

## **Safe Design Best Practices: A Summary of Singapore’s Rooftop Greenery Guidelines**

Michael Behm  
*East Carolina University, Greenville, NC, USA  
behmm@ecu.edu*

Tan Puay Yok  
*National Parks Board, Centre for Urban Greenery and Ecology, Singapore  
tan\_puay\_yok@nparks.gov.sg*

Poh Choon Hock  
*National Parks Board, Centre for Urban Greenery and Ecology, Singapore  
poh\_choon\_hock@nparks.gov.sg*

Angelia Sia  
*National Parks Board, Centre for Urban Greenery and Ecology, Singapore  
angelia\_sia@nparks.gov.sg*

### **Abstract**

As research and practice within the built environment advances, safe design is being recognized as a best practice within a holistic approach to facilitating and influencing site safety. Isolating building elements to target site safety risk within the built environment and tracing them back to design decisions has been effectively utilized as a means to identify safe design suggestions that can then be implemented in future designs. As urban greenery increases globally, standards must be effectively developed to ensure the efficacy of the industry, and safety is no exception. Singapore’s Guidelines on Design for Safety on Rooftop Greenery provides the only recommended guidelines specific to green roof safety with a focus on safe design of the built environment. This proceeding paper reports on 1) the background of green roof safety with a focus on the design of the built environment, 2) details of the aforementioned Singapore guidelines, and 3) the research design and potential outcomes of an upcoming fellowship by the first author to study the implementation of Singapore’s safe design guidelines for rooftop greenery.

### **Keywords**

Safe design; green roof; Singapore; green roof standards

### **1. Introduction**

Singapore is one of the world leaders in green roof installation. Green roofs are recognized by urban planners as an advantageous technique for reducing the negative impact of exterior heat and the resulting carbon footprint of cooling and as a way of mitigating runoff during periods of heavy precipitation. To boost the level of “skyrise” greenery and enhance the city’s image in high activity corridors, Singapore National Parks (NParks) is encouraging building owners to green their rooftops (NParks, 2009). Under the Green Roof Incentive Scheme, NParks funds up to 50 per cent of the cost of installing green roofs on buildings in the Downtown Core and other strategic areas (NParks, 2009). While evaluating resident

perceptions of rooftop gardens, Yuen and Hien (2005) found that Singaporeans would like to see more rooftop gardens and they recognize individual and neighborhood benefits. The use of green roof design techniques can present potential unintended hazards to individuals involved in installation, maintenance, use and to the general public in the area during installation, maintenance and inclement weather.

In Singapore, under the Workplace Safety and Health Act, similar to safe design legislation in Europe and Australia, the person who creates the risk is responsible for mitigation. In specifying the design of a building or structure, the designer should understand how the building or structure can be constructed, cleaned, maintained, and decommissioned or demolished safely. Therefore, the designer of the built environment must study and evaluate the risks to those carrying out the proposed works and others affected by it, such as the public or people using the building or structure in the future.

The Centre for Urban Greenery and Ecology (CUGE) was established by NParks as a regional centre of excellence to advance urban and green living environment, and a one-stop training and knowledge hub in urban greenery and ecology (NParks, 2009). The CUGE Guidelines on Design for Safety on Rooftop Greenery (CS E02:2010) provides the only recommended guidelines specific to green roof safety with a focus on safe design of the built environment. This research reports on 1) the background of green roof safety with a focus on the design of the built environment, 2) CUGE's guidelines, and 3) the research design and potential outcomes of an upcoming fellowship with CUGE by the first author to study the implementation of the safe design guidelines for rooftop greenery.

## **2. Literature Review**

In the archival literature, the concept of safe design for construction and maintenance workers in the built environment can be traced largely to Lorent (1987), who reported that about two-thirds of accidents could be traced to upstream decisions including the design. Shortly thereafter, Lorent was the lead contributor to a European Foundation for the Improvement of Living and Working Conditions (1991) document "From Drawing Board to Building Site" which highlighted the need for better planning, management, and design of the built environment to positively affect a range of business conditions within the construction industry, including worker safety. This document is frequently cited in the archival literature and was one impetus for the Temporary and Mobile Construction Sites Directive of 1992 which, in Europe, placed legislative duties on designers (Anderson, 2000). In Europe, the United Kingdom is regulating safe design through the Construction Design and Management (CDM) regulations; these are arguably the most frequently cited regulations on safe design in the peer-reviewed literature.

