Utilization of Waste Glass and Demolished Brick as Coarse Aggregate for Sustainable Concrete Production

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DECLARATION

I declare that this thesis entitled "Utilization of Waste Glass and Demolished Brick as Coarse Aggregate for Sustainable Concrete Production" is the results of my own research except as cited in the references.

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ABSTRACT

Cement is a vital global construction material, primarily used in concrete production, consisting of inert mineral aggregates like sand, gravel, crushed stones, and cement. crushed brick aggregates in concrete face challenges due to regulations on impurities, water absorption, and lack of understanding of concrete behaviour. The research aimed to prepare sustainable concrete by using waste glass and demolished brick, study the physical and mechanical properties of the concrete produced, and examine the effect of adding broken brick and waste glass as coarse aggregates. The study involved the creation of five different concrete compositions using varying percentages of waste glass and demolished brick, which were then subjected to a curing process for 1, 14, and 28 days. The samples were tested for compressive strength, water absorption and Optical Microscopy. On the 14th day, sample B demonstrated optimum results with a compressive strength of 15.34 MPa and a water absorption rate of 8.4%.

Keywords: Cement, waste glass, crushed brick, curing, concrete

Penggunaan Kaca Sisa dan Bata Dirobohkan sebagai Agregat Kasar untuk Pengeluaran Konkrit Lestari

ABSTRAK

Simen ialah bahan binaan global yang penting, terutamanya digunakan dalam pengeluaran konkrit, yang terdiri daripada agregat mineral lengai seperti pasir, kerikil, batu hancur dan simen. Agregat bata yang dihancurkan dalam konkrit menghadapi cabaran disebabkan oleh peraturan mengenai kekotoran, penyerapan air dan kekurangan pemahaman tentang tingkah laku konkrit. Penyelidikan bertujuan untuk menyediakan konkrit lestari dengan menggunakan kaca sisa dan bata yang dirobohkan, mengkaji sifat fizikal dan mekanikal konkrit yang dihasilkan, dan mengkaji kesan penambahan bata pecah dan kaca sisa sebagai agregat kasar. Kajian itu melibatkan penciptaan lima komposisi konkrit yang berbeza menggunakan peratusan berbeza kaca sisa dan bata yang dirobohkan, yang kemudiannya tertakluk kepada proses pengawetan selama 1, 14, dan 28 hari. Sampel telah diuji untuk kekuatan mampatan, penyerapan air dan mikroskop optik. Pada hari ke-14, sampel B menunjukkan hasil yang optimum dengan kekuatan mampatan 15.34 MPa dan kadar penyerapan air 8.4%.

Kata kunci: Simen, kaca sisa, bata hancur, pengawetan, konkrit

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CHAPTER 1

INTRODUCTION

1.1 Background Study

One of the numerous ways you can lessen waste and pollution is by recycling glass. Glass is frequently found in municipal solid waste containers, including beer, soft drink, wine, and liquor bottles, as well as food, cosmetic, and other product bottles and jars (Pavlů, 2018). Natural resources like sand are used to make the common material known as glass. Even though most glass waste is recycled that make new a glass of products, a sizeable portion remains wasted in landfills. Glass is a useful substance that cannot degrade, nevertheless taking up valuable landfill space (Harrison et al., 2020). Alternative kinds of recycling need to be looked at in order to stop glass trash from going to landfills. Regarding the broken bricks, their usage as aggregates is particularly important because it can help to preserve natural aggregate resources while also greatly reducing the need for trash storage. Nevertheless, there are certain difficulties to employing crushed brick aggregates in concrete, such as limitations imposed by regulations on impurities and water absorption as well as a lack of understanding of the behaviour of concretes can made a crushed brick (Debieb & Kenai, 2008).

Glass is an amorphous solid with a higher proportion of calcium and silica than other materials. It is challenging to dispose of items in a landfill since they do not degrade (Bisht & Ramana, 2018). That represents more than 74% of the collected trash soda. Despite a recent rise in waste glass recycling, lime glass is still removed in landfills and drains. A few of the problems include high recycling costs, source mixing of glass with different colours, and difficulties removing extra chemical warfare and residues from the waste glass stream (Nassar & Soroushian, 2011). Once moisture is present, the alkali-silica reaction is created when the hydroxyl ions in cement concrete mix with the silica component of glass or other reactive materials (Tamanna et al., 2020).

1.2 Problem Statement

Domestic construction waste creates 41 million tonnes every year. People tend to ignore the importance of nurturing natural resources. These are major issues in many countries around the world. It is critical to address this issue locally in order to maintain the ecosystem and natural resources while minimising environmental impact. Several studies have demonstrated that aged concrete is both sturdy and environmentally friendly. In the long run, this will save money on building. Concrete and concrete structures, such as those used for buildings, bridges, dams, etc., have a major harmful impact on the environment due to their widespread manufacture and use. The most major environmental implications of the production of concrete are a slow degradation of natural resources, a great deal of energy use, many released greenhouse gases, and a huge amount of construction and demolition trash. (Pavlů, 2018). Industrial waste has been the subject of numerous studies looking at how well it might replace traditional fine particles in concrete. The utilisation of manufacturing-related industrial waste, such as powdered soda-lime waste, glass, plastic, aluminium, and foundry waste, was examined in a number of studies. However, it is advantageous to use waste products as inputs for production processes when production costs are lower than the cost of using primary resources and market uptake is guaranteed (Bergonzoni et al., 2023). The demolition of bricks is often done on a large scale which will affect the quality of human life especially the settlements near the demolition area. The ongoing situation will have an impact on the environment such as air and water pollution, green gas emissions and threats to human health and other habitats. Thus, the aim of this study is to prove how effectively glass waste and destroyed concrete waste functions and what its engineering features are in order for it to be used.

1.3 Objectives

The following objectives should be followed as per below:

1. To prepare sustainable concrete incorporated with waste glass and demolished brick.
2. To study the effects of wt.% glass waste and wt.% demolished brick and curing time to physical and mechanical properties of the concrete.

1.4 Expected Outcomes

Each material used in this study has an effect based on its own function. Based on the objectives of the study to be conducted, there are several improvements that may be successfully implemented. Concrete's compressive strength from recycle glass and broken brick as coarse aggregates would enhance thus the concrete produce may withstand crushing forces. Sustainable concrete made with these aggregates can nevertheless attain appropriate strength levels for a variety of applications with correct mix design and optimisation.

