ASSESSMENT OF NATURAL VENTILATION IN HIGH RISE HOUSING: THE FACTORS, EFFECTS AND STRATEGIC SUSTAINABILITY

ARC. AKWAOWO, Dianabasi Reuben
Department of Architecture
Akwa Ibom State Polytechnic
Ikot Osura;

OBAMOH, Hannah Yetunde
Department of Architectural Technology
Federal Polytechnic Ukana

AND

UMOH, Ekerete Udo
Department of Architecture
Akwa Ibom State Polytechnic

ABSTRACT

High rise buildings have been increasing in both height and number exponentially, however there is currently no supertall building (greater than 300 meters in height) in existence that uses natural ventilation strategies. Natural ventilation in high rise housing is the use of wind and thermal buoyancy to create air movement in and out of your home without the use of mechanical systems, with the goal of bringing fresh air into your home. The study concluded that: natural ventilation in high rise housing relies on natural forces like wind from the surrounding environment as well as buoyancy forces that develop due to temperature gradients within the building. Natural ventilation is required in high rise buildings to alleviate odors, to provide oxygen for respiration, and to increase thermal comfort. Natural ventilation of buildings depends on climate, building design and human behavior. During night time, and in the summer months' natural ventilation can provide free cooling and reduce your home energy use. One of the recommendations made was that good ventilation strategy should be implemented to aid the proper ventilation of high rise building.

KEYWORDS: Natural Ventilation, Housing, Factors, Effects and Sustainability

Introduction

High-rise type of residential housing is known to be the most compact housing form that is associated with high-density. This type of housing has been accepted and referred to as a sustainable housing solution by planners and policy makers due to its several characteristics. According to Ismail and Wan Mohd Rani (2014), living in a high-rise residential neighbourhood signifies that residents will benefit from superior views, privacy, and the ability to bring more wind into their homes. When designing a decent high-rise residential house, it is necessary to consider the features that will impact the resident's or occupant's overall livability. Thermal comfort is one of the factors that must be considered throughout the planning and design process. Among the criteria are local climate (wind, sun path, and solar angle) and site characteristics such as topography and other natural elements (Ismail & Wan Mohd Rani, 2014).

Accordingly, there are several important issues that would diminish the advantages of living in high-rise residential structures. One of which is the closure of the buildings to each other, thereby reducing air flow around the buildings and blocking views. As a result, natural ventilation systems are incorporated into these building systems, which include some mechanical support; these structures are referred to as mixed-mode or hybrid ventilation buildings. The key advantage of such mechanical augmentation is that interior ambient conditions are less unpredictable, though it will result in higher energy use (Shittu, 2010). Consequently, historic buildings are ventilated naturally, although many of these are being compromised by the addition of partition walls and mechanical systems. Natural ventilation, as the name implies, is a system using natural forces to supply a building with fresh air. Air exchange is accomplished through designed inlets and outlets in a building. It is important to recognise that naturally and mechanically ventilated buildings operate under different principles. Mechanically ventilated buildings use fans to exchange air, which can be controlled to provide the desired air exchange rate. Thermal buoyancy and wind are both dependent on uncontrollable weather (Shittu, 2010). This makes natural ventilation control different. Natural ventilation in high-rise housing has a direct impact on human health, comfort, and general well-being.

Concept of Natural Ventilation

Natural ventilation is a method of supplying fresh air to a building or room by means of passive forces, typically wind speed or differences in pressure between inside and outside. Natural ventilation is the use of wind and thermal buoyancy to create air movement in and out of your home without the use of mechanical systems, with the goal of bringing fresh air into your home. During the night time and in the summer months, natural ventilation can provide free cooling and reduce your home's energy use. Natural ventilation design is typically considered during the home design phase (Green Home Technology Center 2021).

