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EFFECT OF BUILDING MATERIALS ON THERMAL LOAD AND THERMAL COMFORT OF BUILDING AND CFD ANALYSIS OF RADIANT COOLING TECHNIQUES ON SOLAR LAB OF UNIVERSITY BUILDING LOCATED IN COMPOSITE CLIMATE OF INDIA

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ABSTRACT

Making the building energy efficient and improving thermal comfort inside the buildingis drawing attention of the researchers due to the limited stock of conventionalresources. About 40-60% of energy in the form of electricity is consumed by thebuilding itself. About 43-45% energy can be saved by implementing the normssuggested by Energy Conservation Building Code (ECBC) during the construction of thebuilding. Present study investigate the effect of improving the building material on thesolar lab of the ISBM block, Suresh GyanVihar University thereby applying the differenttypes of radiant cooling techniques such as radiant floor cooling ,radiant wall coolingand radiant ceiling cooling to improve the thermal comfort inside the room anddecreasing cooling load. It is shown that about 82% heat gain through the roof, 57%solar heat gain through window can be reduced by using energy efficient measures (EEM) and 25% fanger PMV can be improved. After comparison radiant floor cooling isfound to be best suited for the solar lab.

KEYWORDS: Radiant cooling, CFD analysis, fangerpmv, air temperature, solar heat gain

1. INTRODUCTION

Today because of the energy consumption the whole world is inclined towards finding new techniques and methods to downsize as well as efficient utilization of energy for sustainable development. From various researches it has been found that about 40-60% of energy is consumed by buildings in the form of electricity [4]. For making an energy efficient building (EEB) some building parameters such as materials used during construction, fenestration, insulation, location of air conditioners, chillers etc. are investigated.

Various researchers are focusing on optimum insulation thickness so that rate of heat transfer through the building envelope can be minimized and thermal comfort can be maintained specially in summer season. Morel Ozel [3] investigated in his research that optimum thickness of insulation for east, west, north and south wall should be 4, 4, 3.1, 3.6 cm respectively. It has been found that limestone, concrete and terracotta are the most efficient materials for housing. Apart from these conventional materials COFALIT, a material made by vitrification of asbestos which have remarkable thermal storage property is suggested as a energy efficient building material [6].

After making the building energy efficient the secondary thing is minimizing electricity consumption and improving thermal comfort. Thermal comfort is generally measured by predictive mean vote (PMV) which varies from -3 to +3. Thermal comfort is maximum when the value of PMV lies between -0.5 to +0.5. Radiant cooling methods are implemented in residential as well as commercial buildings due to its efficient cooling and high level of thermal comfort. This technique is more efficient for dry and hot climatic conditions but can be implemented in other zones as well with minor modifications such as dehumidifier. From various researches it has been found that cooling panel area should be 30 to 50% of the ceiling [2]. Further increasing the area would not be beneficial as no considerable drop in temperature were found. The supply air should be from ceiling to floor for maximum thermal comfort. Relative humidity should be between 50-60%. Implementing displacement ventilation system electric energy can be saved up to 13.2% for the chillers and 8% for the whole cooling system [1].

Present study reveals the effect of energy efficient building materials as well as insulation in context of making the building energy efficient. Further various radiant cooling techniques viz. radiant floor cooling, radiant ceiling cooling and radiant wall cooling are analyzed and compared on Energy plus software.

2. LITERATURE REVIEW

MeralOzel in his study found that the highest cooling load is on east and west wall whereas the lowest cooling load is on north wall and the cooling load decreases with the insulation of wall. The value of optimum thickness was found by degree hour and degree day method which is already mentioned earlier.

Shivraj Dhaka suggested that by implementing energy conservation measures which is recommended by energy conservation building code (ECBC) 43% energy saving can be done as compared to conventional methods. He also found that 16% energy saving can be achieved by using thermal adaptation technique.

L.L. Sun and H.X. Yang analyzed the concept of using building integrated photovoltaic (BIPV) as shading and found that more electricity were generated when BIPV claddings were installed on south façade. He prioritize

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shorter photovoltaic module over longer one as the earlier one results in more energy saving effect per unit area.

Wei-Hwa Chiang and Chia-Ying Wang present various parameters in radiant cooling system such as shape, size, weight and surface area of cooling panel. He also find the surface temperature of ceiling, best position of diffuser, supply air temperature, velocity and air density.

