COCONUT SHELL AS PARTIAL REPLACEMENT OF FINE AND COARSE AGGREGATES IN CONCRETE

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SAZLIANA SAHIMA BINTI SIDEK

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

Faculty of Civil Engineering and Earth Resources
Universiti Malaysia Pahang

JANUARY 2017

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ACKNOWLEDGMENTS

First and foremost, I owe my gratefulness to all the people who have made my thesis and experimental study completed in time. Then, I would like to express my deepest gratitude to my supervisor, Dr Chin Siew Choo, who has supported me all the time throughout my thesis and experimental study. When facing problems, she always with her patience to give advice and guidance to help me overcome those problematic situations. I am also grateful for her time consumed to spend on reading and commenting my thesis with the correct grammar and enriched my ideas.

In the concrete laboratory under UMP, Faculty of Civil Engineering, I had been doing experimental works for this experimental study. I am also thankful, to the staffs in the laboratory for their guidance during the experimental testing. I could not have completed my experimental works in time without the kindness and cooperation from the staffs.

I would like to thank my family for giving moral support and unconditional love throughout the final year project. In particular, I would like to thank my friends for their support, care and help throughout my experimental study. I greatly value the friendships that we build among us throughout this 4 years.

ABSTRACT

In the construction industry, the increase in construction material cost is one of the greatest impact to the society. Therefore, there is a need to study on sustainable material in concrete to produce more environmental friendly and sustainable product using waste material. The potential use of agricultural waste in civil engineering and building construction works have been investigated by various researchers. Coconut waste is one of the waste generated by the agricultural process which led to the disposal and management problem that pose a serious challenge towards environmental issues. Malaysia has produced around 555,120 tons, metric by coconut waste. Thus, the highest number of waste will be generated and it is quite worrying to manage huge numbers of coconut waste. The use of coconut shell can help to prevent illegal dumping that cause environmental problems. Aggregate is the main constituent of concrete mix, hence in this study, coconut shell as partial replacement of fine and coarse aggregates were presented and discussed. In this study, the coarse and fine aggregates were partially replaced by coconut shell with percentages replacement of (0%, 2.5%, 5.0%, 7.5% and 10%). The mechanical properties tests considered in this study, including compressive, splitting tensile and flexural strength. Results show that, the compressive strength of 0%, 2.5%, 5.0%, 7.5% and 10% coconut shell replacement achieved the compressive strength of 36.66, 30.93, 29.20, 28.33, 27.34 N/mm^2, respectively. Findings showed that the optimum percentage of aggregate replacement was 2.5%. Hence, splitting tensile and flexural strength are casted using 2.5% replacement of aggregates. Result of splitting tensile strength test attained a maximum strength of 2.68 N/mm^2, 6.8% lower than control cylinders sample. Meanwhile, flexural strength achieved 6.13 N/mm^2,14.6% higher than the control beams. These results show that coconut shell concrete can be used as fine and coarse aggregates replacement in which reduced cost and eco-friendly.

ABSTRAK

Dalam industri pembinaan, peningkatan kos bahan binaan merupakan salah satu impak yang besar kepada masyarakat. Oleh itu, pencarian bahan baru dalam konkrit yang lebih lestari untuk menghasilkan konkrit yang lebih mesra alam sekitar dengan menggunakan bahan buangan telah dijalankan. Penggunaan sisa pertanian dalam bidang kejuruteraan awam dan kerja-kerja pembinaan telah dikaji oleh ramai penyelidik. Sisa kelapa adalah salah satu daripada bahan buangan yang dihasilkan dari proses pertanian yang menimbulkan cabaran yang serius dalam menangani masalah pelupusan dan pengurusan alam sekitar. Malaysia telah menghasilkan sekitar 555,120 tan metric sisa kelapa. Oleh itu, penjanaan sisa akan meningkat dan menyukarkan untuk menguruskan jumlah sisa kelapa yang besar. Penggunaan tempurung kelapa boleh membantu mencegah pembuangan sampah haram yang menyebabkan masalah alam sekitar. Agregat adalah bahan utama dalam campuran konkrit. Oleh itu dalam kajian ini, tempurung kelapa digunakan sebagai sebahagian penggantian daripada agregat halus dan kasar telah dibentangkan dan dibincangkan. Dalam kajian ini, agregat kasar dan halus sebahagiannya digantikan dengan tempurung kelapa dengan penggantian peratusan (0%, 2.5%, 5.0%, 7.5% dan 10%). Keputusan ujian sifat-sifat mekanikal dipertimbangkan dalam kajian ini, termasuk ujian kekuatan mampatan, tegangan dan kekuatan lenturan. Keputusan menunjukkan bahawa, kekuatan mampatan 0%, 2.5%, 5.0%, 7.5% dan 10% sebagai sebahagian penggantian tempurung mencapai kekuatan mampatan 36.66, 30.93, 29.20, 28.33, 27.34 N/mm^2. Keputusan ujian menunjukkan bahawa peratusan optimum penggantian agregat adalah 2.5%. Oleh itu, sampel tegangan dan kekuatan lenturan dihasilkan dengan menggunakan 2.5% sebagai sebahagian penggantian agregat. Keputusan ujian tegangan dan kekuatan lenturan mencapai kekuatan maksimum 2.68 N/mm^2, dimana 6.8% lebih rendah daripada sampel silinder normal. Sementara itu, kekuatan lenturan mencapai 6.13 N/mm^2, dimana 14.6% lebih tinggi daripada sampel rasuk normal. Keputusan ini menunjukkan bahawa konkrit tempurung kelapa boleh digunakan sebagai penggantian agregat halus dan kasar di mana dapat mengurangkan kos dan mesra alam.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is a very important material and widely used construction material since ancient time. Concrete is no doubt an important building material, playing a part in all building structure ("Compressive Strength Of Concrete And Mortar Containing Ashes As Partial Replacement For Cement By Amamat Oluwatoyin Adeyemi , Faculty Of Engineering February 2014," 2014). There are many of high rise buildings and complex structure was built in every national country in the worldwide. Conventional concrete with a dry density between 1900 kg/m3 up to 2600 kg/m3 (Breu et al., 2008). Concrete is functional as construct the type of structure that will cater the load. Concrete was applied to the structures such as wall, column, slab, beam, and girdle for bridge, offshore oil platform and a pre-stressed or precast element of all types. In the 21st century, the developed country like Malaysia also faced with demanding on construction based on the population growth. A composite material that consists essentially of a binding medium, such as a mixture of Portland cement and water, within which are embedded particles or fragments of aggregate, usually a combination of fine and coarse aggregates (Meyer, 2003).

The compositions of concrete is cement, aggregate and water. In concrete, the most commonly used is Portland cement, hydraulic cement which sets and hardens by chemical reaction with water and is capable of doing under water (Meyer, 2003). Portland cement is made up primarily of four mineral components (tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite), each of which has its own hydration characteristics (Meyer, 2003). Table 1.1 shows the types of cement.

Table 1.1: Types of cement

Type	Name
Type I	(OPC) Normal
Type IA	OPC, air-entraining
Type II	(MPC), Modified PC Moderate sulfate resistance
Type IIA	MPC, air-entraining
Type III	RHPC, Rapid Hardening PC
Type IIIA	RHPC, air-entraining
Type IV	LHPC, Low heat of hydration
Type V	SRPC, High sulfate resistance

Source: eng.yu.ac.ir

Second material of concrete is an aggregates which is separated into two parts, coarse and fine aggregates. Aggregates were produced from the crushed stone by the quarry rock, boulders, cobbles, or large-size gravel can be dredged from the pit, river, lake or seabed (Aggregate for Concrete, 2000). Coarse and fine aggregates is defined based on the size of a particle in which the size of coarse aggregate is larger than 5 mm sieve. Whereas, fine aggregate consists of crushed stone like sand with a size less than 5 mm sieve. Figures 1.1 and 1.2 show the material of coarse and fine aggregates, respectively.

Figure 1.1: Coarse Aggregate

Source: http://civilblog.org/2015/03/23/how-to-decide-maximum-size-of-coarse-aggregate-to-be-used-in-concrete//, 2015

Figure 1.2: Coarse Aggregate

Source: http://walkerconcreting.com.au/2016/07/09/properties-of-concrete/, 2016

Lastly, the important material is water as the binder of all materials to complete the mixture of concrete. Water should be clear and free of salts (sulphates and chlorine). For any particular set of materials and conditions of curing, the strength of hardened concrete is determined by the amount of water used in relation to the amount of cement. The advantages of adjusting the water cement ratio are increased compressive and flexural strength, lower permeability and increased resistance to weathering. The less water used, the better quality of the concrete, provided it can be consolidated properly (Suez, 2005).

All the materials of concrete used is mostly from the natural resources, which is being non-renewable. Thus, sustainable concrete shall be produced by using green material. Green material a type of waste material which has low energy costs, high durability, low maintenance requirements and can lead to high-performance concrete. In Malaysia, the large productions waste material has become a crucial issue that needs to be overcome by the government. Waste is an inevitable byproduct that arises from various anthropogenic activities and it is also considered as one of the major sources of environmental degradation since it causes air, land and water pollution and contributes to global warming (Peter, 2010). Waste was divided into four major categories of waste which is municipal solid waste, industrial waste, agricultural waste and hazardous waste.

Malaysia disposed agricultural waste about 1.2 million tons into landfills annually. The major agricultural crops grown in Malaysia were dominated by oil palm (54.5%), the second largest is wood (21.4%), thirds is rice (11.2%) forth is rubber (10.7%), and fifth is coconut (2.2%) (Waste Statistic, 2010). Figure 1.3 shows the proportionate of agricultural waste produced in Malaysia.

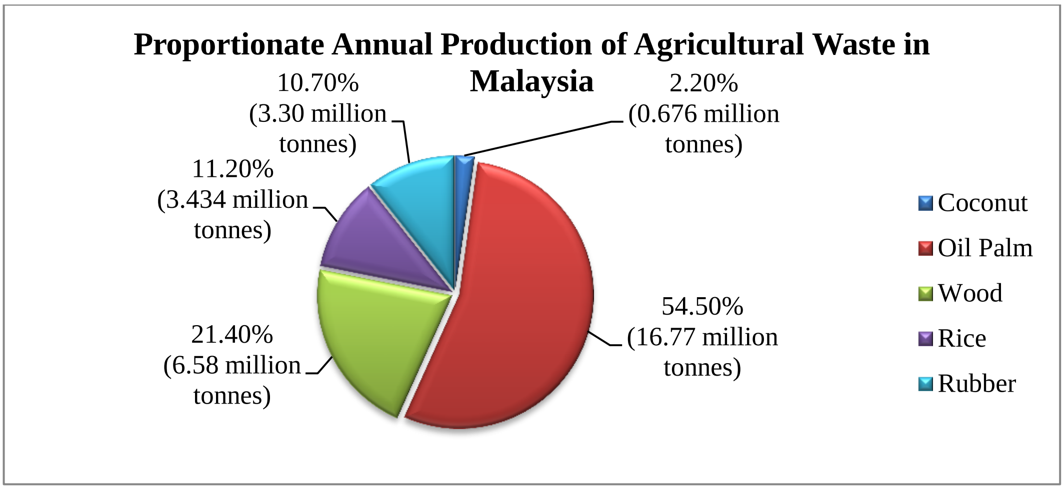


Figure 1.3: Proportionate Annual Production of Agricultural Waste in Malaysia

Source: www.unescap.org, 2010

Based on Pertanian Industri Tani (2009), Malaysia has produced around 555,120 tons metric of coconuts. Thus, the highest number of waste will be generated and it is quite worrying to manage huge numbers coconut waste. Therefore coconut waste is divided into two parts which is coconut shell and coconut husk. Coconut shell is the hardest part of the coconut which is possible to use as partial replacement of aggregate in the development of concrete. The smooth surface on one side of the coconut shell has better workability and high impact resistance compared with the conventional aggregate. Using alternative materials of natural aggregate in concrete production makes concrete a sustainable and environment friendly construction material (Kattire, et al, 2015). Figure 1.4 shows the cross-section of coconut and figure 1.5 shows the coconut shell, respectively.

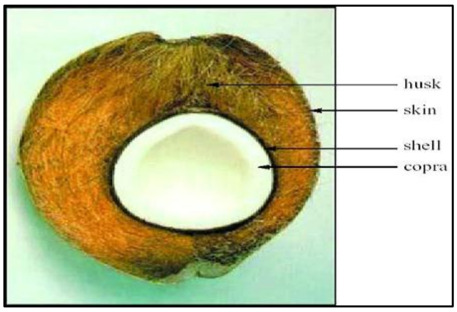


Figure 1.4: Cross-section of coconut

Source: www.fao.org

Figure 1.5: Coconut Shell

Source: www.lifegreencharcoal.com

1.2 PROBLEM STATEMENT

Coconut waste is one of the wastes generated by the agricultural process led to the disposal and management problem which pose a serious challenge towards environmental issues. The potential use of agricultural waste in civil engineering and building construction works have been investigated by various researchers (Osei, 2013). Aggregate used in concrete is the natural resources which are a non-renewable material and quite expensive. There are some negative impacts of more production of concrete like continuous extensive extraction of aggregate from natural resources will lead to its depletion and ecological imbalance (Ahlawat, Kalurkar, 2014). Therefore, used coconut waste a replacement in aggregate will decrease the cost of construction, as well as produces a sustainable environment, friendly and green development.

1.3 RESEARCH OBJECTIVE

The main purpose of this experimental study is to investigate the properties of concrete using coconut waste as partial replacement of aggregates in the mix design. The objectives of this experimental study are stated as follows:

i. To identify the optimum mix design of concrete using coconut shell as a partial replacement of aggregates.
ii. To determine the mechanical properties of concrete using coconut shell as partial replacement of aggregate based on compressive strength, splitting and flexural test.

1.4 SCOPE OF STUDY

The scope of study is to investigate the properties of coconut shells as replacement in concrete. A total of 75 cubes was tested by under compressive strength. 12 cylinders and beams were tested by under splitting tensile and flexural strength test was considered in this study. The size of the cube is 100 mm x 100 mm x 100 mm.

