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Investigating The Effect of Different Building's Orientation on Amount of Cooling Load in Kerman City Located in Hot and Arid Region of Iran

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Abstract

In hot and arid climate regions such as Kerman , overheating spaces in a building is crucial, especially in hot seasons, which causes enhancing cooling load consequently causes increasing energy consumption for creating comfort condition in buildings. Lack of consideration to this problem, causes energy crisis in the first step and in the next step excessive environmental pollution is provided. Prior researches show that form and window area and window orientation in buildings have considerable effect on energy consumption in buildings. The purpose of this research is the effectiveness of different window's orientations on cooling load in Kerman city with using simulation program IES<VE>. Ten rooms with the same characteristics with different Window areas (from 10% WWR to 100%WWR) in different orientations were modeled in simulation program. Then, the amount of cooling load was calculated for each model with different window area and orientations in 22nd of June. The results were compared for different models. The findings of this research indicated that the most cooling load related to the West, East and South orientation respectively.

Keywords: Window to wall Ratio (WWR), Cooling Load, Heat gain, Energy, Building

Introduction

Generated or entered heat into a space in a given time is called heat gain. Heat gain is categorized by the type of transferring heat to the space. Heat gain occurs in building, due to entering heat into space of the buildings and temperature differences and solar radiation. In addition, some activities in buildings generate heat inside buildings (Givoni, 1998). Heat transfer occurs when there is a temperature differences among different places. Direction of heat flow is from higher temperature place to the lower temperature place and flow of heat continues until the temperature of different places becomes same. Heat as a form of energy, based on the principle of energy conservation, is neither created nor destroyed. Just heat transfers from point to the point. There are three type of heat transferring, called conduction, convection and radiation (Givoni, 1998). Heat Conduction is occurred within a material or between materials when they have contact with each other directly and they have different temperature. The amount of heat conduction for different material is varied due to ability of each materials. Heat conduction is an important heat transfer method. Fourier's law is used for calculating heat conduction.

$$q= KA(t1-t2)/L =(t1-t2)/[L/(kA)] \quad (1)$$

In the equation, q is the total heat transfer rate across the area of cross section (A), perpendicular to the x direction. The thermal conductivity is shown as K. Wall thickness is shown by L. When x equal to 0, temperature is shown with t1 and when x equal to L, temperature is considered t2 (ASHRAE Fundamentals Handbook, 2005).

Heat can be transferred within gases by convection. Always hot air goes up while cold air substitutes the hot air. The speed of heat transferred is highly affected by air speed which is close to the building elements. Natural (free) convection is heat transferring within flowing materials taking place by differences between temperatures in two places (ASHRAE Fundamentals Handbook, 2005).

Radiation is considered as a kind of heat transferred with light speed. Heat transfers without any requirement to the material by radiation (Kannan, 1991). If a material has a same absorption and emission a balance condition in temperature occurs. Therefore, the material's temperature does not change but if a material emits more than its absorption, its temperature decreases and vice versa (Givoni, 1998).

In conduction and convection, heat transfer takes place through material. In thermal radiation, energy is emitted from a surface and transmitted as electromagnetic waves, and then it is absorbed by a receiving surface. Whereas conduction and convection heat transfer rates are driven primarily by temperature gradients, radiative heat transfer rates are increased by temperature and unlike conduction and convection, no material is required to transmit electromagnetic energy (ASHRAE Fundamentals Handbook, 2005).

Conduction heat gain, solar radiation through fenestration, skylights and infiltration are considered as heat gain through building design variables. According to Givoni (1998), the amount of Conduction related to inside and outside condition and material properties of wall and windows. Exterior walls, roofs, windows are devices to transfer heat . The amount of heat conduction through building surfaces can be calculated by the following equation:

$$Qc = UA\ (\Delta T) \quad (2)$$

Where:

Qc: Conduction heat flow rate, W

U: Transmittance value, W/m2K

A: area of surface m2

ΔT: differences between Temperature, °C

Heat gain through windows is accounted as one of the effective factors on building cooling load. There are two ways for heat gain through windows. One of them is direct solar radiation, which is transmitted through the glazing area and other one is absorbed radiation transmission into the space (Lam and Li,1999).

Window area and shading coefficient are two effective variables contributing in solar heat gain, therefore, it can be concluded that window area and shading coefficient have important role on amount of cooling load of building as well. Window area is recognized by a parameter called Window Wall Ratio (WWR). WWR means the ratio of windows area to the area of gross wall (Lam et al, 2005).

In order to minimize energy consumption, the amount of heat gain should be reduced. Therefore, the amount of energy for cooling in air conditioning system can be decreased specially during hot months. The most effective parameters on heat gain through envelope are building direction, wall area and its construction and surface finish (wall absorption coefficient), window area, type of glass, roof area and its construction type (Lam et al, 2005).

