

# STUDY OF NEW GREEN CONCRETE PRODUCT BASED ON UNGLAZED FIRED ROOF TILE WASTE



# BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS







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Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

# STUDY OF NEW GREEN CONCRETE PRODUCT BASED ON UNGLAZED FIRED ROOFTILE WASTE

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# DECLARATION

I declare that this project entitled "Study Of New Green Concrete Product Based On Unglazed Fired Roolftile Waste" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



# APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

~

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## DEDICATION

My genuine gratefulness and warmest regard to dedicating this work to my family and friends, especially to my respected parent, Marten Labo and Kuab Baru, constantly encourage and support me. Many thanks to my caring friends whose advice worked for this thesis paper, and who care about my well-being at the same time. I also dedicate this dissertation to my siblings, lecturers, and coursemates, who kindly shared their knowledge



#### ABSTRACT

The unglazed roof tile waste (URTW) potentially replaces fine aggregate concrete to produce new green concrete at 40, 50, and 60%. This research focuses on investigating the mechanical behaviour of URTW as fine aggregate in the concrete mix design. Both fresh and hardened concrete's physical and mechanical properties will be determined. The concrete's mechanical behaviour contained URTW compared to the control mix in terms of its workability during slump test and its percentage of water absorption and compressive strength in a hardened state. The current experiment result of the compressive strength test for new green concrete is improved at an increasing percentage of URTW replacement. The result of the mechanical behaviour as to its compressive strength, workability, and water absorption of new green concrete shall be parallel with the standard value of BS. Specifically, the compressive strength of new green concrete achieved the targeted mean strength of M25 grade concrete at every percentage of replacing river sand with URTW.



#### ABSTRAK

Sisa jubin bumbung tanpa kaca atau unglazed roof tile waste (URTW) berpotensi menggantikan konkrit agregat halus untuk menghasilkan konkrit hijau yang baru pada kandungan 40, 50, dan 60%. Kajian ini bertujuan untuk mengkaji tingkah laku mekanikal URTW sebagai agregat halus dalam reka bentuk campuran konkrit. Sifat fizikal dan mekanikal konkrit segar dan konkrit keras akan ditentukan. Sifat mekanikal konkrit mengandungi URTW akan dibandingkan dengan konkrit campuran kawalan dari segi kebolehkerjaannya semasa ujian kemerosotan atau slump test dan peratusan penyerapan air dan kekuatan mampatan dalam keadaan mengeras. Hasil eksperimen semasa ujian kekuatan mampatan untuk konkrit hijau yang baru telah bertambahbaik pada seiring peningkatan peratusan gantian URTW. Hasil kajian sifat mekanikal mengenai kekuatan mampatannya, kebolehkerjaan, dan penyerapan air konkrit hijau yang baru hendaklah selari dengan nilai standard BS. Khususnya, kekuatan mampatan konkrit hijau yang baru mencapai kekuatan min yang disasarkan pada konkrit gred M25 pada setiap peratusan penggantian pasir sungai dengan URTW



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# LIST OF SYMBOLS AND ABBREVIATIONS

URTW	Unglazed Roof Tile Waste
PCC	Portland Composite Cement
μm	Micrometer
mm	millimeter
AS	American Standard
BS	British Standard
PBM	Planatery Ball Milling
RAWA	Real-time Assessment of Water Absorption
M	Margin
k S	Permitted Percentage Defective Value
s 🚪	Standard Deviation
Fm	Mean Strength Target
fc	Characteristic Strength
Wf	Appropriate Free-Water Content For Fine Aggregate
We	Appropriate Free-Water Content For Coarse Aggregate
<i>w/c</i>	Water-Cement Ratio
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#### **CHAPTER 1**

#### **INTRODUCTION**

#### 1.1 Background

Presently, the growth of building construction has increased yearly over time. Klee (2004) stated that the estimated concrete manufactured each year is roughly 25 billion tons of concrete worldwide. According to Doye (2017), concrete is the ultimate significant contributor to the emission of the greenhouse. At the same time, concrete has unique properties where the recovery often falls between the standard definition of reuse and recycling. (Klee, 2004).

On the other hand, Subhan et al. (2014) believed that most manufacturing industries, especially in developing countries like Asia, are facing with solid waste management. These issues are essential to have extra attention because they could affect the environment badly. At the same time, development of construction, these wastes are accumulated from time to time. Somehow, dumping it could risk the environment because manufactured material contains other material, making it an odd substance to the environment.

By that, many researchers try to solve these issues by doing a lot of research, studying, and improving hypotheses to develop results that could help overcome environmental threat issues. All these studies show that the concrete that 90% depending on natural resources highly impacts the environment. Even though it reduces concrete development by substituting the cementitious material with other substances, it only accepted at least 20% of aggregate content to replace recycled concrete. Klee, (2004).

Producing green concrete based on industrial waste material could benefit both parties. The reason is that environmental threats could be reduced, and solid waste management would improve. So, by the end of this study, perhaps substituting the roof-tile of industrial waste could be sustainable enough to reduce industrial waste.

#### **1.2** Problem Statement

The constant use of natural resources has also slowly become a threat to the environment. Consequently, the culmination in the market is from time to time approximately exponential, meaning the consumption grows at a rate relative to its current value for most materials. Meanwhile, the roof tile manufacturer has difficulty managing the defective roof tiles that have become waste.

In the published paper, using recycled waste roof tiles to produce a new product like an acceptable substitute aggregate in concrete mix design could reduce consumption of natural resources simultaneously reduce environmental impact from dumping. Roof tile is made of 100% clay, and its material behaviour has its very own characteristics. The characteristic of roof tile itself is made to comply with AS 2094-2002 and is tested following AS 4064.4. Generally, all roof tiles are designed and tested to conform to the Australian Standard regarding their material properties, strength, durability, water absorption, and permeability.

Therefore, the idea of considering roof tile industrial waste to substitute fine aggregate to produce new green concrete is considered. Additionally, to substitute the sand in the concrete mix, the size of the crushed roof tile must imitate or be similar to the size of sands. To produce a fine aggregate out of the roof tile, it must go through a few processes, like crushing using Planetary Ball Milling Machine, and the sieving process using Vibrator Sieve Machine with selected parameter setting. Later, the result will be analysed to see if the aggregate meets the British Standard or the other way round.

# 1.3 Objective of Research

# **1.3.1 General Objective**

i. To recycle the unglazed-fired roof tile industrial waste (URTW) into a new green concrete product.

# 1.3.2 Specific Objectives

- To develop a formulation using MS Excel to calculate the proportion of URTW to substitute fine aggregate based on the BRE method.
- ii. To study the physical properties of the unglazed roof tile waste as a fine aggregate in accordance with the British Standard by crushing and milling processes.
- iii. To assess the mechanical behaviour of the produced green concrete based on fired unglazed roof tile industrial waste.

# 1.4 Scope of Research

The area of this study is an extension of parameters that should be explored and focused on. The properties of URTW to be replacing sand in the concrete mix at the maximum quantity is the aim of this research study. As a result, the work is also specified to produce fine aggregate based on URTW using a grading method that ensures the crushed URTW size is within the British Standard's range. To create the fine aggregate based on URTW, the parameter setting to get the desired aggregate size will be identified. Moreover, the new green concrete's strength will be determined at 28 days curing by compressive strength testing. Then, the result of the experiment will be collected from the compressive testing carried on each testing and procedure in this study shall comply with British Standard.

## 1.5 Research Rationale

This research aims to reduce the usage of natural resources (sand) to produce green concrete based on industrial roof tile waste. At the same time, maximising the composition of URTW in the concrete mix is important to ensure that at 28 days compressive strength of the green concrete imitates the conventional concrete mixture. This study's significance also focuses on the parameter of the methodology applied during the process.

The reason for choosing URTW as a substitution for sand is that the waste from the roof tile industry is piling up. With the drawback, this research that focuses on using URTW as sand substitution could be one solution. However, the properties of the URTW shall be investigated deeply to produce the green concrete by taking this research intensely. Hence, conducting this research may provide new improvement ideas for future reference. It will also benefit the roof tile manufacturer and the environment as this research may help manage the solid waste and recycle waste into green concrete.

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#### **CHAPTER 2**

#### LITERATURE REVIEW

#### 2.1 Introduction

Plenty of research studies has been conducted to investigate the various types of waste from material and industrial waste like plastic, ash, glass, and roof tiles used in concrete as an aggregate to produce a new green concrete. It is either being used as fully or partially substitute aggregate in a concrete but depends on the material's properties. Hence, many previous studies have been performed to achieve the right proportion of concrete content without neglecting the standard requirement. Which, in a way, has no severe impact on the concrete's engineering properties. So, this chapter will review previous research findings to investigate the suitable approach as a guide to conduct the current study.

# 2.2 Concrete

In agreement with Somayaji (2001) statement, concrete is the most common construction material used in construction. For example, various applications are widely used, from multistory buildings, dams to railroad ties. The concrete properties are broadly in various applications, which include mechanical properties. The mechanical properties are durability, compressive strength, wear-resistance, and resistance to environmental attack. However, not all its properties are essential, but most of them are.

According to Jackson & Dhir (1996), concrete is mainly made up of several main components. The essential components of a concrete mix are cement, water, and aggregate. In some cases, admixtures will be added to the concrete mix to modify concrete properties. These traditional ingredients are mixed and moulded into the desired size and shape while the mixture is still wet. (Somayaji, 2001). Additionally, as Domone and Illson (2010) stated, a chemical reaction would occur between water and cement after a few minutes when mixed, and this process is called hydration. This reaction will continue over time and produces a complex, strong, and durable material called hardened concrete or merely concrete. (Somayaji, 2001). Also, the tangible property is influenced by the ingredients' composition like cement type, water, and aggregate's size or shape.

#### 2.3 Cement

The essential component in concrete is cement. Conforming to Domone & Illston's (2010) work of studies, cement operates to bind them with aggregate the presence of water during the hydration process. Additionally, Portland cement 95% used in concrete is the most typical type of cement worldwide. However, it is vital to know the cement composition and the chemical process to produce good quality concrete. Moreover, Dvorkin et al. (2010) mentioned in their published book that selecting cement could be crucial too because the consideration should be given. For example, the required concrete properties are strength, the intensity of its growth, aggressive influence of the environment, structural features of the elements, and concrete workability.

Teychenné et al. (2010) specified that cement has different types and strength classes that produce concrete with different strength development rates. Even though the cement's different types would produce different strength ranks, it must obey the British construction standard.

#### 2.3.1 Type of Cement

Generally, cement is divided into two categories for construction and building industry applications. The categories are hydraulic and non-hydraulic cement. Somayaji (2001) stated that hydraulic cement is any cement that, thus from powder-like to solid-state with water. In other words, cement will turn into hardened concrete because there will be a chemical reaction occurs when there is a presence of water. On the other hand, non-hydraulic cement does not require water to change its properties to solid-state.

## 2.4 Aggregate

In concrete mix, aggregate is one of the essential components. Moreover, aggregate often to be a substitute for recycling substances. For example, Kamaruddin *et al.*, (2017) study investigated the potential of plastic waste as construction materials. Additionally, research uses several types of plastics to substitute them as an aggregate in the concrete mix. Furthermore, Etxeberria and Vegas, (2015) reported, their research was about the effect of fine ceramic as recycled aggregate. The intention considering ceramic as a substance that can substitute a fine aggregate in concrete is because the rejected amount of ceramic from industry was tremendous.

As a result, in some cases, it's more essential to reflect about using recycled concrete, plastics, or ceramic waste as a concrete mix alternative. For instance, the influence of replacing recycled aggregate in concrete on mechanical and physical properties needs to be considered. Furthermore, the form, size, and amount of aggregate impacted the mechanical and physical qualities of the concrete. So, in line with the statement of Paultre, (2003), he concludes that aggregate affects the strength of the concrete by considering characteristics written in the Portland Cement Association (1916) study for concrete. Also, the application geometrical requirement shall be determined, just as Brown (1998) reported in his study. However, Rached, Moya and Fowler, (2009) believe that aggregate may affect other mechanical properties of the concrete. For example, the workability, permeability, wear resistance, and low modulus elasticity may affect the cement paste during the shrinkage process.

The previous work of Brown (1998), Paultre, (2003) and Rached, Moya and Fowler, (2009) was about investigating the aggregate effects on the concrete to prove the size and shape of aggregate influenced the concrete's performance. However, a closer look at the literature of the Penn State Department of Engineering, (2016) notes that aggregate surface texture can influence concrete behaviour Teychenné, Franklin and Erntroy, (2010) In their opinion, the aggregate with a smooth surface can enhance concrete's new qualities in terms of its workability. Thus, aggregate with irregular is more chance to have better bonds.

#### 2.4.1 Fine Aggregate

Locally, fine aggregate is produced from river sand (Kang and Weibin, 2018). However, in most construction industries, the standard type of aggregate used is fine aggregate river sand, sea sand, sand-like pit quarry sand, and powder-like crushed stone. Moreover, in most research papers, fine aggregate is often being replaced using recycling aggregate. For example, in Babafemi *et al.*, (2018) previous study, he uses plastic to replace a delicate aggregate in concrete mix design. But then again, by considering plastic as a substitution in the concrete mix as fine aggregate, gradation must be conducted to ensure the size of recycle aggregate is complying to the BS. This restriction is mentioned because the deviations in a fine aggregate gradation significantly influenced concrete properties than coarse aggregates from a series of studies.



Figure 2.1 Fine aggregates (Kumar & Kumar, 2020)

#### 2.4.2 Coarse Aggregate

Brown (1998) described the coarse aggregate quantity in concrete took around 60% to 70% in volume of the mix design. On a side note, its role in concrete is strength and durability. Brown (1998) wrote that coarse aggregate that is not crushed are usually smooth and more round in its shape, contributing lower strength than crushed coarse. By considering the result of the previous study, aggregate is categorised between coarse and fine to assure the aggregate passes the standard of concrete mix through the grading process.

Additionally, in the opinion of Kaplan (1959), his studies show that contrary of the most result of concrete with a compressive strength is higher than 9 MPa, mainly contributed by the occurrence of the coarse aggregate that is prone to give ultimate compressive strength. Nevertheless, the average strength of the concrete may be affected by other factor like the size of coarse aggregate. However, as proven by Bloem & Gaynor (1963), he reported that the outcome of his research assures the growth in the size of the concrete produced lower compressive strengths.



Figure 2.2 Coarse aggregate (Kumar & Kumar, 2020)

## 2.5 Admixtures

Other than the standard traditional mixture of concrete, the admixture is also one of the materials to be considered to produce aggregate. Admixture is added to customise the engineering properties of the concrete without neglecting the construction standard. So, the general rule in the agreement of Jackson & Dhir (1996), is the strength performance of the substantial change due to the admixture added where the hydration process will take place and the amount of water/cement containing the concrete mix.

Though some admixtures are added to modify the workability characteristic and the setting rate of fresh concrete, others change concrete properties at mixing and hardened stages. (Somayaji, 2001). However, Domone and Illston (2010) quote that admixture is added to the concrete to modify some concrete properties.

#### 2.6 Impact of Recycled Material

Initiating recycling waste into new concrete might be the greatest thing to reduce waste on this planet since 85% of the building is concrete. However, consequences will have to be endured to produce a new green concrete and, of course, numerous research studies and experiments on its properties.