The proposed strength of concrete is grade 25 MPa with water cement ratio of 0.5. The maximum size of coconut shell is passed 10 mm and 20 mm sieve similar as the coarse aggregate and fine aggregate passes 5 mm sieve. The percentage coconut shell uses in the mix design is 0%, 2.5%, 5.0%, 7.5% and 10% of coarse and fine aggregates. After the optimum mix design has been determined, 12 of the cylinders and beams were cast to test under splitting and flexural strength testing. The size of the beam is 100 mm (Depth) x 100 mm (Width) x 500 mm (Length) and cylinder is 150 mm (Diameter) x 300 mm (Length).

1.5 RESEARCH SIGNIFICANCE

Data and results of optimum mix design, and mechanical properties are gaining from this experimental study. Based on this data and results, the concrete using coconut shells is sustainable and environmental friendly concrete made using waste material. Attenuation of coconut shell concrete will be cost effective because the coconut waste is a type of agricultural waste. Moreover, the replacement with coconut shell in aggregates also reduces the waste generated for disposed in the landfill. The uses of coconut waste in concrete should be done before the problem of coconut waste generates getting more crucial. Therefore, it will provide more advantages the people, the cost of building become decrease and the coconut waste has been overcome. The use of waste in construction can help to decrease the amount of waste generated and reduce the environmental issue.

CHAPTER 2

LITERATURE REVIEW

2.1 WASTE

Waste is an unavoidable by-product of most human activity. Economic development and rising living standards in the Asian and Pacific's Region have led to increases in the quantity and complexity of generating waste, whilst industrial diversification and the provision of expanded healthcare facilities have added substantial quantities of industrial hazardous waste and biomedical waste into the waste stream with potentially severe environmental and human health consequences (1947). Malaysia, like most developing countries, is facing an increase in the generation of waste and accompanying problems associated with disposal (Lina, 2004). The Malaysian population was 28.96 million in 2010, experiencing 1.6% growth as compared to 28.31 million in 2009 (http://www.malaxi.com, 2010). As such, waste generation has increased by 3% annually, which has alarmed the waste managers (Fauziah and Agamuthu, 2009).

The national average of 1.3 kg/capita is expected to be increasing linearly, reaching 2.23 kg/capita by 2024 (Mohamad et al., 2009). Approximately 30,000 tons of municipal solid wastes are generated daily, covering 83% of the country's waste generated, including agrowastes. About 95% of the total wastes are sent to landfills for disposal (Fauziah and Agamuthu, 2009). Clearly, the way to limit the impact on the environment is by reducing the amount of waste that is generated, or the waste must be recycled, composted or reused (Antonio and Domenico, 2008).

Throughout, the principal sources of waste are residential households and the agricultural, commercial, construction, industrial and institutional sectors. The purposes of these sources are defined as four major categories which are municipal solid waste, industrial waste, hazardous waste and agricultural waste. Figure 2.1 shows the type of solid waste in landfill.

Figure 2.1: Solid waste in landfill

Source: http://news.yale.edu/2015/09/21/solid-waste-disposal-more-doubles-epa-estimates, 2015

2.1.1 Municipal Solid Waste

Municipal solid waste (MSW) is generated from households, offices, hotels, shops, schools, and other institutions. The major components are food waste, paper, plastic, rags, metal and glass, although demolition and construction debris are often included in collecting waste, as are small quantities of hazardous waste, such as electric light bulbs, batteries, automotive parts and discarded medicines and chemicals (United Nations, 2000). By PAHO, definition of solid or semi-solid waste generated in population centers, including domestic and commercial waste, as well as those originated by the small-scale industries and institutions, including hospital and clinics, Market Street sweeping, and from public cleansing (A Global Review of Solid Waste Management, 2012). Figure 2.2 shows the types of municipal solid waste.

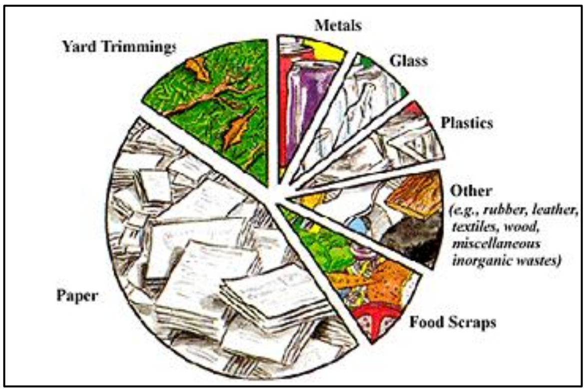


Figure 2.2: Types of municipal solid waste

Source: http://techalive.mtu.edu/meec/module15/MunicipalSolidWaste

2.1.2 Industrial Waste

The general meaning of waste or industrial waste in this study is absolutely as stated in section 2 of the Environmental Quality Act 1974 (Act 127) and Regulations (EQA 1974) stated as waste includes any matter prescribed to be scheduled wastes, or any matter, whether in a solid, semi-solid or liquid form, or in the form of gas or vapor which is emitted, discharged or deposited in the environment in such volume, composition or manner as to cause pollution. In addition, the specific meaning of industrial waste is that it us the products or byproducts of industrial processes (Ishak, 2002). The Department of Environment (DOE Malaysia) has defined industrial waste as water from industrial plants, industrial process effluents, sludge and sawdust (Information Service Unit, DOE, 1995). Indeed, the Refuse Collection, Removal and Disposal Bylaws have also described it as any waste matter generated from any industrial activity (Ipoh City Council, 1989). Figure 2.3 shows the waste was generated by an industrial process.

Figure 2.3: Type of industrial waste generated by an industrial process

Sources: http://www.slideshare.net/esteeseetoh/pollution

2.1.3 Hazardous Waste

Based on waste in 2000, most hazardous waste is the byproduct of a broad spectrum of industrial, agricultural and manufacturing processes, nuclear establishments, hospitals and health care facilities. Hazardous waste is controlled waste that, because of their properties, requires special treatment and control (How to Develop a Waste Management and Disposal Strategy , 2007). Primarily, high volume generators of industrial hazardous waste are the chemical, petrochemical, petroleum, metals, wood treatment, pulp and paper, leather, textiles and energy production plants of coal-fired and nuclear power plants and petroleum production plants. The types, quantities and sources of hazardous waste vary significantly from country to country and are influenced by the extent and diversity of industrial activity (United Nations, 2000). Table 2.1 shows a conservative estimate of the past, current and future hazardous waste generation trends in a number of selected countries (Nelson, 1997).

Table 2.1: A conservative estimate of the past, current and future hazardous waste generation trends in a number of selected countries

Country/Territory	**Estimated annual production, tones x 10^3**		
	1993	**2000**	**2010**
Australia	109	275	514
Bangladesh	738	1075	1560
PR China	50,000	130,000	250,000
Hong Kong, China	35	88	65
India	39,000	82,000	156,000
Indonesia	5000	12,000	23,000
Japan	82	220	415
Malaysia	377	400	1750
Mongolia	15	26	45
Nepal	130	260	450
New Zealand	22	62	120
Pakistan	786	1735	3100
Philippines	15	285	530
Papua New Guinea	25	45	80
Rep. Of Korea	269	670	1265
Singapore	28	72	135
Sri Lanka	14	250	460
Thailand	882	2215	4120
Viet Nam	460	910	1560

Source: Hernandez 1993, UNEP 1994, United Nations 1995 and Nelson 1997

2.1.4 Agricultural Waste

Agricultural waste is the wastes that include natural (organic) and non-natural (non-organic) wastes. Different countries will generate several of agricultural waste based on the type agricultural each country consumes. Malaysia also generates highest of agricultural organic waste, which is derived from several types of crop which is rubber, oil palm, rice, cocoa and coconut.

In Malaysia, 1.2 million tons of agricultural waste disposed into landfills annually. The major agricultural crops grown in Malaysia was dominate by oil palm (39.67%), the second largest is rubber (34.56%), thirds is rice (12.68%) forth is cocoa (6.75%), and fifth is coconut (6.34%) ("Waste Management in Malaysia," 2010). Agricultural waste gradually increases based on the population growth, and it is quite worried to handling and disposal. Expanding agricultural production has naturally resulted in increased quantities of livestock waste, agricultural crop residues and agro-industrial by-product. Table 2.2 provides an estimate of annual production of agricultural waste and residues in some selected countries in the region by ESCAP 1997 (United Nations, 2000)

Table 2.2: Approximate estimate of annual production of agricultural waste and residue in selected countries in the region

Country	**Annual production, million tones**		
	Agricultural waste (manure/animal dung)	**Crop residues**	**Total**
Bangladesh	15	30	45
PR China	255	587	842
India	240	320	560
Indonesia	32	90	122
Malaysia	12	30	42
Myanmar	28	4	32
Nepal	4	12	16
Pakistan	16	68	84
Philippines	20	12	32
Rep. Of Korea	15	10	25
Sri Lanka	6	3	9
Thailand	25	47	72

Source: ESCAP 1997

2.2 COCONUT WASTE

Coconut waste is copious agricultural waste and composes part of kitchen waste. The waste is generated from different parts of the coconut head, namely the husk, kernel, and meat (inner part) ("Waste Composition in Malaysia," 2010). Coconut famous as a multi - functional plant that all parts of its plant can be used in various activities. In Malaysia, coconut has been a long time and source income for some community. The fruit were produced of coconut milk and used in variety of Malaysian food. According to the Food and Agricultural Organization of the United Nation, Malaysia was producing 530 thousand metric tons (530 million coconuts) in 2010 and increases to 1.2 million metric tons (1.2 billion coconuts) in 2020 with 8.7% growth per year to fulfill the demanding. Figure 2.4 shows the achievement and estimate production of coconut in 2000 until 2020, respectively. Demanding on coconuts are increasing every year and generated higher of coconut waste. Therefore, alternatives which ensure a more environmentally friendly approach need to implement.

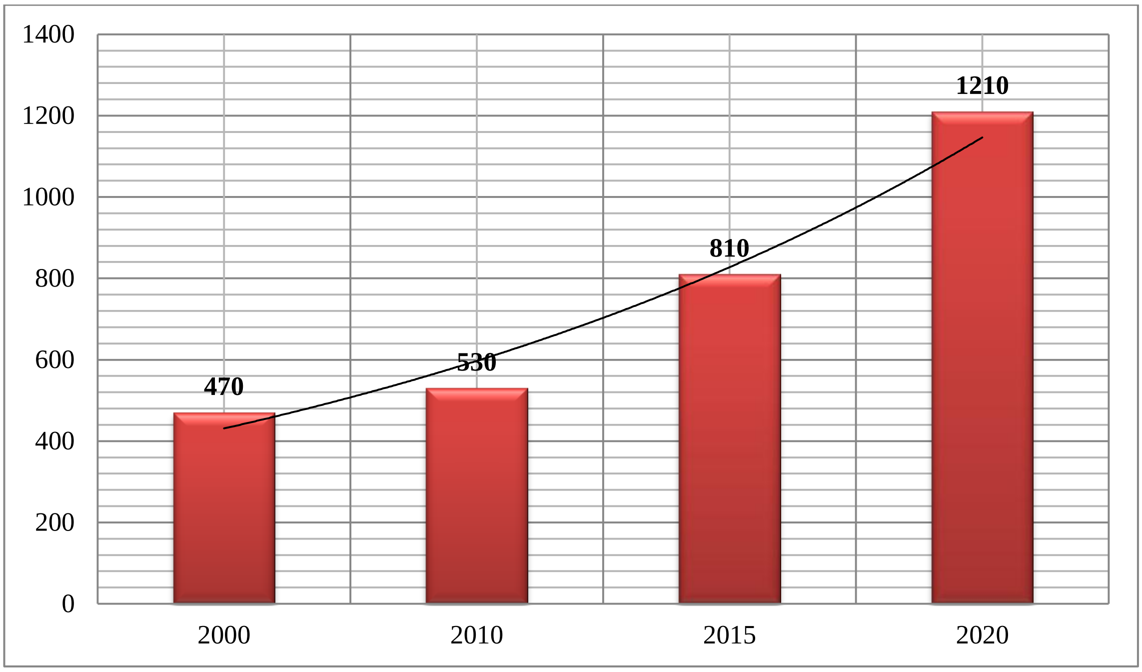


Figure 2.4: Achievement and estimate production of coconut in 2000 until 2020**.**

Source: Ministry of Agricultural and Agro-based Industry Malaysia

However, the coconut waste can be reduced by making more sustainable use of this waste. The recycling of solid waste in civil engineering applications has undergone considerable development over a very long time. Researchers are in search of replacing coarse aggregate to make the concrete less expansive and to lead sustainable development. The use of sugarcane bagasse, wood chips, plastics waste, textile waste, polyethylene, rice husk, broken bricks are some example of replacing aggregate in concrete (Ahlawat & Kalurkar, 2014)

2.2.1 Replacement of Coarse Aggregate

In recent years, there is varies material and waste was used a replacement of coarse aggregate in concrete. There is lot of researcher are searching the replacement and sustainable material in coarse aggregates. The concrete obtained using coconut shell aggregate satisfies the minimum requirements of concrete (Kaur & Kaur, 2012). Coconut shell may offer itself as a coarse aggregate as well as a potential construction material in the field of construction industries and this would solve the problem of reducing the generation of solid waste simultaneously (Kaur & Kaur, 2012). The particle sizes of coconut shell were crushed into the size 5 mm to 20 mm sieve. The percentage use is 2.5%, 5.0%, 7.5% and 10% of the coarse aggregate ratio. Figure 2.5 shows coconut a shell was crushed for coarse aggregate replacement.

Figure 2.5: Coconut shell as replacement of coarse aggregate

2.2.2 Replacement of Fine Aggregate

Fines aggregate may be describable into two major parts, which are natural sand and crushed stone or crushing gravel sand. Sand usually gets from the river and through the processing of crushing granite rock. Based on research have been done, there are a lot of studies and search about the replacement on coarse aggregate, but lack of searching for replacement on fine aggregate. The particle sizes of coconut shell were crushed using a grinder machine is less than the 5 mm sieve. The percentage use is 2.5%, 5.0%, 7.5% and 10% same as the coarse aggregate. Figure 2.6 shows coconut shell was crushed for fine aggregate replacement.

