Effective HVAC System for Schools

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Abstract— **Healthy and comfortable indoor air climates are essential for any type of building environment. Particularly, classroom air environment and thermal comfort has an important role in the teaching and learning process as it could be engaging students in activities that promote their performances, such as understanding of concepts, abilities of problem solving, and attitudes towards learning, and etc. In order to achieve such better indoor air environment and thermal comfort in classrooms, school buildings usually have been operating with air conditioning system by design norms. By carrying out cooling and heating load calculations one can estimate the capacity that will be required for various air conditioning equipment. The types of air conditioning system selection depends on many factors, including the costs to implement, occupancy, provided security and protect from other hazards. Active cooling using refrigerant-based devices can be replaced by passive cooling methods using surrounding natural resources. This study explains known hybrid technologies, mechanically powered, using natural resources.**

Index Terms—**durable, economical & reliable HVAC system, green concept, design policy, alternative for HVAC**

1. INTRODUCTION

The purpose of your school's heating, ventilating and air conditioning (HVAC) system is to provide a comfortable, appropriate environment that is productive for the students. To do that, the HVAC system must manage temperature, humidity, indoor air quality and sound. In addition, you want the HVAC system to be cost effective (both in terms of capital and operating expenses), reliable, easy to maintain and environmentally friendly. This paper will help you learn how to get the ideal HVAC system for your school by design norms (policy). It will explain three criteria for a good HVAC system, and help you apply those criteria to your school. Its purpose is to help you assemble a design team, ask knowledgeable questions, and work with engineers to specify the system that's best for your school at an affordable cost.

2. THE BEST HVAC SYSTEM IS DURABLE

It's not every day that you purchase an HVAC system. HVAC components are a significant capital expense, and durable systems can give you 25 or more years of trouble-free service. Three factors affect the durability of your system, and therefore your long-term investment:

Materials—Equipment that uses durable material stands up to the test of time, from exterior cabinetry to interior machinery. For example, consoles installed in classrooms (such as unit ventilators) should be constructed to withstand classroom use and activity, and should be sealed tight to prevent unauthorized access. Interior components should be designed with a rigid structural base and constructed of galvanized steel, stainless steel and other long-lasting materials to withstand corrosion and to increase the strength of the equipment.

Interoperable controls—Technology continues to advance, and with it the sophistication of your school's building automation system (BAS). But five years from now, when you upgrade or install a new BAS system, will it be able to support the HVAC equipment you install today? Or will you need to install costly translators just so the new controls can "talk to" the old? Requiring equipment manufacturers to design their equipment so it can communicate using open, standard protocols, such as LonMark and BACnet, will make it easier to integrate with multiple BAS upgrades throughout the useful life of the equipment.

Refrigerant—Air-conditioning refrigerant plays a key role when you're considering the longevity of your equipment, regardless of whether you are retrofitting or constructing from scratch. In less than a decade, the most common air-conditioning refrigerant in the world, HCFC R-22, will be phased out of production because of its ozone depleting properties. It will be banned from use in new equipment after 2010. While R-22 refrigerant will be available after 2010, service will have to come from reclaimed refrigerant. New families of refrigerants with no ozone depleting properties (such as HFC R-134a, R-410A and R-407C) have the same safety classifications as the refrigerants you're currently using. And, they are safe, efficient and will be available for the foreseeable future. Taking a proactive approach of asking that new equipment uses these refrigerants not only helps to make sure that it can be fully supported for its useful life, it also helps to protect our environment from the harmful effects of ozone depletion.

3. THE BEST HVAC SYSTEM IS RELIABLE

With decreasing dollars available for maintenance and operation, you simply don't have the staff, time or the money required to babysit an HVAC system. And you shouldn't have to. A reliable HVAC system should deliver sufficient amounts of fresh air at the right temperature and humidity equally throughout a room, and teachers and staff should be able to regulate it. Fortunately, controls and building automation systems make this more possible than ever before. Moreover, reliable also means easy to maintain. Look for these factors in a reliable system:

Easy to access— Your equipment requires scheduled maintenance to keep it at peak performance. Save time for your maintenance staff by buying equipment that is easy to access. Panels should be designed so they can be easily removed and handled by one maintenance person. If they're hinged, they should be easy to open and close with security latches to prevent unauthorized entry. And there should be lots of panels, making it easy for staff to quickly get at controls and interior mechanics for change outs and cleaning. This is true for the individual unit in the classroom as well as for the system-wide unit in a mechanical room or on the roof. The easier your equipment is to access, the better the chance that it will be regularly maintained to keep it running at peak performance and lasting longer.

Easy to operate—Again, controls are a modern answer to easy operation. They display operating and troubleshooting information, saving maintenance staff valuable time if something goes wrong.

Easy to service—Service contracts are available from all manufacturers, and are your best means to keep equipment running smoothly, while saving your staff valuable time.

4. THE BEST HVAC SYSTEM IS ECONOMICAL

Your school district is constantly balancing its capital and operating expense budgets against the function and performance required from an HVAC system. You are looking for the best system your budget will allow, and that means a system that is economical to buy and install as well as economical to operate and maintain throughout its life expectancy. Manufacturers have developed many ways to reduce your first costs and operating costs without compromising on quality.

