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EXAMINATION ON METHODS, TECHNIQUES IN STRUCTURAL DESIGNS OF GREEN WALL CONECEPTS: Application to Concrete brick Wall in Sri Lanka

RAHUMAN A.A.[1] & DILSHANI RANASINGHE W. M. N.[2]
[1,2]Department of Integrated Design, Faculty of Architecture, University of Moratuwa, Sri Lanka.
[1]rahuman0327@gmail.com, [2]dilshaniranasinghe80@gmail.com

Abstract
Green and eco-friendly environment systems are having an evolution within the architecture and design fields. When designing built environments, it is the duty and responsibility of architects and designers to pay attention to environment and ecofriendly factors. With respect to the above, the concept of "green wall" or "vertical garden" reached a rapid development in structural and irrigation systems. Sri Lanka has been home to creative architects and designers for centuries, a fact that the country's ancient irrigation systems, can attest to. This island nation has a monsoon based tropical climate, which is primarily governed by rainfall and humidity, are thoroughly considered when developing irrigation patterns. For plantation purposes, pipelines are often used, and is a major component in vertical garden systems. Considering vertical garden through climatic landscape technology and cost of procedure, this research attempts to explore how different green wall types respond to the Sri Lankan climate, with reference to its basic structural design systems used. The entire process was carried out through the help of RAYMAN software, which was checked by sample testing using a similar type of building within the University of Moratuwa Sri Lanka, University of Wayamba and the University of Jaffna, followed by an analysis of qualitative research methodology, thus based on its simulation, research will conclude that Green facades are more suitable than Living Walls in the Sri Lankan Context.

Keywords: *Green facades, Traditional living wall, Creative structure*

1. Introduction

1.1 RESEARCH BACKGROUND

In a global context, the idea of green and ecofriendly systems is facing an evolution within the fields of architecture and design. As professional of these respective fields, individuals need to think about the environment and eco-friendly design factors when making interventions in the built environment, which has led to the inclusion of green wall or vertical garden into design concepts, causing rapid transformations in structural and irrigation systems. Although blessed with abundant creativity in ancient technology, now lost, is where some of most efficient irrigation systems found in the ancient world are found. Our climatic conditions are also sound for agriculture and plantation, but we seldom find the concept of green walls incorporated into design by architects or designers in Sri Lanka, which leads to the question if issues in irrigation systems and planting material are to cause this lack of incorporation.

Sri Lanka has a tropical climate, which has seasonal monsoon rainfall, so considering irrigation patterns with respect to climatic conditions is a must. For this reason, progress pipelines are often used, and is also a major component in vertical gardens, considering the overall process, climatic landscape technology and cost of procedure.

This research is about what plants grow in green walls in the Sri Lankan context, how irrigation suits for those plants, what are the structures already developed among the world and its availability in the Sri Lankan context. In analysis of structural design, research about types of green wall and which of them are used in Sri Lanka and availability of material and techniques. (Newman, p. & Matan, A. (ed). (2013))

1.2 RESEARCH QUESTIONS

The research revolves around questioning the methods and design elements of a green wall structure or vertical garden structure in high rise buildings, specifically questioning on the used Structural systems, if and whether they are suitable for the climatic conditions of Sri Lanka, or are they yet another system copied with no regard to the climate locale. The research also questions the effects of the surrounding and indoor environments with immediate contact of vertical gardens in high rise buildings. In conclusion, all the questions above should be able to answer the question of which methods are suitable for vertical garden methods and irrigation technology which is compatible with the Sri Lankan context.

2. Identification of Green wall for Energy Saving

This chapter focuses on the important factors to be considered in Green wall construction by analyzing of the structural system, irrigation impotency and planting material influences. It's content will cover, types of facades available, detailing about façade types and therefore, will be discussing theories and rules applied for green wall techniques. Regulation and rules for building wall ratio also will be discussed in this chapter.

