THE POTENTIAL OF PADDY HUSK AS SOUND ABSORBER IN CONCRETE MIXTURE

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by

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I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

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LIST OF ABBREVIATIONS

UNSC	United Nations Statistical Commission
WHO	World Health Organization
NIHL	Noise-Induce Hearing Loss
USM	Universiti Sains Malaysia
SEM	Scanning Electron Microscopy
ICB	Interlocking Concrete Blocks
WCP	Waste Concrete Powder
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
RHC	Rice Husk Concrete
TWC	Treated Wood Concrete
RGC	Rubber Granule Concrete
IEA	International Energy Agency

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ABSTRAK

Kajian ini menilai prestasi komposit berasaskan simen yang dibuat dengan sekam padi dan bertujuan untuk digunakan dalam penghalang akustik. Oleh kerana halangan akustik terdedah kepada keadaan luaran dan beban mekanikal, pelbagai ujian makmal telah dilakukan untuk menilai ciri mekanikal, ketahanan dan akustik komposit. Matlamat kajian ini adalah untuk menentukan sifat fizikal campuran konkrit dengan sekam padi sebagai penggantian separa agregat halus, untuk menilai sifat akustik campuran konkrit dengan sekam padi sebagai penggantian separa agregat halus dan untuk merumus nisbah optimum untuk campuran konkrit dengan sekam padi. sebagai pengganti agregat halus separa untuk pengecilan bunyi. Sampel direka mengikut penambahbaikan kesan bunyi penebat sambil mengekalkan kekuatan. Potensi sekam padi sebagai pengganti dalam campuran konkrit telah dikaji dalam meningkatkan mekanikal dan potensi penghalang. Kekuatan sampel disiasat menggunakan ujian mampatan dan kesan hingar didapati menggunakan ujian penyerapan bunyi menggunakan tiub galangan. Enam sampel disediakan mengikut ujian mampatan iaitu tiga sampel diuji pada umur 7 hari dan tiga sampel lagi diuji pada umur 28 hari. Untuk ujian penyerapan bunyi, sampel disediakan mengikut saiz sebenar tiub impedans, iaitu tiga sampel bagi setiap kategori. Berdasarkan Malaysian Standard MS EN 1992-1-1:2010, Konkrit gred C30 dipilih sebagai kawalan mudah dengan mengambil kira kelas XC1 berkenaan kelas pendedahan yang berkaitan dengan keadaan persekitaran mengikut. Konkrit dengan penggantian 3% mewakili hasil kekuatan mampatan terbaik 30.63 N/mm^2 dan hasil penyerapan bunyi 0.630 A. Oleh itu, kekuatan konkrit mencapai keperluan lebih daripada 30 N/mm^2 untuk mengekalkan kekuatan sambil meningkatkan pekali penyerapan bunyi. Nisbah formula baru untuk menambah baik campuran konkrit dicapai.

ABSTRACT

This work evaluates the performance of cement-based composites made with paddy husk and intended to be used in acoustic barriers. Because acoustic barriers are exposed to external conditions and mechanical loads, a wide range of laboratory tests was performed to evaluate the mechanical, durability, and acoustic characteristics of the composites. This study aims to determine the physical properties of concrete mixture with paddy husk as a partial fine aggregate replacement, assess the acoustical properties of concrete mixture with paddy husk as a partial fine aggregate replacement, and formulate the optimum ratio for concrete mixture with paddy husk as a partial fine aggregate replacement for sound attenuation. Samples were designed to the improvement of insulation noise effects while maintaining strength. The potential of paddy husk as a replacement in the concrete mixture was studied in improving the mechanical potential of the barrier. The strength of the sample is investigated using a compressive test and the noise effect is found using a sound absorption test using an impedance tube. Six samples are prepared according to the compressive test which is three samples are tested on 7 days of age and the other three samples are tested on 28 days of age. For the sound absorption test, samples are prepared according to the actual size of the impedance tube, which is three samples for each category. Based on Malaysian Standard MS EN 1992-1-1:2010, Concrete grade C30 is selected as the control sample by considering XC1 class regarding exposure classes related to environmental conditions in accordance. Concrete with 3% replacement represents the best compressive strength result at 30.63 N/mm^2 and sound absorption result 0.351 A. Hence, the strength of concrete achieves the requirement greater than 30 N/mm^2 to maintain strength while improving the sound absorption coefficient. A new formulate ratio for improving concrete mixture was achieved.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Noise pollution is unpleasant or excessive, which can interfere with human or animal life's activity or balance. However, unwanted sound can interrupt activity where quietness is desirable, distracts concentration, decreases communication quality, and contribute to individual stress. The human norm ear system has the limitation of the sound capacity to perceive and receive sound. Research has focused on the fairly clear quality of life effects associated with intrusive noise annoyance (Bina Iyer, 2021; Yang et al., 2020; Swift, 2010). To do so, a vulnerability assessment of insulation noise to structure must be considered.

This study also looks at the sustainability that can be achieved in the environment. Referring to European Union (2016), the construction sector worldwide has a significant social and economic impact, providing housing and contributing to employment opportunities and economic growth. However, this industry is also responsible for negative impacts, such as depletion of natural resources, significant energy consumption, and waste generation, all of which must be tackled. As a relevant consumer of resources and support for the economy, the construction industry can play an important part in developing innovative strategies for reducing impacts on the environment (United Nations Statistical Commission-UNSC, 2015). Therefore, to decrease waste output, efforts must be concentrated on increasing energy efficiency while applying waste recovery.

To achieve sustainability in the environment, controlling waste production need to be tackled. Paddy husk has been researched as a concrete aggregate replacement for conventional aggregates (Prusty et al., 2016; Makul et al., 2014). When one takes into account the enhanced thermal performance and the decreased environmental impact during the life cycle, rice husk integration offers potential benefits. These studies assess the impacts of waste incorporation on the mechanical characteristics, performance, and durability of concrete (Kocaman et al., 2011). Due to its strength and very useful qualities after hardening, concrete is one of the most often utilized materials. Applying prefabrication technology to the creation of construction materials has various benefits, including enhancing quality and durability, and producing solutions with more appealing and intricate designs, such as hybrid concrete (Fu et al., 2021; Eastman et al., 2003; Sacks et al., 2004). Since a major amount of concrete is still produced annually, it is critical to develop precast solutions and waste material integration strategies to increase sustainability.

