FLY ASH AS PARTIA PRODUCING HIGH FLEXURAL HOLLOW SECTION BEAM

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ABSTRACT

Flexural and ultimate load behavior of hollow concrete beams under one point load is discussed in this research. This research deals with agricultural waste of fly ash in terms of partial cement replacement in hollow section beam. Concrete is both dominant as a construction material and contributor to greenhouse gas emissions due to cement manufacturing. Therefore, replacing Portland cement with fly ash reduces greenhouse gas emissions. In this research, reinforced hollow section beam in rectangular with size 250 mm × 300 mm with 2000 mm length is designed to resist a point load of 50 kN. The percentage proportion testing and curing test is fixed with 30% of fly ash by weight of with 7, 14, and 28 days respectively. Three types of reinforced hollow section beams were constructed in this research which has three different size of the cavity of B1 (40 mm × 100 mm), B2 (50 mm × 100 mm) and B3 (60 mm × 100 mm) along together with one solid beam without hollow part. From this research, the highest ultimate load achieved is specimen B1. Specimen B3 with fly ash content up to 30 % cement replacement resulted in higher load-deflection ratio and proved to be the suitable cavity size in producing high flexural hollow section beam.

ABSTRAK

Lenturan dan kelakuan beban utama pada rasuk konkrit berongga di bawah satu tekanan beban dibincangkan dalam penyelidikan ini. Tesis ini membentangkan penyelidikan mengenai sisa pertanian iaitu abu terbang dalam bentuk separa gentian simen bagi seksyen rasuk berongga. Konkrit kedua-duanya merupakan dominan sebagai bahan pembinaan dan penyumbang kepada pelepasan gas rumah hijau disebabkan oleh pembuatan simen. Oleh itu, menggantikan simen Portland dengan abu terbang dapat mengurangkan pelepasan gas rumah hijau. Dalam kajian ini, tetulang seksyen rasuk berongga dalam bentuk segi empat tepat dengan saiz 250 mm × 300 mm dan 2000 mm panjang telah direka bentuk untuk menahan beban sebanyak 50 kN. Peratusan perkadaran dan penyembuhan ujian adalah tetap sebanyak 30% abu terbang mengikut berat masing masing dengan 7, 14, dan 28 hari. Tiga jenis tetulang besi seksyen rasuk berongga telah dibina dalam kajian ini yang mempunyai tiga jenis kaviti yang berbeza iaitu B1 (40 mm × 100 mm), B2 (50 mm × 100 mm) dan B3 (60 mm × 100 mm) bersama satu rasuk padu tanpa bahagian berongga. Daripada kajian ini, kekuatan beban tertinggi dicapai oleh spesimen B1. Spesimen B3 dengan kandungan abu terbang sebanyak 30% sebagai pengganti simen menghasilkan nisbah beban-lenturan yang tinggi dan membuktikan bahawa ianya sesuai dalam menghasilkan seksyen rasuk berongga dengan kelenturan yang tinggi.

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ASTM	American Society for Testing and Materials

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

According to Namiq, Z.F. (2012), hollow section beam can be defined as closed thin walled section beam. A thin walled beam is classified by relative magnitude of its dimension. The advantages of using hollow cross section are to reduce in self-weight especially in terms of cost, handling and erection for precast cross section. The substantial reduction in terms of material quantities, the materials is less needed other than conventional systems. Recently, the use of waste material such as fly ash as new construction materials has become more common and widespread. Research done by Ahmed Elshekh, A.E. et al. (2013) proved that the compressive strength, tensile and flexural strength were remarkably improved by using fly ash.

1.2 PROBLEM STATEMENT

Fly ash is generally used to conserve energy and resources thus reduce the environmental problems. The replacement of fly ash varies with different percentage and the best percentage obtained is 30% (Rudzionis & Ivanauskas, 2011). In the design of highly elevated reinforced concrete bridge piers, hollow section is often adopted in order to increase in term of flexural strength and reduce self-weight (Chiad, S.S., 2013). However, there is no research made in concrete manufacturing history in which hollow section beam is produce by using fly ash as partial cement replacement.

1.3 OBJECTIVES

The objectives of this research are:

i. To determine the strength of the hollow section beams with three different sizes of cavity when fly ash is added as partial cement replacement.
ii. To determine the effect of cavity size of high flexural hollow section beam.

