Assessing Thermal Efficiency of a Building using RETV Analysis

Hari Srinivas S
Department of Civil Engineering
PES University
Bengaluru, India

Namratha Kuchangi
Department of Civil Engineering
PES University
Bengaluru, India

***Abstract* —*India* is a developing country with a huge population which means our need is only going to be increasing. The residential floor area is going to be doubled and the energy consumption tripled.**
Around 34% of the energy in the housing sector is consumed just for heating, cooling and ventilation of the building. The increase in global warming is causing a drastic change in the environment and the atmospheric temperature. This is causing an increase in the demand of AC and heaters. This brings the question of what should be done. One way out is to increase the thermal efficiency of the building envelope. When the thermal efficiency is increased the temperature outside will not affect the inside temperature to a large extent. It also improves the lighting and ventilation of the building.

India never had a code for the building envelope until in 2018 Eco niwas samitha 2018 was launched to maximize the RETV value for a building. So, this project would also like to increase its awareness in the society and also develop different methods to include it in during the planning and construction of a building.

Keywords—RETV; thermal efficiency;

I. INTRODUCTION

The residential building floor area maybe be increased from 16 million $m^2$to 31.6 million m^2 due to which under Pradhan Mantri Awas Yojana 20 million new homes are planned to be built. Thus, increasing the residential energy consumption, it is estimated to be increased from 246TWh/y to 748 TWh/y by 2030. Approximately 34% of the energy is used for the cooling or warming the building, thus anticipating the rise of AC usage from 8% to around 21% and 40% in 2027 -28 and 2037-38 respectively. Therefore, improving thermal comfort in buildings is very important, which helps in minimizing the cooling energy needs in residential buildings.

The new Energy Conservation Building Code for Residential Buildings (ECBC-R) in the Eco-Niwas Samhita 2018 (BEE, 2018) provides the following provisions

1. To minimize the heat gain in cold climate or heat loss in hot climate,
2. For natural ventilation potential
3. For daylight potential

Building envelope is the barrier which protects the interior of the building from the outside environment. This mostly deals with the design and construction of the exterior surface. The external envelope design and the material used in the construction should include the climatic conditions, should, structurally sound and aesthetic. These elements are the major factors in constructing the building envelope. The building envelope comprises roof, sub floor, exterior doors, windows and of course the exterior walls.

The net heat gain rate through the building envelope of the building (apart from the roof) divided by the area of the building envelope of the building is called Residential envelope transmittance value (RETV). Its unit is W/m. The RETV includes the area of opaque, area of non-opaque, the SHGC value of non-opaque, the U value of the material the orientation of the building and the location of the building.

By doing this we are including the conduction of heat through the opaque and non-opaque surface, convection of heat through openings and heat radiation through the non-opaque surface.

II. OBJECTIVES

- To identify and select a building on which the analysis shall be carried out
- To understand the thermal efficiency of the building using RETV analysis
- To compare the value with the standard RETV values mentioned in the code
- To suggest suitable modifications to achieve the optimal thermal efficiency value

III. PRESENT INVESTIGATION

The selected building for the case study is ‘HABITAT ILLUMINAR ‘for the case study. It is situated in Bangalore, which has a temperate climate. The total area of the project is 4.5 acres. The built-up area is 6 lakhs 50 thousand sq ft. There are 10 blocks. The 10^{th} block is selected for the analysis. The tower has B+G+11floors. The built-up area of the block is 45000 sq ft. It has one set of 2-bedroom house and one set of 3-bedroom house on each floor.

TABLE I. U-value table for different materials.

