Effects of Orientation and Glazing Material on Heat Gain in Semi-Arid Climate of Lahore

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***Abstract*-**Lahore falls in the region of semi-arid zone having long and extremely hot summer and comparatively short and mild winter. The extreme temperature in summer that spans from March to October is responsible for high solar radiation, which causes heat gain in buildings. Sun light obstruction by a horizontal shade at west, due to the low altitude of sun in summers, is not possible. This emphasizes the need of windows with high energy performance. This paper describes a simulated study conducted to test the impact of two parameters of window design i-e orientation and glazing material used, on the heat gain in semi-arid climate. The major component of window is glazing material, which is an important parameter for study regarding heat gain. The orientation is studied as it is one of the fundamental design parameter.

The significance of this study is quantitative evaluation, with the acquisition of measurable data, generated through a software named as "comfen" specifically designed to investigate the window design parameters regarding solar heat gain. In testing both parameters, results show that with the gradual decrease in heat gain, the daylight entering the room is also reduced, which is also not desireable.

***Keywords*-**Heat Gain, Window, Orientation, Glazing Material, Semi-Arid Climate, Daylight

I. INTRODUCTION

The primary function of a building is to provide shelter. The building acts as a barrier between the indoor and outdoor climate conditions. The building envelope, like a filter, must allow the favorable climate conditions inside and obstructing the unfavorable ones. The penetration of solar radiation in the indoor can be desirable or not depending upon the climate of that particular area or region, function of the building and its orientation. Ultra violet rays should be avoided by obstructing sun's heat in the interior, in semi arid climate like that of Lahore, to prevent greenhouse effect. [i]

Window is weakest part of the building envelope thermally and are responsible for increasing the indoor temperature. The artificial cooling systems have been widely used in the buildings to counter this temperature effect and also to achieve the required level of thermal comfort. It is also observed that with the constant increase in cooling loads, there is also an increase in the lighting loads on the buildings. [ii]

According to a research conducted in India, air conditioning and lighting constitutes over 80% of energy use in commercial buildings. (Fig. 1) [iii]

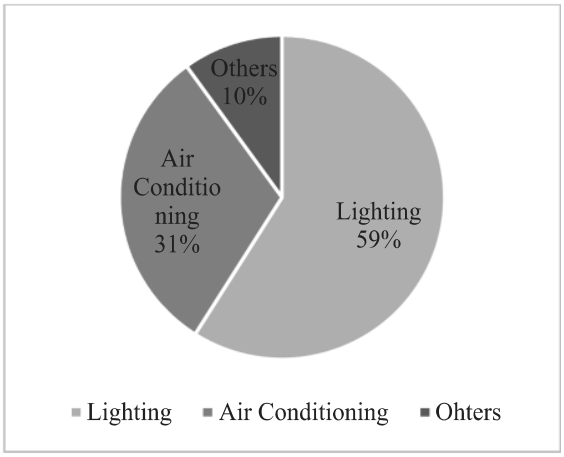


Fig.1. Energy Use Breakdown in commercial Buildings India

There are four factors which control the solar gain entering through windows. These factors are window orientation, window size, Thermal properties of glazing material used and shading devices. [ii] This study is focused to measure the impact of two factors only i-e window orientation and thermal properties of glazing material used.

A. Glazing

Glazing constitutes comparatively a larger part of window design. The transparent materials like glazing are selectively transparent to radiations. Such materials allow short wave radiations which are absorbed by the internal surfaces. These internal surfaces, in return, emit long wave radiations. The glazing material acts as opaque to such long wave radiations and in this way the interior of a building becomes hot in hot climate like that of Lahore. This phenomenon is known as

"Greenhouse Effect" and is responsible for heat gain in the buildings. [i]

The glazing affects the heat gain in a building to a huge extent. A research carried out in India for a building can be taken as a base study. The building of Energy Systems Engineering IIT Mumbai has fully glazed south façade(Fig. 2). The monthly energy demand graph of the building (Fig. 3) shows that there is only cooling load in Mumbai and no heating load. This is because the climate of Mumbai is warm and humid. But the noticeable thing is that due to excessive use of glass on the façade, there is a constant cooling load on the building throughout the year. The cooling loads dominate in the region like India and also there is a constant increase in the lighting loads on the buildings. [iii]

Fig. 2. Fully glazed South façade ofEnergy Systems Engineering IIT, Mumbai [viii]

