Integration of Safety Aspects in the Maintenance Work of a Living Wall: An Overview of Practice and Challenges

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ABSTRACT

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Building maintenance is crucial to prolong a building's lifespan. Conducting the maintenance work can be dangerous, especially if it involves high-rise areas such as walls and roofs. Most literature discusses safety aspects at the construction site, while the safety aspects of maintenance work, which occur after occupancy, received less attention. This paper discusses the potential of integrating safety aspects into the maintenance work of a living wall. Living wall system (LWS) is one of the green design aspects in which the wall is designed to allow for vegetation growth. Maintenance works of a living wall involve various risks especially working in high or difficult places. This paper reviews the maintenance process and techniques adapted for maintaining the living wall through literature. This paper presents the safety practices that have the potential to reduce the risks of conducting maintenance work on the living wall and its potential challenges. It is hoped that this paper raises further awareness that work safety in construction is not only enclosed within the construction site and its vicinity, but safety should also be considered post-occupation, especially when the design demands specific maintenance requirements such as a living wall.

Keywords: *Safety, building maintenance, living wall, maintenance risk, green wall*

Abbreviations: *Living Wall System (LWS)*

INTRODUCTION

Population growth and economic development lead to rapid urbanization in many countries in the world. Although urbanization brings different social and economic advantages, it reduces urban green spaces to accommodate more buildings. The amount of urban green space area in Kuala Lumpur, for example, has a decline of 59.4% in 2012 (a reduction from 24,222 hectares to 14,386 hectares) (Yusof, 2012). Reduction of the city's greenery spaces brings various environmental issues, including increased urban heat island and air pollution (Saharuddin et al., 2019).

It has become a trend to incorporate green design concept into new buildings or retrofit existing buildings in the city area to promote sustainability (Zahir et al., 2014). Vertical greening has gained greater interest in reducing urban heat issues. Placement of growth substrate differentiated green facades with living wall. (Gunawardena and Steemers, 2020). Recent interest in living walls is due to their aesthetic appeal and potential for greater usage in high-rise buildings (Gunawardena and Steemers, 2019). Vertical living walls incorporate vegetation to the walls to replace the greenery that has been removed on the ground. A vertical living wall can also refer as 'green wall', 'vertical gardens', or 'vegetated walls'. It is a system that allows the vegetation to grow on vertical surfaces, such as walls or wall partition, through various mechanisms (Manso and Castro-Gomes, 2015, Susorova, 2015). Vertical living walls benefit the building and surrounding area. It helps conserve energy, reduce urban heat island effects, aesthetically pleasing, enhances outdoor and indoor comfort, and increases the building value (Chroenkit et al., 2019; Pérez-Urrestarazu et al., 2015).

Living wall system (LWS) is one of the types of vertical greening. LWS is a system that uses panels consisting of growing media, support structure, a specialised drainage system that is fixed on the building envelope or frame to promote healthy growth of vegetation (Perini et al., 2013). These components of living walls need to be properly maintained to ensure vegetation survival and growth at the building envelope (Köhler, 2008). Thus, it makes sense that current research on living walls focuses more on the vegetation care and microclimate of the vegetation (Gunawardena and Steemers, 2020; Susorova, I. (2015) and the effect of living walls on the building (Tudiwer and Korjenic, 2017; He et al., 2017). However, the maintenance work of the living wall is also complicated because of the various components to keep the vegetation alive and healthy. Apart from the irrigation system, support structure, and vegetation, the maintenance team also needs to cater for issues regarding water retention, soil substrate, safety, root, pest and disease control, debris removal, pruning, and weed control (Saharuddin et al., 2019). Improper maintenance can affect living wall functionality.

Maintaining living wall also indicate work at high places. As vegetation inspection needs workers' attention, workers would have to be at the same level as where the vegetation is placed. Thus, the safety of the workers is more crucial when maintaining a living wall than working on the ground. Managing safety is basically controlling risks and conditions that can cause harm to the individuals and community either physically, mentally, and emotionally (Maurice et al., 1997). Conducting the maintenance work can be dangerous, especially if it involves high-rise areas such as walls and roofs. Chi et al. (2005) stated falling from height from scaffolding, building girders or other steel structures, ladders and stairs or falling from existing floor opening dues to unguarded openings, inappropriate protections or removal of protection are the main cause of fatalities in the construction industry. Slips, trips, and falls (STFs), struck by objects, and electrocution can also bring hazards to the maintenance work (Growing Green Guide, 2014). Thus, safety practices for maintenance work are essential to ensure the well-being of the maintenance personnel. However, most literature discusses safety aspects at the construction site, while the safety aspects of maintenance work, which occur after occupancy, received less attention (Cheah, 2007).

