Why Building has to be *Airtight*?

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ıbstract

Building envelope has continued its improvement ⁄ith modern cladding and window to meet low OTTV nd trend of green building standards. The development as been significantly reduced cooling load requirement ɔr airconditioning system and power consumption for uildings. Cooling requirement for general office uildings have been reduced from 15 sq.m/refrigeration ɔnnage for old building to 25-30 sq.m/refrigeration ɔnnage for modern building. That reduction in cooling is ractically "half". OTTV has been reduced from 55 ⁄att/sq.m to less than 35 watt/sq.m. Architects are paying ıore attention on protecting solar heat gain through uilding envelope by integration of shading devices.

In hot and humid ambient condition such as ɜangkok, protecting solar heat gain is not the absolute ɔlution. Latent heat gain from humidity could be as high s 30-40% of total cooling load. Therefore, the building nvelope should have both **"thermal and vapor ısulation property"**. That means, building envelope hould have the ability to protect heat as well as moisture. Most architects only ask engineer for their advice on type f insulation and insulation thickness but rarely ask them ɔr their advice on moisture protection and water ermeability through building skin.

Besides, most of the existing building cladding ystem is not airtight. The building is leaking with ncontrolled ventilation or infiltration. Avoiding "Infiltration" is one of the key issues for advanced airconditioning design. "Dedicated Sensible and Latent Cooling" airconditioning design concept is a concept, which focuses on latent cooling treatment. "Building as Cooling Thermal Mass" is example of advanced airconditioning design. Building by itself is actually the major thermal mass to the airconditioning system. In the future, one of the building envelope properties should be **"Air Tightness"**. Only air tight building and controlled ventilation could lead to extremely low cooling load demand of 40-50 sq.m /refrigeration tonnage or less.

The building air tightness is a must, not only for modern airconditioning but also for health and fire safety. It is a must that the building envelope should have controlled ventilation to reduce **risk of airborne contamination. In term of fire safety, air tight building will reduce unpredictable rapid fire occurring**.

Keywords: Control of building "Infiltration"

1. Introduction

Architect and engineer are both building designers, and when they design a building, they should work together as a team to produce integrated building design approach. Since **"Green Building"** is becoming a global trend, as well as a new building specification, building designers are coming up with innovative ideas toward energy efficient building, environmental friendly and safe building. Green building design is truly a whole building design approach. As an airconditioning engineer, we know that the airconditioning system consume about half of the building energy. Therefore, *reduce airconditioning load is the key factor of reducing energy consumption for building*. As described, reducing solar heat gain is not the only solution for cooling load reduction. Since ventilation load is 30-40% of cooling load in hot and humid environment. Reducing "Infiltration" should be more important factor for cooling load reduction. **Building with infiltration adds uncontrolled ventilation load to the airconditioning system**. Infiltrated air could cause condensation at supply air diffuser, air duct, chilled water piping and air handling unit. Incoming moist air could cause mold growing.

Infiltrated ventilation is hard to be extracted from the building once it has been entering, and consume more

nergy for air processing than proper fresh air intake at ıe air handler. Infiltrated buildings are loosing internal ooling storage effect after the airconditioning system has ırn off after working hour. In fact that is the main reason or office building to have started the airconditioning ystem early on Monday morning in order to reach omfort temperature at the start of working time.

igure 1. Dirty eiling supply ir diffuser /hich normally ɔund in ıfiltrated uilding

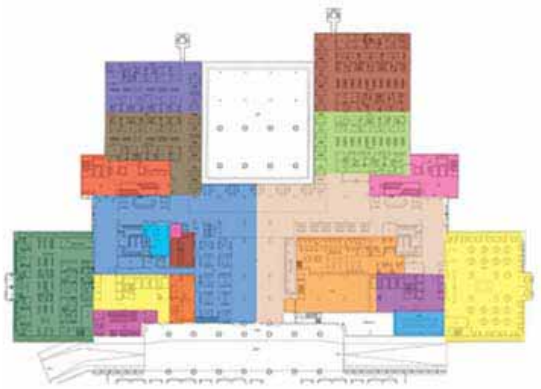
Several office buildings are hot for a few hours on Monday morning. In that case, we could imagine how ıuch energy would be consumed to cool down the uilding. This paper will described building infiltration nd the design methods on how to protect the infiltration.

