EXPERIMENTAL STUDY OF WOOD CHIP AS PARTIAL REPLACEMENT FOR COARSE AGGREGATE WITH RATIO 5%,10 AND 15%

MOHAMD HAFIZ BIN MOHD SALEHIM

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : MOHAMAD HAFIZ BIN MOHD SALEHIM

Date of Birth : 5 APRIL 1993

Title : EXPERIMENTAL STUDY OF WOOD CHIP AS PARTIAL REPLACEMENT FOR COARSE AGGREGATE WITH RATIO 5%, 10% AND 15%

Academic Session : SEMESTER 1 2017/2018

I declare that this thesis is classified as:

- ☐ CONFIDENTIAL (Contains confidential information under the Official Secret Act 1997)*
- ☐ RESTRICTED (Contains restricted information as specified by the organization where research was done)*
- ☑ OPEN ACCESS I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_______________________	_______________________
(Student's Signature)	(Supervisor's Signature)
_______________________	_______________________
New IC/Passport Number Date:	Name of Supervisor Date:

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

SUPERVISOR'S DECLARATION

I/We* hereby declare that I/We* have checked this thesis/project* and in my/our* opinion, this thesis/project* is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

____

(Supervisor's Signature)

Full Name : SHARIZA BINTI MAT ARIS

Position : LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : MOHAMAD HAFIZ BIN MOHD SALEHIM

ID Number : AA13287

Date : 8 January 2018

EXPERIMENTAL STUDY OF WOOD CHIP AS PARTIAL REPLACEMENT FOR COARSE AGGREGATE WITH RATIO 5%,10% AND 15%

MOHAMAD HAFIZ BIN MOHD SALEHIM

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

DEC 2017

ACKNOWLEDGEMENTS

First is thanks to Allah for let me complete this research. Although there is long journey for me to complete this study, but with Allah permission I have reach the end of this research journey.

Second is thanks to my research supervisor, Puan Shariza Binti Mat Aris for your time and sincere guidance that you have given to me from the beginning until the end of my research.

Third is thanks to my parent for the ongoing support. The continuous support has made me stand on the place that I’m standing now. Only Allah can repay the virtues that they have done to me.

Fourth is thanks to my friends for help and opinion. The hand that you lend during producing my research samples and the opinion you give are very helpful for me in the process of completing my research.

Last is thanks to the technicians at Makmal Konkrit dan Struktur Berat UMP for the assistances that provided to me during preparing and testing my research samples.

ABSTRAK

Tujuan kajian ini adalah untuk mengetahui potensi penggunaan hirisan kayu sebagai pengganti bahagian batu dalam konkrit dengan menggunakan ekperimen. Peratus penggantian hirisan kayu kepada batu secara isipadu ialah 5%, 10% dan 15%. Campuran konkrit telah direka untuk mencapai 30MPa kekuatan tekanan pada 28 hari. Hirisan kayu harus direndam didalam air sebelum dicampurkan bersama campuran konkrit yang lain. Dengan cara ini, hirisan kayu tidak akan menyerap air yang dibekalkan untuk proses penghidratan dan dapat membantu meningkatkan ikatan antara permukaan hirisan kayu dan simen. Dua puluh empat kiub sampel dan dua puluh empat prisma sampel telah dihasilkan daripada lapan percubaan campuran yang digaul, dituang dan diawet. Campuran konkrit dihasilkan daripada 0.61 nisbah air kepada simen. Empat campuran dengan peratusan penggantian yang berbeza adalah untuk setiap umur sampel. Air digunakan untuk mengawet sampel. Sampel diuji pada umur 14 dan 28 hari. Ujian makmal yang dijalankan adalah keruntuhan, kekuatan mampatan dan kekuatan lenturan. Ujian dijalankan mengikut prosedur ujian standard ASTM. Kajian ini mendapati bahawa kemerosotan campuran tidak konsisten apabila peratusan penggantian meningkat. Kajian ini juga mendapati bahawa pada umur 14 dan 28 hari, sampel penggantian 5% menghasilkan kekuatan mampatan yang lebih tinggi daripada 10% dan 15%. Pada umur 14 hari, sampel penggantian 5% mempunyai kekuatan lenturan tertinggi yang mana melampaui konkrit kawalan, sementara 10% sampel gantian pada usia 28 hari mendapat kekuatan lenturan yang lebih tinggi daripada 5% dan 15%, tetapi tidak mencapai kekuatan lenturan konkrit kawalan. Untuk keseluruhannya, sampel konkrit kawalan masih mempunyai kekuatan mampatan dan lenturan tertinggi pada 28 hari. Kajian ini menyimpulkan bahawa penggunaan cip kayu adalah diterima dan sesuai, tetapi perlu diingatkan bahawa kekuatan konkrit cip kayu tidaklah sama dengan apa yang direka untuknya.

ABSTRACT

The purpose of this research is to determine the potential of utilization wood chip as partial replacement to coarse aggregate in concrete by experiment. The percent of replacement wood chip toward coarse aggregate by volume are 0%, 5%, 10% and 15%. The concrete mixes designed to reach 30MPa compressive strength at 28 days. The wood chip was soaked in water before mix them with concrete mix. Thus, wood chip will not absorb the water provided for hydration process and it help to improve bond at interface of wood chip and cement. Twenty four cube samples and twenty four prisms samples were mixed, casted and cured from eight trial mixes. The mixes are using 0.61 water to cement ratio. Four mixes with different percentages of replacement is for each sample ages. The water is used to cure the samples. The samples tested at 14 and 28 days ages. The laboratory tests conducted are slump, compressive strength and flexural strength. The tests are conducted according to ASTM standard test procedure. This research discovered that the mixes slump is not consistence as the percentage of replacement increase. This research also found that at age 14 and 28 days, 5% replacement sample produce higher compressive strength than 10% and 15%. At age 14 days, 5% replacement sample has highest flexural strength that surpasses the control concrete, while 10% replacement sample at 28 days age got the higher flexural strength than 5% and 15% but didn't reach the control concrete flexural strength. For overall, control concrete sample still has highest compressive and flexural strength at 28 days. This research conclude that the utilization of wood chip is feasible and appropriate but need to be reminded that the strength of wood chip concrete is not as good as what it is design for.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of study

Nowadays the production of concrete using the old method is not relevant because of some adverse effects on the environment. This issue is very popular among of researchers for last few decades until now. Researchers were continuing their study on the alternative ways to reduce negative effects of the old concrete production method through innovations the new ways of concrete production. Among the inventions of some researchers are using by-products to replace partial of the main ingredient of the concrete. Those by-products should contain the certain characteristics in order to play their role along with others main ingredients to produce concrete with satisfied performance. The common advantages of using the by-products are lower cost of production and less bad effects toward the environment compared with old ways of concrete production.

This research is concentrates on replacement of coarse aggregate by partial content of wood chips in concrete. The first reason for replace coarse aggregate is also same reasons to replace other ingredients in concrete production which is limited of natural resources for preparing the raw materials needed in manufacturing concrete as the large amount of natural resources needed to produce more than 10 billion ton of concrete each year (Meyer 2009). Second reason is the bad impacts of the quarrying toward the environment by disturbance of land and river beds that lead to destruction of habitats in producing the aggregate.

Wood chips are the by-product of the timber industry. As we know that timber industry is one of the major contributors to economy of Malaysia, therefore for sure much of waste producing from the industry activities. The use of waste materials replace parts of aggregates in concrete helping natural sources sustainability and provide safe method of keeping these waste materials instead of dumping it into landfills and causing pollution (Thandavamoorthy 2016). The availability in much quantity, lower cost and its characteristic make the wood chips were chosen to replace some parts of coarse aggregates. Furthermore, form of wood chips that long and thin provide better load distribution toward the existed aggregates in concrete and providing good tension resistance.

The concrete containing waste product especially wood-based is categorized as light weight concrete. The advantages of the lightweight concrete are larger strength-to-weight ratio, greater strain capacity, lower changes of the size of object with a change in temperature and better heat and sound insulation (Chen 2008). However, lightweight concrete also has its correlated disadvantages such as lower indirect tensile strength and lower workability.

The method is uses for conducting this study starting by prepare the concrete samples. The samples mix is designs to achieve 30MPa strength at 28 days. The concrete samples divide by four different percentages of coarse aggregate replacement which is full content of coarse aggregate, five percent of replacement coarse aggregates by wood chips, ten percent of replacement coarse aggregates by wood chips and fifteen percent of replacement coarse aggregates by wood chips. Then tree samples of cube and prism from each different percentage of replacement coarse aggregates by wood chip will be tested for fourteen and twenty eight days after curing day. The test will be applied for the samples are slump, compressive strength and flexural strength that based on ASTM standard procedures as done by (Mohammed 2014) in his research which is wood waste as parts of fine aggregate in concrete.

1.2 Problem statement

The conservative concrete production method is not reasonable for practice today as it cause a lot of harm to environment in it process and expensive cost of manufacture. Others alternatives like replace the main ingredients of concrete with by-products or waste materials should taking into consideration for minimize those negative impacts. First issue is limited of natural resource. All the main raw materials for produce concrete are taking from natural resources which are categorized as limited resources which mean it continue reducing through time. One of the raw materials for concrete production is coarse aggregate. This paper try to solve this issue by replace part of coarse aggregates with wood chip that obtain from timber factory.

Second is an environment issue. The coarse aggregate extraction is done by excavation of the material from river beds and land. This activity disturbing the existed ecosystem of the location that possibly brings to extinction of certain animal species and change the land form. Then, stone is crushing to get into smaller size. The crushed stone later going through screening process for divide it into particulars size. Next is screened crushed stone was stockpiling. Finally the crushed stone at particulars size are transport to concrete batching plants. Those stages if not control properly can lead to the air pollution that harm to human health that attributed by airborne emission from both the stack and disturbed areas at mines location. Through the use of wood chips replace part of coarse aggregate probably minimize the environment issue due to less demand of coarse aggregate for production of concrete.

Third issue is cost of coarse aggregates as raw materials of concrete production. Logically the cost of course aggregate must be expensive as it passed the several processes until forming the coarse aggregate. Hence, construction industry very welcome to new finding that cheaper and effective in order to reduce the cost of construction while achieving the same or satisfied performance with the previous ways.

Fourth issue is a constraint of landfill area for disposal of waste material. Much of waste materials end at landfill site every year. Concerned world society is worry about an increase of waste material because shortage of landfill area as the human population increases by years. This situation forces for finding the alternative ways to deposit those potential materials. One way as what is proposes in this paper is deposited them in the concrete structure. This help in reducing part of volume in the landfill area which suppose to be fill by the potential waste material that can be use in concrete.

The potential method proposes to solve those issue is through the utilization of by-product from the timber industry which is wood chips as partial replacement of coarse aggregates in concrete. This is because the wood chips available in large quantity and cheaper as it is by-product from timber industry which is one of the majors industries contributing to Malaysia economic. Physical form of wood chips which are long and thin make it able to distribute the load more uniformly and in a same time they provide extra tension resistance to the concrete. The density of concrete contained wood chips is less than the normal concrete. Those characteristics is the reasons why wood chips chosen to replace part of course aggregates. The wood chips are by-product from the process of chipping the wood and the wood available to be collected at wood factory around Malaysia. The wood chips use in this research gets from local timber factory located in Kuantan, Pahang at price of RM 3 per gunny bag.