This conceptual paper discusses how safety aspects can be practiced in the maintenance work of a living wall. This paper delves into the concept of a living wall, the process, and the technique of building maintenance before elaborating on the safety practices in the living wall and its potential challenges.

LITERATURE REVIEW

Living Wall System (LWS)

A green wall is one of the types of green building technology, which aims to insulate the building envelope to improve indoor thermal comfort and contribute to energy efficiency (Ragheb et al., 2016). It is a self-sufficient vertical garden mounted to the building's internal or external walls (Weinmaster, 2009). Manso & Castro-Gomes (2015) classify green walls into green façade and LWS. A green façade is a structure that allows vegetation to grow upward from a base structure or allow vegetation to hang and grow downward from intermediate planters (Manso & Castro-Gomes, 2015). LWS adopted the concept of hydroponic culture in which panels consisting of soil or other growing media are fixed to the building surface or frame (Susorova, 2015; Perini et al., 2013). A proper irrigation system ensures balanced nutrient flows to the vegetation for survival (Perini & Rosasco, 2013). Continuous and modular LWS are the two common types of LWS. While modular LWS utilises standard-sized boxes to promote vegetation, continuous LWS uses the permeable screen as pockets to insert vegetation (Manso & Castro-Gomes, 2015; Weinmaster, 2009). Figure 1 illustrates the common structure of a living wall.

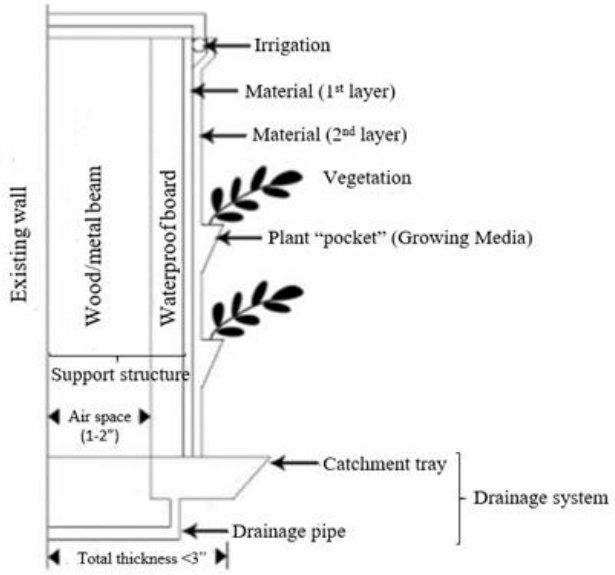

Figure 1: Structure of living wall (Weinmaster, 2009)

An LWS support structure frame installed to support the vegetation can be made of aluminium, galvanized steel, other non-rusting metal, or timber (Weinmaster, 2009). The substrate, which acts as the growing medium, keeps water and nutrient needed for the vegetation. The substrate is made of either organic and/or inorganic material and usually lighter than normal soil (Manso & Castro-Gomes, 2015). An LWS can utilize an extremely large diversity of vegetation on one wall (Loh, 2008). A drainage pipe functions to avoid excess water overflow from irrigation systems or rainwater (Manso & Castro-Gomes, 2015).

In a nutshell, LWS has a more complex structure and requires delicate attention during the maintenance process due to vegetation and irrigation requirements. The maintenance techniques applied for maintaining a living wall shall depend on various factors such as the height of the wall, type of vegetation, and irrigation system. Weather and insect attacks might also be problematic for living walls. As maintenance of walls is naturally involved working at high places, the risk of workers falling or being struck by fallen objects needs to be considered when conducting maintenance work.

The Process and Techniques of Building Maintenance

Building operation and maintenance involve maintaining, repairing, or improving any part of the building components or structure, building services, and compound to ensure the building or parts of the building components function as intended (Adeyemi et al., 2014). Maintenance of the in-use building is important for preserving and extending its life and also promotes the occupant's health, safety, and satisfaction (Kwon et al., 2011). Usually, maintenance work is carried out by a group of workers under the supervision of a building or facility manager. Building maintenance operations can be conducted by an in-house team or outsourced to external parties. The maintenance team must plan, organize and track all maintenance tasks to perform properly. There are five stages of the building maintenance process, i.e., 1) identify work; 2) plan work; 3) schedule work; 4) execute work; and 5) complete work (Wordsworth and Lee, 2001).

