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Evaluation of Energy-Efficient Office Building through Glass Thermal Properties, Shading Devices and Window-wall Ratio

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Abstract - Sustainable development is a more concerning topic due to rapid urbanization, population growth, and comfort in building services. As India is a developing country it consumes almost 30% of energy in lighting, cooling, and heating form, in the commercial building sector. By implementation or adopting energy-efficient codes could provide lead to a sustainable future. In India, BEE has introduced ECBC (Energy Conservation Building Code) 2017 to optimize energy use by using passive strategies and providing comfort levels to occupants in a commercial building. This paper will present the energy performance of the building, for developing process data needed for modeling a new commercial office building was collected from past research related to energy-efficient building. By adopting ECBC prescriptive compliance approaches the reference office building was model through simulation software Design Builder along with the Energy Pulse engine. Using energy-efficient code as a guideline further evaluation of the same building is done by changing 3 building parameters via window glass with increase WWR and shading devices. After simulating the model the results were analyzed for annual total energy consumption and all summer energy consumption. Making use of ECBC's prescriptive compliance approach and simulation software will help in easy implementation and imposing. The use of such codes will lead to a reduction in future barriers and using software will lead to a reduction of manual calculation barriers. After that lastly, the Discount payback period analysis was done for 10% and 6% rates.

Keywords - ECBC 2017, Glazing, Shading devices, WWR, DesignBuilder.

INTRODUCTION

India consumes almost 30% of energy in the commercial building sector [5, 12]. The primary energy consumes in form of heating, cooling, ventilation, lighting, and equipment’s and the secondary energy is consumed by domestic hot water and other loads [15]. A previous study observed that windows help save energy consumption by using glass as a major material and using glass with its thermal properties as lower U-value and high solar heat gain coefficient for passive solar heating applications [10]. The building window design is the major part that affects the received natural light across the building, so for this reason the window must be designed in such a manner that it allows most of the natural sunlight to enter with the required amount into the building and it should balance the light need and heat gain inside the building. So this will help to achieve balance in heat gain and natural daylighting [14]. Among the building envelope glass is the main element that influences the thermal performance of the building, therefore it is essential to study the thermal behavior of the glass for balancing the day lighting and heat gain inside [5]. However, the glazing technologies can help provide sufficient daylight to the building and save energy Moreover, it also enhances the architectural appearance of the building [9]. Using a glass of different types such as single, double, and triple and also affect the energy performance of the building. Shading devices can also contribute to the energy performance of the building, using shades for the facades with large portions glazed. As the provision of glaze is to provide natural lighting and aesthetic appearance to the building but providing glass at large portion can cause heat gain inside the building which would lead to occupant/employee discomfort to overcome this property of glass the application of shades would help provide better energy performance of the building. There are different shading elements such as fixed and movable shading devices that are used to improve the energy performance of the building [6]. The shading design impact and its control on building energy performance are not taken into account at the design stage, eventually, the cooling and lighting energy balance between

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fenestration design and lighting are to be identified [16]. BEE (Bureau of Energy Efficiency), a government body of India with United States AID, has done a study based on the actual performance of the building for conditioned and non-conditioned buildings for all commercial building sectors. The ECBC (Energy Conservation Building Code) was developed for the same aspect by BEE; on 27th May 2007, ECBC was launched for the first time to design or to construct new commercial buildings with minimum efficiency standards. The ECBC in June 2017 was updated which introduced additional new requirements, lighting, HVAC, electrical, building envelopes, and renewable systems [12, 15]. In this paper evaluation of the model would be done with ECBC guidelines by using Design Builder version 7.0.0.093 along with Energy Pluse Engine 9.4 and then changing three parameters such as different types of glass, WWR, and shading devices for the same ECBC model to make energy performance better and the results were analyzed for annual total energy consumption in kWh/m^2, and all summer energy consumption in kWh/m^2. Then lastly a simple discount payback period analysis was performed for 10% and 6% for providing guidelines for selecting the project [11].

Methodology

In this evaluation, the office building is simulated for energy usage which is in form of heating, cooling, and lighting energy loads, by using the simulation tool- Design Builder. The use of the software will help in easy analysis of the model at the initial design stage and with an excuse for any manual calculation. The reference building is a model by using ECBC as a guideline [12]. The glass mandatory value is inputted, then by replacing three glass types- single, double and triple glass are consider with it four different shades are coupled with a 60% increase in WWR [19].

