DETERMINING THE EFFECTIVENESS OF INSULATION LAYERS ON EXTERNAL WALLS BY TRANSIENT THERMAL ANALYSIS

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Abstract - In India we have about 300 clear or sunny days, So In order to achieve comfort conditions in residence and offices the building sector alone represents about 35% energy consumption. In this study the usage of composite exterior walls to reduce the energy demand of the building has been evaluating.

Reducing the heat load of the structure allows for the installation of a smaller heating and cooling system thus electricity is consumed by the air conditioning system during summer days can be reduce to a large extend.

Cooling of interiors can be achieved by use of centralized air conditioner, ceiling fans, evaporative cooling systems for dry climates, dehumidification systems, heat pump systems etc, but this method are costly and also consumes energy so in this study we aim to design an exterior wall with proper insulation or by using composite wall technique. This study evaluates the increase in thermal efficiency of outer wall using layered wall concept with different thermal insulation materials. The study aims around 20% decrease in thermal conductivity from the conventional design using bricks and cement thus the energy consumptions can be reduced.

Design of exterior walls shall be done based on a numerical study using ANSYS Workbench 2022 R2. The thermal efficiency of exterior wall shall be compared with different insulation materials like PU Foam, Fiber glass, Gypsum and Mineral Wool. Comparison shall be made with different ambient temperature conditions.

An Optimized design will be proposed at the final stage of study with respect to the efficiency of layered wall with different insulation materials. This study is concerning about increase in energy consumption, material and resources. By adopting techniques like layered walls as insulation for exterior wall will save energy, resources as well environment health.

***Key words*:** Composite wall, Thermal insulation, ANSYS, PU Foam, Mineral wool, Fibre glass, Gypsum board

1.INTRODUCTION

Exterior wall of a building is directly exposed to sunlight, this produces thermal effect on both the outside and inside the building. While considering the design of a building thermal comfort is one of the most important indoor environmental factors that affects the health and human performance. As the thermal effect inside a building increases energy demand also increases. So, buildings must be designed to reduce thermal effects and energy demands. Providing insulation layers on exterior walls is one of the effective methods to achieve thermal comfort and thereby reducing the energy demands. This study evaluates the increase in thermal efficiency of outer wall using layered wall concept with different thermal insulation materials. Design of exterior walls shall be done based on a numerical study using ANSYS Workbench 2022 R2. The thermal efficiency of exterior wall shall be compared with different insulation materials like PU foam, Fibre glass, gypsum and mineral wool. Comparison shall be made with different ambient temperature conditions and optimisation is done with respect to the efficiency of layered wall with different insulation materials and by using the combinations of the materials.

The more sunlight a surface absorbs, the warmer it gets, and the more energy it re-radiates as heat. That is exactly how the energy travels from the sun to Earth, by solar radiation. Heat can also move from one place to another by being carried in a moving fluid (liquid or gas). This is called convection. As the wall surface which is directly exposed to sun light absorbs heat which comes from the sun, the surface becomes warmer than the surrounding atmosphere. Minimizing energy consumption in air conditioning system can be done with reducing the cooling load in a room, thus the use of air conditioning system is highly necessary to acquire room thermal comfort. Heat from solar radiation which passes through the wall increases the cooling load. Room thermal comfort is a human need in which to rest and do activities.

There are several factors which influence room thermal comfort, namely thermal loads from occupants, equipment, lights/lamps, and thermal load coming from sun rays. In tropical area, the main thermal load is due to the average

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temperature of ambient air exceeding the thermal comfort temperature, as well as sun shine which hits buildings continues into the rooms. Solar radiation which reaches the wall surface partly continues through the wall and a part is reflected. Thermal load which enters the room is solar radiation energy received by wall surface and then through conduction is continued to the surface of the inside part of the wall. Solar radiation energy which can be continued to the inside surface of the wall can reach 90%, depending on the darkness level of the wall. The heat transfer on the wall is also influenced by wall thermal conductivity. The thermal effect inside the building can be reduced by providing insulation layers using materials of varied thermal conductivity. An optimised design will be proposed at the final stage of study with respect to the efficiency of layered wall with these materials and by using the combinations of the materials.

2. OBJECTIVES

- To determine the heat transfer from ambient temperature conditions to inside of building through exterior wall
- To increase the thermal resistance by providing layered wall with PU foams, fibre glass, gypsum, mineral wool
- To find out maximum resistance offered material and panel arrangement
- To evaluate thermal efficiency of optimised model

3. METHODOLOGY

The whole project is divided into sequential steps. The following chart represents the methodology of the work.

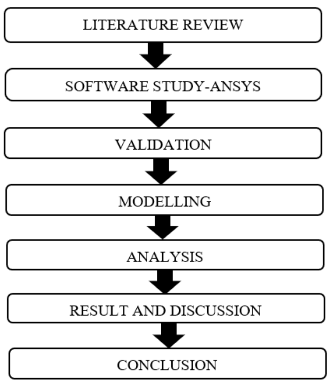

Fig. 3.1 Flow chart diagram for methodology

4. NUMERICAL MODELLING

A single story RCC residential building is modelled in SOLIDWORKS2021. Thermal analysis of model with moving air as medium could not be done in ANSYS software, so in this study the entire building is modelled and flow simulation is done in SOLIDWORKS**.** After obtaining results by flow simulation, the model will then import to ANSYS and the external wall to be analyzed will be optimized by further analysis using ANSYS. After that again flow simulation of optimized model will be doing in SOLIDWORKS.

4.2 MODEL DETAILS

Building type: Single story RCC residential building

Plan area: 80.05 m^2
External wall thickness: 200 mm
Dimension of external wall element
Length: 3200 mm
Height: 2000 mm

Fig. 4.1 shows the plan of the building taken for analysis, Fig. 4.2 shows the 3D view of the modelled building and from Fig. 4.3 to Fig. 4.15 shows the models taken for steady-state analysis.

