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ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 3, March 2018

Analysis of Heating and Cooling Load Caused By Fenestration of a Building Located In New Delhi, India

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***Abstract:*-- Recent Studies suggest that 40 percent of the energy is consumed by buildings during their operational phase alone and one of its major consumer is the HVAC system. This energy can either be traced back to a conventional source or a non-conventional source, but because HVAC system is a specific energy consumer in a building, powering it with a renewable source may be a tight call, thus resorting us to use only conventional source of energy; because pollution too is problem that we have to consider the optimization of energy usage is of prime importance and that is where the building envelope comes into play.**
The main objective of this paper is to analyze the effect on cooling and heating system in a building by considering various glazing technology in windows which form a major part of building envelope. For this analysis CASAnova 3.3 software has been used and the building has been assumed to be situated in New Delhi, India.

***Index Terms*— Glazing; window frames; window to wall ratio; CASAnova 3.3; HVAC; Building envelope.**

I. INTRODUCTION

Buildings consume almost 40% of the world's energy, 16% of the world's fresh water, and 25% of the forest timber, while they are also responsible for almost 70% of sulfur oxides and 50% of the CO2 emissions [1]. Most of the energy that is consumed by the building is either due to cooling to comfortable working temperature or heating it to comfortable working temperatures. Both above depend on up on many factors like, building orientation, weather conditions and seasonal weather changes because the incoming solar radiation is different in different seasons.

Incoming solar radiation in buildings has strong implications on thermal aspects [2]. the glazing of windows influence daylight levels in a building and the view to the exterior environment; if used properly they can also reduce the yearly solar gains and modify thermal exchanges through the building envelope. Therefore, glazing effect of window affect the building energy use for lighting, heating and cooling, and the occupants, thermal comfort [3][4].
The windows used in buildings are classified based on the following (i) frame material (ii)glazing property.

A. Frame material

As we know it, choosing the right material for the application is one of the most important factor when we must find out the overall assessment of the process. In the same way when we talk about windows we must consider the material involved. The most commonly used material are as follows.

(i) aluminum- the main advantage of using aluminum or any other metal as a frame is that, it is strong, maintenance free and in this case very light also. But the main disadvantage is that, it is the very poor insulator. In order to overcome this disadvantage an additional layer must be introduced into the system. This can be in the form of plastic strip placed between the frame and sash.

(ii) fiberglass- the main advantage of fiberglass is that the drawbacks of using an aluminum window frame are not present when fiberglass used.

B. Glazing material

Low-emissivity (low-e) coatings on glazing or glass control heat transfer through windows with insulated glazing [5]. Windows manufactured with low-e coatings typically cost about 10% to 15% more than regular windows, but they reduce energy loss by as much as 30% to 50%. A low-e coating is a microscopically thin, virtually invisible, metal or metallic oxide layer deposited directly on the surface of one or more of the panes of glass [6]. The low-e coating lowers the U-factor of the window, and different types of low-e coatings have been designed to allow for high solar gain, moderate solar gain, or low solar gain. A low-e coating can also reduce a window's visual transmittance- VT unless you use one that's spectrally selective.
Although low-e coatings are usually applied during manufacturing, some are available for do-it-yourselfers. These films are inexpensive compared to total window replacements, last 10 to 15 years without peeling, save energy, reduce fabric fading, and increase comfort.

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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Software details

CASAnova 3.3 is educational software for the calculation of the heating and cooling demand of buildings. We have considered the different relations between parameters such as building geometry, thermal insulation standard, performance of glazing, solar gains as well as the heat and cooling demand of the building [7].

II. METHODOLOGY

As stated above, the location we have considered for our study is New Delhi, India. The weather details and all other necessary details are shown in the following Table1 the coordinates for New Delhi in terms of latitude and longitude are as follows 28.7041° N, 77.1025° E.

Month	Mean temp	Max temp	Min temp
January	14.4	25.2	4.1
February	17.2	28.3	6
March	22.8	36.3	10.4
April	28.5	41.6	15.7
May	32.9	44.5	20.5
June	32.8	44.7	22.8
July	30.7	39.7	24
August	30	36.8	23
September	29	36.7	21.2
October	26.2	36.4	15.5
November	20.4	32.9	8.9
December	15.7	28.1	4.7
All temperatures are in degree celcius			

Table 1: New Delhi weather data

III. METHOD OF CALCULATION

A. To calculate the heating demand of a building

at first the losses due to transmission and ventilation must be summed up [8]. After that, solar and internal gains must be reduced by the utilization factor (which is a function of other parameters) and then subtracted from this sum to obtain the demand for heat:

$$Q_H = V_T + V_L - \eta \cdot (G_S + G_I)$$

Where, QH: heat energy demand, VT: transmission losses, VL: ventilation losses, η: utilization factor, GS: solar gains, GI: internal Gains.