2.1 Design of reference building is developed which complaints to ECBC 2017:

The building is a commercial office building with a rectangular shape [17] with a two-story office building and the design of the building complaints to ECBC 2017. By assumption of the building are done from the previous study, such as 2-story building, the shape of the building is kept rectangular, lighting controls are on and are LED lighting, cooling appliances are to be 5-star rating, remaining data is prescriptive values from the code.

TABLE I
(Base building details summary)

	Activity template		
Occupancy Schedule	Working Profile (days in a week)	Metabolic Factor	
8:00 – 16:00	6	0.90	
	Construction template		
External wall (u-value)	Roof (u-value)	Floor (u-value)	Infiltration in air change
0.4	0.33	2.16	0.5ac/h
	Opening template (ECBC)		
Glazing (u-value)	SHGC	VLT	WWR
3.3	0.27	0.561	40%
	Lighting template		
Lighting	Lighting Controls	LPD	
LED	On	9.5 w/m^2	
	HVAC		
Mechanical vent	Heating	Cooling	DHW
On	On	On	Off

2.2 Design of proposed building is developed by altering glass type, shades and 60% WWR. For making the office building energy-efficient, alternate glass types were selected concerning its thermal properties, shading devices and 60% WWR selected from past research studies and were used for evaluation and they were considered for the same ECBC model. Further evaluation was carried concerning alternate 3 building parameters.

TABLE II
(Glazing types)

Sr. No.	Types of glass
1	Sgl. LoE (e2=.2) Clr. 6mm
3	Dbl. LoE SPEC. SEL. Tint 6/13 Argon
5	Dbl. LoE Spec. Selc. Clr. 3/13/6 Arg.
6	Dbl. Sage glass Climaplus Green No Tint
7	Dbl. SGG XT 60-28 6/16/4
9	Trp. LoE Film (66) Br. 6/13 Air
10	Trp. Sage Glass Climatop Green No Tint

TABLE III
(Shading devices)

Sr. No.	Types of shading devices	Dimensions
1	Overhang, Side fins	1.5 m
2	Overhang, Side fins, Louvre	0.5 m
3	Louver	1 m
4	Side fins	0.5 m

Result and Discussion

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3.1 Calculation of annual and all summer energy consumption for reference model

Simulating the office building in the Design Builder software the following results were obtained, the model was simulated for annual total energy consumption in kWh/m^{2}and all summer energy consumption in kWh/m^2. From tab. 4 it is observed the building consumes 72.7 kWh/m^2 of energy annually and 47.4 kWh/m^2 of energy all summer. This value would be used as a benchmark for the project and alternate glass; shades would be used to make the energy performance of the building best.

TABLE IV
(Results ECBC Model)

Results ECBC Model	
Annual total energy Consumption kWh/m^2	All Summer energy Consumption kWh/m^2
72.7	47.4

3.2 Calculation of annual and all summer energy consumption for propose model

3.2.1 Results for Annual total energy consumption of office building:

As the simulation of the reference model is carried on, the same building would be used for further evaluation with different glass types, shading elements, and WWR. So after simulating the building with alternate parameters following results are obtained. From tab. 5 it is observed that evaluation of building is done for single, double, and triple glass type with four different shading devices.

The single glass shows a poor performance than that of double and triple glass types. Double layer saint global glass along with overhang + side fins show more efficient performance than ECBC mode. As for annually, the office building consumes 63.23 kWh/m2 of energy, and all the triple glass shows the best energy performance of 61.86 kWh/m2 annually. And so on it is observed that overhang+ sidefines 1.5 are more energy-efficient shading devices that save more energy than that of outer shades. Fig 1 helps in understanding the energy performance of the building through various parameters consider for the building.

TABLE V
(Annual total energy consumption kWh/m^2 of proposed building)

Description		Overhang +Sidefins 1.5	Overhang, Sidefins, Louvre 0.5	Louver 1	Side fins 0.5	No Shade
Case 0	ECBC Glaze	-	-	-	-	72.7
Case 1	Sgl LoE (e2=.2) Clr 6mm	91.52	97.29	181.0	132.97	-
Case 2	Dbl LoE Spec Sel Tint 6/13mm Argon	**67.95**	70.64	80.93	84.89	-
Case 3	Dbl LoE Spec Sel Clr 6/13mm Arg	72.49	76.15	77.41	97.64	-
Case 4	Dbl. LoE Spec. Slec. Clr 3/13/6mm Argon	72.82	76.33	77.46	98.35	-
Case 5	Dbl. Sage glass Climaplus Green No Tint	**64.37**	**66.78**	75.6	80.39	-
Case 6	Dbl. SGG XT 60-28 6/16/4	**63.23**	**65.57**	70.21	79.44	-
Case 7	Trp. LoE Film (66) Br. 6/13 Air	**69.69**	**72.41**	85.06	84.97	
Case 8	Trp. Sage Glass Climatop Green No Tint	**61.86**	**63.98**	74.98	74.72	