Nestor Fonseca investigated various methods of radiant cooling for a classroom with uniform and convective environment. He found that horizontal asymmetry in human body is maximum in lateral radiant panel cooling system whereas vertical asymmetry is maximum in floor or ceiling type radiant cooling system.

Nestor Fonseca in his another experimental study cooling power in case of radiant ceiling cooling can be decreased by circulating uniform air near the ceiling with the help of mechanical driver. This happen because the coefficient

Roberto Ansuini and Roberto Larghetti integrated phase change material (PCM) with radiant floor to provide the required thermal inertia without increasing the overall mass. PCM are used to store latent heat and can be used according to the requirement in both summer and winter season.

3. RESEARCH MEHODOLOGY

3.1 BUILDING LOCATION

Solar lab of the GyanVihar University Jaipur (Raj.) which is on the top loor of the ISBM building is taken for the research and analysis. The domain is located at 26.8˚, 75.80˚ and is 390m above the sea level. In summer season temperature varies between 45-48 ˚C and in winter season the minimum temperature can be even 4 ˚C. Humidity is very low in summer and winter season as compared to monsoon season. Jaipur comes in composite zone in five climatic zones of India.

3.2 BUILDING DETAILS

Solar lab is situated at 14m from the ground level and the total surface area of the room is 217.434m². The surface area of the east-west, north-south, ceiling-floor is 20.227m², 31.872m², 56.618m² respectively. Double brick, cement-sand plaster, gypsum plaster and paint is used for making the walls whereas steel sheet with partially pitched roof, concrete, and cement sand plaster is used for making roof and window glass is made up of 6 mm generic clear glass. It is on the west wall of the room. There are two doors in the room facing east and south. Occupancy is given as per the schedule of the University. Construction details are mentioned in table 2.1 to 2.3. Table 2.4 shows the ECBC standards value. Photo A& B of fig 2.1 shows construction layer of wall and roof of original building. Fig 2.2 &2.3 shows geographical location of university and considered building. Fig 2.4, 2.5 & 2.6 shows the simulated photo of building, block and original photo of block.

Table 2.1 Construction detail of outside walls

NO OF LAYERS	MATERIAL	THICKNESS (M)	U VALUE (W/m².K)
7	POLYURETHANE	.0006	1.883
	GYPSUM PLASTERING	.0010	
	CEMENT PLASTER	.0190	
	DOUBLE BRICK	.2150	
	CEMENT PLASTER	.0190	
	GYSUM PLASTERING	.0010	
	POLYURETHANE	.0006	

Table 2.2 Construction detail of flat roof

NO OF LAYERS	MATERIAL	THICKNESS (M)	U VALUE (W/m².K)
5	CEMENT PLASTER	.0190	4.196
	REINFORCED CONCREAT	.1016	
	CEMENT PLASTER	.0190	
	GYSUM PLASTERING	.0010	
	POLYURETHANE	.0006	

Table 2.3 Construction detail of window

NO OF LAYERS	MATERIAL	THICKNESS (M)	CONDUCTIVITY (W/M-K)	U VALUE	VISIBLE TRANSMITTANCE
1	GENERIC CLEAR GLASS	.0006	.9000	5.778	.8810

Table 2.4 ECBC suggested U-value (W/m²K)

WALL	ROOF	GLASS
0.440	0.409	3.30

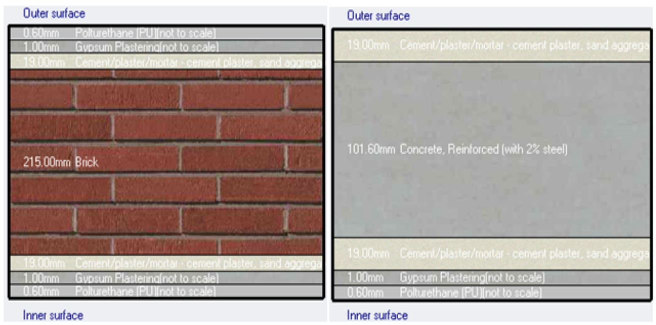

Fig. 2.1(A) Layer of outer walls Fig.2.1(B) Layer of roof

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Fig. 2.2 Geographical location of solar lab

