MECHANICAL PROPERTIES OF CONCRETE WITH DIFFERENT TYPES OF GLASS WASTE AS CEMENT REPLACEMENT MATERIAL

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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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ABSTRAK

Konkrit adalah bahan struktur yang terdiri daripada campuran agregat yang disatukan oleh simen dan air. Ia adalah bahan yang sangat diperlukan dan berguna untuk kerja pembinaan yang mudah dihasilkan dalam pelbagai bentuk dan saiz. Konkrit boleh direka bentuk dalam pelbagai kekuatan untuk mengatasi beban yang dikenakan pada struktur bangunan atau reka bentuk struktur lain tetapi penghasilan simen dalam konkrit boleh menyebabkan kemudaratan terhadap alam sekitar. Untuk mengurangkan kesan alam sekitar daripada pengeluaran simen, kaca terbuang digunakan semula untuk menggantikan simen dalam campuran konkrit. Dalam kajian ini, kesan penggantian simen dalam konkrit dengan sisa kaca dinilai dari segi ujian penurunan, kekuatan mampatan dan penilaian ketumpatan. Matlamat kajian ini adalah untuk menentukan sifat mekanikal konkrit dengan menggunakan sisa kaca dalam bentuk serbuk sebagai bahan gantian simen dan untuk menentukan kesan penggunaan jenis sisa kaca yang berbeza mengikut warna terhadap kekuatan mampatan. Prosedur penyediaan bancuhan dijalankan dengan menyediakan 5 jenis sampel dengan jenis kaca yang berbeza dan peratus penggantian serbuk kaca dengan simen. Ujian penurunan telah dijalankan untuk setiap variasi sampel untuk menentukan kadar kebolehkerjaan apabila menggantikan simen dalam konkrit. Proses pengawetan untuk semua sampel telah dilakukan selama 7 dan 28 hari untuk penentuan kekuatan dan juga ketumpatan kering bagi konkrit yang dikeraskan. Data yang dikumpul untuk kekuatan mampatan dinilai berdasarkan kekuatan 7 dan 28 hari untuk memastikan kesesuaian untuk penggantian simen. Bagi ujian kekuatan mampatan, kekuatan bagi sampel terkawal tanpa penggantian simen adalah lebih tinggi berbanding 10% dan 15% penggantian serbuk kaca. Ketumpatan sampel konkrit juga berkurangan apabila diganti dengan serbuk kaca untuk 7 hari dan 28 hari pengawetan.

ABSTRACT

Concrete is a structural material that comprised as a mixture of aggregates that is bonded together by cement and water. It is a very necessary and useful substances for construction work that is easy to create into varies shapes and sizes. Concrete can be designed in various strength to overcome the load applied on the structure of the building or other structural designs but the production of cement in concrete can caused harm toward environment. To reduce the environmental effect of cement production, glass is being reused to replace the cement in the concrete mixture. In this study, the effect of cement replacement in concrete with glass waste was evaluated in term of slump testing, compressive strength and density evaluation. The aim of this study is to determine the mechanical properties of concrete by using glass waste in powder form as cement replacement material and to determine the effect of using different type of glass waste sorted by colour on compressive strength. The procedure of preparing the mixture were carried out by preparing 5 types of samples with different type of glass and percentage replacement of glass powder with cement. Slump test were conducted for each of the sample variation to determine the rate of workability when replacing the cement in concrete. Curing process for all the samples were performed for 7 days and 28 days for strength determination and also dry density for hardened concrete. Data collected for compressive strength were evaluated based on 7 days and 28 days of strength to ensure the suitability and effect of using glass waste powder for cement replacement. Several test had been evaluated for the concrete sample which were slump test, compressive strength test and density determination. For compressive strength test, the strength for controlled sample with no cement replacement was higher compared to 10% and 15% of glass powder replacement. Density of concrete sample also decrease when replaced with glass powder for both 7 days and 28 days of curing.

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CHAPTER 1

INTRODUCTION

1.1 Background

Concrete is a structural material made up of aggregate typically sand and gravel , which is a hard, chemically inert particle that is cemented together with cement and water. A binder is a substance used in construction that sets, hardens, and clings to other materials in order to bind them together. Cement mixed with sand and aggregate with specified water ratio will produce a concrete mixture (Aspdin, 2020). By replacing cement using glass powder, it actually applies a good sustainable construction practise on site. Silica is the main component of glass. The use of milled ground waste glass as a partial replacement for cement in concrete could be a significant step toward the creation of environmentally friendly, energy-efficient, and cost-effective infrastructure systems (Safarizki et al., 2020). The process of constructing a healthy environment based on ecological principles is known as sustainable construction. Sustainable construction, according to Professor Charles J. Kibert is based on six principles: “conserve, reuse, recycle or renew, protect nature, generate non-toxic and high-quality materials”. The use glass waste powder which came from reuse material is very suitable to replace the cement material because it contributed the extreme amount of carbon dioxide, CO_2 toward surrounding environmental. Concrete which is used to build the majority of the world bridges, roads, dams, and other structures, emits a significant quantity of CO_2. Apart from water, it is the world most consumed product. This industry will continue to harm the environment with over 4 billion tonnes of carbon dioxide per year unless overall emissions are reduced worldwide (Ramsden, 2020). Due to the chemical constituents in glass powder are almost identical to those in cement, it can be used as a partial substitute for cement in a concrete mixture (Safarizki et al., 2020).

Before this, several researchers studied that the use of glass larger than 4.75mm which is the size of coarse aggregate that able to replace aggregate rather than becoming cement replacement cause lower compressive strength with the increase of glass content (Tamanna & Tuladhar, 2020). The compressive strength of concrete containing crushed glass aggregate increased while the compressive strength of concrete containing natural mineral aggregate decreased when glass powder was employed as an aggregate replacement material (Safarizki et al., 2020). Use of large glass material can cause Alkali-Silica reaction throughout the concrete production which may reduce the durability of concrete. When amorphous silica in glass reacts with alkali in cement, an expansive alkali-silica gel is formed. When moisture is present, the alkali-silica gel produced can absorb moisture from the environment and expand inside aggregate micro-cracks. ASR expansion causes concrete cracking which making the concrete more vulnerable to chloride attack. The natural aggregate also can cause ASR because aggregate contain reactive silica material unlike glass itself which have very high amount of silica content. Besides replacing cement and aggregate, some researchers also replace sand with glass which at certain sizing based on sand requirement. If sand is substituted with glass waste at a precise dose, the sand content will be reduced, lowering the negative consequences of sand and making the concrete industry more sustainable (Ibrahim, 2017).

