STUDY ON BEHAVIOUR OF CONCRETE ADDED WITH DIFFERENT LENGTH OF BAMBOO FIBRES

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ABSTRACT

Nowadays, concrete is highly contributed in the construction works for its various advantages such as low cost, availability, fire resistance and others. Generally, concrete is high in compressive strength but relatively low in tensile strength. Steel is the mostly used for the reinforcement of concrete due to its high tensile strength. Alternate materials such as fibres are used to increase the tensile strength of the concrete. Bamboo is natural, cheap and readily available material. Most importantly, bamboo has a high tensile strength. This research is aimed at studying the performance of concrete with bamboo fibres as additives in it. The objective of this research was to experiment the structural behaviour of bamboo fibres reinforced concrete (BFRC) with various length of bamboo fibres as additives. In this paper, 2% of bamboo fibres by volume of the concrete with the length of 40mm and 60mm are added into concrete and compare with the plain concrete which act as the control specimen. 2 tests are tested which are the cube compression test and flexural test. From the test result has shown that the compressive strength of different length of BFRC is lower as compared to the controlled cube specimen. For flexural strength, the 40mm BFRC is the most optimum length as it has shown the almost similar strength with the controlled beam specimen. The flexural strength for the 60mm BFRC is slightly lower than that of the controlled beam specimen.

ABSTRAK

Pada masa kini, konkrit banyak menyumbang dalam kerja-kerja pembinaan disebabkan oleh pelbagai kelebihannya seperti kos rendah, ketersediaan, ketahanan api dan lain-lain. Secara amnya, konkrit mempunyai kekuatan mampatan yang tinggi tetapi agak rendah dalam kekuatan tegangan. Steel banyak digunakan sebagai tetulang konkrit kerana kekuatan tegangannya yang tinggi. Bahan gantian seperti serat juga digunakan untuk meningkatkan kekuatan tegangan konkrit. Buluh adalah bahan semula jadi, murah dan mudah didapati. Yang paling pentingnya, buluh mempunyai kekuatan tegangan yang tinggi. Kajian ini bertujuan untuk mengkaji prestasi konkrit dengan gentian buluh sebagai bahan tambahan di dalamnya. Objektif kajian ini adalah untuk mencuba kelakuan konkrit yang ditambah dengan gentian buluh yang mempunyai pelbagai kepanjangan. Dalam kertas ini, 2% gentian buluh daripada isipadu konkrit dengan panjangnya terdiri daripada 40mm dan 60mm telah ditambah ke dalam konkrit dan memperbandingkannya dengan konkrit biasa yang bertindak sebagai spesimen kawalan. 2 ujian telah diuji iaitu ujian mampatan kiub dan ujian lenturan. Daripada hasil ujian telah menunjukkan bahawa kekuatan mampatan konkrit yang telah ditambah dengan gentian buluh yang terdiri daripada pelbagai kepanjangan adalah lebih rendah berbanding dengan spesimen kiub kawalan. Untuk kekuatan lenturan pula, konkrit yang telah ditambah dengan gentian buluh yang sepanjang 40mm adalah paling optimum kerana ia telah menunjukkan kekuatan yang hampir sama dengan spesimen kawalan. Kekuatan lenturan untuk BFRC 60mm adalah lebih rendah daripada spesimen kawalan.

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LIST OF SYMBOLS

%	Percentage
m	Meter
cm	Centimeter
mm	Millimeter
μm	Micrometer
mt	Metric tons
kg	Kilogram
N	Newton
m^3	Meter cube
mm^2	Millimeter square
N/mm^2	Newton per millimeter square
kg/m^3	Kilogram per meter cube
g/cm^3	Gram per centimeter cube
g/cm	Gram per centimeter
MPa	Mega Pascal
±	Plus-Minus