Fig 2.3 Geographical location of whole University

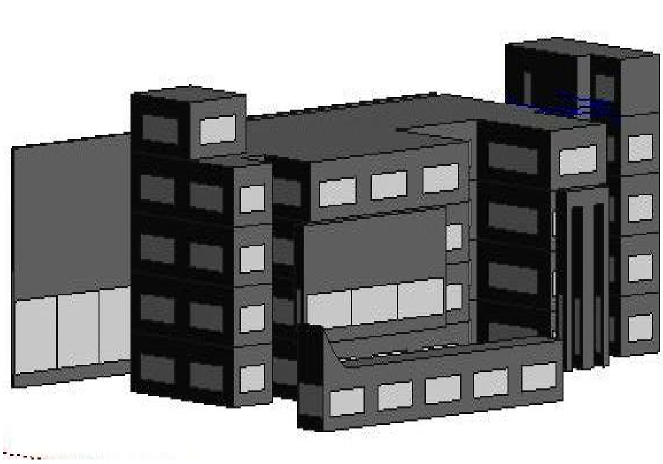

Fig. 2.4 over all Modeled Building

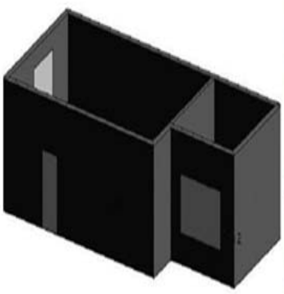

Fig 2.5 Considered block Fig 2.6 Original block

3.3 DATA COLLECTION

In this study, temperature of the four walls, floor and ceiling is measured by using infrared thermometer whereas the temperature of air is measured by using normal thermometer. Inlet air temperature of the window, south door and air temperature at the middle of the room is measured. Inlet air velocity of the window and south door is measured by using anemometer. All the readingswere taken for the 40 hours in the college working days.

3.4 MODEL DESCRIPTION

Solar lab (domain) which is under analysis is constructed by using design building software. First of all the actual parameter such as wall thickness, fenestration and the building materials is given and result were simulated. After that several energy efficient measures according to the norms of Energy Conservation Building Code (ECBC) were given to get the improved result.

Different types of radiant cooling systems such as radiant floor, ceiling and wall cooling is given and compared and finally the best is found out by using design builder. The details of the materials used for making energyefficient building as well as the layer thickness and overall heat transfer coefficient (U value) is given in table 2.5 and2.6 and layers of wall and roof are shown in photograph A and B of fig 2.7

Table 2.5 Construction detail of outside wall with EEM

NO OF LAYERS	MATERIAL	THICKNESS (M)	U VALUE (W/m^2.K)
7	POLYURETHANE	0.0006	0.465
	PERLITE PLASTERING	0.0025	
	CEMENT/PLASTER/MORTAR	0.0254	
	BRICK-AERATED	0.2540	
	CEMENT/PLASTER/MORTAR	0.0254	
	PERLITE PLASTERBOARD	0.0050	
	EPS EXPANDED POLYSTER	0.0400	

Table 2.6 Construction detail of roof with EEM

NO OF LAYERS	MATERIAL	THICKNESS (M)	U VALUE (W/m^2.K)
5	AERATED CONCRETE SLAB	0.12	0.453
	REINFORCED CONCRETE (2% STEEL)	0.1016	
	CEMENT PLASTER	.0190	
	EPS EXPANDED POLYSTYRENE	0.05	
	POLYURETHANE	.0006	

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Fig. 2.7 (A) Layers of wall with EEM (B) Layers of roof with EEM

4. RESULT AND DISCUSSION

4.1 ENERGY EFFICIANCY BY USING EFFICIENT BUILIDNG MATERIALS

Comparison of heat gain through roof, solar heat gain through window, air temperature and Fanger PMV of original building and building with EEM are shown in table 4.1 to 4.4 and graphical comparison is shown in fig 4.1 to 4.4. It is calculated that by modifying buildingmaterial heat gain through roof is reduced up to 82% in month of May, 57.24% and 8.4% reduction is seen in solar heat gain through window and air temperature respectively during peak load month which is found to be in month of May. 25% improvement is noted in average fangerpmv value which is a measurement of thermal comfort.