2.1 THE IMPORTANT FACTORS TO BE CONSIDERED IN GREEN WALL CONSTRUCTION

2.1.1 Structural system
Basic structural design primarily considers construction method or characterizing. There are two basic categories.
Green Facade
Living Walls

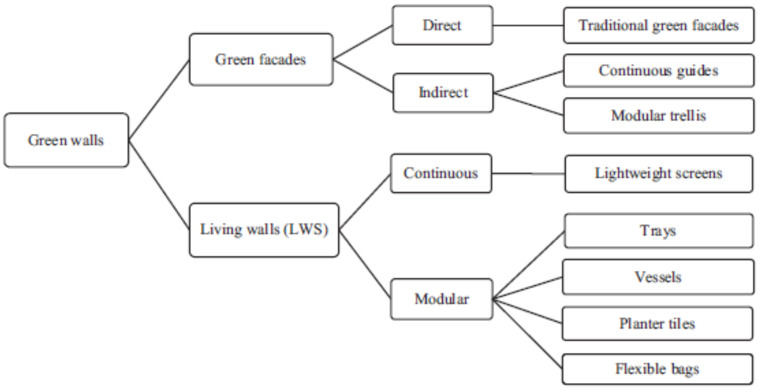

Figure 1 – Classification of Green Walls, in accordance with construction characteristic
(Source: Maria Manso, João Castro-Gomes. (2015).*)*

"Traditional or direct green facades usually have no support structure. They rely on the capacity of climbing plants to attach themselves to the vertical surface. However, when the vegetation fulfils full coverage can become too heavy and the risk of falling is increased."

(Maria Manso, João Castro-Gomes. (2015))

2.2 DIFFERENT TYPES OF FACADES AND THEIR USES FOR GREEN WALL IN SRI LANKA AND THE WORLD

2.1.2 Metal mesh green wall
"A metal Mesh Green wall uses a tightly intertwined grid of aluminum or light weight steel, usually attached to the façade via brackets. Plant typically grow from planters or troughs strategically positioned throughout the Hight of the wall."

(Gabriel Pérez, Julià Coma, Ingrid Martorell, Luisa F. Cabeza. (2014)).

With the above statement, we can identify that a wall partially or completely covered with greenery that includes growing medium like soil, water or other substrate materials, includes an integrated water delivery system.

The metal mesh green wall system provides an eco-friendly living wall system for design and construction professionals. It also has ability to transform space, which changes facades by creating an environment.

2.1.3 Cable Mesh Green Wall
"This type of green façade uses flexible cables that are used to support plants in irregularly shaped and wide span installation."

(Gabriel Pérez, JuliàComa, IngridMartorell, LuisaF.Cabeza. (2014)).

This type is more flexible than the previous, where its basic structure is a cable mesh.

2.1.4 Rigid Green Wall
"This system can utilize two and three dimensioned trellises that can be attached to a wall substrate, build around columns, or can be free – standing".
(Gabriel Pérez, JuliàComa, IngridMartorell, LuisaF.Cabeza. (2014)).

2.1.5 Vegetation mat Living Wall
This has a rigid substratum attached with a fabric layer where the grown plants are interposed into the holes cut, as they can establish their root system in the soil layers which facilitates the growing medium.

2.1.6 Hanging pocket Living Wall
This consists of hanging pockets which bring up the whole structure of this type of green wall. In order to prevent the plants, form oversaturation, the shells are vented to contain excess moisture.

2.1.7 Modular Living Wall
Modular living wall is structured by plants, planting boxes which are built on a vertical surface of a building. The plant box consists of growth medium and supply in a way that's replaceable. Continuous living walls are known as Vertical Gardens. The continuous living walls combine many modular living walls together.

3. Research Design

This research aims to clarify human assisted adaptation towards the hot humid outdoor and with the applicability of the universal thermal climate index, which forecast the thermal comfort votes in urban areas. UTCI (Universal Thermal Climate Index) would be able to reflect the impact on thermal comfort by urban geometry (H/W Ratio, SVF -Sky view factor-) which are outlined by surrounding factors. And the simulating outcome from RAYMAN for selected sites and discussed deviation with manually measured ratio.