. Building compartment

This is a good start for architect and engineer /orking together as team work. When considering uilding compartment, the planning should be able to ıtegrate key functional requirement of compartment, ıch as:

1. Airconditioning zone control
2. Fire compartment
3. Smoke compartment
4. Security zone control

A compartment should be able to serve the entire bove key functional requirement. Otherwise, there /ould be too many fire and smoke dampers, complicate n-off of air handlers, cross contamination, cross talk and everal weak points in the security and access control ystem. Wall line that indicates a compartment should be asy to be understood by normal sense. It should be a traight line and not in jig saw pattern.



igure 2. Example of integrated building compartment ıat serve airconditioning, fire, smoke and security zone

Fire and smoke compartment is necessary to control fire and smoke spread. Allowing evacuation time for occupants and sustain the building until fire protectior system is working and fireman come into action is the key factor of a compartment. If the system works well, there should be minimum damage to life and property. However, when compartment is not airtight, air leakage could initiate unpredictable rapid fire occurring, which is very dangerous to fire fighting activity. “Back draft” could be initiated by infiltrated air, which cause rapid fire or explosion.

Compartment is the basic requirement for airconditioning zoning. Since temperature and humidity conditions are specified differently for each zone, as well as efficient operation, compartment should be well planned and indicated clearly.

Therefore, important building compartment characteristic is “Air tightness”.

3. How to control “Infiltration”

As described, the building should be compartmented and airtight. In that case, the building could be resembled to a refrigerator or could be called a “Cold box” building. Like a refrigerator that is well insulated and airtight, it can maintain low temperature inside the refrigerator, even at sub-zero temperature, by using only a small compressor. A refrigerator does not have to turn off during the night. It runs 24 hours, 365 days without consuming unnecessary energy. If a building has been designed as a cold box, the airconditioning system does not have to be turn off during the night. In that case, the building is cooled 24 hours, 365 days. There will be no need for night time airconditioner or night time small chiller. However, if the building is not airtight and leak, incoming moisture and heat will impose on the airconditioning system. In order to maintain indoor conditions, the airconditioning system has to cover the incurring load at any time when the building is occupied and unoccupied. Since during unoccupied period, the leaking in air and moisture will be stored in the building, which needs to be treated during the start of occupied period. How to install over time split type aircondioner has been a difficult design constraint for architect all the time. Running chiller or cooling towe during over time is expensive and is very inconvenience to tenant.

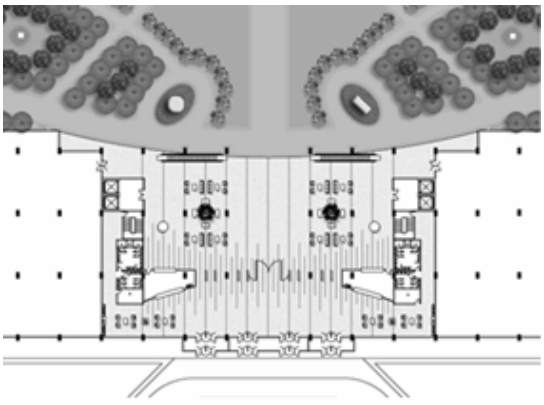
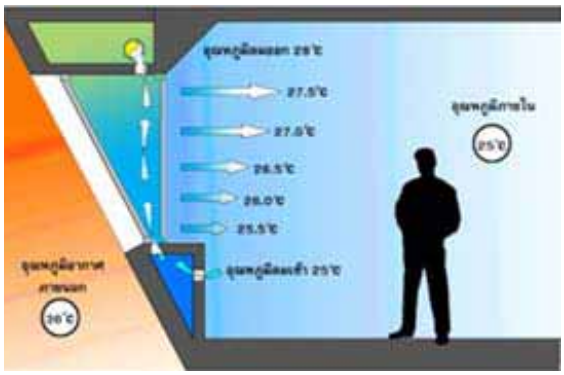


