Natural and Hybrid Ventilation

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Executive summary

Most people disregard the importance of ventilation in the comfort of a building. The ventilation and air circulation in a building is equally as important as all the other building elements such as the columns and slabs. Therefore, this branch of building physics should be greatly appreciated.

In the report below, an analysis is provided of a potential building site for an office building. The comfort and analysis of the various elements that make air circulation all the more useful are analyzed. The building has two proposed sites for its construction the first is an urban center while the second is a green field outskirt 15km south west of London. In the design, the proposed hybrid ventilation system is to make use of the environment and the building structure and to put in place measures that ensure that the air and energy distribution is at the least possible cost. Furthermore, considering that it is an office building, the design has to ensure that there is an efficient balance between the energy obtained from the environment and the mechanical technology, which in turn will ensure that the occupants have full control and knowledge of the building.

Winter and summer pose significant challenge in the design of any ventilation system. As a matter of fact, summer poses a significant challenge compared to winter. All these have been addressed in the report below where there is need for optimal equilibrium between indoor air quality needs and energy use.

To begin with is the stack pressure. Stack pressure is the pressure caused by the difference in density between the inside and outside air and as such, considering that this difference is relatively higher in winter, the stack pressure is proportionally higher. More to this is the fact that the temperature difference is higher during winter than in summer. However, it does not pose a significant threat to the building since the effects of stack pressure are felt in buildings that are

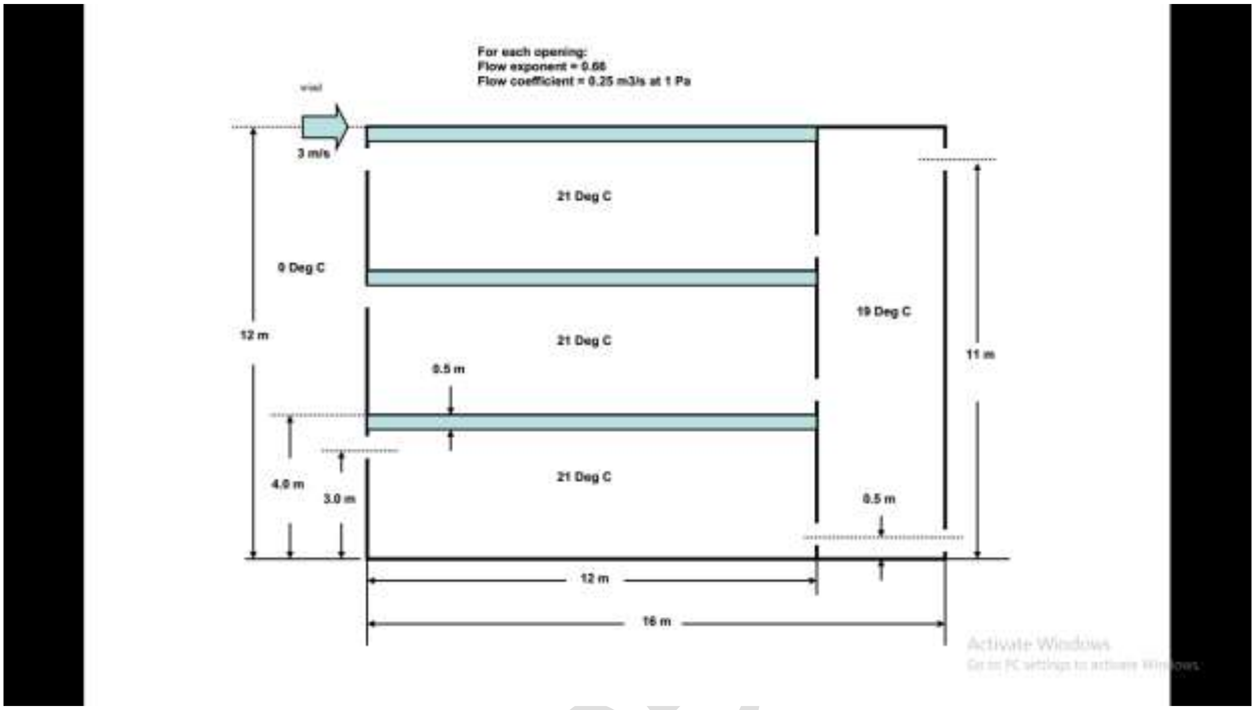
higher than three floors. An increase in the stack pressure means that there is an increase in the total building pressure. The building pressure depends on the wind, stack effect and the pressure due to ventilation. As a matter of fact, the North West side is bound to expect more pressure than any other part of the building and therefore special consideration should be put in place.

