AN EXPERIMENTAL STUDY OF THE STRUCTURAL CAPACITY OF RECTANGULAR BEAM UNDER FLEXURAL TEST – RICE HUSK CONCRETE (0%, 10% & 12% REPLACEMENT)

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Thesis submitted in fulfillment of the requirements
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ABSTRAK

Pengeluaran simen menggunakan sumber semula jadi, tenaga yang tinggi dan menghasilkan jumlah gas rumah hijau yang tinggi. Ia menyebabkan hampir 7% daripada pelepasan karbon dioksida global, kerana pengeluaran satu tan simen Portland biasa mengeluarkan satu tan karbon dioksida. Kini isu utama adalah kesan persekitaran dan kesan kesihatan yang meningkat dari hari ke hari. Oleh itu, penggunaan konkrit hijau dalam pembinaan mestilah digunakan secara meluas sebagai alternatif untuk konkrit konvensional dan kerana manfaat penggunaan konkrit hijau itu sendiri. Konkrit hijau akan mengurangkan pelepasan gas rumah hijau, memulihara sumber semula jadi dan mengurangkan masalah di kawasan tapak pelupusan yang terhad. Penyelidikan untuk kemampanan telah menyebabkan pencarian bahan pengganti yang mungkin menggantikan beberapa sumber semula jadi. Beberapa produk sisa pertanian seperti sekam padi, abu sekam padi, kerang minyak kelapa sawit, abu buangan kayu dan tempurung kelapa didapati berguna sebagai alternatif pengganti untuk simen, agregat halus, agregat kasar dan bahan pengukuhan. Masalah pelupusan sisa pertanian di banyak negara telah mencipta peluang untuk penggunaan sisa agro dalam sektor pembinaan. Walau bagaimanapun, kajian mengenai kapasiti struktur dan prestasinya masih berterusan. Ciri kekuatan dan ketahanan konkrit sekam padi telah dikaji secara meluas tetapi kesesuaiannya untuk digunakan sebagai konkrit struktur masih dalam kajian terperinci dan dipersoalkan. Kajian ini membentangkan prestasi struktur dan tingkah laku rasuk konkrit bertetulang yang menggunakan sekam padi sebagai pengganti sebahagian daripada agregat halus. Kerja-kerja eksperimen telah dijalankan melibatkan sembilan struktur rasuk konkrit berasaskan dimensi 150 mm x 300 mm x 1500 mm. Terdapat tiga rasuk terkawal dengan penggantian 0% dan enam rasuk lain dengan 10% dan penggantian 12%. Data yang dikemukakan dalam kajian ini termasuk kapasiti momen, ciri pesongan, perilaku retak dan beban muktamad yang boleh ditahan oleh rasuk segi empat tepat yang diperbuat daripada konkrit sekam padi. Fokus utama kajian ini adalah untuk menguji keupayaan struktur rasuk segi empat tepat yang terdiri daripada konkrit sekam padi di bawah ujian lenturan.

ABSTRACT

The production of cement consumes natural resources, apply high energy and produce high amounts of greenhouse gases. It cause almost to 7 % of the global carbon dioxide emissions, as the production of one ton of ordinary Portland cement releases one ton of carbon dioxide. Nowadays the major issue is the environmental effects and the health effects which increasing from days to days. Because of that, the utilization of green concrete in construction must be applied widely as the alternatives for the conventional concrete and due to the benefits of the usage of the green concrete itself. The green concrete will manage to reduce the green-house gas emission, conserve the natural resources and reduce the problem on the limited landfills area. The research for sustainability has led to the search for the replacement materials that may replace some of the natural resources. Some of the agricultural waste products such as rice husk, rice husk ash, palm oil shells, wood waste ash and coconut shell have been found useful as replacement alternatives for cement, fine aggregate, coarse aggregate and reinforcing materials. The disposal problem of agricultural wastes in many countries have created chances for the use of agro-waste in the construction sector. However, the research about the structural capacity and its performance is still ongoing. The strength and the durability characteristics of rice husk concrete have been widely studied but its suitability to be used as a structural concrete is still in detail study and questionable. This study presents the structural performances and behavior of reinforced concrete beam which using rice husk as a partial replacement of fine aggregate. The experimental works have been conducted involving nine reinforced rice husk concrete beams of dimension 150 mm x 300 mm x 1500 mm. There are three controlled beams with 0 % replacement and another six beams with 10 % and 12 % replacement. The data presented in this paper include the moment capacity, deflection characteristics, cracking behavior and the ultimate load that can resist by the rectangular beam made of rice husk concrete. The main focus of this study is to test on the structural capacity of rectangular beam made up of rice husk concrete under the flexural test.

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LIST OF SYMBOLS

RHC	Rice Husk Concrete
%	Percentage
Kg	kilogram
mm	millimetre
N	Newton
kN	Kilo Newton
MPa	Mega Pascal
εc	Concrete Strain
εs	Steel Strain
CC	Conventional Concrete
CSC	Coconut Shell Concrete
PSCC	Oil Palm Shell and Palm Oil Clinker Concrete
OPS	Oil Palm Shell
POC	Palm Oil Clinker
SP	Super Plasticizer
W/C	Water Content

LIST OF ABBREVIATIONS

RHC	Rice Husk Concrete
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CHAPTER 1

INTRODUCTION

1.1 Background

The rapid economic growth in the world has led to the increasing demand for the massive and modern construction development from day to day. Human population that increasing every year also become one of the factor that affect the development process. The development in construction includes the development of the residential area, modern skyscraper, high-rise building, airport, port, bridge and other infrastructures. In the construction field, concrete is one of the main building material which has been broadly utilized and significantly contribute to the construction sector. Almost every structures in the world use the concrete because of the durability, affordability, versatility, high strength, and the wide range of its applications. In the simplest form, concrete is a mixture of the cement, water, fine and coarse aggregates. However, the environmental impact of concrete whether its application or production has become serious issues nowadays. The production of cement consumes natural resources, apply high energy and produce high amounts of greenhouse gases. Natural resources especially fine aggregates also will decrease by time and this is the perfect time to find a new way to overcome it. The research for sustainability has led to the search for the replacement materials that may replace some of the natural resources.

This research is focuses on how the structural capacity of beam structure will react when the fine aggregates which is also known as sand is partially replace with the specific amount of raw rice husk in the mixing of concrete. In the components of building, structural beam is an integral part of most structural projects. Beams can be made of steel and wood but the most popular material used is concrete. The main reason for the replacement of fine aggregates is due to excessive use of this natural resources not only in the construction industries but also being used in the water filtration system, production of ceramic, glass, metal processing and in plastic industry. The natural renewal rates of the natural resources has been disturbed by the high demand of its usage. The issue is not only about the lack of the natural resources as part of the building material, but it is also hugely affect the environmental problem. These days, solid waste management and pollution problems have been considered as a crucial issue for Malaysian government which is caused by industrial and agricultural wastes.

Sustainability in construction sector is one of the pressing needs of the developing world owing to the diminishing of natural resources and increasing carbon dioxide emissions resulting from huge production of cement concrete. The research for sustainability has fuelled the search for alternate materials that may replace some of the natural resources. Several industrial by-products such as fly ash, condensed silica fume, blast furnace slag, copper slag, steel scrap, stone wastes, tire ash, fibres etc., and some of the agricultural by products like raw rice husk, palm oil shells, bagasse ash, corn cob, elephant grass ash, wood waste ash, coconut shell & fibres, rice husk ash, tobacco waste, etc have been found useful as additions or substitutions to cement and aggregates. Generally, rice or its scientific name is Oryza Sativa is one of the leading food crops in the world. More than 90% of the world's rice is produced and consumed by Asia on about 11% of the world's cultivated land and we are one of the country. In Malaysia now, about 0.48 million tonne of rice husk (UNDP,2002) still not fully utilized. Rice husk or rice hulls are the natural coatings of seeds, or grains of rice which surround the rice grains during their growth.

By reuse the waste by-product generated from agricultural and industrial production activities to decrease the environmental issues, Malaysia has a significant potential to achieve the objective of sustainable development.

1.2 Problem Statement

Rapid development in the construction industry these days was led by globalization and urbanization. Malaysia is well known as a developing country, increase in population growth, rising standards of living and increasing of urbanization which led to massive demand of construction materials. Due to the growth of population and the numerous construction activities nowadays, there is a lot of demand for these natural sources and they will be running low. Now it is the perfect time for us to consider the other alternative to fully or partially replace the natural resources as the building material. One of best option is to use the by-products or the agricultural waste which easily can get in Malaysia.

Every year, a massive quantity of concrete is needed to fulfil the demand of the rapid growth of construction industries. For every concrete structure basically required tons of sand and gravel coated together with cement. The major problem is the huge production of cement concrete has diminish the natural resources and produce high emission of carbon dioxide (CO2) which both of it cause the negative impacts to the environment. The yearly concrete production is approximately 10 billion cubic meters. The most important and costlier constituent of concrete is cement, which is the binding material. As per the report of the United States Geological Survey, approximately 4180 million tons of cement was produced in 2014 globally. Cement manufacturing accounts for almost 7% of the global carbon dioxide emissions, as the production of one ton of cement (Ordinary Portland Cement) releases one ton of carbon dioxide.

Other than that, sand which is use for concrete was obtained by mined from land quarries and riverbeds. Natural sand is being extracted at an increasing rate due to growing global population which leads an expanding demand for building and housing. This action has caused the expansion of mining to coastal areas and dredging of the seafloor and indirectly increasing the possibility of flooding, affect the marine and river biodiversity, causing coastal and inland erosion, exacerbating the risk of drought and lowering the water table in some areas.

The rice producing countries like Malaysia are facing a severe problem on the disposal of rice husks. In Malaysia, the limited landfills area had caused the environmental problem to the environment and the surrounding populations. If they are dumped as landfill, they can take a lot of area and become a major challenge to the environment. If they are disposed by burning, the ashes will spread to the surrounding areas, create pollution and destroy the beauty of the land. When rice husk is fermented by microorganisms, it enables the emission of methane and thus contributing to the global warming problems. It is not appropriate to use the rice husk as a feed for animals due to the low nutritional values.

Globally, management of solid wastes poses a herculean challenge to develop and developing countries owing to industrial growth, construction booms, rapid urbanization, and consumerism lifestyle. The demand for green concrete in construction industry is spurred by increased regulations to reduce carbon footprint, limit greenhouse gas emission and limited landfill spaces.

1.3 Research Objectives

The main objectives that need to be analysed in this research are:

a) To evaluate the ultimate load that can resist by the rectangular beam made of rice husk concrete
b) To evaluate the moment capacity that can sustain by the rectangular beam made of rice husk concrete
c) To evaluate deflection of the rectangular beam made of rice husk concrete

1.4 Scope of Study

The strength and the durability characteristics of rice husk concrete have been widely studied but its suitability to be used as a structural concrete is still in detail study and questionable. The main focus of this study is to test on the structural capacity of rectangular beam made up of rice husk concrete under the flexural test. The raw rice husk is use as partial replacement for the fine aggregates and it did not involve any additional energy such as burning or combustion of the rice husk. One of the main purpose is to provide a green concrete which promotes sustainable, innovative use of agricultural waste products and as the new alternative material for the production of concrete. The study also will determine on how much percentage of raw rice husk needed to get the optimum or maximum compressive and flexural strength of modify reinforced concrete beam as light weight concrete.

The parameters of the study are including the composition of rice husk, replacement ratio of fine aggregate with rice husk, compressive strength of concrete and flexural strength of concrete. The study and investigation was carried out on rectangular concrete beams of size 0.15 m x 0.30 m x 0.15 m in the laboratory. Casting of concrete will include 10% and 12% ratio of rice husk from the basic concrete grade C25/30. The concrete mix is using Ordinary Portland Cement (OPC). The cube test and flexural test for concrete were tested within the range of 28 days according to the curing period.

For the first outcome, the research is conducting to achieve the ultimate load and moment capacity of rectangular beam made up with raw rice husk as partial replacement for fine aggregates. Next, the objectives is to evaluate the deflection behaviour of the rice husk reinforced concrete beam when a certain amount of load is applied on it.

1.5 Significance of Study

The significant study for this research is to evaluate the structural capacity of rectangular beam made up of rice husk concrete under the flexural test. In future, the result can be used to improve and make changes in the design mix of concrete. Besides that, we are able to know about the real structural capacity that can resist by the reinforced concrete beam made of rice husk concrete.

Having a research on this topic can give a new dimension in construction sector as we want to provide the sustainability and search the replacement for our natural resources. Green concrete promotes sustainable and innovative use of waste materials and unconventional alternative materials in concrete. Suitable standards, more demonstration projects, as well as adequate training, public awareness, cross-disciplinary collaborations, further research and developments are required to promote global adoption of green concrete in large-scale infrastructure projects.

CHAPTER 2

LITERATURE REVIEW

2.1 General

In this chapter, there are an overview regarding the beam as a structure and its types. Besides that, in this chapter, there are literature reviews with evaluation of previous research. This chapter also will focus on the importance of the uses of green concrete and the concrete material itself.

2.1.1 Beam as Structure

For the concept, generally beam is a structural element that primarily resists loads applied laterally to the beam's axis. Bending is the primarily its mode of deflection. The loads applied to the beam result in reaction forces at the beam's support points. The total effect of all the forces acting on the beam is to produce shear forces and bending moments within the beam, that in turn induce internal stresses, strains and deflections of the beam. Historically beams are made up of squared timbers but are also metal, stone or combinations of wood and metal. Loads which carried by a beam are transferred to columns, walls, or girders, which then transfer the force to adjacent structural compression members and eventually to ground.

Classification of beams is basically based on its supports;

- Simply Supported Beam

Simply supported beam is supported at both end. One end of the beam is supported by pin support and other one by roller support. This support allow to horizontal movement of beam. It beam type undergoes both shear stress and bending moment.

- Continuous Beam

This beam is similar to simply supported beam except more than two support are used on it. One end of it is supported by pin support and other one is roller support. One or more supports are use between these beams. One of the application is on the construction of bridges where the length of bridge is too long.

- Cantilever Beam

This beam have structure member of which one end is fixed and other is free. Cantilever beam is one of the famous type of beam use in trusses, bridges and other structure member. It carry load over the span which undergoes both shear stress and bending moment.

- Fixed Beam

This beam is fixed from both ends. It does not allow vertical movement and rotation of the beam. It is only under shear stress and no moment produces in this beams. It is used in trusses and other structure.

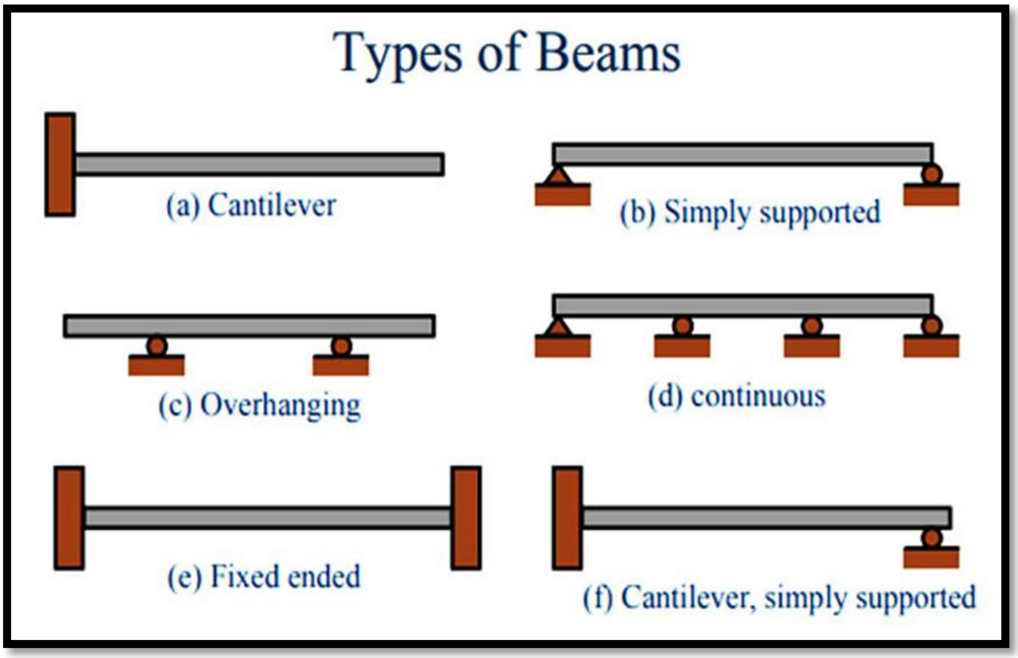


Figure 2.1: Types of Beams

2.1.2 Green Concrete

Green concrete can be defined as the concrete with material as a partial or complete replacement for cement or fine or coarse aggregates. Utilization of green concrete in construction is increasingly adopted by the construction industry owing to the drawbacks of conventional concrete and the numerous benefits of green concrete. The increasing demand for green concrete has been spurred by demand for high quality concrete products, desire of government to reduce green-house gas emission, need for conservation of natural resources and limited landfill spaces. Green concrete comes in various forms such as lightweight concrete, high-volume fly ash concrete, ultrahigh performance concrete, geo polymer concrete to mention a few. Green concrete offers numerous environmental, technical benefits and economic benefits such as high strength, increased durability, improved workability, reduced permeability, controlled bleeding, superior resistance to acid attack, and reduction of plastic shrinkage cracking. (K.M.Liew, 2017) These characteristics promotes faster concrete production, reduction of curing waiting time, reduction of construction costs, early project completion, reduction of maintenance costs and increased service life of construction projects. Green concrete promotes sustainable and innovative use of waste materials and unconventional alternative materials in concrete. Suitable standards, more demonstration projects, as well as adequate training, public awareness, cross-disciplinary collaborations and further research and developments are required to promote global adoption of green concrete in large-scale infrastructure projects.

High demand of natural resources due to rapid urbanization and the disposal problem of agricultural wastes in developed countries such as Malaysia have created opportunities for use of agro-waste in the construction industry. The agricultural wastes can be used as fine aggregate in concrete are raw rice husk sugarcane bagasse ash, groundnut shell, oyster shell, sawdust, giant reed ash, rice husk ash, cork and tobacco waste. The major differences of these agro-wastes are the place from where they collected and the processes to convert into a fine aggregate. In this research we want to apply the raw rice husk which did not involve any other energy such as combustion process and make it as partial replacement for fine aggregates.

2.1.3 Lightweight Concrete as Green Concrete

In this study, we are tends to test on the structural behaviour of the lightweight concrete. Nowadays, the use of lightweight concrete (LWC) has opened the eyes of the world and its get more serious attention. The uses of lightweight concrete has been a feature in the construction industry for centuries, but like other material the expectations of the performance have raised and now we are expecting a consistent, reliable material and predictable characteristics. For the lightweight concrete, the concrete mixture is made with a lightweight coarse aggregate. In some cases a portion or the entire fine aggregates may be a lightweight product. In this study, we are going to use rice husk (lightweight product) as a partial replacement for the fines aggregates. Lightweight concrete has many favourable engineering properties such as its light weight, high strength, low expansibility, good heat insulation, sound dampening qualities, water and fire resistance, durability, stable volume and surely low cost (H.Y. Wang, 2015). In addition, a concrete can be categorized as lightweight aggregate concrete when the aggregate have dry unit weight below than 1200 kg/m3 (Mohammed, 2013).

It is convenient to classify the various types of lightweight concrete by their method of production. These are:

- By using porous lightweight aggregate of low apparent specific gravity, i.e. lower than 2.6. This type of concrete is known as lightweight aggregate concrete.

- By introducing large voids within the concrete or mortar mass; these voids should be clearly distinguished from the extremely fine voids produced by air entrainment. This types of concrete is variously knows as aerated, cellular, foamed or gas concrete.

- By omitting the fine aggregate from the mix so that a large number of interstitial voids is present; normal weight coarse aggregate is generally used. This concrete as no-fines concrete.

Lightweight aggregates concrete are performing well in structure and have many advantages including improved thermal properties, high strength, good tensile strain, reduced the structural loading and have good qualities in fire resistant. This is the main reasons this research paper focus on the structure behaviour of lightweight aggregate concrete that use rice husk as partial replacement. Due to this many advantages of the lightweight concrete, the study is focusing on the study of the structural behaviour of the lightweight concrete which use rice husk as partial replacement for fines aggregates.

2.1.4 Concrete Grade

There are plenty types of concrete grades used in construction industry and it is use for different types of the structures. Grade of concrete is defined as the minimum strength the concrete must possess after 28 days of construction with proper quality control. Grade of concrete is denoted by prefixing M to the desired strength in MPa. For example, for a grade of concrete with 20 MPa strength, it will be denoted by M20, where M stands for Mix. In Malaysia, we use the symbol C instead of M and followed by numbers. The respective ingredient proportions which are Cement: Sand: Aggregate or Cement: Fine Aggregate: Coarse Aggregate.

Grade of concrete construction is selected based on structural design requirements. There are two types of concrete mixes which are nominal mix and design mix:

- **Nominal mix** concrete are those which are generally used for small scale construction and small residential buildings where concrete consumption is not high. Nominal mix takes care of factor of safety against various quality control problems generally occurring during concrete construction.

- **Design mix** concrete are those for which mix proportions are obtained from various lab tests. Use of design mix concrete requires good quality control during material selection, mixing, transportation and placement of concrete. This concrete offers mix proportions based on locally available material and offers economy in construction if large scale concrete construction is carried out. Thus, large concrete construction projects uses design mix concrete.

In addition to concrete mixes, some commercial admixtures or additive generally boosts a concrete grade. But it is not advisable to depend the concrete grade on these admixtures. To be clear, concrete has to attain its designed strength with or without admixture. That is a rule of thumb.

2.1.5 Effect of Concrete Modification towards Environment

Concrete is a mixture of cement, fine aggregate and coarse aggregate, which is mainly derived from natural resources. Increasing population, expanding urbanization, climbing way of life due to technological innovations has demanded a huge amount of natural resources in the construction industry, which has resulted in scarcity of resources. This scarcity motivates the researchers to use, solid wastes generated by industrial, mining, domestic and agricultural activities. Reuse of such wastes as sustainable construction materials take care of the issue of contamination, as well as the issue of area filling and the expense of building materials (Madurwar, 2013). The utilization of some of these by-products provides several advantages such as improve strength and durability properties, reduction in construction cost by the saving of cement and natural aggregates, also environmental benefits like reduction in carbon dioxide emissions and the easy disposal of the polluting waste materials.

Among the agricultural wastes used as fine aggregate in concrete are raw rice husk, sugarcane bagasse ash, groundnut shell, oyster shell, sawdust, rice husk ash, cork and tobacco waste. The major differences of these agro-wastes are the place from where they collected and the processes to convert into a fine aggregate. This paper overview the use of the raw rice husk as agricultural waste and how this type of waste can be utilized in construction industry. Rice husk is not appropriate to be used as a feed for animals due to the low nutritional values. If dumped as landfill, they can take a lot of area and become a major challenge to the environment. If they are disposed by burning, the ashes can spread to the surrounding areas, create pollution and destroy the natural beauty. One of the possible solutions for the disposal of rice husk is to convert them into rice husk ash and incorporate them into cement based materials. The partial inclusion of rice husk ash (RHA) for cement is found to be durable, environmental friendly and economically viable. However as we all know, the burning or combustion process use to produce rice husk ash is not an environmental friendly approach. The uses of raw rice husks in concrete material without any burning has rarely been investigated as the sand partial replacement. However, the process is really environmental way since it is not using any additional energy to produce it.

2.2 Material

In modification of concrete mixing, it need 4 basic raw materials which are cement, coarse aggregate, fine aggregate and water. In this study, the rice husk will be used as partial replacement for fines aggregates. The concept from previous researcher had been used. This sub-topic will explain details on the material that will be used in producing simply supported beam using rice husk concrete.

2.2.1 Rice Husk

Rice (scientific name: Oryza sativa. L) is one of the leading food crops in the world. More than 90% of the world's rice is produced and consumed by Asia on about 11% of the world's cultivated land. The hull or husk is the natural sheath surrounding the rice grains during their growth, constitutes to about 20–25% of the mass of the rough rice. The process of separating (shearing) the hull from the brown rice is known as dehulling. Rice milling is one of the most important industries in countries like India, China, Indonesia, Bangladesh and Vietnam. The purpose of a rice milling process is to remove the by-product of rice such as bran layers, rice husk, rice germ and broken kernels, and then produce an edible rice kernel that is free of impurities. Asia is known as waterlogged tropical areas, which is dominated the production of rice, where rice is the only food crop that can be grown during the rainy season. Therefore, rice is unique unlike other crops that cannot survive in wet environment. Rice production is expected to grow from year to year due to the global demand.

Rice husk is the outermost layer that is covers the rice grain. It is often considered as waste product because the rice producing countries are facing a severe problem on the disposal of rice husks. If they are dumped as landfill, they can take a lot of area and become a major challenge to the environment. If they are disposed by burning, the ashes will spread to the surrounding areas, create pollution and destroy the beauty of the land. When rice husk is fermented by microorganisms, it enables the emission of methane and thus contributing to the global warming problems. It is not appropriate to use the rice husk as a feed for animals due to the low nutritional values. Moreover, natural degradation of rice husk is restricted due to the irregular abrasive surface and its high siliceous composition, which can make it a potential candidate for environmental pollution. In many countries, it has been widely and effectively used as a fuel for rice paddy milling process and power plants.