1.3 Objective

The main objective of this research is to determine the potential utilization of wood chips as partial replacement of course aggregates in concrete. The following is three specific objectives to achieve the main objective:

i. To determine the workability of modified concrete that contained wood chips at different replacement percentage of course aggregates.

ii. To achieve the maximum compressive strength and flexural strength of modified concrete that contained wood chips at different replacement percentage of course aggregates.

iii. To identify the optimum content of wood chips for produce a maximum concrete strength.

1.4 Scope of the study

The reason of this study is conducts is to know the level of capability of wood chips as partial replacement of course aggregates in concrete. The characteristic strength designed is 30MPa. Size of course aggregate is 20mm. Water to cement ratio is 0.61. The concrete mix ratio is 1:2.82:4.39. The percentages of replacement of course aggregates to wood chips by volume are five percent, ten percent and fifteen percent. The density of the wood chip is 146kg/m^3. The modified concrete will be controlled by normal concrete that consist of full content of course aggregate. Two samples from each different percent of replacement including normal concrete will be tested on 14 and 28 days from casting day. Total quantity of concrete main ingredients for all of the samples are 177kg of Ordinary Portland Cement (OPC), 107kg of water, 499kg of uncrushed fine aggregates and 719kg of crushed aggregates and 6.41kg of wood chips. The tests will be applied on the samples are slump, compressive strength and flexural strength. All the test procedures are based on ASTM and BS standard tests procedure.

Then the sample will be cured using water until the test date. All the data from the tests conducted will be analyzed and discussed before end to the conclusion of this research.

First study outcome of this research is to achieve satisfied workability of modified concrete that contain partial percentages of wood chipping as the control concrete. Second research outcome is to determine maximum compressive strength and flexural strength of modified concrete that approximately the strength of control concrete at 28 days from curing date. The third research outcome is to get the optimum content a percentage of partial replacement by wood chips to course aggregates that resulting maximum strength of compressive and flexural. Last study outcomes is to prove that concrete containing wood chips as partial replacement of course aggregates has potential to be adapted in construction industry.

1.5 The importance of the study

This study is chooses due to much of negative impacts of normal concrete production on environment especially process of preparing course aggregates that later are included with others ingredient for concrete production. Through integrating wood chips as partial percentage of replacement coarse aggregates preventing this waste materials from directly depositing in landfill. This help saving the volume of landfill area that supposed to fill by these materials. The characteristic of this product that long and thin make it provide greater load distribution and extra tensile resistance in concrete as what is provided by fibre in fibre-reinforced concrete. Moreover, the availability of this product in large quantity, satisfied performance and cost of the wood chips that are cheaper than others materials will attract interest of concrete production industry. This study gives full supports toward sustainability campaign by choose the waste materials to conserve natural resources.

As mention earlier, the method that will use for testing samples of this research are slump, compression and flexural. Slump tests chosen to determine the workability of samples that consist both modified concrete and normal concrete. By do the slump test, comparison of workability between modified concrete and conventional concrete can be made. Last is compression test and flexural test, these tests are common tests that are applied to determine the maximum strength by test it toughness when impose by certain loads. Satisfied result from the tests making it have bright opportunity to be practiced in construction industry soon.

CHAPTER 2

LITERATURE REVIEW

2.1 General

To make the research about concrete, it is important to know the concrete in more details. In this sub-topic, all the information about concrete will be explained clearly. All the information from others studies that have relationship to this study are gathered in this sub-topic. The three things that are selected for this sub-topic are concrete classification, concrete characteristic and environment impact.

2.1.1 Concrete classification

Nowadays concrete is available in various types. Each type has particular properties to perform specific function. This research focus on two type of concrete in order to determine the capability of wood waste by compares it with the normal concrete. The two type of concrete in this research are normal concrete and lightweight aggregate concrete.

Normal concrete is contain four basic ingredient that are cement, fine aggregate, coarse aggregate and water. No supplementary is add in the mix proportion except the four basic materials mentioned earlier. The compressive strength of normal concrete usually is between 20-40MPa with unit weight 1900-2600 kg/m^3. The perfection of concrete plays the role as structure makes it as the first choice than timber and steel (Meyer 2009). The perfection causes most of buildings are construct using normal concrete, which is the only reason this paper compares wood chip concrete with normal concrete.

Lightweight aggregate concrete is under category of lightweight concrete. According (Mohammed 2013), concrete is classified as lightweight aggregate concrete when the aggregate dry unit weight less than 1200 kg/m^3. The part of conventional aggregate in concrete is replaced by other alternative materials that make the concrete lighter but has acceptable strength. Those alternatives obtain from natural or manufactured. The material uses as replacement which is wood chip that obtain from manufacture of wood-based as waste causes it categorized as natural. The cost of lightweight concrete that is lower than normal concrete like wood chip which is by-product from sawmill that can be possibly obtain by free make it as among the chosen by-products for produce lightweight aggregate concrete. The lightweight aggregate concrete has been successfully applied in construction industry and studies are continuing through time to eliminate the weaknesses existed in lightweight aggregate concrete, so that it can better or as good as normal concrete (Chen 2008).

According to (Mohammed 2014) concrete containing waste wood product is considers as lightweight concrete. Lightweight concrete is considered as structural concrete when it has the strength above 17MPa at unit weight below 1840 $kg/m^{3.}$ From his experiment results, it is clearly showed that wood chipping concrete categorized as lightweight concrete as the maximum strength of wood chipping concrete is 36.5MPa which is greater than specification strength limitation 17MPa and the unit weight of wood chip concrete is 1808 kg/m^3 which is below the maximum unit weight specification that is 1840 kg/m^3 at 10% replacement of wood chipping toward fine aggregate when water-cement ratio is 0.37.

2.1.2 Concrete characteristic

The concrete containing wood wastes product has lower strength, smaller unit weight and higher workability when the percentage of replacement wood chip with fine aggregate is increase (Mohammed 2014). The result of his research exhibits that the higher strength of compressive strength and flexural strength of wood chip concrete are 36.5MPa and 6.39MPa at 10% replacement percentage by volume of fine aggregate when water-cement ratio is 0.37. This research also concluded that the strength of wood chipping concrete still below the strength achieved by control concrete at same water-cement ratio. The slump results from the test indicates the slump is increasing as the percentage of replacement to fine aggregate rising due to the addition of water in the mix in order to avoid it from soaking the water needed for hydration process. More water is added when the wood chip replacement percent is increase.

A research completed by (Thandavamoorthy 2016) regarding wood waste as coarse aggregated in the production of concrete showed that the compressive strength 3% higher than normal concrete, flexural strength 0.8% greater than normal concrete, better workability and lower durability at 15% replacement of wood waste with coarse aggregate when mix proportion is 1:1.26:2.76 at 0.45 water-cement ratio. This research is contradict with the previous research done by (Mohammed 2014) where the strength is lower than the normal concrete when the wood chip is used to replace part of fine aggregate. The different physical properties of wood waste and part of replacement are believed the reasons of divergent end result between the two researches. However, both of the research demonstrates that the strength of wood waste concrete with beyond the target characteristic compressive strength designed for 28 days.

The characteristic of replacement of coarse aggregate by wood chip at certain percentage ca also can be predicted by referring result of other research which the material is wood-based like replacing part of coarse aggregate with oil palm shell. The result presented by the research done by (Daneshmand 2011) which is replace part of coarse aggregate with oil palm for concrete production shows that the compressive strength and workability are decrease as the percent of replacement increase. He said that some the reasons of the strength drop are amount of water is not enough for hydration process due some of water absorb by oil palm shell, irregular shapes of the palm oil shell cause minimum compaction able to be imposed on the concrete mixture and feeble bonds of oil palm shell and cement which is not strong as bonding between stone and cement. Despite that, he successful achieved the objective of the research which is produce lightweight concrete that has high strength above 40 MPa at percentage of replacement lower than 30% when the water-cement ratio is 0.5 and mixing ratio 1:2:4 for 28 days. He also suggested to put additional admixture should be use to improve weaknesses of that material.

According (Ahlawat 2014) based on his research which is replacement part of course aggregate by coconut shell in production of concrete through appropriate experiment exhibited the characteristic of coconut shell concrete which are the strength dropping and workability rising as the percent of replacement increase. The highest strength in the replacement is 19.71MPa at 28 days that is less 2.8% than conventional concrete at 2.5% of replacement course aggregate by coconut shell which using 20MPa design strength. Nevertheless, the strengths at 28 days from all percent of replacement which is below 10% still considered satisfied as it is above 17MPa which categorized as lightweight concrete.

The strength of concrete depends on its durability. Great durability will result to highest strength of concrete. Durability means the ability of the concrete to defend itself from deterioration through time. The compact concrete has greater durability. The compact concrete can be achieved when enough water and cement to produce calcium silicate hydrate gel required for strong bonding between concrete materials. Research that study durability of lightweight concrete done by (Coatanlem 2006) demonstrated that the durability of the mortar that treated with sodium silicate getting bad through time especially when higher percent humid condition. The durability could be worse when sodium silicate is not included in the mixture. Anyhow, regardless of the environment at 16 month, the strength and durability lightweight wood chipping concrete yet complies with the class III RILEM specification in lightweight category and fit together with advance characteristic like resistance to fungal and insect attack, resistance to fire and thermal and acoustic insulation.

The lower thermal conductivity is one of the characteristic that being when wood-based material replaced the aggregate. By using Transient Plant Source (TPS), (Bederina 2009) identified that the thermal conductivity decrease as the replacement percentage of wood shaving toward sand increase, but the mechanical strength also decrease as the replacement of wood shaving toward sand in yield sand concrete. Thus, small portion of wood shaving can be included as extra material to perform its thermal insulation behaviour without replacing the part of aggregate in order to preserve the mechanical strength of the concrete structure. Small percent of replacement might acceptable due only slightly of the mechanical strength decrease. Admixture like sodium silicate will improve the mechanical strength.

(Chen 2008) explained in his research that the advantages of lightweight concrete are higher strength weight ratio, better tensile strain capacity, smaller coefficient of thermal expansion and highest head and sound insulation due to existence of air void in lightweight concrete. The advantages also coming along with the weakness of lightweight concrete that are lower strength and workability causes by segregation and excessive absorption of water during mixing. So in his research, he had successful overcome the weakness of lightweight and improve both workability and strength of concrete by adding mineral admixture which are fly ash, blast furnace and silica fume with small portion of superplasticizer.

2.1.3 Environment impact

The increase of population leads to the higher demand on construction materials that result to the critical shortage of building materials as the resources is decreasing through time. (Mohammed 2014) suggested that one of some alternative offered to overcome the shortage of building materials is by using waste materials in behalf building materials will help sustainability of natural resources.

