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Adapting Extensive Green Roof System as Sustainable Building Design in INDIA

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Abstract:- Green roofing system is innovative step in the path of infrastructure sustainability, India is fast growing population therefore in modern society going beyond the ecologically sustainable system and natural conventional green method of construction due to present need of per capita area consumption that leads global and local warming both, whether green roofing system controls all season temperature variation as well as improve green rating of building. This study based on UHI (Urban heat island effect) of 8-layer green roofing by using locally available waste, it consists experimental study of temperature variation of outdoor as well as indoor in July-August (summer to rainy) found temperature drop of -5^{0}C at outdoor and -2^{0}C at indoor, and cost analysis for 100ft^2 area.

Keyword:- *Green Roof, Green Building, UHI Effect, Statistical Analysis, Outdoor and Indoor Roof Temperature Variation.*

I. INTRODUCTION

Green building and green rating- Building have negative and positive both impact on surroundings, green building improve the positive impact as well as reduce the negative impact on surroundings by reduce trace material, reducing pollution and global warming, using renewable and non-toxic sustainable material, improve utilization of energy and natural resource like water, it improves social and mental health reduce emission of carbon di oxide and environment friendly technique. Strategies behind the concept of green buildings are as following-

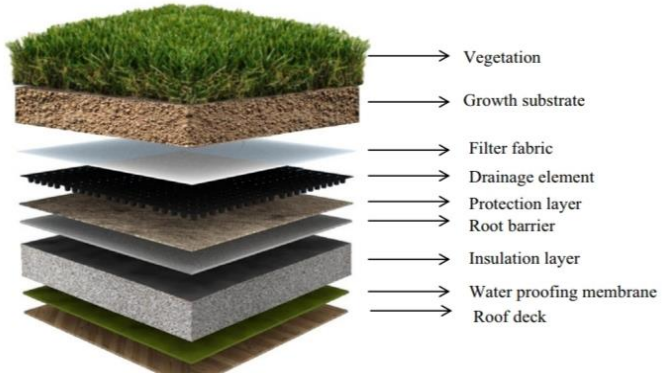
Renewable material utilization, Building Insulation , Indoor air quality, Roofs and walls temperature control, position and types of window to maximum energy utilization for less energy consumption, Water is also very important factor of green building, land scaping, initial cost of green building is higher than the normal building but difference of the cost can cover in 6 months by energy saving and reduce the maintenance, Green building standards are provided by lead certificate based on design, construct, operate and maintenance of the building.

Urban heat island- Urbanization gives negative impact on surroundings, it rise in temperature on a particular buildup area and this area is heated up and with compare to surroundings known are heat island effect.[6] We can see rural or less develop area have less local warming while highly urbanize area is more heated, this is because of surface heat absorption and reflection, every surface material have different heat absorption capacity like soil absorb less heat with compare to concrete surface therefore concrete surface absorb more heat and reduce surrounding air quality and also generate stress to the environment.

Green roofing system- Green roofing technique is part of green building concept to reduce negative stress from environment by improve air quality and reduce indoor, outdoor temperature. It consists of 8-layer system provide top of the roof; these are of three types [5]

I. Intensive green roof system- It is heavy thick layer of more than 30cm, in this system fast growing trees are provided.
II. Semi intensive green roof system- It is medium thick layer of green roofing material 15-30cm, in this system plants are proved.
III. Extensive system- This system is thin as 5-15cm, it can provide in existing building also due to its less impose load it can reduce up to -15^{0}C temperature of citywide.

Figure 1 Green roofing system (Source: own designed)



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LIST OF ABBREVIATION-

UHI Urban heat island
MGR Modular green roof
ER Exposed roof
SR Solar radiation(w/m2)
RH Relative humidity (%)
ΔTo, ΔTi (Outdoor roof and indoor room) temperature difference

To-MGR, To-ER Surface temperature above (modular green roof and exposed roof)

Ti-MGR, Ti-ER Room temperature (modular green roof and exposed roof)

(ΔTo < 0°c), (ΔTi < 0°c) MGR has cooling effect
(ΔTo ≥ 0°c), (ΔTi ≥ 0°c) MGR has warming effect
(δTo-daily), (δTi-daily) Mean of daily surface temperature for (outdoor roof and indoor room)
Rangeo, Rangei (Max. temp. – Min. temp.) for indoor room and outdoor roof

Standard deviation
Max. δTo and Max. δTi Max. daily temperature = (Max. temp. of MGR – Max. temp. of ER) for both indoor and outdoor

