APPLICATION AND ACCEPTANCE OF ECO-FRIENDLY WALLING MATERIALS FOR STATE SECTOR PROJECTS

MASTER OF SCIENCE

IN

CONSTRUCTION PROJECT MANAGEMENT

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DECLARATION

I hereby affirm that this dissertation report is an outcome of my own effort for the best of my knowledge and it contains my own work for the fulfillment of requirement for the higher degree of Masters of Science in Construction Project Management. It does not include any previous written materials submitted for the award of any preliminary degree, higher education or published by any other person or institution except where acknowledgement and references are made in the text.

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The above candidate has carried out research for the Masters under my supervision.

…… …….

Signature Date

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DEDICATION

I would like to dedicate This Report,

To my Parents, Husband,

for their eternal love, affection

and

encouragement which strive me

to make my dream a reality,

and

the teachers, who lead me

to the path of success and honor.

ACKNOWLEDGEMENTS

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ABSTRACT

Eco-friendly materials have promptly grown worldwide with its demarcating benefits to the construction industry. However, in Sri Lanka, construction industry still primarily use traditional methods and standard materials (e.g. conventional bricks and cement masonry blocks). The usage of the Eco-Friendly wall materials is still lagging behind in Sri Lankan construction industry.

Developing countries are also largely responsible for increasing global warming from housing and construction industry. And 90% of households are having thermal issues due to the heated interior of the houses in Sri Lanka hence it is highly required to use alternative Eco-Friendly materials for construction purposes to solve these problems as a developing country. However, it is required to identify why there is less demand in using Eco-friendly construction materials for the construction purposes.

This thesis aims to explore why there is a less demand for Eco-friendly materials for wall construction in Government construction projects in Sri Lanka. Further, it is required to analyze the factors that contribute to lack of demand for Eco-Friendly wall materials in Government construction sector in Sri Lanka and find the strategies to overcome this problem.

The study analyzed the data under three factors namely, psychographic, product-specific and demographic, and found most critical barriers to implementation the Eco-Friendly wall materials in the Government construction projects in Sri Lanka.

Strategies were recommended to increase and promote the Eco-Friendly wall materials (Compressed Stabilized Earth Blocks and Eco-Friendly Wall Panels) in the Government construction sector in Sri Lanka. This thesis provides a critical evaluation on the preferences of EWM and strategies to encourage the adoption for the EWM in Sri Lanka.

This study gives insights on ways to motivate Sri Lankan to use environmental friendly concepts.

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LIST OF ABBREVIATIONS

Abbreviation	Description
PFA	Pulverized fly ash
LOC	Lower oxford clay
CSEB	Compressed Stabilized Earth Block
EC	Embodied Carbon
GB	Green Building
HCB	Hollow Cement Block
MCB	Mud Concrete Block
PCB	Printed Circuit Boards
EWM	Eco-Friendly Wall Materials
EFWP	Eco-Friendly Wall Panels

1.0 INTRODUCTION

1.1 BACK GROUND

Sri Lanka is a developing country and large-scale construction activities including but not limited to new building construction, road improvements, and renovation projects are taking place in the country. Most of these construction projects are being executed with the use of traditional construction material (De Silva et al. 2018). Generally, Sri Lankan industry uses traditional materials such as cement masonry blocks, ready-mix concrete and structural steel etc. Mostly these materials are not eco-friendly concepts and very harmful to the environment.

A study conducted by Kumareswaran et al. (2021) has found that, uncomfortable living conditions are experiencing by the occupants because of interior overheating. It was reported that significant number of households (90%) experience thermal issues. It has been revealed that 35.4% of occupants prefer to stay outdoor and 31.3% used to open the windows. Energy poverty, reduced user comfort, reduced quality of life due to unacceptable indoor air quality concomitant effects were observed, 37% reported respiratory and cardiovascular disease and 62% reported at least one type of illness. This is a harmful situation for the Sri Lankans. On the other hand, Eco friendly material can exist without harm to human health.

In modern days, most of the countries are using eco-friendly materials for the construction works. Especially because it is an environmentally friendly concept and it helps to improve human health. Most importantly, it helps to manage waste collection in the country. Therefore, developed countries attempt to encourage eco-friendly materials for the construction activities to reduce waste collection and it is a long-term cost saving process.

Eco is defined as the environment, habitat or surroundings. The definition of eco is something that is environmentally friendly or sustainable. Therefore, environmentally friendly processes are sustainability and marketing terms referring to goods and services, laws, guidelines and policies.

Eco-Friendly building material is a type of material that doesn't harm the environment, whether in its production, use or disposal and can easily be recycled. Using Eco-Friendly materials is highly beneficial in the long run. Building a green home reduces carbon emissions significantly and saves energy, which results in saving money on energy bills. There are five parameters to identify the green building materials for construction purposes namely Pollution prevention, Waste prevention, Recycled content, Embodied energy of a material and Natural materials.

There are many benefits of eco-friendly materials.

1. Environmental friendly green product
2. Comfortable environment in house
3. Creating a new employment
4. Helps to manage waste collection

The research focused for Eco-friendly wall materials usage of Government sector organizations in Sri Lanka.

1.2 PROBLEM STATEMENT

Eco-friendly materials have promptly grown worldwide with its demarcating benefits to the construction industry. However, in Sri Lanka, construction industry uses traditional methods and familiar materials (Conventional bricks, Cement blocks productions). Even though eco-friendly construction materials are manufactured in Sri Lanka, very few construction projects can be found with eco-friendly materials.

It is required to identify why there is less demand for using eco-friendly construction materials for Sri Lankan building construction industry. It is highly necessary to use alternative Eco-Friendly materials for construction purposes to solve these problems.

1.3 RESEARCH QUESTIONS

There are many benefits of using eco-friendly materials. It helps to manage waste collection and it is an environmentally friendly concept. This research has selected only two categories of eco-friendly wall construction materials. Namely, Eco-friendly wall bricks (Compressed Stabilized Earth Blocks) and Eco-friendly wall panels (EFWP). Focus is on Government sector building construction projects for this research.

The research question that was addressed in this research is.

1. Why there is a less demand for Eco-friendly materials for wall construction in Government construction sector in Sri Lanka.

1.4 RESEARCH OBJECTIVES

Objectives of this research are as follows.

1. Analyze the factors that contribute to lack of demand for Eco-Friendly Wall Materials (EWM) in Government construction sector Sri Lanka.
    a. To identify the awareness and encouragement to the adoption for EWM in Sri Lankan Government construction sector.
    b. To identify the potential of the use of EWM to solve common barriers.
    c. To investigate the barriers to adopt the EWM and competency level of Sri Lankan Government construction sector towards adapting to it.
2. Recommend Strategies to overcome.

1.5 LIMITATIONS

There are many researches related to EWM in construction industry worldwide. Only few researches have been carried out with the purpose of identifying the application and acceptance of Eco-Friendly materials for the wall construction in the Sri Lankan construction industry.

Since this is a new concept to Sri Lanka, limited numbers of researches have been conducted supporting this topic. Hence, required information were gathered referring to the related researches carried out throughout the world. The vital area of research is discovering the effectiveness of EWM in the perspective of Sri Lankan construction sector before the implementation of it.

This study focused on present Sri Lankan Government building construction sector due to the accessibility of information and reachability to professionals in the industry.

There was a considerably small community who have used EWM to distribute the questionnaire survey and due to the Covid-19 pandemic, many difficulties were faced in gathering data for this analytical process. These were identified as the limitations in carrying out this study.

1.6 GUIDE TO THESIS

Chapter 01

Introduction: This chapter provides a general understanding on this research study, “The effectiveness of use of Eco-friendly materials in Sri Lankan construction sector”. It consists the sections namely, background of the research area, problem statement, research question, objectives, limitations to the study and guide to the thesis.

Chapter 02

Literature Survey Chapter 2: Illustrates the prevailing literature related to Eco-friendly materials and green buildings, which provides a clear understanding on the subject area. A comprehensive study was carried out focusing the Eco-Friendly Materials, suitability for the country, benefits and further barriers and recommendations in EWM implementation to filter out vital facts to streamline the proposed study.

Chapter 03

Research Methodology Chapter 3: Demonstrates the research methodology followed to carry out this study. It further provides detailed description on the techniques used to collect and proposed methods to analyze data accurately and appropriately to derive conclusions.

Chapter 04

Data Collection and Analysis: This chapter presents the data collection and analysis carried out in this research. Respondent background, analysis of the identified factors and major issues in construction industry by analyzing the data collected in use of EWM implementation and the summary of analyzed data are presented in this chapter.

Chapter 05

Conclusion: This is the concluding chapter, which provided the gist of the whole research carried out. It consists with proposed strategies to implement and promote EWM in Sri Lankan Construction sector. Finally, it points out provisions to carry out further research on EWM usage in the Sri Lankan Construction sector.

2.0 LITERATURE REVIEW

In this research, literature review was conducted to gather the details regarding Eco-friendly wall material types, current usage, benefits and disadvantages and issues that were identified in the other similar countries, researches carried out in Sri Lanka and what are the recommendations given for the usage of these EWM in the construction industry. More than fifty numbers of research papers were broadly reviewed to collect information for this study.

2.1 ECO-FRIENDLY WALL MATERIAL TYPES

A study was conducted by De Silva and Hansamali (2019) to find out the alternative resources due to the limitation of the resources of natural clay. Manufacturers have faced difficulties with production of clay bricks for the construction purposes due to limitations of resources. The study by De Silva and Hansamali (2019) revealed that by adding more of ceramic sludge, it is possible to reduce the weight of the bricks. It has been reported that the strength can be improved by 32% in comparison to traditional bricks, with the use of 40% ceramic sludge.

Benin et al. (2020) in India have studied on various types of plant fiber polymer-composites. It was a significant research for Sri Lankan manufactures to improve or produce new eco-friendly composite panels for Sri Lankan construction industry.

The energy of the polymer composites bolstered with natural fibres may be stepped forward via way of means of using hybridization. The usage of suitable filler substances can also bring about the development of the properties of the composites. The records concerning diverse natural fibres and their corresponding composite substances portrayed on this manuscript may be applied as a base fabric for extending similarly researches with inside the subject of enhancing the properties of natural fibre reinforced polymer matrix composites. Furthermore, the knowledge regarding the existing natural fibres used for manufacturing polymer matrix composites could help in the discovery of new natural fibres. (Benin et al., 2020)

A study conducted by Jesudass et al. (2021) have discussed the methods of different tests and standards methods for blocks produced with using natural fibres. In this study, tests related to density, compression, water absorption, thermal conductivity and tensile has been considered. It was concluded in the study that fibre used products were more cost effective and sustainable option wehen comparing with the traditional building materials.

2.2 USAGE OF ECO-FRIENDLY WALL MATERIALS

A research has been conducted by Zanatta et al. (2021) in Brazil to study the technical and economic demand for eco-friendly ceramic tiles. This study was carried out to develop a new product considering the following. Those are designing a new product that complying the technical standards, without using by-products as raw materials and carry out complete operational conditions to understand their behavior and identify the failures during product development and production.

"The development of eco-friendly products carried out in the study was created alternatives to increase waste consumption without jeopardizing the production of regular products. In addition, the raw materials types used in environmentally friendly products was limited to the three by-products surveyed, which is far less than it really is, significantly reducing the number of raw materials used in the manufacturing process in most literature. In addition to deactivating potential pollutants, this practice has reduced the amount of waste dumped in landfills, creating value for materials that are not considered very noble and new inputs. Omit the use of things" (Zanatta et al., 2021).

The study by Liu (2017) has showed that great progress in the area of economic, but the consumption of the resources and pollutant emission in high levels. This could be described by the fact that some local governments closely linked to monitor the economic achievements and pay little attention for environmental performances.

The Matsumoto and Chen (2021) 's research in China states that highly industrially environmentally efficient states are predominantly distributed in the eastern region, while less industrially environmentally efficient states are located in the less economically developed western region in China.

As per the above, it has found that authorities of the most developing areas pay little attention on environmental protections, because those authorities needs to closely monitor and achieve the economic developments more than environmental performances.

2.4 ADVANTAGERS AND DISADVANTAGERS OF ECO-FRIENDLY WALL MATERIALS

In the research conducted by Gurupatham et al. (2021), it has compared Compressed Stabilized Earth Blocks (CSEB) with Burnt traditional clay bricks and Cement masonary blocks and was found that CSEB has more efficiency and more environmental benefits when comparing with the traditional materials.

“CSEB can also be used as a wall element without plaster. Therefore using it without plaster can further reduce costs and environmental impacts. The results of this study encouraged construction creators, contractors, and consultants to select the most desirable material for their projects, taking into account the cost and environmental impact of the material's life cycle.” (Gurupatham et al., 2021)

The research conducted by Nawarathna et al. (2021) in Sri Lanka was focused on Embodied Carbon emission in Commercial buildings and data was collected from twenty buildings of Sri Lanka. It was mentioned that developing countries are largely need to be responsible for increasing global carbon emissions from commercial buildings and construction sector.

It was revealed in the research that the substructure, frame, upper floors, and external walls were the key EC contributors of the building. The contribution is about 85–95% of total EC. These elements were identified in this sample as carbon-related elements. They are likely to contribute to the reduction of building EC during the initial design phase of the building through effective design alternatives, material and thickness dimensional changes. Interior walls and partitions, stairs and slopes, and roofs were identified as non-carbon elements, the total contribution of which was less than 20% of EC buildings. These elements have been identified as addressable during the detailed planning and technical design phase of the building to accommodate EC reduce.

In the above research, it has found that effective design alternatives and changing materials can help to reduce the Embodied Carbon emission to the environment. Therefore, this research was a highly encouraging research to promote and introduce eco-friendly building designs with less carbon emission materials for the developing countries.

In the research conducted by Kumanayake et al. (2018) in Sri Lanka, overall Embodied Carbon emission of a building has been annualized by examining a three story building in Gampaha. The results revealed that the embodied carbon content of the building was 629.6kg CO2 / m2. Reinforcing bars, clay bricks and ready-mixed concrete accounted for about 70% of the total

embodied carbon. Although it is relatively small mass, aluminum is a very high carbon-consuming material, so the contribution of aluminum is important.