In comparison to conventional aggregates, waste glass and brick aggregates are typically lighter. It would add into concrete in order to make it lighter, which known for its useful in some applications like lowering the overall structural load or making it simpler to transport and handle the concrete components.

1.5 Scope of Study

The addition of raw materials would result in the production of concrete. Waste glass and demolished brick together has a weight of 0%, 20%, 40%, 60%, 80% and 100% while Portland cement and river sand have a constant weight ratio of 100% each of them. Six samples were created for this research using six different compositions of WG and DB. After curing process, the effect of adding vary numbers of WG and DB compositions were examined.

Other parameters involved in this study is the curing process. The six different compositions will go through a curing process for 1, 7 and 28 days. The samples were cured with potable water which is known as drinking water at an ambient room temperature of 20 °C to 22 °C. The purpose of potable water is to prevent excessive evaporation from the concrete surface since it provides the required moisture content. This prevents quick drying and assures that there is enough water available for the hydration process. It improved toughness and endurance indirectly. Besides, the curing helps concrete constructions become solid and dense. By making the concrete more resistant to numerous external elements such freeze-thaw cycles, chemical attack, and environmental pressures, it helps to improve compressive strength and overall longevity of the concrete.

Compressive Strength Test, density and porosity and Optical Microscopy are among the characterizations technique that will be carry out on the samples to examine the physical and mechanical properties of the concretes.

1.6 Significance of Study

The purpose of this research is to examine how recycled glass and shattered brick can be used as coarse aggregate to create sustainable concrete. This problem encourages more environmentally friendly building practises and aids in lowering the amount of garbage discharged in landfills by using waste items like glass and broken brick as aggregates. This reduces the environmental effect of mining for conventional aggregates and helps protect natural resources.

Besides that, by combining waste glass and demolished brick aggregates, this study enables the evaluation of the durability and performance characteristics of sustainable concrete mixtures. The creation of optimised mix designs that meet or exceed the necessary standards can be facilitated by an understanding of the mechanical properties, durability, and behaviour of these concrete mixes.

Furthermore, enhanced resource efficiency makes it possible to use secondary materials that would otherwise go unused, such as demolished brick and wasted glass turn into concrete. By increasing the value recovered from already-available commodities and decreasing the requirement for primary raw materials, this encourages resource efficiency.

CHAPTER 2

LITERATURE REVIEW

2.1 Sustainable Concrete

Cement stands as a fundamental construction material globally, primarily used in concrete production, which comprises inert mineral aggregates like sand, gravel, crushed stones, and cement. The significance of cement in construction is underscored by its widespread production across nations due to the abundant availability of its primary raw material, limestone (Mukherjee & Vesmawala, 2013). Concrete is one of the most widely used building materials in the world. However, the production of Portland cement, an important element of concrete, results in the significant release of CO_2, a greenhouse gas. The production of one tonne of Portland cement clinker results in the emission of one tonne of CO_2 and other GHGs. In this century, the sustainable growth of the cement and concrete were significantly influenced by environmental concerns. In some areas it is already expected that there will be a shortage or run out of limestone which caused the production of Portland cement to stop as well as being unable to produce concrete. The limestone material needed to make cement is becoming limited in entire geographic areas. The supplies of aggregates for concrete production are becoming insufficient in major cities. Engineers must take sustainability into account while extending the "lifecycle" cost of a structure throughout its usable lifetime. The construction, upkeep, demolition, and recycling of buildings are all included in this (ACI 2004, Coppola et al. 2004, Corinaldesi et al. 2002b, Corinaldesi & Moriconi 2004b, Moriconi 2003). Taking into account all of the short- and long-term effects of the design's societal influence is part of designing sustainably. Therefore, durability is the key issue (Moriconi, 2003). Over 2,000 years ago, concrete was first used. The most notable quality of concrete is how durable and reliable it is. Energy efficiency is better in concrete structures. In comparison to steel or aluminium constructions, they are more environmentally friendly and offer flexibility in design (Cement Association of Canada, 2004).

2.2 Soda Lime Silica Glass

Glass is an amorphous material with relatively high calcium and silica content. Additionally, it is non-degradable, which presents a significant challenge for landfill operations. Despite recent improvements in waste glass recycling, an EPA report from 2013 states that 74% of collected waste glass is still disposed of in landfills. There are a number of challenges, including the mixing of different coloured glasses at the source, the cost, and the challenge of eliminating extra chemical contaminants and residues from the waste glass stream. The main obstacle to using waste glass as a particle aggregate in the production of concrete, particularly soda-lime glass, is the Alkali-Silica reaction (ASR), a key durability concern in the construction industry. The alkali-silica reaction happens when glass containing silica or other reactive components reacts with the hydroxyl ions in cement concrete when there is moisture present. Concrete's alkaline solutions and the siliceous aggregate react chemically, and this reaction takes time to become apparent. According to (Olofinnade et al., 2017) If the aggregate contains "certain siliceous rocks and minerals, such as opaline chert, strained quartz, and acidic volcanic glass" (according to ACI Committee 116), the problem of ASR could also show itself in traditional concrete. The silica in the glass and the alkalis in the cement pore solution have been shown to negatively interact, which causes ASR in the case of glass.

Table 2.1: Elemental composition of waste glass (Source: (Olofinnade et al., 2017))

Element composition	Symbol	Percentage (%)
Sulphur	S	0.19
Iron	Fe	0.27
Potassium	K	1.26
Magnesium	Mg	1.31
Aluminium	Al	1.68
Calcium	Ca	7.41
Sodium	Na	8.74
Silicon	Si	24.80
Oxygen	O	54.35

2.2.1 Physical Properties of Glass

The three main types of used glass are soda-lime, borosilicate, and lead glass. Lead glass is used for creating home glassware, borosilicate glass is used for insulation and laboratory equipment, soda-lime glass is commonly used to make container glass like drink bottles, and plate glass, which is also used in windowpanes. It is because soda-lime glass accounts for the vast majority of the waste glass supply, it is the primary emphasis. Waste glass has the potential to be used as a cement additive or as a partial clinker replacement in Portland cement mixes because of its chemical makeup and potential pozzolanic activity (Harrison et al., 2020).

