Context-Sensitive Guidelines for Green Roof Installation in Residential Buildings of Dhaka City

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Abstract: Rapid urbanization in Dhaka has significantly diminished green spaces, worsening environmental issues such as urban heat, poor air quality, and stormwater management challenges. Green roofs offer an effective solution by integrating vegetation into building rooftops; however, their use in Dhaka remains limited, with only a small share of residential buildings adopting this approach. Most existing installations lack proper technical planning and context-specific guidance, leading to inefficiencies and sustainability issues. This study creates locally relevant guidelines for green roof installation in Dhaka's residential buildings, addressing the gap between global standards and local conditions. Employing a mixed-methods approach—including literature review, field surveys, case studies, and expert input—the research identifies common roof types (extensive, intensive, extensive with designed plantations, and movable pot plants). It examines their components, including waterproofing, drainage, substrate, and plant selection. Results show that many current installations are inconsistent, rely heavily on materials, and lack professional oversight. The proposed guidelines focus on lightweight construction, proper waterproofing, parapet treatment, adequate drainage and overflow systems, and the use of native plants to boost resilience and reduce costs. This study supports sustainable urban growth by providing practical, context-specific strategies for architects, engineers, and policymakers to implement eco-friendly rooftop practices in Dhaka.

Keywords: *Green Roofs, Sustainable Architecture, Urban Resilience, Residential Buildings, Installation Guidelines, and Dhaka City.*

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I. INTRODUCTION

Dhaka, the capital city of Bangladesh, is undergoing rapid growth in both population and infrastructure. It is projected to become the fourth-largest megacity in the world by 2025, with an annual growth rate of 3.6% [1]. This expansion has significantly reduced the city's green spaces [2], intensifying environmental challenges such as rising urban temperatures, declining air quality, and inadequate natural ventilation. The urgency of these problems underscores the need for sustainable solutions. Green roofs—specially landscaped rooftops designed to support plant life—have emerged globally as a viable alternative to ground-level green space. Comprising multiple layers such as waterproofing, root barriers, substrates, and vegetation, green roofs deliver a wide range of environmental and social benefits. These include reducing building energy demand [3], improving urban air quality [4], managing stormwater runoff [5], and mitigating the urban heat island effect [6]. Additionally, they can offer economic benefits, including increased property value and reduced energy costs.

Despite these advantages, the adoption of green roofs in Dhaka remains minimal. A study found that only about 12% of households in the city have installed green roof systems [7]. Moreover, most existing practices lack standardized guidelines or context-specific design strategies, resulting in installations that are often technically unsound and environmentally inefficient. Although detailed technical standards exist internationally—most notably in Germany [8], [9] —they are rarely applicable to Bangladesh's climate, materials, and socio-economic context. As a result, a clear research gap exists: the absence of locally grounded technical guidelines for green roof installation in residential buildings in Dhaka. A handful of studies have evaluated roof systems

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in the city [10], [11], but none have established comprehensive, context-sensitive installation parameters.

This study addresses that gap by analyzing existing green roof practices in Dhaka and developing locally applicable installation guidelines for residential buildings. The research focuses specifically on installation techniques—rather than structural design—because variations in building structures often extend beyond the scope of generalized guidelines. The central research challenge lies in the lack of technical evaluation and design-oriented analysis of existing rooftop practices. While different types of green roofs are theoretically recognized, including extensive, intensive, and semi-intensive systems [12], [13], their standards for implementation in Dhaka have not been adequately studied. For long-term performance and sustainability, most existing roofs lack essential elements such as consistent waterproofing, reliable drainage, and planned maintenance [9], [14]. Two key research questions guide the study: What are the most effective installation techniques for different types of green roofs in residential buildings of Dhaka city? How can suggestive parameters be established as a guideline to develop a suitable green roof system?

The overarching goal is to propose practical, climate-responsive, and context-oriented guidelines for green roof installation that can enhance the sustainability of Dhaka's residential architecture. By addressing the technical shortcomings of current practices, the study seeks to provide actionable knowledge for architects, urban planners, engineers, and policymakers. However, it is essential to note that implementing these guidelines may encounter challenges, such as the availability of suitable materials and the need for specialized skills. The significance of this research is threefold. First, without proper installation techniques, green roofs risk undermining Dhaka's environmental resilience, forfeiting their potential as substitutes for diminishing surface-level greenery. Second, well-implemented green roofs offer long-term benefits in energy savings, thermal comfort, and ecological preservation. Third, the findings of this study can inform future urban planning and policy initiatives, preparing Dhaka for transformation into a more livable and sustainable megacity.

Ultimately, this research evaluates contemporary rooftop greening practices in Dhaka, identifying their strengths and shortcomings, and formulates tailored recommendations for future application. In doing so, it advances sustainable design approaches within the rapidly growing urban context of Dhaka, where the demand for healthier living environments and the pressure on land resources are both intensifying.

II. LITERATURE REVIEW

The idea of green roofs, or vegetated roof systems, is not new. It has a long history of supporting environmental conservation, ecology, recreation, and aesthetics, and is increasingly gaining worldwide recognition. Incorporating plants into building design has traditionally helped address climate change and environmental issues while also improving visual appeal. This review examines the history, primary benefits, classifications, technical challenges, and notable case studies of green roofs, aiming to highlight research gaps and identify future opportunities.

Roof gardens have a long history, with the earliest known example being the Hanging Gardens of Semiramis, one of the ancient world's wonders, thought to be in present-day Syria [12]. This reflects humanity's persistent desire to blend natural elements with built environments. The green roof movement modernized in Germany during the 20th century, initially serving as fire-resistant structures to shield roofs from sunlight [15]. Since the 1970s, Germany has extensively researched green roofs for urban use, developing implementation methods and standards. In 1982, the FLL published technical guidelines and multidisciplinary research [16], which helped integrate green roofs into building codes. Germany now installs at least 13.5 million square meters of green roofs annually, with around 14% of new roofs adopting these systems [17]. The practice has since spread globally, valued for ecological and social benefits, and is increasingly adopted by dense cities like Dhaka as part of urban growth and environmental strategies.

Green roofs offer a wide range of environmental, social, and structural advantages. They help lessen the environmental footprint of urban development by serving as vegetated surfaces that buffer ecosystems [12]. Additionally, they lower air temperatures and reduce the urban heat island effect [12], [18]. Green roofs also filter pollutants from the air and reduce noise pollution. Additionally, they help manage stormwater by slowing runoff and easing pressure on city drainage systems [10], [19]. Lastly, green roofs support biodiversity by providing habitats and connecting urban ecological corridors [20].

Beyond ecological impacts, green roofs provide notable social and cultural benefits. They enhance the aesthetic appeal of urban landscapes and promote well-being [21]. By turning bare rooftops into usable spaces, they create areas for social gatherings, leisure, and recreation [22], which can reduce stress and improve quality of life [10]. Additionally, green roofs can boost property value by increasing building durability and visual appeal [23]. They also support urban agriculture and food security, allowing residents to grow vegetables and herbs [24]. In addition to offering environmental and social benefits, green roofs also enhance building longevity. They shield roof membranes from UV rays, temperature changes, and weather effects, which helps extend their lifespan [10]. Additionally, green roofs enhance fire resistance [21] and act as sound insulators, creating more comfortable indoor environments [10]. Green roofs are typically classified into intensive and extensive systems, with semi-intensive and semi-extensive systems recognized as variations [25]. Intensive roofs resemble natural landscapes and feature substrate layers ranging from 6 inches to several feet, supporting a variety of plants, including shrubs and small trees [26]. Although they are visually appealing, they demand significant maintenance. Extensive roofs, on the

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other hand, are lighter, shallower, and better suited for drought-tolerant species, making them more cost-effective and low-maintenance. The classification depends not only on substrate thickness but also on environmental and structural factors, such as load-bearing capacity, weight, and plant choice.