1.2 Problem Statement

Purpose of using glass waste to replace cementitious material is to overcome various environmental issues associated with the generation of glass waste. Glass garbage bottles that are disposed in landfills have a shorter life cycle, causing land usage issues. Glass bottles and plastic polythene bags are common components of solid trash dumped along the borders of beaches around the country (Ke et al., 2018), posing a threat to marine animals (Nyantakyi, 2020).

The majority of glass had been neglected due to the problem that glass cannot be optically sorted and will be sent to a landfill. A single-stream recycling which the collection and processing systems are able to handle the mixture of all recyclables waste materials that will be separated at the material recovery facilities. Due to the mixture of waste collection, glass waste seems very hard to be managed since it will come in the form of crushed or small piece of various type of glass. Only small portion of glass can be sorted properly throughout the single-stream recycling system. Most of the glass waste the comprised of bottles, mirrors, windows and containers that had been thrown away into a recycling bin will never make it to glass recycling centre and most of it break during the first placement, transport and sorting moments. The facts that 75% of glass that goes through the waste system will be located in the landfill and glass will be decomposed approximately one to two million years for a single bottle.

Based on the problem regards to failure of decomposing the glass and bad emission of carbon dioxide for cement production, this study tends to reuse the waste glass before been thrown away to the landfill and reducing the production of cement by replacing it with the waste glass.

1.3 Objectives

The objectives of this study are:

i. To determine the effect of replacing cement with glass powder.

ii. To indicate reliability of the replacement glass powder in concrete mixture.

1.4 Scope of Work

Throughout this project, a total of 30 samples of concrete cube are conducted at the School of Civil Engineering (SoCE) concrete laboratory. Before conducting concrete cube samples, proper raw material are prepared which comprised of mainly glass waste from recycling centre. The glass waste used in this study were taken from housing residence and recycling centre located at Tzu Chi Environment Protection Education Centre at Taman Sri Nibong, Bayan Lepas, Pulau Pinang. The glass wastes are crushed approximately less than 150 µm to get the similar texture and sizing as cement properties. Standard Ordinary Portland Cement (OPC) is used and material for coarse and fine aggregate must achieve the standard size to ensure good quality of concrete mixture. Concrete mix design form is prepared to ensure that proper calculation for concrete mix ratio is obtained based on specific strength required. Concrete grade 20 is chosen because it is the minimum grade for the reinforced concrete work such as beam, slab and footing at mild exposure which can protect against weather. 3 samples are prepared for each of the mixture proportion for controlled samples, 5% cement replacement, 10% cement replacement for clear glass and coloured glass. Proper procedures for concrete mixture is practiced to avoid wastage or failure during sample preparation. Compressive strength determination for 7 days and 28 days cured concrete were taken to observe the impact of cement replacement with glass waste.

1.5 Dissertation Outline

The dissertation for this project comprises of 5 chapters which are Introduction, Literature Review, Methodology, Results and Discussion, and Conclusion. Chapter 1 of this dissertation provide a glance on the background of study, problem statements, objectives, scope of work and the dissertation outline for overall chapter.

Besides, Chapter 2 related the research topic that distribute into several components including the past studies finding that closely related to the study. The research topic discussed mainly the effect of cement replace with glass waste for concrete by various of research paper produced by students and lecturers. The research components are cited properly to avoid act of plagiarism in this study components.

Moreover, Chapter 3 explained about the methodology and procedures that are conducted for this study. All of the modification of sample preparation are listed to avoid false information happened during laboratory sessions. Each of the steps are explained in details with the additional information of data collection, analysis process and presentation.

Last but not least, Chapter 4 related to the result obtained from the test conducted and discussed in details. Discussion is presented in the form of table, graph and explanation either the result obtained achieved or not. Result obtained must satisfied the research outcomes that shows the success in this study.

Lastly, Chapter 5 conclude the overall achievement that fulfilled the objectives of this project. Recommendation and advice are included as reference for any individual or team that interested to improve this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

For this Chapter 2, various of past researches done by other researches mainly by students which related to this project topic. Researches and information from thesis papers, reports, articles and journal are taken for study purposes in order to improve the recent researches for future knowledges. Moreover, this part will mainly explain and discussed about characteristic of concrete, properties of glass and environmental effect that cause by concrete production and glass waste.

2.2 What is Concrete

Raqifa Rahman Chowdhury (n.d.) stated that concrete is a very important and valuable building material. The cement and water begin a reaction with one another to bond themselves into a hardened mass once all of the constituents - cement, aggregate, and water unit of measurement are mixed in the proper amounts and causes the concrete to harden into a rock-like mass

Ahmed et al., (2016) stated that the science of choosing the best relative quantities of the components of concrete to provide the required qualities is known as concrete mix design. There are numerous variables that have been found to affect the proportions of ingredients in concrete, including specific gravity of materials, type and strength of cement, minimum and maximum cement content, water-to-cement ratio, mixing water requirements, aggregate-to-cement ratio, types, shapes, and maximum aggregate sizes, grading of aggregates, ratio of fine to total aggregate, trapped air content, concrete exposure conditions, and concrete's properties when it is still fresh and after it has hardened. Numerous design elements are interconnected. Designing high-quality concrete requires consideration of qualities like strength, durability, and workability.

Akin Ogun, (2018) explained that mix design discovered the proper mix proportions, concrete mix design entails a number of stages, calculations, and laboratory testing. This method is typically used for constructions that require higher concrete grades, such as M25 and above, as well as massive construction projects that require a considerable amount of concrete. The advantages of concrete mix design are that it gives the proper quantities of components, making concrete building more cost-effective in reaching the requisite structural strength. Because large structures require a great amount of concrete, reducing the quantity of materials used, such as cement, makes the project more cost-effective.