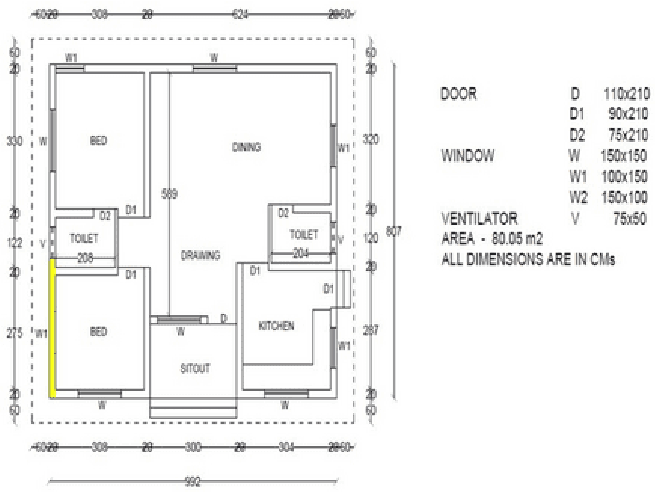

Fig. 4.1 Plan of the building

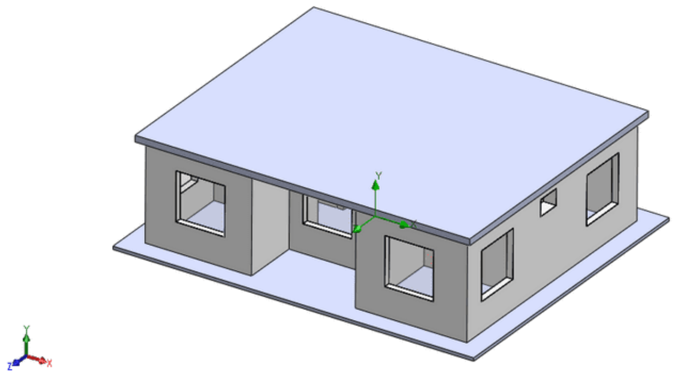

Fig. 4.2 Entire building model

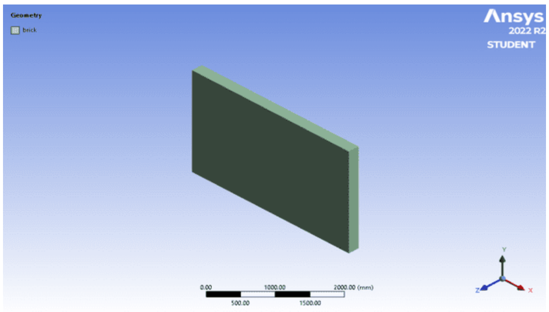

Fig. 4.3 External brick wall element

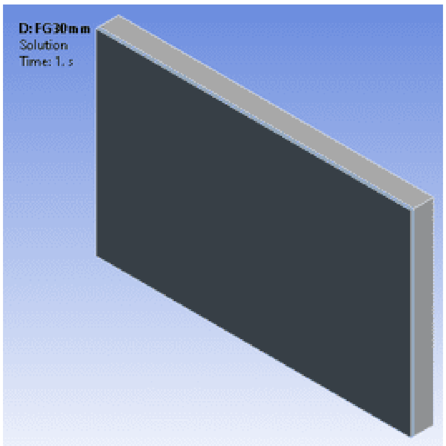

Fig. 4.4 External brick wall element with 30 mm FG

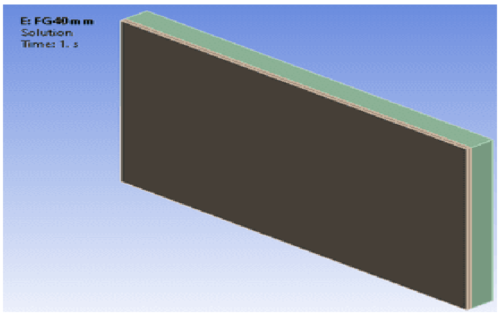

Fig. 4.5 External brick wall element with 40 mm FG

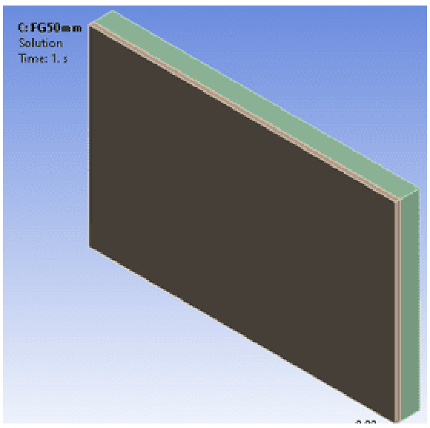

Fig. 4.6 External brick wall element with 50 mm FG

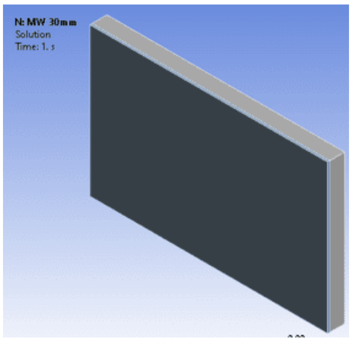

Fig. 4.7 External brick wall element with 30 mm MW

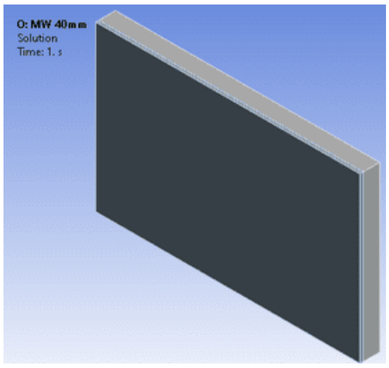

Fig. 4.8 External brick wall element with 40 mm MW

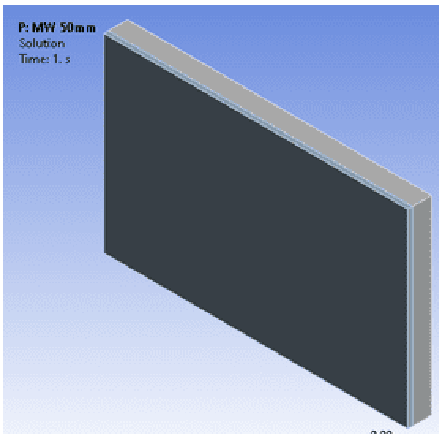

Fig. 4.9 External brick wall element with 50 mm MW

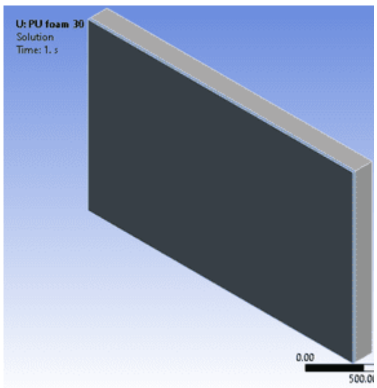

Fig. 4.10 External brick wall element with 30 mm PU

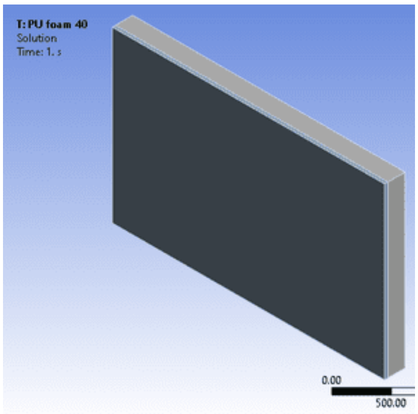

Fig. 4.11 External brick wall element with 40 mm PU

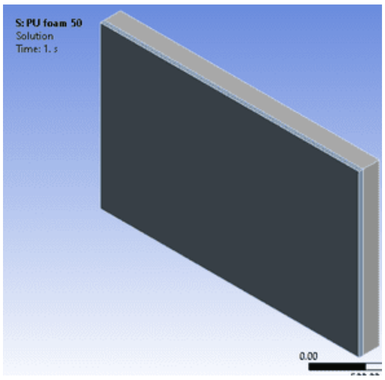

Fig. 4.12 External brick wall element with 50 mm PU

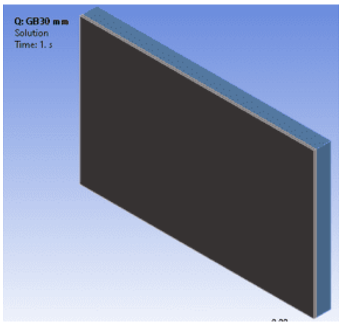

Fig. 4.13 External brick wall element with 30 mm GB

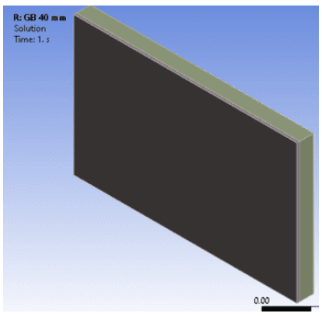

Fig. 4.14 External brick wall element with 40 mm GB

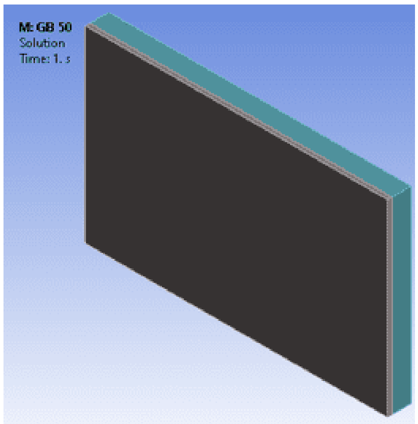

Fig. 4.15 External brick wall element with 50 mm GB

5. NUMERICAL ANALYSIS

