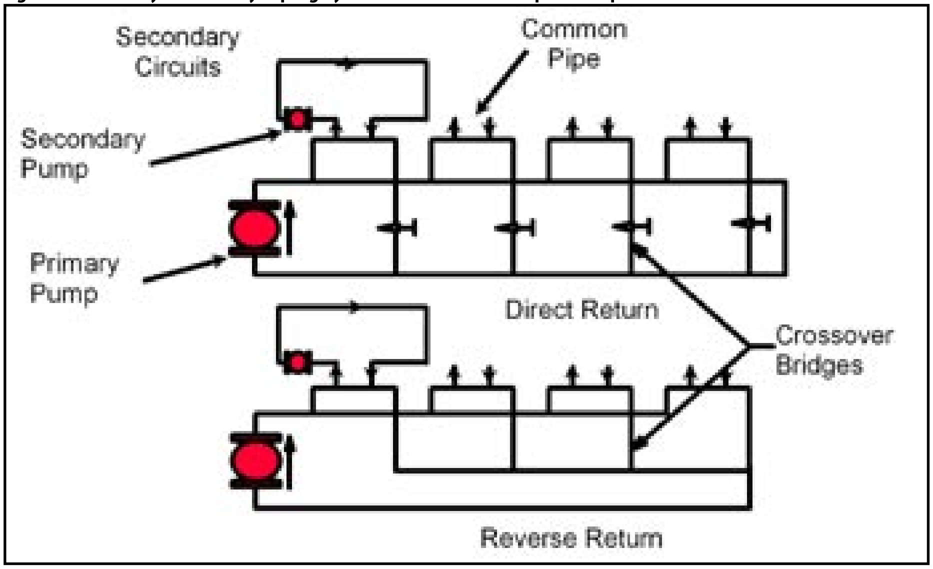
Figure 3. Primary-Secondary Piping System Based on Two-Pipe Principles



Source: Primary-Secondary Pumping Application Manual

perature. At point B, the secondary return mixing with the flow across the common pipe means that the primary return temperature will not be the same as the secondary return.

- **Primary flow is less than secondary flow.** In this case, flow in the common pipe is reversed, mixing at A and diverting at B. Now the secondary return and primary return temperatures are the same, but the supply temperatures are not the same.

A primary-secondary system with many terminals could be designed using either one-pipe or two-pipe principles. Let's first consider a primary-secondary system designed using the one-pipe scheme (**Figure 2**).

The primary loop and its pump provide flow through the boiler or chiller and through the main that connects to each terminal. At each terminal, the closely spaced tees provide a low pressure drop common pipe connection. A secondary pump governs flow in each terminal. The simplest control scheme turns on the secondary pump when flow is required and turns it off to allow the flow to bypass the secondary circuit if flow is not required in the terminal. Many other methods for controlling the secondary supply temperature exist.[1]

Many of the previously discussed advantages and drawbacks in more elementary one-pipe systems apply here as well, such as simplicity in laying out the primary piping and terminals seeing different supply temperatures.

Designers who are aware of these limitations have successfully used one-pipe primary-secondary systems for years.

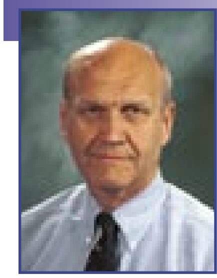
In similar fashion, a primary-secondary piping system can be designed on two-pipe principles (**Figure 3**). In such a system, each secondary circuit sees the same primary supply temperature because of the "crossover bridge" that connects the primary supply to the primary return. These bridges provide a place for installing the tees that define the common pipe connection between the primary and secondary circuits. The bridges can be installed using direct return or reverse return. Once again, the earlier analysis of simpler two-pipe systems can be applied here with similar conclusions.

Figure 3 does not show details in the secondary circuits, but each terminal in the secondary circuit could be controlled by a two-way valve or a three-way valve and bypass. Balancing valves in the crossover bridges of a reverse-return system may not be required if the same primary flow and head loss is required in each case. The reverse-return arrangement makes each circuit equally far from the primary pump, thus equalizing the piping head loss.

Since its invention, primary-secondary pumping has become a common solution to many hydronics problems. Large chiller plants, small radiant panel systems, and multiple boiler systems often use the principles of primary-secondary pumping to provide economy and control. ■

References

1. *Primary-Secondary Pumping Application Manual,* ITT Fluid Handling Division Bulletin Number TEH 775. 1968.



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tract, a trend that also should increase the installation of green roofs.

Installing a green roof is one way a facility owner, manager, designer, and contractor can help the facility meet sustainable/green requirements. Green roofs achieve these goals by replicating the biosphere's methods of sustainability. ■

References

1. "Extensive Green Roofs: What Are the Benefits of Green Roofs?" City of Chicago Department of Planning and Development.

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