THE BEHAVIOURS OF LIGHTWEIGHT FOAMED CONCRETE BEAM WITH DIFFERENT SIZE OF SQUARE HOLLOW SECTION

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A report submitted in partial fulfillment of the requirements

for the award of the degree of the B. Eng (Hons.) Civil Engineering

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UNIVERSITI MALAYSIA PAHANG

JUNE 2014

ABSTRACT

Lightweight foamed concrete is one type of concrete that can be a replacement for conventional concrete which is widely used in construction industry nowadays. High density of conventional concrete makes structural elements heavier compare to the lightweight foamed concrete. Using lightweight foamed concrete as other alternatives to replace the conventional concrete will make the concrete more lighter and by addition of making a hollow section along the beam, it can reduce more weight of concrete itself. The main purposes of this study are to examine the behaviour of beam in term of flexural strength, deflection propagated and crack pattern. The size of beam used in this study is 150x200x3000mm. Four type of sample with different size of square hollow have been used. The sample A with no hollow, sample B with size 45x45mm of hollow size, sample C with size 60x60mm of hollow size and sample D 70x70mm of hollow size and it been placed along the length of beam. The density of lightweight foamed concrete was 1600kg/m^3 with 1:2 of water cement ratio and 1:3 for water sand ratio. The testing that involved in this study is four point flexural tests. The result shows that the flexural strength of the samples reduced due to the different size of square hollow section. The flexural was reduced to 21.85% for Beam B, 22.01% for Beam C and 28.78% for Beam D respectively. Result for deflection shows that hollow beam was having more deflection compared to solid beam. As for deflection profile at a constant loading , Beam A, Beam B, Beam C and Beam D show the same profile but with different value of maximum deflection which is 8.96mm, 9.37mm, 10.14mm and 12.13mm. Cracking pattern result shows same behaviour which is crack at shear and in inclined pattern. First crack loading result for Beam A, Beam B, Beam C and Beam D was 16.2kN, 11.29kN, 10.24kN, and 8.72kN respectively.

ABSTRAK

Konkrit berliang ringan adalah salah satu jenis konkrit yang boleh menjadi pengganti untuk konkrit konvensional yang digunakan secara meluas dalam industri pembinaan pada masa kini. Kepadatan tinggi daripada konkrit konvensional membuat elemen struktur menjadi lebih berat berbanding dengan konkrit berliang ringan. Menggunakan konkrit berliang ringan sebagai alternatif lain untuk menggantikan konkrit konvensional akan membuat konkrit menjadi lebih ringan dan dengan penambahan seksyen berongga di sepanjang rasuk, ia boleh mengurangkan berat beban sendiri terhadap rasuk. Tujuan utama kajian ini adalah untuk mengkaji sifat-sifat rasuk dari segi kekuatan lenturan, bentuk pesongan dan corak keretakan. Saiz rasuk yang digunakan dalam kajian ini adalah 150x200x3000mm. Empat jenis rasuk dengan saiz berongga yang berbeza digunakan. Rasuk A adalah sampel pejal tanpa rongga, Rasuk B dengan 45x45mm saiz rongga, Rasuk C dengan 60x60mm saiz rongga dan Rasuk D 70x70mm saiz rongga dan ia telah diletakkan di sepanjang rasuk. Ketumpatan konkrit berliang ringan adalah 1600kg/m^3 dengan nisbah 1:2 simen terhadap air dan nisbah 1:3 untuk pasir terhadap air. Ujian yang terlibat dalam kajian ini adalah ujian lenturan empat titik. Hasilnya menunjukkan bahawa kekuatan lenturan rasuk telah berkurang kerana perbezaan saiz rongga yang digunakan. Lenturan ini berkurang kepada 21.85% bagi Rasuk B, 22.01% untuk Rasuk C dan 28.78 % untuk Rasuk D. Keputusan pesongan menunjukkan bahawa rasuk yang berongga mempunyai lebih pesongan berbanding dengan rasuk yang pejal. Bagi profil pesongan pada beban berterusan, Beam A, Beam B, C dan Beam Beam D menunjukkan profil yang sama tetapi dengan nilai pesongan yang berbeza, pesongan maksimum ialah 8.96mm, 9.37mm, 10.14mm dan 12.13mm. Corak keretakan juga menunjukkan corak yang sama antara kesemua rasuk iaitu retak di ricih dan dalam corak condong. Daya keretakan pertama untuk Rasuk A, Rasuk B, Rasuk C dan Rasuk D adalah 16.2kN, 11.29kN, 10.24kN, dan 8.72kN.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is the most significant materials that have been used in construction for civil engineering applications. It contains of natural fine aggregates, coarse aggregates, cement and water. In order to gain it strength the mixture of the material has to be different in term of weight and its ratio.

