ACOUSTIC PERFORMANCE OF RHA-SEAWATER CONCRETE WITH COAL BOTTOM ASH AS SAND REPLACEMENT IN LOW FREQUENCY BY SOUND ABSORPTION AND TRANSMISSION

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For my beloved family and friends

Thank you

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ABSTRACT

Concrete production can lead to continuous global pollution such as emission of carbon dioxide gases (CO_2), water pollution, noise pollution and increase the limitation of non-renewable resource usage. The development of concrete with seawater as mixing water, rice husk ash as cementitious material and coal bottom ash as the sand replacement showed a good structural compressive strength at 28 days. Rice husk ash (RHA) increases the C-S-H compound, improves concrete strength and produces less void in the concrete. As for seawater, it tends to induce concrete early strength meanwhile coal bottom ash (CBA) reduces concrete density due to its porous structure. This research is to investigate the sound absorption and sound transmission of concrete with zero freshwaters, replacing cement with 10% RHA and eliminating sand with coal bottom ash (CBA) at 10%, 20%, 30%, 40%, 50, 60%, 70%, 80%, 90% and 100% replacement. Secondary data was obtained through a 100 mm x 100 mm x 100 mm cube compressive strength following BS EN 12390-3:2019. The trial series of seawater concrete with 10% RHA was conducted to determine a strength of more than 50 MPa without CBA achieved at 28 days. The concrete was design based on the DOE (British) Mix Design Method with a constant water-to-cementitious of 0.39. The acoustic performance test was conducted using impedances tube which complies with BS EN ISO 10534-2:2001. Specimens were tested using 100 mm diameter in cylindrical concrete with 100 mm and 200 mm thickness at low frequency to1200 Hz. Result shows that the highest sound absorption coefficient was 0.48 at 400 Hz for 100 mm thickness and 0.52 at 250 Hz for 200 mm thickness. As for sound transmission, thickness of 100 mm and 200 mm achieved 31.08 dB and 25.99 dB of transmission loss (TL) at 1200 Hz, respectively. It can be concluded that, concrete with good strength resulted in lower sound absorption and transmission and better than conventional concrete. This research is in line with Malaysia Construction 4.0 Strategic Plan 2021 – 2025 where advanced building materials is one of the emerging technologies to be developed by integrating new technologies in creating a new product.

ABSTRAK

Pengeluaran konkrit boleh membawa kepada pencemaran global yang berterusan seperti pelepasan gas karbon dioksida (CO_2), pencemaran air, pencemaran bunyi dan meningkatkan had penggunaan sumber yang tidak boleh diperbaharui. Penghasilan konkrit dengan mengunakan air laut sebagai air bancuhanan, abu sekam padi sebagai bahan bersimen dan abu dasar arang batu sebagai gantian pasir menunjukkan kekuatan mampatan struktur yang baik pada 28 hari. Abu sekam padi (RHA) meningkatkan sebatian C-S-H, meningkatkan kekuatan konkrit dan menghasilkan kurang liang dalam konkrit. Pada air laut pula, ia cenderung untuk mendorong kekuatan awal konkrit manakala abu dasar arang batu (CBA) mengurangkan ketumpatan konkrit kerana struktur berliangnya. Penyelidikan ini adalah untuk mengkaji penyerapan bunyi dan penghantaran bunyi konkrit dengan tampa air paip, dengan menggantikan simen dengan 10% RHA dan mengantikan pasir dengan abu dasar arang batu (CBA) pada peratusan 10%, 20%, 30%, 40%, 50, 60%, 70%, 80%, 90% dan 100% gantian. Data sekunder diperolehi melalui kekuatan mampatan kubus 100 mm x 100 mm x 100 mm mengikut BS EN 12390-3:2019. Siri percubaan konkrit air laut dengan 10% RHA telah dijalankan untuk menentukan kekuatan lebih daripada 50 MPa tanpa menggunakan CBA pada 28 hari. Konkrit ini direka berdasarkan Kaedah Reka Bentuk Campuran, DOE (British) dengan air-ke-simen berterusan digunakan ialah 0.39. Ujian prestasi akustik telah dijalankan menggunakan tiub impedans yang mematuhi BS EN ISO 10534-2:2001. Spesimen diuji menggunakan konkrit silinder 100 mm diameter dengan ketebalan 100 mm dan 200 mm pada frekuensi rendah hingga 1200 Hz. Keputusan menunjukkan bahawa pekali serapan bunyi tertinggi ialah 0.48 pada 400 Hz untuk ketebalan 100 mm dan 0.52 pada frekuensi 250 Hz untuk ketebalan 200 mm. Bagi penghantaran bunyi, ketebalan 100 mm dan 200 mm masing-masing mencapai 31.08 dB dan 25.99 dB kehilangan penghantaran (TL) pada 1200 Hz. Dapat disimpulkan bahawa, konkrit dengan kekuatan yang baik menghasilkan penyerapan dan penghantaran bunyi yang lebih rendah dan lebih baik daripada konkrit konvensional. Penyelidikan ini adalah selaras dengan Pelan Strategik Pembinaan Malaysia 4.0 2021 – 2025 di mana bahan binaan termaju merupakan salah satu teknologi baru yang akan dibangunkan dengan mengintegrasikan teknologi terkini dalam penciptaan produk akan datang.

