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Efficient Cooling Using Terracotta

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***Abstract*: This study explores the application of terracotta tubes for efficient cooling using the evaporative cooling method. Terracotta, a porous ceramic material, naturally absorbs and holds water. When water stored within the terracotta structure evaporates, it absorbs heat from its surroundings, creating a cooling effect. This principle is applied in terracotta tubes, which act as passive cooling systems in buildings, greenhouses, or outdoor spaces, reducing the need for energy- intensive mechanical cooling methods. Through systematic analysis, the research assesses the cooling efficiency, water retention capacity, and environmental impact of terracotta-based systems, demonstrating their viability as a sustainable, low-cost alternative for cooling in arid and hot climates. The findings contribute to sustainable architecture and green building technologies, providing insights into eco-friendly design practices that capitalize on natural materials and passive cooling techniques.**

***Keywords*: terracotta tubes, efficient cooling, evaporative cooling, energy efficient, passive cooling system, eco-friendly design, cost effective solutions.**

1. Introduction

Terracotta mud, a type of clay-based material, has been used for centuries in art, architecture, and daily life due to its durability, aesthetic appeal, and accessibility. Derived from the Italian word "terra cotta," meaning "BAKED EARTH," it becomes hard and durable once fired at high temperatures in a kiln. Terracotta clay is typically rich in iron, which gives it its characteristic reddish-brown colour after firing.

Modern uses of terracotta range from flowerpots and cookware to architectural elements like bricks and tiles. Known for its eco-friendly and sustainable qualities, terracotta remains popular in various crafts and contemporary design due to its rustic and earthy aesthetic.

Terracotta, a type of ceramic material made from fired clay, has gained attention in recent years for its potential role in enhancing evaporative cooling systems. Terracotta is a porous material that can absorb and retain water, and when incorporated into architectural and cooling designs, it can help regulate temperature and improve air quality through its cooling properties.

Evaporative cooling is a natural process in which water absorbs heat from the air and evaporates, lowering the ambient temperature. This technique is widely used for climate control in buildings, especially in arid or hot environments where conventional air conditioning can be energy- intensive and costly

India has been grappling with an unusually severe and prolonged heat wave in 2024, with record- breaking temperatures that have Reached up to 48°C in some regions, especially in north-western areas like Delhi and rajasthan this year's conditions have been exacerbated by both human-induced climate change and a stronger-than-average El Niño. These factors combined have led to extreme temperatures that are particularly dangerous due to high humidity, which impairs the body's ability to cool down. In major cities, this problem is worsened by the urban "heat island" effect, where dense infrastructure further traps heat.

This ongoing heat wave underscores the urgent need for climate resilience measures to protect people and mitigate the impacts of future extreme weather, as these events are likely to become more common without significant climate action.

2. Scope of Study

Efficient Cooling Using Terracotta, aims to develop a natural and sustainable cooling system using the evaporative cooling properties of terracotta. With India experiencing severe heatwaves every year, this study focuses on utilizing terracotta's ability to absorb water and cool air naturally, reducing dependence on energy-intensive air conditioners. This will help minimize environmental pollution caused by CFC emissions and lower electricity consumption.

The project will explore the design and optimization of terracotta-based cooling systems, such as panels or walls, to maximize efficiency. It will also examine how these systems can be integrated into homes, offices, and industrial buildings. Prototypes will be developed and tested to evaluate performance, and a comparison with traditional cooling methods will be conducted to highlight the environmental and economic benefits. By promoting the use of terracotta, the project aims to provide a cost-effective, eco-friendly solution to combat rising temperatures while reducing energy consumption and pollution.

3. Objectives

1. To understand the thermal properties of terracotta and its cooling mechanism.
2. To evaluate the efficiency of terracotta-based cooling methods in modern applications.
3. To promote eco-friendly and sustainable cooling solutions

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inspired by ancient techniques.

4. To provide an alternative that can complement the existing air conditioning solutions and reduce their load on energy.

