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IMPACT OF RETROFITTING TECHNIQUES ON THE THERMAL CONDITION OF A UNIVERSITY BUILDING LOCATED IN COMPOSITE CLIMATE OF INDIA

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ABSTRACT

Being the third largest consumer of energy in the world, it becomes important to look for ways to reduce the energy consumed by the buildings. Since buildings provide vast opportunities to save energy, it is the easiest of ways to conserve energy. The block being unconditioned is simulated for checking the impact of energy efficient measures on the thermal comfort using a building energy simulation software Design Builder. The green roof has a great mitigation potential to improve the internal thermal condition of the building. Use of ceiling also helps in reducing the heat load gained from the roof. The effect that different types of window panes have on the thermal comfort is quite significant. Effects of applying a ceiling, different set of glasses and using a green roof individually and in combinations are noted down. It was observed that both air temperatures and thermal comfort of the building can be improved significantly if these parameters are used therby help us improving thermal conditions and paving a way to conserve cooling load in conditioned buildings.Here we are focusing on an unconditioned building block which is the Round Building of SURESH GYAN VIHAR UNIVERSITY, JAIPUR; located in the composite climate zone of the country is used for conducting lectures.

Key words: BES, Green roof, Design Builder, Energy conservation methods, Fanger PMV, Thermal comfort.

1. INTRODUCTION

During the 1960's and 70's, the world was going through a phase of energy crisis. The scientists realized that the conventional sources of fuel would not alone be able to sustain our requirements for a long time to come. So, it became important to look for some alternative sources of energy which were inexhaustible and would be able to fulfill our demands. It was clear that the technology was not ready to harness these sources immediately; so stress on efficient use of available sources became the need of the hour.

Buildings are the third major user of energy in the world contributing to the carbon emissions worldwide. This area holds a key position while planning for sustainable development strategies. [1]If we are able to conserve used by the buildings, then we would be able to take a great load off the conventional fuels. Synnefa et al. in their work shown that 60% of the electricity consumption in the OCED (Organization for Economic and Co-operative Development) economies is consumed by the buildings. [2]This value in India is about 33% out of which the industrial sector consumes 25% alone and rest 8% is by the residential sector. The Energy Conservation and Building Code of India states with confidence that it is possible to reduce the energy consumption of the buildings in India by 40% if the benchmarks created by them are followed. [3]

The virtual or computer simulation of a building with emphasis on consumption of energy and life cycle costs of the equipment run in a building requiring energy like air conditioning units, hot water units, lightings etc. is known as energy modelling. [4].As far as simulating an unconditioned building is concerned, what we really do is determine the thermal comfort of the building and try to restrict it to desirable limits. According to ASHRAE, "Thermal condition is the condition of mind which expresses satisfaction with thermal environment". [5] Thermal comfort is where there is a broad satisfaction with the thermal environment i.e., most people are neither too hot nor too cold.A model given by Prof. P. O. Fanger based on heat balance to evaluate the inside thermal condition. It was the PMV – PDD model. Thermal comfort is determined by the Predicted Mean Vote value and discomfort hours. The block being taken under study here is LT 21 of the round building. LT 21 is at the fourth floor of the building at is used for taking lectures.

Nomenclature	
BES	BUILDING ENERGY SIMULATION
ECBC	ENERGY CONSERVATION BUILDING CODE
PMV	PREDICTIVE MEAN VOTE
ECM	ENERGY CONSERVATION MEASURE
LT	LECTURE THEATRE
MBE	MEAN BIAS ERROR
CvRSME	COEFFICIENT OF VARIATION ROOT MEAN SQUARE ERROR

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The major contributor of building energy is the sun. The solar energy gained by the building adds up to the heat gained by the building. Energy consumption of a building depends upon it location, weather conditions, architectural designs, envelop features such as walls, glazing, roof etc. [6] The roof in this case adds a lot to the heat gained by the building. Absorption, radiation and transmission of the solar radiation take place from the roof. [7] If we reduce the radiation that is transmitted through the roof inside the building, we can improve the thermal condition of the inside of the building.