Material	U-value (W/m2)
Wall (solid concrete block + 15mm plaster on both sides)	1.94
Double glazed aluminium framed windows (5mm thick glass)	5.3
Paints	3.14
Roof	1.8

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For the current investigation, Energy Conservation Building Code-Residential (ECBC-R) Compliance check tool

A. ECBC Tool

The Energy Conservation Building Code-Residential (ECBC-R) Compliance check tool is used for the analysis of the selected structure. It provides the project proponent complete virtual assistance in the form of an easy to use and interactive user interface for evaluating code compliance of the proposed residential building design. It takes the construction details of various building envelope elements such walls, roofs, windows, ventilators & doors as input in dedicated forms and based on the user inputs the code compliance is evaluated. This gives us the RETV value, the U roof value, VLT % and the window to floor area ratio.

We have provided the necessary inputs about the building.

TABLE II. Final results for the current building.

S/No.	REQUIREMENT	CALCULATED	CRITERIA	STATUS
Block-1				
1	WFRop	0.87	12.5	Non-Compliant
2	VLT %	61.67	27.0	Compliant
3	Uroof	2.75	1.2	Non-Compliant
4	RETV	14.41	15	Compliant

1) Window to floor area ratio (WFRop): It is the ratio of openable area to the carpet area of the dwelling units. From the Energy conservation building code manual for composite climatic zone minimum percentage of window to floor area ratio is 12.5% and the calculated value of the project is 8.12% which is non-compliant.
2) Visual light transmittance (VLT): The amount of light in the visible portion of the spectrum that passes through a glazed material. Higher the VLT, more is the daylight received inside the building through glass. From the ECBC manual, the minimum value of VLT is 27% and the calculated value of the project's VLT is 62.17% which is compliant.
3) Thermal transmittance (U-value): It is the rate of heat transmittance through materials. The lower the U-value, the lower is the heat gain/loss in the building. From the ECBC manual maximum U-value is 1.2 and the calculated value of the project's U-value is 2.75 which is non-compliant.
4) Residential envelope transmittance value (RETV): From the ECBC manual the RETV of the building envelope cannot be higher than RETV of 15 W/m2 and the calculated value of the project's RETV value is 13.27 W/m2 which is compliant.

IV. RESULTS COMPARISON WITH DIFFERENT MATERIALS

After a study on the different materials that can be used in the building envelope construction and the RETV analysis was carried out using the different construction material for the same building. The below are the data that is received after the calculation of the values using ECBC tool. This helps in understanding the effect the material has on the thermal efficiency of the building. The analysis helps in choosing the best material for the construction.

