EXPERIMENTAL STUDY OF SAW WOOD DUST (SWD) AS PARTIAL REPLACEMENT FOR FINE AGGREGATE WITH RATIO 5%, 10% AND 15%

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ABSTRAK

Simen, granit dan pasir adalah bahan-bahan konvensional yang banyak digunakan di dalam industri pembinaan untuk menghasilkan konkrit. Pasir sungai yang biasanya digunakan sebagai agregat halus di dalam penghasilan produk konkrit, menimbulkan masalah dalam pelbagai bidang, dimana penggunaan yang berterusan telah memberikan masalah yang serius berkaitan dengan kos, ketersediaan dan kesan alam sekitar. Oleh itu, pelbagai usaha sedang dilakukan untuk menggunakan bahan-bahan tempatan yang sedia ada bagi menggantikan pasir sungai untuk menghasilkan konkrit kos rendah. Habuk kayu adalah salah satu sumber buangan yang dihasilkan daripada pelbagai jenis kayu yang mempunyai ciri-ciri seperti penebat bunyi, konsisten, fleksibel dan ringan. Habuk kayu telah digunakan di dalam pembuatan konkrit, tetapi tidak secara meluas. Kajian ini memberi tumpuan terhadap kesan kekuatan mampatan terhadap konkrit dengan menggantikan sebahagian peratusan agregat halus dengan habuk kayu dalam menghasilkan konkrit yang efektif. Objektif utama kajian ini adalah untuk mengkaji kekuatan lenturan dan mampatan campuran konkrit yang telah diubahsuai. Objektif lain kajian ini adalah untuk mengenal pasti penggunaan optimum habuk kayu sebagai pengganti sebahagian agregat halus dalam konkrit. Kajian ini telah dijalankan di makmal konkrit untuk menentukan kekuatan tertentu habuk kayu yang digantikan kepada sebahagian agregat halus dalam konkrit dengan menggunakan ujian kiub dan ujian lenturan selama 14 hari dan 28 hari. Ujian ini juga dijalankan ke atas kebolehkerjaan konkrit dengan menggunakan ujian kemerosotan konkrit. Keputusan menunjukkan bahawa habuk kayu mempunyai kekuatan mampatan konkrit yang kukuh. Kekuatan mampatan tertinggi diperolehi daripada konkrit kawalan iaitu 21.242 MPa dan 30.699 MPa, manakala kekuatan lenturan tertinggi juga diperolehi daripada konkrit kawalan iaitu sebanyak 6.024 MPa dan 6.417 MPa untul 14 dan 28 hari. Trend untuk kedua-dua ujian menunjukan kekuatan meningkat dengan masa pengawetan tetapi berkurang apabila peratusan habuk kayu meningkat. Kebolehkerjaan konkrit berkurang apabila peratusan habuk kayu meningkat dan hasil kajian untuk 0%, %%, 10% dan 15% adalah 48 mm, 42 mm, 35 mm dan 33 mm. Daripada keputusan beberapa kajian yang lain, peratusan optimum penggantian habuk kayu adalah di antara 10% dan 15%.

ABSTRACT

Cement, granite and sand are conventional materials that heavily uses in construction industry for concrete production. The river sand which is most commonly used fine aggregate in the production of concrete, poses the problem of acute shortage in many area, whose continued use has stated posing serious problems with respect to its cost, availability and environmental impact. Due to this problem, attempt is being made to use the locally available materials to replace the river sand to produce low cost concrete. Saw wood dust (SWD) has been used in concrete, but not widely. This study focuses on the effect of compressive strength on replacing some weight percentage of fine aggregate with SWD in making an effective design mix of concrete. The main objective of this study is to investigate the flexural and compressive strength of modified mix concrete. The other objective to identify the optimum usage of saw wood dust as partial fine aggregate replacement in concrete. Experimental work was conducted in laboratory to determine the specific strength of SWD as partial fine aggregate replacement in concrete by using cube test and flexural test for 14 days and 28 days concrete. Test was also carried out on the workability of the concrete by using slump test. The results show that the SWD concrete has strong compressive strength. The highest compressive strength obtained were found at control concrete which is 21.242 MPa and 30.699 MPa, while the highest flexural strength also at control concrete which is 6.024 MPa and 6.417 MPa at 14 and 28 days. The trend for both test shows that the strength increase with age of curing but decrease as percentage of SWD increase. The workability decrease as percentage of SWD increase and the result at 0%, 5%, 10% and 15% are 48 mm, 42 mm, 35 mm and 33 mm. From the results, optimum percentage of replacement SWD was between 10% and 15% in volume ratio.

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LIST OF ABBREVIATIONS

SWD	Saw Wood Dust
OPC	Ordinary Portland Cement
UMP	Universiti Malaysia Pahang
ASTM	American Society for Testing and Materials

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Concrete is a mixture of cement, water, fine aggregate and coarse aggregate. Concrete plays a vital role in the development of infrastructure, bridge, highways and building that leading to utilization of large quantity of concrete. It is difficult to find out another material of construction that has similar properties like concrete. Concrete is the best material of choice where strength, durability, fire resistance, absorption resistance and impermeability are required. However, cement, granite and sand are conventional materials that heavily used in construction industry for concrete production. The high and increasing cost of this materials has greatly hindered the development of shelter and other infrastructural facilities in developing countries (Olutoge, 2010). As the developing of the entire world keep increased, the construction industry need a large amount of materials. As the consumption of raw materials increases, the demand increases material (Murali and Ramkumar, 2012).

From this problem, many researchers and engineers seek and develop new materials relying on renewable resources. These also include the use of by-product and waste materials in construction. The natural sand mined from the riverbeds is the most widely used as fine aggregate for making concrete. However, the availability of river sand for concrete production is become scarce due to excessive method of mining from the riverbeds, sinking of bridge piers among other, lowering of water table, are becoming common treats (Mageswari and Vidivelli, 2010).

The worldwide consumption of sand as fine aggregate in concrete production is very high and several developing countries have encountered some strain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years. Due to this situation, unmanaged wastes especially in developing countries has resulted in an increasing environmental concern. So, the increase in the popularity of using environmental friendly product like lightweight construction materials in industry has brought about the need to investigate how this can be achieved by benefiting environment as well as maintaining the material the material requirement in standard.

Due to chronic shortage of building materials, the civil engineer has been challenged to convert the industrial waste to useful construction material (Turgut, 2007). The study aims to know the effect of replacing portions of fine aggregate with SWD to its compressive and flexural strength. Considering the rising cost of construction materials, this study inclined to use recycled materials for construction purposes in producing high strength concrete at a low cost product overall.

1.2 Problem Statement

Due to increasing price of material that can be used to produce concrete nowadays has influence from several factor such as high demand from industry, the difficulty to obtain concrete material and the shortage of material. Moreover, the current issues happen where the sand was stolen to meet industry demand by certain parties and also environment problem where the excessive method use to mining the sand from riverbed. From this situation, the uses of partial replacement to replace some part of concrete material can solve the problem. The partial replacement material that use for this study is Saw Wood Dust as fine aggregate replacement. An alternative for substitute the fine aggregate and course aggregate with saw wood dust have been discovered by Dr. F.A. Olutoge in 1995.

In construction industry, saw wood dust have high potential to use as sustainable construction materials. Besides that, saw wood dust also can function as pozzolan materials to act as filler inside the concrete. The research is constructed and conducted to find the effectiveness of saw wood dust as partial replacement of river sand in concrete with different percentage of saw wood dust. The physical properties and chemicals properties are needed to be investigating to ensure the other materials in concrete which are water and Ordinary Portland Cement (OPC) can mix together with the saw wood dust to produce same result compared to normal concretes.

1.3 Objective of Study

Experimental study of saw wood dust as partial replacement for fine aggregate have three main objectives set to achieve the goals, which is:

(a) To investigate the flexural and compressive strength of modified mix concrete using saw wood dust as partial replacement for fine aggregate with percentage 5%, 10% and 15%.
(b) To investigate the workability of modified mix concrete.
(c) To identify the optimum usage of Saw Wood Dust as partial replacement for fine aggregate with percentage 5%, 10% and 15%.

1.4 Scope of Study

The research basically focused about the effect of compressive strength and flexural strength by replacing some weight percentage of fine aggregate with saw wood dust respect in making an effective design mix concrete. The percentage of saw wood dust as partial replacement for fine aggregate are varies from 5%, 10% and 15%. The other focus is to investigate the workability of modified concrete. From the compressive strength result, the optimum dosage can be determine for saw wood dust from graph percent of saw wood dust again strength of concrete.

Generally, all testing will be done in the laboratory Universiti Malaysia Pahang (UMP) and will undergo necessary testing and analysis accordance to the standard requirement for the concrete. This scope of study involved three main test which is compressive test, flexural test and slump test. The research involve 6 samples for each ratio and standard concrete for the both test which is compressive test and flexural test.

1.5 Significant of Study

The important of this research is the partially replacing the fine aggregate in concrete with saw wood dust as it is a by-product materials. The result might affect the production of concrete structure in the construction of structure. The most widely used fine aggregate for the making of concrete is the natural sand mined from the riverbeds. However, the availability of river sand is becoming scarce due to the excessive nonscientific methods of mining from the riverbeds hence there has a risen a need to consider substitute materials for use as filler.

In addition, the use of saw wood dust as partial filler would reduce the quantity of fine aggregate required for building resulting in sustainability of aggregate resources. Since saw wood dust is lighter than fine aggregate, there would be a considerable reduction in dead weight in buildings resulting in reduced reinforcement and ultimately construction costs.

Finally, the environmental impact of utilizing saw wood dust cannot be overlooked considering it is a waste that is widely generated and disposal is mostly done on uncontrolled waste pits and open areas. Therefore, it could be realistic to reduce the reliable of natural resources if the by-product of industry can be use in the concrete manufacturing to improve properties of modified mix concrete and reduce economical sources for material usage.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In construction, concrete plays an important role and it is the main ingredient in structure. Concrete is a building material that is widely used in the construction industry, so the techniques to make a good quality concrete must be understood and observed carefully. Generally, they consist of a mixture of cement, sand, aggregate and water with a certain ratio or designed, the reaction between cement and water will produce C-S-H gel to form the bond between aggregate will give strength and durability to concrete. Concrete in construction is widely used in civil engineering projects around the world with for the following reasons, namely it has good resistance to water, precast concrete structures can be shaped into a variety of shapes and sizes and usually, it is the cheapest and most readily available materials for work (Mehta and Monteiro, 2006).

Concrete can be divided into three groups, namely, light weight concrete, normal concrete, and concrete weight. According to BS5328, light weights concrete are classified as concrete has a density not exceeding 2000 kg/m3. While for normal concrete has a density between heavy 2000kg/m3 and not exceeding to 2600 kg/m3. For concrete in excess of 2600 kg/m3 densities was classified as heavy concrete businesses and create less waste. Moreover, these initiative indirectly reducing the expenses in purchases of financial incentive for consumers and businesses.

According to (Alexander M.G. and Sydney Mindness, 2005), between 70 to 80 per cent out of the total volume of concrete is occupied by aggregate. With this large proportion of the concrete occupied by aggregate, it is expected for aggregate to have a profound influence on the concrete properties and its general performance. Aggregate are essential in making concrete into an engineering material. They tend to give concrete its volumetric stability; they also have a unanimous influence on reducing moistures related to deformation like shrinkage of concrete.

Saw wood dust is a waste that is easily available in our country, Malaysia. Saw wood dust will be used as a material to replace the aggregate in the concrete, it can reduce the density of ordinary concrete and reduces environmental pollution (Mannan, M. A and Ganaphaty, C, 2002). This can be another's waste as the material can be used to produce new products.

2.2 Concrete

Concrete simply can be referred to as a homogenous mixture consisting of aggregates, water and cement acting as an adhesive. This description may depict concrete manufacture to seem simple and straightforward, however it is very easy to make “bad” concrete that would make your design useless if actual concrete properties differ from those assumed during design calculations. Hence the question what can be defined as “good” concrete considering that both types of concrete have similar ingredients. The difference therefore arises from the mode of preparation.

2.2.1 Usage of Alternative Material in Concrete

Standard concrete use cement, water, fine aggregate and coarse aggregate as concrete material. Nowadays, alternative materials can be utilised as a composition to the ingredients of concrete that can be use partially or completely replaced with one or more material in standard concrete. Concrete is used widely in the world due to increase in rate of construction and at same time availability of raw material is decreases. Some of the raw material in concrete omits CO_2 in the atmosphere and cause an environmental problem. Alternative material such as sawdust, glass piece, quarry dust, fly ash and other has been used in concrete either as partial replacement or complete replacement. (M.Geetha Bhargava and J.D.Chaitanya Kumar, 2015) stated in his research paper, there are two method to resolve this problem which is:

(a) Replace alternative materials which is very difficult to manage in term of concrete properties such as durability, workability and strength in concrete.
(b) Replace full or partial alternative materials in standard concrete material.

Based on two method above, the second option is reasonable compare to the first option. Nowadays, a lots of invention in field of concrete technology are carried out to solve the problem related to raw material in standard concrete. The concrete industry leave an enormous environmental footprint on our planet. There is a lot of problem occur related to concrete development such as a large volume of material need to produce billion ton of concrete, emission of CO_2 during Portland cement production and concrete not environmentally friendly with the demands of sustainable development because of factor energy requirement, generation of construction, demolition waste and water consumption. (Meyer.C, 2009) in his research he got the solution to improve all the above situation.

