# BEHAVIOUR OF KENAF FIBER REINFORCED CONCRETE



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## ABSTRACT

*Hibiscus cannabinus* L as known as kenaf is one of the natural fibers that having many advantages such as lightweight, no corrosion andf low cost as alternative reinforcement for reinforced concrete beam. The using of natural fiber in construction fields will improve the promotion of green building materials kenaf fiber is as an alternative to use in concrete structure. The purpose of this research is to study the kenaf fiber of reinforced concrete beam in term of flexural and compression strength with main bar and without main bar added with kenaf fibers. Other than that, this research is to study the effect of amount of kenaf fibers added to the concrete in term of strength, cracking pattern and deflection. The compressive strength test was conducted on the different type of concrete mix. This study was implemented to do the comparison between a normal concrete to the different amount of kenaf fibers. A 3 point bending test also was conducted for beam with main bar and without main bar to determine the flexural strength, deflection and crack pattern. From the flexural test result the beam contain 30kg/m$^3$ give the close result to control beam. As conclusion, the amount of kenaf below than 30kg/m$^3$ can give some improvement on flexural strength of reinforced concrete beam.

# ABSTRAK

Hibiscus cannbinus L dikenali juga sebagai Kenaf adalah tumbuhan semula jadi yang mempunyai banyak kelebihan sebagai contoh ringan, tidak karat and harga murah dan ianya boleh dijadikan sebagai peneguh luaran dalam *konkrit rasuk bertulang. Penggunaan besi tetualang sekarang in mempunyai* peningkatan harga berpunca daripada kekurangan pengeluaran. Kajian ini sebagai jalan alternatif untuk mengurangkan penggunaan besi bertetualang dalam konkrit rasuk bertetualang. Kepentingan kajian ini adalah untuk mengkaji gentian kenaf dalam konkrit rasuk bertetulang dalam bentuk kekuatanan mampatan dan kekuatan lenturan dengan adanya besi dan tiada besi didalam rasuk konkrit. Tujuan lain ialah untuk mengkaji tentang kesan dari jumlah gentian kenaf dalam konkrit dalam bentuk kekuatan, bentuk keretakan dan pesongan. Ujian kekuatan mampatan dijalankan dengan perbezaan jenis campuran konkrit. Ujian ini dilaksanakan untuk membuat perbandingan antara konkrit biasa dan konkrit ditambah dengan gentian kenaf. Ujian 3 titik bengkokan juga dijalankan pada rasuk yang mempunyai besi dan tidak mempunyai besi untuk mengkaji kekuatan lenturan, pesongan dan bentuk keretakan. Daripada hasil ujian lenturan mendapati rasuk yang mempunyai 30kg/m$^3$ mengikut rapat rasuk biasa. Kesimpulannya jumlah kenaf bawah 30kg/m$^3$ boleh memberi peningkatan pada kekuatan lenturan dalam rasuk konkrit bertetulang.

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# ABBREVIATIONS

| | |
|---|---|
| ASTM | American Society for Testing and Materials |
| KFCB 30 | Kenaf fiber reinforced concrete with 30 kg/m$^3$ |
| KFCB 60 | Kenaf fiber reinforced concrete with 60kg/m$^3$ |
| NC | Normal Concrete |
| UMP | University Malaysia Pahang |
| LVDT | Linear Variable Displacement Transducer |

# CHAPTER 1

# INTRODUCTION

## 1.1 GENERAL

The research development of material like concrete in civil engineering have been widely expend throughout the years. The purpose of having this research is to find result in which the most important aspect are considered, financial constraint, environmental compatibility and availability. Concrete is mainly use in construction fields. It is contain a composite including course aggregate, fine aggregate, cement and water. According to cement and concrete institute, the characteristic of concrete it tends to be brittle and stronger in compression but having weakness in tension. Therefore, it can be modified by adding the fiber to obtain the higher strength of the concrete compare to normal concrete.

