BEHAVIOUR OF REINFORCED RECYCLED CONCRETE AGGREGATE BEAM WITH ADDITION OF STEEL FIBER AND KENAF FIBER (HYBRID)

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ABSTRAK

Penggunaan agregat konkrit kitar semula (RCA) di dalam campuran konkrit sebagai pengganti untuk separuh agregat kasar semula jadi sudah semakin meningkat dalam industri pembinaan. Keuntungan konkrit kitar semula penting kerana ia melindungi sumber semula jadi. Walau bagaimanapun, secara amnya jumlah konkrit yang mengandungi konkrit kitar semula di dalam konkrit. Ini cenderung untuk meningkatkan sifat-sifat pengeringan pengecutan konkrit baru dan ia akan membawa kepada masalah dengan campuran tidak boleh dilaksanakan dan kekuatan. Idea untuk menambah serat untuk campuran konkrit yang mengandungi agregat dikitar semula boleh berubah sifat bahan konkrit dan ia akan memperbaiki tingkah laku. Kajian ini bertujuan untuk menyiasat kekuatan rasuk konkrit bertetulang dengan menggantikan 25% daripada agregat semula jadi dengan agregat kitar semula dan mengkaji kelakuan struktur gentian keluli dan serat kenaf (hibrid), apabila ditambah ke dalam kitar semula bertetulang rasuk konkrit. Dalam kajian ini, empat nombor rasuk dibina, yang biasa rasuk kawalan dan rasuk yang lain dengan 25% daripada agregat konkrit kitar semula ditambah dengan (0%, 1% dan 2%) daripada gentian keluli dan serat kenaf (hibrid). Dengan menambah gentian keluli dan serat kenaf (hibrid) ke dalam rasuk konkrit kitar semula harus meningkatkan kekuatan konkrit, mengawal retak konkrit dan bon lemah konkrit.

ABSTRACT

The use of recycled concrete aggregate (RCA) in concrete mixture as partial replacements of natural coarse aggregate is growing interest in the construction industry. Concrete recycling gains importance because it protects natural resources. However, generally contains amount of recycle concrete aggregates in concrete. This tends to increase the drying shrinkage properties of the new concrete and it will leading to problems with unworkable mix and strength. The idea to add fibers to a concrete mixture containing recycled aggregate may change material properties concrete and it will improve behaviour. This study aim to investigate the strength of reinforced concrete beam by replacing 25% of natural aggregate with the recycle aggregate and To study the structural behaviour of steel fiber and kenaf fiber (hybrid), when added it into the recycle reinforced concrete beam. In this study, four numbers of beam constructed, which is normal control beam and another beam with 25 % of recycle concrete aggregates added with (0%,1% and 2%) of steel fiber and kenaf fiber (hybrid). By adding steel fiber and kenaf fiber (hybrid) into the recycled concrete beam should be enhance the concrete strength, control concrete cracks and weak bonds of concrete.

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LIST OF ABBREVIATIONS

RCA	Recycled concrete aggregates
RRCB	Recycled reinforced concrete beam
BS	British Standard
ASTM	American Society of Testing Material
SSD	Saturated surface dry
KFRC	Kenaf fiber reinforced concrete
SRFC	Steel fiber reinforced concrete

CHAPTER 1

INTRODUCTION

1.1 Background of study

Recycle concrete aggregates is a part of environmental considerations that become a common feature in construction industry. Concrete recycling gains importance because it to protect natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete or other application. There are a variety of benefits in recycling concrete rather than dumping it or burying it in a landfill. Aggregate is one of the most vitally important materials in use for concrete production as it profoundly influences concrete properties and performance**.** According to Khaldoun Rahal (2005) the environmental impact of the production of the raw ingredients of concrete such as cement and coarse and fine aggregates is considerable. The scale of the problem makes it prudent to investigate other sources of raw materials in order to reduce the consumption of energy and available natural resources, and to achieve a more green concrete.

The recycled concrete aggregates can be defined as crushed concrete composed fragment coated with cement mortar from demolition of the old structures or waste cube test that has been processed to produce aggregates suitable for use in new concrete. The processing, as with many natural aggregates, generally involves crushing, grading and washing. The fine aggregate, however, generally contains a considerable amount of old cement paste and mortar. This tends to increase the drying shrinkage and creep properties of the new concrete, as well as leading to problems with unworkable mix and strength.

The ratio of the flexural strengths to the compressive strength is in the range of 16-23% and 9-13%, respectively (Katz, 2003). These value are about 10-15% lower compared to the normal concrete. A study by Rao, shows a reduction in strength of 15-20% to reference concrete at 100% replacement (Rao, 2005). In order to improve the strength of concrete the idea to add fibres to a concrete mixture with recycled aggregate may change material properties of such concrete, improve behaviour and bring about new types of applications. Fibre reinforced concrete with recycled aggregate can be considered as optimal structural concrete for various applications. The approach to design of fibre reinforced concrete with recycled aggregate is defined by this method, or the philosophy, of the design, which is reflected in the composition of fresh concrete, in the case of fibre reinforced concrete this process is its complete opposite. The composition is given in advance and subsequently its properties are proofed and its applicability in building industry.

Natural fibers are prospective reinforcing materials in concrete and their use has been more traditional than technical. The advantages of kenaf fiber reinforced concrete (KFRC) included increasing toughness, enhancing cracking behaviour, enhanced durability and improving fatigue and impact resistance have been well presented in the previous research. Steel, polypropylene and synthetic fibres are the main materials used to control concrete cracks and weak bonds of concrete. As the needed for these materials is becoming higher and their cost is also rapidly increasing. Therefore, there is a need to explore alternative materials to ensure that the price of fibre is within an affordable limit for both small and large scale construction purposes.

1.2 Problem statement

The waste cube concrete which have been tested will be collected from the laboratory storeroom to been thrown out. This will make the laboratory store full of waste cube concrete. The waste cube concrete from concrete laboratory can be used as a recycle concrete aggregate. But, the effect of using recycle aggregates concrete in production of concrete mixture is the quality of recycle aggregate is usually lower than that of natural aggregate due to remaining mortar particle, surface crack, and higher water absorption of recycle concrete aggregate. This will cause negative effects on mechanical properties, air content, workability and durability of fresh concrete. Therefore, addition of fibers to the recycled aggregate concrete will overcome the problems, as the fiber increase compressive, tensile and flexural strength of the concrete (Abdulhadi, M, 2016).

1.3 Objective

This study aims to determine the behaviour of reinforced concrete beam made from combination of steel fiber and kenaf fiber with recycled concrete aggregates. Thus the objectives of this study as follow:

1. To investigate the strength of reinforced concrete beam by replacing natural coarse aggregate with the recycled concrete aggregate.

2. To compare the behaviour of reinforced concrete made up of natural coarse aggregates and recycled concrete aggregates.

3. To study the structural behaviour of steel fiber and kenaf fiber (hybrid fiber), when added it into the reinforced recycled concrete aggregates beam.

1.4 Scope of study

The scope of study involves the process in order to obtain the characteristic of the recycled reinforced concrete beam (RRCB). This reinforced concrete is produced by following the specification based on Reinforced Concrete Design Manual Book, Eurocode 2(2nd Edition). The test on reinforced recycled concrete aggregates structure (beam) are conducted in structural laboratory in UMP, Gambang.

The properties of the beam structure:

1. 4 number of beams constructed:
    1. Standard control beam,
    2. Control beam with 25 % of recycle concrete aggregates
    3. Recycled concrete aggregates beam with hybrid fibres – 1% of steel fiber and kenaf fibre (hybrid fiber)
    4. Recycled concrete aggregates beam with hybrid fibres – 2% of steel fiber and kenaf fiber (hybrid fiber)
2. Beam dimension: 150 mm x 200 mm x 1500 mm
3. Nominal concrete cover: 25 mm
4. Characteristic concrete strength: 25 N/mm^2
5. Characteristic steel strength: 500 N/mm^2
6. Number of steel bar: 4
7. Diameter of steel bar: 12 mm
8. Diameter of link: 6 mm
9. Dimension of cube: 150 mm x 150 mm
10. Test to be carried out: Slump test, Compressive Strength test and Flexural Strength test

1.5 Significance of study

The aim of study to determine the strength of reinforced recycled concrete beam added with steel fiber and kenaf fiber (hybrid fiber). There a several tests are need to be carry out on the recycled reinforced concrete beam to know either the structural behaviour of the beam had improved or not. Based on the result, we can determine the structural behaviour of steel fiber and kenaf fiber (hybrid fiber), when added it into the reinforced recycled concrete aggregates beam. In addition, the study also is conducted to find the alternative methods to minimize the consumption of natural aggregates used in concrete by replacing natural coarse aggregates.

