AN EXPERIMENTAL STUDY OF THE STRUCTURAL CAPACITY OF COMPOSITE BEAM (CONCRETE CAST I-BEAM)

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AN EXPERIMENTAL STUDY OF THE STRUCTURAL CAPACITY OF COMPOSITE BEAM (CONCRETE CAST I-BEAM)

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ABSTRAK

Rasuk komposit adalah satu jenis sistem yang menggabungkan kelebihan struktur keluli dan struktur konkrit untuk membentuk struktur bangunan yang lebih baik untuk pembangunan masa hadapan. Pada masa kini, rasuk komposit selalu digunakan untuk membina struktur mega seperti jambatan dan empangan. Rasuk komposit mengandungi keluli rasuk, simen, agregat, dan campuran dengan air (konkrit). Campuran ini boleh menjadi berbeza-beza mengikut keperluan sesuatu struktur tersebut. Konkrit adalah struktur yang boleh dibentuk menjadi sebarang bentuk yang baik dalam rintangan mampatan, namun lemah dalam rintangan ketegangan. Objektif utama kajian ini adalah untuk menentukan beban muktamad, pesongan rasuk dan tekanan terikan komposit di bawah ujian rasuk. Ujian beban empat titik, menggunakan mesin Magnus Frame akan dijalankan untuk mencari beban muktamad dan pesongan rasuk komposit. Sampel akan disediakan dengan sewajarnya, dan ujian rasuk akan dijalankan masing-masing berikutan urutan supaya mendapatkan hasil yang terbaik dan mencapai objektif yang ditetapkan. Tiga rasuk komposit sampel akan disediakan untuk ujian rasuk, di mana setiap rasuk campuran disediakan dengan keadaan yang sama. Semua sampel rasuk komposit diuji di Struktur Makmal berat, Fakulti Kejuruteraan Awam dan Sumber Alam, Universiti Malaysia Pahang dan juga ujian mampatan untuk menentukan kekuatan konkrit. Dapatan kajian ini menunjukkan bahawa objektif utama telah dicapai. Keputusan yang telah menunjukkan bahawa, beban muktamad yang komposit saiz rasuk 0.15m x 0.3m x 2m dengan I-rasuk saiz 127 x 76 x 8 yang diperolehi adalah 179.58kN. Sebaliknya, pesongan maksimum untuk saiz rasuk yang sama boleh sehingga 15.8mm. Berdasarkan kajian sebelum ini, nilai yang diperolehi bagi beban maksimum dan pesongan adalah dalam lingkungan keupayaan rasuk komposit dan lengkung tegasan-terikan bagi keluli dan bahan konkrit mengikut pola tipikal lengkung. Corak untuk kedua-dua bahan adalah lebih kurang sama. Peningkatan ketegangan kedua-dua bahan berkadar terus dengan tekanan sehingga ia mencapai ketegangan bahan maksimum. Ini menunjukkan kedua-dua bahan rasuk komposit mula gagal. Kemudian, kedua-dua bahan ketegangan membangunkan perleheran yang memaparkan mengurangkan kedua-dua nilai terikan, manakala tekanan kekal yang sama pada peringkat tersebut. Akhir sekali, dengan peningkatan beban dan tekanan, membentuk retak dan gagal rasuk komposit dan menunjukkan nilai negatif kedua-dua tekanan.

ABSTRACT

Composite beam is type of system that combines the advantages of steel structure and concrete structure to form better building structures for future development. Nowadays, composite beam has been extremely used for built such a mega structures such as bridge and dam. Composite beam contain steel, cement, aggregates, and blend with water. This mixtures is varies on what to build and for what purpose. Concrete is a structure that can be formed into any shape which is good in compression resistance, however weak in tension resistance. The main objectives of this study is to determine ultimate load, deflection of composite beam and stress-strain curve under beam test. The four point load test, using Magnus Frame Machines will be conducted to find ultimate load and the deflection of the composite beam. Samples will be prepared accordingly, and the beam test will be conducted respectively following the sequences in order to come out the best results and achieve the objectives set. Three sample composite beam will be provided for the beam test, in which varies with the location of connector for each composite beam. All the samples of the composite beam are tested at Fakulti Kejuruteraan Awam dan Sumber Alam, Heavy Structure Laboratory, University Malaysia as well as the compressive test which to determine the concrete strength. The finding of this study shows that objectives have been achieved. The results that have been obtained shows that, the ultimate load that composite beam size 0.15m x 0.3m x 2m with I-beam of size 127 x 76 x 8 can sustained is 179.58kN. On the other hand, the maximum deflection for the same beam size can be up to 15.8mm. Based on the previous study, the value obtained for maximum load and deflection is in the range of composite beam capacity and the stress-strain curve for steel and concrete material follows the typical pattern of curve. The pattern for both material was about the same. The both material strain increase directly proportional to the stress until it reached maximum material strain. This indicate the both material of composite beam begin to fail. Then, the both material strain developing necking which shows the decreasing of both strain value, while the stress remained the same throughout the stage. Lastly, with increasing of load and stress, develop a crack and failed to the composite beam and shows that, the negative value of both strain.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Composite beam is type of system that combines the advantages of steel structure and concrete structure to form better building structures for future development. As early as 1808, the first structures with iron sections and concrete preceded the emergence of reinforced concrete with non-rigid round bars as propagated by (Monier Bracher 1949). Besides that, according to Monier Bracher, 1949 the composite action of composite beam is achieved by connect the steel and concrete material elements by means of connector. Shear connectors between concrete and steel in composite beam can play an important role in the shear response of a structure. The connector provide necessary shear connection for composite action in flexure, and can be used to distribute the large horizontal inertial forces in the beam to the main lateral load resisting elements of the structure.

As the world of industry revolutionize, the safety, cost and period of projects has been manipulate in order to get the best result of it. The manipulation of it in construction industry, the most common and frequently encountered combination of construction material are the design and implementation of steel-concrete composite members for building and offshore structures. The main factor used of reinforced of concreted beam produce minimum wastage of material. Therefore in terms of cost of the projects for using composite beam, lower than reinforced concrete beam. This long term efficient money consume due to composite beam reduce the wastage of material and labor mistake during construction works. Besides that, in terms of duration of projects which can influence the cost of project, composite beam obviously gives short period time of project due to its excellence in product manufacturing compare to reinforced concrete beam?

1.2 Problem Statement

The development of the industry today has mainly focusing on the strength and safety of structural members of projects. One of the method used to replace traditionally reinforced concrete structure is composite of steel-concrete materials. The replacement of composite beam compare to the traditional reinforced concrete beam brings more advantages compare to its disadvantages. The main focus replacement of composite beam is regarding to the structural and safety of structures components of building. The previous experimental shows the increasing of structural capacity of composite beam compares to traditional reinforced concrete beam. The composite beam which is combination of concrete and steel beam which connect by means of connector to act as a unit to produce high stiffness which resulting increasing of strength and stiffness of the composite beam with minimum used of materials (Johnson and Willmington, 1972).

1.3 Objective

The main objective of this study is to determine the experimental study of the structural capacity of composite I Beam with modified connectors. The following are for thesis study:

(a) To find the ultimate load, moment and deflection of composite beam under experimental flexural test.
(b) To investigate location of connectors for optimum composite action of steel and concrete elements in order to find ultimate load, moment and deflection of composite beam.

1.4 Scope of Study

Scope of this study will focus on experimental study for structural capacity on the use of combination between steel I-beam and concrete material to produce composite beam rather than use traditional reinforced concrete beam. The results will be used for selection of composite beam whether it can be used to produce building structure of high quality for future development.

This study also focusing on the use of connector in order to produce strong bonding between the two steel I-beam and concrete. The connector use is a simple connector which being applied by the method of welding.

Steel I-beam used size section of 124 x 74 x 8 UB, meanwhile for concrete studies using the cube size of 150mm x 150 mm x 150mm. The concrete studies produce by normal weight concrete in term of strength and workability and concrete strength supposed to be tested is C20/25 for compressive strength test.

Simply supported beam composite beam of size 0.15m x 0.3m x 2m will be produced from the combination of steel I- beam size section 124 x 74 x 8 UB and concrete strength of C20/25.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In construction, beam plays an important role and it is the main ingredient in structure. Concrete is a building material that is widely used in the construction industry, so the techniques to make a good quality concrete must be understood and observed carefully. Generally, they consist of a mixture of cement, sand, aggregate and water with a certain ratio or designed, the reaction between cement and water will produce C-S-H gel to form the bond between aggregate will give strength and durability to concrete. Concrete in construction is widely used in civil engineering projects around the world with for the following reasons, namely it has good resistance to water, precast concrete structures can be shaped into a variety of shapes and sizes and usually, it is the cheapest and most readily available materials for work (Mehta and Monteiro, 2006).

Concrete can be divided into three groups, namely, light weight concrete, normal concrete, and concrete weight. According to BS5328, light weights concrete are classified as concrete has a density not exceeding 2000 kg/m3. While for normal concrete has a density between heavy 2000kg/m3 and not exceeding to 2600 kg/m3. For concrete in excess of 2600 kg/m3 densities was classified as heavy concrete businesses and create less waste. Moreover, these initiative indirectly reducing the expenses in purchases of financial incentive for consumers and businesses.

According to (Alexander M.G. and Sydney Mindness, 2005), between 70 to 80 per cent out of the total volume of concrete is occupied by aggregate. With this large proportion of the concrete occupied by aggregate, it is expected for aggregate to have a profound influence on the concrete properties and its general performance.

Aggregate are essential in making concrete into an engineering material. They tend to give concrete its volumetric stability; they also have a unanimous influence on reducing moistures related to deformation like shrinkage of concrete.

Oil palm shell is an organic waste that is easily available in our country, Malaysia. Palm shells will be used as a material to replace the aggregate in the concrete, it can reduce the density of ordinary concrete and reduces environmental pollution (Mannan, M. A and Ganaphaty, C, 2002). This can be another's waste as the material can be used to produce new products.

2.2 Beam

According to (Dr Ibrahim Assakkaf 2002), a beam is generally considered to be any member subjected to principally to transverse gravity of vertical loading. The term transverse loading is taken to include end moments. There are many types of beams that are classified according to their size, manner in which they are supported, and their location in any given structural. Based on the manner in which they are supported there six type of beams:

(a) Simply supported beam
(b) Cantilever beam
(c) Overhanging beam
(d) Continuous beam
(e) Fixed ended
(f) Cantilever simply supported

2.2.1 Structural capacity of beam

2.2.1.1 Shear

The ultimate shear capacity of deep beams is dependent on the strength of concrete as well as on the strength, amount, and placement of the reinforcement (Zenon A. Zielinsk and Marco Rigott 2016).

The ultimate shear resistance of reinforced concrete beams is increased with an increase of steel fibre content. Other than that, doubly reinforced concrete beam will provide higher shear resistance compare to singly reinforced concrete beam (Byung Hwan Oh 1992).

Reinforced steel fibre concrete beam have higher shear load and greater ductility in flexural failure than similarly plain concrete beams (Teck-Yong Lini, P. Paramasivam, and Seng-Lip Le 1987).

With increasing the concrete strength of the beam, the ultimate shear load of the concrete beam increased as well (Javad VASEGHI AMIRI and Morteza HOSSEINALIBEGIE 2004).