Lightweight foamed concrete have gained the popularity because of the low density of concrete compare to the conventional concrete and can be apply in different type of construction applications. With the mixture of sand, cement, water and foam the lightweight foamed concrete have been formed and containing millions of evenly distributed, consistently sized air bubbles or cells. This type of foamed concrete is the most innovative green technology of idea in order to replace the conventional concrete which has several advantages compare to the conventional concrete. The density of lightweight foamed concrete can be in range 300 to 1800 kg/m^3 which more slightly less than conventional concrete that have density of 2400 kg/m^3. Thus, it can reducing the self-weight of concrete and dead load of structure when in designing stage which can affected the cost of production and time consuming of the structure to be made and complete the construction.

There were variety types of hollow section in beam that been widely applied in civil engineering application such as circular, rectangular which can meet the structural needs according to its functions. In this study, square hollow section has been used in order to reducing the weight of foamed concrete.

1.2 OBJECTIVES

The main objectives in this study were:

(i) To determine the ultimate load of lightweight foamed concrete beam with different size of square hollow section.

(ii) To determine the deflection profile of lightweight foamed concrete beam with different size of square hollow section.

(iii) To observe the crack pattern of lightweight foamed concrete beam with different size of square hollow section.

1.3 PROBLEM STATEMENT

High density of conventional concrete makes structural elements heavier compare to the lightweight foamed concrete. Using lightweight foamed concrete as other alternatives to replace the conventional concrete was make the concrete more lighter and by addition of making a hollow section along the beam, it can reduce more weight of concrete itself. In addition, the excessive usage of formwork have affected the surrounding environment for work at site. So, by using this precast lightweight foamed concrete beam it can reduce and minimize the formwork use for the beam. Other than that, mobile crane and tower crane will not be use in order to lift the precast beam because it can be lift by using manpower between 3-4 people. However, it will only limit for single to two storey buildings construction only.

1.4 SCOPE OF STUDY

In this study the four point test were involve for the investigation to get the ultimate load of beam, observing the crack pattern and deflection profile of the beam.

Figure 1.1 shows the four point flexural testing setup. There were 4 sample that have used with different size of hollow section which to determine the most effective size that can be used in civil engineering industry. The density that used for this foamed concrete was 1600kg/m^3 for the 4 samples.

The value for the deflection was measure by Linear Variable Displacement Transducer (LVDT) and it also connected to data logger to obtain the ultimate load before beam failure and also the deflection profile data. The crack pattern can be obtained by observation on how the cracks occur. Table 1.1 shows the type of samples used in this research.

Table 1.1: Type of samples

Sample	**Beam size (mm)**	**Hollow size or opening (mm)**	**Reinforcement bar**	**Link reinforcement**
Beam A	150x200x3000	No hollow (0%)	4Y12	R8-250
Beam B	150x200x3000	45x45 (6.75%)	4Y12	R8-250
Beam C	150x200x3000	70x70 (16.3%)	4Y12	R8-250
Beam D	150x200x3000	95x95 (30.0%)	4Y12	R8-250