Another major contributor of heat is the windows. The external windows also add to the heat gained by the building. They are the source of unwanted heat gains and losses adding to thermal discomfort and energy consumed by the building. [8] The glasses used in the present building were that of Saint Gobain reflective (Blue) having a width of 5mm. Instead of that Guardian Sunguard AG50 glass having a low u-value was used.

Roofs occupy about 3.8 x 10^11 m2of urban area which is about 20% of the total area. Other than a ceiling, another way to reduce heat gained through the roof is the use of green roofs. This is one of the hottest measures used today as they have a great capability of keeping the radiation away from entering the building. A green roof is a cover of vegetation along with the growing medium over a waterproofing membrane. Apart from reducing heat gained through the roof it also reduces noise, improves air quality, increases shelf life of roofing materials etc. [9] A green roof is of two types: Intensive having a growing medium of 20cm or more and requiring irrigation and; Extensive having a growing medium of 10-15cms and does not generally require irrigation facilities. [10]The one applied in our building in as extensive one having vegetation and growing medium of 20cms each. The insulating membrane is a roofing tile of 1cm thick. The LAI kept in this case is 5 which is the maximum value that can be had. The choice of vegetation and type of green roof depends upon the location and type of building. [10]

2. METHEDOLOGY

2.1 LOCATION ANALYZED

The building is located in the pink city of the country, Jaipur which is having co ordinates of 26.92 degree north and 75.82 degree south. Jaipur is at a height of 1414 ft. above sea level.[11] It falls in the composite climate type of the country as described by the ECBC guide manual [2]. The coordinates of the place is 26.92 degree north and 75.82 degree south. The building on which the study is being conducted is a university building of SURESH GYAN VIHAR, established in the year 2000 at Mahal, Jagatpura, Jaipur – 302025. The top view and South facing view of the building is shown in fig 1 and fig 2.

respectively.

Figure 1: Top View of Round Building

Figure 2: South facing view of round building

2.2 MODEL DESCRIPTION

The classroom which is being modeled is located on the fourth floor of the building named LT 21;covers a floor are of 84.985 m2. The height of the ceiling is 11ft 1in. The classroom has the entry facing west. There are two doors at the front of the classroom having a dimension of (1.497m x 2.498m). There are windows above each door of same width and height of 1.04m.The east wall is an arc shaped wall having continuous windows at the top with a height of 0.572m. First set of four windows has a dimension of (0.613m x 2.248m). The second set of same number of windows measures (0.419m x 1.625m). The classroom has two tube lights and 5 ceiling fans which add to the electrical consumption of the block. There is a lobby of width 4.03m outside the classroom which leads to an open courtyard. Model generated of the building and the classroom being taken under consideration is shown in figure 3 and fig 4.

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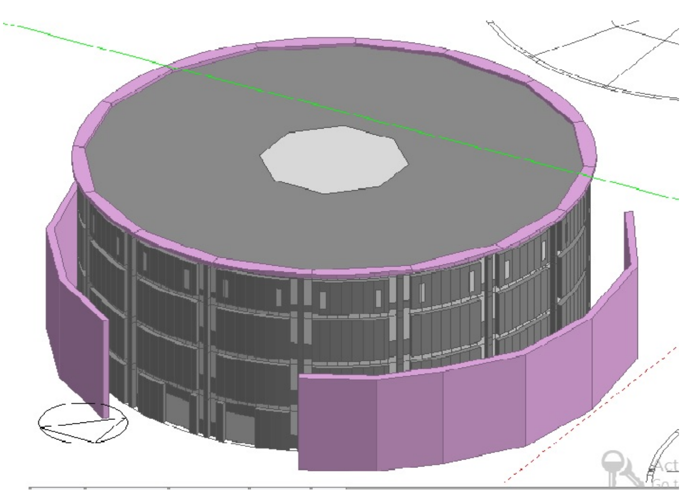