Every year about 2500 million tonnes of solid wastes generates from human activities on earth, those solid wastes are identified produces from industry, agricultural and domestic. Some wastes such as fly ash, rice husk ash, wood waste, bottom ash, marble powder, cooper slag and others have proven their own potential in making the concrete. Among the available waste materials mention earlier, wood waste is only the one that readily available with free of cost at everywhere. According (Thandavamoorthy 2016) about 136 million tonnes of wood waste are estimated produce annually worldwide. Much of solid wastes give environment threat that causing destruction to the land and surrounding area where they are dumped.

Production of Portland cement burdens much more to the environment compares to preparation of aggregate in forms concrete. The idea to ensure sustainability of environment is use as much concrete, but with a little of natural resources as possible , this can be done by replace as much as possible the concrete materials with other potential materials like by-product of industrial processes and recycled materials in order to preserve the natural resources (Meyer 2009).

The reduction use of conventional aggregate also one of alternatives helps to reduce the destruction of nature. This can be done by replace as much as possible part of aggregate whether coarse aggregate or fine aggregates at strength and workability that meet design requirement. The popular replacement of aggregate successful applied are recycled concrete, palm oil shell and others materials that commonly recognize as waste material. Each one of them might have the side effect to the concrete.

2.2 Material

The basic concrete constituents for normal concrete are cement, water, coarse aggregate and fine aggregate. To make wood chip concrete, we add wood chip as the fifth constituent. In this sub-topic, all the five concrete components information is collected from the recent research that has the similar study concept. With the information, this research will choose what kind of all the five material that will be applied for making the samples.

2.2.1 Cement

Cement is the key ingredient in concrete composition. It is bonding material, this make cement capable of bonding mineral fractions into compact body. The general properties of cement are silicates and aluminates of lime. There are different types of cement exist. Each of them has different functions in order to fulfil the requirement of construction conditions. Table 2.1 describes the types of cement with their characteristics and application that according to American Society for Testing and Material (ASTM) standards.

Table 2.1: Type of Portland cement

ASTM description	General description	Characteristic	Applications
Type I	Ordinary Portland	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Modified cement	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	Rapid-hardening Portland	Ground more finely, may have slightly more C_3S	Rapid construction. Cold weather concreting

Type IV	Low heat Portland	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare
Type V	Sulfate-resisting Portland	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White Portland	No C_4AF, low MgO	Decorative (otherwise has properties similar to Type 1)

Source: ASTM.

From those types of cements mentioned in table above, ordinary Portland cement is most widely used than other type of cement. Therefore this research prefers to choose ordinary Portland cement in making of samples than others. To ensure the ordinary Portland cement working as it's should, local cement industry must complies the regulations stated in Malaysia Standard MS : 522 : Part 1 : 2003. This standard will cover the manufacture, chemical and physical requirements, storage, sampling and marking of ordinary Portland cement.

According (Mohammed 2012) based from his research, chemical composition and properties contained in ordinary Portland cement type 1 which comply to ASTM C150 (ASTM, 2005f) identified by him through appropriate tests are SiO_2 20.54%, FeO_3 3.63%, Al_2O_3 5.32%, CaO 63.33%, MgO 1.08, SO_3 2.18%, C_3S 46.96a%, C_2S 26.33%, C_3A 7.96%, C_4AF 11.05%, Loss of ignition 2.5%, specific gravity 3.1g/m^3 and specific surface area 3091cm^2/g.

2.2.2 Coarse aggregate

Aggregates are act as filler in concrete structure. At least three-quarters of concrete volume is occupied by aggregate. The large portion of aggregate is giving great impact on concrete performance and properties (Daneshmand 2011). Aggregate is important because it is making concrete as engineering material. Besides, aggregates chosen as it economical, it also offer technical advantage to concrete by providing higher volume stability and better durability than hydrated cement paste alone. ASTM prescribe that course aggregate comprises material larger than 4.75mm in size. There are two type of coarse aggregate which are natural deposit gravel and crushed rock. Basalt, granite and limestone are common groups of stone that are crush to produce crushed coarse aggregate.

The ideal grading curve of coarse aggregate is recommended for achieve full compaction, it can be recognize through grading curve when the percent of passing spread evenly along the particle size from the finest to the coarsest. (Sales 2011) had managed to get 20.9Mpa compressive strength as reference concrete for comparison with composite of water treatment sludge and sawdust, the result show that concrete with composite as coarse aggregate is less 9.8Mpa than reference concrete that using the crush basalt stone as coarse aggregates that have size of 4.8, 6.3, 9.5 and 19mm in percentage of retained 100, 98.8, 84.4 and 1.1 percent. So, the result of the research show that the great mechanical properties of stone as coarse aggregate and fraction can't be compare with other materials.

2.2.3 Fine aggregate

Fine aggregates take directly from its natural existence without needed crush process to obtained desire particles size as what is do for forming coarse aggregate. ASTM has set the size of fine aggregate should smaller than 4.75mm. The function of fine aggregates is to fill the space that can't be reached by coarse aggregate in order to form the compacted concrete. Same as coarse aggregate, various sizes of coarse aggregate help in produce highly compacted concrete. There are several types of sand commonly use in Malaysia industry which are pit sand that obtained by quarrying of sand that deposited in soil, river sand that taken from beds and banks of river, sea sand which collected from sea shores or sea beaches and crushed stone that produce from crushed certain types of bigger stone into sand. Research done by (Bederina 2009) on comparing between dune sand and river sand to produce sand concrete with addition of wood shavings proved that river sand very helpful produce higher concrete strength than dune sand.

2.2.4 Water

Water is the key for activation of concrete hydration process. To ensure the cement hydrates as it should be, the water must clear and free of humus, alkalis, acids and sulfates. Normally in Malaysia industry practice, portable water is acceptable to be used in concrete mixing without needed approval from qualification testing. (Ahlawat 2014) has successful conducted his research on coconut shell as partial replacement of coarse aggregate in concrete by produced lowest compressive strength of concrete tested that is 18.91MPa which still categorized as structural lightweight concrete by using portable water for mixing and curing in production of samples.

2.2.5 Wood chip

The replacements of coarse aggregate by wood chip lighten the weight of concrete structure. Each type of wood own different characteristics which later contribute to mechanical characteristic of concrete when it is replaced parts of coarse aggregate. Local researches didn’t state the specific type of wood that is used to replace part of aggregates. Wood type such as Meranti tembaga, Merawan and Sesenduk are common types of wood that process in Malaysia as they grow faster than other types of wood.

The wood chip used for replacement formed when debarked log cuts off by run it through chipper along with edge and other discard for shaping wood slabs. The weakness of wood chip is absence of much pore that vitiates the mechanical characteristic of woodchip concrete due to weak structure and high water absorption of wood chip itself , however this problem can be reduce by appropriate treatment on the wood chip while preserve insulating qualities (Bederina 2009). To make the concrete strength increase from day today, (Lo 2007) suggested to pre-wet the wood chip, this is because the strength of the concrete continually increase as wood chip release the water into interfacial zone.

(Mohammed 2014) used wood chip taken from the mechanical processing of raw wood in the sawing process at factory that has 257.7kg/m^3 bulk density, a specific gravity of 0.288 and 290.2% absorption for study the mechanical properties of concrete when its coarse aggregate is replace by wood chip.

2.3 Method

In this sub-topic, all the information about the methods that have been used by other researchers is assembled. This information helps this research to decide the best methods that will be used after required consideration have been made. Among the method that needs to discuss in this sub-topic are the design mix for produce samples, the types of test will apply on the samples and how the samples will test.

2.3.1 Testing method

The first test will be carried on the samples is slump test. Slump test uses to measure the workability and consistency of fresh concrete before it sets. With slump test, both supplier and consumer can check whether the fresh concrete workability produces fulfil the design demand or otherwise. The general slump test step start with place the cone mould on the plate and press the foot pieces by the legs to ensure it does not move during filling the fresh concrete mix. Then fill the cone mould with fresh concrete mix in three layers, each layer approximately 1/3 height of the cone mould. Tamp each layer with 25 strokes using tamping rod, distributes the strokes uniformly over the cross-section of the layer. After that, remove the mould gently by holding the handle and moving it vertically in. Last step is measure the different between the height of the top of mould and the cone shaped fresh concrete mix.

The way of slump test carrying depends on the standard referred to. (Daneshmand 2011) determined the workability of the samples in his research that study about the impact of Oil Palm Shell (OPS) as part of coarse aggregate for high strength concrete by conducted slump test that followed B.S. 1882:1970 part II. Different with (Mohammed 2014), to obtain workability value, he did the slump test in his research regarding study of properties of concrete containing wood chipping as partial replacement to fine aggregate according to procedure outlined in ASTM C143. Otherwise, (Thandavamoorthy 2016) define the slump height of samples in his research on the study of wood waste as coarse aggregate in production of concrete based on the ways stated in IS: 1199 (1959).

Second test is flexural test. Flexural strength determines from flexural test. Flexural test considers three fundamental stresses that are compressive, tensile and shear. Through flexural test, measurement of samples strength in beam condition can be identified. The rough procedure of the flexural test begins by place the prism sample horizontally on two supports at the end of both beam ends. Then force will be applied on the top of the beam either one or two force point. Flexural strength obtained after the prism samples fails.

Different standard has different steps to run the flexural test, but the basic of the steps almost same. To obtain the flexural strength on his research about strength and durability, (Haque 2004) has conducted the flexural test on his samples according to ways stated in BS EN 12390-5:2000. (Mohammed 2014) also did the flexural test for define his samples flexural strength, he prefer ASTM C293 as his guide to conduct the test. On the other hand, (Thandavamoorthy 2016) determine flexural strength of his samples by carried out the flexural test as describe in IS: 516 (1959).

Third test is compressive strength test, it represents the ability of the concrete to sustain certain load that compress a cube sample. Compressive strength determine through compressive strength test. From the compression test, fundamental variables such as strain, stress and deformation can be measured. In short, the test starts by place a sample between two plates in compression test machine. Then specify the volume of a cube sample in machine system. After that the machines push simultaneously from the upper and bottom surface of that sample. Compressive strength acquired when the cube sample fails.

The specific compression test method varies between standards. (Daneshmand 2011) used BS 1881 part II as guideline to him when he conducted the compression test on his samples. The compressive strength also determined by (Mohammed 2014) through compression test that carried as what is stated in BS EN 12390-3. Besides, to get the samples compressive strength, (Thandavamoorthy 2016) run out compression test as specified in IS: 516 (1959).