#### 2.6.1 Compressive Strength

Theoretically proven by Ceesay and Miyazawa (2019), compressive strength concrete with recycled aggregate reduces compared to the traditional concrete design mix, especially at the low water/cement ratio. As Midorikawa (2009) reported, compressive strength with w/c 0.5 that contained clay roof-tile coarse aggregate has higher than the standard aggregate concrete expected to develop rough surfaces provide excellent binding between cement paste and aggregate. However, some experimental of Midorikawa et al. (2009) design based on British Standard has failed to meet the mean strength. Factors of failures might be caused due to the high volume of w/c content, lack of water content, a low volume of cement, or high amount of coarse and fine aggregate. As a result, Mishra (2012) portrayed failure could also happen when the quantity of the cement content appears to be insufficient to coat the aggregate particle. Less cement content means low strength properties because the cement and the aggregate bind are not strong.

Based on data analysis testified by Giridhar (2015), with the increase percentage of ceramic proportion, the compressive strength of the concrete decrease. For 40% substitute for coarse aggregate, the compressive strength reduced 5.6%, which is minimal at 28 days, and it may be safely used in the concrete composition. However, Etxeberria and Vegas (2015) reports that compressive strength developed with a raised in percentage of recycled aggregate replacement. The strength of the concrete for 35% of recycled aggregate at 28 to 365 days, achieved the greatest compression strength. Then again, the reduced strength of the concrete mixed with a larger proportion (50%) is most primarily lead to the aggregate's more heterogeneous composition and the inclusion of odd material.



Figure 2.3 Compressive strength increases from 28 to 356 days of curing (Etxeberria and Vegas, 2015)

#### 2.6.2 Porosity

Generally, White (2012) defined porosity in his paper as the volume of pores to the volume of bulk rock and is unusually expressed as a percentage. The ability of water to move through the porosity is defined as permeability. Meanwhile, on the Spanish code on structural concrete, the porosity is higher than the typical mix design. Besides, the recycling aggregate of ceramic origin has even higher water absorption value than the nature aggregate (Kaplan, 1959; Espino, n.d.; Bloem & Gaynor, 1963). On the report of García-González et

al., (2015), Both porosity and pore dispersion of concrete have a considerable influence on its mechanical characteristics. Additionally, Gómez-Soberón, (2002) proved in his study that there is a vast difference between natural aggregate and recycled aggregate on their porosity. (García-González et al., 2015)

#### 2.6.3 Water Absorption

The ability of water to penetrate into the concrete's pore is called water absorption. Fundamentally, the purpose of the water absorption is to give an estimation of concrete's porosity volume. A Recycle aggregate of ceramic origin has an even higher value of water absorption compared to natural aggregate (García-González *et al.*, 2015). A closer look at Alsayed & Amjad (1996), previous work, their findings conclude that the water absorption of concrete made with recycling concrete is higher while the natural aggregate has lower water absorption. However, by confirming the findings of Alsayed & Amjad (1996), parallel with their study where water absorption is higher when recycle concrete contain lumps or unwanted materials.

Nevertheless, Based on BS 1881-122: 2011, the water aborption is determined when the concrete sample is submerged in water tank and weight of the concrete cube is taken at 28 days. To measure the quantity of water penetrate into the concrete, calculation will be made using the equation of correction factor.

$$Correction \ Factor \ = \frac{Volume \ (mm^3)}{Surface \ area \ (mm^2) \times 12.5}$$
 Eq (1)

Some research also says that gradation could affect the water absorption percentage because the uniform size of aggregate will affect the compaction factor where it might not be compacted properly. Therefore, well-graded aggregate needs to be conducted so the void in between larger aggregate will be filled by finer size of aggregate. (Alsayed and Amjad, 1996).

According to Tam *et al* (2008), BS is not the accurate method to measure water absorption in recycling aggregate that contains concrete. Thus, in his previous study of finding the new method to determine water absorption, he suggested using real-time assessment of water absorption (RAWA). RAWA approach claimed to deliver more accurate result and much simpler to use and not to mention it proposed to provide a real-time water absorption time-interval. Briefly saying, the RAWA concept is drying the concrete using the oven, then using pycnometer method to observe the water reduction.

#### 2.7 Method of Design of Normal Concrete Mixes (BRE1997)

Corresponding to Domine and Illston (2010) understanding, the process of mix design is about determining the right proportion of the ingredient in the mixes by calculating its ratio. (cement:fine aggregate:coarse aggregate and water/cement ratio). In additions, to produce an economical concrete mix considering using admixtures is added. Jackson & Dhir (1996) explained that several different approaches to mixing design had been widely used recently, and one of its most common is the 'Design of Normal Mixes' (DOE, 1988) method. Nevertheless, like Hughes' approach, another approach is used for mix design, and is also applicable to design a concrete mix design.

Fundamentally, the principle of the proposed method is to focus on the factors that could cause effects on the concrete's characteristics. They are countless numbers of properties of concrete to be determined. However, only a few of the properties are necessary to be measured, the workability of fresh and hard concrete lastly, at 28th day, the compressive strength will be determined.

## 2.8 British Standard

The mechanical property of a concrete usually measured by destructive testing for its compressive, tensile, and flexural strength in concrete design. In order to obtain concrete mechanical properties, tests are being conducted on specimens following the BS standard. Typically, most of the destructive methods implemented on the specimen are done on, the concrete cylinder or cube. (Bhatt, MacGinley, and Choo, 2006). Moreover, Pawar, Sharma, and Titiksh (2016) believe that an optimising aggregate gradation may enhance the concrete's properties in terms of its mechanical and durability. So, a good gradation of aggregate contributes to better self-compacting processed reduces the potential of segregation. Though, every method applied must conform to international standards like BS, ASTM, JIS, etc. As for the current research study, all testing methods, testing concrete cube samples, properties testing on aggregate, and the type of cement determined by the BS below.

Table 2.1 Selected mechanical properties testing on aggregate, cement, and concrete

Test	Standard or origin of country and Measurement Principle
Aggregates	BS 882:1992: Specification for aggregates from natural sources for concrete
UNIVER Aggregates	SITI TEKNIKAL MALAYSIA MELAKA BS EN 12620, 2013: Aggregates for concrete
Aggregates	BS 812-1: 1975: Methods for determination of particle size and shape
Cement	EN 196-1, 2016: Methods of testing cement. Determination of strength
Hardened concrete	BS EN 12390-2, 2000: Making and curing specimens for strength tests
Hardened concrete	BS EN 12390-3, 2002: Compressive strength of test specimens
Hardened concrete	BS EN 1881: Part 122 A: Determination of water absorption
Concrete	BS EN 206-1:2000: Specification, performance, production, and conformity
Concrete	BS1881-108:1983: Method for making test cubes from fresh concrete
Concrete	BS 1881-111: 1983: Method of normal curing of test specimens (20°C methods)
Concrete	BS1881-116:1983: Method for determination of compressive strength of concrete cubes

## 2.9 Standard Strength

Akin (2003) explained the standard concrete strength is measured by compressive testing according to BS and conforming the guideline in EN 196-1 at 28 days. The most typical way to assess concrete's capability is to analyse its compressive strength, which has become a requirement in concrete mix design. Jackson and Dhir (1996) wrote that maximum compressive load on concrete determine the compressive strength per unit area. As Domone & Illston (2010) stated, most countries, especially in the UK, specified the concrete's size for the destructive testing is sufficiently large to ensure results are not excessively influenced. Concerning the standard that Domone & Illston (2010) follows, up to 40 mm is suitable for a 150 mm for maximum sizes and suggested for concrete mix design is the maximum aggregate sizes in the concrete mix. The cube is normally cast and lubricated in steel moulds, carefully tamp for approximately 25 times to remove trap air and to ensure that opposite faces are smooth and parallel.

Plentiful of previous research about the factor of aggregate influence on the concrete is widely proven. For example, the shape, size, surface texture, and aggregate affect the new and complex concrete character. On a side note, the properties of concrete generally influence by the water/cement ratio, and type of cement. Bhatt, MacGinley, and Choo (2006) stated that the w/c is the vital factor influencing concrete strength. Commonly, the strength characteristic of concrete will be graded on the 28th day at being cured. To make a concrete cube specimens, BS EN 12390: Part 3 is referred for a standard size of 100mm or 150 mm for compressive strength tests. Meanwhile, for the compressive testing procedure shall comply with the BS EN 12390:3:2000. Any testing conducted to test the mechanical properties of concrete must conform to their method and result with the strength class table in 2.3, which meet the terms of the EN 196-1 requirement.

		Compressiv	e Strength, Ml	Pa	– Initial	
Strength	Early	strength	Standar	d strength	setting	Sound- ness
class	Two days	Seven days	28	days	time min	min
32,5 N	-	≥16,0	> 22 5	< 52.5	$\geq 75$	-
32,5 R	$\geq$ 10,0	-	$\geq$ 52,5	$\leq$ 52,5	-	-
42,5 N	$\geq$ 10,0	-	> 12 5	< 62.5	$\geq 60$	$\leq 10$
42,5 R	$\geq$ 10,0	-	≥ 42,5	$\leq 02,3$	-	-
52,5 N	$\geq$ 10,0	-	> 52 5	-	$\geq$ 45	-
52,5 R	$\geq$ 10,0	-	≥ 52,5	-	-	-

Table 2.2 The BS strength class of 32.5 grade of CEMII/B-M

Table 2.3 Minimum of concrete cube compressive strength at 28 days

Concrete Grade	Compressive Strength at 28 days, kN/mm <sup>2</sup>
M20	20
M25	25
M30	30
WALNINIA A	

# 2.10 Specification of Aggregates

The aggregate size is determined by the process of grading, where the particle size distribution is conducted with sieve analysis. By referring to the aggregate for concrete, the percentage passing sieve test specification is as shown in table 2.4.

Table 2.4 Grading of coarse aggregates from BS 812-102:1984

	Mass passing test sieve in percentage (%) for nominal size Limits for declared grading				
Sieve size, mm					
	40 mm to 5mm	20 mm to 5 mm	14 mm to 5 mm		
50.0	100	_	_		
37.5	90 to 100	100	_		
20.0	35 to 70	90 to100	100		
14.0	25 to 55	40 to 80	90 to 100		
10.0	10 to 40	3 to 60	50 to 85		
5.0	0 to 5	0 to 10	0 to 10		
2.36	_	_	_		

Sieve of size, mm	Limits	Mass passing test sieve in percentage (%) Limits for declared grading		
		С	F	Μ
10.00	100	-	-	-
5.00	89-100	-	-	-
2.36	60-100	60-100	65-100	80-100
1.18	30-100	30-900	45-100	70-100
0.60	15-100	150-54	25-80	55-100
0.30	5-70	5-40	5-48	55-100
0.15	0-20	-	-	5-70

Table 2.5 Grading requirement for fine aggregates from BS 812-102:1984

#### 2.11 Summary of Research

Based on the research that has been done in this chapter, cementitious materials are vital in every proportion of concrete mix design. For example, the type of cement used to design concrete has its grade stated in the BS guideline depending on its construction purposes. Cementitious material like cement, aggregate, and water is the essential ingredient of concrete mix. However, some previous works by researchers have alerted us of how vague the consumption of natural resources for construction is to threaten nature. With some of the brilliant ideas of researchers, recycling or waste could substitute the consumption of natural sources, but under few circumstances.

The circumstances are like green concrete's physical and mechanical properties might differ from natural sources. For example, in Alsayed & Amjad's (1996) research paper, with the increase size aggregate to the maximum, the workability of the fresh concrete will reduce. However, Kett (2000) said that adding mineral admixtures composed of fine solid particles could expand the workability and concrete durability. On the other hand, as for recycled concrete, the water absorption is more excellent so adding the volume of water could improve the workability.

Successively proven, most research studies reported that the aggregate properties greatly affect the properties of the concrete, especially its compressive strength. However,

there is none of the research studies has successfully proven that using roof tile as a fine aggregate in full scale gives a desired compressive strength. Other issues are that most of the research studies are none of the research stated in the life span or the sustainability of the green concrete. Therefore, addressing all the issues and information above, it's an opening door for research to be conducted in more detail. With the information gathered, developing a new approach for efficient methodology technique for new green production. The primary aim of the research is precise, and the following Chapter 3 shall discuss the selected testing and specification on the current study.



#### **CHAPTER 3**

## METHODOLOGY AND RESEARCH DESIGN

#### 3.1 Introduction

Methodology, research design, experimental parameters, including sampling conducted is covered in this chapter.

## 3.2 Research Design

Quantitative research of this study is aiming to understanding the characteristics of URTW to replace sand in concrete mix and investigate the difference and similarities in terms of its mechanical properties at 28 days. This study is also focusing on the structure to plan and execute research experimental data analysis.

Furthermore, the research design basically is divided into several parts to conduct the experiment, which is materials and equipment used and tools for data collection and analysis. For a more systematic and understandable process flow, figure 3.1 shows how the experiment will be conducted. Additionally, all methodologies conducted in this study in accordance to the British Standard


Figure 3.1 Process flow compression strength testing on concrete cube

### **3.3** Experimental Details

The experimental research illustrates a generic scenario of concrete strength growth as it cures at different ages. Meanwhile, the properties of the concrete mix ingredient are kept constant except for fine aggregate. Fine aggregate varies at the different compositions to investigate the concrete compressive strength at 28 days by conforming to the standard strength of cement in BS EN 12390:3:2000 guideline. The experimental work is performed using river sand, crushed coarse aggregate, and Portland Composite Cement, (CEM II/B-M) grade 32.5R. The detail of each material property used will be explained briefly in the following section as written in the literature review and the type of grade concrete to be produced is M25

### 3.4 Mix Design Calculation BRE Method

One of the various factors that could influence the strength of the concrete is the mix design that involves calculation to determine the right parameter for the desired strength on the 28th day. Basically, in BRE Method, there are five important stages in the flow process of mix design. Each of these stages, focuses on a different component of the design and concludes with a significant final parameter or proportional unit.. The concrete mix design is usually written in a form then all the values are calculated manually. However, as for this research study, the formulation for the mix design calculation was developed to ease and lessen any careless mistake during manual calculation. The formulation was created using Microsoft Office Excel by complying with the BRE Method. (Teychenné, Franklin and Erntroy, 2010).

Stage one is to determine the characteristic strength, target mean strength and water/cement ratio. Firstly, the grade of concrete chosen is M25 as a benchmark to design the concrete mix. M25 means a grade of concrete in which M stands for a mix of concrete and numerical figure 25 stands for compressive strength of concrete cube such as 25 N/mm2

after 28 days of curing. To produce the strength of concrete with a minimum of 25N/mm2, a concrete mix with a higher value is needed. Because, after any possible strength losses, the concrete designed will be equal to or greater than 25N/mm2. Teychenné, Franklin and Erntroy, (2010) wrote that any proportion of defectives may be defined in the guideline of BS 5328 for the characteristic concrete strength. Thus, the defective level of 5% in line with international reccomendation can be referred to in BS 810.



To design concrete with characteristic strength of 25N/mm<sup>2</sup>, a target mean strength and the current margin to be used in the mix design needed, and the equation is as shown in eq 1. In addition, the standard deviation must be known to calculate the target mean strength of the concrete at 28 days.

$$M = k \times s \tag{Eq 1}$$

Where M = Margin

k = Permitted percentage defective value

s = Standard deviation

*k* is a constant mathematically derived of the normal distribution, and the increase f defective is decreased. As stated in BS5328, the value of *k* is equal to 1.64. So, the *s* value is taken from figure 3.2 by taking  $25N/mm^2$  as the characteristic strength to get the value of *s*.