Fiber reinforced concrete may be defined as the concrete contain fibrous material which increases its structural integrity (Huzaifa, 2008). The needs to use fiber in the concrete is to be able sustain load at deflection, increase the toughness and strength. In addition, some fiber reduces the strength of concrete and some fiber provides greater impact, abrasion and shatter resistance in concrete. It is depend on the type of fiber. Many types of fiber can be used such as steel, glass, synthetic and natural fibers. Natural fibers have the potential to improve the usage of material related to environmental friendly.

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

Kenaf is one of the most generally used natural fibers in the concrete mix. Currently, there are many new usage of kenaf including building material, absorbents, animal feeds and paper product. Kenaf has a good in mechanical properties and can grow very quick, rising with height of 4-5 m in within 4-5 month growing season and the diameter is around 25-35mm regarding to Li Y (2006). Furthermore, kenaf have two components which are bast and core fibers. According to A. Elsaid (2010), advantages of natural fibers include increased toughness, enhanced cracking behavior, enhanced durability and improved fatigue.

. A part from these, the implementation of additive the kenaf fibers in concrete mixture will enhance the reducing of the durability in term of propagation of the concrete crack. The potential of kenaf fibers to enhance the increasing the strength of the concrete can be proved by Shuhada (2011) by using kenaf fiber added in the beam structure can obtain the higher ultimate load compare to control beam. From that, gaining higher ultimate load is the main focus to improve the strength of the concrete with kenaf fibers. Indirectly will increase the flexural and compressive strength and reduce the deflection of the beam.

## 1.2 PROBLEM STATEMENT

Natural fiber are related to the concept of sustainable building that use the green building material in design and construction fields.( Roodman and Lenssen1995) mentioned the activities of building and construction consume 3 billion tons of raw materials for one year or 40 percent from the total use by people worldwide. It will be a matter for the development of building due to the reduction of material sources followed by years. A part form these, other alternative can be used to solve the problem involved by using the green material in the design of the building.

Green building material is a renewable material. The effect of using green material is it can reduce the environmental impact associated with the pollution and internationally promotes conservation of dwindling nonrenewable resources. Kenaf fibers are one the natural fibers that can be promote as green building material in the structure design. Capability of kenaf fibers to be tested by adding with reinforced concrete beams. The potential of kenaf fiber as an alternative medium to replace

conventional materials or synthetic fibers as reinforcement in composite have been studied by H M Akil (2011).

## 1.3 OBJECTIVES OF STUDY

The objectives of these studies are:

1. To study the strength of compressive and flexural of reinforced concrete beam added with kenaf fibers.
2. To study the effect of amount of kenaf fibers added to the concrete in term of strength, cracking pattern and deflection.

## 1.4 SCOPE OF RESEARCH

The scope of this research is as follows:-

1. The beam size considered is 150mm x 150mmx 1000mm.
2. The cube size considered is 150mm x 150mm x 150mm.
3. The fibers used are kenaf MR fibers with diameter at range of 0.1 - 2.5mm and length of 30mm.
4. No stirrup will be provided for reinforced concrete beam.
5. Diameter of reinforcement bar is 8mm.
6. Using formwork for beam and plastic moulds for cube sample.
7. The total samples for beam is six which three for main bar and three without main bar.
8. The total samples for cubes is eighteen which six samples for each concrete mix and three cube samples is testing for 7 days and remain is testing for 28days.
9. The concrete mix consists of three different designs mix; first mix is for normal concrete, second mix is concrete added with 30kg/m$^3$ and third mix is concrete added with 30kg/m$^3$.
10. The location of the research will be held in concrete laboratory, University Malaysia Pahang (UMP).

11. The testing related to the research are slump test, compressive strength test and flexural test.

## 1.5 EXPECTED OUTCOME

The expected outcome form these studies are:

1. Kenaf fibers concrete mixture will be more strength in flexural strength
2. The potential of Kenaf fibers to enhance the delay cracking.
3. The used of Kenaf fibers to promote as a green building materials.