Shah & Shah (2014) concluded that concrete mix design is the process of choosing appropriate concrete materials and calculating their relative proportions with the goal of producing a concrete with the needed strength, durability, and workability as efficiently as feasible.

2.3 Mechanical Properties of Concrete

Akin Ogun (2018) stated that the grade of concrete is denoted as M15, M20, and so on, with the letter M denoting the concrete mix and the numbers 15, 20 denoting the stipulated compressive strength (fck) of 150mm cube at 28 days, expressed in N/mm2. As a result, the compressive strength of concrete is measured. The most common concrete grades are M20 and M25, while greater concrete grades should be utilised in severe, very severe, and extreme conditions.

Ayub et al., (2014) explained that mechanical parameters like as shrinkage and creep, compressive strength, tensile strength, flexural strength, and modulus of elasticity are used to evaluate the performance of concrete. However, in the case of concrete in which cement is partially replaced by mineral admixtures, all mechanical properties are not directly associated with compressive strength, and the effects of the same amount of different mineral admixtures on the mechanical properties of hardened concrete are not directly associated with compressive strength. The following is a list of the differences between the impacts of different minerals on mechanical properties.

Alam (2019) stated that concrete becomes stronger over time. Ordinary cement concrete increases its final strength by around 70 to 75 percent in just 28 days and by roughly 90 to 95 percent over the course of a year. In many cases, it is preferable to evaluate the suitability of a concrete before the 28-day test results are available. The 28-day strength may be estimated to be 1.5 times that of the 7-day strength in the absence of particular information on the ingredients used to make concrete.

2.4 How Cement is Made

Lafarge Exshaw Cement Plant, (2017) explained that the dry technique is the most prevalent method of producing Portland Cement. Quarrying the primary raw materials, primarily limestone, clay, and other materials, is the first phase. The rock is crushed after quarrying. There are various stages to this. The rock is initially crushed to a maximum size of roughly 6 inches. The rock is subsequently reduced to around 3 inches or smaller in secondary crushers or hammer mills. The crushed rock is pulverised, blended, and fed to a cement kiln with other components like iron ore or fly ash.

In massive cylindrical steel rotating kilns walled with special firebrick, the cement kiln warms all of the components to over 2,700 degrees Fahrenheit. Kilns can be as large as 12 feet in diameter. The slurry or finely ground raw material is put into the upper end. A roaring explosion of flame, created by perfectly regulated burning of powdered coal, oil, alternative fuels, or gas under forced draught, can be found near the lower end. Certain elements are pushed off in the form of gases as the material travels through the kiln. The remaining elements combine to produce clinker, a new material. Clinker emerges from the kiln in the form of grey marble-sized balls. Clinker is discharged red-hot from the kiln's bottom end and is usually cooled to handling temperature in a variety of coolers. The hot air from the coolers is pumped back into the kilns, saving fuel and increasing burn efficiency. Cement manufacturers crush the clinker once it has cooled and combine it with small amounts of gypsum and limestone.

Whiting, (1895) stated that the wet, dry, and semidry manufacturing techniques are named after the raw materials are ground wet and fed to the kiln as a slurry, ground dry and fed as a dry powder, or ground dry and subsequently moistened to form nodules that are fed to the kiln.

2.5 Physical Properties of Cement

Gopak Mishra, (2019) stated that many elements influence the properties of concrete, the most important of which being the percentage of cement, sand, aggregates, and water in the mix. The proportions of these components determine the varied qualities of concrete.

"Properties of Cement- Physical & Chemical - Civil Engineering," (n.d.) explained that cement strength is tested in three ways: compressive, tensile, and flexural. The strength of a specimen is affected by a number of parameters, including the water-cement ratio, cement-fine aggregate ratio, curing circumstances, specimen size and shape, moulding and mixing methods, loading conditions, and age. The following should be considered while assessing the strength which are cement mortar strength and cement concrete strength are not directly related. The strength of the cement is only a quality control metric. The strength tests are therefore carried out on the cement mortar mix rather than the cement paste. Finally, because cement increases strength over time, the time of the test should be specified.

Haimei Zhang, (2011) studied that the hydration, setting and hardening, strength, and heat of hydration are all affected by the size of cement particles. The larger the overall surface area of the cement particles and the larger the area in contact with water, the finer the cement particles are. As a result, hydration will occur quickly, setting and hardening will occur quickly, and early strength will be high. If the cement particles are too fine, however, they can easily react with the water and calcium dioxide in the air, destroying the cement storage. In the hardening phase, if the cement is too fine, it will shrink a lot. As a result, the finer the cement is ground, the more energy is lost and the cost rises. Cement particles typically have a grain size of 7-200 micro meter (0.007-0.2mm).

2.6 Chemical Properties of OPC Cement

Jahagirdar et al., (2019) studied that X-ray fluorescence (XRF) analyzer is used to determine the chemical composition and compound content of OPC and PPC cement. Aluminium oxide, or alumina, is responsible for the cement's quick setting property. The presence of the required amount of alumina lowers the clinkering temperature. Excess alumina weakens the cement.

Calcium silicates and aluminates are formed when a suitable amount of lime is present. A lack of lime in the cement decreases its strength and causes it to set too quickly. Excess lime causes cement to expand and crumble, making it unsound. The maximum amount of lime allowed in Portland cement is 60-67 percent as shown in Figure 2.4 below.

Iron oxide contributes to the colour of cement and also serves as a flux. It participates in a chemical reaction with calcium and aluminium at very high temperatures to generate Tricalcium Alumino ferrite (C_4AF), which gives cement hardness and strength. Fe_2O_3 content as stated in Figure 2.5 in cement should be between 0.5 and 6%, according to specifications.

Silica is the chemical name for silicon dioxide. To dicalcium and tricalcium silicate, a sufficient amount of silica needs be present in cement. The inclusion of silica in cement contributes to its strength. The amount of silica in cement that is acceptable is around 30%. The estimated limit of Silicon dioxide, according to the requirements, is 17 to 25 percentage. Figure 2.6 showed the Silica Oxide content in the OPC cement production.

