BEHAVIOR OF STEEL FIBRE IN REINFORCED RECYCLED CONCRETE AGGREGATE BEAM

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BEHAVIOR OF STEEL FIBRE IN REINFORCED RECYCLED CONCRETE AGGREGATE BEAM

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ABSTRACT

This paper is to investigate the effects of replacing natural coarse aggregates (NCA) with recycled concrete aggregates (RCA) and additional of steel fibres (SF) on compressive strength and flexural strength of concrete. There are four beams are provided with concrete mix design in this project by partial replacing NCA by 25% RCA and by adding 0%, 1% and 2% of SF. To determine the flexural strength, the beams of size 150mm X 250mm X 1500 mm were casted. To determine compressive strength of concrete mix, 24 cubes of size 150mm x 150mm x 150mm were prepared and tested after the period of 7 and 28 days of water curing.

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ABSTRAK

Kajian ini adalah untuk mengkaji kesan menggantikan agregat kasar asli (NCA) dengan agregat kitar semula konkrit (RCA) dan tambahan gentian keluli (SF) pada kekuatan mampatan dan kekuatan lenturan konkrit. Terdapat empat rasuk disediakan dengan reka bentuk campuran konkrit dalam projek ini dengan separa menggantikan NCA sebanyak 25% RCA dan dengan menambah 0%, 1% dan 2% daripada SF. Untuk menentukan kekuatan lenturan, rasuk saiz 150mm X 250mm X 1500 mm telah digunakan Untuk menentukan kekuatan mampatan konkrit, 24 kiub saiz 150mm x 150mm x 150mm telah disediakan dan diuji selepas tempoh 7 dan 28 hari pengawetan air.

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LIST OF SYMBOLS

%	Percentage
kg	Kilogram
mm	Millimetre
N	Newton
MPa	Mega Pascal
kN	Kilo Newton

LIST OF ABBREVIATIONS

ASTM	American Section of the International Association for Testing Materials
BS	British Standard
3R	Reduce, Reuse, Recycle
pH	Potential of Hydrogen

CHAPTER ONE

INTRODUCTION

1.1 Introduction

All through history, concrete as a building material has been broadly utilized and contributed significantly to the built environment. In simplest form, concrete is a mixture of three basic component of water, aggregate and Portland cement. As many developing countries all over the world are recycling and reuse area alternatives to minimize the impact of energy and raw material consumption on the environment. The recycle concrete aggregate as another waste that can be potentially used for concrete production. The recycle concrete can be obtained from construction and demolition waste (Preet Singh S.,2016). The strength of recycled concrete is less than the natural concrete and water absorption is more than the natural aggregate. The use of recycled concrete do not affect the fresh and hardened properties of the concrete and will give the similar results as a normal concrete. Recycling of waste concrete not only reduces the demand for extraction the natural raw material landfill space but it is also save the landfill spaces.

There are many advantages using concrete in construction. First, ingredient of concrete are easily to get in most of the places. Next, concrete can withstand with a high temperature and its can be manufactured to desired strength with economy. Concrete casting also can be done in working site which make it economical. Recycle concrete as an another source and waste material for production new concrete and its can solve the environment produce by old concrete (Zhu H.B and Li X.,2009). There are several benefits of recycled concrete in construction. The use of recycled concrete will save cost of project or construction because the materials are less expensive to produce. It is also a green construction in the process of harvesting stone and then crushing it down to size requires the use of natural resources and material processing. Although there are many advantages of using recycled concrete. But there are still some disadvantages in recycle aggregate. The use of recycled concrete will decrease in strength and modulus. Recycled concrete has higher absorption capacity range from 3% to 9%. The strength of recycled concrete lower than natural concrete. It also reduced workability due to higher absorption capacity and lower bulk specific gravity. In this experiment, fibre is use to overcome the disadvantages of recycled concrete.

Fiber is a concrete fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete. In this experiment , steel fibres was used to increase the properties of recycle concrete .

Steel fibres can be used in recycled concrete, since it has a less durability than natural concrete and it will be increase the durability of concrete made with partial replacement of natural concrete with recycled concrete. The use of steel fiber in concrete is one of the important modified method to alter the brittle failure nature of structure concrete (Wei M., 2009). In this experiment, 25 % of recycle concrete with 0%, 1% and 2% steel fibres is use to test the strength of structure and to explore the important modified according to failure nature. Over the past three decade, the using of steel fibre has been investigated to improve the performance of statically determinate and indeterminate structures (Zamanzadeh Z., 2015), since concrete has low tensile strength and fails in a brittle manner. Other than that, steel fibres in the concrete can also enhance the mechanical properties, ductility and energy absorbing capacity under seismic, impact and blast loading. Transfer stresses across the cracked section and providing to concrete a residual strength is one of the most important functions of steel fibres. (Ding Y., 2012).

1.2 Problem Statement

Recycle concrete aggregates (RCA) are widely used in the construction industry. Use of recycled aggregate in concrete can be useful for environmental protection and economical term. Nowadays, the waste from construction are increasing in time so to overcome this issue, recycle concrete aggregate will be used. In laboratory of University Malaysia Pahang, a lot of cubes are not used and need to be demolished. To overcome this problem, the cubes are used as a recycled concrete. In addition, the use of RCA leads to a possible solution to the environmental problem caused by concrete waste and reduces the negative environmental impact of the aggregate extraction from natural resources.

Recycled concrete has disadvantages in term of strength. Therefore, to overcome this problem , steel fibres with volume of 0%, 1% and 2% are used. Steel fiber-reinforced concrete (SFRC) is a a composite material that improves the characteristic of concrete by mixing steel fiber with recycle concrete. The recycled concrete aggregate have different strength compare to natural aggregate. The strength of recycle concrete is less than natural aggregates.

1.3 Objectives

i. To study the behavior of steel fibre reinforced replaced with 25% of recycle concrete aggregate

ii. To investigate the performance of steel fibre in recycled reinforced concrete beams

1.4 Scope of Study

i. Size of cube is 150mm x 150mm x 150mm
ii. Size of coarse aggregate is 15mm to 20mm
iii. Size of beam is 150mm x 200mm x 1500mm
iv. The volume of steel fiber is 0%, 1% and 2%
v. Total of cube is 24 cubes
vi. 25% of recycled concrete of cube
vii. Concrete with grade 25
viii. Diameter of main bar is T12
ix. Diameter of link bar is R8
x. Concrete cover is 25
xi. Test conducted are compressive test and flexural test

1.5 Importance of the study

This study is important because the use of Steel Fibers Recycled Concrete to investigate the strength of the beam structure. Roughly a lot of waste concrete can be obtained from construction and demolition waste. The use of recycled concrete also saves landfill space. Recycled concrete aggregate has less weight per cubic yard, therefore it will reduced cost for materials for overall project or experiments. As a solution, Steel Fiber is use to increase the strength of recycled concrete aggregate. Steel Fibers are typically added to concrete in low volume dosages and have been shown to be effective in reducing plastic shrinkage cracking. Steel fiber do not significantly alter free shrinkage of concrete, however a high enough dosages they can increase the resistance to cracking and decrease crack width Therefore steel fibres in concrete can minimize cracks in hardened concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The demand of concrete is expanding quickly occasionally due to rapid urbanization. In Malaysia, the supply of concrete is still meets the demand but the price of concrete has increased. Concrete is composed of cement, coarse aggregate, fine aggregate, water and various admixtures. 60% and 75% of the concrete volume was comprised by coarse aggregate. (West J.S., 2011). However, recent studies have shown that natural aggregate sources are in decline (West J.S., 2011). As a result, the industry must facing a risk of increased material costs and will be required to consider another alternative aggregate sources. (West J.S., 2011). Therefore, the recycled concrete aggregate was used as an alternative to reduce the material cost. The applications of recycled concrete aggregate in highway construction as a road base materials are very board and have been in use for almost 100 years. The major objective for this experiment are to find out the results in the strength characteristic and the best method to achieve high strength concrete with recycled concrete. Recycled concrete has a lower compressive strength compare to natural aggregate. To improve primarily the post-cracking tensile and crack control characteristic, steel fibres were used in reinforced recycle concrete aggregate.

2.2 Recycled Concrete Aggregate

Recycled concrete aggregate is a simple process. It involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. Other than that, do use recycled concrete aggregate in new concrete report that concrete with RCA performs equal to concrete with natural aggregate. However, recycled concrete aggregate has the potential to be applied over a broad range of structural member types, based on the examples of structural behavior (Grzywa M., 2014). The use of recycled concrete aggregate generally increase the drying shrinkage and decreases the compressive strength compared to natural concrete aggregate. (Murali G.,2010).

2.3 Properties of Recycled Concrete Aggregate

The recycled concrete aggregate used as a component of the new concrete mixture implies a thorough understanding of its basic properties. Considering that some of them may significantly differ from the properties of aggregates obtained from natural resources.

2.3.1 Densities

Recycled concrete aggregate have a lower density and higher water absorption compare to natural aggregate. It is because of the hardened cement paste that remains attached to the aggregate particles. Higher water absorption causes a higher water/cement ratio if the recycled concrete aggregate is incorporated in new concrete. Recycled concrete aggregates with different sizes will have a different densities

2.4 Fiber Reinforced Concrete

Concrete is most widely used construction material in the world due to its ability to get cast in any form and shape. It also replaces old construction materials such as brick and stone masonry. Now, the application of adding fibres to reinforced concrete become more popular among people who are involved in construction fields. The strength and durability of concrete can be increased by adding some fibres into reinforced concrete. The additional of fibres to concrete can improved mainly its post-cracking behavior and also alter tensile strength. These advantages according to the type of fibres and volume of fibres added to recycled concrete aggregate. The properties of the concrete change when a large volume of fibres is apply in recycled concrete. (Furlan Jr., 1997).

2.5 Types of Fibres

A fibres is a small discrete reinforcing material produced from various materials. For example steel, plastic, glass, carbon and natural materials in various shape and size.

2.5.1 Steel fiber

Steel fibre reinforced concrete is a composite material which is from cement concrete mix and steel fibres as a reinforcing. The steel fibres have various of volume fractions. According to Rai A., Joshi Y.P.,2014 , it has been shown in the research that fibres with low volume fractions(<1%), in fibre reinforced concrete, have an effect on both the compressive and tensile strength.