1.2 Problem Statement

According to Grossi (2021) and Choiniere (2010), an example of unwanted sounds such as traffic sound, construction tools, airplanes, and leaf blowers harms human health and well-being. According to World Health Organization - WHO (2004), for a technical meeting on sleep health, excessive noise can cause hearing loss, disturbs sleep, and triggers hormones that could affect the immune system, metabolism, and cardiovascular system.

Noise exposure for long period can lead to a negative impact such as hearing loss and speech interference, and also may contribute to sleep disturbance and increase high blood pressure when continuous noise exposure happened (Isa et al., 2018). The excessive noise with continuous ringing in the ears will produce the symptom of tinnitus and Noise-Induce Hearing Loss (NIHL) will damage the cochlea in the inner ears where the hair cell cannot regrow and no treatment (Zaiton et al., 2015).

The principal byproduct of commercial rice processing is the husk. Paddy husks are a major source of pollution and have no commercial use. It is low in density and has a high volume. A fibrous substance primarily made of cellulose, lignin, and silica is insoluble in water. This material also has little nutritional benefits and resists deterioration from the elements (Genieva et al., 2008).

A huge percentage of the produced rice husk gets dumped untreated in the soil. The decomposition of paddy husk takes around five years and a significant amount of methane (CH_4) is produced because of this operation. Uncontrolled outdoor burning of the paddy husks is another option for disposal, although this process releases a lot of carbon monoxide (CO) and carbon dioxide (CO_2) (Della et al., 2001). Turning them into products is the best way to make use of those materials.

Several studies have provided data that shows replacement material in concrete mixture give a negative impact on the strength of the sample. The characteristic of the paddy husk gives some improvement in the mechanism of the mixture in term of workability, strength, and durability. Industry can allow tackling this issue by generating products. In addition, fewer studies have been done to comprehend the effects of presenting paddy husk in a concrete mixture with a certain percentage of occupational noise pollution.

1.3 Objectives

This research aims to investigate the potential of paddy husk as a replacement in the concrete mixture. Observations are carried by their workability, strength, density, and sound absorption coefficient. The objectives of this study are:

a) To determine the physical properties of concrete mixture with paddy husk as partial fine aggregate replacement.

b) To assess the acoustical properties of concrete mixture with paddy husk as partial fine aggregate replacement.

c) To formulate the optimum ratio for concrete mixture with paddy husk as a partial fine aggregate replacement for sound attenuation.

1.4 Scope of Work

In this project, the potential of paddy husk is investigated by formulating the optimum ratio for concrete mixture with paddy husk as a partial fine aggregate replacement for sound attenuation. In industrial rice processing, the production of paddy husk as waste is in plenty amount. Method to innovate that waste into a product by adding into the concrete mixture as a replacement with river sand. Paddy husks have similar characteristics to river sand, in terms of sizing. Paddy husks are collected from Tan Ah Boy Sdn. Bhd. Rice Factory at Jitra, Kedah has an elongated shape, ranges from 1 mm to 3 mm wide, and is about 10 mm long.

This experiment is conducted to study the physical properties of the potential for reducing noise and waste generation. The compressive test is proposed to identify the physical characteristic which is the strength of samples while sound absorption tests are used to find the specific sound absorption coefficient using an impedance tube (Siemens PLM Software). Six samples prepared for the compressive test is representing three cubes for 7 days curing period and three cubes for 28 days curing period. Sample for sound absorption test required three tube samples for both 7 days and 28 days of curing period. The curing tank is able of maintaining a constant temperature and stopping moisture loss from the specimen. The average reading is determined to get an accurate result.

Before the future investigation, the trial mixture is proceeded with a 10% replacement on Concrete grade C30 to identify the workability, strength, and sound absorption coefficient of the sample. Based on that investigation, the selected percentage replacement were 0%, 1%, 3%, 5% and 10%. Every physical and acoustical properties can be compared to formulate the optimum ratio of concrete mixture with paddy husk as a partial fine aggregate replacement for sound attenuation.

1.5 Dissertation Outline

This study consists of five chapters, which are the introduction, literature review, methodology, results, and discussion, as well as conclusion. Chapter 1 of this study discussed the background of the study, problem statement, objectives, scope of work, and dissertation of work.

Chapter 2 is the literature review, which discusses the related review or research articles done by previous researchers such as paddy husk cement-based composites for acoustic barriers, sustainable performance criteria for concrete buildings, potential paddy husk ash produce ultra-high performance concrete, effects of paddy husk on strength, water permeability and workability of the concrete mixture.

Chapter 3 is relating to the methodology of this study, which describes the overall flow method and general steps involved in the prepared sample and characteristic analysis procedures such as testing on concrete using a compressive machine (compressive strength test) and impedance tube Siemens PLM Software (sound absorption test).

Chapter 4 refers to the results and discussion of this study, which will cover the results obtained from the analyses. The results obtained will be thoroughly discussed based on the vulnerability functions.

Chapter 5 is the conclusion of this study, which concludes the overall achievement of this result based on the objectives. The contribution of this study to civil engineering will be discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, this research is broken down into several components while the findings and results generated by laboratory testing related to the sample structure characteristic are discussed. To achieve sustainability, this study is important to find a way to avoid noise pollution. Besides, a few case study examples of preparing sample methods are utilized to estimate the efficiency of paddy husk as a replacement in terms of improving sound absorption. Moreover, this chapter also compiles most of the preparation, testing, and observation related to studies carried out.