Natural ventilation does not require mechanical systems to move outdoor air. Instead, it relies entirely on passive physical phenomena, such as wind pressure or the stack effect. Natural ventilation openings may be fixed or adjustable. Adjustable openings may be controlled automatically (automated), controlled by occupants (operable), or a combination of both. Cross ventilation is a phenomenon of natural ventilation (Gids 2010). Utilizing natural ventilation in buildings offers additional benefits besides energy usage reductions. Research has shown that the acceptable thermal comfort range for naturally ventilated buildings is significantly larger than for buildings with standard mechanical HVAC systems (De Dear and Brager, 2002). Natural ventilation is one of the most fundamental techniques to reduce energy usage in buildings. If the cooling capacity of ambient air can be harnessed to increase indoor thermal comfort, then the necessity for mechanical space conditioning lessens. Natural ventilation relies on natural forces: wind from the surrounding environment as well as buoyancy forces that develop due to temperature gradients within the building. Buildings can be designed to take advantage of either the driving force or a combination of both.

Natural ventilation, unlike fan-forced ventilation, uses the natural forces of wind and buoyancy to deliver fresh air into buildings. Fresh air is required in buildings to alleviate odors, provide oxygen for respiration, and increase thermal comfort. Climate, building design, and human behaviour all influence natural ventilation in buildings.

- It helps to moderate internal temperatures.
- It helps to moderate internal humidity.
- It helps in replenishing oxygen.
- It helps in reducing the accumulation of moisture, odours, bacteria, dust, carbon dioxide, smoke and other contaminants that can build up during occupied periods.
- It helps in creating air movement which improves the comfort of occupants.

Concept of Housing

Housing, or more generally, living spaces, refers to the construction and assigned usage of houses or buildings collectively, for the purpose of sheltering people. A house is a building for people to live in. It is usually built for a family (parents and their children) (MacMallian Dictionary 2010). Housing is one of the most important tangible needs of an individual besides food and clothing. Different researchers explain the concept of "housing" differently. For example, Smith (2001) defines housing as a commodity or as a tangible asset with potential return; Jevons (2004) defines housing as a fixed asset regardless of whether the housing is owned or rented, or as a capital that is similar to a machine if it is operated by a worker, but as a commodity if it is not operated. The concept of "housing" was described by Melnikas (2000) as a specific and relatively limited, physically and biologically close place where people and groups of people can live their biosocial lives by receiving services, performing house chores, and other biosocial activities. Most modern houses have special areas or rooms for people to do the things that they need to live comfortably. A modern house has a place to cook food, a place to eat, a place to sleep, and a place to wash. These things are usually done in separate rooms, which are called the kitchen, the sitting room, the bedrooms, the bathroom, and the toilet (or lavatory). Many houses have a separate dining room for eating meals and a separate laundry room. In some houses, the toilet is in the bathroom, and in other houses it is separate. Many houses may also have a "study" or computer room, and a "family room" where the children can play games and watch television. However, the planning or provision delivered by an authority ensures that members of a society have a home in which to live; whether this is a house, or some other kind of dwelling, lodging, or shelter, is a social issue (Gwendolyn, 2004). Many governments have one or more housing authorities, sometimes also called a housing ministry or housing department.

Housing has an essential role in the economic development of each country, accounting for 10–20% of total economic activity in the country, as well as being the biggest fixed asset of households. The need for housing is not only one of the basic human needs but also an indicator of the living standards of the population. Today, it is a topical issue that housing has to be comfortable, economical, and reasonably maintainable, as well as architecturally expressive and compliant with the environment (Henilane, 2015). The house has followed a man through history; it is one of the man's oldest and most long-lived cultural objects. They have been protected against the environment, and there are rooms for business and social life, capital investment, and symbolism. Home and house are concepts that are inextricably linked, with shape, function, and technology so intertwined and meaningful that they do not change quickly. Housing is the umbrella term for different types of accommodation in which one has temporary or permanent shelter to live, sleep, work, or relax. All kinds of homes, company buildings, schools, museums, and offices are covered below (Lane 2006). Also, it concerns the provision of such forms of accommodation by, for example, municipal and national authorities. However, the concept of housing provides a host of basic human needs, particularly shelter, personal property, safety, and privacy. Permanent housing ("residence") is also a prerequisite for the full engagement of a person in society, so the state differently supports it.