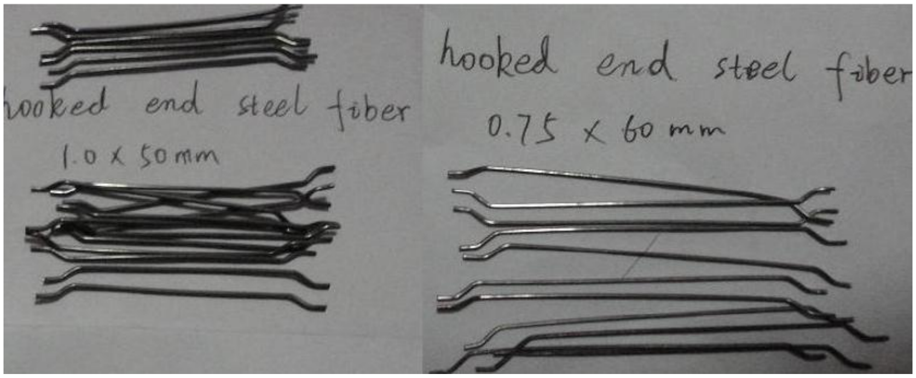
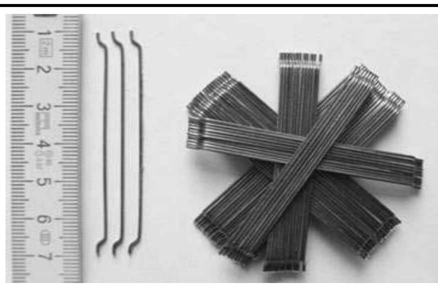
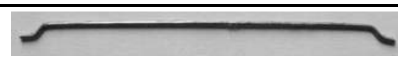
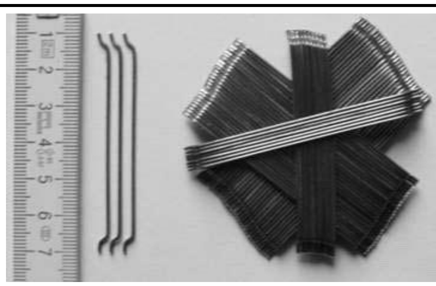
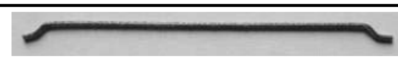
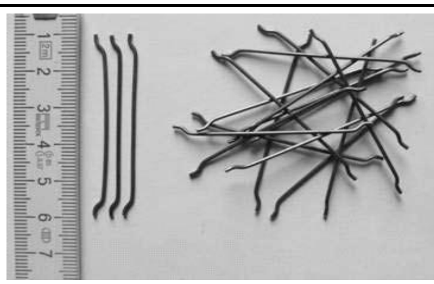
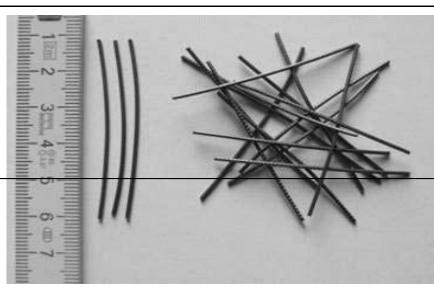
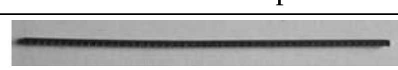
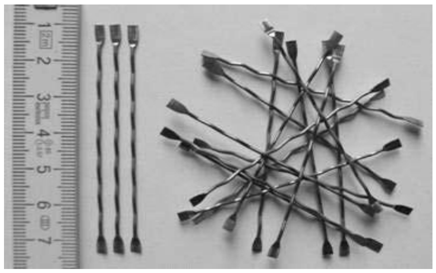
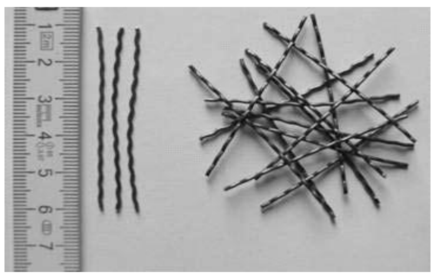
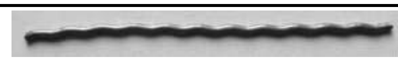


Figure 2.0: Steel Fibre

Table 2.0: Type of Steel Fibres

Variant	Illustratio	Geometr	Variables
1		 Form: straight Surface: plane End anchorage: hooked ends Allocation: glued	l_f = 60mm d_f = 0,75 mm λ = 80 f_t = 1050 n_f = 4600 kg^{-1}
2		 Form: straight Surface: plane End anchorage: hooked ends Allocation: glued	l_f = 60 d_f = 0,90 mm λ = 67 mm f_t ≥ 1000 n_f = 3200 kg^{-1}
3		 Form: straight Surface: plane End anchorage: hooked ends Allocation: separate	l_f = 50 mm d_f = 1,05 mm λ = 48 f_t = 1000 n_f = 2800 kg^{-1}
		 Form: straight Surface: plane	l_f = 50 mm d_f = 1,00 mm λ = 50

4		End anchorage: none Allocation: separate	f_t ≥ 1100 n_f = 2900 kg^{-1}
5		 Form: corrugated Surface: plane End anchorage: end paddles Allocation: separate	l_f = 60 mm d_f = 1,00 mm λ = 60 f_t = 1100 n_f = 2450 kg^{-1}
6		 Form: corrugated Surface: plane End anchorage: none Allocation: separate	l_f = 50 mm d_f = 1,00 mm λ = 50 f_t ≥ 1100 n_f = 2850 kg^{-1}

Sources from Holschemacher K., Muller T.

2.5.2 Glass Fibre

Glass Fiber reinforced concrete basically a concrete composition of material like cement, sand, water and admixtures, in which short length discrete glass fibres are dispersed. Glass fibres improved tensile strength and impact strength of the material.

Figure 1.1: Glass Fibre

2.5.3 Polymer Fibre

There are many ways to minimize the failure of the concrete structures made of steel reinforced concrete. The used of polymer fibres composite onto structure also helps to increase the toughness and tensile strength and improve the cracking and deformation characteristic of the resultant composite.

Figure 2.2: Polymer Fibre

2.5.4 Natural Fibre

Local interest has been demonstrated through research work performed. In addition to industrial fibres, natural organic and mineral fibres have been also investigated in reinforced concrete. Wood, sisal, jute, bamboo, coconut, asbestos androckwool, are examples that have been used and investigated

Figure 2.3: Natural Fibres

2.6 Component of Concrete

Concrete is a composite material with variable properties. The ingredients mixing ratio of concrete is variable and determined by the properties of ingredients and mix design. Concrete is consist of three main ingredients, which are Portland cement, aggregates and water. Admixtures are added to adjust the concrete mixture for specific performance criteria.

1) **Cement**

Cement is a well-known as construction material and highly needed in construction works. There are many types of cements available in the market and each type is used under certain conditions due to its special properties. A mixture of cement and sand when mixed with water to form a paste is known as cement mortar while the composite product obtained by mixing cement, water and aggregate is called cement concrete.

The cement that is commonly used is Portland cement. It is necessary to understand the characteristics and behavior of the ingredients in order to obtain a strong, durable and economical concrete mix. Portland cement is defined as hydraulic cement which mean a cement that not only hardens by reacting with water but also forms a water-resistance product. The function of cement is, first to bind the sand and course aggregates together and second is fill in the voids between sand and course aggregates particles to form a compact mass.

Cement is produce through the chemical combination of calcium, silicon, aluminum, iron and other ingredients. Common materials used to produce cement include limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore. When these ingredients were heated at high temperatures, it form a rock-like substance that is ground into the fine powder, which is called cement.

i. Portland Cement

Portland cement is the material that having adhesive and cohesive properties, which provide a binding medium for the discrete ingredients. It is obtained by burning together in a certain proportion, a mixture of naturally occurring argillaceous materials (containing alumina) and calcareous materials (containing calcium carbonate or lime) to a partial fusion at high temperature. The common argillaceous materials are clay, shale, slate and selected blast-furnace slag while the calcareous materials are limestone, chalk, oyster shells and marl. The basic components of the manufacturing process is shown in Figure 5.

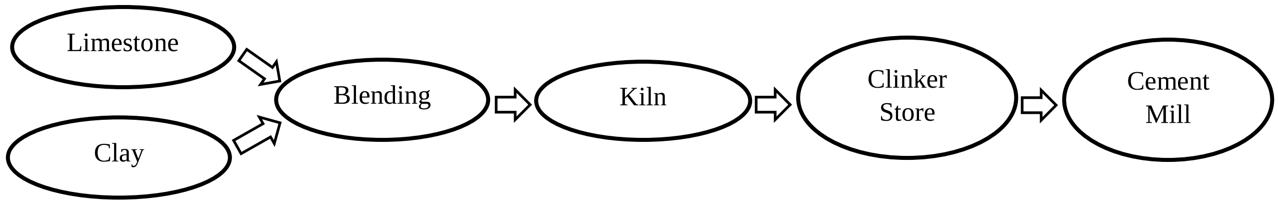


Figure 2.4: The basic components of the cement-manufacturing process

The clinker that is the product that obtained on burning is cooled and ground to the required fineness to produce a cement. Gypsum is also included into the final process in manufacturing to standardize concrete setting time. The amount of gypsum is about three per cent by weight of clinker. It is available in different type and each of it has its own distinct anti-corrosion or damage properties.

ii. Special-purpose Cements

The special-purpose cements are manufactured for the specific performance requirements. The regularly used ones are as the following:

1) OPC-based cements
2) Non-OPC cements

These cements have some further classifications and description.

OPC-based Cements

1) Rapid-hardening Portland cement

This cement is used where a rapid strength development is required. The rapid gain of strength is accompanied by a higher rate of heat during the hydration of cement. This may have advantages in cold weather concreting but a higher concrete temperature may lead to cracking due to following thermal contraction, and should not be used in mass concreting. It is recommended for prefabricated concrete construction, road repairs and in applications requiring early stripping of forms.

2) Low-heat Portland cement

This cement has exceptional performances such as sulfate corrosion resistance, high final strength, good lasting properties, lower hydration heat, anti-seepage and also good resistance to rupture. It is cannot be used in cold weather conditions because it will retard the setting time than in ordinary weather. This cement is recommended for the use in mass concrete construction such as dam where the temperature is rise by the heat of hydration, which can become excessive.

3) Sulphate-resisting cement

Sulphate-resisting cement is more resistant to the action of mineralized water containing sulphate than ordinary Portland cement, which is it is complete assurance against sulphate attack. It also slow the hardening and has lower heat of hydration. It is used in structures that are exposed to soil or ground waters where sulphate concentrations are higher than normal.

4) Masonry cement

Masonry cement mortar is superior to lime mortar, lime-cement mortar and cement mortar. It combines the desirable properties of cement mortar relating to strength and setting and lime mortar relating to workability and water-retention. Thereby, a masonry cement produces a smooth, plastic, cohesive and strong yet workable mortar. The cracks due to shrinkage and temperature movement are considerable reduced.

5) White Portland cement

The process of manufacturing white cement is the same as ordinary Portland cement but the amount of iron oxide, which is liable for grayish color, is limited to less than one per cent. White Portland cement is used particularly for architectural purposes, such as precast curtain walls and facing panels, terrazzo surfaces, cement paint, tile grout and decorative concrete. Generally, white cement is ground finer than gray cement.

