Effect of Recycled Aggregate Concrete with Glass Fiber on Concrete Properties

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ABSTRACT

Waste materials have becoming an issue worldwide nowadays. From construction to transportation, all these wastes contribute to serious environmental problem. Therefore, an urgent need of an alternative in reducing the waste is highly recommended. In this study, recycle aggregate concrete (RAC) obtained from crushed concrete and glass fiber are used in the concrete mix. Furthermore, concrete made from glass fiber and recycled coarse aggregate as partial replacement of coarse aggregate is studied for workability, compressive and flexural strengths. In this study, recycled coarse aggregate used as partial replacement of coarse aggregate by percentage replacement 20% with natural aggregate. Glass fiber was used to replaced 1 % and 2 % of the total weight of cement. This study concentrated on the workability, compressive strength and flexural strength of the RAC with different percentage of glass fiber. One test was conducted for workability of fresh RAC namely slump test. Meanwhile, cubes were subjected to compressive strength test and beams were subjected to flexural strength test. All the specimens were cured in water for 7and 28 days. The results indicated that the fresh RAC exhibit a significant decrease in workability with increasing percentage of glass fiber. However, the strength of the recycle aggregate concrete is increasing with increased percentage of glass fiber. This is due to the physical properties of the RAC and glass fiber. In general, the results suggested that the glass fiber used to replace the cement should be more than 2 % in order to achieve higher strength.

ABSTRACT

Bahan-bahan buangan telah menjadi isu di seluruh dunia pada masa kini. Dari pembinaan ke pengangkutan, semua sisa ini menyumbang kepada masalah alam sekitar yang serius. Oleh itu, keperluan mendesak alternatif dalam mengurangkan sisa sangat disyorkan. Dalam kajian ini, konkrit agregat kitar semula (RAC) yang diperoleh daripada konkrit dan serat kaca dihancurkan digunakan dalam campuran konkrit. Selain itu, konkrit yang diperbuat daripada gentian kaca dan agregat kasar yang dikitar semula sebagai penggantian sebahagian daripada agregat kasar dikaji untuk kebolehkerjaan, kekuatan mampatan dan lenturan. Dalam kajian ini, agregat kasar yang dikitar semula digunakan sebagai penggantian sebahagian daripada agregat kasar oleh penggantian peratusan sebanyak 20% dengan agregat semulajadi. Serat kaca digunakan untuk menggantikan 1% dan 2% daripada jumlah berat simen. Kajian ini tertumpu pada kebolehkerjaan, kekuatan mampatan dan kekuatan lenturan RAC dengan peratusan serat kaca yang berlainan. Satu ujian telah dijalankan untuk kebolehlaksanaan RAC segar iaitu ujian kemerosotan. Sementara itu, kiub tertakluk kepada ujian kekuatan mampatan dan balok dikenakan ujian kekuatan lenturan. Semua spesimen telah sembuh di dalam air selama 7and 28 hari. Hasilnya menunjukkan bahawa RAC segar mempamerkan penurunan ketara dalam kebolehpasaran dengan peningkatan peratusan serat kaca. Walau bagaimanapun, kekuatan konkrit agregat kitar semula meningkat dengan peningkatan peratusan gentian kaca. Ini disebabkan sifat fizikal RAC dan serat kaca. Secara umum, keputusan menunjukkan bahawa serat kaca yang digunakan untuk menggantikan simen perlu lebih daripada 2% untuk mencapai kekuatan yang lebih tinggi.

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LIST OF ABBRREVIATIONS

BS	British Standard European Norm
ACI	American Concrete Institute
ASTM	American Standard Test Method
POC	Ordinary Portland Cement
RAC	Recycled Aggregate Concrete
RAC0	Recycled Aggregate Concrete with 0% Glass Fiber
RAC1	Recycled Aggregate Concrete with 1% Glass Fiber
RAC2	Recycled Aggregate Concrete with 2% Glass Fiber
RC	Reinforced Concrete

LIST OF SYMBOLS

N/mm2	Newton per millimeter square
KN	Kilonewton
N	Newton
mm	Millimeter
m	Meter
MPa	Megapascal
Kg	Kilogram

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Demolition of old and deteriorated buildings and traffic infrastructure, and their substitution with new ones, is a frequent phenomenon today in a large part of the world. The main reasons for this situation are changes of purpose, structural deterioration, rearrangement of a city, expansion of traffic directions and increasing traffic load, natural disasters (earthquake, fire and flood)(Malešev, Radonjanin, & Marinković, 2010)

Recycled aggregate (RA) is aggregate resulting from the processing of inorganic material previously used in construction. According to the European Standards for concrete there is a full possibility for the use of RA in concrete. The acceptable ways for the use must be determined nationally, i.e. according to the national specifications. As RA can include all kind of inorganic materials from the C&D waste, i.e. concrete, concrete masonry units, mortars, aerated concrete and also clay masonry units (bricks and tiles), it is not as good a material for concrete production as recycled aggregate concrete (RAC). RCA is made of solely crushed concrete. Separation of concrete material already during the demolition phase is essential to make it easier to produce good quality RCA.(Kuosa, 2012)

Malaysia is expected to exceed 15,000 tons of solid wastes generation daily. The major solid wastes are generated in Malaysia from agricultural, industrial, municipal and mining sources. The disposal of these wastes has become a major environmental problem in Malaysia and thus the possibility of recycling the solid wastes for use in construction materials is of increasing importance.(Safiuddin, Jumaat, Salam, Islam, & Hashim, 2010). Presently, a huge amount of waste is generated in construction sites. The estimated total construction waste generated from a project site during the construction of a new building is around 27,068.40 tonnes.(Ismail, Hoe, & Ramli, 2013).

Some benefits of using RCA are illustrated below:

1) Controlling the over-discharge of construction and demolition wastes that otherwise would have been disposed in landfills.

2) Decreasing the dependence of the construction industry on natural aggregates, thereby preserving natural resources, provides savings from the treatment of waste disposal, and yields alternative sources for urban areas facing shortage of natural aggregates.

3) Cost reduction where the availability of recycled aggregate as an alternative can provide balance and control of the price of aggregate in the market, which has continued to increase due the depletion of the natural aggregate supply.

Therefore, it can be modified with fiber so as to enhance its properties. In this research, glass fiber is taken into consideration for this purpose.

In general, some fibers are lower in the strength of recycled aggregate and some fiber provides greater impact, abrasion and shatter resistance. However, this can refer to the type of fiber reinforced with the RAC. In fact, there are many types of fiber can be used such as steel, glass, synthetic and natural fibers.

Glass fiber as a kind of low cost material has many properties similar with carbon fiber, such as good thermal stability, good chemical corrosion resistant and better mechanical strength.(Zuo, Chen, Luo, & Chen, 2015)

Glass fibers, also known commercially as ‘fiberglass’, are most extensively use reinforcements for polymer matrix composites due to their combination of low cost, high strength and relatively low density. Unlike carbon or Kevlar fibers glass fibers are isotropic thus avoiding loss of properties when loaded in the transverse direction. Fiberglass is produced by pulling molten glass through orifices at a temperature where the glass has just the right amount of viscosity.

1.2 PROBLEM STATEMENT

These days, the recycled concrete is obtained through the demolition of concrete elements of buildings, roads, bridges, and other structures, also it comes from the residue of fresh and hardened rejected units in precast concrete plants.

Recycled aggregate concrete works as alternative of natural resources which is in shortage. RCA it has a range of environmental and economic benefits such as it reduces the space required for the landfill disposal. Recently, the major challenge that our society communities facing is that recycling will help to conserve natural resources for next generations where the natural resource protection is one of the important parts of environmental issues. The recycling of concrete waste into recycled aggregate concrete (RAC) has been investigated as a potential source of construction concrete.

In an increasingly urban world, the growth in waste generation, particularly in construction and demolition waste. Environmental problems resulting from CDW disposal are a cause for concern because of the impacts that illegal disposal sites (which occur routinely) have on cities and their surroundings. This issue has been extensively debated and has stimulated interest in environmentally sustainable solutions. In this context, environmental legislation has become stricter, with a tendency to make waste generators responsible for their own waste, ultimately leading to the adoption of waste minimization and recycling policies. In Malaysia, the local environment is affected by a great amount of concrete waste this is due to the limitation of disposal sources and the renovation of buildings. In recent years, a popular topic has been researched by many researchers which is the replacement of the natural aggregates at the concrete production through the use of recycled aggregates. Thus, it is so important that coming up with new methods and strategies for replacement and use a proper additive such as glass fiber.

In this research, glass fiber is proposed to be used as an additive. This is due to the glass fiber composites strength/weight ratios are higher than those of most other materials and their impact resistance is phenomenal. Further they possess resistance to moisture and outdoor weathering and resistance to heat and chemicals. These properties are coupled with ease of fabrication.

1.3 AIMS AND OBJECTIVES

Reducing the environmental problems is the main aim in this research which generated from dumping the construction and demolition wastes and these environmental problems can be achieved by recycling the construction and demolition wastes to produce concrete standard. However, the three main objectives have been listed as shown below to achieve the aim of this study:

i) To investigate the proper replaced percentage of the recycled aggregate concrete.

ii) To investigate the workability of the recycled aggregate concrete with glass fiber

iii) To investigate the compressive strength of the recycled aggregate concrete with glass fiber.

iv) To investigate the flexural strength of the recycled aggregate concrete with glass fiber.

1.4 SCOPE OF STUDY

The compressive and flexural strengths were conducted to determine the effectiveness of RAC and glass fiber. Regardless of the limitations of the available laboratory facilities of recycled aggregate concrete (RAC), the scope of this research is as follows:

- The cube size considered is 100mm x 100mm x 100mm.
- The beam size considered is 500mm x 100mm x 100mm
- The fiber used is e-glass fiber with diameter 14 microns and length of 25mm.
- Using plastic moulds for cubes and steel moulds for beams.

This experiment is carried out through two phases as shown below:

PHASE 1

The total samples for cubes are 12 to study the 28 days compressive strength of recycled aggregate concrete, three cubes for each percentage of recycled aggregate concrete.

1) Cubes 1 contained 0% recycled aggregate concrete.
2) Cubes 2 contained 20% recycled aggregate concrete.
3) Cubes 3 contained 50% recycled aggregate concrete.
4) Cubes 4 contained 100% recycled aggregate concrete.

20% was the best percentage of RCA which showed increasing in compressive strength, so this percentage was considered in Phase 2.

PHASE 2

The total samples for cubes are 18 to study the 7 and 28 days compressive strength of concrete mixes, three cubes for each day will be casted and tested.

1) Cubes 1 contained 20% RAC with 0% glass fiber.
2) Cubes 2 contained 20% RAC with 1% glass fiber.
3) Cubes 3 contained 20% RAC with 2% glass fiber.

- The total samples for beams are 24 to study the 7 and 28 days flexural strength of concrete mixes, three beams for each day will be casted and tested.

1) Beams 1 contained 20% RAC with 0% glass fiber.
2) Beams 2 contained 20% RAC with 1% glass fiber.
3) Beams 3 contained 20% RAC with 2% glass fiber.

- The location of the research will be held in concrete laboratory, University Malaysia Pahang (ump).
- The testing related to the research are compressive strength and four points bending test.
- Slump test to determine the slump of cohesive concrete of low to high Workability of concrete.

1.5 SIGNIFICANCE STUDY

The concrete production is very important and this fact approves that the aggregates is the main component of concrete and are much demanded. Due to the fact that, in some countries, the natural aggregates are a scarce resource, it is necessary to find a new source of aggregates by adopting of recycling to enhance the concrete production. The recycling of aggregate has come into sight to achieve the two main goals:

a) To maintain the price of concrete, which until now was the cheapest construction material.

b) To preserve the environment, without creating piles of waste over the world.