The safety of any operation is determined long before the people, procedures, and equipment come together at the work site (Stephenson, 1991). Too often safety professionals seek to implement behavior based safety programs too quickly. With regards to safe operations, Reason (2000) writes that efforts should not focus on changing the human condition, but rather we should seek to influence the conditions under which humans work. Safe design of the building's permanent features is an influence on the ultimate safety on site. Safe design is about arranging conditions for workers to be successful (safe) and utilize the proper tools, training, procedures, and known safe behaviors.

In the United States, regulations such as those in the United Kingdom, Australia, and Singapore, are not likely in the short term. However, researchers and governmental organizations are seeking ways to implement Prevention through Design. Consider the United States' National Institute of Occupational Safety and Health's (NIOSH) definition, where the concept of safe design (or Prevention through Design (PtD) can be defined as:

*Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment.*

NIOSH is also evaluating the relationship between worker safety and the green building movement. As part of its National Occupational Research Agenda within the construction sector, a Green Jobs Coordinating committee has been convened. Its purpose is to explore and evaluate the practicality of integrating worker safety and health into the United States Green Building Council's (USGBC) pilot and innovative design credit system for green building design. Because green buildings and specific green elements, such as green roofs, are becoming more popular, one concern is that worker safety will be viewed with an add-on piecemeal type approach. For example, at the Las Vegas Mirage City Center, a USGBC Gold certified building, six construction workers died in an 18-month period (CPWR, 2008). Ivanovich (2008), a news papers reporter, posed the question "how many construction site deaths should there be to make a building 'not green' regardless of the environmental benefits?" Green construction and sustainable construction are not synonymous. Sustainability includes broader considerations, including worker safety and health. Environmental gains cannot be offset by continued poor safety performance. This is particularly profound in the U.S construction industry where in the past few years, the industry employed around 7% of the nation's workforce yet accounts for approximately 20% of the nation's occupational fatalities (BLS, 2010). Behm et al (2009) made the case for the integration of worker safety with the green building movement by rationalizing that for green buildings to be considered sustainable, construction safety and health concepts must be integrated into upstream considerations.

### **3. CUGE Standard CS E02:2010, Guidelines on Design for Safety on Rooftop Greenery**

International green roof guidelines were reviewed for safety design provisions. Germany's FLL guidelines mention safety but not specific to building design. The CUGE standard sets out requirements for worker safety by addressing performance in the design, installation, and maintenance phases (CUGE, 2010). They are unique in that they are the only specific guidelines in the world detailing safe design of the built environment specific for green roofs. While this paper will focus on design phase considerations, installation and maintenance considerations discussed in the CUGE guidelines are also mentioned.

#### **3.1 Safe Design**

The guidelines set out provisions that design professionals should consider when planning rooftop greenery within the built environment and applies to new buildings and retrofitted roofs.

The building's load bearing capacity must be established by a structural engineer and must not be exceeded during installation, maintenance, and decommissioning. Other international guidelines also highlight the structural load calculation as a key safety requirement. Germany's FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau) also discusses the need for structural determination to determine vegetation types. The American Society for Testing and Materials (ASTM) develops and publishes numerous green roof standards including one for determining the dead load of green roof systems. The standard includes a spreadsheet and considers the dry and wet weight of the vegetation and supporting materials. In February 2011, a green roof in Chicago in the United States collapsed (Knapschaefer, 2011). Cost can be an issue for a building owner. In Singapore, Wong et al (2003) estimated the structural cost of a roof deck with a roof garden is approximately 50% more than that of a roof deck without a roof garden.

Poorly maintained vegetation can pose a fire hazard. In 2010, the American National Standards Institute (ANSI), Single Ply Roofing Industry (SPRI), and Green Roofs for Healthy Cities, jointly published the standard, External Fire Design Standard for Vegetative Roofs. Recognizing the importance of this issue, the National Association of Fire Marshalls has created an entire website devoted to fire safety and green buildings. The website includes a section specific to vegetated roofs. See <http://greenbuildingfiresafety.org/index.html>. The CUGE Standard recognizes fire risks and mentions references to the Fire Safety Act and that fire risks should be minimized.

Working at height increases the risk of serious injury to workers from falling. The CUGE guidelines recommend that working at height be minimized, and that features that reduce the risk of falling be introduced in the building design. Strong wind is also recognized as a condition which will exacerbate the risk to workers. During construction, proper staging of the roofing materials and consideration of temporary wind breaks must be considered. Additionally, a warning regarding the use of aerial platforms in windy conditions is provided (CUGE, 2010).