6) Colored Portland cement

By mixing mineral pigments with ordinary cement, colored Portland cement may be obtained. The amount of coloring material may be different from 5 to 10 per cent. The strength of cement is affected if the percentage exceeds 10 per cent. The colored cements are broadly used for artificial marble, floors finishing, textured panel faces, window sill slabs, stair treads and many more.

7) Hydrophobic cement

Hydrophobic cement is used in places where water is predominant. These type of cement contains some of the admixtures like napthalene soap, acidol and petrolatum (oxidised) along with others. These admixtures form a thin film layer over the cement grains. In initial stage, the setting of hydrophobic cement is slow because the admixtures surrounding as a thin film over the cement grains prevents the interaction with water. However, its strength after 28 days is equal to that of ordinary Portland cement. This cement can be used in cold weather conditions. Commonly, this cement is used in construction of spillways, dams and under water constructions.

8) Air-entraining Portland cement

Air-entrained Portland cement is a special cement that can be used with good results for a various of conditions. It has been developed to produce concrete that is resistant to freeze-thaw action and to scaling caused by chemicals applied for severe frost and ice removal. In this cement, very small quantities of air-entraining materials are added as the clinker is being ground during manufacturing. Concrete that made with this cement contains tiny, well-distributed and completely separated air bubbles. The bubbles are so small that there may be millions of them in a cubic foot of concrete. The air bubbles provide space for freezing water to expand without damaging the concrete. The amount of water loss and the capillary/water-channel structure will be reduce by using this air-entrained cement in concrete.

9) Expansive cement

Expansive cement do not shrink while hardening but expands slightly with time. This cement does not suffer any overall change in volume on drying. It can reduce or control the volume changes that occur during curing by using expansive cement. This cement is commonly used for grouting anchor bolts and grouting machine foundation.

10) Oil-well cement

Oil-well cement is used for cementing work in the drilling of oil wells where they are subject to pressures and high temperatures. This cement was produced by inter-grinding Portland cement clinker, fly ash, gypsum and certain admixture which is retarder in suitable proportions. The retarder prevent quick setting and retain slurry in mobile condition to facilitate penetration to all fissures and cavities.

<u>Non-OPC Cements</u>

1) High-alumina cement

This cement is very reactive and produce very high early strength. At the age of 24 hours and even at six to eight hours, about eighty per cent of the ultimate strength was developed. It is also has an initial setting time that is about four hours and the final setting time that is about five hours. Generally, no additives are added to alumina cement. This cement is more workable than Portland cement if water-cement ratio is same. The strength will be affected by rise in temperature. Furthermore, this cement also resistant to chemical attack and suitable for under sea water applications.

2) Magnesium phosphate cement

This cements has very high early strength and quick in setting. It is suitable for rapid patching mortar for road and aircraft run-ways, which can typically be re-opened in about 45 minutes. It has very good adhesion to a wide variety of aggregates. This cement has good water and freeze thaw resistance. It has high bond strength and low shrinkage rates.

ii. Aggregate

Aggregates are inert granular materials such as sand, gravel and crushed stone. Aggregates are generally cheaper than cement and deliver greater volume stability and durability to concrete. The aggregate is used especially for the purpose of providing bulk to the concrete. Aggregate need to be hard, strong, clean and free of absorbed chemicals or coatings of clay that could cause the deterioration of concrete to get a good concrete mix. The aggregate is frequently used in two or more sizes to increase the density of the concrete mix. Aggregate is set between 60 to 75 percentage of the total volume of concrete and commonly divide into two distinct categories which is fine aggregate and coarse aggregate.

Fine aggregate generally consist of natural sand or crushed stone that is the particles are passing through a 4.75 mm sieve. Sand is generally considered to have a lower size limit, which is about 0.07 mm. Then, coarse aggregate consist of crushed gravel or stone that is the particles are retained on the 4.75 mm sieve. Natural gravel and sand are usually dredged from a river, pit, lake or seabed. To produce crushed aggregate, quarry rock, boulders, cobbles or large-size gravel must be crush first. Other than that, recycled concrete is a viable resource of aggregate and it has been used in granular sub-bases, soil-cement and also in new concrete.

The particle-size distribution for aggregate is determine by grading. Grading limits and maximum aggregate size are specified because these properties affect the amount of aggregate used as well as cement and water requirements, workability and durability of concrete. In general, if the water-cement ratio is chosen correctly, a wide range in grading can be used without a major effect on strength. Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. To produce workable concrete, angular, rough-textured and elongated particles require more water than smooth and rounded aggregate. Therefore, the cement content also must be increased to maintain the water-cement ratio. The amount of cement paste required for the mix can be affected by the void content between particles. To decrease the void content, the aggregate size must be large enough and improve the grading.

3) Water

Water is the important ingredient, which is forms a paste that binds the fine and course aggregates together by mixed with cement. The concrete will be hardening through a process called hydration when water, aggregate and cement mix together. Hydration is a chemical reaction in which the major composite in cement form chemical bonds with water molecules and become hydrates. In order to prevent side reactions from occurring which may weaken the concrete, the water needs to be clean or otherwise interfere with the hydration process.

The role of water is important because the water/cement ratio is the most critical factor to produce the concrete. The grade of concrete, type of aggregates, the workability and durability will be influenced the water/cement ratio. The concrete strength will be reduce if too much water is added in concrete, while if too little water is added, the concrete will be unworkable. Concrete needs to be workable so that it may be consolidated and shaped into different forms.

Concrete is susceptible to cracking and shrinkage if water/cement ratio is high. Shrinkage leads to micro-cracks, which are zones of weakness. Excess water will squeezed out of the paste by the weight of the aggregate and the cement paste itself once the fresh concrete is placed. The water bleeds out onto the surface when there is a large excess of water. The usual way to achieve a high strength and high quality concrete is by using a low water/cement ratio, but it does not guarantee that the resulting concrete is always appropriate for concrete countertops. The results of good concrete is come from good mix design and a low water/cement ratio is just one part of a good mix design.

4) Admixtures

Admixtures are the chemical compounds in concrete other than cement, aggregates and water that are added to the concrete mix immediately before or during mixing to modify the specific properties of concrete. The use of admixtures should not affect the performance of the concrete and should offer an improvement not economically achievable by adjusting the proportions of cement, aggregates and water.

The admixtures have formulated chemical composition and special chemical action that are used to modify certain properties of concrete. They are used essentially to modify the performance of hardened concrete, to ensure the quality of concrete, to reduce the cost of concrete construction and to overcome certain emergencies during concreting operations. The rate of hydration or setting times, workability, dispersion and air-entrainment are the properties that commonly be modified.

The admixture is generally added in a small quantity. To ensure proper quantity of the admixture in concrete, a degree of control must be exercised. Most admixtures are supplied in ready-to-use liquid form. The effectiveness of an admixtures depends on several factors including water content, type and quantity of cement, mixing time and temperature of the concrete and air.

Functions of Admixtures

There are many functions of admixtures to modify fresh concrete properties such as:

1) To increase workability without increasing water content.
2) To accelerate the initial set of concrete like to speed up the rate of development of strength at early ages.
3) To retard the initial set like to keep concrete workable for a longer time for placement.
4) To reduce the heat of hydration.
5) To reduce the segregation in grout and concrete mixtures.
6) To increase the strength of concrete by reducing the water content and by densification of concrete.
7) To increase the durability of concrete.
8) To decrease the capillary flow of water through concrete and to increase its impermeability to liquids.
9) To increase the resistance to chemical attack.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This study investigates the behaviour of steel fibre reinforced concrete. As comparison purpose, normal Reinforced Concrete Beam act as a control beam which compare with Fibre Reinforced Beam.

Data that are obtained in this study are the compressive strength, cracking pattern and ultimate load carrying capacity for the Reinforced Concrete Beam to fail.

3.2 METHODOLOGY FLOW CHART

The methodology or process can be shown in the figure below:

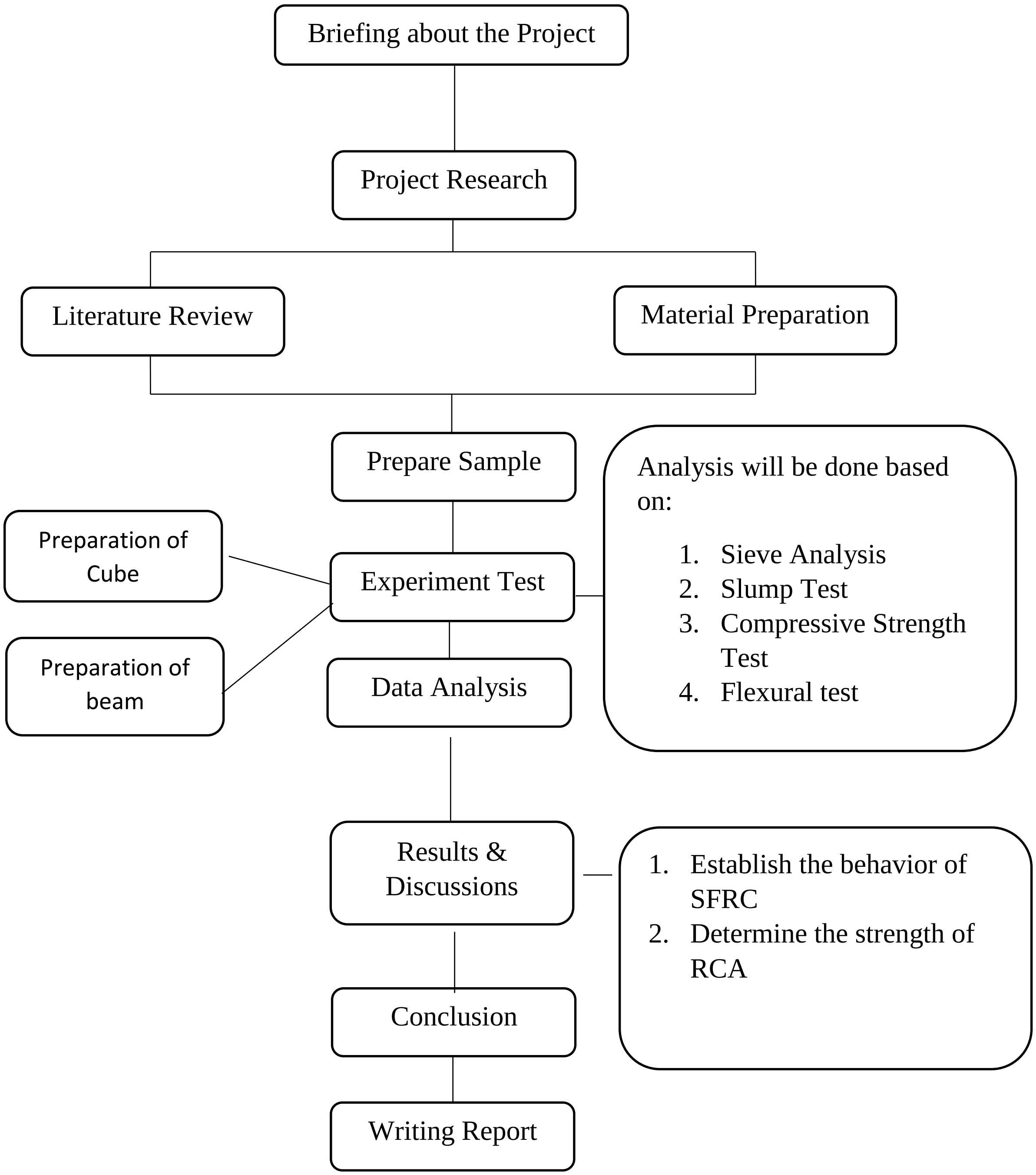


Figure 3.0: Methodology Flow Chart

3.3 Material Preparation

3.3.1 Water

Tap water was chosen for the concrete mixing and curing process in this study. Water is considered as an important ingredient that required for concrete mixing and water make the mixture of concrete easy to handle. The pH value and impurities in the water may affect the compressive strength and setting time of the concrete. The quality of tap water that being used satisfied the requirements for concrete mixing.

