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Topic: Can natural ventilation replace mechanical ventilation in multistory buildings

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1. Introduction:

Mechanical ventilation or HVAC (heating, ventilation and air-conditioning) might seem to be a resent invention, but the basics of the machinery like we know it today, was already invented in the 19th century. After optimizing and commercializing these basic HVAC-units, the big migration to the Sun Belt in the United States was made possible around the 1920's.

Looking even further back in time, we can give a great example from the civilization of Ancient Egypt. During that time they already applied the principles of air conditioning using tall grasses like reeds, soaking them in water and letting the dry desert air carry the moisturized air throughout the rooms of the house. During Roman times the aqua ducts were led trough the walls causing a similar effect in combination with the Mediterranean winds.

All this time the end purpose of HVAC did not change, to create thermal comfort together with a pleasant moist indoor air quality.

Not long ago, a mechanical HVAC-unit was still limited to one room and one function only. But during the last few decades these systems of mechanical ventilation became bigger and more complex, providing fresh air to complete houses, or even a complete building project such as malls or sport infrastructures. The possibilities of filtering the air, heating/cooling the air depending on what's required, putting fire containing mechanisms in them, made them into beautiful examples of mechanical engineering.

With the introduction of the vapor barrier and airtight buildings, the use of mechanical ventilation gradually blossomed. Promptly this system became the key-factor in the building. Besides acting as a fresh air supplier it also functioned as a moist regulator within the construction, not just providing, but controlling the complete indoor climate. Due to these improvements, the use of mechanical ventilation became mandatory by law in multistory buildings in Denmark and in most European countries.

But is mechanical ventilation really the key factor in deciding where we should build our future around or are there other types of ventilation that can provide the building with the same quality of air and overall indoor climate? More and more buildings make use of mixed types of ventilation, natural and mechanical. Evidently they are even going back to the use of only natural ventilation and other passive cooling/heating solutions.

How do natural and mechanical ventilation weigh up against each other? Does it depend on the design of the building, the user, and the materials? Is there a possibility to use natural ventilation separately or will it always only be used as a support to a mechanical ventilation system?

Although mechanical ventilation seems to have been with us for quite a while, the most conventional and most easy applicable way of adapting the indoor climate to our specific needs, it has always been through the means of natural ventilation or passive cooling of the building. If it was by wind ventilation, adapting the colors of our houses to reflect the sun, installing atria or galleries, it all helped in the integrated design of our environment to our personal comfort.

2. Problem formulation

Since people started building their very first settlements, they tried to adapt their environment as much as possible to their own comfort. This local adaptation pattern has led to significant cultural differences across the world.

The white houses, which we can find around the Mediterranean Sea, are often characterized by their location near/on hill flanks and their small windows. The white color reflects most of the sunlight, while the small windows act as the openings through which natural ventilation can occur from the sea side to hill flank, following a natural pattern of rising air. At the same time the windows were kept small, to keep the abundance of sunlight out of the inner living quarters of the house as much as possible.

Besides shaping our houses and cities according to our needs and environment, we have also partly altered the daily rhythm in our everyday lives (circadian rhythm). For example the siesta in Spain. This habit has become a tradition and is now part of the UNESCO world heritage. Despite that the economy has changed to a more competitive model and the technologies of air conditioning have improved, the Siesta is still strongly woven in the DNA of the Spanish people and in extend to that of most of the Mediterranean.

For a more extreme example we can turn to the province of Yazd, located in central Iran. In the contrary to the western approach of conditioning each room to have a suitable climate, the Yazdi (the people from Yazd), select each room for its specific climate during each season.
The Yazdi that live in the traditional houses have developed a daily pattern that enables them to live in a seemingly hostile environment. Starting a hot summer day by sleeping on the floor, the Yazdi will move to the shade and enjoy the relative coolness of the courtyard situated in the north side of the building. After that they will rest throughout the hottest moments of the day in the cellar, the coolest place to be. Towards the evening the courtyard is initially cooled by throwing a bit of water on the hot stones but it will cool down even more as the evening proceeds.

In autumn they use different rooms of the building, moving from the coolness of the north-facing summer wing, to the south facing winter-wing. The winter-wing is deliberately exposed to the sun so they can use the sun load to heat up the thermal mass, which on its turn keeps the room warm during the cold winter nights.

Figure 1: Courtyard of house in Yazd (source: Fabienkhan (personnal picture) [CC BY-SA 2.5 (http://creativecommons.org/licenses/by-sa/2.5)], via Wikimedia Commons)

For Western standards this migration habit throughout the day and between the seasons is unthinkable. But by doing so, the Yazdi have obtained a certain degree of comfort within their daily life.
The climate of central Iran cannot be compared to that of the Western Europe, or to most of the Western world in general and the example given might seem a bit extreme when looking at our own daily lives. But from the way they adapt to their environment gives us a great opportunity to learn a few things to our own advantage, that is why this example is essential in the buildup of this elective.

Ever since the HVAC has introduced itself to the market, the sales of air conditioners have only gone up. In Europe alone, the amount of HVAC's sold, rose 22% between 2002 and 2006. At the same time the energy consumption for cooling within the EU, is predicted to go up from 1.900 GWh in 1990 to 44.430 GWh in 2020 according to the book “Advances In Passive Cooling”.