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British Standard
CEM	Certified Energy Manager
EN	European Standards
OHSAS	Occupational Health and Safety Assessment Specification
MS	Malaysia Standard
OPC	Ordinary Portland Cement
FRC	Fibre Reinforced Concrete
NFRC	Natural Fibre-Reinforced Concrete
SFRC	Synthetic Fibre-Reinforced Concrete
KFRC	Kenaf Fibre-Reinforced Concrete
CFRC	Coconut Fibre-Reinforced Concrete
BFRC	Bamboo Fibre-Reinforced Concrete
HSFRSCCs	Hybrid Steel Fibre-Reinforced Self-Compacting Concrete
LOI	Loss On Ignition
MR	Modulus of Rupture
W/C	Water to Cement Ratio
USGS	United States Geological Survey
CO_2	Carbon Dioxide
C_3A	Tricalcium Aluminate
C_3S	Tricalcium Silicate
C_4AF	Tetracalcium Alumino Ferrite
MGO	Magnesium Oxide

SO_3	Sulphate
CL^-	Chloride
CaCO3	Calcium Carbonate

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

There are a lot of developing countries undergo urbanisation process due to the rapid population growth. Therefore, more infrastructures and building are needed to facilitate the population in these countries. The construction industry in the developing country including Malaysia is growing rapidly. Nowadays, concrete is highly contributed in the construction works for its various advantages such as low cost, availability, fire resistance, etc. and it is one of the main elements of the building (M.M. Rahman et al, 2011). Hence, concrete is essential for the construction industry.

Concrete is a mixture of cement, aggregates, sand, water and some chemical admixtures. Traditionally, concrete has a high compressive strength but low tensile strength. Therefore, steel which has a high tensile strength is generally used to reinforce the concrete. However, steel is relatively high cost and use of steel should be limited. In addition, manufacturing process of steel consume a lot of energy. Therefore, it is necessary to reduce the use of steel by using more environmental friendly, low cost and less energy consuming materials to enhance the concrete properties is a major concern nowadays.

Cement has been reinforced with natural fibres for several years, particularly in developing countries that used materials such as bamboo, sisal, jute and coir with some success. These natural materials are cheap and have environmental benefits since they are renewable and non-toxic. However, bamboo still has more and better advantage among these natural fibres although most of these studies give positive results.

Bamboo species can grow at rates up to 20 cm per day and full height of approximately 20 m is reached in half year time. The strength of bamboo increases with its age and maximum strength is reached after 3 to 4 years. Bamboo has a high tensile strength and able to attain up to 370 MPa (M.M. Rahman et al, 2011). The strength to specific weight ratio of bamboo is six times greater than that of steel. Ability of bamboo in nitrogen and carbon dioxide in the air is very beneficial to the environment.

Many researches have been done on the use of bamboo as reinforcement for composites. The bamboo is in cylindrical shape limits the direct use of it in some engineering systems. Therefore, there is alternative that the bamboo is extracted into fibres from the culm and the bamboo fibres are use as reinforcement of polymeric matrices (E. Trujillo et al, 2014). Bamboo fibre is capable to capture large CO_2 and consume low energy per kg of fibres (E. Trujillo et al, 2014). The mechanical strength of the bamboo is the highest among natural fibre and have the lowest density with is 0.9G/cm^3 (Shah Huda et al, 2012). The flexural strength of autoclaved bamboo fibre reinforced cement composites is greater than 18 MPa and about 1.3 g/cm of density when a fibre loading of 14% is used (R.S.P Coutts et al, 1995). Humberto C. Lima Jr. et al (2007) did a research on the durability analysis of bamboo as concrete reinforcement. The durability of bamboo was evaluated by changing the tensile strength and Young's modulus of bamboo. As a result, the bamboo tensile strength is comparable with the best timber type and even steel that used in construction.

In this research, tensile property of the concrete with bamboo fibre as an additive was observed.

