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Modification over the Standard Use of Plastic Bottles to Provide Natural Ventilation for Residential Buildings

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ABSTRACT: Summer season has never been easy going in Indian states such as Rajasthan, Madhya Pradesh, Maharashtra and other western states. In this hot, dry summer there has been a gradual increase in the temperature levels due to the intense heat waves which takes over many parts of the India, killing hundreds of people and making lives uncomfortable for others. People of weaker section living in dry and drought affected areas are conceived to be the worst hit.The focus of this paper is on possibilities of developing a system that will cool the air in a natural, economical, and environmental friendly way. This may be achieved by assembling a system comprising of plastic bottles on a sheet to provide ventilation and reduce temperature of the room. The main objective here is to check the feasibility of such a system and to verify its working. This might provide relief to economically weaker section of society.

Keywords-Air Temperature, Cooling techniques, Eco-friendly, Plastic Bottles, Ventilation.

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I. INTRODUCTION

Ventilation is the process of changing air in an enclosed space. A proportion of air in the space should be continuously withdrawn and replaced by fresh air from outside to maintain the required level of air purity. [1] During the summer season there is a gradual increase in the temperature levels due to the intense heat waves which take over many parts of the India. Due to rapid increase in industrialization as well as population, there has been a rise in pollution levels as people are using Water-coolers and Air Conditioners to cool indoor air. These mechanical equipments not only contribute to global warming, but also consume high amounts of power. The use of plastic bottles to reduce indoor air temperature and reduce waste generated by leftover plastic seems like an appropriate solution.

It works on the principle of compressing air, where hot air gets converted to preferably cool air. This concept is taken from early age architecture. In places like, Fateh-pur sikri fort, Boondi fort, Kota Mahal, Amer (Amber) Fort, excellent ventilation techniques were provided to cool the inside environment. [2] In Fateh-pur Sikri Fort they have used Chattar (Chatri) placed on top of roof through which air enters the palace room in a culvert like structure which goes on decreasing in size as it reaches the room. Here, air was compressed in the duct and passed through surrounding heavy stones such as Rhyolite which ultimately cooled the air. This surrounding medium is beneficial to cool the air as the molecules travel through the duct into the room.

The plastic bottles (open from both ends- mouth and base) are placed at regular intervals on a plate of appropriate dimensions to be fitted in the ventilation opening of house. Such use of plastic bottles has previously been done in Bangladesh, by the name of Eco-cooler, to provide relief from high temperatures. [3]

In this paper, we have tried to use this ancient technique in modern architecture to provide relief from high temperature up to some extent. And we have successfully shown the reduction in temperature by the use of this cooling plate.

1.1 Problem Statement

The focus of this paper is on possibilities of developing a system that will cool the air in a natural, economical, and environmental friendly way. This will be done by using used plastic bottles, to reduce temperature of the surrounding.

1.2 Working Principle

The system works on the Joules Thomson principle which describes the change in temperature of gases by sudden contraction and is a great theory to validate the concept.

Another concept to give credibility to this theory is Bernoulli's theorem, **o**n the basis of velocity and pressure relation obtained from Bernoulli's equation; if the area is decreased then

velocity will increase. Therefore, pressure will decrease resulting in lowering the temperature.

II. DESIGN OF PLATE

The plate consists of a frame and plastic bottles placed at regular intervals.

2.2 Plastic bottles

Plastic bottles are cut from bottom part and act as a wide opening which allows entering of air into the plate. The narrow end (mouth) of the bottle provides sudden contraction and therefore will be on the interior side of plate which is facing the room. Plastic bottles will be of cold drinks or soft drinks (example- mineral water bottle, soft drink bottles) which can be reused here, in an economical way to support cooling of air in the living area.

2.2 Materials used to build frame-

1. Thermocol – for simulation model testing
2. Layer of sand-cement, talc, limestone sandwiched together – for testing in permanent houses

2.2.1 Styrofoam – Thermocol sheets are made of expanded polystyrene beads. Polystyrene is a synthetic aromatic polymer madefromthe monomer styrene. [4] Styrofoam or thermocol sheet is an inexpensive material and an excellent insulator. The material limits thermal transfer. Thus, a structure insulated with Styrofoam will maintain a comfortable temperature inside, regardless of the conditions on the outside. [5]

Thermocol sheets are used in this project to make a dummy model, with the sole purpose of testing and understanding the working principle.