It does not require much to say that the HVAC is not a very sustainable solution in long term, even if you only look at the shear energy consumption that goes along with it.

But an even bigger problem is how the HVAC is sold to the general public. By using the term "thermal comfort" (which generally is used to define a state of mind that expresses satisfaction with the thermal environment) in a way of assuring the use of HVAC, is a relatively far from the truth. Most of the tests done on HVAC and the conditioning of rooms are done in enclosed spaces or climate chambers without taking into consideration most or at least some of the principal environmental factors such as wind, sun, thermal mass and shading by environment (neighboring buildings, vegetation). By doing so, they are selling a morphed representation of the real life scenario, stating that every room should be conditioned as an independent system on its own.
Due to this certain approach, a disconnection between the building and its environment can be seen frequently in the design of new buildings, bringing us back to the first ideas taken from Yazdi described above.

Due to the success that HVAC has had in the last decade in conditioning the indoor climate, we can distinguish a gap in between the research of natural ways of ventilating and the cooling of buildings. Not only have we forgotten about this field in research, our legislations has become more and more orientated towards, and in favor of the HVAC. The amount of plot-size that can be used for a building, the amount of u-value for walls, air-tight buildings etc. At first sight, all these measurements are in favor of a sustainable design but at the same time they are proven to be even more in favor of the HVAC.

The problem evident with this approach of the building envelope is that we are cutting ourselves off of our environment, while in many cases it is possible to apply systems that can provide us with better air quality and zero emissions. It puts to the question why the building has to be fully conditioned for the needs of people that initially all have individual wishes of their own, especially when it comes to thermal comfort. These days we look at the indoor climate as a uniform fixed system while a more dynamic approach would be a healthier option. There is nothing wrong with wearing a pullover indoors during the winter months and a T-shirt during summer if in this way we would create a better balance between the indoor climate that we are able to shape and the outdoor climate that we have to cope with throughout our daily lives. Looking further, it is the minimum adaptation we can make towards our climate and our fellow people. Hence the second lesson we can take, looking back at the adaptations other people have made in their daily lives to achieve thermal comfort.

To achieve a building that makes good use of natural ventilation and other passive cooling/heating methods, the building must be designed accordingly although this asks a better cooperation between the architect and the engineer. This is maybe an interesting subject to work on as an ATCM.
Of course there are also organizations that try to incorporate sustainable solutions. A building rating system has been created, called LEED or "Leadership in Energy and Environmental Design" and is made to create certificates to buildings that make a substantial effort in improving the air quality, use of green materials or the of use water efficient solutions, within the building. But since the LEED

system does not assure a good indoor air quality (IAQ) since it only looks at the impact on the environment, I will not be discussing it further in this elective.

In the frames of this elective I will focus mainly on HVAC and try to show exactly why it has become so widely accepted in our modern day society. In parallel, I am curious to investigate what kinds of natural ventilation is available and what is the design criteria to incorporate these building techniques. Consciously aware that when speaking about natural ventilation, it is difficult to look at it from a one dimensional angle. In most cases, applying natural ventilation goes hand in hand with other relevant design choices, considering the solar loads, heat pumps and thermal masses. As follows, I will try to introduce as many of these integrated solutions, so it would be possible to sketch the most downright picture as possible.

3. Need for ventilation?

Ventilation is a the foremost part of the building's design. It enables its occupants to have a suitable thermal environment and a good indoor air quality (IAQ) by replacing the air in the room/building, making sure that mold formation and other moist related damages to the building are reduced to a minimum.

More specific ventilation is needed to:

- provide sufficient oxygen
- dilute (body)odors
- dilute to concentration of carbon dioxide produced by occupants and combustion
- dilute other internally or externally generated pollutants

Inside the building.

At first glimpse you might expect that the provision of oxygen would be of great importance compared to the other qualities that have to be fulfilled. But the requirements for oxygen are less than the ones for diluting carbon dioxide, even these on their own turn are of less need than the air needed for diluting body odors or the air needed to dilute other pollutants, like tobacco smoke, to acceptable levels.

Ventilation is also used to provide the occupants with thermal comfort as mentioned before and these requirements are mostly even higher than the ones for IAQ.

The means of providing a good IAQ and thermal comfort differ greatly from each other. Normally this is done by natural means but hybrid solutions in combination with internal thermal mass and complete mechanical solutions, are being used more frequently. This last option is a lot more energy consuming and has negative impact on the environment and on the indoor air-quality in general, as introduced in the following chapter.

4. Heating, Ventilation and Air Conditioning (HVAC)

As stated previously, HVAC can be seen as the general conditioning of the indoor air quality. One way or another, advanced systems of natural ventilation can fall under this definition as well. In this chapter I will only talk about mechanical ventilation, the way it works and what sort of impact it has on our daily lives and our environment. Furthermore, I am eager to research what are the advantages of HVAC and what has helped the system to become so widely accepted.

Theory

The development of HVAC systems is mainly based on research done in physics on thermodynamics, fluid mechanics and heat-transfer during the 19th century (beginning of industrial revolution). The system can be placed in the field of the mechanical engineering where they applied the principles found in the disciplines mentioned previously.

The name “mechanical or forced ventilation”, is used due to these units always relying on a source of electrical power to pass their functions.