2.2.2 Reinforcement Bar

Rebar also known as reinforcement bar or reinforcing steel is a steel bar or mesh of steel wires used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and hold the concrete in compression. Concrete is strong under compression, but has weak tensile strength. Rebar significantly increases the tensile strength of the structure. Rebar's surface is often patterned to form a better bond with the concrete. The most common type of rebar is carbon steel, typically consisting of hot-rolled round bars with deformation patterns.

In simplest words, concrete is sufficiently strong to compression forces by nature, but tension force can crack it. Deformed rebar on reinforcing bar have been standard requirement since 1968. According to Eurocode 1992-1-1:2004 clause 3.2.2 (3), the application rules for structure design and detailing are specific to yield strength range from 400Mpa to 600Mpa. The research study on rice husk aggregates concrete will state the yield strength of rebar as constant which is 500MPa (72.5 psi) referred to the Eurocode standard and the type of material is high-yield steel.

2.3 Method from Previous Study

There were several study before this succeed to make beam structure that based on lightweight concrete. Among of them used fibre reinforced polymer, palm oil shell and coconut shell as partial replacement for aggregates. All the application of these study will be the reference paper in the process of making lightweight simply supported beam structure with rice husk mix concrete. There are several criteria that can be learn from other researcher such as in term of the amount of sample, the type of testing on the structure and the design of the beam.

2.3.1 Research 1: Study on Reinforced Lightweight Coconut Shell Concrete Beam Behaviour under Torsion (K.Gunasekaran, Department Of Civil Engineering, SRM University, Kattankulathur, India, 2014)

This study paper aimed to investigate and evaluate the results of coconut shell concrete beams subjected to torsion and compared with conventional concrete beams. This research study is related to rice husk concrete beam due to the use of coconut shell as fine aggregate replacement. Both of the material are from agricultural waste.

2.3.1.1 Method and Results

In this study, it includes general cracking characteristics, pre cracking behaviour and analysis, post cracking behaviour and analysis, minimum torsional reinforcement, torsional reinforcement, ductility, crack width and stiffness. Material that have been used are coconut shell concrete (CSC) and conventional concrete (CC) which have minimum compressive strength of 25MPa at 28 days. It was fixed as target strength with minimum workability consideration. The study used eight (8) beams, four (4) with coconut shell concrete and four (4) with conventional concrete.

Concrete grade used in this study is M25. The cross-sectional dimension of beam is 200 mm x 275 mm and the length of the beam is equal to 1200 mm centre to centre for both CSC and CC. Tables below showed properties of concrete used in this study.

Table 2.1: Properties of Concrete Used

Parameters	**CSC**	**CC**
Min targeted strength (MPa)	20-25	20-25
Cement content (kg/m^3)	510	320
Sand (kg/m^3)	750	710
Coconut shell (CS), (kg/m^3)	332	-
Crushed granite stone (kg/m^3)	-	1171
Water-cement ratio (w/c)	0.42	0.55
Mix ratio	1:1.47:0.65:0.42	1:2.22:3.66:0.55
Slump (mm)	06	10
28 day hardened density, (kg/m^3)	1970	2385
28 day compressive strength, MPa	26.40	27.00

Table 2.2: Details Reinforcements for Both CC and CSC beams

Beams	**Area of longitudinal reinforcement, ($mm^{2)}$**	**Spacing of transverse reinforcements, (mm)**
CC1 and CSC1	312.15	120
CC2 and CSC2	452.38	90
CC3 and CSC3	383.08	100
CC4 and CSC4	257.48	150

Table 2.3: Diameter and Numbers of Bars used in Beams

Beams	**Longitudinal reinforcement**	**Transverse reinforcement 2-legged**
CC1 and CSC1	2H8 mm Ø at top 2H10 mm Ø at bottom	8 mm at 150 mm c/c
CC2 and CSC2	2H10 mm Ø at top 2H10 mm Ø at bottom	8 mm at 120 mm c/c
CC3 and CSC3	2H10 mm Ø at top 2H12 mm Ø at bottom	8 mm at 100 mm c/c
CC4 and CSC4	2H12 mm Ø at top 2H12 mm Ø at bottom	8 mm at 90 mm c/c

A loading frame of capacity 40 tones used to test beam in this study. Load was applied by means of a hydraulic jack of capacity 25 tones. Twist of the beam was measured by using dial gauges which are fixed at both sides of twist meter with at least count of 0.01 mm. The researchers study is mainly about the torque. From table below,it is clearly states that there was almost similar behavior in torsion between CC and CSC.

Table 2.4: Result of Torsional Strength

Beams	**Torque (kN.M)**	**Twist, θ (rad/m) x 10^{-3}**	**Torque (kN.M)**	**Twist, θ (rad/m) x 10^{-3}**
CC1	8.09	19.40	11.77	58.90
CC2	10.30	28.25	15.01	58.25
CC3	11.04	26.25	18.03	57.50
CC4	12.51	27.00	19.50	56.80
CSC1	7.36	20.10	13.54	64.70
CSC2	9.56	25.20	17.66	64.10

CSC3	9.86	24.20	19.50	63.30
CSC4	11.77	36.20	20.25	60.10

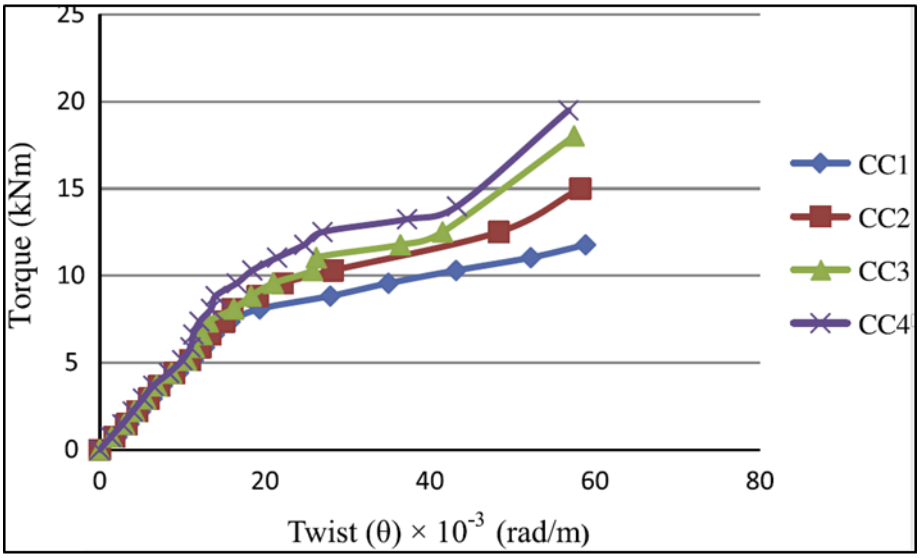


Figure 2.2: Torque versus Twist for CC1 to CC4

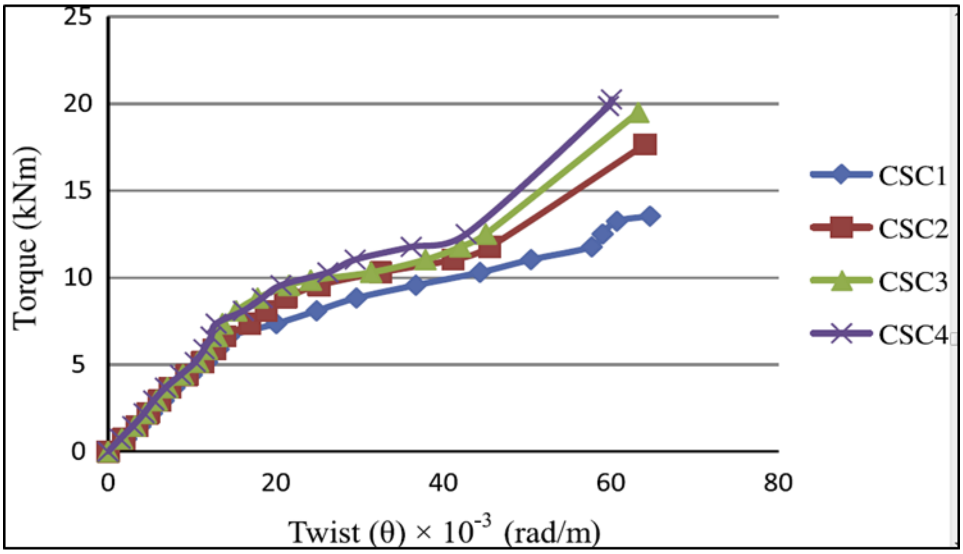


Figure 2.3: Torque versus Twist for CSC1 to CSC4

2.3.2 Research 2 : Flexural Performance of Reinforced Concrete Oil Palm Shell & Palm Oil Clinker Concrete (PSCC) Beam (Md Nazmul Huda, Department Of Civil Engineering, Faculty of Engineering; University of Malaya, 50603 Kuala Lumpur, Malaysia, 2015)

This paper presents the structural performance of singly reinforced oil palm shell and palm oil clinker concrete (PSCC) beam. The structural-grade lightweight aggregate concrete, PSCC has been produced from the combination of oil palm shell (OPS) & palm oil clinker (POC) which are an agricultural waste and a by-product of palm oil industry.

2.3.2.1 Method and Results

The produced lightweight concrete has the compressive strength of 46 MPa. The experimental works have been conducted involving six singly reinforced beams of dimension 150 mm x 250 mm x 3300 with varying reinforcement ratios (0.70–1.26%). For each type of reinforcement ratio, two beams have been tested under four point bending until failure. The data presented in this paper include the mode of failure, moment capacity, deflection characteristics, cracking behaviour and ductility indices. Although PSCC has a low modulus of elasticity, the moment capacity and the deflection of singly reinforced PSCC beams are acceptable as the span-deflection ratio satisfies the allowable limit provided by BS 8110. All PSCC beams show typical flexural performance and experiences ductile failure giving sample amount of warning before the failure.

There were four trial mixes performed in the laboratory to obtain grade 45 concrete with a high workability. The water-cement ratio was kept constant for all the mixes. About 2% of super plasticizer was used in all the mixes to achieve workability. Trial mixes were designed with the optimum cement mixes according to the recommendation for high strength sanded-LWC by ACI 213R-87 [21]. Sieved mining sand was selected as the fine aggregate. In this study, OPS along with POC were used as coarse aggregate in different proportion for the trial mixes. In the trial mix TM-1, the total volume of coarse aggregate was divided into two parts such as 50% for the OPS and other 50% for the POC. The quantities of OPS and POC in TM-2, TM-3 and TM-4 mix are 60% & 40%, 70% & 30% and 40% & 60% respectively. The details of the concrete mixes with their properties are presented in Table 1. For each mixture, three cubes (100 x 100 x 100 mm), three prisms (100 x 100 x 500 mm), three small cylinders (U100 x 200 mm) and three big cylinders (U150 x 300 mm) were cast and cured under water. At the age of 28-days, the specimens were tested to obtain compressive strength, splitting tensile strength, flexural strength and modulus of elasticity. The hardened concrete properties of four mixtures are presented in table below.

Table 2.5: Concrete Mix Proportions in kg/m3

Mix ID	**Cement**	**Water**	**W/C ratio**	**SP**	**Sand**	**OPS**	**POC**
TM – 1	450	158	0.35	2%	1158	148	195
TM – 2	450	158	0.35	2%	1025	212	187
TM – 3	450	158	0.35	2%	1013	248	141
TM – 4	450	158	0.35	2%	1048	142	281

Table 2.6: Mechanical Properties of PSCC for Different Mixture

Mix ID	**Oven dry density**	**Compressive strength (MPa)**	**Splitting tensile strength (MPa)**	**Flexural strength (MPa)**	**Elastic Modulus (GPa)**
TM – 1	450	158	0.35	2%	1158
TM – 2	450	158	0.35	2%	1025
TM – 3	450	158	0.35	2%	1013
TM – 4	450	158	0.35	2%	1048

In this study, total six numbers of PSCC rectangular beam specimens were fabricated and tested. All specimens have the rectangular geometry with a cross sectional area of 150 mm x 250 mm and the length of the specimens was 3300 mm. The PSCC beams were simply supported and tested under two-point loading. An Instron testing machine of the capacity of 500 kN with built-in load cell was used in the testing.

Table 2.7: Comparison between Experimental and Theoretical Ultimate Moment.

Beam ID	**Experimental ultimate load, P (kN)**	**Experimental ultimate moment, Mexp (kNm)**	**Theoretical design moment, Mtheo, (kNm)**	**Capacity ratio, Mexp/Mtheo**
1B1	36.73	21.12	23.81	0.89
1B2	39.94	22.97	23.81	0.96
2B1	53.23	30.61	35.13	0.87
2B2	52.28	30.06	35.13	0.86
3B1	57.96	33.33	41.14	0.81
3B2	64.41	37.04	41.14	0.90

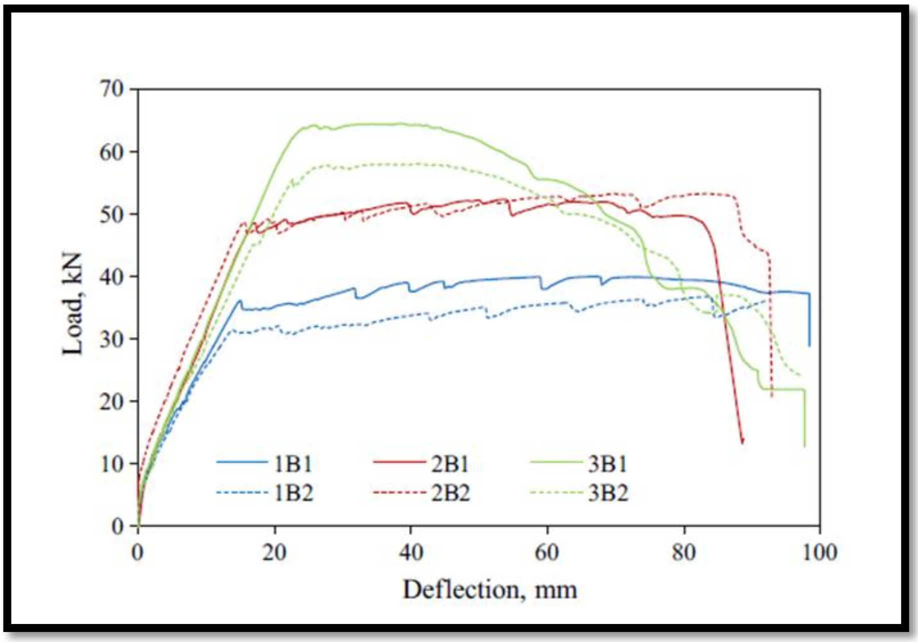


Figure 2.4 Experimental load-deflection Curve

Table 2.8: Deflection of Reinforced PSCC Beams at Service Load.

Beam ID	**Theoretical service moment, (kNm)**	**Experimental deflection, Dexp (mm)**	**Theoretical deflection, Dtheo (mm)**	**Dexp/Dtheo**	**Span/Dexp**
1B1	14.88	9.46	9.63	0.98	317.0
1B2	14.88	8.94	10.47	0.85	335.6
2B1	21.95	10.32	13.95	0.74	290.5
2B2	21.95	11.90	13.70	0.87	252.1
3B1	25.71	15.84	15.19	1.04	189.4
3B2	25.71	14.35	16.88	0.85	209.0

CHAPTER 3

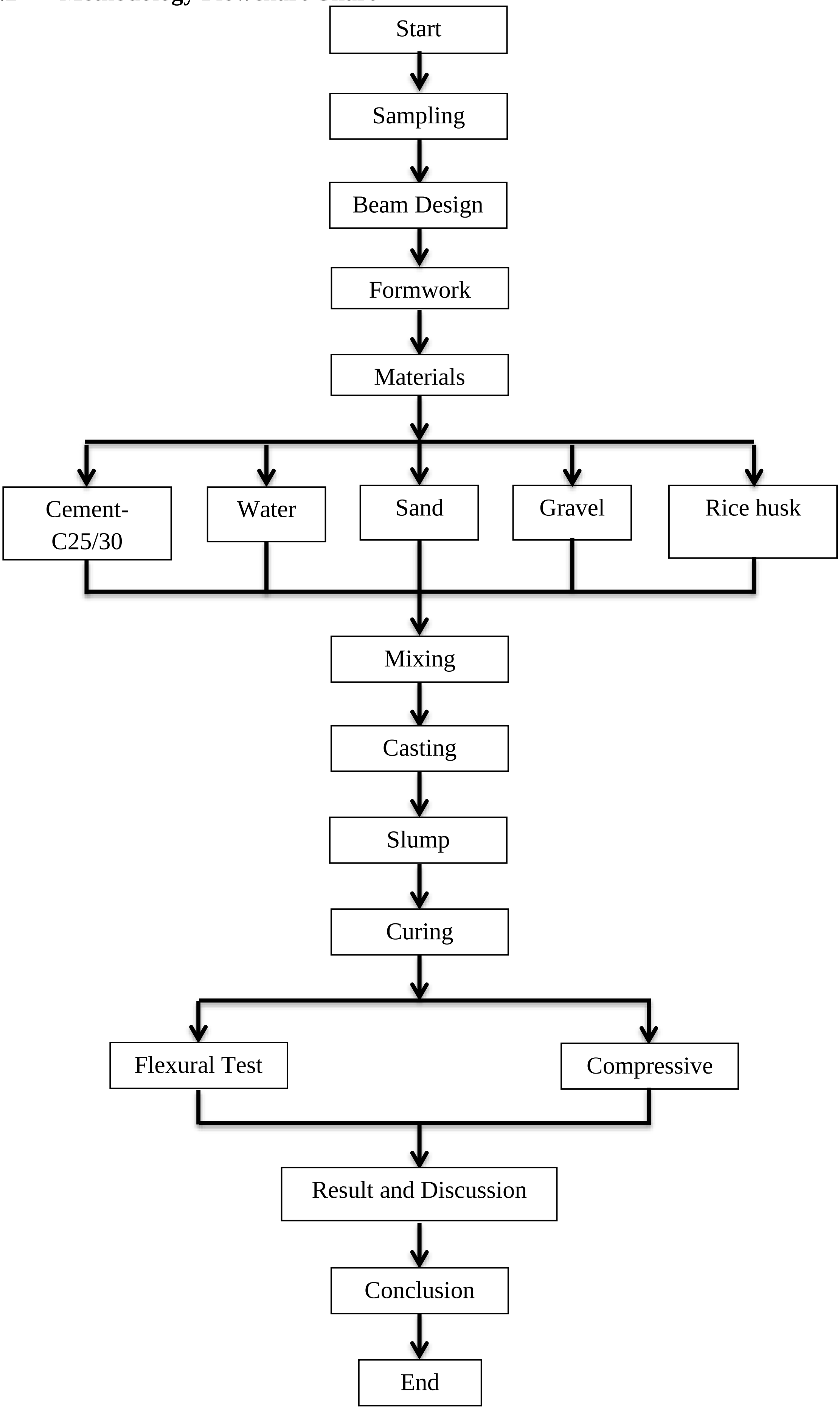
METHODOLOGY

3.1 Introduction

This chapter describes the methodological aspects used in collecting, analysing and evaluating the data. Methodology refers to various sequential steps in studying a problem with certain objective in view. It describes the methods and process applied in the entire subject of the study. It is the way to study systematically about the research problem.

In order to complete the report, various methods will be applied. The data will be collected from many sources. Most of the information will be gathered through the articles, journals and websites. Under this chapter, it includes introduction, methodology flow chart, materials preparation, concrete mix design, reinforcement design, the principles of parameter used, tests conducted and the expected results. The main objective of this chapter is to explain various methods for testing and materials used for data collection, analysis and evaluation. They are discussed in detail in this chapter.

3.2 Methodology Flowchart Chart



3.3 Preparations of Materials

There are several type of materials that are used in this study which are listed below:

3.3.1 Cement

Cement is a type of binder that sets and hardens to adhere to building units such as stones, bricks, and tiles. It is the most important component of concrete and being used in construction sector worldwide. In general concrete construction, Ordinary Portland Cement (OPC) is the most common cement that are used when thereis no exposure to sulphates in the soil or groundwater. For the manufacture of OPC, the raw materials required are calcareous material such as limestone or chalk and argilaceous materials such as clay or shale. The mixture of these materials is burnt at a high temperature of approximately 1400 ^{o}C in a rotary kiln to form granular substance called clinker. Clinker is then cooled and grounded with a requisite amount of gypsum into fine powder known as portland cement.

OPC is a grey coloured powder. It is capable of bonding mineral fragments into a compact whole when mixed with water. This hydration process results in a progressive stiffening, hardening and strength development. For this study, OPC which are selected and used is with a brand name Orang Kuat certified to MS ISO 9001, MS ISO 14001 & OHSAS 18001. OPC is chosen because this cement is specially formulated for high early age strength. Orang Kuat is suitable for concreting structure, precast, brickmaking, and all general applications, where high strength is needed to improve productivity.

Orang Kuat OPC is produced using the most advanced energy efficient cement production process. It is made to reduce the environmental foot print during the production of this product which is the reduction of using Carbon Dioxide (CO2). The OPC will be stored away from air moisture in the concrete laboratory to ensure the cement was in good condition during the experimental period.

3.3.2 Coarse Aggregates

In this study, granite obtained from civil engineering lab was used for concrete mixing. Granite is formed naturally from stone that was quarried and crushed to produce various sizes of aggregate. Commonly, it is used in construction industry as coarse aggregate. The aggregate used was cleaned and dried before concrete mixing. The size of aggregate use is larger than 4.75 mm which follow the ASTM standard for coarse aggregate. The well graded aggregate can be achieved by using several sizes of aggregates and its depend on each other. The bigger sizes of aggregate will provide strength meanwhile the small one will fill up the gap between larger aggregate.

3.3.3 Fines Aggregates

Fine aggregate is made up of crushed stone or sand that is used in concrete mixed. In this study, natural sand was used as fine aggregate. The function of fine aggregate is to fill up the void that cannot be reach by coarse aggregate due to its smaller size. For this study, the fine aggregate that was used is river sand. River sand is most preferred choice for the fine aggregate. River sand is a product of natural weathering of rocks over period of time.

3.3.4 Water

The water–cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix and has an important influence on the quality of concrete produced. A lower water-cement ratio leads to higher strength and durability, but may make the mix more difficult to place. Besides that, water act as an activation of chemical process that will help to bind all the material during concrete mixing. The water used must be free from chemical effect and should have clear impurities. Tap water is suitable enough to be used as the source of water for concrete mixing.

3.3.5 Rice Husk

For this study, rice husk act as partial replacement for the fine aggregates in the concrete mixing. The different percentage of rice husk will be implemented in order to get the ideal ratio as well it can be used as a solid beam structure. The rice husk sample was collected from the Kilang Beras Bernas Pahang which located in Kuala Rompin, Pahang. To remove the unwanted particle, rice husk will be getting the sieve process to get its raw rice husk material. In addition, the rice husk will be dried in oven for 24 hours in order to reduce its moisture content.

3.4 Concrete Mix Design

The process of selecting the appropriate materials of concrete and determining their relative proportions with the materials of producing concrete as economical as possible can be defines as the good concrete mix design. For concrete mix design, the mix is chosen from the previous study which is the properties of concrete by using rice husk as partial replacement of fine aggregates. The study is done by (Isma Farhan, 2017). Table below shows the concrete mix design for this study.

Table 3.1: Concrete Mix Design

Percentage Replacement (%)	**Water, kg**	**Cement, kg**	**Aggregate**		**Rice Husk, kg**
			Fines (kg)	**Coarse (kg)**	
0	46	78	242	214	0
10	46	78	217.8	214	6.08
12	46	78	212.96	214	7.30

3.5 Reinforcement Design

The reinforcement design in this study is according to the Eurocode 2. Beam is design as simply supported beam with a span of 1.5 m length. The design for simply supported beam is refer as design for rectangular section. The diameter of deformed bar that we used is 12 mm. For this study, the design calculation is only for standard concrete beam. In addition, the concrete density used in the calculation is 25 kg/m3 and the loading consider is only the self-weight of the beam. All the calculation design is based on the dimension of the beam which is 150 mm of width, 300 mm of height and the length is 1500 mm.