In this research, glass fiber is proposed to be used as a synthetic additive so as to enhance the quality of recycled aggregate. This can be done through conducting certain tests for this purpose. Durability, performance, toughness and strength of the final products will be investigated on the next stages. In a nutshell, it is hoped that this research will be a small contribution in the advance of the utilization of the recycled aggregates as construction material in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 RECYCLED AGGREGATE CONCRETE

2.1.1 GENERAL

Recycled aggregate concrete is a Concrete that generated from solid scheduled waste. In general, it is derived from the materials that used in a product or in construction industry such as construction and demolition. However, the natural aggregate concrete that has been used for long decades are placed to recycled aggregate concrete. Also recycled aggregate concrete is an excellent solution to keep materials of demolition to be disposed in landfill. There are two main stages to product recycled aggregate concrete (RAC), crushing of demolished concrete, and screening and removal of contaminants such as gypsum, paper, wood, plastics and reinforcement.(Malešev et al., 2010)

When demolished concrete is crushed, a certain amount of mortar and cement paste from the original concrete remains attached to stone particles in recycled aggregate. This attached mortar is the main reason for the lower quality of RCA compared to natural aggregate. Technology of RAC production is different from the production procedure for concrete with natural aggregate. Because of the attached mortar, recycled aggregate has significantly higher water absorption than natural aggregate. Therefore, to obtain the desired workability of RAC it is necessary to add a certain amount of water to saturate recycled aggregate before or during mixing, if no water-reducing admixture is applied. One option is to first saturate recycled aggregate to the condition ―water saturated surface dry, and the other is to use dried recycled aggregate and to add the additional water quantity during mixing. The additional water quantity is calculated on the basis of recycled aggregate water absorption in prescribed time.(Junak, Stevulova, Junak, & Stevulova, 2013)

Great efforts have been made by researchers in order to investigate the characterization of these types of aggregate. And those researchers have investigated about mechanical, physical and durability properties of recycled aggregates concrete, and mechanical, durability and structural properties of RCA. This study is concentrating on recycling of concrete waste as an aggregate in structural concrete in flexure and punching shear.

2.1.2 CONSTITUENT MATERIALS IN CONCRETE

Concrete is the major materials of structures and it is very useful due to its fire and weather fair resistance and its tensile strength. Concrete components are cheap materials and it is suitable to be cast in the required shape and has good compressive strength. Thus, humidity dose not impact concrete. Moreover, the main reason for high demand of concrete, it has several advantages such as it will not be burnt or attacked by insects. Concrete is a highly complex material. The slump flow of concrete is not only determined by its water content, but is also influenced by other concrete ingredients. These ingredients include cement, blast furnace slag (Slag), fly ash, water, super plasticizer, coarse aggregate and fine aggregate.

Concrete components such as aggregate which is the most important component of Concrete and it mostly occupied a very high percentage 70 % to 80 % of concrete volume. Aggregate is desirable materials which come from the natural rocks, crushed stones, gravels and sands. Therefore, properties of fresh and hardened concrete are affected by aggregate. However, aggregate is separated into two types, the first type is fine aggregates which are particles smaller than the coarse aggregate with less 4.75mm and it is equal to 75um or larger. Fine aggregate generally contains of manufactured particles or natural with ranging size from 1.50mm to 4.75mm and occupy 0 to 15% of overall volume of aggregate. Also, fine aggregate has few types such as sea sand, pit and river sand. The Second type is coarse aggregates which are particles greater than 4.75mm, also mostly range between 9.5mm to 73.5mm in diameter and can occupy 2/3 of aggregate volume. Also, coarse aggregate is produced from natural disintegration and stone or crushed gravel. In addition, coarse aggregate has many types such as basalt, granite, calcareous and marble.

2.1.3 CONCRETE WASTE AND CONCRETE RECYCLING

In general, concrete waste that is related to the Construction and Demolition (C & D) waste is originated and developed once construction of new, or modifications occurred to existing urban infrastructure such as transportation systems. As the world's population increases, the amount of C & D waste is also increasing. This is the fact that cannot be denied specially in urban communities. Moreover, finding alternative materials and reduce the waste in order to enhance environment protection is an increased social request to governmental department and industries in developed countries also to understand that the depletion of natural resources is a serious threat. Therefore, there is a general awareness that recycled C & D waste including RC aggregates can be treated, enhanced and utilized used for the purpose of construction.

By far the most common method for recycling dry and hardened concrete involves crushing. Mobile sorters and crushers are often installed on construction sites to allow on-site processing. In other situations, specific processing sites are established, which are usually able to produce higher quality aggregate. Sometimes machines incorporate air knives to remove lighter materials such as wood, joint sealants and plastics. Magnet and mechanical processes are used to extract steel, which is then recycled.

Typically, coarse RCA (> 4.75 mm) is much easier to use in concrete production than fine RCA (< 4.75 mm). This is because after normal concrete crushing and sieving operations the proportion of good natural aggregates is much higher in the coarse portion than in the fine portion. After advanced RCA production methods, coarse RCA can basically consist of solely natural aggregate. Instead fine RCA typically contains more cement paste which absorbs water and makes the concrete production more challenging. Cement paste may also include harmful substances for concrete such as chlorides and sulphates. Especially fine RCA quality is dependent on the C&D waste quality, as also coarse graded RCA quality if the cement paste content that is adhered on the aggregate surfaces after the crushing and other processing operations remains high. By forceful C&D waste sorting and processing it is possible to produce high quality recycled aggregates for concrete production.(Kuosa, 2012)

a) concrete waste

b) recycled aggregate

Figure 2.1: concrete waste and recycled aggregate

In figure 2.1 shows recycled aggregates which is a term used to describe crushed concrete or asphalt from construction debris that is reused in other building projects. This collection of construction refuse is mainly used for road base, cement concrete or other infrastructure projects.

2.1.4 BENEFIT OF USING RAC

2.1.4.1 ENVIRONMENTAL CONSIDERATIONS

Concrete is the major construction material commonly used all over the world. By reducing the use of energy materials, we can make increment in resource efficiency. Thus, for the production of concrete the waste materials obtained from the demolished or renovated structures are utilized. The reuse of this demolition waste in the form of recycled concrete coarse aggregate considered as an effective attempt to make economic and environmental advantages.(Jacob & John, 2016)

Environmental Benefits of using recycled aggregate concrete are summarized below:

- It is resources efficient minimizing depletion of natural resources
- Conservation of aggregates and energy
- Reduction of landfill
- Reduction of greenhouse gases
- Sequestration of carbon
- Reduce land use
- Reduce impact of landscape

2.1.4.2 ECONOMIC FACTORS.

In addition to the environmental benefits, using recycled concrete can also be economical, depending on the situation and local conditions. Factors include:

- Proximity and quantity of available natural aggregates
- Reliability of supply, quality and quantity of C&DW (availability of materials and capacity of recycling facility)
- Public perceptions regarding the quality of recycled products
- Government procurement incentives
- Standards and regulations requiring different treatment for recycled aggregate compared to primary material
- Taxes and levies on natural aggregates and on landfill

2.1.4.3 OTHER USES

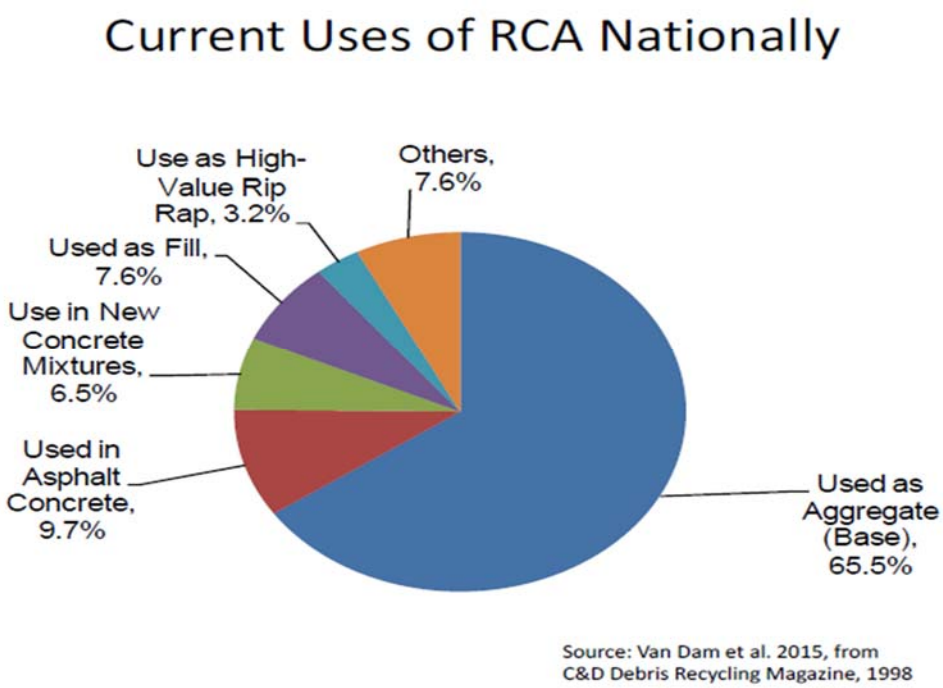

Figure 2.2 Current uses of recycled aggregate concrete

The use of recycled materials for construction is a sustainable move in the construction industry as it shown in figure 2.2. It prevents materials from having to be collected for building while also preventing more refuse from entering the landfill.

2.1.5 SOURCES OF MATERIAL FOR THE PRODUCTION OF RECYCLED AGGREGATE

The impact of a rapidly developing area for construction building includes the use of a high amount of natural aggregate and the problem produced by the huge volume of construction and demolition waste. The amount and composition of construction waste materials are shown in figure 2.1.2. It shows that aggregate and concrete comprise a large proportion of the waste. Both findings indicate that the waste levels are high and that a large portion of potentially useful demolition waste, such as concrete waste, is directly disposed in landfill sites without being fully utilized. The availability of waste as a source for recycling has the potential of continuous yield as recycled aggregate can be a solution to the management of waste disposal problem and at the same time serve as a substitute for natural aggregates.