2.7 Chemical Composition of Glass

	Bulk oxide, w/w %											Fineness	Density,
	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MnO	MgO	TiO_2	SO_3	P_2O_5	m^2/kg	kg/m^3
PC	17.93	5.22	2.97	62.03	0.20	1.76	0.140	4.06	0.360	3.76	0.440	388	3150
D	71.14	2.60	0.17	1.32	3.30	1.70	0.006	0.62	0.006	0.00	0.023	608	3688
L	65.52	1.22	0.11	5.11	12.35	1.88	0.010	2.95	0.027	0.14	0.038	542	2767
F	69.61	1.34	0.08	11.30	11.21	0.56	0.008	0.46	0.028	0.13	0.021	502	2741
G	67.80	1.53	0.36	10.93	11.09	0.55	0.018	1.58	0.062	0.03	0.023	463	2723
A	69.26	1.42	0.43	8.89	11.43	0.51	0.018	3.08	0.052	0.01	0.026	542	2843

Figure 2.1: Chemical Composition, Fineness and Density of Portland Cement and Waste Glass

Based on the Figure 2.1 above showed the chemical composition for fineness and density of Portland cement and waste glass. Fineness was determined using a laser diffraction particle size analyzer, specific surface area using a nitrogen adsorption technique, density using a specific gravity bottle or pycnometer, and chemical composition using an X-ray fluorescence spectrophotometric analysis (Kara et al., 2016).

2.8 Pozzolonic Reaction of Glass Powder

Zheng, (2016) studied which at the same hydration ages in general, the reference blend's portlandite content was higher than blends containing coarse or fine glass powder. The formation of C-S-H (Calcium Silicate Hydrate) is a result of Portlandite being consumed by glass grains in a pozzolanic reaction which cause a reduction in Portlandite content with time in glass powder with concrete mixture. A bigger amount of outer C-S-H was formed close to the glass grains in the paste after 60 days, the reaction ring around the glass grains is pretty even, and the spaces between the grains are adequately filled. At 60 days, the line separating coarse glass grains from precipitated portlandite or outer C-S-H that was created by the hydration of cement on the surface is still visible. On the surface of the coarse glass grains, a layer that is looser at 90 days may be visible. This layer eventually grows denser. Later ages reveal a denser matrix when compared to blend with quartz.

2.9 Alkali-Silica Reaction (ASR)

Huang et al., (2021) studied that the inhibitory mechanism of glass powder on ASR expansion may be caused by the probable pozzolanic property of ground glass powder when paired with the expansion rate and SEM diagram study results. When used as an auxiliary cementitious material in concrete, glass powder's SiO_2 is more actively involved in the pozzolanic process, consuming OH in solution and slowing down ASR, which prevents the production of ASR gels. It is crucial in preventing the growth of ASR. The conclusion drawn from the aforementioned trials is further supported, namely that "the addition of glass powder will improve the inhibitory effect on ASR expansion."

Afshinnia & Rangaraju, (2015) stated that the combination of glass powder and ASR-prone coarse aggregates demonstrated much lower expansion than control specimens in accelerated mortar bar and micro concrete prism tests when applied as an aggregate replacement material. This outcome demonstrates the usefulness of glass powder in reducing ASR-induced expansion.

Afshinnia & Rangaraju, (2015) studied that due to their small particle size, the glass powder particles may easily react with the alkaline pore solution in the early phases, leading to the rapid creation of a highly fluid ASR gel that diffuses into the nearby cement paste. This method may also be helped by the fact that the cement paste matrix's porosity is composed of bigger pores when the cement is young, which makes it easier for the ASR gel to penetrate the paste microstructure without considerably increasing the restraining stress required to promote expansion.

Tamanna & Tuladhar, (2020) stated that glass recycling is problematic due to inconsistencies in chemical composition and the presence of contaminants. Furthermore, the lack of local recycling facilities, along with high transportation expenses, makes recycling a costly procedure.

2.10 Result of Mechanical Testing based on Research Paper

2.10.1 Slump Test

Elaqra et al., (2019) studied that the increasing improvement in workability is caused by the content of glass powder. The increase in workability can be attributed to the addition of additional water to the mixture as the proportion of real water to cement rises with the amount of glass powder. Due to the usage of the free water in the hydrate product formation, the slump after 15 minutes was reduced.

Khatib et al., (2012) stated that the slump value of concrete that has had varied amounts of glass powder substituted for cement. The slump gradually increases as the amount of glass powder in the mixture increases.

Nassar & Soroushian, (2012) studied that the presence of milled waste glass is seen to slightly increase slump. This might be explained by glass powder behaviour of low water absorption capacity.

Mosaberpanah et al., (2019) explained that the opposite of how nano-silica affects UHPC's workability is accurate with waste glass powder. Results indicate that replacing waste glass powder with cement has slightly improved UHPC flow at all levels and increased slump because glass powder's surface structure is smoother and more crystallised than cement and glass powder absorbs less water than cement.

2.10.2 Compressive Strength Test

Nyantakyi et al., (2020) observed that the results revealed that the strength of 30% mixed colour glass concrete reduced by 20.76% in comparison to the control mix, and that the strength of 30% brown colour glass concrete, which had the greatest strength value for single colour concrete, declined by 21.84% in comparison to control mix (0 % glass). Weak bonding between glass powder and aggregates is the cause of the observed reduced compressive strength of glass concrete mixtures comprising 30%, 50% and 70% glass powder.

Islam et al., (2017) stated that during the age of 90 days, recycled glass concretes with additions of 10, 15, and 20% glass offered mean compressive strengths greater than the control concrete, with 10% cement substitution providing the highest value among them.

Rahma et al., (2017) studied there were a noticeable loss of strength during the initial stages of hardening in the case of 350 and 400 kg cement; this loss of strength was influenced by the rate of glass powder. However, this strength reduction was followed by a modest improvement in the days that followed, and it gets better at older ages of 28 and 56 days.

