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Energy Conservation in Building

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ABSTRACT: The building sector accumulates approximately a third of the final energy consumption. Consequently, the improvement of the energy efficiency in buildings has become an essential instrument in the energy policies to ensure the energy supply in the mid to long term moreover is the most cost-effective strategy available for reducing carbon dioxide emissions. This paper is studying the main objectives for an effective sustainable building taking into account the environmental sustainability aspect, where it has introduced the main principles for developing building concept and the governor concepts for this development for forming sustainable building skins, also it is focusing on the different techniques in terms of natural ventilation, shading techniques, and energy conservation and its role in enhancing the internal environment. The main objective of the paper is to investigate the impact of different ventilation strategies that can be implemented in new and existing buildings in hot climates So that it can reduce the amount of energy needed for building and sustainability in this climate.

Keywords: *Net zero energy building, Energy efficiency, Energy Conservation*

INTRODUCTION

In the recent years, contemporary architecture has been deeply influenced by the urgent need for reducing harmful emissions in the atmosphere. The building sector constitutes in fact one of the most energy consuming sectors of the world economy. However, buildings are also potential and powerful agents able to carry out with effectiveness and in relatively rapid time's actions to minimize emissions, through the drastic reduction of their energy consumption. Monitoring the building life-span throughout the whole year is one of the most interesting aspects that could challenge contemporary approaches if conditions of change and variability are reflected in a continuous refinement of the design.

With regard to energy consumption, sustainable building is often directed at energyefficient use of fossil fuels and the generation of renewable energy through technical appliances. These measures may be considered adjustments to a furthermore traditional way of building, ignoring the fact that the building itself can be innovated to an intelligent, responsive or even proactive device.

The need for energy efficient buildings has been systematically addressed by several countries and international organizations, as a step for the reduction of energy consumption and the mitigation of CO_2 emissions. The EU Directive recast on the Energy Performance of Buildings has determined that new buildings should meet the nearly-zero energy target by the end of 2020 (Irective, 2010).

The selection of the appropriate energy efficiency measures for the attainment of the net zero energy balance is dependent on various parameters. Climate type is one of the factors that should be taken into account during the design stage of a net zero energy building.

On the other hand, in warm and hot climates energy demand for cooling usually exceeds that for heating. The challenges in such an environment are to manage solar heat gains and internal loads effectively to implement low-consumption cooling systems and to implement passive techniques for the mitigation of cooling loads. Ventilation, the process by which fresh air is circulated in a building, is essential for the assurance of acceptable air quality. Furthermore, ventilation could be applied in order to provide thermal comfort and contribute to the reduction of cooling loads and the minimization of active cooling systems operation. In particular natural ventilation forms a passive cooling alternative which does not burden the energy balance of the building, as it is driven by natural forces. In case that natural ventilation is not sufficient due to the need for increased and controllable air flow rates, mechanical or mixed-mode ventilation could be implemented instead, at the expense of higher energy requirements.

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MATERIALS AND METHODS

Energy Conservation

The idea of sustainable building uses a very little energy and depends mainly on renewable energy resources in cooling, ventilation, and lighting processes. In addition there are passive cooling systems which is considered the most efficient way in conserving energy where is targets to make use of available technologies to cool building naturally without the need of power energy and it's mainly based on five main natural processes: radiation, evaporation, ventilation, shading, and insulation (Allard, 1998). So, this paper focuses on two of these techniques: ventilation and shading and how building skins deal with it to create a low energy profile which is a major goal for designing sustainable buildings that produce energy more than it consumes. Clearer and efficient technologies are required to further develop and expand the role of alternative energy sources (EDF, 2010).

That is why it is important for architects to consider some issues for energy-efficient and sustainable design from the moment the decision is made to construct a building until the building usage. Since buildings' façades are considered one of the major components in buildings industry where façade is considered the face of the building and its direct contact to the outer environment; energy efficiency aspects need to be considered in buildings' facades technologies. The building envelope or skin comprises the outer elements of a building, including the foundation, walls, roof, windows, doors and floors (Handbook et al., 1999).

The energy conservation concern emerged after the price the world was paying for neglect of environmental forces was too high. In light of that, sustainable design and buildings therefore became a high priority in the market. They largely depend on renewable energy and resources in designing ventilation, cooling and lighting aspects of the building. Passive cooling systems have been rendered to be the most dependable and efficient way in energy conservation that targets mainly to use readily available materials and technologies to naturally cool buildings through the processes of radiation, evaporation, ventilation, shading and insulation (EDF, 2010).

Energy use is one of the most important environmental issues and managing its use is inevitable in any functional society. Buildings are the dominant energy consumers.