Concept of High Rise Housing

A "building" is a structure that has walls, floors, a roof, and typically windows. A skyscraper, also called a high-rise building, is one with multiple stories, and its occupants rely on elevators [lifts] to move up and down the building. Most countries refer to tall buildings as "high-rise buildings," whereas Britain and several European countries refer to them as "tower blocks" (Wikipedia 2009). A high-rise building is one that is taller than the maximum height of a building. High-rise building foundations are typically made out of concrete piers, piles, or caissons that are lowered into the earth to withstand very severe gravity loads. The first high-rise buildings were constructed in the United States in the 1880s. They arose in urban areas where increased land prices and high population densities created a demand for buildings that rose vertically rather than spread horizontally, thus occupying less precious land area (Britannica Encyclopaedia, 2013). A high-rise building is typically one that has 12 or more stories and is used for both commercial and residential purposes. The rise of these mammoth structures throughout the world may seem to be a recent development, but they have a surprisingly long history and go a long way back, as long as 2500 years, it would seem. However, the oldest high rises belong to history or to myth. There was the Tower of Babel from the Bible. In ancient Rome, they built "insulae" apartment blocks that housed most of the urban population; some of these buildings were 10 stories or more (Wikipedia 2009).

Environmentally, they are not very sustainable. High-rebuilding affects wind funnelling (the horizontal movement of air), wind direction, wind speed, and causes increased turbulence. They consume an excess amount of power and energy (almost twice the amount needed for horizontal buildings) for lighting, heating, or cooling purposes. Glass and metal used for building them absorb excess heat, which in turn leads to more power consumption for cooling the interiors. The principal means of vertical transport in a high-rise is the elevator. It is moved by an electric motor that raises or lowers the cab in a vertical shaft by means of wire ropes. Because of their height and their large occupant populations, high-rises require the careful provision of life-safety systems. Fire-prevention standards should be strict, and provisions for an adequate means of egress in case of fire, power failure, or other accident should be provided. Although originally designed for commercial purposes, many high-rises are now planned for multiple uses. The combination of office, residential, retail, and hotel space is common. See also building construction (Habib 2013).

Types of Housing

Houses can be built in a large variety of configurations. It may be a single-family detached home or a multi-family residential dwelling. Both may vary greatly in scale and the amount of accommodation provided (Apperly, 2007). Below are the different types of houses.

Bungalow: In some places, the word "bungalow" is used for any house that is all on one level. The word came from India and, for a long time, was used for a house that is built all on one level and has a verandah where people can sit or work outdoors, but under a shady roof. A bungalow often has a hall down the middle of the house to let the breeze blow through. Bungalows are often seen in countries with hot summers, for example in India, South East Asia, South Africa, parts of the United States, South America, Australia, and New Zealand. In regions with flooding, a bungalow is often built on wooden "stilts" or a high basement. Bungalows were almost always built of wood in the 1800s, but starting in the 1920s, it became fashionable to build them out of brick as well.

An example of a Cottage

Cottage: A small house is often called a cottage. Apart from that, it is also called a small space. In England, where this word comes from, it is used to mean a house that has one main storey, with a second, lower storey of bedrooms that fits under the roof upstairs. Cottages are usually found in villages or in the countryside (Wikipedia, 2018). They are built from materials that can be found nearby. In many places, the word "cottage" is used to mean a small, old-fashioned house. In the United States, the word "cottage" is often used to mean a small holiday home.