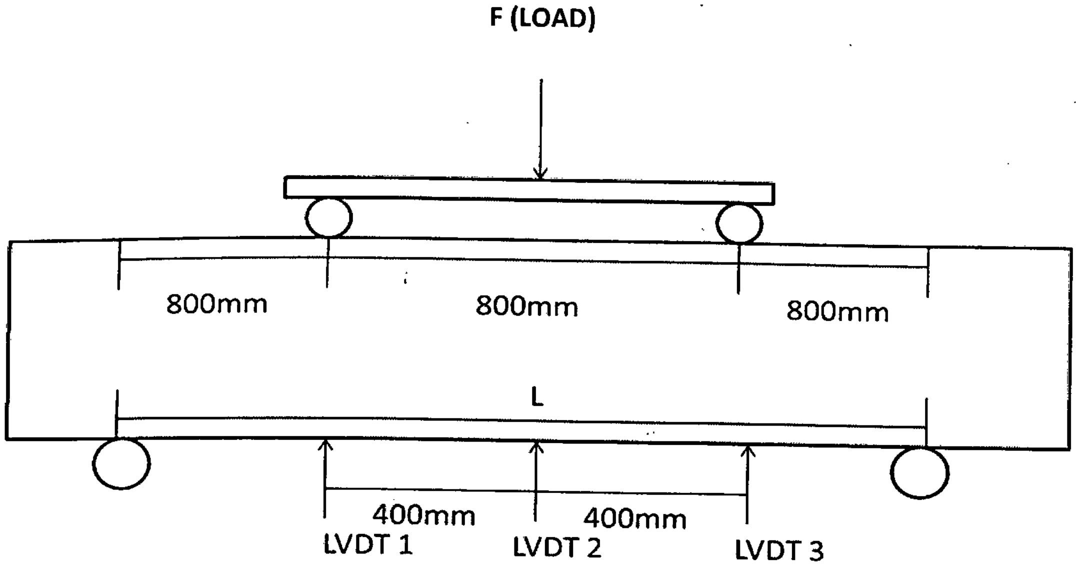

Figure 1.1: Four Point Test referring BS 1881-Part 118-83

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter the literature review were discussed about the relevant materials and method that involved in lightweight foamed concrete and hollow section of the beam. Some of the experiment about the comparison between solid beam with hollow beam but with same cross section and same reinforcement has been made before. The material use such as lightweight foamed concrete, advantages using the foamed concrete and the physical properties of lightweight foamed concrete also have to discuss in this chapter. In addition, the past researcher about the outcome of the behavior of hollow beam such as the effect of compressive strength, effect of the deflection and the observation of crack pattern towards the hollow section of the beam also been discussed. Since the topic is related to the structural element which is beam and materials such as foamed concrete, several past researches in construction industry also been discussed in this chapter.

2.2 APPLICATION OF LIGHTWEIGHT FOAMED CONCRETE

Foamed concrete is the concrete that containing the find sand with lightweight material such as cement, water, and foaming agents. The foamed concrete not contains any large aggregates and it was a vast majority concrete in construction industry. The density range between 300-1800 kg/m^3 of foamed concrete can be used in a lot in applications of civil engineering such as bridge abutment, void fillings, wall construction, tunneling and etc (Puttapa et al., 2008). Foamed concrete is the concrete which can generally self-leveling, self-compacting and may be pumped because of it smooth particles.

The main specialties of lightweight concrete are its low density and thermal conductivity. Its advantages are that there is a reduction of dead load, faster building rates in construction and lower haulage and handling costs.

Romans have been used the lightweight foamed concrete since eighteen century. The United State have been use the lightweight foamed concrete for shipbuilding and concrete blocks when in First World War. Nowadays, with the growth of technology, the lightweight foamed concrete has become widely used. In masonry construction, lightweight foamed concrete have been used as a loose-fill insulation where it can prevents the fire ratings, noise transmission were reduce and as a termite resistant (Ismail et al, 2010).

Foamed concrete has been used to fill old sewers, basements, storage tanks and voids under roadways that defects caused by heavy rain. It can be applied even through small openings making the work much easier and cheaper than other methods. If necessary, it can also be pumped into position over considerable distance. Because of behavior that good in thermal properties, foamed concrete has been used as an insulating material on roofs, in housing foundations and floors. Its inherent fire resistance has also been exploit in a wide range of uses, such as tilt-up firewalls, vaults etc.