2.3.2 Design mix

Mix proportion affect characteristics of concrete. To meet the design characteristic strength, it is important calculating the mix proportion correctly. As (Daneshmand 2011), he produced high strength concrete with design characteristic strength greater than 40 MPa at 28 days by using cement/water ratio of 0.5 with mixing ratio 1:2:4 for 0%, 10%, 20%, 30%, 40% and 50% replacement of coarse aggregate by Oil palm Shell (OPS). On the other hand, to meet the design strength of standard samples that is above 40 MPA at 28 days, (Mohammed 2014) used 3 water cement ratio that are 0.37, 0.41 and 0.57 with mix proportions of 1:0.45:1.22, 1:1.31:1.14 and 1:2.03:1.76 for 4 levels replacement of fine aggregate to wood chipping by volume with 0%, 10%, 15%, 20% and 30% for each water cement ratio in his paper. Otherwise, concrete mix with characteristic strength of 25 MPa at 28 days was designed by (Thandavamoorthy 2016) used w/c ratio of 0.45 with adopted mix proportion was 1:1.26:2.76 for replacement of 0%, 15%, 20% and 25% of wood waste to coarse aggregate.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the method will use for run this project. To achieve the objective of research, it is importance for do research correctly as the standard referred. Therefore, all the works in this research must be understand properly in order to get high of accuracy results. For this research most of samples preparation and tests are based on American Society for Testing Materials (ASTM) and British Standard (BS). The research tests will run as did by (Mohammed 2014) in his research paper with title "Statistical models for concrete containing wood chipping as partial replacement to fine aggregate".

There are several tests that are carried out in this research for review the effectiveness of using wood chip to replace coarse aggregate in concrete. They are slump test, compressive strength test and flexural strength test. To recognize the behaviour of modified concrete especially on mechanical properties of wood chip concrete, it will be compared to control concrete and among percent of replacement coarse aggregate by wood chip. The correct method of conducting the tests will contribute to logical discussion and conclusion at end of research which help to achieve the objectives of this research.

3.2 Methodology flow chart

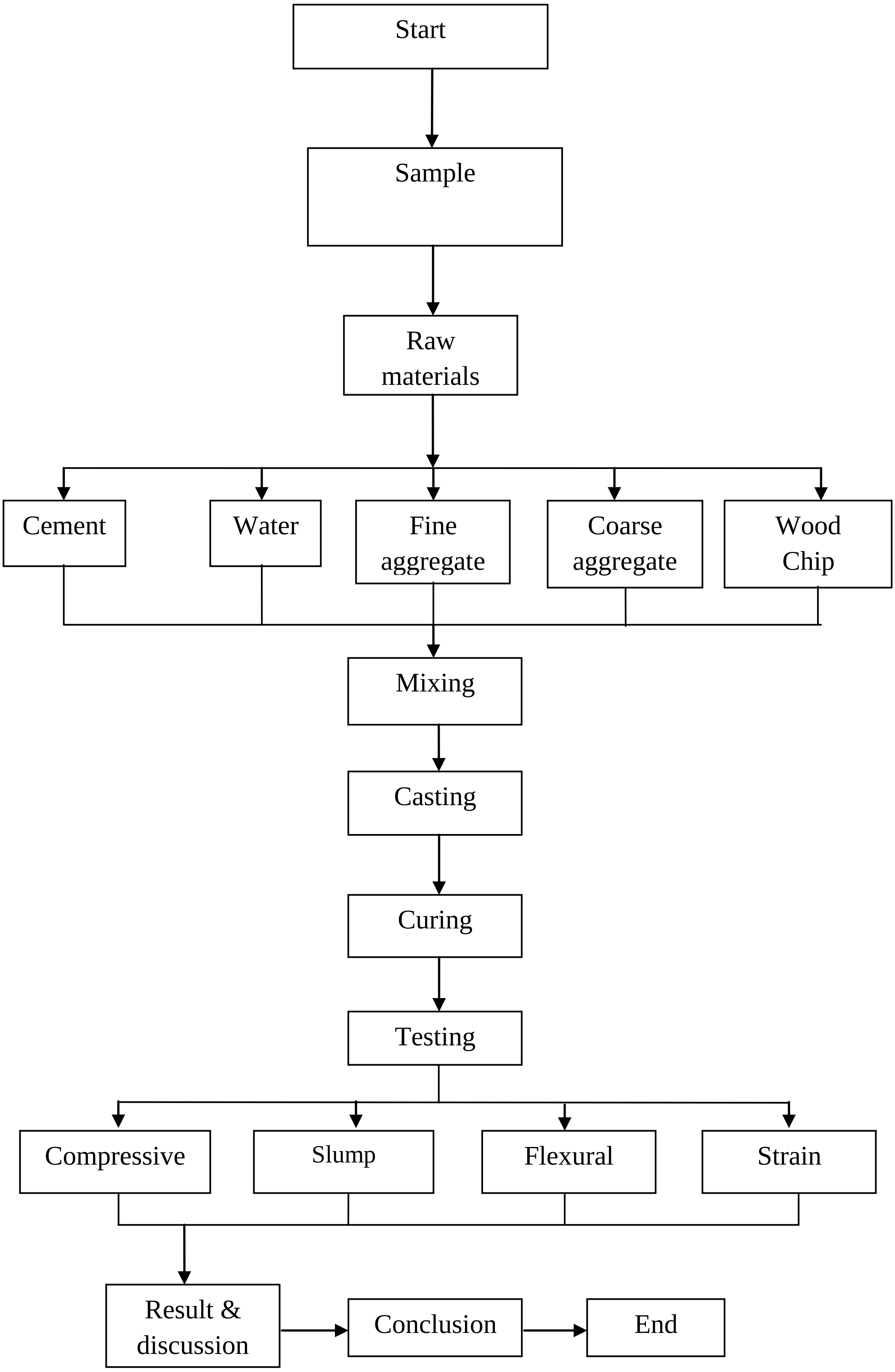

Figure 3.1 Methodology flow chart

The flow charts before represent the process of the research that starting from preparation of samples and end with doing conclusion from the tests results. The research begins at start process. After that, target strength of mix proportion is achieved by doing the trial and mix. Then casting is carry out by using the mix proportion. The samples will cure by wet gunny until their testing age that are 14 days and 28 days. The result obtain will use for analysis before come out with conclusion.

3.3 Material used

This research decides to produce normal strength concrete than high strength concrete. This is because normal concrete has high demand compared with high strength concrete. So, the materials will be selected should have the specification for produce normal strength concrete. The materials specification will be explain further under this sub-topic.

3.3.1 Wood chip

Wood chip will use in this study obtained from wood processing factory (RISING WOOD PRESERVATION SDN BHD) located at Kuantan, Pahang for RM 3 per gunny sack. The wood chip length is longer than 10 mm with thickness lower than 1 mm. Figure 3.1 below is physical image of wood chip.

Figure 3.2 Wood chip

3.3.2 Cement

Cement is responsible for bonding of materials intergradations in the mix. Water is need for activate the chemical reaction. In this research, the type of cement will use is Orang Kuat Ordinary Portland Cement. By using this cement, the exact mechanical properties of wood chip concrete easily prevail without influence by other factor. Orang Kuat Ordinary Portland Cement follows specification of porland cement as outlined in BS 12:1958. The Figure 3.3 below shows Ordinary Portland Cement Orang Kuat brand.

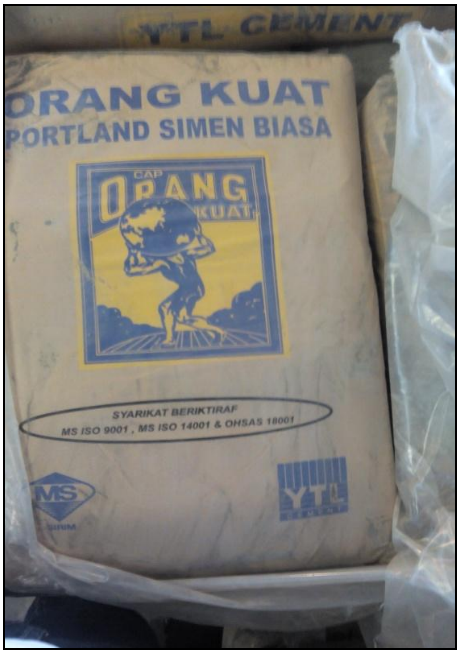

Figure 3.3 ORANG KUAT PORTLAND SIMEN BIASA

3.3.3 Fine aggregate

The type of fine aggregate use is uncrushed fine aggregate. Uncrushed fine aggregate means it is in original physical state when taking from its origin. According to ASTM, the size of fine aggregate should smaller than 4.75 mm. To obtain the particles size below 4.75 mm, natural sand is wash and sieve for remove the particles bigger than them. Fine provide contribution to mechanical function of concrete by filling the void that can’t be reached by coarse aggregate. This will make the concrete become denser and stronger than the concrete that only have coarse aggregate in concrete. The gradual size distribution is important for making solid concrete. Figure 3.4 shows the river sand that is used for making this research samples.

Figure 3.4 River sand

3.3.4 Coarse aggregate

ASTM specify that the particles bigger than 4.75 mm is categorized as coarse aggregate. Coarse aggregate is like bond in body. Without it, the body no even can't stand. So, aggregate play prime role in contribution of concrete strength. The type of coarse aggregate use in preparation of samples is crushed aggregate. Crushed mean there are crushed from bigger stone by force. This is the reasons why its physical form is angular. The angular physical form provides the better interlocking function to restrain movement than rounded physical form. This is a bit much contributing better strength of concrete.

However, it is essential to make sure that use of gradual size of fine aggregate, thus the empty space can be full fill. It is also recommended to use coarse aggregate that have proper gradation. Proper gradation means that samples contain all standard of fractions of coarse aggregate and fine aggregate. This will minimize the existence of voids in concrete. Concrete that contain well graded aggregate require less surface for cement paste and water which leading to more economical, higher strength, lower shrinkage and greater durability. Excess of paste above that required to fill the voids in the sand and excess of mortar above require to fill the voids in the stone also improve the workability due to the fine material that lubricate the bigger particles.

3.3.5 Water

Water will use in for mix the concrete should clear impurities and free from chemical contain. In Malaysia, water tab as in Figure 3.6 is enough to be use in concrete mix. It is important to control the water content in concrete. Water can't be added or reduce without approval someone that has the power. Excess of water than it should be lead to higher workability and lower concrete strength. While short of water is otherwise. 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.

Figure 3.5 Tap water

3.4 Concrete mix design

Concrete mix designed using method as stated in "Design of normal concrete mixes" book written by D. C. Teychenne, R. E. Franklin and H. C. Erntroy. This book published on 1975. The design of concrete mix are driven by require characteristic strength and slump which are 30 MPa and 10 mm – 30 mm. The design concrete mix determined by follow the steps in the book. The design concrete mix obtained using this method is 266 kg/m^3 for cement, 170 kg/m^3 for water, 802 kg/m^3 for fine aggregate and 1,228 kg/m^3 for coarse aggregate. Figure 3.7 below shows the stages of determine the design concrete mix for control concrete.