4. Materials & Methodology

A. Operating Principle

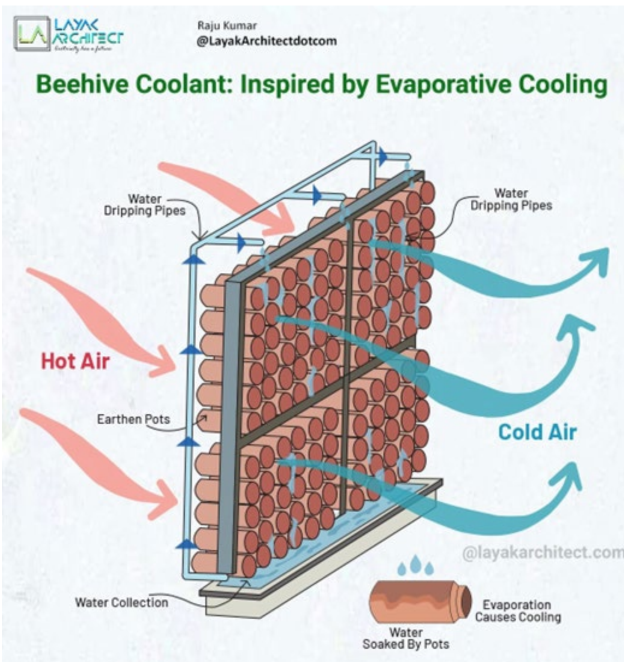

Fig. 1.
Source: Layakarchitect.com

This cooling system is truly based on evaporative cooling. "Evaporative cooling is a process in which a liquid (usually water) absorbs heat to transition into a gas (vapor), thereby lowering the temperature of the surrounding environment". This occurs because the liquid molecules with the highest energy escape as vapor, taking heat away from the remaining liquid, which cools down as a result.

As in the fig 8 the arrangements are made that the terracotta tubes are placed in a beehive pattern, pump and pipe connections are made to flow the water down ward so the terracotta tubes become wet and this arrangement is very useful as water is reused. When the warm air passes through these tubes the warm air is converted to cool and pleasant air due to evaporative cooling.

This system will work continuously as water is reused so no refilling of water is required and also it is energy efficient as it involves a 18 watt submersible pump which needs less electricity.

B. Materials

In our project terracotta tubes are the major material which are made with terracotta clay, basically it is in cylindrical structure which has large opening at one side and a small opening at the other side, the structure is so because when the natural warm air passes through the large opening it get condense and due to evaporative cooling the air coming out will be comparatively cool. These terracotta tubes were made by potters in kalaburagi as we informed him about our project work and all the dimensions then they designed this tubes according to our considerations and it took almost 2 weeks to prepare these pots as it requires high skill and time to complete. Also the process involves making of clay tubes and then dried under sun for 4-5 days after completely dry these are burnt in kiln at 1000°c-1400°.

Steel frame is one which holds the tubes in position and also in a beehive pattern, which helps the system to be cool and it is a easy way to transfer water to all the tubes using this effective steel structure. Firstly we took the accurate size of the window where this setup is being placed and then we instructed the frame maker that we require the frame for the project and as per our requirements he made the frame.

The water storage tank is essential as the water is circulated all through the structure. The water tank provides a steady supply of water for prolonged cooling without a tank we would have to frequently fill the tank which will interrupt the cooling process. The water in the tank can be cooled or even chilled (using ice packs) which further enhances the cooling effect. This is especially beneficial in hot, dry climates. The water storage tank was made with the iron sheet which was mould into the shape.

A 20 watt submersible pump is used to circulate water from the water tank to the terracotta tubes. The pump draws water from the tank and distributes it to the top of the structure. Gravity then lets the water flow down through the tubes, keeping them moist. Since the tubes need to stay wet for optimal cooling, a submersible pump provides continuous water flow, ensuring the tubes remain moist as long as it runs. Submersible pumps are generally low-power devices, so they consume minimal energy, helping keep operational costs low.

Fig. 2.

Pipes in this system play a critical role in water distribution, and circulation. Pipes are used to direct water from the tank to the top of the structure. As the pump moves water, these pipes guide it evenly across the tubes, ensuring a uniform flow to keep the tubes consistently wet. Pipes connect the submersible pump to the tank, allowing water to flow through the system effectively. They help maintain a closed system where water can be circulated without leaks.

