THERMAL CONTROLLING IN BUILDING USING PHASE CHANGING MATERIALS

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Abstract - *This project aims to provide an overview of the role and potential of PCMs in enhancing the energy efficiency and comfort of buildings. Phase-changing materials (PCMs) have garnered considerable attention as thermal control materials in buildings due to their ability to store and release large amounts of energy during phase transitions. Paraffin and beeswax are two commonly used phase-changing materials (PCMs) that offer effective temperature control in buildings. Paraffin wax and beeswax both exhibit phase transitions at temperatures suitable for building applications. The paraffin and beeswax integrated into building materials like gypsum mortar offer several advantages. Firstly, it reduces the reliance on mechanical heating and cooling systems, thereby lowering energy consumption and utility costs. Additionally, it enhances thermal comfort by stabilizing indoor temperatures and reducing temperature fluctuations. Furthermore, paraffin and beeswax PCMs contribute to environmental sustainability by reducing carbon emissions associated with conventional heating ventilation and air conditioning (HVAC) systems. Performing a thermal analysis of paraffin and beeswax integrated into the gypsum mortar using ANSYS software involves simulating the heat transfer behavior of these phase-changing materials. Steady-state thermal analysis is done, and compressive strength is identified by performing compression tests on gypsum and PCM-incorporated cubes. By comparing the results, it is found that the combination of gypsum with paraffin is more effective in terms of thermal control than gypsum with beeswax. But compressive strength is greater for the combination of gypsum and beeswax.*

Key Words: *Phase changing materials, Paraffin, Beeswax, ANSYS, Steady state analysis, Explicit dynamic analysis.*

1.INTRODUCTION

Energy consumption in buildings has become one of the most urgent issues in most countries worldwide. Globally, the energy consumed for space heating and cooling is as high as 40% and 61% of the total energy demand in commercial and residential buildings, respectively. The incorporation of phase change materials (PCMs) into building envelopes has the desired impact of controlling the thermal load, thereby resulting in remarkable energy savings. PCMs are implemented to minimize the cooling and heating loads through the building envelope due to their massive potential for energy storage during melting and solidification, thereby maintaining an acceptable thermal comfort. Paraffin and beeswax are the most commonly available PCMs that can be incorporated with gypsum mortar to make gypsum boards, which can be used as facades, partition walls, and also when incorporated into building components such as walls, ceilings, or floors.

2.THE METHODOLOGY FOLLOWED IN THIS PROJECT

- Collection of materials like PCMs, gypsum etc.
- Selecting dimension of cubes and boards.
- Thermal analysis using ANSYS and explicit dynamics analysis for stress v/s strain curve.
- Plotting graph.
- Casting cubes and board for compression test.
- Comparing the results.

4. THERMAL ANALYSIS USING ANSYS

ANSYS is used to identify how a product will function with different specifications, without building test products or conducting crash tests. It uses computer-based numerical techniques to solve complex problems. The range of problems ANSYS can solve is immense and could be anything from fluid flow, heat transfer, stress analysis and many more.

4.1 Steady State Thermal Analysis

Steady-state thermal analysis using ANSYS involves analyzing the temperature distribution within a structure or system when the temperature does not change with time. Maximum of 100°C is applied and the minimum temperature obtained for gypsum board, gypsum + Paraffin with 5 different percentage and gypsum + beeswax with 5 different percentages is shown in the following figures

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The steps followed for thermal analysis:

To design the model in ANSYS workbench for thermal, open ANSYS and add steady state thermal analysis to workspace

1. Once steady- state thermal is added, click on geometry and open space claim. Space claim is the space where you create 3D models.
2. Once space claim is open, select the plane you want to create the geometry. Draw a rectangle of dimension 20cm by 20cm. exit sketch and use pull command to add height to the drawing. Height of 2cm is added to the drawing making it into a 3D model
3. Open engineering data to input the material data to create a new material
4. Open model workbench to make a mesh of the design
5. Once mesh is created, open setup module to input the boundary condition of the analysis
6. Add boundary condition of required temperature to one face of the design

Solution tab is opened and volumetric thermal is added.