3.3.2 Cement

Portland cement was used in this study which is commonly used for construction building. Portland cement also a finely pulverized material that develops its binding property using water. Other than that, cement was stored away from air moisture in the concrete lab to ensure the cement was in good condition during experimental period.

3.3.3 Coarse Aggregate

For this study, gravel was used in concrete mixing. Gravel 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.

3.3.4 Fine Aggregate

The fine aggregate that used for concrete mixing in this study was river sand. River sand was selected because it easier to obtain and it was free from clay, organic material and chemical .The river sand was checked to ensure that it was free from other organic materials inside before used it.

3.3.5 Recycled Aggregate

In this study, the process of preparing recycled aggregate is needed. The sources of aggregate is from a cube that can be found at the concrete laboratory of faculty of civil engineering. Cubes are collected and compiled through the process of destruction. The cubes are crushed to obtain a desired aggregate size. In the study, the aggregate used is 15mm to 20mm. To get the correct size, sieve analysis process should done. Sieve analysis process is to find the aggregate size required to apply for certain. In this study, 25% of recycled concrete aggregate was used.

Figure 3.1: Crushed the recycled concrete aggregate into smaller size

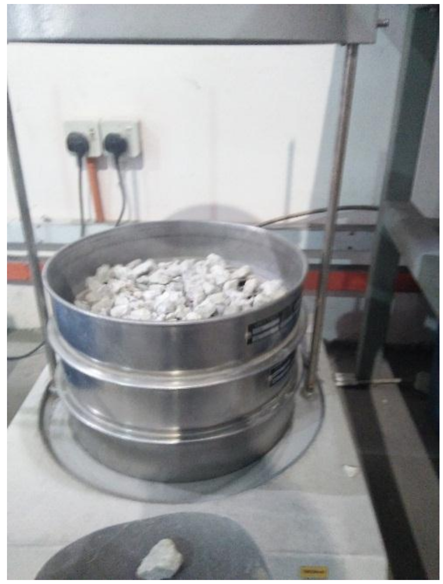


Figure 3.2: Sieve recycle concrete aggregate into 15mm -20mm

3.3.6 Steel Fibre

A Steel fibre is used as addition elements in the concrete. The fibers presence helps delay the time of fracture and fail. The volume of steel fibres are used is 0%, 1% and 2%. This is intended to provide a comparison between the compressive strength of reinforced recycled concrete and steel fiber reinforced recycled concrete.

3.4 Concrete Mix Design

Concrete mix design may be defines as the process of selecting the appropriate materials of concrete and determining their relative proportions with the materials of producing concrete as economical as possible. The purpose is to ensure the most optimum proportions of the component materials to fulfill the requirement of the structure being built.

Table 3.1 : Concrete Mix Design

Type of Beam	Normal concrete (NCA)	Recycled concrete aggregate (RCA)	RCA +1% SF (RCA1)	RCA + 2% SF (RCA2)
Material	Weight (kg/m3)	Weight (kg/m3)	Weight (kg/m3)	
Cement	380	380	380	380
Water	190	190	190	190
Fine aggregate	990	990	990	990
Course aggregate	890	670	670	670
Recycle Aggregate	0	223	223	223
Steel Fibre	0	0%	1%	2%
w/c ratio	0.5	0.5	0.5	0.5

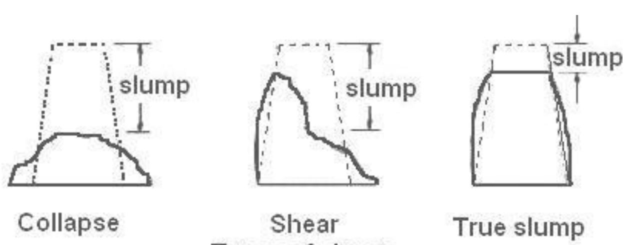
3.5 Reinforced Recycled Concrete Beam

A total of four RRC Beam were produced to undergo the flexural test. One of the beams will be acts a control beam, and the other three beam will be fitted with Steel Fiber Recycled Concrete with different volume of steel fiber. All the designs for all these beam accordance with the British Standard.

3.6 Test Conducted

3.6.1 Slump Test

Slump test also been done during the mixing of concrete to ensure the concrete has sufficient workability as well as to meet the design requirement. The apparatus of slump test consists of slump cone, base plate, tamping rod and measuring scale. Internal surface of the cone should be cleaned properly. Then, the base plate should be placed on a horizontal and smooth surface. Filled the cone with fresh mixed concrete in 3 layers. Tamped 25 times by using tamping rod for each layers. After filling is completed and concrete is leveled, slowly lifted the cone in the vertical direction. Placed the cone besides the slump concrete and placed the tamping rod over the cone to measure the slump. The decrease in the height of the center of the slump concrete is called slump and is noted with measuring scale



Types of slump

Figure 3.3: Slump Test

3.6.2 Compressive Strength Test

The objective of this test is to determine the compressive strength of concrete. Compressive strength testing machine which located in concrete laboratory was used to conduct this test. This test was conducted with the standard dimension of 150mm x 150mm x 150mm. By using oil, lubricate the inside of the cube moulds thoroughly to avoid from adhere to moulds. Fresh concrete was poured into the moulds and properly compacted by using vibration table to prevent from having any voids. Then, the moulds are kept for 24 hours for concrete setting. After 24 hours, the moulds were removed and the specimens were put into the water tank for curing process. These specimens were tested by compressive strength testing machine after 7, 14 and 28 days curing. The load was applied slowly and continuously increased until the resistance of the specimens to the increased load breaks down and cannot sustained anymore. The results were noted and the maximum load that is applied to the specimens were being recorded to bring out in the report.

Figure 3.4: Compressive Strength Test

3.6.3 Flexural Strength Test

Flexural strength test is used to determine the flexural modulus or flexural strength of a material. Generally, three core stresses were presented, which is tensile, compressive and shear when a specimen was placed under flexural loading. Therefore, the flexural properties of a specimen are the result of the combined effect of all three stresses as well as the geometry of the specimen and the rate the load is applied.. The specimens are tested by using Flexural Testing Machine at Structural laboratory, which is the machine consist of two supports and two loading points. The specimen is placed on two supporting pins a set distance apart and a third loading pin is lowered from above at a constant rate until sample failure. The specimens were continuously placed with load until rupture occurs. The maximum load carried by the specimen during test were recorded and the specimen cross section at one of the fractured faces were being measured.

Figure 3.5: Flexural Test

3.7 Preparation of Formwork

In this experiment, plywood was used to construct the formwork for reinforced recycle concrete beam. Oil was applied to the formwork surface before the concrete mixture has been poured. Oil was used to avoid from adhere to the formwork. The size of plywood is 150mm x 200mm x 1500mm.

Figure 3.6: Preparation of formwork

3.8 Preparation of Steel Reinforcement

The reinforcement that was used is steel bar 12mm for main reinforcement and 8mm for link. All the steel bar were cut according to required length using the cutter while bending machine was used to bend the reinforcement. The reinforcement and links were tied together using pliers.

Figure 3.7: Preparation of steel reinforecement

3.9 Preparation of Concrete Cover

In this study, the size of concrete cover was used is 25. Concrete cover will tied together with reinforcement before put into formwork. The used of concrete cover to avoid reinforcement attach with formwork

Figure 3.8: The making of concrete cover

3.10 Casting of Beams

After the reinforcements were placed into the plywood formwork, the concrete mixture was poured into the formwork. In order to make sure that concrete filled the formwork completely, the plywood was vibrate continuously using vibrator for compaction purpose. The beams surface is smoothen using a trowel. Figure 3.9 shows example of casting beam.

Figure 3.9: Casting Beam

3.11 Curing

For the curing of the Reinforced Concrete beams, wet gunny sack was used. The Reinforced Concrete beams were continuously cured until the beams were ready to be removed from the formwork. After curing process, the beams surfaces were painted with white as the cracks can be easily seen during testing.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter present the results obtained from the testing conducted on the specimens. The study aims to compare the cracking pattern and the strength of the concrete between controlled beams, recycle concrete beams and fibre beams. The data and results has been recorded, expressed and analyzed in the tables, graphs and charts forms to show the relationship between parameters. The results have been discussed and analyzed to draw out the conclusions.

4.2 Slump Test

The slump test is a method used to determine the consistency of concrete. The consistency or stiffness of the concrete shows the fluidity of the concrete indicating how much water has been used in the mix, and is often measured by concrete slump. Table 4.1 and Figure 4.1 shown variation in slump for controlled beam , 25% of recycled concrete aggregate(RCA) beam, 25% of RCA with 1% of steel fibre and 25% of RCA with 2% of steel fibre.