Reducing first costs— Equipment manufacturers have invested heavily in the design and construction of their equipment, and that means you can save money when you buy and install equipment. These days, manufacturers can build an air handling unit sized to your available space rather than having your school building designed around the size of the HVAC equipment. On the other hand, if you need equipment exactly the same size as the equipment you're replacing, manufacturers can do that, too. Unit ventilators sized the same as they were 30 years ago will save you the cost of modifying an opening in the classroom wall. And that same unit ventilator will feature the latest in HVAC technology so that it delivers today's requirements for fresh air, quiet operation and energy efficiency. Today's equipment is also modular, allowing components and options that can help save energy and improve indoor air quality to be factory-installed, thereby reducing field installation costs. Larger components can be shipped assembled or by section, reducing the time to set them up and install them. Equipment testing is also performed extensively at the factory, saving on first cost dollars and helping to promote reliable start-ups.

Reducing operating costs—The more efficient equipment is, the less energy (usually generated by fossil fuels such as oil, coal or gas) is required to operate it. All reputable manufacturers design their equipment to meet minimum industry standards for efficiency. Some manufacturers can exceed these standards because they can incorporate new technologies that help to reduce energy consumption. And of course, the more efficient the equipment, the more you can save in gas and electricity costs. While all equipment is efficient to some extent, a better question to ask might be: How can I optimize efficiency? Optimizing efficiency can pay for itself over a short period of time with energy savings. Many states also offer energy rebates that can be applied toward the cost of installing HVAC equipment.

Recover energy and money—One way to optimize efficiency and qualify for a rebate is to include energy recovery devices with your HVAC system. These are wheels or plates installed in equipment that recover heat (and moisture, as is the case with energy recovery wheels) and use it to pre-condition the ventilation air stream. They can reduce capacity requirements for refrigeration, heating and humidifying. This means your system can be smaller, and that saves you money in both installed and operating costs.

5. WHAT IS THE MOST ECONOMICAL, RELIABLE AND DURABLE HVAC SYSTEM FOR MY SCHOOL?

To a design engineer, a school consists of different zones or spaces, each with specific needs for heating, cooling and ventilating. Classrooms generally have high ventilation requirements (three times that of an office), but only when occupied. Dedicated classrooms, such as science and computer areas, require extra ventilation and cooling. Administrative areas require lower heating and cooling, but are occupied over longer hours. Cafeterias need special ventilation for food preparation, and gymnasiums, occupied during the day and evening, have a range of load requirements and scheduling demands. Factor in a school's age, size, construction (such as walls, lights, doors and windows), zone requirements and local climate, and you can see why schools present unique challenges for meeting HVAC requirements. Your ideal system will be able to balance all the elements. Many different types of equipment and configurations are available to meet the requirements for your school. These configurations fall into two basic design categories: zoned comfort systems, which condition individual zones; or one central system, which conditions an entire school.

a. Zoned Comfort systems

Zoned comfort systems (such as unit ventilators, water source heat pumps and fan coils) provide heating, cooling and conditioning (e.g., humidity control by unit ventilators) to individual classrooms or zones. The advantage of a zoned comfort system is that one unit can provide cooling to one space while another unit is providing heating to a different space. The units can be controlled so that their space is not cooled or heated when it is not occupied, which helps reduce operating costs. Ideal for new or existing buildings, zoned comfort systems are easy to service and can rival the most advanced centralized systems for energy efficiency.

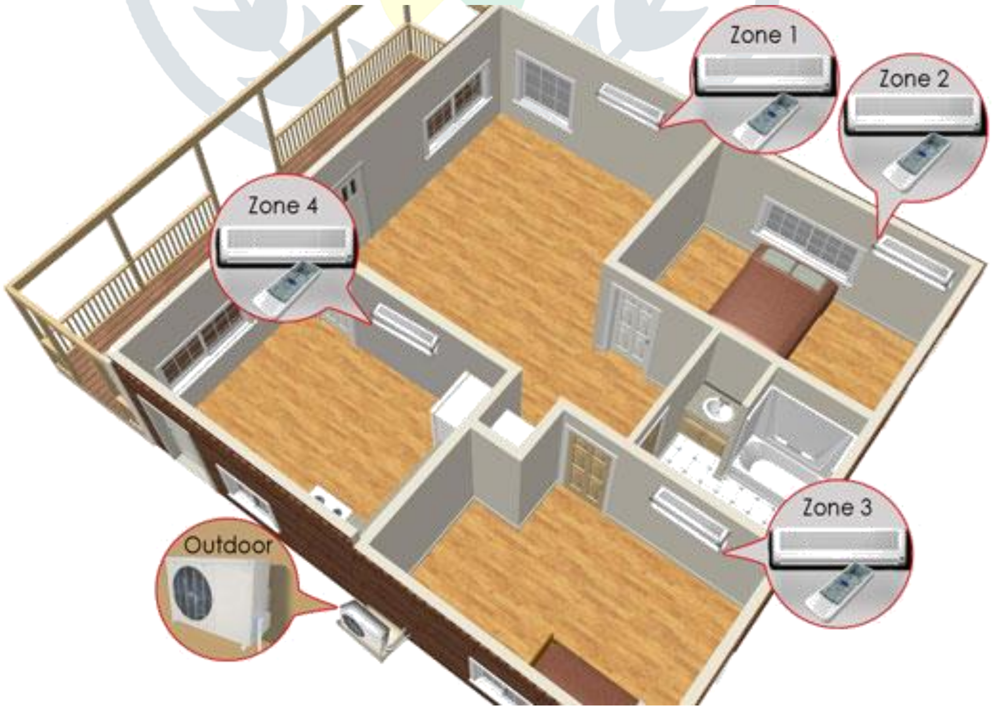

Fig.1 Zoned comfort systems (such as unit ventilators) can heat one space while cooling another.

b. Central Systems

Unlike zoned comfort systems, which control individual zones, a central system controls many zones (such as a block of classrooms, the administrative area or the gymnasium). These systems condition air in a remote location, such as a mechanical room or on a roof, and distribute it through ductwork to the occupied spaces. Central systems can include air handling units and chiller plants, rooftop systems and vertical self-contained systems.