An example of a Cottage

Cabins: A cabin is a small dwelling constructed of wood. To be more specific, they are constructed of logs. The term "cabin" is often used to refer to less finished and architecturally simple structures (Hasa, 2016). They are usually less finished than cottages. While cottages are painted and adorned, giving them a finished look, cabins do not have that. Additionally, cabins are almost always rural. That is, they are mostly found in villages, whereas a cottage can be located in either a rural or urban area. Cabins have a rustic look and are cruder than cottages. They may not come with modern conveniences like electricity.

An example of a Cabin

Mansion: A mansion is a big grand house, usually with two stories and sometimes more. A mansion often has beautiful architecture and shows that the person for whom it was designed and built was rich. Mansions often have beautiful gardens. Sometimes a mansion does not belong to a private family but to a town council, to a big business company, or to a church or college, and is a place for a person with an important job to live and to entertain guests (Wikipedia, 2018). A mansion often has rooms which are not found in ordinary houses, such as a drawing room, a ballroom, a library, and a music room. Mansions often need servants to help keep them in order, and there are often special rooms where the servants do particular jobs, such as cleaning the silver tableware.

An example of a Mansion

Yurt: The yurt is the primary housing structure used by the Mongols in Mongolia. The Mongols are nomadic people. Yurts can be packed up and moved easily, making them an ideal type of home for nomadic people. Yurts vary in size from approximately 12 feet in diameter. They are relatively inexpensive to build. A yurt is a round structure with a wall and roof made from waterproof fabric. It is mainly used for picnics.

An example of a tent

Palace: A palace is a house that is very grand for people like kings and queens or other rich people. Many palaces are the homes of royal or aristocratic people. A palace is frequently used instead of a castle; a palace differs from a castle in that its primary function is only as a residence; they were not built to defend. Instead, palaces were luxurious structures that housed royalty and nobility and often also housed government functions.

An example of a palace

Factors to be put into Consideration in Building High Rise Housing

Human Comfort Criteria

When a tall structure is subjected to lateral or torsional deflections under fluctuating wind loads, the resulting oscillatory movements can induce different responses in the occupants of the building. Motions that have psychological or physiological effects on the occupants can make the structure undesirable (Suguna, 2019).

Stiffness and Drift

Adequate stiffness is a major consideration in the design of tall buildings. In terms of ultimate limit state, lateral deflections must be limited to prevent second-order P-delta effects due to gravity loading. In terms of serviceability limit states, deflections must be maintained at a sufficiently low level to allow proper functioning of non-structural components; to prevent excessive cracking, and to avoid any redistribution of load to non-load bearing partitions, in-fills, cladding, and glazing; to prevent dynamic motions from becoming large enough to cause discomfort to occupants (Suguna, 2019).

The drift index (the ratio of maximum deflection at the top of the building to the total height) provides an estimate of the lateral stiffness of a building. The Design drift index limits used range from 0.0015 to 0.0030. Generally, lower values should be used for hotels or apartment buildings than for office buildings, since noise and movement are more disturbing in the former. As the building height increases, the drift index coefficients should be decreased to the lower end of the range to keep the top story deflection at a suitably low level.

Strength and Stability

Furthermore, Suguna (2019) states that the prime design requirement for ultimate limit state is that the building structure should have adequate strength to resist and to remain stable under extreme force conditions that may occur during the design life of the building. This demands an analysis of the forces and stresses that will occur in the members as a result of the most critical possible load combinations, including the augmented forces that may arise from P-Delta effects. An adequate reserve of strength must be present. Special care must be paid to critical members whose failure could prove catastrophic in initiating a progressive collapse of part of or the entire building. Additional stresses due to creep, shrinkage, and temperature must also be included. A check must also be made to ensure that the applied lateral forces will not cause the building to topple as a rigid body (Suguna, 2019).