1.2 PROBLEM STATEMENT

Generally, concrete is high in compressive strength but relatively low in tensile strength. Tensile strength of plain concrete is typically 8% to 15% of its compressive strength (Vasudev R et al, 2013). Crack of the concrete is usually occurred when there is a stress on the concrete that exceed the tensile strength of the concrete. Concrete would almost fail from tensile stresses even when loaded in compression. Thus, concrete is usually reinforced with material in high tensile strength so that both tensile and compressive strength of concrete are satisfactory. Other than that, fibres are widely used to enhance the performance of concrete from cracking. Fibres are distributed throughout the concrete mix to limit the size and extent of cracks. Bamboo fibre is proven that has high tensile strength where it can attain 370MPa. Bamboo is extracted into fibres and added into normal concrete mix to investigate further and understand the behaviour of concrete with bamboo fibres as an additive.

1.3 OBJECTIVES

The main aim of this research is to experiment the structural behaviours of the normal concrete with various length of bamboo fibres as an additive. The bamboo fibres will be added into normal concrete mix in this research.

i. To determine the workability of the concrete added with the length of 40mm and 60mm of bamboo fibres by 2% of the volume of concrete.
ii. To investigate the flexural strength of the concrete added with the length of 40mm and 60mm of bamboo fibres by 2% of volume of concrete.
iii. To determine the compressive strength of the concrete added with the length of 40mm and 60mm of bamboo fibres by 2% of volume of concrete.

1.4 SCOPE OF RESEARCH

There were few limitations in this research as listed and explained below.

i. Same concrete mix design will be used for both normal concrete and concrete with bamboo fibres as an additive.
ii. 30 MPa will be used for the design strength.
iii. Only Orang Kuat Portland Cement certified to MS 522-1: 2007 (EN 197-1 : 2000), CEM l 42.5 N / 52.5 N and MS 522 : Part 1 : 2003 cement will be used.
iv. Bamboo used is collected from bamboo forest in Hulu Langat, Selangor.
v. Bamboo fibres length of 4cm and 6cm will be used.
vi. The diameter of bamboo fibres range from 1 mm to 2 mm will be used.
vii. 2% of bamboo fibres by volume of concrete will be added for the tests.
viii. For flexural strength test, specimen of 100mm x 100mm x 500mm will be used and tested on 7^{th}, 14^{th} and 28^{th} day.
ix. For compression test, specimen of 150mm x 150mm x150mm will be used and tested on 7^{th}, 14^{th} and 28^{th} day.

x. For curing process, the concrete will be put in the water curing tank located at the concrete laboratory of Civil Engineering for 7, 14 and 28 days.

xi. Standard of BS1881: Part 116:1983 will be used for compression test

xii. Standard of BS1881: Part 118 will be used for flexural test.

1.5 RESEARCH SIGNIFICANCE

It is clearly understood that the tensile strength of concrete is low but only high in compressive strength. Tensile strength of the concrete is concerned by engineers as failure of structure might happen when the concrete without reinforcement is used. Since the bamboo is originally high in tensile strength and it is added into concrete in fibres forms to enhance the performance of the concrete. The recommendation of the bamboo fibres as an additive in the concrete is beneficial due to the availability and low cost. Besides that, bamboo fibre is one of the sustainable materials that can be easily available.

1.6 EXPECTED OUTCOME

When the normal concrete is added with bamboo fibres, the expectation is that:

i. The flexural and compressive strength of the concrete with bamboo fibres as an additive will be higher than normal concrete.

ii. The flexural and compressive strength of the concrete with bamboo fibres as an additive will be higher as the bamboo fibres length is longer.

CHAPTER 2

LITERATURE REVIEW

2.1 CONCRETE

Concrete is the main materials of structures in present days. High demand of concrete in construction field especially in the developing country indicates that the concrete is very advantageous. Concrete is a composite material which made up from cement, aggregates, water and sometimes with admixtures added in it. The proportion of the materials used in the mix depends on the concrete mix design based on the requirement of a structure. There is expectation that the global rate of cement and concrete production will increase more than 2.5% annually over the next decade (Wil V.Srubar III, 2014).

Generally, concrete is only high in compressive strength but low in tensile strength and limited ductility. Cracking or failure of structure can be occurred on the low tensile strength of concrete when load is applied on it. Elastic deformation in concrete was caused by propagation of internal crack of concrete which lead to additional crack to occur when load is applied.

