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EXPLORING ROOF STACKING IN EXISTING BUILDINGS TO ACCOMPLISH SUSTAINABLE ARCHITECTURE: A CASE STUDY APPROACH

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ABSTRACT

The global community is currently facing an array of challenges, posing substantial threats to human survival, including environmental degradation, resource depletion, and population growth. The positive impacts outlined in the Agenda 2023 are strategically designed to address these highlighted concerns, recognized as the root causes of numerous challenges. Among these challenges, urban sprawl stands out as a critical issue requiring sustainable solutions. Upgradation in the context of constructing on top of existing structures is more desired sustainable approach to make cities sustainable and resilient. Roof stacking emerges as a preferred sustainable strategy to meet the evolving needs of urban populations. This research is based on exploratory method to find the parameters that makes roof stacking an efficient and sustainable approach. The study reviews previous literature on the roof stacking of historic buildings, establishing a set of standards through content analysis, for evaluating three particular buildings (Irving Street Brewery in Australia, Hearst Tower in United States of Amercia and Fahle House in Estonia) as case studies. The research assessed seven key aspects of sustainable architecture, examined in the article including heritage, technology, materials, services, form, fenestration, and access. The findings demonstrate that all three cases while quite distinct from each other with the blend of old with the new structures in the integration of seven performance parameters in order to achieve sustainable architecture.

Keywords: Sustainability, roof stacking, sustainable architecture, existing buildings, old structures.

INTRODUCTION

A multitude of challenges is converging in the world today, posing a threat to the fundamental existence of mankind. In this context, the Sustainable Development Goals (SDGs) presented by the United Nations are of paramount importance, as they comprehensively address the problems that the world is currently grappling with (Jensen, 2022). The 11th Sustainable Development Goal emphasizes the imperative of making existing cities safe, resilient, and sustainable. It can be deduced that ensuring the sustainability of cities is a pressing need in the current times. Numerous challenges are posed in the endeavor to make existing cities sustainable.

Primarily, one of the issues faced by existing cities is urban sprawl. Ongoing research is dedicated to exploring strategies for achieving sustainable urban densification. Among these strategies, roof stacking stands out as a viable approach to enhance the sustainability and resilience of both cities and buildings (Amer & Attia, 2017). Roof stacking has been proven to reduce energy consumption by 17% (Amer and Attia, 2019).

Secondly, existing cities often have a significant number of old buildings in their inventory (Pitarch et al., 2020). These existing buildings are consuming a significant portion of a country's energy worldwide (Hwang and Tan, 2012). Sustainability cannot be solely achieved through the design and construction of new, greener, and sustainable buildings. The impact of a newly constructed green building on sustainability takes time to materialize. It is estimated that a new building can demonstrate energy savings and its influence on sustainability after a time span of approximately 26 years, as opposed to utilizing existing buildings (Che Husin et al., 2019). The building sector accounts for 40% of global energy consumption. Despite this significant percentage, there are ample opportunities for reducing emissions on a large scale within this sector (Hwang and Tan, 2012). In brief, the sustainable upgrading of existing buildings offers numerous advantages and plays a key role in enhancing the resilience and sustainability of cities. It can be concluded that upgrading old buildings stands as a sustainable approach to making existing cities more resilient and sustainable. To address the growing needs of the population, roof stacking emerges as a sustainable strategy for enhancing existing buildings, presenting a preferable alternative to new construction. Moreover, this method aligns with the principles of resource conservation and urban sustainability, contributing to a more environmentally conscious and adaptive urban landscape.

This research centers on the concept of roof stacking as a sustainable approach for the gradual improvement of existing buildings. Building professionals should prioritize recent data and techniques to make informed decisions, given the heightened awareness about sustainable development, in order to contribute to the overall sustainability of buildings (Hwang and Tan, 2012). As mentioned earlier, the refurbishment or upgrading of energy in existing buildings represents the future of a sustainable building approach, primarily because existing structures constitute a significant portion of the built environment. Roof stacking has been identified as an effective strategy in this context (Knippers and Speck, 2012).

The research concentrates on the factors contributing to roof stacking in existing buildings to achieve sustainability. The study aims to identify various performance parameters that impact the ability to enhance old buildings with sustainable architecture and energy performance. It also explores and investigates sustainable architecture and key aspects that make existing buildings sustainable.