Temperature meter is a handy tool used to measure temperature in various places without any human efforts. It not only measures but gives accurate temperature without errors. In this project will fix this meter to measure the surrounding temperature and note the temperature hourly.

C. Assembly of Prototype

The assembly is simple as the terracotta tubes are fixed in the gaps provided in the steel frame as shown in the Fig. 3 the tubes are placed in a same manner that all the large openings of should be in one frame and the steel frame measures 1 m in length, 0.20 m in width and 1.2 m in height, then the steel frame is placed in the water storage tank(e) (the dimensions of tank is 1m in length, 0.25m in width ,and 0.25m in height) and then it is fixed with bolts then all the necessary pipe connections are made and the pump is submersed in the water tank. Now the model was kept in the window of our college Geotechnical laboratory and it was tested as shown in Fig. 4.

Fig. 3.

Fig. 4.

5. Experimental Results and Discussion

A. Study of Room Temperature

This section of the study examines the variations in air temperature and humidity within the test room to determine a stable period for these parameters, which is crucial for the accuracy and reliability of parametric tests, daily temperature and humidity fluctuations were monitored over 1 week, revealing a distinct pattern: temperatures increase throughout the day, peaking around 3 PM, while humidity levels decline inversely, reaching their lowest point at the same time. Notably, air conditions stabilize between 2:30 PM and 5:00 PM, during which both temperature and humidity show minimal fluctuations. Consequently, this timeframe was selected as the optimal period for conducting parametric tests. By ensuring stable air conditions during this window, the accuracy and reproducibility of the findings are significantly enhanced.

We kept our project setup for observation. We have noted the temperature both room temperature and outside temperature so as to compare both by plotting graph as time vs temperature the results for the test are as fallows.

Table 1

Description of the construction materials

S.No.	Materials	Quantity	Specifications	Notes
1	Terracotta tubes	1	Thick: 0.5 mm Length:0.20 m Dia: large-0.09 m small-0.06	As an important material needed for the project
2	Steel frame	1	1 by 1.2 m	Used to hold the terracotta tubes
3	Water storage tank	1	Length: 1 m Width: 0.25m Height: 0.25m 64 liters	It is used to store the water
4	Submersible pump	1	20 watts	It is submersed in the water tank and will supply water throughout the tubes
5	Pipes and junctions	1	Dia 0.01m Length: 4 feet	It is used to connect the pump and necessary connections using junction
6	Digital temperature meter	2		Used to note the temperature both room temperature and outside temperature

On the day 1 i.e., on 27/12/2024 we started our project testing and the following results were observed.

Table 2
Day 1: 27/12/2024

Time in Hours	Outside Temp in °c	Room Temp. In °c	Difference in Temp in °c
12:00 PM	27.7	27.8	0.1
1:00 PM	28.8	26.4	2.4
2:00 PM	29.4	24.6	4.8
3:00PM	29.2	25.5	3.7
4:00 PM	28.8	24.6	4.2
5:00 PM	28	24.3	3.7

For the above reading graph is plotted as below.

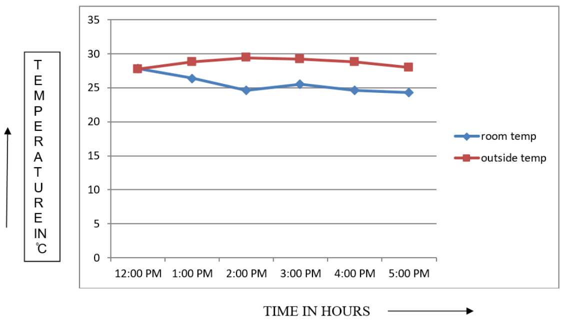

Fig. 5.