Result is run for a 1000 iteration set a minimum. Result will run until the temperature result is reached

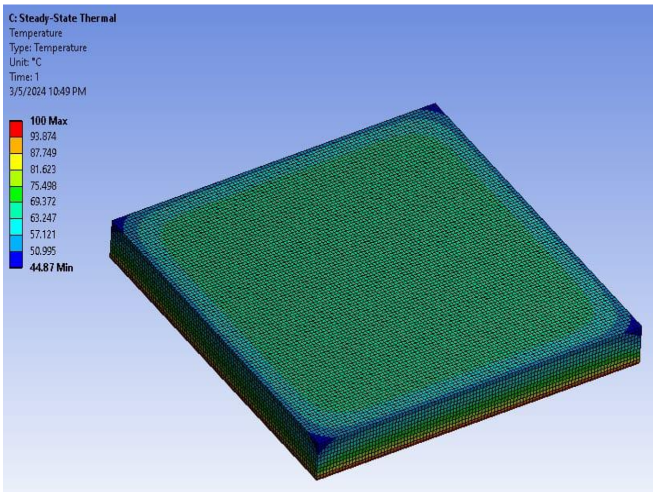

Fig -1: Thermal analysis of gypsum board

Max temperature applied - 100℃
Min temperature obtained - 44.87℃

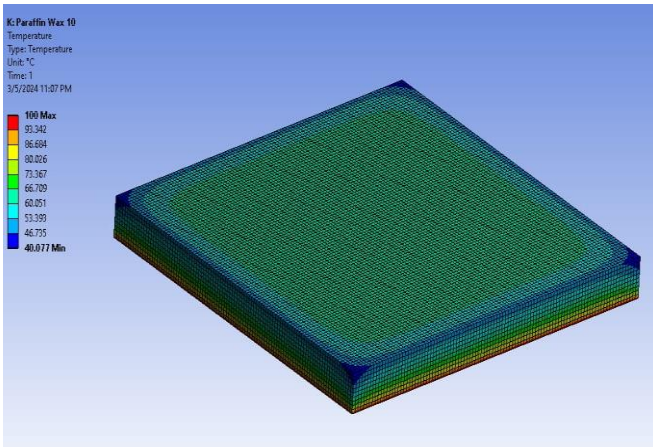

Fig -2: Thermal analysis of gypsum with 10% paraffin board

Max temperature applied - 100℃
Min temperature obtained - 40.077℃

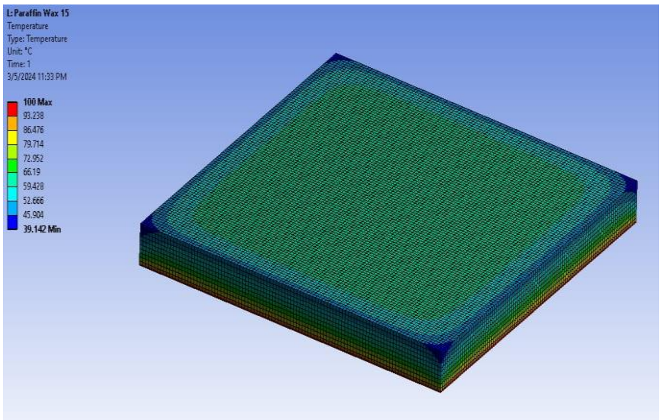

Fig -3: Thermal analysis of gypsum board with 15% paraffin board

Max temperature applied - 100℃
Min temperature obtained – 39.142℃

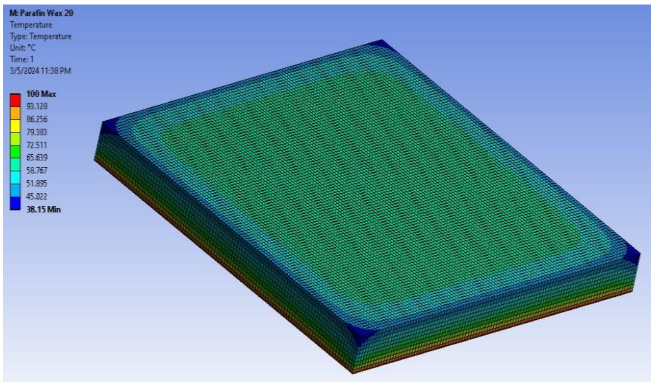

Fig -4: Thermal analysis of gypsum board with 20% paraffin board

Max temperature applied - 100°C
Min temperature obtained - 38.15°C

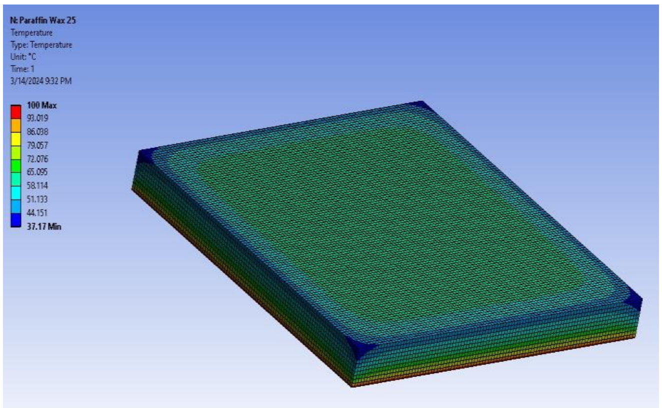

Fig -5: Thermal analysis of gypsum board with 25% paraffin board

Max temperature applied - 100°C
Min temperature obtained - 37.17°C

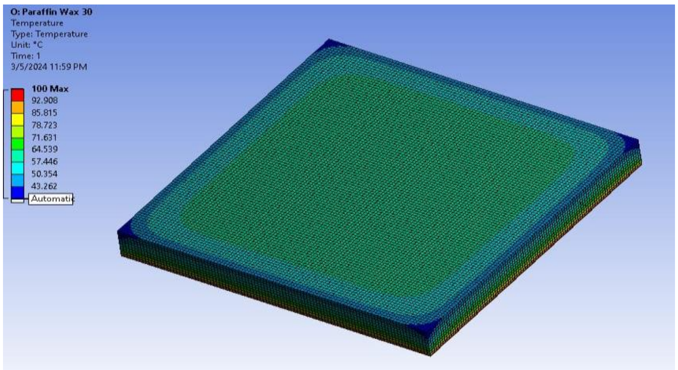

Fig -6: Thermal analysis of gypsum board with 30% paraffin board

Max temperature applied - 100°C
Min temperature obtained - 43.262°C

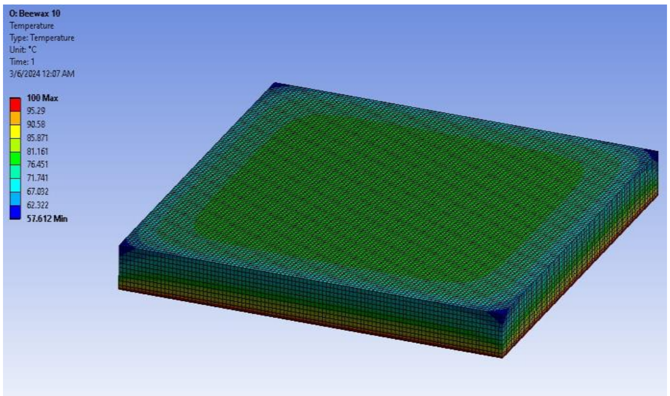

