Unleashing the Potentials of Traditional Construction Technique in Bio-climatic Building Designs: A Case of *Ambalam*, Sri Lanka

Malsha S. Mendis, Malthi Rajapaksha, and Rangika U. Halwatura

***Abstract*—Sustainable strategies in traditional tropical buildings were found deliberated in respond to its' users and the climate of the context. An assessment was performed on material usage in Bio Climatic Designs, focusing on Ambalam; a well-preserved heritage structures found in tropics, Sri Lanka. Literature evident that few researches were conducted on '*Ambalam*' within the South Asian region, even within that lesser research have been focused on sustainable material usage and user comfort aspects. The study therefore fills the research gap intends to evaluate the design aspects and unleash on construction material utilization under traditional technology, material Compositions and their combinations along with the building orientations which affected on user comforts. *Ambalam*(s) have self-survived for decades with passive means with no consumption of energy. Location, the orientation and the designs are well planned making lesser impact on the existing environmental and social setting. Thus, it has been socially sustainable for ages by being a public community place with no conditions applied for its users, encouraging the social harmony and hospitality characteristics of Sri Lankan culture.**

***Index Terms*—*Ambalam*, building orientation, bio climatic architecture, timber.**

I. Introduction

A comprehensive bioclimatic design in such a given urban environment investigates and assess the building's admission to natural resources while captivating the negative influences that prevail around the context [1]. The associated constraints are important at the starting point for architectural design as they comprise the potentials on leading to creative, innovative and remarkable architectural solutions.

A construction that exists in a state of constant stability can be basically introduced as buildings [2]. Space- functional point and layout of the buildings are the main constraints when designing. The building components and services are then integrated into such a building to comply with building regulations and insulation standards.

A thorough interpretation of a traditional building's function and its building fabrics has to consider the building itself as the main implement in providing a comfort to the inhabitant as a rich comfortable shelter for its targeted activities despite the fact maintaining an impact towards natural environment for future generations.

A. Aims and Objectives

This paper aims at identifying the significance of '*Ambalam'(s)* buildings as a sustainable traditional tropical building type; with a view determining its comparative bio climatic design practice along with material usage found in Sri Lankan vernacular architecture. In achieving the above aim, the objectives of the study are to:

1) Examine the building orientation of '*Ambalam'* Structures in Sri Lanka
2) Investigates the qualities of timber as a building material

II. Ambalama

The buildings called '*Ambalam*'(s) are an open colonnaded structure with a hip roofed shelter, hosted as a prestigious building type that comes under vernacular Architecture in Sri Lanka [3]. Significant sustainable building characteristics out of ancient architecture can be identified within *Ambalam(s)* structures.

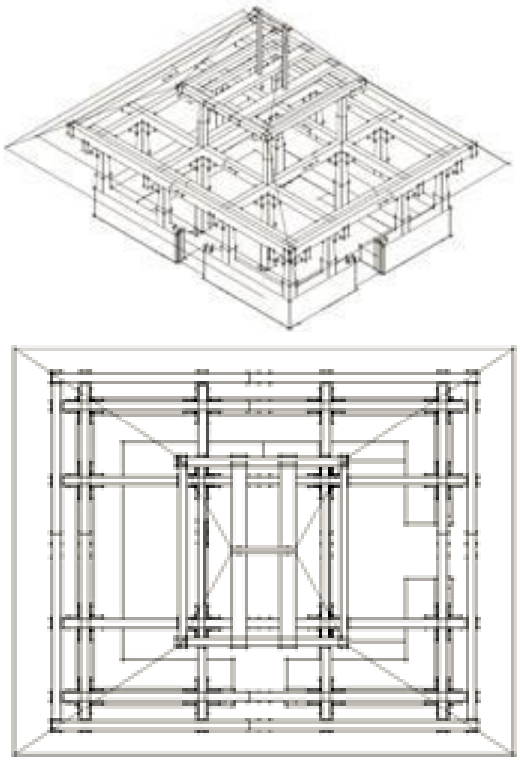

Fig. 1. *Mangalagama Ambalama* illustration model; A - Isometric view. *Mangalagama Ambalama* illustration model; B – Plan.

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These structures itself have designed and built for high durability and lesser maintenance catering as a demanding multifunctional public place for any type of visitor for free of charge. *Ambalam*(s) can be hosted as a perfect living sample which contains a preserved living proof of vast construction materials utilized in Vernacular Architecture, Sri Lanka [3], [4]. Since Sri Lanka is a tropical country with an intermediate temperature and humidity along with a sturdy sunshine throughout the year.