Figure 3.3 Relationship between standard deviation and characteristic strength (Teychenné, Franklin and Erntroy, 2010)

The target mean strength is determined by complying with the design codes specifications for designing the concrete mix. The calculation to define the target mean is by the equation below:

اويون سيتي تيڪنيڪل مليسيا ملاك UNIVERSITI  $f_m = f_c + M$  UNIVERSITI TEKNIKAL MALAYSIA MELAKA Eq (2)

Where,  $f_m =$  Mean strength target

 $f_c$  = Characteristic strength

$$M = Margin$$

Next, stage two is to determine the water content for the slump is assumed to be in the range of 60mm to 180mm with 20mm crushed coarse aggregate and uncrushed fine aggregate. Meanwhile, for this research study, the type of the aggregate for coarse and fine is different, so equation (3) is used to calculate the water content.

Where,  $W_f$  = Appropriate free-water content for fine aggregate  $W_c$  = Appropriate free-water content for coarse aggregate

Based on figure 3.5, the water demand for fine aggregate is 195 kg/m3 and 225 kg/m3. By applying the equation (3), as for free water content, the total will be 205 kg/m3.

Slump (mm)		0–10	10–30	30-60	60–180
Vebe time (s)		>12	6-12	3-6	0-3
Maximum size					
of aggregate	Type of				
(mm)	aggregate				
aLAYSIA					
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

Figure 3.4 Approximate of water content for various levels of workability(Teychenné, Franklin and Erntroy, 2010)

The following stage is to define the cement by using equation (4) to calculate the cement content needed for the mix design: When the value of cement content is against the maximum or minimum, the minimum value must be adopted w/c will be modified.

Cement Content = free water content / free w/c ratio 
$$Eq (4)$$

The fourth stage of the calculation estimates aggregate content needed for the concrete mix density that can be taken from figure 3.4. The calculation to estimate the aggregate content is subjected to the water content and its relative density of combined aggregate in the saturated surface-dry condition (SSD). Equation (5) determines the total weight of the aggregate. From figure 3.4, the water content of 205kg/m<sup>2</sup> for 20 mm crushed aggregated of specific gravity is 2.6 the wet density will be 2350kg/mm<sup>3</sup>.



Figure 3.5 Estimated wet density of fully compacted concrete

Total Aggregate content = D - C - W Eq (5) (Saturated and surface-dry)  $D = \text{density of concrete, } kg/m^3$  $C = \text{cement content, } kg/m^3$  $W = \text{the free-water content, } kg/m^3$ 

The selection of fine and coarse aggregate contents is the final step in the mix design equation. To begin, the fraction of fine aggregate obtained in figure 3.6 and the total content calculated in step 4 are needed.

Fine aggregate content = Total aggregate content  $\times$  proposition of fine Eq (6)

Coarse aggregate = Total aggregate content  $\times$  proposition of fine Eq(7) content



Figure 3.6 Recommended proportion of fine aggregate according to the percentage

passing a 600 um sieve

### 3.5 Material Preparation

### 3.5.1 Cement

In conrete mix, cement is the essential ingredient. Chemical reaction occurs when cement react with the present of water then bind sand and gravel to harden to form a concrete. The ratio of mixed concrete is according to the guideline-based on Ordinary Portland Cement, (CEM II/B-M) grade 32.5 was used. This type of cement is available in 50 kgs bags which complied to MS EN 197-1:2014 CEM II/B-M 32.5R.



Figure 3.7 Portland Composite Cement (CEM II/B-M) grade 32.5 R

Table 3.1	Showing the	e Properties of	(CEM II/B-M)	grade 32.5 R	(Declaration and
	0	1	( )	0	

ALAYSI.	
Item	MS EN 197-1 :2014 CEM II / B-M 32.5R
Initial setting time (minutes)	≥75
Mortar Prism Compressive strength	
Two days (N/mm2)	$\geq 10$
28 days (N/mm2)	≥32.5
Soundness (mm)	<10
Sulphutic Anhydride SO3 (%)	< 3.5
Chloride (%)	< 0.1
san .	

Cement, 2021)

## 3.5.2 Unglazed Roof Tile Waste (URTW)

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UNIVERSITITEKNIKAL MALAYSIA MELAKA Unglazed roof tile waste (URTW) is made of 100% clay with a synthetic colourant used as a fine aggregate to substitute river sand in a concrete mix design at different compositions. The form of URTW is shown in figure 3.1 and has not been crushed yet. With the structure of the URTW in large size, few crushing stages are needed to ensure the URTW imitates the size of sand.



Figure 3.8 Inside view of URTW before being crushed



### 3.5.3 Coarse Aggregate

Coarse aggregate in concrete contains particle that is majority larger than 5mm in size. In the concrete mix design for this study, crushed coarse aggregate is used depending on the desired workability for fresh concrete properties during the slump test. The coarse need to be washed to remove dirt and impurities that cover the gravels. The procedure of selecting the size of coarse is by doing sieve analysis that complies with BS BS EN 12620, 2013.



Figure 3.10Unwashed crushed coarse aggregate



# 3.5.4 Fine Aggregate

As for fine aggregate, river sand is used in the concrete mix. The river sands will usually be washed to remove the dirt that covers the sand. Then the sand is dried using the oven or traditionally air dry the coarse. The reason is to get more accurate data for sieve analysis. This process is a crucially important step to do before mixing it in the concrete to avoid any impurities that could affect the structure. Additionally, fresh concrete properties also could be affected if dring the slump test. The process of sieve process shall conforms by referring to BS 812-102:1984.



Figure 3.12 Washed river sand as fine aggregate

### 3.5.5 Water

Water is the most critical element in the concrete mix because a chemical reaction happens that allows the will bind with other material. Therefore, it facilitates mixing, placing, and compacting fresh concrete. The primary process of raw material preparation in this study is that the calculated proportion of the component to produce cement is mixed using a concrete mix design concept. Each of the components is prepared by following the BS 5328-1:1997 process.

### 3.6 URTW Crushing ITI TEKNIKAL MALAYSIA MELAKA

Crushing URTW could be vital as it needed to be crushed within a particular parameter to avoid the particle size of the aggregate being too fine or the other way round. This section will briefly explain the machines and the parameter used for crushing the URTW into fine aggregate. Figure 3.7 shows the crushing machine to crush the URTW raw material into debris-like particles shows in figure 3.8. At this stage, the size of the crushed URTW is still too large for fine aggregate.



Figure 3.13 Crusher machine



Figure 3.14 URTW after the first stage of crushing



Figure 3.15 Cassava crusher crushes



Figure 3.17 Roselle cutting machine crushes URTW to 5mm



Figure 3.16 3mm size of URTW



Figure 3.183mm size of URTW

After the second crushing, either 3mm (Cassava Crusher) or 5mm (Roselle Cutting Machine) aggregate size, the URTW will be ground using Planetary Ball Mill machine more commonly known as PBM, crush the URTW for the final stage. The concept of planetary ball milling is the cylinder compartment filled with three- or four of 80-mm diameter and another seven- or six of a 30-mm diameter of steel balls. The high-energy frequent impact of balls is how the grinding of the sample is carried out. The mill grind process starts when the base plate provides the centrifugal force to the grinding balls. So, the cylinder compartment rotates Independently (in the opposite direction), making the balls hit the bowl's inner wall several times. Since the bowls rotate in opposite directions, the grinding process is done due to friction occurring in the bowl between the steel balls. As for the experiment, the speed of the cylinder to rotate is 280 revolutions per minute for at least 20-25 minutes to grind approximately 200 grams - 280 grams per batch. The parameter used for 3mm and 5mm size of aggregate is shown in table 3.2 below.

The crushing process of URTW is carried out in three stages to get the acceptable aggregate range of size determined by the British Standard guideline as elaborated in the literature review. However, the maximum size for fine aggregate is 5 mm. Therefore, aggregate larger than 5mm will be considered coarse aggregate. A grading process is conducted to identify the crushed URTW is within the standard.

Feeding sample	Size of	Grinding	RPM	Steel ball size (Diameter, mm)	
	aggregate	ume		30	80
	3 mm	20 minutes	280	7	3
UKIW	5 mm	25 minutes	rev/min	6	4

Table 3.2 Parameter to grind URTW



Figure 3.19 Planetary ball mill machine





Figure 3.20 Cylinder bowl with three of Figure 3.21 Filled the twin bowl with 80 diameter balls and seven of 30 diameter MALAYSIA URTWKA balls



Figure 3.22 Control system of the machine



Figure 3.23 URTW powder-like after grinding

### 3.7 Grading

Fine and coarse aggregate used in the manufacture of cement concrete is made of various sizes, ranging from nominal and maximum to the smallest specified. Therefore, gradation is explained on how various aggregate sizes are distributed according to their particle size. In other words, gradation is also known as particle-size distribution where it refers to proportions by mass or weight. Sieve analysis will be conducted to determine the particle distribution for grading fine of aggregate by following the British Standard practice BS812: Part 1.

### 3.8 Sieve Analysis

Gradation of aggregate is determined from sieve analysis where the aggregate passes through a series of sieves then weights the retained particle in each sieve. Thus, a sieve is an apparatus in around shape with a square opening of different sizes comply with BS 410 which specifies the appropriate aperture and size. The weighted result will be expressed as in percentage and compared with the grading limit specified in BS 812-102:1984

The relative proportion of particles retained or passing through each set of sieves placed in decreasing order is determined by the sieve analysis (figure 3.15) from 50.0 mm, 2.36 mm, 1.18 mm, 600  $\mu$ m, 300  $\mu$ m, and 150  $\mu$ m for fine aggregate. As for coarse aggregate, the aperture size is 50.0 mm, 37.5 mm, 20.0 mm, 14.0 mm 10.0 mm and 2.36 mm. The particle retained (figure 3.17) in each of the sieves will be weighted and carried out in a mechanical vibrating sieve shaker machine (figure 3.16) where duration for fine aggregate 10 minutes and 20 minutes A graph is drawn to plot the particle distribution curve alongside the percentages of weights retained in the series set of the sieve in figure 3.19.



Figure 3.24 Fine aggregate sieve



Figure 3.25 Coarse aggregate sieve



Figure 3.26 Sieving in the process by using vibrating sieve shaker machine



Figure 3.27 Retained aggregate according to its size after the sieving process

### 3.9 Mix Proportion of Concrete

The percentage of concrete materials is determined by conventional concrete mixes based on desired strength by following the traditional strength of regular concrete (BS EN 206, 2013). Figure 3.1 shows the flow process on how to mix concrete design is conducted. The mixes should be made in compliance with BS 181: Part 125 requirements. For this research study, the mix proportion of concrete is calculated in the created formulation as explained in 3.4. Therefore, the total quantity for each ingredient is calculated and tabulated in table 3.3. However, the quantity for each proportion of 0%, 40%, 50%, and 60% are tabulated in table 3.5. Each ratio will have six samples for three different days of curing (seven, 14, and 38 days). The total sample for this experiment is 36 samples with varying percentages of URTW proportion.

After all the materials properties have been analysed (size of aggregate and type of cement used), each ingredient will be mixed in the mixing tray in a dry state. Then, the water is added gradually into the mixing. The mixing process can be done by hand, as shown in figure 3.19. The workability of the well-mixed concrete will be tested through a slump test explained in 3.9.



Figure 3.28 Control mixture



Figure 3.29 Experimental mixture



Figure 3.30 Equipment needed for the conrete mixing process



Figure 3.31 Mixing all ingredient and gradually add in water manually



Figure 3.32 Fresh wet concrete being well mixed

Batch no.	Sample	% of replacement with URTW	Sand (kg)	URTW (kg)	Coarse aggregate (kg)	Cement (kg)	Water (kg)	w/c ratio
1	CM0	0	7.2	0	6.7	4.8	2.4	0.5
2	URTW40	40	4.3	2.9	6.7	4.8	2.4	0.5
3	URTW50	50	3.6	3.6	6.7	4.8	2.4	0.5
4	URTW60	60	2.9	4.3	6.7	4.8	2.4	0.5
	Total		18	10.8	26.8	19.2	9.6	0.5

Table 3.3 Quantities of materials for the concrete mix per cubic meter

### 3.10 Slump Test

In mix design of concrete, slump test is conducted to investigate the workability of the fresh concrete after mixing. Workability of fresh concrete needed to be measured to ensure the efficiency of handling the fresh concrete during casting. However, each step of the process must comply the procedure stated in BS 1881: Part 102 for slump test and BS 1881: Part 104 for vebe time test. Vebe time test is the time taken measured for the slump to drop from original height of the slump cone.





Figure 3.33 Slump test for control mix Figure 3.34 Slump test for URTW50



Figure 3.35 Self-compacting process in a steel mould to remove trapped air



Figure 3.36 Steel moulds of 100mm x 100mm without fresh concrete in it



# 3.11 Curing NIVERSITI TEKNIKAL MALAYSIA MELAKA

Concrete curing regulates the rate and level of moisture loss from concrete during cement hydration. Usually, this process will take 24-48 hours to ensure the concrete is fully hardened. However, the temperature for this process is to be assumed at room temperature. Generally, the ultimate strength of the concrete is increased by keeping the concrete much longer in the water. Curing occurs immediately after concrete placement and finishing, and it entails maintaining ideal moisture and temperature conditions for lengthy periods, both at depth and near the surface. A sufficient quantity of water is present in properly cured concrete for continuous hydration and developing strength, volume stability, freezing and thawing resistance, and abrasion and scaling resistance.

30/n 50%	30/11 50%	2019 50%
2 216 kg	2.237kg	2.198kg
51	51	34
28days	7 days	.79 days
30/11 50%	1/12	viz 502
2.1864g	2.208	2122 kg
S2	7 hri	7 hri
28days	52	5 4
2.0/11 50/	1/12 507.	1/12
2.218 ×9	2.216	2.169
53	7 hri	3hri
28 days	53	5.4

Figure 3.38 Concrete cubes immersed in a tank filled with water

### 3.12 Water Absorption

After removing the sample from the concrete cube cured for 24 hours, the water absorption process took place. When the concrete is hard enough to be handled, it will be immersed in water for seven, 14, and 28 days. Before being immersed in the concrete cube, its weight will be recorded. So, on the day of concrete to be tested, it will be weighed again to investigate the weight difference between before and after immersion.



Figure 3.39 Weighing the concrete cube at 7days age before compression strength testing

### 3.13 Mechanical Testing

In this section, mechanical testing is conducted on the concrete cube after being cured for a certain period of days. Destructive testing will be carried out on the concrete using hydraulic press compression strength testing.

#### **3.13.1 Compressive Strength Test**

The mechanical properties of the hardened concrete are determined after being cured in water for seven, 14, and 28 days. Using Class 1 Motorised Hydraulic Compression Machine Electrical Operated in Compression Mode, the strength of the hardened concrete is determined. The machine-classified under Class 1 as it meets the tolerance of percentage error  $\pm 1.0\%$  as written in BS EN 12390-4:2000. The strength of the concrete usually defines the maximum load that the concrete can endure. The loading rate of the machine is set up to 4-8kN/s for 100mmx100mm size of concrete cube. Finally, the testing result will be recorded and analysed in Chapter 4. This procedure must comply with BS 1881: Part 116.



Figure 3.40 Compressive strength test in progress



Figure 3.41 Green concrete before compression strength conducted



Figure 3.42 After compressive testing conducted on green concrete at 28 days

### 3.14 Limitation of Proposed Methodology

There are some limitations in conducting the methodology after a research study has been completed and a part of the experiment completed. The limitation of the methodology is the time frame to experiment because the testing to determine the mechanical properties are destructive testing. By means, the experiment needs more samples to prepare for the experiment. In addition, the equipment for tensile strength is limited because the mould of the equipment is not available in the laboratory. Other than that, tensile testing is not relatively easy to conduct because the absence of concrete tensile machine for direct tension test is not available in the laboratory. However, some alternative ways to determine the tensile strength is by conducting indirect testing of cylinder and modulus rupture.