In the research conducted by Weerasinghe et al. (2021) in Sri Lanka, it is mentioned that Green buildings have been found to save 19%, 25%, and 36% on operating costs, energy consumption, and CO2 emissions respectively compared to traditional buildings. The study has also found that green building construction costs are about 29% higher than traditional buildings, while green buildings (GB) save 23% in operation and 15% in maintenance. However, GB also has an additional cost of 16% in terms of residual value compared to traditional buildings. Further, it was mentioned in the study that the conclusion made are based on the collected data of the selected buildings. Therefore, the type of the building and features of the building could give different outcomes. It has been recommended to address those shortfalls in future researches.

A research that was focusing on tourism of Sri Lanka mentioned that “this study was emphasized the importance of spatial atmosphere for the eco-efficiency of tropical hotels, which play a central role in sustainable tourism initiatives.” (Rajapaksha, 2017)

A research that was conducted by Udawattha and Halwatura (2017) in Sri Lanka, have investigated the suitability of the wall materials in Sri Lanka. As a result, the overall ranking was given with the best scenarios in mind and found that Mud concrete block (MCB) were the most suitable for building affordable houses. Cabook was the second best wall Material, because it has low cost, low carbon emissions and low energy consumption. However, in contrast to the second best case, Cabook has many limitations, such as lack of resources to produce Cabook in the local market. The brick and hollow cement block (HCB) are inferior building materials. Brick appear to be superior to HCB because it was made from burning coconut husks using clean energy. However, the embodied energy and life cycle costs involved were relatively higher than the MCB and Cabook. Not only the embodied energy contain, but also the reusability was slightly lower than other walling materials. In addition, a hollow cement block made from quarry dust that was required far more non-renewable energy to produce it. Therefore, finally it has been revealed that hollow cement block was the worst building material overall for tropical climates like Sri Lanka.

In the research conducted by Zhang and Biswas (2021) many benefits of interlocking brick versus conventional brick has been highlighted. ”Traditional masonry consists of sun-dried bricks that are connected to each other by layers of mortar. Due to the low tensile and shear strength of mortar, breakage always begins at the mortar or the interface between brick and mortar. In addition, structural quality and building efficiency are highly dependent on the experience and capability of

the bricklayer. Therefore, in the last few decades, thin-layer or dry stack construction methods have been introduced to increase construction efficiency." (Zhang and Biswas, 2021).

Many of the benefits of using interlock bricks instead of traditional clay bricks were identified that supports to reduce construction time, minimize labour cost and improve the structural performance and quality of the construction.

In this research also it has mentioned that over the last few decades, different interlocking bricks have been introduced that can help to improve the quality and efficiency of construction. When comparing to the conventional brick, production rate of the interlocking brick could be increased to over five times. This is equivalent to 20-40% of saving the labor cost of using interlocking brick for construction. Since the interlocking bricks were self-aligned, the skill requirements of the bricklayer could also be reduced. In addition, the introduction of an interlock mechanism was expected to improve the toughness and strength of masonry structures made of interlock bricks. These features could be very suitable for rural areas where there was always a shortage of skilled workers to build traditional brick structures.

It was highlighted that replacing conventional clay bricks with interlocking bricks helps to enhance the eco-efficiency performance without compromising structural integrity in the above research.
The research regarding recycling e-waste conducted by Arya and Kumar (2020) has revealed that the informal recycling sector controls recycling not only in India but also in other developing countries such as Ghana, Vietnam, China, Nigeria, Thailand, Indonesia and the Philippines, where workers were extracting metals in acid bath, exposed to the emission of toxic substances in the process of melting PCBs open burning of wire stacks etc.

The research was conducted by Rahmat et al. (2016) have explored that alternative raw materials and energy efficient technologies for making bricks with law cost. As a result, Unfired LOC-PFA bricks have shown energy efficiency and suggests remarkable economical alternative to firing building materials. Therefore, it has recommended the use of eco-friendly building materials, which will be a great contribution to the concept of green building.

The research regarding development of thermally efficient fibre-based eco-friendly brick conducted by Raut and Gomez (2016) has found that the glass powder and palm oil fly ash used block have gained strength with low density, good thermal performance and satisfactory level of mechanical performance also.

In the research conducted by Coletti et al. (2015), regarding the sustainable brick production found that a high quality brick can be obtained under the low firing temperature, hence reducing energy consumption and production costs. Therefore these results was made an appreciated contribution to the development of brick production and to the improve final quality of products.

The research by Zhang and Biswas (2021) have identified that the structural mechanical performance can be improved by replacing traditional bricks with interlocking blocks. This design strategy also significantly reduces construction time, minimizes labor costs, and improves mechanical performance. In the technical eco-efficiency framework, four out of five interlocking bricks with PT tendons, rebar and mortar have the required level of compressive and tensile strengths while reducing the environmental impact and cost at a good manner. Therefore, these interlocking bricks called as "environmentally efficient" bricks.

It also concluded that most of the interlocking brick works (i.e. without mortar, rebar, tendon, grout etc.) have shown better eco-efficiency performance than conventional bricks to deliver same compressive and tensile strengths. In addition, the conventional bricks were not found to be completely eco-efficient but it was eco-efficient based on tensile strengths only.

In Rabello and Ribeiro (2021) ‘s research revealed the thermal analysis showed that the presence of both types of vermiculite in the vegetable polyurethane matrix can provide thermal stability during thermo gravimetric analysis and flame retardancy during flammability testing. Finally, it is concluded that the addition of increasing vermiculite to the vegetable polyurethane matrix will enable the production of excellent thermal insulation bricks of 70% by weight of raw vermiculite, reducing the energy costs of residence.

The study conducted by Garciaa et al. (2021) have showed that Latin American companies interested in eco-efficiency was beginning to consider strategies to reduce the impact of pollution and climate change on market value. This recommendation was aimed to enhance innovation between companies in emerging markets to reduce the inefficiencies of the production processes, which represent sunk costs and to reduce CO2 emissions to improve the eco-efficiency of companies.

“Several concretes with different properties have been developed to improve the pre-wall durability as well as end product sustainability.” (Martins et al., 2021).

2.3 SUITABILITY OF ECO-FRIENDLY WALL MATERIALS

The study by Emmanuel (2004) have found that the most widely used wall materials in Sri Lanka were brick, cement masonry blocks , Cabook (hardened offshore masonry block common in southwestern Sri Lanka), random rubble, watte and daub. Study has further evaluated the Environmental suitability based on ESI, which depends on embodied energy, LCC, and reusability. The results have shown that wattles and daub was the most environmentally friendly wall materials among all materials considered. Cement masonry block was least suitable material. However, there are significant variations in the ESI subcomponents. Wattle and Daub have the lowest embodied energy, but they were not really reusable (but recyclable). Cabook and brick have the highest reusability.

The research by Gavali and Ralegaonkar (2019) have investigated that Alkali-activated bricks were one of the zero cement products that have used industrial waste such as fly ash (FA), rice husk ash (RHA), boiler ash, bottom, cement slag, blast furnace slag and mine residue. These bricks were developed by alkali activation of raw materials, including silica and alumina, to produce eco-efficient, high-strength products. It was investigated the performance of alkali-activated bricks developed by activating industrial waste (CBA and SD) and it could apply to load-bearing masonry. The technical and economic feasibility of the proposed building design (support structure with developed AAB bricks) was investigated and compared with existing cases of one-story houses (skeletal structures). A comparative study found that the proposed building construction was a better solution to traditional building practices in terms of cost and energy. Compared to traditional building practices, the developed high-strength bricks (14.5 MPa) have reduced construction costs by almost 7% and embodied energy and operating energy by 22% and 13%, respectively. The study concluded that the development of sustainable alkali-activated fossils and the use of these high-strength mixed ash bricks in load-bearing structures were environmentally efficient and practical construction methods.

The research by Arya and Kumar (2020) have highlighted that India needs a lot of attention to environmentally friendly technologies. This technology have several advantages such as limiting use of natural resources, energy saving, environmental protection and improve well-being.

Emmanuel (2004) have found from a research that among Brick, Cement masonry units, Cabook, Rubble and wattle and daub, environmentally most suitable material is Wattle & daub and least is cement masonry units. In addition, while wattle & daub has lowest embodied energy, it is not reusable (but can recycle) and Cabook and brick has the best re-usability.

2.4 BARRIERS TO IMPLEMENT ECO-FRIENDLY WALL MATERIALS

The research performed by Joyram (2019) has found the factors that influencing the usage of the eco-blocks from Mauritian perspective. The factors included in a list under the of psychographic, product-specific and demographic factors. In fact, these factors were important for construction marketers to understand and predict the behavioral intent and acceptance of this new product. Eco-block producers were working with the government to promote eco-friendly construction by successful awareness campaigns to promote eco-block sales in target markets while ensuring energy efficiency in the building sector.

2.5 RECOMMENDATIONS FOR IMPLEMENTATIONS

The research by Alam et al. (2021) in Bangladesh, has found that the large-scale production of non-biodegradable waste from electrical appliances causes great environmental damage. The use of biopolymer-based nanomaterials has the potential to provide a promising approach for creating environmentally friendly and sustainable devices. In this work, gelatin / single-walled carbon nanotube (Gel / SWCNT) nanocomposites were produced by a simple and economical water-based casting process. It has recommended to reduce e-waste production and implementing eco-friendly wall material, which was useful for construction field.

In the research conducted by Arya and Kumar (2020) has recommended the following strategies to manage e-waste in Asian countries with reference to the research done in India. The recommendations were; proposed suitable technological advances to treat the harmful components and recovering precious elements in e-waste, knowledge enhancement programs, improve and effective management to reduce e-waste generation, customer responsibility about e-waste management rules, development to optimal supply chain enabling green policies and development of value added products such as concrete bricks, interior decorative materials from e-waste.

Coffey et al. (2021) research has revealed that Eco-anxiety was a concept used to understand the relationship between climate change and the anxiety associated with recognizing the negative effects of climate change. Evidence suggests that further conceptual clarity and theoretical progress were needed to advance the conceptual understanding of eco-anxiety. In the review also showed that most of the evidence came from Western countries and that more research was needed in other parts of the world. Indigenous peoples, children and adolescents were identified as at risk if their living experience with ecological fear was unclear and requires further research.

Majority of commercial buildings are constructed by using reinforced concrete in Sri Lanka. Therefore, research by Kumanayake et al. (2018) has mentioned that it is required to find substitute material to replace cement and need to modify mix design concerning about low carbon emission materials. Therefore, use of recycling and reuse materials has been highlighted for the construction. Six Strategies have been proposed for reducing embodied carbon of buildings such as; designed with save quantities of materials, modified concrete properties, used alternative low-carbon building materials, made use of recycling and reuse potential of materials, carbon emission as an evaluation criteria for energy efficient buildings and Eco-labeling for building materials.

2.6 CONCEPTUAL FRAMEWORK

The below figure (Figure 01) elaborates the literature about the eco-friendly wall material usage in Sri Lanka.

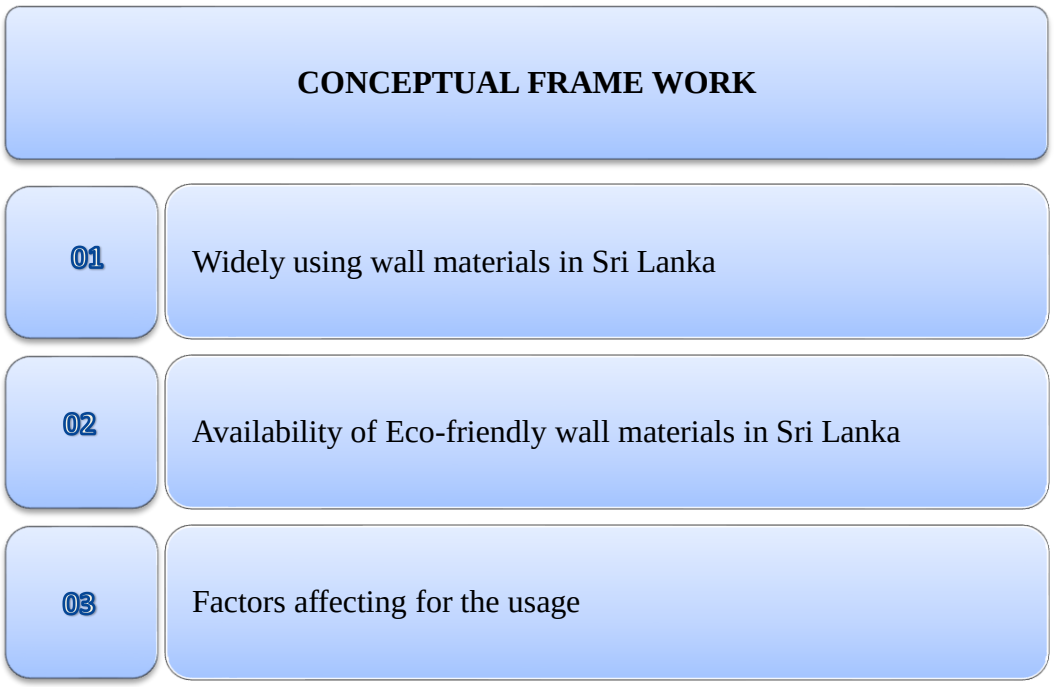

Figure 1- Framework

01. Most using wall materials in Sri Lanka

Most of the construction projects are executed in the Sri Lanka with the use of traditional masonry construction material. (De Silva et al. 2018) Generally, Clay bricks and Cement ready-mixed concrete walls were being mainly used for the wall construction purposes in Sri Lanka.

02. Availability of eco-friendly wall materials

Compressed Stabilized Earth Blocks (CSEB) and Eco-friendly wall panels (EFWP) are mostly available wall materials in the Sri Lankan market. There were number of researches were conducted regarding the CSEB and EFWP in Sri Lanka. Hence in this research, CSEB and EFWP are used for the data collection purposes.

