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The impact of Vernacular architecture on the thermal comfort of office building - using court and green roofs techniques

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Abstract. Although the effect of natural ventilation on, indoor heat conditions and minimizing energy efficiency loads of an atria, there is lack of knowledge on how different design parameters affect atria with green roof technique heat conditions. In the last 25 years, researchers proposed and created many ways to simulate numerical and experimental buildings to test the effectiveness of ventilation and thermal comfort inside spaces of atria. This paper investigates the impact of Vernacular architecture on thermal comfort of office buildings - using the court & green roof techniques & the role of natural ventilation in hot temperatures, with suitable design parameters and applying them to improve the performance of thermal comfort and decreasing energy use by using Energy Plus software.These parameters include court configuration and contents such as characteristics of openings and geometry and, then combining these parameters of the courtyard with green roof properties in the hot arid zone like in Egypt.
It also focuses on different techniques of ventilation that can be utilized in atria as a hybrid ventilating technique. For this reason, based on literature review and simulation tool, investigation of energy efficient courtyard design according to shape will be done, ventilation, and performance of the courtyards in terms of thermal comfort, so that energy-efficient performance of the building can be improved with court & green roof system. Thus, it is expected from the results of this study to encourage building designers and decision makers to consider the terms of environmental concerns and energy efficient building design in the design phase of building.

Keywords: Green roof; Hybrid Ventilation; Energy Efficient; Court Yard.

Introduction:

This paper discusses the relation between the green roof office building in Egypt with the thermal performance of courtyard. The main objectives are:

To explore that if in Egypt's climate a courtyard can provide a low-rise office building with thermal comfort and energy-efficient indoor environments, and also, outdoor thermal comfortable environment. To emphasis the increasing need for an Active and Passive System for architectural design efficiency, to enhance the effect of Facades and Energy Consumption and to examine the impact of Vernacular architecture on the thermal comfort of office building - using court and green roofs techniques.

Office buildings in Cairo from the 1880's, due to economic reasons, had undergone limited façade renovation. Split air-conditioning systems pierced and distorted building facades, leading to indoor thermal discomfort.

Energy production increased by 57% in ten years, while energy use of commercial buildings increased by 7-8% every year. Implementing second building skin technique has been tried by many famous architects in Europe, Australia and Japan (Hamza, 2005). This paper explores the effect of Vernacular architecture of office building - using court and green roof techniques on Energy efficiency and thermal comfort.

Atrium is identified as an area added to a building which is transparent at least from one side which is commonly repetitive. Atrium is an architectural element in many types of building as shopping megamalls, administrative buildings and academic buildings. It's not easy to Design and control atria's thermal settings, due to many aspects of the space such as: large area sides, usage zones with small dimensions, ceiling elevated, Atrium affords and protects interior spaces from unfavorable outer climatic surroundings. The inner space can be used as a pedestrian passage over the ground. It is mostly popular in shopping malls that requires wide moving passage, as well as administrative buildings providing more walkable spaces. Its environmental advantages make owners and designers use it in the buildings. allowing acceptable solar heat and daylighting beside increasing thermal comfort are added advantages of the atria.

The of atria's natural characteristics depends strongly on climatic conditions parameters such as: gaining solar energy and daylighting access.

In low temperatures and during hot days, an atrium is a perfect sun lounge making a shield zone between hot undesirable outdoor conditions and comfortable indoor zones.

Green roofs technologies can also help to limit some of the negative effects of urban hardscapes by reintroducing a natural sustainable landscape into urban environment without making big changes to city infrastructure. Green roofs can also provide a number

of social, environmental and economic benefits to an urban region.

Literature Review

The main objective of upcoming preview is to introduce and explain the aspecs of climatic design of courtyard in buildings. This will help in explaining the effect of building shape in case of energy; also finding effective techniques to use and increase this structural form can be done by further research, considering different impacts of courtyard buildings in advance is very important. also, main information and ideas referred to the characteristics & origins of courtyards in building design are considered a main aim.