The wind pressure depends on a lot of variables such as the angle of incidence, the terrain and obstacles and more to this is the fact that it is relatively higher above the ground and therefore, the terrain chosen and all the named variables will determine the pressure and the ventilation requirements.

Another important consideration taken in the design of the proposed building is the heat loss and requirements for the buildings. The thermal resistance of the elements that are used in the design of the building determines the heat lost to the surrounding.Therefore,the building should be modified in such a way that there is sufficient heat loss during summer and proper heat resistance during winter.

Contents

The diagram of the building is as shown below



The following parameters are known for the building:

1. Total floor area 1500m2, distributed in three floors.

2. Total occupancy 120 occupants, engaged in sedentary (office) activities.

3. Winter design conditions: 21oC in office areas, 19oC in circulation/auxiliary areas, external temperature 0oC, wind velocity 3m/s.

4. Summer design conditions: 25oC not be exceeded for 5% of the working hours in the offices areas (higher temperatures might be accepted in circulation/auxiliary areas). External temperature 23oC, wind velocity 4.5m/s.

Calculation of pressure and opening areas

Stack pressure at each external opening

$$\Delta p_{stack} = -C_d \frac{\rho_i g}{g_c} \Delta h \frac{T_i - T_o}{T_o}$$

Where

ρi =the average density of the air present in a typical building and is equal to 0.075 lbm/ft3(= 1.20 kg/m3)

Δh = refers to the difference in elevation from a predetermined and neutral ground with positive indicating an upward direction while negative a fall in the vertical distance .The units for measurement taken as ft (m)

g = 32.17 ft. /s2 (9.80 m/s2) This is the acceleration caused by gravitational pull [gc= 32.17 (lbm· ft)/(lbf· s2)]

Ti and To = the temperatures measured on an absolute scale (the indoor and outdoor temperature respectively), °R (K)

Cd = This is a variable that takes into account the resistance to the flow of air between two consecutive floors and is known as the draft coefficient

There are 5 direct openings between the building and the environment (3 openings between $0^0 Cand\, 21^{0C}$ and 2 openings between $19^0 Cand\, 0^0 C$)

Assuming a standard building height (between floors) of about 4 meters:

Stack pressure between the offices and the outside

Stack pressure between the front sides and the external environment

-6.03×10^{-3} *pascals*

Stack pressure between the circulation and outside

-5.74×10^{-4} *pascals*

Considering that the building is a low rise building of about three floors, the stack pressure is not expected to be so high. The stack effect tends to be relatively small in low-rise buildings, up to about five floors, but in high-rise buildings it can dominate and should be given close attention (Kreith, 2001).However, the pressure difference due to stack effects is linear with the neutral position the midheight.Therfore, there is no flow of air into or outside the building at midheight. In the dissipation of pressure from the building into the surrounding, leaks play a very pivotal role. Leaks are found between the window and wall interface, door and wall interface, roof and wall interface and joints between interior partitions among others. However, the estimation of the total air available (inflow and outflow), is zero. This is because the quantity of air available into the building does not change. As a matter of fact, air flowing into the building is usually the same as the air flowing out of the building

Wind induced pressure at each external opening

$$\Delta p_{wind} = \Delta C_p \frac{\rho}{2} V$$

$\Delta C_p = C_p - (-0.2)$ =0.25+0.2=0.45

Where

v = this is the wind speed on a natural field whereby there is no interference by building structures m/s

vf = Usually take as 0 because it is difficult to measure the wind speed at the building boundary

ρ= air density, kg/m3

Therefore, the pressure induced by the wind is observed at the opening where there is presence of wind i.e. north West direction

Therefore, the wind induced pressure=0.27 pascals at the edge where the wind is predominant, the south west.