Transient thermal analysis of a residential building with normal brick wall was done in SOLIDWORKS 2021. Normal brick wall element of 3.2m x 2m was analysed in steady state using ANSYS 2022 R2. Layered wall with different materials and thickness was analysed using ANSYS 2022 R2 in steady state condition. Brick wall with 200 mm thickness with an insulation layer of 40 mm thick gypsum layer inside is obtained as optimised model. Transient thermal analysis of building with optimised wall model was done in SOLIDWORKS 2021. For analysis ambient temperature and inside room temperature is taken as 45^{0}C and 30^{0}C respectively. In conjugate heat transfer analysis, a flow rate of 450 CFM is provided which is the flow rate for 1 ton AC. In this analysis ACs with 16^{0}C were run for 2 minutes.

Fig. 5.1 and Fig. 5.43 shows the surface plot of building model with 200mm thick normal brick wall and brick wall insulated with 40 mm thick gypsum board respectively from conjugate heat transfer analysis.

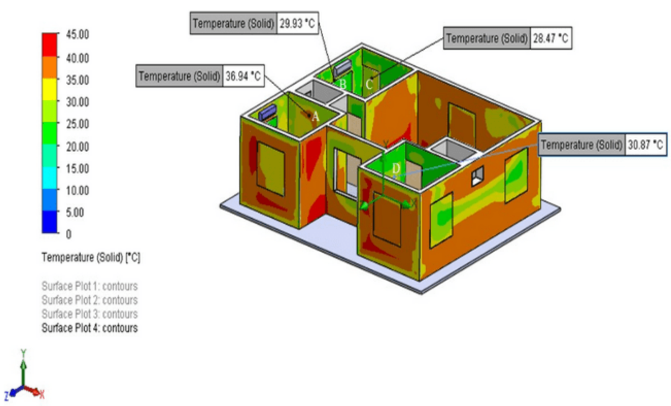

Fig. 5.2 shows meshing of wall element taken for steady-state analysis, Fig. 5.3 shows the boundary conditions provided for steady-state analysis.

Fig. 6.1 Surface plot of model with

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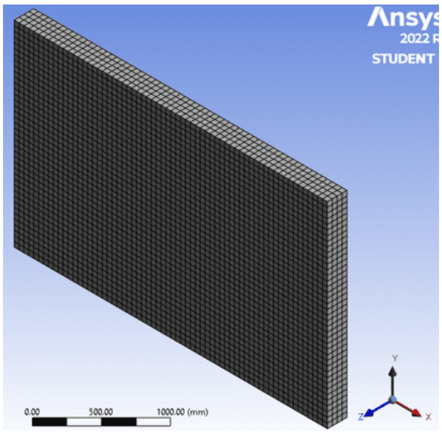

Fig. 5.2 Meshing of wall element

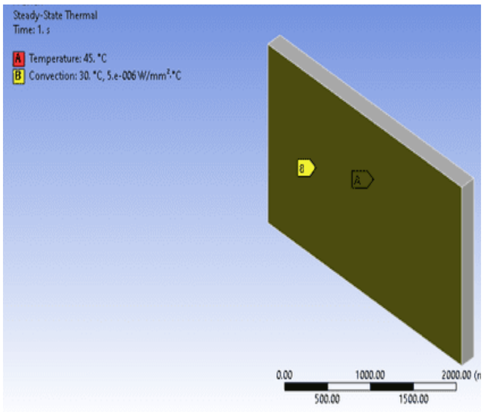

Fig. 5.3 Boundary conditions

From Fig. 5.4 to Fig. 5.42 shows the temperature transfer across wall thickness, temperature distribution path and temperature plots for the 13 models from steady-state analysis.