B. To calculate Solar gains

The solar gains entering the building through the windows per time interval are [8]:

$$G_S = \sum_{\text{all windows}} g_F \cdot (1 - r_F) \cdot A_F \cdot H_F$$

GS: solar gains, gF: g-value of glazing, rF: frame ratio of window, AF: surface area of window, HF: solar radiation on window surface

C.Internal gains

The expected internal gains resulting from devices and persons are determined from the heated floor area [8]:

$$G_I = A_{hfa} \cdot q_{int}$$

Where, g_I: internal gain, A_{hfa}: heated floor area
Q_{int}: specified internal mass

D.Transmission losses

$$\begin{aligned} V_T = & \sum_{\text{all walls}} U_W \cdot A_W \cdot (T_S - T_A) \cdot \Delta t \\ & + \sum_{\text{all windows}} U_F \cdot A_F \cdot (T_S - T_A) \cdot \Delta t \\ & + k_B \cdot U_B \cdot A_B \cdot (T_S - T_A) \cdot \Delta t \\ & + k_D \cdot U_D \cdot A_D \cdot (T_S - T_A) \cdot \Delta t \end{aligned}$$

V_t: transmission losses, U_w U_f:heat tranfer coefficient of wall and window U_b: heat transfer coefficent of ground floor , U_d: heat transfer coefficient of upper most ceiling

A_w A_f: surface area of wall and window A_b: surface area of ground floor A_d: surface area of uppermost ceiling T_s: indoor air temperature, T_a: ambient temperature K_b: correction of U-value (ground floor), Kd: correction of U-value (upper most ceiling), Δt: calculation period

E.Ventilation losses

Supplementary to transmission losses a building has losses due to ventilation - warm inside air is replaced by colder ambient air [8].

The ventilation losses are:

$$V_L = n \cdot V \cdot c_{air} \cdot \rho_{air} \cdot (T_S - T_A) \cdot \Delta t$$

V_l: ventilation loss, n air change rate(1/h), V: exchangeable volume of indoor air, T_s: indoor air temperature, T_a: ambient temperature, Δt: calculation period,

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$P_{air,}C_{air}$: volumetric thermal capacity of air (0.34Wh/m^3k)

F.Effective capacity of heat storage

$$C = c_{AW} \cdot A_{AW} + c_{IW} \cdot A_{IW}$$

A_{aw}: exterior wall area A_{iw}: interior wall area C_{aw} C_{iw}: specific thermal storage of exterior and interior wall.

Construction type	c_{AW} / c_{IW}
Lightweight:	25 kJ/ (m² K)
Medium:	65 kJ/ (m² K)
Heavy:	105 kJ/ (m² K)

The above-mentioned formulas have been used for the calculation of HVAC loads inside the building we have considered. This analysis has resulted in values of the HVAC loads on an annual basis [8].

IV. BUILDING ASPECTS

The building we have considered in New Delhi, India is of 2400sq.ft which is a south facing two story building. The heating system used here is an electric direct heating and the source of energy is electricity.

It has two windows on either side that is on the Eastern and the Western side. In this paper we have done an analysis for the fore mentioned building based on three criteria which are as follows –(i)double glazingping frame with aluminum frame (U=1 W/m^2K) (ii)single glazing with aluminum frame. (iii)In addition to the above-mentioned cases we have also performed an additional analysis where the building is not enveloped by cement nor brick but solely by glass.

Length of north and south facade:	14.5 m
Length of west and east facade:	15.4 m
Height (without roof):	5.5 m
Number of floors:	2
Deviation from south direction	28.0 °
Ground area:	223.3 m²
Useful area:	357.3 m²
Volume total:	1228.2 m³
Air volume:	982.5 m³

Table 1: Building Geometry

From the above table 2 the area, volume, deviation from south pole, and number of floors are specified.

