BEHAVIOUR OF REINFORCED CONCRETE BEAMS WITH OPENING ADDED WITH KENAF FIBER

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ABSTRAK

Kajian ini membentangkan tentang penemuan program penyelidikan eksperimen yang dilakukan untuk meningkatkan tingkah laku struktur konkrit bertetulang gentian bertetulang (FRC) serat semulajadi dengan membuat pembukaan di hujung struktur konkrit yang dibuat dengan menggunakan serat kenaf. Perkadaran campuran yang sesuai dan prosedur pencampuran dikira untuk menghasilkan balok dengan pecahan jumlah kenaf, Vf dari 0%, 1% dan 2%. Kekuatan mampatan, kekuatan lenturan spesimen konkrit bertetulang serat kenaf (KFRC) dibentangkan dan dibandingkan dengan tingkah laku spesimen kawalan konkrit biasa. Keputusan eksperimen menunjukkan bahawa kelakuan KFRC dan ujian pemampatan kedua-duanya berkurangan dengan peningkatan pecahan pecahan.

ABSTRACT

This paper presents the findings of an experimental research program that was conducted to improve the structural behaviour of natural fiber reinforced concrete (FRC) beam with opening at end which is made using kenaf fiber. Appropriate mixture proportions and mixing procedures are calculated to produce beam with kenaf volume fractions, Vf of 0%, 1% and 2%. The compressive strength, flexural strength of kenaf fiber reinforced concrete (KFRC) specimens are presented and compared to the behaviour of plain concrete control specimens. The experimental results indicate that the behaviour of KFRC and compression test were both decreasing with increasing volume of fraction.

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LIST OF ABBREVIATIONS

KFRC	Kenaf Fibre Reinforced Concrete

CHAPTER 1

INTRODUCTION

1.1 Background

Natural fiber is widely used in the construction field as the strengthening material. There are few types of fiber can be used as the composites materials in concrete mixing. Few study of kenaf fibre has proven that kenaf fibre is capable to enhance the load carrying capacity (Ezekiel Babatunde et al., 2015),(Azrizal, 2015),(Mohsin et al., 2016). This study added kenaf fiber in the mixture to study the behaviour of beam with opening at end. It is proved that kenaf fiber exhibits higher strength values in terms of tensile and flexural properties, as compared to other natural fibers (Nishino et al., 2003). Furthermore, a finding suggest that fibres also have the potential to serve as part of shear reinforcement in reinforced concrete structures and is allowed for a reduction of the shear reinforcement while maintaining the ductility ratio, load-carrying capacity as well as controlling the crack propagation (Mohsin, 2012).

Opening in beams has become necessity in construction to provide lines and facilitates passage for electrical lines, water pipes, telecommunication cables with the purpose of a more systematic layout (Mondal, 2011). The shape and size can be various depends on its requirement of using and the behaviour of the beam. Previously, Manoharan and Tripathi (2017) has studied the analysis of circular opening and it is concluded that as the depth of opening increases, stress concentrations increases at the opening boundaries. The opening provided is of circular shape was very effective, it shows less stress concentrations at the web openings and will be easy to fabricate. However, in a research by (Osman et al,. 2017), he reported that shear behaviour of reinforced concrete (RC) beams with circular web openings without additional shear reinforcement beam start to fail mainly by brittle shear failure in which the diagonal shear cracks that formed at the top and bottom chords of the beams led to concrete shear failure.

In some cases, the height of a building floor is limited and has sufficient space to fit all the essential services because of the size of the beam. This design has been practically used since many years before however the presence of the opening beams, it is believed that it also leads to some problem in terms of cracking, excessive bending and decreasing in strength. In 2013, Alsaeq (2013) made a research on how web openings would impact the effective width of beams. It is concluded that web openings influence the effective width of composite beams. Structural analysis of a failures RC beam with openings in a building under construction is conducted and the analysis implies that defectively constructed openings have an impact on the behaviour of load-bearing elements (Zdanowicz and Wojdak, 2013).

Figure 1.1 Multiple opening in a beam

Figure 1.2 Cracking at the bottom of the beam near the opening.

(Source: Łukasz Zdanowicz, 2013)

There are failures of opening beams happened in the past cases for example brittle fracture caused from insufficient reinforcement, fragile fracture caused by corner cracking and crisp failure from insufficient strength of concrete. The beam most likely to fail at the location of the opening and the moment-shear interaction of the tested steel reinforced concrete beams with opening did not agree to the interaction proposed for the structural steel with opening (Chen, Li and Kuo, 2008). However, in study of analysis of steel beams with circular opening reported that analytical results for beams with circular opening show that there is no much variation in the deflection values when compared with solid beam results for all the cases considered (Manoharan et al., 2017).

1.2 Problem Statement

Beam with opening is essential to the construction these days to some of relevant purposes. However, the effect of making opening in beam is unpredictable. The hollow part of the beam may affect the changes in strength and later can cause to structural failure. Therefore, to study the strength, mix design is design by adding with different percentage of kenaf fiber.

The location of the beams also has to be taken into consideration where the failure might happen due to loading transferred. The presence of an opening itself will reduced the load carrying capacity and the stiffness of the beam. One opening at an end of the beam and compare with the one without the opening.

1.3 Objective of the Study

The strength of the beam with opening will be improved by using kenaf fiber as the additional reinforcement, the study will include few related objectives that will help in achieving the aims or the main purpose of the investigation are as below;

i. To improve performance of RC beam contains of different percentage of kenaf fiber.
ii. To study the behaviour of three RC beam with opening and RC beam without opening as the control beam.

1.4 Scope and Limitation of Study

The experimental progress considered the test for concrete.

- Beam design calculated according to Eurocode 2 using diameter bar of 12mm and link of 6mm.
- 4 beams including control beam with dimension of 1200mm length, 400mm height and 150mm width.
- Providing of 4 specimens of beams containing of a different amount of kenaf fiber : 0%, 1%, 2% and beam without opening will be conducted.
- Steel Yield strength, fyk= 250 N/mm^2
- Concrete Compressive strength, fck=25 N/mm^2
- Steel size of Y12 and link of 6 mm.
- Type of opening is circular and the location of the opening is at the one end of the beam.
- Involving 18 cube with dimension of 150 mm x 150 mm x 150 mm to be tested on 7 days and 28 days.
- Test considered for concrete test is slump test, compressive strength test
- Test considered for beam test is flexural test

1.5 Research Significant of Study

This study will give out a better understanding and exposure of the advantages of kenaf fiber as materials used in concrete to help in beam strengthening. The consideration and application of using kenaf fiber in construction and building for better environment and the quality of the structure. The finding of this study will be beneficial to the those in construction field that it is plausible to use kenaf fiber as the in concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 General

The study is mainly about considering on improvement of opening beam using kenaf fiber as the alternative materials used in the beam. Opening beam has become trend these days in order to complete the building structure. Beam is one of the transfer elements in one structure building. The lifespan of the structure element could be extended with improving the strength of the beam. Besides, the opening at the beam itself is one of the contributing factors to the weakness of the element. In this chapter, literature review is prepared to do the research studies. The classification of opening is discussed, the effect of the opening including the types of failure and crack that might occur to the element will be explain.

2.2 Beam with Opening

Opening has become an essential in construction for building to create a systematic layout to allow for the passage of services. The use of beam with opening has become trend over the pass years in construction. In this study, further review is done to support the improvement of the performance of beam with opening.

2.1.1 Classification of Opening

Opening can be of different sizes and shapes whether a rectangular, circular, triangular or irregular shape. The shape is design accordingly to the purpose of the opening. However, the most common used is circular and rectangular shape. According to (Al-sheikh, 2014), the circular shape has the circular opening is the best shape of opening that showed the least reduction in ultimate load among other shapes. With regard to the size of the opening, there are no exact definition to decide whether the opening is big or small however it is reported by (Mondal, 2011), a circular opening may be considered as large when its diameter exceeds 40% of the depth of the web. However, (Alsaeq, 2013) research found that the best shape for the opening, in the deep beam consider, is the narrow rectangular one with the long sides extended in the horizontal direction but this shape may not be suitable for practical cases.

2.1.2 Location of the Opening

The position of the opening is important to the aftereffect because at some position, opening may not be suitable to apply and more failures will occur (Al-sheikh, 2014) studied about the effect of different location of the opening where the best location of the opening in the beams is in the middle of the beam. Location of openings has a large effect, where this effect is the largest when openings location is at shear zone and a small effect when openings location is at flexure zone.

