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EXPERIMENTAL INVESTIGATION OF INLET DUCT ELEVATION ON THE INDOOR THERMAL ENVIRONMENT

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Abstract:
Air distribution is extensively used for thermal consolation. The distribution of air is necessarily non uniform with a few subzones withinside the occupied region cooler than the others, which differentiated the thermal choices of occupants. Non uniform air distribution can also additionally go to pot thermal consolation which make discomfort to the end user. This takes a look at proposes to make use of non-uniformity of air distribution to enhance the pleasure of thermal choices. This study investigated the air change effectiveness and temperature variation within a common close room using the air discharged through the circular tube type duct. The experiment has to be conducted with a conditioned air discharged through the duct maintained at different locations vertically withinside the test space. The test point is marked in test room at 1m distance from the duct position. The vertical temperature variation recorded using thermocouple ladder which placed at test point. Thermocouple ladder of 3m having 30 thermocouples set vertically on it at 10cm distance from each to collect the temperature readings is used in experiments. The present study gives the comparative study of temperature distribution along the conditioned air exhaust duct position and which support to examine the optimise location of duct withinside the closed room.

Index Terms: Thermocouple, ACE (Air Change Effectiveness), Mixing and Displacement Ventilation, Thermal Consolation, Test Position etc.

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I. INTRODUCTION

The subject of quit user, the thermal consolation and wholesome surroundings at low consumption of electricity is a final intention of heating, ventilation and air conditioning (HVAC) systems. However, in cutting edge society, the tempo of existence is rapid and paintings stress is increasing. The people have consequently prolonged their paintings durations withinside the workplace by spending approx 80% of their time in workplace. A certified workplace surrounding can enhance paintings performance, at the same time as defensive the fitness of workplace staff. By the previous research it is proven that once the workplace employees are happy with indoor surrounding, their work efficiency may be multiplied with the aid of using 15% to 20%. Many energies green constructing technology related to extended thermal insulation and air tightness were implemented withinside the low-temperature heating buildings. Unfortunately, those technology can also additionally motive inadequate clean air to be provided via way of means of infiltration and can accordingly result in bad indoor air high-satisfactory and accelerated healthful symptom. To keep away from this problem, a mechanical air flow machine, inclusive of a blending air flow machine or a displacement air flow machine, for clean air deliver need to be incorporated with the low-temperature heating structures. Compared to the low-temperature heating machine, a hybrid machine with floor/ceiling heating and blending/displacement air flow will create a brand new scenario in regards to air distribution and air flow effectiveness; i.e., the indoor air distribution in a room with floor/ceiling heating structures can be modified via way of means of the mixing with blending/displacement air flow, and the air flow effectiveness of blending/displacement air flow machine can be inspired via way of means of the mixing with floor/ceiling heating structures.

Building air flow immediately impacts indoor air quality, and impacts occupants' health and productivity. Among diverse varieties of air flow, the maximum well known and used air flow techniques are blending air flow (MV) and displacement air flow (DV). In MV air is provided with excessive momentum at ceiling degree so as to dilute the tainted and cool/heat room air with cleanser and cooler/hotter deliver air to decrease the contaminant attention and adjust the temperature. DV alternatively is predicated on low momentum bloodless air provided at once into the occupied quarter at ground degree, inflicting thermal stratification withinside the room. Hence, DV is limited to handiest getting used for cooling of rooms.

The present study deals with the air distribution in a closed room at different locations of duct position along with various test points considered in that room. This study explores the air distribution in a closed room, for that the investigation was performed on sunny days in summer season. The at actual temperature and humidity were collected at various test point locations and get analyse it with comparative study of these parameter. The main objective of this paper to present the experimental results of cooling air distribution and temperature variation in room area by the various position of duct.

II. METHODOLOGY

Climatic Condition:

The aggregate of excessive temperature and humidity with low wind pace makes it tough to obtain thermal consolation withinside the humid tropical climates. Globally those tropical climates occupy a massive region of the world, that's inhabited with the aid of using extra than billion people. The present study was performed on sunny days withinside the season of summertime and the study examined at the region having the subtropical climate i.e., at Bhopal, India. The outside temperature oscillates among 22^0 C to 40^0 C and the common annual temperature is 28^0C in which the outdoors relative humidity varies from 40% -60%. The air velocity at the outlet of duct inside the room is 5.3m/s.