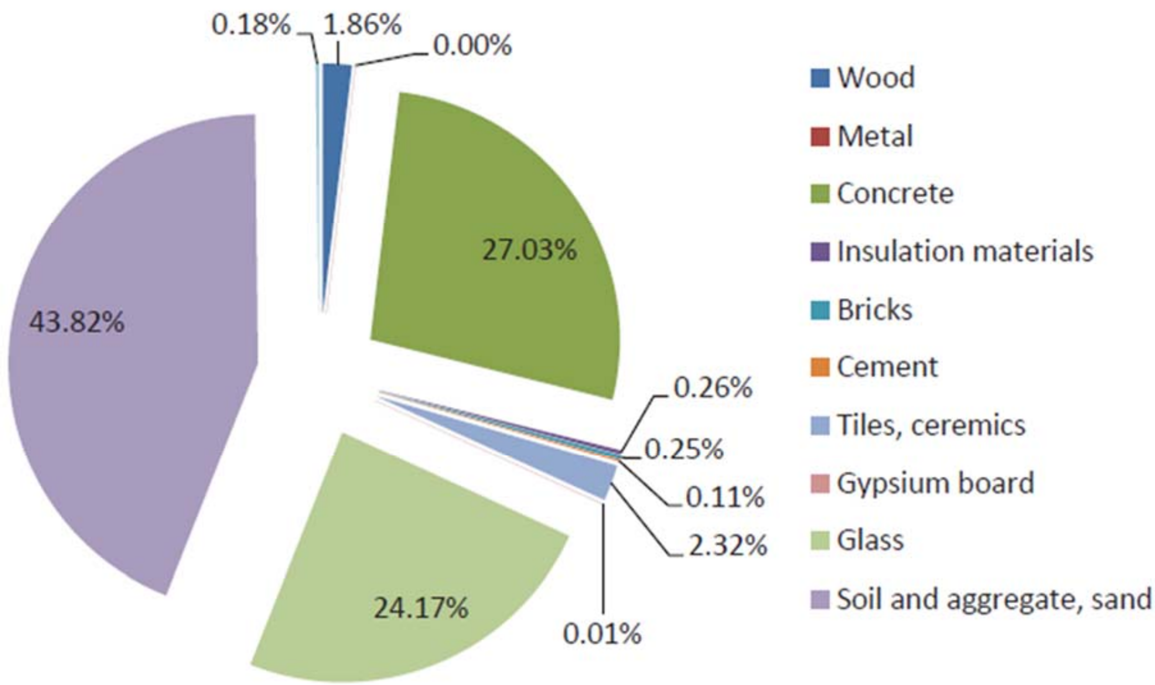

Figure 2.3 Sources of crushed material from a building construction

2.2 FIBER

2.2.1 GENERAL

The compressive strength of recycled concrete is typically higher than the tensile strength and recycled concrete is comparatively crisp. For many applications, recycled aggregate more and more become popular with small, randomly distributed fibers. Increasing the flexural strength is the main purpose of fibers. In addition, fibers also increase the material toughness. Fiber is defined as a composite concrete material that consisting of a cement matrix reinforced with discontinuous discrete fibers (glass, metal, or other synthetic material). Also, Fiber is defined as small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fiber is often described by a convenient parameter called "aspect ratio”. The aspect ratio of the fiber is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

Nowadays, improvements of properties of the recycled aggregate concrete have been studied such as producing the fiber. In addition, the small fibers are distributed randomly in the recycled aggregate concrete during mixing, and thus improve recycled aggregate concrete properties in all directions. Fibers help to improve flexural strength, shrinkage cracks, pre-crack tensile strength and impact strength.

2.2.2 SYNTHETIC FIBER

For millennia mankind depended on the natural world to supply its fiber needs. But scientists, as a result of extensive research, were able to replicate naturally occurring animal and plant fibers by creating fibers from synthetic chemicals. It is often noted that there are three kinds of man-made fibers: those made by “transformation of natural polymers” (also called regenerated cellulosic), those made from synthetic polymers and those made from inorganic materials (These include the fibers made of glass, metal, ceramics and carbon.) But by far the largest groups of man-made synthetic fibers being produced today are made from synthetic polymers. (Giwa, Isa, & Idris, 2013)

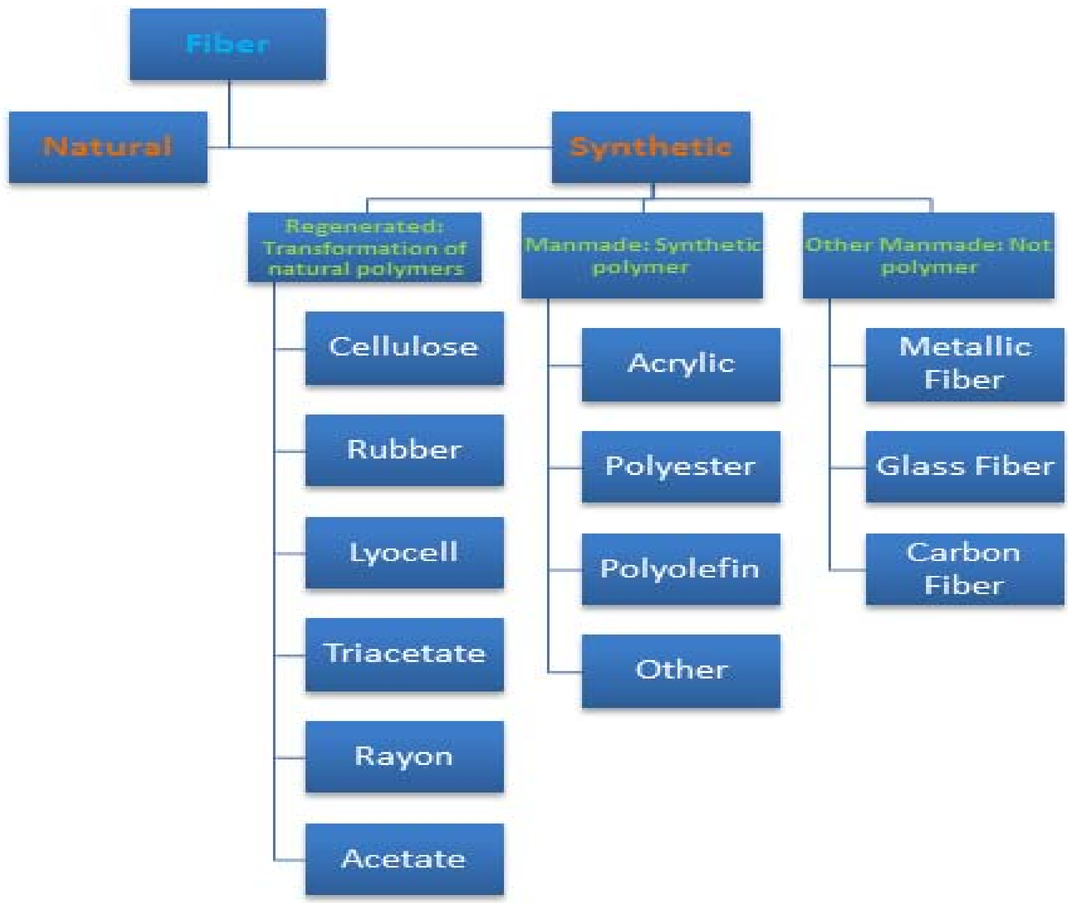

Figure 2.4 Synthetic Fiber

There are several advantages and disadvantages for synthetic fibers:

Advantages:

1- Strong: Synthetic fibers are strong so they can take up heavy things easily.
2- Retain their original shape: Synthetic fibers retain their original shape so it's easy to wash and wear.
3- Elastic: Can easily be stretched out.
4- Soft: Synthetic fibers are generally soft so they are used in clothing materials.
5- Color: Varieties of colors are available as they are manufactured.
6- Cost: Clothes made by synthetic fibers are generally cheaper than those made by natural fibers.

Disadvantages

1- Does not absorb moistures: Synthetic fibers do not absorb sweat, trapping heat in our body.
2- Rough feel: Synthetic fibers may give rough feel, making it unsuitable for pyjamas, underwear, etc.

2.2.3 GLASS FIBER

Concrete reinforced with fibers (which are usually steel, glass or ―plastic fibers) is less expensive than hand-tied rebar, while still increasing the tensile strength many times. Shape, dimension and length of fiber is important. A thin and short fiber, for example short hair-shaped glass fiber, will only be effective the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase the concrete tensile strength.(Gornale, Ibrahim Quadri, Mehmood Quadri, Md Akram Ali, & Shamsuddin Hussaini, 2012).

Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete.(Rao, Rakesh, & Narayana, 2013).

The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used verities of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement where AR-glass has improved alkali resistant characteristics.(Technology, 2013). Chemically, glass is silicon di-oxide (SiO_2) Glass fibers used for structural applications come in two types E-Glass and S-Glass. Glass Fiber has many Principal advantages such as Low cost and high strength. (Tiwari, 2015).

Table 2.1 Comparison of typical properties for some common fibers.

Materials	Density (g/cm^3)	Tensile Strength (MPa)	Young modulus (GPa)
E-Glass	2.55	2000	80
S-Glass	2.49	4750	89
Alumina (Saffil)	3.28	1950	297
Carbon	2.00	2900	525
Kevlar 29	1.44	2860	64
Kevlar 49	1.44	3750	136

(Technology, 2013)

The advantageous properties of E-glass generally outweigh the disadvantages which include:

- Low modulus
- Self-abrasiveness if not treated appropriately leading to reduced strength
- Relatively low fatigue resistance
- Higher density compared to carbon fibers and organic fibers.

2.3 METHOD TEST

2.3.1 WORKABILITY

The goal of a workability test should be to provide a standard measurement that evaluates the performance of a mix- true in the desired application. While the Slump Test ASTM C143 has been widely used as a specification to evaluate workability, it is not useful for mixtures with low flowability.(Cook, Ley, & Ghaeezadah, 2014).

2.3.2 COMPRESSIVE STRENGTH

Compressive strength is an important material property of concrete and is often related to the quality of the concrete. Compressive strength is commonly used in material specification as it can be easily tested and other properties of concrete can be correlated to the compressive strength. As such, most RAC studies have included the effects of RAC addition on the compressive strength of concrete.(Pickel, 2014)

2.3.3 FLEXURAL STRENGTH

The other term of flexural strength are bending strength, modulus of rupture or fracture strength. flexural strength provides two useful parameters, namely: “the first crack strength, which is primarily controlled by the matrix”, and “the ultimate flexural strength or modulus of rupture, which is determined by the maximum load that can be attained.(Harcourt, 2012) The flexural strength is one of the mechanical attributes of concrete. The flexural strength of concrete is needed to identify the maximum loads that the concrete can sustain at certain times. Theoretically, there are limits of concrete in receiving the loads apply before it yields or rupture. The flexural strength will be the same as tensile strength if the material used is standardized. The flexural strength is likewise recognized as the material’s ability to resist deformation under loads applied. The flexural strength is almost 10 to 20 % at the same as compressive strength that depending on type, size and volume of aggregates used in concrete production. Thus, the selection of aggregates is a vital in determining the strength of concrete. Generally, a beam is used to identify the strength of modulus of rupture. This is due beam will have a larger in size that make it easier to find the maximum point of stress and strain in beams compared to cube specimen. The max strain and stress also are calculated on the incremental load applied.

2.4 SUMMARY

The literature review has shown the vital effects in influence the good concrete production and has shown good properties of aggregates which come from construction waste. This is based on the previous studies that have been done for many waste materials as coarse aggregate. However, there are some materials that seem not suitable to be used as a coarse aggregate replacement. Keeping and increasing researches in managing and controlling the construction waste is a useful solution for environmental problems.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The research methodology involves a specific procedure in order to obtain knowledge on a certain parcel of reality. Different methods usually produce different results that may be compatible or contradictory. Work planning of systematic is so important to confirm that this work will be carried out with an organized and successful. The procedure adopted by this study is in progress to illustrate the overall process achieving the objective target involved in such project.