2.3 Effect of Creating Opening in Beams

The presence of opening in beam has leads to some problems in behaviour of the element such as reduction in stiffness, excessive cracking, excessive deflection and reduction in beam strength. Web openings in a reinforced concrete beam reduces the capacity of the beam to carry load and increases its service-load deflections and crack widths (Diggikar, Mangalagi and Harsoor, 2013),(Mansur, 2006),(Mohamed, Shoukry and Saeed, 2014),(Osman et al., 2017).

Opening in beams has altered the simple beam behaviour to a more complex problem. Due to an abrupt change, the corner of the opening is subjected to high stress concentration that may lead to excessive cracking. Previously, (Al-sheikh, 2014) has a study about the flexural behaviour of RC beams with opening. In the conclusion, stated that RC beams with large opening at flexure zone, excessive flexural cracks were found at the tension zone around the openings while RC beams with large opening at shear zone, shear cracks were found around the openings. However, (Ali et al., 2010) stated in the research that the presence of an opening in shear zone of R.C concrete beam with height of 0.4 the beam depth and with length of 2.5 its depth significantly decreases its cracking and ultimate load.

2.1.3 Failure Mode of Beam Opening

There are various types of failure depending on the cause of the various applied load or the tension received by the beam. The opening has leads to few failures that need attention to be improved. There is no exact analysis of the behaviour of beam with opening. A research by Alsaeq (2013) made conclusion by using ANSYS 12.1 software, the load carrying capacity of deep beam with opening obtained was 20% less than the experimental results, i.e. the ANSYS 12.1 model exhibits less strength than the experimental data. In another research, Shear Behaviour of Reinforced Concrete (RC) beams with circular web openings without Additional Shear Reinforcement beam start to fail mainly by brittle shear failure in which the diagonal shear cracks that formed at the top and bottom chords of the beams led to concrete shear failure (Osman et al., 2017). Previously, in the study of steel reinforced concrete beam with opening by (Diggikar et al., 2013) stated that the beams subjected to high moment to shear ratio, predominant bending, developed minor shear cracks at the corners of the opening in addition to flexural cracks occurred on the bottom of the beams close to the load applied region, and the failure was primarily attributed to the flexural failure associated with minor shear cracking.

2.4 Natural Fiber

Natural fiber is widely used in the construction field as the strengthening material. There are few types of fiber can be used as the composites materials in concrete mixing. Natural fiber represents all forms of fibers from woody plants, grasses, fruits, agriculture crops, seeds, water plants, palms, wild plants, leaves, animal feathers and animal skins. By products of pineapple, banana, rice, sugarcane, coconut, oil palm, kenaf, hemp, cotton, abaca, sugar palm, sisal, jute and bamboo are among the fibers that is common to use as composites. Natural fiber has the potential as reinforcement. Natural fibers have the properties, composition, structures and features that are suitable to use as reinforcements or fillers in polymer composites.

Increasing in the fiber content does not give the guarantee that the performance of a beam will improved in terms of mechanical properties. However, there is advantage with increasing the fraction volume of the fiber. In a research of coconut fiber reinforced concrete, at 5% addition of coconut fiber with a water cement ratio of 0.5, compressive strength tests yielded best results, flexural and tensile strength is increasing with a maximum at 5%. However, the compressive strength decreased on further fiber addition (B.H. et al., 2014).

This statement is supported in a study of the effects of coconut fibers on the properties of concrete, it is reported that the fiber content is increasing and the mix became more cohesive. However, workability decreased as the fiber content increased. The compressive strength, split tensile strength and flexural strength has a increasing trend up to 2%. Later, strength decreased with the increase in fiber content. CFRC with 2% fiber content has higher compressive strength, split tensile strength and flexural strength as compared to that of PC (B.H. et al., 2014) and (Ramli et al., 2013).

In other research, it was found that the coconut fiber can be used as reinforcement. Increasing content of coconut fiber will increase the compressive strength and modulus of rupture until some optimum composition. Increasing content of coconut fiber will increase the compressive strength and modulus of rupture until some optimum composition (Nadzri et al., 2012).

Figure 2.1 Coconut fiber

In previous research by Mostafa and Uddin (2015) and Minas and Bryant, (2015), that study on the effect of banana fibers on the compressive and flexural strength of compressed earth blocks. This experimental study is conducted to evaluate the influence of banana fiber length on the compressive and flexural strength. The results made plain that the treated 50 mm fibers were the better performing fiber in this study. Compared to the unreinforced specimens, specimens reinforced with 50 mm fibers at 0.35% by weight, were 94% and 77% higher, in terms of flexural and compressive strength, respectively.

Different from the conclusion derived from a research of experimental studies on coconut fiber and banana fiber reinforced concrete stated the addition of coconut fibers and banana fibers significantly improved many of the engineering properties of the concrete, notably compression, and tensile strength. Both fibers have the ability to resist cracking and spalling. However, the addition of fibers poorly affected the compressive strength, as expected, due to difficulties in compaction which consequently led to increase of voids. Despite its excellent properties, coconut fiber and banana fiber as an enhancement of concrete is unlikely to replace steel for the vast majority of structures (Coutts, 1990).

While for kenaf fiber, it is known that kenaf fiber is suitable as strengthening materials for RC beams and the load capacity and stiffness is increased. Kenaf is a warm season plant, which requires a short period of sunlight.

Figure 2.2 Kenaf fiber

Juliana and Paridah (2011) did a research on the evaluation of basic properties of kenaf (*Hibiscus Cannabinus* L.) particles as raw material for particleboard. As the conclusion of the research, density of kenaf stem was much dense compared to the core. The green moisture content was higher in the bottom to the top in both kenaf stem and core. Kenaf stem can be processed into fine particles suitable for making particleboard at a recovery rate of 74% (based on oven dry weight).

From a series of mechanical tests, which showed pultruded samples, they also displayed a significant improvement in terms of structural performance characteristics, such as flexural strength, modulus, and impact resistance. The application of kenaf fiber reinforced composite as an alternative composite material, especially in building and construction, is highly plausible with both lightweight and low cost as its main driving forces (Akil et al., 2011).

As the properties of kenaf fiber, the density of kenaf reported by Juliana and Paridah (2011) on the evaluation of basic properties of kenaf (Hibiscus Cannabinus L.) particles as raw material for particleboard ranged between 0.319 and 0.369 g/cm3 (stems) and 0.269 and 0.307 g/cm3 (core). While Ribot et. al (2011) reported the density of kenaf fiber was found to be 0.75g/m3 which is considered high when compared with other natural fiber.

A research by (Hafizah et al., 2014) of strengthening reinforced concrete beams using Kenaf Fiber Reinforced Polymer Composite Laminates shows that Kenaf/Epoxy composites had the highest ultimate tensile strength compared to Kenaf/Polyester composites and Kenaf/Vinyl Ester composites. All composites' strength gradually increased when the fiber volume fraction increased. While Subhajit Mondal made a research of strengthening and rehabilitation of reinforced concrete beams with opening and conclude that fiber Reinforce Polymer is suitable to use for strengthen and rehabilitate the beams with small opening only. Fiber reinforced polymer does not show the same efficiency for strengthened and rehabilitated beams.

2.5 Overview

Based on the review above, the researches about the failure and effect of the opening beam to the behaviour in certain situation and what are the possible method to use as well as the suitable materials to be test in this study. Various failure that occur causing from the opening during both of analysis and experimental will need another way to improve the behaviour of the beam. According to the observation and research study, kenaf fiber has the high potential materials to use to use as the additional reinforcement for the experimental work. Circular opening has also shows the potential of having the best shapes with having the least crack analysis during previous research. Herewith, this research includes all the literature review shown and combined all the characteristic of the possible approach to improve beams with opening by adding kenaf fiber in the mixture of the concrete beams. Different value of volume of fraction use is to differentiate the effectiveness of adding kenaf fiber in the mixture.

CHAPTER 3

METHODOLOGY

3.1 Preparation of Concrete Ingredient

Materials and method of preparation is described in this chapter in detailed.