Min. δTo and Min. δTi Min. daily temperature = (Min. temp. of MGR – Min. temp. of ER) for both indoor and outdoor

Ta-daily Daily temperature variation
Sunny day (Ta-daily < 0°c) daily temp. variation has cooling effect (outdoor and indoor)

Cloudy day (Ta-daily ≥ 0°c) daily temp. variation has warming effect (outdoor and indoor)

Max. Ta-daily and Min. Ta-daily Max. and Min. daily temp. variation

δTa- daily overall daily temperature variation

II. LITERATURE REVIEW

This paper is mainly studied regarding green roof properties, environment, social and monetary benefits. This article tries to studies, that how the overall performance of green roofs can be work in reducing storm water and energy costs, improving air quality and ecological performance. By emphasizing the need to develop cost-effective green roof practices for considering several benefits of green roof for natural surroundings.[1]

This research studied about caparison to conventional roofs, green roof examines many benefits, by increasing urban biodiversity, decreases the energy consumption of a building, mitigate noise and must importantly reduction the roof surface temp and surrounding air green roof can reduce up to (-15°c), city-wide ambient temp, whereas compared to the conventional roof, green roof lowers the temperature up to (-2°c to -4°c).[2]

This research gives conceptual knowledge about the sustainable development of the economy when promoting engineering construction work. For green construction right merging new materials to be selected for improving the total quality of construction and reduce the problem facing heat insulation, environment protection strategy, and energy-saving impact.[3]

This paper reviewed the role, requirement, performance, and material of components of a green roof such as anti-root membranes, filter, drainage and substrate, vegetation. Each component of a green roof is selected in such a way that it gives the best results depends on a geographical location, climate condition, physical and characteristic properties.[5]

The study shows that the full-scale EGR in a sub-tropical monsoon climate, found to be a slight cooling effect in all three heights (30 cm – (-0.09°c)), (60 cm – (-0.23°c)) and (120 cm – (-0.09°c)) resp. On a sunny day the max. warming effect at three heights was (1.59°c, 0.59°c, 0.38°c) resp in the daytime for weather scenario, sunny days have the highest impact on the EGR for thermal performance compare to less impact cloudy and rainy days.[6]

This is experimental study for temperature variation outdoor as well as indoor, found average temperature variation outdoor and indoor are 1.8^0C and 0.9^0C.[7]

This article analysis on both tradition green roof structure such (intensive, extensive and semi-intensive) and modular green roof system. For gaining profit and benefits in environment, social and ecological design of green roof technologies. Alternative resources and innovative methods are proposed for a new building that involves green infrastructure and smart green cities development.[8]

In this experimental analysis give a pure idea about range of bulk density, dry density, water holding capacity, soil depth and P_H value of extensive green roofing growth medium as 77kg/m^3, 600kg/m^3, 36%, 2-15cm, 5-8P_H respectively.[13]

III. METHODOLOGY

3.1. Material- Green roofing material provided in following layers (top to bottom) [3,4]

1. Plants and vegetation
2. Growth medium- organic soil made up by 40% locally available soil +40% Vermeer compost + 20% coco peat
3. Filter layer- Geo textile item bags (domestic waste)
4. Drainage layer (polystyrene tray)
5. Root barrier- Jute carpet
6. Insulation - Synthetic foam
7. Water proofing layer- polythene film seat
8. Modular type basket movable for support.[8]

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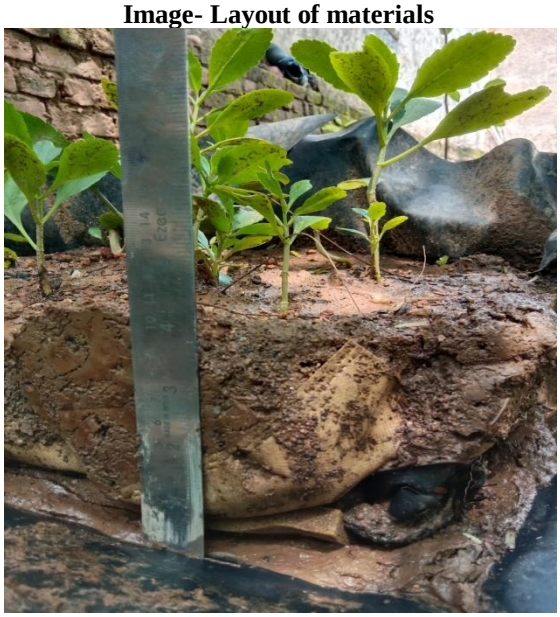
Image- Layout of materials



3.2 Testing and Temperature variation justification-

Growth medium is laboratory tested for 2 soil samples made up with SAMPLE 1 - (Soil 40% + Verme-compost 40% + Coco peat 20%)
SAMPLE 2 – (Soil 30% + Verme-compost 30% + Coco peat 20% + Sand 20%)

Temperature measuring device for outdoor and indoor monitoring period, digital pyranometer (Solar radiation), digital thermo couple (surface temperature) and hygrometer (relative humidity).[6] Outdoor radiation sensor applied on 60cm above the surface level as well as on surface also on both areas (Green roofing area and normal condition roofing area) to detect the temperature variation.

