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A Study of Efficiency of Natural Ventilation Strategies in a Library Building

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ABSTRACT: The control and design consideration of ventilation is the most subtle yet important concern in building design. A natural ventilation cooling strategy has the potential to serve as the main source of fresh air for a building. Further, natural ventilation is considered to contribute to improving the thermal comfort in buildings. Library buildings are an integral part of a community and academic campus that offers interaction and pursuit of knowledge. Therefore, a well-designed and efficient natural ventilation system is mandatory for the visitors and workers of a library. As a result of advancement and awakening in implementing and considering sustainability in building design, the importance of maintaining desirable indoor air quality and thermal comfort has been increasingly recognized. As a consequence of poor ventilation strategies implemented in libraries, there has been excessive use of air-conditioning which led to high energy consumption and poor indoor air quality. The research tends to understand the impact of the natural ventilation strategies and the related variables on passive cooling in the case of a library building. Since the major factors that affect ventilation are the orientation of the building, external features, position, and size of openings, this paper will also review the effect of orientation and efficiency of ventilation strategies on the passive cooling of a library that is a necessary attribution towards maintaining good indoor environment quality and subsequently sustainability. The study aims to identify the roles and requirements which contribute to efficient passive cooling.

KEYWORDS: Natural Ventilation, Library, Passive Cooling, Thermal Comfort, Indoor Air Quality, Sustainability.

INTRODUCTION

A library is a facility that provides knowledge and information that facilitates and encourages the reading and researching culture in the community and among students. They house the main resources for wider understanding and learning perspective in the form of books or other advanced technological material made available for users. Furthermore, the comfort of the occupants and the maintenance of optimum airflow is an important aspect that is required to be considered for a library. The users or visitors of a library require an optimum amount of light for visual comfort for a comfortable reading experience. In addition, the circulation of fresh air provided through openings and clean air ducts is required for the well-being of the library building as well as the occupants. (Jackson, 2021) have underlined issues related to the ventilation in the buildings with respect to the modern design concepts and contemporary architecture.

Furthermore, (Emmerich, et al., 2001) by highlighting the issues and parameters that influences the natural ventilation systems of the buildings including the factors affecting the comfort of the building occupants. A well-ventilated library that allows an effective exchange of indoor air with fresh outdoor air provides fresh air movement and cooling. As a result, it eliminates the recirculation of air that carries bacteria and other harmful microbes in the absence of exchange of indoor air with outdoor air. A properly designed and well-functioning ventilation strategy can also reduce the energy consumption of the building by minimizing the use of mechanical ventilation and power lighting (Basu et al., 2019, 2017; Seshadhri & Paul, 2018).

VENTILATION STRATEGIES

The basic definition of ventilation is the movement of air within the interior of a building and between the building and outdoors. The ventilation strategies can be generally categorized into stack-ventilation type, cross ventilation type, and single-sided ventilation type. The cause or motive force for ventilation stated by (Sinden, 1977) are 1) wind (dynamic) and 2) convection induced by a temperature difference between indoors and outdoors (thermal). The stack-ventilation strategy relies on thermal forces, caused by temperature differences between the indoor and outdoor air. Therefore, a higher shaft will ultimately result in a larger cross-sectional area with a greater temperature difference that means more air movement will be available with a greater motive force. (Jackson, 2021) stated that stack ventilation is effective in deeper plan spaces by making use of the central lobby to draw air from the outside and up through the center of the building.

(El-nafaty, et al., 2018) noted that poor natural ventilation in library buildings results in excessive energy consumption through mechanical ventilation. (Jackson, 2021; Altaş & Özsoy, 1998; Basu et al., 2019; Sinha & Rastogi, 2017) underlined that the increasing energy consumption of the building sector contributes significantly to global warming due to greenhouse gas emissions. (Lomas, 2006) noted that the implementation of stack ventilation for buildings with deeper plans can improve the use of natural light reducing the CO_2 emission associated with artificial lighting.

Stack ventilation

Stack-ventilation is also termed buoyancy-driven stack-ventilation. The stack effect is more effective and greater when there is a greater temperature difference between the indoor and outdoor. (Emmerich, et al., 2001) noted that even the smallest wind will induce pressure distributions on the building envelope that will also act to drive airflow.

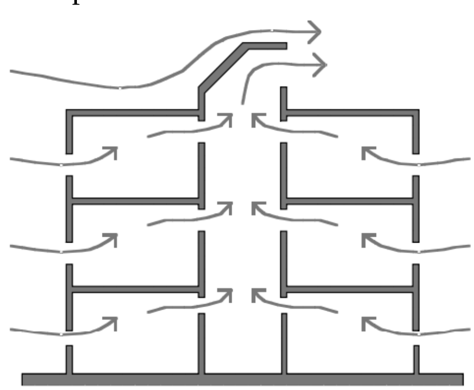

Figure 1: Buoyancy-driven stack-ventilation; Source: (Emmerich, et al., 2001)

In this context (Lomas, 2006) highlighted the influence of design and constraints which affects the performance of the stack ventilation wherein it is essential to incorporate the design features pertaining to the ventilation of the shafts according to the overall design of the building which may improve the quality of built environment. The important affecting factors of ventilation systems also have the impact on the overall cost inculcated for implementing the ventilation systems as per the requirement. In addition, it was also stated that wind effects may well be more important than buoyancy effects in stack-ventilation schemes, thus the successful design will seek ways to make full advantage of both.