Table 3.1 below shows the mix design calculated to determine the appropriate workable proportions of the cement, water and aggregate using trial mix design method. For volume of fraction, Vf=0%, the mixture of cement, fine aggregate, coarse aggregate and water with a total of use for two beams and six cubes are 89.17kg, 121.25kg, 225.18kg and 37.45kg respectively. While for Vf=1% and Vf=2% use the same amount of cement, fine and coarse aggregate however the amount of kenaf added is different which is 1% and 2% per metre cube of the specimen use with the value of 0.72kg and 1.438kg respectively. The total of superplasticizer used for Vf=0% is 1 litre per metre cube and amount of superplasticizer used in Vf=1% and Vf=2% is same that is 0.6 litre per metre cube. Kenaf fiber with length of 3mm and diameter of 0.1mm and 2mm as shown in figure 1.

Table 3.1 Concrete mix details for 1 m^3 of concrete mix.

Materials	V_f = 0%	V_f = 1%	V_f = 2%
Cement (kg/m^3)	89.17	50	50
Fine Aggregate (kg/m^3)	121.25	68	68
Coarse Aggregate (kg/m^3)	225.18	126.5	126.5
Water (kg/m^3)	37.45	21	21
Kenaf fibers, (kg)	0	0.72	1.438
Superplasticizer (L/m^3)	1	0.6	0.6

Figure 3.1 Kenaf fiber

3.1.1 Cement

The cement type used in this research is Ordinary Portland Cement where it is the most common type of cement in general use around the world as a basic ingredient of concrete. The composition and manufacture of the cement used is sets by the Department of Standards Malaysia certified to MS 522-1: Part 1 2007 (EN 197−1:2000), CEM I 42.5 N/ 52.5 N and MS 522 : part 1 : 2003 ; whether ordinary or rapid-hardening, shall be obtained by pulverizing clinker, consisting mostly of calcium silicates obtained by heating to partial fusion a predetermined and homogeneous mixture of materials containing principally lime (CaO) and silica (SiO_2) with a smaller proportion of alumina (Al_2O_3) and iron oxide (Fe_2O_3).

In order to ensure good quality control, 50 kg per package is delivered and stored in air dry storage in laboratory.

Figure 3.2 Ordinary Portland Cement (Orang Kuat)

3.1.2 Coarse Aggregate

Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Coarse aggregates are particles greater than 4.75mm, but generally range between 10 mm to 40 mm in diameter. They can either be from primary, secondary or recycled sources. Coarse aggregate that is widely used in construction field are usually gravel, crushed stones or recycled concrete. In this research, crushed stones and gravel with average of 10 mm to 40 mm diameter is preferable which affect in strength and workability.

Figure 3.3 Uncrushed gravels

3.1.3 Fine Aggregate

Fine aggregate usually is sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregate these can be from Primary, Secondary or Recycled sources. Throughout the mixing, the use of the fine aggregate must be uniform by sieve method before mixing. The use of sand as the fine aggregate in this research is selected and it should be in dry condition and free from impurities.

Figure 3.4 Sand

3.1.4 Water

Water is essential in the process of hydration for cement as well as to provide workability during mixing and placing. The water shall be free from impurities and cleaned. Normal tap water will be used in this research for mixing and curing process. The amount of water will be used as what has been calculated in mix design.

3.1.5 Superplasticizer

Plasticizer responsible to increase the plasticity or viscosity of a material. Plasticizer are chemical admixtures that can be added to concrete mixtures to improve workability when kenaf fiber is added in the concrete mix in this research. In order to produce stronger concrete, adequate water must be added which makes the concrete mixture less workable and difficult to mix, necessitating the use of plasticizers, water reducers, superplasticizers or dispersants.

For this experimental program, Sika Viscocrete 2199 was used. In was mixed in the concrete containing 1% of cement weight to facilitate the workability.

Figure 3.5 Superplastisizer (Sika Viscocrete 2199)

3.1.6 Kenaf Treatment

The solution used for kenaf treatment is 1%-6% of sodium hydroxide (NaOH) mixed with water. The kenaf fiber is soaked for 24 hours in the solution after it was clean to avoid any impurities. A research by Meon et al., (2012)on improving tensile properties of kenaf fibers treated with sodium hydroxide found that the alkalization treatment has improved the tensile properties of the short kenaf fibers significantly as compared to untreated short kenaf fibers. It is also highlighted 6% NaOH yields the optimum concentration of NaOH for the chemical treatment. In this research, 1% of NaOH from the weight of water is used to treat the kenaf and let it soak for 24hour. The kenaf was left to dry on room temperature before mixing it together with other ingredients.

Figure 3.6 Solid NaOH before mix in the water

3.1.7 Formwork

Plywood is use as the formwork for the casting of beam and engineered formwork system for cube specimens. PVC pipe of 100mm diameter will be used to form the shape of the opening at the end of the 3 beam. Traditional timber formwork was made in the laboratory made of plywood. Plywood was cut into required size to cast the beam of 1200 mm in length, 150 mm width and 400 mm in height.

Figure 3.7 Beam formwork using plywood

Figure 3.8 Cube mould (150 mm X 150 mm X 150 mm)

3.2 Preparation of Beam

The beam samples will be divided into 3 different content of kenaf fiber with volume fractions (V_f) of 0%, 1%, 2% provided with shear reinforcement. The 3 beams will be compared to the control beam without opening and kenaf fiber content.

Preparation of concrete ingredient shown in the details below. Mix design is calculated to determine the appropriate workable proportions of the cement, water and aggregate using trial mix design method.

Table 3.2 Details of beam samples

Beam	Vf (%)	Opening
Control Beam	0	No
KF00	0	Yes
KF01	1	Yes
KF02	2	Yes

3.3 Laboratory Testing

In this research, the laboratory testing considered the beam and cube will be investigated and conducted.

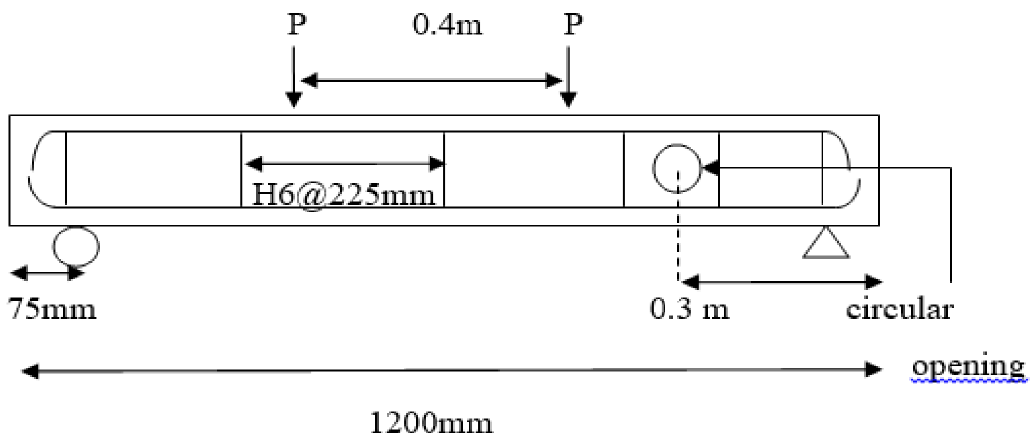


Figure 3.9 Specimen arrangement

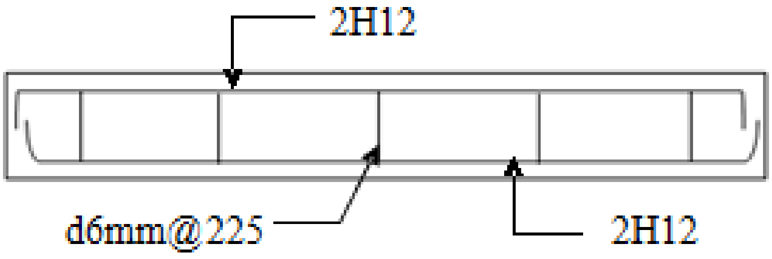


Figure 3.10 Cross-Section A-A

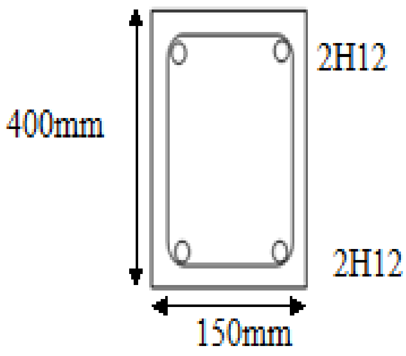


Figure 3.11 Cross-Section B-B

3.1.8 Slump test

The concrete slump test measures the consistency of fresh concrete before it sets or hardens. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. The slump test is used to ensure uniformity for different loads of concrete under field conditions.