Most of the HVAC-units consist of:

- A compressor unit (that creates heat/cooling)

- A fan unit (which transfers the air)

- A duct unit (which distributes the air)

-* humidifier (passive or active, which brings the air to the desired moist levels)

-* filter (which purifies the air)

Due to their specific ways of filtering or humidifying HVAC-units, you can find many different types of mechanical ventilation, such as “Air handling Units”, for bigger projects or evaporative coolers in drier areas.

Practical pro’s and con’s

The success of mechanical HVAC can be linked to a variety of reasons.

- HVAC is relatively easy to install

- It doesn't have too many requirements when it comes to the building type or place of installment (besides sizing the unit and choosing the right aggregator for the specific job)

- The units are relatively small

- No extensive integrated design is necessary

- It enables people to live in a comfortable indoor climate

Because of these features, the sales of mechanical HVAC have gone up even more since the recent heat waves of the past 10 - 15 years, especially in the Central- and Southern-Europe. That global warming has had positive effect on the sales of mechanical HVAC.

Even more so in the cities that HVAC is welcomed with open arms due to its limited demand in space and fast installment options. Although the HVAC seems to be very beneficial, providing coolness where needed, the HVAC is actually having a negative impact on a relatively new phenomenon taking place in cities - the Heat Island Effect.

In short, the Heat Island Effect describes the effect of the temperatures in cities that are higher than those measured in their rural surroundings. This effect is caused by the dense architecture, transportation, density of population, less ventilation by the height of the architecture and heating of the buildings. In winter this effect has a beneficial impact on the heating costs within the city but in summer it appears exactly the opposite. The Heat Island Effect can be as big or even exceed a 10ºC temperature difference between the city and its surroundings. This effect increases the amount of days with 30ºC (tropic day) and 25ºC during the night. These peaks in temperature result in peak usage of HVAC, which in its turn cause peaks in electricity consumption. For example in Tokyo an increase of 1ºC ambient temperature increases peak electricity demand by 1.8 giga watts and this is equivalent to the production of two medium sized nuclear power plants or a cost close to 2.5billion US$, the economic effects of HVAC use become very clear as well. *(Murakami 2006)*

On top of the additional costs created by HVAC, it also has a negative impact on the Heat Island Effect itself. Although the HVAC unit creates coolness inside the building, the unit itself generates a significant amount of heat. This heat is given off to the environment, increasing on its turn the Heat Island Effect even more.

Most of the new buildings that are designed to have HVAC, are built to create a stable and constant indoor climate. To keep the indoor climate of these buildings (mostly office buildings, schools, elderly homes) as stable as possible, they prevent the opening of the windows since that would have a negative effect on the work of the HVAC-unit.

This flaw in the design resulted in many deaths across Europe during the heat wave of 2003. People living in poorly ventilated rooms but with HVAC, were unable to pay the utility bills and/or were unable to open windows to create additional ventilation. During that heat wave, the energy consumption peaked with 10% compared to 2002 and caused a peak in the price up to 1000 Euros per megawatt hour. As a result, one of the advantages of the HVAC, its fast respond time became one of its biggest flaws.

These examples show what the shortcomings of mechanical ventilation are. We could say that the drawbacks of HVAC systems include:

- An increase in peak electricity load

- Environmental problems associated with ozone depletion and global warming

- Indoor air quality problems

Although HVAC causes some significant problems, it is still widely accepted and applied even more frequently to new buildings. This continuous growth of HVAC can be brought back on a few requirements and legislations that are present these days for our buildings.

- An increasing reliance on automatization and central control of the building

- Increased first-cost expenditure of the building (HVAC engineer is mainly paid according to the cost of the cooling and heating systems, not the cost of the building itself)

- Thin, airtight envelopes replace sustainable walls and well-designed openable windows.

- Prediction of the buildings performances

- Minimization of the floor area to plot ratio, which works in favor of deep-plan buildings

Deep-plan buildings seem to be efficient in reducing heating and cooling loads because of good volume-to-surface ratios. But by eliminating light wells and courtyards at the center of shallow plan buildings on deep sites, they increase the running costs of the building, since mechanical ventilation and artificial lighting replace natural ventilation and daylight.

The main problem is that most buildings these days are designed from an engineering point of view rather than an architectural. A lot of buildings barely make use of the thermal mass of the building and even replace entire facades by glass curtain walls without practical use and without compensating this in the further design. Another problem can be found in the occupant's mentality. Demanding a building that has instant reaction time to the people's wishes, instead of wanting a building that is stable trough time and adapts to the seasons. In general a person is able to adjust fully to the outdoor temperature in about a week. All in all, a building that makes good use of the thermal mass in order to change gradually in relation to the outdoor temperature, could provide a solution in some cases.

5. Natural ventilation

Natural ventilation is the process of adding and extracting air from a specific room or building without the means of mechanical ventilation or HVAC.

Natural ventilation can occur by the means of wind ventilation or buoyancy-driven ventilation and both can be driven and/or influenced by the thermal mass of the building or by passive cooling. The energy conservation in the thermal mass of the building and different means of passive cooling are also the most efficient and cheap alternatives to the conventional HVAC.