'Identify work', which is the first stage in the building maintenance process, shall analyse the building's condition, forecasting future needs, set targets, and identify potential risks. This stage is about setting targets and objectives, including budget allocation, time frame, specific requirements, and life expectancy of the components, product, or elements that are being maintained (Patanapiradej, 2006). This stage identifies and controls risks associated with the maintenance tasks through an effective record of the tasks, risks, resources, and other relevant information on the works (Palmer, 2019).

‘Plan work’ includes all the functions related to preparing work orders, bills of materials, purchase requisitions, labour planning sheets, work standards, and all the data required before scheduling and releasing work orders. This stage where work plan for the building maintenance is formulated to comprise of job content and the resources, such as staff size, parts, and material, special tools and equipment, safety procedure, the time needed, and expenses must be identified and planned accordingly (Palmer, 2019; Jin et al., 2016). At the 'schedule work' stage, the maintenance team shall prepare a detailed maintenance schedule. This schedule shall include time to perform the task, the maintenance personnel, and the appointed supervisor (Palmer, 2019; Olanrewaju & Abdul-Aziz, 2015). In terms of the maintenance process, the 'plan work' and 'schedule work' stages serve different functions, where the 'plan work' stage determines the resources required in that maintenance task and the method to procure it. In contrast 'schedule work' stage decides how the resources are scheduled to fulfill the targets and objectives established.

'Execute work' is the fourth stage in the building maintenance process. At this stage, the work will be executed as per schedule using the allocated resources without compromising the organization’s objectives (Olanrewaju & Abdul-Aziz, 2015). The building’s maintenance performance must be monitored, corrections for any situation need to be performed, and risk must be controlled. The final stage is 'complete work'. This stage is reporting stage in which the work done must be reported, including feedbacks and further suggestions for further improvement, where necessary (Wordsworth and Lee, 2001).

The building maintenance techniques can be classified as ‘planned’ and ‘unplanned’ maintenance (Mydin, 2015). The five stages of building maintenance apply to both maintenance techniques. ‘Unplanned maintenance’ occurs when the tasks are performed without a scheduled plan to carry out after certain damage or failure (Basri et al., 2016). This type of maintenance is more expensive than ‘planned maintenance’ because the tasks are basically to correct and repair an emergency immediately, requiring ad hoc assets and resources (Olanrewaju & Abdul-Aziz, 2015). These repairs usually require prompt intervention and rectification.

‘Planned maintenance’ is performed based on a schedule as preventive or corrective measures. ‘Corrective maintenance’ is performed to repair or replace components that fail to perform their expected function (Mydin, 2015). The parts that require repair work or replacement can be inconvenient to both the occupants and maintenance organisation because they can cause damage to the component and directly or indirectly affect other components.

‘Preventive maintenance’ has two categories: condition-based and pre-determined maintenance. Condition-based maintenance is performed when there is significant deterioration to the component (Mydin, 2015). In this type of maintenance, the condition of the said component is tracked and assessed to determine any evidence of the deteriorated condition. The evaluation process can range from visual to detailed inspections using certain tests or tools (Horner et al., 2012). ‘Pre-determined maintenance’ is where the regular maintenance tasks are performed at a certain interval to prevent the building’s components from degradation and failure (Cruzan, 2020).

Maintenance techniques can be combined when solving each maintenance problem, prioritizing the user’s health and safety, expenses of maintenance tasks, and quality of the outcome (Horner et al., 2012). Maintenance tasks are relatively still personnel-intensive, requiring the skills and expertise of the maintenance personnel to inspect the damage and oversee the rectification procedures (Mjema, 2002). As such, the safety of the people needs to take into consideration when performing maintenance tasks.