It acts as a massive sample library to investigate the vulnerability of the shelter as a structure that has been entirely or partial constructed out of timber with combination of other construction materials such as Granites, mortar and brick.

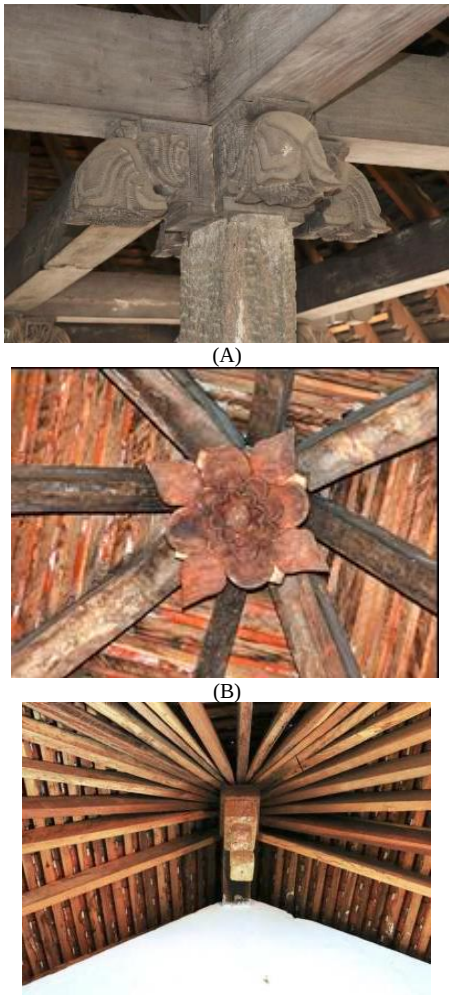
III. The Structure of 'Ambalama'

Vernacular architecture in Sri Lanka can be expressed as an art of creating thoughtful structures and spaces including proclamations that can be consumed as a communicative medium of the privileged owners, which had always influenced with the social facts. From past years, back mankind delivers and perceives elements through various expression. '*Ambalam*' structures are fascinating living proof with non-permanents bondage of structure with the floor plan, which structurally perceives the temperedness of the construction.

Structurally in some cases; The timber joists, bearers and the posts placed on stones used as footing. The entire timber structures are directly placed on stones. There are no single visual or physical joinery alone with post and the footing [3], [5], [6]. While the entire load was in the stone; structurally stable where it is perfectly withstanding for wind and rain. Also, in some cases; built on raised platforms like podiums. This secretly express the impermanence of the structure [3]. This contains a crucial scientific logic raising the structure above the ground preventing the timber structure contamination caused to rain water or flooding water over the area. Also prevent touching the capillary water present in wet floors. Many structures were constructed on bedrocks. Raising the structure above the ground level also prevent the biological degradation caused due to the fungi, insects and bacteria. *Ambalam(s)* also represents the refined vernacular architecture with advanced materials and technologies. Among them processed timber utilized in Sri Lankan context is remarkable [3].

In Kandyan timber architecture, the bulk sections have been made aesthetically appealing and lighter by beautiful, elaborated wood carvings and decorations. Kandyan timber architecture which has a distinctive character of its own dates from the Gampola period (1341-1415AD) [7].

The main task of *Ambalama* is to serve as a resting place. In that case, the roof is one of the most primary requirements of the shelter as a resting place; further the most momentous structural element as well. When considering the roof of majority of typical kandyan buildings (doubled pitched hipped roof) and tiled with semi cylindrical barrel clay tile roofs (Sinhala ulu) can be observed same as in *Ambalam* structures.



(A) (B) (C)

Fig. 2. (A): *Pekada*, (B): *Madolkurupaawa*, (C)*: Kenimadala.*

It is collaborated with improved technology in joinery such as *'Kanimadala', 'Madolkurupaawa'* and *'Pekada'* emphasizing the accumulated wisdom found in vernacular architecture [3], [6], [8]. Timber has taken a unique and a splendid role in these '*Ambalam*'(s) structures when considering the utilization of construction materials. Moreover, the structural engineering aspect found in these timber structures are a significant area to study, where the major significance will be the joinery detailing with the unique inherit qualities expressed in timber species.