2.2.1.2 Moment

Temperature distribution in the cross section of composite beams is generally that the highest temperature occurred in slab soffit, followed by the lower flange .then the web and then the upper flange. This temperature distribution causes the difference of structural behavior between steel beam and composite beam. The deformation of steel beam appears directly correspondent to temperature distribution in the cross section. On the moment of the beginning of fire exposure, the composite beam moves upward. And also, at the beginning of fire exposure, thermal expansion of slab soffit causes greater elongation of the composite beam than in the steel beam. The influence of these behaviors can be seen in the analyses of I-shaped structural frames. At the beginning of fire exposure, the bending moments at the end of the span of composite beam decrease, and the bending moment at the middle of span increases. And the bending moments at the restraint columns of composite beam are greater than that of steel beam. In spite of these differences between steel beam and composite beam, analyses of structural frames in this paper show that the fire resistance of structural frame with I-section steel beam and the structural frame with composite beam is almost the same. (T. Morita, T. Wakamatsu, H. Uesugi and H. Saito 2015).

With increasing the concrete strength of the beam, the ultimate moment of the concrete beam increased as well (Javad Vaseghi Amiri and Morteza Hosseinalibegie 2004).

Reinforced steel fiber concrete beam have higher moment capacity and greater ductility in flexural failure than similarly plain concrete beams (Teck-Yong Lini, P. Paramasivam, and Seng-Lip Le 1987).

According to (Rene E. Walther 1957) the ultimate moment of simply supported beam increase with the increase of concrete strength, ratio of tension reinforcement, ratio of web reinforcement, ratio of compression reinforcement, and prestressing.

2.2.1.3 Stress-Strain

Both the normal stress and shear stress in bending depend strongly on the L/t ratio. This effect for shear failures is not easily predicted. For tensile failures, it is reasonably well predicted by the mechanics-of-materials theory (E. Sideridis and G. A. Papadopoulos 2003).

2.2.1.4 Deflection

The resistance to the deflection of fiber-reinforced concrete beams is increased with an increase of steel fiber content. The fiber-reinforced concrete beam showed concentration of inelastic deformation at the ultimate stage in one large crack, while inelastic deformation was more evenly distributed in the normal and high-strength concrete beams without fibers (Byung Hwan Oh 1992).

2.3 Materials

2.3.1 Concrete

Concrete is a composite material and has been called pourable stone and sand composed of coarse granular material and finer material '(the aggregate or filler)' embedded in a hard matrix of material '(the cement)' that fills the space between the aggregate particles and glues them together. We can also consider concrete as a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregates. The oldest concrete discover dates from around 7000 BC. It was found in 1985 when a concrete floor was uncovered during the construction of a road at Yiftah El in Galilee, Israel. It considered of a lime concrete, made from burning limestone to produce quicklime which when mixed with water and stone then hardened to form concrete (Brown 1996).

The water penetrability of lightweight concrete is more sensitive to the extent of initial curing that it is for normal weight concrete. Normal weight concrete best strength development took place under a continuous water-curing regime. (Husain Al-Khaiat and Naseer Haque, 1999).

The concrete which has substantially lower mass per unit volume then the concrete made of ordinary ingredients is called lightweight concrete. The aggregates used are lighter in weight and has been a feature in the construction industry for centuries, but like other material the expectations of the performance have raised. Lightweight concrete structural has an in-place density on the order of 1440 to 1840 kg/m^3 compared to normal weight concrete a density in the range 2240 to 2400 kg/m^3. The strength of light weight concrete varies from 17 MPa to 40 MPa. The concrete mixture is made with a lightweight course aggregate and in some cases, the entire fine aggregates may be a lightweight product. Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay or slate materials that have been fired in a rotary kiln to develop a porous structure. (Satish Chandra and Leif Berntsson 2002)

Concrete having a density greater than 2500 kg/m3 is known as high density concrete or heavy weight concrete. High density concrete are widely used for radiation shielding in nuclear power plants, hospitals, ballast in offshore locations etc. Conventional concrete is also a good shielding material provided that space is not a consideration. But space is a definite consideration in many applications. In such cases it is not possible to place the desired amount of normal weight concrete in given space. In such cases heavy weight concrete is used. The key to heavy weight concrete is the aggregates. High density aggregates are used to get high density concrete. The quality and types of aggregates are the most important factors in the selection process of aggregates. (Athira Suresh and Ranjan Abraham, 2015).

Concrete is considered a quality that has a high compressive strength, durable and not easily permeable in water. While a good quality concrete structures is the vanes smooth, compact and not porous when the mold is opens. For low quality concrete will become brittle, easily cracked, and permeable in water. Therefore, to ensure good quality of concrete, several things need to be addressed before, during and after the concrete is provided. Concrete compressive strength, density and workability of concrete are the main parameter to be determined before designing the structural members. While, the process of casting, process of compacting and process of curing operations at the construction site, must be addressed to ensure a good quality concrete. Strength and durability of concrete depends on the amount of water in the concrete mix and the degree of compaction applied. Therefore, these matters should be noted (Wong, Like Kee, 2001): Viscosity of the mixture must be appropriate to allow the concrete is mixed well. May be carried, cast, and worked easily and does not occur separation of a mixture of original material.

2.3.1.1 Cement

Cement should be suited to the exposure, such as sulphate-resistant cement to help prevent sulphate attack. Sulphate-resistant cements, however, like other Portland or blended hydraulic cements, are not resistant to most acids or other highly corrosive substances (Beatrix Kerkhoff 2007).

The compressive strength gain at early ages of Portland cement concrete is lower than that of ordinary Portland cement concrete. Lack of proper Pozzolanic reaction in the presence of fly ash in Portland Composite Cement concrete strength is lower at early age. The pozzolanic activity of fly ash also contributes to the strength gain at later stages of continuous curing. But at later ages, the strength of Portland Composite Cement concrete and Ordinary Portland Cement is almost same to continuous curing. At continuous curing condition, Portland Composite Cement concrete for the target strengths of 17.24 MPa, 27.58 MPa, and 41.37 MPa requires 50 to 70 days, 80 to 100 days and 180 to 200 days respectively to gain full target strength and at 14 days curing condition, it requires 90 days and 180 days to gain the target strength of 17.24 MPa and 27.58 MPa respectively. But it fails to gain the target strength of 41.37 MPa in 365days at 14 days curing condition. The compressive strength of five different compositions cement increased with increasing curing time. Adequate curing at early ages as well as at later ages is essential in the strength development of Portland Composite Cement concrete. It can be concluded that drying ambient conditions reduce the strength potential of Portland Composite Cement concrete as the secondary (pozzolanic) reaction fails to contribute to the development of strength. This characteristics of strength development can significantly increase the use of Portland Composite Cement in construction of mass concrete to be used in water related structure (Md. Alhaz Uddin, Mohammed Jameel, Habibur Rahman Sobuz, Md. Shahinul Islam, and Noor Md. Sadiqul Hasan 2012).

2.3.1.2 Coarse aggregate

May be either gravel or crushed stone. Makes up 40%-45% of the mixture, comprised of particles greater than 1/4” and the range of size 4.75 mm (3/16 in.) to 50 mm (2 in.) (Retained on No. 4 sieve) (Eng. A.Al Kourd and Eng. Adel Hammad 2009).

Workability in the fresh phase and strength in the hardened form of structural concrete are, to a great extent, dependent on the gradation of the combined aggregate batch, and the proportioning of different size aggregate groups is a crucial step in concrete mix design (Richardson 2005).

2.3.1.3 Fine aggregate

Normally called sand, this component can be natural sand or crushed stone, and represents particles smaller than 3/8". Generally accounts for 30%-35% of the mixture. The range of size is <4.75 mm; >75 Njm (0.003 in.) (retained on No. 200 sieve) (Eng. A.Al Kourd and Eng. Adel Hammad 2009).

The mechanical behaviour and collapse potential of fine aggregate such as silty sand and sandy silt is depend on intergrain contact density. Other than that, the strength of sandy silt is typically higher than that of pure silt which can choose as a suitable fine aggregate in concrete mix proportions (S. Thevanayagam, T. Shenthan, S. Mohan and J. Liang 2002).

2.3.1.4 Water

Almost any natural water that is drinkable and has no pronounced taste or odor can be used as mixing water for making concrete (Eng. A.Al Kourd and Eng. Adel Hammad 2009).

The water-cement ratio or the water-cementitious materials ratio (where applicable) should not exceed 0.45 by weight (0.40 for corrosion protection of embedded metal in reinforced concrete). (Beatrix Kerkhoff 2007).

For a given soft clay, the cementation bond strength increases as water-void/cement ratio, w/c decreases. Consequently, the yield stress in consolidation and compressive strength increases with the decrement of w/c. The stress-strain response and compression characteristics in pre-yield state are practically the same as long as the w/c value is identical. The void ratio plays a significant role on the compressibility in post-yield. Even though the samples having the same w/c value develop practically the same strength and compressibility in pre-yield state (Suksun Horpibulsuk, Apichat Suddeepong, Cherdsak Suksiripattanapong, Avirut Chinkulkijniwat, Arul Arulrajah, and Mahdi Miri Disfani 2014).

2.3.2 Steel

Under positive bending, it was found that initial stiffness and ultimate strength of composite beam averagely increased 67% and 27% respectively, compared to steel beam without slab. Under negative bending, similar ultimate strength of specimens with or without slab was obtained. This composite action disappeared after 3% drift of loading and then lateral strength slowly deteriorated until fracture of bottom flange. Substructure loaded by near-fault protocol performed well showing good strength and ductility slightly better than that of other tests where fracture of bottom flange and separation of beam and slab was visualized during test. Moreover, test performance revealed that cross beams and shape of stirrups in the panel zone have only marginal effect on the shear transfer in panel zone due to the strong column and weak beam design for all specimens (Chin – Tung Cheng and Cheng – Chih Chen 2004).

According to (Resmi Mohan and Preetha Prabhakaran 2015) as compared to solid beam and steel beam with circular opening, steel beam with hexagonal opening showed more load carrying capacity. Steel beam with hexagonal opening showed more strength because during its fabrication process there is no loss of material, but for the fabrication of circular opening there is loss of materials.

2.4 Method

2.4.1 Testing Method

2.4.1.1 Three point bending test and equation

The three point bending test measures the force which is required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without bending. Three – point test configurations, are used to obtain flexural strength and flexural modulus. The rotation of the cross sections in the deformation process leads to the contact zone between specimen and cylindrical supports changing in a three point bending test. The classical theory of deflection of beams neglects the square of the first derivative in the bending moment equation and cannot be used when the slopes of the beam are large. In many cases large deflections cannot be obtained without straining the beam plastically but, when the thickness of the beam is small compared with its width, large deflections within the elastic limit of the material are possible. The maximum deflection of a beam carrying a central concentrated load, that is, when submitted in three point bending, was different than that predicted by the simple bending theory due to a number of variables that should be considered (J. C. Venetis and E. P. Sideridis 2015).

However, an appropriate choice can reduce the effect of these variables on the results of the tests. The load – deflection curve is not linear but deflection variations increase with corresponding increments of load. Also, it was estimated that when the reactions are assumed perpendicular to the beam there is a lateral component tending to change the deflection and slope since the buckling component of the perpendicular reactions becomes predominant (J. C. Venetis and E. P. Sideridis 2015).