Test Room:

The room which used for investigation and experimental setup is located on the ground floor in building at Government Women Polytechnique, Bhopal (INDIA). The schematic outline of the experimental setup is given in figure. The room under consideration has a dimension of 6 x 2 x 3.5m. The room has an approximate usable floor area is $18m^2$ and usable height is about 3.5m. The outside wall has a total area of $21m^2$, including two windows of size 1.2m 2 each. The conditioned air is supplied through a circular pipe duct having diameter is 0.2m, which is settle down at 2.2m from left wall and 3.80m from right side wall. The duct has three opening positions as 1.5m distance from each for the discharge of air as shown in figure. The conditioned air is supplied through duct as one position is open and others two must remain closed, the outlet of duct is circular with an opening area of $0.031m^2$. The test space has facility to measure the temperatures (°C) of air at the inlet of the tube into the room and the air temperatures at several point of the test space with the help of thermocouple. The straight vertical tree form structure, thermocouple tree fitted with thermocouples at every 10 cm distance and up to the 3m height in the room is used for the data collection as shown in **Figure 1**.

(a) **(b)**

Figure 1: Experimental Setup a) Temperature Logger b) Test Room

In current research work, to perform investigation a test point was marked at 1m distance from the position of conditioned air duct. Thermocouple tree is used to get the values of vertical temperatures at every 10 cm height from the floor level and up to the 3-meter height. The anemometer was fixed on the outlet of duct to note the velocity air.

Measurement Parameter:

Air velocity and temperature were measured on test points and at different heights in test area. To measure the temperature 30 temperature sensors are mounted on a ladder and a velocity meter is used to measure the velocity of air at the outlet of duct. The minimal velocity that can be measured at the outlet of duct is 5.3m/s and the accuracy is about ± 2%. The arrangements of sensors on ladder are shown in **Figure 1(b).**

Test Conditions:

The three different test conditions have to investigated as:

1. Top Position duct
2. Middle Position duct
3. Bottom Position duct

The duct has arrangement to supply the conditioned air through one duct while other two positions have to closed.

III RESULTS AND DISCUSSION

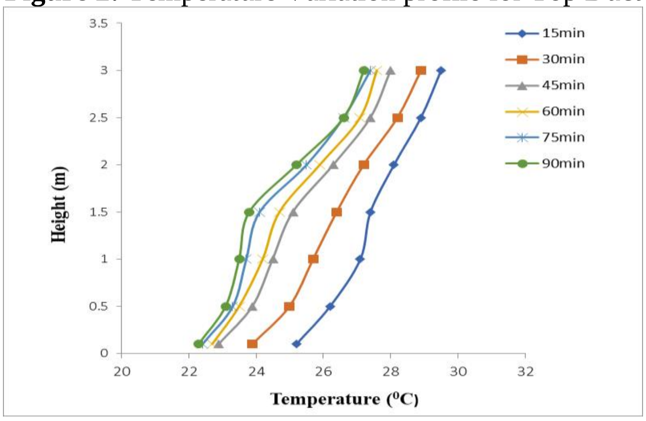
The indoor thermal environment is investigated by measuring the vertical temperature distribution at noted test point. The indoor temperature variation is examined at 15Minutes, 30Minutes, 45Minutes, 60Minutes, 75Minutes and at 90Minutes.

Top Position duct is open for air discharge:

Table 1: Variation of temperature along height for Top Duct

Height from ground	Temperature Variation along the Height at different Time Laps					
	15Min	30Min	45Min	60Min	75Min	90Min
0.1	25.2	23.9	22.9	22.7	22.4	22.3
0.5	26.2	25	23.9	23.5	23.3	23.1
1	27.1	25.7	24.5	24.2	23.7	23.5
1.5	27.4	26.4	25.1	24.7	24.1	23.8
2	28.1	27.2	26.3	25.9	25.5	25.2
2.5	28.9	28.2	27.4	27.1	26.6	26.6
3	29.5	28.9	28	27.6	27.4	27.2