Conferring to the medieval timber architecture, "Pekada" is a structural element in the joinery known to the beam and the pillar interference, where it handles the load transfer to the ground (Fig. 2). This significant intermediate structural bracket can be still seen clearly in *Ambalam* structures. Architecture acts a medium that facilitate diverse senses to people through the elements and spaces; '*Pekada*' is a simply interesting proof for that which has been presented with highly detailed carving on it. The architectural elements and the spaces within the '*Ambalam'(s)* facilitate to perceive the security and moral, relaxation and discipline alone with the users' comfort.

"*Kenimadala*"; is a well-known term utilize in medieval Sinhalese timber structures to the point where the rafters get together at the top as a circular superior on the roof.

"*Madol Kuruppuwa*"; not in as the exact elements but another evident of a significant structural element under

structural aspects were the intermediate connection between rafters and the ridge plate at outer side of the pitched roofs. Its structural stability through compression, under medial architectural terms. The clearance between the joinery of *Madol Kurupuwa*; rafters and ridge plate interface and the end of the ridge plate that tends the *Madol Kurupuwa*: (Fig. 2) a freedom to rotate. Another significance with '*Ambalam*'(s) structures are the structural strength in the timber frame work; not a single steel nail or glue has been used with the joinery other than the wooden pegs;(Fig. 2), but '*Madol kuruppuwa'* has gained its structural stability through compression [6]. Ex-*Panavitiya*, Badulla *Ambalama*. In the above sense, '*Ambalam*' buildings can be identified as a package of traditional knowledge on timber construction.

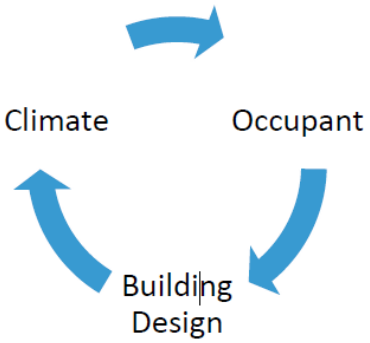


Fig. 3. Illustration model of bio climatic architecture.

IV. Bioclimatic Architecture

Bioclimatic architecture is the interaction between the climate, occupants and the building design; (Fig. 3). This approach in architecture promotes true green principles such as 'Carbon Neutrality' that involves with a lesser amount of environmental impacts and meets social needs in a cost effective manner, helping to preserve resources and biodiversity [9]. Bioclimatic design approach also is an appropriate basis which involves buildings by filtering and modifying the external / internal climate for occupants' thermal and visual comfort, to deal with energy efficiency opportunities in buildings [10]. The basic elements that involve with bioclimatic designs are passive solar systems, which incorporated onto buildings and utilize environmental sources such as air, sun, wind, vegetation, water, soil, sky for heating, cooling and lighting the buildings.

A. Building Fabric

The building fabric / building envelope protects the building occupants and plays a major role in regulating the indoor environment. It controls the conditions that are capable to transmit between the exterior and interior of the building such as heat, which is gain and lost from building through the fabric itself [11]. The building fabric be required to facilitate for ventilation and daylight whereas providing thermal comfort, moisture protection etc. Design considerations on the building fabric are major factors in determining the amount of energy requires in a buildings' operation. Also, the overall environmental life-cycle impacts and energy costs associated with the production and transportation of different envelope materials are vary greatly.

B. The Effects of Climate on Man

Changing weather conditions, expanding agriculture and population and the development of metal tools altered early man's shelter needs. With respond to the locally sourced construction materials, climate and changing conditions has created an incredibly a vast number of structures.

According to literature the atmospheric conditions stimulates and invigorate human activities. Therefore, man's energy and health depend in diverse measure on the direct effect on his living environment. In certain Climatic areas where excessive heat or cold prevails, energy is lessened by the biological strain of adaptation to the extreme conditions. Environmental constitutes such as light, sound, climate, space together act directly upon human body.

Shelter is one of the major components for fulfilling the requirements of comfort. It simply modifies the natural environment that leads to the optimum conditions of livability. Ideally, the satisfaction of all physiological needs would constitute the criterion of an environmentally balanced shelter. Another climatic element such as Air movement directly effects on human body cooling. That does not decrease the temperature but causes a cooling sensation on human skin due to the heat loss by convection and also because of the increased evaporation from the human body.

