The Development of a Decision-Support System (DSS) for Selecting Best-Fit Zero-Carbon Building Materials; The Cases of Iran and New Zealand Building Industries

Ali Hashemi Araghi, School of Built Environment, Massey University, New Zealand.
Eziaku Rasheed, School of Built Environment, Massey University, New Zealand.
Priya Vishnu, School of Built Environment, Massey University, New Zealand.

SYNOPSIS

A zero-carbon building is a green and environmental-friendly structure designed and functioning with the primary objective of eliminating or reducing carbon dioxide, thereby positively impacting natural resources and climate change. The current worldwide focus on sustainability and decreasing carbon emissions have significant consequences for the construction sector.

The purpose of this qualitative study is to determine the factors that influence the decision making involved in material choice for zero-carbon buildings by senior construction professionals. In addition, this study seeks to provide mechanisms to overcome the barriers for stakeholders to meet the sustainability challenges in the industry. The research investigates decision-making changes between conventional and sustainable construction and provides a pathway for zero-carbon construction. It will be essential to develop insights into responsible sourcing as an area of growing industry relevance and compare the influence of these factors between New Zealand and Iran. Comparing these two countries with quite different building materials and construction practices could show some interesting emergent properties that both countries could benefit from. The culture of using these materials and the reasons behind their use can advance the body of knowledge in the construction sector. The scope of this proposal is sufficiently well-defined to make the project feasible in the time allocated.

The findings of this study will be beneficial to society, considering that zero-carbon buildings play an important role in the move to a more sustainable future. The greater demand for greenhouses for individuals and companies justifies more effective constructional approaches. Thus, government, businesses, and individuals that apply the recommended approach derived from the results of this study will be able to sustain the environment better. The New Zealand and Iranian construction industry stakeholders, will be guided on what materials should be used to improve resources efficiency. For researchers, the study provides insight into critical areas that have received limited attention in zero-carbon construction and renewable construction materials.

Keywords: Zero Carbon Building, Sustainability, renewable energy, construction materials

INTRODUCTION

Over the last few decades, the world's population has increased more rapidly than ever before. In Iran, the housing demand rises daily. Due to the lack of structural materials, houses are expensive as a significant part of society cannot afford to buy homes or apartments, especially in Tehran (Rouhani, 2019).

According to the research published by United Nations (2009), more than 40% of the construction industry's global energy consumed leads to operational carbon emissions and one-third of worldwide greenhouse gas emissions (Pearce & Ahn, 2017). It is also estimated that more than 50 per cent of the water and energy that flows into buildings is wasted (U.S. Energy Information Administration, 2021).

The building and construction sector makes up approximately 20% of New Zealand's greenhouse gas emissions (Ministry of Business Innovation and Employment, 2020). In Iran, this sector is responsible for 24.1% of CO2 emissions, which is more than household sectors, occupied by 23.4% (worldometers, 2020). Research indicates that until 2025, scientists forecast that buildings will be the largest consumers of energy, even more than transportation systems and industrial sectors (Li et al., 2018).

Adding to the issue is the traditional materials used in building construction which consumes 56% more energy in the long term. U.S. Energy Information Administration (2013) indicates that the increasing number of new building construction will consume a large amount of energy which adds a burden to the environment. Economically, this will cost residents a vast amount of money on utility, while simultaneously, environmentally, it will emit carbon dioxide. Buildings consume more than 40 per cent of energy usage and produce 24 per cent of greenhouse gas emissions (Riedy, 2012).

Reducing carbon emissions in structures will be crucial to achieving the Paris climate aims and net zero emissions by 2050 while simultaneously eliminating the negative impacts. However, green buildings alone may not completely solve the potential problems. One practical solution is exploiting local natural resources or materials from the origin to construct zero carbon buildings. In the long-term, these locally sourced zero carbon structures will contribute to both society and the environment; consequently, they will achieve economic, environmental, and social sustainability. In this research, the authors investigate which factors have the most influence when choosing zero-carbon building materials in Iran and New Zealand.