The test is carried out using a metal mould in the shape of a conical frustum known as a slump cone that is open at both ends and has attached handles. The tool typically has an internal diameter of 100 mm at the top and of 200 mm (7.9 in) at the bottom with a height of 305 mm. The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages. Each time, each layer is tamped 25 times with a metal rod measuring 16 mm in diameter. The mould is carefully lifted vertically upwards, so as not to disturb the concrete cone. The concrete then slumps (subsides). The slump of the concrete is measured by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone.

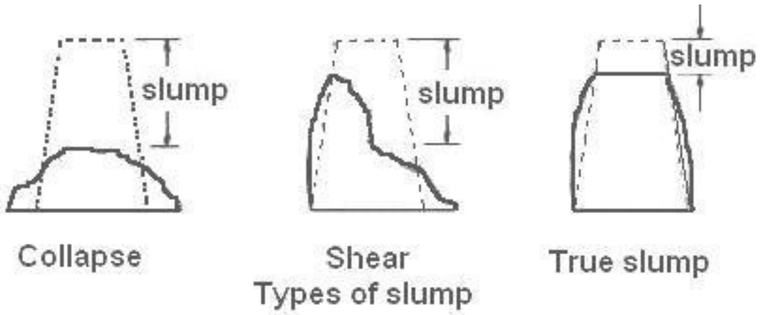


Figure 3.12 Types of slump

Slump is decided based on the category of workability the mix have by measuring the slump height of the mix. In this study, the targeted slump height is 75mm, which categorize as medium workability.

3.1.9 Compression Strength Test

One of the method to check whether concrete is fit for purpose is to carry out a cube test which measures the compressible cube strength of the concrete and relates directly to the required design strength specified by the designer.

A total of 12 cube specimens are tested by compression testing machine after 7 days curing and 28 days curing. Load should be applied gradually till the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Figure 3.13 Compression machine

3.1.10 Flexural Test

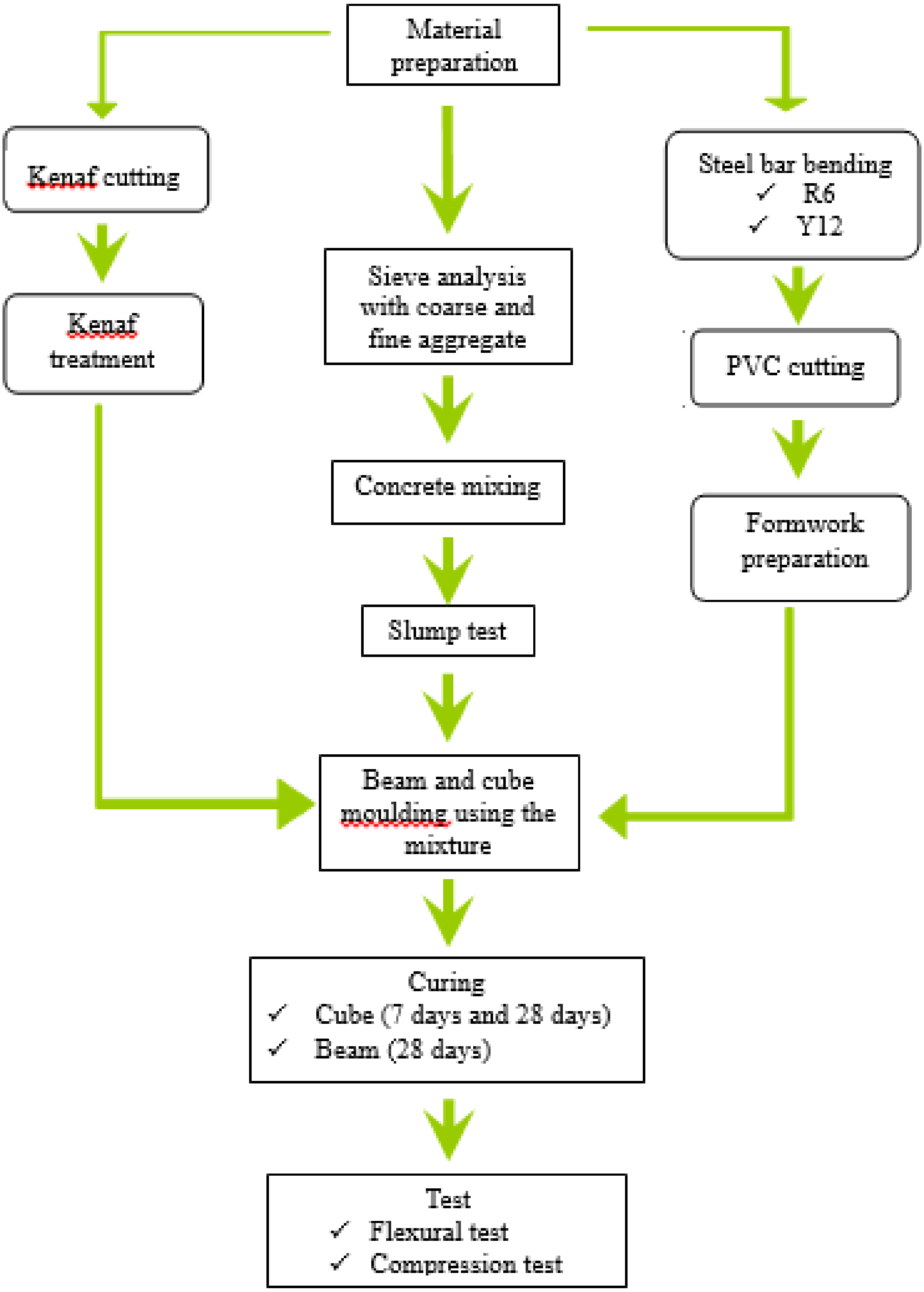
According to the standards of flexural test (BS 1881: part 118: 1983), all of the hardened concrete must be tested. 4 beams specimens with length of 1200 mm, cross-section of 150 mm width and height of 400 mm will be tested under the 2-point loading system in the middle of the longer span.

Figure 3.14 Flexural machine

3.4 Result to be obtained

In concrete flexural test the data to be collected are time, force, displacement and strain. All elements are tested until it failed. All the data will be recorded during the experimental work. For the concrete compression test, the ultimate strength of the concrete will be obtained. While flexural test resulted in maximum load capacity it can sustain. All the parameters of the experimental work is considered to be obtained.

3.5 Methodology Flow Chart



CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The aim of this research is to increases structural performance of a beam with opening by producing fiber reinforced concrete of kenaf fiber. Structural behaviours such as compressive strength, flexural strength and crack pattern is observed. All the tests conducted according to the standards has been discussed in methodology. The results and detail analysis of data from experimental works are shown as follow.

4.2 Compression Test Result

The concrete specimens of cubes were cured in water for 7 and 28 days before testing of compressive strength. The results of the test conducted are shown in Table 4.1, Figure 4.1 and Figure 4.2.

Based on the results, the development of strength in 7 days for Vf=0% content in the concrete has the highest value which is 41.767Mpa as compared to Vf=1% and Vf=2% that is 20.240Mpa and 20.254Mpa respectively. Therefore, the difference in value between control specimen and Vf=1% and Vf=2% turn out to be 51.54% and 51.51% respectively. However, there is subtle increment of strength for Vf=2% as compared to Vf=1% during early 7 days of curing.

The strength development of both Vf=1% and Vf=2% volume of fraction are still increasing with days that is 25.807Mpa and 23.880Mpa respectively however it is not as high as the control specimen at 28 days with the value of 50.168Mpa. As compared with the targeted concrete strength, sample with volume of fraction 1% has achieved 25Mpa at 28 days but 2% volume of fraction is slightly below the target. From the result, the compressive strength of control specimen at 28 days is 48.56% and 49.08% higher than 1% and 2% specimen respectively.

Table 4.1 Summary of compressive strength and maximum load of the specimen according to different volume of fraction, Vf.