Research Methodology

IES (VE) program has ability to simulate various results for energy in building for different purposes. Beevor (2010) specified the accuracy of IES (VE) in term of energy consumption in buildings. The ability of IES (VE) simulations to get accurate data was evaluated (Beevor, 2010).

Overall performance of a building can be evaluated by using IES (VE). The IES (VE) program has ability to calculate different values of the buildings. Furthermore air temperature, solar heat gain, and cooling loads can be determined by using IES (VE). Therefore, there is a possibility to compare the experimental data in real world and virtual environment to get the accuracy of simulation program (Beevor, 2010). The IES (VE) has ability to calculate heat gain respect to the Heat Balance Method. ASHRAE weather data is used for calculation energy requirement for one design day per month (Waddell, Kaserekar, and Ten, 2010). IES (VE) has enough validity with accurate results in term of both thermal analysis and humidity inside buildings. IES (VE) has the ability to simulate precisely for any hours during specific day and differences are not more than 10% to 20% with measured data. Therefore, it can be summarized that IES (VE) can be used for the simulation of air temperature and relative humidity in building design project and research purpose (Leng et al, 2012). IES (VE) was chosen as the most positive simulation program to evaluate energy consumption in buildings (Attia et al, 2009). IES (VE) is the high accuracy simulation software due to its validated system. Furthermore ASHRAE Standard validated APACHEsim (Attia and De Herde, 2011). Nikpour et al. (2013) proposed the IES<VE> has enough validity in term of heat gain (Nikpour, Kandar, and Mousavi, 2013). Nikpour and Sedighpour (2015) used IES<VE> for specifying the correlation between window area and heat gain through conduction and solar radiation.

This research was conducted through simulation program IES<VE>. Ten rooms with 6 meters length and 6 meters width and 3 meters height were modeled in Model IT option in IES<VE>. Different models are shown in figure 1. Each models was modeled and simulated in 3 different orientations (South, east and west) and cooling load were determined for each models in each orientation.

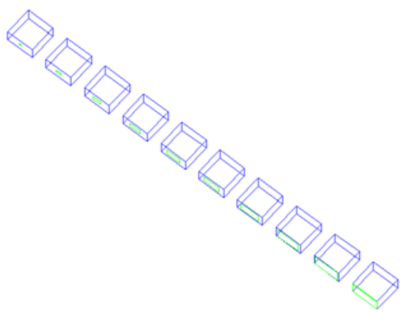

Figure 1: Different models in IES<VE>

Construction details of external wall, roof, ground and external windows were considered the same.Construction details of the models are as follows: U-Value of floor, roof, wall and window are 0.2510,0.2499,0.3520 and 2.06 W/m2k,respectively.Detail construction of wall is shown in figure 2.

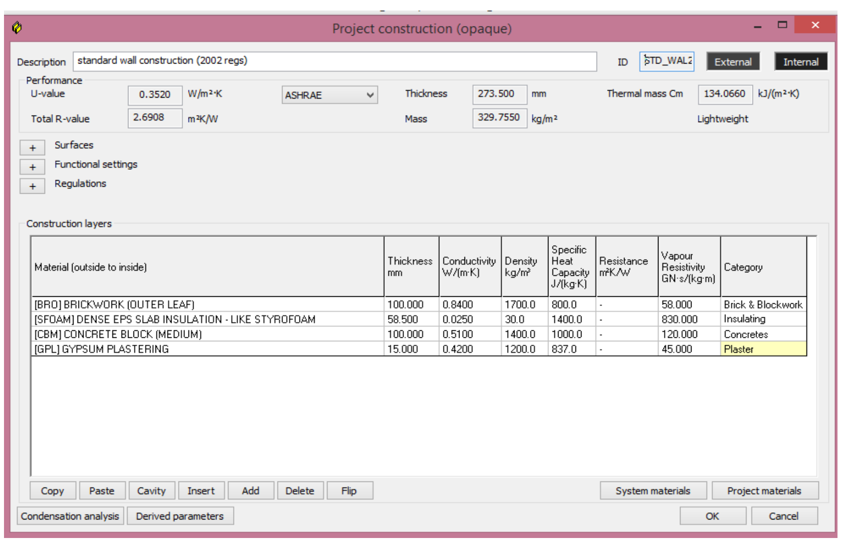

Figure 2: Detail construction of wall

Window areas in these rooms are different from 10% WWR (Window to Wall Ratio) to 100% WWR. All windows in models are evaluated in different orientation. Then, under APlocate option in simulation location, it was set for Kerman city. Also, weather data of Kerman was selected for simulation weather data. Then, all models were simulated under Apache option under Energy section of IES<VE> simulation program. Then, the cooling load is achieved for each model (Figure 3).