2.3 Bricks

In construction and building, bricks are a common building and construction material worldwide. Bricks made traditionally are either made of plain Portland cement (OPC) concrete or clay that has been fired at high temperatures in a kiln. Energy-intensive, damaging to the environment, and producing a lot of garbage are quarrying processes used to obtain clay. An enormous amount of greenhouse gases is released during the high temperature kiln fire in addition to significant energy consumption. On average, clay bricks emit 0.41 kg of carbon dioxide (CO_2) per brick and have an embodied energy of about 2.0 kWh.

Table 2.2: Chemical composition of brick (Source: (Lin et al., 2010)

Chemical composition (%)	Brick
CaO	0.52
SiO_2	63.21
Al_2O_3	16.41
Fe_2O_3	6.05
Na_2O	1.19
K_2O	2.83
MgO	1.11
Pozzolanic activity	107

2.4 Portland Cement

Tricalcium aluminate, tetra calcium alumino ferrite, and calcium sulphate, sometimes known as gypsum, are the main ingredients in Portland cement (OPC). It can bind mineral pieces together when there is water present thanks to its adhesive and cohesive qualities, creating a continuous, compact mass of masonry (Singh, 2020). Limestone and clay (or shale), which are extremely straightforward and readily available minerals, are used to make Portland cement, a complex product. To generate a raw meal with a precise chemical composition, these two basic ingredients must be combined in very precise ratios with some extras (Aïtcin, 2016).

Table 2.3: Chemical composition and physical properties of Portland cement

Chemical composition mass (%)		Physical properties	
SiO_2	24.08	Initial setting (min)	68
Al_2O_3	19.40	Final setting (min)	185
Fe_2O_3	6.28	Specific gravity	3.15
CaO	74.25	Soundness (%)	0.52
MgO	3.96		
K_2O	0.85		
Na_2O	0.33		
TiO_2	0.62		
P_2O_5	1.21		

2.5 Sand

Natural aggregates from commercial sources, including river sand and granite, were used in this investigation. The concrete used in this experiment was made from river sand with particle sizes that ranged from 0.075 to 4.75 mm and granite with a maximum particle size of 12.5 mm. The physical characteristics and particle size distribution of river sand and granite are shown here.

Table 2.4: Physical properties of the aggregate and glass aggregate materials (Source: (Aïtcin, 2016))

Physical properties	Natural aggregate		Waste glass aggregate
	Sand	Granite	Granular glass aggregate (CWG)
Fineness Modulus	2.69	2.85	2.73
Water absorption (%)	0.42	0.25	0.36
Specific gravity	2.62	2.70	2.40
Aggregate Crushing value (ACV) %	-	24	43
Aggregate Impact value (AIV) %	-	10	39

2.6 Characterization Technique

Different types of characterizations were applied to the sustainable concrete produced with the inclusion of soda lime silica glass, and demolished brick as coarse aggregates. This study was able to determine the minute features of the samples, the maximum pressure that a concrete sample can take, and components of a material's composition and surface structure from the characterizations.

2.6.1 Density and Porosity

The proportion of pore volume to the overall volume is known as porosity. The following factors affect porosity are the aggregates, pore distribution, diagenesis and cementation. Referring to table 2.5, further processing and testing are applied to the concrete samples made from the previously mentioned. Glass aggregate has a lower specific gravity than sand, so it is obvious that the addition of wasted glass led to a modest weight reduction. For the control, 5%, 15%, and 20% waste glass replacement mixtures, the fresh densities were 2442, 2426, 2405, and 2399 kg/m^3. The findings show that as the waste glass ratio rises in comparison to the controlled mix, the dry density tends to decrease. This is also related to the fact that glass aggregate has a lesser density than real sand does. This is further supported by the fact that all concretes exhibit a risen in density with the period of curing. the density rose by 1.4%, 0.7%, 0.47%, and 0.37% for control, 5%, 15%, and 20% waste glass replacement mixes when comparing concretes that have been curing for 7 days to those that have been curing for 28 days. As the amount of waste glass increases, the density increases less rapidly with hydration time (Abdallah & Fan, 2014).

Table 2.5: Waste glass concrete's density (source: (Abdallah & Fan, 2014)

Mix	Dry density kg/m³ at ages of		
	7 days	14 days	28 days
Control	2365	2378.6	2398
5% WG	2358.5	2364.3	2374.2
15% WG	2354.8	2362.9	2366.1
20% WG	2351.4	2359.7	2360.2

2.6.2 Compressive Strength Test

The ability of concrete to withstand loads before failing is known as its compressive strength. Figure 2.6.2.1 displays the compressive strength of the cubic specimens reviewed on 28 and 56 days, respectively, with RCA (recycle coarse aggregate) for w/c = 0.35. The primary feature depicted in this figure is comparable to that in Figure 2.6.2. When NCA (natural coarse aggregate) was substituted with RCA by 25%, 50%, 75%, and 100%, the compressive strength was decreased by 2.6%, 5.9%, 8.0%, and 9.6% on 28 days and by 3.0%, 9.4%, and 10% on 56 days. As compared to the specimens with w/c = 0.55, it is seen that the strength difference between the specimens examined on 28 days and 56 days is only from 3% to 6.7% (Zheng et al., 2018). Harrison et als'., (2020) said that due to the presence of waste glass, previous studies on its mechanical properties have produced varying results. Fine glass particles functioning as filler material and offering more hydration sites for the cement or the pozzolanic activity that glass exhibits can both have a positive effect on compressive strength. Due to the silica in the glass, which increases pozzolanic activity, fine glass particles might offer more hydration sites for the cement particles, increasing the amount of cement hydrates that form.

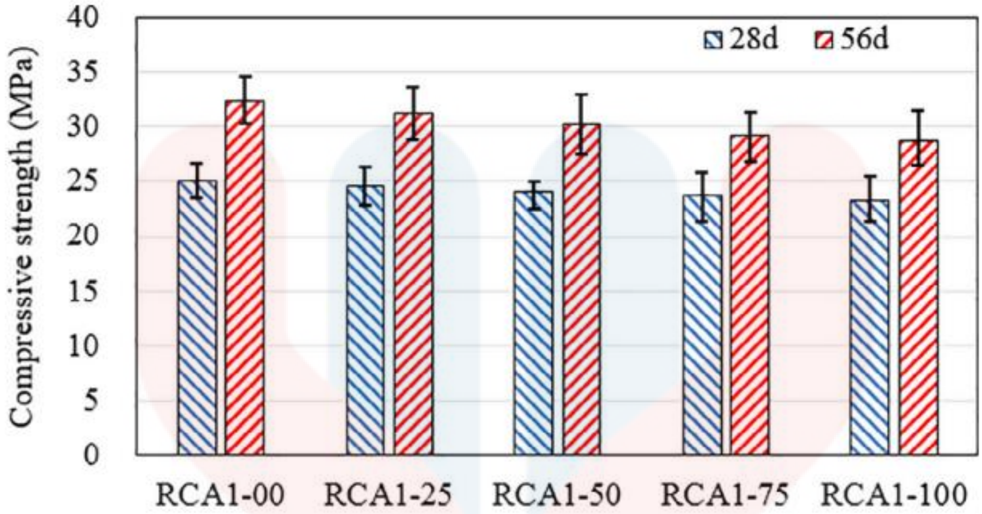


Figure 2.7: Specimens' compressive strengths with RCA at 28 and 56 days (w/c = 0.55) (source: (Zheng et al., 2018)

