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VENTILATION SHAFT DESIGN IN ENHANCING INDOOR AIR MOVEMENT FOR PUBLIC BUILDING

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ABSTRACT: The conditions of dense built environment, land topography and the needs on having deep-plan buildings seems inevitable nowadays. The situations give a poor impact on building indoor natural ventilation. Therefore, the application of stack ventilation strategy has become more important. This is due to the limitation of natural cross ventilation potential. This paper presents a design proposal strategy based on the research aim to provide a good natural ventilation for a new proposed Waterfront Marina & Club building in Penang. Based on stack effect ventilation strategies as references, the project introduced an atria like ventilation shaft with consideration of the building oreantation based on the site context. As the sea breeze is coming from the East side of the building, the shaft is designed open facing the direction to act as wind catcher before transporting the air movement vertically through the shaft. At lower levels, the air movement is spread to all other spaces connected to the main corridor. The shaft is not only depending on the sea breeze but may also functioned as stack effect throat to move the air vertically due to the difference of air pressure via the levels.

Keywords: Stack effect ventilation, cross ventilation, stack effect throat

1. Introduction

Good indoor natural ventilation helps in improvising the indoor air quality (IAQ). The situation may minimize the energy consumption which also may reduce greenhouse gas emission and occupant illness associated with Sick Building Syndrome [1]. Natural ventilation is the process of replacing air at area via air movement physics. The process does not require any mechanical system but relies totally on passive natural physics of environment like wind pressure and stack effect. Basically, there are two types of natural ventilation that occurs in building which are wind driven ventilation and buoyancy driven ventilation [2]. Both processes happened due to the different pressures caused by the wind around and inside a building or structure. While wind driven is basically horizontal, buoyancy-driven ventilation moves mostly in vertical direction. It occurs because of the directional buoyancy force that may happened because of air pressure differences between the interior and exterior. Basically, if both approach were used accordingly on a design, it may become reliable on having a good and proper design.

2. Research Background

This research is based on a project proposal of Waterfront Marina and Club of Tanjung Bungah, Penang. It was a hypothetical design project on actual site where all the constraints had to be analysed and synthesized in developing the design.

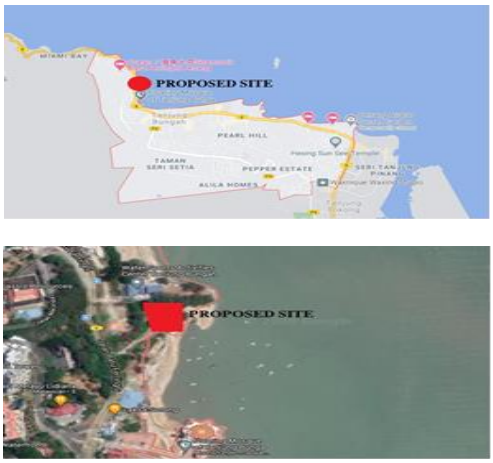

Figure 1 The Key Plan and Location Plan of Proposed Site

The site location is near the Northern beach of Penang Island. Penang Island enjoys the equatorial climate like any other parts of Malaysia. Based on Penang Climate data for the year of 2020 and 2021, it is quite often, the temperature is higher than the mainland, as it is surrounded by the sea. The temperatures may reach as high as 35°C during the day. The temperatures range between 29°C - 35 during the day and 26°C - 29°C during the night generally. As it is located at the beach, it is exposed to the strong wind and sea breeze. Based on the site surrounding environment, the best wind flow may be flowing at higher points with less surrounding obstructions. The condition brings potential in relying to natural ventilation as a medium to cool the indoor spaces of the building.

The proposal design of Waterfront Marina and Club is considering a method that may enhance the overall indoor natural ventilation to the building. The purpose of the element is to achieve thermal comfort for the building with less depending on mechanical ventilation. The method is focusing on the area where 70% -80% of human circulation movement like lobby area and pathways connects one area to another. In order to propose the design, this research looks into the potential of stack effect ventilation as well as wind catcher elements application on the design.