Figure 2: Temperature Variation profile for Top Duct



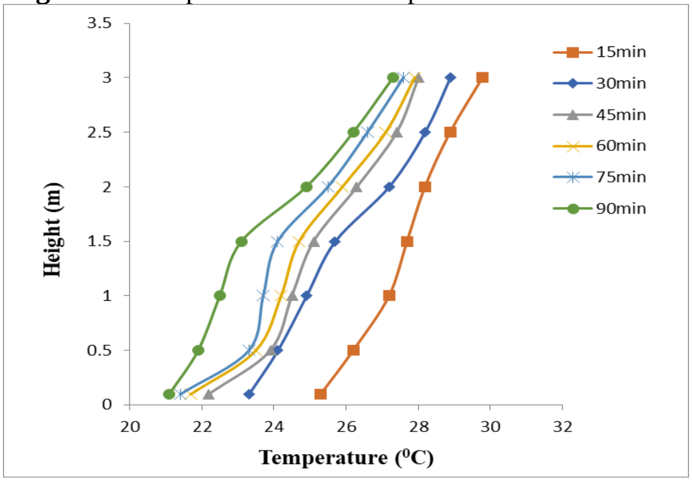
The conditioned air released through the top position duct and temperature variation recorded along the height from the ground at different time laps. The temperature profile trend indicates that temperature changes were influenced by both height and time and with higher elevations, expressing lower temperatures. The percentage of reduction in temperature was 17.30% with respect to height in the first 30min which was more comparatively other time laps.

Middle Position duct is open for air discharge:

Table 2: Variation of temperature along height for Middle Duct

Height from ground	Temperature Variation along the Height at different Time Laps					
	15Min	30Min	45Min	60Min	75Min	90Min
0.1	25.3	23.3	22.2	21.7	21.4	21.1
0.5	26.2	24.1	23.9	23.5	23.3	21.9
1	27.2	24.9	24.5	24.2	23.7	22.5
1.5	27.7	25.7	25.1	24.7	24.1	23.1
2	28.2	27.2	26.3	25.9	25.5	24.9
2.5	28.9	28.2	27.4	27.1	26.6	26.2
3	29.8	28.9	28	27.9	27.6	27.3

Figure 3: Temperature Variation profile for Middle Duct



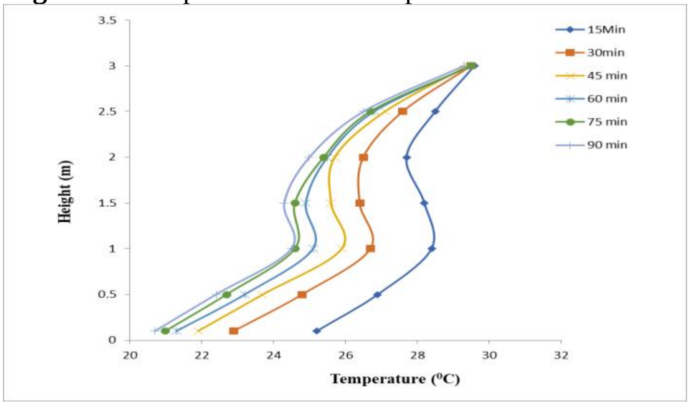
The middle position duct was activated to release the conditioned air and temperature change recorded using the thermocouple ladder at various time laps. The percentage of temperature reduction in first 15minutes analysed 13.42% more in lower zone (upto 1.5m height from groud surface) compare to upper zone (height 1.5m to 3.5m from ground). Where the percentage of temperature reduction afetr 75min was analysed 22.78% more in lower zone compare to upper zone.

Bottom Position duct is open for air discharge:

Table 3: Variation of temperature along height for Bottom Duct

Height from ground	Temperature Variation along the Height at different Time Laps					
	15Min	30Min	45Min	60Min	75Min	90Min
0.1	25.2	22.9	21.9	21.3	21	20.7
0.5	26.9	24.8	23.7	23.2	22.7	22.4
1	28.4	26.7	25.9	25.1	24.6	24.5
1.5	28.2	26.4	25.6	24.9	24.6	24.3
2	27.7	26.5	25.7	25.5	25.4	25
2.5	28.5	27.6	27.1	26.8	26.7	26.5
3	29.6	29.5	29.4	29.5	29.5	29.3