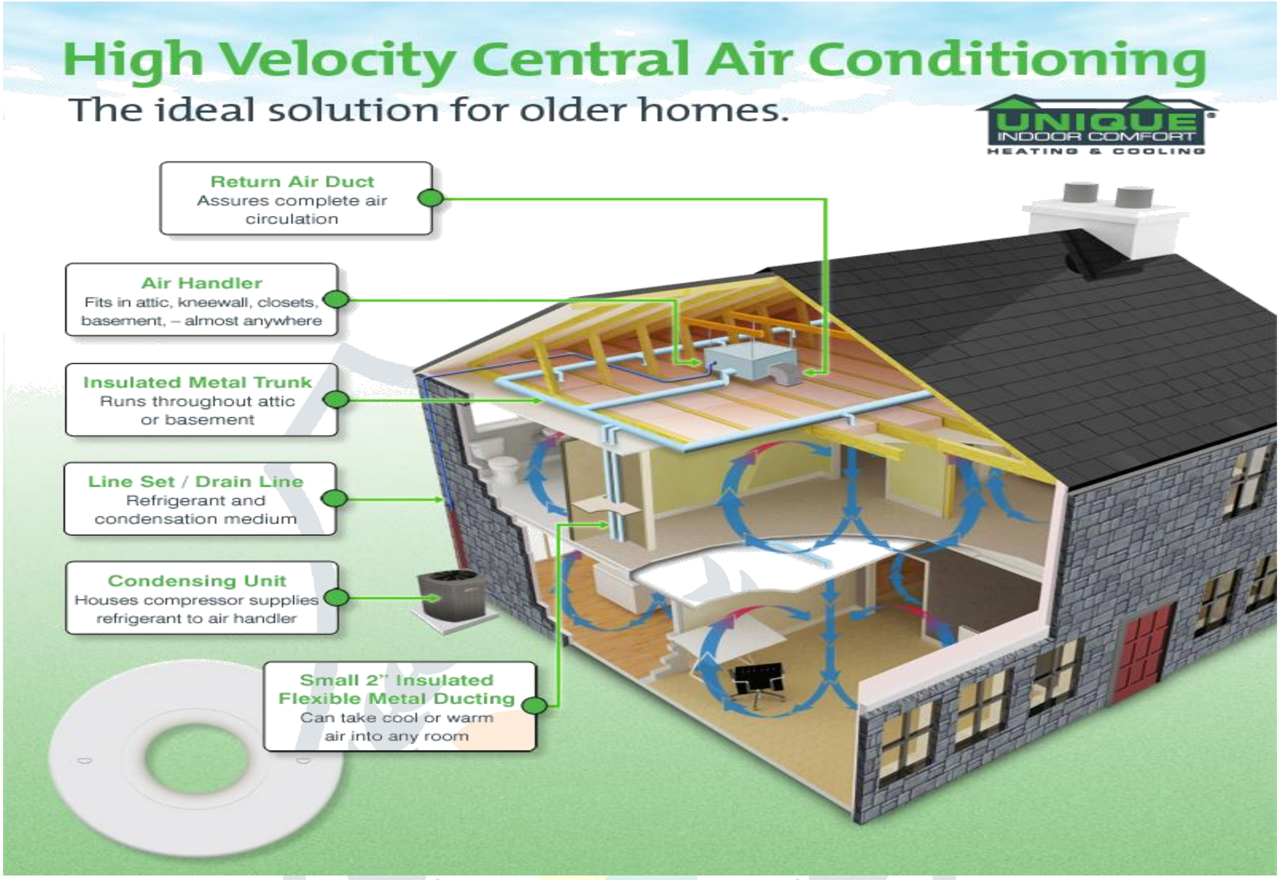

Fig. 2 Centralized systems deliver heating or cooling to several zones from one unit

6. A WORD ABOUT GREEN

A "green," "sustainable" or "high performance" building generally means that it is designed to provide a safe, healthy and comfortable environment while having the least impact on the environment, both during construction and throughout its useful life. In most cases, it is your planning and follow-through that makes the difference between whether your school can qualify as green. HVAC manufacturers help you achieve your green goals by offering a variety of products, such as earth-friendly refrigerants, energy recovery systems, CO2 sensors and high-efficiency geothermal heat pump systems. Several organizations exist to help you achieve energy-efficient recognition and rating for your school. Their prerequisites and credits may already be required by local codes, or they make sense to be incorporated as part of your school's best practices design.