2.1 Previous Related Works

Stack ventilation strategy has been used since long time ago to enhance indoor natural ventilation. Wind towers were used as building components to provide comfortable air movement in early Minoan period [3]. While the Romans in 3rd century BC, had developed the hypocaust heating system by combining ventilation with combustion [4].

Even in Malay traditional house, consideration of tropical climate context was found in its architectural design as well. Most of the design combines high double tiered roof together with large and multiple openings in a form of windows or crafted ornaments. The floor layout is open with less partitions [5]. The houses were also designed on stilts with elevated floors. The gaps between the flooring wood plank may allow natural ventilation to move into the building from underneath. These characters allow free air movement to move around and across the building as shown in Figure 2.

2.2 Stack Effect Ventilation

There are several stack ventilation techniques inherited from vernacular architecture worldwide which are still in use today. The common techniques which work efficiently involve building elements such as interior atria, the jack roof with openings, clerestory windows, openings at the roof ridge and ventilation louvers [6]. The basic physics of air movement remain as the key in designing the building with the elements application as shown in Figure 2.

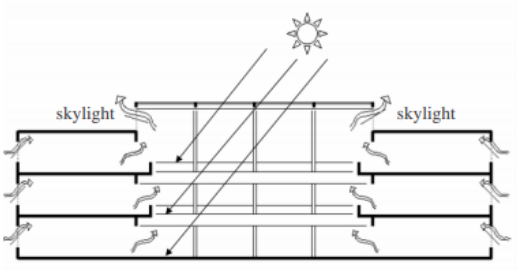

Figure 2 Natural ventilation building elements application on building [6]

In certain conditions, static surrounding air movement allows an exploration of design for stack effect ventilation to work effectively. It could be enhanced by the application of ample atrium that act as the stack effect throat, stack devices and ventilation shafts.

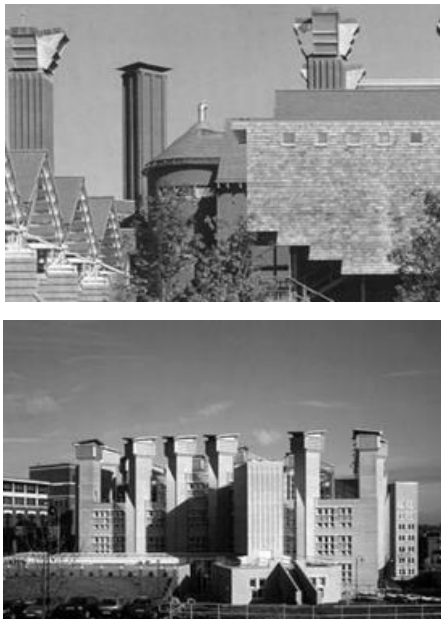

Figure 3 Actual application of stack ventilation towers at The De Montfort University, UK (above), and Frederick Lanchester Library, UK (below) [7]

As stack effect is best to perform with longer neck of stack throat, stack ventilation towers are introduced and became a conventional architectural building elements associated with natural ventilation strategy. With the high vertical façade above the roof, this element is not only effective in increasing the buoyancy pressure available to drive an upward or downward flow, but also effective to work as a wind catcher element (Figure 3).

3. Design Development

Site analysis was performed physically on site to identify the major wind direction on site. As the East side of the building is facing the sea, most of the wind flow direction on site is from the East. However, due to the landform and surrounding neighbourhood, the site may not have the advantage of the wind flow directly at ground level. Therefore, the building natural ventilation strategy is to capture the crossing air movement at upper level and transfer it to the respective other levels. A ventilation shaft concept is introduced for the purpose to take the advantage of the site condition.

The strategy is not new and has proven to be successful in previous research. A study on hypothetical room in 25 storeys building in Thailand shows an improvement of air movement by attaching a ventilation shaft to help air movement in and out vertically into or out of the room. Two rooms as shown in Figures 4 and 5 were studied with one attached with a vertical ventilation shaft to be compared with each other on the aspect of air movement and thermal condition.