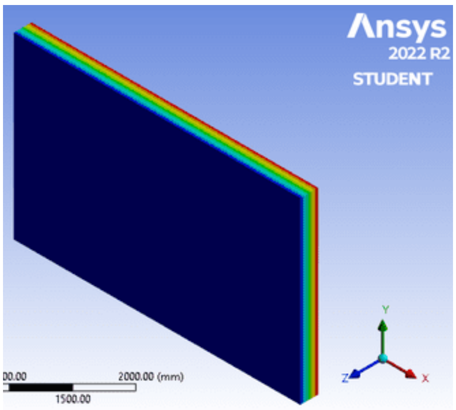

Fig. 5.4 Temperature transfer across 200mm thick brick wall

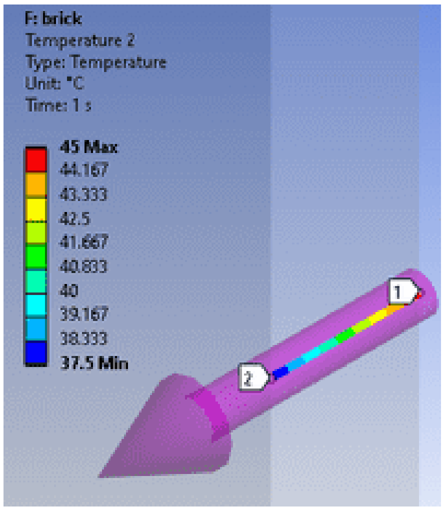

Fig. 5.5 Temperature distribution path of 200mm thick brick wall

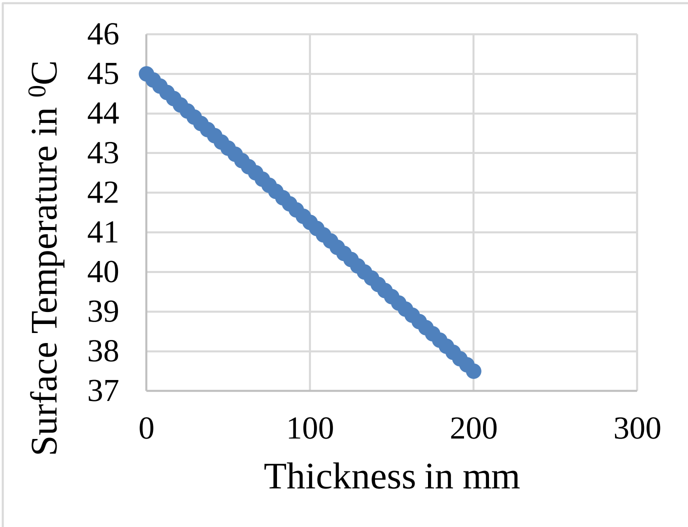

Fig. 5.6 Temperature plot of 200mm thick brick wall

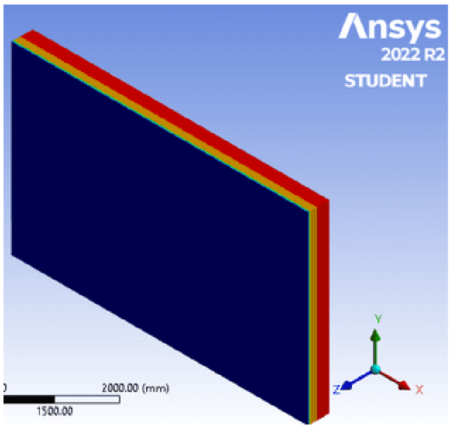

Fig. 5.7 Temperature transfer of brick wall with 30mm thick FG

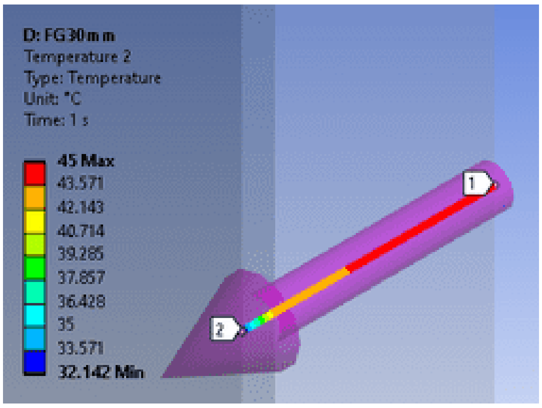

Fig. 5.8 Temperature distribution path of brick wall with 30mm thick FG

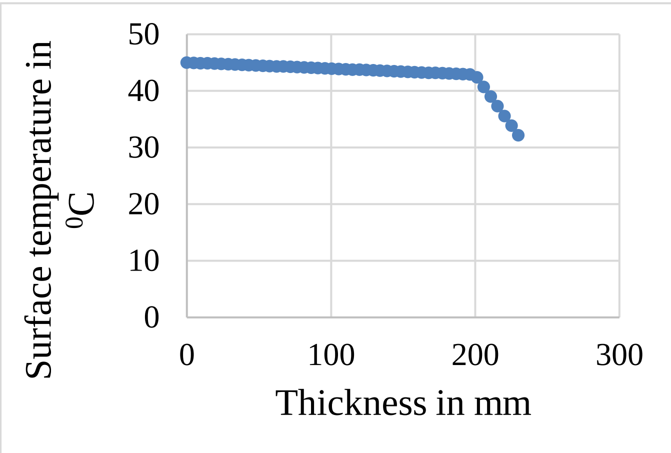

Fig. 5.9 Temperature plot of brick wall with 30mm thick FG

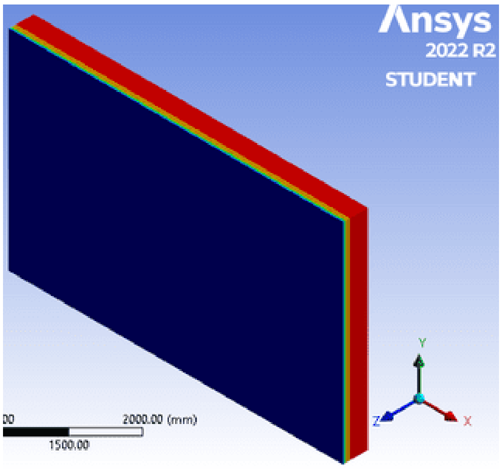

Fig. 5.10 Temperature transfer across brick wall with 40mm thick FG

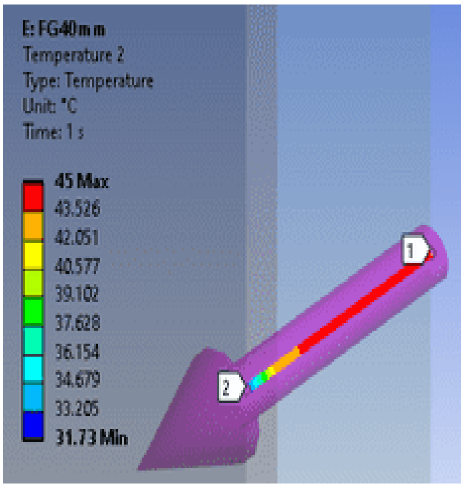

Fig. 5.11 Temperature distribution path of brick wall with 40mm thick FG

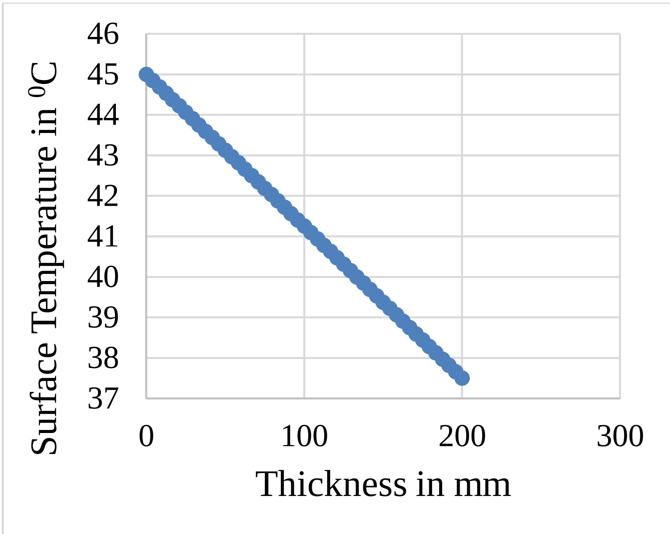