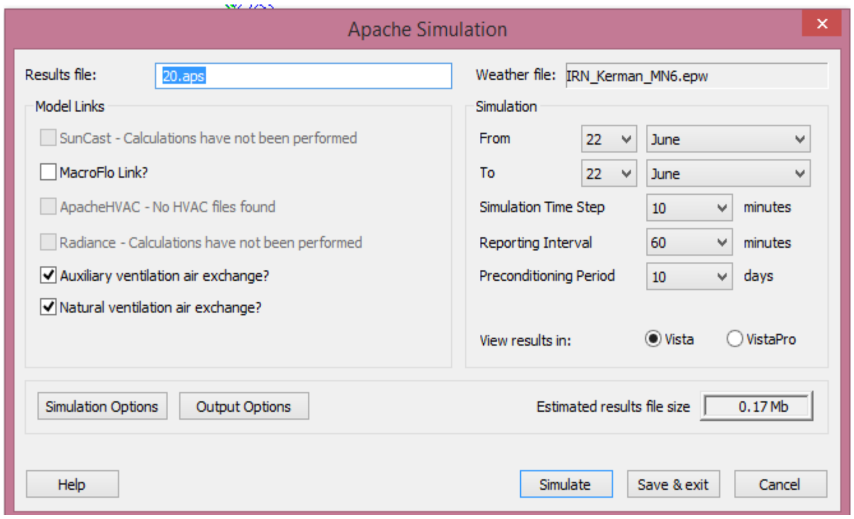

Figure 3: Apache Simulation page in IES<VE>

Results and Discussion

The amount of cooling loads in models with south orientation with different Window areas are tabulated in table 1.

Table 1: Cooling load of models with south orientation according to different WWR (kW)

WWR	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Conduction Gain	8.57	9.11	9.99	11.22	12.79	14.68	16.87	19.35	22.11	25.11

Amount of cooling load equals to sum of heat gain through conduction and heat gain through solar radiation for whole room during a day. As it is identified in table 1, cooling load for a room with south orientation of window is increased from 8 KW to over 25 KW for 10% WWR to 100% WWR respectively. Figure 4 also shows the increasing cooling load in rooms with windows faced to south with different window area (from 10% to 100%).

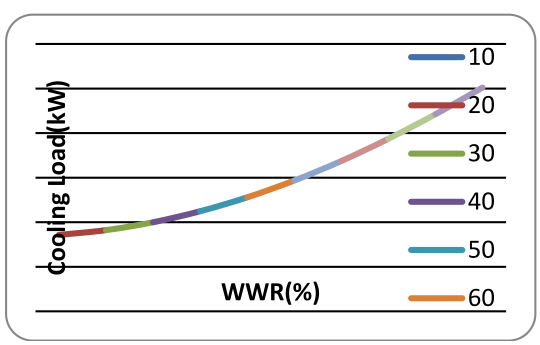

Figure 4: Cooling load of models with window facing south on 22nd of June according to different WWR (kW)

Amounts of cooling load of models which have window facing to East for different window area on 22nd of June in Kerman city are tabulated in table 2.

Table 2: Cooling load of models with East facing windows on 22nd of June according to different WWR (kW)

WWR	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Solar Gain	8.73	9.75	11.42	13.75	16.70	20.24	24.23	28.97	34.08	39.62

In model with 10% WWR while window is located in East orientation, cooling load is just 0.2 kW higher than cooling load in model with same window area which has window facing to the South but amount of differences in model with South window and East window increases with increasing WWR and this differences reach to 11 kW when 100% WWR is applied which shows increasing more heat transfer through solar radiation. The amount of cooling load in models with different WWR facing East is shown in Figure 5.