2.2 CEMENT

Cement is the most important material in the concrete where cement has the most effects on the properties of concrete. There are many types of cement with different composition such as Rapid Hardening Cement, Quick setting cement, Low

Heat Cement, Sulphates Resisting Cement, Blast Furnace Slag Cement, High Alumina Cement, White Cement, Coloured Cement, Pozzolanic Cement, Air Entraining Cement and Hydrographic cement which can be found in the industry nowadays.

Rapid Hardening Cement consists of increased lime content where is able to attain high strength in early days. It is commonly used in concrete where formworks are removed at early stage. Quick setting cement consists of small percentage of aluminium sulphate as an accelerator and reducing percentage of Gypsum with fine grinding. It is usually used in works which need to be completed in very short period and concreting static and running water. Low Heat Cement is manufactured by reducing the tricalcium aluminate (C_3A) and it is very useful in massive concrete construction such as gravity dams. Besides that, the Sulphates Resisting Cement is produced by maintaining the percentage of C_3A below 6% which increases the power against sulphates. Generally, it is used in construction exposed to severe sulphate action by water and soil in places like canal linings, culverts, retaining walls and others.

Blast Furnace Slag Cement is obtained by grinding the clinkers with about 60% of slag and resembles more or less in properties of Portland cement. It can be used for works where economic consideration is predominant. High Alumina Cement is produced by melting mixture of bauxite and lime and then grinding with the clinker. It is rapid hardening cement with initial and final setting times of about 3.5 and 5 hours respectively. It is commonly used in works where concrete is subjected to high temperatures, frost and acidic action. White Cement and Coloured cement are usually used for decorative purposes. White Cement is produced from raw materials which are free from Iron oxide whereas the Coloured cement is produced by mixing mineral pigments with ordinary cement. White cement is more costly compared to other types of cements.

Pozzolanic Cement is prepared by grinding pozzolanic clinker with Portland cement and commonly used in marine structures, sewage works and for laying concrete under water such as bridges, piers and so forth. Air Entraining Cement is obtained by adding indigenous air entraining agents such as resins, glues, sodium salts of Sulphate and others during grinding of clinkers. It is frequently used to improve workability of concrete with smaller water cement ratio and to improve frost resistance of concrete. Lastly, Hydrographic cement has high workability and strength and it is produced by mixing water repelling chemicals. The summary for the composition and the uses of different types of cement are shown in Table 2.1.

Table 2.1: Types of cement, their composition and uses

Type of Cement	Composition	Purpose
Rapid Hardening Cement	Increased Lime content	Attains high strength in early days it is used in concrete where form work are removed at an early stage
Quick setting cement	Small percentage of aluminium sulphate as an accelerator and reducing percentage of Gypsum with fine grinding	Used in works is to be completed in very short period and concreting in static and running water
Low Heat Cement	Manufactured by reducing C_3A	It is used in massive concrete construction like gravity dams
Sulphates Resisting cement	It is prepared by maintaining the percentage of C_3A below 6%which increases power against sulphates	It is used in construction exposed to severe sulphate action by water and soil in places like canals linings, culverts, retaining walls, siphon, etc.
Blast Furnace Slag Cement	It is obtained by grinding the clinkers with about 60% slag and resembles more or less in properties of Portland cement	It can used for works where economic consideration is predominant
High Alumina Cement	It is obtained by melting mixture of bauxite and lime and grinding with the clinker it is rapid hardening cement with initial and final setting time of about 3.5 and 5 hours respectively	It is used in works where concrete is subjected to high temperatures, frost and acidic action
White Cement	It is prepared from raw materials free from Iron oxide	It is more costly and is used for architectural purposes such as precast curtain wall and facing panels, terrazzo surface, etc.
Coloured cement	It is produced by mixing mineral pigments with ordinary cement	They are widely used for decorative works in floors
Pozzolanic Cement	It is prepared by grinding pozzolanic clinker with Portland cement	It is used in marine structures, sewage works and for laying concrete under water such as bridges, piers, dams, etc.
Air Entraining Cement	It is produced by adding indigenous air entraining agents such as resins, glues, sodium salts of Sulphates, etc. during the grinding of clinker.	This type of cement is specially suited to improve the workability with smaller water cement ratio and to improve frost resistance of concrete
Hydrographic cement	It is prepared by mixing water repelling chemicals	This cement has high workability and strength