MATERIALS AND METHODS

This study employed an exploratory approach to achieve specific objectives. Furthermore, the methodology adopted is based on a case study grounded in theory. The scope of study involves a literature review as the initial step to identify performance parameters for sustainable upgrading of existing buildings through roof stacking. The research then progresses with an analytical study of three selected cases based on the parameters identified in literature review. The analytical study concludes with an explanation of the amalgamation of new and old features contributing to sustainable upgrading of existing buildings. The research is finalized by identifying key variables that must be considered in sustainable upgrading through roof stacking of existing buildings, adopting an exploratory approach in research.

RESULTS AND DISCUSSIONS

Roof Stacking

Roof stacking is a strategy employed to achieve urban densification and address the growing needs of the urban population. It involves adding additional floors on the rooftops of existing buildings (Amer and Attia, 2017). Roof stacking is not a new concept and has a long history, particularly in European cities. It has now proven to be a sustainable strategy for accommodating people (Amer and Attia, 2019). The significance of additional floors on roofs of existing buildings has increased post-COVID-19. The need for usable space in buildings has evolved in the aftermath of the pandemic, with organizations now requiring new additional floors in offices to facilitate social distancing (Charles Gillott, Buick Davison, 2021). It can be concluded that roof stacking is a sustainable solution in many ways.

Performance Parameters of Roof Stacking to Achieve Sustainability Through Literature Review

Existing literature plays a pivotal role in exploring the diverse factors that need consideration during vertical extension of existing buildings to attain sustainability. Key aspects emphasized include materials, technology, heritage preservation, services, and the seamless integration of old and new elements, with specific attention to form, fenestration, and access. The initial aspect delved into is the adoption of energy-efficient and sustainable technologies for the upgrading of existing buildings (Maclean, 2012). Climate-friendly features such as thermal insulation in roofs and walls, laser, and prismatic panels, owing to their capacity to enhance comfort and energy efficiency, fall under the category of sustainable technologies (Cutler et. al.,2008).

The architectural legacy of any building should be protected while adding extra floors on the roofs of existing buildings (Maclean, 2012).One way is to design new structures with elements, features and structural components that complement old buildings (Busch, 1991). Heritage and sustainability have a strong relationship and go hand in hand due to fact that some buildings and places bear the heritage value beyond their architectural significance.

Material selection is important aspect in achieving sustainability and providing stability to buildings technically (Busch, 1991). Selection of green materials require the qualities of strength, moveable and detachable components (Roth, 2012). Lighter materials are preferred while roof stacking like steel and glass (Peck, 2008).

Services have been identified as a crucial component of sustainable architecture, and it is recommended that architectural divisions should be separated for warmth, venting, and climate control. Moreover, all hydrocarbons must be categorized in accordance with its end use, energy consumption must be at least 90% (Cutler et. al., 2008). Moreover, installation of automatic meter readings is mandatory to evaluate energy performance (Arango, 2011).

Integrating the new structures and components with old ones is a challenge and in most cases, is not achieved in ideal manner (Andreescu et al., 2016). The conjunction is necessary to achieve the optimum relationship between the ancient and new buildings, especially through emphasizing aspects like architectural fenestration, shape, and access. Increased prevalence is the term used to describe how openings, primarily windows and doors, are arranged on a building's façade. Good daylight design greatly benefits from thoughtful fenestration opening orientation or layout (CHPS, 2002). The north facing windows in southern hemisphere are desir able for good daylight and south facing windows require protection from high altitude sun via horizontal overhang. The east and west facing windows are not desired due to low altitude sun (CHPS, 2002).

An integral element of the building-on-top strategy is the structural construct, which appears to be linked to the arrangement or shape of the building (Kwon, 2014). Formwork is considered a fundamental occurrence that imparts meaning to the observer, involving the physical shaping of the surroundings and material objects in people's environments. Morphology focuses on the visual elements of a structure, encompassing features such as brick walls, wooden columns, stained glass windows, stone-paved pathways, copper roofs, and garden designs, among others (Arango, 2011).

Patterns can be constructed by incorporating various elements, such as a window being constituent part of a wall. Building elements like brickwork, porcelain, and gravel, while individually distinct, collectively constitute both entities. Despite their differences, these elements contribute to the overall composition of the patterns.

Connectivity is another important element of architectural

Table-1: Matrix of Aspects Revealed Through Literature Review.