According to (Irina Petrescu, Cristina Mohora, and Constantin Ispas 2013) the equation of deflection simply supported beam is:

$$\Delta f = \frac{\mathrm{P}L^3}{48\mathrm{EIy}}$$

P = Point load (kN)

L = Length span of beam (m)

E = Young Modulus for material (MPa)

Iy = Second moment of inertia in the y – axis (m4)

2.4.1.2 Four point bending test and equation

The four-point flexural test fixture is able to quickly evaluate the flexural strength of tubes with a flexural stiffness in the stated range. The test method for conducting the test usually involves a specified test fixture on a universal testing machine. The impact fixture provides a method of producing damage induced by a glancing blow to the tube wall. Understanding of flexural strength, flexural fatigue performance, and damage tolerance under flexural fatigue loading provides a good reference or guideline to how durable tubes will be in actual use. Incorporating the four-point flexural fixture provides the desired bending moment with two important aspects. The first is the need to minimize the applied loads while producing the maximum bending moment. The second is the presence of a region with a constant bending moment. These features made it possible to test critical sections of a tube such as those with induced damage. For this reason, the four-point flexural fixture with rubber load applicators is believed to be a suitable method of testing the flexural strength of thin-walled composite tubes. Though there are many different methods of evaluating fatigue performance, the use of a rotating four-point fatigue fixture is believed to be well suited for this application. This test methodology was found to be a good match for the needs of this project which include the ability to test thin-walled composite tubes with a relatively low flexural stiffness and strength, the ability to test a specific region of a tube, and the ability to test all angle orientations around the tube axis. However, short cracks which run parallel to the tube fibre on the outer layer are easy to miss during inspection. Thus, this type of damage was identified as the focus for this study of thin-walled composite tubes. The difficulty in studying this form of damage is that no available impacters are able to consistently produce such damage. A new impacter was needed which would produce this damage. It is believed that a suitable method for introducing this damage is to focus on the deformation which can introduce such cracks (Bryce Ingersoll 2010).

The Flexural Strength or modulus of rupture (fb) is given by

fb = fl/bd2 (where the loading span is half of the support span)

or

fb = 3fa/bd2 (where the loading span is one over three of the support span)

Where,

a = the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

f = max. Load (kg)

2.4.2 Composite Beam

Recently, as the use of high-performance materials and complex composite methods has increased, the need for advance design specifications for steel-concrete composite structures has grown. For this, joint research to develop an independent design code for composite structures was performed by some organizations in order to achieve sustainable design strength, and deformation of composite beam. According to (Lan Chung, Jong-Jin Lim, Hyeon-Jong Hwang, and Tae-Sung Eom 2016), existing design standard such as AISC 360-10 (American Institute of Steel Construction 2010), KBC 2014 (Architectural Institute of Korea 2014), Eurocode 4 (European Committee for Standardization 2004a) and JSCE 2009 (Japan Society of Civil Engineers 2009) were used as the calculation method for design strength of steel-concrete composite member can divided into the load and resistance factor design method (LRFD) and partial factor method (PFM). Below are the design review made by (Lan Chung and Friends 2016).

AISC 360-10 (American Institute of Steel Construction 2010)	
Design Format	Load and resistance factor design
Design Moment Strength, M_d	$M_d = \phi\ M(fk)$

Resistance factor ϕ or safety factor γ for material	$\phi = 0.9$
Characteristic material strength fk (Mpa)	Concrete $21 \leq fck \leq 70$ Steel $fyk \leq 525$
Plastic stress	Concrete = 0.85 fck Steel = 1.0 fyk
Design Strength, M_d	$M_d = \phi M_{pl}$, $\phi = 0.9$ (Plastic) $M_d = \phi M_{nl}$, $\phi = 0.9$
KBC 2014 (Architectural Institute of Korea 2014)	
Design Format	Load and resistance factor design
Design Moment Strength, M_d	$M_d = \phi\ M(fk)$
Resistance factor ϕ or safety factor γ for material	$\phi = 0.9$
Characteristic material strength fk (Mpa)	Concrete $21 \leq fck \leq 70$ Steel $fyk \leq 650$

Plastic stress	Concrete = 0.85 *fck* Steel = 1.0 *fyd*
Design Strength, M_d	$M_d = \phi M_{pl}$, ϕ = 0.9 (Plastic) $M_d = \phi M_{nl}$, ϕ = 0.9
Eurocode 4 (European Committee for Standardization 2004a)	
Design Format	Partial Factor Method
Design Moment Strength, M_d	$fd = fk/\gamma$ and $M_d = M(fd) / \gamma_b$
Resistance factor ϕ or safety factor γ for material	Concrete $\gamma_c = 1.5$ Steel $\gamma_s = 1.0$ Reinforcing bar $\gamma_r = 1.15$
Characteristic material strength *fk* (Mpa)	Concrete $20 \leq fck \leq 60$ Steel $fyk \leq 460$
Plastic stress	Concrete = 0.85 *fck* Steel = 1.0 *fyd*

Design Strength, M_d	$M_d = Mp_l$ or βMp_l
JSCE 2009 (Japan Society of Civil Engineers 2009)	
Design Format	Load and resistance factor design
Design Moment Strength, M_d	$M_d = \phi\ M(fk)$
Resistance factor ϕ or safety factor γ for material	$\phi = 0.9$
Characteristic material strength fk (Mpa)	Concrete $21 \leq fck \leq 70$ Steel $fyk \leq 525$
Plastic stress	Concrete = 0.85 fck Steel = 1.0 fyk
Design Strength, M_d	$M_d = Mp_l / \gamma_b$ and $\gamma_b = 1.1$

The provisions for the flexural design of composite beam, the design format of Eurocode 4 and JSCE 2009 which use partial factor method were compared with those AISC 360-10 and KBC 2014 which based on load and resistance factor design. For positive bending, M_d and ϕ of Eurocode showed decreasing trends as the depth of the plastic neutral axis increased. In particular, the reduction factor β reduced the design values further for high-strength steel. Eurocode 4 produce the highest M_d compare to others standard codes (Lan Chung, Jong-Jin Lim, Hyeon-Jong Hwang, and Tae-Sung Eom 2016).

2.5 Previous study

The style used for this subchapter 2.2 is *Heading 2, UMP Level 2*.

2.5.1 Journal: Experimental and analytical study on ultimate strength behaviour of steel-concrete –steel sandwich composite beam structures (Jia-Bao Yan, National University of Singapore, 2014)

This paper takes an experimental and analytical approach to study the ultimate strength behaviour of steel-concrete-steel sandwich composite beam by using the advantage of steel beam and concrete form together by act of connector. Eighteen composite beam with variation of material during preparation of sample were tested under a four-point bending test.

2.5.1.1 Method of use

The ultimate strength behaviour of steel-concrete-steel sandwich composite beam structures were investigated. Eighteen composite with variation of material during preparation of sample were tested under a four-point bending configuration in order to study the behaviour of ultimate strength due to certain condition of composite beam during sample preparation variation.

2.5.1.2 Results

Ultimate strength behaviour and failure modes were observed depending on the effect of concrete strength.

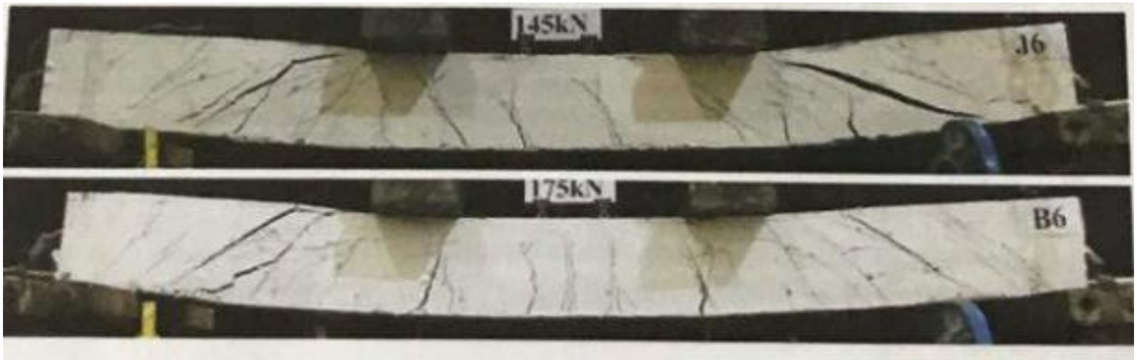


Figure 2.1 : Typical pattern crack for composite beam

Cracks appeared between the load points (constant bending moment). By increasing the load, other cracks appeared in the regions with shear and flexure, leading to beam failure.

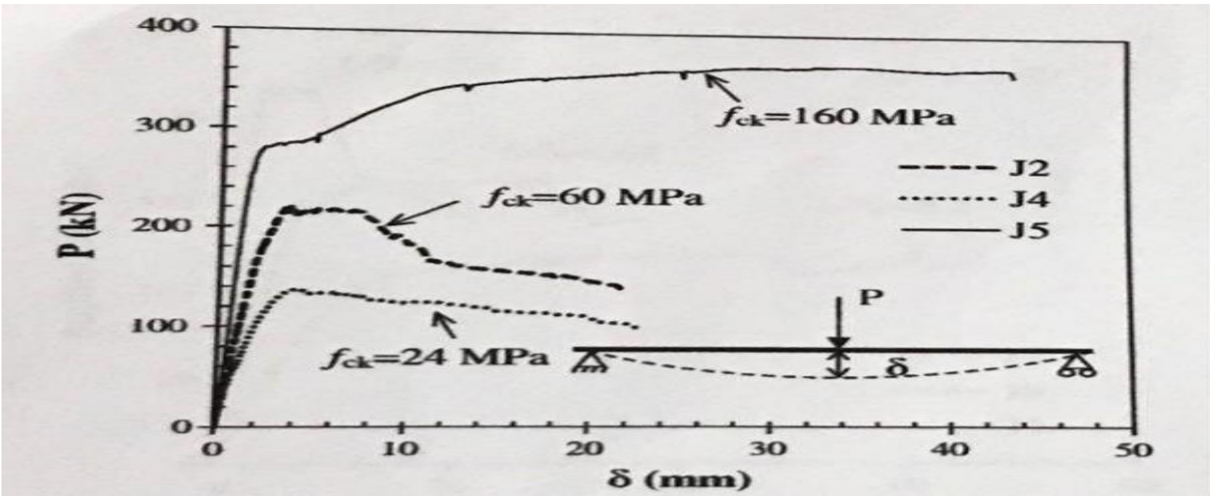


Figure 2.2 : Load vs. displacement curve

From figure 2.2, beams made with different concrete grades, shows that, the load for concrete core of 24Mpa, 60Mpa and 160Mpa are 137.2kN, 221.2kN and 368.3kN respectively.

2.5.1.3 Conclusion

From the study, the following conclusions may be drawn that, it can be found that as the strength of concrete core increase from 24 to 60 and 160 MPa, the ultimate load carrying capacity of the composite beam also increase.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In construction, beam plays an important role and it is the main ingredient in structure. Concrete is a building material that is widely used in the construction industry, so the techniques to make a good quality concrete must be understood and observed carefully. Generally, they consist of a mixture of cement, sand, aggregate and water with a certain ratio or designed, the reaction between cement and water will produce C-S-H gel to form the bond between aggregate will give strength and durability to concrete. Concrete in construction is widely used in civil engineering projects around the world with for the following reasons, namely it has good resistance to water, precast concrete structures can be shaped into a variety of shapes and sizes and usually, it is the cheapest and most readily available materials for work (Mehta and Monteiro, 2006).

Concrete can be divided into three groups, namely, light weight concrete, normal concrete, and concrete weight. According to BS5328, light weights concrete are classified as concrete has a density not exceeding 2000 kg/m3. While for normal concrete has a density between heavy 2000kg/m3 and not exceeding to 2600 kg/m3. For concrete in excess of 2600 kg/m3 densities was classified as heavy concrete businesses and create less waste. Moreover, these initiative indirectly reducing the expenses in purchases of financial incentive for consumers and businesses.