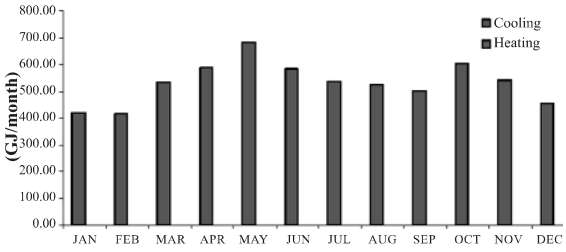


Fig.3 Monthly Energy Demand Graph [viii]

Glass was formed accidently some 4000 years ago in Eastern Mediterranean. [iv] Thin sheets of glazing material became available 2000 years after invention of glass, which were appropriate to be used in windows. It marked the beginning of the relationship between glazing material and windows, though the use of glazing in buildings being limited [v]. The trend in Architecture was changed entirely after Industrial revolution. Vertical expansion became possible with the invention of Iron / steel as construction material and frame structure. Further the invention of artificial heating and cooling systems made the architects free from the constraints that had ever determined the form of building. The larger windows or windows with larger part of glass and entire glazed wall became a trend due to all these advancements. [vi]

There are some factors through which the thermal performance of a glazing material can be assessed/ checked. These factors are Solar Heat Gain Co efficient (SHGC), U-Factor, Shading Co-efficient (SC), and Visible Light Transmittance (VLT). [vii].

B. Orientation

Heat gain can be reduced to an appreciable limit if the windows are oriented in right direction especially in hot climate. In this way, desired level of comfort can be attained. Large windows facing wrong direction can be responsible for excessive solar gains in summer and huge heat loss in winter. Excessive solar gains in summer and huge heat loss in winter is the result of in appropriate design of the windows e.g large windows facing East and West. The reason is that the amount of solar radiation received by the window on North and South is less than that received on East and West. For this reason, these orientations are considered critical and can be handled only through appropriate window design. [i].

II. OBJECTIVES

This aim of this work is to study the role of some transparent materials and orientation regarding the solar heat gain, through computer simulation. The role of orientation is studied by measuring the performance of different glazing materials on all orientations. Further, the performance of a single window at varying orientations is studied.

The research is conducted for the climate of Lahore, located between 31 degree North to 33 degree North Latitudes and, 73 and 75 degrees East longitudes. The Climate of Lahore falls in the semi-arid (Steppe) with hot summer and mild winter zone [viii]. It has hot climate for 8 months and has mild winter for the rest of 4 months. Hence the hot season predominates the whole year.

III. METHODOLOGY

A. Computer Simulation

In order to conduct this research, computer software is used. The name of the software is "Comfen". Comfen is a tool which investigates key parameters of windows which affect the thermal and visual comfort. According to different books and research publication, the key variables of window design that affect the heat gain through windows are Window Size, Glazing Type, Shading Device, Window shape, Orientation etc. But in this study, we are

focusing the two parameters i-e Thermal properties of glazing material used and Orientation.

Comfen requires some information at the start of each project before conducting the simulation. Every project requires a name, location, building type and vintage. Location includes weather data for energy plus simulation. Building type includes the lighting and occupancy. The building type can be set to office, Mid-rise Residential, Hotel, Hospital etc. Each type controls its specific occupancy and lighting along with equipment schedules. Vintage is restricted to new ASHRAE 90.1 2004. Four different types of windows are analyzed to conduct this study.

B. Description of Windows Analyzed

The four different types of windows have been analyzed in the software having the same area and frame and having 4 different types of glass materials. The windows analyzed are explained in Table I.

TABLE I
U FACTOR, SHGC VALUE AND VT VALUES FOR THE WINDOWS INVESTIGATED

	Window 219	Window 233	Window 234	Window 235	Window 236
Glazing	Single Clear	Double Clear	Triple Clear	Double Low solar Low-E Clear	Double Low solar Low-E Tinted
Frame	Al/with Break	Al/with Break	Al/with Break	Al/with Break	Al/with Break
U-Factor	1.09	0.48	0.36	0.24	0.16
SHGC	0.81	0.70	0.67	0.26	0.1
VT (% daylight)	89	79	74	64	58

Solar Heat Gain Co efficient (SHGC) : ratio of solar heat gain through glass to the incident solar radiation

U-Factor : heat flow through glazing from warmer side to cooler side. It is inversely proportional to R value which is thermal resistance whereas U value is thermal conductance.