3.1 REASEARCH FLOW CHART

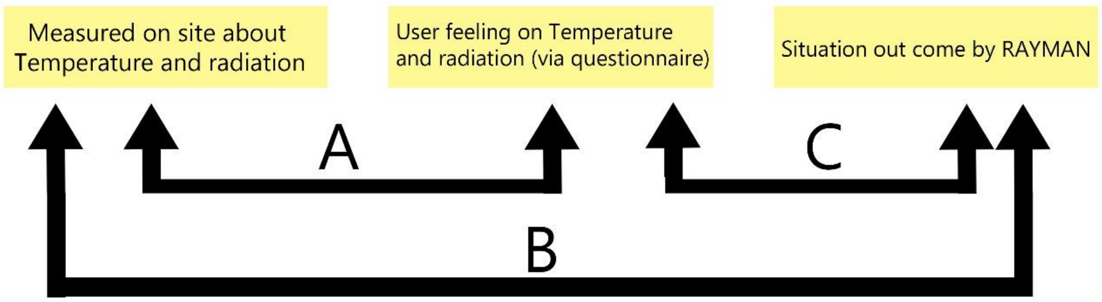

Figure 2 – Research Flow Chart (Source – Authors' Collection)

Research will be conducted in accordance to three major functions.

A – Comparing measured on-site data on temperature and radiation, with user feeling on temperature and radiation (Via – questionnaire),

B- Comparing measured on-site data about temperature and radiation and situation outcome by RAYMAN".

C-The conclusion.

3.2 SELECTING BUILDING DATA FOR COLLECTING
For collecting primary data, three local universities were selected, based on their location, with reference to climatic zones.

3.2.1 Climate Zone

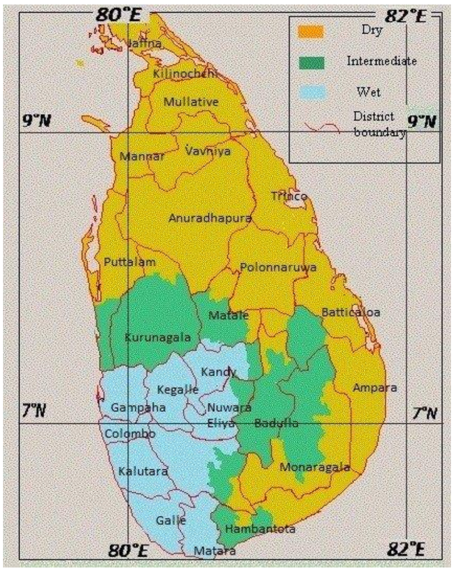

Figure 3 - Map of Sri Lanka, Climatic Zones (dry, intermediate and wet zones) of Sri Lanka, arbitrarily demarcated based on the annual rainfall.
(Source -
:https://www.researchgate.net/publication/260252714_On_the_road_to_eliminate_malaria_in_Sri_Lanka_Lessons_from_history_challenges_gaps_in_knowledge_and_research_needs)

3.2.2 Selected universities for data collecting
For this study there are three buildings were selected. Each buildings from each climate zones.

- University of Moratuwa (Wet Zone)
- University of Wayamba (Intermediate Zone)
- University of Jaffna (Dry Zone)

3.3 ONSITE DATA MEARSUREMENTS

Figure 4 - Building Canyon at UoM selected building (Source: Authors' Collection)

Figure 5 - Building Canyon at UoM Selected Building (Source: Authors' Collection)

Figure 6 - Building Canyon at UoW Selected building (Source: Authors' Collection

Figure 7 - Buidling Canyon at UoJ Selected Building (Source: Authors' Collection)

The experimental research was conducted in an open space and a building canyon in the University of Moratuwa, the University of Wayamba, and University of Jaffna, covering areas of outdoor of the building and building canyons of brick buildings, with relevance to the study.

Before commencing experiment, a pilot study was conducted in a open space of the university, the vintage pro 02 weather station was identified and familiarized in order to extract information during this time, as well as how to handle equipment, extract data, setting of equipment, set the environment, and leveling of weather station. Participant questionnaires were also distributed which lead to identifying problems that subsequently effect the final experiment, and thereby avoiding any such behaviors that would tamper ability of conducting a reasonable experiment.

3.4 MODELING: BASE CASE USING RAYMAN SOFTWARE

Many climatic parameters and conditions were affected in their temporal spatial behavior by the natural and artificial morphology on macro and micro levels. These effects are therefore important in different levels of regional and a variety of other applications. (*Matzarakis 2001, Matzarakis et al ,2007 ,2010*).
As an example, the thermal outputs from the human body has a great deal of application in bioclimatology and applied climatology, standard climate data, such as air temperature, humidity and wind speed, and is needed to calculate and quantify thermal bioclimatic conditions. (Hoppe 1999, Matzarakis et al 1999). One of the most important environmental parameters used to derive modern thermal indices, however, are short and long wave radiation (and the derived mean radiant temperature). There can be determined using special techniques that have been developed for urban climate studies, with a broader use in applied climatology. (Matzarakis et al 1999, Matzarakis, 2008).

