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Energy Savings Due to Passive Strategies in Contemporary High-rise Residential Buildings Hot and Dry Climate

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Abstract

Globally, the development of sustainable design techniques is becoming imperative, particularly with the idea of high-rise structures to keep up with the rapidly expanding cities. Approaching design sustainably by developing various sustainable methods is becoming necessary worldwide. Strategies for passive design may be useful in achieving the social, economic, and environmental goals of sustainability. This paper discusses the importance of passive design strategies in high-rise buildings, particularly in the context of hot and dry climates, to reduce the energy consumption and environmental impact of buildings. The paper presents a literature review of studies that demonstrate the effectiveness of passive design strategies in high-rise apartments and mixed-use buildings. The first study examines an integrated passive design approach to improve the thermal performance of the building envelope for high-rise apartments in Hong Kong. The second study proposes a new approach to passive design strategies based on the traditional courtyard architecture in arid climates and investigates the potential of sky courts in high-rise buildings to reduce energy consumption. This paper aims to highlight the need for advanced green building simulation software to test various passive design strategies in high-rise residential buildings of hot and dry climates to achieve sustainability.

Keywords: High-rise residential buildings, passive design, hot and dry climate, contemporary passive design, sustainability

INTRODUCTION

The AEC industry is increasingly recognized as a major contributor in our globalizing world, it dominates the world economy, climate, and global trends. For example, 40% of raw materials are used in building construction globally yearly, and around 30–40% of a nation's energy input is used in buildings [1]. Increasing population and living standards are leading to energy issues because of a possible energy shortage in the future. The World Watch Institute estimated that buildings around the globe consume at least 40% of the world's energy and 16% of the water used annually. Therefore, recent significant advancements in a number of areas, including transportation, the commercial, industrial, and residential sectors, have raised concerns about the rise of energy in emerging nations [1]. The large-scale consumption of energy in buildings for heaters and air-conditioner systems

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for room temperature control poses a huge problem [2]. Attempts are undertaken globally to minimise the demand on heating and cooling systems on various sizes, depending on the obstacles encountered. It is imperative to note that in these aspects fire safety is of utmost importance, especially in summer seasons [3, 4]. In the design and construction domain, researchers have lately deemed bioclimatic design, the use of renewable energy, and passive design techniques like well-thought-out building envelopes to be the primary means of reducing environmental load.

Among the clever techniques to create a suitable interior temperature in high-rise structures are appropriate shading, particularly for apertures, building orientation, vegetation around buildings, and appropriate materials for the façade. Shading devices are regarded as important components of building façades because they prevent heat from entering glass windows, which reduces the possibility of overheating [4]. In order to handle this circumstance, it is crucial to think about utilizing a variety of building envelope design configurations and assemblies [5].

Aim

Identify various passive design strategies in high-rise residential buildings of hot and dry climate.

Objectives

- Identify existing passive design strategies for high-rise buildings in hot and dry through a comprehensive literature review.
- Identify key passive deign strategies that can be applied in high-rise residential buildings in hot and dry climates.

Research Questions

- What is the impact of passive strategies incorporated in building envelope of high-rise residential buildings?
- How software simulations help in improving the design of passive strategies?

LITERATURE STUDY

The literature looks into various aspects of energy saving through passive strategies in contemporary high-rise residential buildings by taking the case of various research papers. In the literature primarily the building envelope components along with the sky courts as a building design feature for the high-rise buildings of the future.

The climate significantly affects the performance of a building and has an impact on design decisions. The impact of the building's total energy performance is directed towards the technological and architectural solutions that influence performance.

Building Envelope Components

The building envelopes provide the functional purpose of physically dividing the inside of the structure from the surrounding surroundings. (Figure 1) Because of the physical characteristics of thermos, indoor thermal comfort, and energy savings are all impacted by the building envelope. They are subjected to variations in humidity, airflow, temperature, rain, sun exposure, and other environmental elements. The building envelope systems are mainly divided into two systems: the transparent and opaque systems. Elements like walls, roofs, floors, and insulation are part of opaque systems and windows, skylights, and glass doors are part of transparent systems.