Many studies show cultural, social, environmental and formal advantages of the courtyard building.

Future fossil fuel lack and the limited sustainable energy resources capacity encourages us to discover efficient and passive building forms; one such as building with courtyards.

Botanical realms originated Several trials on green walls especially the areas with biodiversity (Manso et al, 2015). At the beginning of the 1980s Green elevations had a major act in the development of the ecology of cities. The majority of successful projects depending on planted roofs was seen in Germany (Vijayaraghavan et al, 2016). from the beginning of the 20th century the first program was comprehensively used practically by reconstructing the houses with plantation on the roofs. about 246.000 m2 of plantation was constructed into the facades of buildings placed in Berlin Between the 80s and the late of 90s, (Pérez et al, 2011). About 20 to 25% of the total surface of urban areas is considered for green roofs. So plantation of the roofs has great effect on the building and urban environment (Raji et al, 2015). Green roofs which is called also eco-roofs, living roofs and roof gardens is defined: the roofs covered with green plantation and growing reservoir with ways of irrigation (Pisello et al, 2015).

Green roofs are capable of providing many advantages to urban areas in terms of aesthetical visual and environmental considerations (Vijayaraghavan et al, 2016). Reducing gas emissions and greenhouse effect, urban heat island effects in places of high population & air pollution, increasing the quality of water in city, preventing acidic rain by increasing pH values, improving the durability of internal membranes and decreasing the risks of flood by accommodated excessive water can be defined as some of its advantages (Coma et al, 2016). Added to the above, livimg roofs can also increase the well-being of users in urban communities, thermal insulation, saving the Energy used, shading and evapotranspiration techniques, highlighting the important role of living roofs in the microclimatic conditions of indoor spaces and thermal performance of buildings (Coma et al, 2016). In summer, 80% approximately of the heat flowing from roofs of the buildings can be reduced by living roofs (Karteris et al, 2016). A little temperature difference in inner and outer air conditions can decrease the annual energy consumption (Bevilacqua et al, 2016).

Courtyard, patios and atria.

Courtyard is defined in as a flat land area that is completely or partially enclosed by sides of a building' (Cambridge Dictionary). In houses courtyard is considered from the eldest shapes of local architecture from at least five thousand years ago and it located in many special forms in many cities of the earth. Other than the area of the Middle East, where temperature and civilization gave unique shapes to the special styles of courtyards in houses, some altered forms of courtyards in India, North Africa (Morocco & Egypt), China, Southern Europe (Italy, Spain and Greece), Latin America (Fig 1).

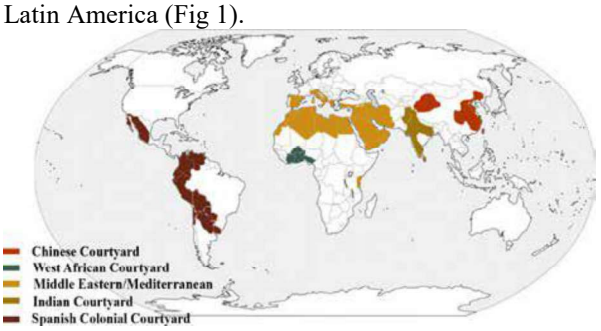

Figure 1. Courtyards World Distribution (image after (Vellinga et al., 2007).

Definition of courtyards

Courtyards related to a special kind of space, which is 'transition space.' This expression includes a many types of spaces from a path or a passage to a terrace. common zones are the spaces 'in-between' architectural areas where the outer and inner temperatures are controlled without systems of air conditioning (Chun et al., 2004).

The different forms of transitional area may be classified into 3 main types (Fig. 2).

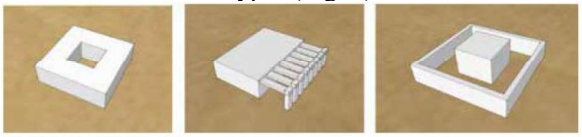

Figure 2. Transition spaces different shapes. type 1 (right), building surrounded by open space, type 2 (middle), the existing building attached to open space, Type 3 (left), in the building there is the open space (image after (Chun et al., 2004).