2.2 Noise Pollution

Noise pollution is a kind of pollution that has a negative influence on health and well-being across the world. Unwanted sound is what we call noise. Noise is a significant contributor to aggravation, as evidenced by the aftereffect of continuous observation of commotion at proportional degrees of public attention, training, administration, and auxiliary outlining. Noise can cause hearing loss, sleep disturbance, cardiovascular illness, decreased productivity, bad social behavior, irritation responses, absenteeism, and other health issues. Noise, like prolonged stress, harms overall health and well-being (Bina Iyer, 2021).

Other than that, Yang et al., (2020) introduce that noise pollution is a significant health issue in the contemporary world, and minimizing residents from noise exposure would help prevent the following well-known health consequences such as sleep problems, learning impairment, cardiovascular illnesses, metabolic syndrome, hypertension, ischemic heart disease, increased risk of diabetes, obesity, and annoyance. Road traffic, train traffic, airports, and industrial facilities are all typical sources of noise pollution. Road traffic noise has become a serious environmental problem for people due to its widespread distribution and long-term effects.

According to the Department of Environment Ministry of Nature Resources and Environmental Malaysia, limitation sound levels can be divided into five levels. Specifications for permissible sound levels, and limit sound levels (L_{Aeq}) for road traffic is shown in Table 2.1.

Table 2.1 Permissible sound levels, limit sound level (L_{Aeq}) from road traffic (Schedule 4, Annex A - Department of Environment Ministry of Nature Resources and Environmental Malaysia., 2007).

Receiving Land Use Category	Day Time 7.00 am - 10.00 pm	Night Time 10.00 pm - 7.00 am
Noise Sensitive Areas Low Density Residential Areas	55 dBA	50 dBA
Suburban Residential (Medium Density)	60 dBA	55 dBA
Urban Residential (High Density)	65 dBA	60 dBA
Commercial, Business	70 dBA	60 dBA
Industrial	75 dBA	65 dBA

2.3 Sound Absorption

Referring to Anshuman Shrivastava, in Introduction to Plastics Engineering (2018), the amount of energy absorbed by a sound wave as it travels through a certain thickness of the material is called the absorption coefficient. Sound absorption and reflection of an insulating wall are depicted schematically in Figure 2.1. The sound wave may suffer reflection or absorption when traveling from air into an absorbing substance, resulting in energy loss and dampening effects. Sound is absorbed by a polymeric substance by converting sound waves into heat.

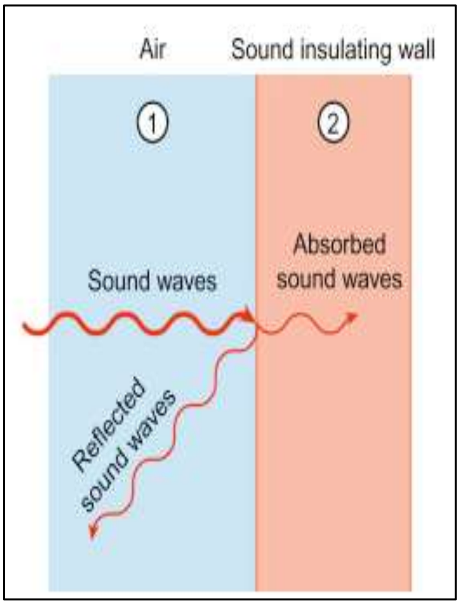

Figure 2.1 Mechanism of sound absorption and reflection of an insulating wall (Anshuman Shrivastava, 2018).

Regarding Ramadhansyah Putra Jaya, in New Materials in Civil Engineering (2020), the sound absorption test was carried out using an impedance tube, two microphones, and digital frequency analysis equipment, as per the standard test technique for the impedance and absorption of acoustical materials. The sound absorption coefficient of absorptive materials has been measured using this testing machine. The impedance tube was filled with a porous concrete sample. Then, using a broadband signal from a noise source, the planned waves are created in the tube.

Sound pressures are measure concurrently at two separated sites in the tube's sidewall to decompose the stationary sound wave pattern into forward and backward moving components. Processing an array of complex data from the observed transfer function is used to calculate the normal incidence absorption coefficients for the acoustical material. The apparatus required for this test is shown in Figure 2.2.

Figure 2.2 Setup apparatus required for sound absorption test (Ramadhansyah, 2020).

As shown in Figure 2.3, the one-third octave frequency ranges represent the sound absorption data for typical sound incidence.

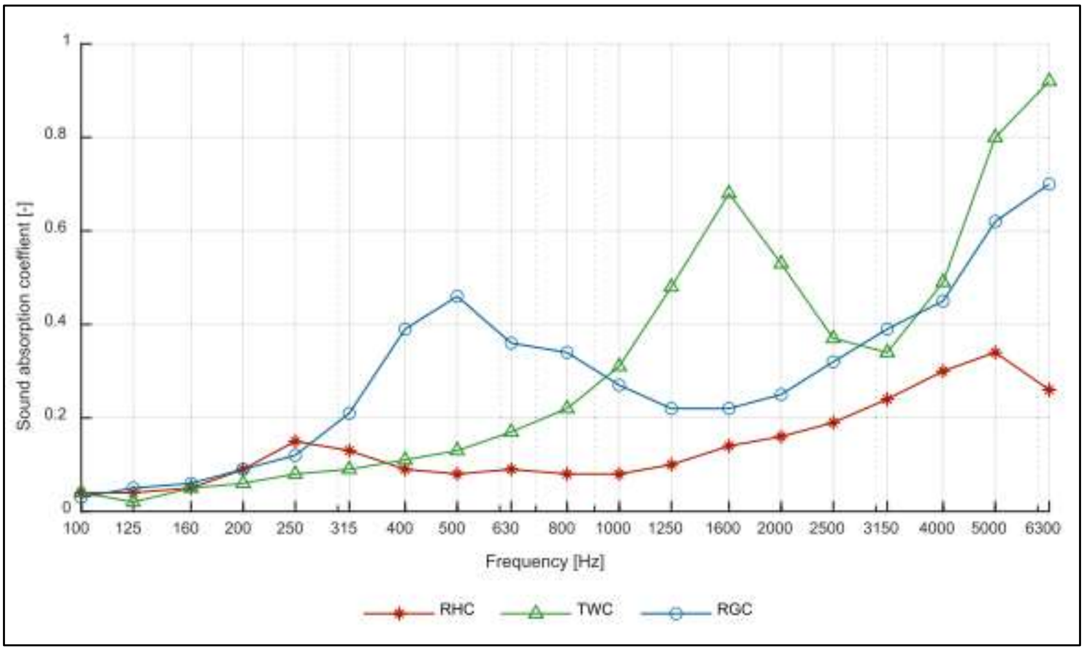

Figure 2.3 Sound absorption coefficient results for normal sound incidence, (Marques et al., 2021).