Table 4.1 Monthly heat gain through roof

MONTH	HEAT GAIN THROUGH ROOF (kWh)	
	ORIGINAL BUILDING	EEM BUILDING
JAN	-194.906	0.835637
FEB	-104.775	8.636765
MARCH	68.55378	30.32045
APRIL	213.7209	36.95488
MAY	223.4709	40.53132
JUNE	210.5925	36.25222
JULY	167.9375	30.35544
AUG	107.6767	24.89079
SEP	70.46751	23.27305
OCT	-26.9131	25.64525
NOV	-161.479	11.45911
DEC	-219.242	4.911243

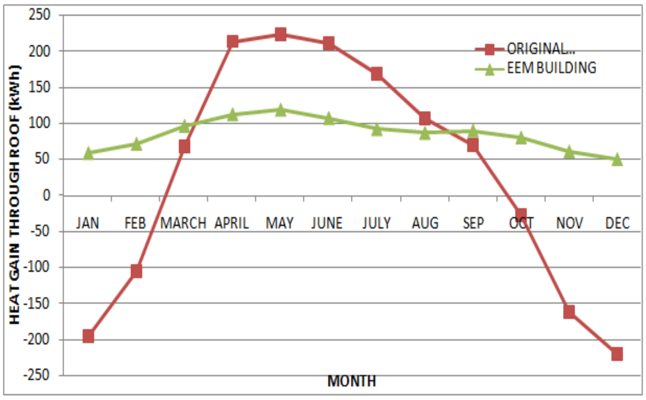

Fig 4.1 heat gain through roof

Table 4.2 Monthly solar heat gain through external window

MONTH	SOLAR HEAT GAIN THROUGH EX WINDOW (kWh)	
	ORIGINAL BUILDING	EEM BUILDING
JAN	139.0403	59.71693
FEB	168.6481	72.4339
MARCH	225.3507	96.79739
APRIL	262.0614	112.5602
MAY	276.821	118.8956
JUNE	250.094	107.397
JULY	215.3241	92.4791
AUG	203.1315	87.24641
SEP	209.9964	90.19749
OCT	188.2505	80.85818
NOV	144.0825	61.88418
DEC	119.527	51.33838

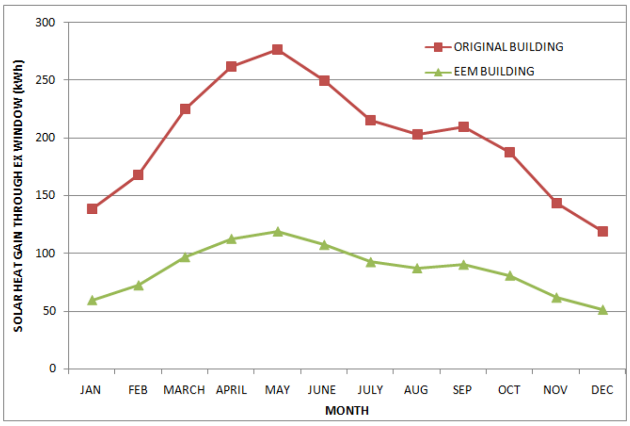

Fig 4.2 Solar heat gain through ex window

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Table 4.3 Monthly air temperature

MONTH	AIR TEMPERATURE(°C)	
	ORIGINAL BUILDING	EEM BUILDING
JAN	21.14038	19.1577
FEB	24.24151	21.53527
MARCH	30.72397	27.37926
APRIL	37.4525	33.5577
MAY	39.4759	36.13084
JUNE	39.36554	36.03242
JULY	35.32168	32.36863
AUG	33.59166	30.97842
SEP	34.87268	31.8541
OCT	33.58017	30.38086
NOV	28.25347	25.68745
DEC	21.30957	19.58468

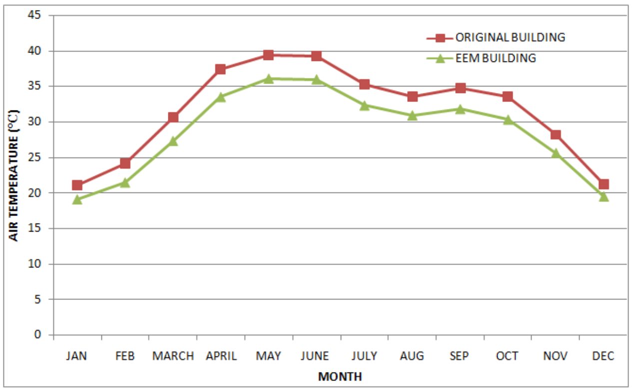

Fig 4.3 Air temperature of room

Table 4.4 Monthly fanger PMV

MONTH	FANGER PMV	
	ORIGINAL BUILDING	EEM BUILDING
JAN	1.021803	0.659305
FEB	1.450898	0.936962
MARCH	2.436359	1.766192
APRIL	3.776318	2.70297
MAY	4.238013	3.300018
JUNE	4.319681	3.356054
JULY	3.505126	2.737444
AUG	3.14945	2.493094
SEP	3.342089	2.556568
OCT	2.945704	2.252577
NOV	2.101084	1.537625
DEC	1.072571	0.736622