Buildings consume energy and other resources at each stage of building project from design and construction through operation and final demolition (Schimschar et al., 2011). According to Lenzen and Treloar (Lenzen & Treloar, 2002). the kind and amount of energy use during the life cycle of a building material, right from the production process to handling of building materials after its end life can, for example, affect the flow of greenhouse gases (GHGs) to the atmosphere in different ways over different periods of time. Their consumption can be largely cut back through improving efficiency, which is an effective means to lessen greenhouse gas emissions and slow down depletion of nonrenewable energy resources (Lee & Chen, 2008). With this realization, increasing more attention is being paid to the improved energy conservation in building sector over the years, partly because the sector harbours a considerable potential of primary energy saving and reduction of emissions, having a negative impact on the environment (Sasnauskaite et al., 2007). Energy use in a life cycle perspective includes energy needed for both operational and embodied energy. The operational energy requirements of a building can be considered as the energy that is used to maintain the environment inside that building (Dimoudi & Tompa, 2008) Thormark (Thormark, 2006) life cycle analysis of building shows that operational energy accounts for 85–95% of the total energy consumption and CO_2 emissions of a building which comes from occupancy through heating, cooling, ventilation, and hot water use. This will include energy from electricity, gas, and the burning of fuels such as oil or coal.

As the energy needed for operation decreases, more attention has to be paid to the energy use for the material production, which is the embodied energy. The embodied energy of a building is the total energy required in the creation of a building, including the direct energy used in the construction and assembly process, and the indirect energy that is required to manufacture the materials and components of the building (Huberman & Pearlmutter, 2008). This indirect energy will include all energy required from the raw material extraction, through processing and manufacture, and will also include all energy used in transport during this process and the relevant portions of the energy embodied in the infrastructure of the factories and machinery of manufacturing, construction and transport. The energy life of a building can therefore be considered to be made up of numerous inputs of operational and embodied energy throughout a building life cycle as shown in Fig.1.

Principles of Ventilation Systems

Ventilation is the process of supplying fresh air to an indoor space or removing stale air from a room or building, in order to mitigate or eliminate air contaminants and control humidity and temperature

Ashrae et al., 2007). Purpose-provided ventilation is distinguished from unintentional flow of air, such as infiltration and duct leakage, which often act counteractively to ventilation and degrade its performance (Liddament, 1996).

Outdoor air flowing into a space by ventilation could be either mixed with or displace indoor air. In the first case, ventilation is characterized as "mixing" and is enhanced by the natural forces of wind or by the proper design of air suppliers. In "displacement" ventilation, outdoor air is introduced through suppliers located at the lower levels of the ventilated space and gradually displaces indoor air. The latter is exhausted through outlets placed at the higher levels of the space. (Hardy, 2014). Ventilation is classified into the following categories:

Natural ventilation is generated from the effects of wind and temperaturethrough intentionally provided or other existing openings of the building, such as windows and doors.(Fig. 2)

Mechanical ventilation is provided from the operation of

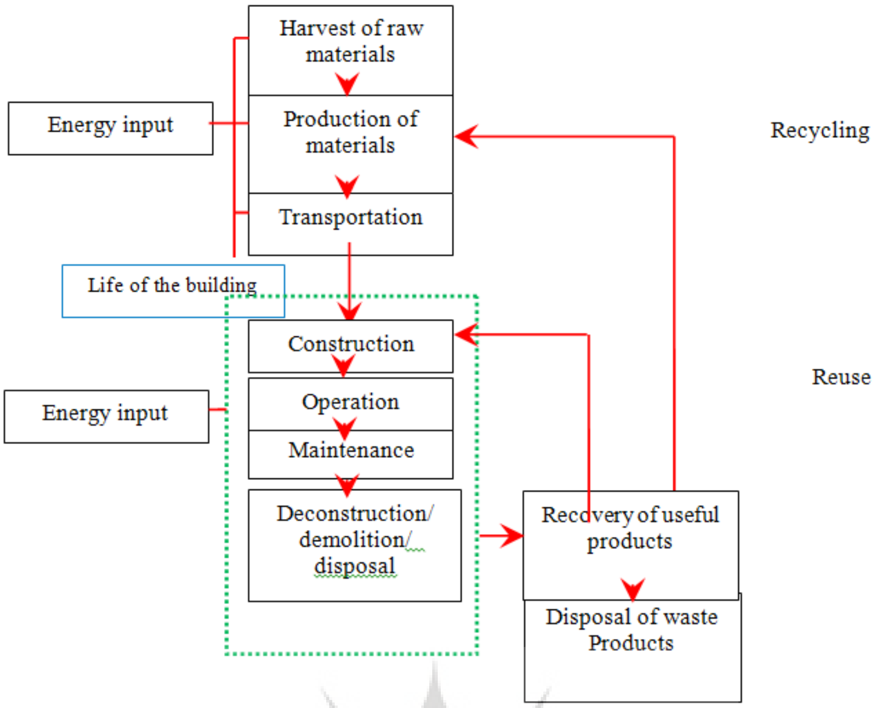

Fig. 1: Stages of energy input during the life of a building.

mechanical equipment, such as fans or HVAC systems. Operable windows or wind-driven turbine ventilators do not fall into the category of mechanical ventilation.