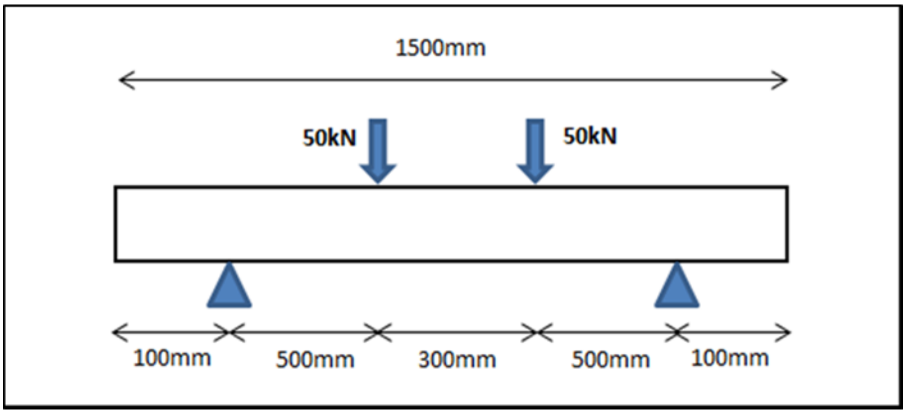


Figure 3.1: Simply Supported Beam

Reinforced Concrete Beam Design:

$\epsilon M_A = 0(cw + ve)$

$0.5(50) + 0.8(50) - 1.3(R_B) = 0$

$R_B = 50kN$

$\in F_y = 0 \uparrow +ve$

$R_A - 50 - 50 + 50 = 0$

$R_A = 50kN$

For Loading

Shear Force Diagram (SFD)

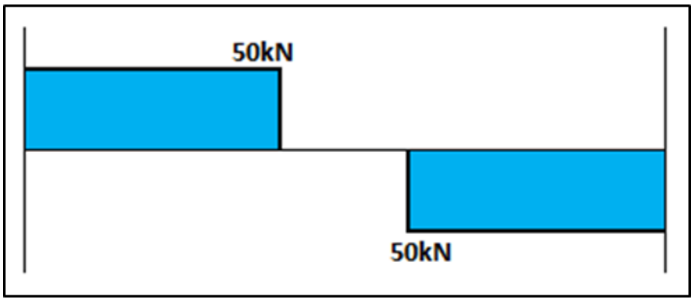


Figure 3.2: Shear Force Diagram

Bending Moment Diagram (BMD)

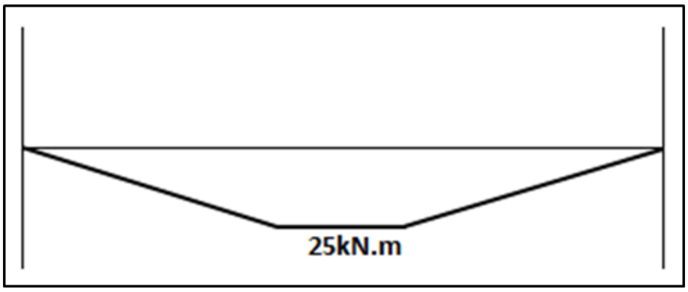


Figure 3.3: Bending Moment Diagram

For Selfweight

$$Beam\ Selfweight = (0.15 \times 0.3) \times 25 = 1.125kN/m$$

$$1.125\frac{kN}{m} \times 1.5m = 1.688\ kN$$

$$W_d = 1.35(1.688) + 1.5(0) = 2.278kN$$

$$M = \frac{(2.278 \times 1.5^2)}{8} = 0.481kN.m$$

$$M_{ED} = 25kN.m + 0.481kN.m = 25.481kN.m$$

- Concrete strength, fck = 25 N/mm^2
- Steel strength, fyk = 500 N/mm^2
- Ø $bar_{,t}$ = 12 mm
- Ø link = 6 mm

Durability, fire resistance and bond.

- $C_{nom,bond}$ = 12 mm + 10 = 22 mm
- $C_{nom,\ durability}$ = 25 mm + 10 = 35mm

R60; b_{min} = 120 ; a = 40

- $C_{nom,fire}$ = 40 – 6 – 6 = 28 mm **Use: Cnom = 35 mm**

Effective depth, d

$$d = h - C_{nom} - \emptyset link - \frac{\emptyset bar}{2}$$

$d = 300 - 35 - 6 - \frac{12}{2} = 253mm$ **Use d = 253mm**

Maximum moment design, Med = 25.481 kN.m

$$k = \frac{25.481 \times 10^6}{25 \times 150 \times 253^2} = 0.106 < 0.167 \ \ (compression\ not\ required)$$

$$z = d\left[0.5 + \sqrt{0.25 - \frac{0.106}{1.134}}\right] = 0.90d$$

$$As, req = \frac{25.481 \times 10^6}{0.87 \times 500 \times 0.90 \times 253} = 257.26\ mm^2$$

Proposed 3H12 (339 mm^2)

$$As, min = 0.26(\frac{2.6}{500})(150 \times 253) \leq 0.0013(150 \times 253)$$

$As, min = 51.53 \geq 49.34$ **As,min = 51.53 mm^2**

$As, max = 0.04bh = 0.04 \times 150 \times 300 = 1800\ mm^2$ **As,max = 1800 mm^2**

Shear reinforcement design

$$V_{Rd,max} = \frac{0.36(150)(253)(25)(1 - \frac{25}{250})}{(25 + \tan 22)} = 105.851\ kN$$

- Ved = 50 kN < Vrd,max = 105.851 kN ; **Use θ = 22^0**

$$\frac{Asw}{S} = \frac{50 \times 10^3}{0.78(500)(253)(25)} = 0.203$$

Try H6 = 56.6 mm^2

$$spacing, S = \frac{56.6}{0.203} = 278.8$$

Maximum spacing, Smax = 0.75(253) = 189.8mm

Minimum link

$$\frac{Asw}{S} = \frac{0.08 \times \sqrt{25} \times 150}{500} = 0.12$$

Try H6 = 56.6 mm^2

$$spacing, S = \frac{56.6}{0.12} = 472\ mm$$

Use shear & minimum link; H6-175

$$V_{min} = (\frac{56.6}{175}) \times (0.78 \times 500 \times 253 \times 2.5)$$

$$Vmin = 79.78\ kN > Ved = 50\ kN$$

Use V minimum = 50 kN

Deflection

$$\rho_0 = \sqrt{25} \times 10^{-3} = 0.005 \quad < \quad \rho = \frac{265.39}{150 \times 253} = 0.007$$

$$l/_d = 1.0 \left[11 + 1.5\sqrt{25}\left(\frac{0.005}{0.007 - 0}\right) + \frac{1}{12}\sqrt{25}(\frac{0}{0.007}) = 16.36\right]$$

- Modification factor 2 = 1.0
- Modification factor 3 = (339/257.26) = 1.32

$$(l/_d)_{allowable} = 16.36 \times 1.0 \times 1.32 = 21.60$$

$$(l/_d)_{actual} = \frac{1500}{253} = 5.93 < (l/_d)_{allowable}$$

Deflection Pass!

Cracking

$$fs = \frac{500}{1.15} \times \frac{1}{1.35}\left[\frac{100 + 1.125(1.5)}{1.35(101.685)}\right]\frac{1}{1} = 238.56 \sim 240$$

Wk = 0.3 mm; fs = 240 N/mm^2; max bar spacing = 200 mm

$$S_{actual} = \frac{150 - (2 \times 35) - (2 \times 6) - 12}{3 - 1} = 28\ mm < Smax = 200mm$$

Cracking Pass!

Detailing

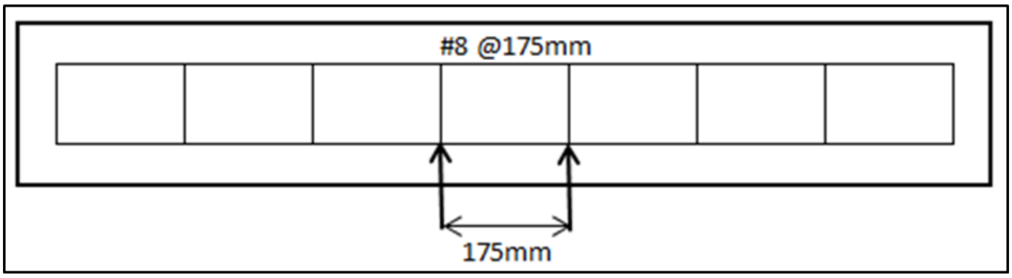


Figure 3.4: Diagram of Link Spacing

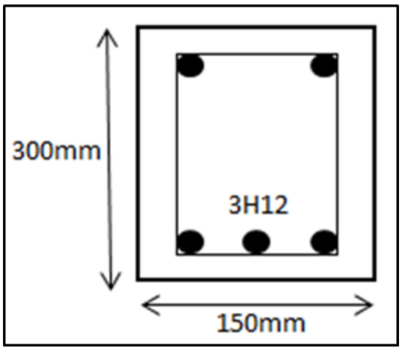


Figure 3.5: Detailing of Beam

3.6 Parameter Testing

The Magnus universal testing frame is constructed of a twinned steel channel frame fastened with high tensile fixings. This creates an overall structure size of 4.61 m long, 2.53 m high and 1.2 m wide and a working space of 4.0 m long x 1.6 m high. The machine use to find the flexural strength of the reinforced concrete structure. Besides that, the flexural test evaluates the tensile strength of concrete. The result of flexural test on concrete can be expressed in MPa unit. The test can be conducted either in four point load test (ASTM C78) or centre point load test (ASTM C293). For this study, the test is conducted in four point load test (ASTM C78). There are several parameters that are important to be taken in order to ensure the structure have good quality and follow the requirement standard. The parameters which involve are listed as follows:

- Flexural

Flexural strength, also known as modulus of rupture, or bend strength, is a material property, defined as the stress in a material just before it yields in a flexure test. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a four point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of yield.

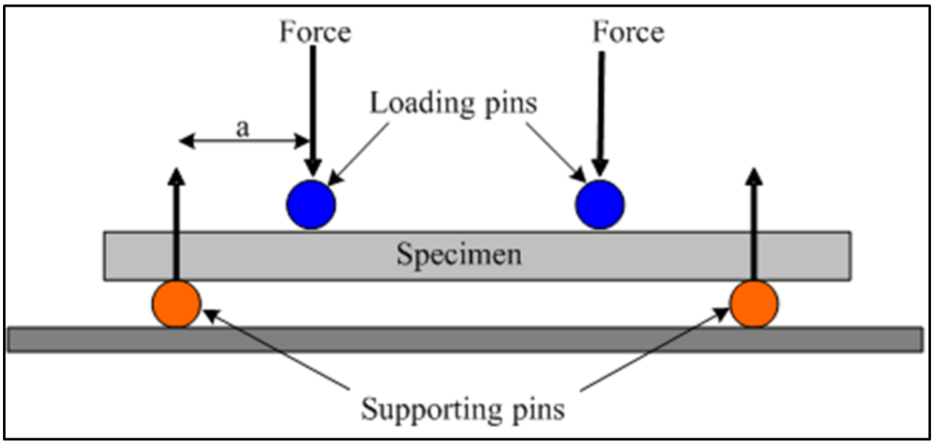


Figure 3.6: Four Point Loading Flexural Test

- Strain of Concrete

Strain is defined as the change in length of a stressed structural element divided by the original length of the unstressed element. Tensile strength of material is determined in the laboratory by pulling on a specimen until it breaks. While the test is conducted, both the stress and strain are recorded. The maximum stress that the specimen can withstand is called the ultimate strength of that particular material. We want to know the stress where the material stops behaving elastically.

Beams are structural elements that are subjected to bending forces. When bending occurs, the beam is subjected to tension and compression simultaneously. The tops of the upper row of rectangles are shortened, and the bottoms of the lower row of rectangles are elongated. Thus, we see that the top of the beam is in compression and the bottom of the beam is in tension.

- Strain of Steel

Steel is good in tension and it is use as reinforcing material in concrete. Steel strain can be defined as deformation of steel due to stress. All ductile material such as structural steel can be analysed by its ability to yield in normal temperature. In other words, it is a measure of how much a metal has been stretched or compressed when compared to its original length. If there is an increase in the length of a piece of metal due to stress, this is referred to as tensile strain. It is compressive strain if there is a reduction in length.

- Deflection

When a beam structure is placed under load the behaviour is the action or actions that can be observed as the beam responds to that load. The behaviour is primarily observed by the visible external effects, notably deflection and cracking. Deflection is the measure of displacement of the element when placed under load and depends upon many factors including, but not exclusively, material type, span, cross sectional shape and supporting elements. From this, we also can observe the structural capacity that can resist by the rectangular beam made up of rice husk concrete.

3.7 Sample Preparation

In this study, there are two types of sample have been prepared which are rectangular and the cube. For the rectangular beam, the test conducted was flexural test and the cube was used for compressive strength testing. Rectangular beam used wooden formwork while for the cube, plastic mould been used in casting process. The dimension of cube samples is 150 mm (W) x 150 mm (L) x 150 mm (H) while the sample of beam have dimension of 150 mm (W) x 300 mm (H) x 1500 mm (L).

For compressive strength testing, three (3) sample of cubes was taken from the same concrete used to cast the beam. In addition, there are nine (9) samples of beam have been cast which were three (3) controlled beam that contains 0% of rice husk aggregate and six (6) rice husk concrete beam with different percentage of rice husk replacement (10% and 12%). The three (3) controlled beams used as reference for normal concrete beam structure to compare with the rice husk concrete beam structure at the end of the study.

3.8 Test Conducted

Before we can know the structural capacity of rectangular beam under the flexural test, there are several testing procedure that we need to follow first in this study. Slump test and the compressive strength test were done in this study to determine the properties of the concrete samples and the workability of the concrete itself. Last but not least, the flexural test is the most important part on this study.

3.8.1 Slump Test

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

Workability is one of the important things in freshly mixed concrete. Workability of concrete means the ability to work with concrete. It is includes the ease of placing, compacting, moulding and finishing of concrete in the required form. The workability test that used in this study is slump test. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is used to ensure uniformity for different loads of concrete under field conditions. The slump is carried out as per procedures mentioned in ASTM C143/C 143M-05.

The required equipment for slump test are cone shape mould, base plate, temping rod and measuring scale. For the procedure, the steel slump cone is placed on a solid, impermeable, level base and filled with the fresh concrete in three equal layers. Each layer is rodded 25 times to ensure compaction. The third layer is finished off level with the top of the cone. The cone is carefully lifted up, leaving a heap of concrete that settles or ‘slumps’ slightly. The upturned slump cone is placed on the base to act as a reference, and the difference in level between its top and the top of the concrete is measured and recorded to the nearest 5 mm to give the slump of the concrete.

3.8.2 Compressive Strength Test

We can have a clear view and judgement on whether the concreting has been done properly or not just with this test. Compressive strength is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture. Some materials fracture at their compressive strength limit; others deform irreversibly. Compressive strength is a key value for designing structures. The compressive strength of concrete is the most common performance measurement used by engineers when designing buildings and other structures.

For this study, three (3) samples were placed in cube mould with size 150 mm x 150 mm x 150 mm. Then, concrete was poured into the mould and tempered properly to reduce air void in the concrete. Moulds will be removed after 24 hours and the samples will be put in water for curing process. After 28 days of curing process, the samples were tested by using compression strength testing machine. From the testing, load was applied gradually at the rate of 1 N/mm^2 per second till the specimen fails. Then, load at the failure divided by area of specimen gives the compressive strength of concrete.

Figure 3.7: Compressive Test Machine

3.8.3 Flexural Strength Test

The main purpose of the flexural strength test is used to determine the flexural modulus or flexural strength of a material. From the testing, we can determine the result of three core stresses which are tensile, compressive and shear when a sample was placed under flexural loading. In addition, the flexural properties of a sample are the result of the combined effect of all three stresses as well as the geometry of the sample and the rate the load is applied.

For this test, beam sample with dimension 150 mm x 300 mm x 1500 mm were cast. After 24 hours of casting, the mould of the sample were removed and then undergo through the curing process for 28 days. The load implemented will increased and the failure load is noted at cracking of beam sample. Nine (9) beams were tested under four point loading flexural test by using Magnus Frame and their average value was taken.

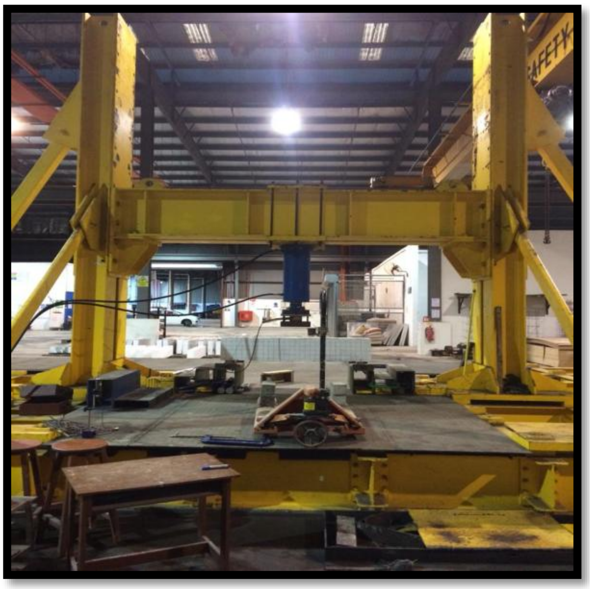


Figure 3.8: Magnus Frame

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The experimental results for each tests conducted are presented in this chapter. The results are presented in form of table and graph. The results includes slump test result, maximum load, maximum compressive strength and flexural strength test results. Based on these results, it can be utilized to determine the structural capacity and performances of reinforced concrete beam made up of rice husk. A set of data of modified concrete which are generated from this tests will be further used for the analysis and comparison with the controlled reinforced concrete beam.

4.2 Slump Test

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Table 4.1 and Figure 4.1 showed the variation in slump for 0%, 10% and 12% replacement of rice husk for fines aggregates in mix proportion.

Table 4.1: Slump Test Result

Percentage Replacement (%)	Slump Height (mm)
0	61
10	55
12	54

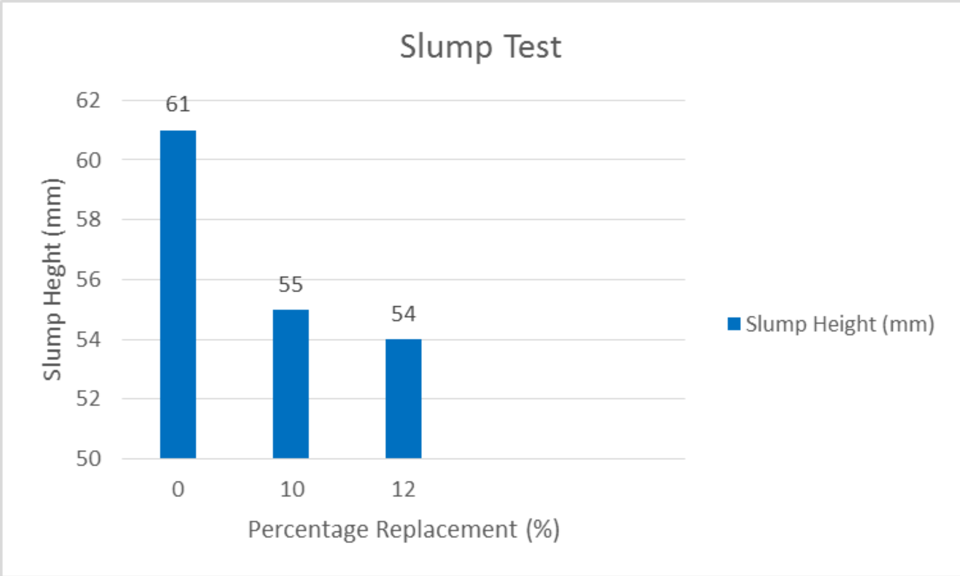


Figure 4.1: Slump Test for All Mix Proportion

Figure 4.1 shown the decreasing value of slump height from 0% replacement mix proportion to 12% replacement mix proportion. The characteristic of rice husk which is water absorbing maybe become the cause of this reduction. From the test, the data recorded showed that the highest value of slump height was 61 mm, which goes to 0% replacement of rice husk while the lowest value of slump height was 54 mm which obtained from 12% replacement. In 10% replacement of rice husk, the slump height was recorded at 55 mm. The workability of concrete's final strength (water/cement ratio) have been affected by the concrete mixture and the ratios of ingredients. As example, the higher the slump, the higher the amount of water in concrete mix which make the mixture contain more fluid and ease of placing, compacting, moulding and finishing of concrete. Therefore, 0% replacement of rice husk in mix proportion can be described as the highest workability of concrete among the mix proportion.

4.3 Compressive Strength Test

Compressive strength is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture. The test also indicates the major compressive strength which was carried out according to ASTM C-39. For this study, samples which are placed in cube mould with size 150 mm x 150 mm x 150 mm were tested. Then, the cube samples were cured in water and tested for compressive strength at the curing age of 28 days. The average compressive strength results was taken from the three of cube samples. The result of average compressive strength from the different percentage of rice husk replacement with curing period of 28 days are shown in Table 4.2.

Table 4.2: Compressive Strength Test for 28 Days Curing Period

Percentage Replacement (%)	Load (kN)	Compressive Strength (MPa)
0	716.4	31.84
10	418.17	18.59
12	363.63	16.16

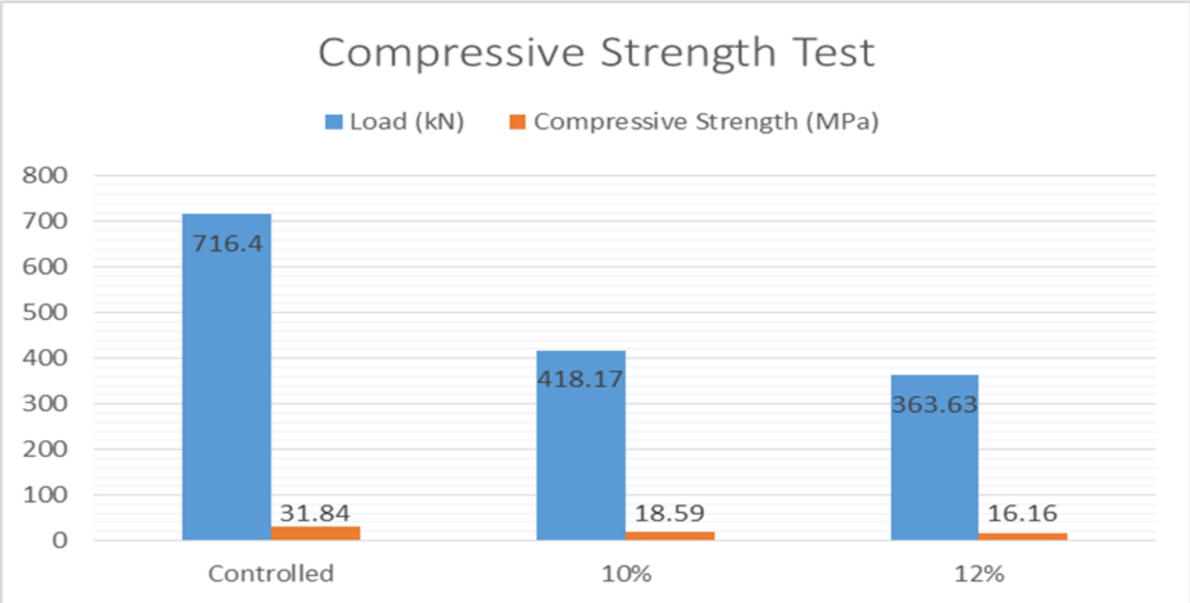


Figure 4.2: Comparison of Compressive Strength Test

The compressive strength test results indicate that the partial replacement of rice husk with fines aggregates at certain percentage of replacement caused a decrease in load and compressive strength of the concrete readings. From the graph, it is clearly observed that there is a downward trend in both load and compressive strength readings in graph of 28 days of curing period. The load and compressive strength readings was highest at 0% replacement of sand with rice husk with reading of 716.4 kN and 31.84 MPa respectively. The minimum value of load and compressive strength readings were recorded at the 12% replacement of sand with value of 363.63 kN and 16.16 MPa respectively. The reading values of load and compressive strength for 10% were recorded at 418.17 kN and 18.59 MPa respectively, the reading values are with amount in between the value of 0% and 12% replacement of rice husk.

The reduction in load and compressive strength reading may be affected by the pore structure induced by the rice husk addition. As rice husk content increases, the specific area increases, thus requiring more cement paste to bond effectively with the rice husks. Since the cement content remains the same, the bonding is therefore inadequate. The load and compressive strength reduces as a consequence of the increase in percentage of rice husk. It can be observed that the 28 days curing period compressive strength for 10% and 12% replacement of sand with rice husk concrete were above the specified value of 15 MPa, which are 18.59 MPa and 16.16 MPa respectively. Therefore, the concrete produced in this study can be classified as lightweight concrete (BS 8110, 1997) as shown in Table 4.3.

Table 4.3: Recommended Grade of Concrete

Grade	Characteristic strength, MPa	Concrete class
7 10	7.0 10.0	Plain concrete
15	15.0	Reinforced concrete with lightweight aggregates
20 25	20.0 25.0	Reinforced concrete with dense aggregates
30	30.0	Concrete with post tensioned tendons
40 50 60	40.0 50.0 60.0	Concrete with pre tensioned tendons

Source: BS 8110 (1997)

4.4 Flexural Strength Test

For flexural test, the beam samples were tested based on four point loading flexural test which according to the ASTM C78. The test only conducted after all the beam sample finished the 28 days of curing process. The method of curing process for beam samples use the wet gunny to fully cover the beam samples. Figure and table shown below in subchapter of flexural strength test recorded all the data collected from the test.

4.4.1 Mode of Failure (Cracking)

Observed failure mode was pure flexural for each beam samples which represents as controlled beam, beam samples with 10% and 12% replacement. The most important characteristics of concrete is it is strong in compression and very weak in tension. Due to its weakness in tension capacity, concrete will fail suddenly and in brittle manner under flexural unless it is reinforced with steel. Figure 4.3 until 4.5 shows the mode of failure of all the tested beam.