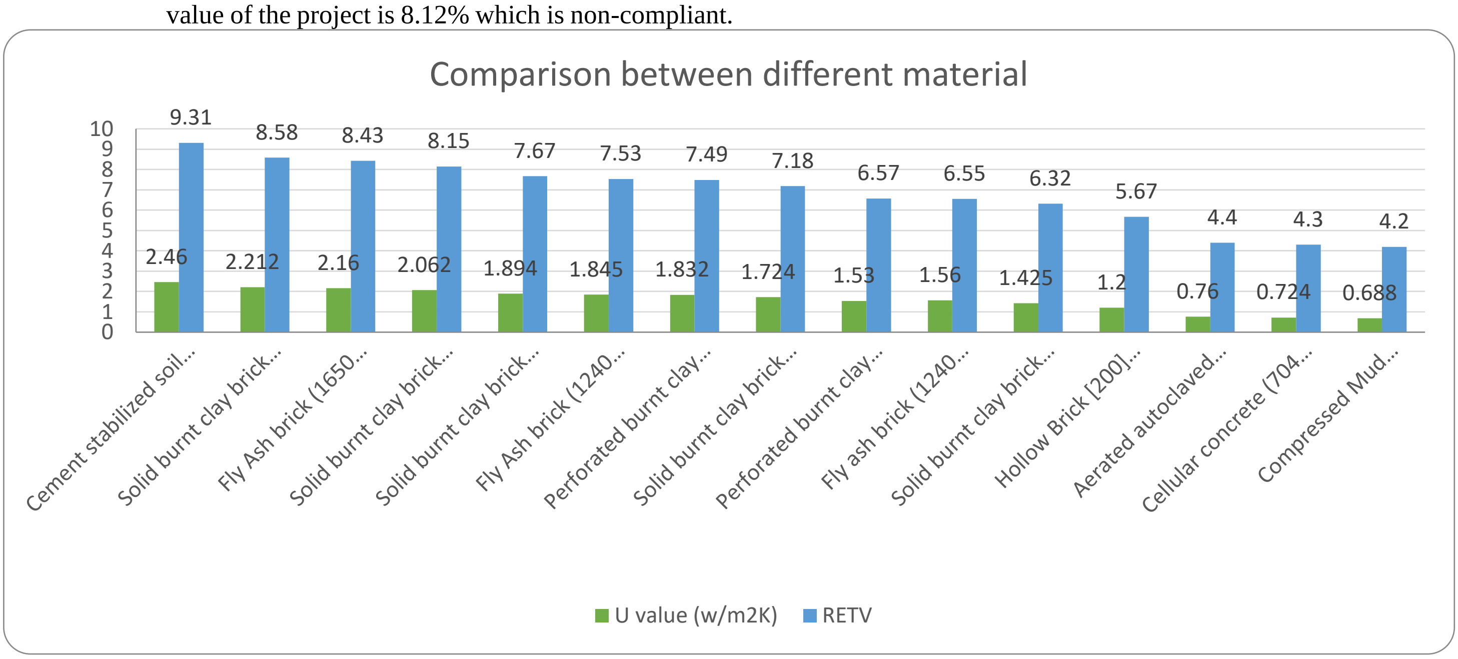

Fig. 1. Comparison between different materials.

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V. METHOD OF ANALYSIS

The present study deals with two types of analytical software

A. CARBSE tool
B. Equest software

A. CARBSE tool

Centre for advanced research in building science and energy developed a free online tool for thermal transmittance or thermal conductance (U-value) for the wall and the roof. The tool can be used for selection of building material, for building energy modeling and analysis. This tool is supported by ministry of new and renewable energy, government of India. By entering the location, assembly type, material of the wall and thickness of the wall, this tool provides U-value of the assembly by using static and dynamic methods and thermal properties of individual layers.

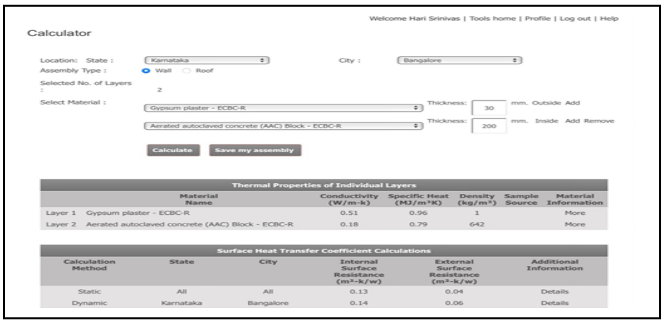

Fig. 2. U-value calculator for different materials.

B. Equest software

Equest is a USA based software which is used to analyze the building energy which gives professional level results. It also allows the user to get the detailed analysis of building design technologies using building energy simulation techniques. This also helps in easy 3D modelling of the building.

The below is the 3D model output from the Equest software. The 3D model clearly shows the shape and the different zones of each floor. The model has been created by using two different types of shell i.e for the ground floor and for the remaining floors. Because of the use of floor multiplier the floors from 3rd floor to 10th floor is not visible but the software takes these floors also into consideration. By using floor multipliers space in the memory can be saved and also reduces computation time.