As seen from the 1ST type, the structure is totally surrounded by open area like the case in bus stations, pergolas, or canopies The 2nd type describes semi-opened attached areas which are half covered such as a terrace, an arcade, a shaded street or a passage. 3RD type includes atriums, courtyards. (Chun et al., 2004).

Similar types that looks like the courtyard are the atrium and patio: patio is a small type of courtyard which exists in Latin -American or houses in Spain. It occasionally is with high roof such as a shed. it also can be seen in high temperatures areas in West of Europe.

An atrium is a glass roof covered court, these types of buildings have different thermal behaviour and will not be discussed in this research (Dunham, 2006).

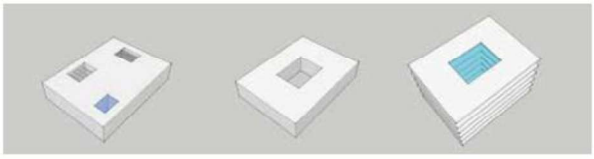

Figure 3. from Left: starts with a courtyard, then atria then: a patio,

one of the major differences in local architecture between any 2 regions are the courtyards. contemplation design in Yazd, leads to centered Courtyards (Courts that are engraved in the land) in the structures which are totally enclosed by rooms from all elevations (Dunham, 2006).

Central courtyards lead to effective and small humidity and cooling and microclimate inside the building which is separated totally from the outer hot-desert temperature by walls with non-porous properties. All the openings are opened on the central courtyard and all areas of the house is organized around it (Mabb, et al, 2008).

Hot wind flowing at the outer atmosphere hardly can enter the courtyard's central microclimate, specifically when the width of the yard is smaller than its depth. some examples, the yard depth is as between 3 to 4 m. Yazd central courtyards contains mostly pools with shallow depth, plantation and shrubs, which reduces with each other the fluctuation temperature in the structure and provides, cooler, humid and therefore comfortable setting for the dwellers. about 90% of local houses in Yazd have central courts (IPCC, et al, 2007).

Briefly , central-courtyards

Increasing in the shadow cover of yards by making the surrounding walls taller' (Pirnia, 2010), Increasing the ability of keeping the night cool air through the night in the yards in daytime (Soflaei, 2010), Providing an easy way to subsurface water canals to pass under the houses (Keshtkaran, 2010), to create an airflow by the use of difference in temperature of different parts of the building (Foruzanmehr, 2010).

Types and shapes of Courtyards

Courtyards can appear in circular, rectangular or square forms. Reynolds (2002) indicated that many of the courtyards were designed in the past as rectangular or square shapes (Reynolds, 2002). In the meantime, (Edwards et al, 2006), indicated that courtyards with circular shapes were seen in the local architecture of the samba old village (Edwards, 2006). Hyde, 2000 stated the three common design shapes of courtyards which are semi closed, semi opened and closed courtyards [8], as indicated in Figure 4.

Closed courtyards are commonly used in deep plans providing big level of lighting, cross ventilation and privacy. from another side, the semi closed courtyard is always designed between the sructures and expected to be a semi private space with shaded area. Finally, the semi opened courtyard provides the least amount of privacy but also providing a direct access to the building , also vision and ventilation.

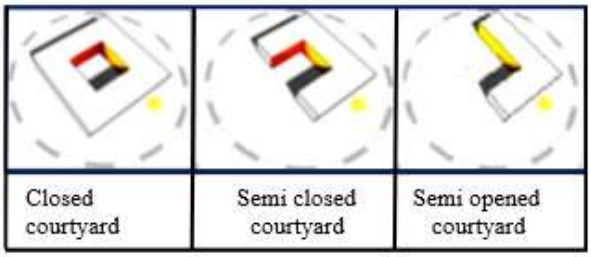

Figure 4. Courtyards types (Hyde, 2005).