Fig. 5.12 Temperature plot of brick wall with 40mm thick

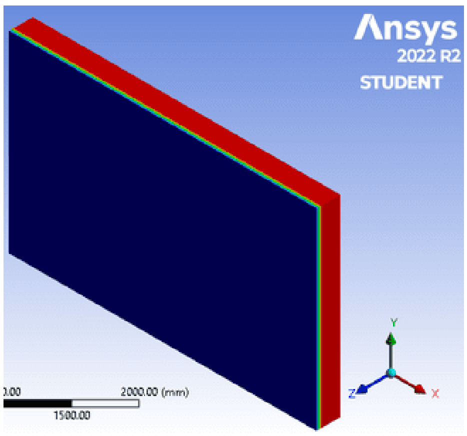

Fig. 5.13 Temperature transfer across brick wall with 50mm thick FG

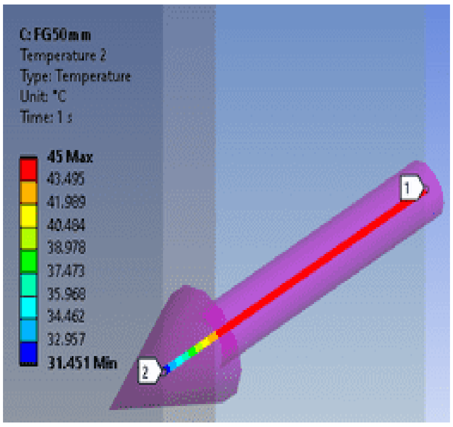

Fig. 5.14 Temperature distribution path of brick wall with 50mm thick FG

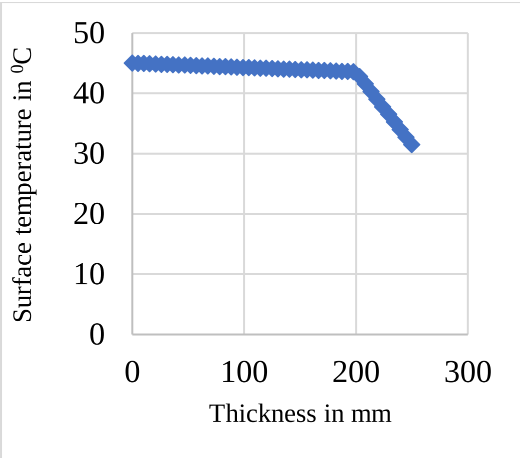

Fig. 5.15 Temperature plot of brick wall with 50mm thick FG

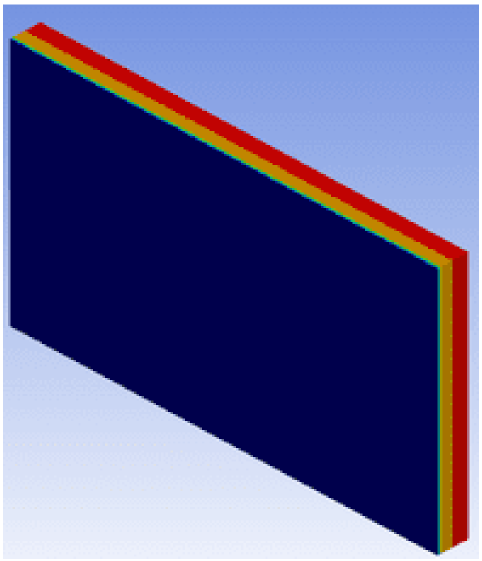

Fig. 5.16 Temperature transfer across brick wall with 30mm thick MW

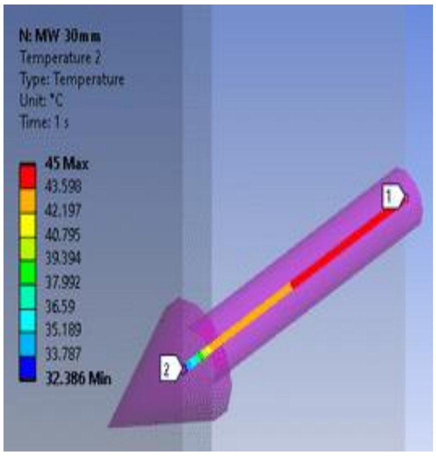

Fig. 5.17 Temperature distribution path of brick wall with 30mm thick MW

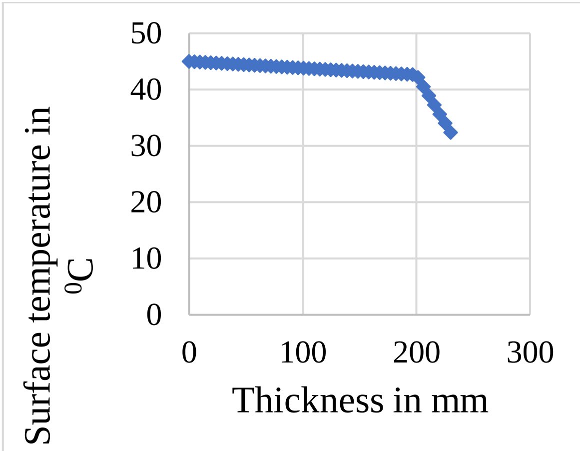

Fig. 5.18 Temperature plot of brick wall with 30mm thick MW

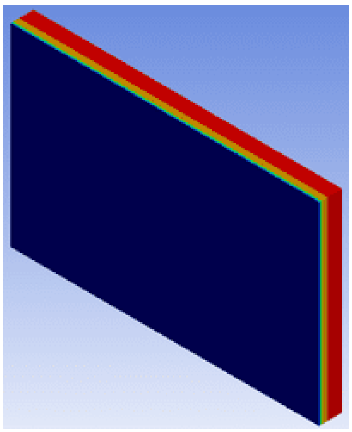

Fig. 5.19 Temperature transfer across brick wall with 40mm thick MW

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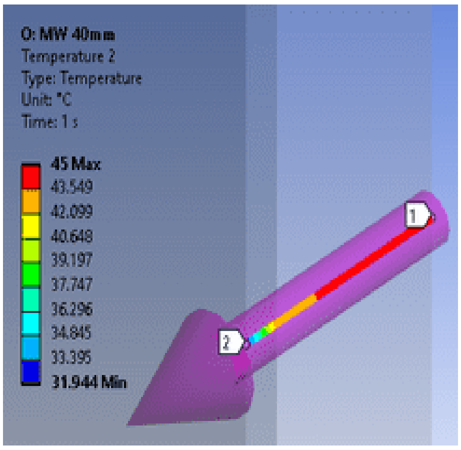

