Natural and Forced Convection Strategies for Energy-Efficient Buildings Inspired From Termite Mounds

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ABSTRACT

- Buildings are responsible for the annual consumption of 40 percent of the world's energy. So there is a need to provide energy-efficient building designs.
- The potential of natural and forced convection techniques in buildings should be implemented to reduce energy consumption.
- It is found that by integrating passive solar design strategies, energy-efficient equipment, and renewable energy sources, energy-efficient buildings can effectively optimize energy usage and reduce dependency on non-renewable energy sources.

PROBLEM STATEMENT

Rising global temperatures necessitate energy-efficient building designs. This study explores natural and forced convection strategies inspired by termite mounds to optimize energy consumption while ensuring comfortable indoor environments. The challenge is to harness these mechanisms effectively to reduce reliance on energy-intensive cooling systems.

OBJECTIVES

- The primary aim of the project was to study the temperature regulation in the termite mounds.
- To implement the techniques used by termite mounds to the residential rooms and buildings.

LITERATURE REVIEW

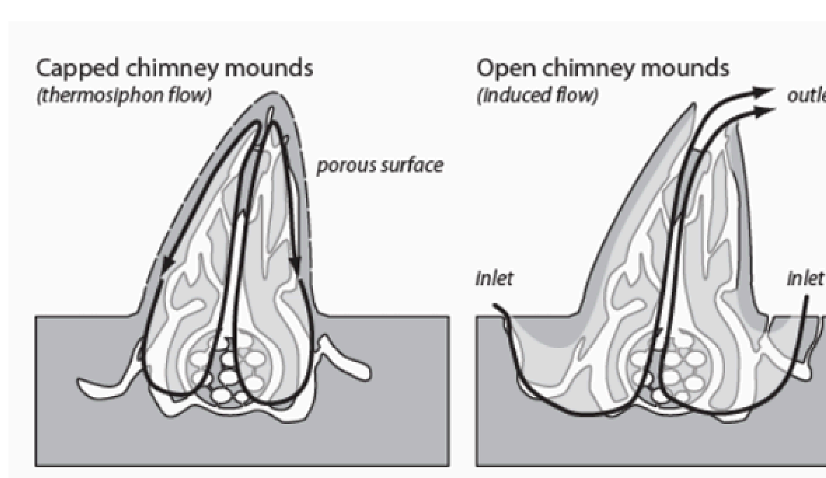

Fig-1

- Naturally inspired techniques can be used to develop strategies to reduce energy consumption in buildings.
- Here lies the concept of biomimicry: The technique of improving man-made systems by taking hints from the designs seen in nature such as termite mounds, Atriums, and courtyards, Jaalis, Jharokhas, etc.
- Planning a building so that windows, doors, and vents are positioned thoughtfully to promote natural airflow.

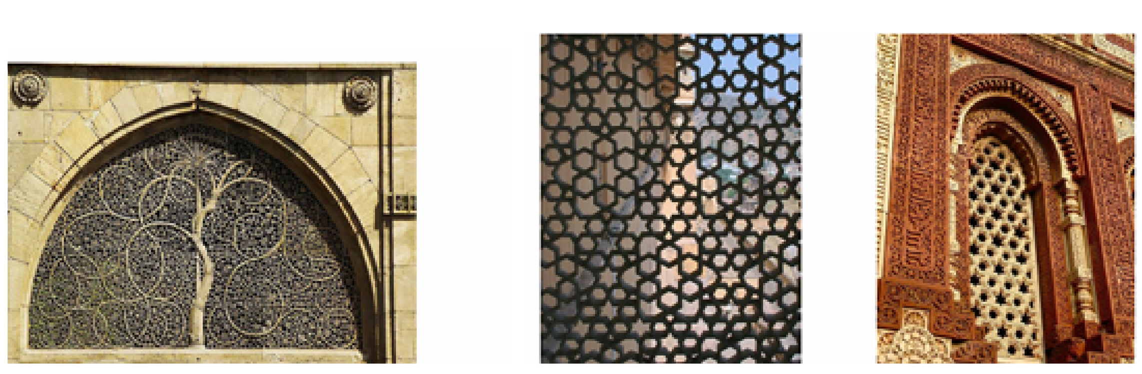

Fig-2

- Jaalis: While blocking off direct sunlight, 5 the jaali's elaborate lattice structure lets diffused sunshine inside the building. This keeps the interiors of the building colder by reducing solar heat gain
- Atriums and Courtyards: By allowing hot air to escape, these open spaces offer shade and cooling via evaporative processes.

