BEHAVIOUR OF HYBRID FIBERS IN REINFORCED RECYCLED CONCRETE AGGREGATE BEAM (50% OF RECYCLED AGGREGATE)

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ABSTRAK

Bahan bangunan hijau dapat mengurangkan pencemaran dan menggalakkan pemuliharaan mengurangkan sumber yang tidak boleh diperbaharui. Kitar semula batu baur konkrit adalah bahan konkrit sisa yang telah dihancurkan dan kemudian dikitar semula untuk digunakan sebagai bahan binaan hijau. Campuran konkrit yang menggunakan batu baur konkrit yand dikitar semula biasanya mempunyai kekuatan yang rendah berbanding campuran konkrit normal. Dengan menambah kenaf dan serat keluli (hibrid) ke dalam adunan, ia mungkin mempunyai potensi untuk memperbaiki bertetulang sifat-sifat simen dan juga mengatasi kelemahan bertetulang batu baur konkrit yang dikitar semula. Empat rasuk dibina dalam kajian ini, iaitu rasuk standard kawalan dan tiga lagi rasuk dengan 50% daripada batu baur konkrit yang dikitar semula menggantikan batu baur kasar ditambah dengan (0%, 1% dan 2%) jumlah serat hibrid. Gentian hibrid yang dicampur ke dalam batu baur konkrit yang dikitar semula di dalam rasuk bertetulang mempunyai potensi untuk menjadi lebih mulur berbanding rasuk konkrit normal.

ABSTRACT

Green building material can reduce the pollution and promotes conservation of reducing non-renewable resources. Recycled concrete aggregate is a waste concrete material that have been crushed and then recycled to be used as green construction material. Concrete mixture that use recycled concrete aggregate usually have low in strength compared to normal concrete mixture. By adding kenaf and steel fiber (hybrid) into the mixture, it may have potential to improve reinforced the properties of cement and also overcome the weakness of reinforced recycled concrete aggregate. Four beams are constructed in this study, which is standard control beam and another three beams with 50 % of recycled concrete aggregates replaced coarse aggregates added with (0%,1% and 2%) volume of hybrid fibers. Hybrid fibers reinforced recycled concrete aggregate beams had potential to become more ductile compared to normal concrete beam.

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LIST OF SYMBOLS

-	NaOH	-	Sodium Hydroxide
-	P_y	-	Load At Longitudinal Reinforcement Yields In Tension
-	P_{max}	-	Maximum Load
-	P_u	-	Ultimate Load
-	δ_y	-	Deflection At Yield
-	δ_{max}	-	Deflection At Maximum
-	δ_u	-	Deflection At Ultimate
-	μ	-	Ductility Ratio
-	mm	-	Milimeter
-	kN	-	Kilo Newton

LIST OF ABBREVIATIONS

-	NRCB	-	Standard Control Beam
-	RAB0	-	Beam With 50 % of Recycled Concrete Aggregates Replaced Coarse Aggregates Added with 0 % Volume of Hybrid Fibers
-	RAB1	-	Beam With 50 % of Recycled Concrete Aggregates Replaced Coarse Aggregates Added with 0 % Volume of Hybrid Fibers
-	RAB2	-	Beam With 50 % of Recycled Concrete Aggregates Replaced Coarse Aggregates Added with 0 % Volume of Hybrid Fibers
-	RCA	-	Recycled Concrete Aggregates

CHAPTER 1

INTRODUCTION

1.1 General

The research development of green construction material like concrete in civil engineering have been widely consume throughout the years. The most important aspect to be considered in this research are financial constraint, environmental compatibility and availability. In construction fields, concrete is mainly used in worldwide. Concrete is a composite that including course aggregate, fine aggregate, cement and water. The characteristic of concrete which its tends to be brittle and stronger in compression but having weakness in tension. Recent studies indicate that the researchers had been given attentions toward green building material, which benefits in reducing the environmental impact associated with the pollution and internationally promotes conservation of reducing non-renewable resources.

Recycled concrete aggregate is a waste concrete material that have been crushed and then recycled to be used as green construction material (Trčková J. et al., 2011), (Kazberuk M.K et al.,2014), (Singh S.P et al.,2016). The recycled concrete aggregate has same properties like the natural coarse aggregates but less in strength compared to the natural coarse aggregates. In order to cater the weakness of recycled concrete aggregate, additional of fibers into the mixture of concrete will helps in enhancing the strength of concrete.

Fiber reinforced concrete can be defined as the reinforced concrete contain fibrous material which increases its structural integrity (Subashini L.M et al., 2015). Fiber benefits to improve reinforced the properties of the cement and also overcome the weakness of reinforced concrete in tension. The needs to use fiber in the concrete is to be able sustain load at deflection, increase the toughness and strength. In addition, some fiber reduces the strength of concrete and some fiber provides greater impact, abrasion and shatter resistance in concrete. It is depending on the type of fiber. Many types of fiber can be used such as steel, glass, synthetic and natural fibers. Natural fibers have the potential to improve the usage of material related to environmental friendly.

Natural fibers are one the easier to obtain the sources of the material. It is cheaper compare to other fiber and low in energy level using the technology and local manpower. However, the utilization of natural fibers is less popular in construction fields. Many types of natural fibers can be used such as sisal, coconut coir, bamboo, jute, and sugarcane bagasse. Sisal fiber reinforced concrete has been used in making roof tiles, pipes and tanks. The natural fibers used in this investigation are kenaf fibers as known as Hibiscus cannabinus.

Kenaf is one of the most generally used natural fibers in the concrete mixture. Currently, there are many new usages of kenaf including building material, absorbents, animal feeds and paper product. Furthermore, kenaf have two components which are bast and core fibers. Advantages of natural fibers include increased toughness, enhanced cracking behaviour, enhanced durability and improved fatigue (Elsaid,2010).

A part from these, the implementation of additive the hybrid fibers, which are kenaf and steel in concrete mixture will enhance the delay in term of propagation of the concrete crack. The potential of hybrid fibers can enhance the increasing the strength of the concrete by using kenaf and steel added in reinforced beam structure can obtain the higher ultimate load compare to control beam. Moreover, gaining higher ultimate load is the main focus to improve the strength of the concrete with hybrid fibers. Indirectly will increase the flexural and compressive strength and reduce the deflection of the beam.

1.2 Problem Statement

Recycled and reused of construction materials are related to the concept of sustainable building that use the green building material in design and construction fields. (Roodman et al,1995) mentioned the activities of building and construction consume three billion tons of raw materials for one year or forty percent from the total use by people worldwide. It will be a matter for the development of building due to the reduction of material sources followed by years. A part form these, other alternative can be used to solve the problem involved by using the green material in the design of the building.

Green building material is a renewable material. The effect of using green material is it can reduce the environmental impact associated with the pollution and internationally promotes conservation of reducing non-renewable resources. Recycled concrete aggregate are waste material that have been crushed and then recycled to be used as green building material in the structure design. Most of concrete mixture that use recycled aggregate usually have low in strength compared to normal concrete mixture.

1.3 Objectives of Study

The objectives of these studies are:

1. To study the behaviour of 50 % of coarse aggregates replaced by recycled aggregates in reinforced beam added with hybrid fibers (kenaf and steel).
2. To study the effect of hybrid fibers (kenaf and steel) on reinforced recycled concrete aggregate beam.

1.4 Scope of Study

The study is conduct based on specific scope in order to ensure the specified scope of the study area. The characteristic of the recycled concrete beam produced are follow the specification based on Reinforced Concrete Design Manual Book, Euro code 2 (2nd Edition). The test on the specimens (beam) are conducted in structural laboratory in UMP, Gambang.

The properties of the beam:

1. Number of beams need to be constructed: 4
   i. Standard control beam (NRCB),
   ii. Beam with 50 % of recycled concrete aggregates replaced coarse aggregates added with 0 % volume of hybrid fibers (RAB0),
   iii. Beam with 50 % of recycled concrete aggregates replaced coarse aggregates added with 1 % volume of hybrid fibers (RAB1),
   iv. Beam with 50 % of recycled concrete aggregates replaced coarse aggregates added with 2 % volume of hybrid fibers (RAB2).