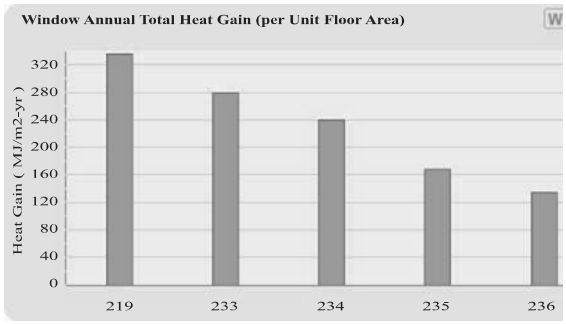
Shading Co-efficient : **SC** = SHGC/ heat gain through 3mm clear glass.

Visible Light Transmittance : is the percentage of visible light striking the glazing that will pass through. Visible transmittance values account for the eyes' relative sensitivity to different wavelengths of light. Glazing with a high visible transmittance appear relatively clear and provide sufficient daylight and unaltered views; however, they can create glare problems. It determines the visual performance of glazing. . Higher VLT, high will be the light penetration [ix]

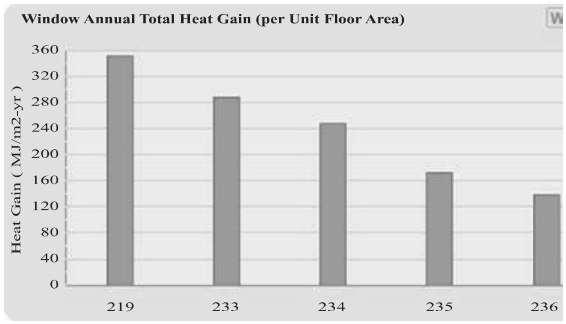
By putting the weather file of Lahore, the above mentioned windows have been analyzed in comfen. The five windows have been analyzed on 4 different orientations in order to observe the thermal performance of different glass types with reference to heat gain and light.

IV. RESULTS

A. Thermal Performance of Glazing Material Used

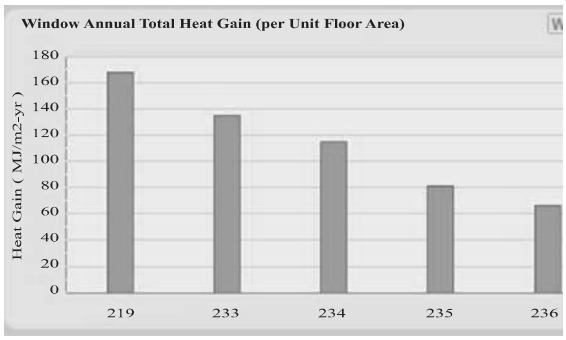


(a)

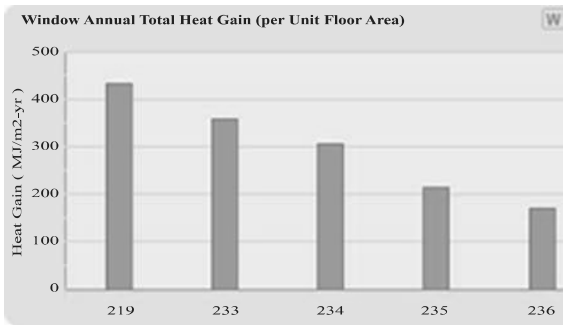


(b)

Fig. 4. Comparison Charts of Annual Heat Gain through (a) East and (b) West facing windows



(a)



(b)

Fig. 5. Comparison Charts of Annual Heat Gain through (a) North and (b) South facing windows

Now the four selected windows are compared to analyze for daylight. The windows that have been compared for daylight area as mentioned in Table II.

TABLE II
U-FACTOR, SHGC AND VT VALUES OF THE WINDOWS INVESTIGATED

	Window 233	Window 234	Window 235	Window 236
Glazing	Double Clear	Triple Clear	Double Low solar Low-E Clear	Double Low solar Low-E Tinted
Frame	Al/ Break	Al/ Break	Al/ Break	Al/ Break
VT	0.79	0.74	0.64	0.58
U-Factor	0.48	0.36	0.24	0.16
SHGC	0.70	0.67	0.26	0.1

The results generated for comparison of daylight are as under.