Figure 3: Model of Round Building generated in dB

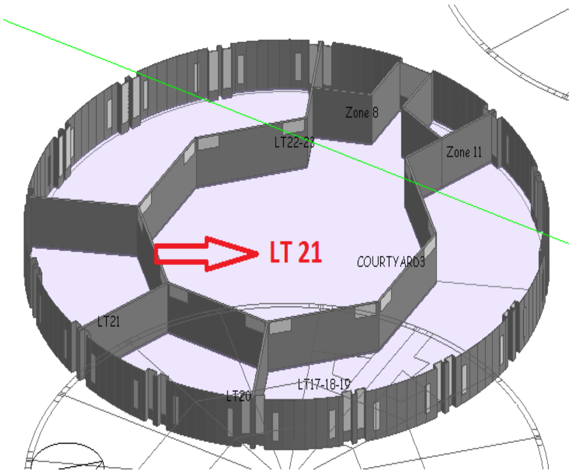

Figure 4: LT 21 at top floor generated in dB

2.3 MEASUREMENT OF AIR TEMPERATURE

For the validation of the work, the air temperature of the block was recorded for a total period of 70 hours spread over a time span of ten days with seven readings being recorded each day. These readings were compared with that given by the simulation software and mean bias error and coefficient of variation root mean square error was calculated. These values were checked whether the felt within acceptable limits of 10% and 15 [12] as specified by Dhaka et al. [6] A graph comparing the measured and simulated values has been shown below in graph 1. Image of thermometers installed in the classroom is shown in fig 5.

Figure 5: Thermometer put in LT 21 for air temperature measurement

2.4 CONSTRUCTION DETAILS

The table 2-1 and 2-2 given below shows the construction layer by layer of the building envelope, namely the roof, external walls and the internal partition and the openings respectively. Also given below is the image of layers of construction of external wall, internal wall and the roof generated by the design builder in fig 6, 7 and 8 respectively.

Table 2-1 Construction layers of building envelope

MATERIALS (OUTER TO INNER)	ROOF (M)	EXTERNAL WALLS (m)	INTERNAL WALLS (m)
Wall Paint (PU)	-	0.001	0.001
Gypsum Plaster	-	0.002	0.002
Cement Plaster	0.0191	0.0191	0.0191
Concrete	0.1524	-	-
Bricks	-	0.2032	0.1016
Cement plaster	0.0191	0.0191	0.0191
Gypsum Plaster	0.002	0.002	0.002

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Wall Paint (PU)	0.001	0.001	0.001
U-value (W-m2/K)	3.802	1.911	2.118

Table 2-2 Specifications of Building openings

OPENING	**THICKNESS (m)**	**U-VALUE (W-m2/K)**	**SCHG**
Saint Gobain SGG	0.005	5.701	0.672
Guardian Sunguard AG	0.005	3.330	0.330
Door	0.035	2.251	-

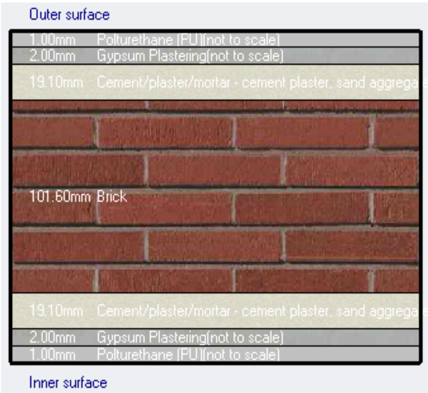

Figure 6: Internal Wall

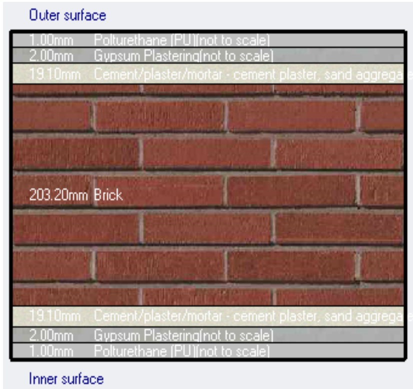

Figure 7: External Wall

Figure 8 Roof Layer Construction

2.5 ENERGY CONSERVATION MEASURES

The retrofitting techniques that has been under lens in this work is the use of a ceiling at a height of 0.3m from the top; use of a green roof, and different set of windows having a lower u value. These simple ECMs having been abbreviated as described further. The block with ceiling is ECM Ceiling, abbreviated as ECM C; block with green roof is ECM Green Roof, abbreviated as ECM GR and the block with different set of windows, ECM Glazing is abbreviated as ECM G After applying the ECMs, the changes in the construction of the roof is shown in table 2-3 given below. The changes in the ECM G are shown in table 2-2.