2. Dimension of each beam: 150 mm x 200 mm x 1500 mm
3. Nominal concrete cover: 25 mm

4. Total load pointed on specimen: 70 kN
5. Characteristic concrete strength: 25 N/mm^2
6. Reinforcement bar:
    i. Main bar : 460 N/mm^2 ; Tensile steel bar (T); Diameter = 12 mm ; 5 bars for each beams (compression = 2 bars, tension = 2 bars)
    ii. Link: 250 N/mm^2; Round steel bar (R); Diameter = 6 mm with spacing of 130mm
7. Cement: Ordinary Portland Cement (OPC)
8. Admixture: Superplasticizer (Sika ViscoCrete) = 5 Liter per m^3
9. Recycled concrete aggregate: Crushed waste normal concrete cube from structural lab
10. Fiber:
    i. Steel fiber: Hooked end steel; Length = 60 mm; Diameter = 0.75 mm
    ii. Kenaf bast fiber; Length = 30 mm; Diameter = 0.1 mm to 2 mm
11. Concrete cube: Dimension = 150 mm x 150 mm x 150 mm; 6 cubes for each concrete mixture
12. Percent of wastage: 10 %
13. Test to be carried out:
    i. Slump test = True slump in range of 95 mm to 105 mm
    ii. Cube test = 3 cubes will be tested for each mixture on 7^{th} and 28^{th} day
    iii. Bending test = 4-point bending test on each beam

1.5 Significance of Study

The expected outcome form these studies are:

1. Hybrid fibers reinforced recycled concrete aggregate mixture will be more strength in flexural strength.
2. The potential of hybrid fibers to enhance the delay cracking on reinforced recycled concrete aggregate beam.
3. The used of hybrid fibers and recycled concrete aggregate to promote as a green building materials.
4. Hybrid fibers can improve the strength of the reinforced recycled concrete aggregate beam.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Concrete is a common main construction material that are widely used in most of construction project around the world. However, there numerous number of construction around the globe that demand a large amount of natural materials in order to produce cement and aggregate. This had cause the depleting of natural sources and creates major environmental problems. Moreover, sustainable waste management is another major issue faced by many developing countries around the world. In order to minimize the environmental impact and consistency energy of concrete used for construction project, reuse of waste construction materials can benefit which leads to sustainable engineering approaches to concrete mix design. Many of developing countries around the world are recycling and reuse construction material as alternatives towards using green material building in order to minimize the impact of energy and raw material consumption on the environment. A possible solution to these problems is to recycle demolished concrete and produce an alternative aggregate for structural concrete in this way (Malešev M. et al.,2010). Recycled concrete aggregate is a waste construction material that had been crushed and then recycled due to its potential to be used for concrete production as green building material.

Recycled concrete aggregate have same properties like the natural aggregates but less in strength compared to natural coarse aggregates (Singh S.P et al, 2016). Over past few years, the researchers had been given attentions towards the utilization of waste materials. In order to increase the durability of the concrete mixture that contains with recycled concrete aggregates, additional of admixture and fiber can be used. Admixture helps in increasing the workability of concrete at constant water cement ratio. Use of fibers makes significant improvements in flexure, impact and fatigue strength of concrete (Subashini L.M et al.,2015).

Fibers are a part of thin elements come from synthetic and natural fibers. The fibers used in mixing concrete can be divided into two part which are natural fibers and synthetic or man-made fibers. The examples of synthetic fibers include carbon, polypropylene, asbestos, polyethylene, steel, Cotton, and acrylic (Ticoalu A. et al.,2010). Meanwhile, natural fibers are fibers from plant such as vegetable, woods, and bamboo. There will be more natural fibers come from agricultural waste may become a product such as coconut husk and kenaf fibers. From part of the plant where the fibers are sourced, the fibers can be classified into bast fibers (jute, flax, hemp, ramie and kenaf), leaf fibers (banana, sisal, agave and pineapple), seed fibers (coir, cotton and kapok), core fibers (kenaf, hemp and jute), grass and reed (wheat, corn and rice), and other types of fibers (Sanadi A.R. et al.,1995).

In this research, hybrid fibers which included steel and kenaf fiber will investigate. Fibers reinforced concrete can be considered as material relatively short continuous fibers are randomly distributed throughout the matrix in order to overcome the problems brought about by the low tensile strength and strain capacity of a plain concrete mix. Therefore, addition of fibers to concrete can be used to overcome the problem, as the fiber increase compressive and flexural strength of the concrete (Singh et al, 2016). Therefore, the feasibility of combination between synthetic fiber and natural fiber as one of the source of hybrid fibers would be investigated.

2.2 Recycled Concrete Aggregate

Sustainable construction indicates that designing a reinforced concrete structure with suitable durability during a particularized service life. Among the achievable solutions that have potential to sustain environmental-friendly construction materials in the industry, the use of recycled concrete aggregates to produces new concrete. Over the past few years, the researchers had been given attentions toward recycled concrete aggregate as the waste concrete material promotes green building material (Kazberuk M.K et al.,2014; Trckova, J et al.,2011). Recycled concrete aggregate (RCA) is a waste material that mainly obtained and then recycled from demolition of old building structure and waste concrete materials at construction site.

The recycling of the collecting waste materials supports in diminishing of natural resources, especially sand and gravel, and also large amount of waste management problems that occurs in worldwide. If the vision of a sustainable material flow is to be realized, the amount of recycled waste has to be increased. The building industry in particular is a major consumer of materials and, at the same time, a major producer of waste (Kazberuk M.K et al.,2014). One possibility is to recycle and reuse inorganic building waste as concrete aggregates (Chen et al., 2003). The use of waste materials from the demolition of concrete structures as recycled concrete aggregate replaced coarse aggregate in concrete has been widely applied and practiced in construction industry today.

Compared to natural aggregates, recycled concrete aggregates usually have greater in absorption of water due to greater porosity, poor in density and strength by relating to coarse aggregate (Malešev M. et al.,2010). Subsequently, structural members that used recycled concrete aggregate as building materials are regularly experience lesser physical and mechanical properties compared to normal concrete that contains coarse aggregate (Richardson et al.,2011; Kou S.C. et al.,2012). Thus, the effect will directly lead to low mechanical performance and underprivileged of durability behaviour of the structures.

2.3 Fibers Reinforced Concrete

According to the terminology adopted by American Concrete Institute (ACI) Committee 544, there are four categories of Fiber Reinforced Concrete which are Steel Fiber Reinforced Concrete, Glass Fiber Reinforced concrete, Synthetic Fiber Reinforced Concrete and Natural Fiber Reinforced Concrete. It also provides the information about various mechanical properties and design applications (Singh R. et al.,2016). Fibers Reinforced Concrete helps to reinforced the cement with steel and synthetic fibers and thus improve the properties of concrete. Fibers also enhance the properties of natural materials for example electrical wires which are made from fiber optic wires. The application of adding small and randomly distributed fibers to reinforced the concrete become more popular in construction fields nowadays. Observation will be made on the increasing of energy absorption capacity and toughness of the material. Other than that, the purpose of using the fiber is to increase the tensile and flexural strength of concrete (Ashik K.P et al.,2015). It is shows that the use of fibers need to be improved to transform the technology of fibers until it truly helps for all fields in industries, especially the construction industry.

Generally, the function of using the fiber reinforced concrete is to cater the weakness in tension which can alters the behaviour of the fiber-matrix composite after it has cracked and enhance to improve the toughness of the reinforced concrete. The addition of steel fibers aids in converting the brittle characteristics to a ductile one. The principal role of fibers is resisting the formation and growth of cracks by providing pinching forces at crack tips. In addition, a marginal improvement in tensile strength also results and fiber reinforced concrete has higher ultimate strain than plain concrete (Lim D.H et al.,1999). However, a large extent on the type and amount of fibers added will influence the extent of crack control. Recent studies performed on a high performance fiber reinforced concrete in a bridge deck found that adding fibers provided residual strength and controlled cracking (Mohsin S.S et al,2016). There are fewer and narrower cracks in the fiber reinforced concrete even though the fiber reinforced concrete had more shrinkage than the control (Subashini L.M et al.,2007). The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied, shock or impact loading. (Chanh V.N et al.,2005).