C. Usage of Sustainable Building Materials in Ambalama

The key considerations in designing a sustainable architecture are the impact on the environment, risk protection to user safety with the material usage, resource consumption, energy consumption and environmental friendliness at the end of building's life etc [10]. Accordingly to the ancient practice of vernacular architecture, timber is identified as a material with all above characteristics and lowest environmental impact on its production and its life cycle too. Therefore, use of timber as the main building material in almost every Ambalam building found in Sri Lanka is significant in the sustainability point of view.

V. Materials

This study comprises of Six *Ambalam* Structures in Sri Lanka in six different locations. The Six different locations lead to conclude on a comparison among the *Ambalam* Structures and investigate the similar technology and the strategies that were followed by the constructors on constructing the *Ambalam* Structures.

TABLE I: List of the Case Studies

Name of the case study	Location
Badulla *Ambalama*	Kachcheriya land in the middle of the Badulla town
Kadugannawa *Ambalama*	Kadugannawa
Karagahagedara *Ambalama*	Kurunegala road, Narammala
Mangalagama *Ambalama*	Rambukkana Division in the Kegale District
Naranwala *Ambalama*	12 kilometers away from Kandy towards Gampola.
Padiwita *Ambalama*	Kumbiyagoda road, Higula

VI. Results

Facts and impacts of building orientation and climate response of the ancient '*Ambalam'(s)* structures have been rarely investigated in the literature. Even though, it is important to identify the climatic response of these buildings, mainly focusing on their orientating. This study Investigates on the material manipulations and the building orientation of '*Ambalama'(s)* located in different locations of Sri Lanka. Six case studies were selected randomly.

Fig. 4. Badulla *Ambalama*.

Fig. 5. Karagahagedara *Ambalam*.

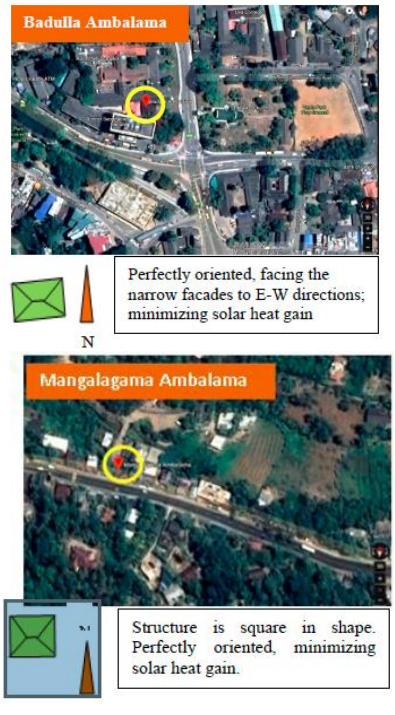
Fig. 6. Naranwala *Ambalama*.

Sri Lanka as a fertile island owing for an abundance of natural vegetation. The trees of the island have long been prized for their large pristine timbers, rich coloring, and valuable structural qualities. Among the Sri Lankan government forests and the home gardens consists of more than 400 woody species. This includes natural regenerations and artificial planted species too. Most of the close investigations of the column details; the craftsmen had intense on utilizing the timber along the grain instead of using perpendicular. Tendrils and the tips of the carved elements which have gone across grains have got wrecked away can be still observed. The nature of timber use to carve is considerably important, hard woods with greater longevity and luster are difficult to shape Fig. 10; It is interesting to explore on how vernacular architectural structures grant insights towards inherit design strategies in construction within this framework, the paper emphasizes building orientations of the six case studies. This Cleary reflects the layout and the orientation has integrated with the tropical climate and uses of local resources of inhabitants.

Fig. 7. Kadugannawa *Ambalam*.

Fig. 8. Padiwita *Ambalam*.

Fig. 9. Mangalagama *Ambalam*.