## 1.6 METHODOLOGY

This research is started with first stages which are preparing the samples such as making formwork, preparing the main reinforcement bars, cutting kenaf. Second stage is casting the concrete including three type of concrete and curing for 7 days and 28days. Third stages are testing the samples which are slump test, compression test and flexural test. Final stages are analysing the result and come out with data and graph.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

Concrete mix is containing of aggregates, Portland cement, and water, and many contain other cementations materials and/or chemical admixtures. It will contain purposely entrained air obtained by use of admixture or air-entraining cement and some amount of entrapped air. Chemical admixtures such as super plasticizers are functionally used to accelerate, improve workability, reduce mixing water requirements, increase strength, retard or alter other properties of the concrete. The calculation of concrete proportions involves a balance between economy and requirements of place ability, strength, durability, density, and appearance. Concrete proportions must be calculated to gain workability, consistency, density, strength, and durability, for the particular application.

The nature of concrete is it has higher compressive strength, low thermal, stiffness, low toxic and electrical conductivity. The others thing that make concrete is more important is concrete can be shaped into geometrical properties. But, concrete also have disadvantages which concrete is weak in tension and brittle. Fibres are a part of thin elements comes from synthetic and natural fibers. The fibers used in mixing concrete can be divided into two part which are natural fibres and synthetic or man-made fibres. The examples of synthetic fibres include carbon, polypropylene, asbestos, polyethylene, steel, cotton, and acrylic. Meanwhile the examples of natural fibres are fibres from vegetable, woods, and bamboo. There will be more natural fibres come from agricultural waste may become a product such as coconut husk and kenaf fibres.

Kenaf fibres as one of natural fibres source will be more deeply to investigate in this research. Fibres reinforced concrete can be considered as material relatively short continuous fibres are randomly distributed throughout the matrix in order

to overcome the problems brought about by the low tensile strength and strain capacity of a plain concrete mix. Local organic such as most of natural fibres represent an available resources for fibre reinforced materials are relatively expensive, and make it difficult to provide adequate solutions to the housing needs of such areas of the world (Ramirez, 1992). Therefore, the feasibility of natural fibres as one of the source of fibres would be investigated.

## 2.2 FIBRES REINFORCED CONCRETE

The use of Fibres Reinforced Concrete (FRC) improved the properties of concrete with the reinforced the cement with steel and synthetic fibres over last 30 to 40 years ago. Fibres also enhance the properties of natural materials for example motor vehicle tyres are made from fibre reinforced rubber. Now, the application of adding small and randomly distributed fibres to reinforce the concrete become more popular among people who are involved in construction fields. The increasing of energy absorption capacity and toughness of the material will be observed. Other than that, the purpose of using the fibres is to increase the tensile and flexural strength of concrete. It is shows that the use of fibres needs to be improved years by years to transform the technology of fibres until it truly help for all fields including the construction industry.

Fibres reinforced concrete can be considered as material relatively short continuous fibres are randomly distributed throughout the matrix. in order to overcome the problems brought about by the low tensile strength and strain capacity of a plain concrete mix.The technology related to the development of Fibres Reinforced Concrete (FRC) are begin since during the past decades. Peoples named Romualdi, Batson, and Mandel in the early 1960s, they published the paper work about the FRC to the attention of academic and industry research scientists around the world. It means that the FRC have been developed from time to time. There are several type of FRC that people used in industry such as steel fibres, carbon fibres, synthetic fibres and natural fibres.

Generally, the function of using the FRC is to overcome the weakness in tension alters the behaviour of the fibre-matrix composite after it has cracked and improve the toughness. According to Anette Jansson (2008), he stated that the potential benefits of using fibres in concrete are improved crack control and also can give impact of designing

more slender structures. However, a large extent on the type and amount of fibres added will influence the extent of crack control.