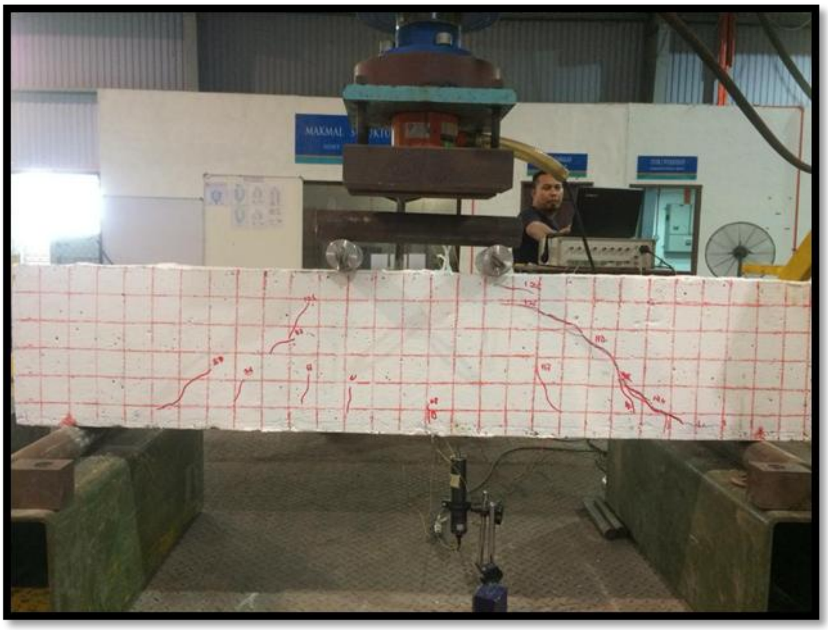


Figure 4.3: Flexural Failure for Controlled Beam

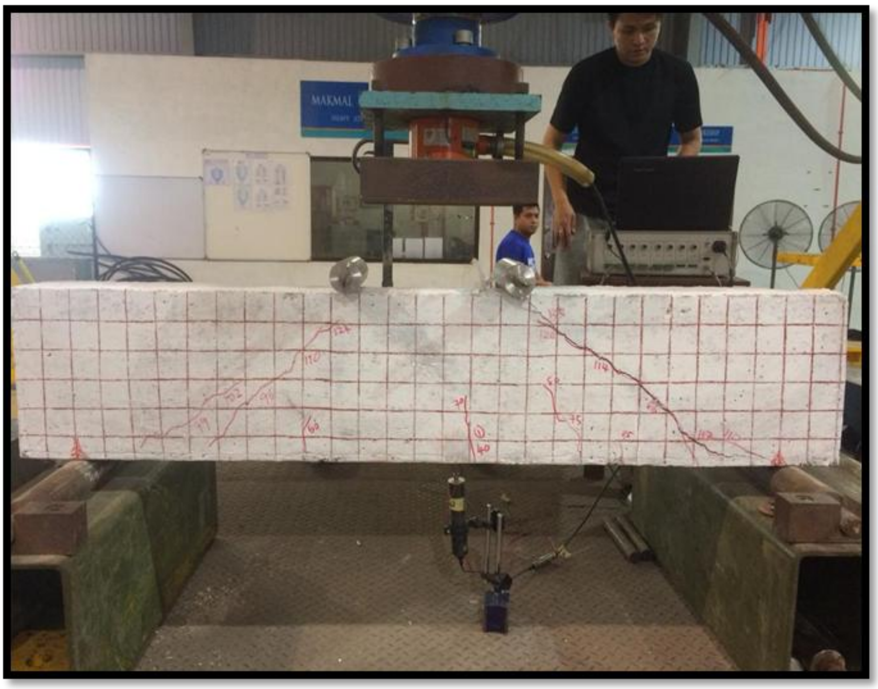


Figure 4.4: Flexural Failure for 10% Sample Beam

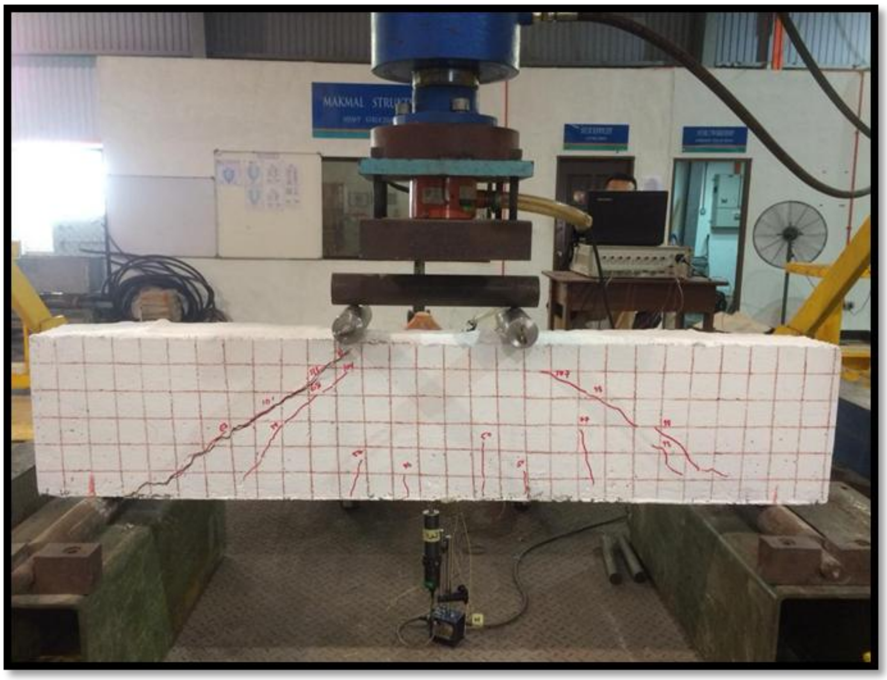


Figure 4.5: Flexural Failure for 12% Sample Beam

Based on the figure shown, all beam samples having the typical flexural failure. As all the beams were designed as under-reinforced beam, yielding of tension steel occurred first. Then this was followed by the crushing of concrete at the compression zone. Such behaviour was expected for the flexural failure. So failure started with a flexural crack in the bending zone and the crack was propagated to the neutral axis. After that, all the cracks started to be inclined to the middle of the beam to create the compression zone and then, gradual crushing of concrete occurred in this zone. From the figure shown, the beam sample with 10% and 12% replacement of rice husk experienced more tension crack compared to the sample of controlled beam. Both 10% replacement of beam sample and controlled beam experienced their first crack at range of 55 kN to 60 kN while for the 15% replacement of beam sample, it got the first crack at 46 kN. The tension cracks which happen at tension side of the beam is due to the yielding of tension steel which occurred first than the shear cracks. Shear cracks happen when the cracks starts to propagate to the neutral axis and crushed the concrete at compression zone. The experimental testing also confirmed substantial deflection before the ultimate failure of the beam.

4.4.2 Maximum Load

Table 4.4 Result on Maximum Load (kN) Resisted by Beam

No.of sample	**Controlled (kN)**	**10% (kN)**	**12% (kN)**
1	121.206	112.821	130.251
2	137.565	99.771	113.026
3	121.928	126.745	135.093
Average	126.900	113.112	126.123

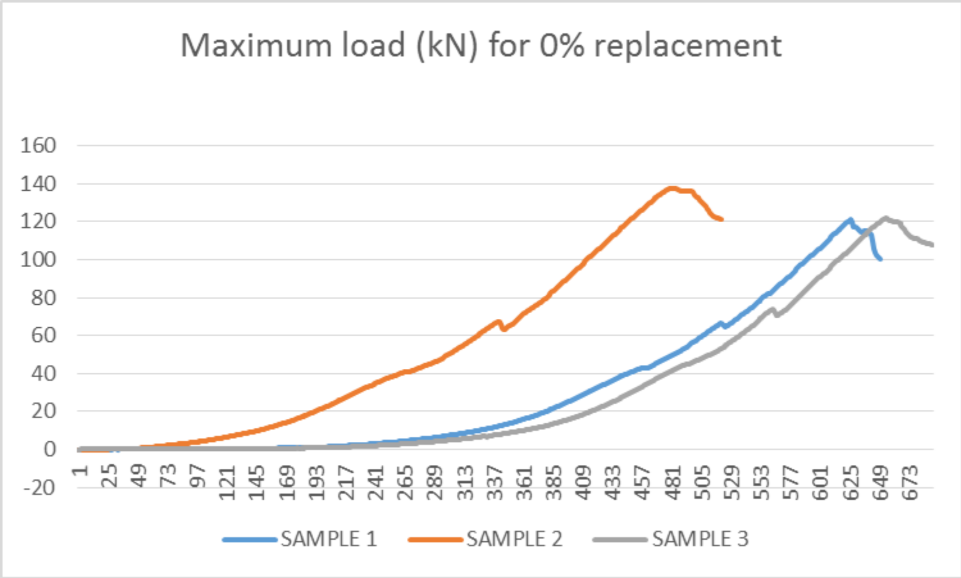


Figure 4.6: Maximum Load Readings for Controlled Beam

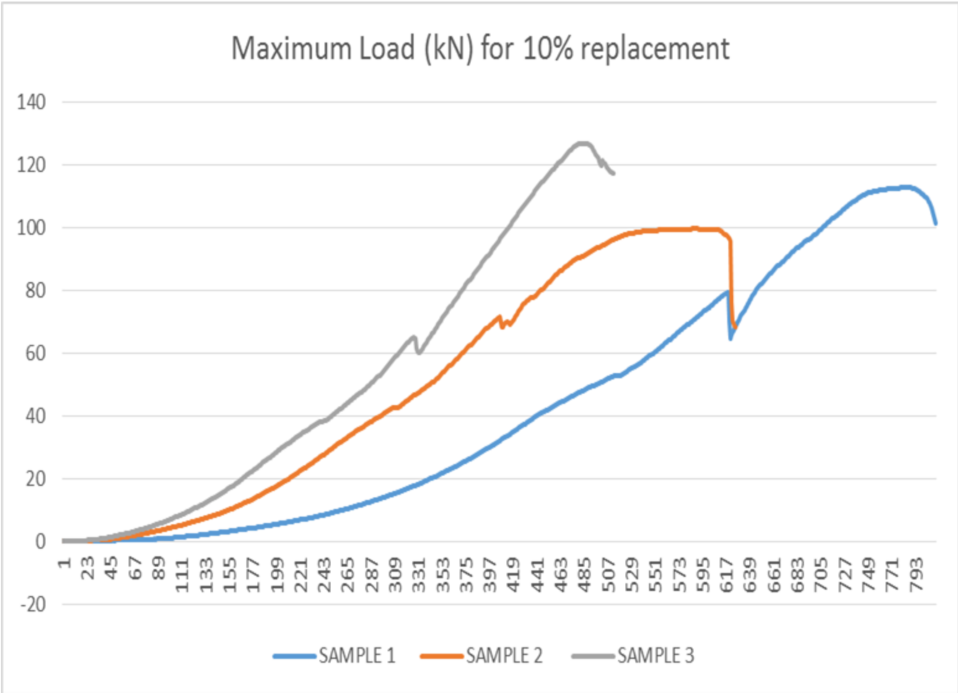


Figure 4.7: Maximum Load for 10% Beam Sample

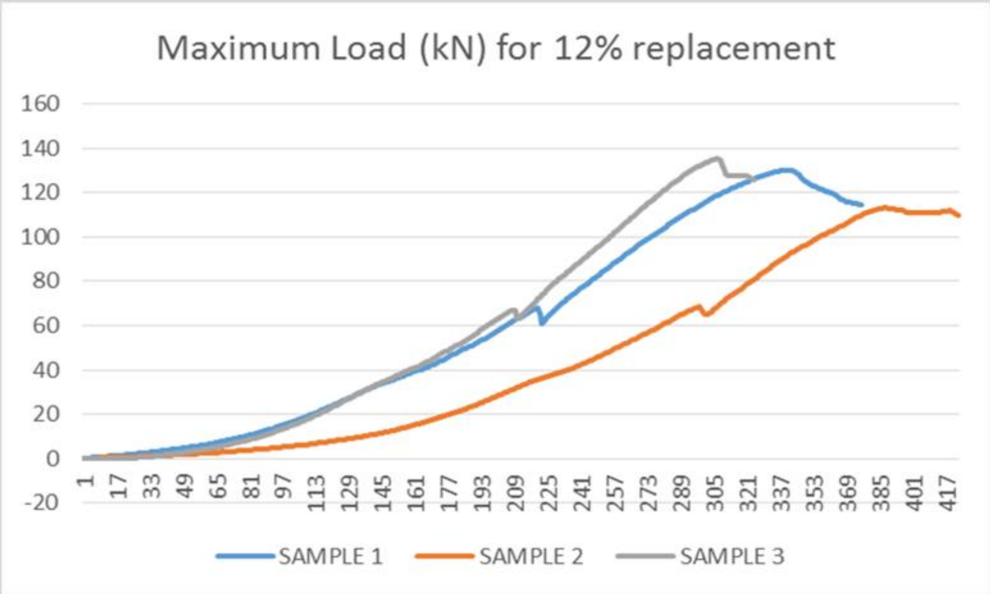


Figure 4.8: Maximum Load for 12% Beam Sample

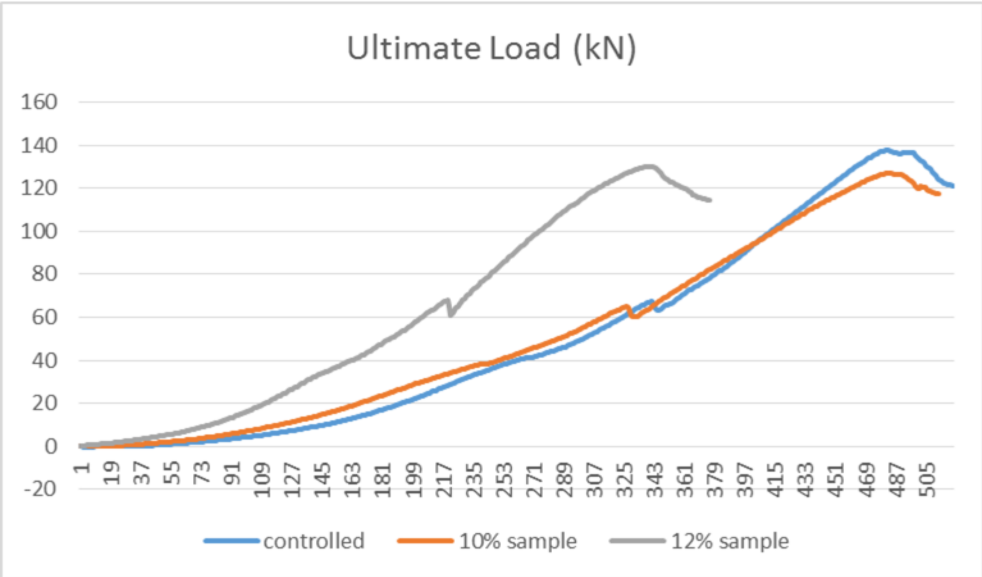


Figure 4.9: Average Maximum Load for All Samples

Based on the data recorded, the average load for all beam samples with 0%, 10% and 12% replacement showed the different value of maximum load that can sustained by each sample of beams. For controlled beam, the average maximum load that was recorded is 126.900 kN while the average maximum load that were recorded by sample beam with 12% replacement recorded the value of 126.123 kN. The slightly difference between both reading suggest that the replacement at 12% have not hugely affected the maximum loading capacity. The sample beam with 12% replacement almost achieve the maximum load obtained by the controlled beam. The graphical curve also suggest the typical curve for ultimate loading curves where the load increasing linearly until it reach it failure mode. For the sample beam with 10% replacement, the data recorded value of 113.112 kN which is the lowest value of average maximum load obtained compared to the controlled and sample beam with 12% replacement. However, the load recorded still exceed the value of the design load which is 100kN. The different value recorded may happen due to effect from the properties of the rice husk itself. The water absorbent characteristics in rice husk has contribute to the effect on the strength of concrete. The rapid decreasing of water content will affect the design mix of concrete in term of the water ratio and as a result, the bonding between others material become weak.

4.4.3 Deflection

In simple word, deflection is the degree to which a structural element is displaced under a load. The deflection distance of beam sample in this study were recorded by placing a transducer at the centre of the bottom of the beam. The data recorded for the deflection is in unit of millimetre (mm) and the result is shown in Table 4.5.

Table 4.5 Result on Deflection (mm) Occurred on Beam

No.of sample	**Controlled (mm)**	**10% (mm)**	**12% (mm)**
1	7.207	10.857	12.823
2	7.893	13.436	10.436
3	7.519	9.425	10.830
Average	7.540	11.239	11.363

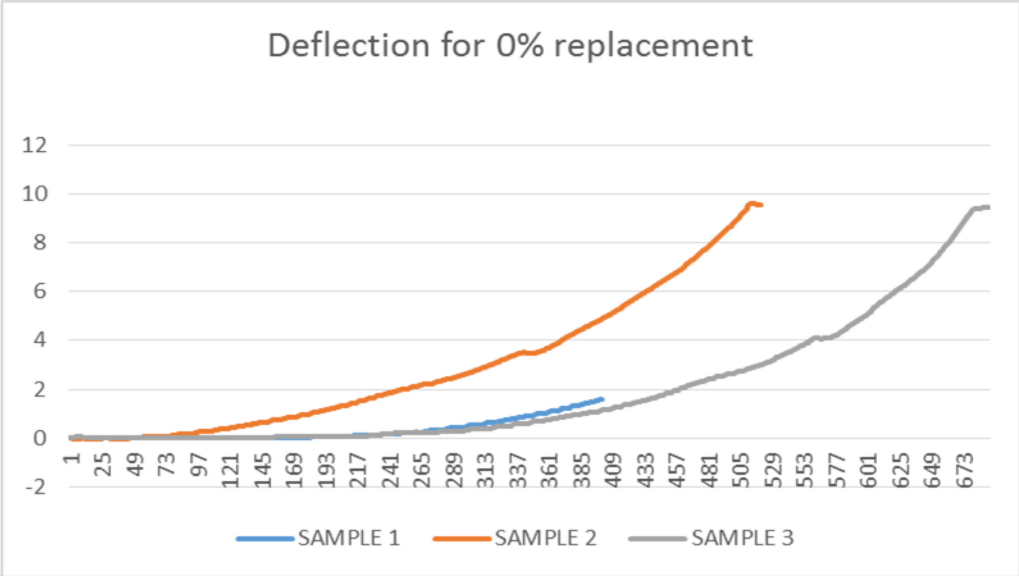


Figure 4.10: Deflection Curve for Controlled Beam

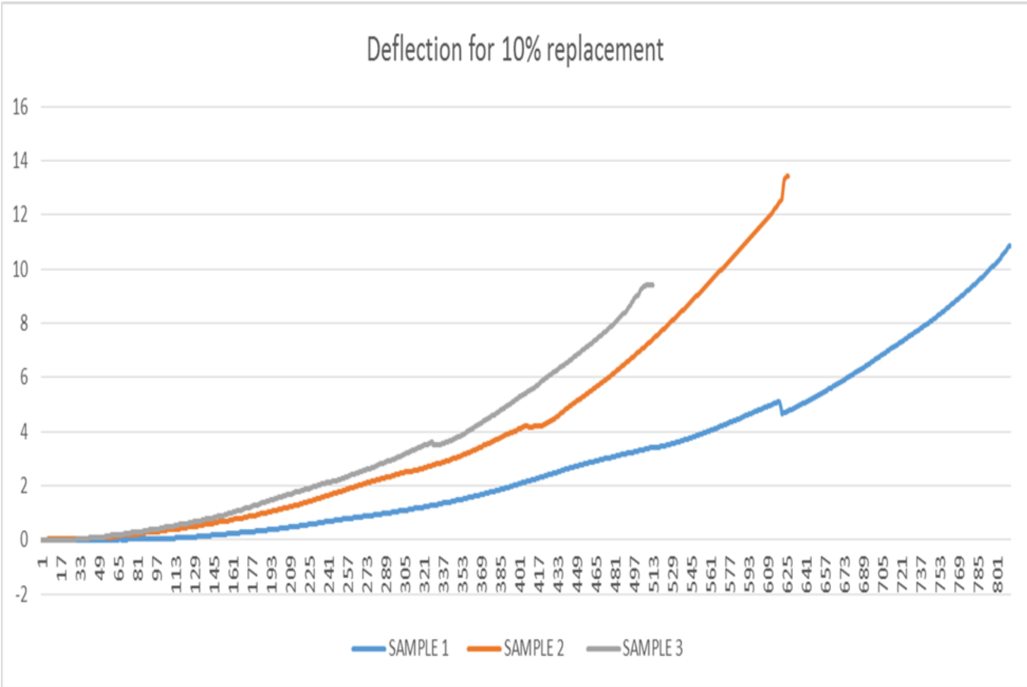


Figure 4.11: Deflection Curve for 10% Beam Sample

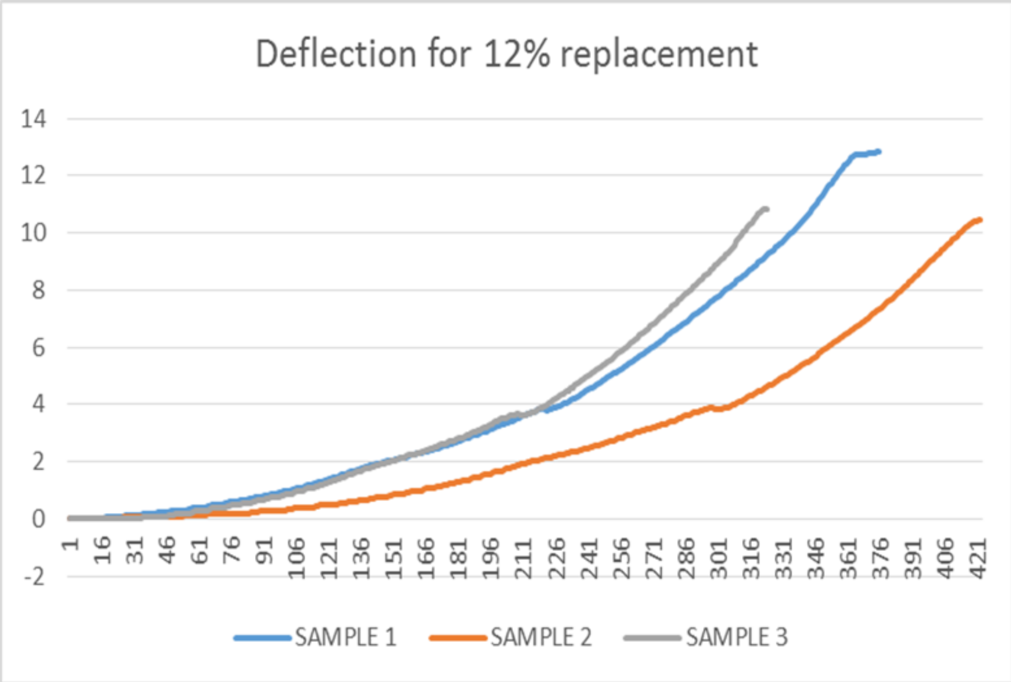


Figure 4.12: Deflection Curve for 12% Beam Sample

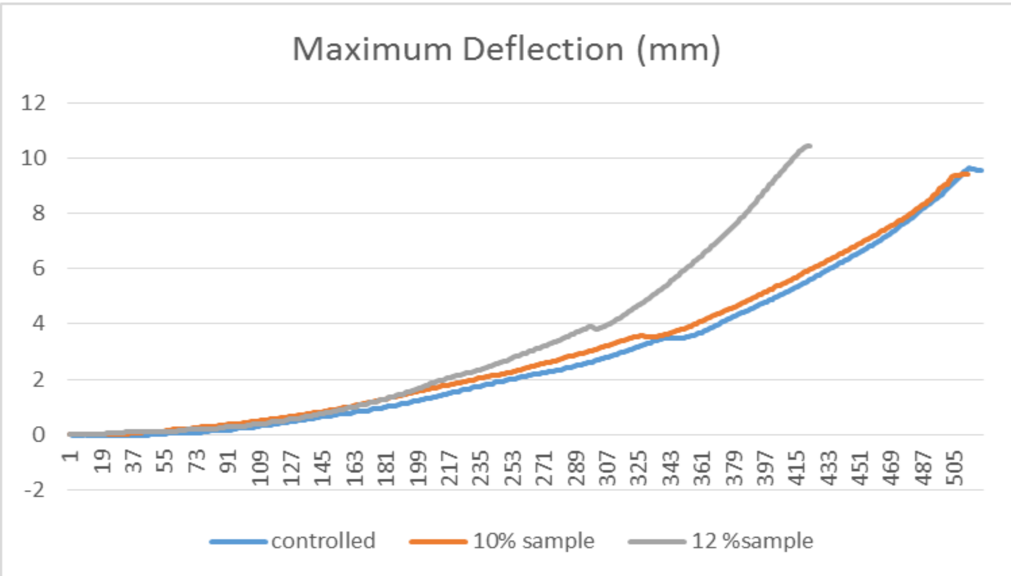


Figure 4.13: Average Maximum Deflection for All Samples

The graphical curves showed that the reading of the deflection increased when the load was applied on top of the beam sample. The deflection that were recorded by the controlled beam are around 7 mm until 7.5 mm. For the samples beam with 10% and 12% replacement, the data which recorded the average reading of deflection for both samples showed the slight difference between them. The average reading of deflection for beam sample with 10% and 12% showed the deflection reading which are 11.239 mm and 11.363 mm, respectively. The beam samples with the percentage of rice husk inside showed the high value of deflection compared to the sample of controlled beam.