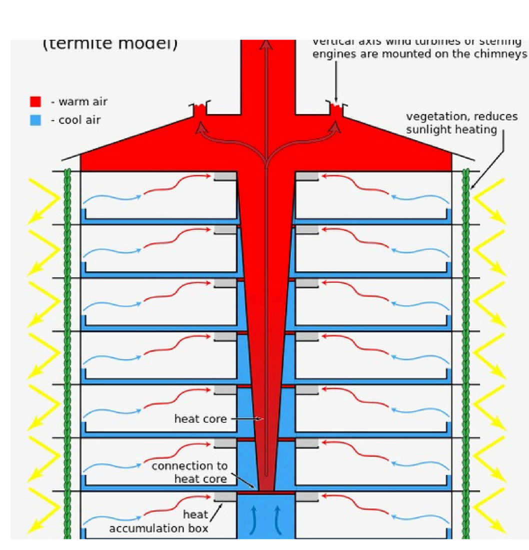

Fig-3

- Eastgate uses 35% less total energy than the average consumption of six other conventional buildings with full HVAC in Harare. The saving on capital cost compared with full HVAC was 10% of total building cost. During the frequent shut downs of mains power, or of HVAC due to poor maintenance in the other buildings, Eastgate continues to operate within acceptable comfort levels with its system running by natural convection.
- The Earth Air Tunnel (EAT) system is a passive cooling and heating technique can be used in building design to reduce energy consumption. It involves the use of underground tunnels or pipes to pre-condition fresh air before it enters the building's ventilation system.

SIMULATION DETAILS AND THEIR RESULTS

- We performed simulations of 2-D termite mounds using ANSYS Fluent. We studied the temperature variations inside the mound. We considered a closed-capped mound with a room and metabolic heat generation inside it.

Simulation of Closed Capped Mound:

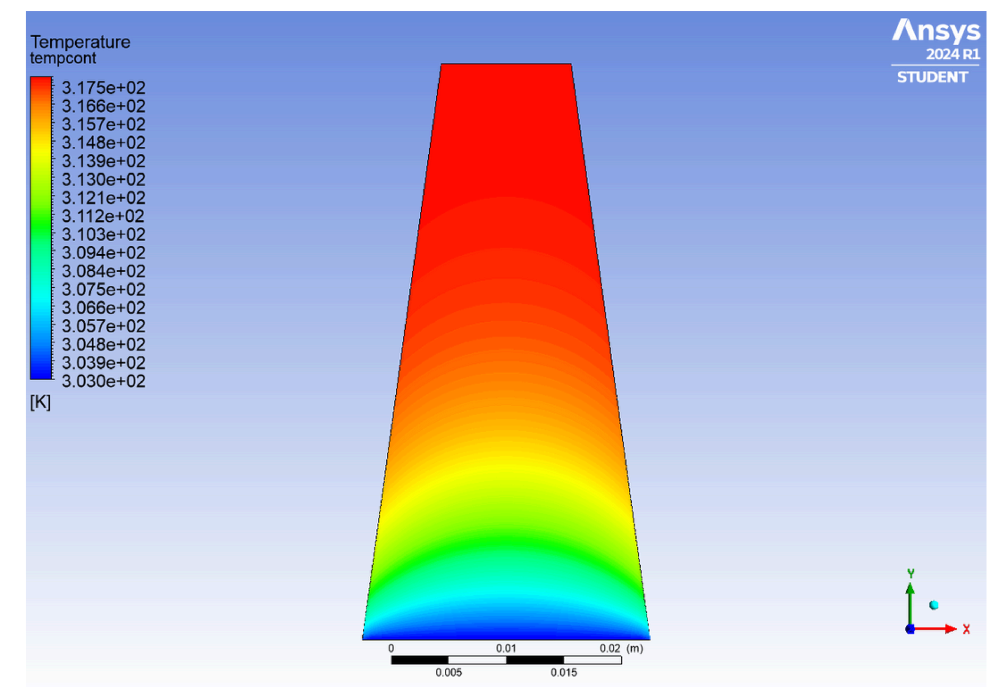

Fig-4

Observing the conical mound, it becomes apparent that its base maintains a temperature of 303 Kelvin (K). Moving upward, the temperature gradually rises, reaching 317.5 K at its peak as one would expect. Figure shows the heat transfer coefficient along the outer wall. Remarkably, the value obtained, standing at 3.84 $W/m\ K$, gives us the validation of the numerical result with the analytical value.

Simulation of a mound with a room:

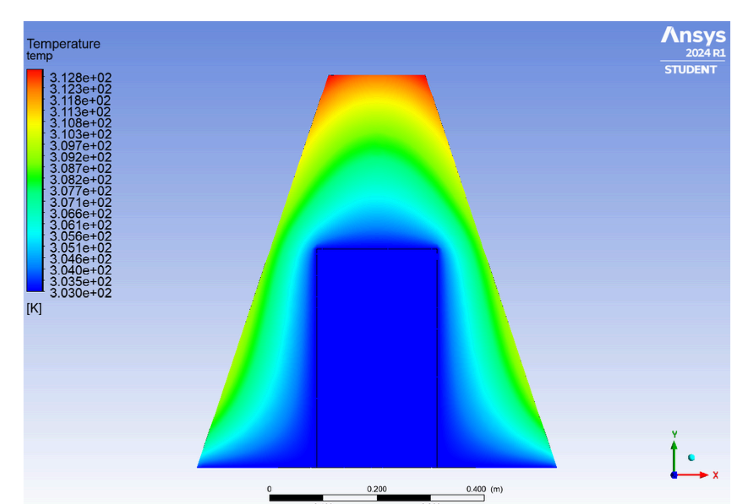

Fig-5

1) The temperature profile became more refined, showing alterations in thermal distribution throughout the mound.
2) When we compared the updated temperature profile with a closed capped mound, we noticed a considerable change i.e. the cooler area expanded considerably, while the region with higher temperatures contracted and became primarily concentrated at the top of the mound.

Simulation of a mound with a room and heat source:

