IMPLEMENTATION OF GREEN MATERIALS AS SUPPLEMENTARY CEMENT REPLACEMENT IN THE CONSTRUCTION INDUSTRY

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DEDICATION

To God the father, God the son and God the Holy Spirit

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ABSTRACT

Previous research has shown that supplementary cementations materials (SCM) can help reduce the usage of cement in concrete manufacture. However, despite the consensus among stakeholders on the urgent need to de-carbonize cement production and adopt green concrete for construction activities, current usage of supplementary cementations materials is still at a stagnant stage. The aim of this research is to study the effectiveness of implementation of green materials as supplementary cement replacement in the Malaysian construction industry. To achieve the research aim, questionnaires survey was distributed and interviews were conducted with industry players in multiple cement, precast and ready mix concrete companies. This research also conducted concurrent triangulation mixed method approach where the data was collected, coded and analyzed using Statistical Package for Social Sciences (SPSS) Version 24 and Microsoft Excel Software 2016. The method of analysis used was cross tabulation, exploratory factor analysis and mean score ranking for the quantitative data while content analysis was used in analyzing the qualitative data. The research findings indicated that there was moderate level of awareness but low level of compliance. This study also discovered multiple challenges hindering the application of SCM in the construction industry ranging from lack of knowledge and technical knowhow on quality and importance of SCM, the inactiveness of regulatory bodies in regulating and the enforcement of policies. Finally, this study also proposes key strategies such as training of industry players, enforcement of policies and increased awareness and enlightenment program to promote the application of green materials as supplementary cement replacement.

ABSTRAK

Kajian lepas menunjukkan bahawa bahan tambah pengganti simen (SCM) boleh membantu mengurangkan penggunaan simen dalam pembuatan konkrit. Walaupun terdapat persefahaman di antara pihak berkepentingan mengenai keperluan untuk mengurangkan pengeluaran simen dan mengguna pakai konkrit hijau untuk aktiviti pembinaan, penggunaan bahan tambah pengganti simen semasa masih di tahap yang rendah. Tujuan penyelidikan ini dijalankan adalah untuk mengkaji keberkesanan pelaksanaan bahan hijau sebagai bahan tambah pengganti simen dalam industri pembinaan Malaysia. Untuk mencapai matlamat penyelidikan, soal selidik telah dibuat dan wawancara telah dijalankan dengan panel dari industri dalam pelbagai syarikat konkrit simen, pratuang dan siap konkrit. Kajian ini juga menggunakan kaedah *concurrent triangulation mixed* di mana data dikumpulkan, dikodkan dan dianalisa menggunakan *Statistical Package for Social Sciences* (SPSS) Versi 24 dan Perisian *Microsoft Excel 2016*. Kaedah analisis yang digunakan adalah tabulasi silang, analisis faktor penjelajahan dan skor min kedudukan untuk data kuantitatif manakala analisis isi kandungan digunakan dalam menganalisis data kualitatif. Penemuan penyelidikan menunjukkan bahawa terdapat tahap kesedaran yang sederhana tetapi tahap pematuhan yang rendah. Kajian ini juga menemui beberapa cabaran yang menghalang penggunaan SCM dalam industri pembinaan yang terdiri daripada kekurangan pengetahuan dan pengetahuan teknikal mengenai kualiti dan kepentingan SCM, ketidakcekapan badan pengawalseliaan dalam mengawal selia dan penguatkuasaan dasar . Akhir sekali, kajian ini juga mencadangkan strategi utama seperti latihan untuk panel industri, penguatkuasaan dasar dan meningkatkan kesedaran dan pencerahan untuk mempromosikan penggunaan bahan hijau sebagai bahan tambah pengganti simen.

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CHAPTER 1

INTRODUCTION

New technologies are developed rapidly to supplement the present practices for greener buildings, one key objective which these technologies should fulfil is the need to be designed to minimise adverse consequence on human health and its environment by creatively using water, energy and other resources, while decreasing amount of waste, pollution and degradation of the environment (Shiva, 2016). It is attainable with the development of effective codes and practices to meet the present challenges before us. (Holm, 2003).

The application of green construction is a practice of creating structures and using processes which are environmentally friendly and resource efficient throughout a building's lifecycle starting from design, construction, operation, maintenance, renovation and deconstruction. This is to ensure safety, quality, and meet basic requirements which seek to upgrade the quality of our planet, thus reducing the impact on the environment (Riddell, 2017).