Safety in Building Maintenance

Safety is about controlling the conditions and risks that can cause physical, psychological, or physical harm to people (Niciejewska and Kirilliuk, 2020). Holmes et al. (1999) found that risk at the workplace was largely attributed to the work nature, poor individual work practices, and work pressure

due to budget and time limitations. Safety culture at the workplace is crucial to create an environment that responds to the needs of the employees and protect the delicate nature of human (Törner and Pousette, 2009). Health and safety at the workplace concern the health of the workers, either physically and mentally (Eguchi et al., 2012). Safety is a necessity. Achieving zero accidents at the workplace requires positive and proactive safety culture (Choudhry et al., 2007). Promoting work safety minimises, if not eliminates, injuries, illnesses, or fatalities dues to work activities, affecting the person, the families, and the employers (Langford et al., 2000).

Building maintenance can impose various hazards and risks (Salleh et al., 2016). Maintenance operations can involve various equipment, complicated machinery, unconventional tasks, and difficult working spaces (Olanrewaju et al., 2011). In confined spaces, maintenance personnel is more vulnerable due to noise, vibration, overheating and undercooling, radiation, chemical risks, biological risks, and psychosocial risks (McManus, 2018).

In high spaces such as a living wall, the workers are vulnerable to fall from height, slip, trip, and fall (STF), struck by falling objects, and electrocuted. Fall from height is one of the highest risks as maintenance tasks usually involved climbing to a higher position via a ladder. STF is about imbalances of the foot or poor awareness of the surrounding. Slips happen when there is weak friction between the foot and the floor, causing imbalance. Trips happened when the person lost balance because the foot accidentally collides with an object or is unaware of the change in the surface level. Falls is a free-falling movement from higher to lower level (Chang et al., 2016). Although fatalities are rare consequences of STF, they can cause serious injuries such as chronic low back pain, head injuries, or ruptured discs, apart from more common injuries such as sprains and strains (Yeoh et al., 2013). Being struck by objects mean an injury because of forced contact or impact with an object or equipment (Wu et al., 2013). Electrocution, which can cause skin, respiratory, and many other system injuries (Spies and Trohman, 2006), accounts for approximately 9% of all deaths in the construction industry in the USA (Janicak, 2008). Thus, many risks are involved in building maintenance works, making safety aspects crucial to being embedded in the working culture.

Maintenance of Living Wall

Survival and continual growth of vegetation on a living wall would require regular maintenance activities. Maintenance is also important to ensure all necessary components of a living wall can operate and function as expected (Perini et al., 2013). Improper execution of maintenance tasks on a living wall can cause failure on one or more of the living wall components, taking a toll on the vegetation. Detail planning is also needed for maintenance tasks because of the various living wall components that would require extra maintenance attention and strategy (Saharuddin et al., 2019). Chew and Conejos (2016) indicate that maintaining living wall usually follow standard building maintenance practice due to the absence of industry standards in this technical system.

Thus, the five stages of building maintenance, i.e., 'identify work', 'plan work', 'schedule work', 'execute work', and 'complete work', are also applicable for maintaining a living wall. In the ‘identify work’ stage, the maintenance team shall inspect the condition of the living wall and identify the maintenance task required. The purpose of having proper maintenance stages is to ensure the performance and quality of the work executed, reduce unplanned maintenance costs, and mitigate any risk associating with the maintenance work. The procedure follows the common steps of maintenance management (Chanter and Swallow, 2007). In the 'plan work' stage, the maintenance team shall prepare a detailed and thorough maintenance plan and schedule. The maintenance plan of the living wall should include a clear description of maintenance objectives, performance goals, personnel responsibilities, training requirements, safety equipment, and resources (Growing Green Guide, 2014). A maintenance schedule shall be developed in the 'schedule work' stage to ensure the resources are scheduled to fulfill the tasks and objectives established. In the 'execute work' stage, the maintenance personnel shall perform scheduled maintenance tasks formulated by the maintenance team (Olanrewaju & Abdul-Aziz, 2015). In the 'complete work' stage, the maintenance team reports the performance of living wall

maintenance work to the management department, receives feedback from them, and improves based on feedback.

Without maintenance, faulty or deteriorate components may be left undetected and can lead to failures of the living wall (Growing Green Guide, 2014). Depending on the source of the problem, the maintenance of the living wall can also apply various techniques such as corrective, condition-based, pre-determined, and unplanned maintenance. Corrective maintenance is adopted when the living wall components fail to perform or show signs of impending failure (Mydin, 2015). Under condition-based maintenance, the tasks are mostly inspection-based to identify where the problem may lie (Mydin, 2015). The maintenance works are carried out after detecting the problem that affects either appearance or functionality of the components. There are two types of pre-determined maintenance, namely routine and cyclic maintenance. Routine maintenance involves undertaking maintenance works regularly to ensure the living wall maintains its appearance, functionality, and safety (Au-yong et al., 2016), while cyclic maintenance is scheduled interventions at lesser intervals (Chanter & Swallow, 2017). The difference between these two maintenance techniques is in terms of the frequency of undertaking the task. Unplanned maintenance is executed when there is an emergency or when the components need immediate correction or repair works to prevent serious consequences such as personal injury or further damage that can affect property damage (Olanrewaju & Abdul-Aziz, 2015). Table 1 summarises the maintenance task related to each of the key components of the living wall.