03. Factors affecting for the usage

In the research conducted by Joyrama (2019) regarding the usage of Eco-friendly materials in the Mauritian construction industry, three factors that are to be considered have been revealed. Factors affecting the usage such as psychographic, Product specific and Demographic factors have been identified. Under the psychographic factors, cost effectiveness, customer preferences, product awareness and quality preferences have been considered. For this study, concerned Product specific factors were strength and sustainability of the product. Demographic factors which was evaluated were education level, experience in years, number of projects handled in the last seven years period and level of adoption for the eco-friendly wall materials.

3.0 RESEARCH METHODOLOGY

This chapter describes about the research methodology that was followed for this research. It provides detailed description of techniques and methods followed for data collection.

The research methodology contains the steps with detailed description in the Table 1 and summarized in the flow chart presented in Figure 2. The research area was proposed having a general idea on Eco-friendly wall materials for building construction and it was further defined following a desktop study.

A preliminary literature review was carried out to upgrade the latest knowledge related to the subject area. After that, a comprehensive literature review was carried out to collect data associated with the study. Simultaneously, an industry survey was conducted with the purpose of identifying the projects using Eco-friendly wall materials. Moreover, Expert interviews were carried out by interviewing Eco-friendly material users, Eco-friendly material producers, project managers, construction managers and other subject related experts, to collect hands on experience of stakeholders of top tier projects.

With the outcome of the literature review and the expert interviews, a questionnaire was drafted and a pilot survey was carried out to refine and adjust the questionnaire as appropriate to the study. Modified questionnaire was circulated mostly targeting the Engineers and Architects involved in Government sector construction projects of the country. Designers were specially considered, as they are the key role players of initiation of the project. Subsequently, analysis was performed on collected data.

Main Steps of Methodology	**Detail Description of the steps**
1.0 Preliminary study	1.0 Literature Review
	2.0 Conduct Interviews using Closed ended questioner
	• Targeted population
	• Architects
	• Design Engineers
	• Construction Engineers
	3.0 Factors addressed in the Questionnaire under the main three areas
	• Psychographic Factors Cost effectiveness

	Quality preferences Customer preferences (Aesthetic Appearance) Product Awareness
	• Product Specific Factors
	Strength of the Product Sustainability of the Product Construction Time period Maintenance Cost
	• Demographic Factors Experience in years Education qualifications Number of projects in last seven years
2.0 Analysis of Data	1.0 Use of SPSS analyzing method to analyze statistical and categorical data
3.0 Identification of key factors	1.0 Approach to derive strategies
	• Determining top three factors that barriers to implement
	• Recommendations
4.0 Strategies	1.0 Find the strategies to overcome

Table 1-Research Methodology

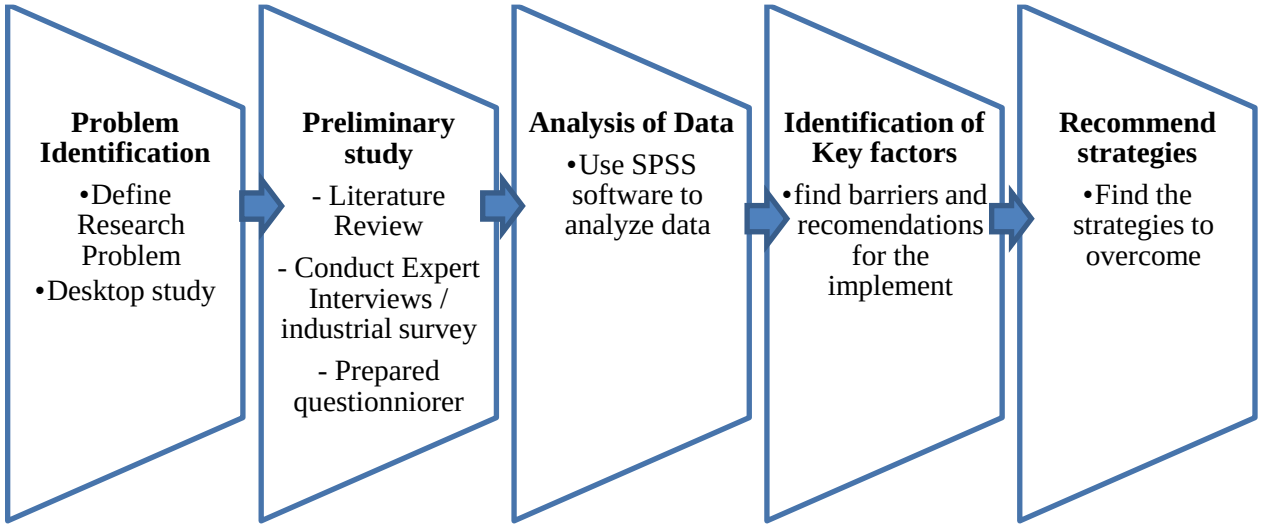

Figure 2- Flow of Methodology

3.1 METHOD OF COLLECTION OF DATA

Several methods were followed to collect the required data such as literature survey, experts' interviews, industrial survey, data collection from eco-friendly wall material producers and contractors. After the pilot study, a questionnaire was prepared to collect data. A questionnaire means a list of questions prepared to collect data from the respondents about their attitudes, experiences, or opinions. Questionnaires can be used to collect qualitative or quantitative information. Questionnaire method is a commonly used research method in a market researches. Questionnaire is a specific tool to collect the data. By Designing a questionnaire with reliable and valid questions, it helps to collect most suitable data related to research objective. This research was conducted during the COVID pandemic situation and the questionnaire enabled to collect data via email and other electronic means when physical meetings with people was limited. hence, questionnaire method is a more suitable method to collect data for this research.

Questionnaire survey was conducted targeting government sector especially design engineers and Architects and as well as construction Engineers.

3.1.1 Literature Review

Literature review was the component that started from the very beginning until the end of the study. A broad literature review was conducted as the primary research method for this study through electronic searches of journal databases and accessing scholarly literature via web engines, Google Scholar and Science Direct to figure out the Eco-friendly wall materials, strength, sustainability,

environmental benefits, use and major issues in Sri Lankan construction industry, barriers and recommendations in Eco-friendly wall material implementation etc.

More than fifty research papers were broadly reviewed to collect information for this study. Further, desktop study was carried out to identify suitable method to analyze the collected data and statistic subject area was studied comprehensively using websites and you tube videos and tutorials to become familiar with SPSS software as well as related important details.

Qualitative and Quantitative research methods are fundamentally different techniques. But its objectives and applications can be over lap in some areas. Qualitative analysis methods are more suitable to collect more deeper understanding about the data and motivational ideas relating to the topic.

3.1.2 Expert Interviews/ Industrial Survey

An industry survey was conducted with the purpose of identifying the projects using Eco-friendly concepts. Expert interviews were carried out interviewing manufacturers, project managers, construction managers and other subject related experts, to collect hands on experience of stakeholders of top tier projects. This was the methodology used to identify the Eco-friendly wall material usage and implementation level of Sri Lankan construction industry.

Experts gave comments regarding Eco-friendly concepts and most of them are familiar with eco-friendly floor and roof materials. However, much interest has not been payed on eco-friendly wall materials. Most of experts expressed that clients do not prefer to proceed the works with new concepts and therefore that was a major barrier to implement eco-friendly wall materials for the Sri Lankan construction industry. Eco-friendly wall panels are highly expensive and available low cost wall panels in the market are low quality products.

Regarding eco-friendly wall bricks, manufactures emphasized that there is a considerable amount of demand for the brick, but the issue is to find out the resources. Most of them highlighted about the soil permit related issues.

Properties of Eco wall materials are as follows.

	Eco Brick-01	**Eco Brick-02**
Dimensions of Block	12 x 6 x 4 inches	29 x 14 x 9 cm
Weight (Kg)	7.2	More Specification attached below
Strength KN/mm2	6.5	
Water absorption (vary as per the requirement)	12% - 10%	
Cement Content	12% - 11% (Ordinary Portland Cement)	5% - 7%
Remarks	Balance % consists with laterite soil. After compression, 14 days curing process.	Sand and gravel content over 65% and silt and clay 35% Minimum 14 days curing It takes 28 days to gain full strength Carbon emission kg CO2/m3 49.36 (Manual) 51.53 (Motorised) Sri Lanka Standard 1382:2009 specification for CSEB for construction

Table 2 - Properties of Eco-Bricks

Physical characteristics	Specified limits
Dry density	>1750 kg/m^3
Total water absorption	<15%
Dry compressive strength	Grade 1: >6.0 N/mm^2
	Grade 2: >4.0 up to 6.0 N/mm^2
	Grade 3: 2.8 up to 4.0 N/mm^2 (not applicable for interlocking blocks)
Wet compressive strength	Grade 1: >2.4 N/mm^2
	Grade 2: >1.6 up to 2.4 N/mm^2
	Grade 3: >1.2 up to 1.6 N/mm^2 (not applicable for interlocking blocks)
Flexural strength (bending strength)	>0.5 N/mm^2
Pitting depth (Erosion resistance)	<10 mm
Linear expansion of block upon saturation with water	<0.10%

Table 3 – physical characteristics of CSEB from Sri Lankan standards (SLS 1382-1:2009)

Width	Upto 1187mm
Height	2438mm, 2743mm, 3048mm
Thickness	54mm
Sound Transmission Class	STC 32 dB
Sound Absorption Co-Efficient	NRC 0.62
Impact Resistant	2.36 MPa
Weight	18.5 Kg/M2
Thermal Conductivity	K= 0.081 W/mk
Thermal Resistance	R=0.62M2 K/W
Fire Resistance	Upto 2 Hours
Raw Finish	Craft Paper 337gsm/ Hardboard clad with Acoustic Pattern perforation

Table 4 – Properties of Eco-wall panel -01

3.1.3 Questionnaire Survey

Questionnaire was developed based on the literature review and industrial survey conducted with experts. The content of the questionnaire can be mainly divided in to four segments namely general

information, collect data on affecting factors, barriers for the implementation and recommendations to overcome.

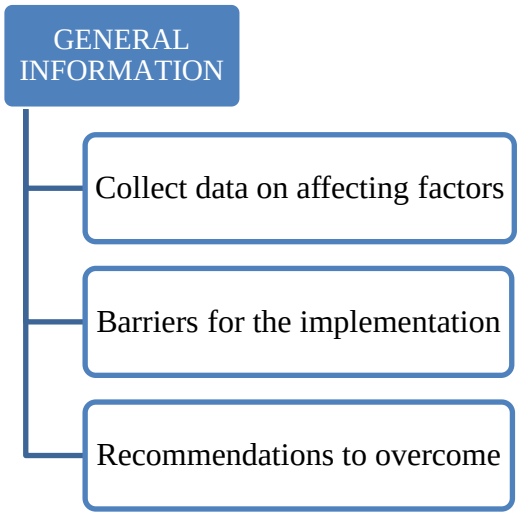

Figure 3-Structure of the Questionnaire

Under the general information, data was collected about the samples general details such as name of the sample, working information and special other qualifications. For the data collection on affecting factors, the conceptual framework identified the factors affecting the usage of EWM under the three categories namely; Psychographic, Product specific and Demographic factors. The questionnaire focused on these factors and categorized most critical sub factors to gather more accurate details.

- Psychographic factors
  - Cost effectiveness
  - Customer preferences
  - Product awareness
  - Quality preferences
- Product-specific factors
  - Strength of the product
  - Sustainability of the product
  - Construction time period
  - Maintenance cost
- Demographic factors
  - Educational level
  - Experience in years

- Number of projects handled
- Level of adoption for the concept

Under the affecting factors, Educational qualifications, Category of engagement in the field and Experience in years in the relevant category, Awareness and adoption level, Knowledge and awareness with the eco-friendly wall materials and the preference for the usage or introduce this concept to the Sri Lankan construction field were gathered. Further, data was collected on the past experience regarding the usage of EWM. Each sample's perception about the suitability of eco-wall materials for the Sri Lanka was found. Sample's knowledge about the materials in depth was also explored.

In the barriers that were identified relevant to implementing and popularity for the implementation, each sample's recommendations to overcome above issues as per individual opinions were collected.

3.1.4 Data collection by Questionnaire

Data collection by the questionnaire have focused to construction projects carried out by the Government sector of Sri Lanka. In Sri Lanka, huge number of government construction projects are carried out in the Colombo district area. Hence, data was collected from the Design Engineers, Construction Engineers and Architects who are engaged in the work in Colombo city area. Questionnaire was focused to gather their knowledge regarding eco-friendly wall construction projects and collected their issues to find out the actual reasons for the lack of demand for the usage. Samples taken for this research is indicated in Table 2.

Sample No.	**Area of Expertise**	**Experience/ (Years)**	**Designation**
1	Building & Bridges Structural Designs and Environmental Engineering	20	Design Engineer
2	Building Designs & Geo Specialist	21	Deputy Director (Eng.)
3	Construction Project Management & Structural Designs	20	Design Engineer
4	Buildings & Landscaping Designs	15	Project Architect
5	Town Planning, Buildings & Landscaping Designs	35	Chief Architect
6	Buildings & Landscaping Designs	21	Project Architect
7	Planning & Designing	22	Design Engineer

8	Construction Project Management	25	Director (Eng.)
9	Building Constructions	12	Construction Engineer
10	Buildings Designs	35	Senior Architect
11	Construction Project Management	20	Construction Engineer
12	Construction Project Management, Building Designs & Environmental Engineering	15	Construction Engineer
13	Building Designs	18	Design Engineer
14	Buildings & Landscaping Designs	12	Project Architect
15	Buildings Designs & City Planning	30	Project Architect
16	Buildings Designs	21	Project Architect
17	Environmental Engineering	10	Construction Engineer
18	Construction Project Management	23	Director (Eng.)
19	Construction Project Management	12	Construction Engineer
20	Landscaping Specialist	30	Planning Architect
21	Structural Building Designs	28	Design Engineer
22	Building Constructions & Project Management	25	Deputy Director (Eng.)
23	Structural Building Designs	21	Design Engineer
24	Building Constructions & Designs	16	Construction Engineer
25	Buildings & Landscaping Designs	16	Project Architect
26	Town Planning, Buildings Designs	14	Project Architect
27	Building Constructions & Project Management	20	Project Engineer
28	Project Planning	15	Design Engineer
29	Structural Designs and Construction Projects	15	Design Engineer
30	City Planning & Buildings	23	Deputy Director (Eng.)