Fire

For tall buildings, fire prevention and protection, smoke control, fire-fighting and escape must be given due consideration in the design process. Suguna (2019) claims that the stresses in the members can be evaluated using knowledge of the temperature gradient across the members and the degree of restraint provided by the supports and surrounding structure. The elasticity modulus, or stiffness and strength, deteriorate rapidly as the temperature rises and the resistance to loads is greatly reduced. At 700 C, the yield strength of steel is only 10-20% of its value at room temperature, and the elasticity modulus drops by 40-50%. The critical temperature at which large deflections or collapse occur will depend on the material used, the nature of the structure and the loading conditions.

Foundation Settlement

The gravity and lateral forces acting on a tall building will be transmitted to the earth through the foundation system. For the purpose of foundation design, conventional methods apply. The design engineer should be concerned with the influence of any foundation deformation on the structural behaviour of the building and on the soil-structure interactive forces. The foundation deformations may influence the design in two ways. First, if the bases of vertical elements yield, a stress redistribution will occur, and the extra loads imposed on other elements may further increase the deformations there.

Effect of High Rise Housing

Air pollution: There are many sources of air pollution in the city, such as cars that produce CO. With increasing the height, the density of CO will also increase. If there is a tower, this increase can happen till around 6–9 floors. After that, this increase will be irregularly decreased (Hayati and Sayadi, 2012). As known, the wind load increases with increasing height (Fad and Karadelis, 2013). So, if the tower has a wind flow from above to below, the CO will be separated around and make the volume of the pollution bigger.

Sunshine: A skyscraper can get a solar panel easily, especially the upper floors because of its height. What about the impacts of the building on the surrounding area? Making shadows and avoiding getting solar radiation directly from the sun are the two points that many researchers concede about it (Hayati and Sayadi, 2012). The effects of this shadow and shading are different in different climates and block the sun's access, sun light, and solar sun (Sakinç and Sözen, 2012). For instance, in a hot climate zone, shading the urban space over a long period of time is good and helpful for daily activity. On the other hand, in designing the Passivhous buildings in a cold climate, there will be no solar gain for the buildings, especially the low-rise buildings around the tall buildings.

Wind flow: For the wind flow, as for the sunshine, there are two different sides. Tall buildings can either create wind flow past urban buildings or avoid airflow within urban planning. If the buildings are not near to each other, these impacts will be minimised to a very low level. Tall buildings can change the direction of the wind in urban planning (Hayati and Sayadi, 2012). On the other hand, if there is quite a high density with similar building heights, the ventilation will be better. For air shadow, tall buildings in urban planning increase the air shadow. This shadow increases with the increasing height of buildings. Building depth is not very effective until more than four times the building height (Dedar Salam Khoshnaw et al. 2016).

Views: Regarding the view, high-rise buildings, not like low-rise, do block the view and visuals from other locations of the city because of their height. In many cities, such as London, there are some rules for avoiding blocking views (Baiz et al. 2016). Protected views are an important issue in urban planning, especially if there is a great global icon or historical landmark in the city and existing high-rise buildings.

Natural Ventilation in High Rise Housing

Natural ventilation, which is the process of supplying fresh air and removing it from an indoor space without using any mechanical devices in order to dilute and exhaust pollutants, is often an element of green or sustainable architecture (Kleiven, 2003). Tall buildings, being a large segment of high-tech contemporary architecture, can benefit from natural ventilation by reducing operation energy (as well as construction energy due to installing the devices) and more importantly, by providing healthy and comfortable indoor environments for occupants. Provision of fresh air and a connection to the outdoors, which are the main requirements of natural ventilation, can be achieved by operable windows, double facades, ventilation stacks, balconies, patios, terraces, atriums, and gardens in a tall building (Irwin, et. al., 2008). Occupants can control and increase fresh air provision as needed. Depending on the climate as well as personal preferences, cooling loads or at least ventilation loads can be reduced.