By using alternative material such as fly ash, ground granular blast furnace slag, recycle concrete, recycle tyre, recycle plastic and other recycle material can solve this problem. Those alternative material will be use as partial replacement on cement and aggregate. To meet principle of sustainable development, he summarize the strategies as follow:

(a) Replace as much as possible Portland cement by cementitious material especially those material are by-product of industrial process.
(b) Replaced natural sources with recycle material.
(c) Reduced amount of material needed for replacement to improve durability and service life.
(d) Reuse wash water.
(e) Reduced the material needed in order to improve concrete mechanical and other properties.

Based on reference from journal, all the suggestion is to solve the environmental and technical problem regarding concrete production. Researcher and engineer try their best to create a new concrete product that has similarity with standard concrete by using partial or fully replacement their material with alternative material that end up at landfill.

2.2.2 Workability of Concrete

Concrete mix in its fresh state should be consistent in such manner that it can be compacted easily by the desired manner without excessive effort, a property broadly referred to as workability. The American Concrete Institute describes workability “as that property of freshly mixed concrete or mortar that determines the ease with which it can be mixed, placed, consolidated and finished to a homogenous condition”. Similarly, Japanese Association of Concrete Engineers defines workability “as that property of concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed and compacted due to its consistency, the homogeneity with which it can be made into concrete, and the degree with which it can resist separation of materials”. (Neville, 1981) simply defined workability as the amount of useful internal work necessary to produce full compaction.

Workability is dependent on concrete properties especially the water to cement ratio. Excessively dry mixes have low workability hence difficult to compact. The need for compaction becomes apparent when we compare the degree of compaction to the resulting strength. Poorly compacted concrete results in presence of voids which greatly reduces its strength with research showing that 5% voids can reduce strength by as much as 30% .The workability of fresh concrete can be determined by a simple, inexpensive and relatively accurate test referred to as the slump test which is fully described in BS 1881:103:1993.

The apparatus consists of a mould in the shape of a frustum of a cone. The mould is filled with concrete in three layers of equal volume. Each layer is compacted with 25 strokes of tamping rod. The slump cone is lifted and the change in height of the concrete is measured. Figure 2.1 shows the different type of slump. Often the only type of slump permissible is the true slump where the concrete remains intact and retains a symmetric shape. A collapsed slump or shear slump is considered out of range of workability that can be determined by the workability test.

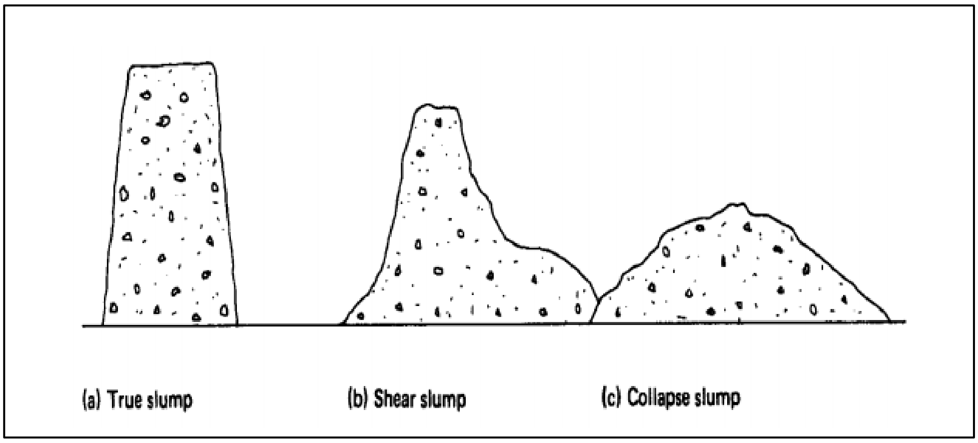

Figure 2.1: Different types of slump

Concretes with the same slump can exhibit different behaviour when tapped with a tamping rod. For example few fines concrete will tend to fall apart when tapped. Such concrete is only suitable for applications such as pavements or mass concrete. This can be a useful basis in evaluating our concrete considering that this study involves partial substitution of fines.

The slump test has several advantages. It is widely used worldwide hence can be used as a common basis of measurement of workability. It is relatively accurate hence can be applied in a site to quickly determine if a concrete is to be accepted or rejected. Finally it is simple and inexpensive to perform.

Cohesiveness is an aspect of workability, it affects segregation of which bleeding is a special case. This is especially important in instances of transporting before being placed. Segregation of concrete refers to the separation of the constituents of the heterogeneous mixture so that their distribution is no longer uniform. This often results due to differences in size of particles and their specific gravities of the mix constituents. There are two types of segregation exhibited in concrete. One involves separation of coarse aggregates as they tend to settle more than the finer aggregates. The second form of segregation is manifested by separation of the grout which is the cement plus water from the mix. This property is specifically essential in this study considering that the sawdust is relatively light compared to the other concrete constituents.

However the actual extent of segregation depends on the handling and placing of the concrete. If the concrete does not have to travel far and is transferred directly to the final position, risk of segregation is reduced. The method of compaction would also influence degree of segregation. Even though vibration provides the most valuable means of compacting concrete, improper use of the vibrator increases the danger of segregation.

2.2.3 Water to Cement Ratio of Concrete

Water is required for various functions in a concrete mix. Primarily, it is needed for cement hydration, which consists of series of processes that are responsible for development of strength in concrete. It is also required for workability of the concrete. When concrete is fully compacted, its strength can be taken to be inversely proportional to the water cement ratio. This implies that for fully compacted concrete made with sound and clean aggregates, strength can improved by reducing the weight of water used per unit weight of cement. This would imply that use of minimal amount of water would result in a stronger concrete.

However this is not entirely true as this would render the concrete not workable making compaction difficult. Lack of proper compaction results in voids in concrete and consequently reduced strength. On the other hand excess water causes development of capillary voids in concrete causing porosity and permeability hence reduced strength. From the above it can be deduced that just the right balance of water to cement ratio needs to be determined to obtain a strong but also workable concrete mix. Water contained in concrete consists of that added to the mix and that originally held by the aggregates at the time when they were introduced into the mixers. The latter water may be absorbed within the pore structure of the aggregate whereas some exists as free water on the surface of the aggregate hence not different from the water added direct into the mixer.

When the aggregate is not saturated and some of its pores are therefore air filled, a part of the water added to the mix will be absorbed by the aggregate. Aggregates are often assumed to be saturated with surface dry conditions when used in concrete. This implies that the effective water in the concrete mix is the water in excess of that contained in the pores of the aggregate. For this reason, the mix proportioning data are based usually on the water in excess of that absorbed by the aggregate that is the free water. It is therefore necessary that in translating laboratory results into mix proportions to be used on a site, care be taken to specify if water cement ratio referred to is total or free water**.**

2.2.4 Hardened Concrete Properties

The primary requirement of concrete in its hardened state is satisfactory compressive strength and durability. The strength of concrete is often considered its most important property and is used as a basis to determine the quality of concrete. This is vital since it‘s the element ultimately considered in structural design. Test for compressive strength is done by crushing cast concrete cubes made according to specifications contained in BS 1881:108:1983.The 28th day strength is always taken as a depiction of the concrete strength, although the 7th day strength can be determined to check development in strength.

The strength of concrete is greatly influenced by two factors namely the water/cement ratio and the degree of compaction. Although there are other factors that may have influence such as porosity of the concrete, the above two are considered critical especially when referring to strength of concrete at a certain age that has been cured in water at a certain temperature. These have been broadly looked at below as they would have a significant impact on the concrete strength in the study**.**

2.3 Material

2.3.1 Cement

Cement is a binder and material having adhesive properties and cohesion, which enables fine and coarse aggregate binding to one whole. Cement clinker produced from the powder which usually contains Lime (CaO), Silica (Si02), Alumina (Al203) and Iron Oxide (Fe203). In construction, cement is used as bonding to unite aggregate, bricks, blocks and others.

The most important types of cement used as a component in the manufacture of concrete and masonry mortar a combination of cement and aggregate to form strong building material. Cements used in construction can be characterized as being either hydraulic or non-hydraulic. There are various types of cement used in construction on the properties of concrete required. The most common type of cement to make concrete has set and hardened properties of aqueous conditions through a chemical reaction between cement and water. This type of cement known as hydraulic cement. There is also a need air to cement hardened, the cement is known as non-hydraulic cement (Gambir.M.L, 1995).

Hydraulic cements such as Portland cement, set and become adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack. The chemical process for hydraulic cement found by ancient Romans used volcanic ash (activated aluminium silicates) with lime (calcium oxide). For non-hydraulic cement will not set in wet conditions or underwater, rather, it sets as it dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting.

There are various types of cement produced for a particular purpose and satisfaction of the particular properties required. Among the most common type of cement used was ordinary Portland cement. Cement in hardened more rapidly, lower heat and white.

2.3.1.1 Type of Cement

Cement is the main materials in concrete production. It was develop from natural cement in early of nineteenth century in Britain and its name was derived from "Portland stone", a type of stone that can be found in Isle of Portland in England. Nowadays, cement become essential in every construction works to use in structure such as building, tunnel, bridge and others.

Cement is a finely pulverized, dry material that by itself is not a binder. In present of water and cement minerals, the chemical reaction known as hydration process will takes place. (Concrete: Microstructure, Properties and Materials, 2006). Cement usually acts like glue because its properties to binds aggregate which are sand and gravel together. There are many types of cement used in the construction materials, such as:

(a) *Ordinary Portland Cement*

Ordinary Portland Cement (OPC) is the commonly used in concrete construction for the case that there is no exposure to sulphates in groundwater or soil. The raw materials in Ordinary Portland Cement consist of lime, silica, alumina and iron oxide. Every year huge production of Ordinary Portland Cement is produce and used for construction of building, road and bridge and local purposes.

(b) *Sulphate Resistance Cement*

Sulphate Resistance Cement is blended cement that design to improve the performance of concrete particularly in condition where there is a risk of 7 damage to concrete from sulphate attack. It is recommended to be use in places where concrete is in contact with ground water, seacoast and sea water. It is a type of Portland cement with the quantity if tricalcium aluminates are less than 5% in the cement content

2.3.1.2 Chemical Composition of Portland Cement

Compound of raw materials such as lime, silica, alumina and iron oxides will interact with each other in the Furnace to form a series of products that are more complex. This reaction produces four main compounds such as Table 2.1.

Table 2.1: The main compounds of portland cement (Ismail,M.A.K, Mohd Sam,A.R, Sumadi,S.R, Hussin,M.W, 2007).

MAIN CHEMICAL COMPOUND OF PORTLAND CEMENT

Name of compound	Chemical composition	Usual abbreviation	Reaction
Tricalcium silicate	$3CaO.SiO_2$	C_3S	Quick reaction
Dicalcium silicate	$2CaO.SiO_2$	C_2S	Slow reaction
Tricalcium aluminate	3CaO.A2O3	C_3A	Very quick reaction
Tetracalcium aluminoferrite	4CaO.Al2O3. Fe2O3	C_4AF	Not very important

Source: The main compounds of Portland cement, (2007).

Result of the compound C3S and C2S hydration will produce the desired characteristics of the concrete. While alumina and iron that produce C3A and C4AF will help to reduce the temperature required to produce the C3S from 2000°C to 1350°C (Ismail,M.A.K, Mohd Sam,A.R, Sumadi,S.R, Hussin,M.W, 2007). This will save energy and costs to produce Portland cement.

2.3.1.3 Types of Portland Cement

The ASTM has listed five types of Portland cement, but for the design is type IV. Physical and chemical characteristic, this cement varies primarily in their originality and C3A content them. In terms of performance, they differ primarily in the initial hydration rates and their ability to withstand attack sulphate. The General characteristics of this type are listed in Table 2.2.

Table 2.2: Types of Portland cement (ASTM)

	Classification	Characteristics	Applications
Type I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Moderate sulfate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V	High sulfate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White color	No C_4AF, low MgO	Decorative (otherwise has properties similar to Type I)

Source: ASTM (2005)

2.3.2 Aggregate

Aggregates accounts to up to 75% of concrete by volume thus have a significant effect in its properties and performance. Cement without aggregates can only be applied to a few special purposes, a majority of concrete applications are only possible due to the presence of aggregates. Modern construction has seen the use of aggregates of various types with the evolution of technology. This has led to development of highly complex mixtures which may consist of several binders, admixtures and aggregates of different types and sizes. In short, the use of aggregates has become a little more than simply being a bulk constituent for mass and economy.

2.3.2.1 Functions of Aggregates in Concrete

Aggregates have a number of functions in concrete:

(a) They contribute to concrete strength through mechanical interlock between aggregate particles hence making the concrete stiff and rigid, a property necessary for its engineering uses.

(b) Reduce moisture related deformations in concrete such as shrinkage hence providing volumetric stability to the concrete.
(c) They provide durability to the concrete as they are generally more stable of all the constituents in concrete.
(d) Provide bulk of concrete allowing it to be placed.
(e) Impart wear resistance to concrete making it suitable for use on pavements and hydraulic structures.
(f) They restrain creep and thus aid in limiting long term deformations.