3.5 SIMULATING OUTCOME BY AUTHOR AND RAYMAN ON UNIVERSITY OF MORATUWA.

Table 1 - Simulating outcome by Author and RAYMAN software on University of Moratuwa (Source: Author's Animation Creation)

Date	15.07.2019			(By Measurement (Indoor)) Gact	(By software (Indoor)) Gact
Place	University of Moratuwa				
Time	Air Temperature	Rel. Humidity	Wind Velocity		
8:00	26	85	12	25	26
9:00	28	76	15	36	34
10:00	29	72	16	43	43
11:00	29	69	17	42	45
12:00	29	70	16	46	46
13:00	29	71	15	45	45
14:00	29	72	15	43	42
15:00	28	72	15	34	36
16:00	28	76	15	25	27

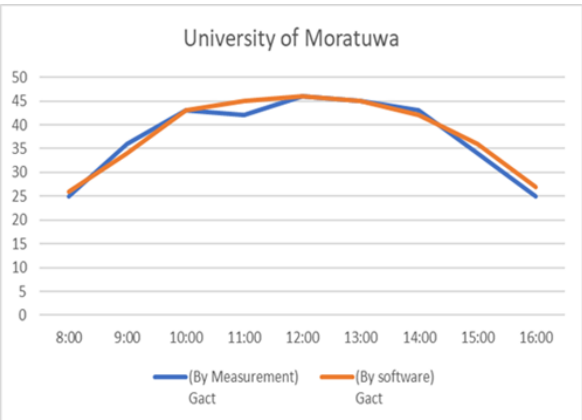

Figure 8 - Simulating outcome by Author and RAYMAN software on University of Moratuwa (Source: Author's Animation Creation)

Table 2 - Simulating outcome by Author and RAYMAN software on University of Wayamba

Date	15.07.2019			(By Measurement (Indoor)) Gact	(By (Software)(Indoor)) Gact
Place	University of Wayamba				
Time	Air Temperature	Rel. Humidity	Wind Velocity		
8:00	26	66	8	25	26
9:00	27	61	10	36	34
10:00	28	56	12	42	43
11:00	30	51	13	44	45
12:00	30	52	13	46	46
13:00	30	52	13	45	45
14:00	30	53	13	45	42
15:00	29	57	122	36	36
16:00	28	57	10	25	27

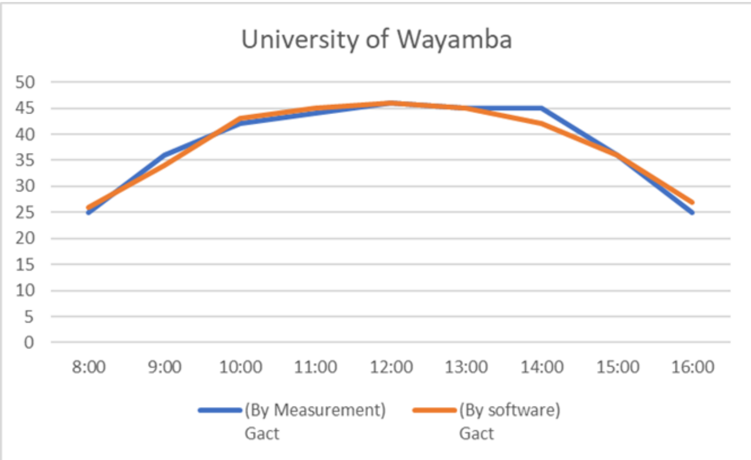

Figure 9 - Simulating outcome by Author and RAYMAN software on University of Wayamba
(Source: Author's Animation Creation)

3.6 SIMULATING OUTCOME BY AUTHOR AND RAYMAN SOFTWARE ON UNIVERISTY OF JAFFNA

Table 3 - Simulating outcome by Author and RAYMAN software on University of Jaffna (Source: Author's Animation Creation)