2.4 Natural Fibers Reinforced Concrete

Natural fibers reinforced concrete have raised positive interests in construction design and materials in recent years due to the need for development of environmental friendly materials. Presently, the global warming occurs world widely due to worst environmental pollution. In order to cater for solution to overcome the environmental problem, green building materials such as additional of natural fibers in concrete, need to be design by engineers. The use of natural fibers in construction materials will less harmful to our environment. The use of natural fibers is particularly beneficial to local usage and industries.

The fact that natural fibers are sourced from plants which are renewable in origin and the fact that they can be easily biodegraded has encouraged more research into this field. Examples of natural fibers that have been used in research and development of fiber composites system are hemp, jute, cotton, flax, coir, kenaf, pineapple leaf fiber, banana leaf fiber and several others (Ticoalu A. et al.,2010). Production of natural fibers with low cost investment and lower durability, makes the fiber treatments become an interesting material to improve by researchers. Most of previous study used many type of natural fibers in concrete shown in Figure 2.1 below, because the sources can be find easily by comparing with others fiber such as steel fiber and glass fiber.

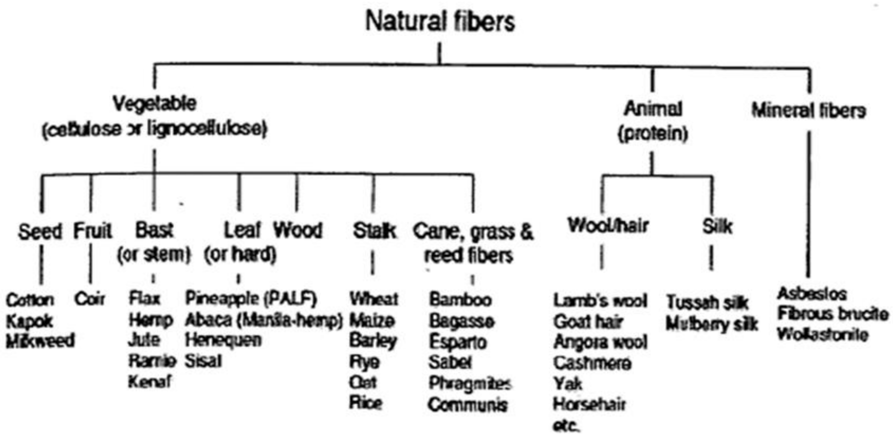

Figure 2.1 Type of *natural fiber*
Source: Elsaid et al (2010).

Furthermore, the cost of having this material, natural fibers are economical and this will make these materials are applicable for low-wage countries. Interest in Natural Fiber Concrete is growing for many reasons including their potential to replace synthetic fibre reinforced plastics at lower cost with improved sustainability (Pickering K. et al.,2016). The main properties of natural fibers are depending on factors such as the length of fibers used, the volume fraction and the type of fibers. Recent study of fiber reinforced concrete stated that the addition of fibers will not affect the compressive strength due to its density while tensile and flexural strength and toughness will increase (Lee B.H et al.,2009). The advantages and disadvantages of natural fibers are summarised in Table 2.1.

Table 2.1 Advantage and disadvantage of natural fiber concrete

- Advantages	- Disadvantages
- Low density and high specific strength and stiffness	- Lower durability than for synthetic fiber composites, but can be improved by treatment
- Fibers are a renewable resource, for which production requires little energy	- High moisture absorption, which results in swelling
- Fibers can be produced at lower cost than synthetic fiber	- Lower strength, in particular impact strength compared to synthetic fiber composites
- Low emission of toxic fumes when subjected to heat	- Lower processing temperatures limiting matrix options
- Low hazard manufacturing processes	- Greater variability of properties

Source: Cao Y. et al (2008).

2.5 Kenaf Fiber Reinforced Concrete

Kenaf fibers as one of natural fibers source will be more deeply to investigate in this research. Kenaf is a 4000 years old crop with roots in ancient Africa which has been recently introduced and successfully grown in many parts of the United States. Kenaf fibre comes from a plant named 'Kenaf' which is a plant in the Malvaceae family, is in the genus Hibiscus and is probably native to southern Asia although its exact natural origin is unknown (Hasan N.M.S et al.,2015). The kenaf plant can grow to heights of 3.5 – 4.5 m within 4 – 5 months with annual fiber yields of 6 to 10 tons of dry fiber/acre, which is approximately four times greater than that of southern pine trees (Zaveri M., 2004).

Local organic such as most of natural fibers represent an available resource for fiber reinforced materials are relatively high-cost, and make it difficult to provide solutions to industry needs especially in construction. Therefore, the feasibility of natural fibers as one of the source of fibers would be investigated. Kenaf denoted as industrial kenaf due to of its great interest for the production of industrial raw materials Kenaf is comparatively commercially available and economically cheap amongst other natural fibre reinforcing material (Saba N. et al.,2015). There are several factors contribute to the properties of kenaf fibers in mixing concrete which are fiber type, length, volume fraction, and density of the fibers as shown in Table 2.2 below.

Table 2.2 Properties of kenaf fibers in concrete

Fiber	Diameter (mm)	Ultimate stress (MPa)	Density (kg/m^3)	Specific stress	Water absorption (%) for 24hours
Kenaf	0.15 - 0.30	350 - 600	1500	0.22 - 0.44	0.95

Source: Bharath V. et al (2015).

Kenaf fiber is the most suitable natural fiber that are renewable and biodegradable resources. Use of kenaf fibers are increasing as significant natural material sources contributing towards the development of eco-friendly assets for the automotive, sports industries, food packaging and furniture industries (Anuar et al,2011). Based on previous research, the mixture proportion of kenaf fibers in concrete are one of the most important factors affecting the strength of fibers reinforced concrete. The suitable mixture proportions are established for kenaf fiber reinforced concrete with fiber contents of 1.2% and 2.4% (Elsaid et al.,2010). They also found that cracking behaviour of kenaf fiber enhances the durability of concrete at relatively low cost compared to other types of fibers. Because of its high stiffness, strength values and also has higher aspect ratios which made it suitable to be used as reinforcement (Sanadi et al.,1995). Kenaf fiber also suitable for producing lightweight structures due to its physical properties of light weight, competitive tensile strength, stiffness, and vibration damping properties.

It will more flexible possibly due to exposure to environmental conditions, decay, and damage caused by insects and other pets. Kenaf is a hardy, strong and tough plant with a fibrous stalk, resistant to insect damage and requires relatively fewer amount of or no pesticides (Saba N. et al.,2015). The study further shows the stress-strain curve of the kenaf fibers is approximately linear to failure regardless of the location from which the fibers are taken. The selection of using fibers in this research is because the previous study indicated that the evaluation of kenaf core as an absorbent material for cleaning oil spills. According to researchers, the kenaf bast fibers possess striking mechanical properties that make them as a replacement to glass fibers as reinforcing elements as they are taken from bast, core, and pith and make it suitable for various applications (Faruk O. et al., 2010; Paridah MT. et al.,2011; Karimi S. et al.,2014).

On the other hand, The Naval Facilities Engineering Service Centre mentioned that the core particles outperformed other natural absorbent materials by a significant margin (Technical Report,1999) as shown in Table 2.3.

Table 2.3 Characteristic of kenaf fiber

- Bast	- Core
- Tough fiber outer layer - 35% by weight - Long, strong fibers make a higher quality product - Better engineering qualities	- Soft inner layer (including pith) - 65% by weight - Most absorbent natural material on earth

Source: Technical Report (1999).