Green-roof items

Green-roofs consists of agricultural components and popular roofing systems.

There are three layers in a green roof from the bottom (Barrio, 1998) – elements that provide structural strenth; a growing reservoir (which always Includes soil) and the plant shade (components selected as per particular application).

Figure 6 shows the different elements in a living roof system.

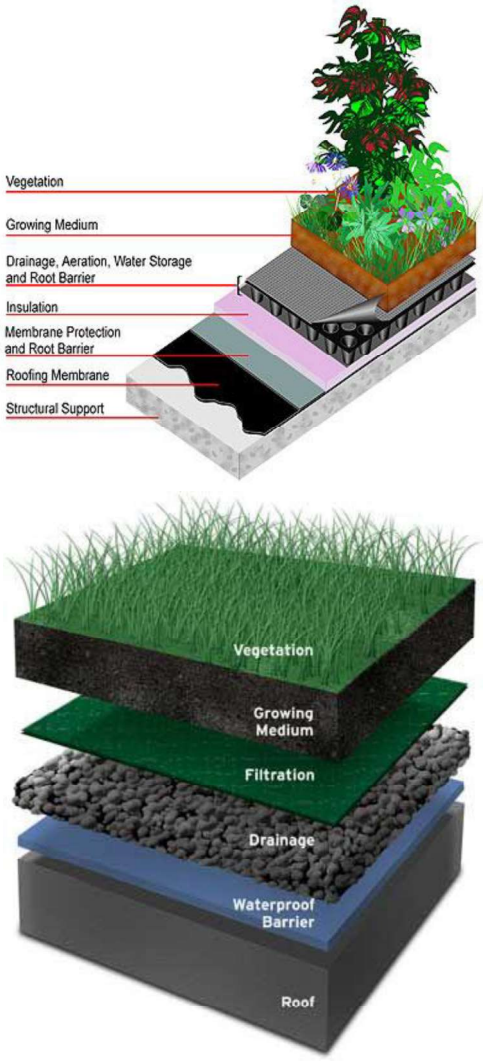

Figure 5. living Roof section introducing the different layers (Snodgrass & Mclntyre, 2010).

Different green roof types

There are 3 different system types of green roof,

Extensive green roofs:(Fig. 5) which is the 3rd type. Which needs a minim. maintaining technique & may be it doesn't need irrigation at all. This type of green roofs has less weight and minimum soil, which helps in cost minimizing and decreasing the roof loads as well (Stater, 2008).

Intensive green roofs:(Fig. 5) it is almost like a roof garden, mostly as a garden or a park, because the weight includes plantation, growth medium, irrigation, these type of gardens must be implemented over a concrete floor base.

Semi intensive living roofs: also called Simple living roofs are planted with shallow plantation or horizontal cover plants. It needs to be maintained regularly. A moderate toleration of structure compared to the intensive green roof, making it a more reasonable priced type of living roof. However, it is more expensive and complicated than extensive roofs. such roofs are always inaccessible.

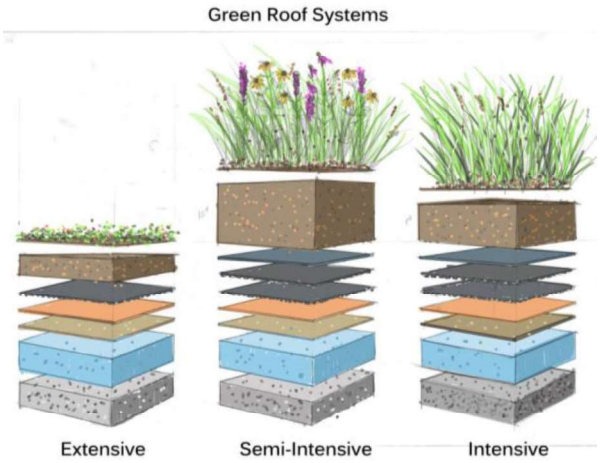

Figure 6. Intensive, semi intensive and Extensive types (Miller, 2012).

the main advantages of the green roofs are that it mitigates effects of urban heat-island, Creates inside the building a high energy efficiency, air pollution reduction, different biodiversity creation, increase buildings marketability, produces reduction in noise levels, job opportunities, water quality improvement, increase the service life time of roofing materials, controlling the storm water run roof and many other economic issues, (Miller, P.E., 2012).