Table 2-3 Construction layers after application of ECMs.

MATERIALS (OUTSIDE TO INDISE)	**ROOF WITH CEILING (m)**	**GREEN ROOF (m)**	**GREEN ROOF + CEILING (m)**
Vegetation	-	0.2	0.1
Soil	-	0.2	0.2
Roof Tile	-	0.01	0.01
Cement Plaster	0.0191	0.0191	0.0191
Concrete	0.1524	0.1524	0.1524
Cement Plaster	0.0191	0.0191	0.0191
Gypsum Plaster	0.002	0.002	0.002
Wall Paint (PU)	0.001	0.001	0.001
Glass Wool	0.08	-	-

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Air Gap	0.3	-	0.3
Gypsum Plasterboard	0.01	-	0.01
U-value (W-m2/K)	0.395	0.788	0.814

2.6 VALIDATION

The value of MBE and Cv(RSME) were calculated by the equations 1-4. The value of MBE was found to be 4.4% while the Cv(RSME) was 7.06. These values are within limit as given by the IPMVP and ASHRAE [12] So, it can be said that the building simulation performs within acceptable limits. The equations used to calculate the values are given below,

$$\textbf{MBE (\%)} = \frac{\sum_{period} (S-M)_{interval}}{\sum_{period} M_{interval}} \text{ x } 100 \quad \textbf{(Eq. 1)}$$

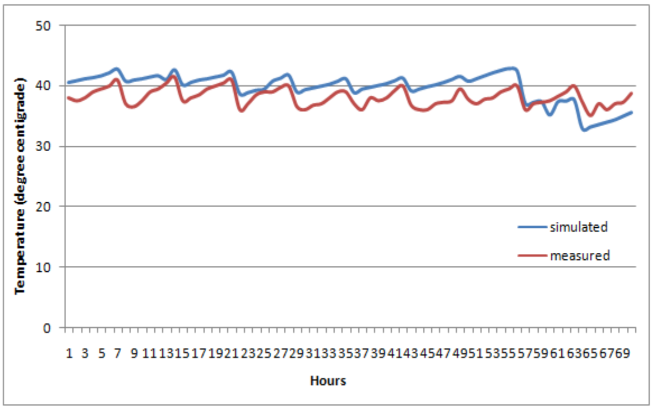
Where S is the simulated air temperature and M is the measured air temperature of LT 21.

$$RMSE_{period} = \sqrt{\frac{\sum (S-M)^2_{interval}}{N_{interval}}} \quad \textbf{(Eq. 2)}$$

Here, N is the no of intervals in the given period.

$$A_{period} = \frac{\sum_{period} M_{interval}}{N_{interval}} \quad \textbf{(Eq. 3)}$$

$$C_v(RMSE_{period}) = \frac{RMSE_{period}}{A_{period}} \text{ x } 100 \quad \textbf{(Eq. 4)}$$



Graph 2-1 Simulated and measured air temperatures

3. RESULT AND DISCUSSION

3.1 BASE CONDITION

Base condition is the present state of the building. Below in the table 3-1 given are the values of air temperature, Fanger PMV and Discomfort hours of the building in the present situation. These values will be compared with those of the ECM states in successive cases.

Table 3-1 Behavior at base condition of building

MONTH	AIR TEMPERATURE (°C)	FANGER PMV	DISCOMFORT HOURS (hrs)
JAN	20.37394	-0.91528	41
FEB	24.07678	3.14E-02	19
MAR	30.39595	1.895313	135
APR	37.62376	4.453645	130
MAY	40.51548	5.737963	80
JUN	40.60106	5.824742	0
JUL	36.20061	4.30785	114
AUG	34.06407	3.480472	134
SEP	34.87732	3.638945	148
OCT	32.86327	2.681573	114
NOV	27.65652	1.082551	79
DEC	20.50238	-0.84119	9

3.2 ENERGY EFFICIENT MEASURES

3.2.1 ECM Glazing

The windows fitted in the base condition of the building are that of Saint Gobain. They are blue reflective type having a width of 5mm. In this ECM measure, the windows were replaced by that of Guardian Sunguard AG50 glasses of the same width. As a result, we observed that the peak average air temperature reduction in the month of April by 0.9 degree centigrade. The annual average reduction of air temperature was 2%. The thermal comfort parameter also reduced by 0.3 points during the same time denoting 5% reduction. Table 3-2 gives the output.