2.3.2.2 Classification of Aggregates

Classification of aggregates can be based on size, specific gravity or source of the aggregates.

2.3.2.3 Classification by Sizes

Classification by sizes groups aggregates into two groups namely:

(a) Fine aggregates have particle size less than 4.75mm and are retained on 75µm sieve.
(b) Coarse aggregate have particle size more than 4.75mm.

2.3.2.4 Fine Aggregates

Fine aggregates consist of particles between the sizes stated above. Sand is the most common fine aggregate used in concrete. It consists small angular or rounded grains of silica. Grading of fine aggregates has a great influence on the workability of a concrete mix. This is because it influences the total aggregate area to be wetted and the relative aggregate volume in the mix. In order to ensure proper workability, one should conform to standard grading which ensures that the voids one particle are filled by particles of the next smaller size. Apart from workability, finer fractions of fine aggregates with sizes minus 150µm have a great influence on the segregation and bleeding of the concrete. This is because they are light and are easily separated from other concrete constituents.

2.3.2.5 Functions of Fine Aggregates in Concrete

Fine aggregates perform the following functions in concrete:

(a) Act as filler and fill the voids between the coarse aggregates. They are smaller hence are able to occupy the small voids between the larger coarse aggregates.
(b) Reduce porosity of concrete. Porosity in concrete results due to presence of voids which can adequately be filled by well graded fine aggregates as smaller particles are able to occupy the very tiny voids.

2.3.3 Water

Water is the key ingredient to mix cement together to form paste that binds aggregates. The presence of water causes the hardening of concrete through process of hydration. According to BS 3148, "Test for Water for Making Concrete", the water must meet the requirement that it should be free from impurities or particles that can give adverse effect to the properties of concrete (Wong, Like Kee, 2001). The impurities are acids, alkalis, sulphates, chlorides, and others. The role of water is important to prevent side reaction during hydration process which may weaken the concrete. Normal tap water is the most suitable to be use in concrete mixing. Water in the concrete mix is to the hydration and workability of concrete.

Water used in mixing concrete should also be free from impurities such as Suspended solids, organic matter and sea salt. Water containing the algae is not suitable for mixing concrete for algae to trap air and air content in concrete will reduce the strength of the concrete. Algae from the 0.09 percent (%) increase to 0.23 percent (%) would increase the air content of 10.6 percent (%) and lead to concrete strength decreased by 50 percent (%) (Kumar Mehta,R, 1991). Uses of sea water in reinforced concrete mixing are not suitable because it will cause danger due to reinforcement corrosion due to chloride content in water.

Suitable water is water containing dissolved solids less than 2000-ppm. Therefore, the water supplied in the water supply system can be used safely because it contains dissolved solids less than 2000-ppm (Kumar Mehta,R, 1991). According ASTM C1602, Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete, defines sources of mixing water as:

2.3.3.1 Batch Water

Batch water discharged into the mixer from municipal water supply, reclaimed municipal water, or water resulting from concrete production operations. This is the main source of mixing water in concrete.

2.3.3.2 Water Added by the Truck Operator

According to ASTM C94 (AASHTO M 157) allows the addition of water on site if the slump is less than specified, provided the maximum allowable water-cement ratio is not exceeded and several other conditions are met.

2.3.3.3 Recycled Water

The recycled water are Non-potable water and water resulting from concrete production operations can be used as mixing water in concrete provided the acceptance criteria given in ASTM C1602 are met. Water recovered from processes of concrete production includes, the first one is wash water from mixers or that was a part of a concrete mixture. Second, water collected in a basin as a result of storm water runoff at a concrete production facility, or other water that contains quantities of concrete ingredients. According ASTM C1603, the solids content in recycled water generally ranges from 2½ to 10 percent. The maximum permitted solids content for water to be used in concrete is 50,000 parts per million, or 5 percent, of the total mixing water and should be tested.

2.4 Concrete Quality

Concrete is considered a quality that has a high compressive strength, durable and not easily permeable in water. While a good quality concrete structures is the vanes smooth, compact and not porous when the mould is opens. For low quality concrete will become brittle, easily cracked, and permeable in water.

Therefore, to ensure good quality of concrete, several things need to be addressed before, during and after the concrete is provided. Concrete compressive strength, density and workability of concrete are the main parameter to be determined before designing the structural members. While, the process of casting, process of compacting and process of curing operations at the construction site, must be addressed to ensure a good quality concrete. Strength and durability of concrete depends on the amount of water in the concrete mix and the degree of compaction applied. Therefore, these matters should be noted (Wong, Like Kee, 2001): Viscosity of the mixture must be appropriate to allow the concrete is mixed well. May be carried, cast, and worked easily and does not occur separation of a mixture of original material.

2.4.1 Factors Affecting the Strength of the Concrete

In designing a concrete mix, the aspect of concern is to obtain concrete with high strength levels without compromising on other features such as durability and permeability. In the previous study, there are many factors influencing the strength of concrete cutter, not least the influence of water-cement ratio, aggregate-cement ratio, degree of compaction and grading.

2.4.2 Water-Cement Ratio

Water-cement ratio can be defined as the ratio of water weight by weight of cement used in concrete mix. For fully compacted concrete, concrete strength is inversely proportional to the water-cement ratio. Water-cement ratio will determine the porosity of the cement at the level of complaints specific hydration. Addition of water-cement ratio will reduce the compressive and tensile strength and increase shrinkage of the concrete. Therefore, for a good mix of water-cement ratio should be lowered. However, if the concrete lack of water, the level of workability will be less.

2.4.3 Aggregate-Cement Ratio

Aggregate-cement ratio of concrete strength influences the level of either medium or high. There is no doubt that the aggregate-cement ratio is only a secondary factor in influencing the strength of concrete (Nevelle A.M., 1995). In a mixture of less cement or a mixture with the aggregate-cement ratio, high air voids, voids, will form and it will have adverse effect on the strength and durability of concrete.

2.4.4 Degree of Compaction

Compaction of concrete will be more convenient if the water content in the concrete mix a lot. Compaction is done is to remove the air-air trapped in the aggregate, coarse aggregate, fine and cement in concrete mixtures. Therefore, compaction is done to ensure that the concrete is at a maximum level of strength and have minimal porosity.

2.4.5 Grading

Aggregate gradation is also a determining factor on the strength and quality of concrete. One method is through the sieve analysis. Sieve analysis done by using a sieve-BS410 British Standard sieve which is the distribution of particles of granular materials among various sizes, usually expressed in terms of cumulative percentages larger or smaller than a series of sizes of sieve openings or the percentages between certain ranges of sieve openings. Results from a sieve analysis are used in three ways, which are to determine if the material meets specifications, to select the most suitable material and to detect variations in grading that are sufficient to warrant mixing select sizes or an adjustment of concrete mix proportions. In directly, this aggregate gradation direct impact on the workability of concrete and affect the workability of concrete strength.

The ASTM C 33, Standard Specification for Concrete Aggregates, grading requirements for coarse and fine aggregates and there are several reasons for specifying grading limits and maximum aggregate size, most importantly, workability and cost. For instance, very coarse sands produce harsh and unworkable concrete mixtures, and very fine sands increase water and cement requirements, and are uneconomical. Aggregates that do not have a large deficiency or excess of any particular size produce the most workable and economical concrete mixtures.

Coarse aggregates used in concrete making contain aggregates of various sizes. This particle size distribution of the coarse aggregates is termed as “Gradation”. The sieve analysis is conducted to determine this particle size distribution. Grading pattern is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above.

Figure 2.2 shows the categories of aggregate grading. A sample of the well graded aggregate containing minimum voids will require minimum paste to fill up the voids in the aggregates. Minimum paste means less quantity of cement and less quantity of water; leading to increased economy, higher strength, lower shrinkage & greater durability. The workability is improved when there is an excess of paste above that required to fill the voids in the sand, and also an excess of mortar (sand plus cement) above that required to fill the voids in the coarse aggregate because the fine material lubricates the larger particles.

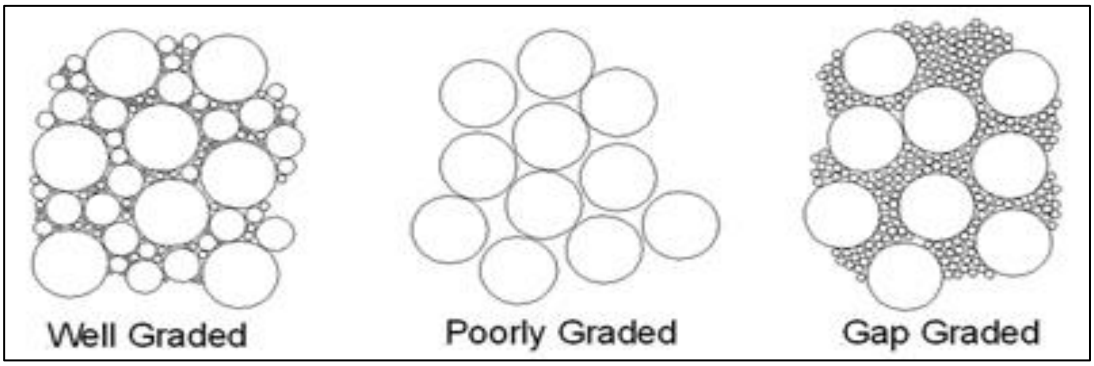

Figure 2.2: There are three categories of aggregate grading

Source: ASTM C 33, (2005)

2.4.6 The Categories of Aggregate Grading

Proper gradation of coarse aggregates is one of the most important factors in producing workable concrete. Proper gradation ensures that a sample of aggregates contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids. Below are the explanation about aggregate grading:

(a) *Well Graded*

Well-graded aggregate has a gradation of particle size that fairly evenly spans the size from the finest to the coarsest. A slice of a core of well-graded aggregate concrete shows a packed field of many different particle sizes. It is characterized by the S- shaped in gradation curve.

(b) *Poor Graded*

Poor-graded aggregate is characterized by small variation in size. It contains aggregate particles that are almost of the same size. This means that the particles pack together, leaving relatively large voids in the concrete. It is also called “uniform-graded”. It is characterized by steep curve.

(c) *Gap Graded*

Gap-graded aggregate consists of aggregate particles in which some intermediate size particles are missing. A core slice of gap-graded, or skip grade, concrete shows a field of small sized- aggregate interspersed with slightly isolated, large aggregate pieces embedded in a small sized aggregate. It is characterized by a gradation curve with a hump in between.

2.5 Saw Wood Dust

(Prof.R.Sathish Kumar, 2012) stated in his research paper about properties of concrete varied with alternative construction material. He use cement, fine aggregate, coarse aggregate, sawdust, rice husk ash, brick bats, recycled aggregate as alternative materials in concrete. The compressive strength of sawdust concrete is nearly to 10-15% compare to standard concrete. The maximum Average Compressive Strength of sawdust contained concrete of 7 days and 28 days is 20.26 kg/cm^2 and 43.22 kg/cm^2 and their water-cement ratio is 0.75. From his research, a higher sawdust replacement content in concrete will result to decreases compressive strength of specimen. The comparison of compressive strength of sawdust concrete with standard concrete are given in Table 2.3.

Table 2.3: The comparison of compressive strength of sawdust with standard concrete

Sl No	Types of concrete	Prop	W/C	Compressive Strength (7days) Kg/cm^2	Compressive Strength (28days) Kg/cm^2
	Conventional concrete	1:2:4	0.56	166	328
	Saw dust concrete	1:(1.5+0.5):4	0.7	18.89	31.11
	Saw dust concrete	1:(1.5+0.5):4	0.75	19.09	32.36
	Saw dust concrete	1:(1.5+0.5):4	0.8	17.78	30.35
	Saw dust concrete	1:(1+0.5):3	0.7	20.12	42.11
	Saw dust concrete	1:(1+0.5):3	0.75	20.26	43.22
	Saw dust concrete	1:(1+0.5):3	0.8	19.19	39.32
	Saw dust concrete	1:(1.25+0.25):3	0.7	18.11	30.33
	Saw dust concrete	1:(1.25+0.25):3	0.75	18.63	30.44
	Saw dust concrete	1:(1.25+0.25):3	0.8	18.42	30.14

(Tomas.U.Ganiron Jr, 2014) has studied on effect of replacement of fine aggregate with sawdust in concrete for building construction. Concrete a composite material that made from water, cement, fine aggregate, coarse aggregate and some admixtures. The present paper deals with the replacement of fine aggregate with sawdust compared to standard concrete. The three specimens was cast according to curing period which is 7, 14 and 28 days. The highest compressive strength is gained from 7 days sample which was not cured in that period and strength of sawdust concrete decrease as the water-cement ratio less than 0.45 curves is dropping down, that shows the workability of sawdust concrete is decreases. The sawdust concrete showed 10% reduction in weight compared to standard concrete which got about 40% weight. Due to mixing the concrete with sawdust, the workability and consistency parameters are varied from standard concrete. He also stated that sawdust concrete is cheaper than the fine aggregate in the standard concrete.

(Dilip Kumar et al., 2014) researched on low cost construction material for concrete as sawdust and investigated on the effect of introducing the cost between sawdust uses as sand replacement with sand use in standard concrete. There made concrete specimens by replacing the sand with 10%, 15% and 20% sawdust and there conclude that at the initial stage, with the increase in the percentage replacement of sawdust, the compressive strength increases. While using sawdust as a sand replacement will decrease their weight and it can be used as lightweight concrete in civil engineering application.

