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Comparative analysis of ceiling swirl diffuser and under floor swirl diffuser placement in indoor environment

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Abstract

In an indoor environment proper air distribution is important for cooling as well as comfort condition and it is managed by placing an air conditioning duct inside the room. In this research work we placed both the ceiling based and under floor based swirl diffuser to evaluate the performance characteristics for thermal comfort condition inside the indoor space. We have formed wooden swirl diffuser having the angle 100, 110, 120 and placed inside an acrylic sheet wooden room of size 4ft x 4ft x 5ft and supply cool air by air conditioning duct both ceiling side or under floor side for comparative analysis of air pattern and temperature variation throughout the indoor space. After this analysis we can able to suggest which type of placement of diffuser is better and provide proper air distribution inside the indoor space.

Keywords

Air diffuser, Temperature distribution, Indoor environment, Comfort criteria.

1.Introduction

Air diffuser is device that is designed to prove uniform air flow to throughout a room. It works to increase the efficiency of air conditioning units by dividing and distributing cooled air. It provides greater comfort to occupants when the even air flow is maintained. Air diffuser is mostly mounted on ceilings and sometimes on walls. The type, size and location of the diffuser depend on many factors. This includes the layout of building or room, location of doors and windows and a type of air conditioning system being used. Air diffusers are device that suffer as the end point for HVAC unit. Diffusers circulate fresh air into rooms and are found in both residential and commercial buildings. Common referred to as air diffusers to as air vents. Diffuser comes in several shapes and size are often found in floors and ceiling. Diffuser is also sometimes referred to registers. According to Alantsupply.com .they can be made of metal or wood, though wood is less common are usually found in the home. The concept of air diffuser is relatively simple, air flows naturally through a duct. The diffuser capture this air, as it come through the air conditioning system and splits the forced air into smaller streams. The tiny current of air is then directed in an even flow throughout the room. This stream cannot typically be the felt while the air is circulating. When this air conditioning devices is placed in a room, the temperature will usually drop faster than when one is not used. Since the room can be cooled quickly, the thermo state may be turned up more at night in order to save energy. It is important for a humid weather. It is bit costly but easily installable. It is customizable and can be made in any color as per the décor. It is the common air diffuser to be installed at home. Those that cover vents in walls are somewhat larger than other residential type and are preferred when and air conditioning vent is along the lower edge a wall. Air diffuser helps air conditioning units more efficiently. They do not need a power source in order to operate. They are large any looking to efficiency of an air conditioning unit and provide even air temperatures in both commercial and residential environment.

2.Criteria for comfort

ASHRAE (American society of heating, refrigerating, and air conditioning engineering) has developed an industry related standard to describe comfort requirements in buildings. The standard is known as ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy. The purpose of this standard is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within the space. The Standard allows the comfort charts to be applied to spaces where the occupants have activity levels that result in metabolic rates between 1.0 met and 1.3 met and where clothing is worn that provides between 0.5 clo and 1.0 clo of thermal insulation. The comfort zone is based on the PMV values between -0.5 and +0.5.clo: a unit used to express the thermal insulation provided by garments and clothing ensembles, where 1clo = 0.155 m2 °C/W (0.88 ft2•h•°F/Btu). An ASHRAE standard helps us to design a perfect comfortable environment which provides satisfaction to occupants to do their moderate work efficiently. Various standards have been made by American society of heating, refrigerating, and air conditioning engineering in their handbook. The comfort level conditioning the PMV method (predictive mean vote) has been recorded. The modified comfort zone chart has been considered for study purpose for various comfort region analysis. The figure shows the charts in the chart humidity ration has been plotted against the operating temperature. The chart shows the humidity ratio limit for comfort condition suggested by ASHRAE

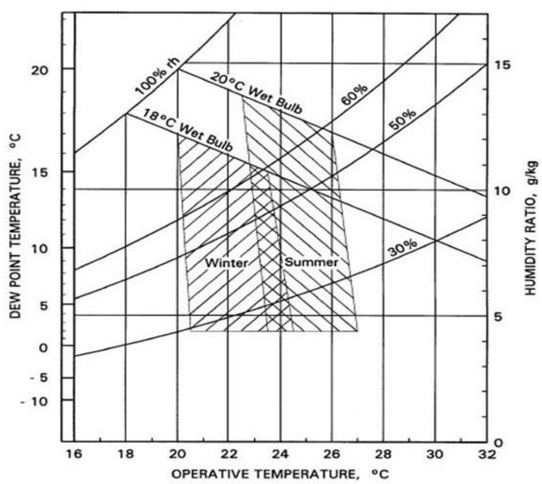


Figure 1 ASHRAE summer and winter comfort zone

There are six factors which affect the thermal comfort.