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CBA	-	Coal bottom ash
CCB	-	Coal- combustion product
C&D waste	-	Construction and demolish waste
C-S-H	-	Calcium -silicate-hydrate
C-A-S-H	-	Calcium-aluminium-silicate-hydrate
DoE	-	Department of Experiment
FSO	-	Federal Statistic Office
SAC		Sound absorption coefficient
RHA	-	Rice husk rice
WtE	-	Waste-to-Energy

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background study

Nowadays, the combination of incorporating sustainable resources in concrete elements is trending to find a more environmental friend and excellent specific strength material in the research world. The air pollution, water pollution, sound pollution, greenhouse effect, and other activities that contribute to the world have a bad effect on the environment's future. Like other countries, Malaysia also takes part in helping the development of sustainable resources to replace the current resources. For example, the replacement of concrete raw materials with a waste product to minimise the negative effects on the environment, such as fly ash (FA), coal bottom ash (CBA), and rice husk ash (RHA). Waste-to-Energy (WtE) as the energy recovery can support the Twelfth Malaysia Plan 2021-2025 (RMK-12, 2021) through term 3; the Malaysian government states the advancing sustainability with, enhancing sustainable energy, advancing the green growth and transforming the water sector as the central point.

Meanwhile, according to the Green Technology Master Plan 2017-2030 (KeTTHA, 2017) for the building sector under the policy of the Construction Industry Transformation Programme, the policy aims the use of green materials can exceed the sustainability requirement and comply with all new buildings at least at minimum green building standard. This helps the usage of green technology increase in the future. Besides, concrete is influenced by recycling material as the main goal to assist the development of the construction industry.

The research started by utilising waste materials such as fly ash, coal bottom ash, and rice husk ash as cement constituents. The results reveal these materials give benefit from improving the compression strength rather than the normal concrete use in the construction industry. Conventional concrete blocks are made from freshwater, cement, river sand, and aggregate. As part of concrete making, the demand for freshwater is also divided into mankind, agricultural industry, and fauna. Thus, from the standpoint of sustainability, using seawater to mix concrete can be beneficial (Younis *et al*.,2018). The experimental examination demonstrated that seawater specimens had about comparable strength to freshwater specimens (Hussain, Md Noor, & Caronge *et al.*, 2019).

Moreover, the use of the concrete block with a combination of waste has been proven as good in terms of strength (Zhao *et al.*, 2020) and durability (Jitendra & Khed, 2020). Several factors influence the concrete strength, such as raw material quality, water-cement ratio, concrete compaction, humidity, and curing of concrete. In a concrete block's development, the value of compressive strength and acoustic performance, such as sound absorption and transmission, is an important part of creating a good concrete block. The high value of water absorption can affect the performance of concrete with the presence of fungus. Meanwhile, high sound absorption is a good qualification in concrete block development. Therefore, the combination of RHA-seawater concrete with CBA can explore the compactable result as the conventional concrete block.

Apart from being strong and durable concrete, the function of sound transmission and sound absorption are important to guarantee persons in residential premises have suitable living circumstances, including acoustic comfort. The range of sound that can detect is about 20 Hz until 20,000 Hz, known as acoustic for the ordinary human being. Less than 20Hz is known as infrasonic, while more than 20,000Hz is known as ultrasonic (El-Mesery *et al.*, 2019), as shown in Figure 1.1.