From all the related journal shows that replacement of fine aggregate with sawdust will get better strength with adequate dosage of sawdust. It also prove that by using sawdust as partial replacement for sand will reduce the weight of concrete that transform into lightweight concrete and it reduce the cost of material.

2.5.1 Origin

Sawdust refers to fine particles of wood resulting from cutting, grinding or drilling of timber. It may also result from the burrowing on wood by small animals like ants. Sawdust has been applied to various uses due to its varied properties.

2.5.2 Chemical Composition

The chemical composition of sawdust is complex often similar to the wood from which they are derived. Wood tissue is made of chemical components which are distributed non uniformly as a result of the anatomical structure. As a result, the chemical behaviour of wood cannot be determined in detail from the properties of the component substances. The principal components of wood include Carbon, Hydrogen, Oxygen (O) and small amounts of Nitrogen. The chemical analysis of a number of species of softwoods and hardwoods shows that proportion of these elements in percentage of oven dry weight of wood are approximately: Carbon 49-50%,Hydrogen 6%,Oxygen 44-45% and Nitrogen 0.1-1%.

Carbon, hydrogen and oxygen combine to form the principal organic components of wood substances namely cellulose, hemicellulose, lignin and small amounts of pectin substances. The terms cellulose and hemicellulose are generic, and each include a number of chemically related compounds. Separation and quantitative analysis of each in the laboratory has shown that the proportions in percentage of oven dry weight of wood are approximately:

(a) Cellulose: 40-45%, about the same for both hardwoods and softwoods.
(b) Hemicellulose: 20% in softwoods, 15-35% in hardwoods.
(c) Lignin: 25-35% in softwoods, 17-25% in hardwoods.

2.5.3 Physical Properties

(a) Flammable Sawdust is flammable especially when dry hence has been used as a ready source of fuel by manufacturing charcoal briquettes which are then burnt to produce energy.
(b) Hygroscopic Sawdust is hygroscopic, it has a tendency to absorb moisture when in contact with liquid water or water vapour. Due to this property, it has been used to absorb spills.

2.5.4 Sawdust Use in Concrete

In the construction industry, sawdust has been used to develop sawdust concrete which consists of Portland cement, sand, sawdust and water to give a slump of between 25- 50mm.This kinds of concrete has been found to bond well with ordinary concrete. The sawdust used often requires treatment. Chemical treatment is necessary to prevent rotting since it‘s organic.

Secondly it serves to make the sawdust neutral to prevent reactions that would adversely affect the concrete during hydration and setting. This has often been achieved by making sure the sawdust is clean without a large amount of bark. Finally it would lower moisture movement in the sawdust as it has a tendency to absorb water. Best results are obtained when sawdust of between 1.18-6.3mm in size.

However due to the variable nature of different kind of sawdust, use of a trial mix is recommended. This kind of concrete can achieve density ranging from 650 to 1600 kg/m3 .Sawdust concrete resulting from use of sawdust from tropical hardwoods have recorded compressive strengths of 30N/mm2, splitting strength of 2.5N/mm2 with a density of 1490kg/m3.Recent studies have shown successful use of sawdust as a brick material However due to the limited research on it, there has been no standard and codes developed to guide use.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discussed on the methodology used for this research. To get the objectives of study, a good and accurate assessment should be obtained. Thus, the methodology implemented in the study is very important matter. The methodology should be carefully planned and arranged so as to yield result that are accurate and covers all the aspects either of the theory or practical. The main focus of this research is to determine compressive strength, flexural strength and slump height of the modified mix concrete with the partial replacement of fine aggregate with saw wood dust.

In reviewing, the effectiveness of using saw wood dust as partial replacement for fine aggregate in the modified concrete, there are several tests, that are carried out in this researched. The experimental are conducted in the Heavy Concrete Laboratory Universiti Malaysia Pahang. The laboratory testing is performed to obtain the data and compressive strength, slump height and flexural strength of modified concrete. The test are conducted to identify the optimum usage of saw wood dust as partial replacement for fine aggregate in the modified concrete from the analysis. The test result are compared with the standard concrete for the strength and workability. Data obtained from these tests are analysed to obtain a decision that the research achieve the goals and objective of this study. Figure 3.1 shows the flowchart of this research and it's to ensure the flow of this study can be carried out smoothly.

The methodology for this study is refer to this journal title "Investigation of properties of concrete using sawdust as partial replacement for sand" by Oyedepo, Oluwajana, Peter Akande from 2014.

3.2 Flowchart of Methodology

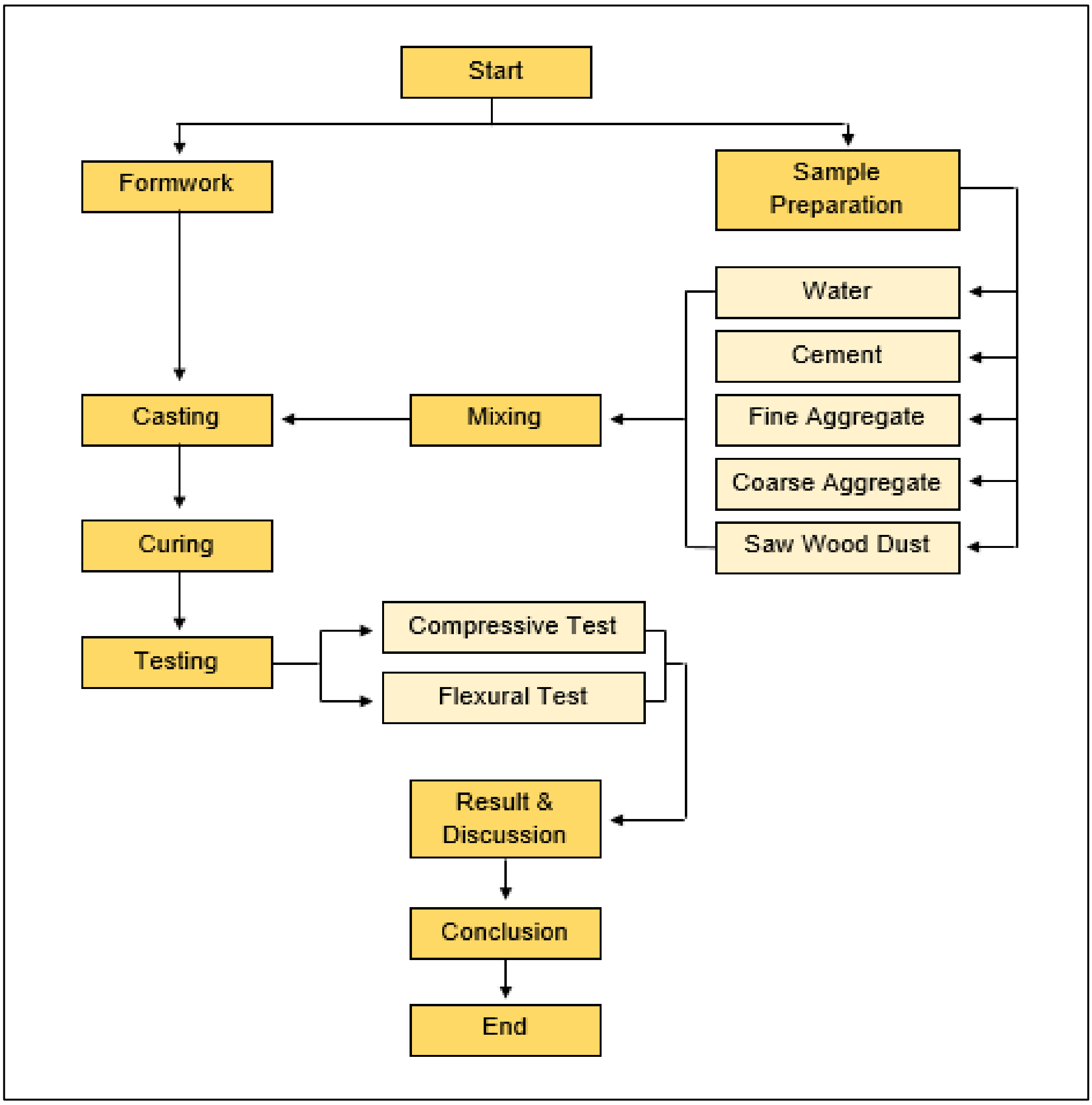

Figure 3.1: Represented the Flow Chart of the Process of This Research

First, the research is started. Then, trial and mix is done to get the mix proportion of the concrete that achieved the targeted strength. Next, by using the mix proportion, casting is carried out and after it is done, the specimen is cured by wet gunny for 14 and 28 days. After 14 and 28 days, testing is conducted for the specimen. The analysis is done by using the results that was obtained from the testing conducted. Each work carried out must have careful planning in order to achieve the goals and objectives. Figure 3.2 illustrate the plan of work study in order to complete the research.

Determining the Research Title

- Clearly discuss with the supervisor on the topic that are selected.

Literature Review

- Searched reference materials that related to topic of the study.

Laboratory Research

- Conduct experiments in laboratories for research data.

Result and Analysis

- Processing of data were obtained from laboratories test.
- Make a conclusion of test that have been made.

Writing Research Report

- Provide a complete report regarding the results of studies that have been executed.

Figure 3.2: The Plan of Work Study

3.3 Material Used

3.3.1 Saw Wood Dust

Saw wood dust (SWD) are used as a lightweight aggregate as the replacement for fine aggregate in this research. The saw wood dust samples required were obtain from the timber factory located at Kuantan, Pahang from a heap of wood shavings and saw wood dust which considered as waste. Figure 3.3 shows the heap of saw wood dust at timber factory. It was established that the saw wood dust available was a mixture from different types of wood that are available in Malaysia hence could be acquired locally.

Figure 3.3: The Heap of Saw Wood Dust at Timber Factory

3.3.2 Cement

The cement used in the mixes ratio 1:3 to river sand. The ordinary Portland cement was produced by YTL Cement Sdn. Bhd. This cement product is suitable for concrete making and all general purpose applications. During preparation of the materials, the cement that has been weighted was kept in airtight container to avoid the effect to the cement reaction with air and vapour. Table 3.1 shows the chemical composition of Ordinary Portland Cement.

Table 3.1: The Chemical Composition of Ordinary Portland Cement

Chemical Constituents	Percentage by mass in cement (%)
Calcium Oxide (CaO)	46
Silica Oxide (SiO_2)	43.1
Aluminium Oxide (Al_2O_3)	5.0
Ferric Oxide (Fe_2O_3)	2.6
Loss On Ignition (LOI)	1.3
Magnesium Oxide (MgO)	1.1
Potassium Oxide (K_2O)	0.5
Sodium Oxide (Na_2O)	0.2
Manganese Oxide (MnO_3)	0.2

Source: Dr. Kimberly Kurtis

Cement is a soft grey powder that was mixed with water and other substance to make concrete. It can define as the binding element that was used to bind others materials together. The type of cement that used in this research was YTL Cement Sdn. Bhd. Figure 3.4 below shows the type of cement use for this research.

Figure 3.4: Type of Cement use for the Research

3.3.3 Coarse Aggregate

Aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone that were used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as asphalt concrete and Portland cement concrete). Aggregate is also used for base and sub base courses for both flexible and rigid pavements. Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the by-product of other manufacturing industries.

Coarse aggregates were used in concrete making contain aggregates of various sizes. This particle size distribution of the coarse aggregates is termed as “Gradation”. The sieve analysis is conducted to determine this particle size distribution. Grading pattern is assessed by sieving a sample successively through the entire sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above. Figure 3.5 shows the example of coarse aggregate that use for this research. The workability is improved when there is an excess of paste above that required to fill the voids in the sand, and also an excess of mortar (sand plus cement) above that required to fill the voids in the coarse aggregate because the fine material lubricates the larger particles.

Figure 3.5: The Coarse aggregate use for This Research

3.3.4 Fine Aggregate

Fine aggregate as shown in Figure 3.6 is natural sand which has been washed and sieved to remove particles larger than 5mm and coarse aggregate is gravel which has been crushed, washed and sieved so that the particles vary from 5 up to 50mm in size. The fine and coarse aggregate are delivered separately. Because they have to be sieved, a prepared mixture of fine and coarse aggregate is more expensive than natural all-in aggregate. The reason for using a mixture of fine and coarse aggregate is that by combining them in the correct proportions, a concrete with very few voids or spaces in it can be made and this reduces the quantity of comparatively expensive cement required to produce a strong concrete.

Figure 3.6: The Example of Fine Aggregate or Sand

3.3.5 Water

Water is needed to mix the material and during hydration process of the concrete. The type of water used to bind the materials is ordinary tap water. Tap water is used because it is assure clean, easy to obtain and not harmful in the hydration process of cement. Water used in mixing concrete shall be from sources that are clean and approved.

In addition, water used shall be free from contaminants such as suspended solid, organic matter and so on. Therefore, the amount of water in concrete controls many fresh and hardened properties of concrete including workability, compressive strengths, permeability and water tightness, durability and weathering, drying shrinkage and potential for cracking. For these reasons, limiting and controlling the amount of water in concrete is important for both constructability and service life.