Different elements of living roof structure such as:

Drainage: its function is to transport waste water to inner & outer drains. To use this system is very efficient, as extra water can cause the death of plantation, and it is very harm to the structure system of the roof. Also, there is drainage system designed to water saving, and helping the use of this drainage type of (Fig. 6) leading to the possibility of saving water for future extra usage (Technology. C, 2008).

Waterproofing: An essential objective of roofs that hides in itself, is waterproofing capacity. In fact, it involves a hot or cold liquid-applied membrane and impervious concrete, (Technology, 2008).

METHOD AND KEY PARAMETERS

The simulation will be conducted with the aid of "Design-Builder" software tool as shown in Fig. 7 which is mainly dependent on (Energy Plus). The investigated aspects: energy consumption, air temperature and relative humidity for proper evaluation of "Base-Case"& (investigated case study).

Through the study, two atrium shapes of roof are studied in natural ventilation increasing simulation zone sensible cooling and thermal comfort. Different methods were done to study cross ventilation and air movement in structures such as multi zone experimental.

Evaluation of the structural behavior of the buildings for putting an extra high weight such as the living roof on the top of the building will be done, since different shapes of living roofs (Extensive Intensive and Semi Intensive) have various weights. The best suitable solutions must be chosen.

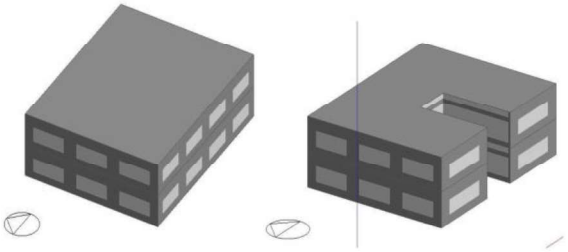

Figure 7. Architecture plans of Base-Case & courtyard and green roof Model, Design Builder Screen shoot.

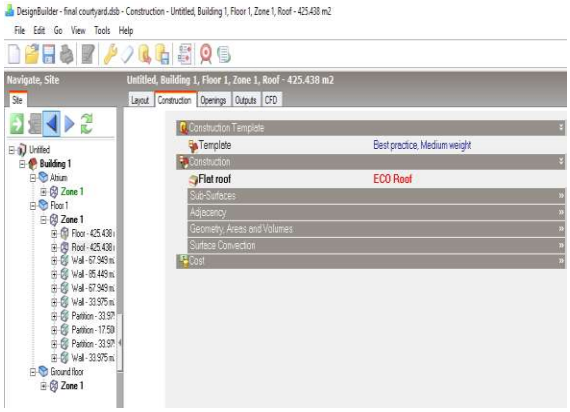

Figure 8. Set-points adaptation (18C°:24C°) & Extensive green roof adaptation, Design Builder Screen shoot.

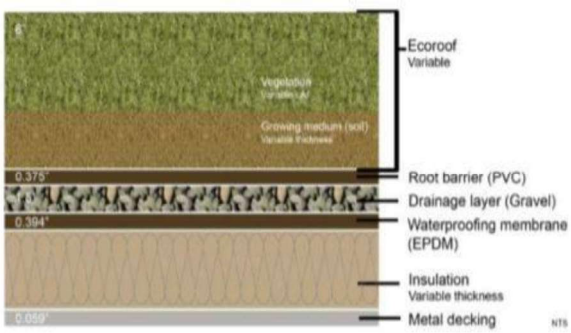

Figure 9. different layers of the green roof assembly as modelled in design builder.