2.11 Testing Conducted for Concrete with Glass Waste

Elaqra et al., (2019) explained that in order to establish the ideal percentage of glass powder as a partial replacement for cement, this research experimentally examines the impact of GP on the strength of concrete. The investigation's goal is to examine how fresh and cured concrete reacts to various glass powder concentrations.

According to the findings of Nyantakyi et al., (2020), slump values of 30%, 50%, and 70% for both mixed and single-color glass concrete were marginally lower than for the control concrete mix (which contained 0% glass). An increase in the amount of glass bottle powder in the concrete mix may be the cause of the slump values decreasing.

Rahma et al., (2017) studied that despite having no absorption, normal concrete without plasticizer experiences a decrease in workability as the rate of glass powder increases. This phenomenon may be explained by the high surface tension that is created by the fines and high surface area of this powder, which is what allows it to capture the necessary amount of water for consistency. The water that has been held back returns at the same time as the hydration process develops over time, which results in a minor improvement in concrete strength.

Islam et al., (2017) stated that at 7, 14, 28 and 56 days old, concrete with glass added had lower mean compressive strengths than control concrete (concrete with 0% glass). At the age of 90 days, recycled glass concretes with additions of 10, 15, and 20% glass offered mean compressive strengths greater than the control concrete, with 10% cement substitution providing the best value among them. The compressive strength of the 25% glass addition was around 2% less than that of the control concrete.

2.12 Summary of Literature Review

Concrete mixture must be prepared using proper method by using concrete mix design form based on British Standard and Code of Practise. The mechanical properties of concrete from the slump test showed the decrease of workability while for the compressive strength test also showed the reduction of strength when replaced with glass powder. Different colour of glass replacement produced a different result of test evaluation due to different chemical composition based on the Figure 2.1 above.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In this chapter 3, the flow of study explain from the beginning of material finding based on the project proposal. The design life of a structure is the amount of time that can be used as intended by the designer before being replaced. It should still be functional after this time has passed. The nature and use of the element under consideration will determine the design life. Based on our desired design, BS EN 1990, Eurocode - Basis of structural design (Eurocode 0) provides indicative design lives for a variety of structures. The design working life must achieved 50 years of working life to be used for building structures and other commence structures with reinforcements based on table 3.1.

Table 3.1 Indicative Design Working Life

1.6 Design Life

The design working life for a structure is given in EN 1990: Cl. 2.3. The Malaysian values for design life as present in The Malaysian National Annex to Eurocode are shown in Table 1.2.

Table 1.2: Indicative design working life

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures
2	10 to 30	Replaceable structural parts e.g. gantry girders, bearings
3	15 to 25	Agricultural and similar structures
4	50	Building structures & other common structures
5	120	Monumental buildings structures, bridges, and other civil engineering structures

(Source: Table NA1 MS EN 1990: National Annex)

3.2 Mix Design

The design of concrete strength 20 N/mm^2 was considered as ordinary concrete group since it considered for mild exposure usage in construction structures. The proportion of mix ratio for grade 25 and below usually had their own mix ratio of cement, sand and aggregate without the need of calculation the mix design form. In order to get the precise and good mix proportion based on the type of materials and required strength, mix design calculation must be used without taking the existing nominal concrete mix for grade 20 which is 1:1.5:3. Table 3.2 shows 6 type of exposure condition based on BS 8110.

Table 3.2 Exposure Condition Based on BS8110

Environment	Exposure conditions
Mild	Concrete surfaces protected against weather or aggressive conditions
Moderate	Exposed concrete surfaces but sheltered from severe rain or freezing whilst wet Concrete surfaces continuously under non-aggressive water Concrete in contact with non-aggressive soil (see sulfate class 1 of Table 7a in BS 5328-1:1997) Concrete subject to condensation
Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing or severe condensation
Very severe	Concrete surfaces occasionally exposed to sea water spray or de-icing salts (directly or indirectly) Concrete surfaces exposed to corrosive fumes or severe freezing conditions whilst wet
Most severe	Concrete surfaces frequently exposed to sea water spray or de-icing salts (directly or indirectly) Concrete in sea water tidal zone down to 1 m below lowest low water
Abrasive[a]	Concrete surfaces exposed to abrasive action, e.g. machinery, metal tyred vehicles or water carrying solids
NOTE 1 For aggressive soil and water conditions see 5.3.4 of BS 5328-1:1997. NOTE 2 For marine conditions see also BS 6349.	
[a] For flooring see BS 8204.	

Mix design form that was used to calculate the mix ratio of concrete taken from the "Design of Normal Concrete Mixes" which was the British "DOE method". Overall procedures for concrete mix design flow comprised of 5 stages which were determining free water or cement ratio for target mean strength. Next, determine the free water content for targeted workability. Then, combine the result for stage 1 and stage 2 for cement content determination. Next, determination of total aggregate content and the last one deals with the selection of fine and coarse aggregate contents.

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CONCRETE MIX DESIGN

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Table 1 :Concrete mix design form

Stage	Item		Reference or calculation	Value
1	1.1	Characteristic strength	Specified	20 N/mm² at 7 days; Proportion defective 5 per cent
	1.2	Standard deviation (σ)	Fig 3	8 N/mm² or no data ____ N/mm²
	1.3	Margin (*k x σ*)	C1	(k = 1.64) 1.64 x 8 = 13.12 N/mm²
	1.4	Target mean strength	C2	20 + 13 = 33 N/mm²
	1.5	Cement type	Specified	OPC / SRP / RHPC
	1.6	Aggregate type : coarse		limestone
		Aggregate type : fine		river sand
	1.7	free-water / cement ratio	Table 2, Fig 4	} Use the lower value
	1.8	*Maximum free-water / cement ratio*	*Specified*	
2	2.1	Slump or V-B	Specified	Slump 60-180 mm or V-B 6-3 s
	2.2	Maximum aggregate size	Specified	20 mm
	2.3	Free - water content	Table 3	225 kg/m³
3	3.1	Cement content	C3	225 ÷ 0.52 = 432.69 kg/m³
	3.2	*Maximum cement content*	*Specified*	kg/m³
	3.3	*Minimum cement content*	*Specified*	kg/m³ - Use if greater than Item 3.1 and calculate Item 3.4
	3.4	Modified free-water /cement ratio		
4	4.1	Relative density of aggregate (SSD)		known/ assumed
	4.2	Concrete density	Fig 5	2400 kg/m³
	4.3	Total aggregate content	C4	2400 - 225 - 432.69 = 1742.31 kg/m³
5	5.1	Grading of fine aggregate	BS 882	Zone
	5.2	Proportion of fine aggregate	Fig 6	35% per cent
	5.3	Fine aggregate content	C5	35% x 1742.31 = 609.81 kg/m³
	5.4	Coarse aggregate content	C5	65% - 1742.31 = 1132.50 kg/m³

