An investigation of Microclimatic Influence of Greening Roofs, Walls, and Terraces in Urban Dwellings: A Case of Uttara, Dhaka

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Abstract

While the call for an urban lifestyle along with various thoughts of aesthetics is growing, the capital of the most important delta in the global Dhaka is continuously lowering its greens. New thoughts like green roofs, partitions and terraces are emerging to make a rescue plan for Dhaka. Unique types of greenery systems consisting of Green roofs (GR), green walls (GW), Garden balconies (GB), sky gardens (SG) and indoor sky gardens (ISG) are brought within the dwellings. Vertical gardening has advanced to offer possibilities for the dwellers to revel in the surroundings inside the form of balconies (verandas), courtyards, open terraces, green pockets, rooftop gardens, façade greening, and to make up for a number of the loses in the floor. To analyze how the spatial best of a residence adjustments with a greening gadget and without a green device. This paper tries to evaluate the microclimatic and aesthetical impact of roof, wall, and terrace greening structures on a city house.Through the evaluation of temperature and humidity management on a diurnal foundation and communal interest evaluation. The thermal effectiveness is measured by way of the contrast between a building with inexperienced and an adjacent building without inexperienced. From the 3-case examination, it became located that the participants of every residence felt comfortable with their greening.

Keywords: *: Microclimatic Impact, Greening System, Urban Dwellings Lifestyle, Thermal Effectiveness.*

1.0 INTRODUCTION

In Dhaka, the rooftops are an enormously untapped resource. The conventional uses of the rooftops are cloth drying, barbecuing, occasional social gatherings etc. Contemporary approaches to greening buildings are characterized by the integration of planting and supporting structures with the construction of the building itself [1]. Urban green is fast diminishing in dense cities like Dhaka resulting in a multitude of socio-cultural and environmental problems. Urban ecology is the direct victim of diminishing greens contributing to some extent towards global warming [2]. With the brisk and spontaneous urbanization process, high population concentration, land use changes, and loss of green spaces, cities like Dhaka are increasingly facing challenges to cope with heat island effects, stormwater runoff, air pollution, and habitat shift [3].

Green plants act as natural filters, increase the city's biomass, counteract climatic changes, and regulate the indoor climates of buildings by insulation against extreme heat and cold [4]. In the dwellings, vertical gardening has evolved to provide opportunities for the dwellers to enjoy the surroundings in the form of balconies (verandas), courtyards, open terraces, green pockets, rooftop gardens, façade greening, and to make up for some of the loses in the ground [5]. The B. Raji and Martin's paper literature review looks at a time frame from 1977 through late 2013 and encompasses five greenery concepts including the green roof (GR), green wall (GW), green balcony (GB), sky garden (SG) and indoor sky garden (ISG) [6]. Plants provide a habitat for urban wildlife. There is a need to offer an improved environmental quality by bringing nature back into the city. That's why it is a very new common practising idea in urban vertical landscaping of Dhaka is improvising the greenery concept.

1.1 Purpose of Study

The research endeavours to explore the heat-related effectiveness of residential dwellings in the identical locale under matching circumstances and climate, focusing on the subsequent goals:

• To investigate the thermal efficiency of dwellings in Uttara, Dhaka, with and without green buildings on the roof, walls, and terraces.

• To compare the thermal comfort and aesthetics of these two temperature profiles, as well as the zones of comfort and discomfort, based on the presence of greenery in each zone.

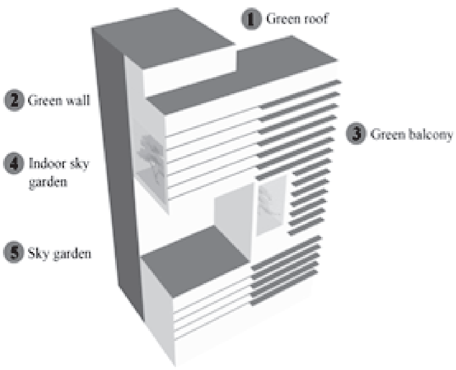


Fig. 1. Different ways of integrating greenery Systems on buildings. (Source: Raji et al [6]).