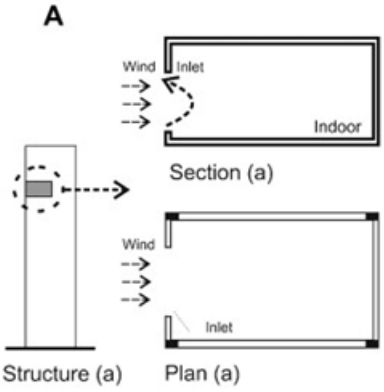

Figure 4 The design of Room A located at one of the levels in a 25-storey building. Room A is without a ventilation shaft [8].

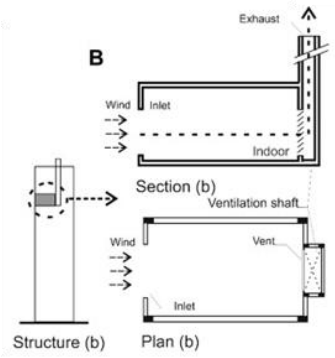

Figure 5 The design of Room B located at similar level with Room A in a 25-storey building. Room B has a ventilation shaft [8].

At the Waterfront Marina and Club building, the main corridor is designed to be open and curvy facing the sea to face the wind direction and the sea view at upper floors. Whereas at ground floor level, the central corridor also acts as the lobby area directing to adjacent spaces as shown in the Floor Plan in Figure 6. The main entrance is directly linked to the lobby where the users can enjoy the sea view from the point.

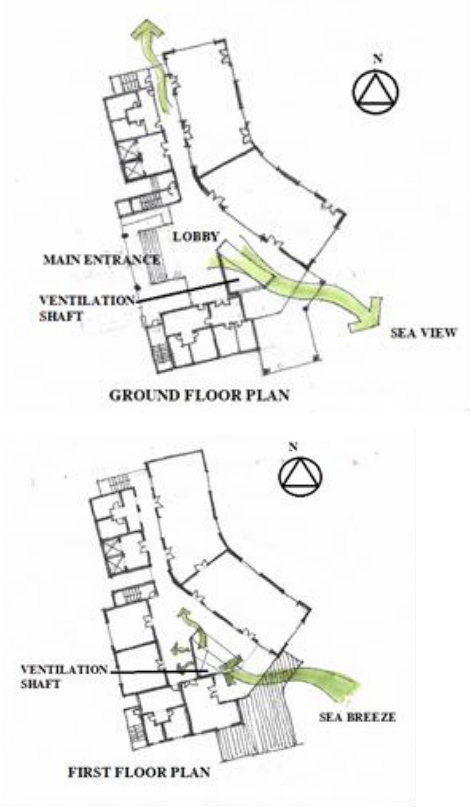

Figure 6 The Waterfront Marina and Club Ground Floor Plan

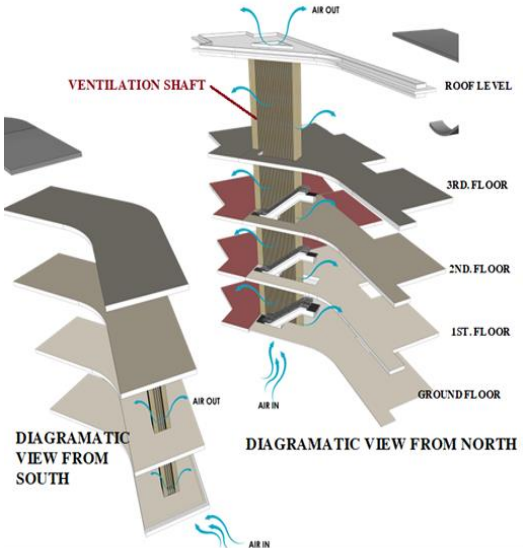

Figure 5 The design proposal for the ventilation shaft at the building core location

3. Conclusions

From the literature surveys, it is confirmed that the stack ventilation strategy could be an effective strategy to ventilate the building, especially in the condition when the area is lack of wind effect. Historical review on its development since ancient times has proven its effectiveness, especially in region where the indoor-outdoor temperature different is high enough to induce the air flow through buoyancy. Hence, stack effect ventilation may be used as an important strategy in building design as it allows the building cooling and ventilation process to happen with low operating costs and maintenance than it does by depending on mechanical systems. It is quite interesting to see the stack effect ventilation strategy being implemented in architectural design soon.

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