2.6 Conclusion

It is observed that a number studies has been conducted on recycled aggregate reinforced concrete and also natural fiber reinforced concrete, but still there is lack of findings of an experimental research on behaviour coarse aggregates replaced by recycled aggregates in reinforced beam added with kenaf and steel fiber (hybrid) has yet been explored. This study attempts at investigating the strength, ductility, mode of failure and cracking pattern of a new hybrid fibers in reinforced recycled aggregate concrete beam.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will elaborate more on the methodology used from beginning until the end of the research. This research mostly conducted at Structural Laboratory of Universiti Malaysia Pahang, Gambang campus accordance with British Standard (BS) or the American Society of Testing Material (ASTM), based on the suitability and availability of the equipment in the laboratory for the respective tests. The test is conducted toward recycled concrete aggregates that had been replaced coarse aggregates in reinforced recycled concrete aggregates beam based on concrete mix design. The concrete sample test that involved in this study are Slump test, Compression test and Flexural test. Figure 3.1 below shows the flowchart of activities that involved.

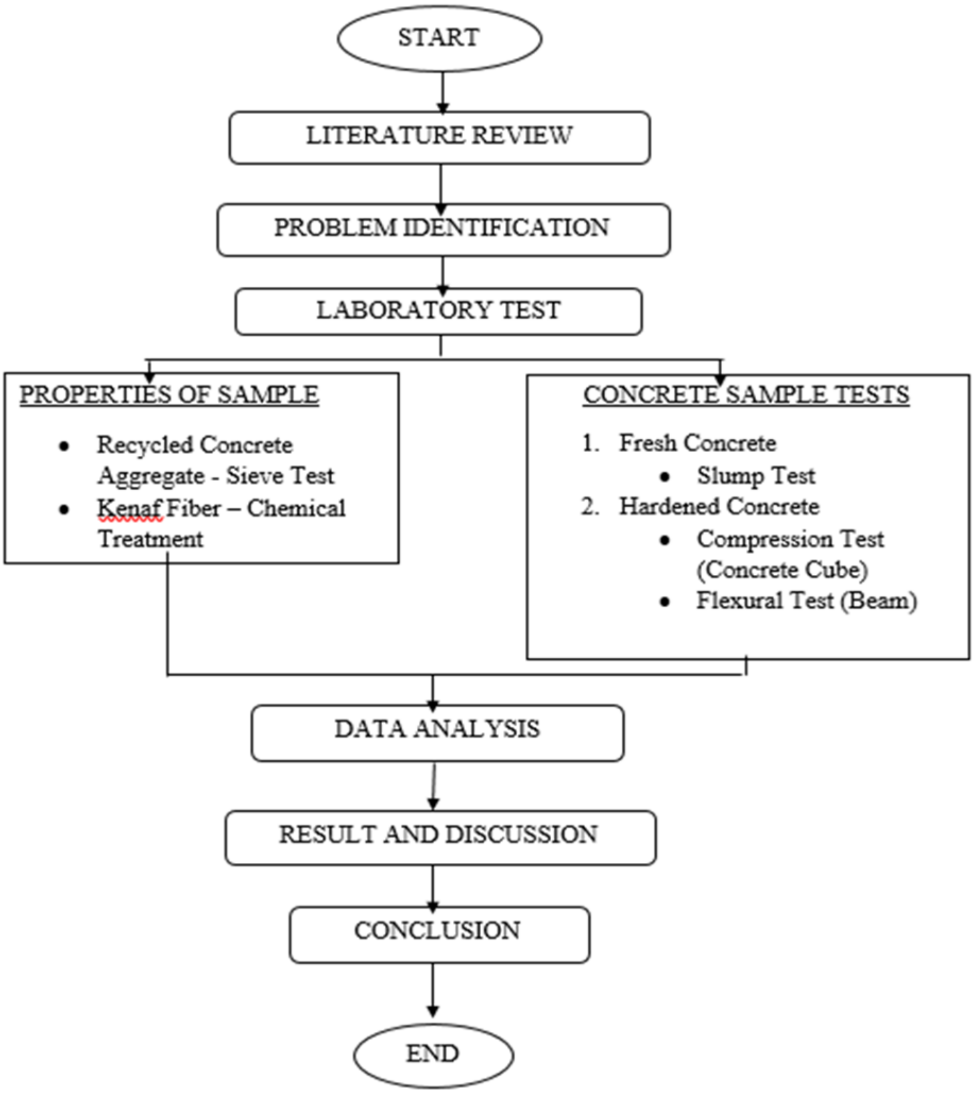

Figure 3.1 Flow chart of methodology

3.2 Preparation of Material

In this study, four numbers of reinforced beams are prepared with different type of concrete mixture which are standard control beam (NRCB), and another three beams with 50 % of recycled concrete aggregates replaced coarse aggregates added with hybrid fibers in volume of 0% (RAB0), 1% (RAB1) and 2% (RAB2). Twenty-four cubes are prepared to measure the compressive stress of the mixtures. The target of the compressive strength must be achieved is 30 MPa. Concrete mix design for all beams used in this study are shown below in Table 3.1.

Table 3.1 Concrete mix design

Materials	NRCB	RAB0	RAB1	RAB2
Cement (kg/m^3)	325	325	325	325
Aggregates (kg/m^3)	912	912	912	912
Sand (kg/m^3)	949	949	949	949
Water (kg/m^3)	195	195	195	195
W/C ratio	0.55	0.55	0.55	0.55
Superplasticizer (kg/m^3)	4.72×10^{-3}	4.72×10^{-3}	4.72×10^{-3}	4.72×10^{-3}
Kenaf fiber (kg/m^3)	0	0	3.37×10^{-4}	6.74×10^{-4}
Steel fiber (kg/m^3)	0	0	1.13×10^{-4}	2.26×10^{-4}

3.2.1 Recycled Concrete Aggregates

Recycled concrete aggregate is obtained from the waste concrete materials, which are the old specimens (normal concrete cubes) that had been used for concrete compressive strength tests. These specimens are found mainly outside the Structural Laboratory of Universiti Malaysia Pahang. Concrete cubes are collected and then it will be crushed. Usually, the crushing process can be done by using a concrete cube crusher machine, called Jaw Crusher. or crushing process can be done manually by using sledgehammer. The concrete cubes will be crushed into smaller chunks according to the desired aggregate size. This crushing process control activities to obtain the desired aggregate size. In the study, the aggregate size used for the purpose of concrete mixture is less than 20 mm and the crushing process will be done in both ways. The amount of recycled concrete aggregates needed is 50 percent from the total amount of coarse aggregates needed in concrete mix design. Recycled concrete aggregate have the same properties of natural aggregates but the strength is less and water absorption is more than natural aggregates. In order to increase the strength of the concrete made with partial replacement of natural aggregates with recycled aggregates, additional of admixture and fibers are completely necessary.

3.2.2 Steel and Kenaf Fibers (Hybrid)

Fibers are generally utilized in concrete to manage the plastic shrink cracking and drying shrink cracking. They also lessen the permeability of concrete and therefore reduce the flow of water. Some types of fibers create greater impact, abrasion and shatter resistance in the concrete. Usually fibers do not raise the flexural concrete strength. The quantity of fibers required for a concrete mix is normally determined as a percentage of the total volume of the composite materials. The fibers are bonded to the material in the concrete mixtures, and allow the fibers reinforced concrete to withstand considerable stresses during the post-cracking stage. The actual effort of the fibers is to increase the concrete toughness.

Hybrid fibers which are combination of steel fiber and kenaf fiber, will be added into three of reinforced recycled concrete aggregates beam in this study in order to cater the weakness of the concrete. The volume of hybrid fibers added to reinforced recycled concrete aggregate beam are 0%,1% and 2% respectively, which means half of volume of hybrid fibers are steel fiber and another half are kenaf fiber. The hooked end type steel fiber with a length of 60 mm and a diameter of 0.75 mm are added into the mixtures as shown in Figure 3.2a. The samples of kenaf included in the mixture are kenaf bast type with diameter that range between 0.1 mm to 2 mm, and being cut in range between 25 mm to 30 mm in length as shown in Figure 3.2b. The sample of kenaf are treated with chemical solution named Sodium Hydroxide (NaOH) for two days and then dried for 3 days.