Books	**Key Aspects**						
	Access	**Form**	**Fenestration**	**Heritage**	**Materials**	**Services**	**Technology**
Maclean, A. 2012. *Up on the Roof: New York's Hidden Skyline Spaces*. Priinceton Architectujral Press	●	●	●	●	●		●
Peck, S., 2008. *Award Winning Green Roof Designs*. Schiffer Publishing.	●	●	●				●
Busch, A. 1991. *Rooftop Architecture - The Art of Going Through The Roof*. Henry Holt & Company.	●			●	●		●
Bloszies, C. 2012. *Old Buildings, New Designs*. Princeton Architectural Press.		●		●		●	
Roth, M. 2012. *Roof Architecture and Design*. Braun Publishing				●			●

Journal Articles	Key Aspects						
	Access	**Form**	**Fenestration**	**Heritage**	**Materials**	**Services**	**Technology**
Bose, S and Sarkar, S. 2015. “Top Floors of Low-Rise Modern Residences in Kolkata: Preliminary Exploration towards a Sustainable Solution,” *Current Science*, 109, No 9(2015): 1581-1589.				●	●		●
Hwang, B. G., and Tan, J. S. 2012. “Green building project management: obstacles and solutions for sustainable development,” *Sustainable development*, *20*, 335-349.				●	●		
Knippers, J., and Speck, T. 2012. “Design and construction principles in nature and architecture.” *Bioinspiration and biomimetics*, *7*, No 1, 015002.	●	●	●	●	●		●
Andreescu, I., Gaivoronsch, V., & Mosoarca, M. 2016. “Old and New – the Complex Problem of Integrating New Functions into Old Building,” Procedia Engineering, 161, 1103-1108.						●	●
Cutler, B. et. al., 2008. "Interactive selection of optimal fenestration materials for schematic architectural daylighting design." *Automation in Construction* 17, No. 7: 809-823.	●		●		●	●	●
Kwon C., 2013. “Form or performance in sustainable architecture,” *International Journal of Sustainable Building Technology and Urban Development*, 5, No 1: 21-27		●					
Arango et. al., 2011. “Architectures” *Journal of Information Architecture*, 3, No 1: 41-47		●		●	●		●
CHPS Best Practices Manual. 2002. “Day-lighting: Day Light and Fenestration Design.”	●	●	●	●	●	●	●

sustainability (Peck, 2008). The incorporation of accessible technology that improves disabled people's usage of buildings is emphasized (Roth, 2012). By removing obstacles like uneven or slippery surfaces, steep hills, and heavy doors, access solutions should also make it possible for people to get where they need to go quickly (Peck, 2008). The inclusion of these publications helps to provide a wider perspective on sustainable architecture because it highlights additional crucial building components that are important for realizing sustainable design.

The following matrix illustrates the breadth of the literature examined in order to identify important aspects related to building on top / roof stacking of already-existing structures. The first step of the data collection ends with the establishment of criteria to assess the 3 selected cases.

Case Studies: Introduction

In this section, the three selected buildings are assessed based on the criteria established in section B. Their reason for selection is that these are projects of renowned architects and acknowledged among the world's most sustainable structures in relation to roof stacking. In order to accomplish architecture integrity, three cases have been critically analyzed in this section using roof stacking. (See table 2 for construction details of three cases)

Table 2 is showing the basic information about the 3 selected buildings. Irving Street Brewery is a project upgraded by Tzannes Associates in 2015 by building a trigeneration power plant on the roof top. The original brewery building was developed by Tooth & Company in 1900. It provides an illustration of how a heritage-listed building can be transformed into a hydroelectric plant (Dunn, 2015; Wilkinson, 2019).

The Hearst Tower is acknowledged as a first sustainable building in New York City in 2006 and was awarded LEED Gold certification the same year. The project was conceived by Norman Foster. The steel and glass structure were constructed on the top of an original brick masonry building designed by Joseph Urban in 1928. This building on roof top approach makes it the first green and sustainable office building in the city (Partners, 2012).

Fahle House received attention because of its multiple challenges like risk factor from real estate point and controversy generated from point of heritage conservation. It was originally developed by Architect Erich Jacoby as a voluminous boiler house in 1926. The Fahle House complex encompasses a six floor apartment on the roof top of an old limestone building and makes it a perfect example of roof stacking (Architects, 2016).