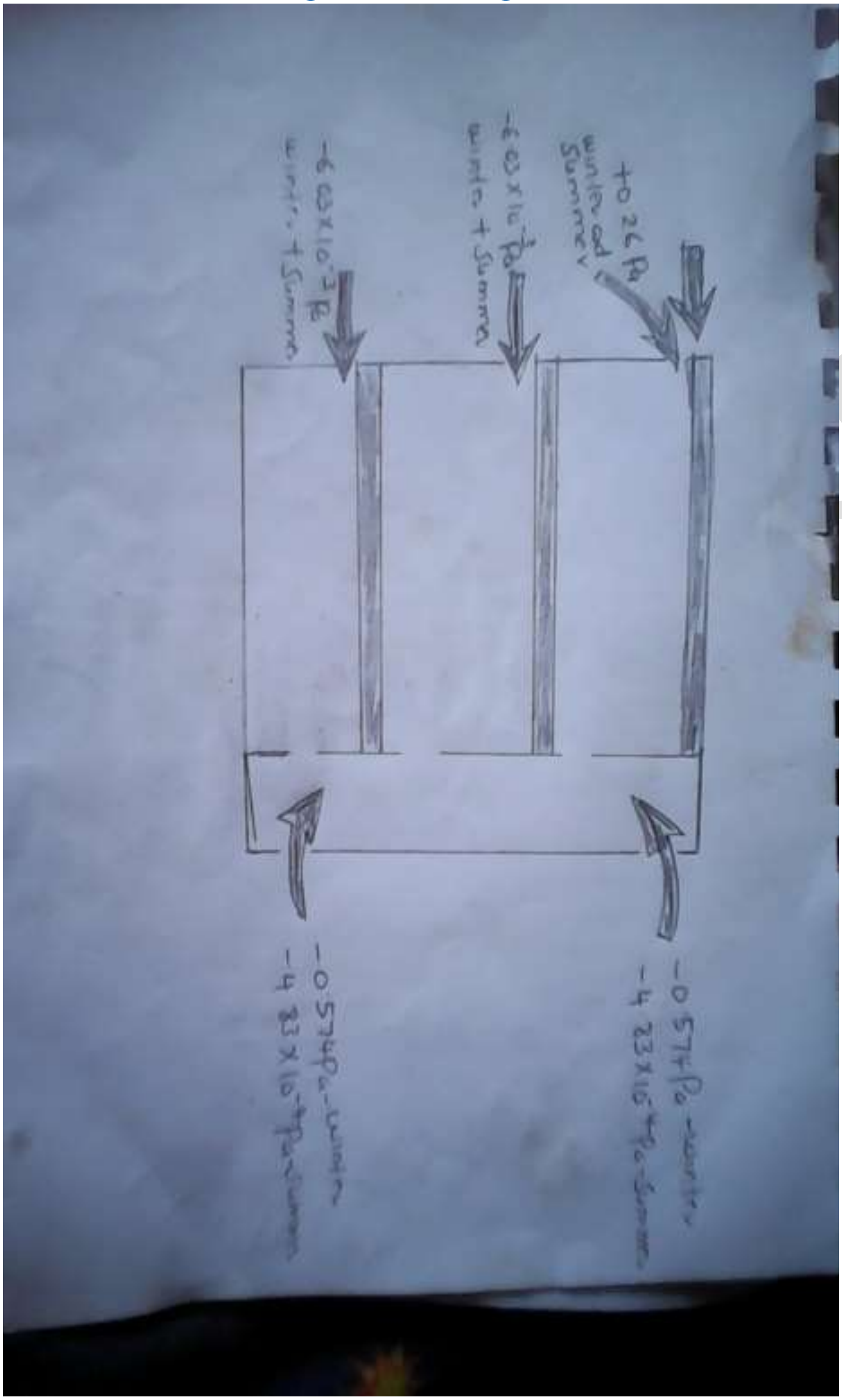
For summer

From the N-W side=0.26 pascals

Side Without wind=- 6.03×10^{-3} *pascals*

Back= -4.83×10^{-4} *pascals*

Flow networks describing the flow during the two seasons



The air flow into the building is expected at higher rates during the winter than in summer. Air flow is primarily controlled by the temperature difference between the outdoor and indoor and an increase in the deficit results into more inflow. More to this is the fact that the stack pressure is high during winter than in summer and as such, there is air movement from the building into the surrounding as well as air movement from the surrounding into the building. In the figure depicted above, the negative sign indicates that there is an outflow of air into the building while a positive sign indicates an inflow of air into the building.

The individual pressure terms are nonlinear and therefore the design cannot take the individual airflows and put them together.

Orifice type opening area

$Q = C_d A^2 \rho^{0.5}$

Q=air flow

C_d = Coefficient of discharge (0.61-0.65)

ρ =density (1.20kg/m30

Δp =pressure difference

A=area of opening

In our case

$Q = C(\mathrm{p})^n$ Where c is the flow coefficient

N is the flow exponent

P is the pressure difference hence Q=0.068m3/s assuming laminar flow

A=0.30 m^2

Ventilation flow rate calculation

Determination of the air change

For business offices, the typical air change per hour=6-8 (Falke, 2016)

The volume of each floor= $500 \times 4 = 2000m^2$

Taking the maximum air change= 2000×8 =16000

Required CFM= $\frac{volumeofroom \times airchangesperhour}{60\min utes}$ =266.67

6400 per day

On the aspect of ventilation rates

Ventilation rate per person= $\frac{airchangesperhour \times density \times height}{60}$

2133.36cfm/per person

Furthermore, in summer

$$V_{\sup.summer} = \frac{\sum Q_{summer}}{\rho_{\sup}.\Delta h} = \frac{\sum Q_{summer}}{\rho_{\sup}.C_p.\Delta t}$$

Which is the same case in winter

Where

$\rho_{\sup}$ – is the average density of supply air [kg/m3]