Environmental factors:

- Air temperature
- Radiant temperature
- Air velocity
- Humidity

Personal factors:

- Clothing Insulation
- Metabolic heat

The recommended temperature range to optimize indoor thermal comfort for most people is 19°C to 28°C.

3.Modeling of diffuser

The reference for the modeling is taken from the journal paper "Performance and flow characteristics of floor swirl diffuser under different operating and flow parameters" by Suraj, International Journal of Mechanical Engineering and Technology (IJMET), ISSN0976 – 6340(Print), ISSN 0976 – 6359(Online) Volume 4, Issue 4, July - August (2013)",specified as ground swirl diffuser modeled on 3D modeling software. The prototype wood model of the ground swirl diffuser turned into fabricated and designed to check its performance below unique operating and flow situations experimentally. The research was executed inner an acrylic sheet timber room with ground swirl diffuser fashions mounted on the roof and under floor. This test has been finished on three distinctive models of ground swirl diffuser having unique slot angles of 10^0,11^0,12^0

The recommended temperature range to optimize indoor thermal comfort for most people is 19°C to 28°C. This temperature range is appropriate for the sedentary or near sedentary physical activity levels that are typical of general office work. This recommendation assumes that people dress appropriately to the external seasonal demands.

4.Experimental setup

The experiment is performed in open space inside the workshop area of department of Mechanical engineering LNCT, Bhopal Campus. The purpose of this study is to find which type of placement of air diffuser provides better cooling or air distribution inside a closed space. The experiment is based on predicting the nature and behavior of air diffused by three different types of swirl diffusers having slots with draft angle of 100,110,120, respectively under different operating and flow conditions. In our experiment we just want to compare the effect air distribution through the ceiling based diffuser and under floor diffuser and experiment is performed to evaluate the thermal comfort produced in a room equipped with heat load of 1500W load capacity with both swirl diffusers. The graphs are plotted between temperature of diffused air inside the room and vertical height from the floor level.

In our study we refer the under floor test data of Prof.Deenoo Pawar and Mr.Mihir in their experiment work "performance analysis of flow characteristics of swirl diffuser for floor based air conditioning system'' and compare with our experiment data and validate with our under floor test result and justified which type of placement of air diffuser is giving satisfactory results. Some assumptions are applied in the investigation of experimental and numerical analysis. Metabolic rate and preference of closing in the office varies from the people to people. The standard values for metabolic rate and closing factor are to be considered. The activity of a sedentary occupant is estimated to be 1.2 met and the clothing insulation is 1.0 clo in winter and 0.5 clo in summer. Ventilation effectiveness for DCV is estimated to be 1.0, as it is for the mixing ventilation. The experimental set-up is situated in a clean area with

excellent air quality. Acrylic sheet wooden room is closed while performing the experiment and heat transfer from room door due to leakage is neglected.
We have assumed that the position of the room with respect to sun direction and altitude is identical for heat load calculation. So no effect has been considered. Only sensible heat of air is measured for calculation neglecting latent heat.

It contains an acrylic sheet wooden room of size 4 by 4 by 5 feet with dissimilar models of swirl diffuser installed at the ceiling level and under floor. The conditioned air from air conditioner is supplied from the bottom through a duct of reducing cross-section to increase the air flow velocity through the diffuser. A heater of 1500W is placed inside the room to provide a heat load for ceiling based diffuser placement and 1000W heater placed for under floor diffuser placement for creating minute load variation. Heater is placed near the location x2. A temperature sensing instrument with six thermocouple wires is placed inside the room to measure the temperature at six locations vertically at a distance of 0.7 feet. There are four exhaust vents at the top surface of the wooden block through which ventilation is carried out inside the room.

There are six locations at the floor inside the room where readings of temperature have to be noted and the variation in temperature of air is to be studied.
We execute the test and compare both the under floor and ceiling based diffuser result as shown in table and graphs and analysis the comparisons to conclude our study.