Table 5- List of Interviewees

3.1.5 Data analysis

Collected data was analyzed by a standard data analysis process namely SPSS analysis. SPSS analytical tool is capable of analyzing Categorical variables of the qualitative analysis. Hence, this tool was used to analyze the data collected from the questionnaire.

3.1.6 Summary of research methodology

This chapter describes the research methodology breaking in to several steps. It includes steps, which was planned methodology to precede the research, data collected methods such as literature review, expert interviews, industrial survey and detail description about questionnaire, and method used for data analysis.

4.0 DATA ANALYSIS

Data analysis chapter describes procedure followed in analyzing collected data. It consists with respondent background, experience level and category of engagement, awareness and adoptability, past experience, suitability of the Eco-friendly wall materials and barriers to the implementation.

4.1 RESPONDENT BACKGROUND

Thirty numbers of responses were received for the questionnaire survey from Design Engineers, Construction Engineers and Project Architects, Project Managers and Construction Managers. Most of them are involved in Government construction projects in Sri Lankan construction industry.

4.2 EXPERIENCE LEVEL AND CATEGORY OF ENGAGEMENT

Collected data from all samples on number of experience in years and education qualifications were used as input parameters for the software analysis. Number of years of experience divided into three categories namely as over twenty years' experience, between fifteen to twenty years' experience and below fifteen years' experience. Collected sample's experience ranges percentages shown in the following Table 6.

Experience divided into ranges

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<=20yrs	18	60.0	60.0	60.0
	<15	5	16.7	16.7	76.7
	15<=19	7	23.3	23.3	100.0
	Total	30	100.0	100.0	

Table 6-Experience Levels

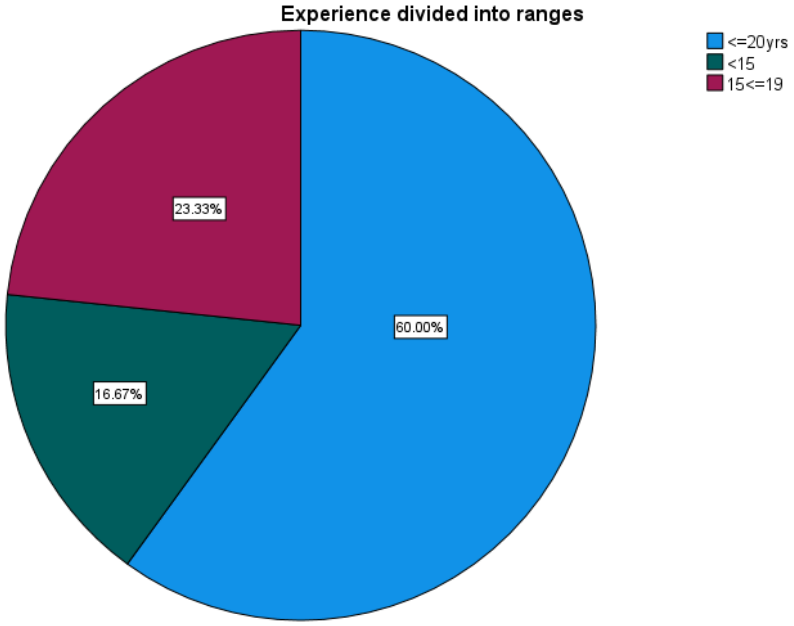

Figure 4-Experience shown with percentages

As per the above Figure 4, only 16.67% samples have below fifteen years' experience and remaining 83.33% have more than fifteen years' experience. Among those 83.33%, 60% samples have over twenty years' experience. Hence, it can be considered that the sample consists with well experience individuals.

Collected data on educational qualifications were used as an input parameter for data analysis. Collected samples consists with Architects, Design Engineers and Construction Engineers. In the Below Table 7 and Figure 5, the collected sample's category of engagement is shown.

Catagory of engagement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Archi	10	33.3	33.3	33.3
	Eng	20	66.7	66.7	100.0
	Total	30	100.0	100.0	

Table 7 - Category of engagement

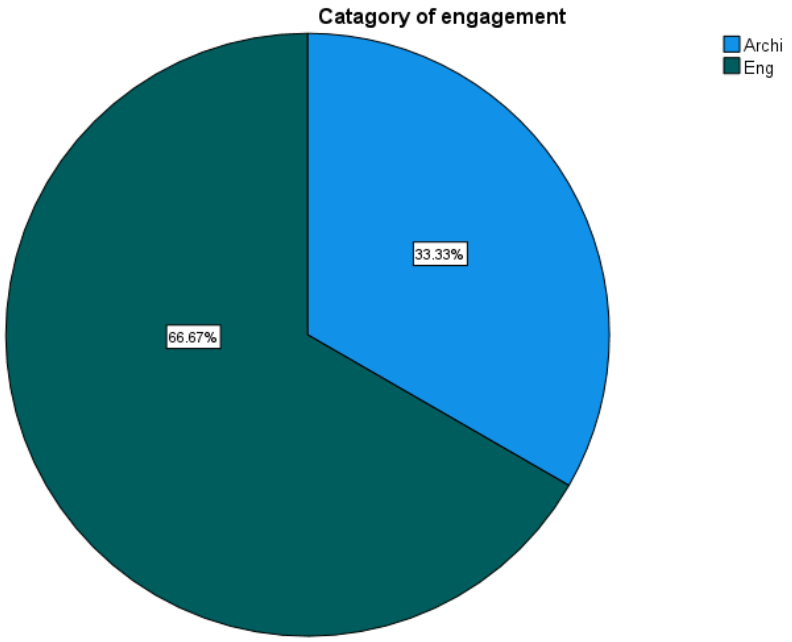

Figure 5-Category of Engagement with percentage

The collected samples were consists with 66.67% of Engineers and balance 33.33% consists with Architects. Hence it can be stated that majority of the sample consists with Engineers.

4.3 AWARENESS AND ADOPTABILITY

Data was collected on sample's awareness level about the eco-friendly wall materials and their level of encouragement to introduce the product to the construction field was collected by the questionaire. Collected data were analyzed by using the SPSS analysis and sample's awareness about the Eco-friendly wall materials and their encouragement to adoption for this new concept were shown in the following tables.

Awarness about eco wall materials

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	30	100.0	100.0	100.0

Table 8-Awareness about Eco-friendly Materials

As per the above Table 8, all the samples were aware about the Eco-friendly wall concept. However, it was required to identify the level of awareness of the samples. Therfore sample's levels of awareness were further divided into five levels. Those divided levels were as follows.

1 2 3 4 5	
1.Well Known	4. Little
2.Known	5.No
3. Middle	

Table 9 - Five category levels of awareness

Collected data on five-category level of awareness were used as an input parameter for data analysis. After the analysis, each sample's awareness level was clearly identified as follows.

Level of Awareness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	6	20.0	20.0	20.0
	2	15	50.0	50.0	70.0
	4	9	30.0	30.0	100.0
	Total	30	100.0	100.0	

Table 10 - Sample's Level of awareness

As per the Table 10, it can be identified that only 20% of the considered sample were well aware about the EWM and 30% of the considered sample have little knowledge about the eco-concept. Other 50% of the sample was aware about this concept and hence, it can be considered that samples poses a considerable level of knowledge about the Eco-friendly wall construction materials.

The considered samples preference for the adoptability is shown as follows.

Like to Adapt for ECo concept

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	30	100.0	100.0	100.0

Table 11 - Preference of adaption for Eco-Concept

As per the Table 11, all considered samples prefered to introduce EWM to the construction field. But as per the questionnire survey realized that most of samples were not confident and not much famillier about the eco-concept. Therefore it was required to identify the level of adoption of the samples clearly. Therfore sample's levels of adoption were further divided into five levels. Those divided levels were as follows.

1 2 3 4 5	
1.Highly Recommended	4. Not Aware
2.Recommended	5.No
3. Acceptable	

Table 12 - Categorization the Level of Adoption

The Table 12, shows the categories of level of adoption of each considered sample. The collected data from the questionniore survey were used as an input parameter of the data analysis. The results obtained from the analysis are given below.

Level of Like for Adaption

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	12	40.0	40.0	40.0
	3	15	50.0	50.0	90.0
	4	3	10.0	10.0	100.0
	Total	30	100.0	100.0	

Table 13- Level of preference to adopt

With reference to above two tables (Table 12 and Table 13), no any samples highly recommends this concept to the construction field. The 40% of considered samples have recommended introducing the product to the field and 50% of considered samples have accepted the eco-concept with apprehensively. In addition, other 10% samples are not aware about the concept and have no proper vision to use or propose the concept to the construction field.

Hence it can be summarized that the majority of the samples were aware about the EWM and agreed and willing to introduce the EWM concept to the construction field.

4.4 PAST EXPERIENCE WITH THE ECO-FRIENDLY WALL MATERIALS

The considered sample's past experience related to the EWM were collected in the questionniore survey and concurrently collected the total number of projects that each sample was handled in the last seven years. The number of projects that samples have used or proposed Eco-friendly bricks (CSEB) and Eco-friendly wall panels among the total projects handled were seperatly counted.

Past experience related to EWM of the samples was analyzed and summarized details are shown as follows.

Past Experience with Eco wall materials

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	18	60.0	60.0	60.0
	yes	12	40.0	40.0	100.0
	Total	30	100.0	100.0	

Table 14- Past Experiences with Eco-Products

As per the analyzed details presented in the Table 14, 60% of the considered samples does not have experience with EWM and only 40% of the considered samples have the past experience with EWM. Therefore it was required to identify the level of adoption of the samples clearly. However sample's levels of involvement were further divided into five levels. Those divided levels are as following Table 15.

1 2 3 4 5	
100% - 01	25% -04
75% - 02	0% -05
50% - 03	

Table 15 - Categorized Level of Involvement

Collected data from the questionnaire survey related to above levels of involvement and the analyzed data given in the Table 16 below.

Level of involvement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	3	10.0	10.0	10.0
	4	6	20.0	20.0	30.0
	5	21	70.0	70.0	100.0
	Total	30	100.0	100.0	

Table 16 - Level of Involvement

With reference to the Table 15 and Table 16, it was found that 70% of considered samples have zero percent of involvement with the eco-concept. It showed that majority of the considered samples does not poses active involvement with EWM construction projects. In addition, it was required to highlight that percentage value found with zero involvement in the Table 16 was not tally with the Table 14 summarized data percentage. That is because in Table 14, it showed that 60% of samples does not have past experience with the concept. Reason for the difference is identified in the analysis.

Although samples mentioned that they have past experience, the considered samples have not involved with required knowledge with the subject matter. Therefore in depth analysis found that Table 16 has given more accurate results compared to the Table 14. Further, Only 10% of samples have fifty percent of involvement with experience and 20% of samples have twenty five percent of involvement with past experience related to the EWM construction projects.

Total number of projects that the considered sample's handled in the past seven year's period was collected by the questionnaire survey. The collected data were used as input parameters to the SPSS analysis and the total projects handled in past seven years were divided in to three categories based on number of projects executed. Analyzed data as given in the below Table 17.

total Projects handled in last 7yrs ranges

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<=150	13	43.3	43.3	43.3
	<=50	2	6.7	6.7	50.0
	50<x<150	15	50.0	50.0	100.0
	Total	30	100.0	100.0	

Table 17 - Projects Handled in Last Seven years

As per the above table, it was found that 43.3% of the considered samples have completed more than 150 number of projects in the past seven years period and 50% of the considered samples have completed in between 50 to 150 number of projects. Number of projects handled less than fifty was only 6.7% as per the analysis.

Above analyzed data was presented in a graph below in order to have more clarity.

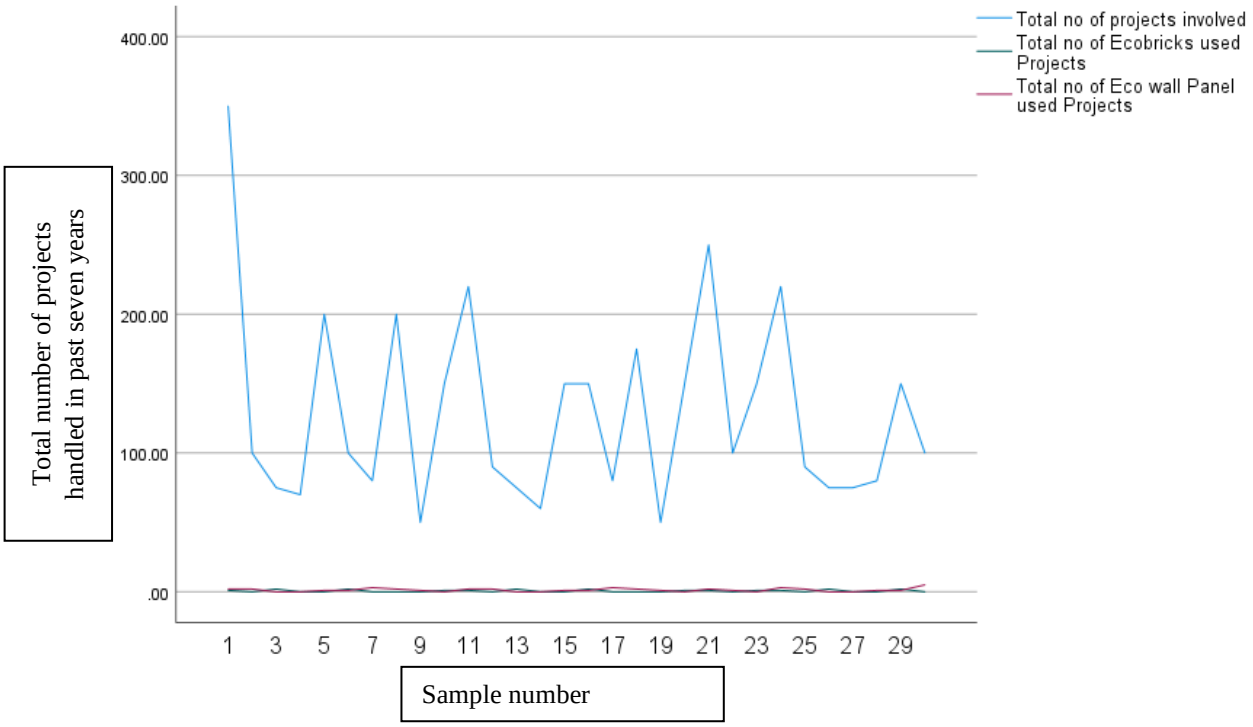

Figure 6 - Total Projects versus Eco-Friendly wall Material used Projects

As per the Figure 6 above, the total number of projects handled versus total number of EWM used number of projects in past seven years are separately shown. As per the Figure 6, it can be identified that majority of the samples have handled more than fifty number of projects in past seven years period. However, it was required to consider that they have significantly low number of projects with considering the handled total number of projects.