U values of the walls:	
north:	0.20 W/(m² K)
south:	0.20 W/(m² K)
east:	0.20 W/(m² K)
west:	0.20 W/(m² K)
Absorption coefficient of the walls:	0.5
Upper floor:	
Towards:	totally insulated roof
U value:	0.20 W/(m² K)
Lower floor:	
Towards:	soil
U value:	0.20 W/(m² K)
Door (north facade):	
Area:	1.0 m²
U value:	0.50 W/(m² K)

Table 2: Insulation values

From the above table 3 the insulation value of all faces of the building and for two floors are given.

Interior temperature:	23.0 °C
Limit of overheating:	27.0 °C
Ventilation:	
Natural ventilation	0.60 1/h
mechanical ventilation	0.00 1/h
Heat recovery	0%
efficency factor of AC	2.5 kWh_{cool} / kWh_{electr}
Internal gains:	25.0 kWh/(m² a)

Table 3: Building operating conditions

From the above table 4 the building operating condition including the ambient set temperature and the overall efficiency factor of the AC systems used inside the building have been specified.

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ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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	SINGLE GLAZING WITH ALUMINUM			
PARAMETERS	NORTH	SOUTH	EAST	WEST
Windows area (m²)	0	0	8.5	8.5
Fraction of windows area at the facade	0.00%	0.00%	10.00%	10.00%
Kind of windows	others	others	others	others
U value glazing (W/(m² K))	5.8	5.8	5.8	5.8
U value frame (W/(m² K))	0.45	0.45	0.45	0.45
G value glazing	0.92	0.92	0.92	0.92
Fraction of frame	10.00%	10.00%	10.00%	10.00%
Shading	30.00%	30.00%	30.00%	30.00%

Table 4: single glazing with aluminum frame

	DOUBLE GLAZING WITH ALUMINUM			
PARAMETERS	NORTH	SOUTH	EAST	WEST
Windows area (m²)	0	0	8.5	8.5
Fraction of windows area at the facade	0.00%	0.00%	10.00%	10.00%
Kind of windows	others	others	others	others
U value glazing (W/(m² K))	1	1	1	1
U value frame (W/(m² K))	0.45	0.45	0.45	0.45
g value glazing	0.52	0.52	0.52	0.52
Fraction of frame	10.00%	10.00%	10.00%	10.00%
Shading	30.00%	30.00%	30.00%	30.00%

Table 5: Double glazing with aluminum frame

As mentioned above the other analysis that we have done in our paper is the analysis of our building when the entire structure is made of a glass façade with an aluminum support structure. The main reason why we have chosen aluminum is because of it very less cost and light weightiness and its ability to resist cracking but at the same time they have a very long-life cycle. Although they have such advantages the also have some disadvantages like, acting like radiators thus bringing both unwanted heat and coldness in to the room, so they must be protected with thermal bricks.
Even though they have a quite a lot of disadvantages, they are recyclable thus making them a very tough competitor to fiber glass and vinyl. And that is why we have chosen aluminum in our analysis and that is why it being is used in most of the constructions off late.

	STRUCTURE MADE OF GLASS FAÇADE			
PARAMETERS	NORTH	SOUTH	EAST	WEST
Windows area (m²)	79.8	79.8	84.7	84.7
Fraction of windows area at the facade	100.00%	100.00%	100.00%	100.00%
Kind of windows	others	others	others	others
U value glazing (W/(m² K))	1	1	1	1
U value frame (W/(m² K))	0.12	0.12	0.12	0.12
g value glazing	0.52	0.52	0.52	0.52
Fraction of frame	20.00%	20.00%	20.00%	20.00%
Shading	30.00%	30.00%	30.00%	30.00%

Table 6: Structure made of glass facade

From the above table the we have the various parameters that we have considered it the construction of our building.

