FLEXURAL BEHAVIORS OF SEMI-PRECAST LIGHTWEIGHT FOAM CONCRETE BEAM

MUHAMMAD AMIRUL ASYRAF BIN ADANAN

A thesis submitted in fulfillment of the
requirements for the award of the degree of
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

JULY 2014

ABSTRACT

Lightweight foam concrete is revolution of concrete from conventional concrete due to density. The major materials that contains in lightweight foam concrete are cement, water, fine sand and foam. This study focus on the reduce weight of lightweight foam. With reduce a weight of beam, the contractor can using manpower to lift up the beam and the contractor can save money from rent or used lift machinery on site. The aim in this study was to investigate the performance of semi-precast Lightweight Foam Concrete beam in term of flexural strength, deflected shape and failure mode. Lightweight foam concrete in study was used sand cement ratio (s/c) and water cement ratio (w/c) which is 1.5 and 0.5 respectively. The width and length of the beam was constant which are 150mm and 3000mm respectively. Four samples with different height which is 200mm, 180mm, 170mm and 160mm were designated as Beam 1, Beam 2, Beam 3 and Beam 4 respectively. All samples were painted and tested under four point test. Linear Variable Displacement Transducers (LVDT) was connected to data logger to determine the flexural strength and deflected shape. Four point tests also can be determining the ultimate load of concrete that it can stand before failure. Based on the result from those outcomes which can obtain are the deflection measurements of the beam also the crack pattern by the observations. The result shows that the flexural strength of the samples was increase to certain degree of percentage of 27.430% and 34.311% which is Beam 3 and Beam 4. For deflection result shows that Beam 2. Beam 3 and Beam 4 was comparing to Beam 1 and the percentage of increment 1%, 134.263% and 40% respectively. All the beams show the same deflection profile. The first crack loading for Beam 1, Beam 2, Beam 3 and Beam 4 was 8.72kN, 8.59kN, 6.95kN and 5.94kN respectively. The crack pattern result shows the behaviour.

ABSTRAK

Konkrit buih ringan adalah revolusi konkrit dari konkrit biasa disebabkan ketumpatan. Bahan-bahan utama yang terkandung di dalam konkrit berudara ringan adalah simen, air, pasir halus dan buih. Fokus kajian kepada berat mengurangkan buih ringan. Dengan mengurangkan berat rasuk, kontraktor boleh menggunakan tenaga kerja untuk mengangkat rasuk dan kontraktor boleh menjimatkan wang daripada sewa atau jentera angkat yang digunakan di tapak. Tujuan kajian ini adalah untuk menyiasat prestasi separuh pratuang berudara Ringan rasuk konkrit dari segi kekuatan lenturan, dipesongkan bentuk dan mod kegagalan. Konkrit brudara ringan dalam kajian telah digunakan nisbah pasir simen (p/s) dan nisbah air simen (a/s) yang merupakan 1.5 dan 0.5 masing-masing. Lebar dan panjang rasuk adalah tetap yang berturutan150mm dan 3000mm. Empat sampel dengan ketinggian berbeza iaitu 200mm, 180mm, 170mm dan 160mm telah ditetapkan sebagai Rasuk 1, Rasuk 2, 3 dan Rasuk Rasuk 4 masing-masing. Semua sampel telah dicat dan diuji di bawah empat ujian mata. Linear Variable Displacement Transduser (LVDT) telah disambungkan kepada data logger untuk menentukan kekuatan lenturan dan bentuk terpesong. Empat ujian titik juga boleh menentukan beban muktamad konkrit bahawa ia boleh berdiri sebelum kegagalan. Berdasarkan keputusan dari Mereka hasil yang boleh mendapatkan adalah ukuran pesongan rasuk juga corak retak oleh pencerapan. Hasilnya menunjukkan bahawa kekuatan lenturan sampel peningkatan kepada tahap tertentu peratusan 27,430% dan 34,311% iaitu Rasuk 3 dan Rasuk 4. Untuk hasil pesongan menunjukkan bahawa Rasuk 2. Rasuk 3 dan Rasuk 4 telah membandingkan untuk Rasuk 1 dan peratusan kenaikan 1%, 134,263% dan 40% masing-masing. Semua rasuk menunjukkan profil pesongan yang sama. Pembebanan retak pertama bagi Rasuk 1, Rasuk 2, 3 dan Rasuk Rasuk 4 berturutanadalah 8.72kN, 8.59kN, 6.95kN dan 5.94kN. tingkah laku ditunjukan hasil corak retak.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