Safe worker access and exit is necessary to install and maintain the green roof and its components. In general, there are two types of green roofs. Roof gardens, or intensive roofs, are built for access by the general public and therefore worker access is usually already built in. However, safe access for any equipment must be considered. Extensive roofs are not designed for public use and therefore access for workers and any equipment might not be addressed in the design phase. The CUGE guidelines address this potential access issue. Additionally, extensive roofs might be installed on a sloped surface up to 30 degrees. This poses unique access hazards, exacerbates falling potential, and necessitates that safety measures be taken to avoid soil erosion. These stipulations are mentioned in the built environment considerations (CUGE, 2010).

Service facilities such as washing areas, storage for equipment, and space for handling maintenance materials are necessary for effective installation and maintenance of rooftop greenery. A rooftop can be a harsh environmental and exposure to heat and chemicals may require clean water on the roof. Mechanical and electrical systems are sometimes placed on the roof. The relationship and design of the rooftop greenery in relationship to these systems may present hazards that could be avoided or significantly reduced by proper design (CUGE, 2010).

Health considerations such as the reduction of hazardous chemicals, excessive noise, and mosquito control are also design considerations. The reduction of hazardous chemicals is related to the types of plants specified and also to the maintenance guidelines which are developed in the design phase. Singapore has specific mosquito control guidelines and requirements put forth by the National Environment Agency. The safe design of rooftop greenery should avoid conditions that contribute to mosquito breeding (CUGE, 2010).

There is the belief that vegetated roofs utilizing native plants require such little maintenance that safety and health issues are insignificant. No vegetated roof is “maintenance free” (Luckett, 2010). Native species are not necessarily more successful on green roofs than non-native species (Getter et al, 2009). However, while plants could not actually be native to rooftops, many plant species have evolved in extreme environments and are adapted to green roof conditions (Getter et al, 2009). Plant selection can influence frequency of roof access and thus overall risk after installation. The CUGE guidelines recognize the relationship between plant selection and resultant worker safety risk. Recommendations include selecting plants that require less frequent maintenance, hardy plants that are drought tolerant and disease resistant, and in areas of strong wind, plants that are wind tolerant. The plants should complement the building and the ease of access to the plants should be considered in their design.

The CUGE guidelines note that rooftop trees are exposed to greater winds forces. This creates the potential for broken branches and thus it is not advisable to plant trees near the building’s edges. Furthermore, adequate space is needed to maintain trees and thus planting too close to the edge is also a falling hazard. The trees must be adequately anchored and this may increase maintenance and inspection frequencies. Tree stability for rooftop greenery is an emerging science. Rahardjo et al (2009) discuss implications on tree stability and wind loading effects for rooftop trees referencing an unpublished final year project from Nanyang Technological University in Singapore. Within the building considerations section, trees are also mentioned and should they be the tallest point on the building, provisions must be made to protect them from being struck by lightning.

Works scheduling considerations are included and recognized as affecting worker safety. CUGE recognizes that fall protection provisions might be an afterthought and therefore has included reminders in this section about fall protection. Fall protection is mentioned frequently in the document; its importance cannot be underestimated. Designing to simplify the construction process is recognized. Jergeas and Van der Put (2001) highlighted that constructability and safety are co-related. Specific recommendations include the design of joints for correct assembly, staging of materials, and the placement of vegetation.

### **3.1 Safety considerations during installation and maintenance**

If properly followed, the guidelines on safe design of rooftop greenery arrange conditions for installation and maintenance workers to be successful and safe. However, it is still the responsibility of these organizations to safely manage their projects and to supervise and train their workers to work safely. Integrated relationships between designer and construction/maintenance firms has shown to be beneficial for worker safety performance (Atkinson and Westall, 2010). The CUGE guidelines advise appointing a Project Safety and Health Coordinator, whose role is to coordinate between the client, designer, and constructor to communicate safety and health risks of the project. Guidance for work site management includes the following: risk assessment to be conducted; proper briefings for work starts; adequate supervision; redirecting traffic; mean of communication; proper execution of site work procedures; proper use of maintenance equipment; adequately qualified workers; promoting a culture of safety on the worksite; proper use and provision of equipment; protection from falling; prevention of equipment falling from height; and appropriate notification during maintenance. Additionally, the methods utilized for the transportation of landscape materials to the rooftop may present unacceptable risks. Considerations for falling hazards (of people, materials and equipment), safe mechanisms of transporting materials, and considering the calculated load bearing weight of the structure must be considered during installation and maintenance (CUGE, 2010).