The essential components of construction are materials. For mechanical strength gain in a building, an appropriate design, and properties of material used are necessary (Umar et al, 2012). Materials used in construction ingest energy and resources and produce pollution, waste, water, air during its manufacturing process. The need for maintenance works or replacement could also occur, hence a need for suitable selection of green materials (Lloret, 2011). The potential for enhanced performance, more sustainable construction and innovation largely lies in the materials, it is therefore key to innovation in construction to understand the properties of the materials used (Schmidt et al, 2018).

Green materials are environmentally friendly materials which reduce the impact on the environment. They are non-toxic, and are gotten from reused, recycled, renewable or natural sources. It is vital for considerations to be given when selecting materials, however, as good as performance requirements are, more consideration should be given towards materials with lower Greenhouse Gas (GHG) emissions (Aghdam et al, 2018). This is only attainable through a step-by-step approach of investigating, evaluating and making a choice. It is hence achievable by a constant, up-to-date information assessment for truly green materials (Froesschle, 1999; Ogunkah et al, 2012). The ability to blend the social, economic and environmental consideration is key in this decision making process (Akadiri et al, 2013), so that reusable, recycled and salvaged agro-industrial waste, biodegradable, naturally processed products, materials with low emission of volatile organic chemicals (VOC) and those which will reduce the quantity used without sacrificing durability, yet saving energy and water or other ozone depleting substances are the best choices (Fithian, 2009; Mehta, 2014).

Concrete is the most commonly used construction material worldwide (Aitcin, 2000; Mobasher, 2008) with its basic ingredients of cement, fine aggregate, coarse aggregate and water. Cement consumes large quantities of natural material and is one of the major contributors to air pollution. Nearly 7% of the world's CO_2 emission can be attributed to cement; for each ton of cement produced, a ton of greenhouse gas is released into the atmosphere (Meyer, 2009). Cement requires a revitalization and rebirth because of the maintenance, durability and environmental challenges. The production processes in Portland cement manufacture releases greenhouse gases and uses large amount of energy (Bondar, et al, 2011). Fortunately, advancements have been made to produce more environmental, economical and sustainable material as supplementary cement replacement (Schmidt et al, 2018). This supplementary replacement can be used based on substitute composition, binding phases and application of green materials thus creating synthesized cement from recycled resources and mineral waste (Phair, 2006). This is referred to as supplementary cementitious materials (SCM) which will assist in reducing usage of non-renewable resources, improve workability, durability, and will not compromise other concrete's properties. Example of existing supplementary cement replacement, is pozzolanic materials from industrial waste (fly ash (PFA), silica fumes (SF), slag), ashes from agricultural waste (groundnut husk ash, millet ash and corn cob ash, palm oil fuel ash (POFA) (Altwair et al, 2010; Hossian et al, 2016). A proportion of these materials usually between 10-30% play a significant role when incorporated in Ordinary Portland Cement as a replacement and a binder. They minimize the permeability of concrete hence is appropriate for use in reinforced concrete where resistance against corrosion, acid and sulphate attack is required, (Adole et al, 2011) with a lower heat of hydration and cohesiveness.

1.1 Background

The construction industry, especially in industrialized nations, is considered the world's largest sector, as it houses individuals, families, economic activities, and the cultural customs of society with a purpose to protect life, health, psychological, social welfare, and host economic activities while sustaining beauty and cultural values. (Holm, 2003). The sector however, is associated with enormous environmentally related problems which is faced globally. The demands on the products and services of the ecosystem keeps growing and is outpacing the regenerative and absorptive ability of the atmosphere. (Zakaria, 2011). Despite the initiatives being made, there is a further degradation of natural resources and an increase in greenhouse gasses with a larger world population growth prediction which has been estimated to rise by at least 50% to reach 9 billion in another 50 years, hence an even faster worldwide consumption rate. (McCarthy, 2001)

The construction industry accounts for close to half of all non-renewable resources used up by mankind, it is therefore seen as one of the least sustainable industries in the world. Mankind has overtime tried to influence the natural environment to suit its needs by a continuous involvement in one form of construction or the other. (Powmya, & Abidin, 2014). Today, civilization depends on buildings and its content for existence but the current level of resource consumption cannot be sustained by our planet. (Dixon, 2010).

Approximately 40% of energy produced in the world is consumed by the construction sector. (Pérez-Lombard et al., 2008), this has impacted the environment in its consumption of energy both directly and the embodied energy in the materials it uses.