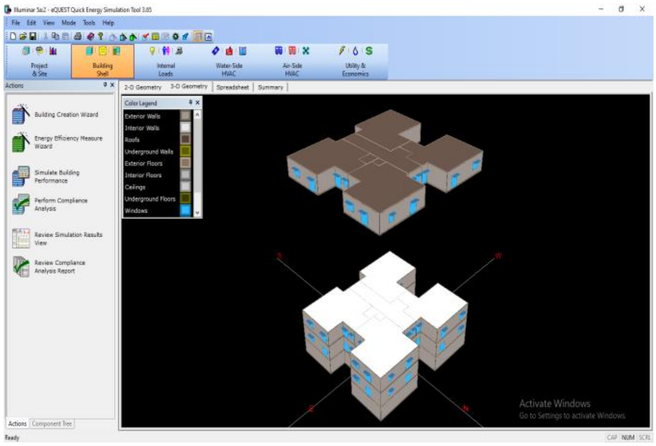

Fig. 3. The final model.

The total energy consumed by the entire unit is 365130 KWH. This is calculated based on US standards. From the below table and the graph, the maximum electricity is consumed by the space cooling, ventilator fans. The electricity consumption value is high during the summer and the value is less in the winter this is because of the outside temperature.

TABLE III. Table which shows annual electricity consumption of the whole building.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	5.39	10.32	17.39	20.71	20.54	11.78	10.93	9.20	9.90	9.01	5.97	4.36	135.48
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.05	0.02	0.00	-	-	-	0.00	-	0.00	0.00	0.03	0.04	0.14
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	6.17	5.75	6.47	6.20	6.03	5.70	5.62	5.47	5.27	5.51	5.55	5.99	69.72
Vent. Fans	5.57	4.27	5.11	5.98	5.86	3.52	3.45	2.99	3.18	3.20	3.99	5.47	52.58
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	2.55	2.30	2.54	2.46	2.55	2.46	2.55	2.55	2.46	2.55	2.47	2.55	29.99
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	6.65	5.93	6.48	6.29	6.60	6.29	6.57	6.52	6.33	6.61	6.37	6.57	77.21
Total	26.38	28.59	37.99	41.64	41.57	29.75	29.12	26.72	27.14	26.88	24.37	24.98	365.13

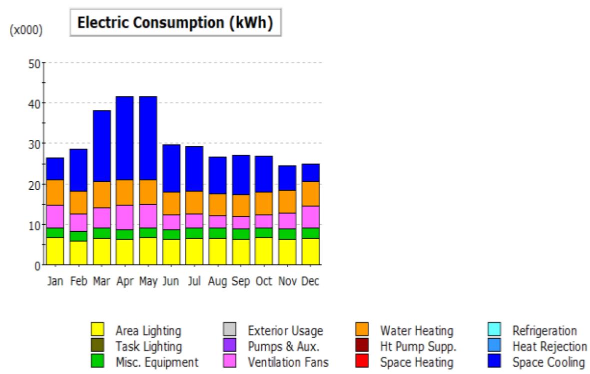

Fig. 4. Graph which shows annual electricity consumption of the whole building.

C. Using different U values and getting the respective electricity consumption.

The same simulation was performed using different materials by changing the U value in the wall construction details. The below is the graph which shows the U value and the electricity consumption for different materials.

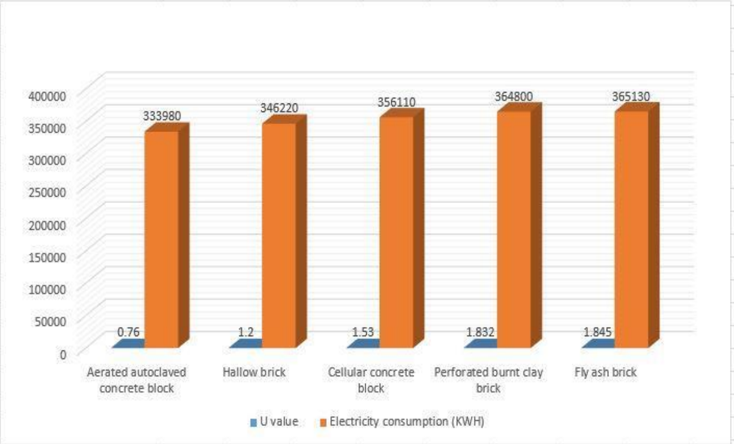

Fig. 5. Comparison of U value and corresponding electricity consumption for different material.