Concrete mix design form

Job title PSM

Stage	Item	Reference or calculation	Values
1	1.1 Characteristic strength	Specified	30 N/mm² at 28 days; Proportion defective 5 %
	1.2 Standard deviation	Fig 3	4 N/mm² or no data ____ N/mm²
	1.3 Margin	C1 or Specified	(k = 1.64) 1.64 × 4 = 6.56 N/mm²; ____ N/mm²
	1.4 Target mean strength	C2	30 + 6.56 = 36.56 N/mm²
	1.5 Cement type	Specified	OPC/SRPC/RHPC
	1.6 Aggregate type: coarse Aggregate type: fine		Crushed/uncrushed Crushed/uncrushed
	1.7 Free-water/cement ratio	Table 2, Fig 4	0.61
	1.8 *Maximum free-water/cement ratio*	*Specified*	– ; Use the lower value 0.61
2	2.1 Slump or Vebe time	Specified	Slump 10-30 mm or Vebe time ____ s
	2.2 Maximum aggregate size	Specified	20 mm
	2.3 Free-water content	Table 3	160(2/3)+190(1/3) 170 kg/m³
3	3.1 Cement content	C3	170 ÷ 0.61 = 279 kg/m³
	3.2 *Maximum cement content*	*Specified*	– kg/m³
	3.3 *Minimum cement content*	*Specified*	– kg/m³
			use 3.1 if ≤ 3.2 use 3.3 if > 3.1 – kg/m³
	3.4 Modified free-water/cement ratio		– ; –
4	4.1 Relative density of aggregate (SSD)		2.7 known/assumed
	4.2 Concrete density	Fig 5	2,465 kg/m³
	4.3 Total aggregate content	C4	2,465 - 279 - 170 = 2,016 kg/m³
5	5.1 Grading of fine aggregate	Percentage passing 600 μm sieve	– %
	5.2 Proportion of fine aggregate	Fig 6	39 %
	5.3 Fine aggregate content	C5	2,016 × 0.39 = 786 kg/m³
	5.4 Coarse aggregate content	C5	2,016 - 786 = 1,230 kg/m³

Quantities	Cement (kg)	Water (kg or *L*)	Fine aggregate (kg)	Coarse aggregate (kg) 10 mm	20 mm	40 mm
per m³ (to nearest 5 kg)	280	170	790		1,230	
per trial mix of 0.16 m³	45	27	126		197	

Items in italics are optional limiting values that may be specified (see Section 7)

1 N/mm² = 1 MN/m² = 1 MPa (see footnote to Section 3).
OPC = ordinary Portland cement; SRPC = sulphate-resisting Portland cement; RHPC = rapid-hardening Portland cement.
Relative density ≡ specific gravity (see footnote to Para 5.4). SSD = based on a saturated surface-dry basis.

Figure 3.6 Normal concrete mix design

3.5 Parameter used for testing

First is slump test. The parameter need for do the slump test is the design slump. The design slump determine before design of concrete mix. To obtain require workability, the height of slump should within the design slump which is 10 mm – 30 mm.

Second is compressive strength test. The first parameter in this test is type of sample. The type of sample is cube. The second parameter is size of sample. The size of sample is 150 mm x 150 mm x 150 mm (W x L x H). The third parameter is loading rate. Loading rate use in this test is $1N/mm^2$ per second.

Third is flexural strength test. The first parameter is span between the support block, span between the load applying block and span shoulder of the beam. Figure 3.8 illustrate those spans. The second parameter is type o sample. The type of sample is beam. The third parameter is size of sample. The size of sample is 150 mm x 150 mm x 750 mm (W x L x H). The fourth parameter is loading rate. The loading rate for this test is 7.3 kN/s.

The fifth parameter is formula to calculate modulus of rupture (MPa). The formula to determine modulus of rupture using formula $R = PL/bd^2$. From the formula, R stand for modulus of rupture in unit MPa, P stand for maximum applied-load got from testing machine in unit N, L stand for span length in unit mm, b stand for average width of specimen in unit mm at the fracture and d stand for average depth of specimen in mm at the fracture.

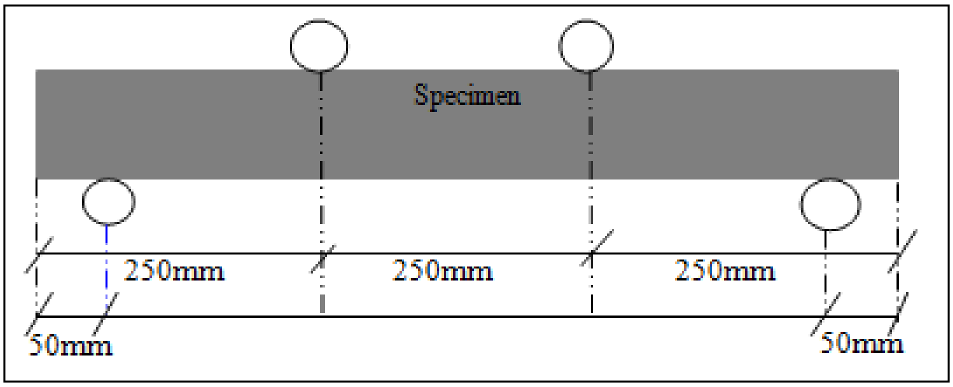

Figure 3.7 Flexural strength test (Third-point loading) span

3.6 Sample of preparing

There are two types of samples in this research that are cube and prism. Those type of mould readily available in concrete laboratory. The moulds use in this study made up from plastic for cube samples and steel for prism samples. The dimensions of cube and prism samples are 150 mm (W) x 150 mm (L) x 150 mm (H) and 150 mm (W) x 150 mm (L) x 750 mm (H). Total number of samples need for this research is 24 cube samples and 24 prism samples. Sample will prepare as the concrete mix design ratio which is 1:3.1:2.7 and 0.58 water to cement ratio. Table 3.1 show the weight of material for control concrete, 5% of replacement, 10% of replacement and 15% replacement for 6 cube samples and 6 prism samples.

Table 3.1 Total weight of materials for produce samples

Percent of replacement coarse aggregate by wood chip (%)	Weight of material (kg)				
	Cement	Fine aggregate	Coarse aggregate	Wood chip	Water
0	44.23	124.78	194.28	0.00	26.85
5	44.23	124.78	184.56	1.07	26.85
10	44.23	124.78	174.85	2.14	26.85
15	44.23	124.78	165.14	3.20	26.85

The weights of materials for preparation of samples are 177kg of Ordinary Portland Cement (OPC), 107 kg of water, 499 kg of uncrushed fine aggregate, 719 kg of crushed coarse aggregate and 6.41kg of wood chip. The method of preparation samples is according to American Society for Testing Materials (ASTM). Four batch of concrete mix produce. First batch is for control concrete second batch for 5%, third for 10% and fourth for 15% replacement of coarse aggregate by wood chip. The wood chip is soaking in water for one day before put together with concrete mix. Water absorption is determine by minus the weight of wood chip before soaking in water to weight of sample after soaking in water.

In short, the preparation of batch of concrete mix with 5% of replacement of coarse aggregate by wood chip start with soaking the wood chip in water for one day. Then weigh the cement, water, fine aggregate and coarse aggregate as the concrete mix design ratio that is 1:2.82:4.39 and 0.61 water to cement ratio. After that, fill all the materials in mixer. When the all the material mix well, bring the concrete mix out of mixer. Then immediately does the slump test as stated in ASTM standard procedure. Next, place the fresh concrete in 6 prisms mould and 6 cube moulds. Three samples of cube and three samples of prism are for each 14 days and 28 days of testing age. Once finished, let the concrete harden for one day. When the samples are hardened, cure them with water until ages of testing.

3.7 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 according to ASTM C143/C 143M – 05. It is use for measure the consistency of plastic concrete. It is sustainable for detecting changes in workability. This test is being used extensively on site. There are four types of slump which is true slump, zero slump, shear slump and collapse slump as shown in Figure 3.9 below.

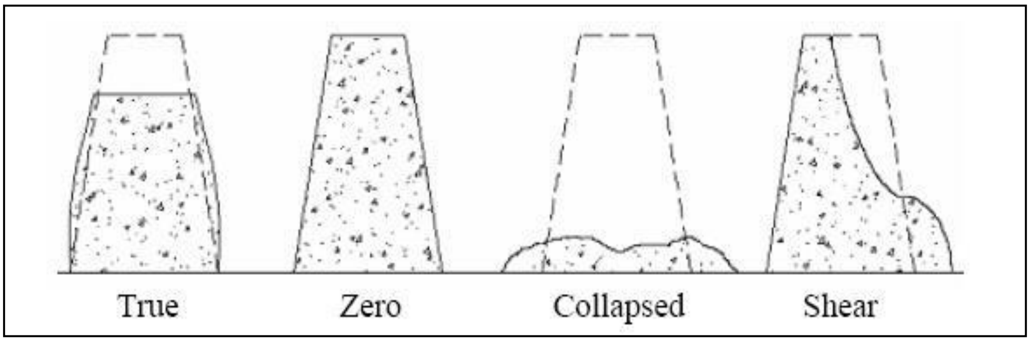

Figure 3.8 Types of slump

The apparatus use in slump test is mould, tamping rod and measuring devices. The mould shall made of metal with thinner of the mould is not less than 1.5 mm. The form of mould shall be the lateral surface of frustum cone with base 200 mm in diameter, the top is 100 in diameter and the height is 300 mm. Foot pieces shall be provided at the side of the mould. The specification of tamping road is 16 mm in diameter, 600 mm in length and rounded hemispherical tip at both ends. Measuring device such as ruler or metal roll-up measuring tape can be used.

The first step is during filling the fresh concrete, hold firmly in place wet mould than place on a flat, moist and rigid surface by standing on the two pieces. After that, rod the each three layer throughout its depth with 25 strokes of tamping rod where one layer is one third the volume of the mould. The strokes shall distribute uniformly over the cross section of each layer by making half of strokes near perimeter and another half of vertical strokes spirally toward the centre.

For top layer, ensure that the fresh concrete is heap above the mould before rodding start. When the rodding result subsidence below the top edge of the mould, add additional fresh concrete to keep an access of concrete above the mould at all times. Then, when the rodding of top layer done, strike off the surface of the concrete by means of a screeding and rolling motion of tamping road. Next is removing the mould immediately by raising it carefully in a vertical direction. The test shall complete in 90 seconds. Last step is measure the slump by determining the vertical difference between the top of the mould and the top surface of the specimen.

3.8 Compressive strength test

Compressive strength test are test that are widely used worldwide to measure the strength of the concrete, where concrete grades and different age will give the different strength. This test is one of the damage concrete tests based on specification of BS EN 12390-3:2009 (British Standard Institution 2009). Compressive strength of the concrete can be calculated using the following formulae.

These specimens are tested by compression testing machine after 14 days and 28 days curing. Load should be applied gradually at the rate of 1N/mm2 per second until the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. The size of cube that used is 150mm x 150mm x 150mm.

Compressive strength, fcu =P/A (N/mm^2)/Pascal

Where

P = ultimate load (N)

A = surface area of a cube (mm^2)

The type of compressive strength testing machine use is MATEST S.p.A. TREVIOLO 2408 ITALY that has 2,000 kN capacity. Figure 3.10 is MATEST S.p.A. TREVIOLO 2408 compression machine.