Days	Compressive strength (Mpa)		
	Vf = 0%	Vf = 1%	Vf = 2%
7	41.767	20.240	20.254
28	50.168	25.807	23.880

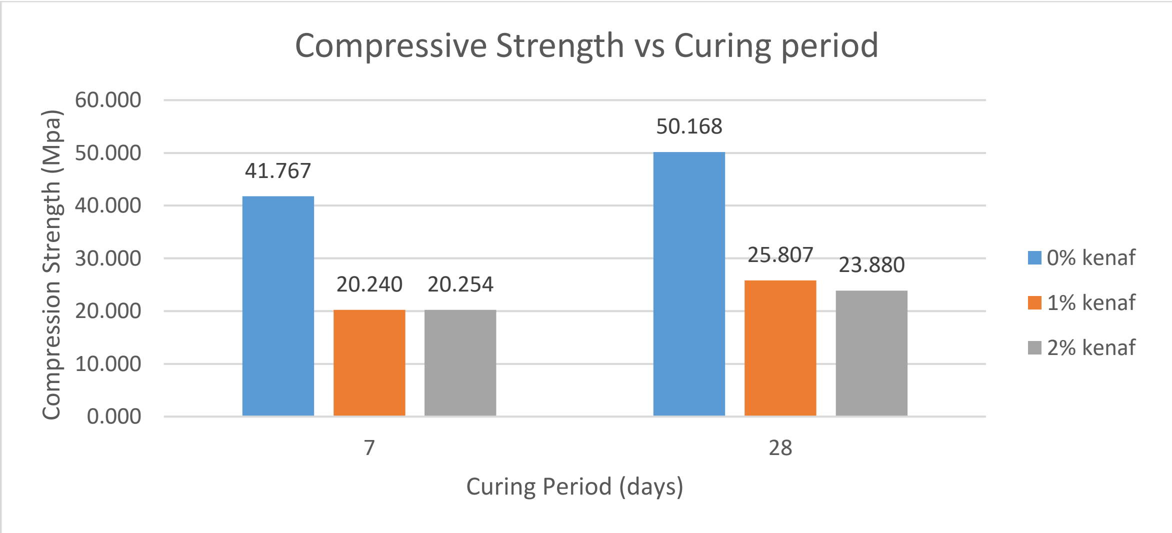


Figure 4.1 Compressive strength vs curing period

On previous research, (Mohsin *et al.*, 2016)show that the control specimen is higher than specimen with kenaf fiber but still increasing with increasing fiber content. In most of the cases, the compressive strength of the concrete with fiber is lower as compared to the concrete without fiber. However, (Azrizal et al., 2015) research on a study on kenaf fiber reinforced concrete block show that the strength decreases gradually as the kenaf content increases. The study stated that the reason it happened because the specimen absorbed more water that the control specimen.

4.3 Flexural test result

The flexural test was conducted on 28 days for all types of beam after curing it. The results of the test are shown in Figure 4.2, Figure 4.3. The first crack and ultimate load of the beam are shown in Figure 4.4.

Figure 4.2 shown below indicated to the comparison of control beam with opening and beam without opening. As the result, control beam without opening shows higher loading than the beam with opening. The first load of deflection of control beam without opening is at 261kN while for beam with opening decreasing to 161kN. Likewise, the maximum load for specimen with opening is at 347.21kN and specimen with opening lowered down to 278.07kN.

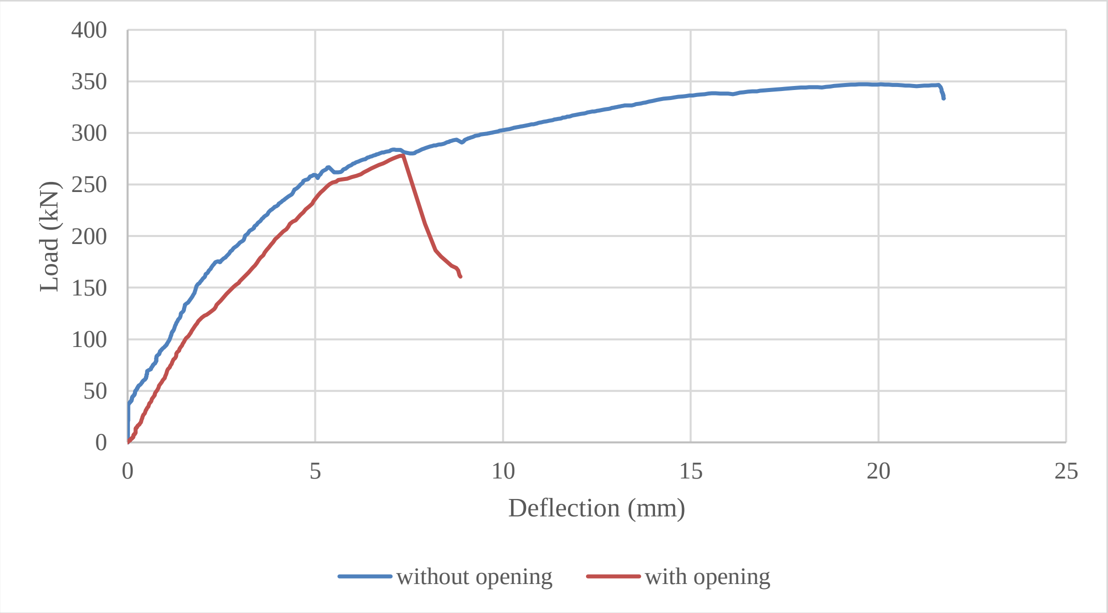


Figure 4.2 Deflection curve of control beam with opening and without opening

4.1.1 First Crack Pattern

The first crack pattern and the ultimate load of each beams are represented in the Figure 4.4 below. The pattern tells that for Vf=0% has the highest value of load which is 161kN followed by Vf=2% and Vf=1% which having load of 155kN and 140kN respectively. In the meantime, the ultimate load pattern is showing a decreasing manner where Vf=2% has the lowest ultimate load which is 54.82kN while Vf=0% has the highest value and followed by Vf=1% that is 160.83kN and 57.30kN respectively.

Table 4.2 The summary of first crack pattern and ultimate load

Vf (%)	Pu (kN)	$F1_{crack}$ (kN)
0	160.83	161
1	57.30	140
2	54.82	155

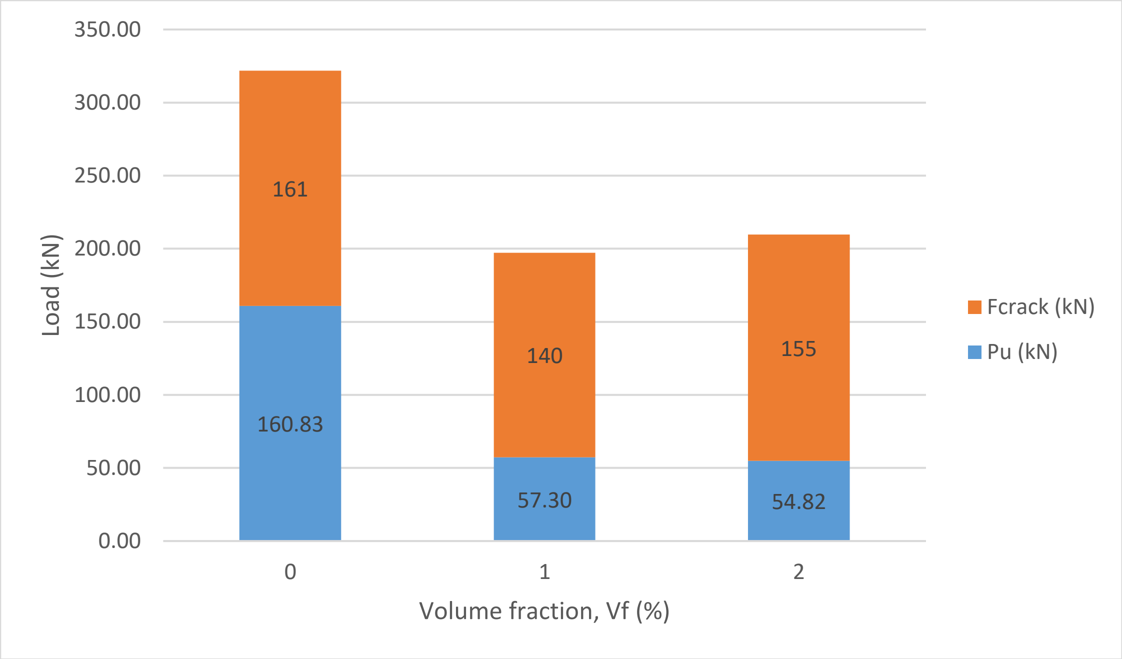


Figure 4.4 First crack pattern and Ultimate load.