PHASE 1

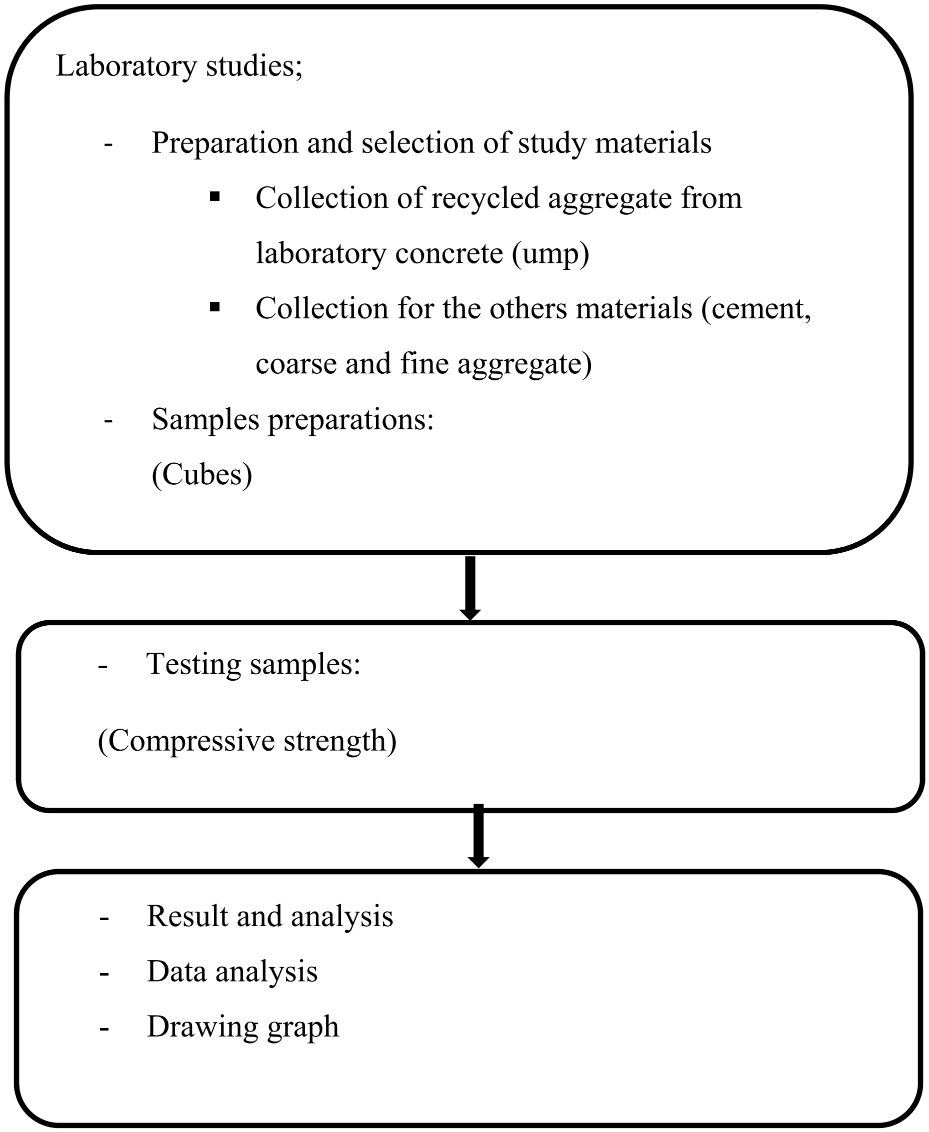

Figure 3.1 The flow chart of the research methodology (phase1)

This experiment was carried out through two phases. In the first phase, glass fiber was not used. However, there were 12 cubes to study the 28 days compressive strength of recycled aggregate concrete, three cubes for each percentage of recycled aggregate concrete (0%, 20%, 50% and 100%). After testing and 20% RAC was the best percentage which showed increasing in compressive strength, then that percentage will be considered in Phase 2.

PHASE 2

Laboratory studies;

- Preparation and selection of study materials
    - Collection of recycled aggregate from laboratory concrete (ump)
    - Collection for the others materials (cement, coarse, fine aggregate, and glass fiber)
- Samples preparations
- Cubes and beams

Testing samples

Compressive strength and flexural strength

- Result and analysis;
- Data analysis
- Drawing graph

Project presentations

Figure 3.2 The flow chart of the research methodology (phase2)

In the second phase, glass fiber will be used and mixed with recycled aggregate concrete, and there were 24 cubes and 24 beams to study the 7 and 28 days compressive and flexural strength of recycled aggregate concrete.

3.3 PREPARATION OF RECYCLED AGGREGATE FROM CONCRETE LAB

The preparation of recycled aggregate is the preliminary stage of the study, the used aggregate is taken from concrete lab. the concrete waste consists of used coarse and fine aggregate that mostly been gathered up from cubes after the concrete compressive strength tests performed from previous experiment students in laboratory lab concrete (UMP).

The aggregate concrete waste will be gathered to undergo a crushing process. The crushing machine used is crusher located at concrete lab. The machine is simply applied to crush the aggregate concrete waste into small aggregate, like the size of coarse aggregate required. In addition, during the crushing process, all materials have to be removed.

The next procedure is to crush the aggregate concrete chunks by using hand tools such as hammers. The crushing process is controlled to get the desired size of aggregates. In this research, the size of aggregates required for concrete mixing is between 14 to 20 mm. Moreover, for the separation size of every aggregate, the crushed aggregate concrete needs to be sieved analysis. The sieve analysis process is to accomplish the specific size of aggregate required. Finally, the aggregate should be washed to make sure that is clean from any other materials.

Figure 3.3 Crusher Machine

The crusher is a machine designed to reduce large rocks into smaller rocks, gravel, or rock dust as it shown in figure 3.3. Crushers may be used to reduce the size, or change the form, of waste.

Materials with primary and secondary crushers handling coarse materials, and tertiary and quaternary crushers reducing ore particles to finer gradations.

3.4 THE MATERIALS USED IN CONCRETE MIXING

The concrete mixing materials of this study will consist of cement, coarse aggregate, sand, water and glass fiber. However, utilize the materials in concrete mixing have to achieve the specific requirement to confirm that the concrete will be produce is according to the specifications and not fails. The precaution ought to be taken during mixing the materials which have to according to the ratio of materials provided according to the standard.

3.4.1 WATER

When water and cement is mixed, it forms a paste that coats and binds the aggregate particles together. Through a chemical process called hydration, the paste hardens and gains strength. The strength of the paste is determined by the applied ratio of water to cement. The quantity of water divided by the amount of cement gives the water to cement ratio. A low water to cement ratio leads to high strength but low workability while a high water to cement ratio produces a low strength concrete but good workability. A careful balance of cement to water is therefore required when preparing the mix. Water/cement ratios in the range between 0.4 and 0.6 provide a good workability without compromising the quality of the concrete. Hand-mixed and hand-placed concrete requires more water to secure sufficient workability (water/cement ratio between 0.5 and 0.65).(Moore, 2010)

3.4.2 CEMENT

Portland cements are hydraulic cements, meaning they react and harden chemically with the addition of water. Cement contains limestone, clay, cement rock and iron ore blended and heated to 1200 to 1500 C°. The resulting product "clinker" is then ground to the consistency of powder. Gypsum is added to control setting time.(Kourd & Hammad, 2010) Cement is the most costly of the ingredients required to produce concrete. This implies that in order to minimize the costs of the concrete, the amount of cement used depends on the purpose for which the concrete is required. Concrete grade for this experiment used M30 which contains one-part cement, one part fine aggregate and three parts of coarse aggregate. Moreover, maximum size of the cement particles is 0.09 mm and the average diameter of the particles are smaller than 0.045 mm.

3.4.3 COARSE AGGREGATE

For the coarse aggregate, the preparation process consists of two stages. The first stage involves the provision of natural aggregates that are often used for concrete mixing. The selection of the types of coarse aggregate is based on the accessibility of the aggregate at the lab. Coarse aggregate will be weighed till it get the required amount. Then, the coarse aggregate that has been weighed was piled in the lab in an open area. This procedure is done for drying process of coarse aggregate. This is very vital to ensure that the water content in the aggregate has been removed entirely because it can affect the strength of the concrete. Moreover, it is important to remove all the materials from coarse aggregate as wood and clay. Then, coarse aggregate must be strained to get the required size. The size of coarse aggregate is 14 to 20 mm. sieve analysis for coarse aggregate is so important procedure to separate each size of coarse aggregate and preserve the quality of coarse aggregate.

Figure 3.4 recycled aggregate concrete after sieve

Figure 3.4 illustrates the preparations of recycled aggregate concrete which has been recycled from concrete lab waste. However, the recycled aggregate concrete should pursure the same steps as natural aggregate for a drying process.

3.4.4 FINE AGGREGATE

The fine aggregate that will be used in concrete mixing is sand that passing the specification during the grading process. Usually the sand that is used consists of the type of not ground. Before mixing process, the sand needs to be heated for one day before the mixing is conducted that is to prevent a significant humidity in the sand and thus able to influence the water cement ratio content in the concrete mix.

For this research, the sand is select from laboratory availability that is sand from the river. The size of fine aggregate or sand must lower than 4.75 mm. fine aggregate is also required to adopt the same procedure as coarse aggregate that is sieve analysis to produce the required size.

3.4.5 GLASS FIBER

The samples of glass fiber will be prepared by cutting the samples in 25 mm in length. It will be added with amount 1% and 2% of total volume to concrete mix respectively.

3.5 PRE-MIXIING EXPERIMENTS

The concrete production process is done after all the materials for mixing are prepared. There are three stages in producing concrete sample such as:

3.5.1 MIXIING PROCESS

The mixing process is made by using a concrete mixer machine at the laboratory. By using concrete mixer the quality and ratio of materials can be controlled. Furthermore, the shorter time is necessitated for the merging process to be performed by using mixing machine. However, table 3.1 shows concrete mix design for all mix.

Table 3.1 concrete mix design

Materials (Kg/m³)	Sample A	Sample B	Sample C	Sample D
Cement	327	327	327	327
Coarse Aggregate	1024	1024	1024	1024
Sand	889	889	889	889
Water	190	190	190	190
W/C ratio	0.58	0.58	0.58	0.58
Glass Fiber	0	0	3.27	6.54

3.5.2 COMPACTING PROCESS

After the concrete mixed is ready, the next step was to pour the concrete into mould that has been set up in the lab. at the same time, compaction process needed to be performed as soon as the concrete casting made. The concrete compaction process consists of three layers where each layer must be compacted first. For every layer the concrete will be blow 35 times with tamping bar. After the compaction process is done, the surface of concrete was flattened.

3.5.3 CURING PROCESS

This process is the final stages in concrete production. Generally, curing process function is to ensure the hydration occur properly where humidity in the concrete can be prohibited. The curing process can only be performed after the concrete that has compacted after 24 hours at room temperature. Then, the concrete mold was removed the hardened concrete produce is added into the water tank. The hardened concrete was immersed in water for 7 and 28 days for curing. After the curing process completed according to the days required, then the concrete is ready for tested. The curing process is based on BS 1881-3:1970.

3.5.4 SAMPLE PRAPERATION

The sample consists of cubes and beams for concrete mixing. Table 3.2 shows the rate of replacement of coarse aggregate with recycled aggregate and glass fiber added to the mix in percent. The only flexural test will use beams as sample, while compressive test will used cube as sample.

3.6 TEST METHODS

In this study will include two tests, which is compressive strength and flexural strength test:

3.6.1 SLUMP TEST

Slump test is done to test in roughly the uniformity of concrete mixing to ensure it's not too melted and not too dry. However, in this test, is so sensitive in getting the different consistency of mixing. The most suitable concrete to be used is a concrete that have a higher and a medium workability during this test. The ideal height of slump test is approximately 75-+25 mm.

The equipment used in this test is a conical mold made from pieces of metal G16 and a steel rod with a diameter of 16 mm with a ruler. During the slump test process, there are three types of slump that can occur. The types of slump that will occur are true slump, rich slump and collapse slump. Figure 3.5 shows the types of slump occur.in every the conducted, there will be one of that slump that will occur.

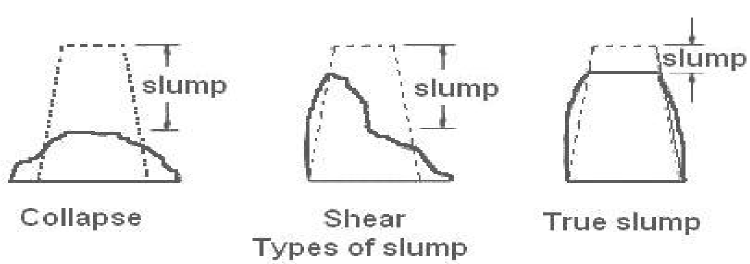

Figure 3.5 types of slump test

True slump shows a good workability of concrete and suitability for used. However, rich slump and collapse is showing that the concrete mixing experienced deficiencies in cohesive characteristics or the concrete is too wet. The slump test is conducted in accordance with BS1881: part 102:1983.