Figure 3.2a Sample of *steel fiber*

Figure 3.2b Sample of *kenaf fiber*

3.2.3 Formwork

Steel beam mould with dimension of 150 mm x 200 mm x 1500 mm is used for casting sample of beams instead of plywood formwork. The mould's surface is covered with oil before concrete mixture is placed inside the mould. Meanwhile, the plastic mould with dimension of 150 mm x 150 mm x 150 mm are used for concrete cube. All of the equipment can be obtained from structural lab. Figure 3.3a and 3.3b show the beam mould and plastic cube mould that has been used in this study.

Figure 3.3a Beam mould

Figure 3.3b Plastic cube mould

3.2.4 Reinforcement Bars

The main bar that will be used is tensile steel bar (T) with 12 mm of diameter for main bar as shown in Figure 3.4a. All the steel bar will be cut according to require length using the cutter machine and then rebar will be bend manually without professional equipment, using a pair of steel pipe. The rebar will be tied with link, round steel bar-type (R) with diameter of 6 mm as shown in Figure 3.4b. The requirement for having the reinforcement bar in concrete beam is to improve the strength of the beam in term of flexural strength.

Figure 3.4a Main bar (T12)

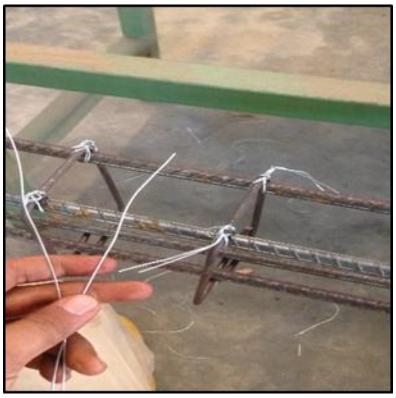

Figure 3.4b Link (R6)

3.2.5 Spacer Block

The size of spacer block is following to the design for the thickness of concrete cover which is 25mm. Spacer block is use to hold the reinforcement bar in the beams. Materials used to cast spacer block are ordinary Portland cement, fine aggregate and water. Figure 3.5 below shows the construction of spacer block.

Figure 3.5 Casting spacer block

3.3 Casting Beam

Concrete mixtures are poured into the formwork that have reinforcement bar placed inside. Vibrating poker are used to make the concrete mixtures compact and entirely occupied the formwork. In this study, four numbers of reinforced beams are prepared with different type of concrete mixture which are standard control beam (NRCB), and another three beams with 50 % of recycled concrete aggregates replaced coarse aggregates added with hybrid fibers in volume of 0% (RAB0), 1% (RAB1) and 2% (RAB2). The beams are designed as rectangular beam with dimension of 150 mm x 200 mm x 1500 mm. The main bar used is Tensile steel bar (12mm), which are two bars used for compression and others two for tension. Round steel bar (6mm) used as links with spacing of 130 mm. The detailing of beam can be seen in Figure 3.6a and 3.6b. After that, two amounts of hybrid fibers contents in volume (1% and 2%) are added to concrete mixture in order to examine the effect hybrid fibers in reinforced recycled concrete aggregate beams. The beam with normal concrete mixture, is considered as the control beam.

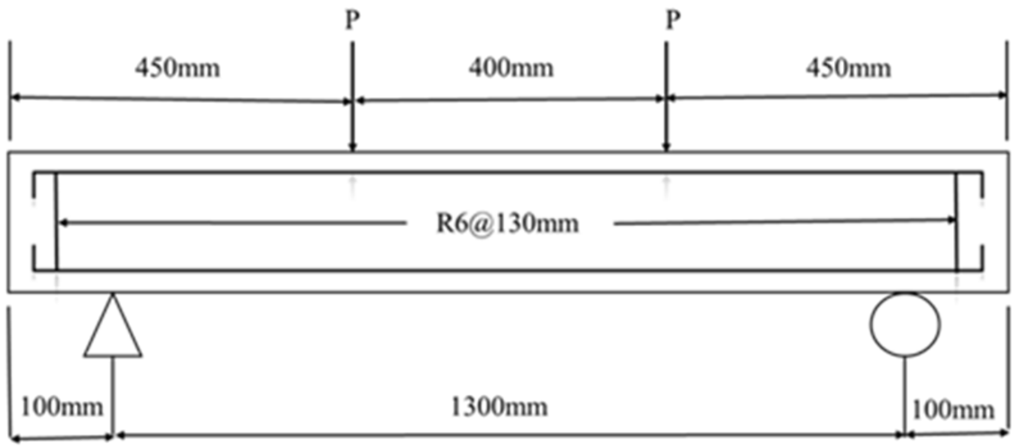

Figure 3.6a Load arrangement and dimension of beam

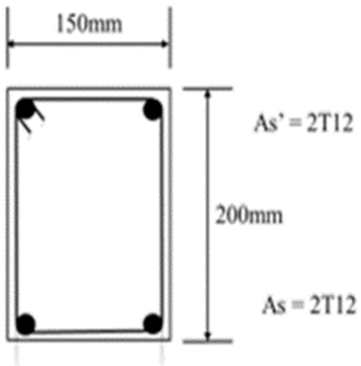

Figure 3.6b Cross-section of beam detailing

3.3.1 Curing

Wet gunny sack will be used to curing the beams and water curing will be used for concrete cube. All beams will be continuously cured until 28 days. Meanwhile, the cubes will be cured for 7 days and 28 days.

3.4 Laboratory Test

For this study, all test is carried out accordance with British Standard (BS) or the American Society of Testing Material (ASTM). The summary of the standard use and the laboratory tests are shown in Table 3.2.

Table 3.1 Summary of laboratory test

Materials	Test	Standard
- Recycled concrete aggregates	Sieve analysis test	BS 882: 1983
	Concrete mix design	DoE, HMSO, 1988
- Fresh concrete	Slump test	BS EN 12350: Part 2 (2009)
- Hardened concrete		
-Concrete cube	Compressive test	BS 1881: Part 1 16: 1983 ASTM C 39 – 03
- Beam	Flexural test	BS 1881: Part 1 18 ASTM C 78 - 02

3.4.1 Sieve Analysis Test

In general, this method is applicable only to clean granular material, which usually implies clean sandy or gravel soil. However, this test has been performed by using recycled concrete sample that had been crushed since it has similar physical properties with natural aggregate and sieved by mechanical sieve shaker. The sizes of sieve that had been used are 20 mm, 10 mm and 5 mm. It is to separate the coagulate materials to become finer particle and also to gain recycled concrete aggregate, sizes of 20 mm.

3.4.2 Concrete Mix Design

Concrete mix design is based on the principle of Department of the Environmental (DoE) method of mix design. This method links the various factor involved in the process of designing a mix. It will be seen that specified variables and additional information as initial information in the design. In order to clarify the sequence of operation, the process of mix design is divided into five stage, which are deals with strength leading to the free-water/cement ratio, workability leading to the free - water content, cement content, determination of total aggregates content and selection of fine and coarse aggregate contents. For recycled concrete aggregates, steel and kenaf fibers (hybrid) will be used, in percent, based on the volume of the concrete mixture.

3.4.3 Slump Test

Slump test is carried out to measures the consistency of plastic concrete. It is suitable for detecting changes in workability. This test is being used extensively on fresh concrete at site. The concrete mixture used in the concrete casting of all beams are ensured to achieve a slump in the range of 95 mm to 105 mm.

3.4.4 Compressive Test

The main purpose of the concrete compression test is to determine the compressive strength of hardened concrete specimen with reference to the standardized method. Normally, this test will be conducted immediately on the concrete specimens (concrete cube) after removal from curing tank. The size of the concrete cube used in this test is 150 mm x 150 mm x 150 mm. Three hardened concrete cubes shall be used in the measurement of concrete strength at age of 7th days, and 28th days. Concrete specimen is subjected to the compression load and the specimen is tested to its failure and maximum load achieved. The target of the compressive strength must be achieved is 30 MPa.

3.4.5 Flexural Test

This test is to determine the flexural strength of hardened concrete specimen by the use of the simple beam that had been design, size of 150 x 200 x 1500 mm. The beams are tested under four-point bending test. The test is carried out on the 28th day.