Figure 1.1 The sound frequency ranges (El-Mesery *et al*., 2019)

The amount of sound reflection in modified concrete is shown in strongly dependent on the aggregate type, pore size and distribution, and changes in concrete mix design elements. Heavyweight and hard materials reflect a major percentage of sound energy, whereas lightweight porous materials absorb it well (Holmes *et al*., 2014). Thus, different kinds of concrete perform differently sound conductors, such as thick combinations are excellent sound reflectors, whereas light mixtures can absorb sound (Fediuk *et al*., 2021).

1.2 Problem statement

In Malaysia, the water demand rose in domestic and industry sectors from 4.8 billion in 2000 to 9.5 billion in 2020 (Anang *et al.*, 2020). From this statistic, the development of domestic houses, industrial areas, and all the activities to involve human life will increase to fulfil human needs. The increase of houses rises the usage of concrete materials such as river sand, cement and water. According to the United Nations World Water Development Report 2019, the freshwater supply in 2050 is estimated that over 570 cities to occupy 685 million people will have limited freshwater accessibility due to increase of human population and urbanisation. Depletion of freshwater is also caused by climate change. Next, the sand quarrying from the riverbed may cause a rapid change in bed configuration in response to the changes in inflow. Quarry work destroys the landscape of the earth, which can lead to downstream movement, scouring, or accumulation of sediment while provoking shoreline erosion (Ozean, Musaoglu & Seker, 2012).

Furthermore, the emission of carbon dioxide gases (CO_2) due to the burning process from cement production leads to fossil fuel ignition. It create indirect greenhouse gas emissions from various sources, including external generation of electricity used by cement producers, production of clinker purchased from various suppliers, third-party transportation, third-party production and preparation of routine and alternative fuels (Bakhtyar *et al.*, 2017). Annually, more than 4 billion tons of cement are produced, contributing to 8% of global CO_2 emissions (Lean *et al.*, 2018), while Malaysia alone produces 2,254 thousand tonnes in 2020 rather than 1,417 thousand in 2019, according to the Department of Statistics Malaysia. Additionally, the increase in the human population in Asia elucidates the increase in rice consumption. Paddy in Malaysia is considered the most important crop under the food subsector and produced a total of 2.7 million metric tonnes in 2016. Malaysia's total paddy cropping area is about 0.70 million hectares (R. B. Radin Firdaus, 2020). The RHA was substituted in concrete to improve the strength of concrete in compressive strength and durability (Tambichick *et al.*, 2018) with 10% of replacement. According to current available data, roughly 83% of Malaysia's energy will be generated by fossil fuels by 2024 (58% coal and 25% gas), with the coal used for electricity creating a significant quantity of coal bottom ash (CBA) and fly ash (FA). It suggests that from 2014 to 2024, the amount of coal used to produce energy would increase from 43% to 58%. (Rafieizonooz *et al.*, 2022). The CBA as a waste product was used for sand replacement as well-graded material and its particle size distribution is similar to river sand with the interlocking characteristic (Singh & Siddique, 2016).

Seawater concrete has been explored among researchers. The combination of RHA-seawater concrete with CBA block was discovered by developing compressive strength and water absorption in concrete as the major requirement in commercial concrete (Hussain *et al*., 2019). However, the data of this concrete block for acoustic performance, such as sound absorption and transmissions, is still lacking. The combination of RHA-seawater concrete with a high volume of CBA as the sand replacement somehow is the main point of acoustic performance because of the porous structure in the concrete block mixture.

Moreover, noise pollution played a part in this problem. The high level of industrial and transportation noise causes environmental noise pollution, making it a critical environmental issue. As a result, various issues arose, including veiled warning signals, increased possibilities of hearing problems, and more work-related stress (Fediuk *et al*., 2021). Working conditions at the number of specialists' jobs when the maximum permitted level of infrasound and noise is exceeded (Slivina *et al.*,2020). Thus, this research investigates the sound absorption and transmission of the RHA-seawater concrete with CBA for 10% RHA and 10% to 100% of CBA. The major objective is to explore the behaviour of the RHA-seawater concrete with CBA in perspective to building services. This combination can produce positive outcomes and is set as a reference to construction practitioners, especially on concrete blocks.