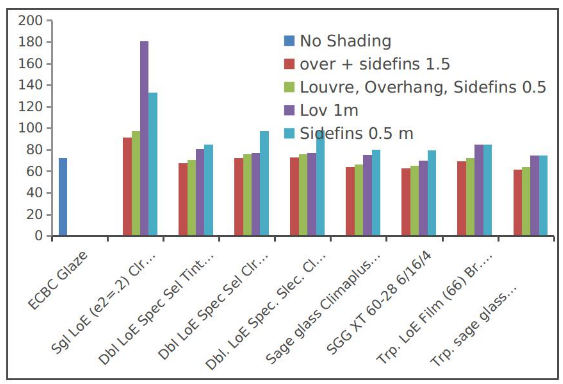

Fig. 1 Graphical presentation of annual consumption in kWh/m^2

3.2.2 Results for All summer total energy consumption of office building:

As the simulation of reference model is carried on, the same building would be used for further evaluation with different glass types, shading elements, and WWR. So after simulating the building with alternate parameters following results are obtained. From tab. 6 it is observed that evaluation of building is done for single, double, and triple glass type with four different shading devices.

The single glass shows a poor performance than that of double and triple glass types. Double layer saint global glass along with overhang + sidefins show more energy-efficient performance than the ECBC model. As

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for all summer, the office building consumes 42.12 kWh/m^2 of energy and from all the triple glass show best energy performance of 40.82 kWh/m^2 for all summer. And so on it is observed that overhang+ sidefines 1.5 are more energy-efficient shading devices that save more energy than that of outer shades. Fig 2 helps in understanding the energy performance of the building through various parameters consider for the building.

TABLE VI
(All summer total energy consumption kWh/m^2 of proposed building)

	Description	Over hang +Side fins 1.5	Over hang, +Side fins, Louvre 0.5	Louver 1	Side fins 0.5	No Shade
Case 0	ECBC Glaze	-	-	-	-	47.35
Case 1	Sgl LoE (e2=.2) Clr 6mm	60.56	62.9	61.16	78.59	-
Case 2	Dbl LoE Spec Sel Tint 6/13mm Argon	**44.98**	**46.42**	52.85	53.32	-
Case 3	Dbl LoE Spec Sel Clr. 6/13mm Argon	48.26	49.94	51.02	60.11	-
Case 4	Dbl. LoE Spec. Slec. Clr 3/13/6mm Argon	48.49	50.13	51.33	60.26	-
Case 5	Dbl. Sage glass Climaplus Green No Tint	**42.62**	**43.87**	51.71	50.56	-
Case 6	Dbl. SGG XT 60-s28 6/16/4	**42.12**	**43.27**	**46.75**	50.32	-
Case 7	Trp. LoE Film (66) Br. 6/13 Air	**46.03**	47.56	54.96	53.4	-
Case 8	Trp. Sage Glass Climatop Green No Tint	**40.82**	**42.01**	49.02	47.44	-