Fig. 5.20 Temperature distribution path of brick wall with 40mm thick MW

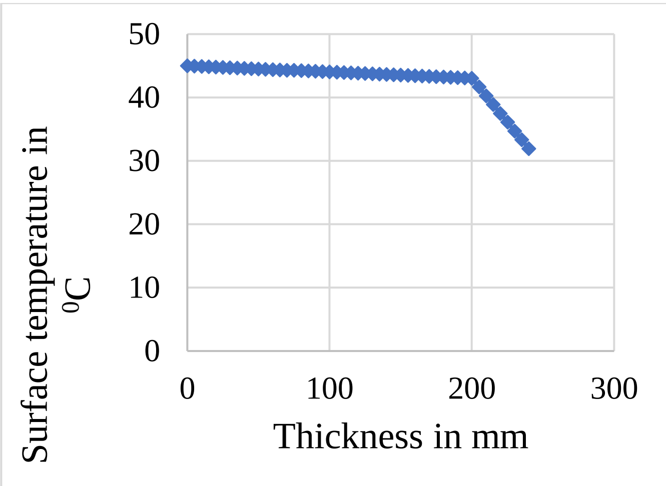

Fig. 5.21 Temperature plot brick wall with 40mm thick MW

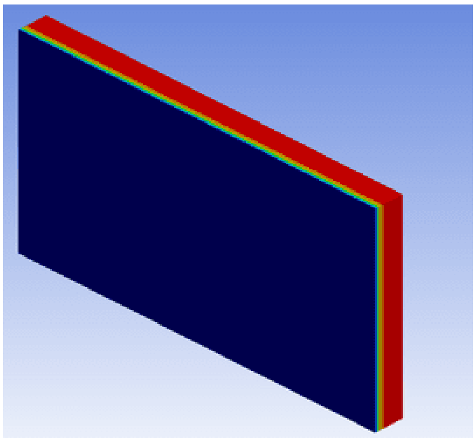

Fig. 5.22 Temperature transfer across brick wall with 50mm thick MW

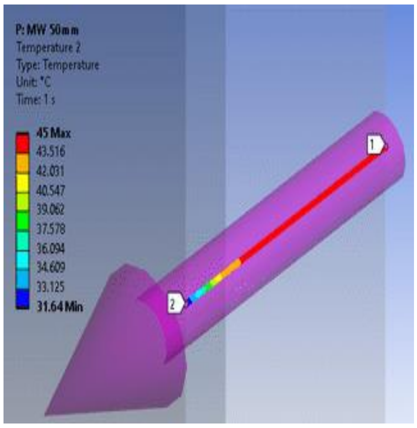

Fig. 5.23 Temperature distribution path of brick wall with 50mm thick MW

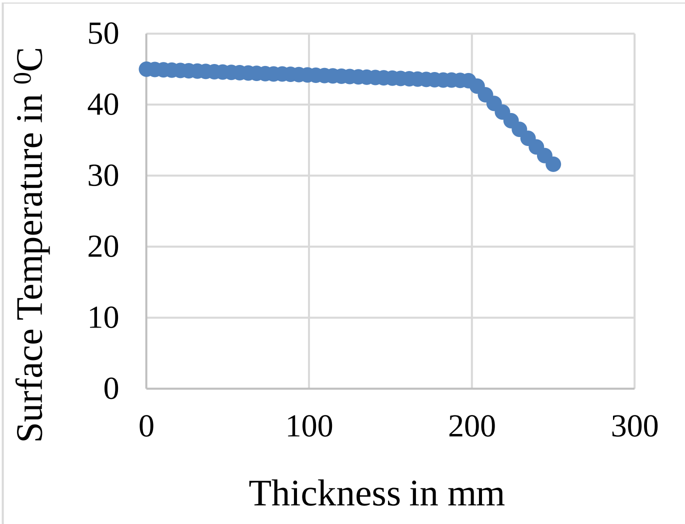

Fig. 5.24 Temperature plot of brick wall with 50mm thick MW

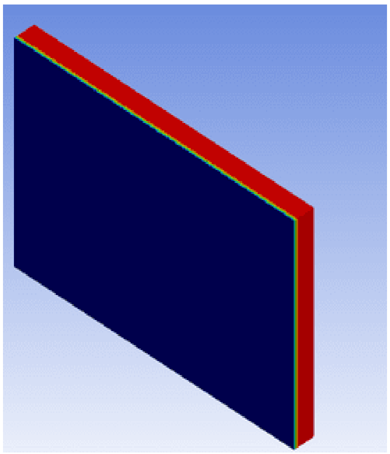

Fig. 5.25 Temperature transfer across brick wall with 30mm thick PU

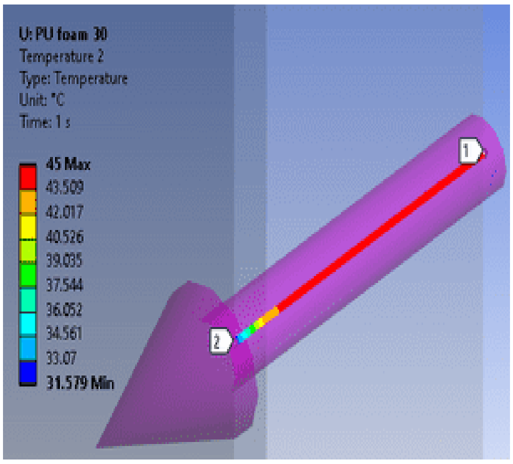

Fig. 5.26 Temperature distribution path of brick wall with 30mm thick PU

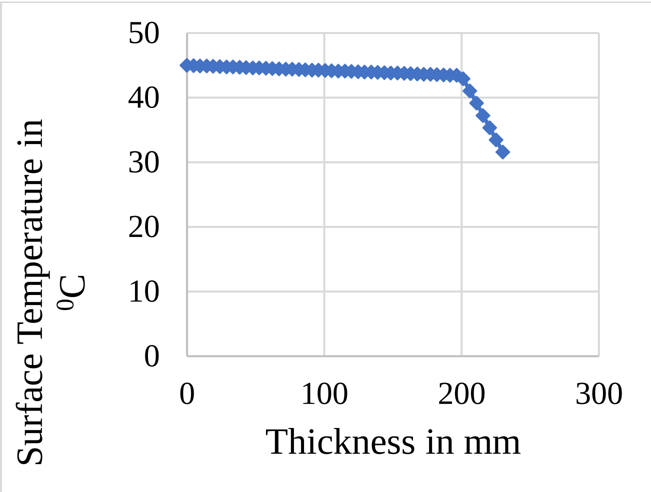

Fig. 5.27 Temperature plot of brick wall with 30mm thick PU

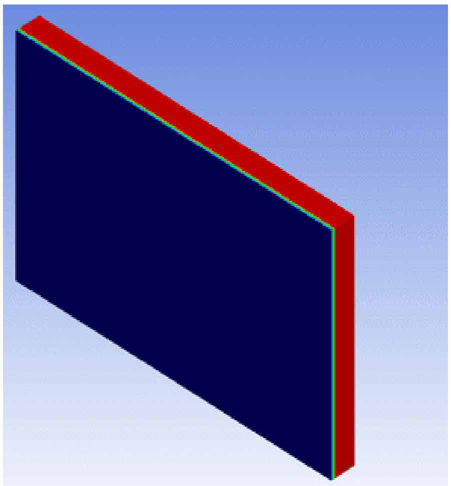

Fig. 5.28 Temperature transfer across brick wall with 40mm thick PU

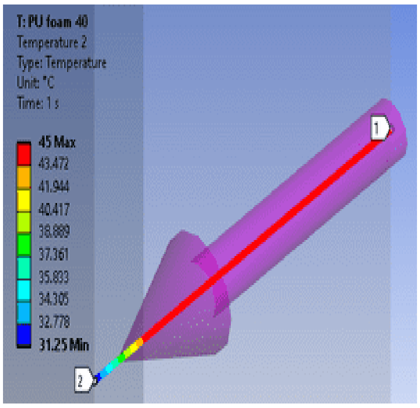

Fig. 5.29 Temperature distribution path of brick wall with 40mm thick PU

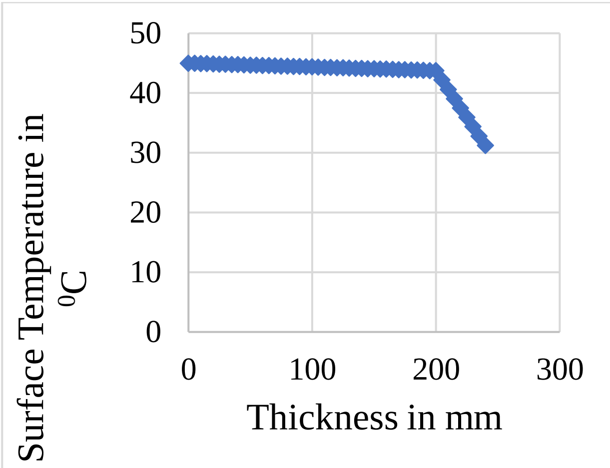

Fig. 5.30 Temperature plot of brick wall with 40mm thick PU

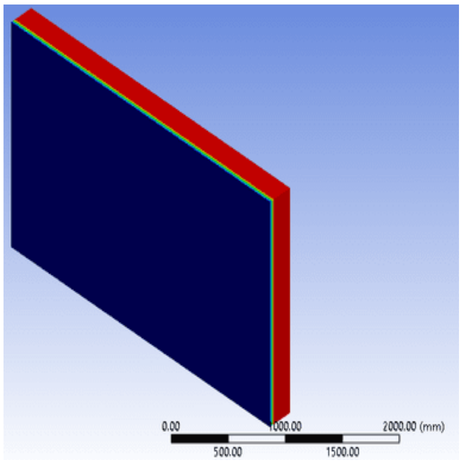

Fig. 5.31 Temperature transfer across brick wall with 50mm thick PU

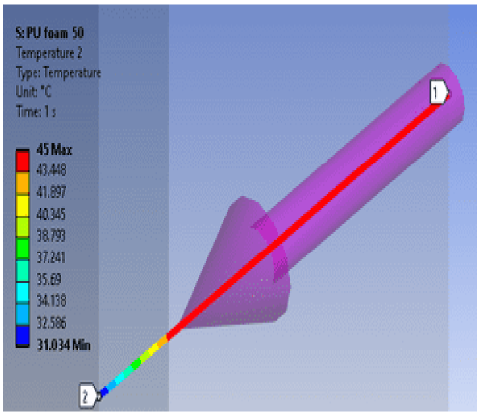

Fig. 5.32 Temperature distribution path of brick wall with 50mm thick PU

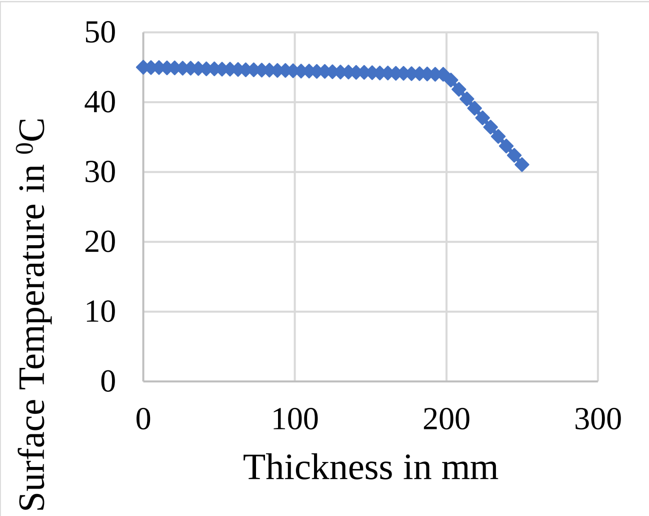

Fig. 5.33 Temperature plot of brick wall with 50mm thick PU

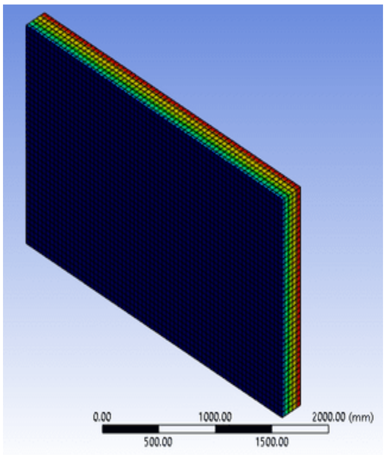

Fig. 5.34 Temperature transfer of brick wall with 30mm thick GB

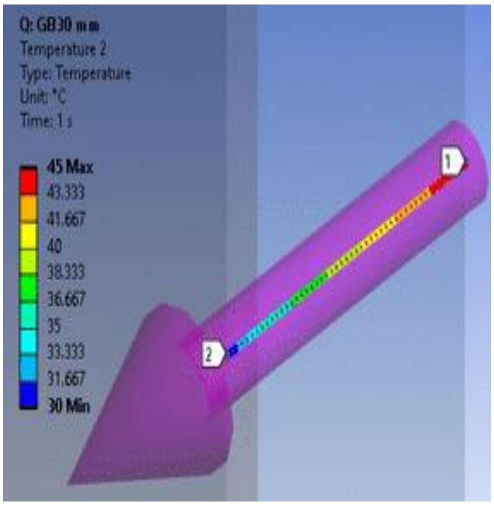

Fig. 5.35 Temperature distribution path of brick wall with 30mm thick GB

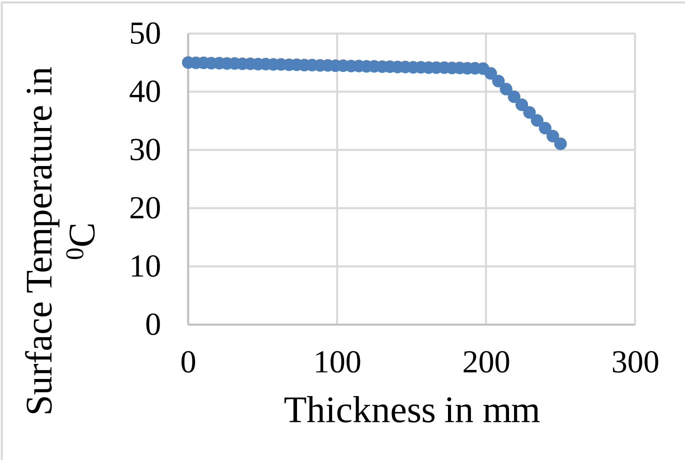