The transfer of heat and mass takes place through various methods in the buildings. For transparent systems, solar radiation and conduction via window glazing. Conduction via the outside walls, roof, floor slabs, partitions, and ceiling of an opaque system. Dissipation of heat and moisture from interior materials, equipment, illumination, and occupants. Heating/cooling and humidification or dehumidification through HVAC systems.

Further discussing about the natural ventilation through building envelops lowers energy consumption, reduces greenhouse gas emissions, and improved thermal comfort and indoor air quality. Various design strategies and techniques, including the use of double skin facades and proper placement and sizing of openings. Building form has a significant impact on thermal comfort and energy usage [6]. Building strategies like roof design and permeable walls, shade verandahs, courtyards, and plan orientation can reduce solar radiation. Shape of the building can affect energy consumption, daylighting, and air movement, and research on high-rise buildings suggests that increasing height can improve outdoor ventilation. The optimal building shape for hot and humid regions is found to have a length-to-width ratio between 1:1.7 and 1:3, with 1:1.7 being the most suitable.

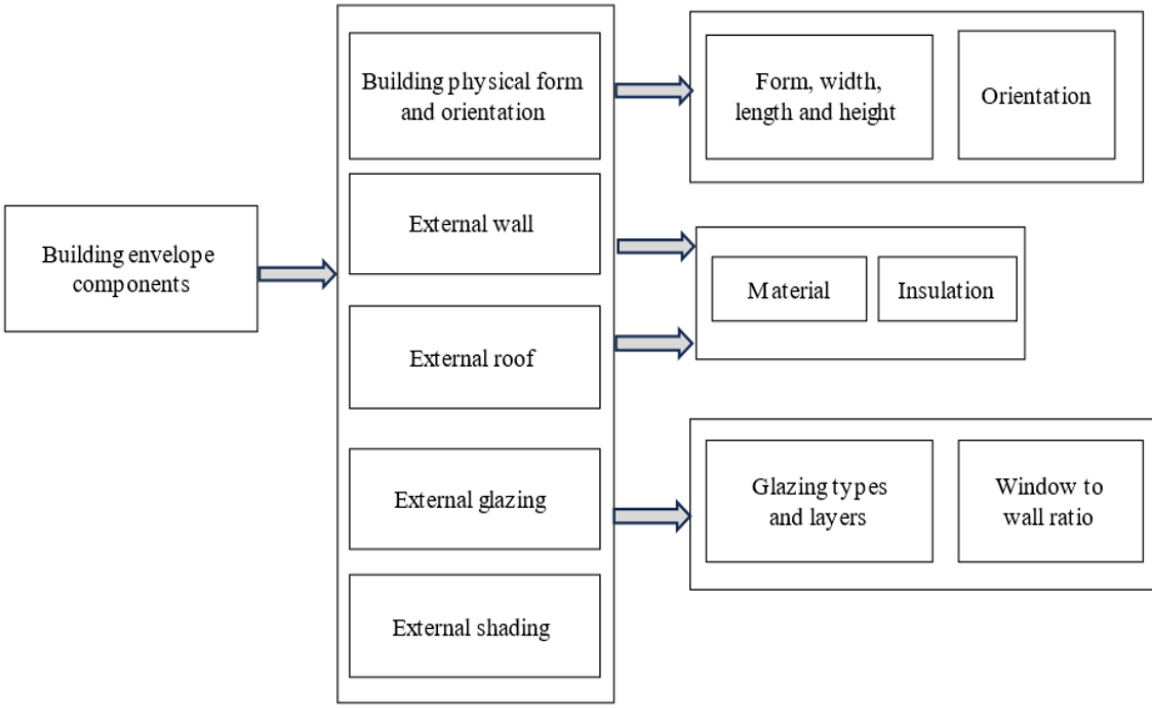

Figure 1. Building envelope components in architecture (Mirrahimi et al., 2016).