3.3.5.1 Water Cement Material Ratio (w/cm)

The w/cm ratio is a modification of the historical water-cement ratio (w/c ratio) that was used to describe the amount of water, excluding what was absorbed by the aggregates, to the amount of the Portland cement by weight in concrete. Figure 3.7 below shows the water use to mixing the concrete.

Figure 3.7: Water Use to Mix the Concrete

3.4 Design Concrete Mix

Concrete mix design is defined as the appropriate selection and proportioning of constituents to produce a concrete with pre-defined characteristics in the fresh and hardened states. In general, concrete mixes were designed in order to achieve definite workability, strength and durability. The selection and proportioning of materials depend on the structural requirements of the concrete, the methods of concrete production, transport, placement, compaction and finishing. Through this research, the saw wood dust (SWD) is use as partial replacement for fine aggregate.

Mix design for all sample is similar but in different ratio of partial replacement of saw wood dust. SWD will be substituted into the mix design by using unit weight method based on percentage. The concrete mix will be designed for casting cube and prism. The concrete mix design should achieved the compressive strength of 30 N/mm^2 on 28 days and for cylindrical was 25 N/mm^2 on 28 days. The total collapse for the slump test is about 25-50mm. The trial mix design will represent in the Table 3.2. The trial mix design below for all sample which is 3 sample for compressive test and 3 sample for flexural test.

Table 3.2: The Concrete Mix Design

Type of Beam	**Control**	**5% of SWD**	**10% of SWD**	**15% of SWD**
Material	**Weight (kg/m3)**	**Weight (kg/m3)**	**Weight (kg/m3)**	**Weight (kg/m3)**
Cement	26.062	26.062	26.062	26.062
Water	15.005	15.005	15.005	15.005
Fine Aggregate	80.555	76.527	72.499	68.471
Course Aggregate	71. 472	71. 472	71. 472	71. 472
SWD	0.000	0.863	1.726	2.589
w/c ratio	0.58	0.58	0.58	0.58

3.5 Sample of Preparation

From the preparation of mix design, the sample of this experiment are provided. Concrete mix design made from one sample which is based on experimental sample by using saw wood dust (SWD) with ratio 5%, 10% and 15%. The result of modified concrete with each ratio will be compared to standard concrete. Therefore, all experimental result can be determined whether it is better or not.

3.5.1 Saw Wood Dust Concrete (SWDC)

The material use in the concrete mix design is Ordinary Portland Cement (OPC), saw wood dust, fine aggregate, coarse aggregate and water. Saw wood dust will be obtained from the wood manufacturing and will be clean to make sure no impurities in it. All the material will be mixed together with mixer machine.

After mixing process, the concrete paste need to test for slump test to get workability data. After that, the concrete paste will be distributed into each mould that made either from plastic or steel. The size concrete for cube test is 150 x 150 x 150mm and for flexural is 150 x 150 x 750mm as shown in figure 3.8. The concrete need to be removed one day after casting and need to cure. With the age of curing, the concrete will be tested in the laboratory.

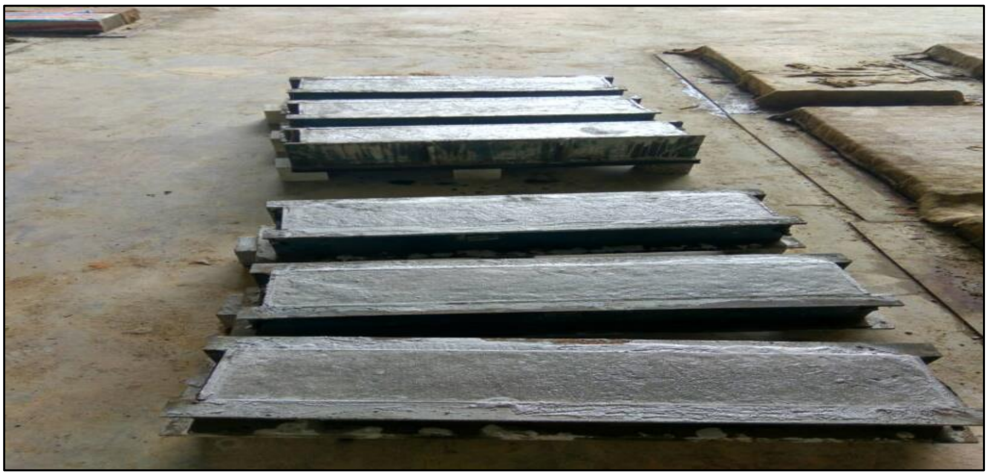

Figure 3.8: The Size of Beam Steel Formwork

3.6 Curing Concrete Sample

For control the moisture content of concrete during the hardening process, curing need to take place. This stage is important because it can minimize dehydration and heat stress in the concrete which can cause crack on the surface of the sample after fully harden. It’s also important to keep the concrete curing because to make sure the concrete can achieve unlimited strength at 28 days.

Sample preserved in this research using immersion in tank of water for cube test and wet gunny for prism test. In this research, the age of curing investigated is 14 and 28 days. All the sample need to test according to age of curing. Figure 3.9 shows the cube concrete sample immersed in water tank and Figure 3.10 shows the prism coating by wet gunny.

Figure 3.9: The Cube Concrete Immersed in Water Tank

Figure 3.10: The Prism Coating by Gunny

3.7 Test Conducted

Each sample or cube test made in accordance with the test specified. The test are performed in the materials and structures laboratory FKASA in accordance with the established procedures. Among the test conducted in this study are as slump test, compression test and flexural test.

3.7.1 Workability Test

Workability may be defined as the property of the concrete which determines as ability to be placed compacted, and finished. It is the most term relating to fresh concrete of these three operations, the greatest emphasis should be placed on compaction to eliminate of air voids, since the consequences of inadequate compaction are serious. It also can be independent characteristic as follows:

(a) Consistency is the firmness of form of a substance or the ease with which it will flow. It is measure of wetness and fluidity.
(b) Mobility is the ease which concrete mix can flow into and completely fill the formwork or mould.

Compatibility is the ease which a given concrete mix can be fully compacted to remove all trap water and to achieve maximum possible density. Next is the increase in compressive strength with an increase density.

3.7.1.1 Slump Test

The workability of a concrete mix is defined as the case with which it can be mixed, transported, placed and compacted in position. Slump test is carried out to measure the consistency of plastic concrete. It is sustainable for detecting changes in workability. This test is being used extensively on site. There are three types of slump which is true slump, shear slump and collapse slump as shown in Figure 3.11.

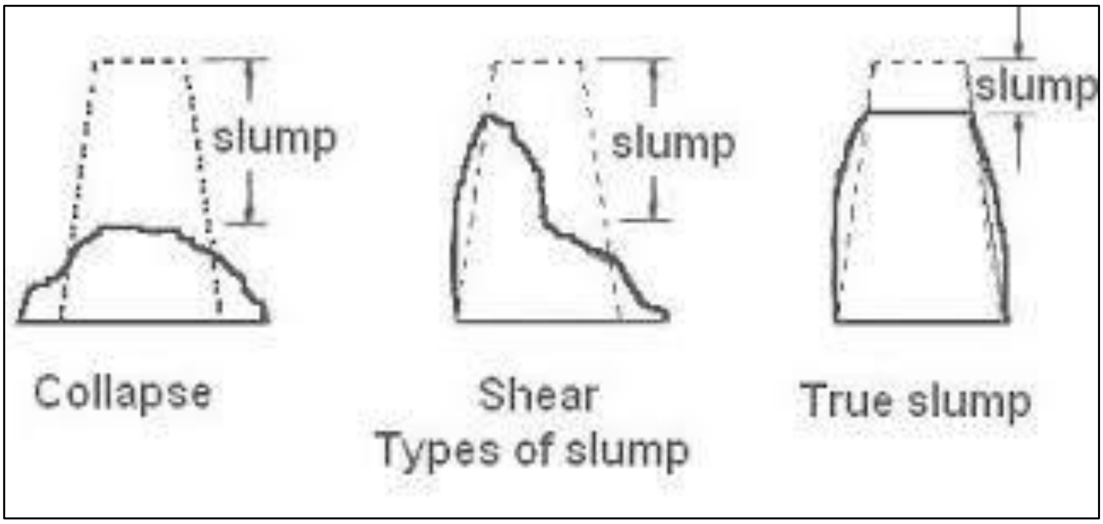

Figure 3.11: Types of Slump

Source: M.L. Gambhir, (2009)

3.7.1.2 Apparatus

Apparatus	Description
Cone Mould	Has a diameter of 100 mm and 200 mm below and height 300mm
Steel rods	Has a diameter of 16 mm and the length is 600 mm with both ends shaped hemisphere
Sampling tray	This tray mould is used to cover the cone
spatula	Used for mixing concrete and put into the mould
Ruler	Used to measure the debris

3.7.1.3 Procedure

i) The mould for the slump test is a frustum of a cone, 300 mm (12 in) of height. The base is 200 mm (8in) in diameter and it has a smaller opening at the top of 100 mm (4 in).

ii) The base is placed on a smooth surface and the container is filled with concrete in three layers, whose workability is to be tested.

iii) Each layer is temped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end.

iv) When the mould is completely filled with concrete, the top surface is struck off (levelled with mould top opening) by means of screening and rolling motion of the temping rod.

v) The mould must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot - rests brazed to the mould.

vi) Immediately after filling is completed and the concrete is levelled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump.

vii) The decrease in the height of the centre of the slumped concrete is called slump.

viii) The slump is measured by placing the cone just besides the slump concrete and the temping rod is placed over the cone so that it should also come over the area of slumped concrete.

ix) The decrease in height of concrete to that of mould is noted with scale. (Usually measured to the nearest 5 mm (1/4 in).

3.7.2 Compressive Test

Compressive strength test are test to measure the strength of the concrete, where concrete grades and different age will give the different strength. This test is based on specification of BS 1881: part 116: 1983 (British Standard Institution 1983). The machine for test compressive strength is ADR 2000 as shown in Figure 3.12.

Figure 3.12: The Compression Machine

3.7.2.1 Apparatus

i) Compression machine
ii) Broom

3.7.2.2 Procedure

i) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

ii) Take the dimension of the specimen to the nearest 0.2m

iii) Clean the bearing surface of the testing machine

iv) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

v) Align the specimen centrally on the base plate of the machine.

vi) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.

vii) Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails

viii) Record the maximum load and note any unusual features in the type of failure.

3.7.3 Flexural Test

Flexural testing is used to determine the flex or bending properties of a material. Sometimes referred to as a transverse beam test, it involves placing a sample between two points or supports and initiating a load using a third point or with two points which are respectively call 3-Point Bend and 4-Point Bend testing as shown in Figure 3.13. This test based on ASTM 78-02. The machine use for this test as shown in Figure 3.14.

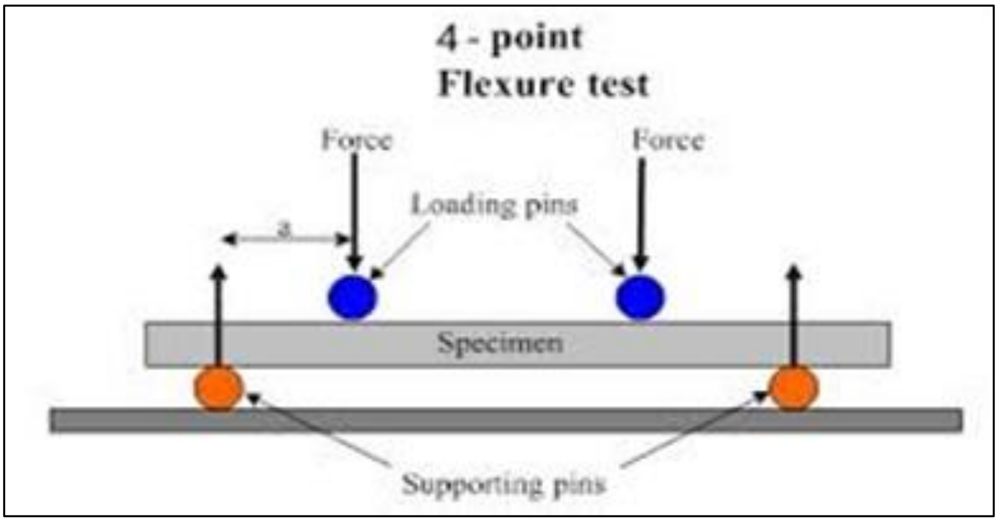

Figure 3.13: Example of 4-Point Flexural Test

Source: ASTM C78 (2005)

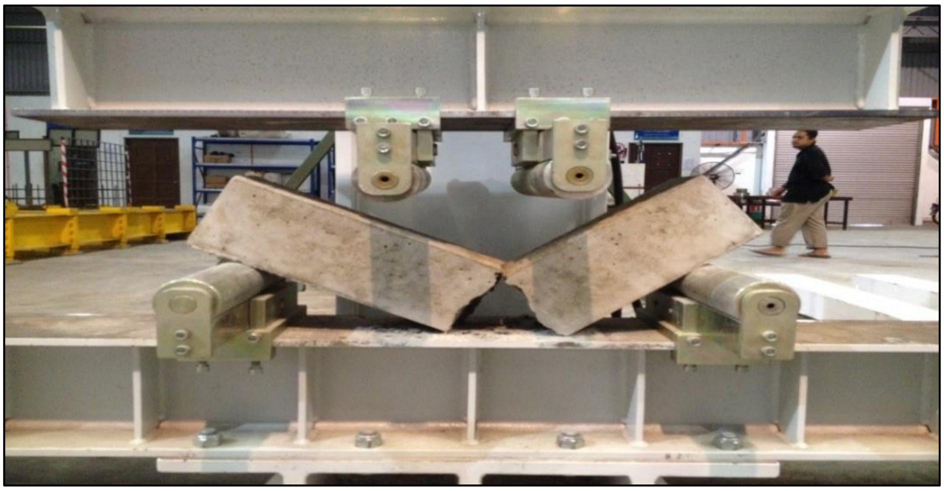

Figure 3.14: The Machine of Flexural Test

3.7.3.1 Apparatus

Apparatus	**Description**
Prism mould	Size are 150 x 150 x 750 mm (when size of aggregate is less than 38 mm). so that's the aggregate is 20 mm
Tamping bar	The size is (40 cm long, weighing 2 kg and tamping section having size of 25 mm x 25 mm)
Flexural test machine	The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsion stresses or restraints.