Figure 3.9 MATEST S.p.A. TREVIOLO 2408 COMPRESION MACHINE

The test start with wipe testing machine bearing surfaces, clean and remove loose grit material from the surface of specimen that will contact with the platens. After that, wipe the overmuch water from the surface of specimen before put it in the testing machine. Then, setting the position of specimen to ensure the testing machine imposes the load perpendicularly to direction of casting. Auxiliary platens or spacing blocks can be used between the specimen and platens of testing machine.

Next adjusts the specimen to the centre of lower platen. Then align the platen with the top and bottom of the specimen. Next step is insert the data like size of cube and loading rate will apply on the specimen. The constant loading rate is within the range 0.6 MPa/s $\pm$ 0.2 MPa/s. After that, close the hydraulic valve by rotate it at clockwise direction and start the machine. If the upper platens far from the specimen surface push the pressure pump until the upper platen touch the surface specimen and release then release it. Last is record the maximum load when specimen meets structure failure and sketch the fracture pattern.

3.9 Flexural strength

Flexural testing is used to determine the tensile strength. Sometimes referred to as a transverse beam test, it involves placing a sample between two points or supports and two applying load. Flexural strength is an indirect measure of the tensile strength of concrete. It measure the maximum stress on tension faced of an unreinforced concrete beam or slab at the point of failure in bending. In this research the type of flexural strength will test on samples is third point loading. The test is conduct by refer to ASTM C 78 – 02. Maximum stress and strain are calculated on the incremental load applied. Results are shown in a graphical format with tabular results including the flexural strength (for fractured samples) and the yield strength (samples that did not fracture). Typical materials tested are plastics, composites, metals, ceramics and wood.

The apparatus use in flexural strength is loading apparatus. The loading machine use for testing is UTEST 300kN AUTOMATIC FLEXURAL TESTING MACHINE. To ensure that the forces apply to the beam is perpendicular to the face of the specimen and apply without eccentricity, bearing blocks is employs in making flexure test of concrete using the third point loading method. The loading rate for this test is 7.3kN/s. Figure 3.4 below shows the UTEST 300kN AUTOMATIC FLEXURAL TESTING MACHINE.

Figure 3.10 UTEST 300 kN AUTOMATIC FLEXURAL TESTING MACHINE

First step is bring moist-cured specimen to test hall immediately after removal from moist storage. Surface drying of the specimen leads to reduction in measurement of flexural strength. With respect to the moulded position, turn the test specimen on its side and centre it to the support blocks. After that, make sure the loading system in relation to apply force adjusts to the centre of the specimen. Then contact the load-applying blocks with surface of the specimen and apply load of between 3% and 6% of estimated ultimate load. Next step is applying the load continuously and without shock. Rate of load apply shall increase constantly to the breaking point. The rate of load apply that constantly increase the extreme fibre stress is between 0.86MPa/min and 1.21MPa/min until rupture occurs.

Calculate the loading rate using equation $r = Sbd^2/L$ where r is loading rate in MN/min, S is rate of increase in extreme fibre stress in MPa/min, b is average width of the specimen in mm , d is average depth of the specimen in mm and L is span length in mm. Last is after determine the maximum applied load that take from testing machine, calculate the modulus of rupture using formula $R = PL/bd^2$.From the formula, R stand for modulus of rupture in unit MPa, P stand for maximum applied-load got from testing machine in unit N, L stand for span length in unit mm, b stand for average width of specimen in unit mm at the fracture and d stand for average depth of specimen in mm at the fracture.

3.10 Sample preparation process

To obtain the high quality sample, the sample must be produce based on certain standard. For this research, all is based on ASTM, except for compressive strength test. First stage to produce this research samples is mixing. Make sure the concrete mix is well integrated before stop the mixing. Figure 3.12 shows the mixing process. Third stage is taking slump reading for slump test. The slump test must be carry immediately after mixing is end. Figure 3.13 shows the picture when the slump reading is taking during slump test. The fourth stage is casting. The concrete will hardens in less than 10 minutes when the mixing is complete, so the concrete must be cast as soon as possible. Figure 3.14 shows the condition when the fresh concrete mix is cast into the mould.

The fifth stage is compacting. The concrete mix is compacts using concrete vibrator machine. Compaction eliminates the air voids and fills the empty space in the mould. Figure 3.15 shows compacting process for this research concrete mix. The sixth stage is curing. The samples are cured using water for 14 and 28 days. The cube samples is cured by soaking in water and prism samples is cure by cover them with wet gunny bag. Figure 3.16 shows the cube samples that are being curing in the water tank. The seventh stage is testing. Cube samples as in Figure 3.17 is testing to obtain compressive strength, while a prisms sample as in Figure 3.18 is testing for determine flexural strength. The load rate for compressive strength is 1kN/s and the load rate for flexural strength is 1.2kN/s. The samples are test when they have cured for 14 and 28 days.

Figure 3.11 Mixing

Figure 3.12 Slump test

Figure 3.13 Casting

Figure 3.14 Compacting

Figure 3.15 Curing

Figure 3.16 Compressive strength test

Figure 3.17 Flexural strength test

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter we will discuss the performance of samples based on results acquired from tests that have been conducted. The tests are carried out as the methods have been discussed in the previous chapter. The results are concentrating on the mechanical properties of concrete which is compatible with the objectives of this research. The results represented compressive strength, flexural strength, slump and unit weight of samples which arranged according to their method of test, curing day and percentage of replacement. To make the discussion more clear, the results are present in tables and graphs.

In detail, the result are obtained from compressive strength test on twenty four (24) cubes with dimension of 150mm x 150mm x 150mm and flexural strength test on twenty four (24) prisms with size 150mm x 150mm x 750mm, they are tested after had cured for 14 and 28 days. The results will be discussed by compare them with variables existed in this research and the previous researches that this research referred to.

4.2 Slump of concrete mixes

To obtain the samples, concrete had been mixed for eight times. Four mixes is 4 different percentages of replacement of wood chip by coarse aggregate for 14 days of curing and another 4 mixes for 28 days of curing. As the concrete mix designed, the slump should be in the range of 10 to 30mm. The result of slump is present in table 4.1. The highest slump is 35mm which obtained from concrete mix with 5% of replacement by wood chip for 28 days of curing and the lowest slump is 3mm which taken from 15% of replacement concrete mix by wood chip for 28 days of curing by wood chip for

28 days of curing and the lowest slump is 3mm which taken from 15% of replacement concrete mix by wood chip for 28 days of curing.

Table 4.1 Slump test results

Wood chip	0%	5%	15%	20%
Slump: Mix for 14 day	10	5	25	20
Slump: Mix for 28 day	11	35	4	3
Average	10.5	20	14.5	11.5

Figure 4.1 shows average slump for 14 and 28 days concrete mixes. The slump is increase from 0 to 5 percent of replacement, however the slump is drop from 5 to 15 percent of replacement. Based on Figure 4.1 the highest average slump is slump of 5 percent of replacement and the lowest average slump is slump of 0 percent of replacement.

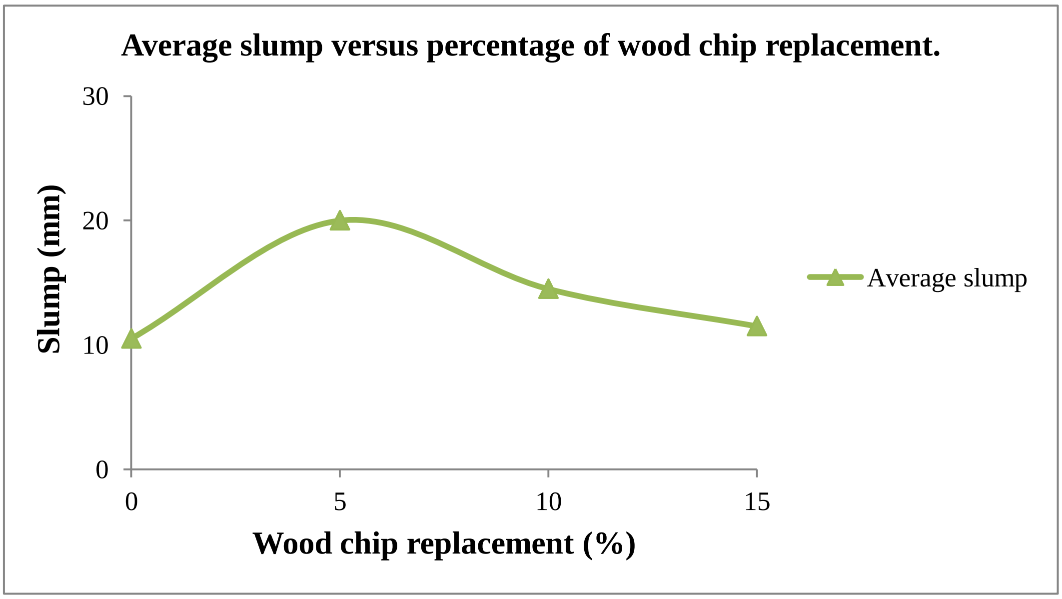

Figure 4.1 Average slump versus percentage of wood chip replacement

The slump for all mixes as shows in Table 4.1 should have same slump due to the same proportions quantity for the mix of 14 and 28 day curing, but the reality is both mixes have different slump. This is happen because of the different of capability of wood chip to absorb in the water as it has been soaked for one day before mixing and release out the water during mixing. Another factor that is thought to affect the slump is the different content of water in one group of wood chip with another group that depend on the origin of the woods had processed. Third factor is the physical form of the wood chip, its elongated shape hold the fresh concrete from easily collapse, this make the slump result low than what it is should be as in the design. The slump is recorded below than 10mm when mixing concrete for 5 percent of replacement for 14 days and when mixing concrete for 10 and 15 percent of replacement for 28 days. The slump for 5 percent replacement by wood chip concrete mix for 28 days of curing is exceeded than what it designed where the slump is 35mm.

The slump results represent the workability and consistency of the fresh concrete. To know the mix will be function as it should be, the slump must be in range as what it has been fixed in concrete mix design which is 10-30mm. Therefore, based on Table 4.1, the concrete mixes that are in workability and consistency as it design are 0, 10 and 15 percent of replacement concrete mixes for 14 days and 0 percent of replacement concrete mixes for 28 days.

4.3 Hardened concrete unit weight

Table 4.2 is the unit weight of samples with at different percentage of replacement by wood chip that is taken after subjected to water curing for 14 and 28 days. The highest unit weight is unit weight of control concrete for 14 days of curing sample which is 2351.61kg/m^3 and the lowest unit weight is unit weight of 15% of replacement for 28 days of curing sample that is 2191.01kg/m^3. The unit weight of the wood chip concrete samples can't surpass the unit weight of control concrete, however they are close to the unit weight of control concrete with 0.5% lower than the unit weight of control concrete. The highest unit weight for both 14 and 28 days samples age is wood chip concrete samples with 5% of wood chip replacement.