Furthermore, the deflection curve shown in Figure 4.3 is of three beams with different volume of fraction of kenaf fiber. The first deflection of 0% volume of fraction is at 161kN while 1% and 2% volume of fraction first deflection is at 155kN and 140kN respectively. Meanwhile, the maximum load for 0%, 1% and 2% specimen are 278.07kN, 184.70kN and 172.53kN respectively. To conclude, the increment of volume of fraction, Vf, decreased the load resistant of the beam.

On previous research, (Syed Mohsin *et al.*, 2016) kenaf fiber reinforced concrete beams showed decreasing in strength with increasing in volume of fraction of kenaf fiber. Similarly, in this study with increasing volume of fraction of kenaf fiber, the load resistant of the beam seemed to be decreasing. It is recommended to use proper curing method and to properly vibrate the mix during casting to avoid honeycombing to occur and later resulted in reducing the flexural strength of the beam.

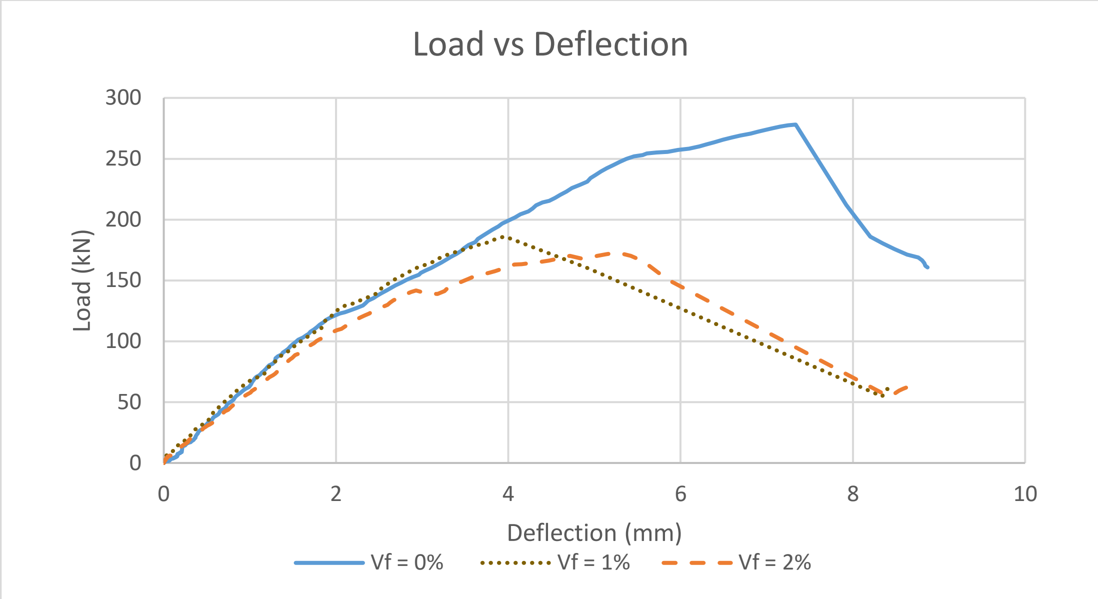


Figure 4.3 Deflection curve of beam with opening

4.1.2 Key Parameters and Ductility

Tables 4.2 and 4.3 show the key parameters of strength and ductility resulted from the load deflection curves. The key parameters include Py which is the loading at yield and its respective deflection (δy), Pmax representing maximum load carrying capacity and its respective deflection (δmax), and ultimate load at failure and its respective deflection (δu). Ductility ratio (μ) is calculated by dividing the ultimate deflection to the deflection and yield. From the tables, it shows that the maximum load carrying capacity (Pmax) and yield load (Py) of beam specimen without opening is higher than beam with opening. All the parameters of beam with opening shows higher values than that beam with opening added with kenaf fiber. Moreover, with increment volume of fraction from Vf=1% to Vf=2% shows increasing in yield load (Py) but still below the control beam, Vf=0%. However, the maximum load carrying capacity (Pmax) of 2% is decreasing same as the ductility ratio which is 172.53 and 2.90 respectively.

Table 4.3 Key parameters and ductility of control beam without opening.

Vf (%)	Py,0 (kN)	δy,0 (mm)	Pu,0 (kN)	δu,0 (mm)	Pmax,0 (kN)	δmax,0 (mm)	μ0 =
0	266.94	5.36	333.58	21.74	347.21	19.70	4.06

Table 4.4 Key parameters and ductility of beam with opening added with kenaf fiber.

Vf (%)	Py (kN)	δy (mm)	Pu (kN)	δu (mm)	Pmax (kN)	δmax (mm)	μ=
0	254.39	5.61	160.83	8.87	278.07	7.34	1.58
1	131.15	2.21	54.82	8.34	184.70	3.88	3.78
2	141.65	2.93	57.30	8.49	172.53	5.23	2.90

Figures shown below illustrates the strength and ductility of the KFRC beams normalised to control beam (Vf= 0%) against fibre content. In Figure 4.5, the yield load (Py) were normalised to control beam and the pattern show that KFRC beam with Vf= 1% were drop and later slightly going up with Vf= 2% KFRC. While based on Figure 4.6, the trend of maximum load (P_{max}) shows a constant drop at every addition of Vf in the KFRC. However, the ductility shown in Figure 4.7 is showing a trend where it is increase at Vf=1% with value of 0.93 then later drop with Vf=2% of 0.71 value.