Figure 4: Temperature Variation profile for Bottom Duct



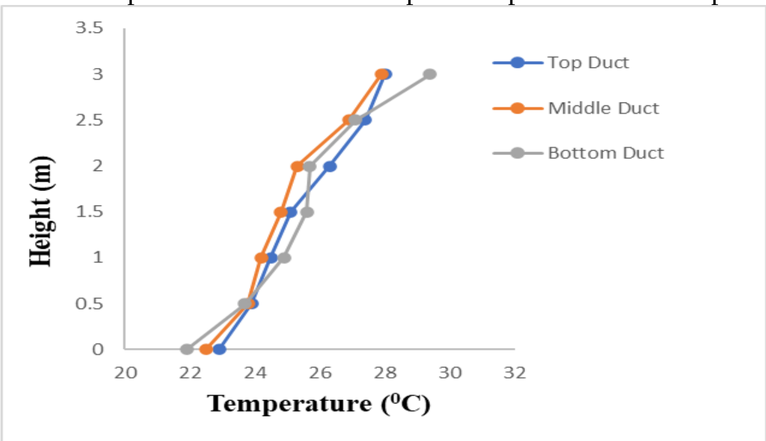
While the bottom position duct was used to release the conditioned air inside the test room. It analysed that beyond a certain height the temperature reduction was noticed in minimal change. Intermediate heights, such as 1.5m and 2.0m, seem to experience the highest temperatures, especially as the observation period extends.

Comparative study of air distribution according to duct position at Test Point Location

Table 4: Temperature variation comparative with duct positions

Thermal Environmental Investigation (Vertical height in meter)	Temperature (^{0}C) according to Discharge air Duct Position		
	Top Location Duct	Middle Location Duct	Bottom Location Duct
0.1	22.9	22.5	21.9
0.5	23.9	23.8	23.7
1	24.5	24.2	24.9
1.5	25.1	24.8	25.6
2	26.3	25.3	25.7
2.5	27.4	26.9	27.1
3	28	27.9	29.4

Figure 5: Temperature Variation Comparative profile with duct positions



As the vertical height increases, the temperature values for the different duct positions tend to converge. This suggests that, at greater heights, the influence of duct position on temperature diminishes, and the thermal environment becomes more homogeneous. Intermediate heights, around 1.5 and 2.0 meters, seem to exhibit optimal temperatures, especially for the Bottom and Middle Location Ducts. This implies that there might be an ideal height range where the discharge air duct's positioning has a more pronounced impact on maintaining a desirable thermal environment. At lower heights (0.1 to 1.0 meters), there are noticeable temperature fluctuations across different duct positions. This suggests that the impact of duct position on temperature is more significant closer to the source, highlighting the importance of careful positioning for effective thermal control in these regions. At the highest height (3.0 meters), there is a substantial difference in temperature between the Top and Bottom Location Ducts. This indicates that the influence of duct position on temperature remains significant even at elevated heights, emphasizing the need for considering duct placement for maintaining a stable thermal environment.

IV CONCLUSION:

The article presented investigations on the thermal comfort inside a test room. The test setup is equipped with an air conditioner, air distribution system with adjusting flow passages and instrumentation. To investigate the indoor thermal environment, vertical temperature distribution is analysed at the marked test point 1m distance from the duct position. The conditioned air was supplied through a duct. Three ducts set vertically from a ground as 0.1m height, 1.5m height and, at 3m height with the arrangements of opening and closing of ducts as per experimental consideration. The objective of the study is to investigate the impact of the elevation of the inlet duct into the test room on the indoor thermal environment. The vertical temperature distribution is a good measure of estimation of the indoor thermal environment. The temperature distribution was continuously observed and recorded at different test position. The readings were taken at an interval of 15 minutes for 3 hours. The results are presented in the form of vertical temperature variations. The results indicate the indoor thermal environment produced in the test room. At the intermediate heights around 1.5m to 2.0m from ground i.e up to the middle zone the percentage of temperature reduction recorded 37.45% where below the 1.0m height it was noticeable 44.32%. At the upper zone i.e around the height of 3.0m the temperature reduction was 17.48% which very less compare the other two zones. These outcomes suggest necessity about to set the duct positions inside the room.

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Conflict of Interest

No conflicts of interest between the authors.

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