A green building design is not only dependent on Air conditioning system but also concentrating on the following areas

1. Site selection in sustainable way
2. Water efficiency (in Plumbing engineering service)
3. Environmental Friendly ideas
4. Energy efficient lighting / Day lighting
5. Material selections
6. Effective optimizing the operations & maintenance

Among the above engineering services, this report will only be concentrating on Air conditioning system due to the following reasons,

1. Air conditioning is the major consumer of energy in building – around 57% (refer to Figure 3)
2. It has a direct impact in the Occupant's health
3. It has major contribution to Ozone depletion & Global warming
4. It has major impact on occupant's productivity and contributing to "Absenteeism".

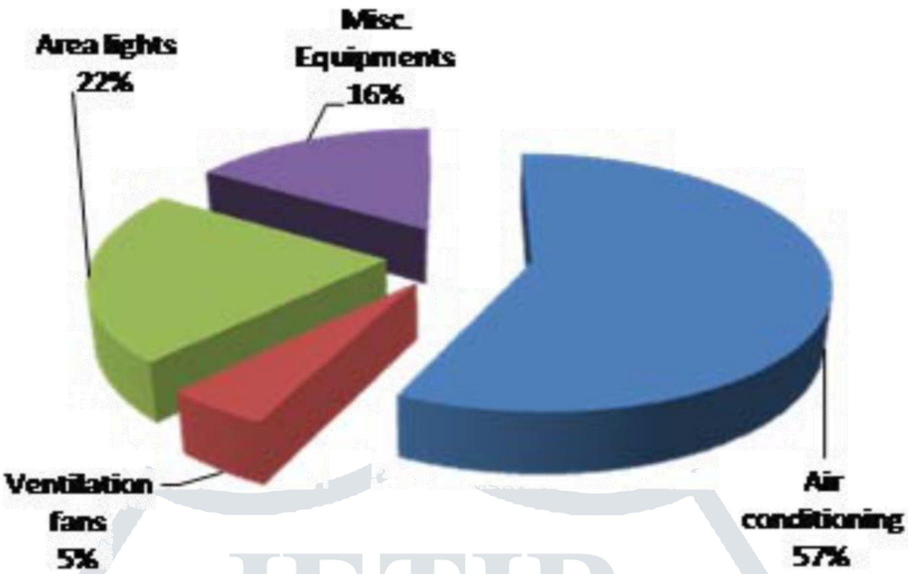

Fig 3. Break-up of energy consumption in a typical building

7. DECS POLICY FOR AIR CONDITIONING

Department of Education and Children Services (DECS) has provided policy requirements for the provision of 'air conditioning' (ventilation, heating and cooling), including the performance benchmarks, the technical standards and the evaluation procedures for the design, assessment of possible and suitable alternative solutions, and the provision of such equipment.

This Policy contains:

1. General policy and standard information to assist sites in understanding the appropriate ventilation, heating and cooling provisions for spaces in schools and children's centers, and those involved in developing facilities briefs for new and redevelopment projects.

2. Specific technical standards to advise Professional Service Contractors and Facilities Management Contractors on detailed requirements for plant and equipment selection.

a. INDOOR AIR QUALITY (IAQ)

Schools present unique challenges for achieving good IAQ. For example, the population density of an average classroom (900ft² classrooms with thirty students) is three times that of a typical office. ASHRAE has developed Standard 62.1-1999, Ventilation for Acceptable Indoor Air Quality. It is in normative language and has become the minimum standard of care in most building codes.

Std 62.1-1999 provides two procedures to obtain acceptable indoor air quality. Table 1 represents the ventilation rate procedure, which is the most popular. There is also the Indoor Air Quality Procedure. The later requires identifying and controlling known and specifiable contaminants. The minimum outdoor air rates listed in STD 62.1-1999 represent the minimum supply air volume to the space. The total supply air can be made up of the minimum outdoor air and acceptable recalculated air. It is acceptable to supply more air to meet the heating or cooling loads. The HVAC system design must be able to maintain space temperature and humidity conditions at the minimum outdoor air rate. During certain periods, this may be too much air and the classroom will be over cooled. In this case, some form of reheat would be required rather than reducing the airflow.

Table 1 – Outdoor Air Requirements for ventilation From ASHRAE Std 62.1-1999

Application	Estimated Maximum occupancy (P/1000 ft²)	Outdoor Air Requirements Cfm/ person
Classroom	50	15
Laboratories	30	20
Training Shop	30	20
Libraries	20	15
Auditoriums	150	15

b. HEAT LOAD CALCULATIONS

Accurate load calculations are critical to a well-designed HVAC system. Estimates for infiltration and drafting should be based on the actual school design, not on estimates from previous projects. Although some spaces will have high sensible heat gains, outdoor air will be the dominant load, particularly in modern buildings. The HVAC system is decentralized with an energy recovery outdoor air system. Most of the outdoor air cooling occurs in the outdoor air unit (20% of the total load). Additional outdoor air cooling is required at the classroom unit (another 13%). The total outdoor air load is 33% of the classroom load. The glass, wall and roof loads are much smaller. Even if they were larger (poor or older construction), the outdoor air load would still be the dominant parameter in the load analysis. The high population density should also be noted. The occupants represent 26% of the total load. Like the outdoor air load, this occurs in every classroom. School loads differ from office building loads because of their low sensible heat factors (sensible cooling/total cooling).A typical sensible heat factor for offices are 0.90. Therefore, equipment designed for office environments will not be suitable for school environments. Again, the outdoor air load is dominant, representing 63% of the heat loss from the space. An important conclusion can be drawn from these load calculations. All of the classrooms will behave approximately the same and their behavior will be dictated by the outdoor weather. The details of just how the school zones will behave can only be found by performing the necessary heating and cooling load analysis.