1.4 SCOPES OF STUDY

The scopes of study of this research are as follow:

i. Size of beams 250 mm × 300 mm with 2000 mm length is designed to resist a point load of 50 kN.
ii. The designed strength of concrete grade is 35 N/mm^2.
iii. The percentage proportion testing and curing test is fixed with 30% and 7, 14, and 28 days respectively.
iv. Three types of beams with three different size of the cavity of 40 mm × 100 mm, 50 mm × 100 mm and 60 mm × 100 mm.
v. This test is conducted to acquire the effect of cavity size of the hollow section beam with fly ash contents.

1.5 EXPECTED OUTCOME

This research is done to achieve the objective project and the expected outcome will be obtained is:

i. Compare the flexural strength of the hollow section beams when three different sizes of cavity are used.
ii. The effect of cavity size of the hollow section beams when fly ash is used as partial cement replacement.

Figure 1.1 below show the cross section of the hollow section beam which is constructed in this research. The hollow section part is designed to be located on the tension part of the beam with reinforcement bar of 4Y20, link R8 and 160 mm spacing links. Three different sizes of cavity is constructed which is 40 mm × 100 mm, 50 mm × 100 mm and 60 mm × 100 mm which denoted as a × b.

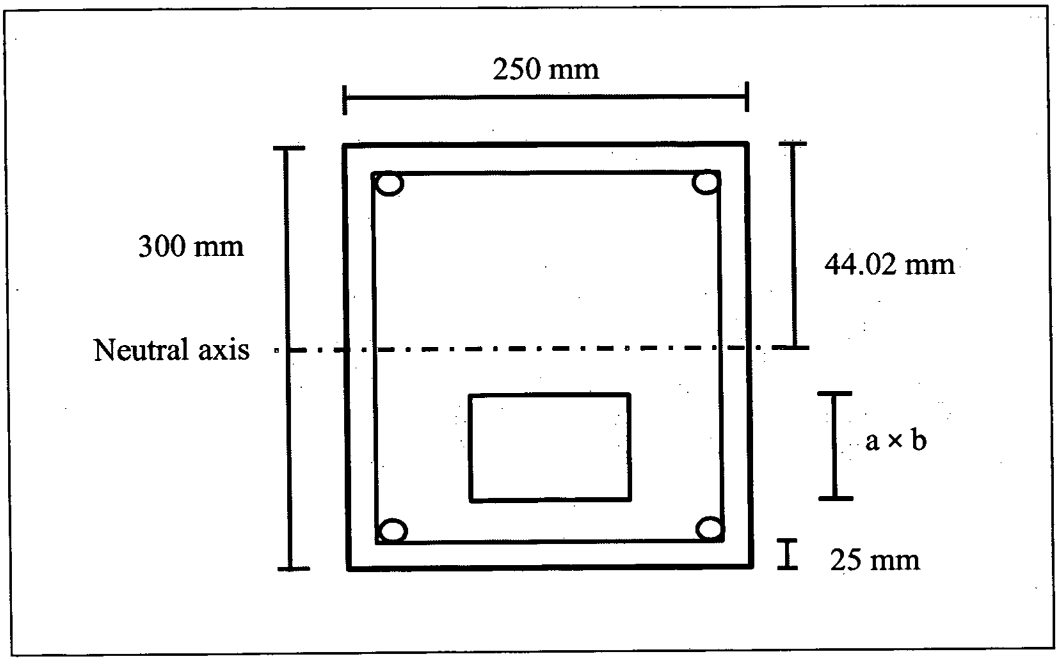

Figure 1.1: Cross-Section of Hollow Beam with 4Y20, R8-160 mm.

Figure 1.2 below shows the stress-block diagram for concrete section. The stress block consists of strains and stress part in which x is denoted as the neutral axis.