Hybrid or mixed mode ventilation, in which the complementary or concurrent operation of naturally-driven ventilation and mechanical systems is implemented (Ashrae et al., 2007).

The primary tasks of ventilation systems - either mechanical or natural- are as follows:

Control and improvement of indoor air quality, with the displacement or dilution of indoor air pollutants by the provision of clean outdoor air.

Direct adjective cooling, where the warm indoor air is displaced or diluted by the flow of outdoor, cooler air.

Direct personal cooling, where outdoor air at lower temperatures than the indoor is directed at an adequate rate to the building occupants and allows the transfer of heat and moisture from them.

Indirect night cooling, where the building fabric is pre-cooled by outdoor air during night resulting in the indirect cooling of indoor spaces (Schimschar et al., 2011)

Factors Influencing Ventilation Design

The design of a ventilation system has to consider several requirements and constraints related to building characteristics, local clim atic conditions, local environment, installation and maintenance cost, regulations and standards, as shown in Fig.3. The amount of ventilation has to satisfy indoor air quality and thermal comfort requirements and at the same time

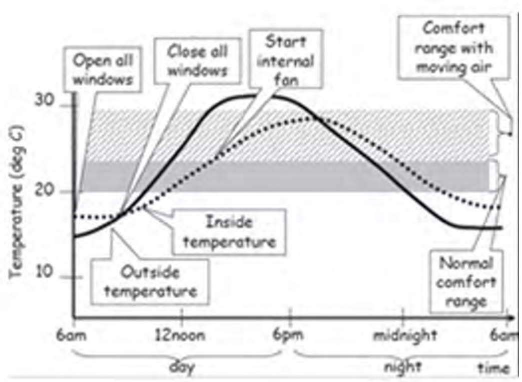

Fig. 2: Natural ventilation principles. (Source: Saadatian et al., 2012)

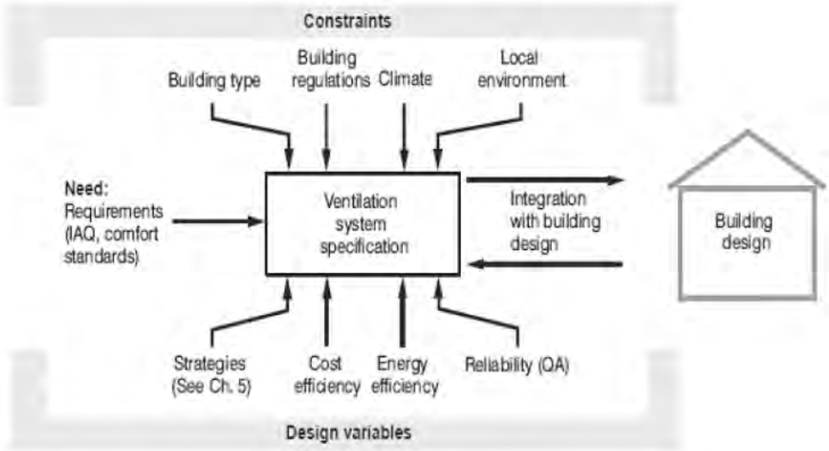

Fig..3: Ventilation design parameters. (Source: Liddament, 1996)

energy consumption induced by ventilation should be kept at acceptable levels. Specific regulations and standards define the minimum requirements for the rate of ventilation, but additional ventilation may be demanded, depending on indoor conditions (e.g. excess heat loads), climate or the local environment.

The characteristics of the building are determining for the selection of the ventilation strategy and therefore they should be carefully accounted for. Those include:

Building type. Different building types and sizes have diverse needs in terms of ventilation.

Occupancy and occupant habits.

Number, sizing and placement of openings.

Geometry of the ventilated space.

Space availability for the installation of the ventilation system.

Air tightness, as the level of building air tightness determines the required ventilation rate.

Sources of air leakage and infiltration which could detriment ventilation performance if their contribution to the air flow inside the building is significant. (Liddament, 1996).

The severity of the climatic conditions is an important constraint for the design process. Mild and moderate climates with short or medium heating or cooling seasons can be efficiently served by natural ventilation or a hybrid ventilation strategy, as energy losses caused by ventilation are usually low. In severe climates with more than 3000 heating or cooling degree days, the implementation of mechanical systems may be mandatory, as natural ventilation may not be capable of providing the required ventilation rate to an air-tight building structure and the associated ventilation losses could increase considerably heating or cooling loads. The microclimate of the area might be affected by the local environment in terms of air flow pattern and outdoor temperature.

The selection of the proper ventilation strategy should be based on the aforementioned requirements and constraints and also consider factors as:

The cost for the implementation of the ventilation strategy which should be evaluated by a payback period or a net present value calculation process. A life cycle planning approach will be a more reliable approach for the evaluation of the cost performance.

The energy performance in terms of ventilation heat losses or energy requirements for the operation of mechanical components of ventilation.

The reliability and ease of maintenance of the system to be implemented.

Design Approaches for Natural Ventilation

Various building design approaches could be implemented to maximize the effect of natural ventilation. The suitability of such design strategies depends on the local climate or architectural trends.