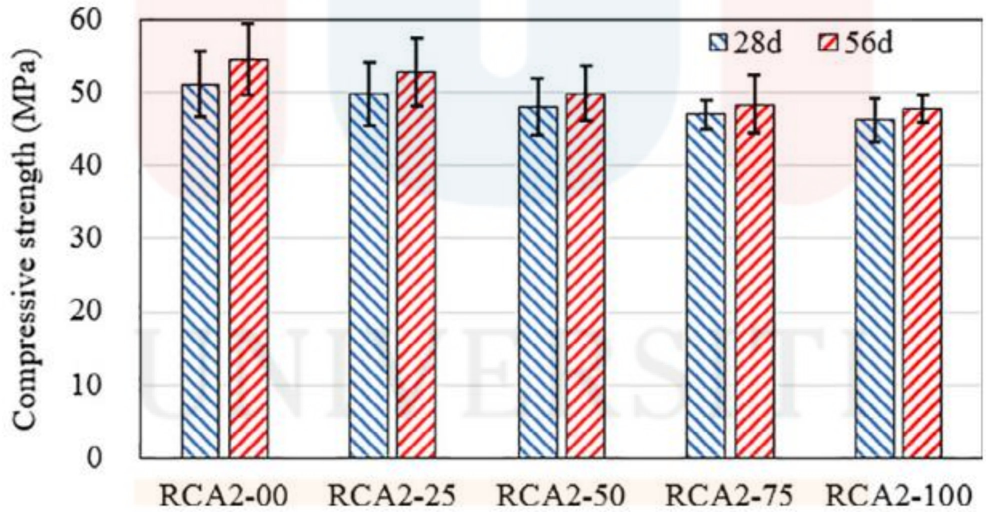


Figure 2.8: Specimens' compressive strengths with RCA at 28 and 56 days (w/c = 0.35).

2.6.3 Optical Microscopy

The various aggregate types found in the concrete sample can be recognised and examined using optical microscope. The microscope can assist in differentiating between waste glass particles, broken brick fragments, and other forms of aggregates utilised in the concrete mixture by looking at the shape, colour, and texture of the aggregates. It can also be used to examine how wasted glass and broken brick aggregates are distributed throughout the concrete matrix. Identifying the aggregate distribution and matrix-aggregate bonding is also helpful. Additionally, it can offer details on the microstructure of the concrete, such as the size and shape of the cement particles, the presence of hydration products, the general pore structure, revealing details about the material's general composition, quality and structure.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

In this research, the following materials are needed. The composition of soda lime silica glass, demolished bricks, Portland cement, sand and water as shown in Table 3.1

Table 3.1: Compositions of materials

Mixture	Cementious material	Aggregate materials			Water-cement ratio
	Portland cement (%)	Fine aggregate	Coarse aggregate		
		River sand (%)	Waste glass (%)	Demolished brick (%)	
Control	100	100	0	5	0.7
10% (WG and DB)	100	100	5	5	0.7
20% (WG and DB)	100	100	10	10	0.7
30% (WG and DB)	100	100	10	20	0.7
40% (WG and DB)	100	100	30	10	0.7

3.2 Sample Preparation

3.2.1 Mixing

All the raw materials such as Portland cement, sand, soda lime silica glass, demolished brick and water are weight according to the composition as stated in Table 3.1. Before mixing, sand and coarse aggregates firstly need to be sieve. Then the raw materials will mix manually by using hand with any suitable equipment until it is homogenous.

3.2.2 Moulding

After mix, the mixture will be cast into hand moulds with dimensions of 20mm×25mm×20mm for 24 hours only.

3.2.3 Curing

The six different compositions will go through a curing process for 1, 14 and 28 days. The samples will be cured with potable water which is known as drinking water at an ambient room temperature of 22 °C to 25 °C.

3.3 Sample Characterization

3.3.1 Density and Porosity

After this procedure evacuates the air from a chamber housing the samples, they will be immersed in water. The samples will then be weighed before and after being submerged in water in order to determine the apparent porosity and apparent relative density using the water absorption equation 3.1.

Water Absorption (%) =

$$(m2(b,v)-m1m1)\times 100\% \qquad \text{Equation 3.1}$$

Where:

m1: is the mass of the dry brick

m2: is the mass of wet brick

3.2.2 Compressive Strength Test

ASTM C39 is usually the common international standard of compressive strength test onto concrete cube samples with the dimension 20mm×25mm×20mm. All samples will be fully crushed in this test. By performing this test, it is possible to calculate the sample's young modulus, maximum force, stress, and strain.

3.2.3 Optical Microscopy

Prepare the concrete sample in thin slices or polished parts. Concrete is frequently studied through the use of thin pieces, whereas polished sections enable surface inspection. It enhances the observations for all types of samples using a magnification range of 10x to 100x.