Wind-driven ventilation can be classified as cross-ventilation or single-sided ventilation and depends on wind behavior, on the interactions with the building envelope, and on openings or other air exchange devices such as inlets or chimneys. The climatic characteristics of the urban space, such as the wind around the building, are crucial when evaluating the air quality and thermal comfort inside, as air and heat exchange depend on the wind pressure on facades. The pressure effect of the wind on the building is primarily determined by the building's shape, the wind direction and velocity, and the influence of the surroundings, which are the factors determining the pressure coefficient. In addition, the mean pressure difference across a building's envelope is dependent upon the mean wind velocity at upper levels of the building and the indoor air density as a function of atmospheric pressure, temperature, and humidity (Wood and Saliba, 2013).

Buoyancy-driven ventilation, also known as the stack effect or chimney effect, occurs due to differences in the density of interior and exterior air, which mostly results from differences in temperature. When there is a temperature difference between two air volumes, the warmer air will have lower density and be more buoyant, thus rising above the cold air, creating an upward air stream. The pressure differences generated by buoyancy are mainly dependent on the stack height, or the height difference between air intakes and exhaust openings, and the air density difference as a function of temperature and moisture content in the air.

In order for a building to be ventilated adequately via buoyancy-driven ventilation, the inside and outside temperatures must be different so that warmer indoor air rises and escapes the building at higher apertures. If there are lower apertures, then colder and denser air from the exterior enters the building through them, thereby creating flow displacement ventilation. However, if there are no lower apertures present, then both in-and out-flow will occur through the high-level openings. This latter strategy still results in fresh air reaching a low level, since although the incoming cold air can be designed to mix with the interior air, it will always be denser than the bulk of interior air and hence fall to the floor. Buoyancy-driven ventilation increases with greater temperature differences and increased height between the higher and lower apertures in the case of displacement ventilation. When both high and low-level openings are present, the neutral plane in a building occurs at the location between the high and low openings at which the internal pressure will be the same as the external pressure (in the absence of wind). Above the neutral plane, the air pressure inside will be positive and air will flow out of any intermediate level apertures created. Below the neutral plane, the air pressure inside will be negative and external air will be drawn into the space through any intermediate level apertures (McWilliams, 2012).

Natural ventilation in buildings can rely mostly on wind pressure differences in windy conditions, but buoyancy effects can augment this ventilation and ensure airflow rates during still days. Buoyancy-driven ventilation can be implemented in conditions when air inflow in the building does not rely solely on wind direction. In this respect, it may provide improved air quality in some types of polluted environments, such as cities. For example, air can be drawn through the backside or courtyards of buildings, avoiding the direct pollution and noise of the street facade. Wind can augment the buoyancy effect but can also reduce it depending on its speed, direction and the design of air inlets and outlets. Therefore, prevailing winds must be taken into account when designing for buoyancy-induced ventilation (McWilliams, 2012). It should be noted that a reverse buoyancy effect could occur when the outside air temperature is significantly higher than the internal building temperature. In such a circumstance, air can enter a tall building at upper levels and discharge from lower levels. This reverse effect can be difficult to manage. Although the wind-and buoyancy-driven natural ventilation can occur separately, they are more likely to occur at the same time. Thermal buoyancy will generally dominantly occur on a calm and temperate day, as wind-driven ventilation will require a windy day.

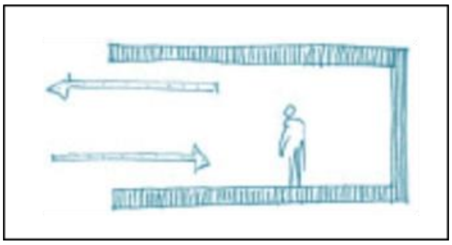
Strategic Sustainability of Natural Ventilation in High Rise Buildings

Natural ventilation is based on fundamental heat transfer mode by supplying and removing air through an indoor space using natural techniques. Two forces are very important when it comes to natural ventilation: wind pressure and the buoyancy effect (Karadağ, 2013).