Foamed concrete also have been use in precast elements in structural such as raft foundation for houses, providing base for storage tank, grouting of segmental tunnels and as a blinding materials. Foamed concrete also use for making blocks and bricks to act as panel wall or structural wall in construction of buildings or housing and it was widely use in this century.

2.3 ADVANTAGES AND DISADVANTAGES OF FOAMED CONCRETE

The main specialties of lightweight concrete are its low density and thermal conductivity. That is some of advantages that can be included when using lightweight foamed concrete as the main materials for the construction of structural elements. Furthermore, this type of concrete does not settle and the compaction is not necessary. This condition occurs because this concrete was free flowing concrete which make it easier to fill all the voids in structural elements when in casting process. Lightweight foamed concrete also the most highly cost effective compared with other methods and contributed to fasten the work. Table 2.1 shows the distribution of advantages and disadvantages of the lightweight foamed concrete.

Table 2.1: Advantages and disadvantages of lightweight foamed concrete

Advantages	Disadvantages
i. Rapid and relatively simple construction iI. Economical in terms of transportation as well as reduction in manpower iii. Significant reduction of overall weight results in saving structural frames, footing or piles iv. Most of lightweight concrete have better nailing and sawing properties than heavier and stronger conventional concrete	i. Very sensitive with water content in the mixtures ii. Difficult to place and finish because of the porosity and angularity of the aggregate. In some mixes the cement mortar may separate the aggregate and float towards the surface iii. Mixing time is longer than conventional concrete to assure proper mixing

2.4 COMPRESSIVE STRENGTH

Foam concrete is created by uniform distribution of air bubbles throughout the mass of concrete. Foam concrete is produced by mechanical mixing of foam prepared in advance with concrete mixture, and not with the help any chemical reactions. There were three physical properties that can be discussed in this chapter which is compressive strength of foamed concrete, economic life of foamed concrete and reduction of foamed concrete weight.

Compressive strength is the most used element in design the structural elements it was the primary physical properties of concrete. It also the most important elements which are fundamental properties used for quality control for lightweight concrete.

2.5 EFFECT OF HOLLOW SECTION TO THE FLEXURAL STRENGTH

The bending of the structure is depending on the load that been applying on the structural elements in construction. Solid rectangle beam can resist the bending when the beam is design with applying the main bar reinforcement and link reinforcement based on the load that been applied on the beam. According to Alnuaimi et al. (2007) beam resisted the applying load so the maximum displacement measured was higher in the solid beam compare to the hollow beam. In addition the experimental that been done Barney et al. (1977), mentioned that the opening or hollow section, the shear force was affecting the flexural strength and directly proportional with the deformation of the structural elements such as beam. The ultimate load of beam with the hollow section slightly different respectively according to the hollow section sizes and ultimate load will decrease according to the increasing of percentage opening of hollow section. (Chiad et al, 2013).

2.6 EFFECT OF HOLLOW SECTION TO THE DEFLECTION OF BEAM

The hollow beam was deflected more than the solid beam. Therefore, the behavior of the deflection of the hollow beam or an opening beam required to investigate. Collins et al. (1991), made a research about the deflection of the composite beam with web opening. They also describe and come out with the procedures to calculate the deflection of the beam. According to Chiad et al. (2013), the deflection for hollow beam was slightly lesser than the solid beam. Furthermore, the hollow in the structural elements required in nowadays building design for the satisfaction of requirements of placing of ventilation, heat, water and electricity pipe Nie et al. (2005). In addition, according to Rahal et al. (2000), in order to observed the crack pattern and the deflection of the beam, the crack inside the core or hollow of the beam must be measured respectively with the deflection of the beam. Therefore, various types of graph need to construct in order to get the data, which graph of deflections against crack, load against deflection and load against crack.

2.7 EFFECT OF HOLLOW SECTION TO THE CRACK PATTERN

According to Al Nuaimi et al. (2007), hollow beams cracked at lower loads than the solid beams and there were more larger number of crack occurs on the hollow beam compare with the solid beam because the hollow section or opening of in the hollow beam acted to decreasing the applying load on the reinforcement bar which is leads to the increase cracking load. This shows that the solid beam can resist higher applying load than the hollow beam. Besides that, in observation of crack pattern, solid beam able to withstand the higher load before the first crack than the hollow beam.