Assembly-

12 bottles were affixed in this thermocol sheet of size (36 x 72) cm and the base diameter of bottles was 9cm, mouth diameter 1cm, and height of bottle after cutting the base was 26cm.

2.2.2. Sandwich plate – Frame modification was made, to the Styrofoam (Thermocol sheet) by introducing different layers of cooling material. By the word sandwich we mean, an arrangement of layers of such cooling materials, one over another in respect to their use.

The very first layer from inlet side (cut open base of bottles) which runs along the exterior side of the house comprises of cement mortar in ratio 1:5. This layer ensures a stiff base to the structure and also reduces transfer of thermal effect in the plate. This layer is then followed by a thermocol sheet on top of it which acts as a barrier in transfer of heat. As per research, certain buildings like provide gaps in their walls to trap the excessive heat waves. Likewise, we provided adequate spacing, just after the thermocol sheet, to trap the excessive heat. Throughout our whole modification, our aim was to reduce the heat effect, thus right after the gap we have used limestone powder along with talc ore powder- which here act as natural coolant. Although there is no scientific research available which verifies that limestone can also be used as a cooling material, but the fact that limestone was used on large extent for passive cooling in early era architecture supports our strategy that it can be recommended as a cooling material. Talc being a metamorphic rock is used as a cooling material so a small portion of talc was added to limestone.

The modus operandi for construction of this sandwich plate was mainly dependent on various alterations that can be made to nullify the thermal effect by providing suitable surrounding medium. These different layers one by one have either reduced the thermal effect or acted as a cooling medium to the air entering at inlet.

This sandwich plate is a unique thought of creating a model which consists of important cooling materials that can be effectively used. Sandstone, Limestone and Talc are sedimentary rocks used as natural coolants. The cement-sand (1:5) layer blocks the heat from entering inside. As talc cannot be used individually due to its low binding property, it is mixed with limestone and then applied. And after proper finishing with a layer of Plaster of Paris, it appears aesthetically good.

Assembly-

Cement mortar – 2.4 cm thick
Thermocol used as an insulator – 0.4 cm thick
Cement mortar – 2.4 cm thick
Void layer – 5 cm thick
Talc and limestone mix – 7.6 cm thick
12 bottles were used to make this plate. The base diameter of bottles was 9cm, mouth diameter 1cm, and height of bottle after cutting the base was 26cm.
Size of this sandwich plate was (57 x 45) cm with a thickness of 17.8 cm.

III. SIZE OF PLATE

The size of plate or ventilation shaft depends upon various factors which are described in IS 3362-1977, but the plate designed by the team was of size (45 x 60) cm or [1.5 x 2] ft, was only used for testing purpose. As the size of ventilation varies, the number plates can be added or subtracted to cater our needs. The size used here was for ease of testing and only to verify the principle.

IV. TESTING & RESULTS FOR STYROFORAM PLATE

Thermocol plate for simulation model testing –To prove the working of model and justify the working principle, we first conducted testing on a prototype of model i.e. on Styrofoam sheet, which consists of 12 plastic bottles installed in a thermocol frame.

As this preliminary test was conducted in January 2017, when the temperature was low (about 25°C to 28°C), so to create a warm environment in the testing room, a halogen light and heater coil were used. The room was isolated, packed and the temperature was made to rise and warm air was circulated using a table fan. The room temperature was maintained and room was isolated. Then the warm air was made to pass through the test box, from the face of plate which consisted of the base of bottles (rear end).

Dimensions of test box- (60 x 75 x 40) cm
Number of bottles- 12
Size of thermocol sheet- (36 x 72) cm
Base diameter of bottle- 9 cm
Mouth diameter- 1 cm
Height of bottle after cutting the base- 26 cm

The observations from the test made it apparent that our theory was crystal clear, the phenomenon of change in temperature by sudden expansion and sudden contraction occurs and thus further improvements can be implemented by alteration in this basic model.

The results obtained were quite satisfactory. The temperature inside the test box was measured after two minutes, a temperature difference of 4°C approximately was observed.
Thus, temperature variation was observed and the effect of test plate was verified.