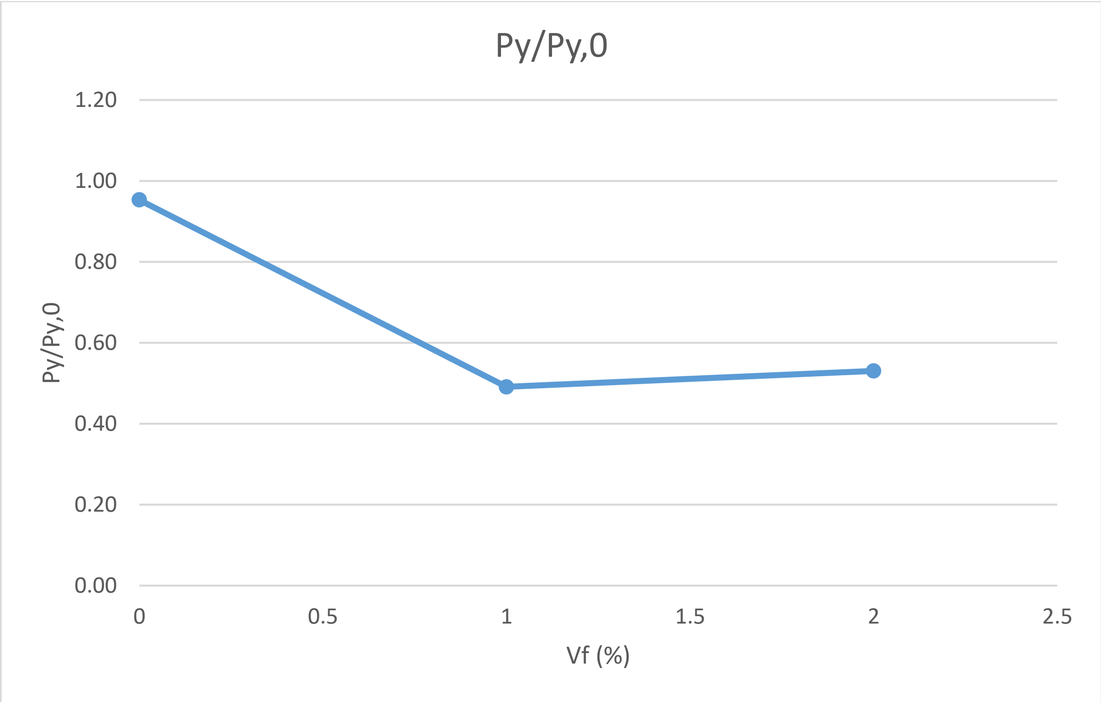


Figure 4.5 Graph Py/Pyo versus Vf

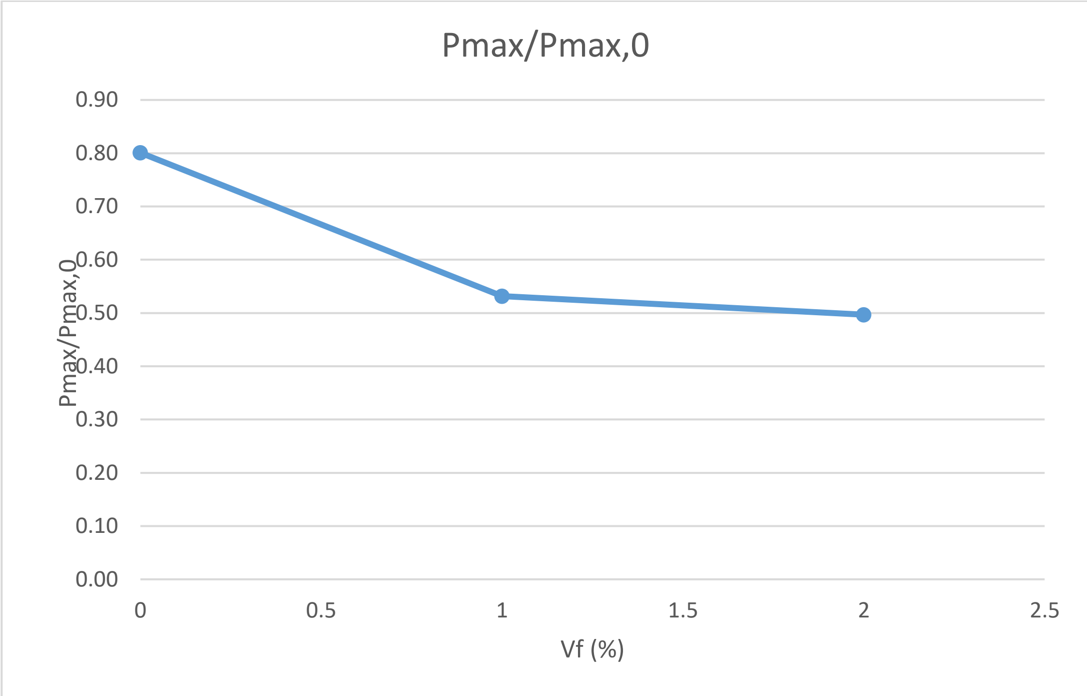


Figure 4.6 Graph Pmax/Pmaxo versus Vf

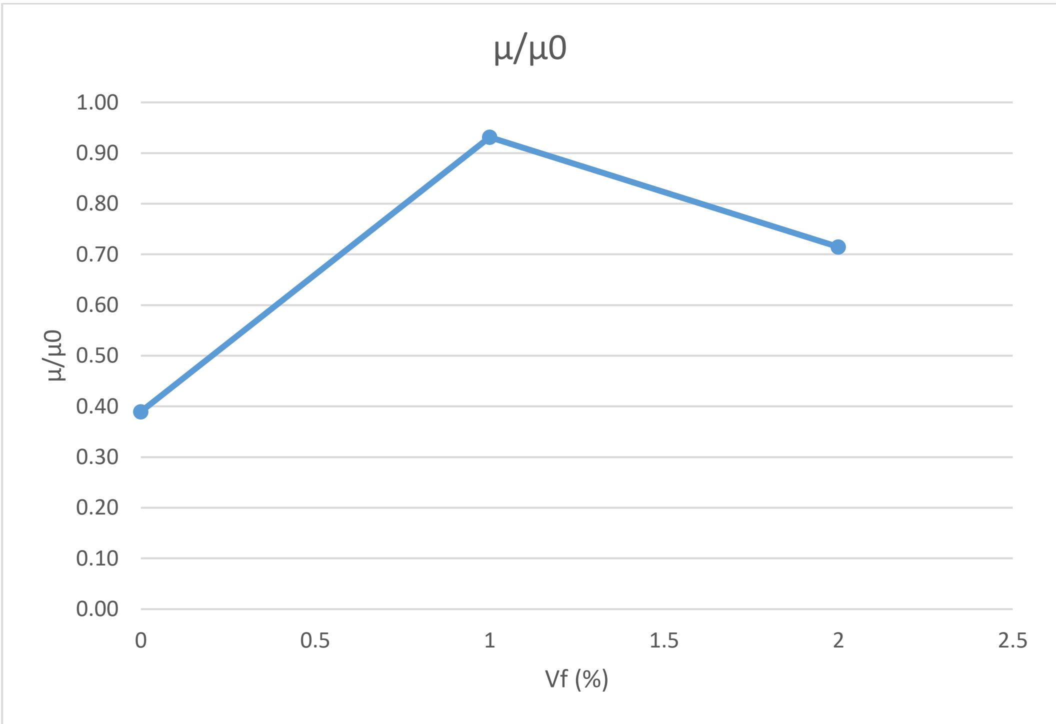


Figure 4.7 Graph μ/μ0 o versus Vf.

4.4 Failure Mode of Concrete Beam

Figure 4.8 to Figure 4.11 represents the cracking pattern and failure mode of control beam without opening, control beam with opening, beam with volume fraction of Vf=1% and Vf=2% respectively. Cracking pattern of control beam without opening is in the mid-span shows that the failure mode is bending mode while for beam KF00 shows cracking at the opening observed as shear mode failure. As for beam KF01 and KF02, failure mode observed were also in shear mode where the cracks happened near the opening and finally fail at the end near the support.

Table 4.5 Failure mode of beam with different volume of fraction.

Beam	Vf (%)	Failure Mode
Control Beam	0	Deflection
KF00	0	Shear
KF01	1	Shear
KF02	2	Shear

The figure 4.8 shown of the control beam without opening that cracks and failed in the middle of the beam and it is observed as deflection failure. However, control beam with opening in figure 4.9 shows shear failure where it cracked and failed near the opening which is at the end of the beam. Furthermore, figure 4.10 and figure 4.11 show similar failure mode where the cracks happened at the opening and failed at the bottom end of the beam.

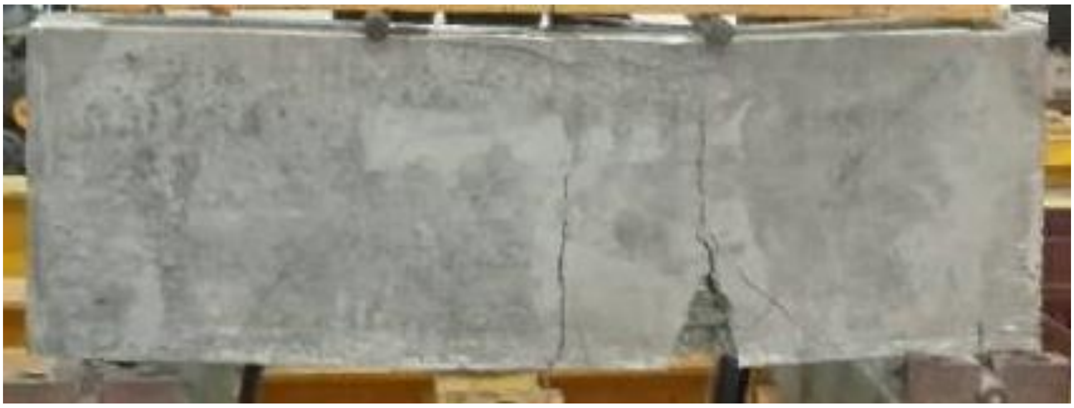


Figure 4.8 Control beam without opening

Figure 4.9 Beam KF00 with opening of Vf=0%

Figure 4.10 Beam KF01 with opening of Vf=1%

Figure 4.11 Beam KF02 with opening of Vf=2%

4.5 Summary

In this chapter, the behaviour of controlled reinforced beam and Kenaf Reinforced Beam (KFRC) are explained and discussed. The main parameters considered in this study is the cracking pattern and the behaviour of the beams. The structural response of both type of beam by means of load at max (Pmax), yield load (Py), ductility ratio (μ), load strain and mode of failure of beams were presented. The load at yield (Py) of KFRC is improved however maximum load (Pmax) of KFRC beam is not improving where it is decreasing with Vf=2%. To conclude, the increment of volume of fraction, Vf, decreased the load resistant of the beam. The ductility (μ) of KFRC is increasing only up to Vf=1%, thus only sufficient amount of kenaf can be added to the mix to be used in order to improve the structural properties of kenaf fibre.

CHAPTER 5

CONCLUSION

5.1 Introduction

The objective of the study is to improve performance of RC beam contains of different percentage of kenaf fiber and the behaviour of three RC beam with opening and RC beam without opening as the control beam. The volume fraction ranging from 0%, 1% and 2%. All the specimens were subjected to undergo curing for 7 and 28 days before testing.