3.3 Research Flowchart

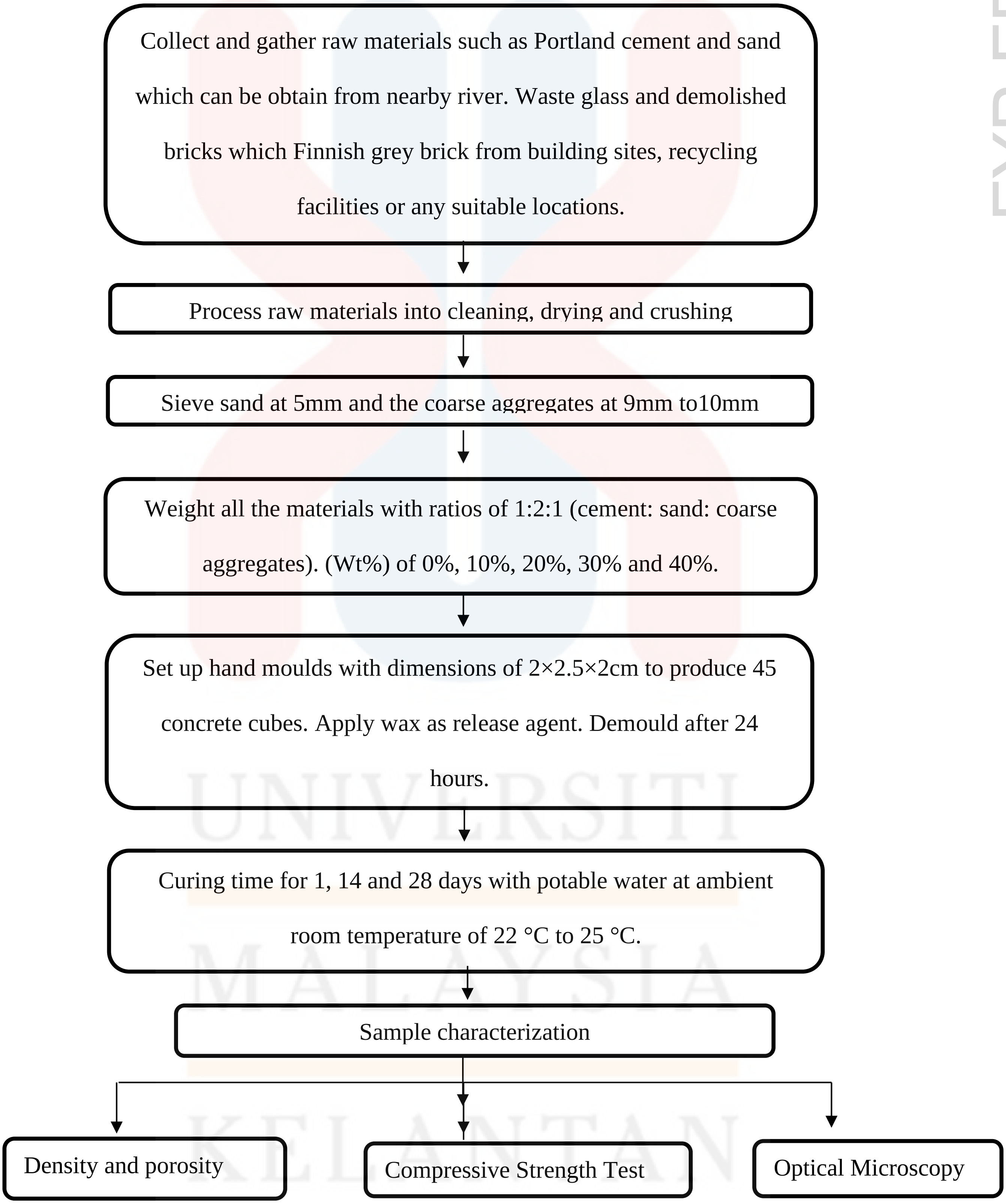


Figure 3.3: Research flow chart for *the production of sustainable concrete*

CHAPTER 4

RESULT AND DISCUSSION

4.1 Water Absorption

The ability of concrete to draw and keep water within its internal pores and capillaries is referred to as water absorption. It is expressed as the proportion of water weight that the concrete adds to its dry weight. Greater absorption may be a sign of possible problems with durability, such as increased efflorescence or cracking.

Table 4.1: Specimen's initial mass of water absorption before immersion

Samples	Initial mass (g)		
	Day 1	Day 14	Day 28
Control	15.47	17.25	18.16
A (10% WA and DB)	17.61	17.22	18.08
B (20% WA and DB)	17.25	17.55	16.87
C (30% WA and DB)	16.62	16.73	16.04
D (40% WA and DB)	12.76	12.82	17.43

Table 4.2: Specimen's final mass of water absorption after immersion

Samples	Final mass (g)		
	Day 1	Day 14	Day 28
Control	17.04	19.08	19.66
A (10% WA and DB)	19.24	18.77	19.65
B (20% WA and DB)	18.81	19.03	18.18
C (30% WA and DB)	18.07	18.20	17.49
D (40% WA and DB)	18.07	14.51	18.88

Based on table 4.2, all three days for the control sample showed an increase in water absorption. On the first day, the weight of concrete before immersion was 15.47g and increased to 17.04g. then 17.25g increased to 19.08g on the 14th day and continued to increase on the 28th day from 18.16g to 19.66g. the capillary absorption capacity of concrete, which is related to its water absorption characteristics, exerts a significant effect on the material's durability and is closely associated with its pore structure (Wang et al., 2022).

It is evident that all three days of observation of sample A demonstrated a consistent trend of increasing water absorption. Specifically, on the initial day of observation, the weight of the concrete before immersion was recorded at 17.61 g, which subsequently increased to 19.24 g. This pattern persisted on the 14th day, where the initial weight of 17.22 g saw an increase to 18.77 g. Furthermore, on the 28th day, the weight of the concrete before immersion measured 18.08 g, and it further increased to 19.65 g. Thus, the observed increase in water absorption over the course of the study period indicates a notable trend in the behaviour of the sample. The water absorption of concrete is influenced by various factors, including relative humidity, sample conditioning, and the composition of the concrete. For instance, samples conditioned at different relative humidities can exhibit significantly different water absorption levels (J. Castro et al., 2011).

For sample B, on the first day, the concrete weighed 17.25 g before immersion, and it increased to 18.81 g. On the 14th day, it started at 17.55 g and went up to 19.03 g. Then, on the 28th day, it went from 16.87 g to 18.18 g. This shows that sample B consistently absorbed more water over time. As aggregate particle size decreases, the specific surface area of a given mass of aggregate increases. This increase in surface area is accompanied by a greater number of surface holes, leading to a stronger water absorption capacity (Cao et al., 2022).