Comparative Analysis of features of the three cases

Table 3 is showing a comparison among the 3 selected cases in terms of performance parameters of sustainable development identified after literature review in section B. The results are discussed according to afore mentioned parameters in table 3 one by one and all the 3 cases are discussed as under.

Heritage

The cultural values are transferred to future generation through physical artefacts and heritage buildings in a society (Knippers and Speck, 2012). The Irving Street building represents the marvelous example of heritage conservation adopting the roof stacking strategy and extends the old building in vertical direction. This project comes under adaptive reuse. Efforts have been made to amalgamate trigeneration plant over the roof of the original brewery buildings (Figure-1).

Table-2: Information on Case Studies.

Case Studies	Location	Date of the Host Building	Date of Addition on Top	Building on Top	Architect Associated with Addition on Top
Irving Street Brewery	Sydney Australia	Designed by Maurice Halligan and F. H. B. Wilton in 1900 and Constructed on 1910	Completed in 2015	Power Plant	Tzannes Associates
Hearst Tower	New York, U.S.A.	Constructed in 1928 by Architect Joseph Urban	Construction began in 2003 and ended in 2006	Offices	Norman Foster
Fahle House	Tallinn, Estonia	Constructed in 1926 by Architect Erich Jacoby	Completed in 2007	Apartments	KOKO Architects

Table-3: Common and Different Features of the Three Cases.

Elements	Irving Street Brewery	Hearst Towers	Fahle House
Heritage	Protects heritage	Protects heritage	Protects heritage
Technology	Employs recent technologies	Employs recent technologies	Employs recent technologies
Materials	Employs steel	Employs steel and glass	Employs glass
Services	Offers energy efficient services	Offers energy efficient services	Offers a range of services such as offices, restaurants etc.
Form	Diagrid form	Conical form	Cubic form
Fenestration	Horizontal fenestration	Vertically located concave glass windows	North-side facing windows
Access	Offers access from bridge	Offers access from escalators	Offers access from staircase

The designers of Hearst Tower depict the excellence in the preservation of heritage through the addition of space and light. The elegant tower of steel and glass rests on the roof top of original stone building making this project an example of sustainable conservation of heritage value. The original façade look is preserved and newer addition as roof stacking has been balanced with old one (Figure-2).

The 3rd case of Fahle House also contributes in preservation of old factory building by conserving the historic interior and surfaces of walls and floors where possible. This project further represents roof stacking as a sustainable strategy by establishing a six-story apartment building on top of the old steam generator (Figure-3).

Technology

The energy design of any building is very important and if designed carefully, can contribute to buildings' sustainability. The optimal internal environment can be created by employing renewable energy system (Knippers and Speck, 2012). An inner-city mixed-use neighborhood benefits with use of Irwing Brewery Buildings through its efficient technology for hot and cold water supply. Similarly, Hearst Tower has attained a 40% reduction in total energy

Figure-1: Irving Street Brewery.
Source: http://architectureau.com/articles/irving-street-brewery/

Figure-2: Hearts Tower.
Source: https://www.skyscrapercenter.com/building/hearst-tower/2245

Figure-3: Fahle House.
Source: https://www.archdaily.com/780385/fahle-house-koko/569874d4e58ece22610000b5-fahle-house-koko-image?next_project=no

consumption through different energy saving mechanisms, making it a unique case in terms of sustainable upgradation. Fahle's house does not achieve reduction in energy consumption as compared to the level of the other 2 cases. The requirement of artificial light is reduced by introducing the glass block on the upper floor of the new construction to receive ample daylight.

Materials

The use of ecological and recycled materials is very significant in attainment of sustainable architecture. Materials not onlycontribute to durability of a structure but are also vital to achieving sustainability (Hwang and Tan, 2012). The Irving Street Brewery Building has been upgraded by roof stacking with the addition of floors made of external metal mesh. In this regard, refurbishment of building considered the use of ecological light weight material (Figure-4).

The Hearst Tower has incorporated steel in the roof construction to incorporate the light weight characteristic of the material. This proved a sustainable strategy in its upgradation. The Hearst Tower uses four-story triangular frameworks, as opposed to the traditional steel beams found on many skyscrapers (Figure-5).

The Fahle building also exemplifies the efficient use of environmentally friendly materials in the pursuit of sustainable architecture. The structure is built on limestone wall and integrates glass in the construction of the upper component. The employment of glass on the upper part serves to reduce extra weight and loads, and allow penetration of natural light into the building (Figure-6).