Figure 4.2 show the graph trend for unit weight results at different percent of replacement and days of curing. The graph show that there is reduction of unit weight as the wood chip replacement percentage is increase. This occurs because the wood chipping is lighter than coarse aggregate, so the samples unit weight tends to become smaller when the percentage replacement of wood chip is rise. The graph also notifies that unit weight of samples cured for 14 days is bigger than samples cured for 28 days. The loss of water in hardened concrete samples due to evaporation is believed as one of factor samples that cured for 28 days is lighter than samples that cured for 14 days although both were cured using water. The way of mixing and compacting are handled is another potential factor that distinguishes them, which mean sample cured for 14 days is well compacted than samples cured for 28 days.

Table 4.2 Samples unit weight

Curing days	Unit weight (kg/m^3)			
	0%	5%	10%	15%
14	2351.61	2340.74	2313.88	2197.83
28	2331.75	2331.26	2224.40	2191.01

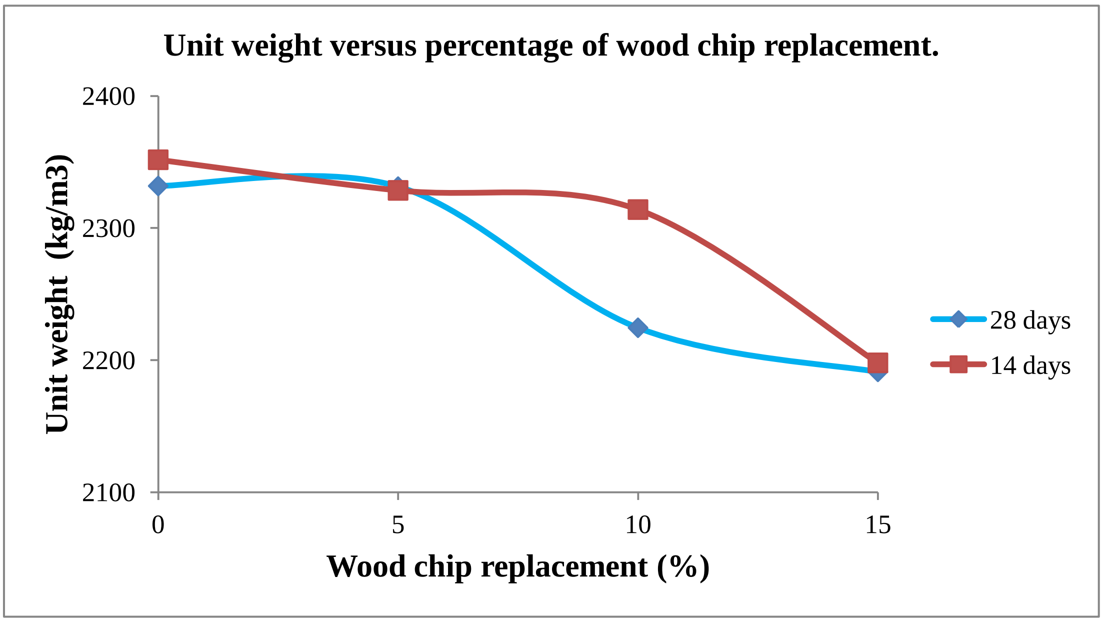

Figure 4.2 Unit weight versus percentage of wood chip replacement

4.4 Compressive strength of cube sample

Compressive strength represents the maximum capability of the hardened concrete to receive certain load which cause to its failure. Before define the compressive strength, the samples are cure for certain time. Cure allows the samples to develop their strength until they reach ultimate strength. For this research, the samples are cure by soaking them in curing tank for 14 and 28 days. Table 4.3 is the result of compressive strength for concrete samples with different percentage of replacement by wood chip and days that they are cured. For 14 days of curing, the control concrete sample achieves the highest compressive strength which is 40.39MPa, while the lowest compressive strength is 20.49MPa which is resulted from 15% replacement by wood chip.

Furthermore, for 28 day of curing, control concrete sample recorded as the sample with highest compressive strength which is 36.77MPa and the lowest compressive strength is possesses by 15% of replacement by wood chip sample which is 18.83MPa. Among the samples with percent of replacement, sample with 5% of replacement has the highest compressive strength than 10% and 15% of replacement by wood chip for both 14 and 28 days of curing where the compressive strength is 32.64Mpa and 26.10MPa.

Figure 4.3 shows that the compressive strength is gradually drop as the percentage of replacement coarse aggregate by wood chip increase. The logical reason why the compressive strength is decrease when the percentage of replacement coarse aggregate by wood chip is increase is the weak mechanical properties of wood chip which is not comparable with strong mechanical properties of coarse aggregate.

Coarse aggregate contribute strength toward concrete by its mechanical properties such as strength, toughness and hardness. On the properties of wood chip are opposite the mechanical properties of coarse aggregate which are brittle, decay and deterioration, this is one of reasons why the compressive strength decline as the percentage of replacement is increase. The graph in the Figure 4.3 also shows that sampled cured for 14 days is slightly stronger than sample cured for 28 days. The way they are handling during mixing and compacting and are possibly cause for a little different in strength between samples cured for 14 days and sample cured for 28 days.

Table 4.3 Compressive strength results

Curing days	Compressive strength (MPa)			
	0%	5%	10%	15%
14	40.39	32.64	25.97	20.49
28	36.77	26.10	25.24	18.83

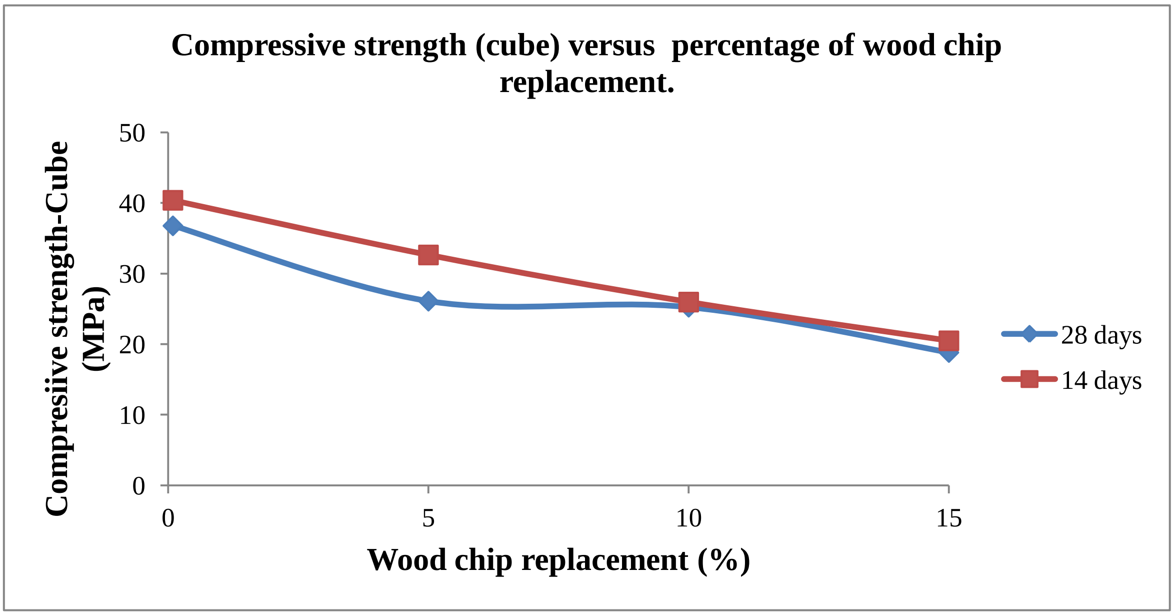

Figure 4.3 Compressive strength versus percentage of wood chip replacement

4.5 Flexural strength of prism sample

Table 4.4 indicates the flexural strength at different percent of replacement coarse aggregate by wood chip samples and days they are cured. The percentage of replacement coarse aggregate by wood chips used as samples for flexural strength test are 0%, 5%, 10% and 15%. The samples tested at the end of their curing days, in this case they are two curing period, 14 and 28 days. The bigger flexural strength for samples cured for 14 days is sample at 5% of replacement by wood chip where the result of flexural strength is 5.13MPa which is bigger than flexural strength of control sample, while the smallest flexural strength is at 10% of replacement by wood chip which the result is 3.54MPa. For sample cured at 28 days, Table 4.4 shows that the highest result of flexural strength is coming from control sample which is 4.91MPa, meanwhile the weakest flexural strength is at 15% of replacement by wood chip which the result of flexural strength is 3.90MPa.

As what shows in Figure 4.4, for 14 days of curing, the graph is rise steadily from control to 5 percent of replacement by wood chip, then the graph is slightly drop from 5 to 10 percent of replacement and lastly climb up gently from 10-15 percent of replacement by wood chip but didn't reach the high of 5 percent of replacement by wood chip. For 28 days of curing, the graph is drop gradually from control to 5 %

replacement, at the middle the graph start to go up from 5 % to 10% of replacement but not as high as control, at the end from 10% to 15% of replacement the graph fall again.

From the graph, it clearly notifies that the highest flexural strength for both times of curing is for sample with 5 percent of replacement by wood chip that cured for 14 days. The possible reasons why the sample has be replaced 5% of coarse aggregate by wood chip has the highest flexural strength is because of the content of wood chip in the concrete turn the concrete to fibre reinforced concrete. As other fibres, wood chip will contribute by distribute the load more uniformly between concrete constituents and improve the tensile strength of the concrete sample. However the situation is different for samples cured for 28 days. Although sample with 10% of replacement by wood chip has the higher flexural strength than 5% and 15% of replacement for 28 days of curing, but its flexural strength little less than control concrete sample. The graph pattern is not consistent between 14 days and 28 days of curing, different properties from one group of wood chip with another is the main reason that makes them function differently in concrete.

Table 4.4 Flexural strength results

Curing days	Flexural strength (MPa)			
	0%	5%	10%	15%
14	4.61	5.13	3.54	3.65
28	4.91	4.34	4.63	3.90

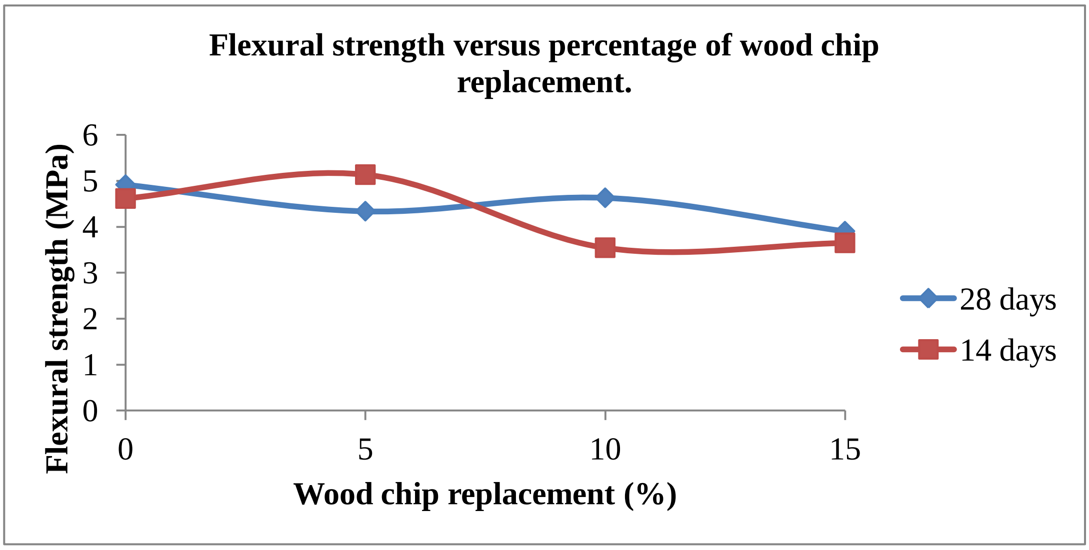

Figure 4.4 Flexural strength versus percentage of wood chip replacement

4.6 Discussion

From Figure 4.1, its show slump of wood chip concrete is erratic. The consistency and workability of concrete mix for 14 days is different from 28 days. Overall, most of the samples with percentage of replacement are out of the slump range that predetermined during concrete mix design where the slump should be in range of 10 to 30 mm, even so some of them which are mixes with 10 and 15 percent for 14 days are in the range as set.