The analyzed data from the data analysis is given in the following tables separately.

Total no of Ecobricks used Projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	17	56.7	56.7	56.7
	1.00	7	23.3	23.3	80.0
	2.00	6	20.0	20.0	100.0
	Total	30	100.0	100.0	

Table 18 - Total CSEB used Projects

As per the results in the above Table 18, 56.7% of the considered samples have not used or proposed Eco-friendly wall bricks (CSEB) for their construction projects in past seven years. Balance percentage have proposed CSEB for their construction projects, but it was only for one or two projects from the total number of projects which they have handled.

Total no of Eco wall Panel used Projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	9	30.0	30.0	30.0
	1.00	9	30.0	30.0	60.0
	2.00	8	26.7	26.7	86.7
	3.00	3	10.0	10.0	96.7
	5.00	1	3.3	3.3	100.0
	Total	30	100.0	100.0	

Table 19 - Total Eco-wall Panel used Projects

As per the data in the Table 19, 30% of the considered samples have not used or proposed Eco-friendly wall panels for their construction projects in past seven years. Others have involved as per the analysis, but it was significantly little number of projects. Only one sample have handled five projects which is the maximum figure under this review. Nine samples have not handled any eco-friendly wall panel used projects.

As an example, sample number one is a Design Engineer with twenty years' experience and he has handled 350 numbers of projects in past seven years and eco-friendly wall materials have been used only for three numbers of projects. Sample number fifteen is an architect with thirty years' experience and she has handled 150 numbers of projects and have used eco-friendly wall materials only for one project.

Therefore, it elaborates that in Sri Lankan Government construction sector, although Engineers and Architects have initiated many numbers of building construction projects per year, most of them have not been encouraged to introduce eco-friendly wall materials for their projects. Hence, it was identified that Government sector officials were not encouraged to promote EWM for the construction projects in Sri Lanka.

4.5 SUITABILITY FOR SRI LANKAN INDUSTRY

Data were collected related to suitability of the EWM separately for the Eco-friendly wall bricks (CSEB) and Eco-friendly wall panels by the questionnaire survey. Since in the literature review and industrial survey / experts interviews have identified the most of the preferences for the both materials were highly differ with each other.

In this chapter, suitability was analyzed under several areas such as cost effectiveness, strength and sustainability, construction time period, maintenance cost and also preferences related to the esthetic appearance of the product.

Definitions of the above terms can be elaborated as follows.

Strength : The ability to withstand an applied load without failure or plastic deformation.

Sustainability: A systematic approach to using and reusing materials more productively over their entire life cycles.

Esthetic: Feeling or expressing overwhelming happiness or joyful excitement.

Esthetic appearance: Good and positive feeling about the material.

Construction time: The elapsed period from the commencement of site works to the completion time of building. It is usually specified prior to the commencement of construction (Nkado, 1995).

Maintenance cost: Costs incurred when performing routine actions to keep an asset in its original condition.

Cost effectiveness: Production of good results without costing a lot of money

Suitability: The quality of having the properties that are right for a specific purpose.

4.5.1 Suitability of Eco-friendly Bricks (CSEB)

In the questionnaire survey collected data on suitability of CSEB and used as an input parameter for the analysis. Suitability survey was conducted with collecting data related to strength of the product, sustainability of the product, esthetic appearance of the product, construction time period,

cost effectiveness, maintenance cost and also each samples recommendation related to most suitable application. Collected data samples were analyzed and results are shown in the following tables.

4.5.1.1 Strength of CSEB

Table No 20 shows considered sample's satisfaction about the CSEB. 86.7% of samples are satisfied about the strength of the block. 6.7% are not aware about the strength. Only balance 6.7% was not satisfied about the strength of the CSEB.

Strength of Eco Bricks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	good	26	86.7	86.7	86.7
	low	2	6.7	6.7	93.3
	notaware	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Table 20- Satisfaction about strength of CSEB

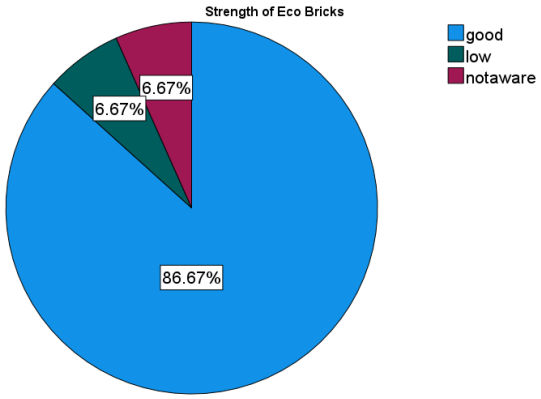

Figure 7- Percentages about satisfaction of Strength

4.5.1.2 Sustainability of CSEB

Collected data on sustainability of the product used as an input parameter to the analysis. In the following table (Table 21) summarize the results that were obtained from the analysis. Majority of the considered sample (86.7%) were satisfied about the sustainability of the product.

sustainability of Eco bricks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	good	26	86.7	86.7	86.7
	low	2	6.7	6.7	93.3
	notawae	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Table 21 - Satisfaction about Sustainability of CSEB

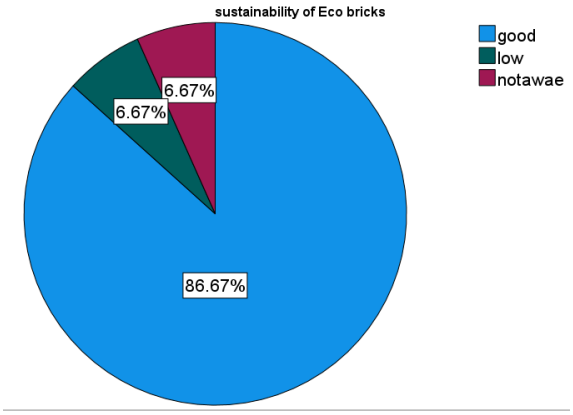

Figure 8- Percentages of satisfaction about Sustainability

4.5.1.3 Esthetic Appearance of CSEB

Data on esthetic appearance of the CSEB were collected by the survey and collected data were used as an input to the analysis. In the following table (Table 22) shows the results obtained from the analysis. The majority of the sample have recommended the esthetic appearance of the product and it was 93.3% from the total considered.

Easthatic Appearance of Eco Bricks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	good	28	93.3	93.3	93.3
	no	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Table 22 - Esthetic Appearance of CSEB

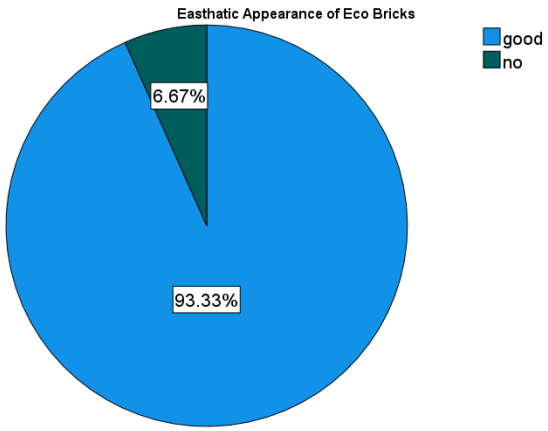

Figure 9- Percentages of Esthetic Appearance

4.5.1.4 Construction Time Period and Maintenance Cost of CSEB

Under the product- specific factors, data were collected on samples satisfaction regarding the product's construction time period and the maintenance cost.

Construction Time Period

Data were collected under the five category levels in the questionnaire survey. Hence, more accurate data was able to collect. The divided categories were as follows.

1. Highly effective
2. Effective
3. Same
4. Not effective
5. Not aware

Collected data on construction time period use as an input parameter to the analysis and results are presented in Table No 23.

Construction Time period of Eco Bricks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Effectiv	26	86.7	86.7	86.7
	HiglyEff	2	6.7	6.7	93.3
	notaware	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Table 23 - Construction Time Period of CSEB

As per Table 23, it is shown that most of the samples agreed that concept is a more effective concept. Majority of the sample mentioned that CSEB construction method have effective construction time period when comparing with the traditional wall construction method. This is 86.7 %. Only two samples were not familiar with the construction time period of CSEB and as per the collected data, that two samples belongs to architects.

Maintenance Cost

Data was collected under the five category levels in the questionnaire survey. Hence it was able to collect more accurate data related to maintenance cost of the product. The divided categories were as follows.

1. High
2. Little high
3. Same
4. Low
5. Not aware

Collected data on maintenance cost use as an input parameter to the analysis and results are presented in Table 24.

Maintenace Cost of Eco Bricks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	12	40.0	40.0	40.0
	low	9	30.0	30.0	70.0
	notaware	2	6.7	6.7	76.7
	same	7	23.3	23.3	100.0
	Total	30	100.0	100.0	

Table 24 - Maintenance Cost of CSEB

As per the Table 24, it is shown that majority of the sample has mentioned that maintenance cost of CSEB is high (40%) and same (23.3%) with comparing the traditional construction wall blocks. Only nine samples have mentioned that maintenance cost of CSEB is low. Hence, it can be considered that majority does not recommend the maintenance cost of the product.

4.5.1.5 Cost Effectiveness of CSEB

Under the psychographic factors, data was collected on samples satisfaction regarding the product's cost effectiveness.

Data was collected under the five category levels in the questionnaire survey. Hence, more accurate data was able to collect. The divided categories are as follows.

1. Highly (highly cost effective)
2. Yes (Cost effective)
3. Same
4. No (Not cost effective)
5. Not aware

Analyzed data are presented in the following Table 25.

Cost Effectiveness of Eco wall Bricks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Highly	11	36.7	36.7	36.7
	notaware	15	50.0	50.0	86.7
	same	4	13.3	13.3	100.0
	Total	30	100.0	100.0	

Table 25 - Cost effectiveness of CSEB

As per the results shown, 36.7% of considered samples have recommended CSEB as a highly cost effective product when comparing with the traditional construction wall blocks. But 50% of the considered samples are not aware about the cost of the product. It is the lack of awareness about the concept and is a major barrier to promote the product in the Government construction sector.

Table 24 and Table 25 shows samples' awareness on the cost effectiveness and maintenance cost of the CSEB product. When comparing with the maintenance cost, more samples are in the opinion that this material can be produced with high maintenance cost, even though initially it was identified as a cost effective concept.

The cost effectiveness of CSEB versus the years' experience range of the samples and total number of projects handled in past seven years are summarized in the following Table 26. As per the results

presented in the table, it can be identified that majority of who are not aware about the concept are those who are having significant experience in the field.

Case Summaries[a]

				ID	Experience divided into ranges	Total no of projects involved
Cost Effectiveness of Eco wall Bricks	Highly	1		1	<=20yrs	350.00
		2		7	<=20yrs	80.00
		3		8	<=20yrs	200.00
		4		11	<=20yrs	220.00
		5		17	<15	80.00
		6		18	<=20yrs	175.00
		7		21	<=20yrs	250.00
		8		22	<=20yrs	100.00
		9		25	15<=19	90.00
		10		28	15<=19	80.00
		11		29	15<=19	150.00
		Total	N	11	11	11
	notaware	1		2	<=20yrs	100.00
		2		3	<=20yrs	75.00
		3		4	15<=19	70.00
		4		9	<15	50.00
		5		10	<=20yrs	150.00
		6		12	15<=19	90.00
		7		13	15<=19	75.00
		8		14	<15	60.00
		9		19	<15	50.00
		10		20	<=20yrs	150.00
		11		23	<=20yrs	150.00
		12		24	15<=19	220.00
		13		26	<15	75.00
		14		27	<=20yrs	75.00
		15		30	<=20yrs	100.00
		Total	N	15	15	15
	same	1		5	<=20yrs	200.00
		2		6	<=20yrs	100.00
		3		15	<=20yrs	150.00
		4		16	<=20yrs	150.00
		Total	N	4	4	4
	Total	N		30	30	30

Table 26 - Summary of Cost Effectiveness with Experience and Total Projects

4.5.1.6 Most suitable type of application of CSEB

Under the psychographic factor, data were collected on sample's preferences regarding the suitability of the applications.

Data were collected under the five category levels in the questionnaire survey. Hence, more accurate data were able to collect. The divided categories are as follows.

1. Office buildings
2. Hotel buildings
3. Healthcare buildings
4. Residence
5. Playground pavilions

Collected data were analyzed by the SPSS analysis and results are as follows.