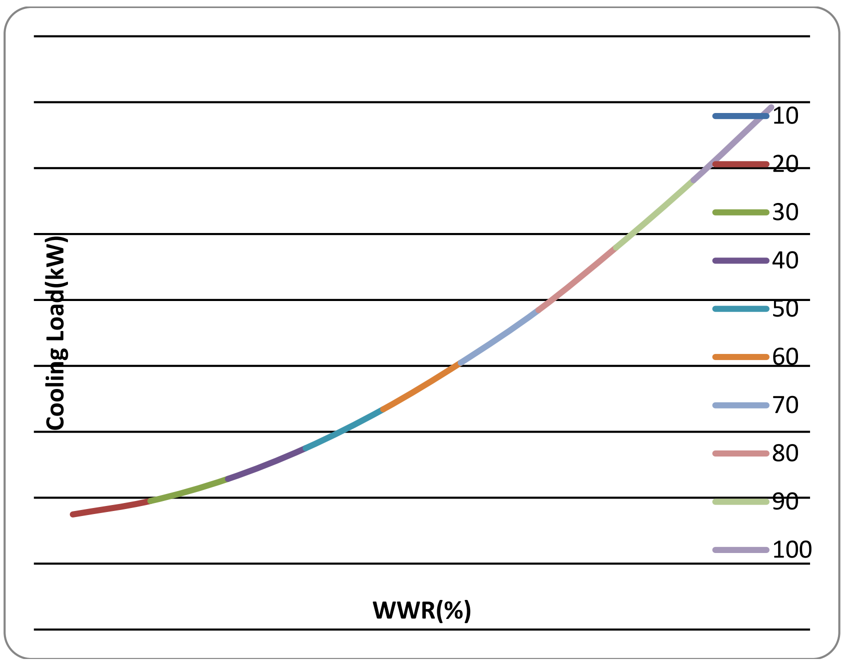

Figure 5: Cooling load of models with East facing windows on 22nd of June according to different WWR (kW)

The amounts of cooling load in a model with west window facing for different window area on 22nd of June in Kerman city are tabulated in table 3.

Table 3: Cooling load of models with West facing windows on 22nd of June according to different WWR (kW)

WWR	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Solar Gain	8.74	9.81	11.51	13.91	16.96	20.62	24.87	29.66	34.96	40.05

The amount of cooling loads of models with West window facing for all window areas are higher than models facing South or East but amounts of cooling loads in models with west window facing and models with East window facing does not have significant differences. The amounts of increasing cooling load in models with west window facing with increasing window area on 22nd of June are shown in figure 6.

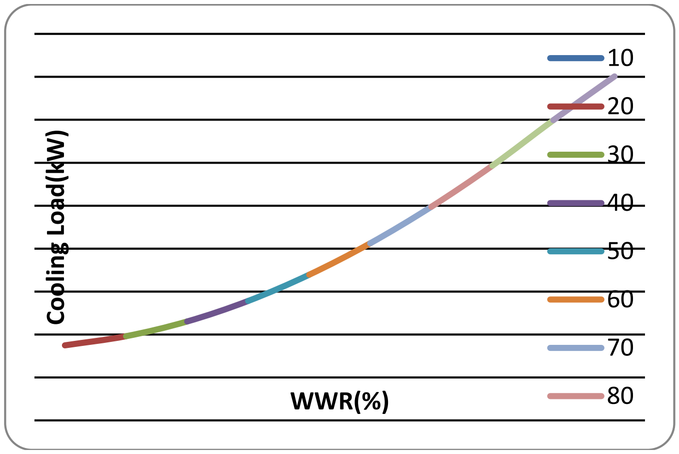

Figure 6: Cooling load of models with West facing windows on 22nd of June according to different WWR (kW)

Figure 7 shows amount of cooling load of different models with different WWR and different orientation of windows. As it has been shown, A model with South facing window Regardless of window area has the lowest cooling load in compare with a model with East or West window facing, furthermore differences in cooling load with increasing window area in a model with south window facing with compare to the model with east or West window facing, become more significant.

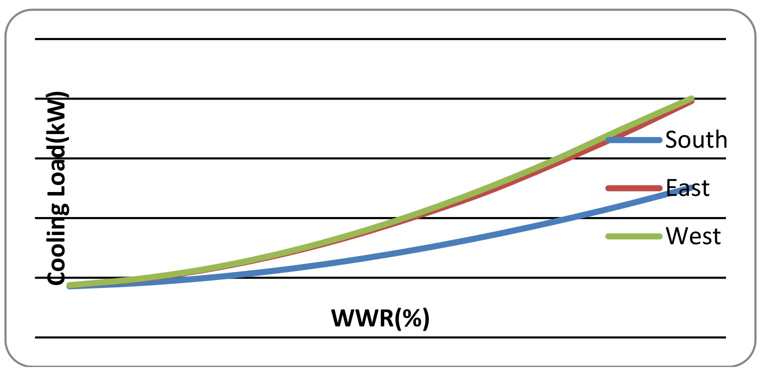

Figure 7: Cooling load of models with different orientation of windows on 22nd of June according to different WWR (kW)

Regarding to more vertical of solar radiation in summer season consequently, south window facing rooms receive less solar radiation and due to the less altitude during sunrise and sunset, rooms with East and West window facing receive more direct solar radiation. Therefore, these reasons can justify the result of this research.

Conclusion

Findings which have derived from comparison the cooling loads of different model with different orientation of windows with using IES<VE>, shows that cooling load on 22nd June in a room with South window facing for all window areas is lower than cooling load in a model with East or West window facing. Therefore the best selection of window orientation in hot and arid region such as Kerman is south orientation however it is better to use the minimum window area. Furthermore decreasing cooling load means decreasing the amount of energy consumption. The other result of this research is increasing progressively of cooling load according to the increasing window area in rooms with East and West window facing.

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