Figure 2 10^0 swirl diffuser

Figure 3 11^0 swirl diffuser

Figure 4 12^0 swirl diffuser

Figure 5 Top view of various locations inside the room

Figure 6 Front view of the experimental set-up

Figure 7 Air distribution pattern through ceiling Swirl Diffuser

Figure 8 Air temperature measurement with thermocouple

Figure 9 Air distribution pattern through under floor Swirl Diffuser

5.Result

In our first test which is based on ceiling type diffuser placement inside our prototype room and various temperatures reading we obtained and mentioned in the tabular format. Study of air distribution along with temperature and vertical height we have plotted graphs to understand the variation for comparatively study work.

We execute the test and compare both the under floor and ceiling based diffuser result as shown in table and graphs and analysis the comparisons to conclude

Experimental Readings:

Condition1: When exhaust all vent is opened

Initial Room Temperature = 32^0C

Room Temperature with load 1500W without a.c = 38^0C

Table 1 Variations in temperature vs. height at location X1 without load

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	28	27	26
2	1.0	27	27	26
3	1.5	28	27	26
4	2.0	27	25	25
5	2.5	27	26	26
6	3.0	26	26	25

Table 2 Variations in temperature vs. height at location X1 in condition 1 with load 1500W.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	22	24	22
2	1.0	23	23	22
3	1.5	22	24	23
4	2.0	23	24	23
5	2.5	23	25	22
6	3.0	23	23	21

Table 3 Variation in temperature vs. height at location X2 in condition 1 without load

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	27	28	27
2	1.0	28	28	26
3	1.5	27	27	27
4	2.0	28	27	26
5	2.5	26	28	26
6	3.0	28	27	26

Table 4 Variations in temperature vs. height at location X2 in condition 1 with load 1500W.

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	25	25	24
2	1.0	24	25	24
3	1.5	23	24	23
4	2.0	24	24	23
5	2.5	25	25	23
6	3.0	25	25	24

Table 5 Variations in temperature vs. height at location X3 in condition 1 without load

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	28	28	26
2	1.0	27	28	26
3	1.5	27	27	25
4	2.0	25	26	27
5	2.5	26	27	26
6	3.0	26	26	25

Table 6 Variations in temperature vs. height at location X3 in condition 1 with load 1500W

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	24	25	23
2	1.0	24	24	24
3	1.5	25	24	24
4	2.0	24	25	23
5	2.5	23	24	24
6	3.0	23	24	23

Table 7 Variations in temperature vs. height at location X4 in condition 1 without load

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	27	28	27
2	1.0	27	27	26
3	1.5	28	27	27
4	2.0	27	27	27
5	2.5	28	28	26
6	3.0	28	27	26

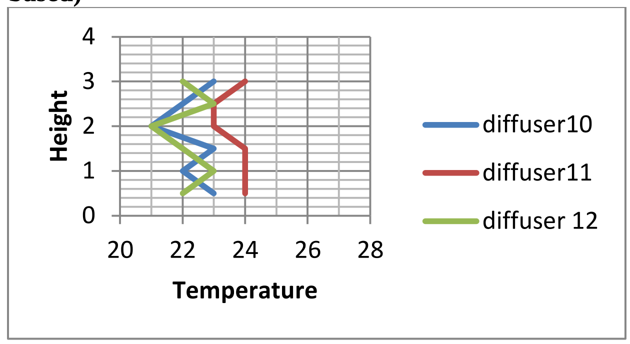
Table 8 Variations in temperature vs. height at location X4 in condition 1 with load 1500W

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	24	24	22
2	1.0	23	25	24
3	1.5	23	25	23
4	2.0	24	24	22
5	2.5	25	23	24
6	3.0	24	24	23

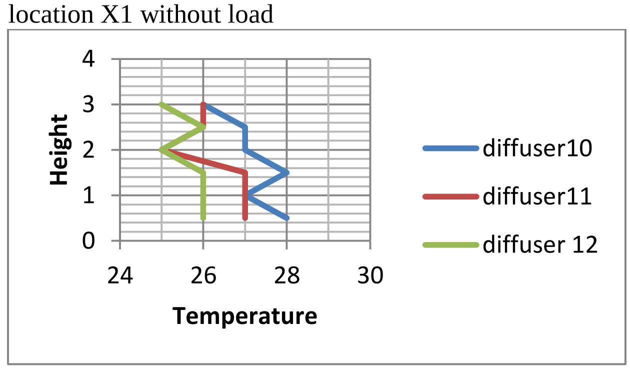
Table 9 Variations in temperature vs. height at location X5 in condition 1 without load