Figure 3. Example of building entrance with air lock vestibule

igure 4. Example of building entrance with onsideration of wind effect

In order to control infiltration, the building envelope nd window system have to be airtight. It is advisable ıat the wall is using double skin design, as well as the /indow system. Practically, it is almost impossible to onstruct an airtight wall and window system with only ne layer. Looking at a basic material such as silicone ealant for joints, no one can guarantee the workmanship nd life of the sealant after installation. With double skin, ıe exterior skin will protect against weather, while inner kin will insulate the building. The system is similar to uman skin which also have outer and inner layer. With ouble glazed window, the exterior glass will protect olar heat and wind velocity, while the inner glass will esist the transfer of heat from exterior glass. Wind ressure will be diminished after passing exterior glass nd window frame. When entering the second frame, the /ind pressure will be minute and will not pass the second ame. This is also a very effective means of protecting ain storm. The double glazed window with separate /indow frame will not provide thermal bridge and revent heat conduction from exterior window frame.



igure 5. Example of double skin building

Double skin wall may not affect overall construction ost when using proper details. Double window system nd wall may not affect overall construction cost when the window area is controlled at less than window to wall ratio of 1/3. Government center project is a good example of cold box design concept with “Air flow window” that can be constructed within government tight construction budget. The project controls both window to wall ratio and building envelope area to useable floor area. Therefore, cost of building skin per floor area is not higher than conventional building, though cost of building skin per sq.m alone is higher.

Building entrances have to be limited, since building entrance is the opening of infiltration. The entrances should not be in the wind direction. Be reminding that a cubic feet of infiltrated air is equivalent to 80 Btu/ h in average. A door opening inward a convenient store could easily add 1 ton of refrigeration to the store. Opening outward could significantly reduce infiltration. Some convenient store is now changing to automatic sliding door.

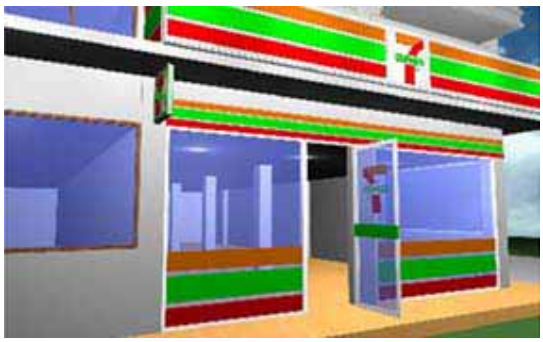


Figure 6. Door opening direction has a lot of effect on infiltration

Several building has very high infiltration at the entrance lobby due to large door opening. It is a wrong decision to use frameless door for the entrance, since the door has large gap between the door and the frame that allow a lot of infiltration. Such door will not protect rain, dust or insects. In order to reduce infiltration, that affects indoor temperature, some building install air curtain which are useless. It is advisable to provide lobby as an air-locked vestibule. The controlled lobby should be partitioned as a compartment. External door should be air lock door of either revolving door or double door. When using double door, the first door should be at least 3.00 m distance from the second door in order to allow the first door to close before the opening of the second door. Emergency door for evacuation is an exception and may incorporate on the side.

Figure 7. Air lock revolving door is an effective means of preventing infiltration. However, it might not be suitable for high traffic and carts

Limitation of entrance is also important for security nd access control.