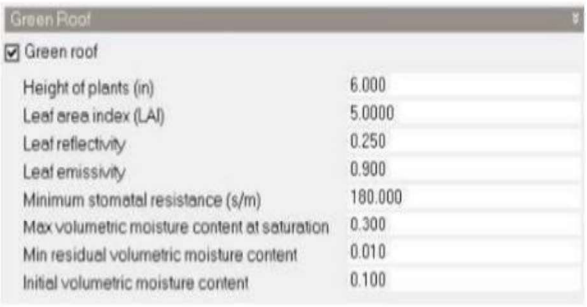

Figure 10. green roof parameters related to vegetation Eco roof layer).

RESULTS AND FINDINGS

Air Temperature: The annual energy air temperature of office area of the building, In order to determine the highest degree of operative air temperature with base case and case with courtyard with green roof.

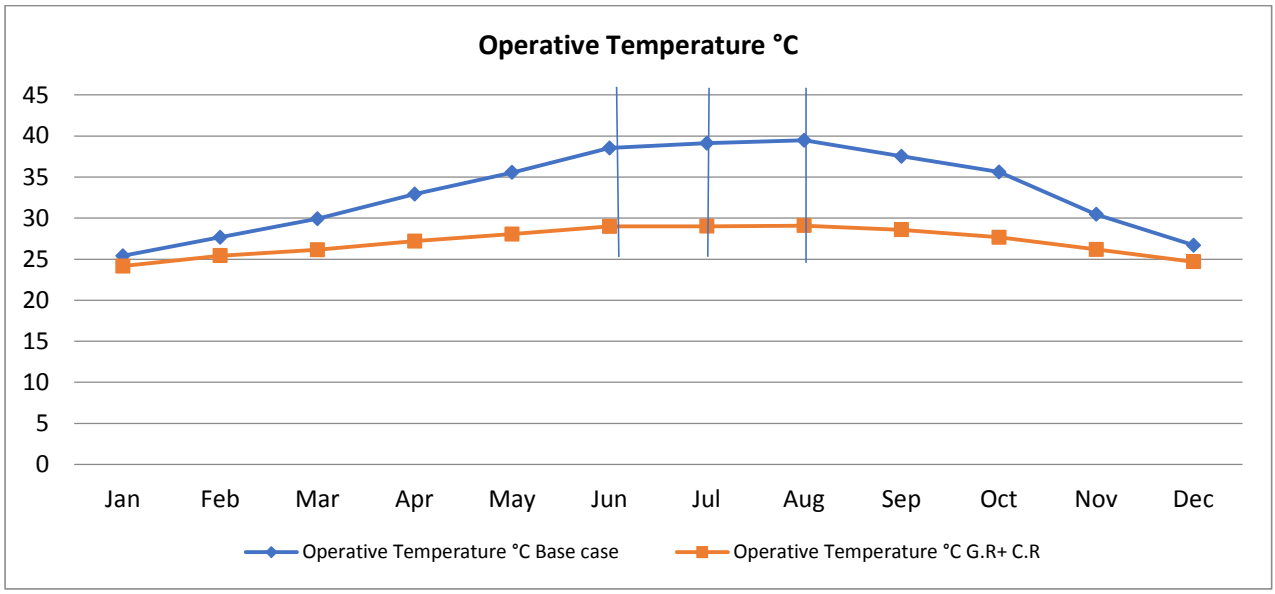

Figure 11. Annual results of air temperatures of Base-Case & courtyard and green roof model.

Fig. 11 Result showed that the annual air temperature for the case with courtyard with green roof achieve 270C,27 0C and 28 0C in June, July and August respectively, while the base case achieve 380C,38 0C and 39 0C in June, July and August respectively which the reduction in air temperature more than 100C.