Building walls play a crucial role in providing thermal and acoustic comfort while maintaining the building's aesthetic appeal. The wall design can enable passive control of indoor conditions by regulating the transfer of outdoor temperature. Today's buildings require high thermal inertia to maintain stable temperature and relative humidity despite changing external conditions [7].

In hot and muggy conditions, controlling thermal comfort and energy efficiency in high-rise structures depends heavily on the building envelope. The impact of building envelope components on indoor air temperature reveals a strong relationship between various components and energy consumption reduction. Building shape also significantly affects energy usage. Passive design strategies can achieve tremendous energy savings, but the overall thermal performance of building envelope components must be considered, including optimal window-to-wall area, appropriate glazed window materials, and shading devices, to reduce reliance on mechanical systems.

Courtyards to Sky Courts

The modern city is defined by high-rise buildings or towers, which can accommodate a large population while conserving land and energy. High-rise buildings have the potential to achieve sustainable benefits, economically, environmentally and socially. However, their construction and operation require huge amounts of energy and materials, resulting in high costs and environmental

impacts. To achieve more energy-efficient buildings, a new balance is required between sustainability and function, considering environmental factors to reduce building energy demand [8]. Reintroducing passive heating and cooling techniques, such as sky courts, can improve the environmental and economic impacts of high-rise buildings.

Passive design focuses on maximizing the use of natural resources such as light and ventilation to enhance the comfort of building occupants and reduce energy consumption. Courtyards have been identified as a key passive design element that can help to maintain indoor thermal comfort through controlled natural ventilation. However, while much research has been done on the use of courtyards in low and medium-rise buildings, less attention has been paid to their use in high-rise buildings.

Skycourts are a relatively new concept that has been proposed as a way of incorporating the benefits of courtyards into high-rise buildings. Skycourts are essentially recreational social spaces located at the pinnacle of tall buildings and can provide users with opportunities for social interaction, as well as memorable skylines and panoramic views. Skycourts can also help to create a socio-environmental balance within high-rise buildings, by forming a hierarchical network of open spaces that complement existing open spaces at ground level. Although sky courts have been identified as having significant social, environmental, and economic benefits, little research has been done on their efficiency as a passive design element in high-rise buildings, and little information is available on the impacts of skycourt geometry in different climate regions.