Implementing green roofs requires careful attention to structural strength, drainage, waterproofing, and ongoing maintenance. Key components include plants, substrates, drainage and filter layers, root barriers, waterproofing membranes, and insulation [27]. Assessing load-bearing capacity is essential to prevent roof failures, and retrofitting existing structures often presents financial and technical challenges. Proper waterproofing is crucial in preventing moisture infiltration, while effective drainage systems mitigate flooding, clogging, and soil erosion [9]. Irrigation methods vary, such as sprinklers, drip systems, and capillary watering, with rainwater harvesting and recycling recommended for increased efficiency [9]. Routine maintenance, including fertilization, weeding, watering, and repairs, is crucial for long-term success.

Germany has led the development of modern green roofs since the late 20th century, creating technical guidelines and incentive programs that have encouraged widespread adoption worldwide. Dhaka, while still in the early stages of implementation, has started practicing rooftop greening as part of its response to rapid urban growth and environmental issues. Green roofs are now utilized in various ways around the world, demonstrating their adaptability across diverse regions and climates. Despite global recognition, gaps remain in green roof research and practice. Literature points out the lack of standard guidelines, context-specific design solutions, and consistent classification of roof types and materials. For cities like Dhaka, additional research is necessary to evaluate performance, find suitable local materials, and adapt international practices to local climate and socio-economic conditions. The limited availability of research resources also hampers systematic classification of roof types, highlighting the need for better accessibility and categorization.

In summary, the literature shows that green roofs are both a historically proven and technologically advanced approach for sustainable urban growth. Their progression from ancient gardens to modern ecological systems highlights humanity's long-standing effort to blend natural elements into constructed environments. The benefits—ranging from environmental enhancements and stormwater control to social well-being and increased longevity—are compelling. However, the absence of localized guidelines, especially in Dhaka, emphasizes the need for context-specific research. Maximizing the ecological, social, and economic benefits of green roofs is crucial for speeding up their adoption and fostering more resilient, livable cities.

III. METHODOLOGY

A combined methods analysis and descriptive approach are employed in this study to examine the current installation of green roofs on private buildings in Dhaka. This includes both qualitative and quantitative methods. The primary goal was to learn about the various types of green roofs, examine their components, and understand their maintenance systems. The aim was also to develop installation techniques feasible in that area. This section discusses the actions taken and explains why the chosen method was suitable for the study.

➢ *Research Approach*

The research method consisted of three main stages: a comprehensive literature review to understand global practices and identify areas requiring further research; a case study analysis combined with a field survey to document various types of green roofs in Dhaka; and a comparative analysis of the findings to propose adaptable installation standards for green roofs.

This multi-layer approach enables the study to evaluate both theoretical models and real-life practices. A case study method was especially applicable because green roofing in Dhaka is relatively new and has limits documented practice in Dhaka [10].

➢ *Literature Review*

A thorough literature review was conducted to improve the theoretical foundations of green roof technologies. Journal articles, books, policy documents, technical manuals, and reports were among the sources used. International recognized standards (e.g., FLL guidelines from Germany) and case studies from Germany, Singapore, Canada, the U.S., and Malaysia were highlighted [9], [14]. These helped frame the essential elements of green roofs, such as irrigation, drainage, insulation, layering systems, and plant selection. The review also pointed out that Bangladesh lacks such localized standards. However, countries such as the U.S. and Germany have developed technical installation recommendations [12], [16].

➢ *Field Study and Case Analysis*

The study conducted on-site field investigations and selected four sample case studies to understand how green roofs are being implemented in Dhaka city. This enabled the collection of data on design elements, building techniques, and maintenance procedures in real-time.

➢ *Location of Study*

Dhaka, the capital of Bangladesh, is the location where this research will be carried out. The city is suitable for research due to its rapid urban expansion and severe environmental crisis. The green-roof featured residential buildings were selected from the following neighborhoods: Dhanmondi, Malibagh, Mirpur, Uttara, Muhammadpur, Wari, and Paltan. These areas were selected as they represented both the socio-economic variety of the city and its architectural features.

➢ *Sample Selection and Typology*

After screening numerous buildings, only a few were found to have green roof features in the area (Fig. 1). Based on relevance and availability, four different types of green roofs were selected for the case study.