## 2.3 NATURAL FIBRES REINFORCED CONCRETE

Natural fibres reinforced concrete have raised good interests among people involved in construction designing in recent years due to the need for development of environmental friendly material. Nowadays, peoples are facing the global warming caused by worst environmental pollution. They need to find the solution how to overcome the environmental problem. Alternatively, construction designer need to design the building that related to green material such as using the natural fibres in concrete. The use of natural fibres will less harmful to our environment. The advantages of using natural fibres are resistant to fire and easy to fine the sources. Relating to the natural fibres in reinforced concrete, most previous study used many type of natural fibres in the concrete such as bamboo, coconut, jute, flax, kenaf and vine.

The usage of FRC among people nowadays are extensively due to the statement from Swift DG (1979) The used of sisal fibres reinforced concrete tiles, corrugated roofing sheets, pipes, gas tanks, water tanks and silos are also being used widely in area state of African countries. These type of fibres easy to fine the sources compare the other fibre like steel fibres and glass fibres. Other than that, the cost of having this material is cheaper. It can be proved by statement from natural fibre specialist additional key advantages of natural fibres are their high strength and stiffness per weight along with benefits such as acoustic isolation, safety management, rapid production and potentially lower cost.

The main properties of natural fibres are depending on factors such as the length of fibres used, the volume fraction and the type of fibres. Study of jute FRC stated that the addition of fibres will not affect the compressive strength due to its density while tensile and flexural strength and toughness will increase according to Mansur MA (1982). Previous study indicated that the minimum fibres volume fraction required to provide significant improvement in the mechanical properties of cement composites was approximately 3% (Rancines PG, 1976).

**Table 2.1: Advantages and disadvantages of using natural fibres**

| Advantages | Disadvantages |
|---|---|
| Producible with low investment at low cost, which makes the material an interesting product for low-wage countries. | Lower durability, fibre treatments can improve this considerable. |
| Environmental friendly<br>It is renewable resources; the production requires little energy CO2 is used while oxygen is given back to the environment. | Moisture absorption, which causes swelling of the fibres. |
| Low specific weight , which result in a higher specific strength and stiffness than glass | Lower strength properties, particularly its impact strength.<br>Price can fluctuate by harvest result or agricultural politics. |

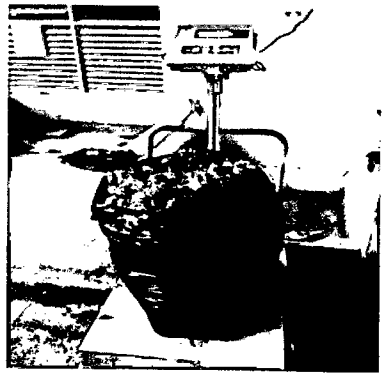
Sources from J.C. Villar (2008)

## 2.4 KENAF FIBRE REINFORCED CONCRETE

Kenaf or its scientific name Hibiscus cannabinus have started to plant so much in malaysia. According to Malaysian Agricultural Research and Development Institute (MARDI), government of Malaysia are planning to expand the plantation of kenaf in Kelantan and Terengganu.

In addition, it will be the main sources for the country in the future. Regarding to MARDI, the kenaf grows quickly, rising to heights of 3.66m-4.27m (12-14 feet) in as little as 4 to5 months. Besides that, the other study show that kenaf yields of 6 to 10 tons of dry fiber per acre per yearare generally 3 to 5 times greater than the yield for pine trees which can take from 7 to 40years to reach harvestable size. Upon harvest, the whole kenaf plant is processed in mechanical fiber separator similar to a cotton gin.