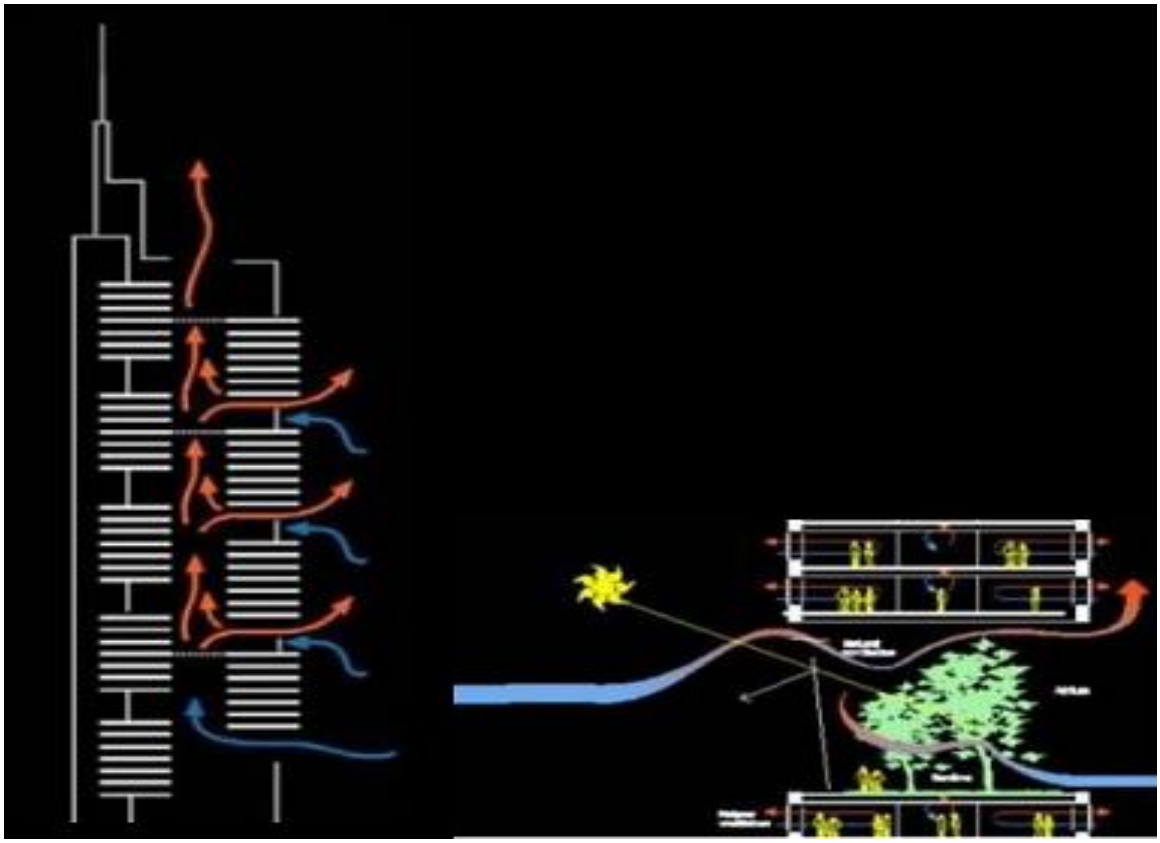

Figure 2. Sections showing the natural ventilation strategy adapted through the Skycourt in Commerzbank headquarters Frankfurt, germany (fosters + partners n.d. 1997).

Further, (Figure 2) Skycourts can provide a medium for different levels of interaction, fostering a sense of community and promoting community life, which enhances psychological comfort. Greenery in sky courts can also improve the health and well-being of occupants, as it has been found to reduce stress, physical pain, and cholesterol levels. Skycourts can also act as environmental filters, allowing

daylight and fresh air to penetrate the interior of high-rise buildings while avoiding direct solar gain. This potential of sky courts positively impacts the environment by acting as a thermal, light, and acoustic buffer/filter. Greenery in sky courts can lower the temperature of its surroundings and improve air quality. Sky courts may also reduce the impact of solar radiation and glare, acting as acoustic buffers between spaces, and have the potential to separate spaces [9].

CONCLUSIONS

In conclusion various passive strategies can be incorporated in the context of Hot and Dry climates. Discussing sky courtyards, Skycourts can improve the metropolitan environment from a social, environmental, and economic standpoint. Together with building a feeling of community, a secure location for interaction and enjoyment, and more ecologically friendly settings, it has the ability to significantly reduce energy usage and generate cash. Skycourts can be included in an architectural plan to utilize solar energy and airflow to heat, cool, and illuminate the structure. This has a significant potential to save energy and enhance the residents' health and quality of life. To sum up, this notion has two main effects. The first is that high-rise buildings' sky courts may serve the same purpose as traditional courtyards. The sky court could qualify as a passive cooling method, which brings us to our second point. On the other hand, the building envelope is the most crucial design element to control thermal comfort. It is crucial because it affects the energy efficiency for high rise buildings. According to studies, there is a substantial correlation between the decrease of energy consumption and cooling in buildings and different architectural components such shading devices, external walls, external roofs, external glass, and insulation. Additionally, a building's design, including its length, breadth, and height, has a big impact on how much energy it uses. Studies have also demonstrated significant reductions in highrise buildings' energy use when adopting passive design techniques.

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