Figure 2.6: Coconut shell as replacement of fine aggregate

2.3 CONCRETE

Concrete is a composite material that consists essentially of a binding medium, such as a mixture of Portland cement and water, within which are embedded particles or fragments of aggregate, usually a combination of fine and coarse aggregate (Meyer, 2003). Concrete is the premier construction material around the world and is most widely used in all types of construction works, including infrastructure, low and high-rise buildings and domestic developments (Rao, 2015).

The utilization of concrete is increasing at a higher rate due to development in infrastructure and construction activities all around the world (Ahlawat & Kalurkar, 2014). Therefore, four types of concrete usually used in construction is generally concrete which is produced based on British and European standard in designed strength minimum cement content. General concrete most commonly used in foundations or domestic flooring. Second is reinforced concrete range are most commonly used where steel reinforcement is present to produce strength and durability qualities. These help to reduce the risks of the steel being attacked by aggressive chemicals. Third is standard concrete mixes have a broad range of uses and while there is no guaranteed designed strength in British and European standard. Their uses range from kerb backing to concrete slabs. Lastly is designed concrete are usually specified by the engineer or architect and it is manufactured to achieve particular strength (Wikipedia, 2012).

These details would be found on the construction drawings, specification or bill of quantities (Wikipedia, 2012). The type of concrete is designed based on the variety purposed structure in construction. Performance and behavior each concrete can be determined based on several tested on concrete such as mechanical and durability properties testing. The type of result can be determined based on the testing is the density, compressive strength, flexural strength, splitting tensile strength, workability, water absorption and chemical attack of concrete. These results are used to determine the performance and behavior of concrete in terms of high quality, durable construction material of high impermeability.

2.3.1 Performance of Concrete with Coconut Shell

In view on energy saving and sustainable development, there are many researcher searches of suitable material to replace the conventional material used in concrete. Conventional concrete has good performance on the strength, durability, workability, and properties. Coconut shell was chosen because of the characteristic of the material is suitable as replacement aggregate in concrete.

Besides that, the used coconut shell in concrete indirectly increases the performance of the concrete itself. Coconut shell aggregate resulted acceptable strength which is required for structural concrete. Furthermore, concrete with coconut shell shows good impact of resistance (Apeksha Kanojia, 2015). As compared to conventional concrete, coconut shell concrete presents better workability. The increase of percentage coconut shell use in concrete can be used to produced lightweight concrete and the replacement on optimum percentage coconut shell can be used to produced structural concrete (Osei et al., 2013).

2.3.2 Behavior of Concrete with Coconut Shell

Concrete behavior is related to the performance of concrete. Behavior of concrete can be determined under testing of concrete. Concrete behavior was analyzed based on the appearance of the concrete. The type behavior of concrete under compressive strength, flexural and splitting tensile strength shows on cracking of the concrete. The compressive, flexural and splitting tensile behavior of coconut shell concrete was comparable to control concrete. Replacement by using coconut shell in concrete will be affect the behavior of that concrete. All Beams exhibited typical failure in flexure with vertical flexural cracking appearing in the pure bending region. Coconut shell concrete generally exhibited good ductility due to the energy absorbing nature of the concrete (Melorose et al., 2015). The concrete with coconut shell has better workability because of the smooth surface on one side of the shell (Kumar, 2014). Coconut shell concrete in higher of percentage replacement can used for non-load bearing structure (Reddy et al., 2014). Concrete with coconut shell absorbing and retaining moisture is more because of higher porosity in its shell structure.

2.4 CONCRETE WITH COCONUT SHELL AS PARTIAL REPLACEMENT OF AGGREGATE

The concrete obtained using coconut shell aggregates satisfies the minimum requirements of concrete. Concrete using coconut shell aggregates resulted in acceptable strength required for structural concrete. Coconut shell may offer it as a coarse aggregate as well as a potential construction material in the field of construction industries and this would solve the environmental problem of reducing the generation of solid wastes simultaneously (Shinde & Engg, 2013). Coconut shell concrete has better workability because of the smooth surface on one side of the shells (Apeksha Kanojia, 2015). The impact resistance of coconut shell concrete is high when compared to conventional aggregate. The amount of cement content may be more when coconut shell is used as an aggregate in the production of concrete compared to conventional aggregate concrete (Kaur & Kaur, 2012). Coconut shell concrete can be used in rural areas and places where coconut is abundant and may also be used where the conventional aggregates are costly. Coconut shell concrete is also classified as structural lightweight concrete (Kambli & Mathapati, 2014).

2.4.1 Mix proportion of Coconut Waste in Concrete

Mix design is the process of selecting an optimum proportion of cement, aggregates and water to produce a concrete with specified properties workability, strength and durability (Rao, 2015). Mix proportion of coconut was used are variety due to other researcher. Based on (Kaur & Kaur, 2012), different mix ratio of 1:2:4, 1:11/2:3 and 1:3:6 by following ratio 0% to 100% an increment of 25%. In a research conducted by Olanipekun on the comparative cost analysis and strength characteristic of concrete by using crushed granular coconut as a substitute for conventional coarse aggregate in following ratio 0%, 25%, 50%, 75% and 100% with mix ratio 1:1:2 and 1:2:4.

A concrete mix ratio of 1:2:4 by volume, with a water cement ratio of 0.6 was used as control to which the properties of all other mixes were compared with 20%, 30%, 40%, 50% and 100% replacement (Osei et al., 2013). The different mixes were prepared by replacing 10%, 20% and 30% of coarse aggregate by coconut shells and the proportion use is 1:1.48:2.99 (Kamal & Singh, 2015). These variety of mix ratio will produce a different results.

2.4.2 Advantages Coconut Shell in Concrete

Using coconut shell has several advantages based on other research. Concrete using coconut shell aggregates resulted in acceptable strength required for structural concrete. Coconut shell has speacialbility to hold the resistance whereas it proven by Shinde and Engg in 2013, the impact resistance of coconut shell concrete is high when compared with conventional concrete. The uses of coconut shell in concrete can help in waste reduction and pollution reduction (Kaur & Kaur, 2012). As we know the material of concrete are mostly expensive. By using coconut shell as a replacement of aggregate it can reduce the material cost in construction because of the low cost and abundant agricultural waste (Kambli & Mathapati, 2014). The several advantages of coconut shell concrete, which are benefit of managing environmental problem and construction industry.

2.5 MECHANICAL PROPERTIES OF CONCRETE COCONUT SHELL

Performance of concrete is evaluated from mechanical properties which include shrinkage and creep, compressive strength, tensile strength, flexural strength, and modulus of elasticity. But the compressive strength of concrete is the most important characteristic and it is generally assumed that an improvement in concrete compressive strength will improve its mechanical properties. However, in case of concrete in which cement is partially replaced by mineral admixtures, all mechanical properties are not directly associated with compressive strength, and the effects of the same amount of different mineral admixtures on the mechanical properties of hardened concrete are not same.

2.5.1 Compressive Strength

A compression strength test was conducted in accordance with ASTM C39/C39M. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete and the material uses. The compression test is simply the opposite of the tension test with respect to the direction of loading (Rao, 2015). In some materials such brittle and fibrous ones, the tensile strength is considerably different from compressive strength. Therefore, it is necessary for the test under tension and compression separately. Compression test results in mechanical properties that include the compressive yield strength, compressive ultimate strength, and compressive modulus of elasticity in compression (Rao, 2015). Figure 2.7 is the equipment of compression test.

Figure 2.7: Compressive strength machine

2.5.2 Splitting Tensile Strength

A splitting tensile strength test was conducted in accordance with ASTM C496. The splitting tensile test is well known indirect test used to determine the tensile strength of concrete. Due to difficulties involved in conducting the direct tension test, a number of indirect methods have been developed to determine the tensile strength of the concrete. The tensile strength at which failure occurs is the tensile strength of concrete (Shaikh et al., 2015). Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete determines which the concrete members may crack. Figure 2.8 shows the machine of splitting tensile strength.

Figure 2.8: Splitting tensile strength Machine

2.5.3 Flexural Strength

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6 inch (150 x 150 mm) concrete beams with span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C78 (Third Point Loading) or ASTM C293 (Center Point Loading). Flexural is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained from laboratory tests for given materials and mix design. The results was determined by center point loading, sometimes by as much 15% (National Ready Mixed Concrete Association, 2000). Figures 2.9 and 2.10 show the two types of point loading in flexural testing, respectively.

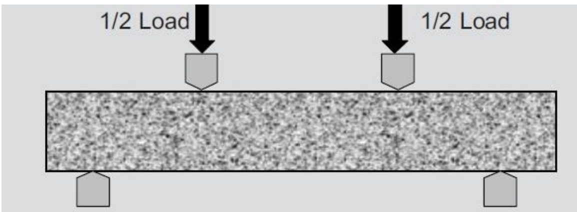


Figure 2.9: Third Point Loading (ASTM C78)

Source: http://www.aboutcivil.org/flexural-strength-of-concrete.html, 2014

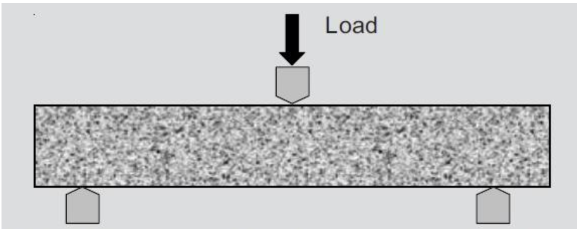


Figure 2.10: Center Point Loading (ASTM C293)

Source: http://www.aboutcivil.org/flexural-strength-of-concrete.html, 2014

2.5 SUMMARY OF FINDINGS

This research is conducted to investigate the properties of coconut shells as a replacement of aggregate in concrete. Therefore, there are three tests were conducted in this study, which is compressive strength, splitting tensile strength and flexural strength. Research gaps were identified based on the literature review.

The materials used in coconut shell concrete are aggregates, coconut shells, cement and water. Coconut shell is a waste product. Therefore, it should be treated before used. In this study, the coconut shell was through the clean, dry and crushing into coarse and fine aggregates size before the concreting process. For compressive strength, the percentage use for replacement of aggregates is 0%, 2.5%, 5.0%, 7.5% and 10%. The testing was conducted for 75 concrete cubes with a size of 100 mm x 100 mm x 100 mm. The cube was immersed in water in 1, 3, 7, 14 and 28 days. The purposed of testing is to investigate the strength and determine the optimum mix design coconut shell concrete. After the optimum mix design was obtained, the process of casting 12 samples of the beam and the cylinder was conducted. The samples are prepared for the testing of splitting tensile and flexural strength. The purposed of this tests is to determined the strength of coconut shell concrete in resisting the direct tension and bending load. The cylinder and beam sizes used is 100 mm (Depth) x 100 mm (Widhth) x 500 mm (Length) and 150 mm (diameter) x 300 mm (Length), respectively.

Based on the results obtained from the optimum mix design of coconut shell concrete can be identified. Hence, the strength of coconut shell concrete in resisting the direct tension and bending load can be determined under the splitting tensile and flexural strength tests. The effectiveness of coconut shell as replacement of aggregate in concrete was studied. In this study, coconut shell was dried for 24 hours to remove the moisture content that can be decreased the strength of concrete. From this, the viability of this method can be investigated.

CHAPTER 3

METHODOLOGY

3.1 OVERVIEW

Methodology is the flow from the beginning until the end of theprocess. The process involved in this project is preparation of material for coconut shell concrete, laboratory work and testing. Material preparation was included crushing coconut shell, prepare all the material and moulds use for concrete process. After the laboratory work done, the testing was performed for compressive, flexural and splitting tensile strength.

3.2 FLOWCHART RESEARCH

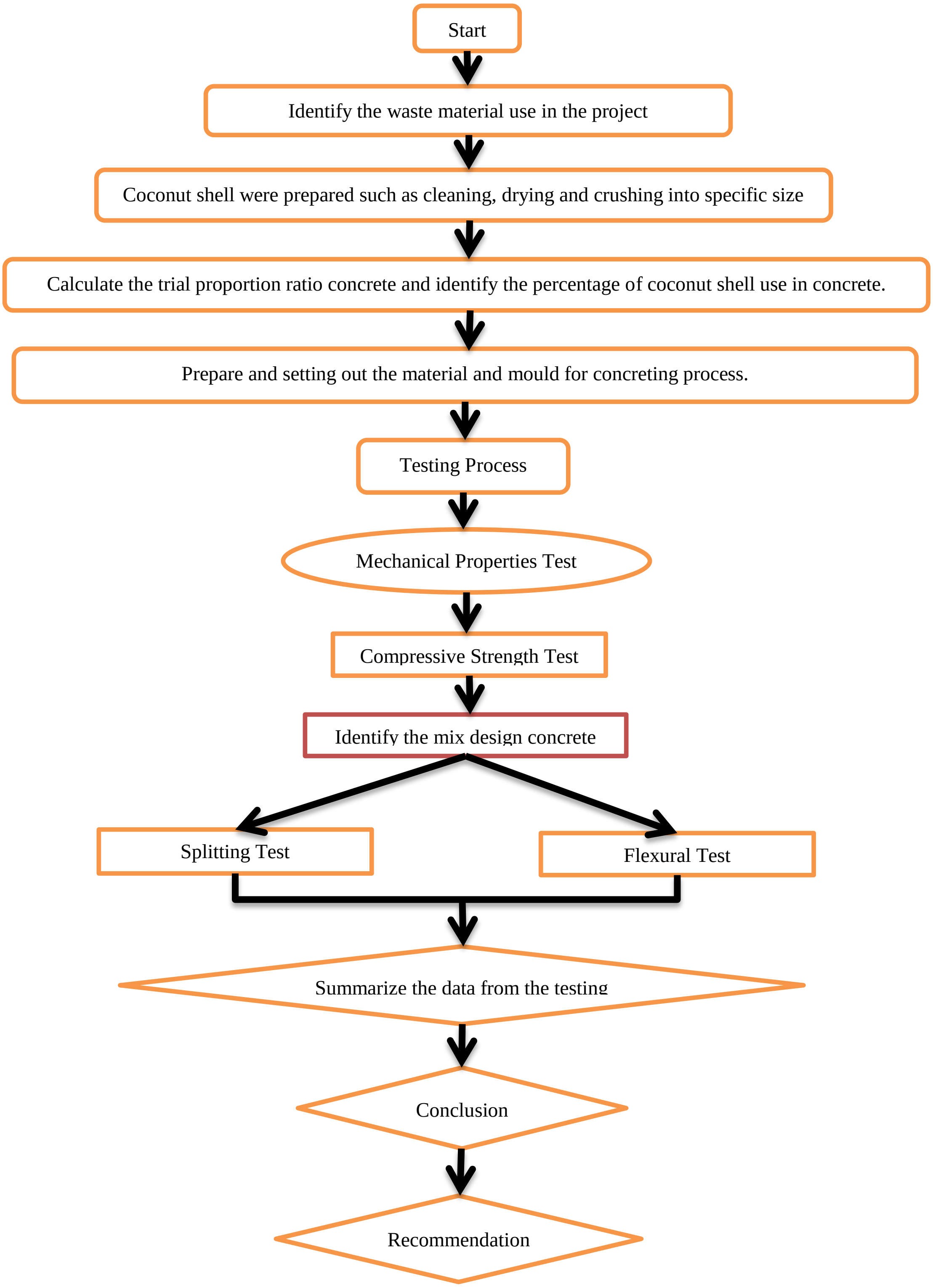


Figure 3.1: Flowchart research

3.2 PREPARATIONS OF COCONUT SHELL CONCRETE

Coconut shell concrete was used coconut shells as a replacement for two types of aggregate which is fine and coarse. Before the mixing concrete process, the preparation of material needs to be completed. The materials used in the project are coarse and fine aggregates, Portland cement, coarse and fine aggregates of coconut shell as partial replacement of aggregates and water as a binder concrete.