### UNIVERSITI TEKNIKAL MALAYSIA MELAKA

### 3.15 Summary

For this chapter, the methodologies are conducted to determine fresh and hard concrete's physical and mechanical properties with different composition percentages for URTW but maintaining the same ratio following the relevant part of BS 1881. A slump test is conducted to determine the fresh concrete's physical properties. Meanwhile, by using Class 1 Motorised Hydraulic Compression Machine Electrical Operated approach to determine compression strength. The methodology's primary purpose is to determine the proportion of cementitious material to get the desired strength of concrete after 28 days. This method is widely used in experiment practices according to structural construction BS.

The methods applied in this experiment are generally available, and the data is obtained accurately for compressive strength testing. On the contrary, obtaining the consistency of particle distribution is not entirely defined due to the planetary ball milling machine's performance. In particular, the concept of this experiment is to manipulate the traditional concrete mix design by replacing unglazed roof-tile waste as fine aggregate simultaneously to reach the standard strength of traditional concrete design. Simultaneously, aggregate gradation is conducted rightfully to ensure the particle distribution is consistent because every proportion of the material could affect concrete mechanical performance. The next chapter intends to present several studies and demonstrate to verify the previous study. Concurrently, analysis of the data for validation is to be proposed in the following

experiment.



### **CHAPTER 4**

### **RESULTS AND DISCUSSION**

### 4.1 Introduction

This chapter presents the results and analysis based on the research study in Chapter 2 and conducted as explained in Chapter 3, which will be discussed in more detail, especially on its mechanical properties when a compressive strength test is conducted. The data and analysis obtained will guide further research and improvement.

### 4.2 Analysis of Experimental Data

In this section, the analysis for every result is presented. Without neglecting the requirement in BS, all results presented are valid to be reviewed for further study.

### 4.2.1 Fine Aggregate Grading

Numerous experiments have been conducted by complying with BS EN 12620:2013 Aggregates for Concrete, with the conformity of BS 206-1. As for this research study, UNIVERSITIEEKNIKAL MALAYSIA MELAKA crushed URTW must follow the same standard to fulfil the required parameter. The grading process of URTW gives out the result as shown in the plotted graph to ensure the curve of the outcome is within the limit of BS.

The total quantity of URTW needed to replace fine aggregate in the concrete mix is 10.85kg. However, the PBM cylinder bowl could only have the capacity of approximately 200grams per cycle. Therefore, the grinding of URTW is repeated several times to get the total quantity of 10.85kg to design three different proportions of the concrete mixture. To ensure the size of URTW follows the BS EN 12620:2013 requirement, the ground URTW will be sieved and record the data for analysis. The data from the sieve analysis must obey

the BS 882:1992, where the total quantity of material to be sieved at once is less or equal to

1kg.

Sieve Size, mm	Sieve Weight, kg	Mass Retained, kg	% Material Retained	% Cumulative Retained	% Passing
10.00	0.358	0.00	0.00	0.00	100.00
4.75	0.369	0.03	3.10	3.10	96.90
2.36	0.400	0.19	18.72	21.82	78.18
1.18	0.379	0.29	28.63	50.45	49.55
0.60	0.347	0.28	28.03	78.48	21.52
0.30	0.317	0.15	14.61	93.09	6.91
0.15	0.333	0.06	5.51	98.60	1.40
pan	0.235	0.01	1.40	100.00	0.00
		1.00			

Table 4.1 Sieve analysis of sand

Table 4.2 Sieve analysis of URTW

Sieve Size, mm	Sieve Weight, kg	Mass Retained, kg	% Material Retained	%Cumulative Retained	% Passing
10.00	0.358	0.000	0.000	0.000	100.000
4.75	0.369	0.000	0.000	0.000	100.000
2.36	0.400	0.103	9.372	9.372	90.628
1.18	0.379	0.227	20.655	30.027	69.973
0.60	0.347	0.339	30.846	60.874	39.126
0.30	0.317	0.223	20.291	81.165	18.835
0.15	0.333	0.159	14.468	95.632	4.368
pan	0.235	0.048	4.368	100.000	0.000

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Figure 4.1 Sieve analysis of percentage passing of sand and URTW

### 4.2.2 Coarse Aggregate Grading

Based on the BS EN 12620:2013 Aggregates for Concrete, with the conformity of BS 206-1, sieve analysis is conducted for coarse aggregate to ensure that the size is acceptable to be mixed with other cementitious materials. As written in BS 882:1992, the quantity of the coarse to be sieved is 3 to 4 kg for 20 minutes long. If the result of percentage passing is off the lower and upper limit, it is advised to repeat the process until the result of percentage passing is within the limit.

Size Seive, mm	Sieve Weight, kg	Mass Retain, kg	% Material Retain	% Cumulative Retain	% Passing
20	1.556	0.16	4.61	4.61	95.39
14	1.252	0.71	20.10	24.72	75.28
10	1.165	1.42	40.43	65.15	34.85
5	1.263	1.22	34.85	100.00	0.00
2.36	1.037	0.00	0.00	100.00	0.00
pan	0.878	0.00	0.00	100.00	0.00
	2	3.51			

Table 4.3 Sieve analysis of coarse aggregate



Figure 4.2 Sieve analysis of percentage passing of sand and URTW

#### 4.2.3 Workability

The workability of the freshly mixed concrete is measured during the slump test by its dropping from the original height of the standard slump cone, as explained in subtopic 3.9. Workability is measured to ensure that the concrete mixer is sufficiently workable to be properly consolidated. Most importantly, the concrete could be moved or placed in form without segregation.

Conversely, the graph in figure 4.3 shows that URTW40 and URTW60 workability are 35mm, which is not in the acceptable range and is lower than CM0. The acceptable workability based on the BRE method should be between 60mm-180 mm within 0s-3s vebe time. On the other hand, the slump value from URTW50 is within the range, giving good workability compared to URTW40 and URTW60. By referring to the slump value of URTW40 and URTW60, the workability is lower than CM0 could be caused by various factors.

One of the factors that could affect the slump value is the properties of the concrete mix ingredient. For example, the material's porosity, the type of cement used, or the preparation method before mixing. When the volume of porosity of the material (sand, URTW, and gravel) is higher, the water absorption level increases, resulting in the fresh concrete's workability during the slump test.

Batch no.	Sample	% of replacement with URTW	slump value, mm	Acceptable slump value, mm (BS 1881:part 102)
1	CM0	0	80	
2	URTW40	40	35	100 (0
3	URTW50	50	65	180-00
4	URTW60	60	35	

Table 4.4 Slump Value of Fresh Concrete



Figure 4.3 Workability of Fresh Concrete

### 4.3 Water Absorption Concrete

Water absorption of the concrete is determined as the increased mass resulting from immersion. At 28 days, the concrete will be weighed, and the results aare then recorded. However, to ensure the data recorded is valid, each procedure need to comply with BS 1881-122:1983. Based on the data tabulated in Table 4.2, maritime code BS 6349 requires that water absorption must not exceed 3% or 2%.

As for the concrete, every proportion is within the range where the highest water absorption is URTW50, followed by CM0. The inconsistent value of water absorption could be caused by various factors. One of the factors could be the porosity volume and size of the concrete's porosity. The porosity of the concrete might be caused during the casting process when the tamping method is not done correctly, leaving the concrete with air trapped within the concrete. Other than that, the properties of URTW, which was proven in a previous study has higher porosity volume compared to sand could be the factor that affect the slump value.

Batch no.	Sample	% of URTW replacement with	% absorption water at 28 days	Max % of water absorption of the concrete	Min % of water absorption of the concrete
1	CM0	0	1.697	3	2
2	URTW40	40	1.668	3	2
3	URTW50	50	1.707	3	2
4	URTW60	60	1.634	3	2

Table 4.5 Water absorption of concrete at 28days



Figure 4.4 Water absorption of concrete at 28 days

### 4.4 Green Concrete Compressive Strength

The concrete compressive strength development is recorded as shown in table 4.4 and plotted in the graph shown in figure 4.5. For this research study, the concrete grade standard M25 was chosen as a scale to determine the compressive strength of green concrete. The concrete mix was designed by using the ratio of 1:1.5:1.38 (cement, fine aggregate, coarse aggregate) and 0.50 w/c ratio and replaced the sand with URTW by 40%,50%, and 60.

The compressive strength results illustrated in figure 4.5 the pattern of average compression based on the experiment performed. CM0 is made with zero percentage of

URTW strength performance shows that it passed the minimum concrete grade compressive strength at 28 days, which is 32N/mm. The minimum compressive of the concrete needed to achieve is 25N/mm2 at 28 days. The green concrete containing 40%, 50%, and 60% of URTW shows an increasing compression development of the concrete.



Table 4.6 Compressive strength of concrete

Figure 4.5 Compressive strength of concrete at 28 days

### 4.5 Summary

Based on the experimental results and analysis obtained, the behaviour of fresh and hardened concrete is evaluated by conducting methods proposed in Chapter 3. Firstly, the behaviour of fresh concrete was examined during the slump test. As a result, the value of the slump will indicate the workability of the concrete. CM0 and URTW50 successfully achieved the acceptable slump value, mm, in accordance with BS 1881:part 102; however, URTW40 and URTW60 are not. According to the BRE method, if the slump value is not within the standard range, advisedly, the w/c should be modified.

Nonetheless, with the value of slump out of range, the w/c of the mix is not modified to maintain the ratio of the mix to get a comparable results at the end of the experiment. The reason slump value is important to be within the range is because when the slump value is low, the workability of the concrete is also low. Workability is important at this stage because the concrete needs to be moved and placed in a steel mould to make a concrete cube. During the process of making the test cube, the procedure must comply with BS 1881: Part108: 1983. Making concrete cubes is as vital as other processes because a wrongly procedure may lead to false refalseat the end of the experiment. Since the slump value for URTW40 and URTW60 is 78% lower than CM0. Hence, it's quite difficuilt to cast the cube since the workability of the fresh concrete is low too. When the workability is low, there is a chance that the air trap volume in the concrete will be higher. Traditionally, self-compacting is done to remove the air trap by tamping the concrete during casting. Despite that, URTW50 workability is 20% lower than CM0 but still within the acceptable range (60 mm to 180 mm) of standard slump test comply with BS 1881:part 102.

According to Etxeberria and Vegas (2015), an increased percentage of recycled aggregate resulting in increased water absorption of the concrete. Similarly with Khatib's (2005) study reported that an increased replacement percentage of recycle aggregate results

in increasing water absorption. Yet, water absorption of the concrete for this experiment shows inconsistent values between 40%, 50%, and 60% replacement of URTW. Proven in the study of V. Giridhar (2015), about the significant effect on the concrete's behaviour influenced by the aggregate properties, the inconsistence trendline of the water absorption result. In other words, it means that different type of aggregate use could give different output because the properties of aggregate influence the behaviour of the concrete.

A previous study by V. Giridhar (2015) about the properties of waste aggregate influence the strength of concrete, reported that the strength of the concrete decreases gradually due to higher water absorption. But, looking at Etxeberria and Vegas (2015) study, an increase of replacement of waste aggregate lead to higher strength compared to conventional concrete after 28 days of curing. Correspondingly to the study of Jatjo and Abdullah (2021), their analysis shows similarity in the compression strength development of concrete at 28 days with an increasing percentage of waste aggregate replacement.

An analysis of this study shows that green concrete mix developed higher strength than conventional mix with respect to the concrete grade M25 minimum target of 25N/mm2. From the result acquired, concrete containing URTW has improved its bonding between cement paste and aggregate compared to conventional concrete. Hence, figure 4.6 portrays the relation between compression strength versus workability to show which proportion has better performance. The proportion of URTW40 and URTW60 compression strength successfully achieved the target mean strength, but both concrete's workability is not acceptable. As for URTW50, the target mean strength achieved and the workability during the slump test is within the range.



Figure 4.6 Compression strength versus workability



### **CHAPTER 5**

### CONCLUSION

### 5.1 Conclusion

By developing the mix concrete design using the formulation, the proportion of every quantity of the ingredient is easily to be determined without calculating it manually to avoid miscalculation. The formulation was carefully developed based on BRE method to satisfy the required compressive strength. A value for water/cement (w/c) ratio is estimated for an appropriate test age (generally 28 days) and cement type.

Other than that, the roof tile physical properties from a big piece were crushed by complying with the BS EN 12620, which covers recycled aggregate properties for use in concrete in conformity with BS EN 206-1. The physical properties of the URTW must imitate the size of sand, so the parameter of the milling machine is specified

Mechanical behaviour of the produced green concrete based on unglazed roof tile industrial waste is determined by compressive strength machine. The analysis obtained shows that green concrete shows an improvement in the compression strength at 28 days. For further study on the improvement, the material preparation before mixing the fine aggregate (sand) needs to be immersed in water for some time to avoid false value during slump test.

### 5.2 **Project Potential**

The study finding could be applied to a typical concrete mix for construction. Additionally, by using roof tile industrial waste provided, this study could reduce natural resources. Furthermore, the strength achieved by the concrete is more than the target mean strength of M25. The compressive strength has improved, but not all the sample workability is within the range. So, the best ratio to use as M25 grade concrete is the proportion of URTW50. So, it could be concluded that 50% replacement of unglazed roof tile waste in concrete can safely be used in the concrete composition without considerable loss of compressive strength in construction.