c. SOUND LEVEL

In recent years sound has moved to the forefront as a key parameter in the quality of the learning environment. Table 2 is the recommended sound levels from the 1999 ASHRAE Handbook. Classroom construction makes it more difficult to achieve low sound levels than in office spaces. There is little material to absorb sound energy and the hard, dense surfaces reflect sound energy back into the room. Sound generating mechanical equipment (fan coils, water, source heat pumps, and fan powered VAV) should be located in the corridor where possible. Figure 3 shows the recommended duct design for a classroom. A return air elbow is recommended for all systems when a corridor ceiling plenum is used for the return air path. Fire dampers may be required in both the supply and return ducting, depending on the rating of the wall between the classroom and the corridor. Special care should be taken in selecting diffusers. For a standard classroom of 1000ft², four- diffusers are recommended. If less than four diffusers are used, the required throw may make them too noisy. Most diffuser catalogs are based on only one diffuser in the space and a room absorption of 10dB re 10-12 watts. While these are acceptable assumptions for an office, they may be insufficient for a classroom. As a rule of thumb, for each additional diffuser, subtract 3 dB from the cataloged NC rating (i.e., for 4 diffusers, subtract 9 dB from the cataloged performance). Volume control dampers should be located between the flex duct and the main duct, away from the diffuser. Duct velocities should be limited to 800-1000 fpm to minimize sound issues. The supply duct should be acoustically lined for the first 10 ft. The return air elbow should also be lined. If duct lining is not acceptable, a sound attenuator with an insertion loss of 10 dB at 125 Hz is recommended.

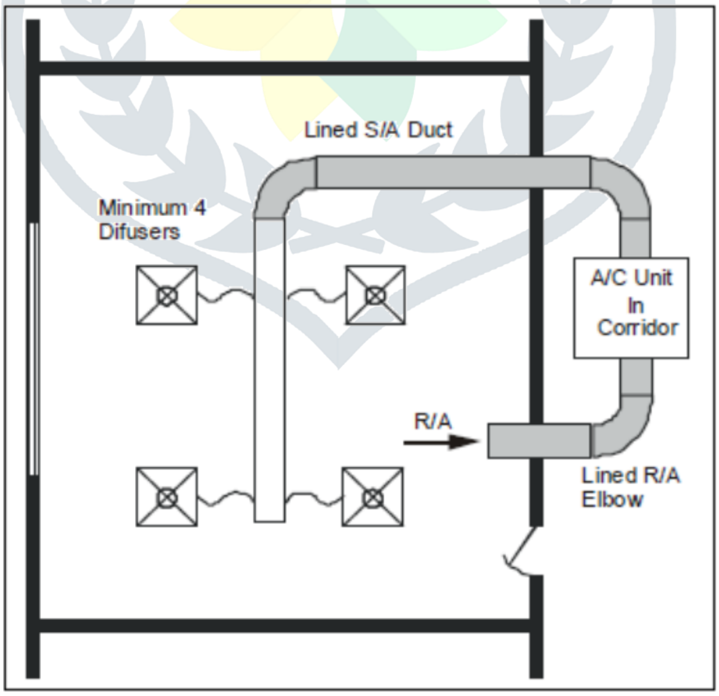

Fig 4. Classroom Duct Design for Good Acoustics

Table 2- Recommended sound levels

Space	A – Sound Levels dB	Desired NC (Noise Criteria)
Libraries, classrooms	35-45	30-40
Laboratories, shops	40-50	35-45
Gyms, multipurpose, corridors	40-55	35-50
Kitchens	45-55	40-55

d. MAINTENANCE

Equipment is to be located where it is readily accessible for routine maintenance and eventual replacement, and appropriate access is to be provided. Where possible avoid locating equipment on roofs and in roof spaces, unless there is already safe access with platforms and catwalks. Ceiling mounted equipment must be supported from structural frames and accessible from under the ceiling. Temperature sensitive equipment is to be located in a well-ventilated area.

e. SECURITY

Equipment located where it is publicly accessible shall have appropriate and approved security screening and/or cages to protect it from damage, whilst still allowing ease of maintenance access.

8. COOLING WITHOUT AIR CONDITIONERS: STUDY ON ALTERNATIVES

Interior comfort depends on the control of temperature. Active cooling using refrigerant-based devices can be replaced by passive cooling methods using surrounding natural resources. Savings are not only obtained by avoiding refrigerant gases (these gases are 1000 to 10,000 times more harmful to the climate than CO_2), but also by reducing energy demand. This study explains known hybrid technologies, mechanically powered, using natural resources. The different natural cooling systems presented in this study are all existing and have been used for years although often overshadowed by the arrival of air conditioners. Current technologies are mature enough to control indoor temperatures according to a standard demand while keeping a good ratio of energy consumption. If this temperature was the average standard everywhere, it is understandable that in countries with much warmer climate like South-east Asia, the work on the building, installation and technical energy consumption (total embodied energy) would be much more complicated. In most tropical climate countries, buildings are equipped with air conditioners. Construction standards are relatively poor and non-insulated, leading to large energy losses. External heat enters buildings too easily and in return, cold air provided by the cooling device seeps out too easily. Reflecting on the relation between building and local climate is too rarely taken into account. And when it is, research on the characteristics of materials available to improve the thermal insulation of the building is too often overlooked as the contractor and the architect quickly focus toward decisions.