Window Catchers/Towers

Wind towers (or wind catchers) have been extensively used in the Middle East for thousands of years, as a passive cooling technique providing natural ventilation. The principles that determine the operation of a traditional (vernacular) wind catcher have been utilized for the development of modern wind towers. (Hughes et al., 2011).

Wind towers are divided into quadrants (openings). Both the wind forces and the buoyancy effect enhance natural ventilation through a wind catcher implementation. Positive pressures in the windward side of the wind catcher drive fresh air in and suction pressure on the leeward side exhausts warm air out of the building. The "stack effect", which acts as a complementary force, is driven by temperature differences between indoors and outdoors. The buoyancy of the warm air causes it to rise and be exhausted through the wind catcher, when external temperature is lower than internal temperatures (Saadatian et al., 2012).

The number of the openings of the wind catcher and the incidence angle of the prevailing wind affect ventilation rates. When wind is the dominant driving force, ventilation efficiency decreases with the increase of the number of the openings. In buoyancydriven ventilation, multi-opening wind catchers provide enhanced performance. The phenomenon of

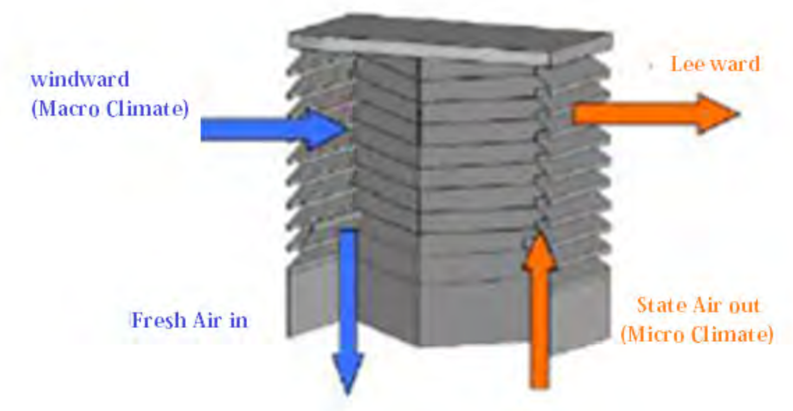

Fig.4: Cross-section of a commercial wind-catcher. (Source: Hughes et al., 2011)

"short-circuiting", where fresh air is exhausted without being circulated in the indoor space, may occur in specific incidence angles of the wind. (Fig. 4)

Solar Chimney

The solar chimney is another passive cooling technique for natural ventilation support.

The airflow through the solar chimney is generated by the mechanism of buoyancy, when air density in the inlet of the chimney is different than in the outlet. Solar chimneys, as wind towers, were commonly used in hot and arid climates.

The mechanism for the operation of a solar chimney in natural ventilation mode is as follows: In the upper side of the solar chimney, a black metal sheet or a black-painted surface is heated by solar energy during the day and the heat is transferred to the air inside the chimney. The generated suction pressure reinforces air flow, as warm stale air is risen up and exhausted through the solar chimney. (Fig. 5) (Hughes et al., 2011).

Ventilated Facades

The Trombe wall is a combination of a massive wall and an exterior glazing surface, where an air channel is created in between. (Fig. 6)

This design approach can be used both for winter heating and summer cooling, depending on the configuration of glazing surface dampers and trombe wall vents. During summer, the lower vents of the massive wall are opened and so does damper (B) of the glazing area. The other dampers (A) and vents remain closed. The heated air in the air channel generates buoyancy forces which draw warm air through the opened vents and dampers (Chan et al., 2010).

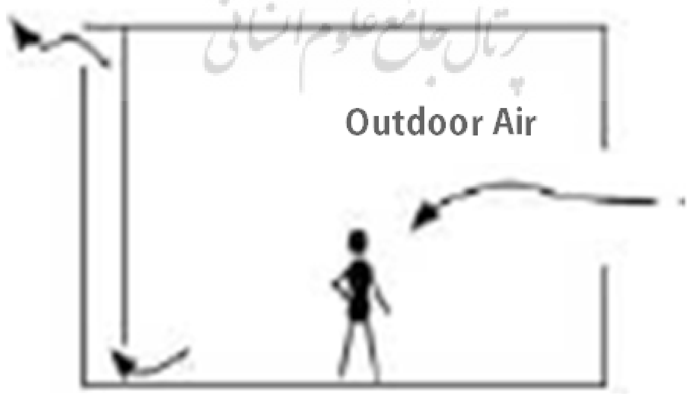

Fig..5: Solar chimney natural ventilation mode. (Source: Hughes et al., 2011)

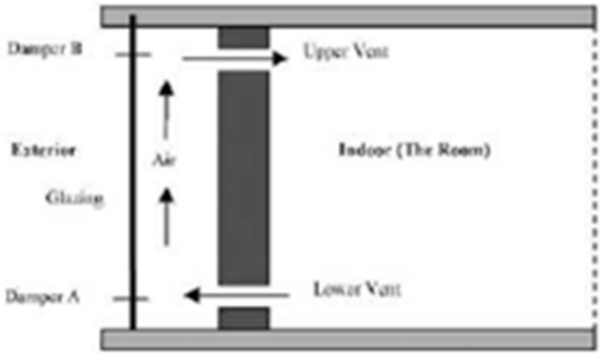

Fig.6 : Trombe wall. (Source: Saadatian, et al., 2012)

RESULT AND DISCUSSION

Mechanical Ventilation Systems

Mechanical ventilation systems operate independently of the natural forces of wind and buoyancy.