4.4.4 Stress-strain of Concrete

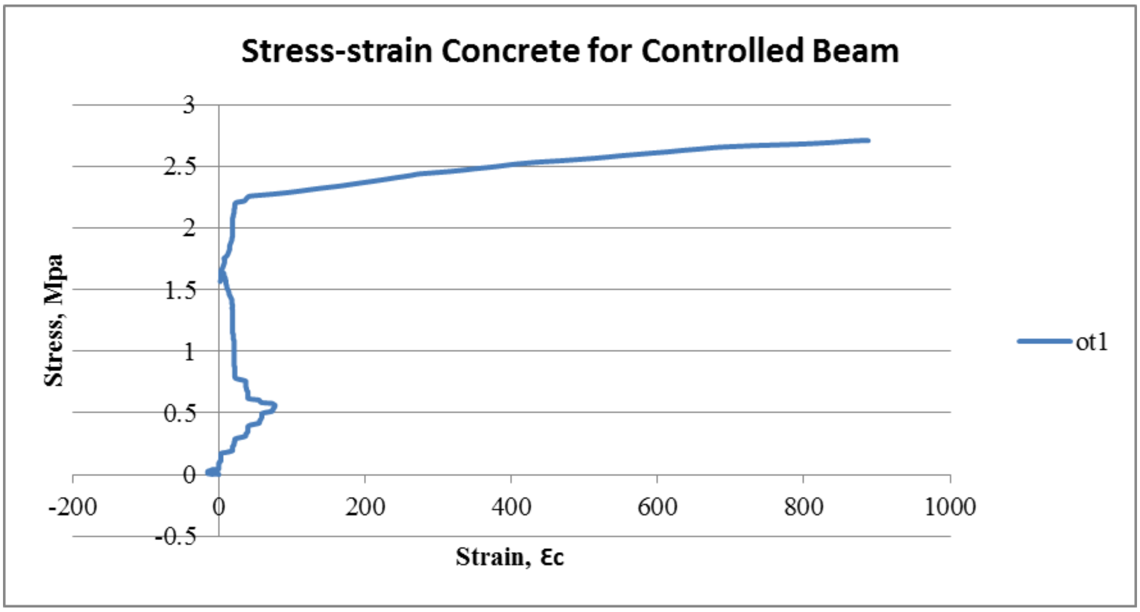


Figure 4.14: Average Stress-Strain Concrete for Controlled Beam

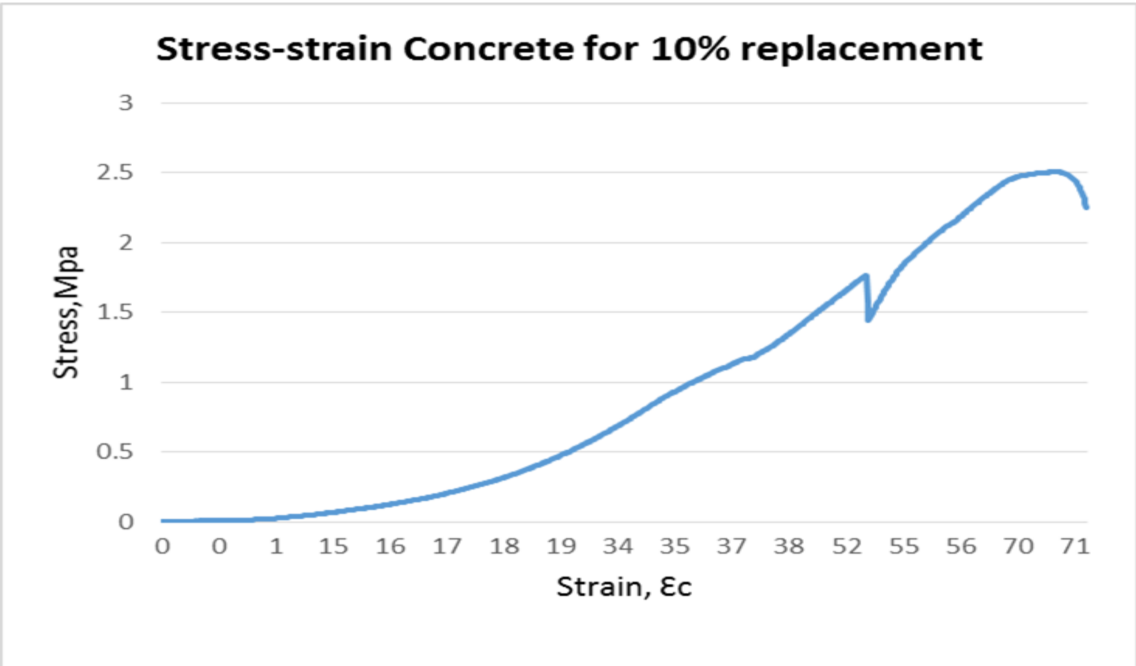


Figure 4.15: Average Stress-Strain Concrete for 10% Sample Beam

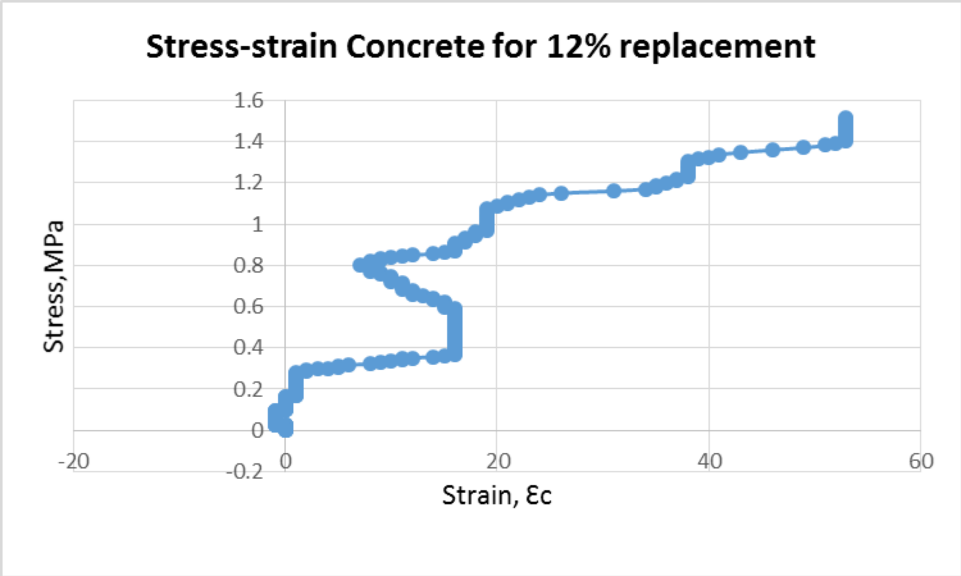


Figure 4.16: Average Stress-Strain Concrete for 12% Sample Beam

The reading of concrete strain are from the strain gauge that was placed at the surface of concrete which located at the bottom part of beam sample. The graphical curve for stress-strain relationships for controlled beam show the typical graph curve for strain of concrete. The addition of certain percentage of rice husk had effect the stress value of the concrete beam. From the graphical curves, it is obviously shown that the stress value decrease as well as the increasing of the percentage of rice husk replacement.

4.4.5 Stress-strain of Steel

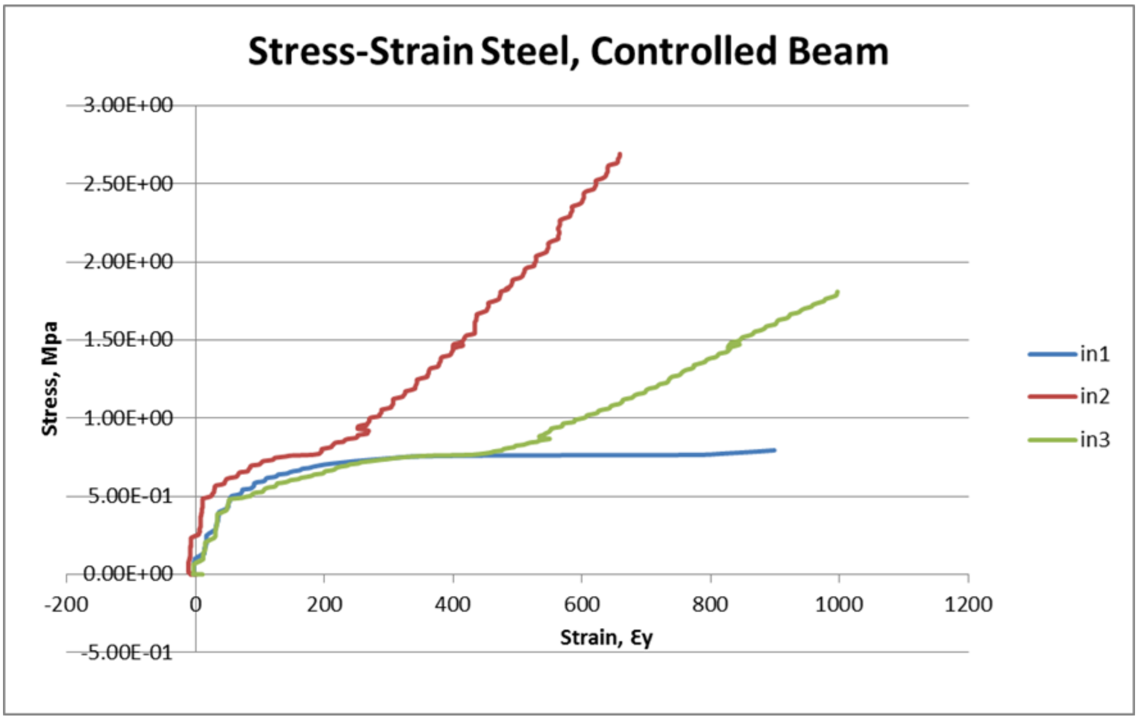


Figure 4.17: Average Stress-Strain Steel for Controlled Beam

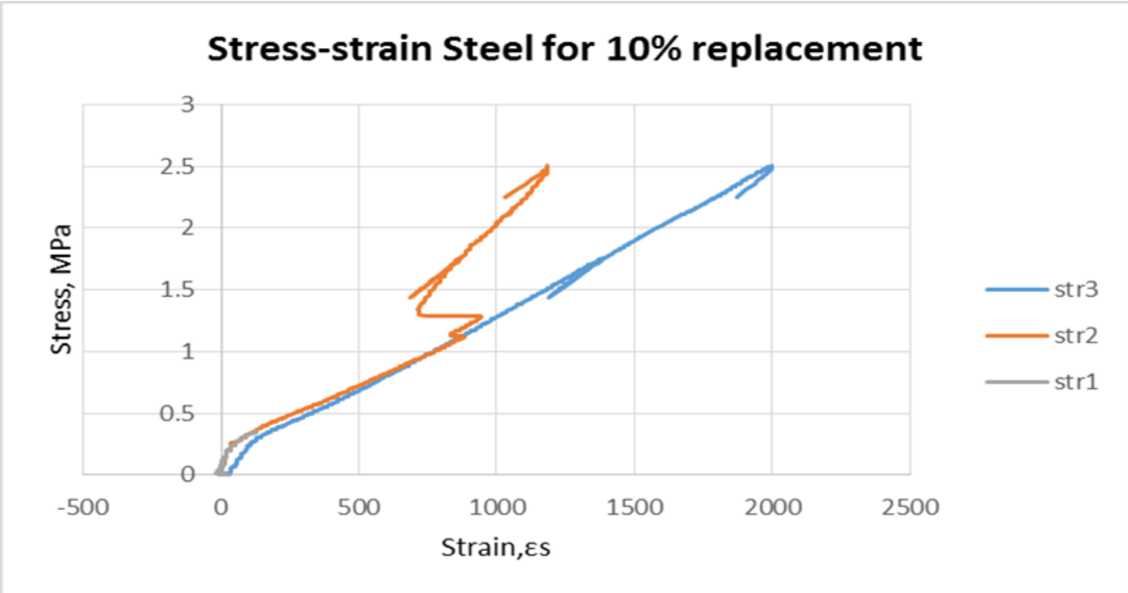


Figure 4.18: Average Stress-Strain Steel for 10% Beam Sample

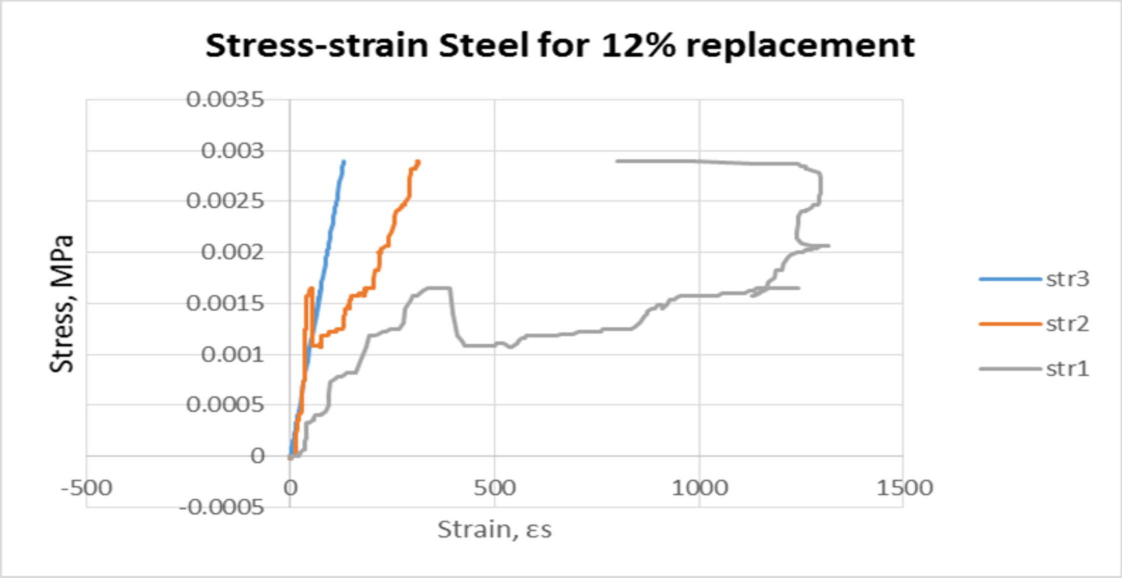


Figure 4.19: Average Stress-Strain Steel for 12% Beam Sample

From the graph above, the reading curve for all sample of beams which include controlled beam, sample beam with 10% replacement and 12 % replacement showed the approximate curve like the typical curve for stress-strain steel. For the controlled beam and sample beam with 12% replacement, the data recorded showed that both of samples exceed the value of 2.5 MPa before it reach the fracture point or breaking point. Breaking point is point where the strength of material breaks. In this study, the stress-strain reading for steel showed a series of unsatisfactory data which influenced the data plotting and graphical curve of stress-strain of steel. It is might be caused by the damage of strain gauges which located inside of the beam during the concreting work.

4.4.6 Maximum Moment Capacity

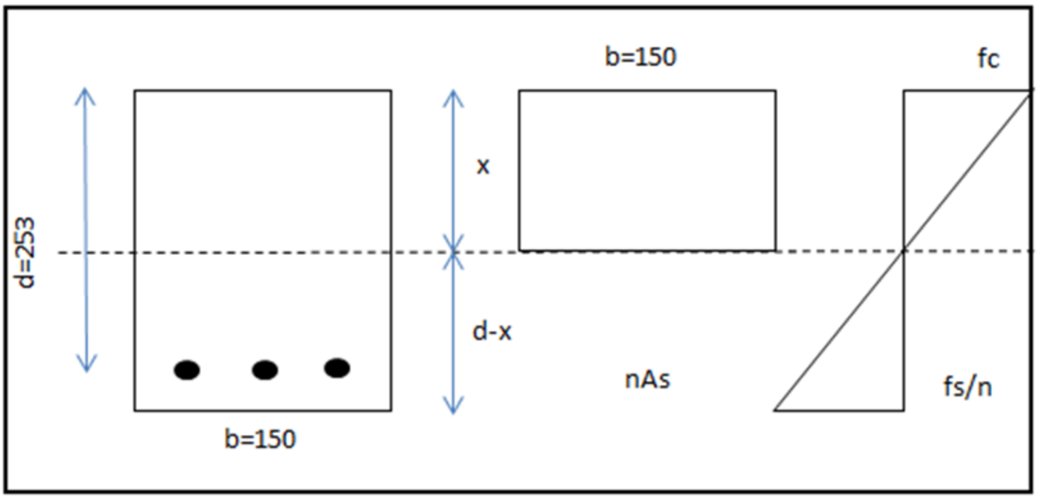


Figure 4.20: Moment Capacity of Singly Reinforced Beam

$$Ec = 4700\sqrt{fck} = 4700\sqrt{25} = 23500\ MPa$$

$$Es = 200000\ MPa$$

Modular Ratio:

$$n = \frac{Es}{Ec} = \frac{200000}{23500} = 8.5$$

Allowable Stress:

fs = 140 MPa for steel grade G275 ; fc = 0.45 (25) = 11.25 MPa

Steel Area:

$$As = 3 \times \frac{1}{4}\pi(12^2) = 108\pi\ mm^2$$

$$nAs = 8.5(108\pi) = 918\pi\ mm^2$$

Moment of Area:

$$150(x)\left(\frac{x}{2}\right) = nAs(d-x)$$

$$75x^2 = 918\pi(253-x)$$

$$75x^2 + 918\pi x - 232254\pi = 0$$

$$x1 = 81.26, x2 = -119.72$$

Use x= 81.26 mm

Moment Inertia:

$$I_{NA} = \frac{150x^3}{3} + nAs(d-x)^2$$

$$I_{NA} = \frac{150(81.26^3)}{3} + 918\pi(253-81.26)^2$$

$$I_{NA} = 111890728\ mm^4$$

Moment Capacity Concrete:

$$fc = \frac{Mx}{I_{NA}}$$

$$11.25 = \frac{M(81.26)(1000^2)}{111890728}$$

$$M = 15.49\ kN.m$$

Moment Capacity Steel:

$$\frac{fs}{n} = \frac{M(d-x)}{I_{NA}}$$

$$\frac{140}{8.5} = \frac{M(253-81.26)(1000^2)}{111890728}$$

$$M = 10.73kN.m$$

Use Safety Value of Moment M, capacity = 10.73kN.m

CHAPTER 5

CONCLUSION

5.1 Introduction

From previous chapter, the results of the study were tabled and the findings of the study were discussed in detail. In this chapter, the conclusions of the study and the proposed recommendations for future study were provided. The main idea for this study is to check the structural capacity of rectangular beam made up of rice husk concrete under the flexural test. The study is divided by using different percentage of rice husk replacement.

5.2 Conclusion

From the above experimental investigations, the flexural behaviour of RHC beam was found to be comparable to the other types of lightweight concrete beam and this study gives encouraging results for the use of rice husk to be used as fine aggregate in the production of structural lightweight concrete beam. The following conclusions can be drawn on the basis of the experimental results.

- All RHC beams showed typical flexural performances under four point loading flexural test. As the beams were under reinforced, yielding of the tensile reinforcement took place before crushing of the concrete (compressive) in the pure bending zone.

- For controlled beam, the average maximum load that was recorded is 126.900 kN while the average maximum load that were recorded by sample beam with 12% replacement recorded the value of 126.123 kN. The slightly difference between both reading suggest that the replacement at 12% have not hugely affected the maximum loading capacity. The sample beam with 12% replacement almost achieve the maximum load obtained by the controlled beam. For the sample beam with 10% replacement, the data recorded value of 113.112 kN which is the lowest value of average maximum load obtained. The average ultimate load that can resist by both controlled and sample beam with 10% and 12% replacement showed good results which exceed the design load calculated in beam design which is 100 kN. The partial replacement of RHC from 10% to 12% in concrete beam suggest that it will effect on the structural strength of sample.

- The deflection reading that were recorded by the controlled beam are around 7 mm until 7.5 mm. For sample beams with 10% and 12% replacement, data recorded showed slight difference between them which are 11.239 mm and 11.363 mm. The huge difference of deflection between sample beams and controlled beam conclude that the beam samples with 10% and 12% of rice husk inside deflect more compared to the controlled beam. However, the deflection under the design service loads for the reinforcement RHC beams were within the allowable limit of deflection in beam design which is 21.6 mm.
- This RHC beams can be used in the construction of single-storey house and the simple structure. The brief studies need to be conducted to develop the suitable design formula for RHC as the design can be used in the construction of heavy structures or high-rise buildings.
- Further investigation is recommended to understand more about the structural capacity and structural behaviour of RHC beams.

5.3 Recommendations for Future Study

Some recommendations from this subchapter might be useful to make sure that rice husk concrete can be used as solid structural member and can be applied in construction industry. Further investigation is recommended to study more about the structural capacity and behaviour of rice husk concrete beam. Besides that, the brief studies need to be conducted to develop the suitable design formula or design mix for RHC as the design can be widely used in construction industry.

Next, the brief studies also can find out the best or optimum ratio of rice husk replacement in reinforced concrete beam design. Rice husk concrete beam have many potential to be used as lightweight structural member and in future it might replace the conventional method that been used for many years in construction industry.