3.2.1 Coconut shell preparation

The coconut shells were collected from local shop selling of coconut milks. The Coconut shells are cleaned from the husk and fiber on the top and inside of coconut shell. After cleaning process, coconut shell will through the drying process of sundry in 24 hours approximately. The next process is crushing coconut shells by using a hammer into small chips manually and using grinder machine for the smaller size. The materials passed through 10 mm and 20 mm sieve was used to replace coarse aggregate. Therefore, materials passed less than the 5 mm sieve was used as replacement on fine aggregate. Figures 3.2-3.7 shows the process of preparation coconut shell, respectively.

Figure 3.2: Process of crushing coconut shell using hammer

Figure 3.3 shows the coconut shell were crushed using hammer and were stored in a clean container. This shells was used as a replacement of coarse aggregate in concrete.

Figure 3.3: Coconut shells were crushing using hammer

Figure 3.4 shows the coconut shells were crushed using grinder machine for size less than the 5 mm sieve. This shell was used as replacement of fine aggregate in concrete.

Figure 3.4: Coconut shells were crushing using grinder machine

Figure 3.5 shows the sieving process for both coconut shells. The sizes sieve used in range 28 mm, 20 mm, 14 mm, 10 mm, 5 mm and pan. Coconut shells passing 20 mm and 10 mm sieve was stored in a container for coarse aggregate replacement. Therefore the shells passing the 5 mm sieve are stored in another container for fine aggregate replacement.

Figure 3.5: The coconut shells was sieved to classified size as a replacement on aggregate

Figure 3.6 shows the coconut shells after sieving process. The size of coconut shell is less than the 5 mm sieve.

Figure 3.6: Size of coconut shells passing the 5 mm sieve as a replacement on fine aggregate

The figure 3.7 shows of coconut shell passing 10 mm and 20 mm after sieving process. The sieving process was conducted for 10 minutes approximately.

Figure 3.7: Size of coconut shells passing 10 mm and 20 mm sieve as a replacement of coarse aggregate

3.2.2 Preparation work before concreting and mold

The mould of size 100 mm (Length) x 100 mm (Width) x 100 mm (Depth) for cubes, 100 mm (Depth) x 100 mm (Width) x 500 mm (Length) for beams and 150 mm (Diameter) x 300 mm (Length) for the cylinders are prepared before mixing. Total 75 cubes, 12 cylinders and beams were cast. The bolts of the molds carefully tightened to avoid concrete mixture coming out of the moulds when vibration takes place. Then moulds are cleaned and oiled on all contact surfaces of the moulds. This process is to prevent the formation of a bond between concrete and moulds. Figures 3.8 and 3.9 show the process of oiled cube, beam and cylinder moulds, respectively.

Figure 3.8: Preparation on cube moulds for compressive test

Figure 3.9 shows the preparation of beam and cylinder moulds. When prepared the moulds, extra handle care need implemented because the moulds are heavy and may lead to injuries.

Figure 3.9: Preparation of beam and cylinder moulds for splitting tensile and flexural strength test

After preparation of moulds done, the next process is preparation of materials for the mixing process. All the materials was weighing separately and was placed in a different container for ease during the mixing process. Figure 3.10 shows one of the materials was weighing during preparation material.

Figure 3.10: Weighing all the materials that used in concreting process

Normal aggregate that passed 20 mm sieve was used for coarse aggregate. The sand passing through 4.75 mm was used for fine aggregate. Water cement ratio used in this project is 0.5. Moreover, for coconut shell the size passing 10 mm and 20 mm sieve as coarse replacement and passing the 5 mm sieve as fine replacement are used. Figure 3.11 shows the materials use in coconut shell concrete.

Figure 3.11: All the materials were already prepared for the casting process

3.2.3 Concreting, casting and curing process

Production of mix design for concrete 25 MPa in the laboratory is carried out by the BS method of concrete mix design BS 8110. Coconut Shell concrete is produced by adding coconut shells in different percentage from 0% to 10% with an increments of 2.5% replacement in concrete. Ingredients such as cement, sand, coarse aggregate and coconut shell were mixed together in dry condition in a mixer for a 2 minutes, water was mixed after the materials was blended into the machine. Finally, all the ingredients were allowed to mix in the machine for a period of at approximately 5 min. Extra cares is taken to avoid segregation of concrete. Figures 3.12 and 3.13 show the process of mixing concrete, respectively.

Figure 3.12: Process of mix the materials into mixing machine

Figure 3.13 shows the mixing process was completed. After the machine mixing was stopped, ensured that the mixed was well blended and no segregation process was occurring.

Figure 3.13: The concrete has already done in mixing

The fresh concrete was placed in the moulds by trowels. It ensured that the representative volume is filled evenly with all the specimens to avoid the segregation. Concrete was placed in moulds into 3 layers. Each layer will compacted by using vibrator table. The compaction process was conducted to remove entrapped air or void in the concrete. Figures 3.14- 3.16 show the placing and vibrating process, respectively.

Figure 3.14: The process placing concrete into cube molds

Figure 3.15 shows the process of casting beams. The concrete was placed into moulds into 3 layers and the compaction process were conducted.

Figure 3.15: The process of placing concrete into the cylinder and beam moulds

Figure 3.16 shows the process of compaction. All the moulds were placed at vibtrator table. The process was conducted for approximately 1 min. Compaction cannot be conducted in a long time to avoid segregation, which is the water will occur at the surface of concrete.

Figure 3.16: The process of vibrating using the vibrator table

The concretes are worked using a trowel to give uniform surface. After finished, the surface was trimmed using a tool for achieving good surface finish. The concretes are marked with a label after the initial drying. Figures 3.17 and 3.18 show the process of placing concrete was done for cylinder and beam specimens, respectively.

Figure 3.17: Casting concrete for beams already done

Figure 3.18 shows the cylinders were done in concreting. The cylinders were allowed for 24 hours before the process of remoulding. The surface of the cylinders was trimmed for achieving good surface and the cylinders was marked with a label.

Figure 3.18: Casting concrete for cylinders already done

The control and coconut shell concrete specimens are remoulded after 24 hours of casting and kept in water tank for curing. The process of curing was conducted for 1, 3, 7, 14 and 28 days. Figure 3.19 shows the remoulding concrete process.

Figure 3.19: The process of remolding concretes

The specimens are remoulded after 24 hours of casting and immediately stored for curing. Concrete grade 25 MPa was designed for control and coconut shell concrete specimens with partial replacement of 0% to 10% with an increment of 2.5% are cured in the curing tank for 1, 3, 7, 14, and 28 days. Figure 3.20 shows the curing process.

Figure 3.20: The curing process of cubes, beams and cylinders after remolding

3.3 LABORATORY TESTING

Compressive testing is carried out on a compressive testing machine (CTM) of capacity 2000 kN with standard ASTM C39/C39M. 75 cubes are tested for 1, 3, 7, 14 and 28 days. Splitting tensile and flexural strength test ar carried out on splitting tensile and flexural machine. 12 beams and cylinders are tested for 7, 14 and 28 days.

3.3.1 Compressive Test

A cube compression test is performed on standard cubes of control and coconut shell concrete with partial replacement of 0% to 10% with an increment of 2.5% of size 100 (Length) x 100 (Width) x 100 (Depth) mm after 1, 3, 7, 14 and 28 days of immersion in water for curing. The compressive strength is defined as resistance of concrete to axial loading. The cube was placed in a compressive testing machine, and load was applied. The standard compression strength was conducted based on ASTM C39/C39M. The results were recorded. Figures 3.21 and 3.22 show the sample of the cubes and the process of compression test, respectively. Figure 3.21 shows the sample of cubes was conducted on the compression strength test. The cubes was wiped and weighted before the testing. Each percentage provides 3 cubes for testing. The strength was recorded and the average was calculated.

Figure 3.21: Sample of the cubes was used for compression test based on curing day.

Figure 3.22 shows the process of compression test. The cube was placed into the machine and the load was applied to the cube. The cube will fail and crack will occur because of the pressure load applied.

Figure 3.22: The process of compression test

After the compression test was done, the strength was obtained and results were recorded. The crack patterns will appear on all the side of the cube because of the compression process. Figure 3.23 shows the example pattern of cracking on cube specimen.

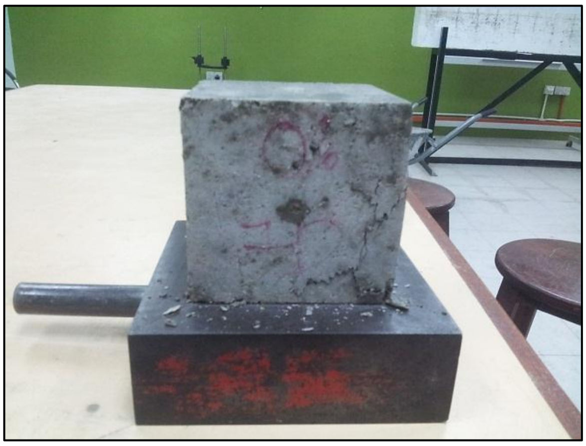


Figure 3.23: The cracking pattern front side of the cube

3.3.2 Splitting tensile test

The splitting tensile test is well known indirect test used to determine the tensile strength of concrete. Due to difficulties involved in conducting the direct tension test, a number of indirect methods have been developed to determine the tensile strength of the concrete. In these tests, in general a compressive force is applied to concrete specimens in such a way that the specimen fails due tensile stresses induced in the specimen. The tensile strength at which failure occurs is the tensile strength of concrete. During this investigation the test was carried out on the cylinder by splitting along its middle plan parallel to edges by applying the compressive load to opposite edges. Figures 3.24 and 3.25 show the sample of cylinders and the process of the splitting tensile test, respectively.

Figure 3.24: The cylinders are conducted on the splitting tensile test based on curing day

Figure 3.25 shows the results after testing. From the top surface of cylinders was occurred crack patterns when the specimens were achieved failure limit.

Figure 3.25: The process of splitting tensile test

The maximum loads are recorded and calculated by using the formula to obtain the actual strength. Figure 3.26 shows the maximum load was applied to the cylinders until reached failed and led to the cracked on the specimens.

Figure 3.26: The cracking pattern of cylinders after splitting tensile test

3.3.2 Flexural test

Three-point load was adopted to measure the flexural strength of coconut shell concrete (CSC). As per ASTM guidelines C293, beams of 100 (Depth) x 100 (Width) x 500 (Length) mm size are casted. The load was applied without shock and was increased until the specimens failed, and the maximum load applied to the specimens during the test was recorded. The appearance of the fractured faces of concretes failure was noted. Figures 3.27 and 3.28 show the sample of the beam and the process of compression test, respectively.

Figure 3.27: Sample of beams was used for flexural strength test based on curing day

Figure 3.28 shows the process was conducted using the machine. The beams were placed on the center of the roll. The loads applied to the beams until it failed.

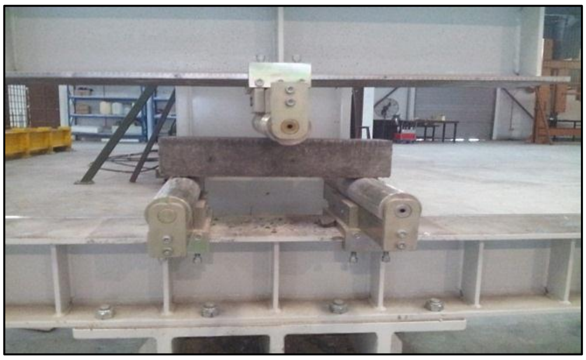


Figure 3.28: The process of flexural strength testing

After the flexural strength test was done, the reading of the strength was appeared and recorded. The beams will break into two parts in a certain time after the load applied to the beams. Figure 3.29 shows the example beam specimens after the testing.

Figure 3.29: The beams specimens after the flexural strength test

The preparation of the materials until the testing process was explained clearly step by step in this methodology chapter. All the process, method, standard follows based on previous research coconut shell concrete and British Standard (BS) 8110. The results of each test were discussed in the next chapter.

CHAPTER 4

RESULT AND DISCUSSION

4.1 OVERVIEW

In this section, the results in terms of compression strength, flexural strength and splitting tensile strength testing resulted are presented.

4.2 COMPRESSIVE STRENGTH

Compression test was conducted on standard cubes (100 x 100 x 100 mm) of control and coconut shell concrete with partial replacement of 0% to 10% with an increment of 2.5% that cured in water for 1, 3, 7, 14, and 28 days. The results of compressive strength are shown in Table 4.1.