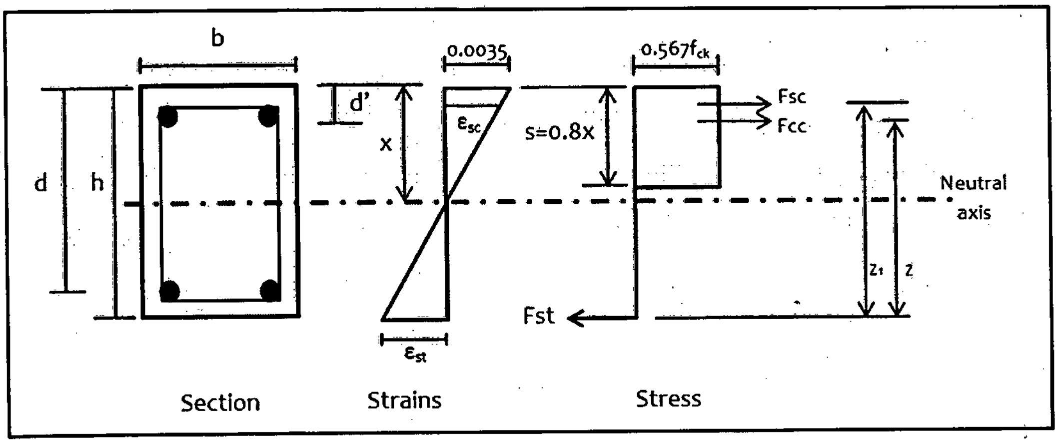

Figure 1.2: Stress-Block Diagram

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO CONCRETE

Concrete is the most widely used man-made construction material mostly in every type and size of engineering including architectural structure of all around the world. Concrete is majorly used in the manufacturing of buildings, beams, roofs, columns, floor slabs, footings, staircases, highways including bridges and so forth. Typically, concrete contains approximately 70% to 80% aggregates (coarse and fine) and 20% to 30% cement paste by mass (Tangchirapat, W. et al., 2013). Concrete is a compound material consisting of aggregates enclosed in a matrix cement paste. The strength of concrete depends upon the strength of these components, their properties and the bond strength between the paste and aggregate surface (Kodur et al., 1998)

Concrete is widely known for its advantages in terms of maintenance because concrete does not corrode therefore it needs no surface treatment and the strength of concrete itself increases with time. Besides, it has the ability to resist fire in terms of safety. The manufacturing and technology of concrete is thriving in tandem with the growth of development. Back in the days, people used traditional methods to produce concrete but nowadays there are more advance and sophisticated machine for concrete production.

2.2 CONCRETE MATERIALS

Cement production is an energy intensive process which also has an important effect on the environment. Basically, cement is pulverised finely and dry that the material itself is not binder instead to develop the binding property as a result of hydration. There are many types of cement in the market nowadays for example Ordinary Portland Cement (OPC) which is commonly used in production of concrete. As for this investigation, 30% of fly ash will be tested for the cement replacement.

Aggregate is an essential component of concrete and has significant effect on fresh and hardened concrete properties. Commonly known as inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. Aggregates, which account for 60% to 75% of the total volume of concrete, are divided into two distinct categories which is fine and coarse aggregate. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5-mm sieve. Meanwhile, coarse aggregates are any particles greater than 4.75 mm, but generally range between 9.5 mm to 37.5 mm in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

Water is also one of the crucial proportions for the production of concrete. The water–cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. It has an important influence on the quality of concrete produced. The lower the water cement ratio, the higher the final concrete strength. The advantages of low water cement ratio are it reduces drying shrinkage and cracking yet given lower permeability to the concrete itself.

2.3 ENVIRONMENTAL ISSUE OF PORTLAND CEMENT

Describing sustainable concrete as concrete incorporating by-products or waste material is not something new to be discussed. In fact, public researched dated back in the 1930s aware of this usage of fly ash as partial cement replacement (Andrea V. Solis. et al., 2011). Producing one ton of Portland cement releases about one ton of carbon dioxide (CO_2) greenhouse gas into atmosphere and as a result of this production 1.6 billion tons of carbon dioxide is released every year which is estimated at about 7% of the carbon dioxide production worldwide (Mehta, 2001 & Malhotra, 1999).

A more extensive use of industrial by-products with pozzolanic or cementitious characteristics in concrete mixtures can contribute to reduced emission of carbon dioxide and a saving of natural resources. Therefore, replacing Portland cement with fly ash reduces greenhouse gas emission. This is supported by Zachar, J. (2011) as for every ton of cement manufactured; 1 ton of greenhouse is produced. This means for every ton of cement made, 1.7 ton of raw materials must be mined or transferred. As the results, higher transportation of energy use and costs is consumed because of the supply of suitable raw materials near cement-manufacturing facilities is reduced every year.