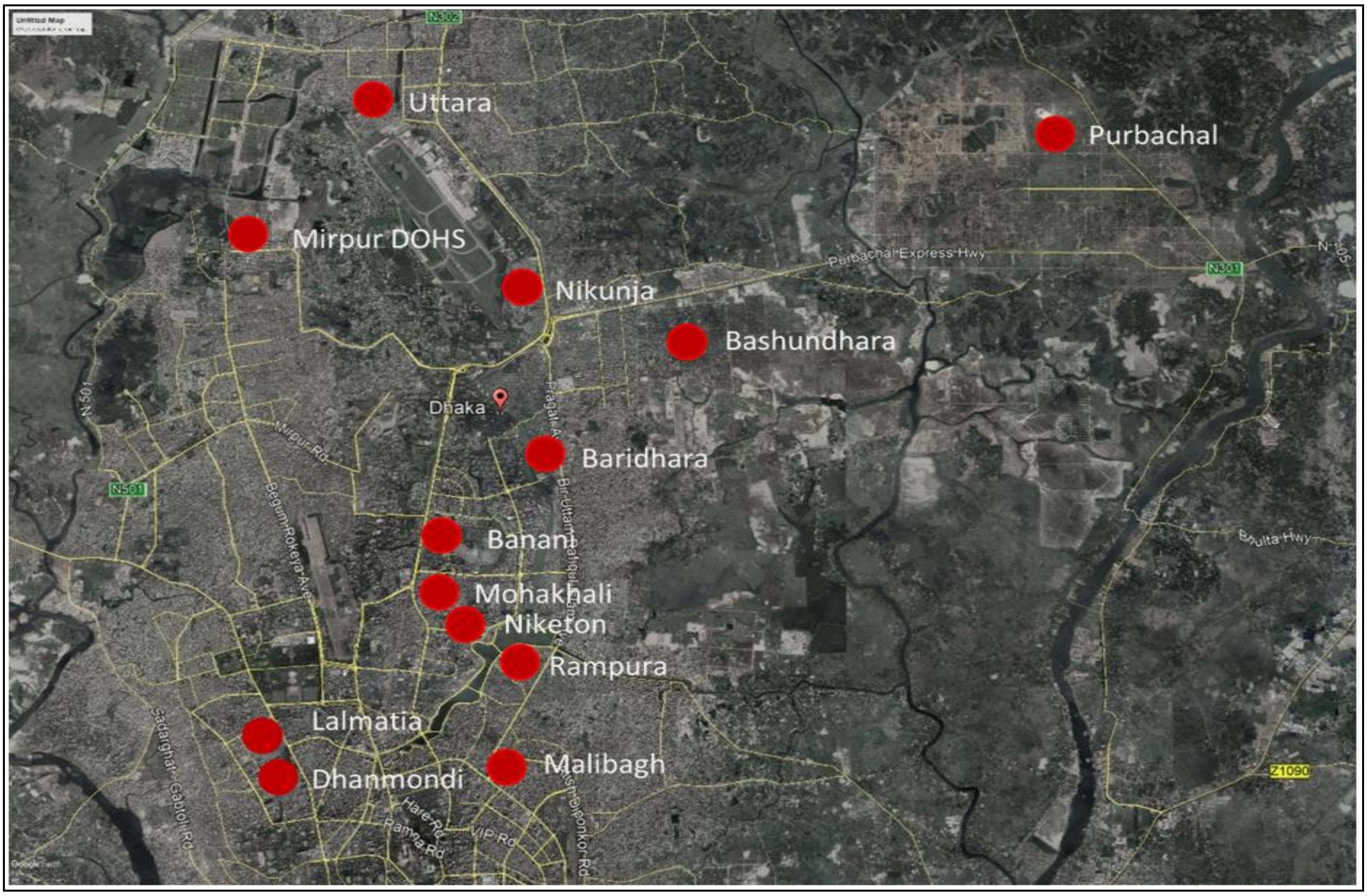

Fig 1 Locations of Selected Case Study Areas in Dhaka
Source: Google Maps

- *The Following Four Different Types of Green Roofs are:*

✓ Extensive – This type is common in all international and local places (Fig. 2-3). Its main characteristics include a shallow thickness of the required components, characterized by small, foliage-like herbs and grass [10], [27].

✓ Intensive – This type is less common. Only three (3) intensive green roofs have been found from the total survey (Fig. 4). It has thick component layers that can accommodate various types of large plants, such as bushes, shrubs, and small trees [27].

✓ Extensive with Designed Intensive Plantation – This type is a common type of green roof, characterized by small foliage and large plants with various layers. It shares similarities with semi-intensive green roofs. Large plants can be easily accommodated in fixed or movable planter pots, thereby reducing construction costs and allowing for aesthetic design flexibility (Fig. 5). Most extensive green roofs feature large plants in movable pots, allowing for efficient plant management.

✓ Movable Pot Plant – Six movable pot plants were identified during the pilot survey. Live flowers and plants are typically displayed in portable, enclosed, and small containers [28]. This category encompasses one of the most common types of green roofs found in the local area (Table 1). It features a variety of plant types and different sizes and styles of pots (Fig. 6).

Table 1 Case Study of Each Type of Green Roofs According to Location

Green roof Type	1-Extensive	2- Intensive	3- Extensive with Designed Intensive plantation	4- Movable Pot Plant
Location 1	Purbachal	Mirpur DOHS	Niketan	Rampura
Location 2	Dhanmondi	Baridhara	Bashundhara	Uttara
Location 3	Baridhara	Bashundhara	Mohakhali	Mohakhali

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➢ *Data Collection*

Data collection was performed through visual inspection, photographic documentation, on-site measurements (e.g., roof area, substrate depth, drainage layers), and semi-structured interviews with architects, homeowners, and maintenance personnel. No formal questionnaire survey was included in this summarized version. Each case was documented with photos of green roof components, plant types, and construction materials. Notes were also taken on irrigation systems, accessibility, load-bearing structures, and user behavior.

➢ *Analytical Process*

The analysis involved a comparative review of case data, focusing on the roof layering technique, waterproofing quality and use, root barrier and drainage installation, substrate type and depth, vegetation type, and irrigation and maintenance systems. This framework was built on international standards and literature [9], [14], but it was adapted to suit the local context of Dhaka, where formal guidance is primarily available.

➢ *Expert Conclusion*

The experts consulted to validate the findings included landscape architects, structural engineers, urban planners, and horticulturists. They observed that most green roofs in Dhaka are built without professional guidance, often neglecting essential components like insulation, root barriers, and proper drainage. Additionally, experts highlighted the absence of municipal regulations or incentives to encourage green roof development [10],[7].

➢ *Documentation Tools Used*

The data collection involved several tools: a DSLR camera for photos, sketchbooks for roof layouts and notes, AutoCAD for measuring spaces, Excel for organizing technical data, and Adobe Photoshop for visual presentations. Given the small sample size and the research's specific focus, all case study data were manually collected and integrated.

➢ *Visual Documentation of Green Roof Types*

Sample images from field documentation are shown below.

Fig 2 Extensive Green Roof
Source: Rafia, 2020

Fig 3 Extensive Green Roof
Source: Ehsanul, 2020

Fig 4 Intensive Green Roof
Source: Ameen, 2020

Fig 5 Extensive with Designed Intensive Plantation
Source: Faisal, 2020

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Fig 6 Intensive Pot of Extensive with Designed Intensive Plantation
Source: Shatotto, 2020

➢ *Rationale for Method Choice*

The case study and field survey methods were selected for several reasons: green roofs in Dhaka are poorly documented, and there are no formal installation guidelines in the local policy. Most green roofs are installed informally, so direct experience is more valuable than secondary data. Due to the small sample size, a comparative approach provided more insightful results than statistical analysis. Previous research also suggested similar methods for studying under-researched, context-specific urban phenomena [12], [17].

➢ *Limitations of the Methodology*

Although the methodology successfully achieved the goals of this study, it had several limitations: the limited number of existing green roofs in residential areas narrowed the scope, access to many buildings was restricted due to privacy and security concerns, the study did not include load-bearing structural analysis since it varies by building and depends on construction drawings, and environmental performance metrics like heat reduction and water retention were not directly measured as the focus was on installation regulations. Despite these limitations, the case study approach allowed for a detailed and targeted analysis of current options, installation methods, and potential improvements.

The methodology of this study was designed to address the specific challenges of analyzing green roofs, a relatively new and underutilized urban feature, within the context of Dhaka city. The researcher provides a grounded and context-sensitive analysis of current installation practices. To achieve this, they combine literature, practical field data, and expert input on the problem. This approach enabled the creation of practical, contextual design guidelines to assist architects, lawmakers, and homeowners. Thus, they can be encouraged to provide environmental-friendly rooftop landscaping.

IV. RESULTS

This study aimed to compare installation methods across various common green roof types by analyzing data from case studies, an online survey, informal interviews, and a literature review. It highlights findings from residential buildings in Dhaka and aims to improve understanding of current practices. The previous chapter described four green roof types based on a pilot survey. Since movable pot plants were not part of the detailed structural assessment, this chapter focuses on three types: extensive, intensive, and extensive with designed intensive plantations. It examines the layers of each type, identifies practical solutions and techniques, notes typical problems, and offers recommendations for improving future green roof construction. The study excludes explicitly detailed calculations of structural loads and plant species analysis, concentrating only on layer thickness comparisons. Green roof installation involves multiple layers, each essential for sustainability and functionality. This review covers the waterproofing layer, insulation, root barrier, protection layer, drainage layer, filter layer, substrate layer, and vegetation layer. Three types of green roofs were studied to analyze each of these elements. The analysis draws on field research, interviews, surveys, and literature to identify both standard practices and variations.