Other than that, the concrete with recycle concrete aggregates showed lower compressive strength than those for normal concrete of similar composition. A maximum drop of 24% was noted for the medium grade recycle aggregates concrete made with recycled concrete aggregate from the lower grade normal concrete. Therefore, the steel fibre and kenaf fibre will be added into recycle concrete to overcome this problem.

This study hopefully would improve the structural behaviour of steel fibre and kenaf fibre (hybrid), when added it into the recycle reinforced concrete beam. Besides that, the use of recycled concrete aggregates into the mixture concrete provides a promising solution to the problem of concrete waste. Recycled concrete aggregate can be used for making normal structural concrete with the addition of hybrid fibre.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Concrete is a mixture of cement, sand, coarse aggregates, water and chemical admixture. The normal concrete is it has a good insulation which is good insulator of noise, heat and does not allow them to transmit completely, but less chances of buckling and electrical conductivity. However, previous studies shows that recycled concrete aggregate may seem a second-best material because its use is being driven not by concrete performance requirements but rather by the requirement to create a more sustainable concrete.

Fibers for reinforced concrete have been used since the technology has improved significantly, in addition to the fibers can be applied to other fields. In the early age, mortar and straw have been used to produce bricks of mud for their reinforcement. As an advanced fibre technology, cement has been reinforced by many type of fibres in the early twentieth century. Fiber reinforced concrete is concrete that uses other materials mixed in the cement to reinforce the concrete structure. These fibres can make the concrete stronger and more resistant to extreme temperature. It also improve the concrete's water resistance. There are four types of fibre-reinforced concrete which is steel fibre, glass fibre, synthetic fibre and natural fibre reinforced concrete.

Fibres are usually used in concrete to control shrinkage cracking. It also lower the permeability of concrete and thus reduce bleeding of water. Some of fibres create greater impact, abrasion and shatter resistance in concrete. Normally fibres does not increase the flexural strength of concrete, thus fiber cannot replace fully structural steel reinforcement. Some fibres reduce the concrete strength. Fiber reinforced concrete is less expensive than hand-tied rebar, while it can increase the tensile strength. Length, dimension and shape of fiber is main important factor for producing great fiber reinforced concrete. A thin and short fiber for example short hair-shaped glass fiber, will only be effective the first few hours after mix with the concrete but will not increase the concrete tensile strength.

Table 2.1 Different types of fibres used for fibre reinforced concrete

Fiber Reinforced Concrete	Material
Synthetic	Polyprolene and Nylon
Glass	Fibre glass
Natural	Plant and hay or hair
Steel	Thin steel wire

2.2 Recycled Aggregates Concrete (RCA)

Nowadays recycled concrete aggregates become most important part of environmental that has become a normal feature in the construction industry. The structures made of concrete are demolished, concrete recycling is an increasingly common method of utilizing the rubble. Recycling of waste concrete is done to reuse the concrete rubble as aggregates in concrete (T. U. Ganiron Jr, 2014). Common recycle waste material come from construction, renovation, or demolition of structure, including buildings, roads, and bridges. Type waste material such as crush concrete, wood, rock, sand, and steel. This waste material gained attention as concerns about its environmental effect.

Normally demolished concrete were shipped to landfills for disposal, but it's give environmental negative effect, so the concrete need to be recycled. Therefore recycling activities very important to achieve environmental sustainability. Crushing and screening systems start with primary jaws, cones and/or large impactors taking rubble from 30 inches to 4 feet (T. U. Ganiron Jr, 2014). Producing a high quality aggregate, processed in steps with time and effort involved in crushing, pre-sizing, sorting, screening and contaminant elimination.

2.2.1 Aggregate grading

The grading of recycled concrete aggregate normally satisfies the standards for natural aggregate, while in the case of recycled fine aggregate, composition corrections are often necessary, because, according to many practical experiences, it was found that there was often a certain amount of grains larger than what is required by standards for natural aggregate(S. Marinković, 2009) It has been shown that the presence of recycled fine aggregate has a negative impact on the physical-mechanical properties of concrete, therefore, even though through a careful mix design and application of appropriate production technology these effects can be reduced to an acceptable level, in practical application, a fine fraction of recycled

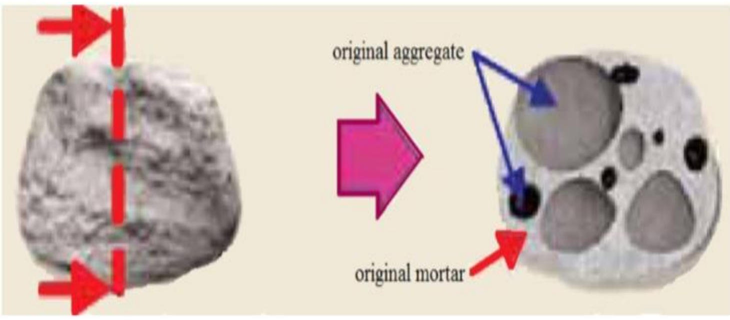

Figure 2.1 Appearance of the recycled aggregate grains

2.2.2 Water absorption

Water absorption of recycled aggregate is a characteristic by which this aggregate differs most from the aggregate obtained from natural resources. According to previous research, it has been shown that recycled concrete aggregate has a significantly higher absorption level compared to natural aggregates. The researchers from the University of Hong Kong recommend that the amount of recycled aggregate in structural concrete should range from 20% to 30%, in order to ensure that the maximum water absorption of aggregate used is less than 5% (D. Jevtić, 2009). It is known that the aggregates from domestic natural resources have negligible absorption, up to 1% as maximum, while the value of the classically recycled coarse aggregate typically ranges within the interval from 3.5% to 10%, and for the fine aggregate, within the interval from 5.5% to 13% (C. S. Poon, 2008). Through the influence of the water-cement ratio porosity and consistency, an increased water absorption of recycled aggregate also influences a range of physical-mechanical properties of fresh, as well as hardened new concrete.

2.2.3 Bulk density of aggregate

The bulk density of the recycled concrete aggregate, due to a higher porosity of mortar layer, has a lower value than the bulk density of natural aggregates and their difference decreases if recycling is conducted by an advanced technology, which can remove a significant portion of the old cement mortar. Also, the smaller the fraction, the greater the amount of cement mortar in the total mass of aggregates, so the bulk density is clearly lower. According to previous research, it was shown that the bulk density of recycled concrete aggregate normally the average by 10% lower compared to the bulk density of natural aggregates (V. Radonjanin, 2009)

2.3 Fibers Reinforced Concrete

Fibers reinforced concrete is the concrete with addition of steel fibres which is to improve the propriety of this material. When steel fibers is adding to the concrete mix, it will leads to a significant increase the toughness of the mix concrete. The fibers interlock and entangle around aggregate particles and considerably reduce the workability while the mix becomes more cohesive and less prone to segregation (Colin D. Johnston, 2001). Unfortunately, the fibers are likely to be considerably more expensive than the convectional steel bar. Thus fibers reinforced concrete is not likely to replace conventional reinforced concrete (Perumalsamy, 1992).

Besides that, fiber act as a crack arrestor restricting the development of cracks and thus transforming an inherently brittle matrix for example Portland cement with its low tensile and impact resistance, into a strong composite with superior crack resistance, improved ductility and distinctive post-cracking behaviour prior to failure (Arnon Bentur, 1990). The advantages of fiber concrete were underlined by the previous research work, it can be conclude that the addition of steel fibers into the fresh concrete mix in a certain amount, improved the bond between the mortar matrix and the aggregates, and enhancing the energy absorption and toughness behavior (Hadi, 2009) and (Paultre et al.,2010).

Further, the study were carried out by (Antonius et al.,2014), proved that the steel-fiber concrete maintained it is good ductility performance, even when exposed to substantially high temperatures. The steel fibers placed in concrete are also less liable to corrosion when compared to the reinforcement concrete bars used in reinforced concrete structure (J-L. Granju, 2005). The steel-fiber concrete showed that the presence of these fibers take a major role in the deformation pattern of the resulting concrete, so that the fracture process of the concrete material can be controlled through the use of steel fiber (Antonius,2015).

The steel fibers used for the concrete had a length to diameter ratio of 50. This ratio was found most effective in terms of the benefit of the bridging mechanism between the mortar and the fibers (M.M. Ziara,1995). The test results on mortar with steel fibres have shown that the addition of fibres lead to increases in compressive strength and the strain at peak stress (Fanella, 1985),

Some studies have been done to investigate the effect of fibre content on the post-peak softening branch of the compressive stress-strain curve of SFRC [Hughes,1977], the increase in the volumetric ratio of steel fibres leads to a relatively flatter post-peak softening branch in the stress-strain curve of mortar with steel fibers. However the property improvement can only be obtained by ensuring uniform distribution of fibers and consolidation of the matrix around the fibers

2.4 Kenaf Fiber (Natural Fiber)

Kenaf fiber comes from a plant named 'Kenaf' which is known as Hibiscus cannabinus and is closely related to cotton and jute (Hongqin et al. 2007). Kenaf has a great in being one of the material that have been used in production of raw material in construction industry. Kenaf is comparatively cheap and economically amongst other natural fibre material. Several experimental studies have been conducted previously to explore the potential of kenaf fibre as reinforcement.