Table 4.1: Compressive strength of coconut shell concrete

Concrete Age, Days	0% (MPa)	2.5% (MPa)	5.0% (MPa)	7.5% (MPa)	10% (MPa)
1	18.32	15.43	14.32	12.21	11.43
3	24.61	19.77	19.58	19.56	18.53
7	28.24	23.34	23.25	22.87	22.55
14	32.61	26.54	26.32	26.03	25.33
28	36.66	30.93	29.20	28.33	27.34

Figures 4.1-4.5 show the comparisons between 0% for control concrete with 2.5% up to 10% replacement of coconut shell, respectively. Figure 4.2 shows the strength from 1 day to 28 days of concrete. For 1 day concrete age, the strength of 0% and 2.5% is 18.32 MPa and 15.42 MPa, respectively. The strength of 15.42 MPa is lower with a difference of 8.6%. Next is 3 days of curing, the strength of 0% and 2.5% was recorded 24.61 MPa and 19.58 MPa, respectively. The strength of 19.58 MPa is lower with a difference of 11.4%. For 0% and 2.5%, the strength is 28.24 MPa and 23.25 MPa for 7 days concrete age, respectively. The strength of 23.25 MPa is lower with a difference of 9.7%. Thus, for 14 days the strength of 0% and 2.5% was 32.61 MPa and 26.54 MPa, respectively. The strength of 26.54 MPa is lower with a difference of 10.3%. Lastly is 28 days, the strength is 36.66 MPa and 30.93 MPa for 0% and 2.5%, respectively. The strength 30.93 MPa of 2.5% were recorded is lower with a difference of 8.5% compared to the control samples. Concrete age at 1 and 3 days were not be considered due to the early strength of the materials. Based on 7, 14 and 28 days the percentage was increased proportionally up to 28 days.

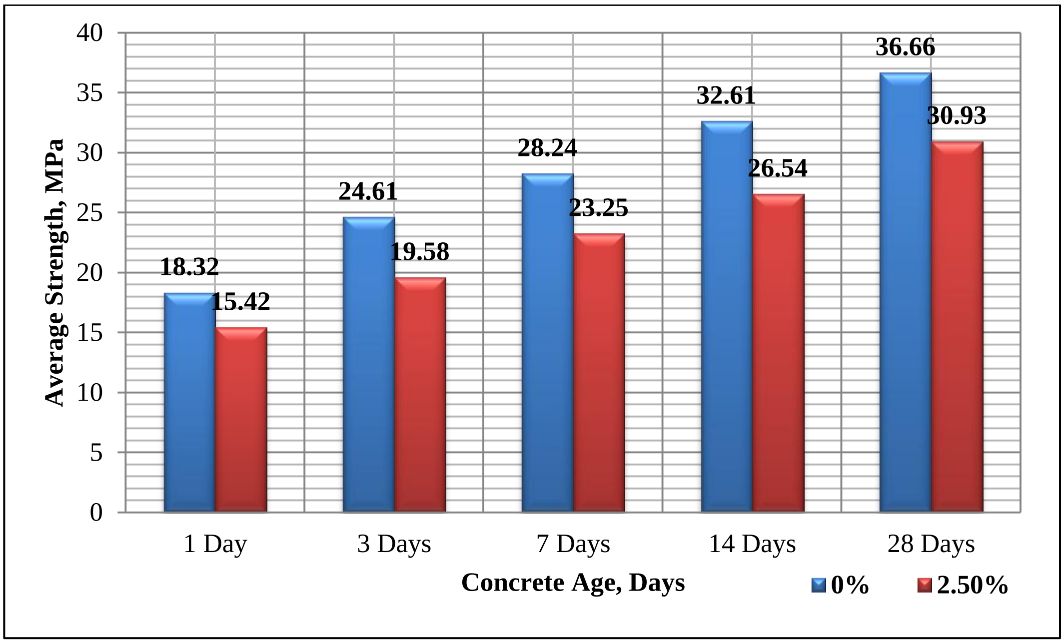


Figure 4.1: Comparison of compressive strength between 0% and 2.5% replacement

Figure 4.2 shows the strength of 0% and 5.0% replacement. For 1 day concrete age, the strength is 18.32 MPa and 14.32 MPa for 0% and 5%, respectively. The strength of 14.32 MPa is lower with a difference of 12.3%. Next is 3 days of curing, the strength was recorded 24.61 MPa and 19.77 MPa for 0% and 5%, respectively. The strength of 19.77 MPa is lower with a difference of 10.9%. Next strength is 28.24 MPa and 23.34 MPa for 7 days of concrete age of 0% and 5%, respectively. The strength of 23.34 MPa is lower with a difference of 9.5%. Next, for 14 days the strength was 32.61 MPa and 26.32 MPa of 0% and 5%, respectively. The strength of 26.32 MPa is lower with a difference of 10.7%. Lastly, 28 days strength is 36.66 MPa and 29.2 MPa of 0% and 5%, respectively. The percentage a difference is lower of 11.3% for 29.2 MPa.

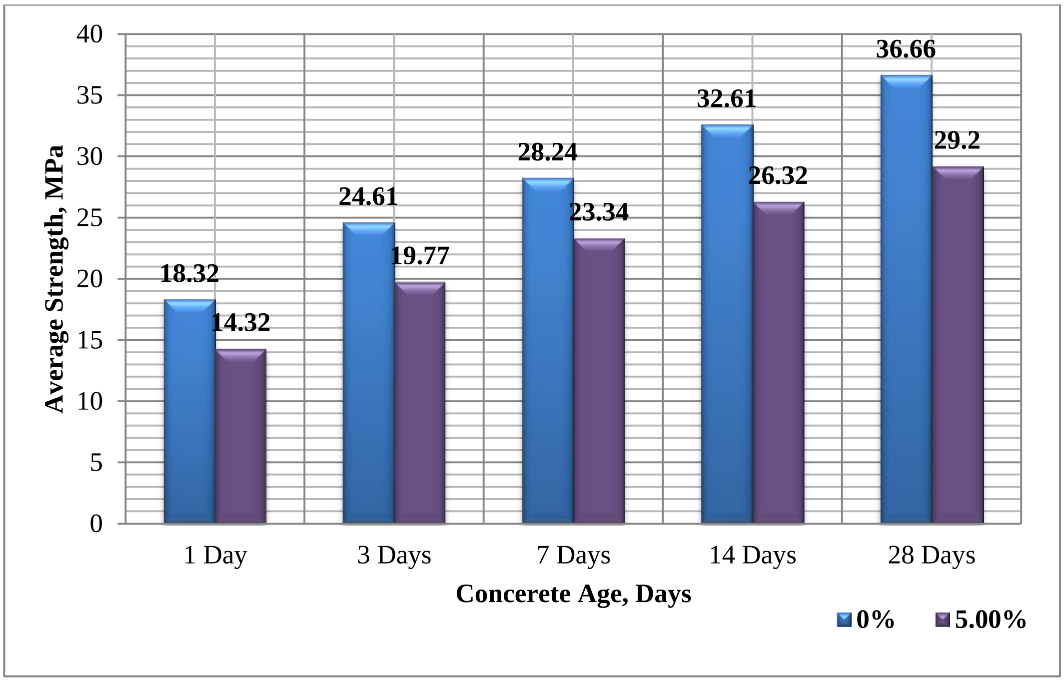


Figure 4.2: Comparison of compressive strength between 0% and 5.0% replacement

Figure 4.3 shows the strength of 0% and 7.5% replacement. For 1 day concrete age, the percentage difference is lower by 20% for 12.21 MPa of 7.5% which lower than control beam. Second is 3 days of curing, the strength was recorded 24.61 MPa and 19.56 MPa for 0% and 7.5%, respectively. The strength of 19.56 MPa is lower with a difference 11.4%. Third percentage difference is 10.5% was recorded for 22.87 MPa at 7 days of 7.5% is lower compared to control strength. Forth at 14 days the strength was achieved 32.61 MPa and 26.03 MPa of 0% and 7.5%, respectively. The strength of 26.03 MPa is lower with a difference of 11.2%. Lastly, the 28 days strength is 36.66 MPa and 28.33 MPa for 0% and 7.5%, respectively. It shows the lowest difference of 12.8% for 28.33 MPa.

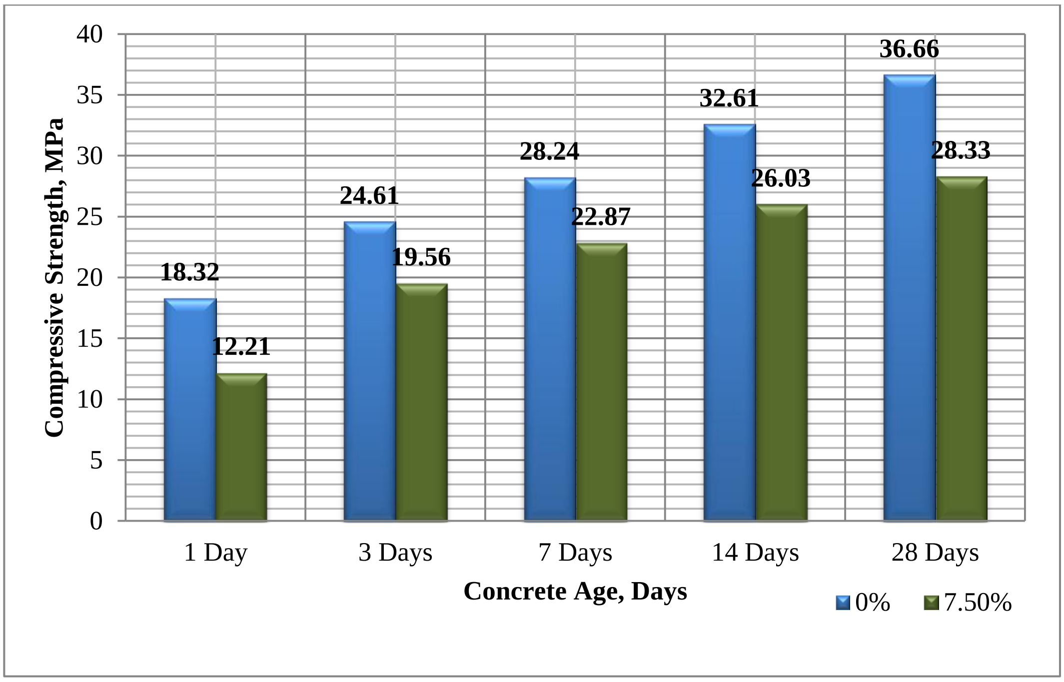


Figure 4.3: Comparison of compressive strength between 0% and 7.5% replacement

Figure 4.4 shows the strength of 0% and 10% replacement. For 1 day concrete age, the strength 18.32 MPa and 11.43 MPa for 0% and 10%, respectively. The percentage difference of 23.2% is lowest for 11.43 MPa. For 3, 7, 14 and 28 days, the strength was 18.53 MPa, 22.55 MPa, 25.33 MPa and 27.34 MPa of 0% and 10%, respectively. The 7.5% strength for 3, 7, 14, and 28 days are lower with a difference of 14.1% to 11.2%, respectively.

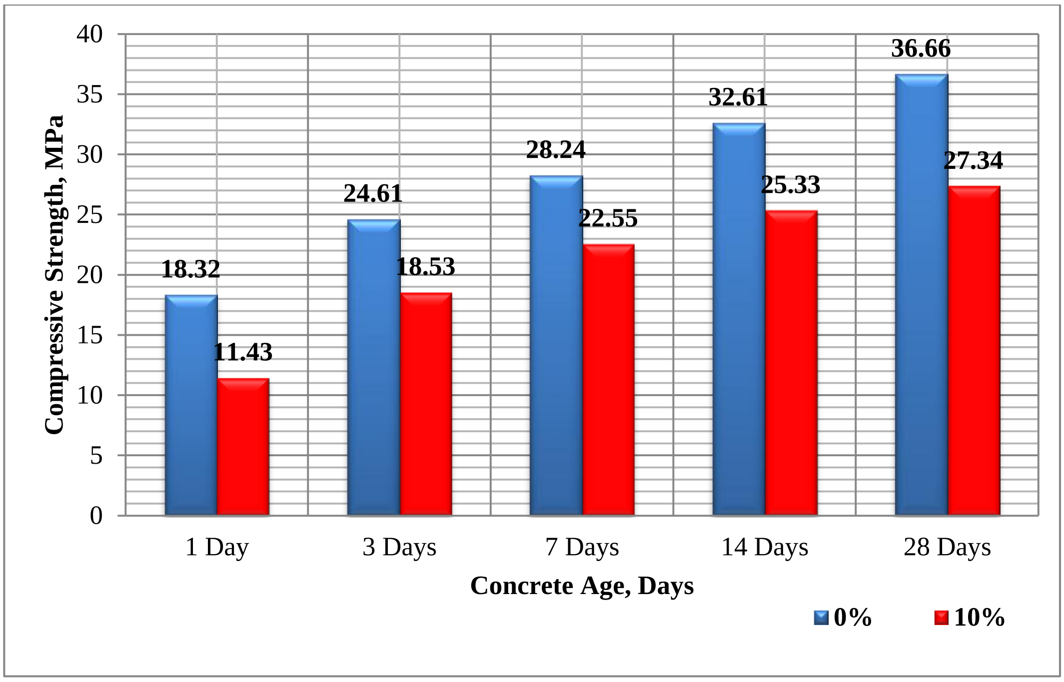
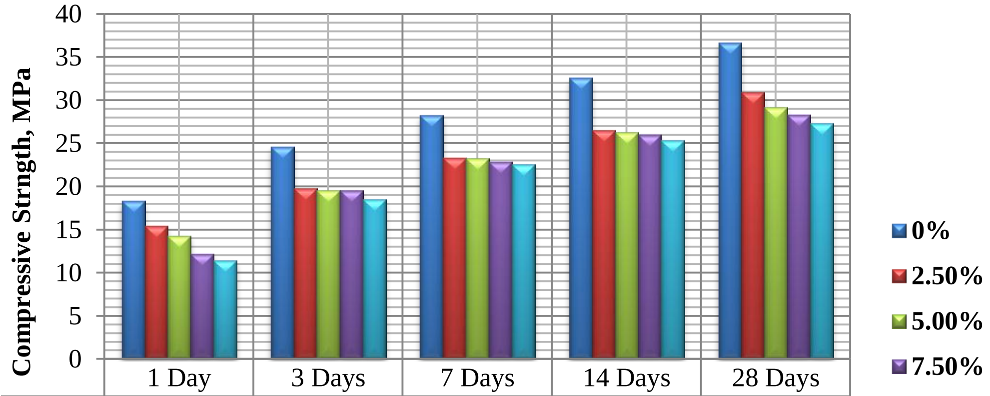


Figure 4.4: Comparison of compressive strength between 0% and 10% replacement

Figure 4.5 shows the summary of compressive strength of 0% up to 10% replacement. In general, the strength of all concretes increased accordingly with concrete age. From the results analysis, it was found that 2.5% replacement coconut shell (fine and coarse aggregates) has gained the most optimum results is higher than other percentages at 28 days. Based on the results, it can be concluded that the increase in percentage of coconut shell use, a decrease in strength was recorded. This possible reason is because of the shape of coconut shell is more flatted compared to conventional aggregate with angular shape. Because it has a better interlocking properties in the conventional aggregates compared to coconut shells. The mix was chosen for the mechanical properties test, including splitting tensile and flexural strength that are presented in the next section.