Table 1: Recommended Maintenance Tasks for Living Wall Components (Gunawardena and Steemers, 2020; Growing Green Guide, 2014)

Maintenance Components	Living Wall Maintenance Tasks
Planting planning	• Placement of vegetation
Vegetation growth	• Inspect and remove vegetation's waste such as leaves and weeds
	• Inspect for signs of pests or disease and propose treatment
	• Control of irrigation volume and frequency
	• Inspect the vegetation after any weather events
Weed problem	• Monitor for any weed growth in the vegetation
	• Apply weed control treatment
Climbing vegetation	• Regular trimming of vegetation to maintain density and appearance
	• Eliminate any growth that can affect fixtures such as windows and drains
	• Pruning to restore steams and encourage new basal growth
	• Monitor and record vegetation health and vitality
Substrate	• Monitor the depth and density of the substrate
Irrigation system	• Conduct tests to the irrigation system regularly
	• Inspect and monitor automated irrigation system
Vegetation nutrition	• Record of fertilizer addition and level of pH
	• Provide adequate fertilizer to maintain nutrition level
Drainage system	• Remove any obstruction in the drains
	• Regular check on the plumbing, filter sheet, and other equipment
Non-vegetated zones	• Remove any vegetation growth on non-vegetated zones
Wind protection system	• Check on the system regularly, especially after an extreme weather event
Safety system	• Ensure all safety equipment such as fall arrest system, PPE, etc., are in good condition.
	• Ensure no obstruction to the access points such as ladders and stairways
	• Check on electrical safety system to avoid any electrocution
	• Provide adequate space to conduct the maintenance task
	• Provide safety signs and block access to the maintenance work area from public or non-maintenance personnel
Other fittings	• Inspect and repair any loose or damaged attachments or fittings

The maintenance tasks of the living wall listed in Table 1 can be further grouped according to the most suitable type of maintenance techniques. The tasks are summarised in Table 2.

Table 2: Relating Living Wall Maintenance Tasks with Maintenance Techniques

Maintenance Technique	Maintenance Tasks
Corrective Maintenance	• Placement of vegetation • Apply weed control treatment • Remove any obstruction in the drains • Remove any vegetation growth on non-vegetated zones • Inspect and repair any loose or damaged attachments or fittings
Condition-based Maintenance	• Inspect for signs of pests or disease and propose treatment • Inspect the vegetation after any weather events • Provide adequate fertilizer to maintain nutrition level • Check on the system regularly, especially after an extreme weather event
Pre-determined Maintenance	• Inspect and remove vegetation's waste such as leaves and weeds • Control of irrigation volume and frequency • Regular trimming of vegetation to maintain density and appearance • Eliminate any growth that can affect fixtures such as windows and drains • Monitor for any weed growth in the vegetation • Pruning to restore steams and encourage new basal growth • Monitor and record vegetation health and vitality • Monitor the depth and density of the substrate • Conduct tests to the irrigation system regularly • Inspect and monitor automated irrigation system • Record of fertilizer addition and level of pH • Regular check on the plumbing, filter sheet, and other equipment • Ensure all safety equipment such as fall arrest system, PPE, etc. are in good condition • Ensure no obstruction to the access points such as ladders and stairways • Check on electrical safety system to avoid any electrocution • Provide adequate space to conduct the maintenance task • Provide safety signs and block access to the maintenance work area from public or non-maintenance personnel
Unplanned Maintenance	• Any emergency that requires immediately to prevent further consequences to the living wall, vegetation, or the workers