Kenaf fiber consisting of following properties which includes its density is 1320 Kg/m3, Tensile strength is 260 N/mm2 and moist absorption is 10-12%, with the average diameter of fiber is 67.6 mm (Jawaid et al,2015). The compressive strength properties of kenaf fiber composite mortar with fiber contents of 1%, 2% and 3 %. It was observed that the compressive strength decreased with increasing fiber volume and length (Moses et al,2015). The previous experimental results of a series of tensile test conducted on continuous kenaf fiber with different types of thermoset resin. It is found that composites performance increased gradually with every increment of fiber volume fraction (Hafizah et al, 2014).

Even though the number of application natural fibre into fibre reinforced concrete is increasing day by day, but there is still lack of information about their behaviour and properties. Thus, more research is needed to find the possibility of using natural-fibre materials in green construction applications.A number of experimental studies have been conducted past to explore the potential of kenaf fiber as reinforcement in polymers (Yong et al,2014).

The natural kenaf fibre reinforced concrete (KFRC) increase toughness, enhance cracking behaviour and durability and improve fatigue and impact resistance. A large number of researches carried out on synthesis and characterization fibers based on different materials and their applications (Beglarigale et al,2014). The 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). Kenaf fibres are the main materials used to control concrete cracks, weak bonds and spalling of concrete. An investigated have been conducted that kenaf fibre reinforced concrete generally show more distributed cracking and higher toughness than normal concrete (Elsaid et al,2010).

Table 2.2: Properties of kenaf fiber

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

Figure 2.2 Type of kenaf fiber

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter clarifies the methodology in order to get all the data information and achieve all objectives for this study. The methodology will explains laboratory tests procedure, and analysis of data works. This study started with the selection of materials and followed by searching and reviewing of literature reviews of previous study and researches. The laboratory test will be conducted at Structural Laboratory of University Malaysia Pahang, campus Gambang with accordance to British Standard (BS) or the American Society of Testing Material (ASTM). A flowchart of research methodology process is shown in Figure 3.1.

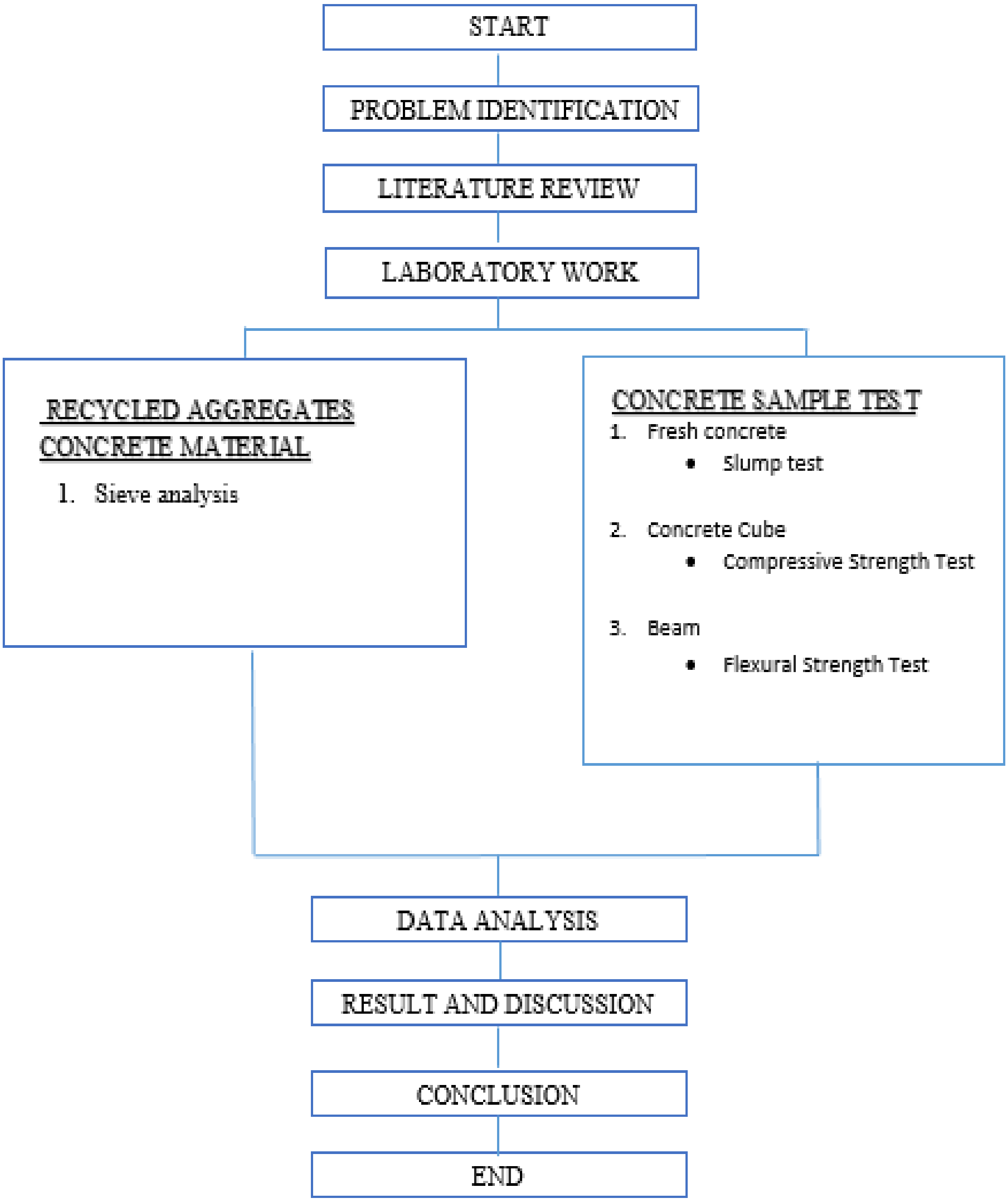

Figure 3.1 Flowchart of Project Methodology

3.2 Material Selection

Material that used in this study were discuss detailed in this topic. The material is recycled aggregate, fine aggregate, coarse aggregates, ordinary Portland cement, reinforcement bar, steel fibres and kenaf fibres. The total weight for this specimen was been calculating in mix design.

Table 3.1 Concrete beam mix design

Type of Beam	Control (Beam A)	25% of RCA (Beam B)	25% of RCA + 1% of Hybrid fibre (Beam C)	25% of RCA plus 2% of Hybrid fiber (Beam D)
Material	Weight (kg/m^3)	Weight (kg/m^3)	Weight (kg/m^3)	Weight (kg/m^3)
Cement	355	355	355	355
Fine aggregate	966	966	966	966
Coarse aggregate	700	700	700	700
Recycled Concrete Aggregate (RCA)	0	244	244	244
Steel Fibre	0	0	$1.13x10^{-4}$	$1.13x10^{-4}$
Kenaf Fibre	0	0	$3.37x10^{-4}$	$3.37x10^{-4}$
Water	220	220	220	220
Superplasticizer	16	16	16	16

3.2.1 Fine Aggregate

Fined aggregate are usually known as sand which must comply with coarse, medium or fine grading requirement. The fine aggregate act as a filler in concrete and it was air dried to acquire SSD condition to ensure that the water cement ratio does not affected

Figure 3.2 Fine aggregates

3.2.2 Coarse Aggregate

Coarse aggregates are particles greater than 4.75mm, but normally the range coarse aggregates is between 9.5mm to 37.5mm in diameter. Gravels generally the most of coarse aggregate used in concrete mixture with crushed stone making up most of the remainder. The coarse aggregates must sieve before added into the concrete mixture. The design size for coarse aggregates is between 15mm to 20mm.

3.2.2.1 Natural Coarse Aggregate

In this research, natural coarse aggregates which have been prepared by the Structural Laboratory of University Malaysia Pahang. The natural aggregates need to be sieve to get the design size of 20mm – 15mm. the natural aggregate were air dried for obtaining saturated surface dry (SSD) condition for ensuring that the water cement ratio will not be affected.