Indoor temperature variation detects through green roof model or small-scale prototype sensors are applied inside the prototype model.[7]

Frequency of temperature measurement is hourly in day time for compete week.

3.3 Cost estimation-

Cost estimation for 100ft^2 roof is also done with local rates, every item is available in different quantum's so there is rate analysis is done and found Rs.150/2.15 ft^2 (1 MGR) and Rs.7200/100 ft^2(47 MGR).

Soil, Verme compost, Coco peat, Sand, Non-woven geo-textile bag, Polystyrene tray, Jute durrie, Synthetic foam, Polyethylene film sheet, Modular basket, and Plants/vegetation as Locally available, Rs.440/19 kg, Rs. 100/5 kg Rs. 190/47 kg, Rs. 190/47 bag, Rs. 940/47 pcs, Rs. 630/21m, Rs. 300/6 sheet, Rs. 315/21m Rs.1900/47basket, and Rs. 1600/ 100 ft^2 respectively.

IV. RESULTS AND ANALYSIS

4.1 Selection of growth medium- Growth medium samples tested in laboratory for water absorption and P_H value found 46%, 36% water absorption of Sample-1 and Sample- 2 respectively, and PH value is 7.88 and 8.05 of sample-1 and sample-2 respectively. Therefore, sample of organic soil used for performance is mode up with 40% local soil, 40% verme compost +20% coco peat.[13]

Bulk density of growth medium found as 570 kg/m^3, dry weight density of growth medium as 80kg/m^3 and soil depth is found as 8cm.

4.2 Experiment results (outdoor and indoor)

Daily Thermal performance of MGR and ER- Daily thermal performance recorded as following-

TABLE 4.1 OUTDOOR ROOF SURFACE TEMPRATURE (°C)					7 DAYS	
DATE	**To-MGR**	**To-ER**	**ΔTo**	**SR (W/m2)**	**RH (%)**	**Weather, Rainfall(mm)**
12/7	34.7	38.1	-3.4	357	57.2	Cloudy (0.5mm)
13/7	39.6	45.5	-5.9	976	58.8	Sunny
14/7	40.7	44.2	-3.5	800	58.8	Sunny
15/7	39.3	44.7	-5.4	708	44.4	Sunny
16/7	41.3	46.2	-4.9	702	31	Sunny
19/7	28.4	29.4	-1	57	69.8	Rain (9mm)
20/7	31.9	33.9	-2	256	68.8	Rain (3mm)

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TABLE 4.2 INDOOR ROOM TEMPRATURE (°c)						10 DAYS
DATE	**Ti-MGR**	**Ti-ER**	**ΔTi**	**SR (W/m2)**	**RH (%)**	**Weather, Rainfall(mm)**
1/8	27.4	28.0	-0.6	301	80	Rain (4.2mm)
2/8	26.2	26.4	-0.2	143	87	Rain (1.3mm)
3/8	26.8	27.2	-0.4	643	82	Sunny
4/8	27.0	27.7	-0.7	441	85	Rain (8mm)
6/8	28.3	29.7	-1.4	951	73	Sunny
7/8	28.6	30.0	-1.4	1080	74	Sunny
8/8	29.0	30.5	-1.5	810	83	Rain (7.1mm)
10/8	28.9	30.9	-2	1007	72	Sunny
11/8	29.4	30.7	-1.3	1023	69	Sunny
12/8	28.2	30.0	-1.8	494	70	Sunny

Statistical Analysis- For measuring statistical analysis of extensive green roof. Firstly, calculate the mean of daily surface temperature for both indoor room and outdoor roof surface as (δTo-daily and δTi- daily). Considering height of 60cm for both MGR and ER resp.