Portland cement is the most common type of cement in general use around the world. Different types of Portland cement are manufactured to meet different physical and chemical requirement for specific purposes, such as durability and high-early strength. American Society for Testing (ASTM) has designated six types of Portland cement, designated Types I-V and white Portland cement.

Type I Portland cement consist of fairly high C_3S content for good early strength development. It is used in general construction such as bridges, pavements, most buildings, precast units and so forth. Type II Portland cement is classified as moderate sulphate resistance that has low C_3A content which is less than 8%. It is commonly used in structures exposed to soil or water containing sulphate ions. Types III Portland cement has high early strength which may have slightly more C_3S. It is used for rapid construction or cold weather concreting works.

Type IV Portland cement has low heat of hydration or slow reacting because it has low content of C_3S where it should be less than 50% and C_3A. Generally, it is used in massive structures such as dams. Type V Portland cement has high sulphate resistance due to very low C_3A content which is less than 5% and it is commonly used in structures exposed to high levels of sulphate ions. The white Portland cement has no C_4AF content and low MgO content and it is white in colour. It is often used for decorative purposes. The type I Portland cement is the more suitable type of Portland cement to be used in this research since it is for general construction. The general characteristics of six types of Portland cement are shown in Table 2.2.

Table 2.2: General features of the main type of Portland cement

	Classification	Characteristics	Applications
Type I	General purpose	Fairly high Tricalcium Silicate (C_3S) content for good early strength and development	General construction (most buildings, bridges, pavements, precast units, etc.
Type II	Moderate sulphate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulphate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams
Type V	High sulphate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulphate ions
White	White colour	No Tetracalcium Alumino Ferrite (C_4AF), low Magnesium Oxide (MgO)	Decorative (otherwise has properties similar to Type I)

Ordinary Portland Cement (OPC) is the most common type of cement where it is grey in colour. The yearly production of portland cement is approximately 3.3 billion metric tons (mt) according to U.S. Geological Survey (USGS) in 2011 (Kemal Celik et al, 2014). The chemical composition of OPC is shown in Table 2.3. The common percentage content in OPC are 0.4% of insoluble residue, 3.2% of Loss On Ignition (LOI), 2.7% of Sulphate Content (SO_3) and 0.02% of Chloride (Cl^-).

Table 2.3: Chemical composition of OPC

Chemical Content	Chemical Composition (%)
Insoluble Residue	0.4
Loss On Ignition (LOI)	3.2
Sulphate Content (SO_3)	2.7
Chloride (Cl^-)	0.02

Manufacturing of Portland cement caused emissions of carbon dioxide (CO_2) which is one of the major problems faced by the concrete industry. There is research has shown that about 400 kg of CO_2 is emitted into atmosphere for every 600 kg of cement (Swaptik Chowdhury et al, 2014). The emission of CO_2 leads to the global warming as the construction development is flourishing. The rate of environmental degradation is increased and more exploitation of natural resources for raw material is needed due to high demand of cement in concrete production. Therefore, it is necessary for the industry to approach in the use of less concrete for structures, less cement content in concrete and less usage of clinker in production of cement (Kemal Celik et al, 2014).