OPC	Ordinary Portland Cement
UMP	Universiti Malaysia Pahang
LVDT	Linear Variable Displacement Transducer

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concrete is frequently material that used at Malaysia in construction industry. Concrete is mixed from three element which is cement, aggregate and water. Normally in construction the conventional concrete that its grade is 2400kg/m^3 or 23kN/m^3 but with use lightweight concrete the density of concrete can be reduce. It means the lightweight foam concrete is less weight than normal concrete. This study is to reduce more weight of concrete in lightweight foam concrete. In lightweight foam concrete is consists the expanding agent and it function to increase the volume of concrete. The density normally designs between 300kg/m^3 up to 1840kg/m^3 lightweight foam and the 87 % to 23% is lighter than normal concrete.

The method for this experiment study is original the Industrial Building System (IBS) theory that introduced by Construction Industry Development Board Malaysia (CIDB) for local construction. IBS is an innovation for solution for new technology in Malaysia constructions. The main objective of IBS at Malaysia in 1998 to reduce the dependency on foreign labors and increase the productivity and also to improving the local construction quality (Mohamad et al, 2009).

According to (Yahya & Shafie, 2012), character of IBS can identify all the mass produced either in factory or site factory with strict quality control that minimize the site activities for example beams, slabs, column, walls and staircase.

Normally for reduced the time consume of construction, the contractor will replace the conventional method in construction the concrete structure frame with the IBS. But the problem with the class F contractors which IBS need to provide the machines to lift the structural. With use same concept of IBS, semi-precast beam was precast semi at ground then the workers will pulled out the beam at the right position. Then, the concrete will pour the left of beam

1.2 PROBLEM STATEMENT

In Malaysia a lot of building was used reinforcement concrete as its structure. Crane or concrete pump machinery was used to concrete the structure. But normally in site, contractor rent the crane or concrete pump machinery because contractor can afford to buy it

A beam is one of element that have in reinforcement concrete structure. Normally was place horizontal and it function is to withstand the load primarily by resisting bending. Bending moment create from external loads, own weight, spam and external reactions. And normal concrete was used in common building.

It case to reduce the weight of concrete beam and can lift by manpower, normal concrete was change to other material that more light than normal concrete. The material that was used is lightweight foam concrete. Based Narayanan et al., (2000) in lightweight foam concrete is consists the expanding agent and it function to increase the volume of concrete. The density normally designs between 300kg/m^3 up to 1840kg/m^3 lightweight foam and the 87 % to 23% is lighter than normal concrete. But still heavy to lift up by using manpower, with change the method concreting it can reduce the weight. The method that was used is semi-precast with its mean the beam was semi-precast at ground then after first casting was harden, the beam lift up the correct position then finish casting was done.

1.3 OBJECTIVES OF STUDY

The main objectives of this study are:

i. To determine the ultimate load of semi-precast Lightweight foam concrete beam with different depth of beam.

ii. To determine the deflection profile of semi-precast different depth of beam Lightweight foam concrete beam.

iii. To observe the cracking pattern of semi-precast Lightweight foam concrete beam with different depth of beam

1.4 SCOPE OF STUDY

In this experiment study, the effect of semi-precast beam on its flexural strengths is aware. All sample beams were constant in length and width, which is 3000mm and 150mm respectively. Hence, the sample beam were varies in height which is 200mm, 180mm, 170mm and 160mm were designated as Beam 1, Beam 2, Beam 3 and Beam 4 respectively. The density foam concrete is 1600 kg/m^3. Table 1.1 shows the semi-precast section size.

All samples were tested under four point tests. Three linear variable data transducer (LVDT) were place along the beam and were connected to data logger as shown in Figure 1.1. The crack propagated and crack pattern were observed during the testing. Figure 1.2 shows the cross-section of beam. The test that involved is four point test and the result can get from this test are the ultimate load before the beam fail, deflection of beam and crack pattern. The ways to get deflection is by used linear variable displacement transducers. Then for crack pattern is by observation on the beam. Next is to get ultimate load by doing data logger. Table 1.2 shows mix proportion of concrete mixing.