TABLE 4.3 OUTDOOR ROOF SURFACE TEMPRATURE (°c) for MGR					
DATE	**MAX. TEMp**	**MIN. TEMP.**	**MEAN (δTo-daily)**	**Rangeo**	**Standard Deviation**
12/7	37.1	30	34.7	7.1	1.12
13/7	41.7	37.3	39.6	4.4	0.73
14/7	44.8	37.8	40.7	7	1.32
15/7	42.4	37.5	39.2	4.9	0.74
16/7	44.8	37.8	41.3	7	1.01
19/7	29.3	26.8	28.4	2.5	0.41
20/7	33.5	30.2	31.9	3.3	1.33

TABLE 4.4 INDOOR ROOM TEMPRATURE (°C) for MGR					
DATE	**MAX. TEMP**	**MIN. TEMP.**	**MEAN (δTi- daily)**	**Rangei**	**Standarddeviation**
1/8	28.4	25.8	27.4	2.6	0.34
2/8	27.1	25.0	26.2	2.1	0.25
3/8	27.4	26.2	26.8	1.2	0.15
4/8	28.9	25.0	27.0	3.9	0.55
6/8	29.1	27.6	28.4	1.5	0.17
7/8	29.2	28.2	28.6	1	0.13
8/8	29.8	27.8	29.1	2	0.28
10/8	29.3	28.5	28.9	0.8	0.09
11/8	30.2	28.1	29.4	2.1	0.29
12/8	29.4	27.6	28.2	1.8	0.22

Extreme thermal values are as following-

TABLE-4.5 OUTDOOR ROOF SURFACE TEMPERATURE (°C)						
DATE	**Max.Temp. MGR**	**Min. temp. MGR**	**Max.Temp. ER**	**Min. temp. ER**	**Max. δTo**	**Min.δTo**
12/7	37.1	30	42.7	32.4	-5.6	-2.4
13/7	41.7	37.3	47.4	42.1	-5.7	-4.8
14/7	44.8	37.8	47.3	41.1	-2.5	-3.3
15/7	42.4	37.5	48.1	42	-5.7	-4.5
16/7	44.8	37.8	48.4	42.5	-3.6	-4.7
19/7	29.8	26.8	30.4	27	-1.1	-0.2
20/7	33.5	30.2	37.8	30.3	-4.3	-0.1

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TABLE-4.6 INDOOR ROOM TEMPERATURE (°C)						
DATE	**Max.temp. MGR**	**Min. temp. MGR**	**Max.temp. ER**	**Min. temp. ER**	**Max.δTi**	**Min.δTi**
1/8	28.4	25.8	29	26.2	-0.6	-0.4
2/8	27.1	25	27.4	25.3	-0.3	-0.3
3/8	27.4	26.2	28	26.2	-0.6	0
4/8	28.3	25	30.2	25.1	-1.3	-0.1
6/8	29.1	27.6	30.5	28.8	-1.4	-1.2
7/8	29.2	28.2	30.6	29.7	-1.4	-1.5
8/8	29.8	27.8	32	28.3	-2.2	- 0.5
10/8	29.3	28.5	31.3	30.5	-1.5	-2
11/8	30.2	28.1	31.7	29.3	-1.5	-1.2
12/8	29.4	27.6	31.3	29.2	-1.9	-1.8

Maximum and minimum overall daily temperature variation is also studied together-

TABLE 4.7 For (Ta-daily < 0°c)							
SUNNY DAYS				**CLOUDY DAYS**			
Surface	DAYS	Ta- daily	Min. Ta-daily	Surface	DAYS	Ta- daily	Min. Ta- daily
Outdoor	4	-4.32	-4.8	Outdoor	3	-0.9	-2.4
Indoor	6	-1.28	-2	Indoor	4	-0.32	-0.5

TABLE 4.8 For (Ta-daily ≥ 0°c)							
SUNNY DAYS				**CLOUDY DAYS**			
Surface	DAYS	Ta- daily	Max. Ta-daily	Surface	DAYS	Ta- daily	Max.Ta-daily
Outdoor	4	-4.37	-2.5	Outdoor	3	-3.66	-1.1
Indoor	6	-1.38	-0.6	Indoor	4	-1.1	-0.3

Overall daily temperature variation observes as-

TABLE- 4.9 (Overall observation of temperature variation)							
For (δTa-daily < 0°c)				**For (δTa-daily ≥ 0°c)**			
Surface	Days	δTa-daily	Min.δTa-daily	Surface	Days	δTa-daily	Max.δTa-Daily
Outdoor	7	-2.85	-4.8	Outdoor	7	-4.07	-1.1
Indoor	10	-0.9	-2	Indoor	10	-1.27	-0.3

4.3 Cooling and warming effect:

Outdoor roof surface temperature- Total extreme values are observed in (19/07 and 13/07) dates resp. for maximum temperature variation of daily readings and minimum temperature variation of daily readings. It comes as, (Max. δTo) is (-1.1°c) and (Min δTo) is (-4.8°c) resp.