This study presents the behaviour of beam with opening added with kenaf fiber. All the experimental test was designed to achieved the objective of this study. The analysis of the data shows the outcome of the volume of fraction of kenaf fiber on the behaviour of the beam with opening. The cube test of compressive strength shows the strength of the concrete. The experimental results are analyzed by observing the crack pattern and the ultimate load of each beam by observing the failure mode.

5.2 Conclusion

Based on the results and analysis on Chapter 4, the following conclusion are drawn from the experimental works;

- Additional of kenaf fiber in concrete does not improve the compressive strength of concrete compared from control specimen. However, the concrete will still undergo increasing in strength during curing period with time.

- As the fiber content increasing, the concrete seemed to be gradually decreasing and does not guaranteed will have higher strength despite having an increment in volume of fractions as time passes.

- The results of flexural behaviour obtained in this study shows where the load carrying capacity of 0% beam specimen is higher than 1% followed by 2% volume of fraction of kenaf fiber.

- Furthermore, in this study the ductility as well as compressive and flexural behaviour of all beams showed a decreasing manner in value as the kenaf fiber increasing.

5.3 Recommendation

The results of this study showed the behaviour of the beam is improving up to Vf=1% and dropped with Vf=2%. The dropped of the trend could be because of during mixing stage. It is believed that during mixing and casting, it should be made properly. Honeycomb existed due to improper water cement ratio and excessive vibration are also one of the contributing factor in decreasing of strength of the beam. The existing of honeycombing is believed because of few factors. Improper water/cement ratio that causes poor workability and poor vibration technique. It is recommended to have proper vibration and the right water/cement ratio to avoid honeycombs to occur.

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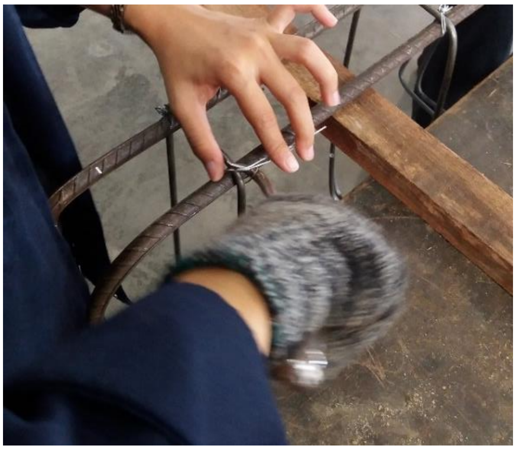
APPENDIX A

Reinforcement link (6mm)

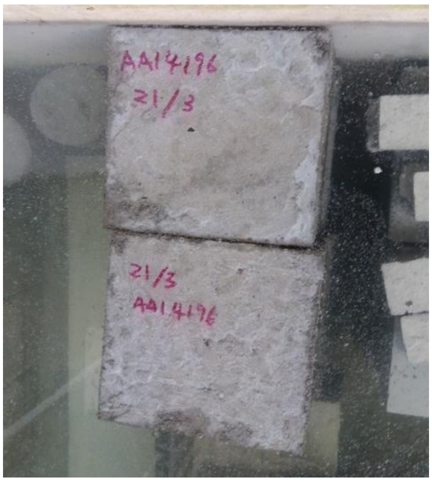


Reinforcement set up

Making hole for the opening at beam formwork

Preparation for kenaf treatment

Mixing and casting



Curing method (water curing)

APPENDIX B

Cube size: 150 x 150 x 150 (mm)

Beam size: 150 x 400 x 1200 (mm)

Density kenaf fibre = 550-1400kg/m^3

Assume density (kenaf fibre) = 650kg/m^3

Density steel fibre = 7400-8100kg/m^3

Assume density (steel fibre) = 7800kg/m^3

Cube:

Volume of cube + 20% waste = 0.00405m^3

0.5% kenaf = 0.00405 x (0.5% x 650) = 0.013kg

1% kenaf = 0.00405 x (1% x 650) = 0.026kg

2% kenaf = 0.00405 x (2% x 650) = 0.053kg

0.5% steel fibre = 0.00405 x (0.5% x 7800) = 0.158kg

1% steel fibre = 0.00405 x (1% x 7800) = 0.316kg

Beam:

Volume of beam + 20% waste = 0.0864m^3

0.5% kenaf = 0.0864x (0.5% x 650) = 0.28kg

1% kenaf = 0.0864x (1% x 650) = 0.56kg

2% kenaf = 0.0864x (2% x 650) = 1.12kg

0.5% steel fibre = 0.0864x (0.5% x 7800) = 3.37kg

1% steel fibre = 0.0864x (1% x 7800) = 6.74kg

Volume of beam + 20% waste = 0.0864m^3

Control beam (ingredient for 1 beam)

Coarse aggregate = 0.0864 x 1142.44 = 98.707kg

Fine aggregate = 0.0864 x 615.16 = 53.15kg

Cement = 0.0864 x 452.4 = 39.087kg

Water = 0.0864 x 190 = 16.416L

Beam with 1% hybrid fibre (ingredient for 1 beam)

Coarse aggregate = 0.0864 x 1142.44 = 98.707kg

Fine aggregate = 0.0864 x 615.16 = 53.15kg

Cement = 0.0864 x 452.4 = 39.087kg

Water = 0.0864 x 190 = 16.416L

Kenaf fibre = 0.28kg

Steel fibre = 3.37kg

Beam with 2% hybrid fibre (ingredient for 1 beam)

Coarse aggregate = 0.0864 x 1142.44 = 98.707kg

Fine aggregate = 0.0864 x 615.16 = 53.15kg

Cement = 0.0864 x 452.4 = 39.087kg

Water = 0.0864 x 190 = 16.416L

Kenaf fibre = 0.56kg

Steel fibre = 6.74kg

Beam with 1% kenaf fibre (ingredient for 1 beam)

Coarse aggregate = 0.0864 x 1142.44 = 98.707kg

Fine aggregate = 0.0864 x 615.16 = 53.15kg

Cement = 0.0864 x 452.4 = 39.087kg

Water = 0.0864 x 190 = 16.416L

Kenaf fibre = 0.56kg

Beam with 2% kenaf fibre (ingredient for 1 beam)

Coarse aggregate = 0.0864 x 1142.44 = 98.707kg

Fine aggregate = 0.0864 x 615.16 = 53.15kg

Cement = 0.0864 x 452.4 = 39.087kg

Water = 0.0864 x 190 = 16.416L

Kenaf fibre = 1.12kg

Volume of cube + 20% waste = 0.00405m^3

<u>Control cube (ingredient for 1 cube)</u>

Coarse aggregate = 0.00405 x 1142.44 = 4.627kg

Fine aggregate = 0.00405 x 615.16 = 2.49kg

Cement = 0.00405 x 452.4 = 1.832kg

Water = 0.00405 x 190 = 0.77L

<u>Cube with 1% hybrid fibre (ingredient for 1 cube)</u>

Coarse aggregate = 0.00405 x 1142.44 = 4.627kg

Fine aggregate = 0.00405 x 615.16 = 2.49kg

Cement = 0.00405 x 452.4 = 1.832kg

Water = 0.00405 x 190 = 0.77L

Kenaf fibre = 0.013kg

Steel fibre = 0.158kg

<u>Cube with 2% hybrid fibre (ingredient for 1 cube</u>

Coarse aggregate = 0.00405 x 1142.44 = 4.627kg

Fine aggregate = 0.00405 x 615.16 = 2.49kg

Cement = 0.00405 x 452.4 = 1.832kg

Water = 0.00405 x 190 = 0.77L

Kenaf fibre = 0.026kg

Steel fibre = 0.316 kg

<u>Cube with 1% kenaf fibre (ingredient for 1 cube)</u>

Coarse aggregate = 0.00405 x 1142.44 = 4.627kg

Fine aggregate = 0.00405 x 615.16 = 2.49kg

Cement = 0.00405 x 452.4 = 1.832kg

Water = 0.00405 x 190 = 0.77L

Kenaf fibre = 0.026kg

<u>Cube with 2% kenaf fibre (ingredient for 1 cube)</u>

Coarse aggregate = 0.00405 x 1142.44 = 4.627kg

Fine aggregate = 0.00405 x 615.16 = 2.49kg

Cement = 0.00405 x 452.4 = 1.832kg

Water = 0.00405 x 190 = 0.77L

Kenaf fibre = 0.053 kg