Table 1.1: Proposed semi-precast section size

Sample	Depth (Y)	Main reinforcement	Secondary reinforcement
Beam 1 (Control sample)	200	2T12- Top 2T12- Bottom	R8-250
Beam 2	180	2T12- Top 2T12- Bottom	R8-250
Beam 3	170	2T12- Top 2T12- Bottom	R8-250
Beam 4	160	2T12- Top 2T12- Bottom	R8-250

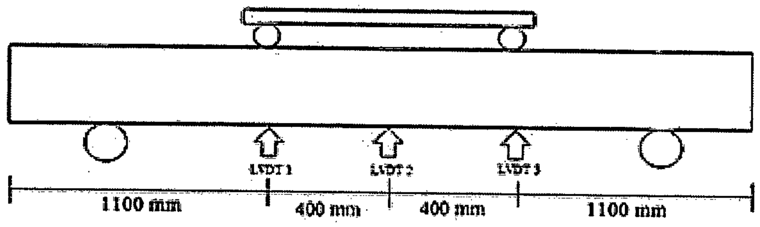

Figure 1.1: 4-point test.

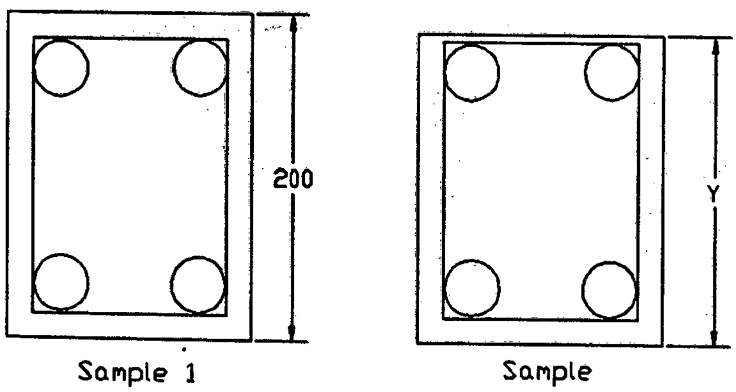

Figure 1.2: Proposed cross-section of semi-precast beam mention in text

Table 1.2: Mix proportion of concrete mixing

Quantities	Cement (kg)	Fine aggregate, sand (kg)	Water (kg)
Per 1 m^3	530	796	266
Per 0.36 m^3	191	287	96
Ratio	1	1.5	0.5

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter discuss the lightweight foam concrete with explanation and defines. This chapter also states the advantages and disadvantages of lightweight concrete in construction. With use lightweight foam concrete as main material in research, the properties of lightweight foam concrete and effect size to beam performance were discussed.

2.2 AERATED/FOAMING CONCRETE

Lightweight foam concrete form cement paste which air-voids are entrapped in cement paste that because of foaming agent. With properties that have in foaming concrete such high flowability, controlled low strength and excellent thermal insulation. With can change the density of concrete by properly controlled the foaming agent. (Ramamurthy et. al, 2009). This supported by Narayanan et al., (2000) stated that Lightweight foam concrete is produce by injection of air or remove the finer sizes of the aggregate. And with replacing finer with hollow, cellular or porous aggregate will produce Lightweight foam concrete. The density of Lightweight foam concrete is in range 300kg/m^3 to 1800kg/m^3.

Many factor can effect to production of stable foam concrete mix are selection of foaming agent, method of foam preparation and the addition for uniform air-void distribution, materials section and mixture design strategies, production of foam concrete, and performance with respect to fresh and hardened state are greater significance. (Ramamurthy et. al, 2009).