➢ *Waterproofing Layer*

The waterproofing layer is the most crucial one. It prevents water seepage and protects the roof structure from harm. Both membrane sheets and chemical coatings are used for waterproofing in all varieties of green roofs found in Dhaka. Chemical coatings were used more frequently in research for their cost-effectiveness. They were usually used on cast concrete surfaces. However, the professionals surveyed for this study generally supported the use of membrane sheets. They suggested this for its quicker installation, lighter weight, and longer lifespan. Membrane sheets are typically applied in thicknesses ranging from 1.5 mm to 4 mm and are either self-adhesive or require a torch for application. The durability of bitumen and asphalt-based membranes, which have a lifespan of 15–20 years, is another reason why the literature suggests their use. Despite these benefits, green roofs do not use standardized materials. Some do not waterproof the inside of parapet walls, increasing the possibility of leakage (Fig. 7).

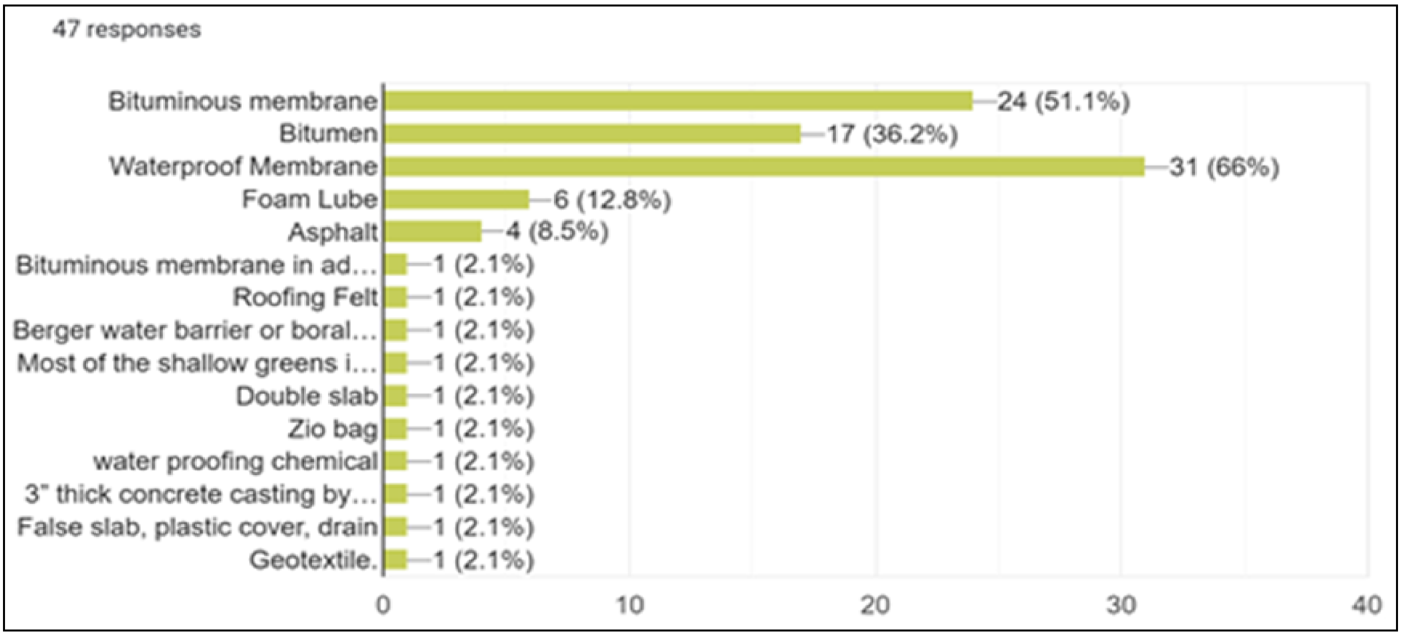

Fig 7 Use of Different Waterproofing Materials.

➢ *Insulation Layers*

The green roofs examined in Dhaka lacked insulation layers. Discussions with experts revealed that such components are deemed unnecessary in Bangladesh's tropical climate. In moderate and dry regions, materials such as polystyrene, Styrofoam, and EPS are often used to enhance energy efficiency and provide waterproofing protection. However, in Dhaka, high costs and limited benefits hinder the widespread adoption of these measures. Some professionals were utterly unaware of insulation materials, and many believe that the green roof system itself provides adequate insulation, making additional layers unnecessary (Fig. 8).

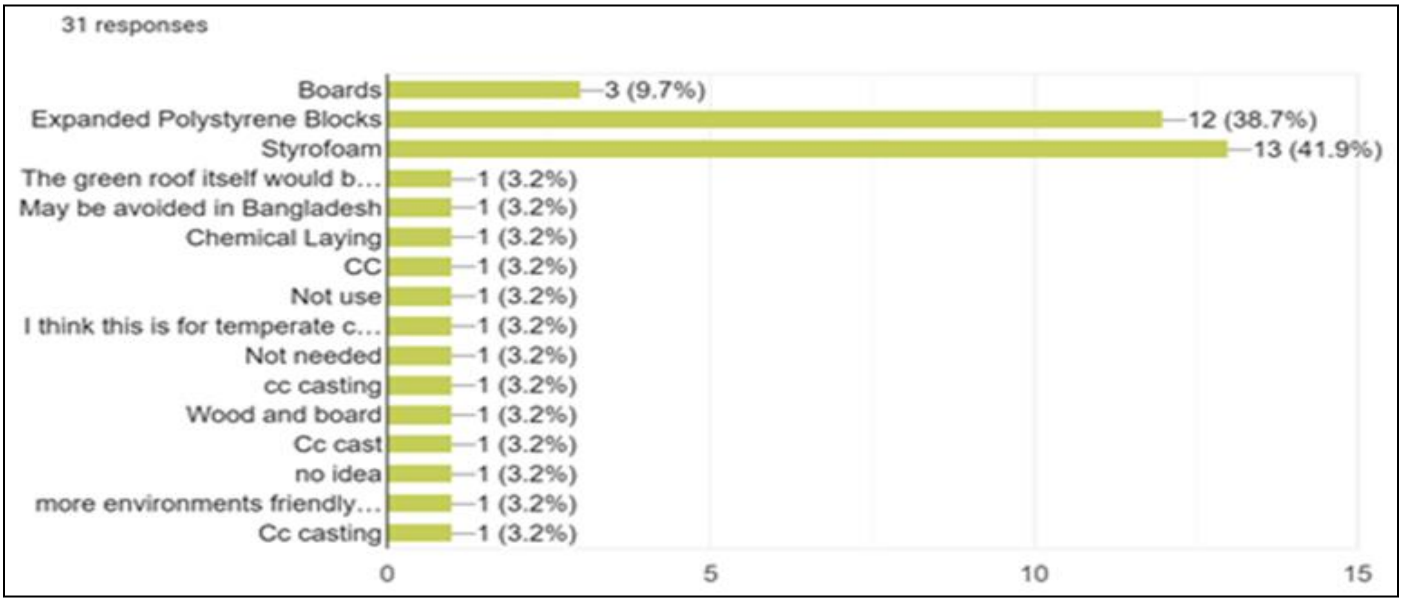

Fig 8 Use of Different Insulation Materials.