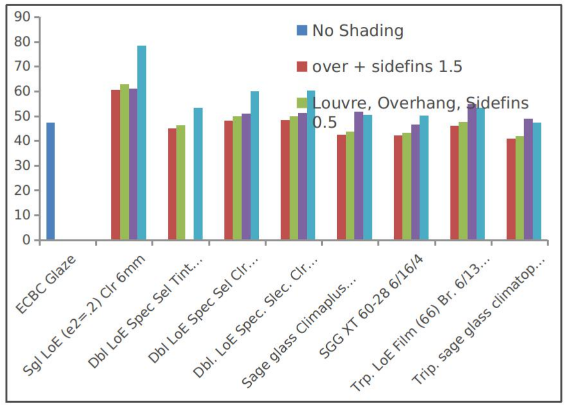

Fig. 2 Graphical presentation of all summer consumption in kWh/m^2

3.2.3 Variations in energy save for annually and all summer:

Evaluating the model for 3 types of glass, 4 types of shading devices, and increased window-wall ratio gave the result with annual energy consumption and all summer energy consumption in kWh/m^2. From tabl.7 the energy save for both annual and all summer energy consumption is calculated with respect to ECBC model, the percent saves in energy is calculated and the following results are accounted single glass consumes more energy in form of heating, cooling, and lighting which is -25.89% annually and -27.89% all summer. Double glass consumes moderate energy which is 13.03% annually and 9.99% all summer. And triple glass saves almost 14.91% of energy annually and 13.79% of energy all summer; this shows the triple glass with overhang & sidefins is more energy-efficient than other two glass types.

TABLE VII
(Energy save for annually and all summer)

Type of glass	Annual energy consume kWh/m^2	All summer energy consume kWh/m^2	Energy save in percent (Annually)	Energy save in percent (All Summer)
ECBC Glaze	72.7	47.35	0%	0%
Single Glass	91.52	60.56	-25.89%	-27.89%
Double Glass	63.23	42.62	13.03%	9.99%
Triple Glass	61.86	40.82	14.91%	13.79%

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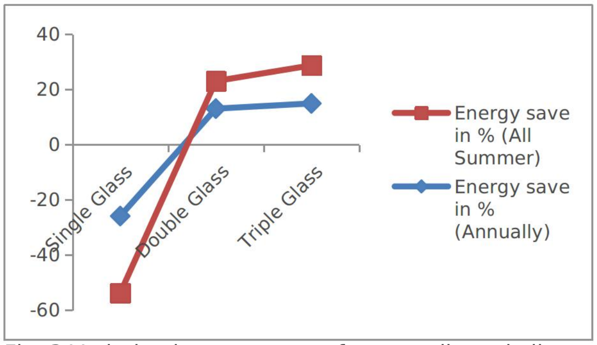

Fig. 3 Variation in energy save for annually and all summer

Discount Payback Period Analysis

The cost of the project was estimated from the Design Builder software which shows 254877587.3/- INR for ECBC, 259451577.2/- INR for Double glass saint globin glass, and 333280262.1/- INR for triple-layer sage glass. The payback period is the period required for the initial investment of a model to be recovered by the accumulated savings. It's a simple method to calculate the period of time the project will recover the cost. A simple calculation was done for the office building with triple-layer glass and shading elements.

The discount payback period was calculated for triple glass as this glass shows more energy-efficient performance of the building. The discount rates were assumed to be 10% and 6% [11]. It was taking 4.86 years for a 10% discount rate and 4.32% for a 6% discount rate. This simple calculation will help to select the project at its initial stage.

CONCLUSIONS

In the present paper, the ECBC model is as reference model 3 parameters are changed to evaluate the energy performance of the building, single, double and triple types of glass with different thermal properties and different gap gas, 4 types of shading elements are used which are of fixed type and increased window-wall ratio of 60% is used.

From the results conclusion are made:

- Case 0- ECBC model is provided as a benchmark for minimizing energy standard and it consumes 72.7 kWh/m^2 of energy for annual total energy and 47.35 kWh/m^2 of energy for all summer consumption by an office building.
- Case 1- Single glass shows poor energy performance even after coupling with shading elements as its least energy consumption is 91.52 kWh/m^2 for annual total and 60.56 kWh/m^2 for all summer.
- Case 2, 3, 4, 5, and 6- Shows the performance of double glass type with all 4 different shading elements out of which Saint Globin Glass shows good energy performance with overhang & sidefins 1.5 shading element i.e. 63.23 kWh/m^2 for annual total energy consumption and 42.12 kWh/m^2 for all summer energy consumption.
- Case 7 and 8- Triple glass-sage shows best energy performance than the rest of the glass with overhang & sidefins shading element and 60% WWR.
- Triple glass when coupled with overhang & sidefins, and 60% WWR, it performs better than other glass as it saves 14.91% of energy annually. The single clear glass performs the worst with -25.89% of energy annually; negative sign represents the overuse of energy concerning the ECBC model. The double glass shows moderate performs as compare to all of 13.03% save in energy annually.
- By performing simple calculation as discount payback period analysis, this helps as a guideline for selecting the project at the initial stage it is not accurate, more variations can be performed but this is a simple calculation for roughly analyzing the project budget. So the calculation for 10% discount rate 4.86 years is observed & 6% discount rate 4.32 years is observed.

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