2.3 ADVANTAGES AND DISADVANTAGES OF LIGHTWEIGHT CONCRETE

Table 2.1 shows the advantages and disadvantages of lightweight concrete (Kamsiah et al 2004)

Table 2.1: Advantages and disadvantages of lightweight foam concrete:

Advantages	Disadvantages
Fast for simple construction	Water content in mixed is sensitive.
Reduction in manpower	Porosity and angularity of the aggregate can cause the hard to place and finish.
Reduction in weight that can results in reducing structural frame, footing or piles	Need longer time to mixing compare to conventional concrete

2.4 PROPERTIES OF LIGHTWEIGHT FOAM CONCRETE

Foamed concrete differs from the other class of aerated concrete in a way air is being introduced into a cement-based media. Therefore, it follows the properties of aerated concrete which would have much similarity to foamed concrete. The physical properties discussed are density, fresh state properties, stability and compressive strength.

2.4.1 Density

The density, or more precisely, the volumetric mass density, of a substance is its mass per unit volume. The symbol most often used for density is ρ (the lower case Greek letter rho). Mathematically, density is defined as mass divided by volume. In some cases (for instance, in the United States oil and gas industry), density is loosely defined as its weight per unit volume, although this is scientifically inaccurate this quantity is more specifically called specific weight.

Density in lightweight foam concrete can be divided in two state either fresh or hardened state. In control mix design and casting fresh state was required. Many density of lightweight foam concrete required in hardened state compare than fresh state. Indicate the moisture condition and specific density needs compare to the properties of lightweight foam concrete. The difference sources can effect of degree of dryness. (Ramamurthy et. al, 2009).

On other hand, parameter such as cement-sand and water-cement ratio, curing type of foaming agent and size of distribution of sand can be affected to the strength of lightweight foam concrete (Hamidah et al., 2005).

2.4.2 Fresh state properties

Lightweight foam concrete cannot be subjective to vibrator due to properties foam concrete that excellent in self-compactability and flowbility. These properties are influenced by water content and foam in concrete (Ramamurthy et. al, 2009).

2.4.3 Stability

Foam concrete is consistency in stability which that its density ratio is near to 1 based on density in fresh over design density. That was proofed by (Ramamurthy et. al, 2009).

2.4.4 Compressive strength

The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some material fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.

The most important properties of concrete and also include lightweight foam concrete is compressive strength (Ramamurthy et. al, 2009).The compressive strength of Lightweight foam concrete will depend on the density, initial water/cement ratio and cement content. The density of the foam can have an influence on the ultimate strength, particularly for the lower density foam concretes. Uniformly sized small bubbles appear to produce higher ultimate strength at all densities (Sulaiman, 2011). And this statement also supported by (Hamidah et. al, 2005) state that the compressive strength of lightweight foam concrete at 60 days of age, increase when the sand-cement ratio is decrease.

2.4.5 Flexural and Splitting Tensile strengths

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a four or three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress.

Tensile strength is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. And Splitting Tensile strengths is method of determining the tensile strength of concrete using a cylinder which splits across the vertical diameter.

The ratio of flexural strength to compressive strength of lightweight foam concrete is in range 0.25-0.35. (Valore, 1954) and according to Ramamurthy et. al (2009) the splitting tensile strength of lightweight foam concrete is lower than normal weight concrete.

2.5 EFFECT OF SIZE BEAM DEPTH TO BEAM PERFORMANCE

For normal concrete, the increment of size causes the flexural strength become smaller. This effect of size that attributed to various causes (Bazant & Planas 1998). This also supported by Patil & Sangle, 2014 said that with increasing the spam and also depth were produce the decrement due to flexural strength. This causes of the increasing the moment of inertia.

The depths of beam were influence the ultimate strength. Ultimate strength is increase and were produce by increases the increasing the beam depth. (Rao & Vijayanand).

2.6 BENDING

The bending moment is a measure of internal stress due to the average in a structural element when the external force or moment applied to the element that causes the element to bend. Internal stresses in the cross section of structural elements can be resolved into force resultant and couple the resultant. For balance, this time created by external forces must be balanced with the pair due to internal stresses. The resulting internal couples called the bending moment and the resulting internal forces called shear (transverse to the plane of the element) or the normal (along the plane of the element).

The forces and moments on either side of the section must be equal in order to counteract each other and maintain a state of equilibrium so the same bending moment will result from summing the moments, regardless of which side of the section is selected. There is two of bending which is sagging and hogging. Sagging cause when clockwise bending moments are taken as negative, then a negative bending moment within an element. And for hogging is cause when positive moment.