Based on the data, porous absorbers are inefficient at low frequencies due to decreased particle velocity (nearly to zero) towards the back boundary. The sound absorption coefficient for each sample was below 0.15 placed up to 250 Hz frequency. However, by increasing the thickness, this performance may be increased. Mineral wool, for example, has a sound absorption value of 0.11 for a sample 25 mm thick and 0.35 for a sample 50 mm thick at 250 Hz. Changing the form of the surfaces, particularly by introducing edges, might also help increase low-frequency sound absorption. RHC still has a worse sound absorption coefficient for all frequencies higher than 250 Hz. The various compositions, as well as the surface features of the samples, might explain these outcomes. Figure 2.4 shows a sample of rice husk (RHC), treated wood (TWC), and recycled rubber granules (RGC).

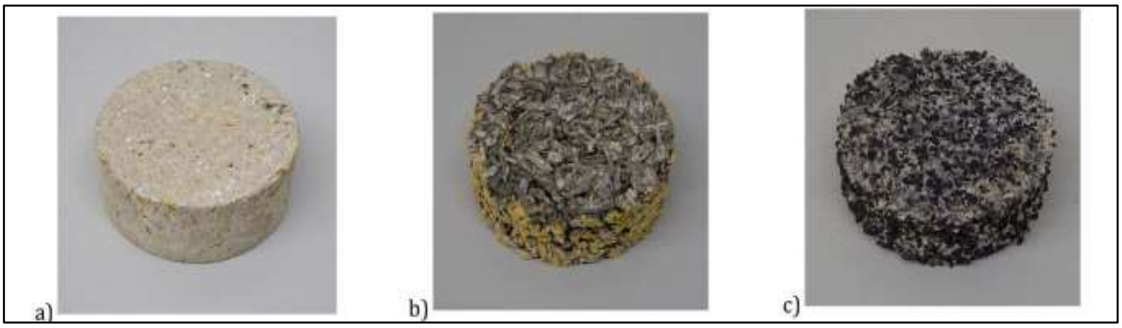

Figure 2.4 Samples with 100 mm diameter used in the impedance tube: a) RHC; b) TWC; c) RGC (Marques et al., 2021).

Although the RHC composite has a larger open porosity than the RGC composite, the higher b/a ratio helps to smooth the surface of the samples, minimizing sound absorption. Furthermore, the soaked rice husk concentration might result in a more homogenous mix, lowering the sound absorption ability of these composites. In addition, the TWC formulation has stronger sound absorption across a larger frequency range and has higher open porosity outcomes.

The pores inside the composites are influenced by the aggregate size. Big porosity is generated when only large particles are employed and no small aggregates are used. Although larger pores are preferable, the experiments on composite mortars made of used tire rubber particles indicated that composites with finer but tightly linked pores are more successful at absorbing sound (Corredor-Bedoya et al., 2017).

Other research emphasizes the impact of aggregate physical characteristics such as structure, porosity, and shape on sound absorption performance (Li et al., 2019). Furthermore, the RHC's high cement concentration lowers air spaces inside the composites, which helps to lower sound absorption performance shown in Figure 2.4. The sound absorption measurements from the reverberation chamber are displayed in third-octave frequency bands with a range of 100 to 5000 Hz in Figure 2.5 and Table 2.2.

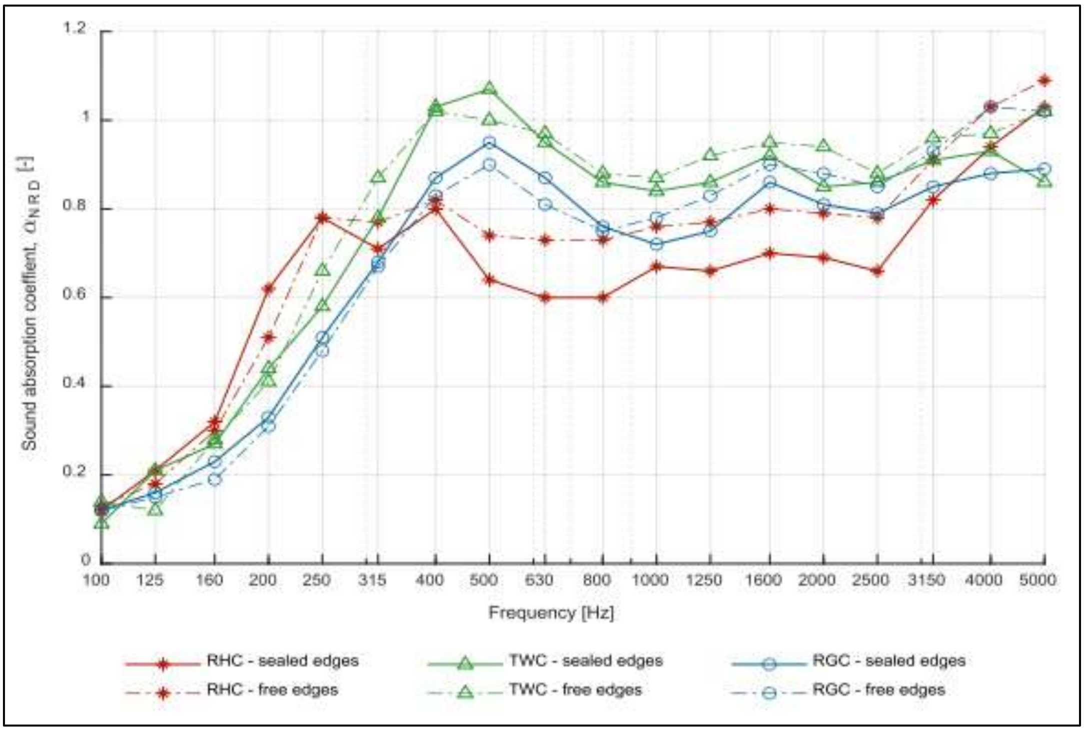

Figure 2.5: Sound absorption results, with free and sealed edges (Marques et al., 2021).