Cross ventilation

In a cross-ventilation scheme, inlets and outlets are provided typically of windows to promote the flow of air through a building. Lack of cross ventilation refuses an effective air movement through a building since there is an absence of an outlet opening. (Emmerich, et al., 2001) noted that a significant difference in wind pressure between the inlet and outlet openings and minimal internal resistance to flow is needed to ensure sufficient ventilation flow.

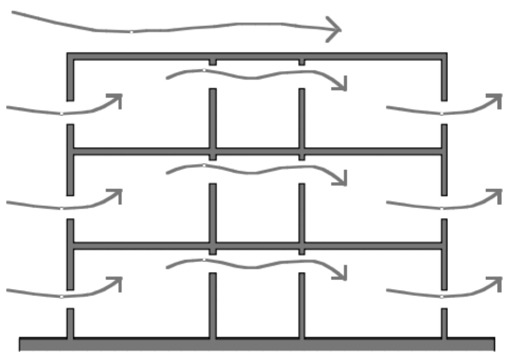

Figure 2: Cross-ventilation; Source: (Emmerich, et al., 2001)

Single-sided ventilation

A single-sided ventilation scheme consists of an opening on one side of a wall in a room of a building. It is effective for single rooms where openings are provided at different heights on the wall. (Emmerich, et al., 2001) noted that ventilation airflow in such a case is driven by room-scale buoyancy effects, small differences in envelope wind pressures, and/or turbulence. Consequently, it has been noted that the driving forces for single-sided ventilation tend to be relatively small and highly variable.

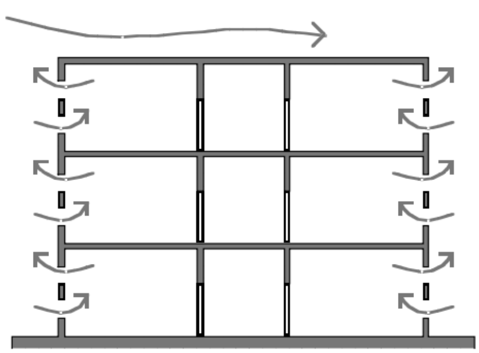

Figure 3: Single-sided ventilation; Source: (Emmerich, et al., 2001)

VENTILATION AND DESIGN

In terms of efficiency, (Jackson, 2021) stated that cross ventilation is the most effective means of natural ventilation for buildings with not more than 12–15-meter depth where the air is allowed to pass from one side of the building to the other. It was also stated that windows should permit simplicity of control by building occupants and controlled ventilation that will not cause draughts. (Emmerich, et al., 2001) noted that single-sided ventilation offers the least attractive natural ventilation solution but, nevertheless, a solution that can serve individual offices. According to (El-nafaty, et al., 2018) the ventilation strategies including the above-mentioned types of ventilation are significant for the overall ventilation system in a library building, wherein the maintenance and upkeep of the shafts also have a particular significance.

Orientation and geometry

In order to determine an efficient ventilation strategy and the effect of thermal comfort in a building, the shape of a building is an important aspect that regulates the areas that are exposed to the exterior climate through walls and ceilings. As far as the orientation and geometry of the library building is concerned (Lomas, 2006) highlighted an importance locations of air inlet which is an essential factor to archive the he desired functional performance. A favorable orientation of a building to allow maximum inlet of external air is also an important consideration that is required from the planning stage. According to a case study conducted by (Jackson, 2021) in Peckham Library in Southwark, London, it has been demonstrated that the inverted "L" shaped form generates a natural, harborage meeting point simply in the front of the facility which is accompanied by an open area around it. The north-oriented walls of the Peckham Library have vivid glasses that allow for an ample amount of natural sunlight to illuminate the building and allow an optimum inflow of air through the building.

Design of façade and openings

Facade designs are often attempted in order to add aesthetics to a building. In terms of a library building, façade treatment or design is also entertained to encourage the creativity and modernism of a library building that encourages access, exploration, and exposure to knowledge. In addition, properly designed and placed openings allows a desirable inflow of air required for the comfort of occupants and well ventilation of the building (Gopikrishnan & Paul, 2017). (Jackson, 2021) noted from his case study that the pre-paginated copper and metal mesh distinction with colored glass allows durable and expressive textures and colors with openings along the height of the sitting angles from which readers, as well as the interior of the building, can receive and experience an optimum flow of air.

Ventilation effects on occupants

Besides the improvement of indoor environment quality and reduction in energy implications, it has been noted by (Emmerich, et al., 2001) that some studies have indicated that occupants reported fewer symptoms in buildings with natural ventilation compared to buildings with mechanical ventilation. Further increasing productivity of occupants by reducing absenteeism, reducing health care costs, and improving worker productivity. The physical comfort of visitors and staff in a library building has to be incorporated into the design considerations in order to minimize health-related issues or problems that can be caused by insufficient airflow and the use of mechanical ventilation systems.

CONCLUSION

Passive cooling in a building allows hygienic indoor requirements of occupants as well as the well-being of the building. In the context of a library building, natural ventilation strategies reduce the energy consumption and health implications for the occupants thereby contributing to the increase of sustainability of the building. The passive ventilation of a building enhanced the natural airflows and takes advantage of them to allow a healthy learning and accessible environment. The physical aspects that are to be considered to ensure an efficient ventilation system includes building geometry, orientation, strategic architectural features, façade, and operable windows or openings.

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