2.4 FLY ASH

Recently, the use of waste material as a source of aggregate in new construction materials has become more common and widespread. There is an increased interest in developing sustainable or what is sustainable as one solution for these concerns (Andrea V. Solis et al., 2011). Fly ash is a mineral admixture that is mainly a by-product of the coal-fired power plants. It is a waste material and is dumped on the land adjoining thermal plants and township. It is classified as pozzolanic material according to ASTM C 618 (ASTM'C 618).

Usually, the use of fly ash as partial cement replacement of cement has many beneficial effects on the fresh and hardened properties. From theoretical considerations and practical experience the authors determined that, the quantity of fly ash replacement is between 15% - 30% depending on some factors. It sustainably improves the properties of high strength concrete mixtures such as workability, ultimate strength and tensile. Fly ash consists of fine, glossy particles that are spherical in shape, with some coarse crystalline matter and varying amounts of unburned carbon particles.

2.5 PREVIOUS STUDY OF FLY ASH AS PARTIAL CEMENT REPLACEMENT

According to previous study made by Kou, S.H. et al., (2007), fly ash can be used as partial cement replacement for cement or as an additional cementitious material in concrete. The different applications of fly ash produce concrete with totally different properties. Previously, fly ash property was known more and more deeply, and fly ash concrete has a wide practical stage. Fly ash is better than other kind of volcanic ash in material source and properties. The effects of fly ash on the properties of concrete have been documented by many researchers.

Cement can be replaced by fly ash in various percentages. In the meantime, studies done by Zachar, J. (2011) reported that 30% of fly ash as cement replacement rate produces concrete which is very suitable for pre-stressed or precast operation in the industry. Various researched also have proved 30%-40% of cement replacement of fly ash is suitable in production of concrete (Long, G.Ch. et al., 2005). He also stated that fly ash is better than any other kind of volcanic ash in terms of material source and properties. The results proved that the addition of fly ash in concrete remarkably influence its strength.

This is supported by Adams, T.H. (1998) and Naik et al. (1989), 40% replacement of cement by fly ash resulted in an increase in strength of concrete of 23% and 38% at 28 days and 56 days respectively. In these cases of fly ash using possibilities in ordinary concrete production are obvious (Rudzionis & Ivanauskas, 2004). Using fly ash as a partial cement replacement in concrete is effective on many level. For example, fly ash reduces the permeability of concrete, reduces the heat of hydration and increase the strength (Zachar, J. 2011).

Table 2.1: Standards Limit and Chemical Composition of Fly Ash

Chemical Properties	Fly Ash	ASTM C618 (%)	TS EN 450
SiO_2	52.5	-	-
Al_2O_3	22.82	-	-
Fe_2O_3	5.34	-	-
$SiO_2+Al_2O_3+Fe_2O_3$	80.66	70.0 min	-
CaO	7.16	-	-
MgO	2.56	5.0 max	-
Cl^-	0.003	-	0.1 max
Free CaO	0.1	-	1.0 max
K_2O	0.99	-	-
Na_2O	0.48	1.5 max	-
SO_3	0.2	5.0 max	3.0 max
Loss of ignition	3.35	6.0 max	5.0 max
Moisture	0.07	3.0 max	-

Sources: Atis, C.D. et al. 2009

Table 2.1 above shows the standard limit and chemical compositions of fly ash contents according to ASTM C618 (Atis, C.D. et al. 2009)

2.5.1 Hardening and Curing Period

As for hardening and curing period, Long, G.Ch et al. (2005) mentioned that the results are specific to the material presented and to the test age of 28 days. The values of these further strength and strength effect of fly ash gains depend upon the particular raw materials and curing condition owing to the variations in the properties of concrete and the pozzolanic effect of fly ash with age.

2.5.2 Cavity Size of Hollow Section

There is no further study regarding the cavity size of the hollow section beams yet as of my research is focusing on the cavity size of the hollow section itself. The purpose of this research is to reduce the amount of concrete in the tension part of the beam and that is the reason why the hollow section is created in the first place. According to Yassin, M.S. (2012), based on the assumptions made in EuroCode 2 (EN 1992:C1.6, 1 (2) P), the strength of concrete in tension area is roughly one-tenth of compressive strength, and the concrete below neutral axis is rather small compared to the tensile force in the steel part. Hence, the contribution of the tensile stresses in the concrete in terms of flexural capacity of the beam is rather small and therefore can be neglected.