According to (Alexander M.G. and Sydney Mindness, 2005), between 70 to 80 per cent out of the total volume of concrete is occupied by aggregate. With this large proportion of the concrete occupied by aggregate, it is expected for aggregate to have a profound influence on the concrete properties and its general performance.

Aggregate are essential in making concrete into an engineering material. They tend to give concrete its volumetric stability; they also have a unanimous influence on reducing moistures related to deformation like shrinkage of concrete.

Oil palm shell is an organic waste that is easily available in our country, Malaysia. Palm shells will be used as a material to replace the aggregate in the concrete, it can reduce the density of ordinary concrete and reduces environmental pollution (Mannan, M. A and Ganaphaty, C, 2002). This can be another's waste as the material can be used to produce new products.

3.2 Flowchart of methodology

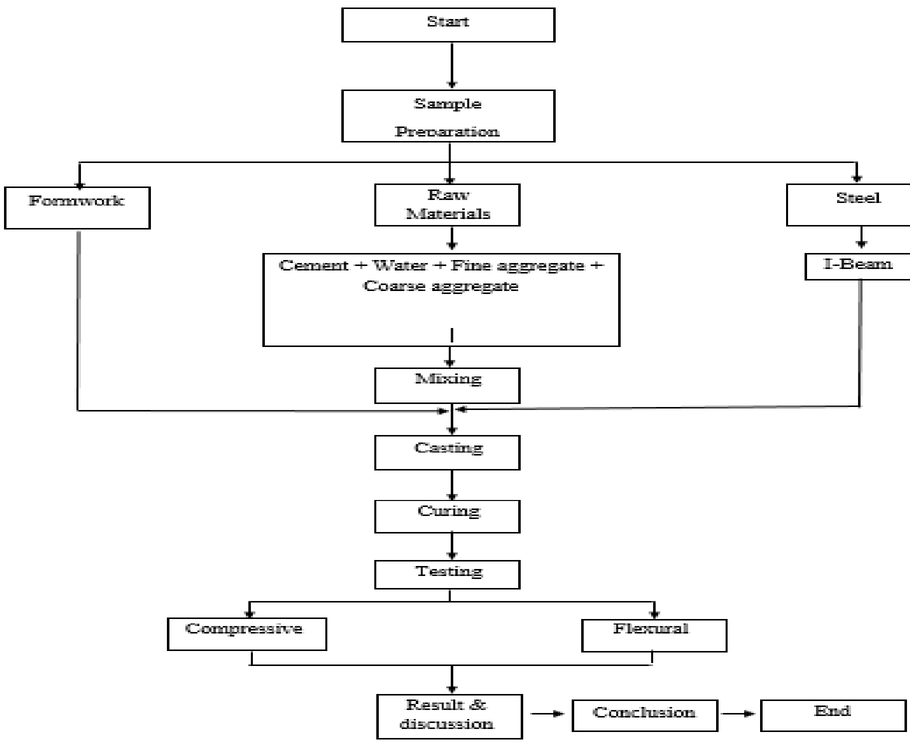


Figure 3.3 : Represented the flow chart of the process of this research

Each work carried out must have careful planning in order to achieve the goals and objectives. For this study work plan was made as shown in Figure 3.4

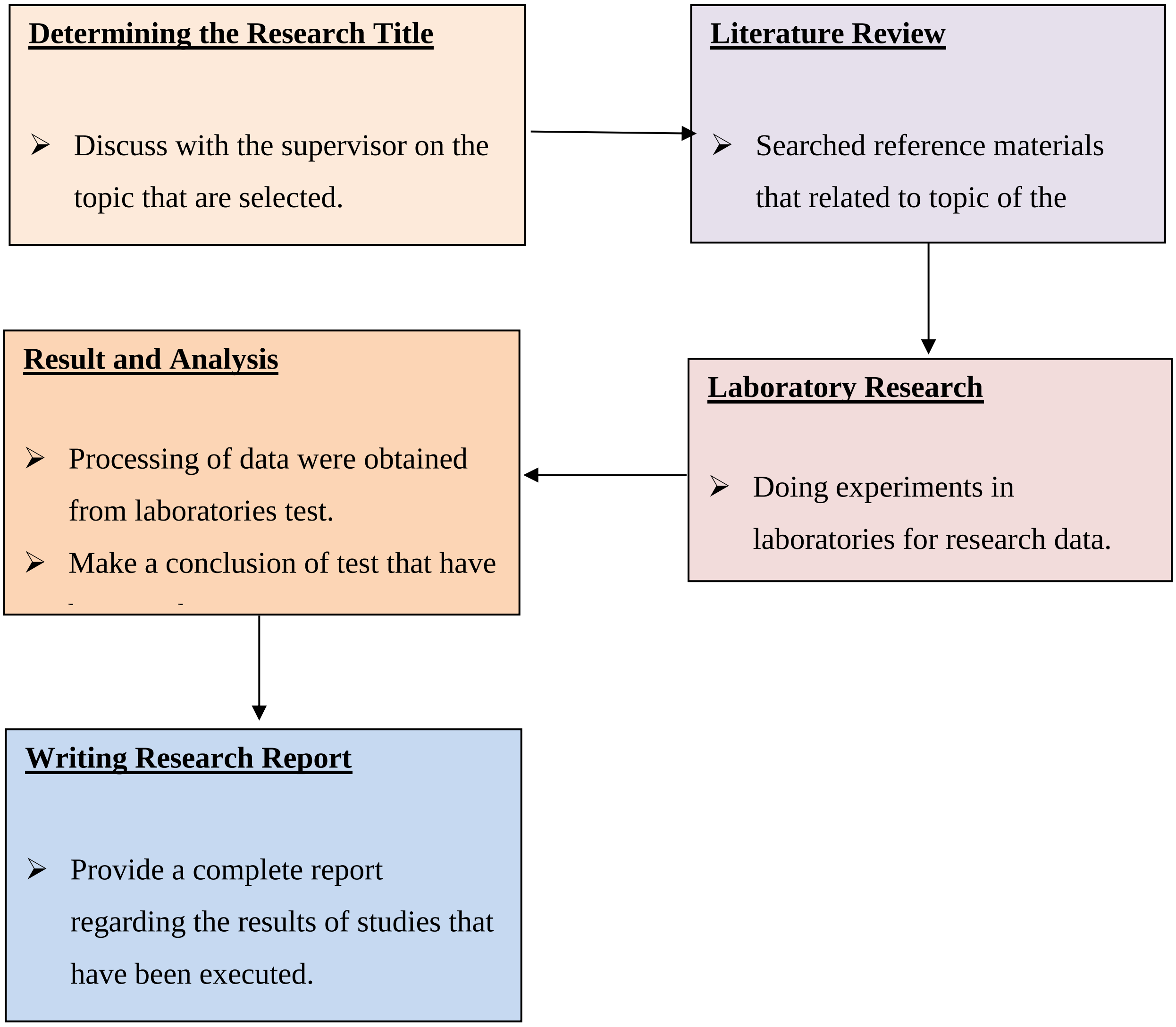


Figure 3.4 : Study work plan

3.3 Concrete mix design and trial mix

Concrete mix design is a method to identify the control and standard ratio of concrete for beam design purposed. The concrete mix design will be used after it achieve the optimum and criteria set for concrete ratio. Concrete mix designed for all sample will be the same, in order to achieve the tally and simultaneously results at the end of experimental study.

During conducted the trial mixed, the samples of cube will be design to compressive strength of 25 N/mm^2 on it ultimate strength on 28 days and for the cylindrical is 20 N/mm^2 on it ultimate strength on 28 days. The workability of concrete mix design according to slump test will be in range of 70-90 mm total collapse. Appendix A shows the ready mix design used for thesis experimental study.

3.4 Beam Properties

The type and shape of beam that will be used in my research purposed is simply-supported rectangular composite beam (I-Beam). Steel I-beam will be used is size section of 124 x 74 x 8 UB. The overall size of composite beam will be 0.15m x 0.3m x 2m. Meanwhile, others materials that will be used for research purpose is Ordinary Portland Cement, maximum crushed 20mm coarse aggregate and sand. The testing beam is normal weight concrete beam due to the materials used which is consist of normal weight of cement and coarse aggregate. Below is the dimension of the steel I-beam.

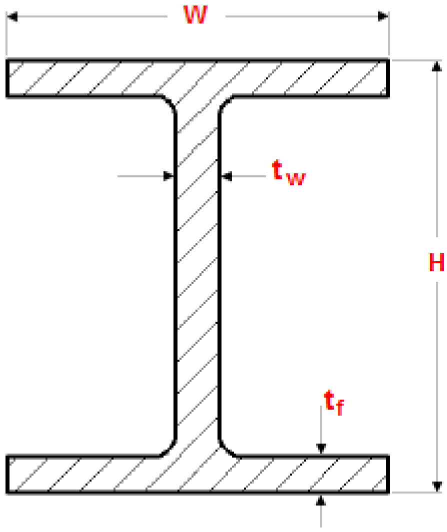


Figure 3.5 : Dimension of I-Beam

Where,

W = 74mm

H = 124mm

$t_w = t_f$ = 8mm

3.5 Testing equipment

Testing equipment that will be used in this experimental study of the structural capacity of composite I Beam (Concrete cast I-Beam) is Magnus frame in determining the ultimate load, flexural strength and deflection of the composite beam. Other than that, concrete cube for standard mix design will used concrete compression testing machine in order to determine concrete strength.

3.6 Parameters used for testing

Parameter to be obtained at the end of the experimental study are ultimate shear and moment, and deflection of the composite beam.

3.7 Sample preparing

The size of beam samples preparation will be 0.15m base x 0.3m height x 2.0m long of the span and test for three sample. Each sample will be same in order to obtain accurate parameter by meaning of the average of the parameters. The size of steel I-Beam that will be use 124 x 74 x 8. The used of this size section because of its size and properties will be efficient in the size of beam samples.

3.8 Test Conducted

3.8.1 Compressive strength test

3.8.1.1 Apparatus

(a) Testing Machine : Concrete Compression Testing Machine

(b) Testing will be conducted at Fakulti Kejuruteraan Awam dan Sumber Alam Heavy Structures laboratory, University Malaysia Pahang.

Figure 3.6 : Compression strength test machine

3.8.1.2 Procedure

(a) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

(b) Record the mass of specimen of cube concrete.

(c) Clean the bearing surface of the testing machine

(d) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

(e) Align the specimen centrally on the base plate of the machine.

(f) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.

(g) Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails.

(h) Record the maximum load and note any unusual features in the type of failure.

(i) Parameters obtain : Concrete strength (Mpa)

This stress is not the true stress, since the cross section of the sample is considered to be invariable (engineering stress).

$$\sigma = \frac{F}{bd}$$

Figure 3.7 : Stress calculation

- F is the axial load (force) at the fracture point
- *b* is width

  d is the depth or thickness of the material

3.8.2 Beam Test (Magnus Frame)

3.8.2.1 Apparatus

(a) Beam Test : Four point load test

(b) Testing Machine : Magnus Frame and data logger for results obtained.

(c) Testing will be conducted at Fakulti Kejuruteraan Awam dan Sumber Alam Heavy Structural Laboratory, Universiti Malaysia Pahang.

Figure 3.8 : Magnus Frame Machine

Figure 3.9 : Data Logger

3.8.2.2 Procedure

(a) Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.

(b) Connect the strain gauge to the data logger.

(c) Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be **3d** and the distance between the inner rollers shall be **d**. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.

(d) The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.

(e) The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Based on test conducted, result and data have been collected. These data were used in the analysis and conclusions related to the study as well as to achieve the goals and objectives.