Before cutting process



After cutting process

**Figure 2.1**: Sample of kenaf before and after process

Kenaf fibres as one of natural fibres source will be more deeply to investigate in this research.. Local organic such as most of natural fibres represent an available resources for fibre reinforced materials are relatively expensive, and make it difficult to provide adequate solutions to the housing needs of such areas of the world (Ramirez, 1992). Therefore, the feasibility of natural fibres as one of the source of fibres would be investigated. Regarding to Touzinski GF, (1973) mentioned that the kenaf comprises 35-40 % bast fibre and 60 - 65% core fibres by weight of the kenaf's stalk.

**Table2.2**: Summary of Tensile Strength and Young's Modulus, *E* for Various Type of Natural Fiber

| Type of Fiber | Diameter (mm) | Tensile Strength (MPa) | Young's Modulus (MPa) | References |
|---|---|---|---|---|
| Kenaf | 0.04-0.81 | 18-250 | 430 | [9,10] |
| Jute | 0.082-0.04 | 29- 345 | 2200 | [9,10] |
| Oil palm | 0.25-0.447 | 58-71 | 478-1703 | [8,11] |
| Coir | 0.04-0.45 | 15-175 | 400-600 | [9,12] |
| Banana | 0.08-0.25 | 54-754 | 7700-20000 | [9] |
| Pineapple | 0.02-0.08 | 413-1627 | 34500-82500 | [9] |
| Sisal | 0.05-0.2 | 568-640 | 9400-15800 | [9] |

Sources from Aziz (1982)

There are several factors contribute to the properties of kenaf fibres in mixing concrete which are fiber type, length, volume fraction, and density of the fibers. Based on previous research, volume percentages of fibers are one of the most important factors affecting the strength of fibres reinforced concrete (Fordoz, 1984). The optimum fibre's length and volume fraction of the fibrous type are around 25mm and 3 percent respectively according to (Aziz, 1982).

Characterize the basic tensile properties of kenaf MR fibres have been studied in the past. The result indicate that the average tensile strength of kenaf fibres range from 157 MPa to 600MPa. Meanwhile, the average ultimate tensile strain and elastic modulus of the fibres range from 0.015 to 0.019 and 12,800MPa to 34,200 MPa respectively. A part from these, the location along the stalk from which the fibres are taken is depended by the mechanical properties of the fibres (Xue Y, 2007).

Fibres are taken from the ends of the stalk tend to be weaker meanwhile fibres from the middle of the stalk tend to be stronger. It will more flexible possibly due to exposure to environmental conditions, decay, and damage caused by insects and other pets. The study further show the stress-strain curve of the kenaf fibres is approximately linear to failure regardless of the location from which the fibres are taken.

The selection of using fibres in this research is because the previous study indicated that the evaluation of kenaf core as an absorbent material for cleaning oil spills. On the other words, The Naval Facilities Engineering Service Centre mentioned that the core particles outperformed other natural absorbent materials by a significant margin.

Kenaf fibres was chemically pulped without the core when kenaf material is mechanically pull out from the core, it will produced around 57% yields of fibres. The bast comprises 17.4% to 28.6% on a whole stalk dry weight basis. The individual kenaf fibers are up to 5.0 mm long averaging, 2.6 mm in length and 20 mm in width. Chemical bast pulp is well suited for specialty papers, such as high quality stationery or filter paper. Bast pulp, compared to softwood pulp, has a similar tensile strength, but greater tear strength and bulk fiber, thus it could serve as a replacement for softwood pulp.

Pulping kenaf fibres and core fibers can give advantages towards the environment because the process requires less chemicals and less energy compared to standard pulping processes for wood fibres. The kenaf fibres also can serve as virgin fibres for increasing recycled paper strength and quality. Although the kenaf bast fibres

strands were once only considered for use as a cordage fibres in such products as burlap, carpet backing and rope.

A variety of additional uses has developed for the bast fibres strands day by day. These include use in, carpet padding, and automobile dashboards, can be changed from fibreglass and other synthetic fibres, textiles and as fibres for injection moulded and extruded plastics. Kenaf bast fibres strands are currently in commercial use in other environmentally friendly products like fibres lawn mats impregnated with grass seed and spray on soil mulches for use along highway rights of way or construction sites to prevent soil erosion from water and wind.