Green Building Materials used in Construction

Zero carbon building materials are different from traditional construction materials. Generally, raw materials are used to produce zero carbon structure materials using natural resources as minimum as possible. It mainly uses garbage, tailings, and further types of waste materials to decrease manufacturing costs the waste of natural resources. Zero carbon structures reduce energy production processes and pollution-free manufacturing technology, plummeting environmental risks and controlling costs. The strategy of zero-carbon building products is about improving the quality of human life as the main goal (Cai & Sun, 2014). A review of literature provides numerous Green building materials used in construction, such as those described below:

- Low Carbon Brick: In recent years' engineers and scientists discovered a new technology for making brick that does not need high-temperature fire and escapes the usage of high-energy materials like Portland cement. This knowledge solves the disposal issues associated with construction and demolition waste mitigation. (PTI, 2021).
- Wood (Timber): Timber is a renewable and natural material that reduces carbon dioxide emissions. There are different types of timber construction systems such as cross-laminated timber, and timber frame not only reduce carbon emissions but also bring the

positive aspects of up-to-date construction methods. Therefore, using this type of build system could reduce construction time, decrease waste, increase safety. (Wood for good, 2021).

- Bamboo: Considering bamboo as a green and sustainable material is still debated. Supporters believe that due to its sustainable harvesting, and similar properties to wood, bamboo could be a green alternative to other materials used in the construction and interior design. (Inbar, 2021). However, others argue that the environmental expenses of bamboo production and the fact that most bamboo jungles are far from western countries outweigh bamboo's green advantages (Inbar, 2021).
- Raupo: Raupo is from the same family as the bulrush, and it is counted as a sustainable material, mainly was common in New Zealand around the shallow edges of lakes. Collecting it is easy; moreover, it is dry to assemble into constructions quickly. Thatched into rows, the stems slow water penetration and provide a suitable thermal insulation level. Alsoraupo may have been used with a timber framework (Isaacs, 2005).
- Fibreglass: Fibreglass is one of the best choices when engineers and architectures look for energy-efficient, green, and sustainable materials because of its composition and low energy required to produce fibreglass from raw materials. Usually, fibreglass does not need extra materials to reinforce it, so decreasing the windows doors' weight and bulk could help cut the transportation budget. (ENERGY STAR, 2021) Furthermore, fibreglass has a long lifecycle, and even if it is broken, it could recycle and use again. (ENERGY STAR, 2021).
- Structural Insulated Panels (SIPs): Structural insulated panels (SIPs) are a kind of sandwich panel with an insulating foam core, widely used in the construction industry, including residential and light commercial. Oriented strand board (OSB) is one kind of board. Under factory-controlled conditions, SIPs can be manufactured and fabricated to fit almost all building designs. This kind of building system brings strong, energy-efficient and cost-effective (The Structural Insulated Panel Association, 2021).
- Cordwood: Cordwood construction is a versatile, economical, low-impact, and beautiful building technique. Instead of using standard long logs, short logs are used to build a wall. For cordwood construction, well-seasoned cedar is preferred to wood because it is naturally rot-resistant (McLeod, 2017). Cordwood building structures can last at least 150 years. This building method can use local construction materials at minimal cost and bring low material impact (Henstridge, 2021).
- Straw Bale: Its structural elements usually are oats, rice, wheat and rye straw that are usually covered by stucco, plaster, clay, or other treatment on the interior and exterior sides of a bale wall. This building method offers a sustainable, bio-based insulation material for structure resulting from cereal food crop production (Walker, et al., 2020).
- Earthbags: Earthbags are excellent material for zero carbon buildings due to their resistance to moisture damage. Installing and building houses with earthbags is easy, decreasing construction expenses. When filled with insulation such as perlite or scoria, earthbag walls and foundations enable you to grow plants year-round. (Geiger, 2009).
- Steel: One of the most popular construction materials is steel structure, which is often used with concrete to make extraordinary and lifelong buildings. Because of its versatility, sustainability, flexibility, and cost-effectiveness are often chosen as the main building material. (allplan, 2019).
- Thatch: It is a traditional but common roofing material. The building elements commonly use dry vegetation, such as straw, palm leaves, and water reeds that are

naturally sourced. Therefore, the building materials can be sourced locally and eco-friendly (Mohanram, 2018).