Whole house ventilation systems are classified into the following main categories:

Exhaust ventilation systems;

Supply ventilation systems;

Balanced ventilation systems;

Energy or heat recovery ventilation systems. (Fig.7)

Mechanical ventilation integrated to an HVAC system (Energy. Gov, 2014).

Different variations or combinations of these system types can be applied according to the specific needs of the building and the particular constraints. Mechanical ventilation systems may operate continuously or intermittently, they may be single or multipoint by incorporating fans for exhaust and/or supply or they can be connected to an air-handling unit (Russell et al., 2007).

Mechanical ventilation can be also applied to enhance natural ventilation in a hybrid configuration, where the infiltration leakages or purpose provided openings are used for the supply or exhaust of outdoor “make-up” air.

Applications of mechanical ventilation include:

Large commercial buildings;

Apartments or single family residences;

Office buildings.

It has been noted that the performance of natural ventilation relies heavily on the local climate (temperature, humidity). Mechanical ventilation can overcome these limitations of applicability, especially in severe climatic conditions. The most significant advantage of mechanical ventilation systems compared to natural ventilation is that they can maintain acceptable ventilation rates. This capability results in reliable temperature regulation and provision of acceptable indoor air quality.

Despite of the fact that state-of-the art systems provide enhanced efficiency, components of mechanical systems consume a considerable amount of energy. However, increased consumption can be mitigated by heat recovery, which can be

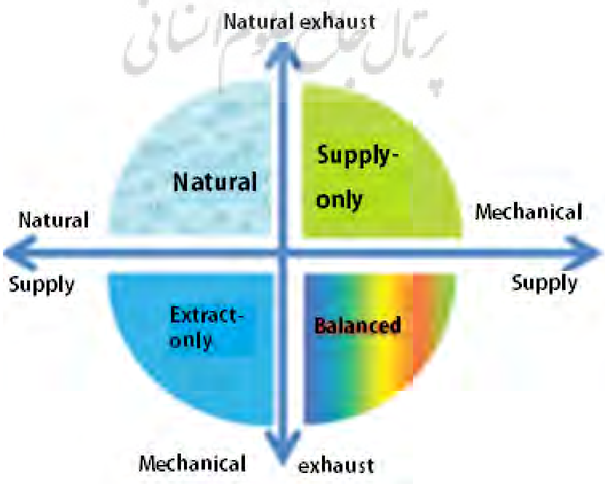

Fig.7: basic types of ventilation systems.

implemented effectively in mechanical ventilation systems.

Mechanical Extract Ventilation

The efficiency of the system is improved by maintaining the under-pressure induced by the mechanical system above the level of wind or buoyancy induced pressure, in order to minimize air infiltration. Passive air inlets such as trickle vents or louvers should be placed properly on the building envelope in order to drive fresh air in a controllable manner. They should also be installed away from sources of pollution in order to provide clean air (Russell et al., 2007). Exhaust systems may be further classified into the following configurations:

Single point exhaust. The air is extracted to the outside by means of a single fan placed usually in the bathroom or in an external wall. The fan is not ducted to the individual rooms of the ventilated zone. An inherent disadvantage of this configuration is that the passively supplied air is not uniformly distributed, especially when internal partitioning exists (Russell et al., 2007). (Fig.8)

Intermittent instead of continuous operation can be implemented in mechanical extract systems. The exhaust fan runs at a higher rate for only part of time and provides increased ventilation rates during operation. Usually, the fan is adjusted for automatic operation by a timer or can be regulated manually by the occupants of the building (Russell et al., 2007). Exhaust ventilation systems are more appropriate for cold climates, as moisture problems in wall cavities may emerge in hot and humid regions, due to the depressurization of the ventilated space (Energy.Gov, 2014).