3.6.2 COMPRESSIVE STRENGTH TEST

The quality of good concrete will be identified through this test. Also, the value result of this test will be provided the overview of the bending, modulus of elasticity, durability, permeability and strength of tensile. For getting good concrete it is difficult to be permeable and can be exposed to severe exposure and also durability from wear out. In Figure 3.6, shows a machine utilized in compressive strength test. The test is accordance to BS EN 12390-3:2002. The cube size 100 mm x 100mm x 100 mm is used. The compressive strength test is used to get the value, compressive strength of hardened concrete at specific an age that is (28) days for phase1 and (7 and 28) days for phase2. Therefore, the total of 36 samples of cubes is prepared for each proportion replacement of recycled aggregate concrete. a cube sample is inserted in the middle of the machine and a metal plate is placed above the cube sample that is between the cube and the surface of the applied load.

It is important to make sure that the surface of cube sample is smooth before the test is conducted. The reading value shows in the digital meter are recorded and it will give the value of the maximum load can be sustained by the sample cube concrete before it fails. The compressive strength is expressed in MPa $\left(\frac{N}{mm^2}\right)$ and the load value is recorded and the compressive strength can be calculated by the following formula:

$$\text{Compressive strength} = \frac{maximum\ load(N)}{surface\ areao\ fcube(mm^2)} \qquad \text{Equation (1)}$$

Figure 3.6 Compressive Strength Machine

Figure 3.6 shown a compressive testing machine, also known as materials testing machine or materials test frame which used to test the tensile strength and compressive strength of materials.

3.6.3 FLEXURAL STRENGTH TEST

Flexural strength is known as modulus of rupture. The modulus of rupture of beam is identified the fails to occur in the tension part. Moreover, it measures the tensile strength of concrete and measure of a beam to resist failure in bending. It is measured by loading concrete beams with a span length at least 3 times of depth. This test also includes the use of beams sample size 500 mmx 100 mmx 100mm, this test, the four points loading method are utilized and it is determined by British standard(1881:part118:1983). the formula for the flexural strength is: modulus of rupture, $\sigma = \frac{FL}{bd^2}$ Equation (2)

Where

F= maximum applied load

L= beam length (500mm)

b=beam width (100mm)

d=beam depth (100mm)

Figure 3.7 Flexural Strength Machine

Figure 3.7 shown a flexural testing machine which designed to test the flexural strength of concrete beams. Its design provides maximum rigidity throughout their working range as the downward movement of the piston applies load.

CHAPTER 4

RESULTS AND ANAYSIS

4.1 INTRODUCTION

The results on physical properties of recycle aggregate concrete as coarse aggregate replacement and glass fiber as cement replacement, so both are presented in this chapter. In this study, two series of mix formulation were prepared comprises of 1 % and 2 % of glass fiber. A RAC were conducted as a control mix. For each series of formulation, the tests conducted were comprises of slump test to determine the workability of RAC with glass fiber and compression test to obtained the compressive strength of hardened RAC with glass fiber. In addition, flexural test to obtain the flexural strength of hardened RAC with glass fiber and the proper percentages for RCA itself were also investigated.

4.2 RESULTS ON COMPRESSIVE STRENGTH OF REPLACEMENT PERCENTAGE OF RAC

The values of compressive strength of recycled concretes aggregates, with different replacement percentages of coarse recycled aggregates and strength variations of concrete mixes in relation to reference concrete

Table 4.1 Result of Replacement Percentage of RAC

		Compressive strength Nlmm²			
Specimen	Percentage of RAC %	Sample 1	Sample 2	Sample 3	Average
A	0 %	45.15	44.81	46.17	45.38
B	20 %	42.72	43.23	44.51	43.49
C	50 %	40.31	39.93	41.03	40.42
D	100 %	36.67	40.82	38.56	38.68

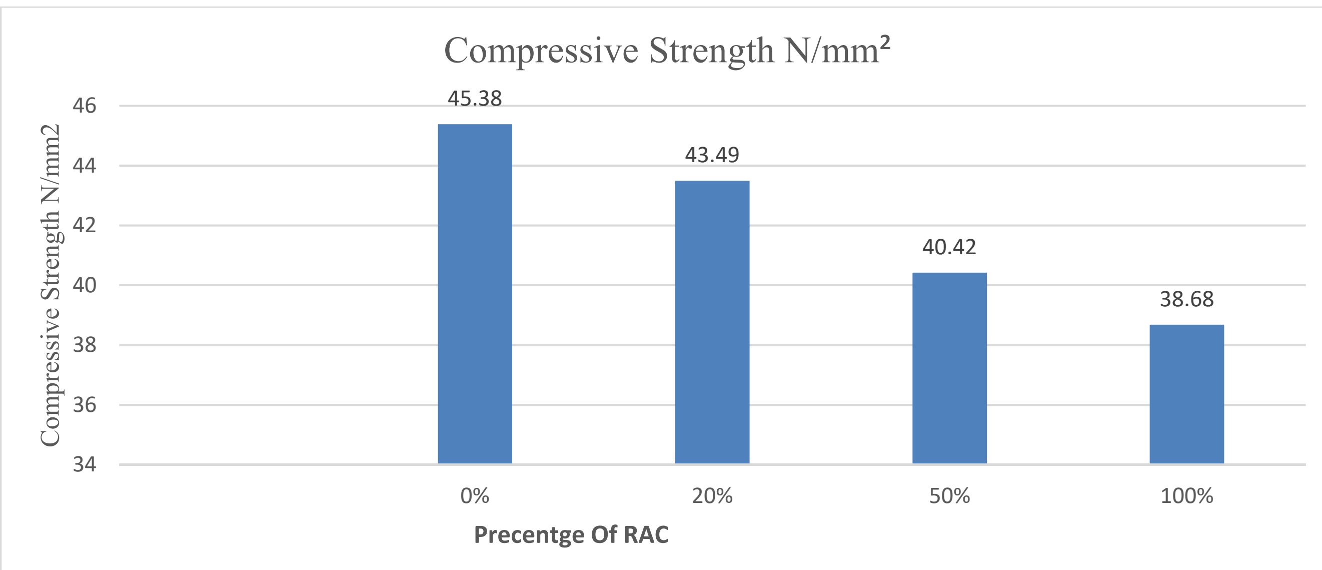

Figure 4.1 Compressive Strength of Replacement Percentage of RAC

The compressive strength of recycled aggregates concrete is lower than those of the control concrete 45.38 N/mm². The highest value of compressive strength for RAC is 43.49 N/mm². Also, it shown that, the physical characteristics of particles recycled aggregate concrete itself are suitable for used as aggregate. However, the proper percentage of RAC is 20% and the water absorption for particles RAC is too high.

4.3 RESULTS ON WORKABILITY OF RECYCLE AGGREGATE CONCRETE WITH GLASS FIBER

In this present study, the physical properties of recycle aggregate concrete (RAC) with replacement of different percentage of glass fiber were investigated. Two different percentage of glass fiber namely 1% and 2% as partial replacement of cement. In order to analyze the workability of this concrete, slump test is conducted. The control mix is RAC with 0% glass fiber is named RAC0. In addition, the second and third mix are named RAC1, RAC2 respectively, where RAC1 contains 1% glass fiber and RAC2 contains 2% glass fiber of total cement weight.

4.3.1 RESULTS ON SLUMP TEST OF RECYCLE AGGREGATE CONCRETE WITH GLASS FIBER

In this study, two volumes percentages of glass fiber were conducted 1% and 2% as partial replacement of cement. Table 4.2 shows the results of slump test of fresh RAC with different percentage of glass fiber. The control mix is RAC with 0% glass fiber is named RAC0.

Table 4.2 Slump Test Result for RAC with different percentage of Glass Fiber

RAC with different percentage of glass fiber as cement partial replacement (%)	Slump (mm)	Type of Slump
RAC0	37	True
RAC1	32	True
RAC2	29	True

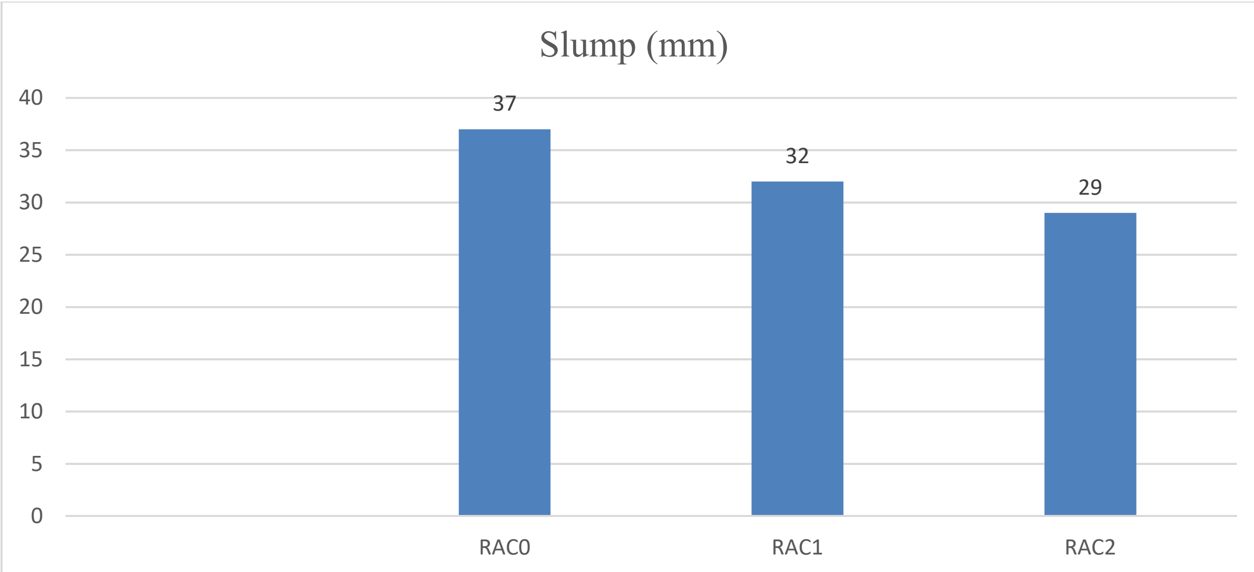

Figure 4.2 Slump Test Result for RAC with different percentage of Glass Fiber

Generally, slump test indicates the behavior of a compacted concrete cone under gravitational force. It is essentially is a measure of consistency or the wetness of the mix. According to data on slump, it was displayed that the addition of glass fiber decreases the workability of concrete as it showed in Figure 4.2 and slump for RAC0, RAC1 and RAC2 as true slump. This due to the balling or clumps of glass fiber in the mix, so this phenomenon known as "balling," is normally avoided by shaking the fibers into the mix through some equipment after all the other ingredients have been added.

Figure 4.3 Slump Test

Figure 4.3 shown the slump after adding glass fiber in the fresh concrete mix. The slump is true due to the existence of glass fiber since it does not bind well with other materials causes balling. Besides, glass fiber absorbs more water which a similar property of RAC.

4.4 COMPRESSIVE STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH GLASS FIBER

In this study, hardened recycle aggregate concrete (RAC) was designed with different percentage of glass fiber namely 1 % and 2 % of total cement weight. Recycle aggregate concrete with 0% of glass fiber RAC0 was prepared as control mix. All the specimens were tested using the compression machine in accordance to the ASTM Specification C 39-3. The effect of using different percentage of glass fiber to compressive strength of RAC will be discussed in this present section.

4.4.1 COMPRESSIVE STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH 0% GLASS FIBER

Table 4.3 and Figure 4.4 displayed the compressive strength of recycle aggregate concrete. From the experimental result, the strength developments of compressive strength of RAC0 at different days were analyzed.