Natural ventilation in all means is a critical aspect within this system of passive cooling and is part of the integrated design method which includes solar load control, heat dissipation, which in their turn are influenced by the thermal mass of building. Clearly all of these factors are closely linked together. But this also means that to achieve a good practical application of these methods, a good understanding of the micro climate of the building, its location and the environment of the building in general, must be obtained.

5.1 Factors that influence natural ventilation

Making good use of natural ventilation does bring along some design issues and the solutions for these will be given in a later chapter. Another aspect that must be considered first is the location of the building and thus the different climatic regions where natural ventilation is applied and on a smaller scale, the direct environments in which the building is placed.

A broad climatic classification can be given in following terms:

- Climatic regions with high cooling load...

- Climatic regions with high heating load...

- Climatic regions with moderate heating and cooling load...

Each of these climatic regions have specific requirements and have different implications on the buildings. In a climatic region with high cooling load it will probably be more beneficial to keep the heat away by means of shading and vegetation rather than in regions with high heating load. At the same time both will still be in need of a fresh air supply to keep a good indoor air quality.

This brings us to the factors considering the placement of the building in its direct environment

- Degree of urbanization (rural, urban, .../ density)

- Orientation to the sun

- Wind orientation

- Plantation, neighboring buildings, relief

The factors given here will be specific for each building and will play a key-role in the further design of the building, since they will have a direct impact on the air pathways, heat-storage and shading which you want to create in your building or are already present.

Other factors to be taken in consideration in the design strategy applied to the building are

- Building systems (primary building components)

- Operational principles

- Cooling effectiveness/ Orientation for exposure to cooling breeze

- Floor-plan zoning according to usage

- Appropriate application of windows and glazing

- Effective shading

- Appropriate application of thermal mass

- Adequate levels of insulation

- Usage of light colored roofs and walls

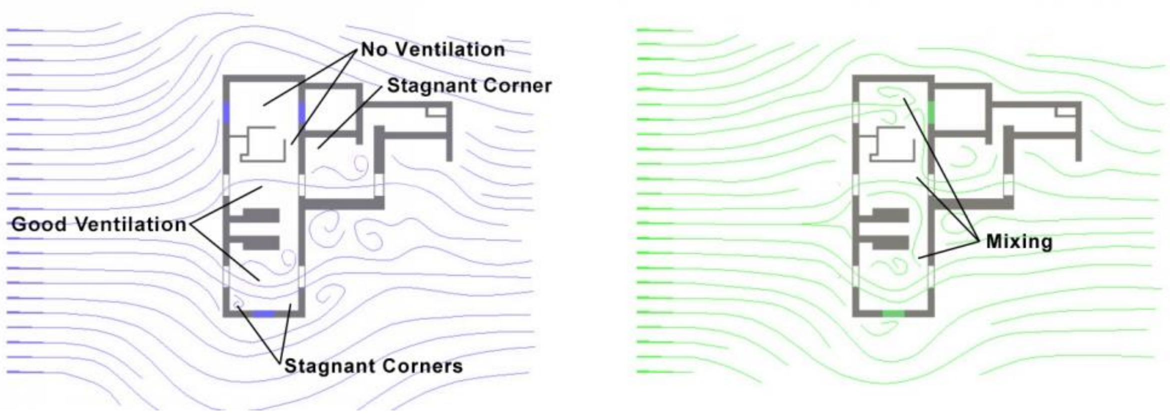

Figure 2: floorplan zoning and the different effect of wind driven ventilation with different placed windows (source: http://sustainabilityworkshop.autodesk.com/buildings/wind-ventilation)

The choice of these elements will be strongly influenced by the wishes of the client and enduser, but have to be taken by the designer, in order to obtain the right conditions for natural ventilation and passive cooling to occur.

5.2 Types of natural ventilation/passive cooling

5.2.1 Wind driven ventilation

As I mentioned previously, wind ventilation is the process of adding and extracting air from a specific room or building. Wind ventilation is driven by the wind that surrounds the building, which is let into the building by the means of openings and windows within the building envelope. This way there zone of high pressure will be created at inlet side and a zone of lower pressure (suction) on the outlet side. Wind ventilation can also be seen as wind infiltration, when that happens at a place where it does not intentionally occur, it is considered as a building flaw.

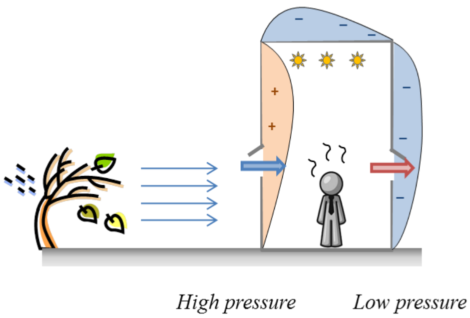

Figure 3: Difference in pressure (source: coolvent.mit.edu)

Wind ventilation is by far one of the cheapest ways of ventilating a building since it does not need drastic interventions in the building's design. Although when small changes are made, the effect of this process can increase its impact considerably.

These small changes consist of:

- The the orientation of the openings/windows
- The placement of the hinges (scoop or divert the wind)
- The amount of ventilation openings
- The placement of the ventilation openings

When we take a look at the last two factors, the amount and the placement of the ventilation openings in a room, we can see 2 different categories arising: single sided ventilation and cross ventilation.