1.2 Scope and Contribution of Study

The three residences share analogous floor plans, orientations, volumes, and roofing materials, yet diverge in terms of their greening systems. The focal point of the investigation lies in discerning variations in indoor temperatures and human comfort levels between the two greening systems and a non-greening system. The study's successful conclusion has the potential to impact the adoption of building greening systems.

1.3 Limitations of the Study

The research is confined to three house types within the same Dhaka locality, solely relying on both on-site field investigations for thermal comfort and computer-generated data.

The most common places in a building that can be used to accommodate vegetation are roof greening, vertical greening, terrace planting and using indoor plants in atria, especially in the design of high-rises. This paper tries to analyze the microclimatic effects of green roofs, green walls and green terraces on residential buildings in the context of Dhaka and comes up with some observations on how the residence spatial characters are changed through implementing green. This paper also investigated the microclimatic impacts in the field of temperature effectiveness, and humidity control, which was measured from the readings of a hygrometer on a diurnal basis and then a graph was created to show the difference.

2. LITERATURE AND THEORY

A comprehensive literature review was done based on green roof history, types, plant materials and its benefits towards the environment, economy and social factors. The resources of the study are fundamental, sourcing from journals and articles which are mostly drawn from between the years 2015 and 2022, to ensure the most updated data on green roofs in Dhaka cities. Papers were selected and examined to identify the range of green roof benefits within research concerns and factors that are attributed to the environment, economy and social factors. The factors are then discussed based on the current scenario and existing literature. The reviews will later determine the research gaps to be undertaken for future research.

2.1. Types of Greening System

An extensive green roof is strictly limited in its plant selection and functional purposes; therefore, it requires less maintenance. The development of extensive green roofs is usually implemented on the existing building's rooftop. Nowadays, green roofs are designed for multiple types of buildings known for their deep substrates and various plants are used for intensive green roofs while the shallower substrates are for extensive green roofs. An intensive green roof is quite similar to the conventional ground-level gardens and they are usually built concurrently with the building construction and require substantial investment in plant care. [7].

Table 1: General Advantages of Different Green Roof Types Source: Green Roofs in Sustainable Landscape Design

Extensive	Semi-Intensive	Intensive
Lightweight	Combines best features of extensive and intensive	Greater diversity of plants
Suitable for large areas	Utilizes areas with greater loading capacity	Best insulation properties and stormwater management
Low maintenance costs and no irrigation required	Greater coverage at less cost than intensive	Greater range of design
It may be suitable for retrofit projects	Average maintenance	Often accessible
Lower capital costs	Greater plant diversity than extensive	A greater variety of human uses

2.2. Effects of Greening System

Green roofs with usability and accessibility can be an exciting public space for all age groups to gather, stroll, play and enjoy nature. Green roofs, in contrast to barren roofs, may also offer accepted visibility to the neighbouring buildings. The potential therapeutic values of green roofs enhance the quality of life reducing stress and increasing positive feelings [I] In Singapore, green roofs reduce cooling load by 10% of the usual building with a conventional roof [I]. Green roofs could provide a natural refuge area for an urban citizen to renew themselves spiritually as most of their lives are spent in urban areas for urban tasks. The aesthetic potential of green roofs may help enhance the visual, artistic and qualitative value of the built environment. The addition of a variety of plants with fragrant blossoms and colourful foliage on the green roof may stimulate the senses and allow urban dwellers to relax and rejuvenate [8]. Green roofs help to soften the artificial urban landscape and provide visual relief from the concretized environment for urban citizens by providing relaxation and restoration ambience in the city. Apart from that, it also enhances architectural designs to create iconic landmarks in the city. Implementing extensive green roofs will reduce 60% of heat gain compared to bare roofs in temperate climates.

EGR reduced pedestrian-level air temperature by 0.4–0.7 °C, and IGR by 0.5–1.7 °C, with maximum effect in open-set low-rise sites. An individual green roof can reduce roof surface temperature by 15–45 °C, near-surface air temperature by 2–5 °C and building energy consumption by up to 80% [5].

2.3 Social Gathering Controlled by the Existence of Green Roof & Walls

Community roof gardens create safe spaces to interact and improve the physical space of the neighborhood. The research found that gardens and farms beautified the neighborhoods and employed and benefited residents, which, in return, created more local pride and attachment to the space [9]. Community gardens, in particular, were cited as a place where people built trust which encouraged neighborhood watches and a general concern for others in the neighborhood. The green roofs are mainly designed to have visual and aesthetic benefits. And offer spaces for the owners preferably, for relaxing, strolling, gathering, playing and enjoying contact with nature, and for the building occupants in some cases [10].