3.5 Conclusion

The objective of this chapter is to explain in detail about the methodology in this study. Every details about materials, equipment used and also test conducted are explained based on the flow chart of methodology. The result and discussion of the study will be presented in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The result of each samples after conducting test are discussed and analysed in this chapter. All of the result are examined in order to study about the reinforced recycled concrete aggregate beam compared to reinforced concrete beam. The result and analysis of all test will be discussed and presented in form of Table, graph and chart. There are four type of reinforced concrete beam which are standard control beam (NRCB), beam with 50 % of recycled concrete aggregates replaced coarse aggregates added with 0 % volume of hybrid fibers (RAB0), beam with 50 % of recycled concrete aggregates replaced coarse aggregates added with 1% volume of hybrid fibers (RAB1), and beam with 50 % of recycled concrete aggregates replaced coarse aggregates added with 2 % volume of hybrid fibers (RAB2). All of these beams are analysed and comparison are made based on result obtained.

4.2 Workability

The slump test is conducted for every concrete mix in this study as a workability test for each concrete mixture. The result of workability for each sample can be seen in Table 4.1.

Table 4.1 Result of slump test for each sample

Sample	Height of slump (mm)	Type of slump
NRCB	100	True
RAB0	84	True
RAB1	40	Shear
RAB2	40	Shear

The workability of the concrete can be determined based on the type of slump of each sample after slump test are conducted. The super plasticizer has been added into each mixture in order to improve the workability of the concrete. The amount of super plasticizer is based on 0.1% of weight of cement content. Based on the analysis of the result obtained in Table 4.1, type of slump for sample (NRCB) and sample (RAB0) are the same which are shear slump. This is similar to design mix approved. For the next sample which are sample (RAB1) and sample (RAB2), the result of the slump tests is true slump. This is because the mixture of concrete is dry due to the mixture contains kenaf fibers, natural fibers that have mechanical properties in absorbing water. Therefore, the workability of sample without hybrid fibers are higher compared to sample of with additional of hybrid fibers.

4.3 Compressive strength

The cube test is made for every concrete cube from each sample of concrete mixture. Each sample contains six samples of concrete cubes, which are three samples of cubes will be tested at the age of 7th days and another three samples of cubes will be tested at the age of 28th days. This test is to determine the compressive strength of standard control concrete, concrete that contains recycled aggregate and also concrete that contains recycled aggregate added with hybrid fibers which are steel fibers and kenaf fibers. The target of the compressive strength must be achieved is 30 MPa. The result of compressive strength for all sample is shown in Table 4.2 and Figure 4.1.

Table 4.2 Compressive strength of all sample

Compressive Strength (N/mm^2)								
	NRCB		**RAB0**		**RAB1**		**RAB2**	
No. of cubes	**7 days**	**28 days**	**7 days**	**28 days**	**7 days**	**28 days**	**7 days**	**28 days**
1	53.76	61.15	41.42	46.38	32.50	38.63	34.25	38.12
2	48.13	62.47	32.23	45.64	36.30	37.55	34.08	40.94
3	52.11	50.41	40.49	45.78	34.11	37.69	34.09	30.42
Mean	**51.33**	**58.01**	**38.05**	**45.93**	**34.30**	**37.54**	**34.14**	**36.49**

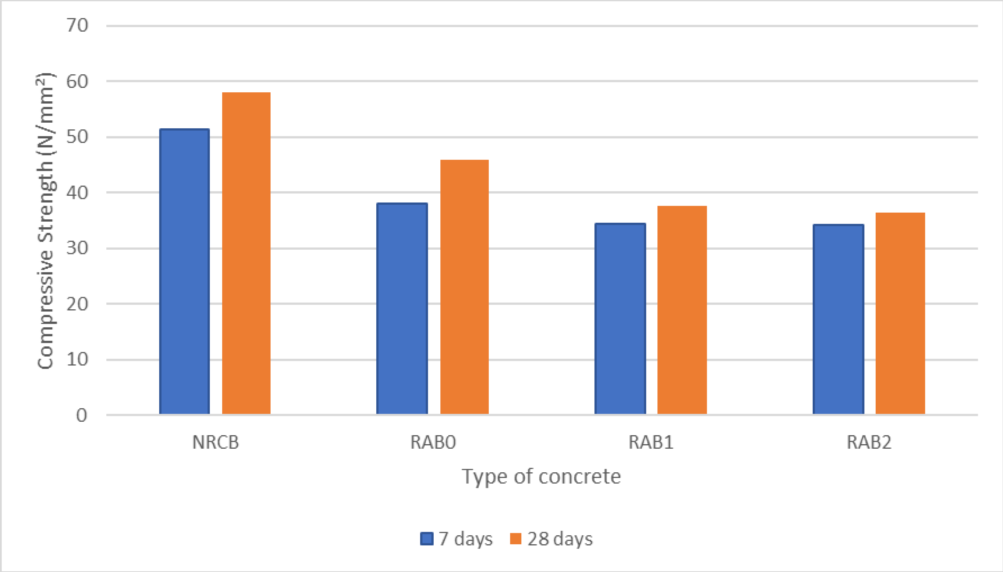

Figure 4.1 Compressive strength for all sample

Table 4.2 and Figure 4.1 above presented the result with different type of concrete mixtures after being cured for 7 days and 28 days. The compressive strength result shows that all concrete samples are achieve the desired strength of 30 MPa. By comparing the result, sample of concrete that contains recycled concrete aggregate have lower compressive strength in 7^{th} and 28^{th} days compared to standard control concrete sample. The low strength performance is due to the high amount of recycled concrete aggregate used in concrete mixture. The concrete become brittle due to recycled concrete aggregate absorb more water compared to natural coarse aggregate. This may affect the binding between cement and recycled concrete aggregate become weaker.

4.4 Load Deflection Curves

Figure 4.2 below illustrates that the result of load displacement for all beams after flexural test had been done. The parameters are identified and summarized in Table 4.3, namely: the load at which the longitudinal reinforcement yields in tension (P_y) and its corresponding deflection (δ_y), the maximum load (P_{max}) representing the load-carrying capacity and related deflection (δ_{max}), the ultimate load (P_u) 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) and the ductility ratio (μ) defined as $\mu = \delta_u / \delta_y$.

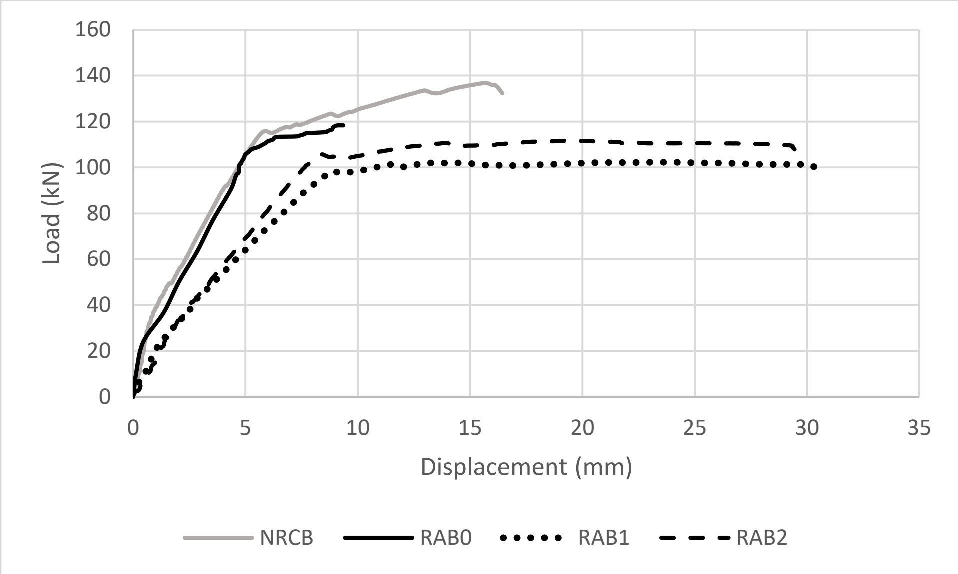

Figure 4.2 Load – deflection curves for beams

Table 4.3 Summary of the significant values in the load-deflection curves for beams

Sample	NRCB	RAB0	RAB1	RAB2
P_y (kN)	115.470	105.661	98.331	103.648
δ_y (mm)	5.784	4.996	9.935	8.045
P_{max} (kN)	136.780	118.275	102.288	111.674
δ_{max} (mm)	15.716	9.167	23.880	19.646
P_u (kN)	132.220	79.918	100.288	106.467
δ_u (mm)	16.437	11.987	30.505	29.493
$\mu = \delta_u / \delta_y$	2.842	2.399	3.070	3.666

Previous research on kenaf fiber reinforced concrete beams indicates that the strength of the beams increased consistently with the increase of the fiber content (Mohsin S.S. et al,2014). However, in the present study, sample of concrete with fibers has lower strength compared to sample of NRCB. This may due to sample with fibers contain materials that absorb much water which are recycled concrete aggregate and kenaf fiber. This may lead the beams to become honeycomb beams which have low strength and stiffness in load carrying capacity.