## **4. Discussion**

The Guidelines on Design for Safety for Rooftop Greenery, CS E02:2010, prescribes safety requirements for the design, installation, and maintenance of rooftop greenery. By isolating specific building elements, such as rooftop greenery, targeting their site safety risk within the built environment and tracing them back to design decisions, has proven to be effective as a means to identify safe design suggestions that can then be implemented in future designs. The design risk assessment process is a method to utilize these suggestions as outlined within the CUGE standards, but also to identify unique project specific risks. Building owners, designers, roofers, landscapers can and should utilize this guideline during their respective green roof work in order to enhance site safety.

Behm (2011) visited nineteen green roofs in the United States to observe safety issues associated with the building design. Fall protection issues were observed on 11 of the 19 roofs visited. Six of the roofs had poor access; two of these roofs are not maintained any more due to unsafe access, and another is maintained sporadically and not as frequently as the building occupants would like. CS E02:2010 highlights these rooftop greenery risks but goes beyond falls and access issues in a more comprehensive manner. The growing interest in the use of green roofs means that their design and maintenance have to be investigated more thoroughly in order to determine the sustainability of such systems (Emilsson et al, 2007), and to develop standards and guidelines (Dvorak and Volder, 2010). Worker safety, a key component of the social dimension of sustainability, cannot be an afterthought in the development of standards and best practices. Green roof organizations, building owners, and designers seeking to incorporate safety into the design of the green roofs should look to the CUGE guidelines for design standards and best practices.

## 5. Future Research

The first author of this proceeding will be undertaking a research fellowship with the CUGE May through August of 2011. At the time of the conference, the author will report on activities to date. The objective of the proposed research fellowship is to assess the implementation of CS E02:2010 Guidelines on Design for Safety for Rooftop Greenery and its effects on the work of design professionals and on the safety of workers. Specifically, the proposed research will:

- a) Evaluate design professionals' (architects, landscape architects, arborists, etc.) perceptions of the feasibility and utilization of the design suggestions within CS E02:2010 and the effects on their rooftop greenery designs (cost, quality, aesthetics, and ease of design implementation).
- b) Evaluate perceived and actual hazards to individuals involved in installation and maintenance associated with green roofs and walls and to the public in adjacent areas.
- c) Identify hazards associated with the installation and maintenance of vertical greenery systems.

Design professionals will be interviewed to determine the feasibility and utilization of the design recommendations within CS E02:2010 and the effects on their rooftop greenery designs (cost, quality, aesthetics, and ease of design implementation). An interview format that allows for the collection of both qualitative and quantitative data will be developed. A review of the questionnaire by CUGE researchers will ensure the interviews will be comprehensive and collect appropriate data to assess CS E02:2010. Vertical greenery systems will also be included in the assessment; green walls are not specifically included within CE E02:2010, but can present similar hazards. Wong et al (2010) found that there is a lack of technical information, maintenance instructions, and information on plants suitable for vertical greenery systems in Singapore.

The researcher will also accompany roofers, landscapers, and other workers who install and maintain rooftop and vertical greenery to assess the CS E02:2010 guidelines. This assessment will determine hazards and risks associated with rooftop and vertical greenery and how they are managed in practice. A checklist will be developed that represents major design components with the CS E 02:2010, such as fall protection, roof access, tree stability, planting considerations, and understanding the nature of the work during installation and maintenance. Design suggestions and safe work practices for green walls will also be developed.

The projected outcomes of the research will provide CUGE and rooftop greenery professionals in Singapore with:

1. Assessment data that measures how CS E02:2010 is being utilized and its effect on both worker safety and on rooftop greenery design practice.
2. Training program development for design professionals to help them carry out their work related to CS E02:2010.
3. An assessment of hazards associated with the installation and maintenance of green walls.
4. A descriptive listing of proposed safe design solutions and work practices associated with green walls.

The outcomes of this research will also benefit international green roof organizations to include safe design provisions in future guidelines. The United States has a dismal construction safety record when compared to the other countries who have implemented safe design. Safe design is not a panacea but it certainly represents the life cycle type of forward thinking necessary to take a holistic approach to safety management within the built environment. Therefore, there is much to learn about incorporating safe design thinking, and doing so absent the likelihood of regulations in the near future. By learning from and partnering with organizations who have implemented and embraced best practices, such as the CUGE, the built environment in the 21<sup>st</sup> century can become safer, greener, and more sustainable.

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