Multi-Point Exhaust Systems

System Components:

1) Quiet, efficient multi-port exhaust fan;
2) Several passive wall or window vents;
3) 3-4" diameter ventilation ductwork, grilles;
4) Programmable timer with speed switch System Operation:

Exhaust fan operates continuously on low;

Bathrooms have exhaust ports instead of spot fans;

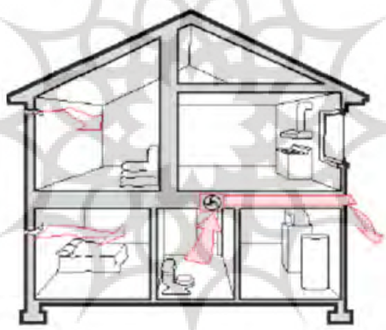

Fig.8: Single-point exhaust system. (Russell et al., 2007)

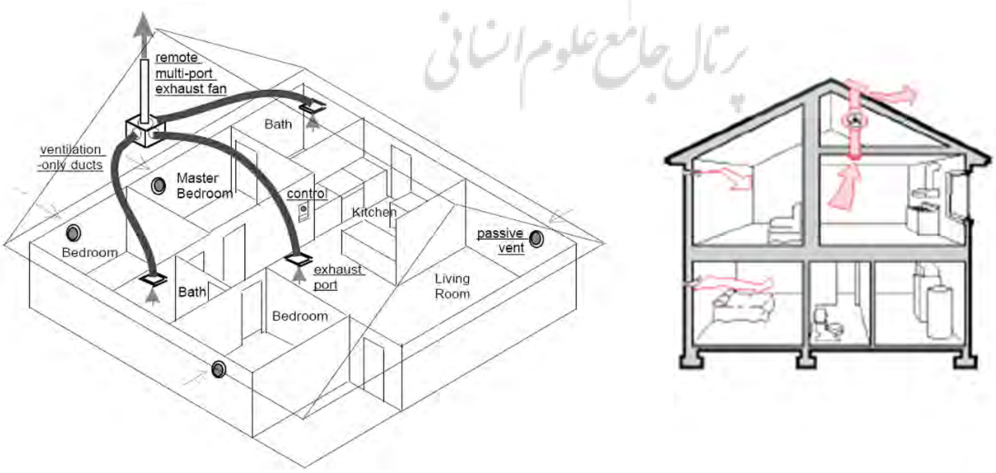

Fig .9: Multi-point exhaust system.

Residents can temporarily boost the ventilation rate.

Mechanical Supply Ventilation

A central fan is used to supply fresh air into the building and pressurize the ventilated space, forcing indoor stale air to be displaced through unintentional infiltration leaks or purpose provided vents and openings (Liddament, 1996).

The pressurization of the building prevents contaminants from entering the ventilated space. However, it could increase the risk of the indoor, warm air being pushed through the building envelope cracks and generating moisture and mold, when reaching cold surfaces. Therefore, mechanical supply ventilation is not appropriate for cold climates, but it is suited more for hot or mixed ones.

Supply ventilation systems have the ability to exercise control over the incoming air more efficiently than the exhaust systems. The location of the supply air fan should be optimized for efficiency maximization. In many cases, thermal comfort and air quality requirements can be satisfied only by the filtration and pre-conditioning of the supply air. The process of recirculation, where supply air is mixed with indoor air and recirculated to the supply fan, can be applied when thermal comfort conditions are inadequate (Russell et al., 2007).

Similarly to the mechanical exhaust systems, supply ventilation can be single-point or multi-point. In the first case, air is inserted to the building through a central fan and is distributed about the rooms through openings and/or vents in a natural manner. In multipoint configuration, a ducting system connected to the central fan distributes evenly the supply air about the internal spaces of the building (Russell et al., 2007).

Balanced Ventilation System

Balanced ventilation combines supply and extract ventilation systems, each connected to a discrete ducting system. Fresh outdoor air is inserted through the supply system and equal amounts of indoor stale air are exhausted through the exhaust system. Therefore, pressure inside the ventilation space is balanced and the airflow is better regulated.

Usually, supply fans are located in “occupied” spaces, such as bedrooms and living rooms and exhaust is located in kitchens and bathrooms, where pollutant concentration and moisture is increased (Awbi, 2007).

Balanced ventilation uses a supply fan and an exhaust fan to regularly exchange indoor air; both fans move similar volumes of air, so indoor pressure fluctuates near neutral or "balanced.” From a safety and health perspective, balanced pressure is better than negative indoor pressure, but not as beneficial as positive indoor pressure, which helps keep outdoor pollutants outdoors!

Particularities:

controlled air flow rates (inlet and outlet);

filtration of the inlet air;

possibility of heat recovery;

used in a polluted and noisy environment.

Fig.10: Mechanical supply ventilation. (Source: Energy.Gov, 2014)

Ventilation System Components

HRV unit containing exhaust and supply fans, and air-to-air heat exchanger;

exhaust and supply ducts and grilles;

programmable timer with speed Switch Ventilation System

Operation:

air is supplied to bedrooms, exhausted from bathrooms;

sensible heat is recovered from exhausted indoor air;

residents can temporarily boost theventilation rate.