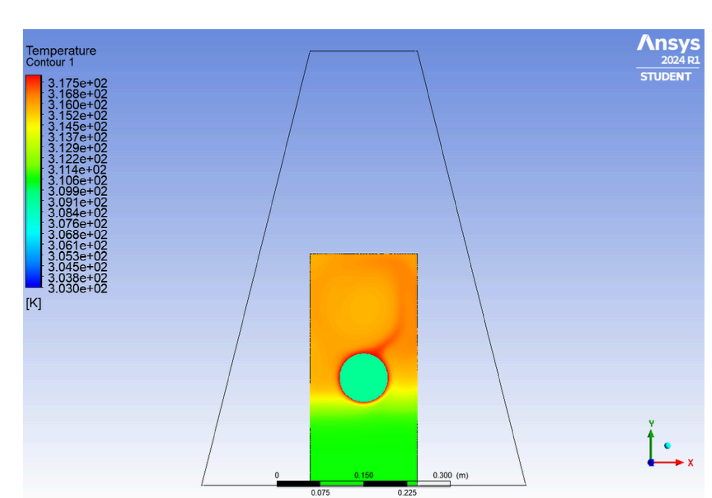

Fig-6

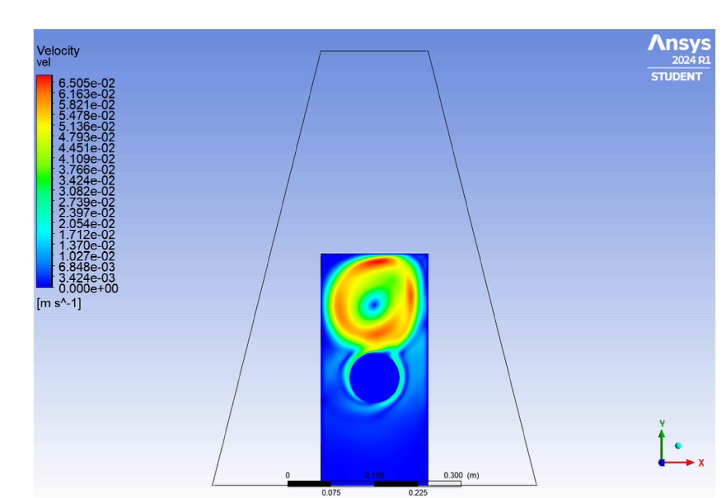

Fig-7

Implementing the study of termite mounds to a residential room:

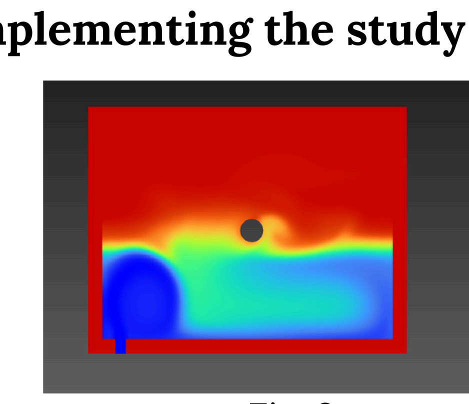

Fig-8

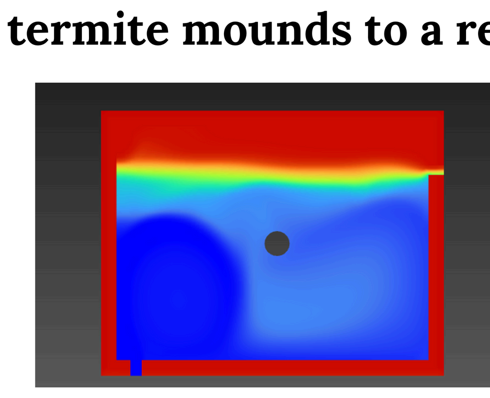

Fig-9

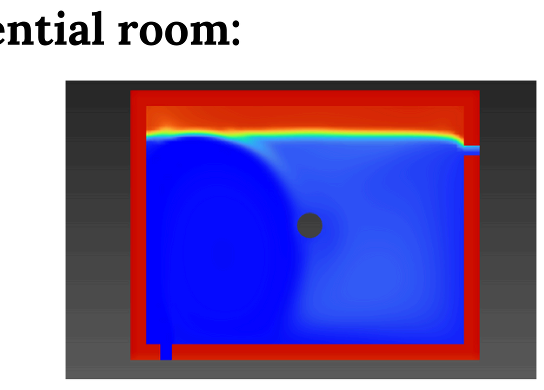

Fig-10

- In Fig.8 We monitored the temperature profile inside the room every 60 seconds. After solving the model for the first 60 seconds, we got the following profile inside the room. Where the major area of the room is hot. Since the cold air will first start to cool the area closer to it.
- After 180sec, In Fig.9 We can see a major part of the room is cooled After 360sec, In Fig.1o.The room is fully cooled. A normal residential room of 4*3m needs a flow rate of 0.07m^3 per cool(303K) air in 6min.

CONCLUSION

By doing the project, we analyzed how the termite mounds regulate the temperature inside the mound. We then implemented those techniques in the residential rooms and buildings. We then plotted the temperature profile inside the room and calculated the amount of time required to cool the whole room with cool air at 303K as velocity inlet. The EastGate Center has implemented a similar technique which saves 35% of energy as compared to the HVAC System. Hence, by implementing the forced convection method we can reduce the energy requirement to cool the buildings.

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