Other than that, Alnuaimi et al. (2007), also state that the beam with high flexural and displacement leads to failure before it crushing. In this context, the hollow beam have high flexural and displacement compare to the solid beam. Similarly, Bhatt et al (1979), mentioned that the solid beam cracked at a higher load than the hollow, which also one of the contributing factors that can causes to the cracking on the beam. Mitchell et al. (1979), also explains that the earlier cracking of the hollow sections may be due to stress concentrations at the sharp corners. According to Chiad et al. (2013), mentioned that the when the ultimate load been applied on the beam in between 12.8% to 21.8% of the range, the first crack on beam have occurred.

From the research conducted by Yang & Chen (2005) states that there have two type of crack pattern which is smeared crack and discrete crack which able to occur on structural element when it was in failure condition. Smeared crack modes and discrete crack modes is process where the works of meshing the crack pattern is carrying on when the crack start to propagated. This type of crack pattern is when the crack started to appear at mid-span and propagate upward with increasing crack width. As the load is increasing, the crack is propagate half of the beam and gradually curved towards the loading point.

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 will follow the flow of research and according to plan that have been made. In beginning part of in this chapter, the research planning by flow chart explains.

In this chapter also explain about the research and study that have been carried out, materials uses and testing conducted according to the specifications that have been stated. This part also gives the output of the clear point of view about the research and clearly shown how the objective of this research achieved. In addition, the flows of the research start from literature review until how the result obtained from the testing. Materials used for lightweight foamed concrete such as fine aggregates, cement, water, foaming agent and polystyrene to make a hollow in beam samples. Test that involved in this study which is four point test that been done in Faculty of Civil Engineering and Earth Resources (FKASA) laboratory.

3.2 RESEARCH PLANNING

Figure 3.1 shows the flow chart of the research in this study.