2.3 AGGREGATES

Aggregate are the important ingredient in concrete. Aggregate are granular material, derived from the most part from the natural rocks, crushed stones, or natural gravels and sands. Aggregates generally occupied 70% to 80% of total volume of concrete. Thus, aggregates have important influence on the properties of both fresh and hardened concrete. Aggregates serves as reinforcement to increase the overall strength of the concrete. In order to ensure good quality of concrete, aggregates need to be clean, hard, free from absorbed chemicals or coatings of clay and other fine materials that could cause deterioration of concrete. The amount of cement paste required to obtain desired concrete strength is depend on the void spaces between aggregate particles during the concrete mix design. According to Murat Ozen et al. (2013), more cement paste is needed if uniformly graded aggregates are used due to the large voids between aggregates whereas less cement paste is only required if aggregates if well gradation is used because the particles in the aggregates are densely packed. There are two types of aggregates used in the concrete mix which are coarse aggregates and fine aggregates.

2.3.1 COARSE AGGREGATES

Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. The coarse aggregates occupy 2/3 of total volume of aggregate. All natural aggregates originate from bed rocks. Coarse aggregates are usually consists of uncrushed gravel or stone which is produced from natural disintegration and crushed gravel or stone.

Basalt Granite

Calcareous Marble

Figure 2.1: Type of coarse aggregates

Source: Christiano Gonilho Pereira et al (2008)

Few types of aggregates such as basalt, granite, calcareous and marble are shown in Figure 2.1. Basalt is a dark-coloured, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. It most commonly forms as an extrusive rock, such as a lava flow. Granite is a light-coloured igneous rock with grains large enough to be visible with unaided eye. It is formed from the slow crystallization of magma below Earth's surface. Calcareous, also known as sedimentary rock, is formed from or contains a high proportion of calcium carbonate ($CaCO_3$) in the form of calcite or aragonite. Marble is a metamorphic rock formed when limestone is exposed to high temperature and pressures. It is mainly composed of the mineral $CaCO_3$ and usually contains other minerals such as clay minerals, quartz, iron oxides and others.

The shape of the coarse aggregates is one of the contributors to the concrete strength. The development of cracks due to stress is mainly depends on the shape of coarse aggregates. According to C.G. Rocco et al. (2008), smooth gravels leads to cracking at lower stresses than rough and angular crushed rock. C.G. Rocco et al. (2008) have conducted research on the effect of aggregate shape on the fracture and mechanical properties of standard concrete. Christiana Gonilho Pereira et al. (2008) have done a research on the influence of natural coarse aggregate size, mineralogy and water content on the durability of structural concrete of strength class C30/37 at age 28 days. As a result, the aggregate size and its water content has significant effect on the durability properties of concrete whereas the aggregates mineralogy had no influence on the durability properties of concrete.

Nowadays, there are numerous researches on the alternative replacement for the use of natural coarse aggregates in concrete mix due to the limited availability of natural aggregates and production of the construction waste is increasing. The use of recycled aggregate in the manufacture of concrete is growing due to the environmental benefits.

2.3.2 FINE AGGREGATES

Fine aggregates are particles that smaller than 4.75mm and equal to or larger than 75 µm. Fine aggregate usually consists of natural or manufactured particles ranging in size from 150mm to 4.75mm. Fine aggregate occupy 0 to 15% of total volume of aggregate. There are few types of fine aggregates such as river sand, sea sand and pit sand which have shown in Figure 2.2.

Pit sand

River sand

Sea Sand

Figure 2.2: Different type of sand used in construction

Pit sand which also known as coarse is procured from deep pits of abundant supply and it is generally red-orange in colour. The coarse grain is sharp, angular and certainly free from salts. River sand is obtained from river streams and banks. It is fine in quality unlike pit sand. River sand has rounded grain and generally white-grey in colour. Sea sand is taken from seas shores and it is commonly in distinct brown colour with fine circular grains.it contain salt which tends to absorb moisture from atmosphere and bring dampness.

The fine and coarse aggregates are usually blended such that the fine aggregate is more than enough to fill in the voids within the coarse aggregate. Thus there is excess of fine aggregate coating the coarse aggregate particles to mitigate the particle interlocking action and improve the flowability and passing ability of the concrete produced (A.K.H. Kwan et al, 2014). In addition, the specific area of the blended