Quantities	Cement (kg)	Water (kg or l)	Fine aggregate (kg)	Coarse aggregate (kg)
per m³ (to nearest 5 kg)	432.69	225	609.81	1132.50
per trial mix of 0.0072 m³	3.12	1.62	4.39	8.15

Item in italics are optional limiting values that may be specified (see Section 7)
1 N/ mm2 = 1 MN/ m = 1 MPa (see footnote on page 8)
OPC = ordinary Portland cement; SPRC = sulphate-resisting Portland cement; RHPC = rapid-hardening Portland cement
Relative density = specific gravity (see footnote on page 15)
SSD = based on a saturated surface-dry basis

Figure 3.1 Mix Design Form for Grade 20 N/mm²

Preparing material which glass waste were taken from Tzu Chi Environment Protection Education Centre at Taman Sri Nibong, Pulau Pinang

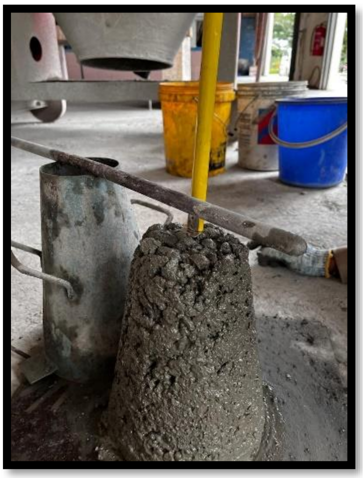
Transforming glass waste into powder state using crusher machine and ball mill with sieving of 150 micro meter

Identify ratio for concrete mixture of concrete grade 20 using mix design form which designed for 30 samples of $100mm^3$ mould size

Cement in the concrete mixture will be replaced by glass powder of 10%, 15% of clear glass and 10%, 15% of combined coloured glass

Sample preparation of 6 cube sample for each mixture variation of controlled sample, clear glass replacement and coloured combination glass of $0.0072\ m^3$ for 6 samples and test were conducted as shown in figure 3.2

Test on fresh concrete:



Test on concrete:

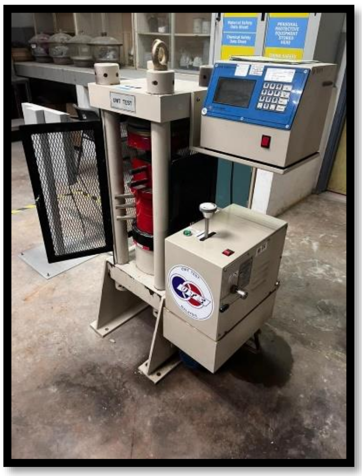


Figure 3.2 Flow of Work Progress in Concrete Laboratory USM Engineering Campus

3.3 Sample Preparation

The purpose of this study was to identify effective percentage of glass powder replacement with OPC Cement in term of compressive strength observation. Samples were prepared to proceed with compressive strength of concrete specimens with 10% and 15% glass powder replacement and controlled sample of concrete grade 20.

3.3.1 Preparation of Glass Powder

The glass waste had been taken from the Tzu Chi Environment Protection Education Centre at Taman Sri Nibong, Pulau Pinang. Other than that, it also had been collected from residence houses that stored glass bottle at their places as shown in Figure 3.3 below. At the recycling centre, the collector had sold all the glass waste for one ringgit per kilogram.

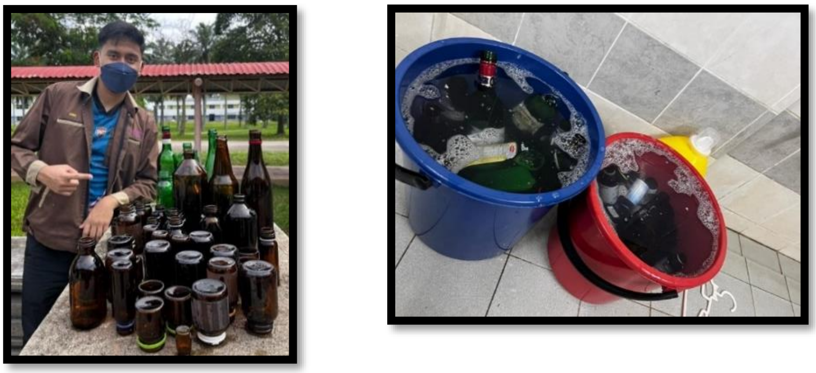


Figure 3.3 Collection of clear glass and colour glass waste

First of all, glass bottle must be cleaned before crushing to avoid any leftover residue at the bottle that might affect the glass powder state. All the glass waste must be crushed into small piece using crusher machine before going into ball mill process that turn solid glass waste into powder form. Proper attire must be applied namely glove, laboratory jacket and mask. All the glass waste must be sorted based on the coloured which comprised of clear, brown and green glass from recycling centre. After the process of grinding in the ball mill machine, the powder form of glass must be sieved using 150 µm sieve. Figure 3.4, 3.5 and 3.6 showed the crusher machine, ball mill grinding machine and sieving process for glass.