Table 3
Day 2: 28/12/2024

Time in Hours	Outside Temp in °c	Room Temp in °c	Difference in Temp
10:00 AM	28.8	28.7	0.1
11:00 AM	26.6	25	1.6
12:00 PM	27.5	25.2	2.3
1:00 PM	28.5	25.5	3
2:00 PM	29.4	25.2	4.2
3:00 PM	29.3	24.5	4.6
4:00 PM	28.8	23	5.8
5:00 PM	28.6	23.2	5.4

Graph is shown for the above table.

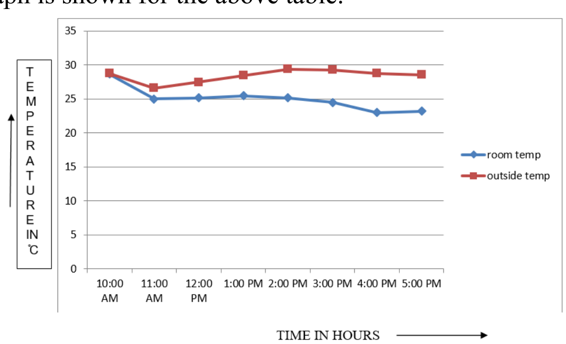

Fig. 6.

Table 4
Day 3: 31/12/2024

Time in Hours	Outside Temp in °c	Room Temp in °c	Difference in Temperature
10:00 AM	26.6	26.3	0.3
11:00 AM	27.2	25	2.2
12:00 PM	27.7	25.1	2.6
1:00 PM	28.8	24.3	4.5
2:00 PM	29.4	24.1	5.3
3:00 PM	29.3	23.2	6.1
4:00 PM	28.8	22.7	6.1
5:00 PM	28.4	22.9	5.5

Graph is shown for the above table

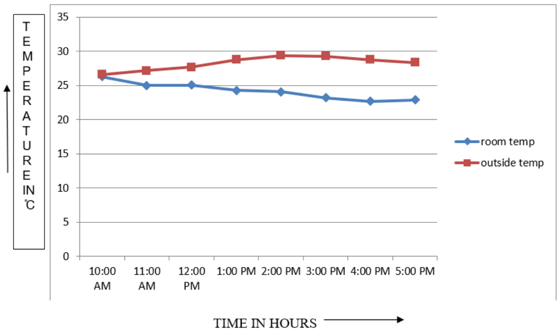

Fig. 7.

Table 5
Day 4: 2/1/2025

Time in Hours	Outside Temp in °c	Room Temp in °c	Difference in Temperature
10:00 AM	29.8	26.4	3.4
11:00 AM	27	24.8	2.2
12:00 PM	28.1	25.7	2.4
1:00 PM	29.6	24.9	4.3
2:00 PM	28.5	23.6	6
3:00 PM	26.5	24.6	3.6
4:00 PM	26.2	23.5	2.9
5:00 PM	25.6	22.7	2.9

Graph for above table is shown below.

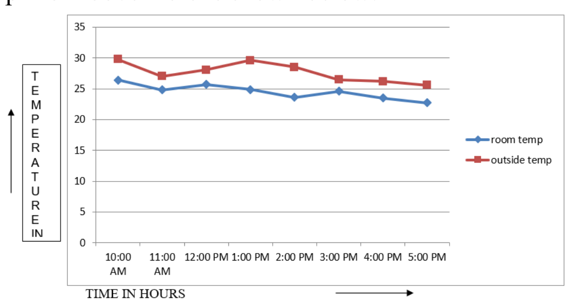

Fig. 8.

Table 6
Day 5: 6/1/2025

Time in Hours	Outside Temp in ℃	Room Temp in ℃	Difference in Temperature
10:00 AM	28.5	24	4.5
11:00 AM	28.1	22	5.2
12:00 PM	27.7	21.7	6
1:00 PM	29.4	23.1	6.3
2:00 PM	31	23.3	7.7
3:00 PM	30.2	21.3	9
4:00 PM	26.8	18.9	7.9
5:00 PM	26.1	17.4	8.7

Graph for above table is shown below.