- Composites: A combination of two construction materials that have enhanced features when used together than they do apart is known as composite construction. The most common composite material used in construction is concrete. Other materials such as Fibre-reinforced polymer (FRP), Carbon-fibre-reinforced polymer (CFRP), and Glass-fibre-reinforced plastic (GFRP) are also used widely. Composites are generally used in the construction industry for architecture, bridges, infrastructure, refurbishment, etc. The features of composites include low maintenance, fire-resistant, superior durability, lightweight and short construction times (Ostrowsk, et al., 2020).
- Natural Fibre: The use of natural fibres reinforces the strength properties of the composites. Some natural fibres include coconut fibres, sisal fibres, jute fibres, flax fibres, etc. To achieve eco-friendly composites, natural fibres are sustainable and renewable resources. Natural fibres have numerous advantages, such as renewability, lightweight, cost-effectiveness, biodegradability, and high specific properties (Girijappa, et al., 2019).
- Polyurethane: Polyurethane, a plastic material, is used in a wide variety of applications, including in building insulation, construction applications, cushioning for furniture, carpet, composite wood panels and so on. Polyurethane has several advantages, such as strength-to-weight ratio, insulation properties, durability and versatility. Polyurethane plays a vital to support our daily lives to be more convenient and environmentally friendly (American Chemistry Council, 2021)
- Cellulose: Cellulose, a molecule, comprises carbon, hydrogen and oxygen atoms. The core element found in plant cell walls is cellulose. It is a superior insulation material with low embodied energy and can against air infiltration. News-print and other wood fibre made paper are the source of cellulose building. Thus, it is a recycled material (Lea, 1996).
- Cork is probably one of the most sustainable and eco-friendly construction materials. It is chemical-free, non-toxic, waterproof, 100% recyclable, fire retardant, and soundproof (WILLIAMS, 2020).
- Stone: Stone counts as a green material for buildings because it is natural and durable. Also, the stone is recyclable and could last for years if it receives appropriate maintenance and care. (Vierra, 2016).

METHODOLOGY

This research assesses the impact of material sourcing for zero-carbon building. We will use a questionnaire and interviews with experts across the industry, such as civil engineers, architects, environmental engineers, project managers, construction managers, developers and major clients in New Zealand and Iran. This research intends to answer the following questions:

1. What factors influence construction professionals' decision-making when considering material choices for conventional and sustainable practices?
2. What are the similarities and differences between New Zealand and Iran?
3. What are the zero-carbon building effects on the environment?
4. What are the zero-carbon building effects on resource efficiency?
5. How does the usage of recycled and reusable materials compare between the New Zealand and Iran construction sectors?

This research uses a mix of quantitative and qualitative methods to investigate the effects of green building materials on the environment and resource efficiency by using interviews and a Doodle survey, made using an online data gathering platform, will be used as the principal instruments of the survey. Target participants for this research are professionals working in construction companies in New Zealand and Iran.

CONCLUSION

The findings of this study will be beneficial to society, considering that zero-carbon buildings play an essential role in the move to a more sustainable future. The greater demand for zero carbon houses for individuals and companies justifies the need for more effective constructional approaches. Thus, governments, businesses, and individuals that apply the recommended approach derived from the results of this study will be able to sustain the environment better. It will help them reduce the building and maintain costs on structures. The New Zealand and Iranian construction industry stakeholders will be guided on what materials to use to improve resources. For researchers, the study provides insight into critical areas that have received limited attention in zero-carbon construction and renewable construction materials.