With over 40 million tons of carbon dioxide and the amount of carbon dioxide emitted in the manufacturing process of construction materials, as shown from statistics, 4.2% of global carbon dioxide emissions can be attributed to cement production alone (Boden, et al. 2009). This in turn contributes to global warming from the greenhouse effect. The construction, maintenance and use of buildings has negatively impacted our environment and there are irreversible changes in the world's climate, atmosphere and ecosystem, with buildings being the greatest producers of harmful gases such as CO_2. Quite alarming is construction's total energy, consumption of resources and carbon emissions to the environment. (Rostami et al, 2017).

The application of strategies by the global cement industry to reduce CO2 emissions began in the 1990s, major producers under the platform of the Cement Sustainability Initiative (CSI) have worked together and dedicated substantial effort to make known mitigation solutions to the problem. This effort has also received the support of policymakers working towards promoting energy efficiency and accelerated de-carbonization. According to the International Energy Agency (2009), these efforts have focused on four (4) major strategies which are electric and thermal efficiency, alternative fuel use, clinker substitution and carbon capture and storage (CCS).

A number of reasons have been advanced on why the industry has not moved quickly over time. Firstly, the capital intensity of cement production relative to revenue means that it can take several years to recoup investments in infrastructure (Placet and Fowler, 2002). This has discouraged producers from shifting to new methods that might diminish existing assets. Secondly, there has been a lack of financial incentives for the sector to adopt mitigation solutions (The Economist, 2016). Thirdly, the broader construction sector, within which the cement and concrete sector is embedded, tends to shy away from taking such kind of risk. Rather, there is a tendency as well as a strong preference for holding on to practices and products with proven track records (Giesekam, Barrett and Taylor, 2015).

Malaysia has joined other emerging and industrialized nations in demonstrating considerable commitment toward innovations that could abruptly reduce overall emissions by introducing changes to cement composition. For instance, the Cement and Concrete Association of Malaysia, being the Standard Writing Organization for cement, has effectively required the advancement and adjustment of the new Euro standard for cement in bolstering the improvement of blended cement. With the new cement standard, an aggregate of 27 types of cement are now permitted to be produced with 26 of them being blended cement. Furthermore, Malaysian government's target is to achieve a 40% deliberate reduction of CO2 emission by 2020 in the Low Carbon Society Blueprint project toward transforming Malaysia into a low carbon nation (Bakhtyar, 2017; Yuzuru and Siong, 2013).

The annual volume of cement production in Malaysia is estimated at 20 million tonnes with an energy consumption of about 12% of the total energy consumption in the country (Madlool et al., 2011). The average electrical energy consumption of a modern cement plant in Malaysia is around 110-120 kWh per tonne of cement (Alsop, 2005). Thermal energy represents around 20-25% of the cement production cost. Cement Additives Quality Improver Polymer (CAQIP) is created from an integrated polymer (palm oil waste) and waste materials from petrochemical industries for production of sustainable cement. According to Bakhtyar, Kacemi, and Nawaz, (2017), CAQIP has enhanced productivity and quality while reducing CO2 outflow, crushing and clinking energy and upgraded production of sustainable cement and concrete in Malaysia.

In the manufacture of OPC and sustainable cement, industrial scale trial of CAQIP in local cement plants has significantly enhanced efficiency and achieved 8.3-27.5% saving effectiveness, 24.73-86.36% clinking energy, and 7.70-21.57% crushing energy. Furthermore, CO_2 and other GHG emissions have significantly reduced to 21.90-90.0% through the substitution of clinker with other materials like out-spec clinker (50-100%), limestone waste (5-25%), and fly ash (25-35%) (Bakhtyar, et. al., 2017).

However, the National Ready Mixed Concrete Association (NRMCA) conducted a survey of 57 American companies involved in the production of ready mixed concrete to determine the average amounts of cement, fly ash, slag cement, and silica fume used in a cubic yard of ready mixed concrete. The analysis revealed that 34% of all ready mixed concrete produced was with straight Portland cement; 2.2% with blended cement only, 56% with fly ash as the only supplementary cementitious materials (SCM), 5.1% with slag cement as the only SCM, 0.1% was with silica fume as the only SCM, and 2.8% was with more than one SCM (ternary mixtures) (NRMCA, 2012). The lack of adequate incentives for investors, followed by inadequate information regarding the financial and economic benefits and opportunities, as well as the limited range of green products and materials are the greatest challenges affecting the promotion of green construction (Simpeh and Smallwood, 2015).

1.2 Problem Statement

Cement is a major component of concrete which is the most widely used construction material in the world. It is estimated that more than 4 billion tons of cement are produced every single year (Lehne and Preston, 2018). In addition, the Cement production is projected to grow, and the bulk of this growth will take place in developing countries like Malaysia due to rapid urbanization and industrialization. The thermal and chemical combustion processes involved in the production of cement are a major source of carbon dioxide (CO_2) emissions which contribute about 8 per cent of annual global CO_2 emissions (Olivier et al, 2015).