Bending moment was maximum at mid-span and notch of beam (Raghu,2010). Jeng & Shah, 1985 have founded that to be applicable only for beam with s/w=4 which is s for spam and w for depth of beam.

2.7 SPAN-DEPTH RATIO (L/D)

Concrete structure, this applies only to beams and slabs. The span is the length from a centre of support to another in the direction in question. The depth is the average depth from the top of the beam/slab to the bottom. The span-to-depth ration thus is the span divided by depth.

Expressions are developed for steel-reinforced concrete one-way slabs and beams to satisfy deflection control flexural strength requirements. (Bischoff & Scanlon, 2009). In others hand, deflection control based on the span to depth (l/d) ratio (Várkonyi, 2001). Span-depth ratio (l/d) can represent the deep beam or shallow beam. For deep beam (l/d) about 5 or less. (Rashid & Kabir, 1996).

2.8 CRACK & FAILURE MODE

Crack was when beam subjected to flexural-shear and it can be classified into three type cracking mechanism. These are six type crack mechanism flexural tension cracks, flexural-shear cracks, diagonal tension shear crack, dowel crack, shear compression crack and flexural compression crack. Figure 2.1 shows the diagram of location of cracks.

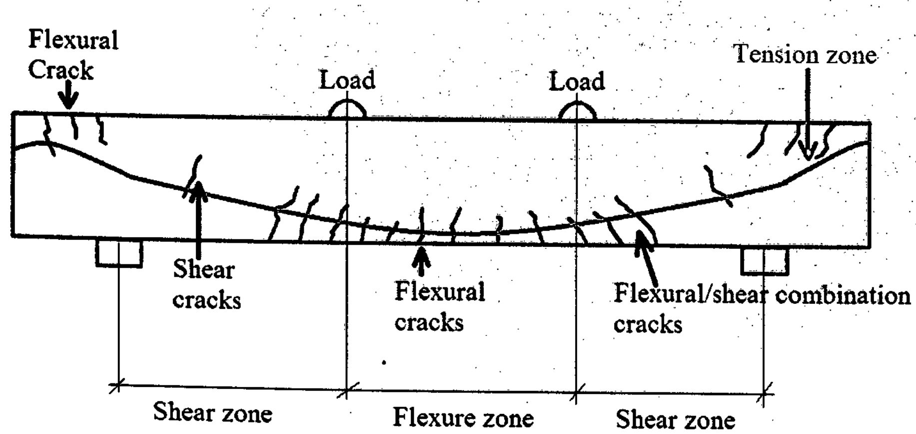

Figure 2.1: Diagram of location of cracks

Load configuration used in case of experimental program which is 4 point test was influenced the crack pattern of samples. The entire shear crack occurs within at shear zone and for flexural compression and flexural tension cracks occur at flexural zone.

Expressions are developed for steel-reinforced concrete one-way slabs and beams to satisfy deflection control flexural strength requirements. (Bischoff & Scanlon, 2009). In others hand, deflection control based on the span to depth (l/d) ratio (Várkonyi, 2001). Span-depth ratio (l/d) can represent the deep beam or shallow beam. For deep beam (l/d) about 5 or less. (Rashid & Kabir, 1996).

2.9 DEFLECTION

Deflection is the degree to which a structural element is displaced under a load. It may refer to an angle or a distance. The deflection distance of a member under a load is directly related to the slope of the deflected shape of the member under that load.

For deflection, the maximum deflection decrease will when depth of beam increases. (Al-Azzawi et al., 2010). In other hand, deflections at mid span are able to increase to increases of static moment evaluated at mid-span (Lignola, 2007).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

From the past chapter, obviously, been stated the past research and rough information in order to make a guideline for this research to make sure it follow the flow of research and according to plan that have been made. In the early part of this it explain the research planning by the flow chart.

In the chapter, discussed the experimental test and materials that in this research. For concrete the materials used are cement, aggregate, water. The entire test conducted in Universiti Malaysia Pahang (UMP) light structure laboratory. For this study, the materials used are Ordinary Portland cement (OPC), fine aggregate, water and foam agent that used to produce the foam concrete. Then after 28 days, the sample tested by using 4 point test and produce ultimate load, deflection profile and the cracking pattern of semi-precast Lightweight foam concrete beam with different depth of the beam were recorded.