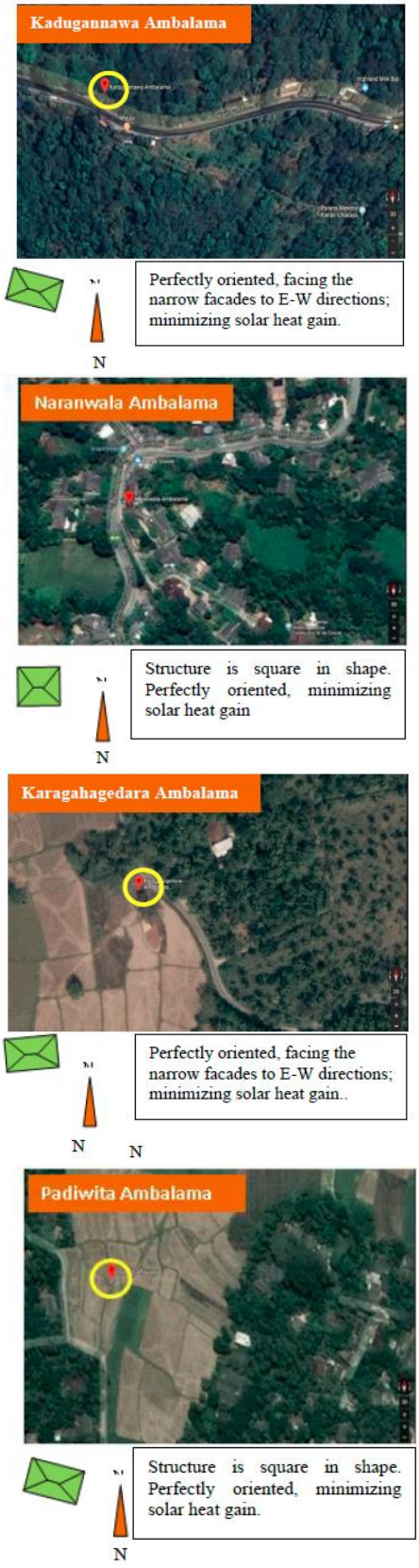


Fig. 10. Above figures explore building orientation.

VII. Discussion

Remains of these medial building provides evidence for utilize contribution features and the technologies. Analyzing and investigating the significance tends Designers, architects, and engineers to increase the usage of timber blending it natural properties towards an indigenous design criteria [12].

TABLE II: Dominantly Visible Timber Species and Its Grading System Respective to State Timber Cooperation (STC) Sri Lanka

COMMON NAME	BOTANICAL NAME	TIMBER CLASSIFICATION(STC)
Gammalu	Pterocarpus marsapium	Special Class Upper
Na	Mesua ferrea	Class I
Wal del	Artocarpus nobills	Class I
Mee	Madhuca Longifolia	-
Kumbuk	Terminalia arjuna	Special Class
Nedun	Pericopsis mooniana	Supper Luxury Class
Jak	Artocarpus heterophyllus	Luxury Class

These Ambalam structures design approach is perfectly established based on the accumulated local knowledge of inhabitants, cultural value, and the deep understanding of natural environment. The building or the structural orientation, where high-pitched roof not only encourages stack effect function but also acts as solar shading devices. Besides, Ambalama structure allows cross-ventilating breezes beneath the dwelling to cool. Also, the large roof eaves for effective sunshine. Ventilated roof space helps to reduce the internal temperature of the structure. Conceptual compartment with open interior spaces with minimal partitions allow proper ventilation. Most of the Ambalam Structures were constructed on raise platforms like stumps and podiums whilst also mitigating the effects of occasional flood as well as ensuring safety of the user or the travelers from possible attack by wild animals.

TABLE III: Sustainable Construction Strategies

Sustainable construction Strategies	Description
Cross Ventilation	Open Colonnaded structure allows easy passage of air and better ventilation.
Construction material usage	Timber performs favorably in terms of energy use and ease of construction.
View and Vegetation	Vegetation helps to cool down micro environmental Temperature. (evaporative cooling)

Majority of Ambalam Structures are open colonnaded structures; ex - Badulla *Ambalama*, Karagahagedara *Ambalama*, Naranwala *Ambalama*, Padivitiya *Amabalam.* Some are with half raised walls; Mangalagama *Amablam*, kadugannawa *Ambalama*. But all of them are capable of obtaining natural lighting while capturing high-velocity of air movement [12]. Together these features have been proven to *Ambalam* Structures to be one of the effective passive design for a tropical building, as it increases the overall construction's thermal comfort and energy efficiency [13].

Bio climatic architectural designs also persists through an infrastructure that bridges to inhabitants shelter and initiate

the layout of cities themselves. These together perceives the cities Political stability, strength of the ruling power, economic prosperity and the establishment, and the spread of religious Aspects with the city to the sustainability and expansion of a developed road network during the period with in it town and country plan [14].