3.0 METHODOLOGY

To achieve the stipulated aim, the study presented in this paper traces the following steps:

1. Provide a broad examination of "Greening system in a residential building in Architecture
2. Defining Roof, Wall and Terrace Greening System.
3. Describing two residential buildings in Dhaka as a case Study in terms of Green Building aspects.
4. Recognize the advantages of implementing criteria for Green Building strategies aiming to optimize energy efficiency and indoor air quality.

3.1 Site Selection

The field studies were conducted in three buildings in house 3,4,5 at sector 11, Sonargaon Jana Path Road, Uttara, Dhaka. The building is randomly selected with a roof, wall and terrace greening facility and without the facility. In the first step of this study, the three types of residential flats are selected for analysis purposes. The single residential flat (1750sq/ft.), Duplex residential flat (2650 sq. /ft.) and another Duplex residence flat (1800sq. /ft.). The streets on N-S are shaded by building shadow. The building is an apartment building with an extensive green roof.
The boundary wall is a green wall with creepers on it. And the setback area is full of ornamentor bushes and plants. The buildings all are north-south oriented and the court creates space for vertical green as well as orienting the whole space towards itself. This green aesthetics & the green preparations on the roof make people share their leisure & create an interactive environment.

Case study 03 (House C)
Case study 02 (House B)
Case study 01 (House A)

Figure 2: Lutron LM 8102

3.2 Field Measurements

Air temperatures, relative humidity was measured at the site at 26th & 27th August, 2018. The measurements were taken at a 4-hour interval starting from before the sunrise (7 a.m.) to midnight (7.00.p.m). The measurements were taken at 1.2 m above the ground both from the indoor point and also in the outdoor pedestrian point. The on-site investigations took place within a structure equipped with a basement. In the initial phase of the research, an infrared temperature monitoring sensor was utilized to observe the air temperature at three distinct locations, both below ground and at ground level in this edifice. During this stage, the Lutron LM 8102 environment meter was employed to gauge indoor air temperature (Tin), outdoor air temperature (Tout), and relative humidity (RH%) at each level, both indoors and outdoors, in three different spots within the chosen building. Figure 2 provides a visual representation of the multi-meter in use.

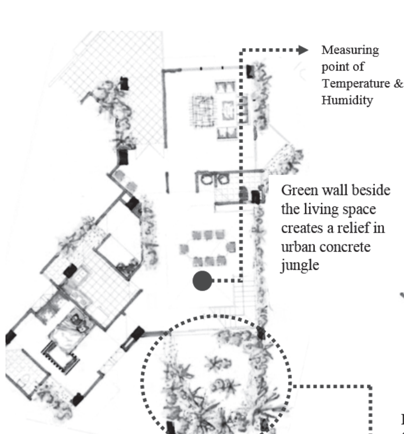


Figure 04: Extensive Green Terrace of studied House, Case study 01(Duplex residence), Ground floor plan, Source: Developed by Author

Figure 05: Extensive Green Terrace of studied house, Case study 01(Duplex residence), First-floor plan, Source: Developed by Author Author

Figure 06: Image of green terrace of case study 01(duplex residence),Source: Developed by Author Authors

3.3 Observations & Explorations

The social interactions & and gatherings are listed in a chart on time basis. Activities & and involvement to green roof & and green wall is analyzed by mapping through plans and sections.