➢ *Root Barrier*

The root barrier prevents plant roots from penetrating and damaging the roof's structure and waterproof membrane. In Dhaka, the typical thickness of the root barrier is a 2–4-inch layer of concrete. Polythene sheets or damp proofing courses (DPC) are often placed inside the parapet wall to provide additional protection for the waterproofing. However, instead of treating this layer as a separate component, most green roofs consider it interchangeable with the protective layer. This approach differs from international standards, which specify the use of specialized materials, such as polyethylene membranes, for better performance. Because concrete can crack when roots exert pressure, it is generally discouraged in literature for use as a root barrier. Despite this, concrete is still widely used in Dhaka due to its familiarity and affordability (Fig. 9).

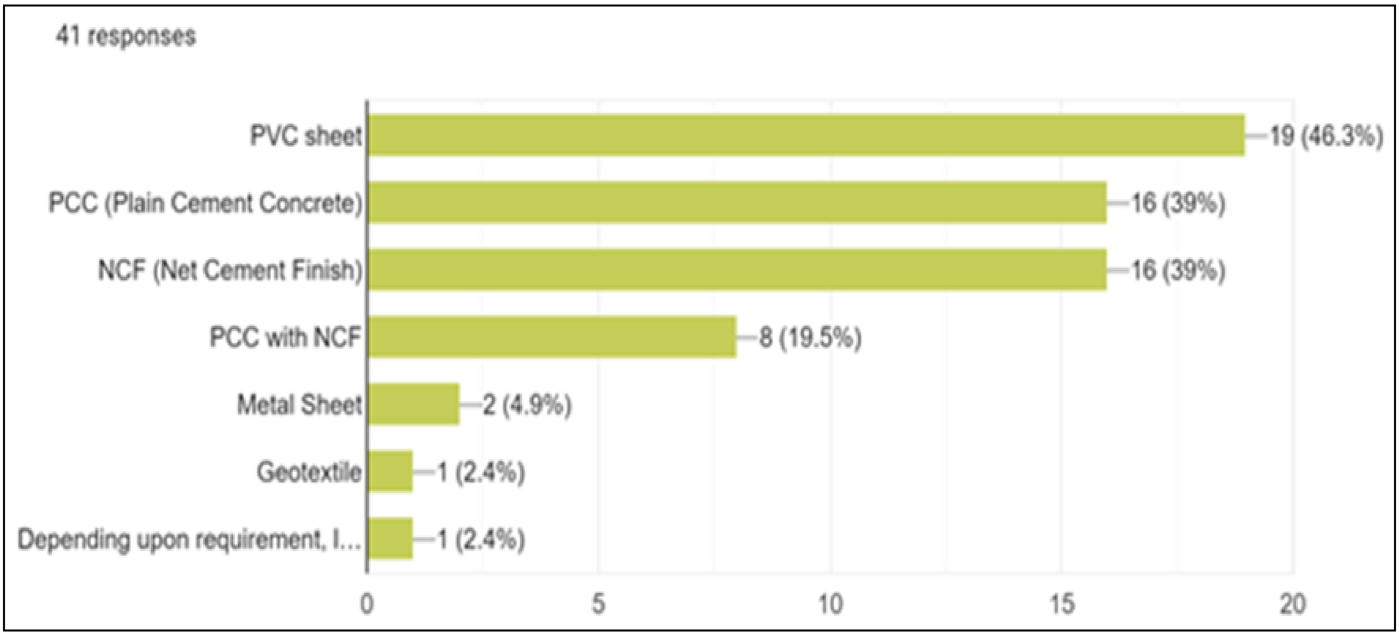

Fig 9 Use of Different Root Barrier Materials.

➢ *Protection Layer*

The protection layer safeguards the waterproofing membrane against mechanical damage, ensuring its longevity. In most green roof studies, this layer is not considered separately; instead, it is positioned adjacent to the root barrier, typically made of concrete, reinforced concrete, or treated with damp-proof chemicals. Some experts and literature suggest using geotextiles or polystyrene sheets because of their lightweight, durable, and flexible properties. However, these materials are not commonly used in Dhaka. When geotextiles are employed, they provide additional filtration and protection, particularly when installed within the parapet wall. Nonetheless, the widespread use of concrete for this layer adds unnecessary weight and complicates long-term maintenance (Fig. 10).

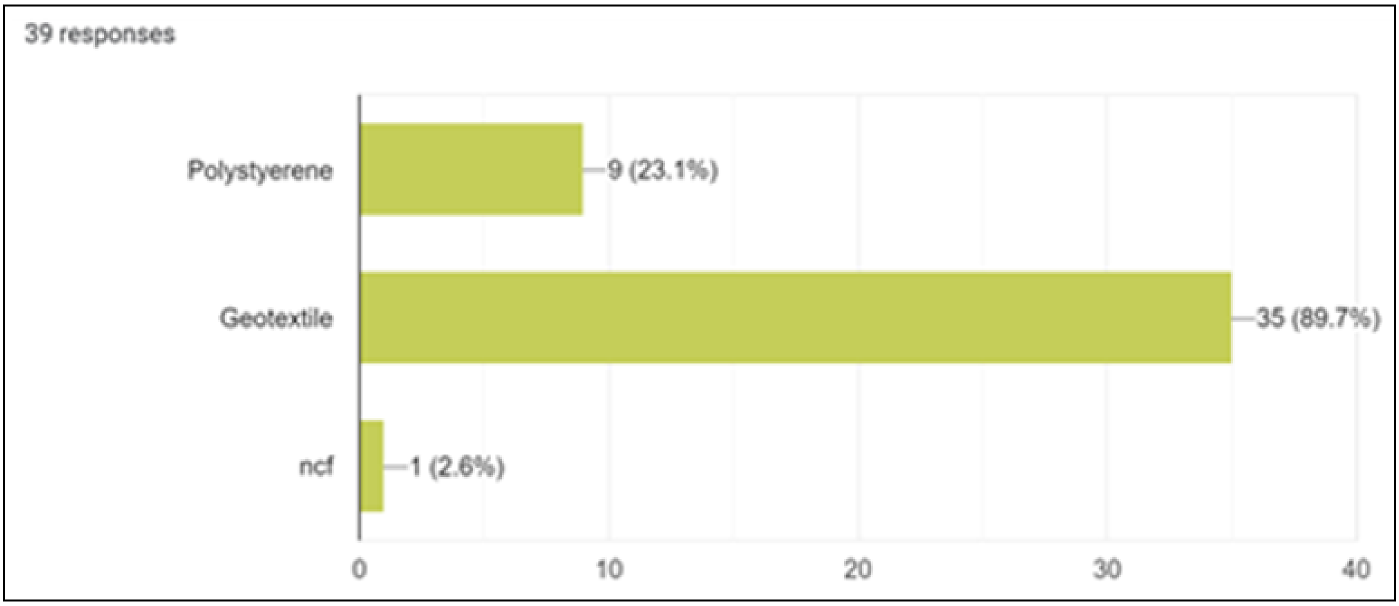

Fig 10 Use of Different Protection Materials

➢ *Drainage Layer*

The drainage layer is crucial for removing excess water from the roof, thereby preventing waterlogging and structural damage. Commonly available and affordable materials such as stone chips, gravel, and brick chips are widely used in Dhaka. To avoid clogging from fine particles, some green roofs incorporate perforated PVC pipes wrapped in geotextile within the drainage layer or use concrete casting. In some instances, plastic egg crates have been employed for drainage because they are lightweight and facilitate better water flow. However, due to their higher cost and limited market availability, these are less common in Dhaka compared to abroad. Overall system efficiency and reliability suffer from a lack of standardized design, particularly in terms of drainage slope and pipe placement, regardless of the material used (Fig. 11).