This chapter focusing towards results obtained from laboratory test including compressive strength cube test and Magnus Frame test. Based on test conducted, result and data have been collected. These data were used in the analysis and conclusions related to the study as well as to achieve the goals and objectives. The results were analyzed as well as discussed in tables and figures forms. The specimens were cured and tested at 28 days. The information could be very practical for upcoming study and future development of building materials. There are two type of test that had been conducted which are compressive strength test, Magus Frames test which is the 4 point loading experiment. Lastly, this chapter describe about the cracking pattern to show the behavior and analyses the properties of the composite beam (Concrete cast I-Beam).

The structural capacity and stress-strain of composite beam (Concrete cast I-beam) properties presented and discussed throughout this chapter particularly.

4.2 Compression Test results

Table 4.1 : Maximum load for compressive strength test

Sample	**Compressive load 28-days (kN)**	**Average compressive load (kN)**
Sample 1	1125.9	
Sample 2	1028.3	1077.9
Sample 3	1079.6	

Table 4.2 : Maximum strength for compressive strength test

Sample	**Compressive strength 28-days(MPa)**	**Average compressive strength (MPa)**
Sample 1	25.02	
Sample 2	22.85	23.95
Sample 3	23.99	

Table 4.1 and Table 4.2 shows the results of maximum load and compressive strength of concrete at the age of 28 days. It indicates the maximum strength of ready mix concrete which is on the 28 days.

Based on the table 4.1, the average maximum load obtained from the three samples of concrete cube with the section of 0.15m x 0.3m is 1077.9kN. The value achieve from the sample 1, sample 2, and sample 3 which is 1125.9kN, 1028.3kN and 1079.6kN respectively.

From the table 4.2, the average maximum compressive strength test obtained from the three samples of concrete cube with the section of 0.15m x 0.3m is 23.95MPa. The maximum compressive strength test value obtained by dividing maximum load to the area of section. The value of 23.95Mpa is obtained from the average of three sample, sample 1, sample 2 and sample 3 which is 25.02MPa, 22.85MPa and 23.99MPa respectively. This results shows that, the concrete of C20/25 is approximately achieve according to the experiment parameters and setting stated on the research methodology.

4.3 Load vs. deflection of composite beam (Magnus Frame Test)

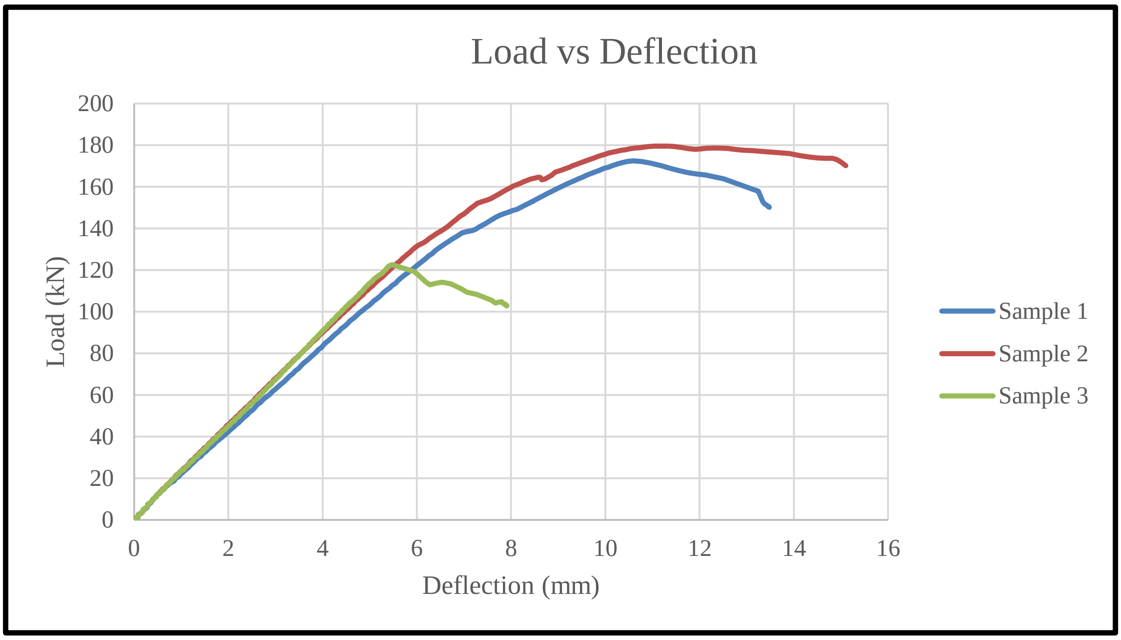


Figure 4.10 : Load vs. deflection of composite beam on 28 days

Table 4.3 : Maximum load and deflection for composite beam

Beam	**Maximum load (kN)**	**Maximum deflection(mm)**
Sample 1	172.5	13.48
Sample 2	179.58	15.1
Sample 3	114.25	7.91

Based on the graph of load vs. deflection of composite beam, figure 4.10, the three samples of composite beam undergoes the same pattern of load vs. deflection. The graph shows that, the load increases directly proportional to the deflection until it reach the highest load that can be sustained by the composite beam. As the deflection continuously increases, the load decreases after it reach it maximum load which indicates the failed of composite beam.

Based on the table maximum load and deflection of composite beams, table 4.3, sample 1, sample 2 and sample 3 has the maximum load of 172.5kN, 179.58kN, and 114.25kN respectively. The results shows that, the maximum load of composite beam can be up to 179.58kN before it failed in term of strength. Meanwhile, the maximum deflection of sample 1, sample 2, and sample 3 are 13.48mm, 15.1mm and 7.91mm respectively. The results shows that, the highest deflection experienced once the composite beam failed is 15.1mm.

Based on the similarity, sample 1 and sample 2 have approximately the same range of maximum load and deflection, meanwhile, sample 3 is out of the range compare to sample 1 and 2.

4.4 Load vs. steel strain (Magnus Frame Test)

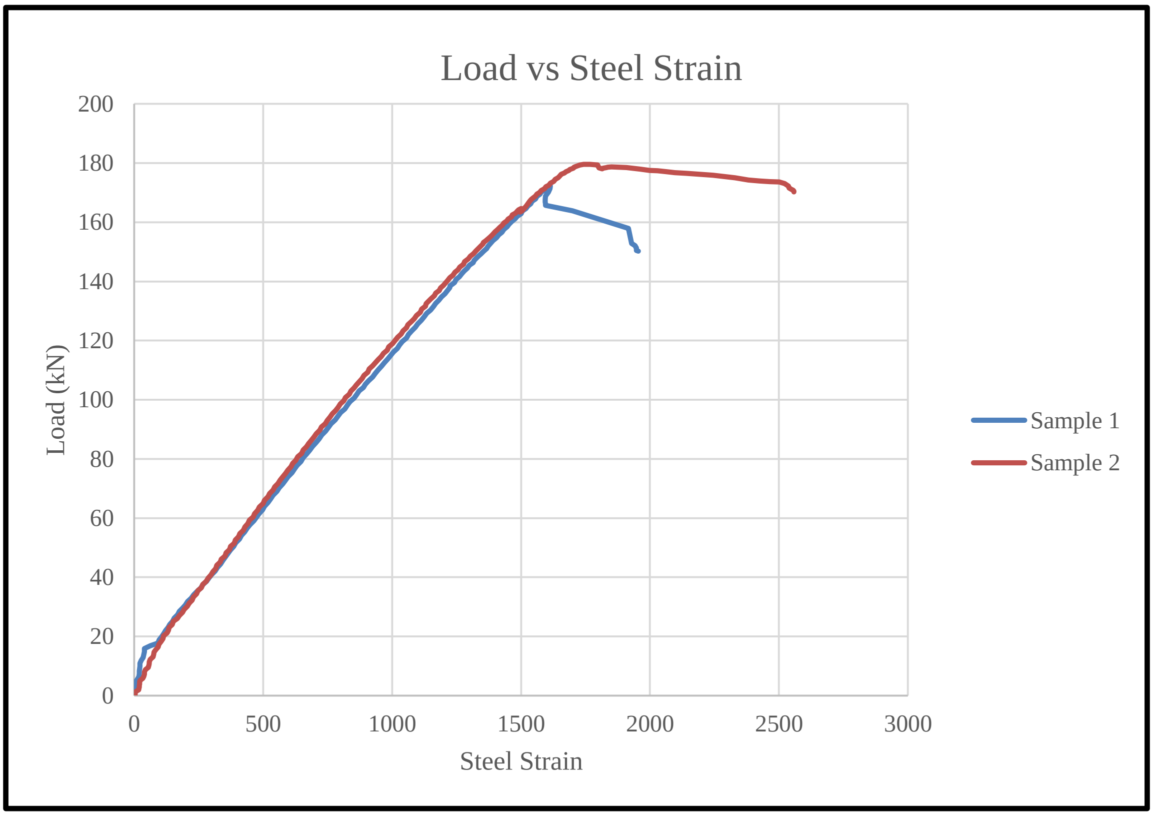


Figure 4.11 : Load vs. steel strain for composite beams on 28 days

Table 4.4 : Maximum steel strain for composite beams on 28 days

Beam	Maximum Steel Strain
Sample 1	1955
Sample 2	2558
Sample 3	-

Based on the figure 4.11, the graph shows that, the steel strain increase directly proportional to the load until it reach it maximum load which indicates the steel can return to its original shape after the load is removed. Once the composite beam experienced the maximum load, the load begin to decrease, however, steel strain will keep increase until it undergoes plastic stage and lastly, develop fracture.

Based on table 4.4, the maximum steel strain of composite beam sample 1 and 2 are 1955 and 2558 respectively. This indicate the maximum steel strain that can be sustain by the steel in composite beam is 2558. Sample 3 have no value of steel strain because the strain gauge not functioning due to concrete weight that broke it during the preparation of sample

4.5 Stress vs. concrete strain (Magnus Frame Test)

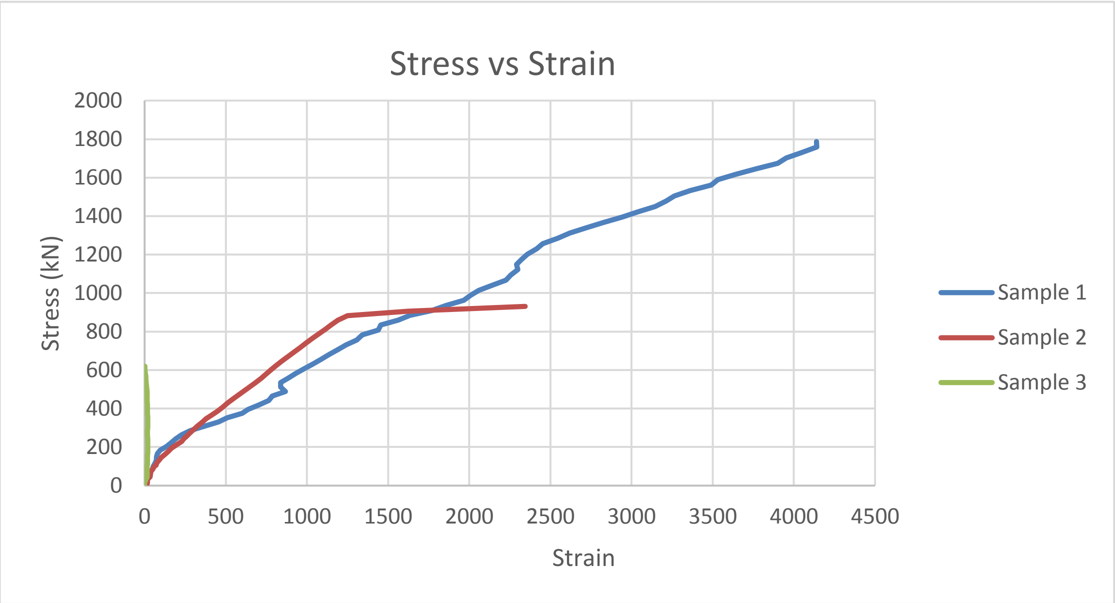


Figure 4.12 : Graph of stress-strain for concrete of composite beams on 28 days

Table 4.5 : Maximum concrete strain for composite beams on 28 days

Beam	**Maximum concrete strain**
Sample 1	4139
Sample 2	2345
Sample 3	19

Based on the graph stress-strain for concrete, figure 4.12, of composite beam on 28 days, sample 1 and sample 2 shows the same pattern of stage. The concrete strain increase directly proportional to the stress until it reached maximum concrete strain. This indicate the concrete of composite beam begin to cracked. Then, the concrete strain developing in crack which shows the decreasing of concrete strain value, while the stress remained the same throughout the stage. Lastly, with increasing of load and stress, develop a crack and failed to the composite beam and shows that, the negative value of concrete strain.