Table 2.2: Sound absorption results with free and sealed edges (Marques et al., 2021)

Sample	α_w [−]		SAA [−]		$DL_{\alpha,\ NRD}$ [dB]	
	Sealed edges	Free edges	Sealed edges	Free edges	Sealed edges	Free edges
RHC	0.70	0.8	0.68	0.75	5	6
TWC	0.85	0.9	0.84	0.86	8	9
RGC	0.75	0.8	0.74	0.75	6	7

The TWC sample had the maximum sound absorption coefficients from 315 to 3150 Hz, according to the data. Outside of this range, however, the RHC samples show an increase in sound absorption ability at lower and higher frequencies. As the absorption area is lower by sealing the edges of the samples, the sound absorption coefficients are reduced. Nonetheless, the findings suggest that employing rice husk, as acoustic barriers might be a viable and cost-effective alternative to other lightweight materials such as treated wood.

2.4 Material

Numerous building materials have been explored that include waste from many sectors, including mortars (Silva et al., 2016), concrete (Brito et al., 2013), and insulating materials (Asdrubali et al., 2015). Due to its durability and good practical qualities after hardening, concrete is one of the most extensively utilized materials. However, according to the International Energy Agency – IEA (2018), cement manufacture, which is a key component of contemporary concrete and mortars, has a severe influence on the environment. Because a large amount of concrete is still produced each year, it is critical to create techniques for improving its sustainability by utilizing waste materials and generating precast solutions. Because a large amount of concrete is still produced each year, it is critical to create measures to enhance its sustainability, such as utilizing waste materials and producing precast alternatives.

The application of prefabrication technology to the development of building materials has various benefits, including improved quality and durability, the possibility to create solutions with more attractive and sophisticated designs, and the reduction of energy and water use (Baglivo et al., 2016; Chen et al., 2010). Additionally, cement-based composites, such as acoustic barriers and cladding panels, may quickly adapt to complicated geometries and combinations before hardening. In addition to these advantages, using cement-based composites in precast parts with increased thermal and acoustic performance may satisfy the functional requirements of the final solutions.

Referring to Figure 2.6, rice husk is obtained in Portugal's Baixo Mondego agricultural area (Figure 2.6a), has an elongated form, is 1 to 3 mm broad, and is around 10 mm long. The apparent bulk density of the rice husks examined varies between 90 and 110kg/m^3. Granlund supplied the wood aggregates (Figure 2.6b). This firm makes laminated aggregates from neutralised wood aggregates that have been process with sodium silicate for use in lightweight concrete. Wood particles having an apparent bulk density of 380 kg/m^3 and particle sizes of 2–8 mm (width and length) were chosen for the cement-based mixtures. Biosafe supplied the recycled rubber granules (Figure 2.6c), which were made by mechanically grinding old tires into an uneven spherical form. Rubber granules measuring 2–4 mm and having a bulk density of roughly 430 kg/m^3 is used to make cement-based composites. Sieving is used to determine the particle size distribution of the various aggregates (CEN-European Committee for Standardization EN 933-1, 2012).

Figure 2.6: Materials used in the composites: a) Rice husk; b) Treated wood; c) Recycled rubber granules (Marques et al., 2021).

Paddy husk has been investigated as a possible alternative for traditional aggregates in concrete. These investigations look at the impacts of waste integration on concrete's mechanical behavior and durability, whereas integrating rice husk offers potential benefits in terms of increased thermal performance and lower environmental impact across the life cycle (Rosa et al., 2015).

The use of rice husk in the building industry is not new. The majority of rice husk research and applications in building materials concentrate on eliminating the organic component. Much of the recent research has focused on utilizing rice husk ash as a partial substitute for Portland cement in cement concrete to enhance the mechanical performance and durability of concrete mixtures (Prusty et al., 2016; Van et al., 2014; Van Tuan et al., 2011; Givi et al., 2010).

There are also few instances of natural rice husk being included into composite materials using mineral binders, with obvious advantages in terms of thermal insulation and density reduction (Sisman et al., 2014; Chabannes et al., 2014). However, cement mixtures including the percentage of paddy husk may still be used for many helpful studies into durability and improved acoustic qualities.

2.5 Experimental Setup on Sample Testing

This study takes an experimental approach to the characterization of these cement-based composites and different test methods were selected for this purpose. The samples were tested after a curing period of 7 and 28 days and each sample perform several test samples. Physical and mechanical tests were performed to assess sound absorption coefficient, workability, and compressive strength.

Regarding the result (Marques et al., 2021) in Table 2.3, the findings observe that between 315 to 3150 Hz, the treated wood concrete (TWC) sample has the highest sound absorption coefficients. For lower and higher frequencies outside of this range, the effectiveness of sound absorption of rice husk concrete (RHC) has improved. As the absorption area is decreased by sealing the sample edges, the sound absorption coefficients decrease. However, the findings suggest that employing rice husk as acoustic barriers can be a workable and affordable alternative to other widely used lightweight materials, including treated wood. For the durability characteristic, a Visual inspection was performed on the cubic samples to look for material disaggregation or cracking. Figure 2.7 shows that there were no observable indications of material disaggregation or substantial cracking during wet-dry cycles while representing the sample before and after the compressive test.

Table 2.3: Compressive strength variation after wet-dry cycles: a) Before cycles; b) After cycles (Marques et al., 2021).