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	28	28	27
2	1.0	27	28	26
3	1.5	28	27	27
4	2.0	27	28	26
5	2.5	26	27	26
6	3.0	27	27	26

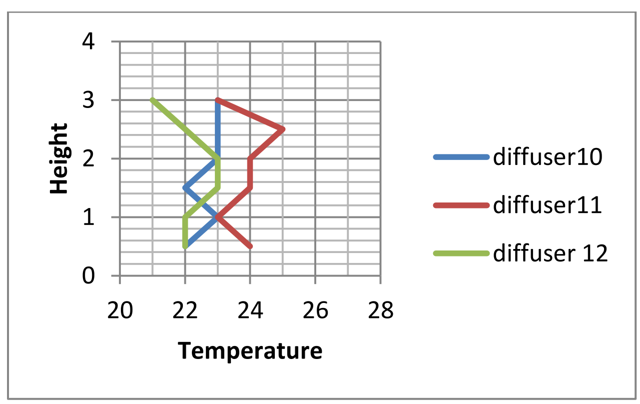
Graphical Representation of Results (Ceiling based)



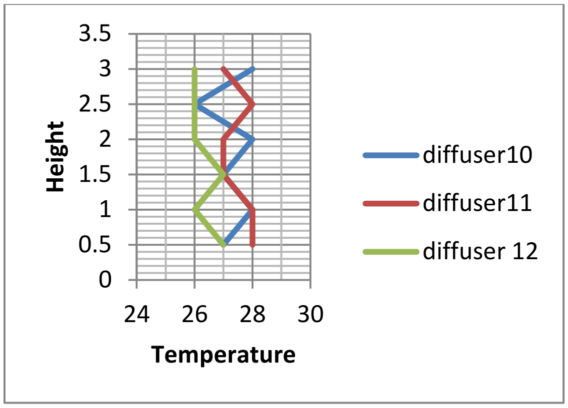
Graph.1 Variation in temperature vs. height at location X1 without load



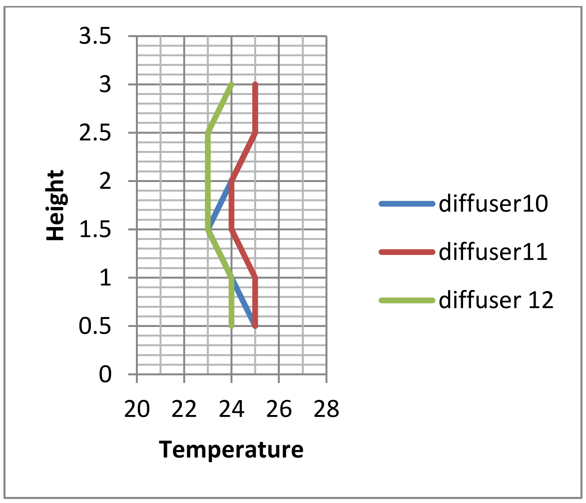
Graph.2 Variation in temperature vs. height at location X1 with load 1500W



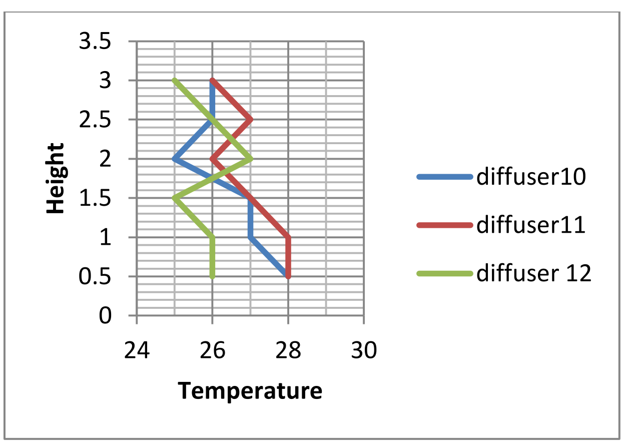
Graph.3 Variation in temperature vs. height at location X2 without load



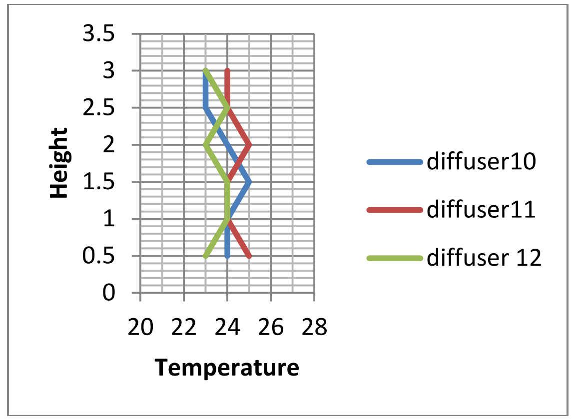
Graph.4 Variation in temperature vs. height at location X2 with load 1500W