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### APPENDICES

	WEEK													
TASKS	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<b>PREPARATION &amp;</b>	PLA	NNI	NG	r			1			-	r	1		
Project title														
selection														
Project discussion														
with supervisor														
Background study														
Problem statement														
	AALA	YSIA												
Project objectives			1900											
<b>RESEARCH STUD</b>	Y	1	1	5										
Literature review														
DEVELOP						-			-					
METHODOLOGY	ten ,													
PROJECT IMPLEN	MEN'	ТАТ	ION	$\leq$	2	2	2	j		n, 1	in	0		
	10	10		-				j.	2.0		- 10 M			
Compressive Test	ER	SIT	TE	KN	KA	L M	AL	AYS	IA	MEI	.AK	A		
URTW Crushing														
Grading of fine aggregate														
WEEKLV														
PRESENTATION														
REPORT														
WRITING														
PRESENTATION														
					ada 1									
Planning				A	ciual									

# APPENDIX A Gantt Chart Bachelor Degree Project 1

	WEEK													
TASKS	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<b>PREPARATION &amp;</b>	PLA	NNI	NG	_		-			-			-	_	
Project overview														
Project milestone discussion with SV														
<b>RESEARCH STUD</b>	Y													
Literature review														
DEVELOP METHODOLOGY														
PROJECT IMPLE	MEN'	ГАТ	ION											
	T													
URTW Crushing	ALA	YSIA												
Grading of fine			10							-	_			
				-					-					
Concrete mix design														
Compressive	then.													
strength test	1			-										
WEEKLY	,o L		lo,	4	2	<u>`</u>	2	ũ.:	~~~		·au	91		
PRESENTATION	10	11		-				· `-	97° 9.9	<i>v</i>	10 m			
REPORT UNIV WRITING	ER	SITI	TE	KN	KA	LM	AL	AYS	IA	MEI	AK	A		
	+													
PRESENTATION														
Planning	Actual													

# APPENDIX B Gantt Chart bachelor's degree Project 2

MIX D	SIGN CALCULATION FOR POP	RTLAND CEN	1ENT				
Stage	Item	Reference	Value			Unit(s)	
	characteristic strength	specified	25	N/mm²	at	28 days	
	defective proportion, k	Table 1	5.0%		k	1.64	
	standard deviation, s	Figure 3	8				
	margin, M		13.12	N/mm <sup>2</sup>			
1	target mean strength, fm	figure 3	38.12	N/mm <sup>2</sup>			
-	cement strength class	specified	ordinary portland cement			32.5	42.5
	aggregate type: fine	190	uncrushed				
	coarse	NY I	crushed				
	free water/cement ratio	table 2, figure 4	0.57	1	lower value	0.5	
	max free-water/cement ratio	specified	0.5	1		0.5	
	slump or vebe time	specified	60-180	mm or Vebe time		N/A seconds	
2	max aggregate size		20	mm			
	free-water content					205 kg/m3	268
	cement content					410 kg/m3	536
	max cement content	specified				kg/m3	
5	min cement content	specified				kg/m3	
	modified free-water/cement ratio						
	relative density of aggregate (\$SD)	known/assumed	(precentage passing 600 µ	ım sieve)		2,55	
4	concrete density	figure 5		1 A A	·	2350 kg/m3	
	total aggregate content	~~~ , <u>~</u>		w, and	w, ~9	1735 kg/m3	1546
	grading of fine aggregate	, U	1 <sup>4</sup>	· · · ·	V	21 %	
5	proportion of fine aggregate			10		52 %	
-	fine aggregate content	C5	1735	0.52	NALE I A	902 kg/m3	804
	coarse aggregate content	c5 ENN	1735	A 0 902	MELA	833 kg/m3	742
	Quantities	compant (k-)	fine aggregate	coarse aggregate	water		
	Quantities	cement (kg)	(kg)	(kg)	(kg or litre)		
	per m3 (to nearest 5kg)	536	804	742	268		
	per trial mix of (m3) 0.009	4.8	7.2	6.7	2.4		
	ratio	1	1.50	1.38	0.50		

APPENDIX C Modified Mix Design Formulation Created Using MS Excel

### Turnitin Originality Report

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Mohd Rosli Date : 17th January 2022 TABLE OF CONTENTS PAGE DECLARATION APPROVAL DEDICATION ABSTRACT ABSTRAK ACKNOWLEDGEMENTS TABLE OF CONTENTS LIST OF TABLES LIST OF FIGURES LIST OF SYMBOLS AND ABBREVIATIONS LIST OF APPENDICES 1.1 1.2 1.3 1.4 1.5 2.1 2.2 2.3 2.4 2.5 2.6 INTRODUCTION Background Problem Statement Objective of Research 1.3.1 General Objective 1.3.2 Specific Objectives Scope of Research Research Rationale LITERATURE REVIEW Introduction Concrete Cement 2.3.1 Type of Cement Aggregate 2.4.1 Fine Aggregate 2.4.2 Coarse Aggregate Admixtures Impact of Recycled Material 2.6.1 Compressive Strength 2.6.2 Porosity 2.6.3 Water Absorption i ii iii iv vi vii x xi 1 1 2 3 3 3 3 4 5 5 56 67899101011122.7 Method of Design of Normal Concrete Mixes (BRE1997)13 iv 2.8 British Standard 2.9 Standard Strength 2.10 Specification of Aggregates 2.11 Summary of Research RESEARCH DESIGN AND METHODOLOGY 3.1 Introduction 3.2 Research Design 3.3 Experimental Details 3.4 Mix Design Calculation BRE Method 3.5 Material Preparation 3.5.1 Cement 3.5.2 Unglazed Roof Tile Waste (URTW) 3.5.3 Coarse Aggregate 3 .5.4 Fine Aggregate 3.5.5 Water 3.6 URTW Crushing 3.7 Grading 3.8 Sieve Analysis 3.9 Mix Proportion of Concrete 3.10 Slump Test 3.11 Curing 3.12 Water Absorption 3.13 Mechanical Testing 3.13.1 Compressive Strength Test 3.14 Limitation of Proposed Methodology 3.15 Summary RESULTS AND DISCUSSION 4.1 Introduction 4.2 Analysis of Experimental Data 4.2.1 Fine Aggregate Grading 4.2.2 Coarse Aggregate Grading 4.2.3 Workability 4.3 Water Absorption Concrete 4.4 Green Concrete Compressive Strength 4.5 Summary CONCLUSION 5.1 Conclusion 5.2 Project Potential REFERENCES APPENDICES 14 14 16 17 19 19 19 21 21 26 26 27 28 29 30 30 34 34 36 38 39 40 40 41 42 42 44 44 44 44 46 47 48 49 51 54 54 56 62 v LIST OF TABLES TABLE TITLE PAGE Table 2.2 Selected mechanical properties testing on aggregate, cement, and concret 14 Table 2.3 The BS strength class of 32.5 grade of CEMII/B-M 15 Table 2.5 Grading 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34 Figure 3.23 URTW powder-like after grinding 34 Figure 3.24 Fine aggregate sieve 35 Figure 3.25 Coarse aggregate sieve 35 Figure 3.26 Sieving in the process by using vibrating sieve shaker machine 35 Figure 3.27 Retained aggregate according to its size after the sieving process 35 Figure 3.28 Control mixture 36 Figure 3.29 Experimental mixture 36 Figure 3.30 Equipment needed for the conrete mixing process 37 Figure 3.31 Mixing all ingredient and gradually add in water manually 37 Figure 3.32 Fresh wet concrete being well mixed 37 Figure 3.33 Slump test for control mix 38 Figure 3.34 Slump test for URTW50 38 Figure 3.35 Self-compacting process in a steel mould to remove trapped air 38 Figure 3.36 Steel moulds of 100mm x 100mm without fresh concrete in it 39 Figure 3.37 Steel mould filled with fresh concrete and labelled 39 Figure 3.38Concrete cubes immersed in tank filled with water 40 Figure 3.39 Weighing the concrete cube at 7days age before compression strength testing 40 Figure 3.40 Compressive strength test in progress 41 Figure 3.41 Green concrete before compression strength conducted 41 Figure 3.42 After compressive testing conducted on green concrete at 28 days 42 and lower limit 46 Figure 4.2 Sieve analysis of percentage passing of sand and URTW within the upper and lower limit 46 Figure 4.3 Workability of Fresh Concrete 48 Figure 4.4 Water absorption of concrete at 28 days 49 Figure 4.5 Compressive strength of concrete at 28 days 50 Figure 4.6 Compression strength versus workability 53 ix LIST OF SYMBOLS AND ABBREVIATIONS URTW Unglazed Roof Tile Waste PCC Portland Composite Cement µm Micrometer mm millimeter AS American Standard BS British Standard PBM Planatery Ball Milling RAWA Real-time Assesment of Water Absorption M Margin k Permitted Percentage Defective Value s Standard Deviation Fm Mean Strength Target fc Characteristic Strength Wf Appropiate Free-Water Content For Fine Aggregate Wc Appropriate Free-Water Content For Coarse Aggregate w/c Water-Cement Ratio x LIST OF APPENDICES APPENDIX APPENDIX A APPENDIX B APPENDIX C TITLE PAGE Gantt Chart Bachelor Degree Project 1 62 Gantt Chart bachelor's degree Project 2 63 Modified Mix Design Formulation Created Using MS Excel 61 xi INTRODUCTION 1.1 Background Presently, the growth of building construction has increased yearly over time. Klee (2004) stated that the estimated concrete manufactured each year is roughly 25 billion tons of concrete worldwide. According to Doye (2017), concrete is the ultimate significant contributor to the emission of the greenhouse. At the same time, concrete has unique properties where the recovery often falls between the standard definition of reuse and recycling. (Klee, 2004). On the other hand, Subhan et al. (2014) believed that most manufacturing industries, especially in developing countries like Asia, are facing with solid waste management. These issues are essential to have extra attention because they could affect the environment badly. At the same time, development of construction, these wastes are accumulated from time to time. Somehow, dumping it could risk the environment because manufactured material contains other material, making it an odd substance to the environment. By that, many researchers try to solve these issues by doing a lot of research, studying, and improving hypotheses to develop results that could help overcome environmental threat issues. All these studies show that the concrete that 90% depending on natural resources highly impacts the environment. Even though it reduces concrete development by substituting the cementitious material with other substances, it only accepted at least 20% of aggregate content to replace recycled concrete. Klee, (2004). Producing green concrete based on industrial waste material could benefit both parties. The reason is that environmental threats could be reduced, and solid waste 1 management would improve. So, by the end of this study, perhaps substituting the roof-tile of industrial waste could be sustainable enough to reduce industrial waste. 1.2 Problem Statement The constant use of natural resources has also slowly become a threat to the environment. Consequently, the culmination in the market is from time to time approximately exponential, meaning the consumption grows at a rate relative to its current value for most materials. Meanwhile, the roof tile manufacturer has difficulty managing the defective roof tiles that have become waste. In the published paper, using recycled waste roof tiles to produce a new product like an acceptable substitute aggregate in concrete mix design could reduce consumption of natural resources simultaneously reduce environmental impact from dumping. Roof tile is made of 100% clay, and its material behaviour has its very own characteristics. The characteristic of roof tile itself is made to comply with AS 2094-2002 and is tested following AS 4064.4. Generally, all roof tiles are designed and tested to conform to the Australian Standard regarding their material properties, strength, durability, water absorption, and permeability. Therefore, the idea of considering roof tile

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industrial waste to substitute fine aggregate to produce new green concrete is considered. Additionally, to substitute the sand in the concrete mix, the size of the crushed roof tile must imitate or be similar to the size of sands. To produce a fine aggregate out of the roof tile, it must go through a few processes, like crushing using Planetary Ball Milling Machine, and the sieving process using Vibrator Sieve Machine with selected parameter setting. Later, the result will be analysed to see if the aggregate meets the British Standard or the other way round. 1.3 Objective of Research 1.3.1 General Objective i. To recycle the unglazed-fired roof tile industrial waste (URTW) into a new green concrete product. 1.3.2 Specific Objectives i. To develop a formulation using MS Excel to calculate the proportion of URTW to substitute fine aggregate based on the BRE method. ii. To study the physical properties of the unglazed roof tile waste as a fine aggregate in accordance with the British Standard by crushing and milling processes. iii. To assess the mechanical behaviour of the produced green concrete based on fired unglazed roof tile industrial waste. 1.4 Scope of Research The area of this study is an extension of parameters that should be explored and focused on. The properties of URTW to be replacing sand in the concrete mix at the maximum quantity is the aim of this research study. As a result, the work is also specified to produce fine aggregate based on URTW using a grading method that ensures the crushed URTW size is within the British Standard's range. To create the fine aggregate based on URTW, the parameter setting to get the desired aggregate size will be identified. Moreover, the new green concrete's strength will be determined at 28 days curing by compressive strength testing. Then, the result of the experiment will be collected from the compressive testing carried on each testing and procedure in this study shall comply with British Standard. 1.5 Research Rationale This research aims to reduce the usage of natural resources (sand) to produce green concrete based on industrial roof tile waste. At the same time, maximising the composition of URTW in the concrete mix is important to ensure that at 28 days compressive strength of the green concrete imitates the conventional concrete mixture. This study's significance also focuses on the parameter of the methodology applied during the process. The reason for choosing URTW as a substitution for sand is that the waste from the roof tile industry is piling up. With the drawback, this research that focuses on using URTW as sand substitution could be one solution. However, the properties of the URTW shall be investigated deeply to produce the green concrete by taking this research intensely. Hence, conducting this research may provide new improvement ideas for future reference. It will also benefit the roof tile manufacturer and the environment as this research may help manage the solid waste and recycle waste into green concrete. LITERATURE REVIEW 2.1 Introduction Plenty of research studies has been conducted to investigate the various types of waste from material and industrial waste like plastic, ash, glass, and roof tiles used in concrete as an aggregate to produce a new green concrete. It is either being used as fully or partially substitute aggregate in a concrete but depends on the material's properties. Hence, many previous studies have been performed to achieve the right proportion of concrete content without neglecting the standard requirement. Which, in a way, has no severe impact on the concrete's engineering properties. So, this chapter will review previous research findings to investigate the suitable approach as a guide to conduct the current study. 2.2 Concrete In agreement with Somayaji (2001) statement, concrete is the most common construction material used in construction. For example, various applications are widely used, from multistory buildings, dams to railroad ties. The concrete properties are broadly in various applications, which include mechanical properties. The mechanical properties are durability, compressive strength, wear-resistance, and resistance to environmental attack. However, not all its properties are essential, but most of them are. According to Jackson & Dhir (1996), concrete is mainly made up of several main components. The essential components of a concrete mix are cement, water, and aggregate. In some cases, admixtures will be added to the concrete mix to modify concrete properties. These traditional ingredients are mixed and moulded into the desired size and shape while the mixture is still wet. (Somayaji, 2001). Additionally, as Domone and Illson (2010) stated, a chemical reaction would occur between water and cement after a few minutes when mixed, and this process is called hydration. This reaction will continue over time and produces a complex, strong, and durable material called hardened concrete or merely concrete. (Somayaji, 2001) . Also, the tangible property is influenced by the ingredients' composition like cement type, water, and aggregate's size or shape. 2.3 Cement The essential component in concrete is cement. Conforming to Domone & Illston's (2010) work of studies, cement operates to bind them with aggregate the presence of water during the hydration process. Additionally, Portland cement 95% used in concrete is the most typical type of cement worldwide. However, it is vital to know the cement composition and the chemical process to produce good quality concrete. Moreover, Dvorkin et al. (2010) mentioned in their published book that selecting cement could be crucial too because the consideration should be given. For example, the required concrete properties are strength, the intensity of its growth, aggressive influence of the environment, structural features of the elements, and concrete workability. Teychenné et al. (2010) specified that cement has different types and strength classes that produce concrete with different strength development rates. Even though the cement's different types would produce different strength ranks, it must obey the British construction standard. 2.3.1 Type of Cement Generally, cement is divided into two categories for construction and building industry applications. The categories are hydraulic and non-hydraulic cement. Somayaji (2001) stated that hydraulic cement is any cement that, thus from powder-like to solid-state with water. In other words, cement will turn into hardened concrete because there will be a chemical reaction occurs when there is a presence of water. On the other hand, non-hydraulic cement does not require water to change its properties to solid-state. 2.4 Aggregate In concrete mix, aggregate is one of the essential components. Moreover, aggregate often to be a substitute for recycling substances. For example, Kamaruddin et al., (2017) study investigated the potential of plastic waste as construction materials. Additionally, research uses several types of plastics to substitute them as an aggregate in the concrete mix. Furthermore, Etxeberria and Vegas, (2015) reported, their research was about the effect of fine ceramic as recycled aggregate. The intention considering ceramic as a substance that can substitute a fine aggregate in concrete is because the rejected amount of ceramic from industry was tremendous. As a result, in some cases, it's more essential to reflect about using recycled concrete, plastics, or ceramic waste as a concrete mix alternative. For instance, the influence of replacing recycled aggregate in concrete on mechanical and physical properties needs to be considered. Furthermore, the form, size, and amount of aggregate impacted the mechanical and physical qualities of the concrete. So, in line with the statement of Paultre, (2003), he concludes that aggregate affects the strength of the concrete by considering characteristics written in the Portland Cement Association (1916) study for concrete. Also, the application geometrical requirement shall be determined, just as Brown (1998) reported in his study. However, Rached, Moya and Fowler, (2009) believe that aggregate may affect other mechanical properties of the concrete. For example, the workability, permeability, wear resistance, and low modulus elasticity may affect the cement paste during the shrinkage process. The previous work of Brown (1998), Paultre, (2003) and Rached, Moya and Fowler, (2009) was about investigating the aggregate effects on the concrete to prove the size and shape of aggregate influenced the concrete's performance. However, a closer look at the literature of the Penn State Department of Engineering, (2016) notes that aggregate surface texture can influence concrete behaviour Teychenné, Franklin and Erntroy, (2010) In their opinion, the aggregate with a smooth surface can enhance concrete's new qualities in terms of its workability. Thus, aggregate with irregular is more chance to have better bonds. 2.4.1 Fine Aggregate Locally, fine aggregate is produced from river sand (Kang and Weibin, 2018). However, in most construction industries, the standard type of aggregate used is fine aggregate river sand, sea sand, sand-like pit quarry sand, and powder-like crushed stone. Moreover, in most research papers, fine aggregate is often being replaced using recycling aggregate. For example, in Babafemi et al., (2018) previous study, he uses plastic to replace a delicate aggregate in concrete mix design. But then again, by considering