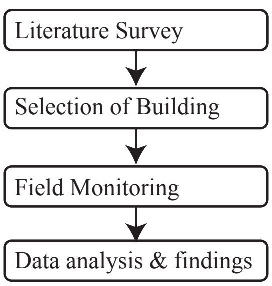


Figure 07: Structure of the research work

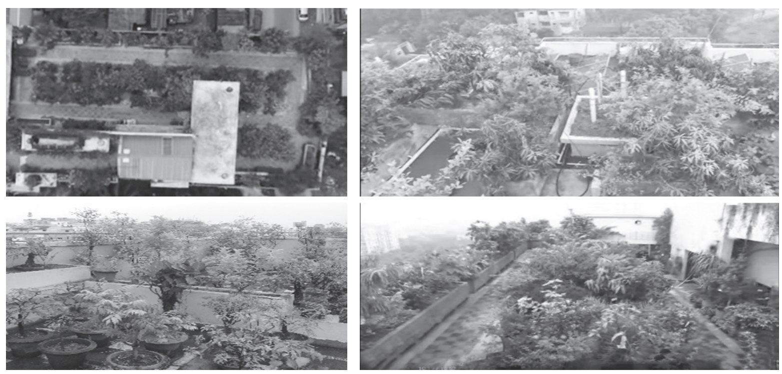


Figure 08: Image of Extensive Green Roof of case study 02
Source: Developed by Authors

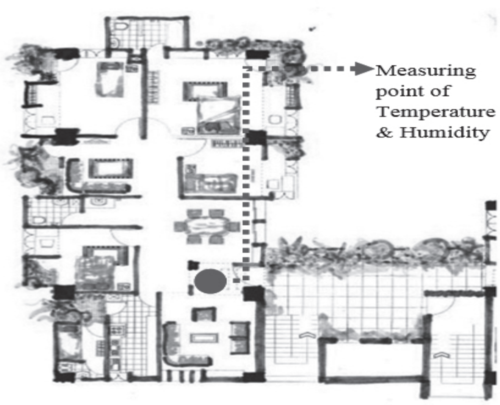


Figure 09: Extensive Green Roof of studied house Case study 02 (Single residence), floor plan
Source: Developed by Authors

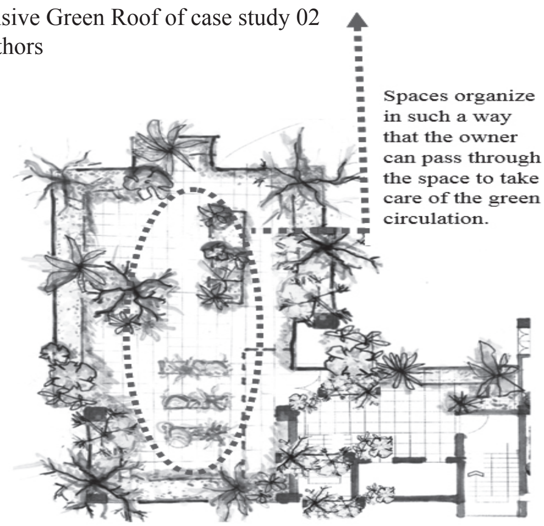


Figure 10: Extensive Green Roof of studied house Case study 02 (Single residence), Roof floor plan
Source: Developed by Authors

The infrared temperature monitoring sensor was employed to track the air temperature at three distinct points on each floor of the various buildings. During this stage, measurements were limited to indoor air temperature (Tin) and outdoor air temperature (Tout), as well as relative humidity (RH%) indoors. The Lutron LM 8102 environment meter was utilized to measure these parameters at three different locations within the chosen building. Figure 2 illustrates the multi-meter in action.

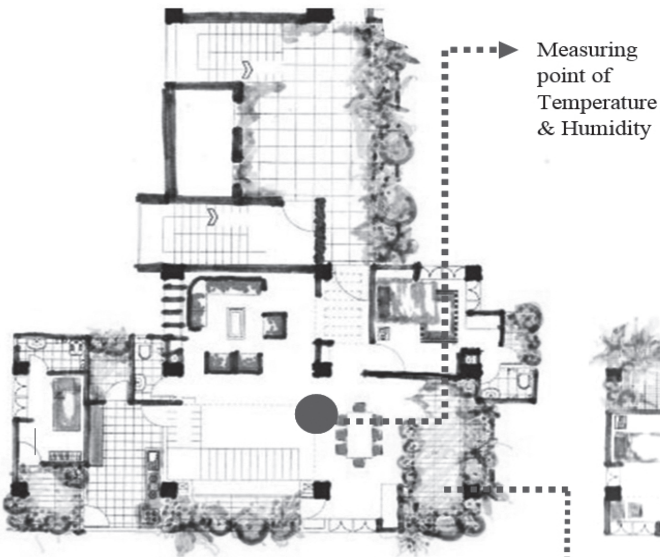


Figure 11: Extensive Green Wall of studied house, Case study 03 (Duplex residence 02), Ground floor plan. Source: Developed by Author