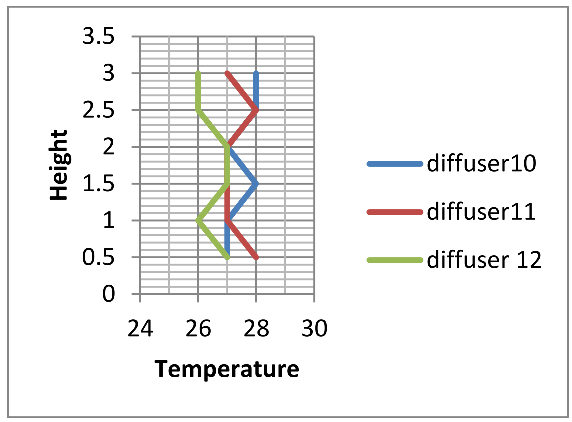
Graph.5 Variation in temperature vs. height at location X3 in without load



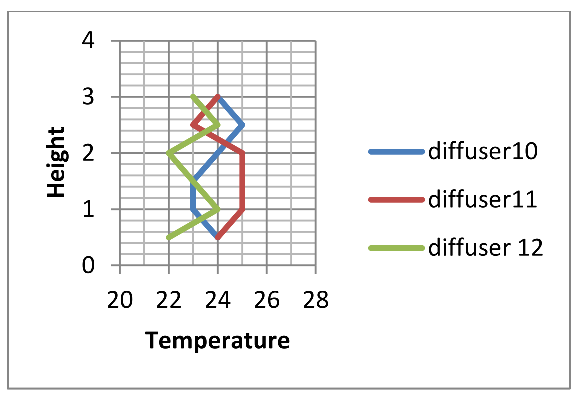
Graph.6 Variation in temperature vs. height at location X3 with load 1500W



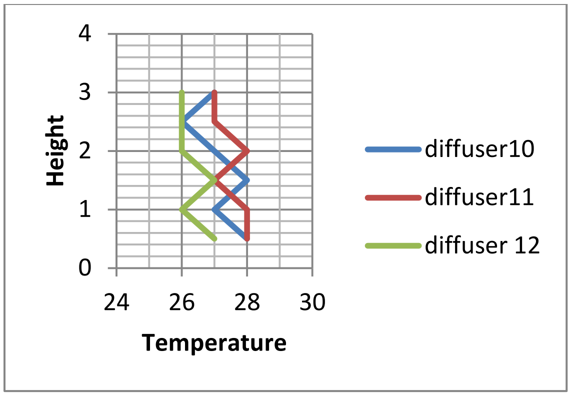
Graph.7 Variation in temperature vs. height at location X4 without load



Graph.8 Variation in temperature vs. height at location X4 with load 1500W



Graph.9 Variation in temperature vs. height at location X5 without load



Graph.10 Variation in temperature vs. height at location X5 with load 1500W

In our second test which is based on under floor type diffuser placement inside our prototype room we obtained reading and mentioned in the tabular format. Study of air distribution along with temperature and vertical height we have plotted graphs to understand the variation for comparatively study work.

Condition1: When exhaust all vent is opened
Initial Room Temperature = 320C
Room Temperature with load 1000W without a.c = 380C

Table 10 Variations in temperature vs. height at location X1 in condition 1 without load

S. No.	**Height (ft.)**	**Temperature (^{0}C)**		
		10^0	**11^0**	**12^0**
1	0.5	21	21	22
2	1	21	22	22
3	1.5	22	22	23
4	2	22	23	23
5	2.5	23	23	23
6	3	23	24	24

Table 11 Variation in temperature vs. height at location X1 in condition 1 with load 1000 W

S. No.	**Height (ft.)**	**Temperature (^{0}C)**		
		10^0	**11^0**	**12^0**
1	0.5	24	25	25
2	1	23	22	22
3	1.5	22	22	22
4	2	22	23	23
5	2.5	23	23	23
6	3	23	23	23

Table 12 Variation in temperature vs. height at location X2 in condition 1 without load