Safety Practices in Maintaining Living Wall

Workers' health and safety are important in any construction project, and it does not stop once the project is over (Behm and Poh, 2012). Health and safety are extended at the post-occupancy stage, which covers most of the building life. Building maintenance ensures the sustainability of the building. However, according to Behm and Poh (2012), safe design aspects is not incorporated in design standard and usually initiated as the site. The maintenance of the living walls can be considered high-risk due to the height factor. Executing maintenance tasks may require permanent or temporary support, including the appropriate equipment to access the vegetations, living wall structures, and drainage system (Gunawardena and Steemers, 2020). In high places, cranes and gantries are needed to support the maintenance workers, including any required tools and equipment to do the maintenance task. Proper spaces need to be planned and allocated to ensure a safe place to work to avoid. Inadequate maintenance access can also lead to safety risks (Pérez et al., 2014). Thus, maintenance work of the living wall is similar to any tasks involving high places. Maintenance workers are susceptible to a high risk of falling from a height, STF and being struck by an object (Salleh et al., 2016).

Achieving a successful living wall is complicated, although the appearance is of natural simplicity. This complication is because creating a vertical wall requires a complex system to match all the easily available compositions on the ground, which includes the need for the support structure, ensure an adequate amount of water, oxygen, nutrients, pH levels, and lighting for healthy growth of vegetation and the choice of suitable plants (Riley, 2017). Living walls require more human touch as it needs a careful inspection to detect any vegetation problems or for many vegetation care. Maintenance work is usually labour intensive. Proper planning, management, and control are crucial to avoid any accidents and injury with people's involvement.

Despite an increased interest in a living wall, the maintenance of these walls is a challenge due to inappropriate design considerations. According to Chew and Conejos (2016), poor design consideration of living walls will lead to safety issues during maintenance work. They identified various technical and environmental defects that can lead to safety risks such as withering plants, structural corrosion, felt and planter boxes bursting, cracks on planter box ledges, fixtures improperly secured, water leakage, poor irrigation, soil loosening, presence of algae, and mould and poor choice of vegetation only increase the risk to the workers when they do their maintenance work. Furthermore, roots entering voids and cracks will damage the building surface, increasing risk and safety issues during maintenance work (Manso and Castro-Gomes, 2015). Maintenance access for cleaning and maintaining the living wall is paramount to ensure the living wall is properly maintain and to ensure the incorporation of proper safety elements during the work (Chew et al., 2019). Thus, access and safety of maintenance work should be considered during the design stage of the building and not as an afterthought.

For a living wall close to the ground level, the maintenance procedure could be less complicated and less risky. As the height of the living wall increases, various safety measures need to be considered, such as support structure, working spaces, equipment, maintenance materials, goods, etc. (Behm and Poh, 2012). Proper safety practices are required to govern the living wall's maintenance management and procedures and reduce the risks when conducting maintenance work on the living wall, especially when it involves high places. A safety practice guide will be useful to assure the safety of maintenance personnel while conducting their works. Many safety practices can reduce the risks of maintaining living walls: safety policy, safety officer, safety awareness and training, safety equipment, and safety signs.

The maintenance organization is responsible for establishing well-structured safety practices for its workers. A well-documented safety policy is crucial to guide and direct maintenance personnel in carrying out the works (Ali and Chua, 2011). Having rules, regulations and precautions clearly stated in the safety policy will ensure the tasks will be strictly followed by maintenance personnel. These rules, regulations, and precautions must be developed based on the risk of the maintenance work (Behm and Poh, 2015). The safety officer is crucial in planning and implementing safety policies and supervising the safety of maintenance personnel. The safety officer shall ensure that all maintenance tasks comply and adhere to safety requirements (Adnan et al., 2019). To improve safety awareness, the workers are expected to attend safety seminars and training (Koirala, 2018). Through that process and work experience, the workers will identify, understand, and control the risks associated with maintaining a living wall. There is various safety equipment that can be used by the maintenance team when executing their works, such as personal protective equipment (PPE), which includes a personal fall arrest system, hard hat, safety glove, boots, etc. (Ammad et al., 2020), barricades, safety ladder, lift equipment, and scaffolding (Behm and Poh, 2015). Apart from raising awareness and conduct training on safety, maintenance workers should also know how to operate safety equipment (Growing Green Guide, 2014). Safety signs are part of the action not only to protect the workers but the passer-by. The signs shall warn people that the maintenance task is ongoing and keep them away from the particular location.