D. Electricity bill calculator:

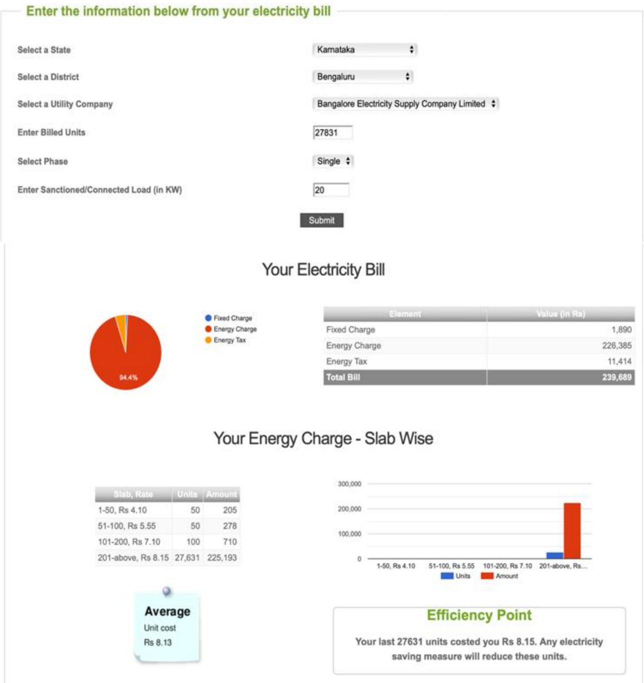

Fig. 6. Electricity bill calculator for all the states in India.

This is a free government tool to calculate the monthly electricity cost. It is calculated by dividing the annual electricity consumption of the building equally for all months in a year.

By selecting the state, district and electricity supplying company, then by specifying the monthly electricity consumption, phase (single phase or three phase), and the sanction load, the user will be able calculate the electricity cost.

The table below gives information about the type of bricks used and the annual electricity cost of the same building if the walls are constructed entirely by specific type of brick as mentioned in the table, by using a government tool called as online electricity bill calculator. The annual electricity cost for different materials can be calculated by inputting their respective electricity consumption values in the tool.

From the table if aerated autoclave concrete blocks instead of fly ash bricks for constructing the wall then this can save an annual electricity cost of Rs 2,66,592 thus reducing the operational costs of a building.

TABLE IV. The list of material and respective electricity cost.

Type of brick	Annual electricity cost
Aerated autoclaved concrete block	Rs 28,76,268
Hallow brick	Rs 29,81,004
Cellular concrete block	Rs 30,65,736
Perforated burnt clay brick	Rs 31,40,088
Fly ash brick	Rs 31,42,860

CONCLUSION

- The main intension of the project was to understand the importance of RETV value and how the value places a significant role in understanding the building envelope efficiency.
- The research from the project helped to draw the connection between RETV value, U value and electricity consumption. This helps in showing the importance of the material used in building construction and the thermal transmittance of the material.
- From the above tool and analysis, we can conclude that higher the U value lower the RETV value which means that the thermal insulation of the building material is good. If the thermal insulation is high then the influence of the outside temperature on the inside is less. Therefore, this reduces the cooling/heating load thus reducing the electricity the importance of other parameters like SHGC value, the building orientation which plays a huge role in determining the REVT value is also understood because of the results from the project.
- If RETV analysis is implemented in everyday construction about 20% of cooling energy and 25 million KWH electricity can be reduced and also reduce 100 million tons $C0_2$ of released in the atmosphere (The values are taken from BEE website). This is the main point to take away from the project. The amount of change it brings about in our daily life by changing material used in construction and design changes.

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