Based on the table 4.5 the results shows that, the maximum concrete strain for sample 1, sample 2 and sample 3 are 4139, 2345, and 19 respectively. This can indicates that, the maximum concrete strain can be sustained by the concrete of composite beam are 4138 before it's failed in term of crack.

4.6 Cracking pattern of composite beam (Concrete Cast I-Beam)

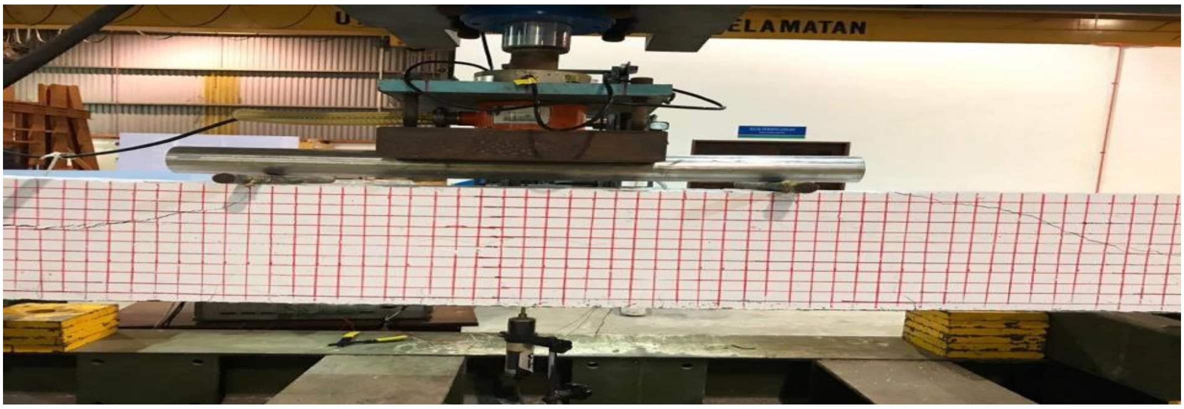


Figure 4.13 : Cracking pattern of composite beam sample 1

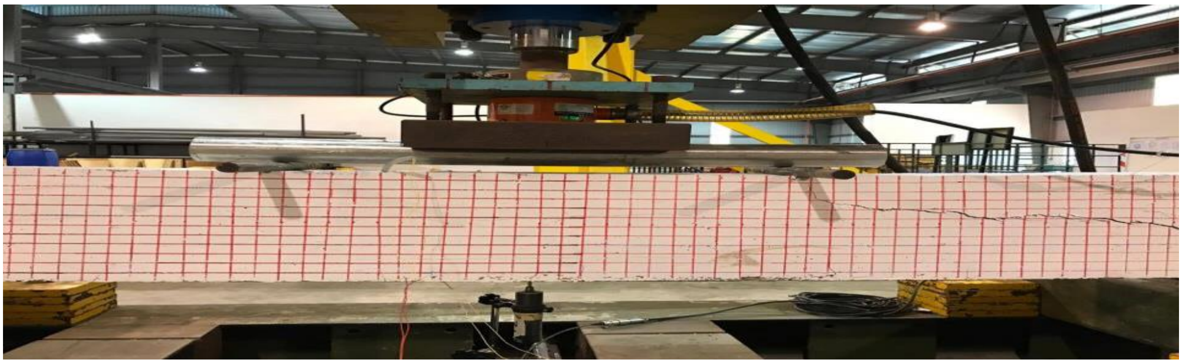


Figure 4.14 : Cracking pattern of composite beam sample 2

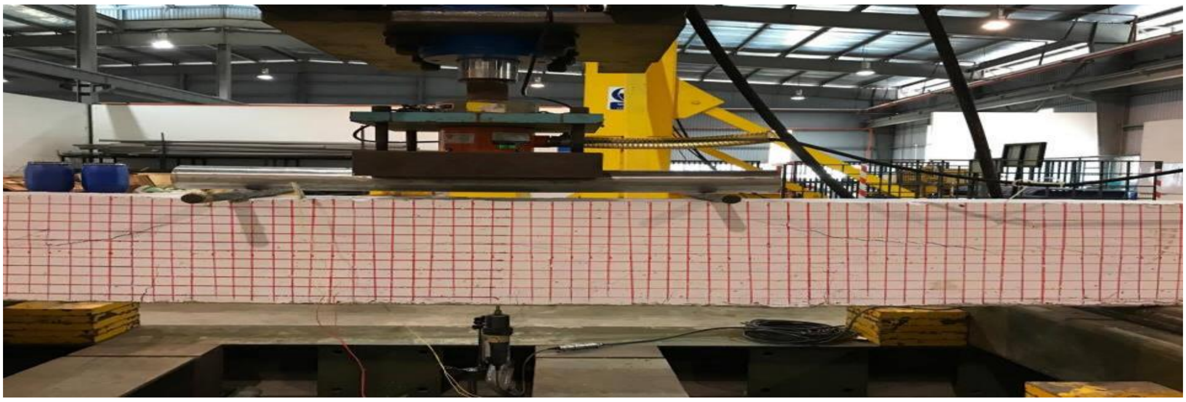


Figure 4.15 : Cracking pattern of composite beam sample 3

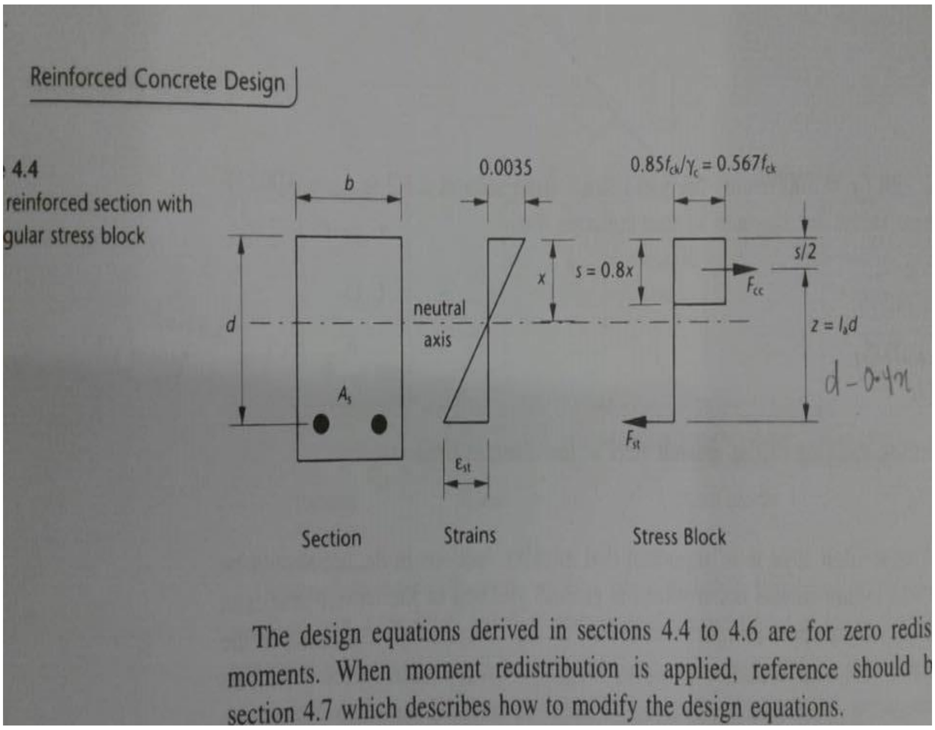
Figure 4.13, 4.14 and 4.15 shows that the cracking pattern of composite beam after testing. The cracking pattern occurred along the load at the top until the support at the bottom both side. The maximum cracking diameter observed from the composite I-beam was 0.4mm.

4.7 Discussion on compare between experimental results to the theory and previous study in 2.5

4.7.1 Compression strength to the concrete grade proposed

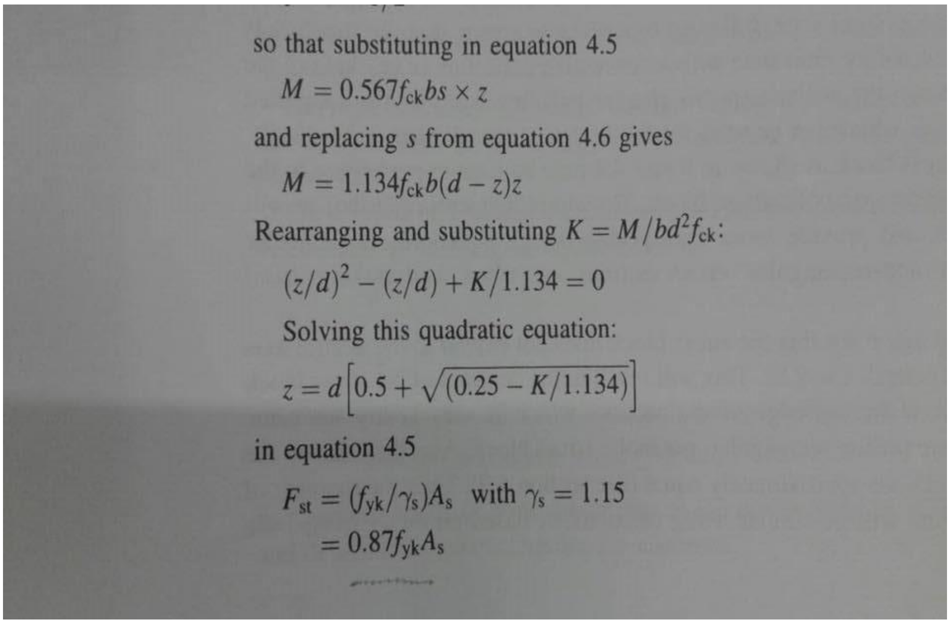
From table 4.2, the average compressive strength for concrete cube 0.15mx0.15mx0.15m is 23.95Mpa, meanwhile the proposed concrete grade in research methodology was 25Mpa. The results can be accepted as the value of 23.95Mpa come close to 25Mpa and which is affected by a little margin of strength. The results value is not accurate to 25Mpa due to lack of labour during prepare concrete mix and hydration of concrete due to heating while mixing of concrete.

4.7.2 Experimental ultimate load compare to the theory and previous study



The design equations derived in sections 4.4 to 4.6 are for zero redis
moments. When moment redistribution is applied, reference should b
section 4.7 which describes how to modify the design equations.