Challenges of Implementing Safety Practices in Living Wall Maintenance Work

Safety practices create a safe working environment for maintenance personnel (Ali, 2009). For living walls that involve working at high places, vegetation and water requirements, and machinery, it is bound to have certain challenges. Understanding those challenges would enable better mitigation of work risk and safety control. A total of 5 challenges of practicing safety aspects for living wall maintenance are identified from literature which are 1) personnel attitude and experience; 2) lack of management commitment and financial constraint; 3) weather issues; 4) lack of comprehensive safety policy or requirement, and 5) complexity of living wall maintenance work.

Personnel Attitude and Experience

Lack of experience and skilled maintenance personnel is a problem as it influences their attitude in complying with the safety requirement. The majority of unskilled maintenance personnel, in Malaysia for example, are imported from Indonesia, Myanmar, Pakistan, India, and the Philippines (Abdul-Rahman et al., 2012). The lack of knowledge of these unskilled maintenance workers can increase the risk of associating with maintenance work because of their lack of experience and disregard for rules and regulations. The maintenance personnel imported from other developing countries have a poor attitude and are influenced by their own culture (Mahalingam & Levitt, 2007). A complex maintenance task such as a living wall would require specific knowledge that unskilled workers from developing countries may not possess (Saharuddin et al., 2019), which can affect their ability to identify, understand, and avoid the risks associated with specific maintaining tasks (Vitharana et al., 2015). Information on safety signboards can also be misunderstood (Tam et al., 2010). These foreign workers can sometimes unwilling to adhere to the organisation's safety policy (Korkmaz & Park, 2018). Language and communication barriers are the main obstacle in implementing the safety practices, especially if it involves those from different ethnicities and foreign workers (Abdul-Rahman et al., 2015; Jaselskis et al., 2008).

Lack of Management Commitment and Financial Constraints

There is a lack of management commitment when it comes to building maintenance. Ghani et al. (2008) stated that comprehensive safety practice is not fully implemented among maintenance personnel due to lack of enforcement by the management. Cut off budget from top management is another issue that limits the implementation of comprehensive safety practices (Ali et al., 2010). With budget cuts, adequate training and purchasing of safety equipment are becoming more difficult (Nielsen, 2014), resulting in a poor grasp of safety importance and practices (Ali & Chua, 2011). Purchasing PPE, safety equipment, safety signs, hiring safety officers (Tanko and Anigbogu, 2012), and conducting safety education and training using a new technological approach (Li et al., 2015) maintenance work requires a proper plan and additional cost.

Many organisations have appointed safety officers to oversee the safety aspects of the maintenance work. However, Crumbley (2014) indicated that these safety officers do not have the autonomy to strictly enforce the safety rule and regulations without the approval of the top management. In most cases, the top management may interfere with the level of safety being practiced for the work done.

This issue may worsen if the company is new or small. A comprehensive safety practice for maintenance work may be difficult to be practiced in a small organisation due to the financial vulnerability and lack of resources (Choi et al., 2012), which makes business survival is more critical than investing in safety practice (Hon et al., 2012; Champoux & Brun, 2003).

Weather Issues

The living wall will usually have interior and exterior surfaces. While the interior walls have a controlled environment, the exterior is subjected to nature and weather conditions. Strong winds are some of the common weather conditions that can impose difficulties in maintaining the exterior living walls and may also increase the frequency of maintenance work to mend any damage to the vegetation and its support system. Outdoor weather could also influence vegetation growth and require closer observation (Charoenkit and Yiemwattana, 2021).

Lack of Comprehensive Safety Policy or Requirement

It is common practice for government projects to award maintenance contracts to the lowest bidder (Alshehri et al., 2015). To be the successful tenderer of the maintenance contracts, they would cut their budget on certain least important aspects. Basic safety requirements must still be met, but comprehensive safety requirements may be side-lined (Choi et al., 2012). Meswani (2008) indicated that most of the safety policies or requirements tend to be general. Thus, a specific requirement for specific elements such as a living wall is not provided. The lack of safety indicators and measures, official safety data, and on-site accident records will make it difficult to implement safety practices and identify the risks associated with living wall maintenance (Cheah, 2007).