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APPENDIX A

DATA FOR FLEXURAL TEST (CONTROLLED BEAM)

Load, kN	Deflection, mm	Strain of Concrete	Strain of Steel 1	Strain of Steel 2	Strain of Steel 3
0	0	0	0	0	0
0	0	0	0	0	0
0.056	0.004	0	0	2	0
0.075	0.009	0	0	3	0
0.092	0.037	0	0	3	0
0.111	0.064	0	0	4	0
0.09	0.077	0	0	3	0
0.094	0.065	0	0	2	0
0.089	0.041	0	0	2	0
0.098	0.034	0	0	1	0
0.099	0.011	0	0	0	0
0.126	0	0	-1	-1	0
0.176	0	0	-2	-2	-1
0.163	0	0	-3	-3	-1
0.196	0.002	0	-4	-3	-1
0.177	0.001	0	-6	-5	-1
0.193	0.002	-1	-5	-6	-1
0.211	0.001	-1	-5	-7	-1
0.224	0.002	-2	-5	-8	-1
0.223	0.002	-3	-5	-8	-2
0.244	0.002	-3	-5	-8	-2
0.233	0.002	-4	-6	-9	-2
0.242	0.002	-5	-7	-9	-2
0.25	0.001	-5	-7	-9	-2
0.229	0	-6	-7	-9	-2
0.222	0	-7	-8	-9	-2
0.227	0	-7	-8	-9	-2
0.197	0	-7	-9	-9	-2
0.172	0	-8	-10	-9	-2
0.136	0	-9	-11	-9	-2
0.144	0	-9	-10	-9	-2
0.146	0	-10	-10	-9	-2
0.157	0	-9	-10	-9	-2
0.162	0	-9	-11	-9	-2
0.16	0	-8	-10	-9	-2
0.195	0	-10	-11	-9	-2
0.189	0	-10	-12	-9	-2

0.194	0	-11	-12	-9	-2
0.208	0	-11	-12	-9	-2
0.205	0	-10	-12	-9	-2
0.207	0	-10	-12	-9	-2
0.202	0	-11	-12	-9	-2
0.196	0	-11	-12	-9	-2
0.223	0	-11	-12	-9	-2
0.195	0	-11	-12	-9	-2
0.205	0	-11	-13	-9	-3
0.207	0	-10	-12	-9	-2
0.22	0	-10	-12	-9	-2
0.238	0	-10	-12	-9	-2
0.217	0	-10	-12	-9	-2
0.218	0	-11	-13	-9	-2
0.236	0	-11	-12	-9	-2
0.223	0	-11	-12	-9	-2
0.235	0	-10	-13	-9	-2
0.232	0	-11	-12	-9	-2
0.247	0	-10	-13	-9	-2
0.26	0	-10	-13	-9	-2
0.271	0	-10	-13	-9	-2
0.261	0	-11	-13	-9	-2
0.251	0	-11	-13	-9	-2
0.249	0	-12	-13	-9	-2
0.252	0	-11	-13	-9	-2
0.247	0	-11	-13	-9	-2
0.245	0	-11	-14	-9	-2
0.238	0	-10	-14	-9	-2
0.254	0	-8	-13	-7	-2
0.263	0	-8	-12	-7	-2
0.283	0	-9	-12	-7	-2
0.277	0	-10	-12	-8	-2
0.28	0	-11	-12	-8	-2
0.281	0	-11	-13	-9	-2
0.282	0	-11	-13	-9	-2
0.276	0	-10	-12	-9	-2
0.273	0	-9	-13	-9	-2
0.3	0	-9	-13	-9	-2
0.294	0	-9	-13	-8	-2
0.308	0	-10	-12	-7	-2
0.311	0	-11	-12	-8	-2
0.314	0	-11	-12	-7	-2
0.322	0	-11	-12	-7	-2
0.303	0	-11	-12	-7	-2

0.306	0	-11	-12	-7	-2
0.327	0	-11	-12	-6	-2
0.338	0	-11	-12	-7	-2
0.334	0	-11	-12	-6	-2
0.333	0	-11	-12	-6	-2
0.361	0	-11	-13	-6	-2
0.355	0	-11	-13	-5	-2
0.357	0	-11	-14	-6	-2
0.345	0	-11	-14	-6	-2
0.351	0	-11	-14	-5	-2
0.354	0	-11	-14	-5	-2
0.36	0	-12	-14	-6	-2
0.344	0	-12	-14	-6	-2
0.358	0	-11	-14	-5	-2
0.363	0	-11	-14	-5	-2
0.334	0	-12	-14	-6	-2
0.325	0	-12	-14	-6	-2
0.328	0	-12	-14	-5	-2
0.365	0.001	-11	-14	-3	-2
0.365	0.001	-11	-14	-3	-2
0.355	0	-13	-15	-3	-1
0.348	0.001	-13	-14	-4	-1
0.366	0	-14	-15	-5	-1
0.389	0.001	-13	-14	-5	-1
0.406	0	-14	-14	-4	-1
0.378	0.001	-13	-14	-3	-1
0.379	0.001	-14	-15	-2	-1
0.394	0	-15	-15	-2	-1
0.386	0.001	-14	-15	-2	-1
0.409	0.002	-14	-14	-2	-1
0.394	0.002	-14	-15	-2	-2
0.38	0.001	-14	-15	-3	-2
0.364	0.001	-14	-15	-2	-2
0.387	0.001	-14	-15	-2	-2
0.42	0.002	-14	-15	-2	-2
0.427	0.001	-14	-15	-1	-2
0.419	0.001	-15	-15	-1	-2
0.392	0.001	-15	-15	-2	-1
0.417	0.001	-15	-15	-3	-2
0.455	0.001	-15	-15	-1	-1
0.461	0.004	-15	-15	-29	-1
0.434	0.015	-15	-15	-104	-1
0.434	0.012	-15	-15	-104	-1
0.41	0.005	-15	-15	-104	-1

0.408	0.008	-14	-15	-104	-1
0.443	0.006	-15	-15	-104	-1
0.456	0.01	-15	-15	-104	-1
0.464	0.015	-15	-15	-104	-1
0.469	0.016	-15	-15	-104	-1
0.468	0.012	-15	-15	-104	-1
0.455	0.011	-15	-15	-103	-1
0.455	0.012	-15	-15	-103	-1
0.462	0.012	-15	-15	-103	-1
0.481	0.015	-15	-15	-103	-1
0.494	0.018	-15	-15	-103	-1
0.492	0.018	-15	-15	-103	-1
0.487	0.018	-15	-15	-103	0
0.498	0.02	-15	-15	-103	0
0.508	0.022	-15	-15	-103	0
0.496	0.021	-15	-15	-103	-1
0.482	0.023	-15	-15	-103	0
0.492	0.022	-15	-15	-103	-1
0.48	0.022	-15	-15	-103	-1
0.492	0.024	-15	-15	-103	-1
0.499	0.02	-15	-15	-103	0
0.5	0.023	-15	-15	-103	0
0.532	0.025	-15	-15	-103	0
0.543	0.025	-15	-15	-103	0
0.529	0.027	-15	-15	-103	0
0.53	0.028	-15	-15	-102	0
0.545	0.03	-15	-15	-102	0
0.529	0.03	-15	-15	-102	0
0.532	0.031	-15	-15	-102	0
0.553	0.035	-15	-15	-102	0
0.594	0.038	-15	-15	-102	0
0.596	0.038	-15	-14	-102	0
0.586	0.04	-15	-15	-102	0
0.584	0.039	-15	-15	-102	0
0.6	0.038	-15	-15	-102	0
0.576	0.04	-15	-15	-102	0
0.592	0.039	-15	-15	-102	0
0.614	0.038	-15	-15	-102	0
0.615	0.039	-14	-15	-102	0
0.583	0.04	-14	-15	-102	0
0.604	0.039	-14	-15	-102	0
0.602	0.041	-15	-15	-102	0
0.629	0.042	-15	-15	-102	0
0.637	0.041	-15	-15	-102	0

0.66	0.042	-15	-15	-102	0
0.659	0.042	-15	-15	-102	0
0.679	0.045	-14	-15	-102	0
0.648	0.045	-14	-15	-102	0
0.635	0.044	-14	-15	-102	0
0.622	0.043	-14	-15	-102	0
0.662	0.043	-14	-15	-102	0
0.668	0.046	-14	-15	-102	0
0.707	0.045	-14	-15	-102	0
0.689	0.046	-15	-15	-102	0
0.663	0.047	-15	-15	-102	0
0.689	0.049	-15	-15	-102	0
0.711	0.051	-15	-15	-102	0
0.693	0.052	-15	-15	-102	0
0.708	0.052	-15	-15	-102	0
0.739	0.054	-15	-15	-102	0
0.751	0.054	-15	-15	-102	0
0.767	0.054	-15	-15	-102	0
0.797	0.057	-15	-15	-102	0
0.791	0.057	-15	-15	-102	0
0.79	0.06	-15	-15	-102	0
0.796	0.061	-15	-15	-102	0
0.805	0.063	-15	-15	-102	0
0.786	0.064	-15	-15	-102	0
0.8	0.065	-15	-15	-102	0
0.838	0.065	-15	-15	-102	0
0.861	0.066	-15	-15	-102	0
0.855	0.067	-15	-15	-102	0
0.872	0.073	-15	-15	-102	0
0.895	0.072	-15	-15	-102	0
0.887	0.074	-15	-15	-102	0
0.919	0.075	-15	-15	-102	0
0.925	0.077	-15	-15	-102	0
0.94	0.078	-15	-15	-102	0
0.967	0.079	-15	-15	-102	0
0.978	0.08	-15	-15	-102	0
0.975	0.08	-15	-15	-102	0
0.997	0.08	-15	-15	-102	0
1.03	0.08	-15	-15	-102	0
1.046	0.08	-15	-15	-102	0
1.104	0.081	-15	-15	-102	0
1.124	0.081	-15	-15	-102	0
1.134	0.081	-15	-15	-102	0
1.152	0.081	-15	-15	-102	0

1.193	0.081	-15	-15	-102	0
1.219	0.081	-15	-15	-102	0
1.227	0.081	-15	-15	-102	0
1.246	0.081	-15	-15	-102	0
1.26	0.081	-15	-15	-102	0
1.293	0.081	-14	-15	-102	0
1.305	0.081	-13	-15	-102	0
1.351	0.081	-12	-15	-102	0
1.399	0.082	-13	-15	-102	0
1.425	0.082	-13	-15	-102	0
1.444	0.083	-13	-15	-102	0
1.462	0.084	-12	-14	-102	0
1.472	0.084	-12	-14	-102	0
1.513	0.085	-12	-14	-102	0
1.526	0.085	-11	-13	-102	0
1.56	0.086	-10	-13	-102	0
1.567	0.088	-9	-12	-102	0
1.585	0.089	-10	-12	-102	0
1.628	0.09	-8	-11	-102	0
1.633	0.095	-9	-11	-102	0
1.675	0.1	-8	-10	-102	0
1.713	0.15	-9	-11	-102	0
1.735	0.179	-9	-12	-102	0
1.806	0.178	-10	-11	-102	0
1.866	0.179	-8	-8	-102	0
1.905	0.179	-6	-7	-102	0
1.941	0.179	-5	-5	-102	0
1.976	0.179	-2	-4	-102	0
2.012	0.18	-1	-2	-101	0
2.023	0.18	-1	-2	-101	0
2.064	0.187	0	-1	-101	0
2.062	0.194	0	-1	-101	0
2.099	0.195	0	-1	-100	0
2.118	0.195	0	-1	-99	0
2.173	0.195	0	0	-98	0
2.195	0.195	0	0	-98	0
2.225	0.195	0	0	-97	0
2.265	0.195	0	0	-97	0
2.313	0.195	0	0	-96	0
2.357	0.195	0	0	-94	0
2.437	0.197	0	0	-94	0
2.463	0.206	0	0	-94	0
2.519	0.211	0	0	-93	0
2.554	0.217	0	0	-93	0

2.599	0.226	0	0	-93	0
2.627	0.233	0	0	-93	0
2.704	0.24	0	0	-91	0
2.746	0.256	0	0	-90	0
2.773	0.22	0	0	-91	0
2.81	0.196	0	0	-89	0
2.861	0.195	0	0	-90	0
2.928	0.194	0	0	-91	0
2.968	0.195	0	0	-92	0
2.988	0.195	0	0	-93	0
3.061	0.195	0	0	-94	0
3.089	0.195	0	0	-92	0
3.133	0.195	0	0	-93	0
3.187	0.195	0	0	-93	0
3.248	0.195	0	0	-93	0
3.311	0.195	0	0	-93	0
3.351	0.196	0	0	-93	0
3.372	0.199	0	0	-93	0
3.454	0.209	0	0	-92	0
3.479	0.222	0	0	-91	0
3.546	0.233	0	0	-91	0
3.592	0.243	0	0	-90	0
3.665	0.257	0	0	-91	0
3.73	0.265	0	0	-89	0
3.765	0.273	0	0	-88	0
3.824	0.275	0	0	-88	0
3.848	0.276	0	0	-87	0
3.926	0.276	0	0	-87	0
3.965	0.276	0	0	-87	0
4.033	0.276	0	0	-87	0
4.072	0.277	0	0	-86	0
4.137	0.278	0	0	-86	0
4.173	0.28	0	0	-86	0
4.219	0.283	1	0	-86	0
4.267	0.287	1	0	-86	0
4.315	0.291	1	0	-86	0
4.398	0.293	1	0	-86	0
4.454	0.293	1	0	-86	1
4.508	0.293	1	0	-86	1
4.559	0.293	1	0	-86	1
4.659	0.295	1	0	-86	1
4.74	0.305	2	0	-86	1
4.793	0.32	2	0	-86	1
4.847	0.333	2	0	-86	1

4.889	0.347	2	0	-86	1
4.953	0.361	2	0	-86	1
5.03	0.37	2	0	-86	2
5.077	0.373	3	0	-86	2
5.147	0.374	2	0	-86	3
5.207	0.374	3	0	-86	3
5.274	0.374	3	0	-86	4
5.333	0.375	3	0	-86	3
5.388	0.377	3	1	-86	4
5.499	0.38	3	1	-86	5
5.586	0.385	3	1	-85	6
5.65	0.389	3	1	-85	6
5.723	0.39	3	1	-85	7
5.79	0.391	3	1	-85	6
5.86	0.391	3	1	-85	6
5.956	0.398	3	1	-85	7
6.006	0.414	3	1	-85	7
6.084	0.429	3	1	-85	7
6.164	0.444	3	1	-85	7
6.244	0.461	3	1	-84	7
6.347	0.47	3	1	-84	6
6.426	0.471	3	1	-84	7
6.513	0.472	3	1	-84	7
6.574	0.472	3	1	-84	7
6.652	0.474	3	2	-84	8
6.74	0.477	3	2	-84	8
6.842	0.482	3	2	-84	9
6.909	0.487	3	1	-84	10
7.013	0.488	3	2	-84	10
7.041	0.488	3	2	-84	11
6.758	0.488	3	1	-84	8
7.003	0.502	3	2	-84	10
7.19	0.533	3	2	-83	11
7.304	0.559	3	2	-83	12
7.443	0.568	3	2	-83	13
7.557	0.569	3	3	-83	14
7.649	0.569	3	3	-83	15
7.746	0.571	3	3	-83	15
7.828	0.573	4	3	-83	15
7.922	0.579	5	3	-83	16
8.016	0.585	6	3	-83	16
8.098	0.586	9	3	-83	16
8.176	0.586	11	3	-83	16
8.286	0.589	12	3	-83	16

8.408	0.609	15	3	-83	16
8.5	0.632	15	3	-83	16
8.591	0.654	17	3	-83	16
8.689	0.666	18	3	-83	16
8.823	0.667	19	3	-83	16
8.921	0.667	19	3	-83	16
9.063	0.67	19	3	-83	16
9.136	0.676	19	3	-83	16
9.255	0.683	19	3	-83	16
9.358	0.684	19	3	-81	16
9.448	0.685	19	3	-80	16
9.579	0.7	19	3	-77	16
9.711	0.724	19	3	-76	16
9.81	0.751	19	3	-76	16
9.891	0.764	19	3	-74	16
10.019	0.764	19	3	-72	16
10.132	0.766	19	3	-71	17
10.247	0.769	19	4	-69	17
10.389	0.778	19	4	-68	17
10.508	0.781	20	5	-68	17
10.612	0.782	20	7	-68	17
10.761	0.797	20	9	-68	17
10.9	0.822	21	10	-68	18
10.977	0.845	21	12	-68	18
11.119	0.86	21	14	-68	18
11.254	0.862	21	14	-68	18
11.4	0.864	21	17	-68	18
11.58	0.868	21	18	-68	18
11.713	0.877	21	18	-68	18
11.858	0.879	21	18	-68	18
11.984	0.88	22	19	-67	19
12.159	0.895	22	19	-67	19
12.326	0.917	22	19	-67	19
12.512	0.941	22	19	-66	19
12.656	0.957	22	19	-66	19
12.82	0.96	22	19	-66	19
12.967	0.96	22	19	-65	19
13.098	0.963	23	19	-65	19
13.289	0.968	25	19	-65	19
13.479	0.975	28	20	-65	19
13.654	0.977	31	20	-65	19
13.816	0.977	34	21	-65	19
14.008	0.98	36	21	-65	19
14.163	0.998	37	21	-65	19

14.35	1.022	37	21	-65	19
14.534	1.046	37	21	-65	20
14.725	1.057	37	21	-65	22
14.893	1.057	37	21	-65	25
15.082	1.059	38	22	-64	27
15.28	1.063	39	22	-61	29
15.472	1.071	39	22	-58	31
15.655	1.074	40	22	-57	33
15.873	1.075	40	22	-52	34
16.089	1.089	40	22	-49	34
16.284	1.113	40	24	-49	34
16.488	1.14	40	26	-49	34
16.718	1.154	40	29	-49	35
16.926	1.155	40	31	-49	35
17.138	1.157	40	35	-49	35
17.419	1.163	40	37	-48	36
17.624	1.171	40	37	-48	36
17.844	1.172	41	37	-47	36
18.084	1.189	43	37	-47	37
18.316	1.214	47	38	-46	37
18.561	1.241	51	38	-46	37
18.784	1.252	55	39	-46	37
19.013	1.254	56	39	-46	37
19.289	1.258	56	40	-46	37
19.561	1.268	56	40	-46	37
19.798	1.272	56	40	-46	37
20.053	1.296	57	40	-46	37
20.364	1.328	58	40	-46	38
20.627	1.349	58	40	-46	38
20.867	1.351	59	40	-46	38
21.132	1.354	59	40	-44	40
21.442	1.364	59	40	-41	44
21.717	1.367	59	42	-37	47
22.039	1.379	59	46	-34	49
22.325	1.413	59	50	-32	51
22.584	1.443	62	53	-31	53
22.875	1.448	68	55	-31	53
23.189	1.451	73	56	-30	53
23.487	1.461	74	56	-30	53
23.765	1.465	74	56	-29	53
24.083	1.479	74	57	-28	53
24.392	1.51	76	58	-28	54
24.7	1.543	76	58	-28	54
25.053	1.546	77	59	-28	55

25.353	1.553	77	59	-28	55
25.676	1.562	75	61	-27	56
26.005	1.566	73	68	-23	56
26.313	1.597	59	75	-12	56
26.613	1.636	57	94	8	57
26.924	1.643	56	109	24	69
27.28	1.649	55	119	31	72
27.563	1.659	45	141	48	86
27.881	1.667	40	163	64	106
28.22	1.703	40	171	76	111
28.53	1.738	40	185	82	122
28.922	1.742	40	190	87	128
29.262	1.749	40	204	99	131
29.575	1.758	40	212	106	146
29.908	1.775	40	231	126	160
30.265	1.822	40	247	143	176
30.551	1.839	39	261	157	188
30.925	1.845	38	273	170	202
31.282	1.855	38	281	176	211
31.625	1.865	38	295	191	221
31.984	1.903	37	302	195	227
32.338	1.935	37	316	210	239
32.669	1.939	37	322	215	247
33.077	1.952	37	336	230	259
33.442	1.965	37	352	241	271
33.829	2.005	37	367	250	280
34.149	2.034	37	382	266	295
34.517	2.038	33	396	276	307
34.873	2.05	27	413	288	317
35.227	2.064	23	429	303	333
35.613	2.109	22	445	310	348
35.988	2.131	22	455	322	355
36.345	2.137	22	465	324	368
36.743	2.148	22	473	330	372
37.084	2.157	22	483	340	385
37.425	2.196	22	491	342	389
37.766	2.228	22	501	346	395
38.088	2.233	22	507	358	406
38.439	2.244	22	519	360	409
38.749	2.248	22	521	361	422
39.058	2.274	22	534	362	426
39.359	2.307	22	539	373	434
39.692	2.326	21	543	377	443
39.977	2.331	21	556	379	445

40.329	2.341	21	559	380	458
40.685	2.345	21	572	389	462
40.998	2.369	21	576	395	464
41.302	2.4	21	583	397	478
41.642	2.423	21	593	398	481
41.968	2.428	21	596	401	487
42.288	2.438	21	609	413	498
42.631	2.442	21	613	415	500
42.987	2.468	21	618	417	510
43.305	2.508	21	630	421	517
43.641	2.522	21	633	432	519
43.928	2.526	21	645	434	530
44.256	2.536	21	649	435	536
44.55	2.539	21	651	436	537
44.747	2.544	21	653	444	540
44.877	2.564	21	664	450	551
44.973	2.586	21	666	451	553
44.986	2.606	21	667	451	553
45.088	2.619	21	667	451	554
45.367	2.62	21	669	451	556
45.705	2.624	21	672	453	558
46.038	2.635	21	684	454	570
46.363	2.638	21	687	457	573
46.684	2.663	21	688	468	574
46.974	2.694	21	698	470	583
47.294	2.717	21	705	472	590
47.601	2.72	21	707	472	592
47.851	2.73	21	714	473	593
48.107	2.735	21	722	484	604
48.434	2.754	21	725	488	609
48.767	2.783	21	726	490	611
49.067	2.813	21	737	491	612
49.358	2.816	20	741	493	623
49.667	2.824	20	742	504	628
49.947	2.832	20	744	507	630
50.269	2.841	20	748	508	633
50.576	2.871	20	759	509	645
50.872	2.905	20	761	512	647
51.214	2.914	20	762	523	648
51.562	2.923	19	764	525	657
51.913	2.93	19	776	527	664
52.345	2.954	19	780	529	667
52.775	2.993	19	775	541	674
53.19	3.011	19	709	544	683

53.584	3.021	19	704	546	685
54.038	3.029	19	704	549	693
54.457	3.061	19	704	561	702
54.849	3.101	19	704	564	705
55.286	3.111	19	704	565	717
55.718	3.123	19	680	574	721
56.166	3.14	19	601	581	724
56.63	3.178	19	593	583	736
57.108	3.206	19	594	584	740
57.558	3.229	19	595	596	744
57.979	3.295	19	595	629	757
58.427	3.308	19	596	639	759
58.879	3.321	19	602	645	763
59.37	3.35	19	610	654	776
59.864	3.392	19	611	657	778
60.36	3.405	19	613	658	790
60.833	3.419	18	614	670	795
61.328	3.447	19	614	674	800
61.853	3.49	19	622	676	812
62.365	3.505	18	630	683	815
62.87	3.516	18	631	691	825
63.368	3.549	18	632	694	832
63.874	3.593	18	633	694	837
64.388	3.606	17	638	703	850
64.902	3.625	16	647	711	852
65.451	3.671	15	649	713	865
66.02	3.699	14	651	719	870
66.591	3.718	14	651	729	879
67.146	3.763	13	658	731	888
67.735	3.795	12	666	736	893
68.339	3.812	11	667	747	905
68.948	3.85	11	667	750	907
69.505	3.887	10	669	752	916
70.074	3.898	10	678	764	925
70.661	3.914	10	686	767	928
71.208	3.954	9	688	768	941
71.725	3.99	9	693	774	944
72.216	4.009	8	704	784	949
72.697	4.048	7	706	786	960
73.135	4.084	7	707	787	962
73.485	4.087	7	707	787	963
73.711	4.094	5	707	789	963
73.24	4.096	3	705	787	962
71.654	4.083	3	688	774	947

70.508	4.048	2	672	766	939
70.513	4.048	2	670	765	938
71.069	4.079	3	675	766	942
71.617	4.087	3	685	768	943
72.1	4.091	3	686	768	944
72.544	4.097	3	688	769	945
72.966	4.102	3	688	780	955
73.444	4.109	3	696	785	961
73.971	4.135	3	704	787	963
74.577	4.171	3	706	795	975
75.304	4.189	5	714	804	981
76.068	4.2	6	722	812	994
76.822	4.233	7	724	822	1002
77.58	4.276	8	725	824	1016
78.222	4.293	8	725	834	1019
78.548	4.34	8	725	838	1023
78.951	4.382	7	730	839	1032
79.592	4.402	10	741	842	1037
80.28	4.453	12	740	845	1047
80.97	4.492	13	741	857	1055
81.661	4.549	14	741	860	1061
82.327	4.581	15	743	861	1073
82.979	4.605	15	744	861	1077
83.681	4.657	15	752	861	1090
84.384	4.681	16	759	861	1094
85.042	4.711	17	761	861	1108
85.719	4.763	18	762	869	1111
86.394	4.782	18	768	876	1122
87.069	4.819	19	778	877	1129
87.723	4.866	19	780	879	1135
88.369	4.886	19	781	879	1146
88.939	4.939	19	781	880	1149
89.517	4.976	19	787	881	1160
90.121	4.991	19	795	887	1166
90.558	5.041	19	796	889	1167
90.867	5.081	19	796	884	1168
91.402	5.137	19	798	891	1178
91.978	5.17	19	799	895	1183
92.57	5.213	19	800	896	1185
93.194	5.265	19	799	898	1196
93.754	5.342	19	802	898	1203
94.328	5.375	20	810	898	1206
94.972	5.427	20	815	908	1219
95.625	5.461	21	817	913	1222

96.27	5.499	21	818	915	1234
96.85	5.551	21	820	916	1240
97.487	5.579	22	830	916	1244
98.136	5.634	22	833	917	1257
98.77	5.669	22	834	920	1259
99.348	5.724	24	835	928	1271
99.929	5.757	35	836	932	1277
100.517	5.801	37	836	932	1283
101.106	5.848	39	836	932	1295
101.664	5.881	42	837	933	1299
102.24	5.934	66	843	933	1311
102.75	5.965	86	850	934	1314
103.31	6.019	104	852	935	1322
103.917	6.052	121	854	935	1331
104.572	6.095	140	855	935	1335
105.238	6.14	161	859	935	1349
105.904	6.169	179	869	941	1352
106.577	6.209	196	871	947	1257
107.211	6.242	213	872	950	-6321
107.861	6.275	229	873	951	-17028
108.501	6.323	244	878	952	-17597
109.161	6.351	261	888	953	-17597
109.811	6.4	275	889	953	-17597
110.416	6.444	304	891	953	-17597
111.03	6.499	329	891	954	-17597
111.648	6.536	349	891	957	-17597
112.252	6.577	371	891	964	-17597
112.855	6.625	390	891	969	-17597
113.447	6.662	408	892	969	-17597
114.054	6.715	434	892	971	-17597
114.645	6.755	469	898	972	-17597
115.225	6.812	499	907	972	-17597
115.832	6.854	527	908	972	-17597
116.412	6.902	549	910	973	-17597
116.911	6.941	571	910	977	-17597
117.377	6.996	592	910	980	-17597
117.852	7.035	614	913	986	-17597
118.419	7.097	636	922	987	-17597
118.963	7.145	660	926	988	-17597
119.498	7.206	683	927	989	-17597
120.063	7.249	727	928	990	-17597
120.6	7.306	787	928	990	-17597
121.047	7.35	824	929	990	-17597
121.497	7.41	849	929	990	-17597