Table 3-2 Behavior of LT 21 after applying ECM glazing

MONTH	AIR TEMPERATURE (°C)	FANGER PMV
JAN	19.79494	-1.07026
FEB	23.39544	-0.15387
MAR	29.69696	1.70063
APR	36.70724	4.086433
MAY	39.71963	5.429388
JUN	39.8015	5.521276
JUL	35.52224	4.041389
AUG	33.46274	3.243142
SEP	34.22136	3.374262
OCT	32.17147	2.485815
NOV	26.93197	0.883336
DEC	20.00868	-0.97452

3.2.2 ECM Ceiling

A ceiling was applied at a height of 0.3m from the present condition. A layer of glass wool was also applied of width 8cms at first. The width of the ceiling board was 1cm. The construction details have been discussed earlier in table 2-3. The effect of applying ceiling was that, we received a maximum 1.7 degree dip in average air temperature leading to a total 2.5% annual reduction. The Fanger PMV value was reduced by 12% which was about 0.72 points. The output has been shown in table 3-3. The construction layer of roof after applying a ceiling is shown in fig 9.

Table 3-3Annual behavior of LT 21 after applying ECM Ceiling

MONTH	AIR TEMPERATURE (°C)	FANGER PMV
JAN	20.5346	-0.86617
FEB	23.9521	7.15E-04
MAR	29.4622	1.608921
APR	35.97576	3.742465
MAY	38.75454	4.971444
JUN	38.91106	5.102819
JUL	34.84772	3.722671
AUG	33.07607	3.049616
SEP	33.84033	3.186594

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OCT	32.17332	2.475896
NOV	27.66567	1.094161
DEC	20.89963	-0.71968

Figure 9: Roof layer after applying ECM Ceiling

3.2.3 ECM Green Roof

In case of applying a green roof to the building, we have to use an intensive type as there is shortage of rainfall. There was a layer of insulation roof tile applied of 1cm above which was a 20cms soil cover. The vegetation was allowed to grow to a height of 20cms as well. The LAI has been kept 5. Construction details have been discussed earlier in table 2-3. 2.4 degree reduction (max) was observed in average air temperature and Fanger PMV values improved by 1.45 points. The results have been shown in table 3-4. Layer of green roof applied is shown in fig 10.

Table 3-4 Behavior of LT 21 after applying ECM Green Roof

MONTH	AIR TEMPERATURE (°C)	FANGER PMV
JAN	20.37992	-0.90885
FEB	23.04005	-0.26732
MAR	28.43475	1.290792
APR	34.30281	3.003264
MAY	37.3549	4.35357
JUN	38.16655	4.770531
JUL	34.56321	3.589872
AUG	32.83651	2.940813
SEP	33.21794	2.908152
OCT	31.49177	2.266145
NOV	27.14075	0.939227
DEC	21.03687	-0.67442

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Figure 10: Roof layer after applying ECM Green Roof

3.2.4 ECM Ceiling + Glazing

The reduction in average air temperature was 2.8 degree centigrade at maximum during June and the Fanger PMV value improved by 1.2 points during the same period. There was a reduction of 5% in average air temperature annually. All these led to a reduction of 17 discomfort hours annually. The results are given in table 3-5 below.

Table 3-5 Data for ECM ceiling + ECM glazing

MONTH	AIR TEMPERATURE (°C)	FANGER PMV	DISCOMFORT HRS (hrs)
JAN	19.89375	-1.04688	30
FEB	23.24814	-0.20456	12
MAR	28.64095	1.356004	133
APR	34.87412	3.253654	130
MAY	37.64883	4.485522	80
JUN	37.76991	4.614103	0
JUL	33.96733	3.3358	114
AUG	32.33699	2.721773	134
SEP	33.06113	2.834841	148
OCT	31.37197	2.228907	114
NOV	26.91552	0.87368	84
DEC	20.38715	-0.86277	7

3.2.5 ECM Green Roof + Ceiling

With an average reduction of 4.6 degree in air temperature and 2 points in PMV values, this ECM measure led to annual reduction in air temperature by 8%. The total discomfort hours also reduced by 41. Table 3-6 gives the values.