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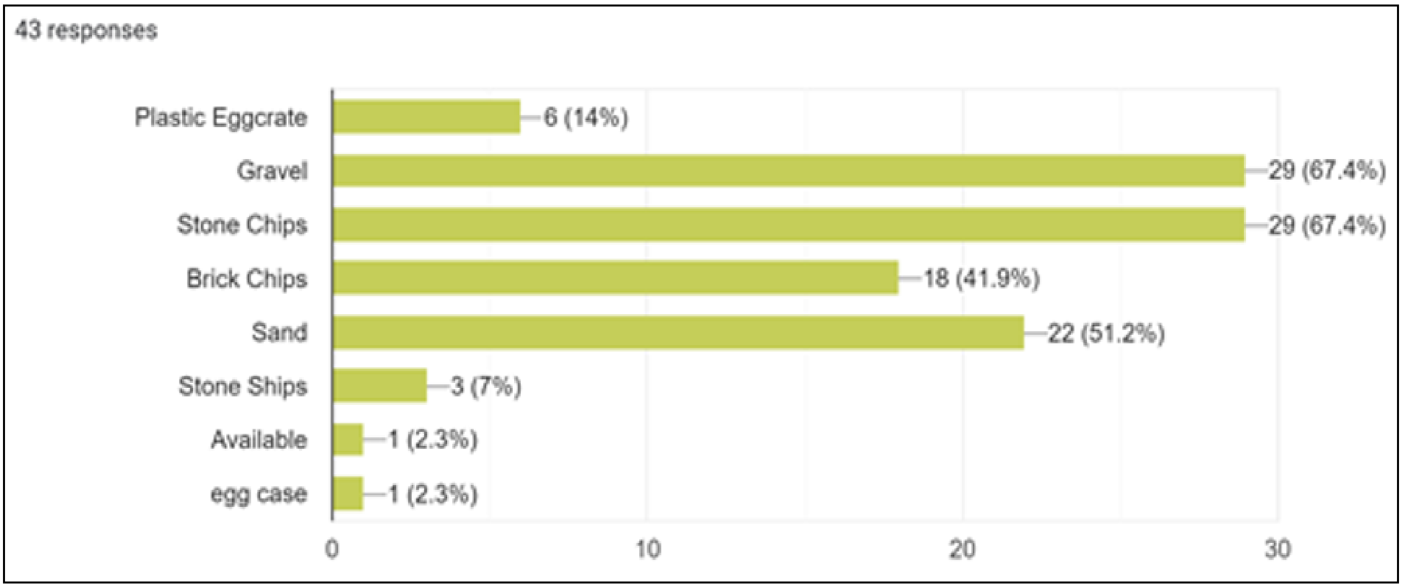

Fig 11 Use of Different Drainage Materials

➢ *Filter Layer*

The filter layer, situated between the substrate and drainage layers, prevents organic matter and soil from clogging the drainage system. It is inexpensive and locally accessible. Sylhet sand is frequently used as a filter material in Dhaka. Geotextile sheets, being lighter, thinner, and offering better filtration, are considered more efficient. However, researchers note that geotextiles are rarely utilized, despite recommendations from experts. When used, geotextiles help control root penetration, improve drainage, and reduce overall layer thickness. Literature supports the use of synthetic materials, such as stone or expanded clay, as alternatives for this layer. Most roofs do not include geotextiles, leading to poor water drainage and increased weight (Fig. 12).

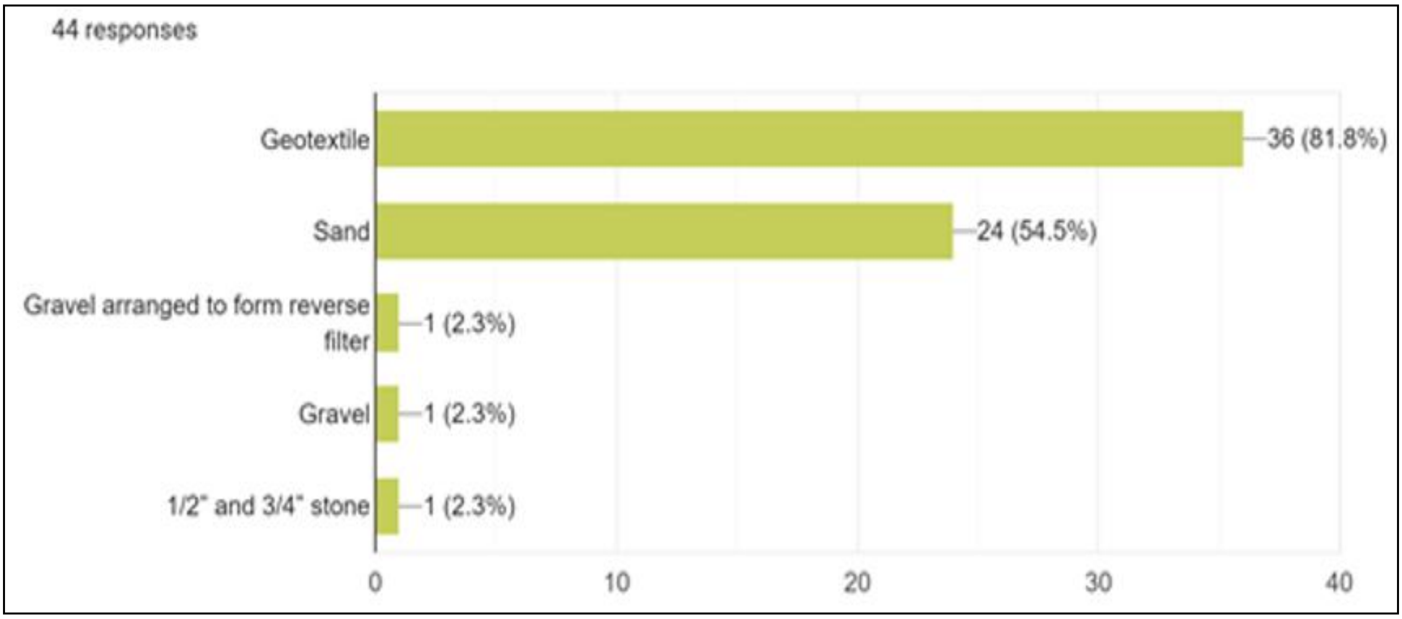

Fig 12 Use of Different Filter Materials.