S. No.	**Height (ft.)**	**Temperature (^{0}C)**		
		10^0	**11^0**	**12^0**
1	0.5	21	21	22
2	1	22	22	22
3	1.5	22	22	23
4	2	22	23	23
5	2.5	23	23	23
6	3	23	23	24

Table 13 Variation in temperature vs. height at location X2 in condition 1 with load 1000 W

S. No.	**Height (ft.)**	**Temperature (^{0}C)**		
		10^0	**11^0**	**12^0**
1	0.5	25	26	24
2	1	24	25	24
3	1.5	23	23	23
4	2	23	23	23
5	2.5	24	24	23
6	3	24	24	24

Table 14 Variation in temperature vs. height at location X3 in condition 1 without load

S. No.	**Height (ft.)**	**Temperature (^{0}C)**		
		10^0	**11^0**	**12^0**
1	0.5	21	21	22
2	1	21	22	22
3	1.5	22	22	23
4	2	22	22	23
5	2.5	23	22	23
6	3	23	23	23

Table15 Variation in temperature vs. height at location X3 in condition 1 with load 1000 W

S. No.	**Height (ft.)**	**Temperature (^{0}C)**		
		10^0	**11^0**	**12^0**
1	0.5	26	25	26
2	1	25	25	25
3	1.5	23	23	25
4	2	22	22	22
5	2.5	22	22	22
6	3	22	22	22

Table 16 Variation in temperature vs. height at location X4 in condition 1 without load

S. No.	**Height (ft.)**	**Temperature (^{0}C)**		
		10^0	**11^0**	**12^0**

1	0.5	21	21	21
2	1	22	21	22
3	1.5	22	21	22
4	2	22	22	22
5	2.5	23	22	22
6	3	23	22	22

Table 17 Variation in temperature vs. height at location X4in condition 1 with load 1000 W

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	26	26	25
2	1	25	26	25
3	1.5	25	25	23
4	2	24	23	23
5	2.5	23	23	22
6	3	23	22	22

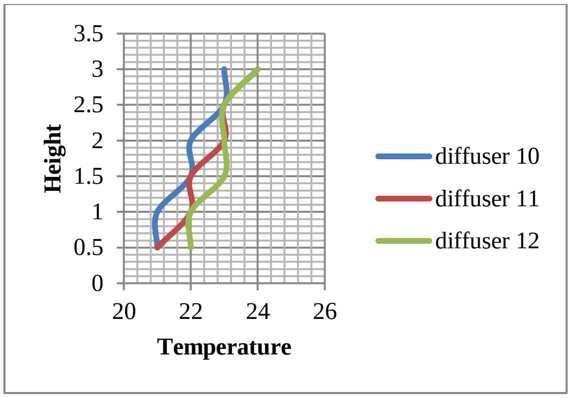
Table 18 Variation in temperature vs. height at location X5in condition 1 without load

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	20	21	21
2	1	21	21	21
3	1.5	21	22	22
4	2	22	22	23
5	2.5	22	23	23
6	3	23	23	23

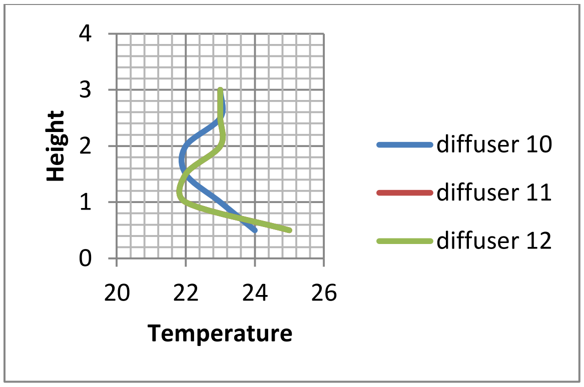
Table 19 Variation in temperature vs. height at location X5 in condition 1 with load 1000 W

S. No.	Height (ft.)	Temperature (^{0}C)		
		10^0	11^0	12^0
1	0.5	26	26	25
2	1	25	25	25
3	1.5	24	25	24
4	2	23	23	23
5	2.5	23	23	23
6	3	23	22	22