Table 4.1: Slump Test

Type of beam	Slump Height,(mm)
NCA	100
RCA	86
RCA1	89
RCA2	95

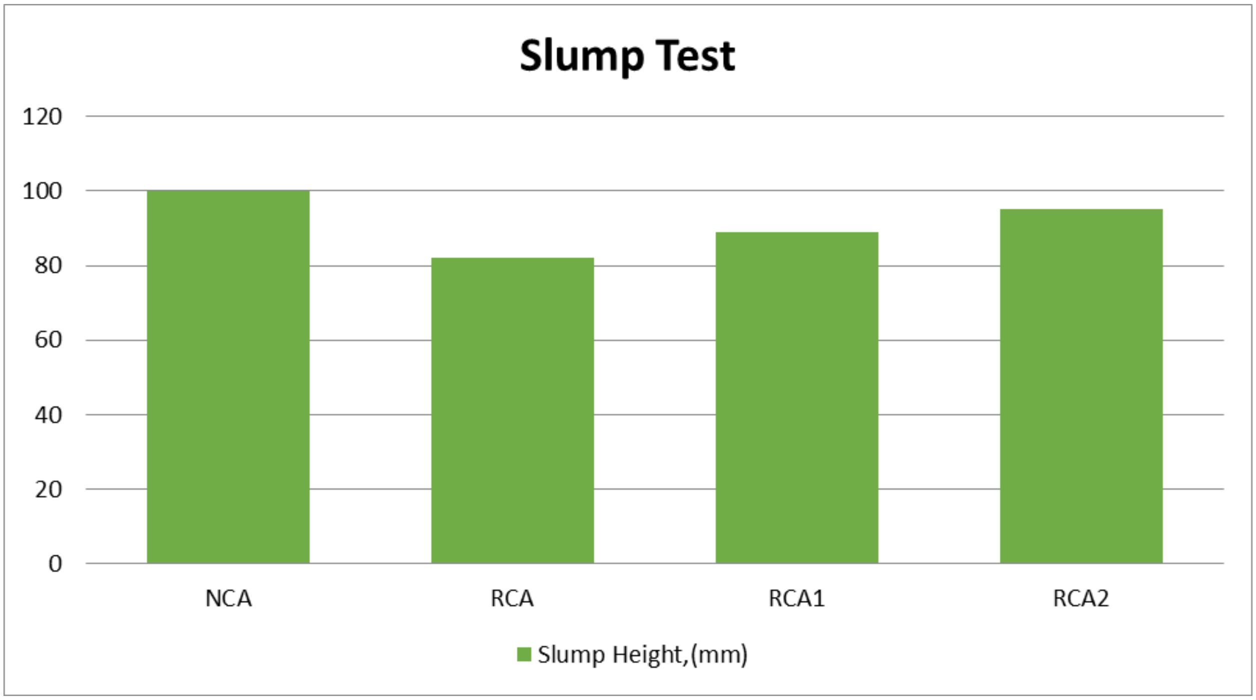


Figure 4.1 : Slump Test Results

Figure 4.1 shown the decreasing value of slump height of NCA to RCA but the trend of bar chart shown the increasing value of slump height of , RCA, RCA1, and RCA2. The reason of this reduction maybe because of the characteristic of the RCA, which was water absorbing. It can be seen that the highest value was 100 mm, which goes to controlled beam while the lowest value was 82 mm that obtained from RCA. The concrete mixture and the ratios of ingredients affect the workability of the concrete's final strength (water/cement ratio). In terms of workability, the higher the slump value, the higher the amount of water and as a result the mixture is more fluid for working the concrete and finishing. Therefore, controlled beam was found to be the highest workability among the other mix proportion.

4.3 Compressive Strength Test

The purpose of this test is to determine the compressive strength of the controlled beam, recycle beam and fiber beam. The compressive strength of the concrete is the most valuable property in the concrete as is describes the overall quality and the characteristics of the concrete. The sample cubes with the dimension of 150 mm x 150 mm x 150 mm were tested. The sample cubes were cured in water and tested for compressive strength at the curing age of 7 and 28 days. The compressive strength average was taken from the result of three sample cubes. Based on the result presented in Table 4.1, it can be observed that the concrete compressive strength value is different based on the curing period of 7 and 28 days. It can be seen that the control cube of RCA has increase in strength with days. Cube with RCA also increase with days but not strong enough as NCA cube. Same as with RCA1 cube, the compressive strength also increase with days but not strong as controlled cube but the strength is more than RCA. The compressive strength of the cube with RCA2 also have increasing strength with days, but not strong as controlled cube and but the strength is more than RCA cube and RCA1 cube.

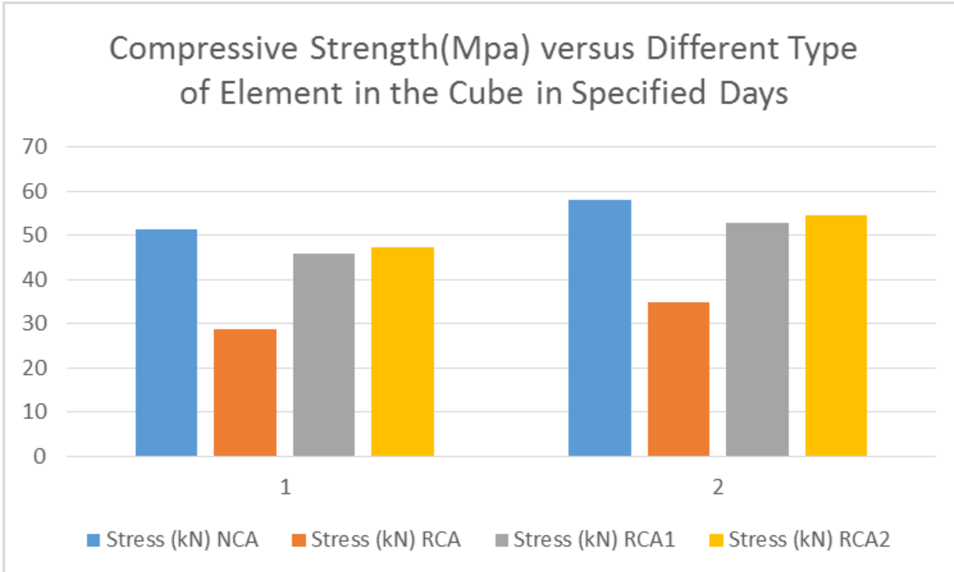


Figure 4.2: The value of compressive strength with different type of mixture

Table 4.2: The average value of stress with days

Days	Stress (kN)			
	NCA	RCA	RCA1	RCA2
7	51.33	28.67	45.97	47.37
28	58.01	34.73	52.93	54.45

The test results indicate that Steel Fibre addition into RCA caused an increased in compressive strength of the concrete. It can be clearly observed that a clear upward trend in load and compressive strength for all graph of 7 and 28 days curing period. The load and compressive strength was highest at 0% replacement of RCA and 0% of steel fibre, 51.33 Mpa respectively and minimum at RCA, which the load and compressive strength were obtained to be 28.67 Mpa respectively for 7 days curing period. At 28 days curing period, the highest load and compressive strength goes to NCA, which found to be 58.01 Mpa while the lowest value goes to RCA, which compressive strength was 34.73 Mpa.

It can be observed that the 28 day curing period compressive strength for control, RCA1 and RCA2 were above the specified value of 25 Mpa, which are 38.68 Mpa, 35.29 Mpa and 36.25 Mpa respectively.

4.4 Flexural Test Results

The purpose of this test are to get the cracking pattern of the beams. Besides that, the graph of the load versus deflection curve for each beam also can be compare. In this test, each of the beam has been subjected to the continuously load until the beam has failed. The cracking pattern appear after the beam has failed. The tests for flexural strength of concrete were conducted for NCA, RCA beam, RCA1 and RCA@ from the basic concrete grade C25/30 at the curing period of 7 days and 28 days. The results are compiled in the given below.

4.4.1 Load (kN) versus Flexural Strength(Mpa)

Figure 4.3 shown the pattern of load versus flexural strength

4.4.1.1 NCA Beam

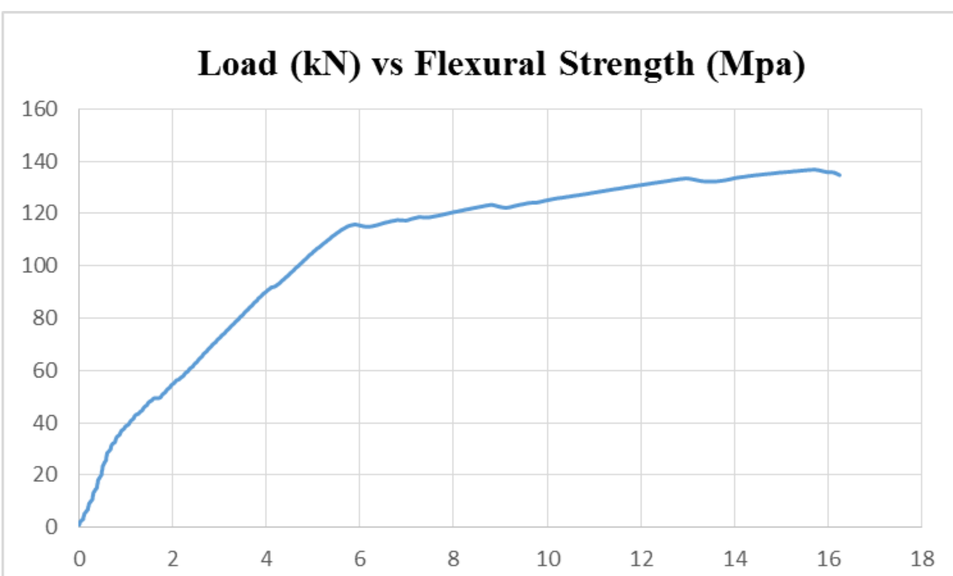


Figure 4.3 : Load versus Flexural strength (NCA beam)

At the first deflection, the load is at 20.65 kN. The second deflection occur when the load is reach at 44.36 kN. It seems that the NCA beam is going to fail but the NCA beam still can resist the load from the flexure test. The load is constantly applied until the third deflection is appear when the load is at 63.17 kN. The fourth deflection occur when the load is applied at 84.27 kN. The final deflection occur when the load is applied at 136.78 kN before the NCA beam has failed.

Table 4.3: Flexural Test for NCA beam

Curing Period, (Day)	Load, (kN)	Flexural Strength, (Mpa)
28	136.78	15.716

4.4.1.2 RCA Beam

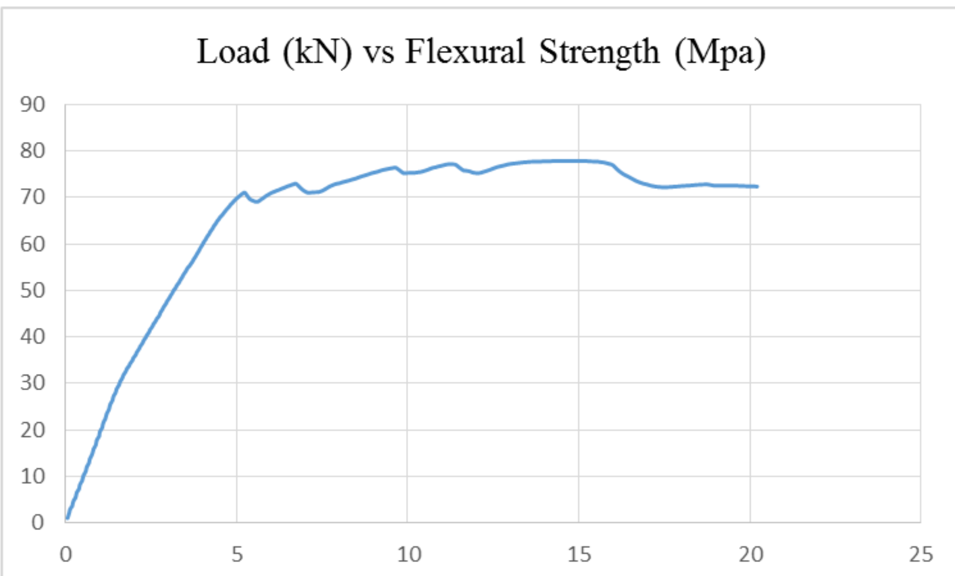


Figure 4.4 : Load versus Flexural Strength (RCA Beam)

At the first deflection, the load is at 11.14 kN. The second deflection occur when the load is reach at 25.08 kN. It seems that the controlled beam is going to fail but the controlled beam still can resist the load from the flexure test. The load is constantly applied until the third deflection is appear when the load is at 37.48 kN. The fourth deflection occur when the load is aplied at 66.74 kN. The final deflection occur when the load is applied at 72.5 kN before the controlled beam has failed.