The complexity of Living Wall Maintenance Work

Establishing a viable living wall system that can be maintained for a long time will require knowledge and careful planning (Gunawardena and Steemers, 2020). The living wall is complex because it has many elements to ensure the condition is suitable for the healthy growth of the vegetation (Riley, 2017). This additional care from maintenance personnel may cause them to ignore or fail to pay full attention to their safety practices. Besides vegetation, leakage of irrigation pipe, which required unplanned maintenance, will cause the floor to become slippery and increase the risk of STF to maintenance personnel when carrying out their work (Omar et al., 2013)

DISCUSSION AND CONCLUSION

The growing interest in living walls creates new specialisation in building maintenance (Behm and Poh, 2012). Maintenance is required throughout the entire period for the living wall to function as intended. The safety aspects of living wall maintenance work are essential to protect the safety of the maintenance personnel. Maintaining a living wall is considered a high-risk job due to the involvement of high areas. The workers will be exposed to a few types of risk: fall from height, STF, falling objects, and electrocution from using electrical items near water components (irrigation system). This paper discusses the maintenance process and technique of living walls, the safety practices adopted for maintenance work of living walls, and challenges in implementing safety practices for maintenance work of the living wall. The building maintenance process generally consists of 5 stages: identify work, plan work, schedule work, execute work, and complete work. The same process could be applied for living wall maintenance work as well, with the scope focused on living wall components. It is suggested that maintenance of the living wall should focus on using corrective maintenance and preventive maintenance, including conditioned-based maintenance and pre-determined maintenance. Unplanned maintenance should only be reserved for an unexpected situation or beyond their control (Basri et al., 2016). Preventive maintenance is more recommended in living wall maintenance work due to several reasons: 1) it reduces the frequency of corrective maintenance; 2) it maintains the condition of the vegetations; 3) it reduces the potential of unplanned maintenance and 4) it improves the safety aspects of the surrounding (Horner et al., 2012)

Many safety practices can reduce the risks of maintaining living walls: safety awareness, safety policy, safety equipment, safety education and training, safety signs, and safety officers. Safety awareness is one of the most important safety practices in the workplace (Vitharana et al., 2015). Conducting a safety awareness seminar is important to ensure the maintenance personnel has a high degree of safety understanding to identify the risks at hand and always be vigilant in living wall maintenance to prevent accidents. The preparation of a comprehensive safety policy for any maintenance work involves the collaboration between top management and maintenance personnel (Ali and Chua, 2011). Sufficient safety equipment is crucial to ensure the work is conducted safely and secured. Management needs to allocate a certain budget to purchase this safety equipment (Ali, 2009). Regular safety education and training should be part of the norm in maintenance work to educate on the use of safety equipment, fire drill exercise, and to understand safety policy and SOP (Vitharana et al., 2015). Strategically placing safety signboards while performing living wall maintenance tasks is important to keep passer-by away from the location or warn the workers to take extra caution when walking or working in that area (Zamanian et al., 2013). In most building maintenance work, safety officers would be appointed to oversee the safety aspects. Their expert opinion should be respected when it comes to ensuring safety is uphold and not being tied by the hidden agenda of the top management (Widajati et al., 2017).

Managing building maintenance is not without any challenges as it involves people, money, machinery, and mostly in either remote or high locations. The same notion is also applied to maintaining a living wall. While normal building maintenance involved repairing or replacing the damaged or unsafe product or structure, LWS increase the difficulty by having live vegetation and irrigation system as part of the wall elements itself. The complexity of the living wall structure leads to another difficulty, that is, the workers' knowledge and experience as they are expected to know beyond conventional building maintenance and to include understanding on managing and handling vegetations and irrigation systems when maintaining the living wall. While working at high places, it is crucial to have proper safety equipment, ranging from a boom lift, scaffolding, harnesses, etc. Weather issues are common for living walls with exterior surfaces. Extra attention must be given to the exterior vegetations as it also affects the aesthetic appearance of the building. Lastly, having a comprehensive safety policy or requirement will ensure a holistic coverage of safety procedures and guides. Building maintenance work can either be handled by an in-house department or outsource to an external party. An in-house team with clear safety rules and regulations may find it easier to incorporate safety policy as they will most likely have better support from the management. An external party, however, secures the job through competitive tender. To cut the budget, they may compromise on the safety aspect and may not be bounded by the owner's safety requirement.

The safety aspects of living wall maintenance work are essential to protect the safety of maintenance personnel. In this paper, the maintenance process and technique of living walls, the safety aspects of living wall maintenance, and the challenges of practicing safety aspects for living wall maintenance are explored. It is hoped that this discussion opens a further avenue to promote a safer workplace for building maintenance workers, especially when maintaining a living wall, which is more delicate and contributes to greening the urban area.

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