Δh taken as hsup – hex,. This is mainly in winter when hsup is greater than hex and it is the difference in specific enthalpy between the supply gas and the exhausted gas[kJ/kg]

Δh taken as hex – hsup, this is mainly in summer when hex is greater than hsup, and it is the difference between the supply and exhausted gas measured in [kJ/kg]

Δt is the difference between tsup and tex which occurs mainly in winter when tsup is greater than tex,.This is the difference in temperature between the supply and exhausted gases usually measured in [°C, vagy K]

Δt is the difference between tex and tsup and occurs mainly in the summer season when if tex is greater than tsup.This is also the difference in temperature between the supplies and exhausted gases taken as [°C, or K]

C_p – This is the mean enthalpy capacity taken at constant pressure and is measured in[kJ/kgK]

Thgerefore.the ventilation flow rate in:

Summer= $\frac{2133.33}{0.96 \times 1.190 \times 2} = 933.70$ per day per person

Winter= $\frac{2133.33}{1.44 \times 1.245 \times 9} = 132.22$ per day per person

The heat capacity of the summer air being 1.190 with its density 20% lower than 1.20kg/m3. The heat capacity for the winter air being 1.245 and its density 20% higher than 1.20kg/m3.

The aspect of air interchange and determination of the ventilation rate is very important in building design because it considers the capacity of the available air and its ability to suffice the air requirements of the occupants. As matter of fact, too much air and too little air have adverse effects on the body. Not sufficient air in a building leads to building sickness while too much air leads to wastage of energy In this, air interchange refers to the volume of air from the outside environment that crosses the path of the building and is conditioned on crossing the boundary. Not only is the determination of the air interchange complicated, it is a very unique task requiring the comparison of air flows in buildings that have the same orientation as well as in models that may be relt. There are various methods used in determining the ventilation rate of any building but the most important is by the use of a tracer gas.