3.2 RESEARCH PLANNING

Figure 3.1 shows the research experimental flow for this study:

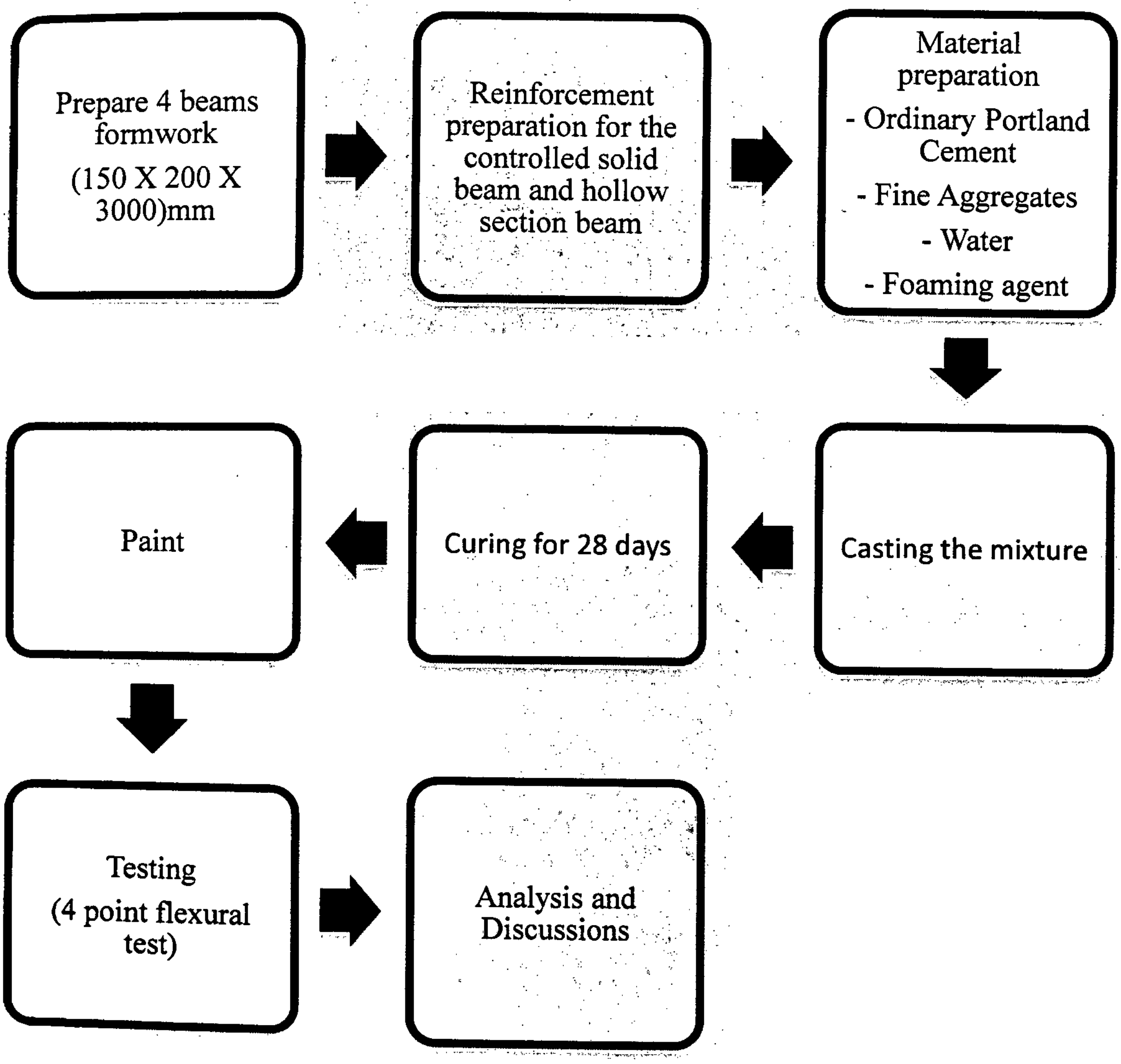

Figure 3.1: Researches experiment works flow.