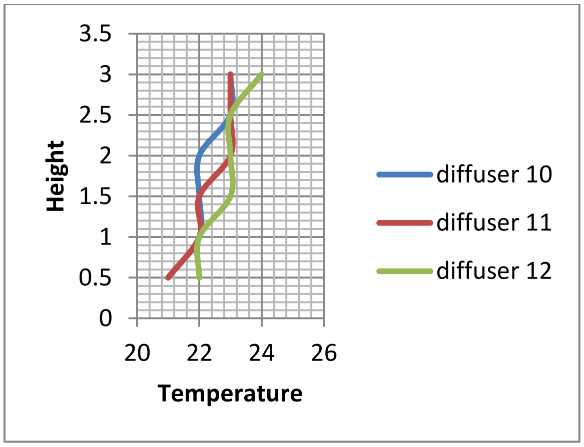
Graphical Representation of Results (Under floor)



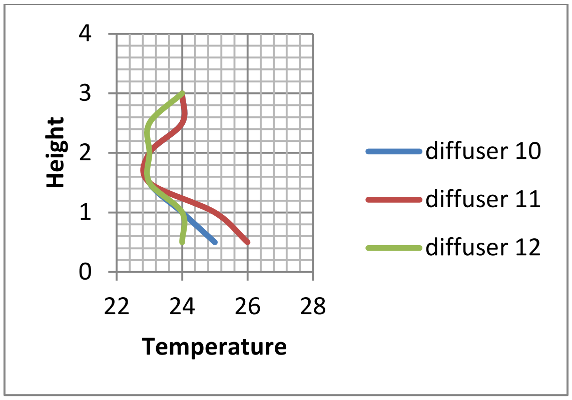
Graph.11 Variation in temperature vs. height at location X1 in condition 1 without load



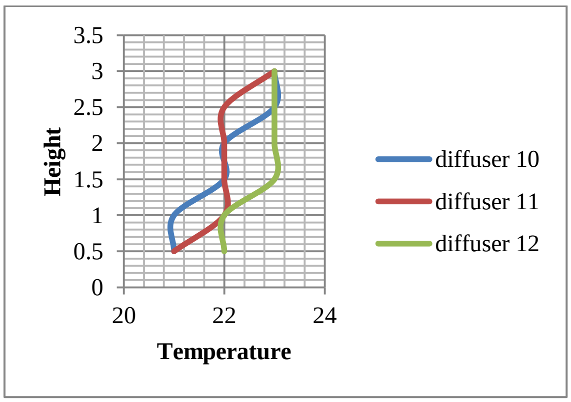
Graph.12 Variation in temperature vs. height at location X1 in condition 1 with load 1000 W



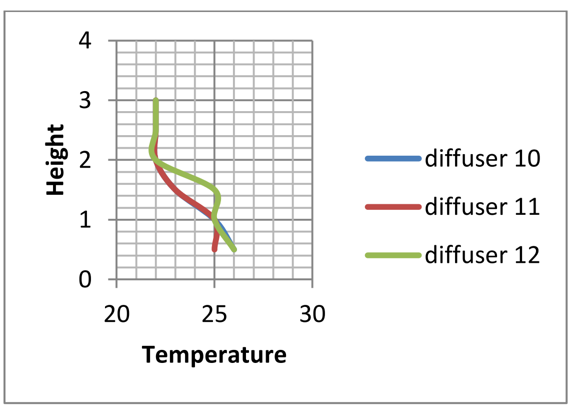
Graph.13 Variation in temperature vs. height at location X2 in condition 1 without load



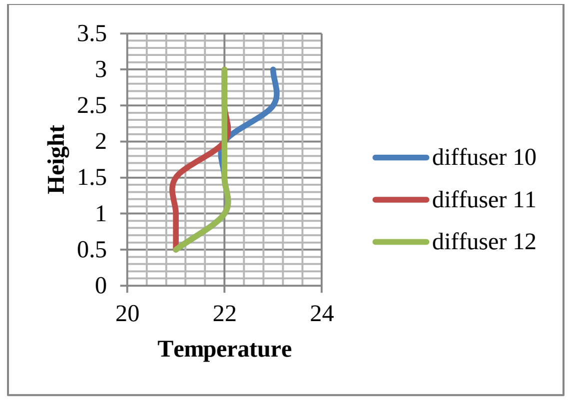
Graph.14 Variation in temperature vs. height at location X2 in condition 1 with load 1000 W