Table 4.3 Compressive Strength of RAC0

Days / Cubes	Compressive Strength (N/mm^2)			
	Sample 1	Sample 2	Sample 3	Average
7	23.88	23.17	24.99	24.01
28	35.71	34.08	34.62	34.80

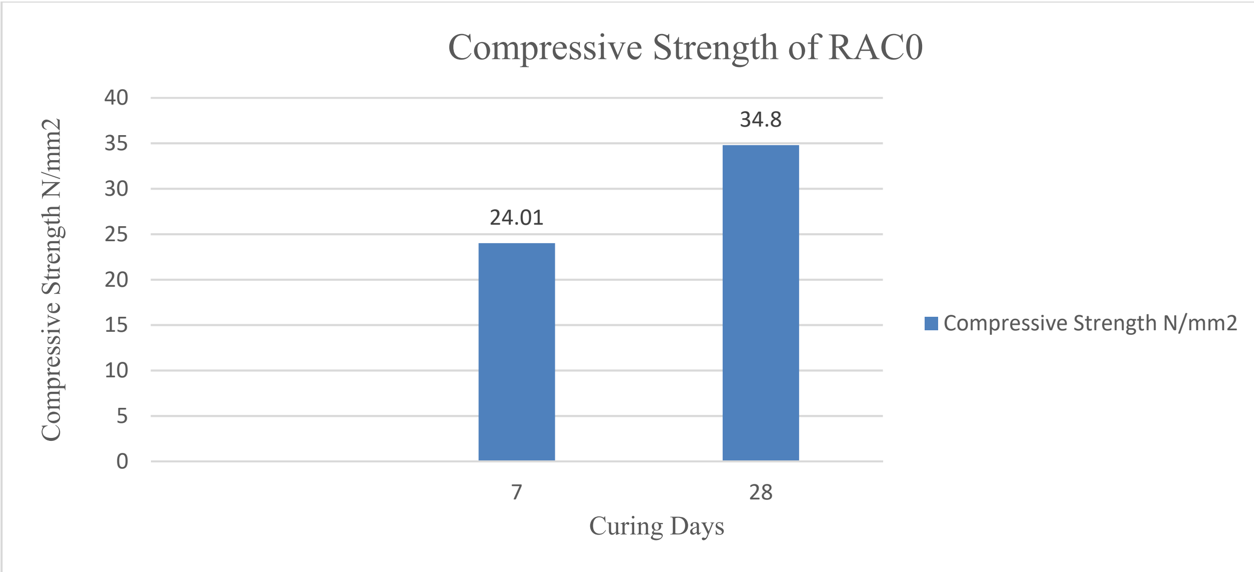

Figure 4.4 Compressive Strength of Recycle Aggregate Concrete with 0% glass fiber

According to the result, it was illustrated that compressive strength of the RAC were increases while days curing day for 7 and 28 days increased. It was inclined that the compressive strength increased about 31% when RAC0 curing at 28 days compared to 7 days. It was showed that the RAC0 without replacement of glass fiber at 28 days obtain highest strength. This is due to Concrete gains strength with time after casting. It takes much time for concrete to gain 100% strength and the time for same is still unknown. The rate of gain of concrete compressive strength is higher during the first 28 days of casting and then it slows down. So, it's almost close to its final strength, thus we rely upon the results of compressive strength test after 28 days.

4.4.2 COMPRESSIVE STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH 1% GLASS FIBER

To determine if there were differences in the compressive strength for the different types of curing days, it was illustrated in Table 4.4 and figure 4.5. According to the result, the strength was gained after RAC1 tested at 7 and 28 days. Three samples were prepared for each day to get the precise value.

Table 4.4 Compressive Strength of RAC1

Days / Cubes	Compressive Strength (N/mm²)			
	Sample 1	Sample 2	Sample 3	Average
7	26.42	23.89	25.53	25.28
28	34.35	35.08	36.38	35.27

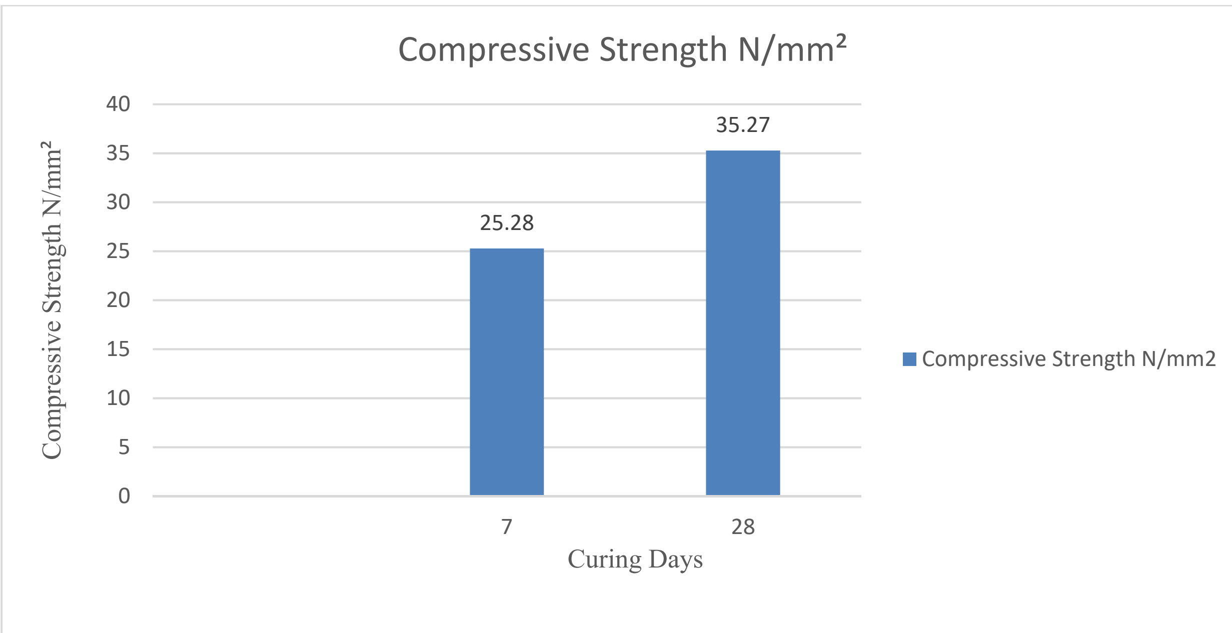

Figure 4.5 Compressive Strength of Recycle Aggregate Concrete with 1% glass fiber

According to the result obtained, it was indicated that compressive strength of the RAC1 was increased with increases in a day of curing. It was displayed that the minimum compressive strength of RAC1 is 25.28MPa and the highest compressive strength is 35.27MPa. It was inclined that the compressive strength increased about 28.32% when RAC1 curing at 28 days compared to 7 days. This due to properties of glass fiber which helps to resist the load and transfer it from one to the other.

4.4.3 COMPRESSIVE STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH 2% GLASS FIBER

Table 4.5 and figure 4.6 illustrate if there were differences in the compressive strength for the different types of curing days. According to the result, the strength was gained after RAC2 tested at 7 and 28 days. Three samples were prepared for each day to get the precise value.

Table 4.5 Compressive Strength of RAC2

Days / Cubes	Compressive Strength (N/mm²)			
	Sample 1	Sample 2	Sample 3	Average
7	26.01	27.19	24.82	26.01
28	35.26	36.98	35.13	35.79

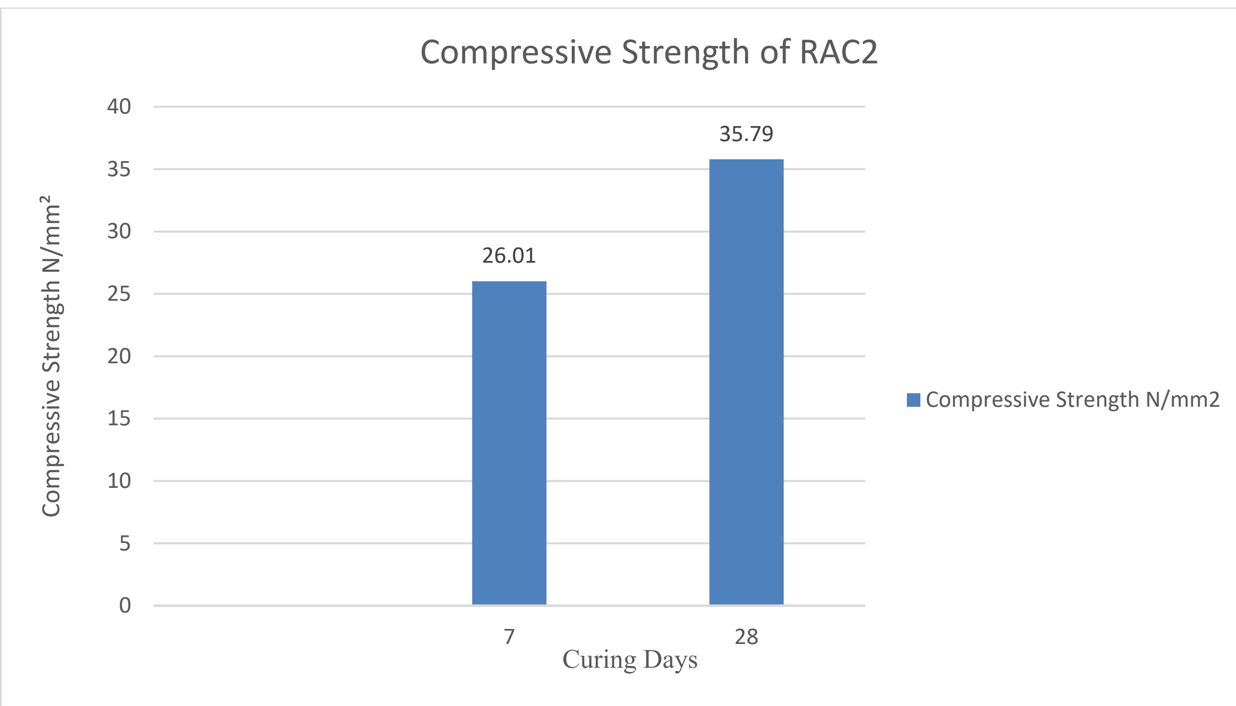

Figure 4.6 Compressive Strength of Recycle Aggregate Concrete with 2% glass fiber

It indicated that the compressive strength is increased with an increase subjected to different type of curing duration according to the result obtained. It was displayed that the highest compressive strength is at 28 days which value 35.79 MPa. It was inclined that the compressive strength increased about 27.32% when RAC2 curing at 28 days compared to 7 days. This due to properties of glass fiber which helps to resist the load and transfer it from one to the other.

4.4.4 COMPARISON OF COMPRESSIVE STRENGTH BETWEEN RECYCLE AGGREGATE CONCRETE WITH DIFFERENT PERCENTAGE OF GLASS FIBER NAMELY 1% AND 2%

The comparison of RAC with different percentage of glass fiber namely 1% and 2% of total cement weight were shown in table 4.6. Plain recycle aggregate concrete act as control mix. The data obtained were used to plot the bar chart as shown in Figure 4.7. The relationship between compressive strength and different percentage of glass fiber were analyzed to determine if there were differences in mean compressive strength among the different curing days.