Figure 3.3 Natural coarse aggregates

3.2.2.2 Recycled Concrete Aggregate

Recycled concrete aggregate which are the concrete cubes that had been used for concrete compressive strength tests. These specimens can be found outside the Structural Laboratory of University Malaysia Pahang. Concrete cubes are collected and then it will be crushed. Usually, the crushing process begins with a concrete crusher machine, called Crusher Jaw. The concrete cubes will be crushed into smaller chunks according to the desired aggregate size. The aggregate size used for the purpose of concrete mixture is 20 mm to 15mm. The amount of recycled aggregates needed is 25 percent from the total amount of coarse aggregates needed in concrete mix design.

Figure 3.4 RCA

3.2.3 Steel Fibers

Unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibres is to fill the cracks surface. Steel fibre is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fiber composites possess increased extensibility and tensile strength, both at first crack and at ultimate particular under flexural loading and the fibers are able to hold the matrix together even after extensive cracking

Figure 3.5 Steel Fiber

3.2.4 Kenaf Fibers

The fibres were extracted from the bast through retting bacteria process. The existing moisture content in kenaf fibre was less than 6%. The fibre used in the experiment was kenaf fibre which is added at different percentage of 0% (for control specimen), 1% and 2% respectively. The samples of kenaf are prepare by cutting the samples in range between 25mm to 30 mm in length and 3mm in width. It will be add to concrete mix with amount of 30kg/ $m^3$and 30kg/m^3.

3.2.5 Formwork

Plywood formwork is used to pour fresh concrete for the four type of beams. The formwork is constructed based on the beam structural dimension which is 150mm x 200mm x 1500mm. Make sure the formwork is watertight to avoid any slurry leakage. The formwork should be checked for alignment, verticality before pour the concrete.

Figure 3.6 Formwork for beam

3.2.6 Reinforcement Bars

The steel reinforcement with diameter size 12mm will be used as a main **bar.** All the steel bar will be cut according to specific length using the cutter machine while electrical bending machine will be used to bend the steel bar. The main steel bar will be tied using a steel bar with diameter of 6mm.

Figure 3.7 Reinforcement Bar

3.2.7 Spacer block or concrete cover

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 construct spacer block is ordinary Portland cement, fine aggregate and water.

3.3 Casting Concrete

3.3.1 Casting Beam

Beam structure will be cast in situ method with concrete grade 25 N/mm^2. The concrete shall be placed in accordance with Specification for concrete cast in place. Concrete mixtures will be poured into the formwork. Vibrating poker is used to make sure the concrete mixtures will entirely occupied the formwork. In this study, four beams will be design and constructed with different condition, (1. Normal concrete beam, 2. Concrete beam with 25 % of recycled concrete aggregates, 3. Recycled concrete beam with addition 1% of hybrid fibers, 4. Recycled concrete beam with addition 2% of hybrid fibers.)

Figure 3.8 Compaction work

3.3.2 Casting Cube Concrete

Cubes concrete are casted in cast iron mould of prescribed dimensions. BS1881. The concrete is placed in the iron mould cube. The size iron mould cube is 150x150x150mm. Oil should be applied into the iron mould before pouring the concrete mixture. Compaction of each layer is achieved by not less than 35 strokes for 150mm cubes. A standard tamping bar of a 25mm square of steel section is used for this purpose.

3.3.3 Curing work

Water is the best method of curing as it satisfies all the requirements of curing. It is important that measure the curing water before the concrete is covered with membranes. Water curing can be done by doing this method which is immersion, ponding, spraying and wet covering. All beams will be continuously cured until 28 days. Meanwhile, the cubes will be cured for 7 days and 28 days.

Figure 3.9 Curing process using wet covering

3.3 Laboratory Works

In this study, all test has been carried out accordance to British Standard (BS) or the American Society of Testing Material (ASTM). All the material testing, procedure, and the testing method will be presented in this chapter.

3.4.1 Sieve Analysis of Aggregate (BS 882: 1983)

First of all we need to take the representative sample which is take the samples with a minimum of 25kg of aggregates. However, this test has been conducted by using recycled aggregate concrete that had been crushed and mix it with natural aggregates. Then wash it with a clean water and weigh the sample before oven drying. The sizes of sieve that had been used were 20 mm, 10 mm and 5 mm.

Figure 3.10 Sieve Analysis

3.4.2 Slump Test

Slump test is to determine the workability of fresh concrete mix prepared at the laboratory or the construction site during the progress of the work. The equipment required for slump test is slump cone, base plate, measuring tape and temping rod. The slump cone height is 30 cm, bottom diameter 20 cm and top diameter 10 cm. The tamping rod is of steel 16 mm diameter and 60 cm long and rounded at one end. The slumped concrete takes various shapes, which is true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of too wet a mix. Only a true slump is any of use in the test.

Figure 3.11 Slump Test

3.4.3 Concrete Compressive Test (BS 1881: Part 1 16: 1983, ASTM C 39 – 03)

Concrete compressive strength test is to determine the strength of concrete. After finishing the cube. It should be stored at a temperature of 15°C to 25°C, the cubes are to be tested at or more than 7 days. The concrete cubes are removed from the moulds between 16 to 72 hours, usually this done after 24 hours. The cubes are generally tested at 7 & 28 days unless specific early tests are required, at the time of testing the specimen is placed in a “Compression Testing Machine”. The cubes are tested on the face perpendicular to the casting face. The compression machine exerts a constant progressing force on the cubes till they fail.

Figure 3.12 Compressive Strength test

3.4.4 Flexural Strength Test

Flexural strength test is to determine the tensile strength of the concrete. The test performance accordance with as per BS 1881 : Part 118 : 1983. A simple plain concrete beam is loaded at one-third span points. The size of specimen is 150x200x1500 mm. the typical arrangement for the test is shown in figure below. Equal loads are applied at the distance of one third from both of the beam supports. It induces equal reaction same as the loading at both of the supports. The above loading configuration it is clear that at the middle one-third portion, in between two loadings, beam is subjected to pure bending. No shear force is induced within this portion. It is this portion of beam where maximum pure bending moment of Pd/2 is induced accompanied by zero shear force.

Figure 3.13 Flexural strength test

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, all the result from samples that had been test were analysed and discussed. The laboratory test was carried out to identify engineering properties of recycle concrete with addition of steel and kenaf fiber and compare to normal concrete. The result of compressive strength test, slump test and flexural strength test will be discuss in this chapter. The graph, bar chart, and table will be used for presented the analysis data. The purpose of this study is to improve the characteristic of the samples for green construction in the future. There were four type of concrete mix which are normal concrete (NC), concrete with 25% of recycled concrete aggregates (RCA), concrete with 25% of recycled concrete aggregates (RCA) and addition 1% steel fibers and kenaf fibers (Hybrid fibers) and concrete with 25% of recycled concrete aggregates (RCA) and addition 2% steel fibers and kenaf fibers (Hybrid fiber) were analyzed and make a comparison based on the result test.

4.2 Slump Test

Slump test is to determine the workability of fresh concrete mix prepared at the laboratory. Every process including material that involved in concrete mixing affects the workability of concrete. The workability of concrete is measured in terms of how to control it can be mixed, transported to the construction site, placed in the form and compacted. The super plasticizer was applied to the concrete mix in order to improve the workability of the concrete mixture.

Table 4.1 Slump test between different types of concrete

No. of sample	Type of concrete sample	Height of slump test (cm)	Type of slump
1	Normal concrete (Beam A)	100	Shear slump
2	25% RCA (Beam B)	82	Shear slump
3	25% RCA + 1% Hybrid fibers (Beam C)	86	Shear slump
4	25% RCA + 2% Hybrid fibers (Beam D)	88	Shear slump

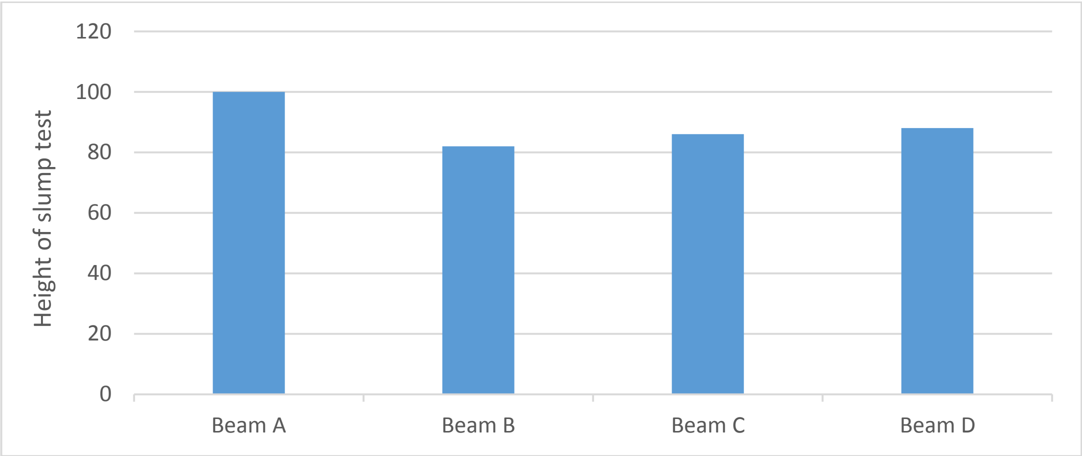

Figure 4.1 Chart for slump test

From the analysis data of slump test, the workability of the samples can be measured with the type of slump and height of the slump test. The type of the slump for all sample are shear shape. Therefore the height of slump are different between types of concrete sample. For normal concrete (Beam A), the height of the slumps is 100 mm. For 25% RCA (Beam B), the height of slump is 82 mm. For 25% RCA with addition of 1% Hybrid fibers (Beam C), the height of slump is 86 mm. Meanwhile, the 25% RCA with addition of 2% of Hybrid fibers (Beam D) the height of slump is 88 mm. Thus the normal concrete (Beam A) is the high workability concrete based on the height of the slump test.