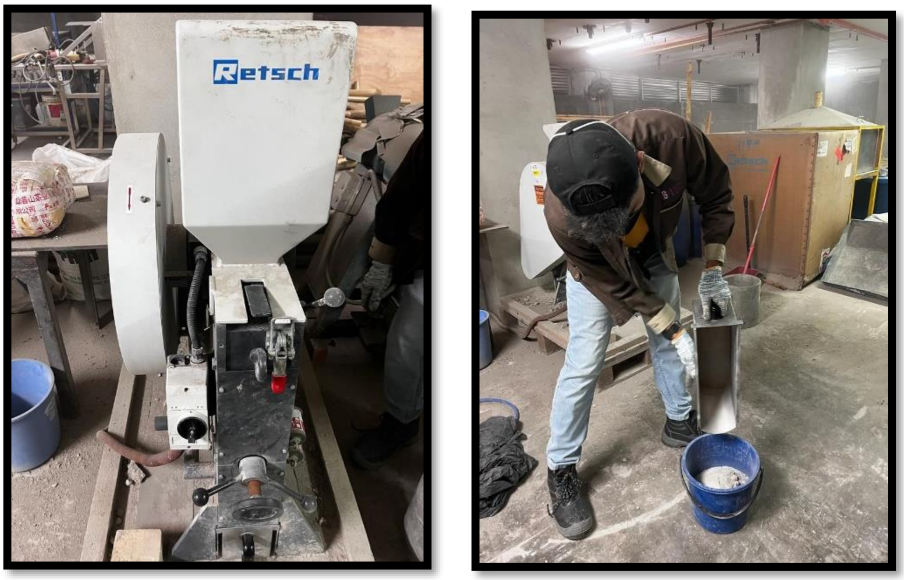


Figure 3.4 Crusher machine (left) and the product of crushed glass (right)

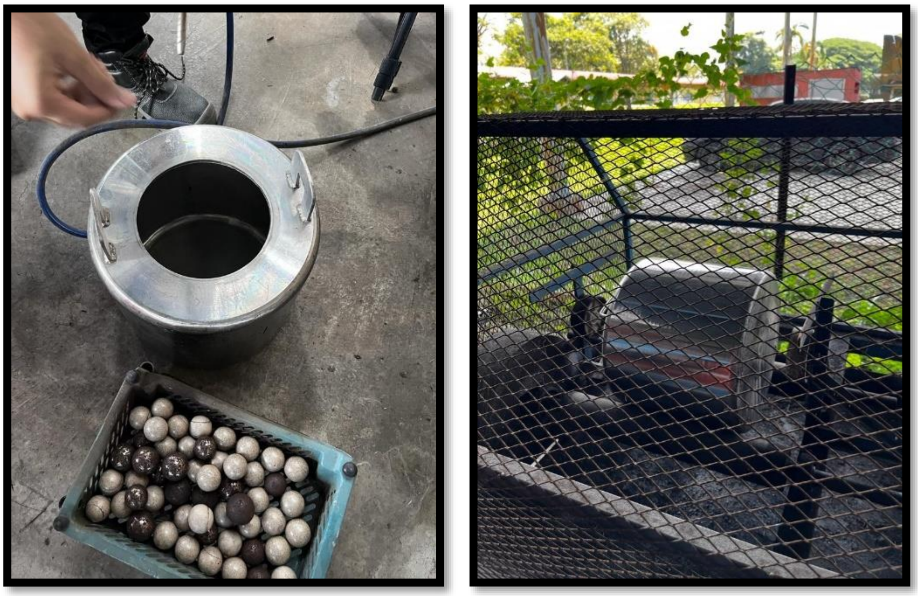


Figure 3.5 Ball Mill Grinding Machine

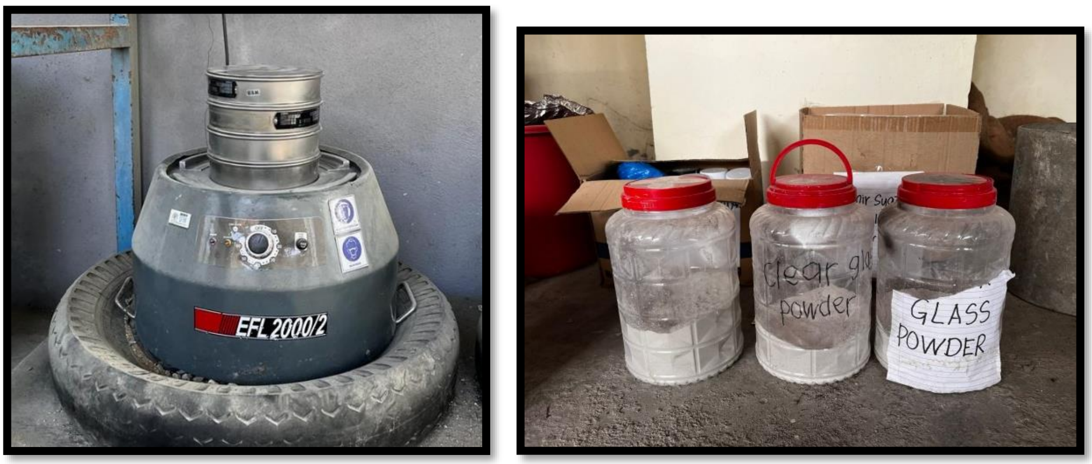
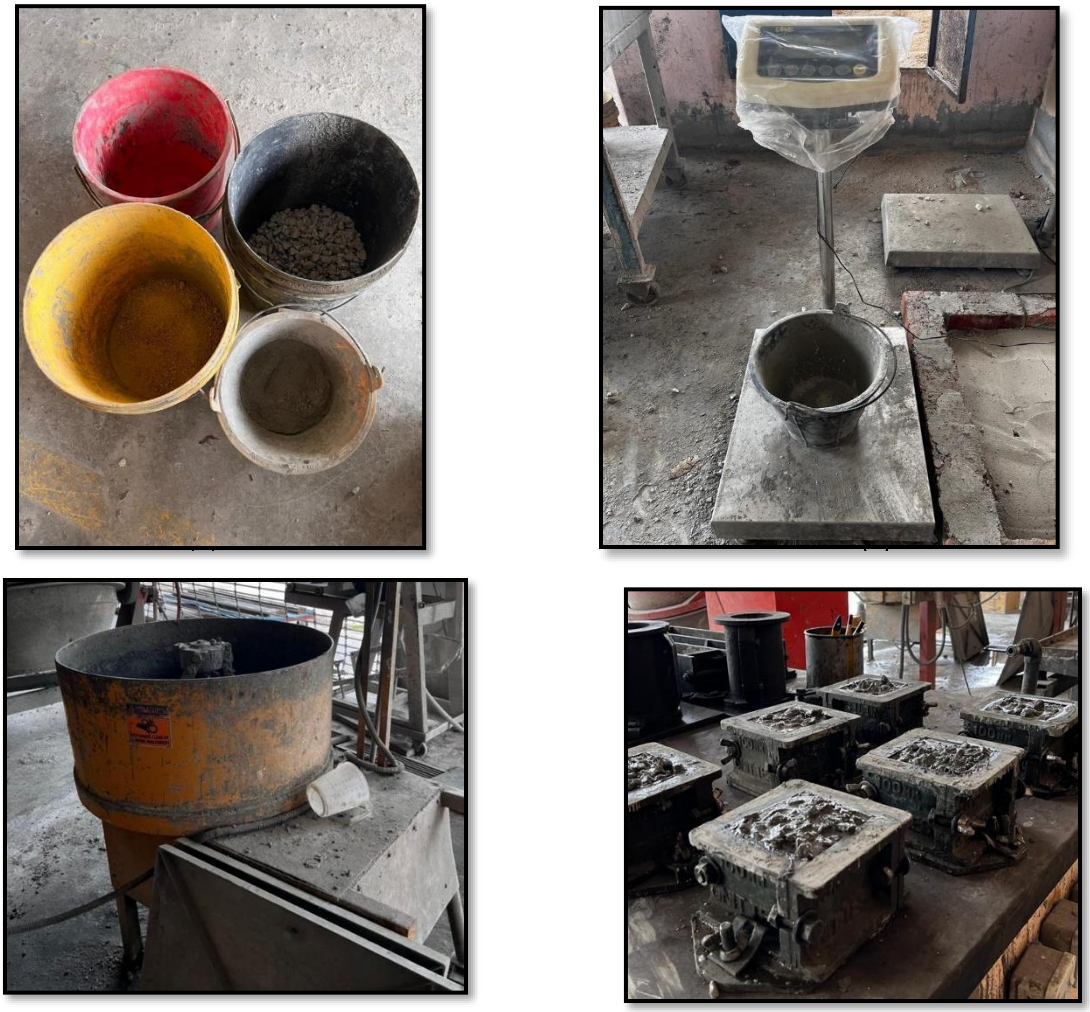