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plastic as a substitution in the concrete mix as fine aggregate, gradation must be conducted to ensure the size of recycle aggregate is complying to the BS. This restriction is mentioned because the deviations in a fine aggregate gradation significantly influenced concrete properties than coarse aggregates from a series of studies. Figure 2.1 Fine aggregates (Kumar & Kumar, 2020) 2.4.2 Coarse Aggregate Brown (1998) described the coarse aggregate quantity in concrete took around 60% to 70% in volume of the mix design. On a side note, its role in concrete is strength and durability. Brown (1998) wrote that coarse aggregate that is not crushed are usually smooth and more round in its shape, contributing lower strength than crushed coarse. By considering the result of the previous study, aggregate is categorised between coarse and fine to assure the aggregate passes the standard of concrete mix through the grading process. Additionally, in the opinion of Kaplan (1959), his studies show that contrary of the most result of concrete with a compressive strength is higher than 9 MPa, mainly contributed by the occurrence of the coarse aggregate that is prone to give ultimate compressive strength. Nevertheless, the average strength of the concrete may be affected by other factor like the size of coarse aggregate. However, as proven by Bloem & Gaynor (1963), he reported that the outcome of his research assures the growth in the size of the concrete produced lower compressive strengths. Figure 2.2 Coarse aggregate (Kumar & Kumar, 2020) 2.5 Admixtures Other than the standard traditional mixture of concrete, the admixture is also one of the materials to be considered to produce aggregate. Admixture is added to customise the engineering properties of the concrete without neglecting the construction standard. So, the general rule in the agreement of Jackson & Dhir (1996), is the strength performance of the 9 substantial change due to the admixture added where the hydration process will take place and the amount of water/cement containing the concrete mix. Though some admixtures are added to modify the workability characteristic and the setting rate of fresh concrete, others change concrete properties at mixing and hardened stages. (Somayaji, 2001). However, Domone and Illston (2010) quote that admixture is added to the concrete to modify some concrete properties. 2.6 Impact of Recycled Material Initiating recycling waste into new concrete might be the greatest thing to reduce waste on this planet since 85% of the building is concrete. However, consequences will have to be endured to produce a new green concrete and, of course, numerous research studies and experiments on its properties. 2.6.1 Compressive Strength Theoretically proven by Ceesay and Miyazawa (2019), compressive strength concrete with recycled aggregate reduces compared to the traditional concrete design mix, especially at the low water/cement ratio. As Midorikawa (2009) reported, compressive strength with w/c 0.5 that contained clay roof-tile coarse aggregate has higher than the standard aggregate concrete expected to develop rough surfaces provide excellent binding between cement paste and aggregate. However, some experimental of Midorikawa et al. (2009) design based on British Standard has failed to meet the mean strength. Factors of failures might be caused due to the high volume of w/c content, lack of water content, a low volume of cement, or high amount of coarse and fine aggregate. As a result, Mishra (2012) portrayed failure could also happen when the quantity of the cement content appears to be insufficient to coat the aggregate particle. Less cement content means low strength properties because the cement and the aggregate bind are not strong. Based on data analysis testified by Giridhar (2015), with the increase percentage of ceramic proportion, the compressive strength of the concrete decrease. For 40% substitute for coarse aggregate, the compressive strength reduced 5.6%, which is minimal at 28 days, and it may be safely used in the concrete composition. However, Etxeberria and Vegas (2015) reports that compressive strength developed with a raised in percentage of recycled aggregate replacement. The strength of the concrete for 35% of recycled aggregate at 28 to 365 days, achieved the greatest compression strength. Then again, the reduced strength of the concrete mixed with a larger proportion (50%) is most primarily lead to the aggregate's more heterogeneous composition and the inclusion of odd material. Figure 2.3 Compressive strength increases from 28 to 356 days of curing (Etxeberria and Vegas, 2015) 2.6.2 Porosity Generally, White (2012) defined porosity in his paper as the volume of pores to the volume of bulk rock and is unusually expressed as a percentage. The ability of water to move through the porosity is defined as permeability. Meanwhile, on the Spanish code on structural concrete, the porosity is higher than the typical mix design. Besides, the recycling aggregate of ceramic origin has even higher water absorption value than the nature aggregate (Kaplan, 1959; Espino, n.d.; Bloem & Gaynor, 1963). On the report of García-González et al., (2015), Both porosity and pore dispersion of concrete have a considerable influence on its mechanical characteristics. Additionally, Gómez-Soberón, (2002) proved in his study that there is a vast difference between natural aggregate and recycled aggregate on their porosity. (García-González et al., 2015) 2.6.3 Water Absorption The ability of water to penetrate into the concrete's pore is called water absorption. Fundamentally, the purpose of the water absorption is to give an estimation of concrete's porosity volume. A Recycle aggregate of ceramic origin has an even higher value of water absorption compared to natural aggregate (García-González et al., 2015). A closer look at Alsayed & Amjad (1996), previous work, their findings conclude that the water absorption of concrete made with recycling concrete is higher while the natural aggregate has lower water absorption. However, by confirming the findings of Alsayed & Amjad (1996), parallel with their study where water absorption is higher when recycle concrete contain lumps or unwanted materials. Nevertheless, Based on BS 1881-122: 2011, the water aborption is determined when the concrete sample is submerged in water tank and weight of the concrete cube is taken at 28 days. To measure the quantity of water penetrate into the concrete, calculation will be made using the absorption percentage because the uniform size of aggregate will affect the compaction factor where it might not be compacted properly. Therefore, well-graded aggregate needs to be conducted so the void in between larger aggregate will be filled by finer size of aggregate. (Alsayed and Amjad, 1996). According to Tam et al (2008), BS is not the accurate method to measure water absorption in recycling aggregate that contains concrete. Thus, in his previous study of finding the new method to determine water absorption, he suggested using real-time assessment of water absorption (RAWA). RAWA approach claimed to deliver more accurate result and much simpler to use and not to mention it proposed to provide a real-time water absorption time-interval. Briefly saying, the RAWA concept is drying the concrete using the oven, then using pycnometer method to observe the water reduction. 2.7 Method of Design of Normal Concrete Mixes (BRE1997) Corresponding to Domine and Illston (2010) understanding, the process of mix design is about determining the right proportion of the ingredient in the mixes by calculating its ratio. (cement:fine aggregate:coarse aggregate and water/cement ratio). In additions, to produce an economical concrete mix considering using admixtures is added. Jackson & Dhir (1996) explained that several different approaches to mixing design had been widely used recently, and one of its most common is the 'Design of Normal Mixes' (DOE, 1988) method. Nevertheless, like Hughes' approach, another approach is used for mix design, and is also applicable to design a concrete mix design. Fundamentally, the principle of the proposed method is to focus on the factors that could cause effects on the concrete's characteristics. They are countless numbers of properties of concrete to be determined. However, only a few of the properties are necessary to be measured, the workability of fresh and hard concrete lastly, at 28th day, the compressive strength will be determined. 2.8 British Standard The mechanical property of a concrete usually measured by destructive testing for its compressive, tensile, and flexural strength in concrete design. In order to obtain concrete mechanical properties, tests are being conducted on specimens following the BS standard. Typically, most of the destructive methods implemented on the specimen are done on, the concrete cylinder or cube. (Bhatt, MacGinley, and Choo, 2006). Moreover, Pawar, Sharma, and Titiksh (2016) believe that an optimising aggregate gradation may enhance the concrete's properties in terms of its mechanical and durability. So, a good gradation of aggregate contributes to better self-compacting processed reduces the potential of

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segregation. Though, every method applied must conform to international standards like BS, ASTM, JIS, etc. As for the current research study, all testing methods, testing concrete cube samples, properties testing on aggregate, and the type of cement determined by the BS below. Table 2.1 Selected mechanical properties testing on aggregate, cement, and concrete 2.9 Standard Strength Akin (2003) explained the standard concrete strength is measured by compressive testing according to BS and conforming the guideline in EN 196-1 at 28 days. The most typical way to assess concrete's capability is to analyse its compressive strength, which has become a requirement in concrete mix design. Jackson and Dhir (1996) wrote that maximum compressive load on concrete determine the compressive strength per unit area. As Domone & Illston (2010) stated, most countries, especially in the UK, specified the concrete's size for the destructive testing is sufficiently large to ensure results are not excessively influenced. Concerning the standard that Domone & Illston (2010) follows, up to 40 mm is suitable for a 150 mm for maximum sizes and suggested for concrete mix design is the maximum aggregate sizes in the concrete mix. The cube is normally cast and lubricated in steel moulds, carefully tamp for approximately 25 times to remove trap air and to ensure that opposite faces are smooth and parallel. Plentiful of previous research about the factor of aggregate influence on the concrete is widely proven. For example, the shape, size, surface texture, and aggregate affect the new and complex concrete character. On a side note, the properties of concrete generally influence by the water/cement ratio, and type of cement. Bhatt, MacGinley, and Choo (2006) stated that the w/c is the vital factor influencing concrete strength. Commonly, the strength characteristic of concrete will be graded on the 28th day at being cured. To make a concrete cube specimens, BS EN 12390: Part 3 is referred for a standard size of 100mm or 150 mm for compressive strength tests. Meanwhile, for the compressive testing procedure shall comply with the BS EN 12390:3:2000. Any testing conducted to test the mechanical properties of concrete must conform to their method and result with the strength class table in 2.3, which meet the terms of the EN 196-1 requirement. Table 2.2 The BS strength class of 32.5 grade of CEMII/B-M 15 Strength class 32,5 N 32,5 R 42,5 N 42,5 R 52,5 N 52,5 R Compressive Strength, <u>MPa Early strength Standard strength</u> Two days Seven days 28 days -  $\geq$  16,0  $\geq$  10,0 -  $\geq$  32,5  $\leq$  52,5  $\geq$  10,0 - $\geq$  10,0 -  $\geq$  42,5  $\leq$  62,5  $\geq$  10,0 -  $\geq$  10,0 -  $\geq$  52,5 - - Initial setting time min  $\geq$  75 -  $\geq$  60 -  $\geq$  45 - Sound- ness min - - ≤ 10 - - - Table 2.3 Minimum of concrete cube compressive strength at 28 days Concrete Grade Compressive Strength at 28 days, kN/mm2 M20 20 M25 25 M30 30 2.10 Specification of Aggregates The aggregate size is determined by the process of grading, where the particle size distribution is conducted with sieve analysis. By referring to the aggregate for concrete, the percentage passing sieve test specification is as shown in table 2.4. Table 2.4 Grading of coarse aggregates from BS 812-102:1984 Mass passing test sieve in percentage (%) for nominal size Sieve size, mm Limits for declared grading 40 mm to 5 mm 14 mm to 5 mm 50.0 100 - - 37.5 90 to 100 100 - 20.0 35 to 70 90 to 100 100 14.0 25 to 55 40 to 80 90 to 100 10.0 10 to 40 3 to 60 50 to 85 5.0 <u>0 to 5 0 to</u> 10 <u>0 to</u> 10 2.36 - - - <u>Table</u> 2.5 <u>Grading</u> requirement for fine aggregates from BS 812-102:1984 Sieve of size, mm Limits Mass passing test sieve in percentage (%) Limits for declared grading C F M 10.00 100 - - - 5.00 89-100 - - - 2.36 60-100 60-100 65-100 80-100 1.18 30-100 30-900 45-100 70-100 0.60 15-100 150-54 25-80 55-100 0.30 5-70 5-40 5-48 55-100 0.15 0-20 - - 5-70 2.11 Summary of Research Based on the research that has been done in this chapter, cementitious materials are vital in every proportion of concrete mix design. For example, the type of cement used to design concrete has its grade stated in the BS guideline depending on its construction purposes. Cementitious material like cement, aggregate, and water is the essential ingredient of concrete mix. However, some previous works by researchers have alerted us of how vague the consumption of natural resources for construction is to threaten nature. With some of the brilliant ideas of researchers, recycling or waste could substitute the consumption of natural sources, but under few circumstances. The circumstances are like green concrete's physical and mechanical properties might differ from natural sources. For example, in Alsayed & Amjad's (1996) research paper, with the increase size aggregate to the maximum, the workability of the fresh concrete will reduce. However, Kett (2000) said that adding mineral admixtures composed of fine solid particles could expand the workability and concrete durability. On the other hand, as for recycled concrete, the water absorption is more excellent so adding the volume of water could improve the workability. Successively proven, most research studies reported that the aggregate properties greatly affect the properties of the concrete, especially its compressive strength. However, there is none of the research studies has successfully proven that using roof tile as a fine aggregate in full scale gives a desired compressive strength. Other issues are that most of the research studies are none of the research stated in the life span or the sustainability of the green concrete. Therefore, addressing all the issues and information above, it's an opening door for research to be conducted in more detail. With the information gathered, developing a new approach for efficient methodology technique for new green production. The primary aim of the research is precise, and the following Chapter 3 shall discuss the selected testing and specification on the current study. METHODOLOGY AND RESEARCH DESIGN 3.1 Introduction Methodology, research design, experimental parameters, including sampling conducted is covered in this chapter. 3.2 Research Design Quantitative research of this study is aiming to understanding the characteristics of URTW to replace sand in concrete mix and investigate the difference and similarities in terms of its mechanical properties at 28 days. This study is also focusing on the structure to plan and execute research experimental data analysis. Furthermore, the research design basically is divided into several parts to conduct the experiment, which is materials and equipment used and tools for data collection and analysis. For a more systematic and understandable process flow, figure 3.1 shows how the experiment will be conducted. Additionally, all methodologies conducted in this study in accordance to the British Standard Figure 3.1 Process flow compression strength testing on concrete cube 3.3 Experimental Details The experimental research illustrates a generic scenario of concrete strength growth as it cures at different ages. Meanwhile, the properties of the concrete mix ingredient are kept constant except for fine aggregate. Fine aggregate varies at the different compositions to investigate the concrete compressive strength at 28 days by conforming to the standard strength of cement in BS EN 12390:3:2000 guideline. The experimental work is performed using river sand, crushed coarse aggregate, and Portland Composite Cement, (CEM II/B-M) grade 32.5R. The detail of each material property used will be explained briefly in the following section as written in the literature review and the type of grade concrete to be produced is M25 3.4 Mix Design Calculation BRE Method One of the various factors that could influence the strength of the concrete is the mix design that involves calculation to determine the right parameter for the desired strength on the 28th day. Basically, in BRE Method, there are five important stages in the flow process of mix design. Each of these stages, focuses on a different component of the design and concludes with a significant final parameter or proportional unit.. The concrete mix design is usually written in a form then all the values are calculated manually. However, as for this research study, the formulation for the mix design calculation was developed to ease and lessen any careless mistake during manual calculation. The formulation was created using Microsoft Office Excel by complying with the BRE Method. (Teychenné, Franklin and Erntroy, 2010). Stage one is to determine the characteristic strength, target mean strength and water/cement ratio. Firstly, the grade of concrete chosen is M25 as a benchmark to design the concrete mix. M25 means a grade of concrete in which M stands for a mix of concrete and numerical figure 25 stands for compressive strength of concrete cube such as 25 N/mm2 21 after 28 days of curing. To produce the strength of concrete with a minimum of 25N/mm2, a concrete mix with a higher value is needed. Because, after any possible strength losses, the concrete designed will be equal to or greater than 25N/mm2. Teychenné, Franklin and Erntroy, (2010) wrote that any proportion of defectives may be defined in the guideline of BS 5328 for the characteristic concrete strength. Thus, the defective level of 5% in line with international reccomenedation can be referred to in BS 810. Figure 3.2Normal distribution of strengths