4.3 Compressive Strength Test

Concrete compressive strength test is to determine the strength of concrete. It was determine after curing for different type of concrete after 7 days and 28 days. The purpose of compressive strength test is to fulfil the objective of the research and to study the strength of the concrete after adding material such as recycle concrete aggregates, steel fibers and kenaf fibers. Three samples were provided for the every different type of compressive strength test. For this study case, the target compressive strength that need to obtain is 30 MP.

4.3.1 Normal Concrete (Beam A)

The compressive strength test of the normal concrete sample (control sample) is shown in the table 4.2 for age 7 days and 28 days. The differences of the concrete strength can be determine by comparing the age of the sample concrete. The average of compressive strength for normal concrete for 7 days and 28 days are 51.33 N/mm^2 and 58.01 N/mm^2 respectively. The result shown that the increasing average of compressive strength is proportional to the days of concrete ages. The compressive strength for 28 days is higher than 7 days with 11.5%. This is due to the hydration process of concrete sample that happen until the maturity of concrete.

4.3.2 25% RCA (Beam B)

The table 4.2 shows that the average value of compressive strength for concrete containing 25% of recycle concrete aggregates for the ages 7 days and 28 days. The result of compressive strength for 25% RCA concrete for 7 days and 28 days are 28.67 N/mm2 and 34.73 N/mm2 respectively. It shows that the increasing of compressive strength proportional to the increasing of concrete curing days. The percentage different between 7 days and 28 days is 17.45%. Based on the compressive strength result, the strength for sample concrete that contain recycle aggregates concrete is lower than normal concrete (control). This result shows that by using the recycle concrete aggregates can decrease the strength concrete.

4.3.3 25% RCA with addition of 1% Hybrid fibers (Beam C)

The table 4.2 indicates the average result of compressive strength for concrete containing 25% of recycled concrete aggregates with addition of 1% Hybrid fibers for the ages 7 days and 28 days. The result shows the 25% RCA with addition 1% Hybrid fibers for 7 days curing is 35.51 N/mm2 followed by 41.62 N/mm2 for 28 days. Observably, it shows the increasing of concrete strength proportional to the increase of curing days. The percentage increase by 14.68%. Based on the compressive strength result, it shows that the concrete containing 25% of recycle concrete aggregates with addition of 1% Hybrid fibers is higher strength than concrete containing 25% of recycled concrete aggregates only. This is because adding Hybrid fibers into recycled concrete aggregates can increase the concrete strength.

4.3.4 25% RCA with addition of 2% Hybrid fibers (Beam D)

The table 4.2 shows the result of compressive strength for concrete containing 25% of recycle aggregates with addition 2% of Hybrid fibers as for curing 7 days and 28 days. The result compressive strength for the 25% RCA with addition of 2% Hybrid fibers at 7 days curing and 28 days curing are 36.86 N/mm2 and 40.28 N/mm2. Apparently, the result value shows the increasing of strength proportionate to the ages concrete increase. The percentage different is 8.49%.

Table 4.2 Compressive strength for cubes sample

Compressive Strength N/mm^2								
	Beam A		Beam B		Beam C		Beam D	
No. of cubes	7 days	28 days	7 days	28 days	7 days	28 days	7 days	28 days
1	53.76	61.15	26.84	38.59	36.47	40.05	36.91	39.28
2	48.13	62.47	26.06	31.16	35.67	43.71	35.98	39.10
3	52.11	50.41	33.11	34.43	34.39	41.09	37.70	42.47
Mean	**51.33**	**58.01**	**28.67**	**34.73**	**35.51**	**41.62**	**36.86**	**40.28**

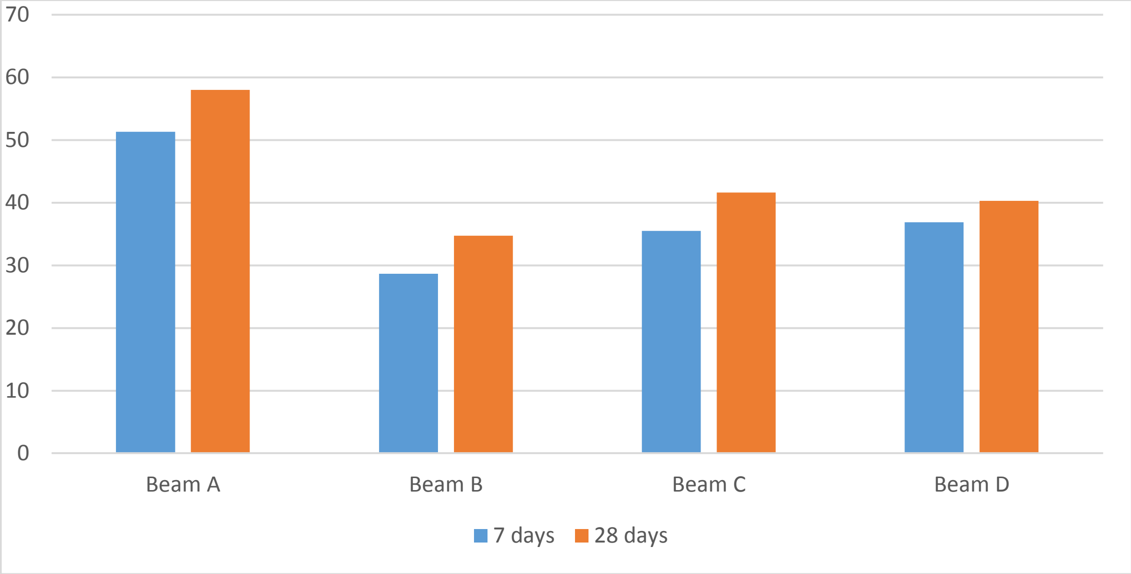

Figure 4.2 Bar chart for compressive strength test

4.3.5 Comparison of Compressive Strength between Different Types of Concrete Sample

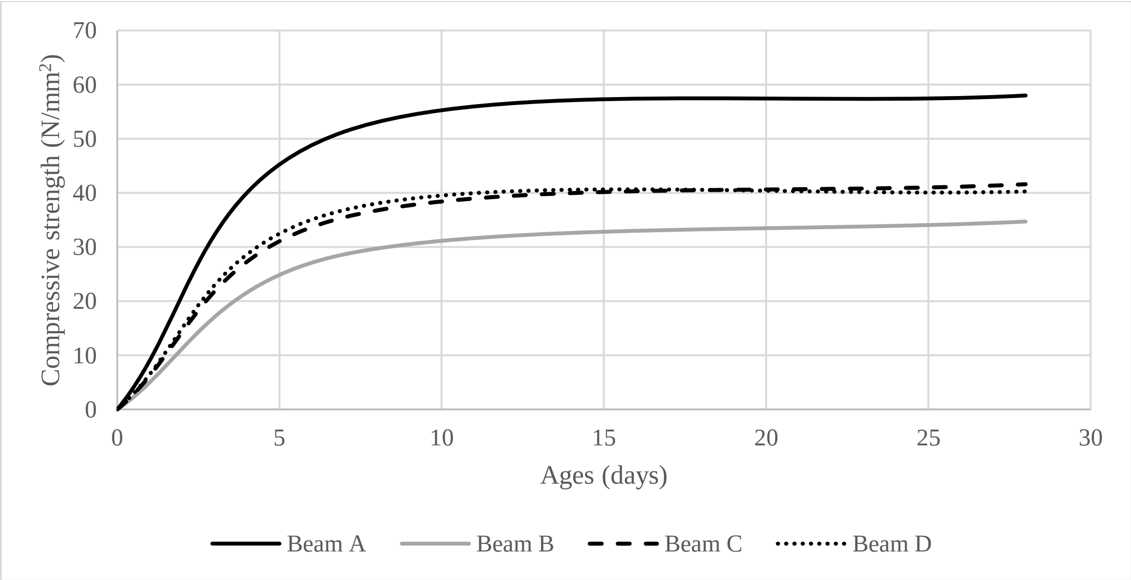

Figure 4.3 Combination of Compressive Strength Test

Based on figure 4.3, the result indicates different type of concrete which containing 25% of recycled aggregates with addition of Hybrid fiber in the concrete mix design for curing 7 days and 28 days. The graph shows that the normal concrete had the highest compressive strength compare to the others sample which is the concrete containing recycled concrete with and without addition of hybrid fibers for 7 days curing. The percentage different of compressive strength between Beam A and 25% RCA (Beam B) is 44.15%. For the 25% RCA with addition of 1% Hybrid fibers (Beam C) the different between (Beam A) is 30.82%. Meanwhile for 25% RCA with addition of 2% Hybrid fibers (Beam D) the different is 28.19%.