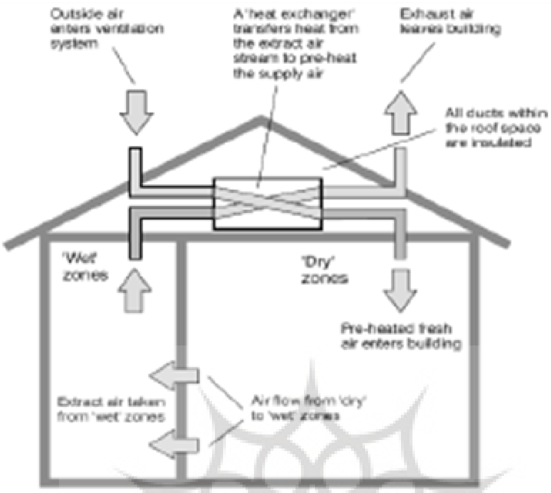

Fig .11: Mechanical balanced ventilation. (Source: Liddament, 1996)

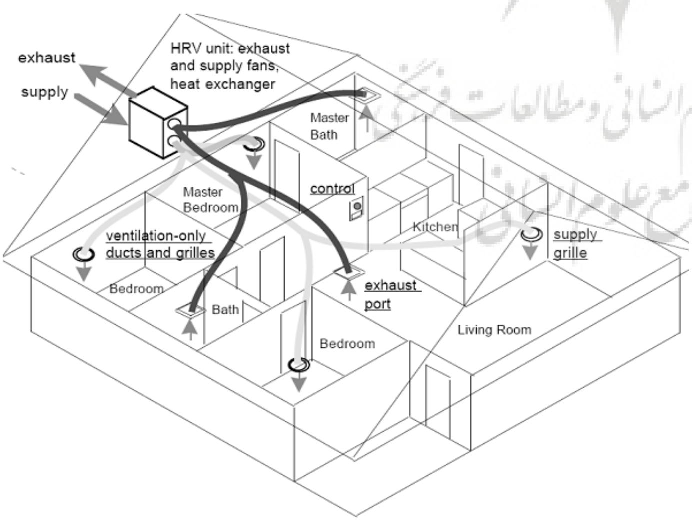

Fig .12: Balanced Ventilation with Heat Recovery.

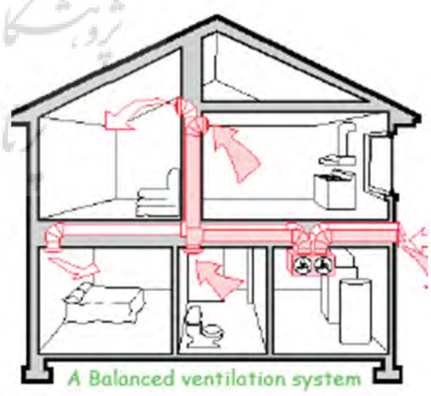

Fig .13: Balanced Ventilation system.

Table 1: Masdar Headquarters, Abu Dhabi, United Arab Emirates strategies

<table>
<tr><th colspan="3">Masdar Headquarters, Abu Dhabi, United Arab Emirates</th></tr>
<tr><td colspan="2"></td><td>Masdar headquarter located in Masdar city, Abu Dhabi, United Arab Emirates under the supervision of The Masdar Initiative, Abu Dhabi,
United Arab Emirates, it was designed by Adrian Smith and Gordon Gill Architecture and constructed during the period from 2008 to 2010;
This project far exceeds LEED standards; a similar sized LEED platinum building would still emit 6,000 metric tons of carbon dioxide a year (Fig. 14).

Fig. 14. Layout of Masdar City. (Smithgill, 2010)</td></tr>
<tr><td colspan="2">Climatic Conditions of the Site</td><td>Abu Dhabi’s climate is considered to be subtropical climate, with temperatures that vary from warm in winter months to hot in summer with sunny blue skies prevail throughout the year and rainfall is infrequent which have effected on building architecture design to fulfill environmental And climatic requirements either on building scale or landscaping scale (Abudhabi, N.D).</td></tr>
<tr><td colspan="2">Strategies</td><td>Masdar Headquarter is overcoming the desert climate by the presence of some sustainability strategies integrated within building facades that limit external heat gains and making use of natural cooling potentials as ground, sky and outside air.</td></tr>
<tr><td>Strategies</td><td>Ventilation</td><td>Masdar Headquarter integrated different energy efficiency strategies one of these technologies integrated into facades is Highthermal- mass exterior glass cladding which blocks direct solar radiations and decreases the internal cooling loads, while remain transparent to allow natural light into the building. (Fig. 15)
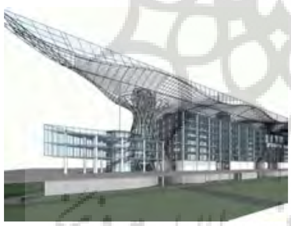
Fig. 15. High-thermal mass exterior glass cladding blocks direct solar radiations and decreases the internal cooling load. (Smithgill. 2010)
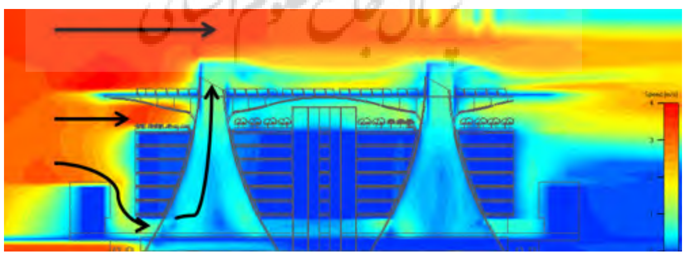
Fig 16. Wine cone CFD analysis and airflow optimization.</td></tr>
</table>

Masdar Headquarters, Abu Dhabi, United Arab Emirates

Strategies

Shading Techniques

Masdar Headquarter is protected from direct sun radiation by lightweight rood with PV cells on the external facades in order to reduce the solar gain (Fig. 17) where it creates a cool environment beneath and reduces the demand for air conditioning. (Bellerophon, 2008)

Roof and façade with PV cells in order to reduce the solar gain.