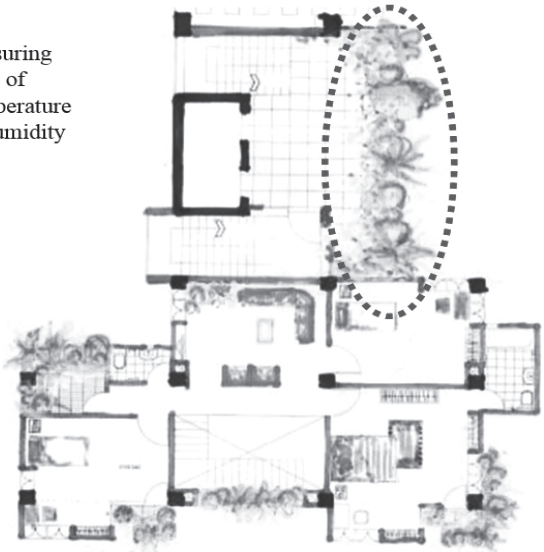


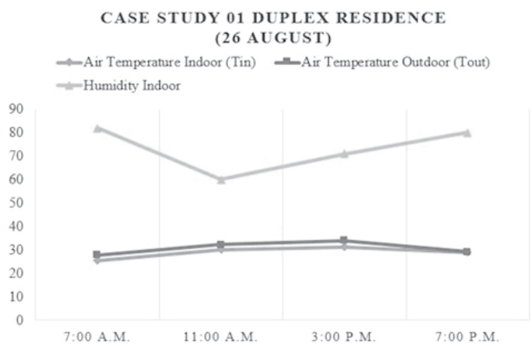
Figure 12: Extensive Green Wall of studied house Case study 03 (Duplex residence02), First floor plan Source: Developed by Author

Figure 13: Image of Extensive Green Wall of case study 03. Source: Developed by Author

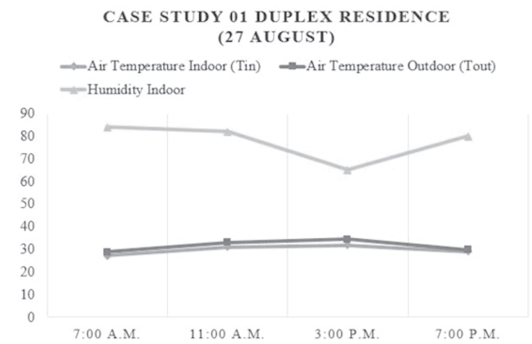
- CREEPERS, as the most common species for Green to grow vertically
- Creating's medium to grow more: can create a green wall by climbing up the boundaries.
- Greens growing in terrace spaces give a green view in setbacks.
- Green roofs and walls are one of the most convenient solutions for making the 'house' feel like a 'home'.

4. Results and Discussions

The Duplex House is near about 2650 sq. /ft. The sensitive implementation of trees, grass, shrubs, and creepers has a great influence on rich presentation value and aesthetical value for both the guest and residential perception. In a Duplex residence inside is cooler than outside all along the day-time. The temperature of the Duplex Residence was taken at the point of the dining space on a very near space of green terrace. The indoor temperature of the house is comfortable temperature according to Graph 01 and Graph 02.



Graph 01: Air Temperature & Humidity Chart 26thAugust, Case Study 01. Source: Developed by Authors



Graph 02: Air Temperature & Humidity Chart 27thAugust Case Study 01. (Source: Developed by Authors

On one of the medium hot days (August 26th), the temperature ranges from 25.4 C at 7:00 AM Indoor to 33.8 C at 3.00 PM AT outdoors with a diurnal variation of 8.4C. In case study one inside remains cooler than the outside during the daytime, from 7 AM- 7 PM but after 3 PM inside temp is slightly higher than the previous temperature point. The residential perception about the green terrace that the terrace is the only reason to lower downing inside temperature in the daytime is from 7AM-7PM