Fig. 5.36 Temperature plot of brick wall with 30mm thick GB

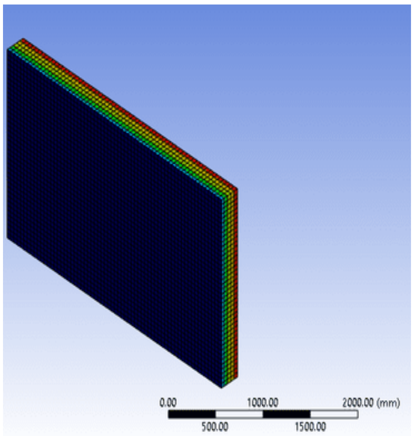

Fig. 5.37 Temperature transfer across brick wall with 40mm thick GB

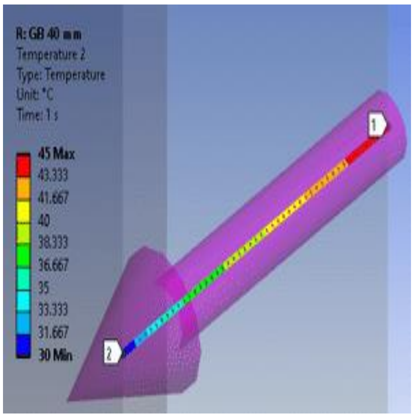

Fig. 5.38 Temperature distribution path of brick wall with 40mm thick GB

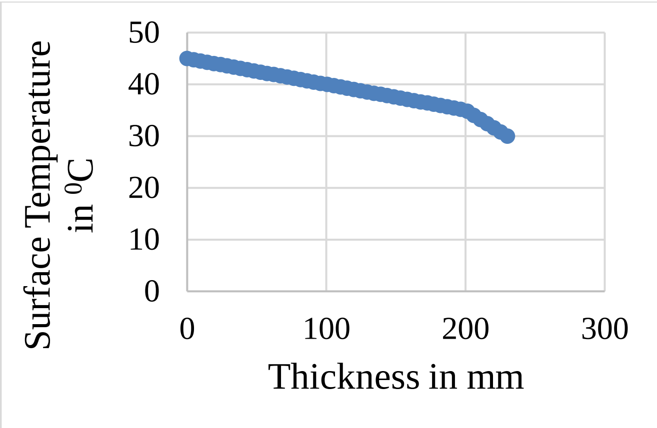

Fig. 5.39 Temperature plot of brick wall with 40mm thick GB

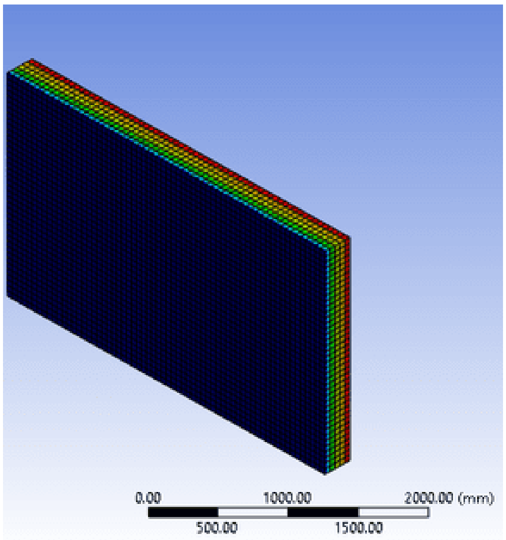

Fig. 5.40 Temperature transfer across brick wall with 50mm thick GB

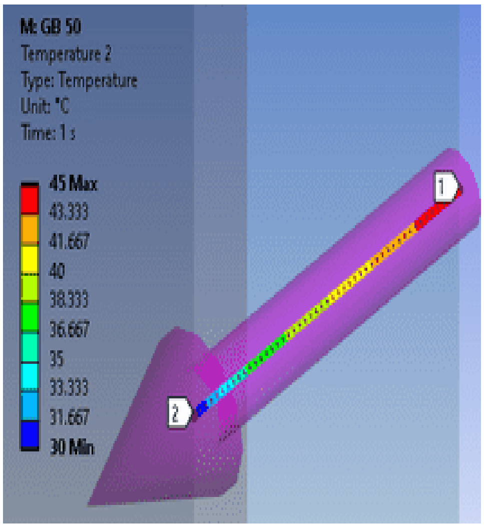

Fig. 5.41 Temperature distribution path of brick wall with 50mm thick GB

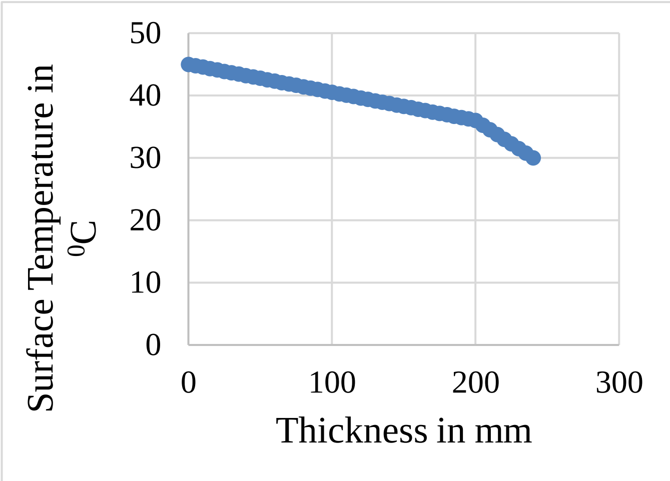

Fig. 5.42 Temperature plot of brick wall with 50mm thick GB

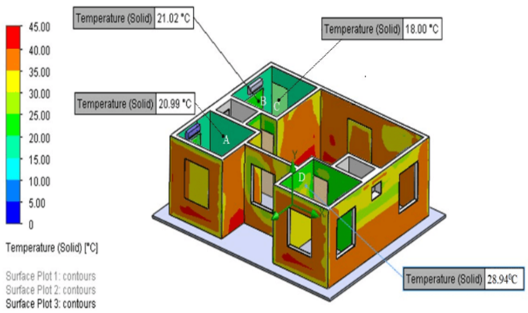

Fig. 5.43 Surface plot of model with brick wall

6. RESULTS AND DISCUSSION

In phase -I Steady state thermal analysis is conducted for the external brick wall with the introduction of fiber glass, mineral wool, PU foam and gypsum board to determine the effectiveness of insulation. Steady-state thermal analysis is done for 13 wall models to determine the heat transfer through the thickness of wall. As the base line iteration, a normal brick wall of 3.2mx2m with 200mm thickness is used for the study with ambient temperature of 45^{0}C and inside temperature 30^{0}C. From the analysis the inside surface temperature is evaluated as 37.5^{0}C, thus a ΔT of 7.5^{0}C is achieved. Table 6.1 shows the detailed results from steady-state analysis.

Table 6.1 Minimum temperatures from steady-state analysis

Material	**Surface temperature (^{0}C)**	**Decrease in temperature (%)**
Brick	37.5	-
FG 30	32.14	14.29
FG 40	31.73	15.39
FG 50	31.45	16.13
MW 30	32.38	13.65