Single sided ventilation

Single sided ventilation is the ventilation process that occurs when we create an air inlet (window, opening, inlet device) on only one side of the building envelope or room. Although the initial handling of opening a window or an inlet device is seemingly easy, the real process that is created is rather complicated. There are numerous variables that have to be considered like air velocity, wind turbulence, heat in the room and of the air coming in, window/inlet opening. For that reason we will only handle the main principle of this process.

The most known way of single sided ventilation, like mentioned earlier, is the one where we open the window of a room. When we do this, we create an airflow within the room. This flow will usually consist of an inlet of colder air flowing downwards, heating up in the room (because of the people, heating, computers etc.) and leaving the room again outwards above the mentioned incoming colder air. This airflow can change according to the seasons or vary between (summer) day and night.

One way of enhancing the airflow and thus the air-exchange, is by separating the air inlet and the air outlet and placing them respectively on the bottom and top side of the wall used for single sided ventilation. Both streams are separated and the natural path of the air is respected.

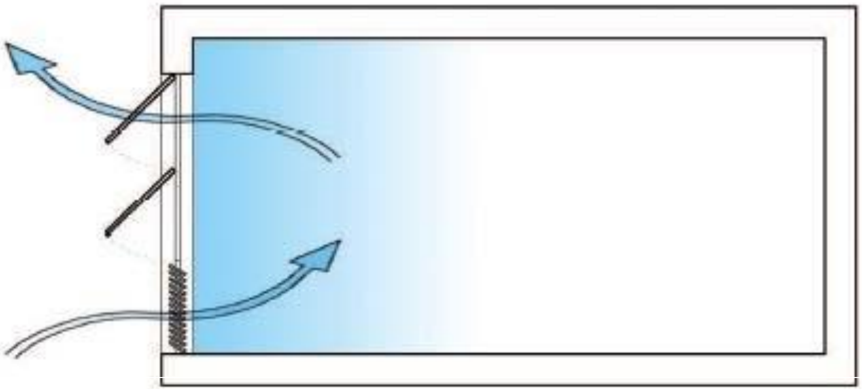

Figure 4: Single sided ventilation (source: www.gov.scot/publications/2007/02/28144045/7)

Cross ventilation

Cross ventilation occurs when we place the windows on opposite sides of the room, thus creating an airflow throughout the entire room. The same principle of colder inlet air being heated up by the rooms interior and the warmer air leaving the room is applied, with the difference of that we can steer the airflow a lot better. This makes it a lot easier to predict the behavior of the ventilation.

In this case placing the inlet and outlet in different heights also enhances the stream of the airflow. In more complex systems we can make use of a chimney or play with the height of the room or building to optimize the effect even more. Not forgetting that it will still consist of just one single enclosed space. Another way of adapting the airflow to our comfort is by using different sizes for the inlet and outlet openings. The inlet will be placed at the windward side with higher pressure and the outlet will be placed at the leeward side with lower pressure.

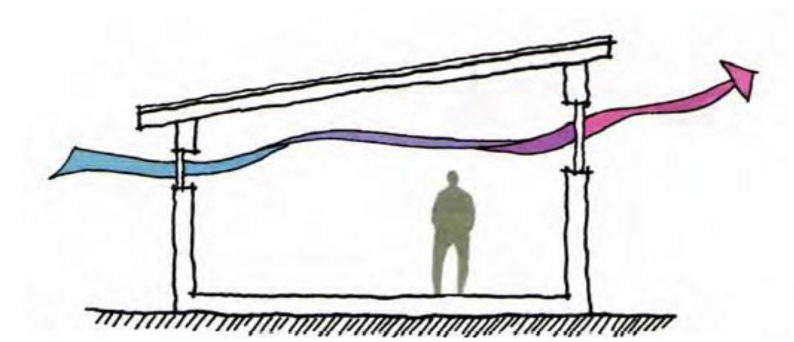

Figure 5: Cross ventilation (source: arch3230samanthaweiser.wordpress.com)

Both of these principles are very dependent on the orientation of the building according the the main wind direction that occurs on the site. If there is still a need for ventilation in a room which has a different orientation with wind driven ventilation, we tend to use breeze steering ventilation.

Steering breeze ventilation

Steering breeze ventilation makes well use of the placement of the hinges (scoop or divert) or creates an architectural feature (casement windows, wing walls, fences) to obtain the airflow needed to naturally ventilate the space.

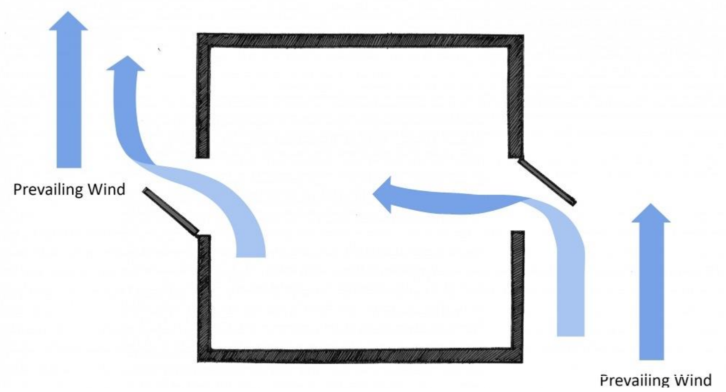

Figure 6: Steering breeze ventilation (source: sustainabilityworkshop.autodesk.com/buildings/wind-ventilation)

Taking in notice that all the above types of natural ventilation are easy applicable and do not require a large range of design skills to work. On the other hand they are also very dependent on their environment to work properly and are subject to a numerous amount of variables before they can deliver a good air quality.