Fig -7: Thermal analysis of gypsum board with 10% beeswax board

Max temperature applied - 100°C
Min temperature obtained - 57.612°C

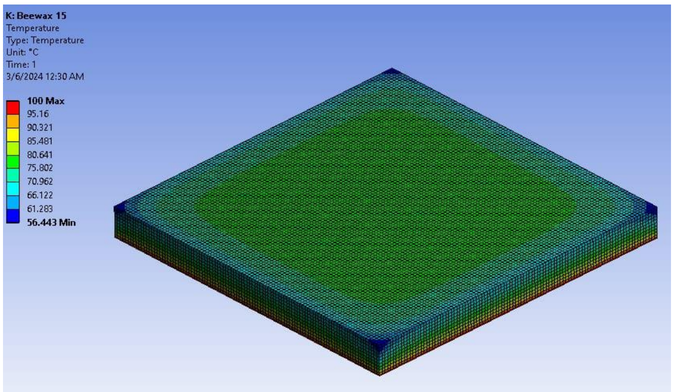

Fig -8: Thermal analysis of gypsum board with 15% beeswax board

Max temperature applied - 100°C
Min temperature obtained - 56.443°C

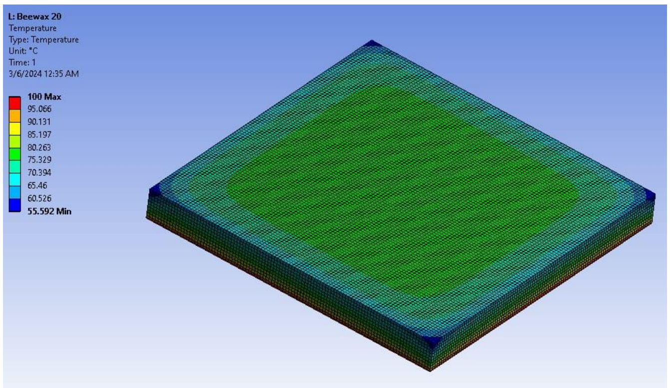

Fig -9: Thermal analysis of gypsum board with 20% beeswax board

Max temperature applied - 100°C
Min temperature obtained - 55.592°C

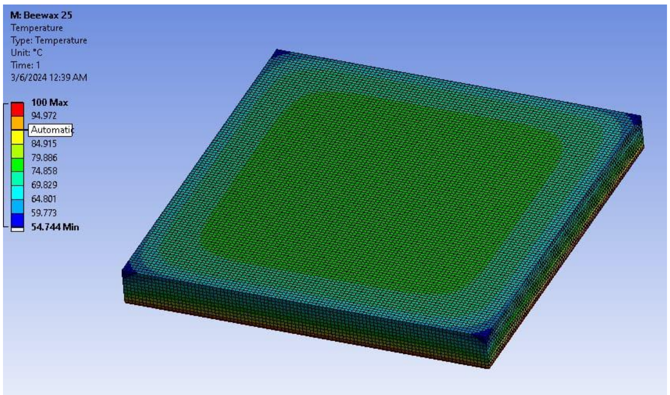

Fig -10: Thermal analysis of gypsum board with 25% beeswax board

Max temperature applied - 100℃
Min temperature obtained - 54.744

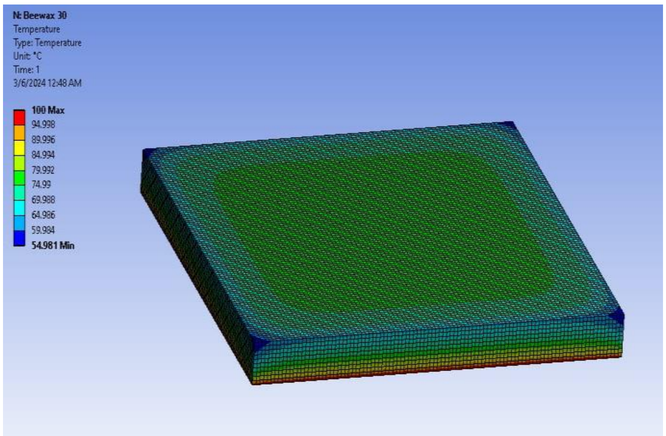

Fig -11: Thermal analysis of gypsum board with 30% beeswax board

Max temperature applied - 100℃
Min temperature obtained - 54.981℃

4.2 Explicit Dynamics Analysis

Explicit dynamics analysis in ANSYS involves simulating dynamic events characterized by high-speed deformations, displacements, and short durations, where inertia and damping effects are significant.

The steps followed for Explicit dynamics.

To design the model in ANSYS workbench for explicit dynamics, open ANSYS and add explicit dynamics to workspace.

1. Once explicit dynamics is added, click on geometry and open space claim. Space claim is the space where you create 3d models.
2. Once space claim is open, select the plane you want to create the geometry. Draw a rectangle of dimension 20cm by 20cm. exit sketch and use pull command to add height to the drawing. Height of 2cm is added to the drawing making it into a 3D model
3. Open engineering data to input the material data to create a new material
4. Open model workbench to make a mesh of the design
5. Once mesh is created, open setup module to input the boundary condition of the analysis.
    a. One face of the design is set a fixed
    b. Opposite side is set to deformation of 10mm per second

Solution tab is opened and stress and strain is selected as the solution

Result is run for a fixed time of 5 min. If the design doesn't rupture, then an additional time is added to the analysis until the full design brakes. The stress strain data is collected as a CSV data file. Stress v/s strain graph of 25% paraffin wax with gypsum and 25% beeswax with gypsum is only plotted, since these percentage gives minimum temperature in each combination.