Analyzing the locations and placements of the existing archeological monuments like Ambalam(s), includes ruins of neglected road patches of long established ancient road ways road junctions, ferries, rural settlements, monastery sites and geographical distribution of tanks which was highly utilizing in the medieval period. A well-ordered road system in a country replicates the political, economic stability strength and social and cultural development

Timber is one of the major construction materials utilized in the above case studies. As indicated in Table II; are suspected as highly utilized timber species under vernacular timber architectural constructions. In contrast to other construction materials such as glass, steel and aluminum, timber can often be reused. It can be remanufactured without any interruption.

Trees acts as storage sinks for carbon. In the phenomena of wood production through nature a tree takes carbon dioxide (CO_2) and returns oxygen (O_2). Therefore, utilizing saw logs for long –life statures or in constructions, timber ensures that the CO_2 remains and retains fixed for long period of time.

TABLE IV: CO_2 STORAGE AND CO_2 RELEASE OF FOR MAJOR CONSTRUCTION MATERIALS; SOURCE – FERGUSON *ET AL*. 1996 [15]

Material	Carbon released (kg/m^3)	Carbon stored (kg/m^3)
Rough sawn timber	15	250
Steel	5320	0
Concrete	120	0
Aluminium	22000	0

VIII. CONCLUSION

Being the richest component of the country's cultural heritage in Sri Lanka ;*Ambalam* , a way side resting place , is also recognized as the utmost sustainable building in the past, even until today, due to its design and construction process that takes into account energy efficiency, indoor environmental qualities, sustainable site planning, and the uses of local materials and resources.

It is identical that medieval constructors have appropriately integrates affordability and sustainability through traditional Construction techniques to obtain bio-climatic building designs.

High strength to weight ratio has led timber to perform favorably in terms of energy use and ease of construction in comparison to other construction materials.

The term, combining biology and climate, refers to the design of buildings in accordance to the local climate is technically known as bioclimatic building design. This design architecturally comprises physiological and psychological need bases on comfort. Together this implies maximizing the utilization of the available natural resources, prior to any energy enhancement by active means.In Vernacular Architecture the choice of passive design strategies for climatic control in buildings was based on experience. Ventilation requirements in vernacular architecture were attained by natural means. Natural ventilation is one of the most important passive cooling techniques.

Using environmentally friendly technologies and construction materials contribute to the sustainable development of the construction industry. The six case studies have emphasized the spatial and functional arrangement, maximizing natural lighting and ventilation, building orientation and construction materials and their combination plays a major role under the continuity of the Vernacular architectural concepts into a modern contemporary Sustainable building development.

Passive cooling techniques are accompanying to the thermal comfort of the occupants. These were possible in achieving this comfort by reducing the heat gains, thermal moderation and removing the internal heat of the structure. Cooling is the transfer of energy from a space to a space, in order to achieve a lower temperature than that of the natural surroundings.

Most of the *'Ambalam'*(s) Structures are designed to use as little energy as possible while providing the best possible comfort conditions. Square and the rectangle Shape and arrangement of the *Ambalam* as result of the building plot options and its environment. Permeability and orientation of the case studies briefly analyses of similarities. These are namely plan layout, opening and orientation of the envelope and the facade systems employed. The suitable location of the *Ambalam* structures construction depends on the climate, the direction of the winds, the presence of trees and landscaping features, uses and the internal layout. It determines the design strategies are best suited for a specific climatic context and for the level of architectural complexity.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

All three authors contributed to Conceptualization and methodology. Authors M.S Mendis and Malthi Rajapakse contributed for field observations and data collection, data analysis and manuscript writing. Author Prof. Rangika Halwatura supervised the research work, reviewed and edited the final manuscript. Finally, all authors had approved the final version of this manuscript.

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- F.R. Arooz, , R.U. Halwatura, Mud-concrete block (MCB): mix design & durability characteristics, Case Studies in Construction Materials, Volume 8, June 2018, Pages 39–50
- R.U. Galagoda , G.Y. Jayasinghea, R.U. Halwatura , H.T. Rupasinghe, The impact of urban green infrastructure as a sustainable approach towards tropical micro-climatic changes and human thermal comfort, Urban Forestry & Urban Greening, 2018
- S Pathirana, ·A Rodrigo, ·R U Halwatura,Effect of building shape, orientation, window to wall ratios and zones on energy efficiency and thermal comfort of naturally ventilated houses in tropical climate, International Journal of Energy and Environmental Engineering, 2018.

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- Award for Outstanding Research award with distinction, University of Moratuwa. 2017
- Presidential Awards for Academic Publications, 2018