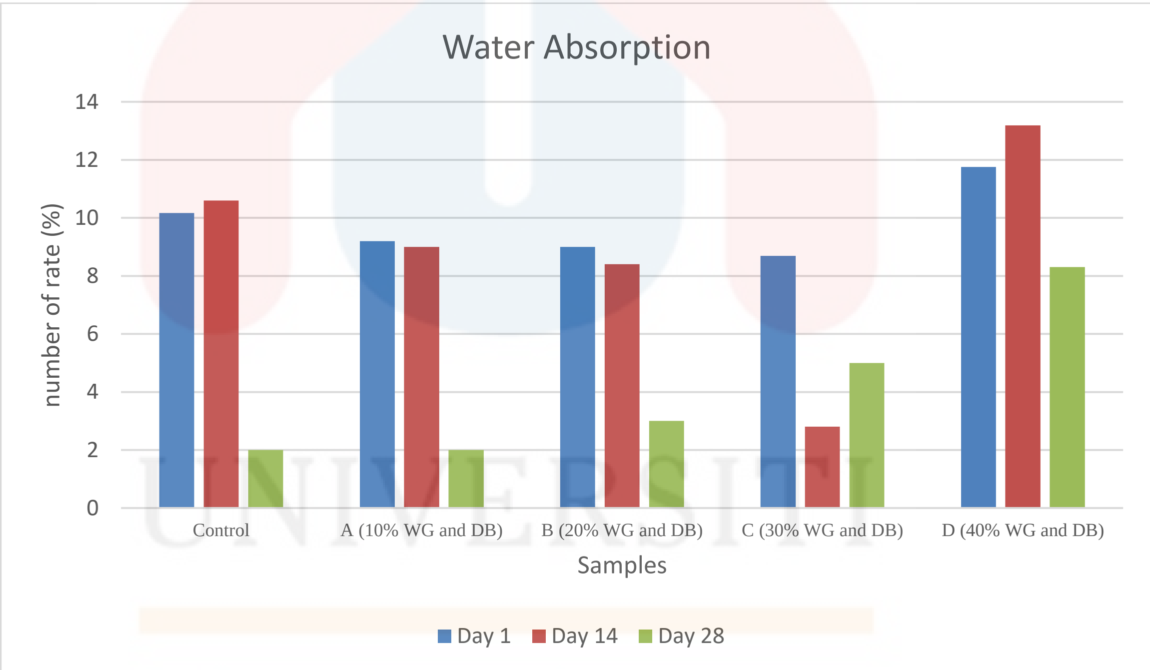


Figure 4.1: Overall water absorption rate after 1, 14 and 28 days of immersion

Sample C exhibited a rise in concrete absorption rate of 8.69%. This trend persisted through the 14th day, with the absorption rate reaching its highest point at 8.78%. Continuing the examination, by the 28th day, the absorption rate further increased to 9.04%. the water absorption of concrete can be affected by the volume of aggregates and the presence of certain treatments or coatings (Onyeka, 2019). Sample D demonstrated a significant surge in the absorption rate of the concrete, recording an increase of 11.76% on the first day. Continuing through the 14th day, this trend persisted, with the absorption rate escalating to 13.9%. Subsequently, by the 28th day, while still showing an increase, the rate moderated to 8.31%.

In the context of this thesis, the discussion of the water absorption behaviour of concrete, particularly when incorporating waste glass and demolished brick as coarse aggregates, is highly relevant. Understanding how these alternative aggregates may influence the water absorption characteristics of concrete is essential for evaluating the sustainability and performance of the resulting material. This discussion can provide valuable insights into the potential benefits and considerations associated with the use of waste materials in concrete production.

4.2 Compressive Strength

Compressive strength is a fundamental property of concrete that refers to its ability to withstand loads before failure. It is the most common and well-accepted measurement of concrete strength and is the main criteria used to determine if a given concrete mixture can withstand the structural and cost requirements of a project. Compressive strength tests are regularly used to describe concrete's strength because they are reliable and easy to perform. The test involves breaking a sample of concrete, usually in the form of cubes and cylinders, to determine the maximum strength the concrete can endure. The size and shape of the sample may also affect the indicated strength.

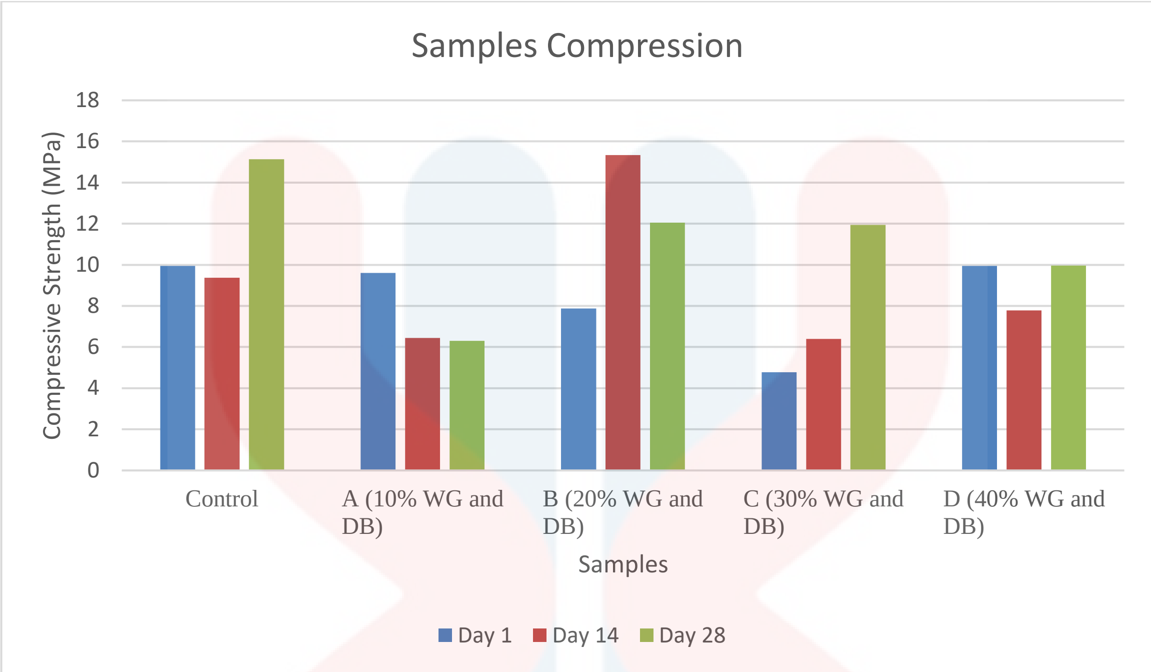


Figure 4.2: Samples compression after 1, 14 and 28 days of curing

The compressive strength of the Control sample, without any recycled aggregates, exhibited a notable increase over the three days, with recorded values of 9.95 MPa, 9.37 MPa, and 15.13 MPa, respectively, as depicted in figure 4.2. This trend underscores the impact of curing duration on the concrete's ability to withstand pressure or load. The observed increase in compressive strength with extended curing days is consistent with findings from previous studies, emphasizing the significance of curing strategies in achieving the desired strength properties. Research has shown that the compressive strength of concrete specimens is slightly larger in specimens cured with water, underscoring the impact of curing methods on concrete strength (Abdel-Hay, 2017).