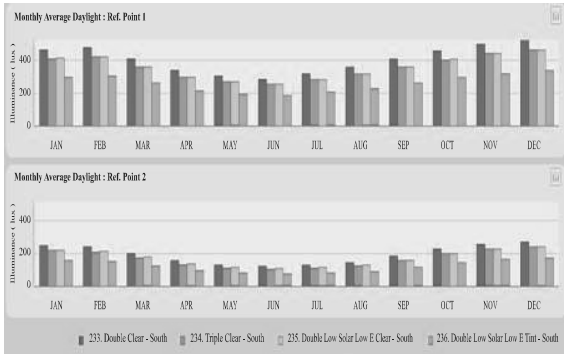


Fig. 6. Comparison charts of Monthly Average Daylight through South facing windows

B. Orientation

The effect of orientation is studied in the software by orienting the same window on all the 4 sides. The window of the same area having aluminium frame with thermal break and having Low Solar Low E Tinted glass is analyzed on 4 sides and graph (Fig 5) is obtained.

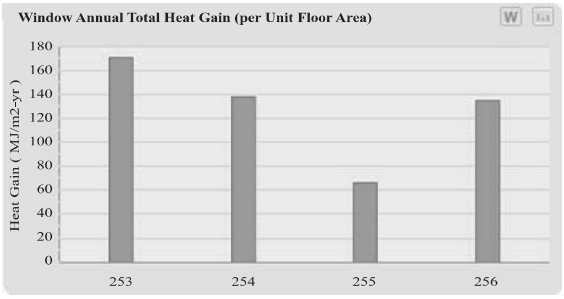


Fig. 7.Comparison graph of window facing 4 sides
Scenario 253: Window facing South,
Scenario 254: Window facing West
Scenario 255: Window facing North
Scenario 256: Window facing East

V. DISCUSSION

A gradual decrease in solar heat gain is observed on all orientations by varying the glass type in the same window from single clear to Low Solar Low E Tinted glass. The heat gain is largest when single clear glass is used and is lowest when double Low solar Low E tinted glass is used. It is however observed that on east and west orientations, the amount of solar gain is higher (up to 360 MJ / m2-yr) than on north orientation (up to 170 MJ / m2-yr). The solar heat gain is highest at south orientation i-e up to 400 MJ / m2-yr Fig 3. This shows that in the hot climate like that of Lahore, it is preferable to have more surface area of the building oriented towards north and south and lesser surface area or window opening towards east and west.

Four windows have been selected for the comparison of daylight. Results generated are contrary to those generated comparing the heat gain. The window having the Low Solar Low E tinted glass allow minimum daylight to enter i-e up to 300 lux. And the window having double clear glass (with comparatively larger heat gain) allow larger amount of daylight i-e more than 400 lux. These results are calculated by orienting the windows towards south. It can be stated, on the basis of results that by controlling the heat gain through different types of high performance glass, the daylight entering the buildings is also controlled. The big challenge therefore is to reduce the heat gain through the window glazing without compromising the daylight coming inside the building.

Orientation can be studied by the results generated previously. The heat gain is highest on south. The range of heat gain on south for the selected windows is approximately from 200-400 MJ / m2-yr. This range varies on the other orientations. On the North orientation, it is lowest i-e 70-170 MJ / m2-yr. On East and West, this range is approximately 140-370 70-170 MJ / m2-yr. The Orientation is studied further when a selected window is analyzed on 4 orientations for heat gain. The window is energy efficient and Low Solar Low E tinted glass is used. It is observed that heat gain is minimum when oriented towards North Fig 5.

VI. CONCLUSION

The heat gain and daylight are the two phenomenon that go simultaneously and cannot be separated. The need is to control the heat gain in the buildings and also to incorporate natural light efficiently. In this way the cost on the artificial systems of cooling and lighting can be reduced. Orientation factor can be tackled easily by giving windows on the recommended orientation (preferably North and South) in hot climate of Lahore. And windows on every orientation should be dealt separately keeping in view

the sun angle and the quality and magnitude of light coming inside. The most important parameter in this context is the glazing material in the window as it covers a larger part of the window opening. The effective way to do this is to use a combination of glass types in the windows. And windows on every orientation should be dealt separately keeping in view the sun angle and the quality and magnitude of light coming inside.

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