Eco Bricks Most Suitable for

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Hotels	11	36.7	36.7	36.7
	Office	2	6.7	6.7	43.3
	Residenc	17	56.7	56.7	100.0
	Total	30	100.0	100.0	

Table 27 - Most Suitable construction for CSEB

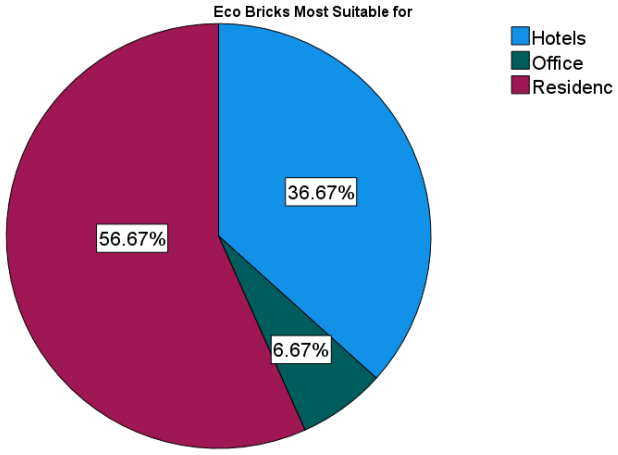

Figure 10- Suitability in Percentages

As per the data in Table 27, it can be elaborated that 56.7% of considered samples have recommended that CSEB are more suitable for residence construction projects and 36.7% samples have recommended for Hotel building projects.

Most of the Government sector top hierarchy officers have not considered this product as a suitable product for office buildings and public places, but was highly recommended for residence and hotel sector projects. By referring to Figure 10, a clear view of the outcome can be seen.

The most suitable application of CSEB versus the years' experience range of the samples and total number of projects handled in past seven years are summarized in the following Table 28. Number of CSEB used or proposed projects in the past also shown there. Hence it can be identified that

how many number of projects they have handled in the past seven years period and their level of encouragement to introduce Eco-friendly bricks to the government construction sector.

				ID	Experience divided into ranges	Total no of projects involved	Total no of Ecobricks used Projects
Eco Bricks Most Suitable for	Hotels	1		2	<=20yrs	100.00	.00
		2		5	<=20yrs	200.00	.00
		3		6	<=20yrs	100.00	2.00
		4		10	<=20yrs	150.00	1.00
		5		11	<=20yrs	220.00	1.00
		6		15	<=20yrs	150.00	.00
		7		16	<=20yrs	150.00	2.00
		8		17	<15	80.00	.00
		9		18	<=20yrs	175.00	.00
		10		24	15<=19	220.00	1.00
		11		25	15<=19	90.00	.00
		Total	N	11	11	11	11
	Office	1		3	<=20yrs	75.00	2.00
		2		20	<=20yrs	150.00	1.00
		Total	N	2	2	2	2
	Residenc	1		1	<=20yrs	350.00	1.00
		2		4	15<=19	70.00	.00
		3		7	<=20yrs	80.00	.00
		4		8	<=20yrs	200.00	.00
		5		9	<15	50.00	.00
		6		12	15<=19	90.00	.00
		7		13	15<=19	75.00	2.00
		8		14	<15	60.00	.00
		9		19	<15	50.00	.00
		10		21	<=20yrs	250.00	1.00
		11		22	<=20yrs	100.00	.00
		12		23	<=20yrs	150.00	1.00
		13		26	<15	75.00	2.00
		14		27	<=20yrs	75.00	.00
		15		28	15<=19	80.00	.00
		16		29	15<=19	150.00	2.00
		17		30	<=20yrs	100.00	.00
		Total	N	17	17	17	17
	Total	N		30	30	30	30

Table 28 - Summary of CSEB Suitability

4.5.1.7 Summary of CSEB

With reference to the all above results, most of the considered samples are highly satisfied with the strength, sustainability, appearance and about the construction time period of the product. But when considering about the cost, most of the samples are not much aware. It can be identified that majority have less awareness of the product and still they have no motivation to adopt the new technology.

Table 29 presents the analyzed data from the SPSS analysis and in the Table 30 quantified the summarized data to gain the clear meaning of the results.

Case Summaries[a]

	Experience divided into ranges	Catagory of engagement	Cost Effectiveness of Eco wall Bricks	Strength of Eco Bricks	sustainability of Eco bricks	Easthatic Appearance of Eco Bricks	Construction Time period of Eco Bricks	Maintenace Cost of Eco Bricks	Eco Bricks Most Suitable for
1	<=20yrs	Eng	Highly	good	good	good	Effectiv	same	Residenc
2	<=20yrs	Eng	notaware	good	good	good	Effectiv	low	Hotels
3	<=20yrs	Eng	notaware	good	good	good	Effectiv	High	Office
4	15<=19	Archi	notaware	notaware	notawae	good	notaware	notaware	Residenc
5	<=20yrs	Archi	same	low	low	good	Effectiv	low	Hotels
6	<=20yrs	Archi	same	good	good	no	HiglyEff	High	Hotels
7	<=20yrs	Eng	Highly	good	good	good	Effectiv	same	Residenc
8	<=20yrs	Eng	Highly	good	good	good	Effectiv	same	Residenc
9	<15	Eng	notaware	good	good	good	Effectiv	low	Residenc
10	<=20yrs	Archi	notaware	good	good	good	Effectiv	low	Hotels
11	<=20yrs	Eng	Highly	good	good	good	Effectiv	High	Hotels
12	15<=19	Eng	notaware	good	good	good	Effectiv	low	Residenc
13	15<=19	Eng	notaware	good	good	good	Effectiv	High	Residenc
14	<15	Archi	notaware	notaware	notawae	good	notaware	notaware	Residenc
15	<=20yrs	Archi	same	low	low	good	Effectiv	High	Hotels
16	<=20yrs	Archi	same	good	good	no	HiglyEff	High	Hotels
17	<15	Eng	Highly	good	good	good	Effectiv	High	Hotels
18	<=20yrs	Eng	Highly	good	good	good	Effectiv	High	Hotels
19	<15	Eng	notaware	good	good	good	Effectiv	low	Residenc
20	<=20yrs	Archi	notaware	good	good	good	Effectiv	low	Office
21	<=20yrs	Eng	Highly	good	good	good	Effectiv	High	Residenc
22	<=20yrs	Eng	Highly	good	good	good	Effectiv	same	Residenc
23	<=20yrs	Eng	notaware	good	good	good	Effectiv	low	Residenc
24	15<=19	Eng	notaware	good	good	good	Effectiv	High	Hotels
25	15<=19	Archi	Highly	good	good	good	Effectiv	same	Hotels
26	<15	Archi	notaware	good	good	good	Effectiv	High	Residenc
27	<=20yrs	Eng	notaware	good	good	good	Effectiv	High	Residenc
28	15<=19	Eng	Highly	good	good	good	Effectiv	same	Residenc
29	15<=19	Eng	Highly	good	good	good	Effectiv	same	Residenc
30	<=20yrs	Eng	notaware	good	good	good	Effectiv	low	Residenc
Total N	30	30	30	30	30	30	30	30	30

Table 29 - Summary Table of Sample survey of CSEB

ANALIZED SUMMARY FOR ECO-FRIENDLY WALL BRICKS

Sample Categories: Architects, Design Engineers, Construction Engineers

Experience Leve	x<=20	60.00%
	15<x<20	16.70%
	x<=15	23.30%

TYPE OF ECO-FRIENDLY WALL MATERIAL	STRENGTH		SUSTAINABILITY		ESTHETIC APEARANCE		CONSTRUCTION TIME PERIOD		MAINTENANCE COST		COST EFFECTIVENESS		MOST SUITABLE	
Eco-Friendly Wall Bricks	Accepted	86.70%	Accepted	86.70%	Accepted	93.30%	Effective	93.30%	High & Same	63.30%	Highly Effective	36.70%	Residence	56.70%
											Not aware	50.00%	Hotels	36.70%

Table 30 - Summarized findings of CSEB

All considered samples have high experience and have highly involved in the building construction projects in Sri Lanka. As per the above summarized results, it can be identified that majority of the samples are satisfied about the strength, sustainability, esthetic appearance and construction time period of the CSEB. However, majority are not satisfied with the maintenance cost of the product. When considering about the cost effectiveness, 50% of the considered sample are not aware about the cost of the product. 36.7% samples have recommended the product as a cost effective product when comparing with the traditional wall products. The majority of the considered sample has recommended the CSEB for residence construction and hotel construction projects.

4.5. 2 Suitability of Eco-Friendly Wall Panels (EFWP)

The questionnaire survey collected data on suitability of EFWP and used as an input parameter for the analysis. Suitability survey was conducted with collecting data related to strength of the product, sustainability of the product, esthetic appearance of the product, construction time period, cost effectiveness, maintenance cost and also each sample's recommendation related to most suitable construction applications. With reference to the collected data samples, analysis was performed. Results are shown in the following tables.

4.5.2.1 Strength of EFWP

Table 31 shows considered samples analyzed results about the EFWP. 83.3% of the considered samples are satisfied about the strength of the product and balance 16.7% are not aware about the strength of the eco-product.

Strength of Eco Wall Panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	good	25	83.3	83.3	83.3
	notaware	5	16.7	16.7	100.0
	Total	30	100.0	100.0	

Table 31 - Satisfaction about Strength of Eco-Friendly Wall Panel

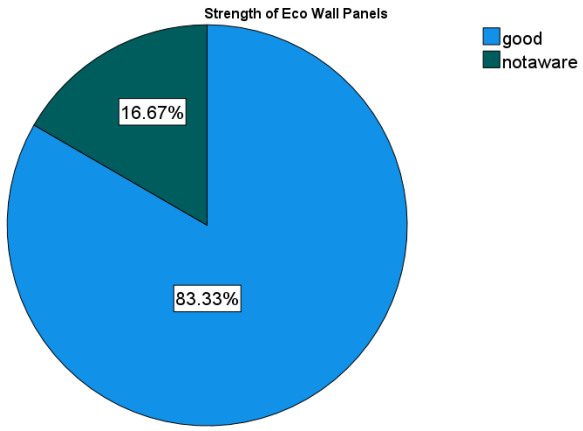

Figure 11- Strength in Percentages

4.5.2.2 Sustainability of EFWP

Collected data on sustainability of the product used as an input parameter for the analysis. The following table (Table 32) summarizes the results obtained from the analysis. Majority of the considered sample (83.3%) are satisfied about the sustainability of the EFWP product.

sustainability of Eco Wall Panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	good	25	83.3	83.3	83.3
	notaware	5	16.7	16.7	100.0
	Total	30	100.0	100.0	

Table 32 - Satisfaction about the Sustainability of Eco-Friendly Wall Panels

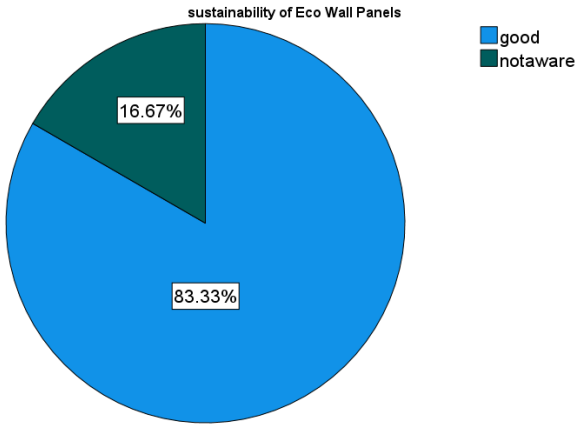

Figure 12- Sustainability with Percentages

With reference to the collected data, it is shown that most of the samples have highly accepted the strength and sustainability of the eco-friendly wall panels.

4.5.2.3 Esthetic Appearance of EFWP

The questionnaire survey collected the data on esthetic appearance of the EFWP and used as input parameters to the analysis. Following table (Table 33) shows the results obtained from the analysis. The majority of the samples has recommended the esthetic appearance of the product and it was 86.7% from the total considered.

Easthatic Appearance of Eco Wall Panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	best	12	40.0	40.0	40.0
	good	2	6.7	6.7	46.7
	like	12	40.0	40.0	86.7
	No	2	6.7	6.7	93.3
	notaware	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Table 33 - Satisfaction about the Esthetic Appearance

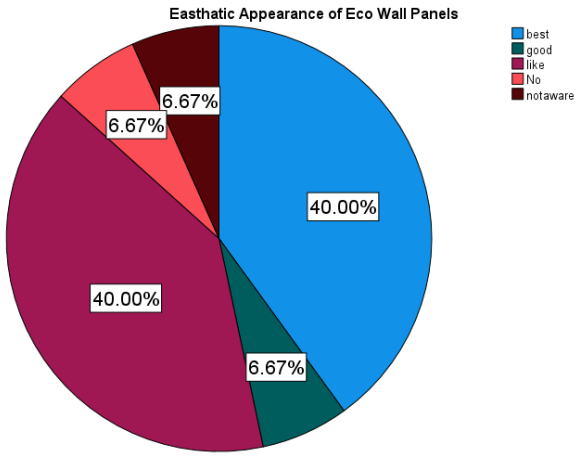

Figure 13- Esthetic Appearance with Percentages

4.5.2.4 Construction Time Period and Maintenance Cost of EFWP

Data was collected on the construction time period and maintenance cost for this eco-product with comparison to the traditional materials as per the awareness of the samples. In the questionnaire survey, under the product- specific factors, data was collected on samples satisfaction regarding the product's construction time period and the maintenance cost.

Construction Time Period

Data were collected under the five category levels in the questionnaire survey. Hence, more accurate data was able to collect. The divided categories are as follows.

1. Highly effective
2. Effective
3. Same
4. Not effective
5. Not aware

Collected data on construction time period is given in Table 34.

Construction Time period of Eco Wall Panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Effectiv	22	73.3	73.3	73.3
	low	4	13.3	13.3	86.7
	notaware	4	13.3	13.3	100.0
	Total	30	100.0	100.0	

Table 34 - Construction Time Period of Eco-Friendly Wall Panels

As per the Table 34, it is evident that most of the samples have agreed that this concept is a more effective concept. Majority of the samples have mentioned that EFWP product have effective construction time period when compared to the traditional wall construction products. This is 73.3%. Only four samples were not familiar with the construction time period of EFWP.

Maintenance Cost

Data were collected under the five category levels in the questionnaire survey. The divided categories were as follows.

1. High
2. Little high
3. Normal (Same)
4. Low
5. Not aware

Collected data on maintenance cost of wall materials are given in Table 35.