	1 Day	3 Days	7 Days	14 Days	28 Days
0%	18.32	24.61	28.24	32.61	36.66
2.50%	15.43	19.77	23.34	26.54	30.93
5.00%	14.32	19.58	23.25	26.32	29.2
7.50%	12.21	19.56	22.87	26.03	28.33
10%	11.43	18.53	22.55	25.33	27.34

Figure 4.5: Summary ofcompressive strength between 0% and 2.5%, 5.0%, 7.5%, 10% replacement

In addition, the results of compressive strength were analyzed based on the crack patterns obtained when it has reached the failure. There are 2 types of condition to indicate the failure based on the shape and crack of cubes which is satisfactory and unsatisfactory. Figures 4.6 and 4.7 show the various failures of a cube based on BS EN 12390-3:2009, respectively.

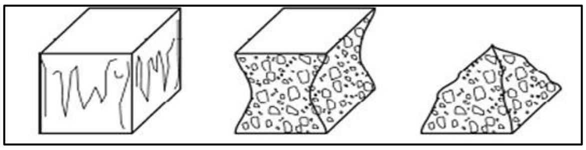


Figure 4.6: Satisfactory failures of cube specimens

Source: www.qemsolutions.com/news/a-simple-guide-to-concrete-cube-testing, 2013

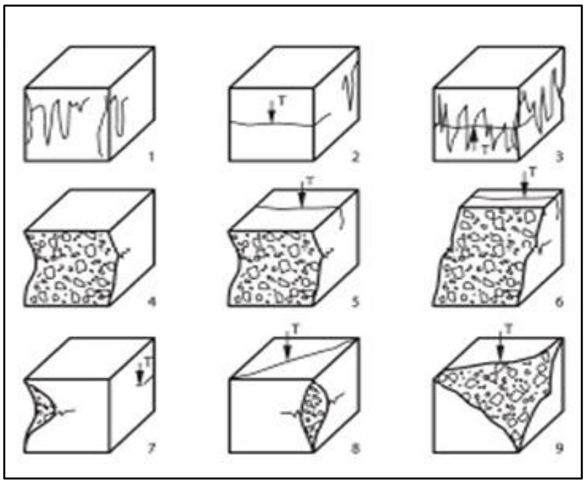


Figure 4.7: The some unsatisfactory failures of cube specimens

Source: www.qemsolutions.com/news/a-simple-guide-to-concrete-cube-testing, 2013

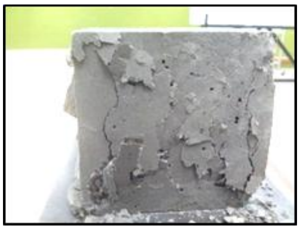
Figures 4.8 (a), (b), (c), (d) ad (e) show the factures of cube for 0%, 2.5%, 5.0%, 7.5% and 10% at 7 days concrete age, respectively. Based on the appearance of the cube 7 days with 0% and 2.5%, Figures 4.8 (a) and (b) show the crack was filled the surface hairline crack, respectively. Figures 4.8 (a) and (c) show the 0% and 5% of replacement specimens. For 5% cube it shows that the crack lines at the bottom edges was quite large compared to 0% at 7 days. It shows that the increased in percentage of replacement will decrease the limit of cube to resist the load. Figure 4.8 (a) and (d) show the crack pattern was under satisfactory failure, respectively. The 7 days concrete for 7.5% show that the crack was worst and can be clearly seen compared to the control. Figures 4.8 (a) and (e) show the crack pattern of 0% and 10% cubes at 7 days concrete age, respectively. Based on the factures of two cubes, it was under satisfactory failure. This is because of the specimens was not broken or fully crushed.

(a) The crack patterns of cube sample of 0% for 7 days

(b) The crack patterns cube sample of 2.5% for 7 days

(c) The crack patters cube sample of 5.0% for 7 days

(d) The crack patterns cube sample of 7.5% for 7 days



(e) The crack patters cube sample of 10% for 7 days

Figure 4.8: **(a)** The crack pattern of cube sample of 0% for 7 days, **(b)** The crack pattern of cube sample of 2.5% for 7 days, **(c)** The crack pattern of cube sample of 5.0% for 7 days, **(d)** The crack pattern of cube sample of 7.5% for 7 days, **(e)** The crack pattern of cube sample of 10% for 7 days

Figures 4.9 (a) and (b) show the crack pattern for cubes at 14 days with 0% and 2.5% of replacement, respectively. Similar crack pattern and the failure was obtained as discussed for the age of 7 days. The cube samples were in satisfactory failure. Next concrete at 14 days for 0% and 5% as shown in Figures 4.9 (a) and (c), respectively. The crack pattern at the bottom edge of 5% was found quite large as compared to the control. These cubes were determined to be satisfactory failure. Next is the comparison between 0% and 7.5% for 14 days concrete, respectively. The crack pattern was getting worse for 7.5% compared to the control as shown in Figures 4.9 (a) and (d), respectively. Figures 4.9 (a) and (e) show the concrete crack pattern at 14 days. Both of the cubes were in the group of satisfactory failure, whereby the actual shape was still maintained after 10% fracture. The cube at 10% did not show a significant crack pattern on concrete surface.

(a) The crack pattern of cube sample of 0% for 14 days

(b) The crack patterns cube sample of 2.5% for 14 days

(c) The crack patters cube sample of 5.0% for 14 days

(d) The crack patterns cube sample of 7.5% for 14 days

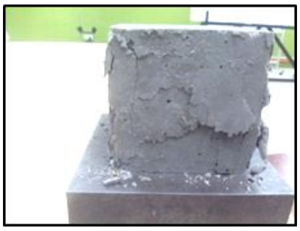
(e) The crack patters cube sample of 10% for 14 days

Figure 4.9: **(a)** The crack pattern of cube sample of 0% for 14 days, **(b)** The cube crack pattern of sample of 2.5% for 14 days, **(c)** The crack pattern of cube sample of 5.0% for 14 days, **(d)** The crack pattern of cube sample of 7.5% for 14 days, **(e)** The crack pattern of cube sample of 10% for 14 days

For the 28 days, the pattern failure was satisfactory for 0% and 2.5% cubes. Comparing these two cubes, the crack pattern obtained was found a similar crack on the edges of the specimens, as shown in Figures 4.10 (a) and (b), respectively. Next for 0% and 5% specimens at 28 days, was categorized under satisfactory failure as were of crack lines found on 5% cubes. These can be seen in Figures 4.10 (a) and (c), respectively. Figures 4.10 (a) and (d) show the cubes and it was located under satisfactory failure, respectively. The 7.5% replacement show the crack lines had fully covered the surfaces. These specimens shown for 28 days age of concrete. Last but not least is the crack pattern at 28 days concrete age for 0% and 10% replacement. From Figures 4.10 (a) and (e) show the failure pattern of cube specimens, respectively. It can be classified as satisfactory failure. It can be summarized that the concrete becomes more brittle when the percentage of replacement aggregates was increased.

(a) The crack pattern of cube sample of 0% for 28 days

(b) The crack patterns cube sample of 2.5% for 2 days



(c) The crack patters cube sample of 5.0% for 28 days

(d) The crack patterns cube sample of 7.5% for 28 days

(e) The crack patters cube sample of 10% for 28 days

Figure 4.10: **(a)** The crack pattern of cube sample of 0% for 28 days, **(b)** The crack pattern of cube sample of 2.5% for 28 days, **(c)** The crack pattern of cube sample of 5.0% for 28 days, **(d)** The crack pattern of cube sample of 7.5% for 28 days, **(e)** The crack pattern of cube sample of 10% for 28 days

4.2 SPLITTING TENSILE TEST

The splitting tensile strength test was conducted on standard cylinders is 150 mm (Diameter) x 300 mm (Length) of control and coconut shell concrete with partial replacement of 0% and 2.5% that cured in water for 7, 14, and 28 days. The results of splitting tensile strength are listed in Table 4.2.

Table 4.2: Splitting Tensile Strength of Coconut Shell Concrete

Concrete Age, Days	0% (MPa)	2.5% (MPa)
7	2.48	1.90
14	2.91	2.32
28	3.07	2.68

The splitting tensile strength of coconut shell concrete at 28 days is presented in Figure 4.11. For the control concrete, the splitting tensile strength is 2.48 MPa and 1.90 MPa for 0% and 2.5%, respectively at 7 days. The early strength of 2.5% shows a lower strength of 13.2%. Next, the strength was recorded for 14 days was 2.91 MPa and 2.32 MPa of 0% and 2.5%, respectively. At 14 days, 2.5% replacement concrete still in a lower value with a difference of 11.3%. Lastly, for 28 days, which is increased improve percentage to 12.7% with strength 3.07 MPa and 2.68 MPa. The result shows, the coconut shell concrete not good in splitting tensile strength. This may be due to the characteristic of coconut shell, which is it lower in resisting the direct tension. At 28 days, splitting tensile strength obtained was 3.07 MPa and 2.68 MPa for 0% and 2.5%, respectively. The replacement at 2.5% aggregate still shows a lower value compared to the control, with a difference of 6.8%. Overall, I can be concluded that coconut shell as course and fine aggregates replacement in concrete was very little improvement in concrete, with less bending behavior since a lower value was obtained in splitting tensile strength.

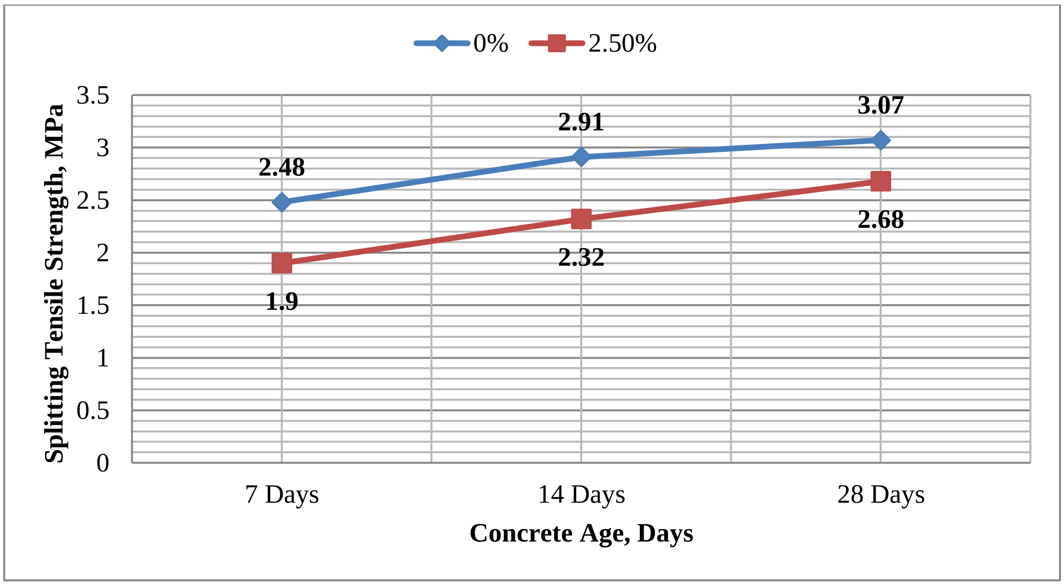
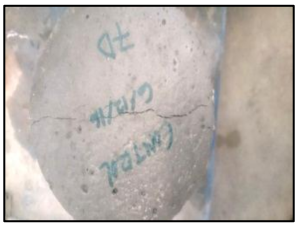


Figure 4.11: Comparison of splitting tensile strength between 0% and 2.5% replacement

The results of splitting tensile strength also can be analyzed based on the crack pattern when the specimens have reached the maximum limits to resist the load. Figures 4.12 (a) and (b) show the crack pattern of 0% and 2.5% cylinders for 7 days, respectively. In 0%, a tiny crack line was observed at the center, but for 2.5% the crack lines was seen around the surface. The cylinder was still intact for both percentages as the cylinders are still in their actual shape. The condition specimens for both percentage are in actual shape which is not split into two parts. The failure pattern was categorized as axial split.



(a) The crack patterns cylinder sample of 0% for 7 days

(b) The crack pattern cylinder samples of 2.5% for 7 days

Figure 4.12: **(a)** The crack pattern cylinder sample of 0% for 7 days, **(b)** The crack pattern cylinder samples of 2.5% for 7 days

Next is the Figures 4.13 (a) and (b) show the 14 days cylinders of 0% and 2.5% replacement, respectively. The failure pattern for both percentages is in the form of axial split.

(a) The crack patterns cylinder sample of 0% for 14 days

(b) The crack pattern cylinder samples of 2.5% for 14 days

Figure 4.13: **(a)** The crack pattern cylinder sample of 0% for 14 days, **(b)** The crack pattern cylinder samples of 2.5% for 14 days

The failure pattern of 0% and 2.5% replacement was in axial split at 28 days. Figures 4.14 (a) and (b) show that the line was traced and propagated and penetrated the whole of specimens.