RESULT

	BUILDING DATA		
PARAMETERS	SINGLE GLAZING WITH ALUMINUM FRAME	DOUBLE GLAZING WITH ALUMINUM FRAME	STRUCTURE MADE OF GLASS FAÇADE WITH ALUMINUM FRAME
Mean U value:	0.41 W/(m² K)	0.31 W/(m² K)	0.52 W/(m² K)
Specific transmission losses:	317.0 W/K	243.8 W/K	405.2 W/K
Specific ventilation losses:	211.2 W/K	211.2 W/K	211.2 W/K
Sum specific losses:	528.2 W/K	455.0 W/K	616.4 W/K
Thermal inertia:	69.9 hours	81.2 hours	50.8 hours
Maximum heating load:	9.2 kW	7.9 kW	10.2 kW
Maximum specific heating load:	25.9 W/m²	22.0 W/m²	28.6 W/m²
Maximum cooling load:	9.7 kW	7.3 kW	54.7 kW
Maximum specific cooling load:	27.3 W/m²	20.5 W/m²	153.1 W/m²
Limit temperature for heating:	20.7°C	20.3°C	21.1°C
Effective heating days:	116 days	111 days	120 days

Table 7: Building parameters

From the above table and comparing single and double glazing we can infer that the sum specific losses, maximum heating load, maximum specific heating load, maximum specific cooling load in higher in single glazing compared to double glazing window type. There is decrease in effective heating days in double glazing. window type.

Once the simulation was completed, we arrived upon the following results which have been depicted in the following tables.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

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The below table shows us in brief the heating demand and the cooling demand for each of the individual analysis. In below table there is a column named as zero energy hours; zero energy hours are defined as those hours where we require neither cooling load nor heating load. In short there is no requirement of the HVAC system to be in working condition

MONTH	WINDOW TYPE														
	SINGLE GLAZING WITH ALUMINUM FRAME					DOUBLE GLAZING WITH ALUMINUM FRAME					STRUCTURE MADE OF DOUBLE GLAZING GLASS				
	HEATING		COOLING		ZERO ENERGY HOURS	HEATING		COOLING		ZERO ENERGY HOURS	HEATING		COOLING		ZERO ENERGY HOURS
	DEMAND (kWh/m²)	HOUR	DEMAND (kWh/m²)	HOURS		DEMAND (kWh/m²)	HOUR	DEMAND (kWh/m²)	HOURS		DEMAND (kWh/m²)	HOUR	DEMAND (kWh/m²)	HOURS	
JAN	3.8	744	0	0	0	3.4	744	0	0	0	0.1	15	4.4	511	218
FEB	1.1	672	0	0	0	1.1	672	0	0	0	0	0	7.5	663	9
MAR	0	349	0.1	27	368	0	418	0	0	326	0	0	14.8	744	0
APR	0	0	2.6	620	100	0	0	1.3	523	197	0	0	21.8	720	0
MAY	0	0	6.3	744	0	0	0	4.3	744	0	0	0	27.2	744	0
JUN	0	0	5.7	720	0	0	0	3.8	720	0	0	0	24.4	720	0
JUL	0	0	3.4	744	0	0	0	2.1	744	0	0	0	19.5	744	0
AUG	0	0	2.9	744	0	0	0	1.6	621	123	0	0	18.9	744	0
SEP	0	0	2.5	720	0	0	0	1.2	703	17	0	0	19.9	720	0
OCT	0	0	0.7	406	338	0	1	0.2	162	581	0	0	17.4	744	0
NOV	0	587	0	0	133	0	669	0	0	51	0	0	10.6	720	0
DEC	2.6	744	0	0	0	2.4	744	0	0	0	0.1	4	5.9	652	88
TOTAL	**7.5**	**3096**	**24.2**	**4725**	**939**	**6.9**	**3248**	**14.5**	**4217**	**1295**	**0.2**	**19**	**192.3**	**8426**	**315**

From the above table we can infer that the cooling demand decrease drastically by 40% when the glazing is change from single to double. There is also increase in zero energy hours by 27% and 8% decrease in heating demand. We can also see that the full glass façade structure made of double glazing has significant decrease in heating load but there is huge increase in cooling demand with reference to double glazing with aluminum frame.

It can also be seen from the table that the double glazing with aluminum windows are the most effective of all in terms of our considerations. This statement can be claimed valid under the zero energy hours data as shown in the above table.