- Unpredictable airspeeds and – amounts
- Dependent on the air-quality from outside
- Chance of draught
- limited to single rooms or spaces with limited width

To prevent these disadvantages, we can work with a different set of tools as will be described in the next chapter.

5.2.2 Buoyancy driven ventilation

Buoyancy driven ventilation takes place when there is a difference in air pressure in the space. In buildings, this effect takes mostly place when there is a difference in air temperature. In a smaller scale we already described this process in the chapter about cross ventilation, but then the outside winds were still the driving factor behind the ventilation.

Buoyancy driven ventilation is caused by a difference in in outer and inner air temperature. When the outer air is colder and thus denser, it will place itself underneath the hotter air already present inside the building. On its turn, it will then heat up and create and upward flow of air until it reaches the higher opening and leaves the building. This effect will become greater with bigger temperature differences and with greater height of the room itself. In the case of buoyancy driven ventilation the inlet and outlet can both be spaced at the height of the ceiling or have a different inlet on the lower side of the space and an outlet placed higher up.

The big advantages of buoyancy driven ventilation are:

- No need for wind-speeds
- Same airflow
- More variety of/in – and outlet placement

The biggest advantage of this principle is the numerous variety of opportunities it brings along.

Stack effect

The best way to explain the stack effect is through the way the chimney of the fireplace works. The fire creates an inward suction of the denser indoor air and by heating up the air, it gets a lower density and rises up through the chimney and eventually moves outside. The narrow neck of the chimney increases this effect by giving the air a higher speed and thus lowering the pressure. This is why the stack effect is also called the chimney effect.

We already explained how the buoyancy principle works and noticeably its relationship to the stack effect is obvious. The only thing that is missing, is the chimney of the building. Since most multistory buildings do not use fireplaces for heating, the designer must think of different solutions to create the same effect. Another difficulty lies in the consistency of the air-quality throughout the entire building. As we know, the hotter, more polluted air will rise in the building and on its turn contaminate the floors above.

Architects and engineers have come up with some solutions for these problems. For example *chimney ventilation*.

Instead of using a fireplace and chimney to create airflow they use solar-power to heat up the ventilation chimney located on the top of the building. The air inside the ventilation chimney will be heated up and on its turn create a buoyancy effect which sucks out the remaining air of the building. That air will then again be replaced with new, cooler and fresher air.

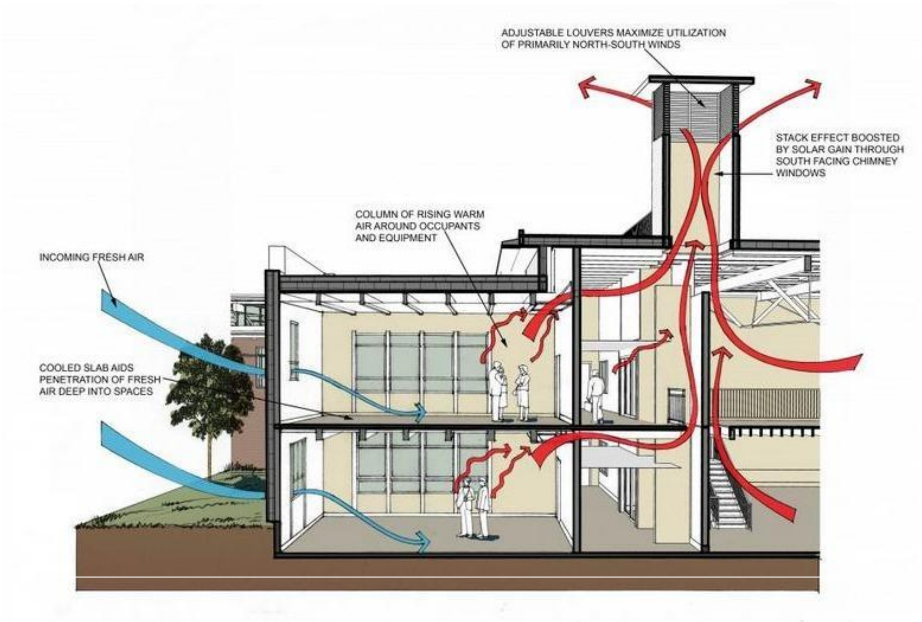

Figure 7: Example of chimney ventilation (source: Okanagan College Centre of Excellence in Sustainable Building Technologies and Renewable Energy Conservation, 2010)

Another alternative for chimney ventilation is *Atrium ventilation*

Atrium ventilation uses a central atrium mostly covered in glass as its heat gain, to create the upwards airflow needed for stack ventilation.

An additional benefit of this type of ventilation is that the central atrium can be used for plantation which will benefit the air quality and act as moist regulation of the building. That sort of a space can also be used as a lounge, public space or cafeteria.