MW 40	31.94	14.83
MW 50	31.64	15.63
PU 30	31.57	15.81
PU 40	31.25	16.67
PU 50	31.03	17.5
GB 30	30	20
GB 40	30	20
GB 50	30	20

Fig. 6.1 shows the combined results of models from steady-state analysis

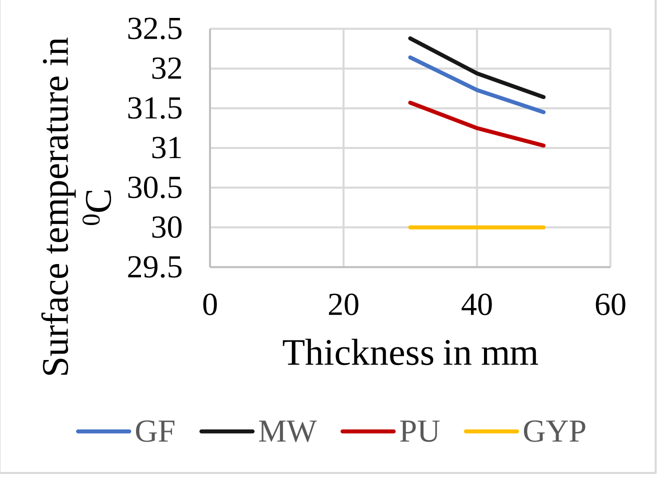

Fig. 6.1 Combined result of steady-state analysis

In phase-II Transient conjugate heat transfer analysis is conducted for the entire building model with normal brick wall and wall with optimized insulation from phase-I study to determine the heat transfer inside the building. Table 7.2 shows the comparison of surface temperatures obtained from conjugate heat transfer analysis.

Table 6.2 Surface temperatures from transient thermal analysis

Model	**Surface Temperature (^{0}C)**			
	A	B	C	D
Brick wall	36.94	29.93	28.47	30.87
Brick wall with 40 mm thick gypsum layer	20.99	21.02	18	28.94

7. CONCLUSION

Steady state thermal analysis is done to determine the effectiveness of insulation with various thickness and material properties. It is observed that the gypsum has 20% more heat resistance compared to normal brick wall. At the interior face of the external wall with gypsum as insulation the temperature transferred is very minimal. From the transient conjugate heat transfer analysis, without gypsum insulation the side wall is at 36.94^{0}C while running the AC for 2 minutes. Temperature at the same region can be reduced to a range of 20.99^{0}C while using gypsum board of 40 mm thickness as insulation. Gypsum board can effectively reduce the heat transfer due to its very low conductivity thus the electricity consumption is reduced.

8. FUTURE SCOPE

The model can be analyzed with different ambient temperatures and insulation materials.

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