The campaign to reduce global CO_2 emissions has been backed by governments and organizations who understand that the present rate of greenhouse gases emission into the atmosphere poses serious danger to future life and prosperity on earth (Abuzeinab, 2015). Previous study has shown that supplementary cementations materials can help reduce the usage of cement in concrete manufacture.

However, despite the overwhelming consensus among stakeholders on the urgent need to de-carbonize cement production and adopt green concrete for construction activities, it is perceived that the level of compliance in the Malaysian construction industry is still low (Bakhtyar, et. al., 2017).

This is thereby raising serious concerns on the preparedness and willingness of the country to go green. Thus, there is a need to evaluate the current application and effort on de-carbonization of cement and adoption of green concrete for construction activities in Malaysia. In addition, this study is also interested in uncovering the major challenges that hinder the application of these green materials. This would pave the way for the country to explore the potentials for scalable and sustainable alternatives to traditional carbon-intensive cement and concrete.

1.3 Research Aim and Objectives

The aim of this research is to study the effectiveness of implementation of green materials as supplementary cement replacement in the Malaysian construction industry. The study would seek to achieve the objectives shown below.

1.3.1 Research Objectives

The objectives of the research are:

(a) To determine the level of awareness and compliance on the application of green materials as supplementary cement replacement in the Malaysian construction industry.

(b) To identify the major challenges hindering the application of green materials as supplementary cement replacement in the Malaysian construction industry.

(c) To analyse key strategies that could be adopted to promote the application of green materials as supplementary cement replacement in the Malaysian construction industry.

1.4 Research Questions

The research objectives are intended to answer the following research questions:

i. What is the level of awareness and compliance on the application of green materials as supplementary cement replacement in the Malaysian construction industry?

ii. What are the major challenges hindering the application of green materials as supplementary cement replacement in the Malaysian construction industry?

iii. What key strategies could be adopted to promote the application of green materials as supplementary cement replacement in the Malaysian construction industry?

1.5 Research hypotheses

In line with the research objectives and questions, the following null hypotheses shall be tested:

i. H_0 - There is a significant level of awareness and compliance on the application of green materials as supplementary cement replacement in the Malaysian construction industry.

   H_1 There is no significant level of awareness and compliance on the application of green materials as supplementary cement replacement in the Malaysian construction industry.

ii. H_0: There are major challenges hindering the application of green materials as supplementary cement replacement in the Malaysian construction industry.

H_1: There are no major challenges hindering the application of green materials as supplementary cement replacement in the Malaysian construction industry.

iii. H_0: There are effective strategies for promoting the application of green materials as supplementary cement replacement in the Malaysian construction industry.

H_1: There are no effective strategies for promoting the application of green materials as supplementary cement replacement in the Malaysian construction industry.

1.6 Scope of the Study

The goal of this study was to investigate the current status and reason for non-implementation of green materials as supplementary cement replacement in the construction industry. In addition, this study focused on the Malaysia construction industry mainly the cement, and concrete manufacturer. Literature review was utilised to provide guidance for the direction of this study and as basis for the questionnaire and interview. A local survey of industry players (i.e., engineers, technicians, administrators etc.) from cement and concrete companies who were the respondents and an in- depth protocol interview for seven participants from different organisations within the construction industries was also carried out concurrently. Online survey method and a direct handing over of the instruments were employed using four level Likert scale questionnaire survey approach as quantitative data while interviews were used to collect qualitative data in order to achieve the goal. The findings of this study will help improve the implementation of green materials as supplementary cement replacement in construction industry.

1.7 Significance of Study

With an increase in the emission of CO_2 and other greenhouse gases in the atmosphere during the production of ordinary Portland cement, and a need for reduction in the use of natural resources by the application of low CO_2 supplements as cement replacements for Portland cement clinker for a sustainable built environment; the study intends to enable the Malaysian construction industry see its current status as regards its level of application of green materials as supplementary cement replacement, The findings will help establish a need for an increased awareness of its importance and long-term benefits and furthermore, an immediate application in the industry while bridging the gap between the present researches made and trends in developed nations and its application in the industry. It will proffer ways of helping to increase awareness and the establishment of laws to enforce it. It will benefit the Malaysian construction industry (cement industry, pre-cast concrete industry), industry leaders, research agencies, non-governmental organizations, policy makers and the academia.

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