The compressive strength for 28 days after curing process indicated that Beam A which is normal concrete still performed the highest strength compare to the other three type of concrete. Concrete containing 25% RCA (Beam B) had lower strength than normal concrete with 40.13%. For the 25% RCA with addition of 1% Hybrid fibers (Beam C) the different between normal concrete is 28.25%. Meanwhile for the 25% RCA with addition of 2% Hybrid fibers (Beam D) the different is 30.56%. This result shows that the concrete containing recycled concrete aggregates with or without addition of Hybrid fibers will produce lower compressive strength from normal concrete sample.

The compressive strength of concrete clearly decrease after using the recycled concrete aggregates into the mix design by replacing natural coarse aggregates. The addition of steel fibers and kenaf fibers (hybrid fiber) into the recycle concrete aggregates did not enhance the improvement of the strength. The recycle concrete aggregates and kenaf fibers were determined as absorption material which is absorb water from the concrete. It will disturb the hydration process in the concrete.

Table 4.3 Compressive Strength ratio to control

25% RCA		25% RCA + 1% Hybrid Fiber		25% RCA + 2% Hybrid Fiber	
7 days	28 days	7 days	28 days	7 days	28 days
0.56	0.60	0.69	0.72	0.72	0.69

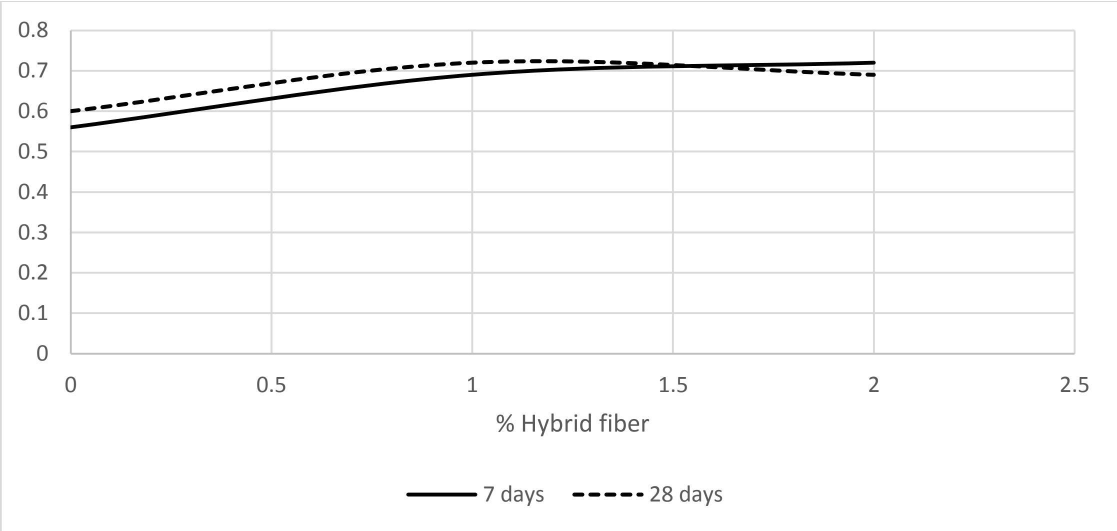

Figure 4.4 Ratio of hybrid fibers volume to the normal concrete

Based on the figure and table above shows that the compressive strength ratio to the normal concrete. The result indicates that concrete sample containing recycled concrete aggregates with addition of hybrid fiber show the higher ratio for 7 and 28 days compared to the recycled concrete aggregates sample which without adding hybrid fibers. Thus, by adding the hybrid fibers into the recycled aggregates can improve the strength of the recycled concrete sample.

4.4 Load Deflection Curve

Figure 4.5 below shows the load deflection curve result after flexural strength test for each reinforced beam sample. The value for load deflection curve were summarize in the table 4.4. The maximum load (Pmax) representing the load carrying capacity related to deflection (δmax). The load at the longitudinal reinforcement yield in tension (Py) related deflection (δy). The ultimate load (Pu) representing the residual strength related to deflection (δu) and the ductility ratio (μ) defined as $\mu = \delta u / \delta$y.

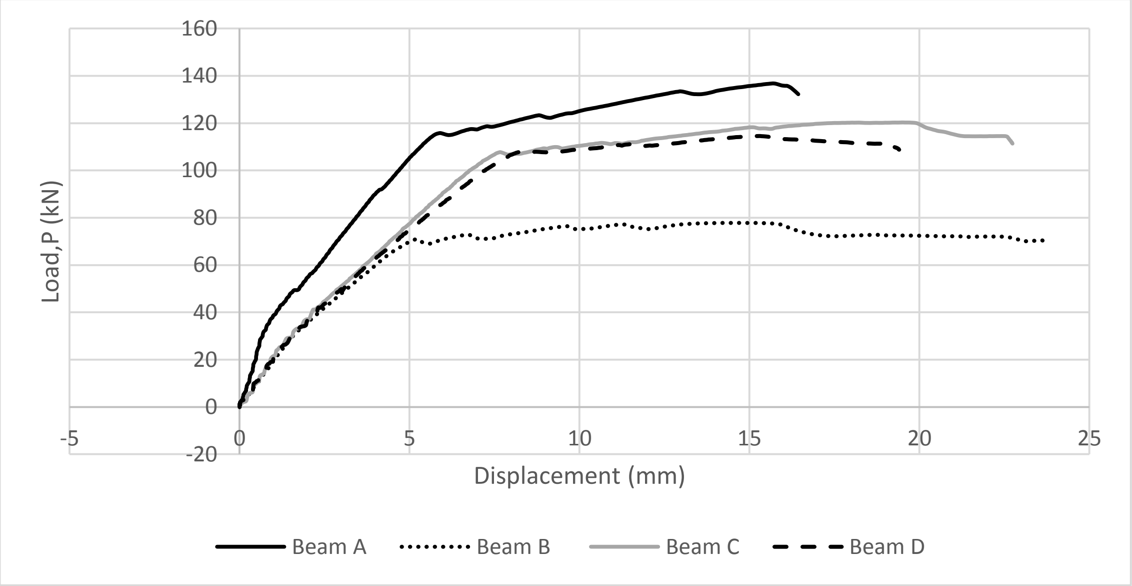

Figure 4.5 Load deflection curve for reinforced beam sample

The figure 4.5 indicates result sample normal concrete beam (Beam A) and sample concrete beam containing 25% of recycled concrete aggregates (25% RCA) had the different pattern of steep slope during load increasing from the beginning. Meanwhile, for the sample concrete beam containing 25% of recycled concrete aggregates with addition of 1% and 2% Hybrid fiber shows the graph shown the same pattern of steep slope from the beginning and the graph remain constant during the maximum load applied on the beam. This shows that the normal concrete is more toughness compared to other sample concrete beam.

Table 4.4 Summary value in the load-deflection curves

Sample	Beam A	Beam B	Beam C	Beam D
Py (kN)	115.40	71.25	106.64	105.05
δy (mm)	5.78	6.94	7.89	7.794
Pmax (kN)	136.78	77.82	120.29	114.55
δmax (mm)	15.72	14.58	19.51	15.31
Pu (kN)	132.22	69.11	111.35	108.77
δu (mm)	16.44	22.06	22.74	19.40
$\mu = \delta u / \delta$y	2.84	3.18	2.88	2.50

The table 4.4 show that normal concrete beam had a higher maximum load carrying capacity (Pmax) and yield load (Py) than other sample concrete beam. It clearly that the fiber giving impact to hold the matrix together. The ductility ratio shows the increasing after addition of 1% of hybrid fiber. But unfortunately, the ductility remain decrease after adding 2% of hybrid fiber. Therefore, by adding hybrid fiber into the concrete will not managed a ductile characteristic concrete material.