Table 4.4: Flexural Test for RCA

Curing Period, (Day)	Load, (kN)	Flexural Strength, (Mpa)
28	72.50	19.626

4.4.1.3 RCA1 Beam

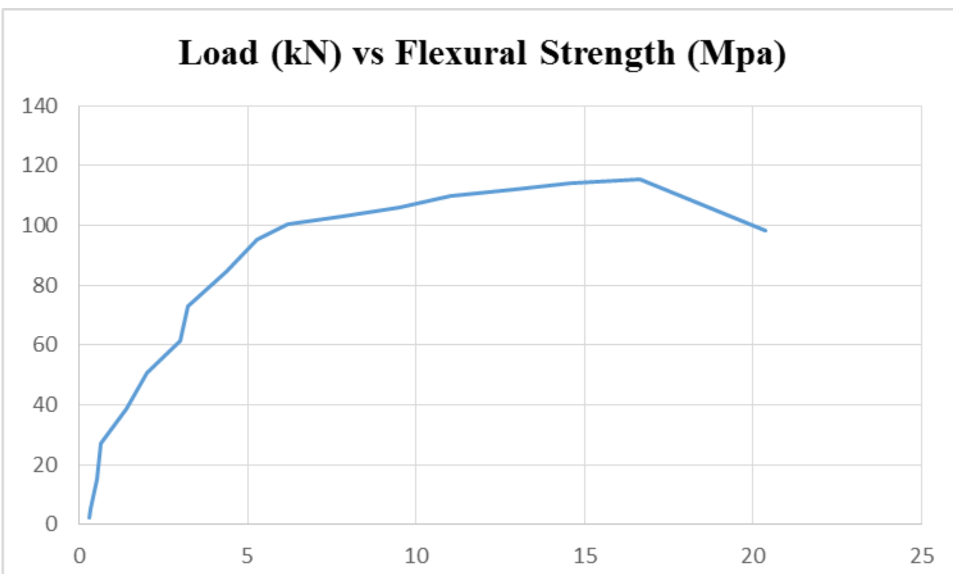


Figure 4.5: Load versus Flexural Strength (RCA1)

At the first deflection, the load is at 11.14 kN. The second deflection occur when the load is reach at 25.08 kN. It seems that the controlled beam is going to fail but the controlled beam still can resist the load from the flexure test. The load is constantly applied until the third deflection is appear when the load is at 37.48 kN. The fourth deflection occur when the load is aplied at 66.74 kN. The final deflection occur when the load is applied at 72.5 kN before the controlled beam has failed.

Table 4.5: Flexural Test for RCA1

Curing Period, (Day)	Load, (kN)	Flexural Strength, (Mpa)
28	115.309	16.656

4.4.1.4 RCA2 Beam

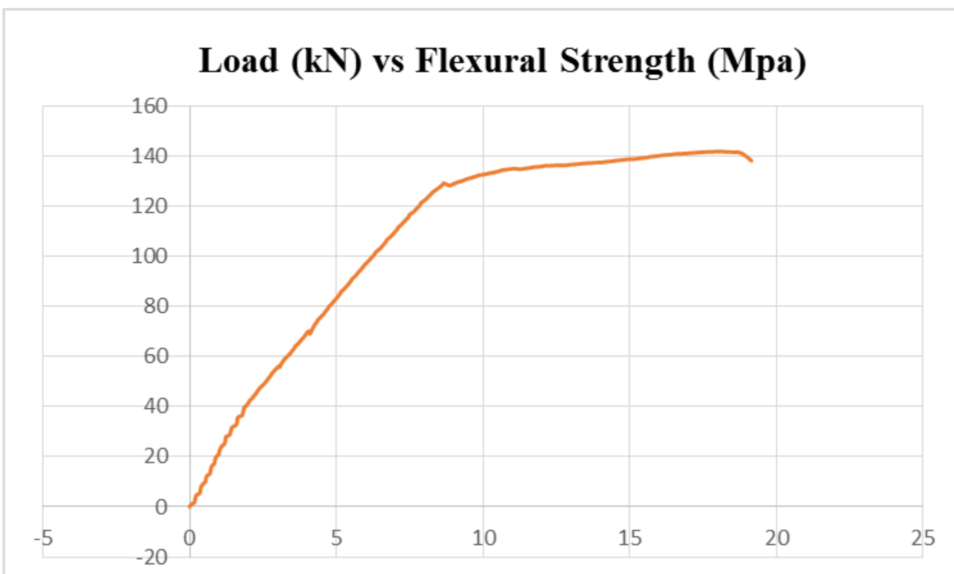


Figure 4.6 : Load versus Flexural Strength (RCA2 Beam)

At the first deflection, the load is at 11.14 kN. The second deflection occur when the load is reach at 25.08 kN. It seems that the controlled beam is going to fail but the controlled beam still can resist the load from the flexure test. The load is constantly applied until the third deflection is appear when the load is at 37.48 kN. The fourth deflection occur when the load is aplied at 66.74 kN. The final deflection occur when the load is applied at 72.5 kN before the controlled beam has failed.

Table 4.6: Flexural Test for RCA2

Curing Period, (Day)	Load, (kN)	Flexural Strength, (Mpa)
28	141.786	17.952

4.4.1.5 Comparison of Load versus Compressive Strength

Figure 4.7 presented the result of load deflection for each type of samples after flexural test had been done. The parameters were identified and summarized in Table 4.7, namely: the load at which the longitudinal reinforcement yields in tension(P_y) and its corresponding deflection(δy), the maximum load(Pmax) representing the load-carrying capacity and related deflection(δ_{max}) , the ultimate load (Pu) representing the residual strength(taken as the minimum of the load at failure or 85% of the maximum load to ensure its practical usefulness) and associated deflection(δ_u) ant the ductility ratio (μ) defined as $\mu=\delta_u/\delta_y$.

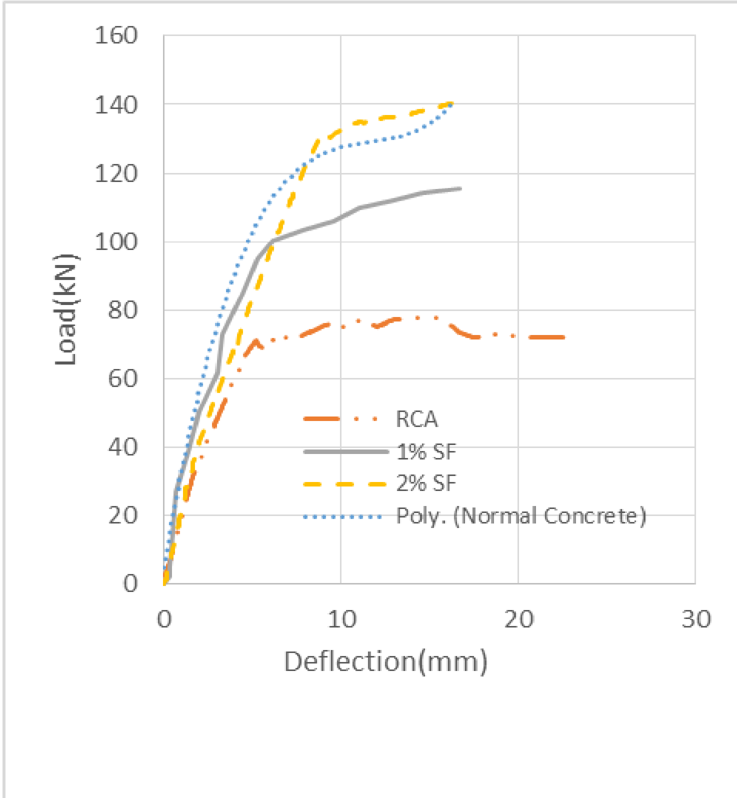


Figure 4.7 : Load deflection curve

Table 4.7 : Comparison of load with compressive strength

Type of Beam	Load(kN)	Compressive Strength
NCA	136.78	15.716
RCA	72.50	19.626
RCA1	115.309	16.656
RCA2	141.786	17.952

Table 4.8: Summary of the significant values in the load deflection curves for beams

Type of beams	NCA	RCA	RCA1	RCA2
P_y (kN)	115.40	71.25	101.2	130.63
δ_y (mm)	5.78	6.94	7.51	8.09
P_u (kN)	104.25	69.11	98.36	138.19
δ_u (mm)	18.85	22.06	21.32	19.41
P_{max} (kN)	136.78	77.82	118.7	141.08
δ_{max} (mm)	15.71	14.58	17.83	23.41
$\mu=\delta_u/\delta_y$	3.26	3.18	2.84	2.40

From Table 4.8, it could be seen that the maximum load carrying capacity (Pmax) and yield load (**P_y**) of the standard control beam are higher than that with recycled concrete aggregate. Evidently, the fibres are acting to hold the matrix together. In term of ductility, it was observed that the ductility ratio (μ) of beams with RCA increase. The highest ductility is observed from beams with RCA. Therefore, it could be concluded that the addition of recycled concrete aggregate and fibres managed to introduce a ductile characteristic into the concrete material.

4.5 Maximum Ratio

The ratio between the maximum load (Pmax) of each samples and that for standard control ($Pmax,_0$) is shown in figure 4.8. There is a upward trend in the *(Pmax/Pmax,0)* ratio as observed from the figure for sample without additional of recycled concrete aggregate and steel fibers. As for the sample contain fibers, the percentages are increased. Based on this figure, it can be concluded that the maximum load ratio increases with the increases of the steel fiber volume ratios.