1.3 Research question

RHA-seawater concrete with coal bottom ash was explored previously for its compressive strength and water absorption (Hussain *et al*., 2019). Exploration of sound transmission and sound absorption is yet unexplored. Therefore, a few questions were constructed within this study given as below:

1. How does CBA as sand replacement affect the compressive strength of the RHA-seawater concrete?
2. What percentage of CBA to give a good performance against sound absorption and sound transmission?
3. How the microstructure image defines the compressive strength and the acoustic performance through the mineral compound, porosity and spectrum?

1.4 Research objectives

The main objective of this research is to investigate the compressive strength and durability of seawater concrete containing RHA as cement constituent and CBA as sand replacement. In order to achieve the main objective, the following specific objectives are listed.

1. To determine the compressive strength development of RHA-seawater concrete containing 0% to 100% volume of coal bottom ash CBA.
2. To investigate the sound absorption and transmission performance of RHA-seawater concrete containing 0% to 100% volume of coal bottom ash CBA.
3. To analyse the microstructure of the RHA-seawater concrete with coal bottom ash using a scanning electron microscope (SEM).

1.5 Scope of study

The main study is to determine the acoustic performance of seawater concrete was added to the RHA and CBA at low frequency. 10% RHA was used as a replacement for ordinary Portland cement (OPC) by weight combined with seawater and coal bottom ash (CBA) as a replacement for sand in concrete. The volume of CBA as sand was 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. Table 1.1 shows the detail of the scope of study in this research. Firstly material's physical propertieswas tested such as specific gravity, sieve analysis, water absorption, pH, scanning electron microscope (SEM) and particle size analysis (PSA) to ensure the material's properties follow specifications to use in the Department of Environment (DoE) method as mixture design for testing compressive strength, sound absorption, and sound transmission of concrete. Next, to follow the objective 1, the specimens' size 100 × 100 × 100 mm was tested in 7 days and 28 days as the design strength is 50 MPa at 28 days. The standard used was BS EN 12390-1-2012 for compressive strength of trial mixtures (3 mixtures) and actual mixtures (11 mixtures) by using compressive strength using the universal testing machine (UTM). The second objective, two sizes were used in cylindrical shape with different thickness (100 mm and 200mm) in sound absorption and transmission by using impedance tube. The standard used was BS EN ISO 10534-2:2001. The final outcome is to analyse the acoustic results in low frequency by using the regression analysis. Lastly for objective 3, the microstructure of concrete is used to analyse the concrete surface and the chemical reaction in concrete mixture by SEM-EDX. It was conducted for concrete with 0%, 20%, 40%,60%, 80% and 100% of CBA. Overall total numbers of specimen is 156 specimens.

1.6 Significant of study

Based on this study, the reuse of RHA and CBA in concrete production can minimise pollution and maximise the use of waste in industries. The feasible development approach can fulfil the Malaysian Government plan in Twelfth Malaysia Plan 2021-2025 (RMKe-12) to increase the usage of green technology in the construction industry. Green technology can be spread into several categories, i.e., in green buildings and recycling waste as WtE. It can break down the barrier of the waste material, including the construction and demolition waste (C&D waste) used as green building materials. It also an alternative to community related issue of air pollution that comes from the production of RHA and CBA that can harm the ecosystem and environment by recycling the waste to create beneficial products. For industry practices, it helps to reduce the landfills or dump places. This can save RHA and CBA disposal costs, and the waste storage for non-recycled waste. Meanwhile, for acoustic performance, the concrete might benefit the sound absorption and transmission more than normal concrete. Thus, the hearing problem and noise pollution coming from sound-related issues further can reduce.

1.7 Novelty of study

CBA is a porous material to promote low density and potential to create sound absorption and transmission performance. This research introduced seawater-RHA concrete with a high volume of sand replacement with CBA, but within acceptable structure strength. This study was generated and used as a future study.

1.8 Thesis outline

The thesis consists of five (5) chapters. The elements of the chapter explained the content of the thesis. Chapter 1 started with the introduction of the RHA-seawater concrete with CBA was started with the background of study, problem statement,

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VITA

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