Table 4.6 Compressive Strength of RAC0, RAC1 and RAC2

Days / Cubes	Compressive Strength (N/mm^2)		
	RAC 0%GF	RAC 1%GF	RAC 2%GF
7	24.01	25.28	26.01
28	34.8	35.27	35.79

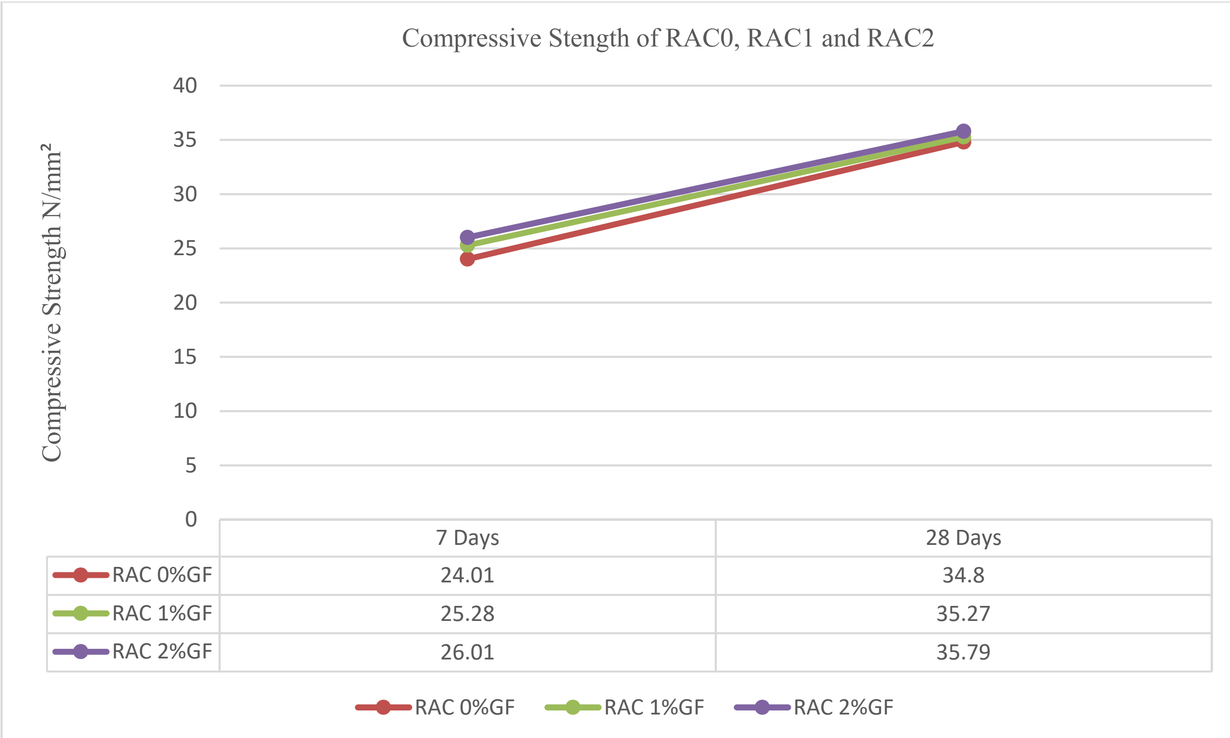

Figure 4.7 Comparison of Compressive Strength between RAC0, RAC1 and RAC2

According to the result obtained, it was showed that the compressive strength increases with an increase in curing days. RAC without replacement of glass fiber achieved the required compressive strength after 28 days. The strength for both RAC with 1% and 2% glass fiber was also increasing with curing age.

RAC0 also achieved highest strength of 34.8 MPa. However, the compressive strength for recycle aggregate concrete was increased with increasing percentage of glass fiber. For 7 days curing period, the compressive strength of RAC1 and RAC2 was in range of 5.02% to 7.69 % compared to plain RAC0. Meanwhile, the compressive strength for 28 days of curing was within range of 1.33 % to 2.78% compared to plain RAC0.

The addition of glass fibers into the concrete mixture marginally improves the compressive strength at 7 and 28 days. It is observed from the experimental results, that the compressive strength of concrete increases with addition of Percentage of glass fibers. The 1% and 2% of glass fiber as partial replacement of cement shows better result in mechanical properties. The concrete mix binds the fibers together and helps transfer loads from one fiber to another. Without glass fiber would not possess its strength and would be more prone to breakage and cracking.

4.5 FLEXURAL STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH GLASS FIBER

The main objective of this section is to investigate the performance of recycle aggregate concrete with a different percentages proportion of glass fibers 1% and 2% as partial replacement of cement. Recycle aggregate concrete with 0% of glass fiber RAC0 was prepared as control mix.

4.5.1 FLEXURAL STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH 0% GLASS FIBER

Table 4.7 and Figure 4.8 displayed the flexural strength of recycle aggregate concrete. From the experimental result, the strength developments of flexural strength of recycle aggregate concrete at different days were analyzed.

Table 4.7 Flexural strength of RAC0

Days / Cubes	Flexural Strength (N/mm^2)			
	Sample 1	Sample 2	Sample 3	Average
7	3.10	3.23	3.25	3.19
28	6.07	5.79	5.88	5.91

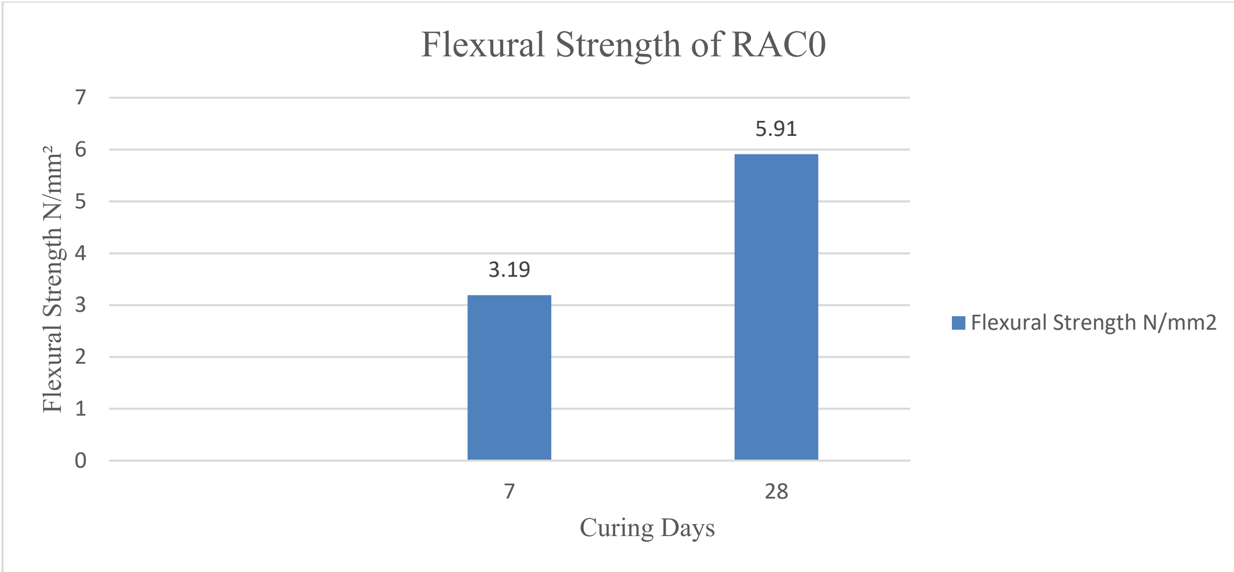

Figure 4.8 Flexural strength of Recycle Aggregate Concrete with 0% glass fiber

According to the result, it was illustrated that Flexural strength of the RAC were increases while days curing day for 7 and 28 days increased. It was inclined that the Flexural strength increased about 46% when RAC curing at 28 days compared to 7 days. It was showed that the RAC0 without replacement of glass fiber at 28 days obtain highest strength. This is due to Concrete gains strength with time after casting. It takes much time for concrete to gain 100% strength and the time for same is still unknown. The rate of gain of concrete flexural strength is higher during the first 28 days of casting and then it slows down. So, it's almost close to its final strength, thus we rely upon the results of flexural strength test after 28 days.

4.5.2 FLEXURAL STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH 1% GLASS FIBER

To determine if there were differences in the Flexural strength for the different types of curing days, it was illustrated in Table 4.8 and figure 4.9 According to the result, the strength was gained after RAC1 tested at 7 and 28 days. Three samples were prepared for each day to get the precise value.

Table 4.8 Flexural Strength of RAC1

Days / Cubes	Flexural Strength (N/mm²)			
	Sample 1	Sample 2	Sample 3	Average
7	3.41	3.32	3.11	3.28
28	6.51	6.19	6.29	6.33

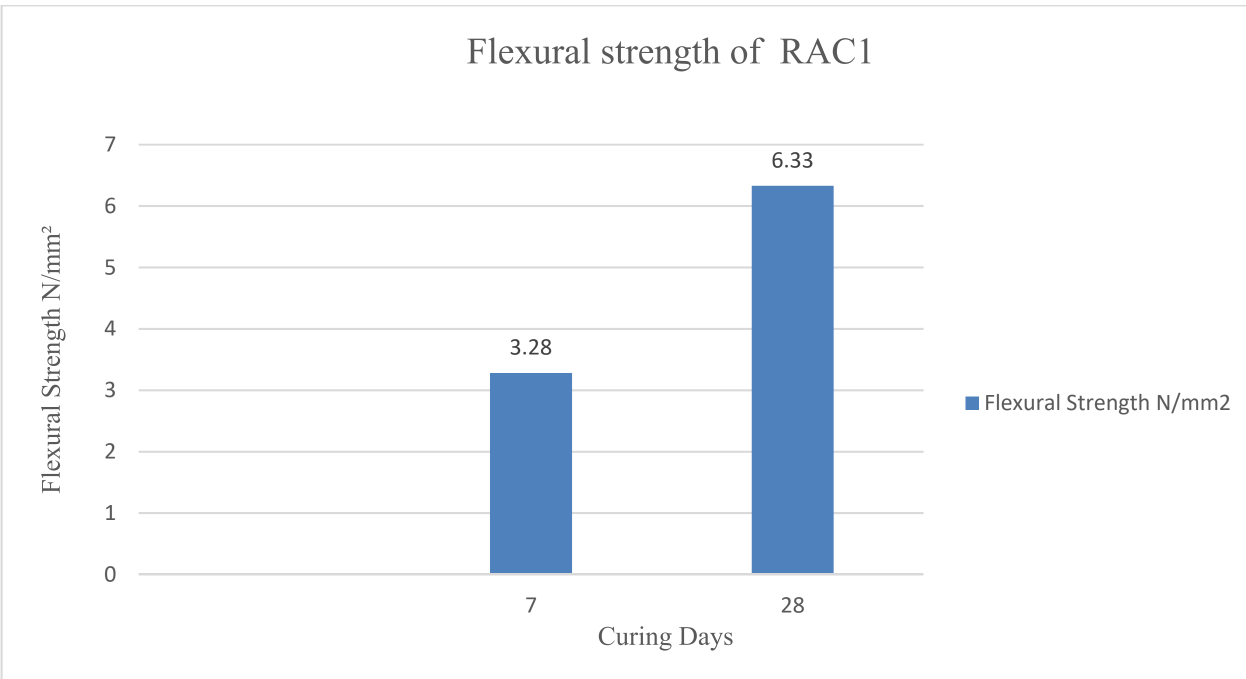

Figure 4.9 Flexural strength of Recycle Aggregate Concrete with 1% glass fiber

According to the result obtained, it was indicated that Flexural strength of the RAC1 was increased with increases in a day of curing. It was displayed that the minimum Flexural strength of RAC1 is 3.28MPa and the highest strength value is 6.33MPa. It was inclined that the Flexural strength increased about 48.18% when RAC1 curing at 28 days compared to 7 days. This due to the glass fiber strength under compressive loads is high. And the fiber orientation determines the effectiveness of fiber resistance to loads.

4.5.3 FLEXURAL STRENGTH OF RECYCLE AGGREGATE CONCRETE WITH 2% GLASS FIBER

Table 4.9 and figure 4.10 illustrate if there were differences in the flexural strength for the different types of curing days. According to the result, the strength was gained after RAC2 tested at 7 and 28 days. Three samples were prepared for each day to get the precise value.