Figure 4.16 : Stress block diagram from source Seventh Edition Reinforced Concrete Design to Eurocode 2 by Bill Mosley



so that substituting in equation 4.5

$$M = 0.567 f_{ck} bs \times z$$

and replacing s from equation 4.6 gives

$$M = 1.134 f_{ck} b(d - z)z$$

Rearranging and substituting $K = M/bd^2 f_{ck}$:

$$(z/d)^2 - (z/d) + K/1.134 = 0$$

Solving this quadratic equation:

$$z = d\left[0.5 + \sqrt{(0.25 - K/1.134)}\right]$$

in equation 4.5

$$F_{st} = (f_{yk}/\gamma_s)A_s \quad \text{with } \gamma_s = 1.15$$

$$= 0.87 f_{yk} A_s$$

Figure 4.17 : Formula of ultimate load from source Seventh Edition Reinforced Concrete Design to Eurocode 2 by Bill Mosley

Table 4.6 : Ultimate load of experimental test, theory and previous study

Composite Beam	**Maximum Load (kN)**
Sample 2 from experimental study (Beam Size : 0.15mx0.3mx2m) (Steel size : 124 x 64 x 8 mm)	179.58
Theory from stress block diagram	395
Previous study in subchapter 2.5 (Beam Size : 0.1m x 0.2m x 1.6m) (Steel Size : 100 x 50 x 3 mm)	137.2

Based on table 4.6, the results shows that the value of maximum load from sample 2 of experimental study and previous study in the range of 100-200kN. The different of maximum load between the two studies comes from the beam size and steel size used in both study. It can be said that, as the size of composite beam and steel increase the maximum load increase as well. The maximum load that comes from the formula of stress block diagram shows the value of 395kN and the highest obtained in compare to others. This might be the Eurocode 2 includes safety of factor the load, therefore the maximum load is higher than the others. Appendix B shows the manual calculation of theory for maximum load of composite beams.

4.7.3 Experiment stress-strain curve compare to the theory

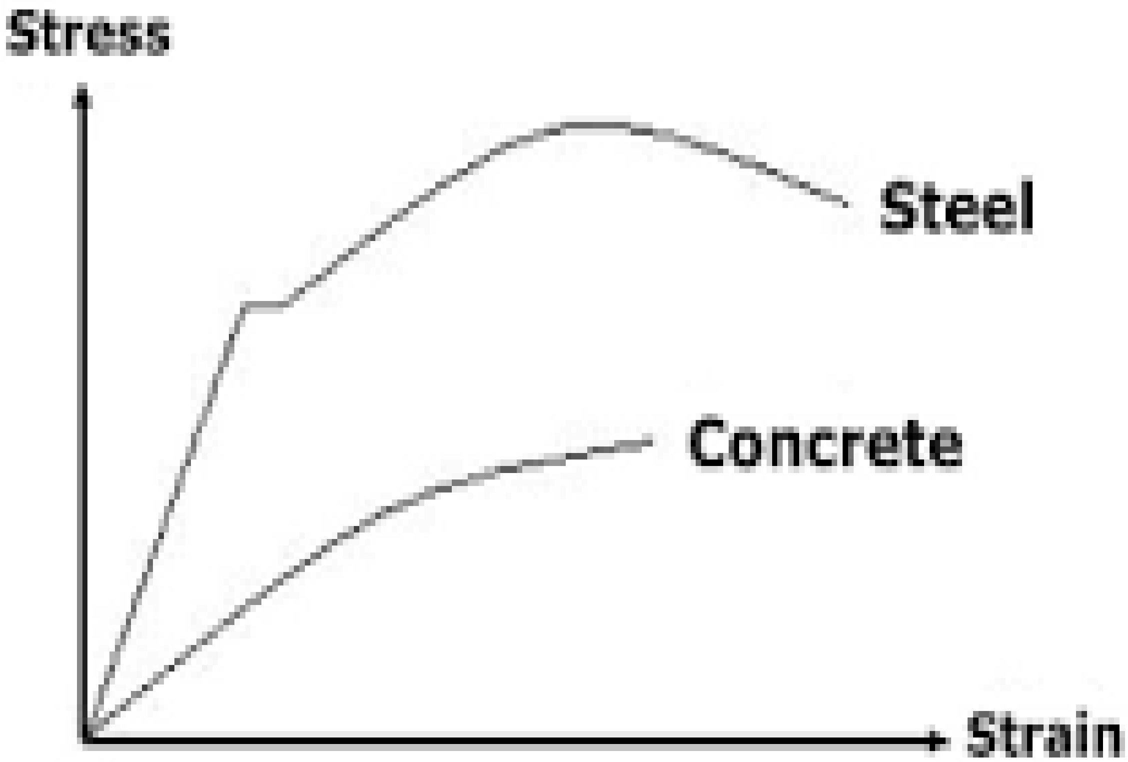


Figure 4.18 : Typical stress-strain curve graph for concrete and steel material source from Engineering Tech

Based from figure 4.11 and figure 4.18, it shows that, the stress-strain curve graph of experimental study and typical stress-strain curve graph for steel shows that the similarities in the pattern. The steel strain increase directly proportional to the load or stress until it reach it maximum load or stress which indicates the steel can return to its original shape after the load or stress is removed. Once the composite beam experienced the maximum load or stress, the load or stress begin to decrease, however, steel strain will keep increase until it undergoes plastic stage and lastly, develop fracture. Therefore, the stress-strain curve for steel can be accepted.

Based from figure 4.12 and figure 4.18, it shows that, the stress-strain curve graph of experimental study and typical stress-strain curve graph for concrete shows that the similarities in the pattern. The concrete strain increase directly proportional to the stress until it reached maximum concrete strain. This indicate the concrete of composite beam begin to cracked. Then, the concrete strain developing in crack which shows the decreasing of concrete strain value, while the stress remained the same throughout the stage. Lastly, with increasing of load and stress, develop a crack and failed to the composite beam and shows that, the negative value of concrete strain.

4.7.4 Deflection and Load vs. deflection curve graph

Based on the theory, the deflection limitation for the reinforced concrete beam of size 0.15mx0.3mx2m is 5.6mm. However, the maximum deflection for the three sample from experimental results, table 4.3 shows that, all the value exceed deflection limitation for the beam. This is happening due to composite beam have the advantages combination of steel I-beam and concrete together that can pull higher deflection compare to the reinforced concrete beam.

Based figure 2.2, graph from previous study and figure 4.10, it shows that the pattern of the graph is the same, and indicates that the graph achieve the pattern of typical load vs. deflection curve of composite beam.

CHAPTER 5

CONCLUSION

5.1 Introduction

Composite beam was founded to be a good replacer of reinforced concrete beam in producing high structural capacity strength with a small quantity of waste material. This chapter will discuss the conclusion of this study that is about compressive, structural capacity and cracking pattern of composite beam (concrete case I-beam). According to result and analysis from the experimental laboratory testing this chapter will discuss the conclusion made from the previous chapter, which that follows research's objective of the study.

5.2 Conclusion

(a) Ultimate load

- The ultimate load of composite beam size 0.15m x 0.3m x 2m with I-beam of size 124 x 74 x 8 for sample 2 is the highest among the three sample, which is 179.58kN. Compare to sample 1 and sample 3 which have 172.kN and 114.25kN respectively. This can be indicates that, the highest load that can be sustain by composite beam size 0.15m x 0.3m x 2m with I-beam of size 124 x 74 x 8 is 179.58kN.

(b) Maximum deflection

- The maximum deflection of composite beam size 0.15m x 0.3m x 2m with I-beam size 124 x 74 x 8 for sample 2 is the highest among the three sample. Sample 2 has 15.8mm, which is greater than sample 1 and sample 3 that have maximum deflection of 13.48mm and 7.91mm respectively.

This can be indicated that, composite beam size 0.15m x 0.3m x 2m with I-beam size 124 x 74 x 8 can take a deflection up until to 15.8mm.

(c) Stress-strain

- Concrete = The maximum concrete strain that composite beam size 0.15m x 0.3m x 2m with I-beam size 127 x 76 x 8 can up to 4139.
- Steel = The maximum steel strain that composite beam size 0.15m x 0.3m x 2m with I-beam size 127 x 76 x 8 can up to 2558.

(d) Others

- Maximum cracking that composite beam size 0.15m x 0.3m x 2m with I-beam size 127 x 76 x 8 is 0.04mm.

5.3 Recommendation for future use

Upon completion of an experimental study of the structural capacity of composite beam (concrete cast I-beam), recommendation can be applied in order to increase the structural capacity of beam and produce a better engineering that good in term of environmental friendly and economical as well. Below are the list of the recommendations are as follows:

(a) Install a better formwork material such as steel that been manufactured according to the size of beam in order to avoiding the mistake during preparation of wood formwork that can lead to produce composite beam that not have accuracy of overall size.

(b) Used a better steel cutter that can produce a smooth surface cutting on the steel I-beam.

(c) Do a lot of research on the study of the composite beam because composite beam offers as a potential replacement of traditional reinforced concrete beam that are more environmentally friendly as well with reducing waste material.

(d) Ensure all the material is in good condition such as concrete, steel and wood formwork to produce the best results outcome.

(e) Ensure that, the strain gauge to be fully protected using more suitable protector such as steel tube that can reduce and prevent the strain gauge broken during preparing of composite beam sample.

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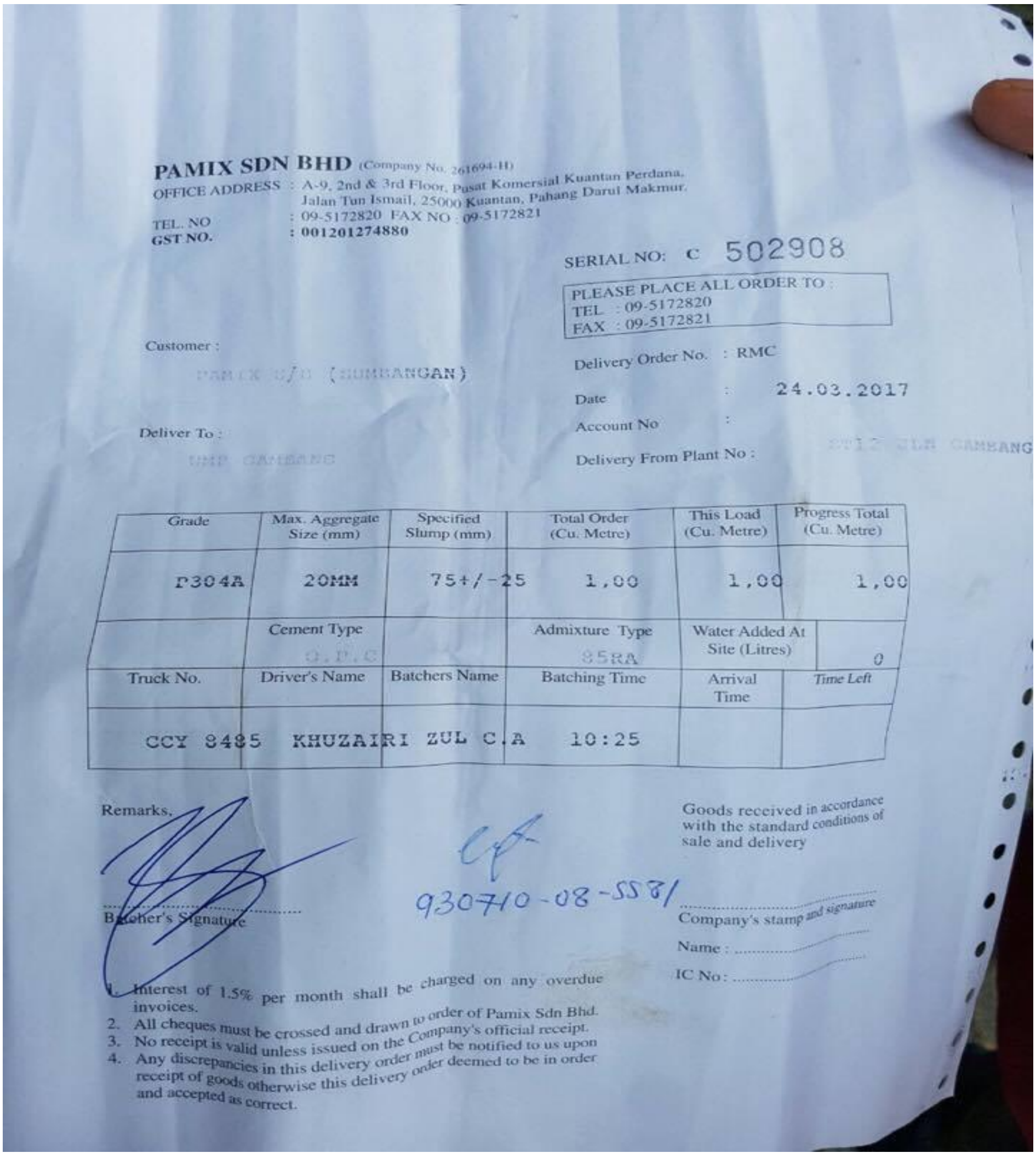
APPENDIX A
READY MIX FORM