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To design concrete with characteristic strength of 25N/mm2, a target mean strength and the current margin to be used in the mix design needed, and the equation is as shown in eq 1. In addition, the standard deviation must be known to calculate the target mean strength of the concrete at 28 days,  $Mi^2 = ki^2 \times si^2$  (Eq. 1) Where  $Mi^2$ Margin ki? = Permitted percentage defective value si? = Standard deviation k is a constant mathematically derived of the normal distribution, and the increase f defective is decreased. As stated in BS5328, the value of k is equal to 1.64. So, the s value is taken from figure 3.2 by taking 25N/mm2 as the characteristic strength to get the value of s. Figure 3.3 Relationship between standard deviation and characteristic strength (Teychenné, Franklin and Erntroy, 2010) The target mean strength is determined by complying with the design codes specifications for designing the concrete mix. The calculation to define the target mean is by the equation below: fi?mi? = fi?ci? + Mi? Eq (2) Where, fi?mi? = Mean strength target fi?ci? = Characteristic strength Mi? = Margin Next, stage two is to determine the water content for the slump is assumed to be in the range of 60mm to 180mm with 20mm crushed coarse aggregate and uncrushed fine aggregate. Meanwhile, for this research study, the type of the aggregate for coarse and fine is different, so equation (3) is used to calculate the water content. 2 3 Wi?fi? + Wi?ci? 1 3 Eq (3) Where, Wi?ci? = Appropriate free-water content for coarse aggregate Wi?fi? = Appropriate free-water content for fine aggregate Based on figure 3.5, the water demand for fine aggregate is 195 kg/m3 and 225 kg/m3. By applying the equation (3), as for free water content, the total will be 205 kg/m3. Figure 3.4 Approximate of water content for various levels of workability(Teychenné, Franklin and Erntroy, 2010) The following stage is to define the cement by using equation (4) to calculate the cement content needed for the mix design: When the value of cement content is against the maximum or minimum, the minimum value must be adopted w/c will be modified. Cement Content = free water content / free w/c ratio Eq (4) The fourth stage of the calculation estimates aggregate content needed for the concrete mix density that can be taken from figure 3.4. The calculation to estimate the aggregate content is subjected to the water content and its relative density of combined aggregate in the saturated surface-dry condition (SSD). Equation (5) determines the total weight of the aggregate. From figure 3.4, the water content of 205kg/m2 for 20 mm crushed aggregated of specific gravity is 2.6 the wet density will be 2350kg/mm3. Figure 3.5 Estimated wet density of fully compacted concrete Total Aggregate content = Di? - Ci? - Wi? Eq (5) (Saturated and surface-dry) D = density of concrete, kg/m3 C = cement content, kg/m3 W = the free-water content, kg/m3 The selection of fine and coarse aggregate contents is the final step in the mix design equation. To begin, the fraction of fine aggregate obtained in figure Figure 3.6 Recommended proportion of fine aggregate according to the percentage passing a 600 um sieve 3.5 Material Preparation 3.5.1 Cement In conrete mix, cement is the essential ingredient. Chemical reaction occurs when cement react with the present of water then bind sand and gravel to harden to form a concrete. The ratio of mixed concrete is according to the guideline-based on Ordinary Portland Cement, (CEM II/B-M) grade 32.5 was used. This type of cement is available in 50 kgs bags which complied to MS EN 197-1:2014 CEM II/B-M 32.5R. Figure 3.7 Portland Composite Cement (CEM II/B-M) grade 32.5 R Table 3.1 Showing the Properties of ( CEM II/B-M) grade 32.5 R (Declaration and Cement, 2021) Item MS EN 197-1 :2014 CEM II / B-M 32.5 R Initial setting time (minutes) ≥ 75 Mortar Prism Compressive strength - Two days (N/mm2) ≥ 10 28 days (N/mm2) ≥32.5 Soundness (mm) <10 Sulphutic Anhydride SO3 (%) < 3.5 Chloride (%) < 0.1 3.5.2 Unglazed Roof Tile Waste (URTW) Unglazed roof tile waste (URTW) is made of 100% clay with a synthetic colourant used as a fine aggregate to substitute river sand in a concrete mix design at different compositions. The form of URTW is shown in figure 3.1 and has not been crushed yet. With the structure of the URTW in large size, few crushing stages are needed to ensure the URTW imitates the size of sand. Figure 3.8 Inside view of URTW before being crushed Figure 3.9 Outside view of URTW before being crushed 3.5.3 Coarse Aggregate Coarse aggregate in concrete contains particle that is majority larger than 5mm in size. In the concrete mix design for this study, crushed coarse aggregate is used depending on the desired workability for fresh concrete properties during the slump test. The coarse need to be washed to remove dirt and impurities that cover the gravels. The procedure of selecting the size of coarse is by doing sieve analysis that complies with BS BS EN 12620, 2013 Figure 3.10Unwashed crushed coarse aggregate Figure 3.11 Washing coarse aggregate 3.5.4 Fine Aggregate As for fine aggregate, river sand is used in the concrete mix. The river sands will usually be washed to remove the dirt that covers the sand. Then the sand is dried using the oven or traditionally air dry the coarse. The reason is to get more accurate data for sieve analysis. This process is a crucially important step to do before mixing it in the concrete to avoid any impurities that could affect the structure. Additionally, fresh concrete properties also could be affected if dring the slump test. The process of sieve process shall conforms by referring to BS 812-102:1984. Figure 3.12 Washed river sand as fine aggregate 3.5.5 Water Water is the most critical element in the concrete mix because a chemical reaction happens that allows the will bind with other material. Therefore, it facilitates mixing, placing, and compacting fresh concrete. The primary process of raw material preparation in this study is that the calculated proportion of the component to produce cement is mixed using a concrete mix design concept. Each of the components is prepared by following the BS 5328-1:1997 process. 3.6 URTW Crushing Crushing URTW could be vital as it needed to be crushed within a particular parameter to avoid the particle size of the aggregate being too fine or the other way round. This section will briefly explain the machines and the parameter used for crushing the URTW into fine aggregate. Figure 3.7 shows the crushing machine to crush the URTW raw material into debris-like particles shows in figure 3.8. At this stage, the size of the crushed URTW is still too large for fine aggregate. Figure 3.13 Crusher machine Figure 3.14 URTW after the first stage of crushing Figure 3.15 Cassava crusher crushes URTW to 3mm Figure 3.17 Roselle cutting machine crushes URTW to 5mm Figure 3.16 3mm size of URTW Figure 3.18 3mm size of URTW After the second crushing, either 3mm (Cassava Crusher) or 5mm (Roselle Cutting Machine) aggregate size, the URTW will be ground using Planetary Ball Mill machine more commonly known as PBM, crush the URTW for the final stage. The concept of planetary ball milling is the cylinder compartment filled with three- or four of 80-mm diameter and another seven- or six of a 30-mm diameter of steel balls. The high-energy frequent impact of balls is how the grinding of the sample is carried out. The mill grind process starts when the base plate provides the centrifugal force to the grinding balls. So, the cylinder compartment rotates Independently (in the opposite direction), making the balls hit the bowl's inner wall several times. Since the bowls rotate in opposite directions, the grinding process is done due to friction occurring in the bowl between the steel balls. As for the experiment, the speed of the cylinder to rotate is 280 revolutions per minute for at least 20- 25 minutes to grind approximately 200 grams - 280 grams per batch. The parameter used for 3mm and 5mm size of aggregate is shown in table 3.2 below. The crushing process of URTW is carried out in three stages to get the acceptable aggregate range of size determined by the British Standard guideline as elaborated in the literature review. However, the maximum size for fine aggregate is 5 mm. Therefore, aggregate larger than 5mm will be considered coarse aggregate. A grading process is conducted to identify the crushed URTW is within the standard. Table 3.2 Parameter to grind URTW Feeding sample Size of aggregate Grinding time RPM Steel ball size (Diameter, mm) 30 80 URTW 3 mm 5 mm 20 minutes 25 minutes 280 rev/min 7 3 6 4 Figure 3.19 Planetary ball mill machine Figure 3.20 Cylinder bowl with three of 80 diameter balls and seven of 30 diameter balls Figure 3.21 Filled the twin bowl with URTW Figure 3.22 Control system of the machine Figure 3.23 URTW powder-like after grinding 3.7 Grading Fine and coarse aggregate used in the manufacture of cement concrete is made of various sizes, ranging from nominal and maximum to the smallest specified. Therefore, gradation is explained on how various aggregate sizes are distributed according to their particle size. In other

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words, gradation is also known as particle-size distribution where it refers to proportions by mass or weight. Sieve analysis will be conducted to determine the particle distribution for grading fine of aggregate by following the British Standard practice BS812: Part 1, 3.8 Sieve Analysis Gradation of aggregate is determined from sieve analysis where the aggregate passes through a series of sieves then weights the retained particle in each sieve. Thus, a sieve is an apparatus in around shape with a square opening of different sizes comply with BS 410 which specifies the appropriate aperture and size. The weighted result will be expressed as in percentage and compared with the grading limit specified in BS 812-102:1984 The relative proportion of particles retained or passing through each set of sieves placed in decreasing order is determined by the sieve analysis (figure 3.15) from 50.0 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm, and 150 µm for fine aggregate. As for coarse aggregate, the aperture size is 50.0 mm, 37.5 mm, 20.0 mm, 14.0 mm 10.0 mm and 2.36 mm. The particle retained (figure 3.17) in each of the sieves will be weighted and carried out in a mechanical vibrating sieve shaker machine (figure 3.16) where duration for fine aggregate 10 minutes and 20 minutes A graph is drawn to plot the particle distribution curve alongside the percentages of weights retained in the series set of the sieve in figure 3.19. 34 Figure 3.24 Fine aggregate sieve Figure 3.25 Coarse aggregate sieve Figure 3.26 Sieving in the process by using vibrating sieve shaker machine Figure 3.27 Retained aggregate according to its size after the sieving process 3.9 Mix Proportion of Concrete The percentage of concrete materials is determined by conventional concrete mixes based on desired strength by following the traditional strength of regular concrete (BS EN 206, 2013). Figure 3.1 shows the flow process on how to mix concrete design is conducted. The mixes should be made in compliance with BS 181: Part 125 requirements. For this research study, the mix proportion of concrete is calculated in the created formulation as explained in 3.4. Therefore, the total quantity for each ingredient is calculated and tabulated in table 3.3. However, the quantity for each proportion of 0%, 40%, 50%, and 60% are tabulated in table 3.5. Each ratio will have six samples for three different days of curing (seven, 14, and 38 days). The total sample for this experiment is 36 samples with varying percentages of URTW proportion. After all the materials properties have been analysed (size of aggregate and type of cement used), each ingredient will be mixed in the mixing tray in a dry state. Then, the water is added gradually into the mixing. The mixing process can be done by hand, as shown in figure 3.19. The workability of the well-mixed concrete will be tested through a slump test explained in 3.9. Figure 3.28 Control mixture Figure 3.29 Experimental mixture Figure 3.30 Equipment needed for the Figure 3.31 Mixing all ingredient and conrete mixing process gradually add in water manually Figure 3.32 Fresh wet concrete being well mixed Table 3.3 Quantities of materials for the concrete mix per cubic meter % of Batch no. Sample replacement with URTW Sand URTW (kg) (kg) Coarse aggregate (kg) Cement Water w/c (kg) (kg) ratio 1 CM0 0 7.2 0 6.7 4.8 2.4 0.5 2 URTW40 40 4.3 2.9 6.7 4.8 2.4 0.5 3 URTW50 50 3.6 3.6 6.7 4.8 2.4 0.5 4 URTW60 60 2.9 4.3 6.7 4.8 2.4 0.5 Total 18 10.8 26.8 19.2 9.6 0.5 3.10 Slump Test In mix design of concrete, slump test is conducted to investigate the workability of the fresh concrete after mixing. Workability of fresh concrete needed to be measured to ensure the efficiency of handling the fresh concrete during casting. However, each step of the process must comply the procedure stated in BS 1881: Part 102 for slump test and BS 1881: Part 104 for vebe time test. Vebe time test is the time taken measured for the slump to drop from original height of the slump cone. Figure 3.33 Slump test for control mix Figure 3.34 Slump test for URTW50 Figure 3.35 Self-compacting process in a steel mould to remove trapped air Figure 3.36 Steel moulds of 100mm x 100mm without fresh concrete in it Figure 3.37 Steel mould filled with fresh concrete and labelled 3.11 Curing Concrete curing regulates the rate and level of moisture loss from concrete during cement hydration. Usually, this process will take 24-48 hours to ensure the concrete is fully hardened. However, the temperature for this process is to be assumed at room temperature. Generally, the ultimate strength of the concrete is increased by keeping the concrete much longer in the water. Curing occurs immediately after concrete placement and finishing, and it entails maintaining ideal moisture and temperature conditions for lengthy periods, both at depth and near the surface. A sufficient quantity of water is present in properly cured concrete for continuous hydration and developing strength, volume stability, freezing and thawing resistance, and abrasion and scaling resistance. 39 Figure 3.38 Concrete cubes immersed in a tank filled with water 3.12 Water Absorption After removing the sample from the concrete cube cured for 24 hours, the water absorption process took place. When the concrete is hard enough to be handled, it will be immersed in water for seven, 14, and 28 days. Before being immersed in the concrete cube, its weight will be recorded. So, on the day of concrete to be tested, it will be weighed again to investigate the weight difference between before and after immersion. Figure 3.39 Weighing the concrete cube at 7days age before compression strength testing 3.13 Mechanical Testing In this section, mechanical testing is conducted on the concrete cube after being cured for a certain period of days. Destructive testing will be carried out on the concrete using hydraulic press compression strength testing. 3.13.1 Compressive Strength Test The mechanical properties of the hardened concrete are determined after being cured in water for seven, 14, and 28 days. Using Class 1 Motorised Hydraulic Compression Machine Electrical Operated in Compression Mode, the strength of the hardened concrete is determined. The machineclassified under Class 1 as it meets the tolerance of percentage error  $\pm$  1.0% as written in BS EN 12390-4:2000. The strength of the concrete usually defines the maximum load that the concrete can endure. The loading rate of the machine is set up to 4-8kN/s for 100mmx100mm size of concrete cube. Finally, the testing result will be recorded and analysed in Chapter 4. This procedure must comply with BS 1881: Part 116. Figure 3.40 Compressive strength test in progress Figure 3.41 Green concrete before compression strength conducted Figure 3.42 After compressive testing conducted on green concrete at 28 days 3.14 Limitation of Proposed Methodology There are some limitations in conducting the methodology after a research study has been completed and a part of the experiment completed. The limitation of the methodology is the time frame to experiment because the testing to determine the mechanical properties are destructive testing. By means, the experiment needs more samples to prepare for the experiment. In addition, the equipment for tensile strength is limited because the mould of the equipment is not available in the laboratory. Other than that, tensile testing is not relatively easy to conduct because the absence of concrete tensile machine for direct tension test is not available in the laboratory. However, some alternative ways to determine the tensile strength is by conducting indirect testing of cylinder and modulus rupture. 3.15 Summary For this chapter, the methodologies are conducted to determine fresh and hard concrete's physical and mechanical properties with different composition percentages for URTW but maintaining the same ratio following the relevant part of BS 1881. A slump test is conducted to determine the fresh concrete's physical properties. Meanwhile, by using Class 1 Motorised Hydraulic Compression Machine Electrical Operated approach to determine compression strength. The methodology's primary purpose is to determine the proportion of cementitious material to get the desired strength of concrete after 28 days. This method is widely used in experiment practices according to structural construction BS. The methods applied in this experiment are generally available, and the data is obtained accurately for compressive strength testing. On the contrary, obtaining the consistency of particle distribution is not entirely defined due to the planetary ball milling machine's performance. In particular, the concept of this experiment is to manipulate the traditional concrete mix design by replacing unglazed roof-tile waste as fine aggregate simultaneously to reach the standard strength of traditional concrete design. Simultaneously, aggregate gradation is conducted rightfully to ensure the particle distribution is consistent because every proportion of the material could affect concrete mechanical performance. The next chapter intends to present several studies and demonstrate to verify the previous study. Concurrently, analysis of the data for validation is to be proposed in the following experiment. RESULTS AND DISCUSSION 4.1 Introduction This chapter presents the results and analysis based on the research study in Chapter 2 and conducted as explained in Chapter 3, which will be discussed in more detail, especially on its