The use of a tracer gas in the determination of the ventilation rate basically depends on continuity and the conservation of mass.In this, the amount of tracer gas injected into a room is continually measured, particularly the concentration. The concentration of the tracer gas in the building ot the room is the most important determinant in the ventilation rate and as such, various injection methodologies and analytical models have been devised.

Ventilation Heat loss for a 24 hr. period of summer

Assuming that the walls are the only elements that lose heat (U=0.35W/m2K)

$$Q = UA\left(T_1 - T_2\right)Watts$$

Ventilation heat loss= $\frac{1}{3}NV\Delta T$(w)

Where U-thermal transmittance

A-surface area of building element

N-number of fresh air changes per hour

V-Volume of inside space

K-degrees kelvin

W-watts

Hence heat loss by walls $0.35\times4\times12\times2\times(21-12)=302.5watts$ = atrium and outside

$0.35\times10\times4\times(19-12=)98watts$ Between the circulation and outside

So, the ventilation heat loss for a floor= $\frac{1}{3}\times266.67\times500\times9=400KW$ maximum considering the atrium temperature

Specific fan power= $\frac{electricalpowerinput}{airflowthroughtheunit}$ =1.5×132.22 =198.33kw

Cooling ventilation energy required

The number of air shifts=933.70 per person per day

The air supply temperature=23 degrees celcius

Inside temperature=21 degrees Celsius

Hence the difference=2

Considering that the humidity of the external air is higher, so is the density and as such

$\frac{55}{65}\times933.70=790.05$ watts

To accomplish this energy requirement, there are four possible scenarios:

The first is a presence of a natural inlet and a natural outlet. In this. Both the inlet strategy and outlet strategy of the ventilation are purely natural such as openings that link the outside environment with the interior of the building. Furthermore, louvres, doors and chimneys may be used but this is particularly useful in air interchanges of up to 3 per hour. Therefore, the underlying factor is the prevailing wind conditions, the stack effect of rising warm air currents, and adventitious openings around doors and windows (Chadderton, 2007).

The second scenario is the hybrid system consisting of a natural inlet but a mechanical outlet. As in the first scenario of air flowing into the building, this system consists of the same inlet but the gases out of the room are extracted through duct systems or fans and it is particularly useful ion offices and factories where there is an accumulation of dangerous fumes in the work place. Basically, there is a creation of pressure \difference between outdoor and indoor with the indoor having a slightly lower static air [pressure than the outside. The air moves into the interior through open windows, grills and louvres. However, the incoming air is not monitored and as such, the air is slightly impure and contains fumes and other contaminants which might need to be looked into.Furthemore, during winter, the air may need to be warmed because of the lower environmental temperatures.

The third scenario is that of a natural outlet but mechanical inlet;. The system is basically a reverse of the second scenario where the air flows out of the building in a more natural manner through windows and other openings while the inflow is mechanized. Therefore, in monitoring the incoming air, the temperature is set within the desired limits offering a more reasonable solution to places that have prolonged winters but more so, it is important in underground offices and rooms.

The third scenario is that where the inlet and outlet are both mechanized: Though not a hybrid system, it presents a really good, but costly option, for places where the inflow and outflow of air need to be continuously monitored. An aspect that may call for this type of ventilation is the architecture of the building whereby there is need to control the movement and the types of eddies created in the building. In this, some buildings are easily affected by the movement of air inside that there is the need to ensure that the distribution of turbulences and eddies is continually monitored.