Table 3-6Data for ECM ceiling + Green Roof case

MONTH	AIR TEMPERATURE (°C)	FANGER PMV	DISCOMFORT HOURS (HRS)
JAN	19.65723	-1.12473	34
FEB	22.407	-0.47016	6
MAR	27.40878	0.963737	121
APR	32.98636	2.424014	130
MAY	35.83159	3.687407	80
JUN	36.06642	3.883716	0
JUL	33.37617	3.066133	114
AUG	32.00145	2.563906	134
SEP	32.39367	2.526359	148
OCT	30.55445	1.968643	114
NOV	26.20982	0.646165	74
DEC	20.38003	-0.87659	6

3.2.6 ECM Green Roof + Glazing

Reduction in average monthly air temperature by 5 degree centigrade during April and Fanger PMV value by 2.27 points the total discomfort hours reduced by 51. The total annual reduction in average monthly temperature was 9%.

Table 3-7Values for the case ECM green roof + glazing

MONTH	AIR TEMPERATURE (°C)	FANGER PMV	DISCOMFORT HOURS (HRS)
JAN	19.41622	-1.17949	34
FEB	21.90051	-0.60347	2
MAR	27.19834	0.905589	121
APR	32.47894	2.177416	130
MAY	35.6538	3.583743	80
JUN	36.05531	3.849828	0
JUL	33.14748	2.96154	114
AUG	31.66394	2.420276	134
SEP	31.90487	2.31206	148
OCT	30.21175	1.869117	114
NOV	25.85776	0.559406	72
DEC	20.18435	-0.91353	3

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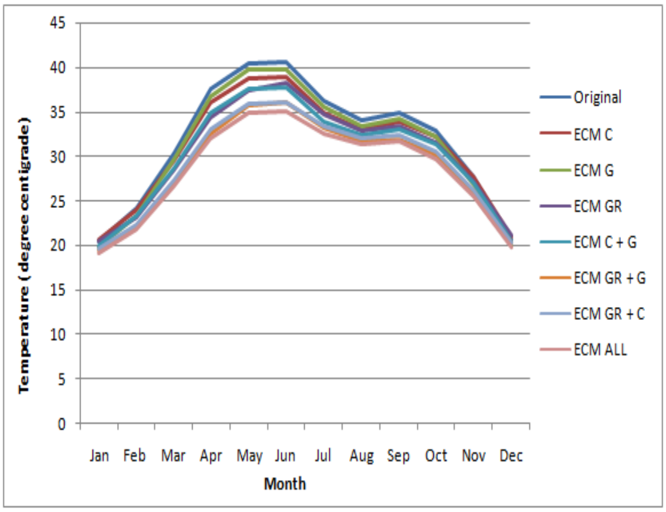
3.2.7 ECM All

Combining all the ECM measures gave us the best results. There was a maximum average monthly air temperature reduction 5.7 degree centigrade during May with PMV value falling by 2.5 points which was a 43% reduction from the original case. Annual reduction in average monthly air temperature reduction was by 10.5%. Discomfort hours, as a result reduced by 74 hours.

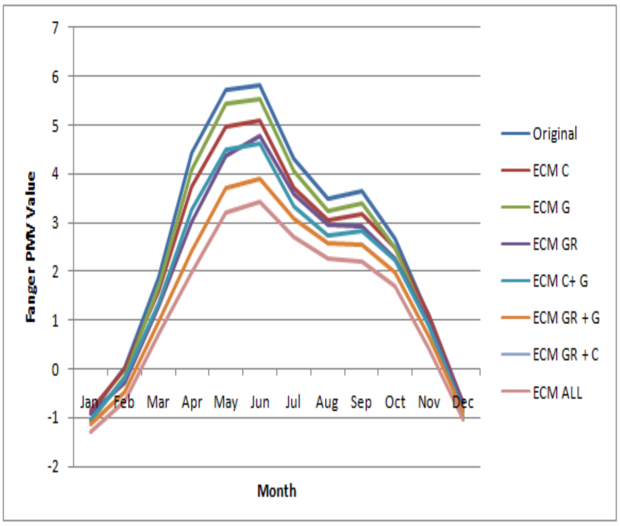
Table 3-8showing data when all the ECM's have been applied simultaneously