Using Excel, a graph is plot to find the stress strain graph

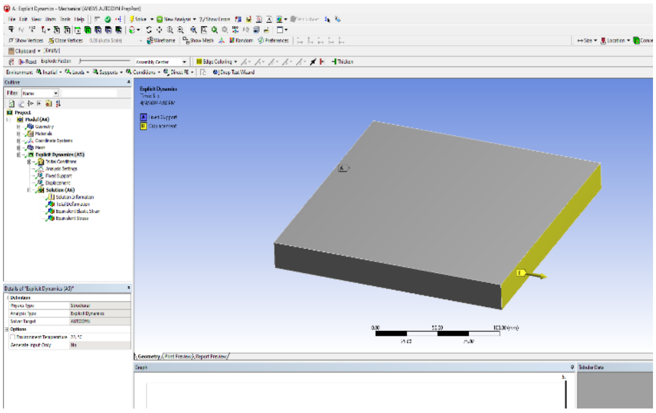

Fig -12: Model created for explicit dynamic analysis

5.COMPARISON OF RESULTS

5.1. Temperature

From figure1 minimum temperature obtained for gypsum board is 44.87℃. The minimum temperature obtained for Gypsum with PCMs combination with percentage 10%, 15%, 20%, 25%, 30% are shown below in the following charts.

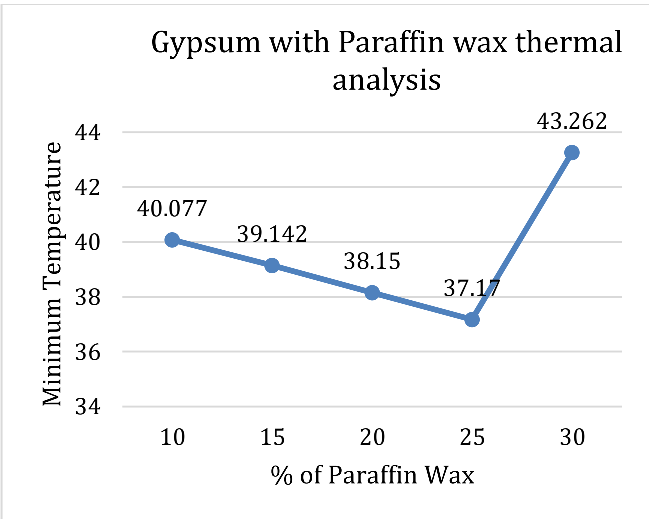

Chart -1: Minimum temperature obtained by gypsum with paraffin combination

From chart1 we can see that there is minimum temperature obtained at 25% of paraffin with gypsum.

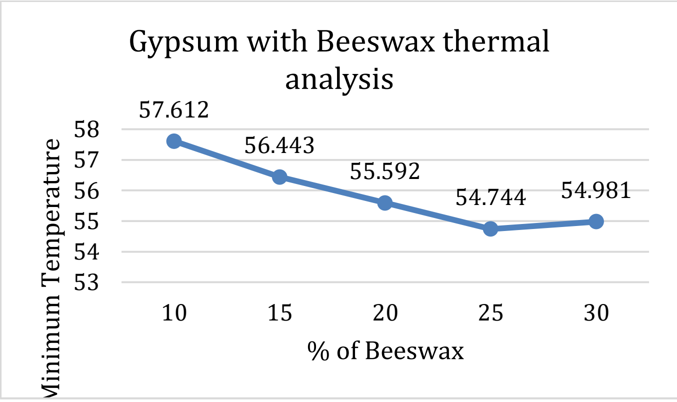

Chart -2: Minimum temperature obtained by gypsum with Beeswax combination

From chart2 we can see that minimum temperature is obtained at 25% beeswax. In the case of beeswax after 25% the temperature doesn't change much that means it reaches to its saturated point.

When compared the gypsum with 25% paraffin shows low thermal conductivity compared to ordinary gypsum board and gypsum + beeswax combination. Therefore, gypsum + Paraffin is more preferable than gypsum + beeswax.

5.2. Stress v/s Strain

The results obtained from thermal analysis shows that 25 % paraffin with gypsum shows the low thermal conductivity, therefore stress v/s strain curve is plotted for 25% paraffin with gypsum.

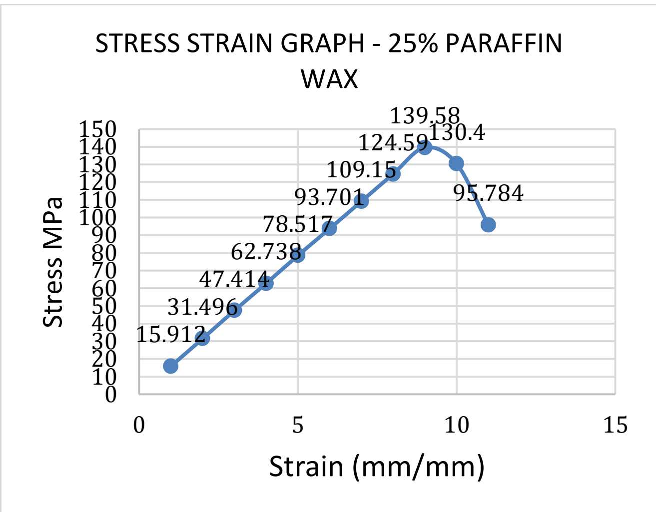

Chart -3: Stress v/s Strain curve of Gypsum + 25% paraffin wax

The results obtained from thermal analysis shows that 25 % beeswax with gypsum shows the low thermal conductivity, therefore stress v/s strain curve is plotted for 25% beeswax with gypsum.