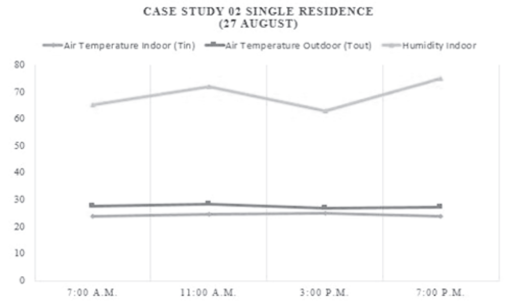
Time	Air Temperature Indoor (Tin)	Air Temperature Outdoor (Tout)	Humidity Indoor
7:00 a.m.	25.4	27.6	82
11:00 a.m.	30.2	32.3	60
3:00 p.m.	31.1	33.8	71
7:00 p.m.	28.7	29.2	80

Chart 01 Duplex Residence 26 august

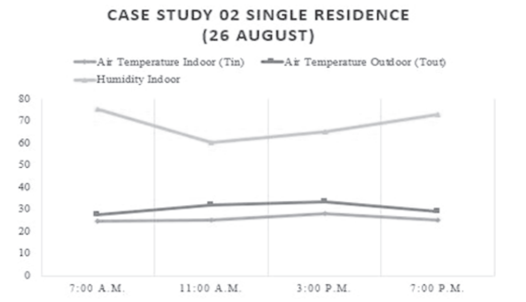
Time	Air Temperature Indoor (Tin)	Air Temperature Outdoor (Tout)	Humidity Indoor
7:00 a.m.	27.2	28.8	84
11:00 a.m.	31.0	33.0	82
3:00 p.m.	31.8	34.5	65
7:00 p.m.	29.0	29.8	80

Chart 01 Duplex Residence 27 august

From the assembled and data interpretation, it appeared that the humidity of indoors is varied in both day at 26th and 27th. Indoor Humidity reaches the low points at 11.00 AM at 26th August and to 3.00PM at 27th August. In both day the humidity was variable to 60 to 85. Four-hour gap between taking the humidity range At that moment, synchronizing with Tout and achieving the highest values for both temperature and relative humidity (RH%) at 7.00 AM for both 26th and 27th August.In Case Study 2 the Single Floor Residence is near about 1750 sq. /ft. The overall findings of that residence are the extensive green wall. Different kinds of small, medium and big trees are organized in a designed manner. Spaces are organized in such a way that the owner can pass through the space to take care of the green circulation. The case study 2 floor level is immediately below the green roof level.



Graph 03: Air Temperature & Humidity Chart 26 th August. Case Study 02(Source: Developed by Authors)



Graph 04: Air Temperature & Humidity Chart 27th August. Case Study 02
(Source: Developed by Authors)

Time	Air Temperature Indoor (Tin)	Air Temperature Outdoor (Tout)	Humidity Indoor
7:00 a.m.	24.4	27.4	75
11:00 a.m.	25.0	32.0	60
3:00 p.m.	28.2	33.2	65
7:00 p.m.	25.2	29.2	73

Chart 02 Single Residence (26 august)

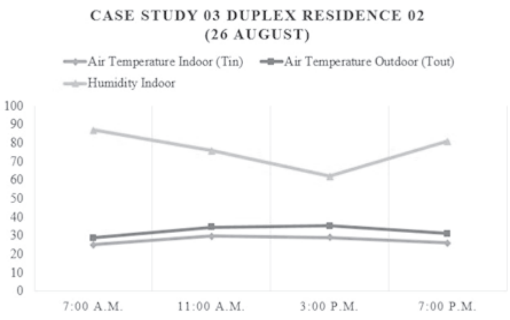
Time	Air Temperatu re Indoor (Tin)	Air Temperatu re Outdoor (Tout)	Humidity Indoor
7:00 a.m.	23.8	27.5	65
11:00 a.m.	24.7	28.2	72
3:00 p.m.	25.0	27.0	63
7:00 p.m.	24.0	27.2	75

Chart 02 Single Residence (27 august)

The temperature ranges from 33.2 C at 3:00 PM at outdoor to 24.4 C at 7.00 AM at indoor with a diurnal variation of 8.8C. The graph and the chart show that the overall temperature of the residence is magnificently low than the outdoors. The residential perception about the house is the roof garden is a great influencer to cool down the overall temperature of the apartment.