TECHNOLOGICAL POSSIBILITIES

Several techniques are available and applicable in new construction and renovation. The approach can be done on several levels

Category A - Airflow

The first source of heat perception within an indoor space is related to the stagnation of ambient air. One of the earliest forms of natural ventilation is simply opening the windows to renew the volume of air in the room. The first category presented in this report includes techniques providing natural air without mechanical aid.

Category B - Exchange

This other category, related to the outdoor climate, works on the thermodynamic properties of the building. The heat exchange that occurs between the exterior and the interior leading to fresh air for inside ventilation but also supplying warmth for cold months.

Category C – Protection

In extension to this chapter, another approach suggesting taking the problem from an other angle by considering that it’s not bringing in cold air that cools a house, but preventing hot air from entering. Here we see various proven techniques and material properties in addition to the standard construction rules .

Category D - Control

Finally, we will overview current technologies in controlled ventilation devices, electrically fed, which offer great advantages in heavy demand of air renewal.

A. AIR FLOW

1. Geothermal well

Natural air conditioning system based on the simple fact that the soil temperature at 1.60 m depth is higher than room temperature in winter and lower in the summer. The well takes advantage of the capacity of the ground to resist changes of air temperature (Thermal mass). The outside air is sent in the building passing through a tube of a certain length buried at least 1.5 meters into the ground. The air enters one extremity of the tube coming out of the ground a few meters away from the building. The soil type also influences the performance of air cooling. This system is often mixed with mechanical ventilation for maximum efficiency and good air renewal. A house constantly ventilated by this system sees its inner temperature considerably reduced compared to the same house that ventilates 0.5 volume / hour day not using buried tubes. Several materials are available for tubes used to deliver air flow in the building. The choice must go toward a material offering rigidity to compression (by the earth), being moisture-proof and well insulated from bacteria and radon. Inside the building, the air passes through a fan with a recovery system for eventual humidity created by the change of temperature of the air between the outside and the inside. Distribution of fresh air inside the building is provided by PE tubes (different than those for air extraction) integrated in the walls or slabs. Air distribution fans are usually located on top parts of walls or slab.

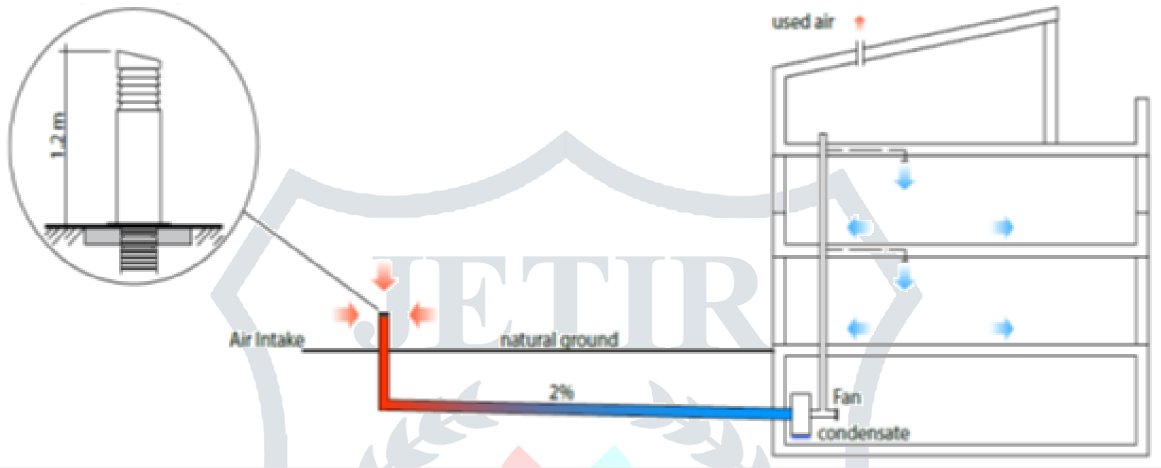

Fig.5 Principal of operation of geothermal well

2. Solar chimney

The solar chimney is a natural ventilation system composed of a vertical duct, often painted black, exposed to sunlight. During the day, the sun heats the duct creating a suction effect drawing air up the chimney (convection) to ventilate and cool the building. The solar chimney is probably one of the oldest ventilation devices. Other names can be attributed like wind tower which is a traditional Persian architecture element. This same type of architectural element exists in many other countries in the Middle and Near East. Different types of chimneys exist, but their composition remains the same. A surface to capture the heat located at the top of the chimney is crucial to ensure good solar gain, insulation and thermal properties of the chimney are also crucial. The position, height and the section of the chimney will be crucial, as will the design of the inlet and exhaust vents to adjust the desired ventilation rate. To optimize the effect of cooling, it is possible to mix a solar chimney system with a Geothermal Well to supply with fresh air without additional mechanical ventilation. Another device for improving the whole system would be to integrate it in a wall with high thermal mass built behind a glass panel exposed to the sun. The heat absorption is greatly increased through the glass creating a greater suction effect while heating the wall at the rear which accumulates heat that can be returned at night to heat indoor spaces in cold winter nights. Another variation of the solar chimney is the Solar Attic. Often, these attics are overheated in summer due to their exposure to direct sunlight. With the installation of a solar chimney, the ubiquitous hot air can improve the chimney convection, as well as the performance of the ventilation.