PAMIX SDN BHD (Company No. 261694-H)
OFFICE ADDRESS : A-9, 2nd & 3rd Floor, Pusat Komersial Kuantan Perdana, Jalan Tun Ismail, 25000 Kuantan, Pahang Darul Makmur.
TEL. NO : 09-5172820 FAX NO : 09-5172821
GST NO. : 001201274880

SERIAL NO: C 502908

PLEASE PLACE ALL ORDER TO :
TEL : 09-5172820
FAX : 09-5172821

Customer :
[illegible] (SUMBANGAN)

Delivery Order No. : RMC
Date : 24.03.2017
Account No :

Deliver To :
UMP GAMBANG

Delivery From Plant No : [illegible] GAMBANG

Grade	Max. Aggregate Size (mm)	Specified Slump (mm)	Total Order (Cu. Metre)	This Load (Cu. Metre)	Progress Total (Cu. Metre)
P304A	20MM	75+/-25	1,00	1,00	1,00
	Cement Type		Admixture Type	Water Added At Site (Litres)	0
	O.P.C		85RA		
Truck No.	Driver's Name	Batchers Name	Batching Time	Arrival Time	Time Left
CCY 8485	KHUZAIRI	ZUL C.A	10:25		

Remarks,

Batcher's Signature

930710-08-5581

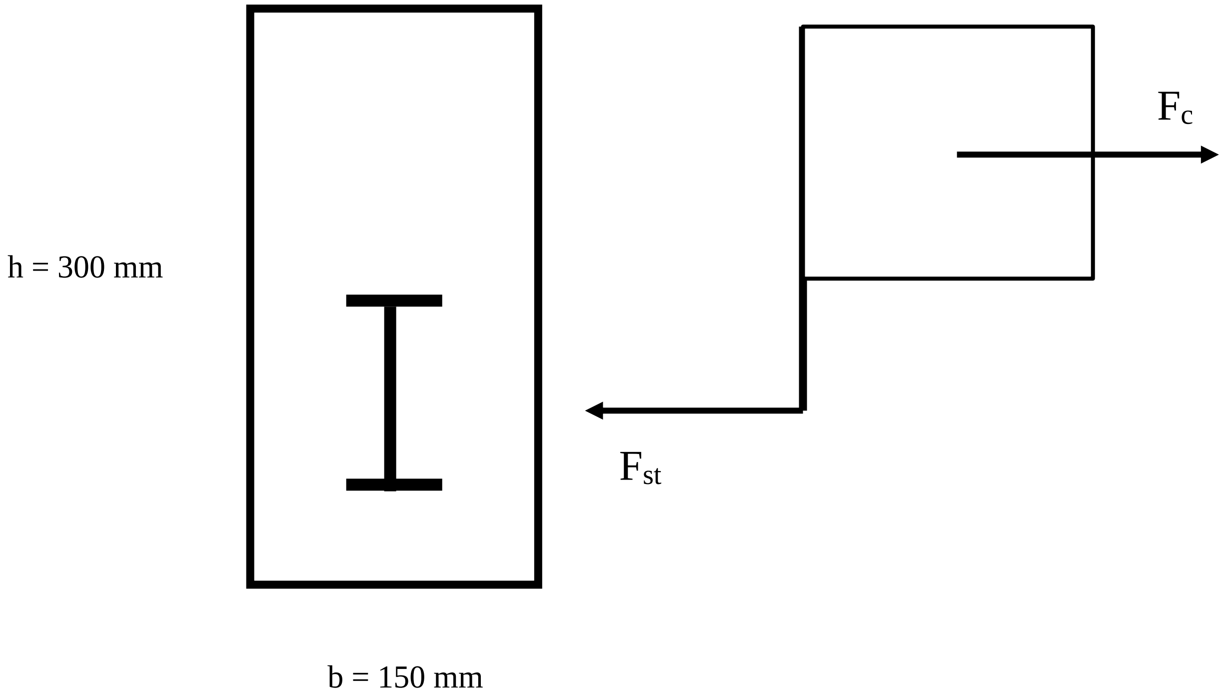
Goods received in accordance with the standard conditions of sale and delivery

Company's stamp and signature
Name :
IC No :

1. Interest of 1.5% per month shall be charged on any overdue invoices.
2. All cheques must be crossed and drawn to order of Pamix Sdn Bhd.
3. No receipt is valid unless issued on the Company's official receipt.
4. Any discrepancies in this delivery order must be notified to us upon receipt of goods otherwise this delivery order deemed to be in order and accepted as correct.

APPENDIX B

CALCULATION OF THEORY FOR MAXIMUM LOAD OF COMPOSITE BEAM



$F_{cc} = 0.567fck(b \times 0.8x) = 0.454fck\ bx$

$F_{st} = 0.87fykA_s$

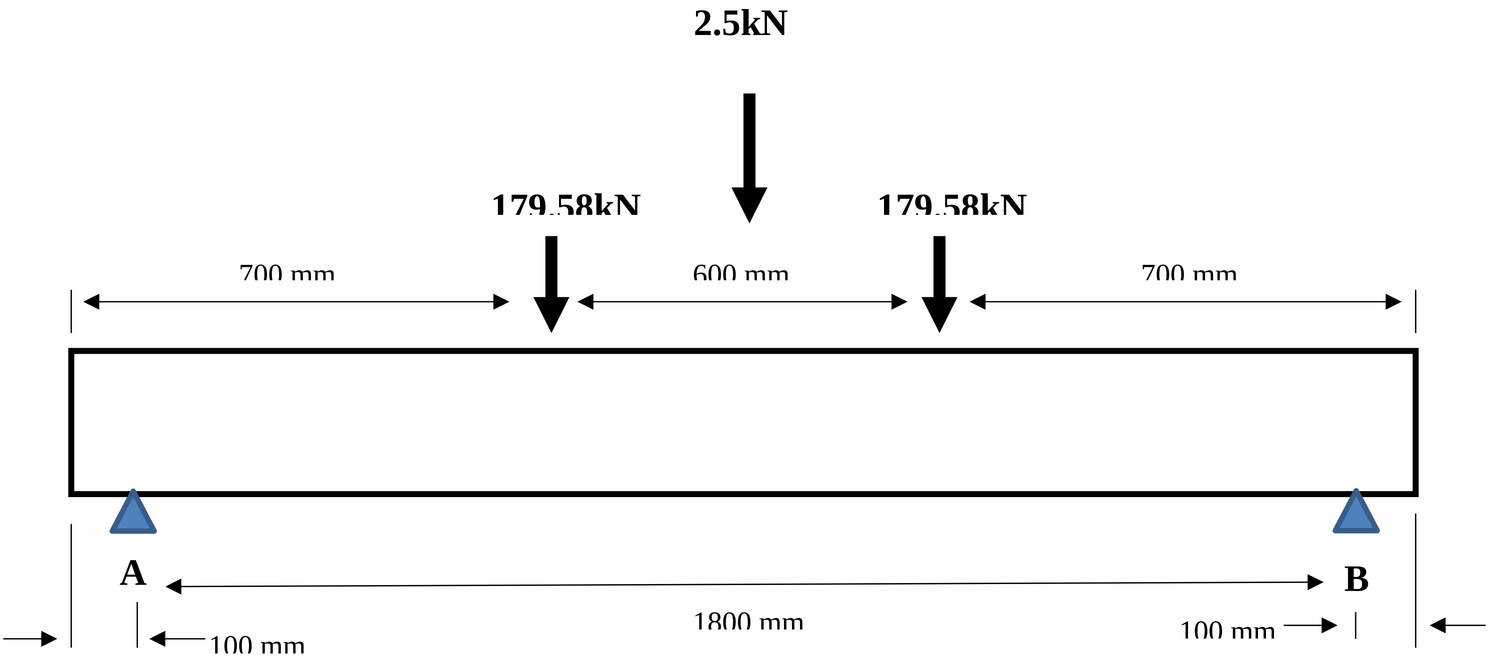
$F_{cc} = F_{st}$

$0.454(25)(150)x = 0.87(275)(1650)$

$x = 231.9\ mm$ (Neutral axis)

$F_{cc} = F_{st} = 0.87(275)(1650) = 395kN$

APPENDIX C
CALCULATION OF LOAD AT SUPPORT OF COMPOSITE BEAM



$$selfweight\ beam = selfweight\ concrete + selfweight\ steel$$

$$= (0.15 \times 0.3 \times 25) + (13.0 \times 9.81 \div 1000)$$

$$= 1.125 + 0.13$$

$$= 1.255\ kN/m$$

$$P1 = (0.13 \times 1.94)\ + (\ 1.125 \times 2)$$

$$P1 = 2.5kN$$

$$V_A = V_B = \frac{(2.5 \times 0.9) + (179.58 \times 0.6) + (179.58 \times 1.2)}{1.8}$$

$$= 180.83\ kN$$

APPENDIX D
PREPARATION SAMPLE OF COMPOSITE BEAM

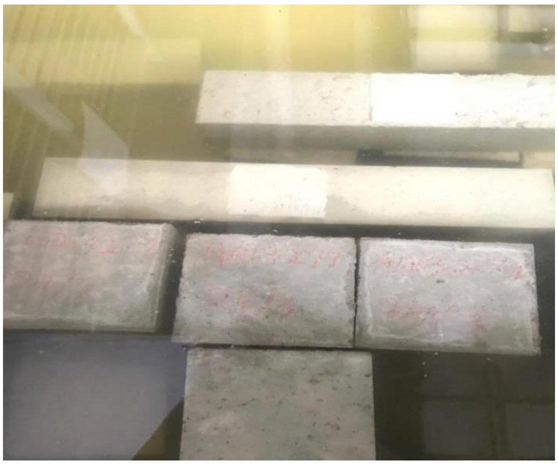
Formwork preparation

Steel I-Beam preparation

Steel I-Beam cast into the formwork

Pouring concrete to the formwork

APPENDIX E
COMPRESSIVE STRENGTH TEST SAMPLE AND TEST



Curing of concrete cube

Concrete cube subject to test

Results of compressive strength test