On the other hand, it can be seen that the deflection of the beams with hybrid fibers (RAB1 and RAB2) are higher compared with beam without fiber (RAB0) and control beam (NRCB). The ductility of beam with fibers increases with the increase of fiber content by comparing to beams without fibers. This may due to additional of fibers have potential in improving the ductility of the concrete.

4.5 Strength Ratio

Figure 4.3 below indicate the strength ratio for all beams. There is downward trend in the both ratios for beams without fibers (NRCB and RAB0) to beam (RAB1) before upward at beam (RAB2) as observed from the figure. This may due to the samples that containing recycled concrete aggregate (RAB0, RAB1 and RAB2), are liable to break compared to sample of NRCB that contains natural coarse aggregate. Additional of fibers into the sample (RAB1 and RAB2) are not helps in achieving higher maximum load capacity.

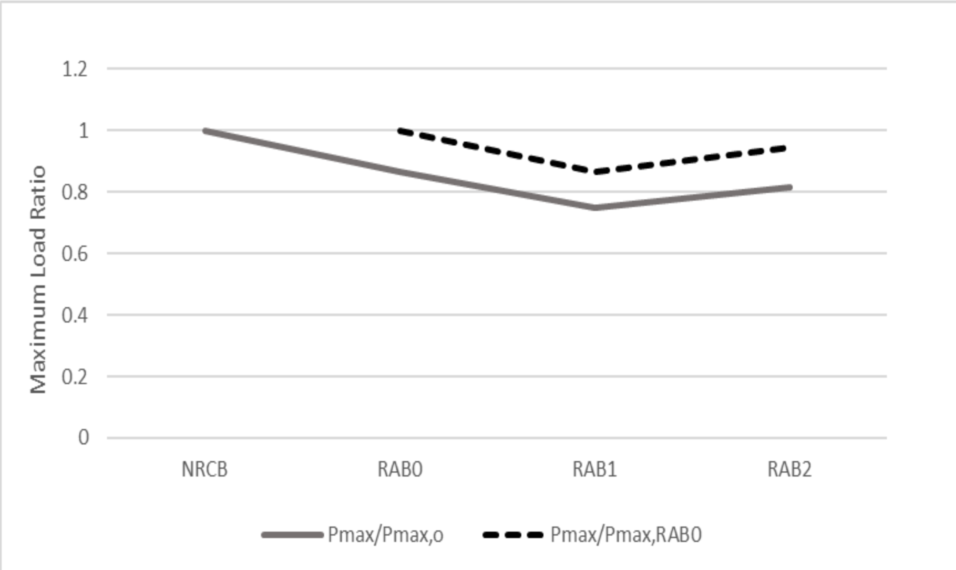

Figure 4.3 Graph maximum load ratio versus sample of beams

4.6 Ductility Ratio

The ductility ratios of all beams are normalised by dividing them by the ductility ratio of the standard control beam (NRCB) and also ductility ratio of the the recycled concrete aggregate beam without fibers (RAB0). The results are plotted against the type of concrete beams as depicted in Figure 4.4. There is an improvement observed in the ductility with the inclusion of hybrid fibers increased for both ratios when compared to control beam. Meanwhile, beam without hybrid fibers (RAB0) shows lowest performance in term of ductility than the beams with hybrid fibers. Therefore, additional of fibers into mixture helps in improve the ductility of the beams as the fibers act as shear reinforcement in the beams.

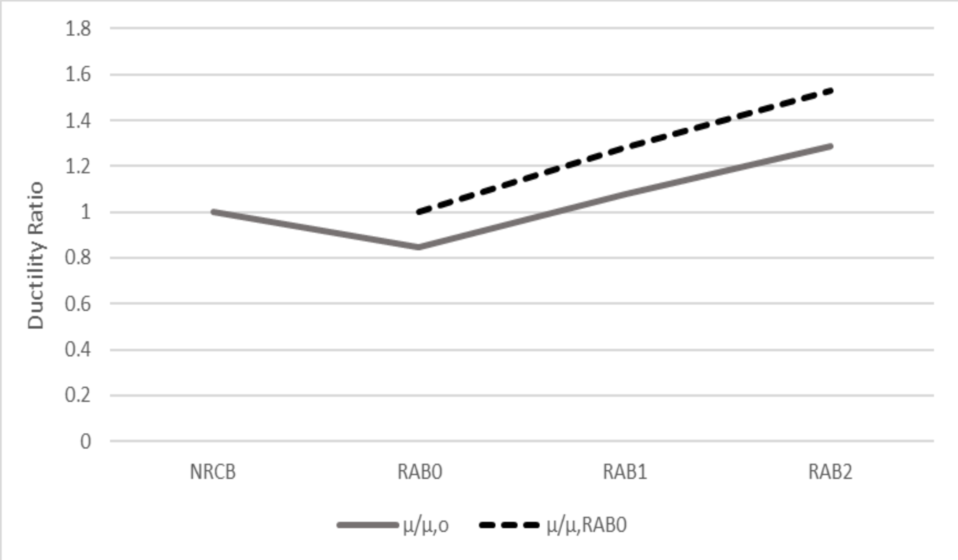

Figure 4.4 Graph ductility ratio versus sample of beams

4.7 Cracking Behaviour

There some technical problem occurs during data collecting on sample. The collected data has been lost and cannot be retrieved. Therefore, the discussion will be made for beams with fibers only. Based on the result obtained in Table 4.4, as the volume of hybrid fibers increase, the load on first crack also increased. Therefore, additional of hybrid fibers enhance to control cracking on the beams. This is due to fibers act in the beam as shear reinforcement that helps in delay cracking on the beams.

Table 4.4 Mode of failure for beams

Sample	Load on 1st crack (kN)	Mode of failure
NRCB	N.A	Bending – shear failure
RAB0	N.A	Bending – shear failure
RAB1	33.458	Bending failure
RAB2	47.171	Bending failure

Cracking patterns can be observed after sample of beams failed on flexural test. Cracking patterns can be analyse by sketching and numbering the patterns of crack when the load is applied on the sample of beams. Usually, the crack will start to appear from the bottom of the beam during loading. The crack will increase as the load increases. Figure 4.5a to 4.5d, present the cracking pattern for all samples in the study.