(a) The crack pattern cylinder samples of 0% for 28 days

(b) The crack pattern cylinder sample of 2.5% for 28 days

Figure 4.14: **(a)** The crack pattern cylinder samples of 0% for 28 days, **(b)** The crack pattern cylinder sample of 2.5% for 28 days

4.3 FLEXURAL STRENGTH

The flexural strength test was conducted on standard beams (100 x 100 x 500 mm) of control and coconut shell concrete with partial replacement of 0% and 2.5% that cured in water for 7, 14, and 28 days. The results of flexural strength are listed in Table 4.3.

Table 4.3: Flexural strength of coconut shell concrete

Concrete Age, Days	0% (MPa)	2.5% (MPa)
7	3.07	1.92
14	4.29	3.82
28	4.57	6.13

Figure 4.15 shows, the comparison of flexural strength and concrete age for control (0%) and coconut shell concrete (2.5% replacement) at 7, 14 and 28 days. The results, it shows that 7 days concrete age was recorded 3.07 MPa and 1.92 MPa, respectively with a difference of 23%. Next, at 14 days the strength is 4.29 MPa and 3.83 MPa, respectively. The percentage was suddenly decreased to 5.7%. Moreover, for the 28 days, the strength of 2.5% replacement is higher than the control with 6.13 MPa with a difference of 14.6%. From the flexural strength results, it was found that the beam in 28 days can resist higher load because of the strength was more than the control.

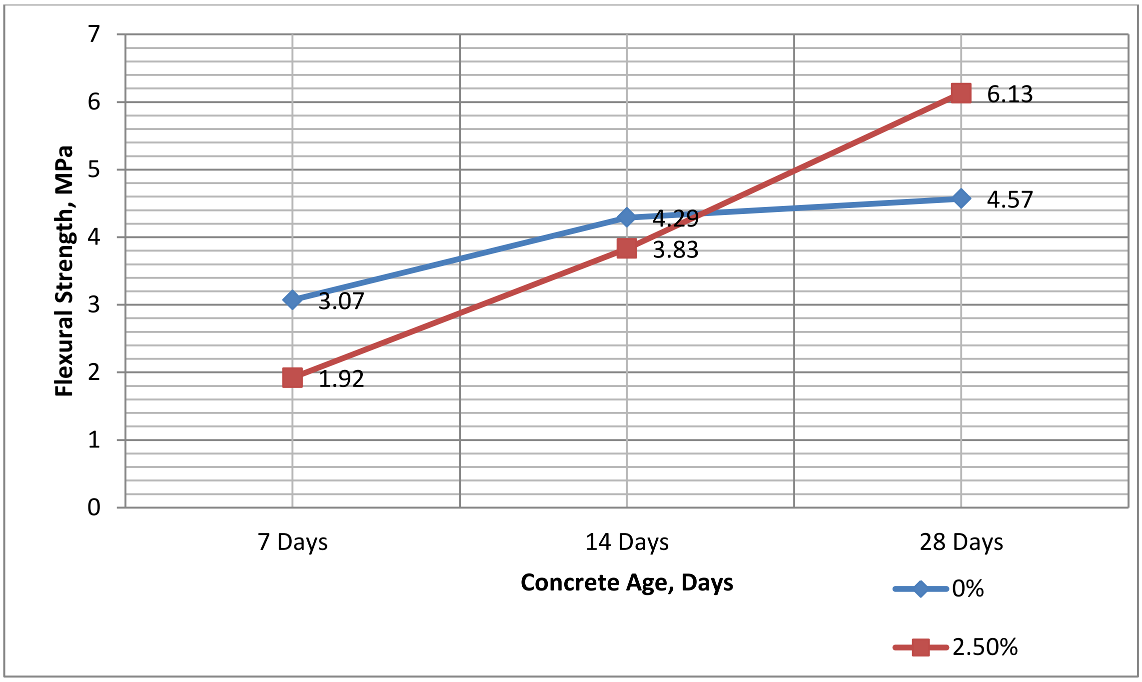


Figure 4.15: The comparison strength between 0% and 2.5% for 7, 14 and 28 days

Figures 4.16 (a) and (b) show the failure pattern of beams for 7 days, respectively. The beams was conducted for 0% and 2.5% were broken into two parts, respectively. It is because the beams was cast as plain concrete. The concrete was categorized under fully brittle failure.

(a) The crack pattern beam sample of 0% for 7 days

(b) The crack pattern beam samples of 2.5% for 7 days

Figure 4.16: (a) The crack pattern beam sample of 0% for 7 days, (b) The crack pattern beam samples of 2.5% for 7 days

Figures 4.17 (a) and (b) show the crack pattern of 0% and 2.5% of 14 days, respectively. Similar as 7 days, the beams were broken into two parts and can be determined as a fully brittle failure.

(a) The crack patterns beam sample of 0% for 14 days

(b) The crack pattern beam samples of 2.5% for 14 days

Figure 4.17 (a): (a) The crack pattern beam sample of 0% for 14 days, (b) The crack pattern beam samples of 2.5% for 14 days

Figures 4.18 (a) and (b) show the for the failure pattern of 0% and 2.5% replacement at 28 days, respectively. The specimens were broken into two parts after the load directly applied. It can be summarized that is the coconut shell as replacement of aggregate behave similar as control beam as concrete is weak in tension and brittle in nature. The addition of 2.5% coarse aggregates did not show significant effect on the crack pattern and failure mode of beams.

(a) The crack pattern beam samples of 0% for 28 days

(b) The crack pattern beam samples of 2.5% for 28 days

Figure 4.18: (a) The crack pattern beam samples of 0% for 28 days, (b) The crack pattern beams samples of 2.5% for 28 days

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 OVERVIEW

In this section, the conclusion on compressive strength, flexural strength and splitting tensile strength was summarized.

5.2 CONCLUSION

From the results obtained, the following conclusion can be drawn based on the objectives. There are two objectives of this project, first is to identify the optimum mix design of concrete using coconut shell as a partial replacement of aggregate. Based on the result, it can be concluded that based on the compressive strength at 28 days the 2.5% replacement was chosen as an optimum mix design for this project. It is because the strength of 2.5% is 30.93 MPa is higher compared to other percentage replacement

The second objective is to determine the mechanical properties of concrete using coconut shell as partial replacement of aggregate based on compressive strength, splitting tensile strength and flexural strength. From the results, it can be concluded that the coconut shell concrete of compressive strength was obtained decreased when the percentages of replacement is increased. The strength of coconut shell concrete was more than ranged of design grade 25 MPa. Hence, it can be used in structural components in construction field. In splitting tensile strength, results show that the coconut shell concrete were lowest in resisting direct tension and low in bending properties. Lastly is flexural strength, it can be concluded that the coconut shell concrete was higher in resist bend strength and higher stress. This may be due to the shape of coconut shell which is flat and can increase the failure time.

5.3 RECOMMENDATION

In this study, recommendations that listed below are for the future research guidance.

i. Durability factor can be determined by carrying some durability tests on the coconut shell cube specimens.
ii. Lightweight construction units can be made by using these wastes like panels & block production, internal wall casting and outdoor furniture.
iii. Combination with fly sh can also be an option for future experimentation.

REFERENCE

Ahlawat, D., & Kalurkar, L. G. (2014). Coconut Shell as Partial Replacement of Coarse Aggregate in Concrete, *2014*, 61–64.

Apeksha Kanojia, S. K. J. (2015). Performance of Coconut Shell as Coarse Aggregate in Concrete: A Review, *4*(07), 77–80.

Compressive Strength Of Concrete And Mortar Containing Ashes As Partial Replacement For Cement By Amamat Oluwatoyin Adeyemi , Faculty Of Engineering February 2014. (2014), (February).

Ishak, B. (2002). The law of industrial waste management in Malaysia.

Kamal, J., & Singh, P. J. P. (2015). Experimental Study on Strength Characteristics of M25 Concrete with Partial Replacement of coarse aggregate with coconut shell and cement with Fly Ash, 4373–4381. http://doi.org/10.15680/IJIRSET.2015.0406114

Kambli, P. S., & Mathapati, S. R. (2014). Application of Coconut Shell as Coarse Aggregate in Concrete : A Technical Review, *4*(3), 498–501.

Kaur, M., & Kaur, M. (2012). A review on utilization of coconut shell as coarse aggregates in mass concrete. *International Journal of Applied Engineering Research*, *7*(11 SUPPL.), 2063–2065.

Kumar, N. (2014). Effect of Partial Replacement of Cement with Fly Ash and Coarse Aggregate with Coconut Shell on properties of concrete, *3*(5), 72–80.

Learning, I., & Disclaimer, C. R. (n.d.). How to develop a waste management and How to develop a waste management and disposal strategy, *44*(0).

Material, C. (n.d.). Concrete 1.

Melorose, J., Perroy, R., & Careas, S. (2015). No Title No Title. *Statewide Agricultural Land Use Baseline 2015*, *1*. http://doi.org/10.1017/CBO9781107415324.004

National Ready Mixed Concrete Association. (2000). CIP 16 - Flexural Strength Concrete. *NRMCA Publications*, 1–2.

No Title. (2010), *2024*, 14–57.

Osei, D. Y., Engineering, C., & Coast, C. (2013). Experimental assessment on coconut shells as aggregate in concrete. *International Journal of Engineering Science Inventions*, *2*(5), 7–11.

Page, H. (n.d.). Aggregates for Concrete, (69792).

Papers, K. (n.d.). What A Waste A Global Review of Solid Waste Management.

Rao, K. V. (2015). Engineering Study On Strength Properties Of Coconut, 42–61.

Reddy, B. D., Jyothy, S. A., & Shaik, F. (2014). Experimental Analysis of the Use of Coconut Shell as Coarse Aggregate, *10*(6), 6–13.

Shaikh, A. S., Thorat, S. B., Unde, R. V, Shirse, P. S., Shaikh, A. S., Engineering, C., & Polytechnic, A. (2015). Advance Concrete-Aggregate replaced by Coconut Shell.

Shinde, L. M., & Engg, M. T. S. (2013). A Review on Consumption of Agricultural Waste Material (Coconut Shell) As Aggregate in Design Mix Concrete, 5–6.

United Nations. (2000). Solid waste management. *State of the Environment in Asia and the Pacific*, 170–194. Retrieved from http://www.unescap.org/esd/environment/soe/2000/download.asp

Wikipedia, F. (2012). Types of concrete, 1–10.

APPENDIX A

MIX DESIGN CALCULATION

Determination of Water Cement Ratio	
Margin, M	= KS = 1.64 x 8 = 13.12 N/mm^2

Calculation of Target Mean Strength, f_m	
f_m	= f_c + M = 25 +13.12 = 38 N/mm^2

Determination of Free Water Content	
Slump/Vebe Time	30 - 60
Maximum Size Aggregate	= 20 mm = 210 Kg/m^3

Determination of Cement Content	
Cement Content	= Free Water Content / Water Cement Ratio = 210 / 0.5 = 420 Kg/m^3

Determination of Total Aggregate Content	
SSD	2.7
Concrete Density	2400 Kg/m^3
Total Aggregate Content	= D-C-W = 2400 – 420 - 210 = 1770 Kg/m^3

Determination of Fine & Coarse Aggregate Contents	
Fine Aggregate	< 5 mm
Fine Aggregate Content	= Total Aggregate Content x Proportions of Fines = 1770 x 36% = 637 Kg/m^3
Coarse Aggregate Content	= Total Aggregate Content – Fine Aggregate = 1770 - 637 = 1133 Kg/m^3

APPENDIX B

CALCULATION OF MATERIAL USED FOR COMPRESSIVE STRENGTH

Control Concrete (0%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.015 m^3 x 420 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Water	0.015 m^3 x 210 Kg/m^3	3.2
Wastage	0.1 x 3.2	0.3
Total	3.2 + 0.3	**3.5**
Fine Aggregate	0.015 m^3 x 637	9.6
Wastage	0.1 x 9.6	1.0
Total	9.6 + 1.0	**10.6**
Coarse Aggregate	0.015 m^3 x 1133	17.0
Wastage	0.1 x 17.0	1.7
Total	17.0 + 1.7	**18.7**

Coconut Shell Concrete (2.5%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.015 m^3 x 420 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Water	0.015 m^3 x 210 Kg/m^3	3.2
Wastage	0.1 x 3.2	0.3
Total	3.2 + 0.3	**3.5**
Fine Aggregate	0.015 m^3 x 637	9.6
Wastage	0.1 x 9.6	1.0
Total	9.6 + 1.0	10.6
2.5% Coconut Shell (Fine)	0.025 x 10.6	**0.3**
97.5% Fine Aggregate	10.6 – 0.3	**10.3**
Coarse Aggregate	0.015 m^3 x 1133 Kg/m^3	17.0
Wastage	0.1 x 17.0	1.7
Total	17.0 + 1.7	18.7
2.5% Coconut Shell (Coarse)	0.025 x 18.7	**0.5**
97.5% Coarse Aggregate	18.7 – 0.5	**18.2**

Coconut Shell Concrete (5%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.015 m^3 x 420 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Water	0.015 m^3 x 210 Kg/m^3	3.2
Wastage	0.1 x 3.2	0.3
Total	3.2 + 0.3	**3.5**
Fine Aggregate	0.015 m^3 x 637	9.6
Wastage	0.1 x 9.6	1.0
Total	9.6 + 1.0	10.6
5% Coconut Shell (Fine)	0.05 x 10.6	**0.5**
95% Fine Aggregate	10.6 – 0.5	**10.1**
Coarse Aggregate	0.015 m^3 x 1133 Kg/m^3	17.0
Wastage	0.1 x 17.0	1.7
Total	17.0 + 1.7	18.7
5% Coconut Shell (Coarse)	0.05 x 18.7	**0.9**
95% Coarse Aggregate	18.7 – 0.9	**17.8**

Coconut Shell Concrete (7.5%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.015 m^3 x 420 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Water	0.015 m^3 x 210 Kg/m^3	3.2
Wastage	0.1 x 3.2	0.3
Total	3.2 + 0.3	**3.5**
Fine Aggregate	0.015 m^3 x 637	9.6
Wastage	0.1 x 9.6	1.0
Total	9.6 + 1.0	10.6
7.5% Coconut Shell (Fine)	0.075 x 10.6	**0.8**
92.5% Fine Aggregate	10.6 – 0.8	**9.8**
Coarse Aggregate	0.015 m^3 x 1133 Kg/m^3	17.0
Wastage	0.1 x 17.0	1.7
Total	17.0 + 1.7	18.7
7.5% Coconut Shell (Coarse)	0.075 x 18.7	**1.4**
92.5% Coarse Aggregate	18.7 – 1.4	**17.3**