Maintenace Cost of Eco Wall Panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	4	13.3	13.3	13.3
	low	10	33.3	33.3	46.7
	normal	12	40.0	40.0	86.7
	notaware	4	13.3	13.3	100.0
	Total	30	100.0	100.0	

Table 35 - Maintenance cost of Eco-Friendly Wall Panels

As per the Table 35, it is evident that majority of the samples have mentioned that maintenance cost of EFWP have normal (40%) and low (33.3%) with comparing the traditional construction wall panels. Only four samples have mentioned that maintenance cost of EFWP is high. Hence, it can be considered that majority have recommended the maintenance cost of the product more suitable for the construction projects.

4.5.2.5 Cost Effectiveness of EFWP

In the questionnaire survey under the psychographic factors, data was collected on samples satisfaction regarding the product's cost effectiveness.

Data were collected under the five category levels in the questionnaire survey. The divided categories were as follows.

1. Highly (highly cost effective)
2. Yes (Cost effective)
3. Same
4. No (Not cost effective)
5. Not aware

Analyzed data were presented in the following Table 36.

Cost Effectiveness of Eco wall Panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	16	53.3	53.3	53.3
	notaware	5	16.7	16.7	70.0
	same	6	20.0	20.0	90.0
	yes	3	10.0	10.0	100.0
	Total	30	100.0	100.0	

Table 36 - Cost effectiveness of Eco-Friendly Wall Panels

As per the results shown, 53.3% of considered samples have not recommended EFWP as a cost effective product when comparing with the traditional wall panels. In addition, 16.7% of the considered samples are not aware about the cost of the product. It is the lack of awareness about the concept and it is a major barrier to promote the product. The 20% of samples have expressed that there is no cost difference when comparing with the traditional wall panels such as aluminum partitions, glass partitions etc.

The Table 35 and Table 36 shows that samples' awareness with the cost effectiveness and maintenance cost of the EFWP product. When considering about the maintenance cost, majority are in the view that this product is not much different comparing to the traditional products.

The cost effectiveness of EFWP versus the years' experience range of the samples and total number of projects handled in past seven years were summarized in the following Table 37. As per the

results presented in the table, it was identified that majority of samples have mentioned that EFWP is a high cost product.

Case Summaries[a]

				Experience divided into ranges	Total no of projects involved
Cost Effectiveness of Eco wall Panels	no	1		<=20yrs	350.00
		2		<=20yrs	100.00
		3		<=20yrs	200.00
		4		<=20yrs	100.00
		5		<15	50.00
		6		<=20yrs	150.00
		7		<=20yrs	220.00
		8		15<=19	90.00
		9		<=20yrs	175.00
		10		<15	50.00
		11		<=20yrs	150.00
		12		<=20yrs	250.00
		13		<=20yrs	150.00
		14		15<=19	220.00
		15		<15	75.00
		16		<=20yrs	100.00
		Total	N	16	16
	notaware	1		<=20yrs	75.00
		2		15<=19	70.00
		3		15<=19	75.00
		4		<15	60.00
		5		<=20yrs	75.00
		Total	N	5	5
	same	1		<=20yrs	80.00
		2		<=20yrs	150.00
		3		<=20yrs	150.00
		4		<=20yrs	100.00
		5		15<=19	80.00
		6		15<=19	150.00
		Total	N	6	6
	yes	1		<=20yrs	200.00
		2		<15	80.00
		3		15<=19	90.00
		Total	N	3	3
	Total	N		30	30

a. Limited to first 100 cases.

Table 37 - Eco-Friendly Wall Panels with Experience and Total Projects

4.5.2.6 Most suitable type of application of EFWP

Under the psychographic factor, data were collected on samples preferences regarding most suitable type of application of the product.

Data was collected under the five category levels in the questionnaire survey. The divided categories were as follows.

1. Office buildings
2. Hotel buildings
3. Healthcare buildings
4. Residence
5. Playground pavilions

Collected data were analyzed by the SPSS analysis and results are as follows.

Eco Wall Panels Most Suitable for

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hotels	8	26.7	26.7	26.7
	office	22	73.3	73.3	100.0
	Total	30	100.0	100.0	

Table 38- Suitability of Eco-Friendly Wall Panels

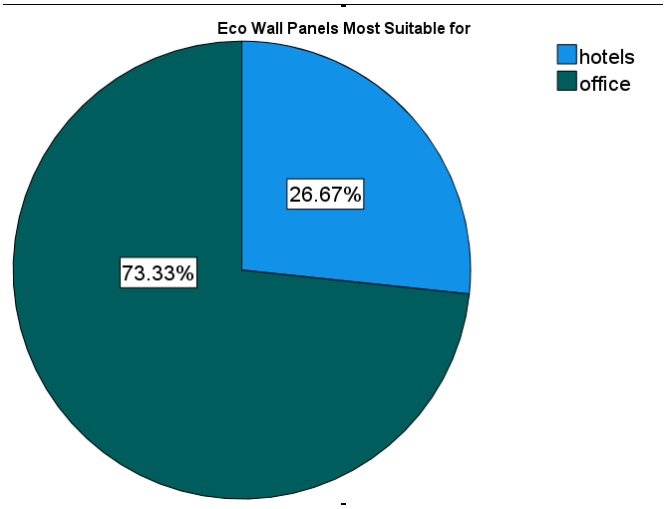

Figure 14- Suitability with Percentages

It was identified that the 73.33% of considered samples are in the view that EFWP is more suitable for office building construction and 26.67% are in the view that it is suitable for Hotel buildings.

Most of the government sector top hierarchy officers have not considered this concept as suitable for residence buildings and exterior places. But have highly recommended for office and hotel building construction projects.

All data collected samples were highly experienced and have highly involved for the building construction projects in Sri Lanka.

4.5.2.7 Summary of EFWP

With reference to the above results, most of the considered samples are highly satisfied with the strength, sustainability, esthetic appearance, construction time period of the product and also about the maintenance cost. However, when concerning the cost, majority of the samples have not recommended the cost product.

Table 39 presents the analyzed data from the SPSS analysis and in the Table 40 quantify the summarized data to gain a clear meaning of the results.

Case Summaries

	Catagory of engagement	Experience divided into ranges	Cost Effectiveness of Eco wall Panels	Strength of Eco Wall Panels	sustainability of Eco Wall Panels	Easthatic Appearance of Eco Wall Panels	Construction Time period of Eco Wall Panels	Maintenace Cost of Eco Wall Panels	Eco Wall Panels Most Suitable for
1	Eng	<=20yrs	no	good	good	best	Effectiv	normal	office
2	Eng	<=20yrs	no	good	good	like	Effectiv	low	office
3	Eng	<=20yrs	notaware	notaware	notaware	notaware	notaware	notaware	office
4	Archi	15<=19	notaware	notaware	notaware	like	notaware	notaware	hotels
5	Archi	<=20yrs	no	good	good	good	Effectiv	High	office
6	Archi	<=20yrs	no	good	good	No	Effectiv	High	office
7	Eng	<=20yrs	same	good	good	best	Effectiv	normal	office
8	Eng	<=20yrs	yes	good	good	best	Effectiv	normal	office
9	Eng	<15	no	good	good	like	Effectiv	low	hotels
10	Archi	<=20yrs	no	good	good	like	Effectiv	low	hotels
11	Eng	<=20yrs	no	good	good	best	low	normal	office
12	Eng	15<=19	no	good	good	like	Effectiv	low	office
13	Eng	15<=19	notaware	notaware	notaware	notaware	notaware	notaware	office
14	Archi	<15	notaware	notaware	notaware	like	notaware	notaware	hotels
15	Archi	<=20yrs	same	good	good	good	Effectiv	High	office
16	Archi	<=20yrs	same	good	good	No	Effectiv	High	office
17	Eng	<15	yes	good	good	best	low	normal	office
18	Eng	<=20yrs	no	good	good	best	Effectiv	normal	office
19	Eng	<15	no	good	good	like	Effectiv	low	office
20	Archi	<=20yrs	no	good	good	like	Effectiv	low	office
21	Eng	<=20yrs	no	good	good	best	Effectiv	normal	office
22	Eng	<=20yrs	same	good	good	best	Effectiv	normal	office
23	Eng	<=20yrs	no	good	good	like	low	low	hotels
24	Eng	15<=19	no	good	good	like	low	low	hotels
25	Archi	15<=19	yes	good	good	best	Effectiv	normal	office
26	Archi	<15	no	good	good	best	Effectiv	normal	office
27	Eng	<=20yrs	notaware	notaware	notaware	best	Effectiv	normal	office
28	Eng	15<=19	same	good	good	like	Effectiv	low	hotels
29	Eng	15<=19	same	good	good	like	Effectiv	low	hotels
30	Eng	<=20yrs	no	good	good	best	Effectiv	normal	office
Total N	30	30	30	30	30	30	30	30	30

Table 39 - Analyzed data of Eco-Friendly Wall Panels

ANALIZED SUMMARY FOR ECO-FRIENDLY WALL PANELS

Sample Categories: Architects, Design Engineers, Construction Engineers

Experience Leve	x<=20	60.00%
	15<x<20	16.70%
	x<=15	23.30%

TYPE OF ECO-FRIENDLY WALL MATERIAL	STRENGTH		SUSTAINABILITY		ESTHETIC APEARANCE		CONSTRUCTION TIME PERIOD		MAINTENANCE COST		COST EFFECTIVENESS		MOST SUITABLE	
Eco-Friendly Wall Panels	Accepted	83.30%	Accepted	83.30%	Accepted	86.70%	Effective	93.30%	Nomal	40.00%	Not Effective	53.30%	Office	73.30%
									Low	33.30%	same	20.00%		

Table 40 - Summarized analyzed details

As per the above summarized results, it can be identified that majority of the samples satisfied about the strength, sustainability, esthetic appearance and construction time period of the EFWP. However, majority are not satisfied with the cost of the product. When considering about the cost effectiveness, 53.3% of the considered sample have identified the product as a high cost product. 20% of the samples have expressed that the product cost is not much different when comparing with the traditional wall panel products. The majority of the considered sample have recommended the EFWP for office construction projects.

4.6 BARRIERS FOR THE IMPLEMENTATION

Barriers for the implementing eco-friendly wall concepts were identified with two categories as organization based barriers and exterior barriers. Organization based barriers are those occurring due to policies, procedures, guidelines and perception. External barriers are those occurring due to government policies, regulations and standards.

4.6.1 Organization based Barriers

The practical implementation of the change process is highly difficult in the government sector. Based on the barriers identified from the questionnaire survey, three critical areas can be identified as organization based barriers.

1. Resistance to change

Most of the samples have informed that it is very difficult to transform for the new technology in the government sector, because this concept is not much familiar to them, any one not accepting to face the new risk.

Sample number fifteen mentioned that there are enough audit quarries for them. Therefore, they cannot introduce new technologies and make it another issue.

More are fear to attempt for the new concept, as Government sector procedures are based on the works with the approved standard materials and methods.

Sample number two mentioned that it is preferred to propose EWM for the construction projects, but do not have enough time to conduct a feasibility study or for innovations. Further, it was mentioned that if architects includes the concept in their designs, they could precede it without any issue.

Sample number fifteen mentioned that they are not aware about the strength and sustainability of the product. Therefore, Engineers need to introduce this concept to the field.

2. Top management style

Most of samples have highlighted the top management barriers. Because as mentioned in the previous case, officers of the government sector are normally attempting to the work with the traditional concepts and standard methods which was mentioned in the standard documents. Therefore top management officers are not accepting to approve new concept without provable details.

3. Scarcity of material and skilled labour

Most of the government sector authorities have not registered eco-friendly wall material suppliers and skill contractors as their standard suppliers. Hence, even though Engineers and Architects proposed eco-friendly wall materials for the construction, there is a doubt whether the outcome will be as expected.

Therefore, it is of interest to understand why above challenges seem to be more problematic in the government sector construction projects.

4.6.2 External Barriers

Based on the barriers identified from the questionnaire survey, three critical areas can be identified as external barriers.

1. Products freely not available in the market

This is especially aims the eco-friendly wall bricks. When comparing with the cement blocks and traditional clay bricks, this eco-brick is not freely available in the market. Hence, customers have to face difficulties to get the supply as per the demand.

2. Clients are not familiar with the new technology

Most of the clients does not agree to adopt new technology. This is because eco-construction works are not familiar to them and they fear to take risk on investments. Most of them are concerned about following.

a. Fire and security issues
b. Less awareness
c. Less of knowledge
d. Insects and spider webs attacks
e. Request colour variants
f. Highly believing that not suitable for exterior walls

3. High maintenance cost

With reference to the external appearance of the eco-friendly brick, concerns regarding the high maintenance cost were raised. Surfaces with groves and with cavities that cause to retain dust and helps to grow fungus and moss. Regular maintenance are needed to be done for the exterior walls. Hence, most believes this concept is not suitable for tropical countries like Sri Lanka.

4.7 RECOMMENDATIONS MADE BY QUESTIONAIRE SAMPLES

Thirty numbers were responded for the questionnaire survey from consists of Engineers and Architects, including project managers and construction managers. Most of them are involved in top tier projects in Sri Lankan Government construction sector. They have given their recommendations to overcome above mentioned barriers and those collected data are summarized as follows.

1. Majority has mentioned that government sector officers are less aware about the EWM and therefore it is necessary to arrange more awareness programs among government officers.
2. Need to promote the products among the stakeholders to create a demand.
3. Preferences to locally manufactured products can help to promote the product
4. Majority recommended CSEB and EFWP are most suitable for interior walls, for external applications the product quality needs improvement
5. Majority highlighted that improvement of CSEB with the pleasing esthetic appearance with different colours may improve customers attraction and suit to any kind of construction in the market.
6. Maintenance cost can be Improved with more smooth external surface finishes and reducing gaps.
7. Majority recommended that EFWP are more suitable for office construction projects and suggest to produce and supply low cost and high-quality products to the market.