There are practices of installing split type irconditioner in a room with a wall exhaust fan. Even ıere is an argument that at one time, the exhaust fan was sed in a room which could have smoking. This is a bad ractice, since the exhaust fan creates negative room ressure and promotes infiltration. Such room will have ust and high humidity. Exhaust fan is normally 8 inches ı diameter at capacity of 150 CFM, and will suck onditioned air out of the room. Airconditioner will be ınning with higher cooling load and consume a lot of nergy. The proper method of supplying fresh air into the irconditiong space is to install fresh air unit. Fresh air nit with supply fresh air fan and exhaust fan, including ir to air heat exchanger is available.

Opening a door into the room will introduce more ıfiltrated air into the room when compare with open the oor outward. If outward opening is not possible, sliding oor would be a better choice. Size of door opening has ignificant effect on the rate of infiltration.

igure 8. Installation of split type airconditioning unit /ith an exhaust fan

igure 9. Fresh air unit with fresh air/exhaust air fan and ir to air heat exchanger

. Breathable wall

Like human skin, building skin construction is breathable". The necessity of exterior skin to be reathable is to allow trapped moisture inside the wall to isperse, so that the wall will not get damp. Wall construction has cavities. These cavities trap air and moisture. When indoor temperature is lower than dew point, the trapped moisture will be condensed and soaked in the wall material. That will deteriorate the wall material and might promote mold growing. Each material is permeable. Exterior wall should be weather proof as well as breathable or permeable. Selected exterior paint, such as acrylic paint, should also have this property. Vinyl wall paper is not recommended as interior finish, since it will peal off after a certain period of time by vapor pressure inside the wall. Autoclave aerated concrete (ACC) block wall has water absorption of 30% and porous. Therefore, it should be incorporate with cement finish and acrylic paint. The block wall construction alone is not a vapor barrier.

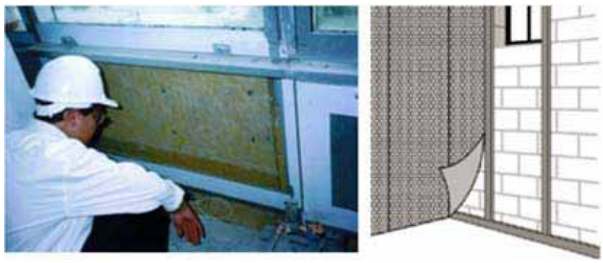


Figure 10. Example of breathable wall construction

5. Vapor barrier

The building wall material should be able to protect moisture or vapor pressure. When there is different moisture level between inside and outside of the building, the higher moisture from outside will penetrate into the building by vapor pressure. Outside vapor pressure is normally 4.8 kPa, while indoor vapor pressure is normally 1.8 kPa for airconditioned space. Therefore, differential vapor pressure is approx. 3 kPa. If there is wall cavity, the trapped moisture could have vapor pressure of 6.2 kPa, and differential vapor pressure with indoor vapor pressure could be 4.4 kPa. There fore, the inner building skin should be incorporated with vapor barrier, such as plastic sheet or aluminum foil. The outer building skin is weather protection, water protection, and should be breathable to disperse trapped moisture within the wall outward. Without vapor barrier, a lot of moisture will penetrate into the room and affect the cold box ability. Building with high moisture permeability could be noticed by excessive drain at fan coil and air handling unit.

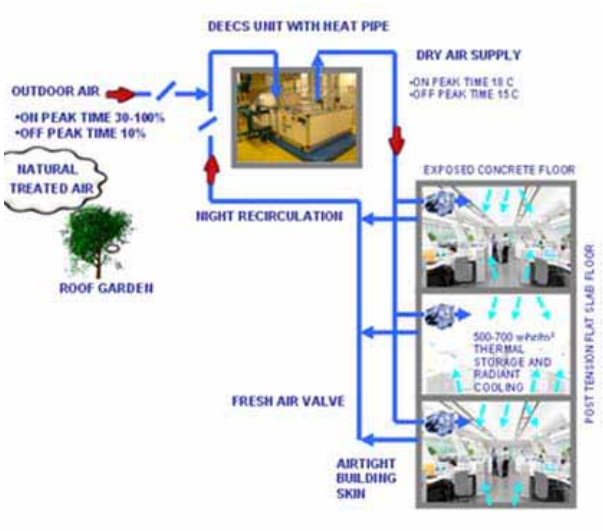
Figure 11. Installation of vapor barrier

igure 12. Totally
rapped fiber
lass insulation is
good choice of
ıermal and vapor
ısulation