3.7.3.2 Procedure

i) Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross section of the beam mould and throughout the depth of each layer.

ii) Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.

iii) Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be **3d** and the distance between the inner rollers shall be **1d**. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.

iv) The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.

v) The load shall be applied at a rate of loading of 400 kg/min for the 150.00 mm specimens and at a rate of 180 kg/min for the 100.00mm specimens.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Based on test conducted, result and data have been collected. These data were used in the analysis and conclusions related to the study as well as to achieve the goals and objectives. Therefore, this chapter describe the results of the experiments have been performed.

4.2 Slump Test

Consequently, after conducting laboratory tests based on particular standard methods, the results below were obtained. The workability of concrete batches for different percentages of SWD using slump test is shown in the Table 4.1 and Figure 4.1.

Table 4.1: Slump Test Result (mm)

Sample (%)	W/C Ratio	Slump (mm)	Slump Type
Control	0.58	48	True Slump
R1-5%	0.58	42	True Slump
R2-10%	0.58	35	True Slump
R3-15%	0.58	33	True Slump

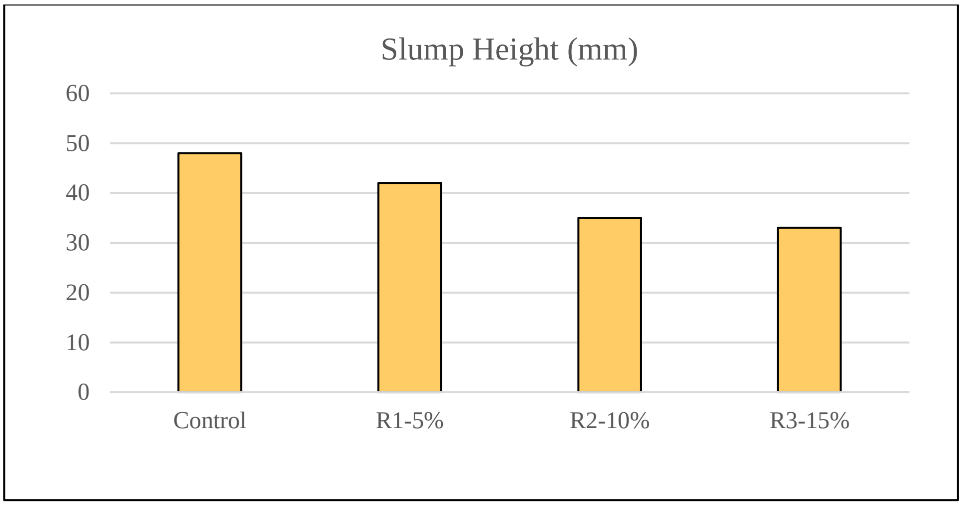

Figure 4.1: Slump Height for SWD Concrete

The mix samples with constant water/cement (W/C) ratio of 0.58 exhibited medium to high workability. It is obvious that workability of concrete reduces as the amount percentage of SWD increases for all sample where it shows a spike in workability, to which from that point, as the percentage of SWD increases, the workability of the concrete was decreased. This can be attributed to the fact that since the control aggregate is denser than the SWD aggregate. This implies that more cement paste is required for the lubrication of the aggregate, hence reducing the entire fluidity of the mix, thereby reducing the height of the slump.

Similarity, the decrease of the slump height in 5%, 10%, and 15% SWD as percentage of SWD aggregate was increased and was equally be attributed to w/c ratio. With w/c ratio of 0.58 used for all the mixes, the hydrated cement paste became less watery and more viscous because the SWD is absorb the water. This process permits the penetration of cement into the OPS aggregate. Furthermore, it reduces the amount of cement paste available for lubrication and hydration. Therefore, it can leads to a decrease in the free movement of cement paste in the mixed and consistently leads to a decrease in slump.

From the previous paper, it state the workability of concrete increases when the percentage of saw wood dust increases. After 50% percentage replacement, the workability can be attributed to the difficulties encountered in achieving a uniform mix due to increase in surface area as well as high water absorption of saw wood dust introduce into the concrete cube.

4.3 Compression Test

Table 4.2: Maximum Load for Compressive Strength Test

Sample (%)	14 days (KN)	28 days (KN)
Control	477.941	690.722
R1- 5%	427.879	614.057
R2- 10%	387.784	530.928
R3- 15%	331.070	381.085

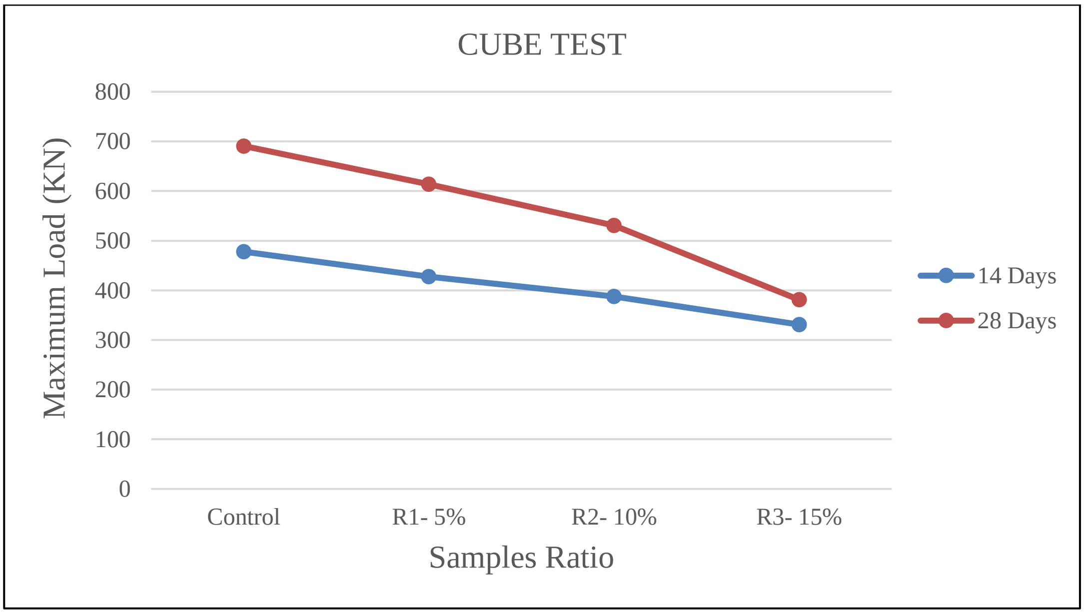

Figure 4.2: Maximum Load of the Cubes

Table 4.3: Maximum Strength for Compressive Strength Test

Sample (%)	14 days (MPa)	28 days (MPa)
Control	21.242	30.699
R1- 5%	19.017	27.291
R2- 10%	17.235	23.597
R3- 15%	14.714	16.937

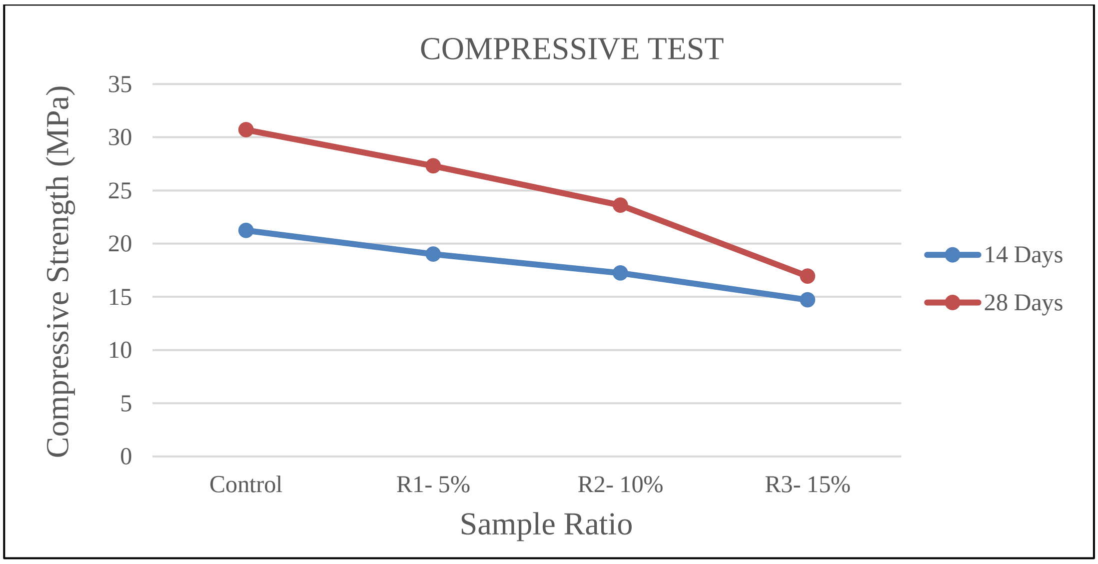

Figure 4.3: Compressive Strength of the Cubes

Figure 4.2 and Table 4.2 shows the development of maximum load compressive strength of concrete with age of curing. Figure 4.3 and Table 4.3 showed the result of compressive strength. It indicates the different amount of SWD that were added, as it affects the strength of the concrete. The rate of strength gained was substantial as the curing days increase; on the other hand, the strength of the concrete specimens is reciprocal to the percentage of SWD added. As the percentage of SWD increase, the compressive strength of the concrete decreases, vice versa.

As it is clear, 0% SWD attained the maximum strength at 14 to 28 days, as SWD gradually replaces the fine aggregate, so the concrete strength was dropped when replace the SWD with 15% ratio. These phenomena could be explained from the fact that SWD are the organic materials that happen to be lighter and less strong than sand.

Furthermore, the reduction in strength of concrete strength as a result of increment in the added percentage of SWD as fine aggregate could be attributed as a result of the highly irregular shapes of the SWD, which prevent full compaction with usual fine aggregate, there by affecting the strength of the concrete.

In addition, the bonding between SWD and cement paste are not as strong as that of control concrete because the surface of SWD are smooth compare to river sand that cause the normal concrete more strength compare to SWD concrete. However, for SWD concrete, 10% as partial replacement of SWD was increased modestly at 14 and 28 days of curing age. The results of this age curing were 17.235 MPa and 23.597 MPa.

As a conclusion, with respect to the general strength of all samples, it can be noted that 0% to 10% are highest strength of compression test that can achieve targeted mean strength which is 30.000 MPa. Taking 28 days as the reference of curing age, 0% to 10% are certified as the highest condition of strength for concrete.

Table 4.4: Compressive Test for 14 days curing age

Sample of Percentage Replacement (%)	**Load (KN)**	**Compressive Strength (MPa)**
Control	477.941	21.242
R1- 5%	427.879	19.017
R2- 10%	387.784	17.235
R3- 15%	331.070	14.714

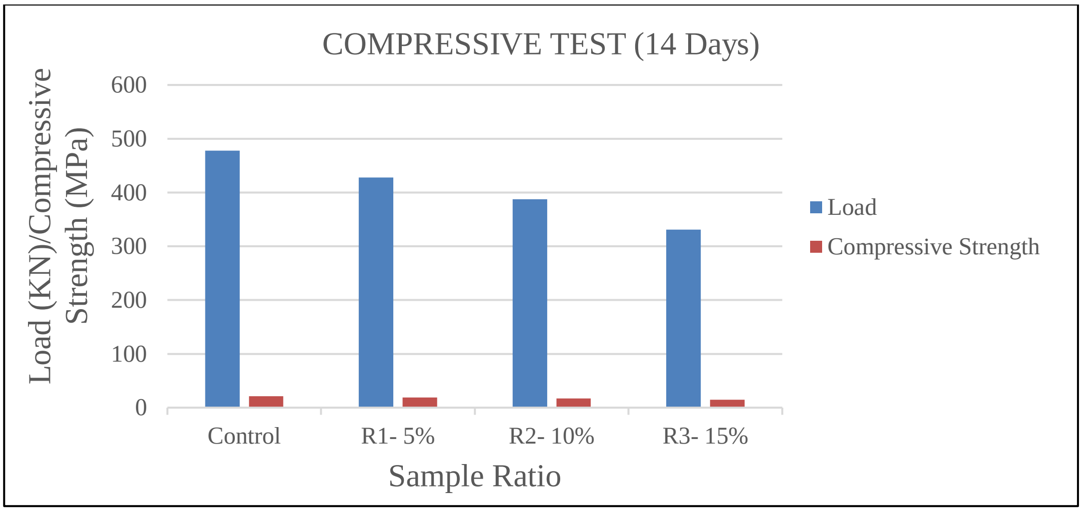

Figure 4.4: Compressive Test for 14 days curing age

Table 4.4 and Figure 4.4 shows the development of compressive strength of different ratio concrete with age of curing. It indicates the different amount of SWD that were added, as it affects the strength of concrete when cured the sample at 14 days. The rate of strength gained was substantial as the curing age, while on the other hand, the strength of control concrete are highest strength but for 10% partial replacement of SWD was increased steadily at 387.784 KN for load and 17.235 MPa for strength.