121.897	7.453	872	929	990	-17597
121.928	7.519	888	929	990	-17597
121.081	7.599	875	920	984	-17597
120.567	7.67	871	911	972	-17597
120.447	7.736	862	910	972	-17597
120.33	7.806	855	910	971	-17597
120.154	7.873	854	910	970	-17597
120.036	7.933	852	910	969	-17597
120.043	8.001	847	910	969	-17597
120.04	8.065	837	910	969	-17597
119.966	8.127	836	910	967	-17597
119.521	8.204	834	908	955	-17597
118.993	8.28	825	903	953	-17597
118.023	8.365	816	890	942	-17597
117.312	8.446	803	880	934	-17597
116.774	8.514	798	873	931	-17597
115.714	8.599	786	861	917	-17597
114.674	8.682	778	846	906	-17597
113.826	8.765	763	835	897	-17597
113.071	8.846	759	823	889	-17597
112.346	8.926	744	815	879	-17597
111.936	8.999	743	811	878	-17597
111.649	9.072	740	801	876	-17597
111.407	9.144	731	799	872	-17597
111.208	9.211	725	799	863	-17597
111.039	9.28	725	798	861	-17597
110.811	9.345	723	797	861	-17597
110.416	9.388	716	788	860	-17597
109.836	9.409	707	780	850	-17597
109.476	9.419	705	776	843	-17597
109.221	9.423	703	766	842	-17597
109.037	9.426	694	762	842	-17597
108.829	9.429	688	762	840	-17597
108.642	9.434	688	761	839	-17597
108.46	9.437	687	760	838	-17597
108.31	9.442	685	759	825	-17597
108.199	9.444	685	757	824	-17597
108.067	9.433	680	751	814	-17597
107.947	9.444	671	747	856	-17597

APPENDIX B

DATA FOR FLEXURAL TEST (10% BEAM SAMPLE)

Load, kN	Deflection, mm	Concrete Strain	Steel Strain 1	Steel Strain 2	Steel Strain 3
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	16
0.043	0.001	0	0	-1	35
0.069	0.003	0	0	-1	34
0.088	0.002	0	0	-4	20
0.116	0.004	0	0	-4	23
0.128	0.007	0	0	-5	-8
0.108	0.007	0	0	-10	-9
0.145	0.007	0	0	-10	-11
0.207	0.007	0	0	-4	-11
0.165	0.008	0	0	-7	-11
0.204	0.009	0	0	-10	-12
0.187	0.01	0	0	-9	-12
0.206	0.011	0	0	-9	-12
0.232	0.011	-1	0	-6	-12
0.25	0.012	-1	0	-7	37
0.245	0.012	-1	0	-8	17
0.25	0.012	-1	0	-10	19
0.279	0.012	-1	0	-8	9
0.284	0.012	-1	0	-7	15
0.292	0.012	-1	0	-9	9
0.343	0.012	-1	0	-8	119
0.337	0.012	-1	0	-11	87
0.352	0.012	-1	0	-12	72
0.387	0.012	-1	0	-14	62

0.439	0.012	-1	0	-15	48
0.461	0.013	-1	0	-15	47
0.499	0.013	-1	0	-15	46
0.5	0.014	-1	0	-15	46
0.522	0.016	-1	0	-15	46
0.601	0.021	-1	0	-15	46
0.647	0.026	-1	0	-8	67
0.73	0.031	-1	0	0	311
0.775	0.038	-1	0	0	315
0.826	0.044	-1	0	0	170
0.877	0.047	-1	0	0	342
0.938	0.051	-1	0	0	75
0.995	0.055	0	0	0	26
1.059	0.06	0	0	0	4
1.124	0.069	0	0	1	31
1.197	0.081	0	0	1	149
1.266	0.09	0	0	0	427
1.332	0.093	0	0	0	466
1.398	0.093	1	1	1	454
1.44	0.094	1	3	1	455
1.499	0.095	1	5	1	443
1.589	0.097	1	6	1	435
1.676	0.101	1	7	1	431
1.772	0.105	1	7	1	434
1.843	0.109	1	8	1	433
1.919	0.11	1	8	1	426
2.004	0.11	1	9	2	377
2.095	0.113	1	10	1	163
2.13	0.127	1	10	2	89
2.206	0.139	1	11	2	102
2.285	0.148	1	11	2	112

2.374	0.156	1	12	2	132
2.433	0.167	0	12	1	131
2.521	0.183	0	12	2	129
2.611	0.19	0	12	2	137
2.694	0.191	0	13	3	139
2.773	0.191	0	13	3	139
2.889	0.193	0	14	3	160
2.987	0.195	0	15	3	163
3.065	0.201	0	15	3	157
3.128	0.206	0	15	3	155
3.239	0.208	0	15	3	155
3.303	0.209	0	15	3	156
3.374	0.214	0	15	3	158
3.486	0.225	0	16	3	158
3.594	0.236	0	15	3	194
3.717	0.244	0	15	3	192
3.829	0.251	-1	16	3	198
3.931	0.259	-1	16	3	44
4.028	0.276	-1	16	3	66
4.109	0.287	-1	16	3	66
4.214	0.288	-1	16	3	4
4.295	0.289	-1	16	3	-16
4.416	0.291	-1	16	3	49
4.532	0.295	-1	16	3	105
4.665	0.3	-1	16	3	258
4.795	0.305	-1	16	3	353
4.9	0.306	-1	16	3	376
5.001	0.308	-1	16	3	384
5.101	0.317	-1	17	3	375
5.232	0.331	-1	17	3	391
5.372	0.34	-1	17	4	380

5.489	0.346	-1	17	3	379
5.636	0.355	-1	17	4	380
5.761	0.371	-1	17	6	417
5.873	0.384	-1	18	10	436
5.991	0.386	-1	18	12	407
6.129	0.387	-1	18	12	30
6.264	0.39	-1	18	12	-11
6.387	0.396	-1	18	17	-6
6.552	0.402	-1	18	18	2
6.703	0.403	-1	18	19	7
6.838	0.404	-1	18	19	4
6.959	0.418	-1	19	19	-5
7.084	0.433	-1	19	19	7
7.221	0.442	-1	19	19	9
7.376	0.451	-1	19	19	14
7.514	0.468	-1	19	20	26
7.694	0.481	-1	19	20	28
7.834	0.484	-1	19	20	28
7.971	0.486	-1	19	21	29
8.105	0.49	-1	20	21	41
8.279	0.497	-1	23	21	51
8.439	0.501	-1	26	21	65
8.594	0.502	-1	26	22	91
8.748	0.511	-1	27	22	144
8.898	0.527	-1	28	22	131
9.055	0.538	-1	30	22	121
9.208	0.547	-1	33	22	194
9.376	0.563	-1	34	22	166
9.544	0.579	-1	34	22	104
9.704	0.582	-1	34	22	85
9.864	0.584	-1	35	24	84

10.013	0.588	-1	35	23	83
10.177	0.596	-1	35	24	84
10.331	0.598	-1	35	26	84
10.547	0.6	-1	36	29	84
10.697	0.615	-1	36	32	85
10.847	0.631	-1	36	35	91
11.047	0.64	-1	37	37	99
11.208	0.652	-1	37	37	99
11.405	0.673	-1	37	37	99
11.597	0.679	-1	37	37	99
11.753	0.681	-1	37	37	100
11.926	0.685	-1	37	38	99
12.115	0.694	-1	37	38	99
12.325	0.696	-1	38	39	101
12.53	0.703	-1	39	39	103
12.672	0.722	-1	41	40	167
12.904	0.733	-1	43	40	130
13.085	0.741	-1	45	40	144
13.297	0.76	-1	46	40	133
13.47	0.776	-1	50	40	146
13.661	0.778	-1	52	41	141
13.839	0.782	-1	53	45	129
14.071	0.791	-1	53	50	127
14.306	0.794	-1	54	54	128
14.533	0.799	-1	54	56	134
14.756	0.821	-1	55	56	155
14.976	0.834	-1	55	57	142
15.175	0.847	-1	56	58	150
15.384	0.869	-1	56	59	159
15.603	0.875	-1	57	59	248
15.805	0.877	-1	61	59	244

16.003	0.885	-1	65	60	260
16.221	0.891	-1	69	63	255
16.463	0.896	-1	71	68	241
16.685	0.917	-1	71	74	233
16.923	0.933	-1	72	74	240
17.154	0.952	-1	73	75	153
17.381	0.971	-1	73	75	146
17.611	0.975	-1	74	76	151
17.819	0.985	-1	74	77	144
18.082	0.99	-1	74	77	158
18.341	1.006	-1	76	77	162
18.593	1.026	-1	82	77	166
18.849	1.042	-1	85	80	175
19.086	1.067	-1	89	91	177
19.352	1.071	-1	90	93	178
19.622	1.079	-1	90	93	181
19.878	1.087	-1	91	94	182
20.144	1.101	-1	92	95	195
20.393	1.123	-1	93	95	210
20.67	1.14	-1	93	96	210
20.947	1.163	-1	93	96	211
21.204	1.169	-1	93	105	211
21.441	1.176	-1	93	111	211
21.73	1.184	-1	-1233	112	227
21.99	1.195	-1	-7106	114	230
22.282	1.218	-2	-14592	114	232
22.533	1.232	-2	-18856	124	247
22.796	1.258	-3	-18856	130	260
23.066	1.266	-3	-18856	132	264
23.323	1.275	-4	-18856	135	265
23.561	1.282	-4	-18856	147	268

23.831	1.296	-4	-18856	149	269
24.116	1.318	-6	-18856	151	278
24.395	1.335	-7	-18856	151	285
24.688	1.36	-8	-18856	153	287
24.937	1.366	-8	-18856	164	288
25.243	1.376	-9	-18856	168	297
25.503	1.384	-11	-18856	170	303
25.75	1.407	-11	-18856	170	304
26.027	1.423	-11	-18856	176	305
26.281	1.447	-12	-18856	185	306
26.574	1.461	-12	-18856	187	308
26.811	1.467	-14	-18856	188	320
27.105	1.477	-14	-18856	191	321
27.38	1.486	-15	-18856	201	323
27.658	1.508	-16	-18856	204	325
27.91	1.522	-16	-18856	206	327
28.225	1.545	-15	-18856	207	335
28.484	1.558	-14	-18856	215	340
28.731	1.565	-14	-18856	222	342
29.002	1.574	-15	-18856	224	343
29.249	1.581	-15	-18856	225	343
29.469	1.603	-16	-18856	230	349
29.755	1.616	-15	-18856	241	359
29.98	1.633	-14	-18856	243	452
30.205	1.654	-14	-18856	244	427
30.413	1.658	-13	-18856	253	415
30.682	1.668	-13	-18856	260	434
30.941	1.675	-13	-18856	262	431
31.202	1.692	-13	-18856	262	486
31.462	1.71	-13	-18856	271	478
31.732	1.734	-13	-18856	279	476

32.004	1.753	-14	-18856	281	469
32.252	1.758	-12	-18856	285	470
32.487	1.768	-12	-18856	296	471
32.778	1.775	-13	-18856	299	469
32.988	1.794	-12	-18856	300	470
33.213	1.809	-12	-18856	314	470
33.443	1.819	-12	-18856	317	483
33.679	1.838	-11	-18856	318	509
33.938	1.851	-9	-18856	327	495
34.15	1.855	-9	-18856	334	491
34.389	1.866	-11	-18856	336	490
34.664	1.871	-12	-18856	338	491
34.893	1.89	-11	-18856	351	491
35.13	1.907	-11	-18856	354	503
35.322	1.924	-9	-18856	356	508
35.564	1.947	-8	-18856	369	509
35.825	1.952	-8	-18856	373	646
36.018	1.963	-8	-18856	379	520
36.264	1.973	-8	-18856	390	552
36.505	1.997	-7	-18856	392	494
36.754	2.012	-6	-18856	399	359
36.967	2.04	-6	-18856	407	318
37.189	2.049	-6	-18856	410	308
37.441	2.058	-6	-18856	414	310
37.676	2.066	-6	-18856	426	314
37.861	2.082	-5	-18856	428	392
37.989	2.098	-4	-18856	431	408
38.066	2.111	-4	-18856	440	400
38.151	2.133	-4	-18856	444	415
38.236	2.142	-4	-18856	445	416
38.347	2.144	-3	-18856	447	398

38.505	2.147	-2	-18856	447	359
38.692	2.155	-3	-18856	450	329
38.875	2.161	-4	-18856	461	310
39.088	2.17	-4	-18856	465	348
39.304	2.189	-4	-18856	466	355
39.592	2.202	-4	-18856	473	361
39.851	2.218	-4	-18856	482	362
40.09	2.241	-4	-18856	484	362
40.401	2.248	-3	-18856	493	375
40.686	2.259	-4	-18856	502	408
40.926	2.278	-4	-18856	512	324
41.2	2.299	-4	-18856	521	325
41.493	2.325	-4	-18856	536	325
41.778	2.34	-5	-18856	551	337
42.064	2.351	-7	-18856	559	356
42.341	2.365	-6	-18856	572	374
42.63	2.393	-5	-18856	578	376
42.928	2.412	-4	-18856	593	384
43.204	2.434	-4	-18856	596	387
43.521	2.442	-3	-18856	610	397
43.768	2.453	-2	-18856	615	408
44.033	2.467	-2	-18856	629	414
44.286	2.489	-3	-18856	632	417
44.637	2.505	-3	-18856	643	417
44.878	2.532	-2	-18856	649	449
45.144	2.538	-3	-18856	653	454
45.429	2.542	-2	-18856	666	476
45.742	2.555	-2	-18856	670	485
46.009	2.584	-2	-18856	682	473
46.264	2.595	-1	-18856	688	470
46.478	2.594	-1	-18856	697	468

46.74	2.617	-1	-18856	705	500
47.009	2.634	-2	-18856	710	505
47.32	2.644	-2	-18856	723	497
47.604	2.656	-4	-18856	727	509
47.905	2.681	-4	-18856	741	562
48.17	2.713	-4	-18856	743	552
48.47	2.739	-4	-18856	756	579
48.752	2.752	-4	-18856	767	586
49.052	2.774	-2	-18856	780	591
49.363	2.79	-1	-18856	790	549
49.652	2.817	-1	-18856	799	544
49.957	2.829	-1	-18856	813	545
50.249	2.838	-1	-18856	818	545
50.554	2.849	-1	-18856	831	528
50.851	2.873	-1	-18856	838	550
51.184	2.895	-1	-18856	852	578
51.541	2.909	0	-18856	860	570
51.872	2.925	0	-18856	872	581
52.233	2.93	0	-18856	882	616
52.588	2.94	0	-18856	891	655
52.944	2.955	0	-18856	905	630
53.36	2.979	0	-18856	913	591
53.721	3.006	0	-18856	927	565
54.077	3.03	0	-18856	939	631
54.494	3.045	0	-18856	948	629
54.851	3.064	0	-18856	962	625
55.256	3.086	0	-18856	970	614
55.662	3.118	0	-18856	983	637
56.088	3.132	0	-18856	997	642
56.443	3.145	0	-18856	1006	640
56.86	3.17	0	-18856	1020	621

57.269	3.194	0	-18856	1033	653
57.687	3.219	0	-18856	1041	643
58.118	3.232	0	-18856	1056	680
58.53	3.25	0	-18856	1066	675
58.914	3.274	0	-18856	1076	672
59.34	3.295	0	-18856	1091	680
59.752	3.318	0	-18856	1104	723
60.163	3.333	0	-18856	1113	707
60.554	3.356	0	-18856	451	734
60.975	3.375	0	-18856	-12528	717
61.395	3.401	0	-18856	-17835	691
61.769	3.416	0	-18856	-17835	705
62.143	3.43	0	-18856	-17835	737
62.498	3.448	0	-18856	-17835	725
62.851	3.471	-1	-18856	-17835	718
63.196	3.49	0	-18856	-17835	723
63.508	3.511	0	-18856	-17835	720
63.84	3.523	-1	-18856	-17835	717
64.17	3.533	-1	-18856	-17835	729
64.497	3.555	-1	-18856	-17835	758
64.774	3.571	-1	-18856	-17835	773
65.05	3.589	-1	-18856	-17835	751
64.509	3.599	-1	-18856	-17835	704
61.159	3.522	-1	-18856	-17835	670
60.384	3.512	-1	-18856	-17835	690
60.104	3.511	-1	-18856	-17835	683
60.22	3.512	-1	-18856	-17835	725
60.535	3.516	-1	-18856	-17835	674
61.008	3.524	-1	-18856	-17835	744
61.515	3.529	-1	-18856	-17835	752
62.034	3.545	0	-18856	-17835	727

62.52	3.562	0	-18856	-17835	738
63.044	3.575	0	-18856	-17835	701
63.54	3.595	0	-18856	-17835	693
64.039	3.61	0	-18856	-17835	699
64.52	3.62	0	-18856	-17835	764
65.04	3.633	0	-18856	-17835	788
65.583	3.656	0	-18856	-17835	793
66.166	3.677	0	-18856	-17835	857
66.752	3.707	0	-18856	-17835	953
67.297	3.72	0	-18856	-17835	833
67.865	3.744	0	-18856	-17835	791
68.383	3.769	-1	-18856	-17835	784
68.928	3.803	-1	-18856	-17835	757
69.441	3.814	-1	-18856	-17835	803
69.949	3.828	-1	-18856	-17835	859
70.432	3.855	-1	-18856	-17835	1062
70.942	3.876	-1	-18856	-17835	941
71.45	3.904	-1	-18856	-17835	907
71.9	3.921	-1	-18856	-17835	1035
72.374	3.971	-1	-18856	-17835	956
72.881	4.003	-1	-18856	-17835	981
73.378	4.018	-1	-18856	-17835	1020
73.861	4.045	-1	-18856	-17835	1056
74.364	4.068	-1	-18856	-17835	1033
74.833	4.098	-1	-18856	-17835	987
75.334	4.118	-1	-18856	-17835	1041
75.84	4.152	-1	-18856	-17835	992
76.318	4.19	-1	-18856	-17835	968
76.839	4.21	-1	-18856	-17835	989
77.32	4.241	-1	-18856	-17835	1012
77.81	4.271	-1	-18856	-17835	1073

78.251	4.298	-1	-18856	-17835	1127
78.723	4.32	-1	-18856	-17835	1006
79.192	4.351	-1	-18856	-17835	1021
79.664	4.383	-1	-18856	-17835	1065
80.15	4.403	-1	-18856	-17835	1029
80.662	4.429	-1	-18856	-17835	1043
81.138	4.457	-1	-18856	-17835	1062
81.599	4.491	-1	-18856	-17835	1083
82.064	4.511	-1	-18856	-17835	1056
82.516	4.542	-1	-18856	-17835	1065
82.981	4.575	-1	-18856	-17835	1080
83.456	4.598	-1	-18856	-17835	1058
83.9	4.616	-1	-18856	-17835	1014
84.377	4.652	-1	-18856	-17835	1088
84.84	4.69	-1	-18856	-17835	1175
85.288	4.714	-1	-18856	-17835	1358
85.731	4.745	-1	-18856	-17835	1191
86.186	4.78	-1	-18856	-17835	1230
86.654	4.803	-1	-18856	-17835	1085
87.138	4.835	-1	-18856	-17835	1150
87.613	4.868	-1	-18856	-17835	1157
88.047	4.894	-1	-18856	-17835	1162
88.525	4.926	-1	-18856	-17835	1127
88.962	4.957	-1	-18856	-17835	1140
89.444	4.987	-1	-18856	-17835	1115
89.907	5.014	-1	-18856	-17835	1118
90.375	5.05	-1	-18856	-17835	1132
90.796	5.082	-1	-18856	-17835	1121
91.256	5.11	-1	-18856	-17835	1086
91.694	5.14	-1	-18856	-17835	1087
92.152	5.176	-2	-18856	-17835	1243

92.6	5.204	-2	-18856	-17835	1221
93.041	5.234	-1	-18856	-17835	1254
93.504	5.269	-1	-18856	-17835	1243
93.939	5.296	-3	-18856	-17835	1291
94.417	5.33	-3	-18856	-17835	1207
94.888	5.365	-2	-18856	-17835	1247
95.362	5.385	-1	-18856	-17835	1324
95.782	5.41	-1	-18856	-17835	1240
96.255	5.434	-1	-18856	-17835	1204
96.741	5.468	-1	-18856	-17835	1210
97.198	5.495	-2	-18856	-17835	1200
97.687	5.528	-1	-18856	-17835	1200
98.176	5.556	-1	-18856	-17835	1210
98.667	5.576	-1	-18856	-17835	1230
99.164	5.61	-1	-18856	-17835	1213
99.629	5.645	-2	-18856	-17835	1229
100.152	5.674	-2	-18856	-17835	1233
100.609	5.708	-1	-18856	-17835	1277
101.11	5.758	-2	-18856	-17835	1263
101.605	5.808	-3	-18856	-17835	1253
102.058	5.845	-3	-18856	-17835	1251
102.547	5.874	-3	-18856	-17835	1255
103.014	5.909	-2	-18856	-17835	1219
103.496	5.946	-1	-18856	-17835	1181
103.957	5.976	-1	-18856	-17835	1198
104.425	5.999	-1	-18856	-17835	1195
104.927	6.029	-1	-18856	-17835	1195
105.399	6.062	-1	-18856	-17835	1195
105.867	6.096	-1	-18856	-17835	1207
106.333	6.132	-1	-18856	-17835	1213
106.811	6.162	-1	-18856	-17835	1213

107.3	6.195	-1	-18856	-17835	1279
107.755	6.228	-2	-18856	-17835	1285
108.2	6.259	-1	-18856	-17835	1371
108.672	6.293	-1	-18856	-17835	1363
109.164	6.328	-1	-18856	-17835	1318
109.62	6.359	-1	-18856	-17835	1309
110.068	6.394	-1	-18856	-17835	1380
110.489	6.427	-1	-18856	-17835	1352
110.919	6.456	-1	-18856	-17835	1383
111.352	6.489	-1	-18856	-17835	1482
111.784	6.526	-1	-18856	-17835	1491
112.251	6.557	-1	-18856	-17835	1376
112.661	6.592	-1	-18856	-17835	1315
113.095	6.625	-1	-18856	-17835	1297
113.535	6.656	-1	-18856	-17835	1288
113.934	6.692	-1	-18856	-17835	1326
114.319	6.73	-1	-18856	-17835	1452
114.703	6.762	-1	-18856	-17835	1345
115.104	6.797	-1	-18856	-17835	1385
115.503	6.835	-1	-18856	-17835	1427
115.905	6.867	-1	-18856	-17835	1428
116.275	6.902	0	-18856	-17835	1469
116.695	6.938	0	-18856	-17835	1445
117.117	6.97	0	-18856	-17835	1496
117.519	7.007	0	-18856	-17835	1541
117.906	7.04	0	-18856	-17835	1493
118.304	7.076	0	-18856	-17835	1574
118.664	7.111	0	-18856	-17835	1533
119.083	7.145	0	-18856	-17835	1484
119.515	7.18	0	-18856	-17835	1534
119.91	7.216	0	-18856	-17835	1550

120.343	7.251	0	-18856	-16897	1488
120.728	7.287	0	-18856	-4763	1538
121.136	7.325	0	-18856	-3883	-300
121.535	7.359	0	-18856	-6127	1571
121.902	7.397	0	-18856	-8744	1694
122.276	7.433	0	-18856	-13598	1817
122.635	7.471	0	-18856	-17463	1719
123.045	7.51	0	-18856	-17834	1604
123.354	7.545	0	-18856	-17834	1763
123.744	7.582	0	-18856	-17834	1734
124.076	7.622	0	-18856	-17834	1617
124.411	7.658	0	-18856	-17834	1735
124.751	7.697	1	-18856	-17834	1593
125.087	7.731	0	-18856	-17834	1676
125.38	7.768	0	-18856	-17834	1607
125.638	7.811	0	-18856	-17834	1690
125.878	7.849	0	-18856	-17834	1693
126.135	7.891	0	-18856	-17834	1614
126.304	7.93	-1	-18856	-17834	1621
126.531	7.971	-1	-18856	-17834	1747
126.69	8.016	-1	-18856	-17834	1649
126.733	8.06	-1	-18856	-17834	1598
126.74	8.107	-1	-18856	-17834	1598
126.745	8.152	-1	-18856	-17834	1576
126.709	8.202	-1	-18856	-17834	1585
126.626	8.25	-1	-18856	-17834	1599
126.599	8.302	-1	-18856	-17834	1594
126.551	8.346	-1	-18856	-17834	1626
126.493	8.375	-1	-18856	-17834	1647
126.347	8.426	-1	-18856	-17834	1592
126.207	8.48	-1	-18856	-17834	1482

125.803	8.545	-1	-18856	-17834	1521
125.267	8.612	-1	-18856	-17834	1559
124.647	8.677	-2	-18856	-17834	1534
124.092	8.739	-1	-18856	-17834	1566
123.443	8.807	-1	-18856	-17834	1506
122.81	8.895	-1	-18856	-17834	1503
122.108	8.969	-1	-18856	-17834	1457
121.018	9.005	-1	-18856	-17834	1509
120.098	9.026	-1	-18856	-17834	1527
119.75	9.048	-1	-18856	-17834	1521
121.249	9.195	-1	-18856	-17834	1506
120.513	9.254	-1	-18856	-17834	1549
120.338	9.307	-1	-18856	-17834	1486
120.137	9.357	-1	-18856	-17834	1448
119.48	9.379	-1	-18856	-17834	1417
118.893	9.388	-1	-18856	-17834	1454
118.471	9.394	-1	-18856	-17834	1458
118.094	9.403	-1	-18856	-17834	1494
117.82	9.41	-1	-18856	-17834	1419
117.582	9.416	-1	-18856	-17831	1410
117.358	9.422	-1	-18856	-17714	1507
117.192	9.425	-1	-18856	-17222	1489

APPENDIX C

DATA FOR FLEXURAL TEST (12% BEAM SAMPLE)