Date	15.07.2019			(By Measurement (Indoor)) Gact	(By software (Indoor)) Gact
Place	University of Jaffna				
Time	Air Temperature	Rel. Humidity	Wind Velocity		
8:00	26	66	14	25	26
9:00	28	80	28	36	34
10:00	28	56	32	42	43
11:00	30	51	29	44	45
12:00	30	52	26	46	46
13:00	30	52	28	45	45
14:00	30	53	27	42	42
15:00	29	57	28	36	36
16:00	28	57	16	25	27

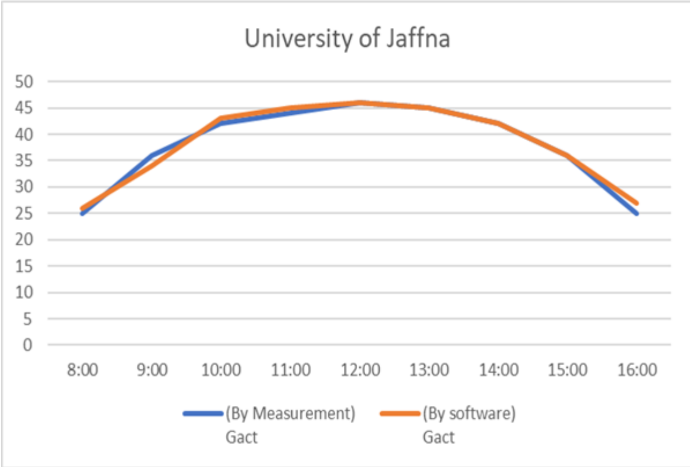

Figure 10 - Simulating outcome by Author and RAYMAN software on University of Jaffna (Source: Author's Animation Creation)

4. Analysis

4.1 INTRODUCTION
According to the data simulation on wet zone based on Green Facades and living walls. Simulations will be presented considering air temperature, relative humidity, and wind velocity during the lapped time. Similar reading will be result of the living wall structures as well. Finally, the results will be analyzed considering both the above-mentioned scenarios.

4.2 SIMULATION ON GREEN FAÇADE AND LIVING WALLS.
According to the discussion on 2.1, Manso M. and Castro-Gomes J. divides green walls into two major parts

- Green Facades
- Living wall

Therefore, this chapter will be mainly based on Green Facades and Living wall.

4.2.1 Simulating on Wet Zone
"As more than half of the world`s population resides in cities, where the neutral environment is being substitute for manmade"

(Woods, A., Bahrami, P., & Safarik, D. (2014))

Green walls are mainly constructed in the most polluted zones of an urban area, therefore, I have based the first simulation on the wet zone of Sri Lanka, with the chosen case study in close proximity to Colombo, the most populated and high in pollution city in the Sri Lankan context

4.2.2 Simulating on Green Façade

Table 4 - Simulation on Green Façade (Source: Authors creation)

Date	15.07.2019			Gact (Green Facades)
Zone	Wet zone			
Time	Air Temperature	Rel. Humidity	Wind Velocity	
8:00	26	85	12	23
9:00	28	76	15	32
10:00	29	72	16	38
11:00	29	69	17	40
12:00	29	70	16	42

13:00	29	71	15	44
14:00	29	72	15	41
15:00	28	72	15	34
16:00	28	76	15	24

4.2.3 Simulating on Living Wall

Table 5 - Simulation on Living wall (Source: Authors creation)

Date	15.07.2019			Gact (Living Wall)
Zone	Wet zone			
Time	Air Temperature	Rel. Humidity	Wind Velocity	
8:00	26	85	12	24
9:00	28	76	15	32
10:00	29	72	16	39
11:00	29	69	17	41
12:00	29	70	16	43
13:00	29	71	15	45
14:00	29	72	15	42
15:00	28	72	15	36
16:00	28	76	15	26