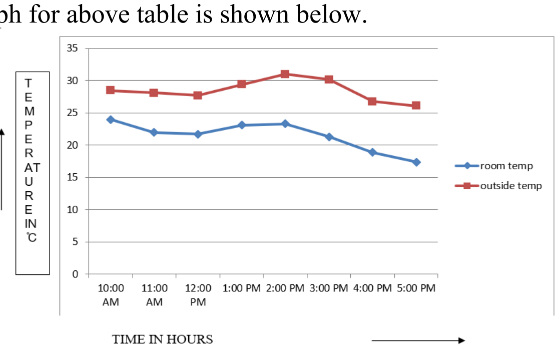

Fig. 9.

Table 7
Day 6: 7/1/2025

Time in Hours	Outside Temp in ℃	Room Temp in ℃	Difference in Temperature
10:00 AM	26.8	26.7	0.1
11:00 AM	27.5	22	5.5
12:00 PM	27.8	21.9	5.9
1:00 PM	28.6	22.4	6.2
2:00 PM	28.9	22.6	6.3
3:00 PM	28.1	21.5	6.6
4:00 PM	27.4	21	6.4
5:00 PM	26.8	20.7	6.1

Graph for above table is shown below.

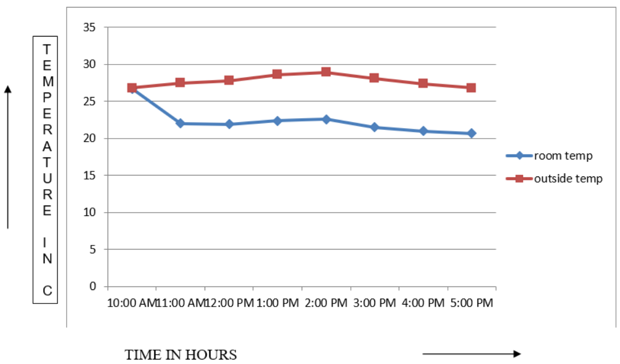

Fig. 10.

Table 8
Day 7: 10/1/2024

Time in Hours	Outside Temp in ℃	Room Temp in ℃	Difference in Temperature
10:00 AM	24.8	24.7	0.1
11:00 AM	26.7	24.6	2.1
12:00 PM	28.4	23.2	5.2
1:00 PM	29.8	23.3	6.5
2:00 PM	29.6	23.2	6.4
3:00 PM	28.9	23.7	5.2
4:00 PM	28.6	23.5	5.1
5:00 PM	28.5	23.1	5.4

Graph for the above table is shown below.

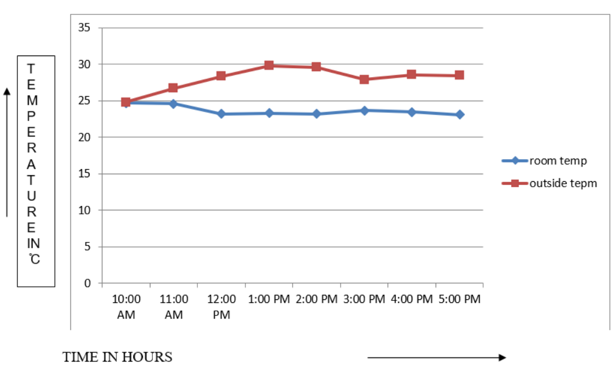

Fig. 11.

Table 9
1-week average graph

Time in Hours	Avg. Outside Temp in ℃	Avg. Room Temp in ℃	Avg. Difference in Temperature
Day 1: 27/12/2024	28.6	25.5	3.15
Day 2: 28/12/2024	28.4	25.03	3.4
Day 3: 31/12/2024	28.2	24.8	3.4
Day 4: 2/1/2025	28.0	24.5	3.5
Day 5: 6/1/2025	28.4	21.5	**6.9**
Day 6: 7/1/2025	27.7	22.3	5.4
Day 7: 10/1/2025	28.1	23.6	4.5

The graph for above table is shown below.