Although very beneficial, we must be aware of overheating in this case. Plants can help temper the indoor temperature, but additional measurements are needed in the form of:

- Additional (temporary) shading
- Use of thermal mass to better regulate the indoor temperature
- Usage of light colors on the exterior surfaces
- Proximity of large water parties

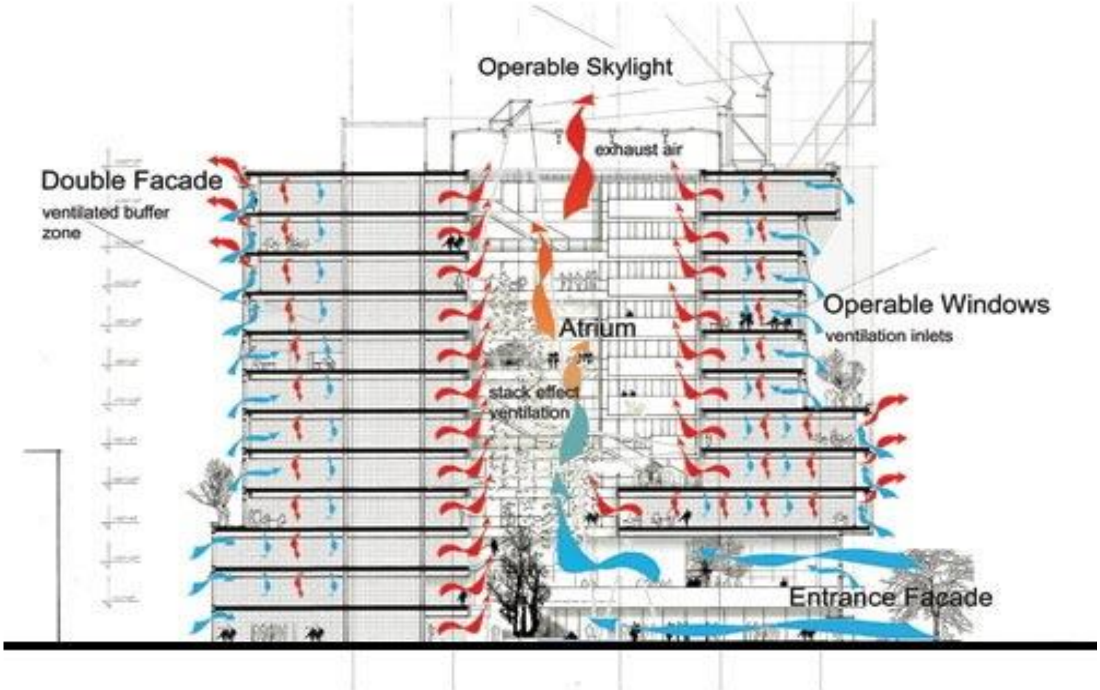

Figure 8: Atrium ventilation of the Genzyme center (source: cg5nb.wordpress.com)

The last example of stack ventilation is *Facade integrated ventilation* or *Double-skin facade ventilation.*

In this case the building's facade contains of two separate glass layers divided by an air corridor (the former chimney). One layer will be made of insulating glass and the air corridor itself will act as insulating layer against extreme weathers, winds and sound-barrier. In the air corridor additional shading is placed behind the first layer of glass to prevent overheating. The sun on its turn will again be the catalyzer of the stack effect.

The air corridor will be separated on each level by an inlet on the lower side and an outlet on the upper side, which can open and close when needed. This makes the system highly adjustable for different types of weather or climate.

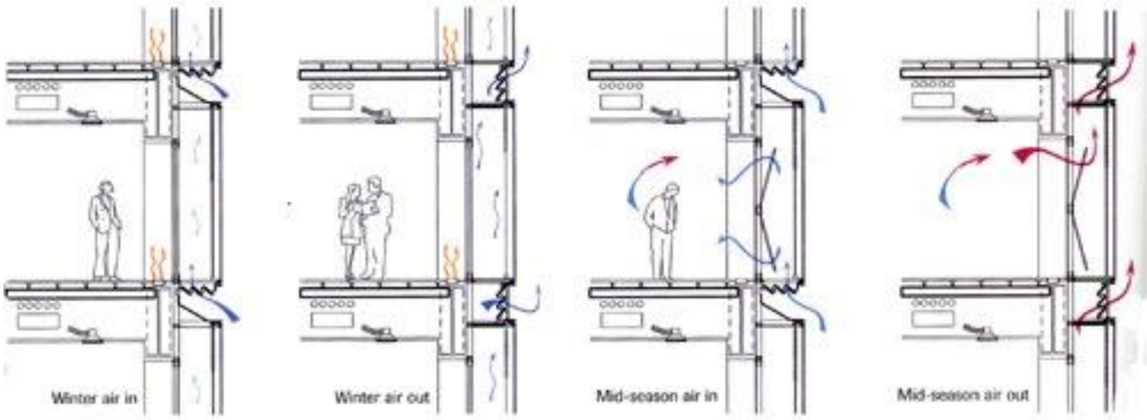

Figure 9: Hybrid mechanical and natural ventilation with double skin façade. Minerva Tower, London. Nicholas Grimshaw, Architect; Roger Preston & Partners, services engineers

The buoyancy effect is not only the driving force behind the stack effect but also plays a big role in other cooling systems such as the Bernoulli's principle.