As per the Collected details from the industrial survey and expert interviews, it is highlighted that some of the government authorities are trying to introduced eco-friendly materials to the industry and encourage the stakeholders. In Construction industry development authority, it is planned to publish green material guideline book for the reference of the government sector construction projects and still it is pending. And in urban development authority, it has started to issue Green Building certificate for building approvals while providing additional marks for green label available materials. This encourages use of eco-friendly materials in government sector construction projects.

5.0 CONCLUSION

5.1 RECOMMENDATION

Based on the above analysis, following recommendations are made.

1. Eco-friendly wall bricks (CSEB) are more suitable for hotel and residence construction projects. Using CSEB is low in initial cost but have a higher maintenance cost. Hence following are recommended;
    a. Improve more types of blocks with a pleasing esthetic appearance with different colour variants to suit for any kind of construction in the Sri Lankan market.
    b. Improve blocks with more smooth external surface finishes, by reducing gaps between two blocks that can help to reduce the maintenance cost of the block.

2. Most of recommended Eco-friendly wall panels (EFWP) are more suitable for office construction but not cost effective. Therefore, it is required to find a method to produce and supply low cost, high quality products to the market.

5.2 CONCLUSION

This research was initiated with the objectives of ;

1. Analyze the factors that contribute to lack of demand for Eco-Friendly Wall Materials (EWM) in Government construction sector Sri Lanka.
2. Recommend Strategies to overcome.

Hence, factors that contribute to lack of demand for Eco-Friendly Wall Materials (EWM) were identified as psychographic, product specific, demographic, and most critical barriers to implementation the Eco-friendly wall materials in the Government construction sector in Sri Lanka were found and elaborated in this thesis.

Following strategies are recommended to increase and promote the EWM products among the Sri Lankans.

1. It is more important to note that in Sri Lanka, eco-friendly wall materials are being produced and utilized in a minor scale and most of the Sri Lankans are not familiar about the eco-friendly wall material concept. Hence, it is required to conduct effective awareness campaigns to promote the products.

2. This can be initiated from the Government sector organizations. It is required to establish a standardized mechanism with collaboration of eco-friendly wall material producers and the government agencies to promote and establish the use of eco-friendly wall materials in Government construction sector in Sri Lanka.
3. Government to provide incentive schemes to manufactures to increase the eco-friendly wall materials production. This may include but not limited to tax concessions, loan schemes etc to purchase high tech machinery.

This study mainly focused on Sri Lankan Government building construction industry at present due to the accessibility of information and reachability to professionals in the industry and future research could focus on private sector. The findings of this research give on ways to motivate Sri Lankans to use environmental friendly concepts.

REFERENCES

1. Yoona,K.B., Ryua,H.M., Leea,G.H., Gopalanb,A.I., Sai-anandc,G. and Leed,D. (2021). Enhanced compressive strength of rammed earth walls stabilized with eco-friendly multi-functional polymeric system: *Science direct*, 152(2021). https://www.sciencedirect.com/science/article/abs/pii/S1364032121009552

2. Zhang, X., and Biswas, K.W. (2021). Development of eco-efficient bricks – A life cycle assessment approach: *Journal of Building Engineering*, 42(2021).

3. PilarRodríguez-Garcíaa, M.D., FernandaGalindo-Manriqueb, A., AimerCortez-Alejandroa, K., BereniceMéndez-Sáenzc, A. (2021). Eco-efficiency and financial performance in Latin American countries: An environmental intensity approach: *Research in International Business and Finance*. 59 (2022). https://www.sciencedirect.com/science/article/pii/S0275531921001689

4. Matsumoto, K., and Chen, Y. (2021). Industrial eco-efficiency and its determinants in China: A two-stage approach. *Ecological Indicators journal*. www.elsevier.com/locate/ecolind

5. Nawarathna, A., Alwan, Z., Gledson, B. and Fernando, N. (2021). Embodied carbon in commercial office buildings: Lessons learned from Sri Lanka. *Journal of Building Engineering journal*, 42(2021). http://www.elsevier.com/locate/jobe

6. Kumanayake, R., Hanbin Luo, H. and Paulusz, N. (2018). Assessment of material related embodied carbon of an office building in Sri Lanka. *Energy & Buildings journal*, 166(2018), pp.250-257. www.elsevier.com/locate/enbuild

7. Raut, A.N. and Gomez, C.P. (2016). Development of thermally efficient fibre-based eco-friendly brick reusing locally available waste materials. Original Research Article; *Construction and Building Material*, 133(2017), pp.275-284.

8. Coletti, C., Cultrone, G., Maritan, L. and Mozzoli, C. (2015). How to face the new industrial challenge of compatible, sustainable brick production: Study of various types of commercially available bricks. *Article in press. Applied clay science*, p.8.

9. Rahmat, M.N., Ismail, N. and Kinuthia, J.M. (2016). Strength and environmental evaluation of stabilized Clay-PFA eco-friendly bricks. Original Research Article; *Construction and Building Material*, 125(2016), pp.964-973.

10. Cornelissen, H.A.W. (1997). Upgrading and quality improvement of PFA, in: S.Gourmans, Waste Materials in Construction. PuttingTheory in Practice, *Elservier,Amsterdam*, 1997, pp. 289–300.

11. Crawley, D. and Aho, I. (1999). Building environmental assessment methods: application and development trends. *Build. Res. Inf.* 27 (4/5) (1999), pp. 300–308.

12. Cultrone, G. and Sebastian, E. (2008). Fly ash addition in clayey materials to improve the quality of solid bricks. *Construction Building Materials*, (2008). http://dx.doi.org/10.1016/conbuildmat.2008.07.001.

13. Weerasinghe, A.S., Ramachandra, T. and Rotimi, J.O.B. (2021). Comparative life-cycle cost (LCC) study of green and traditional industrial buildings in Sri Lanka. *Energy & Buildings journal*, 234 (2021). https://www.sciencedirect.com/science/article/abs/pii/S0378778821000165

14. De Silva, S., De Silva, G.H.M.J.S. and Padmal, H.M.S.S. (2018). Assessment Method for Seismic Vulnerability of Old Masonry Buildings in Sri Lanka. *Science Direct*, 212(2018), pp.61-68. https://reader.elsevier.com/reader/sd/pii/S1877705818300183?token=87160AFCB84308937473BE88372219F6486F5EE10790BC619A55ACDBE2A0F3C756FDB170A0700DEA77DC4B2AE6331EFC&originRegion=eu-west-1&originCreation=20211030132004

15. Rajapaksha, I. (2017). Effect of spatial ambience on thermal adaptation in tropics: Case of free-running shared spaces in coastal hotels of Sri Lanka. *Science Direct*, 180 (2017), pp.975-985. https://reader.elsevier.com/reader/sd/pii/S1877705817317642?token=6D5F31D7AFA2C801973AF2AE0C76E53D14CDF9A259B1A419B3B1BF80293F440A09444A318385B748741B879CE66773A9&originRegion=eu-west-1&originCreation=20211030135910

16. Udawattha, C. and Halwatura, R. (2017). Life cycle cost of different Walling material used for affordable housing in tropics. *Case studies in Construction Materials*, 7 (2017), pp.15-29.www.elservier.com/locate/cscm https://reader.elsevier.com/reader/sd/pii/S2214509516300997?token=84A74E606036E1F

AE86585A3859A8BC5533435367D81771ADD3F49B87A1002689DD81B1DA03AA0196A897E588DDBC87D&originRegion=eu-west-1&originCreation=20211030140121

17. Gunarathnea, N., Wijayasundara, M., Senaratne, S., Kanchana, P.D.K. and Cooray, T. (2021). Uncovering corporate disclosure for a circular economy: An analysis of sustainability and integrated reporting by Sri Lankan companies. *Sustainable Production and Consumption*, 27(2021), pp.787-801. https://reader.elsevier.com/reader/sd/pii/S2352550921000415?token=F5B96B1AAB43DC22590C883FE01977419E5CB53D2D84E204DF1F30F8510496F3401C358204B6E906F9DE560B2903FF43&originRegion=eu-west-1&originCreation=20211031122602

18. Emmanuel, R. (2004). Estimating the environmental suitability of wall materials: preliminary results from Sri Lanka. *Building and Environment*, 39 (2004), pp.1253 – 1261. https://www.sciencedirect.com/science/article/abs/pii/S0360132304000836

19. De Silva, G.H.M.J.S. and Hansamali, E. (2019). Eco-friendly fired clay bricks incorporated with porcelain ceramic sludge. *Construction and Building Materials*, 228 (2019), pp.116754. https://www.sciencedirect.com/science/article/abs/pii/S0950061819321725

20. Martins, R., DoCarmo, R., Costa, H. and Júlio, E. (2021). Load bearing capacity of connections between innovative pre-walls designed to have high durability and eco-efficiency. *Journal of Building Engineering*, 44(2021), pp.103356. https://www.sciencedirect.com/science/article/abs/pii/S2352710221012146

21. Zanatta, T., Rozineide, A., Santa, A.B., Padoin, N., Soares, C. and Riella, H.G. (2021). Eco-friendly ceramic tiles: development based on technical and market demands. *Journal of Materials research and Technology*, 11(2021), pp.121-134. https://reader.elsevier.com/reader/sd/pii/S2238785420321578?token=FEBA9B097C3672DA111335EE9173E4A78C195F6F39E402BCD3FB901EB9C3990A4D6C1DFDE4800BFEAEDB13C804256807&originRegion=eu-west-1&originCreation=20211104064544

22. Alam, R.B., Ahmad, M.H. and Islam, M.R. (2021). Bio-inspired gelatin/single-walled carbon nanotube nanocomposite for transient electrochemical energy storage: An approach towards eco-friendly and sustainable energy system. *Heliyon*, 7(2021) pp.e07468. https://reader.elsevier.com/reader/sd/pii/S2405844021015711?token=263980B10CEBF730E086A5F527391EEDEB46341A1088ADFE818D4AFF2A3677BD634BAA02B9E3283B6991365A1D225636&originRegion=eu-west-1&originCreation=20211104103823

23. Gavali, H.R. and Ralegaonkar, R.V. (2020). Design of eco-efficient housing with sustainable alkali-activated bricks. *Journal of Cleaner Production*, 254(2020), pp.120061. https://www.sciencedirect.com/science/article/abs/pii/S0959652620301086

24. Wen-jie, S., Hong-yuan, F.U. and Gui-yao, W. (2012). Study on a Kind of Eco-concrete Retaining Wall's Block with Water Purification Function. *Procedia Engineering*, 28(2012), pp.182-189. https://reader.elsevier.com/reader/sd/pii/S1877705812007138?token=1736844A500ED72866DB0504E318045E2ECD4F3EBB2C681DF47FE58E74325C883A261C7D6024EB7530BE28DE096CAE04&originRegion=eu-west-1&originCreation=20211104123623

25. Soleimani-Dashtaki, S., Ventura, C.E. and Banthia, N. (2017). Seismic Strengthening of Unreinforced Masonry Walls using Sprayable Eco-Friendly Ductile Cementitious Composite (EDCC). *Procedia Engineering*, 210 (2017), pp.154-164. https://reader.elsevier.com/reader/sd/pii/S1877705817360551?token=76ABB9132569A5D5BBCC513C883F69E1FE519A6C4939B7A8CCE141E3896C60B5479C7908A771550F49D25467E1FDFB33&originRegion=eu-west-1&originCreation=20211104124344

26. Joyram, H. (2019). A critical evaluation on the factors impacting the adoption of eco-block as a green construction material: From a Mauritian perspective. *Journal of Building Engineering*, 25(2019), pp.100789. https://www.sciencedirect.com/science/article/abs/pii/S2352710218303656

27. Benin, S.R., Kannan, S., Bright, R.J. and Moses, A.J. (2020). A review on mechanical characterization of polymer matrix composites & its effects reinforced with various natural fibres. *Materials Today*: *Proceedings*. https://www.sciencedirect.com/science/article/pii/S2214785320347271

28. Arya, S. and Kumar, S. (2020). E-waste in India at a Glance: Current Trends, Regulations, Challenges and Management Strategies; *Journal of Cleaner Production*, 271(2020), pp.122707. https://www.sciencedirect.com/science/article/abs/pii/S0959652620327542

29. Jesudass, A., Gayathri, V., Geethan, R., Gobirajan, M. and Venkatesh, M. (2021). Earthen blocks with natural fibres - A review. *Materials Today: Proceedings*, 42 (2021), pp.6979-6986. https://www.sciencedirect.com/science/article/pii/S2214785321005253

30. Madhu, P., Sanjay, M.R., Pradeep, S., Bhat, K.S., Yogesha, B. and Siengchin, S. (2019). Characterization of cellulosic fibre from Phoenix pusilla leaves as potential reinforcement

for polymeric composites. *Journal of Materials Research and Technology*, 8(2019), pp. 2597-2604. https://www.sciencedirect.com/science/article/pii/S2238785418305830

31. Rabello,L.G. and Ribeiro, R.C.D.C. (2021). A novel vermiculite/ vegetable polyurethane resin-composite for thermal insulation eco-brick production. *Composites Part B: Engineering*, 221(2021), pp.109035. https://www.sciencedirect.com/science/article/abs/pii/S1359836821004194

32. Coffey, Y., Bhullar, N., Durkin, J., Islam, M.S. and Usher, K. (2021). Understanding Eco-anxiety: A Systematic Scoping Review of Current Literature and Identified Knowledge Gaps. *The Journal of Climate Change and Health*, 3(2021), pp.100047. https://www.sciencedirect.com/science/article/pii/S2667278221000444

33. Kumareswaran, K., Rajapaksha, I. and Jayasinghe G.Y. (2021). Energy poverty, occupant comfort, and wellbeing in internally displaced people's residences in Sri Lanka. *Energy and Buildings*, 236(2021), pp.110760. https://www.sciencedirect.com/science/article/abs/pii/S037877882100044X

34. Amani, A., Ramezanianpour, A.M. and Palassi, M. (2021). Investigation on the sustainable use of electric arc furnace slag aggregates in eco-friendly alkali-activated low fineness slag concrete as a green construction composite. *Journal of cleaner production*, 307 (2021), pp.127257. www.elsevier.com/locate/jclepro