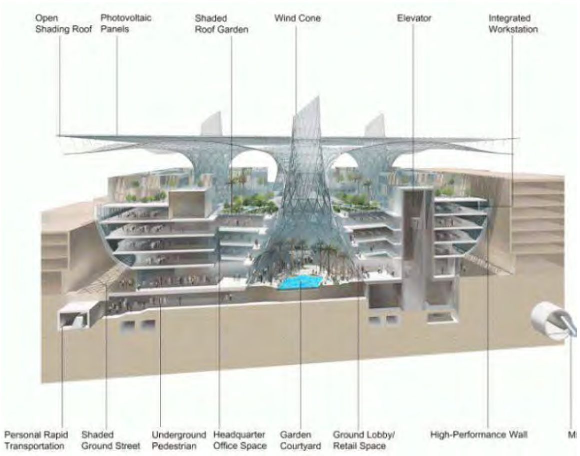

Fig. 17. Power generation from PV panels and shading techniques integrated in Masdar Headquarter. (Smithgill. 2010)

Zero Carbon

Energy Efficiency

Masdar Headquarter aims to be the world's first zero-carbon, zero waste headquarter in Abu Dhabi where energy needed for cooling and lighting will be reduced by controlling the building orientation and design and presence of green spaces to find a balance between shade and sun, and to promote natural-air circulation. One of these systems is energy generation system integrated into building facades which will produce more power than it needs by using renewable sources of energy generation (solar and wind energy) where it will feature the largest photovoltaic power generation system (Smithgill. 2010). (Fig. 18)

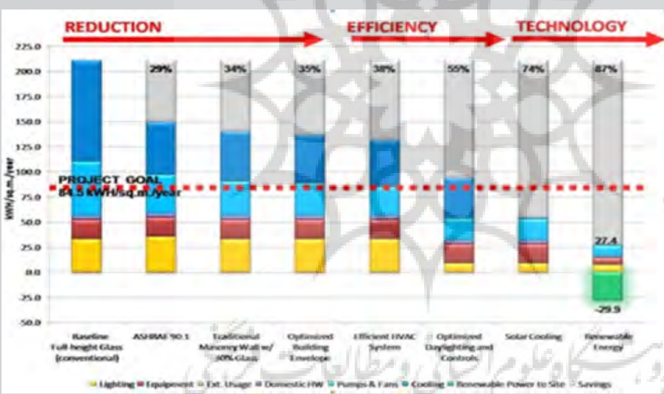

Fig. 18 . Masdar Headquarters positive net-energy optimization process

Solar and PV panels: the 72,000 sq m roof contains one of the world's largest buildings integrated PV displays; it provides energy during building construction and during the building usage .Solar panels on the building's roof and external façade are supposed to produce as much electricity over the course of a year as the building consumes (Smithgill. 2010).

In addition to Masdar headquarter being the first mixed-use positive energy building in the world it will also be the first building to generate power through development of its solar roof and façade before underlying complex, it will also reduce building energy consumption by 61.5% from the annual energy consumption. (Fig. 19)

Fig. 19 . **Natural lighting** Staggered cones bring daylight in addition to side facades.

CONCLUSION

The passive cooling systems for warm climate are still a great way to go since they are the most efficient, sustainable and economical ways yet. If they can be integrated into high-rise buildings to minimize construction, operation and maintenance costs that the intelligent buildings are still struggling with, then energy efficiency and conservation will get much easier all around the world.

This paper has studied the main objectives for an efficient sustainable building taking into account the environmental sustainability aspect:

The most advantageous shading schemes have proved to be external shading device and movable overhangs installed on building facade, considering also the other benefits of external shading as it could be suggested as a very effective design solution against overheating where only the application of external shades reduces the overheating up to 20%.

In this section some recommendations about the appliance of sustainable building technologies in hot climate will be interviewed taking into account the environmental, economic and climatic conditions. in hot climate, moderate winters and very little rainfall which will encourage designers to design passive which will be able to provide natural ventilation, shading and reduce energy consumption. Following some recommendations for the architects and Governments in order to enhance the appliance of sustainable buildings skins strategies on sustainable office buildings.

It should permit training ad education programs that focus attention on building sustainable development.

The government building projects can incorporate and promote energy efficient facades that harmonize with the hot climate.

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