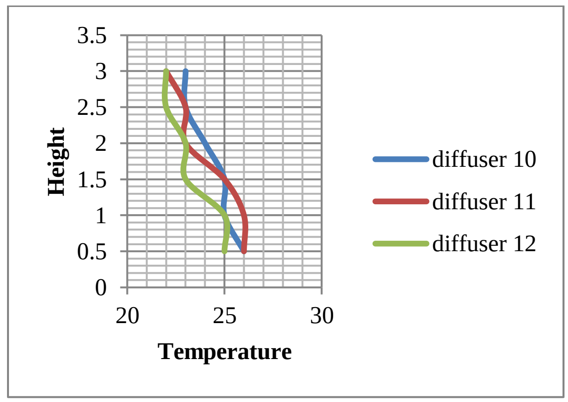
Graph.15 Variation in temperature vs. height at location X3 in condition 1 without load



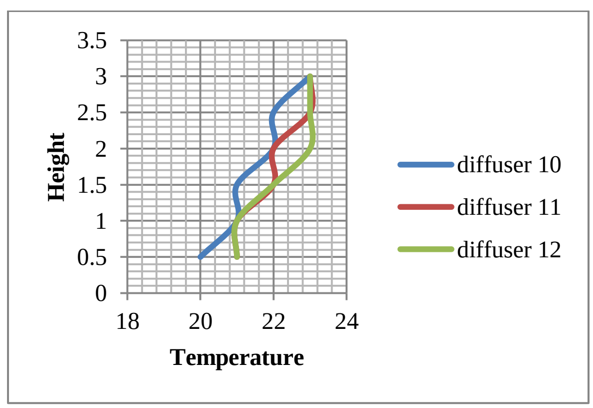
Graph.16 Variation in temperature vs. height at location X3 in condition 1 with load 1000 W



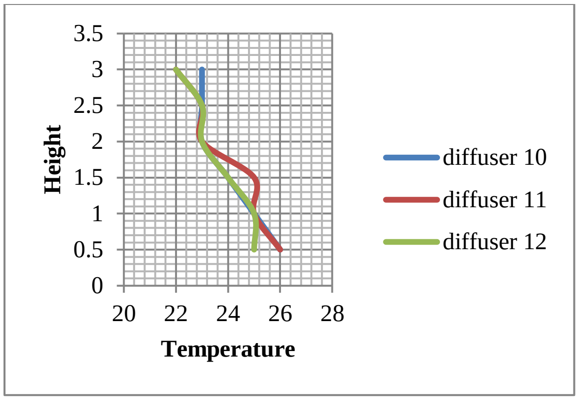
Graph.17 Variation in temperature vs. height at location X4in condition 1 without load



Graph.18 Variation in temperature vs. height at location X4 in condition 1 with load 1000 W



Graph.19 Variation in temperature vs. height at location X5 in condition 1 without load



Graph.20 Variation in temperature vs. height at location X5 in condition 1 with load 1000 W

6.Conclusion and future scope

The results from this experiment work show that an indoor space with ceiling-supply displacement ventilation using ceiling and under floor swirl diffuser can improve indoor air quality because the contaminant concentration in the breathing zone is lower than that of mixing system. It helped us to compare three types of swirl diffuser under different operating and flow conditions. Due to swirl action produced more unidirectional flow was created, the slow recirculation at the occupant zone was eliminated for the ceiling supply ventilation and the risk of cross contamination can be effectively reduced. But for better cooling purpose under floor diffuser placement having swirl blade angle 110 is appropriate The maximum variation in temperature is obtained at location X2. This happens due to presence of heater of load capacity 1500W and 1000W near location X2. As we move away from the heat source variation in temperature differs and we obtained almost uniform temperature at the upper region of the experimental set-up. We have compared the performance of different swirl diffuser models having slot with draft angle 100, 110 and 120 under different operating conditions both ceiling based and under floor based placement and the best performance is obtained with 11^0 swirl diffuser both the cases. For our study we can come on the conclusion that both type of diffuser placement provide better air circulation and temperature distribution inside a space but blade angle play a significant role in the result because swirl action which is help full to mix cool air to inside space so under floor air diffuser having 110 blade angle is most appropriate technique to provide comfort condition inside the room. Form our study compare to ceiling air diffuser. We have also compared the performance of diffuser when only one exhaust vent is opened and when all the four exhaust vents are opened. The temperature profile is more uniform when all the four exhaust vents are opened. This study helps in selecting optimum models for ceiling swirl diffuser and under floor diffuser under different operating conditions. In future work we can also repeat this experiment with humidity measurement, air profile variation, and also find tone of air conditioner used for particular space according to comfort conditions.

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