1. **Wind pressure:** It is based on air movement from high to low pressure zones; it is considered the main principle of cross ventilation systems.
2. **Buoyancy effect**: It is based on the fact that hot air rises and cool air comes in its place. This effect is the main principal of stack ventilation systems.

One usually differentiates between three different ventilation principles for natural ventilation: single-sided ventilation, cross ventilation, and lastly, stack ventilation (Karadağ, 2013). The ventilation principle indicates how the exterior and interior airflows are linked; therefore, how the natural driving forces are utilised to ventilate a building. The principle also indicates how air is introduced into the building and how it is exhausted.

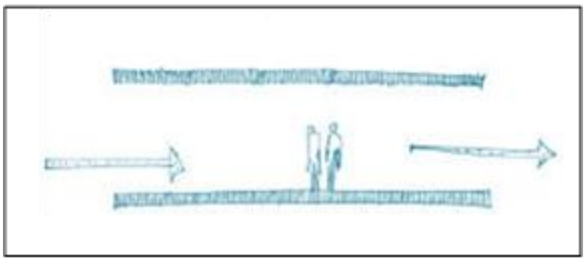
Single-sided ventilation: Only one side of the ventilated enclosure has an opening(s) in single-sided ventilation. As shown in the diagram below, fresh air enters the space through the same opening it being exhausted. This type of ventilation occurs when a space in a cellular layout has an opening on one side and a closed internal door on the other side.



Single-sided ventilation

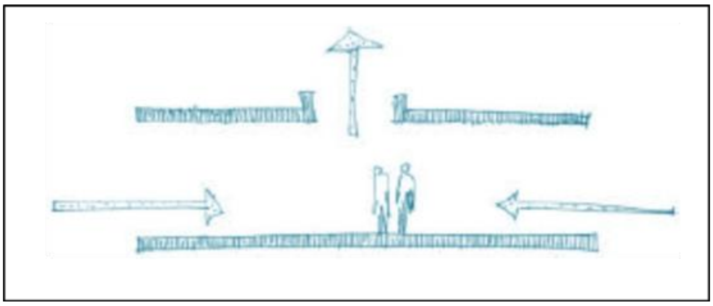
In single-sided ventilation, the effective depth is a maximum of 2.5 times the floor-to-ceiling height. The ventilation rate can be enhanced by the buoyancy effect in cases where ventilation openings are provided at different heights. The greater the vertical distance between the openings and the greater the temperature difference between the inside and the outside, the stronger the effect of the buoyancy. When compared with other strategies, lower ventilation rates are generated and air does not penetrate far into the spaces (CIBSE Application Manual AM10, 2005).

Cross-ventilation: Cross-ventilation is the case when air flows between two sides of a building envelope by means of wind-induced pressure differentials between the two sides. The ventilation air enters and leaves commonly through windows, hatches, or grills integrated into the façades, as shown in the diagram below. The ventilation air moves from the windward side to the leeward side. A typical example is an open-plan office environment where the space stretches across the whole depth of the building.



Cross ventilation

Stack Ventilation: Stack ventilation relies on temperature, density, and pressure differences between the interior and exterior or between certain zones in a building. As indicated in the diagram below, entry of fresh air into a building is at a low level, while extraction is at a high level (a reverse flow can occur during certain conditions).



Stack ventilation

Due to its physical nature, the stack effect requires a certain height between the inlet and the outlet. This can be achieved by e.g. increasing the floor to ceiling height, tilting the profile of the roof, or applying a chimney or an atrium. By its nature, stack ventilation resembles cross ventilation as far as some individual spaces are concerned, in that air enters one side of the space and leaves from the opposite side. The air may flow across the whole width of the building and be exhausted via a chimney, or it may flow from the edges to the middle to be exhausted via a central chimney or atrium (Alahwal, Aboeinen & Mohamed, 2017).