Therefore, the cooling ventilation energy required for the proposed building will depend on the first three natural and hybrid scenarios. However, since we are determining the ventilative cooling requirements of the building, we have to focus primarily on the natural method of cooling the building and as such, the second scenario presents the best option. Cooling ventilation energy is used for preventing the use of mechanical systems while serving the same purpose of cooling the building and its environs. Since this cannot be efficiently achieved in a building, there is the need to establish a fan system that can be used to increase the number of air changes.furthermore,we have to consider that this system only functions properly when the outside temperatures are less than the internal temperatures. The cooling effect is soothing to the building as it is to the occupants. As in our case where the building is to serve the purpose of an office, most workers will be in a state of no motion at most of the times whereby the heat generated from the skin will create a more uncomfortable environment.

An economizer can be used to achieve the ventilative cooling requirements of the building. The system works by allowing cooler air from the outside into the building and preventing the need to recycle air. However, some periods during winter may call for a warmer air and as such other devices such as heaters and radiators may come in handy in ensuring that the air temperature is within the desirable limits.

Additional restrictions imposed for ventilation if the urban site (option 2 site) is chosen for the building

Considering that the urban center is near a busy road and an airport, there is the risk of pollutants in the supply air. Therefore the airflow rate has to factor in the risk of the different potential pollutants such as nitrogen oxide, carbon (IV) oxide etc. Different pollutants have different properties and as such, the designer has to make sure that he/she separates all the possible pollutants and analyses each individually. Another important consideration is the air flow and wind created by the busy road and airport. Not only are roads and airports air pollutants, they are sources of turbulent winds and differential air movement patterns. Therefore the design has to make sure that the aspect of the differential air and wind movement has to be seriously taken into consideration.

Congestion in urban center is the main limitation to the proper supply of air. As in our case, there are 3 story buildings that surround the available site. An increase in the density around a specific area limits the supply of air to our building and as such, precautionary measures need to be considered to counter this potential inadequacy. Furthermore, the availability of buildings around the construction site distorts the flow of air and wind currents and as such, there is an in depth analysis to determine the effects of wind and air around the building site.Furthermore,this effect is to change during the seasons and therefore each season needs to be analyzed separately

Natural forces are less predominant in urban centers than on the countryside. Therefore, the ventilation in urban centers should be highly mechanical. Putting in place a more mechanized hybrid system will ensure that there is no shortage of air circulation.

Strategies using hybrid ventilation to optimize indoor air quality in urban buildings.

The principle of ventilating the building naturally when it is summer while using hybrid ventilation during winter may be an energy efficient strategy that can be used in ensuring that the building is maintained at an optimal temperature throughout the year. The use of mechanical systems is very expensive and their application in summer is very limited with only special circumstances such as the expulsion of toxic fumes from the building justifying the use. However, because winters usually have unfavorable temperatures inside and outside the building, there is justification in the use of mechanical systems that basically monitor the incoming air.

A wind floor concept can be used to enhance natural ventilation. Each building should have a central core to enhance the stack effect on each floor and furthermore, there should be a wind floor to enhance the driving forces of the wind. An observable application of this concept is the Meiji University liberty tower. The building has a unique design such that the central core has been capped with a wind floor whose purpose is to allow the smooth movement of natural forces such as the wind. Furthermore, each floor of the building has openings that allow the inflow of fresh air awhile the exhaust fumes at the top ensure that the used air is expelled from the floor. Something notable about the stability of the stability of the driving force are the four directions that the wind floor is open to. The system is so efficient that it minimizes the energy that the building need to cool down by a very huge percentage from spring, through summer, and finally to the winter season.

Additional fan to natural ventilation is a very good concept. The fan enhances the supply of air during times of weak driving forces or periods when the demand may be more. This is basically a very important aspect of hybrid ventilation but there is very minimal energy use considering that the fan systems have been modified in such a way that the energy requirements can be controlled and monitored.However,the fan system should be designated in such a way that there is difference in the rate of air circulation between the periods of summer and winter.

There should be a stack and wind supported mechanical ventilation which means that some of the mechanical systems should make use of the natural driving forces. The necessary pressure for some of the mechanized systems can be obtained from the natural driving forces. However, the systems should have very minimal pressure losses to prevent inefficiency of these systems.