The compressive strength of sample A, which consisted of 10% waste glass and demolished brick as coarse aggregates, exhibited a notable decrease over the 14th and 28th days compared to the first day. The strength recorded on the first day was 9.60 MPa, which decreased to 6.44 MPa and 6.3 MPa on the 14th and 28th days, respectively, as indicated in the study. This trend highlights the impact of the incorporation of waste glass and demolished brick aggregates on the compressive strength of the concrete. The decrease in strength over time suggests potential challenges associated with the use of these alternative aggregates and emphasizes the need for a comprehensive understanding of their influence on concrete properties. Supportive journals provide further insights into the impact of waste glass on concrete properties. For instance, a study on the characteristics of concrete with waste glass as a fine aggregate replacement reported that the compressive strength of concrete with 20% waste glass content increased by 5.28% at 28 days (Abdallah & Fan, 2014),

Furthermore, the water absorption capacity of concrete is closely linked to its compressive strength. Research has shown that the best water absorption capacity of concrete was achieved at specific curing durations, emphasizing the interplay between curing practices, water absorption, and the resulting concrete properties (Onyeka, 2019). This interplay may contribute to the observed changes in compressive strength over time for sample A, further underscoring the importance of considering water absorption characteristics in the evaluation of concrete performance.

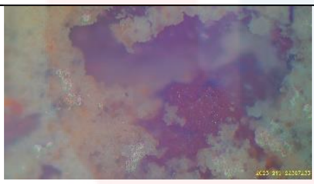
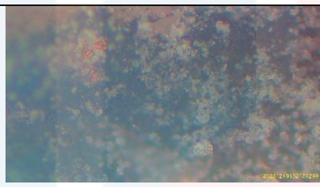
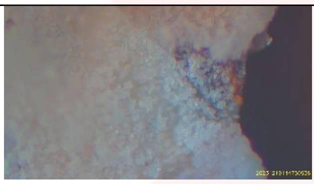
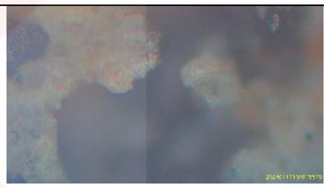
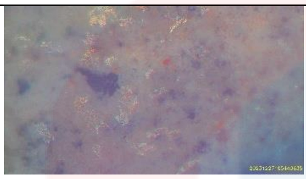
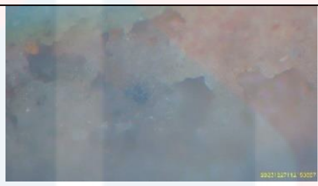
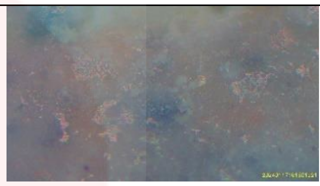
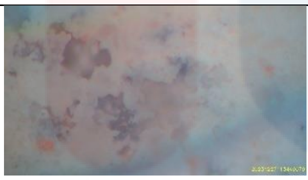
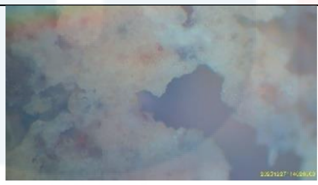
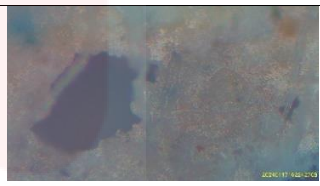
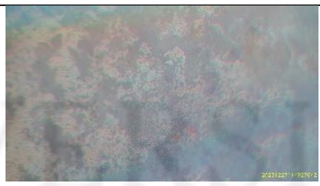
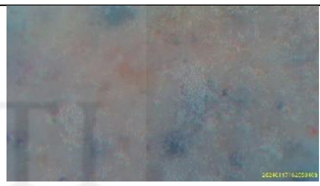
The compressive strength of sample B, which contained 20% waste glass and demolished brick as coarse aggregates, exhibited varying values over the three days, with the highest strength recorded on the 14th day at 15.34 MPa, followed by 12.05 MPa on the 28th day, and 7.88 MPa on the first day. This trend highlights the influence of the curing duration and the incorporation of waste glass and demolished brick aggregates on the compressive strength of the concrete. The observed increase in strength on the 14th day, followed by a slight decrease on the 28th day, suggests a complex relationship between the curing period and the impact of the alternative aggregates on the concrete's mechanical properties. Supportive journals provide additional insights into the impact of waste glass on concrete properties. For instance, a study on the characteristics of concrete with waste glass as a fine aggregate replacement reported that the compressive strength of concrete with 20% waste glass content increased by 5.28% at 28 days (Abdallah & Fan, 2014).

The compressive strength of sample C, which contained 30% waste glass and demolished brick aggregates, exhibited an increasing trend over the three days, with values of 4.77 MPa, 6.39 MPa, and 11.94 MPa recorded on the first, 14th, and 28th day, respectively. This trend highlights the influence of the curing duration and the incorporation of a higher percentage of waste glass and demolished brick aggregates on the compressive strength of the concrete. The observed increase in strength over the 14th and 28th days suggests a potential improvement in the material's mechanical properties over time, despite the initial lower strength.

The compressive strength of sample D, which incorporated 40% waste glass and demolished brick aggregates, exhibited an inconsistent trend over the three days, with values of 9.95 MPa, 9.97 MPa, and 9.88 MPa recorded on the first, 28th, and 14th day, respectively. This inconsistent trend is noteworthy, especially with the 14th day value being the lowest compared to the first and 28th day values. The use of a higher percentage of waste glass and demolished brick aggregates in this sample may have contributed to the observed variations in compressive strength over the curing period. Understanding the time-dependent changes in bonding and homogeneity is crucial for evaluating the overall durability and performance of concrete. Research has shown that the water absorption of concrete after immersion can have a significant effect on its compressive strength, with the absorption capacity influencing the material's behaviour under various conditions (Li et al., 2023).