4.5 Strength Ratio

The normal concrete (Beam A) sample and concrete containing 25% recycled concrete aggregates sample show that the maximum load ratio (Pmax) and (Py) in figure 4.6 below. There show decreasing trend in the ($P_{max}/P_{max,0}$) ratio as observed in the figure for the sample without addition of hybrid fibers. For the sample recycled concrete aggregates with addition of hybrid fibers show the percentage increased. It is similar to the pattern for (Pmax, 0% Hybrid fiber), which is descending for sample without hybrid fiber but increasing when adding the hybrid fibber to the sample. Based on the figure below, it shows that the maximum load ratio will increase when the percentage of hybrid fiber is increased.

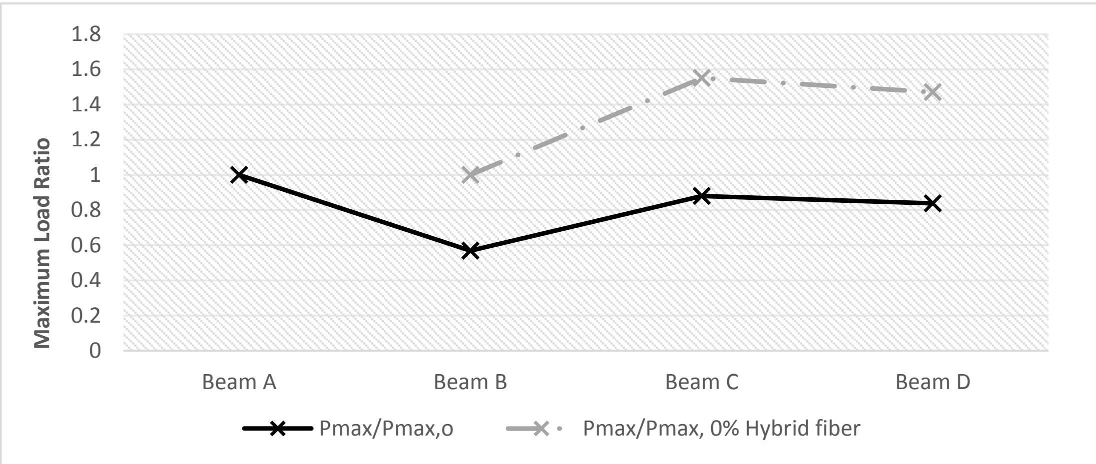

Figure 4.6 Ratio of maximum load to the normal concrete sample and recycled concrete aggregates sample versus hybrid fibers volume graph

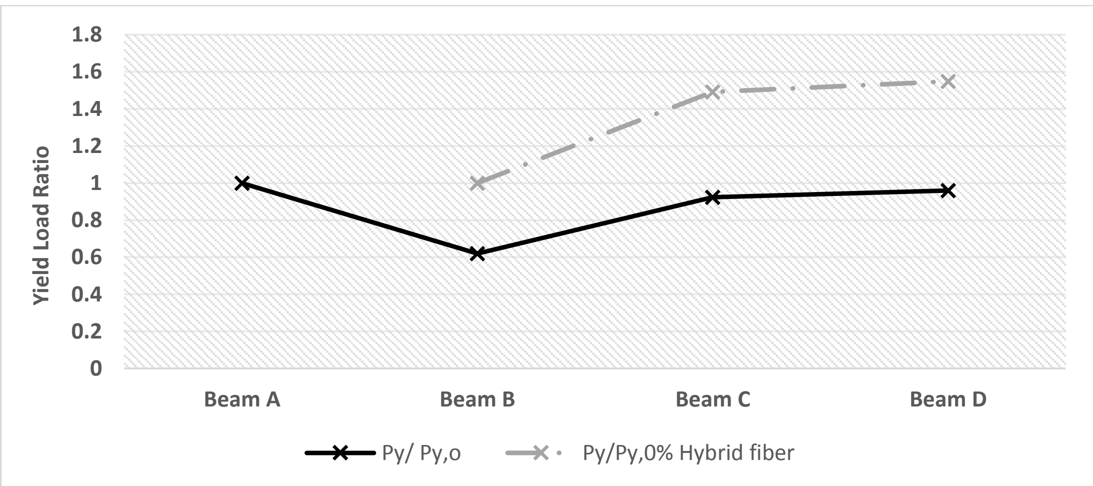

Figure 4.7 Ratio of yield load to the the normal concrete sample and recycled concrete aggregates sample versus hybrid fibers volume graph

The normal concrete sample ($P_{y,0}$) and recycled concrete aggregates with 0% hybrid fibers (Py,0% Hybrid fiber) show the yield load in figure above. It is shows that increasing trend in the both ratio after increasing the volume of hybrid fibers into the concrete beam sample. Thus, the addition of hybrid fibers will have potential to compensate for reduction in conventional reinforcement

4.6 Ductility Ratio

The ductility ratio were analyse by dividing them with the ductility ratio of the normal concrete sample and ductility ratio of the concrete containing recycled concrete aggregates without hybrid fibers. The result shows below there is no improvement observed in the ductility graph after adding the hybrid fibers into the sample. Therefore, the sample with hybrid fibers not will not enhancing ductility

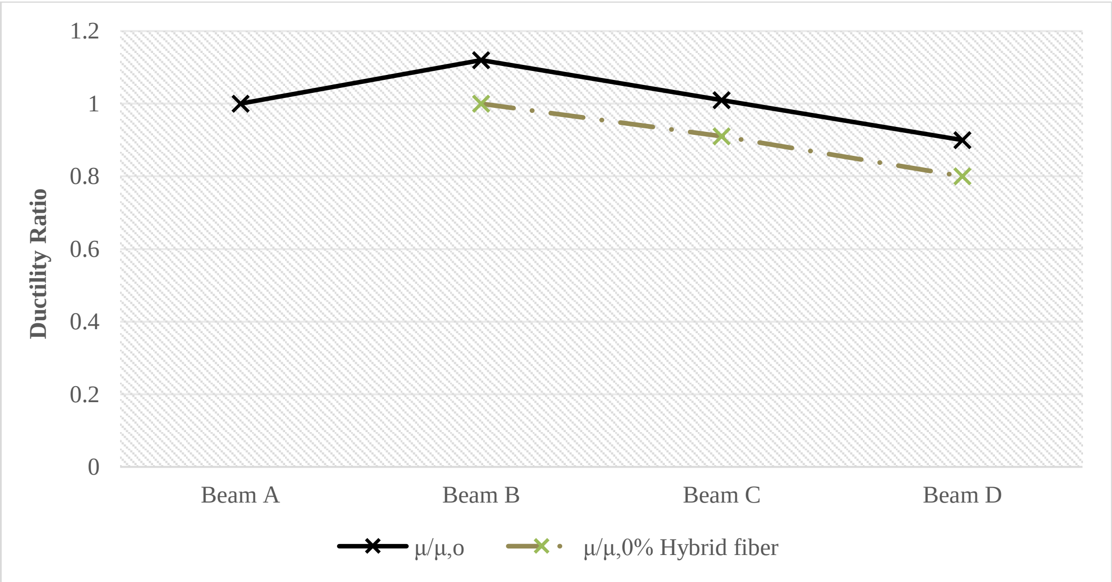

Figure 4.8 Ductility ratio for each sample beam to the normal concrete sample and recycled concrete aggregates sample versus hybrid fibers volume graph

4.7 Cracking pattern

The cracking pattern can be determine after the reinforced concrete beam sample had been testing on flexural strength test. Cracking pattern can be observed by sketching and numbering the pattern crack on the beam sample during the load were applied. Normally, the crack will appear from the bottom part of the beam sample. The figure below show the all the cracking pattern for this study.