. Dedicated outdoor air supply system

More or less, with all the described methods, ıfiltration will still presented, because the building has ırge building skin surface and there are so many joints nd permeates. Therefore, the building should be ressurized and maintain positive pressure. There have een several papers on dedicated outdoor air supply ystem or DOAS. The outdoor air supply system provides ıe building with preconditioned fresh air supply for etter indoor air quality control, as well as pressurizes the uilding. It is an ideal solution for modern irconditioning design.

Positive building pressure is the only way to control uilding permeability. With advanced airconditioning ystem design, the DOAS can also charge the building ith cool air and store cooling energy into the building tructure. Incorporate with demand control, the system ill be able to control indoor air quality as well as ooling demand efficiently. A good designed DOAS hould supply fresh air at average temperature of 18 C nd less than 8 g/kg dry air. With this specification, the ystem will both charge cool energy storage to the uilding, as well as dry the building. In other words, the ystem will store both sensible and latent cooling into the uilding. Building structure with concrete flat slab floor ould be able to store 500 w-hr/ sq.m of sensible cooling.



igure 13. DOAS that supply demand control fresh air ıto the building as well as charging cool energy to uilding structure during night time for the government enter project

Figure 14. Outdoor air unit with wrap around heat pipe that supply dry fresh air into the building

7. Radiant cooling

Radiant cooling is an effective method of cooling that is amazing. Since radiant cooling provides "Operative temperature" which make occupant "feel" cooler than normal room temperature. Radiant cooling average surface temperature is 19 C to avoid possible surface condensation. The system can only be installed in an airtight building, since there is chance that the radiant surface temperature could be fluctuated due to fluctuation of chilled water system pressure and shift the radiant surface temperature. When the floor is sweat, it could be slippery and dangerous.

Building with radiant cooling, including chilled ceiling and chilled beam should be airtight to avoid sweat and condensation along the radiant cooling surface.

8. Low temperature air distribution

Airtight building is also important for a building with "Ice thermal storage" and low temperature air distribution. Since supply air temperature of low temperature air distribution is 7 C, there is chance of condensation at supply air diffuser. Low temperature air distribution should be used when thermal ice storage is used as cool thermal storage in order to reap the benefit of low ice temperature. Air supply diffuser has special design to obtain air induced and mixing ratio of above 10 The diffuser is mostly plastic to minimize risk of condensation.

Figure 15. DEDE training center with low temperature ai distribution system

Leak building could cause risk of condensation on ir duct and chilled water piping. The DEDE energy aining center is the only building that has low emperature air distribution and thermal ice storage. Only ne main air handling unit run the whole building. The roject airconditioning operates successfully because the uilding is a cold box.

. Conclusion

This paper emphasizes the important of airtight uilding characteristic. Architect and engineer as building esigner should put this key characteristic to their uilding design both passive and active. On passive esign, the architect should specify airtight insulated uilding skin with vapor barrier. The building should ave limit entrance, proper entrance location, controlled obby and air lock. Building should be compartmented to ccommodate airconditioning zone control, fire and moke compartment as well as security zone control. On ctive design, the engineer should provide DOAS or fresh ir supply system. There are 4 key factors to reduce ooling load requirement effectively: Control of solar eat gain/ Control of ventilation/ Control of internal heat ain/ and thermal storage. Airtight building is the prime nportant for the control of ventilation and thermal torage. **It could be concluded that airtight building is he indicator of level of quality standard of a building.**