In Case Study 3 the Duplex Residence 02 is near about 1800 sq. /ft. The compiled data that the maximum outdoor air temperature at 26th August is 35.2C at 3.00 PM indoor temperature is a maximum of 29.8C at 11.00 PM and it does not change in different floors. In The temperature range of 27th August from 33.0 C at 3:00 PM at outdoor to 25.7 C at 7.00 AM at indoors with a diurnal variation of 7.3C. The overall findings of that residence are the wall near the living and dining space is extensively green wall. Different kinds of creepers are used for eye refreshment and aesthetical value.

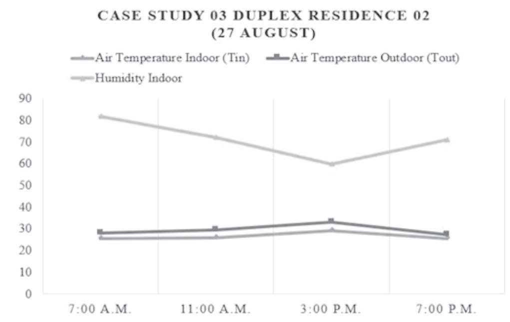
User feedback was collected via a straightforward questionnaire survey to establish the PMV equivalent. The anticipated comfort feedback is subsequently juxtaposed with the user's feedback. If both responses align, a conclusion can be drawn regarding the adequacy of the respective green positions in ensuring thermal comfort. From the questionnaire survey of the three-case study, it was found that the participants of each residence felt comfortable for their greening. Occupants of the second 2nd case study where the roof was extensively green roof felt more comfortable than the other two one.



Graph 05: Air Temperature & Humidity Chart 26th August, Case Study 03 (Source: Developed by Authors)

Time	Air Temperature Indoor (Tin)	Air Temperature Outdoor (Tout)	Humidity Indoor
7:00 a.m.	25.2	28.8	87
11:00 a.m.	29.8	34.5	76
3:00 p.m.	29.1	35.2	62
7:00 p.m.	26.0	31.2	81

Chart 03 Duplex Residence 02 (26 august)



Graph 06: Air Temperature & Humidity Chart 27th August, Case Study 03 (Source: Developed by Authors)

Time	Air Temperature Indoor (Tin)	Air Temperature Outdoor (Tout)	Humidity Indoor
7:00 a.m.	25.7	28.0	82
11:00 a.m.	26.1	29.5	72
3:00 p.m.	29.3	33.0	60
7:00 p.m.	25.7	27.2	71

Chart 03 Duplex Residence 02 (27 august)

5. CONCLUDING REMARKS

This research work is based on the air temperature and humidity measurement of three types of buildings based on three types of greening. Drawing definitive conclusions poses a challenge, leading to the identification of various findings derived from three types of experimental data. The analysis of data and the investigation's results contribute to the recognition of the key insights above, the following major observations can be drawn:

a) At the Measuring point of Temperature and humidity common zones such as the living or dining side of the building, Tout > Tin is in almost every case.
b) Every three cases have average temperature difference between the indoor and outdoor is almost 7°C.
c) Concerning relative humidity (RH%) after 11.00 AM. indoor RH (%) is getting low. It IS staying low to 3.00 PM in almost every three cases.
d) case study 02 which has a very extensive green roof has a higher minimum temperature indoors than outdoors. it also has a lower value indoors than the other two cases.
e) From the questionnaire survey it was found from user perception that the green roof, walls, and terrace are some of the most convenient solutions for making the ‘house’ feel like a ‘home’. It does not need much of someone’s time, it just needs a growing medium.

6. SCOPE AND LIMITATION

In this investigation, we only focused on air temperature and relative humidity (RH%) as key variables. Certain levels of uncertainty were overlooked. Given that the study took place during the summer season, the disparity in air temperature and RH% between indoor and outdoor environments was minimal. To enhance precision and validate our findings, it is imperative to extend the survey to various seasons and locations. Additionally, employing simulation software could offer a valuable means of verification. Expanding the scope of this research to encompass aspects such as greening systems, heating, cooling, ventilation, lighting, acoustics, insulation, safety, and security, and conducting surveys across diverse seasons and locations, will contribute to more accurate and comprehensive results, validated through simulation software.

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