## 2.5 CONCLUSION

This chapter is study in detail the previous research related to natural fiber, using kenaf fiber in term of its advantages and disadvantages. Based on the journal, previous thesis, website and book, the information can be obtained and can be as a guideline to study the behaviour of kenaf fibers in reinforced concrete.

# CHAPTER 3

# METHODOLOGY

## 3.1 INTRODUCTION

The objective of this chapter is to elaborate more on methodology used from the beginning to the end of this research. This research mostly conducted at Concrete Laboratory in University Malaysia Pahang, Gambang campus. It content a brief description of the material used in the concrete mixture and additive material used, including the proportion and parameter that are studied. The testing of this research involving the Slump test, Compression test and Flexural test.

## 3.2 RESEARCH METHODOLOGY

In this research, the research methodology involves a process of finding, identify, analyze, testing and writing. It was summarized in **figure** 3.1

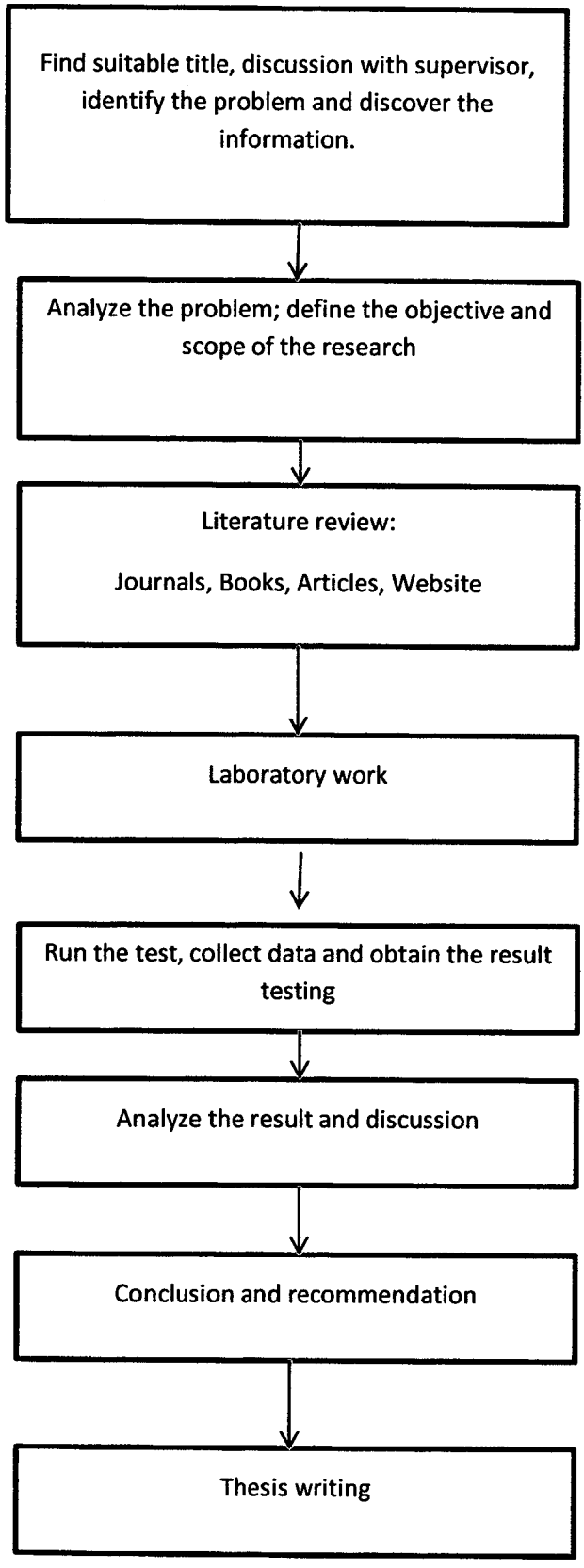



**Figure 3.1**: Flow chart of methodology

## 3.3. PREPARATION OF MATERIALS

Material used to make concrete sample consist of course aggregate, fine aggregate, water, ordinary Portland cement, super plasticizer, and kenaf fibers. These were weighing based on the calculation in design mix. All material were used in mixing concrete including cement, coarse aggregate, fine aggregate, water and additive material which was kenaf fibers. This concrete mixed was intended to achieve