Figure 4.9 Normal Concrete

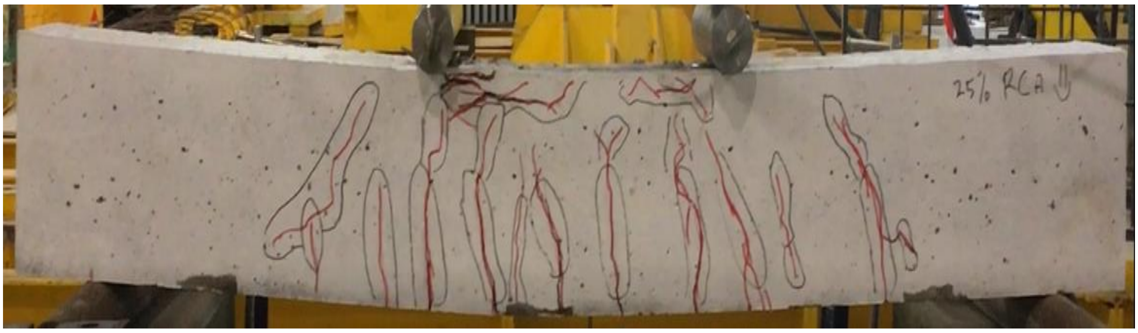

Figure 4.10 25% RCA

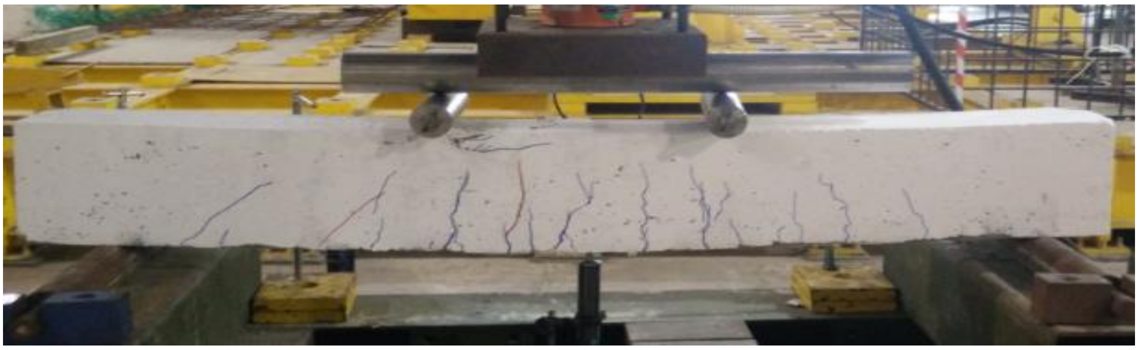

Figure 4.11 25% RCA + 1% Hybrid Fiber

Figure 4.12 25% RCA + 2% Hybrid Fiber

From the figure above, it shows that the all beam sample seen the crack at the top of the section of the intermediate support and bottom of the section where the lateral load was applied. After testing, most of the reinforced concrete beam sample failed in bending mode shown in table 4.5 below.

Table 4.5 Mode of Failure for beams

Sample	Load on 1st crack (kN)	Mode of failure
Beam A	N.A	Bending – shear failure
Beam B	N.A	Bending failure
Beam C	34.485	Bending failure
Beam D	48.546	Bending failure

4.8 CONCLUSION

From the overall result data, it shows that by replacing natural coarse aggregates with the recycle concrete aggregates gave affected the concrete in term of workability and compressive strength. The result were shown with comparing the concrete containing recycle concrete aggregates with and without addition of Hybrid fibers and normal concrete. The compressive strength for concrete containing recycled concrete aggregates gave the lower strength compare to the normal concrete sample even though with addition 1% and 2% of Hybrid fibers into the recycle concrete aggregates mix design. But, there shown the different result in maximum load capacity and yield load. It can be observed that by adding the hybrid fibers it can control the cracking width opening in the section between the intermediate support and the section where the load were applied.

CHAPTER 5

CONCLUSION

5.1 Introduction

This study has shown that the usage recycled concrete aggregates can give effect in the quality of the concrete. This study has been successfully conducted in order to fulfil the 2 objectives that has been outlined in Chapter 1 of this study. The performance of the recycled concrete aggregates beam with addition of steel fiber and kenaf fiber (hybrid) were analysed. Moreover, in this chapter will gives the conclusion and recommendation for the further works in future**.**

5.2 Conclusion

The main focus of this study is on determining the strength of reinforced recycled concrete aggregates beam after addition of steel fiber and kenaf fiber (hybrid) into the mixture. The conclusion drawn from the study are as follows

1. Based on the result, indicates that the compressive strength for 7 days and 28 days after curing process shows that sample normal concrete still performed the highest strength compare to the recycled aggregates concrete with or without addition of steel fiber and kenaf fiber (hybrid).

2. The flexural strength test for the beam sample shows that the concrete containing recycled concrete aggregates with addition of 2% steel fibers and kenaf fibers gave the highest strength compare to the normal concrete and others.

3. For the slump test, the normal concrete shows the highest workability than others sample based on the type and height of slump.

5.3 Recommendation

The results of the laboratory experiment show that by adding the steel fiber and kenaf fiber (hybrid) gives a good contribution in order to improve the strength of recycled concrete. However, there have been several limitation during this research work that would affect the accuracy of the measurements and result. Thus, here are some suggestion for the future study.

1. Future research is required for mechanical testing for example shear strength test, sieve analysis test and water absorption test. This future research will tend to more information about mechanical properties of recycled concrete aggregates beam.

2. Future study should try to increase the volume of steel fiber and kenaf fiber (hybrid) into the recycle concrete aggregates beam. This study to find the effective solution for recycled concrete problem

3. Future research should use order already mix concrete in order reduce time for concreting works

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APPENDIX A

CONCRETE MIX DESIGN NORMAL CONCRETE

Stage	Item	Reference & calculation	Value
1	1.1 Characteristic Strength 1.2 Standard Deviation 1.3 Margin 1.4 Target mean strength 1.5 Cement type 1.6 Aggregate type: Coarse Aggregate type: Fine 1.7 Free water/cement ratio 1.8 Max. free-water cement ratio	Specified Figure 3 C1 or Specified C2 Specified Table 2, Fig 4 Specified	**G30** N/mm² at **28** days Proportion Defective **5 %** **5** N/mm² (k=1.64) 1.64 x **5** = **8.2**N/mm² **30** + **8.20** = **38.20** N/mm² **OPC** **Crushed** **Crushed** **0.58** — use the lower value **0.65**
2	2.1 Slump or V-B 2.2 Maximum aggregate size 2.3 Free-water content	Specified Specified Table 3	Slump **10-30 mm** **20 mm** **190 kg/m²**
3	3.1 Cement content 3.2 Maximum cement content 3.3 Minimum cement content 3.4 Modified free-water/cement ratio	C3 Specified Specified	**190** ÷ **0.58** = **327.59 kg/m²** ______**Kg/m²** **275 kg/m²** – use if greater than item 3.1 and calculate 3.4 ______
4	4.1 Relative density of aggregate (SSD) 4.2 Concrete density 4.3 Total aggregate content	Fig 5 C4	**2.7** known/assumed **2435 kg/m²** **2435** – **327.52** = **1917.41** kg/m²
5	5.1 Grading of fine aggregate 5.2 Proportion of fine aggregate 5.3 Fine aggregate content 5.4 Coarse aggregate content	BS 882 Fig 6 C5	Zoom ______ - ______ - ______ **Per cent** **1917.41** X **0.53** = **1016.23kg/m²** **1917.41**- **1016.23**= **901.18kg/m²**

Quantities	Cement (Kg)	Water (Kg)	Fine aggregate (Kg)	coarse aggregate (Kg)	RCA
Per m³ (to nearest 5 kg)	**355**	**220**	**966**	**700**	**0**
Per trial mix of **0.048375** m³	**18**	**11**	**47**	**34**	**0**

APPENDIX B

CONCRETE MIX DESIGN RCA

Stage	Item	Reference & calculation	Value
1	1.9 Characteristic Strength 1.10 Standard Deviation 1.11 Margin 1.12 Target mean strength 1.13 Cement type 1.14 Aggregate type: Coarse Aggregate type: Fine 1.15 Free water/cement ratio 1.16 Max. free-water cement ratio	Specified Figure 3 C1 or Specified C2 Specified Table 2, Fig 4 Specified	**G30** N/mm^2 at **28** days Proportion Defective **5 %** **5** N/mm^2 (k=1.64) 1.64 x **5** = **8.2**N/mm^2 **30** + **8.20** = **38.20** N/mm^2 **OPC** **Crushed** **Crushed** **0.58** — use the lower value **0.65**
2	2.1 Slump or V-B 2.2 Maximum aggregate size 2.3 Free-water content	Specified Specified Table 3	Slump **10-30 mm** **20 mm** **190 kg/m^2**
3	3.1 Cement content 3.2 Maximum cement content 3.3 Minimum cement content 3.4 Modified free-water/cement ratio	C3 Specified Specified	**190** ÷ **0.58** = **327.59 kg/m^2** ______**Kg/m^2** **275 kg/m^2** – use if greater than item 3.1 and calculate 3.4 ____________
4	4.1 Relative density of aggregate (SSD) 4.2 Concrete density 4.3 Total aggregate content	Fig 5 C4	**2.7** known/assumed **2435 kg/m^2** **2435** – **327.52** = **1917.41** kg/m^2
5	5.1 Grading of fine aggregate 5.2 Proportion of fine aggregate 5.3 Fine aggregate content 5.4 Coarse aggregate content	BS 882 Fig 6 C5 (5.3, 5.4)	Zoom ______-______- ______________**Per cent** **1917.41** X **0.53** = **1016.23kg/m^2** **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)	**355**	**220**	**966**	**700**	**223**
Per trial mix of **0.048375** m^3	**18**	**11**	**47**	**34**	**11**