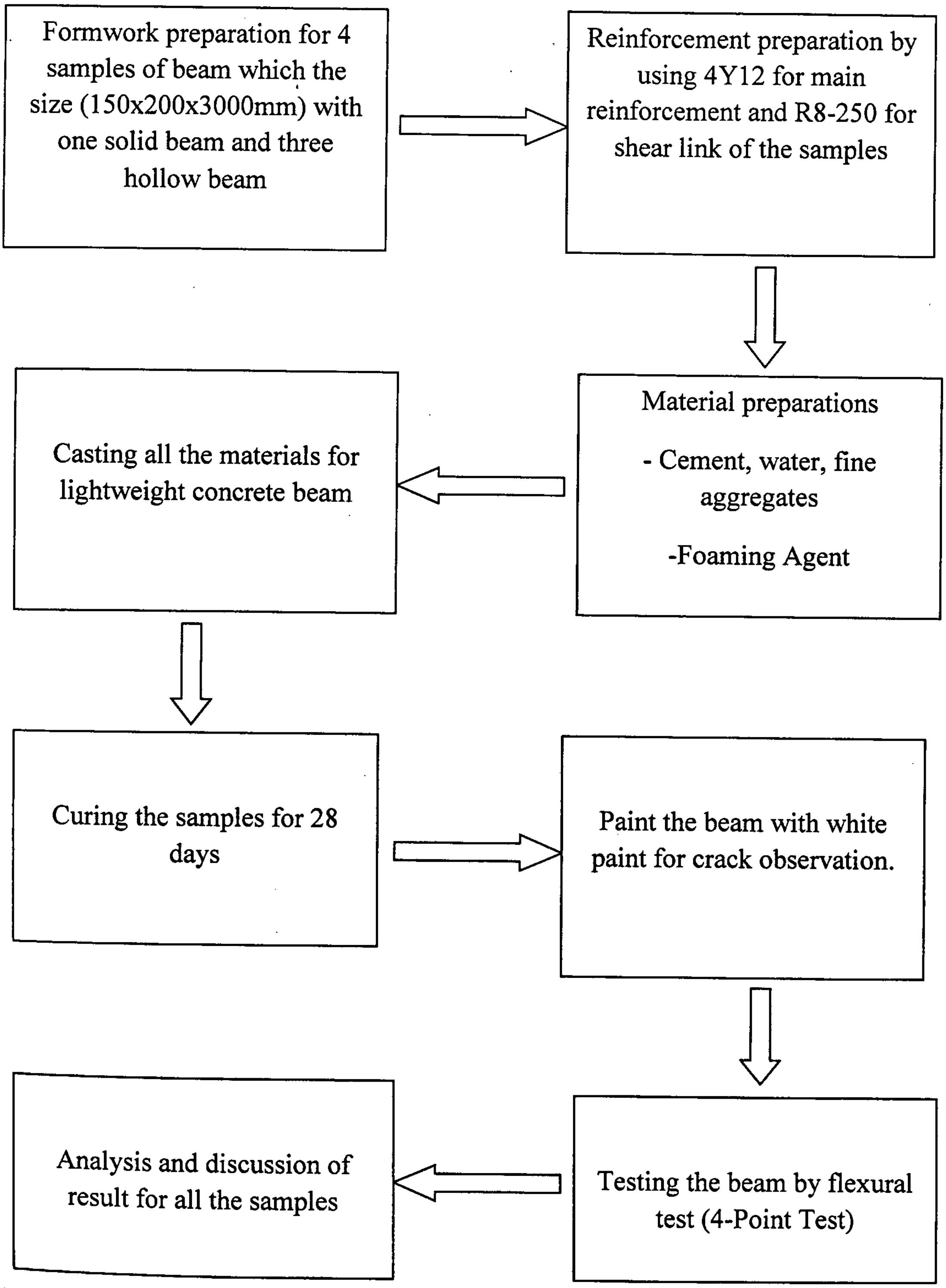

Figure 3.1: Flow of samples experimental

3.3 FORMWORK AND REINFORCEMENT PREPARATIONS

Formwork is the temporary or permanent mould that can be used to pouring the concrete inside it. In the construction, formwork has been used to pouring concrete inside it for structural elements such as beam, column and staircase.

For the early stage of sample preparations, formwork for 4 beams needs to be constructed follow the dimension of the beam which is 150mm x 200mm x 3000mm. The formwork been constructed by using the timber formwork that available in laboratory. Main materials used for the beam formwork is the plywood and woods. The thickness of plywood used is 1.25cm and wood size of 2.6cm x 5.2cm. All the plywood and wood have been cut into desire size according to the sample size. The base and sides of the beam been tight together with the nail and because of the wood was yielding, the gap between side and the base was occurred. So, in order to close the gap, the silicon is the alternatives that used to close all the gaps and to prevent from leakage of the concrete when in casting process. The preparation of formwork need to be done by details and more cautious because it can affect the concrete performance and will make some error for the samples.

Reinforcing steel is commonly used as a tensioning device in reinforced concrete and reinforced masonry structures holding the concrete in compression. In this study 4Y12 of steel have been used for main reinforcement and R8-250 for the shear link and it was provided for the 4 beam sample preparations. The strength of reinforcement used is 460N/mm^2 which is highly available in the market. As for hollow section, polystyrene have been used as the medium to create the hollow and been placed at the centre of the beam. The polystyrene was cut into the desirable size of square hollow size which is dimension of 45mm x 45mm, 60mm x 60mm and 75mm x 75mm. The length of polystyrene is 3000mm in order to make the hollow along the beam and make sure it been place at the center of the beam. Figure 3.2 and Figure 3.3 show the formwork and reinforcement preparation.