Sample		Compressive strength [MPa]	Variation [%]
RHC	a)	9.34 (±1.46)	−15.5
	b)	7.89 (±1.05)	
TWC	a)	5.11 (±1.55)	−24.3
	b)	3.87 (±1.99)	
RGC	a)	1.31 (±0.05)	−36.5
	b)	0.83 (±0.12)	

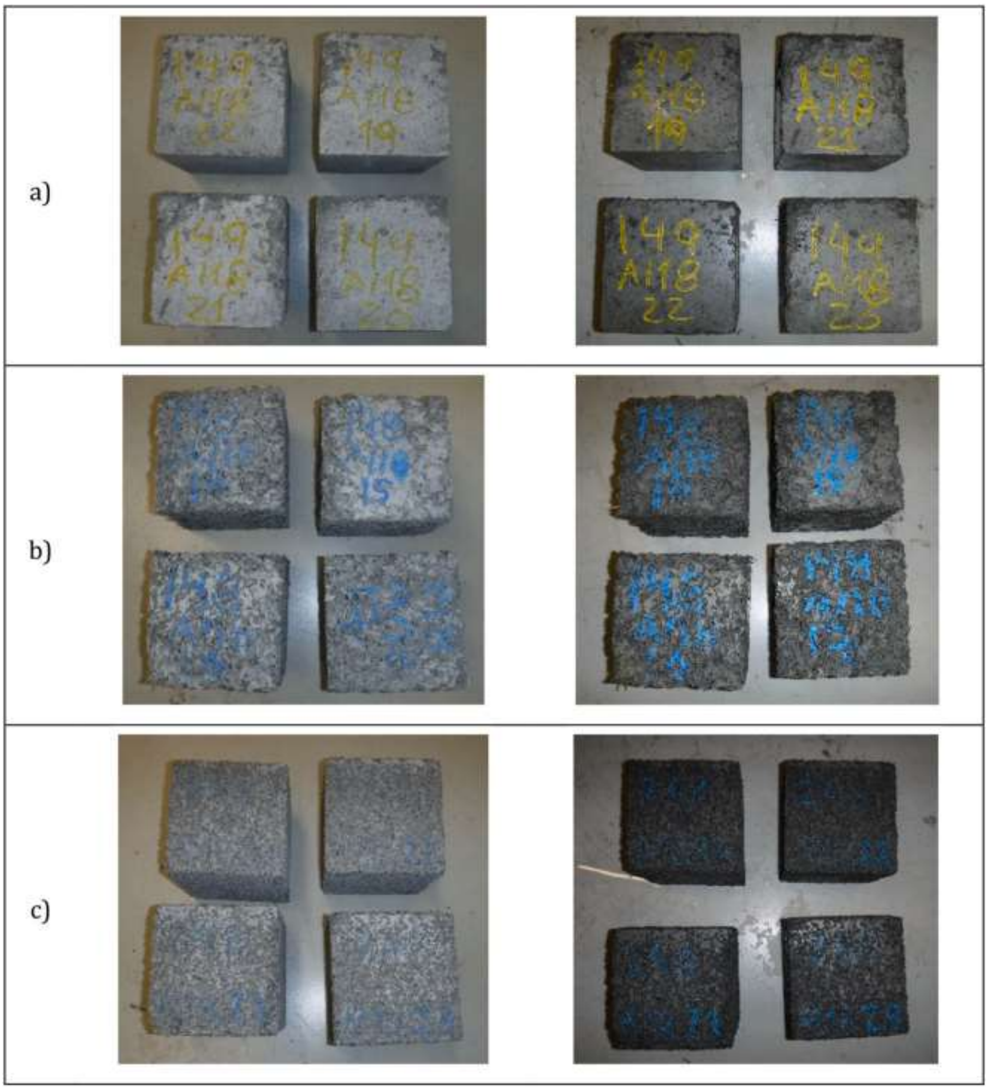

Figure 2.7: Test samples before (left) and after (right) wet-dry cycles: a) RHC; b) TWC; c) RGC (Marques et al., 2021).

The results in Table 2.3 show that rubber granule concrete (RGC) undergoes a greater reduction in compressive strength. Water can enter the composites during the cycles due to their open and large pores. In this test, placing the samples in dry, saturated conditions without regard to temperature. Water can enter the composites during the cycles due to their open and large pores. According to Chabannes et al., porosity and binder-aggregate ratio are related to each other. Air and water from the outside can easily enter the composite when porosity rises, which will affect the aggregate, the matrix, and their interface adhesion.

According to Mohr et al., the fiber-matrix interfaces are where cement-based composites with vegetable fiber begin to degrade during wet-dry cycles. The scientists noted that the re-precipitation of hydrated compounds takes place in air spaces that are created when there is a loss of adhesion between these elements. When using more composites that have porous, the swell and shrinkage of the vegetal aggregates cause changes in the contact pressure across the interface. Hence, the type of sample is related to the effect of the composition of the sample that leads to a change in form of character and ability in form of maintaining durability, and strength while having a suitable sound absorption. A suitable percentage of materials such as rice husk are formulated in this study to achieve all objectives.

2.6 Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) scans the surfaces of substances, particles, and fibers so that small details can be quantified and evaluated through image analysis. Industry can use SEM to address contamination issues, explore component failure, find unidentified particles, or research how chemicals interact with their substrates. Additionally, it can offer a plethora of knowledge to enable the study of substances, compounds, or biological samples. Awoyera et al., (2021) study water absorption, strength, and microscale properties of interlocking concrete blocks made with plastic fiber and ceramic aggregates. Based on this study, the microstructure and mineralogy of selected samples were observed using Scanning Electron Microscopy (SEM). Figure 2.7 shows the result of Scanning Electron Microscopy (SEM).