Based on the bar charts when the curing age at 14 days, the result shows the trend of strength decrease gradually, but the lowest strength of the concrete at 14 days is for 15% partial replacement of SWD as fine aggregate at 331.070 KN for load and 14.714 MPa for strength. By comparing from the previous result, the trends of compressive strength gradually decreases as the percentage of saw wood dust increases.

Table 4.5: Compressive Test for 28 days curing age

Sample of Percentage Replacement (%)	Load (KN)	Compressive Strength (MPa)
Control	690.722	30.699
R1- 5%	614.057	27.291
R2- 10%	530.928	23.597
R3- 15%	381.085	16.937

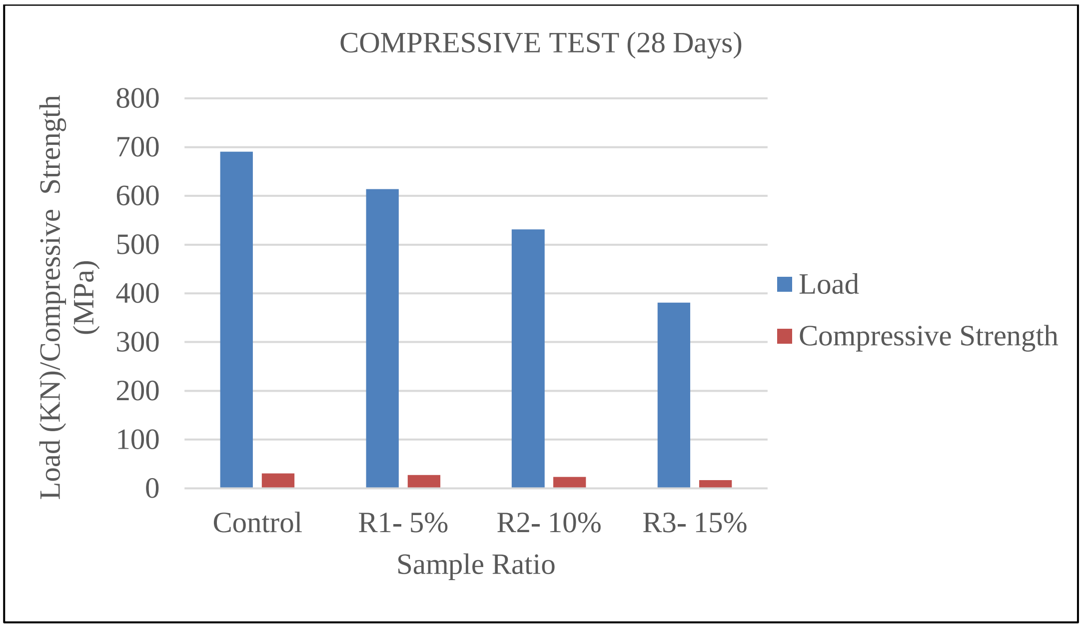

Figure 4.5: Cube Test for 28 days curing period

Table 4.5 and Figure 4.5 shows the development of compressive strength of different ratio concrete with age of curing. It indicates the different amount of SWD that were added, as it affects the strength of concrete when cured the sample at 28 days. Then, for 28 days curing period presented the highest value of load and compressive strength, 690.722 KN and 30.699 MPa, respectively at 0% replacement of sand with saw wood dust concrete.

Besides that, the second highest value for SWD concrete was 5% partial replacement, the value of load at 614.057 KN and the strength at 27.291 MPa. So, the optimum percentage of partial replacement saw wood dust (SWD) as fine aggregate was 10% because it achieve targeted strength which is 23.957 MPa. Conversely, the lowest value of load, 381.085 KN and compressive strength, 16.937 MPa goes to 15% replacement of fine aggregate with SWD concrete at 28 days curing period.

4.4 Flexural Test (4 Point Load)

Table 4.6: Maximum Load with curing age

Sample	14 days (KN)	28 days (KN)
Control	30.12	32.08
R1- 5%	28.27	29.65
R2- 10%	25.72	27.13
R3- 15%	23.55	24.08

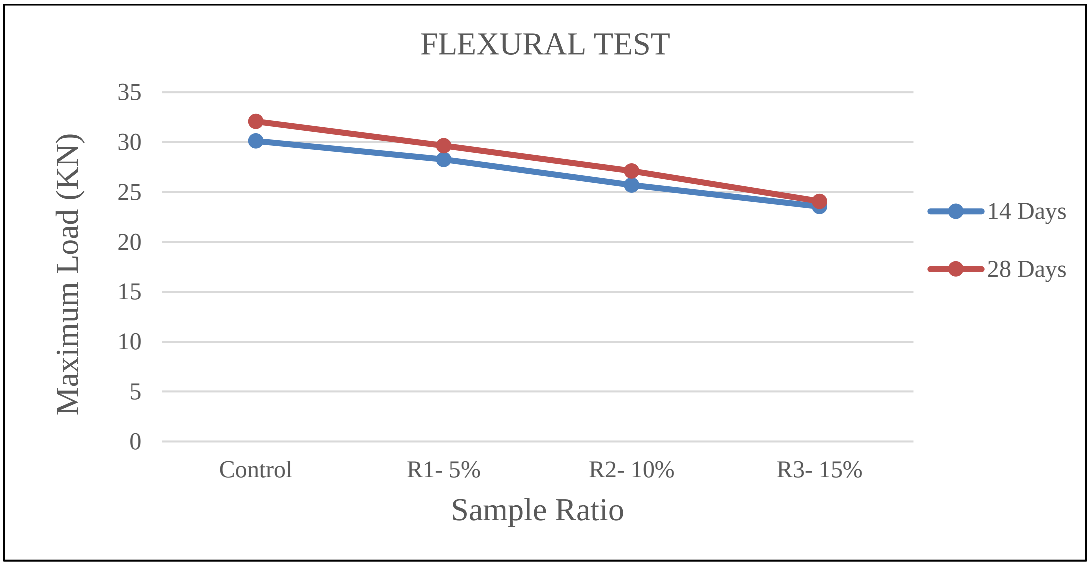

Figure 4.6: Maximum Load of the Prisms

Table 4.7: Flexural Strength with curing age

Sample	14 days (MPa)	28 days (MPa)
Control	6.024	6.417
R1- 5%	5.656	5.930
R2- 10%	5.146	5.425
R3- 15%	4.710	4.817

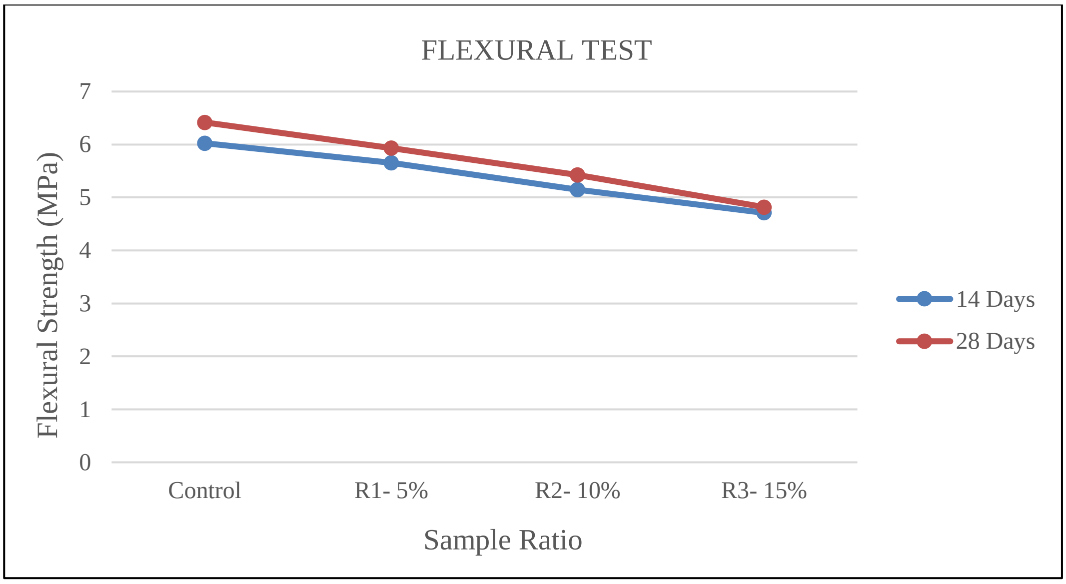

Figure 4.7: Flexural Strength of the Prisms

Based on the Table 4.6 and Figure 4.6, it is shows the maximum loads of the prims. From that, the highest load of flexural strength is control concrete which is 0% SWD at 32.08 KN of 28 days age curing and the lowest load is ratio 3 which is 15% of SWD at 24.08 KN of 28 days curing. The trends for all sample in term of maximum load increases with age of curing but decreases as percentage of SWD increases.

Table 4.7 and Figure 4.7 was shown the flexural strength test results of the prisms. From the results, at 14 and 28 days, the control ratio has highest flexural strength compare to the other sample which is 6.024 MPa to 6.147 MPa. The sample from ratio 3 with 15% SWD has lowest flexural strength which is 4.710 MPa to 4.817 MPa. From the result, the trends show the flexural strength increases with age of curing but decreases as percentage of SWD increases.

Table 4.8: Flexural Test for 14 days curing age

Sample of Percentage Replacement (%)	Load (KN)	Flexural Strength (MPa)
Control	30.12	6.024
R1- 5%	28.27	5.656
R2- 10%	25.72	5.146
R3- 15%	23.55	4.710

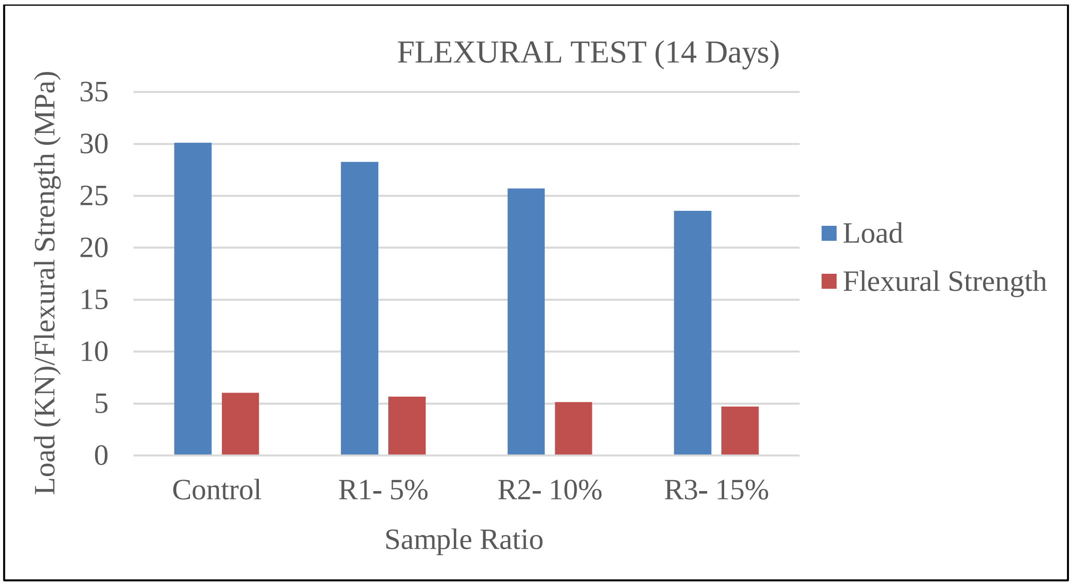

Figure 4.8: Flexural Test for 14 days curing period

Table 4.8 and Figure 4.8 shows the development of flexural strength of different ratio concrete with age of curing. It indicates the different amount of SWD that were added, as it affects the strength of concrete when cured the sample at 14 days. The rate of strength gained was substantial as the curing age, while on the other hand, the strength of control concrete are highest strength but for 10% partial replacement of SWD was increased steadily at 25.72 KN for load and 5.146 MPa for strength.

Based on the bar charts when the curing age at 14 days, the result shows the trend of flexural strength decrease gradually, but the lowest strength of the concrete at 14 days is for 15% partial replacement of SWD as fine aggregate at 23.55 KN for load and 4.710 MPa for strength. By comparing from the previous result, the trends of flexural strength gradually decreases as the percentage of saw wood dust increases.