Other than that, the figures shown the ratio between the maximum load (Pmax) of each samples and 25% of recycled concrete aggregate ($Pmax,_1$). There is a upward trend in the *(Pmax/Pmax,1)* ratio as observed from the figure for sample with additional of recycled concrete aggregate and steel fibers. As for the sample contain fibers, the percentages are increased. Based on this figure, it can be concluded that the maximum load ratio increases with the increases of the steel fiber volume ratios.

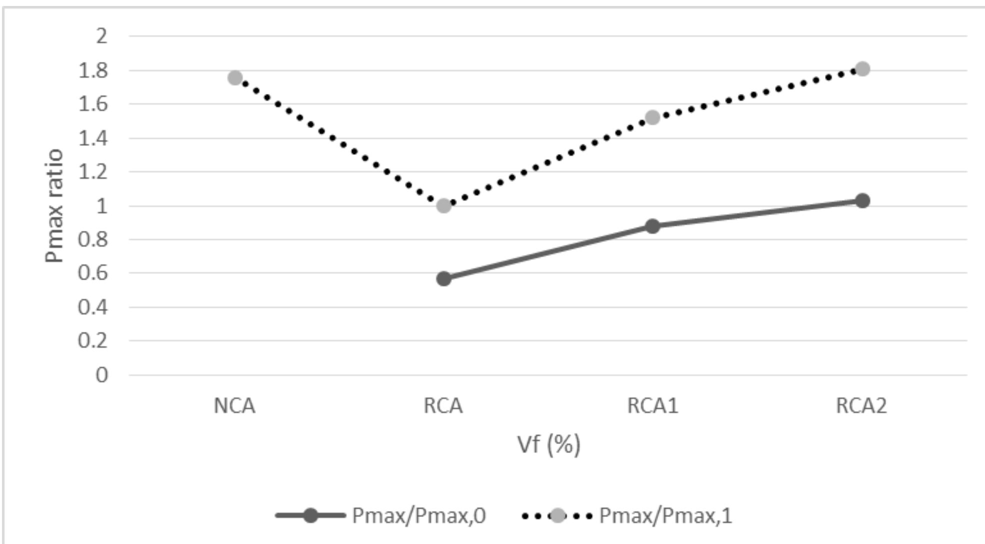


Figure 4.8 : Maximum load ratio curve

Table 4.9 : Maximum load ratio

samples	Pmax/Pmax,0	Pmax/Pmax,1
NCA	1.00	1.76
RCA	0.57	1.00
RCA1	0.88	1.52
RCA2	1.03	1.81

4.6 Yield Ratio

In figure 5 the upward trend was observed between in *(Py/Py,0)* and *(Py/Py,1)* the ratio of yield load(Py) and NCA and the other ratio is between Py and RCA. As for the sample contain fibres, the percentages are increased. Based on this figure, it can be concluded that the yield load ratio increases with the increases of the steel fibre volume ratios.

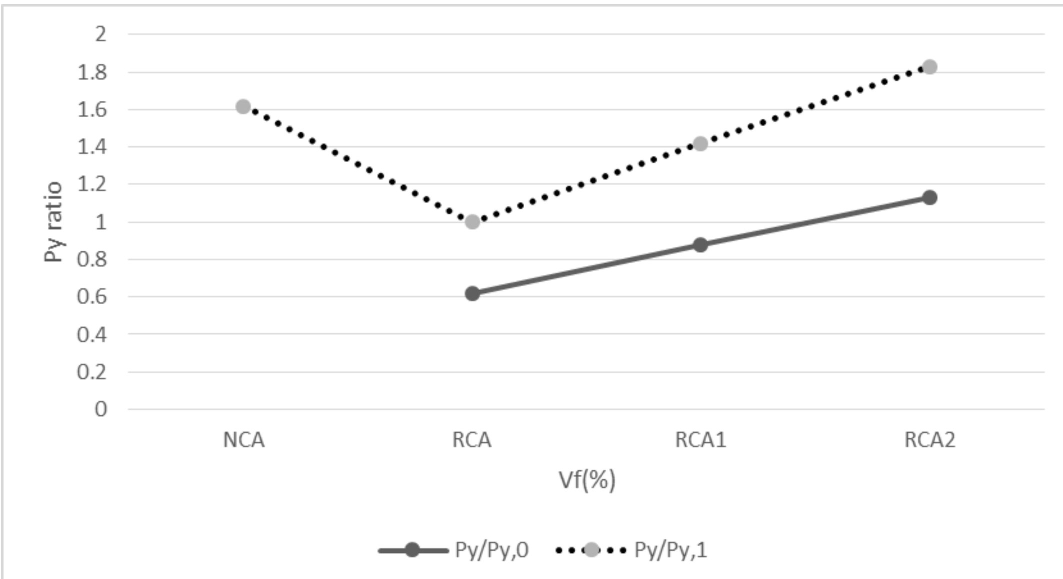


Figure 4.9 : Yield load ratio curve

Table 4.10 : Yield load ratio

samples	Py/Py,0	Py/Py,1
NCA	1	1.62
RCA	0.62	1
RCA1	0.88	1.42
RCA2	1.13	1.83

4.7 Ductility Ratio

It is observed, that the ductility lower depends on volume of fibre in the reinforced concrete. There is a downward trend in the *(μ/μ,0)* and *(μ/ μ,1)* . The ratio of yield ductility (μ) and NCA and the other ratio is between μ and RCA.Since the controlled reinforced concrete beam is more brittle than steel fibre reinforced concrete, hence the ductility showed the lower in the structure properties of beams with the incorporating of RCA. It is highly recommended to use steel fibre to achieve a reasonably good ductile structure that is suitable for design consideration.

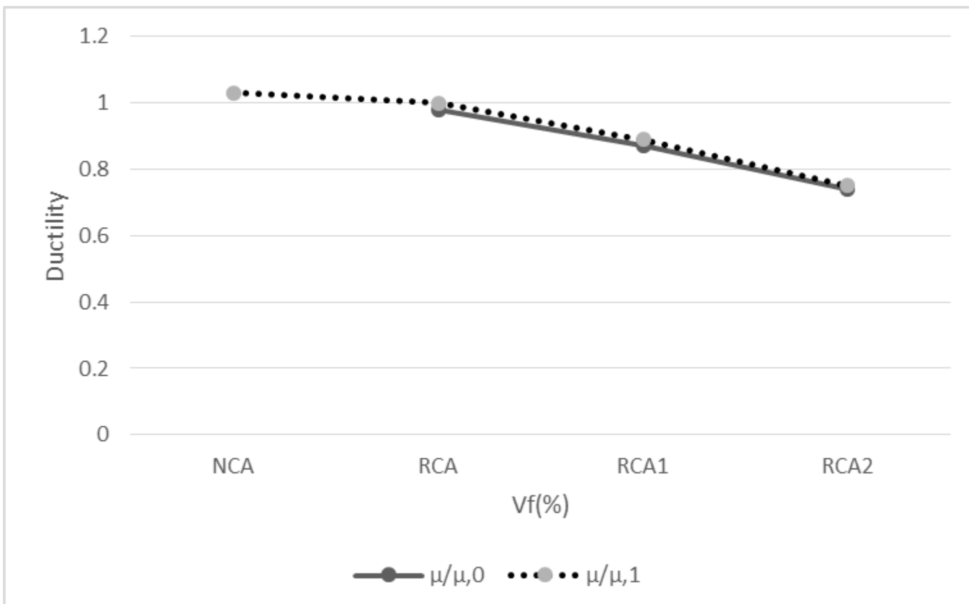


Figure 4.10 : Ductility curve

Table 4.11: Ductility

samples	μ/μ,0	μ/μ,1
NCA	1	1.03
RCA	0.98	1
RCA1	0.87	0.89
RCA2	0.74	0.75

4.8 Cracking Pattern

The cracking pattern happen when the controlled beam has start to fail. At this point, the beam has achieved maximum load. The following figures shows the comparison of the cracking pattern after all the beam has failed.

Figure 4.11 : Cracking pattern for controlled beam(NCA)

Figure 4.12 : Cracking pattern for 25% of RCA(RCA)

Figure 4.13 : Cracking pattern for 25% of RCA with 1% of Steel fibre(RCA1)

Figure 4.14 : Cracking pattern for 25% of RCA with 2% of Steel fibre(RCA2)

Table 4.12 Mode of failure for beam

Sample	Load on 1st crack	Mode of failure
NCA	-	Shear Bending
RCA	-	Bending
RCA1	-	Bending
RCA2	111.96	Bending

From the figures above, it is apparent that most of the beams show cracking propagation along the mid-span and between the loading and support point. During testing, it was observed that NCA Beam(Figure 4.11) failed in bending-shear, whilst, RCA Beam 2(Figure 4.12), RCA1 Beam(figure 4.13) and RCA2 Beam(figure 4.14) failed in bending mode.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In the previous chapter, the results of the study were tabled and the findings of the study were discussed in detail. This chapter provides the conclusions of the study and the proposed recommendations for future study. This study presents the behaviour of the reinforced concrete beam added with recycled concrete aggregate (RCA) and steel fibre. All the experimental test was designed to achieve the objective of this study. The analysis of the data shows the influence of the reinforcement ration on the crack pattern. The analysis of the data for the cube test is to compare the compressive strength of the concrete. The experimental results are analyzed with help of the cracking pattern on the each of the beam.

5.2 Conclusions

After all the results are analysed, the first objective can be concluded. As for steel fiber reinforced recycle concrete (SFRC), it is showed that the strength of structure by using steel fibre and recycle concrete can be improve. Although the maximum load has slightly decrease compare to controlled beam.

Next objective is to compare the cracking pattern when load is applied between normal beam structure, recycled concrete beam and fibre beam structure. Figure 4.11, 4.12, 4.13, and 4.14 shows the cracking pattern of the reinforced concrete beams with different type of fiber. The mode of failure can be identify by compare the cracking pattern of the reinforced concrete beam. It can be concluded that the cracking pattern with bending and shear failure mode of RCA1 and RCA2 beam has low maximum load compare to the NCA beam.

This study provides a further environmental benefit by using recycled concrete aggregate. This will lead to a reduction in the stockpile of such waste material, thus decreasing their impact on the environment and easing the problems associated with the disposal of waste material to landfill. Economic benefits should also be felt by construction industry from lower production cost due to the ready availability and low cost of industrial waste material.

From the investigations carried out, there exists a high potential for the use of recycled aggregate as coarse aggregate in the production concrete. It can be concluded that recycled concrete aggregate can be successfully used in the as coarse aggregate replacement. Therefore, the development of existing knowledge and identification of waste materials to be used in making concrete will provide a valuable contribution in the environmental sustainability of the industry.