Coconut Shell Concrete (10%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.015 m^3 x 420 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Water	0.015 m^3 x 210 Kg/m^3	3.2
Wastage	0.1 x 3.2	0.3
Total	3.2 + 0.3	**3.5**
Fine Aggregate	0.015 m^3 x 637	9.6
Wastage	0.1 x 9.6	1.0
Total	9.6 + 1.0	10.6
10% Coconut Shell (Fine)	0.1 x 10.6	**1.1**
90% Fine Aggregate	10.6 – 1.1	**9.5**
Coarse Aggregate	0.015 m^3 x 1133 Kg/m^3	17.0
Wastage	0.1 x 17.0	1.7
Total	17.0 + 1.7	18.7
10% Coconut Shell (Coarse)	0.1 x 18.7	**1.9**
90% Coarse Aggregate	18.7 – 1.9	**16.8**

APPENDIX C

CALCULATION OF MATERIAL USED FOR SPLITTING TENSILEL STRENGTH

Control Concrete (0%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.03 m^3 x 420 Kg/m^3	12.6
Wastage	0.1 x 12.6	1.3
Total	12.6 + 1.3	**13.9**
Water	0.03 m^3 x 210 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Fine Aggregate	0.03 m^3 x 637	19.1
Wastage	0.1 x 19.1	1.9
Total	19.1 + 1.9	**21.0**
Coarse Aggregate	0.03 m^3 x 1133	34.0
Wastage	0.1 x 34.0	3.4
Total	34 + 3.4	**37.4**

Coconut Shell Concrete (2.5%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.03 m^3 x 420 Kg/m^3	12.6
Wastage	0.1 x 12.6	1.3
Total	12.6 + 1.3	**13.9**
Water	0.03 m^3 x 210 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Fine Aggregate	0.03 m^3 x 637	19.1
Wastage	0.1 x 19.1	1.9
Total	19.1 + 1.9	**21.0**
2.5% Coconut Shell (Fine)	0.025 x 21.0	**0.5**
97.5% Fine Aggregate	21 + 0.5	**21.5**
Coarse Aggregate	0.03 m^3 x 1133	34.0
Wastage	0.1 x 34.0	3.4
Total	34 + 3.4	**37.4**
2.5% Coconut Shell (Coarse)	0.025 x 37.4	**0.9**
97.5% Coarse Aggregate	37.4 + 0.9	**38.3**

APPENDIX D

CALCULATION OF MATERIAL USED FOR FLEXURAL STRENGTH

Control Concrete (0%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.03 m^3 x 420 Kg/m^3	12.6
Wastage	0.1 x 12.6	1.3
Total	12.6 + 1.3	**13.9**
Water	0.03 m^3 x 210 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Fine Aggregate	0.03 m^3 x 637	19.1
Wastage	0.1 x 19.1	1.9
Total	19.1 + 1.9	**21.0**
Coarse Aggregate	0.03 m^3 x 1133	34.0
Wastage	0.1 x 34.0	3.4
Total	34 + 3.4	**37.4**

Coconut Shell Concrete (2.5%)		
MATERIAL	**CALCULATION**	**WEIGHT (KG)**
Cement	0.03 m^3 x 420 Kg/m^3	12.6
Wastage	0.1 x 12.6	1.3
Total	12.6 + 1.3	**13.9**
Water	0.03 m^3 x 210 Kg/m^3	6.3
Wastage	0.1 x 6.3	0.6
Total	6.3 + 0.6	**6.9**
Fine Aggregate	0.03 m^3 x 637	19.1
Wastage	0.1 x 19.1	1.9
Total	19.1 + 1.9	**21.0**
2.5% Coconut Shell (Fine)	0.025 x 21.0	**0.5**
97.5% Fine Aggregate	21 + 0.5	**21.5**
Coarse Aggregate	0.03 m^3 x 1133	34.0
Wastage	0.1 x 34.0	3.4
Total	34 + 3.4	**37.4**
2.5% Coconut Shell (Coarse)	0.025 x 37.4	**0.9**
97.5% Coarse Aggregate	37.4 + 0.9	**38.3**

APPENDIX E

WEIGHT RATIO FOR COMPRESSIVE STRENGTH

Control Concrete (0%)	
ITEM	**WEIGHT (g)**
Total Cement	**6.9**
Total Water	**3.5**
Total Fine Aggregate	**10.6**
Total Coarse Aggregate	**18.7**

Coconut Shell Concrete (2.5%)	
ITEM	**WEIGHT (g)**
Total Cement	**18.2**
Total Water	**0.5**
Total Coconut Shell (Fine)	**10.3**
Total Fine Aggregate	**0.3**
Total Coconut Shell (Coarse)	**3.5**
Total Coarse Aggregate	**6.9**

Coconut Shell Concrete (5%)	
ITEM	**WEIGHT (g)**
Total Cement	**6.9**
Total Water	**3.5**
Total Coconut Shell (Fine)	**0.5**
Total Fine Aggregate	**10.1**
Total Coconut Shell (Coarse)	**0.9**
Total Coarse Aggregate	**17.8**

Coconut Shell Concrete (7.5%)	
ITEM	**WEIGHT (g)**
Total Cement	**6.9**
Total Water	**3.5**
Total Coconut Shell (Fine)	**0.8**
Total Fine Aggregate	**9.8**
Total Coconut Shell (Coarse)	**1.4**
Total Coarse Aggregate	**17.3**

Coconut Shell Concrete (10%)	
ITEM	**WEIGHT (g)**
Total Cement	**6.9**
Total Water	**3.5**
Total Coconut Shell (Fine)	**1.1**
Total Fine Aggregate	**9.5**
Total Coconut Shell (Coarse)	**1.9**
Total Coarse Aggregate	**16.8**

APPENDIX F

WEIGHT RATIO FOR SPLITTING TENSILE STRENGTH

Control Concrete (0%)	
ITEM	**WEIGHT (g)**
Total Cement	**23.1**
Total Water	**11.6**
Total Fine Aggregate	**35.1**
Total Coarse Aggregate	**62.4**

Coconut Shell Concrete (2.5%)	
ITEM	**WEIGHT (g)**
Total Cement	**23.1**
Total Water	**11.6**
Total Coconut Shell (Fine)	**0.9**
Total Fine Aggregate	**34.2**
Total Coconut Shell (Coarse)	**1.6**
Total Coarse Aggregate	**60.8**

WEIGHT RATIO FOR FLEXURAL STRENGTH

Control Concrete (0%)	
ITEM	**WEIGHT (g)**
Total Cement	**23.1**
Total Water	**11.6**
Total Fine Aggregate	**35.1**
Total Coarse Aggregate	**62.4**

Coconut Shell Concrete (2.5%)	
ITEM	**WEIGHT (g)**
Total Cement	**23.1**
Total Water	**11.6**
Total Coconut Shell (Fine)	**0.9**
Total Fine Aggregate	**34.2**
Total Coconut Shell (Coarse)	**1.6**
Total Coarse Aggregate	**60.8**

APPENDIX G1

RAW DATA COMPRESSIVE STRENGTH FOR 0%

1 DAY		
DATE: 17/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2229	17.46
2	2294	19.54
3	2254	17.96
AVERAGE	2259	18.32

3 DAYS		
DATE: 19/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2336.1	26.52
2	2191.5	22.32
3	2287.1	24.98
AVERAGE	2271.6	24.61

7 DAYS		
DATE: 23/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2228.2	27.31
2	2332.7	29.56
3	2262.3	27.84
AVERAGE	2274.4	28.24

14 DAYS		
DATE: 30/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2232.6	32.65
2	2245.4	32.08
3	2203.2	33.10
AVERAGE	2227.1	32.61

28 DAYS		
DATE: 13/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2319.0	36.36
2	2312.6	36.23
3	2218.7	37.41
AVERAGE	2283.4	36.66

APPENDIX G2

RAW DATA COMPRESSIVE STRENGTH FOR 2.5%

1 DAY		
DATE: 25/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2226.5	15.29
2	2156.5	14.21
3	2218.6	16.79
AVERAGE	2200.5	15.43

3 DAYS		
DATE: 27/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2261.4	20.50
2	2177.5	19.75
3	2235.7	19.05
AVERAGE	2224.9	19.77

7 DAYS		
DATE: 31/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2274.2	23.55
2	2226.6	22.33
3	2273.8	23.85
AVERAGE	2258.2	23.25

14 DAYS		
DATE: 7/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2228.6	27.31
2	2336.3	26.26
3	2301.6	26.05
AVERAGE	2288.8	26.54

28 DAYS		
DATE: 21/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2208.5	31.93
2	2195.5	30.41
3	2258.9	30.45
AVERAGE	2221.0	30.93

APPENDIX G3

RAW DATA COMPRESSIVE STRENGTH FOR 5.0%

1 DAY		
DATE: 25/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2182.2	14.63
2	2155.3	14.15
3	2171.4	14.18
AVERAGE	2169.6	14.32

3 DAYS		
DATE: 27/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2220.0	19.72
2	2209.7	20.81
3	2178.3	18.23
AVERAGE	2202.7	19.58

7 DAYS		
DATE: 31/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2279.9	23.55
2	2276.3	23.03
3	2258.2	23.00
AVERAGE	2238.1	23.19

14 DAYS		
DATE: 7/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2223.4	26.08
2	2263.4	26.48
3	2182.0	26.38
AVERAGE	2222.9	26.32

28 DAYS		
DATE: 21/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2143.5	28.97
2	2180.0	28.73
3	2118.0	29.90
AVERAGE	2147.4	29.20

APPENDIX G4

RAW DATA COMPRESSIVE STRENGTH FOR 7.5%

1 DAY		
DATE: 26/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2114.0	12.63
2	2096.5	11.40
3	2198.4	12.61
AVERAGE	2136.3	12.21

3 DAYS		
DATE: 29/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2172.9	20.23
2	2156.0	18.29
3	2189.6	20.16
AVERAGE	2172.8	29.56

7 DAYS		
DATE: 2/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2161.5	22.03
2	2143.3	22.58
3	2151.4	23.99
AVERAGE	2152.1	22.87

14 DAYS		
DATE: 9/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2204.8	26.12
2	2214.8	26.94
3	2146.7	25.12
AVERAGE	2188.5	26.03

28 DAYS		
DATE: 23/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2136.3	28.02
2	2165.3	28.01
3	2187.1	28.94
AVERAGE	2162.9	28.33

APPENDIX G5

RAW DATA COMPRESSIVE STRENGTH FOR 10%

1 DAY		
DATE: 26/8/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2128.1	11.60
2	2131.5	11.98
3	2083.7	10.72
AVERAGE	2114.4	11.43

3 DAYS		
DATE: 29/8/2006		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2226.7	18.88
2	2133.4	18.05
3	2146.1	18.65
AVERAGE	2168.7	18.53

7 DAYS		
DATE: 2/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2142.0	22.80
2	2123.5	22.03
3	2146.0	22.84
AVERAGE	2137.2	22.55

14 DAYS		
DATE: 9/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2184.6	25.74
2	2126.4	25.79
3	2166.9	24.25
AVERAGE	2159.3	25.33

28 DAYS		
DATE: 23/9/2016		
CUBE	WEIGHT (g)	STRENGTH (MPa)
1	2133.9	27.93
2	2133.0	27.39
3	2153.8	26.69
AVERAGE	2140.2	27.34

APPENDIX H

RAW DATA SPLITTING TENSILE STRENGTH FOR 0%

7 DAYS		
DATE: 14/12/2016		
CYLINDER	LOAD (kN)	STRENGTH (MPa)
1	187.6	2.65
2	162.9	2.30
AVERAGE	176.3	2.49

14 DAYS		
DATE: 21/12/2016		
CYLINDER	LOAD (kN)	STRENGTH (MPa)
1	198.4	2.81
2	212.4	3.00
AVERAGE	205.4	2.91

28 DAYS		
DATE:4/1/2017		
CYLINDER	LOAD (kN)	STRENGTH (MPa)
1	217.6	3.08
2	215.5	3.05
AVERAGE	216.6	3.06

RAW DATA SPLITTING TENSILE STRENGTH FOR 2.5%

7 DAYS		
DATE: 20/10/2016		
CYLINDER	LOAD (kN)	STRENGTH (MPa)
1	136.2	1.92
2	133.0	1.88
AVERAGE	134.6	1.90

14 DAYS		
DATE: 27/10/2016		
CYLINDER	LOAD (kN)	STRENGTH (MPa)
1	197.2	2.79
2	181.1	2.56
AVERAGE	189.2	2.68

28 DAYS		
DATE: 10/11/2016		
CYLINDER	LOAD (kN)	STRENGTH (MPa)
1	165.7	2.34
2	161.8	2.29
AVERAGE	163.8	2.32

APPENDIX J

RAW DATA FLEXURAL STRENGTH FOR 0%

7 DAYS	
DATE: 14/12/2016	
BEAM	STRENGTH (MPa)
1	2.72
2	3.42
AVERAGE	3.07

14 DAYS	
DATE: 21/12/2016	
BEAM	STRENGTH (MPa)
1	4.27
2	4.31
AVERAGE	4.29

28 DAYS	
DATE: 4/1/2017	
BEAM	STRENGTH (MPa)
1	4.09
2	5.16
AVERAGE	4.63

RAW DATA FLEXURAL STRENGTH FOR 2.5%

7 DAYS	
DATE: 20/10/2016	
BEAM	STRENGTH (MPa)
1	1.61
2	2.23
AVERAGE	1.92

14 DAYS	
DATE: 27/10/2016	
BEAM	STRENGTH (MPa)
1	4.88
2	4.79
AVERAGE	4.84

28 DAYS	
DATE: 10/11/2016	
BEAM	STRENGTH (MPa)
1	5.20
2	5.07
AVERAGE	5.14