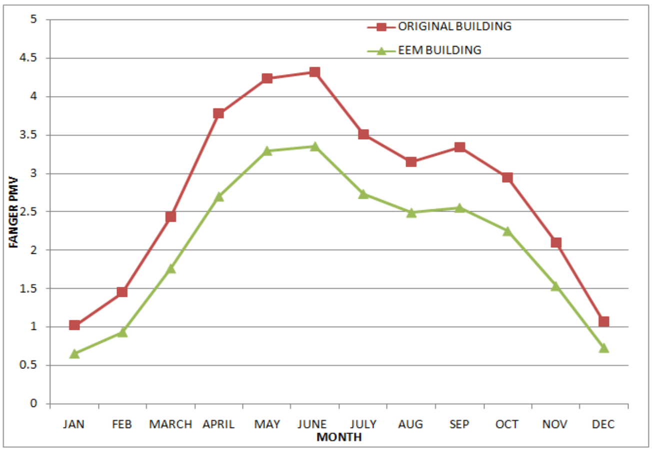

Fig 4.4 Fanger PMV of solar lab

4.2 EFFECT OF RADIANT COOLING ON VARIOUS MEASURES OF BUILDING

Two horizontal slices H1 at 1.1 m and H2 1.75m are taken from the floor because the sitting and standing height of human being is approximately 1.1m and 1.75m respectively. Table 4.5 to 4.8 shows the average value of these slices at four different cases i.e. basic building, floor radiant cooling, north wall radiant cooling, roof radiant cooling. Figure 4.5 to 4.11 shows the different slices representing temperature and velocity contour for each of the four cases. Fig4.12 & 4.13 shows the graphical comparison of temperature of four cases. It has been found in this study that giving 10°C and 15°C radiant floor cooling, reduction in temperature is 9.4% & 5.6% for H1 and 8.4 & 5.9 % for H2 respectively. By giving 10°C and 15°C radiant roof cooling, reduction in temperature is 5.8% & 3.8% for H1 and 7.3% & 5.4 % for H2 respectively and bygiving 10°C and 15°C radiant north wall cooling, reduction in temperature is 5.5% & 2.1% for H1 and 6.4 & 4.8 % for H2 respectively.

Table 4.5 Basic building

	HI	H2
AVG TEMP	34.56	34.87
AVG VELO	0.63	0.72

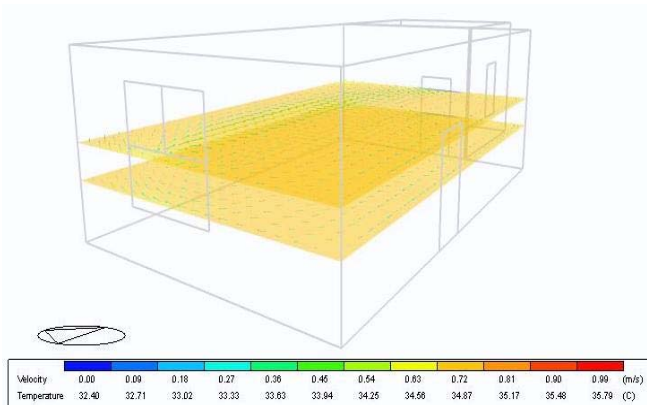

Fig. 4.5 Temp. & velocity contour at h_1&h_2

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Table 4.6 Building with floor radiant cooling