In different climates, different environmental requirements are needed. A variety of design strategies are generated to maintain human comfort in tall buildings. Such strategies can result in significant energy savings and, as a result, improved energy performance, whether the building is to be naturally ventilated all year or only during periods of favourable weather (Gonçalves & Umakoshi, 2010). Some strategy in the four main climates could be:

Hot-Dry Climate: This climate is characterised by high air temperatures surpassing 37°C for much of the year, low humidity levels, almost no precipitation, and ample day-to-night temperature fluctuations. Mitigating solar heat gain is an essential strategy in this climate.

Buildings should ideally be oriented along an east-west axis with the main facade openings positioned toward the north and south. This orientation reduces solar gain during the more problematic lower-sun angle periods in the mornings and afternoons, especially in summer (Givoni, 1998).

Natural ventilation during the daytime may be difficult due to the high external air temperatures and also the amount of particulates (especially sand) in the air (Marcondes, 2010). Some regions can offer a seasonal changeover mixed-mode strategy to achieve an optimal environment. During the hotter months, night-time ventilation can be an effective strategy, utilising the often significant drop from day-to-night-time air temperatures to flush out internal heat gains built up during the day. For this aim, thermal mass can be utilised to restrict internal heat gains and to delay thermal exchanges between the exterior and interior. In fact, effective night ventilation is mainly important for the cooling of a building's exposed structural mass because, without effective cross-ventilation at night, the building's interior may be unbearably hot during the night (Etheridge, 2012). Marcondes (2010) emphasises the same issue by stating that night-time ventilation can be an efficient passive strategy as it benefits from lower external air temperatures to help cool down a building's fabric and dissipate internal heat loads. The same author also notes that the environmental performance of night ventilation can be significantly increased if coupled with internally exposed building materials of high thermal inertia, functioning as heat sinks.

Evaporative cooling strategies coupled with continuous airflow could also be used to increase the moisture content in the typically dry air, lower the temperature, and improve internal comfort. Evaporative strategies include localised evaporative cooling within the facade system or the use of a large centralised water source to help condition a specific area, such as a water feature or fountain in the lobby of a building (Etheridge, 2012).

Cold Climate: Cold climates are distinguished by low average air temperatures (less than -3 °C in winter) and low solar radiation, as most are found above 40° north latitudes. The most important consideration when designing in such extreme climate conditions is the conservation of heat. This can be addressed through both the form of the building and the building envelope. Compact shapes provide more concentrated floor-to-envelope area, which reduces the facade heat loss and gain. Curvilinear shapes also have better aerodynamic performance, which may assist with the natural ventilation strategies in the building. The building should look to benefit from passive solar heating, especially in winter, by orienting the glazed areas of the facade toward the more intense solar radiation. Special attention, however, is needed when specifying the glazing components when considering the low thermal resistance of glass. The use of double and triple glass panels with gas-filled air cavities has become common practise in cold climates. Furthermore, a water feature can help to humidify the incoming dry air in winter (and can be chilled to help dehumidify it in summer), since this is another problem with natural ventilation in cold climates (Wood & Salib, 2013).

Conclusion

The study concluded that natural ventilation in high-rise housing relies on natural forces like wind from the surrounding environment as well as buoyancy forces that develop due to temperature gradients within the building. Natural ventilation is required in high-rise buildings to alleviate odors, provide oxygen for respiration, and increase thermal comfort. It was also concluded that in the construction of high rise buildings, certain things were put into consideration. Climate, building design, and human behaviour all influence natural ventilation in buildings. night time and in the summer months, natural ventilation can provide free cooling and reduce your home's energy use.

Recommendations

From the study and conclusions drawn, the following recommendations were made:

1. Appropriate ventilation system should be adopted for tall buildings. If one ventilation system is not enough to keep natural ventilation stable, more than one can be adopted to keep maintain stability.

2. In the design of tall buildings, necessary criteria should be considered such as the area, height of the building, load on the building and the effects of the tall building on the people living around.

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