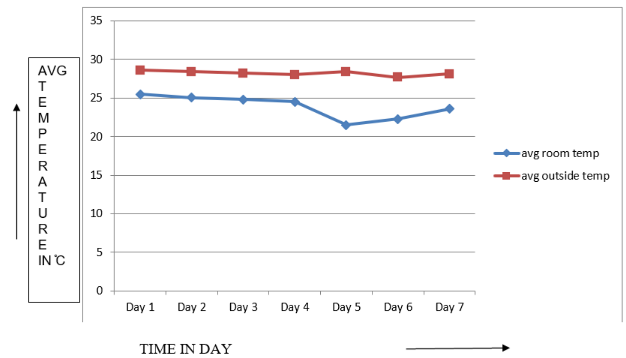

Fig. 11.

6. Analysis of Quantity Water Used

The water storage tank was used in order to supply water although the project model using pump and pipe connections and below are the quantity of water used for the project per day.

Dimensions of the storage tank.
LENTH = 100 CM
BREADTH = 25.4CM
HEIGHT = 25.4 CM

Calculating the volume,
L X B X H
i.e., 100*25.4*25.4 = 64,516 cm^3

Now calculating the capacity of tank in liters.
Since 1 liter = 1000cm^3 convert volume to liters.
Volume in liters= 64900/1000= 64.5 liters.

For the project we have used only 40 liters of water which was sufficient for 3-4 hours and due to reusing of water lot of water was saved.

Despite some loss of water was seen as some leakage was occurred so 5 liters of water was going waste.

7. How Energy and Cost Effective is it

This structure is cost effective as it involves few materials and no other helping equipment's are required as compare to other cooling machines like AC, coolers, etc.

On an average in India 1.5-ton AC is used commonly, so the price of these AC is 30000- 50000 rupees.

After installing it has some maintenance cost which will increase day by day and also it has some service or repair cost.

On an average the daily consumption of AC is 6-8 hours, Average power consumption is 1500watts/HR=1.5 unit/HR,

Power consumption per day 8x1.5=12 units per day and 360 units per month and cost of one unit in Karnataka is 7rs.

AC contributes 4320rs per month, and yearly 51840rs.

In summers daily consumption may increase upto12 hours per day!

But this setup involves only a pump which is of 18-25 watts which will be 0.02 units per hour, and 0.3 units per day and 9 units per month which will be 63rs per month and 756rs per year.

So, this mechanism can provide cool air with least expense. This above information is taken from Bajaj Finserv.in

8. Conclusion

- The objectives aim to explore the thermal properties and cooling mechanism of terracotta, evaluate its efficiency in modern applications, and promote eco-friendly, sustainable cooling solutions inspired by ancient techniques. Additionally, they seek to provide an alternative that complement existing air conditioning systems while reducing energy consumption.
- The project successfully achieved the temperature reduction about 9 degrees on 5th day and continuously reduces the temperature min of 3-4 degree compare to the outside temperature.
- The findings indicate that the terracotta tubes help to reduce the temperature by means of evaporative cooling as temperature is reduced compare to normal atmospheric temperature.
- Despite facing challenges such as finding an alternate way of solutions as to find cheaper material transportation and many other challenges to overcome.
- In conclusion this project has provided valuable insights into cooling system by terracotta and contributes meaningfully to environmental solutions.

9. Scope of Future Study in Terracotta Based Cooling

The scope of future studies in terracotta-based cooling lies in several promising directions. One key area is the optimization of material properties, such as enhancing porosity for improved evaporative cooling while maintaining structural integrity. Research can also explore hybrid materials that combine terracotta with other eco-friendly substances to boost efficiency and durability. Another critical avenue is improving water retention methods to minimize water usage, making the system more sustainable. Furthermore, integrating terracotta-based cooling systems into modern urban designs, such as building facades and outdoor public spaces, could revolutionize passive cooling strategies, especially in urban heat islands. Advances in computational modeling and thermal performance analysis will also play a crucial role in optimizing these systems for diverse climatic conditions and applications.

10. Future Trends

1. Integration with green buildings: Terracotta based cooling systems will be incorporated into green building designs reducing energy consumption and promoting sustainable architecture.
2. Retrofitting existing buildings: Buildings owners will retrofit existing structures with terracotta-based cooling system to improve energy efficiency and reduce cost.

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