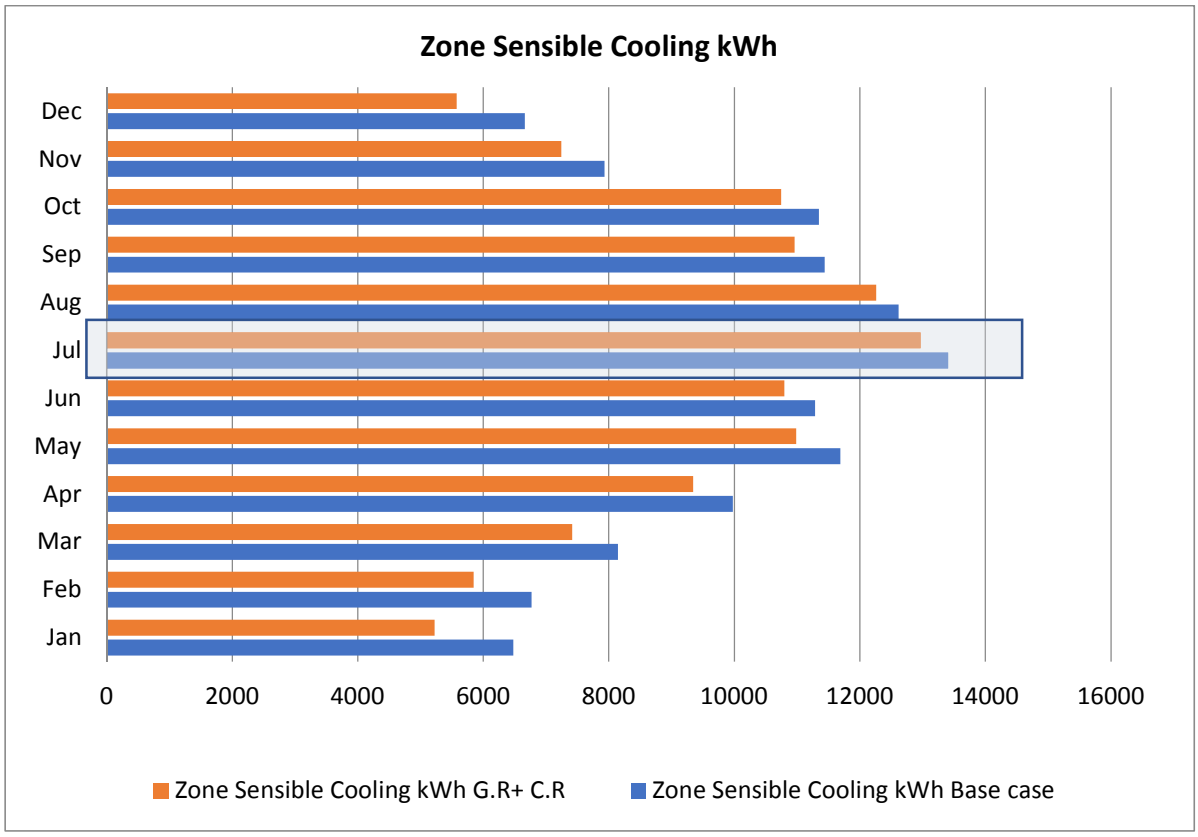

Figure 12. Monthly results of Zone Sensible Cooling kWh of office building with base case and courtyard with green roof Model

Zone Sensible Cooling load

The annual energy consumption of office building with a courtyard with green roof Model configuration examined within the office area of the structure, In order to identify which model reaches the highest level of efficiency in consideration to energy consumption. It could be seen that courtyard with green roof Model has 12968.5 [kWh] that the most energy efficient model compare to the base case with 14409.21 [kWh] in July.

Energy saving in buildings

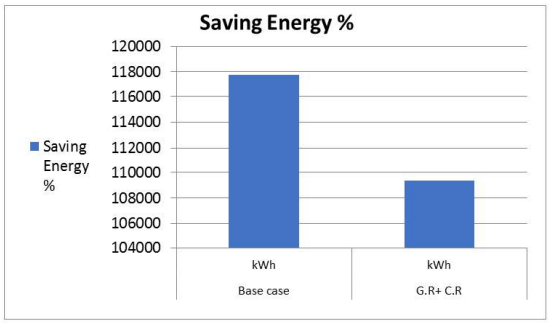

Figure 13. Energy saving in buildings of Base-Case & courtyard with green roof Model.