FLOOR TEMP		HI	H2
10	AVG TEMP	31.25	31.93
15		32.59	32.79
10	AVG VELO	0.36	0.54
15		0.54	0.63

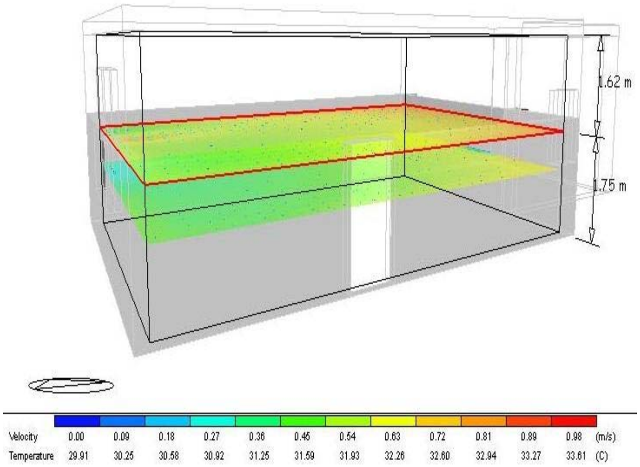

Fig.4.6 Horizontal contour of floor cooling with 10 °C

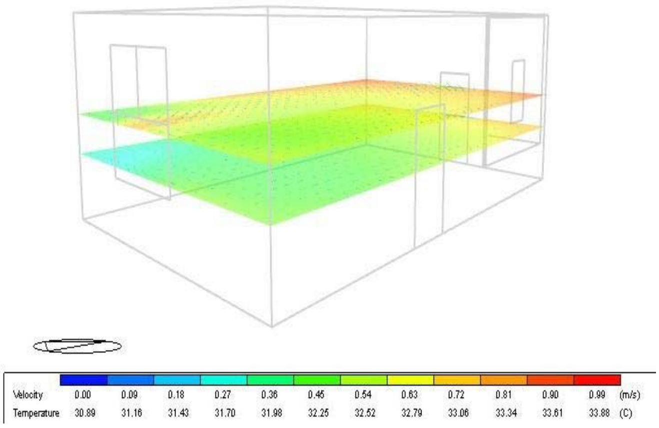

Fig.4.7 Horizontal contour of floor cooling with 15 °C

Table 4.7 Building with north wall cooling

NORTH WALL TEMP		HI	H2
10	AVG TEMP	32.63	32.63
15		33.19	33.19
10	AVG VELO	0.54	0.54
15		0.63	0.63

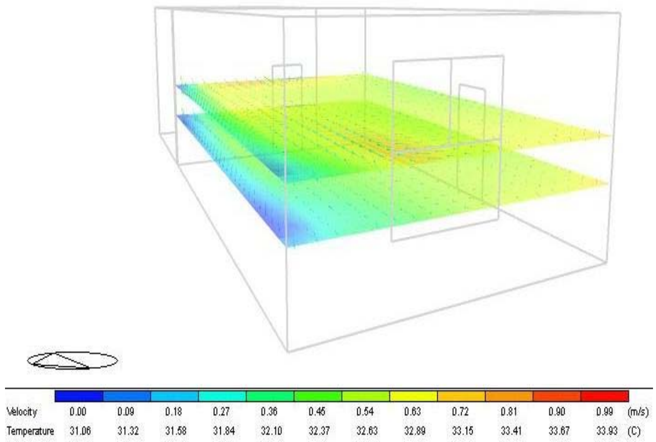

Fig.4.8 Horizontal profile of north wall cooling at 10 °C

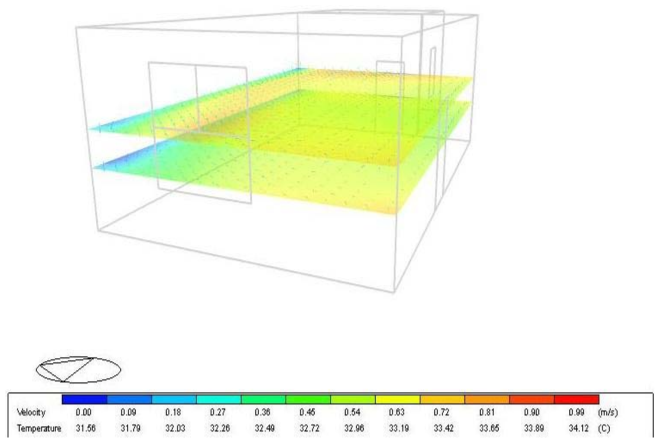

Fig.4.9 Horizontal profile of north wall cooling at 15 °C

Table 4.8 Building with roof radiant cooling

ROOF TEMP		HI	H2
10	AVG TEMP	32.51	32.29
15		33.19	32.96
10	AVG VELO	0.54	0.45
15		0.63	0.54

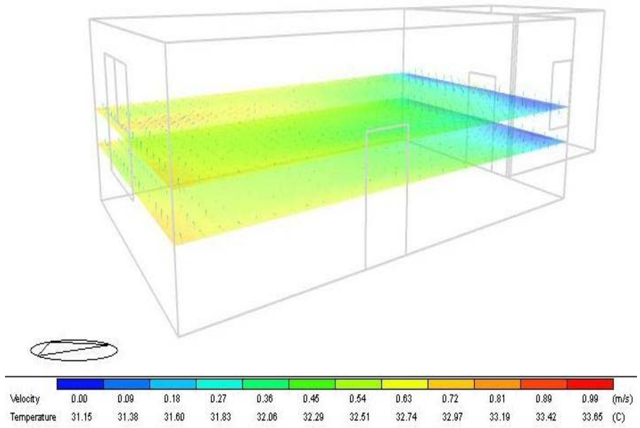

Fig. 4.10 Horizontal profile of roof cooling at 10 °C

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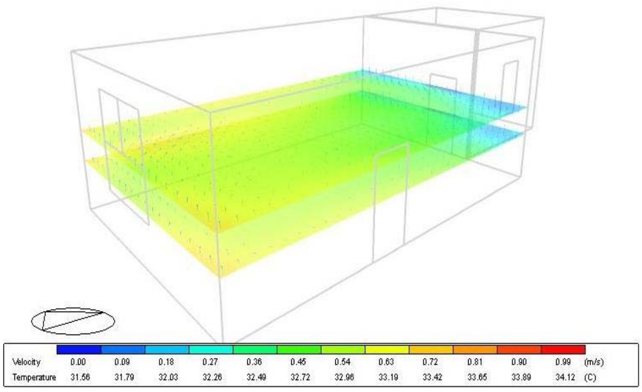

Fig. 4.11 Horizontal profile of roof cooling at 15 ˚C

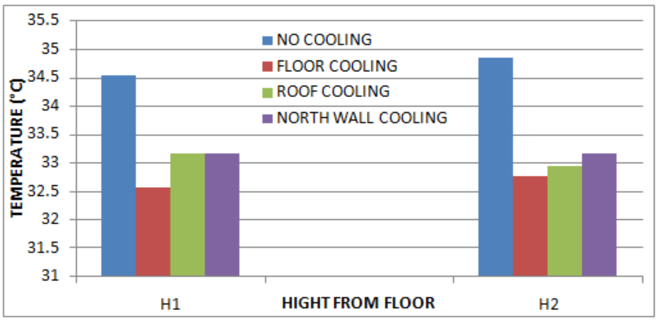

Fig. 4.12 Temperature graph at 10 ˚C radiant cooling