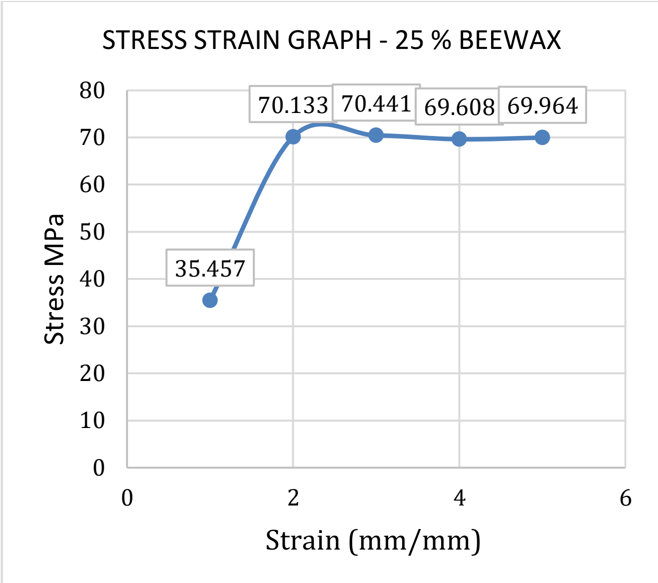

Chart -4: Stress v/s Strain curve of Gypsum + 25% beeswax

From the above two chart breaking point of paraffin is highest compared to beeswax. Considering this paraffin wax is more preferable.

6.CASTING CUBES AND BOARDS FOR COMPRESSION TEST

The steps followed:

Mixture: Mix the gypsum mortar according to the desired specifications, cubes and boards are casted for three combinations that is normal gypsum mortar, gypsum with 25% paraffin mortar and gypsum with 25% beeswax mortar. The percentage of PCMs is selected based on the best result obtained from thermal analysis using ANSYS.

Dimension: cubes with size 7.06 x 7.06 x 7.06 cm are used and boards with size 20 x 20 x 2cm.

Molds Preparation: Clean the molds thoroughly and apply a thin layer oil to prevent sticking.

Filling Molds: Pour the prepared mixture into the molds, ensuring it is evenly distributed and compacted to remove any air voids.

Compaction: Compact the mixture to ensure uniform density and remove any entrapped air bubbles.

Curing: Allow the cast specimens to cure by drying. Demolding: After the specified curing time, carefully demold the specimens from the molds. Take care not to damage the specimens during this process.

Labeling: Label each specimen with relevant information such as the mix design, casting date, and any other pertinent details.

6.1 COMPRESSION TEST RESULTS

Table-1: Compressive strength of different combinations

Sl No.	1	2	3
Materials	Gypsum	Gypsum + Paraffin	Gypsum + Beeswax
Age (Days)	3	3	3
Weight (gm)	472	477	470
Load (KN)	61.62	25.83	38.3
Average Strength (N/mm^2)	12.36	5.17	7.68

From table-1 we can see results obtained from compression test of cubes of gypsum, gypsum + 25% paraffin and gypsum + 25 % beeswax. The weight and load obtained is taken for average of 3 cubes. The results show that gypsum cube had greater compressive strength compared to other two combinations. But gypsum boards incorporated with PCMs can used as facades and non-load bearing structures.

7. CONCLUSIONS

- The use of thermal controlling devices and appliances are consuming a large amount of energy to keep the temperature within comfort range.
- The use of PCM in new and refurnished buildings can decrease the energy consumption.
- This project highlights the effectiveness of thermal controlling after incorporating paraffin wax and beeswax (PCMs), the most commonly found, cheap and easily available material
- By comparing the minimum temperature chart we can see that there is a minimum temperature in the combination of Gypsum + Paraffin which is preferable.
- Beeswax is a non-toxic material but it's thermal conductivity low compared to Gypsum + paraffin combination.
- These findings can serve as a valuable resource for researchers, architects and engineers.

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