4.3 Optical Microscopy

Table 4.3: Samples observed under optical microscopy

Samples	Microscopic Findings (20x)		
	Day 1	Day 14	Day 28
Control			
A (10% WA and DB)			
B (20% WA and DB)			
C (30% WA and DB)			
D (40% WA and DB)			

The examination of non-cross-sectional samples via optical microscopy imposes limitations on the scope of observation, as it is confined to the sample's exterior. In the context of the observations from table 4.3, it is apparent that samples A and C consistently manifested areas with inferior bonding compared to the other samples across all three days. This observation is of great significance as it signifies potential disparities in the binding characteristics of the various samples. It is imperative to comprehend the factors contributing to these binding differences to effectively evaluate the overall performance and durability of the concrete material. The binding properties of concrete are subject to influence by various factors, including the material's composition, the presence of alternative aggregates such as waste glass and demolished brick, and the curing conditions.

The water absorption of concrete after immersion has been found to have a substantial effect on its compressive strength, emphasizing the significance of understanding water absorption in the context of bonding properties. Additionally, the rate of change of the water absorption mass and the differences in aggregate type, mix ratio, and water reducing agent can impact the water absorption ratio of concrete materials. Therefore, it is essential to consider the relative saturation ratio and relative water absorption ratio to mitigate the influence of material differences on research results. Furthermore, the incorporation of waste glass as a fine aggregate in concrete has been shown to enhance its compressive, splitting tensile, and flexural strength, highlighting the potential benefits of utilizing alternative aggregates in concrete production. For instance, the use of alternative aggregates may impact the interfacial transition zone between the aggregates and the cement paste, potentially affecting the bonding properties of the concrete (Roviello et al., 2022).

The examination of non-cross-sectional samples via optical microscopy imposes limitations on the scope of observation, as it is confined to the sample's exterior. In the context of the observations from table 4.3, it is apparent that samples A and C consistently manifested areas with inferior bonding compared to the other samples across all three days. This observation is of great significance as it signifies potential disparities in the binding characteristics of the various samples. It is imperative to comprehend the factors contributing to these bonding differences to effectively evaluate the overall performance and durability of the concrete material. The bonding properties of concrete are subject to influence by various factors, including the material's composition, the presence of alternative aggregates such as waste glass and demolished brick, and the curing conditions. For example, a study on the durability of concrete made with crushed glass aggregates found that the low absorption of such concrete makes it less permeable, promoting durability by restricting water and ion migration within the matrix (S. De Castro & De Brito, 2013).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The utilization of waste glass and demolished brick as coarse aggregate for sustainable concrete production has been investigated in several studies. The research has shown that the compressive strength of the concrete can be significantly influenced by the incorporation of these alternative aggregates. The use of waste glass and demolished brick as coarse aggregates has been found to impact the compressive strength of the concrete, with varying results depending on the percentage of waste glass and demolished brick aggregates used.

5.2 Recommendation

Based on the findings of the research on the utilization of waste glass and demolished brick as coarse aggregates for sustainable concrete production, several recommendations can be made to guide future applications and research in this area. These recommendations are essential for enhancing the understanding and promoting the sustainable use of alternative aggregates in concrete production.

The optimal percentage of substitution of natural coarse aggregates with waste glass and demolished brick to achieve a balance between sustainability and performance can be determined through comprehensive testing and evaluation of the mechanical, durability, and environmental properties of the concrete at varying substitution levels.

Further investigation into the influence of processing methods on the properties of concrete incorporating waste glass and demolished brick aggregates is warranted. This includes assessing the impact of different crushing and treatment techniques on the performance of the resulting concrete, as well as the potential for enhancing the properties of the recycled aggregates through innovative processing approaches.

Conducting long-term durability studies to assess the performance of concrete with waste glass and demolished brick aggregates under various environmental exposures, including freeze-thaw cycles, chemical attack, and aging, is crucial. This will provide valuable insights into the material's resilience and sustainability over its service life.

The development of design guidelines and standards for the use of waste glass and demolished brick aggregates in concrete production is essential to ensure the safe and effective utilization of these alternative materials. This includes considerations for mix design, quality control, and structural applications to support their widespread adoption.

Performing a comprehensive life cycle assessment (LCA) to evaluate the environmental impact and sustainability of concrete incorporating waste glass and demolished brick aggregates is crucial. This will provide a holistic understanding of the material's environmental footprint and support informed decision-making in sustainable construction practices.

Facilitating knowledge transfer and promoting the adoption of sustainable concrete practices within the construction industry through collaboration with stakeholders, dissemination of research findings, and the development of educational resources is crucial. This collaborative approach ensures that best practices are shared, leading to the widespread adoption of sustainable concrete solutions that benefit both the industry and the environment.

In summary, the recommendations outlined above are essential for advancing the sustainable use of waste glass and demolished brick aggregates in concrete production. By addressing these key areas, future research and industry practices can be guided towards the development of high-performance, environmentally friendly concrete materials that contribute to the circular economy and sustainable built environment.

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APPENDIX A

IMAGES

A.1 Raw Materials

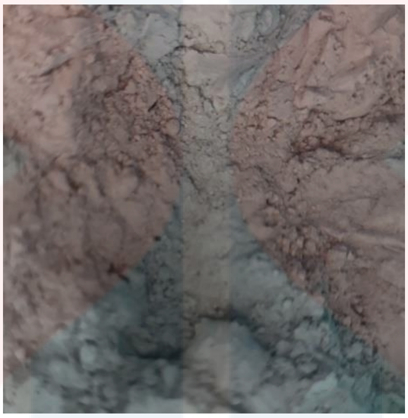

Figure A.1: Portland cement

Figure A.1.1: River sand

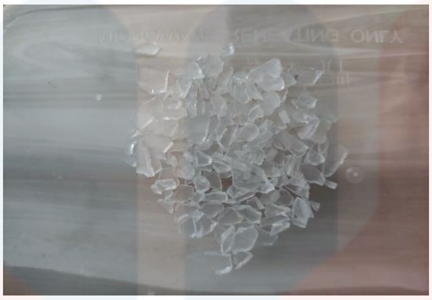

Figure A.1.2: Crushed waste glass

Figure A.1.3: Crushed demolished brick

A.2 Hand moulds

Figure A.2: Hand moulds 2×2.5×2cm dimensions

A.3 Water absorption

Figure A.3: Curing process day 1, day 14 and day 28

A.4 Testing

Figure A.3: Samples tested under compressive strength machine