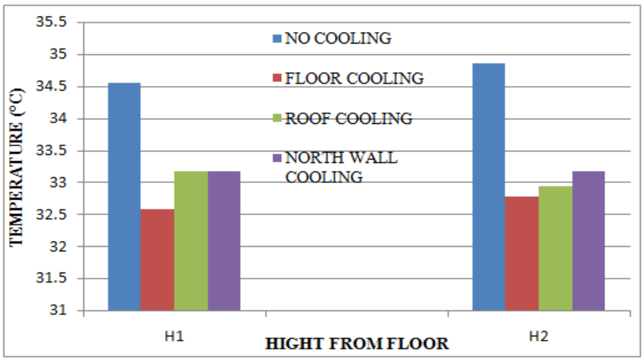

Figure 4.13 Temperature Graph At 15 ˚C Radiant Cooling

5. CONCLUSION

Following conclusion can be drawn by this study-

1. It is calculated that by modifying building material heat gain through roof is reduced up to 82% in month of May, 57.24% and 8.4% reduction is seen in solar heat gain through window and air temperature respectively during peak load monthand the is found to be month of May. 25% improvement is noted in average fangerpmv.
2. In case of radiant floor cooling (10 ˚C), 9.4% and 8.4% reduction in temperature (at H1& H2) is found as compared to the original condition. At 15˚ C the reduction is found to be 5.6% and 5.9%.
3. In case of radiant roof cooling the reduction in temperature at 10˚C is found to be 5.8% and 7.3% and at 15˚C it was 3.8% and 5.4%.
4. In case of north wall cooling reduction in temperature was found to be 5.5% and 6.4% at 10˚C and 2.1% and 4.8% at 15˚C.
5. If we compare the three types of radiant cooling systems, it can be concluded that radiant floor cooling is the best option for the solar lab.

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