The main reason for inconsistency of slump between 14 and 28 days of curing is because of the different properties of one group of wood chip with another that affecting their function in concrete mix such as the capability to absorb and loose of the water and existing water content in them. However the water content can be control by dry wood chips at certain temperature and period and then soak it in water, but inappropriate temperatures probably damage its structure.

In contrast, the research done by (Mohammed 2014) and (Thandavamoorthy 2016) shows that the slump is increase as the percentage of wood chip replacement is increase. To solve the higher water absorption, (Mohammed 2014) just added the additional water which is different with the way this research did which is by soaking the wood chips 24 hours before put in the concrete mix.

Second is unit weight of the sample. Figure 4.2 tells that the unit weight is decrease when the percentage of wood chip replacement is increase. The pattern of unit weight graph is parallel with compressive strength graph pattern as unit weight represents the strength of the samples. The trend of unit weight graph is same with what has discovered by (Mohammed 2014) in his research.

Next is compressive strength result. Figure 4.3 notifies that the compressive strength is decrease as the percentage of wood chipping replacement is increase. The compressive strength of 5% of replacement by wood chip concrete samples for both 14 and 28 days curing periods are 32.64MPa and 26.10MPa which less 7.75MPa and 10.67MPa than control concrete samples. The weak mechanical properties of wood chip compared to coarse aggregate is the main factor causing declining of compressive strength as the percentage of wood chip increase. Even so, sample with 5% of replacement that cured for 14 days has compressive strength that exceeds the characteristic strength designed for concrete which is 30MPa. Therefore, the compressive strength of concrete sample with 5% of replacement cured for 14 days is acceptable as the compressive strength is greater than characteristic strength designed.

The reasons of reduction in compressive strength for samples cured 28 days compares to samples cured for 14 days particularly for sample with percentages of replacement probably cause by deterioration of wood chip. This situation is proven with the discovery by (Coatanlem 2006) in his research about wood chipping concrete where he recorded that there is deterioration of compressive after 16 months. So, to improve the samples compressive strength in the future, this research should find a way to retard the deterioration.

The finding of this research is match with the research did by (Bashar 2014) where the compressive strength is drop as the percentage of replacement increase but do not match with the research did by (Thandavamoorthy 2016). This is because (Mohammed 2014) used wood chip as what is used in this research which is has lower mechanical properties compares to (Thandavamoorthy 2016) that used shredded wood which has better mechanical properties.

Last is flexural strength result. There two different graph patterns established based on the result obtained from flexural strength test. First pattern is for samples that cured at 14 days. The first pattern indicate that the flexural strength is go up gently from control to 5 percent of replacement and then drop drastically from 5% to 15% of replacement by wood chips. The second pattern is for sample that cured for 28 days. The second pattern shows that the flexural strength is fall gradually at the beginning from control to 5% of replacement by wood chip, after that it rise steadily from 5% to 10%, but it not rise as high as control concrete and end with go down slightly from 10% to 15% of replacement.

The trend of flexural strength graph do not match with the research did by (Thandavamoorthy 2016) and (Mohammed 2014). The graph pattern from (Thandavamoorthy 2016) discovery in his research shows that the flexural strength increase steadily at beginning from control to 15% of replacement and at the end it drop suddenly form 15% to 25% of replacement. While the finding by (Mohammed 2014) shows that the graph of flexural strength is drop gradually as the percentage of wood chip increase.

The highest flexural strength recorded for samples with 5% of replacement that cured for 14 days, the strength is surpassed strength of control sample. One of possible cause that makes 5% of replacement by wood chip samples cured for 14 days has the highest flexural strength is the function of the wood chip that change the normal concrete into fibre reinforced concrete.

CHAPTER 5

CONCLUSION

5.1 Introduction

Based on India Standard (IS), at 28 days age, cube in grade range from 10 to 20 is considers as ordinary concrete, while cube with grade between 25 to 55 is consider as standard concrete. In brief, most of cube samples in percentages of replacement are categorized as standard concrete as the control concrete samples, except samples with 15% replacement where they are fall in ordinary concrete category. Therefore it shown that the wood chip concrete for all percentages are applicable to be use as concrete structure, however they must be apply based on their respective performance as what discovered in this research.

This research samples categorized as lightweight concrete. However this research not has strong evidence due to lack of samples oven-dry density data. ICE manual of construction materials page 203 stated that the concrete can be classified as lightweight aggregate concrete when the samples have oven-dry density less than 2000kg/m^3 and made with aggregate with density less than 2000kg/m^3. So, the only reasons this research samples classified as lightweight aggregate concrete is because wood chip density is 146kg/m^3 which is less than then 2000kg/m^3.

5.2 Conclusion

This research is concludes based on its objectives. The objectives are to determine the workability, achieve maximum compressive strength and flexural strength and identify optimum content of wood chip concrete with different percentages of coarse aggregate replacement. Based on this study, it can be concluded that the objectives of this research is achieved. From the result and discussion in chapter 4, the conclusions can be drawn:

The workability of wood chip is not consistence due to different original content of water and capability of wood chip to absorb and loose the water. In term of workability, most of the mixes with percentage of replacement by wood chip unacceptable, except mixes with 10% and 15% of replacement for 14 days of curing period.

The maximum compressive strength among the percentages of replacement for both curing periods is the compressive strength for samples with 5% of replacement. For flexural strength, 14 days age sample with 5% of replacement has the highest compressive strength which exceeded the flexural strength of control concrete, while at 28 days age, sample with 10% of replacement has the higher flexural strength than others percentages of replacement.

To produce wood chip concrete with highest compressive strength at age 28 days, the optimum content of wood chip replacement is 5%. While to produce the wood chip concrete with greater flexural strength at age 28 days, 10% replacement by wood chip is the optimum percentage.

5.3 Recommendation

There are several recommendations that possibly improve the performance of wood chip as part of replacement coarse aggregate in concrete. The recommendations are:

i. Treat the wood chip using saturation treatment. The treatment can be done by immerse it in solution of sodium silicate. This way of treatment will increase the wood chip concrete performance by improve the bond at interface of wood chip and cement.

ii. Separate the wood chip by their species and test them. So, the research can recognize what species of wood that has better function as part of coarse aggregate in concrete to produce great performance concrete as conventional concrete.

iii. Complete the study by do the tests on durability properties of wood chip concrete. So, valuation whether it is applicable to be used in industry or otherwise can be made.

iv. Use wood chip with bigger physical size. The function wood chip with bigger physical size probably will increase the wood chip concrete performance.

v. Replace the wood chip by the weight of the coarse aggregate removed in concrete. This will possibly improve the performance of concrete than what is discovered in this research.

vi. Do the oven dry density to prove wood chip concrete is lightweight concrete. The concrete is classified as lightweight aggregate concrete when it has oven dry density and aggregate density less than 2000kg/m3.

REFERENCES

Lo, T.Y., Tang, W.C. & Cui, H.Z., 2007. The effects of aggregate properties on lightweight concrete. Building and Environment, 42, pp.3025–3029.

Ahlawat, D. & Kalurkar, L.G., 2014. Coconut Shell as Partial Replacement of Coarse Aggregate in Concrete. IOSR Journal of Mechanical and Civil Engineering, 2014, pp.61–64.

Bederina, M. et al., 2009. Effect of the treatment of wood shavings on the physico-mechanical characteristics of wood sand concretes. *Construction and Building Materials*, 23(3), pp.1311–1315. Available at: http://dx.doi.org/10.1016/j.conbuildmat.2008.07.029.

Chen, B. & Liu, J., 2008. Experimental application of mineral admixtures in lightweight concrete with high strength and workability. Construction and Building Materials, 22, pp.1108–1113.

Coatanlem, P., Jauberthie, R. & Rendell, F., 2006. Lightweight wood chipping concrete durability. Construction and Building Materials, 20, pp.776–781.

Daneshmand, S. & Saadatian, O., 2011. INFLUENCE OF OIL PALM SHELL ON WORKABILITY AND COMPRESSIVE STRENGTH OF HIGH STRENGTH CONCRETE. INTERNATIONAL JOURNAL OF ENGINEERING, 9(2), pp. 1584-2665.

Haque, M.N. & Kayali, O., 2004. Strength and durability of lightweight concrete. Cement & Concrete Composites, 26, pp.307–314.

Meyer, C., 2009. Cement & Concrete Composites The greening of the concrete industry. *Cement and Concrete Composites*, 31(8), pp.601–605. Available at: http://dx.doi.org/10.1016/j.cemconcomp.2008.12.010.

Mohammed, B.S. et al., 2012. Properties of crumb rubber hollow concrete block. *Journal of Cleaner Production*, 23(1), pp.57–67. Available at: http://dx.doi.org/10.1016/j.jclepro.2011.10.035.

Mohammed, B.S. et al., 2013. Shear strength of palm oil clinker concrete beams. *Materials and Design*, 46, pp.270–276. Available at: http://dx.doi.org/10.1016/j.matdes.2012.10.021.

Mohammed, B.S., Abdullahi, M. & Hoong, C.K., 2014. Statistical models for concrete containing wood chipping as partial replacement to fine aggregate. *Construction and Building Materials*, 55, pp.13–19.

Mohammed, B.S., Foo, W.L. & Abdullahi, M., 2014. Flexural strength of palm oil clinker concrete beams. *Materials and Design*, 53(16), pp.325–331. Available at: http://dx.doi.org/10.1016/j.matdes.2013.07.041.

Sales, A., De Souza, F.R. & Almeida, F.D.C.R., 2011. Mechanical properties of concrete produced with a composite of water treatment sludge and sawdust. *Construction and Building Materials*, 25(6), pp.2793–2798. Available at: http://dx.doi.org/10.1016/j.conbuildmat.2010.12.057.

Thandavamoorthy, T.S., 2016. Wood waste as coarse aggregate in the production of concrete. *European Journal of Environmental and Civil Engineering*, 20(2), pp.125–141. Available at: http://www.tandfonline.com/doi/full/10.1080/19648189.2015.1016631.