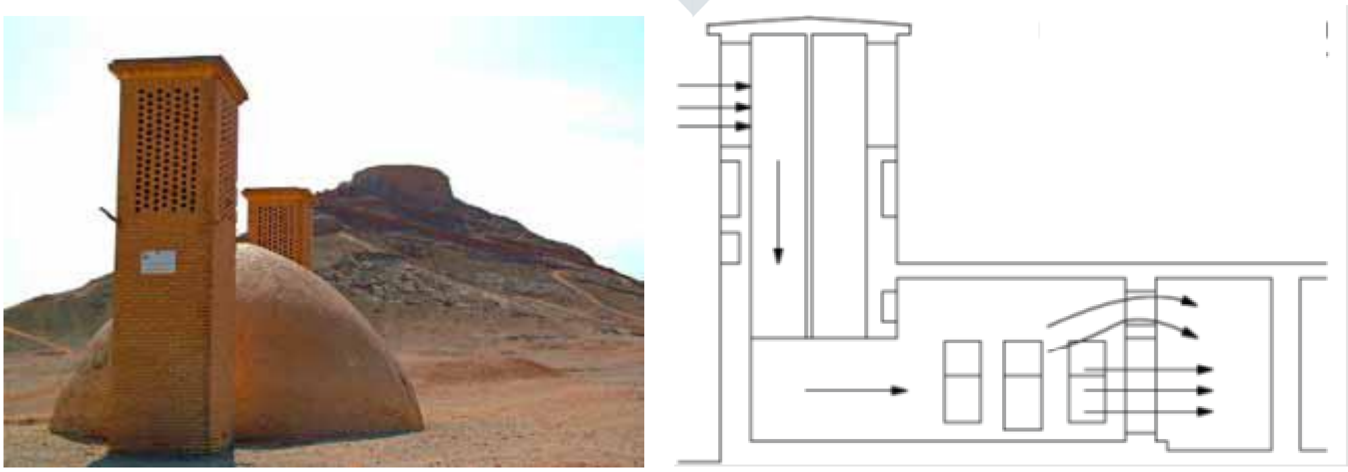

Fig.6 Principal of operation of solar chimney

B. EXCHANGER

1. Adiabatic exchanger:

Adiabatic cooling is an air cooling method based on the evaporation of water. Also referred as air cooling by evaporation or natural air conditioning. The process is simple: hot dry air passes through a moisturized exchanger then cools down naturally. The energy required for the evaporation of water is removed from the air, which consequently cools down. The system gains in efficiency with elevated outdoor temperatures. Beyond 30°C, air can cool down more than 10°C which results in a very effective cooling performance. With this system, a pump feeds filters with water. A fan draws warm air from the outside through the wet filters. The air is then cooled down by evaporation. This system works properly if the buildings are well ventilated in order to rapidly remove the moisture generated by it. The device is usually installed outside. A vent system allows to channel air into the needed area before being discharged through natural openings or through extraction systems. This type of cooling is particularly suitable for large volumes and any building where thermal contributions are important.