It shows, the cooling effect from modular green roof is around (-4.8°c) and warming effect is around (-1.1°c) which results that maximum temperature are also decreases highly.

For Sunny day, extreme value is observed in (14/07 and 13/07) dates resp. It comes out (Max. δTo) is (-2.5°c) and (Min. δTo) is (-4.8°c) resp. It shows, the cooling effect from modular green roof is around (-4.8°c) for sunny day and warming days is around (-2.5°c) which results that maximum temperature variation decreases dorsally in sunny days.

For cloudy and rainy day, the extreme values are measured in (19/07 and 20/07) dates resp. It results in (Max. δTo) is (-1.1°c) and (Min. δTo) is (-2.4°c). This shows that, both cooling effect and warming effect in rainy days are slightly lower than sunny days.

The strongest cooling effect during sunny days is (-4.8°c) in date (13/07) and during cloudy days it is (-2.4°c) in date (20/07). Result shows that temperature variation of daily daytime varied almost consistently in order (Sunny day > Cloudy days).

Indoor temperature-

Total extreme values are observed in (02/08 and 11/08) dates resp. for maximum and minimum temperature variation of daily readings. It comes as, (Max. δTi) is (-0.3°c) and (Min. δTi) is (-2°c) for all experimental days that observed. It shows, the cooling effect from modular green roof inside the room is around (-2°c) and warming effect is around (-0.3°c) which result that maximum temperature variation has no difference compare to exposed roof temperature.

For sunny day, extreme thermal values are observed in (03/08 and 11/08) dates resp. It results in (Max. δTi) is (-0.6°c) and (Min. δTi) is (-2°c). It shows that, cooling effect from modular green roof inside the room is (-2°c) and warming effect is around (-0.6°c) which outcomes that maximum temperature variation inside the room is effect less. It conventionally same to exposed roof temperature.

For cloudy and rainy day, the extreme value is measured in (02/08 and 12/08) dates resp. It results in (Max. δTi) is (-0.3°c) and (Min. δTi) is (-0.1°c) which shows that both cooling and warming effects in rainy days inside the room has lightly difference as compare to exposed roof temperature. It indicates that in cloudy condition the indoor air temperature difference is remain same for both modular green roof and exposed roof.

It indicates that strongest cooling during sunny days is (-2°c) in date (11/08) and during cloudy days it is (-0.1°c) in date (12/08). Result shows that the temperature variation of daily day time in sunny days are high but in cloudy days it has no difference. So, in sunny days the indoor room temperature variation has more relevant for cooling indoor air quality by providing modular green roof over the roof slab.

Therefore, overall temperature variation of outdoor and indoor found as **-4.8^0C and -2^0C** respectively.

V. CONCLUSION

From this overall experimental work, we found-

- Organic soil made by local soil (40%), verme compost (40%) and coco peat (20%) gives 46% water absorption. Soil substrate ranges between 40% to 60% moisture content for the ideal volume for composite of green to perform the good plantation growing in surrounding climate.

Green roofing system is effective to decrease temperature outdoor as well as indoor by and -4.8^0C and -2^0C respectively.

- Green roofing can improve building air quality parameter, reduce maintenance and reduce energy consumption.
- Green roofing can increase the initial cost of building but difference of cost can recover in very soon by energy saving.
- Potable green roofing system can easily be occupied by transferable essentials.

Future scope-

- New finding to make green roof to more integral part for best management practices to urban area. Well researched benefits and establishment of green roofs should be considered.
- Green roof restricted to only few countries like (Europe, America and North-Asian countries). Importance of green should be suggested and conducting a familiar seminar and workshop for separating knowledge about their benefits and sustainability in building is very helpful.
- Green roof for different countries has different climatic condition and surroundings. To overcome this, local research is important for succeeding of green roofs, to enhance their adaptability nature of plants to growth medium and prepare a relevant strategy for implementation in that urbanization.
- Material selection for each component of the green roof should be depend on its life- cycle and cost analysis approaches. In addition, it also understands that each geographical area has its own consumers and distributors for making the real-world growth as a sustainable development.
- This dissertation is restricted to extreme thermal values which reduces urban heat island effect of surroundings. For further studies in the future, researches can elaborate the temperature variation needed for all 3 seasons in the year in Indian climatic condition. Studies can made in both daytime and nighttime also. By this, energy consumption of the building will relate and made building very well adaptable as green structure.

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