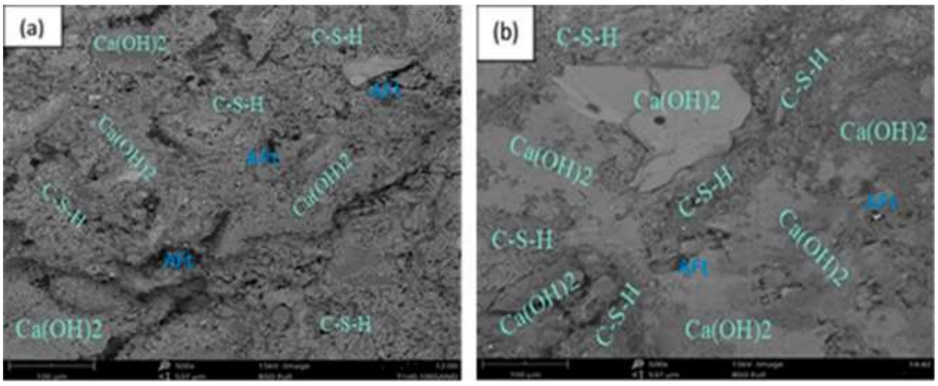

Figure 2.8: Result for SEM analysis (a) Control- interlocking concrete blocks (ICB) and (b) 2%PF – interlocking concrete blocks (ICB) (Awoyera et al., 2021).

Based on Figure 2.8, the result monitored from control- interlocking concrete blocks (ICB) and the 2%PF- interlocking concrete blocks (ICB) showed ettringite, which has been developed due to the somewhat high ceramic content. When concrete is fresh, ettringite forms to prevent cement from flash setting, but when concrete is aged, it indicates that cement has not yet fully hydrated which will cause expansion. It consequently made the concrete material weaker.

It was discovered that when cement was hydrated using waste concrete powder (WCP), calcium silicate hydrate (C-S-H) radiating fibers, which matched the pattern of C-S-H in regular cement, encircled the angular cement grains. Particle ettringite crystals and randomly oriented portlandite ($Ca(OH)^2$) crystals were widely distributed throughout the control-interlocking concrete blocks (ICB) and the 2 percent PF-interlocking concrete blocks (ICB) (Figure 2.8). However, it was discovered that the WCP grains in the 2 percent PF- interlocking concrete blocks (ICB) were covered in a layered CH hydration product that was amorphous (in terms of C-S-H). Short radicular C-S-H outgrowths around cement grains and needle-shaped ettringite crystals make up the majority of the matrix phase (Figure 2.8). An amorphous gel that filled the crevices between the hydrated particles revealed the architecture of the 2 percent hydrated PF-interlocking concrete blocks (ICB).

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the overall flow of the study starting from the desk study on the paddy husk is shown in Figure 3.1. The design of the concrete mixture and testing on samples according to the standard specification was also discussed in this chapter. Table 3.1 shows the reference from Table 2.1 of MS EN 1990- basic of structure design, the design working life of the concrete is designed in category four (50 years) which is referring to building structure and other common structures.

Table 3.1: Indicative design working life (MS EN 1990- basic of structure design, 2010)

Design working life category	Indicative design working life (years)	Example
1	10	Temporary structure.(1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearing.
3	15 to 30	Agriculture and similar structures.
4	50	Building structures and other common structures.
5	100	Monumental building structures, bridges, and other civil engineering structures.
(1) Structures or parts of structures that can be dismantled to be re-used should not be considered temporary.		

In concrete mixture design, the usage of the sample 50 years of working life refers to class XC1. Samples were prepared to achieve the standard that refers to class XC1 based on Table 3.2. Table 3.2 shows the class of the design mix and their recommendations for normal-weight concrete quality for exposure classes XC, XD, and XS, that cover reinforcement for 50 years.

Table 3.2: Recommendations for exposure classes XC, XD, and XS, that cover reinforcement for a 50-year intended working life and 20 mm maximum aggregate size (MS EN 1990- basic of structure design, 2010)

Table NA2. Recommendations for normal-weight concrete quality for exposure classes XC, XD and XS and cover to reinforcement for a 50 year intended working life and 20 mm maximum aggregate size

Exposure conditions[a]			Cement/ combination types[b]	Nominal cover (c_{min} + Δc_{dev})[c] to reinforcement (including prestressing steel) in mm and associated recommended designed concrete and equivalent designated concrete[d]							
				15 + Δc_{dev}	20 + Δc_{dev}	25 + Δc_{dev}	30 + Δc_{dev}	35 + Δc_{dev}	40 + Δc_{dev}	45 + Δc_{dev}	50 + Δc_{dev}
Carbonation induced corrosion	XC1	Dry or permanently wet	All	C20/25, 0.7, 240 or RC25	⇦	⇦	⇦	⇦	⇦	⇦	⇦
	XC2	Wet, rarely dry	All	-	-	C25/30, 0.65, 260 or RC30	⇦	⇦	⇦	⇦	⇦
	XC3 XC4	Moderate humidity Cyclic wet and dry	All except IVB	-	C40/50, 0.45, 340 or RC50	C32/40, 0.55, 300 or RC40 (See Note 3)	C28/35, 0.60, 280 or RC35 (See Note 4)	C25/30, 0.65, 260 or RC30	⇦	⇦	⇦
Chloride induced corrosion excluding chlorides from seawater	XD1	Moderate humidity	All	-	-	C40/50, 0.45, 360	C32/40, 0.55, 320	C28/35, 0.60, 300	⇦	⇦	⇦
	XD2	Wet, rarely dry	I, IIA IIB-S, SRPC	-	-	-	C40/50, 0.45, 380	C32/40, 0.50, 340	C28/35, 0.55, 320	⇦	⇦
			IIB-V, IIIA	-	-	-	C35/45, 0.40, 380	C28/35, 0.50, 340	C25/30, 0.55, 320	⇦	⇦
			IIIB, IVB	-	-	-	C32/40, 0.40, 380	C25/30, 0.50, 340	C20/25, 0.55, 320	⇦	⇦
	XD3	Cyclic wet and dry	I, IIA, IIB-S, SRPC	-	-	-	-	-	C45/55, 0.35, 380	C40/50, 0.40, 380	C35/45, 0.45, 360
			IIB-V, IIIA	-	-	-	-	-	C35/45, 0.40, 380	C32/40, 0.45, 360	C28/35, 0.50, 340
			IIIB, IVB	-	-	-	-	-	C32/40, 0.40, 380	C28/35, 0.45, 360	C25/30, 0.50, 340

NOTES:

1. ⇦ indicates that the concrete given in the cell to the left applies.
2. Reference should be made to BS 8500-1:2002, Annex A for selecting the quality of concrete subjected to freeze/thaw conditions and concrete in aggressive ground conditions.
3. For residential building not exceeding 3 storeys high, use C28/35, 0.53, 300 for XC3 only [16]
4. For residential building not exceeding 3 storeys high, use C25/30, 0.59, 280 for XC3; use C28/35, 0.53, 300 for XC4 [16]

[a] Exposure conditions conform to BS EN 206-1:2000 or equivalent to any Malaysian standards.