REFERENCES

allplan, (2019). Steel for Construction, Austria: Nemetschek Group.
American Chemistry Council, (2021). Polyurethane Applications, Washington D.C: ACC.
Cai, j.-w. & Sun, J., (2014). Brief Discussion on Green Building Materials. Ningbo, China, IOP.
ENERGY STAR, (2021). Fiberglass Green And Sustainability, Schaumburg, Illinois: FGIA.
Geiger, O., (2009). Earthbag Greenhouses, USA: Natural Building Blog.
Girijappa, Y. G. T., Rangappa, S. M., Parameswaranpillai, J. & Siengchin, S., (2019). Natural Fibers as Sustainable and Renewable Resource for Development of Eco-Friendly Composites: A Comprehensive Review, Lausanne: Frontiers.
Henstridge, J., (2021). Durability of Cordwood Homes, Kansas: mother earth news.
Inbar, (2021). How 'Green' Are Bamboo Products?, China: International Bamboo and Rattan Organisation.
Isaacs, N., (2005). Going back in time raupo houses, New Zealand: Branz.
Lea, D., (1996). Cellulose: Building Insulation with High Recovered Content, Low Embodied Energy, Gainesville, FL, USA: Green Building Materials.
Li, J.-F., Ma, Z.-Y., Zhang, Y.-X. & Wen, Z.-C., (2018). Analysis on energy demand and CO2 emissions in China following the Energy Production and Consumption Revolution Strategy and China Dream target. Advances in Climate Change Research, pp. 16-26.
Marsh, J., (2021). How many solar panels do I need for my home? USA: Energy Sage.
McLeod, B. R., (2017). Tricks of the Trade: Building With Cordwood, New Hampshire: northern wood lands.
Ministry of Business Innovation and Employment, (2020). Building for Climate Change: Transforming operational efficiency and reducing whole-of-life embodied carbon, Nw Zealand: MBIE.
Mohanram, A., (2018). Charming thatch, India: thehindu.
Ostrowsk, K. A., Kinasz, R. & Dybeł, P., (2020). The Impact of Surface Preparation for Self-Compacting, High-Performance,Fiber-Reinforced Concrete Confined with CFRP Using a Cement Matrix, Basel, Switzerland: MDPI.
Pearce, A. & Ahn, Y. H., (2017). Sustainable Buildings and Infrastructure: Paths to the Future, U.K.: routledg.
PTI, (2021). Low-carbon bricks developed using C&D waste for energy-efficient walling envelopes. [Online]

Available at: https://www.thehindu.com/sci-tech/science/low-carbon-bricks-developed-using-c-and-d-waste-for-energy-efficient-walling-envelopes/article36494316.ece

Riedy, C., (2012). What is a zero carbon building?, Ireland: Medium.

Rouhani, H., (2019). Iranians struggle to afford housing as prices soar, Doha: Aljazeera.

The Structural Insulated Panel Association, (2021). What are SIPs?, USA: SIPA.

U.S. Energy Information Administration , (2013). International Energy Outlook 2013, Washington DC: EIA.

U.S. Energy Information Administration, (2021). Energy use in homes, Washington DC : EIA.

Vierra, S., (2016). Top Five Reasons Why Natural Stone is a Sustainable Choice for Your Home, Ohio: use natural stone.

Walker, P., Thomson, A. & Maskell, D., (2020). Nonconventional and Vernacular Construction Materials , USA: Woodhead.

Williams, . J., (2020). Why cork could be the sustainable building material of the future, u.k.: Elle Decoration.

Wood for good, (2021). How Can Building With Timber Help Us To Achieve Our Net Zero Goals?. [Online]
Available at: https://woodforgood.com/news-and-views/2021/05/28/the-environmental-and-sustainable-benefits-of-building-with-timber/

Worldometers, (2020). Iran CO2 Emissions. [Online]
Available at: https://www.worldometers.info/co2-emissions/iran-co2-emissions/

The Development of a Decision-Support System (DSS) for Selecting Best-Fit Zero-Carbon Building Materials; The Cases of Iran and New Zealand Building Industries

Araghi Hashemi, A

2022-02-18