compressive strength of grade 25 according to the Design of Normal Concrete Mixes from department of Environment (DOE) Technique. The common type of cement used for the concrete mix was Ordinary Portland Cement (OPC). The crushed and uncrushed types of aggregate had been used for coarse and fine aggregates respectively.

### 3.3.1 Kenaf

The samples of kenaf were prepared by cutting the samples in range between 25mm to 30 mm in length and 3mm in width. It was added with amount of 30kg/m$^3$ and 30kg/m$^3$ to the concrete mix.

### 3.3.2 Formwork

Plywood was used to construct the formwork for beams. Six formworks were provided to cast RC beam and without RC beams. The formwork's surface had been oiled before concrete mixture was placed. Meanwhile for cube samples, the plastic mould will be used and it can be obtained from lab concrete. The formwork was designed based on the dimension of 150mm x 150mm x 1000mm. The timbers in sizes of 2 inches and plywood were used to form the formwork.

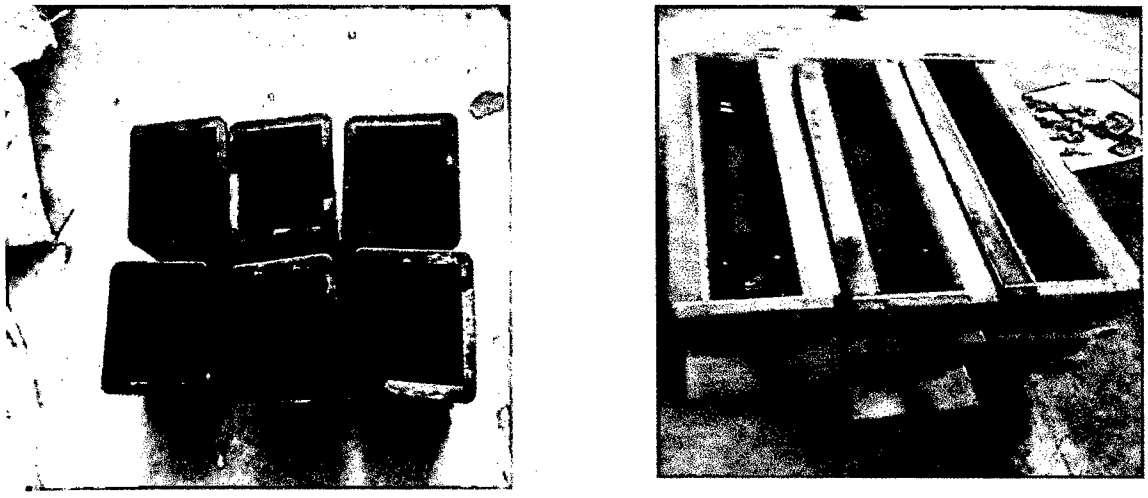


**Figure 3.2**: formwork and plastic mould

### 3.3.3 Reinforcement Bars

**Figure 3.3:** preparation of main reinforcement bars

For the RC beams, the reinforcement that was used is steel bar 8 mm for main reinforcement. All the steel bar were cut according to require length using the cutter machine while electrical bending machine was used to bend the reinforcement. The rebar were tied by using wire. The requirement for having the reinforcement was to improve the strength of the beam in term of flexural strength.