[b] Cement/combination types are defined in BS 8500-2:2002, Table 1.

[c] For values of Δc_{dev}, see 4.4.1.3 (1) and (3) of Table NA1.

[d] The recommended designed concrete is taken from BS 8500-1:2002 and described in this table in terms of strength class, maximum w/c ratio, minimum cement or combination content in kg/m3. The equivalent recommended designated concrete is taken from BS 8500-1:2002 and indicated in this table by the designation RC.

Based on the concrete mix design, the target means strength of the sample is 30 N/mm². The cement type used in the concrete mixture is OPC. Aggregate type for fine and course is uncrushed. Mix design form will provide a design ratio for concrete mixture grade C30 as a control sample.

855 kg of fine aggregate were replaced with paddy husk according to the proposed percentage during the preparation phase. Table 3.3 shows the concrete mix design form used in the preparation of concrete mix.

Table 3.3: Concrete Mix Design Form

Table 1. Concrete Mix Design Form (BRE method) Job title: FYP - Concrete mix with Paddy husk

stage	item		Reference or calculation	Values
1	1.1	Characteristic strength	Specified	30 N/mm² at 28 days; Proportion defective 5 %
	1.2	Standard deviation	Fig. 3	5 N/mm² or no data ... N/mm²
	1.3	Margin	C1	(k= 1·64) x 5 = 8·2 N/mm2
			Specified	... N/mm²
	1.4	Target mean strength	C2	30 + 8·2 = 38·2 N/mm²
	1.5	Cement strength class	Specified	42.5/52.5 (OPC)
	1.6	Aggregate type: coarse		~~Crushed~~/Uncrushed
		Aggregate type: fine		~~Crushed~~/Uncrushed
	1.7	Free-water/cement ratio	Table 2, Fig. 4	0·5 — Use the lower value 0·5
	1.8	Max. Free water/cement ratio	Specified	0·52
2	2.1	Slump or VeBe time	Specified	Slump 60-180 mm or VeBe time 0-3 s
	2.2	Max. Aggregate size	Specified	20 mm
	2.3	Free-water content	Table 3	2/3 (195) + 1/3 (225) = 205 kg/m³
3	3.1	Cement content	C3	205 / 0·52 = 394·2 kg/m³
	3.2	Maximum Cement content	Specified	- kg/m³
	3.3	Minimum Cement content	Specified	- kg/m³
			Do not use less than 3.3 or more than 3.2	350 kg/m³
	3.4	Modified free-water/cement ratio		-
4	4.1	Relative density of aggregate (SSD)		2·65 known/assumed
	4.2	Concrete density	Fig. 5	2380 kg/m³
	4.3	Total aggregate content	C4	2380 - 394·2 - 205 = 1780·8 kg/m³
5	5.1	Grading of fine aggregate	Percentage passing 600 micron sieve	19·5 %
	5.2	Proportion of fine aggregate	Fig. 6	48 %
	5.3	Fine aggregate content	C5	1780·8 x 48/100 = 854·8 kg/m³
	5.4	Coarse aggregate content	C5	1780·8 - 854·8 = 926 kg/m³

Quantities	Cement (kg)	water (kg or lt)	Fine aggregate (kg)	Coarse aggregate (kg)		
				10 mm	20 mm	40 mm
Per m³ (to nearest 5 kg)	350	205	855		925	
Per trial mix of 0.0072 m³	2.52	1.48	6.16		6.66	

(Volume of 6 cube test + 6 tube BA test + Control Sample.)

The ratio of the mixture is 350kg for cement, 205 L for water, 855 kg for fine aggregate, and 925 kg for coarse aggregate. Every percentage fine aggregate replacement is calculated below and the result is summarised in Table 3.4.

The ratio from Concrete mix Design:

Cement (OPC): 350 Kg
Water : 205 Kg
Fine Aggregate : 855 Kg
Course Aggregate : 925 Kg

Compressive Strength Sample (Cube):
Size Sample : 100 mm x 100 mm x 100 mm
Volume Cube : 0.001 m^3
Total Sample : Six samples per mixture
Total Volume Cube : 0.006 m^3

Sound Absorption Sample (Cylinder Tube):
Size Sample : d = 34.8 mm, r = 17.4 mm, h = 55.0 mm
Volume Sample : $\pi r^2 h$
: 0.0000523
Total Sample : Six samples per mixture
Total Volume Cylinder : 0.000313 m^3

Total Volume : 0.006313 m^3
% Precaution (Kg) : 20%
Volume : 0.006313 m^3 + (20/100)0.006313 m^3
: 0.007576 m^3

Weight ratio in Kg for each material:
Weight per cast = Volume x Weight from Concrete Mix Design

Table 3.4: Weight ratio in Kg for each material in the concrete mixture.

Percentage (%)	**Volume (m^3)**	**Cement (kg)**	**Water (L)**	**Fine Aggregate (Kg)**		**Coarse Aggregate (Kg)**
				River Sand	**Paddy Husk**	
0	**0.007576**	2.652	1.553	6.477	0.000	7.008
1	**0.007576**	2.652	1.553	0.065	6.413	7.008
3	**0.007576**	2.652	1.553	0.194	6.283	7.008
5	**0.007576**	2.652	1.553	0.324	6.154	7.008
10	**0.007576**	2.652	1.553	0.648	5.830	7.008