Table 4.9 Flexural strength of RAC2

Days / Cubes	Flexural Strength (N/mm²)			
	Sample 1	Sample 2	Sample 3	Average
7	3.38	3.53	3.22	3.37
28	6.50	6.79	6.48	6.59

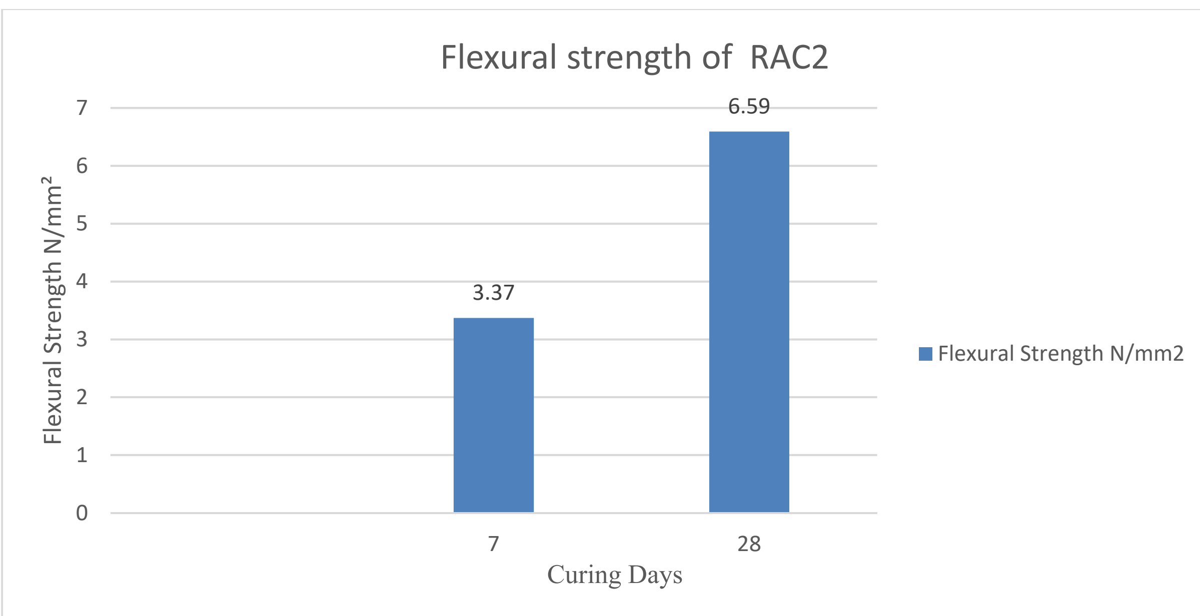

Figure 4.10 Flexural strength of Recycle Aggregate Concrete with 2% glass fiber

It indicated that the Flexural strength is increased with an increase subjected to different type of curing duration according to the result obtained. It was displayed that; the highest

Flexural strength is at 28 days which value 6.59 MPa. It was inclined that the Flexural strength increased about 48.86% when RAC2 curing at 28 days compared to 7 days. The reason of increasing strength is that the glass fiber strength under compressive loads is high. These materials also possess great tensile and flexural strength. The fiber orientation determines the effectiveness of fiber resistance to loads.

4.5.4 COMPARISON OF FLEXURAL STRENGTH BETWEEN RECYCLE AGGREGATE CONCRETE WITH DIFFERENT PERCENTAGE OF GLASS FIBER NAMELY 1% AND 2%

The comparison of RAC with different percentage of glass fiber namely 1% and 2% were shown in table 4.10 Plain recycle aggregate concrete act as control mix. The data obtained were used to plot the bar chart as shown in Figure 4.11 The relationship between Flexural strength and different percentage of glass fiber were analyzed to determine if there were differences in mean Flexural strength among the different curing days.

Table 4.10 Flexural strength of RAC0, RAC1 and RAC2

Days / Cubes	Flexural Strength (N/mm^2)		
	RAC 0%GF	RAC 1%GF	RAC 2%GF
7	3.19	3.28	3.37
28	5.91	6.33	6.59

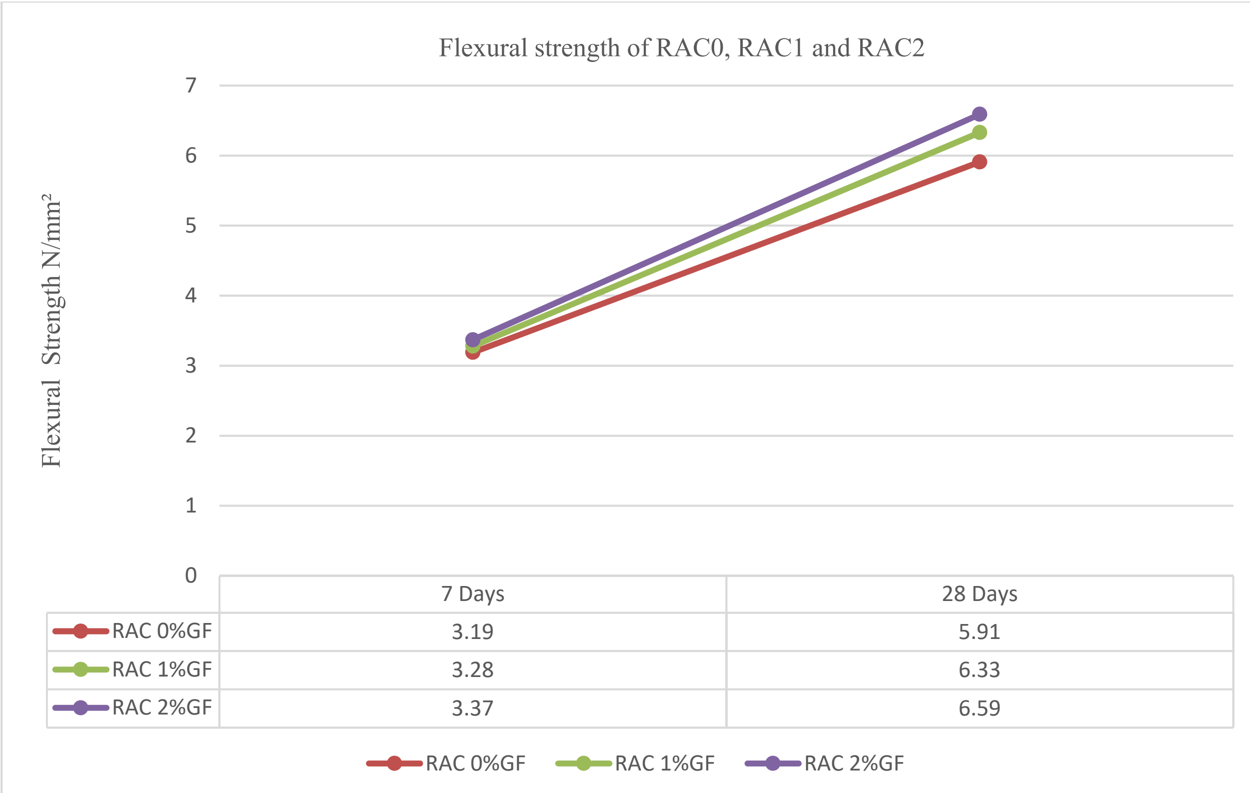

Figure 4.11 Flexural of Strength between RAC0, RAC1 and RAC2

According to the result obtained, it was showed that the Flexural strength increases with an increase in curing days. RAC without replacement of glass fiber achieved the required Flexural strength after 28 days. The strength for both RAC with 1% and 2% glass fiber was also increasing with curing age.

RAC0 also achieved highest strength of 5.91 MPa. However, the Flexural strength for RAC was increased with increasing percentage of glass fiber. For 7 days curing period, the Flexural strength of RAC1 and RAC2 was in range of 2.74 % to 5.34 % compared to plain RAC0. Meanwhile, The Flexural strength for 28 days of curing was within range of 6.64 % to 10.32 compared to plain RAC0.

The addition of glass fibers into the concrete mixture marginally improves the Flexural strength at 7 and 28 days. It is observed from the experimental results, that the compressive strength of concrete increases with addition of Percentage of glass fibers. The 1% and 2% of glass fiber as partial replacement of cement shows better result in mechanical properties due to glass fiber resistance to impact load and cracking.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The objectives of the study were to investigate the effect of RAC with glass fiber on concrete properties. The samples were subjected to same curing periods tested and undergo compressive strength test and flexural strength test.

The following conclusions can be drawn from the results obtained.

i. It shown that, the physical characteristics of RAC itself are suitable for used as aggregate. However, the proper percentage of RAC is 20%.
ii. Result on workability of fresh concrete indicated that the replacement of glass fiber in RAC was significantly affected the workability compared to RAC without glass fiber.
iii. According to the compressive test, the strength of RAC increased with replacement of 1% and 2% by total weight of cement with glass fiber. It showed that plain RAC0 achieved the lowest strength at 7 and 28 days of curing days.
iv. According to the flexural test, the strength of RAC increased with replacement of 1% and 2% by total weight of cement with glass fiber. It showed that plain RAC0 achieved the lowest strength at 7 and 28 days of curing days.

5.2 RECOMMENDATION

Utilization of both recycled aggregate concrete and glass fiber bring new outcome for concrete technology. However, this research can be improved by doing detail study about this concrete in the future. Below are some suggested recommendations for further study in the future.

i. Increase the percentage of glass fiber replacement in this type of concrete since one of the factors that give strength is coarse aggregate. If the percentage of glass fiber that being proposed to replaced coarse aggregate is increased, it will give a better and strong specimen.
ii. Further investigations on the characteristics of the recycled aggregate should be carried out such as in terms of density, shape and texture of the recycle aggregate.
iii. Investigate the glass fiber properties in terms of durability and density after certain duration in concrete.
iv. Add some water to the RAC with glass fiber in order to obtain the same workability as RAC without glass fiber or use superplasticizers in the concrete mixture.

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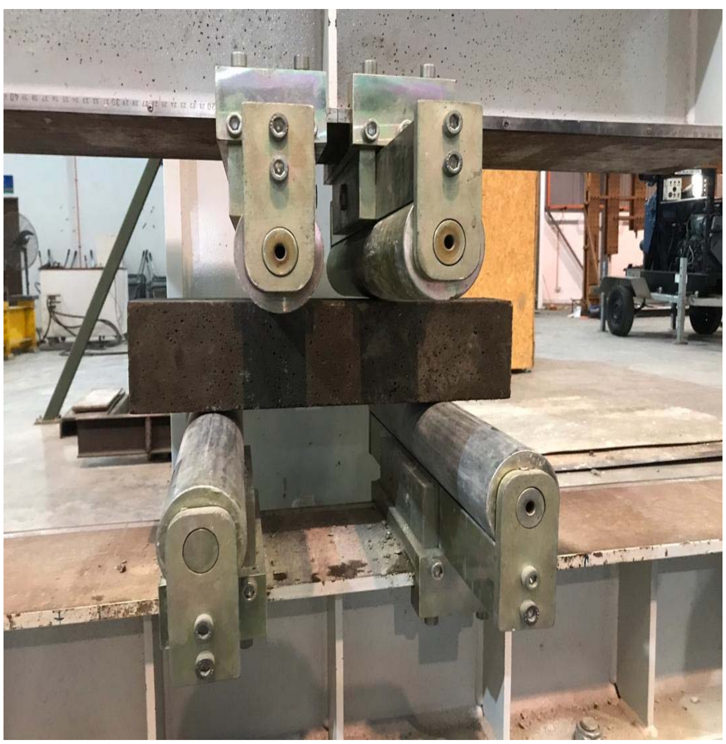
APPENDEX A: SAMPLES DURING FLEXURAL TEST AND COPMRESSIVE TEST



SAMPLES DURING COPMRESSIVE TEST AND FLEXURAL TEST

APPENDEX B: SAMPLES AFTER FLEXURAL TEST AND COPMRESSIVE TEST

SAMPLES AFTER FLEXURAL TEST AND COPMRESSIVE TEST