MONTH	WINDOW TYPE														
	SINGLE GLAZING WITH ALUMINUM FRAME					DOUBLE GLAZING WITH ALUMINUM FRAME					STRUCTURE MADE OF DOUBLE GLAZING GLASS				
	TRANSMISSION LOSS	VENTILATION LOSS	INTERNAL GAIN	SOLAR GAINS	HEAT ENEGY DEMAND	TRANSMISSION LOSS	VENTILATION LOSS	INTERNAL GAIN	SOLAR GAINS	HEAT ENEGY DEMAND	TRANSMISSION LOSS	VENTILATION LOSS	INTERNAL GAIN	SOLAR GAINS	HEAT ENEGY DEMAND
JAN	4.2	3.8	2.1	2.1	3.8	2.9	3.8	2.1	1.2	3.4	5.8	3.8	0.9	8.6	0.1
FEB	2.5	2.3	1.7	2	1.1	1.7	2.3	1.8	1.2	1.1	3.5	2.3	0.5	5.3	0
MAR	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0	0.1	0.1	0	0.2	0
APR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOV	1.2	1.1	1.1	1.2	0	0.9	1.1	1.2	0.7	0	1.7	1.1	0.2	2.6	0
DEC	3.5	3.2	2.1	2.1	2.6	2.4	3.2	2.1	1.2	2.4	4.9	3.2	0.7	7.3	0.1
TOTAL	**11.5**	**10.5**	**7.1**	**7.5**	**7.5**	**8**	**10.5**	**7.3**	**4.4**	**6.9**	**16**	**10.5**	**2.3**	**24**	**0.2**
	ALL THE VALUES ARE IN KWh/ m²														

From the above table on comparing the single and double-glazing window types, we can infer that there is increase in transmission loss, heat energy demand and solar gain in single glazing by 30%, 8% and 41.3%. and in full glass façade structure there is significant increase in solar gain by 81% in comparison with double glazing with aluminum.

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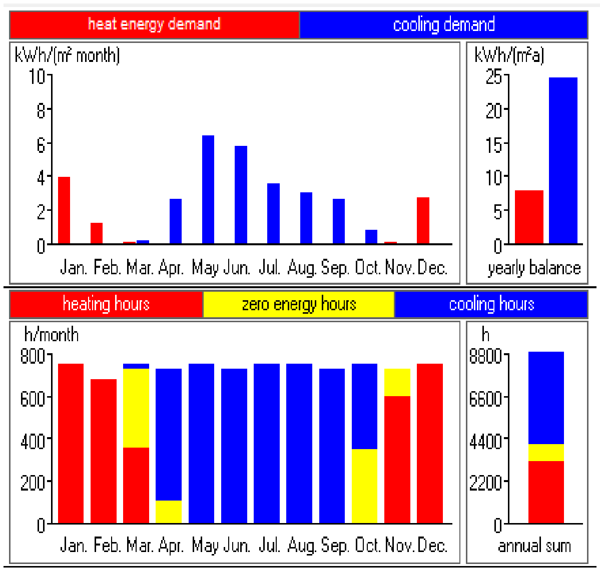
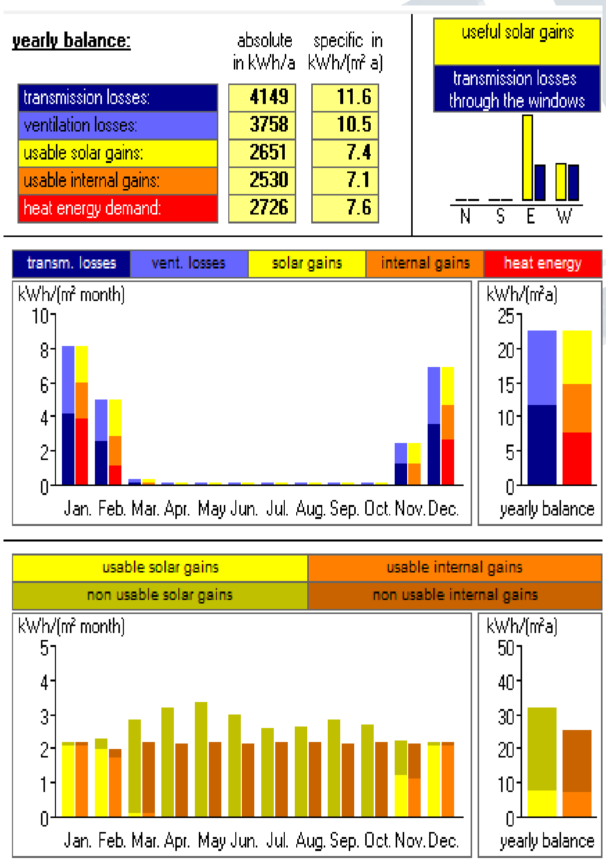
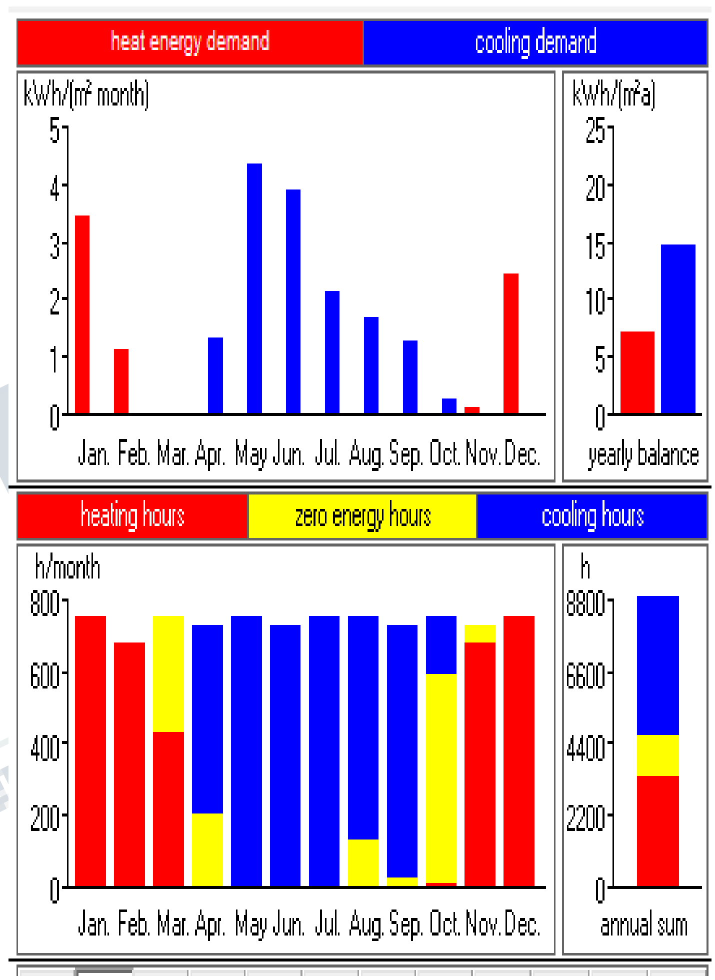