Figure 3.6 Sieving Process using 150 µm sieve and glass powder product (right)

3.3.1 Preparation of Concrete Mixture

Based on the study, it related with the glass powder replaced with cement in concrete and also prepared for the controlled specimen. The concrete mixture will be tested in term of strength development of 7 and 28 days of curing process. There were various of machine and tool used for preparing the concrete mixture namely concrete mixer machine, concrete mould of 100mm sizing, tamping rod, buckets and curing tank. Figure 3.7 below showed the equipment used to prepare concrete mixture.



(c) (d)

Figure 3.7 Buckets (upper left), Electronic Weighing Scale (upper right), Concrete Mixer (lower left) and Concrete Mould of 100mm (lower right)

For sample preparation, 30 samples were prepared for compressive strength test of 100mm x 100mm x 100mm concrete mould size. Total mass for 3 sample mixing in smaller concrete mixer was used which required approximately 8.52kg including water. 6 samples for 5 variations of concrete mixture. 5 variations required 6 samples each for 7 days and 28 days of compressive strength test. Type of variation for these studies were controlled sample, 10% and 15% of coloured glass sample, 10% and 15% of clear glass samples. Figure 3.8 and 3.9 showed the concrete mixture transferred into 100mm concrete mould and undergoes curing process after hardening for 24 hours.

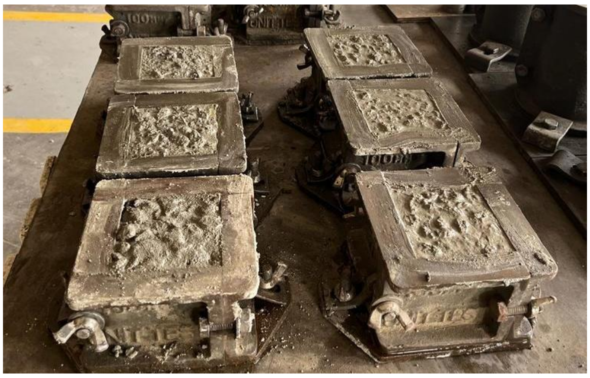


Figure 3.8 Concrete mixture transferred into mould

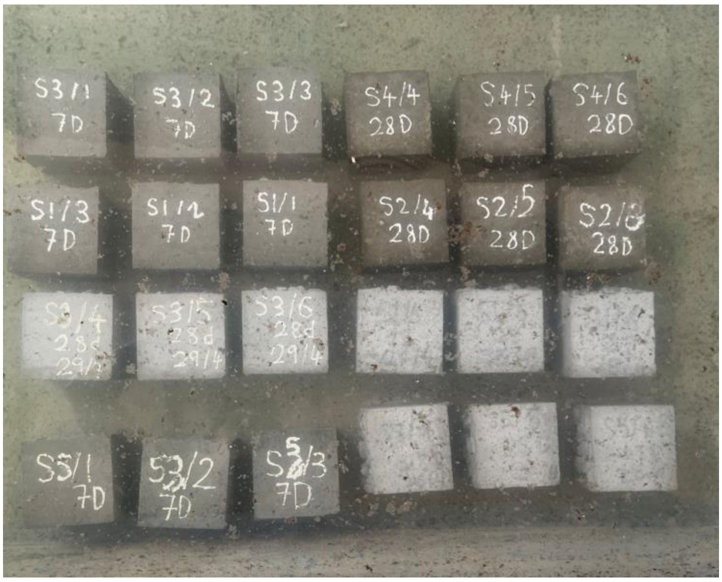


Figure 3.9 Concrete Cube undergoes Curing Process