mechanical properties when a compressive strength test is conducted. The data and analysis obtained will guide further research and improvement. 4.2 Analysis of Experimental Data In this section, the analysis for every result is presented. Without neglecting the requirement in BS, all results presented are valid to be reviewed for further study. 4.2.1 Fine Aggregate Grading Numerous experiments have been conducted by complying with BS EN 12620:2013 Aggregates for Concrete, with the conformity of BS 206-1. As for this research study, crushed URTW must follow the same standard to fulfil the required parameter. The grading process of URTW gives out the result as shown in the plotted graph to ensure the curve of the outcome is within the limit of BS. The total quantity of URTW needed to replace fine aggregate in the concrete mix is 10.85kg. However, the PBM cylinder bowl could only have the capacity of approximately 200grams per cycle. Therefore, the grinding of URTW is repeated several times to get the total quantity of 10.85kg to design three different proportions of the concrete mixture. To ensure the size of URTW follows the BS EN 12620:2013 requirement, the ground URTW will be sieved and record the data for analysis. The data from the sieve analysis must obey the BS 882:1992, where the total quantity of material to be sieved at once is less or equal to 1kg. Table 4.1 Sieve analysis of sand Sieve Size, Sieve Weight, Mass % Material % Cumulative % mm kg 10.00 0.358 4.75 0.369 2.36 0.400 1.18 0.379 0.60 0.347 0.30 0.317 0.15 0.333 pan 0.235 Retained, kg Retained Retained Passing 0.00 0.00 0.00 100.00 0.03 3.10 3.10 96.90 0.19 18.72 21.82 78.18 0.29 28.63 50.45 49.55 0.28 28.03 78.48 21.52 0.15 14.61 93.09 6.91 0.06 5.51 98.60 1.40 0.01 1.40 100.00 0.00 1.00 Table 4.2 Sieve analysis of URTW Sieve Size, Sieve Weight, Mass % Material % Cumulative % mm kg Retained, kg Retained Retained Passing 10.00 0.358 0.000 0.000 0.000 100.000 4.75 0.369 0.000 0.000 0.000 100.000 2.36 0.400 0.103 9.372 9.372 90.628 1.18 0.379 0.227 20.655 30.027 69.973 0.60 0.347 0.339 30.846 60.874 39.126 0.30 0.317 0.223 20.291 81.165 18.835 0.15 0.333 0.159 14.468 95.632 4.368 pan 0.235 0.048 4.368 100.000 0.000 1.099 120 Passing Percentage, % 100 80 60 40 20 0 Sand and URTW Sieve Analysis pan 0.15 0.3 0.6 1.18 2.36 5 10 Sand passing % Sieve Size, mm URTW passing % Lower Limit Upper Limit Figure 4.1 Sieve analysis of percentage passing of sand and URTW within the upper and lower limit 4.2.2 Coarse Aggregate Grading Based on the BS EN 12620:2013 Aggregates for Concrete, with the conformity of BS 206-1, sieve analysis is conducted for coarse aggregate to ensure that the size is acceptable to be mixed with other cementitious materials. As written in BS 882:1992, the quantity of the coarse to be sieved is 3 to 4 kg for 20 minutes long. If the result of percentage passing is off the lower and upper limit, it is advised to repeat the process until the result of percentage passing is within the limit. Table 4.3 Sieve analysis of coarse aggregate Size Seive, Sieve Weight, Mass Retain, % Material % Cumulative % mm kg kg Retain Retain Passing 20 1.556 0.16 4.61 4.61 14 1.252 0.71 20.10 24.72 10 1.165 1.42 40.43 65.15 5 1.263 1.22 34.85 100.00 2.36 1.037 0.00 0.00 100.00 pan 0.878 0.00 0.00 100.00 95.39 75.28 34.85 0.00 0.00 0.00 Passing Percentage, % 120 100 3.51 Course Aggregate Sieve Analysis 80 60 40 20 0 pan 2.36 5 10 14 20 Upper Limit Sieve Size, mm Lower Limit Coarse Aggregate Passing % Figure 4.2 Sieve analysis of percentage passing of sand and URTW within the upper and lower limit 4.2.3 Workability The workability of the freshly mixed concrete is measured during the slump test by its dropping from the original height of the standard slump cone, as explained in subtopic 3.9. Workability is measured to ensure that the concrete mixer is sufficiently workable to be properly consolidated. Most importantly, the concrete could be moved or placed in form without segregation. Conversely, the graph in figure 4.3 shows that URTW40 and URTW60 workability are 35mm, which is not in the acceptable range and is lower than CM0. The acceptable workability based on the BRE method should be between 60mm-180 mm within 0s-3s vebe time. On the other hand, the slump value from URTW50 is within the range, giving good workability compared to URTW40 and URTW60. By referring to the slump value of URTW40 and URTW60, the workability is lower than CM0 could be caused by various factors. One of the factors that could affect the slump value is the properties of the concrete mix ingredient. For example, the material's porosity, the type of cement used, or the preparation method before mixing. When the volume of porosity of the material (sand, URTW, and gravel) is higher, the water absorption level increases, resulting in the fresh concrete's workability during the slump test. Table 4.4 Slump Value of Fresh Concrete Acceptable slump Batch no. Sample % of replacement with slump value, URTW mm value, mm (BS 1881:part 102) 1 CM0 2 URTW40 3 URTW50 4 URTW60 0 80 40 35 50 65 60 35 180-60 200 Workability of Fresh Concrete 180 Slump Value (mm) 160 140 120 100 80 180 80 60 40 20 0 35 CM0 URTW40 URTW50 URTW60 65 35 60 Minimum MaCxiomnucrmete workability of URTW Figure 4.3 Workability of Fresh Concrete 4.3 Water Absorption Concrete Water absorption of the concrete is determined as the increased mass resulting from immersion. At 28 days, the concrete will be weighed, and the results aare then recorded. However, to ensure the data recorded is valid, each procedure need to comply with BS 1881-122:1983. Based on the data tabulated in Table 4.2, maritime code BS 6349 requires that water absorption must not exceed 3% or 2%. As for the concrete, every proportion is within the range where the highest water absorption is URTW50, followed by CM0. The inconsistent value of water absorption could be caused by various factors. One of the factors could be the porosity volume and size of the concrete's porosity. The porosity of the concrete might be caused during the casting process when the tamping method is not done correctly, leaving the concrete with air trapped within the concrete. Other than that, the properties of URTW, which was proven in a previous study has higher porosity volume compared to sand could be the factor that affect the slump value. Table 4.5 Water absorption of concrete at 28days Batch no. 1 2 3 4 Sample CMO URTW40 URTW50 URTW60 % of URTW replacement with 0 40 50 60 % Max % of Min % of absorption water water water at 28 absorption absorption days of the concrete of the concrete 1.697 3 2 1.668 3 2 1.707 3 2 1.634 3 2 Water Absorption of concrete at 28 days 3.5 3.0 3 % of water absorption 2.5 2.0 1.697 1.668 1.707 1.634 1.5 1.0 0.5 0.0 CM0 URTW40 URTW50 URTW60 Concrete % absorption Max % of water absorption water at 28 days of concrete Figure 4.4 Water absorption of concrete at 28 days 4.4 Green Concrete Compressive Strength The concrete compressive strength development is recorded as shown in table 4.4 and plotted in the graph shown in figure 4.5. For this research study, the concrete grade standard M25 was chosen as a scale to determine the compressive strength of green concrete. The concrete mix was designed by using the ratio of 1:1.5:1.38 (cement, fine aggregate, coarse aggregate) and 0.50 w/c ratio and replaced the sand with URTW by 40%, 50%, and 60. The compressive strength results illustrated in figure 4.5 the pattern of average compression based on the experiment performed. CM0 is made with zero percentage of 49 URTW strength performance shows that it passed the minimum concrete grade compressive strength at 28 days, which is 32N/mm. The minimum compressive of the concrete needed to achieve is 25N/mm2 at 28 days. The green concrete containing 40%, 50%, and 60% of URTW shows an increasing compression development of the concrete. Table 4.6 Compressive strength of concrete Batch no. Sample % of replacement with URTW Average Compressive strength at 28d (N /mm2) Grade M25 concrete standard compressive strength Min. Target compressive mean strength at 28d strength at (N/mm2) 28d (N/mm2) 1 CM0 2 URTW40 3 URTW50 4 URTW60 0 32 40 37 50 41 60 41 25 38 25 38 25 38 25 38 Compressive Strength (N/mm2) 40 35 30 25 20 15 10 5 0 32 41 37 41 38 25 50 Compressive Strength of Concrete at 28d 45 CM0 URTW40 URTW50 Concrete URTW60 Average of 28 days comp. strength (N/mm2) Target mean strength at 28 days (N/mm2) Minimum compressive strength at 28 days (N/mm2) Figure 4.5 Compressive strength of concrete at 28 days 4.5 Summary Based on the experimental results and analysis obtained, the behaviour of fresh and hardened concrete is evaluated by conducting methods proposed in Chapter 3. Firstly, the behaviour of fresh concrete was examined during the slump test. As a result, the value of the slump will indicate the workability of the concrete. CM0 and URTW50 successfully achieved the acceptable slump value, mm, in accordance with BS 1881:part 102; however, URTW40 and URTW60 are not. According to the BRE method, if the slump value is not within the standard range, advisedly, the w/c should be modified. Nonetheless, with the value of slump out of range, the w/c of the mix is not modified to maintain the ratio of the mix to get a

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comparable results at the end of the experiment. The reason slump value is important to be within the range is because when the slump value is low, the workability of the concrete is also low. Workability is important at this stage because the concrete needs to be moved and placed in a steel mould to make a concrete cube. During the process of making the test cube, the procedure must comply with BS 1881: Part108: 1983. Making concrete cubes is as vital as other processes because a wrongly procedure may lead to false refalseat the end of the experiment. Since the slump value for URTW40 and URTW60 is 78% lower than CM0. Hence, it's quite difficuilt to cast the cube since the workability of the fresh concrete is low too. When the workability is low, there is a chance that the air trap volume in the concrete will be higher. Traditionally, self- compacting is done to remove the air trap by tamping the concrete during casting. Despite that, URTW50 workability is 20% lower than CM0 but still within the acceptable range (60 mm to 180 mm) of standard slump test comply with BS 1881:part 102. According to Etxeberria and Vegas (2015), an increased percentage of recycled aggregate resulting in increased water absorption of the concrete. Similarly with Khatib's (2005) study reported that an increased replacement percentage of recycle aggregate results 51 in increasing water absorption. Yet, water absorption of the concrete for this experiment shows inconsistent values between 40%, 50%, and 60% replacement of URTW. Proven in the study of V. Giridhar (2015), about the significant effect on the concrete's behaviour influenced by the aggregate properties, the inconsistence trendline of the water absorption result. In other words, it means that different type of aggregate use could give different output because the properties of aggregate influence the behaviour of the concrete. A previous study by V. Giridhar (2015) about the properties of waste aggregate influence the strength of concrete, reported that the strength of the concrete decreases gradually due to higher water absorption. But, looking at Etxeberria and Vegas (2015) study, an increase of replacement of waste aggregate lead to higher strength compared to conventional concrete after 28 days of curing. Correspondingly to the study of Jatjo and Abdullah (2021), their analysis shows similarity in the compression strength development of concrete at 28 days with an increasing percentage of waste aggregate replacement. An analysis of this study shows that green concrete mix developed higher strength than conventional mix with respect to the concrete grade M25 minimum target of 25N/mm2. From the result acquired, concrete containing URTW has improved its bonding between cement paste and aggregate compared to conventional concrete. Hence, figure 4.6 portrays the relation between compression strength versus workability to show which proportion has better performance. The proportion of URTW40 and URTW60 compression strength successfully achieved the target mean strength, but both concrete's workability is not acceptable. As for URTW50, the target mean strength achieved and the workability during the slump test is within the range. Compression Strength vs Workability 80 Compression Strength, N/mm2 70 60 50 65 41 41 40 30 20 10 0 32 32 35 35 37 CM0 URTW40 URTW50 URTW60 Workability of Concrete Compression Fresh Concrete during slump test, mm Strength of concrete, N/mm2 Linear (Compression Strength of concrete, N/mm2) Figure 4.6 Compression strength versus workability 50 45 40 35 30 25 20 15 Slump value,mm 10 5 0 CONCLUSION 5.1 Conclusion By developing the mix concrete design using the formulation, the proportion of every quantity of the ingredient is easily to be determined without calculating it manually to avoid miscalculation. The formulation was carefully developed based on BRE method to satisfy the required compressive strength. A value for water/cement (w/c) ratio is estimated for an appropriate test age (generally 28 days) and cement type. Other than that, the roof tile physical properties from a big piece were crushed by complying with the BS EN 12620, which covers recycled aggregate properties for use in concrete in conformity with BS EN 206-1. The physical properties of the URTW must imitate the size of sand, so the parameter of the milling machine is specified Mechanical behaviour of the produced green concrete based on unglazed roof tile industrial waste is determined by compressive strength machine. The analysis obtained shows that green concrete shows an improvement in the compression strength at 28 days. For further study on the improvement, the material preparation before mixing the fine aggregate (sand) needs to be immersed in water for some time to avoid false value during slump test, 5.2 Project Potential The study finding could be applied to a typical concrete mix for construction. Additionally, by using roof tile industrial waste provided, this study could reduce natural resources. Furthermore, the strength achieved by the concrete is more than the target mean strength of M25. The compressive strength has improved, but not all the sample workability is within the range. So, the best ratio to use as M25 grade concrete is the proportion of URTW50. So, it could be concluded that 50% replacement of unglazed roof tile waste in concrete can safely be used in the concrete composition without considerable loss of compressive strength in construction. 2 3 4 5 6 7 8 10 11 12 13 14 16 17 18 19 20 22 23 24 25 26 27 28 29 30 31 32 33 35 36 37 38 40 41 42 43 44 45 46 47 48 50 52 53 54 55 AYSIA MELAKA



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