2.5.3 Flexural Testing and Ultimate Load

For this experiment, the hollow section will be tested based on its flexural strength and ultimate load. The application of fly ash as cement replacement in the hollow section of concrete is not done yet by any researchers. Nevertheless, the researched done by Ahmad Elshekh, A.E. et al. (2013) investigate that there was no little effect on the tensile strength due to the increase in cement, dosage of super plasticizer and water cement ratios quantity of the mixes. Additionally, the results showed that the splitting and flexural, tensile strength increases with 20% replacement of fly ash. He also stated that the compressive strength, tensile and flexural strength were remarkably improved using fly ash as cement replacement. The brittleness in high strength concrete was higher than the normal concrete due to the fact of the strain significantly decreases with the increase in concrete strength.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter is discussed further regarding the materials used and test methods following various experimental investigations. There are few experiments testing is done in order to achieve the objectives stated in chapter one previously. In the beginning stages, all the information were collected and gathered from previous researches and legal sources such as journals, articles, books and internet sources. Figure 3.1 below shows the flow chart of research methodology conducted in this study.

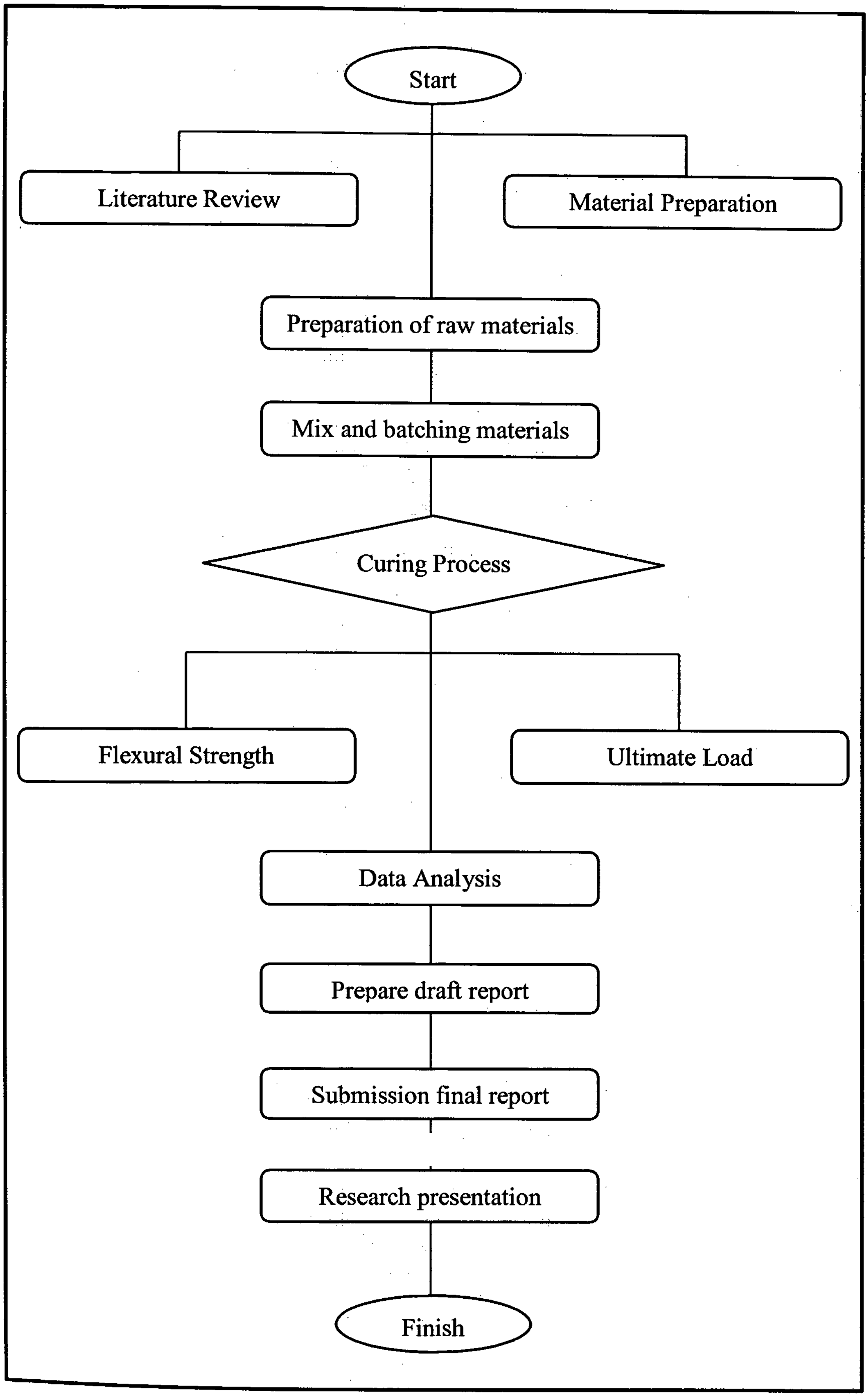

Figure 3.1: Research Methodology Flow Chart

3.2 EXPERIMENTAL WORK

The purpose of the present investigation is to study the effect size of cavity of hollow section beams. Therefore, before preparing for the hollow section beams, the control cubes is prepared first to test the compressive strength to acquire the concrete grade.

Table 3.1: List of Specimens Control Cubes without Fly Ash

Curing age (days)	Cement type	No. of specimen cubes
7	Composite cement	3
14	Composite cement	3
28	Composite cement	3
Total		9

Table 3.1 above shows the list of specimen for control cube. These specimens are made without any additive or replacement of cement. The ordinary cube size of 100 mm × 100 mm × 100 mm size is used and later test for the compressive strength. Total specimens of nine control cubes will be testing altogether according to the curing age respectively.

Table 3.2: List of Specimens for Hollow Section Beams

Cavity size of hollow section	Specimens	Curing age (days)	Percentage Replacement of fly ash	No. of specimens
40 mm × 100 mm	B1	28	*30 %	1
50 mm × 100 mm	B2	28	*30 %	1