MONTH	AIR TEMPERATURE (°C)	FANGER PMV	DISCOMFORT HOURS (HRS)
JAN	19.10372	-1.28084	40
FEB	21.73686	-0.66904	5
MAR	26.64174	0.723898	101
APR	32.04007	1.989175	130
MAY	34.78257	3.212826	80
JUN	35.02935	3.425239	0
JUL	32.54326	2.689307	114
AUG	31.3046	2.250568	134
SEP	31.64781	2.187179	148
OCT	29.73041	1.710791	114
NOV	25.46687	0.424905	57
DEC	19.82658	-1.0351	6

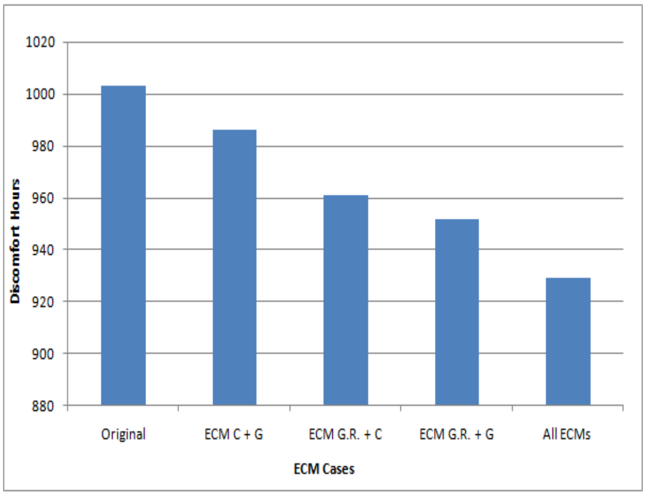
A graph showing the air temperature values, Fanger PMV values and discomfort hours in different ECM cases have been shown below.



Graph 3-1 Air Temperature for LT 21



Graph 3-2 Fanger PMV values for LT 21



Graph 3-3 Discomfort hours

4. CONCLUSION

In this study, some of the energy conservation measures were taken like the use of a ceiling, use of low u-value glasses and a green roof. The results that were obtained for the concerned building were over whelming.

Applying ceiling in the building could lead to a maximum average monthly reduction of 1.7ºC during the summer season. Also the comfort PMV factor could be improved by 0.72 points.

The use of low value glasses lead to maximum reduction of average temperature of a month in summer by 0.9ºC. The PMV value also dipped by 0.3 points.

The use of green roof measure proved to be the best measure of all. This ECM measure gave the best results. The dip in average monthly temperature was recorded to be 2.4ºC and the Fanger PMV value was reduced by 1.45 points.

It was interesting to note that in case of using the measures in combination and not alone could improve the results to a much greater extent. In case of using ECM Ceiling and ECM Glazing together, i.e., applying a ceiling and well as replacing the glasses of the classroom, it was possible to achieve average monthly reduction of 2.8ºC (max.) during the summer month and PMV value got improved by 1.2 points.

The ECM Green Roof and ECM Ceiling condition led to a max average temperature reduction by 4.6ºC which is worth noting. The thermal comfort factor also got reduced by 2 points.

In case of using ECM Green Roof with the ECM Glazing, this combination proved to be the best when using two measures simultaneously. The reduction in average air temperature was 5ºC during the summer months. The P comfort factors too dipped by a considerable 2.27 points.

At last, all the measures were used simultaneously. The caused the average reduction in air temperature by 5.7ºC. The Fanger PMV value decreased by 2.5 points.

It can be noted that these measures were able to improve the thermal condition of the building by a great amount. This area provides vast scope to improve the thermal condition as well as save the energy consumption of the building.

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