5.3 Recommendation

The results of this study shows that Steel Fiber Reinforced Recycled Concrete Beam has big potential to use in the construction. The addition of the steel fibre can increase the strength of the structure beam. This study also prove that steel fibre has consistently increasing in the concrete strength from the beginning until 28 days. It can be proved by review the compressive strength test results in Figure 4.2. The steel fibre and recycled concrete also can increase resistance to plastic shrinkage during curing process. Thus, the steel fibre can reduces the drying water during curing process. Thus, this study hope can improve the quality and potential of steel fibre and recycled concrete in the reinforced concrete beam structure in future.

REFERENCES

A.M Shende, A.M Pande, Pathan. G, *Experimental Study on Steel Fibre Reinforced Concrete*, Volume 1, Issue 1 (September 2012),PP.043-048

Maidl, B. R., & Dietrich, J. (1995). *Steel fibre reinforced concrete*. Berlin: Ernst & Sohn.

Amit Rai, Dr. Y.P Joshi (2016), *Applications and Properties of Fibre Reinforced Concrete*

Mohsin S, Manaf F., Sarbini N, Muthusamy K. (2016) *Behaviour Of Reinforced Concrete Beams With Kenaf And Steel Hybrid Fibre*

Wafa F. Vol 2,pp, 49-63 (1410 A.H./ 1990 A.D) *Properties and Application of Fiber Reinforced Concrete*,

Khalil, A. A., & Ghobarah, A. (2005). *Rehabilitation of reinforced concrete structural walls using fibre composites*.

Compression characteristics and structural beam design analysis of steel fiber reinforced concrete. (1973). Springfield, VA: NTIS.

Batson, G. B. (1977). *Strength of steel fiber concrete in adverse environments*. Champaign, IL: Dept. of Defense, Dept. of the Army, Corps of Engineers, Construction Engineering Research Laboratory.

Pickel, D. (2014). *Recycled concrete aggregate: influence of aggregate pre-saturation and curing conditions on the hardened properties of concrete*. Waterloo, Ontario, Canada: University of Waterloo.

Smith, J. T. (2009). *Recycled concrete aggregate: a viable aggregate source for concrete pavements*. Waterloo, Ont.: University of Waterloo.

Tiwari, P. K., & Sharma, D. A. (2016). Properties of Fibre Reinforced Concrete- A Comparative Studies of Steel Fibre Poly-Fibre. *International Journal of Engineering Research and,V5*(06).

Steel fibre reinforced concrete. The effect on fibre orientation of compaction by vibration. (1972). *Composites,3*(4), 191.

Sinha, D. D. (2011). Characteristic Properties of Steel Fibre Reinforced Concrete with Varying Percentages of Fibre. *Indian Journal of Applied Research,4*(7), 218-220.

Saleh, M. F., Yeow, T., Macrae, G., & Scott, A. (2012). Effect of Steel Fibre Content on the Fatigue Behaviour of Steel Fibre Reinforced Concrete. *7th RILEM International Conference on Cracking in Pavements*, 815-825.

Vázquez, E. (n.d.). Recycled aggregate in concrete. *Use of Recycled Materials,* 41-43. doi:10.1617/2912143691.004

Prince, M. J., & Singh, B. (2015). Bond behaviour of normal- and high-strength recycled aggregate concrete. *Structural Concrete,16*(1), 56-70.

Wedding, P., R., & Khan, A. (1984). Recycled Concrete—A Source for New Aggregate. *Cement, Concrete and Aggregates,6*(1), 17.

Pepe, M. (2015). Recycled Aggregate Concretes. *A Conceptual Model for Designing Recycled Aggregate Concrete for Structural Applications Springer Theses*, 55-89.

J-L. Granju and S.U. Balouch: *Corrosion of Steel Fiber Reinforced Concrete From the Cracks. Cement and Concrete Research*, Volume 35, 2005, pp.572-577.

Antonius: *Strength and Energy Absorption of High-Strength Steel Fiber Concrete Confined by Circular Hoops*, International Journal of Technology, Vol.6(2), 2015, pp.217-226

M.M. Ziara, D. Haldane and A.S. Kuttab: *Flexural behavior of Beams with Confinement, ACI Structural Journal*, Vol.92(1), 1995, pp.103114.

Fanella D.A. and Naaman A.E. (1985). *Stress-Strain Properties of Fiber Reinforced Mortar in Compression*. ACI JOURNAL 82:4, 475-483

Hughes B.P. and Fattuhi N.I. (1977*). Stress-Strain Curves for Fiber Reinforced Concrete in Compression. Cement and Concrete Research* 7:2, 173-184

Abdulhadi, M. (2014). "*A comparative study of basalt and polypropylene fibers reinforced concrete on compressive and tensile behavior*." IJETT, journal.Org, 9(6), 295–300

T. U. Ganiron Jr., "*Waste tire as an asphalt cement modifier for road pavement", International Journal of u- and e- Service, Science and Technology,* vol. 7, no. 5, (2014), pp. 181-194.

T. U. Ganiron, Jr., "*The effect of waste glass bottles as an alternative coarse aggregate in concrete mixture*", International Journal of ICT-aided Architecture and Civil Engineering, vol. 1, no. 2, (2014), pp. 19-30.

S. Marinković, V. Radonjanin, M. Malešev, I. Ignjatović, *Recycled aggregate in structure concretes – technology, properties, application*, Vol. 2 (2009) 58−72.

D. Jevtić, D. Zakić, A. Savić, *Specific properties of recycled aggregate concrete production technology*, Vol. 52−1 (2009) 52−62.

C. S. Poon, L. Lam, *The Effect of Aggregate to Cement Ratio and Types of Aggregates on Properties of Precast Concrete Blocks, Cement and Concrete Composites,* Vol. 30 (2008) 283−289.

V. Radonjanin, M. Malešev, I. Ignjatović, *Recycled aggregate concrete - technology, properties and application*, Beograd 2009, 131−154.

Colin D. Johnston, "*Fiber reinforced cements and concretes" Advances in concrete technology volume 3* – Gordon and Breach Science publishes – 2001.

Perumalsamy N. Balaguru, Sarendra P. Shah, ''*Fiber reinforced cement composites* , Mc Graw Hill International Editions 1992.

Arnon Bentur & Sidney Mindess, ''*Fiber reinforced cementitious composites*'' Elsevier applied science London and Newyork 1990.

M.N.S. Hadi: *Reinforcing Concrete Columns with Steel Fibers. Asian Journal of Civil Engineering*, Volume 10(1), 2009. pp. 79-95.

APPENDIX A

CONCRETE MIX DESIGN NCA

Stage	Item	Reference & calculation	Value
1	1.1 Characteristic Strength	Specified	**G30** N/mm^2 at **28** days Proportion Defective **5 %**
	1.2 Standard Deviation	Figure 3	**5** N/mm^2
	1.3 Margin	C1 or Specified	(k=1.64) 1.64 x **5** = **8.2** N/mm^2
	1.4 Target mean strength	C2	**30** + **8.20** = **38.20** N/mm^2
	1.5 Cement type	Specified	**OPC**
	1.6 Aggregate type: Coarse		**Crushed**
	Aggregate type: Fine		**Crushed**
	1.7 Free water/cement ratio	Table 2, Fig 4	**0.58** — use the lower value
	1.8 Max. free-water cement ratio	Specified	**0.65**
2	2.1 Slump or V-B	Specified	Slump **10-30 mm**
	2.2 Maximum aggregate size	Specified	**20 mm**
	2.3 Free-water content	Table 3	**190 kg/m²**
3	3.1 Cement content	C3	**190** ÷ **0.58** = **327.59 kg/m²**
	3.2 Maximum cement content	Specified	______ **Kg/m²**
	3.3 Minimum cement content	Specified	**275 kg/m²** – use if greater than item 3.1 and calculate 3.4
	3.4 Modified free-water/cement ratio		______
4	4.1 Relative density of aggregate (SSD)	Fig 5	**2.7** known/assumed
	4.2 Concrete density	C4	**2435 kg/m²**
	4.3 Total aggregate content		**2435** – **327.52** = **1917.41** kg/m²
5	5.1 Grading of fine aggregate	BS 882	Zoom ____ - ____ -
	5.2 Proportion of fine aggregate	Fig 6	______ **Per cent**
	5.3 Fine aggregate content	C5	**1917.41** X **0.53** = **1016.23kg/m²**
	5.4 Coarse aggregate content	C5	**1917.41**- **1016.23**= **901.18kg/m²**

Quantities	Cement (Kg)	Water (Kg)	Fine aggregate (Kg)	coarse aggregate (Kg)	RCA
Per m^3 (to nearest 5 kg)	**380**	**190**	**990**	**890**	**0**
Per trial mix of **0.048375** m^3	**19**	**10**	**48**	**44**	**0**

APPENDIX B

CONCRETE MIX DESIGN RCA

Stage	Item	Reference & calculation	Value
1	1.9 Characteristic Strength	Specified	**G30** N/mm^2 at **28** days Proportion Defective **5 %**
	1.10 Standard Deviation	Figure 3	**5** N/mm^2
	1.11 Margin	C1 or Specified	(k=1.64) 1.64 x **5** = **8.2**N/mm^2
	1.12 Target mean strength	C2	**30** + **8.20** = **38.20** N/mm^2
	1.13 Cement type	Specified	**OPC**
	1.14 Aggregate type: Coarse		**Crushed**
	Aggregate type: Fine		**Crushed**
	1.15 Free water/cement ratio	Table 2, Fig 4	**0.58** — use the lower value
	1.16 Max. free-water cement ratio	Specified	**0.65**
2	2.1 Slump or V-B	Specified	Slump **10-30 mm**
	2.2 Maximum aggregate size	Specified	**20 mm**
	2.3 Free-water content	Table 3	**190 kg/m^2**
3	3.1 Cement content	C3	**190** ÷ **0.58** = **327.59 kg/m^2**
	3.2 Maximum cement content	Specified	______ **Kg/m^2**
	3.3 Minimum cement content	Specified	**275 kg/m^2** – use if greater than item 3.1 and calculate 3.4
	3.4 Modified free-water/cement ratio		______________________
4	4.1 Relative density of aggregate (SSD)	Fig 5	**2.7** known/assumed
	4.2 Concrete density	C4	**2435 kg/m^2**
	4.3 Total aggregate content		**2435** – **327.52** = **1917.41** kg/m^2
5	5.1 Grading of fine aggregate	BS 882	Zoom _______ - _______ -
	5.2 Proportion of fine aggregate	Fig 6	________________ **Per cent**
	5.3 Fine aggregate content	C5	**1917.41** X **0.53** = **1016.23kg/m^2**
	5.4 Coarse aggregate content	C5	**1917.41**- **1016.23**= **901.18kg/m^2**

Quantities	Cement (Kg)	Water (Kg)	Fine aggregate (Kg)	coarse aggregate (Kg)	RCA
Per m^3 (to nearest 5 kg)	**380**	**190**	**990**	**670**	**223**
Per trial mix of **0.048375** m^3	**19**	**10**	**48**	**44**	**11**