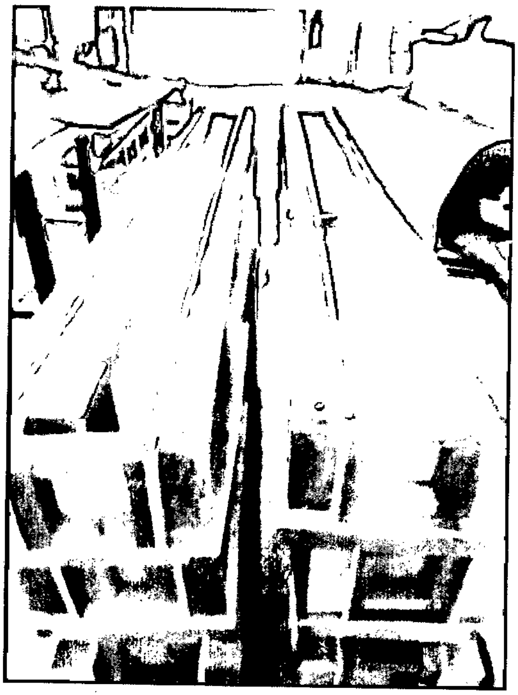

Figure 3.2: Preparation of formwork

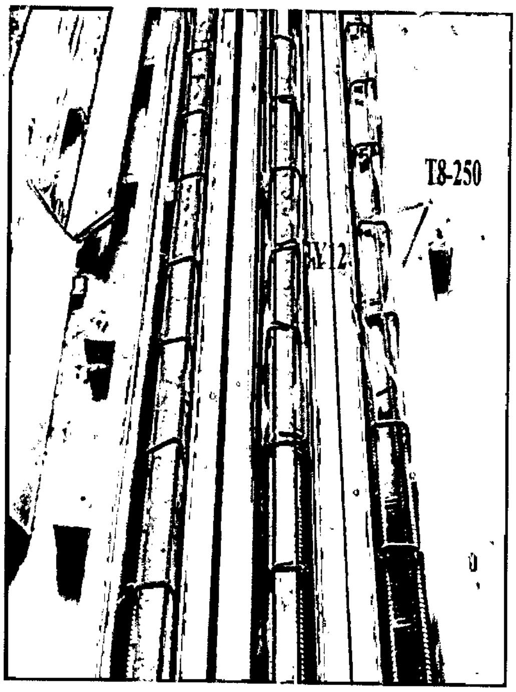

Figure 3.3: Preparation of formwork and reinforcement

3.4 RAW MATERIALS

There were several types of raw material that been used to produce the lightweight foamed concrete such as cement, fine aggregates, water and foaming agent. All the raw materials have been mixed together in mixer to produce the lightweight foamed concrete and been pour into the samples.

3.4.1 Ordinary Portland cement

Nowadays, there were a variety type of ordinary Portland cement that have been used in construction industry and it was been made by a lot of manufacturers and cement factory in order to fulfill the highly demand of concrete that comes with variety of grade and types.

For this study Ordinary Portland Cement (OPC) was used as a type of cement to perform a lightweight foamed concrete. In addition, OPC is the widely use in concrete plant with the basic ingredients in it and highly available to get in the market. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate (which controls the set time) and up to 5% minor constituents as allowed by various standards such as the European Standard. Table 3.1 shows the chemical composition that contains in ordinary portland cement.

Table 3.1: Chemical composition of ordinary portland cement

Cement	**Mass (%)**
Lime (CaO)	60 to 67%
Silica (SiO_2)	17 to 25%
Alumina (Al_2O_3)	3 to 8%
Iron oxide (Fe_2O_3)	0.5 to 6%
Magnesia (MgO)	0.1 to 4%
Sulphur trioxide (SO_3)	1 to 3%
Soda and/or Potash (Na_2O+K_2O)	0.5 to 1.3%

3.4.2 Water

The water used in preparing the sample is clean. The preparation of water by weight was depending on the ratio concrete. Although water is an important ingredient of concrete, little needs to be written about water quality, since it has little to do with the quality of concrete. The mixture of concrete must be done very carefully in order to make sure the concrete is high quality and follow the requirements. In this research, the water used is the ordinary clean tap water.

3.4.3 Fine Aggregates

Granular materials passing 5 mm sieve and retained on 74-micron sieve was used as a fine aggregates which was accordance to ASTM C-15. In this study fine aggregates with size of 6mm have been used as a raw material. The function of this fine aggregate is to increase the workability of the concrete. The fine aggregates used was in the form of uncrushed which obtain from river sand. Figure 3.4 shows the fine aggregates and ordinary Portland cement that been used in this study that available in laboratory.

Figure 3.4: Ordinary Portland cement and fine aggregates