➢ *Substrate Layer*

The substrate layer is the growing medium that supports plant roots. It must retain moisture while allowing nutrients to be accessible and facilitating drainage. Different types of roofs require varying substrate depths. For large plants, intensive green roofs typically need 12 to 36 inches of soil, while extensive green roofs usually use only 3 to 8 inches. To improve texture and reduce weight, materials like beledoash soil, topsoil, cow dung, and compost are commonly used in Dhaka, often mixed with sand, rice husk, or coco dust. Many experts prefer substrate mixes that conform to standard compositions from local nurseries. Literature recommends a mix of 50% lightweight materials, such as rice husk or coco dust, with 50% organic compost to balance weight and fertility. However, in Dhaka, substrate choices are inconsistent and not always tailored to the specific plant type or roof load (Fig. 13).

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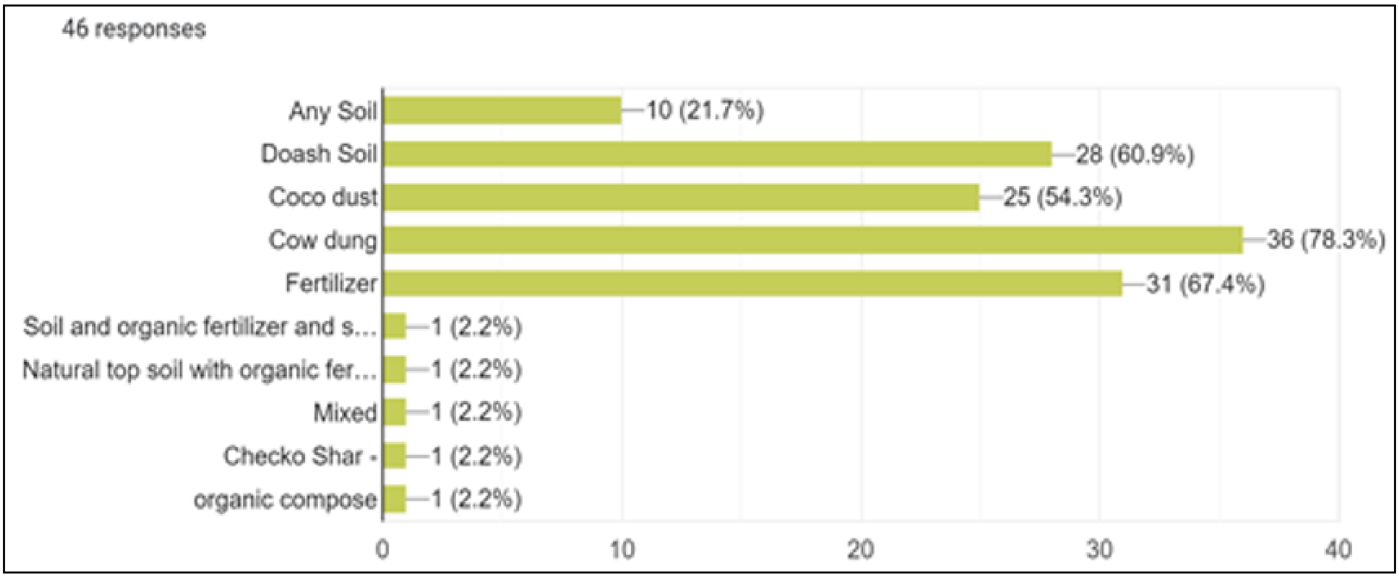

Fig 13 Use of Different Substrate Materials.

➢ *Plants*

Vegetation choices differ significantly based on the roof type. Extensive green roofs, characterized by their thin substrate layers, primarily support grass, herbs, and shallow-rooted plants. These species are suitable for lightweight systems and generally feature fibrous roots. In contrast, intensive roofs can sustain a wider variety of plants, such as fruit trees, shrubs, and flowering plants with deeper taproots, thanks to their thicker substrates. Both plant types are often placed in designed pots, which can be fixed or movable. These pots frequently host flowering and fruiting species, such as roses, guavas, and jamrul. To ensure durability and ease of maintenance, local drought-tolerant species are preferred. Large, unrestrained root plants could potentially damage the green roof system if proper root control measures are not implemented.

➢ *Drainage System*

An effective drainage system is crucial for preventing water damage to green roofs. In Dhaka, most green roofs use perforated PVC pipes embedded in concrete or the drainage layer to collect and reroute excess water. These pipes are generally spaced 4-10 feet apart and are covered with geotextiles to prevent clogging. They often lead to a drainage pit, usually measuring 1'x1', which connects to the central roof drainage system. Some roofs also include elbow joints to allow maintenance access. A few professionals incorporate peripheral drainage channels around the roof to manage runoff from both the green roof and the surrounding hardscape. Movable pots, however, only discharge water onto the roof surface, potentially causing localized retention if they are not located near a drain. Drainage practices vary widely, with slope ratios and pipe placement often based on professional judgment rather than standard design practices. Limited coordination among architects, engineers, and contractors results in inconsistent drainage performance.

➢ *Watering Method*

Watering is essential for healthy vegetation. In Dhaka, the most common approach is manual standing watering, where water is applied directly to plants with hoses or watering cans. This method is popular due to its affordability and ease of use. Some green roofs with lawns utilize sprinkler systems, but these are often discontinued due to poor maintenance. International literature suggests that drip irrigation, capillary watering, or timer-based sprinklers are practical techniques, yet such methods are rarely used in Dhaka. Professionals typically discourage these systems due to the limited capacity of local users and the associated maintenance challenges. Additionally, rainwater harvesting and the use of recycled water for irrigation are uncommon. Most green roofs lack a permanent water connection, relying instead on water drawn from nearby building tanks or wall-mounted faucets. As a result, there is little focus on optimizing efficiency or sustainability in watering methods.

➢ *Comparison of Green Roof Types*

The extensive green roofs are the lightest system among all types because of their thin substrate layer. The range is between 3 to 8 inches, which supports grass, herbs, and small plants. These roofs rely on manual watering and employ conventional drainage methods, utilizing gravel and brick chips at the base. They are suitable for retrofitting onto existing buildings due to their lightweight nature.

Intensive green roofs are heavier and more complex methods compared to extensive green roofs. They need thick substrate layers ranging from 1 to 3 feet in depth. They support large plants, trees, and shrubs. These roofs use similar drainage and waterproofing techniques as extensive roofs. However, for this kind of roof, the load-bearing capacity should be considered. Like extensive roofs, watering is mostly manual despite the potential benefits of automated systems.

This is a hybrid type of green roof system that consists of the lightness of an extensive green roof with the flexibility of intensive plantations in fixed or movable pots. The extensive section has a thin substrate layer with small plants. The pots contain a deeper substrate for larger vegetation.

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Fixed pots share the same drainage system as the roof, while movable pots drain directly onto the main roof. Manual watering is the primary method. This mixed system offers versatility in plant selection, but requires careful design to manage drainage and weight distribution effectively.

➢ *Key Findings*

- All roof types use similar basic layers, with variation in substrate depth and plant types.
- Lack of standards is a significant issue. Most decisions are based on cost or convenience rather than engineering guidelines.
- Drainage and waterproofing are often inadequate or inconsistently installed.
- Coordination among professionals is minimal. Architects, engineers, landscape designers, and contractors often work independently of one another.
- Advanced materials, such as egg crates, geotextiles, and membranes, are underutilized due to cost and limited awareness.
- Mechanical watering and rainwater harvesting are almost absent.