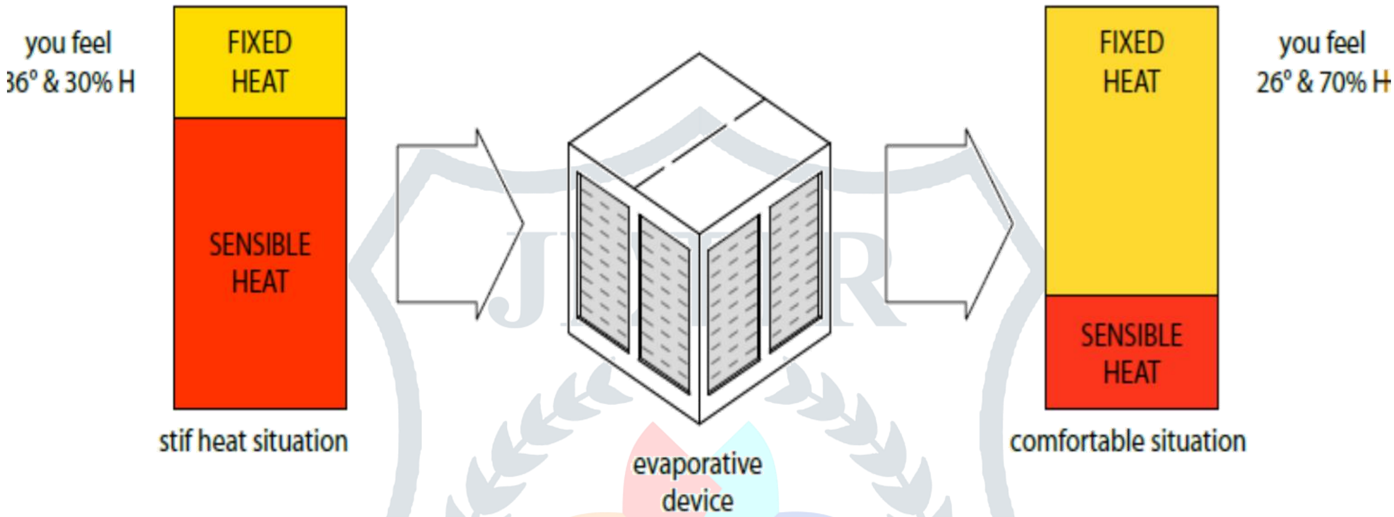

Fig.7 Principal of operation of adiabatic exchanger

C. **PROTECTION**

1. Thermal mass:

The thermal mass of a material is its ability to store and to redistribute energy whatever the season. It defines the speed at which the building cools down or warms up and allows to avoid unwanted variations from outside temperature. The heavier the thermal mass the more it's possible to protect from the temperature and minimize the effects of heat waves. Phase shifts also appear, which allows to delay the overheat in the summer accumulated during the day. In hot and humid climates, thermal mass must be rejected totally. It is important in this type of climate to use solutions with very low inertia and with a strong ventilation. There is no reason for a building, store heat during the day to restore it during nights since nights are almost as hot as days. The use of heavy materials with high thermal mass exposed to the sun would create even more uncomfortable nights. Thus air circulation and renewal appears to be essential to decrease the discomfort resulting from the climate. In constant research to reduce energy waist, intelligent materials appeared in the construction market: phase-change materials or PCM. These materials are based on the physical principle that when a body passes from solid to liquid, it absorbs a certain amount of heat and when it passes from liquid to solid state, it gives away heat. PCMs are usually composed of microcapsules of special paraffin whose melting point is between 21°C and 26°C. Then, in summer, on hot days the walls containing PCM accumulate heat due to liquefaction of the paraffin contained in the microcapsules, resulting in heat prevented from being transmitted to the room. Avoided temperature shift can reach 5°c without energy use. At night when temperature drops, the fresh air in the microcapsules paraffin solidifies, restoring the accumulated heat. Putting forward the use of Thermal mass means using dense materials such as concrete or thick masonry brick and having the insulation outside the structure. It is important that the inner mass of the wall is not subject to variations of the outside temperature. Thermal insulation and thermal inertia are different things.

D. CONTROL

1. Single and double mechanical ventilation:

This type of installation covers a range of mechanical devices designed to ensure the renewal of air inside rooms, especially for humid rooms (kitchens, bathrooms). With single-flow ventilation system, currently the most common, the system is depressurized by an air extractor. A fan placed in the attic or roof draws air through ducts placed in wet rooms. The air-flow is unidirectional, from inside to outside and the air volume control renewed per hour is done manually by the users. The double flow system allows to bring-in fresh air in dry rooms (living room) while the extraction is done in the same way as single-flow system through wet rooms. During winter months, this system can limit heat loss related to the renewal of air. Cold air from the outside is brought into the house by a duct system. Filtered, fresh air passes through a heat exchanger and recovers about 90% of heat from the used air before being distributed in living rooms. Heat exchanger or ventilation installed in the roof or in room in the basement is connected to extractions placed in the kitchen, bathrooms, toilets and hydrants inductions placed in bedrooms and the living room. This system captures the calories from the used air to temper fresh air brought in. Hybrid ventilation, combining the advantages of both modes of ventilation, natural and mechanical, could reduce energy used in building. The system is controlled in response to variations in climatic conditions and automatically switches between natural mode and mechanical assistance.

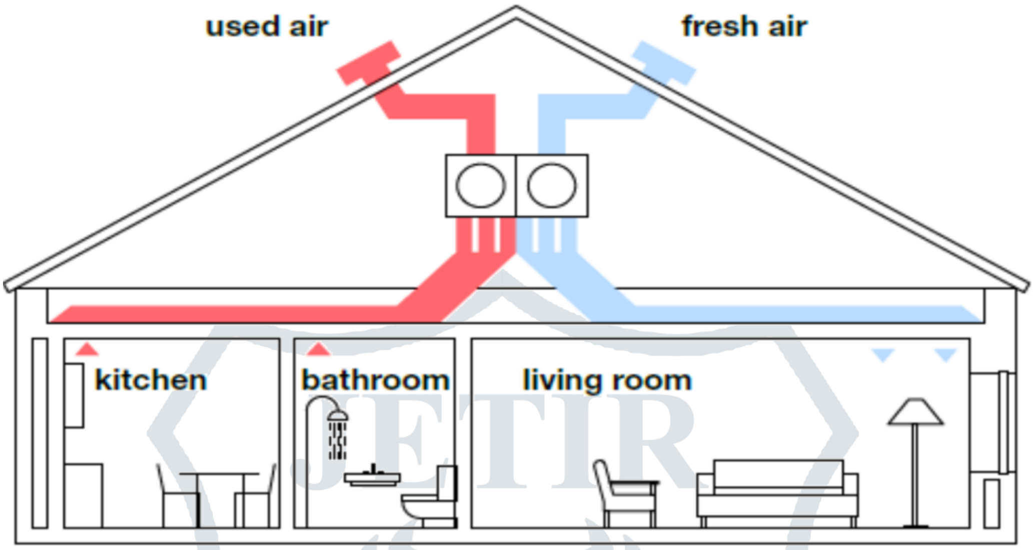

Fig.8 Principal of operation of single and double mechanical ventilation

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