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Fig. 13 show the Energy Saving in Building with the base case and & courtyard with green roof Model.

EVALUATION OF THERMAL PERFORMANCE

In the following part, it is important to calculate all energy savings in the building, using a simulation tool. CFD Analysis will be used which will help in this step. The main aim of applying this software technique is to experiment and evaluate the behavior of the building with and without courtyards and living roof techniques. In fact, different days along the whole year was chosen as an average (in warm season), and the software helps in calculating the loss in thermal energy of building in the average days in cases with green roof and courtyard. The graphs also indicate these changes more clearly.

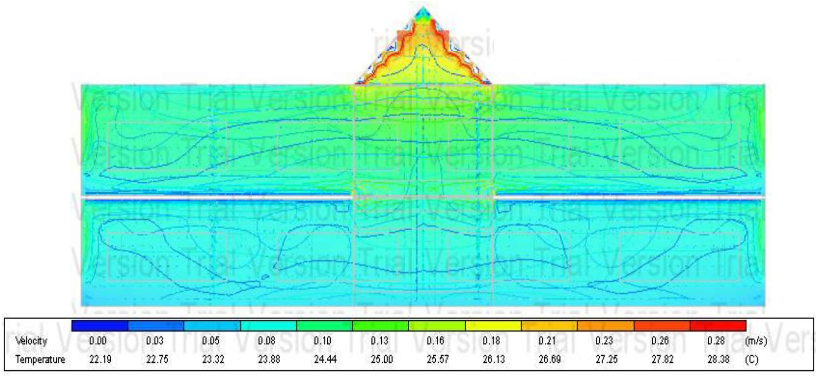

Figure 14. CFD profile-output section showing the temperature gradient & Velocity Vectors in the Room using Courtyard with Green Roof.

As seen from the simulation results in fig. 15 an increase in temperature from 22.19 °C at the bottom opening to about 26.13 °C at the top opening & variation in velocity from 0.03 (m/s)inlet at the bottom opening to 0.28(m/s)outlet at the top opening .

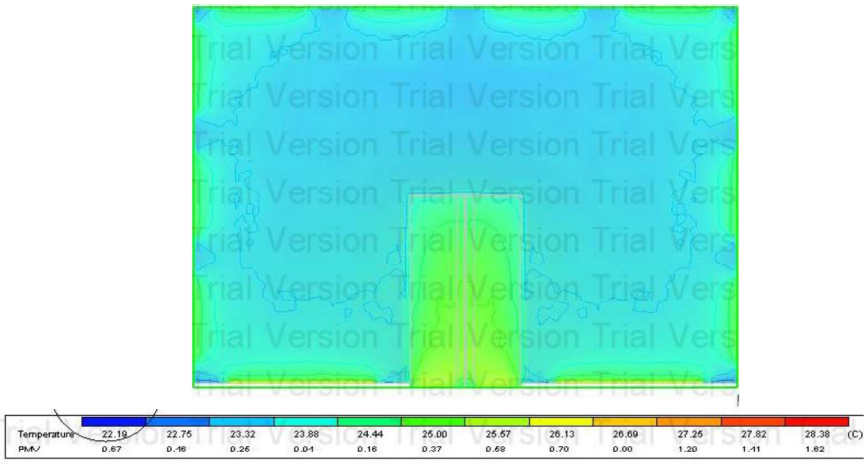

Figure 15. Predicted Mean Vote (PMV) gradient.

Fig.15 Show Predicted Mean Vote (PMV) ranges -0.67 SET inlets near cavity depth which increa outlets.

DISCUSSION AND CONCLUSION

This research shows the Base-Case & courtyard with green roof Model effective on energy consumption and thermal comfort range. This study shows that the DSF has a ability in providing acceptable internal thermal comfort through mixed mode ventilation strategy by using courtyard with green roof techniques.

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