Figure 4.5a Sample NRCB

Figure 4.5b Sample RAB0

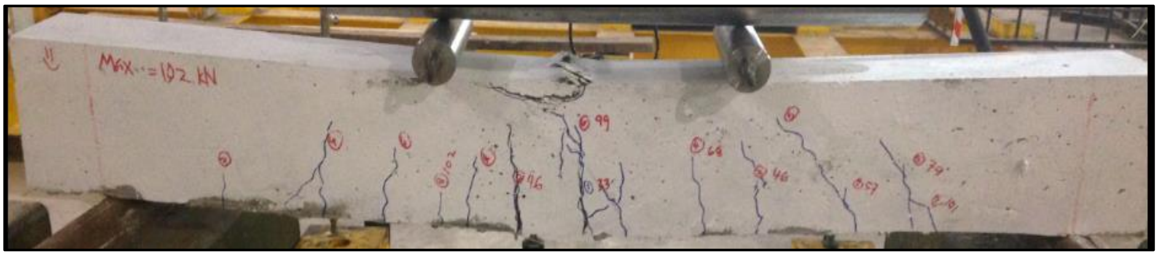

Figure 4.5c Sample RAB1

Figure 4.5d Sample RAB2

During testing, it is observed that beams without fibers failed in bending – shear mode (NRCB and RAB0) as shown in Table 4.4. Moreover, as the hybrid fibers are added to the beams, the failure mode of the beams changes to bending (Beam RAB1 and RAB2). Therefore, additional of hybrid fibers to recycled concrete aggregate beams help in increasing shear strength on beam. The beams without fibers (NRCB and RAB0) have larger crack width compared to beams with fibers (RAB1 and RAB2) as shown in Figure

4.5a to 4.5d above. Therefore, additional of fibers to beams have potential in minimize the crack width on beams.

CHAPTER 5

CONCLUSION

5.1 Introduction

A four-point bending test has been conducted in order to study the behaviour of hybrid fibers in reinforced recycled concrete aggregate beam compared to reinforced concrete beam in term of flexural strength. The compressive test is made for every concrete cube from each sample of concrete mixture. Each sample contains six samples of concrete cubes, which are three samples of cubes will be tested at the age of 7 days and another three samples of cubes will be tested at the age of 28 days. This test is to determine the compressive strength of standard control concrete, concrete that contains recycled aggregate and also concrete that contains recycled aggregate added with hybrid fibers.

5.2 Conclusion

Recycled concrete aggregates beams have lower strength compared to beams contains natural coarse aggregate. There is some potential for improvement in ductility and shear strength for beams contains recycled aggregate by adding hybrid fibers. It can be observed that fibers help control the cracking and minimize crack width opening especially in the section between the intermediate support and the section where the lateral load (P) is applied.

5.3 Recommendation

There are several recommendations can be made in order to improve this study in the future.

1. Use higher amount of steel fiber than kenaf fiber as hybrid fibers.
2. Use excess amount of water to avoid honey comb on the concrete beam.
3. Use vibrator poker during compaction of concrete.

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APPENDIX A
SAMPLE APPENDIX 1

COMPRESSIVE STRENGTH CALCULATION

Size of the cube =150 mm x150 mm x150 mm

Area of the specimen = 3375000 mm^2

Maximum load applied on cube = ……………. N

Compressive strength = (Load in N/ Area in $mm^{2)}$ =……………N/mm^2

Characteristic compressive strength at 7 days is calculated from the mean of the compressive strength = $\frac{sample\ 1+sample\ 2+sample\ 3}{3}$

Similar calculation should be done for 28-day compressive strength

APPENDIX B
SAMPLE APPENDIX 2

CONCRETE MIX DESIGN FORM

Item	Reference or calculation	Values
1.1 Characteristic Strength	Specified	30 N/mm^2 at 28 days Proportion defective 5 percent
1.2 Standard Deviation	Fig 3	5.0 N/mm^2
1.3 Margin	C1	(k=1.64) 1.64 x 5 = 8.2 N/mm^2
1.4 Target Mean Strength	C2	30+8.2 = 38.2 N/mm^2
1.5 Cement Type	Specified	OPC
1.6 Aggregate Type: Coarse		Uncrushed
Aggregate Type : Fine		Uncrushed
1.7 Free-Water/Cement Ratio	Table 2, Fig 4	0.55
1.8 Maximum Free-Water/Cement Ratio	Specified	0.6
2.1 Slump or V-B	Specified	Slump 100mm
2.2 Maximum Aggregate Size	Specified	20mm
2.3 Free-Water Content	Table 3	195 kg/m^3
3.1 Cement Content	C3	195/0.55 = 325 kg/m^3
3.2 Maximum Cement Content	Specified	
3.3 Minimum Cement Content	Specified	325 kg/m^3
3.4 Modified Free-Water/Cement Ratio		
4.1 Relative Density Of Aggregate (SSD)		2.6 known/assumed
4.2 Concrete Density	Fig 5	2380 kg/m^3
4.3 Total Aggregate Content	C4	2380 – 325 – 195 = 1860 kg/m^3
5.1 Grading of Fine Aggregate	BS 882	
5.2 Proportion of Fine Aggregate	Fig 6	51%
5.3 Fine Aggregate Content	C5	0.51 x 1860 = 949 kg/m^3
5.4 Coarse Aggregate Content	C5	1860 – 949 = 912 kg/m^3

Quantities

Per m^3 (to nearest 5kg)

Cement = 325 kg/m^3

Water = 195 kg/m^3

Fine aggregate = 949 kg/m^3

Coarse aggregate = 912 kg/m^3

Per trial mix of $0.048m^3$

Cement = 15.60 kg

Water = 9.36 kg

Fine aggregate = 45.53 kg

Coarse aggregate = 43.74 kg

APPENDIX C
SAMPLE APPENDIX 3

CONCRETE LABORATORY
FACULTY OF CIVIL & ENVIRONMENTAL ENGINEERING
(BS1881:PART116:1983)

<u>CONCRETE CUBE COMPRESSIVE STRENGTH TEST</u>

Grade: NRCB (7 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength (N/mm^2)
1	7.928	7	150	1210	22500	53.76
2	7.965	7	150	1083	22500	48.13
3	7.837	7	150	1172	22500	52.11

Grade: NRCB (28 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength (N/mm^2)
1	7.914	28	150	1376	22500	61.15
2	7.914	28	150	1406	22500	62.47
3	7.977	28	150	1134	22500	50.41

APPENDIX D
SAMPLE APPENDIX 4

CONCRETE LABORATORY
FACULTY OF CIVIL & ENVIRONMENTAL ENGINEERING
(BS1881:PART116:1983)

<u>CONCRETE CUBE COMPRESSIVE STRENGTH TEST</u>

Grade: RAB0 (7 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength (N/mm^2)
1	7.942	7	150	925.3	22500	41.12
2	7.933	7	150	725.2	22500	32.23
3	7.916	7	150	911.1	22500	40.49

Grade: RAB0 (28 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength (N/mm^2)
1	7.924	28	150	1043.2	22500	46.38
2	7.904	28	150	1026.4	22500	45.64
3	7.917	28	150	1029.6	22500	45.78

APPENDIX E
SAMPLE APPENDIX 5

CONCRETE LABORATORY
FACULTY OF CIVIL & ENVIRONMENTAL ENGINEERING
(BS1881:PART116:1983)

CONCRETE CUBE COMPRESSIVE STRENGTH TEST

Grade: RAB1 (7 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength $(\mathrm{N/mm}^2)$
1	7.597	7	150	731.1	22500	32.50
2	7.532	7	150	816.7	22500	36.30
3	7.489	7	150	767.5	22500	34.11

Grade: RAB1 (28 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength $(\mathrm{N/mm}^2)$
1	7.697	28	150	868.8	22500	38.63
2	7.432	28	150	844.5	22500	37.55
3	7.587	28	150	847.6	22500	37.69

APPENDIX F
SAMPLE APPENDIX 6

CONCRETE LABORATORY
FACULTY OF CIVIL & ENVIRONMENTAL ENGINEERING
(BS1881:PART116:1983)

<u>CONCRETE CUBE COMPRESSIVE STRENGTH TEST</u>

Grade: RAB2 (7 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength (N/mm^2)
1	7.970	7	150	770.7	22500	34.25
2	8.152	7	150	766.8	22500	34.08
3	8.126	7	150	856.9	22500	38.09

Grade: RAB2 (28 days)

Sample Mark	Weight (kg)	Sample age (days)	Sample width (mm)	Load (kN)	Length x Width (mm^2)	Compressive strength (N/mm^2)
1	7.970	28	150	857.3	22500	38.12
2	7.942	28	150	920.7	22500	40.94
3	7.924	28	150	684.1	22500	30.42