Table 4.9: Flexural Test for 28 days curing age

Sample of Percentage Replacement (%)	Load (KN)	Flexural Strength (MPa)
Control	32.08	6.417
R1- 5%	29.65	5.930
R2- 10%	27.13	5.425
R3- 15%	24.08	4.817

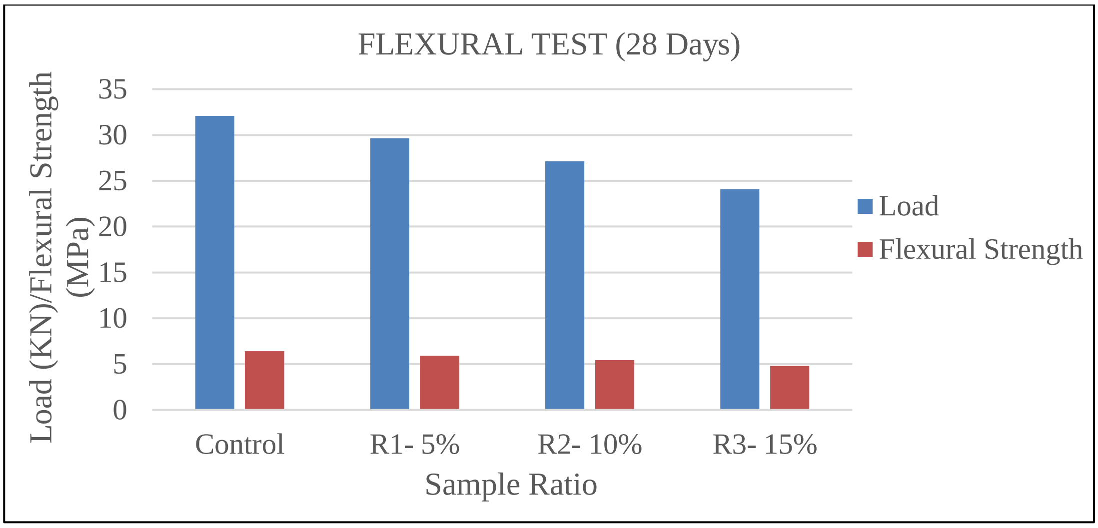

Figure 4.9: Flexural Test for 28 days curing period

Table 4.9 and Figure 4.9 shows the development of flexural strength of different ratio concrete with age of curing. It indicates the different amount of SWD that were added, as it affects the strength of concrete when cured the sample at 28 days. Then, for 28 days curing period presented the highest value of load and flexural strength, 32.08 KN and 6.417 MPa, respectively at 0% replacement of sand with saw wood dust concrete.

Besides that, the second highest value for SWD concrete was 5% partial replacement, the value of load at 27.291 KN and the strength at 5.930 MPa. So, the optimum percentage of partial replacement saw wood dust (SWD) as fine aggregate was 10% because it achieve targeted strength which is 5.425 MPa. Conversely, the lowest value of load, 16.937 KN and compressive strength, 4.817 MPa goes to 15% replacement of fine aggregate with SWD concrete at 28 days curing period.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Introduction

In general, SWD aggregate was founded to be a good replacer of fine aggregate in concrete production. The compressive strength, flexural strength and workability is adequate for a small replacement point of view and according to recycle of waste material.

5.2 Conclusion

From the results of the various tests carried out, the following conclusion can be drawn:

(a) Slump Test (Workability)

From the slump test done, result shown the sample of ratio 3 was the highest of workability at 43mm compared to other specimen which are 47 mm for ratio 1, 55 mm for ratio 2, and 64 mm control concrete.

(b) Compression Test

Based on the result of compressive strength test of the cube, the ratio 2 with 10% was the optimum percentage of compressive strength. On 28 days, 10% OPS was get 25.62 MPa for the compressive strength and for the ordinary concrete got 33.18 MPa. So, both samples were almost getting the same strength of the concrete in range of (20 – 30) MPa.

(c) *Flexural Test*

Based on the result of flexural strength test of the prism, the ratio 1 with 5% was the optimum percentage of flexural strength. On 28 days, 5% OPS was get 7.714 MPa for the compressive strength and for the ordinary concrete got 5.820 MPa. So, both samples were almost getting the same strength of the concrete.

The result has been confirm by refer to journal title “The investigation of properties of concrete using sawdust as partial replacement for sand”. From this journal, it state the workability of concrete through slump test decreases up to 50% of sawdust replacement for sand. The trend is similar for this research. For the flexural strength, by referring the journal title “Experimental study on strength of concrete by partial replacement of fine aggregate with sawdust and robosand”, it state the strength increases with age of curing but decreases as the percentage of saw wood dust increases. The result of compressive strength for 15% at 28 days is 16.44 MPa, almost similar to our research which is 16.94 MPa for the same saw wood dust percentage and the age of curing.

The trend of flexural strength for this research also similar to the journal title “The use of sawdust ash as fine aggregate replacement in concrete” where the strength increases with age of curing but decreases as percentage of saw wood dust increases. The result from this journal shows the flexural strength at 28 days for 15% saw wood dust replacement is 4.81 MPa while our research result is 4.71 MPa a little bit lowest. The suitable optimum usage of saw wood dust as partial replacement for sand is about 10%.

Overall, it can be concluded that the use of saw wood dust will slightly lower the strength of the concrete due to density compared to fine aggregate. It can considered as normal class for strength of concrete due to the compressive strength was above 20 to 30 MPa, but this type of concrete can be applied to build a structure that does not bear the burden of building such as walls and barriers, concrete blocks, stiffness column and so on.

5.3 Recommendations for Future Study

Upon completion of the study of saw wood dust concrete, some suggestion can be submitted for the concrete improvements that can be produce a better engineering materials as well as economical. This is the list of the suggestion are as follows:

(a) Reduce the water cement ratio in concrete to improve the mix. Water ratio will affect the strength of cement concrete.

(b) Make a more detailed study of the concrete because saw wood dust concrete offers as a potential construction material and simultaneously solving the environment problem of reduction is solid waste.

(c) Make sure the material is good condition such as cement, because for control concrete quality, the cement should be fresh to manage achieve required properly

(d) Use admixture to increases the strength of modified concrete. There are possibilities to increase the strength by adding admixture and the test carried out with different admixture which give optimum results.

(e) Use aluminium formwork for cube and prism to get a better result of the concrete. The aluminium formwork is light and it is easy to conduct. It is also can give a better shape of the cube and prism after casting.

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APPENDIX A
COCNRETE MIX DESIGN

CONCRETE MIX DESIGN			
Stage	Item	Reference & calculation	Value
1	1.1 Characteristic Strength	Specified	**G30** N/mm^2 at **28** days Proportion Defective **10 %**
	1.2 Standard Deviation	Figure 3	**4** N/mm^2
	1.3 Margin	C1 or Specified	(k=1.28) 1.24 x **4** = **5.12**N/mm^2
	1.4 Target mean strength	C2	**30** + **5.12** = **35.12** N/mm^2
	1.5 Cement type	Specified	**OPC**
	1.6 Aggregate type: Coarse		**Crushed**
	Aggregate type: Fine		**Crushed**
	1.7 Free water/cement ratio	Table 2, Fig 4	**0.58** use the lower value
	1.8 Max. free-water cement ratio	Specified	**0.65**
2	2.1 Slump or V-B	Specified	Slump **10-30 mm**
	2.2 Maximum aggregate size	Specified	**20 mm**
	2.3 Free-water content	Table 3	**170 kg/m^2**
3	3.1 Cement content	C3	**170** ÷ **0.58** = **293.10 kg/m^2**
	3.2 Maximum cement content	Specified	______**Kg/m^2**
	3.3 Minimum cement content	Specified	**275 kg/m^2** – use if greater than item 3.1 and calculate 3.4
	3.4 Modified free-water/cement ratio		______
4	4.1 Relative density of aggregate (SSD)	Fig 5	**2.7** known/assumed
	4.2 Concrete density	C4	**2456 kg/m^2**
	4.3 Total aggregate content		**2456** – **293.10** = **2162.90** kg/m^2
5	5.1 Grading of fine aggregate	BS 882	Zoom **_____-_____-**
	5.2 Proportion of fine aggregate	Fig 6	______**Per cent**
	5.3 Fine aggregate content		**2162.90** X **0.32** = **692.13kg/m^2**
	5.4 Coarse aggregate content	C5	**2162.90** – **692.13** = **1470.77kg/m^2**

Quantities	Cement (Kg)	Water (Kg)	Fine aggregate (Kg)	coarse aggregate (Kg)
Per m^3 (to nearest 5 kg)	**293**	**170**	**692**	**1471**
Per trial mix of **0.2106** m^3	**62**	**36**	**146**	**310**

APPENDIX B
COCNRETE MIX DESIGN FOR ALL SAMPLE

For 1 m^3 of concrete

Standard mixed design for cube strength of 30 N/mm^2 at 28 days. Weight in kg.

		Saw Wood Dust		
	Standard	**5%**	**10%**	**15%**
Cement	330	330	330	330
Water	190	190	190	190
Fine Aggregate	1020	969	918	867
Coarse Aggregate	905	905	905	905
Saw wood dust	0	16.1	32.2	48.3

APPENDIX C
COMPRESSIVE STRENGTH FOR CONTROL CONCRETE

RATIO	DAYS	SAMPLE 1		SAMPLE 2		SAMPLE 3		AVG. LOAD (KN)	AVG. STRENGTH (MPa)
		LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)		
Standard Ratio C25/30	14	444.896	19.773	475.403	21.129	513.525	22.823	477.941	21.242
	28	760.559	33.803	655.338	29.126	656.270	29.168	690.722	30.699

APPENDIX D
COMPRESSIVE STRENGTH FOR 5% SAW WOOD DUST

RATIO	DAYS	SAMPLE 1		SAMPLE 2		SAMPLE 3		AVG. LOAD (KN)	AVG. STRENGTH (MPa)
		LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)		
5% of SWD	14	411.394	18.284	439.586	19.229	432.656	19.537	427.879	19.017
	28	621.678	27.630	612.494	27.222	607.998	27.022	614.057	27.291

APPENDIX E
COMPRESSIVE STRENGTH FOR 10% SAW WOOD DUST

RATIO	DAYS	SAMPLE 1		SAMPLE 2		SAMPLE 3		AVG. LOAD (KN)	AVG. STRENGTH (MPa)
		LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)		
10% of SWD	14	390.154	17.356	385.339	17.126	387.499	17.222	387.784	17.235
	28	530.058	23.558	528.933	23.508	533.793	23.724	530.928	23.597

APPENDIX F
COMPRESSIVE STRENGTH FOR 15% SAW WOOD DUST

RATIO	DAYS	SAMPLE 1		SAMPLE 2		SAMPLE 3		AVG. LOAD (KN)	AVG. STRENGTH (MPa)
		LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)		
15% of SWD	14	327.425	14.522	334.895	14.884	330.890	14.706	330.070	14.714
	28	380.793	16.924	382.098	16.982	380.365	16.905	381.085	16.937

APPENDIX G
FLEXURAL STRENGTH FOR CONTROL CONCRETE

RATIO	DAYS	SAMPLE 1		SAMPLE 2		SAMPLE 3		AVG. LOAD (KN)	AVG. STRENGTH (MPa)
		LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)		
Standard Ratio C25/30	14	30.89	6.178	29.94	5.989	29.52	5.905	30.12	6.024
	28	30.77	6.154	33.37	6.675	32.10	6.421	32.08	6.417

APPENDIX H
FLEXURAL STRENGTH FOR 5% SAW WOOD DUST

RATIO	DAYS	SAMPLE 1		SAMPLE 2		SAMPLE 3		AVG. LOAD (KN)	AVG. STRENGTH (MPa)
		LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)		
5% of SWD	14	28.61	5.723	28.46	5.693	27.75	5.551	28.27	5.656
	28	29.95	5.990	29.30	5.860	29.70	5.940	29.65	5.930

APPENDIX I
FLEXURAL STRENGTH FOR 10% SAW WOOD DUST

RATIO	DAYS	SAMPLE 1		SAMPLE 2		SAMPLE 3		AVG. LOAD (KN)	AVG. STRENGTH (MPa)
		LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)	LOAD (KN)	STRENGTH (MPa)		
10% of SWD	14	26.25	5.250	25.47	5.095	25.46	5.093	25.72	5.146
	28	26.93	5.386	27.20	5.440	27.25	5.450	27.13	5.425

APPENDIX J
FLEXURAL STRENGTH FOR 15% SAW WOOD DUST

RATIO	**DAYS**	**SAMPLE 1**		**SAMPLE 2**		**SAMPLE 3**		**AVG. LOAD (KN)**	**AVG. STRENGTH (MPa)**
		LOAD (KN)	**STRENGTH (MPa)**	**LOAD (KN)**	**STRENGTH (MPa)**	**LOAD (KN)**	**STRENGTH (MPa)**		
15% of SWD	14	23.38	4.677	23.25	4.651	24.01	4.802	23.55	4.710
	28	24.06	4.812	23.94	4.788	24.25	4.850	24.08	4.817

APPENDIX K
PICTURE OF METHODOLOGY PROCESS

The heap of Saw Wood Dust was taken at mill saw.

The raw material of concrete was prepare for concrete batching.

The mold was prepare for pour the fresh concrete.

The raw material was mix to get fresh concrete.

The slump test was conducted to get the reading.

The prism sample was curing with the gunny for 14 & 28 days.

The cube sample was curing at water tank for 14 & 28 days before test.

The cube sample was test by using compression machine test.

The result for of the cube sample at laboratory.

The condition of cube sample after undergo compressive test at FKASA laboratory.

The prism sample was test by using flexural 4 point load test at laboratory.

The result for prism sample was taken for 14 & 28 days at FKASA laboratory.