➢ *Major Challenges Identified*

- Material selection is inconsistent.
- Heavy materials (bricks, chips, concrete) are widely used, increasing the structural load.
- Maintenance planning is missing. Especially for drainage and irrigation.
- Drainage slopes and layouts are not standardized.
- Poor systems often ignore proper drainage design, leading to wet surfaces and inefficiency.
- No unified guideline exists for green roof installation in Dhaka.

V. DISCUSSION

In Bangladesh, green roofs are not an entirely new concept. In Dhaka's residential buildings, four main types are observed: extensive, intensive, a combination of both with specially designed intensive planting, and movable potted plants. However, the movable potted plants are not classified as formal green roof systems. Proper planning and layering—including waterproofing, drainage, filtration, substrate, and layout—are essential for green roof installation. This study highlights a key issue: the lack of collaboration among nursery experts, engineers, and architects. This gap often leads to long-term technical failures and installation issues.

Waterproofing is a vital component of the green roof system. Self-adhesive membranes are recommended because they are easy to install, durable, and come in various thicknesses. They typically last over 15 years and are compatible with different roof types. Molten bitumen is cheaper and more readily accessible, but it hardens quickly, lacks durability, and is challenging to work with. Professionals should select membrane thickness based on the type of roof and its design needs. For root barriers and protection layers, many opt for a cement concrete (CC) base covered with Net Cement Finish (NCF). This combination offers good protection, is reasonably priced, and is available locally; however, the CC layer can complicate future maintenance. Softer alternatives may help maintain waterproofing over time and are easier to upkeep. Drainage is usually managed with gravel or a plastic egg crate. While gravel adds weight, it is strong, moisture-retentive, and encourages the growth of larger roots. Gravel of different sizes drains water efficiently and compacts well. Plastic egg-crate is lightweight, ideal for heavy-load roofs, and works best with sufficiently thick substrates, offering excellent water drainage without promoting root growth. Filter materials, such as geotextiles, are essential for separating the substrate from the drainage layer. Geotextiles are lightweight, particle-free, and preferred despite being more costly than sand, as they reduce overall load and are easy to install. Sylhet sand, although affordable and widely available, is heavy and may clog drainage if filtration is poor. Combining sand with geotextiles can mitigate this risk, but it increases cost and weight. Substrate choices depend on the plant type: most plants thrive with a lightweight, moisture-retentive mix of 50:50 compost, soil, and rice husk or coco dust. While this mixture is not suitable for large trees, it minimizes the load. For larger plants or trees, topsoil is recommended due to its strength; however, it should be used cautiously because it increases the structural load. A locally available moisture-retaining material, beledoash mixed with cow manure, works well for grass and small plants. Roofs with extensive green areas typically have a substrate depth of 3 to 8 inches, whereas intensive roofs require a depth of 1 to 3 feet.

Native plants are highly recommended for green roofs in Dhaka because they are well-suited to the local climate and soil conditions and require less maintenance. Using native species also supports better ecological balance, as shown by earlier studies [4]. Small plants, such as grass, herbs, creepers, and climbers, are suitable for both extensive and intensive roofs. These plants do not need thick soil layers and can thrive in varying substrate depths. Grass is beneficial for lawn-type roofs, which are designed for walking or seating. Larger plants, such as shrubs and small trees, are suitable only for intensive green roofs. They enhance aesthetics, offer shade, and can support biodiversity, but they should be limited to a height of up to 20 feet to prevent damage from strong winds. Their roots should be trimmed to manage their height and prevent structural issues. Plants with fibrous roots spread horizontally and are ideal for extensive green roofs since they require less depth. Taproot plants grow vertically and need deeper substrate layers, making them more appropriate for intensive systems. Overall, plant selection should be based on root type, height, structure, and purpose—whether the plant is ornamental, edible, or medicinal.

There are two types of drainage systems identified. In the first, the drainage pipe is placed inside the CC layer. This helps the drainage layer stay above, making it thin and lightweight, which allows for materials like plastic egg crate to be used. However, maintenance is challenging because the CC layer must be broken to fix leaks. This system requires excellent waterproofing to prevent long-term damage. In the second system, the pipe is placed within the drainage layer itself. The pipe is perforated to allow excess water in and can be wrapped with geotextile to prevent soil from clogging the drainage. Since the pipe is not set into concrete, this method is easier to maintain. Elbow pipes with caps are needed for cleaning and overflow control in both systems. To manage water during heavy rainfall, overflow pipes should be installed in areas with minimal vegetation. The central drainage pit, which must be filled with filter material to prevent clogging, should be connected to the entire drainage system.

The most common watering method for residential green roofs is manual or standing watering. It is simple, affordable, and easy to manage. Although sprinkler systems are efficient, they are rarely maintained in Dhaka due to technical and financial limitations. Since rooftops are often in regular use, manual watering is suitable for most buildings. The most versatile green roof system combines extensive green roofs with designed intensive plantings. This setup features a large area for grass or small plants, along with built-in or movable planter boxes for larger plants. Fixed planters can share the central drainage system, reducing installation complexity and costs. Movable pots offer flexibility in plant arrangement and the utilization of rooftop space. This hybrid approach supports a variety of plants, including vegetables, fruits, flowers, and herbs, while also promoting urban biodiversity and aesthetics [29].

Effective coordination among architects, engineers, landscape designers, and nursery specialists is crucial for successful green roof construction, particularly in terms of waterproofing and plant selection. Green roofs should be designed to be as lightweight as possible, utilizing lightweight materials in drainage, filtration, and substrate layers to minimize structural loads and construction costs. Excess weight risks damaging or collapsing building elements. Waterproofing treatments must extend to parapet walls; improper sealing can allow rain or irrigation water to penetrate, causing structural damage. Sealing parapets like waterproof tubs helps prevent this. During the monsoon season, overflow drainage is critical, as drainage systems alone may not be able to manage large water volumes quickly. Open-area overflow pipes can prevent waterlogging. Soil choices depend on the intended use: law-mandated soils should be strong and suitable for walking, while intensive roofs require lightweight soils—materials like coco dust and rice husk aid in weight reduction. Larger plants need stronger soil, though this adds weight, so professional advice is recommended. Plant height should be limited, especially on rooftops, as tall plants are at risk of collapsing under wind if their roots are not adequately managed. Root trimming improves stability and growth control; rooftop plants cannot be treated the same as ground-level ones. Green roofs also support urban farming, enabling cultivation of native fruits, vegetables, and herbs for personal or commercial use, which can cut grocery costs and fund maintenance cost management is crucial: high-end imported materials are often unaffordable, and professionals should prioritize local, durable, and cost-effective alternatives to promote sustainable green roof development.

VI. CONCLUSION

This study offers practical guidelines for implementing green roofs on residential buildings in Dhaka. Although survey limitations due to the pandemic affected the sample size, the recommendations are grounded in field studies, expert interviews, and existing literature. The research emphasizes the importance of selecting the right materials, ensuring proper water drainage, and choosing suitable plants. Collaboration among professionals is crucial to avoiding technical issues and achieving sustainable results. Using lightweight construction, local materials, and native plants are key strategies for creating cost-effective and eco-friendly green roofs. These guidelines can lay the groundwork for future green building initiatives and policy development in Bangladesh.

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