Load, kN	Deflection, mm	Strain of Concrete	Strain of Steel 1	Strain of Steel 2	Strain of Steel 3
0	0	0	0	0	0
0	0	0	0	0	0
0.015	0	0	0	0	0
0.032	0	-1	0	0	0
-0.023	0	-1	0	-5	0
-0.055	0	-1	0	-5	0
-0.045	0	-1	0	-3	0
-0.052	0.001	-1	0	-4	0
-0.124	0.001	-2	0	-10	0
-0.171	0.001	-2	0	-10	0
-0.1	0.001	-1	0	-6	0
-0.034	0.003	-1	0	-7	0
-0.013	0.002	-1	0	-6	0
0.008	0.002	0	0	-4	0
0.022	0.003	-1	0	-3	0
0.025	0.003	0	0	-3	0
0.055	0.005	0	0	-2	0
0.083	0.008	0	0	-1	0
0.1	0.02	-1	0	0	0
0.109	0.029	-1	0	-1	0
0.145	0.026	0	0	-1	0
0.181	0.006	0	0	-3	0
0.204	0.014	0	0	0	0
0.261	0.001	2	0	1	0

0.308	0.002	2	0	1	0
0.352	0.035	2	0	-4	0
0.42	0.013	2	0	-13	1
0.48	0.003	3	0	-12	1
0.553	0.002	3	0	-7	1
0.595	0.004	3	0	-7	1
0.68	0.01	3	0	-6	1
0.772	0.023	4	0	-4	1
0.856	0.033	4	0	-2	2
0.95	0.043	5	0	0	2
1.06	0.055	5	1	0	3
1.17	0.073	5	1	1	3
1.288	0.081	6	1	1	3
1.394	0.082	6	2	1	3
1.522	0.082	7	4	1	3
1.609	0.083	7	5	2	3
1.752	0.085	7	6	2	3
1.818	0.087	8	7	2	3
1.978	0.092	8	9	2	3
2.082	0.097	8	10	2	3
2.196	0.099	9	12	2	3
2.309	0.099	9	14	2	3
2.45	0.106	9	15	2	3
2.536	0.126	10	16	3	4
2.719	0.153	10	16	3	5
2.833	0.174	10	16	4	7
2.968	0.179	10	16	4	8
3.124	0.18	10	16	4	11
3.267	0.183	10	16	4	13
3.417	0.189	11	16	4	16
3.568	0.196	11	16	5	18

3.743	0.197	11	16	5	19
3.874	0.205	11	16	5	19
4.003	0.232	11	17	5	19
4.152	0.261	11	17	5	20
4.297	0.276	11	18	5	20
4.47	0.278	11	18	5	21
4.618	0.28	11	18	5	21
4.827	0.289	11	18	5	21
4.999	0.294	11	18	6	22
5.137	0.303	11	19	8	22
5.299	0.34	11	19	14	22
5.506	0.37	11	19	16	22
5.731	0.375	12	19	19	25
5.953	0.376	12	19	20	29
6.108	0.381	12	19	20	32
6.317	0.39	13	19	20	36
6.56	0.392	13	22	20	37
6.78	0.41	13	26	20	37
6.999	0.441	13	32	21	38
7.192	0.468	14	34	21	38
7.413	0.473	14	34	22	39
7.658	0.476	14	34	22	40
7.898	0.486	14	35	23	40
8.106	0.49	14	35	23	40
8.356	0.506	14	36	23	40
8.592	0.544	14	37	23	42
8.84	0.567	14	37	23	46
9.067	0.57	14	37	23	49
9.297	0.571	14	37	23	54
9.595	0.575	14	37	23	56
9.889	0.585	14	37	23	56

10.198	0.603	14	38	25	57
10.514	0.651	15	39	30	58
10.792	0.668	15	44	35	58
11.046	0.669	16	49	38	59
11.393	0.678	17	52	38	59
11.685	0.685	18	53	39	62
12.037	0.704	20	53	39	67
12.326	0.742	20	54	40	73
12.66	0.764	21	55	41	74
13.008	0.77	22	55	41	75
13.332	0.78	21	56	42	76
13.673	0.784	21	56	42	77
13.987	0.808	22	56	42	77
14.373	0.842	25	60	44	80
14.763	0.863	27	69	51	89
15.11	0.867	28	71	56	93
15.499	0.878	28	72	57	95
15.866	0.885	28	73	58	96
16.211	0.923	28	74	60	100
16.634	0.959	28	74	60	110
17.027	0.963	28	76	60	112
17.428	0.974	29	85	64	114
17.856	0.981	29	90	75	118
18.263	1.019	29	92	78	130
18.677	1.057	28	98	86	138
19.107	1.062	25	111	96	154
19.56	1.074	20	125	99	172
19.984	1.093	18	131	112	187
20.411	1.141	18	145	114	201
20.846	1.157	17	148	116	211
21.351	1.169	16	159	116	224

21.822	1.186	16	166	125	235
22.284	1.239	15	170	131	247
22.75	1.256	14	184	133	261
23.228	1.269	14	193	134	278
23.704	1.297	14	203	140	295
24.192	1.348	14	217	148	-458
24.679	1.359	14	223	150	-15427
25.192	1.372	14	236	151	-18649
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26.182	1.45	14	251	153	-18649
26.659	1.462	14	259	153	-18649
27.142	1.482	14	272	154	-18649
27.646	1.534	14	277	165	-18649
28.16	1.55	14	288	168	-18649
28.644	1.564	14	296	169	-18649
29.151	1.6	14	309	171	-18649
29.611	1.643	14	317	171	-18649
30.104	1.654	14	333	173	-18649
30.574	1.669	14	347	184	-18649
31.076	1.721	14	352	187	-18649
31.502	1.743	14	366	187	-18649
31.939	1.754	13	370	187	-18649
32.341	1.766	13	377	189	-18649
32.78	1.81	12	387	190	-18649
33.213	1.84	12	389	190	-18649
33.628	1.85	12	397	190	-18649
34.053	1.861	11	406	194	-18649
34.436	1.903	11	410	202	-18649
34.874	1.937	11	422	205	-18649
35.283	1.945	11	425	205	-18649
35.695	1.956	11	430	207	-18649

36.078	2	11	442	197	-18649
36.495	2.035	10	444	188	-18649
36.939	2.042	10	453	190	-18649
37.348	2.058	9	461	190	-18649
37.823	2.097	8	463	191	-18649
38.262	2.128	7	474	202	-18649
38.743	2.141	7	481	205	-18649
39.189	2.151	6	486	206	-18649
39.662	2.185	5	497	207	-18649
40.13	2.228	4	500	208	-18649
40.603	2.238	3	508	208	-18649
40.77	2.246	2	515	208	-18649
41.071	2.25	2	517	208	-18649
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41.926	2.325	0	527	211	-18649
42.369	2.334	-1	535	220	-18649
42.855	2.346	-1	537	224	-18649
43.312	2.383	-2	543	224	-18649
43.838	2.424	-3	554	225	-18649
44.338	2.436	-4	557	227	-18649
44.882	2.457	-4	570	227	-18649
45.439	2.507	-4	574	227	-18649
45.958	2.529	-4	582	231	-18649
46.504	2.548	-4	591	241	-18649
47.034	2.595	-4	595	242	-18649
47.591	2.622	-4	608	242	-18649
48.111	2.637	-5	611	244	-18649
48.629	2.665	-5	612	245	-18649
49.105	2.709	-5	625	245	-18649
49.587	2.724	-5	629	245	-18649
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50.603	2.774	-5	643	247	-18649
51.08	2.814	-5	647	256	-18649
51.6	2.826	-5	648	261	-18649
52.099	2.84	-5	659	261	-18649
52.613	2.886	-5	664	262	-18649
53.158	2.917	-5	666	263	-18649
53.746	2.936	-5	676	264	-18649
54.39	2.986	-5	683	264	-18649
55.04	3.017	-5	685	266	-18649
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59.612	3.261	-5	737	290	-18649
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61.637	3.385	-6	755	300	-18649
62.293	3.412	-6	758	301	-18649
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64.045	3.51	-6	775	316	-18649
64.609	3.536	-6	777	316	-18649
65.198	3.584	-6	778	317	-18649
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66.632	3.641	-6	794	319	-18649
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65.442	3.669	-5	775	301	-18649
66.432	3.699	-5	782	315	-18649
67.276	3.713	-5	794	319	-18649
68.083	3.754	-5	802	326	-18649
69.053	3.796	-5	814	335	-18649
70.064	3.82	-5	827	338	-18649
71.05	3.879	-5	833	338	-18649
71.992	3.907	-4	841	346	-18649
72.945	3.963	-4	851	353	-18649
73.899	3.998	-3	855	356	-18649
74.825	4.046	-2	867	356	-18649
75.742	4.094	-2	870	360	-18649
76.654	4.14	-1	873	371	-18649
77.577	4.192	-1	885	373	-18649
78.456	4.243	0	888	375	-18649
79.347	4.29	1	891	375	-18649
80.211	4.341	2	903	387	-18649
80.917	4.39	2	905	390	-18649
81.536	4.452	3	906	391	-18649
82.334	4.495	4	907	393	-18649
83.182	4.558	5	907	393	-18649
84.017	4.599	6	-702	398	-18649
84.743	4.664	7	-7807	408	-18649
85.434	4.714	7	-15009	409	-18649
86.129	4.776	8	-18041	411	-18649
86.839	4.829	9	-18041	412	-18649
87.586	4.88	10	-18041	412	-18649
88.368	4.943	10	-18041	414	-18649
89.153	4.987	10	-18041	425	-18649

89.94	5.052	11	-18041	428	-18649
90.77	5.097	11	-18041	430	-18649
91.54	5.161	11	-18041	430	-18649
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95.326	5.436	9	-18041	448	-18649
96.048	5.485	7	-18041	448	-18649
96.815	5.548	5	-18041	449	-18649
97.615	5.598	4	-18041	449	-18649
98.408	5.661	3	-18041	452	-18649
99.199	5.725	2	-18041	462	-18649
100.046	5.777	0	-18041	450	-18649
100.889	5.843	-1	-18041	456	-18649
101.734	5.9	-1	-18041	463	-18649
102.573	5.958	-2	-18041	455	-18649
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105.094	6.152	-2	-18041	435	-18649
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107.556	6.348	-3	-18041	448	-18649
108.401	6.415	-3	-18041	449	-18649
109.18	6.471	-3	-18041	449	-18649
110.005	6.538	-3	-18041	452	-18649
110.787	6.603	-3	-18041	464	-18649
111.591	6.661	-3	-18041	465	-18649
112.414	6.731	-2	-18041	467	-18649
113.258	6.799	-2	-18041	468	-18649
114.075	6.858	-1	-18041	472	-18649

114.841	6.927	-1	-18041	483	-18649
115.598	6.994	0	-18041	482	-18649
116.389	7.057	0	-18041	484	-18649
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119.51	7.343	-1	-18041	493	-18649
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121.062	7.486	-2	-18041	503	-18649
121.774	7.55	-3	-18041	504	-18649
122.515	7.621	-3	-18041	505	-18649
123.205	7.696	-3	-18041	504	-18649
123.895	7.767	-3	-18041	505	-18649
124.587	7.833	-4	-18041	505	-18649
125.275	7.904	-4	-18041	513	-18649
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126.622	8.042	-3	-18041	520	-18649
127.288	8.116	-2	-18041	520	-18649
127.925	8.188	-2	-18041	521	-18649
128.564	8.258	-2	-18041	522	-18649
129.199	8.326	-1	-18041	522	-18649
129.782	8.401	-1	-18041	523	-18649
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130.925	8.548	0	-18041	523	-18649
131.48	8.621	0	-18041	523	-18649
131.997	8.702	1	-18041	523	-18649
132.512	8.776	1	-18041	522	-18649
132.967	8.854	2	-18041	508	-18649
133.436	8.924	2	-18041	504	-18649
133.82	8.999	2	-18041	504	-18649
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135.093	9.298	3	-18041	497	-18649
135.088	9.38	2	-18041	488	-18649
134.636	9.469	0	-18041	485	-18649
132.985	9.575	-3	-18041	464	-18649
129.948	9.704	-4	-18041	427	-18649
128.215	9.819	-5	-18041	410	-18649
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127.451	10.008	-5	-18041	394	-18649
127.36	10.104	-5	-18041	393	-18649
127.361	10.193	-5	-18041	393	-18649
127.468	10.281	-4	-18041	394	-18649
127.475	10.368	-4	-18041	394	-18649
127.348	10.462	-5	-18041	392	-18649
127.376	10.555	-4	-18041	374	-18649
127.499	10.646	-4	-18041	374	-18649
127.671	10.738	-4	-18041	374	-18649
127.157	10.802	-4	-18041	362	-18649
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0.109	0.029	-1	0	-1	0
0.145	0.026	0	0	-1	0
0.181	0.006	0	0	-3	0
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0.261	0.001	2	0	1	0
0.308	0.002	2	0	1	0
0.352	0.035	2	0	-4	0
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0.772	0.023	4	0	-4	1
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0.95	0.043	5	0	0	2
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1.17	0.073	5	1	1	3
1.288	0.081	6	1	1	3
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1.752	0.085	7	6	2	3

1.818	0.087	8	7	2	3
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2.719	0.153	10	16	3	5
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3.568	0.196	11	16	5	18
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4.999	0.294	11	18	6	22
5.137	0.303	11	19	8	22
5.299	0.34	11	19	14	22
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6.108	0.381	12	19	20	32
6.317	0.39	13	19	20	36
6.56	0.392	13	22	20	37

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7.192	0.468	14	34	21	38
7.413	0.473	14	34	22	39
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8.106	0.49	14	35	23	40
8.356	0.506	14	36	23	40
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9.067	0.57	14	37	23	49
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10.198	0.603	14	38	25	57
10.514	0.651	15	39	30	58
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11.046	0.669	16	49	38	59
11.393	0.678	17	52	38	59
11.685	0.685	18	53	39	62
12.037	0.704	20	53	39	67
12.326	0.742	20	54	40	73
12.66	0.764	21	55	41	74
13.008	0.77	22	55	41	75
13.332	0.78	21	56	42	76
13.673	0.784	21	56	42	77
13.987	0.808	22	56	42	77
14.373	0.842	25	60	44	80
14.763	0.863	27	69	51	89
15.11	0.867	28	71	56	93
15.499	0.878	28	72	57	95

15.866	0.885	28	73	58	96
16.211	0.923	28	74	60	100
16.634	0.959	28	74	60	110
17.027	0.963	28	76	60	112
17.428	0.974	29	85	64	114
17.856	0.981	29	90	75	118
18.263	1.019	29	92	78	130
18.677	1.057	28	98	86	138
19.107	1.062	25	111	96	154
19.56	1.074	20	125	99	172
19.984	1.093	18	131	112	187
20.411	1.141	18	145	114	201
20.846	1.157	17	148	116	211
21.351	1.169	16	159	116	224
21.822	1.186	16	166	125	235
22.284	1.239	15	170	131	247
22.75	1.256	14	184	133	261
23.228	1.269	14	193	134	278
23.704	1.297	14	203	140	295
24.192	1.348	14	217	148	-458
24.679	1.359	14	223	150	-15427
25.192	1.372	14	236	151	-18649
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26.182	1.45	14	251	153	-18649
26.659	1.462	14	259	153	-18649
27.142	1.482	14	272	154	-18649
27.646	1.534	14	277	165	-18649
28.16	1.55	14	288	168	-18649
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29.151	1.6	14	309	171	-18649
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34.053	1.861	11	406	194	-18649
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39.189	2.151	6	486	206	-18649
39.662	2.185	5	497	207	-18649
40.13	2.228	4	500	208	-18649
40.603	2.238	3	508	208	-18649
40.77	2.246	2	515	208	-18649
41.071	2.25	2	517	208	-18649
41.475	2.287	1	518	208	-18649
41.926	2.325	0	527	211	-18649
42.369	2.334	-1	535	220	-18649
42.855	2.346	-1	537	224	-18649

43.312	2.383	-2	543	224	-18649
43.838	2.424	-3	554	225	-18649
44.338	2.436	-4	557	227	-18649
44.882	2.457	-4	570	227	-18649
45.439	2.507	-4	574	227	-18649
45.958	2.529	-4	582	231	-18649
46.504	2.548	-4	591	241	-18649
47.034	2.595	-4	595	242	-18649
47.591	2.622	-4	608	242	-18649
48.111	2.637	-5	611	244	-18649
48.629	2.665	-5	612	245	-18649
49.105	2.709	-5	625	245	-18649
49.587	2.724	-5	629	245	-18649
50.087	2.738	-5	631	245	-18649
50.603	2.774	-5	643	247	-18649
51.08	2.814	-5	647	256	-18649
51.6	2.826	-5	648	261	-18649
52.099	2.84	-5	659	261	-18649
52.613	2.886	-5	664	262	-18649
53.158	2.917	-5	666	263	-18649
53.746	2.936	-5	676	264	-18649
54.39	2.986	-5	683	264	-18649
55.04	3.017	-5	685	266	-18649
55.668	3.04	-5	696	276	-18649
56.289	3.093	-5	703	279	-18649
56.959	3.119	-5	706	280	-18649
57.596	3.149	-5	718	282	-18649
58.262	3.202	-5	721	282	-18649
58.948	3.22	-5	725	282	-18649
59.612	3.261	-5	737	290	-18649
60.281	3.308	-5	740	298	-18649

60.948	3.33	-6	743	298	-18649
61.637	3.385	-6	755	300	-18649
62.293	3.412	-6	758	301	-18649
62.925	3.441	-6	759	301	-18649
63.49	3.491	-6	765	306	-18649
64.045	3.51	-6	775	316	-18649
64.609	3.536	-6	777	316	-18649
65.198	3.584	-6	778	317	-18649
65.747	3.603	-6	787	319	-18649
66.231	3.615	-6	793	319	-18649
66.632	3.641	-6	794	319	-18649
67.016	3.673	-6	795	319	-18649
66.905	3.693	-6	794	319	-18649
63.473	3.614	-8	761	287	-18649
63.316	3.603	-7	758	283	-18649
64.36	3.621	-6	761	297	-18649
65.442	3.669	-5	775	301	-18649
66.432	3.699	-5	782	315	-18649
67.276	3.713	-5	794	319	-18649
68.083	3.754	-5	802	326	-18649
69.053	3.796	-5	814	335	-18649
70.064	3.82	-5	827	338	-18649
71.05	3.879	-5	833	338	-18649
71.992	3.907	-4	841	346	-18649
72.945	3.963	-4	851	353	-18649
73.899	3.998	-3	855	356	-18649
74.825	4.046	-2	867	356	-18649
75.742	4.094	-2	870	360	-18649
76.654	4.14	-1	873	371	-18649
77.577	4.192	-1	885	373	-18649
78.456	4.243	0	888	375	-18649

79.347	4.29	1	891	375	-18649
80.211	4.341	2	903	387	-18649
80.917	4.39	2	905	390	-18649
81.536	4.452	3	906	391	-18649
82.334	4.495	4	907	393	-18649
83.182	4.558	5	907	393	-18649
84.017	4.599	6	-702	398	-18649
84.743	4.664	7	-7807	408	-18649
85.434	4.714	7	-15009	409	-18649
86.129	4.776	8	-18041	411	-18649
86.839	4.829	9	-18041	412	-18649
87.586	4.88	10	-18041	412	-18649
88.368	4.943	10	-18041	414	-18649
89.153	4.987	10	-18041	425	-18649
89.94	5.052	11	-18041	428	-18649
90.77	5.097	11	-18041	430	-18649
91.54	5.161	11	-18041	430	-18649
92.323	5.206	11	-18041	431	-18649
93.097	5.266	11	-18041	434	-18649
93.851	5.322	11	-18041	446	-18649
94.576	5.372	10	-18041	446	-18649
95.326	5.436	9	-18041	448	-18649
96.048	5.485	7	-18041	448	-18649
96.815	5.548	5	-18041	449	-18649
97.615	5.598	4	-18041	449	-18649
98.408	5.661	3	-18041	452	-18649
99.199	5.725	2	-18041	462	-18649
100.046	5.777	0	-18041	450	-18649
100.889	5.843	-1	-18041	456	-18649
101.734	5.9	-1	-18041	463	-18649
102.573	5.958	-2	-18041	455	-18649

103.399	6.025	-2	-18041	447	-18649
104.237	6.082	-2	-18041	448	-18649
105.094	6.152	-2	-18041	435	-18649
105.895	6.224	-3	-18041	441	-18649
106.72	6.286	-3	-18041	446	-18649
107.556	6.348	-3	-18041	448	-18649
108.401	6.415	-3	-18041	449	-18649
109.18	6.471	-3	-18041	449	-18649
110.005	6.538	-3	-18041	452	-18649
110.787	6.603	-3	-18041	464	-18649

APPENDIX D

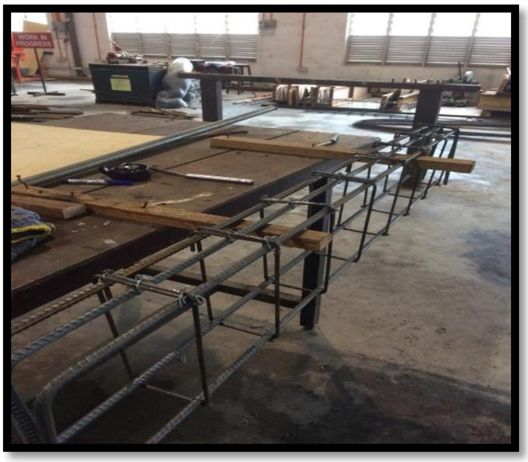
PICTURE OF THIS STUDY

PREPARATIONS OF FORMWORK AND REINFORCEMENT BARS

Formwork Preparation

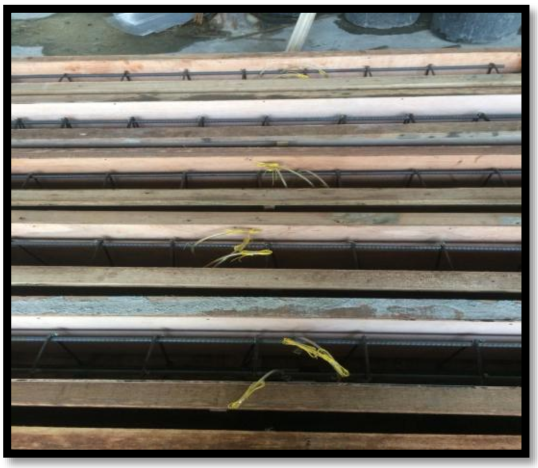
Formwork Installation

Cutting the Reinforcement Bar



Installation of Reinforcement Bar

CONTINUED



Strain Gauges Installation

PREPARATIONS OF SAMPLE

Rice Husk Sample

Washed Sample

CONTINUED

Sieved the Sample

Dried using oven

Concrete Mix

CONTINUED

CONCRETING WORK

Concreting Work

Slump Test

Slump test Result

Concreting Work Done

CONTINUED

Formwork Removal

Curing by Using Wet Gunny

COMPRESSIVE STRENGTH TEST

Sample Preparation

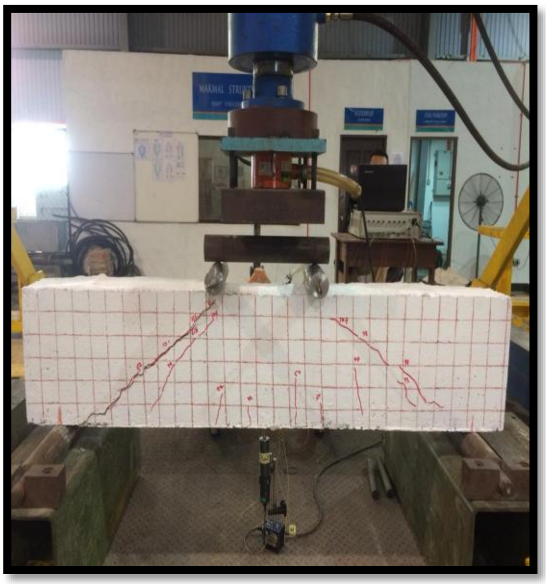
Curing Process

CONTINUED

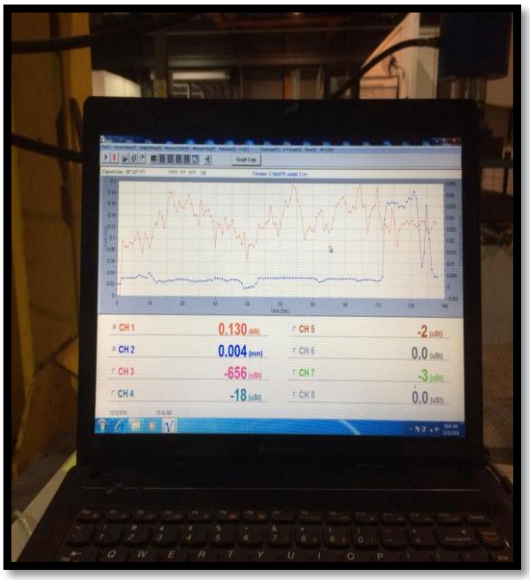
Compression Test

Compression Test Result

FLEXURAL STRENGTH TEST



Flexural Test



Result from Data Logger