4.2.4 Comparing Green Wall with and without Green Wall building interior radiation

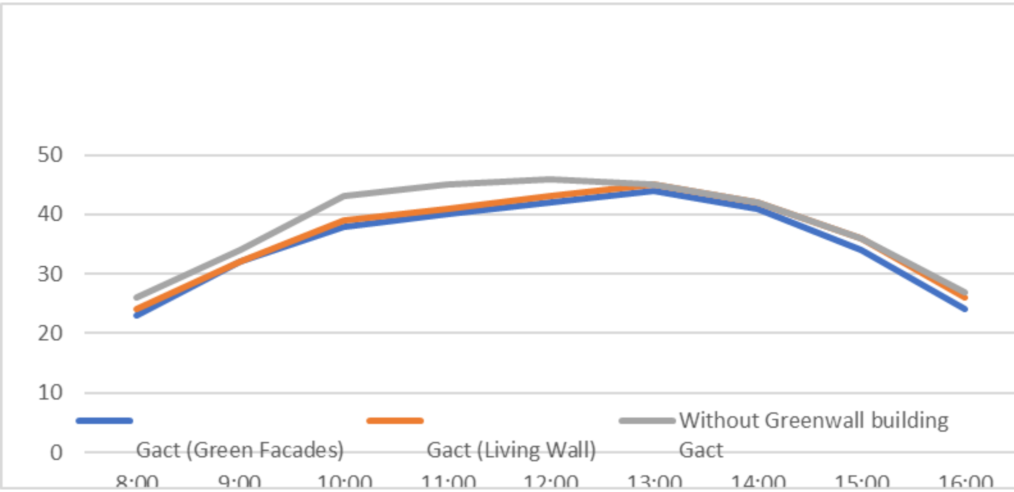

Figure 11 - Comparing Green wall and without Green wall building interior radiation (Source: Authors creation)

5. Conclusion and Recommendation

There are three types of climate zones in the Sri Lanka. The green wall is mainly structured in wet zone. For that this research is mainly based on wet zone. As mentioned above, for this research is took three state universities on three climate zone. There for measured indoor and outdoor temperature and global radiation with user experience how they feel the climate. And computerized simulation also done with those selected sites. Then the outcome of computerizing is manual calculation is mostly similar. Because of that for this research final simulation is done by computerized software.

There are three types of climatic zones in Sri Lanka, where green walls are mainly constructed in the wet zone. For that this research is mainly based on the wet zone. As mentioned above, this research observed three state universities within three climatic zones, measuring indoor, outdoor temperatures and global radiation with user experience, how they felt the climate.

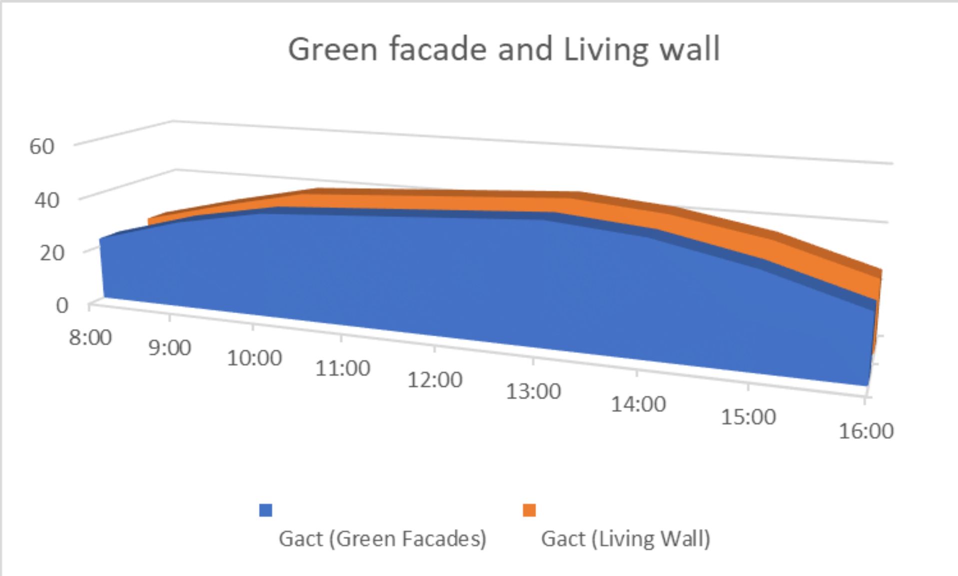

Figure 12 - Comparing Green face building and living wall building interior radiation

computerized simulation was also conducted in the selected areas. selected areas.
As the outcome of the computerized simulation and manual calculations were mostly similar, and for this reason, the final simulation for the research was done only with the aid of computerized software. The readings of the RAYMAN software simulation has been charted in figure 11 shown above. According to the graph, Green façade and living walls give far better results than buildings with no green wall. Therefore, it can be included that reach the conclusion that Green facades are better for the reduction of radiation penetrating brick walls and maintaining better indoor climates.

6. References

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