Figure-4: Integration of Materials.
Source: https://www.meinhardt.com.au/news/irving-street-brewery-up-for-aia-nsw-award/

Figure-5: Use of Steel in Hearst Tower.
Source: https://www.fosterandpartners.com/projects/hearst-headquarters

Figure-6: Integration of Limestone Wall and Glass.
Source: https://www.kaidohaagen.com/photo_17316879.html

Figure-7: Access to Power Plant.
Source: https://www.architectural-review.com/buildings/irving-street-brewery-plant-in-sydney-australia-by-tzannes

Services

Hearst Tower has achieved 26% reduction in total energy consumption than traditional construction due to employment of sustainable and efficient services like rain water collection system at the roof top to collect 1.7 million water gallons every year and the sensor adjusted artificial lighting system that adjusts with available daylight. In terms of services, Fahle House offers more services due to alteration in the plant interior for re arrangement of rooms. The services and offices are located in the old building.

Form

The expanded metal mesh fabric that covers the cooling towers creates a striking visual contrast between the old and new. The somewhat homogeneous fabric that envelops high-rise residential slabs and towers stands in stark remembered contrast to these wonderfully comprehensive forms. The cooling towers at Irving Street Brewery, which are perched atop the historic building, exhibit the building's distinctive architectural form. For instance, the tri-generation cooling towers employed in the renovated structure are its most distinctive feature. The zinc-mesh covering these six curving cooling towers was made specifically for them. The mesh's transparency is constrained to increase the form's solidity and provide permeability for cooling the towers.

Fenestration

Irving Brewery Street building bear clear glass fenestration in horizontal strip having horizontal louvers responsible for large amount of daylight avoiding glare. The Hearst Tower unlike Irving Street Building is composed of massive vertical windows having concave glass. This design admits large amount of daylight avoiding glare and also provide beautiful views of downtown. Fahle House has provision of good fenestration design with respect to daylight. Most of its windows are in the glass faced structure on the roof top of old boiler house and north oriented windows provide good daylight. It can be concluded that all the 3 cases are upgraded considering good quality daylight while designing windows.

Access

The Irving Brewery Street building has a unique feature as far as access to structure at top is concerned. The tri generation tower over the roof is accessed by a bridge (Figure-7).

The Hearst Tower offers a unique access inside the building. A welcoming lobby at the base of Tower which rises up to six floors in the form of atrium provides access to all parts of tower like a city inside (Figure-8).

In case of Fahle House, the building has 2 entrances. One is facing Tartu Highway and the second is opposite to the first entrance which is 2 minutes away from a bus station.

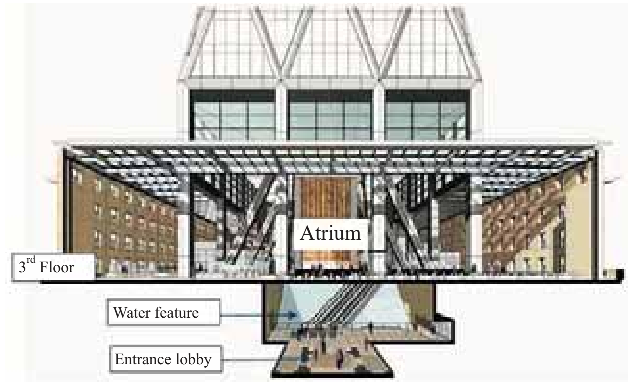

Figure-8: Sectional Perspective.
Source: https://www.archdaily.com/204701/flashback-hearst-tower-foster-and-partners/5038269e28ba0d599b00110a-flashback-hearst-tower-foster-and-partners-image?next_project=no

CONCLUSION

The study effectively explored roof stacking strategy of existing buildings as a sustainable approach, identifying the performance matrix when upgrading existing buildings. The three selected building projects (Irving Street Brewery in Australia, Hearst Tower in United States of Amercia and Fahle House in Estonia) underscore the significance of roof stacking in old buildings to achieve an ecological environment. The attainment of sustainable architecture in the selected buildings is evident through the application of seven performance parameters: Heritage, Technology, Materials, Services, Form, Fenestration, and Access. These case study buildings have effectively achieved sustainable architecture by seamlessly integrating new constructions with existing structures with the consideration of seven performance parameters.

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