Bernoulli's principle

More precisely, Bernoulli's principle uses the differences in airspeed to come to the same conclusion. In this case we look at the problem at a different angle. Instead of using the difference in indoor and outdoor temperature, we will now use the differences in wind speed close to the ground (where it is more obstructed) and higher up in the air (less obstructed). The Airspeed at ground-level will be slower and as we saw in the example of the chimney, slower air will be denser. The higher air is less obstructed, so it will be faster and thus have a lower density. This density difference will result in an airflow going from the ground upwards. Resulting in the same effect as the buoyancy effect and for the same reasons but with different factors.

The Bernoulli principle forces the designer to play with the wind direction, keeping a heavy obstructing base but a more narrow and wind guiding roof. It also has one big disadvantage comparing to stack ventilation, in the way that it always needs wind to create the suction that is needed to ventilate the building. This is why you will mostly see this type of building used near the sea and oceans where the wind is constant and comes mainly from the same direction.

From time to time it is possible to come across projects where the combination of both systems, Bernoulli's principle and stack effect, are used simultaneously. One of these examples is the BedZed eco-village in Hackbridge, London Borough of Sutton.

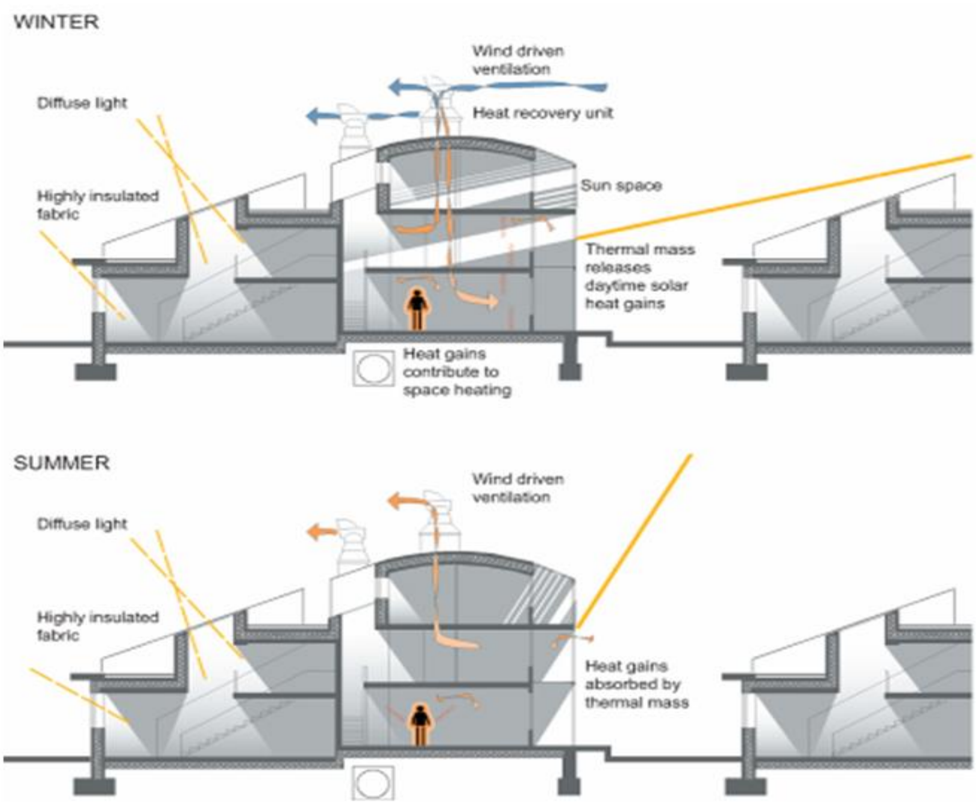

Figure 10: BedZed in summer and winter time (source: pep.ecn.nl)

The chimneys sticking out, emphasize the narrow top and the contrast with the heavy base of the building, these are needed to obtain the bernoulli's principle. At the same time you can notice the light shafts entire deep into the building creating additionally a stack effect in the building. In combination of the two main principles they also use thermal mass to regulate the overall heat gain and heat loss of the building, in that way it is possible to have steady indoor temperature.

Conclusion

Consequently one is only able to scratch the surface of the possibilities offered by natural ventilation although there is always the prospect in going deeper into the importance of thermal mass as a regulator of the indoor air temperature. My main aim was to sketch a relatively clear image of the leading principles out there, regarding natural ventilation.

As a result of my research I acknowledge that to build a building that relies completely on natural ventilation, a great number side factors have to be considered and must be favorable. Although most of these environmental factors can be concurred or made into advantages by means of thorough integrated design and by combining different strategies, it is not always possible to achieve this due to various economic, time-consuming or functional reasons.

On the other hand, natural ventilation can also be a positive factor regarding the budget, especially when looking at maintenance and operation costs, since no electricity would be needed.

All in all, I support the idea that we, as ATCM’s, must strive to incorporate as much of these solutions as possible and encourage our fellow engineers as well as the architects to do the same ,supporting the ecological and ethical ways of thinking.

In my opinion a better cooperation between these different levels of designers would lead to more sustainable and better buildings in general. I see a big role for ATCM’s in furfulling this key role of moderator and communicator within the design process of a building in the future.

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