Table 1- 6 days reading for thermocol plate by artificially heating the room

Date	Time of testing	Temperature at inlet °C	Temperature at outlet °C	Change in temp. °C
18-1-17	3:00 pm	42	37.9	4.1
	4:00 pm	40	35.6	4.4
	5:00 pm	38	33.2	4.6
	5:30 pm	36	31.4	4.6
19-1-17	3:00 pm	45	41.2	3.8
	4:00 pm	43	38.2	4.4
	5:00 pm	41	37	4
	5:30 pm	39	35.2	3.8
20-1-17	3:00 pm	35	31.3	3.7
	4:00 pm	30	25.6	4.4
	5:00 pm	39	34.9	4.1
	5:30 pm	44	39.7	4.3
21-1-17	3:00 pm	33	28.6	4.4
	4:00 pm	36	31.3	4.7
	5:00 pm	41	36.7	4.3
	5:30 pm	39	34.5	4.5
22-1-17	3:00 pm	29	26.2	2.8
	4:00 pm	31	27.1	3.9
	5:00 pm	35	31.0	4.0
	5:30 pm	40	35.8	4.2
23-1-17	3:00 pm	26	25	1.0
	4:00 pm	28	25.3	3.3
	5:00 pm	35	31.1	3.9
	5:30 pm	30.5	26.7	3.8

From this table we can generally observe that ambient temperature is always greater than the temperature at outlet of plate i.e. we have a noticeable cooling effect & the drop in temperature can be seen easily.

However, there can be variation in this data which can be accounted for by the convection effect arising from temperature difference between inside and outside the room, cloud covering and weather changes and thus, these values cannot be generalized.

V. TESTING & RESULTS FOR SANDWICH PLATE

After the principle was verified on the simulation model (Styrofoam plate) the Sandwich plate was installed next, and readings were recorded.

Dimensions of Sandwich plate- (57 x 45 x 17.8) cm
Number of bottles- 12
Base diameter of bottle- 9 cm
Mouth diameter- 1 cm
Height of bottle after cutting the base- 26 cm
The layer by layer division of the 17.8 cm thickness of Sandwich plate-

i. Cement mortar – 2.4 cm thick
ii. Thermocol used as an insulator – 0.4 cm thick
iii. Cement mortar – 2.4 cm thick
iv. Void layer – 5 cm thick
v. Talc and limestone mix – 7.6 cm thick

Table 2 - 10 days reading for month of May for Sandwich plate with wind speed data

Date of test performance	Wind speed, m/s	Temperature at inlet, °C	Temperature at outlet, °C	ΔT
14-5-17	2.0	39.0	32.7	6.3
15-5-17	2.4	40.5	34.6	5.9
16-5-17	3.0	38.2	31.6	6.6
18-5-17	1.8	37.5	31.5	6.0
19-5-17	1.0	39.5	33.4	6.1
21-5-17	1.4	38.5	32.8	5.7
23-5-17	2.6	37.0	31.0	6.0
25-5-17	3.5	39.8	33.4	6.4
26-5-17	1.6	38.3	31.8	6.5
27-5-17	2.4	37.2	31.1	6.1

From the above table we can easily notice that ΔT is in range of 5-7°C. The average ΔT was observed to be 6.16°C

VI. CONCLUSION

It is important to observe and analyze various techniques for passive cooling ventilation. In this paper we have successfully constructed two cooling plates- thermocol (Styrofoam) and Sandwich plate. We have verified the working of this plate as well as the principle of reducing thermal effect.

From the above readings, it can be seen that the Sandwich plate gives better results.

Average ΔT for,
Thermocol plate = 3.96 °C
Sandwich plate = 6.16 °C

This Sandwich plate may be employed as a permanent alteration in conventional ventilation system. We installed the Thermocol plate in tin-shade living space and Sandwich plate in residential apartment and it showed that this simple methodology can be implemented to provide a sigh of relief to the society.

We have assumed the angle of wind with bottle opening is 90°. Data is not available for conditions otherwise.

Variable factors- such as, number of people, working machinery, respiration rate, presence of indoor plants, etc.- inside the living space where a cooling plate is installed are not considered; hence these values cannot be generalized.

For the Sandwich plate, the testing was done in a residential area with ambient temperature, which was in the range of 37.0°C to 40.5°C for the given days, month and year. Thus, the data for other temperatures is not available.

The contribution to coolness (or reduction in temperature) due to individual layers of material in Sandwich plate is unknown.

The effect of variation in geometry, shape, and size of frame and bottles on temperature reduction is unidentified.

Future scope-

The minimum temperature outside, which is required for the working of this cooling plate to show reduction in temperature on the inlet side, can be computed.

Similarly, the minimum wind speed required to sense a cooling effect on the inlet side can be calculated.

Modifications possible in Sandwich plate as per our view-

The cooling effect from different materials (other than mentioned in this paper) can be studied.

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