From the above figures which gives the consolidated graph of the cooling and heating demand with respect to the climate that will be prevalent over a whole year in New Delhi, India.



From the above graph it is very clear that the single glazing windows is used will result in the rise of the cooling load especially in the months of May, June and July, that is, during peak summer. In the second figure, we can see that the useful solar gain and the transmission losses which will be there when the single glazing window is used in our building.



As mentioned above, that the double-glazing windows with aluminum frame are the most advantageous of the lot we have considered, the above graph will give us a better understanding to that statement. It is evident from the graph that both the heating load and the cooling load have reduced by a factor of 2, which is a considerable amount considering the peak summers weather conditions in New Delhi.

From the below figure the specific transmission losses are reduced by close to 3 KWh/m2 when the double-glazing windows are used in the place of single glazing windows. It also evident that the specific heat energy demand of the entire building is being reduced by close to 10%.

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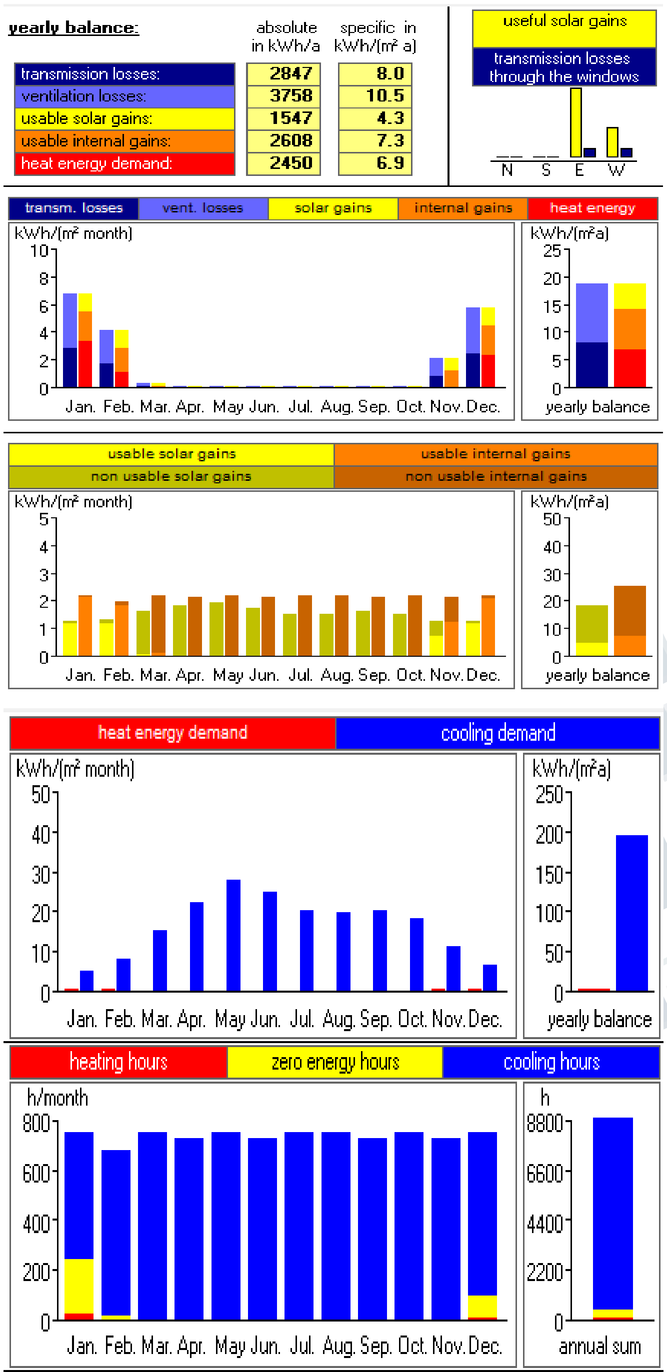
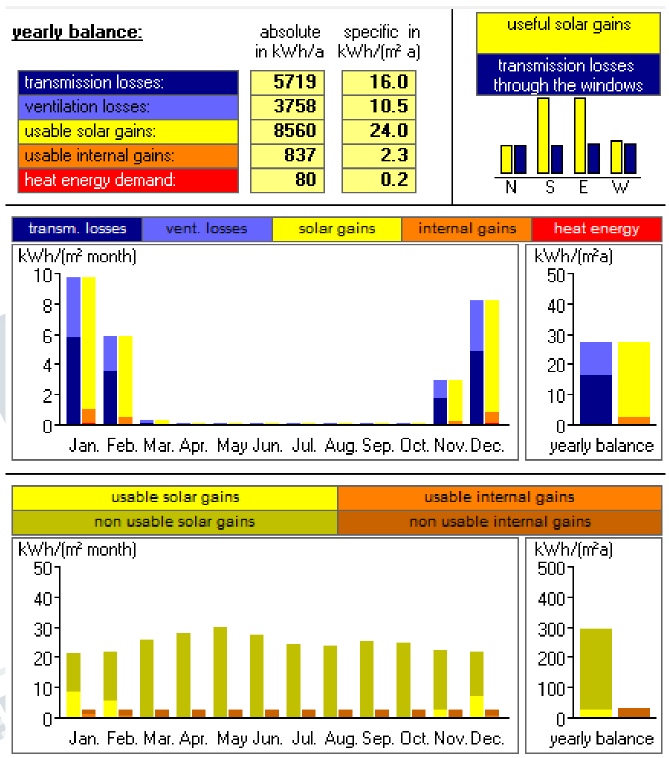


The fact that most of the buildings that are being constructed now are being constructed in this manner is the main reason why 40% of the worlds energy is being consumed by buildings and in specific by the HVAC system of the building. And that is why the cooling demand is very high throughout the year and that is what is evident from the above graph.

As New Delhi is in warm and humid climate, heating load is less, as the building is full glass façade the heating load in winter months is less as the usable solar gain is more, but the transmission losses is seen in all four faces of the building, and usable solar gain is higher in south and east sides of the building. But can only be used in winter months.



CONCLUSION

From the above tables and graphs, it is evident that the double-glazing window with an aluminum frame has more advantage than the other two type of windows we have considered and analyzed them based on the above-mentioned criteria. By using this type of window, the impact on the HVAC will reduce drastically thus helping us conserve the energy with is being wasted.

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