60 mm × 100 mm	B3	28	*30 %	1

*Percentage of fly ash by weight of cement

Table 3.2 above shows the number of hollow section beams which will be casting with approximate size of 250 mm × 300 mm × 2000 mm. As for the control beam, the beam is in standard proportion without any hollow section provided or fly ash as partial cement replacement. The other three beams are the specimens which will be produce with three different sizes of cavity size of B1 (40 mm × 100 mm), B2 (50 mm × 100 mm) and B3 (60 mm × 100 mm). In the meantime, the percentage proportion of fly ash content is fixed with 30% as partial cement replacement by weight. All of these four specimens is later test for its flexural strength to resist point load of 50 kN and deflection.

3.3 SAMPLE PREPARATION AND MATERIALS

In this section, the sample preparation of the cement replacement will be further discussed. This experiment will be cover on preparation of fly ash as cement replacement, dimension and size of the beam with curing day of concrete also cavity size range openings. In this experiment, the material used will be cement, fly ash, water, coarse aggregate and fine aggregate altogether.

3.3.1 Cement

Cement is a binding material in the production of cement concrete. The cement which will be used up in this experiment is composite Portland cement. The properties of cement itself make it fills up the existing voids in the fine aggregate thus makes the concrete impermeable. Meanwhile, it also gives strength to concrete on setting and hardening aspects. Therefore, it binds the aggregate into a solid mass by virtue of its setting and hardening properties when mixed with approximate amount of water.

Table 3.3: Chemical Composition of Composite Portland Cement from YTL Cement Berhad

Constituent	Percentage by weight
Lime (CaO)	62.561
Silica (SiO_2)	19.757
Alumina (Al_2O_3)	5.591
Iron Oxide (Fe_2O_3)	3.393
Magnesia (MgO)	1.233
Sulphur Trioxide (SO_3)	2.382
Phosphorus Pentoxide (P_2 05)	0.078
Nitrous Oxide (N_2 0)	0.019
Insoluble residue	-
Loss of ignition	2.144
Lime saturated factor	0.9498

Table 3.3 defines the chemical composition of composite cement used. The chemical analysis data can be obtained from the manufacturer of the OPC which is YTL Cement Bhd.

3.3.2 Fly Ash

The fly ash source is supplied from the local source from JEV Power Plant, Company of Jimah Energy Ventures Sdn. Bhd. which is located at Port Dickson, Negeri Sembilan. The consumption of fly ash in this research is fixed with 30% cement replacement by weight. This usage of fly ash has reduced the cement contents in the concrete production of hollow section beams.