A mechanical system that uses infrared principles should be used to ensure the quality of air during the hot summer season is maintained at values that are optimal for human activities.Infrqared ventilation is a very advanced system that measures the amount of fresh air supplied to every individual and restricts other types of ventilation during human presence. As a matter of fact, this system leads to significant cut in the ventilation losses but the System needs fans that are monitored as well as ducts that have been properly designed to avoid losses.

Overheating during summers can be an unpleasant condition to the building occupants.Intensiuve ventilation during the night time can be one of the most viable solution. To counter this, Louvres and grilles that should be basically situated throughout the building ensure that the warm air during g the daytime is expelled in a more efficient manner. However, the effect of cooling during the night time may extent to the next day and as such, there should be a predetermined rate of cooling to the building. Therefore, the thermal comfort will be obtained in a more energy efficient method.

The last, but not least, ventilation model to be applied is the use of trichology to determine the levels of carbon(iv)oxide ion the building which may consequently trigger various inlet mechanisms in the building. One of the most important aspect in the comfort of any individual is the sufficiency in the oxygen supply. Many urban centers are polluted and as such, the design of any building has to make sure that there is a provision for the supply of fresh air while the expulsion of carbon(iv)oxide and other toxic gases.

Wind speed at the facade up the third floor of the proposed building

The wind flow pattern is given by the equation

$$U_0\left(Z\right)=U_0.\ln\left(\frac{Z+Z_0}{Z_0}\right)$$

Furthermore

$V_z = V_b K_1 K_2 K_3$ Where k are the risk factors (wind speed, terrain and topography) (Krishna)

Therefore the design speed $= 4.5\times0.94\times0.97$ =4.1031m/s

$Z_2 = \frac{0.5\times1.5}{3} = 0.25$ Assuming height to the third floor is 1.5m

Hence speed= $4.1031\ln\frac{1.5+0.2}{0.2} = 8.78m/s$

This is an indication that the wind speed might be high but not out of the normal and therefore the ventilation system will have to be monitored especially in the winter when the wind speeds are higher.

The relative location of the openings in the plan and the temperature

In the plan of the building, the openings have been distributed evenly in such a way that there is no proper consideration to the wind and stack effects on the north west portion of the building .Furthermore, there is little or no consideration on the change of seasons, the atrium and the circulation. The main aim of designing a building is to make sure that it acts as a filter to the environment. The reason behind this is because the human body produces humongous amounts of heat during sedentary activities, such as in our case. Therefore, the building has to be fine-tuned into a case whereby the heat from the 120 bodies does not bring discomfort into the type of office orientation, and particularly an open office. Therefore, the orientation of the openings should be in such a way that favor cooling during the winter seasons but should also consider heating during the summer conditions.

Wind is an important factor in the design of buildings that have five floors or more. However, the terrain and obstacles determine various design factors. As with the above calculations on stack and wind effect on the building, the pressure at the north west portion of the building is significantly higher than on the other portions.Therefore,the openings should be designed in such a way that they counter the higher pressures. This can be done by increasing the number of openings or by locating the openings such that they offset this effect. As with the circulation, there should be an increase in the number of openings on the back portion to ensure that there is sufficiently amount of air distributed into the office setting.

Considering the temperature allocation throughout and outside the building, there is need for the building service engineer to change them. An indication of the period when the temperatures are measured is an important factor in trying to establish the ventilation requirements of the building. As per the above plan, there is no indication of the season when the temperatures were measured and as such a relatively shallow impression by the engineer.

Bibliography

Chadderton, D. V. (2007). *Building services engineering.*

Falke, R. (2016, Mar 24). *Use the air changes to determine room CFM*. Retrieved from Contracting business: contractingbusiness.com/service/use-air-changes-calculation-determine-room-cfm

Kreith, F. (2001). *Handbook of heating,ventilation and air conditioning.*

Krishna, P. (n.d.). *wind loads on buildings and structures.*